National Transportation Safety Board

Washington, D.C. 20594

Marine Accident Brief

Accident No.: DCA-01-MM-022

Accident Type: Collision

Time and Date: 1343 Hawaiian standard time (24-hour clock), February 9, 2001

Location: Pacific Ocean 9 miles south of Oahu, Hawaii

Vessel Particulars:

Name	*Greeneville*	*Ehime Maru*
Type	Fast-attack nuclear submarine	Fishing and training vessel
Length	362 feet (110.3 meters)	190.9 feet (58.18 meters)
Depth	32.3 feet (9.9 meters)	12.8 feet (3.90 meters)
Beam	33 feet (10.1 meters)	30.5 feet (9.30 meters)
Tonnage	6,330 tons surfaced; 7,177 tons submerged (displacement)	741 (gross)
Propulsion	Nuclear reactor, steam turbine, gear driven	Single screw, medium speed diesel engine driving a 4-blade, high-skew, variable-pitch propeller
Built	1996 by Newport News Shipbuilding, Inc., Newport News, Virginia	1996 by Shin Kurushima Dockyard Company, Ltd., Tokyo, Japan
Owner/Operator	U.S. Navy	Ehime Prefecture, Japan
Persons on board	Crew 106 Civilians 16 Chief of Staff, COMSUBPAC	Crew 20 Students 13 Teachers 2
Injuries	None	9 fatal 1 serious; 9 minor
Vessel damage	$1.44 million	$8.8 million (total loss)
Other costs	Recovery of *Ehime Maru* ($60 million) and compensation ($2.67 million) to Ehime Prefecture for lost equipment and cargo, crew salaries, Japanese response effort, mental health care for survivors, and memorial services for accident victims	

Accident Description[†]

Route of the Ehime Maru

About 1200 local time on February 9, 2001, the Japanese fishing and training vessel *Ehime Maru* (figure 1), with 20 crewmembers, 13 students, and 2 teachers on board, departed pier 9 in Honolulu, Hawaii, en route to fishing grounds about 300 nautical miles south of Oahu. The area weather predictions for the day included a coastal waters forecast advising caution for the waters south of the islands from Kauai to Maui because isolated thunderstorms to the east were generating strong, gusty 15- to 20-knot winds, which, in turn, were producing waves of 8 to 12 feet.[1]

Figure 1. The Japanese fishing vessel *Ehime Maru*, built in 1996, provided fisheries and engineering training to high school vocational students. (Ehime Prefecture photo)

The *Ehime Maru* was in the middle of a 74-day training voyage that had originated in Japan on January 10. During the vessel's 1-day stopover in Honolulu, its air conditioning system was repaired.

† Statements of individuals in this report are based on testimony at the Navy's court of inquiry (see http://news.findlaw.com/hdocs/docs/greeneville/ussgrnvl041301rprt.pdf) and interviews with Safety Board investigators as listed in appendix A. Other information was obtained from a recorder on the submarine that captured various system data and from shoreside radar.

[1] A senior Coast Guard official testified that the February 9 situation report for the area indicated that the winds were 10 knots, the seas were 3 to 4 feet, the visibility was 6 miles, the air temperature was 78° F, the water temperature was 77° F, and the day was slightly overcast.

The *Ehime Maru*'s master had been a mariner for 40 years, 19 years on commercial fishing vessels and 21 years on various generations of the *Ehime Maru*. He had been a master for 8 years and the commander of the *Ehime Maru* since it was commissioned in 1996. He said that when the *Ehime Maru* left Honolulu on February 9, the vessel and its equipment were operating properly. He further stated that, in preparation for the voyage, one of the vessel's two radar sets[2] was turned on about 30 minutes before getting under way. The pilot who directed the *Ehime Maru* from the pier to the sea buoy confirmed that the vessel's radar was energized while he was on the bridge. After leaving the harbor, the radar was set to the 12-mile scale.

The master said that the *Ehime Maru* traveled at 6 knots or less for about a half hour while the crew hoisted the anchor to its stowed position. After the anchor was secured for sea, about 1250, the master activated the autopilot and the fishing vessel proceeded on a southeasterly course (166°) at 11 knots. The route of the *Ehime Maru* took it into an area designated by COMSUBPAC[3] officials for the conduct of a distinguished visitor cruise,[4] a Navy program that promotes the mission of the service by permitting civilians to observe operations on board its vessels. Various senior Navy officials described the operating location as "not a highly trafficked area" that was "about as safe as can possibly be."

The submarine selected to host the visitor cruise was the USS *Greeneville* (figure 2), which was one of five Los Angeles-class fast-attack submarines assigned to Submarine Squadron 1 of the U.S. Pacific Fleet,[5] but which had not been in the Pacific Fleet's regular rotational deployment cycle since 1998.[6]

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[2] Both radar sets were model BR-3440MA-X59, which has 50 kilowatts of output power and operates on a 9375 megahertz (MHz) frequency (X-band).

[3] The acronym COMSUBPAC stands for an individual (the Commander, U.S. Submarine Force, Pacific) as well as the Force command office. This report refers to the person as "the COMSUBPAC" and the command office as COMSUBPAC, without the article "the." A list of all acronyms used in this report appears in appendix B.

[4] The operating area assigned by COMSUBPAC to the *Greeneville* for the distinguished visitor cruise was bounded by 21°10′ N, 19°40′ N, 158°00′ W, and 157°00′ W, which is about 58 miles wide by 75 miles long, or about 4,500 square miles.

[5] The *Greeneville* had been scheduled to begin an extended test voyage on February 9. The submarine's commanding officer (CO) agreed to conduct the cruise; however, he requested that the start of the test voyage be delayed until Monday, February 12, and that the civilian group be taken on a short trip on Friday, February 9. COMSUBPAC officials agreed, thus permitting a cruise that was contrary to Secretary of the Navy Instructions (SECNAVINST) 5720.44A, which stipulated "underway operations will not be conducted solely to accommodate guests."

[6] The *Greeneville* was pulled from the regular rotation in 1998 to be fitted with the Advanced SEAL (sea, air, land) Delivery System, which gave the submarine the operational capability to carry Navy SEAL forces and their equipment to and from hostile areas. For the next 2 years, the submarine went through underway tests and exercises of the system.

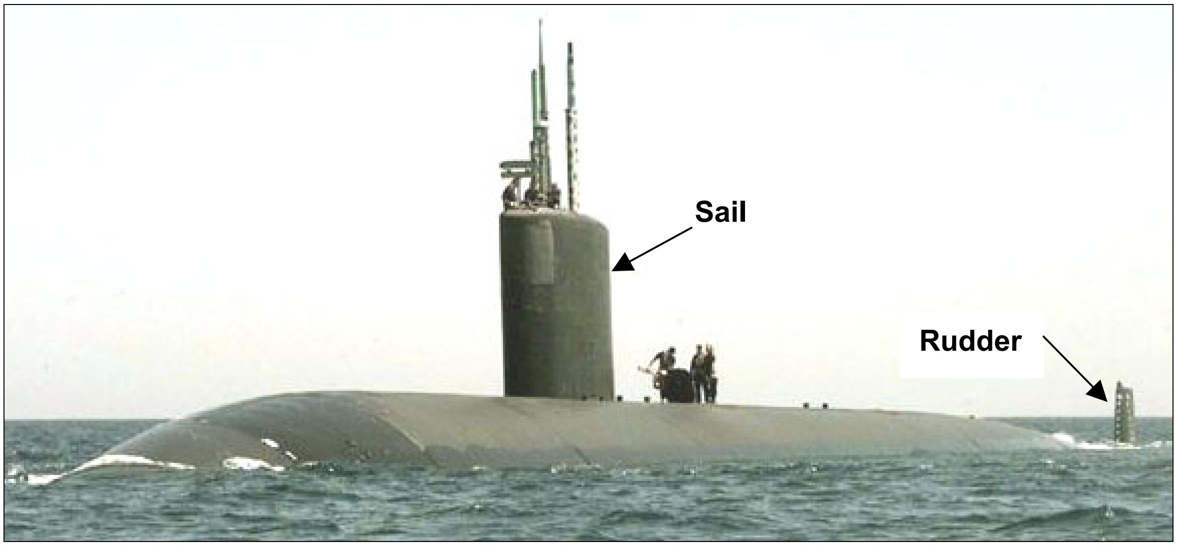

Figure 2. Photograph showing crewmembers at the top of the *Greeneville*'s sail and around a hatch on the main deck. The *Greeneville* was an "arctic-capable" submarine, meaning its sail and rudder had been strengthened to enable it to break through ice. (U.S Navy photo)

On Board the Greeneville

Voyage Activities. The *Greeneville* had departed Pearl Harbor earlier that morning, at 0757, carrying 106 crewmembers (11 officers and 95 enlisted persons), 16 civilian visitors, and the COMSUBPAC chief of staff. At the onset of the voyage, the visitor group received a brief presentation, including a slide show, familiarizing them with the submarine's operations. The civilians were allowed to ride on the main deck and to visit the bridge inside the sail while the submarine transited the harbor, operating on the surface. They subsequently moved inside the submarine, where they were organized into two groups of eight for what the submarine's engineering officer described as the "standard ship tour." The scheduled activities for the visitors also included dining with the ship's officers and observing maneuvers, or "evolutions," which the commanding officer (CO) characterized as designed to demonstrate the submarine's capabilities.

At 0933, the "deck" and the "conn"[7] were transferred from the bridge to the control room (figure 3), where the vessel's navigator, a 14-year veteran of the Navy, was scheduled to assume the duties of officer of the deck (OOD) for the first underway watch. The OOD is a watch position that is second to the position of CO in the operational chain

[7] To have the deck means to supervise all functions and maneuvers of the ship and all personnel on watch. To have the conn means to direct the ship's movement with rudder and engine orders. To ensure safety of operations, some types of evolutions cannot be executed without the review or approval of the CO or, in his stead, the ship's executive officer.

of command, and is responsible for directing vessel movements unless the CO assumes the conn.

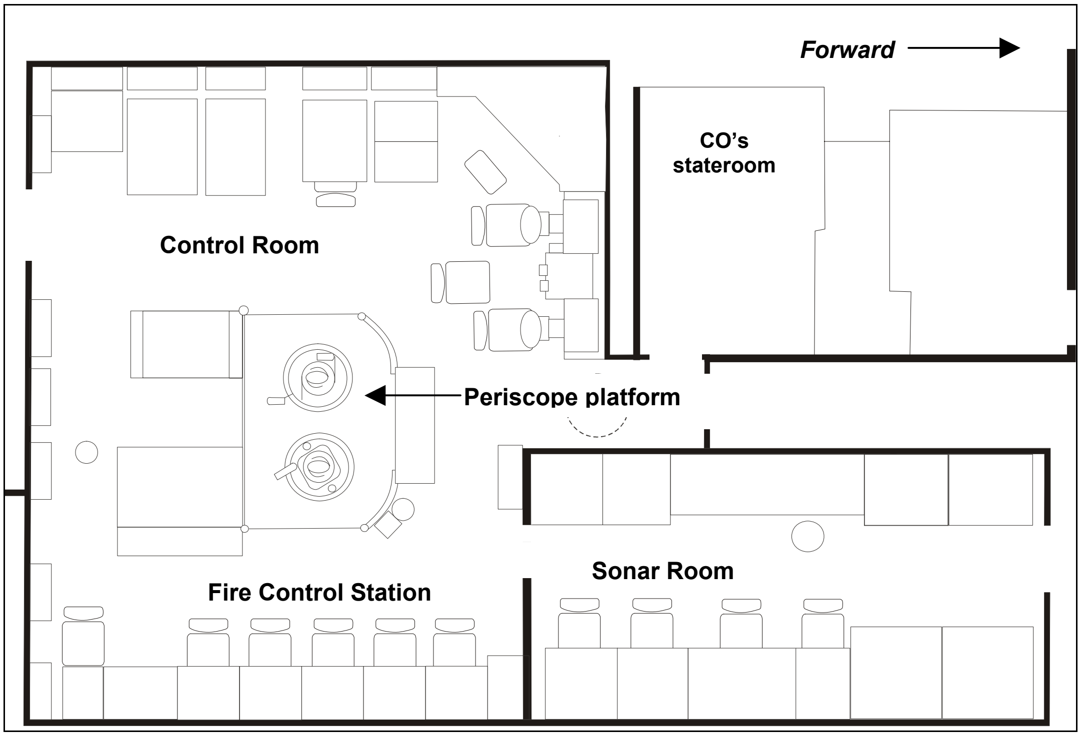

Figure 3. Plan view of the *Greeneville*'s control room, where the underway conning officer directs the ship's movements with rudder and engine orders. On the starboard side of the control room is the fire control station, where the fire control technician of the watch (FTOW) determines "solutions" for the range, course, and speed of "contacts," or other vessels, detected by the sonar system, which is in a separate space forward of the control room. The conning officer, the FTOW, and the sonar supervisor compose the primary members of the submarine's contact management team.

At 1017, the *Greeneville* submerged within its assigned operating area about 18 miles southeast of Pearl Harbor. The OOD testified that as the *Greeneville* submerged and dived to a depth of 150 feet, several civilian visitors were seated at "significant control stations." The OOD said, "We didn't have any specific track to follow," and that the submarine just drove north to south. He said that "[we] didn't want to get too far away from Pearl [Harbor]." He further stated that the plan of the day (table 1), a schedule listing the events and the evolutions established for the cruise, was "fairly tight," without "a lot of time to mess around."

The plan of the day called for lunch to begin at 1100 and end at 1200. The distinguished visitors were to eat in the officers' dining room (wardroom); however, because the wardroom was too small to seat the visitors as one group, they were divided into two groups, and two lunch periods were scheduled to allow them time to dine and be finished before the evolutions were scheduled to begin at 1230. The first group of civilian visitors, joined by the CO, went to lunch at 1045, while the second group of civilians visited the control room and the sonar room.

Table 1. *Greeneville*'s plan of the day for February 9, 2001

Time	Scheduled Event
0230	Reactor startup brief
0300	Reactor startup
0400-0530	Breakfast
0430	Reveille
0500	All hands muster
0545-0645	All hands clean up ship FWD [forward]
0700	Maneuvering watch personnel man the bridge
0715	Station the maneuvering watch
0800	Underway for VIP [distinguished visitor] cruise
1000	Dive
1030	Deep dive
1100-1200	Lunch
1130	Relieve the watch [second underway watch relieves first underway watch]
1230	Angles [depth-change maneuvers involving steep angles, frequently at high speeds; called "angles and dangles" by crew]
1300	EMBT [emergency main ballast tank] blow
1330	Station the maneuvering watch
1400	P/H [ocean point south of the channel entrance to Pearl Harbor]
1500	Moor/return to port

NOTE: Table does not show comments section of the plan, which includes names of crewmen serving in a training capacity during cruise. "Watch" refers to a time period in which a crewmember is assigned to a given duty.

While the civilians were in the sonar room, the crewmembers put the sonar system recorder in the play mode so that the guests could listen to tapes of marine life sounds typically heard underwater.[8] Shortly thereafter, in the control room, the OOD ordered the crew to "rig for deep submergence," and, at 1054, the *Greeneville* submerged to a depth of 700 feet.

After reporting to the CO that conditions were "normal," the OOD ordered the submarine to a classified depth for about a half hour while some visitors were still in the control room. During this time, the crewmembers collected and bottled water samples from the ocean, which were labeled with the classified depth and given to the visitors as souvenirs. At 1134, the OOD brought the vessel up to a depth of 650 feet.

[8] The sonar supervisor said that the crew forgot to reset the recorder before the evolutions began; therefore, the audio received by the sonar system was not captured on tape.

Watch Change. The plan of the day indicated that the second underway watch relieved the first underway watch at 1130. Shortly after 1130, the main propulsion assistant entered the control room to prepare for his duty assignment as the OOD of the second underway watch. The main propulsion assistant had about 6 years of service in the Navy, and the *Greeneville* was his first sea tour. He had reported to the vessel in March 1999 and begun a qualification program for various onboard duty assignments. He had qualified as an underway OOD about 6 months before this distinguished visitor cruise; however, during this time, the *Greeneville* was in the shipyard for 4 months, from September through December 2000. (This officer is referred to as the OOD-2 in this report.)

The OOD-2 said that he learned the Analog-Video Signal Display Unit (figure 4), or AVSDU, was not working when he reported to the control room for his watch. The AVSDU duplicated the contact data displayed on the monitors in the sonar room and permitted the conning officer to observe the vessels being tracked without leaving the control room. The navigator had noted that the AVSDU was inoperable and had reported its status to the CO before the *Greeneville* had sailed that morning; however, the malfunction of the sonar repeater did not meet the criteria for a significant equipment casualty that would have precluded the submarine from sailing.[9]

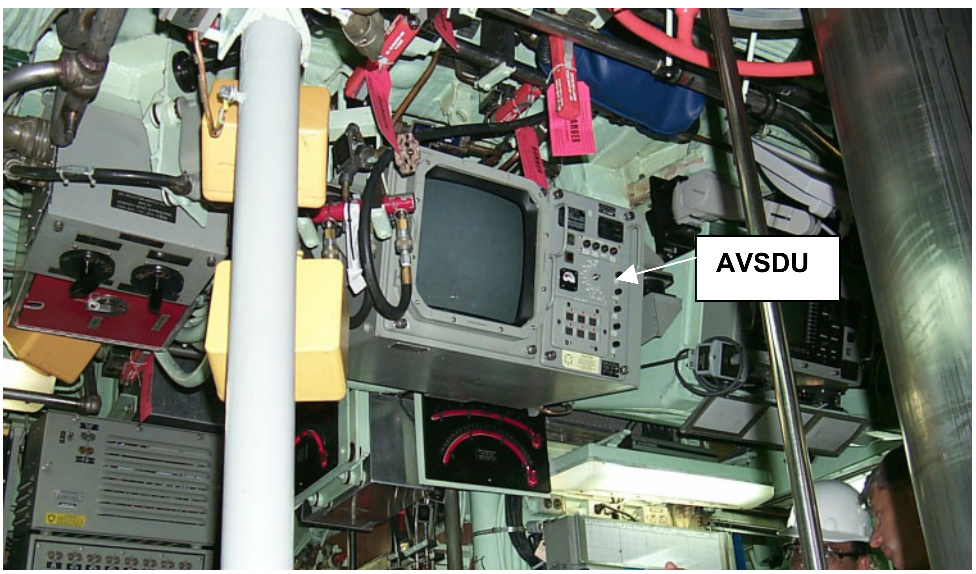

Figure 4. The Analog-Video Signal Display Unit, or AVSDU, was a sonar repeater installed near the *Greeneville*'s periscope platform. On the day of the accident, the AVSDU was not working. (U.S. Navy photo)

The OOD-2 stated that, as part of his status briefing, the OOD of the first underway reminded him that to compensate for the loss of the AVSDU, he needed to "periodically go into sonar to assay the contact picture."

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[9] See *Operational Reports*, Naval Warfare Publication 10-1-10 (Chief of Naval Operations, Washington, DC: 1987).

The first underway OOD said that he observed his watch relief as he did "a normal prewatch tour." The OOD-2 went into sonar and talked to the sonar supervisor to get an idea of what the contacts were. The OOD-2 next reviewed the monitors at the fire control system station "for a little while" and then went over to the chart table to verify the submarine's position and to check the plot to ensure "we were where we should be."

The OOD-2 recalled that when he took over the conn, at 1143, the *Greeneville* was "driving south" at a speed of 10 knots and a depth of 650 feet. He contacted the CO to obtain permission to allow crewmembers in the torpedo room to fire slugs of water from the torpedo tubes while the visitors in the area watched. To give the civilians a sense of how the ship drove, he permitted some of them to sit at the controls under the oversight of qualified technicians while he ordered simple course and depth changes.

About the same time, the first lunch sitting was ending. The CO testified that the lunch period was his first opportunity to talk with the guests. The CO had almost 20 years of service with the Navy and had been assigned the command of the *Greeneville* in March 1999. He said that the visitors were from his home state and as a result of his conversations with them, the first lunch sitting "ran a little long." At 1145, the second group of visitors went to lunch, which was hosted by the submarine's second in command, the executive officer (XO), a 15-year Navy veteran who had served on the *Greeneville* as XO since 2000.

About 1207, the OOD–2 ordered a course change to north to begin the return to the northern part of the *Greeneville*'s assigned operating area. Shortly before 1230, as the *Greeneville* was proceeding on a due-north course of 000°,[10] the sonar system (figure 5) began tracking a contact, bearing 331.2°, which the crew designated S-12.[11] Three crewmen were on duty in the sonar room: the sonar supervisor, a sonar technician at the broadband[12] "stack," or workstation, and a workload share stack operator.

The sonar supervisor had 7 years of Navy service, including 4 years as a qualified sonar supervisor (3 years on the *Greeneville* and 1 year on his previous submarine). He had been assigned to the *Greeneville* in 1997. The broadband stack operator, who had primary responsibility for detecting and tracking sonar contacts, had been in the Navy for 1 1/2 years and had been qualified to stand sonar watch for over a year. The workload share operator, who was responsible for maintaining the sonar log and providing backup to the broadband operator, had been in the Navy about a year and on board the *Greeneville* for 6 months. He had not yet qualified to stand watch in sonar; therefore, he was considered an "under-instruction" operator.

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[10] All bearings are based on true north.

[11] When sonar gains a vessel contact, it is assigned a letter and number designation, such as S-1. The letter "S" stands for sonar and is pronounced using the military phonetic alphabet for S, which is Sierra. The number represents the order in which the vessel is detected.

[12] Broadband refers to a wide range of sound frequencies. The broadband monitor is a visual display of all sound waves around a submarine.

Figure 5. Each sonar workstation, or stack, had two monitors. The two stacks at right displayed system input from hull-mounted arrays. (U.S. Navy photo)

About 1232, sonar gained a new contact (the *Ehime Maru*), bearing 358°, or almost due north. The crew designated the contact S-13. The sonar supervisor assessed it to be a "distant" contact.[13] Reconstructed data show that, at this time, the *Ehime Maru* was about 20 nautical miles away.

According to the sonar supervisor, the acoustic environment was good, and contacts could be heard from a distance of 15 to 20 nautical miles. He said that, as sonar supervisor, he looked for "something with a very high bearing rate, something that may be on our left side drawing right, or right side drawing left," which could represent a "closing" situation (meaning the target is heading toward the submarine). He said that when sonar first gained S-12 and S-13 (the *Ehime Maru*), "they did not have much of a bearing rate."

The sonar system was integrated into the fire control system and relayed bearing data on the contacts held, which was then displayed in four different formats on the fire control monitors. (See figure 6.) The FTOW, the technician manning the watch station, was a 14-year Navy veteran who had been involved in operating fire control equipment 12 of his 14 years in submarines. His work involved performing "target motion analysis"[14] (TMA) of the contacts being tracked by sonar, meaning he was responsible for determining the course, speed, and range of surface and submerged vessels (or

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[13] At the Navy court of inquiry, senior officials testified that for a contact to be considered distant, it is 20,000 yards or more away.

[14] The Navy also refers to target motion analysis as contact motion analysis in some documents.

targets) potentially posing a threat to the submarine. He accomplished TMA by adjusting the knobs at his station monitors to enter estimates for course, speed, and range variables into the fire control system computer and iteratively resolve the motion of the sonar contact relative to the position of the "own ship" (the submarine).

(1) Line-of-sight: shows bearing as a vertical line, contact as a vector at the top of the screen, and own ship as a vector at the bottom of the screen.

(2) Time-bearing: plots contact bearing against time.

(3) TMA: compares incoming sonar bearings, shown as dots, with the bearing generated by the fire control computer for the parameters of course, speed, and range in the computer. Incoming dots appear above the previous dots to form a line of dots. To achieve a tracking solution, the FTOW varies course, speed, and range settings to eliminate the difference between the generated bearings and the actual bearings coming from sonar.

(4) Op-summary: shows position of all contacts and land with respect to position of own ship.

Figure 6. The four display screens at the fire control station, looking left to right, are (1) line-of-sight, (2) time-bearing, (3) TMA, and (4) op-summary. (U.S. Navy photo)

The FTOW said that he followed his usual procedure to determine a solution for S-13 and other contacts, based on the information relayed to him when the sonar system initially gained a contact. He indicated that sonar did not designate any of the contacts as merchant ships. He stated that "just being in Hawaiian waters," he assumed that the contacts were typical of the "traffic around here . . . probably trawlers, fishing vessels [and] pleasure crafts."

The FTOW told Safety Board investigators, "I always put in a closing solution, which means the contact . . . is pointing at us, coming at us . . . and anywhere between 5 and 15 knots" depending on whether the contact is a trawler or a merchant ship. He added that he always initially entered a conservative range, "usually anywhere between 8,000 and 10,000 yards."

He said that if the contact had a low or steady bearing rate, "you assume that he's closing." He also stated that the fire control system needed several bearing rate changes to refine a solution, which he obtained when the submarine changed course, as it did about 1240, when the OOD-2 ordered a baffle clear.[15] The *Greeneville* then resumed a northerly course, which it maintained until about 1310.

Fire control data, as reconstructed by the Navy, show that after the bearing data for S-13 were relayed from the sonar system to the fire control system (at 1232:59), the FTOW entered three closing solutions between 1233:14 and 1240.00. While the FTOW was calculating these early solutions for S-13, the *Ehime Maru* was moving at 6 knots while stowing anchor. The FTOW next entered a closing solution about 16 minutes later, at 1256:00. Then, about 1258, he changed the course for S-13 from closing to "opening," that is, heading away from the submarine.

The FTOW stated that, on the day of the accident, he never tracked more than two or three contacts, which was a light workload. He indicated that, in the past, he had tracked as many as 20 to 30 contacts in high-traffic areas and that on more than one occasion, he had worked with another fire control technician at his station to track more than 40 contacts at a time.

After the second visitor lunch ended, about 1245, the XO went to the CO's stateroom to report that the mess (kitchen and dining areas) would be secured within 5 minutes and to suggest that the ship then begin the angles evolutions, which had been scheduled on the plan of the day for 1230. The CO asked who had the helm and, upon learning that a less experienced helmsman was on duty, directed the XO to replace him with a more experienced helmsman for the high-speed evolutions. The CO then stayed in his stateroom, signing photographs to give as mementos to the civilian guests, while the XO left to join the other crewmembers in the control room.

The OOD-2 told investigators that, shortly before 1300, he realized that, given the position of the submarine, about 17 miles from the unmarked seaward entrance to Pearl Harbor (designated P/H[16]), and the activities listed on the plan of the day, the submarine would be late returning to P/H. The OOD-2 expressed his concerns about returning on time to the vessel navigator, who had returned to the control room after lunch because he wanted to oversee the navigation watchstanders while the submarine performed some of the high-speed evolutions. The navigator later told investigators that he determined the submarine was about 10 or 12 miles from P/H. The navigator said if the submarine had surfaced at that time and driven toward P/H, the *Greeneville* would have arrived there on time. He knew, however, that the CO wanted to do evolutions so he approached the XO and reminded him of the time and the need to get back to P/H by 1400.

The XO then returned to the CO's stateroom to advise him that they had less than an hour before the vessel was due back at P/H. The XO testified that the CO said he

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[15] As is typical of all submarines, interference from noises generated by the *Greeneville* itself prevented the sonar system from reliably detecting sonar signals between approximately 120° and 240° relative to the vessel's bow. This arc astern of the vessel is known as the "baffles" area, and a submarine has to periodically alter course to uncover this null area, or "clear the baffles," for the sonar system.

[16] P/H is located at 21°16′17″ N, 157°56′33″ W, about 6 miles from the northern edge of the *Greeneville*'s assigned operating area on the day of the accident.

would finish signing the photographs for the visitors and remarked, "Well, I guess we are going to be late." Soon after, the navigator went to the CO's stateroom to remind him that the submarine was due back at 1400.

The navigator said that as the CO left his stateroom, he said that he was going "to push the OOD[-2]." The quartermaster[17] indicated that he was present when the navigator questioned whether the *Greeneville* would be able to complete all the planned evolutions and make it back to P/H on time. He stated, "We talked it over with the XO and CO and they thought we could."

The OOD-2 told Safety Board investigators that no senior officer, including the navigator, the XO, or the CO, discussed with him whether or how the plan of events might be changed or evolutions curtailed to avoid being late. He testified that he assumed that some evolutions would be canceled. The OOD-2 stated that the submarine was about 5 miles from the edge of its assigned submerged operating area, and that he was concerned about doing high-speed maneuvers near the edge of the operating area. He further stated that he could not remember whether he voiced his concerns to the officers.

All Visitors Called to Control Room. The XO made an announcement on the public address system inviting all guests to the control room to observe the conduct of the evolutions. The OOD-2 said that before the visitor group gathered in the control room, sonar had been tracking three surface vessels: S-10 to the south and S-12 and S-13 (the *Ehime Maru*) to the north. The OOD-2 said, "We did not have a great contact picture of where they [the contacts] were." At 1245:45, S-10 had "faded," meaning it no longer was being tracked by sonar. The OOD-2 did not order course changes for TMA to improve contact awareness for S-12 and S-13 before the XO invited the guests to the control room.

The COMSUBPAC chief of staff and 15 of the 16 civilian visitors[18] entered the control room about 1310, or about 10 minutes after the scheduled time for the last evolution on the plan of the day. Several visitors then went into the sonar room (figure 7).

Meanwhile, the CO testified that, after exiting his stateroom, he went into sonar to assay the contact picture. He said that he reviewed the sonar display of the contacts with the sonar supervisor, who advised him of two contacts, a merchant vessel to the northwest (S-12) and a surface craft to the north (S-13, the *Ehime Maru*). According to the CO, the sonar supervisor told him that the contacts "were distant, [and] up by land." The sonar supervisor told investigators that he assumed the contacts were more than 10,000 yards away. He said that he based his assumption on three factors—the bearing rate of the contacts was still small, the signal-to-noise ratio (SNR) was relatively low (SNR is a measure of signal strength relative to background noise), and the other sound characteristics indicated that the contacts were probably more distant than close.

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[17] The quartermaster on watch plots the vessel's position on a navigation chart and makes course recommendations to the conning officer. He also maintains the deck log.

[18] One of the civilians became seasick and was resting in a stateroom.

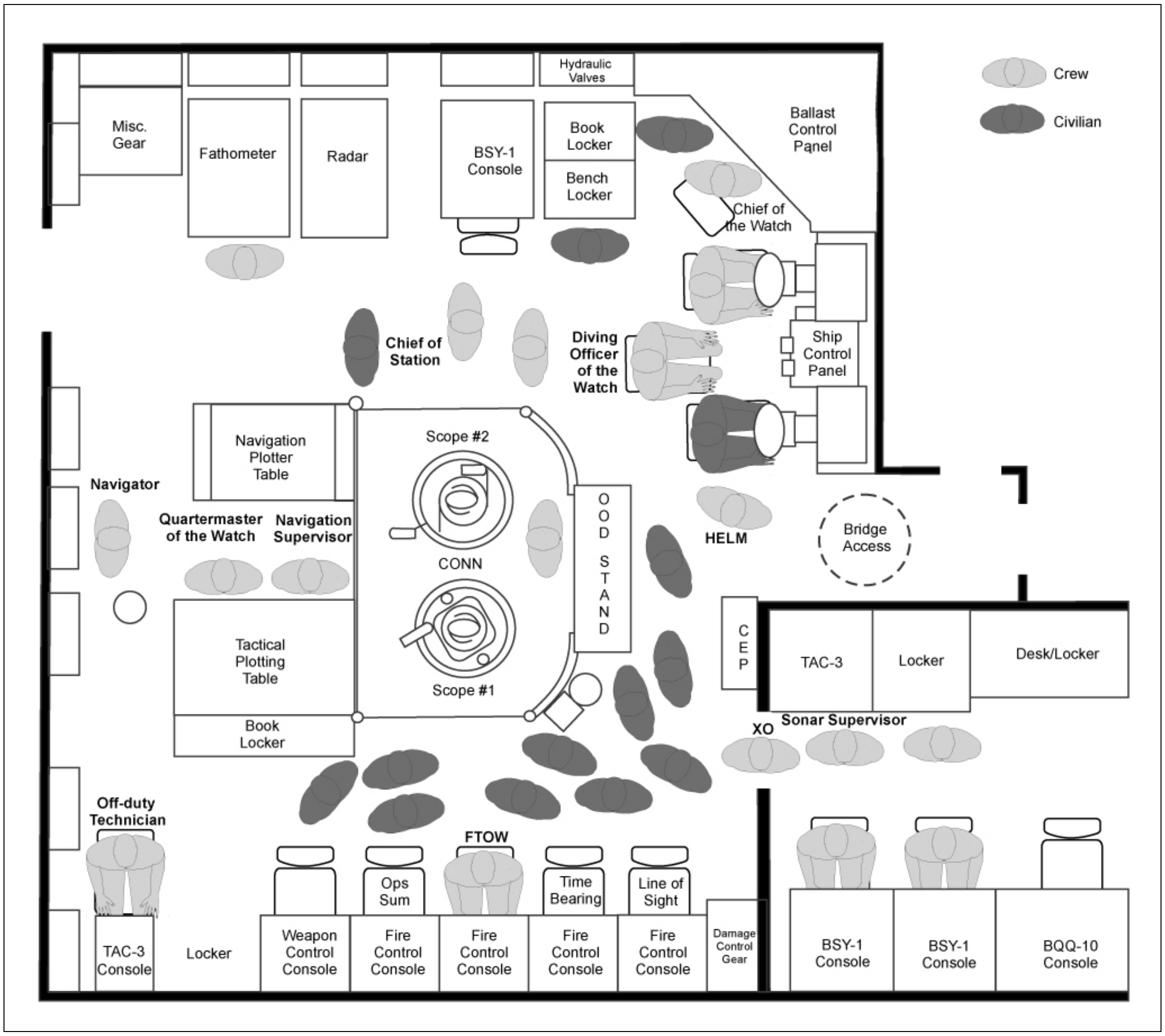

Figure 7. When the *Greeneville* crew began high-speed maneuvers to demonstrate the capability of the submarine to the visitors, 33 people, including crew and civilians, were in the control room and the sonar room. This illustration shows the approximate location of the civilians when the submarine executed the last evolution, an emergency surfacing maneuver.

About 1314, the CO entered the control room and advised the OOD-2 to prepare the submarine to perform the angles and dangles maneuvers. He did not discuss the contacts with the OOD-2 when he returned to the control room. He said that, based on his prior experience overseeing the main propulsion assistant while he operated as an OOD, he was confident that the officer had maintained situational awareness, that is, knew where the submarine was in respect to the contacts. At the Navy's court of inquiry, senior officers and enlisted personnel stated that, as an OOD, the main propulsion assistant had a reputation for being methodical, meticulous, and "not easily pushed." They also indicated that he typically took longer than more experienced OODs to accomplish tasks.

The CO said that the OOD-2 acknowledged his instructions. He further stated,

> I didn't focus on [the OOD-2's] actions. I can't tell you if he did not exit the conn and enter the sonar room, which would have been customary for him to do prior to the conduct of those evolutions. I . . . was looking elsewhere, I was walking around the control room to enhance my situational awareness, my understanding of the contact pictures, looking over . . . to see what we had on time/bearing displays, to see what the Fire Control Technician of the Watch . . . was doing, and looking and engaging the Quartermaster as to our current ship's position to help me understand what our situational awareness was because I had lost it while [I was] in the dining room and . . . stateroom.

The CO testified that he looked at the ops-summary display at the fire control station, which shows the position of all contacts with respect to the position of the submarine. However, he said he did not notice which time history the FTOW had selected for the display, and if a short time history had been selected, the display would not have shown that the OOD-2 had ordered only two course changes (the baffle clear at 1240 and the course change to north at 1245). The CO also stated that he did not look at the plot maintained by the navigation watchstanders. He said if he had done so, he would have realized that the OOD-2 had driven the boat only in a northerly direction and had not driven in easterly or westerly directions that might have provided an accurate contact picture.

Witnesses stated that the CO chatted with the civilians, advising them of the best locations in the control room to observe the maneuvers. Three of the civilians stood on the periscope platform. The FTOW stated that about six or eight visitors stood around the fire control station, blocking his access to the contact evaluation plot (CEP), a large paper graph that was mounted on the bulkhead forward of the periscope stand. The FTOW was required to annotate the CEP with the submarine's heading, the sonar contacts' bearings, and other pertinent observations to provide the OOD with a display of the submarine's position in relation to the known vessel contacts.[19]

Some of the civilians stood in front of the forwardmost two fire control system displays, which the OOD-2 said he typically used to monitor the contact situation. The OOD-2 later told Safety Board investigators, "I didn't have free access all the way over there. I got close enough where I could look at the contact picture and . . . the fire control screens." (See figure 6.) The CO said that when he went to the control room and reviewed the fire control system consoles, the visitors blocked his view of the CEP.

Several crewmembers stated that equipment preparations needed to support higher speed maneuvers delayed the start of the evolutions. According to the OOD-2, the CO "seemed frustrated that he couldn't start the maneuvers right away."

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[19] The *Greeneville* was among the last Navy submarines to be equipped with an automated CEP and did not have one at the time of the accident. All Navy submarines now have automated CEPs that display data for both the submarine and its contacts. Navy officials who examined the *Greeneville* CEP after the accident described the entries made by the FTOW as "very sparse," stating, "There were essentially no contact entries for the hour leading into the collision."

“Angles and Dangles” Begin. At 1315, the CO ordered the *Greeneville*’s speed increased to 14 knots. The OOD-2 stated that for the angles maneuvers—steep angled depth changes, frequently at high speeds—a CO typically gives an OOD the boundaries of where to operate, such as “stay between these two depths” and “change course using this high an angle,” and then allows the OOD to choose the course of action. Both the OOD-2 and the CO stated that, in this instance, the CO stood immediately behind the OOD-2 and ordered the specific course, speeds, and depths that he desired, and the OOD-2 merely repeated the orders to the diving officer and the helmsman.

The OOD-2 said that the CO directed him to order angles up to 30° and depth changes from 650 feet to 150 feet at speeds varying between 10 and 15 knots. The FTOW testified that the “captain was driving the whole evolution,” and the “OOD[-2] was a mouthpiece.” While the ship was going through the evolutions, the CO gave the civilian visitors a running commentary on the maneuvers.

According to the FTOW’s testimony, during the angles and dangles, he was able to track contacts S-12 and S-13 (the *Ehime Maru*) but not “100 percent . . . the whole time.” According to system data, the solution variables for S-13 were not changed for 23 minutes, between 1314 and 1337, while the submarine executed first the angle evolutions and then the high-speed turns.

The FTOW said that because the civilian visitors blocked his access to the CEP and because “you really couldn’t do anything” during the high-speed maneuvers, he stopped maintaining the CEP. He told Safety Board investigators that he did not advise anyone that he had stopped annotating the CEP and, because no one mentioned the plot, he thought that no one noticed that he was not maintaining it.[20] He later told Safety Board investigators that he had been the FTOW on numerous visitor cruises on the *Greeneville* and other submarines in the past and had never maintained the CEP while civilians were in the control room.

About the time of the angles and dangles, a sonar technician who had served on the first watch returned to the sonar room to get his jacket. He testified that several civilian guests were in the sonar room, in addition to the sonar supervisor, the broadband stack operator, and the workload share stack operator. The off-duty sonar technician was a 12-year Navy veteran who had joined the *Greeneville* crew in 2001. He said that he noticed that the sonar supervisor and the sonar technicians were trying to talk to each other and the guests at the same time.

The sonar supervisor asked that the off-watch sonar technician stand by the under-instruction operator on the workload share stack because having “another set of eyes . . . can’t hurt.” The sonar supervisor later testified that he asked the off-watch sonar technician to stay because the under-instruction operator had not completed the sonar qualification requirements, not because the sonar operator at the broadband monitor was

[20] A submarine force operations order (OPORD) stipulates that the FTOW cannot cease maintaining the CEP without permission from the conn.

overloaded. He did not brief the off-watch sonar technician about the contacts that sonar held at that time.

The off-watch sonar technician said that the sonar operator at the broadband stack appeared not to be distracted by questions from the guests. The unqualified workload share stack operator, however, was trying to answer the visitors' questions. At one point, the workload share stack operator started to turn away from the display to talk with the guests, but the off-watch technician told him not to do so. The technician said that he then asked the visitors to leave the sonar room.

The off-watch sonar technician said that during the angles and dangles, he became concerned about an "interference pattern" on the sonar monitor that appeared to suggest that one of the contacts was closing. He expressed his concern to the sonar supervisor, who told him to check to see what data the FTOW had on the contact. Shortly thereafter, the off-watch sonar technician went into the control room and asked the FTOW about "S-10," stating that it appeared to be a close contact. The FTOW said that he made some adjustments on the fire control system to try to put the contact on a closing course, but "it wouldn't fit," and he advised the off-watch sonar technician that the contact was on an opening course.[21]

Begin High-Speed Turns. About 1325, the CO directed the OOD-2 to order a course change to 140°, and the *Greeneville* began executing high-speed turns. According to the sonar supervisor, moving back and forth numerous times "just makes your display [look like] spaghetti. You've got lines in all directions from how the ship's driving. Contacts are kind of fading in and out" as they enter and leave the baffle area. Both S-12 and S-13 faded as they entered the port baffles.

To obtain accurate TMA results, the conning officer is responsible for ordering the submarine on a constant course, speed, and depth for a period of observation known as a "leg," during which the relative motion of the contacts can be observed. According to Navy officials, a minimum of two legs is necessary to determine the solution for a contact, and maneuvers that afford looking at the target from different aspects "very quickly" reduce the possible solutions to "a very limited number."

Shortly before 1331, after the high-speed maneuvers were completed, the CO ordered a speed reduction, a decrease in depth, and a course change to 340°. The CO's Standing Order 6 stipulated that the submarine would be held on course a minimum of 3 minutes to allow sonar and fire control to obtain an accurate contact picture.[22] According to recorded data, the submarine remained on the 340° course for 91 seconds. Of this time,

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[21] System data show that the *Greeneville* lost the track on S-10 more than 30 minutes earlier, about 1245. The Navy court of inquiry concluded that the off-watch sonar technician confused his contact numbers and that based on his observation that the close contact later faded in the baffles during the course turn to 120°, was referring to S-12.

[22] Submarine COs develop standing orders for vessel operating requirements that are based on instructions issued by the Navy's submarine forces commanders. The fleet instructions state that commanding officers "retain the flexibility to adapt/edit their standing orders as long as they meet the core requirements." The 3-minute course standard for TMA is set out in Naval Warfare Publication 3-21.51.1.

the total period that the *Greeneville* maintained a steady depth and speed was about 20 seconds.

Order to Periscope Depth. At 1331, the CO ordered the ship to slow to 10 knots and directed the OOD-2 to make preparations to proceed to periscope depth and to be at that depth within 5 minutes.[23] Figure 8 shows key events, beginning at 1331, on the *Greeneville* relative to the tracks of the submarine and the *Ehime Maru*.

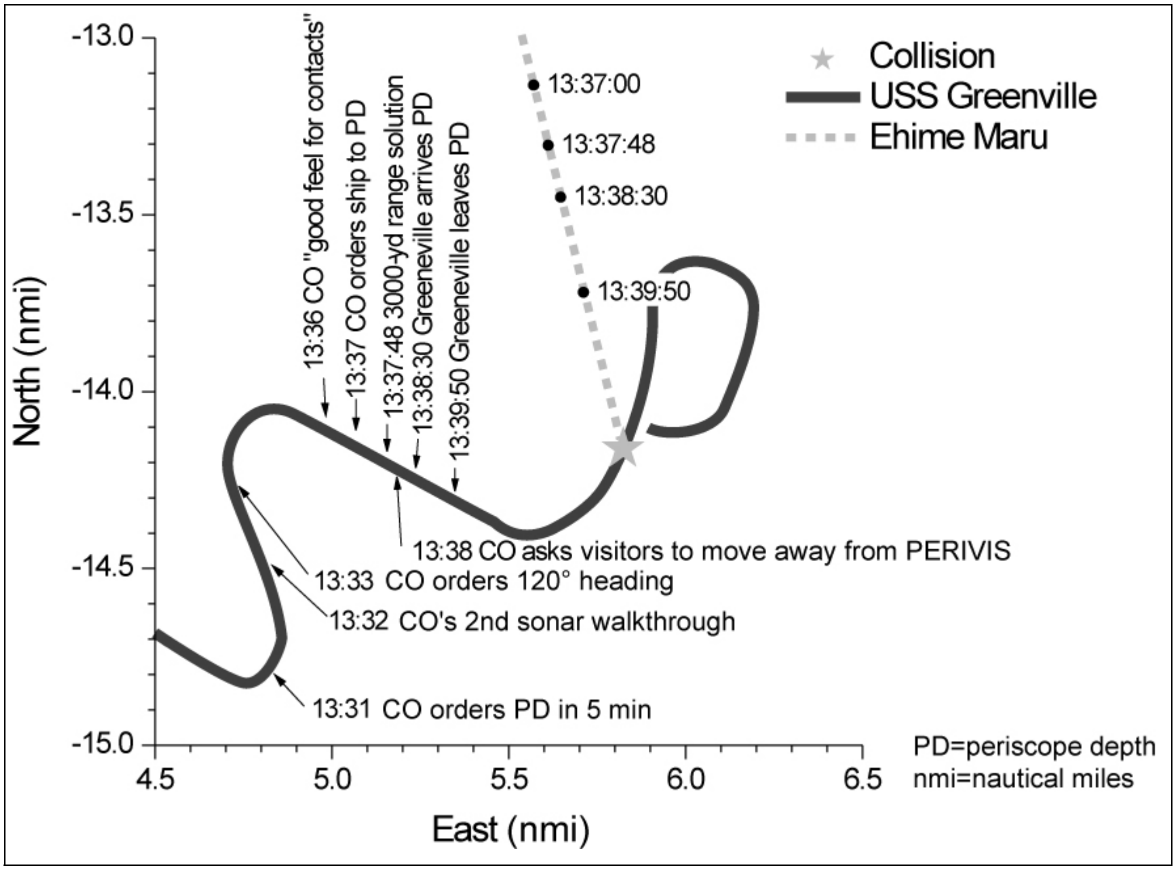

Figure 8. Plot showing the tracks of the *Greeneville* and the *Ehime Maru*. The *Greeneville* track is annotated with key events on the submarine beginning at 1331. The *Ehime Maru* track is annotated with the position of the fishing vessel at some corresponding times.

The CO's Standing Order 6 lists 16 actions and instrument checks, some involving as many as six steps, that the OOD is required to perform when preparing to go to periscope depth. One required action is for the OOD to conduct a periscope-depth briefing with key personnel to verify the contact picture. The CO later told Safety Board investigators,

[23] The CO's own standing orders stipulated that no less than 8 minutes would be allotted for the preparations necessary to go to periscope depth.

> He [the OOD-2] was so . . . slow, I knew that he couldn't get to PD [periscope depth] in 5 minutes. It was my objective to give him a goal to work towards . . . I doubt that any of my experienced officers of the deck could have gotten to periscope depth in 5 minutes.

The OOD-2 stated that when he heard the CO order him to prepare to go to periscope depth in 5 minutes, he considered the directive "unusual" and was concerned about the time limit. He said that when preparing to go to periscope depth, the OOD drives the ship "a certain way . . . so he can get a clear contact picture." To ensure the accuracy of the information, he asks sonar to report all contacts. If the reliability of the data is questionable, the sonar supervisor can advise a good course for TMA, whereupon the OOD orders more maneuvers.

The OOD-2 said that he then reports to the CO explaining the contact picture, including the types of contacts and their bearings, speed, and drift. The CO evaluates the OOD's report and, if convinced that the information is accurate, grants the OOD permission to proceed to periscope depth.

The OOD-2 said that he did not have a periscope-depth briefing because of "the time constraints and the challenge to go to periscope depth rapidly." He further stated,

> I would never think of not doing a periscope brief but, at the time, I had the commanding officer present, the executive officer present, other department heads present, as well as the chief of staff, SUBPAC.

Regarding the actions of the CO, the OOD-2 stated,

> Here's a man with much more experience than I have, much more schooling than I have, [who] can much more rapidly assess and evaluate information . . . I did not believe that he was putting the ship in an unsafe position, and [thought that] . . . the contact picture allowed for safe periscope depth.

Regarding his orders to quickly complete the steps necessary to bring the vessel to periscope depth in less time than indicated in his standing orders, the CO later testified, "I chose to not follow specific things out of my standing orders because I deemed at that time them not to be necessary."

Signal-to-Noise Ratio Increase. Meanwhile, in the sonar room, the broadband stack operator noted that while the submarine was in the middle of the high-speed maneuvers, the SNR for S-13 was "relatively high." Figure 9 shows the SNR data for S-13 (the *Ehime Maru*) that were captured by the *Greeneville*'s sonar system computers on the day of the collision, as plotted by Safety Board engineers.

At this time, the off-watch sonar technician who had been assisting the technicians at the stacks was in the control room, talking with the FTOW. The broadband operator said that he reported the SNR increase on S-13 to the sonar supervisor, whereupon the sonar supervisor "went to the curtain in control."[24] The sonar technician said that he did not know whether the sonar supervisor spoke to anyone about the SNR increase. When asked about the broadband operator's report, the sonar supervisor said that he did not recall being told about the SNR increase.

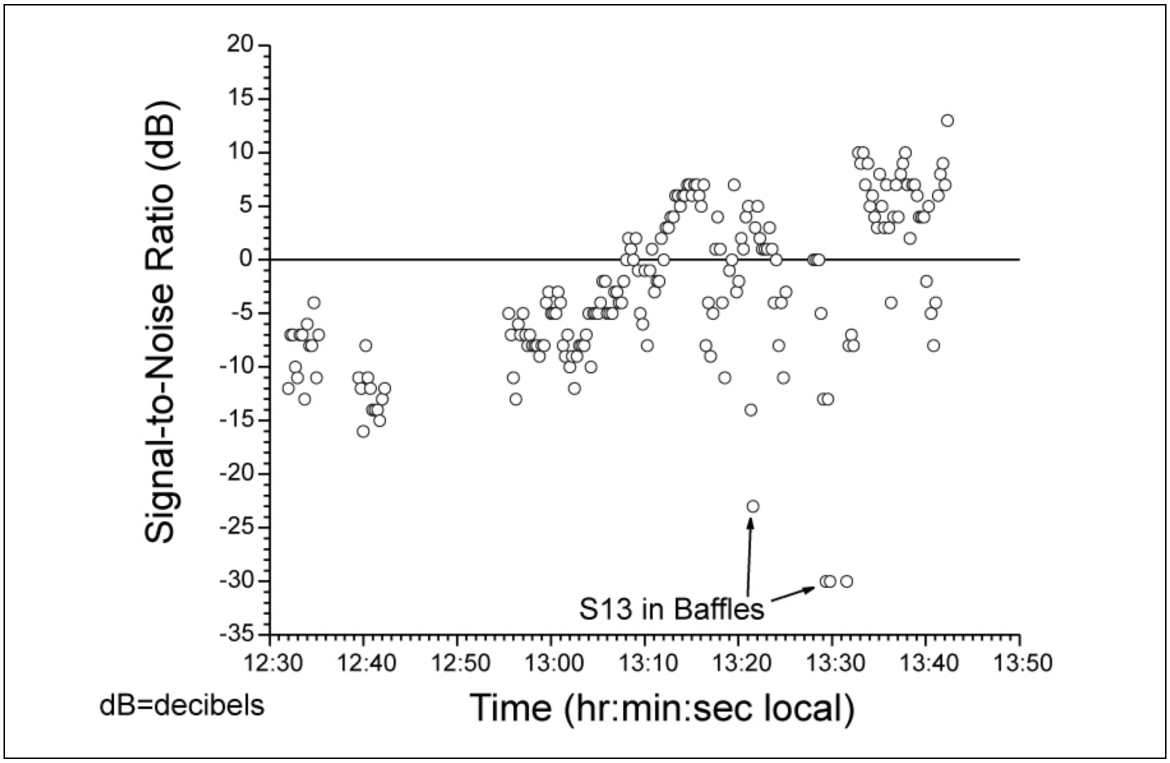

Figure 9. An increase in the SNR for a contact can be an indication that the target is getting closer. In this plot, each circle represents an S-13 signal captured by the *Greeneville*'s sonar system. As indicated in the plot, the SNR for the *Ehime Maru* increased over time except for when the fishing vessel was briefly in the baffle area. Note: The plot developed by Safety Board engineers is not representative of the display on the sonar monitors.

After giving the OOD-2 the order to go to periscope depth, the CO briefly went into his stateroom. From there, he went to the sonar room to assay the sonar picture and "obtain contact awareness." The CO said that as the ship was coming to a keel depth of 150 feet, he overheard the broadband operator tell the sonar supervisor that they had regained "previously held contacts." Recorder data indicate that while the CO was in sonar, the operators regained two contacts, S-12 at 1332:03 and S-13 (the *Ehime Maru*) at 1332:48. According to the sonar supervisor, he did not recall discussing any contacts with the CO while he was in the sonar room.

In the meantime, the XO told the OOD-2 that he would help him determine a course for proceeding to periscope depth by going into the sonar room to get the contacts.

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[24] The aft door of the sonar room had a curtain to block the light from the control room.

The XO later stated that he did so because the AVSDU was not operating. The XO went forward in the corridor and entered the sonar room through its forward door.

As the XO entered the sonar area, the CO was exiting the aft sonar door to go into the control room. About that time, the off-duty sonar technician reentered the sonar room after his conversation with the FTOW. He discussed his concerns with the XO, stating that he did not think he was wrong about the closing contact. The XO checked the fire control screens in the control room, returned to sonar, and asked the off-duty sonar technician how fast the *Greeneville* was operating. The off-duty sonar technician said that he then realized the submarine itself had caused the interference pattern because of the speed it was traveling. He further stated that his suspicions were confirmed when the submarine slowed and the interference pattern went away.

When the CO reentered the control room, he looked at the first monitor, the line-of-sight display, at the fire control station. The CO later told the Safety Board that, at this time (1333), he did not think the contact picture had changed, meaning sonar was holding two contacts. He stated, "I was confident that those contacts remained close along the Oahu coast, operating in that vicinity." He said, "I didn't pick up on the fact . . . that we had driven on north-south legs," meaning the *Greeneville* had not executed turns that would have provided changes in bearing rates.

Upon returning to the conn, the CO ordered a course change to 120° for the *Greeneville* to clear baffles. Concurrently, he announced to the visitors that the purpose of a baffle clear was to allow sonar to check for hidden contacts and prevent a collision at periscope depth. The OOD-2 stated,

> I was a little surprised when . . . the captain directed me to change course. I felt that he . . . was kind of driving the ship at that point . . . He had been kind of driving the ship before then, during the angles and dangles, when he gave me the courses and depths and speeds he wanted to drive.

During the course change, sonar gained a new contact, S-14. The fire control system displayed the automatic first solution for S-14 at 1334:03. The FTOW subsequently determined only one tracking solution for S-14, which he entered into the fire control system at 1334:48.

When the XO entered the sonar room, he positioned himself behind the sonar technicians, looking at the sonar display monitors. The sonar supervisor said that he assumed that the XO had come into sonar because the AVSDU was not working. He further stated that he did not discuss the contact picture with the XO. The XO later told Safety Board investigators that, while in sonar, he observed three contacts. He then stood in the sonar room's aft doorway while the submarine went to periscope depth. He did not give the OOD-2 or the CO any information about the sonar contacts or recommend any course for surfacing.

Shortly after sonar gained contact S-14, the signal for contact S-12 faded in the port baffles. About 1335, the baffle clear was completed, and the submarine was steady on course 120°. Reconstructed system data show that, about this time, the *Ehime Maru* (contact S-13), operating at a constant heading of 166° and a speed of 11 knots, was 3,282 yards from the submarine. When the submarine steadied course, the FTOW was able to resume determining solutions for the contacts. The FTOW said that he had "very low" confidence in his track for S-14 because it was based on "a single leg" that had lasted about a minute.

At 1335:39, the OOD-2 announced on the public address system for the crew to report all contacts. The CO testified that he recalled the sonar supervisor reporting two contacts, S-13 and S-14. The FTOW stated that he recalled sonar reporting three contacts: S-12, S-13, and S-14. About that time, the CO announced that he had "a good feel for the [sonar] contacts." According to the FTOW, the fact that the sonar announcement included S-14 and the CO's statement reassured him that the CO was aware of S-14.

About 1337, about 1 1/2 minutes after the *Greeneville* was on a steady 120° leg, the CO ordered the OOD-2 to proceed to a depth of 60 feet (periscope depth). Reconstructed system data show that, at 1337:00, the *Ehime Maru* was at a range of 2,724 yards, or 1.34 nautical miles. (See figure 8.) The FTOW stated that he quickly updated the solutions for the contacts that he was tracking, including S-12, S-13, and S-14. He described his updating as "rushed" and said that he was still updating his contacts as the submarine ascended to periscope depth. He said that he continued to give priority to analyzing S-14 because of the lack of data on the contact.

The sonar supervisor stated that when the submarine ascended to periscope depth, the monitor displays were changed to a different scale to enable the crew to watch for transient noise that was "different" or "unexpected," such as a quick change in a contact's bearing rate. The FTOW stated that while the submarine proceeded to periscope depth, he monitored the three contacts on the fire control system's time-bearing presentation because a fast bearing rate would indicate a close contact. System data indicate that, at 1337:48, less than a minute before the submarine arrived at periscope depth, the FTOW updated the solution for S-13 (the *Ehime Maru*), changing it from an opening to a closing solution and adjusting the range from 16,000 to 4,000 yards. The dots on the display immediately began to align, an indication that the solution was comparatively accurate. Reconstructed system data show that, at 1337:48, the *Ehime Maru* was at a range of 2,510 yards, or 1.24 nautical miles. (See figure 8.) The FTOW said that he failed to notice the range of S-13 "because he was trying to get everything done" before the submarine reached periscope depth. Standing Order 6 stipulated that the FTOW would notify the conn of all contacts 4,000 yards or less from the *Greeneville*; however, in this case, the FTOW did not report the status of S-13 to either the OOD-2 or the CO.

As the *Greeneville* ascended to periscope depth, the CO asked that some of the civilian visitors move because they were blocking the view of a video monitor that displayed the image seen through the periscope.[25] At 1338:30, the ship arrived at a depth

[25] The periscope video system, or PERIVIS, displayed the periscope image on several monitors throughout the vessel, including a screen near the fire control station. The PERIVIS also had a record feature that could be activated by the person using the periscope.

of 60 feet. Reconstructed system data show that, at this time, the *Ehime Maru* was at a range of 2,315 yards, or 1.14 nautical miles. (See figure 8.)

Periscope Search. The OOD-2 said that when the submarine reached periscope depth, he started to conduct a normal search using the No. 2 periscope.[26] When the periscope broke the water's surface, he executed the rapid low-power searches. He said that he completed his three rapid revolutions and announced, "No close contacts." He said that he was about to begin his next search when the CO took the periscope and began his own search routine. The FTOW said that, in accordance with the usual procedures, no one said anything in the control room or made any reports until they heard the OOD-2 say, "No close contacts," after the initial phase of his periscope search.

The CO later testified that he searched primarily in the sector where he believed the known contacts were located. He stated that he

> swept the scope in low power, went to high power, looked, then panned to the right, saw the island [Oahu] . . . I can only see the mountain peak, I can't see the mountains . . . because of this white haze . . . Then I could see an airplane taking off. . . . I panned to the right where I thought I would see [S-13] the *Ehime Maru*. I looked over at the remote repeater [own-ship's data] and I saw the numbers and [thought] that looks right. That's where the guy is. Didn't see him. Then went to low power and then turned to the right. I think . . . the *Ehime Maru* was perhaps further to the right, and as I swept in low power . . . missed her. And that's the only explanation that I can think of as to why I missed the vessel. It was perhaps too far to the right out of my field of view when I was doing my high power search thinking that the degree of optics that I was covering would encompass and overlap that area of uncertainty.

The FTOW said that when the periscope projected above the water, he shifted his attention to the PERIVIS monitor. He said that the CO did a "quick 360-degree look" in the general direction of the contacts, 40° and 340°, and then stopped on 18°. The CO next ordered the ship "to come up for a high look," a depth of 58 feet, to increase the periscope height of eye. The FTOW described the CO's search as "uncued" because he did not ask fire control to verify the bearings to the contacts, "which is my job." The FTOW stated, however, that he "was confident that the captain knew what he was doing during the periscope search."

The FTOW said that he thought that he had a good range for S-13, and that it was between 5,000 to 6,000 yards while the submarine was at periscope depth. He was under the impression that, of the three contacts, S-14 was the closest. He said, however, that he

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[26] Naval Warfare Publication 3-13.10 requires making at least three 360° low-power sweeps, about 8 seconds per sweep, to search for close contacts as soon as the periscope breaks the surface. If safe operation is indicated, "No close contacts" is announced. The *Greeneville*'s former CO, in describing a standard periscope search, testified that after the initial three sweeps, the OOD would do an air search in which he panned from the maximum elevation view down to the horizon, then would announce, "No airborne contacts." He would then do a 360° low-power search, which took about 45 seconds, followed by a 90° high-power sector search on the point where he terminated the 360° low-power search.

was not surprised when he didn't see a vessel on the PERIVIS because "fire control [is] only as good as the maneuvers you make," and he had "range errors . . . more than 50 percent of the time." He said that he estimated that he might be off by about 2,000 yards for S-13. He said that his confidence in the solutions for the contacts "immediately rose up" when they did not see any vessel through the periscope.

ESM Search. In addition to the periscope search, the movement to periscope depth enabled the technicians at the electronic support measures (ESM) system, located in a separate room behind the control room, to conduct a defensive search to identify and classify sources of detected electromagnetic radiation. Two crewmembers, a qualified and an under-instruction ESM operator, were present in the ESM room when the submarine went to periscope depth. The ESM station had one set of headphones. When the ESM antenna broke the water's surface, at 1338, the under-instruction ESM operator listened on the headset for aural indications of nearby vessels, and the qualified operator listened to the open microphone for the OOD-2's report.[27]

The qualified ESM operator said that he asked the under-instruction ESM operator what he thought, and that he responded there were multiple contacts but none was close. He said that before the OOD-2 announced, "No close contacts," he took the headset and listened to the aural indications. The categories of signal strength range from 1 to 5, with 5 being the strongest. The qualified ESM said that he heard none with a signal strength of 4 or 5, which would indicate a close-in contact. Upon hearing the OOD-2's announcement, the qualified ESM operator told the unqualified operator to announce, "No close contacts."

Emergency Evolutions. The CO testified that because there were "no visual contacts" and because both sonar and ESM had reported no threat contacts, "I called [an] emergency deep as a training evolution. . . . It was obvious that it took the control room party by surprise, which, for a training evolution of this type, I intended to do."

By the time that the CO ordered the emergency deep dive, about 1340, the FTOW had entered three solutions for S-13 using a range value of 3,000 yards. The fire control system display continued to indicate that his solution was accurate. Reconstructed system data show that, at 1339:50, the *Ehime Maru* was at a range of 2,236 yards, or 1.10 nautical miles. (See figure 8.) The FTOW later stated that, just before the emergency main ballast tank (EMBT) blow, he adjusted the range in his solution to 9,000 yards based on the fact that the CO had just completed a visual search and not reported seeing any close contacts.[28]

As the submarine descended, the CO asked the quartermaster the course to P/H, and the quartermaster responded that it was 340°. The CO then ordered a course change to 340° to head the submarine toward its return point.

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[27] Naval Warfare Publication 3-55.42 stipulates that the ESM's defensive aural search should be conducted in the same time as the OOD's initial search for close contacts, that is, within 24 seconds.

[28] Data indicate that the FTOW changed the range to 9,000 yards after the collision.

The guests stated that the CO then asked them whether they would like to participate in the vessel's upcoming evolution, which was the EMBT blow. During this maneuver, high-pressure air is used to force water out of ballast tanks as rapidly as possible to bring the submarine back to the surface in the shortest possible time. For the maneuver, the CO personally assigned one guest to sit in the helmsman's chair and operate the helm controls and stationed another guest to operate the valve levers that released the high-pressure air into the main ballast tanks. A third guest was stationed at the diving alarm. Experienced crewmembers supervised the visitors at the controls throughout the evolution, and the CO narrated what was happening for the visitors' information during the submarine's ascent. The FTOW said that during the EMBT blow, the civilians who were standing were "holding on to stuff—whatever they could grab onto to help stay up."

The sounding of the alarm was the signal to begin the emergency blow maneuver. At this time, witnesses reported, the guest at the high-pressure air controls operated the levers under close supervision of Navy personnel, and the submarine started to rise at a sharp angle. The guests recalled that, shortly afterward, there was a loud noise, and the submarine shuddered. The guests quoted the CO as saying, "What the hell was that?" After the submarine slowed and the periscope could be raised, the CO looked into the periscope and announced that the submarine had struck another ship. (See figure 10.)

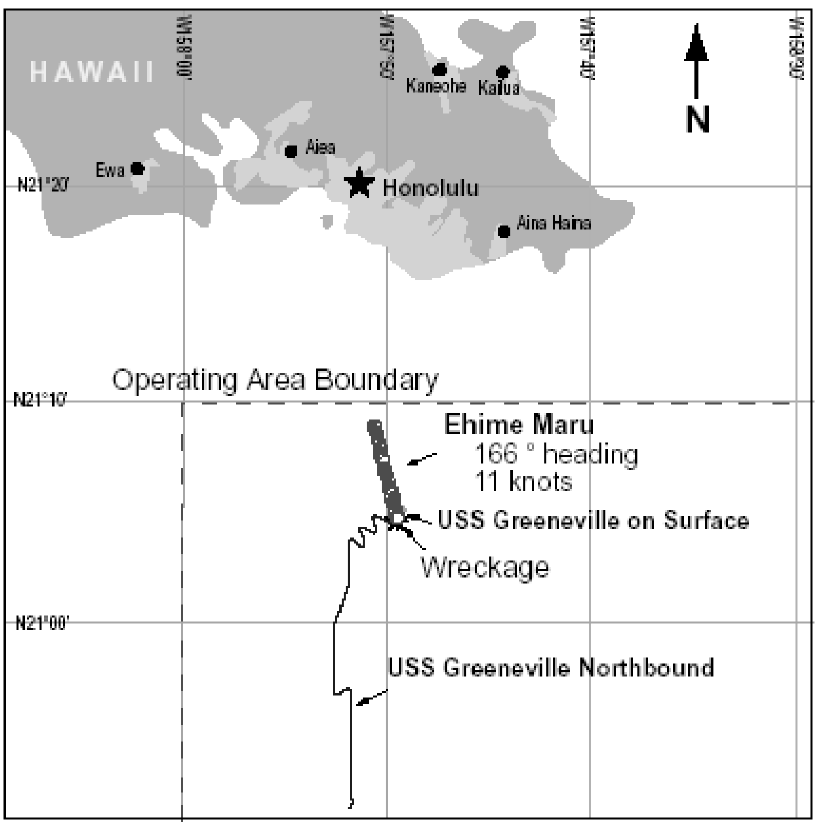

Figure 10. The collision between the *Greeneville* and the *Ehime Maru* occurred about 9 miles south of Oahu, Hawaii, at position 21°05.5′ N, 157°49.1′ W. Dotted line indicates the edge of the submarine's assigned submerged operating area.

The FTOW said that immediately after the collision, he went into sonar and talked with the sonar crew to determine whether they still had the contacts they had been tracking. He said that he was surprised to learn later that the vessel struck by the *Greeneville* was indeed one of the contacts they had been tracking. He said that he assumed that the ship they hit had been “dead in the water,” meaning its machinery was turned off.

Sinking of the Ehime Maru

Personnel on board the *Ehime Maru* reportedly heard two loud noises and felt the fishing vessel shudder. The bridge crew all stated that they did not see anything before the collision. According to the *Ehime Maru*’s master, “There was no ship at all nearby.” He stated that “the range of vision was good” and that “there was no outline of a ship nearby on the radar,” a Tokimec model BR-3440MA-X59. He said that he then felt two impacts and the stern of the ship lifted up.

After the impact on the fishing vessel’s port aft quarter, the *Ehime Maru* bridge personnel looked aft and saw the submarine as it broached the surface of the water. The *Ehime Maru*’s lookout said that after observing the submarine, he turned forward and saw diesel fuel squirting from the fuel tank vent on the forward port side of the fishing deck. The *Ehime Maru*’s master said that he realized immediately that his vessel was in trouble. Within 5 seconds of the collision, the *Ehime Maru* lost all power, including the backup systems on the emergency generator circuit. He said that he tried to call for assistance using the VHF-FM marine band radios, but they would not work. The master directed the chief radio operator to activate the emergency position indicating radio beacon (EPIRB), a portable 406-MHz model with a hydrostatic release, that was installed immediately outside the pilothouse, on the port bridge wing. (See figure 11.) According to witnesses, the chief radio officer was wearing an automatically inflating lifejacket and was near the bridge when the vessel began to sink. No one recalled seeing him reentering the pilothouse, leaving the ship, or swimming in the water.

Meanwhile, on the third deck (the lowest deck of the fishing vessel), the chief engineer, the first engineer, and the first oiler were in the engine control room when the oiler said he heard a loud scrape and then felt an impact. He said that the space immediately went black, and water and fuel flooded the area with such force that he was “violently” knocked about. He said that he could not recall how he was able to escape the engineroom but thought that water gushing in had carried him through the engineroom and up through a deck opening to the second deck. From there, he climbed up the ladder and out of the vessel. He said that he never saw the chief engineer and the first engineer after the impact.

At the same time, on the second deck, the nine students who survived the accident had just finished lunch and were either in the crew mess or in cabins that were immediately forward of the mess. The four students in the crew mess went directly aft. The students in their cabins said that when they looked out into the passageway, they saw

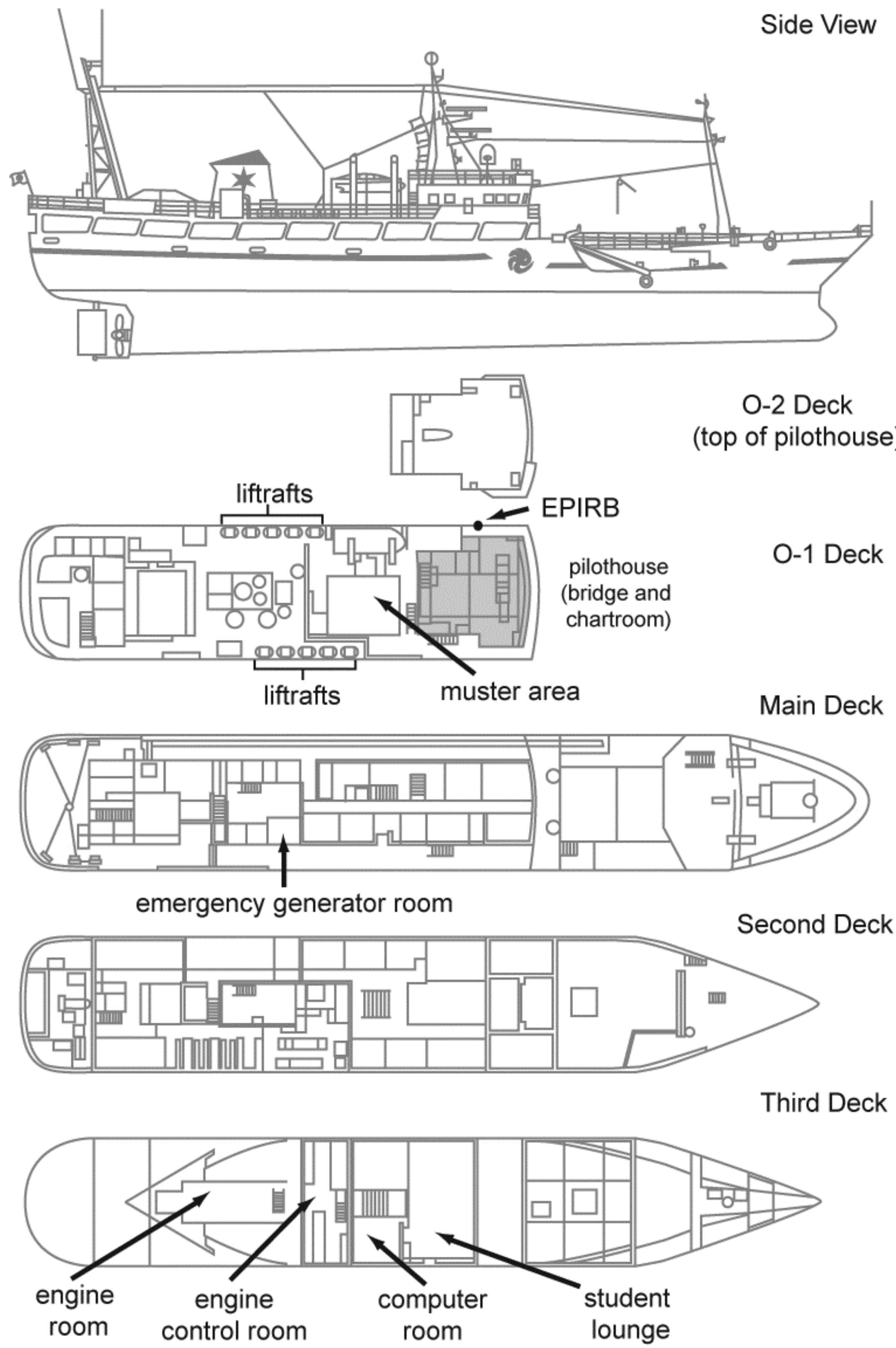

Figure 11. Side view of the *Ehime Maru* and plan views of the decks.

water and oil gushing up the stairwell from the deck below. The *Ehime Maru* was equipped in the berthing areas and at the watch stations with automatically inflating lifejackets that met the standards of the International Convention for the Safety of Life at Sea, 1974 (SOLAS), as amended. Most of the surviving students were able to retrieve the lifejackets from their cabins; other students said that they did not think to do so. They said that as they went aft in the passageway, they had to wade through an ankle-deep mixture of oil and water. Most of the students first went to the fantail area, or stern overhang, of the main deck. From there, they went to the mustering station aft of the pilothouse.

All survivors reported gathering in the muster area behind the pilothouse. Several witnesses stated that after it settled in the water, the *Ehime Maru* then sank by the stern at a 30° to 45° angle within 5 minutes of the collision. As the ship began to submerge, some people went into the water or were washed off by the waves coming over the stern. The remaining personnel attempted to climb a ladder to get onto the top of the pilothouse. Two students were washed off the ladder into the sea. Other students and crewmembers reached the top of the pilothouse only to be washed off by waves as the vessel sank. The oiler stated that he injured his shoulder when a wave washed him against a searchlight mounted on top of the pilothouse. Survivors carried underwater with the sinking ship either swam up to the surface or their lifejackets automatically inflated and carried them up. Witnesses from the submarine and the *Ehime Maru* reported that, after the fishing vessel sank, the water was covered with a heavy sheen of oil.

The *Ehime Maru* also carried 10 SOLAS-approved liferafts in containers mounted with hydrostatic releases that were designed to activate when the vessel sank to water depths ranging from 5 to 25 feet. The raft containers would then float to the surface and be automatically inflated by “tag lines” attached to the vessel with breakaway links.

According to personnel who escaped the vessel and made it to the water’s surface, the liferafts functioned as designed, and survivors were able to climb into them. The second engineer wound up in a raft by himself. He said that the submarine approached him and its crewmen called out to him. He yelled back, but the English/Japanese language barrier prevented him from understanding them.

Emergency Response

After determining that the *Greeneville* had struck a surface vessel, the submarine CO reported the collision to the Navy’s COMSUBPAC operations center at 1348. COMSUBPAC center personnel, in turn, notified Navy command personnel and Coast Guard Group–Honolulu by both landline telephone and VHF-FM marine radio. The Coast Guard and then the Navy began sending search-and-rescue assets to the scene. For a chronology of response events between the collision and the recovery of the *Ehime Maru*’s survivors, see appendix C. An in-depth discussion of response activities follows.

Response Efforts by the *Greeneville*. After the submarine struck the *Ehime Maru*, the *Greeneville*’s engineering officer took over as OOD during the response effort and initiated rescue and assistance measures as required by Operations Procedure (OP)

61-19.[29] In addition, a medical treatment station, manned by a hospital corps technician, was established in the officer's wardroom.

The OOD stated that he and a petty officer manned the bridge, which was located inside the submarine's sail, within 6 minutes of surfacing. The fishing vessel had already sunk, so the OOD conned the submarine toward the *Ehime Maru*'s rafts and debris while the petty officer looked for survivors in the water. Control room personnel searched the area using both periscopes. Because of rough seas, the main deck hatches could not be opened; the only outside access was through the sail access trunk.[30]

The OOD and the lookout were joined on the bridge by the CO and two divers. In preparation for retrieving the fishing boat's occupants, the divers, who were trained in basic first aid, rigged a Jacob's ladder, which is a rope ladder with wooden or plastic steps, down the side of the sail.

As the submarine neared two rafts of survivors, the OOD called out to and tried to communicate with the people; he said that he was not successful, however, because of the English/Japanese language barrier. He saw one person who appeared to be injured lying in a raft. He said that because he had been advised that Coast Guard resources were soon due on scene, he elected not to put a diver in the water. He further stated, however, that if the submarine crew had seen any people from the *Ehime Maru* in the water before the Coast Guard boats arrived, he would have had a diver go to their aid.

Actions by COMSUBPAC. When COMSUBPAC received initial notification at 1348, its command personnel assumed search-and-rescue mission coordination for the Navy response and identified immediately available Navy resources to dispatch to the accident site. At 1355, COMSUBPAC watchstanders notified Coast Guard Group–Honolulu of the accident. Navy officials said that, during the initial phase of the response, they dispatched Navy vessels and aircraft independent of the Coast Guard response. However, COMSUBPAC maintained an open telephone line to Coast Guard Group–Honolulu to keep apprised of developments.

According to Navy officials, at 1504, based on information received about the scope of the accident, COMSUBPAC transferred search-and-rescue mission control of the dispatched Navy assets to the Coast Guard. (See next section.) The COMSUBPAC operations center continued to independently identify and launch Navy air and sea resources, notifying the Coast Guard when the response assets were en route.

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[29] The Naval Sea Systems Command has published the rescue and assistance procedures contained in the Los Angeles Class ship systems operations manual as a separate classified reference document, OP 61-19. The OP includes the actions to take and which crewmember is responsible for taking them should certain types of emergencies occur. The reference document also lists the precautions and the safety limitations that the rescue and the assistance details must follow when responding to an emergency.

[30] Videotape taken by the Coast Guard response helicopter shows large waves washing across the *Greeneville*'s main deck.

Coast Guard Response. According to the duty officer at Coast Guard Group–Honolulu communications center, when he received notification at 1355 of a collision in the area south of Diamond Head, he assumed responsibility as search-and-rescue mission coordinator for the case, in accordance with the agency's standard operating procedures. He first ordered a Coast Guard HH-65A helicopter (No. 6570) on routine air patrol to divert to the accident site and then ordered Coast Guard Station–Honolulu to send rescue boats to the scene.

Coast Guard Station–Honolulu initially dispatched two vessels: a 21-foot rigid hull inflatable boat (RHIB) with 3 crewmembers and a 41-foot patrol boat with 7 crewmembers, including an emergency medical technician. The Group duty officer said that when he realized that the Coast Guard's standby cutter, the *Kittiwake*, was several hours away from the accident site, he ordered the recall of the Coast Guard cutter *Assateague*, which was at home base in a maintenance status. The *Assateague*, staffed with off-duty personnel from several cutters, got under way within 1 hour of notification.

Helicopter No. 6570, with two pilots, a hoist operator, and a rescue swimmer on board, arrived at the site at 1427, about 45 minutes after the collision, and assumed command of the on-scene response. The helicopter pilot centered on the rafts and debris and, at 1446, began a sector search for people in the water.

In the meantime, the RHIB and the patrol boat arrived at the scene at 1431 and 1444, respectively. The RHIB went from raft to raft, counting people, identifying who had sustained injuries, and searching for someone from the *Ehime Maru* who spoke English. According to the coxswain on the RHIB, the master of the *Ehime Maru* was located in a raft and taken on board. The fishing boat master and the RHIB crew continued to count survivors in the rafts and determined that 9 people were missing. The Coast Guard responders radioed a report about the missing personnel to Group Honolulu.

When the Coast Guard patrol boat arrived on scene at 1444, the helicopter lowered its rescue swimmer by hoist to the boat, which then maneuvered next to three liferafts that were tied together. The rescue swimmer moved from raft to raft, assessing the condition of the survivors and treating those who were injured. He immobilized the arm and shoulder of the injured oiler and, using bottled water from the raft survival kits, flushed the eyes of those who had eye irritations from the diesel fuel.

The RHIB retrieved and ferried survivors from the other rafts to the patrol boat, where the EMT-trained crewmember medically assessed their conditions. The on-scene responders then distributed the 26 survivors between the two Coast Guard boats and returned to Coast Guard Station–Honolulu, arriving there about 1615.

Joint Rescue Coordination Center Response. At 1505, the Joint Rescue Coordination Center[31] assumed the responsibility of search-and-rescue mission

[31] The national search-and-rescue plan designates the Coast Guard as the U.S. aeronautical and maritime search-and-rescue coordinator with overall responsibility for the Honolulu region. The agency's

coordinator from Coast Guard Group–Honolulu because of the building magnitude of the case. During the early response, the Joint Rescue Coordination Center did not control or coordinate the influx of Navy resources into the search; however, once the Joint Rescue Coordination Center was advised of the responding Navy resources, center personnel directed the Navy assets to specific search areas and assigned the search patterns.

About the time that the patrol boat and the RHIB were retrieving the *Ehime Maru* survivors, the Coast Guard diverted a C-130 aircraft to the site to relieve helicopter No. 6570 of the on-scene command for the surface and air assets. The Coast Guard cutter *Assateague* subsequently assumed on-scene command of the search and rescue.

Honolulu Emergency Medical Services. The Honolulu emergency medical services dispatcher, working through the communications networks of local hospitals, determined the space availability at the medical facilities and routed ambulances from the Coast Guard Station. The four most seriously injured individuals were taken to Straub Hospital, which treated three of the injured for nausea and eye and throat irritations stemming from diesel fuel ingestion or hypothermia. The oiler was diagnosed with a fractured right clavicle and hospitalized for 5 days.

Because of a lack of available space at Straub Hospital, the remaining five *Ehime Maru* occupants requiring medical attention were taken to Kaiser Permanente Medical Center, where they were treated for eye irritations caused by the diesel fuel and released.

None of the missing personnel was seen after the *Ehime Maru* sank, either by the survivors, *Greeneville* crewmen, or other rescue personnel.

Extended Search Activities

Coast Guard or Navy units were on scene continuously for 22 days, searching for missing personnel. Two civilian vessels of Japanese registry also participated in the search. Initial attempts to locate the fishing vessel were unsuccessful because of bad weather and because of an erroneous report of the accident site. The Safety Board assisted the Navy in determining the location of the *Ehime Maru* by acquiring radar data from the U.S. Air Force 84th Radar Evaluation Squadron and the Federal Aviation Administration (FAA) and filtering the data to plot a track of the *Ehime Maru* that correlated with the time, heading, and speed reported by the master of the fishing vessel. (See discussion in "Safety Board Performance Study" section.) The Navy then moved the search area to the end of the radar track.

On February 16, Navy sonar detected a vessel and, at 1129, Navy personnel were able to identify the fishing vessel by maneuvering a remotely operated vehicle, the *Scorpio II*, so that its video cameras displayed the *Ehime Maru*'s stern plate. The vessel was sitting almost upright in 2,003 feet of water about 1,000 yards from the reported

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Joint Rescue Coordination Center, based in Honolulu, is operated by the Fourteenth Coast Guard District and is jointly staffed by Coast Guard and Air Force personnel.

collision site but almost directly under the end of the radar track. For the next week, two underwater remotely operated vehicles, the *Scorpio II* and the *Deep Drone*, searched the *Ehime Maru*'s exterior and the sea bottom surrounding it for the nine missing persons, with no success. The search effort was suspended on March 2.

Salvage Operations

To retrieve the bodies of the *Ehime Maru*'s missing occupants, the Navy contracted to build a specially designed lifting and spreader assembly, which could be operated from a diving support vessel with heavy lift capability. On October 12, 2001, the *Rockwater 2* lifted the *Ehime Maru* about 100 feet above the ocean floor and transported the suspended fishing vessel to a shallow-water recovery site about 115 feet deep near the Honolulu International Airport's reef runway. A team of Navy and Japanese divers then recovered the victims' bodies, personal effects, and mementos, and videotaped the vessel damage. After the search was complete, the *Ehime Maru* was transferred 16.5 miles out to sea, where it was lowered into its final resting place.

At the request of the families of the victims, their bodies were not autopsied and were returned to Japan. The body of the ninth accident victim could not be located, and he is presumed dead.

Damage Surveys

Ehime Maru. An underwater survey of the vessel's bottom revealed a cut in the hull that began on the starboard side inboard of the bottom near the deckhouse front. (See figure 12.) The cut, between 2 to 3 feet wide, ended on the port side shell in the vessel's engineroom, where it extended vertically from the vessel's bottom to 11.5 feet (3.5 meters) above it (the design waterline mark).

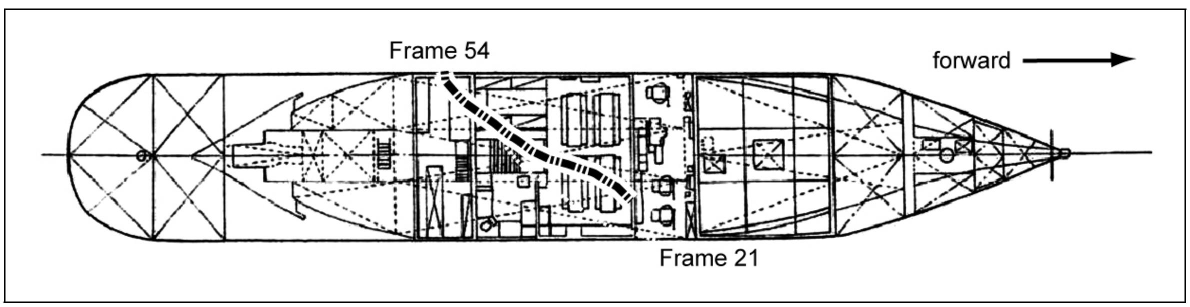

Figure 12. According to diver reports, the line of cut in the *Ehime Maru* extended from frame 21 to frame 54 through both the bottom and the innerbottom of the doublebottom vessel. The cut, therefore, resulted in breaches in the student lounge, the access stairwell to the student lounge, the engine control room, and the engineroom.

The cut proceeded from forward to aft of the vessel and breached the vessel's innerbottom[32] in the student mess, the stairwell, and the engine control room. The cut then proceeded through the bulkhead between the control room and the engineroom, leaving a vertical cutout in the bulkhead that was the approximate shape and size of the *Greenville*'s upper rudder. The vertical outline of the rudder was also visible on the port side shell of the *Ehime Maru*'s engineroom, through which the submarine's upper rudder had exited the fishing vessel's hull. The line of cut had breached several doublebottom (DB) tanks; going forward to aft these tanks included No. 2 fuel oil DB tank (starboard), No. 3 fuel oil DB tanks (starboard and center), and No. 4 fuel oil DB tank (port) in the engineroom. Both the outer and innerbottoms had been cut through. Damage to the control room and to the interior of the student mess and vertical stairtower on the port side of the computer room was visible during the survey. The open vertical stairtower allowed water to immediately flood upward to the upper deck levels of the vessel.

Greeneville. Safety Board investigators conducted a damage survey of the *Greenville* in drydock at Pearl Harbor Naval Shipyard. Investigators found that the sail of the submarine showed no damage. Immediately below the sail, the acoustic hull surface treatment (tiles) on the portside hull had been sheared off in an elliptical pattern about 24 feet long.

The upper rudder, located at the submarine's stern, showed the greatest impact damage. The damage began at the 31-foot draft mark and extended all the way to the top of the upper rudder on both its port and starboard sides. Surface tiles had been sheared off exposing bare metal over most of the rudder surface, and there were several indentations on the rudder's leading edge. One of the larger indentations had punctured the metal skin on the port side. The anchor light had been sheared off the top of the rudder. Other scrapes and missing paint seen on the hull were correlated by the Navy to previously existing wear and tear on the ship. The propeller area had not been damaged.

Safety Board Performance Study

As noted earlier, the Safety Board assisted the Navy in locating the sunken fishing vessel by obtaining Air Force and FAA radar data and extracting the *Ehime Maru*'s trackline. Safety Board engineers also used the radar data as well as own-ship, sonar, and fire control data retrieved from the *Greeneville*'s sonar data logger (SLOGGER) to conduct a performance study of the *Greeneville*, the *Ehime Maru*, and other surface vessels around the time of the accident. Excerpts from that study are summarized below. Note that the study and all the plots exclude the classified speeds and depths exceeded by the submarine during the visitor cruise.

The complete performance study is part of the public docket maintained on this accident by the Safety Board at its headquarters in Washington, D.C. For additional

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[32] The *Ehime Maru* had a doublebottom design, meaning the bottom of the ship had a compartment used for fuel, ballast, and so forth that was topped by a shell plating. This plating is referred to as the innerbottom.

details on the development of the tracks of the *Ehime Maru* and the *Greeneville* and the plots comparing all nonclassified recorded data and fire control solutions, see the public docket.

Ehime Maru *Track*

To determine the position of the *Ehime Maru*, Safety Board engineers sorted the radar data obtained from the Air Force and the FAA and removed any radar return that was not south of the radar site or that originated from aircraft with transponders. The remaining radar returns were plotted as a function of time to identify radar tracks, that is, consecutive radar returns. The radar data having the characteristics of surface ships (slow speed, no aircraft transponder return) were obtained from Honolulu airport, which uses Airport Surveillance Radar Model 9 (ASR-9). The airport radar antenna has an elevation of 68.1 feet and a magnetic variation of 10.5° E. The Safety Board converted azimuth and range data to east and north position from this antenna using the Tracks software program. One track visible in one of the plots ended at 2343 Universal Coordinated Time (UTC), or 1343 local time. This was later established as the time of the collision, initially from witness interviews and then from system data.

The radar tracks in the plots were separated and compared with sonar data. One track ended at the wreckage site and at the 2343 UTC collision time (as seen in own-ship data). This radar track was considered to be the *Ehime Maru*. The track showed the *Ehime Maru* moving at 11 knots on a heading of 166°.

Greeneville *Track*

The digital audio tape (DAT) information captured from the sonar interface unit consisted of TARed (a UNIX compression standard) ASCII data, which Safety Board engineers uncompressed on a UNIX workstation, transferred to a computer, and recorded onto a CD-ROM. The files consisted of data for the *Greeneville*'s motion (own-ship data), towed-array parameters,[33] and sonar and fire control data parameters. The recorded own-ship parameters consisted of time, heading, pitch, roll, depth, and speed. Angular data were obtained from the inertial navigation system. All own-ship data were recorded once a second; however, some data points were missing and the recording time sequence was occasionally offset briefly. Because the speed and direction of a submarine cannot change much in 1 second, Safety Board engineers manually repaired the bad data points. From the own-ship data, the Safety Board developed the plots shown below. Figure 13 shows the *Greeneville*'s keel depth and heading for the period between the ascent to periscope depth and the collision.[34]

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[33] Because the towed array was not deployed, the towed-array parameters were columns of zeros.

[34] The keel depth data held 90.84 feet for 7 seconds immediately before the collision. The Safety Board worked with the Navy to determine the cause of this false reading, but nothing conclusive was determined.

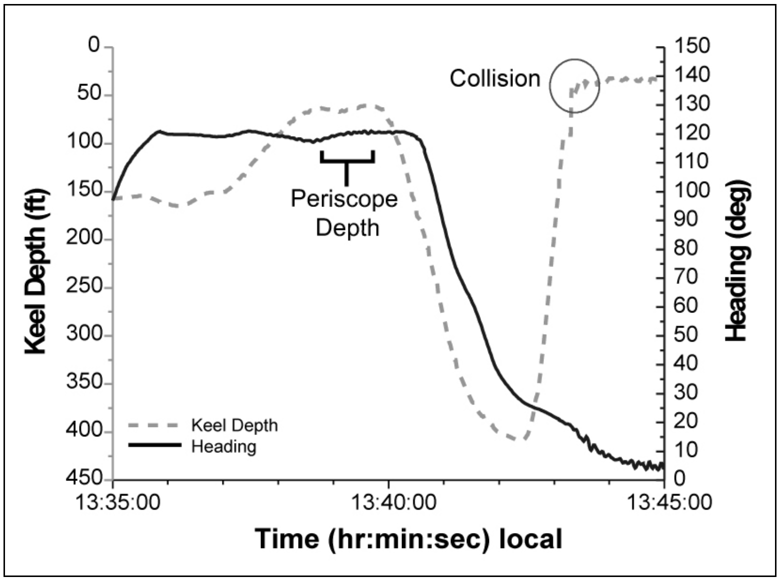

Figure 13. Keel depth and heading of the *Greeneville* between the ascent to periscope depth and the collision.

Integrated Tracks

The integrated plot of the *Greeneville* track and the *Ehime Maru* track developed by Safety Board engineers appears in figure 8. The Safety Board also developed a three-dimensional representation of the *Greeneville* and *Ehime Maru* tracks, beginning with the submarine's ascent to periscope depth and ending at the wreckage site. (See figure 14.)

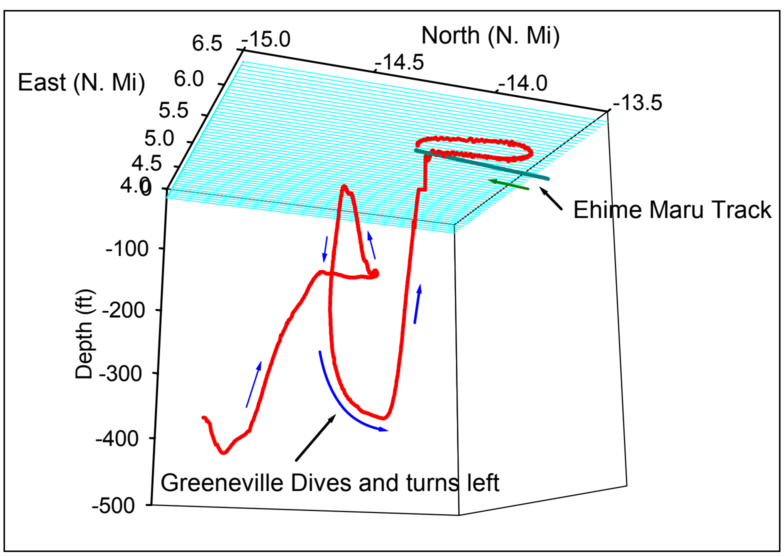

Figure 14. Three-dimensional representation of the *Greeneville* and *Ehime Maru* tracks, showing the submarine's ascent to periscope depth, the diving left turn, the collision with the *Ehime Maru*, and the return to the wreckage site. Note that depth is not to scale with east and north position.

Postaccident Actions by the Navy

Navy Court of Inquiry

General Findings. On February 9, 2001, the COMSUBPAC ordered an official inquiry into the collision between the *Greeneville* and the *Ehime Maru.* In its final report, the court of inquiry issued 26 recommendations, which, among other actions, included disciplinary measures against shore-based officials and six *Greeneville* crewmembers and reviews of various programs and procedures for adequacy and compliance.

Disciplinary Actions. Based on the findings and recommendations of the court of inquiry, the *Greeneville*'s CO was taken to Admiral's Mast,[35] where he was found guilty of committing two violations of the Uniform Code of Military Justice: dereliction of duty and negligent hazarding of a vessel. He was "detached for cause" from his position as CO, which was documented in his Navy officer record. He submitted a request to retire, which was approved, and he retired effective October 1, 2001.

The OOD-2 was taken to Admiral's Mast, where he was counseled for failing to execute his duties to ensure the safe navigation of the ship and to properly supervise watch personnel in the control room. The FTOW was taken to Captain's Mast for failing to report a closing sonar contact (the *Ehime Maru*) in accordance with standing orders.

The XO and the chief of the boat were both admonished for lack of oversight and execution of the enlisted watchbill.[36] The sonar supervisor was admonished for his poor watchstanding and backup of the contact management team and his failure to ensure that only qualified personnel stood watch in sonar.

The FTOW and the sonar supervisor were required to requalify before standing another underway watch in their supervisory positions.

Program Reviews. The court of inquiry report stated that various programs and operating procedures should be reviewed for adequacy and compliance. Table 2 summarizes the tasks the court recommended that COMSUBPAC or the Navy should accomplish.

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[35] Mast is an administrative proceeding where a senior officer can impose nonjudicial punishment for disciplinary offenses that do not merit courts-martial.

[36] Some individuals listed on the watchbill were not on the vessel and, no one was initially assigned to the fathometer watch, which is a station that must be manned when operating within 10 miles of land. The sonar supervisors switched personnel to accommodate for the oversight. The Navy found that, on the day of the accident, 9 of the 13 watch stations during the second underway were not stood by the individuals assigned to them. Several crewmen switched watches with a fellow crewmember without advising their supervisors or obtaining their permission to change duty assignments.

Table 2. Court of inquiry recommendations and actions taken

Task	Actions Taken
Ensure compliance with operating standards that permit only fully qualified sonar technicians to stand sonar watch.	In June 2001, COMSUBPAC issued guidance by classified message to subordinate echelons and all Pacific Fleet submarines reemphasizing sonar watchstanding requirements. The message directed that under-instruction sonar watchstanders be supervised by a qualified watchstander assigned on the watchbill to that station, not by the sonar supervisor. Compliance with sonar watchstanding qualifications and sonar watchstanding proficiency is now routinely inspected during the interdeployment training cycle.
Review the adequacy of the COMSUBPAC Operational Risk Management (ORM) program.	COMSUBPAC conducted an internal audit of COMSUBPAC to ensure compliance with Navy ORM instructions in OPNAVINST (Chief of Naval Operations instruction) 3500.59. In June 2003, Commander of Naval Forces instruction 5040.12 was revised to require that ORM be used in interdeployment training cycle inspections and assessments.
Review the ability and means of submarine squadron commanders and their staffs to provide meaningful oversight and objective feedback to their submarine commanding officers and crews during the interdeployment training cycle.	On August 28, 2002, a classified COMSUBPAC instruction was revised to include comprehensive interdeployment training cycle management. A squadron commander now conducts a 2-week assessment early in each submarine's interdeployment training cycle to identify, among other things, the strengths and weaknesses in basic submarine operations. The assessment results are used to focus training during the interdeployment training cycle to prepare the submarine crew for its next overseas deployment.
Coordinate a review of submarine open-ocean search-and-rescue capabilities and requirements with the lead type commander and make appropriate recommendations to the Chief of Naval Operations.	Naval Warfare Publication 3-50.1 (rev. A) promulgates Navy doctrine for search-and-rescue operations. The publication is subject to periodic review and update. It has been updated by change on three occasions since February 9, 2001. No changes were suggested by the Navy's court of inquiry report and none of the intervening changes relate specifically to submarine open ocean search-and-rescue operations.
Review the maritime traffic density of the Hawaiian operating area with the Coast Guard and other appropriate government agencies every 3 years.	A COMSUBPAC memorandum, dated April 23, 2001, now requires a maritime traffic density review for submarine force training agendas.
Provide information and training to the force concerning the *Greeneville* collision.	On April 23, 2001, COMSUBPAC sent a "lessons learned" message to all COMSUBPAC COs. The message was followed by a classified joint message from the commanders of the U.S. Atlantic and Pacific submarine forces, summarizing the main findings and opinions of the investigation as approved by the Commander of the Pacific Fleet. All submarine wardrooms and senior enlisted quarters have conducted training on the factors that contributed to the collision. A case study of the collision between the *Greeneville* and the *Ehime Maru* has become part of the curriculum at each level of tactical training for submarine officers. In addition, each wardroom is required to train on this case study annually.

The court of inquiry report concluded that the Navy's distinguished visitor program should be fully supported. However, the court recommended that the COMSUBPAC coordinate with the Chief of Naval Operations and the Naval Chief of Information to conduct a complete review of Navy public affairs policy and guidance on the embarkation of civilian visitors, and to issue new guidance that was internally consistent, clear, and more specific. The report also recommended that the approval authority for distinguished visitor embarkations be delegated to commanders at the type level, which is the second echelon to the fleet command. In the case of the Pacific submarine fleet, the type commander was the COMSUBPAC.

Regarding the conduct of distinguished visitor cruises, the court of inquiry recommended that COMSUBPAC identify which evolutions were appropriate for demonstration and reemphasize to the force that classified operational depths and speed limits are inappropriate for civilian cruises. The court of inquiry further recommended that COMSUBPAC establish a formal means for disseminating feedback or sharing information regarding distinguished visitor experiences across the command.

Revision of Instructions Addressing Visitor Cruises

At the Navy's court of inquiry, the COMSUBPAC testified that the Navy had both Secretary of the Navy instructions (SECNAVINST) and OPNAVINST addressing distinguished visitor cruises, a "tiny" but "extremely important" part of the Navy's civilian outreach program.[37] COMSUBPAC had issued operations orders and instructions pertaining to visitors on ships; however, the COMSUBPAC guidance documents basically iterated the policies put forth in the instructions issued by the Chief of Naval Operations and the Secretary of the Navy.

Neither of the publications cited by service officials contained requirements for ensuring the safety of civilians embarked on Navy vessels.[38] The instructions also did not address the procedural issues of whether and when civilians should be permitted in the control room or the sonar room and, if so, how many visitors should be allowed. The guidance did not indicate whether or when interaction between visitors and watchstanders should be allowed or define the role of the CO during a visitor cruise. In addition, the instructions did not specify which maneuvers should be conducted for the benefit of the distinguished visitors or, more importantly, prohibit any deviation from standing orders that might jeopardize the submarine, its crew and passengers, or vessels in the vicinity of the submarine's operating area.

Following the *Greeneville* collision with the *Ehime Maru*, chapter 4 of SECNAVINST 5720.44A was revised in May 2002, transferring the oversight for

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[37] In calendar year 2000, the entire Pacific fleet sponsored 176 guest embarkations, providing cruises for about 8,000 civilians. Of the 176 cruises, COMSUBPAC had 51 embarkations for 1,354 guests. Of the COMSUBPAC guest embarkations, 12 cruises carrying a total of 215 civilian visitors originated from Pearl Harbor. The COMSUBPAC stated that this total was less than the total embarkations in 1999, when SUBPAC hosted 227 civilians on 18 visitor cruises that originated from Pearl Harbor.

[38] In addition, none of the 26 Department of Defense, Navy, and Marine Corps documents cited as references for SECNAVINST 5720.44A addressed safety measures for civilian visitors on Navy ships, nor did they include procedural differences in submarine operations that were unique to visitor cruises.

distinguished visitor embarkations to commanders at fleet level, which for Naval forces in the accident area was the Commander, U.S. Pacific Fleet.

In August 2003, COMSUBPAC issued COMSUBPACINST 5720.1, which contained procedures for handling public visits on Pacific Fleet submarines that supplemented SECNAVINST 5720.44A, Commander of Naval Submarine Forces (COMNAVSUBFOR) OPORD 2000 (appendix 4), and SECNAVINST 5510.34. COMSUBPACINST 5720.1 procedures stipulate rules and requirements for each distinguished visitor embarkation on a Pacific Fleet submarine. The section pertaining to civilian distinguished visitor cruises states, "Civilian embarkations pose a degree of risk that must be properly managed."

The revised COMSUBPAC instructions address omissions in previous guidance documents, for example, interaction between watchstanders and visitors, the conduct or prohibition of certain maneuvers, and whether and how many civilian visitors should be permitted in the control room during certain evolutions. The instructions specify, in part, the following:

- Visitors should receive an introductory safety brief that advises them of what to expect in an emergency and how to don protective gear.
- Embarkations are to remain unclassified. The ship will not exceed unclassified depth or speed.
- The CO "will ensure guests do not inhibit the safe operation of the ship."
- One crewman will be assigned as a dedicated tour escort for every four to eight guests, and the watchbill will include those crewmembers serving as tour escorts. The escorts will have no other assigned responsibilities during the underway.
- The crewmembers assigned as tour escorts should be selected "to ensure first the safety of the visitors, then satisfy their information needs."

The procedural changes now require that requests for cruises be submitted in writing through the submarine's chain of command either to the COMSUBPAC or, if the hosting submarine is deployed, to the fleet commander. The requests must include a schedule of key events, and the force commander must review the planned maneuvers in terms of appropriateness for the assigned operating area, taking into consideration the shipping and fishing vessel density, water depth, and any other hazards to safe conduct. The August 2003 instructions prohibit allowing civilian visitors to operate any equipment; however, as part of the event schedule submission, the CO may propose allowing civilians to operate certain equipment during specific events while under the direct supervision of a qualified watchstander. Such a proposal must be approved by the force commander.

COMSUBPACINST 5720.1 permits up to 24 visitors, including noncrew escorts, on a civilian embarkation. The criterion for selecting an escort who accompanies the guest groups is "to ensure first the safety of visitors, then satisfy their information needs." The CO or his agent must review the itinerary developed for the visitors for areas of "conflict," that is, where overcrowding might occur.

In addition to the required procedures, COMSUBPACINST 5720.1 contains recommended actions for ensuring the safety of ship operations. For example, the initial briefing to visitors should be conducted in the mess facility during the outbound transit so that the piloting party can function without distraction. To ensure that the control room is not overcrowded during evolutions, the plan of the day should include two surface and dive evolutions, the implication being that a guest group of 24 should be divided and fewer visitors allowed in the control room at one time. To ensure that the crew is not distracted while making preparations to go to periscope depth, the visitors should be taken to the mess facilities, where they can watch a movie or a monitor linked to the PERIVIS.

Oversight Changes

During his interview with Safety Board investigators, the COMSUBPAC Deputy Chief of Staff for tactics and training described several "subtle" changes affecting squadron oversight of the *Greeneville* that were not recognized as having a combined detrimental impact until the Navy investigated the collision.

The COMSUBPAC deputy pointed out that a ship typically comes back from one deployment and deploys again within about 15 months. Because the *Greeneville* was a test platform for the Advanced SEAL Delivery System, it was not in the squadron's regular deployment rotation. As a result, Squadron 1 conducted fewer observations of the *Greeneville* and made fewer formal reports on its operations than in the past.

Beginning in 1999, the Navy changed the required oversight practices for the squadrons. Instead of stipulating that, at a minimum, the squadron conduct a tactical examination on a ship every 12 to 15 months, the Navy keyed the tactical examination to the vessel's interdeployment training cycle. As a result of the *Greeneville*'s extended interdeployment training cycle, the squadron had not conducted a formal tactical examination since 1998, when the submarine was fitted with the Advanced SEAL Delivery System.

About the same time that the Navy changed the squadron oversight standards, it also reorganized the squadron commands, which resulted in staff reductions. According to the COMSUBPAC deputy, during the transition period from the old to the new squadron command organization, the oversight infrastructure of the commands was "probably not well focused."

The COMSUBPAC deputy said that while the squadrons were being reorganized and oversight practices were being changed, the newly appointed commander to Squadron 1 "was struggling with another boat that had a . . . series of problems" but that was on a deployment cycle and had to be ready to go to sea by the end of December 2000. He said that when the Squadron 1 commander and other senior personnel visited the *Greeneville*, the "superficial" indicators of readiness all looked good. The boat was clean. The crewmembers were "positive . . . happy with their leadership . . . and proud of their organization." Moreover, crew retention was good.

The COMSUBPAC deputy said, "If we had taken the time . . . and studied in detail . . . the fundamental practices on the ship, I think that we would have seen the harbingers of problems." He stated that since the *Greeneville* collision, the Navy has changed the method for evaluating submarines. All boats are evaluated regularly, regardless of their deployment cycles. The focus is on forcewide performance in a particular area. The evaluation is a multistep process:

- *Basic submarine assessment.* Evaluate the submarine crewmembers to determine their fundamental understanding of their jobs and responsibilities.

- *Corrective actions.* Identify and monitor actions to correct problem areas; evaluate the weak areas the next time the vessel goes to sea.

- *Second formal review.* Two inspections are conducted 6 to 8 or 9 months after the basic assessment to check the ship's readiness to deploy. The first inspection is conducted by the squadron commander, the second by the COMSUBPAC staff and training office. The inspection team "baselines them against everyone else." The squadron commander then directs the CO to correct identified problems.

At a minimum, a ship must receive a passing grade on three major tactical events in a 15-month period. In addition, the submarine must pass two engineering inspections. Squadron personnel are on board and watching and tracking the ship's procedures during all events. Every ship is graded to an absolute common standard by the use of grade sheets. The squadron deputy told Safety Board investigators, "I think there's a great deal of sensitivity . . . to readiness, almost to the point that we've overcorrected in a way." He said that, in late 2001 and early 2002, two or three ships had not left on time because of unreadiness detected in the inspection process.

Operational Risk Management Program Changes

The Navy's court of inquiry found that, "Had *Greeneville*'s CO and crew been practicing the basic tenants of ORM, the collision may have been avoided." The court of inquiry recommended that COMSUBPAC review the adequacy of its current ORM program.[39] The stated purpose of the Navy's ORM program is to minimize risks to acceptable levels, proportional to mission accomplishment. The Navy's ORM is a closed-

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[39] Finding 66 and recommendation 8 of the court of inquiry report (Record of Proceedings, *Court of Inquiry into the Circumstances Surrounding the Collision Between USS* Greeneville *[SSN 772] and Japanese M/V* Ehime Maru *That Occurred Off the Coast of Oahu, Hawaii, on 9 February 2001*, U.S. Navy, April 13, 2001).

loop process that supervisory personnel use to identify and control hazards. The process involves the following five steps:

- Identify hazards;
- Assess hazards;
- Make risk decisions;
- Implement controls; and
- Supervise.

The level of an ORM analysis is time-critical, deliberate, or in-depth, depending on the situation. The depth and formality with which a supervisor conducts an ORM is guided by the following four principles:

- Accept risk when the benefit is greater than risk;
- Accept no unnecessary risk;
- Anticipate and manage risks by planning; and
- Make risk decisions based on the right level of analysis.[40]

As noted in table 2, following the adjournment of the court of inquiry, COMSUBPAC conducted an internal audit of its operations to ensure compliance with Navy ORM instructions. In addition, Navy instructions were subsequently revised in 2003 to include assessments of the use of ORM in training inspections.

Course and Training Changes

After the *Greeneville*'s collision with the *Ehime Maru*, the Navy revised its basic submarine course and all officer training, including the content of courses, entrance tests, and final examinations, the conduct of training, and the appropriateness of assignments for skill development. The courses now integrate the lessons learned from the *Greeneville* accident.

[40] OPNAVINST 3500.39A.

Analysis

In its review of the events in this accident, the Safety Board determined that qualified and experienced members of the combat management team (the conning officer, the FTOW, and the sonar supervisor) as well as senior officers who happened to be in the control room failed to follow procedures designed to ensure safety in operations. The teamwork problems demonstrated on the day of the collision were due in part to the CO's overly directive style, particularly with the OOD-2. However, the failure of key watchstanders to effectively perform their duties and communicate vital information to the conning officer contributed to the CO's committing the following critical errors:

- Failed to perform adequate contact analysis;
- Rushed the procedures for moving to periscope depth; and
- Ordered an emergency surfacing maneuver in the direction of a contact.

Contributing to the operating errors of the combat systems team was their failure to adequately manage the civilian visitors so that they did not distract the watchstanders from the efficient execution of their duties. A detailed discussion of the operating errors follows. The analysis also considers the design of the *Ehime Maru* and the survivability of the fishing vessel in the accident.

Failure to Perform Adequate Contact Analysis

To accurately determine the range, course, and speed of a vessel contact, the combat systems team needed to interact to ensure that a sufficient change in the contact's bearing rate was generated. For the visitor cruise, the *Greeneville* had no established track. The submarine sailed almost straight south and then, with the exception of one baffle clear, almost straight north while operating at a keel depth of 600 to 650 feet during much of the submerged underway. According to Navy officials in charge of tactical training, a crew can do "solution development without maneuvering the ship by using a variety of ranging techniques," and "operating at 600 feet reduces or minimizes the need for a precise solution" until the submarine is preparing to go to periscope depth. Navy officials who testified at the court of inquiry or who were interviewed by Safety Board investigators indicated that TMA could have been performed either immediately before or immediately after the *Greeneville* conducted the evolutions, so long as it was conducted before the submarine proceeded to periscope depth. Thus, it was not inappropriate for the combat systems team to wait until later in the underway, shortly before preparing to surface, to concentrate on contact (or target) motion analysis.

Problems arose, however, when both the sonar supervisor and the FTOW made assumptions about the contacts, including S-13 (the *Ehime Maru*), which later resulted in their providing incomplete and erroneous information to the CO. When sonar acquired S-13, the sonar supervisor correctly assessed that the vessel was distant and that it was not showing much of a bearing rate. However, when the bearing rate remained small for more than 40 minutes, he incorrectly assumed that the vessel was island traffic, on a distant course, and probably moving away from the submarine. He thus failed to properly assess the potential risk, anticipate a dangerous scenario, and advise the CO that the *Greeneville*, steering 000°, and the S-13 (the *Ehime Maru*), bearing 358°, were on closing courses.

The FTOW indicated that sonar did not designate any of the contacts as merchant ships. He stated that "just being in Hawaiian waters," he assumed that the contacts were typical of the "traffic around here . . . probably trawlers, fishing vessels [and] pleasure crafts." He too thought that S-13 was distant and did not enter a tracking solution for the contact for 16 minutes (between 1240 and 1256). As further evidence that he did not consider S-13 a threat contact, at 1257:45, he changed his tracking solution for S-13 to place it on an opening course despite having no analysis showing that the contact was actually opening.

Problems were exacerbated when the CO did not use all his resources to correctly assess the current operating situation when preparing for the conduct of the evolutions in the control room. He elected to confer with his trusted senior petty officers, first visiting sonar, where he was briefed by the supervisor, and then stopping at the fire control station, where he talked with the FTOW. The CO later stated that he had assumed that the OOD-2 had conducted TMA and had been confident that the young conning officer knew where the submarine was in relation to the contacts; yet, he never discussed the contact picture with him. The OOD-2 was aware that the combat systems team "did not have a great contact picture of where [S-12 and S-13] were" before the evolutions began. For his part, the OOD-2 assumed that some evolutions would be cancelled because the submarine was due back at P/H at 1400 and that a senior officer would brief him about the changes. The CO and the OOD-2, as the first- and second-level officers in the operational chain of command, should have conferred, not only about the contacts, but also about the safe completion of the voyage.

The CO testified that he went into sonar to assay the contact picture for himself. He recalled that in his discussion with the sonar supervisor, he was told that sonar held two contacts, a merchant vessel to the northwest [S-12] and a surface craft to the northeast [S-13, the *Ehime Maru*]. The sonar supervisor told the CO that the contacts "were distant, [and] up by land," and more than 10,000 yards away. Thus, the CO assumed that the contacts posed no danger. The sonar supervisor did not advise the CO that S-13 had not shown any bearing drift for 40 minutes, that the course of the *Greeneville* had been on a straight south/north track throughout most of the cruise, or that the submarine and S-13 were on closing courses. Had the sonar supervisor communicated this information, the CO might have recognized the potential risk and not taken the operational shortcuts that he later did.

The CO then entered the control room, where he said he reviewed the fire control monitors and discussed the contact status with the FTOW. The fire control technician made almost the same comments about the contacts being typical Hawaiian marine traffic as the sonar supervisor had done, which reinforced the CO's opinion about the position and course of the contacts. When he approached the conn, the CO then observed and recalled that the AVSDU was not working. If he had reviewed the CEP, which the FTOW maintained until an hour before the evolutions, the CO might have realized that the movements of the contacts and the submarine had been inadequate for good contact analysis. Instead, he chatted with the visitors, advising them where to stand for the best view of the evolutions, which prompted several civilians to position themselves in front of the CEP, blocking the CO's view of it and the FTOW's access to it.

Rushed Procedures for Movement to Periscope Depth

At the onset of the angles and dangles, rather than properly oversee the OOD-2 by having him direct vessel movements that the CO could verify as being correct, the CO essentially took over the conn without acknowledging that he was doing so. He ordered specific depths and turns, which the OOD-2 repeated to the diving officer and the helmsman. As the captain of the submarine, the CO had the authority to assume the conn.[41] However, by removing himself as backup to and overseer of the OOD-2, the CO eliminated a measure of safety redundancy that the Navy had developed for operations.

During the high-speed turns, which lasted between 5 and 6 minutes, the sonar display was scrambled, making it difficult if not impossible for the sonar crew and the FTOW to determine the accuracy of the contact picture. About 1331, as the submarine was beginning to slow on course 340°, the CO abandoned the checks and balances stipulated in his standing orders and started taking procedural shortcuts that adversely affected the ability of his crew to improve their contact awareness, thereby jeopardizing the safety of the cruise. He ordered the OOD-2 to complete preparations to go to periscope depth within 5 minutes, which the CO said even a veteran OOD would probably have difficulty accomplishing.

The OOD-2 attempted to complete the preparations for going to periscope depth, an involved process requiring him to conduct several tests, instrument checks, and, perhaps most important, a briefing with key watchstanders to share information about the sonar contacts. Through this vital communications step with the sonar supervisor, the FTOW, the radioman, the ESM, and the navigation supervisor, the OOD-2 could have ascertained whether the conn needed to order additional movements to improve the TMA.

Meanwhile, the CO had left the conn to go into sonar, where he watched the monitors as two contacts, S-12 (bearing 316.6°) and S-13 (bearing 016.3°), reappeared, respectively, at 1332:03 and 1332:48. He later stated that the displays led him to believe that the contact picture had not changed, whereupon he returned to the control room.

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[41] Navy operating procedures stipulate that the CO announce when he is assuming the conn and that the conning officer (in this case, the OOD-2) announce, "The captain has the conn" to the watchstanders, and "Sir, I have relinquished the conn" to the CO.

The *Greeneville* was arriving at 150 feet, the depth at which the OOD-2 reasonably would order TMA maneuvers, when the CO returned to the conn about 1333 and immediately ordered a course change to 120° to clear the baffles. The CO's actions of interrupting the OOD-2 and reassuming the conn resulted in the OOD-2 not holding the required briefing to discuss the contact environment. Again, the CO did not discuss the contact situation with the OOD-2. For his part, the OOD-2 did not speak up and advise the CO that he had not been able to determine whether additional TMA was warranted. Thus, the two officers again failed to communicate necessary information to one another that would have pointed out the need for improved contact awareness.

The CO's order to change course meant that he allowed the *Greeneville* to remain on the 340° leg less than 2 minutes (1331:36 to 1333:03), rather than the 3 minutes stipulated for TMA in Navy operating procedures. More important, the submarine was on a steady speed and course (to 340°) less than 25 seconds before the course change to 120° began. The baffle clear turn was complete about 1335; however, the CO then ordered the submarine to proceed to periscope depth at 1336:45. Consequently, he did not hold course long enough on either the 340° leg or the 120° leg to permit good TMA, a serious error.

The Safety Board constructed a hypothetical *Greeneville* track, extending the 340° and the 120° legs to 3 minutes each to allow for proper TMA. Figure 15 superimposes the hypothetical track over the actual *Greeneville* track. As shown in the chart, the too-rapid course changes on the actual track resulted in no bearing rate change, which is necessary for accurate identification of the contact's course.

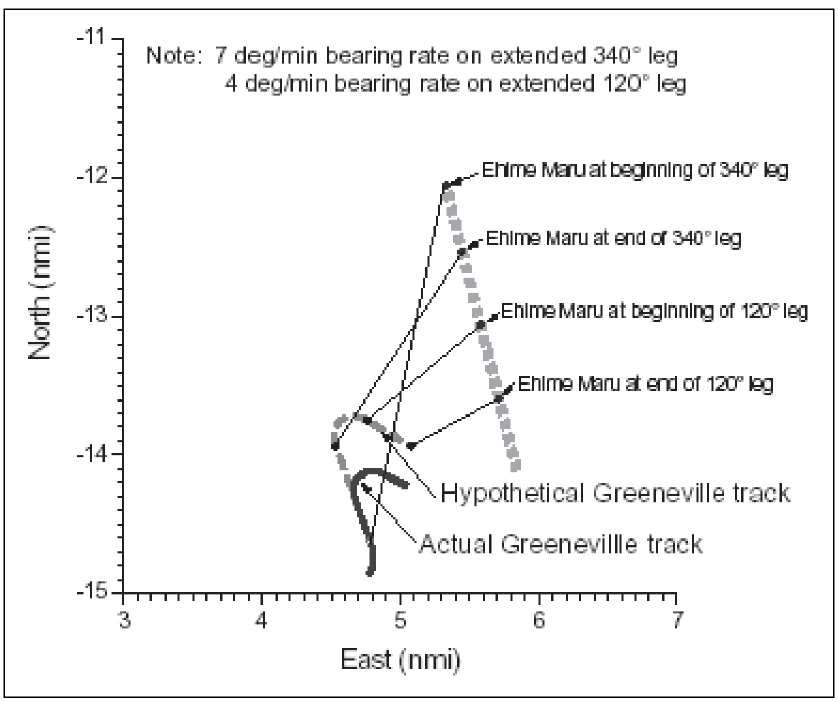

Figure 15. Comparison of *Ehime Maru* bearings with *Greeneville*'s actual track and with hypothetical track calculated for 3-minute legs.

The hypothetical track using 3-minute legs produced bearing rate changes that would have readily revealed the course of S-13 to both the sonar crew and the FTOW. The *Greeneville*'s bearing to the *Ehime Maru* on the hypothetical 3-minute legs would have been as follows:

Beginning of 340° leg……012.1°

End of 340° leg…………..033.0°

Beginning of 120° leg……050.1°

End of 120° leg………….…061.8°

The Safety Board determined that the rate of bearing change would have been about 7° per minute on the 340° leg and 4° per minute on the 120° leg if the legs had lasted the required 3 minutes. Thus, the total S-13 bearing change that the *Greeneville* crew could have obtained if the submarine had stayed on each of the TMA legs for 3 minutes is about 50°, as opposed to a bearing change of about 10° for the actual leg. Such a large bearing change and accompanying rate of bearing change would have alerted the sonar crew and the FTOW to the close proximity of S-13 (the *Ehime Maru*). Moreover, the large bearing changes would have provided sufficient input for the FTOW to develop a high-confidence solution for S-13 that would have placed it nearby and closing.

The CO's conning of the vessel compromised the ability of the combat systems crew to verify the contact picture in other ways. The turn that he ordered for the baffle clear put one of the known sonar contacts, S-12, bearing 316.5°, into the baffle area, the result being that sonar lost the track on the vessel. During the turn, sonar gained S-14, bearing 358°, a potential threat contact to the submarine. The FTOW, having no solution on S-14 and believing that S-13, now 4,200 yards away, was not operating near the *Greeneville*, began to concentrate on S-14 to the exclusion of S-13. However, he could not resume determining solutions for the contacts until the submarine steadied on course 120°, about 1334.

Meanwhile, the CO did not respond appropriately to the sonar supervisor's announcements about the loss of S-12 and the gain of S-14 by determining either their status or whether he needed to conduct additional TMA. Possibly he did not hear the sonar announcements, or perhaps he did not recognize the implication of sonar announcing the loss of one contact and the gain of a new contact. The CO later told Safety Board investigators that he probably would not have made the errors that he did if the AVSDU had been working and he had been able to refer to the sonar repeater.

The CO's comments reflect an operating failure that existed on board the *Greeneville* during this underway. Neither the CO nor the senior members of the combat systems team (OOD-2, sonar supervisor, and FTOW) demonstrated effective ORM when compensating for the inoperable sonar repeater in the control room and for the presence of the civilian visitors near key watchstations. ORM is a decision-making tool used by the Navy and other organizations to increase operational effectiveness by identifying potentially hazardous conditions and adopting procedures aimed at reducing or mitigating the potential for loss. On the *Greeneville*, the standard procedure for compensating for the loss of the AVSDU was for the conning officer to periodically visit the sonar room to assay the contact picture. However, the OOD-2 never visited the sonar room after conducting his prewatch checks.

The CO chose to compensate for the loss of the AVSDU by twice visiting the sonar room and reviewing the monitors there. Upon returning to the conn after his second visit to sonar, he ordered a course change to 120° to clear baffles about 1333. About the same time that the CO was explaining the purpose of a baffle clear to the civilian visitors, sonar gained S-14 at 1333:03. Thus, the CO may not have recognized that the sonar supervisor was announcing a new contact. The CO's possible error as well as the failures discussed later in this analysis, under "Management of Civilian Visitors," demonstrates that the combat systems team should have assessed the combined impact on operations of the inoperable AVSDU and the presence of civilians near the fire control station and the conn and devised better methods for communicating contact information to the conning officer.

Before the *Greeneville* rose to periscope depth, the CO announced to everyone in the control room that he had a "good feel" for the contacts, which had the effect of discouraging backup from his crew. The inexperienced OOD-2 acquiesced to the more experienced commanding officer, and the seasoned FTOW discounted a solution at his fire control station indicating that S-13 (the *Ehime Maru*) was 4,000 yards away or less. The XO, who had told the OOD-2 that he would go to sonar and relay contact information to him, said nothing to either the OOD-2 or the CO to ensure that the conn had accurate information about the contacts.

The CO continued to rush, pushing his crew and truncating recommended steps for safe operation. While at periscope depth, he interrupted the OOD-2's periscope sweep and took over operating the periscope, executing only a few brief sweeps in the general area where he believed the sonar contacts to be. The CO then ordered the submarine to a shallower depth (from 60 feet to 58 feet), raising the periscope 2 feet for a greater height of eye. On this day, the seas were choppy, 3 to 4 feet; the sky was not clear. The CO either failed to recognize the need to compensate more for the choppy seas and the haze or simply did not do so. He did not order the submarine to a shallower depth for a significantly better height of eye and he did not execute a slower, more deliberate sweep to ensure that no vessels were obscured by the haze. Once again, he did not use his crew resources and solicit the feedback or assistance necessary for safety. Normally during the CO's periscope sweep, the FTOW would assist him in putting the periscope on the precise bearings of the sonar contacts, a standard procedure that improves the probability of detection. On this day, the CO did not ask for assistance, and the periscope was not centered on the contacts' bearings.

The crew's behavior immediately preceding the collision suggests that their errors were strongly influenced by the CO's announcement about the contact picture. In effect, the CO's flawed situational awareness regarding the proximity of vessels at the surface reinforced and influenced the watchstanders' own limited situational awareness. The CO was well regarded by his crewmembers, as evidenced by, among other things, the *Greeneville*'s high retention rate, but his popularity may have worked against optimal crew performance. That is, because of his rank and the respect among the crew that he commanded, his crew appeared to have acted as though they believed that if the CO thought the surface was clear, it was.

The two-way communication necessary for effective bridge resource management[42] was not evident on the *Greeneville.* The COMSUBPAC Deputy Chief of Staff for tactics and training told Safety Board investigators,

> The watchstanders had sort of an inherent trust in their commanding officer; they didn't speak up when they should have. [They believed that] . . . if the captain thinks it's okay to go up, who am I to stand in front of him and tell him it's not right, and they kind of just rolled on the captain's decision to go up.

If crewmembers disagreed with the CO's assessment, none spoke up to provide him essential feedback, particularly in the presence of the visitors. Every *Greeneville* crewmember interviewed later by the Navy or by the Safety Board stated that he never doubted the assessment of the CO. After the collision, neither the sonar supervisor nor the FTOW believed that the submarine had struck a contact that they were tracking.

Emergency Surfacing Maneuver Toward Contacts

After his brief periscope sweep, the CO ordered an emergency deep dive. During the submarine's descent, he ordered a course change to 340°. Recorded data indicate a left turn during the dive, consistent with this command. He then announced an EMBT blow, an evolution that he had told the navigator he was going to cancel but later said that he decided to order on the spot for training purposes. Again, the CO's actions demonstrate that he continued to fail to employ ORM during the conduct of this cruise. Navy trainers told Safety Board investigators that the operating instructions pertaining to EMBT blows are classified. They stressed, however, that before executing such an emergency surfacing maneuver, COs should do "additional risk management" to ensure that the watchstanders have good information and existing conditions have been identified.

In the case of the *Greeneville* CO, he took a series of procedural shortcuts rather than perform ORM before executing the EMBT blow. He did not establish effective measures for monitoring the sonar contacts. He did not ensure that effective TMA had been accomplished. He abandoned or truncated measures designed to promote safety redundancy in operations, including his proper oversight role of the conning officer and his conduct of the second periscope sweep. He did not use his crew resources effectively to ensure that he obtained good feedback about the operating environment.

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[42] Bridge resource management, or BRM, is an operational mechanism for ensuring the safe completion of a vessel's voyage. The Coast Guard requires that operators of certain vessels, such as tankers, employ BRM, and the International Maritime Organization recommends that training for seafarer certification include BRM. (See *International Convention of Standards of Training, Certification and Watchkeeping for Seafarers, 1978,* as amended in 1995.)

The CO's actions after ordering the EMBT blow indicate that he added the emergency evolution for the benefit of the civilian visitors. For the evolution, he paid particular attention to ensuring that the civilian visitors were involved in it. He personally assigned one civilian to sit at the helm controls and allowed another to operate the levers at the high-pressure air controls, albeit under the supervision of experienced crewmembers. He then narrated what was happening during the submarine's ascent for the information of the passengers.

The EMBT blow maneuver requires that a vessel's rudder be centered. Recorded data show that as the EMBT blow maneuver began, the vessel's turn rate slowed, consistent with a rudder centering. At the beginning of the EMBT blow, the submarine's heading was 025°. Thus, the CO's conning order was a serious error that resulted in the submarine pointing in the direction not only of S-13, bearing 018°, but also S-14, bearing about 358°.

As the *Greeneville* rose at a high speed, its heading continued to change slowly and was at 018° when the *Greeneville* struck the *Ehime Maru*, slicing open the bottom of the fishing vessel's hull.

Management of Civilian Visitors

In this case, the civilian visitors did not directly cause the accident; however, their presence on the submarine and the manner in which they were accommodated by the crew, especially the CO, had an adverse impact on the safety of operations.

The *Greeneville* cruise on February 9 was conducted contrary to COMSUBPAC instructions, which stipulated that distinguished visitor embarkations "must be scheduled and conducted within the framework of otherwise planned underway operations, and should not be conducted solely to accommodate civilian guests." The *Greeneville* had been scheduled to begin an underway for testing on February 9, and the civilian guests had been scheduled to ride the submarine during the first day of that underway. However, at the suggestion of the *Greeneville* CO, COMSUBPAC had delayed the start date for the test voyage until February 12 and had granted the *Greeneville* CO permission to take the civilian visitors on a 1-day voyage on February 9.

The unintended effect of permitting such a cruise was that the crew did not demonstrate the attention to detail that they reportedly had exhibited during previous underways and training exercises. They either adopted a somewhat informal attitude toward their duties or concentrated on accommodating the visitors to the detriment of their work.

In the findings from the Navy's court of inquiry, officials found fault with the senior crew's preparation of the watchbill for the visitor cruise. The Safety Board considered whether the poorly prepared watchbill and the crew's subsequent switching of watch assignments were factors in the accident and found that in all but one case, key watch stations were manned by qualified crewmembers. Only sonar lacked a required watchstander: an over-instructor to monitor the qualifying technician. Considering that the *Greeneville* rarely held more than three contacts, the sonar supervisor could have easily monitored the qualifying technician. However, he could not properly oversee the qualifying technician and efficiently perform his own duties while accommodating the civilian visitors. As evidence of this, he forgot to reset the sonar recorder after playing sound tapes for the enjoyment of the visitors. He also either did not observe the visitors distracting his crew or did nothing to prevent it once the demanding evolutions began.

According to an off-duty sonar technician, when he returned to the sonar room about the time of the angles and dangles, several civilian guests were in the sonar room, in addition to the sonar supervisor, the broadband stack operator, and the workload share stack operator. He said that he noticed that the sonar supervisor and the sonar technicians were trying to talk to each other and the guests at the same time. The off-watch sonar technician said that the sonar operator at the broadband stack appeared not to be distracted by questions from the guests. The unqualified workload share stack operator, however, was trying to answer the visitors' questions. At one point, the workload share stack operator started to turn away from the display to talk with the guests, but the off-watch technician indicated to him that he should watch the display. The off-watch sonar technician said that he then asked the visitors to leave the sonar room. While it is commendable that the off-watch sonar technician took action to improve the operating environment for the sonar crew, the sonar supervisor should have recognized the distraction that the visitors might pose to the watchstanders and asked the civilians to leave the sonar room before the evolutions began.

Interaction with the guests created scheduling problems and changed the operational dynamic in the control room. The *Greeneville*'s activities for the visitor cruise, as listed on the plan of the day, remained reasonably on schedule until first the CO and then the XO each hosted a civilian group at lunch for an hour instead of the time allotted. The CO testified at the court of inquiry and later told Safety Board investigators that he realized that the submarine would be late returning to P/H because of the delay caused by the long lunches; however, he said that he did not rush the conduct of the evolutions to try and return the visitors on time. He indicated that if he had felt rushed, he would not have continued to sign souvenir photographs in his stateroom, but would have gone into the control room sooner to begin the evolutions. In his 2003 autobiography,[43] however, he indicated that his rushed actions during the evolutions were driven by his knowledge that the civilian visitors needed to be back at Pearl Harbor by a given time for a later appointment.

In the control room, the CO's management of and interaction with the visitors created both physical and communication barriers for his subordinates. After he advised the civilians where to stand for the best vantage point of the upcoming evolutions, six to eight visitors stood on the starboard side of the periscope platform, blocking the FTOW's ready access to the CEP, which the FTOW was required by standing order to annotate to provide the conning officer with a display of the submarine's position relative to the position of known vessel contacts. The FTOW said that he stopped maintaining the CEP

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[43] S. Waddle and K. Abraham, *The Right Thing* (Nashville: Integrity Press, 2003).

because of the presence of the visitors. Given that the visitors also blocked the conning officer's view of the CEP, the FTOW's failure to perform this watch task did not affect the outcome of this accident because neither the OOD-2 nor the CO attempted to review the chart.

Some of the civilians stood in front of two fire control system displays that the OOD-2 used to monitor the contact situation. The OOD-2 later told Safety Board investigators, "I didn't have free access all the way over there."

Although the civilians impeded their work, neither the OOD-2 nor the FTOW asked them to move or told the CO that the visitors were adversely affecting operations. The CO was focused on directing the activities for the civilians rather than managing the civilians to ensure that they did not interfere with the watchstanders' execution of their duties. As a result, the FTOW was reluctant to speak up and interrupt him. Thus, the activities for the civilian visitors stymied communication and prevented the conn from receiving necessary feedback from the crew.

As a result of the Navy's court of inquiry, in August 2003, COMSUBPAC issued new procedural requirements (COMSUBPACINST 5720.1) for handling in-port public visits and embarkations on Pacific Fleet submarines. The COMSUBPAC instructions include provisions designed to ensure not only that visitors remain safe but also that crew operations are not compromised during a civilian embarkation. The crewmembers assigned to oversee the civilian visitors while they are on the submarine must be listed as escorts on the watchbill and they cannot be assigned to a workstation. The CO or his agents are to review the itinerary developed for the visitors for areas of "conflict," for example, areas where overcrowding might occur when all or several civilians are present.

Recommended procedures include conducting the initial visitor briefing in the mess facility during the outbound transit so that the piloting party can function without distraction. To ensure that the control room is not overcrowded during evolutions, the instructions recommend that the plan of the day include two surface and dive evolutions, so that a visitor group can be divided and fewer civilians permitted in the control room at one time. To ensure that the crew is not distracted while making preparations to go to periscope depth, the instructions recommend that the visitors be taken to the mess facilities, where they can watch a movie or a monitor linked to the PERIVIS.

In addition to revising procedures directly related to visitor cruises, the Navy made changes in squadron oversight designed to address safety deficiencies that the Safety Board also noted in its investigation. For several reasons, the *Greeneville* was not subject to the type of oversight that should have revealed shortcomings in the crew's adherence to Navy operating procedures. Factors affecting squadron oversight included removal of the *Greeneville* from the regular deployment rotation when it was equipped with an Advanced SEAL Delivery System, realignment of the squadron and the resulting reduction in oversight personnel, and demands on the newly appointed squadron commander who was given the priority to prepare another submarine for deployment.

The development and implementation of effective operating procedures for all phases of operations is a prerequisite for the safe operation of any vessel, military or civilian. Operating procedures in and of themselves, however, are insufficient to ensure safety unless they are accompanied by systematic oversight of their use by crewmembers or workers in regular operations. Effective oversight provides information not only about how individuals use or comply with operating procedures but also about whether the procedures, as written or established, are effective in an actual operating environment.

As a result of the *Greeneville* accident, the Navy changed its method of evaluating submarines, regardless of their deployment cycles. The squadrons now employ a multistep evaluation process that includes, among other reviews and tests, a basic evaluation of the submarine crewmembers to determine their fundamental understanding of their jobs and responsibilities; identification of procedural problem areas or weaknesses and follow-up monitoring by squadron officials; and a second formal review to check a ship's readiness to deploy.

The changes in squadron oversight procedures as well as the new requirements for distinguished visitor cruises demonstrate that the Navy has recognized the detrimental operating conditions that existed on board the *Greeneville* and has taken additional measures to address the safety of operations on board its submarines. Accordingly, no further action is warranted.

Survivability of the Ehime Maru

The design of the *Ehime Maru* was typical for a ship of that size and service. In addition to meeting industry standards for strength, the ship was fitted with transverse bulkheads and a double bottom in the engineroom to provide a measure of flotation and stability in the event of moderate damage from collision or grounding. This is typical of modern ship design, and the standards reflect historical experience with damages and international consensus on a reasonable degree of protection that should be provided. The damage sustained by the *Ehime Maru* far exceeded the criteria used for design, and the simultaneous flooding of several watertight compartments immediately doomed the ship. The damage scenario is so unusual and extensive that it is considered impractical to modify the basis of watertight design for ships of this size. Accordingly, this accident does not constitute a reason for review or revision of international standards of subdivision and damage stability.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the collision of the USS *Greeneville* with the Japanese fisheries training vessel *Ehime Maru* was the inadequate interaction and communication among senior members of the combat systems team (the commanding officer, the officer of the deck, the fire control technician, and the sonar supervisor), which resulted in the failure to perform adequate contact analysis and adhere to proper procedures for moving to periscope depth; and the commanding officer's decision to order an emergency surfacing maneuver. Contributing to the cause of the accident was the failure of the crew, in particular the commanding officer, to adequately manage the civilian visitors so that they did not impede operations. Contributing to the loss of life was the rapid flooding and sinking of the *Ehime Maru*, which occurred when the submarine's rudder tore through the fishing vessel's lower deck spaces.

Adopted: September 29, 2005

Appendix A

Investigation

The National Transportation Safety Board learned of the *Greeneville/Ehime Maru* accident at 2118 on February 9, 2001, from news media reports. The Safety Board initially launched a five-person investigative team from the Office of Marine Safety, including the chief of the technical services division, an investigator-in-charge, an engineering specialist, a human performance specialist, and a survival factors specialist. A Board Member and representatives from the Safety Board's Office of Government, Public, and Family Affairs joined the team, and the group arrived in Honolulu about 1545 on Saturday, February 10, 2001. A naval architect and an aircraft structures specialist who was proficient in underwater recovery efforts subsequently joined the team. The naval architect documented the damage to the vessels, and the recovery specialist served as liaison to the Navy salvers.

The Safety Board investigated the accident under the authority of the Independent Safety Board Act of 1974, as amended, according to the Safety Board's rules. Team members interviewed the survivors of the *Ehime Maru* between February 11 and 13, 2001. The team also interviewed Coast Guard personnel involved in the search and rescue, emergency medical services officials, the American Red Cross supervisor, and the harbor pilot who took the *Ehime Maru* out of Honolulu. The Safety Board began interviewing crewmembers of the *Greeneville* on February 13, 2001. However, at the time, the CO, the XO, and the OOD-2 declined to assist in the Safety Board's accident investigation. These three officers were eventually interviewed by Safety Board investigators, as indicated below:

- September 2001—the OOD-2
- November 2001—the XO
- March 2002—the CO

The Safety Board also interviewed the commanders of Squadrons 1, 3, and 7, the instructor of the prospective commanding officers course, and the COMSUBPAC Deputy Chief of Staff for tactics and training in March 2002, and the former COMSUBPAC in May 2002.

The designated parties to the Safety Board's investigation were the U.S. Navy, the U.S. Coast Guard, and Ehime Prefecture, Japan, owner of the *Ehime Maru*.

Appendix B

Abbreviations and Acronyms

AVSDU	Analog-Video Signal Display Unit
CEP	contact evaluation plot
CO	commanding officer
COMSUBPAC	Commander, U.S. Submarine Force, Pacific (also command office for U.S. Submarine Force, Pacific)
EMBT	emergency main ballast tank
EPIRB	emergency position indicating radio beacon
ESM	electronic support measures
FAA	Federal Aviation Administration
FTOW	fire control technician of the watch
MHz	megahertz
OOD	officer of the deck (Note: in this report, the OOD of the second underway watch is referred to as the OOD-2)
OP	operations procedure
OPNAVINST	Chief of Naval Operations instruction
OPORD	operations order
ORM	operational risk management
PERIVIS	periscope video system
P/H	"Poppa/Hotel," the unmarked seaward entrance to Pearl Harbor
RHIB	rigid hull inflatable boat
SECNAVINST	Secretary of the Navy instruction
SLOGGER	sonar data logger
SNR	signal-to-noise ratio
SOLAS	International Convention for the Safety of Life at Sea
TMA	target motion analysis
UTC	Universal Coordinated Time
XO	executive officer

Appendix C

Chronology of Events, February 9, 2001

Accident Events

Time	Activity
Pre-0500	Fire control officer of the watch (FTOW) checks fire control equipment in control room and finds that everything operates correctly.
Pre-0700	Navigator reports to commanding officer (CO) that the control room's Analog-Video Signal Display Unit (AVSDU), which provides a backup display of sonar data, is inoperative.
0730	CO greets 16 distinguished visitors at dockside as they board the *Greeneville* at Pearl Harbor. The distinguished visitors are assembled in the crews' mess, where they are given a brief presentation, including a slide show, about the submarine. They are broken into two groups for tours of the vessel.
0757	*Greeneville* departs berth.
0933	Navigator assumes watch as officer of the deck (OOD).
1017	*Greeneville* submerges.
1045	CO joins first group of distinguished visitors for lunch at first seating, which is from 1045 to 1145.
1054	Deep dive.
1103-1131	Dive to classified depth.
1130	Underway watch change scheduled. FTOW assumes watch at fire control console. Sonar supervisor assumes watch in sonar room.
1143	Main propulsion assistant assumes watch as officer of the deck (OOD-2) in the control room.
1145	Executive officer (XO) joins second group of distinguished visitors for lunch at second seating, which is from 1145 to 1245.
1200	Sonar supervisor, in preparation for planned maneuvers, checks sonar stack for loose gear. *Ehime Maru* departs Honolulu.
1207	OOD orders course change to north (000°).
1228:59	Sonar begins tracking contact Sierra 12 (S-12).
1231:59	Sonar begins tracking contact S-13, bearing 358° (the *Ehime Maru*).
1232:59	Fire control system automatically generates first solution for S-13.
1240	OOD-2 orders baffle clear.
1242:15	*Greeneville* changes course to 240°, and sonar drops tracks on both S-12 and S-13 when they enter the baffle area.

Time	Activity	
1245	*Greeneville* resumes northerly course.	
1257	*Ehime Maru* completes stowing anchor and increases speed to 11 knots.	
1306+/-	XO advises CO that ship needs to start maneuver demonstrations if submarine is to meet the distinguished visitors' scheduled return time to Pearl Harbor.	
1310+/-	Visitors enter control room; CO goes into sonar room to assay contact picture. Observes two contacts (S-12 and S-13) to the north and northwest.	
1314	CO enters control room and talks with visitors, advising them of the best locations to observe the submarine's maneuvers.	
1315	*Greeneville* increases speed to 14 knots and begins angle maneuvers ranging in depth from 150 to 650 feet.	
1315-1324	Sonar supervisor and sonar operators, while attempting to track targets, interact with five visitors who enter the sonar room.	
1324+/-	Sonar technician who returns to get his jacket asks visitors to leave the sonar room before *Greeneville* begins rudder maneuvers, or high-speed turns.	
1325	CO directs OOD-2 to order the following turns during the high-speed maneuvers: *Greeneville* to turn right from a course of 000° right to 140°.	
1326:27	*Greeneville* is steady on 140°.	Time steady on course until next turn: 16 sec.
1326:43	*Greeneville* to turn left to 340°.	--
1328:04	*Greeneville* is steady on 340°.	Time steady on course: 23 sec.
1328:27	*Greeneville* to turn right to 120°.	--
1329:47	*Greeneville* is steady on 120°.	Time steady on course: 23 sec.
1330:42	*Greeneville* completes high-speed maneuvers and comes left to 340°.	
1331+/-	CO directs OOD-2 to prepare to go to periscope depth and to be there within 5 minutes.	
1332	CO goes into sonar a second time to determine contact picture; watches as sonar regains S-12 at 1332:03 and S-13 at 1332:48.	
1332:54	*Greeneville* arrives at 150 feet from a depth of 400 feet.	Total time above layer depth[a] is 91 seconds.
1333	CO returns to control room; directs OOD-2 to order a baffle clear to course 120°.	
1333:03	Sonar begins tracking S-14.	
1334:48	Tracking solution entered for S-14; S-12 fades.	
1335	Baffle clear complete. OOD-2 orders sonar to report all contacts; sonar reports S-13 and S-14.	
1336	CO announces that he has "good feel" for contact picture (later stated that he thought the contacts were S-12 and S-13).	

Time	Activity	
1336:45	CO orders ship to periscope depth (60 feet).	
1337:48	As submarine ascends, fire control solution is updated, indicating S-13 (the *Ehime Maru*) is within 4,000 yards.	
1338	Submarine periscope breaks surface of water.	
1339	OOD-2 conducts three rapid 360° periscope sweeps and reports “No close contacts.” Under-instruction operator in ESM room reports “No close contacts” to the conn.	
1339:04	CO takes periscope from OOD-2 and orders the ship to 58 feet.	
1339:30	CO conducts periscope search in the direction where he believes S-12 and S-13 to be.	
1340+/-	CO orders emergency deep.	Total time at periscope depth: 66 sec.
1340	S-14 fades.	
1340+	As submarine begins to descend, CO asks quartermaster the course to P/H. Quartermaster responds 340°, and CO orders turn to 340°.	
1340:34	Submarine starts to come left from 121° to 340°.	
1342:25	*Greeneville* initiates EMBT.	
1343:15	*Greeneville* collides with *Ehime Maru.* (Approximate heading of submarine is 018°.)	

[a]Layer depth is the depth from the surface of the sea to the point above the first major negative thermocline (area of rapid decrease in water temperature) at which sound velocity is maximum.

Search-and-Rescue Events

Time	Event
1343	Collision occurs.
1348	*Ehime Maru* sinks.
1348	*Greeneville* bridge manned.
1348	*Greeneville* radios report of collision to COMSUBPAC.
1355	COMSUBPAC reports collision to Coast Guard Group–Honolulu.
1356	Coast Guard Group–Honolulu diverts helicopter No. 6570 from patrol to scene.
1358	Group–Honolulu directs Coast Guard Station–Honolulu to launch rescue assets.
1400	Station–Honolulu dispatches rigid hull inflatable boat (RHIB) and a patrol boat to scene.
1400	Joint Rescue Coordination Center receives signal from *Ehime Maru*'s EPIRB.
1404	Joint Rescue Coordination Center identifies vessel as *Ehime Maru*.
1406	Joint Rescue Coordination Center contacts Coast Guard Group–Honolulu to investigate.
1420	COMSUBPAC calls Joint Rescue Coordination Center.
1427	Coast Guard helicopter No. 6570 arrives on scene.
1431	Coast Guard RHIB arrives on scene.
1444	Coast Guard patrol boat arrives on scene.
1445	Coast Guard helicopter No. 6570 transfers its rescue swimmer to patrol boat.
1445	COMSUBPAC sorties two torpedo retriever boats, *Hawthorne 5* and *Hawthorne 8*.
1446	Coast Guard helicopter No. 6570 begins area search.
1451	Coast Guard diverts C-130 aircraft from training to scene.
1505	Joint Rescue Coordination Center assumes control of search-and-rescue mission.
1524	Coast Guard C-130 plane arrives and assumes on-scene command.
1538	Coast Guard RHIB and patrol boat depart scene with 26 survivors.
1615	Rescue vessels arrive at Coast Guard Station–Honolulu.
NOTE: Search for missing crewmembers continued between February 9 and March 2. *Ehime Maru* was located on the seafloor in 2,000 feet of water on February 16.	