National Transportation Safety Board

Marine Safety

Washington, D.C. 20594

Group Chairman's Factual Report

Engineering Group

Seastreak Wall Street

DCA-13-MM-005

February 4, 2014

Thomas K. Roth-Roffy

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1. ACCIDENT INFORMATION

Vessel:	*Seastreak Wall Street*
Accident Number:	DCA-13-MM-005
Date:	1/8/2013
Time:	08:41 eastern standard time (UTC -5)
Location:	East River, Manhattan, NY, 40-42.16 N - 074-00.35 W
Accident type:	Allision
Complement:	5 crew, 326 passengers

2. ENGINEERING GROUP

Chairman	Thomas K. Roth-Roffy Office of Marine Safety Washington, DC 20594
Member – U.S. Coast Guard	CWO Arron Van Huysen, USCG CWO Arron Brawner, USCG Domestic Vessel Inspections Branch U.S. Coast Guard Sector New York
Member - Seastreak, LLC	Chris Bierker Director of Vessel Engineering / Fleet Technical Manager
Member – MTU / Tognum	David Sears, Director After Sales Andrew Packer, Sr. Manager, Application Engineering
Member – Servogear AS	Torelief Stokke Managing Director

3. SUMMARY

About 0841 EST on January 9, 2013, the passenger ferry *Seastreak Wall Street*, operated by Seastreak, LLC, allided with the corner of the D2 slip while attempting moor at B slip of Pier 11 in Manhattan, New York. The ferry had departed Atlantic Highlands, New Jersey, approximately 40 minutes before the accident and was destined for Pier 11 to offload passengers. It was the second round trip of the day after an uneventful first run. Seventy-five of 326 passengers aboard sustained minor injuries, four passengers were seriously injured, and one of five crewmembers sustained minor injuries.

4. DETAILS OF INVESTIGATION

4.1. Launch And On-Scene Investigation

4.1.1. A team of five investigators launched from NTSB headquarters and arrived at the accident site within eight hours of the accident. The engineering group's on-scene investigation took place during the period January 9 to 17, 2013. Additional visits to the vessel were made in February 2013 (for damage survey in boat yard), April 2013 (to witness installation of pitch deviation alarm), and June 2013 (to review control operation).

4.2. Vessel Description

4.2.1. General. The *Seastreak Wall Street* (*SSWS)* (figure 1), was a high speed catamaran passenger ferry operated by Seastreak, LLC, of Atlantic Highlands, NJ. The company also operated five other ferry vessels, three of which were "sister vessels" to the *Seastreak Wall Street*.[1] The *SSWS* normally was operated on ferry routes between Atlantic Highlands, NJ; Highlands, NJ; and two locations lower Manhattan, NY, and it was certificated to carry up to 499 passengers and 6 crew members.[2]

Figure 1. Profile view of the Seastreak Wall Street. Photo was taken after the boat was returned to service.

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[1] The three sister vessels and build dates were: *Seastreak New York* (May 2001) *Seastreak New Jersey* (Dec 2001) and *Seastreak Highlands* (Mar 2004).

[2] USCG Certificate of Inspection, temporary COI valid 2012-07-24 to 2013-07-24, issued after repowering

4.2.2. Vessel particulars.

Vessel Name	***Seastreak Wall Street***
Owner/Operator	Seastreak, LLC
Port of Registry	Atlantic Highlands, NJ
Flag	US
Service/Type	Passenger ferry (small passenger vessel, USCG Subchapter K inspection regulations)
Built	Sep 2003, Gladding Hearn Shipbuilding, Somerset, MA, hull number P-342. Design by Incat Crowther[3]
Official number/IMO	CG639896 / 8982010
Classification society	n/a[4]
Construction	Welded marine grade aluminum, twin hull
Draft	6.6 ft (2.0 m)
Length	136.6 ft (41.6 m)
Beam overall	34.2 ft (10.4 m)
Gross Tonnage	417 ITC, 98 GRT
Engine power and type	2 x 2,467 HP (2 x 1840 KW), diesel, geared drive, twin controllable pitch propellers, twin rudders
Service speed	32 knots
Cargo	n/a
Passenger capacity	499 passengers, 6 crewmembers, 505 total persons
Persons on board	5 crew, 326 passengers
Injuries/fatalities	76 minor, 4 serious
Damage estimate	*SSWS*: $166,196.
	Dock barge and sideloader: $333,349, which included $36,000 transportation costs

4.2.3. Arrangement. The vessel was a twin-hulled (symmetrical hard chine) catamaran with a three level deckhouse for passenger seating. The main deck and second deck passenger seating areas were fully enclosed and air conditioned, while the third deck passenger area was open and uncovered. The navigation bridge was at the forward side of the second deck. At the aft side of the main deck was a beverage and snack bar, and three marine heads (water closets). Passenger access between the three superstructure levels was by use of inclined ladders (stairs). Three stairwells were fitted between the first and second deck passenger compartments. At the forward section of the deckhouse was a double width stairwell, and just aft of midships was a single width stairwell at each side of the passenger cabin. Fitted between the second deck (aft of the deckhouse) and open third deck was a

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[3] Incat Crowther is a naval architecture firm company based in Sydney, Australia, with a US office in Lafayette, Louisiana. Incat Crowther website, accessed September 15, 2013, (http://www.incatcrowther.com).

[4] According to section 1.1 of the original version of *Vessel Operating Manual*, the *SSWS* was built to (but not classed to) DNV High Speed Vessel Rules.

double-width stairwell. These four stairwells were aligned with the longitudinal axis of the vessel. Finally, fitted aft of the deckhouse between the main and second decks was a fifth (single-width) stairwell that was aligned with the athwartships axis of the vessel. Passenger access to of the deckhouse (from the exterior) was through two weather-tight doors fitted at the forward side of the deckhouse (port and starboard) and two port and starboard weather-tight doors. Passengers could board the vessel at a ramp fitted at the bow or through boarding areas at the port and starboard sides of the vessel.

The catamaran hulls each had a breadth of 9.0 feet and were connected by a bridging structure on which the deckhouse was mounted. Each catamaran hull had five watertight compartments with spaces for fuel, water, and sewage holding tanks, as well as compartments for the machinery spaces and steering gear. Contained within a machinery space at the aft of each hull was a main propulsion engine, propulsion system electronic controls, main reduction gear (gearset), 110 KW diesel electric generator, and associated auxiliary equipment. An independent steering gear system was fitted in a lazarette compartment at the aftmost section of each hull. Figure 2 is the vessel designer’s general arrangement drawings, outboard profile view and plan views.

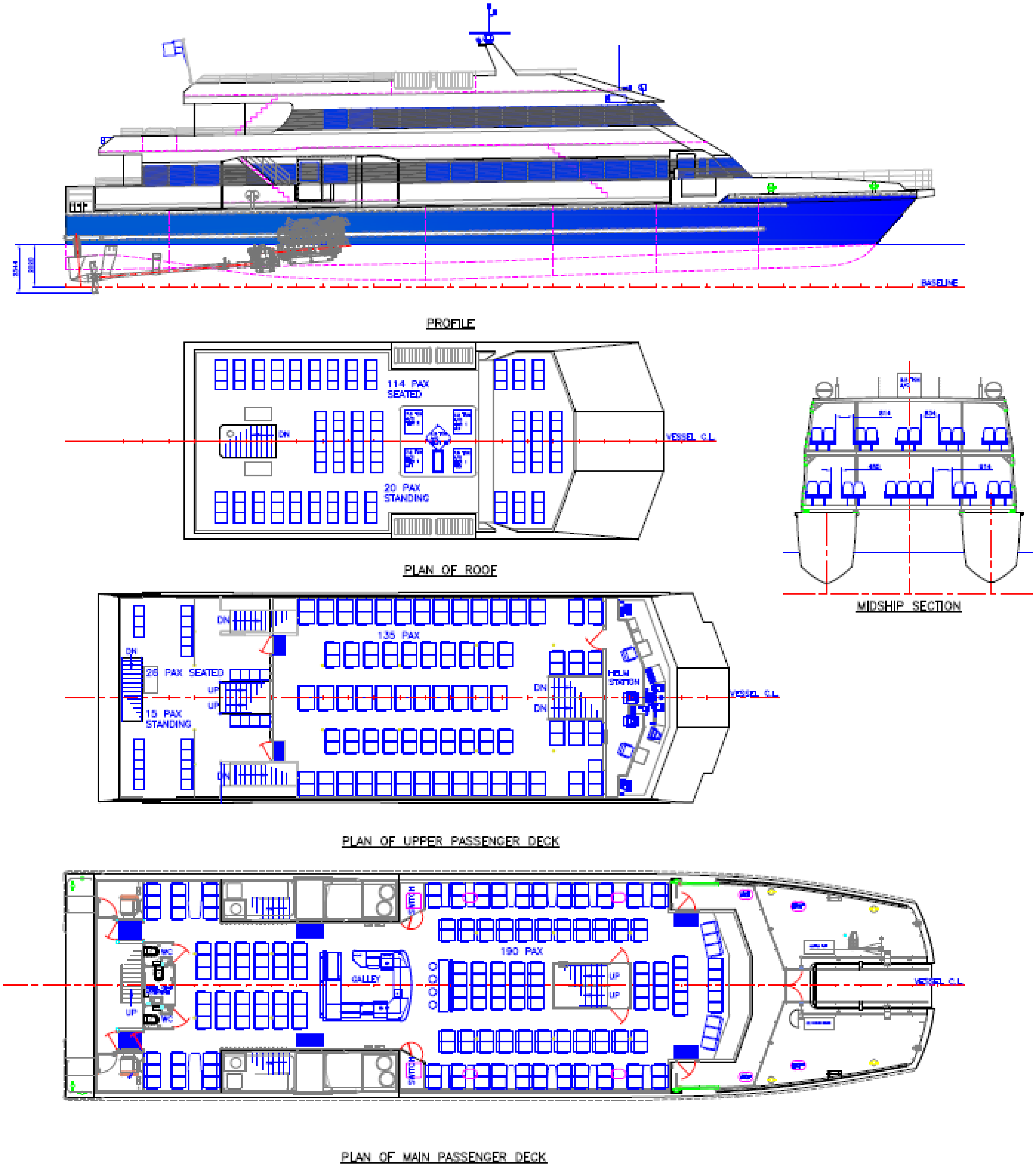

Figure 2. General arrangement drawings - profile and deck plan views. Drawings by vessel designer, Incat Crowther.

4.2.4. Propulsion system. The *SSWS* was fitted with two independent diesel propulsion systems. Each system was fitted in a machinery space at the aft side of each of the two hulls. A new propulsion system had been recently installed in July 2012, during a repowering project that was partially funded by a grant from the US Environmental Protection Agency (EPA). See section 4.8.1 for additional information on the repowering project.

In each catamaran hull, a single diesel engine was arranged to drive a controllable pitch propeller (CPP) through a reduction gear. With the exception of the main diesel engine, the propulsion system was designed, built, and supplied as a branded package by Servogear of Norway.[5] The "Servogear Ecoflow Propulsor"™ branded package was marketed to provide higher efficiency, lower fuel consumption, more economic operation, and less pollution.[6] Figure 3 shows the components of the "Ecoflow Propulsor."

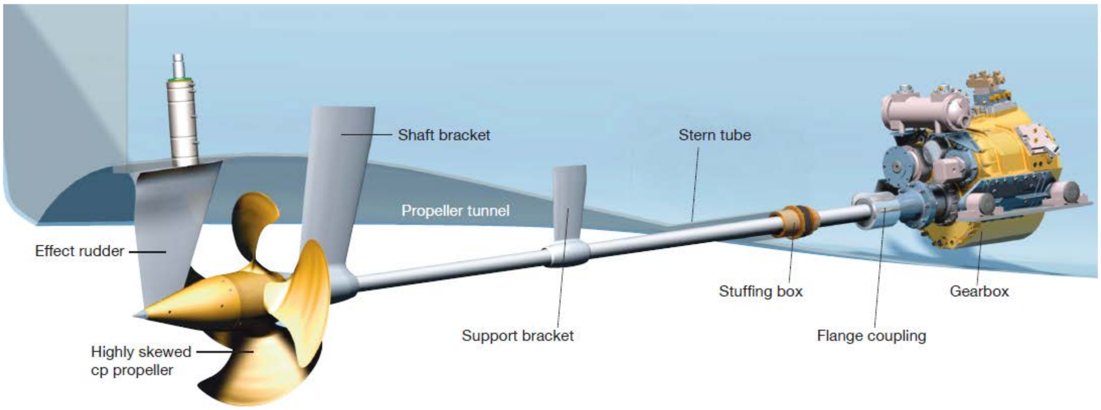

Figure 3. Servogear Ecoflow Propulsor system components. Schematic drawing by Servogear.

The propulsion and steering control systems were provided by Scana Mar-El, a sub-contractor (supplier) to Servogear. Additional details of the propulsion control systems is covered in section 4.2.4.4.

4.2.4.1. Diesel engines. The main propulsion engines were 16 cylinder (V configuration), high speed (1800 revolutions per minute (RPM)), diesel engines. The engines were model number 16V-4000M53, and were fitted with an engine control and monitoring system (ADEC)[7], and were manufactured in Germany by MTU Friedrichshafen, GmbH. The engines had the following characteristics:[8]

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[5] Servogear was a 30-year-old Norwegian small company whose products included high efficiency propulsion systems, gearboxes, and propellers for the fast ferry, workboat, offshore, and yachting industries. Servogear website accessed July 1, 2013, (http://www.servogear.no/index.php). The company was established in 1973 and had about 45 employees at its Rubbestadneset, Norway, office.

[6] "Servogear Ecoflow Propulsor," Servogear, accessed July 1, 2013, http://www.servogear.no/index.php?pageID=42

[7] ADEC is an acronym for Advance Diesel Engine Controller, MTU's branded engine control and monitoring system. See MTU engine technical manual (operating instructions MS150035/00E, section 2.2.1).

[8] Main diesel engine information taken from MTU Operating Instructions Manual, MS150035/00E.

- four-stroke
- electric start
- liquid cooled
- direct fuel injection
- sequential controlled gas turbocharging
- charge air cooling

The main engines were fitted with an electronic engine governor (engine control unit (ECU)) and an electronic engine monitoring unit (EMU). The electronic control unit (ECU) had the ability to store engine data after each engine shutdown. The engine data recorded around the time of the allision is presented in a separate factual report (electronic data factual report, a.k.a recorded data factual report).

The newly built engines were installed in early 2012 as part of the repowering project, and they were certified to be compliant with the US Environmental Protection Agency's Tier 2 emissions standards.[9] Federal regulations for marine compression engine exhaust emissions are found at 46 CFR Part 94.[10]

4.2.4.2. Main reduction gear.[11] Each main engine was connected to a (120 mm diameter) propeller shaft through a non-reversing marine transmission (double reduction arrangement) and a clutch. The gearbox (transmission) had a had a reduction ratio of 3.826 to 1, and was model number ZF 7640 NR EW, made in Germany by ZF Friedrichshafen AG. Incorporated within the reduction gear assembly was a hydraulic power system to control the pitch of the CPP. A hydraulic slide valve controlled hydraulic pressure to a piston that was connected to the pitch control block in the propeller hub through a push-pull rod. The push pull rod was installed within a central linear bore in the propeller shaft. The hydraulic servo valve within the gearbox was positioned through a lever fitted at the outside of the gearbox. The lever was controlled by an electrical linear actuator that was controlled by the propulsion control system.[12]

4.2.4.3. Controllable pitch propeller (CPP). The CPP was an integral part of the Servogear "Ecoflow Propulsor System." The four-bladed, highly skewed propeller[13] was constructed of a nickel-aluminum-bronze (NiAlBz) alloy material, and had a diameter of

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[9] The technical scope proposal by MTU provides details of the main engine installation, including a statement that the engines are compliant with EPA Tier 2 exhaust emissions regulations.

[10] International regulation of marine diesel exhaust emissions began with the entry into force of the International Maritime Organization's (IMO) International Convention for the Prevention of Marine Pollution from Ships (MARPOL) Annex VI regulations in 2005. The US EPA developed national standards for emissions that became effective in 2004. Since 2004 US regulations have been revised to impose more stringent requirements on exhaust emissions.

[11] The reduction gear set fitted between the main engine output shaft and the propeller shaft are variously referred to as "[main] reduction gears, "transmission," and "gearbox" - all terms are equivalent in meaning.

[12] Information about the Ecoflow Propulsor sytem – reduction gears and CPP - taken from Servogear Instruction Manual – Part 1

[13] A highly skewed propeller is defined as one having a skew angle of greater than 25 degrees. The propeller skew can generally be described as the extent to which the tips of one blade projects over the root of the adjacent blade. Carlton, John. "Chapter 3 - Propeller Geometry". Marine Propellers and Propulsion, Third Edition. Butterworth-Heinemann. © 2012. Books24x7. <http://common.books24x7.com/toc.aspx?bookid=50938> (accessed July 18, 2013)

4.92 feet (1500 mm) and skew angle of 45°. By varying the pitch of the propeller blades the vessel could move in the ahead or astern direction without reversing the direction of the propeller shaft. The propellers were outboard turning, that is, as viewed from the stern of the vessel, the starboard propeller turned in the clockwise direction and the port propeller turned in the anti-clockwise direction. The propeller pitch was changed by synchronously rotating each propeller blade through use of a yoke mechanism mounted within the propeller hub. The yoke arm was rotated by the fore and aft movement of an internal rod within the hub. This rod (within the hub) was connected to the push-pull rod contained within a bored opening in the propeller shaft. Figure 4 is cross sectional drawing of CPP system that indicates its major components.

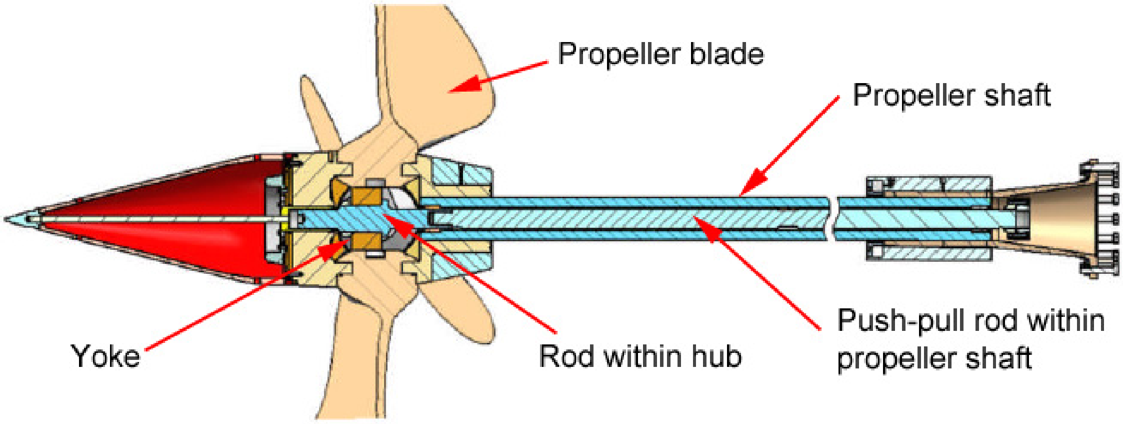

Figure 4. CPP cross sectional drawing. Image by Servogear.

Control of the propeller pitch was done by the propulsion control system in response to load demand from either the throttle input or the separate main engine load control system. Propeller pitch could be automatically reduced by the main engine load control system in response to an engine overload; this reduction in pitch could override any pitch demand ordered by the throttle's pitch order.

4.2.4.4. Propulsion control system. Two independent electronic propulsion control systems were newly installed on the *SSWS* during the early-2012 repowering project. The control systems controlled the main engine RPM, pitch of each CPP, and engagement and disengagement of each main clutch (between the main engine and the reduction gears). The two systems were identical "Neptune Compact" models and were manufactured and installed by Scana Mar El, AS, of Norway.[14] The Neptune Compact model control system was first "type approved" in January 2004 by the

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[14] Information about the propulsion control system is derived primarily from the manufacturer's technical manual "System manual Neptune Compact CPP 23/5."

Norwegian classification society *Det Norske Veritas* (DNV).[15] [16]

The primary system components were a main CPU unit (fitted in the engine room), three maneuvering control stations fitted on the navigation bridge, and miscellaneous sensors and actuators (figure 7).

The three bridge maneuvering control stations were the primary operator interface to the propulsion control system during normal operation. Each of the three maneuvering control stations were identical in design/layout and had all of the necessary components to monitor and control the engine RPM and CPP pitch for each propulsion system (figure 5). In addition, alarm indicators were fitted at each maneuvering control station to alert the operator of abnormal conditions — such as power failure or system failure — within the system. One maneuvering control station was installed at the centerline of the vessel, and one maneuvering station was installed at each side of the bridge (port and starboard). Each control station consisted of two order levers (aka maneuver handles), two button and alarm panels located on either side of the order levers, two rudder angle indicators (analog display), two propeller pitch indicators (digital display), and two main engine and propeller shaft RPM indicators (digital display).

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[15] DNV Type Approval Certificate No. A-12744. Type approval is certification by a recognized testing agency that the system meets the performance and standards to which it was designed. The type approval has to be renewed every two years. DNV type approval process information found at website http://www.dnvusa.com/industry/maritime/servicessolutions/cmc/tyepapproval/

[16] The type certificate indicated that equipment was tested according to DNV "Standard for Certification 2.4, April 20011" It was, among other tests, tested according to EN 60945-EMC and environmental tests, (DnV test report 2003-3383, rev 03), but it was not tested according to the additional standards of IEC 60945 (Maritime navigation and radiocommunication equipment and systems - General requirements - Methods of testing and required test results). The additional standards of IEC 6094 include, for example in , Section 4.2, requirements for design and operation, ergonomics and HMI.

Figure 5. Starboard side propulsion and steering control station. See figure 6 for more detailed view of pushbuttons.

Three operating modes were available to control the main engine RPM and CPP propeller pitch when maneuvering the vessel.

♦ Combinator mode. In this mode the engine RPM and CPP pitch were controlled by movement of the order lever (combinator lever). Each propulsion system had an independently operable handle whose position was determined by visual reference to a linear scale that indicated the percentage of power applied in either the ahead or astern direction. In the combinator mode, the engine RPM and propeller pitch angle followed values along a preset curve in the system software (combinator curve). See Appendix A for table listing the engine RPM and propeller pitch at various power levels.

♦ Backup mode. In this mode the engine RPM and propeller pitch were controlled independently -- the engine RPM was controlled by order lever and the pitch was controlled by the backup system pushbuttons.

♦ Constant RPM mode[17]. In this mode of operation the engine RPM was set to a preset (software adjustable) value that did not vary as the propeller pitch was changed. Movement of the order lever changed the propeller pitch only. This mode was most useful

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[17] The propulsion control system user manual also identifies the "backup" mode as the "individual" mode. See Neptune Compact CPP User Manual, Section 7.1.2. The *SSWS* system was not provided with a separate lever for pitch control as described in the user manual, but rather pitch control was through the use of pushbuttons as described later in this report section.

if the vessel was fitted with a shaft-driven electrical generator that required a constant shaft RPM (to maintain stable a AC frequency), and it was not normally used on this vessel. According to the vessel operating company, at the time of the accident the constant RPM parameter was set to 1100 rpm.

The *SSWS*'s normal mode of operation was the *combinator mode*.

Only one of the three bridge propulsion control stations was able to be in control at a time. Transfer of control was accomplished by the following basic procedure at the station where control is desired:

1. Match the position of order levers (port and starboard) to the in-control station levers' positions, and
2. Push the "In Command" pushbuttons[18] (one for port, one for starboard) at the station to which control is to be transferred. A steadily glowing red-colored LED (light emitting diode) light within the "In Command" pushbutton indicated that the transfer of control had been accomplished.
3. If the position of the requesting control station's order levers are not matched within plus or minus 10% of the in-command station's order levers, an intermittent audible alarm (buzzer) and a flashing LED lamp within the pushbutton will indicate that transfer of control had not been accomplished. If the order levers are not matched within about 15 seconds, the control transfer request will be canceled by the control system, and the LED will stop flashing and the buzzer will stop sounding.

Note: If transfer of propulsion control is performed while the system is operating with pitch in the backup mode, an alarm would not sound to alert the operator that the pitch control is still being operated in the backup mode.

Note: As stated above, if a command transfer request is initiated and the order levers are not matched, a 15 second software timer start that limits the time during which the transfer can be accomplished. In addition, according to the control system manufacturer, if during the 15 second period the In Command button is depressed a second time, the 15 second timer will restart the timer so the timeout period will be lengthened to a new 15 seconds from pushing the button.

Control station buttons and LED indicators. Each of the three control station panels on the navigation bridge used identically shaped pushbuttons and LED lamps to provide a consistent and straightforward user interface to the propulsion control system. On either side of the order lever (aka maneuver handle), the control buttons for each independent (port and starboard) control system were arranged in four distinct groupings that provided a functional arrangement of the buttons and alarms (figure 6).

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[18] These and other "pushbuttons" on the propulsion control panel were membrane type switches rather than mechanical pushbutton switches. The membrane switches had integral red LED lamps to indicate system status.

Group 1. At the top of the panel was the first group of three active buttons (one button was unlabeled and not active). Within this group of pushbuttons and LED indicators were the following:

- **Alarm Reset** pushbutton – used to silence the audible alarm and reset the alarm
- **Light Up** pushbutton – used to increase intensity of panel lighting
- **Light Down** pushbutton - used to decrease intensity of panel lighting
- **Alarm indicators** – six LEDs are used in the central portion of this grouping to indicate when an abnormal condition develops. These indicated alarms (top to bottom in the list) were:

system failure – indicated a system failure from any of a number of possible causes. In addition, when the CPP control was shifted to the "backup" mode by the operator, this LED light would illuminate and the audible buzzer would sound.
emerg[gency] cl[utch] out – disengagement of the engine clutch
pitch act[uator]. release – indicated that the pitch actuator was released
overload – main engine overload condition
eng[ine] local control – control of the engine is at the engine room room
power failure – loss of supply voltage (24 VDC) to the control system. At the time of the accident, the "power failure" LED was functional but it was not labeled to indicate its function.

Group 2. Below the first grouping of buttons was a second grouping of three active buttons and three inactive and unlabeled buttons. All buttons in this group had integral red LED lamps in their upper left had corners.

- **In Command** – used to transfer control of the propulsion system to the station at which the pushbutton was pushed. The LED was illuminated when the station had control of the propulsion system and was dark when control was at one of the other two stations.
- **Load Reduce** - used to reduce the maximum pitch below the maximum limit preset in the system software. The LED was illuminated when the pushbutton was pushed.
- **Load Increase** – used for increasing the maximum pitch up to the max limit preset in the system. The LED was illuminated when the pushbutton was pushed.

Group 3. Below the second grouping of buttons was a third grouping that was dedicated to the backup system for control of the propeller pitch. The grouping had four active and labeled pushbuttons, and two inactive and unlabeled pushbuttons. All buttons in this group had integral red LED lamps in their upper left had corners.

- **Backup Off** – used to deactivate the backup system. The LED was illuminated when backup system was "off" and dark when backup system was active
- **Backup On** – used to shift from normal system to the backup system. The LED was illuminated when the backup system was active and dark when backup system was "off." When the backup mode was manually activated by pushing the "backup on" pushbutton the "System Failure" LED lamp would illuminate and the audible alarm would sound until acknowledged by the operator.
- **Pitch Ahead** – used to control the propeller pitch and was only active while the backup

system is on. The propeller pitch increased ahead as long as the button was pushed.

- **Pitch Astern** – used to control the propeller pitch and was only active while the backup system is on. The propeller pitch increased astern as long as the button was pushed.

Group 4. At the bottom of the panel was the fourth grouping of buttons. This group consisted of four active buttons and two inactive and unlabeled buttons. This group consisted of the following buttons:

- **Constant RPM** - Pushbutton with light for activation and deactivation of the constant RPM mode. An illuminated LED indicated that the constant RPM mode was active. In constant RPM mode the RPM lever had no function.
- **Clutch In** - Pushbutton with light for engaging the clutch, interlocked with 'Clutch Activate'. An illuminated LED indicated that the clutch was engaged, a dark LED indicated that the clutch was not engaged.
- **Clutch Out** – used to disengage the engine clutch, interlocked with 'Clutch Activate'. The button had an LED to indicate that the clutch was disengaged, a dark LED indicated that the clutch was not disengaged.
- **Activate** - Pushbutton with LED light for interlocking the 'Clutch In' and the 'Clutch Out' pushbuttons (to avoid unwanted operation). This button must be pressed prior to these to make them active. The light is on/flashed as long as the function was active.

Figure 6. Propulsion control panel button grouping.

The below table indicates which LEDs were illuminated during each mode of operation. When in backup control, 5 LEDs were illuminated; when in combinator mode only 3 LEDs were illuminated .

	LED / Button Description	**Combinator**	**Backup CPP**	**Constant RPM**
Group 1	System Failure			
	Emerg CL. Out			
	Pitch Act. Release			
	Overload			
	Eng Local Control			
	Power failure			
Group 2	In Command	●	●	●
	Load Reduce			
	Load Increase			
Group 3	Backup Off	●		●
	Backup On		●	
	Pitch Ahead		●	
	Pitch Astern		●	
Group 4	Constant RPM			●
	Clutch In	●	●	●
	Activate			
	Clutch Out			

<u>System alarms</u>. Each control station was fitted with monitoring features that would activate visual and audible alarms to would indicate the loss of (24VDC) control power or the failure of the propulsion system. In event of a system alarm, the propulsion system would automatically shift to the backup mode for control of CPP pitch and sound an alarm (buzzer) to indicate that backup control system was active. The control system did not have the ability to save a history log of system faults, so no record of control system alarms occurring around the time of the accident was available for analysis by investigators. In addition, the *SSWS* was not fitted (nor was it required by regulations to be fitted) with a Voyage Data Recorder (VDR), , so automation systems alarms were not recorded, nor were the propulsion and steering command and response signals.

System redundancy features. The propulsion system was inherently redundant through the fitting of two independent systems within each catamaran hull and at the maneuvering stations. Each propulsion system had fully independent main diesel engines, gearboxes, clutches, propellers, and control power. The propulsion controls on the navigation bridge had fully independent components, including levers, switches, and power supplies. Failure of a major component within one of the propulsion systems – such as a diesel engine, CP propeller, sensor, system software program, or electrical switch – would not affect the normal operation of the redundant second system.

In addition to the gross redundancy afforded by having two fully independent propulsion systems, each propulsion system had a number of design features that improved the reliability of the each propulsion system. Among the reliability improving features were the following:

- **Control power**. Each system had two control power supplies. In event of failure of one of the power supplies, the second power supply would seamlessly provide power to the system.
- **Backup pitch control**. Each system had a backup means to control the pitch of the propeller - in the event of pitch control loss. Direct (backup) control of the pitch control arm was accomplished through an alternate routing of the control signal that bypassed the main control CPU. The electrical signal was directed directly to the pitch actuator via the pitch driver.

As part of the 2012 repowering project plan approval process, the operator of the *SSWS* submitted a qualitative failure analysis for the propulsion control system to the Coast Guard for review, as required by Coast Guard regulations at 46 CFR Part 62.[19] The failure analysis process was intended to improve the safety and reliability of critical vessel control systems. The analysis process required the system designer to explicitly consider the effect on the overall system operability in the event of the failure of an individual component. According to the note at 46 CFR 62.20, “the qualitative failure analysis is intended to assist in evaluating the safety and reliability of the design. It should be conducted to a level of detail necessary to demonstrate compliance with applicable requirements and should follow standard qualitative analysis procedures. Assumptions, operating conditions considered, failures considered, cause and effect relations, how failures are detected by crew, alternatives available to the crew, and possible design verification tests necessary should be included.” In addition to regulations, the Coast Guard provided guidance to owners for preparing the qualitative failure analysis required by regulations as well as the other submissions, such as the design verification tests and periodic safety performance test.

Vessels on international voyages and classified as High Speed Craft under international regulations (IMO High Speed Craft Code (HSC)) or classification society rules (neither of which encompassed the *SSWS*) were required to perform failure analysis of propulsion control systems.[20]

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[19] The FMEA was prepared by SCANA for the Neptune Compact CPP System. The FMEA document listed ten potential system failures, along with the possible causes, expected effects on the system, and the corrective action for each of the failures.

[20] The IMO adopted the International Code for Safety for High-Speed Craft (HSC Code) in 1994 by resolution MSC.36(63). Subsequently, the HSC Code was made mandatory under SOLAS regulations Chapter X. In addition, DNV had rules for the classification of “High Speed, Light

The Coast Guard regulations at 46 CFR 62.10-1 required that vital automation systems “upon failure or malfunction of a component, subsystem, or system, the output automatically reverts to a pre-determined design state of least critical consequence.” This failure condition is termed “failsafe,” and for both a propulsion control system and a controllable propeller pitch system the preferred failsafe state is identified to be “as is.”[21] The Coast Guard required submission of a Design Verification Test document to verify system compliance with the fail safe requirement as well all other applicable requirements of Coast Guard regulations.

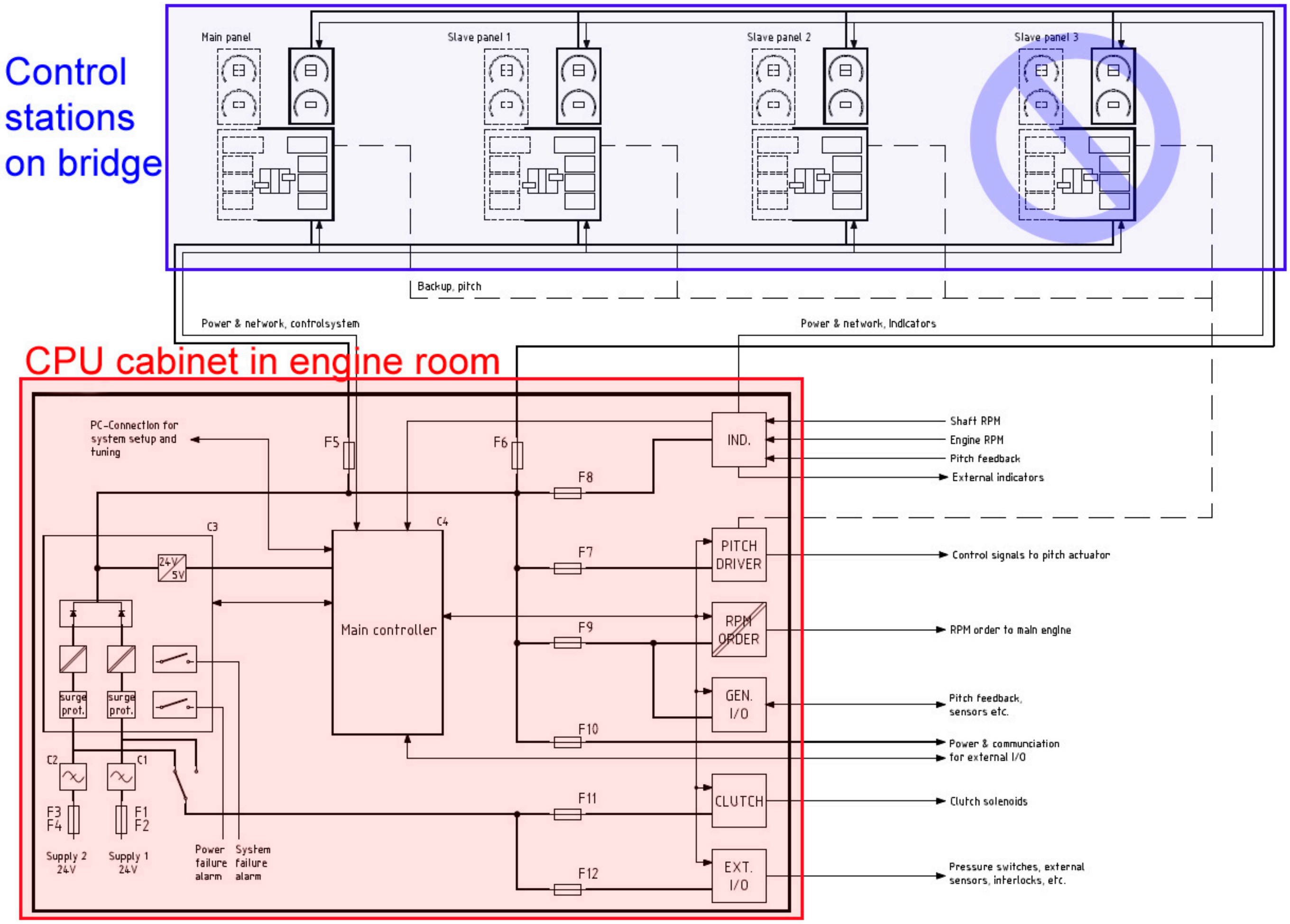

Figure 7. Propulsion control system block diagram - major components. Diagram by Scana Mar EL. The control system had three control stations on the bridge rather than four as shown in the diagram.

Craft and Naval Surface Craft. The IMO HSC Code required that an FMEA be performed on “craft’s systems and equipment to determine whether any reasonable probably failure or improper operation can result in a hazardous or catastrophic effect.”

[21] Terms used in this CFR section are defined at 46 CFR 62.10-1. Table 62-10-1(a) (Typical Failsafe States) indicates that the preferred failsafe state for a propulsion speed control system and a controllable pitch propeller system are “as is,” meaning that the state should not change upon system failure.

4.2.5. Steering system. Two fully independent electro-hydraulic steering gear systems were installed in a lazarette[22] compartment at the aftmost end of each of the two catamaran hulls. The steering systems were model no. ME-SG 23/9, manufactured by Servogear. The steering systems were newly installed in early 2012 as part of the engine repowering project. Each steering system consisted of a high efficiency “effect” rudder,[23] and an electro-hydraulic power system that positioned the rudder through rotation of the rudder stock. A yoke was fitted to the upper end of the rudder stock, and two hydraulically actuated cylinders acted to rotate the rudder stock and the connected rudder. The hydraulic cylinders were positioned by hydraulic pressure from an electric motor driven hydraulic pump (60 bar maximum) mounted within the same compartment. Mechanical stops were fitted near the yoke and cylinders to limit rudder movement to 30 degrees in the starboard and port directions. An electric rudder angle indicator system was connected to the top of the rudder stock by a toothed pulley and belt arrangement. The rudder stock angular position was converted to an equivalent voltage signal through the use of potentiometers. The electrical position signals were used for remote indication of rudder position and as feedback signals to the steering system controller.[24] Electrical limit switches were installed within the rudder angle indicator to stop rudder travel before reaching the mechanical stops. The major components of steering system are shown in figure 8.

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[22] On small vessels, a lazarette is a small compartment below decks, located at the stern of a vessel, in which the steering gear equipment is fitted.

[23] “Effect rudders have an contoured airfoil shape that is intended to reduce the drag on the rudder and to produce lift in the water flow. See “Effect Rudders,” Vankorlaar-Holland, accessed 2013-07-11, http://www.vankorlaar-holland.com/en/effect_rudders.html.

[24] After the accident, the vessel operator modified the rudder angle indicator system to provide separate position sensors, pulleys and belts for the feedback system and the remote rudder angle position indicator. This modification was done in response to Coast Guard requirements to the vessel operator and was intended to improve the reliability of the newly installed steering system.

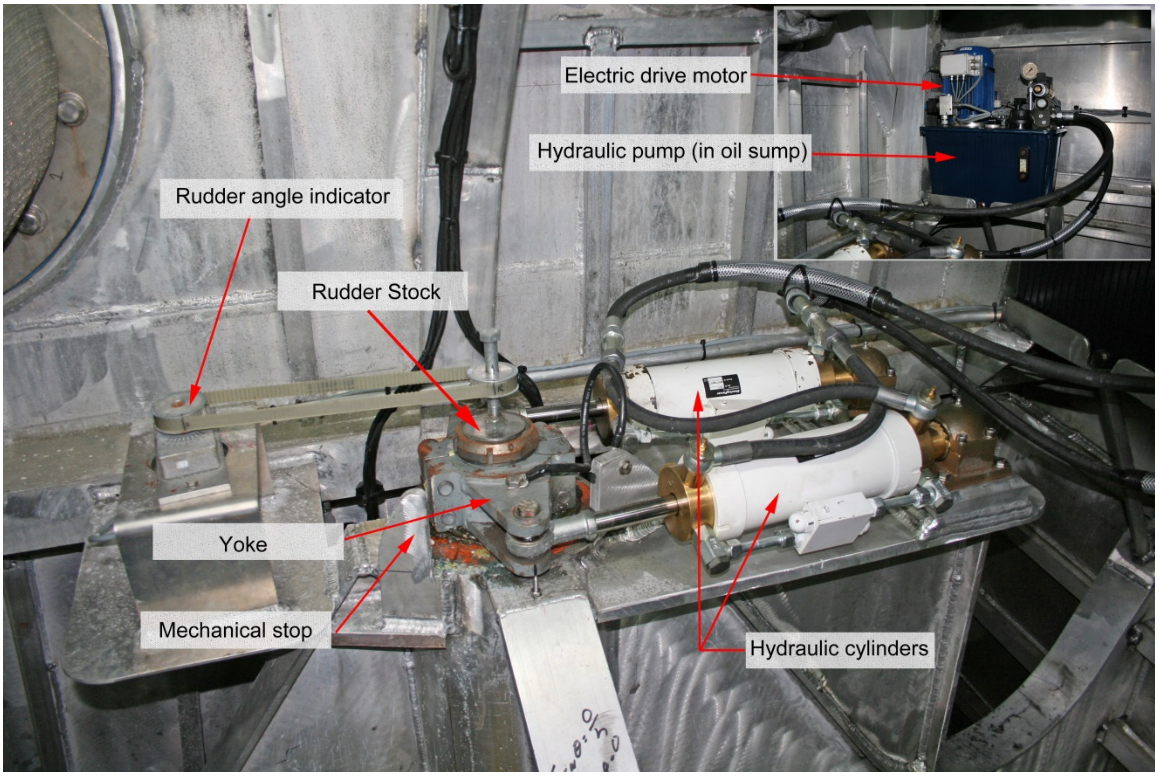

Figure 8. Steering system components in lazarette, starboard unit.

4.2.5.1. Steering control system. Control of the steering system was accomplished by an electronic control system supplied by Scan Mar El, a subcontractor to Servogear.[25] Rotation of the rudder was through linear movement of the cylinders applied to the yoke connected to the rudder stock. The direction of rotation of the rudder was determined by the electric servo control valve, which routed oil pressure to either side of the two hydraulic cylinders. The electrical electric servo valve was activated by the Scana electronic steering control system in response to rudder orders input by the vessel operator on the bridge. The control system had both an automatic control system (with follow up action), and an electrically independent non-follow up back up control system.[26] In addition, the servo valve could be manually positioned to control the rudder position. During normal operation the positions of each rudder were synchronized to each other. The

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[25] Source of information for this section was the Scana Mar-El AS technical manual, System Manual Steering Gear ME-SG 23/9.

[26] In the automatic follow up control mode, when the operator orders a rudder position from one of the control stations on the bridge, the automatic control system begins to move the rudder to the ordered position, and the rudder continues to move until it reaches the ordered position. In non-follow up (NFU) mode, the operator moves the rudder by pushing a button that sends and electrical signal directly to (through a solenoid driver board) the electric solenoid valves in hydraulic system in the steering gear room. In NFU mode, the rudder position changes only as long as the pushbutton is depressed and stops moving when the operator releases the push button. The NFU mode is intended to serve as a backup to the automatic mode. For steering system definitions see Coast Guard regulations for steering gear at 46 CFR Part 58.25-5.

system was rated to move the rudder from side to side (from 30 degrees port to 30 degrees starboard) in 12 seconds (normal speed mode) and 6 seconds (high speed mode). The system was normally operated in normal speed mode.

Remote control of the rudder was possible at each of the three control stations on the navigation bridge by use of the rudder order knob (figure 5). The rudder could only be controlled from one of the three control stations at a time. The procedure for shifting steering control was to simply push the “in command” push button located near the rudder order knob at the station from which control was to be had. Unlike the propulsion control system, it was not necessary to first match the knob position at the control station before taking control of the rudder – pushing the “in command” button resulted in immediate transfer of rudder control. A lamp located within the each of the three “in command” pushbuttons indicated which control station had control of the rudder (only one lamp was illuminated at a time). Unintended activation was prevented by a hinged flip-up (clear plastic) cover over the button.

Each steering system was fitted with alarms for the following monitored parameters: main power loss, control power loss, hydraulic tank fluid level low, electric motor overload, electric phase failure, follow up system power failure, hydraulic filter differential pressure high, and rudder position feedback failure.

4.3. Inspection history.

4.3.1. The *SSWS* was inspected and certificated by the Coast Guard under Subchapter K regulations for small passenger vessels carrying more than 150 passengers or with overnight accommodations for more than 49 passengers (46 CFR Parts 114 to 124). The Coast Guard’s Marine Safety Center reviewed and approved the vessel plans and design calculations before construction began in November 2002.

Beginning in January 2003, the vessel was subject to Coast Guard oversight during the construction phase, and it received initial Coast Guard certification on September 22, 2003.[27] During the nearly ten years after this initial certification, the vessel was subjected to ten regular annual inspections as well as a number of hull inspections (dry docking) and hull damage surveys. Hull inspections were performed as required twice during the five year term of each of the Certificate of Inspections, and damage inspections were performed after the Coast Guard received a report of vessel damage from the operator. Inspection records show that before the January 2013 accident, the vessel had experienced damage (hull and machinery) on seven occasions, and after each reported occasion repairs were certified to have been properly completed.

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[27] Information for this section taken from the Coast Guard’s vessel inspection file (MISLE).

4.3.2. Vital System Automation. Coast Guard regulations for subchapter K small passenger vessels at 46 CFR 121.620(d) required the *SSWS*'s computer (microprocessor) based propulsion control system to meet the requirements of 46 CFR Part 62 regulations for vital automation systems. These regulations required, inter alia, the operator to submit for approval plans for *Design Verification* and *Periodic Safety* test procedures as described in 46 CFR Part 61.40. During the repowering project, the operator of the *SSWS* submitted plans to the Coast Guard's MSC, as required by Coast Guard regulations., At the time of the accident, the plans for design verification and periodic safety performance had not been fully approved.

In addition, regulations at 46 CFR Part 62.35-5(e)(3) required the propulsion control system to be equipped with an alarm on the navigating bridge and in the machinery spaces when a remote propulsion control system fails. However, the regulations did not specifically require the fitting of a pitch deviation (a.k.a. runaway pitch detection alarm or wrong direction alarm) that would provide an alarm to the operator that the commanded propeller pitch was significantly different than the actual pitch. As a result of its investigation of a 2010 accident, the NTSB has recommended to the Coast Guard that new passenger vessels with controllable pitch propulsion systems be equipped with pitch deviation alarms. However, in a written response to the NTSB recommendation the Coast Guard has stated that passenger vessels with remote propulsion controls "are already required by 46 CFR 62.35-5(e)(3) to be equipped with an alarm on the navigating bridge and in the machinery spaces when a remote propulsion control system fails" and that "this existing requirement is sufficient to address the issue raised in the Board's safety recommendation."[28]

Design Verification Test Procedures (DVTP). As part of the repowering project, the operator of the *SSWS* was required to submit to the Coast Guard's Marine Safety Center (MSC) design verification test procedures that would be used to verify that the propulsion control systems were designed, constructed, and operate in accordance with all applicable requirements of 46 CFR Part 62 (Vital Automation Systems), as well as 46 CFR Subchapter F, Marine Engineering and 46 CFR Subchapter J, Electrical Engineering.[29] Before the *SSWS* was certified to carry passengers, the Coast Guard's inspectors (in the inspection zone in which the *SSWS* was to operate) tested the automation systems using the provisionally approved DVTP; the system was shown to function as designed.

Periodic Safety Test Procedures (PSTP). The PSTP was used to demonstrate proper operation of primary and alternate controls, alarms, power sources, transfer override

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[28] Safety recommendation M-12-1 was issued to the Coast Guard in connection with NTSB's investigation of the Andrew J. Barberi accident that occurred in New York on May 8, 2010. For more information, see NTSB accident report MAR-12/01 (http://www.ntsb.gov/doclib/reports/2012/MAR1201.pdf). The NTSB did not agree with the Coast Guard's response to its recommendation, and has informed the Coast Guard that "a current accident under investigation by the NTSB also involves a controllable pitch 46 CFR Subchapter K vessel that underwent a Coast Guard–designated "major conversion," including the installation of a new propulsion system, in the summer of 2012. Preliminary facts indicate that its new electronic propulsion control system does not include a propeller pitch deviation alarm. The lack of this alarm raises the concern that 46 CFR 62.35-5(e)(3) does not, in fact, address the requirement to audibly and visually alert the operator to a deviation between the operator's propulsion commands and the actual propeller response."

[29] The Coast Guard's Marine Safety Center provided a procedure for the review of for the Design Verification Test Procedures of various shipboard automation systems, Procedure Number E2-05, "MSC Guidelines for Design Verification Test Procedures."

arrangement, interlocks, and safety controls.[30] The procedures were submitted to and reviewed by the Coast Guard's MSC. These procedures were intended to used annually as part of the annual certification inspection (COI). Before the repowered *SSWS* entered passenger service, Coast Guard inspectors validated the PSTP and verified proper operation of the vessel's safety systems.[31]

4.4. Maintenance and repair history

4.4.1. Preventive maintenance program. The *SSWS* was maintained by both the vessel crewmembers and a shoreside engineering staff of four persons – the director of vessel engineering, a port engineer, and two mechanics. Although the Coast Guard Certificate of Inspection did not require licensed engineers to be part of the crew, the *SSWS* carried a licensed engineer as part of the five person crew because of its engineering complexity and high main engine horsepower.[32] In addition, technical assistance from manufacturer's service engineers were used for major repairs and maintenance beyond the ability of the vessel crew and shoreside staff.

The company stated that it maintained the vessel according to the recommendations of the individual equipment manufacturers. The operating crew performed basic maintenance actions on the main engines and other equipment according to a checklists contained within the equipment manufacturers operating manual and instruction received in on-the-job training. The completed actions were noted in the engineering log book aboard the vessel. In addition, the shoreside engineering staff tracked maintenance items on a "white board" in the shoreside repair shop. Maintenance and repair records were filed away on a monthly basis.[33]

4.4.2. Repair history. The vessel had undergone a complete propulsion, steering, and diesel generator equipment replacement about seven months before the accident. The company representatives stated that there had been no significant problems with these systems since it left the shipyard in July 2012.[34] The company did not maintain separate formal machinery history (maintenance and repair) records for the ships equipment; maintenance actions were recorded only in the engineering log book.

4.5. Damage

4.5.1. *SSWS*. Damage to the vessel hull was principally to the stem of starboard bow and to forward area of the cross member connecting the two hulls. The damage to the starboard hull consisted a 30 inch-high trapezoid shaped inset into the stem, beginning about 30

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[30] The Coast Guard's Marine Safety Center provided plan review guidelines for Periodic Safety Performance Test of various shipboard automation systems, Procedure Number E2-17, MSC Guidelines for Periodic Safety Test Procedures.

[31] At the time of the accident the PSTP had not received final approval. The Coast Guard inspection file indicated that at the July 2012 COI inspection, the PSPT was required to be revised "to include testing of steering gear control system rudder position feedback potentiometer belt failure in Full Follow Up Mode. This will provide training to the crew in identifying and responding to this failure."

[32] Interview of Director of Vessel Engineering, 2013-01-17, p. 15.

[33] Interview of Director of Vessel Engineering, 2013-01-17, pages 15-17.

[34] Interview of Director of Vessel Engineering, 2013-01-17, pages 24 and 31.

inches above the waterline. The torn stem area extended about 45 inches at its lower side and 76 inches at its upper side. In this area of damage to the hull, the side shell was crushed and peeled away from the hull, and internal frames were displaced. Figure 9 shows the damage at the stem of the starboard bow.

A second area of hull damage was to the connecting structure between the two hulls at the main deck level. This area of damage was at the forward main deck level, just to the starboard side of the forward loading ramp. The plating and frames in this area of the structure (about 18 wide by 19 inches by deep) were torn and displaced. Figure 10 shows this area of damage. Figure 11 shows both areas of the damage to the hull - the starboard bow stem and the starboard main deck.

Other damaged areas of the vessel included minor damage to the interior of passenger cabin, such one broken window glass at the lower end of the forward stairwell (main deck), and one broken glass at the starboard aft door of the passenger cabin (second deck). In addition, one passenger seat back rest was damaged (main deck seating area, aft) such that its tilting movement was unrestrained.

After the accident, a diver found the port propeller to be fouled with a 4-foot length of solid steel bar and a 3-foot length of stranded wire rope (cable). Additionally, when the vessel was hauled out of the water for hull repairs, both the port and starboard propellers were found to be damaged, and the port propeller cone was missing. The damage to the port propeller consisted of gouges and dents at the tips of all blades, along with significant deep scratches on the faces of the blades near their leading edges (figure 12). The starboard propeller damage was less severe that the port propeller and consisted of similar bending and gouging at the tips of all four blades, as well as some limited scratching of the blade faces.

According to Seastreak, cost of damage repairs to the *SSWS* were $166,196.

Figure 9. Damage to stem of starboard hull

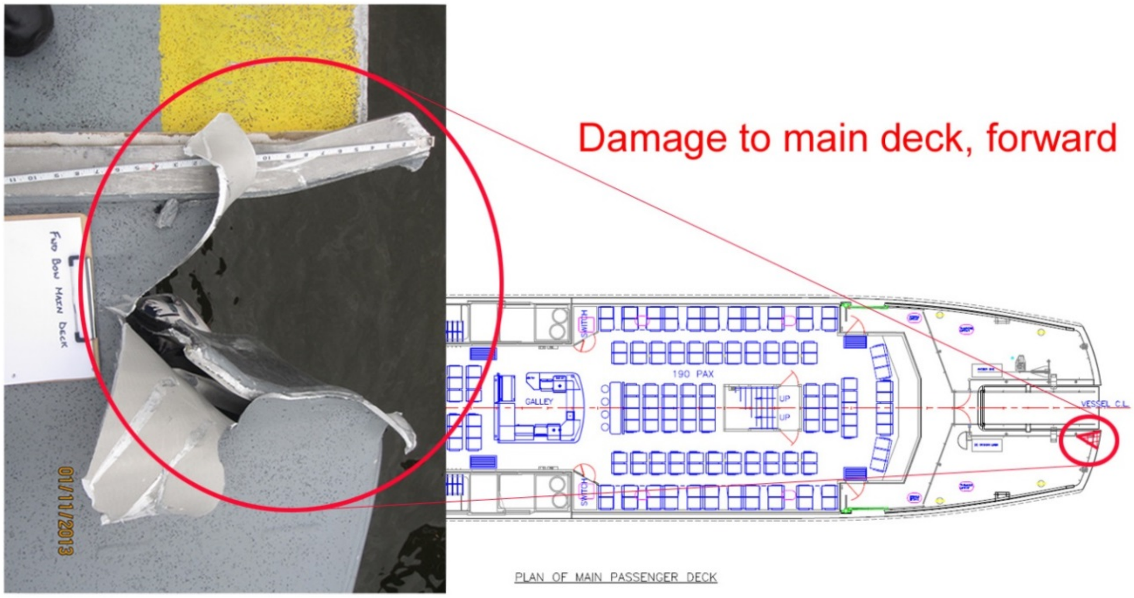

Figure 10. Damage to main deck, near bow loading ramp.

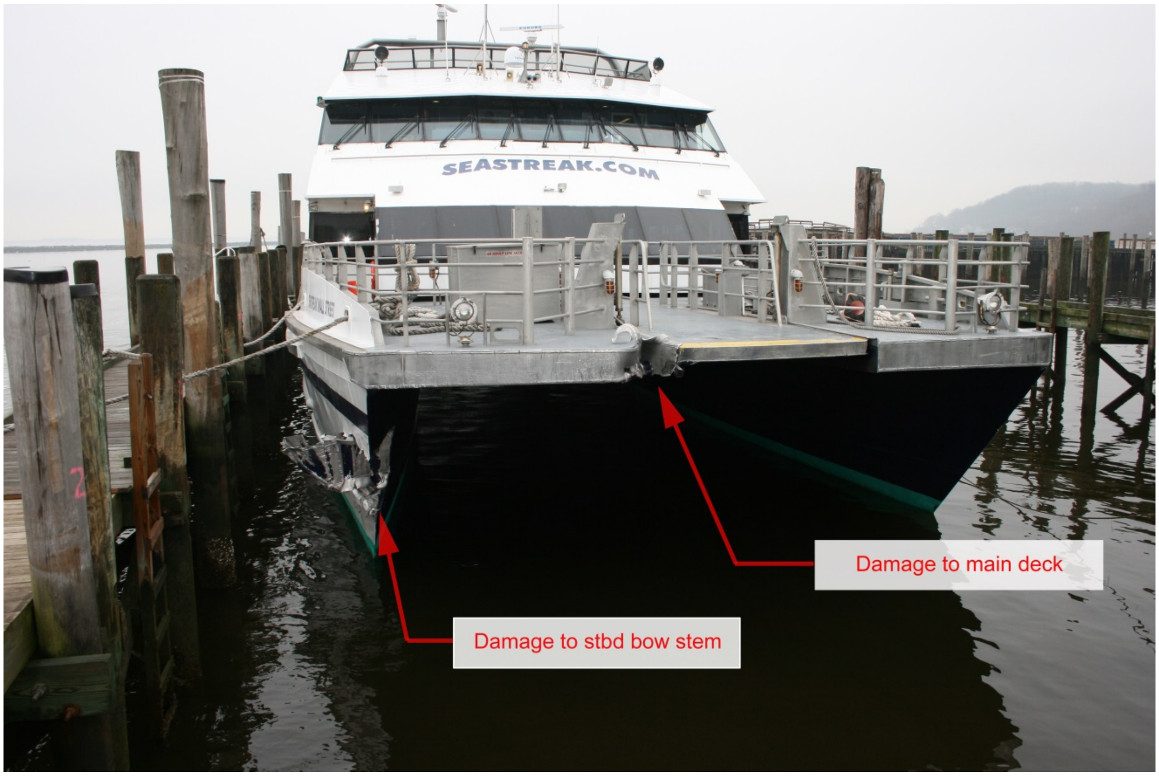

Figure 11. Damage to starboard bow stem and main deck.

Figure 12. Port propeller blade damage. Photo insets show the close up view of the damage to two of the propeller blades.

4.5.2. Slip D2, Pier 11 . According to witnesses, the vessel struck the D2 "sideloader"[35] at slip D, pier 11. The sideloader consisted of a deck barge[36] upon which a moveable platform was mounted, as well as associated fendering, hand railing, and a boarding ramp from the adjacent concrete pier. Damage to the raked deck barge consisted of scratching, indentation, and holing. The hole in the forward side (rake) of the barge was about 8 inches in diameter and about 2 feet above the barge's waterline. Above the hole in the rake was an area of scratches about 2.5 feet wide at the barge headlog[37] (figure 13). Distinct white colored scratches about 4.5 feet in length by 2.5 feet wide were indicated on the main deck of the deck barge. The angle of the scratch relative to the top edge of the headlog was about 45° (figure 14). Damage to ramp and platform fitted to the deck barge consisted of bending damage to a jacking screw used to elevate the platform and fender along with

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[35] The sideloader was used to adjust the elevation of the platform fitted to the dock barge that was used for load/unloading passengers from the side of the vessel. As the floating barge's elevation changed relative to the fixed concrete pier, it was also necessary to adjust the elevation of the platform fitted to the barge in order to maintain an appropriate angle of the ramp between the fixed concrete pier to the platform on the dock barge.

[36] A deck barge has a simple box hull with a heavy-plated, well-supported deck. Deck barges are often used as work platforms or for the carriage of various cargo on their single deck. "Barges and Towboats," Coosa-Alabama River Improvement Association website, accessed September 15, 2013, http://www.caria.org/barges_tugboats.html.

[37] A barge headlog is structural member at the extreme end between the rake shell plating and the deck. The rake is the end portion of the hull, in which the bottom rises from the midship portion to meet the deck at the headlog. The headlog is usually a vertical plate of considerable thickness due to its susceptibility to damage in service. H. Benford, Naval Architecture for Non-Naval Architects (Jersey City, NJ: Society of Naval Architects and Marine Engineers, 1991).

bending and distortion to several hand rails on the platform fitted to the deck barge (figure 15). According to a damage repair invoice, the cost of the repairs to the barge hull, platform, sideloader, and fender was $333,349. This damage cost included $36,000 round trip transportation of the barge to and from the repair facility.

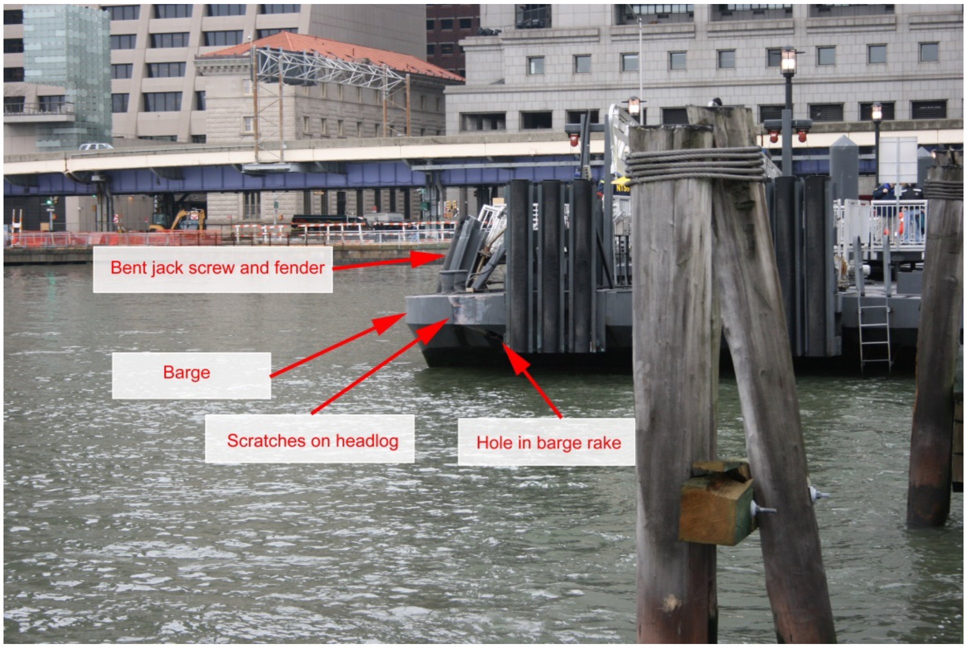

Figure 13. Damage to deck barge and sideloader.

Figure 14. Scratches on deck of deck barge, at an approximate angle of 45° to top edge of the headlog.

Figure 15. Damage to fender, jackscrew, and platform

4.6. Tests and Research

4.6.1. On-scene testing of propulsion and steering. After the accident, investigators (with assistance of a service engineer from the propulsion control system manufacturer) performed functional testing of the propulsion control and steering systems. Both the normal and backup modes of the pitch control system were tested. In addition to functional testing, the propulsion control system hardware was closely examined for indications of poor connections or damage at the various electrical and electronic components within the system. No loose or damaged electrical connections were found at any of the components within the propulsion control system.

With assistance from an engineer from the main engine manufacturer, data from the port and starboard main engine data recording systems were downloaded for analysis. Details of the content of downloaded data is addressed in a separate Recorded Data Factual Report.

Functional testing of the propulsion control system indicated that the system performed as designed. No system anomalies were observed during testing that spanned several days and included multiple control transfers and control manipulations. The response rates of propulsion control and steering systems were determined. The table below documents the test results. The CPP pitch response tests were performed dockside with the main engine clutches not engaged.

Item	**Condition**	**Time**
Port engine response	725 rpm to 1800 rpm (full), clutch out	18 sec
Stbd engine response	725 rpm to 1800 rpm (full), clutch out	19 sec
Port propeller pitch	0 % to 100 % ahead	9.5 sec
Port propeller pitch	0 % to 100 % astern	4.0 sec
Stbd propeller pitch	0 % to 100 % ahead	9 sec
Stbd propeller pitch	0 % to 100 % astern	5.3 sec
Port propeller pitch	100 % ahead to 0 %	7.0 sec
Stbd propeller pitch	100 % ahead to 0 %	6.1 sec
Port propeller pitch	100 % astern to 0 %	4 sec
Stbd propeller pitch	100 % astern to 0 %	5 sec
Port 100 % ahead to 100 % astern (backup control)	100 % ahead to 100 % astern	20.3 sec
Stbd 100 % ahead to 100 % astern (backup control)	100 % ahead to 100 % astern	18 sec
Port rudder response	25° port to 28.5° stbd	8 sec
Port rudder response	28.5° starboard to 25° port	6.8 sec
Stbd rudder response	30° port to 30° starboard	6.7 sec
Stbd rudder response	30° stbd to 30° port	6.8 sec

Transfer of control between the center control station and the starboard control station indicted the following conditions:

- If throttle position (percent) at starboard control station did not match center control station throttle position when the “in command” push button was depressed, a red LED within the “in command” pushbutton flashed, and after about 1.5 seconds, the annunciator would beep intermittently to alert the operator that starboard throttle did not match the center throttle.

- After approximately 15 sec, if the starboard throttle was not matched to the center throttle, the transfer request was cancelled. In addition, the "In Command" LED stopped flashing and the annunciator would stop beeping. Control then remained at the center station, and transfer of control could not be completed until the "in command" button was again depressed.
- Transfer of propulsion control did not occur until order lever positions remained matched for about 0.5 seconds. If the starboard throttle was moved quickly through the position corresponding to the center throttle position, transfer of control did not occur.

4.6.2. Postaccident sea trial. After completion of pierside testing and examination of the propulsion and steering systems, these systems were again functionally tested while the boat was under way in the Sandy Hook Bay and the Lower Bay, north of Atlantic Highlands, New Jersey. On board for the sea trial were engineers from the main engine manufacturer, propulsion control system manufacturer, and propulsion system (reduction gear and CPP system) manufacturer. The under way tests involved shifting of propulsion control between the three stations in the wheelhouse, full power operation, and operation of the CPP system in backup mode. Electronic data was recorded for the main engine and the propulsion controls systems, as well as video recordings of the propulsion control stations. The data collected during the sea trial is addressed in a separate Recorded Data Factual Report.

4.7. Postaccident Actions

4.7.1. After the accident, Seastreak planned to implement the following safety improvements:

- Implement a safety management system, including a formal preventive maintenance system. At the time of this report, this action was still not completed.
- Install a pitch failure alarm. This modification involved the changing of the pitch control arm at the main reduction gears and activation of the alarm feature within the system software. The original pitch control arm had a slip clutch, and the replacement arm did not have the slip clutch. This action was completed in April 2013, before the vessel resumed passenger operations.
- Install a data recorder. The electronic chart system manufacturer provided an upgraded system that recorded vessel position data. In addition, a video camera with recorder was installed in the wheelhouse. Neither the propulsion nor the steering order and response were recorded by the new electronic chart system's recorder. This action had been completed at the time of this report.

4.8. Other information

4.8.1. Repowering project. The *SSWS* propulsion system and diesel generators were changed out during a repowering project at Midship Marine, Inc., shipyard in Harvey, LA, during the period from February through July 2012. The repowering project was classified as a major conversion by the Coast Guard.[38] The operating company of the *SSWS* had received a US Environmental Protection Agency funding grant that covered a portion of cost of the repowering project.[39]

4.8.2. In August 2013, investigators traveled to Norway to interview management from Servogear and Scana Mar El regarding details of the propulsion control system. Among the information collected during the visit and provided by Servogear in a subsequent email amplification, were the following:

- The Neptune Compact system cannot be fitted with motorized throttle control levers. This option is only possible on the Neptune-II system.[40] The Neptune-II solution with motorized levers would about double the price of the remote control system, and it was selected by few, if any, customers on this type of vessel.
- The number of vessels fitted with the Neptune Compact remote control system totaled 169. Of these, 51 were high speed vessels. Among the 51 high speed vessels fitted with a Neptune Compact control system, 9 had more than one bridge panel, and 17 were fitted with an interface to the VDR system.
- The Neptune Compact system could be optionally fitted with an electronic box that provided an interface to a standard voyage data recorder. The cost of the output box was about $1500.[41]
- “The propulsion control system had a crash stop function that would reduce the RPM output to 23% above idle (parameter) if combinator lever is moved fast from ahead to astern (and vice versa) until the propeller pitch has passed through the zero position. The purpose of this feature was to avoid increasing rpm (and thereby thrust) if lever is moved from e.g. 60% ahead to 100% astern.” The crash-stop function is activated only in combinator mode, it is deactivated in back-up mode.
- “If the pitch is moving in the wrong direction due to system failure, it will be detected as a runaway situation. If the pitch is not moving when a new order is given, it is a stall situation. A pitch runaway situation will cause the system to enter the backup mode and give alarm. A stall situation will give an alarm. The detection is related to the speed of pitch feedback. Stall detection require a minimum speed of feedback towards order, else giving alarm. Runaway detects alarm situation if feedback is moving away from order when feedback speed is above a limit. The purpose is to

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[38] In a September 21, 2011, letter, the Coast Guard stated that it had evaluated the proposed modifications to the vessel against the criteria at Title 46, USC §2101(14a) and found that the modifications constituted a major conversion. Accordingly, the company was required to bring the entire vessel into compliance with the latest safety standards where it was both reasonable and practicable to do so.

[39] As part of the Energy Policy Act of 2005, the Diesel Emissions Reduction Act (DERA) authorized funding of up to $200 million annually for FY 2007 to FY 2001. The US Environmental Protection Agency (EPA) promoted clean air strategies under its National Clean Diesel Campaign (NCDC). In 2010 The Port Authority of NY and NJ received a funding award (which was passed through to Seastreak) under project DERA 09-10, which granted $2 million to “Repower four main and two auxiliary engines on one commuter ferry with Tier 2-certified engines.” Project information from the US EPA NCDC website, accessed September 15, 2013, http://www.epa.gov/cleandiesel/index.htm.

[40] According to Seastreak, Servogear did not offer them the more capable Neptune II system.

[41] According to Seastreak, Servogear did not offer this option to Seastreak, LLC, before the propulsion control system was installed on the *Seastreak Wall Street*.

detect failure with the pitch output devices (electromechanical actuator or cable, or the servo system). In this case it was activated in software because customer wanted to detect eventual failures related to gearbox and servo. The function is disabled in Backup mode, meaning that rpm control is in normal operation on lever while pitch is controlled with buttons."

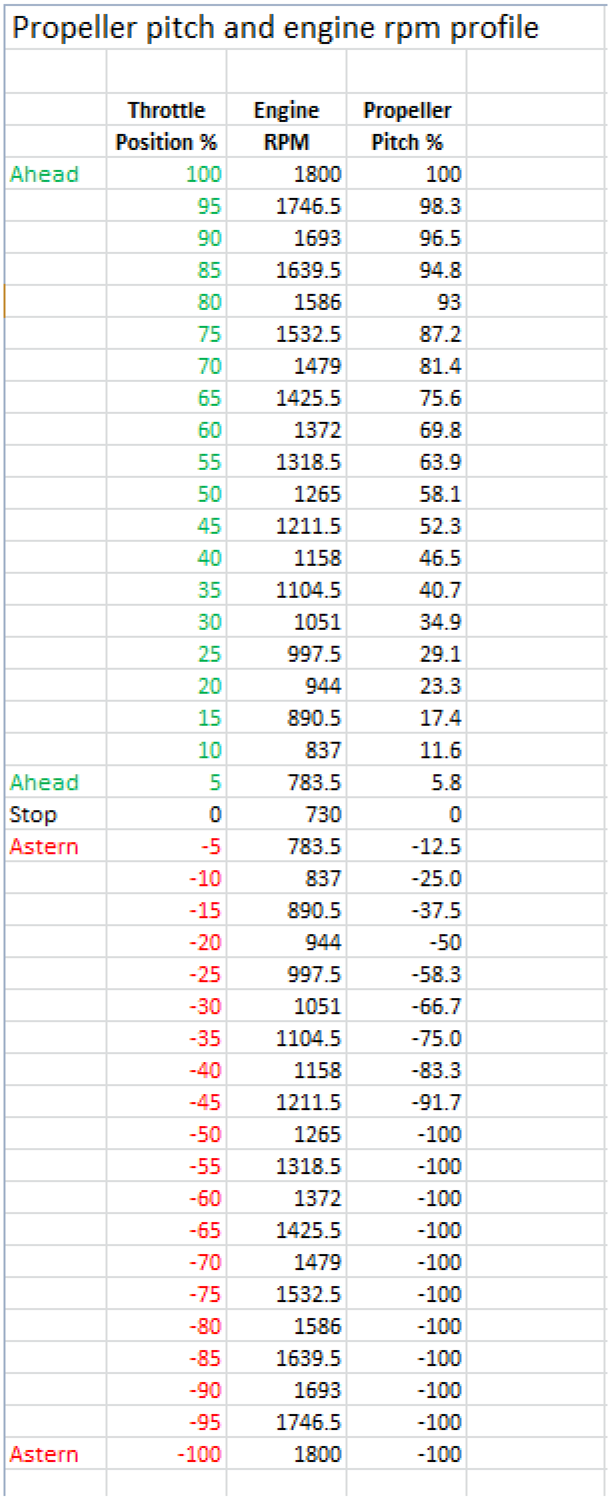
- According to the systems software version history, the initial version of the Neptune Compact main operating software was 02.01, dated 2003-66-20. The version installed on the SSWS was version 02.19, dated 2010-07-14. The Wrong Way Alarm function was added with version 02.04, dated 2005-05-06.

2/4/2014

X T. K. Roth-Roffy

Thomas K. Roth-Roffy, P.E.
Group Chairman
Signed by: Thomas K. Roth-Roffy

Appendix A. Combinator Mode - Engine RPM vs. Propeller Pitch



Propeller pitch and engine rpm profile

	Throttle Position %	Engine RPM	Propeller Pitch %
Ahead	100	1800	100
	95	1746.5	98.3
	90	1693	96.5
	85	1639.5	94.8
	80	1586	93
	75	1532.5	87.2
	70	1479	81.4
	65	1425.5	75.6
	60	1372	69.8
	55	1318.5	63.9
	50	1265	58.1
	45	1211.5	52.3
	40	1158	46.5
	35	1104.5	40.7
	30	1051	34.9
	25	997.5	29.1
	20	944	23.3
	15	890.5	17.4
	10	837	11.6
Ahead	5	783.5	5.8
Stop	0	730	0
Astern	-5	783.5	-12.5
	-10	837	-25.0
	-15	890.5	-37.5
	-20	944	-50
	-25	997.5	-58.3
	-30	1051	-66.7
	-35	1104.5	-75.0
	-40	1158	-83.3
	-45	1211.5	-91.7
	-50	1265	-100
	-55	1318.5	-100
	-60	1372	-100
	-65	1425.5	-100
	-70	1479	-100
	-75	1532.5	-100
	-80	1586	-100
	-85	1639.5	-100
	-90	1693	-100
	-95	1746.5	-100
Astern	-100	1800	-100