Collision between US Navy Destroyer *John S McCain* and Tanker *Alnic MC*
Singapore Strait, 5 Miles Northeast of Horsburgh Lighthouse
August 21, 2017

Marine Accident Report

NTSB/MAR-19/01
PB2019-100970

National Transportation Safety Board

Portions of this report have been designated as Controlled Unclassified Information (CUI) by the US Navy and have been redacted.

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490 L'Enfant Plaza, SW
Washington, DC 20594

National Transportation Safety Board. 2019. ***Collision between US Navy Destroyer* John S McCain *and Tanker* Alnic MC, *Singapore Strait, 5 Miles Northeast of Horsburgh Lighthouse, August 21, 2017*. Marine Accident Report NTSB/MAR-19/01. Washington, DC.**

Abstract: This report discusses the August 21, 2017, collision between the US Navy destroyer *John S McCain* and the tanker *Alnic MC*. The *John S McCain* was overtaking the *Alnic MC* in the westbound lane of the Singapore Strait Traffic Separation Scheme when the destroyer had a perceived loss of steering. While the crew attempted to regain control of the vessel, the *John S McCain* unintentionally turned to port into the path of the *Alnic MC*. As a result of the collision, 10 *John S McCain* sailors died, 48 were injured, and the vessel sustained over $100 million in damage. No one was injured on the *Alnic MC*, and the vessel sustained about $225,000 in damage. There was no report of pollution.

This report identifies the following safety issues: the decision to transfer the location of thrust control on board the *John S McCain* while the vessel was in a congested waterway, the lack of very high frequency communications between the vessels, the automatic identification system data transmission policy for Navy vessels, the procedures for the transfers of steering and thrust control on board the *John S McCain*, the training of Navy bridge watchstanders, the design of the destroyer's Integrated Bridge and Navigation System, Navy watchstanders' fatigue, and Navy oversight of the *John S McCain*.

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

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Acronyms and Abbreviations

AIS	automatic identification system
ARPA	automatic radar plotting aid
ASU	Aft Steering Unit
BCCS	Bridge Command and Control Station
BMOW	boatswain's mate of the watch
CIC	combat information center
CO	commanding officer
CPA	closest point of approach
ECDIS	electronic chart display and information system
EOCC	*Engineering Operational Casualty Controls*
EOSS	*Engineering Operational Sequencing System*
GMDSS	global maritime distress and safety system
GPS	global positioning system
GUI	graphical user interface
HFS	Helm Forward Station
hp	horsepower
HPU	hydraulic power unit
IBNS	Integrated Bridge and Navigation System
IMO	International Maritime Organization
JOOD	junior officer of the deck
JOOW	junior officer of the watch
NGA	National Geospatial-Intelligence Agency
NOAA	National Oceanic and Atmospheric Administration
NTSB	National Transportation Safety Board
OOD	officer of the deck

PA system	public address system
PQS	Personnel Qualification Standard
SCC	Ship Control Console
SMS	safety management system
SOLAS	*International Convention for the Safety of Life at Sea*
STCW Code	*Seafarers' Training, Certification and Watchkeeping Code*
SWO	surface warfare officer
TSS	traffic separation scheme
VDR	voyage data recorder
VHF	very high frequency
VMS	voyage management system
XO	executive officer

Executive Summary

On August 21, 2017, the US Navy destroyer *John S McCain* was overtaking the Liberian-flagged tanker *Alnic MC* while both vessels were transiting the westbound lane in the Middle Channel passage of the Singapore Strait Traffic Separation Scheme. The destroyer crew had a perceived loss of steering, and, while the crew attempted to regain control of the vessel, the *John S McCain* unintentionally turned to port into the path of the *Alnic MC*. At 0524, the vessels collided. As a result of the collision, 10 *John S McCain* sailors died, 48 were injured, and the vessel sustained over $100 million in damage. No one was injured on the *Alnic MC*, and the vessel sustained about $225,000 in damage. There was no report of pollution.

The National Transportation Safety Board determines that the probable cause of the collision between the destroyer *John S McCain* and the tanker *Alnic MC* was a lack of effective operational oversight of the destroyer by the US Navy, which resulted in insufficient training and inadequate bridge operating procedures. Contributing to the accident were the *John S McCain* bridge team's loss of situation awareness and failure to follow loss of steering emergency procedures, which included the requirement to inform nearby traffic of their perceived loss of steering. Also contributing to the accident was the operation of the steering system in backup manual mode, which allowed for an unintentional, unilateral transfer of steering control.

Safety issues identified in this accident include the following:

- The decision to transfer the location of thrust control on board the *John S McCain* while the vessel was in a congested waterway
- The lack of very high frequency radio communications between the vessels
- The automatic identification system data transmission policy for Navy vessels
- The procedures for the transfers of steering and thrust control on board the *John S McCain*
- The training of Navy bridge watchstanders
- The design of the destroyer's Integrated Bridge and Navigation System
- Navy watchstanders' fatigue
- Navy oversight of the *John S McCain*

As a result of this investigation, the National Transportation Safety Board makes new recommendations to the US Navy.

1 The Accident

1.1 Overview

In the early morning on August 21, 2017, the US Navy destroyer *John S McCain* was proceeding in the westbound lane of the Singapore Strait Traffic Separation Scheme (TSS) in bound for a port call in Singapore.[1] The Singapore Strait is one of the busiest waterways in the world. In 2016 alone, 83,740 vessels of over 300 gross tons transited the strait (numerous vessels of less than 300 gross tons, such as fishing vessels, also regularly transit the region on a daily basis).[2] The twin-propeller destroyer was on the outside (northern side) of the TSS lane, making a speed of about 18 knots and overtaking several slower commercial vessels that were also transiting westbound in the TSS. A single crewmember was at the helm of the ship, controlling both steering and propeller thrust from the helm operator position at the Ship Control Console (SCC), as ordered by an officer assigned to control maneuvering of the ship.

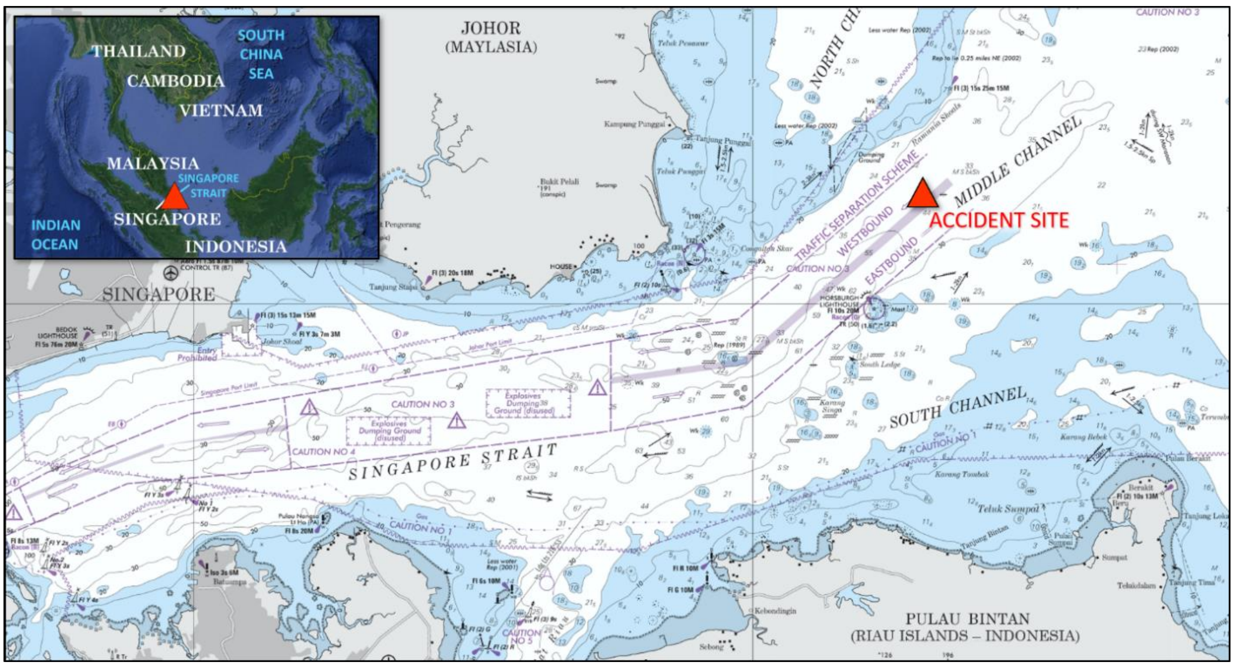

Figure 1. Accident area. (Adapted from National Geospatial-Intelligence Agency [NGA] Chart 71265; inset background by Google Earth Pro)

About 0520, the *John S McCain* commanding officer (CO), who was on the bridge, thought that the helmsman might become overwhelmed responding to steering and thrust commands as the ship maneuvered in the busy shipping lane. Consequently, he ordered a second watchstander—a lee helmsman—to take over responsibility for controlling the ship's propeller thrust.[3] Once the lee

[1] A *TSS* is a designated traffic-management system, adopted by the International Maritime Organization (IMO), that separates vessel traffic proceeding in opposite or nearly opposite directions by the use of a separation zone or line, traffic lanes, or other means. TSSs are generally located in areas of high traffic density.

[2] Hand, Marcus, *Seatrade Maritime News*, "Malacca and S'pore Straits traffic hits new high in 2016. VLCCs fastest growing segment," February 13, 2017, http://www.seatrade-maritime.com/news/asia/malacca-and-s-pore-strait-traffic-hits-new-high-in-2016-vlccs-fastest-growing-segment.html. Accessed October 3, 2017.

[3] *Lee helmsman* is a Navy term for a watchstander who controls thrust, as directed by higher authority—usually the conning officer. The position is generally manned during evolutions when numerous commands to change thrust are anticipated, such as when entering and leaving port, or when the CO deems it necessary. When the position is not manned, the helmsman controls both steering and thrust.

helmsman was in place, the controls for thrust had to be transferred from the helm station to the lee helm station on the SCC. The controls for each propeller had to be shifted one at a time, so the watchstanders began by transferring control of the port propeller about 0521.

Soon after control of the port thrust had been transferred to the lee helm station, the helmsman reported that he had lost control of steering. Without steering control, he could not maintain the *John S McCain*'s heading, and the vessel began to slowly turn to port. The loss of steering was announced over the destroyer's public address (PA) system, and crewmembers proceeded to the vessel's aft steering compartment while the bridge watch team attempted to regain control on the bridge.

About a minute later, control of the starboard propeller thrust was transferred to the lee helm station. Soon after, the CO directed the watch team to slow the ship. The officer of the deck (OOD) ordered the speed reduced to 10 knots and then to 5 knots.

John S McCain crewmembers manned the aft steering compartment (located near the stern of the ship), and after efforts to regain control of steering on the bridge failed, the aft steering watchstanders were ordered to take control. They took control, but control then shifted back to the bridge without explanation. After some confusion, the aft steering watchstanders retook control of steering. While the *John S McCain*'s crew struggled to regain steering, the destroyer's speed progressively decreased while its rate of turn to port increased, bringing the ship across the TSS lane in an increasingly tighter turn.

When the loss of steering was announced on board the *John S McCain*, the tanker *Alnic MC* was transiting in the westbound lane of the TSS, about three tenths of a mile off the destroyer's port side.[4] The single-propeller tanker was making a speed of about 9.5 knots. The master of the *Alnic MC*, who had control of maneuvering (the conn) of the ship, noted the *John S McCain* as it began its turn to port and initially assumed that the Navy ship would pass between his vessel and another vessel ahead of the *Alnic MC*. As the destroyer continued to turn into the path of his ship, he became increasingly concerned. At 05:23:44, he moved the *Alnic MC*'s engine order telegraph from full ahead to half ahead in order to slow his vessel. (He told investigators that he thought he put the engine order telegraph at engine stop, but, upon reviewing engine data after the accident, he learned that he had ordered a reduction to half ahead.)

Once positive control of the *John S McCain*'s steering was reestablished in aft steering, watchstanders moved the rudders to 15 degrees to starboard, as ordered from the bridge. However, this action and the action of the *Alnic MC* master to slow his vessel were not enough to prevent a collision, and, at 05:23:58, the bulbous bow of the tanker struck the port side of the *John S McCain*. The impact breached the hull of the *John S McCain* in a berthing compartment where crewmembers were sleeping, killing 10 sailors. About 3 minutes had elapsed between the reported loss of steering on the *John S McCain* and the collision.

[4] All miles in this report are nautical miles (1.15 statute miles).

1.2 The Vessels

1.2.1 *John S McCain*

The *John S McCain,* a US Navy *Arleigh Burke*-class destroyer homeported in Yokosuka, Japan, was built by Bath Iron Works in Bath, Maine, and commissioned in 1994. According to Navy information, vessels of the class have a full load displacement of 8,261 long tons (8,394 metric tons), a length overall of 504.5 feet (153.8 meters), a beam of 66.4 feet (20.2 meters), and a draft of 32.5 feet (9.9 meters).[5] On the accident date, the vessel had a crew of 280.

Figure 2. *John S McCain* preaccident. (Photo by Navy Mass Communication Specialist Seaman Apprentice Gavin Shields)

Arleigh Burke destroyers have two controllable/reversable-pitch, outboard-turning propellers, which are each driven by two 30,000 horsepower (hp) General Electric LM2500 gas turbine engines. The speed of the vessel is controlled by a combination of propeller shaft rpm and propeller blade pitch. The vessels have two rudders, one behind each propeller, that operate in tandem–that is, they are not operated independently.

The *John S McCain*'s propulsion and steering were controlled via a Northrop Grumman Maritime Systems Integrated Bridge and Navigation System (IBNS). The IBNS was a relatively new system on the ship, having been installed in 2016. Through the IBNS, propulsion and steering could be controlled from four different locations on the bridge: the Helm Forward Station (HFS), the Bridge Command and Control Station (BCCS), and the helm and lee helm operator stations at the SCC. Additionally, steering could be controlled from the Aft Steering Unit (ASU) station, located in the ship's aft steering compartment.

[5] US Navy, *The US Navy Arleigh Burke Class Destroyer*, 2017, http://www.public.navy.mil/surfor/Pages/Arleigh-Burke-Destroyer.aspx, accessed July 6, 2018.

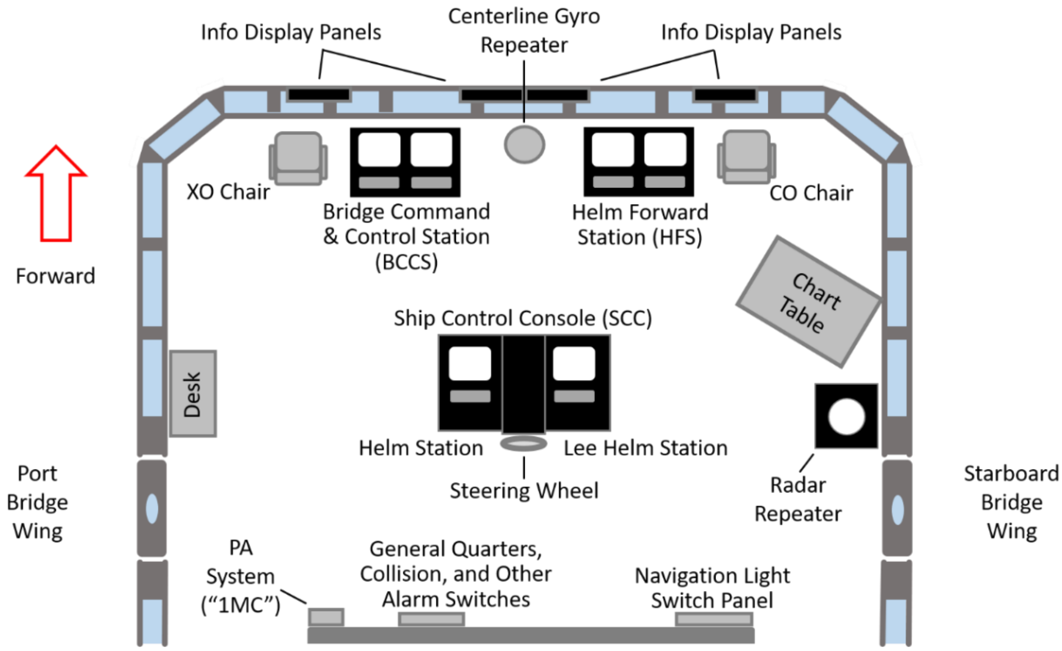

Figure 3. *John S McCain* bridge layout with IBNS control stations. (Illustration not to scale; some equipment not relevant to the accident has been eliminated.)

The bridge control stations contained flat-panel touch screens, and the helm and lee helm stations of the SCC each had a touch screen. (The touch screens at the helm and lee helm stations were identical.) A graphical user interface (GUI) displayed on the touch screen allowed the operator to enter commands for steering and thrust.

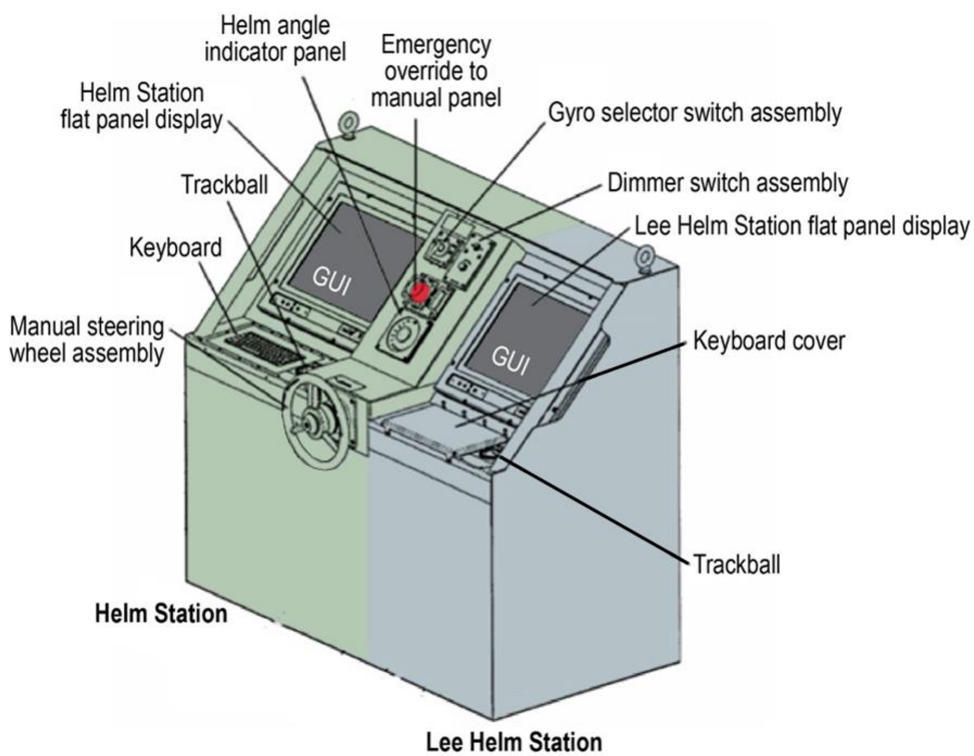

Figure 4. *John S McCain* SCC. (Drawing from IBNS technical manual; color added by NTSB)

The GUI display was divided into regions. In one region of the display, readouts showed the location of the station in control of steering and the mode of steering that was in use. Selecting a button next to the location readout opened a menu on the display that was used to transfer the location of steering control. Selecting a button next to the mode readout activated a menu that was used to change the steering mode.

Figure 5. Steering control region of IBNS GUI display, with opened steering location menu. (From US Navy photo)

Another region on the GUI display had a gyrocompass repeater and a rudder order/angle indicator. Buttons on the display and a rudder on the screen allowed the operator to move the rudders to port or starboard (steering commands could also be manually inputted by a physical wheel at the SCC helm station).

Another region on the GUI display had readouts showing which station was in control of thrust for each propeller and what the currently ordered propeller pitch and rpm were. Selecting a button next to the station readout activated a menu that was used to transfer the control location for each propeller.

The ASU also had a flat-panel display and a physical steering wheel. The ASU was normally used only during an emergency or emergency drill when steering control on the bridge was lost.

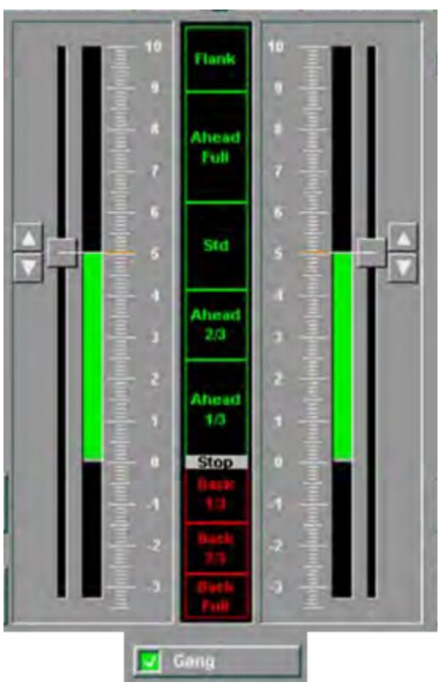

Figure 6. Port and starboard throttles and gang button on IBNS GUI display. (Image from IBNS technical manual)

The thrust for each shaft and the speed of the vessel could be controlled by moving a graphical depiction of a throttle on the GUI display. The throttle for each shaft was independent of the other, but the display allowed the throttles to be linked, or "ganged." When ganged, the movement of one throttle would also move the other throttle by the same amount (both propellers thrust equally).

At sea, where frequent changes to the thrust were not anticipated, control of both steering and thrust was normally located at the SCC helm station, and the helmsman steered the ship using the steering wheel and controlled thrust using the flat-panel display.

The *John S McCain* had five modes to control steering of the vessel. Four of the modes used computers to assist in manual or automatic (autopilot) steering, with the computer-assisted manual mode being the most commonly used mode. The fifth mode of steering was the backup manual mode. It used the same form of communication as the other modes but did not use a computer to assist in steering the ship. Backup manual mode was only available at the SCC helm and ASU stations.

Figure 7. *John S McCain* emergency-override-to-manual button on the SCC.

Separate from the touch screen display controls, the SCC helm station and the ASU each had a steering *emergency-override-to-manual* button (also called the “big red button” by Navy crewmembers). When the button was pressed at the SCC helm or ASU station, steering control would immediately transfer to that station and the steering mode would simultaneously change to backup manual.

Transfer of Thrust Control. The transfer of thrust control between stations on the bridge, such as between the helm station and lee helm station, was normally accomplished via a “coordinated” procedure.[6] During a coordinated station transfer, menus on the GUI display allowed the operator at the station relinquishing control of thrust to offer control—one shaft at a time—to another station. The station operator relinquishing control selected the gaining station in the menu for the first shaft being offered and then verified the selection. This caused an indicator to blink on the GUI display at both stations. The gaining station operator then acknowledged and verified the transfer of control via the GUI display at his station. After these actions were completed, the indicators at both stations would stop blinking. The transfer process was then repeated for the second shaft.

A station operator wishing to gain control could also request control via a similar procedure. To request thrust control from another station, the process stated above was reversed. The procedure for a coordinated thrust transfer between bridge stations was provided in the IBNS technical manual, but it was not provided in the operating procedures manual, known as the *Engineering Operational Sequencing System* (EOSS), held on station at the SCC and ASU.

Transfer of Steering Control. The two primary procedures for transferring steering from one bridge control station to another were the “coordinated” station transfer and the “emergency” station transfer. The coordinated procedure could only be made if steering was in one of the computer-assisted modes of steering (backup manual was not one of the computer-assisted modes) and was a two-step process for both the gaining and relinquishing stations, similar to the procedure for a coordinated thrust transfer. The procedure for a coordinated steering transfer between bridge stations was provided in the IBNS technical manual, but it was not provided as an underway operating procedure in the EOSS manual held on station at the SCC and ASU.[7]

An emergency station transfer was a unilateral transfer and could only be made at the SCC helm station or ASU by pressing the emergency-override-to-manual button at the station. The procedure was provided in the IBNS technical manual and was included in the emergency procedure for loss of steering contained in the emergency procedures manual, known as *Engineering Operational Casualty Controls* (EOCC), held on station at the SCC and ASU.

[6] In addition to the coordinated procedure, a unilateral procedure, in which one station could take control of thrust from another station by action of only one station, was also available. However, the unilateral procedure is not relevant to the accident and will not be discussed further in this report.

[7] The EOSS procedure for aligning the steering system prior to getting under way included a procedure for transferring control from the SCC helm station to the HFS, but no procedure for transferring control between stations while under way was included in the manual.

Per the technical manual and as demonstrated to National Transportation Safety Board (NTSB) investigators on another Navy destroyer equipped with the IBNS, at any time that steering was in backup manual mode, a watchstander at any of the other stations could unilaterally take steering control. When this occurred, the steering mode automatically shifted to the computer-assisted manual mode, and control shifted to that station. This type of transfer was noted in the IBNS technical manual, but it was not provided as a standard procedure.

At the SCC helm station and ASU—stations equipped with a physical steering wheel—the positions of the rudders after a steering control transfer were determined by the position of the gaining station's wheel. This was the case for both computer-assisted and backup manual modes. For stations without a wheel, the rudders moved to 0 degrees after the transfer.

Information display panels were mounted in the forward overhead of the *John S McCain*'s bridge. The screens on each display panel could be individually configured to provide maneuvering and operating parameters, including the rudder input from the steering location, the actual rudder positions, and the pitch and rpm for the propellers. Smaller display panels were also installed on each bridge wing.

1.2.2 *Alnic MC*

The *Alnic MC* was a Liberian-flagged chemical tanker owned by Energetic Tank Inc. and operated by Stealth Maritime Corporation SA. Built in 2008 in South Korea, the vessel was classified by Bureau Veritas.[8] It had an overall length of about 600 feet (183 meters), a beam of 105.5 feet (32.2 meters), a full load displacement of 59,665 long tons (60,622 metric tons), and a full load draft of 42.8 feet (13 meters). On the date of the accident, the vessel was carrying a partial load of cargo, along with ballast water and fuel, giving it a displacement of about 37,200 long tons (37,800 metric tons) and an arrival draft of about 27.1 feet (8.3 meters). The *Alnic MC* had a crew of 24.

Figure 8. *Alnic MC* after the accident. (Photo by US Coast Guard)

[8] *Classification societies* such as Bureau Veritas are nongovernmental organizations that establish and maintain standards for shipbuilding and operations. They may also be delegated by a flag state to perform certain flag-state vessel inspection and certification functions.

The *Alnic MC* was powered by a MAN B&W 6550MC-C slow speed diesel engine, which produced 12,900 hp, directly coupled to a single fixed-pitch propeller. It had a single rudder mounted behind the propeller. The vessel was steered from the bridge via a standing helm console. Steering could be operated in manual, autopilot, and non-follow-up modes.[9] Engine orders from the bridge were transmitted to the engine control room by an engine order telegraph mounted on a separate console.

Figure 9. *Alnic MC* bridge and control equipment. (Photos by Coast Guard)

1.3 Preaccident Events

1.3.1 *John S McCain*

The *John S McCain* left its homeport on May 26, 2017, for a scheduled deployment in the western Pacific, which included a visit to Singapore beginning on August 21. Between 1300 and 1400 on the day before arrival in Singapore, a navigation brief for entering a shipyard in the port was held on board the destroyer. The briefing document was reviewed by the executive officer (XO)—the vessel's second in command—and approved by the CO. Contents of the brief included the watchbill (a listing of watchstanders for the arrival); a schedule of events; weather, tidal, current, and astronomical data; operational (readiness) requirements; chart data; pilot and tugboat information; courses and waypoints; ground tackle and emergency anchorage information; the status of navigational equipment; the internal and external communication plan; how the engineering plant was to be configured; steps to take for emergencies related to a loss or malfunction of equipment and machinery; and an operational risk management plan. Emergency

[9] In *follow-up* mode, the rudder (or rudders) in a steering system will move to the angle that the input device (usually a steering wheel) is set to. In *non-follow-up* mode, the rudder will move in the direction that the input device (commonly a lever) is turned to, either to port or starboard, and continue to move in that direction until the input device is re-centered or the rudder hits the stops.

procedures included actions for the helmsman to complete if a loss of steering was encountered. Between 1305 and 1326, vessel personnel satisfactorily completed a test of the destroyer's steering system.

At 0115 on August 21, the CO of the *John S McCain* came to the bridge because he expected traffic to be heavy and that he would be called often to come to the bridge. He did not take the conn of the vessel. At the time, the destroyer was in "trail shaft" engine configuration. In this configuration, which provided maximum efficiency, only one gas turbine engine provided thrust via one shaft, with the unpowered shaft turning freely as water passed over the propeller blades.

Between 0145 and 0205, a total of nine underway bridge watchstanders, augmented by combat information center (CIC) watchstanders, took control of the navigation and maneuvering of the *John S McCain* as part of the 0200–0700 watch, per the underway watchbill. The helmsman steered the ship and changed propulsion settings (using the wheel for steering inputs and SCC helm station GUI display for propulsion inputs), under orders given by the conning officer. The conning officer, in turn, received helm and propulsion orders from the OOD. A boatswain's mate of the watch (BMOW) had direct oversight of the helmsman, making sure the latter performed as directed.

According to the *John S McCain*'s engineering log, the starboard propeller shaft was brought on line about 0215, bringing the propulsion system to "split plant" configuration. The ship now had both propellers providing thrust, with each propeller shaft being driven by a single gas turbine engine. At 0418, three additional bridge watchstanders joined the bridge watch team under a "modified navigation watch."

At 0436, the *John S McCain*'s CO ordered the steering mode to be switched from computer-assisted manual to backup manual at the SCC helm station. The CO preferred backup manual mode when the ship was docking or undocking, and he stated that the change on the morning of the accident was made to mitigate risk by using a "more direct form of communication between steering and the SCC."

1.3.2 *Alnic MC*

The *Alnic MC* left the port of Mai Lao, Taiwan, on August 15, 2017, with a partial load of pyrolysis fuel oil.[10] The vessel was bound for Singapore with an estimated time of arrival of 1900 on August 21. Deck log entries and checklists showed that the tanker's personnel completed a risk analysis for voyage monitoring, voyage planning, and pilotage on August 15 and satisfactory checks of the vessel's navigation equipment and steering system at 1600 on August 20 and again at 0400 on August 21.[11]

[10] *Pyrolysis fuel oil* is a dark, viscous liquid used as a raw material for the manufacture of carbon black; it can also be used as a low-sulfur fuel oil. Source: MatWeb/Material Property Data, http://www.matweb.com/search/datasheettext.aspx?matguid=e7b56aef221c4c01aab3f8b63cf2f027, accessed July 7, 2018.

[11] In a legal deposition taken in May 2019, the ship's second officer stated that the navigational equipment and steering system checks that were logged on August 21 had not, in fact, been conducted.

At 0000 on August 21, the *Alnic MC* was on a base course of about 193 degrees at a speed of 11.3 knots. About 0400, the 0400–0800 deck watch took over from the 0000–0400 watch. The watch team was composed of the chief mate as the officer in charge of the navigation watch, an able-bodied seaman who could steer the ship but was serving as a lookout because the vessel was in autopilot steering, and an ordinary seaman who also served as a lookout.

The safety management system (SMS) for the *Alnic MC*'s operating company provided guidance for the composition of a bridge watch under varying underway situations. Based on those situations, different watch conditions were developed to increase bridge manning. In open waters with good visibility and little traffic, Watch Condition 1 was used. This watch condition required one licensed officer of the watch and one or two ratings. In open waters in clear visibility with heavy traffic, Watch Condition 2 was set. Watch Condition 2 required two officers and two ratings on watch. One of the officers had to be the master or chief mate, who conned the vessel and supervised the watch. The other officer primarily concentrated on collision avoidance, communications, and navigation. The two ratings could be two able-bodied seamen or one able-bodied seaman and one ordinary seaman. The ratings steered and performed lookout duties.

Watch Condition 3 was generally set during times of low visibility and heavy vessel traffic, when the vessel was in restricted waters, when entering or leaving port, or in certain designated geographic areas of the world, including the Singapore Strait. Manning under Watch Condition 3 was increased from Watch Condition 2 by adding one additional bridge officer. One bridge officer was responsible for collision avoidance and the other handled communications and navigation duties. The master or chief mate and the ratings performed the same functions as in Watch Condition 2.

About 0405, the master came to the bridge and assumed the conn. In addition to the master, the *Alnic MC* now had one deck officer and two deck ratings on the bridge. According to the deck log and the chief mate's statement, the vessel was in Watch Condition 2. The ordinary seaman serving as lookout stated that, at some point prior to the accident, he felt sick, so he went below and did not return until after the collision.

1.4 Accident Events

According to the *John S McCain*'s plan of the day, reveille for applicable personnel was at 0500, breakfast was served between 0500 and 0600, and the "sea and anchor detail"—the condition of augmented manning used for arrivals and departures from port— for the entry in to Singapore was set to begin at 0600. The sea and anchor detail included a master helmsman, a designated lee helmsman, and a helm safety officer.[12]

About 0510, a crewmember (who was not assigned to the watch) was directed to go to the bridge to relieve the 0200–0700 watch helmsman so that the on-watch helmsman could eat breakfast before the sea and anchor detail was set. About 0515, the crewmember arrived on the bridge, and, a few minutes later, he relieved the helmsman. Shortly before the change of helmsmen occurred, the CO decided to man the lee helm station so that the helmsman, who was controlling both steering and propulsion from the helm station, could concentrate on steering alone. Instead of bringing another person to the bridge to man the lee helm station, the relieved helmsman (the one

[12] A *master helmsman* is a Navy watchstander who has an additional qualification and more experience steering the vessel than a standard helmsman. A *helm safety officer* is an officer assigned to observe the helmsman and lee helmsman to ensure that they properly respond to maneuvering orders. A master helmsman and helm safety officer are normally assigned during higher risk maneuvering operations, such as entering and leaving port.

who was to go below to eat breakfast) was redirected to take the lee helm position and control the ship's propulsion.

At 0518, the *Alnic MC* entered the westbound Singapore Strait TSS lane, traveling on a southwesterly course, near the border of the traffic separation zone. The chief engineer told investigators that the engine was in maneuvering mode and that he was in the engine room at the time (as required by the SMS when the ship was in maneuvering mode).[13]

About 4 minutes later, the *John S McCain* entered the TSS and was at the northern extremity of the westbound traffic lane transiting at a speed of 18 knots. At the time, the *Alnic MC* was 45 degrees off the destroyer's port bow at a distance of about 0.6 miles and moving at 9.5 knots at a full ahead engine order. Other vessels in the vicinity, as shown on radar images from the tanker's voyage data recorder (VDR), included the tanker *Team Oslo* moving at 11.0 knots close to and just forward of the *Alnic MC*'s starboard bow, the *Guang Zhou Wan*, also a tanker, traveling at 12.0 knots about 0.5 miles off the port quarter of the *John S McCain* and about 0.4 miles astern of the *Alnic MC*, and the large containership *Hyundai Global*, which was astern and to port of the *Alnic MC* and making speed (16 knots) to overtake the *Alnic MC*.[14]

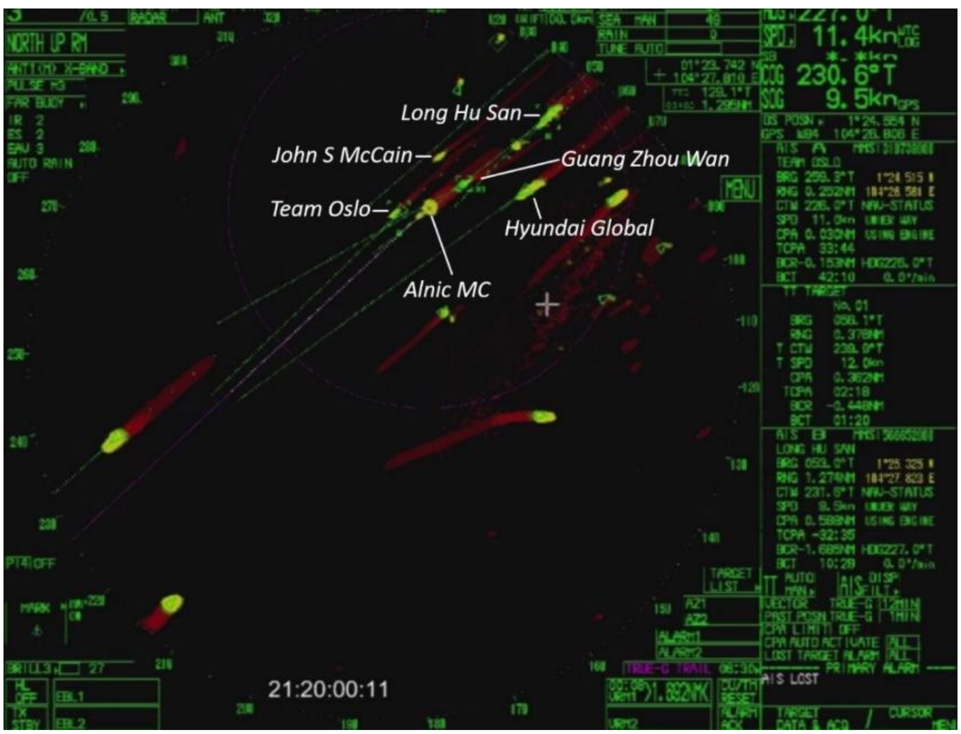

Figure 10. Screen capture from *Alnic MC* automatic radar plotting aid (ARPA) at 0520 on the morning of the accident. (Ship name labels added by NTSB)

[13] When transiting in open ocean at "sea speed," commercial vessels with slow-speed diesel direct-propulsion engines have limited ability to change engine speeds on demand. The engine room may or may not be manned while the vessel is at sea speed. When a range of engine orders is required, such as when entering and leaving port, the vessel's engine is placed in *maneuvering mode*. The engine room is generally manned when in maneuvering mode, and the engine is able to respond to orders (full, half, slow and dead slow ahead, as well as astern orders).

[14] *VDR*s maintain continuous, sequential records of data relating to a ship's equipment and its command and control and capture bridge audio from certain areas on the bridge and on the bridge wings. Regulation 20 of the *International Convention for the Safety of Life at Sea* (SOLAS) Chapter V requires all passenger ships and all cargo ships of 3,000 or more gross tons (International Tonnage Convention), built on or after July 1, 2002, to carry VDRs.

All of the vessels were moving in a southwesterly direction, generally conforming to the axis of the western lane of the traffic scheme. The *Alnic MC* master told investigators that he was aware of a navy warship in the area, having heard the Singapore pilot station attempt to hail the destroyer over very high frequency (VHF) radio. He saw a vessel on his radar screen that was abaft his beam on the starboard side and noted that it was "overtaking some of the ships . . . the trail [of the vessel] was really quite long."[15] Given the apparent speed of the vessel, he assumed that it was the navy ship. VDR presentations from the *Alnic MC*'s X-band radar showed radar returns for numerous ships (contacts) around the tanker, including the *John S McCain*. Although many of the contacts had been acquired and were being tracked by the *Alnic MC*'s automatic radar plotting aid (ARPA), the destroyer had not been acquired by the system. The master stated that he was using the tanker's S-band radar and attempted to acquire the destroyer "a couple of times, but it would not hold." He said that when he went out to the starboard bridge wing, he visually sighted the destroyer.

At this time, the *Alnic MC*'s course was about 227 degrees and the *John S McCain*'s course was about 230 degrees. Data from the destroyer's automated steering log showed that the helmsman was using up to 5 degrees of starboard rudder to keep the destroyer on this course.[16]

Once the lee helmsman was in place aboard the *John S McCain*, the BMOW assisted the watchstanders with shifting control of propulsion from the helm station to the lee helm station on the SCC. The BMOW began the transfer by pressing the buttons on the SCC helm station GUI display to shift the port propeller. According to the helmsman, they completed a smooth transition of port thrust from the helm to lee helm station. The automated thrust log showed that the transfer of port shaft thrust was completed sometime between 05:20:32 and 05:20:48.[17] The throttles had been ganged prior to the transfer; however, during the process of transferring control of each shaft one at a time, the system automatically unganged the throttles.

Shortly after the transfer of the port shaft, the helmsman reported a loss of steering. The helmsman told investigators, "[The rudder] started moving on its own, and I couldn't move it…Normally, during lost steering there would be an alarm indicating lost steering but there was no alarm at all." Although the crew had intended to transfer control of only the propellers to the lee helm, video footage of the ASU station display in the aft steering compartment showed that, at 05:20:39, the mode of steering changed from backup manual to computer-assisted manual and control of steering changed from the helm to the lee helm station. Control of the port shaft and steering was now at the lee helm station, while control of the starboard shaft remained at the helm station. Just prior to the shift in steering control, the rudders had been at 3 degrees starboard, as inputted by the helmsman. As shown in the aft steering video, when steering control was shifted to the lee helm station, the rudder angles immediately moved to 0 degrees. (Steering and thrust logs confirmed the system response and characteristics as seen in the aft steering video.)

According to the *John S McCain*'s emergency procedures and other written directives, the helmsman's first action in response to a loss of steering was to press the emergency-override-to-manual button. This action would have shifted steering to the helm station in the backup manual

[15] A *trail* is a simulated afterglow that follows a radar contact displayed on an automatic radar plotting aid (ARPA). The direction and length of the trail provides the operator an indication of the course and speed, respectively, of the vessel being tracked by the radar.

[16] The steering log recorded parameters of the steering system.

[17] Thrust logs recorded propulsion parameters. The steering log and thrust log readings were not synchronized.

mode. However, the helmsman told investigators that, during the accident, he did not press the emergency-override-to-manual button because he believed that this sent steering control to aft steering (an opinion shared by other bridge watchstanders interviewed by investigators). The OOD told investigators that she did not order the helmsman to press the emergency-override-to-manual button because the steering system was already in the backup manual mode. Instead, she ordered the conn, who in turn ordered the helmsman, to switch hydraulic power units (HPUs).[18] The helmsman told investigators that he tried to switch HPUs from the SCC helm station, but he "could not gain control of them." The steering log showed that steering control remained at the lee helm station in computer-assisted mode for over 2 minutes, until 05:23:02.

In the 1-minute time span from 05:21:19.5 to 05:22:19.5, the *John S McCain*'s heading changed 13.3 degrees to port, toward the *Alnic MC*. The destroyer's rudder angle remained at 0 degrees during this time. According to radar pictures downloaded from the *Alnic MC*'s VDR, the destroyer was nearly abeam of the *Alnic MC* when it began to move toward the tanker.

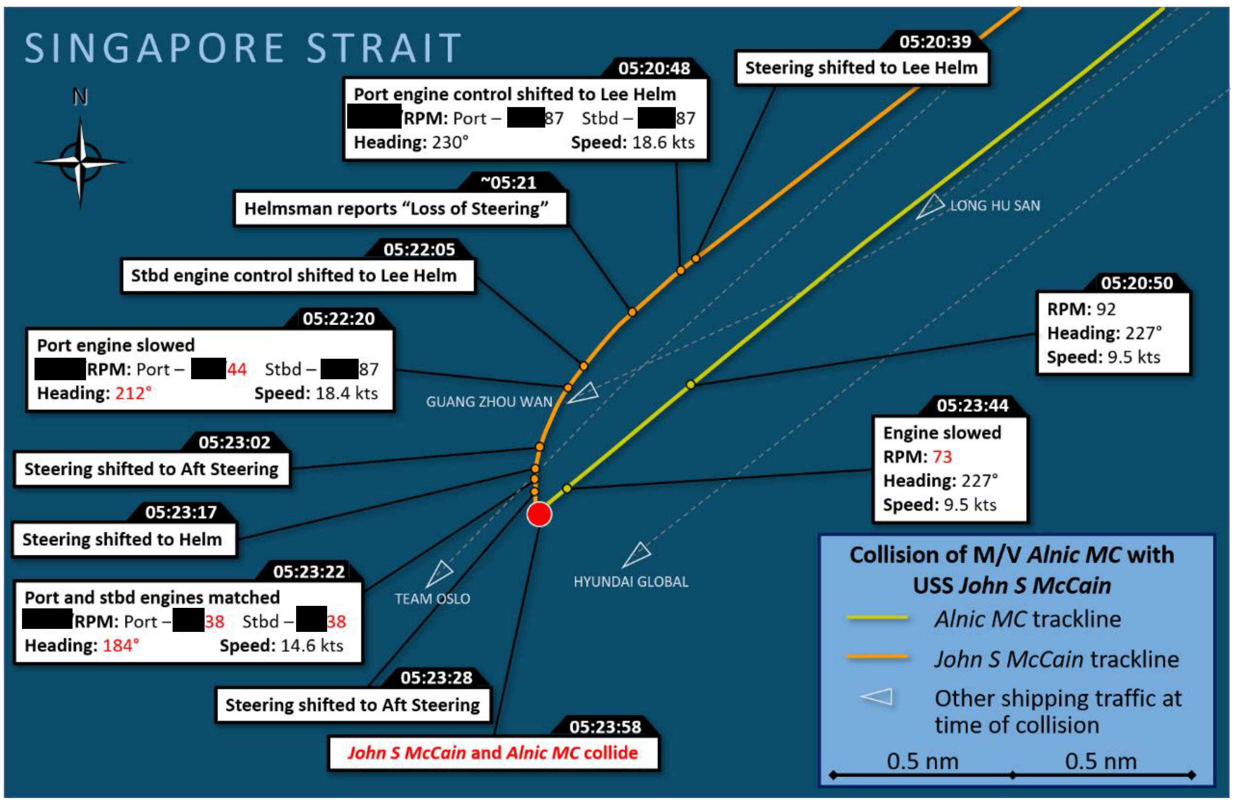

Figure 11. Vessel tracks and accident events.

When the loss of steering was announced by the helmsman, the BMOW left the SCC and, as directed by the OOD, went to the PA system to inform the crew so that personnel could head aft to man the aft steering station. Shortly thereafter, *John S McCain* crewmembers began to arrive in aft steering.

According to the thrust log, by 05:22:05, control of the starboard propeller was shifted from the helm to the lee helm station. The lee helmsman told investigators that he shifted control of the starboard shaft himself by reaching over to the helm station, initiating the transfer of control

[18] HPUs, which include pumps and associated control equipment, direct hydraulic oil to large pistons linked to the rudder post to physically position the rudder at the ordered angle.

on that display, and then completing the actions on the lee helm station display. He said that he had to transfer control himself because the helmsman and BMOW were responding to the loss of steering. Throughout the time that control of thrust had been split between the helm and lee helm stations, the pitch and rpm for both propellers remained the same ([redacted] 87 rpm), providing thrust for the ordered ahead speed of 18 knots. The lee helmsman told investigators that he re-ganged the throttles after he transferred control of the starboard shaft.

The *John S McCain* CO's standing order for "Emergency Steering Procedures" directed the OOD to "display the appropriate day shapes/navigation lights for a ship not under command [in accordance with] COLREGS."[19] According to several crewmembers interviewed after the accident, the CO directed watchstanders to illuminate the not-under-command lighting (two all-round red lights in a vertical line near the top of the destroyer's mast), and the junior officer of the watch (JOOW) stated that he confirmed that the lights were on prior to the collision. During interviews, the bridge team aboard the *Alnic MC* (the master, chief mate, and able-bodied seaman) reported that, prior to the collision, they only saw standard navigation lights on the destroyer and not the not-under-command lights.[20] "Red-over-red lighted" was not logged in the *John S McCain*'s deck log until 0534, about 10 minutes after the accident.

The CO's standing order for a steering casualty also directed the OOD to, "If risk of collision exists, inform those vessels via [VHF radio] that JSM has sustained a steering casualty." The *Alnic MC*'s VDR audio recorded no VHF radio warning from the destroyer to other ships in the area, and crewmembers on the *John S McCain* did not recall making radio calls before the collision occurred.

The CO's standing order further instructed the OOD to "slow to bare steerage way (when practical) and attempt to maneuver to safe waters using engines." As the bridge team attempted to regain control of steering, the CO directed the ship to be slowed. The OOD told investigators that the CO did not specify a speed to slow down to, so she ordered a speed of 10 knots.[21] The lee helmsman stated that he reduced the throttle on the port shaft corresponding to the ordered speed using the GUI display, and that because the throttles were ganged, thrust was reduced for both shafts. The thrust log showed, however, that only the port throttle was reduced in response to the order for 10 knots. The port shaft slowed, from 87 rpm to 44 rpm, at 05:22:20, but the starboard shaft remained at 87 rpm. At this time the vessel's rate of turn to port began to increase, toward the *Alnic MC*. The destroyer's automated log showed the heading changed 27.2 degrees over the 1-minute time span between 05:22:19.5 and 05:23:19.5.

Following the PA system announcement by the BMOW, the *John S McCain*'s aft steering had been manned, and watchstanders in the space established communications with the bridge. The CO ordered aft steering to take control of steering, and the aft steering watchstanders pressed the emergency-override-to-manual button at the ASU station. The steering log showed that steering control shifted from the lee helm station to the ASU station by 05:23:02 and that the

[19] *72 COLREGS* is the abbreviation for the *International Regulations for Preventing Collisions at Sea, 1972*. *Not under command* is defined in the 72 COLREGS as "a vessel which through some exceptional circumstance is unable to maneuver as required by the regulations and is therefore unable to keep out of the way of another vessel."

[20] On a US Navy destroyer, the standard navigation lights, as viewed from the port side, are a red running light, located below the port bridge wing, and fore and aft white masthead lights.

[21] It was unclear from crewmember statements who issued the order to the lee helmsman to reduce speed. During his interview with investigators, the conning officer did not recall ordering the ship's speed reduced until after the collision. However, according to statements by the CO, OOD, and conning officer, the conning officer retained the conn (and thus the authority to issue thrust orders) throughout the accident sequence.

steering mode changed to backup manual. Aft steering watchstanders tested for control and reported that they had control.

About the same time, however, the helmsman pressed the emergency-override-to-manual button at the SCC console on the bridge. He stated that, "We hit the emergency override button to switch over to aft steering." This action took steering control back on the bridge at the SCC helm station, which was recorded on the steering log at 05:23:17.

At some point, the helmsman, who was now being helped by the sea and anchor detail BMOW who had arrived on the bridge (but had not yet taken the watch), realized that he had control of steering. The oncoming BMOW stated, "we announced that we had positive rudder control at the helm."

While steering was being shifted between stations, the CO and the conning officer moved to the port bridge wing. They saw the *Alnic MC* off the port side and, after hearing the steering control was at the SCC helm station, the CO ordered "right standard" (starboard 15 degrees) rudder. The conning officer repeated the order to the helmsman. The CO then ordered the destroyer to be slowed to 5 knots. At 05:23:22, 36 seconds before the collision, the *John S McCain*'s thrust log showed that the thrusts from both the port and starboard shafts were reduced to the same value—[redacted] 38 rpm, which corresponded to the ordered speed.

The helmsman acknowledged the conning officer's rudder order, but before he could move the rudders to right 15 degrees, control was again transferred to aft steering. The aft steering watchstanders told investigators that when steering control shifted to the bridge, the aft steering watchstanders had requested and were given permission to take back control. By 05:23:28, as recorded in the steering log, aft steering had taken control in computer-assisted manual mode.

At the time that control was reestablished in aft steering, the steering log recorded that the rudder input at the ASU station steering wheel was 33 degrees to port. The actual rudder positions as recorded were each about 1 degree to port, and it is unclear how far the rudders moved in response to the port rudder input. (Because the rudders are large surfaces moved by hydraulic machinery, the movement of the rudders will lag behind the rudder input, with the lag time dependent on the amount of change in the rudder position.) However, several watchstanders on the bridge stated that the rudders reached as far as 15 degrees to port. Aft steering watchstanders immediately corrected the rudder input to 15 degrees to starboard, and the next steering log entry, at 05:23:43, recorded the rudder input and rudder positions at 15 degrees to starboard. The rudders remained there until after the collision.

On board the *Alnic MC*, the master saw the *John S McCain* overtaking his vessel on the starboard side. He told investigators that he noted the destroyer as it turned to port, but, considering the speed and maneuverability of a warship, he presumed that it intended to pass between his ship and the tanker *Team Oslo* ahead of him. At 05:23:02, the *Alnic MC*'s VDR recorded a voice on the tanker's bridge stating, "This guy thinks he can cut through." After the accident, investigators reviewed a playback of the accident sequence on the *Alnic MC*'s electronic chart display and information system (ECDIS). The computer-calculated closest point of approach (CPA) of the *John S McCain* to the *Alnic MC*, as displayed on the ECDIS, was never observed to be less than

.18 miles (1094 feet), with the time of CPA varying between +6 and +24 seconds, prior to the collision.[22]

When it became apparent to the *Alnic MC* master that the *John S McCain* would not pass ahead of his vessel, he went over to the tanker's engine order telegraph to reduce the engine speed. He stated that he thought at the time that he had placed the engine order on stop, but he acknowledged, after reviewing the VDR data postaccident, that he had put the engine order on half ahead. According to the *Alnic MC*'s VDR, at 05:23:44 the tanker's shaft speed was reduced to 73 rpm, which corresponded to half ahead, while the vessel remained on a heading of 227 degrees. By this time, the *John S McCain*'s heading was 177 degrees, and its speed was 11.8 knots.

With the *John S. McCain*'s rudder at starboard 15 degrees, the vessel's heading began to shift to starboard, but by that time, the collision could not be averted. Based on the aft steering video from the destroyer, the *Alnic MC* impacted the *John S McCain* at 05:23:58. Seconds later, numerous electronic alarms were recorded on the tanker's VDR bridge audio, and someone from the *Alnic MC* called out "navy ship, navy ship, *Alnic MC*, *Alnic MC*" over the VHF radio (no response from the *John S McCain* was recorded on the tanker's VDR). The bulbous bow of the *Alnic MC* had struck the *John S McCain* at the waterline aft of midships on the port side. The destroyer's hull was breached, causing flooding in several spaces, including berthing areas where Navy sailors were sleeping. After the collision, the *John S McCain* crew made efforts to minimize progressive flooding, ascertain the extent of the damage, rescue personnel, and triage the injured.

1.5 Navigation Equipment

1.5.1 *John S McCain*

The *John S McCain* had an ECDIS and an ARPA that together were a subsystem of the IBNS. The ECDIS/ARPA subsystem received data from the global positioning system (GPS), C-band and X-band radars, and other sources, and included software to assist with the management of surface traffic affecting the vessel's safe movement. The subsystem also included a voyage management system (VMS) used for voyage planning and navigation.

The *John S McCain* was fitted with an automatic identification system (AIS). AIS is a maritime navigation safety communications system that automatically transmits information, including the vessel's name, type, position, course, speed, navigational status, and other safety-related information, to appropriately equipped shore stations, other vessels, and aircraft. AIS also automatically receives information from similarly equipped vessels. Other vessel AIS information can be integrated and displayed on commercially available ECDIS and ARPA systems. The *John S McCain*'s AIS could be configured in broadcast or receive-only modes. In receive-only mode, the destroyer received AIS information about other vessels in the area but did not transmit its own data. Per Navy policy at the time of the accident, naval vessels were not permitted to broadcast AIS information to other vessels but could receive information from other vessels. The *John S McCain*'s AIS was set to receive-only during the accident voyage.

[22] The CPA, calculated by the ARPA, was noted by investigators during the postaccident playback of information recorded by the ECDIS; however, investigators could not determine which of the *Alnic MC*'s radars was used by the ARPA to calculate the CPA or the parameters (such as the time span over which the CPA was calculated) that the ARPA used to calculate these values. Also, there is no evidence that the master was viewing this information during the accident sequence or used the information in his decision making.

1.5.2 *Alnic MC*

Bridge equipment on the *Alnic MC* included ECDIS and ARPA systems that received data from GPS, S-band and X-band radars, and other sources; a global maritime distress and safety system (GMDSS) suite with VHF radios; and an AIS. AIS is required on board all commercial vessels 300 gross tons or more operating on international voyages, and the *Alnic MC*'s AIS was transmitting and receiving information at the time of the accident.

1.6 Personnel

1.6.1 *John S McCain*

At the time of the accident there were no less than 14 crewmembers on the bridge of the *John S McCain*. Some were part of a detailed watchbill (assignment list) and some were in addition to the requirements of the watchbill. All assigned personnel were qualified under the Navy's Personnel Qualification Standard (PQS) for the positions they were assigned. The backgrounds, training, and actions of the crewmembers who had a role in this accident are as follows:

Commanding officer. The CO was in overall charge of the vessel. He was commissioned in 1998 and had held numerous shipboard positions, including damage control assistant and chief engineer, on various ships throughout his career in the Navy. He joined the *John S McCain* on April 20, 2015, first serving as XO before taking command on September 21, 2016. His positions immediately prior to reporting to the ship as XO were at shoreside commands. The CO came to the bridge at 0115 on the accident date.

Executive officer. The XO was second in overall charge of the ship and was responsible to the CO for ensuring the vessel's readiness. He had enlisted in the Navy in 1989, became a fire controlman (a missile and radar technician), and completed a number of ship and shore tours under those skill sets. He was later commissioned as an officer and held shipboard positions, such as weapons officer and combat systems officer, on various Navy vessels. His immediate prior tour of duty, before attending shore-based training for command, was as commanding officer of a shoreside research facility. He joined the *John S McCain* as XO in June 2016. The XO came to the bridge at 0430 on the accident date.

Officer of the deck. The OOD was the bridge watchstander in charge of the safe operation and navigation of the ship and the leader of the bridge watch team. She was commissioned in the Navy in October 2015, reported to *John S McCain* in March 2016, and qualified as OOD on July 30, 2017. The OOD came to the bridge about 0130 and took the watch about 0200.

Junior officer of the deck (JOOD). The JOOD's watchstanding duties were to assist the OOD in carrying out her duties by offering recommendations to the OOD. The JOOD was commissioned in the Navy in October 2015 and was permanently assigned to the guided-missile cruiser *Antietam* as of January 2016. (The *Antietam* did not have the same IBNS to control steering and thrust as the *John S McCain*.) Because the *Antietam* was in the shipyard for repairs, the JOOD was temporarily assigned to the *John S McCain* on May 25, 2017. He began standing JOOD watches in early August 2017. The JOOD came to watch between 0130 and 0145 and, during his watch, assisted the OOD by completing the entering port checklist.

Junior officer of the watch. The duties of the JOOW included checking the radar for surface contacts, plotting surface contacts on a maneuvering board (a paper plotting sheet), making surface contact reports to the CO or OOD, and handling internal communications between the bridge and the CIC. Because a shipping officer, who tracked and plotted surface shipping, was also on watch, the JOOW said that he had also been assisting with external radio communications between other stations and the destroyer. He was commissioned in the Navy in May 2016 and reported aboard the *John S McCain* in August 2016. In October 20, 2016, he qualified as aft steering safety officer and helm safety officer. When the loss of steering was announced, he assumed the duties of helm safety officer.

Conning officer. The conning officer's primary duty was to conduct the movement of the vessel, as directed by the CO or the OOD. The conning officer position is an entry-level watch for new officers, generally requiring no prior qualifications. The *John S McCain* conning officer was commissioned in the Navy on June 23, 2017, and joined the ship on June 30, 2017. He stood his first conning watch on July 3, 2017. On the accident date, he came to watch about 0145.

Shipping officer. The shipping officer's primary duty was to apprise the bridge watch team of surface radar contacts that might affect the vessel's intended movement along its track. The *John S McCain*'s shipping officer enlisted in the Navy in July 2012 and reported aboard the vessel at the end of December 2015. On the accident date, he came to watch as part of the modified navigation detail about 0418.

Boatswain's mate of the watch. The BMOW was the enlisted person who, in addition to other duties, managed the other enlisted personnel on the bridge watch, including the helmsman and the lee helmsman. The BMOW on watch at the time of the accident entered the Navy during the summer of 2015 and came on temporary assignment to the *John S McCain* from the *Antietam.* He joined the destroyer on May 21, 2017, and was qualified as a BMOW, helmsman, and lee helmsman on the same date. He also qualified as a master helmsman on August 8, 2017. On the accident date, he came to watch about 0135.

Helmsman. The helmsman was the enlisted bridge watchstander who was responsible for steering the ship. The helmsman on watch at the time of the accident enlisted in the Navy in February 2017 and joined the *John S McCain* on May 27, 2017. He qualified as helmsman, lee helmsman, and lookout on June 27, 2017. On the accident date, after waking up at 0450, he was asked to relieve the helm so that the helmsman could have breakfast; he relieved the helm about 0515.

Lee helmsman. The lee helmsman was the enlisted bridge watchstander who was responsible for controlling the thrust of the propellers. The lee helmsman on watch at the time of the accident joined the Navy in the summer of 2016. He was temporarily assigned to the *John S McCain* from the *Antietam* on May 26, 2017. He completed his PQS requirements and was qualified as helmsman and lee helmsman on June 23, 2017. On the accident date, he came to watch about 0145 and stood lookout and helm duties. He was relieved on the helm about 0515 and, instead of going to breakfast, was directed to take the lee helm position.

1.6.2 *Alnic MC*

The *Alnic MC* carried a crew of 8 officers, 14 ratings, and 2 cadets. All were credentialed by the Republic of the Philippines, with endorsements from Liberia, in accordance with the *Seafarers' Training, Certification and Watchkeeping Code* (STCW Code) and other International

Maritime Organization (IMO) regulations.[23] At the time of the accident, there were three people on the bridge: the master, the chief mate, and an able-bodied seaman.

Master. The master held a certificate of competence to sail as master on vessels "over 500 gross tons" (indicating an unlimited certificate), with the necessary endorsements. He had sailed as master for 4 years and said that he had made many trips in the Singapore Strait area. He came aboard the *Alnic MC* on April 9, 2017, and this was his first contract aboard the vessel. The master had the conn of the tanker during the accident.

Chief mate. The chief mate held a certificate of competence to sail as master on vessels "over 500 gross tons," with the necessary endorsements. He came aboard the *Alnic MC* on April 12, 2017, and this was his first contract aboard the vessel. He said that he had made many trips on the waters where the accident occurred and was the officer in charge of the navigational watch at the time of the collision.

Able-bodied seaman. The able-bodied seaman on watch during the accident provided investigators a Seafarer's Registration Certificate for able seaman and had sailed in this position for about 7 years. As the able-bodied seaman on watch, he generally steered the vessel and performed lookout duties. He joined the *Alnic MC* on April 12, 2017, and this was his first contract aboard the vessel.

An ordinary seaman was also assigned to the bridge watch at the time of the accident. He had been aboard the vessel for about 4 months; this was his first time sailing as an ordinary seaman and his first time aboard the vessel. At some time before the collision, he said that he was not feeling well and was allowed to go to his room. He was not on the bridge when the vessels collided.

1.7 Training and Qualifications

1.7.1 *John S McCain*

Navy officers and enlisted crew are trained by shipboard and shoreside personnel and qualified by the CO (or a crewmember with delegated authority) under the Navy-wide PQS system developed and monitored by the Naval Personnel Development Command. The PQS mandates minimum watchstanding standards and proficiencies for the personnel performing those functions. To qualify for a watchstation, a crewmember must demonstrate knowledge and proficiency by completing tasks listed in a PQS booklet developed for that watchstation. Individual units may tailor the Navy-wide PQS by adding new tasks to reflect equipment carried on board but not covered in the booklet and by deleting tasks that do not apply to the vessel.

Investigators reviewed the PQS booklets for OOD and "Ship's Control and Navigation," which included the BMOW, helmsman, and lee helmsman watchstations. Among the knowledge requirements, prospective OODs were required to describe to a qualified evaluator the effects on a vessel from a loss of steering control and a loss of thrust control and the actions required to respond to these casualties. They were also required to describe the steering system and demonstrate transferring steering control "from primary control to each alternate method of control." The PQS booklet did not specify the transfer of control between bridge stations.

[23] IMO, *Seafarers' Training, Certification and Watchkeeping Code, as Amended*, STCW Code, 2010.

As part of their qualifications, prospective helmsmen and lee helmsmen were required to define their duties during normal operations and describe how the helm and SCC were used by the watchstanders. A prospective helmsman had to demonstrate a shift of steering units and a transfer of steering control to and from an "alternate steering location." Qualification as lee helmsman was a prerequisite for qualification as a helmsman. A prospective lee helmsman was required to demonstrate positioning throttles to achieve the ordered speed, ganging and unganging of the throttles, and transferring throttle controls to and from the "Engineering Control Station . . . IAW EOSS." The PQS booklet did not include a task to transfer throttle controls between bridge stations. There were no specific steering- or thrust-control tasks in the BMOW PQS; however, helmsman and lee helmsman were prerequisite qualifications for BMOW qualification.

1.7.2 *Alnic MC*

As a commercial vessel engaged in international trade, the *Alnic MC* was subject to the STCW Code and other IMO regulations. Among other provisions, the STCW Code contained minimum experience, training, and assessment requirements for crewmembers. For deck officers, the training included bridge resource management and radar, ARPA, ECDIS, and GMDSS operations. The credentials for the *Alnic MC* crewmembers on watch during the accident showed that they were in compliance with STCW Code requirements for training and qualifications.

1.8 Work/Rest History

1.8.1 *John S McCain*

Investigators reviewed the number of rest hours for the *John S McCain* bridge team during the 24 hours leading up to the accident. The OOD, JOOD, and BMOW each had about 4 hours of sleep prior to watch, and the JOOW and helmsman both had about 5 hours of sleep. The conning officer reported that he had slept about 3 hours the night before his watch. The lee helmsman did not sleep the night before the accident. The CO and XO had about 5 hours and 4 hours of sleep, respectively, prior to coming to the bridge, and both described their quality of sleep as "poor." According to Navy records, the 14 crew on the bridge averaged just over 4.9 hours of rest in those 24 hours.

During the accident voyage, the *John S McCain* had four watch teams assigned to the bridge and five watchstanding periods: 0200–0700, 0700–1200, 1200–1700, 1700–2200, and 2200–0200. In this watch organization, the watchstanding period for each watch team shifted with each cycle of the watch rotation. For example, the watch team that had the 0200–0700 watch would next have the watch from 2200–0200 that evening, and then have the watch from 1700–2200 on the following day. Following the accident, the Navy mandated "circadian watchbill" schedules that followed set watch times each day.[24] (See section 1.14 for more information on actions taken by the Navy following the accident.)

[24] Commander, Naval Surface Forces, messages to surface fleet units, "Circadian Watchbill," May 3, 2013, and "Force-Wide Circadian Rhythm Implementation," September 20, 2017.

1.8.2 *Alnic MC*

The crew of the *Alnic MC* was required to adhere to STCW Code regulations for rest, which mandated a minimum of 10 hours of rest in any 24-hour period and a total of 77 hours of rest in any 7-day period.[25] The 10 hours of rest could be divided into two periods, as long as one of the periods was at least 6 hours in length. According to records reviewed by investigators, the *Alnic MC*'s master had 61 hours of rest in the 96 hours prior to the accident and 14 hours of rest in the immediate 24-hour period. His rest period just prior to the accident was 9 hours in duration. The chief mate had 55 hours of rest in the 96 hours prior to the accident and 16 hours of rest in the immediate 24-hour period, with 8 hours of continuous rest just prior to his watch on the morning of the accident. The able-bodied seaman on watch had 64 hours of rest in the 96 hours prior to the accident and 16 hours of rest in the immediate 24-hour period. He had 8 hours of continuous rest prior to assuming his watch.

The *Alnic MC* had three bridge watch teams assigned to the six traditional watchstanding periods: 0000–0400, 0400–0800, 0800–1200, 1200–1600, 1600–2000, and 2000–2400. Under this watch organization, each watch team stood the same two watches each 24-hour period.

1.9 Alcohol and Other Drug Use

Following the accident, the *Alnic MC* crewmembers who were in safety-critical positions were tested for alcohol use; all results were negative. Drug tests were not conducted for the *Alnic MC* crew. The *John S McCain* crewmembers were not tested for alcohol use after the accident but were tested for drug use; all results were negative.[26]

1.10 Injuries

The collision resulted in the death of 10 sailors in a berthing compartment located near the impact point on the *John S McCain* and injuries to 48 others on board. Five sailors suffered severe injuries and were not able to return to their duties for more than 24 hours.[27] There were no injuries aboard the *Alnic MC*.

1.11 Damage

When the vessels collided, the *Alnic MC*'s bulbous bow opened a 28-foot-diameter hole in the *John S McCain*'s hull, above and below the waterline, resulting in significant structural and flooding damage to several spaces, including crew berthing. Repairs to the hull, internal structures, and equipment were estimated at over $100 million.

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[25] STCW Code, Section A-VIII/1, "Fitness for Duty."

[26] Postaccident military toxicology testing was performed on blood specimens to identify amphetamines, barbiturates, benzodiazepines, cannabinoids, cocaine, opioids, and phencyclidine. The fatally injured crewmembers were also tested for multiple prescription medications.

[27] US Navy, *Report on the Collision between USS JOHN S MCCAIN (DDG 56) and Motor Vessel ALNIC MC*, Washington, DC: Department of the Navy, 2017.

Figure 12. Hull damage to *John S McCain*. (Photos by Navy Mass Communication Specialist 2nd Class Joshua Fulton)

Damage to the *Alnic MC* included a breach of the hull, about 8 feet long, on the starboard bow about 20 feet above the waterline and indentation in the plating on the bulbous bow, bow stem, and just aft of the bow stem on the port and starboard sides. Repair costs totaled about $225,000.

Figure 13. Hull damage to *Alnic MC*. (Photos by Coast Guard)

1.12 Waterway Information

The Singapore Strait is a 60-mile-long body of water, running in a general east/west direction, that connects the South China Sea and the Strait of Malacca. It is bounded on the north by the Malay Peninsula and Singapore and on the south by the Riau Islands of Indonesia. The strait is 20 miles wide at its eastern terminus, narrows to 2.5 miles toward the center, and opens up to about 10 miles at the western terminus. The navigation lanes in the strait are deep throughout.

1.13 Environmental Information

During the 0400 watch relief, the *Alnic MC* crew logged the weather as cloudy skies with approximately 10 miles of visibility. The assistant navigator on the *John S McCain* told investigators that there was no fog, haze, or rain and that the crew could see navigation lights from other vessels at the accident time. Satellite imagery of the area showed scattered cloud cover. Winds were south-southeast at 8 knots, and the *Alnic MC* crew logged the winds as “slight.” The air temperature was 78 degrees F.

According to Naval Oceanographic Office and National Oceanic and Atmospheric Administration (NOAA) forecast models, seas were 1–2 feet, and the current was 1.2 knots from 187 degrees at 0500. At the same time, the set and drift were calculated by the *John S McCain* crew to be 020 degrees and 1.8 knots, as recorded in the ship’s deck log.[28]

Civil twilight on the date of the accident was 0640, with sunrise at 0701. Moonrise was at 0621; the phase of the moon was waning crescent with 0 percent of the visible disk illuminated. According to the *John S McCain* OOD, there was “zero illumination that night.”

1.14 Navy Actions Since the Accident

The US Navy conducted a comprehensive review of this accident as well as other recent accidents that occurred in the western Pacific region and, based on that assessment, initiated several actions to address identified issues. These actions included the following:

- Reviewing and modifying employment schedules of vessels based in Japan to ensure adequate time for maintenance, training, and crew certification;
- Conducting readiness assessments of all vessels based in Japan;
- Adjusting manning policies to ensure Japan-based ships, which operate at a higher tempo in congested waters, are appropriately manned with qualified officers and enlisted personnel;
- Restructuring surface warfare officer (SWO) career paths to ensure sufficient time at sea and time to improve maritime skills training;[29]
- Developing a standardized program to assess seamanship and navigation skills over the course of a SWO’s career;

[28] With the vessel steering about 230 degrees, the current direction was 47 degrees on the port bow.

[29] A *SWO* is a Navy officer who specializes in operating, navigating, and maintaining ships. Other major officer career fields include submarine officers and naval aviators.

- Improving seamanship and individual skills training for SWO candidates, SWOs, quartermasters, and operations specialists;[30]
- Consolidating responsibility and authority for bridge system modernizations;
- Directing the broadcast of AIS information by US Navy vessels when transiting any TSS or high-density traffic area;
- Directing that surface force ships implement watch schedules that account for circadian rhythms;
- Issuing an advisory message recommending changes to the way IBNS-equipped ships operate their steering control; and
- Sharing accident lessons learned and postaccident engineering design review board lessons learned with surface force and fleet commanders, individual vessel crews, and Navy education and training commands.

[30] Quartermaster is an enlisted rating that specializes in ship navigation. Operations specialist is an enlisted rating that specializes in operating equipment in the CIC of a Navy ship. These duties include using radars to track aircraft, submarines, and other surface vessels, controlling aircraft, and performing navigation functions in support of the bridge watch team.

2 Analysis

2.1 Exclusions

At the time of the accident, seas were 1–2 feet, and visibility was about 10 miles. The crews from both the *Alnic MC* and the *John S McCain* reported no concerns related to the weather. The NTSB concludes that weather was not a factor in the accident.

The crew of the tanker reported no problems with the vessel's steering and propulsion systems prior to the accident, and VDR data indicated no problems. Additionally, the *Alnic MC*'s deck and engine officers were trained and credentialed for the capacity in which they were working. The NTSB concludes that the *Alnic MC*'s steering and propulsion systems as well as the credentials of its crew were not factors in the accident.

Following the accident, the Navy conducted inspections of the electrical, mechanical, and hydraulic components of the *John S McCain*'s steering gear. The inspections found minor discrepancies, none which affected the operation of the rudders. The Navy reported no issues with the propulsion systems. The NTSB concludes that the functioning of the electrical, mechanical, and hydraulic components of the *John S McCain*'s steering and propulsion systems was not a factor in the accident.

Because alcohol testing was not conducted for the *John S McCain* crew and drug testing was not conducted for the *Alnic MC* crew, evidence was insufficient to determine conclusively whether alcohol or other drug use was a factor in this accident.

2.2 Actions Precipitating the Collision

As the *John S McCain* entered the Singapore Strait TSS, steering and thrust were being controlled by a single watchstander—the helmsman—from the helm station. The CO directed that the lee helm station be manned because he anticipated that the helmsman would be heavily tasked with steering. When the lee helm position was manned, the crew took actions intended to transfer propeller thrust control from the helm station to the lee helm station using the vessel's IBNS. Thrust for the port propeller shaft was successfully transferred from the helm to the lee helm station. However, at nearly the same time, control of steering was also shifted to the lee helm station, as shown on video of the ASU station and in the steering log. There was no evidence on the video or in the log to suggest that the shift was the result of a system fault. The intended transfer of control for the starboard shaft was not completed until over a minute later. The NTSB concludes that during the process of shifting control of thrust, a *John S McCain* watchstander unintentionally transferred control of steering from the helm to the lee helm station. It is unclear who actually transferred steering to the lee helm station, as both the BMOW and the lee helmsman indicated that they were taking actions to transfer thrust.

Shortly after the transfer of steering control to the lee helm station, the helmsman reported a loss of steering. Although the IBNS touch-screen displays for both SCC stations would have indicated that the lee helm station had control of steering, the helmsman, lee helmsman, and BMOW did not recognize that control had been transferred. Unable to control the rudders from his station, the helmsman perceived that steering control had been lost. The NTSB concludes that the perceived loss of steering by the *John S McCain* helmsman was due to the unintentional transfer of steering control from the helm station to the lee helm station.

Testing of the IBNS and other steering components by the US Navy after the accident revealed no evidence to suggest that software, hardware, or mechanical issues were factors in the accident. The steering and thrust logs likewise revealed no systemic issues. Steering control was available at all times. The NTSB concludes that although the helmsman perceived a loss of steering, there was no malfunction of the *John S McCain* steering system.

On the morning of the accident, the steering system was in backup manual mode, and thus any station, including the lee helm station, could unilaterally take steering control from the helm station [redacted], with no action or acknowledgement by the helm station. The steering location menu would have been open on the lee helm station GUI display with the lee helm location indicator blinking. The indicator would have been blinking at the same time that the port shaft location indicator was blinking while transferring thrust control.

A coordinated transfer of steering would have required both the helm and lee helm to take action and would have required four steps to complete the transfer. However, a unilateral transfer, made possible by the steering system being in backup manual mode, [redacted] could be accomplished by a single watchstander at one station. Based on the video from aft steering and the steering logs, the transfer of steering from the helm station to the lee helm station, which also included a change in steering mode from backup manual to computer-assisted manual, occurred in less than a second. Considering the speed and timing of the control transfer, the NTSB concludes that the unintended shift in steering control from the helm to the lee helm station on the *John S McCain* was likely a unilateral transfer initiated from the lee helm station. The NTSB further concludes that operating the *John S McCain*'s steering system in backup manual mode allowed for the unintentional, unilateral transfer of steering control and contributed to the errors that led to the accident.

John S McCain crewmembers indicated during interviews that in the days preceding the accident, the steering system had alarmed for several minor faults, but none that resulted in a loss of steering. The CO did not indicate that this was a factor in his decision to operate in backup manual mode. Rather, he told investigators that backup manual mode provided a "more direct form of communication between the steering and SCC." He further stated, "We were more comfortable in that configuration" and noted that COs of other ships that he had talked to also preferred to operate in backup manual mode in certain situations. Although the written guidance stated that the normal mode of operation was computer-assisted manual mode, the use of backup manual mode was common on board the *John S McCain* and other similarly equipped ships. However, operating in backup manual mode removed one safeguard against an inadvertent transfer of steering control: the requirement for two watchstanders to take action to complete the transfer.

After the accident, the Navy issued an advisory message to IBNS-equipped ships providing a "recommended action" that mitigates the risk of unintended transfers in backup manual mode. However, given that the steering control directive is provided as a "recommended action" only, the NTSB recommends that the Navy issue permanent guidance directing destroyers equipped with the IBNS to operate in computer-assisted steering modes, except during an emergency.

Prior to the unintentional transfer of steering control, the *John S McCain* helmsman had been using up to 5 degrees of starboard rudder to maintain the ship's ordered heading of 230 degrees. The rudders were at 3 degrees to starboard just before the transfer, but immediately shifted to 0 degrees once the lee helm station took control (as designed for stations without a physical steering wheel). The helmsman believed that the *John S McCain* had suffered a loss of steering and no crewmember recognized that control was at the lee helm station, and thus the destroyer's bridge team was not able to apply starboard rudder in order to maintain the vessel's intended heading in the TSS. Consequently, the destroyer began to turn to port toward the path of the *Alnic MC*. The NTSB concludes that, due to the perceived loss of steering, the bridge team on the *John S McCain* did not input starboard rudder orders needed to maintain the vessel's intended heading, which initiated the destroyer's port turn toward the *Alnic MC*.

The *John S McCain*'s emergency procedures for a loss of steering directed watch personnel to engage the emergency-override-to-manual button at the SCC. Following the announcement of the loss of steering, however, the emergency-override-to-manual button was not immediately engaged by the helmsman. The helmsman told investigators that he thought the button would send control of steering to aft steering. The OOD ordered the helmsman to proceed to the next step in the emergency procedure, which was to shift the HPUs. She told investigators that she skipped the first step because she believed the system was already operating in backup manual mode. Per the IBNS technical manual and as tested by NTSB investigators on another IBNS-equipped destroyer, pressing the emergency-override-to-manual button would have shifted control of steering back to the helm station in backup manual mode. The NTSB concludes that had the *John S McCain* crew pressed the emergency-override-to-manual button at the SCC when the perceived loss of steering occurred, the watch team would have reestablished control of steering and would have likely avoided the collision.

Prior to the transfer of thrust control from the helm to the lee helm station, the throttles controlling the propeller pitch and rpm had been ganged; that is, the throttle controls had been paired so that the actuation of one throttle also moved the other throttle to the same position. During the transfer of thrust control, the system automatically unganged the throttles because the process for shifting control required each throttle to be transferred independently. The lee helmsman told investigators that, after the transfer of control, he re-ganged the throttles. Then, when ordered to slow the ship to 10 knots, he stated that he reduced port thrust and that starboard thrust was also reduced because the throttles were ganged. However, the thrust log showed that only the port shaft rpm was reduced, indicating that the throttles were not ganged as the lee helmsman thought they were (ganged versus unganged was not recorded in the thrust log). As a result, the throttles were mismatched with the port shaft turning at 44 rpm and the starboard shaft turning at 87 rpm. The NTSB concludes that the *John S McCain*'s port and starboard propeller throttles were not ganged when the lee helmsman answered the order to reduce speed, and thus the throttles became unintentionally mismatched when he slowed only the port throttle. With the throttles mismatched, the starboard propeller was providing greater thrust than the port propeller. Data from the destroyer showed that once the throttles were mismatched, the rate of turn to port began to increase, building to more than double the original turn rate following the perceived steering loss. The NTSB concludes that the *John S McCain*'s mismatched throttles resulted in an accelerated rate of turn to port toward the *Alnic MC*.

In addition to the control stations, the *John S McCain* had numerous displays on the bridge and on the bridge wings that showed the propeller pitch and turns. When NTSB investigators visited a similarly equipped Navy destroyer, they noted that the displays were visible from almost anywhere on the bridge. During the accident sequence, the throttles remained mismatched for over a minute, but the CO, OOD, conning officer, and other bridge watchstanders did not recognize the lee helmsman's error, and, consequently, no actions were taken to correct it. The NTSB concludes that the *John S McCain* bridge team was not monitoring the lee helmsman's response to orders and therefore did not recognize that the throttles were mismatched.

While the *John S McCain* crew was attempting to regain control of steering, the control location shifted from the lee helm, to aft steering, to the helm, and back to aft steering. When aft steering gained control for the second time, the rudder input at the ASU steering wheel—as recorded by the steering log—was 33 degrees to port. Because the ASU station had a wheel, the rudders responded by moving to port until aft steering watchstanders corrected the rudder input to 15 degrees to starboard. Due to the lag between the rudder input and the rudders' response, it is likely that the rudders never actually reached 33 degrees to port. However, several bridge watchstanders told investigators that they saw the rudders at 15 degrees to port while they struggled to control the ship. During this time, the *John S McCain* continued to turn to port. The NTSB concludes that while attempting to reestablish rudder control on board the *John S McCain*, an inadvertent rudder input to port from aft steering and the resultant temporary movement of the rudders to port delayed the bridge team's attempt to turn the destroyer away from the *Alnic MC*. During interviews, none of the aft steering watchstanders recalled a rudder order or input of 33 degrees to port. Like the bridge watchstanders, they reported that the rudders reached 15 degrees to port, but they did not know why. The ASU operator may have turned the wheel to port in an attempt to test for control while control was shifting between stations, but this could not be determined conclusively.

An analysis of the track of the *John S McCain* shows decreasing speed and an increasing rate of turn to port until, just seconds before the collision, the destroyer's heading began to shift to starboard. The throttles were matched about 36 seconds before the collision, and aft steering watchstanders brought the rudders to 15 degrees to starboard about 16 seconds prior, but these actions were too late to prevent the accident. The NTSB concludes that the inability to maintain course due to a perceived loss of steering, the mismatch of port and starboard throttles producing an unbalanced thrust, and the brief but significant port rudder input from aft steering combined to bring the *John S McCain* into the path of the *Alnic MC*.

At the time the decision was made to add the lee helmsman to the watch and to transfer thrust control to the lee helm station, the *John S McCain* was transiting the Singapore Strait TSS with no less than five other vessels within 0.75 miles of the destroyer, all making way at different speeds. Furthermore, the *John S McCain* was overtaking the *Alnic MC*, a maneuver that required the Navy vessel to keep out of the way of the tanker. Changes to critical equipment configuration or setup are not advisable during higher risk maneuvering operations, unless the changes cannot be avoided. When they cannot be avoided, it is best to conduct the changes using the most qualified personnel under direct oversight. The *John S McCain* crew's original plan, per the navigation brief held the day prior to the accident, was to split the duties of the helmsman and a lee helmsman when the sea and anchor detail was set at 0600. When the sea and anchor detail was set, a more experienced helmsman—a master helmsman—was assigned to steer the vessel, and an additional officer—the helm safety officer—was assigned to oversee all steering inputs, thrust commands, and control transfers. Had the shift of thrust been conducted earlier—when other vessels were at a greater distance—or with more experienced watchstanders, the errors that led to the accident might have been avoided. The NTSB concludes that the decision to change the configuration of the *John S McCain*'s critical controls while the destroyer was in close proximity to other vessels increased the risk of an accident.

At the time of the accident, Navy vessels did not broadcast via AIS as a matter of policy. Accordingly, the *John S McCain* was not broadcasting on AIS on the accident date. AIS can assist in preventing collisions because it provides useful information (such as the name, course, speed, CPA, and range of the vessel) that is displayed on another vessel's radar and/or ECDIS display.

This information is particularly important in a shipping area such as the Singapore Strait, one of the busiest shipping lanes in the world, where bridge watchstanders must track multiple vessels at once. In this accident, the master of the *Alnic MC* believed that the contact that he was monitoring was a naval vessel, according to statements he made to investigators. AIS data from the *John S McCain*, had it been transmitted, would have confirmed this identification and provided the master with additional relevant navigational information. The NTSB concludes that transmission of AIS information from the *John S McCain* would have improved the situation awareness of watchstanders on surrounding vessels, including the *Alnic MC* bridge team. Since the accident, the Navy has directed that all its ships transmit AIS data when transiting TSSs and other high-traffic areas. (See section 1.14 for more information on actions taken by the Navy following the accident.)

2.3 Actions to Avoid Collision

During the investigation, the NTSB reviewed the actions of the bridge teams of both vessels leading up to the accident, beginning with the *John S McCain*. Operating in a high-density traffic area such as the Singapore Strait requires a high level of situation awareness by the crew. Situation awareness encompasses not only how people perceive information, but also how they combine, interpret, store, and retain that information. Further, having good situation awareness includes being able to take that information and integrate it to determine its relevance to the situation.[31] During the accident, the *John S McCain* helmsman misinterpreted the steering casualty. This error could have been resolved had another crewmember taken the time to confirm the casualty and discover that it was not an actual loss of steering. The GUI displays for the bridge IBNS stations were visible to all the primary watchstanders and would have provided both location and mode of steering information, yet neither the CO, XO, OOD, JOOD, JOOW, conning officer, BMOW, helmsman, nor the lee helmsman realized or corrected the error that began the accident sequence. Also, as previously noted, the bridge watch team did not notice the mismatched shaft rpm that increased the destroyer's rate of turn, even though the information was displayed at various locations on the bridge. The misinterpretation of the loss of steering and the mismatched throttles were not identified or immediately corrected; instead, the bridge team concentrated on the misidentified issue.

Based on the evidence, the *John S McCain* watch team did not fully understand the immediate danger presented by the *Alnic MC* and other vessels transiting in close proximity. When the loss of steering was first reported, they did not warn other vessels via VHF radio despite direction to do so in the CO's standing orders. As the destroyer crossed into the path of the *Alnic MC*, the ship was slowed, and the rudders were eventually brought to starboard 15 degrees. More radical engine or rudder actions, such as engines back full or hard (35 degrees) starboard rudder, would be expected for a vessel in immediate danger of collision, which indicates that the crew did not know that the vessel was about to be struck until moments before the collision. For a number of the bridge watchstanders who spoke with investigators, the collision seemed to come as a surprise.

In order to maintain proper situation awareness, a watchstander must be sufficiently alert to process information and then perform necessary actions, particularly in an emergency. Fatigue

[31] Endsley, Mica, and Daniel Garland, *Situation Awareness: Analysis and Measurement*, Mahwah, New Jersey: Lawrence Erlbaum Associates, 2000.

can negatively influence a watchstander's situation awareness. As will be discussed in section 2.7 of this report, acute fatigue was a factor among the *John S McCain* bridge watchstanders. Given the bridge team's narrow concentration on the misinterpreted steering casualty, the failure to understand the danger presented by the *Alnic MC*, and fatigue among watchstanders, the NTSB concludes that the *John S McCain* bridge team lost situation awareness in the minutes prior to the accident, and, consequently, they did not take sufficient action to avoid the collision.

When the *John S McCain*'s actions became unclear, the *Alnic MC* master could have called the destroyer to clarify the vessel's intentions. However, the *Alnic MC* master had no knowledge of the perceived loss of steering control on board the *John S McCain*. Thus, he believed that the destroyer's initial turn to port was intentional and that the Navy ship would maneuver without risk of collision. Although the destroyer CO's standing order for a steering emergency directed the OOD to warn other vessels over VHF radio, no warning could be heard on the *Alnic MC*'s VDR audio recording, and no *John S McCain* crewmember recalled making radio calls. Had a warning been broadcast immediately upon the perceived loss of steering, the *Alnic MC* master would have known that the destroyer had a casualty nearly 3 minutes prior to the accident. With this information, the master could have taken earlier action to avoid the collision. The NTSB concludes that the lack of a VHF radio announcement from the *John S McCain* alerting nearby vessels of the destroyer's steering casualty, as directed in the CO's standing orders, deprived the *Alnic MC* master of information needed to take action to avoid the collision. Accordingly, the NTSB recommends that the Navy issue guidance to its ships' crews emphasizing the importance of the appropriate use of VHF radio for safe navigation.

Several bridge watchstanders on the *John S McCain* told investigators that not-under-command lighting was illuminated on the destroyer prior to the accident. However, illumination of these lights was not recorded in the deck log until 10 minutes after the accident, and the *Alnic MC* crew did not report seeing the lighting. Thus, the evidence is unclear whether the not-under-command lighting was energized prior to the collision.

Aboard the *Alnic MC*, the bridge team was navigating the slowest vessel in a grouping of several vessels transiting in the TSS, and the tanker was being overtaken on its port side by the cargo vessel *Hyundai Global* and on its starboard side by the *John S McCain*. (There were also vessels ahead of and behind the tanker). As the operator of the stand-on vessel in an overtaking situation, the master of the *Alnic MC* had an obligation to maintain his vessel's course and speed up until the time that he could determine that the actions of the give-way vessels (the overtaking vessels) were insufficient to avoid a collision. At that point—when he determined that his vessel was *in extremis*—he was obligated to take action.[32]

Utilizing sea trial data for the *Alnic MC* and ships of its class, as well as the *John S McCain*'s actual maneuvering up to the point of impact, the NTSB conducted a study to determine the latest time that the *Alnic MC* master could have acted to avoid a collision by slowing his vessel. Based on the reasonable assumption by the master that he did not have the option to turn due to vessel traffic (the *John S McCain* to starboard and the *Hyundai Global* to port), the study did not evaluate an *Alnic MC* turn to port or starboard. The study assumed that the *John S McCain* would have continued along its track at its established turn and deceleration rates, while the *Alnic MC* decelerated at about 1 knot per minute, which was within the tanker's

[32] *In extremis* is defined in this report as the point when a collision between two vessels is imminent and can only be avoided if both vessels take action.

deceleration capability demonstrated during the class sea trials. Based on the results of the study, investigators estimated that the *Alnic MC* master would have needed to order engine stop or emergency crash astern no later than about 05:22:38—80 seconds before the collision—to allow the *John S McCain* to pass ahead without making contact.[33] At that time, the destroyer was 0.21 miles off the tanker's beam on a heading of 205 degrees and at a speed of 17.1 knots. The tanker was on a heading of 227 degrees at a constant speed of about 10 knots. (The study results indicated that the *John S McCain*, with the benefit of crew situation awareness and appropriate steering and/or throttle commands, had opportunity to clear the *Alnic MC* bow until about 30 seconds prior to the collision. After this time, in the absence of corrective vessel path actions, the risk of collision rapidly transitioned from a near miss event to an impending collision event.)

The master stated that he saw on his radar display when the Navy vessel that had been overtaking him began its initial turn to port. He believed that the destroyer intended to pass between his ship and the tanker *Team Oslo* ahead of him. This belief was influenced by his determination that the vessel was a Navy ship, and thus fast and highly maneuverable. As late as 05:23:02, 55 seconds before the collision, the bridge team on the *Alnic MC* continued to believe that the Navy vessel intended to pass ahead, as evidenced by the statement recorded on the tanker's VDR, "This guy thinks he can cut through."

The throttles on the *John S McCain* became mismatched at 05:22:20, about 18 seconds before the *Alnic MC* master would have had to slow his vessel to avoid the collision. Prior to the mismatch, the vessels were not on a collision course, as the *Alnic MC* master had assessed, although they would have passed close to each other. After the mismatch, the *John S McCain*'s rate of turn toward the tanker increased while its overall speed decreased. Investigators considered the ability of the *Alnic MC's* bridge team to detect the change in the destroyer's rate of turn and whether it should have triggered additional concern regarding risk of collision. Reviewing the time span of 20 seconds prior to the *John S McCain*'s throttle mismatch, the destroyer's change in heading was 4.9 degrees; in the 20 seconds after the mismatch, the change in heading was 7.8 degrees—a difference of less than 3 degrees. In darkness, viewing primarily the destroyer's navigation lights, the change in the *John S McCain*'s rate of turn after the throttle mismatch would have been difficult to perceive and would have taken time to develop—likely longer than the estimated 18 seconds that the master had to act.

The risk of collision between two vessels can be easily determined when both vessels are maintaining constant course and speed. The risk of collision is more difficult to determine if one or both of the vessels is turning, even if the rate of turn is constant. In this accident, not only was the *John S McCain* turning, but with the mismatch in throttles, the destroyer's rate of turn to port was not constant—it was increasing. Additionally, the destroyer's speed was decreasing during the turn—from 18.6 knots when the turn began to 10.8 knots just before the collision. These factors would have made it very difficult for the *Alnic MC* master to determine that his vessel was in extremis and that he had to maneuver. Further, because the Navy vessel did not alert vessels in its vicinity to the perceived loss of steering, the *Alnic MC* master had no indication of an emergency on board the *John S McCain* and as such continued to believe that the Navy vessel was attempting to pass ahead of his vessel. Given these circumstances, the NTSB concludes that the *Alnic MC* master could not have reasonably determined that his vessel was in extremis before it was too late to maneuver the tanker to avoid the accident.

[33] Sea trial data for the *Alnic MC* indicate that the deceleration rates for both engine stop and emergency crash astern were not significantly different from the initial order at approximately 15 knots to approximately 6 knots.

The *Alnic MC*'s SMS required the setting of Watch Condition 3 during the transit of the Singapore Strait, which would have added a second deck officer, in addition to the master, to the bridge team. With the second bridge officer, the navigation, communication, and collision avoidance duties would have been split as required by the SMS. One officer would have taken the navigation and communication duties, while the other would have been assigned collision avoidance duties alone. Also, in Watch Condition 3, the ordinary seaman who went below before the collision would have required a relief (if he had not returned to the bridge), providing an additional lookout. The *Alnic MC* remained in Watch Condition 2, however, prior to the accident, and an additional officer or rating was never added to the bridge team. The NTSB concludes that the *Alnic MC* bridge was not manned in accordance with the requirements of the company's SMS. The bridge should have been manned in accordance with the SMS; however, the master was aware of the *John S McCain*, noted its turn, and, as previously concluded, could not have reasonably determined that his vessel was in extremis until it was too late to take action. The NTSB concludes that it is unlikely that the presence of additional watchstanders on the *Alnic MC* bridge would have changed the outcome of the accident.

2.4 *John S McCain* Integrated Bridge and Navigation System

Design standards for human engineering in marine systems and equipment have been codified by ASTM International in Standard F1166, *Standard Practice for Human Engineering Design for Marine Systems, Equipment, and Facilities*, last revised in 2007.[34] The standard "provides ergonomic design criteria for maritime vessels and structures to ensure that maritime systems and equipment are designed in compliance with requirements for human performance, human workload, health and safety, survivability, and habitability." The standard is approved for use by US Department of Defense agencies, including the Navy.

Criteria set forth in the ASTM standard stipulates that vessels, systems, subsystems, and equipment shall be designed to "minimize potential human error incidence in the operation and maintenance of the system, particularly under conditions of stress." During the investigation, the NTSB reviewed the design and operation of the IBNS, with the assistance of the Navy. As previously noted, when the *John S McCain*'s steering system was in backup manual mode, any other station could take control of steering unilaterally [redacted]. This design feature made it possible for the *John S McCain* watchstanders to mistakenly transfer control of steering on the morning of the accident.

According to the ASTM standard, human-computer interfaces such as the IBNS GUI display should follow the design principal of "*simplicity* . . . the dynamic interaction shall be simplified, for example navigation and the data entry tasks shall not require unnecessary actions in order to accomplish the mission." As designed, the shifting of thrust control between IBNS bridge stations was conducted independently for both propeller shafts. During the accident, thrust control for the port propeller was transferred to the lee helm station while thrust control for the starboard propeller remained at the helm station. The need to take separate actions to transfer control of thrust between bridge stations for each propeller shaft added complexity to the procedure during a critical maneuvering situation.

[34] ASTM International (originally the American Section of the International Association for Testing Materials) is a not-for-profit organization that provides a forum for the development and publication of international voluntary consensus standards for materials, products, systems, and services. The organization develops technical documents that are the basis of manufacturing, management, procurement, codes, and regulations for various industry sectors. Source: www.astm.org/FAQ/, accessed August 13, 2018.

Under "general design guidelines," the ASTM F1166 standard states that "all critical and emergency controls shall be identifiable both visually and by touch (for example, shape coding)." While the IBNS maintained physical controls for steering—the wheels at the SCC helm and ASU stations—mechanical throttle controls were not provided. The throttles on the *John S McCain* were actuated via the touch screen. The ASTM standard also notes that touch screens are "appropriate for interactions involving…discrete function controls." A *discrete control* is an actuator that allows for selection between "two or more mutually exclusive operating functions or points along a scale." A *continuous control*, such as a throttle, is an actuator that operates at any point or value along a continuous scale. Mechanical throttles provide complementary information to an operator: direction, force, and the ability to confirm either visually or by touch whether the throttles are ganged and working in unison. Mechanical throttles are used in aviation and on most vessels still operating in the Navy. They are often preferred over touch-screen displays as they provide both immediate and tactile feedback to the operator.

By allowing other stations to unilaterally take steering control, the IBNS backup manual mode increased the potential for the error leading to the inadvertent shift of control during the accident. The transfer of thrust control independently for each propeller shaft was unnecessarily complex, and the touch-screen throttle controls deprived the lee helmsman of tactile feedback when the throttles were unganged and mismatched. The NTSB concludes that the design of the *John S McCain*'s touch-screen steering and thrust control system increased the likelihood of the operator errors that led to the collision. Therefore, the NTSB recommends that the Navy ensure that the modernization of complex systems, such as steering and control systems within the IBNS, incorporates the design principles set forth in ASTM International Standard F1166, *Standard Practice for Human Engineering Design for Marine Systems, Equipment, and Facilities*.

2.5 Operating Procedures

The EOSS procedures on Navy vessels provide the crews with specific steps to complete when performing normal operations on installed equipment. Investigators reviewed the EOSS procedures from the *John S McCain* and found that they did not contain steps for transferring control of thrust between bridge stations, there were no procedures for ganging and unganging throttles, and there were no notes or warnings about actions that automatically unganged the throttles. The reference used in developing these procedures, the technical manual, did not contain instructions for ganging throttles, and there was no description of the "ganged" indicator on the GUI display. Additionally, written instructions did not contain a procedure for shifting steering from one bridge station to another, other than a shift from the SCC to the HFS during the initial steering system alignment. The NTSB concludes that the steering and thrust control written operating procedures on the *John S McCain*'s bridge did not describe the actions needed to transfer control between stations and therefore were inadequate. The NTSB recommends that the Navy revise written instructions for bridge watchstanders on destroyers equipped with the IBNS to include operating procedures for shifting steering and thrust control between all bridge stations. Furthermore, the NTSB recommends that the Navy revise IBNS technical manuals to include a description of and procedures for ganging and unganging throttles and ensure that revised technical manuals are distributed to IBNS-equipped ships.

2.6 Qualifications and Training of *John S McCain* Crewmembers

During interviews, several of the bridge watchstanders provided statements indicating that they were unfamiliar with or had an incorrect understanding of the steering system. The JOOD, JOOW, conning officer, BMOW, and helmsman all believed that engaging the emergency-override-to-manual button at the SCC transferred control to aft steering rather than took control at the SCC helm station. The lee helmsman stated that he did not know that steering control could be shifted to his station. Statements by other *John S McCain* helmsmen and crewmembers who were not on watch during the accident showed a similar lack of knowledge. Only the OOD provided accurate information to investigators about the steering system functionality. Given the broad lack of knowledge and understanding of such a vital system, the NTSB investigated the qualifications and training of the critical watchstanders during the accident.

The helmsman qualified at his position less than 2 months before the accident, but he told investigators that he had gained significant experience prior to qualification while standing the watch "under instruction" (under the oversight of a qualified watchstander), actually pressing the buttons at the helm station. The lee helmsman was temporarily assigned to the *John S McCain* from the cruiser *Antietam*. Although the *Antietam* did not have the IBNS, the *John S McCain* CO qualified the crewmember as helmsman and lee helmsman shortly after he joined the destroyer. The BMOW was also temporarily assigned to the *John S McCain* from the *Antietam*. The CO qualified him as BMOW on the day he joined the destroyer, without any underway instruction. Given differences between the *Antietam* and *John S McCain* systems and the complexity of the IBNS, it is unlikely that either the lee helmsman or the BMOW was proficient with the IBNS when they began standing watch.

The lee helmsman's and BMOW's lack of proficiency should have been mitigated, however, by time and experience standing watch aboard the *John S McCain* in the 3 months preceding the accident. (In fact, the BMOW had recently qualified as a master helmsman, indicating a much higher level of knowledge and proficiency.) Thus, their misunderstandings expressed during the postaccident interviews and the misunderstandings of other crewmembers who were permanently assigned to the *John S McCain* point to a more fundamental issue with the qualification process and training with the IBNS.

The minimum required standards for a person to qualify to stand a particular watch position or to perform a specific function are outlined in qualification standards for Navy personnel. The standards normally include the demonstration of proficiency in all the basic functions of the watch. However, the standards for the helmsman, lee helmsman, and BMOW watches on the *John S McCain* did not include a requirement to demonstrate a transfer of steering or thrust control between bridge stations. The standards booklets did cite the ship-specific EOSS and EOCC, but as previously noted, the *John S McCain*'s EOSS and EOCC did not contain procedures for transferring steering and thrust control between bridge stations, nor did they contain procedures for ganging and unganging the throttles. Because the written procedures did not contain guidance for these evolutions, there was no standard for how watchstanders should be trained in these procedures. Given the lack of knowledge and understanding of the IBNS demonstrated during the accident and postaccident interviews and the lack of a training standard, the NTSB concludes that training on the operation of the IBNS for *John S McCain* watchstanders was inadequate, because it did not ensure that the crew could perform the basic functions of the watch, such as the transfer of steering and thrust control between bridge stations. Therefore, the NTSB recommends that the Navy revise the training standards for helmsman, lee helmsman, and BMOW for destroyers equipped with the IBNS to require demonstrated proficiency in all system functions, including the transfer of steering and thrust control between all bridge control stations.

2.7 Fatigue

Most people will experience fatigue with less than 7–8 hours of sleep in any 24-hour period; sleeping less than 7–8 hours in any 24-hour period leads to *acute fatigue*, whereas habitually obtaining less than 7–8 hours results in accumulated sleep debt leading to *chronic fatigue*. The *John S McCain* lee helmsman did not sleep during the night prior to the accident. The conning officer had about 3 hours sleep, and the helmsman, BMOW, JOOD, JOOW, and OOD had 5 hours or less sleep. In addition, the accident occurred during a time period considered to be a circadian low (roughly 0200–0600), when the body is normally more fatigued and prone to diminished alertness and degraded performance. Furthermore, the ship was operating under a watch schedule that shifted each 24-hour period; consequently, sleep periods for watchstanders were continually changing. Changing sleep periods impact the quality of sleep, which compounds fatigue related to lack of sleep and circadian lows. The NTSB concludes that *John S McCain* bridge watchstanders, particularly the lee helmsman, were acutely fatigued at the time of the accident, which impacted their situation awareness and their ability to respond to the perceived steering emergency. Work/rest records obtained by the NTSB did not provide sufficient information to determine if chronic fatigue was also a factor in this accident.

Prior to the accident, the Navy did not actively address fatigue among crews on Navy vessels. (The Navy has longstanding requirements addressing fatigue and crew rest on Navy aircraft.)[35] In a 2013 message, the Navy recommended that its surface force ships implement circadian watchbills that allow watchstanders to establish sleep patterns resulting in adequate rest. Following this accident and other accidents in 2017, the Navy directed that surface force ships implement the circadian watchbills recommended in 2013, and provided "guidelines" for the amount of sleep that each sailor should receive in a 24-hour period and the maximum number of hours a sailor should work per day to remain effective.[36] While these directives are a step in the right direction, the Navy policy does not require mandatory rest periods similar to the STCW Code requirements for commercial mariners. STCW Code requirements were the result of regulator and shipping industry efforts to develop a work/rest balance that addresses human needs and safety while meeting the demands of the maritime environment. Considering activities such as weapons handling and underway replenishments, Navy operations are as dangerous, if not more dangerous, than commercial operations. While combat and other non-standard operations may require crewmembers to forego adequate rest for short periods, relying on fatigued crewmembers to accomplish normal, daily tasking introduces unnecessary risk. Given the impact that fatigue may have had in this accident, the NTSB recommends that the Navy institute STCW Code rest standards for all crewmembers aboard its vessels.

2.8 Navy Oversight

The NTSB has found that the operating procedures provided to the *John S McCain* for the IBNS were inadequate. Specifically, procedures for the ganging of throttles and the transfer of steering and thrust control between bridge stations were incomplete or nonexistent. Training on the operation of the IBNS was also inadequate, as exhibited by most watchstanders' incorrect understanding of the steering control system and their inability to correctly follow emergency procedures during the accident. Although the CO had a responsibility to ensure that watchstanders

[35] Chief of Naval Operations, *NATOPS General Flight and Operating Instructions*, OPNAV Instruction 3710.7U, Washington DC: Department of the Navy, 2009.

[36] Commander, Naval Surface Force, US Pacific Fleet/Commander, Naval Surface Force Atlantic, *Comprehensive Fatigue and Endurance Management Policy*, COMNAVSURFPAC/COMNAVSURFLANT Instruction 3120.2, San Diego, California: Department of the Navy, 2017.

were properly trained and qualified, the Navy's training organization and the CO's superiors were required to assess and certify that the destroyer was safe to operate and that the watchstander qualification system was effective. The *John S McCain* crew's inability to effectively respond to the emergency calls into question the Navy's assessment and certification process. Additionally, despite significant research and universal standards in place within the marine industry, the Navy had no fatigue mitigation program or standards for ensuring crewmembers aboard the *John S McCain* had adequate rest. The NTSB concludes that the Navy failed to provide effective oversight of the *John S McCain* in the areas of bridge operating procedures, crew training, and fatigue mitigation.

3 Conclusions

3.1 Findings

1. Weather was not a factor in the accident.

2. The *Alnic MC*'s steering and propulsion systems as well as the credentials of its crew were not factors in the accident.

3. The functioning of the electrical, mechanical, and hydraulic components of the *John S McCain*'s steering and propulsion systems was not a factor in the accident.

4. During the process of shifting control of thrust, a *John S McCain* watchstander unintentionally transferred control of steering from the helm to the lee helm station.

5. The perceived loss of steering by the *John S McCain* helmsman was due to the unintentional transfer of steering control from the helm station to the lee helm station.

6. Although the helmsman perceived a loss of steering, there was no malfunction of the *John S McCain* steering system.

7. The unintended shift in steering control from the helm to the lee helm station on the *John S McCain* was likely a unilateral transfer initiated from the lee helm station.

8. Operating the *John S McCain*'s steering system in backup manual mode allowed for the unintentional, unilateral transfer of steering control and contributed to the errors that led to the accident.

9. Due to the perceived loss of steering, the bridge team on the *John S McCain* did not input starboard rudder orders needed to maintain the vessel's intended heading, which initiated the destroyer's port turn toward the *Alnic MC*.

10. Had the *John S McCain* crew pressed the emergency-override-to-manual button at the Ship Control Console when the perceived loss of steering occurred, the watch team would have reestablished control of steering and would have likely avoided the collision.

11. The *John S McCain*'s port and starboard propeller throttles were not ganged when the lee helmsman answered the order to reduce speed, and thus the throttles became unintentionally mismatched when he slowed only the port throttle.

12. The *John S McCain*'s mismatched throttles resulted in an accelerated rate of turn to port toward the *Alnic MC*.

13. The *John S McCain* bridge team was not monitoring the lee helmsman's response to orders and therefore did not recognize that the throttles were mismatched.

14. While attempting to reestablish rudder control on board the *John S McCain*, an inadvertent rudder input to port from aft steering and the resultant temporary movement of the rudders to port delayed the bridge team's attempt to turn the destroyer away from the *Alnic MC*.

15. The inability to maintain course due to a perceived loss of steering, the mismatch of port and starboard throttles producing an unbalanced thrust, and the brief but significant port rudder input from aft steering combined to bring the *John S McCain* into the path of the *Alnic MC*.

16. The decision to change the configuration of the *John S McCain*'s critical controls while the destroyer was in close proximity to other vessels increased the risk of an accident.

17. Transmission of automatic identification system information from the *John S McCain* would have improved the situation awareness of watchstanders on surrounding vessels, including the *Alnic MC* bridge team.

18. The *John S McCain* bridge team lost situation awareness in the minutes prior to the accident, and, consequently, they did not take sufficient action to avoid the collision.

19. The lack of a very high frequency radio announcement from the *John S McCain* alerting nearby vessels of the destroyer's steering casualty, as directed in the commanding officer's standing orders, deprived the *Alnic MC* master of information needed to take action to avoid the collision.

20. The *Alnic MC* master could not have reasonably determined that his vessel was in extremis before it was too late to maneuver the tanker to avoid the accident.

21. The *Alnic MC* bridge was not manned in accordance with the requirements of the company's safety management system.

22. It is unlikely that the presence of additional watchstanders on the *Alnic MC* bridge would have changed the outcome of the accident.

23. The design of the *John S McCain*'s touch-screen steering and thrust control system increased the likelihood of the operator errors that led to the collision.

24. The steering and thrust control written operating procedures on the *John S McCain*'s bridge did not describe the actions needed to transfer control between stations and therefore were inadequate.

25. Training on the operation of the Integrated Bridge and Navigation System for *John S McCain* watchstanders was inadequate, because it did not ensure that the crew could perform the basic functions of the watch, such as the transfer of steering and thrust control between bridge stations.

26. *John S McCain* bridge watchstanders, particularly the lee helmsman, were acutely fatigued at the time of the accident, which impacted their situation awareness and their ability to respond to the perceived steering emergency.

27. The Navy failed to provide effective oversight of the *John S McCain* in the areas of bridge operating procedures, crew training, and fatigue mitigation.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the collision between the destroyer *John S McCain* and the tanker *Alnic MC* was a lack of effective operational oversight of the destroyer by the US Navy, which resulted in insufficient training and inadequate bridge operating procedures. Contributing to the accident were the *John S McCain* bridge team's loss of situation awareness and failure to follow loss of steering emergency procedures, which included the requirement to inform nearby traffic of their perceived loss of steering. Also contributing to the accident was the operation of the steering system in backup manual mode, which allowed for an unintentional, unilateral transfer of steering control.

4 Recommendations

As a result of its investigation, the National Transportation Safety Board makes the following safety recommendations:

To the US Navy:

Issue permanent guidance directing destroyers equipped with the Integrated Bridge and Navigation System to operate in computer-assisted steering modes, except during an emergency. (M-19-8)

Issue guidance to your ships' crews emphasizing the importance of the appropriate use of very high frequency radio for safe navigation. (M-19-9)

Ensure that the modernization of complex systems, such as steering and control systems within the Integrated Bridge and Navigation System, incorporates the design principles set forth in ASTM International Standard F1166, *Standard Practice for Human Engineering Design for Marine Systems, Equipment, and Facilities*. (M-19-10)

Revise written instructions for bridge watchstanders on destroyers equipped with the Integrated Bridge and Navigation System to include operating procedures for shifting steering and thrust control between all bridge stations. (M-19-11)

Revise Integrated Bridge and Navigation System (IBNS) technical manuals to include a description of and procedures for ganging and unganging throttles, and ensure that revised technical manuals are distributed to IBNS-equipped ships. (M-19-12)

Revise the training standards for helmsman, lee helmsman, and boatswain's mate of the watch for destroyers equipped with the Integrated Bridge and Navigation System to require demonstrated proficiency in all system functions, including the transfer of steering and thrust control between all bridge control stations. (M-19-13)

Institute *Seafarers' Training, Certification and Watchkeeping Code* rest standards for all crewmembers aboard your vessels. (M-19-14)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

ROBERT L. SUMWALT, III
Chairman

EARL F. WEENER
Member

BRUCE LANDSBERG
Vice Chairman

JENNIFER HOMENDY
Member

Adopted: June 19, 2019

Appendixes

Appendix A – Investigation Information

The NTSB Office of Marine Safety investigated this accident because it involved a public vessel and a nonpublic vessel, in accordance with Title 49 of the *United States Code*, Section 1131(b)(1), and the joint NTSB-Coast Guard regulations at Title 49 of the *Code of Federal Regulations*, Section 850.15(b)(2).

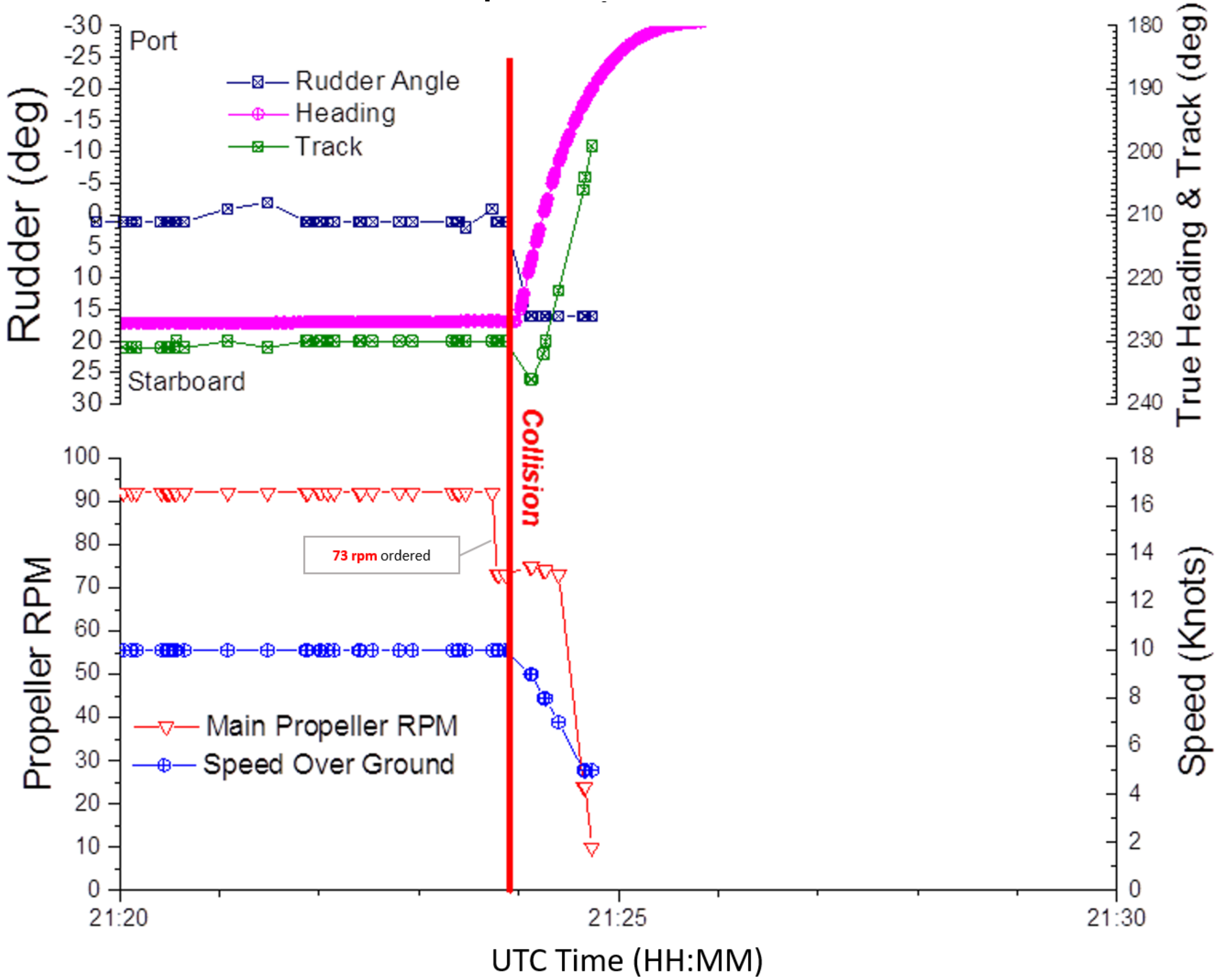
The NTSB was the lead federal agency in this accident investigation. The NTSB delegated its authority to the US Coast Guard to gather documents and perform interviews on behalf of the agency. Coast Guard Activities Far East led these efforts with support from various other Coast Guard units. The NTSB developed the analysis and probable cause based on the evidence gathered by the Coast Guard, additional documentation provided by the US Navy, and visits to two IBNS-equipped *Arleigh Burke*-class destroyers based in Norfolk, Virginia.

Appendix B – Vessel Information

Table B-1. Vessel information.

Vessels	*John S McCain*	*Alnic MC*
Owner/operator	US Navy	Energetic Tank Inc/Stealth Maritime Corporation
Homeport/port of registry	Yokosuka, Japan (homeport)	Monrovia, Liberia
Flag	United States	Republic of Liberia
Type	Destroyer	Tanker
Year built	1994	2008
IMO number	N/A	9396725
Classification Society	N/A	Bureau Veritas
Construction	Steel	Steel
Length	504.5 ft (153.8 m)	600.4 ft (183.0 m)
Draft	32.5 ft (9.9 m)	42.2 ft (12.9 m)
Beam/width	66.4 ft (20.2 m)	105.6 ft (32.2 m)
Displacement	8,261 long tons (8,394 metric tons)	37,204 long tons (37,801 metric tons)
Engine power; manufacturer	Four General Electric LM2500 gas turbine engines, 30,000 hp (22,371 kW) each; twin controllable-pitch propellers	One MAN B&W 6S50MC-C diesel engine, 12,900 hp (9,620 kW); one fixed-pitch propeller
Persons on board	280	24

Appendix C – *Alnic MC* Rudder and Propulsion Parameters



Appendix D – *John S McCain* Rudder and Propulsion Parameters

Rudder and propulsion parameters for the *John S McCain* were compiled and analyzed by the NTSB. However, a graphical presentation of this information (similar to the graph for the *Alnic MC* provided in appendix C) is not provided in this report due to the protected information contained within.

Appendix E – Pertinent Documents Reviewed by Investigators but Protected by the Navy

Certain Navy documents relevant to the accident are not releasable to the public. However, the Navy provided NTSB investigators access to these documents to aid the investigation. A brief description of these documents follows.

Class Advisory - Integrated Bridge and Navigation System (IBNS) Variant Ship Control System Steering and Thrust Location Guidance. This protected message to all *Arleigh Burke*-class destroyers equipped with the IBNS, issued after the accident, provides direction for the configuration of the IBNS.

***John S McCain* Aft Steering Closed-Circuit Television Video.** This protected video captured the equipment and personnel in aft steering prior to, during, and after the collision.

***John S McCain* Deck Log.** This protected logbook contains a chronological record of various bridge and other shipboard evolutions.

***John S McCain Engineering Operational Sequencing Systems* (EOSS)—Bridge and Aft Steering (excerpts pertaining to steering and propulsion).** These protected documents are booklets that contain step-by-step instructions for completing vital shipboard functions under normal operating conditions, such as changing steering and propulsion control from one station to another. The booklet instructions serve as a checklist for vessel personnel to perform the covered functions. Vessel personnel are not expected to memorize the contents of this document.

***John S McCain Engineering Operational Casualty Controls (EOCC)*—Bridge and Aft Steering (excerpts pertaining to loss of steering).** The EOCC is a protected document containing step-by-step procedures for vessel personnel to follow during emergency situations. Steps within an EOCC procedure that are labeled as "immediate actions" are required to be memorized by the responsible watchstander and executed immediately upon identification of the casualty. All steps in the *John S McCain* EOCC for loss of steering were labeled "immediate actions." Although EOCC is considered a subset of EOSS, EOCC procedures are normally kept in standalone booklets. However, on the *John S McCain*, the aft steering EOCC was contained within the EOSS booklet.

***John S McCain* IBNS Test Document.** This protected document was from an on-site technical assistance visit performed on the *John S McCain* in 2017.

NAVSEA Condition Reports for Electrical and Mechanical inspections. These protected reports contain the results of postaccident visual inspections of the *John S McCain's* aft steering equipment.

Personnel Qualification Standard (PQS). Published by the Naval Personnel Development Command, these protected booklets contain a compilation of "the minimum knowledge and skills that an individual must demonstrate in order to qualify to stand watches or perform other specific duties necessary for the safety, security or proper operation of a ship, aircraft or support system."[37]

Technical Manual, Integrated Bridge and Navigation System (IBNS) for DDG 51 Class Ships. This protected manual is guidance for personnel who operate and maintain the IBNS equipment aboard the *Arleigh Burke*-class ships and "provides the description, operation, maintenance, troubleshooting, and repair information" for the IBNS equipment.[38]

[37] Naval Personnel Development Command, *Personnel Qualification Standard for Ship's Control and Navigation*, NAVEDTRA 43492-2J, Norfolk, Virginia: Department of the Navy, 2017, p. 7.

[38] Forward to the *Technical Manual, Integrated Bridge and Navigation System (IBNS) for DDG 51 Class Ships*, 2014, p. 2.

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