United States Coast Guard

Report of the Marine Board of Investigation Into the Implosion of the Submersible TITAN (CG1788361) in the North Atlantic Ocean Near the Wreck Site of the RMS TITANIC Resulting in the Loss of Five Lives on June 18, 2023

MISLE Activity Number: 7724663

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[1] In sections 4.11 to 4.23 in the Findings of Fact, when TITAN is referenced, it is referencing the first TITAN hull, which experienced hull damage and was removed from service in 2019.

[2] In sections 4.24 to 4.39 in the Findings of Fact, when TITAN is referenced, it is referencing the final TITAN hull, which was the hull involved in the casualty.

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IMPLOSION OF THE SUBMERSIBLE TITAN (CG1788361) IN THE NORTH ATLANTIC OCEAN NEAR THE WRECK SITE OF THE RMS TITANIC RESULTING IN THE LOSS OF FIVE LIVES ON JUNE 18, 2023

EXECUTIVE SUMMARY

Five people died when the commercial submersible TITAN imploded on June 18, 2023, in what is considered to be a preventable tragedy. The U.S. Coast Guard's Marine Board of Investigation into the fatal incident found that OceanGate's failure to follow established engineering protocols for safety, testing, and maintenance of their submersible, was the primary causal factor. The investigation further identified the need for proper corporate governance, a professional workplace culture, and improved regulatory oversight, in particular for novel vessel designs and operations.

For several years preceding the incident, OceanGate leveraged intimidation tactics, allowances for scientific operations, and the company's favorable reputation to evade regulatory scrutiny. By strategically creating and exploiting regulatory confusion and oversight challenges, OceanGate was ultimately able to operate TITAN completely outside of the established deep-sea protocols, which had historically contributed to a strong safety record for commercial submersibles. The lack of both third-party oversight and experienced OceanGate employees on staff during their 2023 TITAN operations allowed OceanGate's Chief Executive Officer to completely ignore vital inspections, data analyses, and preventative maintenance procedures, culminating in a catastrophic event.

Mission 5 of the 2023 TITANIC Expedition began at 9:31 a.m. (Newfoundland Standard Time), on June 16, 2023, when the POLAR PRINCE departed the port of St. John's, Newfoundland and Labrador, Canada with 42 persons on board (17 crew, 24 clients, and one non-designated person). The TITAN was secured atop the Launch and Recovery System (LARS) and was towed approximately 370 nautical miles into international waters to the TITANIC wreck site to conduct dive operations. The TITAN was built in 2021 in Everett, Washington, as a 22-foot manned submersible with an 8-foot long carbon fiber pressure hull glued to titanium end sections. Owned by CYCLOPS 2, LLC, chartered by OceanGate Inc. and operated by OceanGate Expeditions, it was not registered, certified, inspected, or classed by any international flag administration or recognized organization.

On June 18, 2023, at 5:15 a.m., the POLAR PRINCE arrived in the vicinity of the TITANIC wreck site location. The average speed throughout the transit of the POLAR PRINCE, with the TITAN and LARS in tow, was approximately 8.3 knots. At 5:48 a.m., preparations began for Dive 88, with OceanGate personnel and contractors being launched from the POLAR PRINCE via small boat to prepare the LARS and TITAN for the dive. At 7:35 a.m., the small boat was loaded with the Dive 88 crew to transport them to the platform. The crew for Dive 88 included the OceanGate CEO as the Pilot, a TITANIC Content Expert, Mission Specialist #1, Mission Specialist #2, and Mission Specialist #3. At 8:30 a.m., the participants for Dive 88 were loaded into the TITAN and the forward dome was secured, sealing all five inside the TITAN.

At approximately 9:14 a.m., the dive commenced as the TITAN disengaged from the platform and began its descent toward the wreck site. The descent was a free fall through the water column, controlled by the vessel's ballast condition. Typically, the TITAN would maneuver near the surface for a communication check but, on this final dive, it did not follow that procedure. Communication between the TITAN and POLAR PRINCE relied on abbreviated text messages, as the TITAN was not equipped with a voice communication system capable of functioning below the surface. At 9:28 a.m., communications confirmed that the TITAN was descending at 33 meters per minute.

At 9:53 a.m., communication was lost with the TITAN, and as a result, the POLAR PRINCE sent the communication, “Do you see Polar Prince on your display?” The TITAN did not respond, and the POLAR PRINCE sent the same message multiple times over the next 13 minutes. At 10:08 a.m., the TITAN responded with a simple “k,” indicating a communications check. At 10:23 a.m., the support vessel and TITAN, at a depth of 2,833 meters, exchanged messages regarding the submersible's position relative to the bow of the TITANIC.

As the TITAN approached the ocean floor, it followed standard procedure by releasing ballast weights to slow its descent. At 10:47:02 a.m., at a depth of 3,341 meters, the TITAN messaged the POLAR PRINCE, reporting "dropped two wts." Six seconds later, at 10:47:08 a.m., at a depth of 3,346.28 meters, the TITAN sent an automated transmission that recorded its final location at 41° 44.06’ North; 49° 56.54’West. At approximately 10:47:09 a.m., the TITAN suffered a catastrophic implosion, resulting in the immediate loss of all lives on board. Two seconds later the TITAN Communications and Tracking Team on the POLAR PRINCE heard a "bang" emanating from the ocean’s surface, which the investigation later correlated to the TITAN’s implosion. After that, all communications and tracking with the TITAN were lost.

The POLAR PRINCE and the OceanGate support personnel conducted missed communication protocols in an attempt to communicate with TITAN and the personnel aboard. The POLAR PRINCE notified the Canadian Coast Guard of the TITAN in distress at 7:10 p.m. on June 18, 2023. The Canadian Coast Guard directed the POLAR PRINCE and OceanGate support personnel to contact the U.S. Coast Guard Rescue Coordination Center Boston, as the distress was located in the Rescue Coordination Center Boston area of responsibility. Rescue Coordination Center Boston initiated the distress phase and identified TITAN’s case as one where there was a grave or imminent danger to a vessel or personnel requiring immediate response.

Following the distress notification, a multi-national search and rescue operation was launched involving ships and aircraft. Ultimately, 11 vessels and four aircraft searched 12,145 square nautical miles of ocean for possible survivors and debris.

On June 22, 2023, at approximately 9:40 a.m., the Pelagic Research Services Odysseus 6000 meter remotely operated vehicle, deployed from the HORIZON ARCTIC, discovered the aft tail cone and other debris of the TITAN on the seafloor. This discovery confirmed the catastrophic loss of the submersible TITAN and the death of all five persons aboard.

The U.S. Coast Guard Marine Board of Investigation determined that the initiating event leading to the loss of the TITAN and the five persons on board which occurred at approximately 10:47 a.m. on June 18, 2023, was the loss of structural integrity of the TITAN's carbon fiber hull. This loss of structural integrity caused the sudden catastrophic implosion of the hull.

Following the implosion, the five individuals aboard were exposed to approximately 4,930 pounds per square inch of water pressure, resulting in the instantaneous death of all five occupants.

The primary causal factors that directly contributed to the casualty include: 1) OceanGate's design and testing processes for TITAN did not adequately address many of the fundamental engineering principles that would be crucial for constructing a hull to the precision necessary for the intended operations in an inherently hazardous environment, 2) OceanGate did not ensure an analysis was conducted to understand the expected cycle-life of TITAN's hull, 3) OceanGate's excessive reliance on a real-time monitoring system to assess the condition of the TITAN's carbon fiber hull and then their failure to conduct a meaningful analysis of the data provided by the system, 4) OceanGate's continued use of the TITAN after a series of incidents that compromised the integrity of the hull and other critical components of the submersible without properly assessing or inspecting the hull, 5) the TITAN's carbon fiber hull design and construction, in terms of winding, curing, gluing, thickness of hull and manufacturing standards, introduced flaws that weakened the overall structural integrity of the TITAN hull, 6) OceanGate's failure to conduct a detailed investigations after the TITAN experienced mishaps that negatively impacted its hull and components during dives conducted prior to the incident, 7) OceanGate's toxic workplace environment which used firings of senior staff members and the looming threat of being fired to dissuade employees and contractors from expressing safety concerns, and 8) OceanGate's failure to conduct preventative maintenance on the TITAN's hull or protect it from the elements during the extended offseason layup period ahead of the 2023 TITANIC Expedition.

Other contributing causal factors include: 1) OceanGate's safety culture and operational practices were critically flawed and at the core of these failures were glaring disparities between their written safety protocols and their actual practices, 2) OceanGate Chief Executive Officer's sustained efforts to misrepresent TITAN as indestructible due to unconfirmed safety margins and alleged conformance with advanced engineering principles provided a false sense of safety for passengers and regulators, 3) OceanGate's senior leaders fostered an organizational culture that allowed mounting financial shortfalls, customer expectations, and operational demands to be prioritized over the Mission Director's authorities and responsibilities for each TITANIC dive, and 4) the lack of comprehensive and effective regulations for the oversight and operation of manned submersibles and vessels of novel design that are constructed and/or operated in the United States and its navigable waterways.

The investigation also determined that the absence of a timely Occupational Safety and Health Administration investigation into a 2018 OceanGate whistleblower's complaint combined with a lack of effective communication and coordination between the Occupational Safety and Health Administration and the U.S. Coast Guard regarding Seaman's Protection Act protocols was a missed opportunity for potential early government intervention ahead of OceanGate's planned testing of the first TITAN hull. Early intervention may have resulted in OceanGate pursuing regulatory compliance or abandoning their plans for TITANIC expeditions.

IMPLOSION OF THE SUBMERSIBLE TITAN (CG1788361) IN THE NORTH ATLANTIC OCEAN NEAR THE WRECK SITE OF THE RMS TITANIC RESULTING IN THE LOSS OF FIVE LIVES ON JUNE 18, 2023

MARINE BOARD'S REPORT

1. Preliminary Statement

1.1. This marine casualty investigation was conducted, and this report was submitted in accordance with Title 46, Code of Federal Regulations (CFR), Subpart 4.09, and under the authority of Title 46, United States Code (USC), Chapter 63. Under 46 USC § 6308, no part of a report of a marine casualty investigation, including its findings of fact, opinions, recommendations, deliberations, or conclusions shall be admissible as evidence or subject to discovery in any civil or administrative proceedings, other than an administrative proceeding initiated by the United States.

1.2. On June 23, 2023, the Deputy Commandant for Operations (DCO) issued the enclosed convening order, Appendix A, directing a Marine Board of Investigation (MBI) to thoroughly investigate the June 18, 2023, implosion of the submersible TITAN which resulted in the death of the five crewmembers aboard.

1.3. The following personnel participated in the MBI: Chair – Mr. Jason Neubauer, Office of Investigations and Casualty Analysis (CG-INV); Lead Investigating Officer – Lieutenant Commander (LCDR) Thomas Whalen, Coast Guard Investigations National Center of Expertise (INCOE); Recorder – Lieutenant (LT) Kelly Steele, CG-INV; Legal Advisor – LCDR Lars Okmark, Office of International Law (CG-LMI); Legal Advisor – LCDR Gim Kang, INCOE; Technical Advisor – LCDR Kathryn Williams, Marine Safety Center; Technical Advisor – Mr. Marc DeJesus, INCOE; Technical Advisor – Mr. Keith Fawcett, INCOE; and Technical Advisor – LCDR Nicole Emmons, Fifth Coast Guard District.

1.4. In accordance with 46 CFR § 4.03-10, on June 26, 2023, OceanGate, Inc., owner of the vessel involved in the marine casualty, was designated as a party in interest and cooperated with the MBI throughout the course of the investigaition.

1.5. On June 26, 2023, the MBI Chair designated Miawpukek Horizon Maritime Services Ltd. and/or Horizon Maritime Services Ltd. ("Horizon Maritime Services"), the owner and operator of the POLAR PRINCE, as a party in interest. On August 13, 2024, the MBI Chair withdrew the party in interest designation for Horizon Maritime Services.

1.6. Under International Maritime Organization (IMO) protocols the U.S. Coast Guard (USCG) designated the following countries to participate in the MBI as Substantially Interested States: Canada, United Kingdom, and France.

1.7. The USCG was the lead U.S. agency for all evidence collection activities involved in this marine casualty investigation. In accordance with 46 CFR subpart 4.40 and 49 CFR part 850, the National Transportation Safety Board (NTSB) conducted joint evidence collection during the fact-finding phase of the concurrent investigations. The National Oceanic and Atmospheric Administration (NOAA); Federal Bureau of Investigation (FBI); Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF); Armed Forces Medical Examiners System (AFMES); Department of Defense DNA Identification Laboratory; Rhode Island Medical Examiner; and Kemper Engineering Services, provided technical assistance.

1.8. The MBI held one public hearing session in Charleston, South Carolina, in September 2024; 26 witnesses testified during nine days of hearings. All witnesses appeared as requested, and representatives from the designated party in interest (PII) participated throughout the hearings. The hearings were live-streamed and archived for the public.

1.9. Throughout the investigation, the MBI became aware of the existence of significant amounts of video footage evidence that could have materially supported the investigation. However, in many cases, the individuals in possession of this evidence, including key witnesses and video owners, were foreign citizens outside U.S. jurisdiction and therefore not subject to subpoena authority under a USCG Marine Board. As a result, the MBI was unable to compel the production of this potentially critical evidence in many instances.

1.10. All times listed in this report, unless otherwise noted, are local to Newfoundland Daylight Time, which is 2.5 hours behind Coordinated Universal Time (UTC). References to time in this report are listed as 12-hour time format and with an a.m. or p.m. to denote morning or afternoon times. Throughout this report, quotes or specific extracts from procedures, rules, testimony, etc. will be displayed in quotation marks.

2. Vessel Involved in the Incident

Figure 1: Submersible TITAN. Source: OceanGate.

Official Name:	TITAN
Identification Number:	CG1788361 [1]
Flag:	Not registered / not documented with any flag administration or state authority.
Vessel Class/Type/Sub-Type:	Submersible
Build Year:	2020
Gross Weight:	~23,000 pounds (10,432 kilograms (kg))
Gross Registered Tonnage:	~4 [2]
Length:	22 feet
Beam/Width:	9.2 feet
Vertical Height:	8.3 feet
Main/Primary Propulsion: (Configuration/System Type, Ahead Horsepower)	4 Innerspace® 1002 electric thrusters; 2 horizontal and 2 vertical (~12 horsepower each at max revolutions per minute)
Owner:	CYCLOPS II, LLC Seattle, Washington USA
Charterer:	OceanGate Inc. Everett, Washington USA
Operator:	OceanGate Expeditions Providence, Bahamas

Table 1: Vessel Particulars.

[1] OceanGate did not register the TITAN with any flag administration or state authority. As a result, it did not have a federal Official Number or state registration number assigned. The CG number listed is a CG database number which is assigned for USCG reference purposes only.

[2] OceanGate did not calculate or get a domestic gross register tonnage (GRT) assigned to the TITAN because they never registered the submersible. The calculation completed by the USCG Marine Safety Center was an estimate based on limited TITAN drawings provided by OceanGate.

3. Deceased, Missing, and/or Injured Persons

Name	Relationship to Vessel	Sex	Age	Citizenship	Status
Richard Stockton Rush III	"Chief" Pilot/Chief Executive Officer (CEO)/Secretary of OceanGate's Board of Directors	Male	61	U.S.	Deceased
Paul-Henri Nargeolet	Content Expert	Male	77	France	Deceased
Shahzada Dawood	Passenger/Mission Specialist #1	Male	48	U.K. and Pakistan	Deceased
Suleman Dawood	Passenger/Mission Specialist #2	Male	19	U.K. and Pakistan	Deceased
Hamish Harding	Passenger/Mission Specialist #3	Male	58	U.K.	Deceased

Table 2: Deceased, Mission, and/ or Injured Persons.

4. Findings of Fact

4.1. The Incident

4.1.1. OceanGate Expeditions advertised missions aboard the submersible vessel TITAN to experience a rare view of the legendary Royal Mail Steamer (RMS) TITANIC (TITANIC) wreck site. OceanGate Expeditions promoted the missions as a longitudinal survey to collect images, videos, and laser and sonar data to determine an assessment of the rate of decay of the TITANIC. The 2023 TITANIC Expedition was advertised as five separate missions, each lasting approximately eight to ten days. Passengers were provided with the opportunity to act as mission specialists, whose training and fees supported the missions. The missions would depart St. John's, Newfoundland and Labrador, Canada (St. John's) aboard a support vessel for the approximate 370 nautical mile (NM) transit to the TITANIC wreck site. The bow of the TITANIC is located at 41˚43'55" N, 49˚56'49" W. The complete details of OceanGate's previous TITANIC Expeditions are covered later in this report.

Figure 2: Map of TITANIC's location. Source: OceanGate Project Execution Plan TITANIC Survey Expedition 2023. Rev B. Source: OceanGate.

4.1.2. Prior to the 2023 TITANIC Expedition, OceanGate expeditions to the TITANIC took place in 2021 and 2022. According to OceanGate, in the two previous TITANIC Expeditions, the TITAN had conducted a total of 33 dives, 13 of which made it to the depth (3,840 meters (m); 12,598 feet) of the TITANIC on the ocean floor.

4.1.3. The submersible vessel TITAN (final hull) was completed in 2021 in Everett, Washington. It was an undocumented, unregistered, non-certificated, unclassed, 22-foot manned commercial watercraft. The pressure hull was approximately 8-feet long, cylindrically shaped, with an inside diameter of approximately 4.5 feet. The hull was constructed with 5 inches of carbon fiber wound filament, which consisted of five layers of carbon fiber glued together with each layer approximately 1 inch thick. The carbon fiber pressure hull was glued fore and aft to Grade 3 titanium segments (rings) which were then bolted to the forward and aft end Grade 3 titanium end domes.

The forward dome was hinged to the starboard side of the forward segment to allow for entry and exit into the TITAN. When closed, the forward dome was secured to the forward segment with 18 bolts. The forward dome was fitted with a 23-inch acrylic frustum window for visibility. The aft titanium dome was secured to the aft titanium segment with 18 stainless steel bolts (9/16 inch) and this section housed various electronics and computers. External to the aft of the pressure vessel was an approximately 5-foot-long tail cone section which housed two lithium batteries, two motor controller pods, buoyancy blocks made of syntax foam, and the tracking system. Per the OceanGate TITAN specifications page, the TITAN could accommodate five persons with a maximum operating depth of 4,000 m (13,123 feet). The TITAN was fitted with four Innerspace electric thrusters (two vertical and two horizontal), which propelled the submersible at three knots (kts). The TITAN hull sat upon a framing system which held other accessories, such as external lights and cameras, and allowed the TITAN to remain upright while sitting on the deck.

4.1.4. The owner of the TITAN, OceanGate, Inc., located in Everett, Washington, contracted the Canadian flagged motor vessel POLAR PRINCE (IMO[3]# 5329566) to be the support vessel for the TITAN's 2023 TITANIC Expedition. The POLAR PRINCE is a 238-foot, 2,062 Gross Ton International Tonnage Convention (ITC), Det Norske Veritas (DNV) classed, General Dry Cargo ship, owned and operated by Miawpukek Horizon Maritime Services, Ltd. The POLAR PRINCE was a former Canadian Coast Guard Ice Breaker, formerly the CCGS SIR HUMPHREY GILBERT from 1959-1986, which was converted into a "research" vessel. The 2023 TITANIC Expedition was the first time the POLAR PRINCE was contracted to support the TITAN and the OceanGate TITANIC Expedition.

Figure 3: Photo taken as the POLAR PRINCE arrived in St. John's, Newfoundland, Canada, taken on June 25, 2023, by the MBI Team, post casualty. Source: USCG.

4.1.5. TITAN was secured atop a 38-foot submersible Launch and Recovery System (LARS) platform. Due to the limited deck space on the POLAR PRINCE, the TITAN atop LARS were towed astern by the POLAR PRINCE at approximately 7-8 kts for the entirety of the 2023 TITANIC Expedition voyages (i.e., approximately 740 NM to and from the TITANIC wreck site and for the duration of the expedition). From this point forward, the term "towing" means the TITAN secured atop to the LARS platform and being towed astern of the POLAR PRINCE.

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[3] The International Maritime Organization (IMO) is the United Nations (UN) specialized agency with responsibility for the safety and security of shipping and the prevention of marine and atmospheric pollution by ships. The IMO's work supports the UN's sustainable development goals.

Figure 4: TITAN / LARS in tow on Mission 1 of 2023 TITANIC Expedition in Conception Bay, Newfoundland on May 13, 2023. Source: OceanGate.

4.1.6. The LARS platform was constructed by Everest Marine in 2018. It measured 38 feet in length, 16 feet 6 inches in width, and 3 feet 8 inches in height, with a total weight of approximately 50,000 pounds (lbs). Made of aluminum, the platform was designed to be submerged to a depth of 10 m (32.8 feet) through the action of the launch platform operator. It featured four air receiver tanks mounted atop the hull, which were used for ballasting. Additionally, the platform could be disassembled into two separate sections for easier transport by roadway.

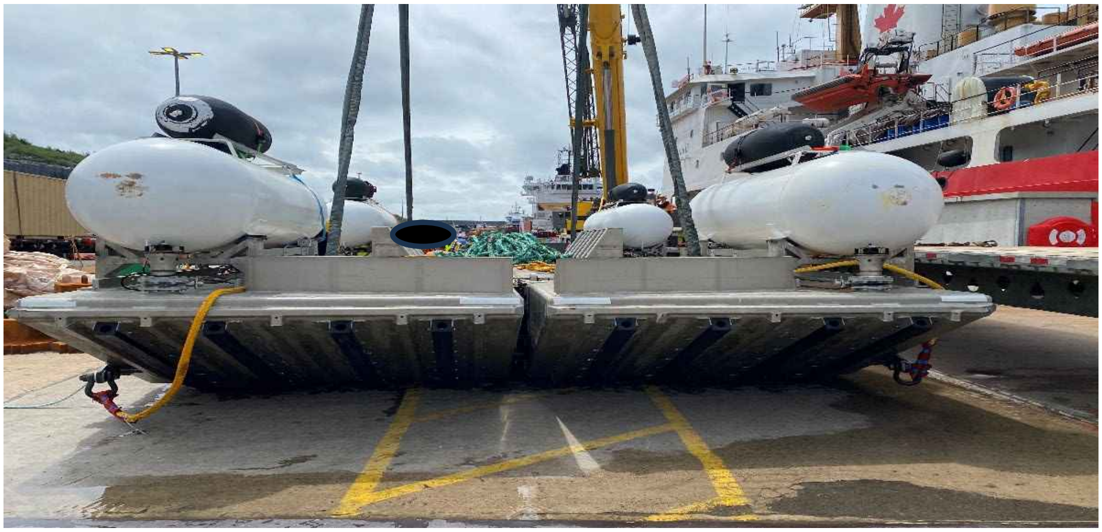


Figure 5: Photo of the TITAN Launch and Recovery System (LARS) in St. John's, Newfoundland on June 25, 2023, taken by MBI team post casualty. Source: USCG.

Figure 6: TITAN atop the LARS, alongside POLAR PRINCE. Source: OceanGate.

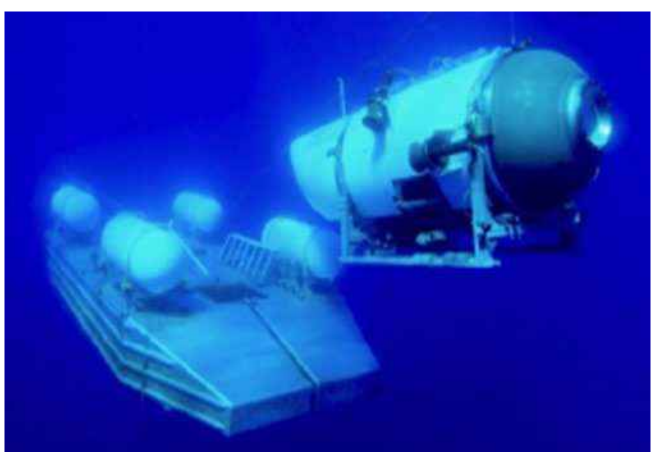


Figure 7: TITAN departing from the LARS at a depth of 10 m (32.8 feet). Source: OceanGate.

Figure 8: OceanGate's 2023 TITANIC Expedition Schedule. Source: OceanGate Expeditions.

4.1.7. OceanGate began Mission 1 of the 2023 TITANIC Expedition on May 12, 2023. During the first four missions of the 2023 TITANIC Expedition, OceanGate and the TITAN did not complete a dive to the depth of the TITANIC wreck site. As shown in Table 1, there were four dives conducted prior to the final dive which were classified as a 419 drill (disabled submersible exercise), two test dives, and an aborted dive. Prior to Dive 88, the accident dive (classified by OceanGate as C2_0088), none of the previous 2023 TITANIC Expedition dives departed the LARS platform.

Dive Number	Date	Dive Location	Dive Time (hours)	Max Depth (m)
C2_0084	5/22/23	Enroute TITANIC	0.5	8
C2_0085	5/31/23	Grand Banks	2.0	10
C2_0086	6/5/23	Grand Banks	2.0	10
C2_0087	6/12/23	Grand Banks	2.0	10

Table 3: OceanGate 2023 TITANIC Expedition Dive Log. Source: OceanGate.

4.1.8. Mission 5 of the 2023 TITANIC Expedition began at 9:31 a.m., on June 16, 2023, when the POLAR PRINCE departed the port of St. John's with 42 persons on board (17 crew, 24 clients, and one non-designated person[4]).

4.1.8.1. The 17-member crew consisted of POLAR PRINCE crew members.

4.1.8.2. The 24 clients consisted of seven OceanGate employees, 12 third-party contractors, three "mission specialists" and two "mission specialist companions."

4.1.8.2.1. The OceanGate Project Execution Plan stated that OceanGate would have other third-party guests on the vessel at different times

[4] Information taken from the POLAR PRINCE Crew Manifest for the return to port on the June 25, 2023. The five deceased mission specialists were included in the number of clients.

depending on the needs of the expedition. These parties consisted of OceanGate partners, contractors, and equipment experts.

4.1.8.2.2. Two of the mission specialists paid $250,000 and the other paid $150,000 for one dive to the TITANIC wreck site. The mission specialists' companions each paid $25,000 to accompany the mission specialists on the support vessel but did not partake in a TITAN dive.

4.1.8.2.3. According to the OceanGate's Project Execution Plan, "mission specialists are OceanGate's guests who help fund OceanGate expeditions. In addition to achieving research and scientific goals, OceanGate strives to ensure that mission specialists have the best experience possible when joining our team."

Figure 9: POLAR PRINCE with the TITAN in tow on the LARS platform, departing St. John's, Newfoundland on June 16, 2023. Source: OceanGate Scientific Director.

4.1.9. In response to the MBI's inquiry regarding the creation of the tow plan, the Master of the POLAR PRINCE stated:

> "From the time I joined the Polar Prince, I started preparing a towing plan for the Barge (LARS/TITAN) in contemplation of getting to/from the TITANIC site safely. I would have consulted with colleagues from time to time on the scope and level of detail of the plan. The towing plan was provided by email for comment to [Director of Logistics[5]] of OceanGate before the Polar Prince left Mulgrave, NS, and a revised towing plan was provided to [Director of Logistics] about two weeks later. OceanGate had no comments on the towing plan or any other aspects

[5] Name redacted / title inserted by MBI.

of the towage of the Barge (LARS/TITAN). The revised Towing Plan was submitted to the Atlantic Pilotage Authority on May 15, 2023, after taking some advice from the local pilots."

4.1.10. According to the POLAR PRINCE Deck Logbook entry from June 16, 2023, after departing St. John's Harbor, the tow of the TITAN was set to 250 m (820 feet) astern of the POLAR PRINCE.

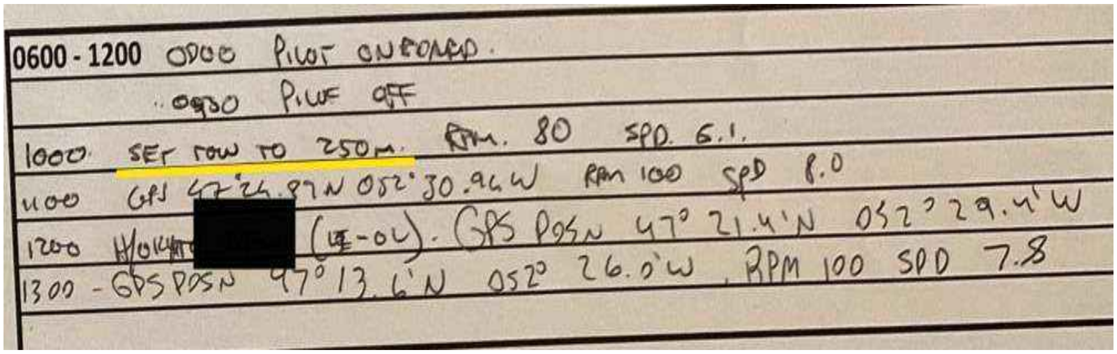

0600 - 1200 0000 PILOT ONBOARD.
0930 PILOT OFF
1000 SET TOW TO 250M. RPM. 80 SPD. 6.1.
1100 GPS 47°24.87N 052°30.96W RPM 100 SPD 8.0
1200 H/O [redacted] (-OL). GPS POSN 47° 21.4'N 052° 29.4'W
1300 - GPS POSN 47° 13.6'N 052° 26.0'W, RPM 100 SPD 7.8

Figure 10: Photo of POLAR PRINCE Deck Log for June 16, 2023, taken by MBI post casualty. The redaction and yellow line were added by the MBI. Source: USCG, June 25, 2023.

Figure 11: OceanGate 2023 TITANIC Expedition, Mission 5, Day 1 (June 16, 2023) Plan of the Day. Source: OceanGate Expeditions.

4.1.11. The weather along the POLAR PRINCE's transit route on June 16, 2023, (Day 1 Mission 5), had a significant wave height of 1.75 m (5.7 feet) and a wind speed of 7.5 m per second (m/s), which is equivalent to slightly less than 15 kts. The primary wave period was 8.5 seconds per wave, with the prominent wave direction off the port quarter (200 degrees off the bow) of the POLAR PRINCE.

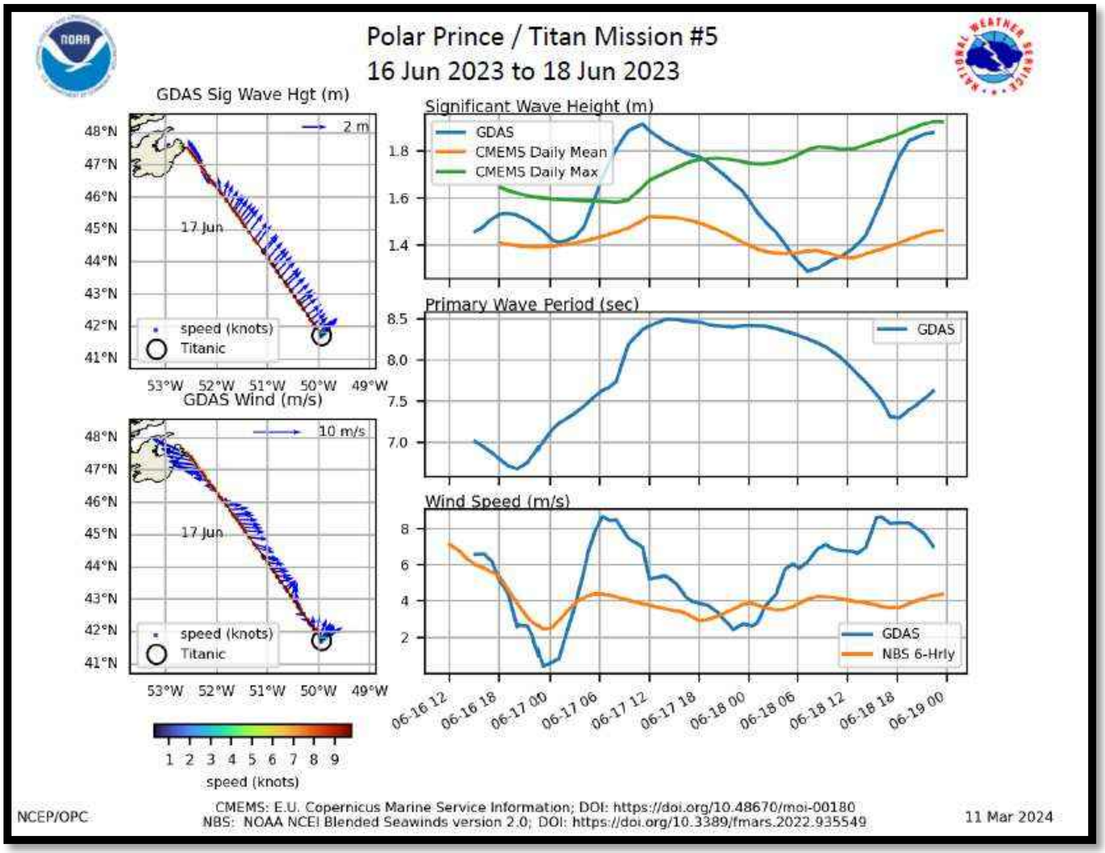
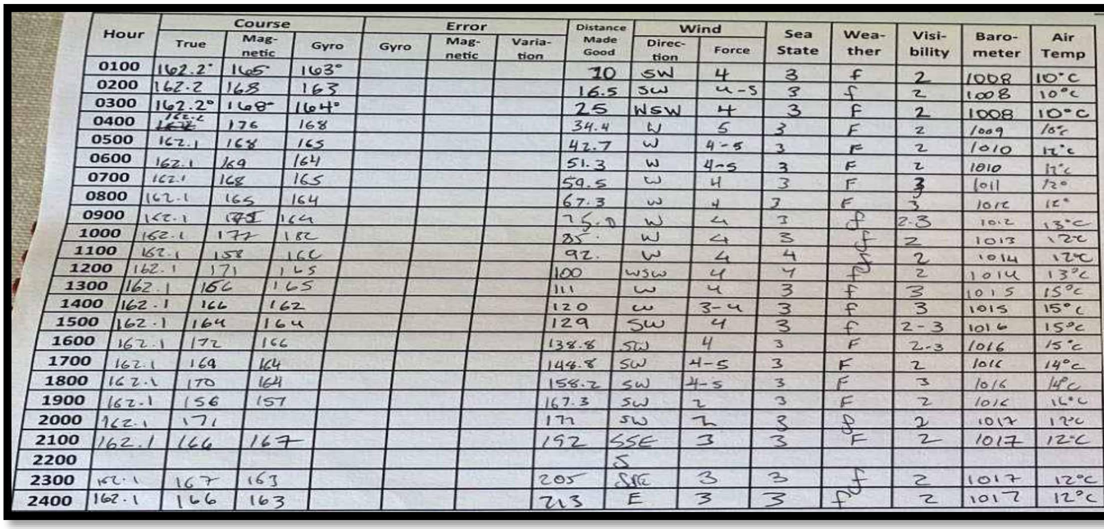


Figure 12: Weather data for the 2023 TITANIC Expedition Mission 5 voyage. Source: NOAA

4.1.12. Mission 5 began with the POLAR PRINCE getting underway with the TITAN in stern tow in east-southeasterly winds, under a low-pressure system near New Brunswick, Canada. On June 17, the sea conditions worsened, with waves reaching about 2 m (6.5 feet) and a wave period of 8.5 seconds. This was due to southwest winds from a passing low-pressure system and a new low forming east of Newfoundland. These winds had traveled a long distance across the water, stretching south from 40 degrees north and west from 50 degrees west. NOAA observed a brief period of calmer weather on the morning of June 18, but southwesterly winds returned later that day. NOAA stated that it appeared that a weak high-pressure system passed early on June 18, 2023, with southwesterly filling back in as the day progressed.



Hour	Course True	Course Magnetic	Course Gyro	Error Gyro	Error Magnetic	Error Variation	Distance Made Good	Wind Direction	Wind Force	Sea State	Weather	Visibility	Barometer	Air Temp
0100	162.2°	165	163°				10	SW	4	3	f	2	1008	10°C
0200	162.2	168	163				16.5	SW	4-5	3	f	2	1008	10°C
0300	162.2°	168°	164°				25	WSW	4	3	F	2	1008	10°C
0400	162.2	176	168				34.4	W	5	3	F	2	1009	10°C
0500	162.1	168	165				42.7	W	4-5	3	F	2	1010	11°C
0600	162.1	169	164				51.3	W	4-5	3	F	2	1010	11°C
0700	162.1	168	165				59.5	W	4	3	F	3	1011	12°
0800	162.1	165	164				67.3	W	4	3	F	3	1012	12°
0900	162.1	[illegible]	164				75.0	W	4	3	f	2-3	1012	13°C
1000	162.1	177	182				85	W	4	3	f	2	1013	12°C
1100	162.1	158	166				92	W	4	4	f	2	1014	12°C
1200	162.1	171	165				100	WSW	4	4	f	2	1014	13°C
1300	162.1	166	165				111	W	4	3	f	3	1015	15°C
1400	162.1	166	162				120	W	3-4	3	f	3	1015	15°C
1500	162.1	164	164				129	SW	4	3	f	2-3	1016	15°C
1600	162.1	172	166				138.8	SW	4	3	F	2-3	1016	15°C
1700	162.1	169	164				144.8	SW	4-5	3	F	2	1016	14°C
1800	162.1	170	164				158.2	SW	4-5	3	F	3	1016	14°C
1900	162.1	156	157				167.3	SW	2	3	F	2	1016	16°C
2000	162.1	171					177	SW	2	3	f	2	1017	12°C
2100	162.1	166	167				192	SSE	3	3	F	2	1017	12°C
2200								S						
2300	162.1	167	163				205	SSE	3	3	f	2	1017	12°C
2400	162.1	166	163				213	E	3	3	f	2	1017	12°C

Figure 13: Photo of the POLAR PRINCE Deck Logbook for June 17, 2023, taken by the MBI after the casualty. Source: USCG, June 25, 2023.

4.1.13. The plan of the day for Day 2 of Mission 5, on June 17, 2023, was as follows:

Figure 14: OceanGate 2023 TITANIC Expedition, Mission 5, Day 2 (June 17, 2023), Plan of the Day. Source: OceanGate Expeditions.

4.1.14. As depicted in Figure 15, a formal dive plan for June 18, 2023, Dive C2_0088, was created in accordance with OceanGate Health, Safety, and Environmental (HSE) Manual 2019 Revision 3 Section 39. B. ii. Specifically, the HSE Manual stated:

"Prior to any manned subsea operations, including those where a submersible is empty but where divers are likely to be in the water, a formal dive plan shall be issued a minimum of 8 hours before the scheduled operation. This dive plan shall be of a format and content as determined by the Director of Marine Operations. The plan shall, at a minimum, include the list of participants, key frequencies, expected weather, dive schedule, risk assessment and emergency contact information."

Titan Dive Plan - C2_0088

Date: 6/18/2023
Operating Channel: Ch 69
Objectives: Wreck Scans | Biological Observation
Configuration:
Primary Location: Titanic
Risk Index: 35

Schedule

Task	Start Time	Duration	End Time	
Ship slows and shortens tow	5:00	0:15	5:15	
Dinghy checks	5:00	0:30	5:30	
Pre Brief in heli hangar	5:30	0:15	5:45	
Launch Max with dive gear and divers	5:45	0:15	6:00	
Remove hatches prep platform for dome crew	6:00	0:30	6:30	
Launch Stewie and transit w dome crew	6:00	0:15	6:15	
Lower Tracking pole	6:15	0:15	6:30	
Close/Open Dome	6:15	0:20	6:35	
Sub Vessel Checks	6:35	1:00	7:35	
Load Crew in Stewie & transit to platform	7:35	0:30	8:05	
Load sub & vacuum	8:05	0:30	8:35	
Platform Prep	8:35	0:15	8:50	
Stopski	8:50	0:05	8:55	
Sink platform	8:55	0:05	9:00	
Remove lock(s)	9:00	0:10	9:10	
Dive	9:10	9:00	18:10	
Raise platform	9:40	0:15	9:55	When sub thru 1,000m
Service Sub/Platform/Dive Gear	9:55	1:30	11:25	
Recovery team mobilizes	17:40	0:30	18:10	When sub thru 1,000m
Sink platform	18:10	0:10	18:20	When ship abeam
Titan Lands	18:20	0:20	18:40	
Remove/Insert lock	18:40	0:10	18:50	
Raise platform	18:50	0:10	19:00	
Close/Open Dome	19:00	0:20	19:20	
Load vessels & transit to ship	19:20	0:15	19:35	
Post Dive Secure	19:35	0:30	20:05	

Figure 15: TITAN Dive 88 Dive Plan. Source: OceanGate.

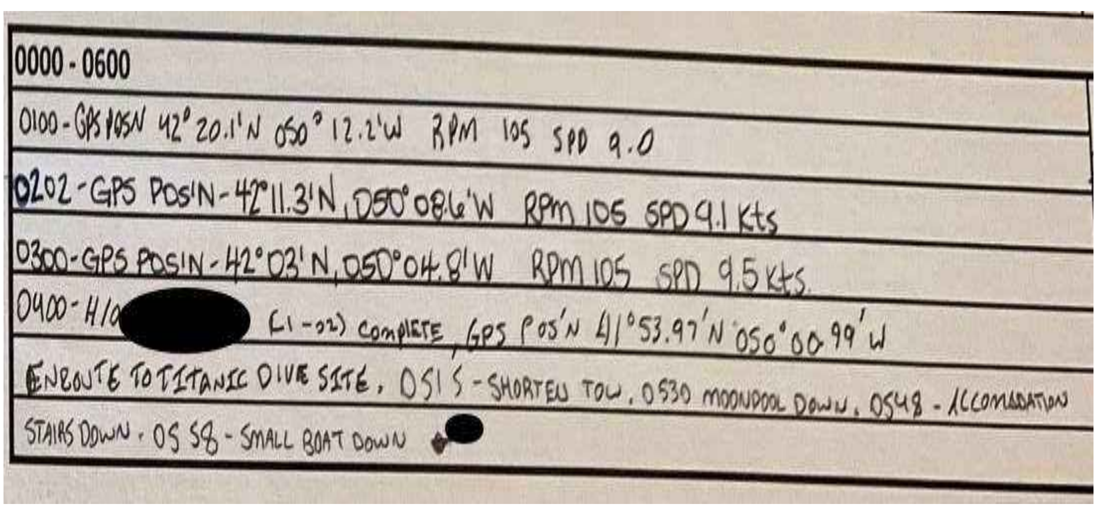
4.1.15. According to the 2023 TITANIC Expedition Launch Webinar, the plan for Mission 5, Day 3, Dive Team A, the team participating as crew on the dive, was as follows:

Figure 16: OceanGate 2023 TITANIC Expedition, Mission 5, Day 3 (June 18, 2023), Dive 88 dive schedule. Source: OceanGate Expeditions.

4.1.16. For the other mission specialists who were not participating as crew members in the dive, their schedule was as follows:

Figure 17: OceanGate 2023 TITANIC Expedition, Mission 5, Day 3 (June 18, 2023), Dive 88, non-dive participant schedule. Source: OceanGate Expeditions.

4.1.17. On June 18, 2023, at 5:15 a.m., the POLAR PRINCE arrived in the vicinity of the TITANIC wreck site location. According to their logbook, they "shortened tow," in order to bring the TITAN closer to the POLAR PRINCE. The average speed throughout the transit of the POLAR PRINCE, with the TITAN and LARS in tow, was approximately 8.3 kts.



0000 - 0600
0100 - GPS POS'N 42°20.1'N 050°12.2'W RPM 105 SPD 9.0
0202 - GPS POS'N - 42°11.3'N, 050°08.6'W RPM 105 SPD 9.1 Kts
0300 - GPS POS'N - 42°03'N, 050°04.8'W RPM 105 SPD 9.5 Kts
0400 - H/O [redacted] (1-02) COMPLETE, GPS POS'N 41°53.97'N 050°00.99'W
ENROUTE TO TITANIC DIVE SITE, 0515 - SHORTEN TOW, 0530 MOONPOOL DOWN, 0548 - ACCOMADATION
STAIRS DOWN. 0558 - SMALL BOAT DOWN [redacted]

Figure 18: Photo of POLAR PRINCE Logbook entry for June 18, 2023, 0000-0600 Watch. Redactions completed by MBI. Source: USCG, June 25, 2023.

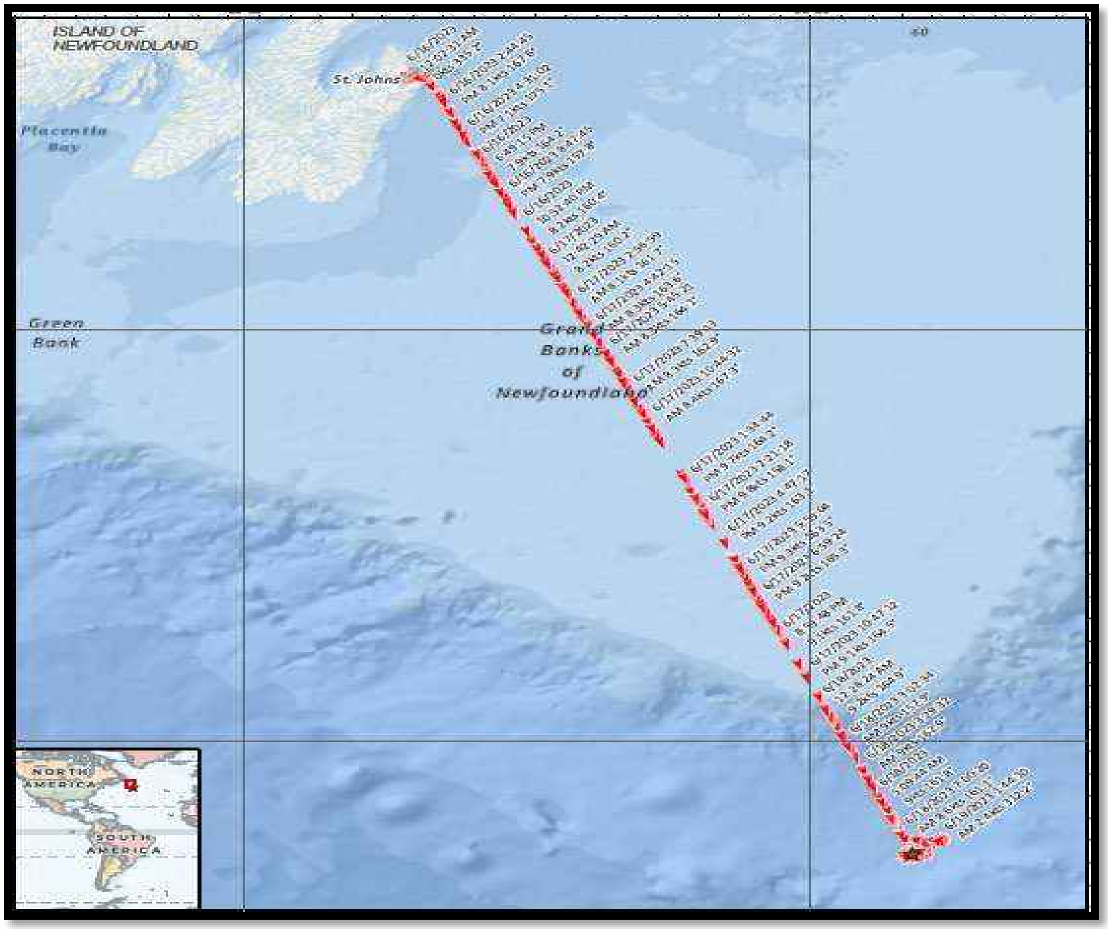
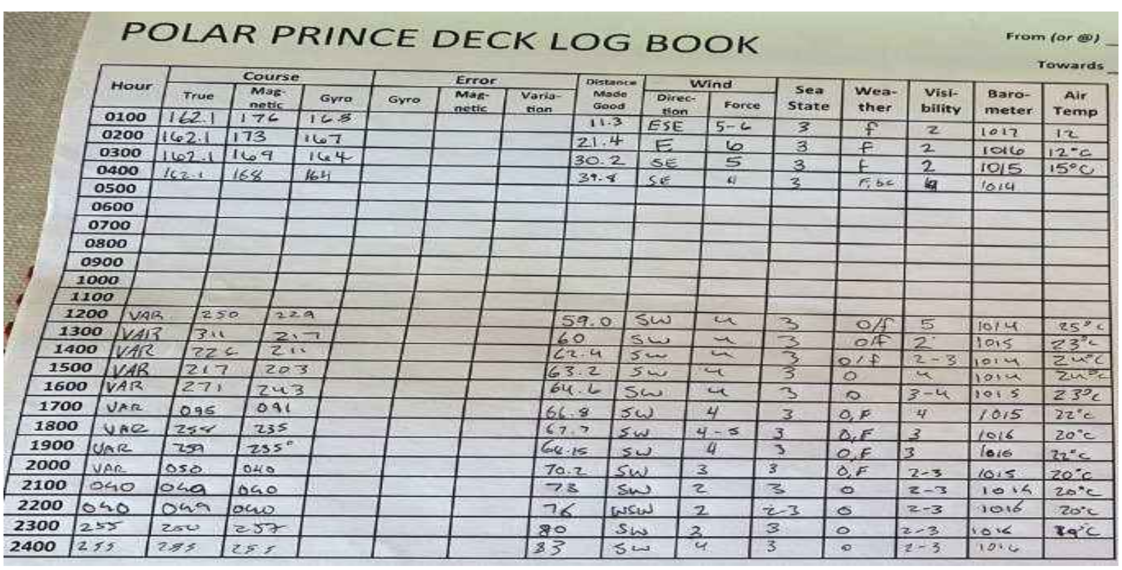


Figure 19: OceanGate 2023 TITANIC Expedition, Mission 5, POLAR PRINCE track line. Source: USCG.

4.1.18. Per figure 20, the on-scene weather upon arrival in vicinity of the TITANIC wreck site was SW winds 13-19 kts with 2-3 m (6.9 to 9.8 feet) wave height.



POLAR PRINCE DECK LOG BOOK

From (or @)

Towards

Hour	Course			Error			Distance Made Good	Wind		Sea State	Weather	Visibility	Barometer	Air Temp
	True	Magnetic	Gyro	Gyro	Magnetic	Variation		Direction	Force					
0100	162.1	176	168				11.3	ESE	5-6	3	f	2	1017	12
0200	162.1	173	167				21.4	E	6	3	f	2	1016	12°c
0300	162.1	169	164				30.2	SE	5	3	f	2	1015	15°c
0400	162.1	168	164				39.8	SE	4	3	f, bc	[illegible]	1014	
0500														
0600														
0700														
0800														
0900														
1000														
1100														
1200	VAR	250	229				59.0	SW	4	3	o/f	5	1014	25°c
1300	VAR	311	217				60	SW	4	3	o/f	2	1015	23°c
1400	VAR	226	211				62.4	SW	4	3	o/f	2-3	1014	24°c
1500	VAR	217	203				63.2	SW	4	3	o	4	1014	24°c
1600	VAR	271	243				64.6	SW	4	3	o	3-4	1015	23°c
1700	VAR	095	091				66.8	SW	4	3	o, F	4	1015	22°c
1800	VAR	254	235				67.7	SW	4-5	3	o, F	3	1016	20°c
1900	VAR	259	255°				68.15	SW	4	3	o, F	3	1016	22°c
2000	VAR	050	040				70.2	SW	3	3	o, F	2-3	1015	20°c
2100	040	049	040				73	SW	2	3	o	2-3	1016	20°c
2200	040	049	040				76	WSW	2	2-3	o	2-3	1016	20°c
2300	255	260	257				80	SW	2	3	o	2-3	1016	19°c
2400	255	285	255				83	SW	4	3	o	2-3	1016	

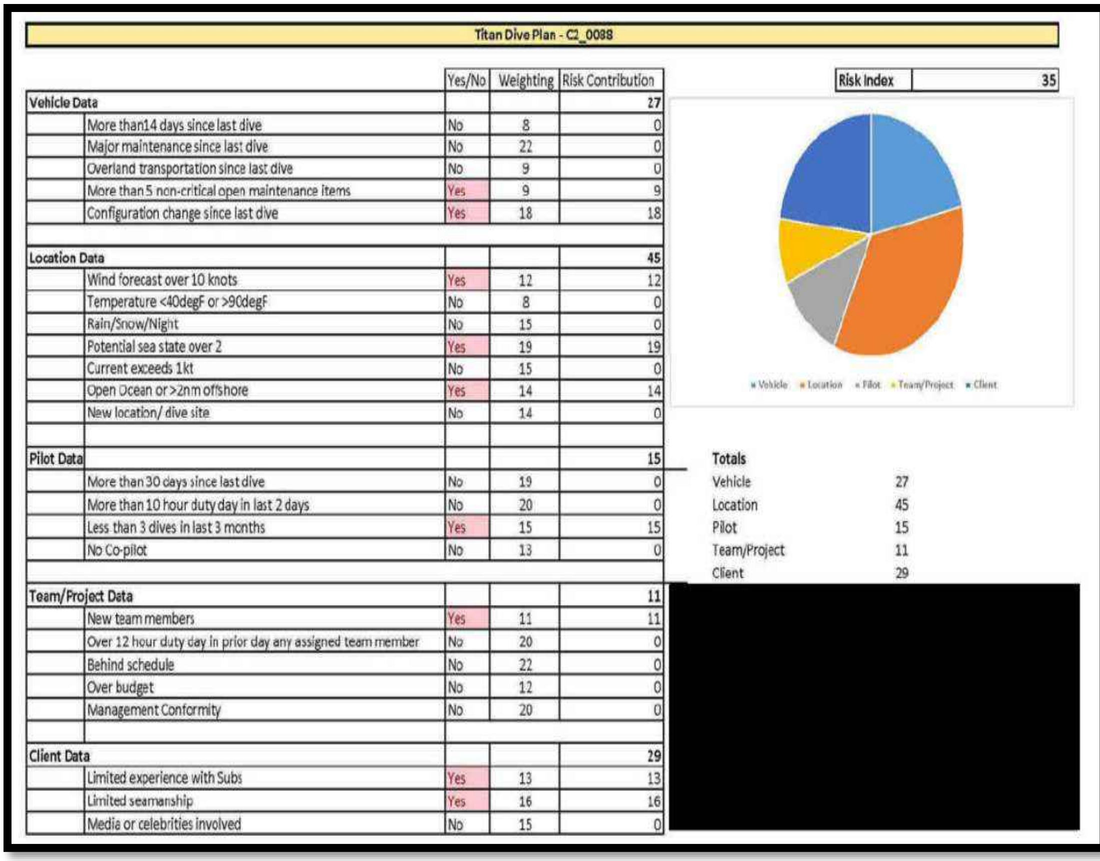
Figure 20: Photo of POLAR PRINCE Deck Log for June 18, 2023, taken by the MBI post-casualty. Source: USCG, June 25, 2023.

4.1.19. At 5:30 a.m., according to the TITAN Dive Plan C2_0088, a 15-minute Final Dive Brief was held in the helicopter-hangar. The helicopter-hangar was an area towards the aft of the POLAR PRINCE which was converted from a helicopter hangar to a social meeting area used for training. There was no helicopter onboard the POLAR PRINCE during the final TITAN expedition.

Figure 21: (left) Photo of POLAR PRINCE helicopter hangar; (right) inside of hangar taken by the MBI post-casualty. Source: USCG, June 25, 2023.

4.1.20. According to the OceanGate Project Execution Plan for the 2023 TITANIC Expedition, May 8, 2023, to June 24, 2023, the tasks to be completed during the Final Dive Brief were: sub weighing/loading calculations, dive plan completion, weather and sea state checks, and the final risk assessment. The OceanGate Project Execution Plan was a document that contained the project specific requirements and operational procedures for the 2023 TITANIC Expedition.

4.1.21. The Final Risk Index for Dive 88 was 35. The Risk Assessment according to the Dive Plan was as follows:



Titan Dive Plan - C2_0088

		Yes/No	Weighting	Risk Contribution
Vehicle Data				27
	More than14 days since last dive	No	8	0
	Major maintenance since last dive	No	22	0
	Overland transportation since last dive	No	9	0
	More than 5 non-critical open maintenance items	Yes	9	9
	Configuration change since last dive	Yes	18	18
Location Data				45
	Wind forecast over 10 knots	Yes	12	12
	Temperature <40degF or >90degF	No	8	0
	Rain/Snow/Night	No	15	0
	Potential sea state over 2	Yes	19	19
	Current exceeds 1kt	No	15	0
	Open Ocean or >2nm offshore	Yes	14	14
	New location/ dive site	No	14	0
Pilot Data				15
	More than 30 days since last dive	No	19	0
	More than 10 hour duty day in last 2 days	No	20	0
	Less than 3 dives in last 3 months	Yes	15	15
	No Co-pilot	No	13	0
Team/Project Data				11
	New team members	Yes	11	11
	Over 12 hour duty day in prior day any assigned team member	No	20	0
	Behind schedule	No	22	0
	Over budget	No	12	0
	Management Conformity	No	20	0
Client Data				29
	Limited experience with Subs	Yes	13	13
	Limited seamanship	Yes	16	16
	Media or celebrities involved	No	15	0

Risk Index	35

Totals	
Vehicle	27
Location	45
Pilot	15
Team/Project	11
Client	29

[redacted]

Figure 22: Dive Plan 88 (C2_0088) Risk Assessment Matrix. Source: OceanGate.

4.1.22. On June 18, 2023, at 5:48 a.m., as per the POLAR PRINCE Deck Logbook, the "accommodation stairs" were placed over the side of the vessel.

Figure 23: Accommodation stairs of the POLAR PRINCE. Source: Former OceanGate mission specialist.

4.1.23. At 5:58 a.m., MAX was launched from the POLAR PRINCE with dive gear and divers. MAX was a 16-foot Seamax® Rigid Hull Inflatable Boat (RHIB), used for operations on the water to ferry people from the launch platform to the vessel. MAX was crewed by the Dinghy Captain, Diver #1, Diver #2, and Dive Support. The MAX crew prepared the platform to support the TITAN dive.

Figure 24: Photo of OceanGate Rigid Hull Inflatable Boats, MAX and STEWIE, aboard the POLAR PRINCE taken by MBI post-casualty. Source: USCG, June 23, 2023.

4.1.24. At 6:24 a.m., STEWIE was launched from the POLAR PRINCE and transited to the LARS. The STEWIE was the same type of vessel as the MAX and was crewed by the STEWIE Captain, Platform Operator, and Platform Assistant. Also transiting on the STEWIE was the dome crew, which consisted of the Dome Close/Open Lead and two Dome Close/Open crew members.

Figure 25: Diver's loading small boat MAX prior to commencing pre-dive checks. Source: OceanGate.

4.1.25. According to the POLAR PRINCE Deck Logbook, the divers commenced their duties at approximately 6:30 a.m. and TITAN vessel checks commenced. In a statement provided by the Platform Operator, “Predive checks for the platform went well and it was ready to go for the planned time of launch.” The submersible predive checks were also completed and the call was made to bring over the crew of TITAN Dive 88 to start loading. Internal and external predive checks were detailed in the OceanGate Manned Submersible TITAN Operations Manual.

4.1.26. At 7:35 a.m., STEWIE was loaded with the Dive 88 crew to transport them to the LARS platform. The crew for Dive 88 was the Pilot, a TITANIC content expert, mission specialist #1, mission specialist #2, and mission specialist #3.

Figure 26*:* Small boat STEWIE transporting mission specialists to the LARS for Dive 88. Source: OceanGate.

4.1.27. At 8:30 a.m., the crew for Dive 88 were loaded into the TITAN and the forward dome was secured. According to the Dome Closing/Opening Lead, the closure was done in accordance with the OceanGate “Closing TITAN’s Dome with Air Caster Rev. A” procedure.

Figure 27: TITAN atop LARS moments before commencement of Dive 88. Source: OceanGate.

4.1.28. At approximately 8:57 a.m., prior to the submerging the LARS platform and the submersible TITAN, a 5-minute "stopski" was conducted. According to the OceanGate HSE Manual, a "stopski" is defined as:

> "A 5-minute delay in operations that shall be inserted before a major action is taken, such as commencing dive operations, lifting of manned vessels or other life critical activity. A stopski was a means of slowing a potentially fast paced, focused operation and permitting all members to review their equipment or role, to ensure all systems were safe and ready for launch."

4.1.29. The Platform Operator provided a written statement to the MBI which stated that, at approximately 9:04 a.m.:

> "Tanks on the platform were vented, and both platform and submersible descend to approximately 30 ft. The submersible then disengaged with the platform, maneuvered away and proceeded to dive. The platform was then returned to the surface. The small boat I was in was required to maintain position near the platform until the submersible gave notice to the bridge that they were passing 1,000 m, and all was good. This was the procedure in case the submersible needed to return to the surface."

Figure 28: Moments after TITAN atop LARS submerged for Dive 88. Source: OceanGate.

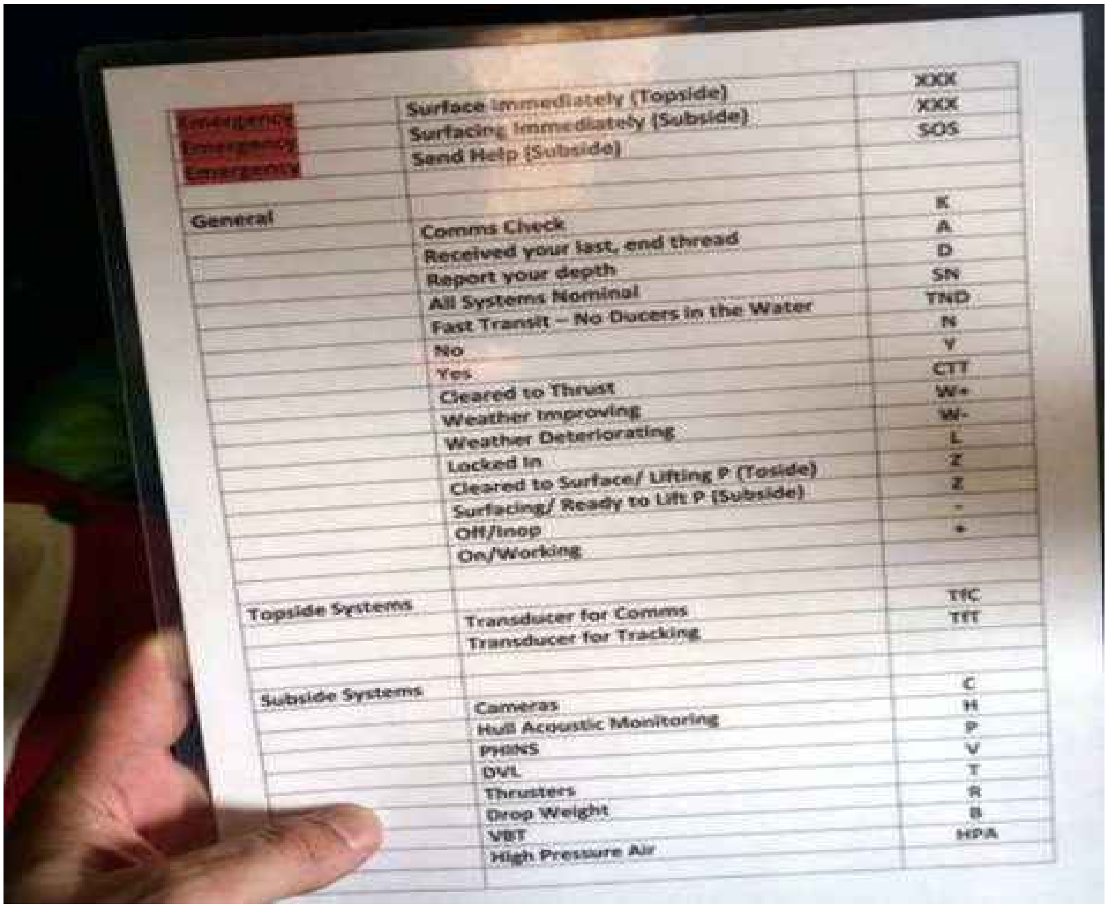
4.1.30. At 9:05 a.m., the TITAN was fully submerged atop the LARS.

4.1.31. At 9:14 a.m., according to the POLAR PRINCE Deck Logbook, the TITAN was disengaged from the LARS platform, maneuvered away, and proceeded to dive with five persons onboard.

Figure 29: LARS resurfacing after TITAN disengaged and commenced Dive 88. Source: OceanGate.

4.1.32. The POLAR PRINCE was fitted with an EvoLogics® Hydroacoustic Modem with Ultra Short Base Line (USBL), selected by OceanGate as TITAN'S sole communications equipment capable of subsurface communications. The installed system used abbreviated text fields to communicate between the POLAR PRINCE and the TITAN. The TITAN was not fitted with a voice communications system capable of communicating while the submersible was operating below the surface.

4.1.33. According to the OceanGate HSE Manual, the Mission Director was to ensure that communications checks were done every 15 minutes for the submersible and every other vessel engaged in operations. The submersible initiated the first set of communications followed by a response from the Mission Director. The POLAR PRINCE was able to track the TITAN and would provide text communication throughout the dive. Positional data was provided automatically from TITAN to the POLAR PRINCE every 5-10 seconds via the EvoLogics Hydroacoustic Modem.



Emergency	Surface Immediately (Topside)	XXX
Emergency	Surfacing Immediately (Subside)	XXX
Emergency	Send Help (Subside)	SOS
General	Comms Check	K
	Received your last, end thread	A
	Report your depth	D
	All Systems Nominal	SN
	Fast Transit – No Ducers in the Water	TND
	No	N
	Yes	Y
	Cleared to Thrust	CTT
	Weather Improving	W+
	Weather Deteriorating	W-
	Locked In	L
	Cleared to Surface/ Lifting P (Toside)	Z
	Surfacing/ Ready to Lift P (Subside)	Z
	Off/Inop	-
	On/Working	+
Topside Systems	Transducer for Comms	TFC
	Transducer for Tracking	TFT
Subside Systems	Cameras	C
	Hull Acoustic Monitoring	H
	PHINS	P
	DVL	V
	Thrusters	T
	Drop Weight	R
	VBT	B
	High Pressure Air	HPA

Figure 30: OceanGate communications sheet. Source: "CBS Sunday Morning" Correspondent.

4.1.34. The OceanGate support members that remained aboard the POLAR PRINCE were responsible for the communications (comms) and tracking of the TITAN. The members responsible were the Mission Director, Mission Director Support, Comms & Tracking, and Comms & Tracking Support #1 and #2.

4.1.35. This support team was situated in the bridge office located in the aft section of POLAR PRINCE's pilothouse. A door separated the bridge and the office that housed OceanGate's personnel and their communications and tracking gear.

Figure 31: POLAR PRINCE's bridge office, which served as the location for OceanGate's dive communications and support team. This space is an office just aft of the bridge. Photo taken by the MBI after the casualty on June 25, 2023. Source: USCG.

4.1.36. Other TITAN mission supporting roles included: dinghy deck coordinator, two deck supports, winch deck lead, charging/servicing lead, two charging/servicing team members, and two members responsible for media.

4.1.37. At 9:18:16 a.m., the POLAR PRINCE sent a "k" communication to the TITAN. According to the OceanGate Communications Sheet, "k" was the abbreviation used to request a "communications check." The approximate depth of the TITAN at the time was 165 m (541 feet). 44 seconds later, the TITAN requested a communications check with a communication of "k" to the POLAR PRINCE.

4.1.38. At 9:19:11 a.m., the POLAR PRINCE sent a communication of "a," which was an abbreviation used to acknowledge that they had "received your last, end thread." Eight seconds later, the TITAN responded to the comms check with the same, "a." The depth of the TITAN at this point was 206 m (675 feet).

4.1.39. At 9:19:36 a.m., the POLAR PRINCE communicated to the TITAN that they have tracking.

4.1.40. At 9:23:04 a.m., the TITAN communicated, "no atm are you on." The POLAR PRINCE responded with "atm is on," and "do not read you on ATM." The TITAN acknowledged with an "a." The depth of the TITAN at the time was 436 m (1,430 feet).

4.1.40.1. The "ATM" was an abbreviation for the acoustic telemetry modem. A device that uses sound waves to transmit data between underwater vehicles, such as submersibles, and surface equipment. Since radio waves do not travel well through water, these modems rely on acoustics to send and receive information, such as sensor readings, location data, and system status updates. Acoustic modems enable communication over long distances in the underwater environment, making them essential for real-time data transfer in applications like oceanographic research, deep-sea exploration, and subsea operations in the oil and gas industry.

4.1.40.2. The acoustic modems operate by encoding data into sound signals, which are transmitted through water and received by surface or underwater receivers. While acoustic modems provide crucial two-way text communications, they have limitations in terms of bandwidth, range, and susceptibility to interference from ambient noise. The communication range can vary depending on water conditions, but in ideal circumstances, they can transmit over several kilometers. However, the data rate is typically low, which restricts the types of information that can be sent.

4.1.41. At 9:28:35 a.m., the POLAR PRINCE texted, “we see you at 33 m/sec,” six seconds later, a follow-up was sent with a correction of “m/min.” This meant that the TITAN was descending at 33 m per minute through the water column.

4.1.42. At 9:31:30 a.m., the POLAR PRINCE stated, “have you at 680 meters”, the TITAN responded 2 minutes later, “Confirmed. Having trouble entering PO will ship I.”

4.1.43. At 9:53:51 a.m., there was a loss of communication between the TITAN and the POLAR PRINCE. Just prior to the loss of communication, the TITAN had noticeably veered off direct course of descent to the TITANIC location. The POLAR PRINCE sent the communication, “do you see Polar Prince on your display?” The TITAN did not respond, and the POLAR PRINCE sent the same message multiple times over the next 13 minutes.

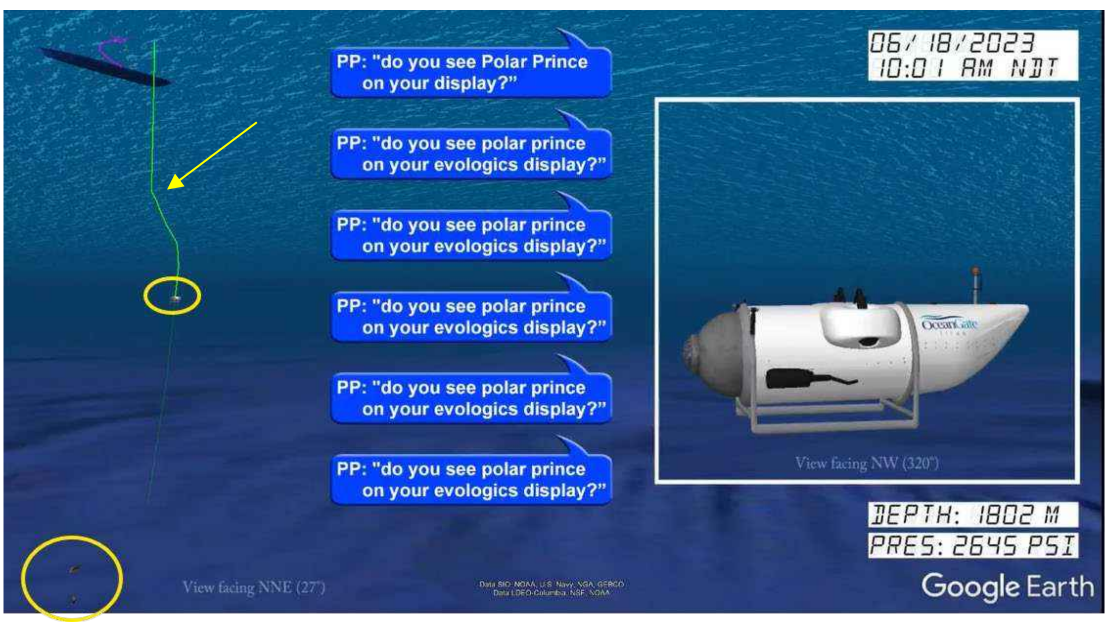


Figure 32: Excerpt of Coast Guard animation. The yellow arrow indicates the depth where TITAN veered off course and temporarily lost communications with the POLAR PRINCE. The yellow circle outlines TITAN and the bottom yellow circle outlines the TITANIC wreck site. Source: USCG Auxiliary.

4.1.44. At 10:08:40 a.m., the TITAN responded with “k”, meaning comms check. The POLAR PRINCE responded with, “do you see polar prince on your EvoLogics display?" Two minutes later the POLAR PRINCE sent a follow-up text directing that "I need better comms from you."

4.1.45. At 10:11:18 a.m., the TITAN responded, "yes," "lost system and chat settings," "this is ph." PH was an abbreviation indicating that TITAN's content expert was sending the submersible's communications. The POLAR PRINCE then messaged, "ack. status? Do you see polar prince on your display?" The TITAN responded, "yes," "all good here." The TITAN was descending during this text exchange from 2,203 m (7,227 feet) to 2,289 m (7,509 feet).

4.1.46. At 10:23.33 a.m., the TITAN texted, "poi orks we are east southeast of the nbow." Two minutes later POLAR PRINCE responded, "we see you east northeast of bow."

4.1.46.1. POI is an acronym for point of interest. The POLAR PRINCE would act as the point of interest and place itself directly above the desired location for the TITAN to navigate towards (in this case, the TITANIC's bow section).

4.1.47. At 10:29:12 a.m., the TITAN asked the POLAR PRINCE, "are you at the bow?" Nineteen seconds later, TITAN sent a follow-up text stating "rssi -60." The acronym RSSI stands for Received Signal Strength Indicator which is measured on a scale of zero to 100 with a strength of zero being the strongest signal. TITAN's indicated signal strength of 60 is generally considered to be an adequate signal, especially when considering the minimal data demands required for TITAN's text communications. The POLAR PRINCE responded, "polar prince not at bow. Making our way there." The POLAR PRINCE then texted, "your position jumps significantly each ping." To which the TITAN replied, "a." The depth of the TITAN was approximately 2,833 m (9,294 feet) at this time.

4.1.47.1. TITAN's intended operational plan was to track off of the position of the surface asset, in this case the POLAR PRINCE. The POLAR PRINCE would attempt to station itself above the bow of the TITANIC and the TITAN would navigate to their position and then use sonar to locate the wreck of the TITANIC.

4.1.48. At 10:36:50 a.m., the POLAR PRINCE texted, "remember to write down the location and time of Niskin[6] deployment." Four minutes later the TITAN messaged, "no Niskin. Never cleaned and string baf." The depth of the TITAN was 3,149 m (10,331 feet) at the time.

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[6] Niskin bottles are used for collecting water samples at various depths to measure physical characteristics such as salinity, dissolved oxygen nutrient concentrations, and dissolved organic and inorganic carbon.

4.1.49. At approximately 10:47:02 a.m., the TITAN sent a message to the POLAR PRINCE, stating, "dropped two wts."[7] The depth of the TITAN was 3,341 m.

4.1.50. At approximately 10:47:08 a.m., the TITAN transmitted its final ping via EvoLogics SiNAPS Data to the POLAR PRINCE; the TITAN was located at 41° 44.06' N; 049° 56.54'W at a depth of 3,346.28 m (10,978 feet).

4.1.51. At approximately 10:47:09 a.m., the TITAN submersible suffered a catastrophic implosion due to the loss of structural integrity of its pressure vessel, resulting in the instantaneous death of all five occupants.

4.1.52. At 10:47:11 a.m., the TITAN communications and tracking team, while in the chart room in the aft section of the POLAR PRINCE bridge, heard a sound described by the leader for communications and tracking as a "bang". Upon hearing the noise, the leader turned to another OceanGate employee assisting with the comms and tracking and stated, "What was that bang?". The assistant did not respond to the question and the MBI was unable to find evidence of any further discussions of the "bang" heard on the bridge of the POLAR PRINCE.

4.1.53. When asked by the MBI if the Master of the POLAR PRINCE had heard or felt anything around the time of the loss of communications with TITAN, the Master provided the following written response: "With the benefit of hindsight, I now believe I felt the POLAR PRINCE shudder at around the time communications were reportedly lost, but at the time we thought nothing of it…it was slight."

Figure 33: Still frame captured from a video of the OceanGate Communications and Tracking Team after a sound was heard coming from outside. The leader of the Communications and Tracking Team is seated on the left. Source: OceanGate.

4.1.54. At 10:47:26 a.m., the communications and tracking team on the POLAR PRINCE received a message from the TITAN, stating, "dropped two wts." The depth of

[7] "wts" means weights that were fitted on the exostructure of the TITAN. Under normal operating procedures, weights were released to slow the descent to the intended operating depth or begin the ascent back to the surface.

the TITAN was approximately 3,341 m. This was the last message that was sent from the TITAN.

4.1.54.1. The MBI determined that the text transmissions between the TITAN and the POLAR PRINCE had an approximate 15 to 30 second delay from when TITAN sent a message to when it was received and displayed on the console being used by the communications and tracking team.

4.1.54.2. The transmission “dropped two wts” means that the TITAN released two of its drop weights. The TITAN was fitted with drop weights which were used to slow their descent and neutralize buoyancy while at or approaching depth. Multiple OceanGate employees confirmed to the MBI that dropping two weights at this depth was likely done to slow the TITAN’s descent as it approached the seafloor and that the dropping of two weights was not an obvious indicator that the TITAN was attempting to make an emergency ascent.

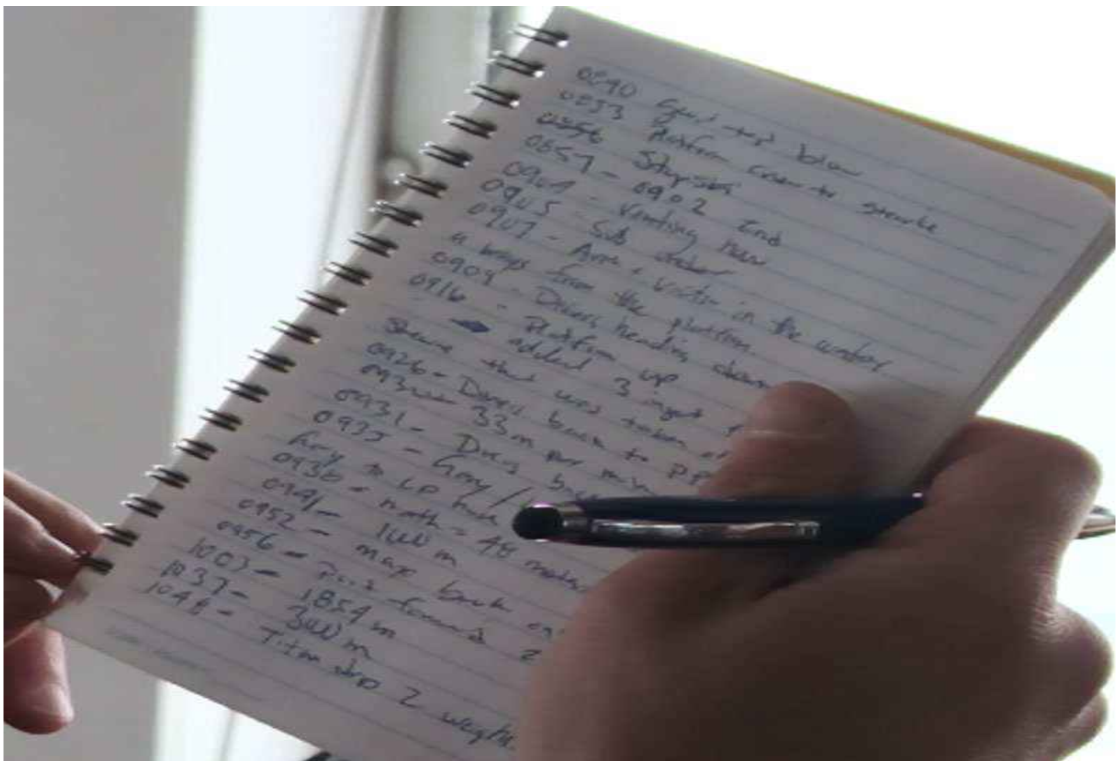

Figure 34: Image of Mission Director notebook. Source: OceanGate.

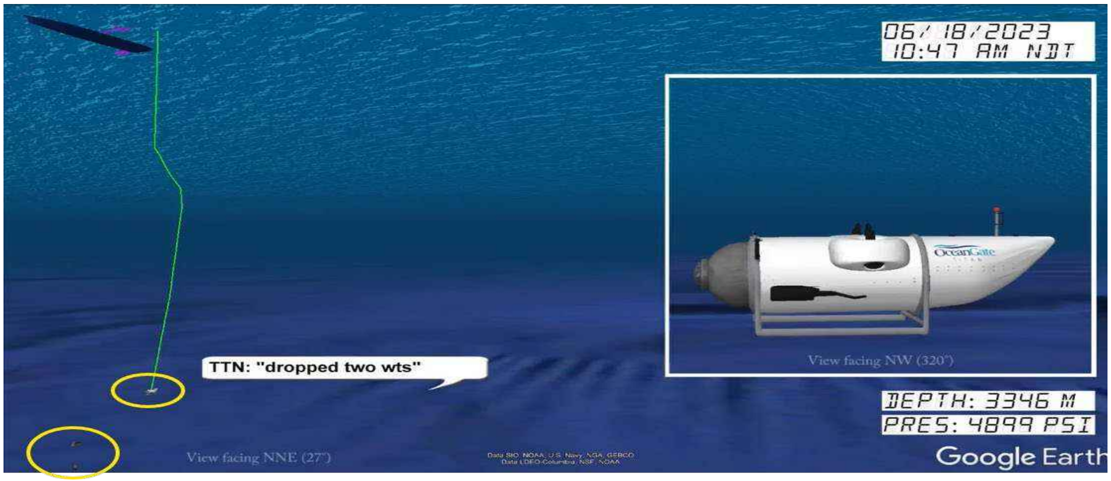

Figure 35: Excerpt of Coast Guard animation at time and location of final message from TITAN. Source: Coast Guard Auxiliary.

4.1.55. At 10:47:32 a.m., the POLAR PRINCE received the ping that was sent at 10:47:08 a.m. from the TITAN (this would be the last TITAN ping). The TITAN's location was 41˚ 44.06' N; 049˚ 56.54'W (as per EvoLogics SiNAPS Data) at a depth of 3,346.28 m (10,978 feet).

4.1.56. When asked by the MBI if the Master of the POLAR PRINCE had heard or felt anything around the time of the loss of communications, the Master provided the following written response: "With the benefit of hindsight, I now believe I felt the Polar Prince shudder at around the time communications were reportedly lost, but at the time we thought nothing of it…it was slight."

4.1.57. At 10:49:11 a.m., approximately two minutes after hearing the "bang", an OceanGate employee assisting with comms and tracking pointed to the tracking computer and stated, "we have lost tracking." The team leader for the communications and tracking team then stated, "for two minutes." The loss of tracking time corresponds with the time of the "bang" sound that was heard. The OceanGate communications and tracking team then sent several messages to the TITAN stating, "lost tracking" and requesting that the TITAN's crew increase the power to their EvoLogics modem. There were no further responses from TITAN.

4.1.58. At approximately 10:51 a.m., the communications and tracking team leader called the Mission Director into the bridge office and notified him that they had not had communications and tracking for four minutes. The team leader also confirmed that tracking had been reliable up until the point where communications and tracking were lost.

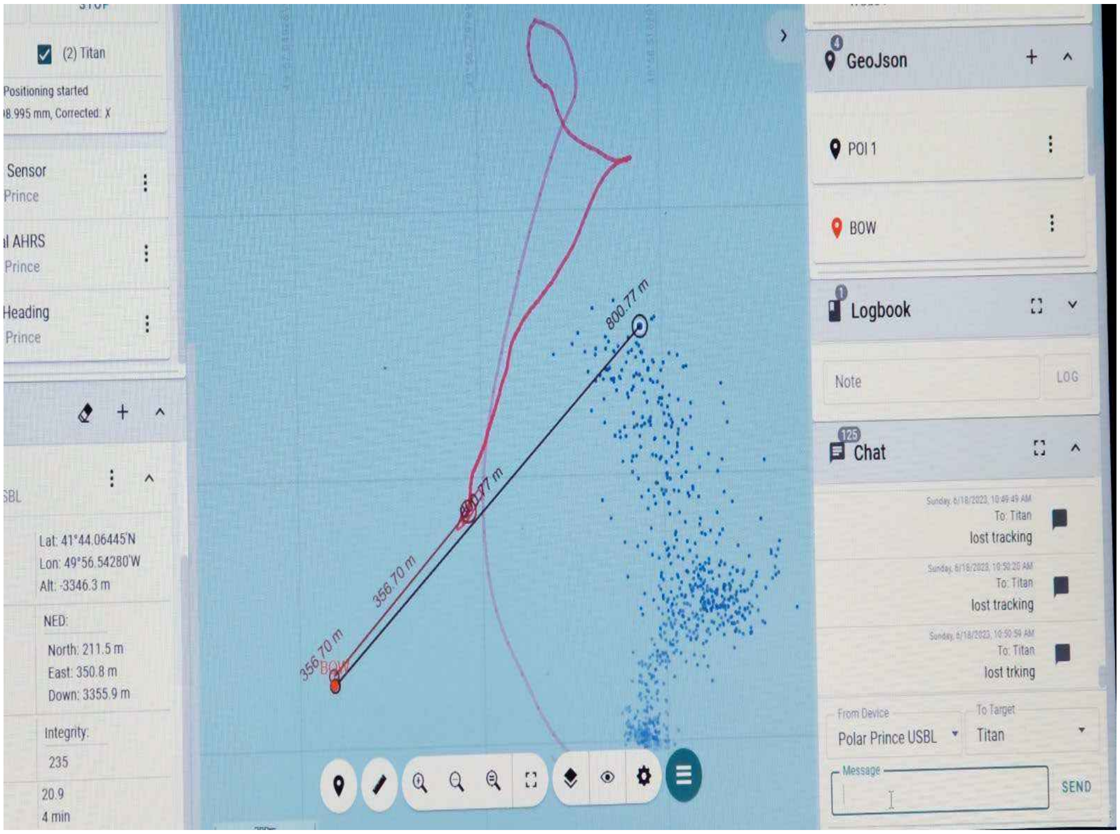

Figure 36: Image of the EvoLogics tracking computer display when the Mission Director was notified of the loss of communications and tracking of the TITAN. Source: OceanGate.

4.1.59. At 11:15 a.m., the Master of the POLAR PRINCE was advised that as of approximately 10:47 a.m., there was a loss of communication with the TITAN. The Master of the POLAR PRINCE stated in a written response to the MBI that, "this was not perceived to be an emergency by OceanGate and that was communicated to me." An entry was then made into the POLAR PRINCE logbook, it stated "1047 lost communication with TITAN."

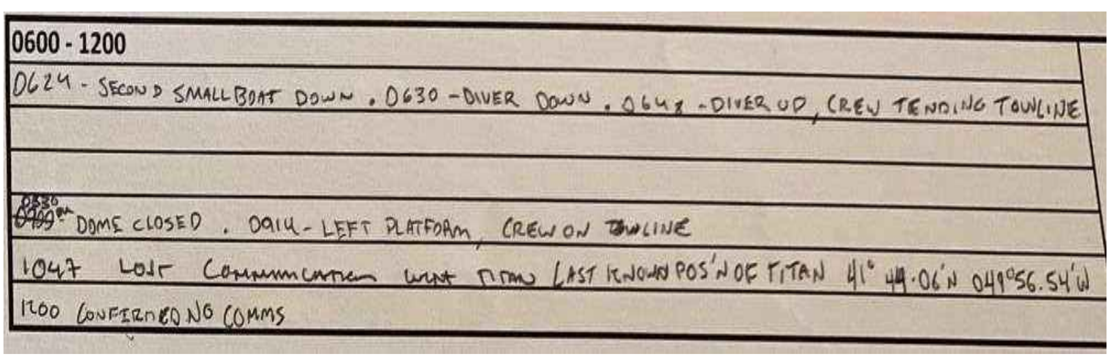
0600 - 1200
0624 - SECOND SMALL BOAT DOWN. 0630 - DIVER DOWN. 0648 - DIVER UP, CREW TENDING TOWLINE
0830 DOME CLOSED. 0914 - LEFT PLATFORM, CREW ON TOWLINE
1047 LOST COMMUNICATION WITH TITAN LAST KNOWN POS'N OF TITAN 41° 44.06'N 049°56.54'W
1200 CONFIRMED NO COMMS

Figure 37: Photo of the POLAR PRINCE Logbook entry for 0600-1200 watch on June 18, 2023, taken by the MBI post-casualty. Source: USCG, June 25, 2023.

4.1.60. According to the Mission Director, OceanGate personnel onboard the POLAR PRINCE followed the missed communications protocol outlined in the OceanGate HSE Manual, which stated the following:

- 15-minute communications check missed (note as missed comms).
- 30-minute communications check missed (note as lost comms).
- 45-minute communications check missed (note as lost sub) additional 15 minutes will be given for appropriate action to be taken.
- Internal contacts and backup personnel will be called following 1 hour of no communications plus required surface time from last known or assumed bottom depth of location.
- An additional 3 hours of local surface search will be done before contacting outside emergency personnel unless circumstances merit a shorter delay.
- A grid search pattern will be done by surface vessel as directed by the Mission Director.

4.1.61. The POLAR PRINCE sent two to three messages every minute until 2:50:09 p.m. None of the messages were answered and the TITAN's location was never reacquired by the POLAR PRINCE.

4.1.62. According to the Mission Director, in accordance with the OceanGate HSE procedures, based upon the last known position of the TITAN and given an anticipated two meter per minute ascent rate, the TITAN was expected to surface at approximately 3:00 p.m.

4.1.63. When the TITAN did not surface, OceanGate followed their HSE procedure, and the POLAR PRINCE began a grid pattern surface search. The grid pattern search resulted in negative sightings.

4.1.64. The Master of the POLAR PRINCE provided the following statement,

> "At (6:27 p.m.) following a meeting in my cabin with amongst others OceanGate staff (REDACTED names[8]), I called the Joint Rescue Coordination Centre (JRCC) Halifax by sat phone but communications with JRCC were shortly thereafter cut-off. When I reestablished communications, I was informed by JRCC that the area of the TITANIC wreck is under the Search and Rescue jurisdiction of Rescue Coordination Center (RCC) Boston[9]."

4.1.65. At 7:10 p.m., on June 18, 2023, in accordance with OceanGate Loss of Communications protocol, after three hours (approximately seven hours and 23 minutes after the last communication) of searching the surface with negative results, the POLAR PRINCE contacted the Canadian Coast Guard. The Canadian Coast Guard referred them to the USCG RCC Boston, due to the TITANIC wreck site being located within RCC

[8] Names redacted by MBI.

[9] RCC Boston is the USCG Rescue Coordination Center in Boston. The RCC BOSTON area of responsibility extends into the Atlantic Ocean, covering the Wreck of the TITANIC.

Boston's area of responsibility. Upon receiving the notification, the First Coast Guard District Command Center entered the distress phase[10].

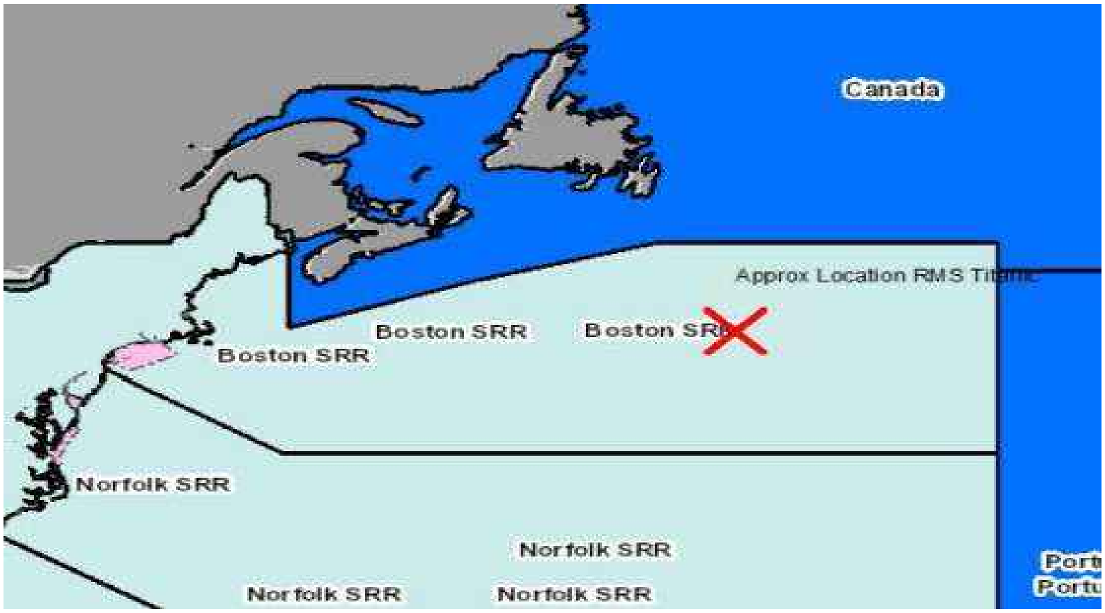

Figure 38: USCG RCC Boston's Search and Rescue Area of Responsibility is depicted showing the approximate location of the TITANIC wreck site. The SAR zones depicted extend out to the high seas well beyond U.S. and Canadia territorial waters. The Canadian Search and Rescue Area depicted in the Figure falls under the responsibility of JRCC Halifax. Source: USCG.

4.1.66. The on-scene commander role was initially designated to the POLAR PRINCE by RCC Boston, due to being the only vessel on scene. The United States Coast Guard First District was not aware of the TITAN's TITANIC Expedition dive operations on this date, or any other previous dive operation at the TITANIC wreck site.

4.1.67. According to Coast Guard officials, prior to launching the C-130, the Coast Guard's first attempt to coordinate search and rescue efforts were directed to the POLAR PRINCE. However, the POLAR PRINCE told the Coast Guard they were taking their tasking from OceanGate's Mission Director and were not going to do any active surface searching directed by the USCG. On June 18, 2023, at 10:00 p.m., the USCG Ice Patrol C-130 fixed wing aircraft was the first asset deployed from Newfoundland, later to be joined by P-3 aircraft with sonobuoys.

4.1.68. RCC Boston established a multi-agency, multinational Incident Management Team to coordinate resources, analyze data, and oversee remotely operated vehicle (ROV) operations. A USCG officer testified that no single agency or country possessed all the necessary assets, requiring collaboration between public and private sectors. The Undersea Rescue Command (San Diego), the International Submarine Escape and Rescue Liaison Office (ISMERLO), U.S. Navy, and Canadian Coast Guard worked together to source available ROVs.

[10] Distress Phase: The DISTRESS phase exists when grave or imminent danger, requiring immediate response on- scene to the distress site, threatens a watercraft or person. https://www.dco.uscg.mil/Portals/9/CG-5R/manuals/COMDTINST%20M16130.2F.pdf

4.1.69. On June 19, OceanGate contacted the U.S. Air Force's RCC for emergency transportation of a Pelagic® Odysseus ROV from Buffalo, NY—an asset not originally included in OceanGate's emergency response plan. The U.S. Air Force Reserve's 910th Air Wing airlifted Odysseus aboard a C-130 to Newfoundland. Meanwhile, the HORIZON ARCTIC, which had initially departed St. John's on June 18 at 9:00 p.m., returned to port before reaching the accident site. The vessel was quickly modified to accommodate and deploy Odysseus, departing again at 05:00 a.m. on June 21. SAR personnel testified that what would typically take two weeks—mobilizing an ROV, modifying a vessel, and assembling a crew—was achieved in days.

Figure 39: Surface search and aviation assets that responded to the search and recover efforts for the TITAN. Source: USCG.

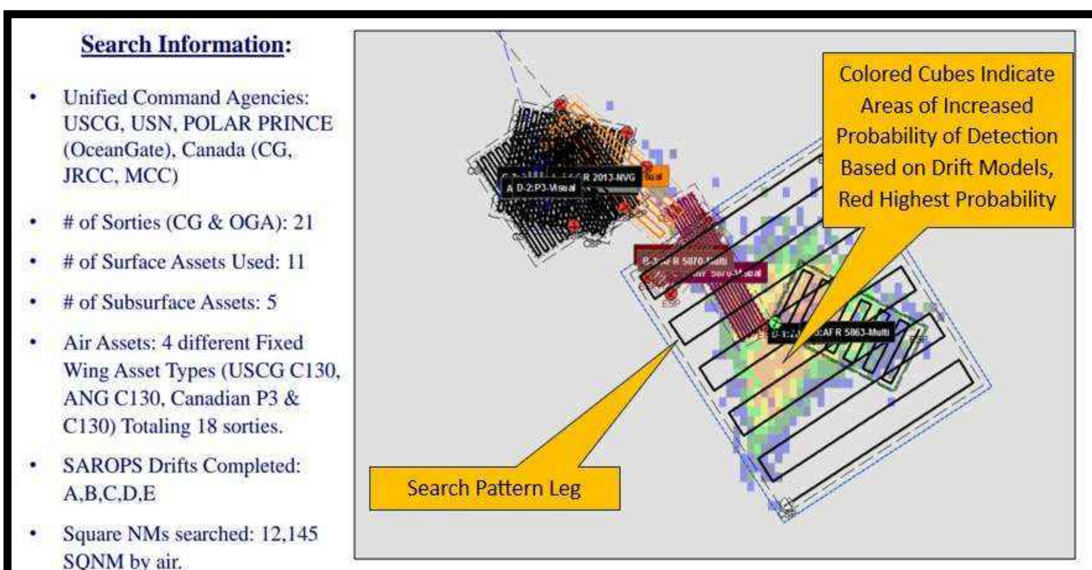

Figure 40: USCG briefing slide detailing searches conducted for the TITAN and its passengers. Source: USCG.

4.1.70. On June 20, 2023, at 05:17 a.m., the pipe laying vessel DEEP ENERGY, the first ROV capable vessel arrived on scene with ROVs. Over the course of the next few days, 11 vessels and 4 aircraft were used to search 12,145 square miles.

4.1.71. The French research vessel ATALANTE responded from mid-ocean, carrying the 6,000-meter-capable ROV VICTOR 6000. A 100-member ROV crew was flown to Newfoundland and transported by the Canadian Coast Guard's ANN HARVEY, where they rendezvoused with ATALANTE early on June 22. The ATALANTE and HORIZON ARCTIC arrived at TITAN's last known location and commenced search operations.

4.1.72. On June 22, 2023, at approximately 09:40 a.m., the Pelagic Research Services Odysseus ROV, deployed from the HORIZON ARCTIC, discovered the aft tail cone and other debris of the TITAN on the seafloor after an extensive search. This discovery provided conclusive evidence of the catastrophic loss of the TITAN and the death of the five individuals aboard.

Figure 41: ROV image of TITAN aft tail cone. Source: Pelagic Research Services, June 2023.

4.2. Additional Supporting Information

4.2.1. Coast Guard Investigation Authority Over OceanGate and the TITAN Incident

4.2.1.1. A "marine casualty or accident" under 46 CFR § 4.03-1 is defined as a casualty or accident that involves "any United States vessel wherever such casualty or accident occurs." Per 46 CFR § 4.40-5, which prescribes the joint NTSB and USCG regulations for the investigation of major marine casualties, a "vessel of the United States" is defined, in part, as a vessel that is "owned in the United States" or "owned by a citizen of the United States and not registered under a foreign flag." Further, a major marine casualty is defined in 46 CFR § 4.40-5 as a casualty that results in property damage initially estimated at $500,000 or more or which poses a "serious threat, as determined by the

Commandant and concurred in by the Chairman,[11] to life, property, or the environment by hazardous materials."

4.2.1.2. The USCG had jurisdiction to investigate this incident because the TITAN was a U.S. vessel owned in the United States by OceanGate, Inc., a company based in Everett, Washington, and was involved in a marine casualty or accident that resulted in a material failure which impaired the vessel's operation, affected the vessel's seaworthiness, and resulted in the loss of multiple lives per 46 CFR § 4.03-1(b). The casualty also constituted a major marine casualty due to the complete loss of the submersible vessel, which was valued at more than $500,000. Additionally, the deep-sea operation of the TITAN and any similarly configured vessels pose a serious threat to life, property, and the environment.[12]

4.2.2. Coast Guard Inspections Authority

4.2.2.1. The TITAN was considered a vessel of the United States, as per 46 USC § 116. The term vessel of the United States means a vessel documented under Chapter 121 of this title (or exempt from documentation under Section 12102(c) of this title), numbered under Chapter 123 of this title, or titled under the law of a State. The small passenger inspection regulations in 46 CFR § 175.400 define a "vessel of the United States" as a vessel documented under Chapter 121 of this title . . . . or titled under the law of a State." Per 46 USC § 3101, a small passenger vessel is subject to inspection under applicable regulations under 46 CFR subchapter T, parts 175-185. Per 46 CFR § 175.110, subchapter T regulations apply to a submersible vessel (also defined in 46 USC § 2101(47)) operated with at least one passenger for hire.

4.2.2.2. The submersible vessel TITAN was owned and operated in the state of Washington, thus subjecting it to Washington state vessel registration. OceanGate operated its other submersibles with passengers for hire, and the TITAN submersible operated with passengers for hire, thus subjecting the TITAN to inspection per 46 USC § 3301 and the applicable regulations in 46 CFR subchapter T.

4.2.2.3. OceanGate did not submit an Application for Inspection (CG Form Number 3752) to the USCG, nor was the TITAN ever issued a Certificate of Inspection (COI) to serve as a small passenger vessel.

4.2.2.4. Per 46 USC § 3301 a "small passenger vessel" is subject to inspection under this part.

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[11] The term "Chairman" refers to the Chair of the National Transportation Safety Board.

[12] In addition, the Coast Guard has authority to investigate a marine casualty involving a United States citizen on a foreign passenger vessel under 46 USC § 6101(e) and 46 USC Chapter 63 and the regulations promulgated thereunder in 46 CFR Part 4.

4.2.2.5. Per 46 USC § 2101(47)(D), a "small passenger vessel" is as a vessel less than 100 gross tons that is a submersible vessel carrying at least one passenger for hire.

4.2.2.6. Per 46 USC § 2101(49), a "submersible vessel" is a vessel that is capable of operating below the surface of the water.

4.2.2.7. Per 46 USC § 2101(29), a "passenger" is an individual carried on the vessel except the following- (i) the owner or an individual representative of the owner or, in the case of a vessel under charter, an individual charterer or individual representative of the charterer; (ii) the master; or (iii) a member of the crew engaged in the business of the vessel who has not contributed consideration for carriage and who is paid for on board services.

4.2.2.8. Per 46 USC § 2101(30), a "passenger for hire" is defined as a passenger for whom consideration is contributed as a condition of carriage on the vessel, whether directly or indirectly flowing to the owner, charterer, operator, agent, or any other person having an interest in the vessel.

4.2.2.9. Per 46 USC § 2101(5), "consideration" is an economic benefit, inducement, right, or profit including pecuniary payment accruing to an individual, person, or entity, but not including a voluntary sharing of the actual expenses of the voyage, by monetary contribution or donation of fuel, food, beverage, or other supplies.

4.2.2.10. Per 46 USC § 2101(4), "commercial service" includes any type of trade or business involving the transportation of goods or individuals, except service performed by a combatant vessel.

4.2.2.11. Per 33 CFR § 1.01-20(a), Officers in Charge, Marine Inspection (OCMIs) have been designated and delegated to perform, within each OCMI's jurisdiction, the following functions: Inspection of vessels in order to determine that they comply with the applicable laws, rules, and regulations relating to safe construction, equipment, manning, and operation and that they are in a seaworthy condition for the services in which they are operated; shipyard and factory inspections; the investigation of marine casualties and accidents; the licensing, certificating, shipment and discharge of seamen; the investigating and initiating of action in cases of misconduct, negligence, or incompetence of merchant marine officers or seamen; and the enforcement of vessel inspection, navigation, and seamen's laws in general.

4.2.2.12. Per 46 CFR § 175.100, the purpose of "subchapter T" is to implement applicable sections of Subtitle II of Title 46 USC, which require the inspection and certification of small passenger vessels. The regulations in this subchapter have a preemptive effect over State or local regulations in the same field.

4.2.2.12.1. While submersibles that carry at least one passenger for hire are subject to 46 CFR subchapter T, the USCG does not have inspection standards applicable to the design or construction of submersible vessels. As a submersible's size, means of propulsion, nature of operation, and cargo carried (if any) are similar to those on surface vessels, as regulated under 46 CFR, the appropriate standards are applied to ensure a degree of safety equivalent to that obtained on surface vessels. U.S. Coast Guard Navigation and Vessel Inspection Circular (NVIC) NO. 5-93 GUIDANCE FOR CERTIFICATION OF PASSENGER CARRYING SUBMERSIBLES provides guidance for certification of passenger carrying submersibles under 46 CFR subchapter T - Small Passenger Vessels. This NVIC is intended to outline a basis for determining equivalency of U.S. passenger carrying submersibles to conventional small passenger vessels. Since the applicable regulations were developed primarily with surface craft in mind, many specific features cannot be applied to or may otherwise be inappropriate for a submersible. The USCG's current compliance approach to the novel design and unique operational hazards of passenger submersibles is to require a level of safety equivalent to that required for a surface craft of similar size and service for owners pursuing a COI to operate as a small passenger vessel. To assist prospective owners with the process of certifying a novel design, the USCG's Office of Design and Engineering Standards (CG-ENG) issued CG-ENG Policy Letter 01-23 to provide owners and operators with guidance on how to submit design standard equivalencies for consideration as a Design Basis Agreement (DBA).

4.2.2.12.2. Through the DBA process, the USCG evaluates alternate arrangement or novel design proposals to ensure that the arrangement, fitting, appliance, apparatus, equipment, calculation, information, or test provides a level of safety equivalent to that established by applicable regulatory standards. If approved, a DBA serves as a standards framework for the design, plan review, inspection, and certification of novel vessels or floating facilities.

4.2.2.13. Per 46 USC § 2101 (24), an "Oceanographic Research Vessel" is a vessel that the Secretary[13] finds is being employed only in instruction 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. Vessels of less than 300 gross registered tons (GRT) may be designated as uninspected Oceanographic Research Vessels (ORVs) by the local OCMI in accordance with 46 CFR Part 3.

[13] In 46 USC § 2101, the "Secretary" refers to the Secretary of the department in which the Coast Guard is operating, which is currently the Department of Homeland Security (DHS).

4.2.2.13.1. After determining that such a vessel is employed exclusively in oceanographic research, the OCMI must issue a Letter of Designation that is valid for a period of two years. This letter designates the vessel as an ORV and advises the owner/operator that the vessel must maintain exclusive operations in oceanographic/limnologic research or instruction and that any deviation from such exclusive use, such as carriage of freight or passengers, would constitute a violation of the inspection statutes. USCG policy for ORVs does not require a USCG inspector to visit a submersible or surface vessel in person prior to issuing the two-year ORV designation letters.

4.2.2.13.2. As of October 5, 2023, there were 309 surface vessels, and no submersibles designated as ORVs by the USCG.[14]

4.2.2.14. Although OceanGate had requested ORV letters for the other two submersibles they owned and operated, the company did not request a Letter of Designation from the Coast Guard requesting that the TITAN be designated as an ORV. As a result, an ORV Letter of Designation was never issued for TITAN.

4.2.2.15. The USCG is the nation's lead federal agency charged with the superintendence of the U.S. Merchant Marine and steward for the associated International Conventions. In executing these responsibilities, the USCG prescribes regulations and develops policies to ensure that inspected and certain uninspected vessels are safely manned with qualified and competent mariners.

4.2.2.15.1. 46 CFR Parts 1-40 does not recognize nor require a merchant mariner credential (MMC) specific to the operation of a submersible. However, 46 CFR §11.201(l) clarifies that the Coast Guard may modify the service and examination requirements in this part to satisfy the unique qualification requirements of an applicant or distinct group of mariners. As an example, the Coast Guard may also lower the age requirement for OUPV[15] applicants. The authority granted by an officer endorsement on a MMC will be restricted to reflect any modifications made under the authority of this paragraph. The local OCMI is responsible for determining MMC criteria specific to their area of operation and for imposing those limitations to increase the safety of the

[14] Prior to the incident, the ANTIPODES and CYCLOPS I were the only two submersible operating with USCG issued ORV Letter of Designation. Following the incident, OceanGate sold both submersibles and their Letters of Designation have been invalidated by the USCG.

[15] An "operator of an uninspected passenger vessel (OUPV)" is an individual who is credentialed by the USCG and responsible for the direction and control of an uninspected passenger vessel (UPV), which is a surface vessel that carries six or fewer passengers for hire and is not subject to the same level of inspection requirements as inspected passenger vessels. Submersibles carrying at least one passenger for hire are required to be inspected. Thus, an OUPV credential would never be permitted for a submersible operator.

operation. For example, the Sector Honolulu OCMI imposes local limitations for passenger submarine[16] operations conducted by Atlantis Submarines Hawaii LLC, which operates USCG certified small passenger submersibles in the Fourteenth Coast Guard District.

4.2.2.15.2. At the time of the casualty, Mr. Richard Stockton Rush III held a USCG issued Master of 25 GRT Inland MMC, obtained on March 16, 2020. The attainment of his credential was directly influenced by OceanGate's communication to the National Maritime Center in 2020, wherein OceanGate falsely declared the TITAN submersible's gross tonnage to be 26 GRT in order to ensure that Mr. Rush had the requisite sea time on a sufficiently sized vessel to obtain his credential.

4.2.2.15.2.1. Following the incident, the MBI requested a tonnage estimate for the TITAN from the USCG Marine Safety Center. Due to the absence of detailed plans necessary for precise calculations, an official admeasurement could not be performed. However, an informal assessment estimated TITAN's gross tonnage to be 4 GRT.

4.2.3. International Regulations

4.2.3.1. The IMO is a specialized agency of the United Nations responsible for globally regulating maritime transport. Passenger ships that carry more than 12 passengers and operate on international voyages must comply with all relevant IMO standards, including safety regulations and requirements for the prevention of pollution from ships. The TITANIC disaster of 1912 led to the first International Convention for the Safety of Life at Sea (SOLAS) treaty being adopted and there have been many revisions to maritime safety regulations since then, both in response to major incidents and because of a proactive approach to keeping the regulations up to date. Generally, the SOLAS treaty applies to cargo ships of 500 gross tons or more operating internationally and passenger ships carrying more than 12 passengers on international voyages.

4.2.3.2. SOLAS specifies minimum standards for the safe construction, equipment, and operation of merchant ships operating internationally. No mandatory regulations exist within SOLAS, specifically relating to the operation of passenger submersibles, because they do not fall under the current application provisions of the Convention.

4.2.3.3. The IMO has developed and issued guidelines on the design, construction, and operation of passenger submersible craft (see Marine Safety

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[16] Submarines are defined as underwater vessels capable of conducting voyages independently without the assistance of a support vessel. Submersibles require a support vessel for transit, launching, and recovery at a dive site.

Committee (MSC).1/Circ.981), which provide internationally agreed safety standards for their design and operation. The Guidelines are applicable to submersible craft adapted to accommodate passengers and are intended for underwater excursions with the pressure in the passenger compartment at or near one atmosphere.

4.2.4. Classification Societies / "Third Party" Surveyors

4.2.4.1. The purpose of a Classification Society is to develop and apply its rules for construction and maintenance of ships (structural, engineering, and mechanical system), and perform statutory certification as a Recognized Organization (RO) acting on behalf of a Flag Administration. The U.S. authorizes ROs to conduct compliance related functions on behalf of the U.S. Flag Administration.

4.2.4.2. The role of classification and Classification Societies has been recognized in SOLAS and in the 1988 Protocol to the International Convention on Load Lines. Flag administrations, like the USCG, rely on Classification Societies as technical experts to ensure vessels meet the standards outlined within their rules, which meet or exceed the regulatory standards. Nine of the following 12 Classification Societies (except the Croatian Register of Shipping, the Indian Register of Shipping, and the Polish Register of Shipping) have specified Rules that could have been applicable to the design and construction of a submersible, like the TITAN, had OceanGate elected to have their vessel "classed." More than 50 organizations around the world offer classification services. The following 12 Class Societies are members of the International Association of Class Societies (IACS).

Figure 42: All IACS Approved Classification Societies, Source: https://iacs.org.uk/class-activities/iacs-members.

4.2.4.3. IACS' mission is to establish, review, promote, and develop minimum technical requirements in relation to the design, construction, maintenance and survey of ships and other marine related facilities. IACS also works to assist international regulatory bodies and standard organizations to develop, implement and interpret statutory regulations and industry standards in ship design, construction and maintenance with a goal of improving safety at sea and marine environmental protection.

4.2.4.4. American Bureau of Shipping (ABS) Classification Society Background

4.2.4.4.1. The ABS Classification process for submersibles includes the following steps:

4.2.4.4.1.1. Rule Development: Establish and maintain recognized technical standards known as the "Rules."

4.2.4.4.1.2. Design Review: Check that the design of the submersible is in compliance with the Rules.

4.2.4.4.1.3. Material and Equipment: Certify that the material and equipment that will be incorporated into the vessel complies with Rule requirements.

4.2.4.4.1.4. New Construction Surveys: Check that the submersible is built and tested per the Rules.

4.2.4.4.1.5. Surveys After Construction: Check that the submersible is maintained in compliance with the Rules throughout its life cycle (i.e., this process is commonly referred to as "maintaining class" in the maritime industry.)

4.2.4.4.2. At the time of the incident, ABS had extensive experience with underwater units since the 1960s and they had classed approximately 100 submersibles worldwide. Currently, ABS has 30 submersibles in class. Other underwater units currently classed worldwide with ABS include: 43 Saturation, Mixed Gas and Air Diving Systems,1 Submarine Rescue System - Handling System,1 Undersea Habitat, and 3 Hyperbaric Facilities.

4.2.4.4.3. ABS classed OceanGate's first submersible, ANTIPODES, as ABS A1.

4.2.4.4.3.1. The submersible was built in 1973 as the diver-lock out submersible PC-1501 by Perry Submarine Builders, which was classed with ABS.

4.2.4.4.3.2. The submersible has a steel pressure hull (ASTM A537 Class 1) and is designed for a depth of 305 meters of seawater (MSW) (1,000 feet of seawater (FSW)). Operated for several years in the North Sea oil fields of Europe transporting commercial divers.

4.2.4.4.3.3. The PC-1501 was sold in 1988 and had major modifications conducted from 1995 to 1997 under ABS survey protocols. During that time, it was converted to a 5-person submersible, which included the removal of the diver-lockout compartment. The submersible was rechristened as the XPC-15.

4.2.4.4.3.4. The XPC-15 was sold in 1999 and renamed as the ANTIPODES.

4.2.4.4.3.5. Modifications were conducted in 1999 under the ABS survey to increase the submersible's electrical and life support capacity. The ANTIPODES conducted tourist dives in Milford Sound, New Zealand and it maintained ABS class during this period.

4.2.4.4.3.6. The XPC-15 was purchased by OceanGate in 2009 as an ABS classed submersible.

4.2.4.4.4. ABS had no involvement with OceanGate's deep sea TITAN hulls, including the first hull, which was taken out of service in 2019 or the final hull which was involved in the incident.

4.2.4.4.4.1. OceanGate did not submit a Request for Classification (RFC) to ABS for the submersible TITAN. As a result, ABS did not perform any design reviews or surveys.

4.2.4.4.5. The ABS Underwater Rules do not permit the use of carbon fiber composites for Pressure Vessels for Human Occupancy (PVHOs). While the ABS Rules do have provisions for consideration of alternative arrangements and novel concepts, over the many decades ABS has been classing submersibles and other underwater units, these provisions have never been used to class a carbon fiber composite PVHO.

4.2.4.4.6. When non-standard designs, materials or construction techniques are intended to be used, one of the options available in the industry is to develop an American Society of Mechanical Engineers (ASME) PVHO Case following the guidelines outlined under Non-Mandatory Appendix D of the ASME Safety Standard for Pressure Vessels for Human Occupancy (PVHO-1).

4.2.4.4.6.1. An ASME PVHO Case is a document developed by the designer / builder and approved by the ASME – PVHO Standards Committee that provides alternative requirements to those specifically indicated in the ASME PVHO Standard due to the use of new technology, materials, or other special circumstances.

4.2.4.4.7. While ABS has never classed submersibles or other underwater units that employ carbon fiber composite PVHOs. A number of ASME PVHO Cases have been developed for the use of non-metallic materials for PVHOs: Examples include ASME PVHO Case #11, Case #12, etc. However, these are for surface based internal pressure applications (e.g., medical hyperbaric chambers, transfer trunks for diving, etc.) that operate at relatively mild pressures (in the range 4 to 80 pounds per square inch gauge (psig)).

4.2.4.4.8. The acceptable materials for PVHOs are specified under Section 4/3 of the ABS Rules for Building and Classing Underwater Vehicles, Systems and Hyperbaric Facilities (ABS *Underwater Rules*). For metallic plates, the acceptable materials include steel, aluminum, Grade 5 Titanium, and stainless steel. Metallic materials used for bolts, extrusions, forgings, and shapes are required to comply with a recognized standard, such as the American National Standards Institute

(ANSI) and are to be at least of similar quality to the plate materials specified above.

4.2.4.4.9. The post-construction periodic survey requirements for classed PVHOs are specified under Section 7-11 of the ABS Rules for Survey After Construction. These include the following: visual examination of the PVHO pressure boundary after removal of protective coatings and thermal insulations in selected locations, gauging of the pressure hull, if required, non-destructive testing of highly stressed areas such as lifting lug welds, out-of-roundness measurements, if required, and a test dive.

4.2.4.4.10. Additionally, ABS is also familiar with the use of industry standards such as ASTM E1932-12 for acoustic emission monitoring. Acoustic emission testing (AET) is a passive nondestructive examination technology that has been successfully applied to the detection and monitoring of crack propagation, corrosion activity, cavitation erosion, and leaking in structures constructed of steel, aluminum, composite and other materials. An ABS Senior Principal Engineer stated the following during MBI testimony:

> "Our understanding is that with the exception of the TITAN, the underwater industry has not been employing real time structural health monitoring systems on submersibles or other underwater units. In ABS' experience, such systems have not been used so far on ABS classed submersibles or other underwater units."

4.2.4.4.11. For submersible carbon fiber composite PVHOs, there are currently no ABS class requirements for inspection and testing. Conversely, for carbon fiber composite surface vessels, the ABS inspection and testing requirements are outlined under Chapter 6 of the ABS Rules for Materials and Welding.

4.2.4.4.12. Neither the ABS Underwater Rules, nor the Rules of other IACS member Class Societies address carbon fiber composite PVHOs. Further, ABS is not aware of any industry standards in place when the incident occurred addressing carbon fiber composite PVHOs for external pressure applications.

4.2.4.4.13. The only acceptable material for PVHOs per Section 4/3 of the ABS Underwater Rules is cast polymethyl methacrylate, that meets the requirements of ASME PVHO-1.

4.2.4.4.14. For submersible new construction acrylic windows (i.e., view ports), the detailed testing and inspection requirements are specified under Section 2 of the ASME PVHO-1 Standard. This includes material testing, pressure testing, as well as inspection for manufacturing defects and flaws.

4.2.4.4.15. For in-service submersible acrylic windows, the detailed testing and inspection requirements are specified under Section 2 of the ASME PVHO-2 Standard. This includes inspection for in-service damage, as well as testing for window life extension of service.

4.2.4.5. Det Norske Veritas and Germanischer Lloyd (DNV GL)

4.2.4.5.1. DNV GL has never applied their Rules to vessels of similar hull material of the TITAN, but they have classed manned submersibles which fully meet the DNV GL classification requirements.

4.2.4.5.2. DNV GL Rules do contain specific requirements for fiber reinforced plastics, primarily for submersible exostructure components,[17] but those Rules have intentionally never been applied to a PVHO to date.

4.2.4.5.3. According to a DNV Surveyor, carbon fiber has not been accepted as suitable material for the construction of submersible PVHOs, especially when subject to external pressure experienced at ocean depths. According to DNV GL, carbon fibers are not considered suitable for significant compressive loading conditions. Accordingly, no equivalency standards have been developed for the type of application that was used for the submersible TITAN.

4.2.4.5.4. Approved materials for submersible PVHOs are listed in guidance from DNV GL Rules, RU-UWT Pt.2 Ch.5 Sec.2 and Sec.3, DNV-RU-SHIP Pt.2 Ch.2 (for example various pressure vessel and fine-grained structural steels, approved aluminum and titanium alloys, acrylic plastic).

4.2.4.5.5. Testing for these submersible hulls can be found in the DNV GL Rules, RU-UWT Pt.7 Ch.1 Sec.2. Testing requirements include annual inspections of the pressure hull assembly, tightness tests, dimensional checks, and non-destructive wall thickness tests of the submersible pressure hull as part of the 5-year renewal survey. Acrylic also requires testing as per ASME PVHO-2.

4.2.4.5.6. The acceptable material to be used for windows for a DNV GL certification is acrylic plastic polymethyl methacrylate (PMMA), as

[17] Exostructure is the area outside the pressure vessel.

per DNV-RU-UWT Pt.2 Ch.5 Sec.6 and RU-SHIP Pt.2 Ch.3 Sec.5, ASME PVHO-1.

4.2.4.6. American Association of Mechanical Engineers (ASME) - Pressure Vessel for Human Occupancy Standards (PVHO)

4.2.4.6.1. Founded in 1880 as the American Society of Mechanical Engineers, ASME is a not-for-profit professional organization dedicated to fostering collaboration, knowledge exchange, and skill enhancement across all engineering disciplines. It champions the essential contributions of engineers to society. Through its comprehensive array of codes and standards, publications, conferences, and professional development initiatives, ASME lays a foundation for advancing technical knowledge and promoting a safer world.

4.2.4.6.2. The ASME Boiler and Pressure Vessel Code is a comprehensive design framework encompassing 13 sections across 34 binders. It features indexed material properties categorized by alloy and temperature, along with design regulations for boilers, nuclear applications, heat exchangers, and pressure vessels. Notably, it includes provisions for "design by analysis" as detailed in Section VIII, Division 2, Part 5.

4.2.4.6.3. ASME PVHO-1 is a crucial design and safety code that outlines the requirements for the design, fabrication, inspection, testing, marking, and stamping of pressure vessels intended for human occupancy, specifically those with an internal or external pressure differential exceeding 2 psi. This standard also addresses the design, fabrication, inspection, testing, cleaning, and certification of piping systems associated with PVHOs. A PVHO is defined as a pressure vessel that encases a human being within its pressure boundary while subjected to a pressure differential greater than 2 psi. Examples of PVHOs include submersibles, diving bells, personnel transfer capsules, decompression chambers, recompression chambers, hyperbaric chambers, high-altitude chambers, and medical hyperbaric oxygenation facilities.

4.2.4.6.3.1. In an interview with a CBS News correspondent concerning PVHOs, OceanGate CEO Stockton Rush stated, "The viewport is made of seven-inch-thick plexiglass acrylic. This is an area where I deviated from conventional practices. Much of the submersible industry adheres to PVHO standards, which function like a regulatory body, though it is actually a volunteer group that has established various guidelines."

4.2.4.6.4. ASME PVHO-2 provides post-construction guidelines for the operation and maintenance of PVHOs. It was originally focused on windows and has expanded to look at PVHOs as a system, with an emphasis on life support and safety. It does not address the pressure vessel design in depth, but instead defers to other codes (e.g., ASME Section VIII, Class Societies).

4.2.4.6.5. As detailed in the ABS section 4.2.4.5, when non-standard designs, materials, or construction techniques are intended to be used, one of the options available in the industry is to develop an ASME PVHO Case following the guidelines outlined under Non-Mandatory Appendix D of the ASME Safety Standard for Pressure Vessels for Human Occupancy (PVHO-1).

4.2.4.6.6. Non-Mandatory Appendix D of ASME PVHO-1 addresses non-standard designs and materials. It requires comprehensive information regarding the proposed materials, accompanied by a thorough design analysis that accounts for all relevant loads and environmental conditions. For prototype testing, the standards outlined in PVHO-1 include the following:

- Proof Pressure Testing: 3 full-scale pressure hulls to be pressure tested to 6 times Maximum Allowable Working Pressure (MAWP) without failure.

- Creep Testing: Model or full-scale pressure hulls to be subject to 10,000 hours (1 year and 1-1/2 months) of sustained pressurization without failure. Alternative options include testing 1 pressure hull to 3 times MAWP or 5 pressure hulls to 2 times MAWP.

- Cyclical Pressure Testing: Full-scale pressure hull to be cyclically pressure tested over multiple pressure cycles to MAWP. The number of approved operational cycles would then be limited to half the number of cycles tested, minus 1,000 cycles.

- Production Proof Testing: The production unit (i.e., actual pressure hull) to be subjected to a hydrostatic pressure test of 1.5 times MAWP for 1 hour.

- Third-Party Witnessing of the Testing: All testing is to be witnessed and signed off by an independent third-party agency (e.g., a Classification Society).

4.2.4.7. OceanGate Blog Content Post, “Why Isn’t TITAN Classed?”

4.2.4.7.1. In an OceanGate blogpost titled "Why Isn't TITAN Classed?" released on February 21, 2019, OceanGate addressed the role and what they perceived as limitations of classification societies in ensuring vessel safety, particularly in the context of their carbon fiber TITAN submersible. OceanGate began by explaining that classification, performed by societies, serves to reassure stakeholders like ship owners, insurers, and regulators that vessels meet established standards in design, construction, and inspection.

4.2.4.7.2. However, OceanGate emphasized that while classing is essential for structural integrity and baseline safety, it does not guarantee that operators adhere rigorously to proper operating procedures or exhibit sound decision-making abilities—factors they considered crucial for mitigating risks at sea. They argued in the blogpost that human error, a significant factor in most marine and aviation accidents, is not adequately addressed by class rules alone. In OceanGate's view, the omission of operating procedures underscored the importance of maintaining a high level of operational safety through continuous attention, effort, and a strong company culture focused on safety—a commitment OceanGate stated they prioritized deeply.

4.2.4.7.3. One of OceanGate's original stated goals was "to pursue the highest reasonable level of innovation in the design and operation of manned submersibles. While classing systems are willing to pursue the certification of new and innovative designs and ideas, they often have a multi-year approval cycle." The blogpost also stated that bringing an outside entity up to speed on their innovations, such as carbon fiber pressure vessel hulls and the real time hull health monitoring (RTM) system is "anathema"[18] to rapid innovation.

4.2.4.7.4. OceanGate underscored the limitations of traditional vessel classing processes when it came to ensuring comprehensive safety for their submersible operations. While classing by recognized classification societies certified that a vessel met structural and safety standards, OceanGate argued that this alone would not sufficiently guarantee safety during their dive missions. They pointed out that classing assessments typically focused on the structural integrity of the submersible and were conducted periodically, often annually or every few years. This approach, they contended, overlooked critical operational factors essential for safe dives, such as real-time environmental conditions, crew readiness, emergency response protocols, and adherence to specific operational procedures.

[18] Anathema is defined as someone or something intensely disliked or loathed. (Source: Merriam-Webster Dictionary)

4.2.4.7.5. OceanGate emphasized the importance of complementing classing with their own rigorous risk management strategies. As an example, they conducted RTM assessments to continuously monitor the condition of their submersibles, ensuring that any potential issues were promptly identified and addressed. According to their blogpost, they conducted a meticulous 25-point risk assessment before each operation, methodically evaluating both surface-level risks and subsea performance factors. This proactive approach aimed to mitigate risks comprehensively, beyond the scope of what traditional classing alone could achieve.

4.2.4.7.6. OceanGate concluded the blogpost by stating, "But by itself, classing is not sufficient to ensure safety. In part, this is because classing does not properly assess the operational factors that are vital for ensuring a safe dive and because classing assessments are done annually (at best) and do not ensure that the operator follows procedures or processes that are the key to conducting safe dive operations."

4.2.4.7.7. During his address at the GeekWire Summit on April 14, 2022,[19] Mr. Rush discussed the challenges OceanGate faced regarding the role of Classification Societies and their TITAN submersible. He pointed out that these societies' regulations and standards were extensive and thorough (over-the-top), yet they did not encompass materials like carbon fiber, which OceanGate chose to use in the construction of the TITAN.

4.2.4.7.8. Mr. Rush also highlighted the difficulty of innovating beyond established norms by noting, "when you're outside the box, it's really hard to tell how far outside the box you really are." This statement was made while reflecting on the nature of OceanGate's approach with the TITAN, which needed to push through technological boundaries and employ advanced materials that diverged from traditional vessel construction methods. Furthermore, Mr. Rush acknowledged the substantial gap between existing regulatory frameworks and OceanGate's progressive solutions.

4.2.5. State Registration of the TITAN

4.2.5.1. Vessel numbering requirements for a U.S. vessel are contained in 33 CFR § 173.11, which details the various requirements for numbering vessels of the United States. The regulation states, "this subpart (Vessel Numbering) applies to each vessel equipped with propulsion machinery of any type used on waters subject to the jurisdiction of the United States and on the high seas beyond the territorial seas for vessels owned in the United States."

[19] https://www.youtube.com/watch?v=9PGpjEDc96I

4.2.5.2. Federal regulations in 33 CFR § 173.15- Vessel Number Required, state, "(a) Except as provided in § 173.17, no person may use a vessel to which this part applies unless: (1) It has a number issued on a certificate of number by the issuing authority in the State of principal operation; and (2) The number is displayed as described in § 173.27."

4.2.5.3. The TITAN was designed and constructed in the State of Washington. The TITAN also operated upon Washington state waters on 11 dives. The State of Washington vessel regulations state: "to navigate, operate, employ or moor your vessel in Washington, you must have a Washington title, registration card and registration decals. The registration card must be onboard whenever you use your vessel. All vessels that require registration must be titled through the Washington State Department of Licensing."

4.2.5.3.1. The Revised Code of Washington Title 88, Navigation and Harbor Improvements, Chapter 88.02 Vessel Registration, Section 550 Registration and Display of Registration number and decal required states, "(1) Except as provided in this chapter, a person may not own or operate any vessel, including a rented vessel, on the waters of this state unless the vessel has been registered and displays a registration number and a valid decal in accordance with this chapter. A vessel that has or is required to have a valid marine document as a vessel of the United States is only required to display a valid decal."

4.2.5.4. Both the ANTIPODES and the CYCLOPS I were properly registered in the State of Washington. According to Washington State records, the TITAN submersible was never registered in the State of Washington and the MBI could not find evidence indicating that it was registered in any other U.S. state or documented in any other country.

4.2.6. State of Washington Boiler and Unfired Pressure Vessel Laws

4.2.6.1. The TITAN's crew compartment was, by definition, an unfired pressure vessel. It was designed to be a closed vessel for human occupancy under pressure from the ocean depths.

4.2.6.2. The State of Washington has a professional organization, the Board of Boiler Rules, which oversees the safety of boilers and unfired pressure vessels. The Board of Boiler Rules consists of five members appointed by the Governor. The Board's function is to formulate definitions and rules for the safe and proper construction, installation, repair, use, and operation of boilers and unfired pressure vessels in this state.

4.2.6.3. The rules of the Board, WAC 296-104-010 state, "Unfired pressure vessel" shall mean a closed vessel under pressure.

4.2.6.4. The rules of the Board, WAC 296-104-210 Construction—

> "What are the requirements for construction of boilers and unfired pressure vessels of special design? Boilers and unfired pressure vessels of special design require a special certificate granted by the Board of Boiler Rules. At a minimum the following information shall be supplied to obtain Board approval for special designs: Construction drawings, design calculations, material specifications, and a written evaluation by a professional engineer knowledgeable with boilers and unfired pressure vessels. Upon board approval a Washington special number will be assigned by the chief inspector. The installation will be subject to the regular inspections required by WAC 296-104-100 and any additional conditions as required by the Board."

4.2.6.5. There is no evidence that OceanGate ever contacted the Washington Board of Boiler Rules, nor received a Certificate of Compliance in accordance with Washington State Law.

4.3. Founding of OceanGate Inc.

4.3.1. On August 31, 2009, a Certificate of Formation for DeepFlight Technologies, LLC was filed by the legal representative of the CEO, Mr. Rush. This document designated the CEO as the Board Manager of the entity.

4.3.2. On October 9, 2009, a Certificate of Amendment was filed, officially renaming DeepFlight Technologies to OceanGate, LLC. The founders of OceanGate LLC. included Mr. Rush and the Co-founder. OceanGate, LLC is registered as a business entity in Everett, Washington, with the Secretary of State of Washington. OceanGate was incorporated on August 31, 2009, in the state of Washington.

4.3.3. The Co-founder brought experience from the aerospace sector, having previously worked with various startups focused on innovation and commercialization. In 2003, he established the International Association of Space Entrepreneurs, a non-profit organization dedicated to fostering aerospace-related ventures and startups.

4.3.4. In 2009, OceanGate LLC acquired its first submersible, ANTIPODES. Originally designated as PC-15, ANTIPODES was constructed in 1973 by Perry Submarines for operations in the North Sea's oil fields. In 1999, it was purchased by Submarine Adventures, which renamed it ANTIPODES and utilized it for tourist missions in Milford Sound, New Zealand. The ANTIPODES is a 13-foot steel-hulled submersible capable of accommodating five individuals, with a maximum diving depth of 305 m, and it is classified as an A1 submersible by the ABS.

4.3.5. On June 11, 2010, OceanGate Foundation was established as a non-profit entity in Seattle, Washington, also registered with the Secretary of State. The Unified Business

Identifier (UBI) for this organization is #603024695, categorizing it as a Washington State Nonprofit Corporation within the Regular Corporation business category.

4.3.6. On January 5, 2011, OceanGate, LLC submitted an amended report in the State of Washington, listing its corporate address as 111 80th St SW #250, Everett, Washington 98203. This Limited Liability Company amendment indicated that its primary business activity was oceanographic research and identified the Mr. Rush (managing member) along with the Co-founder as members of the LLC.

4.3.7. On December 13, 2011, OceanGate Acquisition, Inc. was created in the State of Washington. The Co-founder was listed as President and Mr. Rush was the Secretary.

4.3.8. On December 29, 2011, OceanGate, LLC and OceanGate Acquisitions Inc. merged to become OceanGate Inc.

4.3.8.1. Existing shares from OceanGate, LLC. and OceanGate Acquisitions were transferred to OceanGate Inc; holders of those shares were the Natomas Partners L.P., Mr. Rush, the Co-founder, and the OceanGate Foundation.

4.4. Vision / Business Plan of OceanGate

4.4.1. The Co-founder of OceanGate articulated that his initial vision was to "give humanity greater access to the ocean." This vision centered on the acquisition of a fleet of four to five deep-ocean submersibles, each engineered to reach depths of 6,000 m while accommodating up to five passengers. The strategic intent was to enable these submersibles to be deployed globally without reliance on a dedicated mothership. Designed for containerization, the fleet of submersibles envisioned could be prepositioned at various locations with the capability to easily mobilize to ports around the world to either operate independently or aboard any suitable charter vessel as opportunities became available.

4.4.2. In 2009, OceanGate acquired the submersible ANTIPODES, a steel-hulled vessel rated for a max depth of 300 m and classed it under ABS A1 standards. OceanGate used ANTIPODES as a testbed for submersible operational procedures. Mr. Rush and the Co-founder recognized there was burgeoning public interest in oceanic exploration, as well as the emergence of a high-end market for deep-sea tourism. This dual insight—demand for scientific inquiry and adventurous underwater experiences—became the cornerstone of OceanGate's business strategy.

4.4.3. While operating the ANTIPODES, with its 300 m depth limitation, Mr. Rush and the Co-founder were simultaneously working to solidify their vision and identify submersibles capable of reaching 6,000 m. Through outreach within the submersible industry, they discovered that while manufacturers had the capability to build such vessels, the associated costs exceeded their financial parameters and were outside of their business management plan. The Co-founder noted that a recalibration of their business model or the pursuit of more viable engineering solutions was necessary. Mr.

Rush opted to pursue the latter, initiating a shift in strategy from chartering existing submersibles to constructing new ones. This transition was conceptualized as a three-phase plan: first, to operate within the submersible sector using ANTIPODES; second, to gain expertise in submersible construction; and third, to develop a vehicle capable of deep-ocean operations.

4.4.4. In the second phase, OceanGate chose to design both the external and internal operating mechanisms on an established standard steel hull submersible while concurrently developing their concept of a potential carbon fiber hull submersible. In 2013, OceanGate acquired the LULA 500, a steel submersible rated for 500 m, which was subsequently renamed CYCLOPS I. OceanGate and the University of Washington-Applied Physics Lab equipped the CYCLOPS I with various internal and external accessories, for operational testing and application development related to the future submersible, TITAN. The objective for TITAN was to reach the deep ocean floor, specifically the depth at which the TITANIC rests—approximately 3,800 m, or 12,500 feet below sea level.

4.4.5. In an article published by Oceanographic Magazine, Issue 20: TITAN Meets TITANIC,[20] Mr. Rush stated the following when asked about his rationale for targeting the TITANIC wreck site:

> "We are endeavoring to increase underwater access for the public. There is one underwater site known by billions—an accessible location that many aspire to visit: the TITANIC. This focus directed our efforts; if we were to approach the TITANIC, we needed to evaluate our existing technology. We recognized that reaching 4,000 m was critical for access to the site. This realization guided our decisions regarding materials, such as the selection of titanium, the incorporation of carbon fiber, and the choice between acrylic or glass viewports."

4.4.6. Utilizing carbon fiber for the hull would significantly reduce the vehicle's weight and enhance buoyancy. This reduction in weight decreased transportation costs, which Mr. Rush believed were the greatest costs associated with submersible operations. Mr. Rush stated that utilizing carbon fiber for the hull of the submersible offers significant advantages, primarily through its exceptional strength-to-weight ratio. By integrating this lightweight material, the overall weight of the submersible is markedly reduced, leading to enhanced buoyancy. Mr. Rush believed this increase in buoyancy would not only improve stability but also contribute to superior handling characteristics, allowing for more precise maneuverability underwater. The reduction in weight has important implications for transportation. A lighter submersible can be transported more efficiently, resulting in lower shipping costs when moving the vehicle around the globe. This efficiency is especially crucial for operations requiring frequent deployment in various locations, as it reduces logistical challenges and expenses. Overall, Mr. Rush

[20] https://oceanographicmagazine.com/product/issue-20-antarctica-cousteaus-call/

believed that a carbon fiber hull would not only optimize a submersible's performance but also make it more cost-effective for worldwide transport and operations.

4.4.7. Regarding the shape of the submersible, an ABS Senior Principal Engineer stated,

> "So typically, what we have seen is any time you go below a depth of 1,000 m seawater or 3,280 feet seawater, the shape of the pressure hull is spherical. We have not seen cylindrical pressure hulls being used beyond a depth of 1,000 m seawater. The reason is that a spherical pressure hull is the best shape for external pressure, as the stressors are evenly distributed around the hull."

4.4.7.1. A spherical submersible configuration can typically accommodate a maximum of three occupants. OceanGate strategically decided to design and construct a larger cylindrical submersible capable of accommodating five individuals. This new design deviated from the traditional spherical configuration, adopting a cylindrical hull that provides increased interior space for crew members, equipment, passengers, and scientific instruments. It was believed that a cylindrical hull would provide greater comfort and flexibility for the interior layout, catering to crew needs while optimizing the use of onboard technology.

4.4.8. In a June 29, 2013, interview with Space Shark Media,[21] Mr. Rush articulated OceanGate's strategic objective of developing more cost-effective methodologies for deploying submersibles across diverse revenue streams. This statement underscored OceanGate's commitment to reducing the financial barriers associated with submersible technology, making deep-sea exploration more accessible and commercially viable.

4.4.9. On October 1, 2014, the OceanGate Board of Directors unanimously approved a plan to establish a separate LLC to own the CYCLOPS I submersible. Ownership in this newly formed LLC would be offered to investors with preferred returns. The plan involved selling interests in the LLC through a private securities offering under Rule 506(b) of SEC Regulation D. The sale price of CYCLOPS I to the LLC was set at $1,000,000. OceanGate Inc. would then provide operational and maintenance services to the LLC.

4.4.10. On the same day, OceanGate's CEO signed the Master Charter Agreement as the "Owner/Managing Member" of CYCLOPS I, LLC, while the Chief Operating Officer signed on behalf of OceanGate Inc. as the Charterer. The agreement outlined that the Charterer would use the Owner's submersible for various missions, as detailed in Schedule 1 Mission Profiles submitted over time. Regardless of mission completion, the Charterer committed to a minimum usage fee of $82,500 per quarter in advance, deducted at the following day rates:

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[21] https://www.youtube.com/watch?v=dVN3rKP1epY

- $5,000 per day for missions benefiting the Charterer.
- $7,500 per day for missions benefiting other entities.
- $2,000 per day for static display.

4.4.11. A CYCLOPS I, LLC investor presentation titled "A Unique Cash Flow Generating Commercial Ocean Services Opportunity" detailed OceanGate's plan to place the vessel into a special-purpose LLC, retaining a minimum 10% ownership stake while selling the remaining 90% for $1 million to accredited investors. This structure was intended to serve as the model for future OceanGate vessel ownership entities. Investors in CYCLOPS I, LLC would have participation rights in other OceanGate projects and submersibles, with the first five investors committing $100,000 or more becoming eligible for submersible pilot training.

4.4.11.1. According to the presentation, over the next two years, CYCLOPS I, LLC and its CYCLOPS I submersible were contracted to OceanGate for a minimum of 30 dive days and 60 static display days per year, generating at least $330,000 in annual revenue. This charter contract, with defined variable costs, was projected to generate an internal rate of return (IRR) exceeding 13% over five years, with an expected payback period of approximately four years. Additionally, OceanGate's partnership with Global Diving and Salvage, along with prior engagements with the US Navy and DARPA, was anticipated to further increase dive opportunities and investment returns. The MBI was unable to identify any dives conducted for Global Diving and Salvage, the US Navy, or DARPA.

4.4.12. Cash distributions from the LLC were structured as follows:

- 90% of all net income went to investors until full capital recovery and a preferred 10% annual return.
- Distributions were split 60% to investors and 40% to OceanGate.
- Accelerated depreciation tax benefits allocated to investors, where permitted, enhanced after-tax returns.
- The financial projection anticipated five years of operation with nearly $500,000 in annual gross profits, followed by the vessel's sale.

4.4.13. In December 2016, OceanGate established CYCLOPS II, LLC, with the CEO of OceanGate as its initial manager. On January 31, 2017, OceanGate entered into a Purchase and Sale Agreement with CYCLOPS II, LLC to transfer ownership of the CYCLOPS II (first TITAN hull) Submersible Pressure Vessel. According to the agreement, "This five-person submersible, capable of diving beyond 2,500 meters, was sold for $5,000,000 under the following payment schedule:

- $3,000,000 at the initial purchase agreement signing
- $1,000,000 upon completion of the main pressure hull
- $1,000,000 upon the first successful dive to at least 2,500 meters

4.4.14. The subscription price per unit for CYCLOPS II, LLC was $50,000. Per the original Subscription and Investment Agreement, OceanGate was responsible for operating, maintaining, and managing the submersible and its associated assets. In return, CYCLOPS II, LLC paid OceanGate an annual management fee of $50,000, while OceanGate, as Charterer, agreed to pay minimum lease fees to the LLC:

Gross Annual Charter Days	**2017**	**2018**	**2019**	**2020**	**2021**
Dive Days	5	45	60	75	75
Static Days	10	10	10	5	5
Transport Days	20	20	40	40	40
Gross Annual Charter Fees	**$165,000**	**$765,000**	**$1,030,00**	**$1,230,00**	**$1,230,00**

Figure 43: Excerpt from a newsletter to CYCLOPS II, LLC Members re: Charterer commitments and payments. 2019, 2020, and 2021 appear to be missing a "0", equating the Gross Annual Charter Fees at $1,030,000 and $1,230,000 respectively. Source: CYCLOPS II, LLC.

4.4.15. OceanGate's operations were partially funded by investments and revenue generated from individuals participating in dives. These participants have been referred to with various titles over the years, including citizen scientists and mission specialists. According to the OceanGate Project Execution Plan of 2023, "Mission specialists provide financial support to underwrite OceanGate's expeditions." The fees for OceanGate's mission specialists to participate in a dive to the TITANIC wreck site significantly increased over time, rising from $105,129 in 2021 to $250,000 for both 2022 and 2023.

4.4.15.1. Mission specialists were encouraged to actively engage in OceanGate's missions alongside the crew. Their responsibilities included operating equipment, performing maintenance tasks, drafting procedures, tracking operations, cleaning the submersible, charging batteries, and executing additional duties as directed by OceanGate management. According to the Project Execution Plan, "This involvement not only financed expeditions but also gave participants a direct engagement in deep-sea exploration, delivering a unique and immersive experience in marine science."

4.4.16. At the christening of the first TITAN hull in 2018, Mr. Rush expressed gratitude to the shareholders, stating:

> "I would like to extend my appreciation to all our shareholders, whose steadfast support has been instrumental to this project. The era of government funding has diminished. The future of exploration now rests with private enterprises, reminiscent of the early 20th century, where individuals of means facilitate exploration."

4.4.17. Mr. Rush elaborated on OceanGate Expeditions' funding model, leveraging media engagement and public participation to support scientific research. By filming wrecks and underwater sites like the TITANIC, OceanGate attracted interest from individuals and organizations willing to finance these expeditions. The CEO emphasized that by involving funders directly in the expeditions, OceanGate established a sustainable funding model that permitted regular returns to sites such as the TITANIC—an uncommon practice in deep-sea exploration, which was often hindered by high costs and logistical challenges.

4.4.18. Mr. Rush planned for future OceanGate expeditions to extend beyond the TITANIC, to achieve broader underwater exploration. This included the development of a new submersible capable of reaching depths of 6,000 m. OceanGate aimed to diversify its exploration targets, planning dives to regions such as the Azores and hydrothermal vents in 2024, as well as investigating the wreck site of the car carrier FELICITY ACE.

Figure 44: OceanGate Future Expeditions. Source: OceanGate Expeditions.

4.4.19. Prior to its removal in June 2023, OceanGate's website stated that the company was privately owned and dedicated to enhancing access to the deep ocean through the innovation of next-generation crewed submersibles and launch platforms.

4.5. Board of Directors

4.5.1. The Bylaws of OceanGate stated that all corporate powers shall be exercised by or under the authority of, and the business and affairs of the corporation shall be managed under the direction of, the Board of Directors except as otherwise provided by the laws under which the corporation exists or in the Articles of Incorporation. Mr. Rush was listed as the Secretary and signatory to certify the bylaws of the corporation by the Board of Directors effective December 16, 2013. According to information provided by OceanGate, at the time of the incident, OceanGate Inc. had six members on the Board of Directors. OceanGate's Board of Directors met regularly. OceanGate's CEO, Mr. Rush, was the individual primarily responsible for controlling the flow of information to the Board.

4.5.2. On August 7, 2013, OceanGate brought on a USCG Retired Rear Admiral (RADM (ret.)) to the Board of Directors and in an article posted on PR Newswire[22] the new Board Member was quoted as stating the following, “I hope to help bring operational and regulatory expertise to this 21st-century emerging industry. I truly believe manned submersibles can help solve some of our country’s most pressing issues, including development of offshore energy sources, discovery of new sources of rare minerals, or find the next generation of biomedical cures.” RADM (ret.) was asked by Mr. Rush, who at the time were both Board Members for BlueView® Technologies, to be part of the OceanGate Board of Directors.

4.5.2.1. RADM’s (ret.) military career in the USCG included a combat tour commanding the patrol boat POINT WHITE in Vietnam and the South China Sea. He also commanded the Coast Guard Cutter BASSWOOD in the Western Pacific, operating in regions such as Guam, Micronesia, and the Philippines, and led cutters Juniper, Taney, and Chase in the Atlantic and Caribbean theaters. In 1987, he made history by becoming the first Commodore of the Caribbean Squadron, where he oversaw the largest joint Coast Guard-Navy air and surface force assembled since World War II, focusing on maritime drug surveillance and interdiction operations throughout the Caribbean.

4.5.2.2. In addition to his operational roles, RADM (ret.) held several key shore positions, including commanding all USCG units on eastern Long Island and serving as a liaison officer to the Commander in Chief of the Navy's Atlantic Fleet in Norfolk. He also acted as a political officer at the U.S. Mission to the United Nations in both New York and Geneva. Currently, RADM (ret.) serves as the president of a veteran-owned small business in Washington State that specializes in marketing and business development for the maritime industry, as well as government and legislative affairs.

4.5.2.3. In an MBI interview, RADM (ret.) was asked about the accuracy of a PR Newswire press release describing his oversight on regulatory issues; he stated, “No, sir. I stressed to (Mr. Rush) on numerous occasions that my background was not in the marine safety realm or a regulatory realm. I told him I was a surface operations officer in the Coast Guard, spent over 13 years at sea. I know about safety at sea, but regulatory issues or -- I mean, I'm not a naval architect, I'm not a naval engineer. I have no expertise in those areas whatsoever.”

4.5.2.3.1. RADM (ret.) stated the following regarding his specific role for which Mr. Rush asked him to participate: “My best recollection of how the Board operated was, it was a strategic based Board not a tactical group of people. And (Mr. Rush) was not a -- he was not a person who

[22] OCEANGATE Adds Rear Admiral [name redacted by the MBI] to Board of Directors (prnewswire.com)

sought, to the best of my recollection, a lot of input from the members of the Board or direction."

4.5.2.3.2. When RADM (ret.) was asked if he had reviewed the bylaws when he joined OceanGate's Board of Directors he responded that he could not recall ever receiving a copy of them.

4.5.2.3.3. RADM (ret.) stated the following regarding his interpretation of OceanGate's vision or mission statement:

> "[O]f the vision, the goal, the objective, was to create a manned submersible that could explore deep ocean depths. I considered (Mr. Rush) to be an absolute pioneer in the development of those types of vehicles. I was excited to be a member of the Board, for which, by the way, I never received a dime. Okay? Board members were given stock options annually, a small number. I never exercised any. Again, (Mr. Rush) was and always will remain to me a hero."

4.5.2.3.4. During the MBI interview, RADM (ret.) was asked if he recalled any concerns raised by OceanGate Board members, including himself, regarding TITAN's regulatory compliance. He responded, "To the very best of my recollection, I do not . . . . the Board meetings were informative. It was information about this is what we're going to do coming to the Board members from (Mr. Rush). And again, I mean, there were some general questions and comments about that, but the Board operated on consensus, and I don't ever recall a Board member -- or at any meeting a Board member registering, you know, well, I just don't agree with that and I'm not onboard. That never happened in any Board meeting I was a member of."

4.5.3. According to a press release on May 16, 2022, a former NASA astronaut became a member of the OceanGate Board of Directors. OceanGate, Inc. announced his appointment to the company's Board of Directors and stated that a veteran NASA Space Shuttle astronaut and experienced submersible pilot would help to expand opportunities for deep ocean research, exploration, and discovery ahead of the 2022 TITANIC Expedition.

4.5.4. Another Board Member at OceanGate, has served, throughout their career, as a founding principal, President, and CEO, setting strategic direction and overseeing investment strategies. Holding a Juris Doctorate and a Bachelor of Science degree, they co-founded a Trust Company and a real estate fund and served on multiple boards.

4.5.5. One of the Board Members for OceanGate was a software consultant specializing in portfolio risk management and quantitative trading systems. They hold a Bachelor of Science degree in Electrical Engineering and a Master of Science degree in Physics from Washington University. He commenced his career as an electrical engineer, where he developed a range of analog devices, including particle detectors, optoelectronic transceivers for telecommunications networks, and antennas and radios for mobile devices.

4.5.5.1. According to a former Director of Engineering, he was responsible for the hardware for the Real-Time Monitoring System for the TITAN hulls.

4.5.6. The Board included the CEO and Founder of an investment advisory firm that offered strategic guidance to CEOs across sectors such as financial services, asset management, technology, real estate, and oil and gas. Prior to founding the firm, the Board member worked in the financial sector including several international corporations. The Board member also co-chaired community partner programs including pro bono consulting with non-profit organizations.

4.6. Administration / Marketing of OceanGate

4.6.1. OceanGate employed a comprehensive marketing strategy to promote its expeditions, leveraging a variety of channels to reach potential clients, investors, and the public. The company made extensive use of social media platforms, media relations, online content, and partnerships with social media influencers. These efforts were coupled with ongoing press releases and newsletters aimed at engaging potential investors and mission specialists. Additionally, OceanGate organized outreach initiatives with the final TITAN submersible, traveling across the United States, where the public could attend displays and seminars outlining the company's expedition plans. To further reach its target audience, CEO Stockton Rush actively engaged in public speaking, presenting OceanGate's vision at various clubs and organizations, such as the Explorers Club in New York City. According to the Director of Administration, OceanGate aimed to engage the 1% of the 1% and the ultra-high net worth adventure explorer to take part in the expeditions.

4.6.2. In early 2017, OceanGate announced expeditions for the summer of 2018, to the TITANIC, with the price of a ticket as $105,129. This price was the inflation-adjusted cost of a first-class ticket to stay in the Vanderbilt suite of the TITANIC on its maiden voyage in 1912 ($4,350). In the announcement, in 2017 the CEO stated that the 54 positions that are open for next year had already been filled, representing over $5 million in revenue for OceanGate.

4.6.3. According to OceanGate correspondence, the support vessel for the 2018 TITANIC Expedition was scheduled to be the offshore supply vessel (OSV) ISLAND PRIDE, a 103 m (338 foot) DNV classed sub-sea support vessel. The ISLAND PRIDE was equipped with a helicopter deck for personnel transport, and it could accommodate up to 50 expedition members.

4.6.4. The OceanGate brochure for the 2018 TITANIC Expedition advertised that a helicopter would be used to transport mission specialists from shore to the support vessel. The brochure also stated that the price for the 2019 TITANIC Expedition would be raised to $108,219.

Figure 45: OceanGate 2018 TITANIC Expedition brochure. Source: OceanGate Expeditions.

4.6.5. OceanGate produced a series of short-form promotional videos targeted at potential clients and mission specialists. These short videos showcased various aspects of OceanGate's operations, including the design, construction, and operational capabilities of the TITAN submersible. Key highlights included dive footage, control systems, and safety features. The videos also offered a direct point of contact for viewers seeking further information about the expeditions.

4.6.5.1. In 2022, OceanGate produced a marketing video called, Father and Son Explore the TITANIC: Mission Specialist Stories.

4.6.6. Most passengers, as noted in an OceanGate provided document, paid $105,129 for the 2021 TITANIC Expedition, having secured their contracts in 2018 at the original rate. A mission specialist recalled that after a successful dive in 2021, Mr. Rush was told by a mission specialist that the expedition was worth $250,000 to them. In 2022 and 2023, the participation fee for mission specialists was subsequently raised to $250,000.

4.6.7. To participate in the 2023 TITANIC Expedition, mission specialists were required to sign a Mission Specialist Crew Agreement. This six-page document outlined the qualifications and expectations for participants. Mission specialists had to either complete a 14-hour in-house training course or have prior experience with OceanGate expeditions. Additionally, a USCG MMC or equivalent credential was required. These requirements were listed in the Mission Specialist Crew Agreement, but according to previous mission specialists interviewed by the MBI, these prerequisites were neither completed nor verified by OceanGate, prior to diving in the TITAN.

4.6.8. The $250,000 fee was designated as a "Training and Mission Support Contribution." As outlined in the Mission Specialist Crew Agreement, these contributions supported expedition development, asset construction, vessel acquisition, equipment, and crew expenses. While most participants were required to pay this fee, social media influencers received complimentary dives in exchange for promoting OceanGate's operations.

4.6.8.1. The operating company for the expeditions was originally named Argus Expeditions, which was later changed to OceanGate Expeditions. According to OceanGate representatives, Argus Expeditions was created in 2016 as a Bahamas limited liability company. The company formally changed its name to OceanGate Expeditions Ltd. in 2021, though it was sometimes referred to by that name prior to 2021.

Payment Schedule

The Training and Mission Support Contribution is payable directly to OceanGate Expeditions Ltd., per the schedule below. A non-refundable deposit of $50,000 per person and signed contract is required to reserve participation. This deposit is due 7 days after contract execution. Final non-refundable payment must be made per the schedule below and is required to confirm participation. Final payment is due no later than 180 days prior to the expedition start. If this contract is executed within 180 days of the expedition start, both deposit and full payment will be due.

Purpose	Date	Amount	Details
Deposit	Due upon receipt	$50,000 USD	OceanGate Expeditions' receipt of this non-refundable deposit reserves a position as a Mission Specialist.
Final Payment	Due 180 days prior to expedition start	$200,000 USD	Full balance paid confirms position as a Mission Specialist.

Figure 46: Excerpt from OceanGate 2023 Mission Specialist Agreement. Source: Former TITAN mission specialist.

Training and Mission Support Contribution - Mission Specialist Cancels

In the event that a Mission Specialist cancels her/his participation, is unable to join on the scheduled departure date, is deemed unfit to join the mission, or is unable to satisfy any of the terms of this agreement, Training and Mission Support Contributions will be forfeited as follows:

Date	Amount
Less than 180 from the expedition start	100% of Mission Support Fee

Figure 47: Excerpt from OceanGate 2023 Mission Specialist Agreement. Source: Former mission specialist.

4.6.8.2. OceanGate's refund policy prohibited refunds within six months of the expedition, with participants losing their full contributions if they canceled within 180 days of an expedition's start, unless the cancellation was due to equipment failure, which would then result in a credit for future expeditions. These credits were non-transferable and could not be redeemed for cash.

4.6.8.3. OceanGate's former Director of Administration and Finance explained the company lacked the funds to process refunds because payments collected for expeditions were immediately used to cover operational expenses. Many mission specialists, when interviewed about the refund policy, either did not recall a policy or understood that once they made the deposit, it was likely non-refundable. One former mission specialist recalled, "It was pretty clear that once you started to give a deposit and you were signed on, then you were running the risk that you may not get your money back."

4.6.8.4. Before participation, mission specialists were required to sign a liability waiver acknowledging the risks associated with the TITAN's expeditions, particularly the dangers of operating within an experimental submersible. The liability waiver mentions death 9 times and includes the following key points:

- The submersible had not been certified by any regulatory body.
- The vessel would be subjected to extreme pressures during the dive, with the risk of severe injury or death.
- A portion of the expedition would be conducted inside an experimental submersible vessel.
- Mission specialists had the option to decline participation at any time.

4.6.8.4.1. OceanGate videos showed mission specialists for Dive 88 signing the liability waiver on the POLAR PRINCE while enroute to the TITANIC Wrecksite for Mission 5 of the 2023 TITANIC Expedition. It is unknown if they had received a copy prior to the mission.

4.6.8.5. The waiver also specifically states:

"As of the date of this Release, the experimental submersible vessel has conducted fewer than 90 dives, and of those dives, 13 reached the depth of the *Titanic*." Prior to my participation in the Expedition, there have been as few as 13 dives to *Titanic* depths in the submersible.

4.6.8.5.1. At the time this waiver was presented to the mission specialist, the final TITAN hull had only conducted 35 dives, and of those 13 reached the depth of the TITANIC.

4.6.8.6. Mission specialists were also asked to complete a medical questionnaire, which included questions about their general and mental health, as well as prescription medications. This self-certification process did not involve a doctor's verification of a participant's ability to safely undertake a dive. However, a medical doctor was part of the expedition support staff. According to many of the mission specialists, the completed medical form was never requested by OceanGate, nor asked to be submitted to the company for verification ahead of an expedition.

4.6.9. Operations Division of OceanGate

4.6.9.1. From 2017 to 2023, OceanGate underwent significant changes in its Operations Department, particularly in regard to the role of Director of Marine Operations, which experienced three different individuals appointed during this period. The Director of Marine Operations held a pivotal role within the organization, overseeing critical aspects of safety, asset management, and mission success during submersible expeditions. Their primary responsibilities were to ensure the safety of all crew and clients during submersible dives and surface operations, maintaining and operating OceanGate's marine assets including submersibles and support vessels, and effectively achieving mission objectives in diverse and often challenging underwater environments.

4.6.9.2. OceanGate implemented operational procedures to uphold the safety and security of personnel, contractors, and mission specialists engaged in their deep-sea expeditions. These procedures were crafted to mitigate risks and ensure a controlled environment throughout operations. According to OceanGate Expeditions, personnel who were directly involved in OceanGate's dive missions were required to complete comprehensive safety protocols including training sessions, safety briefings, and continuous monitoring of health and well-being during expeditions. Contractors working for and supporting dive operations were similarly required to adhere to safety standards and undergo appropriate training to align with operational procedures and emergency response protocols. Mission specialists received a pre-arrival orientation outlining the expedition and were required as per their Mission Specialist Agreement to complete 14 hours of training and/or attain a USCG MMC.

4.6.9.2.1. Some former mission specialists interviewed by the MBI stated that the pre-arrival training was never reviewed or confirmed by OceanGate personnel once they arrived onboard. Some stated that there was no vessel familiarization or "mission specialist" training completed while onboard the support vessel.

4.6.9.3. The Manned Submersible TITAN Operations Manual serves as the foundational document for OceanGate's operational activities, specifically detailing the operation of the TITAN submersible. This manual encompasses critical information related to mechanical, electrical, pneumatic, and other associated subsystems essential for the functioning of the TITAN during underwater missions.

4.6.9.3.1. The manual outlined a 105 point pre-dive and a 29 point post-dive checklist to include external and internal components. The TITAN's pre-dive and post-dive checklists did not include verifications or inspections of either the RTM system or the hull.

4.6.9.3.2. Emergency procedures within the TITAN Operations Manual included: power failure of internal batteries, deballasting / jettisoning, CO_2 scrubber failure / excessive CO_2, uncontrolled internal high pressure (HP) air release, loss of communications, smoke / fire, entanglement, stranded on bottom, and flooding.

4.6.9.3.3. The Operations Manual stated that in the event of an emergency, which would necessitate the TITAN to surface immediately, the following actions should be taken:

- Blow high pressure air into the ballast tank to obtain lift.
- Drop trim weights as necessary.
- Broadcast XRAY, XRAY, XRAY clearly on the Acoustic Telemetry Modem (ATM).
- Check CB (citizens band) switched on.

4.6.9.3.3.1. The MBI identified no evidence of a distress message XRAY, XRAY, XRAY from the TITAN on the ATM during the final dive, Dive 88.

4.6.9.3.4. According to the manual's directive, it was meant to be distributed to all pilots and TITAN operations personnel. Additionally, the manual states that it was made accessible to external contractors and regulatory bodies involved in overseeing daily operations in an effort to underscore OceanGate's commitment to transparency and compliance with industry standards.

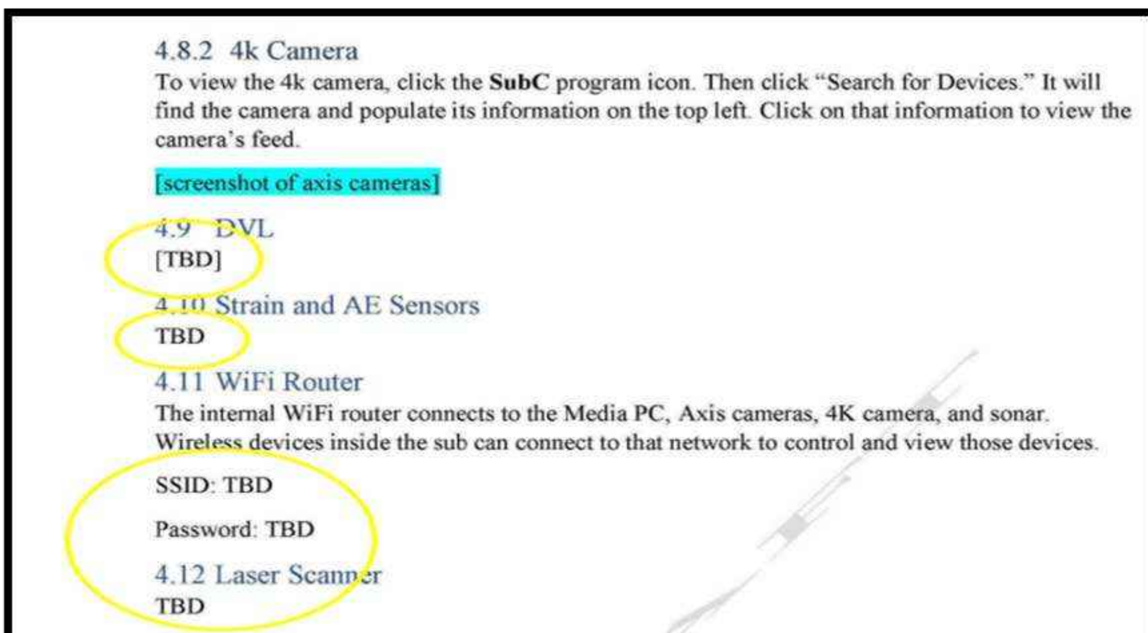
4.6.9.3.4.1. Prior to the casualty, the manual was never provided to the USCG and the MBI did not find evidence indicating that it was ever made to Canadian authorities.

4.6.9.4. The OceanGate TITAN Piloting Manual served as a specialized document designed to inform the submersible pilots about operational upgrades made to the TITAN's software and layout since 2021. This manual was categorized as an engineering operational document, focusing on technical aspects crucial for piloting the TITAN effectively and safely during missions.

4.6.9.4.1. According to the manual, while it covered specific updates and configurations related to TITAN's software and layout, the foundational principles of piloting a submersible were detailed in two primary sources: the ANTIPODES Training Manual and Frank R. Busby's "Manned Submersibles." These resources outline the fundamental skills and theoretical knowledge required for operating a manned submersible like the TITAN, providing comprehensive insights into navigation, maneuvering, emergency procedures, and operational protocols.

4.6.9.4.2. The Piloting manual provides internal procedures for pilot operations such as ensuring proper dome seal, turning "on" and using HP air, powering up TITAN, etc.

4.6.9.4.3. At the time the Pilot Manual was provided to the MBI, the majority of its sections were incomplete. Many of the essential functions were "TBD" (to be determined) in the manual and there was a watermark within the pages of the manual that were consistent with that of a draft.


4.8.2 4k Camera

To view the 4k camera, click the **SubC** program icon. Then click "Search for Devices." It will find the camera and populate its information on the top left. Click on that information to view the camera's feed.

[screenshot of axis cameras]

4.9 DVL

[TBD]

4.10 Strain and AE Sensors

TBD

4.11 WiFi Router

The internal WiFi router connects to the Media PC, Axis cameras, 4K camera, and sonar. Wireless devices inside the sub can connect to that network to control and view those devices.

SSID: TBD

Password: TBD

4.12 Laser Scanner

TBD

Figure 48: Excerpt from the OceanGate Pilot Manual. Source: OceanGate.

4.6.9.4.4. According to a former Director of Marine Operations, there was no Pilot Training Manual for CYCLOPS I when he started working for OceanGate in 2016. Upon his arrival, he created the training manual to serve as a comprehensive guide for the Submersible Pilot Training Program at OceanGate. It was designed to ensure that trainees had a clear understanding of the program's requirements while documenting their progress and achievements as a submersible pilot. The task book was intended to be used in conjunction with both the Pilot Training Manual and the OceanGate Operations Manuals to create a consistent framework for training.

4.6.9.4.5. The primary objective of the task book was to track each trainee’s accomplishments and outline any remaining tasks needed to achieve a “certification” as a submersible pilot at OceanGate. Practical exercises were a critical component of the training, and each task had to be carried out to the satisfaction of the Director of Submersible Operations. This individual was responsible for signing off on practical tasks, lectures, and successfully completed written and oral exams.

4.6.9.4.6. There is currently no submersible pilot USCG MMC Endorsement available to prospective submersible masters. Federal requirements within 46 CFR Parts 10 and 11 do not recognize nor require any MMC or endorsements specific to the operation of a submersible.

4.6.9.4.7. Many of the practical exercises in the task book were structured to be completed during a single dive, emphasizing the importance of hands-on experience. According to the former Director of Marine Operations, once a student demonstrated mastery of the required techniques and knowledge, they would be assessed by a senior pilot or the Director, who would sign the relevant section of the task book to indicate completion.

4.6.9.4.8. Upon fulfilling all written, theoretical, and practical requirements, students would receive a certificate of competence. This structured approach not only ensured thorough training but also fostered consistency in the development of skills necessary for submersible piloting.

4.6.9.5. OceanGate Inc.'s Health Safety and Environmental (HSE) Manual, Revision 3, updated in 2019, opened with a HSE Policy Statement by Mr. Rush, the CEO. The statement outlined OceanGate's commitment to maintaining the highest standards of safety within its operations. The HSE Manual stated that the company viewed safety not only as a legal obligation but also as a moral responsibility to ensure that every employee worked in an environment free from recognized hazards.

4.6.9.5.1.OceanGate, Inc. stated that the policy statement established in their HSE Manual fulfilled its legal obligation and its moral responsibility to provide a place free from recognized hazards. According to the manual, the policy statement served as a cornerstone of OceanGate's overall HSE management process, underscoring its integration into the company's core values and business objectives. It was meant to be communicated transparently and consistently to all stakeholders, including employees, customers, vendors, and subcontractors to emphasize its equal importance alongside other primary business goals.

4.6.9.5.2. OceanGate CEO, Mr. Rush, had the following quote in the HSE Manual:

“The OceanGate HSE philosophy is that, in the performance of our work, the health and welfare of the people involved, and the protection of assets and the environment are the primary concerns. NO JOB IS SO IMPORTANT THAT WE CANNOT TAKE THE TIME TO DO IT SAFELY.”

4.6.9.5.3.According to this policy, any violations were to be promptly reported to management. The HSE management process itself was designed to demonstrate to company management, regulatory bodies, customers, and other stakeholders that OceanGate's equipment and operational practices met rigorous safety standards. This was meant to ensure that submersible operations could proceed without undue risk to personnel or the environment.

4.6.9.5.4.OceanGate stated that incidents are avoidable through diligent adherence to safety protocols and continuous improvements to operational practices.

4.6.9.5.5. The HSE Manual stated that employees were required to comply with all company safety rules and were encouraged to find ways to make the company safer. Employees were also required to attend monthly safety meetings, which were to take place on the first Friday of the month. The meetings were intended to help identify safety problems, develop solutions, review incidents, provide training and evaluate the effectiveness of OceanGate’s safety program. The meeting minutes were to be kept and maintained for a minimum of one year.

4.6.9.5.5.1. The investigation team was unable to locate meeting minutes related to the monthly safety meetings identified in the HSE Manual.

4.6.9.5.6. The HSE Manual stated that the Director of Safety for OceanGate would function as the Company's Safety Officer and was responsible for the administration for the safety program.

4.6.9.5.6.1. No previous OceanGate employees or the RADM(ret.) Board Member interviewed by the MBI could identify who OceanGate had designated as the company's Safety Officer.

4.6.9.5.7. Within the HSE Manual there were 40 chapters, ranging from manual lifting techniques to confined space entry. Dive Operations were covered in Chapter 39 and included roles and responsibilities, dive planning, dive execution, post dive tasks, minimum requirements for submersible TITAN to commence a dive, communications and tracking of the submersible, towing configurations, and platform configuration and protocols.

4.6.9.5.8. Within the HSE Manual it stated that the primary roles and responsibilities for personnel while conducting dive operations were as follows:

4.6.9.5.8.1. The Mission Director is responsible for all mission planning, execution and post dive documentation (entering of squawks and dive data). The Mission Director shall typically not be involved in vessel or equipment operation during a mission.

4.6.9.5.8.2. The Submersible Pilot is responsible for the safe operation of the submersible including all pre and post dive checks. The pilot reports to, and takes direction from, the Mission Director except for submersible safety related items.

4.6.9.5.8.3. The Vessel Captain is responsible for the safe operation of their vessel (e.g., MAX, or tenders). All vessel captains report to and shall follow the orders of the Mission Director unless to do so would potentially cause an unsafe situation.

4.6.9.5.8.4. The Platform Operator is responsible for the launch platform and its operation. Once permission to lift or descend is issued it is incumbent on the platform operator to ensure that the sequence is proceeding nominally and if not to decide whether to terminate the sinking or surfacing operations.

4.6.9.6. Dive planning and execution is the overall responsibility of the Mission Director. Dive plans were required to be completed a minimum of eight hours prior to the scheduled operation. Failure to provide a dive plan within the eight-hour required timeframe would constitute a "*strike*" (OceanGate's use of the term "*strike*" is defined below). Dive plans were required to be posted and made available to all members.

4.6.9.6.1. OceanGate implemented a three-strike system for dives. If there was a total of three or more "strikes" encountered during a dive evolution, the Mission Director was required to cancel the day's dive operation.

4.6.9.6.2. A "strike" was defined within the glossary of the HSE Manual:

> "A major deviation or major problem encountered during a dive operation including during pre-dive preparations that is significant, but not by itself worthy of mission cancellation. Examples of strikes are weather worse than forecast, delays of more than one (1) hour from plan, last minute substitutions of key personnel in dive operations, failures of equipment within MEL guidelines, last minute unscheduled configuration changes."

4.6.9.6.3. Although the MBI witnesses testified that TITAN dives were canceled for various reasons including equipment malfunctions and inclement weather, the MBI could not find written documentation of a TITAN dive cancellation due to the three-strike system.

4.6.9.7. The Mission Director was responsible for monitoring, directing, modifying and potentially cancelling a dive operation. The Mission Director was also responsible for ensuring all pre-dive checks were completed for all procedures and equipment prior to commencing a dive. The Mission Director was required to cancel a dive when it was determined that an unsafe condition existed.

4.6.9.8. The Mission Director was also required to track "anomalies" over the course of the operation. If the number of "anomalies" exceeded 15, it was required to be considered a "strike".

4.6.9.8.1. An anomaly is defined within the glossary of the HSE Manual as "Any deviation from standard or expected performance, procedure, system setup that would not be expected in a "perfect" situation. Anomalies could have been as small as a dive member showing up late to a mission, a delay of more than 15 minutes in any planned step, or even a missing piece of required apparel (e.g., pen, knife, etc.)."

4.6.9.9. The Mission Director was also responsible for post-dive tasks, including the post-dive brief. Any incidents or accident reports were to be submitted or initiated. It was the Mission Director's responsibility to ensure that all "squawks" and the dive summary were entered into the vessel log and to ensure all vessels and systems were prepared for storage or recharged.

4.6.9.9.1. A "squawk" was an acoustic marker identified on TITAN's Real Time Hull Monitoring System. The real-time monitoring data acquired from acoustic sensors and strain gauges had to be extracted from the PC logger hard drive in the aft section of the hull and downloaded for analysis on the support vessel. The data could be analyzed post-dive to determine the health of the pressure vessel.

4.6.9.10. Minimum Requirements, as per the HSE Manual, for Submersible TITAN to Commence Dive:

E) MINIMUM REQUIREMENTS FOR SUBMERSIBLE TITAN TO COMMENCE DIVE

i) The submersible pilot shall ensure the following minimum requirements are met before commencing a dive.
(1) Both Ictineu 150 volt batteries at minimum of 80%.
(2) 24 volt house batteries at minimum of 25 volts.
(3) Main oxygen level at minimum of 2200 psi.
(4) Reserve oxygen level at minimum of 2500
(5) HPA minimum of 5,000 PSI if dive is less than 1,000 meters.
(6) HPA minimum of 10,000 PSI if dive is greater than 1,000 meters.

ii) At the discretion of the pilot, the following list is acceptable to be inoperable before or during a dive.
(1) 2 of 4 external lights.
(2) Sonar if visibility is greater than 10 meters.
(3) Interior lights
(4) Acoustic monitoring system if dive is less than 2,500 meters.
(5) No tracking if dive less than 30 meters and a float is attached to submersible.
(6) Electric drop weight system if dive is less than 30 meters.
(7) DVL if CTD and Sonar are operational.

Figure 49: Excerpt from Chapter 39, Section E of the OceanGate HSE Manual. Source: OceanGate.

4.6.9.11. Part of the dive plan was to determine the Risk Index for the dive. The Risk Index was defined in the glossary of the HSE Manual as:

"A score (from 0-100) that incorporates a diverse potential risk increasing situations such as poor weather, night operations, new locations or new crew. The index is used to focus the team's attention to risk increasing components. The Mission Director may be able to reduce the Risk Index through several actions such as adding a co-pilot, changing time, or doing a test dive prior to open water operations."

4.6.9.11.1. The Risk Index was determined by reviewing each subcategory under the following five categories: Vehicle Data, Location Data, Pilot Data, Team / Project Data, and Client Data. Each subcategory was given a weight or number based on its severity. If the specific condition existed (yes / no), then the weight or number was added to the risk contribution. Figure 50 is TITAN's Dive 88 Risk Index Matrix, where the Risk Index was calculated to be 35. The MBI was unable to determine how the Risk Index number was computed based on the values indicated in Figure 50.

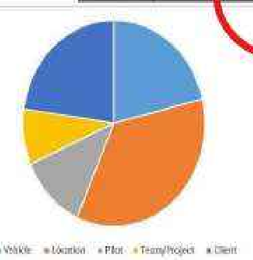
4.6.9.11.2. The MBI was neither provided with nor able to locate any OceanGate documentation assigning a risk classification (e.g., low, medium, high) corresponding to the calculated Risk Index number. As a result, the significance of a Risk Index value of 35 remains unknown. OceanGate employees and mission specialists interviewed were unfamiliar with any formal risk classification system or terminology. The average Risk Index for all TITANIC Expedition dives was 36.

4.6.9.11.3. Former OceanGate employees stated to the MBI that the Risk Index scoring was determined by Mr. Rush, the Mission Director, and possibly the pilot of the mission. No other individuals provided feedback or insight to determine the Risk Index for a dive.

Titan Dive Plan - C2_0088

Risk Index: 35

		Yes/No	Weighting	Risk Contribution
Vehicle Data				27
	More than14 days since last dive	No	8	0
	Major maintenance since last dive	No	22	0
	Overland transportation since last dive	No	9	0
	More than 5 non-critical open maintenance items	Yes	9	9
	Configuration change since last dive	Yes	18	18
Location Data				45
	Wind forecast over 10 knots	Yes	12	12
	Temperature <40degF or >90degF	No	8	0
	Rain/Snow/Night	No	15	0
	Potential sea state over 2	Yes	19	19
	Current exceeds 1kt	No	15	0
	Open Ocean or >2nm offshore	Yes	14	14
	New location/ dive site	No	14	0
Pilot Data				15
	More than 30 days since last dive	No	19	0
	More than 10 hour duty day in last 2 days	No	20	0
	Less than 3 dives in last 3 months	Yes	15	15
	No Co-pilot	No	13	0
Team/Project Data				11
	New team members	Yes	11	11
	Over 12 hour duty day in prior day any assigned team member	No	20	0
	Behind schedule	No	22	0
	Over budget	No	12	0
	Management Conformity	No	20	0
Client Data				29
	Limited experience with Subs	Yes	13	13
	Limited seamanship	Yes	16	16
	Media or celebrities involved	No	15	0



Totals	
Vehicle	27
Location	45
Pilot	15
Team/Project	11
Client	29

Emergency Contacts:
Placentia Coast Guard Radio
St. John's Port Authority
[redacted]

Figure 50: Dive 88 Risk Index. The MBI added the red circle to highlight the Risk Index calculation. Source: OceanGate.

4.6.9.12. Each dive was entered into the Dive Log, which included recording of the following information: the dive number, date, dive location, dive time, max depth, pilot, crewmembers one through four, dive objective, Risk Index, anomalies, payload, total acoustic incidents per sensor, salinity, and dive notes/ comments.

Dive Number	Date	Dive Location	Dive Time	Max Depth (meters)	Dive Objective	Risk Index	Anomalies	Payload	Total Acoustic Incidents per Sensor	Salinity (PPT)
C2_0050	4/29/21	Everett Marina	2.8	3	System Test	41	22			
C2_0051	5/2/21	Everett Marina	3.0	7	System Test	37	31			
C2_0052	5/6/21	AO	4.5	79	System Test	25	33			
C2_0053	5/8/21	Possession Sound	4.0	8	System Test	50	16			
C2_0054	5/12/21	Everett Marina	5.0	3	System Test	41				
C2_0055	5/14/21	Everett Marina	1.5	3	System Test	33				
C2_0056	5/17/21	Big Al	4.9	79	System Test	42		1434		
C2_0057	5/19/21	Marina	2.0	3	System Test	33		1072		
C2_0058	5/20/21	Hat Isl. South	4.5	170	System Test	34		1392		
C2_0059	5/24/21	Marina	2.0	3	System Test	33	14	1418		
C2_0060	5/25/21	Hat Isl. South	4.1	162	System Test	31				
C2_0061	6/30/21	Titanic	2.6	7	System Test	48		1632		
C2_0062	7/3/21	Titanic	5.8	1700	System Test	38		1606		
C2_0063	7/9/21	Titanic	16.0	3840	System Test	38		1631		
C2_0064	7/13/21	Witless Bay	4.9	89	System Test	31				
C2_0065	7/19/21	Titanic	11.3	3500	Exploration	34		1695		
C2_0066	7/24/21	Titanic	10.7	3840	Exploration	35	9	1548		
C2_0067	7/27/21	Titanic	9.5	3840	Exploration	34		1577		
C2_0068	7/28/21	Titanic	11.1	3840	Exploration	42	9	1765		
C2_0069	8/4/21	Titanic	10.7	3840	Exploration	37		1738		
C2_0070	8/5/21	Titanic	10.8	3840	Exploration	41		1754		
C2_0071	6/16/22	150 SE St. John's	3.5	7	System Test	50	13	1722		
C2_0072	6/18/22	Titanic	6.3	1380	Exploration	28	10	1760		
C2_0073	6/20/22	Titanic	27.0	3840	Exploration	22	22	1674	10	
C2_0074	7/1/22	Bay Bulls	5.0	25	System Test	50		1676		
C2_0075	7/3/22	Titanic	13.0	3840	Exploration	30	6	1588	8	
C2_0076	7/6/22	Titanic	12.0	3840	Exploration	30		1594	16	
C2_0077	7/8/22	Witless Bay	4.2	30	System Test	13				
C2_0078	7/11/22	Cameron Canyon	3.5	10	Exploration					
C2_0079	7/14/22	Titanic	11.9	3840	Exploration	34		1674	14	
C2_0080	7/15/22	Titanic	10.9	3840	Exploration	30		1702	12	
C2_0081	7/19/22	Titanic	12.8	3840	Exploration	34	3	1763	20	
C2_0082	7/22/22	Titanic	11.1	3840	Exploration	35		1649		
C2_0083	7/23/22	PH Mystery	12.1	2954	Exploration	42	6	1739	40	
C2_0084	5/22/23	Enroute Titanic	0.5	8	419 drill	30	14			
C2_0085	5/31/23	Grand Banks	2.0	10	Test	40		1333		
C2_0086	6/5/23	Grand Banks	2.0	10	Test	43	14	1450		
C2_0087	6/12/23	Grand Banks	2.0	10	abrted dive	40	8	1472		

Figure 51: Excerpt of Final TITAN hull Dive Log (adjusted to remove names of occupants). Dive 50 was the final TITAN hull's first dive. Source: OceanGate.

4.6.10. Engineering Division of OceanGate

4.6.10.1. Initially, OceanGate's business strategy was to acquire existing submersibles for global contracting, a model that did not require an in-house engineering team. However, as OceanGate recognized the limitations of this model, they pivoted to developing proprietary submersibles, prompting the need for specialized engineering expertise. In 2013, OceanGate engaged Boeing to perform a comprehensive feasibility analysis for a deep-sea submersible utilizing advanced carbon fiber technology. From 2014 to 2016, engineering efforts were primarily spearheaded by the University of Washington's Applied Physics Lab (UW-APL), which played a pivotal role in the Development Project for OceanGate, as detailed in Section 4.9. Throughout this period, all engineering tasks were overseen by Mr. Rush in collaboration with various third-party organizations, which laid the foundation for fabrication of the TITAN's deep sea carbon fiber hull design and construction.

4.6.10.2. In 2016, OceanGate entered a transformative phase by appointing its first Director of Engineering who was given the responsibility of completing the design and development of the CYCLOPS II (first TITAN hull) submersible in conjunction with the UW-APL. This decision represented a critical juncture in the company's evolution, as OceanGate sought to enhance its capabilities in underwater exploration and submersible technology. However, by May 2017, shifts in risk allocation, project vision, and strategic priorities prompted OceanGate to reassess its engineering framework and to assume complete ownership of the engineering process, taking on 100% responsibility for the design and development of the CYCLOPS II (TITAN).

4.6.10.2.1. Despite this shift towards independent engineering, OceanGate continued to utilize the UW Oceanography Pressure Test Facility.

4.6.10.3. In response to the complexities of the system configuration and challenges related to component availability, OceanGate significantly expanded its engineering team to approximately 18 members. This expansion was critical to addressing the multifaceted demands of designing and developing the CYCLOPS II (first TITAN hull). The team included specialists in 3D modeling and simulation to create detailed virtual representations of the vehicle, manufacturers responsible for fabricating and assembling physical components, and electronics technicians and engineers tasked with developing and integrating the electrical systems and instrumentation. Additionally, software engineers were brought on to design the control systems and software interfaces essential for the functionality and operation of the CYCLOPS II (first TITAN hull).

4.6.10.4. Despite the team's growing specialization, there was a notable lack of experience in submersible design, as many of the new hires were either current college students or recent graduates. OceanGate enlisted engineering students from Washington State University Everett to create a "cost efficient" prototype battery system that would be both "safe and affordable."

Abstract

OceanGate provides manned submersible services, assets and operations for ocean exploration. Our submersible pilots and operations crew support the global subsea market with a focus on commercial applications, subsea research and ocean exploration. Our clients are engaged in a broad range of industries and geographic locations, with one common need: safe and affordable manned exploration of the world's oceans.

The idea of a "deep sea" battery is not new. In fact, there is a myriad of companies that currently make a version or two that are rated to some particular depth and provide some particular operating range whether it be characterized by voltage, current, or power. The goal of this project, however, is in efficiency. We, at OceanGate Engineering, postulate that, of the presently available systems, the extremely long lead time to market is not born of necessity and that the proportional high cost is not justified. We further postulate that a system of commercial off the shelf (COTS) parts and low-cost circuits (e.g. Arduino's, Raspberry Pi's, and BeagleBone Black's) can be integrated together to deliver the operational needs of our deep diving submersibles.

Project Description

The scope of the senior design project is to:

- Design an underwater battery system with operational requirements of:
  - 6000 m depth
  - 148 VDC
  - 70 Ah capacity
  - > 10 kWh
  - CAN and Serial communications
  - Charged by any COTS charging system
- This battery would have to be cost efficient and modular in design (i.e. allow for different voltage capacities)
- The battery would have to include a Battery Management System (BMS) that allows feedback to the user (state of charge), protection against over-current, and automatic shutoff when voltage is at minimum charge levels.
- Charging capabilities must also be present.
- Preferred communication to BMS would be either RS-232 or Ethernet.
- Bonus: A software interface for the BMS in both Linux and Windows.

Figure 52: OceanGate Project for WSU-Everett Students. Source: https://www.vice.com/en/article/OceanGate-college-student-cost-efficient-battery/ .

4.6.10.5. In April of 2019, OceanGate hired a Director of Marine Integration and Operations, who later assumed the role of Director of Engineering. During an MBI interview, he described the challenges he was recruited to address, explaining that the engineering team was struggling with skill mismatches and a lack of subsea expertise. He noted that the team largely consisted of young, inexperienced individuals—many with two-year degrees and limited relevant knowledge—resulting in significant gaps in capability. He observed that the team lacked both industry-specific subsea knowledge and the engineering acumen necessary to meet the demands of the project.

4.6.10.5.1. The Director of Marine Integration and Operations joined the company as the first TITAN submersible was preparing for its manned test dives in the Bahamas. Reflecting on the state of the project, he described the TITAN as akin to a "high school project," pointing out the inadequacy of its systems despite being marketed as capable of 4,000-meter dives. He further remarked on the team's morale, stating that many were unhappy with their roles and ill-equipped to tackle the complexities of designing a sophisticated deep-sea submersible.

4.6.10.5.2. Noting a complete absence of engineering procedures, documents, or drawings upon his arrival, the Director of Marine Integration and Operations led OceanGate to adopt the cloud-based CAD (computer aided design) software Onshape® to develop detailed drawings and procedures for their submersibles and operations. In an article for Onshape Magazine, the Director highlighted how the software enabled remote teams to collaborate effectively by allowing them to log in from any web-based device, such as PCs, tablets, or mobile phones. This approach facilitated real-time communication, idea sharing, and quick decision-making, which ensured time-sensitive projects stayed on track and provided new opportunities for innovative remote collaboration.

4.6.10.6. From 2017 until 2023, OceanGate's engineering team experienced significant downsizing. In 2017, the team consisted of approximately 20 members. By 2019, this number was reduced to approximately 12. As of 2023, the engineering team was comprised of just three members: an electronics engineer, an electronics technician, and a software engineer. According to the Expedition 2023 Execution Plan, the position of Director of Engineering during TITAN's final expedition was still to be determined.

4.6.10.7. All three of OceanGate's Directors of Engineering stated that Mr. Rush made all engineering decisions independently, despite having a Director of Engineering in place. The most recent Director of Engineering, who left the position in February 2023, noted frequent disagreements between Mr. Rush and the engineering team regarding quality standards related to modifications. The last Director of Engineering stated that Mr. Rush often prioritized more cost-effective approaches and solutions, which led to ongoing tensions over project execution and safety.

4.6.10.8. At the MBI Public Hearing, when asked who would make the majority of the engineering decisions, OceanGate's former first Director of Engineering stated: "It was Stockton, for sure.... My job as the Director of Engineering is more about rounding up the cattle than it is about making all the choices, for sure."

4.7. Submersible ANTIPODES

4.7.1. In 2009, OceanGate LLC acquired its first submersible, ANTIPODES. Originally designated as PC-15, ANTIPODES was constructed in 1973 by Perry Submarines and was primarily used for diver lock-out operations in the North Sea's oil fields. Following its service in that role, the submersible was upgraded by Deep Sea Adventures® from 1994 to 1995, featuring new 58-inch diameter, hemispherical domes on both ends of the hull. This refurbishment also included new soft tanks, a variable ballast system, and an exostructure.

4.7.2. In 1996, a Russian billionaire acquired Antipodes, and from 1996 to 1999, the submersible was operated for leisure aboard his 150-foot (46 m) yacht, MYSTERE.

4.7.3. In 2000, ANTIPODES was sold to Submarine Adventures, which relocated it to Milford Sound, New Zealand. It was renamed at this point and operated as a tourist submersible until 2004, taking thousands of visitors to experience the fjord with a maximum operating depth of approximately 280 m (930 feet).

4.7.4. In 2009, OceanGate LLC purchased the ANTIPODES for use as a training platform for pilots and operations. This vessel was instrumental in helping OceanGate navigate its submersible operating plan.

Figure 53: ANTIPODES. Source: OceanGate.

Design Depth	1000 FSW
Rated Depth	840 FSW or less depending on most recent ABS supervised test dive
Test Depth	1,250 FSW (381 m)
Overall Dimensions	15' long, 7.5' wide, 8' high (4.5 x 2.3 x 2.4 m)
Crane Weight	14,340 lbs (6,504.5 kg)
Payload	850 lbs (385 kg)
Viewports	Two 58" OD (1.47 m OD) 150 degree spherical sectors with conical edge, seven 8" ID (0.20 m ID) conical frustum
Drop Weight Tray with Lead	916 lbs (412 kg)
Propulsion Thrusters	Six-two hp reversible thrusters, vectored for three axes maneuverability
Speed	Two knots cruising, three knots maximum
Power	Two lead-acid battery banks 120 VDC @ 165ah 12/24 VDC from converters
Backup Power	24 VDC @ 260ah gel batteries
Dive Duration	A maximum dive time of 8 hours duration
Life Support	Normal operation – 5 persons for 8 hours Reserve operation – 5 persons for 72 hours: oxygen supply and carbon dioxide scrubbing capacity, 5 air BIBs, 5 MSA rebreathing units, emergency food and water rations
Classification	American Bureau of Shipping, + A1 Research and Exploration Submersible
Navigation	Digital flux compass, Digital fathometer, analog fathometer, Multi-beam sonar, tracklink and Hi-pack tracking software

Figure 54: ANTIPODES Specifications. Source: OceanGate.

4.7.5. On April 13, 2010, the Co-founder of OceanGate applied for inspection for the ANTIPODES with USCG Sector Puget Sound. He requested a designation letter to operate as an ORV and a COI to operate as a small passenger vessel.

4.7.5.1. Applications for inspection for certification must be submitted to the cognizant OCMI by the vessel's master, owner, or agent on Application for Inspection of US Vessel, Form CG-3752 (see 46 CFR 2.01-1). The application for initial inspection of a vessel being newly constructed or converted must be submitted prior to the start of such construction or conversion. This must be followed by the submittal of plans and specifications required by the applicable regulations.

4.7.6. In June of 2010, OceanGate conducted their first mission utilizing the ANTIPODES on Lake Laberge in the Yukon territory, Canada, on an expedition to the wreck site of the A. J. GODDARD. In collaboration with BlueView Technologies, the dive operation produced the first 3D digital imaging of the sunken 100-year-old tugboat.

4.7.7. On August 8, 2010, Sector Puget Sound issued an ORV Letter of Designation for the ANTIPODES, which stated*,*

> "This designation shall remain in effect until August 30, 2012, in accordance with 46 CFR 3.10-1 (c), provided the vessel does not change employment or deviate from engaging exclusively in oceanographic research operations. Any such changes or deviations may constitute violations of inspection laws and must be reported to this office by the master, owner, or agent of the vessel. A determination will then be made regarding the vessel's eligibility to retain this designation."

4.7.7.1. The ORV Designation Letter was hand delivered by the attending Marine Inspector from USCG Sector Puget Sound on August 30, 2010, after he witnessed a test dive, with an attending ABS surveyor, to 936 feet in Puget Sound, Washington. The test dive was conducted to comply with ABS class rules.

4.7.8. While USCG ORV Letters of Designation are issued from a specific OCMI, they do not limit operation of the ORV to the geographic area within the issuing OCMI's zone.

4.7.9. OceanGate then operated the ANTIPODES utilizing their USCG Sector Puget Sound ORV Designated Letter from September 2010 to October 2010, on a Catalina Island Expedition, within the USCG Sector Los Angeles-Long Beach's OCMI Zone. During the Catalina Island expedition, OceanGate collaborated with the Undersea Voyager Project. While engaged on this project, OceanGate had an incident that damaged the ANTIPODES, which resulted in approximately $10,000 in repairs and termination of the collaboration with the Undersea Voyager Project.

4.7.9.1. An experienced underwater explorer and submersible pilot, who had been hired by OceanGate to pilot the ANTIPODES, stated that the incident he witnessed while contracted on the Undersea Voyager Project, suggested that "the culture of OceanGate was one of "safety is not important[23]." On the 8th dive of the Undersea Voyager Project, according to the hired explorer, Mr. Rush told him to sit the dive out so he could take his "rich friends" on the dive. Prior to that 8th dive, a crewmember removed the battery pod vent cap. The removal of the cap was not identified during the pre-inspection and when the dive commenced, the battery pod became flooded, damaging the batteries.

4.7.10. In July of 2011, OceanGate and the ANTIPODES performed four dives to the depth of 240 feet on the wreck site of the steam ship (SS) GOVERNOR in Elliott Bay, Seattle, Washington. Also, during that expedition, the ANTIPODES conducted a search for the SS DIX in Elliott Bay.

4.7.11. The USCG Marine Safety Center conducted a review of the information provided by OceanGate pursuant to issuance of a COI to ANTIPODES. The Marine Safety Center sent a formal response on March 4, 2011, stating that they would need additional information to assess the submersible for carrying passengers. The pressure calculations, as-built plans and drawings, and supporting documentation requested by the Marine Safety Center were never submitted by OceanGate to the USCG.

4.7.12. In 2011, OceanGate contacted USCG Sector San Francisco to inform them of upcoming submersible operations in Monterey, California. At the time, the ANTIPODES had a valid ORV Designation letter issued by USCG Sector Seattle. However, OceanGate requested that they be allowed to operate as a recreational vessel while in Monterey.

4.7.12.1. In a response to OceanGate's request, the Assistant Chief of Inspections (ACID) at USCG Sector San Francisco contacted the USCG 11th District Legal Office to seek clarification on the "exclusive employment" criteria outlined in the ORV Designation (Marine Safety Manual Volume II, Chapter 4). In response, District 11 Legal assessed the situation and determined that the vessel ANTIPODES did not qualify as being "employed," as it was not charging passengers and thus lacked the consideration defined under regulations. Based on this interpretation, ACID permitted ANTIPODES to operate as a "recreational vessel", which was documented in the Coast Guard's Marine Information for Safety and Law Enforcement (MISLE[24]) database.

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[23] https://www.businessinsider.com/2010-OceanGate-stockton-rush-mission-flooded-deep-sea-explorer-says-2023-7

[24] The Coast Guard MISLE database is used to record all Prevention and Response activities conducted by the USCG (e.g., vessel and facility inspections, marine casualty investigations, SAR cases, law enforcement boardings, pollution responses).

a. Letters of designation. Owners/operators of uninspected, seagoing motor vessels of less than 300 GT and any uninspected motor vessels operating on the Great Lakes that are intended to be operated as ORVs may request a Letter of Designation as an ORV under 46 U.S.C. 2101(18).

(1) After determining that such a vessel is employed exclusively in oceanographic research, the OCMI must issue a Letter of Designation valid for a period of 2 years (see Figure 10-2 for a sample letter). This letter designates the vessel as an ORV, and advises the owner/operator that the vessel must maintain exclusive employment in oceanographic/limnologic research or instruction and that any deviation from such exclusive use may constitute violations of the inspection statutes.

(2) In prior administrative rulings, the study of celestial navigation, seamanship, scuba diving, and other topics, in conjunction with oceanographic research or instruction, has voided a vessel's claim of exclusive employment. Additionally, a vessel documented as a pleasure vessel under 46 U.S.C. 12109 may not secure an ORV designation without surrendering its document, as the vessel would not be used exclusively for pleasure.

Figure 55: Excerpt from USCG Marine Safety Manual Volume II, Section B, Chapter 4, H.4. Source: USCG.

4.7.12.2. In October of 2011, OceanGate and the ANTIPODES conducted 34 dives over 30 days on a Monterey Bay expedition in conjunction with OceanGate Foundation in Monterey Bay and Carmel Bay, California. OceanGate claimed the ANTIPODES conducted the operations as an ORV in accordance with the restrictions detailed in its ORV Designation Letter.

4.7.13. In April of 2012, ANTIPODES began a Miami Expedition. OceanGate's website provided the following update on the new operations,

> "After expanding operations in Miami, Florida in 2012 to meet growing demand from East Coast and Caribbean clients. OceanGate began a 7-month long expedition."

4.7.14. From March 29 to October 31, 2012, OceanGate's ANTIPODES conducted 17 dives across nine dive sites on the Key Biscayne artificial reefs in Miami, Florida.

4.7.15. On June 19, 2012, OceanGate's Co-founder requested a new ORV Letter of Designation for the ANTIPODES from USCG Sector Miami. The original Letter of Designation issued to ANTIPODES was expiring on August 30, 2012. In the renewal request letter he stated,

> "I understand that we have previously submitted to you all of the underlying documentation required for you to make this determination, including the original ORV LOD (Letter of Designation), our Operations & Safety Manual, and our

Operations Plan for Miami. As we have for the past two years, we plan to continue operating the submersible for the purposes of oceanographic research, collecting valuable data for scientific analysis and contributing to the exploration of the marine environment. In doing so, we will continue adhering to the requirements set forth in United States Code and the Code of Federal Regulations for oceanographic research vessels."

4.7.16. On July 5, 2012, Miami Today News published an article featuring insights from the Co-founder of OceanGate, shedding light on the company's unique approach to ocean exploration. The Co-founder emphasized that OceanGate was dedicated to supporting researchers, particularly those lacking sufficient funding. Stating that OceanGate aimed to collaborate with scientists engaged in significant and intriguing projects, often in remarkable locations. To achieve this, OceanGate created expeditions tailored to the researchers' work, financing these missions by involving what he termed "citizen scientists." These individuals became integral members of the crew, contributing to data collection and other essential tasks to advance the expedition's goals. Unlike typical tourism ventures, OceanGate's expeditions were characterized by their focus on meaningful fieldwork, where every participant played an active role. While citizen scientists were allowed to contribute financially, they were also treated as crew members, undergoing training that spanned from two to seven days. This model attracted a diverse clientele, all of whom possessed some financial resources, as participation carried significant costs—ranging from $7,500 to $40,000 per person, depending on the mission's duration and complexity. This innovative blend of research support and public involvement exemplified OceanGate's commitment to advancing marine science while fostering a deeper connection between individuals and ocean exploration.

4.7.17. On August 13, 2012, USCG Sector Miami engaged in discussions with OceanGate's Co-founder regarding the operational plans for their submersible. OceanGate had sought permission for individuals to pay for a training course aimed at qualifying them as submersible pilots. However, USCG Sector Miami determined that such an arrangement would be classified as "passengers for hire," since financial compensation paid for the course would flow to the owner/operator and those receiving instruction would not be considered paid crew members. Consequently, Sector Miami denied OceanGate's request to operate in their OCMI zone.

4.7.18. As a result, the renewal ORV Letter of Designation subsequently issued by Sector Miami was revised from the standard example outlined in the USCG Marine Safety Manual Volume II. This modification explicitly limited the operations of the submersible to oceanographic research. The ORV Letter of Designation, which was issued on August 13, 2012, contained these new stipulations and outlined the regulatory framework under which the submersible would operate. Specifically, the letter stated:

"An Oceanographic Research Vessel is limited to oceanographic research or instruction. Such operations may be conducted by persons in addition to the navigation crew who are adult scientific personnel engaged in research or instruction in oceanography. College students in receipt of instruction at undergraduate or graduate levels are to be currently enrolled in accredited oceanographic courses of study and acting in a capacity as a scientist in training. Personnel allowed on board are restricted to paid crew and college students/scientists.

An Oceanographic Research Vessel cannot engage in the carriage of freight or passengers, towing and salvage, testing of navigation or sonar equipment, or archaeology. Receipt of payment for instruction in vessel operation, scuba diving or seamanship would constitute violations of inspection laws."

4.7.19. On August 23, 2012, USCG Sector San Francisco received an email from the Co-founder of OceanGate, which stated that OceanGate was now affiliated with the OceanGate Foundation and was notifying the Sector of ANTIPODES' plans to operate in Monterey for a duration of two weeks. Subsequently, USCG Sector San Francisco reached out to the Co-founder to discuss the operational details. The Co-founder initially indicated that ANTIPODES would be operating under USCG Sector Miami's ORV letter. However, after further discussion, USCG Sector San Francisco requested a formal letter from OceanGate outlining the specific details of the proposed submersible operations.

4.7.20. On September 17, 2012, USCG Sector San Francisco received a formal letter from OceanGate, indicating their decision not to proceed under the ORV Letter of Designation previously issued by USCG Sector Miami. Instead, OceanGate requested an ORV Letter from USCG Sector San Francisco and proposed to conduct "discovery dives" with the ANTIPODES.

> Even though we generally operate our submarine under an Oceanographic Research Vessel Letter of Designation issued by Sector Miami, during this expedition we will not be getting paid (cash or other consideration) by anyone going in the sub. Instead, we will be supporting two 501(c)(3) nonprofit organizations: the BLUE Ocean Film Festival (www.blueoceanfilmfestival.org) during its biannual awareness-building event and the OceanGate Foundation (www.oceangatefoundation.org) during its annual education and outreach program to the Monterey community. ***Therefore, we will not be operating as an ORV.***
>
> **Phase I:** 24 September to 28 September – static display at BLUE (Portola Hotel)
> **Phase II:** 29 September to 07 October – 5 days of "discovery dives"
> **Dive Sites:** Shipwreck (unnamed barge off Breakwater Cove), depth 50 feet, 2 dive days
> Shipwreck (*Art Riedel Sr.*), depth 300 feet, 3 dive days

Figure 56: Excerpt from OceanGate letter RE: Operations Plan for Monterey 2012 Expedition. Source: USCG.

4.7.21. USCG Sector San Francisco contacted the Co-founder to have him provide a determination on what was a "discovery dive." The Co-founder stated that the ANTIPODES would be manned by three OceanGate employees, with an additional two individuals accompanying them within the submersible during the dives. Although the ANTIPODES could accommodate five people, only three were necessary for its operation. When USCG Sector San Francisco inquired further about the identity of the two additional personnel, the Co-founder revealed that they were either VIPs or independent investors.

4.7.22. USCG Sector San Francisco stated that such an arrangement could be categorized as a "passenger for hire" operation, which would be in violation of the regulations governing an ORV. In response, the Co-founder contested this classification, asserting that their operations were akin to those of a recreational vessel. Acknowledging the complexity of the situation, USCG Sector San Francisco informed the Co-founder that further research would be conducted, promising to keep them apprised of any developments in due course.

4.7.23. On September 17, 2012, USCG Sector San Francisco contacted the Chief of the Domestics Branch at Sector Miami, who confirmed that a meeting had taken place with OceanGate's Co-founder. During this meeting between the two USCG field units, Sector Miami notified Sector San Francisco that they discussed and clarified the operational parameters for the ANTIPODES in relation to its ORV designation.

4.7.24. In September and October of 2012, OceanGate conducted a four week multifaced operation in Monterey Bay, California. These four weeks included engagement with the Deep BLUE Initiative, the BLUE Ocean Film Festival, outreach for the OceanGate Foundation, and two weeks of dives with students and other stakeholders.

> 4.7.24.1. After a review of the records contained in the USCG MISLE database, the MBI was unable to locate records confirming that USCG Sector San Francisco issued an ORV Letter of Designation for the USCG Sector San Francisco OCMI zone that was requested by OceanGate on September 17, 2012.

4.7.25. From June 27-29, 2013, OceanGate used the ANTIPODES to conduct a Lionfish Expedition in South Florida. The expedition took researchers, media, and sponsors (a total of 19 individuals), on four dives over the two-day excursion to document and bring awareness to the invasive species.

4.7.26. From July 22-23, 2014, OceanGate Foundation and Discovery Channel Daily Planet conducted two dives in Elliott Bay, Seattle, Washington to search for six gilled sharks with a celebrity entertainer aboard.

4.7.27. On February 18, 2020, the USCG Marine Safety Center issued a letter to OceanGate stating that their request to be certificated as a small passenger vessel had been disapproved. The denial letter contained the following statement, "As currently built, we have determined that the design does not meet the requirements of 46 CFR Subchapter T, nor does it provide a level of safety equivalent to that intended by existing laws, regulations, and policy."

4.7.28. The next issuance of an ORV Letter of Designation to ANTIPODES was on July 11, 2020, from USCG Sector Puget Sound. From August 13, 2014, until July 11, 2020, there were no ORV Letters of Designation issued to OceanGate from any USCG OCMI zones for the ANTIPODES.

4.8. Boeing Preliminary Design of the OceanGate Deep Sea Submersible Pressure Hull

4.8.1. According to MBI testimony from a Boeing Material and Process Engineer, Boeing and OceanGate entered into a Proprietary Information Agreement and Technical Services Agreement to conduct a preliminary feasibility study for a concept vessel called the CYCLOPS in 2012.

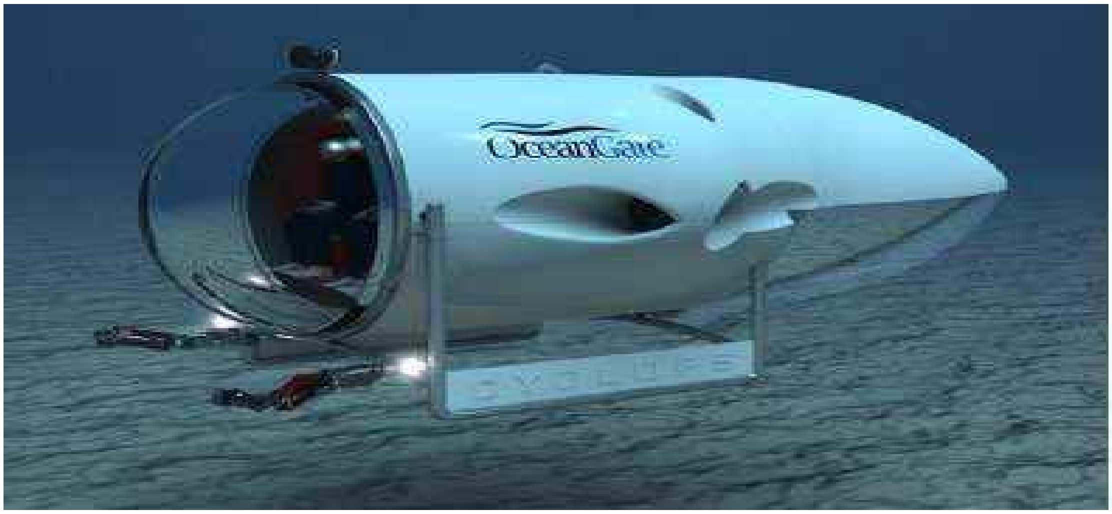

Figure 57: Conceptual Image of OceanGate CYCLOPS Deep-Sea Submersible. Source: Boeing.

4.8.2. On October 21, 2013, Boeing research and technology completed a report for OceanGate on the project to develop a basic design and determine the feasibility of a deep-sea submersible pressure hull constructed primarily of fiber placed composite material. The report stated,

> "The motivation is to create a lean efficient vehicle that can be operated at depth with reduced support vessel requirements due to the reduced weight of the vehicle. The basic design parameters were outlined by the customer, OceanGate."

4.8.2.1. The initial goal with the study was to design a hull capable of 6,000 m; however, the goal was subsequently revised to an 8,600 m operational depth with a 1.5 safety factor while maintaining a net buoyancy of at least 1,200 kg. The design goals, hull design, and materials evolved over the course of the feasibility study.

	Optimum	Allowable Limit	Notes
Net Buoyancy Including aft dome (net) Excluding Fwd dome (net)	>1,400 kg	1,200 kg	Main Assumptions: 1,027 Kg/m^3 Saltwater density Fwd dome net buoyancy(weight) = -719kg
Inside Diameter	1.5 meters	+-0.1 meter	
Length	2.5 meters	+-0.5 meter	
Maximum Operational Depth	8600 meters	8600 meters	
Production cost (beyond 1st hull)	<$1 million	$3 million	Including interface ring, instruments and coatings, not including fused silica dome
Safety Factor	1.5	1.5	

Figure 58: Basic Design Guidelines for OceanGate CYCLOPS Hull. Source: Boeing.

4.8.3. At a depth of 8,600 m, the external pressure was calculated to be approximately 12,562 psi. Boeing's study determined, for a thick-walled cylindrical hull made from reinforced carbon composite, the required wall thickness would be about 9.3 inches, not accounting for any thermal residual stress in the laminate. However, an open-hole structure indicated a negative margin of 83%, necessitating over 32 inches of wall thickness. Therefore, it was crucial to ensure that the carbon fiber reinforced polymer cylinder remained free from perforations or impact damage.

4.8.4. The report stated, "This structure will need to be carefully inspected for manufacturing defects such as porosity, voids, inclusions, and FOD (foreign object debris). The load bearing composite will need some form of internal and external protective coating or barrier. It will also need to be protected with a more durable impact absorbing protective layer such as syntactic foam on the OML (outer mold line) of the hull. The interface with the metallic segment is to be carefully bonded and inspected. It will be void of fasteners, holes, or cutouts of any kind."

4.8.5. The report discussed buckling, indicating that thin-walled tubes under external pressure are vulnerable to compressive loads that may cause buckling. To confirm the critical buckling pressure of this orthotropic[25] material, a full nonlinear finite element model was required to validate the structure's stability and performance.

4.8.6. The report determined that it was possible that a combined failure mode could cause buckling. For example, if ply failure should occur on the inner surface of the cylinder where compression stress is highest, the degradation in strength could

[25] Orthotropic means that a structure has different strengths and stiffnesses along different axes.

precipitate buckling. This risk was particularly critical for this thick-walled orthotropic structure. For this reason, the report recommended taking a conservative approach to protect against all failure modes.

4.8.7. The report covered the mathematical computations to allow for the parameters set by OceanGate. Boeing was able to determine the optimal carbon fiber layout mathematically for the vehicle. Throughout the report, the hull analysis was conducted with quarter symmetry in the radial direction and bisymmetry in the axial direction was developed for two lobe and four lobe stability. The initial design included a cylindrical shape with ends cut straight across. The interface segment was made of Ti6-Al-4V titanium (Grade 6) and featured tapered grips to help distribute loads more smoothly. It also had a conical shape leading to the dome to ensure that the dome aligned correctly within the segment.

4.8.8. The report stated that an effective curing method for the composite hull throughout the manufacturing process, while important, presented significant challenges. The plan involved curing the hull in multiple stages, each consisting of a 0.5 to 1 inch layer of uncured composite material. The careful selection of materials, tooling, and autoclaves was listed as critical for successful cure modeling. To minimize the risk of wrinkles and excessive heat generation during the process, the study indicated the fabrication process would have to adopt a segmented curing approach, which, although more costly and time-consuming, aimed to enhance the overall quality of the hull. Additionally, it was essential to manage thermal residual stresses that could develop during each curing step, requiring diligent monitoring to prevent exotherms.

4.8.9. The report stated that laminate structures such as carbon fiber reinforced plastic (CFRP) were used extensively in the aerospace industry for critical strength and stiffness applications. Defects in structures, such as inclusions, delaminations, and porosity were to be avoided. Conducting post assembly nondestructive evaluation (NDE) would be essential to assuring that only satisfactorily assembled products would be used in service. The report also emphasized that the fabrication of large, complex laminate structures increases the risk of experiencing defects in the manufacturing process.

4.8.10. The report stated that the most common applications of ultrasound were through transmission ultrasound (TTU) or pulse echo (PE). The consolidation of the CPFR was listed as critical to the hull's fabrication and the presence of voids, porosity, or any variation in the resin would diminish its structure load carrying capacity.

4.8.11. The Boeing study stated that when assessing the performance of the structure, it was important to keep typical machining tolerances in mind. Close attention needed to be given to the tolerances given the significant hydraulic loads and the possibility of minor defects worsening as additional layers of carbon fiber were applied. Additionally, selecting the right materials and setting a schedule for replacing seals was listed as key to ensuring the vessel could operate safely. The design assumed the vessel would be used to its full depth capacity and the report emphasized that it was crucial to understand how pressure would affect the hull over time. Many design elements would only be critical at maximum depth and less important during normal operations, which would account for 99% of the hull's usage.

4.8.12. The report stated that one of the most critical components of the design was the bonded joint between the composite hull and the titanium segments. Surface preparation was critical, and little was known about the bond ability between titanium and carbon fiber. Although the shear capability of the joint may be less critical because of the compression loading on the bond line, the compression loads at depth would be greater than what is typically observed in bonded joints. The report emphasized that more research was necessary to understand how this type of joint behaves under these conditions and how the applied loads impact the adhesive bond.

4.8.13. The report stated that the design requirements assumed full utilization of the depth capability of the vessel; however, it was important to understand the actual pressure fatigue profile of the vessel for the evaluation of critical features. Many aspects of the design would be critical only at the limits of the depth profile for the pressure hull and would be less critical for 99% of the operational use of the vessel.

4.8.14. The report concluded that designing a structure with CFRP presented several challenges that must be addressed. The inter-ply strength was approximately two orders of magnitude lower than the fiber direction strength, necessitating careful management to avoid significant interlaminar tensile or shear stresses. Manufacturing constraints, including fabrication time and thermal kinetic effects during the curing of thick composite structures, would further complicate the design process.

4.8.14.1. While cylindrical shapes are relatively straightforward to produce, they generate considerable thermal residual stress due to differences in thermal expansion. More complex geometries, such as spheres or ellipsoids, introduce additional discontinuities that can create gaps or overlaps between adjacent tows of slit tape composite material, leading to local stress variations that reduce structural capability.

4.8.14.2. Although composites are efficient under in-plane loads, complex loading conditions near hardpoints or load transitions require thorough analysis for both pristine and flawed structures. To address these issues, further detailed design work would be necessary, including a small test program to explore outstanding questions, additional modeling and optimization, and the inclusion of peripherals like portals and motor attachments. More research would be needed to define thermal loads and cure shrinkage for the composite cylinder and bonded joint, especially given the greater thickness of this composite structure compared to typical designs.

4.8.14.3. The report emphasized that the time required for fabrication and the extended exposure to elevated temperatures during curing must also be examined, as these factors were largely overlooked in the initial design phase.

4.8.14.4. The report outlined a conceptual design and preliminary feasibility study, indicating that while the submersible's hull design was viable, significant additional work was needed in manufacturing, cure kinetics, material properties, assembly, and dimensional tolerances to ensure structural integrity.

4.9. University of Washington Applied Physics Lab

4.9.1. The Principal Investigator of UW-APL developed a "Collaboratory" initiative to create a bridge between industry and academia, enabling companies to access university research that would typically be inaccessible. The initiative aimed to connect businesses with the expertise they lacked, especially in high-tech fields. This collaboration began with OceanGate, utilizing their existing submersibles for an obstacle avoidance program for the Office of Naval Research.

4.9.1. On November 7, 2012, the Principal Investigator from the UW-APL submitted an unsolicited proposal to OceanGate, Inc., for a deep ocean exploration submersible with a budget of $4,983,589. APL-UW intended to collaborate with OceanGate on the development, construction, launch, recovery, testing, and analysis of a manned underwater vehicle (MUV), also known as CYCLOPS.

4.9.2. The proposal stated, "APL-UW shall work with OceanGate to consider alternatives during the design. Tradeoff studies will be provided to look at the basic design and fabrication of the pressure hull, especially the mating of the pressure hull to the exterior viewing port(s) and necessary through-hull connections for power, oxygen, sensors, communication, etc."

4.9.3. The proposal outlined that APL-UW would utilize existing facilities and collaborate with OceanGate to modify or develop new facilities for the fabrication and construction of the submersible. This process would follow a stepwise approach, testing individual components before integrating them into a "build-test-build" sequence. For both individual components and the final assembled unit, the design, construction, and testing of the launch and recovery system would be prioritized. Initial testing of the pressure hull would be conducted without human presence, after which it would be handed over to OceanGate for final safety approval and testing. APL-UW committed to supporting all aspects of this testing process.

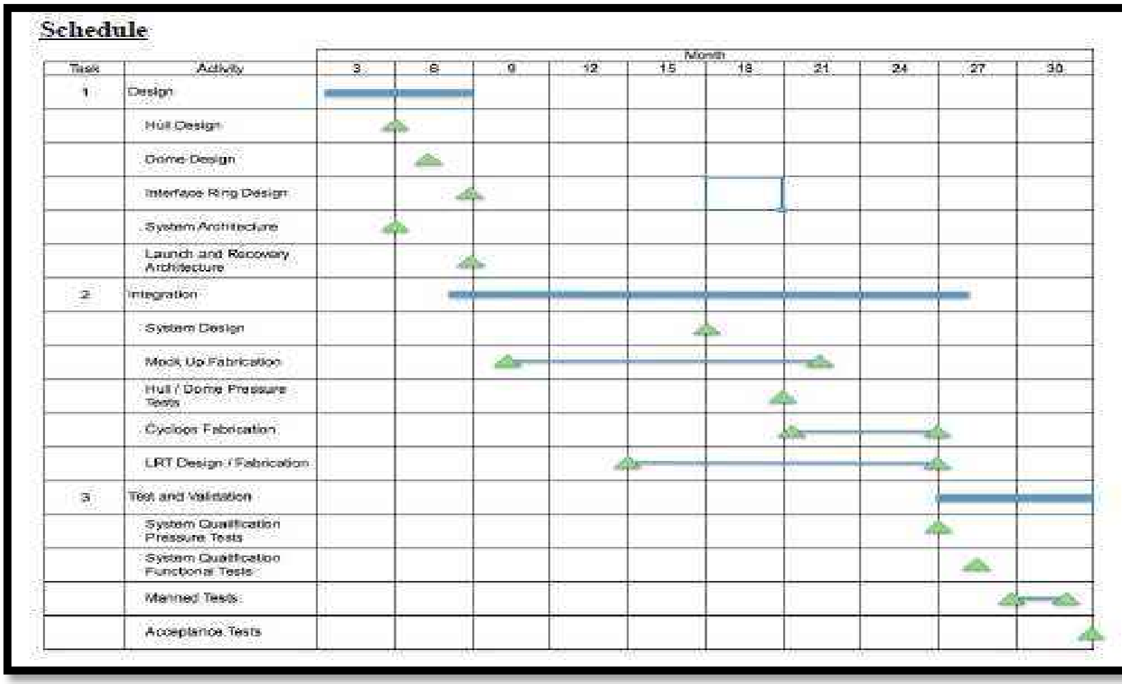

Figure 59: Schedule from UW-APL/ OceanGate Statement of Work. Source: UW-APL.

4.9.4. A project engineer from UW-APL stated that his understanding of the intent of the research proposal was to provide engineering expertise to OceanGate as they worked through the CYCLOPS I and CYCLOPS II projects.

4.9.5. The proposal stated that APL-UW would work to ensure the safety of the submersible, the engineers, and test personnel. It stressed that safety would not be compromised in any aspect of the design, fabrication, or testing. At the time of the proposal, OceanGate did not have a deep-sea submersible.

4.9.6. In approximately May of 2013, the UW-APL and OceanGate project began for CYCLOPS II (TITAN). According to the UW-APL Research Proposal, the design activity, which encompassed hull design, dome design, interface segment design, system architecture, and the launch and recovery architecture would be taking place over the first six months of the project.

4.9.7. The second phase of the project was the integration activity which encompassed system design, mockup fabrication, hull/dome pressure tests, CYCLOPS II fabrication and LRT (Launch, Recovery, and Transport) design and fabrication. The second phase was scheduled to take place from month 6 to month 27 in the project's plan.

4.9.8. The final stage of the project was the test and validation activity, which incorporated system qualification pressure tests, system qualification function tests, manned tests, and acceptance tests. The final phase was scheduled to take place from months 27 to 30 in the project's plan.

4.9.9. During MBI hearing testimony regarding the UW-APL's involvement in the design of OceanGate's carbon fiber pressure submersible hull, the project engineer explained that APL contributed to the initial concept and collaborated closely with Boeing, who provided the necessary expertise in carbon fiber. APL's role included offering insights on deep ocean requirements and load assessments to help Boeing understand the design specifications needed for the hull. While APL assisted in defining the interface between the dome and the carbon fiber structure, they depended on Boeing to lead the actual design process. The collaboration involved a continuous dialogue, where APL would present concepts, receive feedback from Boeing, and either incorporate that feedback or justify their proposed solutions.

4.9.10. At UW-APL in 2016, UW-APL's mechanical engineering representative focused on the submersible's mechanical systems such as bladder designs and landing gear but were not involved with electrical components, as their expertise did not include systems with wiring. Another UW-APL specialist handled controls, while the operations group managed primary power, secondary power, and battery storage. This division of roles ensured that various technical aspects of the project were covered by specialists in their respective fields.

4.9.11. When the project engineer was asked about UW-APL and their involvement in developing the submersible's Real Time Monitoring System, he explained that they collaborated with Boeing, who had the requisite expertise. UW-APL requested that Boeing integrate the monitoring system into one of the third-scale test models to evaluate the system's potential benefits for the program. Boeing representatives were involved in the setup and installation of the system and were present during the tests conducted on the third-scale models to observe the data collection. However, the UW-APL representatives noted that the data collected was not shared with APL, as it was only shared and discussed directly between Boeing and OceanGate.

4.9.12. In May 2017, the collaboration between OceanGate and the UW-APL was terminated due to ongoing engineering disagreements, prompting OceanGate to assume full control over the engineering aspects of their project. The Applied Physics Lab expressed reservations about using glass spheres (see Figure 60) for housing the propulsion motor controller pod for the manned vehicle. UW-APL was concerned about the reliability of glass spheres in general applications, and they highlighted a concerning history of unexpected failures of the glass spheres at significant depths. Given the extreme pressures associated with the depths OceanGate aimed to explore, UW-APL concluded that using glass spheres posed unacceptable risks, particularly in a crewed context, despite their potential suitability for shallower submersible operations.

On glass - been digging up the papers I have found over the several years working with Stockton whenever glass housings come into play; a few summary comments from those papers

17 glass sphere collapsing at 6700 meters is close to 1 kg of TNT (Hollow Glass Spheres Under Pressure in the Ocean-Experiments Show Interesting Properties; Samuel 0. Raymond, Benthos, Inc.) - C2 will not be at 6700 meters and Stockton's idea is partially filled with oil - there is nothing out there for partially filled spheres - we have checked with nautilus and benthos several times and the response is always "we dont know of anybody doing that" and several times they have said we dont recommend this. This would be a research project. By the way I ran some quick calcs and 17" glass sphere at 4000 meters yields .5 kg TNT explosion.

one navy report shows the limit of approx 200 cycles before glass begins to become unpredictable - very sketchy data but points to research needed

another navy report shows zero grease, oil, lube or other allowed on interface surface - ANY lube or grease at higher pressures will fracture glass - period - looking to find that paper but have not found it yet.

bottom line - the glass housing is a deal breaker for me

Figure 60: Excerpt from UW-APL employee to UW-APL project manager regarding the use of glass spheres for the motor pod controllers. Source: UW-APL.

4.9.13. The UW-APL program engineer stated that when the separation of OceanGate and UW-APL occurred, several key submersible design aspects were incomplete. The final design of the carbon fiber hull remained unfinished, with preliminary finite element analysis (FEA) conducted but not sufficiently completed. The team was also still attempting to address hull failures observed during third-scale testing. These failures had not been fully understood or remedied, indicating that the design needed further refinement. Additionally, the transition to titanium spheres from the originally envisioned carbon fiber dome design was still in the early stages, and while preliminary discussions about fabrication costs with foundries had begun, this aspect of the design change was also far from complete. Overall, critical components were still under development and lacked the necessary validation before the collaboration ended.

4.9.13.1. After the collaboration agreement was terminated with UW-APL, OceanGate continued to utilize the University of Washington - School of Oceanography pressure testing facility for one-third scale model and submersible component testing.

4.10. Submersible CYCLOPS I

4.10.1. On January 15, 2013, OceanGate purchased the LULA’500 from Portugal’s Rebikoff-Niggeler Foundation and renamed it CYCLOPS I. According to OceanGate's website, CYCLOPS I was a 21.8-foot, steel-hulled submersible designed to accommodate five people, with an operating depth of 500 m (1,640 feet). The vessel was purchased by OceanGate with the intentions to meet the growing demand for manned submersibles in commercial applications related to biological and environmental surveys, monitoring, and inspections.

4.10.2. Mr. Rush stated that, "Lula's power system provides long-range capabilities, extending our expeditions, and her depth rating will be valuable for various commercial applications."[26] He emphasized that the submersible aligns with OceanGate's commitment to offering cost-effective, manned alternatives for commercial clients, facilitating rapid expansion of their exploration efforts globally. The primary purpose of CYCLOPS I was to serve as a test platform for software, technology, and equipment for the TITAN.

Figure 61: CYCLOPS I loaded for highway transport in 2015. Source: OceanGate.

4.10.3. The CYCLOPS I was designed in accordance with the BS5500 Standard Specification for Unfired Fusion Welded Pressure Vessels and featured a ring-stiffened cylinder with a tapered aft section. It was comprised of three sections joined by bolted O-ring sealed flanges. The internal structure included nine T-section frames made from the same material as the hull, with an overall corrosion allowance of 1 mm factored into the shell plating calculations. Ring stiffeners served as crucial attachment points for pipework, cable trays, and oxygen ducting, enhancing the hull's functionality. A single-point lift system was strategically located near frames 4 and 5, along with mounting lugs for an aluminum exostructure, lower skids, and a drop weight assembly. The viewport was integrated into the design using a machined steel ring welded to the hull, with secure fastenings for the acrylic dome, ensuring both visibility and structural integrity under pressure. Its design emphasized safety, functionality, and adaptability for various operational needs.

[26] https://www.marinelink.com/news/submersible-oceangate350747

Figure 62: Photo of the CYCLOPS I taken by the MBI at its temporary storage site at the NOAA Center for Coastal Fisheries and Habitat Research in Beaufort, North Carolina on October 26, 2023. Source: USCG.

4.10.4. The hull's shell was constructed from 20 mm steel plate, adhering to BS-EN 10028-3 P355NL 1/1.0566 specifications, ensuring high strength and durability. The frames, mounting lugs, tori-spherical dished end, and conning tower cylinder utilized 16 mm plate, compliant with the same standard. Hull joint flanges, hatch reinforcement, lifting lugs, and minor penetration bosses were fabricated from 40 mm plate of the same material specification. The bow viewport ring was made from 100 mm plate to maintain consistency in material quality with BS-EN 10028-3 P355NL 1/1.0566.

Seating	5 persons (1 pilot + 4 crew)
Depth	500 meters (1,640 feet)
Dimensions	664 cm x 283 cm x 217 cm (21.8 ft x 9.3 ft x 7.1 ft)
Payload	567 kg (1,250 lbs)
Weight	9,075 kg (20,007 lbs)
Speed	2.5 knots
Propulsion	Four Innerspace 1002 electric thrusters: 2 vertical, 2 horizontal
Life Support	72 hours for a crew of 5
Navigation & Sonar	Teledyne Blueview 2D and 3D sonar External HD Cameras; Rowe technology (DVL)
Lighting	Two Teledyne Bowtech LED, 40,000 lumens total output
Cameras	Internal: Canon 5D Mark III External: Multiple HD for image capture and navigation
Other	Laser scaler

Figure 63: CYCLOPS I Specifications. Source: OceanGate.

4.10.5. The pressure hull was manufactured, inspected, and tested in compliance with the ABS Rules for Building and Classing Underwater Vehicles, Systems, and Hyperbaric Facilities (1990). To ensure its integrity, the hull, along with all pressure boundary items, underwent a rigorous pressure test to a depth of 631 m (2,070 feet) in a pressure tank located in Kirkbymoorside, United Kingdon in March 1998. The testing procedure included three cycles, each lasting 30 minutes, to simulate operational conditions. Strain gauges were installed at 23 locations inside the pressure hull to monitor any potential deformation and ensure structural reliability during the testing phases.

4.10.6. The CYCLOPS propulsion system features two 17-inch glass spheres designed for multiplexing propulsion power and data outside the pressure hull, with thruster command and feedback being the only data transmitted. Manufactured by Nautilus Marine of Germany, the 1/2-inch-thick glass spheres are rated for depths up to 6,000 m (19,685-feet) and are precision-drilled for cable access. Their asymmetrical design includes a primary sphere with a direct fiber optic connection to the hull and a secondary sphere that communicates through the primary. Each sphere housed motor controllers for two brushless DC thrusters, a multichannel DAC for signal conversion, environmental sensors for monitoring conditions, and a fiber-enabled Ethernet switch in the primary sphere to connect with a computer located inside the hull.

Figure 64: Photo of the inside of the CYCLOPS I taken by the MBI at a temporary storage site at USCG Sector Field Office Fort Macon, North Carolina on October 26, 2023. Source: USCG.

4.10.7. The electrical system of CYCLOPS I consisted of two distinct power systems: a 120-volt (V) system for thrusters and non-critical computers, and an isolated 24V system for sensitive equipment. Main power was provided by two banks of ten Optima 12V Absorbed Glass Mat Marine/RV batteries, located beneath the hull flooring and connected in series to deliver 120V DC. Both banks usually operated simultaneously but could be run individually, with each controlled by a contactor on the control panel. The 120V power was routed to the thrusters through rear penetrators, and a rotary selector switch enabled monitoring of battery voltage and current draw across all systems. Two reserve batteries were allocated for emergency use, supplying the 12V and 24V bus panels, and their voltage could be checked via a meter on the control panel. Additionally, 120V power fed two Vicor AC/DC converters behind the main control panel, which provided the necessary voltages for the 12V and 24V systems.

4.10.8. On December 31, 2014, the UW-APL released a collaborative video displaying the CYCLOPS I being operated with a PlayStation® controller[27]. A few months later, on March 11, 2015, the CYCLOPS I was on display at the Seattle Museum of History and Industry. An article highlighting UW-APL's release stated that the CYCLOPS I used mostly off-the-shelf commercial thrusters and components and that "the vehicle is eventually intended to be rented to clients for research, resource exploration, photography or even tourism, at a cost that would be higher than today's shallow-water subs but lower than the single-person subs now available only to very wealthy explorers."

Figure 65: Photo of the Logitech PlayStation controller inside CYCLOPS I taken by the MBI at its temporary storage site at USCG Sector Field Office Fort Macon, North Carolina on October 26, 2023. Source: USCG.

[27] https://www.youtube.com/watch?v=qV45yMvRRwM

Figure 66: CYCLOPS I on display at the Seattle Museum of History and Industry in 2015. Source: OceanGate.

4.10.9. On April 30, 2015, the CYCLOPS I was conducting a test dive in Everett Marina, Everett, Washington with members from UW-APL onboard when they experienced a malfunction of the latch for the starboard hatch. According to the internal OceanGate Safety Event / Near Miss Report filed for the incident, the description of the issue is as follows: “After the loading of the submersible, while still at the dock, the sub pilot (Mr. Rush) was unable to physically move the starboard hatch latch mechanism to its most fully engaged position. It was able to be moved externally but may not have been able to be released from inside the sub without damaging the actuation lever. The pilot engaged the latch as much as possible from the inside, then attempted to force open the hatch. Being unable to open the hatch with one latch engaged and then with the second latch normally seated, he was confident that there was no chance for the hatch to leak or unseat. However, the external personnel could see that the starboard latch was just barely engaged, and some members were vocally concerned about the anomaly.”

4.10.9.1. The Mission Director for the April 30, 2015, incident decided that the decision to proceed with the operation was a pilot decision and decided to continue ahead with the dive without 100% consensus from the group as to the safety of the partially latched starboard hatch.

4.10.9.2. According to the subsequent analysis within the OceanGate Near Miss Report, the handling of the incident highlighted significant concerns regarding safety culture and decision-making protocols for dive operations. While the functional aspect of hatch engagement was deemed not to pose a safety risk, the absence of team consensus before proceeding was considered a critical procedural failure. The pressure to proceed, influenced by the pilot’s dual role as CEO and the presence of VIP guests, created a "get it done" mentality that undermined safety practices. The pilot's awareness of dissenting opinions further emphasized the need for leaders to prioritize safety over operational pressures by reinforcing that all team members should have a voice in safety-critical decisions.

4.10.9.3. The CYCLOPS I did not have a Letter of Designation from any USCG OCMI Zone to operate as an ORV at the time of the incident in April of 2015.

4.10.10. The OceanGate website advertised regular weekly Puget Sound Research Dives with various organizations such as the University of British Columbia, the University of Washington, and NOAA. OceanGate specifically invited citizen scientists, which they referred to as mission specialists, to participate in these crewed submersible dives.

4.10.10.1. The CEO stated in a 2020 Teledyne podcast, "We do dives in the Puget Sound looking for six-gilled sharks for $5000."

4.10.11. In August of 2015, the OceanGate crew mobilized the CYCLOPS I to Galveston, Texas to conduct dives on the Flower Garden Banks in the Gulf of America off the Texas Coast. CYCLOPS I subsequently completed three dives to a maximum depth of 457 m (1,500 feet).

4.10.11.1. The CYCLOPS I did not have a Letter of Designation from any USCG OCMI Zone to operate as an ORV during the Flower Garden Banks operations.

4.10.12. On December 23, 2015, Mr. Rush informed stakeholders about the soft marketing ahead of the May 7-14 CYCLOPS 1 planned mission to the ANDREA DORIA wreck site. He mentioned that broader sales efforts would be put on hold until they secured a support vessel and formally established Argus Expeditions, which were both anticipated to be completed by the end of January 2016. Mr. Rush stated, "Encouragingly, the first potential client committed to the $20,000 fee for a two-day experience, including one three-hour dive, along with two additional participants at the same fee. With only 12 positions available for the expedition, this early interest was seen as a promising validation of the Argus Expeditions business model."

Figure 67: Map of the general location of the ANDREA DORIA wreck site. Source: OceanGate.

4.10.12.1. On June 2, 2016, the ANDREA DORIA expedition departed from Boston, Massachusetts, heading to the wreck site off Nantucket, Massachusetts. OceanGate was contracted by Argus Expeditions to survey that area. Argus Expeditions focused on scientific and film projects related to shipwrecks and other underwater phenomena. The team spent two days at the wreck site capturing 2-D and 3-D sonar scans, along with videos and still images, using the five-person CYCLOPS I submersible. The CYCLOPS I was towed from Boston to the wreck site location to conduct dives aimed at mapping the wreckage.

4.10.12.1.1. The CYCLOPS I did not have a Letter of Designation from any USCG OCMI Zone to operate as an ORV at this time.

Figure 68: CYCLOPS I being towed by the WARREN JR. to the ANDREA DORIA wreck site in June of 2016. Source: OceanGate.

4.10.12.2. In testimony regarding the ANDREA DORIA expedition, the OceanGate Director of Operations, who served as the assistant pilot to Mr. Rush, described a critical moment during a dive when the CYCLOPS I became stuck under the bow of the ANDREA DORIA wreckage. The assistant pilot stated that Mr. Rush experienced a "meltdown" and refused to let him assist in resolving the situation. When a mission specialist suggested that Mr. Rush hand over the controller to the assistant pilot, the assistant pilot reported that the controller was thrown at him. Upon obtaining the controller, the assistant pilot was able to free the CYCLOPS I from the wreckage and safely navigate it back to support vessel WARREN JR.

4.10.13. From September to October 2016, OceanGate carried out an expedition named the "Eye on the Sanctuaries," which involved a series of submersible missions across the United States. The expedition's website highlighted opportunities for key sponsors to join the crew on submersible dives, allowing them to engage directly with the exploration and research activities. This initiative aimed to promote awareness and appreciation of underwater ecosystems while providing a unique experience for participants.

4.10.14. From October 21 to 25, 2016, as part of the "Eye on the Sanctuaries" tour, OceanGate conducted the Greater Farallon's Survey Expedition. During this expedition, the CYCLOPS I served as the dive platform for mission specialists, who were transported to the dive site each day by a chartered vessel.

4.10.14.1. The CYCLOPS I did not have a Letter of Designation from any USCG OCMI Zone to operate as an ORV at this time.

4.10.14.2. During the MBI Public Hearing, when asked specifically about this expedition and if the mission specialists were actual scientists, the former Director of Marine Operations stated, "No…they were paying passengers. It was people that had money. Even when we did the dives -- we were meant to do a dive the following year I think it was, and it was Farallon (ph.) Islands, but we ended up being weathered off, and we ended up coming into the San Francisco Bay and doing the first manned submersible dives down Alcatraz. The clients had paid to go on this rack that was offshore from San Francisco, were more than happy to be, you know, the fee went towards sitting in the sub and me driving them down to the bottom of Alcatraz Rock."

Figure 69: CYCLOPS I being towed to the dive site around Alcatraz by QUIN DELTA in October of 2016. Source: OceanGate.

4.11. First TITAN Hull Design and Analysis Report

4.11.1. In June of 2015, OceanGate contracted Spencer Composites to analyze and design a carbon fiber hull based on specific parameters set by the company. Spencer Composites, known for their experience in composite materials, had previously designed a carbon fiber-reinforced hull for the DeepFlight Challenger, intended for dives to the ocean's deepest depths. According to a 2010 Composites World[28] report, Spencer Composites utilized a 4-axis CNC (Computer Numerical Machine) adapted for filament winding to construct the hull. Their design incorporated alternating double layers of wound carbon fiber around a core to resist compressive hoop stress and axial fibers to counteract compressive axial stress caused by pressure on the hemispheric endcaps.

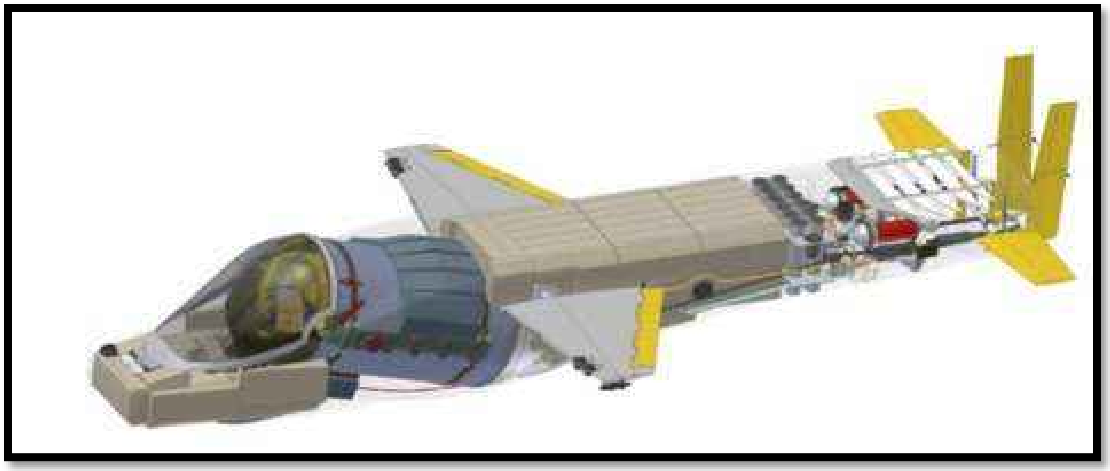

Figure 70: Illustration of the DeepFlight Challenger. Source: OceanGate.

4.11.2. Given that Spencer Composites was subsequently contracted by OceanGate to design the hull of the CYCLOPS II (later known as the first TITAN hull), a similar wound and axial fiber composite design that was used for the DeepFlight Challenger was utilized for OceanGate's carbon fiber hulls. However, a notable difference is that the DeepFlight Challenger was designed for a single occupant, resulting in a significantly smaller surface area. This meant it experienced lower compressive forces from pressure, even though it was engineered to reach depths five times deeper than those planned for the TITAN.

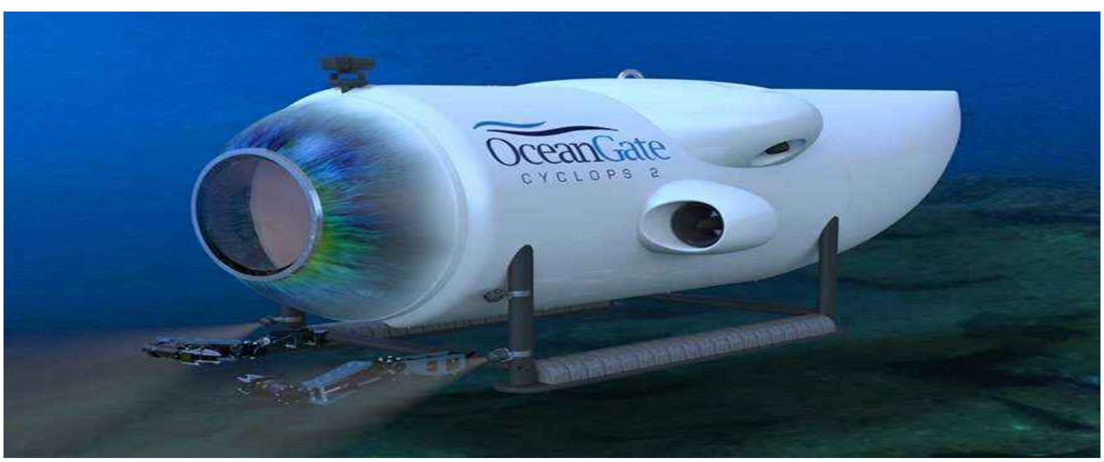

Figure 71: Conceptual image of CYCLOPS II (First TITAN hull). Source: OceanGate.

[28] https://www.compositesworld.com/articles/composite-submersibles-under-pressure-in-deep-deep-waters

4.11.3. On June 25, 2015, Spencer Composites issued a Design and Analysis Report for Full Sized Submersible Vehicle-Cylinder and Dome for OceanGate, Inc. This report summarizes the design and analysis of a filament wound composite external pressure hull for a 6,000-m (19,685-feet) submersible vehicle for OceanGate, Inc. The proposed hull consisted of a CFRP hoop wet wound cylinder with hand laid axial prepreg, Grade 5 titanium interface segments bonded to the CFRP cylinder.

4.11.4. OceanGate set the following parameters for the vehicle:

Parameter	Optimum	Limit	Unit	Source	Comment
Net Buoyancy Including Aft and Fwd Closures	>4000	2000	lbs.	OceanGate	
Hull Composite OD Maximum	68	68	in	OceanGate	
Hull Cylinder Length	100		in	OceanGate	Spherical Domes add ~ 1 OD to OAL
Hull Composite ID Minimum	58	54	in	OceanGate	
Maximum Operational Depth	6000 19680	3000 9840	m ft.	OceanGate	
Safety Factor	2.25	1.5		OceanGate	2.25 is design goal, but <2.25 is acceptable
Cycle Life	10000	1000	Cycles	OceanGate	To maximum rated depth
Max Temperature Submerged	30	30	°C	OceanGate	
Min Temperature Submerged	-5	-5	°C	OceanGate	
Max Temperature on Surface	100	100	°C	OceanGate	Will be covered from UV exposure most circumstances
Min Temperature on Surface	-40	-40	°C	OceanGate	
Density of Sea Water	0.037	0.037	lb/in^3	SCC	Varies w/ temperature & salinity
Design Pressure	9000	9000	lb/in^2	SCC	8740 psi calculated from max depth and density
Design Collapse Pressure	20250	13500	lb/in^2	SCC	Design Pressure x SF
Maneuvering Loads	Negligible			SCC	Assumed Pressure & Temperature Only Significant Loads
Internal Coating	none			SCC	Assumed
External Coating	TBD			SCC	External Sealing of CFRP and Interface Joints is Necessary
Carbon Fiber	37-800	37-800		SCC	Mitsubishi Grafil 37 msi modulus fiber
Dome-Cylinder Alignment/Retention Method	TBD			SCC	Retention method should prevent violent slip when overcoming friction

Figure 72: First TITAN hull composite vessel design basis. Source: Spencer Composites.

4.11.5. The report indicated that, based on research and analysis conducted by Spencer Composites, both the titanium and composite dome configurations should undergo scale modeling tests. The conclusion in the report, completed on June 25, 2015, stated:

> "With conservative assumptions regarding the ultimate compressive strain capability of the 37-800 carbon epoxy laminate, the designed composite hull demonstrates a safety factor of 2.19 when paired with the titanium dome and 2.21 when paired with the composite dome. The derived allowable ultimate compressive strain must be validated through planned sub-scale testing. The plastic collapse load is estimated to be between 1.88 and 2.03 times the design load, meeting the requirements of ASME Boiler and Pressure Vessel Code, Section VIII, Division 3 (Ref. 8). For the sub-scale test article to confirm the composite's strength, the sub-scale dome will need to be heavier to achieve the cylinder's collapse pressure. Following the tests, a decision can be made on whether to use the dome designed in this report or to scale up the heavier sub-scale dome. Regardless, the full-scale dome will be redesigned to incorporate a sight glass and other necessary penetrations."

4.12. One-Third Scale Model Testing

4.12.1. According to the UW-APL's CYCLOPS (TITAN) one-third scale model pressure hull Pressure Test Guidance, the objective of the test was to validate the pressure vessel design was capable of withstanding seawater pressure corresponding to operating in the ocean at a depth of 6,000 m (19,685-feet). The pressure vessel configuration is shown in Figure 73. The pressure vessel material is fiber spun carbon fiber with 17-4 PH1100 stainless steel interface segments.

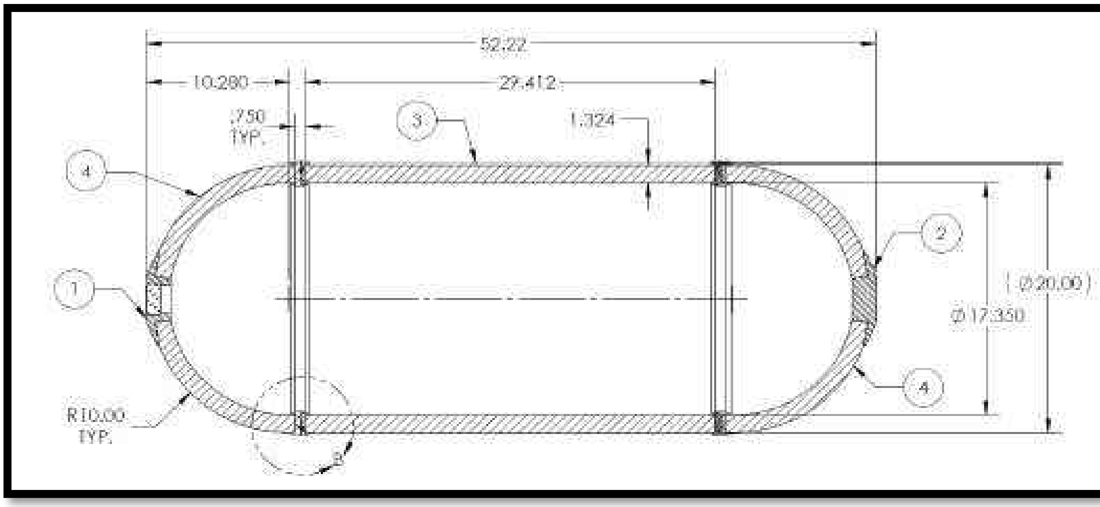

Figure 73: CYCLOPS (TITAN) one-third scale pressure test. Source: UW-APL.

4.12.2. Strain gauges were installed and monitored during this test. All gauges were internal to the test article and the signals were brought out of the pressure test chamber via the Seacon® connectors installed in the pressure chamber endcap. All strain data was captured and recorded with an external laptop computer provided by APL-UW and operated by APL-UW.

Figure 74: First one third scale model produced by Spencer Composites. Source: OceanGate.

4.12.3. All one-third scale models for the original TITAN hull were created by Spencer Composites utilizing the CFRP hoop wet wound cylinder with hand laid axial pre-impregnated carbon fiber sheets.

4.12.4. The first scale test was conducted on December 21, 2015, at the UW-APL School of Oceanography pressure test chamber located at the Ocean Science Building at the University of Washington. During MBI testimony, the UW-APL project engineer stated, "The first one collapsed, it was a catastrophic failure."

4.12.5. Following the failed test, the CEO (Mr. Rush) released a letter to OceanGate's stakeholders on December 23, 2015, stating:

> "As many of you already know, we conducted a pressure test of a one-third scale model of our Filament Wound Carbon Fiber (FWCF) hull. At a pressure of 4,285 psi (the pressure at approximately 10,000-feet of depth) one of the hemispherical endcaps failed just outboard of one of the large stainless-steel inserts. While the failure was unexpected at this depth, it was well short of the design operating depth of 20,000 feet, a FWCF hemisphere was always viewed as an extreme technical challenge. Even Boeing with all their computer capacity admitted they were unable to analyze such a structure. Fortunately, there was no damage to the main cylindrical section, which is the critical part and a shape that is far better understood.
>
> After an initial review yesterday by Spencer Composites (fortunately our new Board member, was able to fly the failed components to them within 5 hours of the failure), it is believed that the hemisphere buckled which was the reason our strain gauges did not give us warning of the failure. For the next test we will include acoustic monitoring which should give a better warning of this type of failure. Being able to consistently predict a pressure vessel failure is a key to ensuring we have a safe system that can operate for many years in varied conditions."

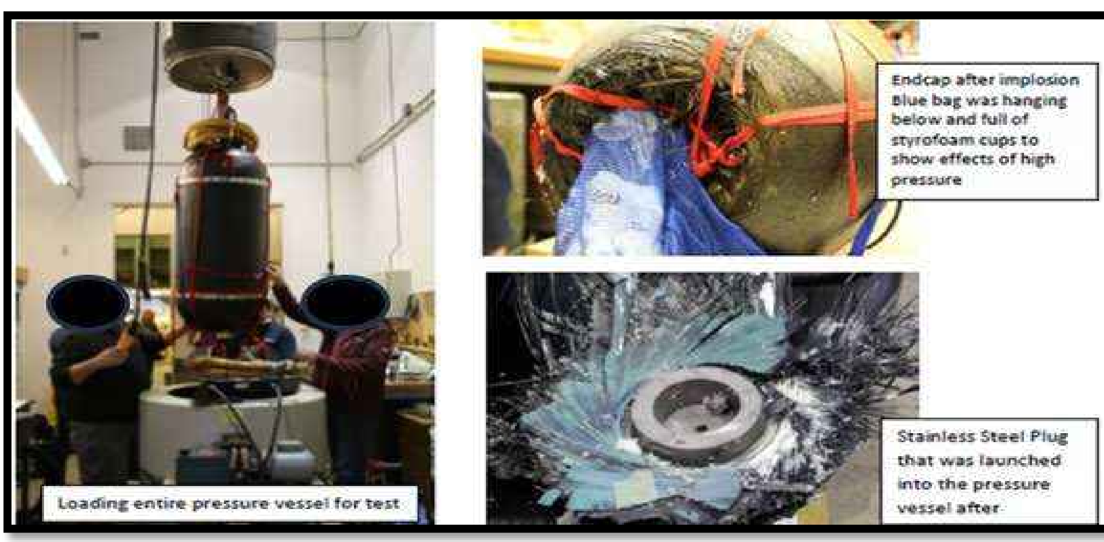

Figure 75: Excerpt from the Mr. Rush's letter to the stakeholders, December 23, 2015: Source: UW-APL.

4.12.6. The failure of the composite endcap prompted OceanGate to discontinue the use of composite end caps in favor of metallic alternatives—specifically titanium, aluminum, or steel. These materials would undergo testing over the next year to evaluate their compatibility with the pressure vessel. Mr. Rush underscored the achievements made so far, emphasizing that OceanGate's core business model prioritizes "extreme efficiency."

4.12.7. In February 2016, as noted in the UW-APL invoice and the OceanGate April 2016 Newsletter, OceanGate conducted the second one-third scale model test of the CYCLOPS II (First TITAN hull) carbon fiber hull cylinder, reaching a pressure of 6,000 psi before imploding, which corresponds to an ocean depth of 4,200 m. The UW-APL project engineer reported, "The second one was also a catastrophic failure, but I believe it was the domes that failed rather than the cylindrical section."

Figure 76: Second one-third scale model produced by Spencer Composite's with metallic domes. Source: OceanGate.

4.12.8. On March 11, 2016, during a third one-third scale model test, the model featured two carbon fiber hemispherical end caps attached to the main cylinder. This time, the team successfully utilized acoustic monitors to anticipate the effects and impending implosion of the hull. According to UW-APL Notebook page 66, failure occurred at 4,009.01 psi, when the top end cap imploded.

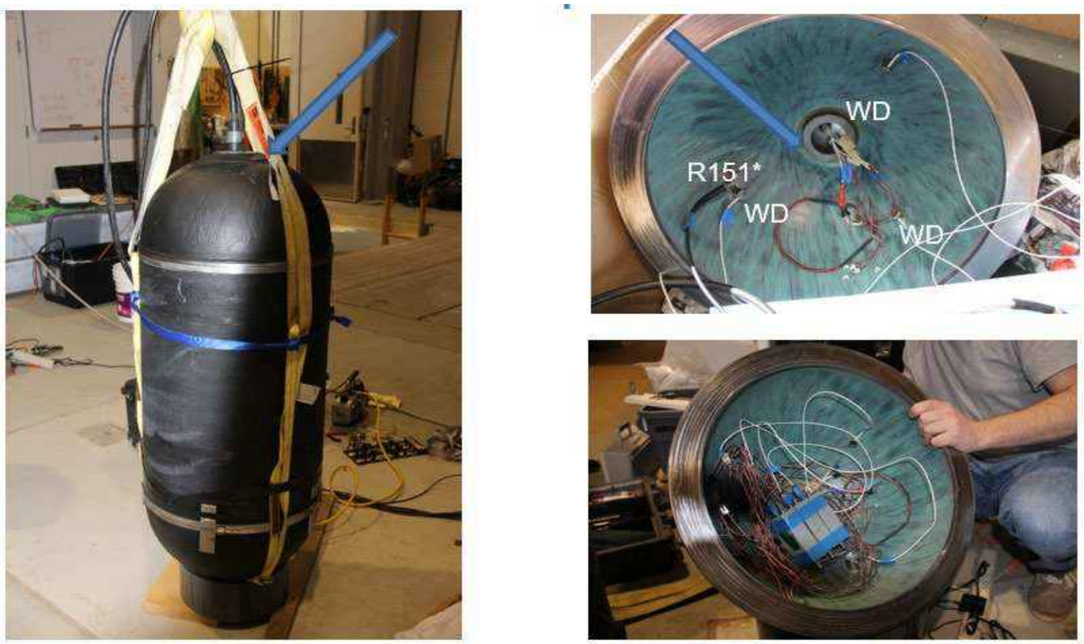

Figure 77: Placement of sensors and preamplifiers in the third one-third scale model test cylinder. Source: OceanGate.

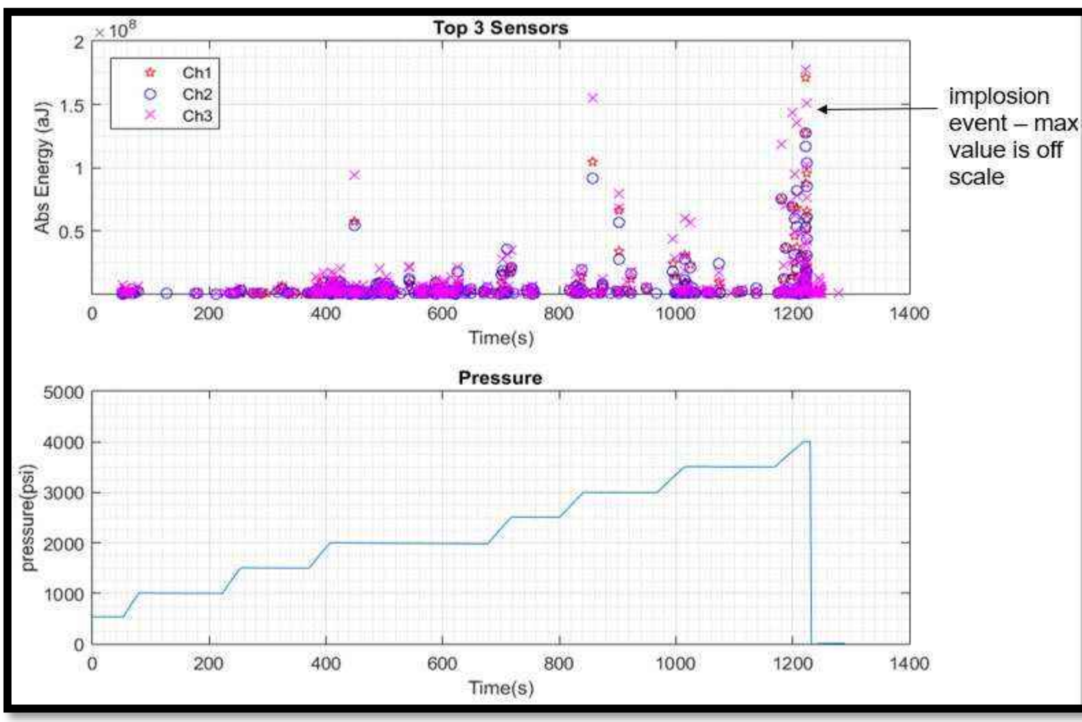

Figure 78: Acoustic emissions of top hemisphere. Source: OceanGate.

4.12.9. On July 7, 2016, the fourth one-third scale model test took place at the UW-APL Lab. The invoice indicated that a total of seven hours of testing was completed, with an additional 12 hours charged for cleanup and repairs. A member of UW-APL commented on the magnitude of the implosion and the cleanup duration. The pressure testing notebook recorded that the pressure vessel imploded at 6,501.84 psi, which equates to an ocean depth of 4,304 m (14,121 feet).

Figure 79: Fourth one-third scale model produced by Spencer Composites post-implosion. Source: OceanGate.

4.12.10. In response to MBI questions about post-failure discussions regarding design improvements, the UW-APL project engineer stated they were not part of those conversations. However, when asked if they would recommend constructing a full-scale hull without a successful one-third scale model test, they suggested that it would be prudent to continue testing the one-third scale model until achieving success before proceeding to full scale.

4.12.11. The one-third scale models tested for deep-sea pressure did not meet the requirements for a full-scale design rated for 4,000 m (13,123 feet) depth. According to OceanGate's Director of Engineering at the time, he urged Spencer Composites to make modifications to the models and to continue testing, but Spencer Composites declined his request to modify the hull design, maintaining confidence that it would withstand the pressures despite the observed one-third model failures.

4.12.12. A proposal was made by the Director of Engineering to the CEO to create a new one-third scale model using titanium for the end domes, with estimated costs of $100,000 to $150,000, but this plan was ultimately denied. The one-third scale models were tested and managed to withstand pressures equivalent to 4,200 m (13,780 feet), which was less than the 4,500 m (14,764 feet) that was the target max pressure depth for TITAN's operations. Overall, while the models demonstrated potential deep-sea capability, they fell short of the expectations outlined in the design specifications.

4.13. Relationship Between OceanGate's Operations and Engineering Departments

4.13.1. In early 2016, OceanGate reinforced its leadership team by hiring a Director of Marine Operations and a Director of Engineering. The Director of Marine Operations relocated from the United Kingdom to Washington State and brought over 25 years of extensive experience in subsea operations, including roles as a submersible pilot, commercial diver, and ROV pilot. His primary responsibilities at OceanGate included ensuring the safety of crew and clients during operations, maintaining marine assets, and achieving mission objectives during various submersible expeditions.

4.13.2. The new Director of Engineering, a project engineer with expertise in materials science and engineering, was responsible for managing the technical development of manned submersibles and related assets. With over ten years of experience in the aerospace industry and a background as a U.S. Navy diver, he was specifically recruited to complete the new TITAN hull. According to the Director of Engineering, OceanGate viewed him as the ideal candidate for the role, as the project vision was already established, and they were in need of someone to carry it to completion.

4.13.3. During MBI testimony, the Director of Engineering stated,

> "At the same time, we'll say, as part of a toxic work environment just within OceanGate itself and between some in OceanGate and the Applied Physics Lab, we separated that relationship with APL, and I took 100 percent of that engineering inside. Then, I started hiring modelers, draftsmen, manufacturing people. So, very quickly, I had to start building a team that was not supposed to exist. Really, I was supposed to be the only engineer. I was just supposed to help Stockton."

4.13.4. Although the CYCLOPS I was intended to serve as a mockup submersible for the CYCLOPS II (TITAN), challenges arose in transferring components to the new hull. Additionally, sourcing a vendor capable of producing titanium end caps of the required size proved challenging. The Director of Engineering expressed concern in an email to an engineer at UW-APL, stating, "Our schedule for CYCLOPS II has become so delayed and critical that a 2017 mission may slip to 2018, as it appears we're going to miss the North Atlantic diving window."

4.13.5. The Director of Operations characterized the working environment at OceanGate as "toxic", stating that the Mr. Rush, the Chief Operating Officer (COO), and the Engineering Department would brush off any concerns he raised regarding serious failure points.

4.13.6. On November 17, 2016, an email exchange between two engineers from the UW-APL highlighted a significant disconnect between the Operations and Engineering Departments at OceanGate. One UW-APL engineer noted to his colleague that during a visit, it was apparent that the Director of Engineering was reluctant to engage with the OceanGate Operations team, describing the situation as "palpable" and expressing confusion about how the organization functioned effectively under such circumstances.

4.13.7. By May 2017, the Director of Engineering proposed a revision to the UW-APL Statement of Work, mandating that all hardware be constructed at OceanGate's facility in Everett, Washington. This proposal raised major concerns for the UW-APL engineer, who pointed out major safety flaws with the use of glass housings (glass motor pod controller housing) near manned vehicles and the impracticality of performing all hardware and software work at OceanGate. The engineer indicated that while they were open to reconsideration, it would have required significant changes to the proposal, particularly regarding materials and logistics.

4.13.8. OceanGate's response acknowledged UW-APL's concerns and sought clarification on UW-APL's willingness to take the lead on the project or provide support if OceanGate decided to build the system independently. This communication reflected the growing tension between the two organizations as they navigated the complexities of the project and differing expectations regarding collaboration.

4.13.9. In correspondence between UW-APL members the following statement was made: "My take then is that OGI (OceanGate Inc.) is looking to implement an unproven technique on a human-inhabited vehicle. It might be fine - but there is no history of data or testing to back that up. Given that, I am inclined to respond with thank-you-but-APL-respectfully-declines. And decline means decline it all: battery selection, control system design, new device integration (acoustic modem, cameras, etc.)"

4.13.10. When the following Director of Engineering was asked about the relationship between OceanGate's engineering and operations teams, he described it as severely dysfunctional, stating, "They didn't talk. They hated each other." He recalled that both directors expressed animosity toward each other saying things like, "that guy's a horrible guy," and they were quick to blame one another. The Director of Engineering observed that there was no communication between the teams and stated, "As far as I could tell, they didn't talk at all. They didn't share any information." The engineering team adopted a secretive stance making assertions like, "no, this is my information. I'll give you the sub when it's ready and you don't need to ask any questions." Meanwhile, the operations team felt uninformed, with a member expressing their frustration in the following statement: "We don't know anything. So, you know, how do we know if it's any good? You want us to dive but we don't know what to do." This lack of collaboration and clarity further complicated the project's progress.

4.13.11. The Director of Operations noted that the engineering department often withheld information from the operations team, which created significant barriers to effective collaboration. Furthermore, when serious concerns were raised with Mr. Rush, the COO, and the Director of Engineering, the concerns were "immediately dismissed," indicating a troubling lack of responsiveness to critical issues within the organization. This culture of secrecy and disregard for operational concerns contributed to the ongoing dysfunction between the teams.

> 4.13.11.1. The Director of Marine Operations stated, "As an experienced engineer and operator of submersibles with over 25 years of experience, I believe my concerns were dismissed due to cost-cutting measures and poor engineering decisions, driven by the desire to reach the TITANIC quickly to start generating profit. There was a clear push to expedite the project, which led to critical steps being overlooked. These concerns were not just mine but also shared by other

experienced professionals, including (NAMES REDACTED)[29], both seasoned submersible pilots. Despite voicing these concerns, we were disregarded. The dismissal of safety concerns by experienced operators is highly abnormal and unacceptable in the submersible industry. Unfortunately, the organization lacked the necessary expertise, with most of the engineering team being inexperienced, fresh out of universities, or even without formal education in submersible design. The leadership, including the CEO, had no prior experience building submersibles, which was evident in the engineering flaws and subpar decisions. Despite my efforts to address these issues and transform the company into something credible, it became clear that the focus was more on image and marketing than on building a safe and reliable operation."

4.14. Manufacturing of Carbon Fiber Hull (Spencer Composites)

4.14.1. In a November 2016 OceanGate Newsletter, OceanGate stated:

> "On December 12, 2016, Spencer Composites will begin laying down the carbon fiber on a stainless steel mandrel that serves as the form for the cylindrical pressure vessel, the carbon fiber is tightly wound and the mandrel in layers and impregnated with resin mandrill is engineered and built to prevent deformation during the winding and curing stages to maintain the tolerances needed to mate with the Titanium hemispheres that connects to both ends of the cylinder. Development of the Titanium hemispheres is also underway, and we expect delivery in spring of 2017 after which we will conduct a pressure test of the entire hull."

4.14.2. Spencer Composites signed the contract with OceanGate to manufacture the CYCLOPS II (First TITAN hull). The contract stated that the submersible should be built to performance parameters of a length of 2,540 millimeters (mm) with an outside diameter of 1,676 mm and a service pressure of 6,600 psi with a pressure safety factor of 2.25. Modeling and analysis of the hull design were conducted using SolidWorks® and COSMOS/M® software, supplied by Dassault Systèmes' subsidiary, Structural Research and Analysis Corporation.

[29] Names redacted by MBI.

Figure 80: Original TITAN hull winding at Spencer Composites in March of 2017. Source: OceanGate.

4.14.3. In March of 2017, the production of the first TITAN carbon fiber hull began at Spencer Composites. The hull weighed 6,000 lbs., measured 56 inches in diameter, and was 100 inches long. The manufacturing process used alternating placements of pre-impregnated carbon fiber and epoxy unidirectional fabrics in the axial direction, combined with wet winding of carbon fiber and epoxy in the hoop direction. In total, the construction comprised 480 plies.

4.14.4. The thickness of the carbon fiber/epoxy hull was 127 mm, approximately 5 inches, which was less than the 6 inches planned for earlier models, such as Mr. Fossett's craft, which was rigorously tested and demonstrated the ability to endure pressures up to 2.5 times its service operating pressure of 6,500 psi. The carbon fiber material used for the first TITAN hull was standard-modulus Grafil 37-800, supplied by Mitsubishi Chemical Carbon Fiber & Composites Inc.

4.14.5. The pre-impregnating carbon fiber for the hull was supplied by Newport Composites, which is now part of Mitsubishi Chemical Carbon Fiber & Composites Inc. The wet-winding epoxy used in the construction was Epon Resin 682, provided by Hexion Inc, and the curing agent was Lindride LS-81K from Lindau Chemicals Inc.

4.14.6. In a May 10, 2017, article from CompositeWorld.com[30], a representative from Spencer Composites stated, "They (OceanGate) basically said this is the pressure we have to meet this is the factor of safety this is the basic envelope go design and build it....and we had six weeks in which to do it."

[30] https://www.compositesworld.com/articles/composite-submersibles-under-pressure-in-deep-deep-waters

Figure 81: Original TITAN hull winding process at Spencer Composites. Source: OceanGate.

4.14.7. In October of 2017, after fabrication was completed, the carbon fiber hull was sandblasted and coated with a 5 mm layer of polyurethane to protect against saltwater intrusion. This protective layer was used to protect against water intrusion, which was considered essential when considering that the hull would be subjected to considerable water pressures at its maximum depths of 4,000 m (13,123 feet).

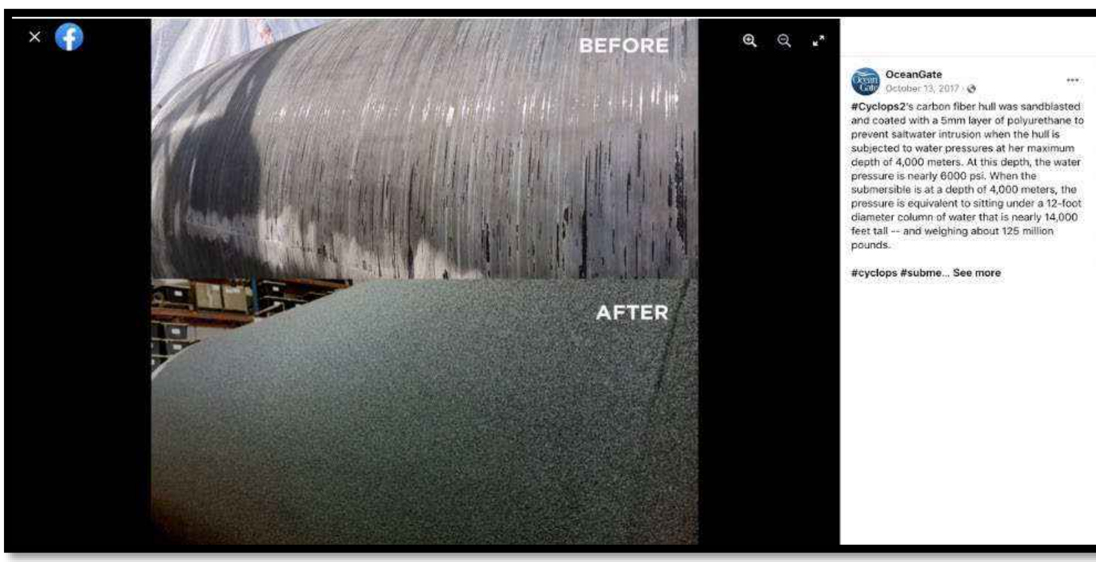

Figure 82: TITAN hull before and after coating with polyurethane. Source: OceanGate Facebook.

4.14.8. The interior of the cylindrical hull was fitted with a fiberglass insert. The insert provides the ability for customization of the interior by enabling the use of different modules tailored for specific users, such as researchers or sightseers. Additionally, the ability to easily remove the insert provided access for thorough inspection of the hull's interior. When the insert was in place, only a small section, appriximately 1-3 inches, of the carbon fiber hull was available for visual inspection.

Figure 83: TITAN Insert. Source: OceanGate Facebook.

4.15. Titanium Fabrication® (TIFAB) / Titanium Segments and Domes

4.15.1. After the one-third model testing revealed the probable failure of composite domes, it was determined that titanium was the most suitable material for the submersible hemispheres (end caps), as well as for the segments that attached the domes to the carbon fiber hull. On December 6, 2016, a purchase order for Grade 3 titanium was completed for TIFAB at a total cost of $475,000. TIFAB forged the titanium forward and aft hemispheres (domes) and the titanium segments, which were designed to be affixed to the carbon fiber hull. Each end cap measured 60 inches in diameter and was constructed to a thickness of 3.25 inches.

4.15.1.1. The titanium dome was initially designed to be grade 5 but was ultimately made from grade 3 titanium. The decision to switch from grade 5 to grade 3 was made by Mr. Rush, due to the higher cost and longer lead time associated with acquiring grade 5, which would have taken twice as long and required overseas sourcing.

4.15.1.1.1. Grade 3 titanium is a commercially pure titanium (CP-Ti) alloy, meaning it has a high level of purity and is made with a minimal number of alloying elements. It is characterized as having excellent corrosion resistance in a wide range of environments, particularly in marine and chemical applications, due to its ability to resist attack by chlorides, acids, and other corrosive substances. However, its strength is moderate compared to other titanium alloys. Grade 3 titanium typically has a tensile strength of around 480 megapascals (MPa), making it suitable for applications where resistance to corrosion is more critical than high strength. Its ductility and formability also make it easier to work with for certain designs.

4.15.1.1.2. In contrast, Grade 5 titanium, also known as Ti-6Al-4V, is an alloy consisting of 90% titanium, 6% aluminum, and 4% vanadium. It is the most widely used titanium alloy due to its significantly higher strength compared to commercially pure titanium. Grade 5 titanium has a tensile strength of around 900-1,200 MPa, which is almost twice the strength of Grade 3. This high strength-to-weight ratio makes it ideal for demanding applications such as aerospace components, aircraft structures, and marine hardware, where both strength and weight reduction are crucial.

Figure 84: Forward TITAN Dome at TIFAB. Source: https://ocean-archives.github.io/.

Figure 85: TITAN titanium segment at TIFAB. Source: OceanGate.

4.15.2. The forward end cap was hinged on the starboard side of the forward segment, to allow for opening and closing and weighed approximately 3,700 lbs. It was also manufactured with a 12.5 inch void for the acrylic window and retaining ring (the window and the ring make up the components of a viewport). The window retaining ring was held on by 16 bolts from the outside. The forward dome had 18 bolt holes that would match up with the segment for closure, which was completed from the outside of the submersible.

4.15.2.1. A former OceanGate Director of Engineering noted that an O-ring was added to the forward segment, which connected to the hinged forward dome. However, Mr. Rush deemed it unnecessary, believing that the metal-to-metal seal would be sufficient under high pressure. During the 2018 exit interview of the Director of Marine Operations, Mr. Rush identified the titanium dome as the weakest link in the TITAN's design and voiced serious concerns about the potential for someone to be struck and seriously injured by the dome.

Figure 86: CAD drawing of TITAN's aft dome and segment. Source: OceanGate.

4.15.3. In December of 2017, the titanium hemispheres were completed and shipped to OceanGate.

Figure 87: OceanGate employee conducting an inspection of TITAN's forward dome. Source: OceanGate Facebook.

4.16. Gluing of Carbon Fiber Hull to Titanium Segments

4.16.1. In July of 2017, the gluing of the carbon fiber hull and titanium segments was carried out with consultation from the manufactures of the hull, Spencer Composites. According to OceanGate's Director of Engineering, Spencer Composites sent two staff members to Alameda, California where large lathes and cranes were used to prepare the gluing interface and align the titanium segments. The Director of Engineering stated that his responsibility in overseeing the process was to ensure the structure was square, straight, plumb, and level, which were considered the key factors for achieving a strong and reliable bond.

4.16.2. The carbon fiber hull and the titanium segments were joined together by glue. Mr. Rush stated that the seal needed to be "uniform and small, but not too small." He further emphasized the importance of precision in the process, saying, "pretty simple, but if we mess it up, there is not a lot of recovery." The adhesive was mixed and applied to both the segment and hull bonding surfaces. When discussing the adhesive's consistency, the CEO compared it to peanut butter, noting that it was "very thick," and unlike a more typical adhesive like Elmers Glue®.

Figure 88: Adhesive applied to carbon Fiber Hull and "c" channel of forward segment in July of 2017. Source: OceanGate Expeditions.

4.16.3. The adhesive used in the adhesion process was HYSOL® EA 9394, also known as Henkel LOCTITE EA 9394 AERO. This adhesive was applied to the ends of the carbon fiber hull and the "C" channel of the fore and aft segments. The "C" channel of the segments was approximately 1.37 depth x 5.01 width inches with a slight taper at 0.88 depth inches in the notch. The hull was then inserted into the "C" channel. To form the joints, the aft joint was created by first lowering the hull down onto the segment, and the forward joint was then formed by lowering the segment down onto the hull, with the entire assembly oriented vertically. According to the Director of Engineering, despite concerns about its flexibility and uncertainty about whether this material had been used in the deep-sea submersible industry before, the adhesive choice was confirmed. OceanGate's Director of Engineering stated that while they had hoped for a more flexible material, "NAME REDACTED (the manufacturer) preferred not to change the adhesive."

Figure 89: Aft titanium segment being placed on the first TITAN carbon fiber hull in July of 2017. Source: OceanGate Expeditions.

4.16.4. In OceanGate's 2021 Gluing Procedure, OceanGate employees, under the direction of Mr. Rush and OceanGate's Director of Engineering, affixed the forward and aft segments to the carbon fiber pressure hull using the same HYSOL EA 9394 adhesive. On January 14, 2021, OceanGate created a full-scale hull assembly procedure and a Titanium End Segments Gluing Procedure, which outlined detailed steps for the process. However, the MBI could not confirm whether a formal procedure for adhesion of the hull had been established in 2017. The 2021 procedures called for an allowance of 4 to 5 days to allow the adhesive to cure, ensuring a proper bond before further assembly.

4.16.5. This timeline of events reveals both consistency and uncertainty in the materials and procedures used during the submersible's construction. The use of HYSOL EA 9394 was confirmed, but the lack of clear documentation in 2017 raised questions about whether proper procedures were followed during the earlier stages of the project. As the development of standardized procedures unfolded in 2021, a more methodical approach was adopted, but gaps in prior practices may have contributed to concerns about the overall integrity and safety of the adhesive application process.

4.17. Acrylic Window

4.17.1. Window Manufactured by Hydrospace Group Inc.

4.17.1.1. In 2017, OceanGate initiated the design and procurement of a specialized acrylic frustum dome window for the TITAN. In June of 2017, OceanGate submitted a purchase order to Hydrospace Group, Inc. (HSG) to create a 23-inch acrylic frustum dome designed for use with PVHO materials certification. The window was intended to meet the PVHO certification requirements and was priced at $33,450. However, OceanGate specifically requested a conical external facing shape and a flat internal facing shape dome window, which would provide better viewing from inside the submersible. This window design, as proposed, was not an approved PVHO geometry, meaning it did not comply with established pressure vessel standards for human occupancy.

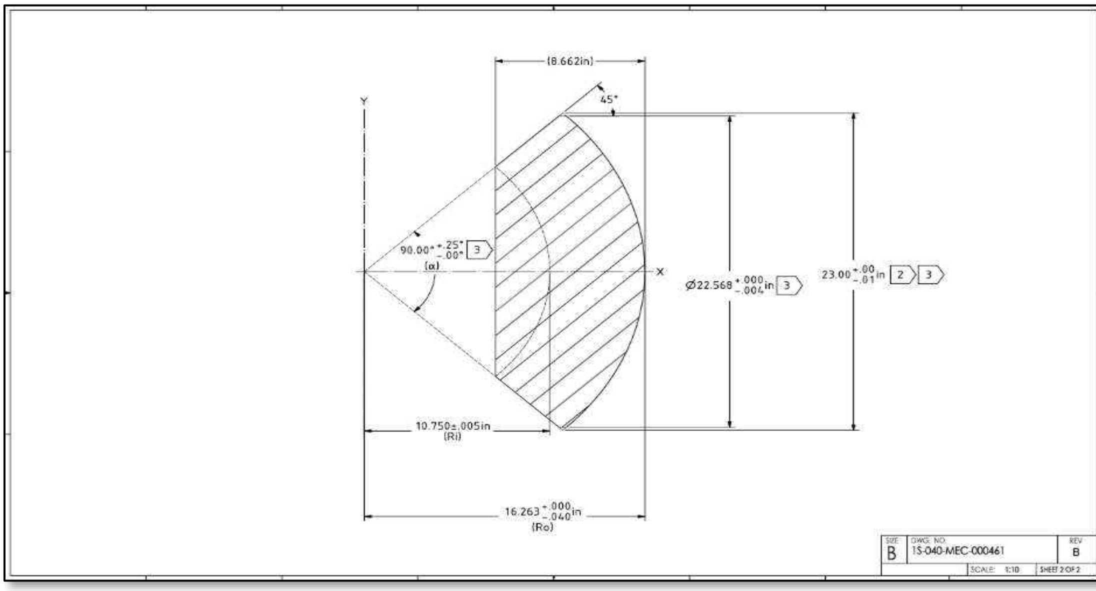

Figure 90: Acrylic Window Drawing for TITAN. Source: OceanGate.

4.17.1.2. Hydrospace Group, in response to the request, suggested a hybrid design combining a conical frustum flat disk window with a spherical sector window. Hydrospace was willing to support the flat dome concept, provided OceanGate performed the necessary work to produce a PVHO drawing and obtain the associated PVHO Design Certification (FORM VP2). This certification would require both an FEA and prototype testing to ensure the window's structural integrity under deep-sea pressures. OceanGate decided not to follow through with producing the required design certification or testing, even for scaled-down models of the flat dome windows. Instead, Hydrospace Group offered to produce a spherical sector dome that would fit the same housing, meet PVHO compliance, and be rated to a depth of 4,000 m (13,123 feet). This alternative offer was also declined by OceanGate.

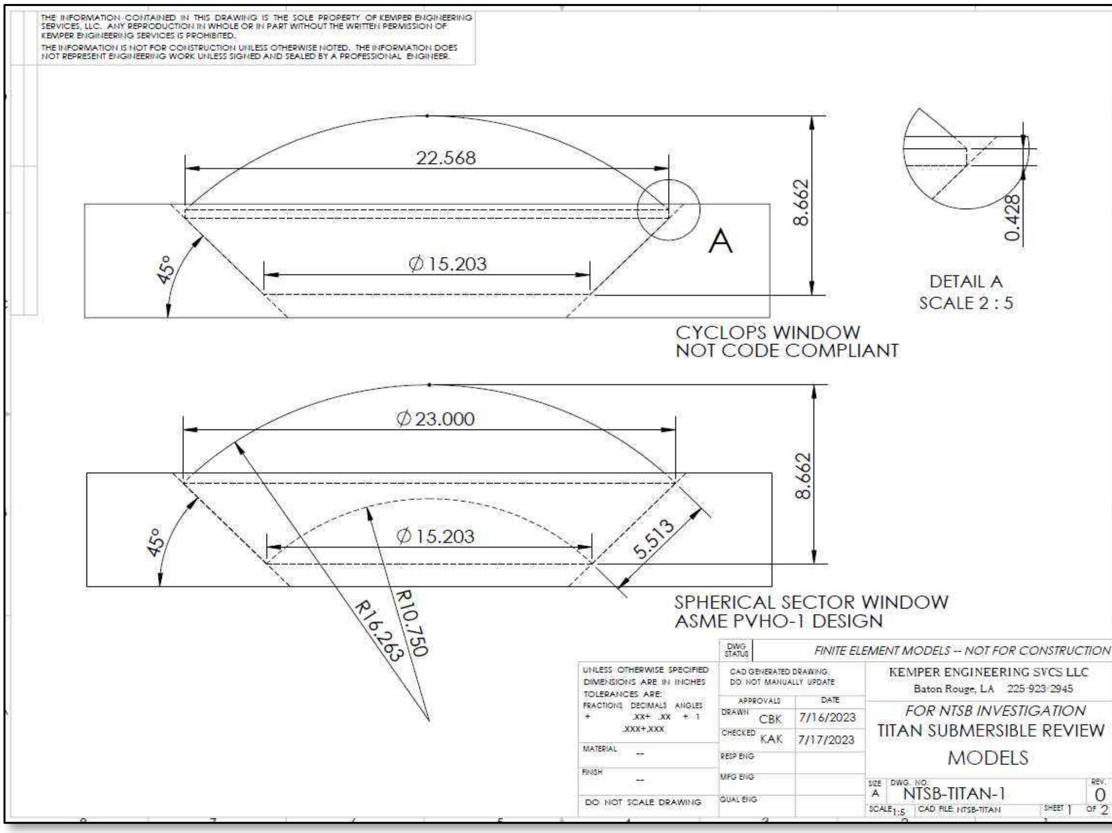

Figure 91: Acrylic Window Design for TITAN; ASME PVHO-1 Non-Code Compliant (top); ASME PVHO-1 Compliant (bottom). Source: Kemper Engineering.

4.17.1.3. OceanGate's decision to forgo testing and certification led to further complications in the development of the window. OceanGate had hoped that combining the strength of a spherical window with the optical clarity of a flat design would meet both their safety and visual requirements. However, the hybrid window concept, combining flat on the inside and round on the outside surfaces, remained a non-standard geometry that could not be certified under existing PVHO guidelines without extensive testing. This meant that OceanGate would need to perform computer analysis, physical testing, or a combination of both to validate the design's safety and optical performance. Without these steps, the hybrid window could not be considered certifiable under PVHO standards.

4.17.1.3.1. Testing a non-standard window design for a submersible requires a multi-phase evaluation to ensure the window's material can withstand extreme deep-sea pressures. The first phase of testing focuses on determining the failure threshold of the material. This involves testing at least five samples to destruction, ensuring that all samples fail at similar pressure levels. The failure points must be statistically consistent to demonstrate that the material behaves predictably. If the samples fail at varying pressure points, it will indicate that the material's performance is unreliable, and further testing would be needed to refine the understanding of its behavior under stress.

4.17.1.3.2. The second phase is cyclic fatigue testing, which simulates the repeated stresses that the window material will experience over time. Cyclic fatigue occurs when material is subjected to repetitive loading and unloading cycles, leading to eventual failure. To test for this, the window must endure 1,000 cycles at its maximum working pressure. This test is designed to ensure that the window can withstand the pressure fluctuations common in deep-sea environments without developing cracks or other defects. The testing period for this phase typically lasts about nine months, and at the end of this period, the window must show no signs of degradation or damage.

4.17.1.3.3. The third phase of testing involves evaluating the creep resistance of the material under sustained pressure. Creep refers to the gradual deformation of a material when it is subjected to constant stress over a long period. Acrylic, the material commonly used for submersible windows, behaves differently than metals and is prone to creep. ASME PVHO-2 standards require that the material be subjected to full pressure for 80,000 hours, which is roughly equivalent to 9.5 years of continuous stress. This long-duration test ensures that the window will not permanently deform under the extreme pressures it faces during deep-sea dives, ensuring it maintains its structural integrity over time.

4.17.1.3.4. To qualify a non-standard window for deep-sea use under PVHO standards, all three phases of testing must be completed, and the window must pass without significant issues. These tests are critical because they simulate the real-world conditions the window will face at depths of thousands of meters. The testing program must also account for the fact that non-standard geometries, like a hybrid window design combining flat and spherical elements, may behave differently under pressure, requiring additional testing and analysis to ensure safety and performance.

4.17.1.3.5. While the testing process for a non-standard window is comprehensive and time-consuming, scale model testing is often used to help predict the performance of full-size windows. However, at least one full-size prototype must undergo the tests to ensure the accuracy of the results. FEA and prototype testing are essential components in the development of such non-standard windows, as they provide insights into the material behavior and structural performance under actual operating conditions. Without these tests, a non-standard window cannot be certified as safe for deep-sea use, highlighting the importance of thorough validation in the design process.

4.17.1.4. When completed, the acrylic forward main window had an inner diameter of 12.5 inches and an external diameter of 23 inches with a center thickness of seven inches. The rating of the window that Hydrospace produced for OceanGate was 945 psi, calculated per the ASME PVHO standard at a temperature of 50° Fahrenheit (F). This pressure rating was marked on the window and registered in Hydrospace's database. However, 945 psi is only rated for a maximum depth of approximately 650 m (2,150 feet).

Figure 92: TITAN acrylic window from Hydrospace Group. Source: https://ocean-archives.github.io/ .

4.17.1.5. This Hydrospace manufactured window was used on the TITAN until December 2019, when it was dropped, damaged, and subsequently replaced.

Date	Dive Number	Issue	Dive Critical (Yes/No)	Open/ Closed	Solution
10/16/2019		Viewport contaminated with carbon fiber dust	Yes	Closed	Remove viewport and clean - New viewport purchased and installed
12/13/2019		Viewport dropped while removing carbon fiber dust	Yes	Closed	Document damage area, polish where required and add incident report to documentation. - New viewport purchased and installed
12/26/2019		Viewport damaged-incident report on dropbox	Yes	Closed	New viewport purchased and installed

Figure 93: Excerpt from OceanGate Maintenance Log. Source: OceanGate.

4.17.2. Window Manufactured by Heinz Fritz GmbH

4.17.2.1. In April of 2020, OceanGate contacted Heinz Fritz GmbH to manufacture a viewport to replace the one that was damaged. Heinz Fritz GmbH offered them two manufacturing options: one with full certification and documentation in line with DNV or ABS standards, and another without these protocols. Heinz Fritz GmbH provides the necessary certifications for windows, including the VP-1 Fabrication Certificate (signed by Heinz Fritz GmbH), the VP-2 Material Manufacturer Certificate (signed by Polyvantis), and the VP-4 Material Testing Certificate (signed by Polyvantis, based on Evonik's 3.1 Material Certificate). However, for full certification, additional documents are required: the VP-2 Acrylic Window Design Certification (signed by the designer or manufacturer of PVHO, with verification from ABS or DNV) and the VP-5 Pressure Testing Certification (typically conducted by the PVHO manufacturer). Heinz Fritz GmbH does not directly supply the VP-2 and VP-5 certifications but can subcontract with DNV for the design verification and a company like Triton Submarines or a test facility for the required pressure testing, which involves using either a replica or the actual window seat with an appropriate pressure chamber or actual deep-sea testing.

4.17.2.2. OceanGate chose the viewport option without the testing and certification documentation. For a manufacturer to proceed under the certification process, an approved drawing was required. If OceanGate had opted for a certified window, they would have first needed to have their design reviewed by a designer, manufacturer, or appropriate third-party authority. The decision not to request PVHO documentation was influenced not only by the extra costs for material testing and documentation at Heinz Fritz GmbH's facility but also by the anticipated length of the design review process. The window was built based on Drawing 1S-040-MEC-000461 REV B, dated October 10, 2017, which Heinz Fritz GmbH received via email on April 19, 2020, from an OceanGate employee.

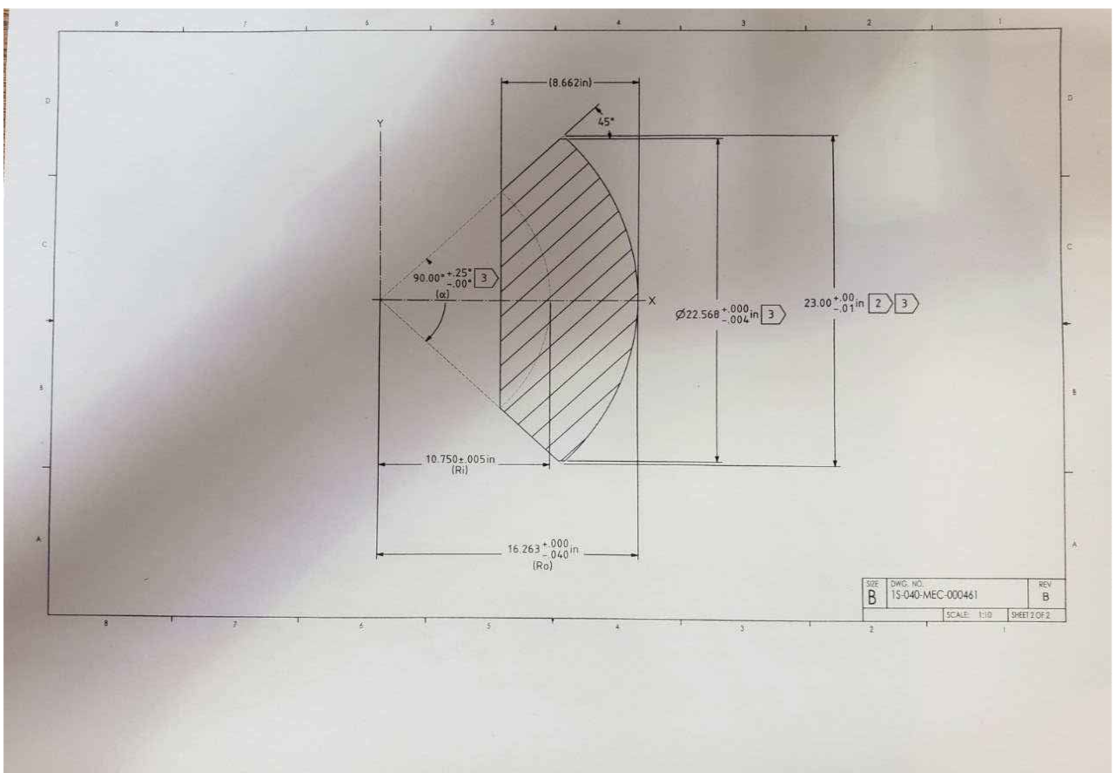

Figure 94: OceanGate Drawing 1S-040-MEC-000461 Rev. B. Source: OceanGate.

4.17.2.3. Heinz Fritz stated that a review of the TITAN's viewport window design and pressure rating was conducted after the implosion. After involving an unnamed party, the calculations were redone, and it was found that the viewport met the required safety standards for the operating depth at the TITANIC wreck site. Specifically, the window's thickness was 5.5 inches, which is thicker than the ½ inch minimum required. The window also has an opening angle of 90°, which is well above the minimum 30° needed. Additionally, the ratio of thickness to the inner radius of the window (about 0.51) is far above the required ratio of 0.06. Based on these measurements, the window design was within the necessary specifications and safe to proceed with.

4.17.2.4. Next, according to the ASME PVHO-1 standard, the safety pressure for a Spherical Acrylic Window was calculated. Using the window's design file, the thickness (t) of the window was 140.75 mm, and the inner diameter (Di) of the viewing area was 386.151 mm. This gave a thickness-to-diameter ratio of 0.3645. Using a chart from the ASME PVHO-1 standard, the critical pressure for the window was found to be about 172 MPa (or 1,720 bar).

4.17.2.5. Using a formula and conversion factors, the design pressure for the window was calculated, assuming a temperature of 10° Celsius (C). The formula used was Short-Term Critical Pressure (STCP) = CF × P, where P is the design pressure, and CF is the conversion factor. To find the pressure (P), the formula is rearranged to P = STCP / CF or in this case P = 172 MPa / 4 = 43 MPa (or 430 bar). This result indicates the window could handle pressure equivalent to a depth of about 4,300 m (14,108 feet).

Figure 95: Window manufactured by Heinz Fritz GmbH. Source: Heinz Fritz GmbH.

4.17.2.6. Regarding the buoyancy of the window, the weight of cast acrylic is 1.19 kg/centimeters (cm)³. The viewport itself weighed 36.79 kg. Although buoyancy in the ocean varies based on water depth, temperature, and salinity, the approximate weight of the submerged viewport was approximately 5.9 kg.

4.17.2.7. Heinz Fritz GmbH manufactured an acrylic window for OceanGate according to the provided drawing and delivered it to OceanGate without any certification documents or PVHO Forms. According to Heinz Fritz, the manufacturing process followed PVHO standards, using the identical raw materials, machinery, grinding, polishing, and annealing methods that they had used during their manufacture of past windows that met the PVHO standard.

Figure 96: Final TITAN Hull's Bow. Source: "CBS SUNDAY MORNING" Correspondent.

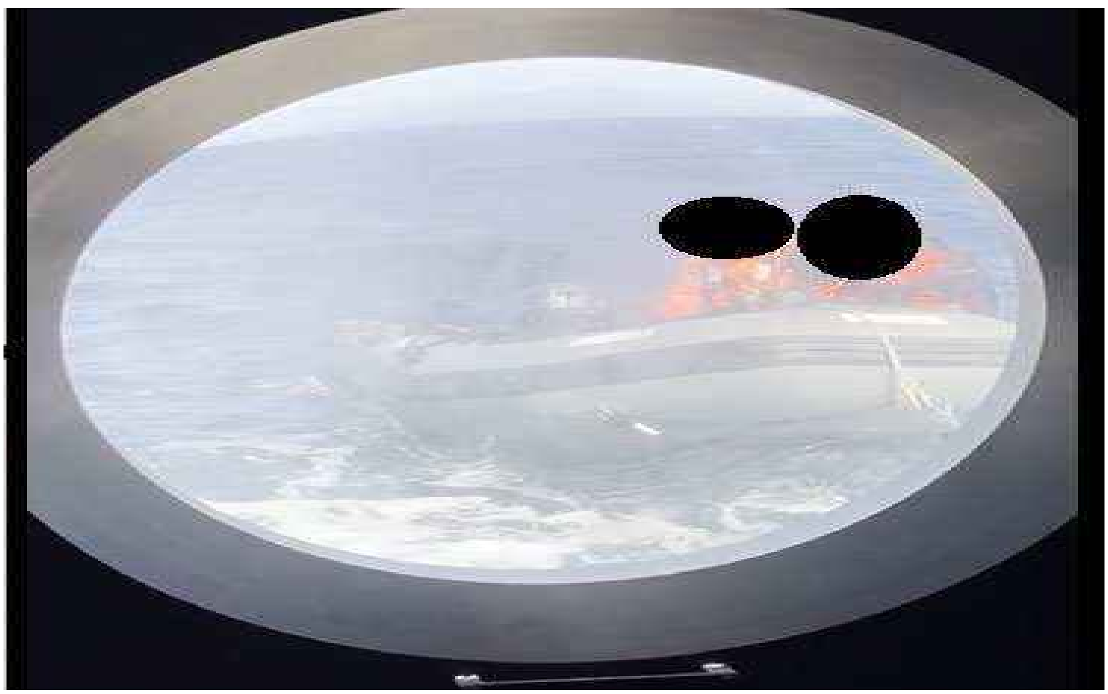

Figure 97: Image of Final TITAN Hull's viewport from inside TITAN in 2023. Source: Former mission specialist.

4.18. Real-Time Monitoring System (RTM)

4.18.1. The first and second (final) TITAN hulls were equipped with an RTM System. The system was a set of acoustic sensors and strain gauges placed throughout the hull to provide real time health monitoring to the pilot of the submersible. Mr. Rush obtained a

Patent for this system: Patent No. US 11,119,071 B1 Systems and Methods for Curing, Testing, Validating, Rating, and Monitoring the Integrity of Composite Structures.

4.18.2. According to a former OceanGate Director of Engineering, "The hardware was designed by a Board member named (NAME REDACTED BY MBI)….He developed the data acquisition hardware for both the acoustic monitoring and strain measurements."

4.18.3. OceanGate's website stated, "This Real-Time Monitoring System samples sound waves through the hull many times per second, providing incredible accuracy and allowing us to assess the health of the hull during the dive."

4.18.4. On June 5, 2018, a Professional Engineer from the Acoustic Emission Technology Consulting wrote a Letter of Affirmation to the Director of Engineering, regarding the use of acoustic emission to help with averting an impending failure of the TITAN submersible. The Professional Engineer stated that acoustic emission real-time monitoring of the TITAN submersible should be able to detect an impending failure sufficiently in advance to prevent catastrophic failure. He further stated that TITAN's acoustic emissions system has much more than the minimum requirements to accomplish OceanGate's objective to create an early notification of impending failure.

4.18.5. The Real-Time Monitoring System consisted of three main components. The first was the data acquisition system, which started with sensors like the R6S sensors from Mistras® as seen in Figure 100 for AE monitoring and strain gauges as seen in Figure 102. These sensors, attached to carbon fiber materials using adhesives like RTV or silicone, detect acoustic emissions (AE). The signals were sent to a hardware system that amplified them and converted them into digital data. Strain gauges, attached to the hull, measured its deformation by changing their electrical resistance as the hull stretched or compressed; a Wheatstone bridge circuit translated these resistance changes into strain readings. This stream of digitized AE and strain data was then sent to a host computer on TITAN for further processing and analysis.

4.18.6. The acoustic sensors and strain gauges were placed throughout TITAN's hull. There were eight groups with each group containing one acoustic sensor and two strain gauges. Acoustic sensors and strain gauges were assigned channel numbers 1 through 8, but sensors and gauges were not always placed in the same location. The image below shows the location of each numbered sensor and strain gauge cluster.

Location	Acoustic sensor number	Strain gage cluster number
Forward titanium dome	–	1
Forward titanium dome	–	2
Composite hull – 3.75 inch from FWD segment - 110° CW from top	1	3
Composite hull – 3.75 inch from FWD segment - 110° CCW from top	2	4
Composite hull – mid span - 110° CW from top	3	—
Composite hull – mid span – 0° (top dead center)	4	5
Composite hull – mid span - 110° CCW from top	5	—
Aft titanium segment - 110° CW from top	6	6
Composite hull – 3.75 inch from AFT segment - 0° (top dead center)	7	7
Composite hull – 3.75 inch from AFT segment - 110° CCW from top	8	8

Figure 98: Location of each numbered acoustic sensor or strain gauge cluster. Clockwise (CW) and counterclockwise (CCW) were designated as if standing aft of the vessel looking forward. Source: NTSB Laboratory Factual Report.

4.18.7. The RTM's instrumentation was located in the interior of the cylinder and segment surfaces. When the TITAN's hull insert was installed, the acoustic and strain gauges were concealed from view.

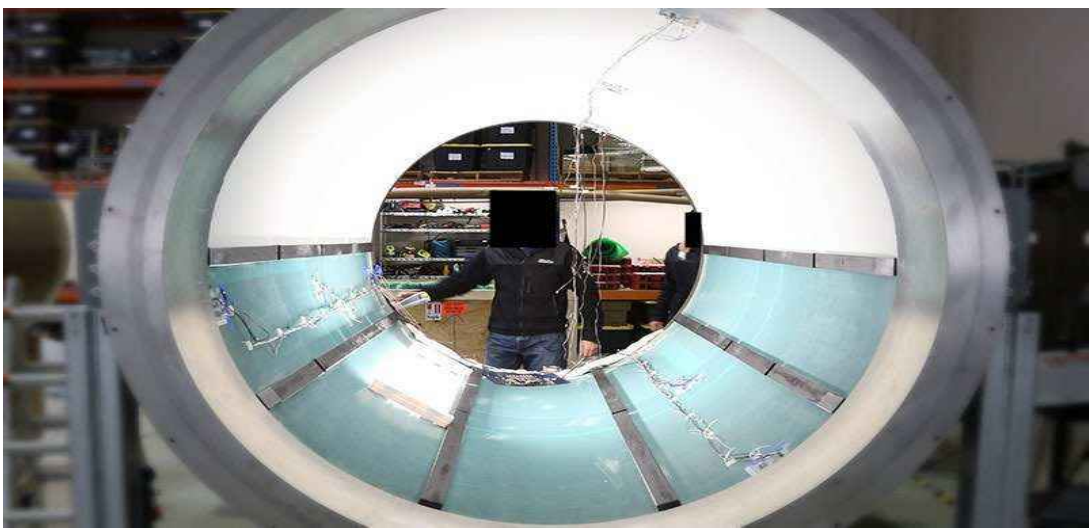

Figure 99: View of RTM system installed on TITAN's inner hull. Source: https://ocean-archives.github.io/ .

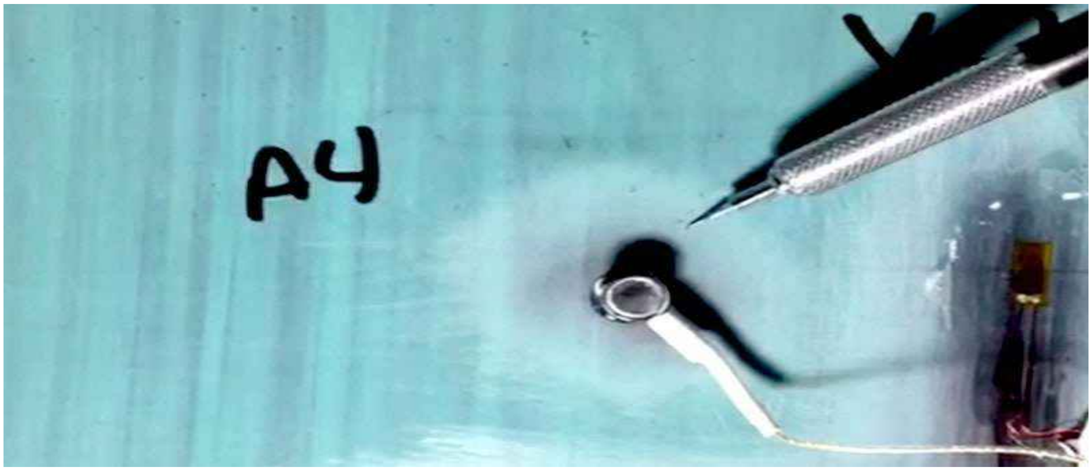

Figure 100: Closeup of a TITAN acoustic sensor. Source: https://ocean-archives.github.io/ .

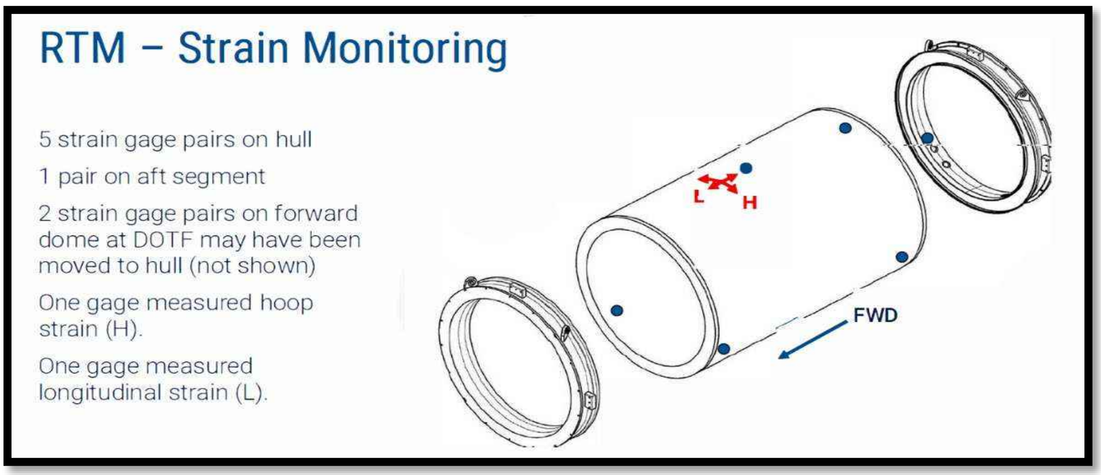

Figure 101: TITAN's strain gauge layout. Source: NTSB Materials Laboratory Factual Report.

Figure 102: Example of TITAN's strain gauging. Source: NTSB Materials Laboratory Factual Report.

4.18.8. The second component of the RTM system was the RTM software, which displayed live feedback via bar graphs for each sensor. These graphs showed instantaneous amplitude, hit counts, and cumulative hit counts, using color-coded indicators (green, yellow, and red) to signal whether readings were within thresholds. The cumulative hit count was also sent to the control computer and integrated with the TITAN's navigation display, allowing the pilot to actively monitor the hull's health alongside other key operating data from other systems.

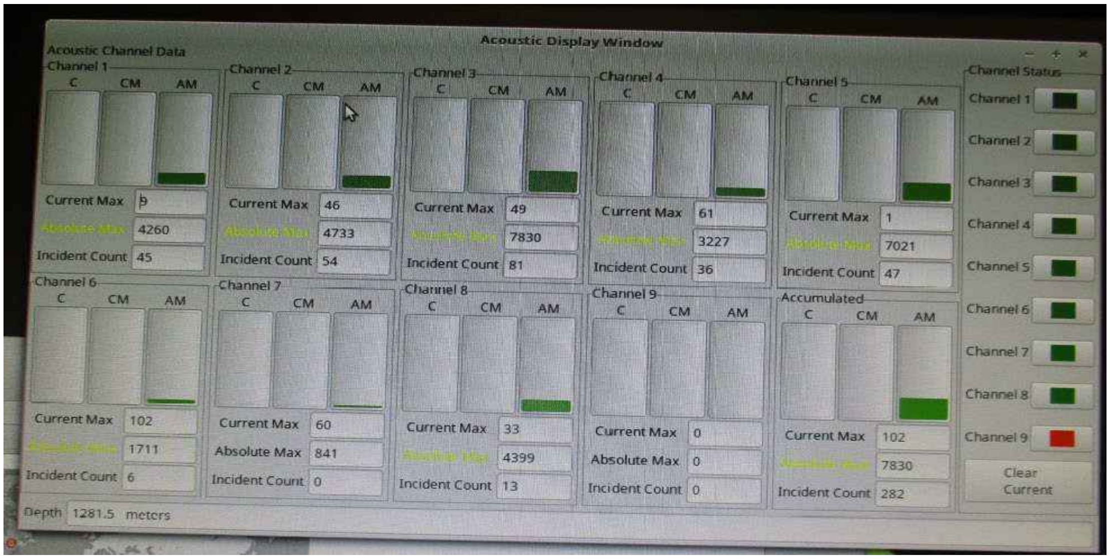

Figure 103: TITAN RTM data from Deep Ocean Test Facility in October 2019. Source: OceanGate.

4.18.9. A former OceanGate Director of Engineering described the function of the RTM system, stating:

> "The idea behind the real-time monitoring was that they could be on a dive, and they could watch the screen and there were – the acoustic energy of each sensor was shown on the screen in terms of a bar graph and the bar graph would show the level of acoustic energy. And so, they could be in – during a dive, they could watch this in real time and see if they were getting acoustic energy that was too high. We had certain criteria for what constituted a hit, and in the AE field there's this concept of a hit, which is a burst of acoustic energy that's over a certain intensity level. And for us, a hit, we classified as 5,000 A/D units on a maximum scale of 32,000."

4.18.10. A former OceanGate Director of Engineering described that the submersible's RTM system's color-coded scheme represented activity levels based on predefined thresholds. The system featured two principal alert levels: a warning level and an alarm level. When the cumulative hit count neared the warning threshold, the sensor's bar graph on the control monitor turned yellow, indicating elevated activity. If the count exceeded the alarm threshold, the bar graph turned red, signaling a critical condition.

4.18.11. Mr. Rush established the criteria for what constituted a "hit," with pre-programmed thresholds determining the system's green, yellow, or red status. These thresholds typically included a warning range of 30–50 cumulative hits, which triggered a yellow bar graph, and an alarm level above 50 hits, which turning the graph red.

4.18.12. According to MBI interviews with OceanGate employees, OceanGate's operational protocol for the RTS warnings mandated that the pilot of the TITAN abort the dive if acoustic hits reached the yellow threshold of 30–50 cumulative hits. However, the MBI could not identify any written OceanGate policies or procedures detailing that a TITAN dive should be aborted based on a yellow warning from the RTM system. Additionally, an MBI review of OceanGate's dive logs for the first and final TITAN hulls and MBI witness testimony from OceanGate employees confirmed that no TITAN dives were ever aborted due to RTM system warnings.

4.18.13. When asked whether the RTM alarms included an audible alarm in addition to the colored bar graph, a former OceanGate Director of Engineering stated the following:

> "There were no audio alarms. We wanted to do that, and Mr. Rush was totally against audio alarms, he didn't want them, but we wanted to do them, but we didn't."

4.18.14. The third RTM system component was the plotting software, which visualized the captured data for analysis. It used both the raw data and condensed hundred-millisecond intervals to generate plots that illustrated trends in AE activity. These plots made it easier to identify bursts of activity related to stress events, with cumulative hit count graphs showing the total activity over time. Together, these RTM components enabled effective real-time monitoring, visualization, and analysis of AE signals to evaluate the material condition of the hull and identify potential issues.

4.18.15. The AE data was stored in two stages. First, the raw data, sampled at 125 kilohertz, was archived. Next, a subsample was taken, capturing the most significant hit within each 100-millisecond interval. This method was called "sample and hold," and it provided a condensed version of the data by presenting the maximum value 10 times per second. While the raw data was archived for future use, the subsample data was used for plotting and analysis, allowing for efficient storage, processing, and review of critical information.

4.18.16. After each submersible dive, the procedure for downloading and managing RTM data involved multiple steps. Initially, strain data and AE plot data (100-millisecond samples) were downloaded to a portable universal serial bus (USB) drive from the data acquisition computer, named the Logger PC. These files were then transferred to the OceanGate server aboard the support vessel's computer, where plots were generated and emailed to relevant parties. The RTM system for the TITAN hulls did not include a capability for OceanGate Communications and Tracking Team members, who monitored dives from a small command and control center on the bridge of the vessel supporting TITAN's dive, to receive the RTM or review the alarm levels in real-time.

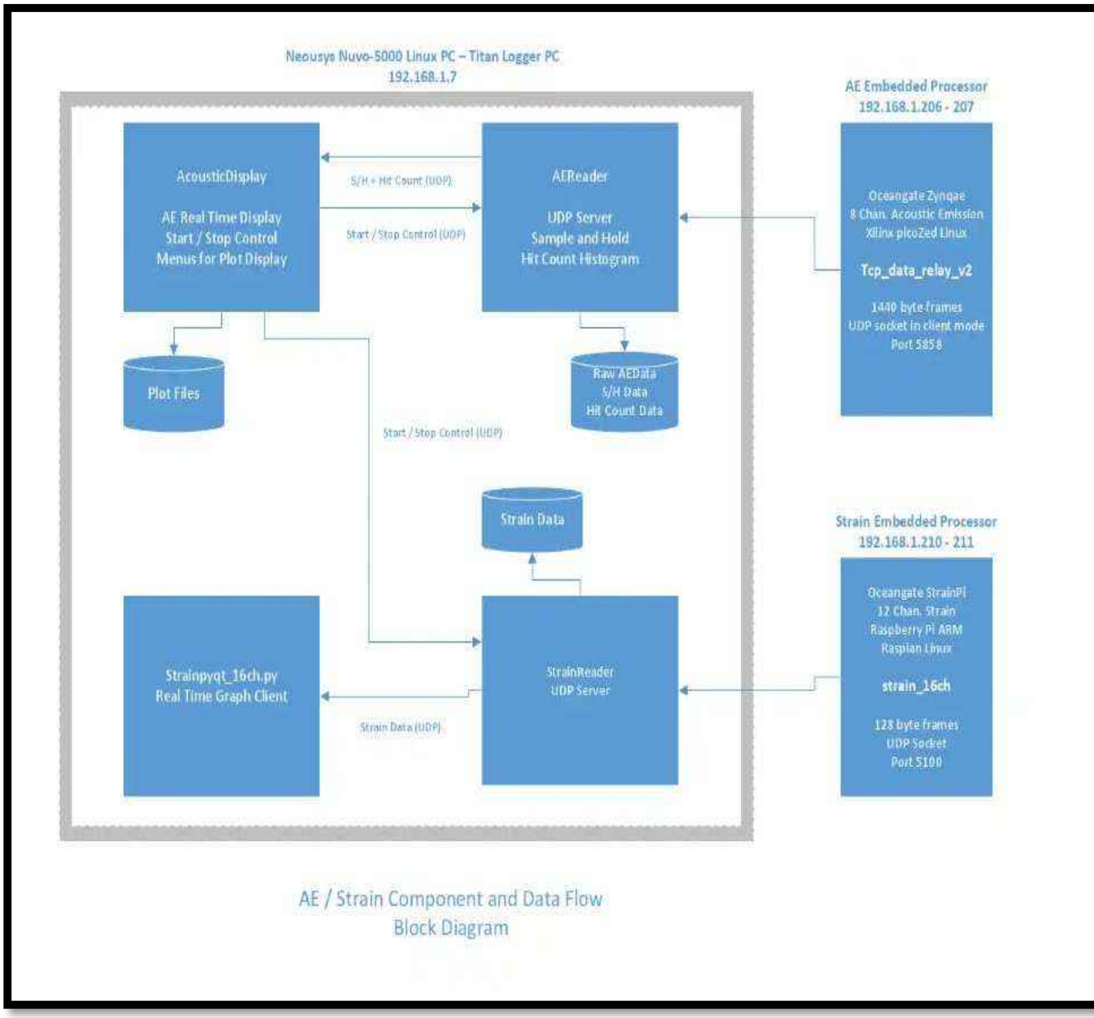

Figure 104: AE Strain Component and Data Flow Block Diagram. Source: OceanGate, 2020.

4.18.17. Every three or four dives, the process described for the 100-millisecond data was conducted for the raw AE data, which was much larger in size—ranging from tens to hundreds of gigabytes. The raw data was uploaded to a separate portable drive, checked for accuracy, and then deleted from the TITAN's computer to prevent storage issues. The raw RTM data was eventually uploaded to a server located at OceanGate's Everett, Washington facility.

4.18.18. Additionally, both the AE and strain plot data were stored in a Bitbucket cloud server, along with the control log files. These files were accessible for future review and analysis. This process ensured that all monitoring data was securely stored and available for further use by OceanGate personnel.

4.18.19. The project engineer from UW-APL testified to the MBI that the data from TITAN's RTM system, when properly characterized, could provide valuable insights into the hull's structural integrity. The data could support maintenance decisions by identifying the need for non-destructive testing (NDT) or determining if the hull had reached its operational limits, possibly requiring retirement from service. However, the project engineer clarified that the system was not designed to predict an impending catastrophic hull failure during a dive. Instead, the RTM system enabled a historical assessment of the hull's condition to facilitate informed decisions before each dive regarding its suitability for planned depths. The project engineer believed that the RTM system should have solely been used as a preventative tool, not a real-time safety alert system.

4.18.20. According to archived RTM data that OceanGate provided to the MBI from TITAN operations, acoustic emissions data for sensors one, three, and five provided no acoustic activity from dives 75 through 83[31]. All other sensors (two, four, six, seven and eight) showed acoustic activity for the dives.

4.18.21. According to the Project Execution Plan for 2023, OceanGate no longer had a Director of Engineering on staff. When the previous Director of Engineering was asked about the lack of AE data for sensors one, three, and five, he stated that he was unaware of the lack of data and that the sensors should have been checked before each dive.

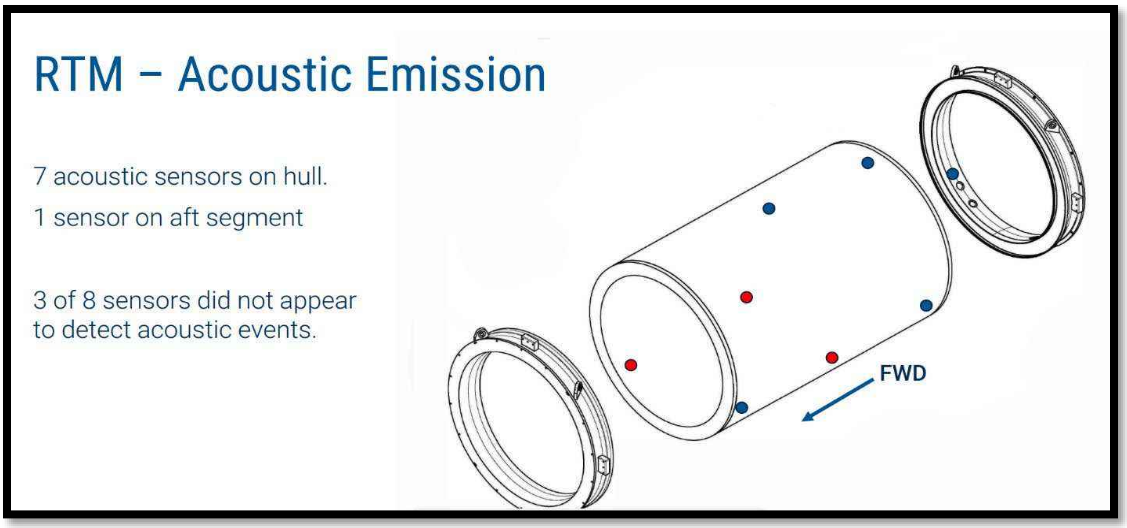

Figure 105: Layout of acoustic emissions sensors in TITAN hull. Blue dots are the location of sensors that provided acoustic Activity. The red dots were the location of the sensors that did not show activity from Dive 76 through Dive 83.
Source: NTSB Materials Laboratory Factual Report.

[31] No real-time monitoring data was available to the MBI from Expedition 2023 (Dives 84-88). The TITAN's severely damaged logger PC, which held the data, was recovered from seafloor. However, no data was able to be recovered despite forensic efforts.

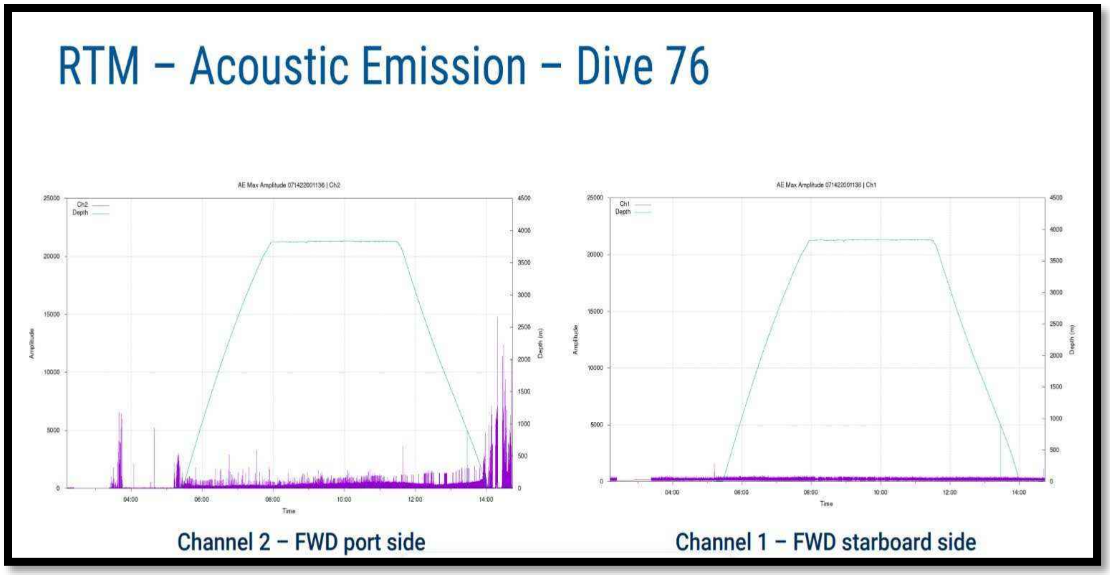

Figure 106: TITAN Dive 76 acoustic emissions for Channel 1 and Channel 2 showing no acoustic emissions, even during periods of launching and recovery. Source: NTSB Materials Laboratory Factual Report.

4.18.22. When asked by the MBI if there were any operational requirements for the number of acoustic sensors and strain gauges that needed to be functioning for TITAN to perform a dive, the former Director of Engineering provided the following response:

> "There were no known outright failures of the acoustic sensors during the mission, but some experienced electrical noise, which we attempted to address. The noise could have been caused by a cell phone or other electronic interference, but all eight sensors were operational and able to read acoustic data despite the noise. For strain sensors, three failed and could not be accessed due to their placement under the insert, leaving 13 working sensors out of 16."

4.18.22.1. The former Director of Engineering also clarified that "once (the RTM system sensors) were glued in and the insert installed, the sensors remained in place for the life of TITAN and were not replaced."

4.19. Launch and Recovery System (LARS)

4.19.1. In 2018, Everest Marine, a division of Penn Cove Shellfish based in Burlington, Washington, custom-fabricated a 35-foot-long aluminum platform for OceanGate. Designed to support a lifting capacity of 20,000 lbs, the platform was 15 feet wide and featured a draft of two feet when fully loaded with the TITAN.

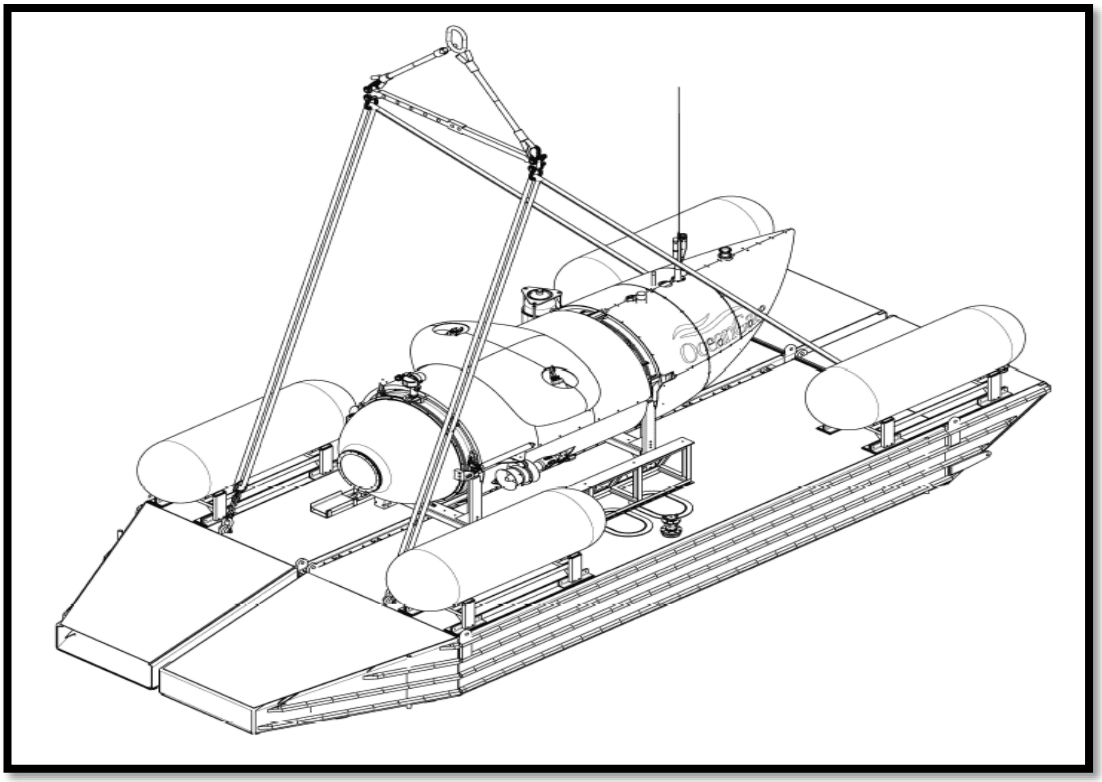

Figure 107: Schematic of the LARS. Source: OceanGate.

Figure 108: LARS on travel lift in Everett, Washington. Source: OceanGate Expeditions.

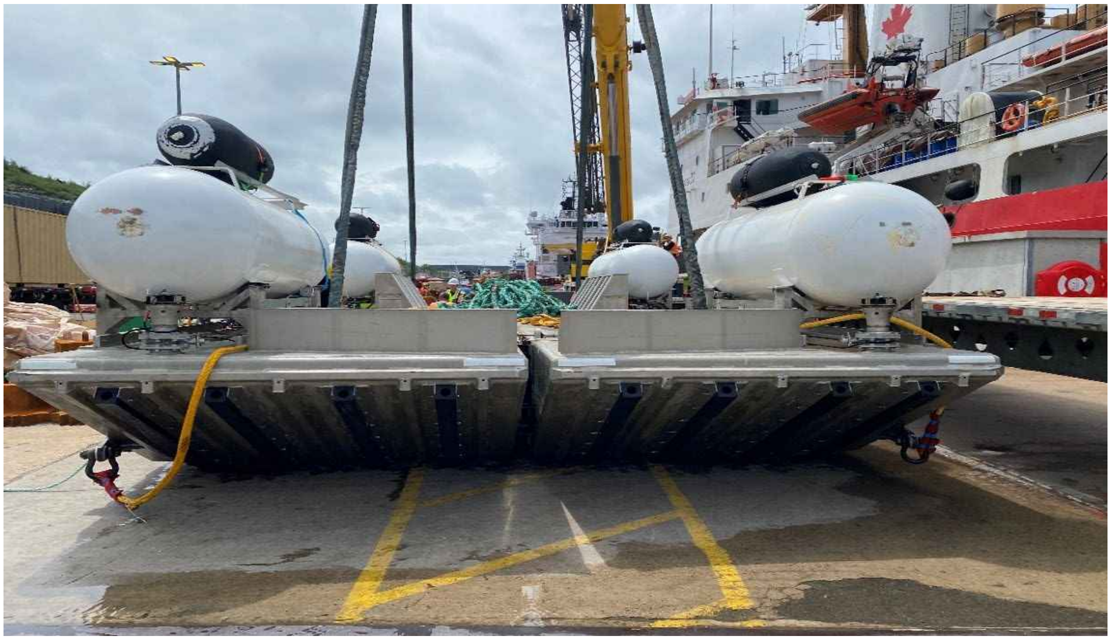

Figure 109: Photo taken by MBI team on June 25, 2023, of the TITAN LARS dockside in St. John’s, Newfoundland post-casualty. Source: USCG.

4.19.2. The concept for the LARS originated from a Hawaiian submersible company that used a pontoon-based barge to tow submersibles to dive sites. The Hawaiian submersible platform pontoons were then flooded, sinking the platform to a depth of approximately 50 feet to facilitate the submersible’s launch.

4.19.3. This LARS concept was viewed by OceanGate as an efficient and cost-effective way to transport and launch the TITAN because it meant that smaller less expensive contract vessels, that did not require the use of an “A” frame or davit launch system, could be utilized as support vessels. It was also seen as a safer way to launch the TITAN because at a depth of 30 m the submersible would be beneath any potential surf zones, which would enable them to launch from the submerged platform without being disturbed by rolling or breaking waves. After the TITAN had launched and was away from the platform, air was released into the flooded voids from the platform’s four air receivers, which raised it back to the surface.

4.19.4. During the 2021 and 2022 OceanGate TITANIC Expeditions, the LARS was transported from St. John’s, Newfoundland to the TITANIC wreck site on the stern of the support vessel HORIZON ARCTIC. During the 2023 OceanGate TITANIC Expedition, the LARS, with the TITAN atop, was towed astern by the support vessel POLAR PRINCE for a distance of approximately 740 NM to and from the TITANIC wreck site for each mission. The total distance the LARS and TITAN were towed for the 2023 TITANIC Expedition was approximately 2,958 NM.

Figure 110: The LARS and TITAN aboard the HORIZON ARCTIC during 2022 Expedition.
Source: Former OceanGate contractor.

Figure 111: Yellow arrow (added by MBI) pointing to the LARS and TITAN being towed astern of the POLAR PRINCE in 2023. Source: OceanGate Expeditions.

4.19.5. The TITAN LARS hull was integrated with four compartmental ballast tanks that could be vented or closed. At the beginning of a dive operation, the TITAN would be affixed (secured) atop the LARS. Support divers would open the vents in the hull, allowing water to enter the hull and the platform would begin to submerge and descend. There were buoys on each corner of the platform with approximately 30 feet of line attached. The platform with the TITAN still affixed would descend to approximately 30 feet, where the TITAN would then be disengaged by the divers and commence its dive.

Figure 112: The LARS ballasting valve is pictured within the yellow circle added by MBI. The photograph was taken by the MBI in St. John's, Newfoundland post-casualty on June 25, 2023. Source: USCG.

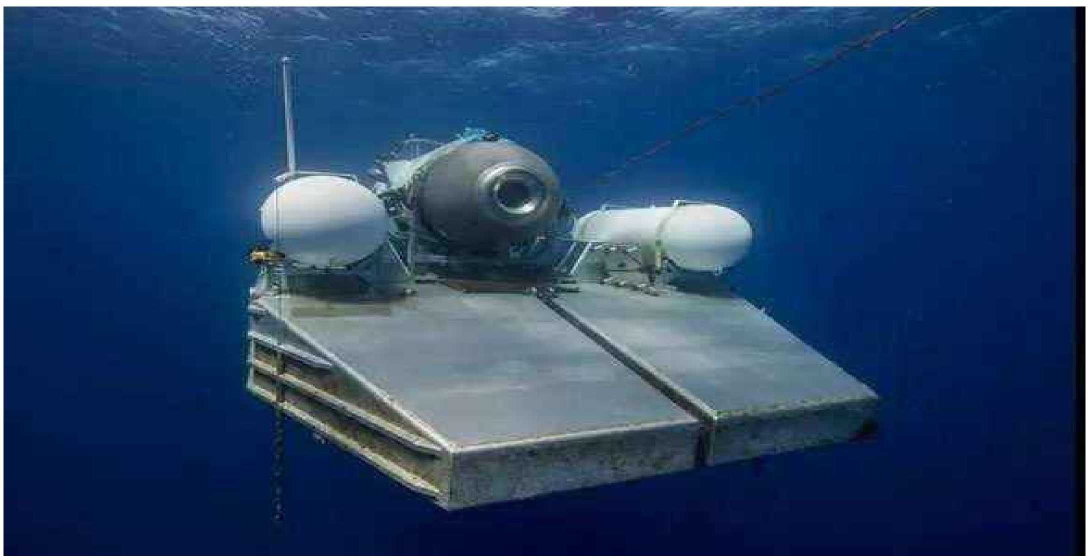

Figure 113: TITAN atop LARS descending. Source: OceanGate Expeditions.

4.19.6. Once the TITAN departed the platform and descended past 100 m, the platform was raised to the surface. The divers would then close the vents, and the platform operator would engage the low-pressure air from the receivers on the platform to fill the hull with air to raise it to the surface. The platform operator would be located in close proximity on the support RHIB to maintain control of the compressed air using a regulator. Figure 114 is an overhead view of the typical arrangement.

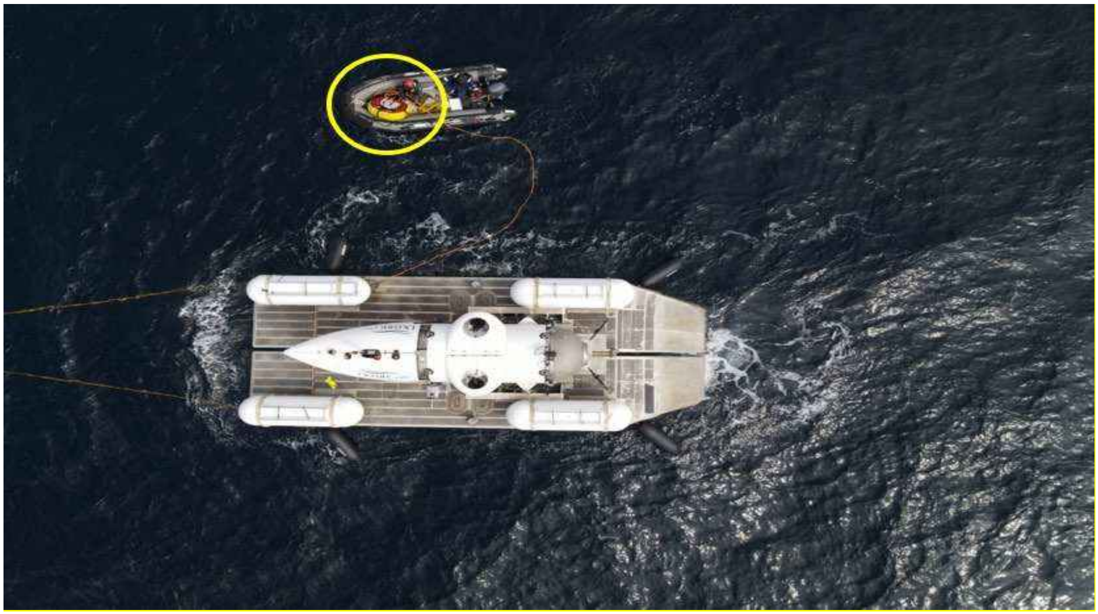

Figure 114: Overhead view of LARS, TITAN, and support RHIB with air regulator system (yellow circle) on 2022 Expedition. Source: Former mission specialist.

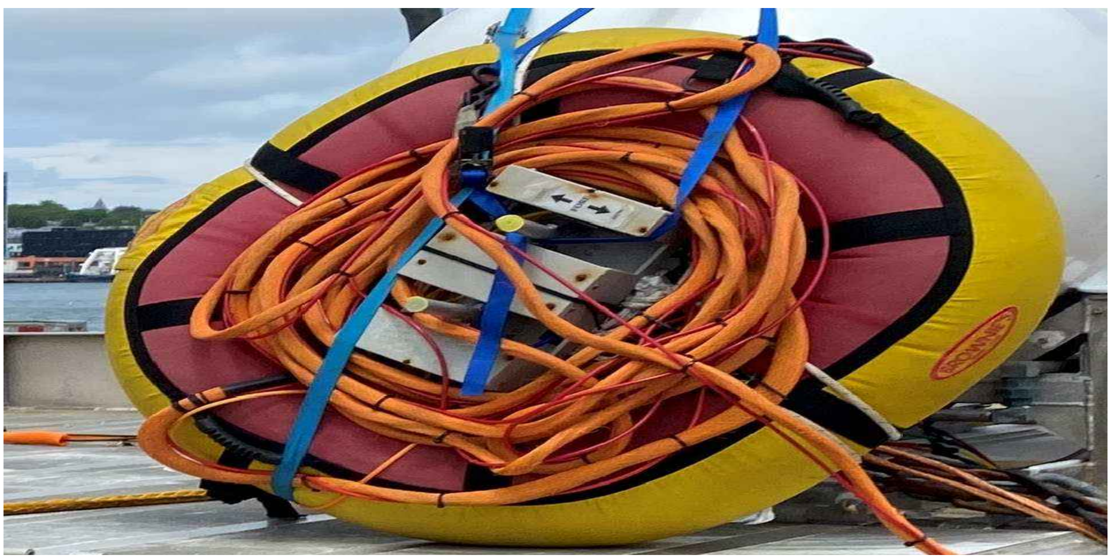

Figure 115: Photo of the air regulator system used to raise the LARS taken by MBI in St. John's, Newfoundland on June 25, 2023. Source: USCG.

4.20. Director of Marine Operations' Report, Firing, and Whistleblower Filing

4.20.1. The Director of Marine Operations for OceanGate was responsible for ensuring the safety of crew members and clients during both submersible and surface operations. This role also involved managing and maintaining all marine assets to ensure mission objectives were met during complex expeditions. As an experienced submersible pilot and chief pilot overseeing all operations and personnel, the individual's contributions were crucial to the safe execution of OceanGate's operations. However, the Director of Marine Operations, who filled the position from 2016 to 2018, reported being largely sidelined by Mr. Rush and the Director of Engineering of OceanGate at the time. Despite his extensive experience with submersibles and his broad OceanGate oversight responsibilities, his safety concerns were often dismissed. These dismissals, coupled with challenging internal company dynamics, undermined his ability to prioritize personnel safety and perform his duties effectively.

4.20.2. The Director of Marine Operations frequently raised safety concerns to the Director of Engineering, but his concerns were often met with hostility. As an example, he observed critical components arriving at the warehouse and identified potential failure points, which he promptly reported to the responsible OceanGate employee or contractor. However, his warnings were largely ignored or dismissed. The Director of Marine Operations also described a toxic work environment, in which Mr. Rush undermined the Operations team, further complicating efforts to address safety issues. The lack of support for his concerns and the overall culture within OceanGate created significant operational challenges, especially given the high-risk nature of the submersible missions.

4.20.3. While OceanGate was preparing for its first expedition to the TITANIC wreck site in 2018, the Director of Marine Operations was tasked with inspecting the CYCLOPS II submersible, which was later renamed TITAN. He began his inspection in December 2017 and, on January 18, 2018, submitted a report highlighting critical safety concerns. The Director of Operations made it clear that with the submersible being handed off from the Engineering team to the Operations team, it was an opportune time to address the safety issues. In his report, he outlined 26 components that required corrective action or further attention, expressing concern that until these issues were addressed, the submersible should not be used in any upcoming trials. According to the Director of Marine Operations, he believed it was important to document these findings and ensure that OceanGate management took them seriously before the submersible was put into operational use with human occupancy.

OCEANGATE CYCLOPS 2 QUALITY CONTROL INSPECTION REPORT

PROJECT NAME:	CYCLOPS 2 (TITAN)	DOCUMENT VERSION NO:	1
PREPARED BY:	[redacted]	DOCUMENT DATE:	18th JANUARY 2018

COMPONENT/DELIVERABLE	INSP DATE	INSPECTION NOTES	CORRECTIVE ACTION/RECOMMENDATIONS	ATTACHMENTS	CLOSED OUT
Viewport, O-ring and fasteners	1/18/18	Viewport was installed by OG Engineering department prior to this inspection, no thorough inspection of acrylic or O-ring could be carried out on inspection date.	Documentation to be issued to Operations department showing completed pressure test results and associated documentation from Hydrospace Group. Engineering Director has denied my requests for these records to be produced		No
Forward Dome	1/18/18	Pitting and scoring evident on external face	None		Yes
Forward Dome sealing face	1/18/18	At the 12 o-clock position it must be noted that a plunge-hole is present. This will create the least path of resistance of sea water on this critical sealing face. A double dove tail O-ring groove has been machined to captivate the O-ring yet with the plunge hole this type of O-ring groove is out- with standard design parameters	Recommend re-machining of the sealing face too correct both the plunge-hole and the O-ring groove as they deviate from standard design parameters	Photos and PDF of O-ring groove are below this report	No
Segment 1 sealing face	1/18/18	Some marks seen at the 9 O-clock position, impact caused by hatch swing	None		Yes
Segment 1	1/18/18	Glued onto the Forward Carbon hull prior to delivery so unable to inspect the attachment face.	Director of Engineering to verify condition of the attachment face prior to gluing occurring. Non-Destructive Testing of the Bond Line should be carried out.		No
Hatch Hinge	1/18/18	Ongoing work so final inspection will be required to be done on completion	Further inspection required upon completion		No
Forward vertical legs	1/18/18	No action items noted	None		Yes
Forward Horizontal support	1/18/18	Where the support meets with the Segment 1 lower attachment bracket, 2 of the 4 bolts are missing, no nuts are present	Bolts and nuts to be secured prior to moving the vehicle		No
Top/Port/Stbd Horizontal beams	1/18/18	No action items noted	None		Yes
Carbon hull and coating	1/18/18	Hull could not be inspected externally due to Rhino-coating having been applied under the direction of OG Engineering department. It must be noted that visible voids and delamination's are present in the Carbon end cut off segments, highlighting the need to carry out Non-Destructive Inspection to verify the hull integrity	Non-Destructive Inspection is required to be undertaken and subsequent results provided to myself prior to any in water Manned Dives commencing. This testing will also provide a solid baseline of the hull condition prior my recommended unmanned pressure testing in the Bahamas April 2018	Photos of delamination's and porosity in Carbon end segments are after this report	No
Ballast Bag and vent mechanism	1/18/18	Glue coming away from seams, no support on the base of the bag preventing air from exiting during thrusting of vehicle in water. Vent mechanism unproven. No vent mechanism seen on forward end of ballast bag	Glue to be reapplied, ballast bag design to be re-assessed.		No
Aft vertical legs	1/18/18	No action items noted	None		Yes
Aft Horizontal support	1/18/18	No action items noted	None		Yes
Stbd penetrators	1/18/18	No action items noted	None		Yes
Port penetrators	1/18/18	No action items noted	None		Yes
Segment 2	1/18/18	Glued onto the Aft Carbon hull prior to delivery so unable to inspect the attachment face	Director of Engineering to verify condition of the attachment face prior to gluing occurring Non-Destructive Testing of the Bond Line should be carried out		No

Segment 2 sealing face	1/18/18	This sealing face could not be inspected as the aft dome was torqued in place by OG Engineering department prior to this inspection	Engineering Director to verify condition of the sealing face prior to sealing it up		No
Aft Dome	1/18/18	Aft dome torqued in place by engineering department prior to this inspection. Pitting and scoring evident on external face	Engineering Director to verify torque settings and witnessed		No
Aft Dome sealing face	1/18/18	This sealing face could not be seen as the aft dome had been torqued in place by OG Engineering department prior to this inspection. Prior to the dome being in its current configuration we noted that at the 6 o-clock position a plunge-hole is present on the O-ring groove. This will create the least path of resistance of sea water on this critical sealing face. A double dove tail O-ring groove has been machined to captivate the O-ring yet with the plunge hole this type of O-ring groove is out- with standard design parameters	Re machining of the sealing face to correct both the plunge-hole and the O-ring groove. Engineering Director to verify condition of the sealing face prior to sealing the dome	Photos and PDF of O-ring groove are below this report	No
Exo-structure	1/18/18	Dissimilar metals used throughout. Rubber spacers for top fairing need to be secured more effectively	Anodes required. Rubber securement required, not zip ties		No
Electrical Pods	1/18/18	No Anodes on any of the cans	Anodes required to prevent corrosion		No
Electrical Pod tray	1/18/18	Dissimilar fasteners used	Fasteners should be assessed		No
Ictineu Battery	1/18/18	Securement in tray using ratchet straps, one strap is tensioned over the upper sealing bolts	Clamping method to secure battery to tray should be considered		No
Battery Tray	1/18/18	No action items noted	None		No
Fairings and thruster support brackets	1/18/18	Vertical Thruster mounting bracket bolts are deflecting off the ballast bag port and starboard. Thruster brackets have differing fasteners	Use of shorter bolts or protection to prevent rupturing the ballast bag. Fasteners should be assessed		No
Thrusters	1/18/18	Snagging hazards evident with the positioning of the oil filled cables	Angled adaptors required to allow for greater protection of cables and neater cable runs		No
Sonar/ Pan and Tilt	1/18/18	Pan and tilt not installed	None		Yes
Anodes	1/18/18	Other than the thruster motor anodes, no anodes were present on vehicle	Anode assessment required		No
HPA System	1/18/18	System is plumbed and charged, verification of leak test required No securement present for the HPA Cylinder	Leak test and system test required. Cylinder securement required		No
Novatech Iridium	1/18/18	Secured onto support bar with zip ties	Clamping arrangement suggested		No
Oxygen system	1/18/18	No access granted on day of inspection	Inspection required		No
House batteries	1/18/18	No access granted on day of inspection	Inspection required		No
HPA system, Blow Vent	1/18/18	No access granted on day of inspection	Inspection required		No
Control / computer systems	1/18/18	No access granted on day of inspection	Inspection required		No
Interior Flooring	1/18/18	Previously a flame test was carried out to determine how flammable this HDPE product was. The sample of material continued to burn and emit toxic fumes when ignition source was removed	The flooring, O2 support brackets and insert spacer material should be replaced	Photos are after this report	No
Computer bay / back wall vinyl wrap material	1/18/18	Previously a flame test was carried out to determine how flammable this vinyl tape was. The sample of material continued to burn and emit black toxic fumes when ignition source was removed	The computer bay and back wall vinyl should be replaced		No

Figure 116: Quality Inspection Report without images. Source: Former OceanGate Director of Marine Operations.

4.20.4. The report included a detailed Quality Control Inspection of CYCLOPS II, which identified numerous safety concerns, particularly with components that were not up to operational standards essential to deep sea operations. These concerns were not just theoretical; the Director of Marine Operations believed they could pose a significant risk to personnel if left unaddressed. The report was an official record that highlighted the necessary corrective actions to ensure the submersible's safety during missions. According to the Director of Operations, his intention was to provide OceanGate with a clear and documented account of the issues that needed attention before any further operations could take place. His emphasis was on ensuring that the submersible was safe to operate, reflecting his primary concern for the well-being of the crew and mission personnel.

4.20.5. On January 19, 2018, the Director of Marine Operations met with Mr. Rush, the Director of Engineering, a Human Resources representative, and the COO, for a two-hour meeting. During this meeting, the Director of Marine Operations argued for additional testing of the TITAN submersible's hull and emphasized the need to address the safety concerns outlined in his report. Although the meeting was crucial to ensuring the safe operations of the new TITAN submersible, there was no formal response, or any subsequent actions taken by the CEO or OceanGate in response to the inspection report. The Director of Operation's recommendations, however, were met with strong resistance and disdain from OceanGate's CEO and other senior company officials. Following the meeting, it became clear to Mr. Rush that he and the Director of Marine Operations were at an impasse regarding how to move forward with the submersible's development and he notified the Director of Operations that he would likely be fired. The meeting lasted two hours and four minutes and was audio recorded by the CEO. The recording was obtained by the MBI and transcribed as MBI exhibit 100[32].

4.20.6. On January 23, 2018, OceanGate fired the Director of Marine Operations. The termination letter stated, "During the meeting on the afternoon of January 19th, it became clear to (Mr. Rush) that you and he were at an impasse regarding the CYCLOPS II hull, and the only option was termination of your employment. Given your qualifications, we are confident that you will find another position soon."

4.20.7. After his termination, the former Director of Marine Operations filed a retaliation complaint with the Occupational Safety and Health Administration (OSHA) on February 6, 2018. He alleged that his dismissal was in retaliation for raising valid safety concerns regarding the first TITAN hull's development and testing plans. He argued that OceanGate had violated the Seaman's Protection Act, which safeguards employees from retaliation for reporting safety issues in the maritime industry. By filing the complaint, he sought to hold OceanGate accountable for dismissing him rather than addressing the serious safety risks he had identified, especially Mr. Rush's plans to test the first TITAN hull at TITANIC equivalent depths with himself and others onboard.

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[32] TITAN Exhibit CG-100

4.20.8. According to an OSHA Fact Sheet[33], "the Seaman's Protection Act (SPA) prohibits persons from retaliating against seamen for engaging in certain protected activities pertaining to compliance with maritime safety laws and regulations. A seaman is any individual engaged or employed in any capacity on board a U.S.-flag vessel or any other vessel owned by a citizen of the United States."

4.20.9. In response to the OSHA complaint, OceanGate filed a lawsuit against him on June 25, 2018, with six causes of action. The lawsuit accused the Director of Marine Operations of violating the Employee Intellectual Property Agreement, which he had signed in conjunction with his hiring in 2016, by sharing confidential information with OSHA.

4.20.10. On February 26, 2018, an OSHA investigator emailed a USCG representative who had previously had the collateral duty and responsibility for monitoring SPA claims regarding the retaliation complaint against OceanGate. Post-casualty digital forensics conducted by the Coast Guard Investigative Service (CGIS) at the request of the MBI determined that this email was not received by the member and therefore was not forwarded to the new member at CG-INV monitoring OSHA cases. Further investigation revealed that other OSHA-SPA communications, not related to the OceanGate case, which were emailed to the same former USCG representative, before and after February 26, 2018, were received and successfully forwarded by the previous OSHA contact to the new USCG OSHA contact at CG-INV. The CGIS examination also identified an email from OSHA, dated August 28, 2019 (a year and a half after the settlement of OceanGate's specific case), sent to the USCG member responsible for overseeing SPA and OSHA matters. The email contained two attachments: SPA Case Listing FY18 and SPA Case Listing FY19. The FY18 listing, which covered SPA cases filed between January 1, 2016, and August 22, 2018, showed the OceanGate Inc. case as "Open." However, the FY19 spreadsheet indicated the OceanGate Inc. case was "Settled Other." The USCG's digital forensic examination found no other relevant OceanGate-OSHA related results and no action was initiated by the USCG's SPA representative on the resolved OceanGate case listed on the FY19 spreadsheet.

4.20.11. During MBI testimony, OceanGate's former Director of Marine Operations, confirmed that he did not engage directly with the USCG regarding his safety concerns regarding the first TITAN hull.

[33] https://www.osha.gov/sites/default/files/publications/OSHA3762.pdf

From: [redacted]
To: [redacted]
Subject: OceanGate Inc./[redacted]-1960-18-073
Date: Monday, February 26, 2018 1:44:00 PM
Attachments: image001.png
[redacted]-CAW.pdf

Dear Sir/Madam:

Enclosed for your information please find a copy of a complaint of retaliation filed under the Seaman's Protection Act as amended by Section 611 of the Coast Guard Authorization Act of 2010, P.L. 111-281 (SPA), 46 U.S.C. §2114. An investigation of the retaliation allegation is currently being conducted by this office. If I can be of further assistance to you, please do not hesitate to contact me at (206) 757-6685.

Sincerely,

[redacted]
Investigator, Whistleblower Program
U.S. Dept. of Labor – OSHA, Region X

Figure 117: Copy of an email sent to the USCG by the OSHA Investigator on February 26, 2018, Whistleblower Program regarding the former OceanGate Director of Operations complaint. Source: OSHA.

4.20.12. According to the OSHA Investigator handling the complaint against OceanGate, he was experiencing a significant backlog of other whistleblower investigations when the OceanGate complaint was filed. The OSHA investigator also stated the following during an MBI interview:

> “Another thing that I remembered about this case, when the company filed the lawsuit against [NAME REDACTED BY MBI], that was a big red flag for us. I had another case where that happened, and it's considered a SLAPP suit[34], and most states have an anti-SLAPP suit law that says you can't, you can't basically intimidate people with lawsuits who are exercising their right under the law to file a complaint with the Government.”

As a result, the investigation into the complaint against OceanGate was never started by OSHA after the evidence was received from both parties. On December 13, 2018, OceanGate’s former Director of Marine Operations withdrew his SPA complaint against OceanGate, citing the emotional toll of the ensuing legal battle and stating that he and his wife had simply wanted the ordeal to be over due to the lack of progress on his case.

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[34] A "Strategic Lawsuit Against Public Participation (SLAPP)," is a lawsuit filed to intimidate and silence critics by burdening them with the costs of legal defense, according to the LII Legal Information Institute. At the time when OceanGate filed the lawsuit against the whistleblower, Washington did not have an anti-SLAPP law in place. Washington’s previous anti-SLAPP law, which was adopted in 2010, was struck down by Washington’s supreme court in 2015. Washington subsequently put the protections against SLAPP suits back in place in July of 2021 with the enactment of the Uniform Public Expression Protection Act.

4.21. Hull Completion / Initial Test Dives / Marine Technology Society Letter

4.21.1. The assembly of the first TITAN submersible was completed in January 2018. From February 6 to April 9, 2018, OceanGate carried out a series of tests and dives with the first TITAN submersible in Everett, Washington. Testing began with two dunk-and-raise operations on February 6, followed by six additional dunk tests over the next two days. On February 12, the first manned dive, reaching a depth of 3 m, was conducted by Mr. Rush and an OceanGate electrical engineer. Over the next month and a half, OceanGate completed 18 more dives, including an open-water dive to 37 m (121.4 feet) on April 9. During this testing phase, 60 issues were recorded in the submersible's Maintenance Log.

4.21.2. In February 2018, during a submersible conference, growing concern was being voiced by prominent members of the submersible industry regarding OceanGate practices and its planned operations. Many professionals in the field, including a Russian expert with extensive experience in TITANIC dives, expressed alarm over the risks associated with OceanGate's operations. This concern escalated at the conference, with attendees discussing the dangers of deep-sea exploration at the TITANIC wreck site, particularly the seemingly casual approach taken by OceanGate, which did not align with industry standards for such high-risk submersible operations.

4.21.3. As the discussions continued at the conference, a member of the conference suggested taking action to address the situation. A group of submersible professionals agreed that something needed to be done, with ideas ranging from legal action to simply voicing concerns. Ultimately, a letter to OceanGate's CEO was drafted, urging Mr. Rush to prioritize safety and adhere to established industry practices. The letter was intended to be a respectful, professional appeal rather than a personal attack, and it was drafted with input from numerous colleagues in the industry. More than 20 professionals signed the letter, representing a global consensus of concern.

4.21.4. Despite receiving broad support, the letter was not formally sent through the Marine Technology Society (MTS), due to organizational rules. The letter was eventually sent to the CEO, who then called the originator of the letter to discuss the contents. Although it was not official communication from the MTS, it was confirmed that the CEO of OceanGate received the letter and responded to it.

4.22. Test Dives in the Bahamas

4.22.1. Upon completion of the first TITAN hull, OceanGate took their operation to Marsh Harbour, Bahamas to conduct test dives. This location provided access to deep waters close to shore, which enabled the crew and submersible to be able to rapidly return to land after operations and minimized costs. The test dives were to be completed prior to the scheduled 2018 TITANIC Expedition departure in June.

4.22.2. In April of 2018, the TITAN and OceanGate staff arrived in Marsh Island, Bahamas. However, after their arrival, the local area experienced a week of bad weather and lightning storms which delayed TITAN's test schedule.

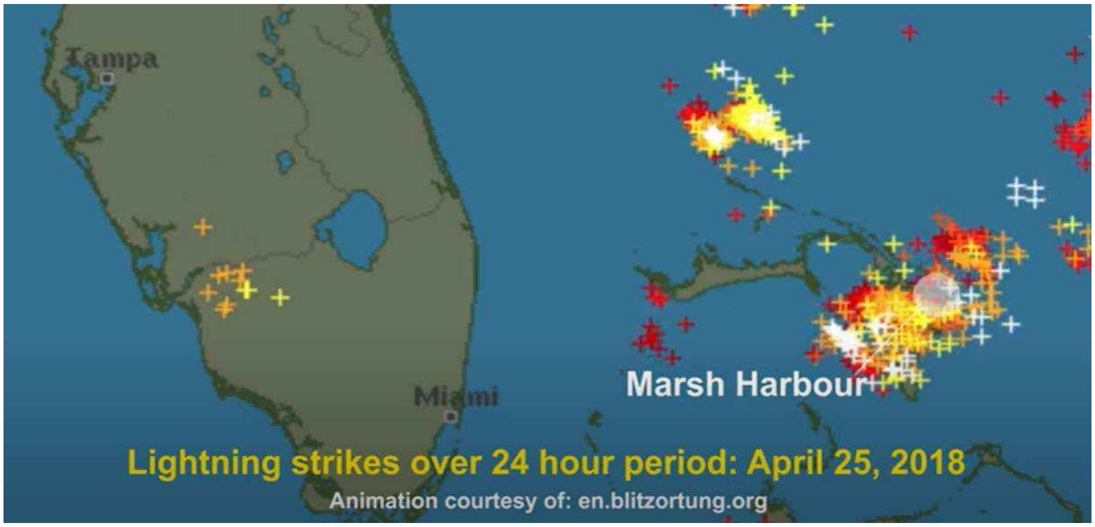


Figure 118: Lightning activity over Marsh Harbour, Bahamas, April 25, 2018. Source: OceanGate Expeditions.

4.22.3. On April 30, 2018, the TITAN was transferred to the LARS platform. During vessel checks, the team observed sporadic electrical system behavior and concluded that, although the TITAN had not been directly struck by lightning, it sustained severe component damage due to overcurrent potentially generated by a nearby lightning strike. The TITAN's maintenance log recorded the replacement of multiple routers, switches, and relay board components. While the engineering team worked on re-wiring the TITAN, the operations team conducted LARS test dives and reconnaissance in preparation for TITAN test dives in the Sea of Abaco.

4.22.4. On May 8, 2018, the TITAN performed its first dive in the Bahamas to a depth of six meters (19.6 feet).

4.22.5. On May 11, 2018, the CEO conducted a solo dive (Dive 20) to a depth of 35 m (114.8 feet). Notes from the solo dive indicated, "Weight perfect. Multiple squawks and operational challenges - see incident and dive reports." The maintenance log documented 15 issues, including: TITAN's aft fairing being ripped off due being towed in shallow waters, ATM failure, drop weight failures at both depth and the surface, and water in the starboard thruster's compensation line. The MBI was not provided with the incident report.

4.22.6. On May 16, 2018, OceanGate announced the cancellation of the 2018 TITANIC Expedition through a blogpost. The post cited complications caused by the weather, stating that since a 4,000-m (13,123-foot) dive could not be achieved at least 45 days prior to the expedition, the mission was postponed to 2019. OceanGate further stated its intention to continue working toward the 4,000-meter goal over the summer.

4.22.7. Throughout June of 2018, OceanGate conducted a series of unmanned TITAN test dives (dives 21- 26). On June 26, 2018, the first TITAN hull successfully reached a depth of 4,000 m during an unmanned dive. The TITAN was towed to the dive site aboard the LARS, manually disengaged, and lowered incrementally to the target depth using a monofilament line. In a June 27, 2018, blogpost, OceanGate detailed that onboard strain gauges, viewport displacement sensors, and a custom acoustic sensor system were used to measure hull integrity by providing data that could be analyzed during and between dives.

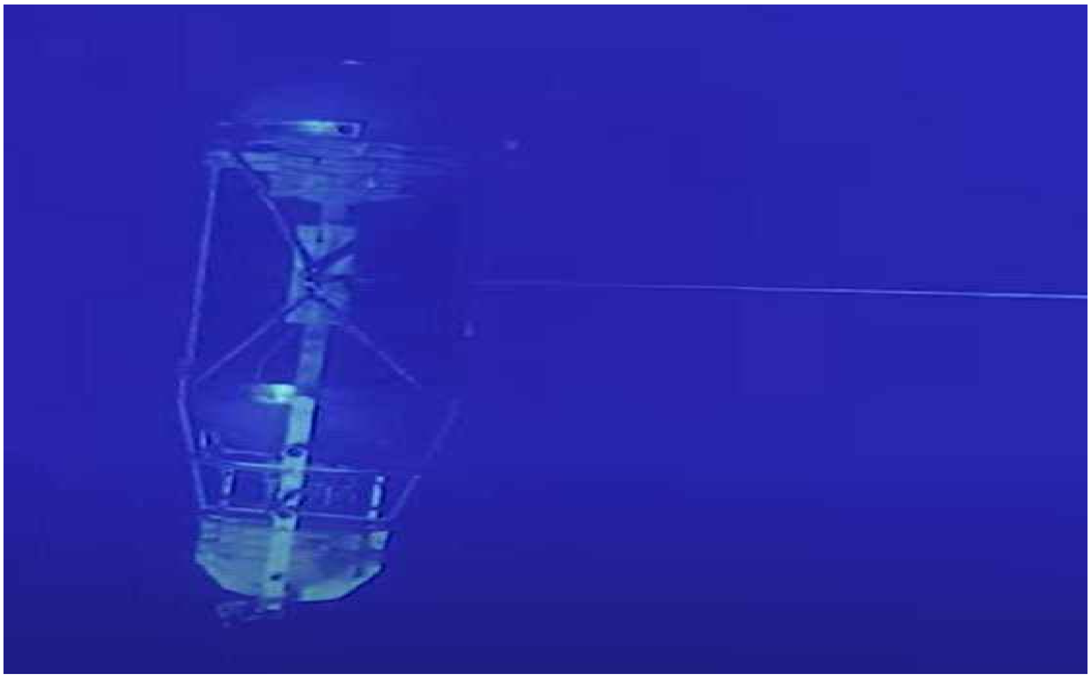


Figure 119: Overhead view of TITAN on monofilament line during its 4,000m unmanned dive in 2018 in the Sea of Abaco near Marsh Harbour, Bahamas. Source: OceanGate Expeditions.

C2_0019	5/8/18	Sea of Abaco - Marsh Harbour	3.9	6
C2_0020	5/11/18	Marsh Harbour Deep Test Site	8.9	35
C2_0021	6/5/18	Marsh Harbour Deep Test Site	4.0	6
C2_0022	6/11/18	Marsh Harbour Deep Test Site	1.5	6
C2_0023	6/19/18	Marsh Harbour Deep Test Site	4.0	6
C2_0024	6/21/18	Marsh Harbour Deep Test Site	8.0	1200
C2_0025	6/23/18	Marsh Harbour Deep Test Site	7.0	2500
C2_0026	6/26/18	Marsh Harbour Deep Test Site	9.5	4000

Figure 120: TITAN dive log excerpt. Column 4 is the length of time in hours and column 5 is the depth in meters. Source: OceanGate.

4.22.8. Each of TITAN's strain gauges were glued to the inner casing using M-bond 200, strain relieved, and covered with a coating to protect them from water or physical damage. In total, 18 strain measurements were taken on the inside surface of the casing.

There were three rows of the strain gauges (positioned at 20 degrees, 140 degrees, and 260 degrees from a reference point of the top of TITAN's circular crew compartment being zero degrees) and in each row there were hoop and axial locations at the forward clevis, mid-case, and aft clevis symmetrical to each other about the mid-case.

Figure 121: Image of TITAN's interior hull shows the acoustic emission and strain gauge instrumentation locations. Source: Former OceanGate Director of Engineering Report.

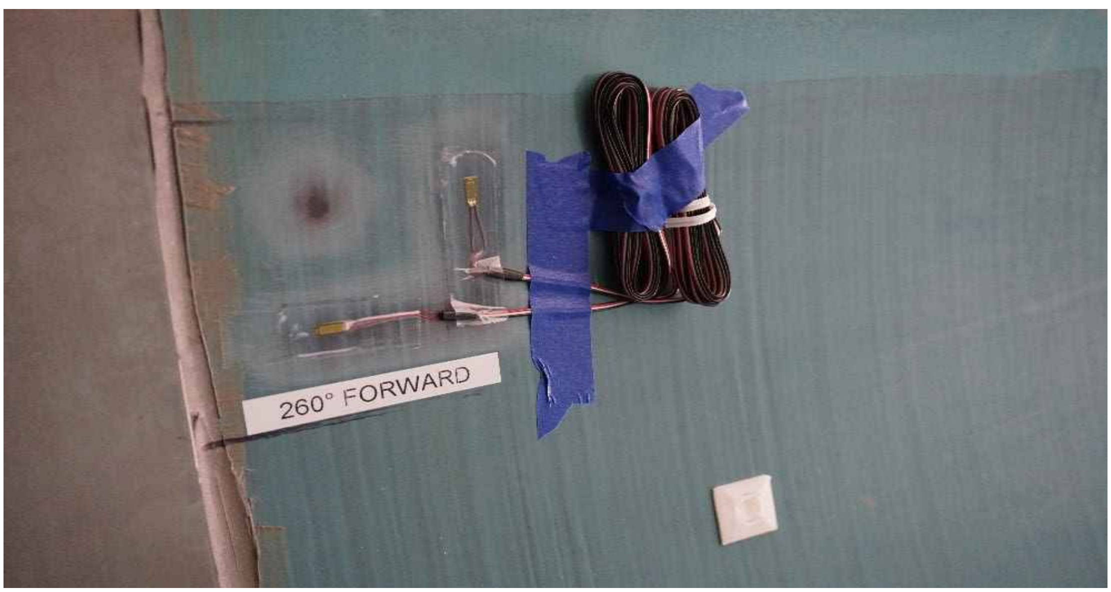


Figure 122: Closeup of a TITAN strain gauge. Source: Former OceanGate Director of Engineering Report.

4.22.9. OceanGate's Director of Engineering analyzed the strain data for the unmanned dives and determined for both the 1,200 m (3,937 foot) and 2,500 m (8,202 foot) dives that there was a close correlation between the measured strain values and the depth profile, which indicated that the strain sensors were functioning properly, as shown in Figure 123. Figure 123 displays the axial and hoop strain measurements from an aft-to-forward direction, with consistent color codes representing the hull's internal surface. A review of the graphs revealed consistent tracking of case movement with load application. However, the Director of Engineering further stated that several anomalies warrant further investigation, including the following items: (a) equal axial and hoop strain mid-case, (b) significant differences in axial strain between the forward and aft sections, (c) significant differences in hoop strain between the forward and aft sections, and (d) the inversion of axial and hoop strain trends between the forward and aft sections.

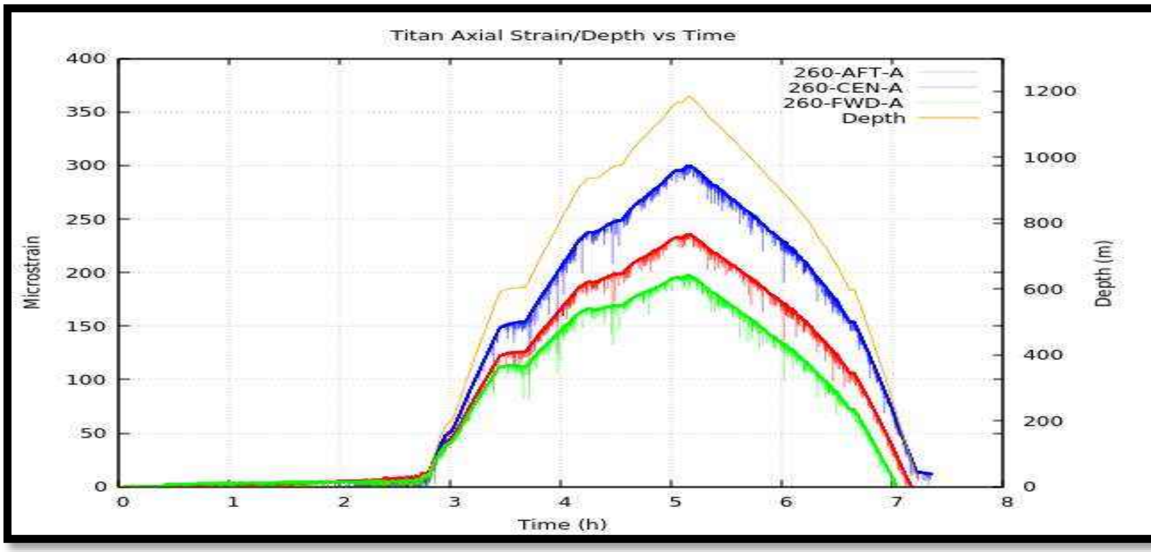


Figure 123: TITAN strain data from Dive 24 to 1,200 m on June 21, 2018. Source: Former OceanGate Director of Engineering Report.

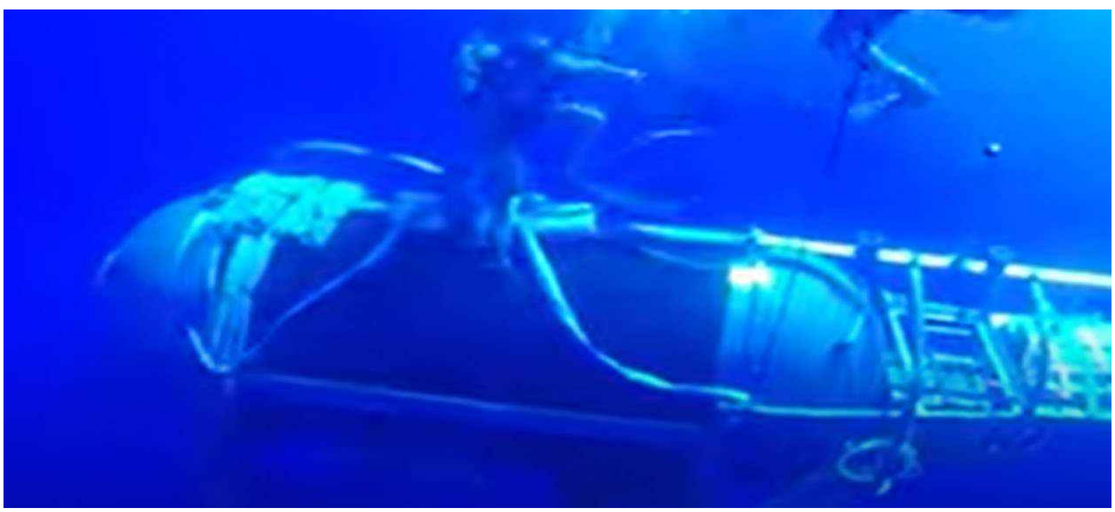


Figure 124: Divers rigging the first TITAN hull for an unmanned dive in 2018. Source: OceanGate Expeditions.

4.22.10. A former OceanGate Director of Marine Operations provided clear warnings against the planned testing of the TITAN while manned during its trip to the Bahamas. The former Director of Marine Operations emphasized that manned testing was not standard practice in the submersible industry. He stressed that for a submersible to be considered safe for manned testing and operations, it must first undergo rigorous pressure testing to ensure the hull's integrity. He pointed out that companies like Triton

Submarines followed this procedure, pressure testing their hulls before building the rest of the submersible. By skipping this essential step, the TITAN submersible and personnel on board for the tests were subjected to unnecessary risk and life-threatening conditions.

4.22.11. From August 1, 2018, to December 7, 2018, the first TITAN hull completed 11 manned dives, reaching a maximum depth of 2,487 m (8,159 feet).

4.22.12. On December 12, 2018, Mr. Rush conducted a solo manned dive aboard the TITAN to a depth of 3,939 m (12,923 feet). Dive logs reported that the RTM detected 153 total acoustic incidents per sensor during the dive. In a OceanGate blogpost, the company stated, “Not only did this dive completely validate OceanGate's innovative engineering and the construction of TITAN's carbon fiber and titanium hull, but it also means systems are a GO for the 2019 TITANIC Survey Expedition—the world’s deepest adventure—scheduled to begin next summer.”

4.22.13. From March 8 to April 14, 2019, OceanGate conducted eight manned test dives in the Bahamas, reaching a max depth of 991 m (3,281 feet).

4.22.14. On April 17, 2019, the U.S. flagged research vessel (R/V) ANGARI (Official Number 1116166) towed the LARS with TITAN aboard for Dive 47 to a site approximately 10 miles off Little Harbour, Great Abaco, in the Atlantic Ocean. From this location, Mr. Rush piloted the TITAN with three additional persons aboard to a depth of 3,760 m (12,336 feet). This significant feat marked the first time a non-military submersible carried more than three people to this depth. Passengers included the President of OceanGate Expeditions, the owner of the Roatan Institute of Deepsea Exploration and the submarine IDABEL, and a field technician for 2G Robotics' underwater laser scanner. The dive lasted approximately 8.3 hours, with 27 issues recorded in the TITAN’s maintenance log.

Figure 125: OceanGate's support vessel VITO towing the LARS with the first TITAN hull loaded onboard to conduct buoyancy testing in the Bahamas in 2019. Source: OceanGate Expeditions.

Figure 126: TITAN preparations prior to the R/V ANGARI towing the LARS out for Dive 47. Source: ANGARI Foundation.

Figure 127: LARS descending with TITAN for Dive 47 on April 17, 2019. Source: OceanGate Expeditions.

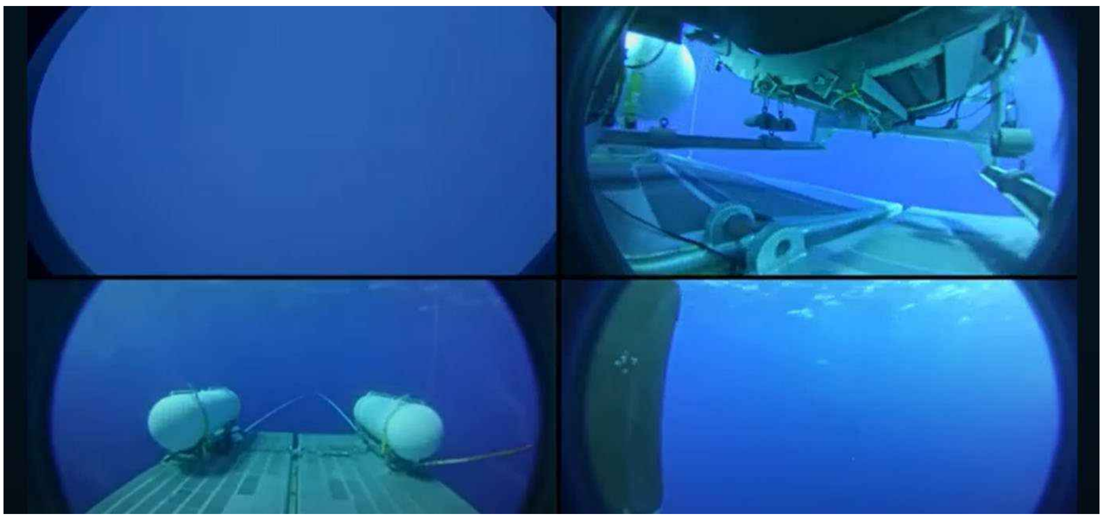


Figure 128: TITAN's cameras capturing departure from LARS on Dive 47. Source: OceanGate Expeditions.

4.22.15. On April 20, 2019, the owner/pilot of the submarine IDABEL sent an email to Mr. Rush stating the following:

> "While I think your concept of RTA (Real-Time Acoustic Monitoring) is sound, I am not sure it applies in this case. The acoustic signatures we observed yesterday do not appear to correspond with typical failure modes such as adhesive bond failure, delamination of air cavities, or random fiber breakage. In my assessment and based on the discussion NAME REDACTED[35] and I had last night, which he concurs with, the sounds we heard seemed indicative of a localized flaw or defect in the hull structure being subjected to significant external pressures, resulting in crushing or damage. The intensity and persistence of the sounds, particularly their continuation at depth, coupled with sounds recorded around 300 feet that suggest a release of

[35] Name redacted by MBI.

stored energy, point to the possibility of a specific area of the hull material experiencing progressive degradation or becoming ‘spongy’.”

4.22.15.1. The owner/pilot of the submarine IDABEL testified to the MBI that the noises heard during his dive on the first TITAN hull had a sharp, percussive quality, resembling the sound of gunshots, and appeared to emanate from a localized region of the submersible’s hull.

4.22.15.2. In a subsequent email to Mr. Rush, the owner of the submarine IDABEL inquired, “So, how many more dives do you intend to conduct in the Bahamas, and what are your go/no-go criteria?” Mr. Rush sent an email response stating, “Yes, we are targeting a few more dives (as many as five) to gather additional acoustic data and gain further operational experience, particularly regarding battery charging at sea and conducting consecutive daily dives.”

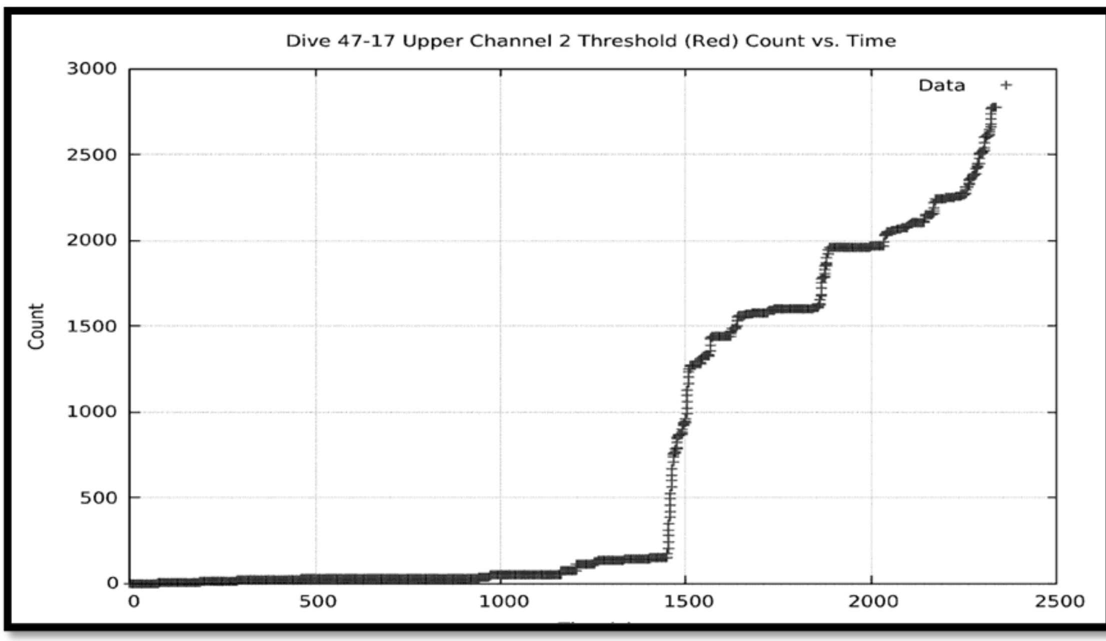


Figure 129: TITAN Dive 47 acoustic event count for channel 2. Source: OceanGate.

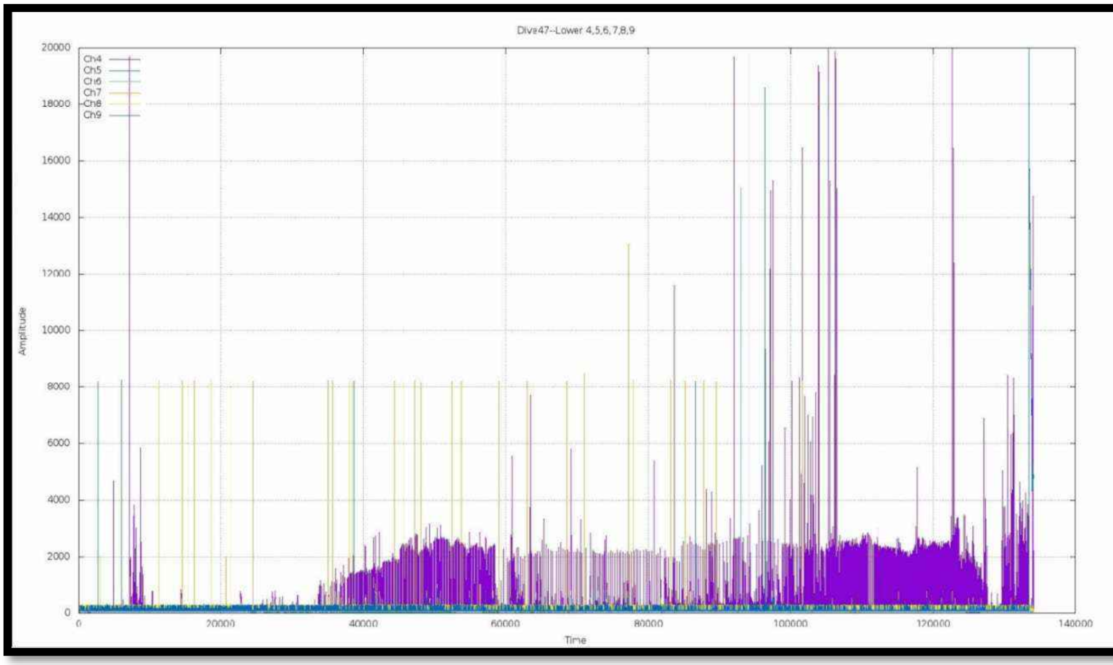


Figure 130: TITAN Dive 47 acoustic event sensor amplitude for lower sensors. Source: OceanGate.

4.22.16. In the spring of 2019, OceanGate's Director of Engineering met with Mr. Rush to discuss the TITAN submersible's planned dives to the TITANIC wreck site. The Director of Engineering testified to the MBI that he expressed serious concerns to Mr. Rush about the submersible's hull, which appeared to be flexing excessively, and noted that alarms were indicating potentially critical structural issues. Despite these warnings, Mr. Rush sought the Director of Engineering's approval to proceed with the TITANIC Expedition. However, the Director of Engineering refused, emphasizing that the first TITAN hull was an untested prototype, with no established safety standards or design benchmarks to operate as a viable manned submersible. The Director of Engineering stated that based on the observed anomalies, proceeding with the TITANIC dive was unacceptable. The Director of Engineering's insistence ultimately compelled Mr. Rush to schedule additional test dives to further assess the TITAN's structural integrity ahead of the planned 2019 TITANIC Expedition.

4.22.17. On May 29, 2019, during a pre-dive inspection in the Bahamas, a TITAN pilot illuminated the forward space between the hull and the insert and identified what appeared to be a crack in the carbon fiber structure. This finding prompted immediate notification to the appropriate OceanGate personnel, and upon further investigation and removal of part of the insert, the crack was confirmed to be in the carbon fiber that comprised the inner layer of the hull. According to a former OceanGate Director of Engineering, the crack extended approximately four feet longitudinally while extending about a third of the way around the hull transversely.

4.22.17.1. The TITAN's carbon fiber outer hull was coated with a polyurethane layer, which concealed the underlying carbon fiber from external view. Internally, an HDPE (high-density polyethylene) insert was positioned approximately three-quarters of an inch away from the hull, creating a small gap between the hull and the internal structure.

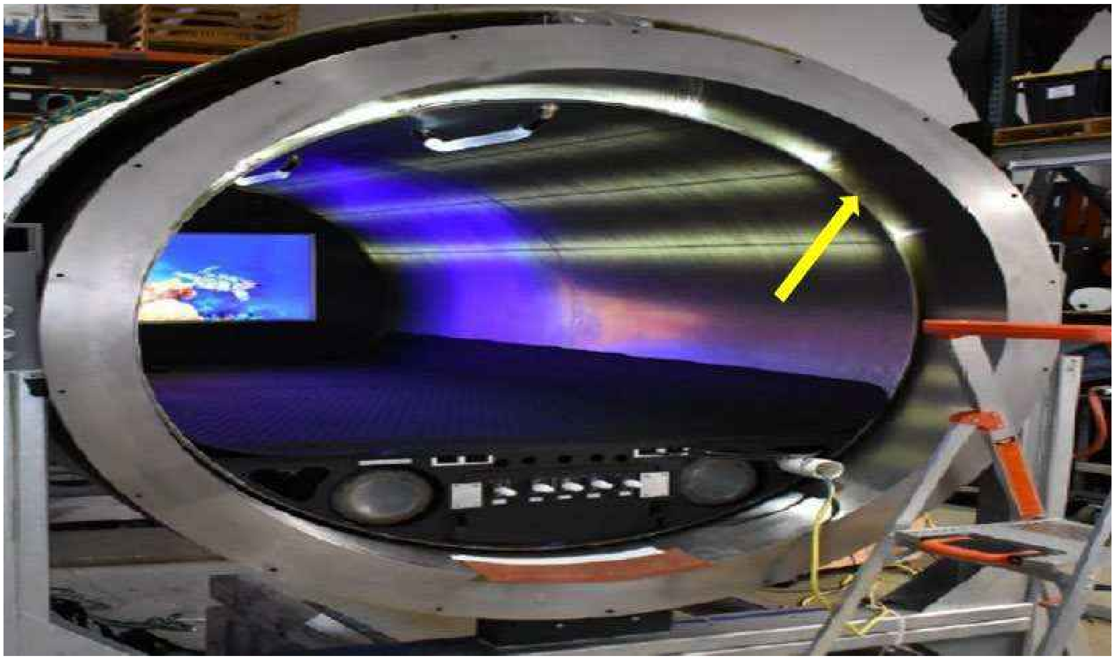


Figure 131: Yellow arrow (added by MBI) pointing to the ¾" gap between the TITAN's carbon fiber hull and its insert. Source: https://ocean-archives.github.io/.

4.22.18. OceanGate's Director of Engineering subsequently emailed a photograph of the crack in the hull, which he immediately identified as a significant structural failure. He informed the COO that the hull was compromised and could not be safely repaired. The Director of Engineering then traveled to the Bahamas to inspect the TITAN, where he confirmed that the crack was both larger and deeper than initially assessed.

4.22.19. On June 5, 2019, OceanGate commenced preparations to transport the first TITAN hull back to their Everett facility in order to conduct a more thorough evaluation of the hull's structural integrity and to assess its suitability for future dives.

4.22.20. On June 13, 2019, GeekWire published an article[36] stating: "Everett, Wash.-based OceanGate has been forced to postpone this summer's deep-sea expeditions to the TITANIC Wreck site due to issues with the intended expedition mothership." According to the article, these complications were related to the Norwegian-flagged HAVILA HARMONY's compliance with Canadian maritime law. OceanGate CEO explained that the vessel's operators at Reach Subsea were concerned that the ship might be impounded if the expedition proceeded as originally planned.

4.22.20.1. After the crack was detected and fully assessed, OceanGate did not make any external notifications (e.g., customers with pending deposits,

[36] OceanGate puts off plans to dive to Titanic shipwreck

government authorities, classification societies) regarding the crack found in the TITAN hull.

4.22.21. During an MBI interview, the former OceanGate Director of Integration and Operations and Director of Engineering provided the following statement regarding the crack found in the first TITAN hull:

> "…there was a crack found in the Bahamas. NAME REDACTED[37] found it during an inspection. He was the one tasked with checking everything, and he found the crack behind the liner where it wasn't visible. Using a flashlight, he spotted it and immediately raised the alarm, which was the right course of action. We brought the sub back, and (Mr. Rush) wanted to disassemble it, locate the crack, and inspect it. He planned to grind it out, repair it, and reassemble the sub in three weeks, then dive it again. I was strongly opposed to diving in a hull with a significant crack, even at the dock. But (Mr. Rush) was insistent—he was focused on making sure the media saw that OceanGate was still in operation, so he could explain the delay in the TITANIC mission. His story was that the (support) ship wasn't available, which was why we couldn't complete the TITANIC dives that year, and he wanted to maintain credibility with the public, despite the critical issues with the sub."

Figure 132: Photo of the first TITAN hull taken by the MBI on August 2, 2023, at OceanGate's Everett, Washington facility. The interior section of the hull where the crack was ground out is visible within the yellow circle added by the MBI. Source: USCG.

4.22.22. On June 24, 2019, OceanGate's COO sent a letter to their prospective mission specialists providing an update on the status of the TITANIC Survey Expedition 2019.

[37] Name redacted by MBI.

In the letter, he stated that the operator of the contracted support ship, HAVILA HARMONY[38], of the TITANIC Survey Expedition 2019 had withdrawn and that their withdrawal caused many challenges for OceanGate as well as a loss of substantial revenue. The COO stated that prior to the cancellation, OceanGate had signed a $1.1 million dollar sponsorship agreement with a major internet brand that had to be cancelled. The COO's letter also contained the following statement:

> "OceanGate Expeditions has been very open about our testing and the unique nature of what we are attempting to accomplish. The vast majority of our Mission Specialists appreciate the complexity of our mission and, while disappointed, are comfortable waiting to 2020 for the mission execution. However, there are those who have "lost confidence" in the project and have requested a refund. Unfortunately, until we have sufficient resources to fulfil our obligations to all our Mission Specialists and expedition partners, we cannot consider refunding Mission Specialist nonrefundable support fees."

4.22.23. The COO's letter also stated that OceanGate's "going forward plans" were to continue testing of their laser and video systems through dives of the first TITAN hull in Seattle, to conduct shark behavior dives in Puget Sound, to conduct wreck dives around Puget Sound and to locate a support ship for the planned 2020 TITANIC Expedition.

4.22.23.1. The letter, nor any other separate correspondence, disclosed that there was a crack found in the carbon fiber hull of the first TITAN, which rendered it incapable of reaching the depths of the TITANIC.

4.22.24. OceanGate's former Director of Engineering stated that Mr. Rush faced significant challenges in meeting his commitments for a TITANIC expedition after the large crack was discovered. There had already been multiple delays over the years and Mr. Rush struggled to provide customers with satisfactory explanations for the cancelled expeditions, at one point claiming that a lightning strike to the first TITAN hull was the reason for a previous failure. As the situation worsened, Mr. Rush's concern shifted to avoiding legal issues or negative publicity for the company, as the damaged first TITAN hull was clearly not ready for the TITANIC mission. However, Mr. Rush publicly sought to deflect blame by claiming the 2019 delay was related to the support ship's withdrawal from the project.

4.22.24.1. On July 16, 2019, Mr. Rush provided a letter to his Director of Engineering which stated, "Due to unforeseen circumstances leading to the cancellation of the TITANIC Survey Expedition 2019, OceanGate Inc. must make difficult decisions regarding the structural changes within the organization." On July 26, 2019, OceanGate fired the Director of Engineering. After the failed hull and cancellation of the 2019 expedition, the Director of Engineering stated, "(Mr. Rush) invited me to lunch and told me—allegedly—

[38] HAVILA HARMONY is a Norwegian flagged OSV (IMO# 9343596).

that (name of an OceanGate Board member) and another Board member said I should have known the hull was compromised and wouldn't work. According to him, the message was clear: either he or I had to go. Then he looked at me and said, 'It's not going to be me'."

4.22.25. According to a former intern and submersible pilot in training, in the summer of 2019, after a crack was discovered in the first TITAN hull, Mr. Rush directed engineers to grind down the inside of the hull to assess the crack's extent, removing the interior fiberglass insert in the process. Despite the compromised hull, Mr. Rush deemed it "operational" with a de-rated depth. She stated that this decision caused significant internal tension, and employees were instructed to keep the crack a secret. Mr. Rush then planned a night dive of TITAN on the tugboat OMAR wreck site in Puget Sound, allegedly to test 3D scanning equipment and falsely portray deep dives to the public. Although the dive was ultimately scrapped, a subsequent incident on August 7th, 2019, during a systems test in the Everett Marina, nearly resulted in disaster.

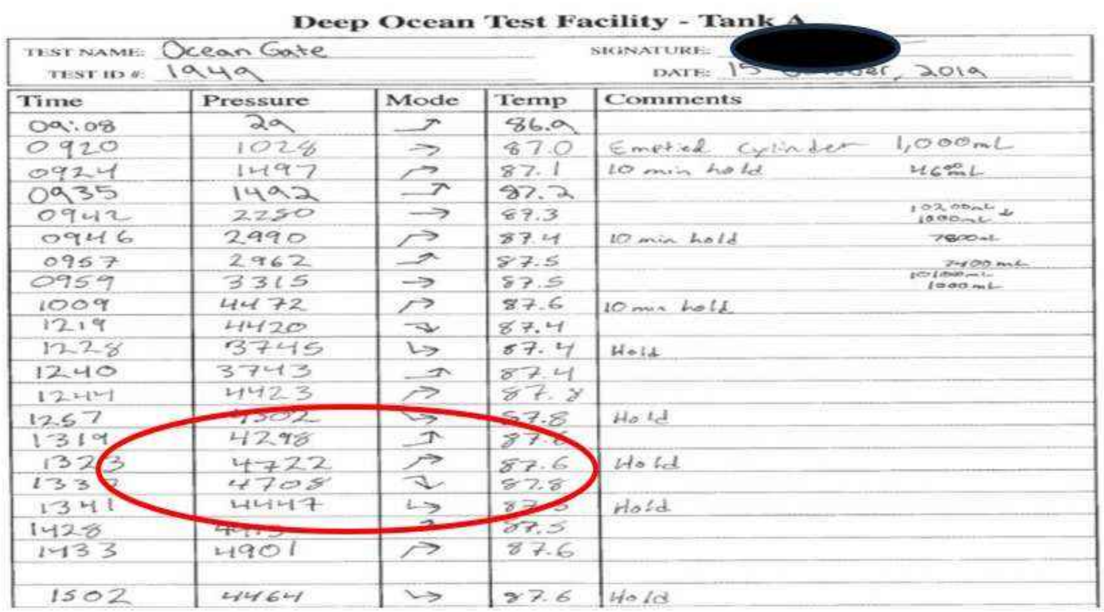
4.22.25.1. During this incident, the improperly secured insert shifted forward (due to the ground down interior of the hull) during a steep descent, stretching the High-Pressure Air (HPA) lines and potentially causing an explosion inside the sub. The batteries also shifted, potentially causing further damage. Following the incident, a heated argument ensued between the former pilot and Mr. Rush.

4.23. Deep Ocean Test Facility Testing of Damaged First TITAN Hull

Figure 133: First TITAN hull's arrival at Deep Ocean Test Facility in Bethesda, Maryland. Source: OceanGate.

Figure 134: First TITAN hull inside Deep Ocean Test Facility chamber on October 14, 2019. Source: OceanGate.

4.23.1. In October of 2019 the first TITAN hull was shipped to the Deep Ocean Testing Facility (DOTF) in Bethesda, Maryland to conduct a pressure test to rate the hull with the crack in the carbon fiber. The cost of the testing was $60,200 for five days. The testing began at 9:08 a.m. on October 15, 2019, and was completed at 4:49 p.m. the same day. The highest psi achieved was 4,722 psi which is equivalent to an ocean depth of 3,743 m (12,280 feet).



Deep Ocean Test Facility - Tank A

TEST NAME: Ocean Gate SIGNATURE: [redacted]
TEST ID #: 1949 DATE: 15 [redacted]er, 2019

Time	Pressure	Mode	Temp	Comments
09:08	29	↗	86.9	
0920	1028	→	87.0	Emptied Cylinder 1,000mL
0924	1497	↗	87.1	10 min hold 460mL
0935	1492	↗	87.2	
0942	2250	→	87.3	102,00mL 1000mL
0946	2990	↗	87.4	10 min hold 7800mL
0957	2962	↗	87.5	7400mL
0959	3315	→	87.5	10100mL 1000mL
1009	4472	↗	87.6	10 min hold
1219	4420	↘	87.4	
1228	3745	↘	87.4	Hold
1240	3743	↗	87.4	
1244	4423	↗	87.8	
1257	4302	↘	87.8	Hold
1319	4298	↗	87.[illegible]	
1323	4722	↗	87.6	Hold
1337	4708	↘	87.8	
1341	4447	↘	87.[illegible]	Hold
1428	[illegible]	↗	87.5	
1433	4901	↗	87.6	
1502	4464	↘	87.6	Hold

Figure 135: DOTF record for testing of the damaged first TITAN hull on October 15, 2019. The red circle (added by MBI) encircles the highest PSI achieved (4,722 psi) for the day. Source: DOTF

4.23.2. On October 16, 2019, testing commenced at 9:13 a.m. and continued until 5:45 p.m., during which the maximum pressure achieved was 2,988 psi at a simulated ocean depth of 2,052 m (6,732 feet). Based on data collected from the RTM System, including acoustic emissions and strain gauge readings, the structural integrity of the hull was assessed, leading to a de-rating of the first TITAN hull to a maximum operational depth of 3,000 m (9,843 feet).

4.23.3. Just one week after the pressure hull for the original TITAN was derated, OceanGate issued a press release announcing plans to construct two additional submersibles, CYCLOPS 3 and CYCLOPS 4, designed to operate at depths of up to 6,000 m (19,685 feet). The press release confirmed that, despite these new submersibles being under construction, OceanGate's dive operations would continue throughout 2020 using OceanGate's existing fleet of submersibles, including the first TITAN hull (now derated), CYCLOPS I, and the ANTIPODES. Additionally, the company indicated that applications were being accepted for mission specialists to join upcoming expeditions, including missions to the Bahamas and the Hudson Canyon off New York.

4.23.3.1. On September 11, 2020, the U.S. flagged OSV RANA MILLER (O.N. 1052663) departed the Hudson River, New York with three "mission specialists" aboard and with the CYCLOPS I in stern tow headed for the Hudson Canyon, off of New York. An OceanGate brochure that was prepared for a Hudson Canyon expedition scheduled for the fall of 2021 provided the following background on their Hudson Canyon operations:

> "The individual mission support fee of $45,000 allows us to dive on sites of scientific importance and include a subject matter expert on every dive. Limited space is available for explorers and adventurers to join the crew of the Hudson Canyon Deep-Sea Discovery Expedition in fall of 2021. OceanGate Expeditions will conduct one week of dives to explore this underwater national treasure, and we hope you will join us."

Figure 136: Image from inside the CYCLOPS I being towed by the OSV RANA MILLER on the Hudson Canyon mission. Source: Former OceanGate Director of Operations.

4.23.4. In a January 9, 2020, article published by GeekWire.com[39], Mr. Rush stated that testing at the DOTF had revealed signs of cyclic fatigue in the first TITAN hull. As a result, the hull's rated depth was reduced to 3,000 m, rendering it insufficient for reaching the TITANIC wreck site. The article also noted that OceanGate had successfully secured $18.1 million in new funding, entirely sourced from inside investors which was “laying the financial groundwork for an expansion of its fleet of deep-sea submersibles and setting the stage for dives to the 108-year-old Titanic shipwreck in 2021.”

4.24. Final TITAN Hull / National Aeronautics and Space Administration (NASA)

4.24.1. According to the Director of Engineering, after the first carbon fiber hull of the TITAN failed, Mr. Rush instructed his engineering team to move forward with building a new submersible. Mr. Rush proposed constructing two new deep-sea submersibles, which seemed unrealistic to the Director of Engineering given the challenges OceanGate had faced with the original design. The Director of Engineering raised concerns with his supervisor, OceanGate’s COO, suggesting that one of the new submersible hulls should be constructed entirely with titanium, as a more reliable alternative to carbon fiber, given the failure of the first hull. The Director of Engineering argued that the industry standard was to build using materials that were known to be safe and viable for deep-sea exploration. However, the COO rejected the suggestion, stating that Mr. Rush had a firm commitment to carbon fiber as the only material he would consider for future submersibles. According to the COO, Mr. Rush had no interest in using anything other than carbon fiber for the cylindrical portion of the hull, regardless of the structural failure that degraded the first TITAN hull.

4.24.2. After the decision was made to build a second submersible, OceanGate decided to reuse the titanium fabrication (TIFAB) end caps, and segments from the first TITAN, as these components were already available and too expensive to fabricate. The new second and final TITAN's carbon fiber hull was to be wound using an Automated Fiber Placement (AFP) system. Initially, OceanGate had partnered with the National Aeronautics and Space Administration (NASA) to build a third-scale model of the hull as part of a project under a NASA Space Act agreement. The Space Act agreements enable NASA to enter into mutually beneficial projects that bolster innovation by assisting with private sector initiatives. NASA’s interest in the TITAN project stemmed from the innovative nature of the design for high pressure operations, specifically the thick laminate being used for the carbon fiber hull.

4.24.3. OceanGate approached NASA for technical assistance in manufacturing a composite cylinder, specifically a thick-walled carbon fiber vessel, which was central to their plans for building a deep-sea submersible. NASA’s role was primarily advisory,

[39] https://www.geekwire.com/2020/oceangate-raises-18m-build-bigger-submersible-fleet-get-set-titanic-trips/

focusing on providing expertise in advanced composite fabrication techniques. NASA's primary interactions with OceanGate involved guidance on how to manufacture the composite cylinder for OceanGate's submersible, although NASA did not perform any actual fabrication or testing.

4.24.4. During MBI testimony, a NASA engineer from the Materials and Process Laboratory at Marshall Space Center in Huntsville, Alabama, testified that OceanGate contacted NASA for assistance in manufacturing a one-third scale model for the new TITAN submersible. In December of 2019, OceanGate's Director of Engineering contacted NASA to discuss the mandrel[40] specifications for the one-third scale model build.

4.24.5. On January 3, 2020, OceanGate issued a purchase order to NASA for the purpose of collaborating in the development, manufacturing, and testing of a carbon fiber vessel. It was specifically focused on construction of a scale model carbon fiber vessel for testing.

4.24.6. On January 29, 2020, OceanGate placed a second purchase order with NASA to support the development of the carbon fiber vessel. The order was specifically for assistance in building and testing a scale model of the carbon fiber hull. To facilitate this, OceanGate purchased 300 lbs of P2362W-19L-013 slit tape from Toray Composites, which was shipped to NASA for use in the construction of the one-third scale model.

4.24.6.1. However, due to the COVID-19 pandemic related suspension of operations at NASA's Marshall Space Flight Center, the carbon fiber tape was never used by NASA, and they ultimately returned it to OceanGate.

4.24.7. On April 26, 2020, OceanGate released a press release stating that they had been granted a Space Act Agreement with NASA. The press release described that a Space Act Agreement is an agreement between NASA and a research sponsor, which allows the sponsor to make use of NASA scientists and facilities for the benefit of the sponsor and NASA. Under the Jet Propulsion Laboratory (JPL) Space Act Agreement, the sponsor (NASA) is granted rights to use the technology developed under the Space Act Agreement only for noncommercial internal use purposes.

4.24.8. OceanGate and NASA formalized their collaboration in early 2020 through a "Reimbursable Space Act Agreement," which was signed on January 30th by OceanGate and on February 4th by NASA. This agreement facilitated the use of NASA's facilities and expertise for the development of a composite cylinder but did not extend to actual manufacturing or testing due to COVID-19 related delays. The agreement allowed

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[40] A mandrel, in the context of creating a cylinder, is a rigid, often cylindrical, core or shaft around which material is formed or shaped. It serves as a form or support during the manufacturing process.

NASA to provide consulting and recommendations on composite fabrication processes, including materials selection and manufacturing techniques.

4.24.9. Despite the disruption caused by the ongoing pandemic, NASA provided remote consultation during the fabrication of OceanGate's one-third scale model. NASA's guidance focused on composite lay-up processes, curing methods, and quality assurance measures for creating a thick-walled composite material suitable for deep-sea submersible operations. However, NASA was not involved in the direct manufacturing or testing of the one-third scale model or the final TITAN hull.

4.24.10. The advice NASA provided to OceanGate primarily involved recommending fabrication processes for the composite material, such as laying down material layers and applying intermittent heated debulks under pressure to achieve the required thickness. NASA also advised on testing methods to assess the properties of the material, specifically recommending coupon-level testing, where small samples of the composite could be tested for structural integrity before the full-scale construction of the submersible.

4.24.11. NASA also briefly discussed the use of multi-curing techniques to reduce defects such as wrinkles in the thick composite laminate. Multi-curing involves building up sections of the composite, curing them, and then bonding additional layers in subsequent stages to reduce imperfections.

4.24.12. Throughout the collaboration, NASA's role was solely advisory, and their work was restricted to providing guidance on the composite fabrication processes, material selection, and potential testing methods. OceanGate was responsible for the hands-on manufacturing of the one-third scale model, including material procurement from suppliers like Toray Composites. Financially, NASA was compensated for its efforts, receiving approximately $40,000 for remote consulting services. However, out of the total estimated cost of $148,874 for the project, NASA ultimately returned roughly $124,000 to OceanGate due to the lack of any physical work performed and the disruption caused by the pandemic.

4.25. Collier Aerospace (HyperSizer) Finite Element Analysis (FEA)

4.25.1. On December 20, 2019, Collier provided a request for proposal (RFP) for engineering services to be performed for OceanGate: FEA Analysis of CYCLOPS 3 Hull. The cost associated with their services was quoted at $33,300. On December 31, 2019, OceanGate issued a purchase order for $33,300 to Collier Aerospace.

4.25.2. On May 21, 2020, another RFP from Colliers was completed for the CYCLOPS 3's Ellipsoid Hull Analysis. The cost associated with the services was $37, 500. On May 29, 2020, OceanGate issued a purchase order to Collier Aerospace for $37,500.

4.25.3. Collier was contracted by OceanGate to conduct static stress analysis on the TITAN vehicle's pressure hull, which included its carbon fiber cylinder, titanium domes, and acrylic viewport, as well as for future vehicle concepts. The scope of their work was limited to static stress analysis and did not extend to fatigue, damage propagation, crack growth, or dynamic loading, which were outside the services Collier provided. Additionally, Collier had no design authority over the TITAN vehicle or its components. According to Collier, the CAD model used for the analysis was created prior to the contract and provided by OceanGate, based on previous work completed by Boeing.

4.25.4. The work was divided into two contracts: one focused on the TITAN vehicle, and the other on designs for a future vehicle that, to Collier's knowledge, was never built. The analysis under the first contract included an FEA with both 2D and 3D models to assess various structural aspects of the TITAN vehicle. This included evaluating the deformation of the vehicle under static loads, analyzing the interfaces between carbon fiber and titanium, and determining the theoretical performance envelope of the pressure hull.

4.25.5. Further tasks involved comparing one-third scale models with full-scale geometry to assess the relevance of scale testing, as well as comparing OceanGate's test results with Collier's FEA predictions. These analyses were conducted to support the design and performance evaluation of the TITAN vehicle and its components. The results of these analyses were presented to OceanGate on a weekly basis via PowerPoint presentations, with regular feedback sessions to guide the direction of future work.

4.25.5.1. Collier's involvement in the one-third scale and full-scale testing accounted for approximately 10-15% of their work, though they were not present during the pressure testing of one-third scale models.

4.25.5.2. For the one-third scale tests, Collier designed a steel ring test fixture to mimic the deformation profile of a titanium end dome, provided input on the stacking sequence for the hulls, and conducted a pre-test assessment of strength and buckling. After the first one-third scale model test, Collier analyzed the failure load and measured wrinkles, attempting to adjust the finite element model (FEM) stiffness to match the observed failure load. However, even after adjustments, the FEM was unable to predict the failure load in the second test due to the magnitude of wrinkles in the carbon fiber layers. Collier recommended that a high-fidelity damage progression model would be needed, a service their company did not offer in their portfolio of available services.

4.25.5.3. For the full-scale tests, Collier contributed by advising on strain gauge placement based on peak strains from the FEA results and providing a spreadsheet to calculate Von Mises stress[41] in the dome. Collier subsequently reviewed strain gauge data collected during the test, observing good correlation in trends with the analysis model. However, they could not compare absolute strain values because OceanGate did not provide the necessary gauge factor for

[41] Von Mises stress is the measured stress applied to a ductile material that is being subjected to a complex load.

the strain gauges. However, Collier was able to inform OceanGate that the relative magnitude between gauges was comparable to the model. Additionally, while Collier was shown the results from the acoustic sensors, they informed OceanGate that they were unable to analyze this data, as it was outside their area of expertise.

4.25.6. Collier's work followed the tasks outlined in the original proposal and was conducted in accordance with OceanGate's specific requests. Since the contract was hourly-based, Collier only performed tasks that were explicitly requested by OceanGate. This ensured that the scope of work remained focused and aligned with the client's needs and objectives throughout the duration of the project.

4.25.7. In response to a question asking Collier if they had modeled fatigue for the new TITAN hull in order to determine how many deep-sea dives would be possible before failure, Collier provided the following written response:

> "Not by Collier. Our company does not have expertise in this area (modeling of crack propagation/fatigue in composites) and therefore we do not offer this service to customers. When we asked OceanGate about this topic, we were told that their acoustic monitoring system would be used to detect damage growth in real time and that this capability had been demonstrated on the previous iteration of the carbon fiber hull."

4.25.8. Collier was unable to model manufacturing process defects or knock-down factors for the full-scale TITAN due to a lack of essential data from OceanGate. Early in the project, Collier recommended testing with thick coupons (1-1.5 inches) to derive accurate material strength allowables, but OceanGate later stated that such testing was not feasible due to the high cost of the required test facilities. Since manufacturing defects are typically accounted for by modifying material strength, and Collier was not contracted to derive material properties for the final TITAN hull, the company did not offer this service. OceanGate did not provide the necessary material strength data, nor was relevant publicly available data accessible for five-inch-thick laminate structures.

4.25.9. When the issue of manufacturing defects was raised, OceanGate indicated that it would be addressed during full-scale testing of the hull. During one-third scale testing, Collier was asked to account for wrinkles by modifying the hull's structural stiffness in those areas. However, this approach was found to be unviable during further testing and was not applied to the full-scale TITAN. The one-third scale tests also did not provide sufficient data to estimate manufacturing process knock-down factors for the full-scale hull.

4.25.10. Collier needed two critical pieces of information to estimate manufacturing knock-down factors for the TITAN: the strength reduction as a function of defect magnitude and the actual magnitude of defects on the full-scale hull. The one-third scale hulls, which had large defects such as wrinkles, were unrepresentative of the full-scale design due to the differences in size and manufacturing processes and therefore could not provide useful conclusions about how defects would affect the full-scale hull. Additionally, OceanGate did not provide data on the magnitude of defects for the full-scale hull, and measurements would have required Non-Destructive Inspection (NDI) or dissecting the hull, both of which were deemed unfeasible by OceanGate.

4.25.11. Due to the substantial safety margin in the material properties provided by OceanGate, OceanGate decided that the strength of the hull would be sufficiently validated through testing and real-time monitoring with acoustic sensors. Although Collier had no prior experience with acoustic sensors, OceanGate assured them that the sensors had been successfully demonstrated on a previous iteration on the first TITAN hull, and OceanGate was confident that the RTM approach would be viable for assessing structural health on the final TITAN hull well ahead of a catastrophic failure.

4.25.12. The safety factor, as was determined by Collier, of the TITAN design was reported to OceanGate in terms of Margin of Safety (MS), with the relationship between MS and Factor of Safety (FS) being MS = FS - 1. A positive MS (FS > 1) indicates that the structure is not expected to fail under the applied load. The analysis used composite material properties specified by OceanGate for the T800/3900 system, with classical aerospace methods employed to check stress and strain in the laminate.

4.25.13. For the carbon hull's material strength, the FS at 4,500 m of seawater (msw) was reported with an additional 1.25 factor applied. In the axial direction, the FS was 8.2 (MS = 7.2) in the general area and 4.6 (MS = 3.6) near a stress concentration at the titanium fitting. In the hoop direction, the FS was 6.6 (MS = 5.6) in the acreage and 6.0 (MS = 5.0) near the titanium fitting. These values far exceed the typical FS requirements for commercial aviation (FS > 1.5) and space launch (FS > 1.4).

4.25.14. For buckling of the carbon hull, the FS was 5.6 (MS = 4.6), which is the ratio of the predicted buckling load to the applied load at 3,800 msw, using a 3D FEM. To put this in context, space launch customers such as NASA typically require an FS of at least 2.15 for buckling in cylindrical structures.

4.25.15. In summary, the safety factors reported for the final TITAN hull design were well above the required thresholds for aerospace applications, ensuring a high margin of safety under the anticipated operating conditions.

4.25.16. OceanGate provided Collier with test results from both the one-third scale and full-scale tests, but OceanGate did not request a reassessment or validation of the analysis model. For the one-third scale tests, Collier reviewed the results and adjusted the analysis model to match the failure load. In the case of the full-scale tests, Collier compared the test results to the analysis model, but OceanGate did not request a reassessment of the model. As was typical for Collier projects, Collier offered to conduct a deeper investigation and comparison between the test results and the analysis to help pinpoint all possible differences. However, OceanGate turned down Collier's offer and informed Collier that they were going to proceed with construction of the remainder of the final Titan hull. As a result, Collier was not asked to perform any additional work on the TITAN and did not have design authority over any aspect of the final version or its components following their initial analysis.

4.26. Toray Composites / Carbon Fiber

4.26.1. The hull of OceanGate's final TITAN hull was made using unidirectional carbon fiber tape pre-impregnated (pre-preg) with epoxy resin. The specific pre-preg system used was Toray Composite Materials America's P2362W-19L, which consisted of T800S-series intermediate modulus carbon fiber and 3900-series epoxy resin, with a cured ply thickness of 0.0075 inches. The rolls were slit into 0.5-inch-wide reels (tows) for use in the manufacturing process.

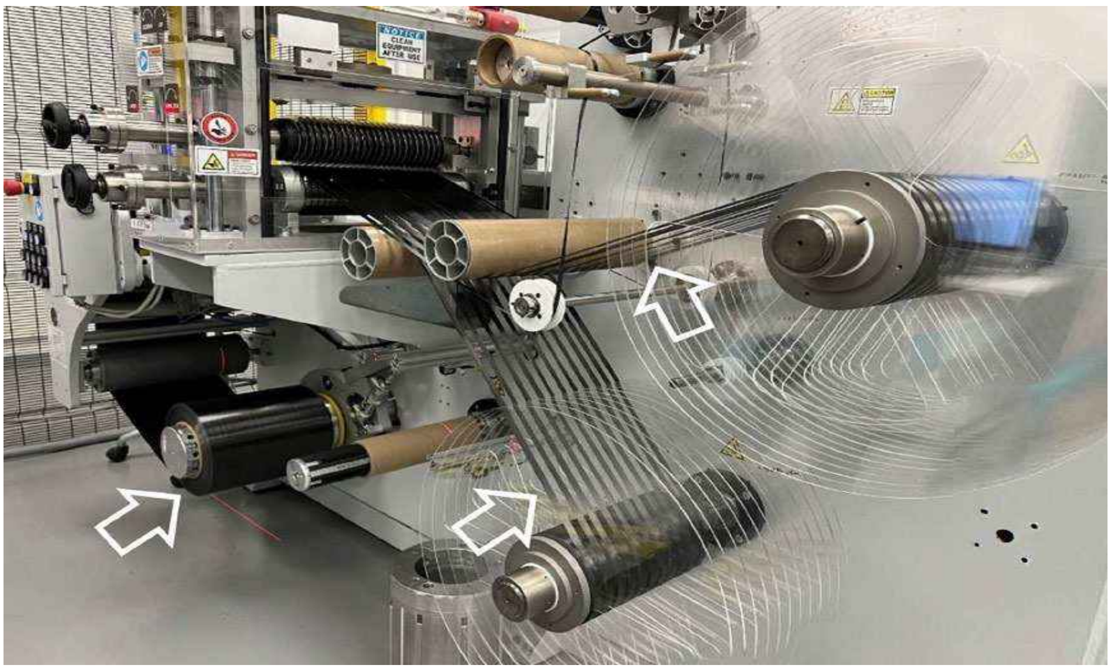


Figure 137: Example of splitting pre-preg rolls into tape. Source: NTSB Materials Laboratory Factual Report.

4.26.1.1. On January 29, 2020, OceanGate purchased 300 lbs of P2362W-19L-013 slit tape from Toray Composites, which were shipped to NASA for the creation of a one-third scale TITAN model. Due to the disruption caused by the COVID-19 pandemic, NASA did not use the material, and OceanGate later retrieved it and transported it back to their facility in Everett, Washington.

4.26.1.2. On February 21, 2020, OceanGate issued a purchase order for 7,700 lbs of P2362W-190U-013 composite material from Toray Composites, valued at $332,101. This material was scheduled to be shipped to Electroimpact, Inc. on May 11, 2020, for use in the final TITAN's construction.

4.26.1.3. Towards the end of March 2020, OceanGate announced that Toray Composite Materials America, Inc. would be their supplier of aerospace-grade pre-preg carbon fiber for the final TITAN hull, advertising the company's commitment to using high-performance materials for the submersible industry.

4.26.1.4. On November 6, 2020, OceanGate purchased an additional 800 lbs of P2362W-19OU-013 composite material from Toray Composites, which was scheduled to be shipped to Electroimpact, Inc. for continued use in the construction of the final TITAN hull.

4.27. Electroimpact, Inc. / Manufacturing of One-Third Scale Model and Final Hull

4.27.1. The COVID-19 pandemic and its impact on NASA's ability to support OceanGate led the company to engage Electroimpact, Inc., a local company, for the layup of the TITAN hull. On April 13, 2020, OceanGate issued a purchase order to Electroimpact, Inc. which included the following services: machine usage and staffing for three weeks, rotator design-engineering efforts to adapt existing design to meet OceanGate needs, rotator-hardware, rotator assembly, installment and alignment, and one-third scale part built (included). The total purchase order for the lay-up totaled $141,300.

4.27.1.1. Electroimpact, Inc. is an aerospace engineering and manufacturing company headquartered in Mukilteo, Washington, just north of Seattle. They specialize in the design, development, and manufacturing of large-scale automated assembly equipment, primarily for the aerospace industry.

Figure 138: Electroimpact, Inc. Automatic Fiber Placement. Source: Electroimpact, Inc.

4.27.2. In May of 2020, Electroimpact, Inc. began the layup for the one-third scale model. The model was laid up using an AFP machine programmed to the specifications provided by OceanGate. The dimensions of the one-third scale model were: 30.3 inches in length, with an inside diameter of 16.97 inches and a wall thickness of 1.5 inches.

4.27.2.1. On May 19, 2020, a wrinkle was identified at ply 40 in the one-third scale model that was perfectly axial from top to bottom. As a result, a decision was made to restart the manufacturing of the one-third scale model.

Figure 139: Wrinkle in the one-third scale hull model for Final TITAN hull (yellow circle added by MBI). Source: OceanGate Expeditions.

4.27.2.2. On May 27, 2020, all 202 plies of the one-third scale model were complete, and the model hull was sent off to Composite Solutions Corporation to be bagged in a laminate cure. It was then sent to Janicki Industries to be heated and cured in their autoclave. The one-third scale models were only cured once during the fabrication process.

4.27.2.3. After the cure, large wrinkles were identified in the one-third scale model.

Figure 140: Wrinkles on the surface and cross section cut of one-third scale model for the final TITAN hull post autoclave cure (yellow circle added by MBI). Source: OceanGate.

4.27.2.4. On June 1, 2020, OceanGate contacted UW-APL to schedule a pressure test in their chamber. UW-APL stated that due to the COVID-19 pandemic, they were only at 10% capacity and had to adhere to strict COVID guidelines. Consequently, UW-APL did not have an opening until the end of July or early

August 2020 to be able to conduct OceanGate's requested pressure test of the one-third scale model.

4.27.2.5. In June of 2020, based on evidence received by the MBI, a second one-third scale hull model was fabricated by an unknown entity. Electroimpact, Inc. stated that they only fabricated one model for OceanGate. The second one-third scale model also had wrinkles in the layup, but according to Collier's analysis, the build quality was better than the first model due to it having fewer delaminations.

4.27.2.6. On July 27, 2020, OceanGate conducted pressure testing on a one-third scale model of their hull. UW-APL, which conducted the testing, invoiced OceanGate for 7.25 hours of work. However, a UW-APL representative indicated in an email to a colleague that the test resulted in a catastrophic failure. A subsequent analysis by Collier determined the hull failed at approximately 3,000 meters (9,843 feet). Collier further clarified that the wrinkles observed in the hull (as depicted in Figure 140) would have been particularly vulnerable due to a combination of factors: misaligned hoop fibers not properly aligned with the load-bearing direction, a resin-rich composition within the wrinkle compared to the surrounding laminate, the relative softness of the resin compared to the fibers, and significant delamination within the wrinkle causing voids that were more susceptible to compression than either the fibers or the resin

4.27.3. According to OceanGate's Director of Engineering, the team was trying to identify a way to produce the hull without any wrinkles, because they knew if they had a wrinkle, it would not pass at the DOTF. The Director of Engineering stated that multicuring was discussed and Mr. Rush did not want to follow that process because it came with great cost. Multicuring means that after a certain number of carbon fiber layers (approximately every 1 inch), the hull would be removed from the mandrel, bagged, and driven to Janicki Industries in Hamilton, Washington for a curing (baking) process, which required additional time and funds. Electroimpact, Inc. remained insistent that the multicure was an essential process to minimize wrinkle deformities in the hull and that they offered to build a five-inch test "slice" with a multicure at no charge to OceanGate to prove that this was the proper procedure.

4.27.3.1. On October 23, 2020, OceanGate's Director of Operations sent Collier Engineering pictures of the five-inch ring cross sections for them to measure the magnitude of wrinkles as part of predicting the wrinkle free cure thickness.

4.27.3.2. None of the one-third scale models were multicured.

4.27.4. During the winter of 2020, Electroimpact, Inc. began the layup of the full-size final TITAN hull. The construction of the final TITAN hull involved a precise ply winding sequence. The fabrication started with two cylindrical plies laid under tension, followed by a longitudinal ply laid without tension. This sequence was repeated until the target number of plies was reached. The cylindrical plies were wound continuously from end-to-end, creating a helical pattern with a slight bias. The direction of this bias was reversed for each subsequent cylindrical ply. There were no 45° torsion plies included, and intermediate debulking steps were incorporated during the fabrication process. A total of 133 layers of pre-preg material were applied, with each layer having a nominal thickness of 0.9975 inches.

Figure 141: Electroimpact, Inc. AFP machine laying up TITAN sequence. Yello areas indicate direction of movement. Source: NTSB Materials Laboratory Factual Report.

4.27.5. The final TITAN hull was constructed in five co-bonded 1-inch carbon fiber layers, a method chosen based on OceanGate's previous experience with test articles and its manufacturing partners. The decision to use the co-bonding process aimed to avoid issues that occurred during the construction of two one-third-scale test articles, which developed wrinkles that contributed to premature implosion. To prevent wrinkle formation, OceanGate limited the layer thickness to one inch before autoclave curing. Each layer was co-bonded to the layer beneath it, with the process of winding, curing, and surface preparation repeated until the desired hull thickness was achieved.

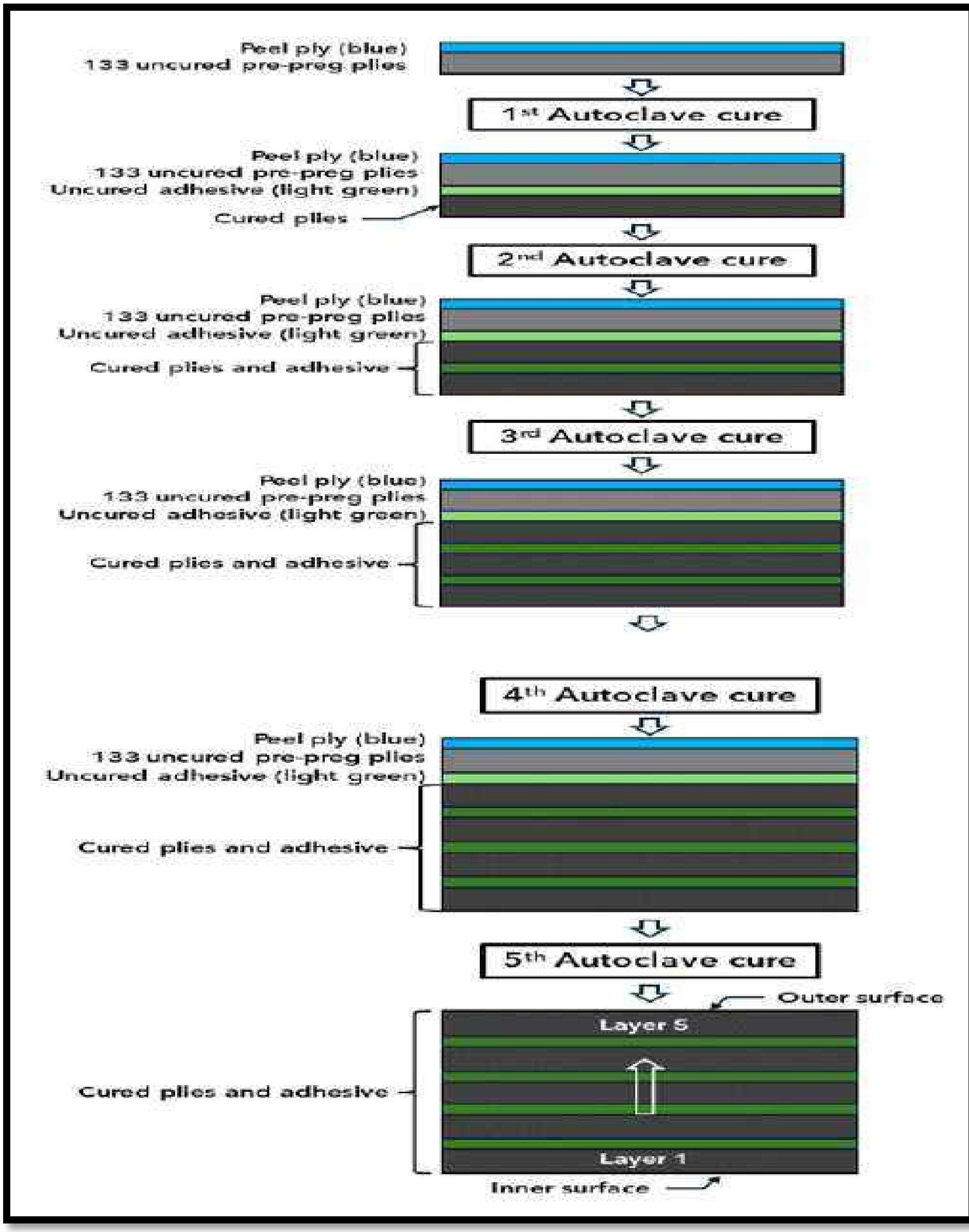


Figure 142: Illustration showing the co bonding process in a cross section of the final TITAN hull construction. Source: NTSB Materials Laboratory Factual Report.

4.27.6. The construction process for the final TITAN hull involved winding the pre-preg material onto a mandrel, curing each layer in an autoclave, removing the peel ply, and applying film adhesive to the freshly cured surface. According to Electroimpact, Inc., the hull arrived back at Electroimpact, Inc. post-autoclave with a peel-ply outer layer in place. This was removed by OceanGate personnel and OceanGate personnel then proceeded to grind out carbon fiber wrinkles on the outer surface to achieve a more uniform cylindrical shape (see Figure 143). A film adhesive, sourced and supplied by

OceanGate, was then applied to the outer surface prior to beginning the next one-inch layer of carbon fiber.

Layer	Fiber bridges (with one or more voids)	Ground wrinkles
1	0	1
2	4	8
3	9	14
4	5	24
5	N/A	N/A

Figure 143: Examination of the cut off ends identified the number of wrinkles per layer that were required to be ground down. Source: NTSB Materials Laboratory Factual Report.

4.27.7. This procedure was repeated for each one-inch layer, with the hull reaching a nominal thickness of approximately five inches once complete. The final TITAN hull's fabrication took place between November 2020 and January 2021.

4.27.8. The hull was constructed with excess material at both ends, which was trimmed off after curing. These excess trim pieces were later examined by the MBI and the NTSB at a USCG facility in Seattle, Washington.

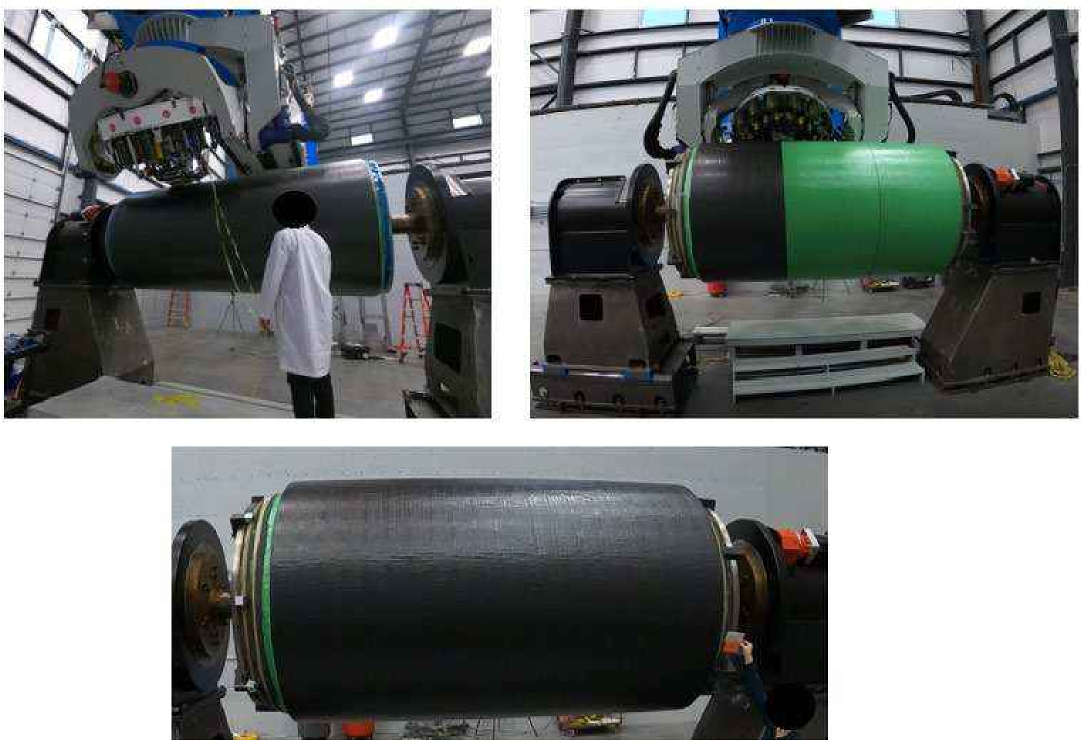


Figure 144: Final TITAN hull under construction at Electroimpact, Inc. Source: OceanGate Expeditions.

Figure 145: Electroimpact, Inc. AFP machine laying up the final TITAN hull. Source: OceanGate Expeditions.

Figure 146: Final TITAN hull and the mandrel. Source: OceanGate.

4.27.9. Upon retirement of the first TITAN hull, its segments were removed, and any carbon fiber hull remnants were removed from the segments through machining. The titanium segments that were being reused from the first TITAN needed to be glued onto the final TITAN hull. According to the OceanGate Titanium End Gluing Procedures, the segments and end segments were scheduled for delivery to Electroimpact, Inc. prior to the arrival of the final TITAN hull on January 28, 2021, from its final cure at Janicki.

4.27.10. The construction process involved bonding the trimmed carbon fiber hull to the forward and aft segments, which were forged and machined from commercially pure Grade 3 titanium (UNS R50550). The segments featured an annular C-shaped channel on their hull-facing sides, into which the hull was inserted and bonded using an epoxy paste adhesive (Loctite EA 9394 AERO). This bonding procedure was part of the assembly for the first Titan hull.

4.27.10.1. The adhesive used to bond the segments to the hull was Hysol EA 9394. According to the Material Specification Sheet, "Hysol EA 9394 is a two-part structural paste adhesive, which cures at room temperature and possesses excellent strength to 350°F/177°C and higher. Its thixotropic nature and excellent high temperature compressive strength also make it ideal for potting, filling and liquid shim applications. Hysol EA 9394 is qualified to MMM-A-132 Rev A, Type I, Class 3."

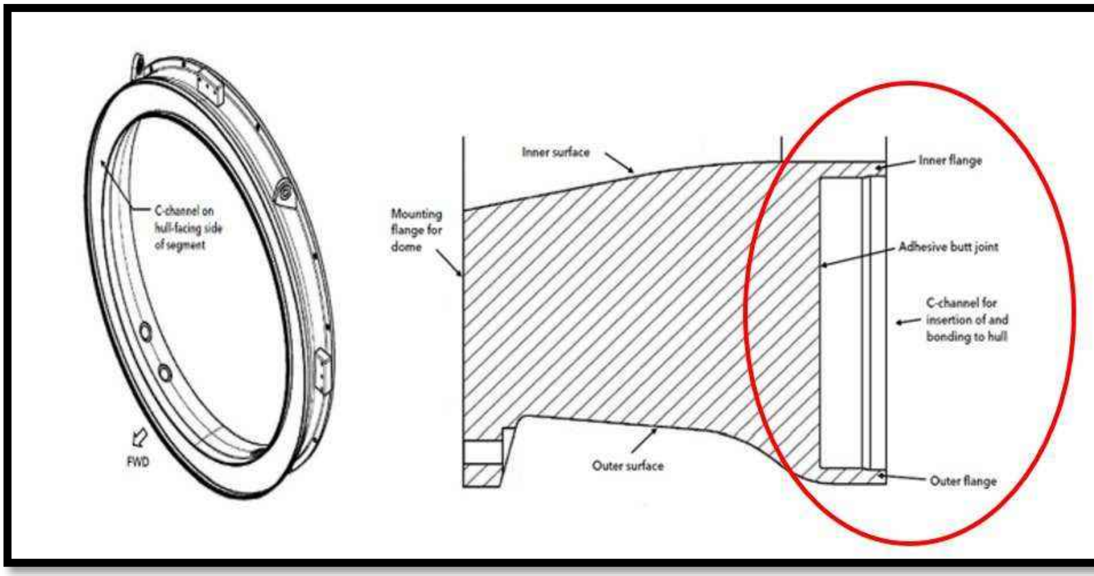


Figure 147: Images showing the segment and cross section of the C-channel of the segment for adhesive bonding of the hull. Source: NTSB Materials Laboratory Factual Report.

4.27.11. Prior to bonding, both the segments and hull surfaces underwent preparation to ensure proper adhesion. They were degreased using methyl ethyl ketone (MEK) to remove contaminants, and their surfaces were roughened with stearate-free sandpaper. Contact angle measurements were taken throughout the process to confirm that the surfaces remained active, with any particles or contaminants removed by filtered shop air. These measures ensured that the bonding surfaces were clean and prepared for optimal adhesive performance.

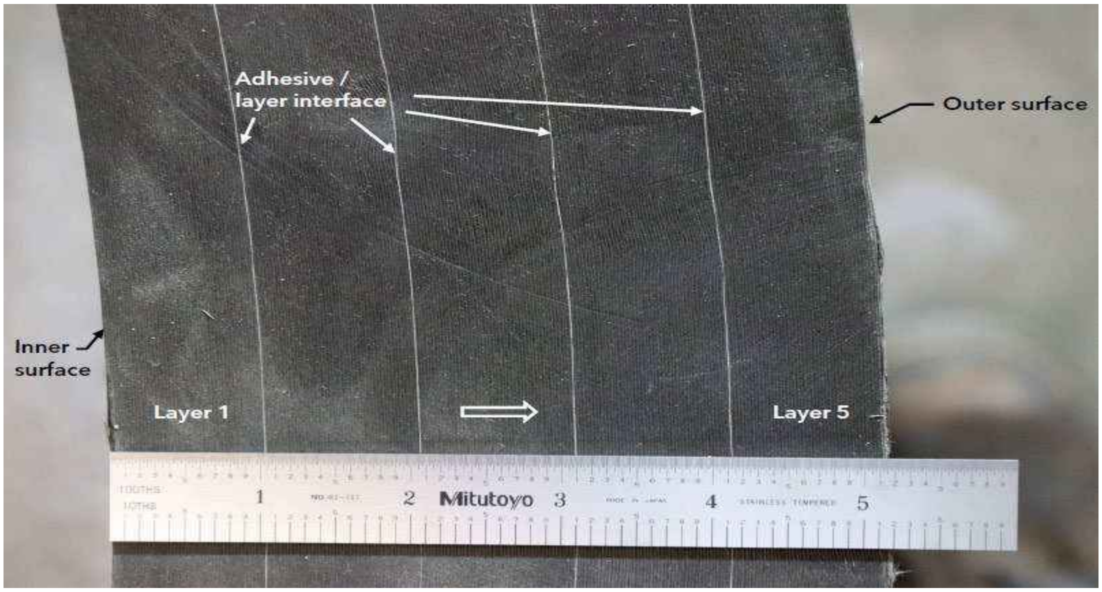


Figure 148: TITAN final hull cross-section showing co-bonded layers. Pieces from full-scale and test hulls were examined in Seattle by MBI the Engineering Team and taken to NTSB lab for material testing. Source: NTSB Materials Laboratory Factual Report.

4.27.12. Once the surfaces were prepared, the adhesive was applied to both the segment and hull, and the hull was then inserted into the C-channel. The assembly was oriented vertically to facilitate the bonding process, with spacers used to control the bond line thickness. The aft joint was formed by lowering the carbon fiber hull onto the segment, while the forward joint was formed by lowering the segment onto the hull, ensuring precise alignment and secure bonding between the segments and the hull. The OceanGate Titanium End Gluing Procedures state, allow "Hysol EA 9394 adhesive to cure for 3 to 5 days."

4.27.13. While the hull was curing, the RTM system was being installed on the inside of the carbon fiber hull. Eight acoustic emission sensors and 16 strain gauges were installed throughout the hull. When the hull was cured and completed, it was covered with a polyurethane material, similar to a truck bed liner, in an attempt to protect the carbon fiber hull from water intrusion.

4.27.14. At the beginning of February 2021, the forward and aft titanium domes were transported to Electroimpact, Inc. to be affixed to the hull's segments. Once the domes were affixed the final TITAN pressure hull was transported across the U.S. via a flatbed truck to the Deep Ocean Test Facility in Bethesda, Maryland.

4.28. Deep Ocean Test Facility (DOTF) Testing of Final Hull

4.28.1. On February 25, 2021, the TITAN hull arrived at the DOTF in Bethesda, Maryland for approximately four days of testing. The test plan was to conduct five simulated dives over four days. Day 1 would be dives to a maximum simulated depth of 3,000 m (9842 feet) and 4,200 m (13,780 feet), Day 2 and 3 would be to 4,200 m and day 4 would conclude with a dive to 4,000 m (13,123 feet).

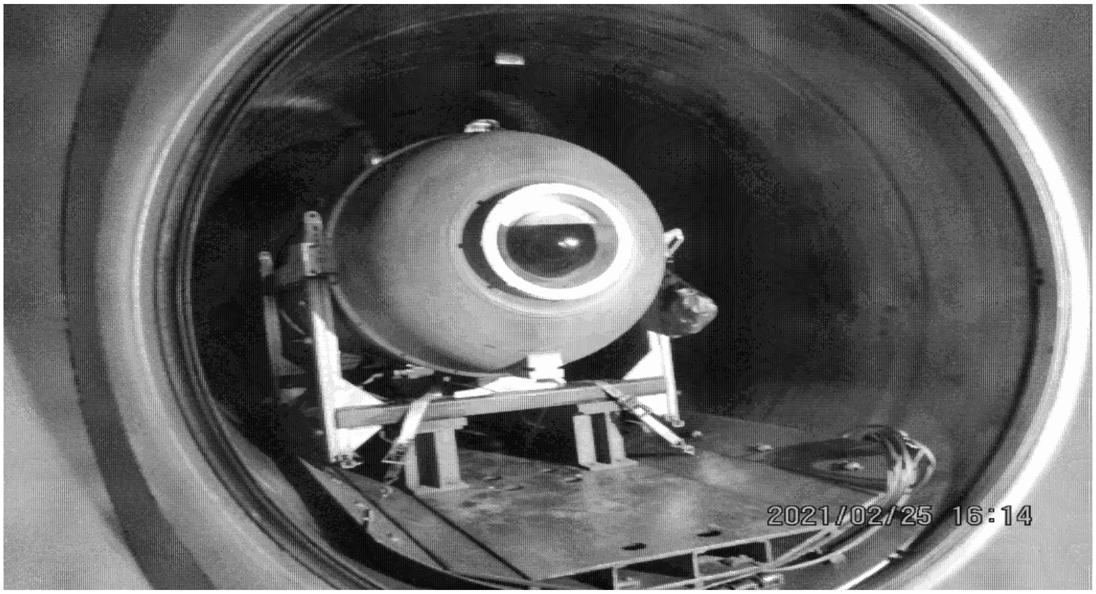


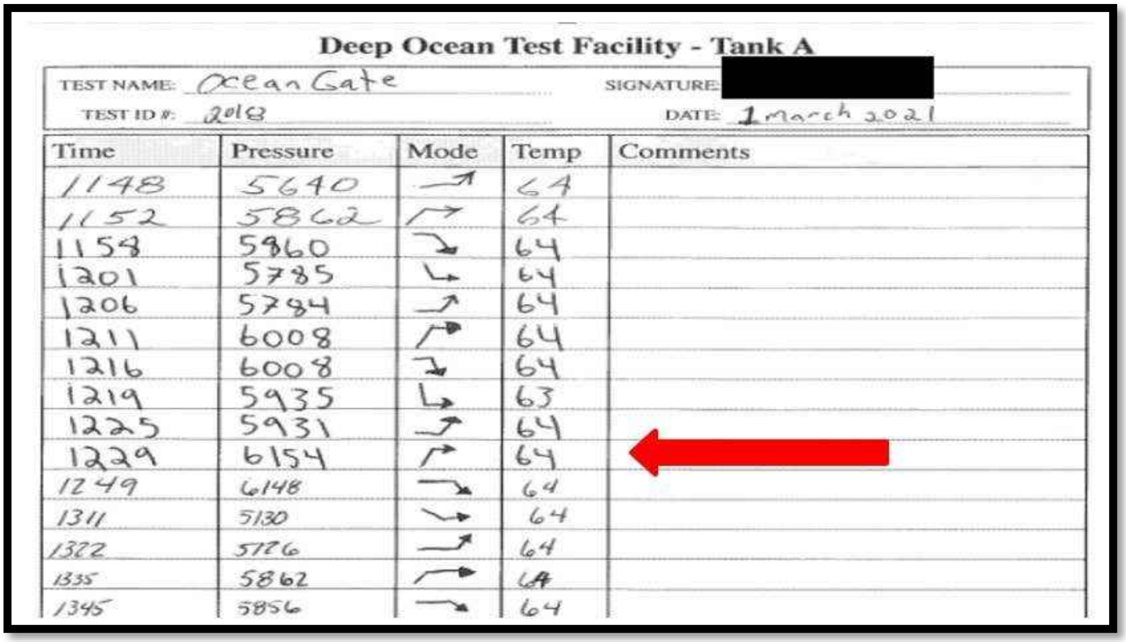
Figure 149: Final TITAN hull at the DOTF in Bethesda, Maryland on February 25, 2021. Source: DOTF.

4.28.2. On February 26, 2021, testing began at 6:28 a.m. and was completed at 4:48 p.m. The final TITAN hull was tested to a maximum depth of approximately 4,000 m (equivalent to 5,862 psi) for two cycles (30 and 40 minutes) for a total of approximately 70 minutes.

1246	5715	↱	61	
1256	5710	↘	61	
1259	5642	↳	61	
1310	5637	↗	61	
1314	5862	↱	61	
1344	5858	↘	61	
1359	5131	↳	60	
1409	5128	↗	61	
1422	5862	↱	61	
1502	5858	↘	62	
1658	26	↳	59	TEST RUN 1 COMPLETE

Figure 150: DOTF Dive Logbook for February 26, 2021, with red arrows added by MBI to indicate the maximum pressures reached (5,862 psi) during the first DOTF test run on the final TITAN hull. The first column is time, the second is pressure, the third is "mode" and the fourth column is temperature. Source: DOTF.

4.28.3. On March 1, 2021, the second DOTF test began at 6:53 a.m. and was completed at 5:40 p.m. The TITAN was tested to a maximum depth of approximately 4,200 m (6,154 psi) and it was held at that maximum pressure for one 20-minute cycle.



Deep Ocean Test Facility - Tank A

TEST NAME: OceanGate SIGNATURE: [redacted]

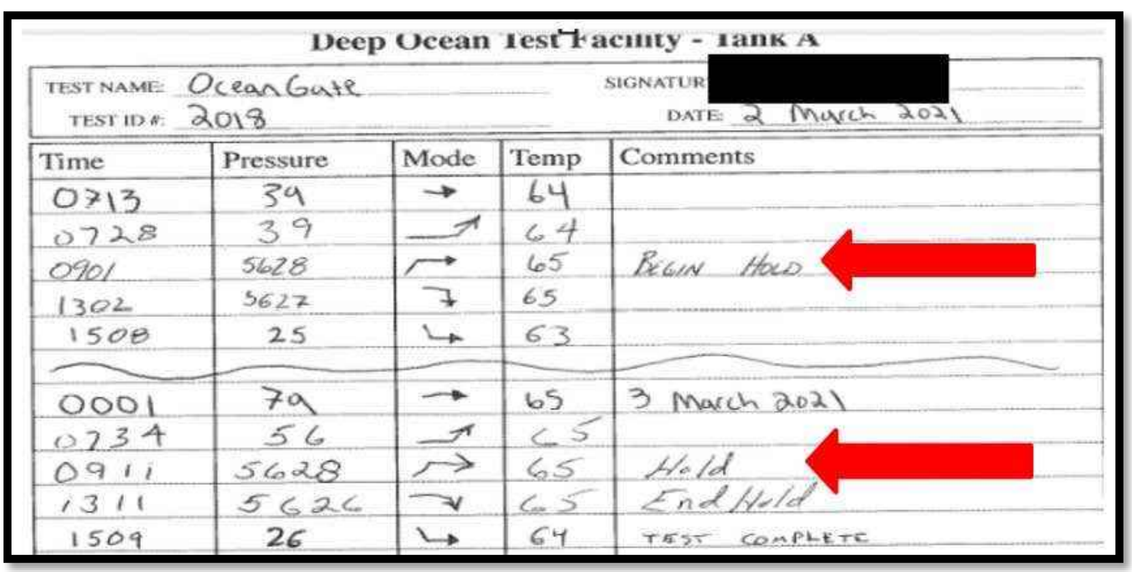
TEST ID #: 2018 DATE: 1 March 2021

Time	Pressure	Mode	Temp	Comments
1148	5640	→	64	
1152	5862	→	64	
1158	5960	↘	64	
1201	5785	↳	64	
1206	5784	↗	64	
1211	6008	→	64	
1216	6008	↘	64	
1219	5935	↳	63	
1225	5931	↗	64	
1229	6154	→	64	
1249	6148	↘	64	
1311	5130	↘	64	
1322	5726	↗	64	
1335	5862	→	64	
1345	5856	↘	64	

Figure 151: DOTF Logbook for TITAN on March 1, 2021. The red arrow added by MBI to indicate the maximum pressure reached (6,154 psi) during the second DOTF test run on the final TITAN hull. Source: DOTF.

4.28.4. On March 2, 2021, the third DOTF test began at 7:13 a.m. and was completed at 3:08 p.m. The TITAN was tested to a maximum depth of approximately 3,840 m (5,627 psi) and it was held at that maximum pressure for one 240-minute cycle.

4.28.5. On March 3, 2021, the fourth DOTF test began at 7:34 a.m. and was competed at 3:09 p.m. The TITAN was tested to a maximum depth of approximately 3,840 m (5,628 psi) and it was held at that maximum pressure for one 240-minute cycle.



Deep Ocean Test Facility - Tank A

TEST NAME: OceanGate SIGNATUR [redacted]

TEST ID #: 2018 DATE: 2 March 2021

Time	Pressure	Mode	Temp	Comments
0713	39	→	64	
0728	39	↗	64	
0901	5628	→	65	BEGIN HOLD
1302	5627	↘	65	
1508	25	↳	63	
0001	79	→	65	3 March 2021
0734	56	↗	65	
0911	5628	→	65	Hold
1311	5626	↘	65	End Hold
1509	26	↳	64	TEST COMPLETE

Figure 152: TITAN March 2nd and 3rd DOTF "max" pressure tests. The red arrows added by MBI indicate the maximum pressure reached (5,628 psi) during the third and fourth DOTF test run on the final TITAN hull. Source: DOTF.

4.28.6. On March 4, 2021, the final TITAN hull departed the DOTF via flatbed truck. When the submersible departed for transport on the roadway, it was not wrapped in any protective material.

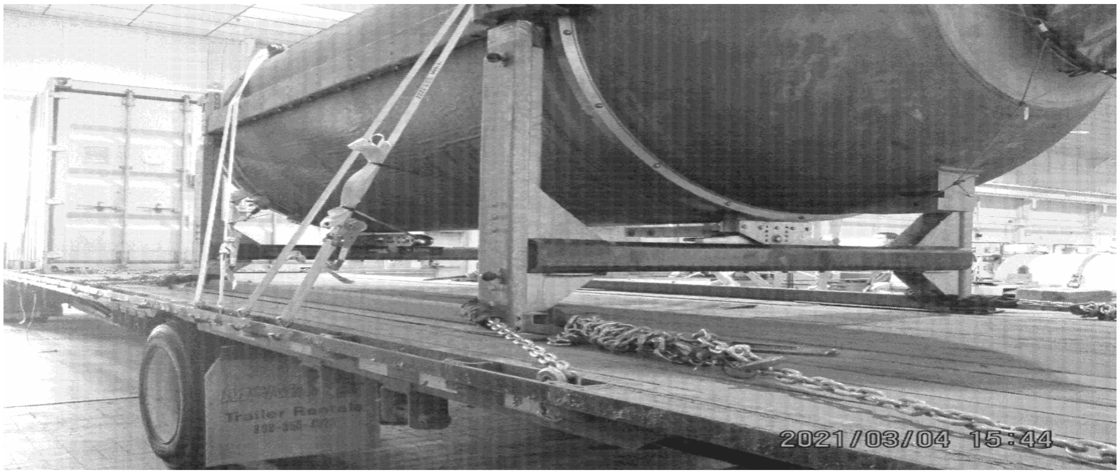


Figure 153: TITAN on flatbed prior to departing the DOTF on March 4, 2021. Source: DOTF.

4.29. TITAN System and Components

Figure 154: Final TITAN hull. Source: OceanGate.

4.29.1. TITAN Pressure Hull / Boundary

Figure 155: Main components of the CYCLOPS II (TITAN) pressure hull. Source: OceanGate.

4.29.1.1. The pressure hull / boundary refers to the pressure hull and the associated fittings that maintain the pressure for the submersible's occupants.

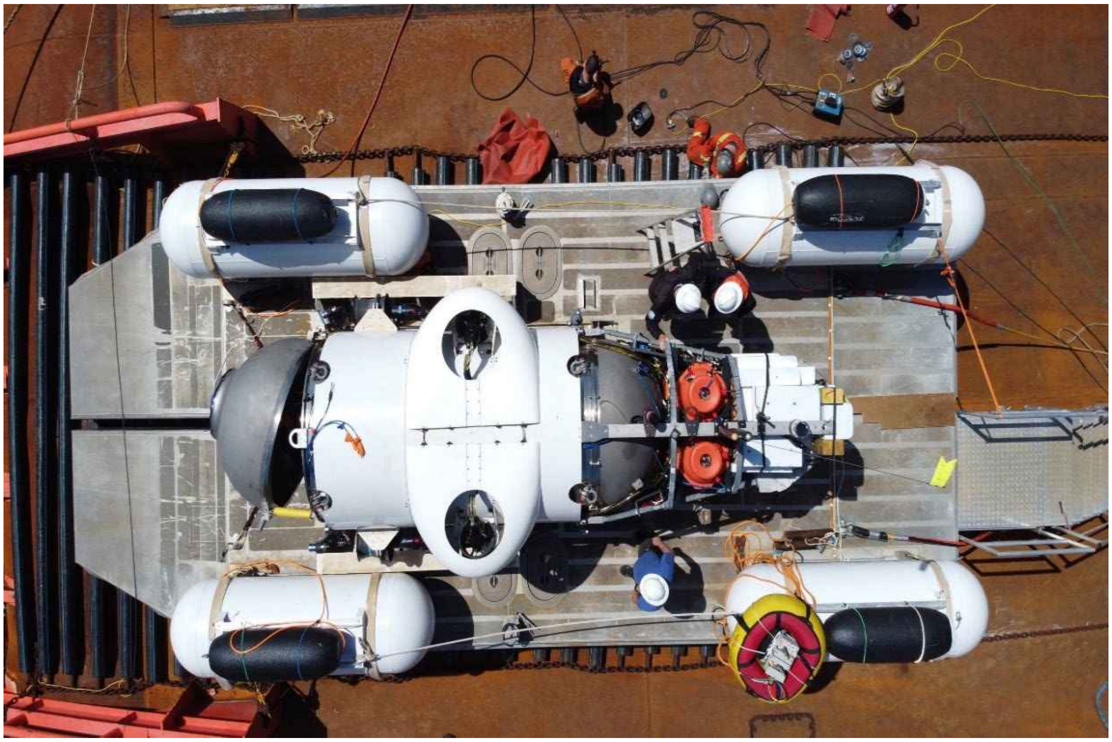


Figure 156: Overhead view of the final TITAN on LARS in 2022 on the deck of it support vessel, the Canadian flagged anchor handling tug supply vessel (AHTS) HORIZON ARCTIC. Source: "CBS Sunday Morning" Correspondent.

4.29.1.2. The pressure boundary of the final TITAN was designed to maintain the watertight integrity of the submersible and its associated equipment. This boundary encompassed the pressure hull, with water and pressure rated fittings for external systems, to protect the internal atmosphere from the immense pressures experienced at depth. The pressure hull itself consisted of a five-inch-thick carbon fiber cylinder, with titanium end segments glued to the ends of the composite cylinder. To provide additional strength and structure, two 60-inch diameter, 3.25-inch-thick titanium hemispherical domes were bolted to the affixed titanium end segments. The forward hemisphere was hinged to allow for entry and exit, and it was also fitted with a 23-inch diameter acrylic viewport.

Figure 157: The TITAN's aft segment is pictured post-accident on July 5, 2023. Two of TITAN's penetrators are visible. The aft segment had four penetrators equipped to supply electrical, air, and hydraulic systems. Source: FBI Evidence Response Team (ERT).

4.29.1.3. The pressure hull was further reinforced by a 7-inch-thick acrylic viewport, which was seated in a machined titanium cutout in the forward dome. This main viewport, with an inner diameter of 12.5 inches and an external diameter of 23 inches, was secured by a retaining ring and 16 bolts and sealed with an O-ring to maintain the pressure boundary. In addition to the viewport, the pressure hull included four penetrators located through the aft segment. The penetrators provided access for electrical, air, and hydraulic systems, without breaching the watertight structure of the pressurized hull.

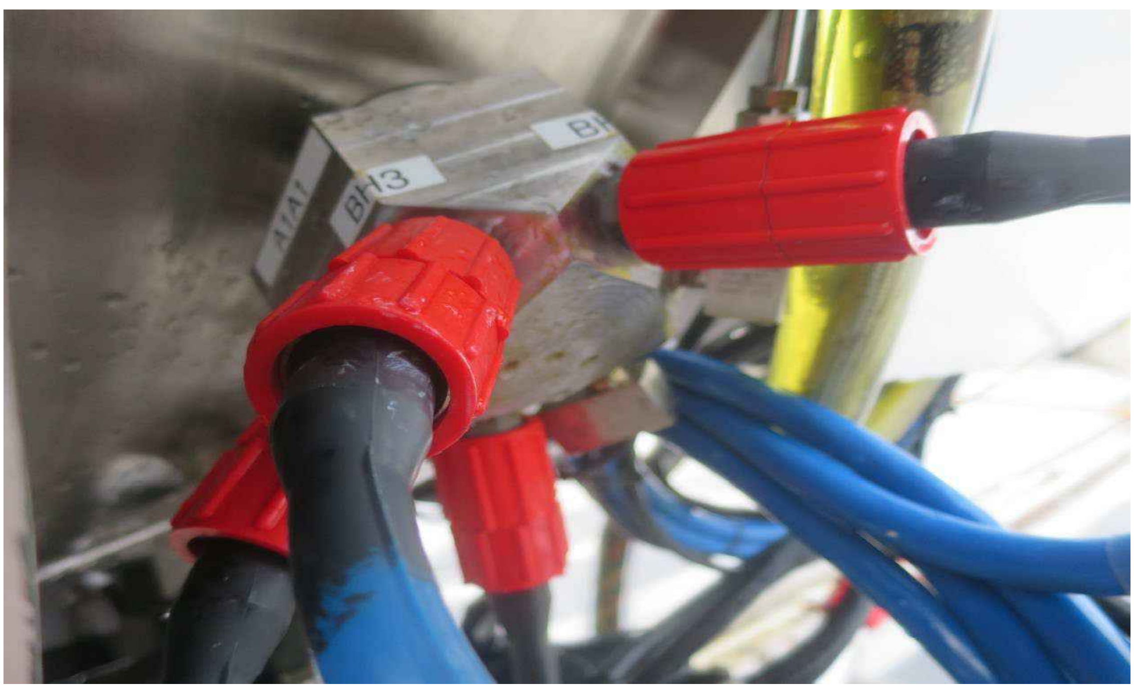


Figure 158: Closeup of a TITAN penetrator running through the aft titanium segment. Source: Former OceanGate contractor.

4.29.1.4. In March 2021, lifting eyes were welded onto the titanium end segments of the pressure hull to serve as lifting points to facilitate lifting of the final TITAN. Prior to the installation of these lifting eyes, TITAN was moved using a sling placed under the forward and aft segments.

4.29.1.5. OceanGate's first Director of Engineering provided the following MBI testimony describing the reservations he voiced to OceanGate regarding the welding of lifting eyes to TITAN's segments:

> "The domes, the rings in the domes, were never designed to take excessive load in the shear direction. That would be a sliding interface…. If you can think of the weight of the hull on the clevis, shear would be pushing on this little lip here and that's, it's a small dimension. The point of (the small clevis) was just to keep (the segment) glued in place because subsea structures, a beautiful thing about them, is it's uniform loading all the way around."

Figure 159: The TITAN's forward segment is pictured post-accident on July 5, 2023. One of the lifting eyes, which was added to the segments by OceanGate in March of 2021, is visible at the bottom of the photo. Source: FBI ERT.

4.29.2. TITAN Exostructure

4.29.2.1. External to the pressure hull was the exostructure or framing on the bottom and aft of the final TITAN hull. The exostructure framing was affixed to the forward and aft titanium segments.

Figure 160: TITAN under construction. The aft tail framework is shown without components installed. Source: OceanGate.

4.29.2.2. The TITAN pressure hull was affixed to a framing and landing gear system. While this frame was intended to allow the final TITAN to remain upright while on a horizontal surface, it also acted as a mounting point for cameras, lighting, scanning systems and other components, which could all be jettisoned to reduce weight in an emergency.

4.29.2.3. At the aft end of the TITAN was a framing system that housed the external batteries, Syntac® foam, a high-pressure air tank, propulsion motor control pods, thruster junction box assemblies, and other electronic relays.

Figure 161: Final TITAN aft exostructure. Source: "CBS Sunday Morning" Correspondent.

4.29.3. Trim and Ballast Systems

4.29.3.1. The trim and ballast of the final TITAN used a combination of high-pressure air and drop weights. An open-bottom bladder was installed on the upper section of the hull of TITAN, serving as a ballast tank. Together with the high-pressure (HP) air system, it helped achieve the desired submerged state of positive, neutral, or negative buoyancy. The fill point was located at the top of the bladder, allowing the system to be filled with air via a needle blow valve actuator located inside TITAN. Venting was controlled by an electric motor, activated through the control computer, which adjusted a vent line to either rise or lower, depending on the desired buoyancy level.

Figure 162: TITAN HPA ballast bag. Source: OceanGate.

4.29.3.2. The high-pressure air system had a working pressure of 10,000 psi and while the 40-liter tank was in the aft exostructure of the TITAN outside the pressure hull, it passed through the hull via a penetrator, allowing the ballast bag to be manipulated by TITAN's pilot to the desired buoyance.

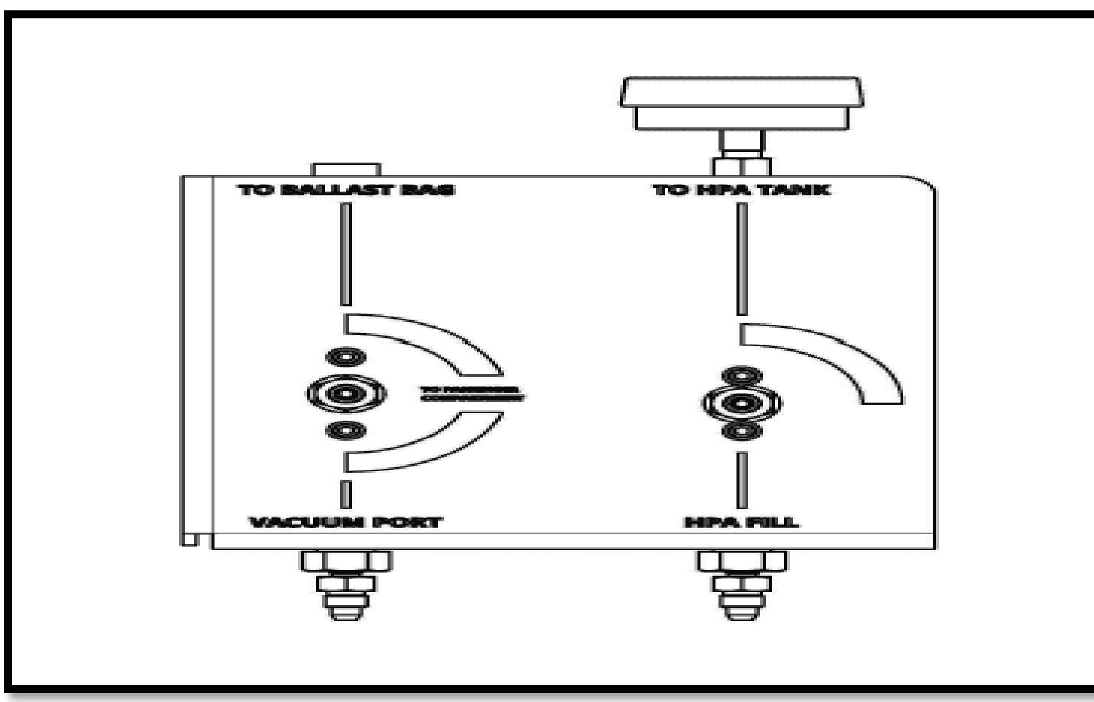


Figure 163: TITAN high pressure air aft cage selector valve. Source: OceanGate

Figure 164: Aft view of TITAN. The yellow arrow added by MBI is pointing to the 40-liter HP air receiver.
Source: "CBS Sunday Morning" Correspondent.

4.29.3.3. Before entering the TITAN, all occupants and their associated gear were weighed to ensure proper buoyancy. Based on the combined weight of the crew and the vessel, lead weights were added to the landing skid to achieve optimal buoyancy before the dives commenced. Additionally, trim drop weights, which could be released individually using electric drop actuators, were stored in a tray that held up to 12 weights, totaling 408 lbs when submerged. Each steel pipe in the tray was 24 inches long and weighed approximately 37 lbs.

Figure 165: TITAN drop weights. Source: OceanGate.

Figure 166: TITAN roll drop weights. Source: OceanGate.

Figure 167: TITAN drop weight actuator. Source: OceanGate.

4.29.3.4. In the case of an emergency where the electric drop weight mechanism failed, the emergency hydraulic system on TITAN was designed to provide backup power in critical situations. It featured a hydraulic hand pump that could activate a drop tray release mechanism, enabling the rapid detachment of all trim weights. Additionally, the system could detach TITAN's entire landing gear as well as all of the lead bricks attached to it, ensuring that the vessel could be lightened rapidly in an emergency.

4.29.3.5. The hydraulic hand pump had a maximum working pressure of 15,000 psi, and it was filled with oil through a fill point located on top of the unit. This system provided a reliable means of emergency weight release, helping to ensure the safety and stability of TITAN during extreme or unforeseen circumstances.

Figure 168: TITAN drop weight hydraulic pump. Source: OceanGate.

4.29.3.6. There were also a set of weights that were attached to the frame via a 24 hour “squib” or sacrificial anode that dissolved in 24 hours. The squibs were in place to automatically release weights after 24 hours in case of an emergency that incapacitated the crew or disabled the other mechanisms for emergency weight release.


Figure 169: TITAN drop weight. Source: OceanGate.

4.29.3.7. The TITAN’s landing skid could be jettisoned in an emergency by way of emergency hydraulic actuator. Dropping the landing skid was considered the last option for increasing buoyancy in an emergency because it could not be recovered if released in a deep-sea scenario like the TITANIC wreck site.

4.29.4. TITAN Internal Layout

4.29.4.1. The TITAN’s carbon fiber hull was fitted with a fiberglass insert. The insert made it possible for handles, computer screens, and electronics to be hung without penetrating or damaging the carbon fiber hull. The insert for the main compartment had a built-in sub floor. According to a former OceanGate Engineer, the insert could be changed out to a differently modified insert specific to the needs of the operation.

Figure 170: Internal aft compartment of TITAN. The TITAN's three servers are visible within the aft dome. Source: OceanGate.

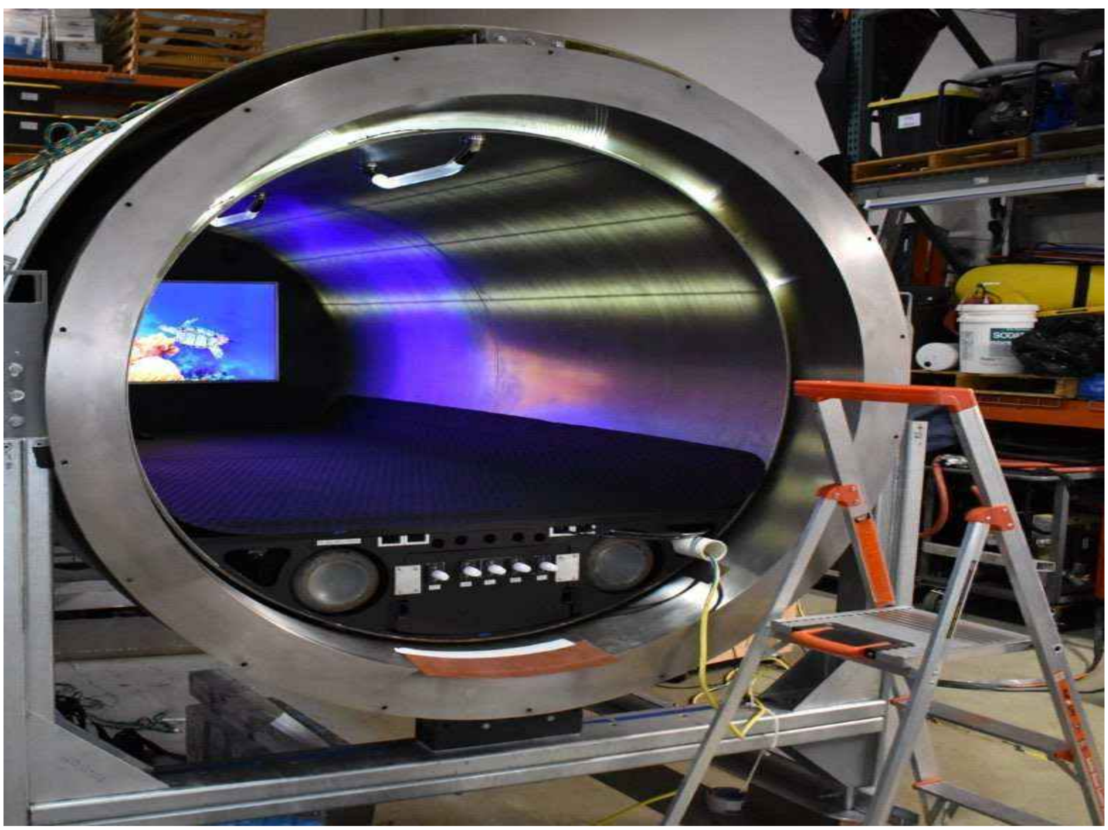


Figure 171: Inside view of the final TITAN, showing illuminated insert. Source: https://ocean-archives.github.io/.

4.29.4.2. The forward dome contained the TITAN's toilet, which was also used as a seat during the dives.

Figure 172: TITAN's toilet. Source: "CBS Sunday Morning" Correspondent.

Figure 173: Inside view of TITAN from forward dome looking aft. Source: "CBS Sunday Morning" Correspondent.

Figure 174: Inside of TITAN facing toward the aft dome. Source: OceanGate

4.29.4.3. The aft dome and the main compartment were separated by a hinged door. The aft dome housed the TITAN's electronics, computers, routers, various hubs, an ethernet switch and the oxygen "day" tank and valve.

4.29.5. High Pressure Oxygen System

4.29.5.1. The HP oxygen system on the final TITAN was composed of one main cylinder and four emergency reserve cylinders, all stored internally within the vessel. The main oxygen cylinder, referred to as the day cylinder, was in the aft equipment bay section of the hull and had a maximum charge of 2,500 psi. The four reserve cylinders, each also charged to 2,500 psi, were distributed under the floor—two forward and two midship on the port and starboard sides. Each cylinder was equipped with its own isolating valve at the neck to control the oxygen flow.

Figure 175: TITAN high pressure system. The image taken with the floor removed. Source: https://ocean-archives.github.io/.

4.29.5.2. Once the main cylinder was opened, oxygen flowed to the flow meter. The flow meter could be manually adjusted using a needle valve to regulate the oxygen supply at a rate of ½ liter per minute per person inside the compartment. This ensured that everyone onboard received the necessary amount of oxygen throughout the duration of the dive.

Figure 176: TITAN oxygen canister positioned under the flooring of the main passenger compartment. Source: OceanGate.

4.29.5.3. The pilot was responsible for monitoring the oxygen levels inside TITAN, using electronic oxygen sensors installed within the vessel. These sensors continuously measured the oxygen concentration in the air, allowing the pilot to adjust the flow rate as needed to maintain the proper levels for the crew's safety and comfort.

Figure 177: TITAN oxygen flow meter. Source: OceanGate.

4.29.5.4. Throughout the dive, the pilot was required to closely manage the oxygen system to ensure that all oxygen cylinders were functioning correctly, and that the oxygen supply was adequate. The ability to adjust the flow rate in real-time helped manage the varying needs of the crew, ensuring safe and efficient operation of TITAN during underwater missions.

4.29.5.5. TITAN's five oxygen tanks provided up to 96 hours of life support for five-member crew.

4.29.6. Carbon Dioxide (CO_2) Scrubber

4.29.6.1. CO_2 levels were continuously monitored by the TITAN control system, with a backup emergency monitoring system in place in case of a control system failure. To further ensure safety, a CO_2 scrubber unit was installed behind the pilot seating area, filled with Sofnolime® CO_2 absorbent. The scrubber's fan was powered through a switch in the TITAN's 24V power system.

4.29.6.2. According to a former OceanGate Director of Engineering, the initial scrubber system in the TITAN, designed and built by Mr. Rush, was a "homemade" system that consistently failed to maintain adequate oxygen levels. This system was not in use on the final TITAN hull. The date of its replacement is unknown. The Director of Engineering provided the following testimony to the MBI:

> "The scrubber was a homemade Stockton thing. I tried to get rid of it multiple times. Always was told no. It was literally made from a Tupperware container that came from Walmart or Amazon or somebody like that. It had liked a screen in the bottom with an air space underneath. You would pour the scrubber into this thing which was a granular chemical material, soap and lime is what it is, right. You'd pour that in there, and then there was a lid, a Tupperware lid that went on and in that Tupperware lid there was a computer fan. You'd attach the computer fan to a battery. That would pull air out of the environment, push it into the scrubber material and then, you know, through the grid at the bottom and out some vent somewhere. So, this thing never really kept up. If you put four people in the sub, it really couldn't keep up with the occupants' breathing rate. So -- and it looked like it was a total piece of junk. I mean it looked like a Tupperware container from Walmart with computer fan on the top."

Figure 178: TITAN's "homemade" CO_2 scrubber. Source: Former Director of Marine Operations.

4.29.6.3. Emergency CO_2 scrubbing was accomplished with Lithium Hydroxide blankets, according to the TITAN Operations Manual, there were enough onboard for 96 hours of atmospheric scrubbing.

4.29.7. Electrical System

4.29.7.1. TITAN's electrical system was divided into two main voltage systems: 150V and 24V. The 150V system provided the main power for the submersible's propulsion motors, with two external lithium polymer batteries rated for full ocean depth. One battery powered the vertical thrusters, while the other fed the horizontal thrusters, ensuring sufficient propulsion throughout the dive. Thus, the 150V system was essential for movement and maneuverability during operations, which has been extended up to 27-hours in duration during the TITANIC Expeditions.

4.29.7.2. The 24V internal battery bank was responsible for powering the house and auxiliary systems. It consisted of four 6V sealed lead-acid batteries, which were installed below TITAN's flooring and connected in series to form a 24V bank. This system supported various subsystems, and its voltage level was continuously monitored via a control panel indicator to ensure operational efficiency.

Figure 179: TITAN's Ictineu Li-Po® battery. Source: OceanGate.

4.29.7.3. The 24V system powered a wide range of auxiliary systems, including the control PC, 4k media PC, acoustic data modem, the scrubber system, external lights, cameras, thruster control spheres, and the sonar pan and tilt. It also powered critical components like the drop weight motors, CB radio (used for communications with OceanGate dive support personnel when TITAN was on or near the surface of the ocean), and the 2G laser scanning system. These systems were vital for monitoring and maintaining TITAN's operations during deep-sea missions.

4.29.7.4. Additionally, TITAN's external systems, which were subjected to extreme pressures, were either oil-compensated, gel-filled, or epoxy-sealed to ensure durability and protection from the harsh underwater environment. The external BIRNS® junction box routed specific systems, providing connectivity for various critical components.

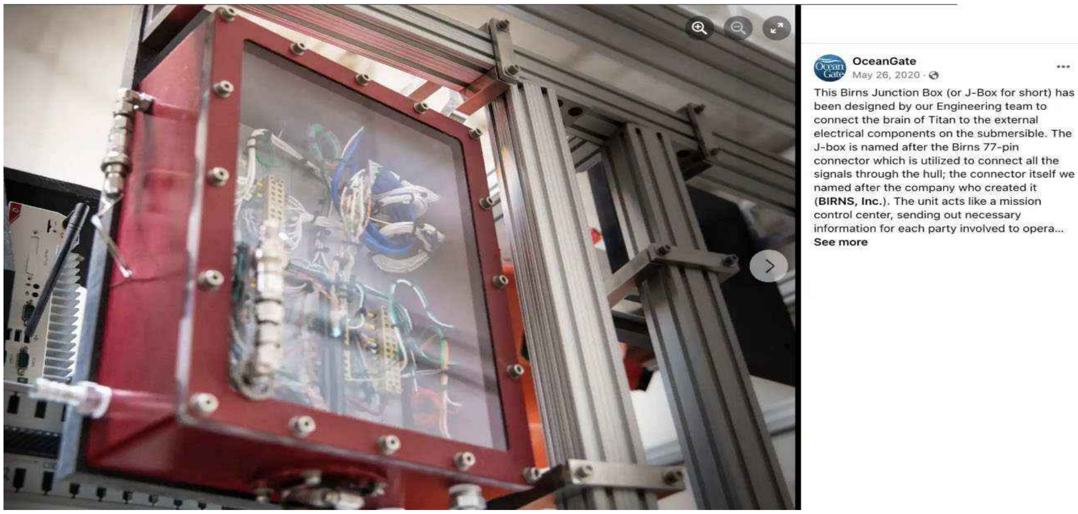


Figure 180: TITAN's BIRNS Junction Box. The junction box connected external electrical components through the pressure hull. Source: OceanGate Facebook.

4.29.8. Propulsion System

4.29.8.1. The TITAN was fitted with four Innerspace 1002HL Hexscreen Electric Thrusters, with two mounted vertically and two mounted horizontally. Each motor could produce approximately 12 horsepower at its maximum revolutions per minute (RPM).

Figure 181: Port side of the final TITAN hull is shown with horizontal and vertical thrusters encircled in yellow by the MBI. Source: "CBS Sunday Morning" Correspondent.

4.29.8.2. TITAN was equipped with two 17-inch glass spheres designed to handle the multiplexing of propulsion power and data outside of the pressure hull. These spheres, manufactured by Nautilus Marine of Germany, were made from ½-inch thick glass and were rated for depths of up to 6,000 m (19,685 feet). Precision-drilled holes in the spheres allowed for the passage of communication and power cables, which were crucial for the functioning of the thrusters. One sphere controlled the vertical thrusters, while the other managed the horizontal thrusters, providing TITAN with full propulsion capabilities.

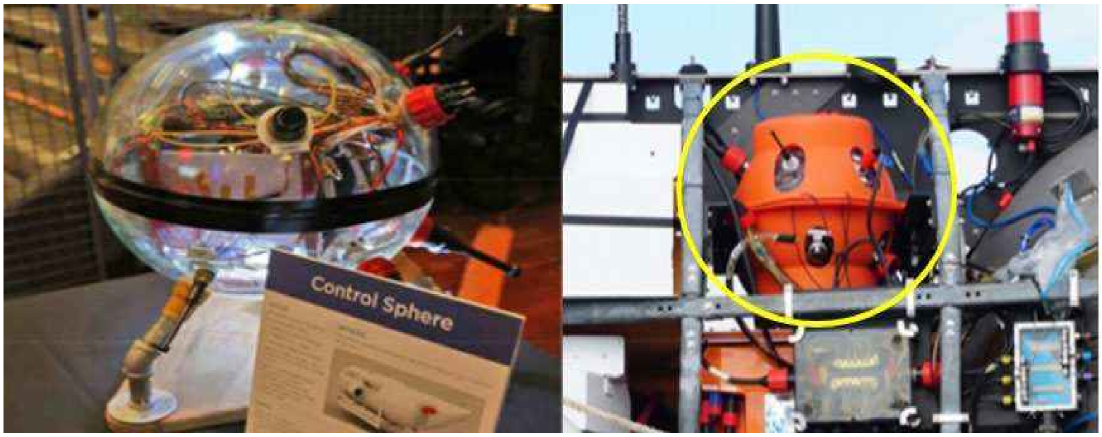


Figure 182: (Left image) Closeup of propulsion glass sphere used by TITAN which was contained outside the pressure hull in a plastic exostructure. (Right image) The orange plastic exostructure that contained the glass spheres in TITAN's aft tail cone is pictured and encircled in yellow by the MBI. Source: OceanGate.

4.29.8.3. The key components inside each sphere included motor controllers for the thrusters, which were brushless DC motors operating at 150V. Each sphere controlled two thrusters, so each contained two motor controllers. A motor control unit in each sphere handled signals to and from the thrusters, as well as supplying the required 150V power. Additionally, the spheres were equipped with temperature and pressure sensors to monitor internal conditions, and these sensors relayed data to the digital-to-analog converter (DAC) device within each sphere for monitoring and control purposes.

4.29.8.4. For communication between systems, each sphere included an ethernet switch/router that facilitated data transmission to the control computer and other onboard systems. The spheres were fitted with specialized connectors and penetrators from SubConn/MacArtney Inc., including high-power connectors for thruster power, low-power connectors for auxiliary systems, and standard Ethernet connectors for cross-sphere data and low-power transfers. These connectors ensured seamless connectivity and efficient power distribution for all of TITAN's critical systems.

4.29.8.5. To maintain operational safety, the spheres were filled with mineral oil, which served two purposes. First, the oil helped to conduct heat away from the motor drives, transferring it to the walls of the sphere and into the surrounding ocean. Second, the mineral oil reduced the sphere's risk of implosion in the event of a failure by minimizing the presence of entrained air. This oil-filled configuration enhanced the durability of the spheres, even under extreme ocean pressures.

4.29.8.6. To protect the spheres when operating at low external pressures, such as when near the surface or in air, a vacuum pump was used to draw down the internal pressure after the oil filling process. This process ensured that the spheres maintained their structural integrity during pressure changes and reduced the likelihood of failure due to pressure differentials.

4.29.9. Communications and Tracking

4.29.9.1. Over the course of their submersible operations, OceanGate utilized different companies and acoustic telemetry modems for their vessel communications and tracking systems. An ultra short base line (USBL) transceiver, mounted on the submersible's support vessel, used acoustic signals to determine distances and bearings to its tracking targets. The USBL transceiver measured the elapsed time for the transponder to receive the signal and then converted that time to distance. By utilizing several transducers, the support vessel's transceiver was able to calculate the angle to any deployed transponders.

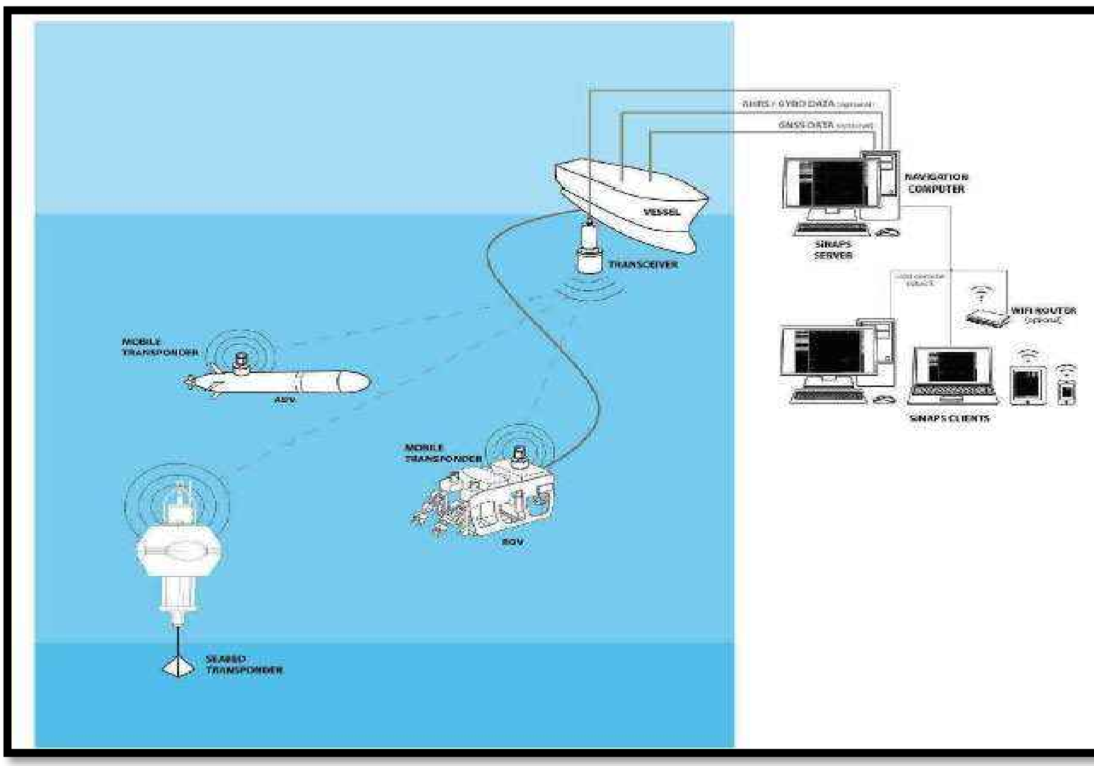


Figure 183: EvoLogics SiNAPS LBL positioning system. Source: EvoLogics SiNAPS Software: version2.x.

4.29.9.2. OceanGate purchased a total of three acoustic modems from EvoLogics including one S2C R Hydroacoustic Modem 7 /170 S and two S2C R Hydroacoustic Modem 7/170s. Evo Logics provided the following statement to the MBI:

> "EvoLogics has limited knowledge as to OceanGate's final use applications of products purchased from EvoLogics. It is believed that OceanGate intended to attach modem (1) to their submarine, the TITAN, and Modem (2), with the external battery, were intended to be placed on the seafloor near the TITANIC wreck, to be used as a "destination beacon" for future dives. EvoLogics has no definitive information as to whether OceanGate ever carried out their placement of this modem (2) on the seafloor, still had plans to, or were carrying it down during their June 18th mission."

4.29.9.3. The POLAR PRINCE was equipped with the Hydroacoustic Modem w/ USBL. The OceanGate team utilized the SiNAPS software for comms and tracking; EvoLogics SiNAPS positioning software controlled the positioning system and provided display features to monitor the mission in real-time.

4.29.9.4. According to the EvoLogics SiNAPS Software: Version 2.x User Guide, "If both the topside and downside devices are connected to their respective instances of SiNAPS, it is possible to exchange short text messages between them during positioning, the Chat widget in the right-side panel allows to send and receive short text messages to/from a remote device connected to another instance of SiNAPS. Short messages sent with the tool will be included in acoustic communication signals between the transceiver and the target(s). This communication is carried out as IMs - short instant messages of the EvoLogics DMAC protocol."

4.29.9.5. The maximum text message size is 64 bytes, which is typically equivalent to 64 characters or roughly 10-13 words.

4.29.9.6. OceanGate relied on Chat widget's limited messaging capability to serve as their sole source of communications between surface support vessel on the POLAR PRINCE and the TITAN's pilot after the TITAN was submerged (VHF radios were available to provide voice communications when the TITAN was at the surface). After reviewing text communications from previous TITAN dives, it was apparent to the MBI that the limitations created by the Chat widget hindered communications and led to over truncation of important messages, which occasionally led to frustration and miscommunications between the TITAN's operator and the communications and tracking team. A former OceanGate contractor familiar with the EvoLogics system provided the following testimony to the MBI regarding OceanGate's decision to combine TITAN's tracking system and communications capability:

> "Normally, there would have been two devices there, you know, your communications which is completely separate from your tracking. This is the first case I've ever, ever seen where it was all done on the same thing which basically means that when one failed so did the other so both tracking and communications were down."

4.29.9.7. Voice communication systems at deep-sea depths had been successfully used for decades prior to TITAN's marine casualty. As an example, the DEEPSEA CHALLENGER L-3 Nautronix acoustic communications system allowed the pilot to communicate with the surface via voice or SMS style messages at extreme depths. Voice communication was the preferred mode so that the solo pilot could simultaneously operate the submersible. The submersible control system (PAC) was also set up to periodically send data strings that included the submersibles vital information such as oxygen and battery levels, depth, and speed. Standard underwater telephone communication channels were used for voice and digital data was sent via L-3 MASQ packets. MASQ is a spread spectrum signaling system developed by L-3 Nautronix to provide reliable through-water communications at any speed and depth.

4.29.10. Computer and Control Systems

4.29.10.1. Onboard the TITAN in the aft compartment there were three Nuvo-5000LP computer towers. The first, a Control PC, ran on Linux and was responsible for running the control program that communicates with the Elmo motor controllers. This PC also maintained logs in a text format, which were stored on a solid-state drive (SSD). The second CPU, the Media PC, ran on Microsoft Windows and handled media tasks, such as interfacing with the 4K camera, sonar systems (BlueView and Oculus Sonar), and other peripheral devices. Finally, the Logger PC, also running Linux, stored AE and strain data from the RTM system.

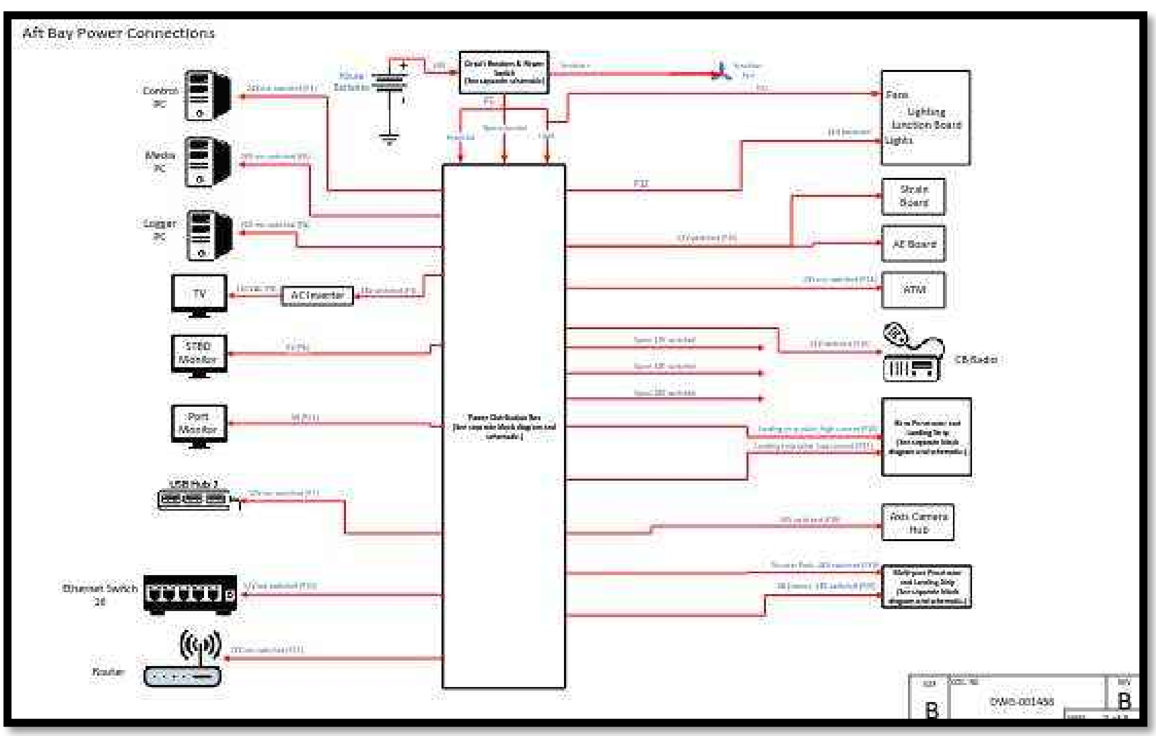


Figure 184: TITAN Aft Bay Power Connections. Source: OceanGate.

4.29.10.2. The data storage for TITAN systems was divided between the PCs: The Control PC stored operating system and software data on an SSD, with logs kept until they were manually removed. The Media PC used a hotspot for storing 4K camera data, transferred through an NTFS[42] file transfer program and the Logger PC handled the AE and strain data storage. The CPUs were arranged in a stack, with the Control PC at the top, followed by the Media PC in the middle, and the Logger PC at the bottom. This configuration allowed for efficient control and data management across different systems and platforms.

Figure 185: TITAN computer enclosure in aft compartment (yellow circle added by MBI). Source: OceanGate.

4.29.10.3. The control system for the TITAN was carried out by one of three Nuvo-5000LP computer towers. The control system of the TITAN submersible allowed the operator inside the submersible to monitor and control various aspects of the vehicle. The main computer system featured a display with multiple screens and tabs for controlling relays, loads, and thrusters. Key information, such as RPM, on/off status, and sensor data (including acoustic and strain gauge hull readings), was displayed in real-time. The system also tracked current limits and protections, with safeguards such as dead man switches, which required the operator to hold the switch to operate the TITAN's thrusters. When the switch was released, all thruster systems stopped.

[42] NTFS is the standard file system used by Windows NT operating systems, including Windows XP, Windows Vista, Windows 7, Windows 8, Windows 10, and Windows 11. It is a proprietary file system developed by Microsoft.

Figure 186: Image of the systems status screen aboard the TITAN. Source: Scientific Director.

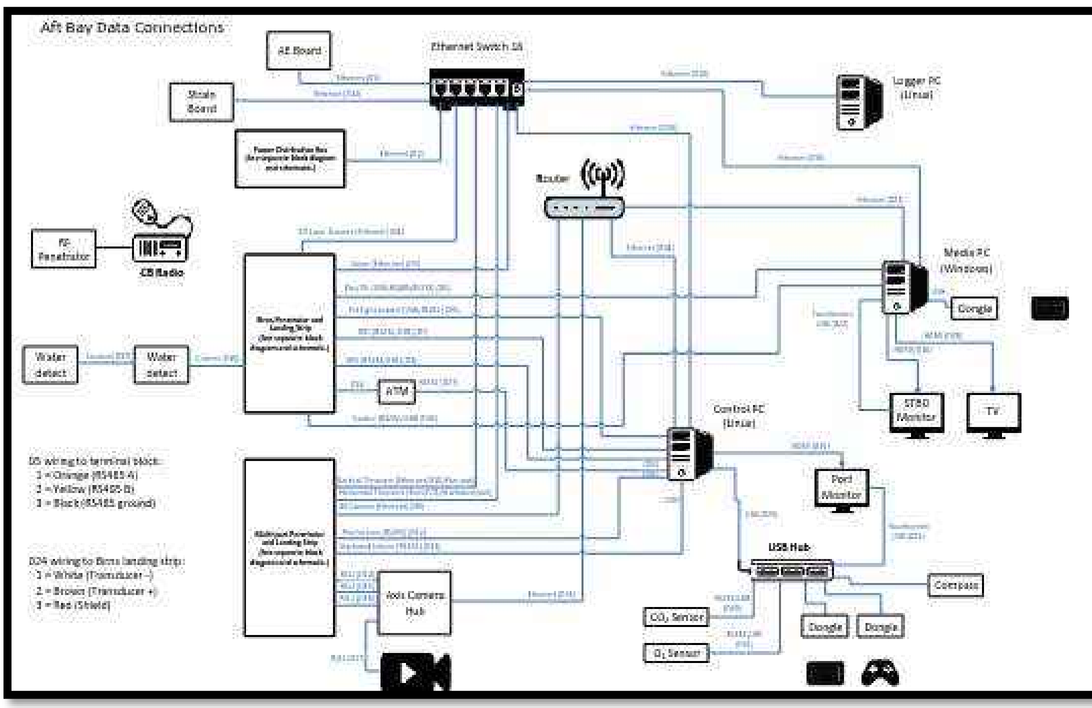


Figure 187: TITAN's Aft Bay Data Connections. Source: OceanGate.

4.29.10.4. The TITAN pilot was able to view real-time data on the submersible's battery management system (BMS), including voltage and current for each battery, as well as the current for individual loads, such as the thruster motors. For components like the drop weight and variable ballast tank motors, individual current sensors provided specific data, allowing the pilot to monitor their performance. The system also included fault detection, with indicators for minor issues like lighting or sensors, which could trigger fault alerts visible on the screen or within the PLC (Programmable Logic Controller). The pilot could access the fault logs to troubleshoot and trace specific issues.

4.29.10.5. The TITAN’s information was visible only to the pilot, who could view the internal screens to monitor the system’s status. While the pilot could access detailed messages and logs, external communication from the TITAN were limited to short chat messages and tracking information which were sent to the support ship. The internal systems allowed the pilot to conduct real-time monitoring and troubleshooting during operations. The support vessel was not able to view or monitor the TITAN’s systems status.

Figure 188: TITAN’s control monitor which was visible to the pilot. Source: “CBS Sunday Morning” Correspondent.

4.29.11. Video, Lighting, and Sonar

4.29.11.1. TITAN was equipped with multiple external video cameras that provided visibility for the pilot and passengers during deep-sea operations. A forward-facing camera was mounted near the viewport next to the sonar, offering the pilot a clear view of the outside environment. This camera was essential for navigation, particularly in operating areas with low visibility. Additionally, there was a belly camera positioned underneath the submersible, which served multiple purposes: it aided in navigation near the seafloor, monitored the dropping of trim weights, and assisted during landing and takeoff from the launch and retrieval platform. An aft-facing camera enabled the pilot to avoid obstacles while maneuvering TITAN in reverse. Lastly, an internal camera provided additional forward visibility by capturing footage through the viewport.

4.29.11.2. The external lighting system on TITAN consisted of four 9,000 lumen LED lights—two mounted on the port side and two on the starboard side—providing a total of 36,000 lumens of illumination. These high-power lights were essential for ensuring visibility in the dark, deep-sea environment, helping the pilot and crew to see their surroundings and operate the submersible safely. The bright LED lights were particularly useful in low-light conditions, which were typical during common during deep dives.

4.29.11.3. In addition to the video cameras and lighting, TITAN was outfitted with a BlueView sonar system for underwater object detection. The sonar was mounted on an electric pan-and-tilt unit, allowing the operator to adjust its angle as needed for optimal scanning of the surrounding area. The sonar system was controlled via BlueView's specialized controls, ensuring accurate and real-time data for the pilot during the dive.

4.29.11.3.1. The sonar used in TITAN was the BlueView M450, which featured a 90-degree field of view and a detection range of up to 300 m (984 feet). Operating at a frequency of 450 kHz, the sonar offered an update rate of up to 25 Hz, ensuring fast and accurate data transmission. The M450 sonar consumed 24 watts of power and was rated for depths of up to 4,000 m, making it suitable for TITAN's TITANIC Expeditions.

4.29.11.4. TITAN's external video cameras, including the four 4K SubC Imaging iCam Rayfin cameras, were live fed into the submersible's video screens. This setup allowed both the pilot and the passengers to have a better view of the submersible's surroundings, enhancing situational awareness. The cameras were strategically placed to ensure complete coverage of the submersible's exterior, giving the crew full visibility from multiple angles during the mission.

Figure 189: TITAN 4K Sub-C Imaging camera affixed to the submersible's forward frame. Source: "CBS Sunday Morning" Correspondent.

4.30. Completion of Final TITAN Hull / Test Dives

4.30.1. On April 29, 2021, the final TITAN hull underwent a buoyancy check at the Everett Marina in Everett, Washington. On May 1, 2021, OceanGate initiated its first platform test dive.

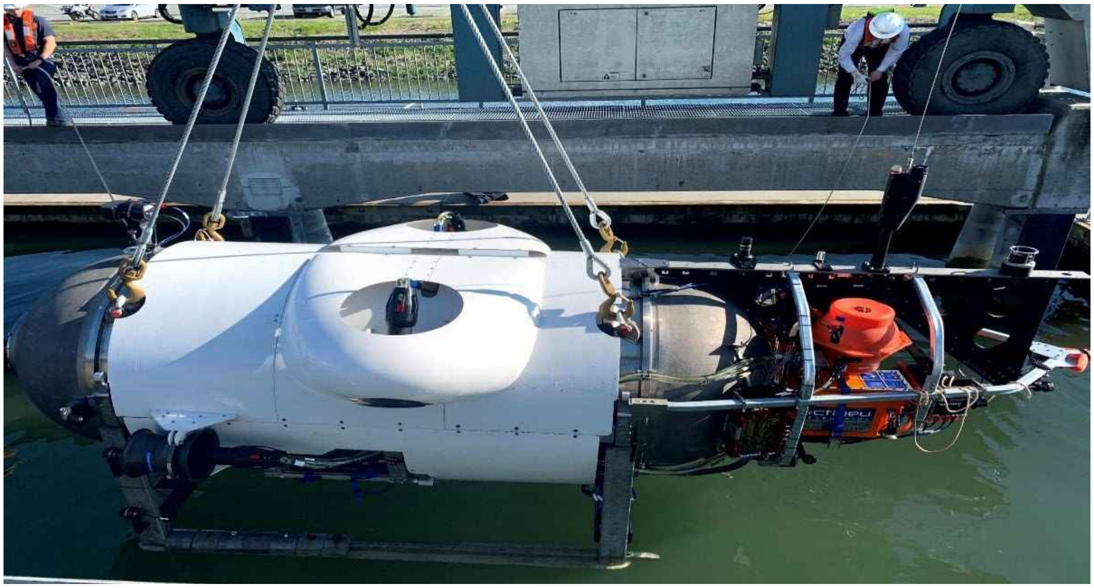


Figure 190: Final TITAN hull being hoisted into the water for a test dive in Everett, Washington in April of 2021. Source: Former OceanGate Director of Operations.

4.30.2. Between April 29 and May 25, 2021, OceanGate conducted a total of 11 test dives in the waters off Washington State, with the deepest dive reaching a depth of 170 m (558 feet). During this testing period, 57 distinct "issues" were recorded in the maintenance log, which required corrective actions. As per the TITAN dive log, these were dives 50 through 60. All dives prior to Dive 50 were with the first TITAN hull; Final TITAN hull dive number one was logged as Dive 50.

4.30.3. On May 12, 2021, during dive 54, a problem was reported at a depth of 3 m (9.8 feet). The pilot radioed and requested an immediate ascent because there was a problem with the passenger compartment CO_2 levels due to a malfunction in the scrubber system. Mr. Rush initially denied the request to surface. OceanGate's Director of Engineering subsequently intervened and urged Mr. Rush to allow the vehicle to resurface in order to properly assess and rectify the safety hazard. After a back-and-forth argument, Mr. Rush eventually relented, and the ascent was initiated to address the problem.

Dive Number	Date	Dive Location	Dive Time	Max Depth (meters)
C2_0050	4/29/21	Everett Marina	2.8	3
C2_0051	5/2/21	Everett Marina	3.0	7
C2_0052	5/6/21	AO	4.5	79
C2_0053	5/8/21	Possession Sound	4.0	8
C2_0054	5/12/21	Everett Marina	5.0	3
C2_0055	5/14/21	Everett Marina	1.5	3
C2_0056	5/17/21	Big Al	4.9	79
C2_0057	5/19/21	Marina	2.0	3
C2_0058	5/20/21	Hat Isl. South	4.5	170
C2_0059	5/24/21	Marina	2.0	3
C2_0060	5/25/21	Hat Isl. South	4.1	162

Figure 191: TITAN final hull system test dives prior to 2021 TITANIC Expedition. Source: OceanGate.

4.31. Permitting of TITAN's Expeditions to the R.M.S. TITANIC Wreck Site

4.31.1. The relationship between the RMS TITANIC, the U.S. District Court for the Eastern District of Virginia (EDVA), and NOAA is shaped by both legal and regulatory frameworks governing the TITANIC wreck site. The EDVA has constructive in rem admiralty jurisdiction over the TITANIC wreck and granted RMS TITANIC, Inc. (RMST) the status of salvor-in-possession in 1994. That status gave RMST exclusive rights to salvage artifacts from the wreck site. The EDVA's jurisdiction and RMST's salvage rights are central to any activity in the vicinity of the wreck site.

4.31.2. NOAA's role in overseeing the TITANIC wreck site is based on its authority under the RMS TITANIC Maritime Memorial Act of 1986, which designated NOAA as responsible for ensuring the wreck's preservation as a memorial. This was further expanded by Section 113 of the Consolidated Appropriations Act of 2017, which prohibits any person subject to U.S. jurisdiction from engaging in any research, exploration, salvage, or other activity that would physically alter or disturb the TITANIC wreck or wreck site unless authorized by the Secretary of Commerce—a role which is delegated, in part, to NOAA.

4.31.3. While NOAA's authority under Section 113 is distinct from the U.S. District Court's admiralty jurisdiction, the two are interconnected, particularly if activities at the wreck site may conflict with RMST's exclusive salvage rights. NOAA has committed to notifying the U.S. District Court of any projects requiring Section 113 authorization and encourages individuals seeking such authorization to coordinate with both RMST and the EVDA. If a project involves the proposed salvage of any TITANIC artifacts, it must receive prior approval from the EVDA, in addition to receiving NOAA's Section 113 authorization.

4.31.4. In 2019, upon receiving delegated authority to issue Section 113 authorizations, NOAA announced in the Federal Register that anyone proposing research, exploration, salvage, or other activities at the TITANIC wreck site must demonstrate compliance with Section 113, which incorporated provisions contained within an existing international treaty entitled the Agreement Concerning the Shipwrecked Vessel RMS TITANIC. To obtain authorization from NOAA, applicants must provide detailed information about their project, including objectives, methodologies, funding, timelines, team qualifications, safety policies, conservation plans, and potential collaboration with museums or institutions. NOAA also encourages individuals to review its TITANIC Guidelines[43] (2001) and the IMO Circular on Pollution Prevention (2012) when planning their expeditions.

[43] https://www.gc.noaa.gov/documents/recoveryguidelines.pdf

4.31.5. In January 2018, NOAA was informed about OceanGate's plans for a series of what OceanGate defined as "citizen science" missions to the TITANIC wreck during the summer of 2018. By March of 2018, NOAA communicated with OceanGate to discuss these plans, and the agency outlined the need for compliance with Section 113 for any proposed activities. However, a May 7, 2018, letter from NOAA to the U.S. District Court for the Eastern District of Virginia indicated that while there were communications about the expedition, no decisions were made regarding Section 113 authorizations. The expedition was ultimately postponed due to after the first TITAN hull cracked and was retired after testing in the Bahamas.

4.31.6. In 2019, OceanGate communicated extensively with NOAA regarding its plans to conduct six week-long manned dives to the TITANIC wreck site, aiming to survey and document the wreck over several years. In an April 5, 2019, letter to the U.S. District Court EDVA, OceanGate proposed its expedition and claimed that its activities would not disturb the wreck or interfere with RMST's salvage rights. OceanGate also disagreed with Section 113, arguing it was unconstitutional and infringed upon the U.S. District Court's exclusive jurisdiction over the site. In response, NOAA requested more detailed information from OceanGate on April 18, 2019, to determine if a Section 113 authorization was necessary. OceanGate responded on April 29, 2019, in a letter to NOAA that it had already provided all the required information. Nevertheless, NOAA sent a follow-up letter on May 20, 2019, indicating that it still lacked the necessary details to assess if a permit was needed for Section 113 authorization. On May 21, 2019, NOAA updated the U.S. District Court EDVA on the status of multiple expeditions, including OceanGate's. However, by July of 2019, OceanGate announced that their planned 2019 TITANIC Expedition was postponed because the scheduled surface support vessel had withdrawn.

4.31.7. From May 11, 2021, to June 16, 2021, a series of communications occurred between RMST, NOAA, EDVA, and OceanGate regarding OceanGate's planned 2021 summer expedition to the TITANIC wreck site. RMST initially filed a report including the OceanGate plan, prompting NOAA to inform OceanGate that a review of Section 113 applicability was necessary. OceanGate, in turn, filed a letter with EDVA outlining its plans for week-long submersible operations with paying "mission specialists," characterizing the expedition as "look but don't touch." Following a request for specific information from NOAA and OceanGate's subsequent response, NOAA determined that a Section 113 authorization was not needed for the 2021 expedition. This determination was communicated to both OceanGate and EDVA, allowing the expedition to proceed.

4.31.7.1. In the May 18, 2021, letter to the EDVA, OceanGate's former legal representative stated that the TITAN was a Bahamian-registered crewed submersible.

4.31.7.2. The Bahamas Maritime Authority (BMA) confirmed that OceanGate approached them in October of 2019 and requested registration for the first TITAN submersible. However, the BMA stated to the MBI that OceanGate never registered the TITAN with the Bahamas.

4.31.8. On May 20, 2022, NOAA notified OceanGate that Section 113 might apply to their planned expedition to the TITANIC wreck site. Concurrently, OceanGate filed a letter with EDVA detailing a similar expedition plan to 2021 and including a draft science plan. Subsequently, EDVA stated they had no objections, pending concerns from RMST or NOAA. On June 13, 2022, NOAA informed OceanGate that Section 113 authorization was unnecessary, a determination relayed to EDVA.

4.31.9. On July 15, 2022, while on Dive 80, the TITAN deviated from its operational dive plan and subsequently violated OceanGate's stated "look but don't touch" posture by entering the TITANIC wreck site and becoming entangled with TITANIC wreckage. During the TITAN MBI hearing, a mission specialist testified that the TITAN subsequently became entangled in debris in the vicinity of the main stairwell of the TITANIC wreckage. This entanglement contradicted OceanGate's statement to NOAA that; "a mission such as this, which will not be conducting any research, exploration, salvage or other activity that would physically alter or disturb the wreck or wreck site of RMS Titanic, does not fall under Section 113 of the 2017 Act, or the International Agreement concerning the Titanic, as it is a non-disturbance data gathering mission."

4.31.10. OceanGate reported the completion of its 2022 summer expedition to EDVA on November 10, 2022. However, their report failed to mention TITAN's entanglement event during Dive 80, which is in direct violation of Section 113 and inconsistent with the NOAA guidelines. In their letter to the EVDA, OceanGate's former legal representative stated that all activities adhered to established legal precedent and NOAA guidelines, emphasizing a "look but don't touch" approach. The letter further asserted that no disturbance to the TITANIC or interference with RMST's rights occurred, and that no artifacts or samples (other than seawater) were collected.

4.31.11. OceanGate's Draft Science Plan for the 2022 Expedition to the TITANIC outlined OceanGate's science objectives, which focused on understanding the wreck site's biodiversity, physical environment, and condition. It stated that the team was to characterize the fauna around the wreck, documenting species composition, habitat use, trophic positions, and size structure, with particular attention on fish, deep-sea corals, and biofouling communities. OceanGate intended to use HD video, still photography, and benthic sampling to accomplish these tasks. Water samples were also to be collected for environmental DNA (eDNA) analysis to assess biodiversity, with samples coming from the bottom and the different water columns. OceanGate committed to gathering physical oceanographic data, including temperature, salinity, oxygen levels, and current velocities, using a conductivity, temperature, and depth (CTD) instrument mounted on the submersible to measure both water column and benthic profiles. Furthermore, two Nortek Aquadopp current meters were to be deployed to obtain data on bottom water currents, which would be retrieved for analysis after the expedition. Coral dispersal modeling was to continue using the oceanographic data collected, and benthic habitat mapping was to be conducted to assess habitat, and species changes around the wreck. The archaeological investigation aimed to document wreck features, debris, and the rate of suspected deterioration, with sediment samples being taken for pH measurements to gain insights into the wreck's environmental condition. Finally, water samples were to be collected for carbonate chemistry analysis to study the potential effects of ocean acidification on the wreck and its surroundings.

4.31.11.1. In a letter to NOAA dated April 20, 2023, OceanGate outlined its ongoing efforts to share the wreck site's exploration with the public. The letter emphasized that OceanGate Expeditions had continued to release videos and other media content from the site, which were then widely viewed, accumulating over five million views on platforms like YouTube® and various other social media channels. Additionally, OceanGate stated that they had hosted lectures and participated in numerous live interviews with television, radio, and print media outlets. OceanGate also communicated that in collaboration with the OceanGate Foundation, they were including scientists and archaeologists on most of their dives, with these experts actively compiling and analyzing their findings. Furthermore, OceanGate highlighted they partnered with eDNAtec, based in St. John's, Newfoundland, to analyze environmental DNA (eDNA) collected from water samples taken near the TITANIC wreck and from a nearby natural reef site. OceanGate stated that the eDNAtec partnership would be continued during the 2023 TITANIC expedition, with eDNAtec planning to make all gene sequences publicly accessible via GenBank once the collection of samples and analysis were completed.

4.31.12. On May 5, 2023, after OceanGate filed a plan to conduct a 2023 TITANIC expedition similar to their 2021 and 2022 expeditions. NOAA subsequently informed OceanGate that a Section 113 authorization was not necessary for its summer 2023 expedition.

4.31.13. NOAA ultimately determined that OceanGate did not require a Section 113 authorization for its 2021, 2022, and 2023 TITANIC expeditions because those expeditions would not physically alter or disturb the TITANIC wreck or wreck site. NOAA made these determinations based on information regarding the expeditions that was provided to the U.S. District Court for the EDVA, submitted to NOAA upon request, which were also posted on OceanGate's website. In reviewing this information, NOAA considered the objectives and methods for OceanGate's expedition, and determined it was unlikely that TITAN operations would physically impact the wreck or wreck site.

Titan does **not** have manipulator arms or any means of retrieving artifacts from the sea floor. No salvage or retrieval of artifacts, coal or rusticles will be conducted. All of the operations planned for the *Titanic* site will be "look but don't touch" in accordance with the type of expeditions expressly authorized by the United States Court of Appeals for the Fourth Circuit in *Haver*, 171 F.3d at 969-71. Any ballast dropped by the submersible will be deposited well clear of the wreck. No additional material will be deposited, and no black water or grey water will be discharged within 15 nautical miles of the wreck site.

Figure 192: Excerpt from OceanGate's letter to NOAA dated April 20, 2023. The notification letter of their 2023 TITANIC Expedition, highlighted that TITAN's operations would "look but don't touch" any TITANIC wreckage or artifacts. Source: NOAA.

Based on the foregoing, NOAA understands that, as in previous years, OceanGate and any agent or contractor for the proposed 2023 expedition will:

- Not discharge garbage, blackwater, graywater, and any other discharges incidental to the operation of OceanGate's expedition vessel within 15 nautical miles of the wreck site;
- Avoid any activities that would physically alter or disturb the wreck or wreck site (including the seabed), including any contact with or landing on *Titanic*;
- Not install, attach, or place any plaques, memorials, or other temporary or permanent fixtures on *Titanic*;
- Not enter, or attempt to enter, with a submersible, ROV, or other devices, sensors, or probes either of the hull pieces;
- Maintain the submersible and its subsystems (*i.e.*, weights, drop weights, skids, appendage) as well as any ROV a sufficient distance from the wreck so as to avoid coming into contact with it on all dives or attempted dives in either normal or emergency operation modes and procedures; and
- Not drop or deposit intentionally or unintentionally any weights or equipment such that they would land on or near the wreck. In all cases, weight or items dropped will be done in accordance with International Maritime Organization Circular MEPC.1/Circ.779 (31 January 2012).

Figure 193: Excerpt from May 5, 2023, NOAA letter to OceanGate exempting OceanGate's 2023 Expeditions from Section 113 authorization. Source: NOAA.

4.31.13.1. Because NOAA determined that OceanGate did not require a Section 113 authorization for its manned dive missions, NOAA lacked the authority to require OceanGate to submit post expedition reporting or other information.

4.32. Canada Fisheries and Oceans Letter of Support

4.32.1. In a May 19, 2021, letter to OceanGate's CEO (Mr. Rush) from Canada's Department of Fisheries and Oceans (DFO), the DFO expressed support for OceanGate's efforts, stating, "DFO supports and advances marine conservation across the country… with the stated goal of increasing protected areas and advancing scientific research." The letter highlighted DFO's intent to collaborate with OceanGate starting in

2021 to assess the potential of its manned submersibles for scientific research, noting that OceanGate's systems offered a unique opportunity for Canadian scientists to explore deep-water ecosystems, a capability that was not available at the time with Canadian equipment.

4.32.2. The DFO also indicated that it would use OceanGate's 2021 expedition as an opportunity to evaluate the TITAN's capabilities, with one of its members participating in the mission. However, while this individual was listed as a passenger for the 2021 expedition, the DFO representative was not recorded in the 2021 expedition dive logs as participating as a crew member on a TITAN dive.

4.32.3. Additionally, the DFO letter outlined plans for further collaboration with OceanGate by stating, "DFO would like to conduct further discussions in the fall to identify and secure opportunities to use the submersibles in priority sites off Canada in 2022 and beyond." The letter mentioned that these discussions could lead to financial contributions for future missions, with an initial contribution of $25,000, plus in-kind support, planned for 2022 to help cover ship time costs.

4.32.4. The MBI did not find evidence of any further collaborations beyond the 2021 TITAN expedition between DFO and OceanGate or evidence of any actual contributions from DFO to OceanGate.

4.33. 2021 OceanGate TITANIC Expedition

4.33.1. On June 4, 2021, pre-deployment checks were completed for the TITAN in Everett, Washington in preparation for the cross-country trip to St. John's, Newfoundland and Labrador, Canada for the 2021 TITANIC Expedition. The TITAN and LARS were transported on a flatbed truck to the A Harvey & Company Marine Base facility in St. John's, where they were subsequently loaded onto the stern of the expedition's support vessel, the HORIZON ARCTIC.

4.33.2. The HORIZON ARCTIC is a 93.6 m (307 foot) Canadian flagged multipurpose OSV, owned and operated by Horizon Maritime Services, a Canadian marine services company. The vessel is specifically designed for a range of operations, including offshore support, icebreaking, and research expeditions in Arctic and sub-Arctic regions. It is equipped with advanced technology for carrying out tasks such as ice management, surveying, and subsea operations, making it suitable for challenging marine environments.

Figure 194: Offshore Supply Vessel HORIZON ARCTIC. Source: MarineTraffic @Jake McNaughton.

4.33.3. On June 24, 2021, the HORIZON ARCTIC crew loaded the TITAN, LARS, and all of TITAN's support equipment aboard the vessel.

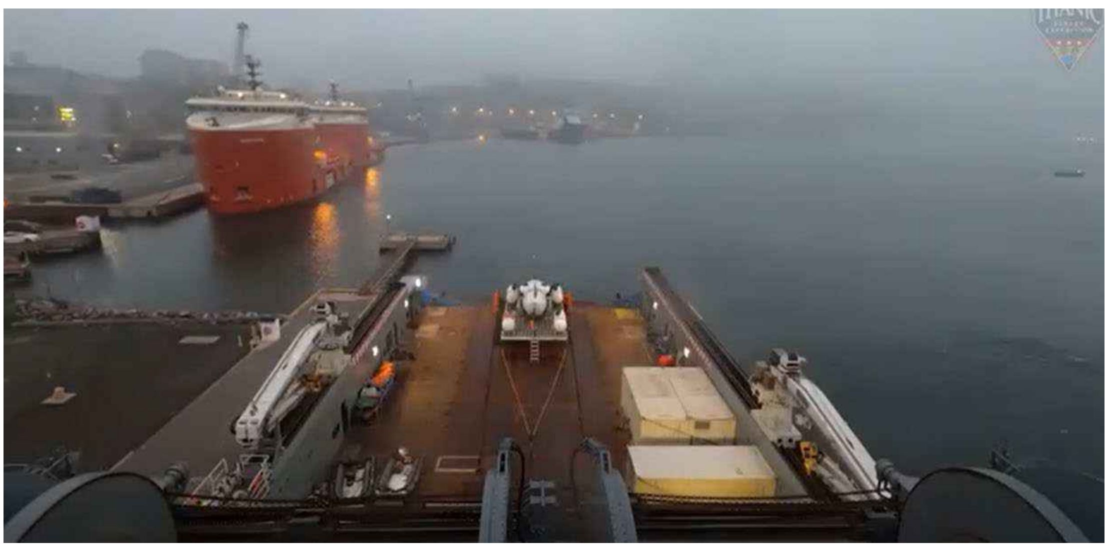


Figure 195: TITAN loaded on the stern deck of the HORIZON ARCTIC prior to the start of the 2021 Expedition. Source: OceanGate Expeditions.

4.33.4. On June 28, 2021, Expedition 2021 officially began with the signing of and raising of the 2021 TITANIC Survey Expedition Mission 1 flag. According to the OceanGate Blog, the vessel transit from St. John's to the TITANIC wreck site was expected to take approximately 40 hours.

Figure 196: TITAN launch and recovery ramp deployed from the stem of the HORIZON ARCTIC on June 29, 2021. The HORIZON ARCTIC served as TITAN's support vessel during the 2021 and 2022 TITANIC Expeditions. Source: OceanGate.

Figure 197: TITAN astern of the HORIZON ARCTIC prior to commencing a dive during the 2021 expedition. Source: OceanGate Expeditions.

4.33.5. OceanGate's dive count for the TITAN submersible was a cumulative total encompassing dives conducted with both the original and final hull. The first TITAN hull was used for 49 dives before being scrapped. The dive counter for the final TITAN hull, the one involved in the catastrophic incident, began at Dive 50. Prior to the 2021 TITANIC expedition, which aimed to reach a depth of 3840 meters, the final TITAN hull had only completed 11 operational dives, reaching a maximum depth of 170 meters.

C2_0050	4/29/21	Everett Marina	2.8	3
C2_0051	5/2/21	Everett Marina	3.0	7
C2_0052	5/6/21	AO	4.5	79
C2_0053	5/8/21	Possession Sound	4.0	8
C2_0054	5/12/21	Everett Marina	5.0	3
C2_0055	5/14/21	Everett Marina	1.5	3
C2_0056	5/17/21	Big Al	4.9	79
C2_0057	5/19/21	Marina	2.0	3
C2_0058	5/20/21	Hat Isl. South	4.5	170
C2_0059	5/24/21	Marina	2.0	3
C2_0060	5/25/21	Hat Isl. South	4.1	162
C2_0061	6/30/21	Titanic	2.6	7
C2_0062	7/3/21	Titanic	5.8	1700

Figure 198: Excerpt of final TITAN hull Dive Log from first ever operational dive to start of 2021 TITANIC Expedition. Source: OceanGate.

4.33.6. On June 30, 2021, after arrival to the coordinates of the TITANIC wreck site, the TITAN conducted its first dive on the site, which was recorded as Dive 61. The dive had a total of five persons onboard: Mr. Rush as the pilot, two other OceanGate personnel, a TITANIC content expert, and a mission specialist who paid $100,000 for the dive. The max depth achieved on the dive was 7 m (23 feet) and OceanGate's notes from the dive indicated that the TITAN experienced a "DVL[44] failure."

4.33.7. After the aborted drive the TITAN and LARS were towed back to the stern of the HORIZON ARCTIC for recovery operations. While the TITAN and LARS were being pulled up the stern ramp and onto the stern of the HORIZON ARCTIC, OceanGate experienced their first "incident" of the 2021 expedition when the forward 3,000 lb titanium dome sheared off of the TITAN and landed on the front of the LARS (see Figure 199). According to TITAN's Maintenance Log, the forward dome was subsequently inspected, reinstalled, and an incident report was completed. The MBI was unable to obtain the incident report filed for the incident. However, OceanGate witnesses testified to the MBI that the dome and installed viewport did not appear to have sustained any damage from the fall. Following the incident, the OceanGate Blog stated, "Necessary adjustments to our operation were notated and a collaborative action plan was developed and implemented. Challenges at sea are often unforeseen and require flexible, creative, and intelligent problem-solving skills."

[44] A DVL is a doppler velocity logger, it uses echo sounding to determine velocity of an underwater vehicle, distance from seabed and other objects, and other environmental characteristics, such as current speed and direction.

Figure 199: TITAN and the LARS positioned on the aft deck of the HORIZON ARCTIC after the forward dome fell onto the LARS during TITAN recovery operations on June 30, 2021. Source: HORIZON ARCTIC crew member.

4.33.7.1. According to OceanGate's Director of Engineering at the time of the 2021 TITANIC expedition, as the TITAN and platform were being pulled up the ramp, it transitioned hard as it reached the horizontal aft deck and the bolts that held the dome on sheered from the weight of the dome. He stated that there were only four of the 18 stainless steel bolts being used to secure the forward dome post-dive. The Director of Engineering stated that prior to the incident, Mr. Rush had directed that only four bolts be used to secure the dome post-dove because he wanted to be able to get the crew in and out of the TITAN quicker and removing or securing 18 bolts took too long. After the incident, according to the Director of Engineering, OceanGate procedures changed, and the dive support crew installed all of the forward dome's 18 bolts for every evolution. A mission specialist, who was aboard the HORIZON ARCTIC at the time, provided the following MBI hearing testimony:

> "When they were pulling it back up onto the deck, I believe what happened was that it came up and the crane was pulling it up the ramp. It got to a point where it was seesawing, you know, the flat plane of the deck and then there's the angled plane of the ramp, which is steep, probably a little too steep. But, again, this was all experimental and we were feeling our way through it.
>
> So, it was teetering back and forth and then the crane operator let it go a little bit too abruptly, and it slammed down on the deck with quite a bit of force.
>
> Now, the complicating factor was that a decision had been made to only install four of the bolts in the 3,500-pound titanium dome. That decision was

made, I was there when the decision was made, I was not, I did not articulate any opinions one way or the other.

The thought was that once the ship went, or the TITAN went to depth, that the pressure would be so intense that you didn't need any bolts. You wouldn't be able to pry it off with a jack. They were trying to minimize the time it took to get the mission specialist out of the TITAN after the mission ended. That decision was made."

4.33.8. On July 3, 2021, the final TITAN dove (Dive 62) to 1,700 m (5,577 feet) with two OceanGate crew, one content expert and one mission specialist who paid $150,000 for the excursion. Due to the dome incident on the previous dive, OceanGate initially planned the dive for OceanGate employees only as a safety check. However, the plan was changed after a mission specialist voiced a strong desire to join the dive despite the risk. While on the dive at 1,700 m, the starboard thrusters failed after a popping sound was heard. During the initial descent of the TITAN submersible, the crew faced significant challenges due to improper weight distribution, causing the vessel to spiral slowly instead of descending in a controlled manner at a gradual angle. This drift, combined with ocean currents, left the crew operating the TITAN at an unusual pitch and off course. Communications with the surface were sporadic, and the TITAN's limited sonar range of only 100 yards made navigation difficult. The situation worsened when one of the thrusters failed. To regain control and ascend, the crew decided to jettison their weights. After one of the pipe weights became stuck, the crew of the TITAN had to physically rock the TITAN back and forth to help dislodge the drop weight. After approximately 20 minutes, the TITAN began to ascend and make its way back to the surface. Up until that point, the final TITAN had only completed 12 dives, with an average depth of 43.9 m (144 feet).

4.33.8.1. The mission specialist who successfully persuaded Mr. Rush to let him join Dive 62, testified to the MBI that he affirmed to Mr. Rush that he was comfortable with the risk, and he reminded Mr. Rush that OceanGate had guaranteed that he would be able to participate in a TITANIC dive.

4.33.8.2. Additional issues encountered during Dive 62 included: two drop weights jammed in the starboard channel, anomalous "hits" on acoustic sensors #1 and #3 (later attributed by OceanGate to non-mechanical sources), intermittent DVL functionality, and an external hull high-pressure valve being incorrectly positioned for the dive.

Figure 200: TITAN being launched from the aft deck of the HORIZON ARCTIC as it prepares for Dive 62 on July 3, 2021. Source OceanGate.

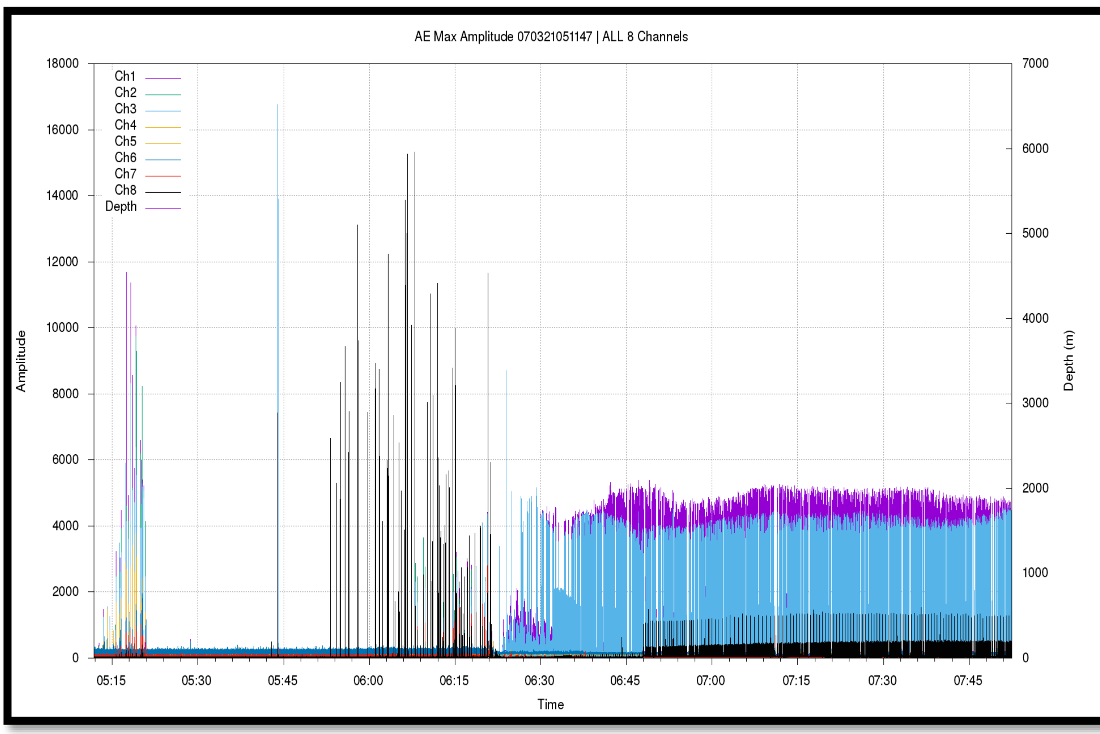


Figure 201: TITAN's acoustic emissions for Dive 62. Source: OceanGate.

4.33.9. On July 6, 2021, Mission 1 of the 2021 expedition was completed. Mission 1 included two dives, which resulted in two incident reports, and 19 issues recorded in TITAN's maintenance log.

Date	Dive Number	Issue	Dive Critical (Yes/No)	Open/ Closed	Solution
6/30/2021	C2_0061	Incident - Forward dome fell off during recovery to ship	Yes	Closed	Inspected and reinstalled - Incident report completed
6/30/2021	C2_0061	DVL not working	No	Closed	Duplicate entry see later entry for resolution
6/30/2021	C2_0061	Floor and toilet damaged when dome fell off	No	Closed	Repaired and reinstalled
7/1/2021		Need CTD for Titanic dive	No	Closed	Rented CTD installed on laser scanned mount
7/2/2021		Sonardyne not communicating with software	No	Closed	Software updated and tested with transducer in the water
7/3/2021	C2_0062	Incident - External hull HPA valve set in wrong position for dive	Yes	Closed	
7/3/2021	C2_0062	Starbord control pod failed at 1,700m after pop sound heard 0 vaccum 0 temp green water alarm	Yes	Closed	Control cable found broken at connector joint area. Cable replaced and tested OK
7/3/2021	C2_0062	Two drop wieghts jammed in stbd channel	Yes	Closed	Wts removed, surface of rail smoothed future wieghts to have more ground edges and greased with heavier grease
7/3/2021	C2_0062	#1 and #3 Acoustic sensros have extreme and unusual events - thousands of hits with 5000-6000 levels only. All other sensors appear normal	No	Closed	Disconnected not needed evaluate for EMI on annual
7/3/2021	C2_0062	Dome hinge retention plate bent	No	Closed	Repaired
7/3/2021	C2_0062	DVL intermittent	No	Closed	Rewired to use GPS cables and tested OK
7/3/2021	C2_0062	External lights flickering and drawing 14 amps	No	Closed	Could not duplicate on surface locking collars installed
7/3/2021	C2_0062	Pan and tilt not functional	No	Closed	
7/3/2021		Port Ictineu battery will not turn on	No	Closed	Replaced BMS board. Removed communications cable to avoid future failures as Elmo board can provide amp and voltage information
7/3/2021	C2_0062	Rear axis camera mount broken	No	Closed	Mount replaced
7/3/2021	C2_0062	Sub comes off platform in rough launch	No	Closed	Installed automatic locking mechanism per CRB
7/7/2021		Stbd horizontal thruster found leaking at main power connector	Yes	Closed	Removed thruster replaced connector with new, reinstalled and calibrated
7/7/2021		Platform float cables found to be different lengths	No	Closed	Replaced two cables with new to match
7/7/2021		Port vertical thruster sticky when turned by hand	No	Closed	Replaced with spare thruster and re calibrated

Figure 202: Excerpt of the final TITAN's Maintenance Log for Dive 61 and 62. Source: OceanGate.

4.33.10. On July 7, 2021, Mission 2 of 2021 TITANIC Expedition commenced.

4.33.11. On July 9, 2021, the final TITAN conducted Dive 63 with Mr. Rush, a Co-pilot and one content expert. The dive lasted 16 hours and reached a depth of 3,840 m (12,598 feet). This was the first time the final TITAN hull made it to the depth TITANIC wreck site. However, during the dive the TITAN had difficulty with tracking its locations and did not ultimately locate the TITANIC wreck.

4.33.11.1. To clarify the TITAN's navigation capabilities at depth, a mission specialist told the MBI, "The TITAN's sonar range is limited to approximately 100 yards. At the ocean floor, this effectively means operating blindly until within that proximity to an object. Given the vastness of the search area, it's entirely possible to descend and completely miss the TITANIC."

4.33.11.2. During Dive 63, the electric motors controlling TITAN's drop weight system failed and the crew was unable to surface on schedule. The crew aboard the TITAN attempted to repair the malfunction by rewiring the drop weight motor actuator, but their efforts were unsuccessful. The crew then tried to dislodge the weights from the tray by rocking the submersible, but this approach also failed. Unable to release the weights through either method, it became necessary to jettison the entire drop weight tray, which enabled the TITAN to ascend to the surface. The failure of the drop weight system was classified by OceanGate as an "incident" following the dive, and a formal report was subsequently filed according to witnesses interviewed by the MBI. However, the MBI was not provided with a copy of the incident report during the investigation. Additionally, during the same dive, the TITAN's aft port fairing was detached, the Blue View sonar system became inoperative, and the DVL experienced intermittent functionality.

4.33.11.3. OceanGate's Director of Logistics who also served as co-pilot of the TITAN during Dive 63 made the following statement to the MBI: "Heard what I thought was what Stockton had described as a, as a -- he described the sound of a -- the carbon fiber cracking as a, as a slap of the ruler on the table, and the -- and I heard a sound related to that on one dive at depth, but that was the only one, one incident of that."

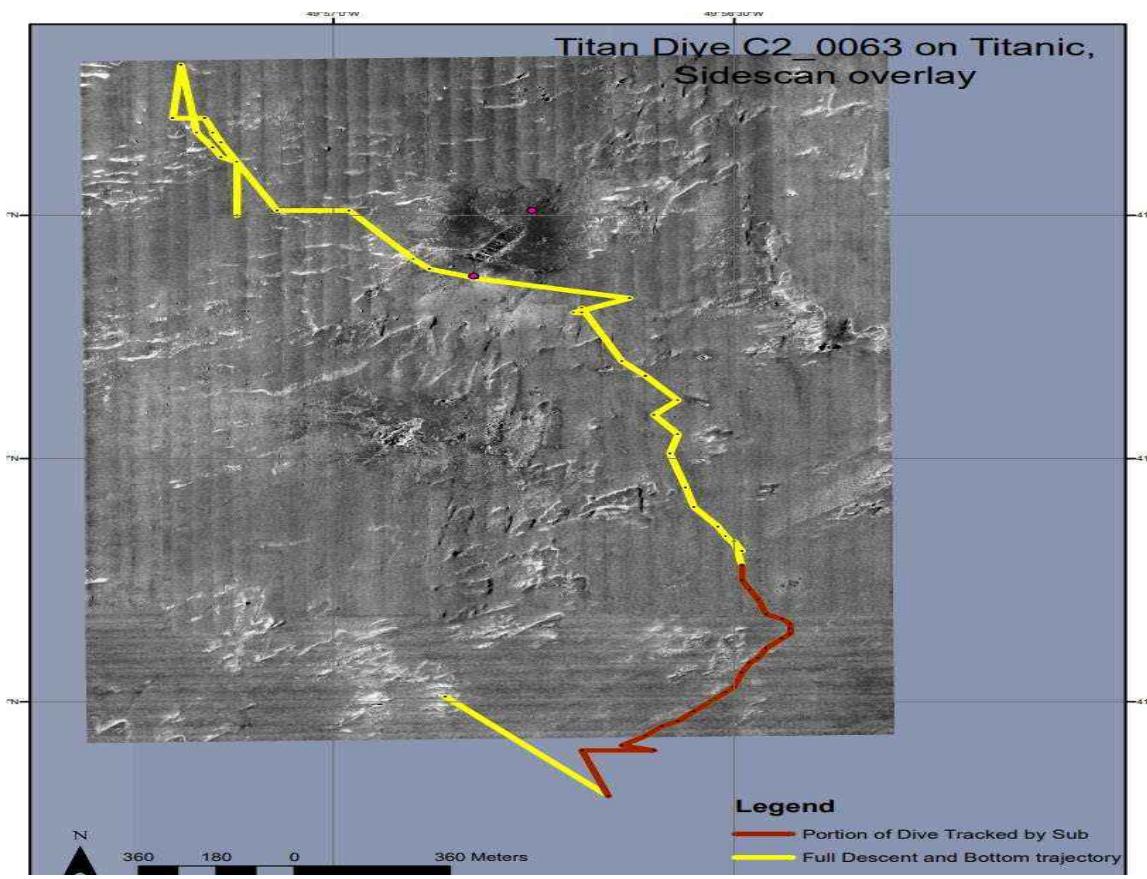


Figure 203: TITAN Dive 63 track is indicated by the yellow and red line. The TITANIC wreck's bow and stern are identified by two pink dots. Source: OceanGate.

Figure 204: Image of the final TITAN hull after surfacing from Dive 63. Source: HORIZON ARCTIC crew member.

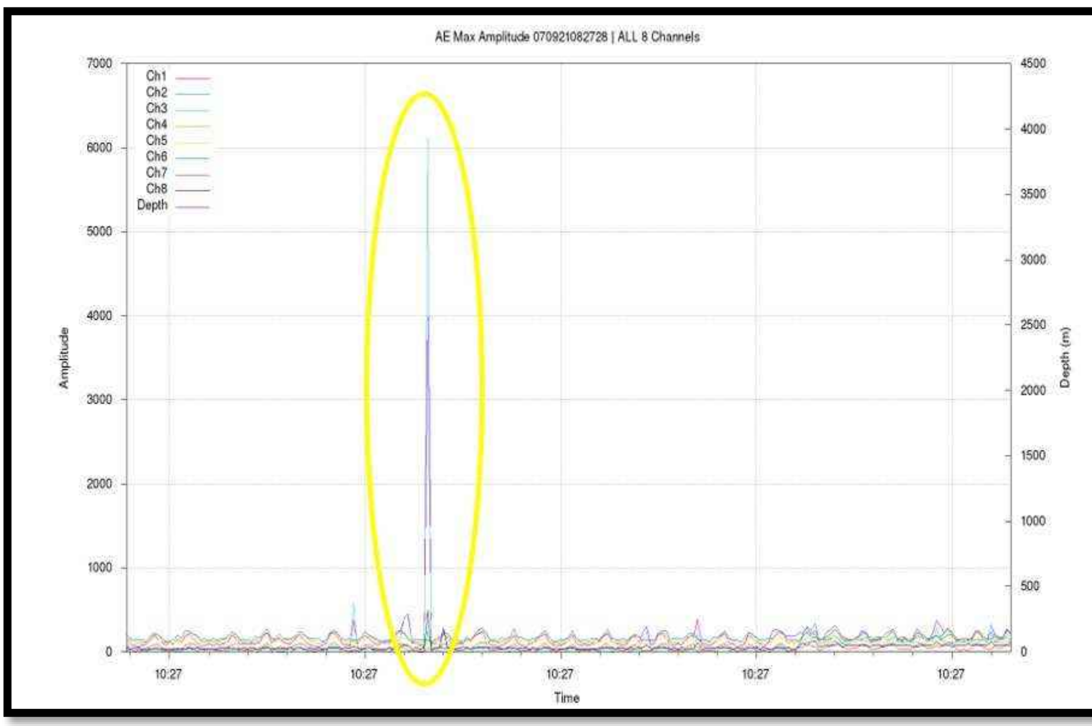


Figure 205: TITAN Dive 63 Acoustic Emissions chart showing the data recorded from a "ruler slap" sound (highlighted in the yellow circle added by MBI). The sound was heard by OceanGate's co-pilot on the mission. Source: OceanGate.

4.33.12. On July 13, 2021, TITAN conducted a system's test dive (Dive 64) in Witless Bay, Newfoundland. The TITAN's drop weights continued to experience deployment issues. The TITAN's Maintenance Log for the dove included the following statement: "Drop weight motors would not drop. Drop weight motors running in reverse."

4.33.13. On July 15, 2021, Mission 2 was completed. Mission 2 included two dives (one to TITANIC depth), which resulted in one incident report, and 16 maintenance issues recorded in TITAN's maintenance log.

Date	Dive Number	Issue	Dive Critical (Yes/No)	Open/ Closed	Solution
7/9/2021	C2_0063	Dropweight carriage/mechanism dropped.	Yes	Closed	Replaced drop weight system including new motors and all associated parts. Tested OK
7/9/2021	C2_0063	Incident - Drop weight tray jettisoned due to failed electric drop weight motors	Yes	Closed	Incident report complete chnages implemented
7/9/2021	C2_0063	Aft port fairing ripped off	No	Closed	Repaired and reinstalled
7/9/2021	C2_0063	Blueview sonar inoperative	No	Closed	Cable found with <100megohm resistance in two lines. Switched to unused twisted pair circuit and tested OK
7/9/2021	C2_0063	DVL intermittent	No	Closed	Cable found with <100megohm resistance in two lines. Switched to unused twisted pair circuit and tested OK
7/9/2021	C2_0063	External LED flights flicker and will ot dim	No	Closed	LED driver circuit found overheating, heatsniks ordered OK to dive if power kept below 80%. Heat sink added.
7/9/2021		Operating Manual, drawings and Titan checklist need modification for passive locking system	No	Closed	Test locking mech installed on platform
7/9/2021	C2_0063	SubC 4K camera has a round halo in middle of screen	No	Closed	Could not duplicate on 89m dive
7/9/2021	C2_0063	VBT motor seems slow 90 seconds to run vs 50 prior	No	Closed	Motor found to be slipping on shaft, locking pin tightened
7/13/2021	C2_0064	Port drop weight motor would not drop	Yes	Closed	weight found jammed installed mud flap to ensure even deployment of weight. Tdropped 12 weights tested OK.
7/13/2021		Dropweight motors running in reverse	No	Closed	Motor + and - swapped. Motors tested OK
7/13/2021	C2_0064	Sonar seem noisy in display	No	Closed	Replaced patched cable with new
7/13/2021		Sub needs second backup sonar	No	Closed	Installed Oculus sonar, mount, wired to spare penetrator and added software to media computer
7/17/2021		Incident - Electrical cable fire in forward dome from dehumidifier	Yes	Closed	Incident report completed, sub inspected and no damage

Figure 206: Excerpt of final TITAN's Maintenance Log for Mission 2 of 2021 Expedition. Source: OceanGate.

4.33.14. On July 16, 2021, Mission 3 commenced and the OceanGate Blog stated, "Although travel restrictions have imposed additional challenges to our crew, we are excited to celebrate the start of Mission 3, TITANIC Survey Expedition 2021. Every mission begins with the signing and raising of a new OceanGate Expeditions flag. Mission 3 is now officially underway, and we look forward to much success. The HORIZON ARCTIC is steaming towards the TITANIC dive site coordinates, marking the official start of Mission 3. The OceanGate Expeditions team and the HORIZON ARCTIC crew conduct pre-dive briefs for ship-sub integration. Both crews work in unison to ensure the expedition goals are achieved."

4.33.15. On July 19, 2021, during Dive 65 the TITAN reached the TITANIC wreck site with a crew of five that included Mr. Rush as the pilot, a co-pilot, a researcher from the University of Rhode Island, and two mission specialists. While in the vicinity of the TITANIC wreck site, the TITAN encountered another problem with its drop weight system, similar to Dive 63, which prevented the crew from releasing the drop weights. As an alternative, the crew attempted to thruster all the way to the surface. However, as the TITAN began its ascent under thruster power from its depth of 3,300 m (10,827 feet) at an ascent rate of 9 m per minute, it rapidly consumed its battery power.

```
7/19/2021 14:15:47.515,<SMS:5509;W1;TS3;RTS3,P0,A1,B0| NOT ABLE TO DROP WEIGHTS.   THRUSTING TO SERVICE
7/19/2021 14:19:14.338,<SMS:5509;W1;TS3;RTS3,P0,A1,B0| NOT ABLE TO DROP.THRUSTING UP
7/19/2021 14:21:28.472,<SMS:5509;W1;TS3;RTS3,P0,A1,B0| NOT ABLE TO DROP. THRUSTING UP
```

Figure 207: Excerpt of TITAN's chat messages to the HORIZON ARCTIC for Dive 65. Source: OceanGate.

4.33.15.1. According to communications from the ATM system, the TITAN's crew inquired with their surface support team on the HORIZON ARCTIC about the temperature at the TITANIC wreck site, because they were contemplating the potential need to descend back to the ocean floor and remain there until the TITAN's squibs released the emergency drop weights. As previously described in Section 4.29.3.6, the squibs were in place as a safeguard to release weights automatically after a dive duration of approximately 24 hours in case of an emergency that prevented the use of TITAN's primary drop weight systems.

4.33.15.2. The Mission Director who was overseeing Dive 65 from the ARTIC HORIZON instructed the pilot (Mr. Rush) to return to the surface by dropping the TITAN's weight tray. However, Mr. Rush responded by asking for more time to consider the Mission Director's order. Mr. Rush was reluctant to release the TITAN's weight tray because there were no spare weight trays available and doing so would prevent the TITAN from conducting any additional dives for the remainder of the expedition. Instead, Mr. Rush remained persistent that he would rather wait the 24 hours for the sacrificial squibs to discharge the additional weight required to allow TITAN to ascend slowly to the surface. The Mission Director for Dive 65 provided the following testimony to the MBI:

> "In the sub, we have -- the word I got from the – another crew member of the sub was that Stockton went around to each passenger or mission specialist, and he said, are you, are you willing to stay down here for 24 hours because if you don't, the company's going out of business. So, he pressured those people to say, 'yes.' The only person who, from my understanding, wasn't in the conversation, but from firsthand information afterwards, the only person that said no was NAME REDACTED (the co-pilot)[45], sorry, one of copilots, and he, he basically texted up to us saying, "I'm, you know, I'm done. Call

[45] Name redacted / position inserted by MBI.

my wife, tell her get me a plane ticket, I'm saying, right, because when I get back up, I'm quitting."

```
7/19/2021 16:54:38.854,>SMS:5509| DROP TRAY?
7/19/2021 16:55:29.410,<SMS:5509;W1;TS3;RTS3,P0,A1,B0| NO DROP TRAY HEADING TO BOTTOM
7/19/2021 16:55:53.968,>SMS:5509| A
7/19/2021 16:56:03.408,<SMS:5509;W1;TS3;RTS3,P0,A1,B0| TELL MY WIFE WHAT IS GOING ON TONIGHT
7/19/2021 16:57:16.103,>SMS:5509| WILL TELL [redacted]
7/19/2021 16:57:52.782,<SMS:5509;W1;TS3;RTS3,P0,A1,B0| BUY ME PLANE TICKET
7/19/2021 16:58:24.087,>SMS:5509| A
7/19/2021 16:59:53.363,<SMS:5509;W1;TS3;RTS3,P0,A1,B0| K
7/19/2021 17:00:06.552,<SMS:5509;W1;TS3;RTS3,P0,A1,B0| DEPTH UPDTES AS WE GO PLEASE
7/19/2021 17:00:37.439,>SMS:5509| RECOMMEND DROP THE TRAY. SEE YOU AT 2375 MTRS
7/19/2021 17:02:44.980,>SMS:5509| RECOMMEND DROP THE TRAY. SEE YOU AT 2420 MTRS
7/19/2021 17:06:48.772,>SMS:5509| RECOMMEND DROP THE TRAY. SEE YOU AT 2500 MTRS
7/19/2021 17:07:45.216,>SMS:5509| UNLESS ALL IN FAVOR MISSION DIR SAYS DROP TRAY
7/19/2021 17:08:45.205,>SMS:5509| UNLESS ALL IN FAVOR MISSION DIR SAYS DROP TRAY
7/19/2021 17:09:57.311,>SMS:5509| UNLESS ALL IN FAVOR MISSION DIR SAYS DROP TRAY. 2550 MTRS
7/19/2021 17:12:16.919,>SMS:5509| UNLESS ALL IN FAVOR MISSION DIR SAYS DROP TRAY. 2600 MTRS
7/19/2021 17:13:55.181,>SMS:5509| NEED COMMS FROM YOU
```

Figure 208: TITAN Dive 65 ATM communication between the TITAN and the surface support team (SMS:5509). Source: OceanGate.

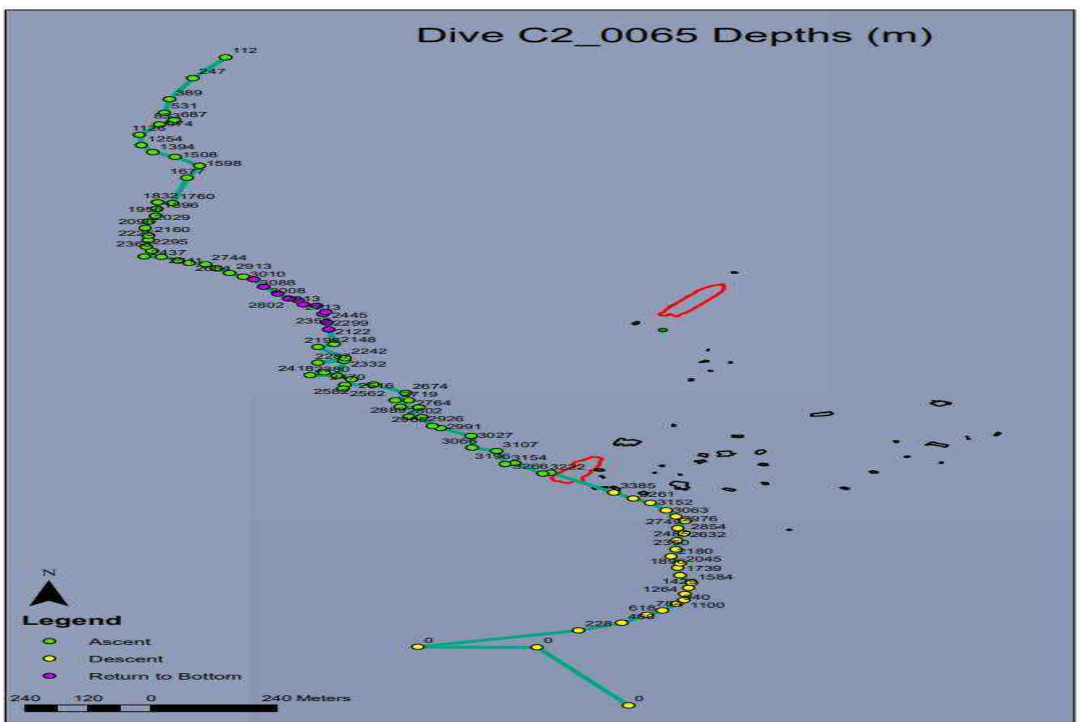


Figure 209: TITAN Dive 65 dive profile. Starting from the bottom of the graphic, the yellow dots indicate TITAN's initial descent, the green dots indicate TITAN's initial attempt to ascend with thrusters, the purple dots indicate TITAN's redescent after its thrusters used up the battery power, and the last set of green dots indicate TITAN's final ascent to the surface after partially releasing the drop tray. Source: OceanGate.

4.33.15.3. After 3.5 hours of troubleshooting and redescending to the bottom, the crew aboard the TITAN was able to manipulate the hydraulic pump for the drop weight tray just enough to release a portion of the tray's weights needed to resurface, without releasing the entire tray.

4.33.15.4. The co-pilot who stated, "TELL MY WIFE WHAT IS GOING ON TONIGHT. BUY ME PLANE TICKET" over TITAN's ATM system, departed the expedition once the HORIZON ARCTIC returned to St. John's and the former co-pilot was never part of any other OceanGate dives.

Figure 210: TITAN partially submerged with HORIZON ARCTIC in the background during Dive 65. Source: Former OceanGate Director of Operations.

4.33.16. From July 24 to 28, 2021, the TITAN completed three dives (Dive 66, 67, and 68) to the depth of the TITANIC. On dives 67 and 68, the LARS sustained damage while returning to the HORIZON ARCTIC.

4.33.17. On July 28, 2021, Mission 4 was completed. Mission 4 included four dives (three to TITANIC depth), which resulted in two incidents and 17 maintenance issues recorded in TITAN's maintenance log.

4.33.18. The TITAN completed two additional TITANIC dives on Mission 5. On August 6, 2021, the OceanGate TITANIC Expedition 2021 came to an end. During the expedition the TITAN made ten dives with six reaching the TITANIC wreck site. OceanGate recorded zero acoustic incidents in their dive log over the 10 dives. During 2021 Expedition, OceanGate documented 72 "issues" in the maintenance log and recorded that the TITAN experienced six incidents. The MBI was not provided with any of the six incident reports referenced in TITAN's maintenance log from the 2021 Expedition.

Date	Dive Number	Issue	Dive Critical (Yes/No)	Open/ Closed	Solution
6/30/2021	C2_0061	Incident - Forward dome fell off during recovery to ship	Yes	Closed	Inspected and reinstalled - Incident report completed
7/3/2021	C2_0062	Incident - External hull HPA valve set in wrong position for dive	Yes	Closed	
7/9/2021	C2_0063	Incident - Drop weight tray jettisoned due to failed electric drop weight motors	Yes	Closed	Incident report complete chnages implemented
7/17/2021		Incident - Electrical cable fire in forward dome from dehumidifier	Yes	Closed	Incident report completed, sub inspected and no damage
7/19/2021	C2_0065	Incident - Drop weight motor failure at depth	Yes	Closed	CRB - Removed drop weight carriage replaced with hydraulic drop system and Stockton Roll weights
7/28/2021	C2_0067 and C2_0068	Incident - Platform sustained damage on return to vessel	Yes	Closed	

Figure 211: Excerpt of TITAN "Incidents" from the maintenance log for Expedition 2021. Source: OceanGate.

Dive Number	Date	Dive Location	Dive Time	Max Depth (meters)
C2_0061	6/30/21	Titanic	2.6	7
C2_0062	7/3/21	Titanic	5.8	1700
C2_0063	7/9/21	Titanic	16.0	3840
C2_0064	7/13/21	Witless Bay	4.9	89
C2_0065	7/19/21	Titanic	11.3	3500
C2_0066	7/24/21	Titanic	10.7	3840
C2_0067	7/27/21	Titanic	9.5	3840
C2_0068	7/28/21	Titanic	11.1	3840
C2_0069	8/4/21	Titanic	10.7	3840
C2_0070	8/5/21	Titanic	10.8	3840

Figure 212: OceanGate TITANIC Expedition 2021 excerpt from the dive log summarizing the dive's completed. Source: OceanGate.

4.33.19. Upon completion of the TITANIC Survey Expedition 2021, the TITAN and LARS platform were demobilized off the HORIZON ARCTIC, placed on the back of a flatbed truck and transported back to the United States.

4.33.20. Rather than returning the TITAN directly back to their facility in Everett, Washington, OceanGate initiated a seven-month roadshow to visit educational institutions, country clubs, and adventure clubs to advertise TITAN and help build future business. OceanGate's Director of Engineering at the time provided the following statement to the MBI:

> "So they were going to bring the sub back in March and we're going to have April, maybe March, I don't know, April, May, and we're going to be gone by

June. So that gives us 8 weeks to fix the sub instead of the 9 months that we should probably have."

4.33.20.1. The TITAN's roadshow visited sites throughout the U.S. including engagements at the University of Rhode Island in Kingston, Rhode Island; the Princeton Club in Lake Forest, Illinois, and multiple other locations until February of 2022.

4.34. 2022 OceanGate TITANIC Expedition

4.34.1. Over the course of the winter prior to TITANIC Expedition 2022, OceanGate's Director of Engineering was fired and an existing member (software engineer) of the OceanGate team was promoted to Director of Engineering. The operational plan for OceanGate's TITANIC Expedition 2022 was similar to 2021. OceanGate contracted the HORIZON ARCTIC as the support vessel, for six missions scheduled to commence on June 14 and end on July 25, 2022.

4.34.2. On May 25, 2022, the TITAN and its associated equipment departed Everett, Washington by flatbed truck for the cross-country drive to St. John's, Newfoundland for the 2022 expedition.

Figure 213: TITAN and a container of equipment loaded on a flatbed departing Everett, Washington for TITANIC Expedition 2022 on May 25, 2022. Source: Former OceanGate Director of Operations.

4.34.3. Mission 1 of TITANIC Expedition 2022 began on June 16, 2022. According to OceanGate records, there were 23 passengers who had paid to be "mission specialists" for the 2022 expedition or who were holdovers from the 2021 expedition. A holdover was a mission specialist who did not get the opportunity to conduct a dive during the 2021 expedition and therefore was allowed to return for a second opportunity for a TITANIC wreck site dive.

4.34.4. The first dive in 2022 was Dive 72 on June 18, 2020, which reached a maximum depth of 1,380 m (4,528 feet) and lasted 6.3 hours. While returning to the support ship (HORIZON ARCTIC), the LARS platform suffered damage, and the aft fairings were torn off.

4.34.5. On June 20, 2022, TITAN and crew conducted Dive 73, which reached a maximum depth of 3,840 m (12,598 feet) and lasted for 27 hours. This was the longest recorded TITAN dive ever conducted. A mission specialist on the dive stated to the MBI that "when we got back to the surface (after about 10 or 11 hours), they had trouble getting us into the submersible's cradle due to the larger waves than when we had launched. So, we ended up spending an extra 15 hours in the submersible for a total of 27 hours." The co-pilot for Dive 73 stated that the weather had deteriorated and while they were attempting to land on the platform, the TITAN's main batteries died leaving them with no thrusters. Thus, the TITAN was unable to thrust and lock the TITAN into the LARS platform. OceanGate attempted to use support divers to lock the TITAN into place, but deteriorating weather made that process unsafe. As a result, the Mission Director for Dive 73 made the decision to wait until the morning before attempting another retrieval.

4.34.5.1. Although the TITAN was successfully recovered the following morning on June 21, 2022, it suffered damage from the unsuccessful attempts to dock the previous day in heavy weather conditions. Specifically, the TITAN's fairings were ripped off, the mounts for its external lights and cameras were damaged, its VHF radio antenna was bent, its Niskin water sampling bottles were destroyed, and a portion of its syntactic buoyancy foam fell off.

Figure 214: Images of the aft portion of TITAN on June 21, 2022, after it sustained damage while attempting to dock with the LARS after Dive 73. Source: Former mission specialist.

4.34.6. Due to the damage from Dive 73 and members contracting COVID-19, OceanGate cancelled Mission 2 of TITANIC Survey Expedition 2022. TITAN did not conduct its next dive until July 1, 2022, which was logged as a system test in the dive log.

4.34.7. On July 3, 2022, Dive 75 was conducted to the depth of the TITANIC. While on the dive, the TITAN's port battery dropped, which caused the pilot's control program to crash.

4.34.8. On July 15, 2022, TITAN conducted Dive 80 on the TITANIC wreck site with a pilot, a content expert, and two mission specialists aboard. Once the TITAN arrived at the seafloor and located the TITANIC wreckage, they began to move from the TITANIC's bow to its mid-section. As the TITAN descended for a closer view of TITANIC's interior, the TITAN became entangled in the TITANIC's stairwell. The mission specialist, sitting next to the content expert, who was piloting the TITAN at the time, testified to the MBI that he leaned over to say, "(content expert), it seems that we're stuck." The pilot quietly acknowledged the situation, replying, "Yes, (mission specialist), we are." For a moment, the TITAN remained trapped, but the content expert was subsequently able to work the controls to free the TITAN from the TITANIC wreckage. Once the TITAN was clear, the mission specialist pushed to continue the dive toward the stern of the wreck, despite the growing concerns of the rest of the crew, who were ready to ascend. Although the team had initially been considering surfacing early, the mission specialist convinced the TITAN's pilot to press on with the mission. However, just as the TITAN neared the stern, the Mission Director overseeing Dive 80 on the support ship HORIZON ARCTIC, expressed safety concerns and ordered the TITAN to surface immediately.

4.34.8.1. A mission specialist stated the following to the MBI regarding the last portion of Dive 80, "When we were ascending, I don't recall the depth, but I think we were fairly close to the surface, though still underwater, when there was a large bang or cracking sound. And, of course, sonic events in a submersible are alarming, so we were all concerned that maybe there was a crack in the hull." The TITAN's RTM system acoustic sensors captured the bang which was more than 25,000 millivolts (mV) amplitude.

4.34.8.2. According to a mission specialist aboard the TITAN during Dive 80, OceanGate performed a post-dive external assessment of the TITAN due to the loud bang. However, the TITAN's insert was never removed to examine the structural integrity of the hull's interior carbon fiber layer. OceanGate subsequently concluded that the "loud bang" heard during the dive was caused by a shift in the TITAN's position within its frame. The mission specialist stated the following to the MBI regarding his understanding of OceanGate's explanation: "It turned out, upon inspection after we got on the ship, that the body of the fuselage of the TITAN had just jumped in its carriage, so there was no damage."

4.34.8.3. An OceanGate Contractor who was assisting with Dive 80 from the HORIZON ARCTIC stated during MBI testimony that during the debrief for Dive 80, which was held at 9:00 a.m. the following morning after the dive (July 16, 2022), that a mission specialist passed that they had "heard a bang as loud as an explosion" as the TITAN was ascending fairly close to the surface. The OceanGate contractor later confirmed with a member of the HORIZON ARCTIC crew who was working on a small boat to help recover TITAN during its ascent from Dive 80, that the crew of the small boat had also heard the loud bang at the surface above TITAN. The OceanGate contractor provided the following MBI testimony when regarding Mr. Rush's reaction after being asked about the loud bang during a later debrief with OceanGate employees: "Just sort of, I felt, brushed it aside. He said it was probably just the sled banging against the frame and then, oh well, deep-sea vehicles just make lots of noise due to pressure changes." The OceanGate contractor was not satisfied with Mr. Rush's and privately raised her concerns with OceanGate's Director of Administration. The OceanGate contractor stated to the MBI that her concerns were not well received and that the Director of Administration told her she had a "bad attitude" and that she did not have an "explorer mindset." At the end of the conversation the Director of Administration asked the OceanGate contractor if she wanted to be sent home. The OceanGate contractor said yes and booked her a flight home the next day. The Ocean Gate contractor then raised her concerns regarding the load bang with OceanGate's Director of Engineering and was reportedly told that the hull had only shifted a few "microns" and that the dives would continue for the 2022 TITANIC Expedition.[46]

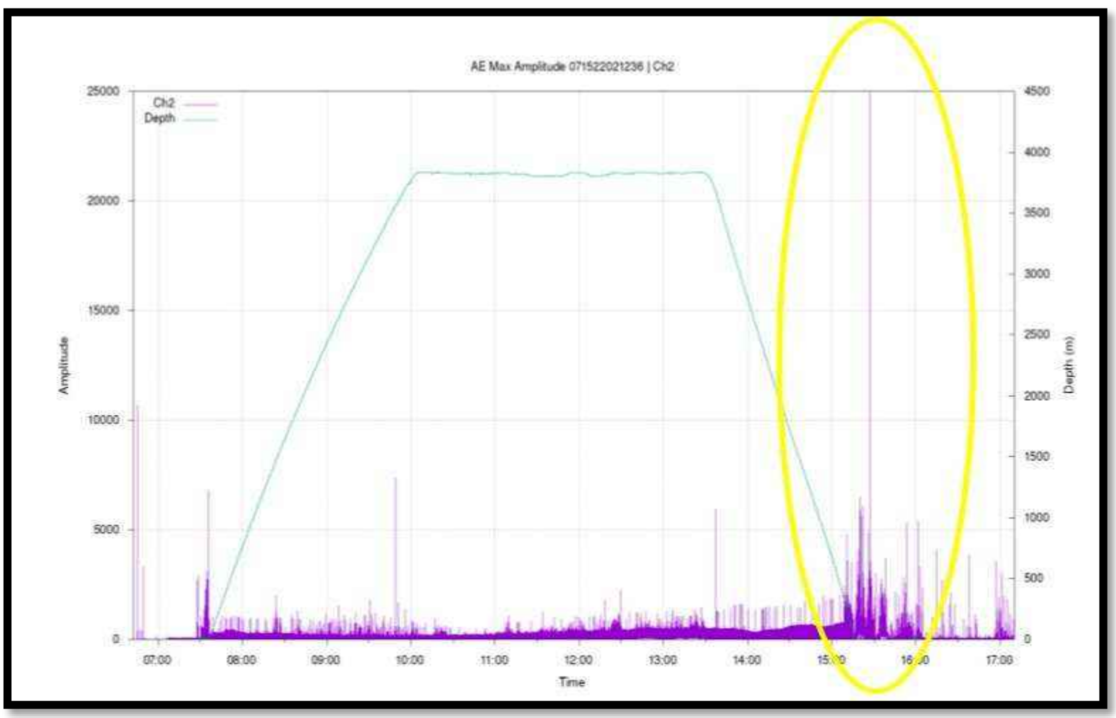


Figure 215: Dive 80 Acoustic Emissions Data for channel 2 (which is located on the forward port side of the TITAN hull). The yellow circle (added by MBI) highlights the acoustic emission for time of the "loud bang" which occurred as the TITAN was still submerged but nearing the surface. Source: OceanGate.

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[46] The testimony provided by the OceanGate Contractor regarding her post-Dive conversation with OceanGate's Director of Administration was refuted by the Director of Administration.

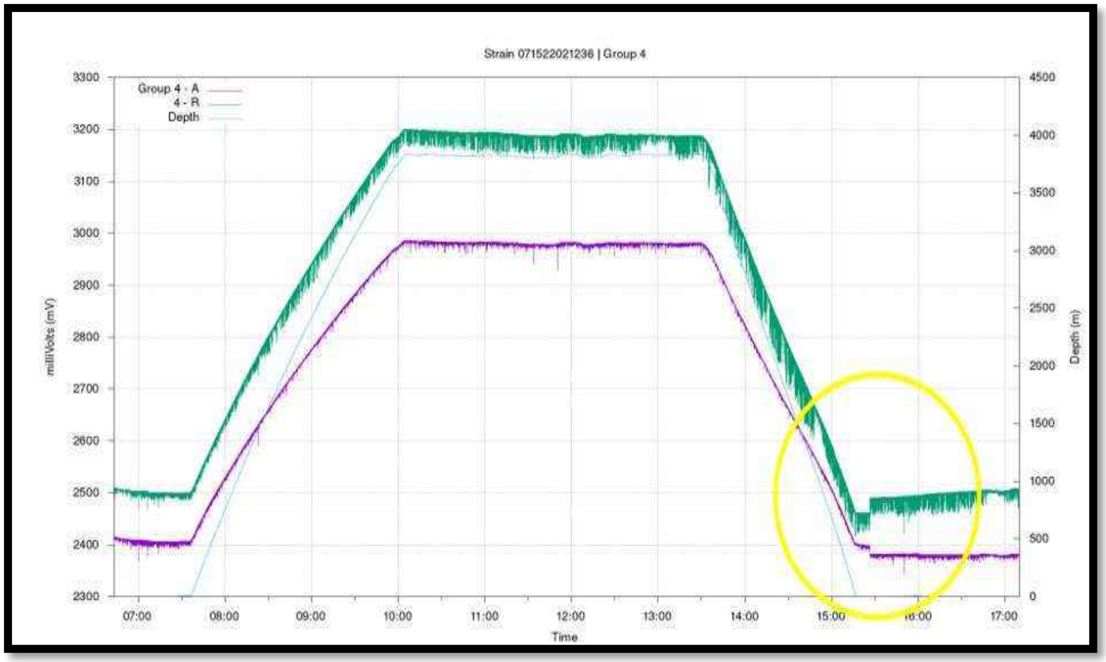

Figure 216: TITAN strain data for Dive 80. The yellow circle (added by MBI) highlights strain data at the time of the "loud bang". Source: OceanGate.

4.34.9. On July 19, 2022, the TITAN and its crew commenced Dive 81 to a depth of 3,840 m (12,598 feet), the location of the TITANIC wreck site. During the descent, the pilot experienced a loss of control over the TITAN's maneuvering systems. The thruster control mapping was found to be incorrect, resulting in unexpected rotational movement. As a result, the pilot was unable to operate the submersible as intended. The pilot later reported that the control program for the thrusters had been reversed, causing forward thrust to produce reverse movement and vice versa. The pilot overcame the malfunctioning thrusters by turning the controller around and operating the controls in reverse.

4.34.10. The final dive of TITANIC Expedition 2022 took place on July 23, 2022, with the dive location designated as "PH Mystery" in TITAN's dive log. The dive reached a depth of 2,954 m (9,692 feet), and according to the dive log, there were 40 total acoustic incidents recorded per sensor. The pilot reported that this dive occurred during the return leg of the expedition and was conducted at coordinates specified by the content expert. The pilot described the site to the MBI as "an old seamount, resembling a volcanic structure," which was populated by various types of marine life. The team conducted an exploration of the area, documented their findings, and then ascended to the surface.

4.34.11. The TITANIC Expedition 2022 concluded on July 25, 2022. While 7 of the 13 dives reached the TITANIC depth of 3840 m, the dive logs recorded a significant 120 acoustic incidents per sensor. Furthermore, the expedition's maintenance log documented 48 maintenance issues and 2 incidents. The incident reports were not provided to the MBI as requested.

Dive Number	Date	Dive Location	Dive Time	Max Depth (meters)
C2_0071	6/16/22	150 SE St. John's	3.5	7
C2_0072	6/18/22	Titanic	6.3	1380
C2_0073	6/20/22	Titanic	27.0	3840
C2_0074	7/1/22	Bay Bulls	5.0	25
C2_0075	7/3/22	Titanic	13.0	3840
C2_0076	7/6/22	Titanic	12.0	3840
C2_0077	7/8/22	Witless Bay	4.2	30
C2_0078	7/11/22	Cameron Canyon	3.5	10
C2_0079	7/14/22	Titanic	11.9	3840
C2_0080	7/15/22	Titanic	10.9	3840
C2_0081	7/19/22	Titanic	12.8	3840
C2_0082	7/22/22	Titanic	11.1	3840
C2_0083	7/23/22	PH Mystery	12.1	2954

Figure 217: OceanGate 2022 TITANIC Expedition excerpt from the dive log. Source: OceanGate.

4.35. 2022-2023 TITAN Storage in St. John's, Newfoundland

4.35.1. On July 12, 2022, OceanGate's Director of Logistics and Quality Assurance emailed A Harvey & Company Marine Base regarding the storage of the TITAN and their gear in St. John's until April, further stating that Memorial University in St. John's was interested in hosting and displaying the TITAN for educational purposes. The Director of Logistics and Quality Assurance outlined three potential options for handling the gear: paying to import it, establishing an extended bond, or filing for an exemption for educational and promotional purposes. In response, a representative from A Harvey Marine Base advised OceanGate that the Canadian Border Services Agency (CBSA) should be consulted to ensure prior agreement on the terms.

4.35.1.1. The value for tax of the TITAN submersible and expedition gear was CA$5,627,539. The resulting Goods and Sales Tax (GST) for the TITAN and associated gear to be imported into Canada was CA$281,382.

4.35.2. On July 26, 2022, the TITAN, the LARS, and associated equipment were demobilized at the A Harvey Marine Base in St. John's, Canada. The TITAN and its equipment were subsequently placed in the parking lot of the facility for approximately 7 months of storage. The TITAN's equipment was stored in two containers; however, the TITAN was not covered nor provided protection from the environment (see Figure 221).

4.35.3. On July 28, 2022, a representative from A Harvey Marine Base was provided with a quote from a vender to cover the TITAN with a form fitting wrap to assist in protecting from the elements. The total cost for the service was CA$1,750 plus tax. That quote was then provided by email to the OceanGate's Director of Operations. A representative from A Harvey Marine Base confirmed to the MBI that OceanGate never responded to their email and that the TITAN was that the service was not provided to protect the TITAN's hull.

Figure 218: Overhead photo of the A Harvey Marine Base in St. John's. The red "x's" indicate the storage location for the TITAN and the Conex boxes storing its equipment. Source: A Harvey.

4.35.4. On September 28, 2022, a representative from A Harvey Marine Base emailed the OceanGate Director of Logistics and Quality Assurance, informing them that while a quote for a tarp for the submersible had been provided, they had not received approval to proceed, so the tarp was not purchased. In reply, the Director of Logistics and Quality Assurance stated that they would discuss the tarp with the OceanGate's Director of Operations.

4.35.5. On October 11, 2022, the Director of Logistics and Quality Assurance sent an email update to A Harvey, stating that Mr. Rush was still having discussion with Memorial University over the agreement to display the TITAN at the University prior to TITAN's planned 2023 TITANIC Expedition. Specifically, Mr. Rush was attempting to ensure that the University's pending letter to CBSA included verbiage that would provide OceanGate maximum relief from Canadian "GST / HST" (Goods and Sales Tax / Harmonized Sales Tax).

4.35.6. On November 3, 2022, OceanGate's Director of Logistics and Quality Assurance stated in an email to A Harvey Marine Base, "We should have a MOU agreement in place with Memorial University soon. As part of the agreement they will be importing the goods, I will send a draft to you after receiving. (Hopefully by the end of the week)."

4.35.7. On December 6, 2022, a representative from A Harvey Marine Base emailed a representative of Memorial University, confirming that the Memorial broker can proceed with importing goods from their docks. However, it was noted that the goods have never been imported under a consumption-type B3 entry before, as they were previously imported using an E29B with a surety bond. For the B3 entry under HS code 9015.80.00.90, which grants full GST and duty exemptions, the necessary Cargo Control document and sub-location code would be provided. The goods qualified as part of a scientific expedition, with Memorial University as the importer (the eligible institution), and OceanGate as the non-resident participant. To qualify for the exemption, the expedition was required to be conducted or sponsored by a recognized scientific or cultural organization or institution, with non-resident participants, and the gathered information was required to be made available to the Government of Canada.

4.35.8. On December 21, 2022, the Marine Institute of Memorial University of Newfoundland and OceanGate Inc. entered into a MOU. The general objective of this MOU was to support mutually advantageous cooperation and collaboration in the areas of ocean exploration, ocean literacy, and ocean technology education, research and training.

4.35.9. On December 23, 2022, an A Harvey Marine Base representative stated to the Memorial University and OceanGate via email, “We wish to proceed to meet with local Customs and get their feedback on the E29B, the regulations are open to interpretation, and we have deduced we have an excellent case for the path of less resistance but again wish to meet with Customs locally first.”

4.35.10. During the negotiations for TITAN’s import to Canada, the TITAN and its storage containers remained in open storage at the A Harvey Marine Base location unprotected from the elements until February 6, 2023.

4.35.11. The average air temperature from the nearest weather station (St. John’s Airport Weather Data) for July 2022 through February 2023 was a high temperature of 84.2 Degrees F, a low temperature of 1.4 Degrees F with an average temp of 39 Degrees F. The total precipitation for the location over the duration was 963 mm.

4.35.12. During MBI testimony OceanGate’s last Director of Engineering state the following when asked whether OceanGate considered doing any testing of the TITAN’s hull during the downtime between the 2022 and 2023 Expeditions:

> “I know we talked about that with (Mr. Rush), especially after 2022, that we really -- what we really wanted to do was bring the sub back, at least, to Everett and pull the insert and look at -- just look at the inside of the hull to see if there were any cracks and it was -- it was very frustrating because it was left in St. John's and left on the dock and we had no way to work on it, no way to look at it and we were told it was a cost issue, you know, that the cost of shipping it back was prohibitive, they were low on money and so, you know, we couldn't do that. And really, that was basically around the time that I left, you know, that I had gotten quite frustrated with some of these issues and had decided to leave the company.”

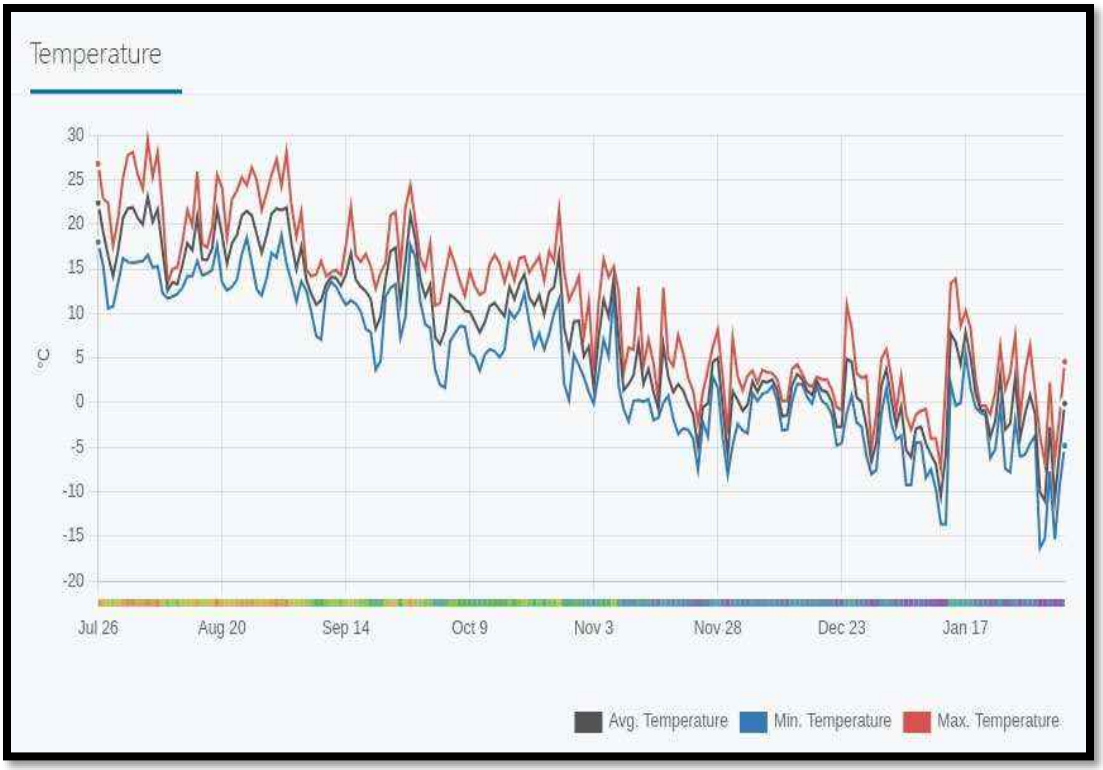

Figure 219: Temperature chart for July 26, 2022, until February 6, 2023, from the St. John's Airport weather station. Source: https://meteostat.net/en/station/71801?t=2022-07-26/2023-02-06 .

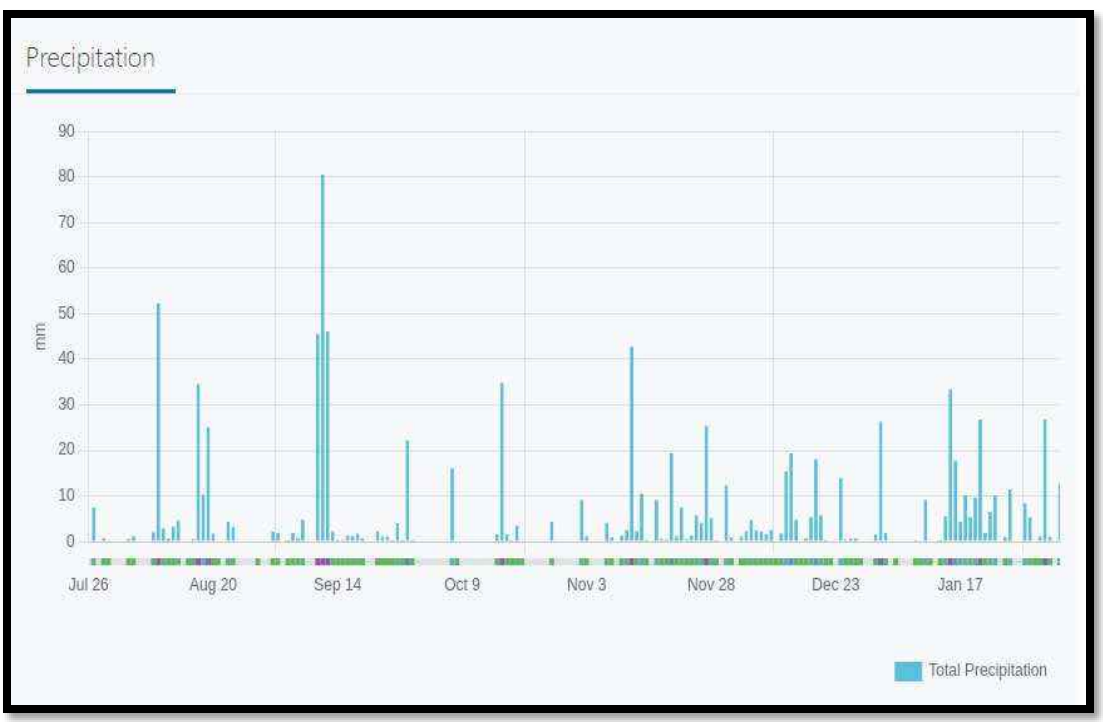

Figure 220: Precipitation chart for July 26, 2022, until February 6, 2023, from the St. John's Airport weather station. Source: https://meteostat.net/en/station/71801?t=2022-07-26/2023-02-06 .

Figure 221: TITAN being prepped at the A Harvey Marine Base parking lot for transfer to the Marine Institute of Memorial University of Newfoundland on February 6, 2023. Source: Former OceanGate Electrical Engineer.

4.35.13. On February 6, 2023, the TITAN was loaded onto a flatbed and transported to building W1002 at the Marine Institute Ridge Road Campus.

Figure 222: TITAN being placed on flatbed for transfer to Marine Institute of Memorial University of Newfoundland on February 6, 2023. Source: Former OceanGate Electrical Engineer.

4.36. The Fisheries and Marine Institute (MI) of Memorial University of Newfoundland

4.36.1. The MI is an educational institution located in St. John's, which is dedicated to education, training, applied research and industrial support of ocean industries.

4.36.2. On December 21, 2022, the Memorial University of Newfoundland, through its Fisheries and Marine Institute, entered an MOU with OceanGate Inc.

4.36.2.1. The objective of the MOU was to “support mutually advantageous cooperation and collaboration in the areas of ocean exploration, ocean literacy, and ocean technology education, research and training.

4.36.2.2. The MOU allowed MI students to apply academic endeavors that support OceanGate and provided opportunities to join OceanGate expeditions to gain work experience. In exchange, the MOU clarified that the Marine Institute would provide space and time for OceanGate personnel to work on their equipment and components to support their expeditions.

4.36.3. On January 16, 2023, the MI released a letter stating that it had entered into a MOU with OceanGate, Inc. to support their annual expeditions to the wreck of the TITANIC and additional dives that may occur at other notable sites. Specifically, the letter stated:

> “While we don’t anticipate MI faculty, staff, and students to be direct participants in the expeditions conducted by OceanGate they will have the opportunity to learn from shoreside support activities and students may serve in cadet placements and work terms on vessels chartered through OceanGate’s relationship with Miawpukek Horizon Maritime Services. MI intends to house OceanGate’s TITAN submersible and its support equipment at its campus sites to further its collaboration and to give its students and faculty hands on opportunities to work with advanced specialized deep sea research equipment. Through the collaborative areas noted above, MI intends to support the efforts of OceanGate to conduct scientific and exploratory expeditions.”

4.36.4. On February 6, 2023, the TITAN arrived via flatbed truck at the MI’s Ridge Road Campus.

Figure 223: TITAN arriving at MI Ridge Road Campus.
Source: Former OceanGate Electrical Engineer.

4.36.5. The TITAN remained stored inside a bay at the MI until April 17, 2023.

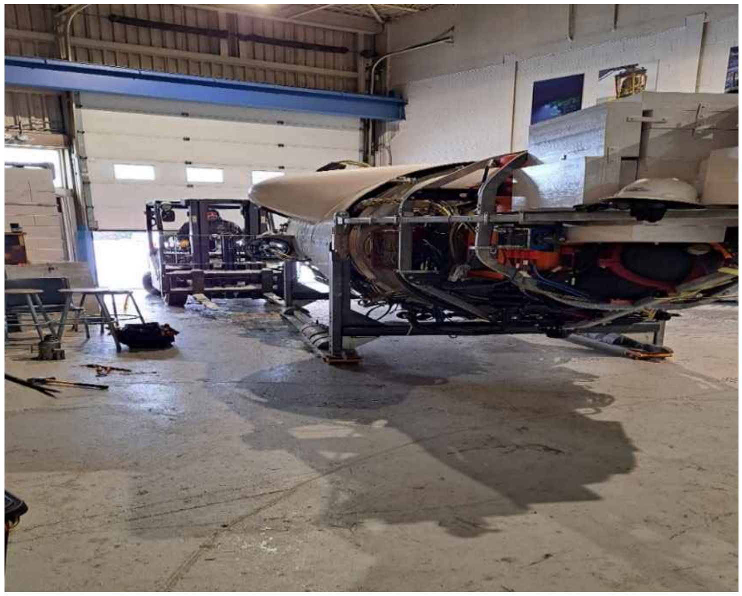

Figure 224: TITAN inside MI's Ridge Road Campus storage facility.
Source: Former OceanGate Electrical Engineer.

4.36.6. On April 17, 2023, the TITAN and associated OceanGate equipment departed the MI Ridge Road Campus via flatbed truck to the MI's Holyrood Marine Base, which would be its launch site for the 2023 TITANIC Expedition.

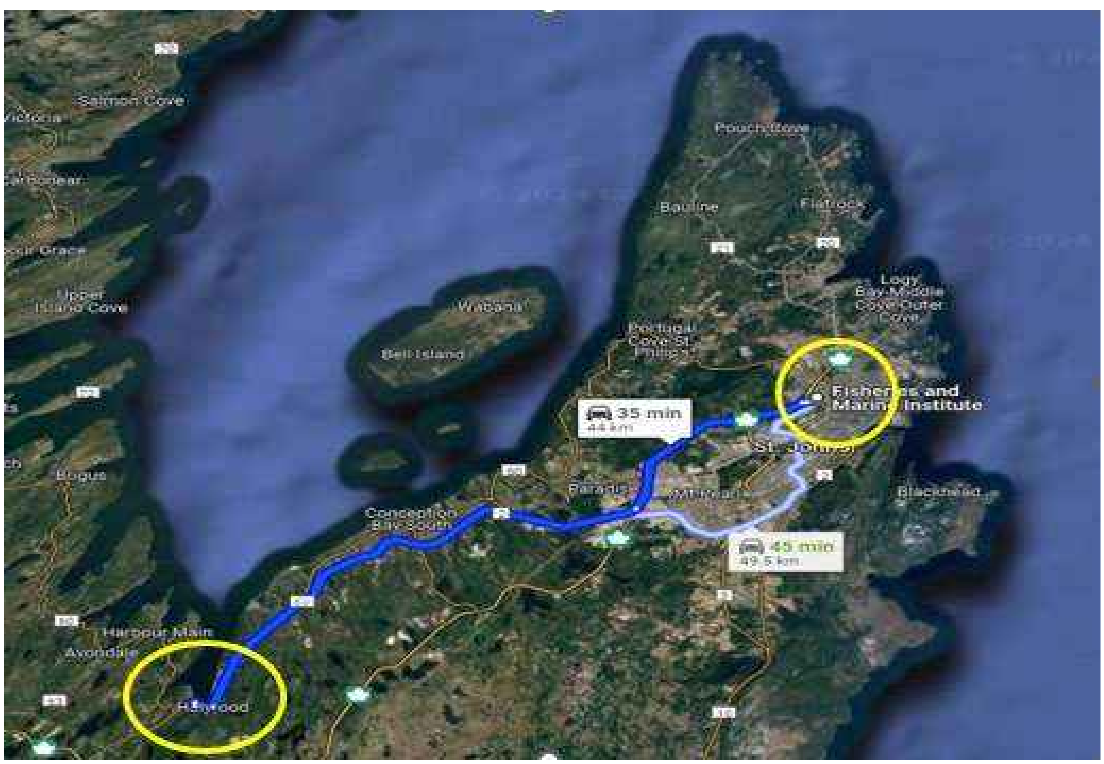

Figure 225: Map indicating route TITAN traveled to the Holyrood Marine base on April 17, 2023: Source: Google Earth.

Figure 226: CCTV footage of the TITAN and other equipment arriving at MI Holyrood Marine Base on April 17, 2023. Source: MI Holyrood Marine Base.

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4.36.7. The TITAN was stored on the dock (see Figure 227) at the MI Holyrood Marine Base facility from April 17, 2023, until May 10, 2023, when it was transferred to the LARS platform in the water.

Figure 227: CCTV footage of the TITAN (in yellow circle added by MBI) on the dock at the MI Holyrood Marine Base on April 24, 2023. Source: MI Holyrood Marine Base.

4.36.8. On May 12, 2023, the LARS with the TITAN atop were towed from the facility to rendezvous with the support vessel for the 2023 TITANIC Expedition, the POLAR PRINCE.

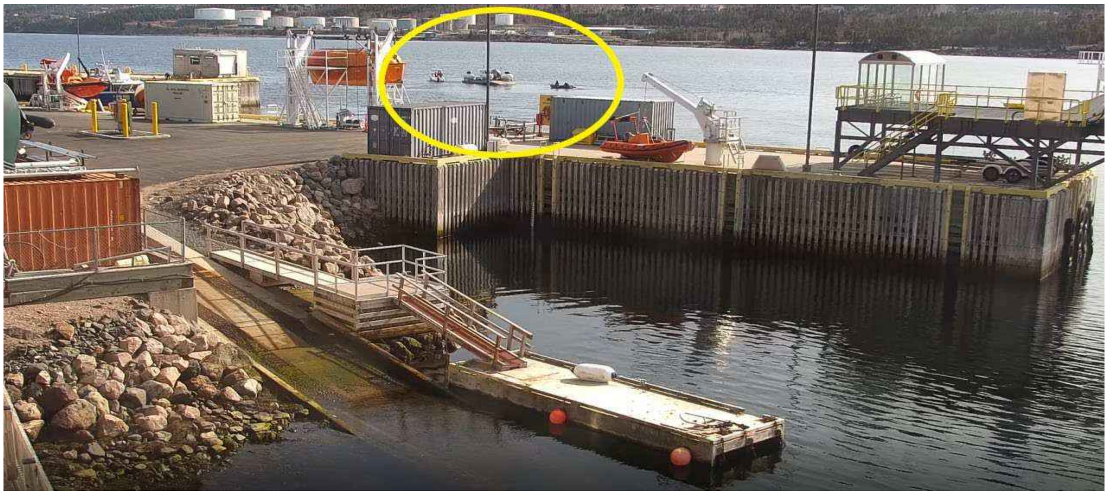

Figure 228: CCTV footage of the TITAN (in yellow circle added by MBI) being towed atop the LARS by a Marine Institute vessel enroute to rendezvous with the support vessel POLAR PRINCE in the South Area of Conception Bay.
Source: MI Holyrood Marine Base.

Figure 229: Yellow line indicates route TITAN and LARS were towed to the rendezvous location with the support vessel POLAR PRINCE (approximate location indicated by the yellow "X"). Source: Google Earth.

4.37. Monetary Advances to OceanGate

4.37.1. During 2022 and 2023, OceanGate received multiple “advances” of financial support from various stakeholders, with the largest contribution of $1.85 million coming from the company’s CEO (Mr. Rush).

4.37.2. Prior to the 2023 TITANIC Expedition, OceanGate employees were asked to temporarily forgo their salaries with the promise of back pay. One former employee provided the following testimony to the MBI hearing regarding what he perceived as OceanGate’s dire financial situation, stating:

"The company was economically very stressed and as a result, [they] were making decisions that compromised safety."

4.38. 2023 OceanGate TITANIC Expedition

4.38.1. The HORIZON ARCTIC, which was utilized as the support vessel for Expeditions 2021 and 2022, was unavailable for use by OceanGate for 2023 operations. For the OceanGate TITANIC Expedition 2023, OceanGate utilized another Horizon Maritime vessel, the POLAR PRINCE as their expedition support vessel.

Figure 230: POLAR PRINCE Source: MarineTraffic@ Andrew Edmonds, 2023.

4.38.2. On May 8, 2023, at approximately 10:56 a.m., the POLAR PRINCE arrived in St. John's, Newfoundland and moored at the A Harvey Marine Base in St. John's. The POLAR PRINCE (IMO# 5329566) is a 238-foot, 2,062 Gross Tons ITC, DNV classed multi-purposed tender vessel, owned and operated by Miawpukek Horizon Maritime Services. The POLAR PRINCE was a former Canadian Coast Guard ice breaker named CCGS Sir Humphrey Gilbert, which operated from 1959-1986. After its Canadian Coast Guard service, it was converted into a research vessel that can provide a wide range of support capabilities. The POLAR PRINCE currently serves as the dedicated training vessel for Miawpukek Horizons Cadet and Trainee program.

Figure 231: 2023 TITANIC Expedition Operational Changes. Source: OceanGate Expeditions.

4.38.3. The POLAR PRINCE underwent upgrades to its accommodations ahead of the 2023 TITANIC Expedition to meet OceanGate's requested expectations for their services.

4.38.4. OceanGate's project schedule identified Pier 12 of the A Harvey Marine Base as the onload location for TITAN's equipment. The POLAR PRINCE subsequently onloaded OceanGate's gear and containers on May 11, 2023, which included three shipping containers (20-feet x 8-feet), containing OceanGate tools and workshop, operations equipment, and spare equipment, and two OceanGate inflatable boats (16-feet x 6-feet). During this time, the LARS and TITAN remained at the MI Holyrood Marine Base as part of the plan to rendezvous at sea with the POLAR PRINCE.

4.38.5. Due to the lack of deck space, launching appliances, and weight handling equipment, the LARS and TITAN had to be towed behind the POLAR PRINCE for the entirety of each 2023 TITANIC mission.

4.38.6. According to the OceanGate's TITAN HSE Manual, the length of tow was determined by sea state with short tow operations (less than 100 feet) only being used in calm sea conditions and long tow operations (greater than 100 feet) being used anywhere outside the marina.

4.38.7. According to the OceanGate Dive Operations Risk Assessment for the TITANIC Survey Expedition 2023 Personnel Chart, OceanGate's Director of Engineering position for the expedition was listed as To Be Determined (TBD).

4.38.8. The OceanGate Project Execution Plan identified that the greatest risk to the TITAN and its crew was the potential for entanglement with a foreign object or being disabled at depth due to system failures which would require surface support and rescue.

For entanglements or disabling events that occurred at depths beyond those accessible by divers, the HSE Manual stated that OceanGate had contacts at Oceaneering and Pheonix International that possessed many ROVs capable of reaching depths up to 4,000 m (13,123 feet).

4.38.8.1. The MBI subsequently confirmed with Oceaneering and Phoenix International that OceanGate did not notify them of their plans for the 2023 TITANIC Expedition and that there were no contracts in place to have emergency deep-sea rescue resources on standby for OceanGate.

4.38.9. According to OceanGate's 2023 Project Execution Plan:

> "The expedition is scheduled to depart from shore on May 11th, 2023, with scientists, content experts, and mission specialists joining the crew in a series of week-long missions. The expedition crew size for each mission is approximately 23 to 27 people, including six to nine mission specialists, submersible pilots, operations crew and content experts. Qualified individuals join the expedition crew as mission specialists after completing a substantial training prior to the start of the expedition and support the mission by helping underwrite the expedition. Mission specialists training includes basic seamanship, submersible operations, emergency procedures, communications, navigation, and submersible systems. They sign an agreement that as a member of the crew they have a duty to fulfill the agreement and their failure to do so may impact on the success of the mission or expedition. Mission Specialists are assigned duties by the Expedition Leader on the submersible and the ship in roles such as watch, communications, navigation, sonar operation, photography, documentation, and dive planning. OceanGate has scheduled an expedition to the TITANIC during the summer of 2023."

4.38.10. On May 12, 2023, at approximately 1:16 a.m., Mission 1 of the 2023 TITANIC Expedition began, when the POLAR PRINCE departed the A Harvey Marine Base and proceeded north into Conception Bay, heading towards the MI Holyrood Marine Base to conduct an at sea rendezvous with the TITAN and LARS platform. Around 09:10 a.m., the POLAR PRINCE arrived at the rendezvous location approximately 0.5 miles off Kelligrews, Newfoundland. Meanwhile, a small boat departed Holyrood Marine Base towing the TITAN atop the LARS. After a 7-mile transit, the TITAN and LARS arrived at the POLAR PRINCE's location and the LARS and TITAN remained in the water. The next few days were spent conducting support vessel and TITAN familiarity training. The additional training was necessary due to the launching arrangements for TITAN, which needed to be conducted at sea rather than on the deck of the support vessel. There were no mission specialists aboard the POLAR PRINCE for Mission 1.

4.38.11. At approximately 1:00 p.m. on May 15, 2023, the POLAR PRINCE with the TITAN in tow traversed from Conception Bay to Spaniards Bay, where they remained until May 18, 2023.

4.38.12. On May 18, 2023, at approximately 11:43 p.m., the POLAR PRINCE departed Spaniards Bay with the TITAN in tow headed to St. John's, Newfoundland.

4.38.13. On May 19, 2023, at approximately 4:00 p.m., the POLAR PRINCE arrived at the A Harvey Marine Base in St. John's, Newfoundland. There were no TITAN dives logged for Mission 1.

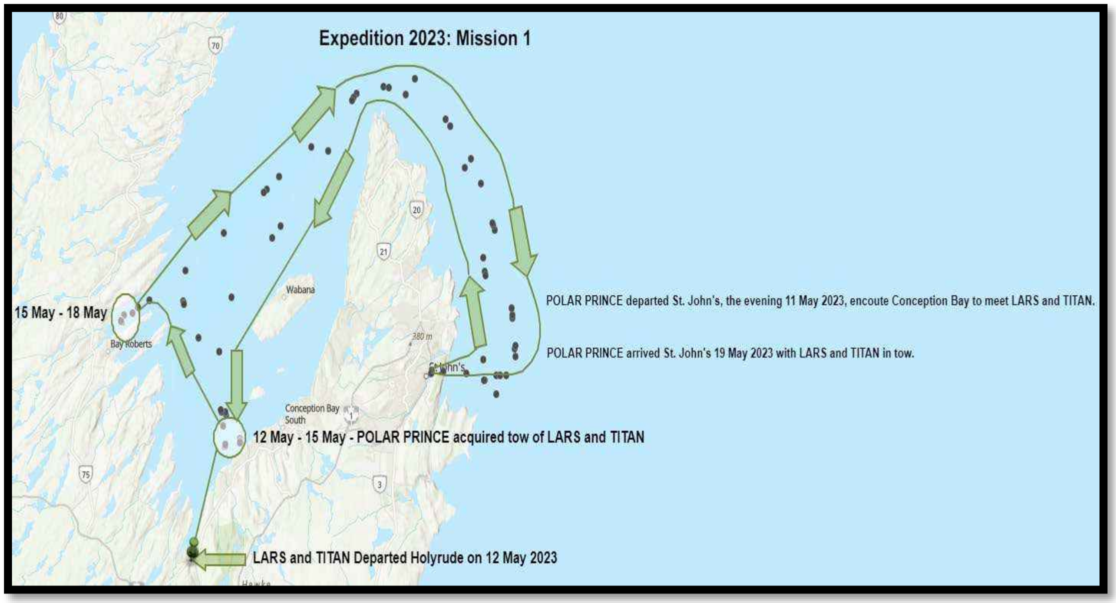

Figure 232: POLAR PRINCE AIS track for Mission 1 of the OceanGate's TITANIC Survey Expedition 2023. Source: USCG Pole Star.

4.38.14. On May 20, 2023, Mission 2 began as the POLAR PRINCE departed St. John's at approximately 12:31 p.m., heading for the TITANIC wreck site. The vessel towed the LARS platform, with the TITAN positioned on top. A mission specialist, who had paid $250,000 to participate in a dive to the TITANIC wreck site, stated that the mission, initially set to start at 7:00 a.m., was delayed due to issues with the LARS. Reflecting on the process of preparing the TITAN for extended towing operations, the mission specialist remarked to the MBI, "Getting TITAN ready for towing was interesting… TITAN is on a specially designed sled for towing that they ballast down at the rear of the sled so that it comes up on plane under tow at about 8 kts. I had to bite my tongue a few times—people working shackles, handling heavy lines without gloves, loose items on deck, etc. I know this sled configuration is new, and teething problems are expected, but I thought they would have sorted themselves out a bit better. There seemed to be a lack of direction."

4.38.15. The on-scene weather conditions for the Mission 2 transit for the POLAR PRINCE with the TITAN in tow were described as gray and windy, with 50 kt winds and 4–5-foot swells. The POLAR PRINCE traveled at an average speed of 7.4 kts, during their 370 NM journey to the TITANIC wreck site.

Figure 233: TITAN atop LARS in St. John's Newfoundland prior to getting underway on for Mission 2 on May 20, 2023. Source: Former mission specialist.

Figure 234: POLAR PRINCE's Automatic Identification System (AIS) track line for Mission 2 of the TITANIC Survey Expedition 2023. The yellow star indicates the approximate location of the TITANIC wreck site. Source: USCG Pole Star.

4.38.16. On May 21, 2023, the POLAR PRINCE continued its journey toward the TITANIC wreck site, navigating through moderate weather conditions with 20 kt winds and seas reaching 3-4 m (10-13 feet). A Mission 2 mission specialist provided the MBI with a diary entry they made while onboard that provided insight into the Mission's command structure. The mission specialist's diary entry included the following passage:

> "The command structure between the Captain of the POLAR PRINCE and the OceanGate CEO/Expedition Manager is unique. Neither holds overall command—decision-making regarding go/no-go calls relies on mutual discussion. Emergencies tend to fall within specific areas of expertise: ship handling is the responsibility of

the captain, while deck operations and submersible activities are managed by OceanGate. The small boats are also handled by OceanGate. They're good people, and I enjoy their company, but I've learned not to suggest improvements, as it often falls on deaf ears."

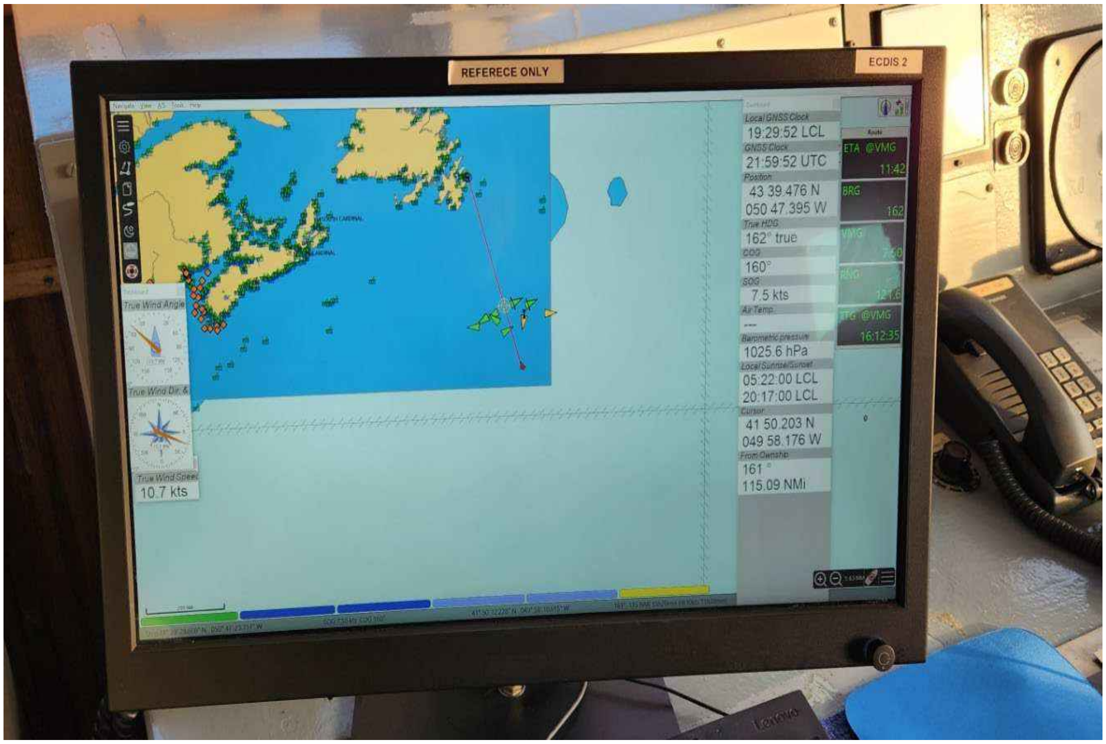

Figure 235: POLAR PRINCE Electronic Chart Display Indicating System (ECDIS) as of May 21, 2023, at 7:23 p.m. The track line of the POLAR PRINCE to the TITANIC wreck site is displayed. Source: Former mission specialist.

4.38.17. On May 22, 2023, the TITAN conducted its only dive for Mission 2 of Expedition 2023, which was an unmanned descent to 8 m (Dive 84). This dive was classified by OceanGate as a "419" drill, which was also referred to in their report as a disabled sub drill. A Mission 2 mission specialist recorded their observations in a dairy entry and shared the following entry with the MBI:

> The delineation between the POLAR PRINCE crew and OceanGate personnel is interesting. The POLAR PRINCE operates the deck equipment, like cranes for launching zodiacs, but OceanGate handles all deck evolutions, such as loading boats and driving zodiacs. The POLAR PRINCE bridge team seemed largely uninterested, not paying much attention to deck work or the tow. I'm not impressed with the seamanship and deck work standards of OceanGate—while they are engineers, the effort feels amateurish. They're making things harder for themselves, with the wrong people in the wrong positions—boat coxswains, for example, didn't know how to raise and lower the outboard or how to prepare a load.

Titan Dive Plan - C2_0084

Date: 5/22/2023
Operating Channel: Ch 69
Objectives: Training System Test
Primary Location:
Risk Index 30

Configuration:

Forward steel ingot	0	0
Ingot	13	611 Place as far fwd as possible
Hydraulic drop weights	0	0
# SR Weights Light	0	0
# SR Weights Heavy	0	0
Crew weight	710	710
# KH Weights	0	0
Total	1,321	
Target	1,674 Difference	353

Schedule

Task	Start Time	Duration	End Time
Pre Brief	7:00	0:15	7:15
Change tow length	7:15	0:15	7:30
Launch/Recover Max&Stewie	7:30	0:30	8:00
Transfer Crew to/From PP	8:00	0:15	8:15
Install/Remove bottom hatches	8:15	0:30	8:45
Raise/Sink Platform	8:45	0:15	9:00
Service Sub/Platform	9:00	2:30	11:30
Lunch	11:30	1:00	12:30
419 Drill	12:30	2:00	14:30
Service Sub/Platform	14:30	2:30	17:00
Post Brief	17:00	0:30	17:30

Figure 236: TITAN Dive Plan C2_0084 for May 22, 2023. Source: Former mission specialist.

4.38.18. On May 23, 2024, the on-scene weather was deteriorating as the POLAR PRINCE was heading to the TITANIC wreck site with the LARS and TITAN in tow. A mission specialist stated he was not confident that he would get to the TITANIC. In his journal he provided the following passage, "Not feeling confident I will get a TITANIC dive before getting back to St. John's. Wx (weather) starting to impact pre-dive preps and TITAN maintenance. Wx at 7:00 a.m.: wind 15 kts, ss 2, swell 1.5 m but forecast for next 18 hours is sea, swell and wind picking up. While not much can be done about weather, I feel that some of the maintenance tasks on TITAN could have been done sooner. I spent a couple of hours this morning on the TITAN platform replacing some too short bolts. Good to be actively working as part of the crew but this and some of the other tasks that need to be done pre dive really could have and should have been done days or weeks ago."

4.38.19. On May 24, 2023, the Editor in Chief of Travel Weekly, who was aboard the POLAR PRINCE in a media capacity stated in an article,[47] "On the fourth day of the mission, when the seas were most active and fog was the thickest, a near-disaster for the sub and platform occurred: At the end of the rope that linked the stern of the ship to the platform, we saw that the front of the platform and the sub were underwater." The MBI was ultimately unable to determine how long the TITAN was towed by the POLAR PRINCE in the partially submerged condition.

[47] https://www.travelweekly.com/Arnie-Weissmann/Trouble-ahead-trouble-behind

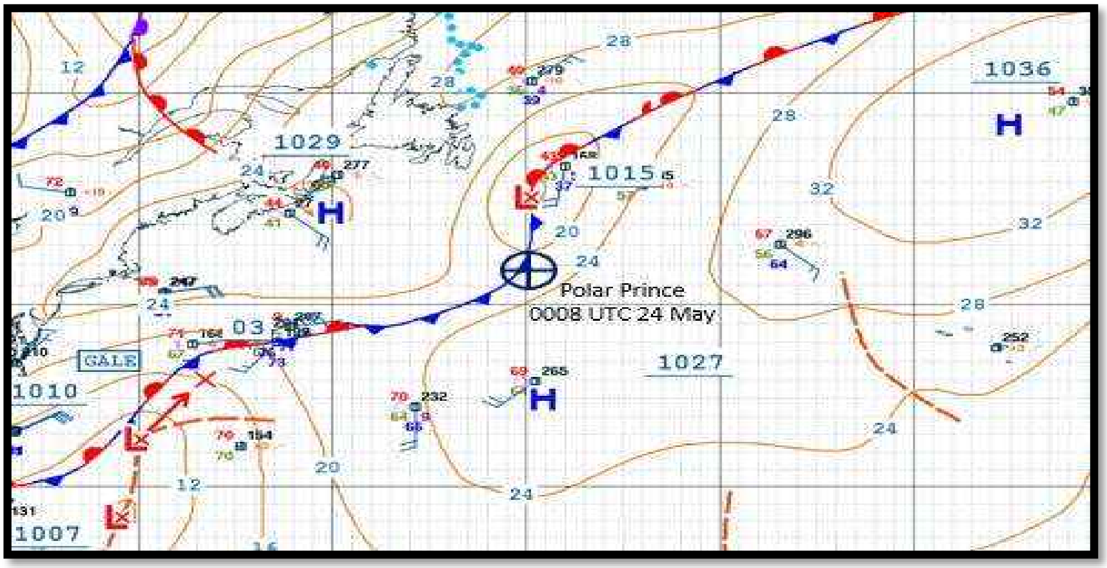

Figure 237: NOAA surface analysis for POLAR PRINCE's position on May 24, 2023. Source: NOAA.

Figure 238: TITAN partially submerged due to complications with the LARS platform at 11:14 a.m. on May 24, 2024. Source: Former mission specialist.

4.38.20. OceanGate crew and divers had to place air bags and buoys under the LARS' sunken bow and inflate them underwater in order to get the bow of the LARS high enough to purge out the water and get air back into the hull for buoyancy. According to the Editor in Chief of Travel Weekly, this process took more than half the day. The Editor in Chief stated, "When I asked how much jeopardy the sub was in, (Mr. Rush) joked, 'So a sub is under water. Why is that a problem? No fishing line was discovered in the platform, though it may have done its damage and then untangled itself,' (Mr. Rush) added."

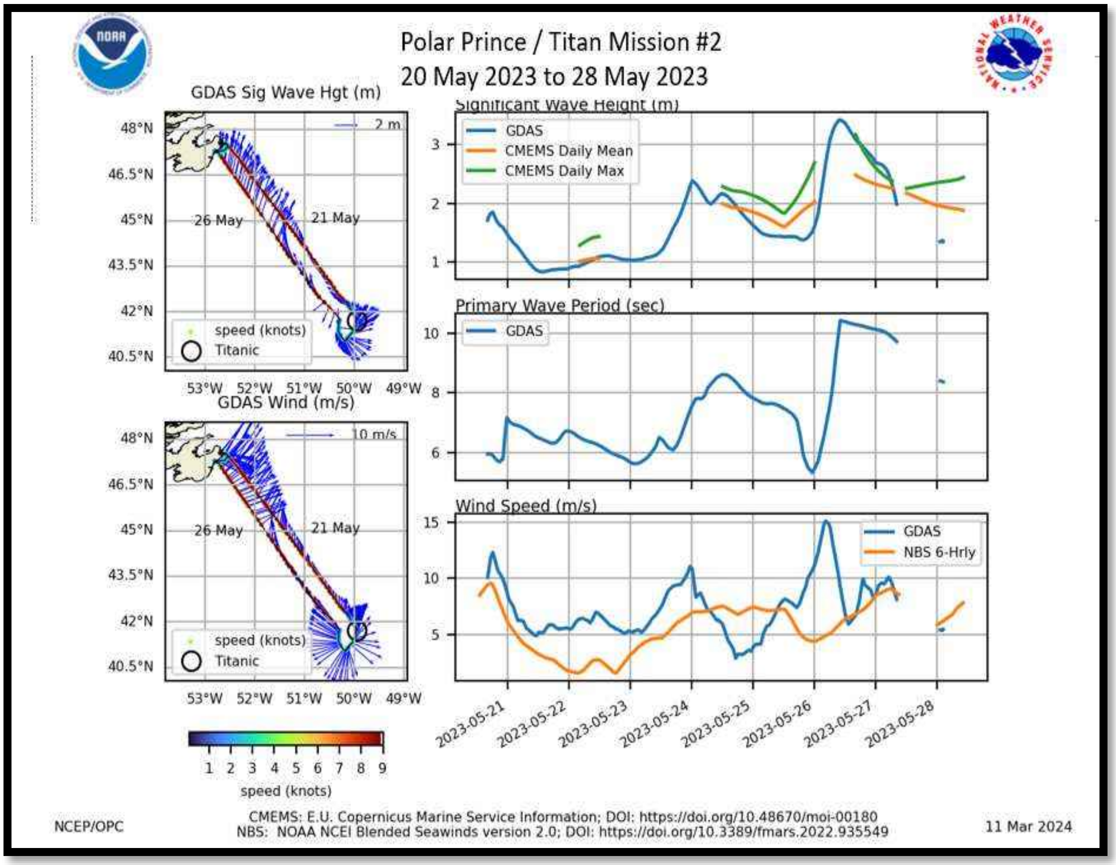

Figure 239: NOAA weather report produced for the POLAR PRINCE's AIS track line for Mission 2 of the TITANIC Survey Expedition 2023. Source: NOAA.

4.38.21. Based on a report NOAA generated for the MBI analyzing environmental conditions encountered by the POLAR PRINCE during Mission 2, the wind speed and wave height matchup points indicated three distinct peaks in wave heights and wind speeds on May 21, 24, and 26. NOAA provided the following summary of the weather conditions experienced by the POLAR PRINCE during Mission 2:

> From May 21st, the weather around the POLAR PRINCE was becoming increasingly turbulent. On May 21st, winds blew from the southwest, driven by a high-pressure system to the southeast and a low-pressure system moving across Labrador to the north.
>
> By May 23rd, a low-pressure system approached from the west and northwest, prompting a Gale Warning. The next day, May 24th, this low was positioned north of the POLAR PRINCE, causing wind speeds and wave heights to increase again.
>
> On May 25th, the winds changed direction rapidly, shifting from the southeast to the north, then northeast, and finally east. A second low-pressure area developed near 43N, 70W on May 24th, also bringing gale conditions and expected to move northeast.

The second low-pressure system reached the vessel on May 26th. This brought winds from the southeast and south-southwest and eventually waves from the west. According to the Global Data Assimilation System (GDAS), this second low caused the strongest winds and highest waves of the mission. Winds shifted from the south-southeast to the west-southwest, and waves came mainly from the south and south-southwest.

4.38.22. On May 25, 2023, the POLAR PRINCE began the transit back to the Canada to conduct a damage assessment of the TITAN after the previous day's incident where its bow had been partially submerged while being towed by the POLAR PRINCE.

4.38.22.1. At a 5:00 p.m. meeting aboard the POLAR PRINCE, according to a mission specialist, Mr. Rush stated that the damage was not as bad as it could have been. Mr. Rush confirmed there were some concerns about communications and an adapter, but otherwise it was considered to be "ok."

Figure 240: TITAN being towed by POLAR PRINCE on May 25, 2024, with missing tail cone due to the May 24th incident, heading to Witless Bay, Newfoundland for a damage assessment. Source: Former mission specialist.

4.38.23. An MBI review of NOAA's report for Mission 2, determined that the POLAR PRINCE encountered maximum wave heights of approximately 3.5 m (11.5 feet) and maximum wind speeds of approximately 15 m/s (29 kts) while towing the TITAN back to Witless Bay, Newfoundland on May 26, 2023.

4.38.24. On May 27, 2023, at approximately 8:28 a.m., the POLAR PRINCE entered Witless Bay, Newfoundland. The transit to Witless Bay averaged 7.84 kts. A mission specialist provided the MBI with the following description of what occurred after the POLAR PRINCE arrived and anchored in Witless Bay:

"Plan was to complete all maintenance and repairs by midday then do a test dive after lunch but myriads of minor repairs, new defects, time taken to ferry people, tool, parts, etc., between platform and the ship soon added up and along with freshening wind, test dive was cancelled and whole day spent at anchor doing necessary maintenance. Although some work was defect rectification, I couldn't help feel that a lot of this maintenance could have been done before sailing."

4.38.25. On May 28, 2023, at 10:11 a.m., the POLAR PRINCE moored up in St. John's. The total distance traveled for Mission 2 of Expedition 2023 was approximately 950 NM and the average speed of the POLAR PRINCE while towing the TITAN to and from the operational areas was 7.6 kts.

Figure 241: The POLAR PRINCE moored at A Harvey Marine Base in St. John's, Newfoundland, the evening prior to embarking on Mission 3 of the TITANIC Survey Expedition 2023. Source: Former mission specialist.

4.38.26. On May 29, 2023, at approximately 12:03 p.m., the POLAR PRINCE departed St. John's for Mission 3 of the TITANIC Expedition 2023.

4.38.27. At approximately 10:41 a.m. on May 30, 2023, the POLAR PRINCE entered a small bay on the southeast side of Avalon Peninsula in St. Mary's Bay, Newfoundland. The transit was approximately 140 NM. A test dive was scheduled for the day, which was not on the Dive Log sheet provided to the MBI by OceanGate. According to a mission specialist, the plan was to do dive preparations in the morning and then a test dive to 100 m (328 feet) in the afternoon for an hour to conduct a full systems check. At approximately 1:00 p.m., five persons, including three mission specialists, entered the TITAN for the test dive. A mission specialist who took part in the test dive stated, "Everything checked out perfectly before lunch but in final checks, the power to the starboard thrusters was intermittent and failed." The five-person crew remained in the TITAN until about 5:00 p.m. to conduct fault findings. However, no fault was identified, and the TITAN crew subsequently returned to the POLAR PRINCE. This dive was not logged in the TITAN dive log.

4.38.28. On May 31, 2023, while in Witless Bay, the TITAN conducted Dive 85. According to a YouTube video posted by a Mission 3 mission specialist, they were going to the Bay to conduct maintenance and correct issues caused by water intrusion and/or being towed through fishing nets. The dive was piloted by OceanGate's Director of Logistics and the Software Engineer. The dive log for Dive 85 included the following remarks: "Locked in engineering test dive, platform heavy, Thruster dead man software issue, no external axis cameras." OceanGate classified the dive as a test dive and dove the TITAN to a depth of 10 m (32.8 feet). 10 m dives were dives which did not leave the LARS platform. During the dive, 13 issues were identified and only four of the 13 issues were classified as corrected in TITAN's Maintenance Log.

4.38.29. On May 31, 2023, at 5:15 p.m., the POLAR PRINCE departed Witless Bay, bound for the TITANIC wreck site. While the POLAR PRINCE was in transit to the wreck site, a Mission 3 mission specialist posted a YouTube video with the following commentary: "The waves were so big though that I could not concentrate because it was throwing us all across the room . . . ."

4.38.30. On June 3, 2023, at 5:11 a.m., the POLAR PRINCE arrived at the TITANIC wreck site. The transit distance was approximately 408 NM. OceanGate had an afternoon dive scheduled; however, it was cancelled due to the weather. There was reportedly heavy fog and a 2 m (6.56 feet) swell on-scene. Due to the adverse weather and sea conditions, no dives were conducted at the TITANIC site and the POLAR PRINCE subsequently departed the area and began the transit back to St. John's.

4.38.31. On June 5, 2023, at approximately 1:30 p.m., TITAN conducted Dive 86 with Mr. Rush as the pilot, an OceanGate software engineer serving as a crew member, and three mission specialists (one of whom posted content on YouTube[48]). The dive was approximately 140 miles to the north of the TITANIC wreck site and went to a depth of 10 m (32.8 feet) and never left the LARS platform. Once the short dive was complete, the POLAR PRINCE commenced the transit back to St. John's at approximately 5:37 p.m.

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[48] https://www.youtube.com/watch?v=O-8U08yJlb8

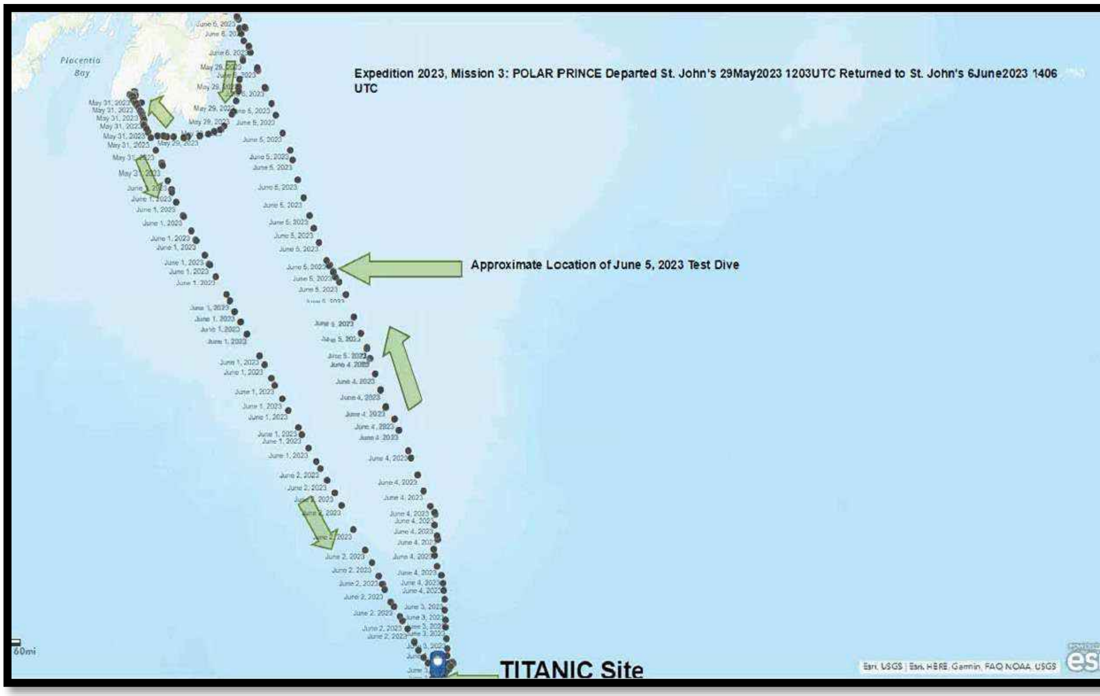

Figure 242: POLAR PRINCE's AIS track for Mission 3 of the TITANIC Survey Expedition 2023. Source: USCG Pole Star.

4.38.32. NOAA provided the MBI with the following weather summary for Mission 3, which ran from May 29 to June 6, 2023:

> On May 29th, a low-pressure system moved north-northeast across Newfoundland and into the Labrador Sea. However, it's important to note that the GDAS weather data might not be entirely accurate for this part of the POLAR PRINCE's journey because it was close to the Newfoundland coast, where GDAS has known limitations.
>
> As the POLAR PRINCE began heading southeast, waves continued to come from the west-southwest until June 1st. By June 4th, the waves had shifted to an east-northeast direction, and their height had increased to 2.3 meters (7.5 feet).
>
> A low-pressure system located to the east-southeast, near 40N, 42W, on June 3rd, generated winds from the north to north-northeast across a large area. As the POLAR PRINCE traveled back towards St. John's, the GDAS data shows that the

winds gradually shifted from north to east-northeast. Wave heights remained around 1.5 meters (5 feet) through June 5th.

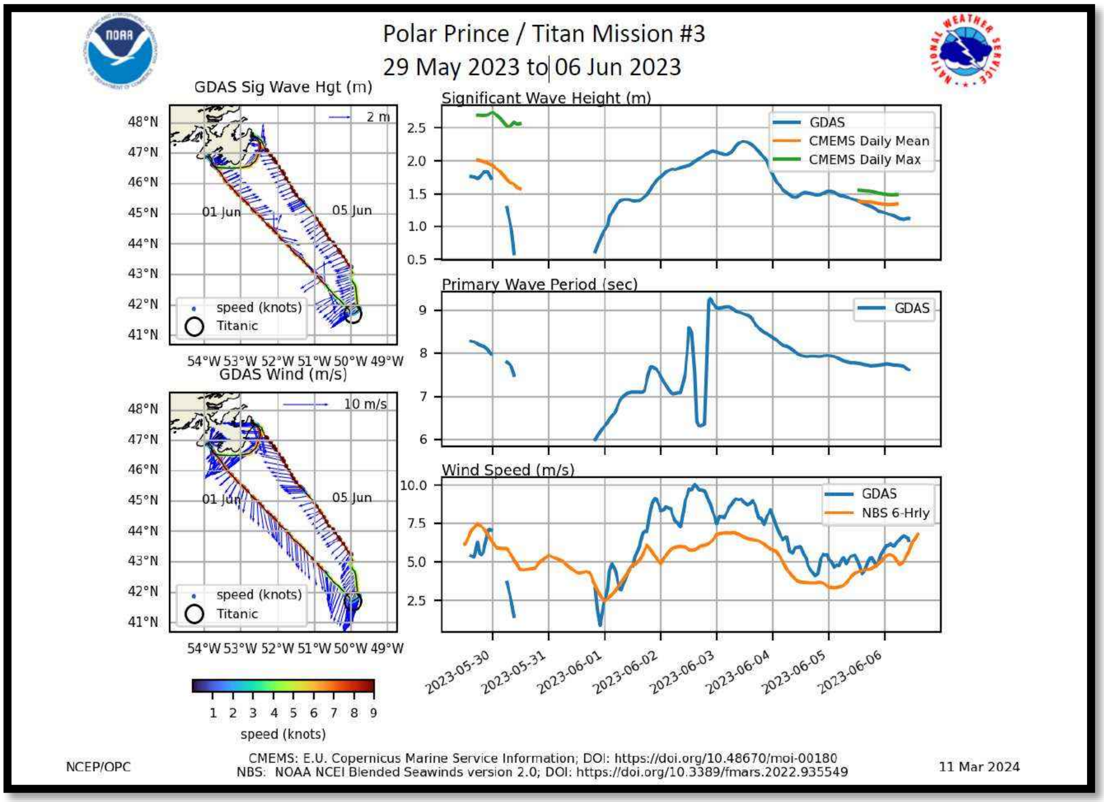

Figure 243: Mission 3 2023 TITANIC Expedition POLAR PRINCE/ TITAN weather. Source: NOAA.

4.38.33. On June 6, 2023, at 2:58 p.m., the POLAR PRINCE arrived in St. John's, which marked the end of Mission 3. The POLAR PRINCE's average speed transiting back to port was approximately 7 kts. The distance traveled on the return transit was 436 NM. The approximate total transit distance for Mission 3 was approximately 980 NM.

4.38.34. On June 7, 2023, at 1:14 p.m., the POLAR PRINCE departed St. John's for the beginning of Mission 4. The POLAR PRINCE headed west on a course for Sable Island National Park. According to mission specialists on Mission 4, the weather in the vicinity of the TITANIC wreck site was not conducive for dive operations, so the POLAR PRINCE transited to an area with more favorable conditions. Along the way, the towline for the TITAN and LARS became fouled in the POLAR PRINCE's propeller. As a result, the POLAR PRINCE was unable to maneuver and remained adrift for approximately six hours until the towline could be cut out and removed from the propellers by divers.

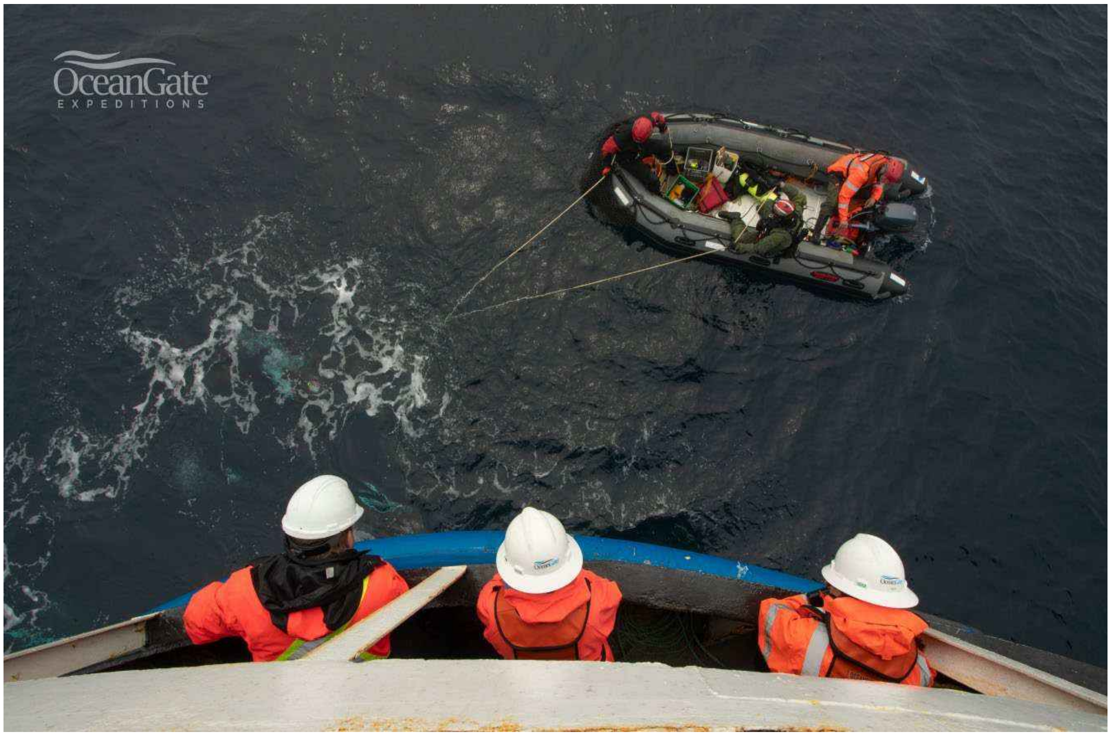

Figure 244: Overhead view from POLAR PRINCE of divers attempting to remove a towline that had fouled POLAR PRINCE's propeller on June 7, 2023. Source: OceanGate Expeditions.

4.38.35. NOAA provided the MBI with the following weather summary for Mission 4 of the TITANIC Survey Expedition 2023:

> On June 8th, between 12:00 and 18:00 Zulu time (Greenwich Mean Time), a strengthening low-pressure system passed over the POLAR PRINCE as it traveled southwest.
>
> Later, a series of low-pressure systems combined to the east of Newfoundland. This resulted in a significant peak in wave height late on June 11th, driven by westerly winds. The circulation from a strong low-pressure system (988 millibars) east of Newfoundland persisted and expanded westward, reaching south of Nova Scotia.
>
> On June 11th, westerly winds increased to approximately 13 meters per second (25 knots), and wave heights reached 2.5 meters (8.2 feet).

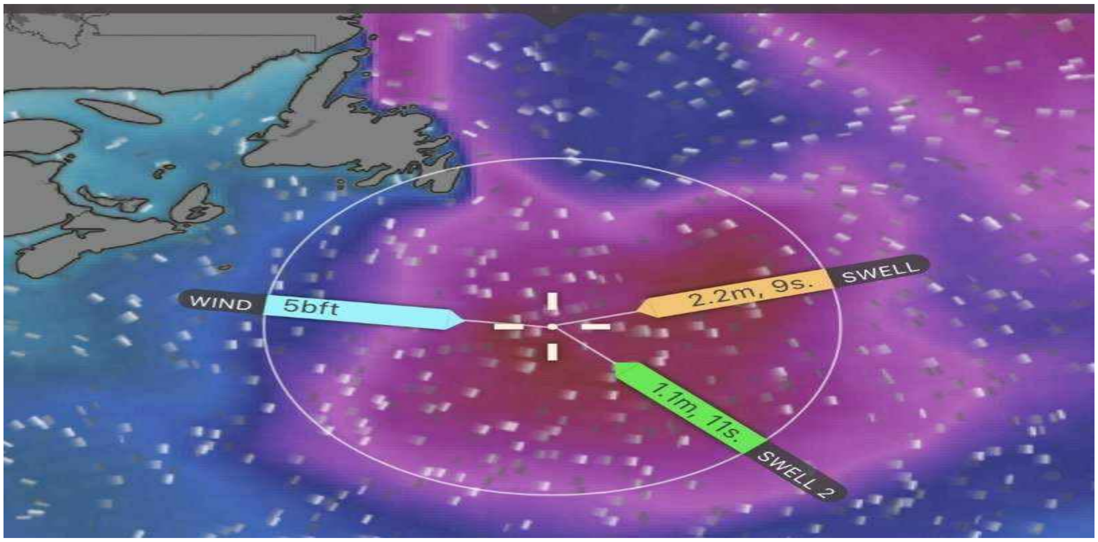

Figure 245: Weather conditions in the vicinity of the TITANIC wreck site on June 12, 2023. Source: Windy.com.

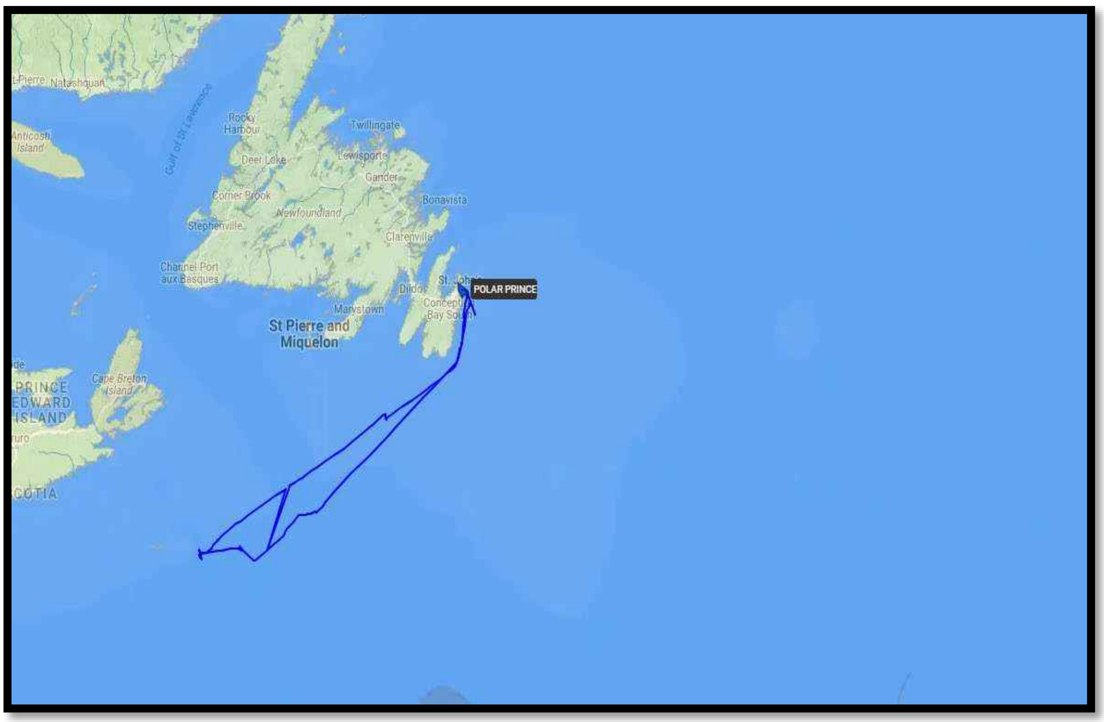

Figure 246: POLAR PRINCE’s round trip AIS track line for Mission 4 of TITANIC Survey Expedition 2023. Source: USCG Pole Star.

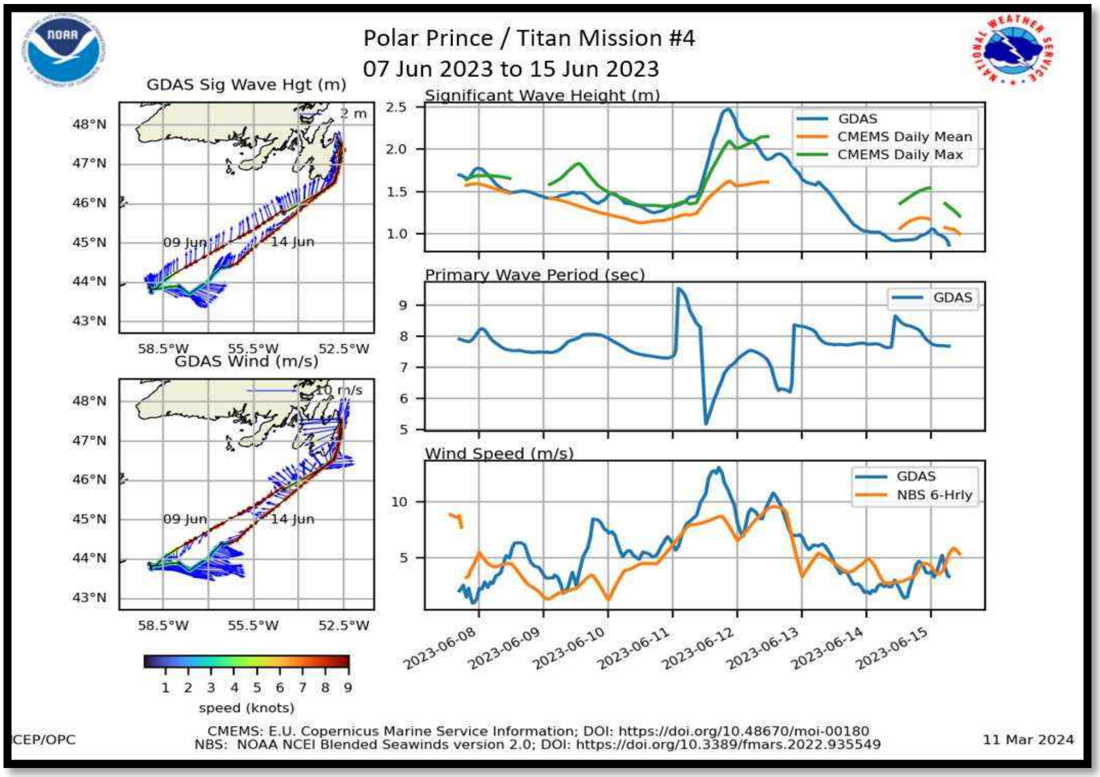

Figure 247: NOAA Weather Report for POLAR PRINCE's AIS track line for Mission 4 of the 2023 TITANIC Expedition. Source: NOAA.

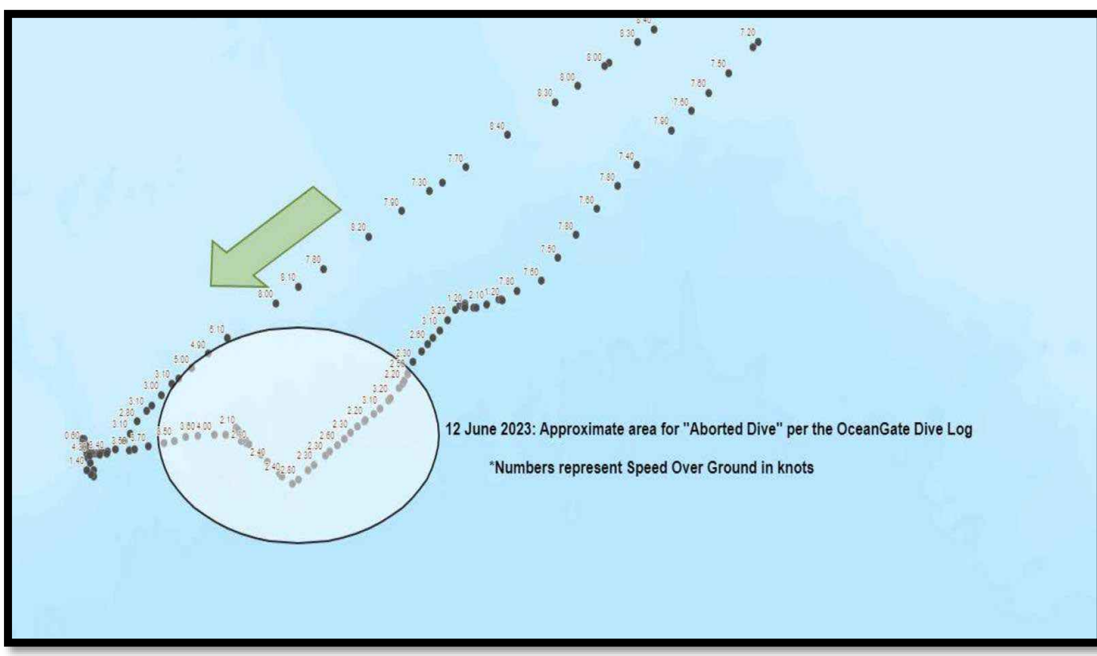

Figure 248: Approximate location of TITAN's aborted Dive 87, during Mission 4 of the TITANIC Survey Expedition 2023. Source: USCG Pole Star.

4.38.36. On June 12, 2023, OceanGate logged an aborted dive (Dive 87). The location was approximately 400 NM to the northwest of the TITANIC wreck site, in the vicinity of Sable Island National Park, Halifax, Canada. To this point in the TITANIC Survey

Expedition 2023, there were had been no “successful” TITAN dives that were able to leave the LARS platform. A mission specialist who participated in Dive 87 stated to the MBI that they felt Mr. Rush was beginning to get “antsy” and “clearly frustrated” and that Mr. Rush made the statement, “I’m going to get a dive in, even if it kills me.”

4.38.37. Two mission specialists (a married couple) from Dive 87 stated to the MBI that they were two of the three mission specialists participating in the dive, along with Mr. Rush and OceanGate’s Scientific Director. During a joint MBI interview, the couple explained that the TITAN was 30 feet underwater, preparing to detach from the LARS platform when the final system undergoing a check, the variable ballast system, malfunctioned. After several attempts to resolve the issue, the TITAN’s crew communicated with the support divers via written messages to ask for assistance. The mission specialists used a piece of paper and wrote, “VBT?” before holding it up to the window (see Figure 249) of the dome to communicate with the assist divers. The divers understood that VBT indicated that there was a potential issue with the platform’s variable ballast tanks and the TITAN’s dive support team attempted to troubleshoot the issue. However, after unsuccessful attempts, Mr. Rush (serving as the pilot for the dive) decided to surface, believing the ballast problem would be easy to fix as the surface. The mission specialist recalled to the MBI that Mr. Rush stated, “This should be a really trivial thing to fix, so let's just surface again. We're going to fix the variable ballast and then do our dive.”

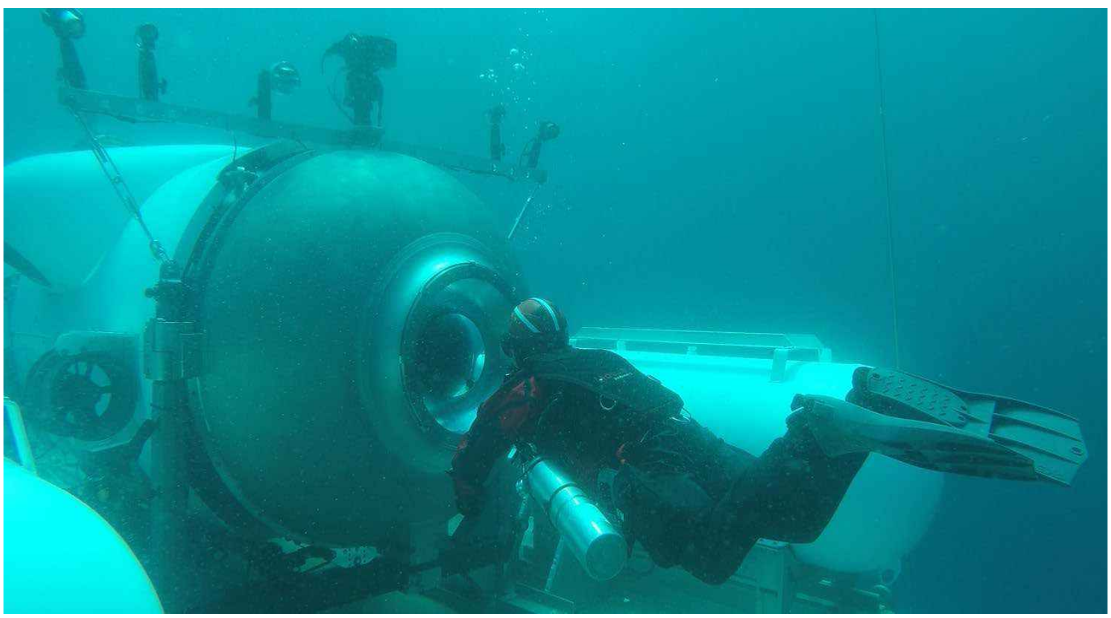

Figure 249: Image of TITAN support diver receiving written instructions from inside the TITAN during a dive that had to be subsequently aborted due to malfunctions. The dive was designated as Dive 87, the dive prior to the dive that resulted in TITAN’s implosion (Dive 88). Source: OceanGate.

Once the TITAN and LARS began the 30-foot ascent back the surface, complications arose. "The release valves for the high-pressure tanks.... weren’t closed properly," one of the mission specialists noted to the MBI. “The divers were supposed to close the valves after flooding the platform to allow air to lift it, but they didn’t. When air was pumped in, nothing happened.” The mission specialists also stated that OceanGate’s dive support personnel made an error with the platform's ballasting system that caused the TITAN to rise uncontrollably by the bow at a 45-degree angle, with the back of the platform still filled with water. The mission specialist stated, "We were all braced in the front, and suddenly we just flew up into the air. It tossed us like laundry. (The other mission specialist) was upside down. We ended up going up at a 45-degree angle and then slammed back down violently. I was holding onto the handle, but it was a rough ride." The mission specialists confirmed that the TITAN's bow was not properly secured to the LARS and that the stern remained hinged to it. As a result, the TITAN's bow was continuously lifted off the platform by passing swells, which would subsequently cause the TITAN's bow to repeatedly slam back down to the metal platform.

Figure 250: Overhead view of OceanGate surface support personnel and divers attempting to fix a ballast system malfunction on the LARS platform during Dive 87. The yellow circle, added by the MBI, marks a diver in the water. Source: OceanGate.

4.38.38. The mission specialists who were onboard Dive 87 as a couple testified to the MBI that, "We felt like we were free, then we'd slam back down," one of the specialists recalled. "It was jarring, very jarring." In the chaos, they reported that Mr. Rush became increasingly frustrated. "(Mr. Rush) was yelling, 'Why is this not getting resolved?' He was really upset, because he couldn't do anything to help," recalled one of the mission specialists. At one point, the sub shifted so much that Mr. Rush reportedly feared it might completely break free from the platform. "He was really concerned that the pins holding it would snap," one of the mission specialists said. Amid the repeated slamming of the TITAN against the metal deck of the LARS as ocean swells continued to lift and drop the bow, the mission specialists recalled that Mr. Rush ordered OceanGate's dive support team to “get a motorcycle tie-down strap, get to the shipping container. Tie down the sub before we break free.”

4.38.39. The divers outside continued to struggle with securing the TITAN to the LARS. A mission specialist provided the following assessment of the situation to the MBI: “It was far more dangerous for the divers trying to secure the sub than for us inside. We were all bracing, but they were at risk of being crushed under the sub. We were really worried about them." Eventually, the issue with the valves for the variable ballast system was rectified and OceanGate dive support personnel were able to secure and level the TITAN on the platform at the surface. A mission specialists stated, “It felt like a long time, though I couldn’t really gauge how long it was. It was definitely a tense situation.” After the TITAN was secured to the platform, the dive support Team proceeded to open the dome, and everyone was safely transported to the POLAR PRINCE.

4.38.40. According to the mission specialists on the dive, during the OceanGate’s post-dive debrief, Mr. Rush expressed his anger, especially towards the platform operator for his “hasty” decision-making regarding the ballast valves and emphasized the importance of following procedures and using checklists to avoid such dangerous and avoidable mistakes. The mission specialists who participated in Dive 87 as a couple testified to the MBI that they were concerned that the TITAN’s hull could have been damaged and potentially fractured during the incident. When they approached Mr. Rush with their concerns, they reported he responded by telling them that the TITAN was basically “indestructible” and that he wasn't concerned at all about the banging and the accident they had experienced because the TITAN was “completely safe.”

Figure 251: Inside of TITAN during Dive 87 incident. Photo taken from the forward dome area looking aft and down. Mr. Rush is sitting against the back wall, the dive’s Chief Scientist is standing on the back wall, and a mission specialist in the front left is positioned upside-down. Source: Former OceanGate mission specialist.

4.38.41. The Chief Scientist aboard the TITAN for Dive 87 explained that the mission began with five people, including Mr. Rush and three mission specialists, entering the TITAN. The seas were about six feet high, and they had descended to 10 m (32.8 feet) when an issue occurred with the variable ballast tanks. This prompted the decision to raise the platform back to the surface. However, as the platform lifted, the platform's forward end behind the TITAN, stayed submerged at a 50-degree angle, causing the passengers to be thrown violently toward the back of the sub. At the same time, the platform suddenly rotated 80 degrees to starboard. This caused the bow of the TITAN to become unseated from the platform, and as the swells rolled, the TITAN slammed back onto it repeatedly. The Chief Scientist described the force of the impacts as "jaw-breaking," and this chaotic situation lasted about 45 to 60 minutes.

> 4.38.41.1. The Chief Scientist described the situation (see Figure 251) to the MBI by stating, "There's nothing to hold on to inside the submersible, it's just a fairly smooth tube. The pilot crashed into the rear bulkhead, and the rest of the passengers tumbled about. I ended up standing on the rear bulkhead, one passenger was hanging upside down, and the other two managed to wedge themselves into the bow end cap."

4.38.42. The platform operator for Dive 87 stated to the MBI that he had conducted the pre-platform checks and confirmed all the ballast valves had been in the correct position prior to the dive. However, the platform operator noted that after OceanGate's dome crew used the high-pressure air to the forward dome's foot mechanism (used to support the dome in place during bolting operations), they had erroneously closed the high-pressure air valve that also served the platform's variable ballast system. As a result, the aft starboard air tank on the platform could not be filled with air until a support diver was able to eventually access the supply valve and open it.

4.38.43. OceanGate did not file an incident report related to the Dive 87 malfunctions. In addition, multiple witnesses testified to the MBI that they did not believe a post-incident inspection was conducted on the TITAN following the incident and the MBI was unable to identify any records in regard to a post-incident inspection.

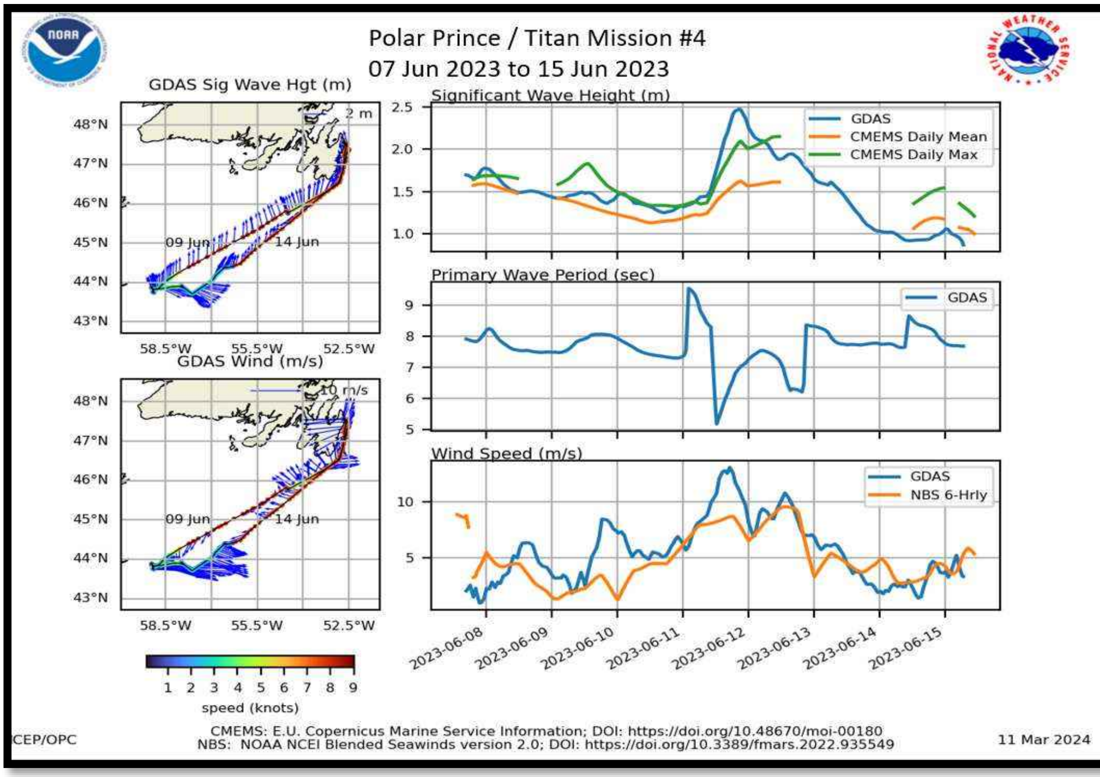

Figure 252: Mission 4 NOAA Weather Report for the AIS track line of the POLAR PRINCE. Source: NOAA.

4.38.44. NOAA provided the MBI with the following weather summary for Mission 4 of the TITANIC Survey Expedition 2023, which ran from June 7th until the date of the TITAN's implosion on June 18, 2023:

> On June 8th between 12-18 Zulu time (9:30 a.m. to 3:30 p.m. local time) a strengthening low pressure passed over the (POLAR PRINCE) on the outbound leg of the transit to the southwest. A series of low-pressure systems consolidated to the east of Newfoundland with peak significant wave height late on June 11th in westerly winds as the circulation from a strong low-pressure east of Newfoundland at 988 mb persisted and the circulation expanded westward to the south of Nova Scotia. Westerly winds increased on June 11tyh to approximately 13 m/s (25.2 knots) with significant wave heights to 2.5 m (8.2 feet).

4.38.45. On June 15, 2023, at approximately 11:23 a.m., Mission 4 of the TITANIC Survey Expedition 2023 was completed when the POLAR PRINCE with TITAN in tow arrived back in St. John's, Newfoundland. The total distance traveled for Mission 4 was approximately 800 NM.

Dive Number	Date	Dive Location	Dive Time	Max Depth (meters)
C2_0084	5/22/23	Enroute Titanic	0.5	8
C2_0085	5/31/23	Grand Banks	2.0	10
C2_0086	6/5/23	Grand Banks	2.0	10
C2_0087	6/12/23	Grand Banks	2.0	10

Figure 253: OceanGate TITANIC Survey Expedition 2023 excerpt from the dive log. Source: OceanGate.

4.38.46. A factual summary of Mission 5 of the TITANIC Survey Expedition 2023 can be found in Section 4.1 of this report. Prior to Mission 5 of the 2023 TITANIC Survey Expedition, the TITAN had been towed approximately 2,958 NM across the Atlantic Ocean and had not completed a dive where the TITAN was able to successfully depart the LARS platform.

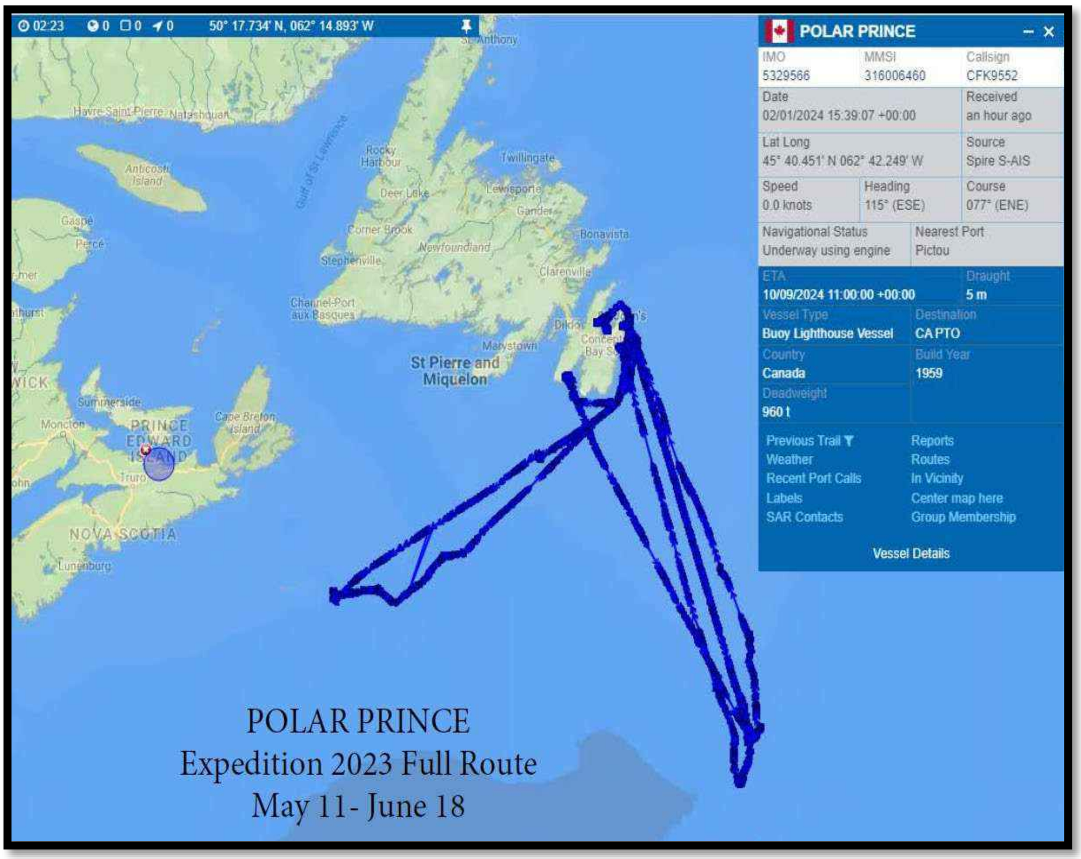

Figure 254: POLAR PRINCE AIS track line for 2023 OceanGate TITANIC Expedition. Source: USCG, Pole Star.

4.39. Summary of Search and Rescue Efforts

4.39.1. The Search and Rescue findings of fact for the TITAN incident that were referenced to conduct the analysis, conclusions and recommendations in this MBI report were developed from MBI testimony by a USCG Eighth District SAR Specialist and the Chair of the USCG TITAN Submersible Search and Rescue After Action Report (AAR) Board.

4.39.1.1. The USCG Office of Search and Rescue (CG-SAR) convened USCG TITAN Submersible Search and Rescue AAR Board on September 8, 2023, which was comprised of five USCG members.

4.39.1.2. The Board was directed to analyze the SAR response, apply Human Factor Analysis to the findings, and provide a report capturing lessons learned and best practices for the SAR Response, as well as provide information relevant to SAR System improvements for subsurface incidents and input to the interplay between the SAR System and the Incident Command System.

4.39.1.3. The Board was tasked with analyzing coordination between the USCG and U.S. Navy, as well as analyzing the limitations and challenges of the USCG's interactions involving subsurface rescue efforts.

4.39.2. The statutory authority for the USCG to conduct SAR missions is contained in Title 14, Sections 102, 521, and 701 of the U.S. Code, stating that the USCG shall develop, establish, maintain and operate SAR facilities and may render aid to distressed individuals and protect and save property on and under the high seas and waters subject to the jurisdiction of the United States.

4.39.3. The AAR Board provided recommendations for improvements in four main categories:

4.39.3.1. Communication Challenges: The review identified opportunities to improve the timeliness of critical incident communication. Incomplete USCG Quick Response Cards (QRCs) and the rapid escalation of the incident overwhelmed the system and suggested potential areas of improvement related to streamlining the SAR System's initial response.

4.39.3.2. Documentation Improvement Areas: The Board observed that case documentation faced challenges due to the high volume of incoming information, the existing SAR documentation system (MISLE database), and the difficulties in capturing all actions taken outside the JRCC. The challenges encountered identified areas for potential system enhancements.

4.39.3.3. Integration Opportunities: The AAR review revealed potential for improved integration between the SAR System and the Incident Command System (ICS). Addressing the challenges in communication flow and decision-making processes between the JRCC and Unified Command could have enhanced the efficiency of the overall incident response.

4.39.3.4. On-Scene Support Enhancement: The review indicated a need for more specific training and qualifications for Coast Guard personnel serving as on-scene representatives and liaisons with response partners. Providing USCG personnel with expertise in next of kin support, public affairs, and SAR system duties could improve on-scene effectiveness. The POLAR PRINCE initially served as On Scene Coordinator for the incident, which created challenges early in the response related to communications and USCG on scene presence.

4.39.4. The AAR Board Chair testified regarding the overall USCG's SAR efforts, emphasizing that the Board considered the TITAN response to be “unprecedented.” The remote area involved significantly hampered the response, initially requiring dependence on the POLAR PRINCE for on-scene coordination and support for the next of kin. While long-range air assets were crucial for conducting the majority of the searches, with a focus on locating the submersible or its crew at the ocean’s surface, the USCG First District JRCC was highly commended for its outstanding performance and innovative approach to this novel maritime SAR challenge.

4.39.5. Based on the AAR Board Chair’s testimony, the USCG operational capabilities are primarily limited to surface and air assets, including small boats, aircraft (both fixed- and rotary-wing), and cutters. The testimony highlighted that the Coast Guard currently lacks dedicated capabilities for subsurface search and rescue. While Chapter 6 of the Coast Guard SAR Addendum addresses procedures for underwater incidents, it explicitly acknowledges the absence of specialized equipment to assist in subsurface operations, instead directing reliance on the U.S. Navy for their technical expertise in the subsurface domain.

5. Analysis

On June 18, 2023, at 10:47:33 a.m., the POLAR PRINCE lost communications with and tracking of the TITAN submersible. The last known position of the TITAN was 41˚ 49.06’ N, 048˚ 56.54’ W at a depth of 3,346 m (10,978 feet). The HORIZON ARCTIC started searching for TITAN upon arrival at its last known location on June 22, 2023. On June 22, 2023, at 08:40 a.m., the Pelagic Research Services Odysseus ROV deployed from the HORIZON ARCTIC discovered the aft tail cone and other debris of the TITAN on the seafloor after extensive searching. This discovery provided conclusive evidence of the catastrophic loss of the TITAN and the death of all five individuals aboard.

The evidence gathered and analyzed by the MBI indicated that on June 18, 2023, at approximately 10:47 a.m., the TITAN’s hull experienced a critical event that compromised the structural integrity of its pressure vessel, resulting in an instantaneous and catastrophic implosion of the TITAN.

There were no witnesses to the implosion or video evidence recovered of the implosion, nor did the TITAN’s crew send any MAYDAY or emergency communications via text through the submersible’s acoustic telemetry modem, which was their only available method of communications with the surface, prior to the incident.

While the MBI was unable to definitively pinpoint the exact failure point of the TITAN’s hull, the facts and evidence collected and analyzed strongly suggest that the most likely initiating event to the tragedy was a loss of structural integrity of the carbon fiber or glue joint within the TITAN’s cylindrical pressure hull.

5.1. Inadequacy of Structural Engineering Analysis.

OceanGate's TITAN submersible design was a complex, high-risk, deep-sea submersible. The design and testing processes for TITAN did not adequately address many of the fundamental engineering principles that are considered crucial for ensuring safety and reliability for operations in such an inherently hazardous environment. These inadequacies related to TITAN's hull included: material selection and manufacturing processes; structural analysis and testing; identification and mitigation of risk factors; and process monitoring during manufacturing.

The feasibility study conducted by Boeing for OceanGate emphasized the need for comprehensive material selection and rigorous manufacturing processes. In the case of TITAN, the use of unproven materials in the deep-sea environment combined with the non-standard cylindrical hull design compounded the risks. The failure to incorporate impact-resistant syntactic foam and ensure adequate bonding between metal-composite interfaces suggests that OceanGate lacked an in depth understanding of material behavior under extreme conditions, such as deep-sea pressures.

Insufficient structural analysis and the lack of rigorous testing were significant failures in TITAN's design. Boeing's feasibility study stressed the importance of validating assumptions and performing extensive tests, particularly when dealing with novel materials and designs. OceanGate failed to dedicate the requisite time and resources to these crucial processes, which likely contributed to undetected vulnerabilities in the submersible's hull.

As an example, the curing process for composite materials is complex and can have significant effects on the overall structural integrity of the hull. Boeing's report highlighted the need to analyze the product during the curing process, particularly when composites are involved, given their sensitivity to thermal cycles and mechanical stress. Thermal and kinetic effects during curing likely impacted the final material properties of the final TITAN, yet there is no evidence suggesting that OceanGate investigated these phenomena in sufficient detail.

One of the most critical challenges with composite structures, particularly in a high-pressure environment, is ensuring reliable bonding between different materials—such as the metal-composite interface. Without detailed research and testing on the bonding capabilities, there was a high risk that structural failure would occur at the interface under the extreme conditions experienced by a submersible. This issue was identified by the Boeing feasibility study and should have been a major area of focus for OceanGate. However, there is no indication that the interface was tested in a comprehensive manner.

Manufacturing defects, whether in the composite layers or the bonding processes, can compromise the structural integrity of the entire submersible. The lack of thorough testing and inspection to identify and address these defects likely contributed to their undetected presence before the implosion. This is common when quality control and rigorous testing are insufficient during the development process. The fact that OceanGate personnel had to grind down layers of carbon fiber to help shape the hull between the one-inch layers of composite are a clear indication that there were defects during fabrication. OceanGate's refusal to explore and potential NDT options recommended by the Boeing feasibility study, indicate they were comfortable moving forward and ignoring any potential defects likely due to the expenses and time involved in conducting the recommended tests.

A robust testing regime would have been crucial to identifying and addressing the potential failure points in TITAN's design. Testing is not just a procedural step, it is a critical means of ensuring assumptions about material properties, design integrity, and real-world performance are valid. By failing to adequately address this critical step, OceanGate exposed not only the submersible but also the lives of its passengers to extreme risk.

The problems leading to the TITAN submersible's implosion reflect a broader failure by OceanGate to follow best engineering practices and, more critically, a disregard for the necessary safety protocols when testing novel designs. The issues with material selection, structural analysis, manufacturing defects, and testing were all red flags that should have been addressed more thoroughly before the submersible was deemed ready for operation with personnel aboard. The Boeing feasibility study's emphasis on rigorous research and testing should have been a guide for OceanGate's engineering team, but many of these critical steps were overlooked or inadequately addressed, resulting in the tragic outcome.

5.2. Lack of Determination of Identifying Failure Points of TITAN's Design / Failure to Properly Investigate Potential Failure Points of TITAN's Design.

Determining potential failure modes is essential when designing complex engineering systems with novel features because such designs often involve unproven technologies, where the behavior of components, materials, or interactions may not be fully understood. Experimental design features introduce unique challenges and risks that may not be captured by traditional testing or prior practical experience. Identifying potential failure modes early in the design process allows engineers to anticipate and address potential weaknesses—whether in material properties, mechanical interactions, or control systems—before they lead to costly or dangerous failures. By evaluating these failure modes, designers can optimize the system to improve reliability, performance, and safety, ensuring that new innovations function as intended under real-world conditions. This proactive approach helps reduce the likelihood of design flaws, enhances system robustness, and ultimately increases the likelihood of successful project outcomes.

There are several different established failure mode systems used for analysis. One such method, used by Classification Societies and the USCG, to systematically determine and prioritize potential failure modes is the use of the Failure Modes & Effects Analysis (FMEA). As the TITAN design utilized untested components, new materials, and unique system interactions the use of FMEA, or another established failure mode evaluation system, would have been essential. Systems like FMEA help engineers anticipate problems before they occur, prioritize risk based on the severity and likelihood of a failure, and develop strategies to mitigate those risks. FMEA enhances decision-making, optimizes design iterations, and contributes to the overall success of complex engineering projects.

Boeing's feasibility study outlined the unique challenges and risk factors associated with OceanGate's design of TITAN and warned that additional research and testing was necessary to ensure a sound design. Boeing emphasized that the purpose of estimating these failure modes is to determine the form of finite element analysis that will produce the most useful results. The MBI could find no evidence confirming that OceanGate identified all potential failure modes of the TITAN submersible in the form of an established failure mode system, such as a FMEA.

Had OceanGate conducted a proactive analysis of the TITAN failure modes, its potential vulnerabilities could have been addressed early in the design phase. Boeing had given OceanGate a roadmap of potential failure areas, and specific items to focus on during the design phase. However, many of these items were either inadequately addressed, or not addressed at all by OceanGate due to time and money concerns. If OceanGate had utilized an established failure mode system, such as a FMEA, and incorporated that into their design iterations, the reliability, performance, and most importantly the safety of the TITAN submersible could have been significantly improved.

5.3. Failure to Follow Boeing's Manufacturing and Testing Specifications.

In 2013, Boeing conducted a preliminary feasibility study for OceanGate, outlining several challenges that needed to be addressed in the design of a composite structure using CFRP. The study concluded that such a design was technically feasible but highlighted several key challenges that needed to be addressed to ensure success. These challenges included issues related to manufacturing processes, cure kinematics, material allowances, assembly methods, and dimensional tolerances.

One notable assumption in Boeing's feasibility study was that the design of the viewport would follow a standard design, and the analysis for a non-standard design was not included in Boeing's study. Additionally, Boeing stressed that any perforations or impact damage to the carbon fiber should be avoided, as these small impacts could aggregate and compromise the integrity of the structure. To mitigate this risk, the study recommended incorporating a more durable, impact-absorbing layer, such as syntactic foam, to protect the outer mold line of the hull.

The optimized design in Boeing's feasibility study specified a CFRP hull thickness of 7 inches. However, OceanGate reduced the final TITAN's design thickness to 5 inches, with a key difference being the exclusion of 45˚ plies from the final CFRP layup. Boeing's preliminary report had indicated that allowable strain tables did not support layups without plies oriented at 45˚. Despite this, the final TITAN design utilized only circumferential and axial CFRP plies, yet no one involved in the project interviewed by the MBI could explain why the 45˚ plies were excluded. In addition, a Boeing Material and Process Engineer involved in the feasibility study provided testimony to the MBI confirming that Boeing was not consulted or involved in any discussion with OceanGate related to OceanGate's decision to exclude the 45˚ plies from the final TITAN hull design.

Another critical aspect identified in the feasibility study was the bonding of hybrid metal to a composite interface, specifically the joints between the titanium end segments and the composite hull. Boeing recognized the performance of these adhesive joints as uncertain and recommended further research to understand the bonding capabilities and the impact of applied loads on these critical adhesive joints.

Boeing’s feasibility study also pointed out several manufacturing challenges associated with large, complex laminate structures. Boeing highlighted the risk of defects such as delamination, which can arise during hull fabrication due to poor fit-up, contamination, or inadequate lamination contact. Additionally, porosity within the CFRP may result from improper curing, pressure, or bagging issues, with the likelihood of defects increasing as the laminate thickness grows. This increase in defect probability is particularly concerning, as voids or variations in the fiber-to-resin ratio can significantly degrade the load-carrying capacity of the structure. To address these concerns, Boeing recommended using NDT, such as PE testing, to detect these potential defects. However, the MBI was unable to identify evidence that OceanGate conducted any NDT on the carbon fiber hull and former OceanGate employees testified that OceanGate only conducted visual inspections of the hull. While testimony from OceanGate employees suggested that NDT such as PE would not be effective for such a thick-hulled carbon fiber structure, Boeing’s Material and Process Engineer provided MBI testimony that Boeing has conducted such NDT on carbon fiber structures of similar or greater thickness for other projects.

To ensure the integrity of thick laminate construction, Boeing emphasized the importance of stringent process monitoring. Any defect in a thick laminate can compromise the effectiveness of subsequent production steps. As a result, thorough inspections for manufacturing defects—including porosity, voids, inclusions, and foreign object debris (FOD)—are essential. Additionally, Boeing recommended the use of non-destructive evaluation (NDE) techniques to verify that all process control steps were followed correctly and that the curing process met specifications. Specifically, their feasibility study recommended that CFRP validation coupons or test components from the hull’s fabrication be retained and used to confirm process integrity and validate design assumptions.

Boeing’s feasibility study also highlighted that potential thermal and kinetic effects during the hull’s curing process were another major concern. Boeing noted that thermal residual stresses could develop because of exothermic reactions during curing, as well as differences in thermal expansion between materials. These stresses could lead to deviations in material performance. To address this issue, Boeing recommended comprehensive 3D cure kinematic modeling to account for the thermal characteristics of all materials used in the composite hull. This modeling would assess residual stresses and identify any variations in material behavior that could result from non-standard curing conditions, including repetitive curing cycles for a structure like TITAN with multiple layers of CFRP. Further work was deemed necessary to define thermal loads and curing shrinkage, especially for the composite cylinder and bonded joints. This recommended modeling was not performed by OceanGate, and there is no evidence that they accounted for these considerations during the construction process.

Boeing's feasibility study found that a carbon fiber hull was technically possible but identified several critical challenges, including manufacturing defects, bonding issues, and thermal stresses during curing. Despite Boeing's recommendations for additional testing and process monitoring, OceanGate's final design reduced the hull thickness, excluded key CFRP structural elements, and failed to implement NDT or advanced modeling, leaving significant uncertainties about the submersible's integrity.

5.4. Insufficient Understanding of Carbon Fiber Material Properties for Deep-Sea Application.

The TITAN's pressure hull was constructed using carbon fiber, a material chosen by Mr. Rush for its "impressive" strength-to-weight ratio. Carbon fiber composites offer high strength while significantly reducing weight compared to other materials traditionally used in submersibles, such as steel or titanium. However, while the strength-to-weight ratio was a considerable advantage, the use of carbon fiber in deep-sea environments remains unproven—unlike the materials with established safety records. There are currently no recognized national or international standards that approve of the use of carbon fiber pressure hulls for submersibles.

Carbon fiber has demonstrated its effectiveness in other applications where the material is primarily under tension (e.g., aircraft hulls where the pressure inside the passenger compartment is pressing outwards). However, in deep-sea conditions, the pressure hull experiences extreme compressive forces, a scenario for which carbon fiber has no established track record and is generally understood to be less effective. Approved materials for pressure hulls of submersibles are typically ductile, meaning they can undergo plastic deformation before failure. These ductile materials exhibit reversible (elastic) deformation within certain stress limits, allowing them to absorb energy and provide a visual indicator without immediate failure. In contrast, carbon fiber is composed of tightly packed carbon atoms arranged in a crystalline structure that offers high strength in specific directions but minimal flexibility. When subjected to stress beyond its limit, carbon fiber does not significantly bend or stretch prior to failure. In a composite structure, carbon fibers are usually embedded in a resin that adds some flexibility; however, the fibers themselves are prone to breaking or cracking under excessive force, and once damaged (i.e., individual fibers break), the material permanently loses some strength in the affected area, which is nearly impossible and highly impractical to repair in a structure like TITAN's hull.

A presentation provided by an ABS Senior Principal Engineer during an MBI hearing session, identified several critical challenges associated with the use of carbon fiber in submersible hull construction. ABS noted that carbon fiber lacked the following: defined safety factors, criteria for hull out-of-roundness, and acceptable tolerances for local deviations from the intended design geometry. Given that carbon fiber composites are anisotropic[49] and highly dependent on the manufacturing process, they are particularly

[49] An anisotropic material or substance has physical properties that have different values when measured in different directions.

vulnerable to defects created during manufacturing. ABS pointed out that issues such as voids, blisters, wrinkles, and porosity can significantly weaken composite structures, potentially accelerating the collapse of a pressure hull under external pressure. Furthermore, ABS emphasized the susceptibility of carbon fiber to fatigue failure from repeated cycles of external pressurization and depressurization, with accumulated damage often going undetected.

An analysis conducted by Colliers/HyperSizer revealed that wrinkles can greatly reduce the load-carrying capacity of a composite structure. In their investigation of the failures that occurred in the TITAN third-scale model testing conducted by OceanGate, they noted that wrinkles misaligned the fibers in the direction of the load created areas where the material was more likely to fail. Additionally, wrinkles are inherently resin-rich and much softer than the carbon fibers. This means that the wrinkles can form voids that compress more easily than the surrounding material, making them more prone to delamination. As a result, the surrounding undamaged areas of the structure are typically stiffer and more load bearing and thus end up bearing a larger percentage of the stresses being exerted on the object, which makes the stiffer sections more susceptible to failure. When local failure occurs near a wrinkle, the laminate may bend or deflect outward, exacerbating the delamination process.

Although carbon fiber is not an approved material for submersible pressure hulls, that exclusion does not rule out its potential use in submersible design. However, when using an unapproved material for a new application, additional engineering steps must be taken to ensure the design's integrity and to account for the uncertainties associated with the new material. For carbon fiber to be considered for deep-sea applications, extensive testing would be necessary to verify assumptions and validate the design, resulting in increased costs and time commitments.

In a post-casualty assessment, the cut-off ends (left over from the fabrication of the main carbon fiber cylinder) of the final TITAN's carbon fiber pressure hull were analyzed and material testing was conducted. According to the report completed by NTSB[50], the hull was constructed using unidirectional, filament-wound carbon fiber pre-impregnated with epoxy resin. The build sequence involved layering two cylindrical plies under tension, followed by one longitudinal ply without tension, repeated until the target number of plies was reached. The winding direction and bias alternated with each cylindrical ply, resulting in a helical pattern. The final structure consisted of 133 plies, with intermediate debulking steps. The calculated hull thickness was approximately 5.02 inches, based on material specifications, while the average thickness of the trimmed ends measured around 5.16 inches. The discrepancy between the main hull and the trimmed ends was likely caused by excessive adhesive, voids, and wrinkles in the carbon fiber.

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[50] See Appendix A: NTSB Materials Laboratory Factual Report 24-011 July 5, 2024

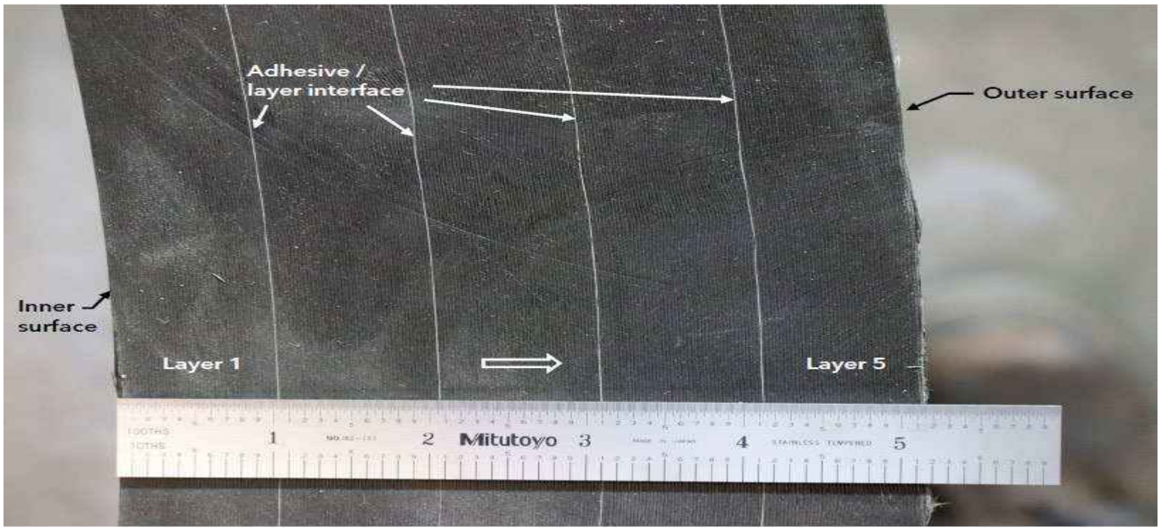

Figure 255: TITAN cut off ends cross section through the hull wall showing the co-bonded layered structure. Source: NTSB Materials Laboratory Factual Report.

Additionally, the NTSB report noted that voids were observed in the adhesive due to fiber bridging or tenting at one or both sides of smaller amplitude wrinkles. Other wrinkles exhibited signs of grinding, suggesting that OceanGate sanded down the wrinkled regions on each carbon fiber layer to be flush with the outer surface. As detailed in the NTSB report, as many as 12 ground layers of carbon fiber were observed in a sample sent to the NTSB lab for analysis. One of the cut-off ends was thoroughly examined to identify the number of fiber bridging/tenting and grinding features in each layer. The findings are summarized in the Figure 256 with Layer 1 being the inner hull. The anomalies identified were consistently present across all quadrants of TITAN's hull. In several cases, the NTSB noted that the presence of a ground out wrinkle or fiber bridge in one layer led to the formation of another bridge or wrinkle in the adjacent layer above.

Layer	Fiber bridges (with one or more voids)	Ground wrinkles
1	0	1
2	4	8
3	9	14
4	5	24
5	N/A	N/A

Figure 256: Number of anomalies identified by the NTSB in each layer of an end trimmed from TITAN's hull during fabrication. Source: NTSB Materials Laboratory Factual Report.

Figure 257: Images of the trimmed end faces under oblique lighting showing wrinkles and waviness in the carbon fiber orientation. Local variations in fiber orientation result in the observed light/dark brightness variations. Source: NTSB Materials Laboratory Factual Report.

Voids were also noted in the adhesive layers bonding the co-cured carbon fiber layers, with the most significant voids observed at the layer 1/2 and layer 3/4 interfaces. Though voids were present at every interface between the 5 layers, those at the 2/3 and 4/5 interfaces were typically discrete and nominally spherical in shape. In contrast, the adhesive voids discovered at the 1/2 and 3/4 carbon fiber interfaces formed elongated features along the lower layer interface. The longer voids between layers 1/2 and 3/4 resulted in separation of the adhesive from the supporting layer beneath.

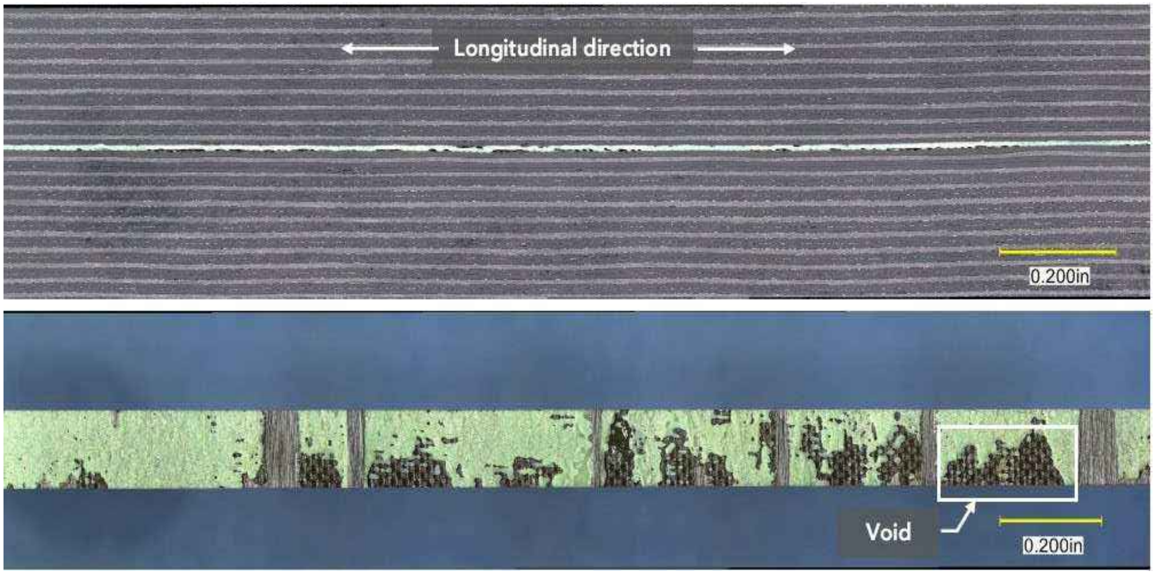

Figure 258: Top Image: Cross section image of the adhesive between layers 1 and 2. Areas of voids are present at the layer 1/2 interface. Lower image: Top view of the adhesive on the interface surface after the above pictured layers were separated by the NTSB lab. Multiple voids are visible where the glue layer was not consistently applied. Source: NTSB Materials Laboratory Factual Report.

Material testing by the NTSB revealed a range of strength values for the carbon fiber, with the selected samples showing no wrinkles in order to represent an idealized scenario.

The manufacturing defects identified in the NTSB report would have reduced the overall strength of the TITAN's hull, with localized reductions in strength at wrinkle sites. In engineering design, it is crucial to fully understand the material properties to ensure the integrity of a structure. Notably, no material testing was conducted on the carbon fiber by OceanGate prior to use, despite suggestions by Boeing in the feasibility study that material testing was a vital step in the process for the use of a new material. While Spencer Composites and Colliers/HyperSizer performed analyses based on assumed material properties, the actual properties of the carbon fiber were never confirmed. Had OceanGate conducted material testing, the company would have better understood the structural analysis, which would have potentially enabled them to calculate a realistic estimate of the hull's cycle life. Additionally, Colliers/HyperSizer was specifically instructed not to perform a fatigue analysis for OceanGate, meaning the only life cycle calculations for the TITAN's hull were based on assumed material properties prior to the construction of the final hull.

5.5. Use of an Un-tested / Un-certified Acrylic Window.

The first acrylic viewport manufactured for OceanGate was a spherical sector window with a flat interior, low-pressure surface. This window featured non-standard geometry that did not comply with PVHO standards. Hydrospace, the manufacturer, certified the window to a pressure rating of 945 psi, corresponding to a depth of only 650 m (2,133 feet). Hydrospace advised OceanGate on how to establish a safe operational depth for the nonstandard window and recommended that OceanGate submit a code case[51] to ASME PVHO for design approval. Additionally, Hydrospace provided OceanGate with a PVHO-compliant alternative window geometry that could fit into TITAN's existing viewport seat.

Hydrospace subsequently reached out to Kemper Engineering to conduct a preliminary study on the behavior of TITAN's non-compliant window. The study revealed significant strain consistent with potential short-cycle failure modes, which could lead to a potential failure at depth. Despite these warnings, OceanGate did not pursue further testing of the window as recommended by Hydrospace, nor did it submit the necessary code case to ASME PVHO. OceanGate also chose not to pursue the PVHO-compliant alternative geometry window that Hydrospace had provided because Mr. Rush believed that a flat inner surface provided the crew of the TITAN with a better view.

PVHO Form VP2 is a required document to certify PVHO windows, confirming that the design has been thoroughly reviewed and meets all engineering standards for safe use at designated pressure depths. However, in the case of OceanGate's non-standard window, Hydrospace was unable to issue the PVHO Form VP2 because OceanGate had not provided the necessary design documentation and calculations. Without this form, Hydrospace could not issue the fabrication certificate (VP1), meaning the window could not achieve official PVHO certification.

Given the substantial discrepancy between the window's rated pressure, of 945 psi, and the enormous pressures encountered at depths of 4,000 m (approximately equivalent to 5,850 psi), Hydrospace strongly recommended that OceanGate refrain from relying on the non-standard window for such deep dives. Instead, Hydrospace suggested that OceanGate purchase a properly certified window, designed for 4,000 m depths. Hydrospace provided drawing specifications for a certified window and also offered to supply additional material to assist with the manufacture of a second, fully certified window. This recommendation was based on the understanding that while the non-standard window could be used experimentally, it was not safe for manned deep-sea use without proper certification.

Hydrospace made it clear to OceanGate that they could proceed with testing the non-standard window, but they should simultaneously acquire a certified replacement window for safety and compliance purposes. The testing of the non-standard window was encouraged, but Hydrospace emphasized the need for caution and recommended the purchase of a certified backup window. This approach was critical for ensuring safety and adhering to PVHO standards, as the non-standard window lacked the necessary specifications for high-pressure, deep-sea use.

Ultimately, Hydrospace's role was to support OceanGate in creating the non-standard window, but also to ensure that they understood the design's limitations and the need for

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[51] An ASME Code Case is an official interpretation or alternative rule to the existing requirements of an ASME Boiler and Pressure Vessel Code (BPVC). It's essentially a temporary or conditional allowance to deviate from the main code rules.

proper certification. Although the window could be tested, the lack of a signed design certificate (VP2) and the window's insufficient pressure rating for 4,000 m depths meant it could not be officially certified for use in deep-sea submersibles. This underscored the critical importance of both testing and certification in the PVHO process.

Acrylic, being a nonmetallic, nonlinear material, requires thorough testing to qualify for PVHO certification, especially for non-standard geometry windows. The testing program is outlined in ASME PVHO-1 Section 2-2.6, which includes proof testing and cyclic fatigue testing. Proof testing involves testing five samples to destruction, while cyclic fatigue testing requires a window to endure 1,000 cycles at maximum working pressure (over 9 months), along with multiple windows subjected to elevated pressure for 300 hours.

Although the window manufactured by Hydrospace met dimensional and material certifications, it could not achieve full PVHO compliance without completing the necessary proof and cyclic testing as per ASME PVHO-1 Section 2-2.6. Since OceanGate did not pursue these tests, Hydrospace could only certify the window to 945 psi, or roughly 16% of the required pressure rating for a 4,000 m depth.

In December 2019, the original window manufactured by Hydrospace sustained damage after being dropped and was taken out of service.

In April 2020, OceanGate approached Heinz Fritz GmbH to manufacture a new acrylic window. Heinz Fritz GmbH confirmed that the window was manufactured according to standard PVHO geometry, specifically as a spherical sector. Photographs supplied by Heinz Fritz corroborate that the window conformed to a spherical shape. The company employed the same raw materials, machinery, and processes—grinding, polishing, and annealing—in accordance with PVHO standards. However, OceanGate explicitly requested that the acrylic window be delivered without PVHO-specific documentation.

During the investigation, OceanGate's remaining employees were unable to initially identify the origin of the second window. Although several former OceanGate employees communicated with Heinz Fritz GmbH, it was confirmed that Heinz Fritz GmbH was the window's manufacturer after Heinz Fritz GmbH reached out to the MBI. Heinz Fritz GmbH was subsequently able to provide the MBI with purchase orders and photographs of the window they manufactured for OceanGate.

It is believed that the window installed on the TITAN at the time of the incident was the one manufactured by Heinz Fritz GmbH. While the window lacked PVHO-specific documentation, it was likely constructed to withstand the pressures at TITANIC depth. A post-accident review of the TITAN's debris indicates that it is unlikely that the acrylic window itself caused the implosion, as no acrylic remnants were recovered from the debris and the damaged hull remnants are not consistent with a failure originating from the window. According to MBI testimony provided by the Principal Engineer with Kemper Engineering Services, the most probable failure mode for the acrylic window would have been inward. In such a scenario, fragments of acrylic would likely have been found in the debris. However, the window's retaining ring was found bent outward, with all the screws on the retaining ring sheared off, indicating that the acrylic window was likely pushed outward and ejected during the implosion. The MBI was unable to locate any part of the window during two salvage missions to recover TITAN debris and it is believed the window was forcibly ejected during the implosion and then buried in the silt layer on the seafloor.

5.6. Flawed Implementation and Application of the TITAN's RTM System.

The TITAN's RTM system was displayed on a screen inside the submersible. This provided the pilot with a visual status of the RTM system through a green-yellow-red color monitoring scheme, driven by system threshold setpoints established by Mr. Rush. Green indicated that the dive could proceed normally, yellow advised that the dive could proceed with caution, and red signaled an immediate need to abort the dive and return to the surface. Mr. Rush was solely responsible for determining and ordering any adjustments to these thresholds, and none of OceanGate employees could explain the rationale or methodology behind the establishment of these setpoints.

OceanGate did not have a thorough testing process to properly analyze and understand the data collected by the RTM system or how its data should be processed as a safety measure. Testing and development of the RTM was limited to two key phases: first, using data obtained from one-third scale models during the development of the TITAN hulls, and later, using data obtained during a single session at the DOTF for each of the full-size hull TITAN hulls. For the first hull, testing at the DOTF was conducted only after the large crack had been found in the interior of the hull, and for the final TITAN hull, only four tests were conducted. The DOTF tests were focused more on proving that the hull could withstand the pressures at TITANIC depths rather than establishing clear acoustic warning thresholds. There was never a full-scale test of TITAN's hull taken to failure, and only a few cyclical tests were performed. The limited number of tests conducted on the full-size TITAN hull raised doubts about the RTM system's data consistency and reliability, especially in regard to forecasting a developing catastrophic failure.

During testing of the one-third scale models and for the first hull at the DOTF, large acoustic emissions signaled warnings of imminent hull failure. However, these tests were too limited to establish repeatable outcomes or to analyze the details of these emissions thoroughly. Despite this, OceanGate engineers and Mr. Rush assumed that these acoustic signals would provide clear, timely warnings before a failure. The problem with that assumption is that the testing was too narrow in scope and lacked a critical follow-up analysis. There was no comprehensive effort to define precise warning thresholds or assess how ongoing acoustic emissions – or cumulative damage developing in the carbon fiber hull – could affect those thresholds. One additional key gap was OceanGate's failure to clearly define what constituted an "acoustic hit." Additionally, OceanGate overlooked potential failure scenarios where a catastrophic implosion could occur without triggering any warning from the RTM system.

MBI testimony provided by a Boeing Material and Process Engineer revealed a critical flaw in OceanGate's approach when he described that buckling, a known failure mode, would not necessarily trigger an alert on the RTM system as an indication of carbon fiber failure. This gap in understanding underscored OceanGate's failure to recognize both the limitations of the RTM system and the behavior of carbon fiber under extreme conditions. Without sufficient testing or a deeper analysis of possible failure scenarios, the company's reliance on the RTM system was dangerously misguided.

Additionally, the RTM system was only operational during dives, meaning any impacts or damage sustained by the submersible between dives went unrecorded. The RTM system also reset its data after each dive, which effectively disregarded the hull's cumulative acoustic emission history. This flaw meant that critical information from previous dives was excluded from influencing decisions in subsequent missions. In addition, TITAN's acoustic activity recorded after surfacing was routinely dismissed by OceanGate as simply "noise" caused by the submersible's docking and attachment to the LARS.

The RTM system was further degraded because three of its eight acoustic sensors were likely inoperable throughout the 2022 and 2023 TITANIC Expeditions. During TITAN's Dive 80, five sensors registered high acoustic amplitudes simultaneously, while three – AE Channels 1, 3, and 5 – did not register any significant readings. Given that AE Channels 3 and 5 were positioned between the operational sensors that provided the high readings, the MBI determined they were not functional, as they would have detected sound during the significant acoustic event. This anomaly, along with the absence of significant data from these three sensors during the entire 2022 expedition, strongly suggests that AE Channels 1, 3, and 5 were nonfunctional for the entirety of the 2023 expedition.

Despite the limitations of the RTM system identified by the MBI, Mr. Rush continuously promoted it as a critical tool for monitoring the submersible's health and keeping TITAN's occupants safe, asserting that it would provide ample warning of catastrophic failure. While multiple engineering experts interviewed by the MBI unanimously agreed that an RTM system should never be the sole determinant of the health of a carbon fiber hull, OceanGate made the decision to rely solely on its data to monitor the TITAN's hull. Thus, the fact that OceanGate operated TITAN with three out of eight sensors (37.5%) inoperable was reckless as it severely compromised their ability to detect potential issues and the potential for catastrophic failure.

Overall, OceanGate's RTM system was fundamentally flawed due to limited testing, overlooked failure modes, malfunctioning sensors, lack of cumulative data tracking, and the dismissal of critical acoustic warnings. These shortcomings left the submersible vulnerable to catastrophic failure. However, despite its limitations and reduced operability, the MBI determined that it still was able to produce meaningful data that should have been carefully reviewed and analyzed by a competent engineer.

5.7. Implications from the Shift in Hull Strain Data After Dive 80 Incident.

The RTM system onboard the TITAN recorded approximately 10 acoustic emission (AE) readings per second and 6–8 strain gauge readings per second during operational dives. The data had to be downloaded from TITAN's onboard computer after each dive. The locations of the acoustic sensors are shown below. Channels 1, 3, and 5 are shown in red because they were confirmed by the MBI to be inoperable for the entire 2022 TITANIC Expedition and most likely remained inoperable for the duration of the 2023 Expedition.

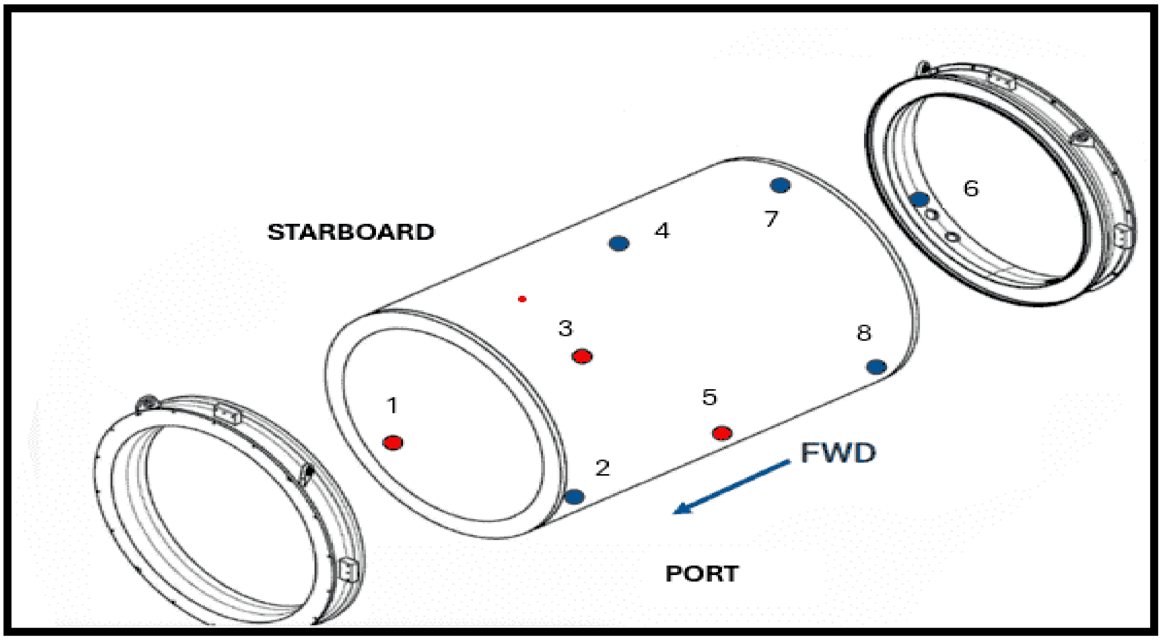

Figure 259: Titan's AE sensor location. Source: USCG.

On July 15, 2022, during TITAN Dive 80, a review of the raw acoustic emissions sensor data revealed increased acoustic emission activity beginning at approximately 3:17 p.m. This increased acoustic activity exceeded 1,000 mV and was observed particularly in AE Channel 4 (mid span – 0º / top dead center) and AE Channel 6 (110º CW[52] from top on aft titanium segment). By 3:18 p.m., AE Channel 2 (3.75 inch from forward segment - 110º CCW from top / forward port) also began to register elevated acoustic emissions. The increases in acoustic activity, especially in AE Channels 4 and 6, continued to intensify culminating in a significant escalation beginning at 3:25:56 p.m.

At 3:26:45 p.m., the TITAN's RTM system recorded a major acoustic emission event that included the following significant readings: AE Channel 2 peaked at 25,687 mV, AE Channel 4 at 25,589 mV, AE Channel 6 at 18,131 mV, AE Channel 7 (3.75 in from aft segment 0º / top dead center, aft) at 25,369 mV, and AE Channel 8 (3.75 inch from aft segment - 110º CCW from top / aft port) at 18,966 mV. In contrast, AE Channel 1 (3.75 inch from forward segment - 110º CW from top / forward starboard), AE Channel 3 (mid span - 110º CW from top / middle starboard), and AE Channel 5 (mid span - 110º CCW from top / middle port) registered amplitudes below 250 mV, indicating that those AE sensors were inoperable. This major acoustic emission is clearly visible on the acoustic emissions plot for AE Channel 2 shown in Figure 260.

[52] Clockwise (CW) and counterclockwise (CCW) are designated as if standing aft of the submersible looking forward.

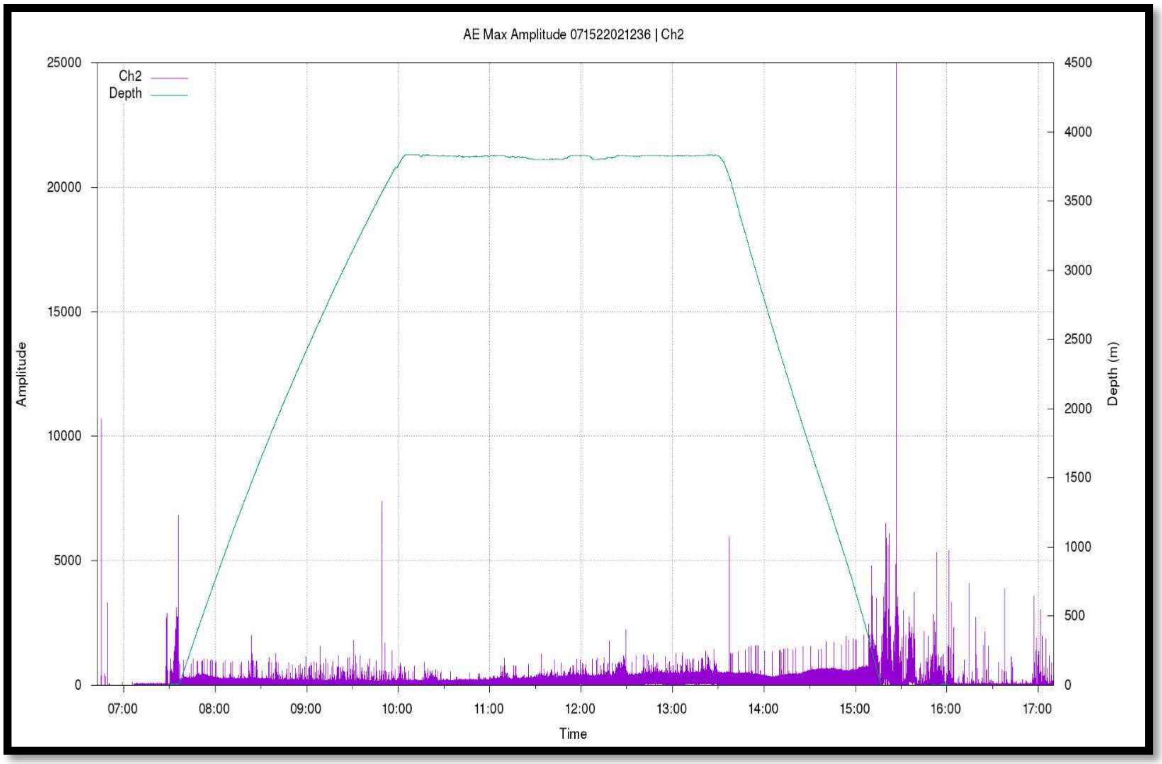

Figure 260: Dive 80 TITAN RTM System AE Channel 2 Plot. The units for the amplitude of the acoustic emission are millivolts (mV). The blue line indicates the depth of TITAN in meters (m) over the duration of the dive. Source: OceanGate.

At the same time as the RTM system was recording the significant acoustic emissions - 3:26:45 p.m. - the strain readings for Group 4, which were co-located with acoustic emission sensors for AE Channel 2 showed abrupt changes. The TITAN's hoop strain[53] (green line, labeled "R" in Figure 261), increased by 15.62 mV. The longitudinal strain[54] (purple line, labeled "A") decreased by 30.5 mV. This abrupt change is clearly visible in the plot of TITAN's Dive 80 strain gauge data displayed in Figure 261.

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[53] Hoop strain measures deformation in the circumferential direction, perpendicular to its length

[54] Longitudinal strain measures deformation along the length of the material. It is the ratio of the change in length of a material to its original length.

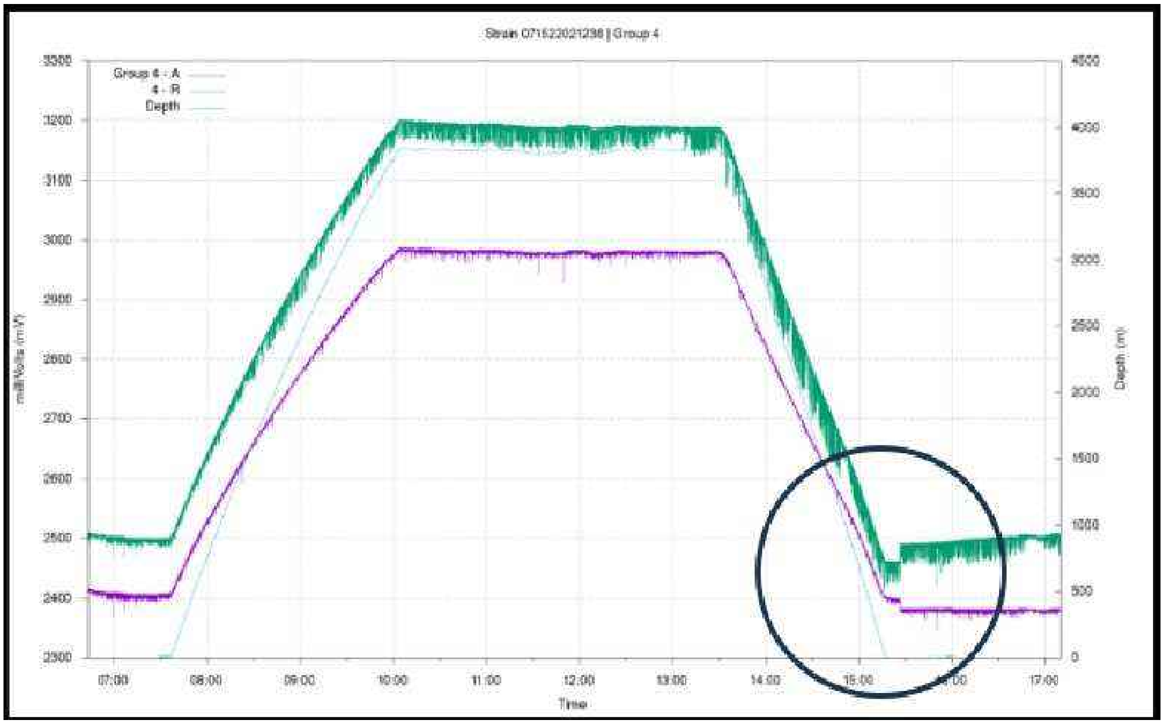

Figure 261: Dive 80 Strain gauge group 4 plot. Source: OceanGate.

The major acoustic emission at 3:26:45 p.m. was also visible in the AE Channel 4 plot, as shown below.

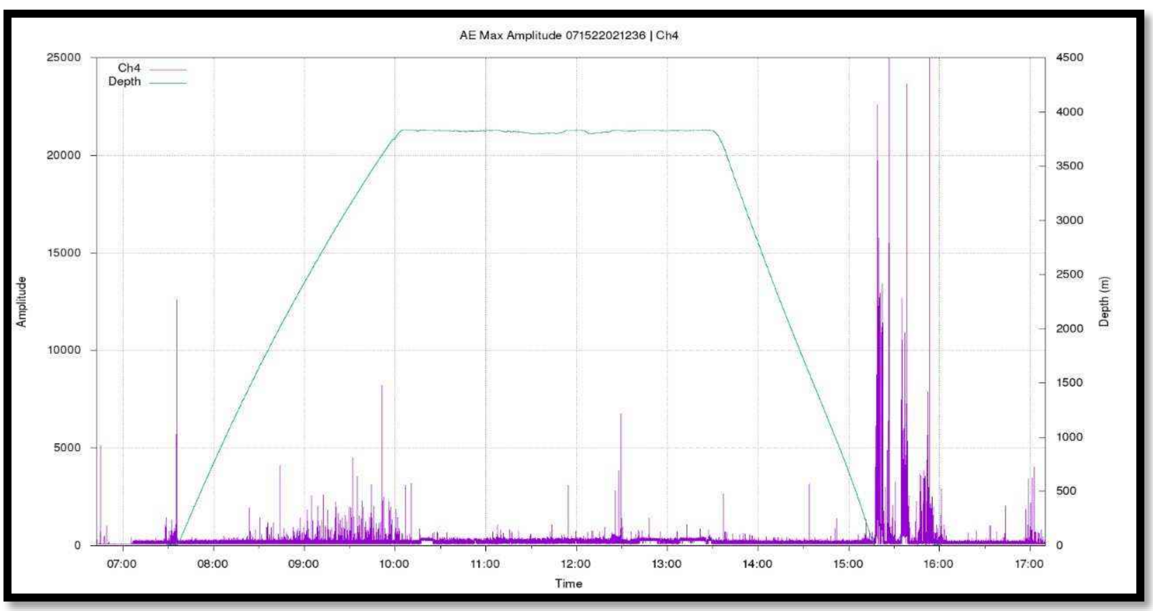

Figure 262: Dive 80 AE Channel 4 Plot. Source: OceanGate.

Similar to the strain readings in Group 4, the strain gauges in Group 5, co-located with the AE Channel 4 sensor, recorded shifts in strain. The hoop strain (green line, labeled "R") increased by 49.12 mV and the longitudinal strain (purple line, labeled "A") increased by 4.5 mV in Figure 263.

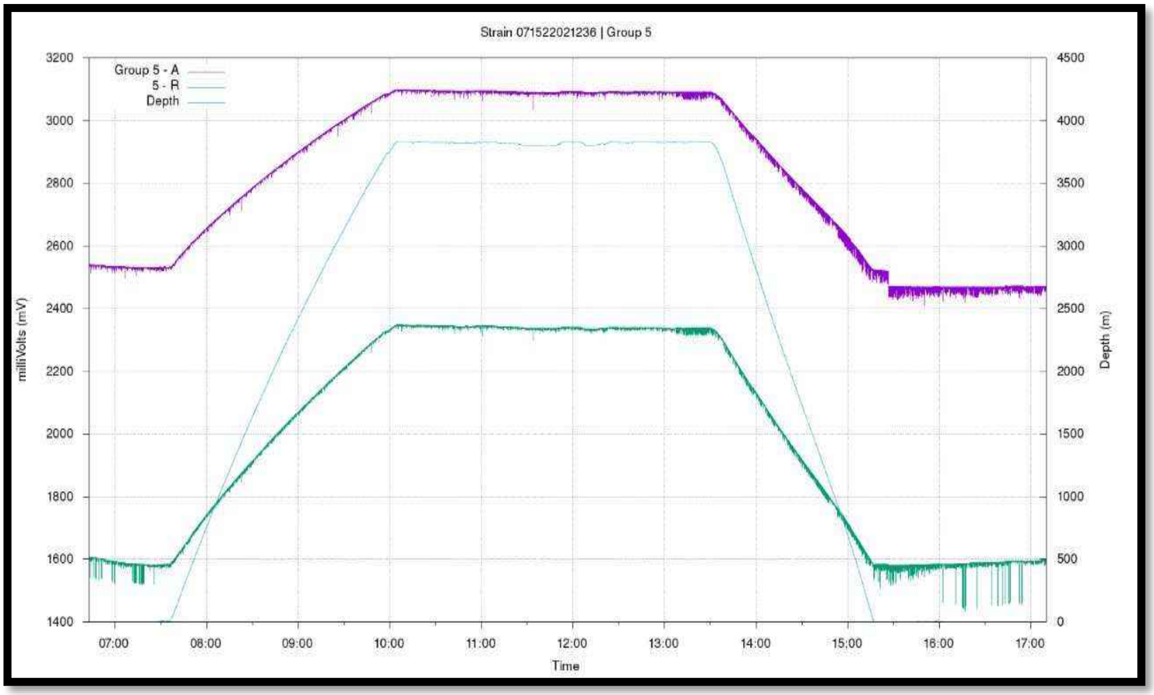

Figure 263: Dive 80 Strain Gauge Group 5 Plot. Source: OceanGate.

These shifts in strain for TITAN's hoop and longitudinal strain in both Group 4 and Group 5 occurred in a fraction of a second and coincided with the large amplitude acoustic event on Dive 80 at 3:26:45 p.m.

For the remaining TITAN dives that occurred after Dive 80's large amplitude event, changes were observed in the strain response of the hull, as noted in the NTSB's report (Appendix B and C). Figure 264 shows the variation in hoop strain gauge output with ocean depth for Group 4 on Dive 80. This was prior to the audible event that was heard by personnel in the TITAN and by support personnel at the surface in a small boat. The audible event occurred as the TITAN was still submerged and approaching the surface. The strain gauge output is plotted on the horizontal axis and ocean depth is plotted on the vertical axis. Because of the strain reduction at depth, the ascent curve is at a lower strain value than the descent curve. Both descending and ascending curves appeared to be linear in Figure 264.

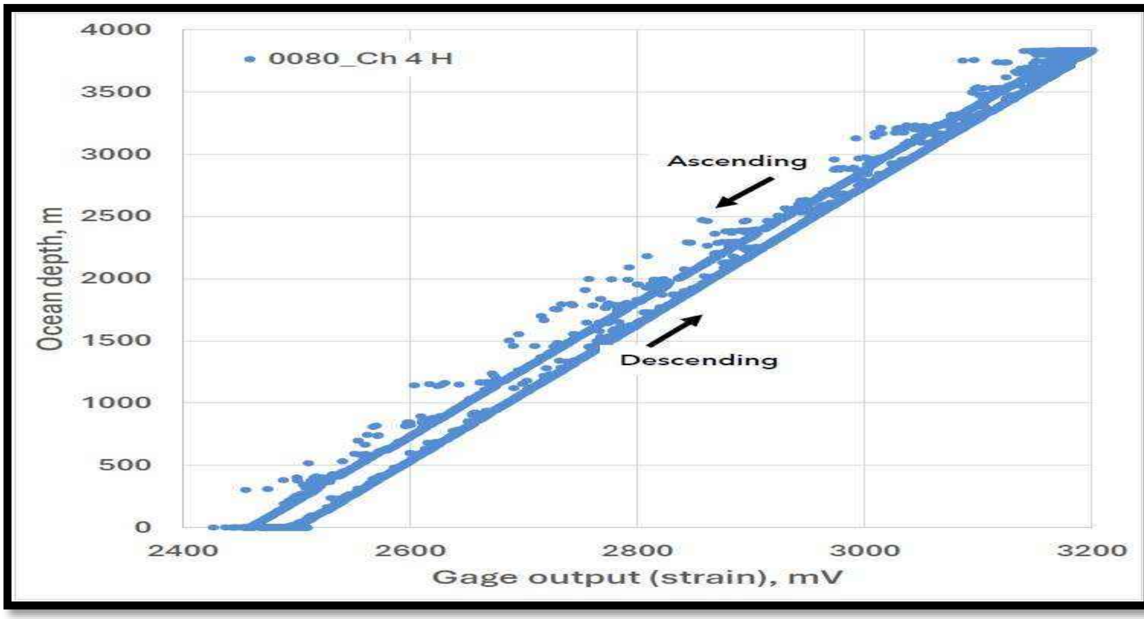

Figure 264: Plot of dive depth as a function of strain gauge output for TITAN's Dive 80 – Gauge Group 4 – hoop strain gauge. Source: NTSB Materials Laboratory Factual Report.

Figure 265 is a comparison between Dive 80 (light blue) and Dive 75 (dark blue). Both dives showed the same linear response (as did Dives 76 and 79, which are not shown).

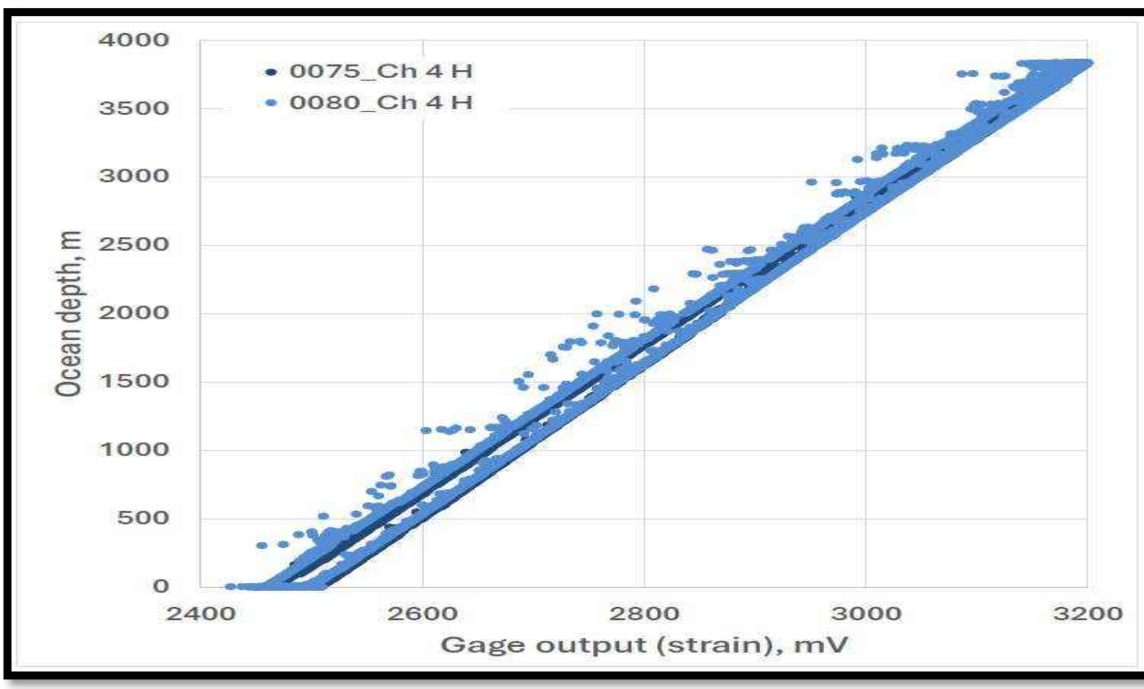

Figure 265: Plot of dive depth as a function of strain gauge output for Dives 75 and 80 – Gauge Group 4 – hoop strain gauge. Source: NTSB Materials Laboratory Factual Report.

Figure 266 shows a comparison between Dive 80 (blue) and Dive 81 (red), which was the first dive conducted after the audible event. The TITAN hull's strain response at shallower depths was non-linear after the large amplitude event.

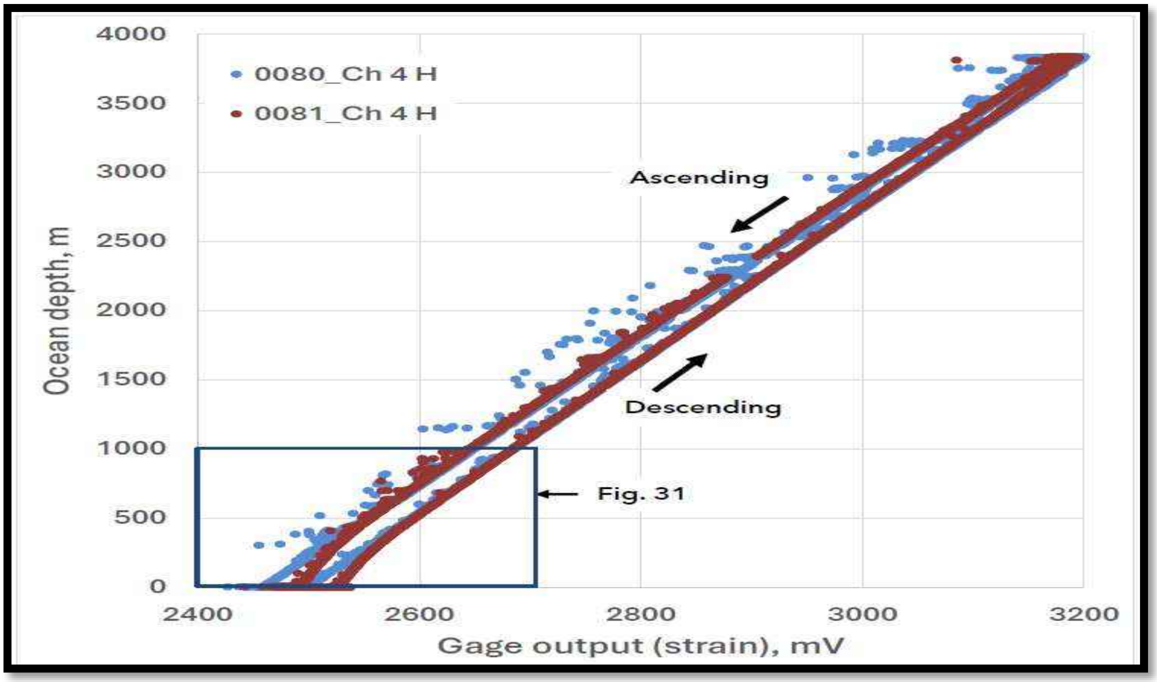

Figure 266: Plot of dive depth as a function of strain gauge output for Dive 80 and 81 – Gauge Group 4 – hoop strain gauge.
Source: NTSB Materials Laboratory Factual Report.

The same non-linear response was observed for Dives 82 and 83. A plot of dive depth as a function of strain gage for Dive 75 and Dives 80 through 83 is shown in Figure 267. The strain for Dives 81, 82, and 83 clearly display non-linear behavior in depths shallower than 500 m (1,640 feet).

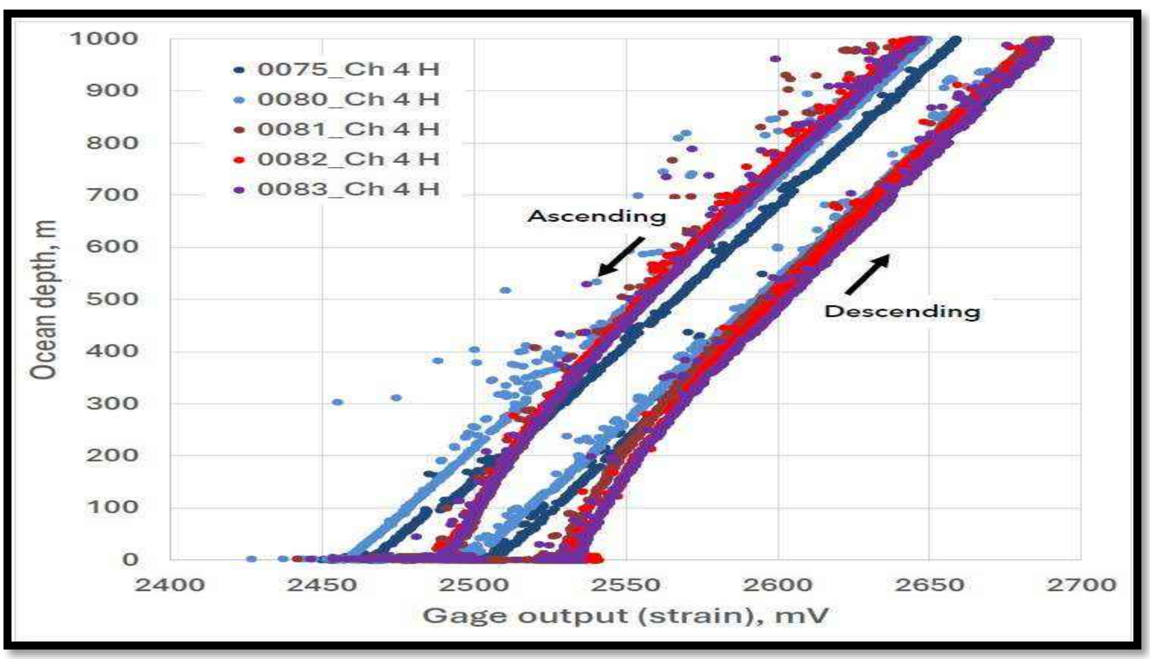

Figure 267: First and last 1000 m of dive depth for Dives 75 and 80 – 83 – Gauge Group 4 – hoop strain gauge.
Source: NTSB Materials Laboratory Factual Report.

The NTSB Materials Factual Report prepared for the TITAN marine casualty also highlighted additional anomalies in the strain gauge data from Dives 81 through 83. For

Gauge Group 4, a plot of the first and last 1,000 m of dive depths for Dives 75 and 80 through 83 showed non-linear behavior and reduced apparent stiffness in shallow depths between 0 and 500 m for the longitudinal strain during Dives 81 through 83. Similarly, data from Gauge Group 5 demonstrated non-linear behavior and reduced apparent stiffness in shallow depths between 0 and 800 m for the longitudinal strain. Gauge Group 8, located on the aft port side, also exhibits non-linear behavior in shallow depths between 0 and 400 m for Dives 81 through 83 in regard to hoop strain.

The transition from a linear to a non-linear response in the strain data across multiple strain gauge groups strongly suggests that the carbon fiber hull sustained irreversible damage at the end of Dive 80. The data suggests that individual carbon fibers began to break as early as 3:18 p.m. while on Dive 80, and as the decompression of the pressure hull continued, the carbon fiber breakage increased until 3:26:56 p.m. where a substantial delamination in the carbon fiber pressure hull occurred. That sudden delamination resulted in the loud bang heard by the personnel inside the TITAN and by OceanGate support personnel in a small boat at the surface and led to TITAN hull's subsequent non-linear responses to pressure at shallow depths across multiple locations on the hull.

Material testing of the debris from TITAN and analysis of the cutoff ends of the carbon fiber revealed significant voids between carbon fiber layers 1/2 and 3/4. The first layer had undergone five separate autoclave cycles and, as a result, would have experienced the most thermal induced stress. OceanGate never investigated the potential residual thermal stresses resulting from the multiple autoclave cycles. At depth, the TITAN's first layer would have borne the greatest pressure. As the submersible ascended and the intense pressure was relieved, the first (inner) carbon fiber layer would have been the last to experience decompression. It is likely that the loud bang heard on the surface during Dive 80 was the result of a sudden delamination occurring between layers 1 and 2 as this pressure was released.

Additional inspection of the TITAN's debris confirmed that there was complete separation between carbon fibers layers 1/2, as well as between layers 3/4. In addition, when the NTSB examined a sample of carbon fiber recovered from the first layer post-accident, they noted rubbing damage on the surface between layers and dust consistent with the adhesive used between the layers. The existence of dust could only have been created by the longitudinal independent movement of the carbon fiber layers, which further supports the hypothesis of delamination between layers 1/2. These observations strongly correlate that the loud bang during Dive 80 was caused by an abrupt delamination between the TITAN's first and second carbon fiber layers, with a possible secondary delamination between layers three and four.

While Mr. Rush was not the pilot of the TITAN during Dive 80, he was made aware of the loud noise during the post-dive debrief. OceanGate's Director of Engineering at the time reviewed the acoustic monitoring data and observed the shift in the strain measurements of a few sensors and reported his findings to Mr. Rush. Members of OceanGate's team aboard the HORIZON ARCTIC for Dive 80 provided MBI testimony that a cursory external examination of the TITAN was conducted following the loud bang with no visible damage identified. However, the portion of TITAN's pressure hull available for inspection was extremely limited, and no effort was made to remove the TITAN's insert or take the submersible temporarily out of service for a more detailed assessment. The TITAN's insert inside the carbon fiber pressure hull prevented a full internal visual inspection and the TITAN's exterior was coated in Rhino Liner®. According to testimony from OceanGate employees, only a small portion of the hull was visible. More critically, if the delamination occurred between carbon fiber layers, there would have been no external visible signs of the damage. Despite the significant inspection limitations, Mr. Rush concluded that the loud bang heard when the submersible surfaced was likely due to a shift in the submersible's position within its frame and directed that no further investigation or assessments were necessary ahead of the next scheduled 2022 dive or during the TITAN's extended layup period ahead of the 2023 TITANIC Expedition.

It is critical to highlight that neither the Director of Engineering nor anyone else onboard with the authority to assess the submersible's safety possessed the necessary engineering expertise to interpret the strain gauge data or understand the significance of the observed shifts. Mr. Rush's confident assertion with very little supporting evidence that the loud bang was merely a shift in the frame is particularly troubling. Mr. Rush lacked the expertise in carbon fiber structures and the necessary knowledge to interpret what the shift in strain data indicated. OceanGate did not follow up to conduct a meaningful analysis of the data, such as plotting strain versus depth over time, which would have provided a clearer understanding of the hull's condition. OceanGate had all sufficient RTM data to demonstrate that the hull's behavior had changed significantly after Dive 80, yet their method of analyzing strain using elapsed time as a variable failed to reveal this critical shift. When the same data was plotted post-casualty with ocean depth as a variable, it became immediately evident that the loud bang, acoustic emissions, and shifts in strain were clear indicators of a material failure in the hull. The failure to properly analyze post-surfacing data—particularly the acoustic and strain anomalies indicative of delamination after Dive 80—represents a grave oversight, due to negligence.

What is most concerning is OceanGate's failure to conduct any meaningful investigative efforts to determine the actual cause of the unidentified noise, which was heard by all personnel on the TITAN and several support personnel. OceanGate staff, content managers, and mission specialists embarked on subsequent TITAN dives without OceanGate having a clear understanding of the RTM data and potential changes to the hull structure. The fact that a significant acoustic emission was detected across all of TITAN's operable sensors, accompanied by a nonlinear response in multiple areas of the hull, should have been a red flag to stop all dive operations. However, OceanGate proceeded to continue scheduled dive operations afterward, without fully understanding the implications of what had occurred during Dive 80.

The debris of the TITAN revealed consistent delamination between carbon fibers layers 1/2, as well as layers 3/4. The initial delamination of the carbon fiber likely occurred after surfacing from Dive 80. The material strength of the carbon fiber was significantly compromised post-delamination. During the TITAN's design phase, strength calculations assumed an intact, 5-inch-thick carbon fiber hull with fully bonded layers. However, the overall strength of the carbon fiber would have been substantially reduced in a delaminated or damaged state. As a result, a full material failure in the form of buckling became far more likely post-delamination.

According to the Boeing feasibility study, "It is possible that a combined failure mode could cause bulking. For example, if ply failure should occur on the inner surface of the cylinder where compression stress is highest, the degradation in strength could precipitate buckling. This is particularly critical for a thick-walled orthotropic[55] structure."

The TITAN imploded during its first dive to depth of the TITANIC Survey Expedition 2023 season. The pre-existing delamination caused during Dive 80 was likely exacerbated by cyclic thermal changes on the hull throughout its outdoor fall and winter storage in Newfoundland following the 2022 expedition, combined with continual impact damage from towing the submersible thousands of miles across the North Atlantic in moderate sea conditions, and the slamming effects TITAN experienced on the LARS platform during Dive 87. Notably, the RTM system was not operational during these periods, leaving any potential damage to the carbon fiber unrecorded. These factors contributed to the progressive weakening of the carbon fiber structure, ultimately resulting in the TITAN's catastrophic implosion. Specifically, the MBI determined that the most likely scenario was that the TITAN's carbon fiber pressure hull suffered a full material collapse due to buckling on its final dive.

5.8. Insufficient Understanding of Adhesive Joint for Deep-Sea Application and the Potential Detrimental Effects on the Hull.

The adhesive for bonding the titanium segment to the carbon fiber hull requires the adhesive to withstand high-bearing stress without extruding from the joint or disbonding from the mating components. Therefore, OceanGate's selection of adhesive material was critical. The Boeing feasibility study identified the bonded joints between the titanium segments and the composite hull as one of the most critical aspects of TITAN's design. The strength and durability of these joints are highly dependent on the surface preparations of both the titanium and the composite material. Boeing highlighted significant uncertainties regarding the performance of these bonded joints, particularly because the compressive loads in the TITAN's configuration exceeded those typically encountered in similar applications. The report emphasized the need to fully understand how such joints behave under these conditions and the impact of sustained loading on adhesive performance.

Boeing and other experts consistently emphasized the need for a testing program to validate the adhesive's behavior under operational conditions. Such testing should have included evaluation of fatigue resistance, sensitivity to improper application (e.g., air bubbles, excess or insufficient adhesive, contamination, etc.), and performance under cyclic compressive

[55] A "thick walled orthotropic structure" refers to a structure with relatively thick walls where the material properties vary depending on the direction you measure them in (orthotropic), meaning the structure has different strengths and stiffnesses along different axes, typically seen in composite materials like wood or layered fiber-reinforced polymers, where the fibers are aligned in a specific direction; "thick walled" simply indicates that the wall of the structure is considerably thick compared to its diameter or other dimensions.

loading and bearing stress. These tests could have confirmed whether the adhesive could maintain bond integrity.

Spacers were used to control bond line, and although OceanGate performed some work related to surface preparation and adhesive application, there was no comprehensive testing effort to validate long-term performance under the specific conditions TITAN would face. Despite repeated recommendations, a full understanding of the adhesive's behavior over time was lacking.

Further complicating the issue was OceanGate's decision to reuse the titanium segments from the previously failed first hull on the final TITAN hull. The original adhesive was removed through machining, leaving tool marks on the bonding surface. These new marks may have interfered with the new bond or reduced surface quality.

The application process for the adhesive introduced additional risk due to its manual nature, making it susceptible to human error. The effectiveness of the bond relied heavily on proper cleaning, accurate mixing, precise application of the adhesive, and strict adherence to the procedure.

Examination of the recovered TITAN debris revealed that the adhesive used to bond the hull to the titanium segments had disbonded from the entire forward segment. The adhesive was mostly disbonded from the aft segment, except for an approximately 90-degree arc located at and centered approximately about the top of the submersible, shown in Figures 268 and 269. The adhesive contained an imprint of the machined edge of the carbon fiber hull near the outer surface, while the inner surface showed a rubbed appearance beginning near the base of layer 4 and extending radially inward as shown in Figure 269. Additionally, an imprint of one of the spacers were present.

Figure 268: Aft segment with remaining adhesive. Source: USCG.

Figure 269: Aft segment under oblique lighting condition showing the disappearance of the hull end machining marks toward the inner surface. Source: NTSB Materials Laboratory Factual Report.

When the carbon fiber delaminated at the end of Dive 80, it is possible that the delamination propagated to one or both of the adhesive joints at the forward and aft segments. Additionally, the independent movement of carbon fiber layers 1 and 2 post-delamination, which was confirmed to have been occurring after post-accident forensic testing identified the existence of adhesive dust created by the friction from the layers rubbing together, would have likely stressed the brittle adhesive joints at the forward and aft segments of the hull. Any crack or separation at either of the adhesive joints would have triggered the TITAN's implosion due to the extreme pressures involved at its final depth. The rubbed appearance of the adhesive on the aft segment could be an indicator that the partial separation of the inner layers already existed. The MBI also determined that the freeze and thaw cycles that the TITAN was subjected to while exposed to the elements prior to the 2023 TITANIC Expedition likely exacerbated any existing imperfections in the adhesive joints between the at the forward and aft segments. An MBI examination of the TITAN's debris supports a scenario involving a failure of a forward adhesive joint. Specifically, a considerable amount of debris was found consolidated in the aft dome and the remnants from the forward viewport were never located. The viewport's retaining ring was recovered bent outward with its 16 bolts sheared off, which indicates that the viewport was ejected outward during the implosion.

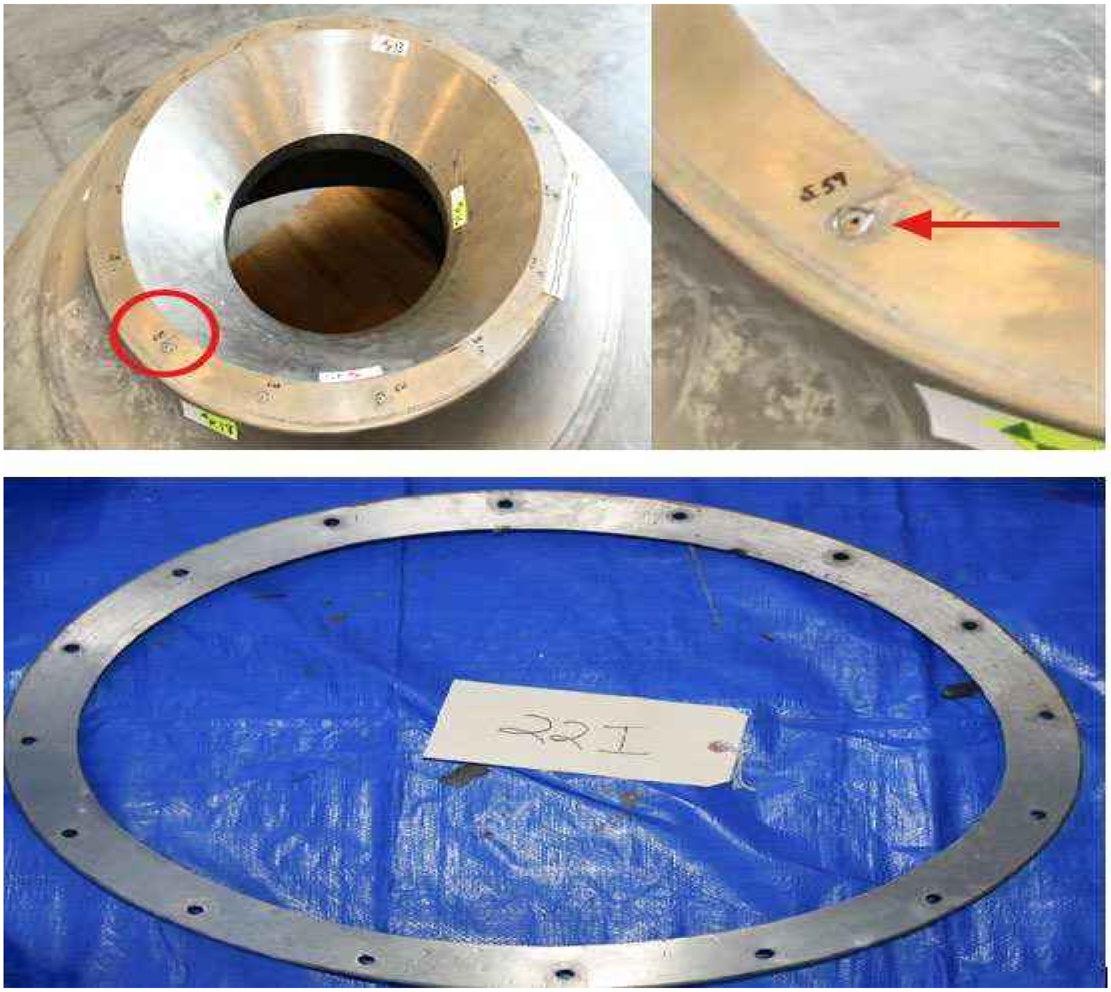

Figure 270: (Top left) TITAN's forward dome is pictured post-accident with all 16 of its viewport retaining ring bolts sheared off. The red circle identifies 1 of the 16 sheared bolts, which the MBI labeled as 5.59. (Top right) A closeup of the sheared window retaining bolt 5.59. (Bottom) TITAN's window retaining ring, which was recovered from the seafloor post-accident bent slightly outwards with elongated bolt holes. Source: FBI ERT.

5.9. Detrimental Effects on TITAN's Hull After the TITANIC Survey Expedition 2022.

Between July 26, 2022, and February 6, 2023, the TITAN was stored outdoors in St. John's, Newfoundland, Canada. During this time, the submersible was not covered or protected from the environmental elements, subjecting it to precipitation and repeated freeze-thaw cycles. Given the exposed state of the hull, it is plausible that moisture entered the pressure hull. If moisture was present within the carbon fiber structure, the freeze-thaw cycles would have caused the moisture to expand and contract, potentially worsening any existing porosity in the carbon fiber, likely leading to further degradation of hull's structural integrity.

During the 2023 expedition season, the submersible was towed behind the POLAR PRINCE for a total distance of more than 2,900 NM. Throughout this journey, TITAN endured significant sea states in the North Atlantic. According to the Boeing feasibility study and testimony presented during the MBI hearing, impact damage while being transported on the LARS platform would likely have led to critical impact on the hull and other critical components. The MBI subsequently determined that being towed across thousands of miles in moderate to rough seas at an average speed of approximately 7.5 kts would likely have subjected the TITAN to repeated impact damage that further weakened its structural integrity of its hull.

Additionally, during Dive 87, the TITAN experienced further stress due to improper ballasting while partially affixed to the LARS platform. According to testimony from mission specialists, while they were inside the submersible, the platform was improperly ballasted, causing the LARS platform and TITAN to tilt at a 45-degree angle. As a result, the TITAN became partially dislodged from the platform and repeatedly slammed against the LARS platform for approximately 45-minutes by passing ocean swells until OceanGate employees were able to correct the ballasting issue. These repeated impacts, described as "bone jarring" by the mission specialists aboard, would have added further stress to an already compromised hull. There is no evidence that OceanGate conducted a post-incident hull inspection or incident report following the Dive 87 ballasting and TITAN recovery failures.

During the TITANIC Survey Expedition 2023, any moisture retained within TITAN's carbon fiber laminate would have been subjected to increasing compressive forces as it descended during Dive 88. This would create a differential pressure situation, with the incompressible moisture resisting deformation and generating localized stress concentrations at the fiber-matrix interfaces. If the laminate was unable to adequately redistribute these stresses — particularly in regions already compromised by past damage or weak bonding —this pressure mismatch could impose mechanical forces on the resin-fiber interfaces. Such forces could degrade the adhesive bonds between layers, initiate microcracking, and promote interlaminar delamination, further undermining the structural performance of the pressure hull.

The cumulative stresses from potential moisture ingress, thermal cycling, towing related impacts, and impacts with the LARS platform likely compounded the suspected delamination initiated during Dive 80 of the 2022 expedition. On June 18, 2023, Dive 88 was the first dive to leave the LARS platform for the TITANIC Survey Expedition 2023 and the weakened carbon fiber pressure hull failed catastrophically while subject to extreme pressures at a depth of 3,346 m (10,978 feet).

5.10. Circumvention of U.S. Laws and International Standards.

OceanGate's Co-founder, who departed the company in 2013, initially envisioned that the company would "create a fleet of four or five deep-diving submersibles, capable of carrying five people, available for charter anywhere in the world without a dedicated mothership." The goal was to increase accessibility to the deep oceans for an industry that had been traditionally limited by high costs and the challenge of mobilizing the proper support infrastructure to remote dive sites. Early on, OceanGate did not plan to build its own submersibles. However, OceanGate was unable to find a company that could build submersibles tailored to their business needs, including the ability to carry five people to depths of 6,000 m without requiring a dedicated (full-time) support vessel. OceanGate's initial steps involved purchasing two used submersibles, the ANTIPODES and the CYCLOPS I, which OceanGate subsequently registered in Washington State. OceanGate did not pursue USCG Certification for Inspection for ANTIPODES or CYCLOPS I, after initially expressing interest with USCG Sector Puget Sound about getting the ANTIPODES certificated as a small passenger vessel.

The Co-founder confirmed that OceanGate understood the USCG's regulations regarding small passenger vessels. They also acknowledged that the ANTIPODES and CYCLOPS I could not operate as small passenger vessels under OceanGate's planned business model due to strict federal laws and regulations. Specifically, it was confirmed by several former OceanGate employees that OceanGate intended to operate at depths well beyond 150-feet[56], which is currently the maximum operational depth the USCG allows for its inspected fleet of small passenger submersibles. However, OceanGate knew that ORVs could carry a pilot, crew, and researchers by simply requesting a Letter of Designation with minimal USCG oversight. OceanGate subsequently reached out to the local OCMI at Sector Puget Sound, to request a Letter of Designation to operate the ANTIPODES within the OCMI zone as an ORV. This request was granted by the OCMI of Sector Puget Sound in August 2010.

In 2011, OceanGate moved it operations to Sector San Francisco's OCMI Zone, where they requested and received an ORV Letter of Designation for the ANTIPODES. That year, OceanGate and the ANTIPODES completed 34 dives over 30 days in Monterey Bay, California. Later, OceanGate expanded operations to Sector Miami to accommodate growing demand from East Coast and Caribbean clients. In June 2012, OceanGate requested an ORV Letter of Designation from Sector Miami, which was initially denied due to OceanGate's practice of accepting payments for passenger pilot training aboard the ANTIPODES. However, the Co-founder stated in an interview with *Miami Today News* in July 2012 that OceanGate's expeditions were designed for researchers and funded by "citizen scientists," a term the company used for their paying passengers, whom they regarded as scientific personnel. As the Co-founder explained during the interview, "This model attracts a diverse clientele, all of whom possess some financial resources, as participation comes with significant costs—ranging from $7,500 to $40,000 per person, depending on the mission's duration and complexity."

The Sector Miami OCMI subsequently issued an ORV Letter of Designation specifying that OceanGate's ORVs could only carry college students enrolled in accredited oceanographic programs and acting as scientists in training. OceanGate was unable to fully implement its business model due to these restrictions, which prompted their return to Sector San Francisco's OCMI Zone, where they had previously received an ORV Letter of Designation for ANTIPODES. In August 2012, OceanGate requested a new ORV Letter of Designation from Sector San Francisco OCMI to conduct "discovery dives" in Monterey Bay. Initially, the plan was for the ANTIPODES to be operated by three OceanGate employees and two VIP investors, but Sector San Francisco classified OceanGate's requested operation as passenger for hire arrangement, which was prohibited under ANTIPODES' existing ORV designation. In response, OceanGate's Co-founder submitted a letter stating that the

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[56] USCG policy limits certified small passenger vessel submersibles to a maximum depth of 150-feet because that is generally considered to be the maximum depth emergency scuba divers can reach for a rescue operation. However, USCG policy does not provide any maximum operating depth restrictions for designated ORVs.

Discovery Dives Expedition would support two 501(c) non-profit organizations, which included the Blue Ocean Film Festival and the OceanGate Foundation.

OceanGate's Co-founder noted that USCG OCMIs exhibited varying levels of understanding and enforcement of submersible operations and the issuance of ORV Letters of Designation. Some OCMIs were open to the concept, while others were more risk-averse and prevented the ANTIPODES from operating as an ORV. This inconsistency led OceanGate to reclassify its operations between different OCMI zones. The company began referring to their paying passengers on ORV excursions as "citizen scientists" and claimed they were scientific personnel, based on the definition of scientific personnel as "individuals on board an oceanographic research vessel only to engage in scientific research, or to instruct or receive instruction in oceanography or limnology."

Over time OceanGate's CEO (Mr. Rush) changed the term used for their ORV passengers from "citizen scientists" to "mission specialists", borrowing the term from the space industry. "Mission specialist" is not formally defined in USCG regulations and is rarely used in the maritime domain. Each "mission specialist" aboard the ANTIPODES, CYCLOPS I, or TITAN paid either OceanGate Inc., OceanGate Expeditions, OceanGate Foundation, or Argus Expeditions to participate in a dive. The payments meet the definition of "consideration" under U.S. law, which makes OceanGate's "mission specialists" passengers for hire, regardless of OceanGate's labeling. OceanGate's Co-founder suggested that OceanGate's reclassification to mission specialist was an attempt to bypass the small passenger vessel regulations and allow their submersibles (ANTIPODES and CYCLOPS I) to be designated as ORVs. OceanGate also started funneling "mission specialist" payments through the OceanGate Foundation, a strategy designed to bypass passenger-for-hire regulations, since the payments for dive the operations went to the 501(c) nonprofit organization rather than directly to OceanGate Inc.

As OceanGate transitioned from ANTIPODES to CYCLOPS I operations in 2015, OceanGate did not contact the Sector Houston-Galveston OCMI to attain an ORV Letter of Designation prior to conducting domestic dive operations. This is most likely due to previous USCG restrictions placed on the ANTIPODES. The carriage of scientific personnel for consideration was only permitted with a valid ORV Letter of Designation under federal regulations, and the CYCLOPS I did not attain one during its initial three years of operations within four different OCMI Zones.

One such mission, CYCLOPS I conducted without a valid ORV Letter of Designation in May 2016, involved a dive excursion on the ANDREA DORIA wreck site, off the coast of Nantucket, Massachusetts. Evidence of this dive and the compensation provided by one of its first confirmed passenger was highlighted in the following excerpt from a December 2015 letter from Mr. Rush to OceanGate stakeholders: "On a very positive note, the first potential client we contacted has committed to the $20,000 fee to join us for 2 days (including just one 3-hour dive) and has also secured two more individuals at $20,000 each despite our lack of significant supporting information." The ANDREA DORIA expedition, which departed Boston on June 2, 2016, and returned on June 9, 2016, included paying participants who were described as "mission specialists," even though the CYCLOPS I did not have a valid

ORV Letter of Designation from the Sector Boston OCMI or a Certificate of Inspection to from the USCG to operate a small passenger submersible.

From October 21-25, 2016, as part of the "Eye on the Sanctuaries" tour, OceanGate conducted the Greater Farallon's Survey Expedition offshore of San Fransico, California. During this expedition, the CYCLOPS I served as the dive platform for mission specialists, who were transported to the dive site each day by a chartered vessel. During the MBI public hearing, when asked specifically about this expedition and if the mission specialists were scientists, former OceanGate Director of Marine Operations stated, "No…they were paying passengers. It was people that had money…. The clients had paid to go on this wreck that was offshore from San Francisco, were more than happy to be, you know, the fee went towards sitting in the sub and me driving them down to the bottom of Alcatraz Rock."

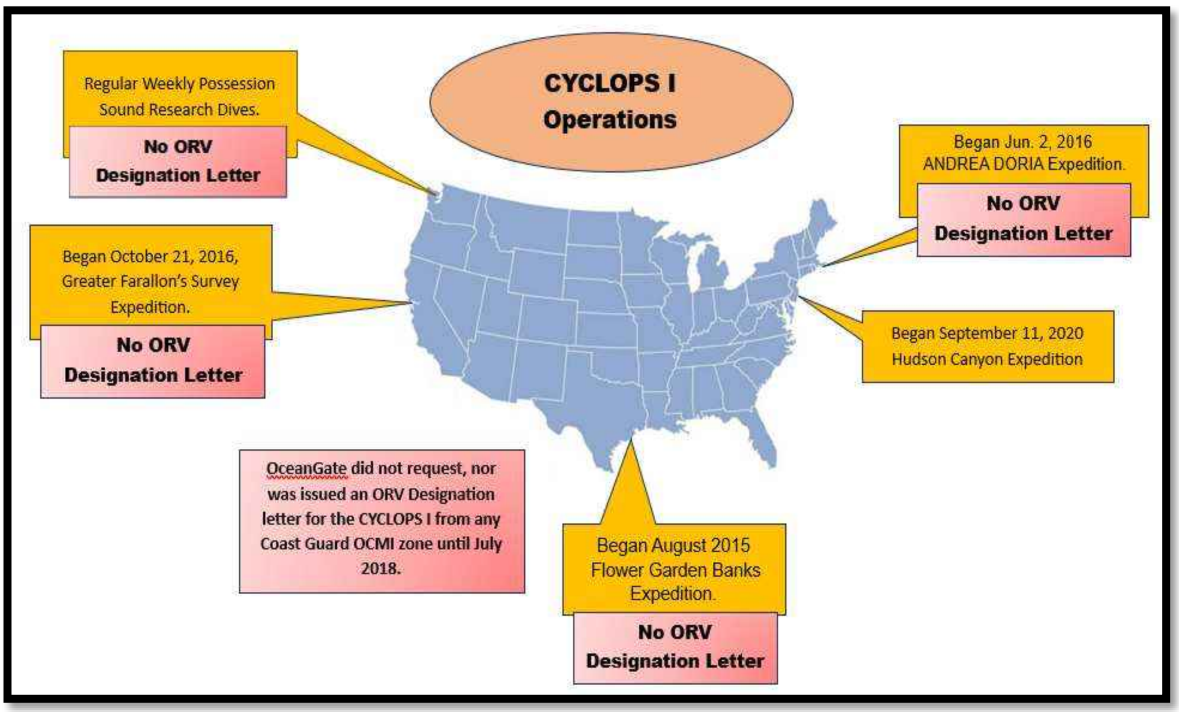

Figure 271: A summary of ORV expeditions conducted by OceanGate's CYCLOPS I. Source: USCG.

Finally, in July of 2018, OceanGate applied for and received its first ORV Letter of Designation from the USCG Sector Puget Sound OCMI for CYCLOPS I. In September 2020 (2 months after the 2018 ORV Letter of Designation had expired), OceanGate conducted a CYCLOPS I dive operation on the Hudson Canyon east of New York City, without an ORV Designation Letter from the Sector New York OCMI. The Hudson Canyon dives included participants who paid $45,000 to join the dive, which was described in the OceanGate brochure as involving "scientific research sites." According to former mission specialists and OceanGate employees who participated in the excursion, the payment was purely for a ride in the submersible, not for scientific research. When asked about the expectations of being a mission specialist on the dive, the mission specialist responded, "The payment was for the dive. You had the option, once you showed up to the expedition, if you wanted to participate or just be an observer and passenger."

During TITAN's design, construction, and testing process, OceanGate did not contact Sector Puget Sound to apply for a Certificate of Inspection or request an ORV Designation Letter for the original or final TITAN hull. They also failed to register or document both TITAN hulls with any state or country, including the United States, making both hulls stateless vessels under international standards. However, the TITAN hulls were still vessels of the United States subject to U.S. laws and federal regulations. Specifically, 18 USC § 9 defines a vessel of United States as a vessel belonging in whole or in part to the United States, or any citizen thereof, or any corporation created by or under the laws of the United States, or of any State, Territory, District, or possession thereof. The first and final TITAN hulls collectively conducted 26 documented dives in Washington State waters[57], which required the hulls to be registered according to Washington State law. OceanGate's former legal representative, in what appears to have been a deceptive claim intended to demonstrate TITAN's legitimacy for TITANIC dives, asserted in a 2021 letter to the EDVA that the TITAN was a Bahamian-registered crewed submersible. This statement was false because OceanGate, after being informed of the Bahamian registration requirements by the BMA in 2019, abandoned attempts to register its TITAN hulls there, likely because BMA required registered submersibles to designed and constructed in accordance with IMO MSC/Circ.981 or other similar standards and also classed by a classification society. After BMA clarified their submersible requirements in response to the 2019 inquiry, they never heard back from OceanGate regarding registration of the first or final TITAN hull. Additionally, in 2017, a USCG Reserve Boarding Officer employed by OceanGate requested a meeting with Mr. Rush and OceanGate's Director of Operations to inform them that the CYCLOPS I operations at the ANDREA DORIA wreck site, and their planned dives to the TITANIC wreck site would constitute illegal small passenger vessel operations under USCG regulations because the submersibles were carrying passengers for hire. The USCG Reserve Boarding Officer testified during the MBI hearing that Mr. Rush responded that he planned to register the TITAN in the Bahamas and operate in international waters to avoid USCG jurisdiction. The USCG Reserve Boarding Officer also testified to that Mr. Rush stated that if he was ever confronted by the USCG that he would buy a congressman. Mr. Rush's response demonstrates that he was aware that his operations were outside regulatory compliance.

[57] The TITAN's test sites were also navigable waters of the U.S. subject to USCG jurisdiction.

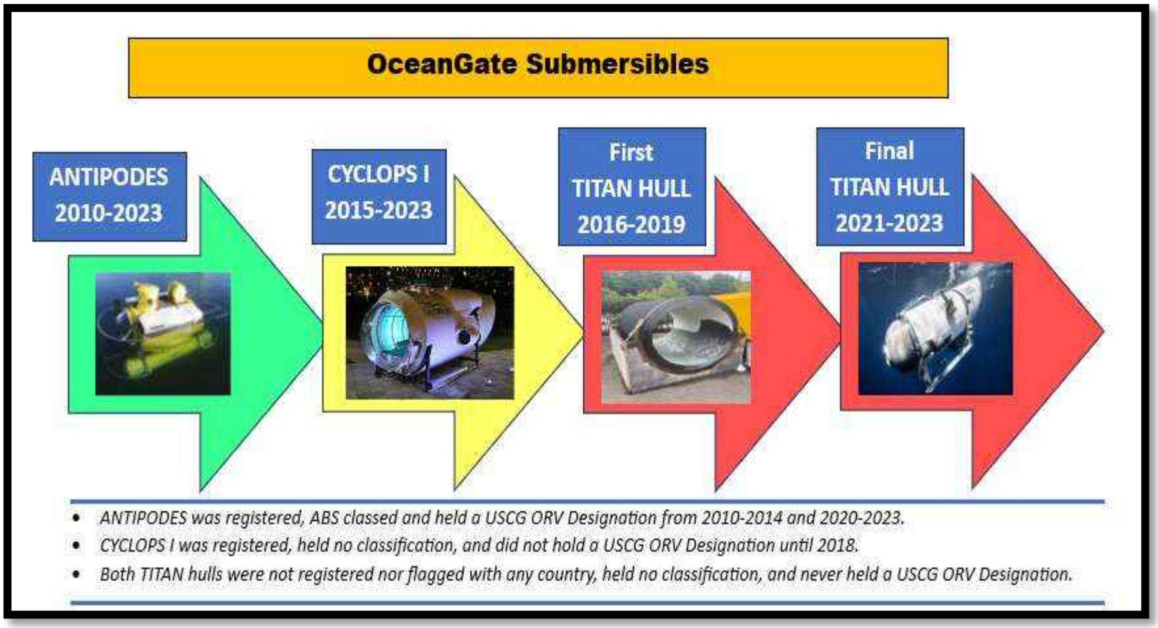

Figure 272: Regulatory compliance history of OceanGate's submersibles. Source: USCG.

OceanGate was clearly aware of the compliance challenges it faced at the classification society, state, and federal levels. In the company's early stages, Mr. Rush sought to comply with regulations by having the ANTIPODES classed by ABS, registered in Washington State, and designated as an ORV by the USCG. However, after multiple interactions with different USCG field units, Mr. Rush realized that OceanGate's submersibles could not meet the stringent requirements for USCG small passenger vessel certification, which led OceanGate to pursue the less stringent ORV designation. However, the ORV designation did not fully align with their business model and resulted in them reclassifying their passengers as "mission specialists" to conceal their illegal passenger operations. Moreover, OceanGate's approach to TITAN's regulatory compliance was marked by a blatant disregard for classification society, state, and federal oversight. Mr. Rush, who claimed that classification societies impeded innovation and regulatory agencies were not up to his technical level, intentionally operated outside the boundaries of existing regulations.

OceanGate's regulatory compliance history, progressing from the ANTIPODES to the CYCLOPS I and culminating in the final TITAN, reveals a disturbing trajectory of escalating disregard for established safety protocols. While initially engaging with regulatory bodies in an apparent attempt to meet industry standards, OceanGate gradually shifted towards selective compliance and, ultimately, willful non-compliance with no independent oversight of TITAN. The company's initial pursuit of ABS classification and USCG Small Passenger Vessel certification for the ANTIPODES suggests there was an interest and awareness of the importance of adhering to maritime safety protocols. However, a distinct change in OceanGate's compliance level is apparent after multiple USCG OCMIs questioned the legality and ultimately blocked OceanGate requests to carry paying passengers and operate ANTIPODES outside the boundaries of its ORV Letter of Designation. It was after those unsuccessful attempts that OceanGate reclassified their ORV passengers as 'citizen scientists' and eventually 'mission specialists' to skirt small passenger certification requirements. OceanGate's complete absence of any regulatory compliance for the TITAN is considered to by the MBI to have been a deliberate strategy that progressively prioritized innovation and operational flexibility over passenger safety. This evolution, marked by a growing willingness to circumvent regulatory oversight, raises profound concerns about OceanGate's company culture and the potential consequences of operating outside recognized regulatory frameworks. In a 2021 media interview with CBS, Mr. Rush confirmed OceanGate's approach by declaring, "I'd like to be remembered as an innovator. I think it was General [Douglas] MacArthur who said, 'You're remembered for the rules you break.' And I've broken some rules to make this."

5.11. Weak Regulatory Framework for Domestic and International Submersibles Operations / Lack of USCG Submersible Expertise.

Submersibles, whether manned or unmanned, present unique challenges in terms of regulatory inspections and safety oversight. In the U.S., the USCG's regulatory framework for submersibles is based on a combination of regulations and USCG policy, including 46 CFR Subchapter T- Small Passenger Vessels (Under 100 Gross Tons), Navigation and Vessel Inspection Circular (NVIC) 5-93, the Marine Safety Manual (MSM) Volume II (COMDTINST M1600.7B), and classifications for ORVs. While these regulations and policies provide some general guidance, their application to submersibles is often inconsistent, outdated, and/or not all encompassing, highlighting the need for a more tailored regulatory approach. The USCG's approach to submersibles, particularly with NVIC 5-93, adapts conventional surface vessel standards in an attempt to address the unique risks and characteristics of submersible operations. However, these regulations are insufficient in addressing the specific hazards as well as the technological advances submersibles have experienced over the past three decades. As a result, the MBI identified gaps in USCG submersible safety compliance and enforcement efforts.

The regulations in 46 CFR Subchapter T provide inspection, certification, and safety standards for U.S. small passenger vessels carrying more than six passengers and fewer than 150 passengers. The Subchapter T regulations are also applicable to submersibles if they carry one or more passengers for hire and fewer than 150 passengers. These standards address vital areas such as construction, stability, lifesaving equipment, firefighting systems, and communication protocols, which can be applied to submersibles carrying passengers for hire. However, certain regulations related to emergencies, such as open deck access and traditional life raft deployment, are impractical for submersibles. To address these challenges, the cognizant USCG OCMI can approve alternative safety measures tailored to submersible operations. Unfortunately, due to the lack of national level guidance and expertise regarding submersible operations, the flexibility provided to USCG field units can lead to inconsistencies in enforcement and application of submersible safety standards. Although submersibles are expected to meet the same safety standards as surface vessels, their unique design and operational environment often render traditional standards inadequate or unfeasible. Currently, the USCG does not have specific inspection standards for the design or construction of submersibles. Instead, standards under Title 46, CFR, are adapted based on the submersible's size, propulsion method, operational purpose, and cargo (if applicable) to attempt to meet a level of safety equivalent to surface vessels.

NVIC 5-93 outlines a compliance framework to help submersibles achieve safety standards equivalent to those of surface vessels. However, it lacks comprehensive, submersible-specific inspection standards and has not been updated since its issuance in 1993. As a result, it does not address technological advancements in submersible design, construction, and operation. The NVIC emphasizes reliance on recognized classification societies, such as ABS, to certify key submersible elements like pressure hulls and buoyancy systems. While valuable, this reliance does not fully mitigate the existing shortfalls in NVIC 5-93. Moreover, submersible operators can propose alternative safety measures for approval, but these proposals may not always be scrutinized thoroughly by the USCG due to a lack of clear national guidance and expertise on submersibles, leading to inconsistent safety practices and enforcement across the U.S. and also internationally. This combination of outdated guidance and flexible regulatory application creates uncertainty for the submersible industry and potential safety risks, underscoring the need for modernized submersible standards specifically tailored to the evolving submersible industry.

The MSM, Chapter 4, outlines inspection protocols for submersibles and recommends that they meet safety standards similar to those of surface vessels. However, these guidelines often rely on generalized vessel standards that do not adequately address the unique hazards associated with submersible operations. Additionally, the MSM erroneously classifies submersibles carrying six or fewer passengers for hire as Uninspected Passenger Vessels (UPVs) under 46 CFR Subchapter C, based on 46 USC 2101(42). This classification is inaccurate and conflicts with current regulations under 46 CFR Subchapter T, which does not recognize, or allow for submersibles to operate as UPVs. Under current regulations, all submersibles carrying at least one passenger for hire must comply with 46 CFR Subchapter T requirements. As one of the primary resources for submersible inspection guidance, the MSM must align more closely with regulatory standards to ensure consistency and avoid creating confusion.

The MSM also serves as the primary guidance for OCMIs in issuing ORV Letters of Designation. At the OCMI's discretion, submersibles used for scientific purposes may be classified as ORVs, allowing them to bypass the majority of the small passenger vessel regulations and avoid USCG inspections and classification society surveys. However, the MSM's vague guidance on ORVs leads to inconsistencies across OCMI zones as highlighted by multiple different approaches to OceanGate's proposed ORV operations prior to their shift to the TITAN. The ORV designation, which is essentially an exemption from any USCG oversight, creates potential vulnerabilities, particularly when submersibles are used to carrying passengers for research dives, effectively exploiting regulatory loopholes. The same weaknesses also apply to the existing fleet of surface vessels with USCG issued ORV Letters of Designation; however, the risks to submersibles are considered higher due to the inherent dangers involved with submersible operations. Thus, strengthening USCG oversight of ORVs involved in operations that constitute a passenger for hire operation is essential.

The inconsistency in USCG guidance on submersibles is further exacerbated by a lack of organizational subject matter expertise. Without specialized knowledge of or training in submersible design, systems, and operations, USCG marine inspectors are often unable to adequately assess these vessels for safety. This lack of expertise undermines the USCG's ability to perform thorough inspections and enforce safety standards with the required competency. Additionally, the absence of a dedicated point of contact (POC) for submersibles at USCG headquarters or within any specific unit (e.g., a USCG National Center of Expertise) prevents the development of focused technical oversight for this unique industry. As a result, this lack of USCG submersible expertise has contributed to regulatory shortcomings and diminished submersible industry confidence in the USCG's ability to oversee submersible operations, leaving the industry with insufficient support, guidance, and oversight.

The absence of international regulatory standards for submersible operations further compounds these issues. While the IMO is responsible for regulating maritime transport and ensuring safety standards for passenger vessels on international voyages, submersibles are not currently subject to IMO regulations. The IMO's SOLAS regulations, which govern passenger ships, set safety standards for vessels carrying more than 12 passengers on international voyages. However, submersibles which carry less than 12 passengers, which is the case for the vast majority of deep-sea commercial submersibles like the TITAN, do not fall under the scope of SOLAS and are not subject to mandatory regulations under this treaty.

The IMO has issued *Guidelines on the Design, Construction, and Operation of Passenger Submersible Craft* (MSC.1/Circ.981), but these guidelines are not mandatory standards. They provide internationally accepted safety standards for submersibles intended for underwater excursions, but they remain voluntary and do not establish binding standards. This reliance on non-mandatory guidelines leaves significant gaps in the regulatory framework for submersibles, particularly as the submersible industry expands and technology advances. As a result, international regulations for submersible operations remain reliant on individual countries to establish and enforce their own regulations and requirements, hindering the development of a consistent and comprehensive safety framework. OceanGate's TITANIC Survey Expeditions, which operated the final TITAN exclusively on the high seas from its support vessel, was able to exploit the absence of mandatory international standards to operate its experimental hull with passengers unimpeded for three seasons. The lack of global regulatory alignment allows for inconsistencies in safety practices across flag administration jurisdictions and on the high seas, complicating efforts to ensure uniform standards for submersible passenger safety.

In conclusion, both domestic and international regulatory frameworks for submersible operations were insufficient to address the complexities of modern submersible technologies and practices when the TITAN tragedy occurred. While U.S. regulations and policies such as 46 CFR Subchapter T, NVIC 5-93, and the MSM provide some limited standards, they are often inconsistent and fail to account for the unique technological challenges and operational risks associated with submersibles. The absence of specific international standards further exacerbates these challenges. The USCG should make an effort in conjunction with the IMO to bolster the existing compliance framework for submersibles. These updates should reflect technological advancements and address inconsistencies in inspection oversight and processes, while also providing a pathway to better facilitate innovations in the submersible industry.

5.12. OceanGate's Toxic Safety Culture.

OceanGate's operational and safety practices were critically flawed, which contributed to the catastrophic implosion of the TITAN submersible. At the core of these failures was a disconnect between the company's stated safety protocols and its actual practices. While OceanGate's 155-page HSE Manual was ostensibly intended to guide high-risk operations, its substance and practical application were woefully inadequate. Only four pages of the HSE manual addressed dive-specific safety procedures—a substantial shortfall for a company centered on deep-sea manned submersible operations. This highlighted systemic issues where submersible safety protocols were either egregiously inadequate or willfully disregarded, leaving critical risks unmitigated.

The analysis reveals a disturbing pattern of misrepresentation and reckless disregard for safety in OceanGate's operation of the TITAN submersible, with Mr. Rush seemingly using inflated numbers to bolster the perceived safety and dive count of the final TITAN hull. OceanGate's cumulative dive count for the TITAN was intentionally misleading; by including the 49 dives of the scrapped original hull, they artificially inflated the operational experience of the final TITAN hull, obscuring the fact that the final TITAN hull had undergone a severely limited number of test dives (only 11, reaching a maximum depth of just 170 meters) before being used for deep-sea passenger voyages to the TITANIC wreck at 3,840 meters. This deliberate manipulation of data created a false impression of the submersible's proven reliability and safety, and crucially, this misrepresentation provided an inflated sense of safety and security to mission specialists. The limited testing of the final TITAN hull directly contradicts any claims of rigorous validation; a mere 11 operational dives to shallow depths is woefully inadequate to assess the structural integrity and long-term performance of a submersible designed for extreme pressures at TITANIC depths, raising serious questions about OceanGate's adherence to established engineering practices and safety protocols.

Compounding these issues, the company's leadership structure concentrated virtually all decision-making power in the hands of its CEO, Mr. Rush. Although OceanGate had a Board of Directors, Mr. Rush's dominant behavior rendered it largely ineffective. MBI witnesses described Board meetings as informational, with Mr. Rush, showcasing accomplishments and dictating decisions. The MBI determined that OceanGate's Board of Directors, despite the appearance of diverse expertise, in practice functioned primarily as a figurehead to add credibility to OceanGate's operations. The inclusion of a retired USCG admiral to help ensure their regulatory compliance was disingenuous as the retired admiral confirmed during an MBI interview that he had no marine safety background or experience when he was added to the Board. The retired USCG admiral couched the Board's role as "strategic based," and he confirmed that Mr. Rush "was not a person who sought, to the best of my recollection, a lot of input from the members of the Board or direction. It was mostly from Stockton, this is the plan, this is the way we're going, and the board would discuss question, comment on, let's say, the way ahead." Overall, the MBI believes Mr. Rush deliberately sidelined OceanGate's Board and did not solicit its collective expertise so he could proceed unchecked with his vision to conduct TITANIC expeditions, regardless of any mounting safety concerns. This style of top-down leadership, which was displayed during all OceanGate operations investigated by the MBI, fostered a culture in which operational objectives consistently overruled safety priorities. Employees, particularly those in technical and operational roles, were dissuaded from and belittled for voicing concerns, creating an environment where safety was sidelined and concerned employees either resigned or were terminated.

A prime example of Mr. Rush's disregard for opposing views from his senior staff was evident during his meeting with his Director of Operations on January 19, 2018, following an internal safety inspection of the first TITAN hull conducted by the Director of Operations. After the Director of Operations made the point that OceanGate had hired him to take a conservative approach to safety, Mr. Rush made the following statement to the group assembled for the meeting, "That's why we hired (the Director of Operations), you know. It is for that level of detail and safety approach to it, was the primary attraction to bringing (the Director of Operations) on board. And now we've gotten to a point where his experience and his estimation of the correct way to do is fundamentally opposite of the approach that I want to take." Earlier in the conversation, Mr. Rush also made the statement that he would not force people to join his "religion" if they were opposed and held opposite views. When considering that the Director of Operations was fired shortly after the meeting with Mr. Rush, the message was clear to OceanGate's remaining senior staff that opposing views needed to be completely stifled.

The MBI also noted that many of OceanGate's engineers lacked the specialized knowledge required for designing deep-sea submersibles, leading to significant capability and knowledge gaps. A former OceanGate Director of Engineering described the building and operation of the first TITAN hull as akin to a "high school project," underscoring the inadequacy of the team's skills and experience. Despite these shortcomings, engineers were pressured by Mr. Rush to meet ambitious deadlines, often at the expense of addressing critical design and engineering flaws. This prioritization of the operational dive schedule left the dive support teams and TITAN submersible ill-prepared to sustain safe operations in extreme deep-sea conditions. This lack of expertise within OceanGate's engineering team was a concern that compounded overtime as OceanGate employees with submersible and engineering experience either left the company voluntarily or were fired by Mr. Rush.

Examples of OceanGate CEO's disdain for traditional submersible safety protocols were abundant. For example, in one incident Mr. Rush opted to use only four bolts to secure TITAN's 3,500-pound forward dome to the submersible, "because it took less time," despite the design requiring 18 bolts. The Director of Engineering, at the time, raised concerns over the reduced bolts and was ignored. This shortcut became an issue during a 2021 TITANIC dive. While being hoisted onto the HORIZON ARCTIC's aft deck, the TITAN suffered a catastrophic failure: the forward dome's bolts sheared as it transitioned from the ramp to the horizontal surface, causing the dome to detach and fall onto the LARS platform. While no one was injured, this incident highlighted OceanGate's propensity to not thoroughly assess operational risks, often prioritizing operational efficiency over safety.

This dismissive approach to safety culture was not limited to engineering decisions. OceanGate's management actively retaliated against employees who raised legitimate compliance related concerns. In 2017, a USCG Reserve petty officer employed by

OceanGate warned the company's "front office" about regulatory non-compliance. Mr. Rush reportedly responded to concerns with hostility and the USCG petty officer claimed Mr. Rush told him that he could "buy a congressman" if the USCG ever became a problem for his TITAN operations. In 2022, a contractor hired by OceanGate raised safety concerns about the navigation system and the way the navigation system was being utilized to track and communicate with the TITAN. Specifically, concerns were raised regarding the constant errors with the TITAN's tracking and navigation system, which stemmed from OceanGate's decision to also use TITAN's tracking system as their sole communications capability with TITAN's Communications and Tracking Team. The same contractor also brought up concerns raised by "mission specialists" after they heard a loud bang inside TITAN while ascending close to the surface from Dive 80. When the contractor voiced their numerous safety concerns to an OceanGate Director, the Director told the contractor, "You have a bad attitude, you don't have an explorer mindset, you know, we're innovative and we're cowboys and a lot of people can't handle that." The contractor who voiced the concerns was subsequently sent home from the TITANIC Survey Expedition 2022, prior to the expiration of her contract. The employee firings sent a clear message that raising legitimate safety concerns as encouraged in an excerpt from OceanGate's HSE included in Figure 273, was not only unwelcomed by OceanGate in practice but often led to the employee's termination. Thus, OceanGate employees felt that raising concerns could jeopardize their potential careers at OceanGate and in the broader submersible industry if they became labeled as a problematic employee.

> **1) ACCIDENT PREVENTION PROGRAM: MANAGEMENT COMMITMENT**
>
> A) EMPLOYEES ARE REQUIRED TO COMPLY WITH ALL COMPANY SAFETY RULES AND ARE ENCOURAGED TO ACTIVELY PARTICIPATE IN IDENTIFYING WAYS TO MAKE OUR COMPANY A SAFER PLACE TO WORK.

Figure 273: Excerpt of OceanGate HSE Manual; Accident Prevention. Source: OceanGate.

Financial instability further compounded OceanGate's challenges, introducing additional risks and pressures to an already insolvent and unsustainable business model. Witnesses described a high turnover of employees, with full-time staff being replaced by contractors and volunteers as financial pressures mounted. By 2023, OceanGate resorted to asking employees to temporarily forgo their salaries in exchange for future repayment. The former Director of Engineering, who left OceanGate in early 2023, testified to the MBI that these economic pressures severely undermined the already low safety standards at OceanGate. "The safety was being compromised way too much," the former Director of Engineering stated to the MBI while reflecting on the growing tension between the company's financial struggles and its operational obligations to mission specialists who often paid years in advance for their chance at a TITAN dive to the TITANIC wreck site.

As these systemic failures escalated, OceanGate's management remained unyielding and increased their disregard for safety. Decisions were made unilaterally at the top, with Mr. Rush often bypassing established protocols and ignoring the concerns of other experienced OceanGate employees and contractors. Several OceanGate employees confirmed that Mr.

Rush was essentially Ocean Gate's CEO, Safety Officer, and primary submersible pilot, which enabled him to set operational safety parameters and then make all final decisions for TITAN operations without adequate input or checks and balances from the Board of Directors, the other OceanGate employees, regulators, or third-party organizations (e.g., classification societies). The cumulative effect was an authoritarian and toxic culture where safety was not only deprioritized but actively suppressed. This toxic environment, characterized by retaliation and belittling against those who expressed safety concerns combined with a lack of external oversight, set the stage for the TITAN's ultimate demise.

Had OceanGate adhered to the safety standards outlined in its own HSE Manual and fostered a culture of transparency and accountability, this tragedy would likely have been averted with the final TITAN hull removed from service well ahead of its implosion. Encouraging employees to voice concerns without fear of retaliation and prioritizing safety over expediency could have prevented the sequence of events that led to the disaster. Instead, the company's systemic failures created an environment where risks were ignored, and consequences were inevitable.

In conclusion, OceanGate's failure to prioritize safety stemmed from deep-rooted flaws in its leadership structure, culture, and operational practices. It was clear during the MBI's investigation that OceanGate's CEO (Mr. Rush) exerted full control over every facet of the company's operations and engineering decisions. His multiple roles (e.g., Co-founder, CEO, Secretary of the Board of Directors, Chief Pilot, primary investor, etc.) enabled him to gradually solidify his centralized and dominant control over all OceanGate decisions and operations. This corporate structure combined with the absence of meaningful external oversight and management's dismissive attitude toward safety concerns, created an environment that enabled TITAN to continue operating with the threat of its eventual implosion growing to almost a certainty. This tragedy serves as a stark reminder of the critical importance of prioritizing safety in high-risk operations and the devastating consequences when it is disregarded.

5.13. Undermining Authority and Overriding Established Hierarchy.

The safety of the TITAN submersible operations was a critical concern given the extreme depths it was intended to reach, and adhering to established safety protocols was paramount. According to OceanGate's HSE Manual, the Mission Director was responsible for monitoring, directing, modifying and potentially cancelling a dive operation when it was determined that an unsafe condition existed. The Mission Director was also responsible for ensuring all pre-dive checks were completed for all procedures and equipment prior to commencing a dive. As OceanGate's key decision-maker, Mr. Rush cultivated an environment where safety concerns of the Mission Director were often dismissed, diminished, or overruled, leading to numerous hazardous situations during OceanGate's dive excursions. These incidents exposed significant gaps in the planning, execution, and safety oversight during the OceanGate operations. However, OceanGate's leadership, particularly Mr. Rush, fostered an organizational culture that increased operational risks, where financial pressures, operational demands, and a disregard for safety measures overshadowed the Mission Director's duties.

The April 30, 2015, test dive of CYCLOPS I at Everett Marina revealed critical flaws in safety culture and decision-making, particularly due to Mr. Rush's dual role as both submersible operator and CEO. When a latch malfunctioned on the ANTIPODES, the OceanGate employee who witnessed the discrepancy raised concerns about the hatch's improper securing; however, the Mission Director allowed the pilot (Mr. Rush) to proceed with the dive without addressing the concern. The OceanGate near miss report for the incident highlighted how Mr. Rush's authoritative position and the pressures created by the presence of VIP guests on the excursion created a "get it done" mentality that undermined standard safety protocols. This pressure to proceed, despite dissenting opinions, reflected a broader organizational tendency, where operational priorities frequently overrode safety considerations. This incident highlights the risks of consolidating operational and leadership roles in high-risk environments, as it can suppress open dialogue and compromise critical safety decisions. A robust safety culture requires leaders to prioritize team input and ensure all concerns are addressed before moving forward.

On May 12, 2021, during Dive 54 in Everett, Washington, a critical issue arose at a depth of 3 meters involving the carbon dioxide scrubber system. The pilot, who also served as OceanGate's Director of Logistics, reported a malfunction and requested an immediate ascent. Initially, Mr. Rush denied this request to surface, despite the serious risks posed by the malfunction. The Director of Engineering subsequently intervened, urging Mr. Rush to allow the submersible to resurface to resolve the issue. After some back and forth discussion, Mr. Rush reluctantly agreed to initiate the ascent. This decision to delay a potentially time critical ascent underscored the Mr. Rush's disregard for safety concerns, prioritizing mission continuity over crew safety.

Another glaring example occurred on July 9, 2021, during Dive 65, when the TITAN descended to the TITANIC wreck site. During the dive, several critical equipment failures occurred, including a malfunction with the drop weight motors, which required the jettisoning of the drop weight tray to begin ascent. Despite the Mission Director's repeated instructions to release the weight tray, Mr. Rush overruled the decision due to concerns about the potential disruption to future expeditions because there were no spare drop weight trays. Rather than releasing the drop weight tray, Mr. Rush formulated a plan to descend back to the ocean floor and remain there for up to 24 hours until the TITAN's sacrificial anodes deteriorated and released the emergency weights. The Mission Director's role, as outlined in OceanGate's safety procedures, was to make such critical safety decisions, yet the Mr. Rush's refusal to adhere to the Mission Director's orders placed the TITAN crew in a hazardous situation at an extreme ocean depth of approximately 3,800 m. Mr. Rush's reluctance to release the weight tray, despite clear safety risks, was influenced by the financial and reputational impact the decision would have had on the company. Mr. Rush reportedly pressured the crew aboard TITAN during the incident to remain submerged for a prolonged period, which deviated from the planned operation, ignored safety protocols, and endangered the occupants. Although Mr. Rush eventually relented after TITAN was able to manipulate tray to drop weights without losing the entire mechanism, this incident highlighted a dangerous disregard for the Mission Director's authority and a willingness to operate TITAN at depth with multiple equipment malfunctions.

A similar disregard for safety occurred on July 15, 2022, during Dive 80, when the TITAN was being operated by the TITANIC content expert who was not an employee of OceanGate nor a qualified pilot. This unqualified member operated the TITAN, while the "qualified pilot" sat in the aft of the submersible. A "mission specialist" then requested that the submersible maneuver closer to the TITANIC wreckage. This maneuver resulted in one of the TITAN's skids becoming entangled in the wreckage of the TITANIC. While the TITANIC content expert managed to free the submersible, the decision to enter the physical wreckage raises several concerns. The primary concern is OceanGate's lack of a risk mitigation plan for an entanglement at depth, which was highlighted by the absence of a standby ROV or secondary submersible to assist in freeing the TITAN from entanglement had the situation been more serious.

To better understand best practices for deep-sea tourism in regard to emergency backup capabilities, the MBI interviewed an ocean explorer due to their extensive experience with deep-sea exploration including a record dive to the Mariana Trench, reaching a depth of 10,908 meters (35,787 feet) on March 26, 2012. The ocean explorer confirmed the importance of having a backup capability on scene, or at least on station and available on the support vessel, for deep-sea operations in areas with entanglement hazards (e.g., the TITANIC and BISMARCK wreck sites, hydrothermal vent tours). He recounted a scenario where a potential entanglement at 12,000 feet was quickly resolved with guidance from a second submersible on scene. Although the ocean explorer confirmed having a second manned on station is ideal, he acknowledged it is expensive and not always an option. As such, he stated a secondary option would be to have an unmanned ROV launched in conjunction with the manned submersible from the same support ship. He also provided the following recommendation on a third option, "I think your third tier, which would be the absolute minimum I would go with in the future….is an observer ROV which can be quite a bit smaller, maybe a spooling fiber vehicle that can just be sent down to assess the situation and make recommendations and call for external assistance if necessary. I would not go below that tertiary level in the future personally."

After TITAN's brief entanglement during Dive 80 there was no on scene capability to assess the condition of the hull at depth. As a safety precaution, OceanGate's surface support crew ordered the TITAN to return to the surface immediately after it was freed. Despite that order from the Mission Director, TITAN's crew continued their TITANIC excursion after successfully disengaging from the entanglement. It is also important to note that entering and contacting the wreckage of the TITANIC violated the terms of TITAN's exemption issued by NOAA under Section 113 of the Consolidated Appropriations Act, 2017. This incident casts doubt on the judgment exercised by individuals in charge of TITAN's operations, particularly given the lack of proper controls over piloting procedures and the missing emergency contingency plans and available rescue resources, such as an ROV or alternate rescue submersible.

Another serious safety concern emerged on July 19, 2022, during Dive 81, when the TITAN experienced issues with its thruster controls. During its descent, the submersible began to oscillate or "yaw" in a horizontal plane, indicating a malfunction. The pilot subsequently discovered that the thruster controls had been inadvertently reversed. While the pilot was able to eventually compensate for the improperly installed thrusters, the pilot did not report the discrepancy to the Mission Director. This failure to communicate critical information to the support ship and the Mission Director created a dangerous situation. Had an emergency arisen during the dive, the misconfigured thruster controls could have caused the submersible pilot to be unable to maneuver correctly, increasing the risk of losing both the submersible and its passengers. The failure to communicate and properly verify equipment functionality prior to dive operations and the unwillingness to abort dives during malfunctions created significant gaps in operational safety procedures at OceanGate.

These examples represent only a fraction of the incidents that occurred during TITAN’s expeditions. Yet they reveal systemic issues within OceanGate’s operations, particularly regarding the Mission Director's duties, and the company's failure to adhere to established safety protocols. There was a notable lack of adherence to incident reporting procedures, with only 12 recorded "Incident Reports" (none of which could be located by OceanGate for the MBI post-incident) logged in the company’s maintenance records. This illustrates the failure to properly document and rectify safety concerns. OceanGate’s operational decisions, particularly those made by Mr. Rush, repeatedly compromised safety in favor of operational continuity, proof of concept, and financial considerations. The multiple failures to follow the Mission Director’s directives, the inadequate risk management practices, and the lack of essential backup equipment on standby, highlight broader systemic failures within OceanGate, ultimately jeopardizing the safety of the TITAN’s crew and passengers.

The incidents surrounding OceanGate underscore a broader lesson in organizational accountability and risk management. Had the company adhered to its documented safety protocols and fully empowered its Mission Directors to enforce operational decisions without interference, many of the failures that ultimately occurred leading up to the TITAN’s implosion might have been avoided including the potential removal of the TITAN from service prior to the incident.

5.14. Absence of a Designated Director of Safety and Mismanagement of Risks.

The investigation into OceanGate's safety and risk assessment processes revealed several critical deficiencies that compromised the safety of their operations, particularly during expeditions to the TITANIC wreck site. One of the most significant issues was the absence of a Director of Safety. The role of the Director of Safety is clearly outlined in the Health, Safety, and Environmental (HSE) Manual, specifically in Paragraph D of Section 1, but the investigation could not identify who held this position at OceanGate and several OceanGate employees indicated that they considered Mr. Rush to be the default Safety Officer. This lack of a dedicated Director of Safety meant there was not a designated individual accountable for overseeing the safety program, leading to a breakdown in safety oversight. Instead, the Mission Director was responsible for both the dives and safety during each mission. However, the Mission Director, who reported directly to Mr. Rush, was frequently overruled by the pilot on submersible-related safety issues, creating a confusing and decentralized safety structure that lacked clear lines of authority and responsibility.

In terms of risk management, OceanGate used a system that involved a Risk Index, which considered anomalies and strikes to assess unusual events that could impact dive decisions. The Risk Index considered factors such as crew health (e.g., fatigue or illness), crew experience level, and equipment condition. When deviations from the “perfect” situation occurred, each deviation was supposed to be counted as an anomaly with multiple anomalies being equivalent as a strike. A strike was defined in the HSE Manual as significant safety issues and if three strikes were identified then the dive was to be canceled. The MBI found no instance where an OceanGate dive was cancelled due to accumulated anomalies or strikes. While anomalies were documented in the dive logs, there was no evidence of consistent identification or documentation of strikes. Additionally, there was no clear evidence to suggest that this system was properly applied, as there was no documentation about how the Risk Index for each dive was calculated. These concerns are highlighted by there being no information on how the Risk Index was evaluated when the TITAN was in transit or during its pre-dive inspection. Also, former OceanGate employees and others interviewed were unaware of how the Risk Index was calculated and left the assessments completely up to Mr. Rush. This lack of clarity and consistent application of the risk assessment system made is completely ineffective.

The HSE Manual and the TITAN Operations Manual did not mention the use of a formal risk assessment system, further complicating the safety evaluation process. However, OceanGate did have a Dive Operations Risk Assessment document, which included a table categorizing various tasks by their likelihood and the severity of their consequences. This risk assessment highlighted hazards such as confined space, motion energy-collision, and entanglement in the Dive Execution Sequence. Despite these efforts, there were noticeable gaps in how certain tasks, like Tracking Operations, were assessed. For example, the risk of losing communications and tracking with the TITAN was acknowledged, but no mitigation strategies were clearly outlined.

Another significant issue was the lack of clarity with how the condition of the TITAN was assessed before dives, especially when it was being towed on the LARS platform. The external coating and insert sleeve potentially concealed cracks or imperfections in the submersible's carbon fiber hull, and it was unclear how OceanGate inspected these potential vulnerabilities. Based on witness interviews, the MBI determined it was unlikely the TITAN’s inner and outer hull was fully inspected while the TITAN was out of service and stored in St. John’s ahead of the TITANIC Survey Expedition 2023 operations.

The failure to classify incidents correctly also contributed to the safety failures. For example, on July 15, 2022, during Dive 80, the entanglement with TITANIC’s wreckage should have been classified as an incident according to the HSE Manual. However, no incident report was filed for this event. The HSE Manual provided clear guidelines for documenting and responding to incidents, yet the failure to do so in this case suggests a breakdown in the system. Similarly, other safety issues, such as thruster control problems on July 19, 2022, during Dive 81 were not addressed with sufficient care. Despite the discrepancy with the primary navigational controls, the dive proceeded after the pilot compensated for the failures instead of ascending for repairs in a controlled environment. This raises concerns about the decision-making process and whether safety issues were adequately considered before continuing the dive.

In conclusion, the investigation revealed multiple flaws in OceanGate's safety and risk management protocols. The lack of a Director of Safety created ambiguity in authority and accountability over safety protocols, while the risk assessment system was inconsistently applied, with anomalies and strikes not properly identified or documented. Serious incidents, like entanglement in the TITANIC's wreckage, were not classified or reported as incidents, undermining the safety procedures outlined in the HSE Manual. Furthermore, safety issues such as mechanical failures were not always addressed effectively, with dives continuing despite significant risks. These deficiencies point to a broader failure in OceanGate's safety culture, highlighting the need for clearer roles, more rigorous safety protocols, and better documentation of incidents to ensure the protection of crew and passengers in future operations.

Overall, had OceanGate appointed a Director of Safety, there would have been someone with a clear mandate to oversee safety protocols, ensure compliance with risk management practices, and intervene when necessary to prioritize the safety of life. Such a position could have significantly reduced the likelihood of incidents and provided an essential layer of safety oversight that was absent from the company's operations. The lack of this critical role ultimately contributed to the systemic failures in safety that compromised the TITAN's expeditions.

5.15. Lack of Formal Pilot Training or Appropriate Merchant Mariner Credentialing.

The lack of formal certification and training protocols at OceanGate significantly impacted the effectiveness and safety of the company's submersible operations, particularly regarding the qualifications of its pilots. The submersible pilot role was critical to ensuring safe and successful expeditions, yet OceanGate did not maintain proper documentation of pilot certifications or qualifications. OceanGate's former Director of Operations indicated that there was no official documentation for the submersible pilots at OceanGate. While Mr. Rush may have been trained and certified by a noted submersible pilot, there was no evidence to show that he was formally documented as a pilot by OceanGate, despite piloting the submersibles ANTIPODES and CYCLOPS I on manned dives in 2019.

The structure of the OceanGate's pilot training program was also insufficient. According to the former Director of Logistics and Quality Assurance, who was a submersible pilot, the training program at OceanGate had a three-tier system: Level 1, Level 2, and Level 3. Level 1 pilots completed foundational training based on the OceanGate Personnel Qualification Standard (PQS). Following this training, they served as pilots in training, gaining practical experience alongside a pilot in command. Level 2 pilots were qualified to dive with a co-pilot, and Level 3 pilots could operate the submersible solo. However, the training program was predominantly internal to OceanGate, with only occasional external pilots serving as contractors to provide Level 3 training. While the company published a training matrix in 2023 that showed the ratings of submersible pilots, this document lacked critical details about how pilots achieved their qualifications, and there was no documentation indicating whether pilots or expedition members had completed their required training.

Moreover, the training process was inconsistent and raised concerns about its rigor. A former Operations Director recounted that at one point during his tenure, OceanGate aimed to qualify pilots in a single day, even for individuals who had never operated a submersible. This approach, described by the former Operations Director as a "huge red flag," suggested that OceanGate's pilot training was insufficient for ensuring the safety of both pilots and passengers. The MBI revealed that OceanGate deliberately misrepresented the TITAN submersible's gross tonnage to the National Maritime Center in 2020, falsely claiming it was 26 GRT[58]. This misrepresentation enabled Mr. Rush to obtain a USCG-issued Master of 25 GRT Inland MMC based on claimed sea time on a vessel of sufficient size. The MBI found that while Mr. Rush was the only OceanGate pilot to hold a USCG Master MMC, and even that was obtained through falsifying the tonnage of the TITAN, possessing such a credential was not a standard or enforced requirement for OceanGate's pilots. This stands in stark contrast to the rigorous vetting process for pilots operating USCG-certified small passenger submersibles in locations like Hawaii and Guam. These pilots are required to hold an MMC, undergo thorough medical examinations, complete satisfactory background checks, and be subject to comprehensive chemical testing programs (including pre-employment, reasonable cause, and random testing) to ensure their suitability and fitness for the critical role of piloting passenger-carrying submersibles. This discrepancy highlights a significant difference in safety standards and regulatory oversight between OceanGate's operations and those of other submersible operators under USCG jurisdiction.

Additionally, OceanGate did not have a dedicated manual for submersible pilots or a comprehensive training guide for the TITAN submersible. The company had a general training program with manuals and checklists that was applicable to all submersible pilots. However, there was no evidence identified by the MBI indicating that the principal pilots, OceanGate’s CEO and the Director of Logistics and Quality Assurance, had completed a specific TITAN training program that would lead to Level 3 certification. A draft TITAN Piloting Manual was created during the 2017–2018 timeframe, but it was incomplete and did not appear to serve as a comprehensive guide for pilots operating the TITAN.

In conclusion, OceanGate's approach to submersible pilot training, qualification, and oversight was inadequate and lacked the rigor necessary for ensuring safe operations. The absence of formal certification, incomplete training manuals, inadequate medical fitness evaluations, and the lack of a comprehensive drug testing program contributed to an environment where submersible pilots were not properly prepared or qualified for the high-risk tasks they were undertaking. Had OceanGate implemented a more formal, structured, and documented pilot training program, many of the critical safety issues encountered by the TITAN over its three seasons of operations could have been avoided or better mitigated. A properly certified and qualified team of submersible pilots, with clear medical and fitness assessments, would have ensured that only individuals with the necessary skills, experience, and physical capabilities operated the submersibles. If proper certification and training

[58] Following the incident, the MBI requested a tonnage estimate for the TITAN from the USCG Marine Safety Center. Due to the absence of detailed plans necessary for precise calculations, an official admeasurement could not be performed. However, and informal assessment estimated the TITAN to be 4 GRT.

manuals had been in place, the pilots would have had clearer guidance on safety and emergency response procedures, reducing the potential for operational errors or failures. Additionally, better oversight and documentation of the entire pilot training process could have ensured that each pilot was adequately prepared for the unique challenges of deep-sea exploration. The lack of these fundamental safety measures likely contributed to the broader operational deficiencies and safety lapses at OceanGate, which, had they been addressed, may have prevented some of the risks and incidents that ultimately led to the tragedy.

5.16. Disregard for Safety Concerns Voiced by Outside Entities.

OceanGate's approach to the development and operation of the TITAN submersible showed a clear pattern of disregarding safety concerns, which resulted in serious risks to both the vessel's integrity and the safety of its crew. This neglect of safety was evident at several critical points, where warnings were either ignored, downplayed, or dismissed outright, often in favor of expediency, financial considerations, or operational goals.

One of the earliest indications of this disregard for safety came in 2017, when OceanGate presented its plans for the TITAN at a Marine Technology Society (MTS) meeting. During this meeting, several industry professionals expressed serious concerns about the submersible's carbon fiber construction and its ability to withstand the extreme conditions of deep-sea dives. These concerns were eventually consolidated into a draft letter in March 2018, intended for the CEO of OceanGate. The letter warned that OceanGate's "experimental" approach could result in catastrophic outcomes. The Chairman of the MTS Committee on Manned Submersibles stated that the MTS Board of Directors considered the letter to be outside the by-laws of the non-profit organization and therefore was never formally sent to OceanGate and Mr. Rush. Despite the letter of concern never being formally sent to OceanGate, a draft version was sent to Mr. Rush. Mr. Rush then called the Chairman of the MTS Committee on Manned Submersible and voiced his displeasure and stated that he was leaving the association, to which the Chaiman stated, "Well, you can't. You never paid to be part of the association. You are a member of the brotherhood. You belong to the community. You have a responsibility to everybody. It's not a paid ticket. So, no, you cannot leave." Following the implosion of the TITAN, MTS leadership clarified that their original concerns regarding TITAN were primarily based on technical disagreements which was within the scope of their business rules, and not the safety issues raised by experts.

Another significant example of OceanGate disregarding safety came after the testing of the first TITAN hull in the Bahamas in April of 2019. An experienced submersible operator was involved in the test dive and reported hearing a loud cracking sound originating from the hull. This test dive participant, who had extensive experience with deep-sea submersibles, immediately raised concerns about the structural integrity of the hull. He pinpointed a specific section of the hull where the majority of the acoustic noises were originating from and suggested that the sounds were indicative of a flaw or defect in the hull that could worsen with pressure at depth. Despite these serious warnings, Mr. Rush dismissed the concerns, opting to continue with additional dives to gather more data. The test dive participant even went so far as to caution Mr. Rush about the potential for catastrophic failure, urging caution and the need for further inspection of the hull for cracking. In an email exchange with Mr. Rush following the dive, the test-dive participant warned that the crack could propagate, potentially leading to a disastrous failure. Despite the warnings, OceanGate persisted with its testing schedule, likely due to pressures from investors and customers.

After reviewing the RTM data from the test dives, OceanGate's Director of Engineering at the time raised concerns about the structural integrity of the first TITAN hull and OceanGate's plan for it to conduct future dives to the TITANIC wreck site. Excessive flexing of the hull and data signaling potential critical structural issues were reported, leading to the Director of Engineering's refusal to approve the TITANIC Survey Expedition 2019. During a pre-dive inspection in May 2019, a large crack in the carbon fiber hull was discovered on the interior surface of the first TITAN's hull, which ultimately led to it being permanently removed from service. The Director of Engineering who raised the initial concerns about the structural integrity of the first TITAN hull was terminated shortly after. Just prior to his termination Mr. Rush reportedly passed to the Director of Engineering that two members of OceanGate's Board of Directors had asserted that OceanGate should have known the hull was compromised and that it would not work and that someone had to take responsibility for it. The Director of Engineering also reported that Mr. Rush clarified that it wasn't going to be himself and that the Director of Engineering would shoulder the blame and be fired. Despite the first TITAN hull being severely compromised with a large crack, OceanGate still considered the hull operational and used it for at least one additional manned dive before the testing was ultimately aborted due to another incident during a descent. The final decision to retire the first TITAN hull was only made after follow up testing at the DOTF confirmed the hull was degraded and not suitable for deep sea operations. OceanGate's handling of the first TITAN hull underscores the company's culture of ignoring internal warnings and external safety concerns in favor of pushing forward with operations, even when safety was obviously compromised.

Moreover, OceanGate's history of disregarding safety concerns is further evident in its former relationships with prominent institutions like the University of Washington's APL, Boeing, and NASA. These institutions were initially involved in various degrees with the conceptual planning, development, and testing of the TITAN. OceanGate leveraged the relationships to lend credibility to its design and aspirational claims, which OceanGate proudly touted on their website and through social media. However, as the TITAN project progressed it became apparent to OceanGate's partners that critical safety concerns were not properly addressed and that OceanGate intended to move forward with manned testing of the TITAN prototype hull on a timeline that could not be accomplished safely. After NASA dropped cooperative plans due to the COVID-19 pandemic, OceanGate's aggressive plans to move forward with manned TITAN operations, contributed to Boeing and APL ceasing their support to the project. Specifically, the APL expressed concerns in 2017 about the unproven materials being used for the external motor pod controllers for the thrusters and ultimately decided to withdraw from the project after Mr. Rush and OceanGate's Director of Engineering dismissed their concerns. After conducting a preliminary feasibility study for the concept, Boeing also declined to participate after OceanGate did not follow their recommendations from the report. During MBI testimony Boeing's Material and Process Engineer who was involved with the feasibility study speculated that Boeing's relationship with OceanGate ended because Boeing's services were too expensive for OceanGate's budget. The MBI concurs with that assessment as OceanGate did not allocate the appropriate time or funds to professionally approach the introduction of a novelly designed deep-sea submersible.

In summary, OceanGate repeatedly prioritized operational goals and financial considerations over safety, ignoring warnings from both industry experts and internal staff. Had OceanGate taken the warnings more seriously, involved independent safety experts, or adhered to more rigorous testing and safety protocols, many of the risks that contributed to the eventual implosion could have been mitigated or avoided entirely.

5.17. Failure to Properly Troubleshoot Hull After Acoustic Events and Safety Culture Relating to the Operation of the TITAN.

A critical failure in OceanGate's safety culture was its disregard for acoustic events and the lack of appropriate troubleshooting after significant events were recorded. Throughout the TITANIC Survey Expedition 2022 season, significant acoustic events occurred, which should have been flagged as early warning signs of potential damage to the submersible's hull. These acoustic events were indicative of stresses on the vessel, potentially caused by issues like cyclic fatigue or structural degradation, yet OceanGate failed to conduct the necessary follow up inspections, analysis, and safety checks to assess the extent of the damage.

Despite these acoustic anomalies, OceanGate's CEO (Mr. Rush) chose to ignore the warnings, accepting the risks associated with continuing dives without thoroughly analyzing the RTM data or investigating the TITAN for potential hull damage. This decision was primarily driven by financial pressures, operational demands, and overconfidence in TITAN's design and construction. Mr. Rush's overconfidence influenced OceanGate's personnel, contractors, and mission specialists, creating an environment where safety concerns were ignored or underemphasized in favor of operational continuity. Mr. Rush maintained confidence in the structural integrity of the vessel, continuously stating to others that the acoustic monitoring system, which had been designed to detect and alert about critical failures during the testing process, would provide an advanced warning if the TITAN was at risk. However, this approach was based on flawed logic. The assumption the monitoring system would alert them during a dive, combined with a lack of understanding regarding the cumulative effects of cyclic fatigue on the hull, ultimately contributed to a failure to act on early warning signs. Despite its limitations, the TITAN's RTM system ultimately did provide the necessary data during the 2022 TITANIC operations to signal that there was a significant structural failure in the hull. However, the concerning readings were either not reviewed, misunderstood, or willfully ignored by OceanGate ahead of the 2023 TITANIC operations.

Had OceanGate heeded the acoustic emission sounds and conducted thorough inspections of the hull and its components after each significant event, many of the issues that led to the eventual catastrophic failure could have been identified and mitigated. Immediate action, such as halting further dives for comprehensive inspections, might have revealed structural damage or defects that could have been addressed before the vessel was subjected to further stress. The failure to address these early warning signs, driven by overconfidence and financial pressure, ultimately contributed to a tragic outcome that could have been avoided with a more responsible approach to safety and operational oversight.

5.18. Misrepresentation of Paying Passengers as Mission Specialists.

The operations and obligations of mission specialists participating in OceanGate's TITANIC expeditions were misrepresented by OceanGate as mandatory duties to conceal that their mission specialists were actually paying passengers. When mission specialists agreed to perform labor intensive duties (e.g., helping to bolt down TITAN's forward dome), OceanGate did not provide adequate training or safety measures, which raises significant concerns about the ethical and legal practices of the company. Mission specialists, who paid substantial fees to participate in the TITANIC dives, were described by OceanGate as integral members of TITAN's expedition team, including participation in scientific tasks. However, despite OceanGate's description, many mission specialists did not participate in any expedition assignments and conducted little to no scientific tasks[59]. The money paid by mission specialists went directly into OceanGate's operating account, with no guarantee of a refund or even a future opportunity for a mission specialist to participate in another dive if a mission was canceled or aborted. According to a former OceanGate Director of Administration, "The (mission specialist) funds went into our regular checking account. They were not separated out or put into a separate trust fund. The funds that came in were immediately, went out to pay operations." The immediate use of mission specialist funds added pressure on OceanGate to conduct TITAN operations to fulfill its obligations and protect its reputation.

OceanGate's communication with mission specialists regarding the cancellation of the 2019 TITANIC expedition was consistent with their pattern of misrepresentations and a lack of transparency that eroded trust in the company's operations. OceanGate's June 24, 2019, letter to mission specialists attributed the cancellation of the 2019 TITANIC Expedition to the withdrawal of the ship operator, HAVILA HARMONY, citing compliance issues with Canadian maritime law. OceanGate's letter failed to disclose the far more pressing issue regarding their discovery of a significant crack in the carbon-fiber hull of the TITAN during an inspection in the Bahamas. According to testimony from OceanGate's Director of Integration and Operations and Director of Engineering, the crack was identified behind the TITAN's liner, where it was not initially visible. Despite multiple concerns voiced by senior OceanGate personnel about the crack and its implications, Mr. Rush insisted on downplaying the issue and floated a proposal to repair the hull within three weeks and resume operations. His decision appeared driven by a desire to maintain OceanGate's public image and credibility, rather than prioritizing safety. The omission of these safety concerns in the letter

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[59] The MBI determined that OceanGate's overall commitment to scientific operations waned after TITAN's 2021 TITANIC expedition. As an example, the MBI could not find evidence of any significant scientific data released by OceanGate from the TITANIC Survey Expedition 2022 and OceanGate did not bother to rig the TITAN's Niskin salinity sampling bottle for the dive to the TITANIC on June 18, 2023, that ended in the implosion.

to mission specialists represented a deliberate effort to conceal the true reasons for the expedition's cancellation.

The letter also described OceanGate's ongoing efforts to secure funding and prepare for future expeditions, stating that the majority of mission specialists were "comfortable waiting to 2020" for the mission's execution. However, it acknowledged that some mission specialists had "lost confidence" in the project and requested refunds. Instead of addressing these concerns transparently, OceanGate's letter framed the delays as logistical challenges beyond OceanGate's control, sidestepping the fundamental issue of TITAN's inability to perform as promised.

OceanGate's financial instability played a significant role in its decision to withhold refunds from dissatisfied mission specialists. Their letter to mission specialists also revealed that the company had signed a $1.1 million sponsorship agreement with a major internet brand, which was lost due to the expedition's cancellation. This financial strain likely influenced the decision to misrepresent the reasons for the delay, as OceanGate sought to preserve its remaining resources and prevent further erosion of confidence among its stakeholders. OceanGate's refusal to refund support fees further underscores the ethical concerns surrounding the company's communication. By failing to disclose TITAN's critical safety issues, OceanGate denied mission specialists the opportunity to make informed decisions about their future participation on OceanGate excursions and potential measure to recoup their financial contributions. This lack of transparency not only damaged the company's credibility but also placed its mission specialists and future participants at risk. Transparency and accountability are essential in high-risk industries, and OceanGate's failure to uphold these principles serves as a cautionary example for any future similar ventures.

Additionally, the signing of liability waivers by mission specialists, which OceanGate required to participate in expeditions, was often timed to occur just ahead of the scheduled dives. The MBI determined that OceanGate's timing was intentional to pressure mission specialists into signing the waivers. A typical OceanGate email to a mission specialist would include a draft waiver and language such as, "Attached is the liability release for the 2022 TITANIC Expedition. Please take the time to review the document. We will discuss this in more detail upon boarding and give an opportunity to ask questions on the contents and to sign at that time." The process was structured so that the mission specialists would be presented with the waiver only after they had pre-paid for the excursion and traveled to the expedition's departure point, where they would then have a brief opportunity to ask questions before signing. This procedure, which was used for mission specialists participating in Dive 88, placed the mission specialists in a difficult position as the waiver's terms were only discussed in detail post-arrival, likely increasing pressure for mission specialists to comply.

OceanGate's training and certification requirements outlined in the 2023 TITANIC MS Crew Agreement were similarly concerning. The agreement stated that mission specialists should complete a 74-hour in-house training course, or have prior OceanGate mission experience, and possibly obtain a USCG MMC or an equivalent mariner credential prior to participating on a dive. However, the MBI determined that no mission specialist was ever required to obtain such credentials, and the training process for each varied greatly. One mission specialist described to the MBI being told by OceanGate that they would be trained in underwater egress procedures using a helicopter water crash simulator; however, the training was never offered. Another mission specialist testified that they had completed some training ahead of their dive via audiovisual presentations aboard the support ship. The lack of clarity and consistency in mission specialist training, combined with an absence of verification for existing credentials, indicate that Ocean Gate did not take the proper steps to keep their mission specialists safe.

Finally, the medical screening process for mission specialists was inadequate and according to some mission specialists, non-existent. Despite the potential risks involved in deep-sea expeditions, the medical form provided by OceanGate was self-certifying, meaning that mission specialists could omit relevant health conditions that might disqualify them from participating. One mission specialist, for instance, had a pacemaker implanted shortly before the mission and was cleared by their physician, even though this clearance was not required by OceanGate's policies. The liability waiver further compounded the risks by acknowledging that "all risks cannot be eliminated from any Expedition," while listing numerous potential hazards, including submersible malfunction, drowning, and even death. The repeated references to the TITAN being "experimental" in the waivers, including two references in the 2022 expedition waiver and three references in the 2023 expedition waiver, highlight OceanGate's uncertainty surrounding the safety of the TITAN. It is important to note that the term "experimental" is not officially recognized to apply to vessels or submersibles under U.S. commercial maritime regulations; however, it is referenced for certain aircraft under aviation standards.

5.19. High Rate of Employee Turnover and Financial Pressures.

OceanGate's operations suffered from severe financial instability, high employee turnover, and a lack of professionally qualified staff, which critically undermined its ability to maintain safety and operational integrity. The company, initially structured with engineering, operations, and administrative groups, once employed over 30 staff members. However, as financial strain intensified, this number dwindled, and contractors began to fill essential roles. Witnesses consistently described financial instability and employee turnover as hallmarks of OceanGate's operations. The former Director of Human Resources and Administration testified that Mr. Rush occasionally used his personal funds to cover operating expenses, underscoring the precarious financial state of the company. From June 2022 to May 2023, Mr. Rush advanced OceanGate Inc. a total of $1.85 million.

OceanGate's former Director of Engineering provided the following summary to the MBI of a lunch conversation he had with Mr. Rush regarding OceanGate's mounting financial pressures:

> "We get back to the office, he takes me to lunch and says, hey, how about -- we don't have any money. We, you know, we're getting sued by all these passengers that didn't get their trip. So even for this year -- that -- our year, not every dive happened. Not every passenger got to get to the bottom. So, you know, some of them were going to. I don't know if they actually sued. I never really knew what was going on with that, but

> you hear these things, right. You hear so and so was suing. I don't know if they actually sued."

By 2023, OceanGate's financial pressures had escalated to the point that employees were asked to temporarily forgo their salaries with promises of repayment in the future. OceanGate's former Director of Engineering provided the following MBI testimony regarding OceanGate's request:

> "I don't know if you heard, there were economic issues with the company asking us to forgo getting paid for periods of time with the promise that they would get us caught up in paychecks after the first of the year. They asked for volunteers. I don't think anybody did it, but it was clear that the company was economically very stressed."

The former Director of Engineering also confirmed that during the same timeframe as their paycheck request, OceanGate's safety standards were declining. The Director of Engineering stated to the MBI he decided to leave OceanGate in early 2023 because "…the safety was being compromised way too much, at least for myself." The Director of Engineering's departure was indicative of a broader exodus of skilled personnel from OceanGate, which resulted in OceanGate needing to rely more heavily on contractor support for the TITANIC Survey Expedition 2023. While contractors can fulfill short-term needs, they often lack the critical institutional knowledge vital in high-risk industries like submersible operations. Therefore, OceanGate's cuts to their full-time employee roster disrupted operational continuity and dangerously weakened the company's capacity to proactively address safety risks.

To ensure the 2023 TITANIC Expedition proceeded unhindered, Mr. Rush left the Director of Engineering position vacant ahead of TITAN's 2023 operations. This consolidation of engineering authority removed a potential intervention to cancel TITAN's 2023 operations. OceanGate's first Director of Engineering testified to the MBI that his refusal to sign off on the first TITAN hull due to damage and concerning RTM data successfully blocked its participation in OceanGate's scheduled 2019 TITANIC Expedition. The first Director of Engineering also stated that his refusal to sign off on the hull angered Mr. Rush and led to the termination of his employment. When considering that Mr. Rush was aware of RTM anomalies and potential damage to the final TITAN's hull sustained during its 2022 TITANIC Expedition, his decision to leave the Director of Engineering position vacant for the 2023 operating season removed the possibility of a replacement Director blocking the expedition or raising concerns with OceanGate's Board of Directors.

OceanGate's financial pressures were also likely behind a critical shortcut OceanGate implemented when they incorporated TITAN's text communications into the existing tracking capability. The decision resulted in TITAN having to rely on a limited (64 characters per message) text-based communication system for the TITAN rather than the industry-standard for submersibles which enables voice communication. Voice communication systems, long established in subsea operations, offer real-time clarity, nuanced context, and collaborative problem-solving capabilities. Voice communication systems enable teams to rapidly report, describe, and respond to anomalies quickly, which is critical to coordinating effective emergency troubleshooting and potential responses. OceanGate's CEO dismissed voice communication as a distraction and preferred text-based systems to maintain control over TITAN's operations. However, this decision centralized authority at the expense of collaborative safety. The reliance on text-based systems diminished situational awareness, as critical urgency and context that could have been conveyed through voice were lost. Moreover, the reliance on this cheaper system reflects the company's broader cost-cutting priorities. The limited capabilities and shortcomings in the system to support timely communications were readily apparent in an OceanGate video of the Communications and Tracking team who were monitoring TITAN's operation at the time of the implosion. Most notably, after a sound is heard at the surface of the ocean that was later correlated to the implosion of the TITAN, the Communications and Tracking Team notices that they have received a new text communication from TITAN. Two minutes later in the video, the Communications and Tracking Team acknowledges that they had lost all communications and tracking with the TITAN two minutes earlier.

Based on MBI testimony, the loss of communications and tracking occurred frequently during past TITAN dives to the TITANIC wreck site and OceanGate did not consider the past events to be an emergency situation or an issue of concern. Based on the hazardous operating conditions at the deep-sea wreck site and the extremely limited search and rescue capabilities on scene, OceanGate's decision to have only one source of severely limited text communications available for TITAN while operating at depth was a dangerous practice.

Industry-standard voice systems, such as those using ultra-short baseline (USBL) technology or acoustic modems, are reliable but require significant investment in hardware, training, and maintenance. By avoiding these costs, OceanGate likely delayed or obscured the identification of TITAN's critical failures. Early signs of structural failure, such as unusual noises or operational abnormalities, could have been communicated more effectively through voice. Furthermore, recorded voice communications could have provided crucial insights into the progression of the incident.

OceanGate's financial mismanagement, reliance on contractors, and prioritization of cost-cutting over safety left the company ill-equipped to manage the complexities and risks of deep-sea exploration. The diminished focus on retaining experienced personnel, combined with decisions like the reliance on limited text-based communications, undermined the operation's safety. These compounded failures ultimately contributed to the catastrophic loss of the TITAN.

5.20. Improper Storage and Transportation of TITAN.

OceanGate's decisions and operational practices surrounding the TITAN reveal a consistent pattern of sacrificing safety and operational integrity for financial gain, culminating in catastrophic consequences. OceanGate's decision to store the TITAN and its associated equipment outdoors in the Canadian winter environment raises significant concerns regarding both the company's operational practices and its willingness to implement imprudent cost-saving measures. In July 2022, OceanGate began discussions with the MI of Memorial University of Newfoundland about potentially storing the TITAN in St. John's, Newfoundland, under an MOU for educational purposes. OceanGate's Director of Logistics and Quality Assurance communicated to the University on July 12, 2022, "We are looking at three options; pay to import, do an extended bond, or to file an exemption for educational promotional purposes." The latter option, which sought to leverage the University's status to avoid Canadian import taxes, was OceanGate's preferred option.

Once the TITAN arrived in Canada the storage conditions of the TITAN were substandard. On July 26, 2022, the TITAN and its equipment were demobilized at the A Harvey Marine Base in St. John's, Canada. However, instead of being stored in a protected environment, the TITAN and its Conex boxes were placed in the facility's parking lot, uncovered and exposed to the elements. On July 28, 2022, a quote was provided by A Harvey for a protective cover for the TITAN at a cost of $1,750, but OceanGate's Director of Integration and Operations reportedly did not respond to the email proposal. Therefore, the TITAN's storage situation was not addressed in a timely manner, and it remained uncovered in a location where it would be exposed to variable weather conditions including temperatures ranging from 1.4° F to 84.2° F and a significant amount of precipitation including freezing rain, sleet, and snow. Based on weather data provided by NOAA, the MBI noted that the TITAN's hull would have been subjected to multiple freeze and thaw cycles during its time stored outside.

In September 2022, A Harvey Marine Base followed up with OceanGate, emphasizing that the TITAN had still not been tarped. OceanGate's Director of Logistics and Quality Assurance reacted to the email by discussing the matter further with the Director of Operations; however, no actions were initiated to protect the TITAN's hull. These delays were indicative of an ongoing lack of urgency or concern about the protection of the submersible. By December 6, 2022, the issue of securing an MOU with the MI of Memorial University of Newfoundland had not yet been finalized, though OceanGate was still pursuing the exemption route, which would allow them to avoid paying duties and taxes. A representative from A Harvey Marine Base outlined the exemption process and the criteria needed to qualify for it by stating in an email to OceanGate, "The goods will qualify as part of a Scientific Expedition, where the importer will be MUN (Memorial University of Newfoundland) as the scientific or cultural organization or institution of learning sponsoring or conducting the expedition, and OceanGate will be the non-resident participant."

Finally, on December 21, 2022, the MI of Memorial University of Newfoundland and OceanGate entered into an MOU, outlining a broad agreement for cooperation in ocean exploration and technology. However, even after this agreement, the TITAN continued to remain uncovered in the same exposed location at the A Harvey Marine Base until February 6, 2023. Despite the formal agreement with the University and the ongoing discussions about importation, OceanGate's continued neglect of the submersible's physical care is alarming. The failure to cover or tarp the TITAN, despite clear recommendations from the storage facility and the availability of a quoted option for a cover, displays OceanGate's broad disregard for the submersible's maintenance and long-term operational service life.

During MBI testimony a Senior Principal Engineer with ABS provided the following MBI testimony on the proper storage procedures for a carbon fiber composite pressure hull:

> "You have to store it in a controlled environment, it has to be well ventilated, away from the sunlight, the temperature has to be controlled between 60- and 90-degrees F, humidity has to be controlled, you should not exceed 80 percent relative humidity. So the storage of the finished product should be in a controlled environment. You expose it to the elements, it can possibly cause degradation of the material, which is -- because it's a composite, it's a little different from steels and titanium which are a little more robust materials and they can take a little more wear and tear. So from our side, looking at (ABS) rule requirements, we recommend that carbon fiber composite hulls be stored under controlled conditions."

OceanGate's decision to charter the POLAR PRINCE instead of a more suitable vessel for support operations, like the HORIZON ARCTIC that was able to store and transport the TITAN on deck, introduced unique logistical and safety challenges related to the need for extensive towing operations. Mission specialists noted that the POLAR PRINCE's towing of the TITAN and LARS platform required additional deck personnel and created significant operational inefficiencies and safety hazards. One mission specialist who participated on the 2023 TITANIC expedition recounted that OceanGate's reliance on volunteers and limited staffing forced unqualified individuals to perform critical roles. Specifically, the mission specialist stated, "Once all the jobs are given out…. there was maybe one OceanGate staff member on the deck, or a volunteer, and then it was basically the mission specialists."

The required towing operations due to the POLAR PRINCE's configuration introduced a wide array of new risks to the 2023 TITANIC expedition. During one 2023 mission, the towing hawser became entangled in the POLAR PRINCE's propeller, temporarily disabling the ship and the LARS platform. Volunteer divers were forced to dive into the North Atlantic and cut the towline free using serrated knives. The use of a smaller support vessel also impeded TITAN maintenance and inspections, as the TITAN remained on the LARS being towed behind the POLAR PRINCE. The new arrangement resulted in limited access to the TITAN during its downtime and OceanGate maintenance personnel could not safely conduct TITAN maintenance operations on the LARS platform while it was under tow. Witnesses reported that vessel-to-vessel transfers conducted as sea for both repairs and passenger transfers to the LARS posed significant safety hazards, especially in moderate sea states.

During MBI testimony OceanGate's last Director of Engineering described the challenges associated with the change to the POLAR PRINCE:

> "…. the main thing was that the decision had been made to not use the HORIZON ARCTIC, to use the POLAR PRINCE and to tow the sub behind the POLAR PRINCE and it would require -- when we were on the ship in 2021 and 2022 there was constant work, almost 24/7, except when they were diving, on the sub, some kind of maintenance or troubleshooting and, you know, we worked very hard on trying to keep things as best we could. And so, this would have required us to work on the platform either while it was being towed or while we were -- you know, we were anchored or in position and the seas are, you know, one to five-meter seas and the platform bobs up and down. And I just did not see that I could do that, that -- and/or I did not feel right that other people who were working for me would be required to do that."

OceanGate's consistent pattern of neglect—evident in its disregard for proper storage, operational shortcuts, and failure to conduct rigorous safety assessments—underscores their troubling prioritization of cost and time-saving measures over safety. OceanGate's repeated prioritization of financial expediency over operational safety had dire consequences that could have been avoided with more responsible decision-making. If the TITAN had been properly stored in a controlled environment, shielded from inclement weather conditions, its structural integrity might have been better preserved. The exposure to large temperature fluctuations and precipitation during its prolonged storage in an outdoor parking lot likely accelerated material degradation, including potential weakening of the hull and other critical components. Furthermore, had OceanGate opted to utilize a more suitable support vessel, such as one similar to the HORIZON ARCTIC, the TITAN would not have been subjected to the risks associated with being towed thousands of miles on the LARS platform across the North Atlantic. Towing the TITAN on the LARS and stowing it on the LARS during downtimes between dives operations made at sea inspections and maintenance exceedingly difficult while also subjecting the TITAN to unnecessary stresses and potentially damaging impacts.

5.21. U.S. Coast Guard's Inability to Execute Subsea Search and Rescue.

Despite a seven-hour initial notification delay dictated by OceanGate's communications plan, and the added hindrance of OceanGate's decision not to confirm any backup deepwater capable assets or voluntarily report their dive operation as recommended by the USCG National SAR Plan, the Coast Guard in conjunction with multiple partners responded to the TITAN distress notification with ingenuity and resourcefulness. The complex deep-sea environment combined with the remote high seas dive site presented extraordinary operational challenges to the rescue mission, yet the international effort showcased the power of unity of effort in what initially appeared to be a desperate race against time. The Coast Guard's unwavering commitment to its SAR operating philosophy drove a relentless pursuit of all available resources until all hope of rescue was exhausted.

OceanGate's 2023 Project Execution Plan identified external deep-sea rescue resources, yet the company failed to proactively engage, notify, or prepare any third-party services for the TITAN expedition. More critically, OceanGate and the POLAR PRINCE lacked the essential on-scene resources – an ROV or a secondary submersible – to conduct their own immediate search and rescue attempts in the event of an emergency. Recognizing its own limitations in deep-sea searches exceeding 3,000 m, the Coast Guard effectively leverages military and commercial submersible and ROV operators to provide crucial support in the rare event of an underwater emergency. Those capabilities were tapped for the TITAN response and within four days, the Coast Guard mobilized assets capable of reaching the ocean floor. The Coast Guard Captain responsible for search suspension authority highlighted this achievement during MBI testimony: "Many would have considered this an almost impossible task. Yet, from Sunday to Thursday morning, we had an ROV on the ocean floor at the site of the TITANIC. Experts from SUPSALV have called this unprecedented, given the logistical challenges involved in deploying those ROVs."

While the TITAN SAR response included the arrival of multiple ROVs on scene initially, they lacked the appropriate depth capabilities and subject matter expertise to effectively conduct search operations. As a result, one ROV was lost early in the SAR effort as an attempt was made to operate it well beyond its rated depth. The USCG was able to coordinate the delivery of more capable ROVs on-scene on June 21st and 22nd that could reach 6,000-meter depths. On June 22, 2023, at approximately 10:30 a.m., a Pelagic Research Services ROV discovered a debris field of the TITAN submersible's forward cone and tail piece, with a second debris field discovered shortly thereafter containing the TITAN's aft portion of the cone. These discoveries led to conclusive evidence of a catastrophic loss of the submersible and all five persons on board.

Based on MBI testimony provided by the Chair of the AAR Board, several key findings emerged regarding the USCG's SAR efforts, highlighting both strengths and areas for improvement. The review identified opportunities to enhance critical incident communications, streamline the SAR System's initial response, and improve case documentation processes. Enhanced integration between the SAR System and the Incident Command System (ICS) and more specific training for on-scene USCG representatives, particularly in next of kin support and public affairs, were also deemed beneficial. The AAR Board Chair emphasized that the Board considered the case unprecedented, with the vast distance involved significantly hampering the response. Despite these challenges and the initial reliance on the POLAR PRINCE for on-scene coordination, the USCG First District JRCC was highly commended for its outstanding performance and innovative approach. The AAR Chair's MBI testimony also confirmed that the USCG's operational capabilities are primarily limited to surface and air assets, lacking dedicated subsurface search and rescue capabilities and relying on the U.S. Navy for expertise in that domain. Though the limitations in the USCG and international response did not ultimately impact the fate of the TITAN and its crew due to the instantaneous implosion occurring prior to the initial distress call, the Case Study's recommendations represent a crucial step in enhancing the USCG's response to future incidents which occur in high-risk environments. By developing and refining techniques and protocols for conducting SAR operations at extreme depths, the USCG can better prepare for future underwater rescue missions, especially in regions with ongoing complex saturation diving operations. Implementing these recommendations will foster a more effective and coordinated effort in future underwater distress situations, ultimately safeguarding the safety and well-being of those operating in these challenging environments.

6. <u>Conclusions</u>

6.1. Determination of Cause

6.1.1. The initiating event for this casualty was the loss of structural integrity of the TITAN pressure vessel. This loss of structural integrity caused the catastrophic implosion of the hull. The MBI determined that the probable failure point of the hull was either the adhesive joint between the TITAN's forward dome and the titanium segment or the carbon fiber hull near the forward end of the TITAN. The causal factors leading to this event were:

6.1.1.1. The design and testing processes for TITAN did not adequately address many of the fundamental engineering principles that would be crucial for ensuring safety and reliability in such an inherently hazardous environment. These inadequacies included the material selection and manufacturing processes, insufficient structural analysis and testing, insufficient identification and mitigation of risk factors, and insufficient process monitoring during manufacturing.

6.1.1.2. There was no meaningful analysis conducted to understand the expected life cycle of the hull as material testing was not conducted, and the analysis of the TITAN hull was based on assumed material properties with minimal manufacturing defects.

6.1.1.3. OceanGate had an overreliance on RTM System to assess the condition of TITAN's carbon fiber hull. They also lacked a standardized process to periodically evaluate the data and conduct appropriate hull assessments when problematic data was recorded.

6.1.1.4. OceanGate continued to use the TITAN for operations after a series of incidents that likely compromised the integrity of the hull and other critical components of the submersible without properly assessing or inspecting the TITAN.

> 6.1.1.4.1. OceanGate did not have an operational procedure or capability to carry out an investigation of the impact of an incident to the hull structure of the TITAN. During the 2023 Expedition, routine inspections and maintenance on the TITAN became more complex because the TITAN had to be kept at sea on the LARS platform. The arrangement also prevented OceanGate from being able to remove hull components and accessories for at sea inspections and repairs after incidents where the hull was likely damaged.
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> 6.1.1.4.2. OceanGate lacked a maintenance plan for the TITAN, and they failed to make maintenance a priority, which was highlighted by their storage of the TITAN ahead of the 2023 Expedition and the extended TITAN towing operations that were required throughout the 2023 Expedition ahead of the implosion.

6.1.1.5. TITAN’s carbon fiber hull design and construction in terms of winding, curing, gluing, thickness of hull and manufacturing standards introduced flaws that weakened its original structural integrity, and those flaws likely worsened over time.

6.1.1.6. OceanGate’s failed to conduct a detailed investigation of the potentially damaging forces exerted on the TITAN’s carbon fiber hull and critical components while diving after incurring what was suspected by many to be significant damage during previous TITAN dives.

6.1.1.6.1. OceanGate failed to conduct any substantial RTM data analysis for the final TITAN hull although data was readily available. After the delamination event during Dive 80, OceanGate lacked the expertise in carbon fiber structures and the necessary knowledge to properly interpret what the shift in strain data indicated. OceanGate did not thoroughly study or contract a third-party provider to conduct a meaningful analysis of the RTM data, such as plotting strain versus depth over time, which would have provided a clearer understanding of the hull's condition during or after the 2022 TITANIC Expedition.

6.1.1.6.2. OceanGate failed to interpret the RTM data from events that they knew were problematic from the 2022 operating season. OceanGate possessed the raw data to clearly demonstrate that the TITAN hull's behavior had changed significantly after Dive 80, yet their method of analyzing strain over elapsed time failed to reveal this critical shift. In addition, OceanGate ignored the obvious fact that the hull had significantly increased acoustic activity, after a period of time during their 2021 TITANIC expeditions when the hull had ceased significant acoustic emissions (i.e., had become "quiet") during deep-sea operations. The alarming increase in TITAN acoustic emissions between TITANIC Expeditions 2021 and 2022 were captured and readily apparent in TITAN's master Dive Log. Thus, a high level of engineering expertise was not required to identify the alarming trend that was developing. On multiple occasions prior to the incident, Mr. Rush touted the innovative safety factor provided by the RTM by describing that it would provide ample warning of impending danger if it ever indicated TITAN's hull was making acoustic noises after a period when it had become quiet.

6.1.1.7. OceanGate's toxic safety culture, corporate structure, and operational practices were critically flawed and at the core of these failures were glaring disparities between their written safety protocols and their actual practices.

6.1.1.8. During early OceanGate ORV operations, Mr. Rush's intentional and systemic efforts to misrepresent ANTIPODES and CYCLOPS I's compliance with standards and partnerships relating to safety, engineering, and regulatory oversight provided a false sense of safety for their passengers (mission specialists and contractors). This intentional skirting of regulations, often achieved by masking the true intentions and operations of the vessels, was a key element incorporated by OceanGate during their strategic development of the TITAN business model.

6.1.1.9. A false sense of safety and security was created by Mr. Rush through his misrepresentation of the TITAN's safety, achieved by falsely claiming substantial safety margins, misleading mission specialists regarding testing procedures, and exaggerating the number of hull test dives for the final TITAN hull.

6.1.1.10. OceanGate's management, particularly Mr. Rush, fostered an organizational culture that increased operational risk and allowed financial pressures, operational demands, and mission specialist expectations, to override their Mission Director’s duties and authorities.

6.1.1.11. The mounting financial pressures on the company in 2023 resulted in an increased risk to TITAN’s hull and its operations.

6.1.1.11.1. OceanGate’s decision to cut costs and store the TITAN submersible and its associated equipment outdoors, unprotected in inclement weather for most of the Canadian winter, exposing the hull to extreme temperature fluctuations compromised the TITAN’s hull integrity.

6.1.1.11.2. The decision to charter the less expensive POLAR PRINCE instead of a more capable vessel, like the HORIZON ARCTIC, for support operations introduced logistical and safety challenges. The selection of the POLAR PRINCE required towing of the TITAN and LARS platform and created significant operational inefficiencies. Most notably, the arrangement made it nearly impossible for personnel to perform at sea maintenance and inspections on the TITAN during the 2023 Expedition.

6.1.1.11.3. OceanGate’s financial instability impacted its inability to retain a stable and qualified workforce, which had profound negative implications. The departure of experienced employees deprived the company of critical oversight, operational continuity, and the ability to address safety risks proactively. Senior OceanGate managers, including the Director of Engineering position, who had successfully persuaded Mr. Rush to cease operations and conduct further testing after concerns arise for the first TITAN hull, were vacant during the 2023 TITANIC Expedition. As a result, OceanGate increased its reliance on contractors, mission specialists, and junior staff members who lacked critical background on TITAN’s operating history and the seniority to challenge Mr. Rush’s authority and decision making.

6.1.1.11.4. The need to secure more capital for OceanGate to sustain operations was paramount to the company’s survival. Mr. Rush was ultimately forced to make significant personal loans to OceanGate just to sustain operations in 2022 and 2023. The pressing need to have TITAN appear fully operational in order to continue securing investor capital, directly impacted multiple decisions related to TITAN's 2023 operations.

6.1.1.12. The lack of comprehensive and effective updated regulations and policies for the oversight and operation of manned submersibles, especially of novel design, constructed and operated in the United States likely contributed to Mr. Rush's decision to proceed completely outside of the existing regulatory framework.

6.1.2. Subsequent to the implosion, the individuals aboard TITAN were subjected to approximately 4,930 psi, resulting in the instantaneous death of all five occupants.

6.2. Evidence or Act(s) or Violation(s) of Law by Any Coast Guard Credentialed Mariner Subject to Suspension or Revocation: Per 46 CFR § 5.61(a)(2), the USCG may initiate proceedings to suspend or revoke a mariner's MMC based on evidence of misconduct that results in serious injury or loss of life. Had Mr. Rush survived the casualty while serving as the Master of the TITAN, the MBI would have recommended that the Commandant initiate administrative action seeking revocation of Mr. Rush's MMC. The MBI found that Mr. Rush acted outside the scope of his credential's authority in multiple respects. First, he served as the Master of a passenger-carrying submersible operating outside U.S. inland waters without the vessel being properly certificated as a small passenger vessel under applicable U.S. law. Second, Mr. Rush's MMC was limited to service on vessels operating exclusively on inland routes (i.e., internal waters) and did not authorize operations in the area where TITAN was deployed. Accordingly, the MBI concluded that Mr. Rush's actions constituted misconduct and fell outside the legal scope of his credentialed authority.

6.3. Evidence of Violations by U.S. Coast Guard Personnel, or any other person: There were no acts of misconduct, incompetence, negligence, unskillfulness, or violations of law by USCG employees or any other personnel that contributed to this casualty.

6.4. Evidence of Act(s) Subject to Civil Penalty: The USCG's administrative Civil Penalty Program is remedial (non-punitive) in nature and meant to compel future compliance. The MBI is not making any referrals for separate civil penalty enforcement investigations against OceanGate because the company has permanently ceased all maritime operations. If OceanGate had continued as a business conducting commercial maritime operations, the MBI would have recommended independent enforcement investigations of the following potential violations:

6.4.1. 46 CFR § 10.201 - Fraud and intentional misconduct. Specifically, as Master of the TITAN, Mr. Rush submitted a fraudulent sea service letter signed by the COO of OceanGate to the USCG National Maritime Center to obtain his USCG Inland Master of 25-GRT Vessels MMC. Specifically, Mr. Rush claimed past service as a crew member on TITAN and falsely claimed its tonnage was 26-GRT, when in fact it had never been registered or admeasured. The TITAN's tonnage was estimated to be 4-GRT in a post-accident admeasurement conducted by the USCG Marine Safety Center.

6.4.2. 46 CFR § 176.100(a) - Failure to have a valid USCG COI onboard a commercial submersible carrying at least one passenger for hire.

6.4.3. 46 CFR § 170.120 - Failure to have a stability letter issued before the vessel was placed in service with passengers for hire onboard.

6.4.4. 46 USC § 2302(a) - "Commercial Vessel" Operating, or interfering with operations of, a commercial vessel in a negligent manner that endangers life, limb, or property of a person.

6.5. Evidence of Criminal Act(s): Per 33 CFR § 1.07-90, the Department of Justice (DoJ) holds final authority over whether to prosecute or decline prosecution in Federal court for violations of Coast Guard-enforced laws or regulations that carry penalties of fines or imprisonment. When evidence of a criminal offense arises in certain cases, the Commandant of the Coast Guard refers cases to DoJ, including: (1) marine casualties or accidents resulting in death, and (2) matters investigated by Marine Boards under 46 CFR part 4. Under the "seaman's manslaughter" statute, codified at 18 USC § 1115, masters, pilots, and executive officers of a vessel may be held criminally liable if their negligence, misconduct, or willful disregard of duties results in the death of a person. Executive officers of a company may also face criminal liability if they knowingly and willfully allow unsafe or unlawful conditions that lead to a fatality.

As a credentialed mariner holding an MMC authorizing service as a Master of Vessels up to 25 GRT on inland routes and having successfully completed the USCG upgrade course *OUPV to Master 100 Tons Mariner Learning System*, Mr. Rush possessed the training and legal authority to act as the Master of the TITAN. In doing so, he assumed the statutory responsibilities and heightened duty of care required of a credentialed master. Moreover, as the CEO of OceanGate, Mr. Rush exercised operational control and bore ultimate accountability for the design, outfitting, and deployment of the vessel. These dual roles, both as the individual charged with on-board command and as the executive with overarching operational authority, imposed on Mr. Rush a heightened responsibility to ensure the safety and seaworthiness of the vessel and its occupants. His combination of licensing, training, and decision-making authority provided him with the requisite knowledge to understand and mitigate the risks associated with submersible operations.

This investigation identified evidence of a potential criminal offense in accordance with 33 CFR § 1.07-90. Specifically, the MBI identified conduct that may constitute a violation of 18 USC § 1115. Had OceanGate's CEO and chief pilot survived the incident, the MBI would have recommended that the Commandant refer the matter to DoJ for their consideration on whether to pursue a separate criminal investigation. The MBI concluded that Mr. Rush, in his dual role as CEO and as the acting Master or Pilot of the TITAN submersible, exhibited negligence that contributed to the deaths of four individuals. As both a corporate executive responsible for the vessel's operation and its Master during the casualty, Mr. Rush may have been subject to criminal liability under the standards set forth in 18 USC § 1115. It is important to note that the determination of whether any crime was committed would be made by the DoJ following its own investigation and analysis, which will not occur in this instance due to the death of Mr. Rush.

6.6. Need for New or Amended U.S. Law / Regulation: These issues are addressed in the Recommendations Section below.

6.7. Unsafe Actions or Conditions that Were Not Causal Factors:

6.7.1. Given that the submersible imploded at depth prior to OceanGate's eventual distress call, the USCG's lack of deep-water search and rescue capabilities is not considered a contributing factor to the personnel casualties. However, it is worth noting that the USCG did not possess these capabilities when the incident occurred, necessitating reliance on military and commercial submersible and ROV operators for assistance. Additionally, the MBI determined that the SAR response conducted in this case would likely not have had the capability to successfully rescue the TITAN and its occupants within the maximum survivability window of 96 hours had the scenario been an entanglement at the bottom rather than an implosion. An entanglement scenario was plausible when considering OceanGate's previous unreported incidents including the TITAN becoming entangled in the wreckage of the TITANIC during Dive 80 of the 2022 TITANIC Expedition and the CYCLOPS I becoming stuck under the bow of the ANDREA DORIA wreckage in 2016. Although manned deep-sea entanglements requiring rescue are extremely rare,[60] OceanGate's three submersible incidents while operating at depth highlight that entanglement threats exist and provide an indicator that the USCG's SAR readiness posture for underwater SAR scenarios, especially in remote areas, should be studied and improved through joint planning and exercises with the U.S. Navy and commercial entities that possess deep sea search and rescue capabilities.

6.7.2. While not considered to be a direct causal factor in the implosion of the TITAN, the MBI identified the lack of consistent regulatory oversight of OceanGate's ORV submersible operations as a critical finding. This stemmed from OceanGate's continued exploitation of the USCG ORV designation's vagueness and inconsistent nationwide enforcement, which enabled passenger-for-hire submersible operations to proceed under the guise of scientific operations with minimal or no regulatory oversight. The uninspected ORV designation available to U.S. research vessels, including submersibles, under 300-GRT creates a regulatory gap that can be exploited. Thus, strengthening USCG oversight of ORVs involved in such operations is crucial to mitigating the existing threat and preventing future incidents stemming from unregulated submersible activities.

7. Actions Taken Since the Incident

7.1. In response to the TITAN tragedy, key actions have been completed to enhance interaction between the USCG and OSHA regarding SPA coordination. OSHA now sends all SPA reports to a group email at CG-INV that is monitored by a full-time duty rotation that

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[60] The last deep-sea rescue occurred in August of 1973. The incident involved the 20-foot submersible PISCES III, which became trapped on the ocean floor with a two-person crew at a depth of 480 m (1,575 feet), 150 miles off the coast of Ireland, in the Celtic Sea. A 76-hour multinational rescue effort successfully rescued the two personnel, resulting in the deepest submersible rescue in history.

coordinates interagency responses to major marine casualties. The USCG has also established internal procedures for receiving, tracking, and responding to OSHA reported SPA and other types of whistleblower cases. In addition, OSHA and the INCOE recently conducted a virtual training session on the Whistleblower Protection Act program for senior USCG senior investigating officers nationwide. The training outlined OSHA's procedures and the process for interagency coordination when concurrent investigations are necessary. CG-INV and OSHA's Whistleblower Protection Act program agreed to continue periodic cross training and communications to help ensure that mariners who are subject to retaliation for raising safety concerns are protected from potential repercussions while concurrently ensuring that any pressing safety concerns are addressed by the USCG. To ensure continuity and further clarify roles after a SPA complaint the MBI is recommending that the USCG and OSHA pursue an MOU (Please see Recommendation #9 under Section 8.).

7.2. Since the incident, the USCG has significantly increased its professional interactions with the submersible industry through various exchanges and venues. These interactions include participation in industry conferences, collaborative discussions on safety best practices, and active engagements with industry leaders to promote improved safety standards.

7.3. The USCG conducted an AAR Case Study of the TITAN Search and Rescue efforts as a crucial step in learning from the incident and adapting future response strategies. While the AAR confirmed the USCG's reliance on surface and air assets and the U.S. Navy for subsurface expertise, the resulting recommendations from the AAR Case Study are being used to develop improved techniques and protocols for conducting SAR operations at extreme depths. This proactive approach aims to enhance the USCG's preparedness for future underwater distress situations and improve the safety of those operating in high-risk underwater environments.

8. Recommendations

8.1. Safety Recommendations

8.1.1. Recommendation #1: The USCG should establish an industry working group to review and update NVIC 5-93. During the investigation, submersible industry leaders indicated to the MBI that current USCG limitations on operating parameters, including the maximum depth of 150-feet for Coast Guard inspected passenger submersibles, was stifling submersible owners from exploring new passenger operations in U.S. navigable waters and also potentially incentivizing operators like OceanGate to conduct non-compliant operations. An update to the NVIC would also provide an opportunity to clearly outline the process for certifying submersibles of novel design.

8.1.2. Recommendation #2: The USCG should pursue an expansion of federal requirements to ensure proper regulatory oversight of submersibles that perform oceanographic research operations. Due to the inherent risks involved with underwater operations, the Coast Guard should require all oceanographic research submersibles to meet the existing inspected passenger vessel requirements of 46 CFR Subchapters T, K, or H, as appropriate based on the submersible's GRT and maximum occupancy (e.g., scientists, researchers). An MBI review of the existing ORV designation regulations in 46 CFR Part 3 confirmed that those existing regulations are only applicable to surface research vessels and the possibility of a submersible ORV does not appear to have been contemplated. As a result, it is recommended that the USCG cease the current practice of designating submersibles as ORVs under 46 CFR Part 3.

8.1.3. Recommendation #3: The Office of Commercial Vessel Compliance (CG-CVC) should ensure that any existing submersible ORVs have their ORV Letters of Designation revoked, and the owners and operators should be directed to pursue inspection for certification under the applicable passenger vessel requirements as described in Recommendation #2.

8.1.4. Recommendation #4: CG-CVC should review and update USCG ORV policy and guidance for surface vessels not subject to inspection under 46 CFR Subchapter U (i.e., vessels less than 300 GRT) to ensure consistent application across OCMI zones and provide clear ORV oversight expectations. The updated policy should include implementing an annual ORV verification by the cognizant OCMI that includes having ORV operators provide an annual signed attestation back to their cognizant OCMI confirming that they understand the rules for ORV operations and that their operations continue to comply with those rules. The revised policy should also include a provision that any owner/operator of an existing ORV that intends to conduct operations outside the OCMI Zone that issued their ORV Letter of Designation, must obtain a new ORV Letter of Designation from the new cognizant OCMI.

8.1.5. Recommendation #5: The appropriate office at USCG Headquarters should harmonize existing regulations regarding what constitutes a legally chartered ORV, including a clarification on what constitutes persons allowed to be carried other than the ORV operators. For example, scientific personnel are currently defined differently throughout 46 CFR (46 CFR 2.01-7, Footnote 7; 46 CFR 188.05-33; and 46 CFR 188.10-71).

8.1.6. Recommendation #6: The USCG should pursue a new regulation which requires all submersibles manufactured, owned, or operated by a U.S. entity or any submersible operating in U.S. navigable waters carrying any occupant other than the owner to be built to the standards of a USCG RO and maintained under those standards.

8.1.7. Recommendation #7: The USCG should pursue an update to the vessel documentation requirements in 46 CFR § 67.7, to require all U.S. submersibles that conduct commercial or scientific operations to obtain a USCG Certificate of Documentation (COD) with an Official Number assigned and recorded in the MISLE database. Federal documentation would provide the USCG awareness on the domestic submersible fleet, while also ensuring that the proper endorsements are added to the submersible's COD. This change would alleviate a significant burden currently placed on state registries which frequently lack the appropriate expertise to register and oversee a submersible conducting commercial or scientific operations.

8.1.8. Recommendation #8: The USCG should review and revise COMDTINST 16000.7B (Marine Safety Manual, Vol. II: Materiel Inspection) and 46 CFR Part 3 to address regulatory gaps related to submersible vessels and ORV designations. Specifically, align definitions and policy guidance to prevent conflicts—such as the current allowance for "recreational submersibles" to carry up to six passengers, which contradicts Subchapter T requirements. Clarify ORV eligibility criteria to restrict commercial passenger activity, require COMDT-level review for high-risk platforms (e.g., manned submarines and submersibles), and mandate CG-CVC and MSC coordination. Additionally, establish a process for reevaluation or revocation of ORV status when operational profiles materially change, ensuring the designation cannot be used to circumvent critical inspection protocols and safety oversight.

8.1.9. Recommendation #9: The USCG should pursue development of an OSHA-USCG MOU on SPA program investigative authorities, responsibilities, and procedures. The new agreement should clarify evidence sharing and joint investigation protocols while also addressing the steps to follow when the USCG needs to conduct an immediate intervention during a pending or active OSHA SPA or safety investigation.

8.1.10. Recommendation #10: The USCG should add resources and expertise within the Traveling Inspection, Training Support & NCOE Staff (CG-5P-TI) dedicated to providing field support for vessels of novel design. The addition should include deployable resources to assist field units during new construction and certification of submersibles and any other vessels of novel design (e.g., wing-in-ground (WIG) craft) that exceed local USCG expertise.

8.1.11. Recommendation #11: The USCG Office of Search and Rescue (CG-SAR) should conduct an evaluation of USCG subsea SAR capabilities in conjunction with the U.S. Navy, commercial subsea entities, and international agency partners to ensure readiness for domestic and international incidents within USCG SAR zones. Examples that could enhance readiness include QRCs, resource lists, interagency agreements, and exercises focused on subsea SAR.

8.1.12. Recommendation #12: The appropriate office at USCG Headquarters should work with the IMO to define and provide applicability for "passenger submersibles" and request that the IMO review, update, and adopt MSC/Circ. 981, *Guidelines for the Design, Construction, and Operation of Passenger Submersible Craft*, as a mandatory international standard.

8.1.13. Recommendation #13: The USCG should pursue a new requirement mandating enhanced communication capabilities for all submarines and submersibles that conduct commercial or scientific operations. It is essential that underwater operations have the ability to rapidly report emergencies and work through potential contingencies with surface entities via voice communications. VHF radios, which are required for passenger vessels inspected under 46 CFR Subchapters T, K, and H, are not available for use by submarines and submersibles during subsurface operations. To address the potential communications gap, this recommended requirement should ensure that USCG inspected submarines and submersibles have voice communication capabilities with surface support entities at the maximum depth of the ocean where operations are authorized.

8.1.14. Recommendation #14: The USCG should pursue a new requirement mandating that owners of submersibles conducting commercial and scientific operations provide notification to the local USCG OCMI prior to conducting operations. The notification should include a dive plan and an emergency response plan capable of responding to the maximum depth of the waterbody where the operations are intended to take place.

8.2. Administrative Recommendations

8.2.1. Administrative Recommendation #1: CG-CVC should initiate a modification to the MISLE database to include a function (i.e., check box) that identifies a vessel as a designated ORV.

8.2.2. Administrative Recommendation #2: It is recommended that the Commandant authorize the use of the official USCG YouTube Channel for the streaming and archiving of all formal marine casualty investigations that hold public hearings.

Thomas F. Whalen
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LCDR Thomas F. Whalen
U.S. Coast Guard
Lead Investigator

Jason D. Neubauer
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Mr. Jason D. Neubauer
U.S. Coast Guard
Marine Board Chair

Enclosure: (1) Marine Board of Investigation Convening Order dated June 23, 2023

Appendix: (A) NTSB Materials Laboratory Factual Report 24-011 dated July 5, 2024
(B) NTSB Materials Laboratory Factual Report 24-012 dated July 5, 2024