Letter of Transmittal

Titanic Positioning
8888 University Drive
Burnaby, BC V5A 1S6
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Dr. Andrew Rawicz
Simon Fraser University
8888 University Drive
Burnaby, BC V5A 1S6

Dear Dr. Rawicz,

Titanic Positioning prepared the attached Functional Specification for its control system of a Dynamic Positioning System (DPS). It was written to provide the engineers at Titanic Positioning a guideline for the project, and a document to help measure progress.

The Functional Specifications outline the desired inputs and outputs of the DPS control system. This document will specify the hardware and software required to create a reliable product. Discussed in the Functional Specifications is a detailed outline of the project, the projected design requirements and testing, limitations of the design, and safety concerns.

If you have any questions or concerns, please contact me at bkh4@sfu.ca. Thank you for your time.

Sincerely,

Bengt Haunerland
Chief Executive Officer
Titanic Positioning

Executive Summary

Offshore supply vessels and industrial ships need to maintain position while transferring cargo. In many cases the traditional ways of station keeping may not be practical. In other words, the ocean may not allow for anchor spread. Therefore, it would be more convenient and practical for the vessel to be able to hold position automatically and with minimum human involvement.

Here at Titanic Positioning, an automatic Dynamic Positioning System (DPS) control system will be developed on a small boat, which will enable the boat to maintain its position while transferring cargo. Several components and sensors such as a GPS and a Motion Reference Unit (MRU) will be integrated into the DPS control system, along with an embedded computer system to allow for Manual Position and Automatic Heading Control.

Once the vessel approaches the platform, the DPS will be used by the pilot for automatic station keeping and position maintenance. In case of emergency, a shutoff button will allow for switching from automatic to manual control.

Initially, a proof-of-concept will be provided by Titanic Positioning. The proof-of-concept will be expandable to be used on larger ships of different configurations.
The following will be considered while creating the proof-of-concept:

- Safety must be considered in every aspect of the design
- Engineering Standards must be taken into account
- Initially Sensors and components must be tested individually by a practical test plan
- The system must be tested as a whole on the boat

The proof-of-concept will use a joystick for Manual Position Control of the boat. In later stages however, Automatic Position Control will be incorporated in the system.

ENSC 440 Functional Specification
Dynamic Positioning Control System

Group 5

Bardia Bogharti – bboghrat@sfu.ca

Bengt Haunerland – bkh4@sfu.ca

Lucie Hiltner – lhiltner@sfu.ca

Yalda Majdi – ymajdi@sfu.ca

Carl Wahlstrom – cwahlstr@sfu.ca

TITANIC

POSITIONING

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III. Glossary

ABS - American Bureau of Shipping

ANSI - American National Standards Institutes

DPS - Dynamic Positioning System

DPS-0 - Is defined as a DPS that has a central manual position control and automatic heading control system.

DPS-1 - Is defined as a DPS that has a central automatic and control and heading system. It also has a manual positioning control.

GPS - Global Positioning System

HMI - Human-Machine Interface

MRU - Motion Reference Unit

NMEA - National Marine Engineering Association

OS - Operating System

SFU - Simon Fraser University

1. Introduction

Marine vessels are sometimes required to maintain a heading or a position in situations where anchoring is difficult or impractical. An automated method of maintaining a heading or position is called dynamic positioning. Dynamic positioning is prevalent in the oil industry, where large transport ships dock at offshore oil platforms. The vessels are required to steadily maintain precise coordinates for hours while cargo is transferred. The position of the vessels must be held constant despite exterior forces, such as wind, waves, and tidal pull. This must be reliably done to ensure the safety of the workers on the rig and the ship, and that no product is spilled in the process.

A Dynamic Positioning System (DPS) is a control network that uses the ship's thrusters to adjust and maintain the ship's position according to feedback input from multiple sensors. The ship's location is adjusted and maintained by the DPS controller, which makes a calculation based on the current location of the ship using a GPS, and sensor information gathered from wind and water current data.

The purpose of the project is to implement a DPS on a 10 meter long boat. The boat will maintain position and heading against external forces, such as the current in the Fraser River. The system will be expandable, and with the addition of further software, will be able to implement full dynamic positioning. The proposed requirements for the DPS are defined in this functional specification.

1.1 Scope

This document describes the functional requirements for a DPS, in compliance with the American Bureau of Shipping (ABS). Titanic Positioning is planning on controlling the thrusters of a ship to perform Dynamic Positioning. This will include Manual Position Control and Automatic Heading Control. This will be achieved by interfacing with a GPS, Motion Reference Unit (MRU), wind sensor, and a user interface.

1.2 Audience

This functional specification is written for the all members of Titanic Positioning and the members of Think Sensor Research who are involved in the project. The document shall be used as a reference for designing, testing, and project management. The functional specification outlines the requirements, test plan, safety and standards for the project. The document will be used to track progress and re-evaluate project goals.

2. Problem Analysis

Dynamic positioning systems are used on ships for heading control and station keeping. Dynamic positioning is used when it is impractical or impossible to anchor the ship. When large ships approach delicate ocean structures (eg, offshore oil platforms), extreme care has to be taken to avoid dangerous situations. Previously, ship captains had to carefully maneuver their ships manually. Station keeping was performed manually, which could be stressful and conducive to error during cargo transfer operations that can last several hours. Alternatively, anchor nets and anchors could be used to prevent the ship from moving or turning, however nets are difficult and time consuming to set up correctly, especially around fixed structures due to entangled lines. If it is possible to use anchors, multiple anchors would be needed to ensure that the ship does not turn. The DPS would be able to solve these problems by performing station keeping automatically by correcting for environmental forces without using anchors or constant manual input from an operator. Table 1 below shows the different levels of automation that can be implemented on a marine vessel.

Manual Control	Human operator controls ship without DPS.
Manual Position Control	Human operator uses joystick to manually set coordinate destination for DPS.
Automatic Position Control	GPS coordinates are set with keyboard from a distance and have automatic fine tune control.
Automatic Heading Control	DPS maintains the direction automatically based on data from the MRU.

Table 1: Definitions of important terminology

3. Design Plan

Titanic Positioning will be constructing a DPS-0 system with the ability to upgrade to DPS-1 at a later date. DPS-0 is a basic Dynamic Positioning System that offers manual position control, and will maintain the position and heading of a ship. To do this, the DPS control system will need the current data for the position and heading of the ship, and the ability to control the ship's motors and thrusters to automatically reposition it. For added control, a wind sensor will also be used, with expansion opportunities for a water current sensor which is required for DPS-1. Table 2 below defines the DPS-0 and DPS-1 requirements according to the American Bureau of Shipping.

DPS-0	A DPS that has a central Manual Position Control and Automatic Heading Control system.
DPS-1	Is defined as a DPS that has a central Automatic and control and heading system. It also has a manual positioning control.

Table 2: defines different class of Dynamic Positioning

A ship using the Dynamic Positioning System (DPS) is run by the control system on an onboard embedded computer. The embedded computer will be housed in a water-tight environment to avoid electrical and fire hazards, and to preserve the integrity of the control system. The embedded computer will have no moving parts, making it more resistant to the shocks and vibrations that are common on ships. The control system will use serial connectors for all input and output signals to retain wiring simplicity and modifiability. The communication lines between the sensors and the embedded computer will use standard marine insulated wiring.

The embedded computer will use a Linux operating system (OS) which will facilitate the expansion of the control system to a higher level DPS at a later date. An OS also makes communicating with the display computer simpler, since the display will require stack communication and an OS has built in function for stack communication. Several of the drivers for the sensors are built in to the OS. The OS provides preconstructed matrix math libraries that will be necessary for the DPS control system. The embedded computer will run Linux because it is well suited for real-time performance and software stability. Using an OS will better enable a large group to work on the project simultaneously.

To properly maneuver a ship, the DPS control system needs to detect the location (coordinates), orientation and heading of the ship. The location coordinates of the ship will be acquired from the GPS. The heading of the ship will be acquired from the Motion Reference Unit (MRU). The MRU also relays data when the ship pitches and/or rolls. Since the GPS will be at the highest point of the ship, when the ship pitches or rolls the GPS will swing and the coordinate reading will not always be taken from the center of the ship. The MRU will be used to correct for the error in the positioning data caused by the swing of the GPS.

The DPS control system will have a wind sensor and a water current sensor. Wind and water forces must be compensated for during maneuvers or station holding. For a DPS-0 the water current sensor is not required, but it is something that is needed once the project is expanded.

The SFU Test Ship uses two outboard motors that can be turned for steering. An angle sensor will be used on the motors so the control system will know which direction the motors are pointing. This will create feedback, which will be safer when maneuvering the ship.

The DPS will require a human-machine interface (HMI) for operators. The HMI will let operators set coordinates, fine-tune positioning adjustments, and provide visual feedback. The DPS control system will have one station with a display screen, a keyboard for Automatic Position Control, and a joystick for Manual Position Control. In the proof-of-concept system, the input and display will be handled by the embedded computer. In the production DPS control system, the interface will have a dedicated computer to minimize time delays, and will have two stations.

Figure 1 below shows the SFU test ship and projected target ship with the motor and thruster layout. The SFU Test Ship is shown with two outboard motors and one bow thruster. The SFU Test Ship uses two 250 HP outboard motors with a limited range of motion. The test ship bow thruster can be run in either clockwise or counter clockwise direction to assist in maneuvering.

The Projected Target Ship has two fixed diesel motors with variable tilt props for propulsion, and four diesel-electric maneuvering thrusters for steering and lateral movements. Figure 1 below shows the motor (black) and thruster (gray) placement on the two ships. Figure 2 shows the proof of concept ship on which the prototype system will be implemented.

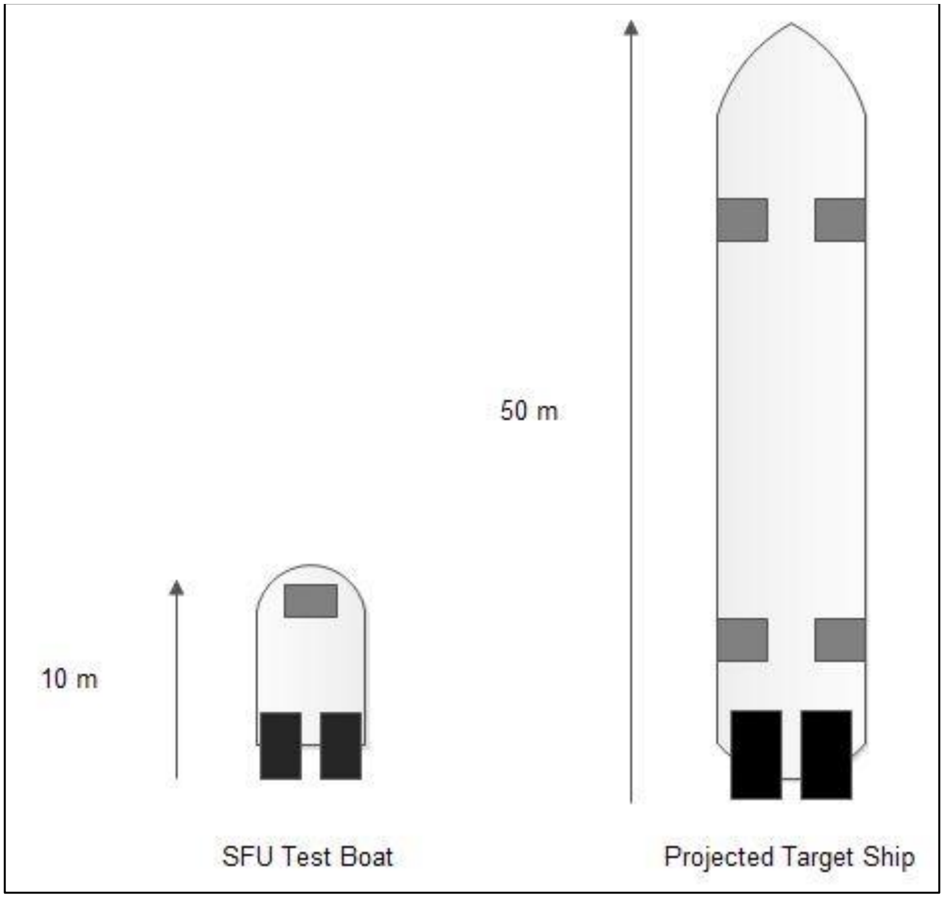

Figure 1: The SFU Test Ship and the Projected Target Ship comparison (not to scale).

Figure 2: The SFU Test Ship

Figure 3 below shows an overview of the system inputs, outputs and controls.

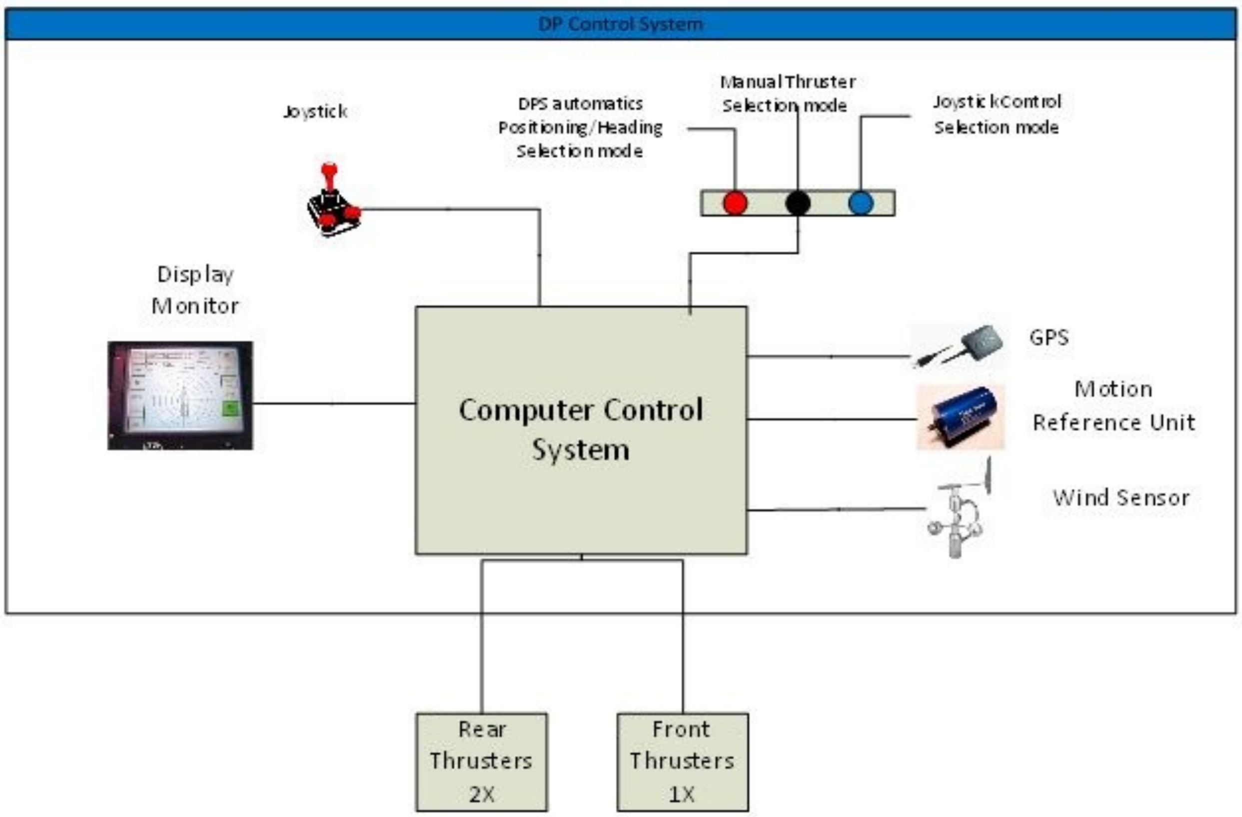

Figure 3: DPS overview

4. Project State

During the course of the term, Titanic Positioning will complete a DPS-0 proof-of-concept design. The project will be expandable for prototype and production purposes. The design will also be expandable for higher classes of Dynamic Positioning, such as DPS-1. The project will be continued after the term by a joint effort from some members of Titanic Positioning and Think Sensor Research. Table 3 shows the differences between the different stages of design.

The proof-of-concept design will use a development board with a separate USB to serial adapter. The USB to serial adapter will be enclosed in a rigid container, with the wires temporarily secured. In the production case, the display computer will incorporate a trackball and keyboard into one module instead of separate components. The projected target ship will also utilize fanning lasers that will be set up on the oil rigs as an additional method of measuring whether the ship is in place. In the production version, a North-seeking gyroscope compass will be used. The North-seeking gyroscope will be needed because the magnetic sensor in the MRU is susceptible to interference from the metal structure of the ship.

	Proof-of-Concept	**Prototype**	**Production**
DPS-0	Off-the-shelf components	Off-the-shelf components	Off-the-shelf components
DPS-0	Development board with external additional serial ports as the control computer	Embedded computer with enclosed serial ports as the control computer	Embedded computer with enclosed serial ports as the control computer
DPS-0	Temporary secured wires	Permanently secured wires	Permanently secured wires
DPS-0	Reused marine GPS	New robust marine GPS	New robust marine GPS
DPS-0	Display, keyboard, and joystick controlled by development board.	Display, keyboard, and joystick controlled by dedicated computer.	Display computer will have a built in trackball and keyboard.
DPS-1		Addition software for Automatic Position Control	Addition software for Automatic Position Control
DPS-1		Water current sensor	Water current sensor
DPS-1			Fanning lasers on dock
DPS-1			North Seeking Gyroscope

Table 3: Comparison of proof of concept, prototype and production

5. Constraints

The project will be limited by financial and time constraints. The SFU Test Ship also has scheduling constraints. The ship is difficult to access as it requires the coordination of multiple parties. Operating the SFU Test Ship will have both costs for fuel and for the time of the captain. Titanic Positioning will create efficient testing plans when using the SFU test ship, to minimize costs. A design constraint includes the size of the ship and the motor arrangement. Since the ship in use has fewer motors and is smaller than a typical vessel, the controls will be limited and the steering controls will be different. The direction of the ship will first be set using the bow thruster, and then the outboard motors will power the ship in that direction. The target ship has four side thrusters, which will allow for lateral movement of the ship. The heavier target ship will also have more inertia, which will change the amount of time and power required from the thrusters.

The time requirements can be an issue since there are only four months to put together a proof-of-concept. As a result, instead of attempting to do full dynamic positioning, we will implement a DPS-0 system which, with further addition of software, will be able to do full dynamic positioning. .

6. Engineering Standards

ABS standards (DPS-0 and DPS-1)

ABS defines the standards for the classification of the level of DPS. The ABS defines the necessary requirements that must be met before a DPS can be commissioned. (1)

American National Standards Institute (ANSI)

The DPS shall comply with the ANSI standards. (3)

Federal Communications Commission (FCC)

Communications protocols shall be in compliance with the FCC. (4)

National Marine Electronics Association (NMEA) - 0183 Standard

“The NMEA 0183 Interface Standard defines electrical signal requirements, data transmission protocol and time, and specific sentence formats for a 4800-baud serial data bus"(2). This standard supports serial communications in a marine environment.

7. Testing Plan

Titanic Positioning will test the system throughout the entire development phase. The sensors will first be tested individually, and then together on our development system. Table 4 outlines the required testing that will be done at SFU in the lab:

Component/sensor to be tested	Test Procedure	Results/Comments
MRU	Tilting and measuring output signal	Ensure the MRU communicates with the embedded computer and that the reading is accurate
GPS	Develop a mobile system and move around campus	Ensure location accuracy and communicates with embedded computer
Wind sensor	Simulating wind using a fan	Ensure the accuracy of wind direction and communicates with embedded computer
Motor Control	Simulating maneuvers	Ensure proper outputs are being communicated to and from the embedded computer
Shutoff Command (switch)	Pushing manually	Verify complete release of control to manual mode
Control Algorithm	Move all sensors and computer on a cart	Verify proper output compensation depending on sensor inputs.

Table 4: Test plan at SFU

The joysticks will be first used by the test engineers to verify throttle and angle control. A Marine Deep Cycle 12V battery will be used on the mobile system suggested for mobile testing at SFU, which will be similar to the power supply on the test ship. The control system will use the ship's internal power supply. Once the initial sensors and motor unit have verified functionality, they will be installed on the test ship. Table 5 shows the test plan for testing on the boat.

Component/sensor to be tested	**Test Procedure**	**Results/Comments**
Shutoff Command (switch)	Pushing manually	Verify complete release of control to manual mode
Control Algorithm	Remain idle and let boat move under water conditions	Verify proper output compensation depending on sensor inputs.
Motor control	Manually adjust destination coordinates	Ensure proper outputs are being communicated to and from the embedded computer

Table 5: Test plan for boat

8. Sustainability and Safety

8.1 Safety

Electrical and Fire: On the vessel there are several electrical and fire safety issues that need to be considered. Even though we plan to use as few loose wires as possible, it is important to ensure all wires are properly secured and insulated. Properly secured and insulated wires will avoid wire damage and prevent overheating. On the boat there is some high power equipment, such as the thrusters. When working with these thrusters, extra precaution will be taken. For example, fuses and breakers should be used to prevent overheating.

Another very important safety precaution is the functionality of the emergency stop for the DPS. The emergency stop should be the first thing to be tested since if there are problems with the DPS during testing, it should be able to quickly turn of the DPS system and return to manual drive.

Mechanical: It is important to stay clear of all moving parts, such as the propellers of the thrusters when the system is running, even when the props are not spinning. It is also important to avoid the moving parts even when they are currently off because someone may not realize and turn on the motors.

Since the motor control is hydraulic and needs an electrical autopilot interface, it is important to install it correctly to avoid spilling hydraulic fluid. It is also possible to get bubbles in the hydraulic fluid, which can cause problems with the functionality of the motor.

Software: The DPS software should have built in safety limits for motor speed and environmental conditions. For example the DPS should not turn the motors on to full power to maintain position and the software should have a limit so the motors do not exceed a specified threshold. The DPS software will warn the user if the weather conditions are not safe enough to run the DPS. For example, if the boat is stuck in a major storm, then it would not be safe to try to maintain position with any accuracy, and it would not be safe to load cargo from a barge.

There is also a need for fault detection software. For example, if the hydraulic motor line or the throttle cable were to malfunction, then a fault should be detected. The user will be informed by the software if any of the sensors send faulty and unreliable data.

Water: Life jackets should be worn when on deck of the ship. The DPS should not be tested while other ships are in the area, or people are in the water.

Environmental: During the project we will be using deep cycle marine batteries, which can be an environmental problem if not recycled properly.

8.2 Reliability

The design will be reliable and consider all points of possible failure. There may be problems caused by the environment that the system will be placed into, hence the design should take those into consideration. Grounding problems could be an issue since some device may not have the grounds tied together. This problem could be fixed by connecting all the grounds to a single node. An example of possible failure is if wiring connectors get moisturized, in order to prevent this hazard, marine graded wires and connectors must be secured in a safe location

All components would be insulated from extreme temperatures to ensure reliable functionality. Several components will be inside an electrical room on a ship, and therefore would be sheltered from the outside environment. Other components will be chosen to have a wider operational temperature range, like the wind sensor.

For the proof of concept redundancy will not be considered, however once the design is expanded to a prototype or higher class of DPS redundancy will be incorporated.

8.3 Environmental Impact

The design shall consider the project lifetime of the components to minimize electronic waste and maximize industrial performance.

Table 6 lists the expected lifetime of the components that will be used in this project:

Component/sensor name	Approximate Lifetime (years)
MRU	10
GPS	5-10
Embedded computer	7
Wind Sensor	2-5

Table 6: Expected lifespan of the components/sensors

The embedded computer can have a lifetime of over 7 years, which would be advantageous because the controller will not need to be replaced on a regular basis and it will also minimize the need for maintenance.

The deep cycle marine battery used for testing components in the lab will be a recycled battery that was used on a previous project. Once testing is done with the battery, it will be stored for future project testing purposes.

9. Conclusion

Maintaining ship heading and position under manual control can be difficult and/or time consuming. A Dynamic Positioning System will perform these functions with reduced input from a human operator. Titanic Positioning, along with Think Sensors Research, will create a DPS Control System, starting with a DPS-0 system on a test ship as a proof of concept, and expanding it to DPS-1 at a later date. This system will be able to maintain position and heading using Manual Position Control and Automatic Heading Control. The operator will have fine tuning control of the GPS coordinates, and the DPS will adjust accordingly.

The DPS Control System will be on an onboard embedded computer, running a Linux OS. Linux was chosen to simplify cooperative coding, for its software stability, and future expandability of the DPS Control System. Using OS will make the communication with the display station simpler. The sensors that the proof of concept system will use are a GPS, a MRU, and a wind sensor. The MRU is used for compensating for ship pitch and roll, and provides heading information. The sensors and communication with the embedded computer will be tested at SFU. The Control System will have emergency warnings and shutoffs, which will also be tested both at SFU and on the test ship. Later systems will include a water sensor, Automatic Position Control, and greater redundancy and backups for improved reliability.

Titanic Positioning will ensure that the system will be long lasting and reliable. Measures will be taken to address electrical and moisture concerns on the ship to ensure system integrity. Precautions against fire, electrical, and mechanical hazards will be taken when installing and operating the Control System. The proof of concept system and future systems will comply with standards set by ABS, ANSI, FCC, and NMEA.

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