Collision between US Navy Destroyer *Fitzgerald* and Philippine-Flag Container Ship *ACX Crystal* Sagami Nada Bay off Izu Peninsula, Honshu Island, Japan
July 17, 2017

Marine Accident Report

NTSB/MAR-20/02
PB2020-101007

National Transportation Safety Board

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Notation 65315
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June 17, 2017

National Transportation Safety Board

490 L'Enfant Plaza SW
Washington, DC 20594

National Transportation Safety Board. 2020. *Collision between US Navy Destroyer Fitzgerald and Philippine-Flag Container Ship ACX Crystal, Sagami Nada Bay off Izu Peninsula, Honshu Island, Japan, June 17, 2017*. Marine Accident Report NTSB/MAR-20/02. Washington, DC.

Abstract: This report discusses the June 17, 2017, collision between the US Navy Destroyer *Fitzgerald* and the container ship *ACX Crystal* off Honshu Island, Japan. The *Fitzgerald* was heading in a southerly direction, bound for the Philippines, and crossing the track of the *ACX Crystal*, east-northeast-bound for Tokyo Bay. Seconds before the collision, the watch officers on both vessels ordered course and speed changes, but the vessels ultimately collided. As a result of the accident, seven *Fitzgerald* sailors died, three were injured, and the destroyer sustained more than $300 million in damage. No one was injured on the *ACX Crystal*, but the vessel sustained damage to its bow. No pollution was reported.

This report identifies the following safety issues: The *Fitzgerald* crew's fatigue, the practice of US naval vessels not to broadcast automatic identification system (AIS) information, failure of both vessels to follow required actions in accordance with the International Regulations for the Prevention of Collisions at Sea, the *Fitzgerald* commanding officer's failure to adequately assess the hazard presented by the vessel's intended transit, and insufficient oversight by the US Navy. As a result of this investigation, the National Transportation Safety Board makes new safety recommendations to the US Navy and Sea Quest Ship Management, Inc.

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Acronyms and Abbreviations

AB	able-bodied seaman
AIS	automatic identification system
ARPA	automatic radar plotting aid
BMOW	boatswain mate of the watch
CIC	combat information center
CO	commanding officer
COLREGS	collision regulations (Convention on the International Regulations for Preventing Collisions at Sea)
DESRON	Destroyer Squadron (Navy unit)
ECDIS	electronic chart display and information system
GMDSS	global maritime distress and safety system
GPS	global positioning system
hp	horsepower
IMO	International Maritime Organization
JOOD	junior officer of the deck
kW	kilowatt
MoBoard	maneuvering board
NOAA	National Oceanic and Atmospheric Administration
NTSB	National Transportation Safety Board
OOD	officer of the deck
PQS	personnel qualification standards (Navy)
SMS	safety management system
SOLAS	International Convention for the Safety of Life at Sea
SORM	Standard Organization Regulations of the Navy
STCW Code	Seafarers' Training, Certification and Watchkeeping Code
VDR	voyage data recorder

VMS	voyage management system
VHF	very high frequency
XO	executive officer

Executive Summary

Accident Summary

About 0130 (local time) on June 17, 2017, the US Navy Destroyer *Fitzgerald* with 315 persons on board was southbound at a speed of about 22.1 knots in the bay of Sagami Nada off Japan's Honshu Island after departing the US Navy Base at Yokosuka, Japan, bound for the Philippines. The Philippine-flag container ship *ACX Crystal*, operated by Sea Quest Ship Management, Inc., with 20 crewmembers on board was east-northeast-bound at a speed of about 18.5 knots, headed to Tokyo, Japan, from Nagoya, Japan. As the distance between the two ships continuously decreased, neither vessel radioed the other. Seconds before the collision, the watch officers attempted to maneuver the vessels to avoid impact, but the actions were too late, and the ships collided. Seven *Fitzgerald* crewmembers died in the accident, and three crewmembers suffered serious injuries. The destroyer sustained extensive damage to its forward starboard side. The *ACX Crystal* sustained damage to its bow; no injuries were reported.

Investigation

The National Transportation Safety Board (NTSB) was the lead federal agency in this accident investigation and delegated its authority to the US Coast Guard to gather documents and perform interviews on behalf of the NTSB. The NTSB developed the analysis and probable cause based on the evidence gathered by the Coast Guard and additional documentation provided by the Navy.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the collision between US Navy Destroyer *Fitzgerald* and container ship *ACX Crystal* was the *Fitzgerald*'s bridge team's failure to take early and substantial action to avoid collision as the give-way vessel in a crossing situation. Contributing was ineffective communication and cooperation among the *Fitzgerald* crew on the bridge and in the combat information center (CIC), and the *Fitzgerald* commanding officer's (CO) insufficient planning for the hazards of the vessel's intended transit. Also contributing was the Navy's ineffective oversight of the *Fitzgerald* in the areas of operations scheduling, crew training, and fatigue mitigation. Also contributing to the accident was the *ACX Crystal* watch officer's lack of early detection of the Navy vessel and insufficient actions to avoid collision once in doubt as to the destroyer's intentions.

Safety Issues

Safety issues identified in this accident include the following:

- ***Fitzgerald* crew's insufficient training.** The surface warfare supervisor missed several critical targets, and the officer of the deck (OOD), who was in charge of the bridge personnel, made some poor navigational decisions and did not request support from the CIC. Further, the tactical action officer (in charge of the CIC) did not ensure that her personnel supported the bridge team.

- ***Fitzgerald* crew's fatigue.** The ship scheduled multiple events on the day before the accident that required the participation of much of the crew, including key watchstanders on the accident watch. All of these watchstanders had little or no sleep before heading to watch. Further, the accident occurred just prior to 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.

- **Practice of US naval vessels not to broadcast automatic identification system (AIS) signals.** The *Fitzgerald* was equipped with AIS, a maritime navigation safety communications system that automatically transmits vessel information to other vessels, allowing early detection of a target. On the day of the accident, the *Fitzgerald* was not transmitting its data, although it was receiving information about other vessels in the area. To track the destroyer's position electronically, other vessels had to rely on visual means or radar. The destroyer was built by design to present a smaller target on radar displays than other (non-military) vessels of similar size. The destroyer's radar signature appeared significantly smaller than that of a comparable merchant vessel of the same size on the radar on the *ACX Crystal*, the container ship with which it later collided.

- **Failure of both vessels to follow required actions in accordance with the Convention on the International Regulations for Preventing Collisions at Sea (COLREGS).** As the *Fitzgerald* proceeded in a southbound direction on the evening of the accident, the OOD picked up three contacts—the *ACX Crystal*, the *Maersk Evora,* and the *Wan Hai 266*—off the destroyer's starboard bow at approximately 12 miles. The three vessels were on parallel paths heading east-northeasterly. Per the COLREGS, when two vessels are crossing, the vessel that has the other on its starboard side shall keep out of the way of the other vessel. The *Fitzgerald* had all three vessels, the *ACX Crystal* the *Maersk Evora,* and the *Wan Hai 266* on its starboard side, and therefore was the give-way vessel to all three ships. Instead, the bridge team on the *Fitzgerald* continued ahead, ultimately crossing ahead of the *Wan Hai 266* and placing the destroyer in the path of the *ACX Crystal*, which resulted in the collision. As a potential collision situation was developing, the second officer on board the *ACX Crystal*, the stand-on vessel, did not take sufficient action when it became apparent that the give-way vessel was not taking enough action to avoid collision.

- ***Fitzgerald* commanding officer not augmenting bridge watchstanding personnel with a more experienced officer while the vessel was crossing busy coastal traffic routes.** The *Fitzgerald* OOD was supported by 6 bridge and 20 CIC personnel, and was manned in accordance with the US Navy's at-sea policy.

- ***Fitzgerald* commanding officer not adequately assessing the hazard presented by the vessel's intended transit.** The vessel's path leading up to the accident crossed major shipping routes off the coast of Japan; however, the risk of transiting through areas known for heavy traffic was not addressed.

- **Insufficient oversight and directive by the US Navy.** The *Fitzgerald*'s schedule leaving port to comply with certification requirements and to return to its deployment schedule provided little rest for the crew on the day before the accident. The Navy had no fatigue mitigation program or standards for ensuring shipboard crews had adequate rest. The Navy was required to assess and certify that the operating procedures and watchstander

qualification system aboard the *Fitzgerald* were effective, but the crew's navigation decisions on the night of the accident indicate the Navy's assessment and certification process requires review.

Findings

- Weather and the steering and propulsion systems on board the *Fitzgerald* and the *ACX Crystal* were not factors in the accident.
- The *Fitzgerald* bridge team, on the give-way vessel, did not take early and substantial action to avoid collision with the stand-on *ACX Crystal*.
- The communication and cooperation among the *Fitzgerald* crew on the bridge and in the combat information center were ineffective leading up to the accident.
- The *Fitzgerald*'s unexplained small course change to starboard minutes before the collision put the vessel on a collision course with the *ACX Crystal*.
- The *Fitzgerald* combat information center personnel did not effectively support the bridge team in tracking nearby surface targets.
- The *Fitzgerald* provided a detectable radar signature, and the second officer on board the *ACX Crystal* should have acquired the destroyer on the automatic radar plotting aid to determine risk of collision.
- When the second officer on the *ACX Crystal* did not receive a response to his signaling attempts and saw no noticeable change in approach from the destroyer, he did not take sufficient action to avoid the collision.
- The absence of an automatic identification system signature broadcast from the *Fitzgerald* likely contributed to the lack of its early detection by the *ACX Crystal* bridge team.
- The *Fitzgerald* commanding officer did not adequately assess the hazard presented by the vessel's intended transit, which crossed busy coastal traffic routes, and should have assigned a more experienced officer to augment the bridge team.
- Several *Fitzgerald* bridge and combat information center watchstanders were likely acutely fatigued at the time of the accident, which impacted their situation awareness and ability to identify and respond to the approaching *ACX Crystal*.
- The Navy failed to provide effective oversight of the *Fitzgerald* in the areas of operations scheduling, crew training, and fatigue mitigation.

Recommendations

New Recommendations

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

To the US Navy

Review and revise fleetwide training and qualification requirements for officers of the deck related to the collision regulations. (M-20-10)

Review and revise bridge resource management training in your approved course curriculum to promote a cohesive team environment and improve communication within and between bridge and combat information center teams. (M-20-11)

Instruct your vessels to broadcast automatic identification system information while operating in the vicinity of commercial vessel traffic at all times unless such broadcast compromises tactical operations or strategic interest. (M-20-12)

To Sea Quest Ship Management, Inc.

Provide additional training for your navigation officers on collision avoidance regulations, radar, and automatic radar plotting aid. (M-20-13)

1 Factual Information

1.1 Background and Precipitating Events

At 1130 (local time) on the morning of June 16, 2017, the day before the accident, the US Navy Destroyer *Fitzgerald* departed the port of Yokosuka on Honshu Island, Japan, about 50 nautical miles northeast of the collision site, to conduct scheduled operations in the bay of Sagami Wan.[1] The *Fitzgerald* first went to an anchorage for about 3 hours, where it received ammunition. The vessel then proceeded to a location in Sagami Wan off the southwest coast of the Miura Peninsula where, between 1800 and 2111, the crew conducted helicopter flight operations and then, between 2133 and 2303, small boat operations.[2]

Figure 1. US Navy Destroyer *Fitzgerald*. (Source: US Navy)

After completing these operations, the *Fitzgerald* was scheduled to conduct engineering drills June 17–18 while en route to operations in the South China Sea, and then continue to Subic Bay, Philippines.

[1] All miles in this report are nautical miles (1.15 statute miles) unless otherwise noted. Weather visibility data may be reported in statute miles.

[2] Supporting documentation for information referenced in this report can be found in the public docket for this accident, which can be accessed from the National Transportation Safety Board's (NTSB) Accident Dockets web page by searching DCA17PM018.

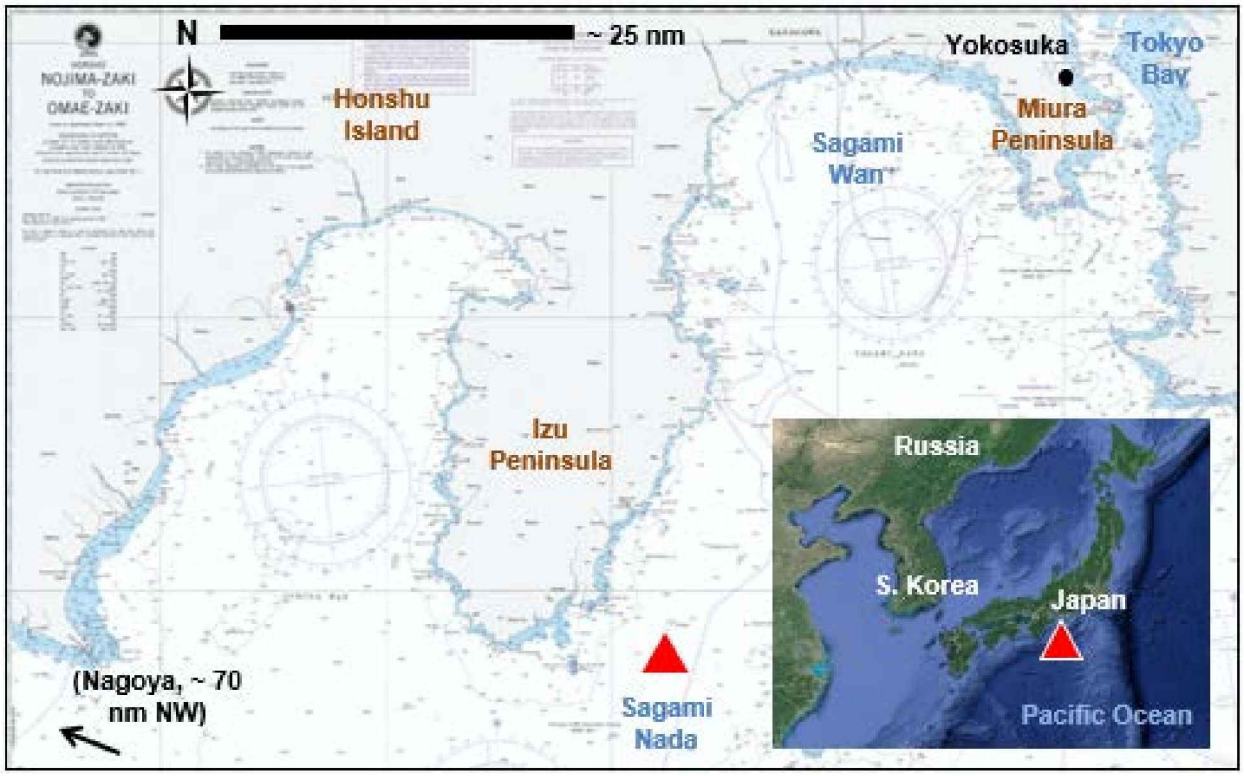

Figure 2. Chart of the accident area off the south coast of Honshu Island, Japan. The accident site is marked with a red triangle. (For more detail, see section 1.8 Waterway Information.)(Source for chart: National Geospatial Intelligence Agency, with annotations by NTSB. Background source for inset map: Google Earth.)

On June 16 at 2200, a watch turnover took place on board the *Fitzgerald* navigation bridge. It was preceded by a watch exchange between the offgoing watchstanders (who had stood the 1700–2200 navigation watch) and the oncoming 2200–0200 personnel. The new bridge complement included six persons:

- **Officer of the deck (OOD).** Directly responsible for the safe navigation and general operation of the ship and in charge of the bridge watchstanding personnel during her shift. She was commissioned in the Navy in August 2014, had served on board the *Fitzgerald* since May 2016, and had previously stood three or four bridge watches in this waterway.

- **Junior officer of the deck (JOOD).** Principal assistant to the OOD. Her duties included recommending traffic management based on information from radar (such as data by automatic radar plotting aid, or ARPA) and from manual plotting. She was commissioned in the Navy in June 2012, had served on board the *Fitzgerald* since September 2016, and had been in this waterway during that time, but had not previously stood a navigational watch.

- **Conning officer.** Assigned to conduct the movement of the vessel, as directed by the OOD, relaying steering and propeller thrust orders from the OOD to the helmsman. The position was an entry-level watch position for new officers or for those who were new to the bridge, generally requiring no prior bridge watchstanding qualifications. He was

commissioned in the Navy in January 2017, and the *Fitzgerald* was his first ship. The accident watch was his first bridge watch on this waterway.

- **Quartermaster of the watch.** Assigned to plot the *Fitzgerald*'s movement and make recommendations to the OOD. He joined the Navy in 2002 and the *Fitzgerald* in September 2016, having previously served on Norfolk, Virginia-based ships in the Mediterranean Sea and the Arabian Gulf.

- **Helmsman.** Assigned to carry out steering and propeller-thrust orders from the conning officer and the OOD. She joined the Navy in 2015 and the *Fitzgerald* in April 2017.

- **Boatswain mate of the watch (BMOW).** The BMOW was the enlisted person who, in addition to other duties, managed the enlisted personnel on the bridge watch including the helmsman and lee helmsman. He joined the Navy in July 2006 and the *Fitzgerald* in May 2015.

The following graphic illustrates the key personnel and their hierarchy in the *Fitzgerald* bridge watch leading up to the accident:

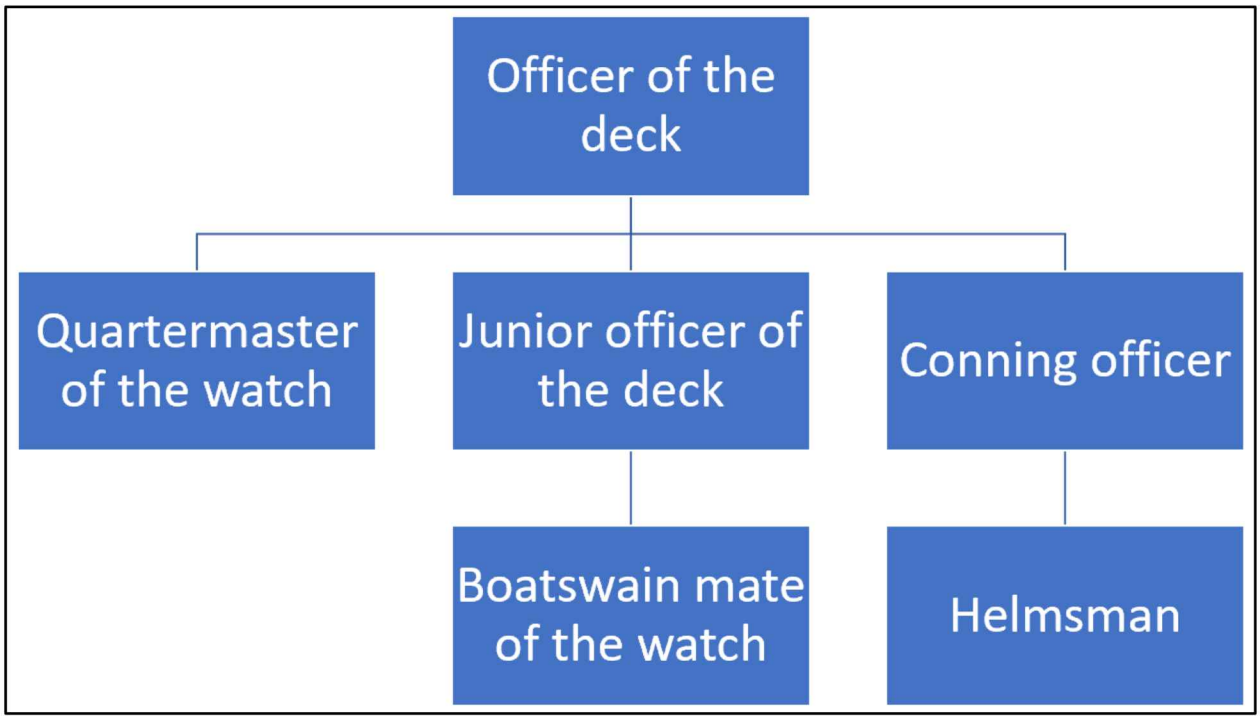

Figure 3. Key members of the *Fitzgerald* bridge watch team leading up to the accident.

The only reported equipment malfunction in the bridge or CIC was an inoperative radar repeater (the SPA-25) in the CIC.[3] It was shut down completely.

[3] A *CIC* is an internal room on board a military vessel that serves as a tactical center and provides processed information for command and control of the nearby area of operations. The CIC focuses on potential security threats and tracks air and surface contacts. CIC personnel coordinate with and support the navigation bridge crew.

The *Fitzgerald*'s first- and second-in-command—the commanding officer (CO) and the executive officer (XO)—had been on the navigation bridge throughout the evening of June 16.[4] About 2300, as the *Fitzgerald* small boat operations ended and the destroyer departed the Sagami Wan training area to begin the voyage south, the CO exited the bridge for the night. Before leaving, he issued the night orders for the transit and advised the OOD of the change. He doubled the standard allowable deviation from the predetermined trackline before the OOD was required to notify him. The CO told investigators he made this change to allow the OOD more leeway in contact avoidance so that he could "get a little more sleep before the next day."[5] The XO left the bridge about 2330, approximately half an hour after the CO.

Like the navigation bridge, the destroyer's CIC also had a watch change for the 2200–0200 shift. The oncoming CIC complement included six persons:

- **Tactical action officer.** Assigned to oversee the defensive and offensive posture of the vessel and to ensure CIC personnel supported the bridge watch. She joined the Navy in December 2008 and, after serving several seagoing and shoreside assignments, joined the *Fitzgerald* in January 2017, qualifying as tactical action officer the following March. She had stood about 10 bridge or CIC watches in the accident waters.

- **Watch officer.** Assigned to supervise the CIC and its operations, ensure all contacts were detected and reported, and ensure all evaluated information was disseminated to pertinent entities, such as the bridge. The watch officer was commissioned in the Navy in 2015 and joined the *Fitzgerald* in December that year. He had made about five transits in the accident waterway.

- **Watch supervisor.** Assigned to report directly to the CIC watch officer and support both him and the tactical action officer. The watch supervisor was also the primary person to plot via maneuvering board (MoBoard) and report the results to the bridge.[6] The watch supervisor joined the Navy in 2006 and the *Fitzgerald* in November 2016, qualifying as CIC watch supervisor in March 2017.

- **Surface warfare coordinator.** Assigned to develop the surface plot after obtaining target information from both the surface warfare supervisor and the optical sight system operator (see below) and evaluate surface contacts contained on the surface plot. Responsible for apprising the bridge watchstanders of surface radar contacts that might impact the destroyer's intended movement, and for populating the surface plot with other

[4] See Section 1.5.1 of this report for information on the CO and XO's experience.

[5] The NTSB delegated its authority to the US Coast Guard to gather documents and perform interviews on behalf of the NTSB in this accident investigation.

[6] Manual plotting is done by placing a mark on a sheet of paper called a maneuvering board (or "MoBoard" for short), corresponding to the radar target's true bearing and range from one's vessel and then repeating this process at a set time interval (usually 3 minutes.) A line connecting the marks and extending in the direction in which the target is moving provides a vector whose closest point to one's vessel is the closest point of approach and the location from one's own vessel where the closest proximity will occur. After vectorially adding one's vessel's course and speed to the target ship's vector, a third vector is obtained by connecting the dots to form a triangle. The length and direction of this third vector gives the target vessel's course and speed.

ship information obtained via automatic identification system (AIS).[7] The surface warfare coordinator joined the Navy in 1994 and the *Fitzgerald* in December 2015. He said that he had made "a couple" of previous trips in the accident waterway.

- **Surface warfare supervisor.** Assigned to identify surface contacts by radar and populate the surface plot or report the surface contact to the surface warfare coordinator. The surface warfare supervisor joined the Navy in 2014 and the *Fitzgerald* in May 2016, and qualified for his current role in March 2017. He had not previously transited in the accident waterway during a CIC watch.

- **Optical sight system operator.** Assigned to visually locate surface contacts via a night-vision-capable optical system. He joined the Navy in May 2015; the *Fitzgerald* was his first ship. Although he stated that he had stood many CIC watches as optical sight system operator, investigators could not determine if any of those watches were in the accident waterway.

The following graphic illustrates the key personnel and their hierarchy in the *Fitzgerald* CIC watch leading up to the accident:

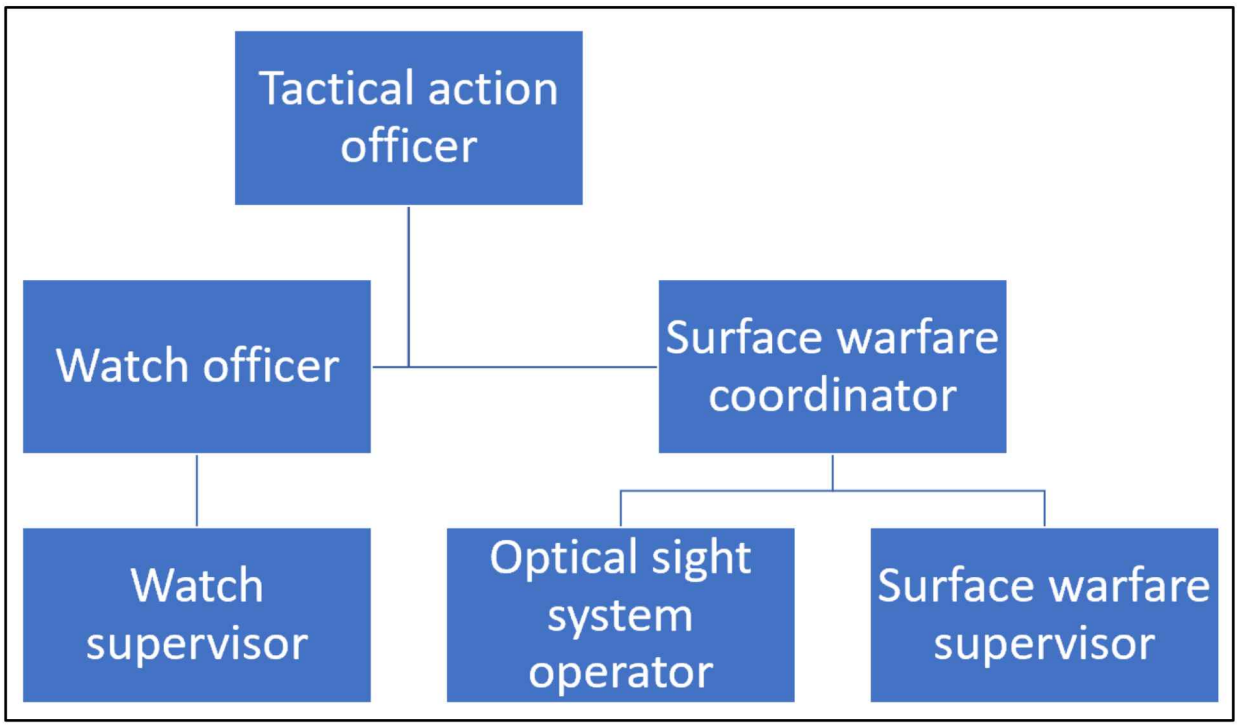

Figure 4. Key members of the *Fitzgerald* CIC watch team leading up to the accident.

[7] *AIS* is a maritime navigation safety communications system. At 2- to 12-second intervals on a moving vessel, the AIS automatically transmits vessel 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. The rate at which the AIS information is updated depends on vessel speed and whether the vessel is changing course. AIS also automatically receives information from similarly equipped vessels. Coast Guard regulations require AIS in waterways governed by vessel traffic control (Title 33 *CFR* Part 164).

As the *Fitzgerald* proceeded southbound, it approached an area of the waterway where the destroyer would be crossing the path of vessels transiting the coast of Japan and heading toward and coming from Tokyo Bay. Per the CO's standing orders, the OOD was instructed to call the CO if other vessels had a closest point of approach (CPA) of less than 3 miles. The report was to be made at 5 miles or 20 minutes prior to the calculated CPA, whichever occurred first. According to the *Fitzgerald*'s voyage management system (VMS), between 2340 and 0025, the destroyer overtook contacts both to port and starboard.[8] At 0033 on June 17, VMS showed five vessels heading in a general northeasterly direction, crossing from starboard to port relative to the *Fitzgerald*, and two vessels heading in the same general direction as the *Fitzgerald* (on the starboard bow). The OOD called the CO to discuss these contacts. To negotiate around these vessels, the *Fitzgerald* deviated from the planned trackline by as much as 3,800 yards (1.8 nautical miles). The destroyer, at an overall speed of about 19–20 knots, proceeded to transit astern of the five northeast-bound vessels, leaving them on its port side, with the closest separation at just under 1 mile. After 0033, although subsequent vessels had CPAs of less than 3 miles from the *Fitzgerald*, the OOD placed no further calls to the CO.

One of the many vessels transiting in the same area was the Philippine-flag container ship *ACX Crystal*. It had departed the port of Nagoya, Japan, about 70 miles west-northwest of the accident site, at 1648 the previous afternoon (June 16) after discharging and loading containers. The *ACX Crystal*, with about 15,330 metric tons of cargo on board, was scheduled to arrive at the Tokyo Bay pilot station at 0500 on the morning of June 17. It was transiting in an east-northeast direction.

Figure 5. Container ship *ACX Crystal*, post collision. (Source: Sea Quest Management)

[8] A *voyage management system* is part of Navy vessels' electronic software suite and is used for voyage planning and navigation. (Also see section 1.3.1.)

The master of the *ACX Crystal* had been working on the bridge while the ship was in Nagoya and during its departure from there until 20 minutes past 2000, when he had transferred the conn to the third officer. He then completed paperwork, including sending an email at 2123, and shortly thereafter went below to rest. As the *ACX Crystal* continued its voyage toward Tokyo, about midnight, the third officer was relieved by the second officer, and an able-bodied seaman (AB) then on watch was relieved by the accident AB scheduled to stand the 0000–0400 watch. From midnight until the accident, the bridge was staffed by the vessel's second officer in charge of the navigation watch, and the AB serving both as helmsman and, when the ship was in autopilot steering, lookout. About midnight on June 17, the *ACX Crystal* was eastbound near the southern tip of the Izu Peninsula, transiting at a speed of about 18 knots. Travelling nearly parallel to the *ACX Crystal* was the Singapore-flag container ship *Wan Hai 266*, also headed to Tokyo Bay and about 2 miles north off the *ACX Crystal*'s port side. The *Maersk Evora* was also traveling nearly parallel to the *ACX Crystal*, approximately 4 miles south and astern of the *ACX Crystal*.

The crew of the *ACX Crystal* reported no problems with the vessel's steering and propulsion systems prior to the accident, and VDR data indicated no problems.

1.2 The Accident

The *Fitzgerald* was equipped with AIS but was not transmitting data to other vessels. Per Navy practice at the time of the accident, naval vessels did not broadcast AIS information to other vessels but could receive information from other vessels. The *Fitzgerald*'s AIS was set to receive-only during the accident voyage. To track the destroyer's position electronically, other vessels had to rely on visual means, radar, and automatic radar plotting aid (ARPA).[9] The destroyer was built by design to present a smaller target on radar displays than other (non-military) vessels of similar size.

According to voyage data recorder (VDR) information obtained from the *ACX Crystal*, about 0108, the *Fitzgerald* was about 12 miles away from the container ship. The *Fitzgerald* OOD told investigators that at that distance, she first noticed two vessels on the bridge SPS-73 radar. She said she tried to "hook" or electronically acquire the vessels but had trouble doing so.[10] According to the Coast Guard, "The OOD stated the closest vessel was *ACX Crystal*, which was being overtaken on her starboard side by a second vessel. Based on diagrams created by the OOD during the interview, along with information obtained from Voyage Data Recorders from *ACX Crystal* and *Wan Hai 266*, the vessel identified by the OOD as *ACX Crystal* may have instead been *Wan Hai 266*." However, the NTSB's review of data from the three ships indicates that the OOD was likely acquiring the *ACX Crystal* and the *Maersk Evora*, with only intermittent identification of the *Wan Hai 266*.

The OOD told investigators that when the *Fitzgerald* was about 10 miles away from the *ACX Crystal* (about 0112, according to VDR data), she could visually see the ship's lights through the bridge windows, off the destroyer's starboard bow. According to the CIC surface warfare

[9] An *ARPA* is a computer-assisted radar data processing system that generates predictive vectors and other ship movement information. ARPAs calculate and display collision-related information and generate potential maneuver scenarios for operators to take to avoid collision with other vessels.

[10] Only acquired radar images will provide computed and informational data (such as AIS) on an ARPA. Acquiring a radar image on the ARPA can be accomplished automatically or manually. Automatic acquisition is accomplished, by the ARPA and without human interaction, after the operator sets time and distance parameters into the unit. Manual acquisition requires the operator to place an electronic cursor over the radar image and press a button.

coordinator—the person monitoring and coordinating the overall surface picture, including all surface radar targets—he scanned his scope for contacts and then went to the restroom sometime between 0105 and 0110 and returned sometime between 0115 and 0120. He said that on his return, he again scanned his radar for targets but initially saw nothing, nor did his support personnel (the surface warfare supervisor and the optical sight system operator) report any targets to him.

About 0115, the second officer on the *ACX Crystal* began a scheduled course change per the vessel's voyage plan. The *ACX Crystal* gradually turned from a mainly eastbound course of 089° to an east-northeast-bound course of about 069°. At 0119, when the course change was completed, the *Fitzgerald* was about 6.5 miles away, still approaching from the north off the container ship's port bow. The second officer said he visually spotted a green light at a distance of about 3 miles, which later was determined to be the *Fitzgerald.*[11] He continued watching the vessel (both visually and on radar) as the *Fitzgerald* drew closer. Both he and the AB stated that the green [starboard] light was the only light they saw illuminated on the target.

The *Fitzgerald* OOD told investigators that when the closer vessel was about 4 miles away, the destroyer's ARPA provided a closest point of approach of 0.75 mile, with that vessel crossing astern of the *Fitzgerald*. A time-aligned overlay of *Wan Hai 266* radar images, *ACX Crystal* radar images, and *Fitzgerald* VMS images between 0121 and 0125 indicated that the OOD used ARPA to acquire and track two eastbound vessels to starboard in this period. The closest vessel was the *ACX Crystal*, and the second vessel was the *Maersk Evora.* The OOD told investigators that, about this time, she discussed the *Fitzgerald*'s distance to the two eastbound vessels with the JOOD, who until this time in the transit had predominantly been performing lookout duties and training the new conning officer in how to stand lookout. The JOOD told investigators that she went to the starboard bridge wing and looked at the *ACX Crystal* through a large set of binoculars called "big eyes." She said that there was a second vessel behind the *ACX Crystal* and that she urged the OOD to come look through the big eyes, which she did. The JOOD said she told the OOD to slow the destroyer's speed, but that the OOD replied that a slowdown would make the situation worse. The OOD told investigators that she thought about turning to starboard and going astern of both vessels but decided against this maneuver because that course would take the destroyer closer toward land. At this time, the vessel was 8.2 miles offshore from the Izu Peninsula.

According to the *Fitzgerald*'s deck log, at 0122, a course change was ordered to 200° (from 190°). About a minute and a half later, at 0124, ARPA information from the *Wan Hai 266* showed that the destroyer had come right, to the new course. The reason for this course change was not revealed during post accident interviews. A study performed by the NTSB determined that the *Fitzgerald* would have passed 0.5 nautical miles ahead of the *ACX Crystal* if the *Fitzgerald* had remained on a course of 190° instead of changing to 200°.[12]

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[11] According to international regulations, as a power driven vessel >50 meters in length, the *Fitzgerald* was required to display green and red navigational sidelights visible at a minimum distance of 3 miles, a masthead light forward and a second masthead light abaft of and higher than the forward one, visible at 6 miles, and a sternlight visible at 3 miles.

[12] The Vehicle Performance Study used GPS position data from the *ACX Crystal* and the *Wan Hai 266* together with *Fitzgerald* course and bearing information from the *Wan Hai 266* to reconstruct and evaluate the pre-collision paths of the *ACX Crystal* and the *Fitzgerald.*

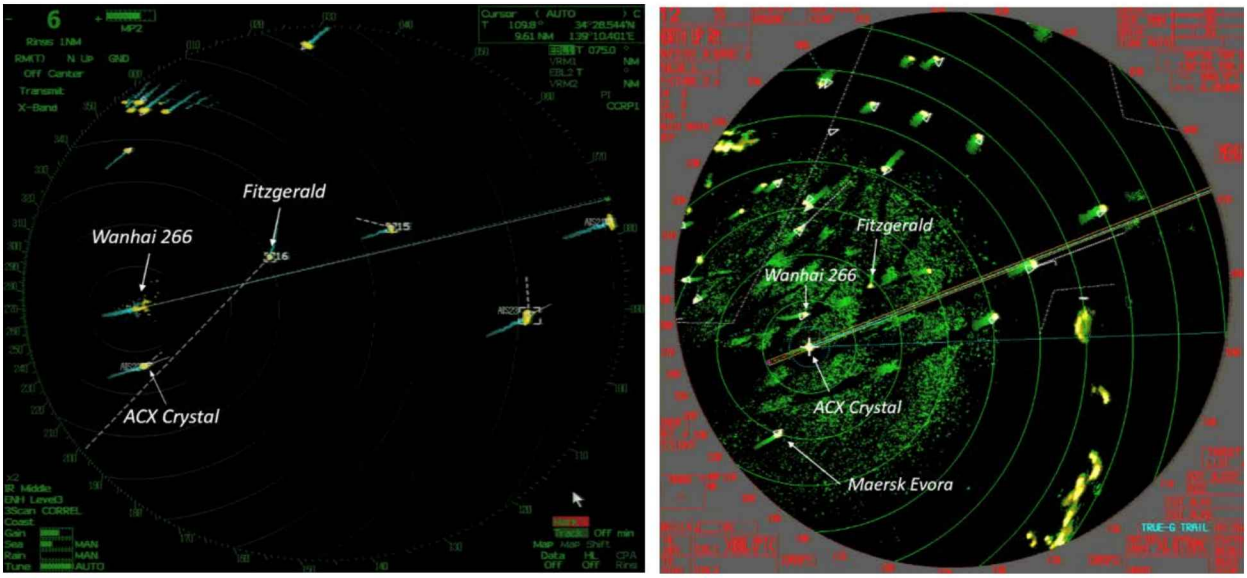

Figure 6. A comparison of radar screens from different vessels before the collision. Left, screen capture from the *Wan Hai 266* electronic navigation software, about 6 minutes before the collision. Right, screen capture from the *ACX Crystal* electronic navigation software (radar and ARPA), at the same time. (Vessel names have been added to screen images.)

About the same time, the second officer on the *ACX Crystal* watched the *Fitzgerald* closely and when the destroyer was about 3 miles away, he checked his radar, looked at the destroyer's green light, checked the radar again, and asked the AB to stand by the wheel.[13] The second officer told investigators he then went to the port side of the bridge and flashed a signal light in the direction of the *Fitzgerald*. According to the Coast Guard Report, this occurred at 0127:35, or about 2.5 minutes after the green light was first observed, and about 3 minutes before the collision. The second officer told investigators that there was no reply to his signaling light. Shortly thereafter, he returned to the radar but then walked back to the port side of the bridge and flashed the signal light twice at the destroyer. He said he was expecting the *Fitzgerald* to turn because the *ACX Crystal* was the stand-on vessel in this crossing situation with the *Fitzgerald* to port, stating: "you are the green light, you are supposed to alter course."

The distance between the *Fitzgerald* and the *ACX Crystal* was now closing at about 50 feet per second as the two vessels were moving toward each other at a speed of relative motion of more than 30 knots.

The *Fitzgerald*'s surface warfare coordinator told investigators that after returning from the restroom to the CIC, he continued checking the radar and communicating with the optical sight system operator to ensure no surface contacts were in the destroyer's immediate vicinity when suddenly he noticed a "pop-up" radar contact on AIS. He said he directed the optical sight system operator to look in the direction of the contact. According to the optical sight system operator, who told investigators that he had visually seen about 80–100 targets in the general area during his watch, he spotted a ship on the given bearing and estimated it to be about 4–5 miles away (investigators later determined that this vessel was the *Maersk Evora*). The optical sight system operator said he

[13] The second officer told investigators that he used the x-band, 3-cm radar, set to a 12-mile range. Its images were recorded by the VDR.

continued turning his camera to the right and then saw the *ACX Crystal*. He said he froze for about 8 seconds because he was stunned at how close the *ACX Crystal* was. The CIC's tactical action officer also saw the image of the *ACX Crystal* on the optical sight system operator's camera but could do nothing in the short time between recognition and the collision.

When the vessels were about 1,000 meters apart, the second officer on the *ACX Crystal* told the AB to apply 10° starboard rudder, then 15° starboard rudder, and finally hard to starboard.

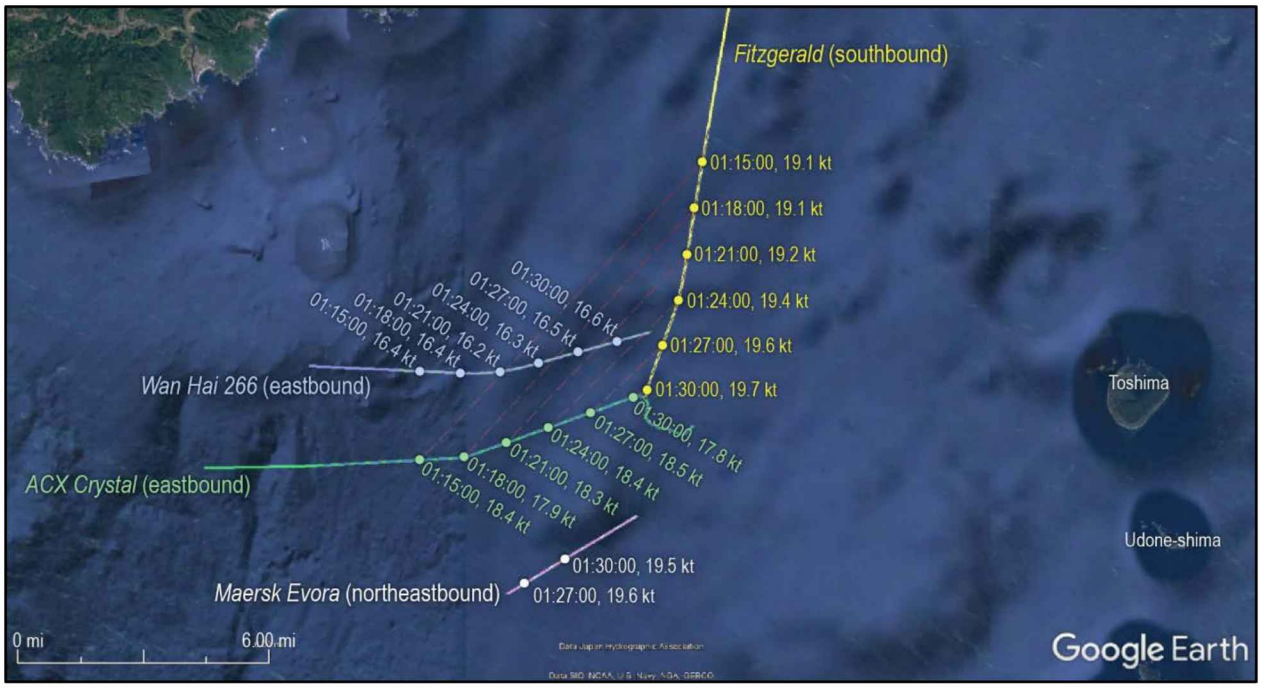

Figure 7. NTSB reconstruction of the paths of the *Fitzgerald*, *Wan Hai 266*, *ACX Crystal*, and *Maersk Evora*. (Background source: Google Earth)

On board the *Fitzgerald*, the OOD had believed during the approach that the destroyer would clear both crossing vessels (the *ACX Crystal* and the *Maersk Evora*, or possibly the *Wan Hai 266* and the *ACX Crystal*). The OOD told investigators that she saw the *ACX Crystal*'s superstructure about a minute before the collision and she realized the *Fitzgerald* was not going to clear the containership. According to the OOD, she initially ordered the conning officer to come hard right, however, she cancelled that order before the conning officer could relay the order to the helmsman. The OOD said she then ordered hard left rudder and ahead flank speed. The BMOW, who was standing near the helmsman, stated that the OOD "gave the order all ahead full for 25 knots, and right after that, all ahead flank." He went on to say that when the OOD gave the order for "hard left rudder" he "just grabbed the wheel" (from the helmsman) and "put it over."

A review of *Fitzgerald* engine parametric data indicated that both the port and starboard engine throttle settings were simultaneously advanced by increments at 0130:06, 0130:14, and 0130:22. Engine monitoring data indicated that both engines responded to the requested commands.

At 0130:32, with the *Fitzgerald* traveling at 22.1 knots and the *ACX Crystal* at 18.4 knots, the vessels collided. Neither the *Fitzgerald* nor the *ACX Crystal* bridge teams sounded any alarms or made any announcements to warn their crews of the impending collision.

The *ACX Crystal*'s bow penetrated the *Fitzgerald*'s hull and superstructure, trapping numerous crewmembers aboard the destroyer, and the vessel took on a 7° starboard list. The *Fitzgerald*'s crew went to work to control the flooding, assist injured crew, and search for the missing. Seven crewmembers, trapped in their berthing compartment, perished. The destroyer sustained damage in excess of $300 million.

Figure 8. Post collision damage to the *Fitzgerald*'s starboard side. (Source: US Navy)

No one was injured on board the *ACX Crystal,* but the container ship sustained damage to its bow and forward compartments. The vessel's forepeak tank sustained a large gash, and a smaller gash was noted in the boatswain's stores compartment. Penetrations to the hull were above the waterline. The cost to repair the *ACX Crystal* was not reported to investigators.

Figure 9. Postaccident damage to the *ACX Crystal*'s bow. (Source: Japan Transport Safety Board)

The *ACX Crystal* crewmembers involved in the incident were not required to be toxicologically tested after the accident, nor was postaccident alcohol testing conducted on the *Fitzgerald* crewmembers. The *Fitzgerald* crew were tested for drugs on June 21, and the results were negative.

1.3 Navigation Equipment

1.3.1 *Fitzgerald*

The *Fitzgerald* had two surface search radars. The SPS-73 radar was primarily used by bridge personnel, and the SPS-67 radar was mainly used in the CIC, but the bridge and the CIC had the capability to use both types of radar.[14] The *Fitzgerald* had a voyage management system (VMS), which was used for voyage planning and navigation. VMS received inputs from numerous sensors

[14] SPS-67 and SPS-73 radar are both short-range radar systems used for surface searches with minor technical capability differences.

and computers including the SPS-73 radar, GPS, and ARPA. This information was overlaid on the ECDIS-N VMS displays located on the starboard side of the bridge and in the CIC.[15]

The *Fitzgerald* was fitted with AIS, which is a maritime navigation safety communications system that automatically transmits vessel 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. The AIS information is broadcast on a VHF frequency as dictated by international regulation. 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 *Fitzgerald*'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 on a dedicated laptop but did not transmit its own data. The laptop displayed information about other vessels and was capable of computing closest points of approach. According to the OOD, there was also a readout for the AIS laptop available, but the only information provided on the readout was the Maritime Mobile Service Identity (MMSI) number, course, and speed of the other ship.

In addition, *Fitzgerald* crew members reported that the propulsion and steering systems of the destroyer were operating properly prior to the collision.

1.3.2 *ACX Crystal*

Bridge equipment on the *ACX Crystal* 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 *ACX Crystal*'s AIS was transmitting and receiving information at the time of the accident. *ACX Crystal* crew members reported that the propulsion and steering systems of the containership were operating properly prior to the collision.

1.4 Organizational Guidelines

1.4.1 *Fitzgerald*

The *Fitzgerald* CO's standing orders were derived primarily from two sources: general COLREGS and the Standard Organization Regulations of the Navy (SORM). The purpose of the SORM is to provide regulations and guidance governing the conduct of Navy personnel, and it applies to both Navy and Marine Corps shipboard personnel. Portions of the guidance could be tailored or amplified to meet a particular vessel's mission, task, and function. This included required reporting, conducting and relieving a watch, organization of at-sea watches, duties of watchstanders, and the relationships between them.

The standing orders required the CIC to:

> 1) track and report (to the OOD) all surface contacts passing within a certain distance of the destroyer; and 2) for contacts with a CPA less than a specified

[15] ECDIS-N is the Navy's version of ECDIS. VMS is the software suite/sub-system of ECDIS-N.

distance, maneuvering board and Digital Dead Reckoning Tracer were to be used to provide course, speed, CPA, and time of CPA to the OOD. The standing orders also required the OOD to make sure that CIC performed these functions and that the OOD was to ensure that electronic aids and maneuvering boards were used, on the bridge, to independently calculate the same information that CIC was calculating. The standing orders also required the OOD to call the CO if the vessel deviated by a predetermined distance from the track line in the voyage plan.

The CO's night orders were supplemental to the standing orders and were issued each evening when the vessel was at sea. Night orders were tailored for the particular event/evening and could temporarily modify the standing orders to suit the current operations. In the night orders in effect at the time of the accident, the CO doubled the distance the vessel could deviate from the voyage plan track before the OOD was required to notify him.

Operational Risk Management (ORM) is a Navy–wide instruction instituted to identify and assess hazards associated with performing tasks and then managing, controlling, or mitigating risks associated with the specific tasks.[16] Operational risk management was part of *Fitzgerald*'s navigation brief for leaving Tokyo Bay.

According to *Fitzgerald*'s operations officer (who was also the accident tactical action officer) the coordination and scheduling of events for the destroyer, such as the night flight operation certification held on the evening of June 16 and the engineering certification scheduled for June 17–18, was planned in conjunction with DESRON 15 personnel.[17] The final schedule was ultimately approved by the *Fitzgerald* CO.

1.4.2 *ACX Crystal*

The master's standing orders called for the watch officer to maintain no less than a 1-mile closest point of approach to all vessels and to closely monitor vessels if the time to the closest point of approach was 6 minutes or less. If the watch officer could not maintain the 1-mile distance, the master was to be contacted.

The Master's night orders for the run between Nagoya and Tokyo included requirements to apply the COLREGS when dealing with other vessels, allow 15 minutes for slowing down the vessel, and call the master if in doubt.

According to the safety management manual of Sea Quest Management, the operator of the *ACX Crystal*, the company was to ensure the safe and reliable operation of its ships and protect the environment. Specific sections of the manual included procedures to be used in special navigation situations and for risk management, and rules for safe navigation of the vessel. Per the rules for safe navigation, bridge management teams were listed for varying environmental and traffic conditions, and there was a table documenting the personnel associated with manning Watch Levels 1, 2, and 3. The bridge manning on board the *ACX Crystal* at the time of the accident was Watch Level 1.

[16] OPNAV Instruction 3500.39C, Operational Risk Management.

[17] Destroyer Squadron 15 (DESRON 15) was the forward deployed squadron command, headquartered in Yokosuka, of a group of destroyers including the *Fitzgerald*.

According to the company safety management system (SMS), under Watch Level 1, the watch officer and AB were responsible for the safe navigation of the vessel.[18]

1.5 Personnel

1.5.1 *Fitzgerald*

When the *Fitzgerald* completed boat operations and started its outbound voyage on the evening prior to the accident, 293 crewmembers and 22 riders were aboard the destroyer.[19] On the morning of the accident, six bridge watchstanders and seven CIC crewmembers had responsibilities associated with developing the surface contact plot or picture. All assigned personnel were qualified aboard the *Fitzgerald* in accordance with the Navy's personnel qualification standards (PQS) for the positions they were assigned. In addition to the crewmembers already mentioned in the accident narrative, key personnel were:

Commanding officer (CO). The CO was in overall charge of the vessel. He first served as executive officer aboard the *Fitzgerald* from November 2015 through March 2017. He then went to various schools until May 2017, when he took over as CO of the *Fitzgerald*. He had extensive experience in the accident waterway.

Executive officer (XO). The XO was second in overall charge of the ship and was responsible to the CO for ensuring the vessel's readiness. He was commissioned in the Navy in October 1999. After serving at shoreside commands for about 7 years, he joined the *Fitzgerald* in March 2017 and had made two trips in the accident waterway.

1.5.2 *ACX Crystal*

As specified on its safe manning certificate, the *ACX Crystal* was required to be manned by a total of 12 officers and ratings. On the accident voyage, the container ship carried a crew of 8 officers, 10 ratings, and 2 cadets. All were credentialed, with endorsements, by the Republic of the Philippines, in accordance with the Seafarer's Training, Certification, and Watchkeeping (STCW) Code and other International Maritime Organization (IMO) regulations. At the time of the accident, the second officer and an AB were on the bridge.

Master. The master was in overall charge of the vessel. He held a certificate of competence to sail as master on vessels over 500 gross tons (indicating an unlimited credential), with the necessary endorsements from the Philippines. He had been a credentialed master for the past 9 years and said that he had made at least 5 trips in the accident waterway. His first contract aboard the *ACX Crystal* was for 9 months. He started his second contract in April 2017.

Second officer. The officer in charge of the navigational watch at the time of the collision, he held a certificate of competence to sail as officer in charge of a navigational watch on vessels over 500 gross tons, with the necessary endorsements. He joined the *ACX Crystal* in April 2017, and this

[18] Watch Levels refer to the level of manning on the bridge of merchant vessels. Under Watch Levels 2 and 3, the master was in charge of the navigation of the vessel and the officer of the watch or extra officer were responsible for monitoring traffic through the use of ARPA and radar.

[19] A *rider* is a person not considered part of the vessel's regular crew but who is aboard to perform a specific function.

was his first contract aboard the vessel. He said that he had made many trips on the accident waterway.

Able-bodied seaman (AB). The AB on watch during the accident provided investigators a Seafarer's Registration Certificate for able-bodied seaman and had sailed in this position for about 10 years. As the AB on watch, he generally steered the vessel and performed lookout duties. He joined the *ACX Crystal* in August 2016, and this was his first contract aboard the container ship.

1.6 Manning

The manning of a Navy ship is designed to support varying Readiness Conditions (Conditions I-IV), as described in OPNAV Instruction F3501-311B. At the time of the *Fitzgerald* accident, the ship was in Readiness Condition III. OPNAV Instruction F3501-311B describes this condition as Wartime, Increased Tension and Forward Deployed Cruising Readiness, wherein the ship shall be capable of meeting the following criteria: 1) able to keep installed systems manned and operating as necessary to conform with prescribed Required Operational Capabilities; and 2) able to accomplish all normal underway maintenance, support and administrative functions. Additionally, the maximum expected crew endurance for Condition III is 60 days, with opportunity for 8 hours of rest each day.

"Fill" is a Navy personnel term and is a measure of the number of personnel onboard who have the correct paygrade and occupational specialty (known as a rating) for the positions in which they are filling. "Fit" is a higher measure and represents the number of personnel onboard with specific experience, training, and qualifications required for the positions they are filling. Because Fit and Fill are normally less than 100 percent due to transitions, attrition, or other shortfalls, the Navy sets manning targets to ensure an even distribution of personnel across the force. According to the *Fitzgerald*'s Manning Brief, dated June 19, 2017, the manning targets for the entire ship were 92 percent Fit and 95 percent Fill. According to the Navy's Manning Control Authority Fleet (MCAF) Directive 15-1, ships outside of the continental United States (such as the *Fitzgerald*) are expected to be continuously manned to approved manning targets, but their actual manning levels on the accident voyage were 88.1 percent Fit and 93.6 percent Fill.

1.6.1 *Fitzgerald*

Navy officers and enlisted crew were 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 mandated 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 deleting tasks that do not apply to the vessel.

Investigators reviewed the PQS booklets for the OOD, the JOOD, the surface warfare coordinator, the CIC watch officer, and the CIC watch supervisor. Each person was required to understand the fundamentals and operation of radar equipment, including how to tune it, and to know the roles and responsibilities of the various members of the bridge and CIC teams. The OOD, the CIC watch officer, the CIC watch supervisor, and the surface warfare supervisor were required to

"discuss" navigation rules (Inland and International Rules of the Road) and how they applied to collision avoidance situations. They were also required to pass a written examination.

The OOD, the surface warfare coordinator, the CIC watch supervisor, and the surface warfare supervisor were also required to demonstrate the use of a MoBoard (maneuvering board) to determine risk of collision per their respective PQS processes.

When a PQS qualification was obtained by an individual, it was valid for the platform/ship on which the person was serving. When the individual transferred to a different ship, he or she had to requalify aboard that vessel.

According to the surface warfare coordinator, the previous CO required weekly training on rules of the road for the entire wardroom;[20] however, if one attained a 100 percent score on the exam, there was no requirement to attend future training sessions or take additional exams. So weekly rules training fell mostly to those junior officers who were qualifying to become OODs. The navigator told investigators that all qualified OODs were required to attend rules of the road training on a quarterly basis.

The new CO had only been on the *Fitzgerald* in the role of commanding officer a few weeks, so it was not known if he also had a plan for rules of the road training. The *Fitzgerald* had spent the majority of 2016 in the shipyard, and so, the CO told investigators that when he came into command, he knew that his bridge and CIC teams would be relatively less experienced when they got under way. He and his team spent "no less than 6 provisions on the watch bill" prior to getting underway the day before the accident because the CO wanted to "place seniority in controlling watch stations…and ensure that there was sufficient levels of forceful backup." He explained that he had a lot of young first-tour division officers going through the qualifications and that he had not personally observed their performance, nor had he been able to assess their abilities as a whole. Although the CO had confidence in the crewmembers' qualifications, he put measures into place to combat their inexperience in order to "increase navigation and seamanship, level of knowledge, and watch team performance" while in the shipyard. Examples of these mitigating factors included having the teams focus on basic ship handling fundamentals, preparing navigation briefs, and using paper charts. The CO said he would then provide scenarios in which the crewmembers would use local nautical charts in restricted water transits, implementing skills they were learning. He said that he considered the performance of his bridge watch to be "satisfactory" and noted no areas of deficiency that required improvement. When the XO described how he built the watch teams, he also said that they went over the watch schedule several times.

The XO stated in his interview that he did not trust the OOD but felt that, given the surface warfare coordinator's experience, he was comfortable with the watch team because the coordinator could back up the bridge team although he was not physically on the bridge. In contrast, when the surface warfare coordinator was asked about his involvement with the bridge, he said, "my involvement with the bridge is somewhat limited." The XO described the OOD as "below average" and said that she had been reprimanded for actions in the CIC in which he found her behavior indicative of overconfidence. When asked why he did not express his concern to the CO, he stated, "because I didn't provide support and backup, I just didn't. I think back and I don't know why I

[20] Wardroom is the ship's dining area where commissioned officers eat. When used as a description for crew, it generally means all commissioned officers of the vessel and not the enlisted crew.

didn't. I think that I trusted the Captain's judgment too, more than my judgment on her performance. You know, I thought that maybe there is an error of what I was seeing compared to what he was seeing." When asked why, if he didn't trust the OOD on the bridge, he did not volunteer to stay up, he replied, "I would say that I was tired at that point and I probably wasn't thinking about what was going to happen next. I was thinking more of 'what are we going to do at 0600 when we start the engineering drills' and not getting from midnight 2330 until 0600."

1.6.2 *ACX Crystal*

As a commercial vessel engaged in international trade, the *ACX Crystal* was subject to the STCW Code and other IMO regulations. Among other provisions, the STCW Code stipulates requirements pertaining to crew experience, training, and assessment. For deck officers who held licenses for unlimited tonnages, the training included bridge resource management (BRM), radar and ARPA operations, ECDIS, and rules of the road. Further, when a licensed officer renewed his mariner credential at the mandatory 5-year interval, radar and ARPA proficiency needed to be re-tested. In addition, all merchant watchstanding personnel are required, by regulation, to obtain familiarization training for the equipment they will be operating prior to assuming the duties they are tasked to perform.

1.7 Work/Rest History

1.7.1 *Fitzgerald*

Investigators reviewed the number of rest hours for the *Fitzgerald* bridge team during the 24 hours leading up to the accident. The OOD awoke at 0400 on the morning before the accident, prepared for getting under way, stood watch leaving the dock, was the safety officer during the ammunition loadout, did some administrative work, and took a 1-hour nap before heading to her 2200–0200 OOD watch. The JOOD, who had been working since 0700 on the morning before the accident, said she also took a 1-hour nap before heading to the bridge for the 2200–0200 watch. According to the 96-hour work/rest record for the surface warfare coordinator, he slept for about 7 hours on the evening of June 15 and about 3.5 hours prior to standing watch on the evening of June 16. The surface warfare coordinator stated that he became fatigued during the last hour of his watch. The optical sight system operator was reportedly so tired that he was falling asleep during the watch, which prompted his supervisor to insist that he stand up while working.

The *Fitzgerald* crewmembers were placed, by position, into watch sections to man bridge, engine, and CIC watch positions ("stations"). The number of crew that stood watch, at any given time, was dependent on the watch condition of the vessel. Watch conditions were set for various operations or threats to the vessel. The number of watch sections for each position depended on the number of qualified crewmembers for that position. Each position had at least three watch sections. If a sufficient number of crewmembers were available, presumably well rested and qualified, a fourth watch would be added to ease the burden on the other watch sections. During the accident voyage, *Fitzgerald* crewmembers were assigned to the bridge covering 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 would shift 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 this accident

and the *McCain*/*Alnic MC* collision,[21] which occurred about 2 months later in August 2017, the Navy mandated "circadian watch bill" schedules that followed set watch times each day.[22,23]

1.7.2 *ACX Crystal*

The crew of the *ACX Crystal* was required to adhere to STCW Code regulations for rest, which mandated a minimum of 10 hours in any 24-hour period and a total of 77 hours in any 7-day period. The 10 hours of rest could be divided into two periods, as long as one of the periods was at least 6 hours long. According to records reviewed by investigators, the *ACX Crystal*'s second officer had 49.5 hours of rest in the 96 hours before the accident and 12.5 hours in the preceding 24 hours. His rest period just before the accident was 9 hours long. No 96-hour report was provided for the AB or the master. Investigators reviewed the *ACX Crystal*'s schedule and noted that the container ship visited three ports on a daily basis commencing on June 13, and the vessel was scheduled to call at Tokyo on the morning of June 17.

The *ACX Crystal* 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 organization, each watch team stood the same two watches each 24-hour period.

1.8 Waterway Information

Sagami Nada bay, where the collision took place, lies off the Izu Peninsula on the southeast coast of Honshu Island. At the northeast corner of Sagami Nada lies the Uraga Suido strait, which leads directly into Tokyo Bay. The overall length of Sagami Nada is about 55 miles and its narrowest point is about 20 miles. The accident occurred near the southern terminus of Sagami Nada, about 5 miles off the southeast tip of the Izu Peninsula.

National Geospatial-Intelligence Agency Publication 158, Sailing Directions (Enroute) for Japan, Vol. I, contains general information about the accident area ports, waterways, traffic separation schemes, and traffic encountered within the ports. It also directs the reader to consult Sailing Directions 120 (Planning Guide) for additional information about the waterways treated in Publication 158. According to the National Geospatial-Intelligence Agency 2015 Planning Guide to the U.S. Sailing Directions for the Pacific Ocean and Southeast Asia, the accident waterway is noted for its heavy traffic and frequent collisions.[24]

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[21] *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.

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

[23] See section 2.3.3: Navy Actions since the Accident, for more information on postaccident actions taken by the Navy.

[24] National Geospatial-Intelligence Agency Pub. 120, 2015, page 210. This publication is free and available on the NGA's internet site. This publication was referenced in NGA Pub 158, the Sailing Directions (Enroute) Japan, Vol. 1.

1.9 Environmental Information

According to numerous crewmembers of both vessels, the visibility on the morning of the accident was good. The *Fitzgerald* OOD estimated the visibility as between 10 and 11 miles and the sea state as about 1–2 .[25] The *ACX Crystal* crew logged the weather as cloudy skies with about 10 miles of visibility. The *ACX Crystal*'s 0200 deck log entry noted north winds at 11–16 knots, air temperature of 68°F (20°C), and sea temperature of 62.6°F (17°C.)

Data retrieved from the Naval Oceanographic Office Global Hybrid Coordinate Ocean Model and the NOAA Wavewatch III model for the accident site around the time of the collision indicated air temperature near 70°F (21°C), sea temperature at 69.5°F (20.8°C), north-northeast winds at 16.67 knots, and a wave height of 2.4 feet. Moonrise was at 2332 on June 16; the phase of the moon was waning, and it was in its last quarter.

[25] According to the World Meteorological Organization, a sea state of 1 was for seas between 0 and .33 feet and a sea state of 2 was for seas between .33 feet and 1.64 feet.

2 Analysis

2.1 Exclusions

At the time of the accident, the sea state was 1–2 and visibility was about 10 miles. The crews from both the *ACX Crystal* and the *Fitzgerald* reported no concerns related to the weather. In addition, the crew of the *ACX Crystal* reported no problems with the vessel's steering and propulsion systems prior to the accident, and VDR data indicated no problems. Similarly, records from the *Fitzgerald* indicated that steering and propulsion were tested prior to the accident and were found in good working order. The only reported equipment malfunction on the *Fitzgerald* bridge or CIC was an inoperative radar repeater (the SPA-25) in the CIC. It was shut down completely and played no role in the accident. The NTSB therefore concludes that weather and the steering and propulsion systems on board the *Fitzgerald* and the *ACX Crystal* were not factors in the accident.

Because investigators were provided only limited toxicological results for the *Fitzgerald* crew and no test results for alcohol or other drugs for the *ACX Crystal* crew, the evidence was insufficient to determine conclusively whether alcohol or other drug use was a factor in this accident.

2.2 Actions to Recognize and Avoid the Collision

2.2.1 *Fitzgerald*

As the *Fitzgerald* proceeded in a southbound direction on the evening of the accident, the OOD picked up two radar contacts (the *ACX Crystal* and the *Maersk Evora*, or possibly the *ACX Crystal* and *Wan Hai 266*) off the *Fitzgerald*'s starboard bow at approximately 12 miles. The two vessels were on a parallel path on an east-northeasterly heading following normal traffic patterns toward Tokyo. Per the COLREGS, when two vessels are crossing, the vessel that has the other on its starboard side shall keep out of the way of the other vessel. The *Fitzgerald* had the *ACX Crystal*, the *Maersk Evora,* and the *Wan Hai 266* on its starboard side and therefore was the give-way vessel to all three ships. The regulations required the *Fitzgerald*, as the give-way vessel, to take early and substantial action to keep clear of the stand-on vessels, and to avoid crossing ahead of the other vessels. The advisable course of action in this circumstance was for the *Fitzgerald* to alter course to starboard and pass well clear of all three vessels.

Rather than taking early and appropriate action, such as turning or slowing to avoid the three vessels as required by the navigation rules (and the CO's standing orders), the bridge team on the *Fitzgerald* continued ahead and ultimately crossed ahead of the *Wan Hai 266* and placed the vessel in the path of the *ACX Crystal* resulting in the collision. Although there was room to pass ahead of the *Wan Hai 266*, doing so was not prudent given the presence of the *ACX Crystal*. The actions of the bridge team on the *Fitzgerald* did not conform to the collision regulations as they approached the *Wan Hai 266* and *ACX Crystal*. Therefore, the NTSB concludes that the *Fitzgerald* bridge team, on the give-way vessel, did not take early and substantial action to avoid collision with the stand-on *ACX Crystal*.

Navy OODs are required to pass a rules of the road test, and each vessel typically has its own requirements for carrying out recurring rules of the road training. Based on the circumstances of this accident, there is a clearly demonstrated need for review of the Navy's training for its watchstanders

related to the collision regulations. Therefore, the NTSB recommends that the US Navy review and revise fleetwide training and qualification requirements for OODs related to the collision regulations.

Given that the OOD on the *Fitzgerald* identified the two vessels at 12 miles out and about 22 minutes before the collision, investigators sought to understand how the accident could have occurred given the numerous resources available to the *Fitzgerald* bridge team and the time available to take appropriate action. The bridge team was made up of six personnel. The bridge team was operating under the CO's standing orders, which, among other things, provided requirements for notifying the CO regarding vessel traffic. Further, the bridge team was supported by watchstanders in the vessel's CIC who were charged with tracking surface contacts and reporting to the bridge. The bridge team is expected to capture and prioritize critical information, analyze that information, and take appropriate action. Training, experience, and standard operating procedures are developed to mitigate errors, particularly in dynamic situations.

Although the *Fitzgerald* OOD identified the two crossing vessels on the vessel's starboard bow at 12 miles' distance on the bridge radar (about 0108), she told investigators she was unable to acquire them at that time using ARPA to determine CPA. When the contacts were first identified, the OOD had sufficient time and could have made use of the resources available to her, including the other bridge watchstanders and CIC. Bridge resource management (BRM) makes use of all available resources, including equipment and information and human resources, to achieve safe operation. Good communication amongst a bridge team is key to successful BRM. The OOD should have communicated with the JOOD about the vessels and asked her to monitor them. The OOD should also have requested assistance from CIC, where numerous watchstanders were available to track the vessels using various means.

According to the CO's standing orders, the CIC was tasked to support the bridge team, and the tactical action officer, as head of the CIC, was to ensure that this occurred. The OOD, per standing orders, was to ensure that the CIC provided the bridge team with information so that the vessel could be safely navigated. During interviews of several of the bridge and CIC watchstanders, investigators learned that little communication took place between members of the bridge team and CIC even though the bridge team had identified vessel traffic and CIC members saw surface contacts on the optical sight system or were aware of the vessel changing course to avoid traffic.

According to Crouch (2013), 60 percent of all marine accidents that fault the human operator are related to ineffective communication. The incorporation of BRM encourages junior officers to be an integral part of a team, putting forth their opinions and, when safety is of concern, challenging their superior officers. Senior officers, in turn, should effectively be more open to gathering feedback from the bridge team. Successful implementation of BRM would ensure that the team is communicating about traffic in the area and should provide a means for anyone to speak up if they believed there to be an issue. It is unclear whether the *Fitzgerald* crew, at the outset of their watch, completed a comprehensive turnover to ensure they all understood the intended plan, the night orders, or the high-traffic area in which they were about to transit. The tactical action officer stated that, after leaving the Tokyo Bay area, no discussion took place about the navigation transit, tracks, or likely high-density marine traffic, and that these discussions were not normally held. Discussion amongst a group allows for different viewpoints and different experiences to be shared. Additionally, it allows the group to collaboratively identify risks, discuss mitigation of those risks, and prepare for the upcoming activities. The lack of communication and failure to use available resources is indicative of a poorly functioning bridge and CIC team. The NTSB concludes that the

communication and cooperation among the *Fitzgerald* crew on the bridge and in the CIC were ineffective leading up to the accident.

The NTSB notes that all bridge officers on seagoing merchant vessels are required to satisfactorily complete formal BRM training, provided by qualified trainers, as part of their licensing requirements. Instilling the concepts of BRM on a regular basis is instrumental in ensuring that the crew understand the challenges of communicating effectively in the bridge and CIC environments. Accidents such as this could serve as examples of how to apply these concepts more appropriately. Given the lack of communication among the bridge team and CIC watchstanders, the NTSB recommends that the US Navy review and revise BRM training in its approved course curriculum to promote a cohesive team environment and improve communication within and between bridge and CIC teams.

When the JOOD reported the contacts to starboard, the OOD had already acquired the *ACX Crystal* using ARPA and determined the CPA to be 1,500 yards (0.75 nautical mile), with the *ACX Crystal* expected to pass astern of the *Fitzgerald*. The OOD told investigators she was comfortable with this distance and began looking at the next vessel (*Maersk Evora*) to determine CPA. Despite the CPA for the *ACX Crystal* being within the reporting requirements to the CO, the OOD did not do so. Instead, she said she planned to do an "after the fact report." This deliberate contravention of the CO's explicit instructions is troubling. Had she followed the standing orders and alerted the CO, it is likely that he would have required the OOD to take action and the accident could have been averted.

At 0120, when the JOOD identified the vessels to starboard, she recommended that they slow the vessel. The OOD did not agree and said she thought it would make the situation worse, although she did not provide any substantive reason she believed this to be true. The OOD also told investigators they discussed turning to starboard but that she was concerned that they would be heading toward land. At this time, the vessel was 8.2 miles from the Izu Peninsula and therefore any temporary course change toward land would not have placed the vessel at risk. Further, there were no contacts to starboard that would have posed a problem had they turned. With the maneuverability of the *Fitzgerald*, a substantial turn to starboard or a reduction of speed would have allowed the *Fitzgerald* to pass safely behind the *ACX Crystal*.

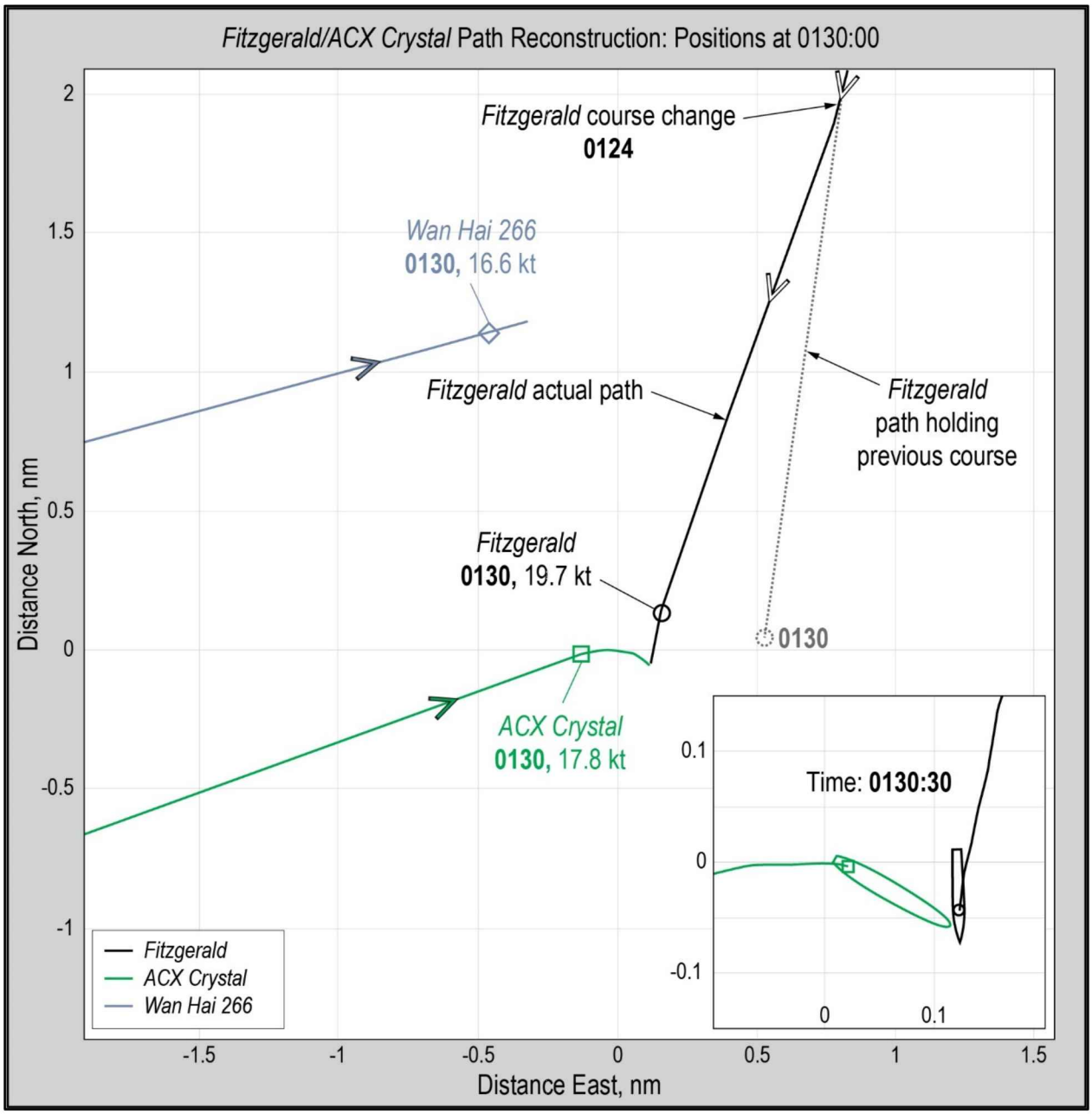

Figure 10. NTSB path reconstruction for *Fitzgerald* and *ACX Crystal*, from data compiled from NTSB Vehicle Performance Study.

The *Fitzgerald*'s deck log shows that a course change was ordered at 0122, and the vessel came right from 190° to 200°. They had steadied on the new course by 0124. This course change proved to be a critical error, and investigators were unable to determine the reason for it. The NTSB conducted a Vehicle Performance Study using GPS data as well as course and speed data for the *Fitzgerald*, *ACX Crystal* and *Wan Hai 266*, to recreate the tracks of the vessels leading up to the accident. The study found that if the *Fitzgerald* had not made the course change from 190° to 200° 8 minutes before the collision, the destroyer would have passed ahead of the *ACX Crystal* with a CPA of about 1,000 yards, or about 0.5 nautical mile. Therefore, the NTSB concludes that the

Fitzgerald's unexplained small course change to starboard minutes before the collision put the vessel on a collision course with the *ACX Crystal*.

Seven watchstanders in CIC were tasked with monitoring the surface picture and supporting the OOD and bridge team by providing radar contact information to the bridge watch. Numerous CIC personnel told investigators that no contacts were close enough to the *Fitzgerald* to warrant plotting; however, when investigators reviewed ECDIS screenshots from the *Fitzgerald*'s VMS, they noted numerous contacts within the CO's tracking and reporting requirements. On the night of the accident, this same information was available in real-time both on the bridge and in the CIC. At least some personnel in CIC did see contacts but did not apparently share this information with other CIC watchstanders. The optical sight system operator, who reported to the surface warfare coordinator as part of the surface watch, told investigators that he visually observed at least 80 contacts using his line of sight camera. The surface warfare coordinator stated that pop-up targets would appear on his radar scope and the surface warfare supervisor's scope had a lot of clutter. Despite the clutter, however, he did not advise any of his supervisors so a technician, who was part of the watch bill, could look at the scope to determine if the issue was related to equipment tuning or operator error. The COLREGS call for every vessel to use all available means appropriate to determine whether risk of collision exists.

The *Fitzgerald* had both SPS-67 radar and SPS-73 radar, but only the SPS-73 radar sent data to the VMS. Neither the surface warfare coordinator nor the surface warfare supervisor switched from the reportedly cluttered SPS-67 radar to the SPS-73 radar or looked at the VMS console, which was overlaid with targets acquired by the SPS-73 radar. Had they done so, they would have seen the targets that were populating the VMS. Not using the SPS-73 radar deprived the surface warfare coordinator from the use of another tool to determine if risk of collision existed. If the tactical action officer or surface warfare coordinator had used the SPS-73 radar, which provided contact information to the VMS and confirmed the presence of vessels near the *Fitzgerald*, the surface watch team could have tracked and provided collision avoidance information to the OOD. In addition, the AIS information, which would have assisted in the tracking and identification of traffic, was available to the CIC watchstanders.

In addition, although the tactical action officer, who was in charge of the CIC, told investigators that CIC's role was to support the bridge team, she did not require the surface warfare supervisor or the surface warfare coordinator to track and report contacts closer than a certain distance to the *Fitzgerald*, despite the CO's standing orders to do so. The NTSB therefore concludes that the *Fitzgerald* CIC personnel did not effectively support the bridge team in tracking nearby surface targets.

2.2.2 *ACX Crystal*

A little after 0100, the *ACX Crystal* was on an easterly heading off Japan's southeast coast, heading for an 0500 pilot station arrival near Tokyo Bay and bound for Yokohama after departing Nagoya earlier on the evening of June 16.

Review of the *ACX Crystal*'s VDR capture of the X-band radar showed that about 0106 on the morning of June 17, a faint radar return was visible of what was later determined to be the *Fitzgerald*. It first appeared when it was approximately 13 miles away and along with the faint target

was a following echo or radar trail.[26] As the target (*Fitzgerald*) and the *ACX Crystal* continued to close, the target signature could be seen appearing and disappearing on the radar. Other vessels' signatures at the same distance and further away had been acquired on the *ACX Crystal*'s ARPA and were being tracked, but the ARPA did not display any information about any of them, such as course or speed.

By 0115, the target signature was steady on each radar capture recorded by the *ACX Crystal*'s VDR (about every 15 seconds). About 0119, the signature displayed radar trails as the *ACX Crystal* completed its course change to port to 069° per the ship's voyage plan. After the *ACX Crystal*'s course change, the *Fitzgerald* was about 6.5 miles away off the container ship's port bow.

The container ship *Wan Hai 266* was travelling east on a parallel path to the *ACX Crystal* and about 2 miles north (closer to the *Fitzgerald*). Investigators reviewed *Wan Hai 266*'s captured ARPA and VDR information and compared it to the *ACX Crystal*'s. At 0114, the *Wan Hai 266* acquired the *Fitzgerald* on its ARPA and held the target along with displayed information up to and through the collision with the *ACX Crystal*. When the *Wan Hai 266* acquired the *Fitzgerald*, the destroyer was 7.3 miles away on a course of 188° true and making 19.8 knots. Although the *Wan Hai 266* was about 2 miles closer to the *Fitzgerald*, the fact that the container ship could acquire the Navy vessel, which was built purposefully to minimize its radar signature and thus produce a smaller radar return than similar-size merchant vessels, meant that the second officer on the *ACX Crystal* could also have acquired the *Fitzgerald* at a similar distance on the *ACX Crystal*'s ARPA.

The steady target that the *Fitzgerald* displayed on the *ACX Crystal*'s radar, and the radar trails that were emanating from the target, show what should have been a clear target of concern as it presented a risk of collision based on the track of the container ship. Prudent seamanship dictates that the target should have been acquired to more accurately determine risk of collision. Acquiring the target on the ARPA would have provided the *Fitzgerald*'s true course, speed, CPA, and TCPA (Closest Point of Approach and Time to CPA respectively). Although the second officer on *ACX Crystal* indicated that he was aware of the vessel (*Fitzgerald*) after he turned the container ship onto the 069 track, he never acquired it. The NTSB concludes that the *Fitzgerald* provided a detectable radar signature, and the second officer on board the *ACX Crystal* should have acquired the destroyer on the ARPA to determine risk of collision.

When the second officer and the AB on the *ACX Crystal* first visually spotted the green (starboard running) light of the *Fitzgerald*, they consulted the radar and determined that the approaching vessel was about 3 miles away. Investigators reviewed the radar display, which showed that the target (*Fitzgerald*) was only about 5 minutes away from collision. The second officer stated the first course of action he took was to grab the signaling lamp and flash it at the green light. According to the Coast Guard Report, this occurred at 0127:35, or about 2.5 minutes after the light was first observed, and about 3 minutes before the collision. The second officer told investigators that there was no reply to his signaling light.

The second officer observed the approach of the vessel by visually checking its green light and looking at the radar. The distance between the vessels was closing rapidly due to the close

[26] A *radar echo* or *trail* is an afterglow of a contact's past positions that follows a contact displayed on a vessel's radar screen. The direction and length of the trail gives the operator an indication of the relative motion of the vessel being tracked by radar.

proximity and the speed of approach of both vessels (at almost 19 knots each). Flashing the lights indicated that the second officer was in doubt.

Left with a potential collision situation developing, although as the stand-on vessel he was supposed to hold course and speed, the second officer on the *ACX Crystal* could take action when it became apparent that the give-way vessel was not taking enough action to avoid collision. He could have tried to radio the oncoming vessel, but with no name or way to identify the *Fitzgerald*, several vessels (or no vessels) might have responded to the broadcast. Further, in addition to signaling with a lamp, he should have sounded the whistle signal with five short blasts to indicate doubt, per the COLREGS. No one aboard the *Fitzgerald* recalled seeing the flashing light. It is possible that a whistle signal from the *ACX Crystal* may have alerted someone on the destroyer of the danger and to take evasive action. Although the second officer did order a series of starboard rudder orders which began changing the vessel's heading to starboard at 0129:25 (about 1 minute before the collision), his effort was not early or aggressive enough to avoid the collision. Therefore, the NTSB concludes that when the second officer on the *ACX Crystal* did not receive a response to his signaling attempts and saw no noticeable change in approach from the destroyer, he did not take sufficient action to avoid the collision.

The *ACX Crystal*'s deck and engine officers were trained and credentialed for the capacity in which they were working. However, as noted above, the NTSB found that the second officer did not adequately use all means to assess risk of collision, and did not take sufficient action to avert the collision. Because a well-trained navigation team is essential for safe operations, the NTSB recommends that Sea Quest Ship Management, Inc., provide additional training for its navigation officers on collision avoidance regulations, radar, and ARPA.

Assessing risk of collision can be and has been successfully accomplished without AIS. However, the worldwide, mandatory use and acceptance of AIS as an added tool to navigators' "all available means" can assist in assessing risk of collision. AIS is required on most commercial vessels. Both the *Wan Hai 266*'s radar and the *ACX Crystal*'s radar depicted the *Fitzgerald*'s radar signature as significantly smaller than that of a comparable merchant vessel of the same size. The destroyer's design included features meant to reduce its radar signature. Investigators' review of the *ACX Crystal*'s VDR radar images showed more than two dozen other larger-size targets acquired on the radar. In addition, there were several smaller targets, displaying the same size signature as the *Fitzgerald*, that were not acquired. It could not be determined why the second officer chose to acquire some targets and not others. Although the second officer was using the radar to plot and acquire even smaller targets so that a full appraisal of the situation and of the risk of collision could be made, it is likely that an AIS tag attached to the signature of the destroyer would have helped the second officer realize that the small radar contact was a US Navy destroyer. AIS would have identified the vessel so the second officer could have called the destroyer by name on bridge-to-bridge radio and given the second officer more information about the true size of the approaching vessel. One of the key purposes of AIS is to identify other vessels. By not broadcasting AIS, the *Fitzgerald* took away one of the primary means of the *ACX Crystal* to identify and detect the destroyer. Therefore, the NTSB concludes that the absence of an AIS signature broadcast from the *Fitzgerald* likely contributed to the lack of its early detection by the *ACX Crystal* bridge team.

The NTSB report on the *McCain/Alnic MC* collision also identified that the transmission of AIS information from the *McCain* would have improved the situation awareness of watchstanders on surrounding vessels. After that accident (which occurred after the *Fitzgerald/ACX Crystal*

collision), the Navy directed all of its ships to transmit AIS data when transiting Traffic Separation Schemes and other high-density traffic areas. However, the *Fitzgerald* CO's standing orders already required that they transmit "when we are transiting a Traffic Separation Scheme, high traffic density areas," yet the *Fitzgerald* was not transmitting prior to the accident, which indicates they may not have recognized the area as high traffic. The Navy's guidance does not define high traffic, requiring individual COs to subjectively determine when to broadcast. Further, the NTSB believes that 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 beneficial, regardless of the amount of traffic or the waterway the vessel is operating in. The NTSB therefore recommends that the Navy instruct its vessels to broadcast AIS information while operating in the vicinity of commercial vessel traffic at all times unless such broadcast compromises tactical operations or strategic interest.

2.3 Operating Procedures

According to Navy risk management policy, "all activities, commands, personnel, and contractors under the direct supervision of government personnel shall apply operational risk management principles . . . ." Investigators noted that the predeparture navigation brief for the *Fitzgerald* in Yokosuka contained the treatment of operational risk management consistent with Navy policy and that the brief was discussed by wardroom personnel before getting under way. However, investigators did not find operational risk management plans for the voyage plan, outbound to sea, after completing boating operations and numerous bridge turnovers. The XO stated that he and the navigator discussed the transit south and then the navigator (separately) discussed the transit with the CO, but no brief was held, similar to the navigation brief for leaving Tokyo Wan, to discuss the transit south. The tactical action officer stated that there was no discussion of the navigation transit, tracks, or likely high-traffic areas and that these discussions were not normally held. Discussion during a briefing among crewmembers, as a group, allows for different viewpoints and different experiences to be shared about the upcoming transit. Additionally, it allows the group to collaboratively identify risks, discuss mitigation of those risks, and prepare for the voyage. Had they held this brief, they may have recognized that their intended path would be crossing the flow of traffic in multiple areas. A likely mitigation for this risk would be assigning a senior officer to remain on the bridge to assist with navigating traffic. There were multiple officers available, including the XO and CO, with more experience. Despite the CO doubling the allowed deviation from their track line, the OOD still had to call the CO for traffic with a CPA of less than 3 miles, and should have called at least three other times (but did not). The NTSB concludes that the *Fitzgerald* CO did not adequately assess the hazard presented by the vessel's intended transit, which crossed busy coastal traffic routes, and should have assigned a more experienced officer to augment the bridge team.

2.3.1 Fatigue

Numerous watch personnel on board the *Fitzgerald* had collateral duties on the day before the accident. Though this type of workload is not uncommon, it is worth noting, given the high tempo of operations leading up to the accident. The OOD was the boat operations safety officer; the tactical action officer was the operations officer and, after completing work in those roles, both went on watch. With the high workload, the crew on watch at the time of the accident had minimal time to rest. The tactical action officer stated she had no rest. The OOD stated that she woke at 0400 the day before the accident and took about an hour-long nap before going on watch at 2200. In the CIC, the

optical sight system operator was reportedly falling asleep, which prompted his supervisor to insist that he stand up while working.

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 of sleep results in accumulated sleep debt leading to *chronic fatigue*. In addition, the accident occurred just prior to 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. Altering sleep periods (such as sleeping primarily during the day for a period of time and then switching to sleeping at night and vice versa) impacts the quality of sleep, which compounds fatigue related to circadian lows.

The surface warfare supervisor missed several critical targets, and the OOD made some poor navigational decisions and did not request support from the CIC. Further, the tactical action officer (in charge of the CIC) did not ensure that her personnel supported the bridge team. All of these watchstanders had little or no sleep before heading to watch. The NTSB concludes that several *Fitzgerald* bridge and CIC watchstanders were likely acutely fatigued at the time of the accident, which impacted their situation awareness and ability to identify and respond to the approaching *ACX Crystal*.

As stated in the NTSB report about the 2017 *McCain/Alnic MC* collision:

> 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.[27]) In a 2013 message, the Navy recommended that its surface force ships implement circadian watch bills that allow watchstanders to establish sleep patterns resulting in adequate rest. Following this and other accidents in 2017, the Navy directed that surface force ships implement the circadian watch bills recommended in 2013. While this directive is a step in the right direction, the primary focus of this initiative is on the watch schedule. It does not fully consider overall work and rest, which is the most critical factor in addressing the fatigue faced by watchstanders. Most notably, the 2013 and 2017 messages do not address nor prescribe mandatory rest periods similar to the STCW Code requirements of 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 is unnecessarily dangerous.

Given the impact that fatigue had in the *McCain* collision, the NTSB issued Safety Recommendation M-19-14, recommending that the US Navy institute Seafarer's Training, Certification, and Watchkeeping Code rest standards for all crewmembers aboard its vessels. In

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

response to this recommendation, the Navy stated they were taking further actions to address crewmember fatigue. Building on their implementation of circadian watchbills provided in the Navy's Crew Endurance Policy, commanding officers are now required to account for fatigue as part of their deliberate planning and risk analysis. In their response to the NTSB recommendation, the Navy stated that they planned to implement crew rest standards that reasonably compare with Seafarers' Training, Certification and Watchkeeping Code (STCW) standards for a 7-day period. STCW crew member requirements reflect a minimum of 77 hours rest within a 7-day period. Assuming a 7-day underway schedule, the Navy now specifies 87 hours of "non-available" (off-duty) time within a 7-day period.

The Navy's Fatigue Management Policy requires enhanced training and planning. According to the Navy, commanding officers review crew watchbills to ensure they meet circadian and watch length/crew day requirements of the Fatigue Management Policy, review the ship's published routines, and observe their actual routines in execution to ensure the ship's routine supports achieving the crew rest standards. Further, the Navy has established an ongoing collaboration between the Surface Force, the Naval Postgraduate School (NPS) and the Navy Health Research Laboratory to develop a basis for measurement and a data collection method that will ensure fatigue policy contents are in place across the Fleet. As part of their fatigue management policy, surveys are to be conducted to measure fatigue as a risk factor by each ship across a 36-month cycle. In its response to the NTSB recommendation, the Navy also stated that the Surface Force remains in close collaboration with NPS in support of leveraging ongoing fatigue management research and tailoring Surface Force policies and associated metrics.

The Navy's proposed policies and plans to address crewmember fatigue, if implemented appropriately, should result in fatigue mitigation and, therefore, the NTSB has reclassified Safety Recommendation M-19-14 as "Closed—Acceptable Alternate Action" on April 27, 2020.

2.3.2 Navy Oversight

The *Fitzgerald*'s aggressive schedule leaving port to comply with certification requirements and to return to its deployment schedule provided little rest on the day before the accident. The schedule for the *Fitzgerald* was developed with the assistance and input of the ship's shoreside command and this type of schedule appeared to be the norm for this area of Navy operations (Forward Deployed Naval Forces).

The bridge team and CIC did not function effectively as a team, and the OOD on watch displayed a lack of familiarity in the application of the rules of the road and did not follow the CO's standing orders. Although the CO had a responsibility to ensure that watchstanders were properly trained and qualified, the Navy's training organization and the CO's superiors were required to assess and certify that the operating procedures and the watchstander qualification system were effective. The *Fitzgerald* crew's inability to effectively navigate in traffic on the night of the accident calls into question the Navy's assessment and certification process.

Based on watchbills reviewed by the NTSB, the ship appeared to be manning and operating equipment in accordance with Condition III requirements. However, based on work/rest records reviewed by the investigators, it was apparent that the ship was unable to meet the criteria of ensuring the crew was able get 8 hours of rest each day, given their schedule of operations. It is conceivable

that this level of manning degraded the watchstanding capability, as well as other operational duties among critical personnel.

Gaps in manning, combined with a lack of experience and training as well as an aggressive schedule, can lead to crew errors. A "can do attitude," which the Navy discussed in its own comprehensive review, can often lead to positive thinking and increased morale. However, without the necessary resources to keep that momentum going, over a period of time, it can lead to erosion of training, morale, and degradation in performance and can desensitize senior leaders to the operational risks associated with this high-tempo work environment. The NTSB concludes that the Navy failed to provide effective oversight of the *Fitzgerald* in the areas of operations scheduling, crew training, and fatigue mitigation.

2.3.3 Navy Actions since the Accident

The US Navy conducted a comprehensive review of this collision and other recent Navy accidents that occurred in the western Pacific region. Based on that assessment, the Navy established a Readiness Reform and Oversight Committee to address the recommendations obtained from the comprehensive review. The committee developed three levels of actions centered around operational safety, effectiveness, and a culture of excellence. The first two levels of action relating to operational safety and effectiveness have been completed. These actions include performing competency checks and assessments, instituting fatigue management policies and tools, improving training, enhancing and prioritizing manning, implementing BRM workshops, standardizing standing orders, and promulgating AIS guidance.

The third level of action relates to a culture of excellence. These actions remain in progress and include continuing enhancements for training, clarifying responsibilities, and improving fleet technologies.

3 Conclusions

3.1 Findings

1. Weather and the steering and propulsion systems on board the *Fitzgerald* and the *ACX Crystal* were not factors in the accident.
2. The *Fitzgerald* bridge team, on the give-way vessel, did not take early and substantial action to avoid collision with the stand-on *ACX Crystal*.
3. The communication and cooperation among the *Fitzgerald* crew on the bridge and in the combat information center were ineffective leading up to the accident.
4. The *Fitzgerald*'s unexplained small course change to starboard minutes before the collision put the vessel on a collision course with the *ACX Crystal*.
5. The *Fitzgerald* combat information center personnel did not effectively support the bridge team in tracking nearby surface targets.
6. The *Fitzgerald* provided a detectable radar signature, and the second officer on board the *ACX Crystal* should have acquired the destroyer on the automatic radar plotting aid to determine risk of collision.
7. When the second officer on the *ACX Crystal* did not receive a response to his signaling attempts and saw no noticeable change in approach from the destroyer, he did not take sufficient action to avoid the collision.
8. The absence of an automatic identification system signature broadcast from the *Fitzgerald* likely contributed to the lack of its early detection by the *ACX Crystal* bridge team.
9. The *Fitzgerald* commanding officer did not adequately assess the hazard presented by the vessel's intended transit, which crossed busy coastal traffic routes, and should have assigned a more experienced officer to augment the bridge team.
10. Several *Fitzgerald* bridge and combat information center watchstanders were likely acutely fatigued at the time of the accident, which impacted their situation awareness and ability to identify and respond to the approaching *ACX Crystal*.
11. The Navy failed to provide effective oversight of the *Fitzgerald* in the areas of operations scheduling, crew training, and fatigue mitigation.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the collision between US Navy Destroyer *Fitzgerald* and container ship *ACX Crystal* was the *Fitzgerald*'s bridge team's failure to take early and substantial action to avoid collision as the give-way vessel in a crossing situation. Contributing was ineffective communication and cooperation among the *Fitzgerald* crew on the bridge and in the combat information center (CIC), and the *Fitzgerald* commanding officer's (CO) insufficient planning for the hazards of the vessel's intended transit. Also contributing was the Navy's ineffective oversight of the *Fitzgerald* in the areas of operations scheduling, crew training, and fatigue mitigation. Also contributing to the accident was the *ACX*

Crystal watch officer's lack of early detection of the Navy vessel and insufficient actions to avoid collision once in doubt as to the destroyer's intentions.

4 Recommendations

4.1 New Recommendations

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

To the US Navy

Review and revise fleetwide training and qualification requirements for officers of the deck related to the collision regulations. (M-20-10)

Review and revise bridge resource management training in your approved course curriculum to promote a cohesive team environment and improve communication within and between bridge and combat information center teams. (M-20-11)

Instruct your vessels to broadcast automatic identification system information while operating in the vicinity of commercial vessel traffic at all times unless such broadcast compromises tactical operations or strategic interest. (M-20-12)

To Sea Quest Ship Management, Inc

Provide additional training for your navigation officers on collision avoidance regulations, radar, and automatic radar plotting aid. (M-20-13)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

ROBERT L. SUMWALT, III
Chairman

JENNIFER HOMENDY
Member

BRUCE LANDSBERG
Vice Chairman

MICHAEL GRAHAM
Member

THOMAS B. CHAPMAN
Member

Report Date: August 3, 2020

Appendix A
Investigation

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

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 NTSB. 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 and additional documentation provided by the Navy.

Appendix B
Vessel Information

Vessels	*Fitzgerald*	*ACX Crystal*
Owner/operator	US Navy	Sea Quest Ship Management, Inc.
Homeport/Port of registry	Yokosuka, Japan (home port)	Manilla, Philippines
Flag	United States	Philippines
Type	Destroyer	Container ship
Year built	1994	2008
IMO number	N/A	9360611
Classification Society	N/A	Nippon Kaji Kyokai (NK)
Construction	Steel	Steel
Length	504.5 ft (153.8 m)	730.3 ft (222.6 m)
Draft	32.5 ft (9.9 m)	39.4 ft (12.0 m)
Beam/width	66.4 ft (20.2 m)	98.8 ft (30.1 m)
Displacement	8,261 long tons (8,394 metric tons)	50,944 long tons (51,762 metric tons)
Engine power; manufacturer	Four General Electric LM2500 gas turbine engines, 30,000 hp (22,371 kilowatts [kW]) each; twin controllable-pitch propellers	One MAN B&W 8K80MC-C diesel engine, 39,200 hp (29,231 kW); one fixed-pitch propeller
Persons on board	315	21

Appendix C
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.

***Fitzgerald* Voyage Management System (VMS) screenshots.** These are protected pictures of the VMS screen displayed on the bridge and in CIC. The pictures show the path of the vessel projected onto an electronic chart of the area. The pictures also show radar targets acquired from the bridge radar's ARPA unit.

***Fitzgerald* forward- and aft-looking Optical Sight System (OSS) camera videos**. These protected videos captured images of surrounding lights and shapes prior to and after the collision.

***Fitzgerald* Deck Log.** This protected log book contains a chronological record of various bridge and other shipboard evolutions.

***Fitzgerald* At Sea Condition III Watch Bill.** This protected document contains the names, ranks/ratings, and watch positions held by *Fitzgerald* crewmembers at the time of the accident.

Crewmember Fitness Reports and Training Jackets. These protected documents contain the evaluations and completed trainings for the accident officer of the deck, junior officer of the deck, tactical action officer, CIC watch officer, CIC watch supervisor, surface warfare coordinator, and the surface warfare supervisor.

Personnel Qualification Standard (PQS). Published by the Naval Personnel Development Command, these protected booklets contain a compilation of "the minimum 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."[28]

Combat Systems Departmental Eight O'clock Reports. These reports for June 13, 2017, contained information on combat systems equipment that was either operational but needed repair, or equipment that was totally non-operational. These reports are considered protected documents.

[28] Introduction to the PQS system, NAVEDTRA 43127-D, page 4.

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