National Transportation Safety Board
Office of Marine Safety

Group Chairman's Factual Report

Engineering and Operations

Accident Number: DCA-01-MM-022

6/28/2002

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A. ACCIDENT

Accident No.:	DCA01MM022
Vessels Involved:	USS *GREENEVILLE* & M/V *EHIME MARU*
Location:	About 9 miles south of Oahu, Hawaii
Date:	February 9, 2001
Time:	1343 HST[1]

B. Operations and Engineering Group Representatives

1) Thomas K. Roth-Roffy
Operations and Engineering Group Chairman
National Transportation Safety Board
Office of Marine Safety (MS-30)
490 L'Enfant Plaza East
Washington, D.C. 20594

2) Party: U.S. Coast Guard
LT Charlie Johnson, USCG
Investigator
USCG Marine Safety Office Honolulu
433 Ala Moana Blvd
Honolulu, HI 96813

LTJG Ken Kusano, USCG
Investigator, USCG
Marine Safety Office Honolulu
433 Ala Moana Blvd
Honolulu, HI 96813

3) Party: US Navy
CDR John D. Caccivio, Jr., USN
Force Training Officer
COMSUBPAC (N-74)
1430 Morton Street, Bldg 619
Pearl Harbor, HI 96860-4664

LCDR Rich Santomauro, USN
COMSUBPAC Code 452
Force EMO

LT Doug Hedrick, USN
SUBPAC Special Projects Officer
COMSUBPAC (N-32)
100 Morton St, Bldg 619
Pearl Harbor, HI 96860-6543

[1] All times are in Hawaiian Standard Time as read on a 24-hour clock, unless specifically noted.

4) Parties: Owner/operator and Japanese government

No representative assigned to group

C. Summary

On February 9, 2001, at 1343 local time, the USS Greenville, (SSN 772), a Los Angeles class nuclear-powered attack submarine, collided with the Japanese Motor Vessel, Ehime Maru, about 9 miles south of Oahu, Hawaii. The Ehime Maru, whose mission was teaching Japanese high school students the fishing trade, was traveling at 11 knots, on a course of 166°, en route to a fishing area. The Greenville was engaged in a distinguished visitor cruise, a Navy program Navy that invites civilians to observe actual operations aboard its vessels. The Greenville struck the Ehime Maru as it completed an emergency surfacing maneuver from a depth of about 400 feet. The Ehime Maru was damaged and sank as a result of the collision, and 9 of the 35 people on board were missing and are presumed to have been killed in the accident. During subsequent salvage operations, the bodies of 8 of the 9 missing persons were recovered. The Greenville was slightly damaged and was able to return to Pearl Harbor under its own power. There were no injuries to any of the persons on board.

D. Details of the Investigation

Ehime Maru

Vessel description and condition

According to officials that oversaw the operation of the vessel,[2] the mission of the vessel was fisheries and engineering training to vocational high school students. The high school is located in Uwajima City, Ehime Prefecture, Japan. The school is a 3-year vocational program with an enrollment of about 200 students. The homeport of the vessel was Misaki, Japan, and it made three voyages per year. Each voyage was about 74 days in length, and the voyages were normally to the north and south sides of Hawaii. The vessel normally entered the port of Honolulu during its mid-voyage break, three times each year. The vessel was capable of carrying 20 crew, 2 teachers and 45 students. The vessel had a Third Class Fishing vessel registration for international voyages. Neither the school nor prefecture performed safety inspections on the vessels. The school officials stated that the national government performed safety inspections, visiting the Ehime after each voyage. The school and prefecture advised on vessel design and modifications. The prefecture funded the vessel's construction and operation and received the income from fishing operations. (See Ehime Maru photos)

According to statements by the captain of the Ehime Maru, the air conditioning system was inoperative when the vessel arrived in Hawaii and that it was repaired before departure from Honolulu. The vessel had no significant engineering deficiencies when it departed Honolulu on the day of the accident.

According to the master of the *Ehime Maru*, before the time of the accident,

> … the radar was rotating and pilot was automatic. The range of vision was good. There was no outline of a ship nearby on the radar. It was past 13:30. It is not clear, but we encountered impact

[2] NTSB interview with Mr. Horita, Principal of the Ehime Prefecture Uwajima Fisheries High School, Ietaka Hotta, and Mr. Takahama, Deputy Superintendent of the Ehime Prefecture Board of Education, on February 13, 2001, at the Ocean Resort Hotel, Waikiki, HI.

and fierce noise as if the tail of the ship was lifted up. There were those two times. There was no ship at all nearby, and I could not judge quickly what impact it was.[3]

Ehime Maru schedule. According to the master of the *Ehime Maru*, the vessel departed Japan on Jan 10, 2001 and arrived in Honolulu on Feb 7, 2001. The Ehime Maru departed Honolulu, pier 9, at 12 o'clock, and was bound for N14, W156. Departure drafts were 2.62 m forward and 4.88 m aft. The vessel was scheduled to arrive at the fishing grounds on the February 11, 2001, and after 30 days, they intended to proceed to Japan, scheduled to arrive there on March 23, 2001.[4]

Vessel Data

Name of vessel	*M/V Ehime Maru*
Port of Registry	Matsuyama City, Ehime Prefecture
Nationality	Japan
Service	Fishing and training
IRCS (call sign)	JCQS
MSIS No.	L8114390
Owner	Ehime Prefecture
Operator	Uwajima Fisheries High School
COFR Applicant	Ehime Prefectural Government, issued 7Sep99
Date Commissioned	June 26, 1996
Builder	Shin Kurishima Dock, Japan
Propulsion system	Single screw, medium speed diesel, gear reduction
Main Engines	Manufacturer: Akasaka, Model: E28BFD 1800PS X 450/215RPM, Akasaka web site: http://www.jsmea.or.jp/kaiin-e/akasaka/indexE.html
Reduction gear	2.09 to 1 reduction ratio
Propeller	4 blade, high skew, variable pitch, CPR65A80VCN 2900
Diesel Generators	Prime Mover: S165L-EN600PS X 450/215 RPM, Generator: TWY38CS6S 500KVA X AC 450
Bow Thruster	Variable pitch propeller, Model: CPR65A80VCN 2900
Emergency Diesel Generator	Yes
Length (LOA)	58.18 m
Length (LBP)	50.0 m
Depth	3.90 m
Beam	9.30 m
Draft	3.50 m
Gross tonnage	741

[3] NTSB interview with *Ehime Maru* master, conducted on Feb 11, 2001.
[4] Interview with *Ehime Maru* master, conducted on Feb 11, 2001.

Displacement at LWL Draft	499 Ton
Fuel Capacity	341 m^3
Lube oil capacity	12 m^3
Crew Size	Complement: 67 total (students 45, instructor 2, crew 20)
Service Speed	Cruise: 12.5 Knots, Max: 15.05 Knots

Equipment descriptions

Radar

1. The vessel was fitted with two identical radar sets with the following specifications
   Manufacturer: Tokimec, Inc (Japan)
   Operating frequency: 9375 MHZ (X-band)
   Model: BR-3440MA-X59
   Output power: 50 KW
   Manufacturer's web page: http://www.tokimec.co.jp/marine/e/br3440.htm

   Radar signal repetition frequency and pulse width:

	Range scale (nm)	Repetition frequency (Hz)	Pulse width (µs)
Repetition frequency and pulse width	0.125 ~ 0.5	3200	0.06
	0.75 ~ 1.5	3200	0.15
	3	1600	0.3
	6 ~12	1600	0.5
	24 ~96	800	1.0

2. Regarding the question of whether or not the radar was in operation at the time of the accident, the following information is relevant.
   a. <u>Statement of the captain of the *Ehime Maru*</u>. During his interview with the NTSB and in testimony before the USN Court of Inquiry,[5] the captain stated that one (of two) radars was turned-on about 30 minutes before getting underway, and remained on until the time of the collision. The range scale was stepped-up from 1.5 NM to 12 NM miles during maneuvering out of the harbor. When the vessel was in the vicinity of H buoy, the radar was set on the 12 NM scale and remained on that setting until the time of the collision.
   b. <u>Statement of the Harbor Pilot</u>. In a telephone interview with the NTSB, the pilot who directed the *Ehime Maru* from the pier to the sea buoy stated that the radar was energized during the time that he was on the bridge.
   c. <u>Findings from USN salvage operation</u>. OMS is waiting for delivery of diver's report from the USN on status of radar console switches.

[5] US Navy Court of Inquiry transcript, p. 1040.

USS Greeneville (SSN 772):

Engineering

The Greeneville was a fast attack nuclear-powered submarine of the Los Angeles class, and was the next to the last vessel constructed in the class. The U.S. Navy's fast attack submarines were designed to seek and destroy enemy submarines and surface ships. Other missions include surveillance and intelligence collection, mine laying, special forces delivery, anti-ship and land strike warfare, and open ocean anti-submarine warfare. In addition to operating independently, they are often assigned as escorts to carrier battle groups and joint task forces. Fast attack submarines have design features that provide stealth and unlimited endurance allowing them to maneuver undetected, even in sensitive forward areas.

The navy lists the following as missions of submarines:[6]

- Sea Control (denying the ocean to hostile naval forces through anti-submarine and anti-surface warfare)
- Anti-Submarine Warfare (detecting and destroying hostile submarines)
- Anti-Surface Warfare (detecting and destroying hostile surface ships)
- Strategic Deterrence (the capability to rapidly launch retaliatory strikes against any nation attacking the United States with nuclear weapons)
- Landing Special Operations Forces (performing covert infiltration of hostile regions by commando forces)
- Search and Rescue (rescuing aviators shot down over the ocean or special operations forces stranded near the ocean)
- Intelligence, Surveillance, and Reconnaissance (listening for hostile actions, electronic communications and information)
- Battle Group Support (providing intelligence and undersea protection for aircraft carriers and their escort ships)
- Mine Warfare (laying minefields to deny ocean areas to hostile forces)
- Cruise Missile Strike Capability (striking ground-based inland targets with conventional-warhead cruise missiles)
- Transportation of personnel and cargo (covertly moving critical forces and supplies)

The Los Angeles class fast attack submarines were built by either of two shipyards (Newport News Shipbuilding Co. or General Dynamics Electric Boat Division) in three variants:

- SSN 688 through SSN 718 – the original Los Angeles class
- SSN 719 through SSN750 - starting with SSN 719 and beyond, the last 31 hulls of the class have 12 vertical launch tubes for the Tomahawk cruise missile, along with an upgraded reactor core.
- SSN 751 through SSN 773 - The final 23 hulls (SSN 751 and later) are referred to as "688I" (for Improved). These vessels are quieter, incorporate an advanced BSY-1 sonar suite combat system, and have the ability to lay mines from their torpedo tubes. They were configured for under-ice operations in that their forward diving planes were moved from the sail structure to the bow, and the sail and rudder were strengthened for breaking through ice. The 688Is also have twelve vertical launch tubes for Tomahawk cruise missiles in addition to the 4 forward torpedo tubes.

[6] From http://www.chinfo.navy.mil/navpalib/cno/n87/faq.html

Around the time of the accident, the U.S. Navy operated 55 fast attack submarines: twenty-eight fast attack submarines were assigned to the Atlantic Submarine Force and twenty-seven fast attack submarines were assigned to the Pacific Submarine Force. These submarines can carry 25 torpedo tube launched weapons - MK 48 torpedoes and Tomahawk cruise missiles.

Vessel Data

Name of vessel	*USS Greeneville (SSN 772)*
Port of Registry	Homeport: Honolulu, HI
Nationality	US
Service	Submerged Warship
Owner	United States of America
Operator	U.S. Navy
Date keel laid	April 16, 1992
Date launched	September 18, 1994, Sponsored by Mrs. Albert Gore
Date commissioned	February 16, 1996
Builder	Newport News Shipbuilding
Propulsion system	Nuclear reactor, steam turbine
Main Engines	Nuclear: 1 GE PWR (pressurized water reactor) S6G; 2 turbines; 35,000 hp, 1 shaft; 1 magnetek auxiliary propulsion motor (SPM secondary propulsion motor), 325 hp
Reduction gear	2 pinion input, single output to propulsion shaft
Length overall	362 ft
Beam	33 ft
Depth	32.3 ft
Displacement, tons	6330 t (surfaced) and 7177 t (submerged)
Crew Size (nominal)	133, 13 officers
Service Speed	25 knots surfaced, 25+ knots, dived (unclas)
Diving depth	800 feet (unclas)
Passenger capacity	Unknown
Combat Systems	AN/BPS-15 A/16 navigation and fire control radar AN/BPS-5H - COTS surface search radar (Furuno) TB-16D passive towed sonar array (subsystem of BQQ-5) TB-23 passive "thin line" towed array (subsystem of BQQ-5) AN/BQG-5D wide aperture flank array AN/BSY-1 spherical bow array AN/BQS-15 close range active sonar (for ice detection) MIDAS Mine and Ice Detection Avoidance System A/N BQR-22 – sonar spectrum analyzer SADS-TG active detection sonar Type 2 attack periscope (port) Type 18 search periscope (starboard) AN/BSY-1 (primary computer);

UYK-7; UYK-43; UYK-44
WLR-9 Acoustic Intercept Receiver
WLR-8(V)2 ESM receiver
APX-72 IFF (transponder only)
Link 11 Tactical data link
OTCIXS Tactical data link

System and Equipment Descriptions

Sensors. The Greeneville was equipped with four primary, independent sensor systems for detecting and tracking surface and subsurface contacts. These four systems were the sonar system, periscope system, and the electronic support measures (ESM) system, and the radar system. During the hour before the accident, the first three sensor systems were employed and the radar system was not employed.

Sonar and fire control

Sonar and fire control. The primary system for detecting and tracking contacts was the sonar system. The sonar system could be operated in either a passive or an active mode. In the passive mode, the system was able to detect acoustic signals over a wide range of acoustic frequencies (broadband and narrowband) and at great distances (often in excess of 10 miles). On the day of the accident the sonar system was operated only in the passive mode.

The ship was fitted with two towed-array sonar systems, but they were not in use before the accident. The towed array cables consisted of acoustic sensors towed behind the vessel at a distance of several thousand feet. Because of the risk of being damaged by the ship's propeller, the towed array sonar system was not deployed during maneuvering operations involving rapid changes in the vessel's heading or pitch angles.

In the active mode the sonar system would emit an acoustic signal and then detect any acoustic energy that was returned. The Greeneville had two separate active sonar systems. The first was incorporated into the main spherical array system located in the bow of the submarine, and it operated in the medium frequency (MF) range. The MF spherical array system was powerful and could detect contacts at long ranges. The second system used operated in the high frequency (HF) range, and its transducers were located on the sail of the submarine. The HF system had a higher resolution and less range, and was intended for detecting ice and floating mines.[7] Although the active sonar system could have been used to detect surface contacts on the day of the accident, according to a navy witness, it was of limited usefulness. The factors cited that limit the utility of active sonar were:[8]

- The need to understand the environment and to set the sonar variability and then to optimize select pre-selected parameters on the active sonar to make use of that understanding of the environment. Understanding the environment is a very challenging task on a submarine because of its temporal and spatial variability.
- The difficulty in interpreting the sonar display. Active sonar, by its nature, returns a great deal of false positive returns. False positive returns are indication of a contact that are actually not, such as biologics, returns from non-solid objects, ray tracing though the water column interruption with the surface picture, waves, swells, distortion caused by the bottom and boundary conditions in the water column.

[7] Testimony of RADM Griffiths during U.S. Navy Court of Inquiry, p. 119-120.
[8] Testimony of RADM Griffiths during U.S. Navy Court of Inquiry, p. 120-121.

- Inability to effectively listen with the passive sonar when the active sonar is in use. Both the aural response of the human operator will have and the visual displays of the sonar system are interrupted by active transmissions from own ship.

The same witness further stated that the passive sonar system was orders of magnitude more effective than any other sensor system available for use in preparing to go to periscope depth:

> [the best sensor is] the passive sonar suite, the main frame passive sonar suite in the *Greeneville's* case. The BSY-1 sonar and its sphere is the best system they have. Over the long haul, orders of magnitude more effective than any other sonar suite to prepare the ships safely to go up.[9]

The former commanding officer of the Greeneville considered active sonar to be of limited value in searching for surface contacts and that he did not routinely use it as part of preparations for going to periscope depth. He stated that "active sonar stinks. It's difficult to pull a surface contact out of background waves unless you've got quiet, you know, sea states." He further stated that

> if you're operating in local area waters, I'm not going to say there's a reason you can't use it. I mean that if you have the ability to man the -- the stack that you should, why, it makes sense to do so. You've got another set of sensors. But the dilemma here is that when you line up for use of your active sonar, it takes away from your passive broadband monitoring on the Legacy systems, so it does in fact impact your operational alignment and configuration and it makes that periscope depth evolution a lot longer. And there's that transition time from when a submarine is at X number of feet below the surface when you're conducting your baffle clear that you want to minimize the time you're there because you're close to the surface, you're -- there is little chance of a collision because of the overlap of a deep draft merchant and the type -- the height of your sail. But there's that issue that you want to get to the surface as quickly as you can so that you can determine there's nothing there. And going through the -- the process of active sonar is just another step that you're adding to a procedure that you're trying to streamline.[10]

The frequency of use of active sonar during preparations for periscope depth varied from submarine from to submarine. Some submarine crews used it routinely, others used it infrequently. The Greeneville did not routinely use active sonar during preparations to ascend to periscope depth.[11]

On the day of the accident, acoustic conditions were "great," and contacts could likely be passively heard to a distance of about 15 to 20 nautical miles.[12] The Greeneville was fitted with an integrated sonar and fire detection systems designated as the model AN-BSY-1. The sonar system could detect sonar signals in an approximately 240-degree arc on centered on the vessel's bow. Because of interference from own ship generated noises, the sonar system was not able to reliably detect sonar signals between approximately 120 and 240 degrees relative to the vessel's head. This blind arc astern of the vessel was known as the "baffles," and the submarine had to periodically alter course in order to uncover this arc for observation by the sonar system (the procedure is know as "clearing baffles.")[13] The sonar system was able to determine and display the strength of the detected signal (termed the signal to noise ratio or SNR) as well as azimuth (horizontal bearing) and depression/elevation arrival angle (vertical bearing) of the sound signal within a few degrees of accuracy. The system displayed a total of 8 depression/elevation (D/E) angles in the range + [b/1] deg to [b/1] degrees. The number of D/E angles in

[9] Testimony of RADM Griffiths during U.S. Navy Court of Inquiry, p. 120.
[10] NTSB interview of former commanding officer, conducted on March 14, 2002.
[11] NTSB interview of former commanding officer, conducted on March 14, 2002.
[12] Testimony of RADM Griffiths during U.S. Navy Court of Inquiry, p. 537.
[13] Testimony of RADM Griffiths during U.S. Navy Court of Inquiry, p. 117.

which a contact was detected often was an indication of its proximity, and contacts detected in the lower D/E's was often the result of a "bottom bounce effect." The SNR of a contact often was an indication of its range, with closer contacts having a higher SNR than distant contacts. However, a lower SNR did not always indicate a distant contact but could be caused by other effects, such as acoustic shadowing or a quiet contact.[14] On the day of the accident, the Ehime Maru presented a narrow bow-on aspect to the sonar system.

Regarding sonar contacts, the sonar supervisor stated that:

> Some of the things I am looking for as a supervisor is something with a very high bearing rate, something that may be on our left side drawing right, or right side drawing left. It would indicate that it could be a closing situation. I'm looking for multiple pass perception on the source sphere. You have eight D/Es that we look at or depress in elevations. In eight windows on each stack, so if I see sound coming in two and three it doesn't tell you he is far away it just has a better indication he is probably more distant than close depending on how loud he is. If he is in all eight DEs he has a better chance to be close than a guy that is in two.[15]

The sonar system display indicated the contact bearing time history in three different time ranges – 8 seconds short time average (STA), 8 minutes - intermediate time average (ITA) and 30 minutes - long time average (LTA),[16] and these displays were commonly referred to as the "waterfall" displays because of their appearance being similar to a waterfall.[17] The ability to see the contact bearing time history in several time averages enhanced the operator's ability to track a contact and to determine the rate of bearing change of a particular contact. Once acquired and designated as a contact by the sonar operator, the sonar system was able to automatically track the contact through a system capability known as ATF (automatic tracker follower).[18] The automated system assigned a tracker letter to sonar contacts when they were first designated as a contact by the sonar operator, and the sonar operator assigned a sequential sierra (S) number to contacts when they were determined to be valid contacts. At the start of the day, the first contact detected would be designated as S-1, and subsequent contacts would be designated as S-2, S-3, etc.

The sonar system also had the capability to display the frequency spectrum of audio signals received from detected contacts. The frequency display could be used to determine the speed of rotation and the number of blades of the contact's propeller and to "classify" the contact based on known similar frequency signatures (DEMON data).[19] The system also had the capability to automatically analyze the contact signal spectrum using a separate piece of equipment, a spectrum analyzer, known as the A/N BQR 22. On the day of the accident, the A/N BQR-22 was inoperative, but, according to navy witnesses, its unavailability for use did not significantly degrade the workload share sonar operator's ability to classify contacts because of the low number of contacts being tracked.[20]

The sonar system interface with the operator was through several cathode ray tube (CRT) displays and input controls, and this portion of the system was located in the sonar room, which was adjacent to the control room. (See figure 1.) The system was fitted with a magnetic tape recorder that could be used to create a permanent record of the sounds detected by the system. Although it was normal procedure to operate the recorder in the record mode, on the day of the accident, the sonar system audio recorder was not activated to record the contact acoustic signals. The sonar supervisor

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[14] Testimony of RADM Griffiths during U.S. Navy Court of Inquiry, p. 537.
[15] Information from NTSB interview of Sonar Supervisor on Feb 14, 2001.
[16] Information from NTSB interview of Sonar Supervisor on Feb 14, 2001.
17 Testimony of CAPT Kyle, Deputy Chief of Staff for Tactics and Training at Commander Submarine Force, U.S. Pacific Fleet, during U.S. Navy Court of Inquiry, p. 697.
[18] Testimony of RADM Griffiths during U.S. Navy Court of Inquiry, p. 128.
[19] Testimony of Sonar Supervisor during U.S. Navy Court of Inquiry, p. 1132.
[20] Testimony of Sonar Supervisor during U.S. Navy Court of Inquiry, p. 1409-1410.

stated that the equipment had been used to play biologic sounds for the benefit of the DVs and that he had forgotten to return the it to the record mode after using the tape machine in the play mode.[21]

A remote sonar display unit, called an AVSDU (Analog Video Signal Display Unit), was located in the control room for use by the OOD and other persons engaged in maneuvering the vessel (see figure 1). The AVSDU provided the same information available to the sonar operators located in the sonar room. On the day of the accident, the AVSDU was inoperative (as a result of the failure of an internal electronic component).[22] During the navy's investigation, the importance of the AVSDU for the safe operation of the submarine was thoroughly established when various navy witnesses testified to its importance. When questioned about the importance of the AVSDU, the former commanding officer stated "it's an important backup for the Officer of the Deck, so he can see what Sonar is looking at" and that "it contains very valuable sonar information."[23] Another witness testified that the "AVSDU was perhaps the most important display that's directly on the Conn" and that it

> allow[ed] the Officer of the Deck to display any of the screens on the main legacy consoles, in this case, the two consoles here in the aft corner of Sonar Control that they are watching in Sonar, so he is able to watch the passive sonar displays or the classification coming from passive sonar displays there in the central part of the Conn. And it's much more of just an oversight of how Sonar is doing. That display allows a good ship driver to make assessments of the parameters of contacts without the use of the fire control system and just mentally, in his head, based on thumb rules and experience. So, it's a powerful display.[24]

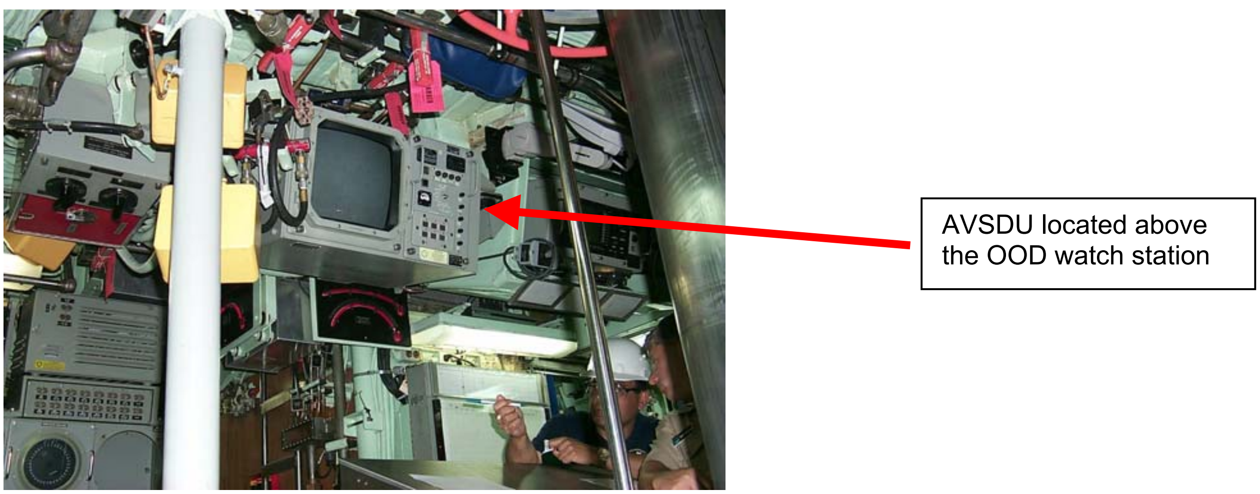

Figure 1 – Sonar display located in control room (AVSDU) (U.S. Navy Photo)

Working in conjunction with the sonar system was the fire control system, which provided the additional ability to determine a "solution" for contacts being tracked by the sonar system. The solution for a contact included its course, speed, and range. The fire control solution was normally obtained by a fire control operator, but the system also had the capability to automatically determine a solution for the contact using a computer algorithm known as KAST.[25] The method by which the fire control operator obtained a solution on a contact was through a process known as "stacking the dots." Stacking the dots involved comparing the expected bearing to the contact against the actual bearing to the contact, and the

[21] Statement of Sonar Supervisor during NTSB interview, Feb 14, 2001.
[22] Testimony of Sonar Supervisor during U.S. Navy Court of Inquiry, transcript p. 1409.
[23] Testimony of CDR Waddle during U.S. Navy Court of Inquiry, transcript p. 1709-1710.
[24] Testimony of RADM Griffiths during U.S. Navy Court of Inquiry, transcript p. 107-108.
[25] Testimony RADM Griffiths during U.S. Navy Court of Inquiry, transcript p. 163.

difference was indicted by a variation in the alignment of a vertical stack of dots.[26] A new dot, which represented the variation in expected from actual bearing to the contact, was generated by the system every 20 seconds.[27] The fire control system provided the ability to display contact information in several different formats. On the day of the accident, the displays were arranged as listed below, forward to aft.[28],[29]

- Line of sight - and it tries to depict the own ship at the bottom, and the target ship at the top with their actual courses the bearing line between them, and their actual speeds so that you have a realistic bottom depiction of one ship verses the other. This display is useful when doing periscope operations and trying to use your visual assessment of the target's parameters and don't have a lot of sonar information on them
- Time-bearing - it's similar to the contact evaluation plot (CEP) in some respects because it provides the bearings over time. The vertical axis time, the horizontal axis is bearings and when you are submerged, it would be providing a history over time of the bearing change to a given contact, and all sonar contacts, as time evolves.
- Mate or FlitMate display – the dot stack display, in which operator was able to rapidly determine the parameters of a contact when sonar bearings are changing over time.
- Ops summary – an overhead display of the submarine and all the contacts relative to the submarine (similar to a radar screen display).

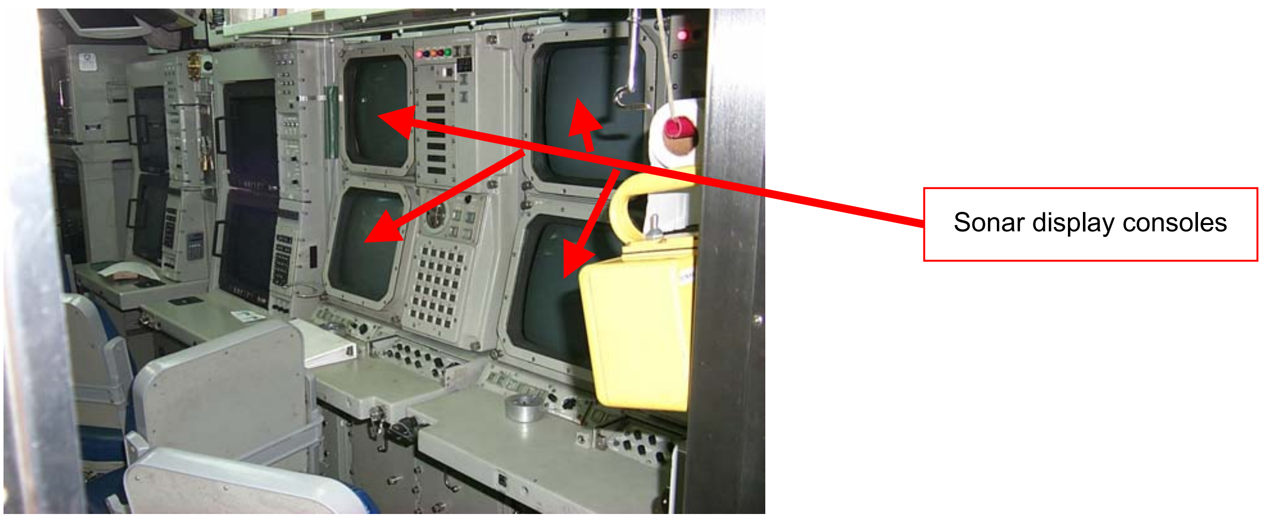

Figure 2 Sonar system consoles. Looking from right to left are the 4 CRT displays associated with the hull-mounted arrays. To the left of these displays were the towed array system displays. (U.S. Navy photo)

[26] Testimony RADM Griffiths during U.S. Navy Court of Inquiry, transcript p. 356.
[27] Testimony Capt Kyle during U.S. Navy Court of Inquiry, transcript p. 678.
[28] NTSB Interview of OOD, Sep 27-28, 2002.
[29] Description of displays from testimony of RADM Griffiths during USN Court of Inquiry, transcript pp. 161-162 and by OOD during interview with NTSB.

Figure 3 - Fire control display and interface consoles. (U.S. Navy photo)

Periscope system. The Greeneville had two independent periscopes that were operated from a raised platform centrally located in the control room (see figure 3). The periscopes were designated as the Type 18B search periscope (#2 or port) and the Type 2F attack periscope (#1 or starboard). The Type 2 optical design dated back many decades. The Type 18 was a relatively newer design that introduced in the late 1960's specifically for photographic reconnaissance with more optical capabilities such as built in TV, photographic camera, image tracking (now deleted), power assisted train operation, line of sight gyro stabilization (single axis), and additional higher magnifications of 12 and 24 power.

According to information provided by the Navy's acquisition command,[30] and by witnesses at the US Navy Court of Inquiry, the periscopes had the following characteristics:

#1 - Type 2F characteristics:

Magnification and respective Field of View (FOV)

1.5X	32 deg. F.O.V.
6X	8 deg. F.O.V.

Elevation angle: -10 deg. to +74 deg.
No internal camera or video capability
Optical stadimeter for estimating contact ranges

#2 - Type 18B characteristics

Magnification and respective Field of View

1.5X	32 deg. F.O.V.
3X	16 deg. F.O.V.
6X	8 deg. F.O.V.
12X	4 deg. F.O.V.
24X	2 deg. F.O.V.

Elevation angle -10 deg. To +60 deg.

[30] In a memorandum to the NTSB dated 02/27/2002, the U.S. Navy's Naval Sea Systems Command (NAVSEA) provided technical information contained in this section.

The Type 18 periscope was configured with a TV video (known as Perivis) and still photo camera. This system also had remote video monitors that allowed others to see what the periscope operator was viewing through the periscope eyepiece. Video monitors were located near the fire control operator watch station, the ship control station, the quartermaster watch station, and the crew mess. The video image could be recorded on magnetic tape if desired. The videocassette recorder (VCR) was installed two compartments forward of the control room. A switch on the periscope right training handle allowed the operator to start and stop the VCR while operating the periscope. Other functions, such as rewind and playback were accomplished by controls on the VCR itself. During daytime operation, the operator's image was not significantly degraded by still or video camera use (the equivalent of about 1 f-stop only). However, one of the *Greeneville's* officers stated that on the day of the accident he had used the periscope and had chosen not to use the Perivis because the conditions were such that he did not want to degrade the view through the periscope. In the interview he stated that "I tell you then that it was bad enough [referring to the weather conditions] that I didn't want the PERVIS, which is the TV system, turned on, because that uses a lot of light from the periscope."[31]

The Type 18 had and optical length of 36 feet (the distance from where the operator looks into the eyepiece up to the horizontal line of sight at the periscope headwindow) and a horizontal line of sight (HLOS) is 64 feet 7 inches above the keel. The Type 2 had an optical length of 40 feet and a HLOS of 68 feet 7 inches.


Figure 4 and 5 - Periscope in raised position (U.S. Navy photo)

According to the information provided by the NAVSEA, neither the of Greeneville's periscopes had radar capability. However, radar capability had been initially incorporated into submarine periscopes during World War II. The standard periscopes in the 1950's were a Type 2 attack periscope and the Type 8 search periscope, which included an ST band radar antenna. The radar antenna was mounted at the outboard the end of the periscope and was used in a "point and shoot" mode to determine contact ranges. Training the periscope provided azimuth control and bearing information. The periscope did not continuously scan like a conventional navigation or search radar. The Type 8 periscope was installed on all US submarines until the introduction of the Type 15 search periscope that incorporated better electronics warfare capabilities. Type 8 and Type 15 optical designs are identical. The Type 15 became

[31] NTSB interview of the vessels "chemistry and the radiological controls assistant," held on Feb 19, 2001.

the standard search periscope for all attack submarines while the Type 8 was used on ballistic missile submarines (SSBNs). The Ohio Class ballistic submarines had both a Type 15 and a Type 8 (with the built in ST radar). When the additional electronics capabilities were incorporated into the periscope in the early 1980's, the Type 8 periscope was selected as the mast to be modified to incorporate this new capabilities. Thus, the periscope radar capability was removed in favor of the higher priority communications capabilities. It is the Navy's belief that periscope radar as described above would not have ensured detection of the Ehime Maru. The operation of the ST radar required the operator to train the periscope on the target and then obtain range by means of the radar. The periscope ST radar was not designed to be used in a search mode.

ESM System

ESM System. The electronic support measures (ESM) system was able to detect and categorize electromagnetic signals over a wide variety of frequencies, including the frequency at which the *Ehime Maru's* radars operated (X-band). The ESM system was designed to provide intercept, surveillance, and signal parameter analysis of electromagnetic signals for threat warning. In addition, the ESM system was able to roughly determine the direction from which the detected electronic emissions originated and, based on signal strength, determine a gross estimate of its range. The system consisted of a small receiving antenna mounted in a dome atop the Type 18 periscope, and two independent receiving systems.[32] The reception of signals required that the antenna be above the surface of the water, although for very strong signals reception at a very shallow depth was possible. The signal from the antenna was split into separate paths and directed to each of the two receivers. The first receiver system, known as the early warning receiver, was located in the control room, with its operator interface controls mounted on the periscope assembly. The detected radio frequency (RF) signals at the early warning receiver were amplified and converted into audio frequency signals, and sent to a speaker mounted in the overhead near the periscope for analysis by the control room watch personnel (primarily the OOD or the periscope operator). The strength and the pattern tonal variations of the detected signals was used a rough indication of the range to the transmitter and hence the level of threat posed by the transmitting facility, typically another ship or an aircraft. The signal strength of the detected signal was classified as one of five levels: one, two, three, four or five, with signal strength five being the strongest and highest threat. The assignment of a particular signal strength level was somewhat a matter of judgment, but each signal strength level did have distinct audio characteristics that the watch officers in the control room were trained to distinguish.[33] However, when asked if he would be able to distinguish between a signal strength 3 and a signal strength 5, a qualified OOD aboard the *Greeneville* stated that he could not, saying "No, I wouldn't. I would go with -- clearly based on what the ESM report, and for him, it is judgment, too."[34] The presence of side lobes[35] in the aural signal was the principal determinant for a signal being classified as signal strength 4 or 5.[36],[37] The detection of a radar emission that was classified by the ESM operator as signal strength 4 or 5 was to be immediately reported as a "close contact."

The other receiver to which the detected signal was routed was a more sensitive and complex receiver system that was installed in a separate compartment (the radio/ESM room) located aft of the control room (see figure 6). This ESM system was designated as the AN-WLR-8 and it was operated by a dedicated specially trained watchstander. The WLR-8 system receivers were able to detect radar

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[32] During U.S. Navy Court of Inquiry, the ESM operator testified that the systems were separate, transcript, p. 1023.
[33] Testimony of RADM Griffiths during Court of Inquiry, transcript p. 294.
[34] NTSB interview of the vessels "chemistry and the radiological controls assistant," held on Feb 19, 2001.
[35] The main signal from a rotating radar antenna is a beam in front of the aerial, similar to the light beam from a rotating searchlight. But, unlike a searchlight, lesser signals are emitted in other directions around the sides and back of the aerial. Any emissions not in the main beam are referred to as side lobes.
[36] Testimony of ESM operator during Court of Inquiry, transcript, p. 1029.
[37] Testimony of RADM Griffiths during Court of Inquiry, transcript p. 293.

emissions and could be programmed to scan sequentially or simultaneously over a wide range of frequency bands and to measure threat signal direction of arrival, frequency, modulation type, pulse repetition rate, pulse width and amplitude parameters. The presentation of the detected signals was displayed on a two cathode ray tube display units[38] Using a database library of radar signals, the signal characteristics of received signal allowed the ESM operator to identify the type of radar transmitter from which the signal originated. The ESM operator, using the same techniques as the control room watchstanders, could also monitor the signals aurally using headphones in order to quickly identify any high threat signals (signal strength 4 or 5).

Figure 6 ESM System (U.S. Navy photo)

Radar system. The vessel was fitted with two radar systems for use primarily when it was underway on the surface. The main radar was the AN/BPS-15 and the secondary radar was a commercial off-the-shelf (COTS) model (AN/BPS-15H) that was manufactured by Furuno, Inc. The main radar antenna could be deployed from a extensible mast while the vessel was at periscope depth or broached, however, extending the mast required opening of the lower hatch on the sail and entry into the bridge trunk to disengage a safety locking pin on the mast (see figure 4). According to a navy investigator, the radar could have been deployed to search for surface contacts before conducting an EMBT blow.

> But if you wanted to, you could also operate radar. Now, this is a significant investment in time to prepare the radar mast for raising, raise the radar mast, get the radar mast rotating and radiating, tune it in so that you start to have a good picture, and then assess that picture, and then add that to the other sources of data you have, secure it, lower it, and then go deep into the blow.[39]

The antenna for COTS radar system was not permanently mounted, but rather, was portable; and its mounting required entry into the cockpit on the top of the sail (see figure 5). Both radar systems were approximately equivalent in terms of capabilities and features. On the day of the accident, the submarine's radar systems were not used to search for surface contacts.

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[38] Factual information on some EMS functions from http://www.fas.org/irp/program/collect/an-wlr-8.htm
[39] Testimony of RADM Griffiths during Court of Inquiry, transcript p. 258.

Figure 4 Main radar antenna (U.S. Navy photo)

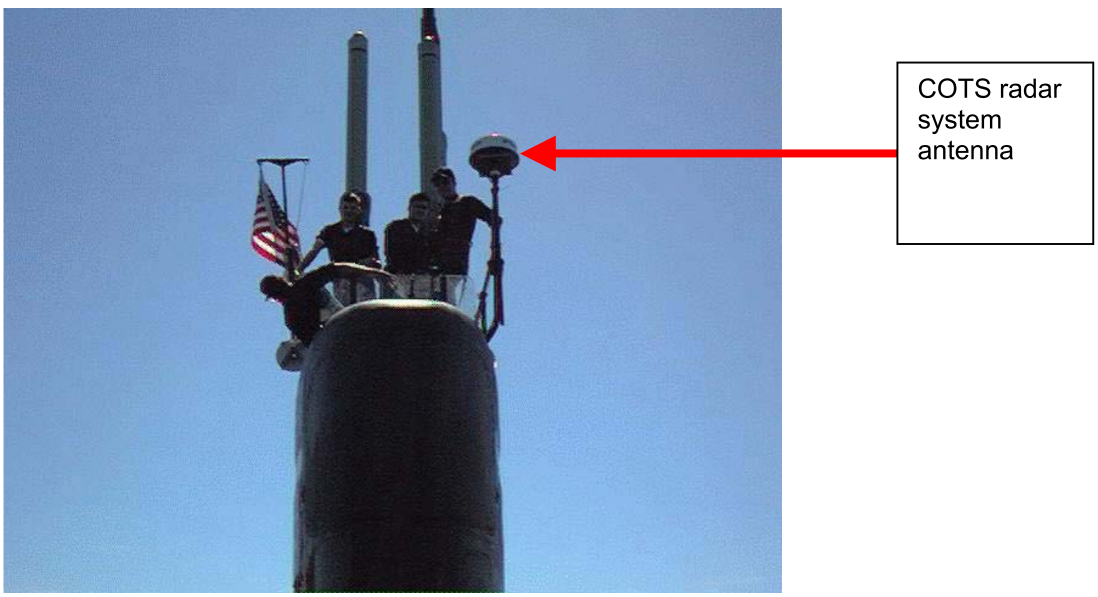

Figure 5 Secondary radar antenna (U.S. Navy photo)

<u>Condition of sensors</u>. After the accident, the Navy performed testing on the sensor systems to determine if any were in a degraded condition at the time of the accident. No significant problems with the equipment were found during the testing. In its final report, the navy's Court of Inquiry concluded that "no

equipment or system failure onboard *GREENEVILLE* directly contributed to the collision."[40] In an interview with NTSB, the former commanding officer of the Greeneville stated that he was not aware of any problems that significantly degraded the capability of the main sensors on the day of the accident, and that they had been satisfactorily tested shortly before the accident date (after the selected restricted availability (shipyard period)).[41]

Operations

Weather conditions. On the day of the accident the weather conditions were described by the submarine's navigator, who was on watch as the vessel left port at the start of the DV cruise, as being "rougher than normal for Pearl Harbor area. Very choppy, kind of a high sea state. Windy. Visibility was--distance to visibility was very good. I could still see the tops of buildings in Honolulu, out to probably about 8 to 10 miles. I could still see them. The problem was that it was very dingy-colored out. Very monotone sky color, kind of off-white. Difficult to-- difficult to see contrast against the horizon against the sky. Just very--kind of an off-white color, I guess is how I'd describe it."

Shortly after the collision, the Greeneville reported to COMSUBPAC that the weather was as follows: weather good, overcast, visibility at least 10,000 yards, sea state 2, wave height and swells 3 to 4 feet.[42]

After his interview with the commanding officer of the submarine, one of the investigating officers in the Navy's Preliminary Investigation recorded the commanding officer's description of the weather with the as follows: "Approximate sea state 2, visibility was hazy. Could clearly see the water could not see land mass of Oahu."

During his Court of Inquiry testimony, the former commanding officer further described visibility as follows: "I saw an aircraft take off, I think it was a 747 maybe a DC-10, so I knew the visibility to the horizon at least 13, 14 miles appeared to be good. But I knew that the height of eye wasn't high enough, so I told Mr. [OOD-2] to bring the ship up a couple of feet." In a subsequent interview with the NTSB, the former commanding officer stated that "I just remember that white belt of haze around the mountain and just seeing the very top of the peaks."[43] At another time during the Court of Inquiry testimony the former commanding officer stated:

> I noticed a haze, again, I specified that when I looked up and I'm pointing here on Exhibit 17 in the direction of Oahu, I couldn't--it was like if there a white belt along the land mass and I could see the prominent peaks of land here on Oahu, on the Waianae Mountain Range, and up here by the Koolaus, but I couldn't see the airport, I couldn't see the Honolulu buildings. I did, in fact, see I think, Diamond Head if I saw--no I can't remember if I saw that or not, but I do know that I saw land, the tops of the peak and the white belt around the island. I didn't know if that was in and around my operating area, but I did notice what was a haze. Gray clouds, almost 100 percent overcast.[44]

Testimony by a senior navy investigator at the Court of Inquiry stated, in reference to the sea conditions, that "the most consistent average of the people we talked to from the *Greeneville* made it 6 to

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[40] Report of the Court of Inquiry, dated April 13, 2001, opinion number 3, p. 102.
[41] NTSB interview of former commanding officer, conducted on March 14, 2002.
[42] Navy Court of Inquiry report, exhibit 45, transcription of COMSUBPAC radio conversation with Greeneville.
[43] NTSB interview of former commanding officer, conducted on March 14, 2002.
[44] Testimony of former commanding officer at U.S. Navy Court of Inquiry, transcript, p. 1778.

8 feet" and "it was an overcast day"[45] Also during the Court of Inquiry, a senior USCG witness testified that, "as reported in [their] situation report for that first day, … weather was reported as seas 3 to 4 feet, with the winds zero-four-five at 10 knots, visibility 6 miles, air temperature 78 degrees Fahrenheit, with a water temperature of 77 degrees Fahrenheit … and it was a bit of an overcast day."[46] And finally, during the US Navy Court of Inquiry, the master of the Ehime Maru described the weather conditions as: "the visibility was around 6 miles" and height of the waves as "1 to 2 meters--not even 2 meters. It would have been around that I would think."[47]

Operating Area

Operating Area. On the day of the accident, the Greeneville operated in a specific area assigned by the submarine operating authority, COMSUBPAC. The assigned area defined the area in which the Greeneville could operate in a submerged condition, however it placed no restriction on its operation while surfaced. The area assigned to Greeneville on the day of the accident was approximately 4500 square miles, or approximately 58 miles wide by 75 miles long. COMSUBPAC assigned operating areas to submarines under its control for limited periods of time, typically one day. In general, the operating areas assigned to submarines in the Hawaiian Islands area were not publicly advertised, and merchant vessels in the area would not know when submarines were actually operating in those areas. The Greeneville was assigned to an area near the island of Oahu, which made possible a short underway period for the DV cruise.[48]

The area to which the Greeneville was operating on the day of the accident was described by a senior navy witnesses as being "not a highly trafficed area."[49] A senior witness stated that although COMSUBPAC had not conducted formal studies of the traffic operating in the areas assigned for submarine operations, the traffic patterns were well known by navy officials, and that the operating area assigned to the Greeneville "was about as safe as can possibly be."[50] The commanding officer of COMSUBPAC stated that

> I am satisfied that we know and have known what the traffic density is coming out of Honolulu. Whether it be fishermen, small merchants going to the other islands, barges and tows, that sort of thing and the tankers, we have a very good feeling. I would tell you also though, sir, that one of things that has to go with this is it's not lost on any of my Skippers, including CDR Waddle, that he has--he has the obligation, truly the obligation, to make sure that the waters above him are free irregardless of where he may be operating. He knows it, everyone of Skippers know that.[51]

According to navy investigators, on the day of the accident the Greeneville did not operate submerged outside of its assigned area.[52] At the time of the accident, the submarine was operating at the northern end of its assigned area, about 5 miles from the northern boundary line.[53] A witness at the navy COI evaluated the Greeneville's assigned operating area as follows

> If I were assigning the GREENEVILLE areas to operate in today to conduct this type of mission, this would be a very logical assigned area. Now there is land obviously protruding into this assigned area. There's also shoal water--relatively shoal water in this region up in here, which the ship would not want to operate deep submerged in. But in general, it is good water, clear shipping

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[45] Testimony of RADM Griffiths, US Navy Court of Inquiry, transcript p. 136.
[46] Testimony of USCG Capt Angert, US Navy Court of Inquiry, transcript p.1325.
[47] Testimony of Hisao Ohnishi, Ehime Maru master， US Navy Court of Inquiry, transcript p. 1039
[48] Testimony of RADM Griffiths, US Navy Court of Inquiry, transcript p. 225.
[49] Testimony of RADM Konetzni during U.S. Navy Court of Inquiry, transcript p. 727.
[50] Testimony of RADM Konetzni during U.S. Navy Court of Inquiry, transcript p. 726.
[51] Testimony of RADM Konetzni during U.S. Navy Court of Inquiry, transcript p. 727.
[52] Testimony of RADM Griffiths, US Navy Court of Inquiry, transcript p. 223.
[53] Distance determined by plotting location of collision and operating area boundaries as indicated on navigation chart (COI exhibit no 17).

lanes, and although you don't want to hit these few buoys that are in there, otherwise, unencumbered by obstructions and reasonable to allow them to operate in and not too far from homeport.[54]

A navigation chart for the Oahu island area had a marked block designated as "Submarine Test and Trial Area." Regarding this area, Commander Pacific Fleet issued a press release that stated:

> The "Submarine Test and Trial Area" that is defined on National Oceanic and Atmospheric Administration (NOAA) chart 19AC019357 was established in 1963, but is no longer used for its original purpose. The range was originally established for submarines coming out of an extended repair period at Pearl Harbor Shipyard to conduct their initial "deep dive." This range was also used to test torpedoes. While this location is no longer used for tests or trial, submarines do periodically operate in or near this area. The marked area still serves as an advisory for vessels, but by no means are submarines restricted to operating only in this area. The area was added to the chart by the U.S. Naval Oceanographic Officer by Notice to Mariners 45(5136)70.[55]

Further, regarding the "Submarine Test and Trial Area," the commanding officer of COMSUBPAC stated the marked area had no significance for the surface mariner using the chart: "I believe if I were a mariner, it would mean nothing. It certainly has meant nothing for over 30 years.[56]

According to a senior NOAA chart technician, the submarine operating zones marked by magenta colored boxes were supposed to have been removed from the NOAA charts in 1997. According to this technician, the U.S.Navy sent a message to NIMA confirming the deletion of the zones but did not send a message to NOAA. NOAA publishes the charts and should have been informed. Unfortunately, at NIMA, the message was received by chart compilers and not the Notice writers. Therefore, the zones were never removed in a Notice to Mariner.[57]

Schedule

Schedule. According to the commanding officer of the submarine squadron to which the Greeneville was assigned, the vessels schedule was as follows:[58]

- The ships schedule was not typical because it was the first submarine fitted to host the Advanced Seal Delivery System (ASDS). That system has been in development and testing for some time, and the *Greeneville* and has not been part of the normal deployed rotation for about 2 years so that she could host the ASDS when it became available for testing and deployment. Sometime in 2000, *Greeneville* was put back into the deployed rotation
- June and July 2000 – EastPac (eastern Pacific) – underway, and inport San Diego and San Barbara
- September through December 2000 – in Pearl Harbor Naval Shipyard drydock for repairs and upgrades (Selected Restricted Availability or SRA)
- Approx 21st of December – underway for sea trials.
- January 5th through February 2nd, 2001 – first underway as a part of the Pre-Overseas Movement period, during which the vessel went to the U.S. West Coast to do post-SRA, (Selected Restricted Availability), acoustic trials, and also to conduct underway training. In port Jan 22 through 26.[59]

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54 Testimony of RADM Griffiths, Navy Court of Inquiry, transcript p. 225
55 Commander Pacific Fleet press release http://www.cpf.navy.mil/cpfnews/0102greeneville8.html
56 Testimony of RADM Konetzni during U.S. Navy Court of Inquiry, transcript p. 729.
57 NTSB interview of NOAA technician conducted on February 15, 2001.
58 Testimony of Capt Richard Snead, CSS1, US Navy Court of Inquiry, transcript p. 913
59 Testimony of RADM Griffiths, Navy Court of Inquiry, transcript p. 325

- Originally scheduled to be at sea the weekend of Feb 10-11 to conduct training in preparation for an upcoming Operational Reactor Safeguards Examination (ORSE). Several days before the accident date, the commanding officer requested schedule change to delete weekend underway period.[60]
- At the time of the accident, vessel was scheduled to deploy to overseas (WestPac) in June 2001.

The ship's deck logbook recorded the following operational events on the day of the accident:

Feb 9, 2001:

- 0756 - all mooring lines were cast off
- 0757 - ship underway 0757
- 1017 – submerged the ship
- 1134 – secure from deep submergence
- 1143 – deck and the conn watch turned-over
- 1336 – raised #2 scope
- 1340 – emerg deep, no close contacts
- 1342 – emergency surfaced the ship, EMBT blow
- 1344 – raised #2 scope
- 1348 – CO has the CONN

Feb 10, 2001:

- 1034 – The ship is moored at pier S-21

Standing Orders. The commanding officer of the Greeneville issued a ship's policy instruction to the crew known as standing orders. The standing orders provided guidance on procedures to be followed in a variety of circumstances such as submerged operations, surfaced operations, navigation, periscope depth operations, and shallow water operations.[61] The commanding officer's standing orders were based on a set of model standing orders issued by the type commander.[62]

Target Motion Analysis (TMA). Target motion analysis (TMA) is the study of relative motion, where a "submarine determines the bearing, range, course, and speed of surface contacts relative to own ship." The process takes sonar data and develops parameters of movement through a coordinated, logical series of assumptions, solutions, and refinements. The submarine's computer solutions (KAST) provide assistance and confirmation to human mental analysis, training, and experience.[63] During normal operations, target motion analysis was done in the control room by the Officer of the Deck (OOD) and the Fire Control Technician of the Watch (FTOW).

Target motion analysis is accomplished by maintaining a constant course, speed and depth of own ship, and observing the relative motion of contacts. This period of observation was referred to as a

[60] Testimony of Capt Brandhuber during US Navy Court of Inquiry, transcript p. 818.
[61] USS Greeneville Instruction C2130.25, U.S. Court of Inquiry Exhibit 1, Enclosure 24, Tab 17.
[62] The model standing orders are enclosures to COMSUBLANT/COMSUBLANT Instruction C3120.25. Commanding officers' are required to prepare ship specific standing orders that meet, as a minimum, the specified core requirements.
[63] Testimony of RADM Griffiths and Capt Kyle, US Navy Court of Inquiry transcript pp. 115-16, 547, 552-553, 564.

TMA *leg*. A minimum of two *legs* was necessary to determine a solution for a contact.[64] The commanding officer's standing orders regarding preparations for ascent to periscope depth specifies that the vessel stay on a course long enough to determine actual bearing rate and direction of relative motion of contacts (about 3 minutes).[65] The order further requires that a course change be made that will produce the maximum speed across the line of sight while minimizing the number of maneuvers necessary to get two legs on the contacts.[66] In general, a direct relationship exists between the number of legs or ship maneuvers and the quality of the solution (more TMA legs makes possible a better contact "solution").[67] Regarding TMA legs, a senior witness at the Navy Court of Inquiry stated that

> … in general, if you have an environment and a target ship that's providing a good, steady, reliable signal so that your fire control and your sonar system have good information to develop from and to analyze, it would take in general, two legs of 3 to 5 minutes per leg, with our digital fire control system and our digital sonar system to determine a pretty good picture of what the ship is doing, and that's bare minimum because a single leg solution would not resolve a lot of ambiguity in what that other ship is doing. So, in summary, the two good legs would allow you to use passive sonar and your systems onboard, to, as a minimum, determine that the contact is not very close and probably have much more information about it.[68]

The process used by the fire control technician in obtaining a solution for a contact was described as follows:

> … this is not an automated process. It's a receive assisted process. It takes the operator's intuition, his own knowledge and training about the contact, information gained from sonar, plus trial and error to come to course, speed, bearing and range. After a couple of maneuvers aboard ship looking at the target from different aspects the number of possible solutions very quickly can go down to a very limited number. And the solution will converge to the answer.[69]

In performing TMA the OOD uses the fire control displays, the sonar display in the control room (AVSDU), and the contact evaluation plot (CEP). The CEP display was a paper plot maintained in the Control Room, on which own ship's data (e.g., course, depth, speed), as well as contact bearings and classification, were periodically plotted. The CEP is a running contact history with bearings across the top and time along the side, placed in a central location, for the benefit of the control room watchstanders.[70] The commanding officer standing orders required the CEP to be maintained at all times.[71] On the day of the accident, the CEP was not maintained for a period of about one hour before the collision. During the Navy's Court of Inquiry, a senior witnesses discussed the CEP as follows:

> The actual entries on the Contact Evaluation Plot were very sparse and there were essentially no contact entries for the hour leading into the collision. There may have been a few, but it was not continuously being maintained. And this is a plot that a ship would normally continuously maintain. And if they ran out the opportunity for the Fire Control Technician of the Watch to make that plot--maintain that plot to the right standards then the ship would augment with an additional

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[64] Testimony of RADM Griffiths, US Navy Court of Inquiry transcript pp. 116-117.
[65] Testimony of former commanding officer during U.S. Navy Court of Inquiry, transcript, p. 1747.
[66] Commanding officer's standing order number 6, periscope operations (USS Greeneville instruction C2130.25).
[67] Testimony of RADM Griffiths during U.S. Navy Court of Inquiry, transcript p. 163.
[68] Testimony of RADM Griffiths during U.S. Navy Court of Inquiry, transcript p. 117.
[69] Testimony of Capt Kyle during US Navy Court of Inquiry, transcript p. 182.
[70] Testimony of RADM Griffiths during US Navy Court of Inquiry, transcript p. 157.
[71] Navy Court of Inquiry, Exhibit 1, enclosure 24, tab 17 (commanding officer's Standing Order numbers 0230 and 0630).

person to keep the quality of the plot up. And they did not have useful data in that hour before the collision on this plot.[72]

…[the quality of data is degraded,] obviously with the AVSDU out and no CEP as a backup. You now have--your options are now further limited and you're now almost obligated to spend more time at fire control or physically going into Sonar and looking at the displays in the Sonar Room itself.[73]

On the day of the accident, each of the TMA legs were less than standard time in duration.[74] Recorded data indicates that the first leg of TMA before ascent to periscope depth was on a course of 340° and was about 1 minutes 20 seconds in length. Regarding the first leg, a witness at the Navy Court of Inquiry stated that he would classify it as marginal and insufficient: because the vessel was slowing down and decreasing depth during the early portion of the leg:

[I would] classify this three-four-zero leg … marginal, only because it's so short and it's not steady. Is there TMA being done? Yes, sir, as evidenced by the fact that someone came up with an answer that is pretty good. Is it a good TMA leg? Is it sufficient? I would say it's not sufficient. It's not sufficient to an independent review or analysis to understand the contact motion.

In addition, the one of the contacts, (S-14), did not receive two legs of TMA. According to recorded sonar data, the new sonar contact S-14 was first acquired (gained) during the turn from 340° to 120°. The former commanding officer stated that he did not realize that S-14 was a newly acquired contact and that only one leg of target motion analysis had been performed on the contact. He stated that

… it wasn't clear to me that Sierra 14 was a new contact, and the reason for this, and again, you know, if it had the AVSDU on the Conn, I could've seen 12, 13, all the other numbers. You know because I didn't have that, I didn't have that Sierra number ingrained in my brain. I remembered here, pointing to Exhibit 4, before we commenced the angles and dangles at 1316, that I had two contacts, one to the Northwest and one to the Northeast. If I'd had the AVSDU, Admirals, I would have known those Sierra numbers, but I didn't. And as such, when we made the maneuver to the course of one-two-zero and Sonar reported, I've got two contacts and from the testimony I've heard Sierra 14, Sierra 13, it was two contacts and I didn't recognize it as a new number. And, that's the problem, if I had recognized it, I would've acted upon it, and I don't think it was clear to the Officer of the Deck either. Why, because not having the AVSDU, it handicapped us. [75]

Regarding the KAST solution, the former commanding officer stated that he did not usually refer to it, but looked only at the system solution generated by the FTOW, and that the KAST system was sometimes very inaccurate, but that, given enough maneuvers, it could be very accurate.

… you look at a system solution, not the KAST. But you expect your fire control operator to balance the KAST solution against his updated solution to make sure it makes sense. I mean, if KAST is telling you the contact's at 2000 yards and your generated solution is at 14,000, you've got a problem.

… if you maneuver frequently enough on a contact to provide the generated bearing rate to allow the computer to come up with an independent solution, then KAST is very good. If you don't,

[72] Testimony of RADM Griffiths during U.S. Navy Court of Inquiry, transcript p. 244.
[73] Testimony of Capt Kyle during US Navy Court of Inquiry, transcript p. 600.
[74] Testimony of former commanding officer during U.S. Navy Court of Inquiry, transcript, p. 1751.
[75] Testimony of former commanding officer during U.S. Navy Court of Inquiry, transcript, p. 1754.

> then KAST isn't very good. Even the computer has its limitations, but over time with adequate maneuvers the KAST solution will give you a solution that is very fair, if not good or accurate.[76]

During the navy's Court of Inquiry, a witness described the reliability of the KAST solution as follows:

> There is an algorithm running in the background that given the right conditions may help you in coming up with an answer. It's called KAST. It puts the data through a common filter and comes up with a suggested answer. These types of maneuvers with high speeds on one side in the other it's often pretty accurate. But it's not always. You have to look at it with a grain of thought-- a salt and consider it as an input to your overall solution.[77]

The former commanding officer stated that he had looked at the fire control displays before during the TMA evolution before the ascent to periscope depth:

> What the FTOW had to work with, I think it's been clear that he had a solution. What I saw on his display led me to believe that the contacts were far--distant on exhibit 4 [area chart] close to the Oahu coast, that's what I believed it to be.[78]

In addition, the commanding officer had looked at the sonar screens ad discussed the contacts with the sonar supervisor while the vessel was on its 340 (first) leg. In an interview, the former commanding officer stated that

> I [walked] into the sonar room and I asked [sonar supervisor], what contacts do you have? Sir, I have these two. What do they sound like? Sound like trawlers or small vessels, small craft. What are the bearings? Here they are. Northwest, northeast. Close or far? They're distant, sir. They're -- they're up by land. Okay. Walk over to fire control system with the GEO display there, and I see two contacts up off the coast of Oahu. It made sense to me. Sonar just told me what they had, fire control has validated that information. I look over at the nav plot. We're here, nine miles away is land, seven miles away. Not an unrealistic solution for a contact going up the northeast to Diamondhead or one traveling northwest, maybe going wherever. So, it made sense to me and that's how I recall ships over the last ten years operating in Hawaii based on my personal experience. I didn't think about a narrow aspect, constant bearing, decreasing range kind of guy. And the KAST solution driving north and south, although the maneuvers were adequate for that solution, over time, over an hour or so, proved to be the more accurate one, unfortunately.[79]

During interviews and testimony after the accident, the on watch sonar supervisor stated that he believed the contacts held at the time were distant, however, he did not recall having specific conversations with the commanding officer while on watch in sonar.[80], [81]

<u>Periscope operations</u>. The navy provided guidance in operation of the periscope to conduct visual searches during tactical operations.[82] Separate guidance was not provided for non-tactical operations,

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[76] NTSB interview of former commanding officer, conducted on March 14, 2002.
[77] Testimony of Capt Kyle during US Navy Court of Inquiry, transcript p 186
[78] Testimony of Greeneville commanding officer at U.S. Navy Court of Inquiry, transcript p. 1762
[79] NTSB interview of former commanding officer, conducted on March 14, 2002.
[80] Testimony of sonar supervisor during U.S. Navy Court of Inquiry, transcript p. 1439 and 1457.
[81] Statement of sonar supervisor during NTSB interview held on February 14, 2001.

such as distinguished visitor cruises. The guidance for performing the initial search at periscope depth contained in the periscope employment manual was as follows:

> 1.3.2. Initial Search at Periscope Depth. As soon as the head window breaks the surface at least three 360 degrees sweeps of approximately 8 seconds per sweep should be made in low-power, trained near the horizon to quickly determine the status of close contacts or nearby floating objects. This initial search is intended to defend against eminent collision and is not intended as a complete horizon search. If a collision is observed an emergency deep should be ordered and the periscope lowered. If safe operation is indicated the announcement "no close contacts" should be made. Following the initial surface search several rapid low-power sweeps at maximum head prism elevation and several more sweeps at 35 to 40 degree elevation should be made to detect the presence of aircraft."
>
> 1.3.3 Continuous Visual Search. Continuous search commences as soon as it is determined that safe periscope depth operations are possible. The recommended process for continuous search is as follows: A 360 degree horizon sweep in low-power; a 90 degree quadrant horizon search in high six times power; another 360 degree low-power sweep; a high-power search of the next 90 degree sector; and so on. Each step in this process should be done slowly. Approximately 45 seconds per sweep. A periodic high elevation search is only necessary if the regular continuous search has been interrupted for more than 1 ½ minutes."

The guidance provided for periscope depth operations were as follows:[83]

- preparations for periscope depth are made at 150 feet depth, TMA conducted to determine contact picture on the surface
- the OOD is required to hold a meeting (called a PD brief) with the sonar supervisor, the radioman of the watch, the ESM watchstander, the navigation ET, and the ship control party to discuss the current contact environment and what evolutions are to take place while at periscope depth.[84]
- when OOD has a good understanding of the contact picture, he makes a summary report to the commanding officer and requests permission to proceed to periscope depth.
- the commanding officer, if he concurs with the OOD's assessment of the contact environment, grants permission for the OOD to take the ship to periscope depth.
- OOD orders that the ship be brought to periscope depth, which is typically about 60 feet.
- As the submarine ascends, the OOD looks through the periscope in the ahead direction for any shape or shadows that may indicated the proximity of a surface contact
- As the periscope head window breaks the surface of the water, the OOD makes three rapid revolutions of the periscope in low power magnification, taking about 8-seconds per revolution. The OOD is searching for any surface contacts that may be nearby and pose a collision threat to the submarine.
- If the OOD does not see any contacts that are nearby, he calls out "No Close Contacts." Conversely, if he sees a close contact, he immediately calls out "Emergency Deep," signaling the ships control party to quickly increase the ship's depth to 150 feet to avoid a collision or engagement by an enemy contact.
- If aerial threats are suspected, the periscope operator then performs a rapid low power search of the overhead area.
- After the rapid low-power search routine, the OOD begins a more deliberate high-power visual search. The high-power search consists of searching a 90-degree sectors in 45

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[82] Naval Warfare Publication NWP 3-13.10, Periscope Employment Manual (Classified), very brief excerpt provided as Exhibit 36 in the navy Court of Inquiry record.
[83] Testimony of RADM Griffiths during US Navy Court of Inquiry, transcript pp. 131-132 and p. 435.
[84] Navy Court of Inquiry, Exhibit 1, enclosure 24, tab 17, Commanding officer's standing order number 6, periscope operations.

second intervals, with intervening low power rapid searches until all four 90 degree sectors of the circle around the ship have been searched. This high power search routing should take about 3 minutes, to complete, plus the additional time needed to perform the intervening low-power searches.

The former commanding officer of the Greeneville described the standard periscope search as follows:

> Following the Officer of the Deck's initial three sweeps to determine no close contacts, he then does an air search, max in elevation, panning down until he reaches the horizon, calls out, "no airborne contacts," and then the next thing he does is he goes into a 360 degree low-power search, takes about 45 seconds and then begins there a 90 degree high-power sector search on the point where he terminates the 360 low-power.[85]

The ship's navigator described the purpose of the periscope depth brief as follows:

… the purpose of the briefs that I give, and I'm--and all the Officer's of the Deck are the same, and I'm sure every submarine's the same. The purpose of those briefs is to discuss evolutions that you are going to do a PD and not safety of the ship type of things. We're talking shooting trash, and broadcast, and positions, and things like that, not--usually I'll do the brief and then I conduct my TMA[86]

On the day of the accident the periscope search was conducted as follows:[87]

- After hearing reports of contacts held by sonar, the commanding officer ordered the OOD to proceed to periscope depth. A PD brief was not held, nor did the OOD make his normal report to the commanding officer regarding contacts. The former commanding officer stated that

  > Because I'd been in the Control Room since the period preceding the angles and dangles here at 1316 on Exhibit 4, I thought I had assay, and therefore in my mind, I justified the Officer of the Deck not making that report. And, you know what, that was wrong because if the Officer of the Deck had made that report, it would've been clear to me that we didn't have a solution on Sierra 14. I would've recognized the new Sierra 14 and done TMA maneuvers to resolve that.
  >
  > when the ship was steady on course one-two-zero and Mr. [OOD-2] made the report to Sonar, "Sonar, Conn steady on one-two-zero, report all contacts," and Sonar reports, "Sierra 14, Sierra 13," my next response to him was, "Mr. [OOD-2], proceed to periscope depth." "Proceed to periscope depth, aye, sir," and that's what happened. [88]

- As the vessel approached the surface the OOD looked through the periscope for shapes and shadows.
- When the periscope broke the surface of the water, the OOD began rapid low-power searches. He completed three revolutions and was about to begin the high power search.

[85] Testimony of former commanding officer, Court of Inquiry transcript p. 1764.
[86] Testimony of *Greeneville* navigator, Court of Inquiry transcript p. 987.
[87] Description of events based on statements of OOD and commanding officer during NTSB interviews and testimony of commanding officer and others at U.S. Navy Court of Inquiry.
[88] Testimony of former commanding officer, Court of Inquiry transcript p. 1757.

- Before the OOD could begin his high power search routine, the commanding officer took control of the periscope from the OOD and began his own search routine.
- The commanding officer searched primarily in the sector he believed that the known contacts were located.
    - In an interview with NTSB, the former commanding officer stated:

> And I remember taking the periscope from Mr. Cohen and turning to the right in a direction where I remember what I thought one of the surface ships would have been. Swept the scope in low power, went to high power, looked, then panned to the right, saw the island, the belt of haze, saw a plane take off thinking, boy, that's really odd, I can only see the mountain peak, I can't see the -- the mountains, but I can just see the very tip tops of them because of this white haze of belt around. Then I could see an airplane taking off. Well, that makes sense because the reef runway extended out beyond the Kualau Mountain range and Wyna Mountain range. And then, I panned to the right where I thought I would see the Ehime Maru. I looked over at the remote repeater, and I saw the numbers and that looks -- 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 what happened is the Ehime Maru was perhaps further to the right, and as I swept in low power looking through here, I -- I missed her. And -- and that's -- 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 -- the degree of optics that I was covering would encompass and overlap that area of uncertainty.[89]

    - During the U.S. Navy Court of Inquiry, the former commanding officer described the events as follows:

> Now, I'm at PD, the three sweeps that Mr. [OOD-2] made in low-power revealed no close contacts. Shortly thereafter, I heard from the Electronics Surveillance Measure Petty Officer, Petty Officer Carter, that he had no threat contacts. I felt a sense of relief that there was nothing close by, there was nothing that was a threat to my ship, we'd safely reached PD. Sonar reported they also had no threat contacts. When I saw Mr. [OOD-2] transition from the surface look, elevating the periscope now for the air search, I took the scope from him. Did a low-power 360 degree sweep, it was slower than the quick look that the OODs do for a close contact, I can't tell you the time, but knowing what I do it was slow enough to pan and see the horizon, I recognized that the ship needed to be raised. When I stopped looking astern, abaft my starboard beam, and then asked Mr. [OOD-2], "Bring the ship up a couple of feet. During that period while I was panning, I turned off the PERIVIS to see if that would make a difference on what I was seeing, it didn't. I looked at the Ship's Data Display for the bearing, the three-four-zero, went to high-power-- it was during that time. I felt the ship surge up and as it surged up, I thought to myself, "this is a good look, this is good, I'm up over the wave tops" and I looked down the line of bearing at three-four-zero and saw nothing. I was in time 6 power, flipped over to zero-two-zero, went to 12, hit the doubler, saw nothing there, flipped back to low-power and continued my

[89] NTSB interview of former commanding officer, conducted on March 14, 2002.

> pan to the right. I ended up ultimately with the scope facing forward and then called the emergency deep.[90]

- The former commanding officer stated that he did not receive queuing instruction from the FTOW regarding the exact bearings to the two sonar contacts. Instead he looked in the directions he believed the contacts were located. He stated that

> there was no queuing from the Fire Control Technician of the Watch because he saw that I was looking down the line of bearings where the two sonar contacts were held.[91]

The sonar bearing to S-13 was approximately 020° during the 120° leg, or from 1334 to 1340. Conversely, the recorded data indicates that the fire control solution bearing to S-13 was approximately 008° from 13:34 to 13:37:48, when, at 13:37:48, the bearing to the Ehime Maru increased to 020° concurrently with the FTOW updated the system solution range to 4,000 yards.

- The total elapsed time at periscope depth was about 66 seconds.[92]

On the day of the accident, the ship's navigator noted difficulty in seeing a light colored contact, and that a dark colored contact at approximately the same range and bearing could be seen much easier.[93] In addition, because of the angle of the Ehime Maru relative to the Greeneville, the image size would have been only about half of what it would have been had the Ehime Maru been broadside to the Greeneville. Finally, considering the height of eye of the periscope and the height of the Ehime Maru, the Greeneville should have been able to see the Ehime Maru at a distance of about 8 miles.[94]

A witness at the navy Court of Inquiry stated the following with respect to why the Ehime Maru was not seen during the periscope search:

> I think the depth of the ship and the amount of time that was devoted to the evolution were obstacles to seeing E*hime Maru*. I think there may have been some--how much time that particular bearing was observed as opposed to all the other bearings they were looking at. And exactly how fast the scope was going around, and--so the ability of a human eye to pick that object up as you're moving fast through a bearing. Clearly I think that the failure to very, very deliberately correlate the exact sonar bearing at that time to a high-power look using verbal coaching to get exactly on the right bearing and then deliberately look there. That was done in a more dynamic way without the verbalization and the teamwork of verbal coaching to the exact right bearing. So there was a little less deliberateness to optimizing your chances given that keel depth and the high-powered scope to see it. That was more informally accomplished. All of those things are factors.[95]

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[90] Testimony of former commanding officer, Court of Inquiry transcript p. 1764.
[91] Testimony of former commanding officer, Court of Inquiry transcript p. 1770.
[92] Testimony of RADM Griffith at U.S. Navy Court of Inquiry, COI Transcript, p. 134, estimates time at PD as 80 seconds. Subsequent analysis of recorded SLOGGER data indicates that total time at periscope depth was 66 seconds.
[93] Statement of Greeneville navigator at NTSB interview on February 21, 2001, and testimony at U.S. Navy Court of Inquiry, COI Transcript, p. 949.
[94] Testimony of RADM Griffith at U.S. Navy Court of Inquiry, COI Transcript, p. 288-289. The ½ visible length estimate is derived from the sine of 30 degrees being equal to 0.5.
[95] Testimony of RADM Griffith at U.S. Navy Court of Inquiry, transcript p. 295-296.

The navy Court of Inquiry criticized the periscope search as not in accordance with standard procedures: “The artificial urgency created by the CO caused him to deviate from NWP guidance and his own Standing Orders when performing TMA, the ascent to periscope depth, and his visual search at periscope depth.”[96]

On the day of the accident, the commanding officer ordered a depth of 58 feet in order to get a “higher look” than the original depth of 60 feet order by the OOD. This keel depth provided a height of eye of the periscope window of approximately 6 feet – 07 inches (64’-07” – 58’-00”) and a distance to the horizon of approximately 2.9 nautical miles. The height of the *Ehime Maru’s* bridge above the waterline was approximately 25 feet, which provided a distance to the horizon of 5.7 nautical miles. Adding the two components gave a distance of 8.6 nautical miles at which the crew of the Greeneville could theoretically have seen Ehime Maru. At the time the Greeneville was at periscope depth, the range to the Ehime Maru was approximately 2500 yards or 1.25 nautical miles. Had the Greeneville decreased its depth to 50, the keel height at which the sail would have just broached, the distance to the horizon from the periscope would have increased by about 1 nautical mile. According to a witness at the navy Court of Inquiry, the Greeneville could have decreased its keel height from 58 feet to 50 feet without detriment to its operations.[97]

<u>ESM Operations</u>. On the day of the accident, the ESM system was manned by a qualified operator and a junior person who was being trained in the operation of the ESM system (U/I or under instruction).[98] When the vessel surfaced, the system detected numerous radar contacts, but none that were classified as signal strength 4 or 5.[99],[100] Consequently, the ESM operator reported “no close contacts” after he heard the OOD made his report of “no close contacts.” After the ESM operator made his initial assessment of the signals that had been detected, he began a more detailed analysis of the signals aimed at classifying the signal types.

During the navy Court of Inquiry, a senior navy investigator testified as to a possible reason why the Ehime Maru was not detected by the ESM as a close contact as follows:

> Now the way that the ESM works on a submarine when your scope first breaks the surface, your antenna is automatically starting to catch these signals. But you have a deluge of signals particularly when you're operating near land 9 miles south of Oahu. Land based, air based radars, in addition to ship based, are going to be inundating the operator. He probably has 10 or more signals at once. And so it takes a finite amount of time not only to determine if any of them are close that are of a shipboard variety, but also analyze them further and refine that input. The time they were at periscope depth of 80 seconds only provided that ESM operator an opportunity to do aural analysis on those signals. He has some sophisticated video digital analysis equipment which allows you to rather quickly break down the parameters, categorize them and assess them for range. At least a rough correlation of range through signal strength. But the operator in ESM did not have time to do that because they were only at periscope depth for about 80 seconds.[101]

And later in his testimony, the same navy witness offered the following information concerning why the Ehime Maru was not classified as a close contact:

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[96] Report of the navy Court of Inquiry, opinion number 14.
[97] Testimony of RADM Griffith at U.S. Navy Court of Inquiry, transcript p. 261.
[98] The description of the events on the day of the accident are based on NTSB interview of the ESM operator and his testimony to the U.S. Navy Court of Inquiry, transcript p. 1023
[99] Testimony of ESM operator at U.S. Navy Court of Inquiry, transcript p. 1024
[100] Testimony of “under instruction” ESM operator, transcript p. 1032
[101] Testimony of RADM Griffiths during Court of Inquiry, transcript p. 140

I know they were listening. I know they used the aural indication. I know this was a tripwire they had established and did not feel they had crossed. So it may be *EHIME MARU's* radar was perhaps in that threshold of where it might have been considered by a routine ship in using routine diligence to determine it was a collision threat or not. It may have been just outside the range where its radar would have provided that indication. I know the ship was trying to make that determination and determine that it was not a collision threat. The ESM operator made a report that we had no initial oral indications that they had a collision threat. So I can't reconstruct that they should have or they shouldn't have. Only theoretically it could have provided enough energy for a reasonable ship and *GREENEVILLE* to have determined that. But that's hindsight and I can't definitively say one way or the other.[102]

A second witness at the U.S. Navy Court of Inquiry testified that the reason why the ESM system failed to detect the Ehime Maru as a close contact was unknown:

ESM propagation is subject to some vagaries just like sonar is. There can be skipping, there can be over, you can bypass the mast, it could be ducted away. But under normal conditions, which I think this day was fairly, oh the weather was a little off, little cloudier than normal around Hawaii, but I don't know of any anomalies that would prevent the signal from reaching the periscope. The antenna--ESM antenna on the boat is actually on the very top of the periscope that they were using. And I don't know of any reason why that signal should not have been there. … I have had--the ESM suite on the ship has been checked out materially, it's--all the bands sweep well, except one of the bands, which was a higher band than the *Ehime Maru's* radar would have been in. That band showed some degradation. But the appropriate receivers for that--that would detect that radar were within specifications, so I don't know a reason why we didn't detect that on ESM.[103]

The former commanding officer of the Greeneville stated that he did not know why the ESM failed to detect the Ehime Maru, but thought the Ehime Maru radar may have been finely tuned and did not have the typical side and back lobes that facilitate identification of a close contact, that the high density of nearby radars and the short amount of time allowed for the ESM operator to analyze the signals may have contributed to the cause.

You have a back lobe, and then you usually have two side lobes. In some of the modern-day radars, you may or may not detect these side lobes or maybe this back lobe, and so, quite often, the difference between a signal strength one contact, which is picking up the main lobe or two, main and back, signal strength three -- which is main, back, and maybe intermittent side and fore is when you've got saturation -- is dependent upon the -- the parameters of this radar.

And I don't know that the ESM wasn't working properly, but the problem that I had, too, is that we're nine miles off the coast of Oahu off of the reef runway where I've got FAA radars, I have other commercial radars operating. So there's a lot of background noise and interference, and in hindsight, you know, could have spent more time up there to let ESM sort it out. But usually, they know pretty quickly when they have a saturated signal or something that indicates a close-to-board threat. In this case, it wasn't detected for whatever reason.[104]

In addition, the former commanding officer stated that the ESM system was outdated, ineffective in electronic surveillance intercept, and difficult to maintain:

[102] Testimony of RADM Griffiths during Court of Inquiry, transcript p. 295
[103] Testimony of Capt Kyle during U.S. Navy Court of Inquiry, transcript p. 619
[104] NTSB interview of former commanding officer, conducted on March 14, 2002.

> … our ESM, the Whirly 8, that thing is a dinosaur and a piece of crap when it comes to electronic surveillance intercept. Chronically burning cards and material problems with it, and you have to be almost a genius to figure out how to troubleshoot, fix, and repair it. And there are a select few individuals in this world who know how to do that.[105]

<u>Emergency surfacing drill (EMBT blow)</u>. The emergency main ballast tank (EMBT) blow is a procedure used to quickly surface a submerged submarine in the event of a casualty that immediately threatens the safety of the submarine. The EMBT blow procedure involves the introduction of high pressure air (4500 psi) into the main ballast tanks from air receivers (storage tanks) located near the main ballast tanks. The flow of air to the ballast tanks can be quickly initiated by the activation of the levers on two pilot valves (also called “chicken switches”) located near the ballast control panel (see figure 10). The volume of air admitted to the main ballast tanks is controlled by the duration of the blow. On the day of the accident, the *Greeneville* conducted a ten-second blow EMBT blow to quickly ascend from a depth of 400 feet.[106]

Figure 6 Video Clip (avi) - Emergency Blow (U.S. Navy video) (double click left picture to activate video)

The EMBT blow procedure and related system hardware was developed after the loss of the USS Thresher in 1963 as part of the Navy’s SubSafe program.[107] The Navy requires that crewmembers perform an EMBT blow procedure (as a casualty drill) once per year, but it is often performed during distinguished visitor (DV) cruises for the entertainment of civilian guests.[108]

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[105] NTSB interview of former commanding officer, conducted on March 14, 2002.
[106] Testimony of RADM Griffiths during Court of Inquiry, transcript p. 216
[107] Testimony of CDR Waddle during Court of Inquiry, transcript p. 1688.
[108] Testimony of RADM Konetzni during Court of Inquiry, transcript pp. 761-762.

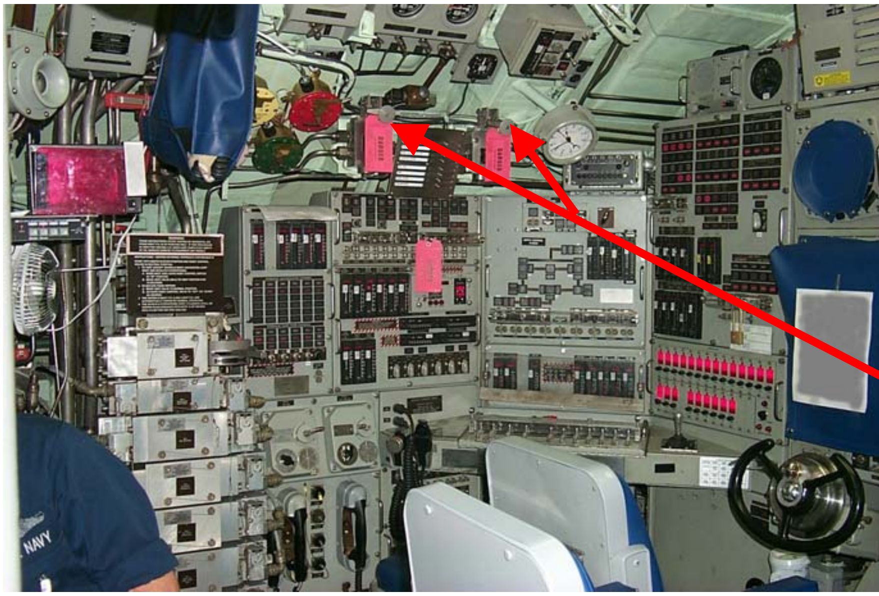

Pilot valves for EMBT blow system above ballast control station – red danger tags hung on activation levers

Figure 7 - Ballast control console and EMBT blow activation valves (US Navy photo)

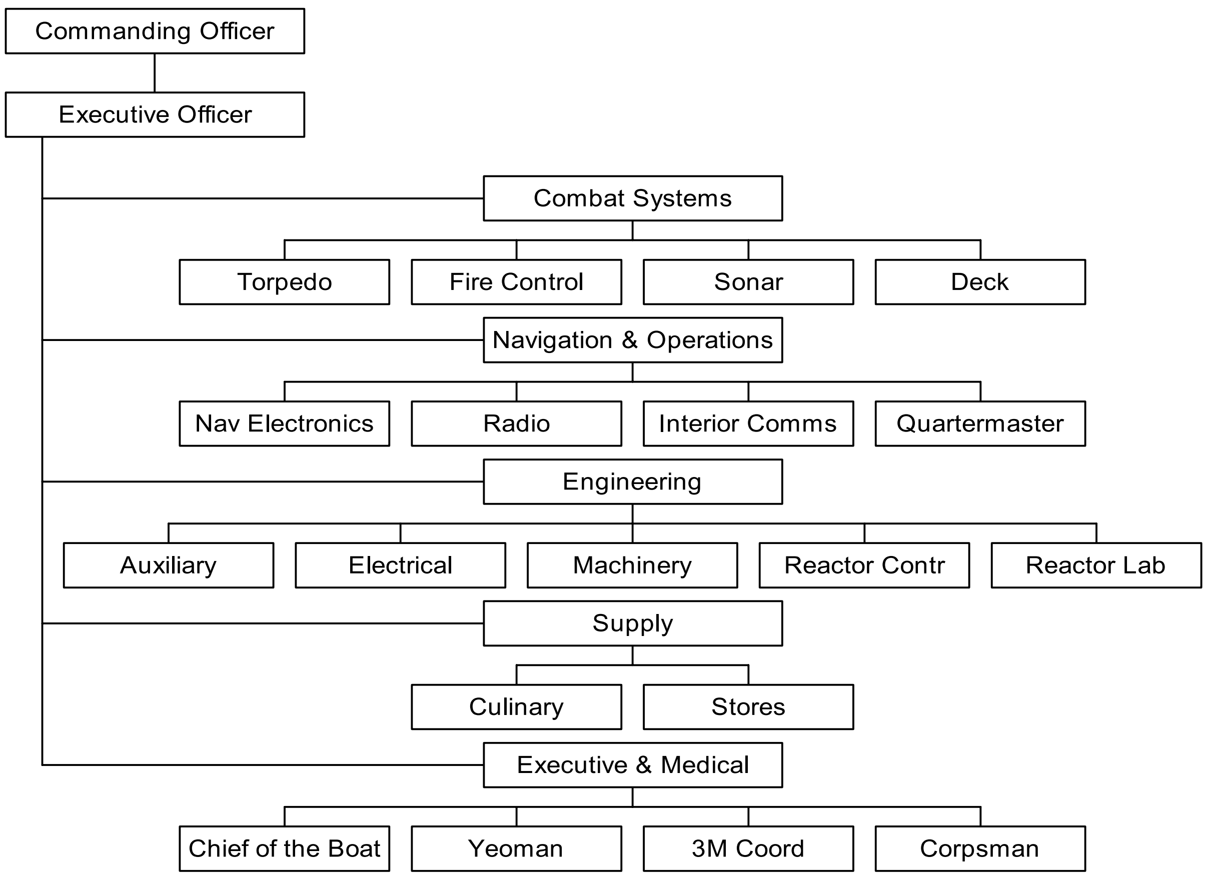
Shipboard organization. The overall responsibility for the readiness and operation of the submarine lied with the commanding officer (CO). The executive officer (XO) was the next senior officer on board, and was responsible for the direct coordination of the administrative and training activities of the ship. The XO was second in command and would assume command in the event the CO was disabled. His duties included: coordination all departments; morale, welfare, and discipline of the crew; assignment of personnel and records; preparation of ships bills and orders; ship's correspondence; supervision all education and training; loading and berthing; approval of crew liberty and leave.

The vessel had two distinct chains of command – the *administrative* chain of command and the *operational* chain of command. In the administrative chain of command the department heads reported to the commanding officer through the Executive Officer. The remaining crewmembers were organized into five departments in what was termed the administrative chain of command. Within each department were several smaller groupings of personnel known as divisions. The officer in charge of the department was referred to as the department head and he was responsible for all aspects of his assigned department. Subordinate to the department heads were the division officers, and they act as assistant to the department head under which they were assigned.

- Navigation & Operations Department – was composed of the Navigation Electronics, Radio, Interior Communications and Quartermaster divisions. This department was responsible for operation and maintenance of navigation and communication equipment and records, and the navigation of the vessel. In addition, the department was responsible for the preparation of operational plans and training schedules, intelligence activities, and tactics.
- Combat Systems Department – was divided into four distinct divisions: Torpedo, Fire Control, Sonar and Deck.
- Engineering Department - divided into five distinct divisions: Auxiliary, Electrical, Machinery, Reactor Controls and Reactor Laboratory Divisions. The department was responsible for the operation, maintenance of ships machinery; damage and casualty control; repair of hull and machinery; power, lighting, air, and water (hotel services).

- Supply Department - consisted of the Culinary and Stores Divisions. This department was responsible for the ordering, receiving, and inventorying stores, as well as the preparation of meals for all shipboard personnel.
- Executive & Medical Department - consists of the following components: The Chief of the Boat (COB); Yeoman, Management and Material Maintenance Coordinator (3M) and the medical corpsman. Their function is to assist the Executive Officer in the discharge of his administrative responsibilities and to maintain the health of the crew.

Adminstrative Organization



Operational organization. Operation of the vessel was accomplished through use of the *operational* chain of command and the watch organization.[109] At the top of the operational chain of command was the commanding officer, who was on call 24 hours per day. The watch organization provided for around-the-clock rotating assignments of personnel assigned to stand watches. The watch organization was designed to conduct and coordinate the actual operations of the ship, and was divided

[109] The shipboard organization and duties of personnel is specified by navy instruction OPNAVINST 3120.32c, the Standard Organization and Regulations Manual (SORM).

into three or more similar groups called *sections*. Separate watch bills were prepared for each of the various operational conditions of the vessel, for example, a in port watchbill for use when the vessel was not underway, an underway watchbill when the vessel was underway, a maneuvering watchbill when the vessel was entering or leaving port or operating near shoals, and a modified piloting watchbill for use when the vessel was operating a certain distance from shoal water. All personnel assigned to stand watches were assigned to one of three or more *watch sections*. The CO and the XO were to be available at all times, and technically they were not assigned to any watchbill.[110] At the time of the accident, the Greeneville was operating with a modified piloting parting, which added several watchstanders to the normal piloting party, such as a navigation supervisor and fathometer watchstander, to assist with the navigation of the vessel.

Below the commanding officer in the operational chain of command was the Officer of the Deck (OOD), who was responsible for the safe navigation of the ship and carrying out the routine of the ship during his watch hours. He was required to keep the CO informed by making scheduled and conditional reports to the CO. The OOD reports directly to ‘the Commanding Officer for the safe navigation and general operation of the ship; to the Executive Officer for carrying out the ship’s routine; and to the Navigator on sighting navigational landmarks, and on making course/speed changes. He monitors the tactical situation closely, analyzing sonar contacts by maneuvering the ship to determine their range and movements and performs TMA.

Normally the OOD would have the *deck* and the *conn*. To have the *deck* means to supervise all functions and maneuvers of the ship and to supervise all personnel on watch, and to have the *conn* means to be responsible for directing the movement of the ship with rudder and engine orders.

The OOD was assisted by a second officer, the Engineering Officer of the Watch (EOOW), who controlled the reactor plant and all engineering evolutions in the propulsion plant. In addition, personnel were assigned to stand watches in the various operating areas of the ship, such as the sonar room, attack center, radio/ESM room, and the ship control station. The following is a brief description of the various underway watch positions.[111]

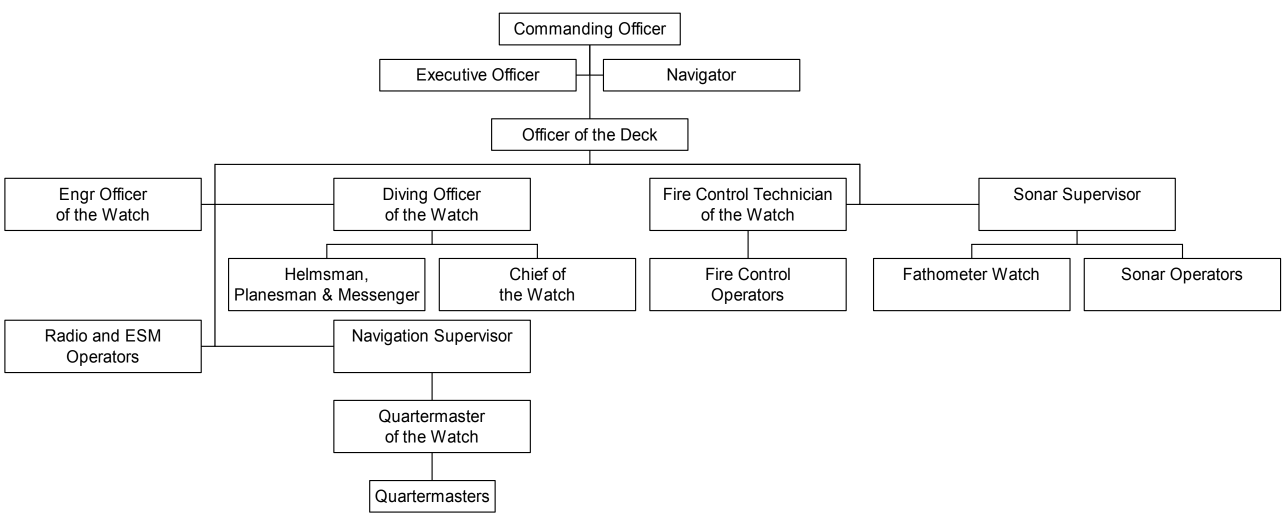
- Engineering Officer of the Watch (EOOW) – in charge of an engineering department watch section. He is responsible for safe and proper performance of engineering department watches and for ensuring that all orders from the OOD concerning the speed and direction of rotation of the main engines are executed promptly and properly.
- Diving Officer of the Watch (DOOW) – responsible for the safe and proper control of the ship while submerged. His primary function was to ensure the ship achieves and maintains ordered depth, but he also has an overall supervisory role for the watchstanders in the control room. His Watch station was located in the ship control center, directly behind the helmsman and planesman. He was the leader of the part of the five man ship control party, and supervised the Chief of the Watch, the helmsman, the planesman, and the messenger.
- Chief of the Watch (COW) – responsible for operating the ships ballast control station to maintain the ship at a neutrally buoyant condition and for ensuring that the ballast is properly distributed to maintain an even vessel trim and list. He generally operates all the auxiliary systems of the ship, high-pressure air, hydraulics, trim and drain and indications that a ship needs to have operated, so that it maintains proper buoyancy. He is a member of the ship control party.
- Helmsman and Planesman (aka Lee Helmsman) – are two separate watch positions that are responsible for operating the ships helm and plane controls to cause the vessel to change course

[110] Testimony of RADM Griffiths at U.S. Navy Court of Inquiry, transcript, p. 106.
[111] Description for watch position from Navy Instruction OPNAVIST 3120.32c – Standard Operations and Regulations Manual and testimony of RADM Griffiths at U.S. Navy Court of Inquiry, transcript, pp. 101-103.

and depth in response to orders from the Conning Officer (normally the OOD). Are members of the ship control party.

- Messenger - a jack of all trades. He rotates in to relieve either the Helmsman or Planesman when they become fatigued position. Generally, he is qualified to be in either of these two seats, but also runs messages, brings coffee and does other duties as assigned by the Chief of the Watch or Diving Officer of the Watch
- Sonar Supervisor – responsible for overseeing the operation of the sonar system and subordinate sonar room watchstanders. Sonar operators are responsible for acquiring, classifying, and tracking all sonar contacts, and for ensuring that sonar contact information is passed to the fire control technician of the watch.
- Fire Control Technician of the Watch (FTOW) – responsible for overseeing the operation of the fire control system and subordinate fire control operators. Fire control operators are responsible for determining the solution (course, speed, and range) for all sonar contacts sent over from the sonar system. In addition, the FTOW is responsible for maintaining the Contact Evaluation Plot (CEP), a paper record of contact bearings and own ship course information. Stands watch in area on the starboard sided of control room called the *attack center*.
- Quartermaster of the Watch (QMOW) – responsible for the proper maintenance of the Deck Log, end for navigational matters.
- Radio Operator – responsible for the transmission and receipt of communications affecting the operations or maneuvering of the ship.
- ESM operator – responsible for operating the ESM system when the vessel is at periscope depth or on the surface. Responsible for identifying and classifying all sources of electromagnetic radiation detected by the ESM system.

Underway Operational Organization
Watch Organization



Shoreside management. The commanding officer of the *Greeneville* had two chains of command in which he reported – an administrative chain of command and an operational chain of command. He received administrative supervision and direction from his squadron commander and operational direction from the submarine operating authority (which was COMSUBPAC for local operations or an operating task force commander (CTF) for deployed operations). The squadron commander and his staff administratively oversaw the crew of the *Greeneville* as well as four other submarines assigned to squadron 1. The squadron commander was responsible for the evaluation and enhancement of the training of submarines in his squadron and for the certification of those submarines for deployed operations. In addition, the squadron commander provided input to COMSUBPAC regarding the operating and maintenance schedule of the *Greeneville.*[112] The commanding officer of the squadron 1 summarized his duties as follows: "So, what my principal role then--the training of the submarines, although I remain responsible for their readiness to deploy and so, quite frankly, the way I run this squadron is to keep my hands, if you will, into those other areas; which the largest piece of which is maintenance because they impact so significantly readiness aboard the ships."[113] The squadron commander had a staff of 16 men, including six or seven officers.

Assisting the squadron commander with certain administrative activities of submarines in the Pacific submarine force was the Naval Submarine Support Command. This command was responsible for communications, supply, medical, and manpower issues. These responsibilities used to be all encompassed in the traditional submarine squadron command, but were divested from the squadrons and consolidated into the Naval Submarine Support Command in Pearl Harbor.[114]

When the Greeneville was deployed overseas (normally to the western Pacific Ocean), the commanding officer of the Greeneville reported to a task force commander (dual-hatted as Commander Submarine Group 7). The task force commander and his staff were stationed in Japan and he was responsible for the operational oversight and control of all forward deployed submarines in his area of responsibility.

The various submarine squadrons in the Pacific area were grouped together under the administrative command of the type commander for submarines in the Pacific, known as Commander Submarine Force U.S. Pacific Fleet (COMSUBPAC). COMSUBPAC provided administrative direction and oversight of the squadron commanders, and indirectly to the commanding officers of the submarine assigned to the Pacific submarine force. In role of Submarine Operating Authority, COMSUBPAC provide operational direction to submarines assigned to the command.

In October 2001, the navy established a new organizational entity and a change in responsibilities for the Atlantic and Pacific Submarine Forces. The Commander, Submarine Forces U.S. Atlantic Fleet assumed additional duties as Commander, Naval Sub-marine Forces (COMNAVSUBFOR). The Commander, Submarine Forces U.S. Pacific Fleet, assumed duties as his Deputy Commander. The stated purpose of the creation of COMNAVSUBFOR was to improve alignment and efficiency by establishing standard fleet-wide practices on both coasts and to create a single voice for submarine readiness requirements, operational and technical needs. The new COMNAVSUBFOR stated "The establishment of COMNAVSUBFOR will enable us to easily reduce the differences in policy, doctrine and procedures within the Submarine Force … and to achieve greater unity of effort in fulfilling the Title 10 responsibilities to organize, train and equip the United States Navy." However, COMSUBPAC and COMSULANT remain the operational commanders in their respective theaters. The establishment of this new "super type-commander" is part of the CNO's vision of restructuring the Navy for greater emphasis on fleet operating forces. Both the Navy's surface and air communities shifted to similar arrangements in October 1999.[115]

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[112] Testimony of Capt Sneed, Commander Submarine Squadron 1, Court of Inquiry, transcript p. 911.
[113] Testimony of Capt Sneed, Commander Submarine Squadron 1, Court of Inquiry, transcript p. 914.
[114] Testimony of Capt Sneed, Commander Submarine Squadron 1, Court of Inquiry, transcript p. 913.
[115] Information on change from
http://www.chinfo.navy.mil/navpalib/cno/n87/usw/issue_13/commander.htm

The superior commands for COMSUBPAC were Commander-in-Chief U.S. Pacific Fleet and U.S. Pacific Command (see figure 9). The operating forces commanders and commanders-in-chief (CINCs) have a dual chain of command. Administratively, they report to the Chief of Naval Operations and provide, train, and equip naval forces. Operationally, they provide naval forces and report to the appropriate Unified Commanders in Chief. As units of the Navy enter the area of responsibility for a particular Navy CINC, they are operationally assigned to the appropriate numbered fleet. All Navy units also have an administrative chain of command with the various ships reporting to the appropriate Type Commander.[116]

[116] Information about the organization of the navy's operating forces and the shoreside establishment was obtained from the navy's official web site http://www.chinfo.navy.mil/navpalib/organization/org-top.html

Shoreside Management Organization

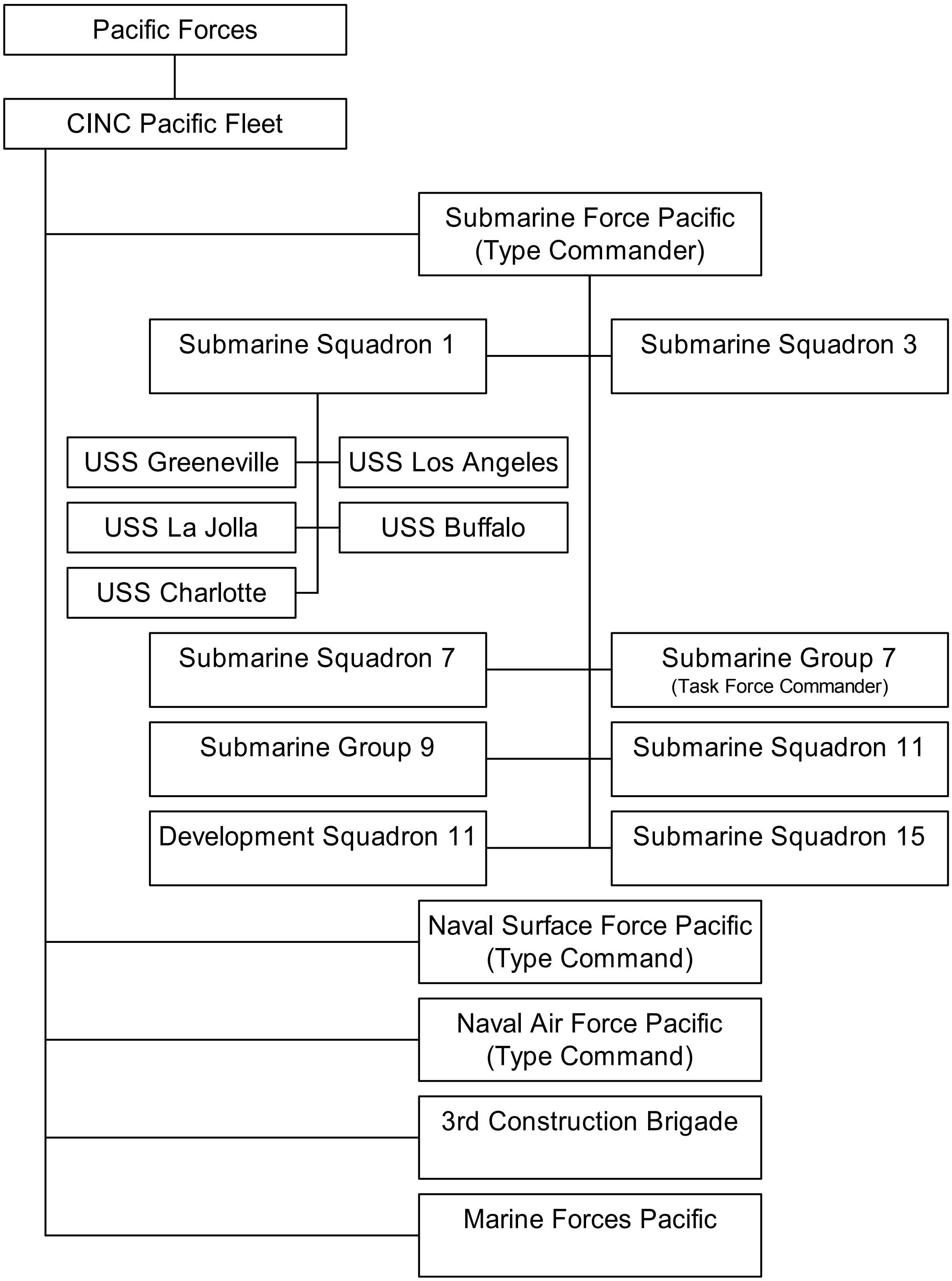

Figure 8 Navy shoreside management organization

Casualty Reporting System. The process for reporting equipment failures within the Navy is the casualty reporting system.[117] The Casualty Report (CASREP) provides the operational chain of command, supporting commands and other agencies with early information concerning equipment casualties that affect the combat readiness of the unit. Navy units are required to submit a CASREP as soon as possible but not later than 24 hours after the occurrence of a significant equipment casualty that cannot be corrected within 48 hours.

A casualty is defined as an equipment malfunction or deficiency that cannot be corrected within 48 hours and which reduces the unit's ability to perform a primary mission, or reduces the unit's ability to perform a secondary mission. (See figure 13).

[117] Guidance for when and how to submit a casualty report is contained in Operational Reports, Naval Warfare Publication (NWP) 10-1-10.

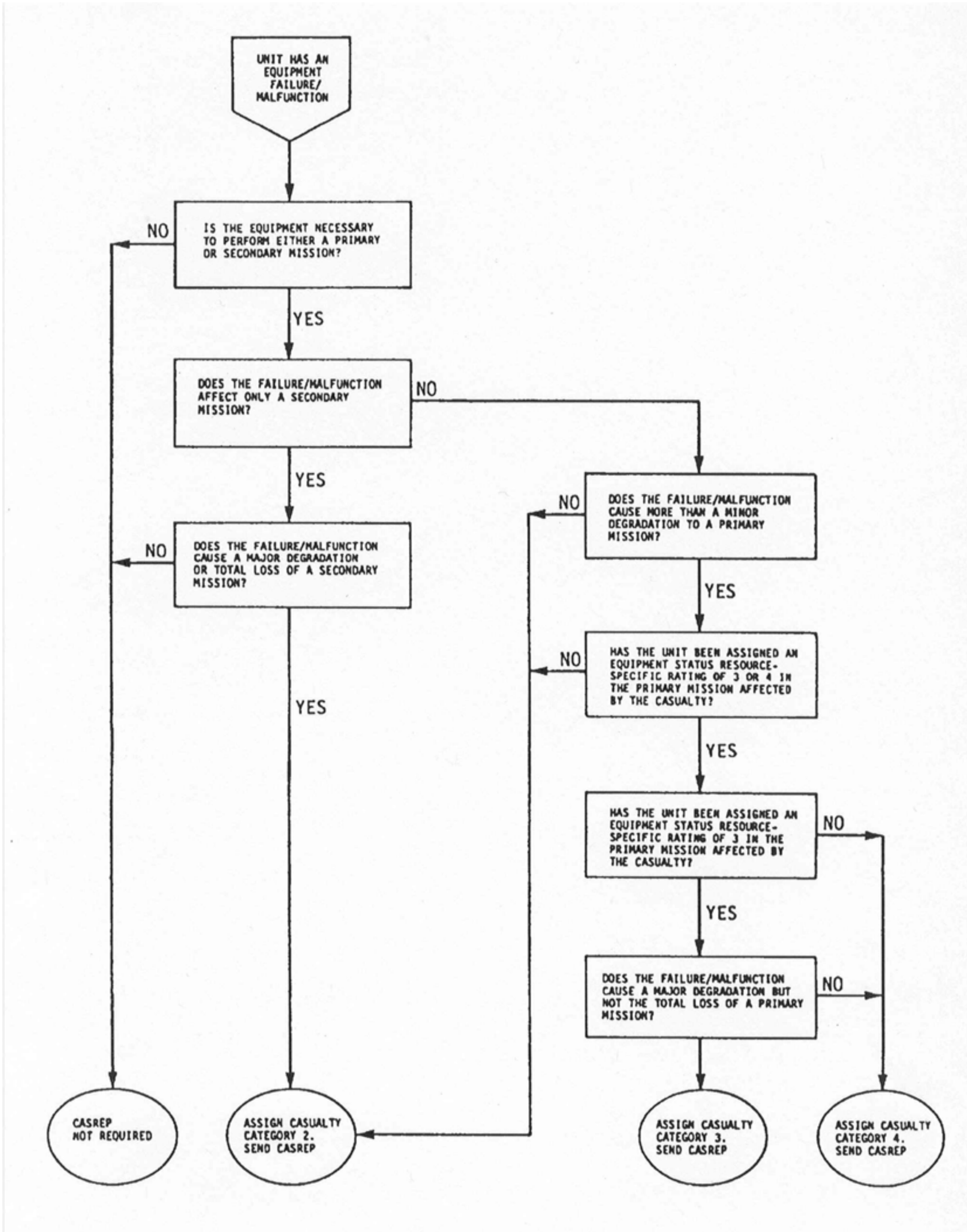

Figure 9 - CASREP decision tree (U.S. Navy figure)[118]

The reporting of casualties is intended to advise operational commanders and support personnel of the status of significant equipment malfunctions that may result in the degradation of a unit's readiness.

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[118] Decision tree taken from navy training manual at http://www.advancement.cnet.navy.mil/products/web-pdf/tramans/bookchunks/14084_ch5.pdf

The CASREP also reports the unit's need for technical assistance and/or replacement parts to correct the casualty. The CASREP usually results in an expedited repair of equipment because the maintenance organization gives priority in the handling of requests for parts or technical assistance when the equipment deficiency has been reported with a CASREP.

On the day of the accident, the AVSDU (the control room sonar display) on Greeneville was inoperative. However, it did not meet the criteria for the submitting a CASREP and none was submitted. The squadron commander of the *Greenville* stated that had he known the AVSDU was inoperative on the day of the DV cruise he would not have allowed the vessel to proceed to sea. In an interview with NTSB CAPT Snead stated:

> The morning of the collision, he got underway, his AVSDU was out of commission, Analog Visual, Sonar Display Unit, the sonar display. I didn't know that. Had I known that, I would not have let him go to sea, because I can't believe that a submarine skipper can get underway for something like a DV cruise, without that. That is the, there are few displays of truth in the control room. That is what I teach my COs, very few.[119]

During the navy's Court of Inquiry, a senior navy investigator testified that the AVSDU was not a critical to the vessel getting underway, but that some form of compensation for its unavailability should have been made:

> … when I was a submarine CO and that piece of equipment was broken, which it rarely was, but did happen, I felt somewhat naked. It was a big deal and I would establish a temporary standing order and direct the crew to add in an additional conservative layer of actions to reduce the risk that was created by having this key aid to the Officer of the Deck out of commission. Of course, with hindsight, I can say the ship should have done that, maybe the ship did consider doing that, but clearly you would not operate with less margin than normal to safety if that was broken. You would bias to operate with more because it's a vital piece of gear.
>
> I believe that a ship should be able to get underway and operate safely and come back at the end of that day without this piece of equipment operating. However, compensation would be appropriate when it was out of commission because of its importance to the Officer of the Deck understanding the ship's contact picture. But certainly it's not a fail to sail item. The ship can operate without that piece of gear. Submarines, in general, have a lot of gear that you can compensate for and continue to operate safely without. And I would put this in that category.[120]

<u>Operational Risk Management </u>(ORM). The purpose of the navy's risk management program is to minimize risks to acceptable levels, proportional to mission accomplishment. According to the Navy's ORM policy instruction, "the ORM process is a decision making tool used by people at all levels to increase operational effectiveness by anticipating hazards and reducing the potential for loss, thereby increasing the probability of a successful mission."[121] Guidance provided in the original 1997 version of the instruction stated, "fleet and type commanders **should** [emphasis added] incorporate the Operational Risk Management into operations, exercises and training." In the year 2000, the navy revised the instruction to say, "All Navy and Marine Corps activities **shall** [emphasis added] apply the principles of ORM in planning, operations and training.

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[119] NTSB interview of CAPT Snead held on March 15, 2002.
[120] Testimony of RADM Griffiths during Court of Inquiry, Court of Inquiry, transcript, pp. 109 and 268
[121] Navy Instruction OPNAVINST 3500.39A dated Sep 26, 2000. Prior version OPNAVINST 3500.39 dated Apr 03, 1997.

According to the navy program instruction, ORM is a closed loop process of identifying and controlling hazards. It follows a 5-step sequence, is applied on one of three levels depending on the situation, and is guided by four principles. The five steps are: Identify Hazards, Assess Hazards, Make Risk Decisions, Implement Controls, and Supervise. The three levels of application of ORM are Time Critical, Deliberate, and In-Depth, and these levels describe the formality and depth of the analysis made. The principles of applying ORM are Accept risk when the Benefit is greater than Risk, Accept no unnecessary risk, Anticipate and manage risks by planning, and Make risk decisions at the right level.[122]

The navy's court of inquiry found that "Had *GREENEVILLE's* CO and crew been practicing the basic tenants of Operational Risk Management), the collision may have been avoided," and recommended "COMSUBPAC review the adequacy of its current Operational Risk Management program."[123]

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[122] Department of the Navy instruction OPNAV Instruction 3500.39A

[123] Report of the U.S. Navy Court of Inquiry, dated April 13, 200, Finding No. 66 and Recommendation No. 8.

Other Information

U.S. Navy Investigations. The U.S. Navy investigated this accident in three separate investigations. The first was termed a Preliminary Investigation and it was conducted from Feb 10 to 14, 2001, with a report completed on February 14, 2001. The second investigation was termed a Court of Inquiry and it included 12 days of formal public hearings.[124] The Court of Inquiry hearings were conducted between March 5 and March 20, and the final report of findings of fact, opinions, and recommendations was made public on April 13, 2001. The third investigation was a safety investigation that was conducted by the Naval Safety Center (OMS needs to request a copy of the final report).

In its report of findings of fact, opinions, and recommendations, the Court of Inquiry issued the following twenty-six recommendations:

1. That the Commander in Chief, U.S. Pacific Fleet, take *GREENEVILLE's* CO, CDR [(b/6)] , to Admiral's Mast to answer for his actions on 9 February. While mindful of the serious and painful consequences of his failures that day, the Court recommends against court-martial due to the absence of any criminal intent or deliberate misconduct on his part. While his actions were negligent and careless and represented a serious departure from the high standards expected of officers in command, they were not so egregious as to warrant trial by court-martial. In reaching its recommendation, the Court also considered CDR [b/6] 20 years of dedicated and faithful service to the Navy and country.
2. That the new Commanding Officer of USS GREENEVILLE take the FTOW, FT1(SS) [b/6], to Captain's Mast to answer for his actions on 9 February. In addition, that Petty Officer [b/6] be made to requalify before standing another underway watch as FTOW.
3. That the new Commanding Officer of USS GREENEVILLE admonish the XO, LCDR Gerald K. Pfeifer, for his lack of oversight of the enlisted watchbill and failure to ensure only qualified personnel were permitted to stand watch.
4. That the new Commanding Officer of USS GREENEVILLE admonish the OOD, LT(jg) [b/6], for his lack of foresight and attention to detail in standing his watch.
5. That the new Commanding Officer of USS GREENEVILLE admonish the COB, MMCM(SS) [b/6], for his lack of forceful backup of the chain of command, lack of oversight of the enlisted watchbill, and failure to ensure only qualified personnel were permitted to stand watch.
6. That the new Commanding Officer of USS GREENEVILLE admonish the Sonar Supervisor, STS1(SS) [b/6], for poor watchstanding and backup of the contact management team and failure to ensure only qualified personnel were permitted to stand watch in Sonar. In addition, that Petty Officer [b/6] be made to requalify before standing another underway watch as Sonar Supervisor.
7. That COMSUBPAC ensure compliance with COMSUBLANT/COMSUBPACINST 5400.40A and NWP 3-21.22.3 standards that permit only fully qualified Sonarmen to stand sonar watches.
8. That COMSUBPAC review the adequacy of its current Operational Risk Management program.
9. That COMSUBPAC provide information and training to the Force concerning the *GREENEVILLE* collision.
10. That COMSUBPAC review the ability and means of Submarine Squadron Commodores and their staffs to provide meaningful oversight and objective feedback to their submarine commanding officers and crews during the Inter-Deployment Training Cycle. The review should include adequacy of Squadron Staff manning and the mechanisms and tools available to the Commodore to fulfill his responsibility to provide proper oversight and feedback.
11. That COMSUBPAC coordinate a review of submarine open ocean SAR capabilities and requirements with the lead TYCOM and make appropriate recommendations to OPNAV.
12. That the Navy DVE Program continue to be fully supported.
13. That COMSUBPAC admonish the Force Public Affairs Officer for failing to provide proper staff oversight and guidance concerning SUBPAC's DV Embarkation Program.

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[124] A Court of Inquiry is an administrative, fact-finding panel convened to investigate serious incidents. It is not a court in the usual sense, but a formal investigative board.

14. That CINCPACFLT coordinate with OPNAV and CHINFO a complete review of Navy Public Affairs policy and guidance on embarkation of civilian visitors and issue new guidance that is internally consistent, clear and more specific.
15. That CINCPACFLT recommend to OPNAV that approval authority for DV embarks be delegable to TYCOMs.
16. That COMSUBPAC, in coordination with the lead TYCOM, forward recommendations to OPNAV for changes to Public Affairs instructions that reflect the unique nature of submarine operations as they pertain to DV embarks.
17. That the SUBPAC Public Affairs Office provide appropriate oversight and guidance to the Force concerning DV embarks.
18. That SUBPAC review what are appropriate evolutions to be demonstrated during DV embarks.
19. That SUBPAC reemphasize to the Force the operational depth and speed limits that are classified and inappropriate for DV embarks.
20. That SUBPAC establish formal means for disseminating feedback or otherwise sharing information regarding DV embark experiences across SUBPAC.
21. That COMSUBPAC review Hawaiian OPAREA maritime traffic density with the USCG and other appropriate government agencies every three years.
22. That COMSUBPAC coordinate with the NOAA to remove reference to the "Submarine Test and Trial Area" from NOAA's "HAWAII to OAHU" chart (#19340) and any other nautical charts used by military and civilian mariners.
23. That COMSUBPAC admonish his Chief of Staff, CAPT Robert [b/6], for failing to professionally carry out his duties and responsibilities on 9 February. The admonishment should specifically address his failure to conduct a proper turnover of his Chief of Staff duties before embarking onboard GREENEVILLE, failure to enforce SUBPAC classification standards pertaining to submarine operating depth and speed, and failure to provide proper staff oversight and guidance concerning SUBPAC's DV Program.
24. That CAPT [b/6] either enforce or cancel his embarkation memorandum. If he decides to enforce it, that he review it and ensure it adequately addresses all categories of embarks, to include DV embarks.
25. That CAPT [b/6]conduct a thorough brief of Acting COMSUBPAC duties and responsibilities whenever a staff officer succeeds him to command.
26. That COMSUBPAC clearly identify to the Force who the Acting COMSUBPAC is whenever an officer succeeds to command.

Additional Figures

Figure 10 ***Ehime Maru*** **underway** ***(photo from Ehime Maru*** **from vessel promotional brochure)**

船橋（コックピット型コンソール等）

Figure 11 ***Ehime Maru*** **bridge, showing radar display units** ***(*****photo from** ***Ehime Maru*** **from vessel promotional brochure)**

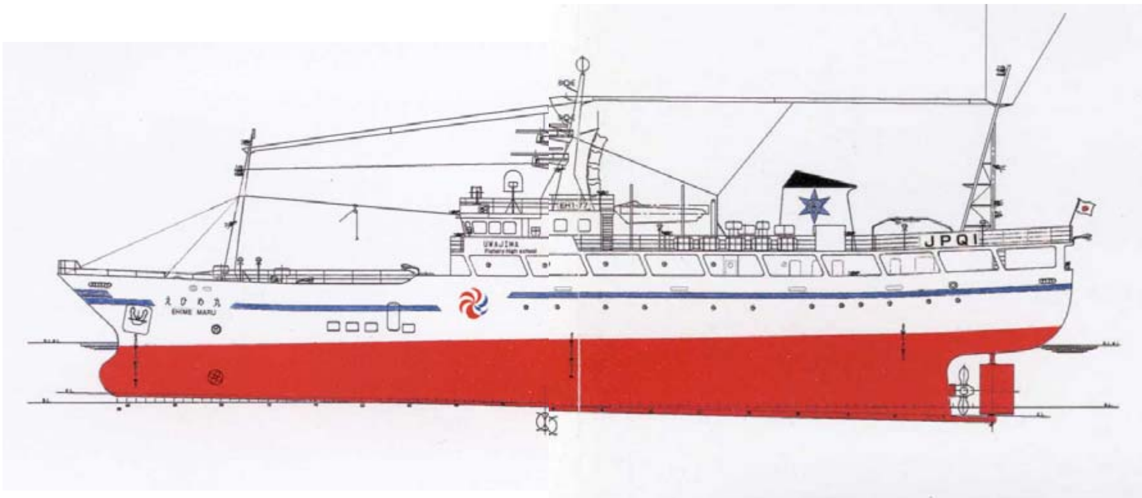


Figure 12 Outboard profile (drawing from Ehime Maru from vessel promotional brochure)

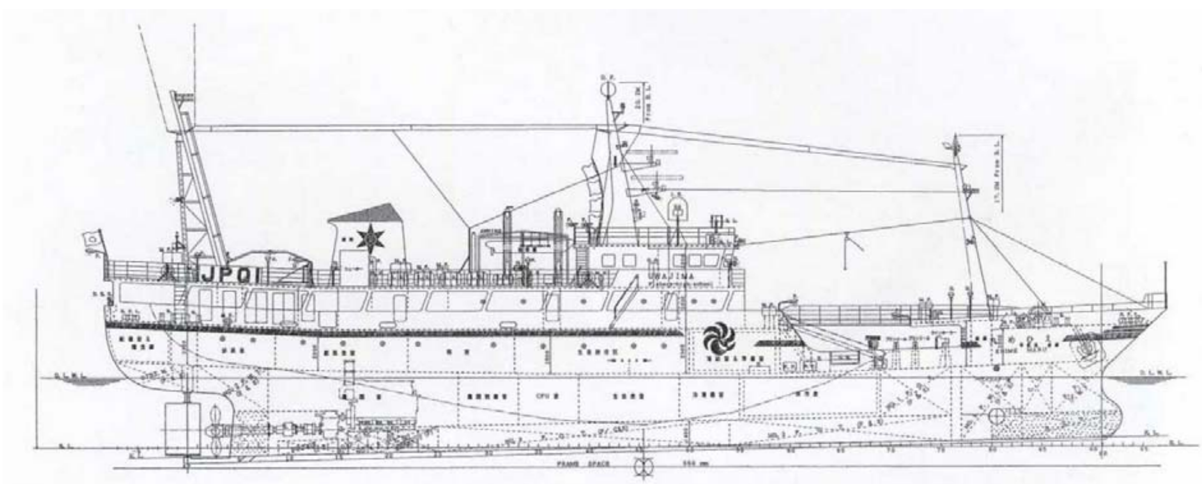
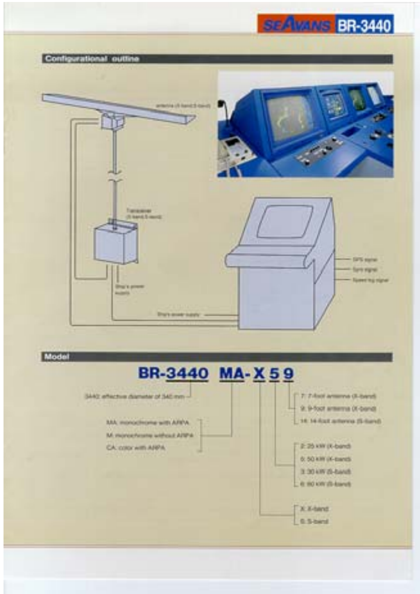
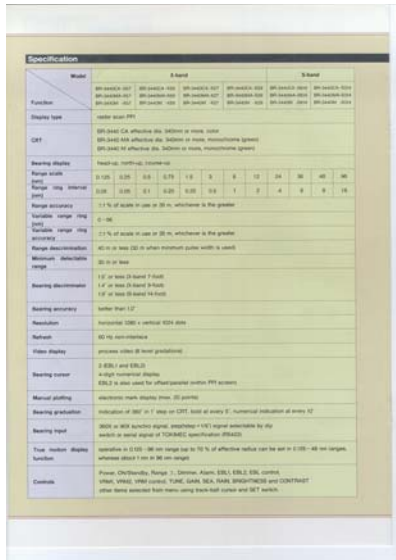


Figure 13 Outboard profile (drawing from Ehime Maru from vessel promotional brochure)





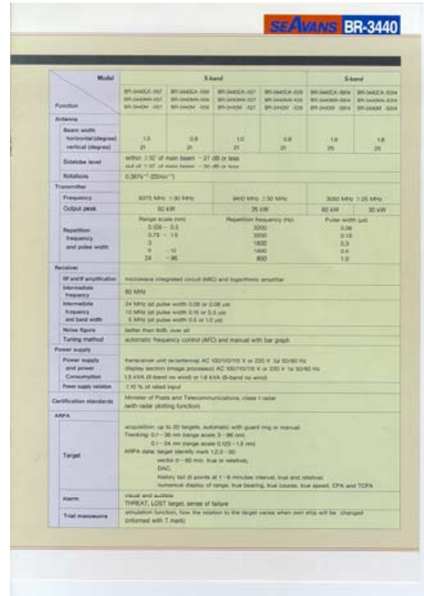


Figure 14 Radar Information from manufacturer's website:

http://63.194.7.195/marine/IMAGES/BR-3440/pages/BR-3440PG_03.htm