National Transportation Safety Board

Marine Accident Brief

Contact of Bulk Carrier *Shandong Fu En* with Ergon-St. James Terminal Wharf

Accident type	Contact	**No.** DCA18FM020
Vessel name	*Shandong Fu En*	
Location	Lower Mississippi River near mile 161, Convent, Louisiana 30°01.82' N, 090°50.40' W	
Date	April 6, 2018	
Time	0637 central daylight time (coordinated universal time – 5 hours)	
Injuries	None	
Property damage	$6.25 million est.	
Environmental damage	None	
Weather	Visibility 10 miles, mostly cloudy, winds south-southeast 11 knots; air temperature 70°F; morning twilight 0621, sunrise 0645, evening sunset 1723, evening twilight ends 1947	
Waterway information	Lower Mississippi River has a project depth of 45 feet at the accident location; high-water conditions were in effect, with the current about 5.4 mph (4.7 knots). The distance between the north end of the Ergon-St. James Terminal and the south end of the Convent Marine Terminal wharves is 1,479 feet (451 meters).	

About 0637 on April 6, 2018, while turning around to head downriver with the assistance of three tugboats, the bow of the bulk carrier *Shandong Fu En* struck Dock 1 of the Ergon-St. James Terminal wharf at mile 160.7 on the Lower Mississippi River during high-water conditions. The *Shandong Fu En*, loaded with coal, had just departed the Convent Marine Terminal wharf, located across the river at mile 160.9. No pollution or injuries were reported, but the vessel and the wharf sustained $6.25 million in damage.

Shandong Fu En before the accident. (Photo by Vincent Maritime)

Accident Events

Built in 2017, the *Shandong Fu En* was a 751-foot-long and 105-foot-wide bulk carrier powered by a slow-speed, direct-drive diesel engine. On April 4, 2018, the vessel moored at the Convent Marine Terminal wharf (mile 160.9) at 1735 and began loading coal for export. The vessel was moored with its bow upriver and had three towboats along the vessel's port side in case the force of the current, moving at about 4.7 knots, threatened the vessel's moorings.[1] The river was at high-water stage (14 feet at the New Orleans Carrollton Gage).

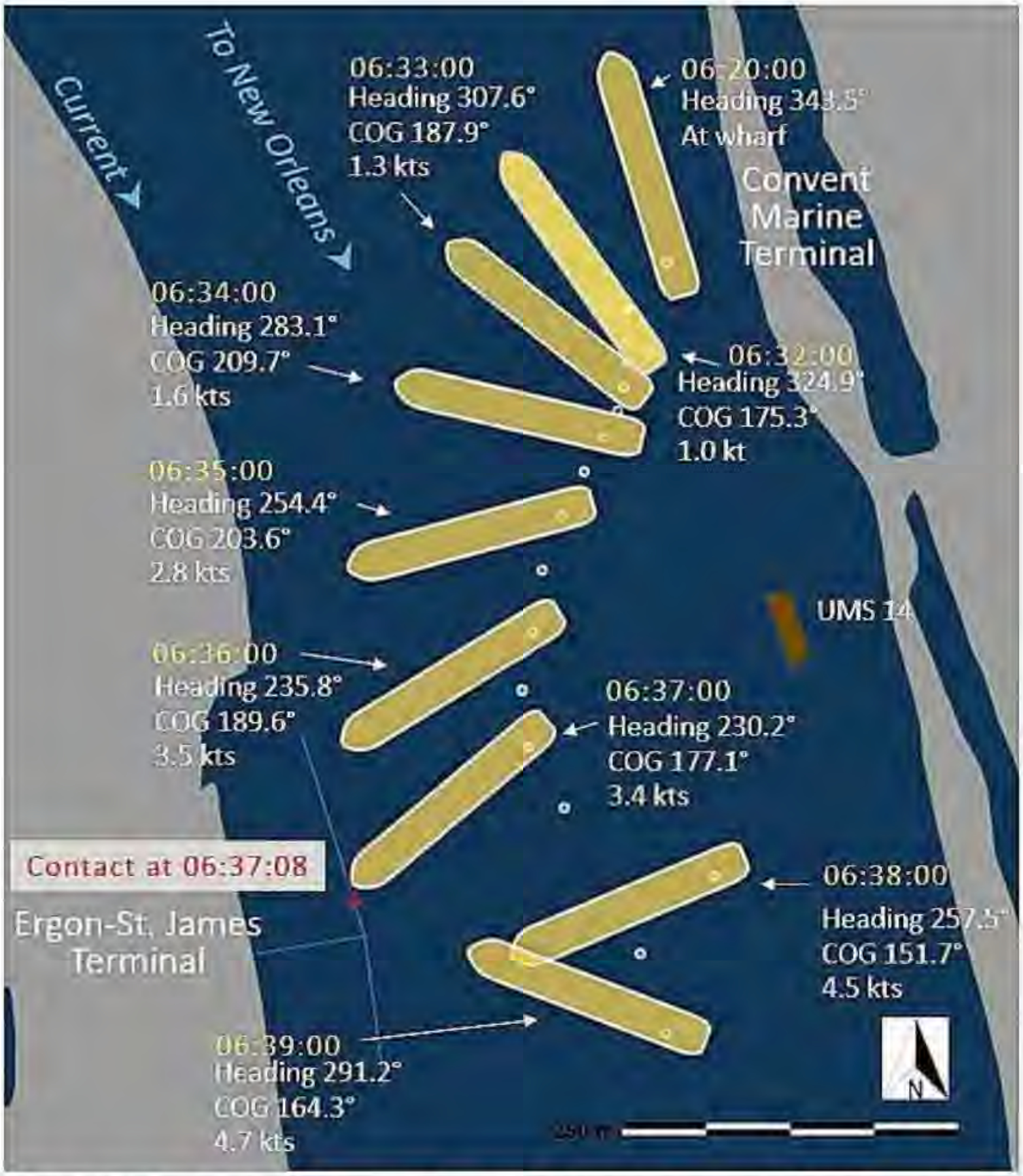
Image of the Mississippi River near Convent, Louisiana. The accident site is marked by a red triangle. (Background by Google Maps)

As an extra precaution during high-water conditions, pilots and tugboats are employed to help keep deep-draft vessels alongside the berth. Therefore, at midnight on April 5, while the *Shandong Fu En* was still loading, a pilot with the New Orleans and Baton Rouge Association

[1] Flood stage is 17 feet and above on the Carrollton Gage.

(NOBRA) came on board the vessel. He planned to stay on board to guide the ship to an anchorage in Reserve, Louisiana, 24 miles downriver at mile 137.

The crew tested the ship's propulsion, steering, and other systems before getting under way; no issues were noted. Three tugboats were assigned to assist the bulker, whose draft was 44 feet, turn in the river. Within the confines of the riverbanks and in the vicinity of the wharf, the pilot planned to swing the vessel's bow to the left/port, across the southbound current and come to a course of 178 degrees (from its original heading of 343 degrees as it lay alongside the wharf) for the voyage downriver.



Trackline of the *Shandong Fu En* from 0620 to 0639, showing the vessel's heading and course over ground (COG). (Map data by Google Maps)

At 0610, the pilot gave orders to begin moving the *Shandong Fu En*. Tugboat *Admiral Jackson* was positioned on the port bow and made fast to the bulker; the *Ned Ferry* was amidships on the port side, not made fast; and the *G. Shelby Friedrich* was at the port quarter, near the stern, not made fast. The pilot provided direction and engine orders to the tugboats and rudder and engine orders to the *Shandong Fu En* crew. With the last lines let go at 0628, the pilot gave orders to move the bulker forward and 150 feet away from the wharf. Usually, he would move a vessel only 30–40 feet away from the Convent Marine Terminal wharf. He told investigators he moved further away from the wharf before beginning the turn to mitigate the risk of colliding with the 220-foot-long-by-65-foot-wide derrick barge *UMS 14* moored astern of the *Shandong Fu En*. He told investigators that once away from the wharf, he planned to make sternway so that the bulker's pivot point would be one-third of its length from the stern. This way, the river current acting on the *Shandong Fu En*'s starboard side would swing the bow counterclockwise.

Voyage data recorder data showed that maneuvering began at 0629:17 as the bulker's heading slowly started moving to port (from 340 degrees) at a rate of turn of less than 5 degrees per minute. About 5 minutes later at 0634:08, the rate of turn momentarily reached as high as 37 degrees per minute. At 0634:56, the pilot ordered dead slow astern, the first of four astern engine orders before the accident. At 0635:09, the vessel's rate of turn had slowed to 22 degrees per minute and its course was 201 degrees, moving slowly across and down the river nearly broadside to the current. At 0635:17, the pilot ordered slow astern; 18 seconds later half astern; and 14 seconds after that, full astern. At 0636:26, thirty-seven seconds after the full-astern order, the *Admiral Jackson* captain radioed, "83 [the pilot], you're pretty close right here." The pilot responded, "I am backing all I got." Less than 15 seconds later, the bow of the *Shandong Fu En* struck the Ergon-St. James Terminal wharf. After a quick assessment of the damage, at 0637:13 the *Admiral Jackson* captain radioed that the ship had hit a mooring dolphin.

Initial impact of the *Shandong Fu En* bow swinging into the Ergon-St. James Terminal wharf at 0637:08. Inset: Screenshot of the *Shandong Fu En* 20 seconds earlier. A crack and three other holes were found in the bulk carrier's shell plate below the waterline. (Video by Ergon-St. James Terminal)

After striking the wharf, the *Shandong Fu En* continued swinging until the vessel was turned around. The pilot then navigated the vessel 13 miles downriver, anchoring the bulk carrier in the Middle Grandview Anchorage (mile 146.8) at 0850. Surveyors examined the vessel and found the forepeak flooded from four penetrations of the shell plate below the waterline—a 6.6-foot-by-2.1-foot crack and three 5.9-inch diameter holes. The initial estimate to repair the damage to the bulk carrier was $250,000. The Ergon-St. James Terminal sustained about $6 million in damage to mooring dolphins and walkways.

Damaged walkway at the Ergon-St. James Terminal about 4 hours after the accident. Inset: Damaged dolphin. (Photo by Coast Guard)

Additional Information

The pilot had 18 years of experience as a pilot, with the last eight of those years on the Mississippi River, including periods of high-water conditions. He told investigators he had moored or undocked 12–20 vessels at the Convent Marine Terminal wharf.

The pilot's 96-hour work/rest history form indicated his only sleep in the previous 36 hours took place the previous day, between 1400 and 1800. The form also showed he had been called (dispatched) to the *Shandong Fu En* 8 hours after his previous assignment, and at the time of the accident, he had been on watch for 12 of the previous 24 hours. Louisiana regulations governing mandatory rest periods for river pilots (LAC 46:LXX.6311) required that "all pilots shall have a minimum of eight hours rest period between turns." A turn is defined as the time from dispatch to the termination of the allotted travel time after leaving a ship. The rules also prohibited pilots from exceeding "12 bridge hours in any 24-hour period."

High-water conditions and associated swift currents are a concern to mariners on the Mississippi River. On the day of the accident, the current was 5.4 mph. Due to the high-water conditions, a pilot and three tugboats were employed to keep the *Shandong Fu En* alongside the dock.

Regulations and restrictions were implemented by the NOBRA Board of Examiners beginning in December 2018 to address high-water concerns for moored vessels. These included temporarily amending their mandatory rest period regulations.[2] Beginning on January 17, 2019, all NOBRA pilots were required to have "a minimum of 12 hours rest period between turns" and on March 14, 2019, the new restrictions also required that a "pilot

[2] The NOBRA Board of Examiners regulates, supervises, and oversees the NOBRA pilots and is charged (by the Louisiana legislature) with maintaining safety of maritime commerce along the Mississippi River.

dispatched to ensure a vessel remains stable at a safe berth shall serve no more than six consecutive bridge hours." Additionally, NOBRA implemented operational rules: 1) on December 14, 2018, mooring and unmooring operations were restricted to daylight hours at a berth that required the use of a mooring boat (assist tugboat); 2) on February 28, 2019, southbound vessels were restricted to daylight transits only and required a pilot on board anchored vessels with a draft of 35 feet or more; and 3) on April 26, 2019, a daylight-only restriction was applied to northbound vessels. These regulations and restrictions remained in effect at the time this marine accident brief was published.

Analysis

No mechanical issues were reported with the tugboats that would have limited the pilot's use of these assets to safely turn the vessel around in the waterway, nor were issues reported with the bulker's steering or engines. According to the three towboat captains who assisted the *Shandong Fu En*, three assist tugboats—maybe even four—were the usual number necessary in high-water conditions to safely move a vessel such as the *Shandong Fu En* off the dock and turn it around. However, after the bulker came off the dock, the river current quickly began to move the vessel toward the right descending bank and downriver. The towboats could have been positioned differently and the full-astern engine orders could have been executed earlier to keep the bulker from drifting. The pilot had completed this maneuver dozens of times previously and was familiar with the challenges of the river being at high-water stage and running at more than 5 mph.

The purpose of work/rest rules, like the rest period regulations for the NOBRA pilots, "is to promote rest and recuperation between periods" of work.[3] Rules and regulations applicable to mariners do not stipulate the amount of sleep they should acquire before standing watch or serving as a pilot. Instead, the rules focus on providing an opportunity to sleep. During rulemaking to address work/rest regulations, the Coast Guard described rest periods as time a mariner would "be allowed to sleep" and said rest included providing mariners with hours away from work so they can "sleep without being interrupted."[4] Internationally, the International Maritime Organization (IMO) emphasizes that "seafarers are [should be] provided with adequate sleep opportunity"[5] and that "duty scheduling and planning is a key factor in managing fatigue." Allowing and providing mariners an opportunity to sleep does not guarantee that they will. The NOBRA policies setting a minimum time between assignments and a limit on hours worked in a 24-hour period followed the Coast Guard and IMO guidelines for providing pilots an opportunity to sleep between assignments.

Even for experienced pilots, fatigue can affect performance in various ways, such as increased reaction times, reduced alertness, and difficulty processing information. It can, therefore, degrade a person's ability to stay alert and attentive to the demands of safely controlling a vessel. Despite the pilot's 96-hour work/rest history showing he complied with regulations, he had only 4 hours of sleep in the 36-hour time span before the accident. The pilot's limited sleep and the fact that he was nearing the end of an 8-hour shift increased the likelihood that fatigue affected his

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[3] FR 34518, June 26, 1997; Interim Final Rule: Implementation of the 1195 Amendments to the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978 (STCW).

[4] Title 46 *Code of Federal Regulations* 15.1101(a)(4) defines rest as a period of time during which a person is off duty, is not performing work (which includes administrative tasks such as chart corrections or preparation of port-entry documents), and is allowed to sleep without being interrupted.

[5] Guidelines on Fatigue, MSC.1/Circ.1598, 24 January 2019, Annex, page 27.

judgment while directing three tugboats and maneuvering the *Shandong Fu En* in challenging high-water conditions.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the contact of bulk carrier *Shandong Fu En* with the Ergon-St. James Terminal wharf was the fatigued pilot's misjudgment of a downstream turning maneuver during high-water conditions.

Mitigating Risk of Fatigue during High-Water Conditions

Pilot organizations have recognized that even for experienced pilots, fatigue can degrade performance especially in challenging conditions aboard deep-draft vessels. Since the accident, the NOBRA Board of Examiners instituted new procedures to mitigate the risk associated with operating deep-draft vessels in high-water conditions on the Mississippi River. These procedures include increasing the sleep opportunity for pilots by 1) lengthening the time between turns from 8 to 12 hours, and 2) reducing the work hours for attended moored vessels from 8 to a maximum of 6 hours per shift. They also include limiting pilot transits and mooring operations to daylight hours.

Vessel Particulars

Vessel	*Shandong Fu En*
Owner/operator	Compass Shipping 10 Corp Ltd
Port of registry	Hong Kong
Flag	Hong Kong
Type	Bulk carrier
Year built	2017
Official number (US)	N/A
IMO number	9734719
Classification society	China Classification Society
Construction	Steel
Length	751.3 ft (229 m)
Draft	44 ft (13.4 m)
Beam/width	105 ft (32 m)
Gross or ITC tonnage	44,120 gross tons
Engine power, manufacturer	13,319 hp (9,932 kW), Single MAN, model 6S60ME-C8.2
Persons on board	20

NTSB investigators worked closely with our counterparts from Coast Guard Sector New Orleans throughout this investigation.

For more details about this accident, visit www.ntsb.gov and search for NTSB accident ID DCA18FM020.

Issued: June 12, 2019

The NTSB has authority to investigate and establish the probable cause of any major marine casualty or any marine casualty involving both public and nonpublic vessels under Title 49 *United States Code*, Section 1131. This report is based on factual information either gathered by NTSB investigators or provided by the Coast Guard from its informal investigation of the accident.

The NTSB does not assign fault or blame for a marine casualty; rather, as specified by NTSB regulation, "[NTSB] investigations are fact-finding proceedings with no formal issues and no adverse parties and are not conducted for the purpose of determining the rights or liabilities of any person." Title 49 *Code of Federal Regulations*, Section 831.4.

Assignment of fault or legal liability is not relevant to the NTSB's statutory mission to improve transportation safety by conducting investigations and issuing safety recommendations. In addition, statutory language prohibits the admission into evidence or use of any part of an NTSB report related to an accident in a civil action for damages resulting from a matter mentioned in the report. Title 49 *United States Code*, Section 1154(b).

Collision of Tankship *Eagle Otome* with Cargo Vessel *Gull Arrow* and Subsequent Collision with the *Dixie Vengeance* Tow Sabine-Neches Canal, Port Arthur, Texas January 23, 2010

Accident Report

NTSB/MAR-11/04
PB2011-916404

National Transportation Safety Board

NTSB/MAR-11/04
PB2011-916404
Notation 8205A
Adopted September 27, 2011

Marine Accident Report

Collision of Tankship *Eagle Otome* with Cargo Vessel *Gull Arrow* and Subsequent Collision with the *Dixie Vengeance* Tow
Sabine-Neches Canal, Port Arthur, Texas
January 23, 2010

National Transportation Safety Board

490 L'Enfant Plaza, SW
Washington, DC 20594

National Transportation Safety Board. 2011. ***Collision of Tankship*** **Eagle Otome** ***with Cargo Vessel*** **Gull Arrow** ***and Subsequent Collision with the*** **Dixie Vengeance** ***Tow, Sabine-Neches Canal, Port Arthur, Texas, January 23, 2010*****. Marine Accident Report NTSB/MAR-11/04. Washington, DC.**

Abstract: This report discusses the January 23, 2010, collision of the tankship *Eagle Otome* with the general cargo vessel *Gull Arrow* and the subsequent collision of tank barge *Kirby 30406*, pushed by towboat *Dixie Vengeance*, with the *Eagle Otome*. The accident occurred in the Sabine-Neches Canal in Port Arthur, Texas. The damages that resulted from this accident were $1.5 million to the *Eagle Otome*, $35,000 to the barge, and $381,000 to the *Gull Arrow*. No crewmember on board the three vessels was injured. As a result of the accident, an estimated 462,000 gallons of oil spilled into the water, and about 136 Port Arthur residents were temporarily evacuated from the area near the accident scene. Safety issues identified in this accident were pilot oversight, mariner fatigue, waterway safety, and bridge control ergonomics. As a result of the investigation, safety recommendations are issued to the U.S. Coast Guard, the Jefferson and Orange County Board of Pilot Commissioners, the Sabine Pilots Association, the American Pilots' Association, and governors of states and territories in which state and local pilots operate.

The National Transportation Safety Board is an independent Federal agency dedicated to promoting aviation, railroad, highway, marine, pipeline, and hazardous materials safety. Established in 1967, the agency is mandated by Congress through the Independent Safety Board Act of 1974 to investigate transportation accidents, determine the probable causes of the accidents, issue safety recommendations, study transportation safety issues, and evaluate the safety effectiveness of government agencies involved in transportation. The National Transportation Safety Board makes public its actions and decisions through accident reports, safety studies, special investigation reports, safety recommendations, and statistical reviews.

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Acronyms and Abbreviations

AIS	automatic identification system
APA	American Pilots’ Association
API	American Petroleum Institute
CEMS	crew endurance management system
CFR	*Code of Federal Regulations*
CPAP	continuous positive airway pressure
FAA	Federal Aviation Administration
FOSC	Federal on-scene coordinator
FRMS	fatigue risk management system
IMO	International Maritime Organization
LOSC	local on-scene coordinator
MPA	Marine Preservation Association
MSU	Coast Guard Marine Safety Unit
MWT	maintenance of wakefulness testing
NOAA	National Oceanic and Atmospheric Administration
NTSB	National Transportation Safety Board
NVIC	Navigation and Inspection Circular
OSA	obstructive sleep apnea
PAWSA	ports and waterways safety assessment
PAWSS	ports and waterways safety system
S-VDR	simplified voyage data recorder
SETWAC	Southeast Texas Waterways Advisory Council
SOLAS	International Convention for the Safety of Life at Sea

SOSC	state on-scene coordinator
STAN	Southeast Texas Alerting Network
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
VDR	voyage data recorder
VHF	very high frequency
VTS	vessel traffic service

Executive Summary

On Saturday, January 23, 2010, about 0935 central standard time, the 810-foot-long oil tankship *Eagle Otome* collided with the 597-foot-long general cargo vessel *Gull Arrow* at the Port of Port Arthur, Texas. A 297-foot-long barge, the *Kirby 30406*, which was being pushed by the towboat *Dixie Vengeance*, subsequently collided with the *Eagle Otome*. The tankship was inbound in the Sabine-Neches Canal with a load of crude oil en route to an ExxonMobil facility in Beaumont, Texas. Two pilots were on board, as called for by local waterway protocol. When the *Eagle Otome* approached the Port of Port Arthur, it experienced several unintended heading diversions culminating in the *Eagle Otome* striking the *Gull Arrow*, which was berthed at the port unloading cargo.

A short distance upriver from the collision site, the *Dixie Vengeance* was outbound with two barges. The towboat master saw the *Eagle Otome* move toward his side of the canal, and he put his engines full astern but could not avoid the subsequent collision. The *Kirby 30406*, which was the forward barge pushed by the *Dixie Vengeance*, collided with the *Eagle Otome* and breached the tankship's starboard ballast tank and the No. 1 center cargo tank a few feet above the waterline. As a result of the breach, 862,344 gallons of oil were released from the cargo tank, and an estimated 462,000 gallons of that amount spilled into the water. The three vessels remained together in the center of the canal while pollution response procedures were initiated. No crewmember on board any of the three vessels was injured.

The National Transportation Safety Board (NTSB) determines that the probable cause of the collision of tankship *Eagle Otome* with cargo vessel *Gull Arrow* and the subsequent collision with the *Dixie Vengeance* tow was the failure of the first pilot, who had navigational control of the *Eagle Otome*, to correct the sheering motions that began as a result of the late initiation of a turn at a mild bend in the waterway. Contributing to the accident was the first pilot's fatigue, caused by his untreated obstructive sleep apnea and his work schedule, which did not permit adequate sleep; his distraction from conducting a radio call, which the second pilot should have conducted in accordance with guidelines; and the lack of effective bridge resource management by both pilots. Also contributing was the lack of oversight by the Jefferson and Orange County Board of Pilot Commissioners.

Safety issues identified in this accident include pilot oversight, mariner fatigue, waterway safety, and bridge control ergonomics. As a result of this accident investigation, the NTSB makes new recommendations to the U.S. Coast Guard, the Jefferson and Orange County Board of Pilot Commissioners, the Sabine Pilots Association, the American Pilots' Association, and governors of states and territories in which state and local pilots operate. The NTSB also reiterates a recommendation and reclassifies a recommendation to the U.S. Coast Guard.

1. Factual Information

Vessels:	Singapore-registered oil tankship *Eagle Otome*, official No. 386067, International Maritime Organization (IMO) No. 9051351, 810 feet long, 138 feet wide, 53,504 gross international tons, steel construction, built in 1994. Total cargo carrying capacity: 693,903 barrels (29,143,926 gallons). Bahamas-registered general cargo vessel *Gull Arrow*, official No. 720410, IMO No. 7930137, 597 feet long, 95 feet wide, 25,846 gross international tons, steel construction, built in 1982. U.S.-registered towboat *Dixie Vengeance*, official No. 506543, 74 feet long, 24 feet wide, 143 gross registered tons, built in 1966. U.S.-registered tank barge *Kirby 30406*, 297 feet long, 54 feet wide, 1,619 gross tons, built in 1993. Total cargo carrying capacity: 30,500 barrels (1,281,000 gallons). U.S.-registered tank barge *Kirby 28112*, 300 feet long, 54 feet wide, 1,632 deadweight tons, built in 2009. Total cargo carrying capacity: 28,323 barrels (1,189,566 gallons).
Accident Type:	Collision
Location:	Sabine-Neches Canal, Port of Port Arthur, Texas, latitude 29°51.6′ N, longitude 93°56.4′ W
Date:	January 23, 2010
Time:	0935 central standard time[1]
Owners:	*Eagle Otome*: AET Inc. Ltd. *Gull Arrow*: Gearbulk Shipowning Ltd. *Dixie Vengeance* and barges: Kirby Inland Marine, LLC
Property Damage:	*Eagle Otome*, $1.5 million *Gull Arrow*, $381,000 *Kirby 30406* barge, $35,000 *Dixie Vengeance*, none
Environmental Pollution:	An estimated 11,000 barrels, or about 462,000 gallons, of Olmeca crude oil released into the Sabine-Neches Canal
Injuries:	None
Complement:	*Eagle Otome*, 22 *Gull Arrow*, 29 *Kirby 30406*, none *Dixie Vengeance*, 4

[1] Unless otherwise noted, all times in this report are central standard time (universal coordinated time –6 hours) and are based on the 24-hour clock.

1.1 Accident Narrative

On January 18, 2010, the 810-foot-long tankship T/V *Eagle Otome* (figure 1) departed the Petroleos Mexicanos terminal in Pajaritos, Mexico. The Singapore-registered vessel, owned and operated by AET Inc. Ltd. (AET),[2] was carrying 576,864 barrels (24,228,288 gallons) of Olmeca crude oil[3] en route to a Sun Oil terminal in Nederland, Texas. The load constituted about 83 percent of the *Eagle Otome*'s total cargo carrying capacity.

Figure 1. *Eagle Otome*. Photo by Iain McGeachy.

Two days later, on January 20, after completing the transit north through the Gulf of Mexico, the *Eagle Otome* arrived at 2318 at the Sabine Fairway anchorage off the coast of Texas and remained anchored there for the next 3 nights. The *Eagle Otome* was originally scheduled to arrive at the Sun Oil terminal on January 25; however, on the evening of January 22, the master was notified that the ExxonMobil facility in Beaumont, just north of Nederland, would receive the tankship the next day.

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[2] At the time of the accident, AET Inc. Ltd. owned and operated 69 petroleum tank vessels. The company had offices in Houston, London, Singapore, Kuala Lumpur, and Gurgaon, India.

[3] Olmeca crude oil is a light sour crude oil produced near the Bay of Campeche in the southern Gulf of Mexico. For more information, see section "1.9.4 Olmeca Crude Oil."

About 0515 on the morning of January 23, the vessel weighed anchor and at 0524, a pilot from the Sabine Pilots Association ("the first pilot") boarded the tankship for the transit to Beaumont by way of the Sabine-Neches Waterway (figure 2). On the bridge of the *Eagle Otome* were the first pilot, the master, a mate, and a helmsman. The first pilot took the conn[4] from the tankship's master and began the approach from sea toward the entrance to the Sabine-Neches Waterway. (For more information, see section "1.10 Waterway Information.") At 0533, the first pilot radioed the Sabine Pilots Association that the vessel was inbound. At 0536, he radioed vessel traffic service (VTS)[5] and informed the watchstander that he was on board the *Eagle Otome* headed for Beaumont. He ordered the tankship's speed to full ahead. The *Eagle Otome* proceeded at about 8 knots as the first pilot issued helm orders to line the tankship up for its northbound course into the fairway channel. According to the *Eagle Otome*'s voyage plan, the transit from the sea buoy (20 miles offshore) to the ExxonMobil berth at Beaumont was about 57 miles.

Figure 2. Aerial image of the region. The Sabine-Neches Waterway is marked by a yellow line. Background by Google.

[4] To have the conn is to direct the steering and propulsion of a vessel. A conning pilot has navigational control of the vessel.

[5] VTS is operated by the U.S. Coast Guard and provides active monitoring and navigational advice for vessels in especially confined and busy waterways. For more information, see section "1.11 VTS Port Arthur" in this report.

Because the *Eagle Otome*'s beam[6] was wider than 120 feet, local waterway guidelines called for two pilots to serve on the vessel through the Sabine-Neches Waterway (see section "1.15 SETWAC Protocol and Sabine Pilots Association Guidelines"). About 0750, a second Sabine pilot ("the second pilot") boarded the *Eagle Otome* as the tankship entered Sabine Pass. About 0800, after a short exchange with the first pilot, the second pilot took the conn of the *Eagle Otome*. The first pilot, still on duty, remained on the bridge to assist the second pilot.

All Sabine pilots, as standard practice, rotate the conn and associated navigational duties during the two-pilot transit through the Sabine-Neches Waterway. At 0904, when the *Eagle Otome* was about 4 miles south of Port Arthur, the two pilots switched the conn again. The first pilot who had boarded the tankship at the Sabine Fairway anchorage now again had navigational control. The *Eagle Otome* was now about 1 mile south of an area commonly referred to as the Texas Island Intersection.[7] At this location, inbound traffic needs to make about a 38-degree turn to starboard. Also at the Texas Island Intersection, the *Eagle Otome* would enter a section of the waterway called the Sabine-Neches Canal, which continued for about the next 12 miles (figure 3).[8] At 0910:32, the first pilot ordered "starboard twenty" to initiate the turn. Between 0911 and 0913, he brought the *Eagle Otome* through the Texas Island Intersection at about 8 knots without incident.

[6] Beam is the width of a ship.

[7] Texas Island, a narrow peninsula jutting out into the waterway, is also sometimes referred to as Texaco Island. The name "Texas Island" originated in the early 20th century and is frequently used today; however, the Coast Guard teaches its personnel to refer to the location as "Texaco Island" because the *Coast Pilot* does so. Navigational charts of the area do not refer to the location by any name.

[8] The Sabine-Neches Canal is 400 to 450 feet wide.

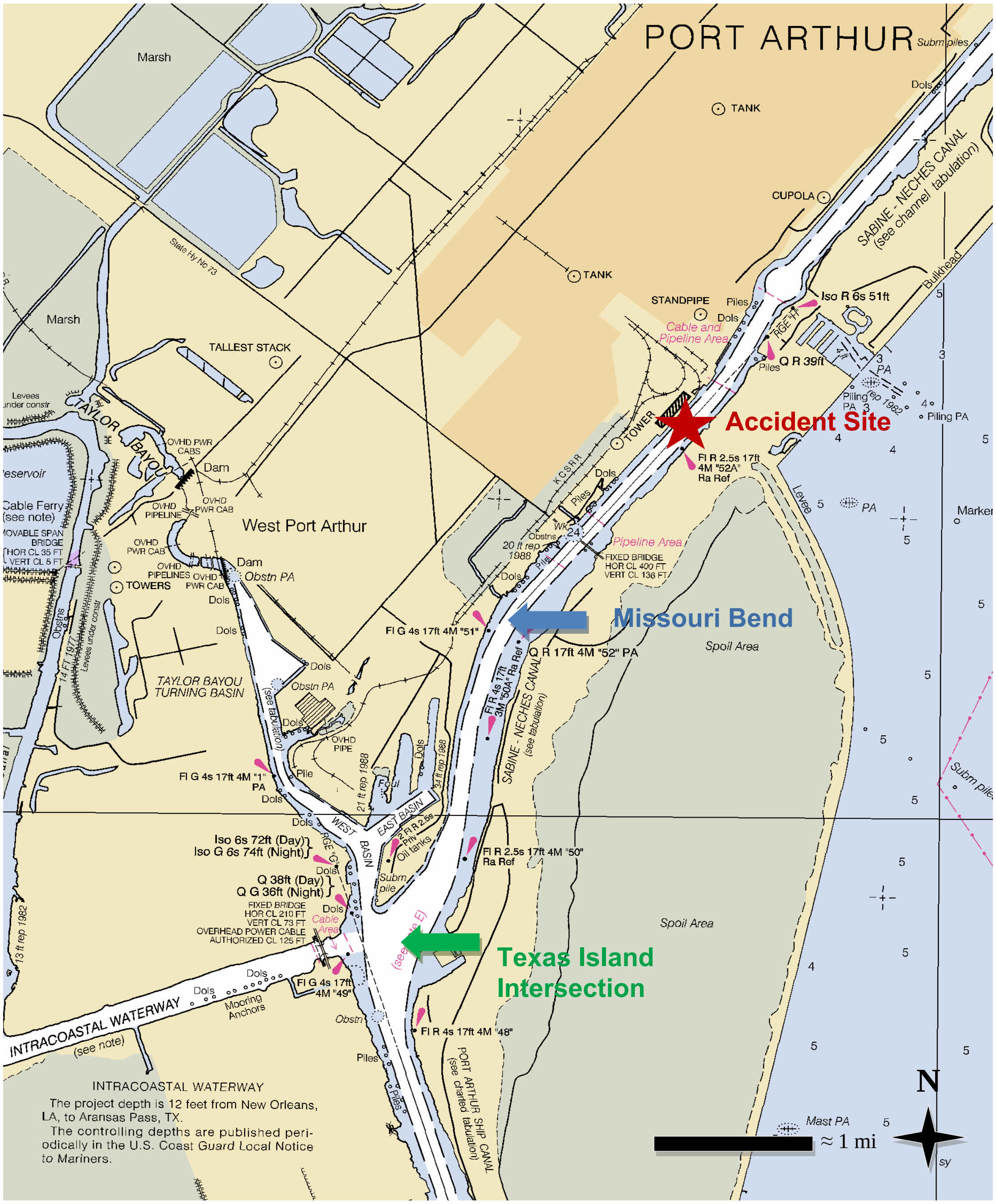

Figure 3. Section of National Oceanic and Atmospheric Administration (NOAA) chart 11342, with the Sabine-Neches Canal running north and northeast. The Texas Island Intersection is marked with a green arrow, Missouri Bend with a blue arrow, and the accident location with a red star.

At 0915, the first pilot placed a security call[9] on very high frequency (VHF) radio channel 13[10] announcing that he was on board the first of two inbound tankships near the

[9] A security call is an informational message of a safety nature that is broadcast so that anyone in the vicinity who is monitoring the channel may hear it.

Texas Island Intersection and inquiring about any outbound traffic in the vicinity of the Gulfgate Bridge[11] in Port Arthur (figure 4). He did not mention the *Eagle Otome* by name (see section "2.10 Use of Vessel Name in Radio Communication").

Figure 4. Dr. Martin Luther King, Jr. Memorial Bridge (formerly named Gulfgate Bridge) in Port Arthur, viewed looking north from on board a tankship similar to the *Eagle Otome*. The Port of Port Arthur can be seen on the left, past the bridge. Photo by the Sabine Pilots Association.

The security call was answered by the master on the towboat *Dixie Vengeance* (figure 5), which was outbound in the Sabine-Neches Canal about 3 miles north of the bridge, pushing two barges with aromatic concentrate.[12] The towboat master identified his vessel by name. The two pilots on the *Eagle Otome* were conversing with each other when the towboat master answered

[10] VHF channel 13 is used for intervessel communication (bridge-to-bridge) for navigation safety purposes. Vessels greater than 65 feet long maintain a listening watch on this channel in U.S. waters.

[11] The first pilot referred to the bridge by its former name, Gulfgate Bridge. The bridge was renamed Dr. Martin Luther King, Jr. Memorial Bridge in 1985. Navigational charts of the area mark the location of the bridge but do not refer to it by any name.

[12] Aromatic concentrate is a feedstock for petrochemical manufacturing. It is a colorless flammable liquid with a flash point of about 10 degrees F. Aromatic concentrate is a mixture of heavy catalytic reformed naphtha, benzene, toluene, and xylene.

the call, and the tankship's simplified voyage data recorder (S-VDR)[13] did not record a response from either pilot. No further radio contact took place at that time. About 20 minutes remained until the *Eagle Otome* and the *Dixie Vengeance* were to meet and transit past each other in the canal.

Figure 5. *Dixie Vengeance* on the Sabine-Neches Canal.

At 0923, the *Eagle Otome* approached another significant turn in the canal, locally referred to as Missouri Bend, where inbound traffic needs to make about a 32-degree turn to starboard. At that point, the master on the *Dixie Vengeance* announced on VHF channel 13 that his towboat was "outbound at the schoolhouse,[14] two loads." The first pilot acknowledged the

[13] VDRs maintain continuous, sequential records of data relating to a ship's equipment and its command and control, and capture bridge audio from certain areas in the wheelhouse and on the bridge wings. Under regulation 20 of the International Convention for the Safety of Life at Sea (SOLAS) Chapter V, all passenger ships and all cargo ships of 3,000 gross tons or more built on or after July 1, 2002, are required to carry VDRs. The *Eagle Otome* was equipped with an S-VDR, which is not required to capture all of the parameters of a standard VDR but is permissible under a July 2006 amendment to SOLAS that applies to vessels built before July 1, 2002.

[14] Local marine traffic and VTS use the term "schoolhouse" to refer to a building located on the west bank of the waterway, about 2 miles north of the bridge. The building is identified by a "cupola" marking on navigation chart 11342.

call-out, mentioning the towboat by name, and engaged in a radio exchange with the towboat master that lasted about 45 seconds. The first pilot informed the towboat master that the tankship was about three-quarters of a mile south of the bridge and was the first of two inbound tankships. The towboat master informed the first pilot that the *Dixie Vengeance* was proceeding at a speed of about 7.9 knots, and the first pilot informed him that the *Eagle Otome* would be slowing down for a ship berthed at the Port of Port Arthur.[15] The two men agreed that the *Eagle Otome* and the *Dixie Vengeance* would meet each other portside-to-portside. The towboat master told the first pilot, "If I need to speed up or slow down to make it easy on both of us, let me know." The *Dixie Vengeance* master later told investigators that he could see the *Eagle Otome* from his location upriver near the schoolhouse when the tankship was near Missouri Bend. The two vessels were about 2.6 miles from each other at that point.

The last rudder order that the first pilot had given to the helmsman before the radio exchange with the *Dixie Vengeance* master was "midship," or zero rudder angle, at 0922:37. When the first pilot ended the conversation with the towboat master, the *Eagle Otome* was near Missouri Bend but had not yet begun the turn to starboard. At 0923:54, which was 1 minute 17 seconds after the midship order, the first pilot ordered "hard to starboard"[16] to initiate the turn. (Postaccident analysis of the tankship's S-VDR data revealed that bank effect[17] had already begun turning the bow to starboard by the time the first pilot's rudder order took effect.) At 0924:11, he eased the starboard turn by ordering "starboard twenty," and at 0924:17, he ordered the speed reduced from half ahead to slow ahead. At 0924:40, he eased the turn further by ordering "starboard ten." He then adjusted the turn by ordering "starboard twenty" at 0924:55. Nine seconds later, at 0925:04, he ordered "midship."

At this point, the first pilot had brought the *Eagle Otome* through Missouri Bend and was attempting to line up the tankship for the passage underneath the bridge, which was located about half a mile north of Missouri Bend. However, despite the midship rudder order, the *Eagle Otome* continued turning to starboard toward the east bank of the canal. At 0925:08, the first pilot then ordered hard to port to counter the starboard turn. When the tankship was close to the east bank, the ship straightened but then started to sheer[18] to port. As a result, the *Eagle Otome* did not steady up in the center of the canal to transit underneath the bridge but instead began crossing the canal toward the west side, approaching the bridge's west foundation. As the *Eagle Otome* sheered to port across the canal, the first pilot ordered hard to starboard rudder and full ahead on the engine to facilitate a correction toward the center of the canal.[19] At 0928:13, he asked the

[15] The *Eagle Otome* needed to slow down so that the hydrodynamic effects of passing would not pull the other ship from its berth.

[16] A "hard" rudder command usually means 35 degrees of rudder angle.

[17] Bank effect is a hydrodynamic effect caused by water pressure between the ship's bow and the near bank. The water pressure creates a cushion, which can force the bow to deflect away from the bank, back toward the center of the waterway. For more information, see section "1.2 Hydrodynamic Forces."

[18] Sheer is a hydrodynamic phenomenon that involves sudden change in the direction of a ship's head and temporary loss of steering control. It can have various causes, such as uneven depths in shallow water or bank effect. For more information, see section "1.2 Hydrodynamic Forces."

[19] A temporary order of full ahead is often used in maneuvering situations to increase water flow across the rudder. The increased flow enhances the turning effect of the rudder.

second pilot, "Is she gonna come back?" Six seconds later, the second pilot responded, "Might." About 1 minute later, after six additional rudder and engine orders, the *Eagle Otome* passed underneath the bridge, close to the west bank, on slow ahead at about 6 knots. The time was 0929.

The 597-foot-long general cargo vessel *Gull Arrow* (figure 6) was berthed at the Port of Port Arthur on the west side of the canal beyond the Dr. Martin Luther King, Jr. Memorial Bridge. Crewmembers and longshoremen were in the process of unloading the vessel's cargo.

Figure 6. *Gull Arrow*, docked portside to an unknown berth. The vessel is shown here in about the same orientation as it was on the day of the accident.

Just before the *Eagle Otome* passed underneath the bridge, the first pilot ordered hard port rudder. He later told investigators that he did this because he expected that, as the *Eagle Otome* neared the west bank of the canal, bank effect would cause the tankship to sheer to starboard and cross the canal toward the east bank. As the *Eagle Otome* passed underneath the bridge with the rudder hard to port, the second pilot and the master briefly conversed about the local area newspapers that the pilots, as a courtesy, had brought on board with them. The first pilot asked the master to place a crewmember on the bow in case they would need to use the anchor, to which the master responded that a crewmember had been on the bow all along.

As the first pilot expected, the *Eagle Otome* began sheering to starboard once its port bow came close to the west bank of the canal. At 0931:26, the first pilot ordered the engine from slow ahead to half ahead. The S-VDR then recorded the second pilot saying, “Take care of the ship. Don’t worry about that one at the dock.” Ten seconds later, at 0931:36, the master asked, “Want full ahead, sir?” The second pilot added, “Rapido.” At 0931:46, the first pilot ordered the speed to full ahead. In his postaccident interview with National Transportation Safety Board (NTSB) investigators, the *Eagle Otome* master stated that he thought that more engine power would help counteract the sheering. At 0931:49, he told the pilots, “I can give more if you want.” Neither pilot answered the master. Seventeen seconds later, at 0932:06, the first pilot ordered the engine reduced from full ahead to half ahead.

At this point, with the rudder still at hard to port, the *Eagle Otome* had sheered from the west bank and was approaching the east bank. At 0932:33, the first pilot ordered the rudder to midship, and at 0932:43, he ordered hard to starboard to counteract an anticipated sheer to port caused by the effect of the east bank. Three seconds later, at 0932:46, the master instructed the crewmember to remove the bars[20] from both anchors, and the crewmember acknowledged the order.

When the *Eagle Otome*’s starboard bow came close to the east bank, the tankship began sheering to port, despite the hard to starboard rudder command (figure 7). At 0933:14, the first pilot asked the second pilot, “Will you talk to this next tow?” The second pilot answered, “What do you want me to tell them? Just one whistle or look out here we come?” The first pilot replied, “One, yeah, look out, the one there is *Vengeance*.” However, neither the S-VDR nor the VHF radio recordings indicated that the second pilot contacted the towboat as the first pilot instructed him to do.

[20] Anchor bars prevent anchors from slipping or deploying if the anchor brake fails. The bars are the last safety mechanism to remove before releasing the anchor brake.

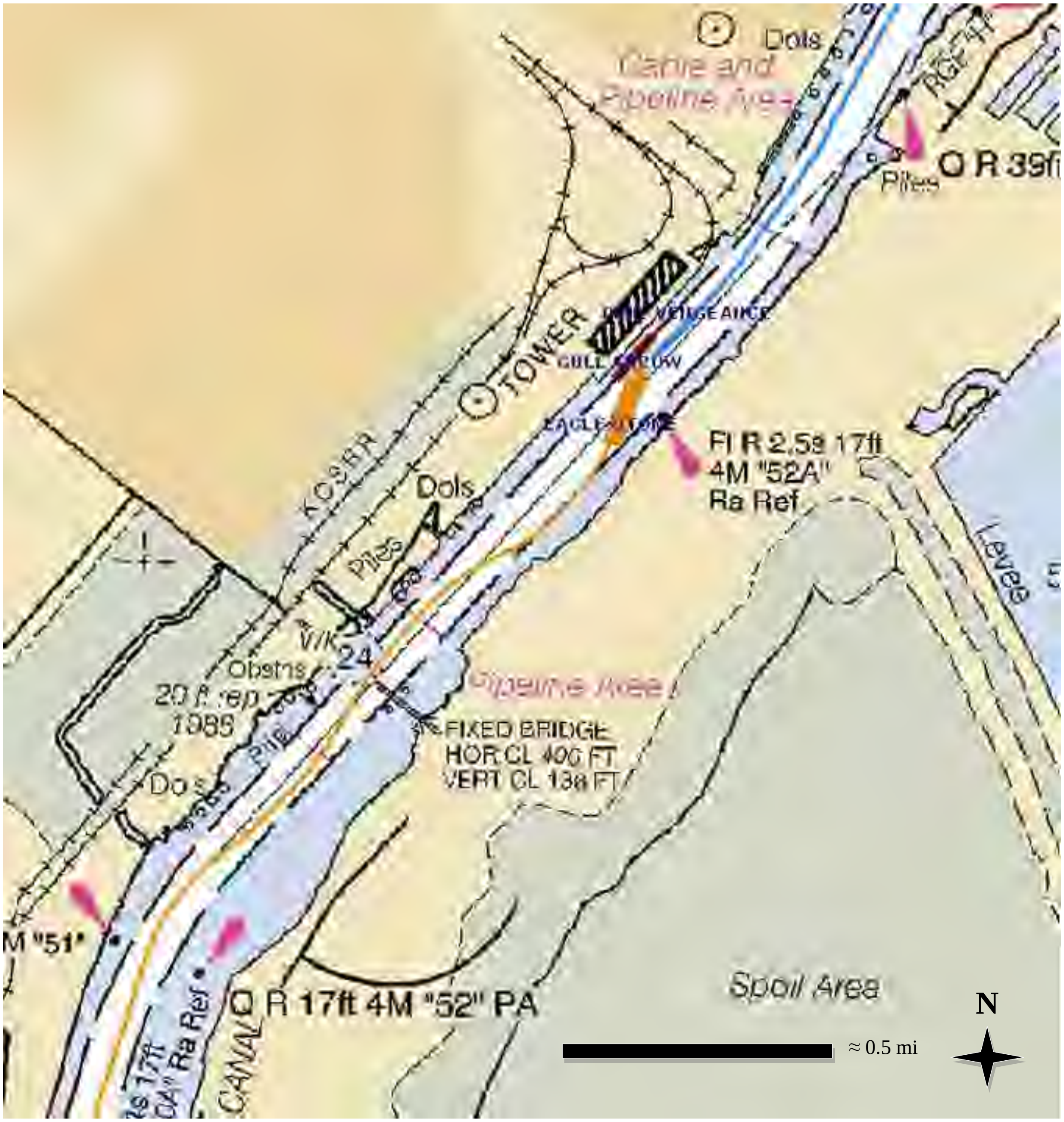

Figure 7. Trackline of the *Eagle Otome*, obtained from the tankship's S-VDR, overlaid as an orange line on NOAA chart 11342, and trackline of the *Dixie Vengeance*, obtained from automatic identification system (AIS)[21] data, overlaid as a blue line.

At 0933:35, the first pilot ordered full ahead on the engine. He told investigators that he did this to increase the water flow across the rudder and thereby enhance the rudder's

[21] AIS is a maritime navigation safety communications system. At 2- to 12-second intervals on a moving vessel, the AIS automatically transmits vessel information, including the vessel's name, type, position, course, speed, navigational status, and other safety-related information to appropriately equipped shore stations, other vessels, and aircraft. The rate at which the AIS information is updated depends on vessel speed and whether the vessel is changing course. The AIS also automatically receives information from similarly equipped vessels.

effectiveness. The *Eagle Otome* master told investigators that, to speed implementation of the full ahead order, he then used the engine order telegraph, which was set to bridge control, to increase the tankship's speed from full ahead to "navigational full ahead." This would gradually increase the tankship's propeller revolutions from about 65 rpm to 90 rpm.[22] To complete the navigational full ahead, a specific button labeled "program by-pass" on the engine control console must be pushed.[23] In his attempt to activate the navigational full ahead, however, the master inadvertently pushed a button marked "manual emergency stop," which was identically shaped and located immediately adjacent to the "program by-pass" button (figure 8).

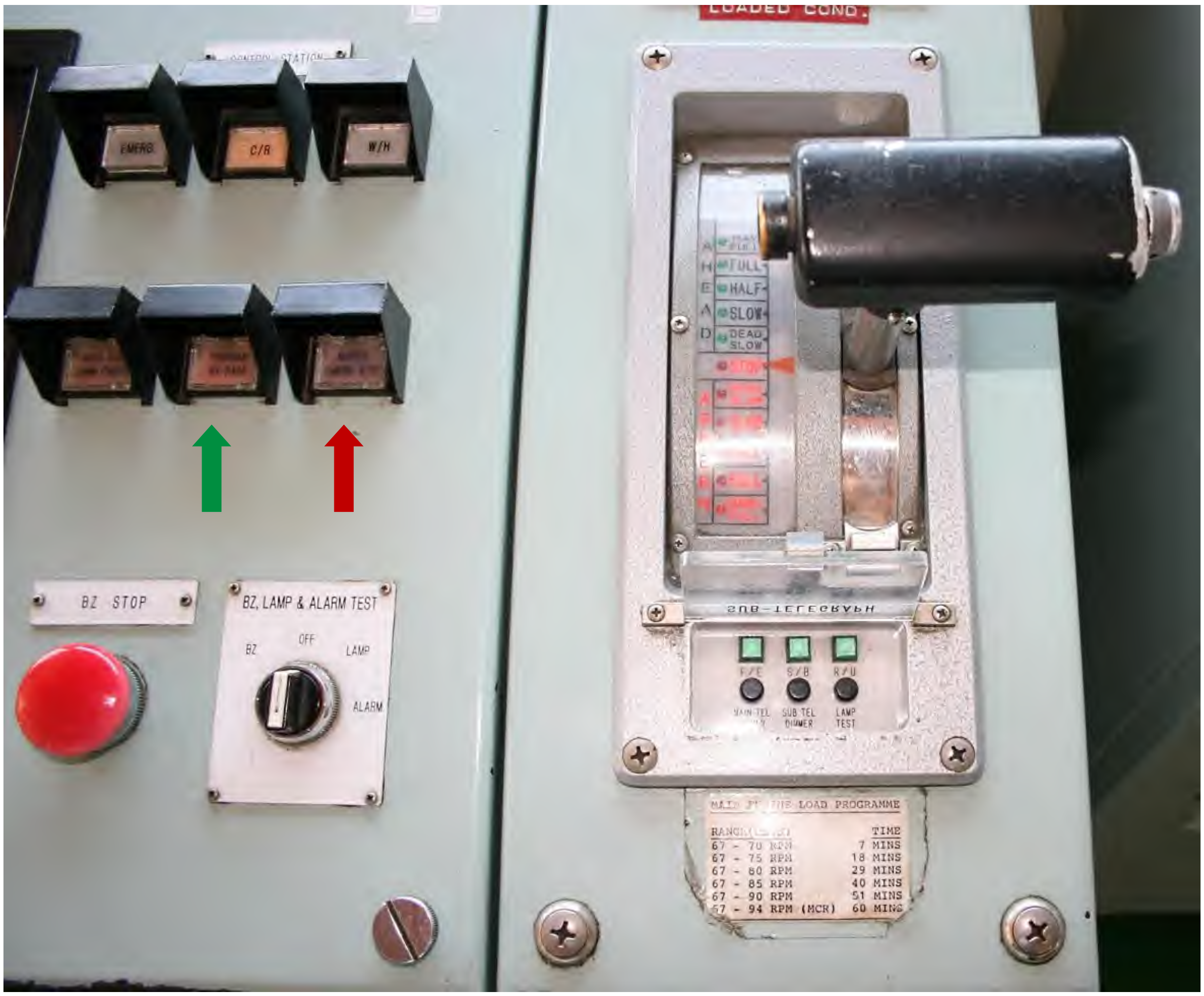

Figure 8. Section of the engine control console on the *Eagle Otome*. Activating the navigational full ahead required pushing the button marked with a green arrow. However, the master inadvertently pushed the "manual emergency stop" button, marked with a red arrow. (The arrows were added to this image; they are not featured on the actual engine control console.)

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[22] A portion of the increased rpm would take effect within seconds. The remainder of the increased rpm would take effect over the course of several minutes to avoid damage to the engine.

[23] On large marine propulsion diesel engines, the engine control system restricts the rate of loading above the normal maneuvering range to prevent damage to the engine from uneven heating. The ship's crew can manually override or bypass the engine loading program in case of emergency, and on the *Eagle Otome* this override required pushing the "program by-pass" button.

Pressing the "manual emergency stop" button caused an alarm to sound, which the S-VDR recorded at 0933:46. One second later, the first pilot instructed the master to drop the starboard anchor, and 20 seconds later ordered the engine full astern. The anchor dropped about 30 seconds after the first pilot ordered it. The master was able to restart the engine about 45 seconds after stopping it, and he then put it to full astern.[24] The first pilot later told investigators that he did not realize that the engine had stopped when he ordered the anchor released. He said that he had already determined at that point that the full ahead engine order, which he had applied about 12 seconds earlier, had not successfully corrected the ship, and thus he ordered the anchor dropped and the engine astern.

About this time, 0934, the *Eagle Otome* was far to the right in the channel. The *Dixie Vengeance* master, who was about 1,000 feet upriver at that point, told investigators that he thought that the *Eagle Otome* was so close to the east bank that the tankship's position would need to be corrected by coming a bit toward the center of the canal. At 0933:55, he radioed, "You sure are wide." No one on board the *Eagle Otome* responded.

The *Dixie Vengeance* master saw the tankship begin to cross the canal toward his side. At 0934:20, he radioed, "Inbound ship looking okay?" and then saw the *Eagle Otome*'s anchor drop. No one on the *Eagle Otome* answered the towboat master's radio call.

The first pilot told investigators that while the *Eagle Otome* was sheering across the canal toward the *Gull Arrow*, he stepped out onto the port bridge wing of the tankship to get a better view of the situation. While on the bridge wing, he sounded 12 blasts of the whistle to alert nearby vessels. The tankship's S-VDR recorded the blasts beginning at 0934:23, and the *Dixie Vengeance* master and the master on board the *Gull Arrow* both said that they heard the whistle blasts. At the time, the *Gull Arrow* master was on the cargo vessel's bridge checking on the installation of a new radar. He stepped out onto his starboard bridge wing, which faced the canal, and saw the tankship heading toward his vessel. He told investigators that he realized that a collision was imminent and that he sounded the *Gull Arrow*'s general alarm. Shortly thereafter, about 0935, the *Eagle Otome*'s port bow struck the *Gull Arrow*'s starboard side.[25]

When the *Dixie Vengeance* master saw the *Eagle Otome*'s anchor drop, he immediately put his engines full astern and alerted his crew by sounding the emergency alarm. According to AIS data retrieved from the *Dixie Vengeance*, the towboat was able to reduce speed from about 6.5 knots to about 4.4 knots but could not avoid the accident. Within seconds of the collision between the *Eagle Otome* and the *Gull Arrow*, the *Kirby 30406*, which was the forward barge being pushed by the *Dixie Vengeance*, collided with the *Eagle Otome* and breached the tankship's starboard ballast tank and the No. 1 center cargo tank a few feet above the waterline.

[24] NTSB investigators determined that when the master inadvertently stopped the engine, the *Eagle Otome*'s speed was about 5.7 knots. According to the vessel's maneuvering diagrams, even if the engine had been put to full astern at that point, the *Eagle Otome* would have needed about 2,625 feet to stop, given the tankship's speed and load. Less than 500 feet separated the *Eagle Otome* and the *Gull Arrow* at that point. When the *Eagle Otome* struck the *Gull Arrow*, the tankship's speed was about 4.6 knots.

[25] The *Eagle Otome*'s S-VDR recorded a sound similar to a metallic clang at 0935:17. It is not known whether this sound resulted from the tankship's collision with the *Gull Arrow* or from the subsequent collision with the *Dixie Vengeance* tow.

As a result of the breach, an estimated 462,000 gallons of crude oil spilled into the water. The vessels remained together in the center of the canal while pollution response procedures were initiated (figure 9). (For more information, see section “1.9 Oil Spill and Recovery Efforts.”)

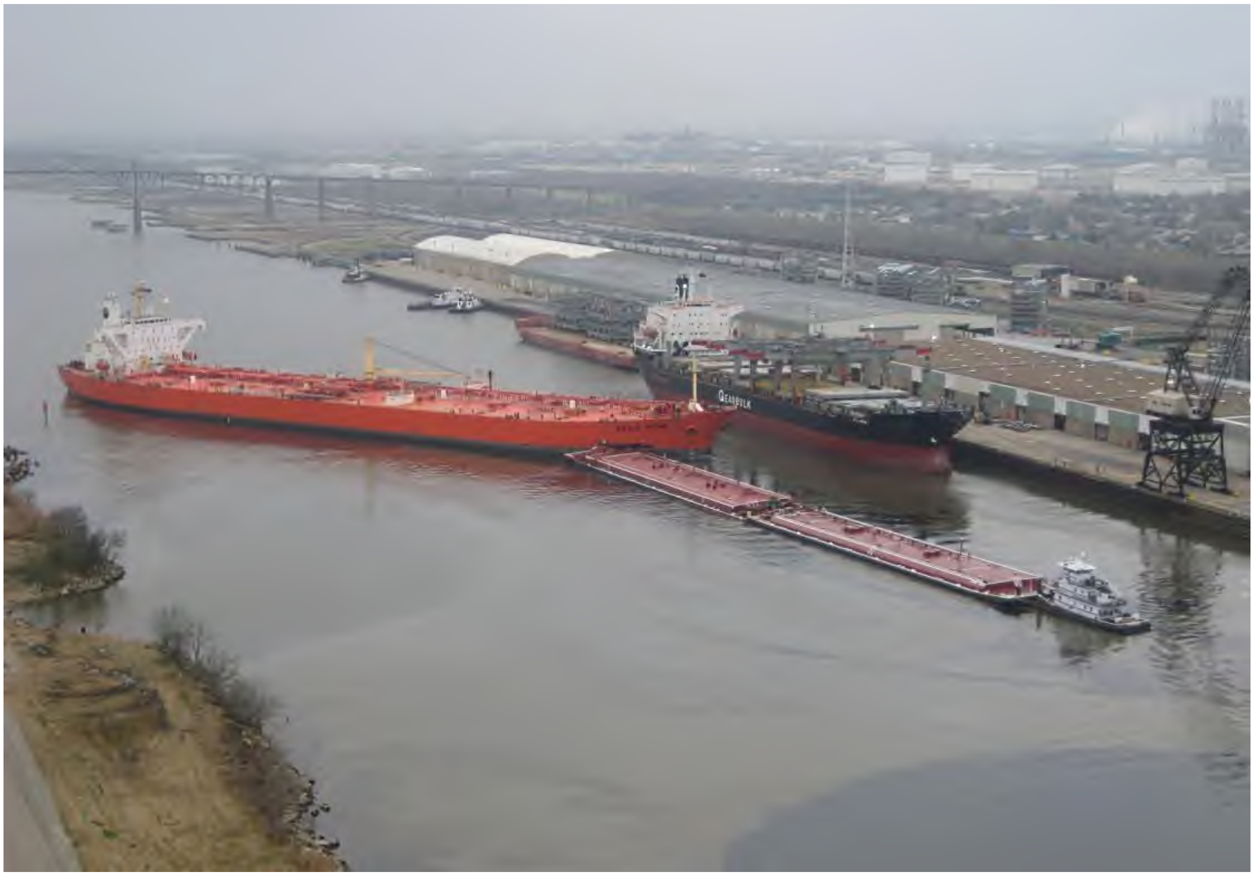

Figure 9. The three vessels after the accident. Overflight photo by the Coast Guard, looking west-southwest.

Shortly after midnight on January 24, as the tide in the waterway changed, the current’s movement dislodged the *Kirby 30406* from the *Eagle Otome*. The crew of the *Dixie Vengeance* maneuvered the towboat and the two barges downriver and anchored near the bridge. The *Eagle Otome* remained in the same anchored position as pollution recovery efforts continued.

1.2 Hydrodynamic Forces

The hydrodynamic force referred to as “bank effect,” which the *Eagle Otome* encountered on the day of the accident, is common. In fact, pilots and experienced mariners regularly use bank effect to their benefit in maneuvering vessels in narrow waterways. The following are brief and general descriptions[26] of the hydrodynamic forces that played a role in the *Eagle Otome*’s transit on the day of the accident.

[26] The descriptions are derived from Henry Hooyer’s book, *Narrow Channels and Their Effects on Ship Handling*, Cornell Maritime Press, Inc., 1983, pp. 85–87 and 89.

Bank Effect and Using Bank Effect to Advantage. When a ship is transiting close to a waterway bank, water builds up between the bow of the ship and the bank. The water build-up results in higher pressure against the bow on the “on-shore” side and a lower pressure on the “off-shore” side. The drop in pressure on one side creates an imbalance, and the imbalance is the source of the bow’s deflection away from the bank. To keep the ship to one side of the waterway, rudder must be applied; the closer the ship is to the bank, the more rudder is needed to compensate for bank effect.

Bank effect can be used to mariners’ advantage, such as in navigating a bend in a narrow waterway. Just before entering the bend, the ship is allowed to come closer to the outside bank of the bend. Once bank effect begins pushing the ship’s bow away from the bank, the mariner can control the bank effect with, as an example, 10 degrees of rudder. While in the bend, the ship will then turn without rudder effort—that is, with the rudder at midship or with only a few degrees of rudder input—because stern suction (explained below) makes the ship turn.

Stern Suction. When a ship encounters bank effect and its bow sheers, the stern comes closer to the bank from which the bow sheered. As a result of the stern’s proximity to the bank, suction on the stern becomes stronger. Large tankships such as the *Eagle Otome* generate strong suction effect in narrow waterways because the length of the ship gives the suction extra leverage and the wide beam causes the ship to ride lower in the water. Mariners who are experienced in taking ships through narrow waterways are able to anticipate suction and control it (such as using the suction to turn the ship).

Breaking a Sheer. Before a sheer develops, bank effect should be anticipated and preemptive rudder applied, such as a momentary 20 or 30 degrees. If that does not steady the ship, increasing the engine rpm can help. Increased engine thrust translates quickly into stronger rudder force (longitudinal inertia prevents the ship from gaining speed too quickly). When the ship steadies under hard rudder and increased engine rpm, the engine should be brought back to the original speed and, if the ship is still close to the bank, the rudder should be decreased gradually. The reason for the gradual rudder decrease is that, as long as the ship is close to the bank, the ship is still under the influence of bank effect. Until the ship is clear of bank effect, some amount of rudder should be applied.

1.3 Injuries

No crewmembers on board any of the three vessels were injured. Four longshoremen who were offloading the *Gull Arrow*’s cargo reported minor injuries in the 2 days following the accident.

1.4 Toxicological Testing

Postaccident drug and alcohol testing[27] was conducted shortly after the accident under Coast Guard supervision. Both pilots and on-duty bridge and engineroom personnel on the

[27] Federal regulations at 46 *Code of Federal Regulations* (CFR) 4.06 require postaccident drug and alcohol testing on all individuals engaged in or employed on board a vessel directly involved in any accident that meets the criteria of a serious marine incident, defined at 46 CFR 4.03-2 as (a) a marine casualty or accident that results in any of the following: (1) one or more deaths, (2) injury that requires medical treatment beyond first aid and

Eagle Otome, the towboat master and the three crewmembers on the *Dixie Vengeance*, and VTS Port Arthur watchstander personnel were tested for illegal drugs and alcohol. In addition, the entire *Eagle Otome* crew was tested for alcohol. All tests were conducted in accordance with Federal regulations, and all results were negative for the presence of alcohol and illegal drugs.

1.5 Postaccident Vessel Testing

1.5.1 *Eagle Otome*

The *Eagle Otome*'s steering system was a conventional electrohydraulic, double-ram, rapson-slide[28] type, positioning a single rudder. Two independent hydraulic pumps were fitted for redundancy and increased rudder response. When the vessel maneuvered in confined waters, both hydraulic pumps were placed in operation to meet the required rudder slew rate.[29]

NTSB investigators tested the steering system on the *Eagle Otome* following the accident and found it to be operating properly. The rudder moved from 35 degrees on one side to 30 degrees on the other side in 23 seconds, with both steering pumps in operation. The steering power failure alarms were tested and shown to operate properly. A visual examination of the steering system exterior did not indicate any significant hydraulic leaks or other maintenance deficiencies.

1.5.2 *Dixie Vengeance*

Coast Guard investigators conducted a postaccident inspection of the *Dixie Vengeance*. All of the mechanical systems that the investigators inspected were found to be in proper working order.

1.6 Damage

1.6.1 *Eagle Otome*

The *Eagle Otome* sustained damage to both its port and starboard sides. The damage resulting from the collision with the *Gull Arrow* was located at the tankship's forward upper port

renders the individual unfit to perform routine duties, (3) property damage exceeding $100,000, (4) actual or constructive total loss of an inspected vessel, or (5) actual or constructive total loss of any uninspected vessel that exceeds 100 gross tons; (b) discharge of 10,000 or more gallons of oil into U.S. waters; or (c) the release of a reportable substance into the environment of the United States. On June 20, 2006, new Coast Guard regulations (46 CFR 4.06-3) took effect requiring alcohol testing within 2 hours of a serious marine incident and the collection of drug-test specimens within 32 hours. The five illicit drugs tested for are amphetamines, cocaine, marijuana, opiates, and phencyclidine.

[28] A rapson-slide mechanism converts rectilinear port/starboard motion produced by heavy rams into accurate movement directly coupled to the ship's rudder post by crosshead pin/slider/fork components.

[29] SOLAS Chapter II-1, Regulation 29.3.2 requires that the main steering gear and rudder stock on vessels be capable of putting the rudder over from 35 degrees on either side to 30 degrees on the other side in not more than 28 seconds. Regulation 29.6.1.1 allows a cargo ship to have all power units in operation to achieve this required rudder slew rate.

side. The damage to the portside shell plating and internal structure extended horizontally about 55 feet and down about 12 feet from the main deck. The damaged compartments in this area were the No. 1 port ballast tank, the forward cofferdam,[30] and the bosun store room, and involved buckling, detachment, and fracturing of the internal structure, which was inset about 3 feet as a result of the impact. The main deck plating, deck railings, and port bulwark were also damaged in this area (figure 10).

Figure 10. Portside damage to the *Eagle Otome*.

The subsequent collision with the *Kirby 30406* created a hole in the *Eagle Otome*'s starboard hull about 30 feet aft of the tankship's bow, above the waterline (figure 11). The side shell plating was punctured and inset across an area about 43 feet long and 10 feet high, extending from the No. 1 starboard ballast tank to the forward cofferdam. Frames and stringers in this area were buckled, fractured, and completely detached in several locations. The damage to the *Eagle Otome* was estimated at $1.5 million.

[30] A cofferdam is a void or empty space separating two or more compartments for the purpose of insulation or for preventing liquid contents of one compartment from entering another in case of a leak.

Figure 11. Starboard side of the *Eagle Otome*, with the *Kirby 30406* lodged in it.

1.6.2 *Gull Arrow*

The *Gull Arrow* sustained a gash about 100 feet long and 3 feet high just below its starboard-side gunwale.[31] According to a surveyor's report, the structural frames in this area were buckled, with six frames broken and distorted. The shell plating below the gash was inset between 1 and 3 feet. On the main deck, 16 sections of handrails, stanchions, and brackets were bent over to an angle of about 45 degrees (figure 12). In the interior spaces of the damaged area, including the engine machine shop and maintenance tunnel, damage was sustained to electrical conduits and to various piping systems, such as sewage and steam. The *Gull Arrow* also sustained damage to its portside hull when the impact pushed the ship into the concrete wharf. On the portside, a 10-foot-high by 115-foot-long section of shell plating, between frames 42 and 79, was inset about 3 inches.

No fuel tank was breached and no fuel was released from the *Gull Arrow*. The damage to the *Gull Arrow* was estimated at $381,000.

[31] The gunwale is the upper edge of a vessel's side.

Figure 12. Damage to the *Gull Arrow*.

1.6.3 *Kirby 30406*

The bow (or rake) of the barge *Kirby 30406* was peeled back in the collision with the *Eagle Otome* (figure 13). The barge's void space on its starboard-side rake was crushed, and about 5 feet of the rake had curled up under the hull plating of the *Eagle Otome*. The cargo tanks remained intact, and no aromatic concentrate product was released.

The damage to the *Kirby 30406* was estimated at $35,000.

Figure 13. Damage to *Kirby 30406*.

1.7 Vessel Information

1.7.1 *Eagle Otome*

The 810-foot-long, 138-foot-wide Aframax[32] tankship was a double-hull crude oil carrier, built in May 1994 as the *Neptune Otome* (renamed *Eagle Otome* in 2000) and registered in the Republic of Singapore. The tankship had 12 cargo tanks with a total cargo carrying capacity of 693,903 barrels. It was powered by a single 16,600-horsepower Mitsubishi Sulzer direct-reversible, slow-speed diesel engine, model 7RTA62, driving a single propeller. As mentioned earlier, the *Eagle Otome*'s steering system was a conventional electrohydraulic, double-ram, rapson-slide type, with one rudder. The *Eagle Otome*'s classification society was the American Bureau of Shipping. The tankship was owned by AET Tanker Holdings Sdn Bhd, headquartered in Malaysia.

1.7.2 *Gull Arrow*

The 597-foot-long, 95-foot-wide general cargo carrier (forest product carrier) was built in January 1982 and registered in the Bahamas. It was powered by a single 11,200-horsepower

[32] The term Aframax is derived from the Average Freight Rate Assessment tanker rate system. Aframax tankers range from 80,000 to 120,000 deadweight tons.

slow-speed diesel engine, model 6L67GFCA, manufactured by B&W Diesel. The ship had a deadweight of 38,787 tons, a gross tonnage of 25,846 tons,[33] and five bulk cargo hatches. The *Gull Arrow*'s classification society was Det Norske Veritas. The ship was owned by Gearbulk Shipowning Ltd., headquartered in Bermuda.

1.7.3 *Dixie Vengeance*

The 75-foot-long, 24-foot-wide vessel was a U.S.-registered canal towboat built in 1966 and modified in 1998. The *Dixie Vengeance* had a gross tonnage of 143 tons and was powered by twin medium-speed diesel engines, Cummins model KTA-38 MO, with ahead propulsion power of 1,700 horsepower. The *Dixie Vengeance* was not inspected by the Coast Guard, nor was it required to be. The two barges towed by the *Dixie Vengeance* were U.S.-registered and Coast Guard-inspected double-hull tank barges. *Kirby 30406* was 297 feet long and 54 feet wide and had a gross tonnage of 1,619 tons. *Kirby 28112* was 300 feet long and 54 feet wide and had a gross tonnage of 1,632 tons. Both barges had a draft of about 10 feet. The *Dixie Vengeance* and the barges were owned by Kirby Inland Marine, LLC, Houston, Texas.

1.8 Environmental and Waterway Conditions

At the time of the accident, the weather at the nearby Beaumont/Port Arthur Southeast Texas Regional Airport was recorded as 65 degrees F, overcast with no precipitation, and winds out of the southeast at 10 knots. Visibility was 6 miles. Nearby tidal currents were 0.9 knot flood at 1306 on January 23 and 1.7 knot ebb at 0405 on January 24. By about 2000 on January 23, the winds were out of the northwest.

1.9 Oil Spill and Recovery Efforts

1.9.1 Notifications of Response Organizations

About 0936, the *Eagle Otome* master radioed Coast Guard Sector Houston-Galveston on VHF radio channel 16[34] to report the accident. At 0938:43, the second pilot told the bridge team that he had notified VTS Port Arthur of the accident and the pollution in the water, and that he had suggested to VTS that the waterway be shut down in the area of the accident.

A Coast Guard petty officer witnessed the accident while on duty at the Coast Guard Marine Safety Unit (MSU) Boat Docks, located about 0.4 mile northeast of the accident location. Within minutes, two Coast Guard boat crews from the MSU Boat Docks launched to the scene. As the boat crews approached the vessels, they noted that the canal was covered in oil. After they determined that no one was injured, the boat crews withdrew to enforce a safety zone to prevent other vessels from entering the oiled section of the canal.

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[33] Deadweight tonnage is the cargo carrying capacity of a vessel, and gross tonnage is a measure of its internal volume, usually used for regulatory purposes.

[34] VHF channel 16 (156.8 MHz) is the international VHF/FM calling, reply, and safety channel. It may also be used for distress and urgency signals.

At 0939, the superintendent of the Port of Port Arthur telephoned VTS and confirmed that oil had spilled into the canal. At 0942, VTS sent a radio broadcast to mariners that the canal at the Port of Port Arthur was closed until further notice. A VTS supervisor also contacted MSU Port Arthur, which alerted its environmental protection and security assets. MSU Port Arthur also notified the Coast Guard Sector Houston/Galveston Situation Unit and the following agencies: Texas General Land Office, Louisiana Oil Spill Coordinator's Office, Louisiana Department of Environmental Quality, NOAA, U.S. Fish and Wildlife Service, and the U.S. Army Corps of Engineers (the Corps). Within the first hour following the accident, an ExxonMobil shipper's representative arrived on scene to provide technical expertise regarding specific hazards of the crude oil and the aromatic concentrate.

The bridge crew on board the *Eagle Otome* also began required notifications. About 10 minutes following the accident, the master notified AET's qualified individual [35] in Houston, who in turn alerted AET's assigned spill management team, Gallagher Marine Systems.[36] The qualified individual also notified AET's designated person ashore[37] and members of AET's emergency response team in Houston. About 1035, Gallagher Marine Systems activated AET's oil spill response organization, Marine Spill Response Corporation. Gallagher Marine Systems also notified the National Response Center, the Texas General Land Office, Louisiana State Police, and the Coast Guard captain of the port in Port Arthur. After AET's qualified individual met with AET's emergency response team in Houston, he traveled to Port Arthur, arriving shortly after 1300. Gallagher Marine Systems personnel were already on site, directing deployment of boom to corral the oil along the banks of the Sabine-Neches Canal.

The *Eagle Otome* bridge crew recorded in the bridge notebook the following additional notifications during the 2 hours after the accident:

- Notified the AET security officer
- Contacted the National Response Center, Washington, DC
- Radioed the *Gull Arrow* and the *Dixie Vengeance* to caution crews about the fire hazards associated with the crude oil and not to use lights
- Provided information about the accident to the primary and alternate qualified individuals
- Provided information to the Coast Guard by radio and telephone
- Provided information to the *Eagle Otome*'s port agent

[35] A qualified individual is a person designated to be notified in the case of an oil spill and who manages the response effort on behalf of the ship owner or operator.

[36] At the time of the accident, AET was in the process of transitioning its qualified individual responsibilities to Gallagher Marine Systems. Following the accident, Gallagher Marine Systems supplied qualified individual services to AET.

[37] The 1998 International Safety Management Code, established for the safe operation of ships and for pollution prevention, states in part that shipping companies should designate a person ashore with direct access to the company's top-level management. The designated person ashore is responsible for monitoring the ship's safety and pollution prevention aspects and for ensuring that shore-based support and resources are provided as required.

1.9.2 Unified Command

Because of the scale of the *Eagle Otome* oil spill, the Coast Guard formed a unified command,[38] initially located at MSU Port Arthur. The unified command comprised a Federal on-scene coordinator (FOSC),[39] who was Port Arthur's captain of the port and commanding officer of MSU Port Arthur; an incident commander, who was AET's qualified individual; a state on-scene coordinator (SOSC), who was a representative of the Texas General Land Office; a local on-scene coordinator (LOSC), who was a captain with the Port Arthur Fire Department; and a deputy incident commander, who was Kirby Inland Marine's qualified individual. Other agencies with on-scene representatives included NOAA, Texas Parks and Wildlife Division, Texas Department of Public Safety, and Texas Commission on Environmental Quality. The incident commander's actions were subject to the concurrence and oversight of the FOSC, the SOSC, and the LOSC.[40]

In addition, the Port Arthur police and fire departments set up a forward command post at the street entrance to the Port of Port Arthur. Together with personnel from the Coast Guard, the Jefferson County Emergency Management, KCS Railroad, and the Texas Department of Public Safety, the police and fire departments coordinated the evacuation of a section of Port Arthur impacted by the crude oil vapor (see section "1.9.4 Olmeca Crude Oil").

1.9.3 Safety Zone

At 1052, the Coast Guard established a safety zone along a 12-mile section of the Sabine-Neches Canal, starting at the Texas Island Intersection to the south. By the end of the day, the safety zone was expanded by 4 miles to the south, encompassing a 16-mile segment of the Sabine-Neches Waterway.

1.9.4 Olmeca Crude Oil

The *Eagle Otome*'s No. 1 center cargo tank, which had a capacity of 73,225 barrels, was loaded with 67,305 barrels of Olmeca crude oil at the time of the accident. Olmeca crude oil is a pale black liquid that contains a complex mixture of petroleum hydrocarbons. It has a flash point

[38] A unified command operates on the principle of shared command response authorities at the Federal and state levels in response to a major pollution event. The current iteration of a unified command stems from Department of Homeland Security Presidential Directive 5.

[39] The FOSC holds the ultimate authority for all decision-making related to the response and is responsible for coordinating and directing Federal response efforts. The FOSC oversees and ensures the adequacy of the response actions and has the authority to take over, or federalize, the response if he or she determines that it is not being properly conducted by the responsible party.

[40] Key provisions of the Oil Pollution Act of 1990 (33 *United States Code* 2701 et seq.) include holding the owner of a vessel from which oil is discharged responsible for damages and costs associated with the removal of the discharge. If a discharge from a vessel poses a substantial threat to public health, welfare, or the environment, the FOSC directs all Federal, state, and private actions to remove the discharge. The vessel owner or operator must act in accordance with the national contingency plan, applicable area contingency plans, and vessel response plans. (Also see section "1.9.8 Vessel Response Plan.")

of less than 100 degrees F and an average specific gravity[41] of 0.826. As with other crude oil, Olmeca contains varying concentrations of hazardous substances, in particular hydrogen sulfide, as well as benzene, toluene, xylene, ethylbenzene, and polynuclear aromatic hydrocarbons. The U.S. Department of Transportation classifies Olmeca crude oil as a "Class 3" flammable liquid.[42] Potential acute health effects from exposure to high concentration levels of crude oil vapors include skin irritation, convulsion, cyanosis,[43] congestion, and hemorrhaging of lungs and internal organs.

1.9.5 Evacuation

Southeast winds carried vapors from the crude oil, mainly of hydrogen sulfide, along with an associated strong pungent odor, into downtown Port Arthur. The fire department's air monitoring results revealed hydrogen sulfide levels at about 1 to 5 parts per million in the general area. The fire department measured the highest hydrogen sulfide concentration dockside next to the *Gull Arrow*, including one measurement of 100 parts per million.[44]

Exposure to high concentrations of hydrogen sulfide can cause headache, dizziness, internal bleeding, suffocation, brain damage, coma, and death. As a precaution, the Port Arthur police and fire dispatch initiated the Southeast Texas Alerting Network (STAN)[45] reverse 911 system to notify local residences and businesses near the accident location about the situation. The police and fire departments also established an exclusionary zone to the northwest of the accident location. The exclusionary zone, which included the Port of Port Arthur, was evacuated as a precaution, beginning shortly after 1100 (figure 14). The police and fire dispatch sent a second STAN reverse 911 message to all residences and businesses in this zone informing them to evacuate. Personnel from the police and fire departments also went door-to-door to ensure that all residents were aware of the evacuation.

[41] Specific gravity is the density of a substance relative to the density of water. Substances with a specific gravity of less than 1.0 float, and those greater than 1.0 sink. Specific gravity is commonly used in environmental response to determine where in a body of water a released substance can be recovered: on the surface or at the bottom.

[42] A Class 3 flammable liquid has a flash point of not more than 141 degrees F. More information about Class 3 flammable liquids is available at 49 CFR 173.120.

[43] Cyanosis results from a lack of oxygen in the blood (as in carbon monoxide poisoning) and can ultimately cause death.

[44] The Occupational Safety and Health Administration considers a hydrogen sulfide concentration of 20 parts per million the permissible exposure limit, not to be exceeded for healthy adults in a work place. A concentration of 100 parts per million is considered immediately dangerous to life and health.

[45] STAN is a multifunction telephone messaging and notification system that gives industrial companies and local agencies the ability to provide the community with important, timely information about emergency incidents and other high-profile events occurring in Southeast Texas. In the event of an emergency that warrants activation, STAN's ring-down system can place phone calls to home numbers providing information on what actions need to be taken. The alert can also be sent as a call or text message to cell phones or as an e-mail.

Figure 14. City map showing the neighborhood that received the initial STAN message about the oil spill and the neighborhood that was evacuated.

In total, about 136 of Port Arthur's approximately 55,000 residents were evacuated.[46] The Jefferson County Community Emergency Response Team and the American Red Cross established a shelter for the evacuees at a senior citizens' recreation center in Port Arthur. After several hours of continuous air quality monitoring, which indicated no concentrations of hydrogen sulfide within detection limits of air monitoring equipment, the evacuation was lifted at 1800 that same day. However, about 20 residents elected to remain in the shelter overnight because of the petroleum odor that remained in some areas.

[46] The residents were evacuated from an area between Houston Avenue to the south and Beaumont Avenue to the north and between 7th Street to the west and the waterway to the east. The evacuated area was about 0.147 square mile in size.

After the residential evacuation was lifted, the forward command post was demobilized about 1600 on January 24, and the response transitioned to cleanup operations. The fire department continued to monitor the air in the vicinity of the cleanup operations, while the police department maintained perimeter security.

1.9.6 Determination of Quantity Spilled

According to notes in the *Eagle Otome*'s bridge logbook, oil continued to discharge from the tankship from the time of the accident at 0935 until about 1012. About 1049, the *Eagle Otome*'s chief officer completed sounding the No. 1 center cargo tank and estimating the amount of oil that had flowed from it. He determined that a total of about 20,532 barrels (862,344 gallons) of oil had spilled from the cargo tank into the ballast tank, and about 11,000 barrels (462,000 gallons) of that amount flowed from the ballast tank into the water. About 1140, a Coast Guard representative at the forward command post received the spill estimate and reported it to MSU Port Arthur. A Coast Guard inspection team boarded the *Eagle Otome* at 1438 to confirm the tank soundings, among other activities. The chief officer, together with a Coast Guard marine inspector, recalculated the amount of oil spilled into the water to be about 10,097 barrels (424,074 gallons).[47] About 1946, the AET qualified individual confirmed to the Coast Guard the amount of oil contained in the No. 1 cargo tank before and after the accident. He later refined the calculation of the amount released into the water to be about 9,452 barrels, or about 396,984 gallons. His calculation took into account that about 11,041 barrels of oil had leaked from the No. 1 cargo tank into the *Eagle Otome*'s starboard ballast tank, and about 40 barrels of oil had spilled into the bow of the *Kirby 30406*.

Despite these lower release estimates by the Coast Guard and the qualified individual, the unified command decided to base its response on the original release estimate (11,000 barrels spilled into the water) that had been disseminated.

1.9.7 Environmental Response Operations

As required by the area contingency plan,[48] the response actions were conducted in accordance with the National Incident Management System.[49] Within this incident command organization, AET's spill management team served as chiefs, and Coast Guard personnel

[47] The *Eagle Otome* chief officer and the Coast Guard marine inspector used tank sounding quantities that were reported in units of gross standard volume, which includes volume correction factors for temperature, density, pressure, and American Petroleum Institute (API) gravity. Similar to specific gravity, API gravity is a measure of how heavy or light a petroleum liquid is compared to water. API gravity is used in petroleum shipping to provide a way to grade the oil and calculate the number of barrels based on metric tonnage. The API gravity of this shipment of Olmeca crude oil was measured as 39.80° API.

[48] The area contingency plan was developed by the Area Committee under the direction of the Federal on-scene coordinator. The Area Committee is a spill preparedness and planning body made up of Federal, state, and local agency representatives. More information can be obtained in Section 4202 of the Oil Pollution Act of 1990.

[49] The National Incident Management System, developed by the Federal Emergency Management Agency, provides a systematic approach to guide agencies at all levels of government as well as nongovernmental organizations and private sector organizations to work together to respond to, recover from, and mitigate the effects of incidents.

generally served as deputy chiefs while performing an oversight role. The organization evolved over time and was outlined in the daily incident action plans. The operations section was organized as follows:

- The protection and recovery branch was subdivided into three geographic divisions and was responsible for oil deflection, containment, and collection activities.
- The vessel decontamination and transit branch was responsible for reopening the waterway to commercial traffic.
- The air monitoring branch was responsible for detecting hydrogen sulfide, volatile organic compounds, and explosive atmospheres.
- The air operations branch provided aerial reconnaissance and photography to map the oil spill and assess resource needs. The crews of two chartered helicopters assisted with the reconnaissance and helped direct oil skimming operations.
- The waterway management branch was responsible for area security and enforcement of safety zones.
- The vessel salvage branch implemented vessel lightering[50] and firefighting plans for the *Eagle Otome* and the *Kirby 30406* barge.
- The wildlife recovery and rehabilitation branch responded to reports of injured wildlife and monitored 48-hour spill trajectory forecasts.
- An incident command post branch employed four field observers in each of the three geographic divisions that were responsible for validating response resource and oil location maps, oil recovery rates, and assessment of the spill response effectiveness.

1.9.8 Vessel Response Plan

Title 33 *Code of Federal Regulations* (CFR), Section 155, Subpart D, Tank Vessel Response Plans for Oil, requires that vessels carrying oil in bulk as cargo and operating on the navigable waters of the United States operate in compliance with a plan approved by the Coast Guard. The Texas Administrative Code also requires vessel owners and operators to submit certain information to the Texas General Land Office from their Coast Guard–approved vessel response plans. Response plan development and evaluation criteria for vessels carrying petroleum oil as cargo are contained in 33 CFR 155.1050, which sets forth the levels of equipment and response capability times that must be identified for planning purposes.

In October 2009, the Coast Guard approved AET's 5-year vessel response plan that was in effect at the time of the accident. The plan covered 52 tankships owned or operated by AET, including the *Eagle Otome*. The plan addressed a worst-case discharge[51] for the *Eagle Otome* of

[50] Lightering involves offloading a vessel's cargo onto another vessel.

[51] The worst-case discharge means a discharge of the vessel's entire cargo in adverse weather conditions.

693,903 barrels, the tankship's total cargo capacity. AET's plan also outlined crew responsibilities, including a requirement that the master make an immediate determination of the danger to which the vessel is exposed and make all required notifications. The priorities identified following a collision included damage assessment by visual inspection; sounding of all tanks; comparing tank soundings to ullage[52] reports; sounding compartments and void spaces; and taking draft and trim readings. The plan also directed oil to be transferred away from the damage, if possible.

1.9.9 Oil Containment Measures

The primary oil spill response organization in the accident was Marine Spill Response Corporation, a national, nonprofit spill response organization funded by the Marine Preservation Association (MPA). Membership in the MPA entitles members to immediate access to spill response services. The *Eagle Otome*'s owner, AET, was a member of the MPA. About 1140 on the day of the accident, a Marine Spill Response Corporation representative arrived at the unified command. Contractors with the Marine Spill Response Corporation arrived on scene shortly after noon, about 2.5 hours after the accident. About 1235, the contractors began deploying oil boom around the *Eagle Otome*. With the assistance of later arriving crews, they also deployed upriver and downriver containment measures. Because of the high air concentration of hydrogen sulfide at the accident site, skimming operations could not begin until nearly 2200 that evening. About 2330, skimming near the vessels was again delayed because of high air concentration of hydrogen sulfide. Although the work stop near the vessels lasted about 4.5 hours, spill containment and recovery measures upriver and downriver from the accident site were not affected.

Marine Spill Response Corporation maintained an inventory of response equipment, including the oil spill response vessel *Texas Responder*, which was stationed in Galveston, about 65 miles southwest of Port Arthur. The 210-foot-long vessel, equipped with oil boom, support boats, and oil skimming equipment, arrived on site shortly after 0400 on January 24. A second oil spill response vessel, the *Gulf Responder*, arrived on scene on January 25. Within 12 hours of the accident, Marine Spill Response Corporation had six oil skimming units and 32,000 feet of oil boom on scene. Within 60 hours of the accident, 35 oil skimming units were on scene with a skimming capacity of 53,620 barrels/day and 63,800 feet of oil boom. In total, the resources deployed in the Port Arthur spill included about 1,000 oil spill response contractor personnel, 200 incident command post personnel, 114 skimmer boats, 12 large skimmer assets, 160,000 feet of oil boom, 400,000 feet of sorbent boom and snare, 83 vacuum trucks, and two helicopters.

Ebbing tidal currents in the waterway carried the oil south about 8 miles. The bulk of the spilled oil was confined to a 16-mile section of the Sabine-Neches Waterway. On-water oil skimming operations continued until February 7. Cleanup of about 96 percent of the affected waterway was completed by February 10. The remaining area was monitored for evidence of oil leaching from the river banks.

[52] Ullage is the measurement of empty space available in a cargo or ballast tank.

The unified command determined that spill recovery operations were complete on February 24, 2010. The incident commander reported that about 32 percent of the total oil released in the accident was removed from the waterway in the spill recovery effort.[53]

1.9.10 Coast Guard Marine Board of Investigation and Public Hearing

The Coast Guard convened a formal investigation of the accident (known as a Marine Board of Investigation). In accordance with 46 CFR Part 4, after a preliminary investigation, testimony is received under oath in a public hearing, with all designated parties in attendance. The NTSB's investigator in charge participated in the preliminary investigation and the public hearing, the latter of which took place in Port Arthur, March 9 through 11, 2010, and he was permitted to ask questions and evaluate material admitted as evidence. (For samples of testimony provided at the hearing, see sections "1.15 SETWAC Protocol and Sabine Pilots Association Guidelines" and "1.16 Jefferson and Orange County Board of Pilot Commissioners."

1.10 Waterway Information

1.10.1 Sabine-Neches Waterway

The Sabine-Neches Waterway is a 64-mile-long waterway along the border between Texas and Louisiana. From the south at the Gulf of Mexico, the waterway comprises the Sabine Pass Channel, the Port Arthur Canal, the Sabine-Neches Canal, and the lower Neches River just south of Beaumont. The shoreline along the Sabine-Neches Waterway comprises man-made structures (such as the Sabine Pass) and mud banks with marshes. The waterway is maintained by the Corps and is dredged to a controlling depth[54] of 40 feet. The waterway is bordered on the west by Jefferson and Orange counties, Texas, and, at its most southern end, by Cameron Parish, Louisiana.

1.10.2 Sabine-Neches Canal

The midsection of the Sabine-Neches Waterway is the approximately 12-mile-long, 400- to 450-foot-wide Sabine-Neches Canal. The Sabine-Neches Canal shares this section of the waterway with the Gulf Intracoastal Waterway, which enters from the west at the Texas Island Intersection and exits the waterway to the east at the intersection with the Neches River.

In 2008, 2,538 tankships and 23,336 towing/tug vessels transited inbound and outbound in the Sabine-Neches Canal. Crude oil shipments accounted for the majority of tonnage through the waterway.[55] Terminals along the waterway include the Port of Port Arthur and the Port of Beaumont

[53] Of the remaining amount of spilled oil, about one-third evaporated from the surface of the water, and the rest dispersed in the water column and through other weathering processes.

[54] Controlling depth is the deepest ship draft that a channel can accommodate; it restricts safe use of the channel to deep drafts of less than that amount. Controlling depth is based on mean lower low water, which is the average of all lowest water levels for tidal days over a period of usually 19 years.

[55] *Waterborne Commerce of the United States, Calendar Year 2008*, Report Number CEIWR-WCUS-08-2 (Washington DC: Department of the Army Corps of Engineers, 2010).

as well as 14 petroleum refineries, a liquid natural gas facility, chemical plants, and bulk/break-bulk terminals that use vessel and barge transportation to move crude oil, petroleum products, liquid and dry chemicals, steel, and dry bulk cargo.[56]

1.10.3 NTSB Calculations of Missouri Bend

NTSB investigators examined channel dimensions to determine if the Sabine-Neches Canal is wide enough at Missouri Bend for vessels the size of the *Eagle Otome*. Using the beam and length of the *Eagle Otome*, the calculations[57] showed that although the minimum turn radius at Missouri Bend is within preliminary guidelines provided by the Corps for channel design,[58] the channel width at Missouri Bend is less than the Corps' suggested minimum for a vessel the size of the *Eagle Otome*. Using the Corps' preliminary guidelines, NTSB investigators calculated that the *Eagle Otome* ideally needs a canal width in the range of 414 to 463 feet at Missouri Bend, as opposed to the actual canal width of 400 feet.

NTSB investigators contacted the Corps about the channel dimensions at Missouri Bend. A Corps director responded that no strict Corps design criteria exist for navigation channel width. The director further stated that the Corps' preliminary guidelines are conservative, the width guidance provided in the engineering manual can usually be reduced, and many shipping channels in the United States are narrower than what the Corps' guidelines stipulate.[59] The Corps uses simulation studies in the planning, design, construction, operation, and maintenance of navigation channels. In 2002, the Corps conducted simulations in the Sabine-Neches Waterway. However, the director stated that no simulation was conducted at Missouri Bend.

The Corps manual states that increasing the width of a channel in a turn can affect the alignment of the current pattern, which can lead to ship steering problems. In addition, increasing the channel width can change shoaling[60] tendencies as well as the rate and location of shoaling areas. Each widening project must be evaluated for local effects of currents, wind, waves, and visibility on ship piloting. (Also see section "1.18.1 Accidents in the Sabine-Neches Waterway.")

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[56] *Study for the Economic Impact of Maintenance Dredging and Economic Impact of Deepening and Widening of the Sabine-Neches Waterway* (Martin Associates, Lancaster, Pennsylvania; Commissioned by the Jefferson County Waterway and Navigation District, 2006).

[57] The calculations, along with a kinematics parameter extraction study, are available in the NTSB public docket.

[58] The Corps published general channel design guidelines in an August 2004 engineering manual titled, "Hydraulic Design of Deep-Draft Navigation Projects." The guidelines are not specific to the Sabine-Neches Waterway and provide only general design guidance. The engineering manual clarifies that final channel designs should be developed through ship navigation studies that incorporate simulation tests with local pilots.

[59] In the past decade, concern has been raised about the increasing size of ships in static-width waterways. See W. Gray and others, "Channel Design and Vessel Maneuverability – Next Steps: When Ships Get Too Big For Their Ditches," *Marine Technology*, Volume 40, Issue 2, April 2003, available at <http://www.usna.edu/naoe/channel/final.pdf>.

[60] Shallowing as a result of sediment accumulation at the bottom.

1.10.4 Ports and Waterways Safety Assessment

The Coast Guard established the ports and waterways safety system (PAWSS) in the late 1990s to address the needs of waterway users and to place greater emphasis on partnering with the marine industry to reduce risk in the marine environment. Part of the PAWSS involved the Coast Guard's promptly establishing a "national dialogue group" of maritime and waterway community stakeholders representing all major sectors of the U.S. and foreign-flag marine industry. The Coast Guard, in conjunction with the national dialogue group, then developed a ports and waterways safety assessment (PAWSA), a risk assessment process that identifies major waterway safety hazards, estimates risk levels in a qualitative sense, evaluates potential mitigation measures, and sets the stage for implementation of selected measures to reduce risk. The Coast Guard conducts PAWSAs by convening a select group of waterway users and stakeholders in a 2-day workshop to address these issues. Participation of local Coast Guard officials is required before and throughout the workshop.

A PAWSA was conducted for the Port of Port Arthur in September 1999. In accordance with a national PAWSA model, the participants identified deep-draft vessels as contributing twice as much risk as shallow-draft vessels. Traffic density, visibility conditions, meeting arrangements, and waterway complexity were also identified as high risk. The participants identified VTS, which in 1999 was not in place in Port Arthur, as having the greatest potential for mitigating waterway risks. As a result of the PAWSA, VTS Port Arthur was established in 2005.

1.11 VTS Port Arthur

The Sabine-Neches Waterway is monitored by VTS Port Arthur, located at MSU Port Arthur, about 6 miles from the accident location. Certain vessels transiting the Sabine-Neches Waterway are required to check in with VTS at various points, and both the *Eagle Otome* and the *Dixie Vengeance* did so. VTS provides three primary services:

- Information, including position, identity, and intentions of vessels operating in the VTS area; meteorological information; aids to navigation status; traffic congestion; and waterway restrictions.

- Navigational assistance, at the request of the vessel operator, by providing information about the operator's own vessel, such as course and speed; position in the waterway relative to the channel axis; landmarks; aids to navigation or other landmarks; and the positions, intentions, and identities of surrounding traffic.

- Traffic organization, including advance planning and notification of movements, congestion, and waterway restrictions. Prioritization of movements and mandatory position reporting could be required as well as establishing speed limits to aid the flow of traffic.

VTS services to mariners are primarily advisory. VTS watchstanders at Port Arthur monitor VHF radio channels 13, 16, and 1A (alpha) and communicate daily with Sabine pilots and others by way of radio communication. At any given time, VTS watchstanders may be monitoring multiple vessels in their sectors of responsibility, displayed electronically on computer screens (figure 15). VTS watchstanders do not monitor one target to the exclusion of other marine traffic unless circumstances warrant it or a vessel operator requests VTS to do so. The primary navigational tools on which VTS operators rely are AIS data received from the vessel and the radar return from various radar-receiving stations located along the waterway. AIS and radar data are combined and received on VTS screens about every 2 to 10 seconds, depending on the transmitting vessel's speed. As a result, the information that is displayed on the VTS screens is delayed by that amount of time.

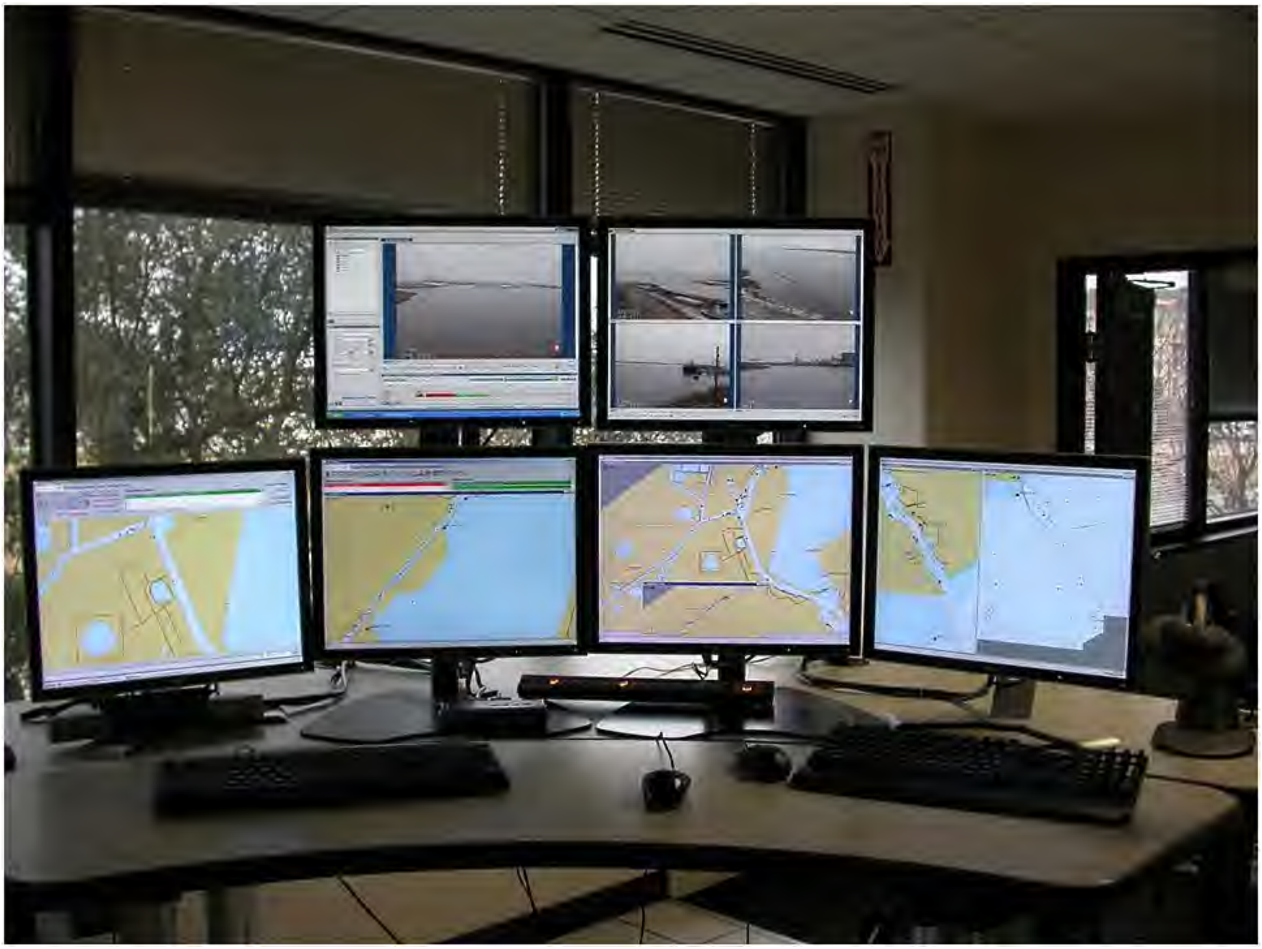

Figure 15. Data screens at VTS Port Arthur. The VTS video cameras did not capture any footage of the accident, only the *Eagle Otome*'s transit through the Texas Island Intersection.

On the morning of January 23, 2010, a VTS Port Arthur watchstander was monitoring the approximately 40-mile-long southern section of the Sabine-Neches Waterway in which the *Eagle Otome* was transiting (from the Sabine Fairway anchorage to just past the accident location). He told investigators that he became aware of the *Eagle Otome*'s inbound approach just before 0900, about 10 minutes after beginning his watch, when the tankship was approaching the Texas Island Intersection. The *Eagle Otome*'s AIS was transmitting data about every 3 to 4 seconds, showing the tankship's name, speed, destination, transited path, draft, and pilot designators. The VTS watchstander recalled that, about the same time, he also saw AIS data from the *Dixie Vengeance* appear on his screen as the towboat entered the northern portion of his monitoring sector in the area near the schoolhouse. Both vessels' names, speeds, and destinations appeared on his computer chart displays.

The VTS watchstander told investigators that from the start of his shift to the time of the accident, radio communication was light. He did not recall hearing any conversation between the *Eagle Otome* and the *Dixie Vengeance* nor any communication from the *Eagle Otome* to VTS during this time.[61]

The watchstander told investigators that he first became aware of the accident when the *Dixie Vengeance* master called VTS to report it. Before that, the watchstander only knew that the two vessels were approaching each other from opposite directions in the waterway near the Port of Port Arthur and near the *Gull Arrow*. He stated that at no point during the *Eagle Otome*'s transit did he think that the tankship might be having a problem. He stated that he felt that the arrangement of the two vessels meeting in that area of the canal was acceptable.

1.12 Personnel Information

1.12.1 Sabine Pilots

First Pilot. The first pilot, age 44, who had navigational control of the *Eagle Otome* at the time of the accident, was a 1988 graduate of the Texas Maritime Academy in Galveston, Texas, where he earned a B.S. in marine transportation. In 1989, he obtained a Coast Guard-issued third mate's unlimited license.[62] After graduating, he worked for a dredging company for about 1 year. He worked for Coastal Tank Ships during the next decade, advancing his license and eventually sailing in a higher rating and advancing in rank. He received his master's unlimited license in March 1997 and became a pilot with the Sabine Pilots Association in July 2006. Before becoming a Sabine pilot, he trained for 2 years with other pilots in the association, repeatedly riding along and training on vessels of increasing length, draft, and tonnage. During his 2-year pilot training, he made at least 500 transits through the Sabine-Neches pilotage area. The first pilot told investigators that he completed training in bridge resource management (BRM)[63] in 1999 and that he had also taken other courses required to maintain his Coast Guard license, such as radar observer classes. The first pilot stated that he had also attended training that was not required by the Coast Guard, such as advanced shiphandling simulator training, and training in shipmaneuvering and docking at the Sabine Pass liquid natural gas terminal.

[61] VTS watchstanders do not specifically listen for any set of exchanges; they monitor multiple frequencies and broadcasts from the entire monitoring sector. The VTS watchstander on the day of the accident was not required to specifically monitor the exchanges between the *Eagle Otome* and the *Dixie Vengeance*; none of those exchanges were directed to VTS.

[62] An unlimited license means any vessel tonnage on any ocean.

[63] BRM is the effective use by a vessel's bridge team of all available resources—information, equipment, and personnel—to safely operate a vessel. BRM was developed to help operators enhance the quality of teamwork and to recognize and mitigate the consequences of operator errors. (Also see sections "1.17 Bridge Resource Management" and "2.3 Division of Piloting Duties; Breakdown in Bridge Resource Management.")

The first pilot had piloted the *Eagle Otome* on one previous occasion and had also piloted similar-sized ships. He had an unblemished record before the accident, with no incidents or accidents in several years of working in the Sabine-Neches Waterway.

Following the accident, the first pilot submitted to the Coast Guard a work/rest schedule for the previous days. According to the schedule, he reported for work mid-morning on Tuesday, January 19. He completed his piloting assignment about 1650, went home, and fell asleep about 2330. The following day, Wednesday, January 20, the first pilot reported waking up about 0745. Because the waterway was closed that day due to fog, he had no job assignments. He went to bed about 2300. The following day, Thursday, January 21, the first pilot reported waking up about 0700 and beginning work mid-morning. He completed his piloting assignment about 1852, returned home, and had dinner. He reported lying in bed and watching television, beginning about 2000. At 2200, he was called for a job assignment. About 0015 the following morning, Friday, January 22, the first pilot boarded a vessel at the Sabine Fairway anchorage and brought it to the ExxonMobil facility in Beaumont. He completed the assignment about 0813 and returned home, where he went to bed about 1015. According to the first pilot, he slept until 1700. He then made dinner, checked on his work status, and was back in bed about 2100. At 0230 on the day of the accident, Saturday, January 23, he was called for the *Eagle Otome* pilotage assignment. He boarded the tankship at the Sabine Fairway anchorage about 0530.

First Pilot's Medical Condition. In April 2008, the first pilot was assessed at a sleep clinic for a sleep disorder. He underwent a polysomnography (sleep study) for severe snoring and daytime fatigue, conditions that had reportedly been manifest for 3 to 5 years.[64] The results led to a diagnosis of obstructive sleep apnea (OSA).[65] In a followup polysomnography, the first pilot was able to sleep effectively with a continuous positive airway pressure (CPAP) device,[66] and he was prescribed CPAP to treat his condition. In subsequent doctor's visits, the first pilot reported that he felt rested in the morning after using the CPAP device but did not use it every night because he found the face mask uncomfortable. After the accident, the first pilot told investigators that he had not used the CPAP device in at least the 4 days before the accident.

The first pilot's last medical evaluation[67] before the accident was completed in February 2009. At that time, the CG-719K form[68] did not require mariners or their health

[64] The results revealed a sleep efficiency of 96.8 percent, a latency to initial sleep of 1 minute, and an apnea + hypopnea index of 26.1 events per sleeping hour, that is, his sleep was disrupted an average of 26.1 times per hour due to insufficient oxygen, all indicating moderate to severe obstructive sleep apnea.

[65] See section "1.13 Fatigue" for additional information about OSA.

[66] CPAP uses air pressure delivered through a mask or nasal device to keep the individual's airway open and oxygen supplied during sleep.

[67] The Coast Guard is responsible for the medical certification of all U.S.-licensed mariners. Regulations at 46 CFR 12.02-17(e) require that pilots of vessels of 1,600 gross tons or more have a yearly medical examination and provide the Coast Guard with the results. Applicants for the licensed and qualified ratings (other than pilots of vessels of 1,600 gross tons or more) must have a medical examination every 5 years. Other than the frequency of examinations, the medical examination and certification requirements for pilots is the same as for other licensed and qualified ratings. Any licensed physician, physician assistant, or nurse practitioner can perform the medical examination, using the guidelines contained in NVIC 04-08.

[68] Part of the evaluation requires the mariner and the examining health care provider to complete a Coast Guard-issued form, CG-719K, to detail the mariner's medical conditions.

practitioners to disclose a diagnosis of a sleep disorder; information about the first pilot's OSA diagnosis and prescribed treatment was not noted on the 719K for that examination[69] (for more information, see section "1.13 Fatigue").

Second Pilot. The second pilot, age 47, who boarded the *Eagle Otome* at the Sabine Pass, graduated from the Texas Maritime Academy in 1985 with a degree in marine transportation and a Coast Guard–issued third mate's license. The first decade after graduation, he worked in the dredging industry and then worked for about 5 years in the offshore oil-drilling industry before becoming a Sabine pilot in 1999. Like the first pilot, he had trained for 2 years before becoming a pilot, as required by the Jefferson and Orange County Board of Pilot Commissioners. He had also previously transited on the *Eagle Otome* and a sister ship. The most recent BRM training course he had completed before the accident took place in 1998.

The second pilot's most recent physical exam before the accident took place in November 2009.

The second pilot also submitted a work/rest schedule to the Coast Guard following the accident. He stated in the schedule that he did not recall what hours he had slept in the 3 days leading up to the accident but that he had received between 6 and 8 hours of sleep each 24-hour period and that the quality of sleep was good. On Wednesday, January 20, he did not work because of the waterway fog closure. On Thursday, January 21, he was called for a piloting assignment about 1000 and completed the work about 1345. About 1315 that same day, he was called for a subsequent piloting assignment, which he completed about 2100. The following day, Friday, January 22, he was called for a piloting assignment about 0530 and completed the work about 1530. The following day, which was the accident day of Saturday, January 23, the second pilot was called about the *Eagle Otome* piloting assignment about 0530, and he boarded the tankship at Sabine Pass about 0750.

1.12.2 *Eagle Otome*

Master. The master, an Indian national, age 35, received a license as third mate in 1998 and then sailed exclusively on board AET vessels in increasingly higher-ranked officer positions. He obtained his master's certificate of competency from India in May 2005. He had worked as master on board two other AET ships for 11 months before the accident. In December 2009, he became master of the *Eagle Otome*. He had made about 10 previous transits on the Sabine-Neches Waterway on board vessels about the size of the *Eagle Otome*. He had also previously transited the Sabine-Neches Waterway on the *Eagle Otome* and recalled having transited previously with the first pilot.

The master completed a BRM training course in March 2009. His most recent physical examination before the accident took place in December 2009.

The master stated that he generally slept well and had a full night's rest during each of the 3 nights before the accident, when the *Eagle Otome* was at anchor at the Sabine Fairway

[69] The subsequent version of the 719K (released in November 2009) inquires about diagnosed sleep apnea. The first pilot reported his diagnosis in the medical evaluation conducted after the accident, in February 2010.

anchorage in the Gulf of Mexico. According to a work/rest schedule that he provided to the Coast Guard following the accident, he went to bed at midnight and rose about 0700 on Wednesday, January 20. On Thursday, January 21, he went to bed about 2300 and rose about 0730. On Friday, January 22, he went to bed about 2200 and rose about 0430 on the morning of the accident to prepare for the pilot boarding and the transit into Beaumont.

Helmsman. The helmsman, an Indian national, age 26, had been an able bodied seaman for 3 years and an ordinary seaman for 4 years before that. He had served on the *Eagle Otome* for nearly 9 months and had made four previous transits in the accident area, each one on board the *Eagle Otome* serving as helmsman. On the day of the accident, he came on duty at 0730. He told investigators that he had never experienced a problem with the tankship's handling.

1.12.3 *Dixie Vengeance*

Master. The towboat master, age 52, told investigators that he had been in the maritime industry for about 10 years and had worked for the towboat operator, Kirby Inland Marine, LLC, for 8 of those years. He had received all his recent mariner training through the company. He held a license as master of towing vessels issued in March 2007 and had worked on board the *Dixie Vengeance* since February 2009. On the day of the accident, he was working the 0600–1200 and 1800–2400 watches.

The towboat master provided a work/rest schedule following the accident. According to the schedule, he had slept about 9 hours during each of the four 24-hour periods leading up to the accident. He reported that he obtained this sleep in 4-hour and 5-hour segments in each 24-hour period because of the watch schedule on the vessel.

1.12.4 VTS Personnel

Watchstander. The VTS watchstander on the day of the accident, age 46, had worked at VTS Port Arthur for nearly 3 years after completing a 3- to 4-month training period. The training consisted of ship-handling knowledge, rules of the road,[70] and area familiarization for identification of facilities, waterways, and channel depths. In addition, he stood 2 months of supervised watches under a VTS training director. He also attended a ship simulator facility to gain familiarization with bridge watchstanding and shiphandling and participated in vessel ride-along programs to become familiar with shipboard operations and aspects of transiting the Sabine-Neches Waterway.

The VTS watchstander told investigators that he worked 12-hour shifts. On the day of the accident, he reported to work about 0845. The day before, on January 22, he worked a shift beginning at 0600. Before that, he had been off from work for 3 days. He told investigators that he had slept about 7 hours during each of the 4 nights before the accident.

[70] Navigation Rules and Regulations: International Navigational Rules Act of 1977 and the Inland Navigation Rules Act of 1980, 33 CFR Subchapter E.

Supervisor. The VTS supervisor on the day of the accident, age 37, had worked at VTS Port Arthur for about 4.5 years after transferring from VTS Houston. He told investigators that he worked 12-hour shifts, and, on the day of the accident, he started at 0600. He estimated that he had slept about 8 hours during each of the 2 nights before the accident. He had been off-duty for 2 days before that and told investigators that he generally slept well.

1.13 Fatigue

1.13.1 Background

Fatigue and its effects on human performance and transportation safety have received considerable attention in recent years. Although most people consider fatigue "as an outcome state, [that is] feeling tired or sleepy,"[71] researchers seek more precise definitions. One widely accepted definition terms fatigue as "a biological drive for recuperative rest."[72] That is, sleep deprivation results in a biological need for restorative sleep and a subjective state of sleepiness.

1.13.2 Causes of Fatigue

The fundamental causes of fatigue are related to the physiological effects of sleep loss, circadian disruption, extended hours of wakefulness, and sleep disorders. Although a variety of factors may have some moderating effects on fatigue, these four physiological fatigue factors are scientifically well-established as the primary underlying mechanisms. Typically, 8 hours of sleep per night will provide most people enough rest to avoid being fatigued the next day,[73] although some may need more sleep and some can sleep less without being fatigued. In general, the less sleep one obtains in any given regular sleep period, the more fatigued one will subsequently become. There are multiple reasons individuals may not obtain sufficient sleep. Insomnia, working long hours, or staying up late all lead to insufficient sleep and thus fatigue.

Circadian rhythms are generated by an internal biological clock located in the brain that controls the 24-hour cycle of physiological systems. For example, within each 24-hour period, people are programmed to be awake during the day and asleep at night. Circadian influences extend to all human systems, beyond regular sleep and wake times, including 24-hour body temperature, digestive, and endocrine rhythms. A person's circadian "clock" is generally programmed for its lowest point between about 0300 and 0500, during which time physiological and mental functioning is reduced. A second circadian low generally occurs between about 1500 and 1700.

[71] L. Di Milla and others, "Demographic Factors, Fatigue, and Driving Accidents: An Examination of the Published Literature," *Accident Analysis and Prevention*, vol. 43 (2011), pp. 516–532.

[72] A. Williamson and others, "The Link Between Fatigue and Safety," *Accident Analysis and Prevention*, vol. 43 (2011), pp. 498–515.

[73] M.M. Mallis, S. Banks, and D.F. Dinges, "Aircrew Fatigue, Sleep Need, and Circadian Rhythmicity." In E. Salas and D. Maurino (Eds.), *Human Factors in Aviation* (2nd Edition), pp. 401–436 (Burlington, Massachusetts: Academic Press, 2010).

Because it is difficult to rapidly change circadian rhythms, most people cannot quickly alter their sleep schedules from one day to the next without experiencing the effects of fatigue. Rather, circadian rhythms adjust slowly to new sleep schedules. The greater the difference between the old and new schedules, the longer the adjustment time needed; substantial schedule changes generally necessitate several days to a week of adjustment time. Thus, a person attempting to work during a period when, up to that point, he or she had been sleeping, will very likely be fatigued.[74]

Medically related sleep disorders can lead to fatigue as well, with OSA the most commonly diagnosed sleep disorder. The airways of OSA individuals become obstructed during sleep, causing loud snoring and, more importantly, breathing interruptions that disrupt sleep, interruptions of which the individuals are often unaware. The more severe the OSA, the more numerous the breathing interruptions and the more likely the individuals are to experience daytime fatigue. OSA is diagnosed through polysomnography, during which the patient sleeps under controlled conditions with key physiological parameters measured to determine quality and quantity of sleep.

Obesity and high blood pressure increase the risk for OSA, and in 2002, a review of the epidemiology of the condition estimated that about 7 percent of the U.S. population has at least moderate OSA.[75] Untreated OSA has been linked to daytime sleepiness, impaired vigilance, mood disturbances, and cognitive dysfunction.[76] As with fatigue in general, individuals with untreated OSA are at higher risk of transportation accidents than those without the condition.[77] Even mild OSA, when untreated, causes performance deficits that can affect safety. Researchers noted the following:[78]

> Pretreatment personal and public health ramifications [of OSA] include increased risk for motor vehicle crashes, occupational injuries, and decreased quality of life. Performance deficits during neuropsychological testing can be documented with even mild [OSA]. With a frequency of 15 apneas-hypopneas per hour of sleep, the decrement is equivalent to that associated with 5 years of aging. [CPAP is considered] the treatment of choice for most patients with [OSA].

[74] Williamson and others, pp. 498–515.

[75] T. Young, P.E. Peppard, and D.J. Gottlieb, “Epidemiology of Obstructive Sleep Apnea: A Population Health Perspective,” *American Journal of Respiratory and Critical Care Medicine*, vol. 165 (2002), pp. 1217-1239.

[76] H.C. Kim and others, “Sleep-Disordered Breathing and Neuropsychological Deficits: A Population-Based Study,” *American Journal of Respiratory and Critical Care Medicine*, vol. 156 (1997), pp. 1813–1819.

[77] J. Teran-Santos, A. Jimenez-Gomez, and J. Cordero-Guevara, “The Association Between Sleep Apnea and the Risk of Traffic Accidents,” Cooperative Group Burgos-Santander, *New England Journal of Medicine*, vol. 340, no. 11 (1999), pp. 847–51.

[78] E.J. Olson and others, “Obstructive Sleep Apnea-Hypopnea Syndrome,” *Mayo Clinic Proceedings*, vol. 78 (2003), pp. 1545–1552.

1.13.3 Fatigue and Cognitive Performance

Fatigue's adverse effects on cognitive performance are particularly relevant to transportation safety because operator effectiveness in contemporary transportation systems depends largely on cognitive rather than physical skills. The adverse effects of fatigue on cognitive performance have been demonstrated.[79] Research has shown that fatigued individuals perform more poorly on measures of vigilance, reaction time, selective attention (the ability to focus on a task while avoiding distraction), logical reasoning, and visual search, among others—all skills that contribute to the quality of a person's performance as a transportation system operator. In one study, sleep-deprived individuals showed evidence of cognitive impairment equivalent to those with positive blood alcohol levels,[80] that is, individuals with 24 hours of sustained wakefulness were comparably impaired on measures of cognitive performance to individuals with blood alcohol levels of 0.10 percent. A later study, comparing the performance of subjects at various levels of sleep deprivation with the performance of subjects at various levels of alcohol impairment, noted that even as little as 2 hours of sleep loss resulted in cognitive performance decrement equivalent to that of consuming two or three beers, or having an average breath alcohol level of 0.045 percent. The subjects' performance with regard to memory, vigilance, and reaction time worsened with increasing sleep loss, closely matching and in some cases exceeding the impairment resulting from alcohol consumption.[81]

1.13.4 Fatigue and Transportation Safety

Because of the adverse effects of fatigue on cognitive skills and the importance of cognitive skills to operator effectiveness, fatigued individuals have been found to be at higher risk of accidents.[82] In 1995, the NTSB examined the role of fatigue in a segment of highway accidents (single-vehicle, heavy truck accidents) and found that a number of sleep-related factors contributed to the accidents.[83] Although motor vehicle and truck operators have been the primary focus of fatigue-related transportation safety research, a link between operator fatigue and accidents has been noted in other transportation modes as well.[84]

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[79] See (a) M. Blagrove, C. Alexander, and J.A. Horne, "The Effects of Chronic Sleep Reduction on the Performance of Cognitive Tasks Sensitive to Sleep Deprivation," *Applied Cognitive Psychology*, vol. 9 (1995), pp. 21–40; (b) M. Gillberg and T. Akerstedt, "Sleep loss and performance: No 'safe' duration of a monotonous task," *Physiology and Behavior*, vol. 64 (1998), pp. 599–604.

[80] D. Dawson and K. Reid, "Fatigue, alcohol, and performance impairment," *Nature*, vol. 388 (1997) p. 235.

[81] T. Roehrs and others, "Ethanol and Sleep Loss: A 'Dose' Comparison of Impairing Effects," *Sleep*, 26, (2003), pp. 981–985.

[82] See (a) Teran-Santos; (b) M.H. Smolensky and others, "Sleep Disorders, Medical Conditions, and Road Accident Risk," *Accident Analysis and Prevention*, vol. 43 (2011) pp. 533–548; (c) J.A. Horne and L.A. Reyner, "Sleep Related Vehicle Accidents," *British Medical Journal*, vol. 310 (1995), pp. 565–567.

[83] *Factors that Affect Fatigue in Heavy Truck Accidents*, Safety Study NTSB/SS-95/01 (Washington, DC: National Transportation Safety Board, 1995).

[84] See (a) S. Folkard, "Transport: Rhythm and Blues," Westminster Lecture on Transport Safety (London: Parliamentary Advisory Council for Transport Safety, 2000); (b) J. Dorrian and others, "The Effects of Fatigue on Train Handling During Speed Restrictions," *Transportation Research, Part F* (2006), pp. 243–257.

The NTSB has identified fatigue as a factor in at least two highly visible marine accidents. The NTSB determined that the March 24, 1989, grounding of the vessel *Exxon Valdez* on Bligh Reef,[85] an accident that caused extensive pollution and environmental destruction to the waters of Prince William Sound, Alaska, was caused, among other factors, by the "failure of the third mate to properly maneuver the vessel because of [his] fatigue and excessive workload … ." The NTSB also found that the June 23, 1995, grounding of the passenger vessel *Star Princess*, also in Alaskan waters, was fatigue related.[86] It determined that the probable cause of that accident was the pilot's "poor performance, which may have been exacerbated by chronic fatigue caused by sleep apnea." Because the NTSB does not investigate all major maritime accidents that occur in the United States and because some accident investigators place less emphasis on investigating fatigue than do others, fatigue likely has played a role in the cause of other marine accidents as well.

1.13.5 Mitigating and Preventing Fatigue in Transportation

Given the complexities of contemporary transportation systems, a systematic approach to fatigue mitigation and prevention is widely considered to be the most effective approach to manage the adverse effects of fatigue on the performance of transportation system operators. The fundamental parameters of such an approach include (1) proper scheduling and effective hours of service rules, (2) operator education, and (3) diagnosis and treatment of sleep disorders.

The Coast Guard rule governing rest and duty periods is found at 46 CFR 15.1111(a). The rule states:

> Each person assigned duty as officer in charge of a navigational or engineering watch, or duty as a rating forming part of a navigational or engineering watch, on board any vessel that operates beyond the Boundary Line shall receive a minimum of 10 hours of rest in any 24-hour period.

Further, 46 CFR 15.1111(b) states:

> The hours of rest required under paragraph (a) of this section may be divided into no more than two periods, of which one must be at least 6 hours in length.

Laws specified in 46 *United States Code* 8104 (n) pertain to tankships and crewmembers on tankers. The law states:

> On a tanker, a licensed individual or seaman may not be permitted to work more than 15 hours in any 24-hour period or more than 36 hours in any 72-hour period, except in an emergency or a drill. In this subsection, "work" includes any

[85] *Grounding of the U.S. Tankship* Exxon Valdez *on Bligh Reef, Prince William Sound near Valdez, Alaska, March 24, 1989.* Marine Accident Report NTSB/MAR-90/04 (Washington, DC: National Transportation Safety Board, 1990).

[86] *Grounding of the Liberian Passenger Ship* Star Princess *on Poundstone Rock, Lynn Canal, Alaska, June 23, 1995*. Marine Accident Report NTSB/MAR-97/02 (Washington, DC: National Transportation Safety Board, 1997).

administrative duties associated with the vessel whether performed on board the vessel or offshore.

As a signatory to the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) of the IMO, the United States, through the Coast Guard, agreed to adhere to and enforce STCW rules, rules that apply to foreign-flagged vessels operating in U.S. waters (such as the *Eagle Otome*), and to U.S.-flagged vessels operating beyond the boundary line on seagoing voyages. U.S.-flagged vessels that operate in U.S. waters are subject to Coast Guard rules and U.S. laws but not to STCW requirements.

The IMO recently revised its STCW work/rest requirements, and these revisions are scheduled to take effect in 2012. The new STCW rules (A-VIII/1) mandate that watchstanders, that is, officers in charge of a watch, or those with "a rating forming part of a watch" must have 10 hours of rest in any 24-hour period and 77 hours of rest in any 7-day period. Hours of rest may be divided into no more than two periods, one of which must be at least 6 hours long. As with Coast Guard rules, exceptions to these rules apply to emergencies or "other overriding operational conditions."

The Sabine Pilots Association, although not a regulatory entity, established a rest period policy for its members. The policy stated that Sabine pilots must have a mandatory rest period of 8 hours after

- Completing a single piloting assignment on board a vessel with a deep draft of 33 feet or greater, heading to or from the sea buoy at the Sabine Fairway anchorage, and starting or ending above the Neches River intersection;

- Completing a second piloting assignment, and fewer than 8 hours passed between the completion of the first job and the assignment to the second job; and

- Any single assignment lasting 12 hours or more.

The rest period begins at the completion of the qualifying assignment, and pilots are not eligible for subsequent assignments until after at least 8 hours have passed.

In a July 5, 2011, e-mail, the Jefferson and Orange Board of Pilot Commissioners ("the commission") informed the NTSB that it does not oversee hours of service issues for the Sabine Pilots Association. Rather, the commission noted that it is primarily concerned with pilot training, standards of pilot selection, and commissioning and recommissioning pilots as their licenses expire and need to be renewed. The commission believes that the Sabine Pilots Association is responsible for enforcing hours of service compliance issues for its pilots.

In a June 22, 2011, e-mail, the American Pilots' Association (APA; the national trade association of professional maritime pilots) informed the NTSB that "under current U.S. Coast Guard legal interpretations" Coast Guard hours of service rules do not apply to state pilots conning tankships such as the *Eagle Otome*. The Coast Guard, independently of the APA, reiterated this view in a July 19, 2011, e-mail to the NTSB. The Coast Guard noted that it did not consider the *Eagle Otome* pilots to be members of the ship's crew. The pilots, the Coast Guard said, were operating under the authority of Texas and not under Coast Guard requirements, adding that "at present, state v. Federal pilotage requirements is an established legal issue."

Major transportation modes in the United States have established hours of service rules and regulations for their operators. For example, in August 2011, the Federal Railroad Administration upgraded its hours of service rules to include provisions for the disruptive effect that working through nighttime hours has on circadian rhythms. The Federal Aviation Administration (FAA) recently initiated the process of upgrading its hours of service rules, contained in 14 CFR Parts 117 and 121. Among the provisions of the proposed upgrade is an accounting for circadian effects on (aviation) pilots' performance by requiring additional rest, or reduced hours of service, for flights beginning in what would be pilots' circadian low periods.

Further, the FAA proposed an alternative to hours of service rules—fatigue risk management systems (FRMS)—in which airlines work with the FAA to develop tailored scheduling rules according to the routes they operate and their particular needs. For example, international flights crossing multiple time zones can lead to disruptions in pilots' circadian rhythms. Airlines may propose different scheduling requirements for its international pilots than for its domestic pilots to take into account the fatiguing effects of rapid transmeridian flight, commonly referred to as "jet lag," on pilot performance.

In a November 20, 2010, letter to the FAA, the NTSB supported the FAA's efforts to upgrade its hours of service rules. In particular, the NTSB supported the FAA's efforts to promote adoption of an FRMS to mitigate fatigue, noting that it was "encouraged by the proposed rules' recognition of FRMS as a way for both [airline] operators and the FAA to make informed decisions about operator-specific exemptions to the rule to address unique operational challenges." In addition to endorsing an FRMS in its proposed rulemaking, on August 3, 2010, the FAA issued an advisory circular on the subject, titled "Fatigue Risk Management Systems for Aviation Safety" (AC 120-103), which provides guidance to develop an FRMS. Further, in July 2011, the International Civil Aviation Organization, with the International Air Transport Association and the International Federation of Air Line Pilots' Associations, issued an FRMS implementation guide for airlines. The guide defined an FRMS as "a data-driven means of continuously monitoring and managing fatigue-related safety risks, based upon scientific principles and knowledge as well as operational experience that aims to ensure relevant personnel are performing at adequate levels of alertness."

Educating operators about the adverse effects of fatigue on their performance can reduce the risk of fatigue to transportation safety as well. The FAA uses all three elements of fatigue prevention by requiring air transport carriers to establish fatigue education programs for their crews and is developing an advisory circular to guide carriers on developing acceptable fatigue training programs.

The Coast Guard has also endorsed operator education regarding the adverse effects of fatigue. On March 21, 2008, it issued Navigation and Inspection Circular (NVIC)[87] 02-08,

[87] The Coast Guard uses NVICs to disseminate information and advisory material to the marine industry. Although the NVIC guidance is not enforceable, the industry usually makes an effort to comply with it. NVICs are sometimes used to disseminate information that will subsequently be proposed as regulations.

describing for vessel owners and operators parameters of an effective crew endurance management system (CEMS). CEMS is the Coast Guard's program, implemented by vessel owners and operators, to educate mariners on fatigue mitigation and prevention strategies. Also, as discussed in the following section, the Coast Guard recently upgraded its requirement for mariners to demonstrate proper and effective treatment for diagnosed sleep disorders.

1.13.6 Coast Guard Restrictions and Waiver

In October 2008, the Coast Guard upgraded its medical oversight system and issued NVIC 04-08 to inform mariners and health care practitioners of its revised medical standards. NVIC 04-08 also provided health care practitioners with guidance and recommended tests to use when conducting a medical examination for Coast Guard licensure requirements, including the issuance of limitations and conditions on mariner licenses. The new standard required mariners diagnosed with sleep disorders to

> Submit [to the Coast Guard] all pertinent medical information and current status report from a qualified sleep medicine specialist. Include sleep study with a polysomnogram, use of medications and titration study results. If surgically treated, [mariner] should have post operative polysomnogram to document cure or need for further treatment.

If the information provided to the Coast Guard indicates that a diagnosed sleep disorder is being successfully treated (for example, by the prescription and use of a CPAP device), the Coast Guard will grant the mariner a waiver and renew his or her license, provided that the mariner adheres to the conditions of the waiver. With regard to OSA, a waiver would require the mariner to provide evidence of "daily or nightly use of the CPAP device for sleep prior to operating under the authority of the credential." The waiver also requires the mariner to annually provide the Coast Guard a "sleep specialist evaluation and evidence of compliance through submission of compliance log or maintenance of wakefulness testing (MWT)."[88]

1.14 Sabine Pilots Association

1.14.1 Organization

The two pilots who were on board the *Eagle Otome* at the time of the accident were members of the Sabine Pilots Association, as are all compulsory state-licensed pilots who navigate ships entering the Sabine-Neches Waterway from foreign ports. Sabine pilots have serviced the local waterways since 1881, and the association's stated goal is to provide smooth and effective pilotage service to the local shipping industry. At the time of the accident, the Sabine Pilots Association headquarters was located in Groves, Texas, just north of Port Arthur. At Sabine Pass, where the second pilot boarded the *Eagle Otome* on the day of the accident, the association maintained a continuously staffed pilot station with four pilot boats. On the day of the accident, 14 pilots were on duty.

[88] MWT evaluates a person's ability to stay awake during the day. The test normally follows an overnight polysomnography and is conducted in four sleep trials spaced 2 hours apart.

The Sabine Pilots Association has no regulatory authority and considers its members to be independent contractors to the ship operators. At the time of the accident, 29 state-licensed pilots were members of the Sabine Pilots Association. The president of the association is elected annually by the pilot members from their current membership and represents the association at the national APA. The Sabine Pilots Association is a member of the Southeast Texas Waterways Advisory Council, or SETWAC (see sections "1.15 SETWAC Protocol and Sabine Pilots Association Guidelines" and "1.16 Jefferson and Orange County Board of Pilot Commissioners.").

1.14.2 Pilot Training

When an applicant is approved to serve as a pilot, he or she begins a 2-year pilot training program.[89] The applicant serves as an apprentice pilot during the first year and is assigned to one of the state-licensed pilots who will oversee the apprentice pilot's progress through the program. The apprentice pilot also serves with different pilots each week in a variety of pilotage assignments. About halfway through the first year of training, the apprentice pilot is given a few weeks off from the pilot rotation to prepare for the Federal license exam. During the exam, apprentice pilots in the Sabine Pilots Association are questioned about the pilotage waters in the Sabine-Neches Waterway and other information. On successfully completing the exam, the apprentice pilot returns to the pilotage rotation and resumes hands-on training. At the end of the first year, the Sabine Pilots Association recommends the apprentice pilot to the Jefferson and Orange County Board of Pilot Commissioners, and if no Sabine pilot makes an adverse recommendation about the apprentice pilot, he or she becomes a "deputy" pilot and begins the deputy year, which is the second and final year of training before becoming a full pilot licensed by the state of Texas.

During the second year, the deputy pilot gradually takes on assignments involving larger tonnage and draft. Although the deputy pilot works mostly alone during the second year, his or her performance continues to be evaluated by other association pilots. Halfway through the second year, the deputy pilot attends a simulator course using both electronic simulation and scaled-down model ships in a maneuvering basin. The course focuses on shiphandling but also on simulated emergencies involving power and rudder failures, all designed to acquaint the deputy pilot with possible real-life emergencies. On successfully completing the simulator course, the deputy pilot returns to rotation training to finish the year. At the end of the second year, if the performance was satisfactory, the deputy pilot becomes a Texas state pilot with the approval of the Jefferson and Orange County Board of Pilot Commissioners.

1.15 SETWAC Protocol and Sabine Pilots Association Guidelines

Because the size of vessels transiting in the Sabine-Neches Waterway began to increase in the 1970s, local parties involved in the waterway's management determined to implement increased safety measures. The parties formed SETWAC, which became a safety committee for the ports and waters of the Sabine-Neches Waterway. Members included marine terminal

[89] The Jefferson and Orange County Board of Pilot Commissioners establishes the training standards for local pilots, and the Sabine Pilots Association arranges for pilots in training to meet these standards.

operators, ship companies, shipping agents, shipyard and repair facilities, directors of local ports, emergency response management, the Corps, and the Sabine Pilots Association. The Coast Guard is a nonvoting member, and the Jefferson and Orange County Board of Pilot Commissioners, although not a member, has an open invitation to attend the SETWAC meetings.

SETWAC members developed policies to facilitate the "safe and secure movement of commerce" in the Sabine-Neches Waterway. The policies were contained in a printed document titled, "Ship Traffic Operating Protocol for the Sabine-Neches Waterway" (see appendix B, "SETWAC protocol"). Three of the policies listed in the SETWAC protocol were the following:

- Vessels with a length of 875 feet or greater, vessels with a beam of 125 feet or greater, and vessels with a deadweight of 85,000 metric tons or greater will only move during daylight hours above the Texas Island Intersection. The *Eagle Otome*'s deadweight was 95,663 metric tons, and its beam was 138 feet; thus, the tankship was restricted to transiting north of the Texas Island Intersection only during daylight hours.

- [Two vessels] with a combined beam that equals or exceeds one-half the channel width will not meet day or night.

- Vessels with an overall length of 860 feet or greater and vessels with a beam of 120 feet or greater must have two pilots on board when transiting the Sabine-Neches Waterway. At 810 feet in length, the *Eagle Otome* was just under the length specification, but its 138-foot-wide beam meant that the SETWAC protocol called for a second pilot.

The Sabine Pilots Association also developed guidelines pertaining to pilotage. Following their inception, the guidelines underwent some transformation; however, the most recent document version, dating from the early 1990s, was called "Guidelines Governing Aboard Vessels Requiring Two Pilots When Transiting the Sabine-Neches Waterway" ("piloting guidelines"; see appendix C). The Sabine Pilots Association designated the two-pilot piloting area of the Sabine-Neches Waterway into five areas. The first and most southern of these areas, piloting area A, stretched (from south to north) from the boarding station at Sabine Pass to beacon 40, located near the Texas Island Intersection. The next area, piloting area B, stretched from south to north, from beacon 40 near the Texas Island Intersection to the "schoolhouse" just north of the Port of Port Arthur. In piloting area A, the Sabine Pilots Association specified that "pilot no. 1" have navigational control and "pilot no. 2" handle radio communication and miscellaneous tasks.[90] In piloting area B, the guidelines specified that "pilot no. 2" have the conn and that "pilot no. 1" handle the radio and miscellaneous tasks. The piloting guidelines also stated, "Both pilots shall be on the navigation bridge of the vessel and either shall be ready, willing, and able to assume command of navigation of the vessel at all times. The above

[90] The association defined "radio" as listening to and handling all radio communications relating to traffic, safety, and position-reporting requirements during the vessel's transit through the waterway. "Miscellaneous" tasks included assisting the conning pilot if requested, providing information regarding dense traffic conditions, watching for clearance or obstructions, arranging for tugs, briefing the ship's master of mooring arrangements, and providing any other assistance to the conning pilot and the ship's master as requested.

guidelines as set by the Sabine Pilots should not be construed as limiting the assigned pilots in the exercise of their good judgment."

After the accident, the president of the Sabine Pilots Association testified at the Coast Guard hearing on the accident that "it is incumbent upon the individual commissioned pilots that they comply with the protocol and any other policies." He also stated that the piloting guidelines served as "the initial framework and blueprint" for establishing the two-pilot system and that, in the approximately two decades or so since the piloting guidelines were drafted, pilot practices had evolved

> … to speak specifically to the swap of the conn or the changeover, the way it's done now is pretty standardized and it's handed down in the training program too as to when each pilot will relieve the other and that … basically evolved in order to accomplish the main element of the system and that was to equitably apportion the transit time between the two individuals.

The pilot association president stated that he thought that the evolution of the piloting guidelines had improved area pilotage and that he was comfortable with the idea that individual pilots applied the guidelines with some variation.[91]

Both of the *Eagle Otome* pilots also testified at the Coast Guard hearing. They indicated that the division of duties specified in the piloting guidelines were not followed as a matter of practice. Also during the hearing, the second pilot reviewed AIS imagery of the *Eagle Otome* commencing the turn at Missouri Bend. On seeing the tankship's position in the canal, the second pilot commented that it appeared that the *Eagle Otome* "may have gotten too deep into the bend." The second pilot also said that, to initiate turns in the waterway, he would input rudder commands of 10 or 20 degrees.

1.16 Jefferson and Orange County Board of Pilot Commissioners

U.S. law gives each state the authority to regulate and administer pilotage requirements for vessels engaged in foreign trade. The state or local pilot commissions set the minimum service and training requirements for state pilots. Usually, but not always, state pilot commissions require that state pilots, in addition to their state pilot license, also hold the appropriate Coast Guard Federal pilot license (endorsement) for the waterway in which they work.[92] According to the Texas Transportation Code, Section 69.015, the Jefferson and Orange County Board of Pilot Commissioners ("the commission") has exclusive jurisdiction over pilot services provided in Jefferson and Orange counties, including stops and landing places on navigable streams fully or partially located in the commission's jurisdiction.

Twenty-four states and two U.S. territories oversee their pilots through pilot oversight organizations. The role of the oversight organizations has historically been to protect the public

[91] Hearing testimony by the president of the Sabine Pilots Association is available in the NTSB public docket for this accident.

[92] Holding a Federal pilot license also requires that the licensee complete the annual Coast Guard medical examination discussed in the section "1.12.1 Sabine Pilots; First Pilot's Medical Condition."

interest by ensuring that the pilots that navigate vessels in local waters are qualified to do so. As was noted in a recent article, “Together, the 24 state systems [and two territories] comprise a national program of navigation safety regulation and environmental protection.”[93] The oversight organizations enforce pilot practices through their authority to license pilots. In general, oversight organizations investigate pilot-related incidents and accidents and address pilot deficiencies identified in their or the Coast Guard’s investigations by suspending or revoking pilot licenses or by requiring the pilots in question to participate in additional training. The application of oversight differs between the various organizations. For example, one developed and applied medical standards—independent of the Coast Guard’s—for the pilots it oversees. Another established hours of service rules for its pilots. Also, members of the various oversight organizations differ in their backgrounds. They include active and retired pilots, attorneys, port facility owners, and those with no background in marine operations. In many states, pilot oversight organizations, in addition to their pilot oversight duties, also establish the rates for piloting services to be collected from ship owners and operators.

Pilots have typically formed associations within each pilot oversight jurisdiction to represent their interests, to serve as liaisons to ship owners to facilitate scheduling and fee collection for pilot services, to schedule and dispatch pilots, and to establish training protocols and apprenticeship practices to conform to oversight organization requirements. The pilot associations, which have no regulatory authority, often participate in local waterway activities to promote safety and best pilot practices. The pilot associations also contribute to the APA, which represents their interests and promotes pilot safety on a national and international level. No comparable national organization exists for local pilot oversight organizations.’

In the public hearing that the Coast Guard convened following the *Eagle Otome* accident, the chairman of the Jefferson and Orange County Board of Pilot Commissioners quoted part of Texas Transportation Code, Section 69.017, with respect to the commission’s duties:

> … establish the number of pilots necessary to provide adequate pilotage service for Jefferson and Orange County ports, establish pilotage rates, make recommendations to the governor about any pilot whose license should not be renewed or should be revoked, adopt rules and issue orders to pilots and vessels when necessary to secure efficient pilot services, provide penalties to persons who are not pilots who operate vessels in and out of the port, establish times when pilot services are available, approve any changes to the locations of pilot stations, examine pilots and determine … the qualifications of applicants for deputy pilot, examine qualifications for full … pilot, and reexamine full … pilots for renewal, investigate complaints about pilots from industry or the public, investigate pilot conduct in marine casualties as defined by the U.S. Coast Guard, consider pilot association applications for rate changes, adopt necessary rules for the regulation of pilots under the Texas transportation statute.[94]

[93] P.G Kirchner and C.L. Diamond, “Unique Institutions, Indispensible Cogs, and Hoary Figures: Understanding Pilotage Regulation in the United States,” *University of San Francisco Maritime Law Journal*, vol. 23 (2010), pp. 168–205.

[94] The hearing testimony by the chairman of the Jefferson and Orange County Board of Pilot Commissioners is available in the NTSB public docket for this accident.

The members of the commission are appointed by the governor of Texas. At the time of the accident, the commission had five members of various backgrounds, none of them with maritime experience. In the postaccident Coast Guard hearing, the commission chairman indicated that he owned marine facilities on the Sabine-Neches Waterway and had served on the commission since 2001. The *Eagle Otome* accident was the first accident that the commission had investigated since his appointment.[95] The chairman also remarked that this was the first accident since 1979 that had resulted in an oil spill in the Sabine-Neches Waterway. He stated that the commission would investigate accidents when the Coast Guard or the pilots reported them to the commission and that the commission would investigate any incident involving a pilot. To his knowledge, no such incident had previously occurred during his tenure. The chairman also stated that he had a standing invitation to attend SETWAC's meetings but had not attended one since his term began in 2001.

The chairman told NTSB investigators that the commission was not a party to the Sabine Pilots Association's piloting guidelines or other guidelines pertaining to ship operations in the Sabine-Neches Waterway and that the commission was not aware of the piloting guidelines until they were introduced as evidence during the postaccident Coast Guard hearing 6 weeks after the accident. The chairman stated that, in general, he understood the reason for the two-pilot guidelines to be waterway safety.

1.17 Bridge Resource Management

BRM is the effective use by a vessel's bridge team (masters, officers, crew, and pilots) of all available resources—information, equipment, and personnel—to safely operate the vessel. BRM, as well as that of crew resource management in aviation from which BRM originated, was developed to help operators enhance the quality of teamwork and to recognize and mitigate the consequences of operator errors. Researchers noted that crew resource management training was "designed to improve teamwork … by applying well-tested tools (e.g., performance measures, exercises, feedback mechanisms) and appropriate training methods (e.g., simulators, lectures, videos) targeted at specific content (i.e., teamwork knowledge, skills, and attitudes)."[96] One of the principles of BRM is that everyone on the bridge should understand his or her responsibilities and be able to freely and professionally communicate observations about the vessel's progress to others on the bridge.

Both pilots on board the *Eagle Otome* had taken BRM training; however, their most recent training before the accident took place more than a decade earlier, in the late 1990s.

[95] The commission's findings and recommendations based on this accident are available in the NTSB public docket for this accident. In part, the commission recommended that Sabine pilots train in BRM and that the Sabine Pilots Association submit revised piloting guidelines to the commission for review and approval.

[96] P. O'Connor and others. "Crew Resource Management Training Effectiveness: A Meta-Analysis and Some Critical Needs." *The International Journal of Aviation Psychology*, 18 (2008), pp. 353–368.

Since 1974, the NTSB has investigated several accidents in which breakdowns in BRM caused or contributed to the accident.[97] (Also see section “1.18.2 Accidents Involving Two Pilots On Board.”)

1.18 Previous NTSB Action

1.18.1 Accidents in the Sabine-Neches Waterway

The NTSB has investigated three previous accidents in the Sabine-Neches Waterway. Two of the accidents, one in 1979[98] and the other in 1980,[99] involved explosions and fires on board tankships. The third accident, which occurred on February 25, 1979, involved a collision between the inbound tankship S/T *Mobil Vigilant* and the outbound tankship S/T *Marine Duval* near Beaumont.[100] Each vessel had a Sabine pilot on board. As a result of its investigation, the NTSB made six recommendations. Safety Recommendation M-80-36 requested that the Coast Guard, in conjunction with the U.S. Army Corps of Engineers and the Sabine Pilots Association, assess traffic control guidelines with respect to maneuvering of large vessels in restricted channels, and, if necessary, revise the guidelines. The NTSB also issued Safety Recommendations M-80-37 through -41 to the Sabine Pilots Association, addressing pilot communication, operation, scheduling, and use of bridge electronic equipment. Safety Recommendation M-80-36 was classified “Closed—Acceptable Action” in August 1981. Safety Recommendations M-80-37 through -41 were classified “Closed—Unacceptable Action” in February 1984 because of the lack of response from the association. In the three decades since Safety Recommendations M-80-36 through -41 were issued, various safety developments have been established that have helped resolve the issues raised in the recommendations. For example, VTS has been implemented, the NTSB and pilot associations across the country communicate regularly with each other, and improved policies have been put in place regarding ship operation in the Sabine-Neches Waterway.

[97] Recent examples include (a) *Allision of Bahamas-Registered Tankship M/T* Axel Spirit *with Ambrose Light, Entrance to New York Harbor, November 3, 2007*, Marine Accident Report NTSB/MAR-09/02 (Washington, DC: National Transportation Safety Board, 2009); (b) *Grounding of Hong Kong-Registered Containership* New Delhi Express, *New York Harbor, Kill Van Kull Waterway, April 15, 2006*, Marine Accident Brief NTSB/MAB-07/02 (Washington, DC: National Transportation Safety Board, 2007); (c) *Allision of Liberia-Registered Fruit Juice Carrier M/V* Orange Sun *with U.S.-Registered Dredge* New York, *Newark Bay, New Jersey, January 24, 2008.* Marine Accident Report NTSB/MAR-09/03. Washington, DC: National Transportation Safety Board, 2009).

[98] *Liberian Tank Vessel M/V* Seatiger *Explosion and Fire, Sun Oil Terminal, Nederland, Texas, April 19, 1979*, Marine Accident Report NTSB/MAR-80/12 (Washington, DC: National Transportation Safety Board, 1980).

[99] *Explosion and Fire on Board the U.S. Tankship* Monticello Victory, *Port Arthur, Texas, May 31, 1981*, Marine Accident Report NTSB/MAR-81/14 (Washington, DC: National Transportation Safety Board, 1981).

[100] *Collision of S/T* Mobil Vigilant *and S/T* Marine Duval *on the Neches River, near Beaumont, Texas, February 25, 1979*, Marine Accident Report NTSB/MAR-80/08 (Washington, DC: National Transportation Safety Board, 1980).

1.18.2 Accidents Involving Two Pilots On Board

On April 15, 2006, the 853-foot-long containership *New Delhi Express* grounded in the Kill Van Kull waterway in New York Harbor.[101] The ship was inbound to Port Newark, New Jersey, after completing a transatlantic voyage from Gibraltar. Two local pilots were on board. One of them, a Sandy Hook pilot, boarded the ship outside New York Harbor and navigated the vessel to the Kill Van Kull waterway. The other pilot, a docking pilot with the Metro Pilots Association, was to bring the ship to the dock at Port Newark. The NTSB concluded, in part, that the two pilots did not adequately communicate with each other about the passage into port. Specifically, the docking pilot who had the conn leading up to the grounding did not clearly communicate to the other pilot and the master his intended maneuvers in a narrow and challenging portion of the waterway near the Bayonne Bridge. As a result of the *New Delhi Express* accident, the NTSB issued Safety Recommendation M-07-3 to state pilot commissions whose harbor pilots work with docking pilots:

> Require your harbor and docking pilots to take part in recurrent joint training exercises that emphasize the concepts and procedures of bridge resource management.

Following a favorable response from the majority of the state pilot commissions, Safety Recommendation M-07-3 was classified "Closed—Acceptable Action" in October 2009.

1.18.3 Pilot Commission Communication

In its investigation of the November 3, 2007, allision of containership M/V *Cosco Busan* with the San Francisco–Oakland Bay Bridge,[102] the NTSB concluded that regular communication among pilot oversight organizations about pilot-related performance data and best practices would enhance the ability of those organizations to effectively oversee pilots. As a result, the NTSB issued Safety Recommendation M-09-5 to the Coast Guard:

> Establish a mechanism through which representatives of pilot oversight organizations collect and regularly communicate pilot performance data and information regarding pilot oversight and best practices.

The Coast Guard did not concur with M-09-5, stating in a July 2009 response that "pilot oversight organizations have not expressed a desire or need to collect and regularly communicate pilot performance data." The Coast Guard further stated that the APA provided enough mechanisms for information exchange among various pilot organizations. Because of the Coast Guard's decision not to implement M-09-5, the NTSB classified the recommendation

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[101] *Grounding of Hong Kong-Registered Containership* New Delhi Express, *New York Harbor, Kill Van Kull Waterway, April 15, 2006*, Marine Accident Brief NTSB/MAB-07/02 (Washington, DC: National Transportation Safety Board, 2007), available at http://www.ntsb.gov.

[102] *Allision of Hong Kong-Registered Containership M/V* Cosco Busan *with the Delta Tower of the San Francisco–Oakland Bay Bridge, November 7, 2007*, Marine Accident Report NTSB/MAR-09/01 (Washington, DC: National Transportation Safety Board, 2009), available at http://www.ntsb.gov.

"Open—Unacceptable Response" in November 2009, pending further response from the Coast Guard.

1.18.4 Change in Mariner Medical Condition

Also as a result of the *Cosco Busan* accident investigation, the NTSB concluded that the Coast Guard's system of medical oversight of mariners lacked a requirement for mariners to report changes in their medical status between medical evaluations (required annually for pilots and every 5 years for non-pilot mariners). As a result of this finding, the NTSB issued Safety Recommendation M-09-4 to the Coast Guard:

> Require mariners to report to the Coast Guard, in a timely manner, any substantive changes in their medical status or medication use that occur between required medical evaluations.

The Coast Guard concurred with the intent of the recommendation but stated that to require all mariners to report changes in their medical condition would require a regulatory change, which the Coast Guard believed would be met with resistance. The Coast Guard stated that it was reviewing options to address the issue. In November 2009, the NTSB classified Safety Recommendation M-09-4 "Open—Acceptable Response."

1.18.5 Hours of Service Rules

In 1999, the NTSB recommended that the Coast Guard change its hours of service rules for U.S. mariners. In a June 1999 letter to the Coast Guard, the NTSB noted that research showed that "insufficient sleep, irregular and unpredictable schedules, [and] working during low points in the circadian rhythm" can "affect … performance." Safety Recommendation M-99-1 asked the Coast Guard to:

> Establish within 2 years scientifically based hours-of-service regulations that set limits on hours of service, provide predictable work and rest schedules, and consider circadian rhythms and human sleep and rest requirements.

In e-mails from the Coast Guard to the NTSB, the Coast Guard stated its belief that providing voluntary educational and guidance programs to mariners would meet the intent of this regulation. However, the NTSB did not agree, citing its belief that a regulatory response, together with voluntary guidance programs, was needed. As a result of the Coast Guard's response, the NTSB classified Safety Recommendation M-99-1 "Open—Unacceptable Response" in November 2007.

1.18.6 Obstructive Sleep Apnea

As a result of experience with OSA in all transportation modes, including marine accidents involving mariners with OSA,[103] the NTSB issued safety recommendations to multiple

[103] (a) *Collision of Staten Island Ferry* Andrew J. Barberi*, St. George, Staten Island, New York, October 15, 2003*, Marine Accident Report NTSB/MAR-05/01 (Washington, DC: National Transportation Safety Board, 2005);

modal agencies in October 2009, including Safety Recommendations M-09-14, -15, and -16 to the Coast Guard:[104]

> Modify Form 719K (Merchant Mariner Physical Examination Report) to elicit specific information about any previous diagnoses of OSA and about the presence of specific risk factors for that disorder. (M-09-14)
>
> Implement a program to identify licensed mariners subject to the Navigation and Vessel Inspection Circular on Medical and Physical Evaluation Guidelines for Merchant Mariner Credentials (NVIC 04-08) and who are at high risk for OSA, and require that those mariners provide evidence through the medical certification process of having been appropriately evaluated and, if treatment is needed, effectively treated for that disorder before being granted unrestricted medical certification. (M-09-15)
>
> Develop and disseminate guidance for mariners, employers, and physicians regarding the identification and treatment of individuals at high risk of OSA, emphasizing that mariners who have OSA that is effectively treated are routinely approved for continued medical certification. (M-09-16)

With regard to Safety Recommendation M-09-14, the Coast Guard was in the process of revising the 719K form to ask specifically about sleep apnea[105] when the NTSB made the recommendation. At that time, the NTSB had seen a draft of the revised form and noted that the revisions included a specific question about OSA and other sleep disorders. However, the draft form did not include any questions about symptoms of OSA, such as snoring or daytime sleepiness. Because the NTSB did not believe that the Coast Guard's revisions to the 719K form were substantial enough, the NTSB issued Safety Recommendation M-09-14.

In March 2010, the Coast Guard partially concurred with Safety Recommendation M-09-14 and said that it would confer with the Merchant Mariner Medical Advisory Committee as to what modifications should be made to the 719K form to best address OSA. As a result, the NTSB classified M-09-14 "Open—Acceptable Response" in July 2010.

The Coast Guard also partially concurred with Safety Recommendation M-09-15 in March 2010 but stated that it could not impose additional requirements on mariners simply for being identified at risk for OSA or for any other condition. The Coast Guard did offer to change NVIC 04-08 to improve the ability of medical practitioners to address potential OSA cases. Again, the Coast Guard stated that it would confer with the Merchant Mariner Medical Advisory

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(b) *Grounding of the Liberian Passenger Ship* Star Princess *on Poundstone Rock, Lynn Canal, Alaska, June 23, 1995*, Marine Accident Report NTSB/MAR-97/02 (Washington, DC: National Transportation Safety Board, 1997), both available at http://www.ntsb.gov.

[104] The letter containing Safety Recommendations M-09-14 through -16, dated October 20, 2009, is available on the NTSB's website at http://www.ntsb.gov.

[105] The Coast Guard's revision of the form was based, in part, on NTSB recommendations related to the 2003 *Andrew J. Barberi* accident and the 2007 *Cosco Busan* accident.

Committee as to appropriate changes to NVIC 04-08. As a result of the Coast Guard's response, the NTSB classified M-09-15 "Open—Acceptable Alternate Response" in July 2010.

The Coast Guard concurred with Safety Recommendation M-09-16 and, in March 2010, stated that it was drafting an alert to mariners, employers, and physicians about the risks of OSA. As a result of the Coast Guard's action, the NTSB classified M-09-16 "Open—Initial Response Received" in July 2010.

As of the date of this report, the Coast Guard was reviewing how it might implement the three recommendations. It has not yet drafted the alert to mariners recommended in M-09-16.

1.19 Postaccident Action

Following the accident, the *Eagle Otome*'s operating company, AET, notified the NTSB that the company had elected to take certain corrective and preventive measures. For example, AET determined that all of its ships would immediately start using escort tugboats northward from the Texas Island Intersection. AET also covered and marked the "engine emergency stop" button on all its vessels' engine control consoles. Senior AET deck officers also attended river transit simulator training.

The Sabine Pilots Association also notified the NTSB of some corrective measures that it had taken following the accident. In a December 2010 letter, the president of the pilot association stated, in part, that after the accident both of the *Eagle Otome* pilots had attended BRM refresher training with emergency shiphandling simulation. He also stated that the entire Sabine Pilots Association was to attend this refresher training as soon as scheduling would permit, which he anticipated would be in the first quarter of 2011 (NTSB investigators confirmed that this training was completed in February 2011). The president confirmed that AET had increased the use of tugboat assistance for loaded tankships in the 400-foot-wide section of the waterway and that the pilot association fully supported AET's initiative to do so. With respect to the piloting guidelines, the president stated that the association was in the process of revising and updating the document so that it would more closely reflect how the two-pilot system was being conducted.

2. Analysis

This analysis begins with a summary of the accident sequence, followed by a brief discussion of factors that were neither causal nor contributory to the accident and then a discussion of factors that were found to have caused or contributed to the accident.

2.1 Accident Summary

The *Eagle Otome* was en route from Pajaritos, Mexico, to an ExxonMobil facility in Beaumont, Texas, with a load of crude oil. About 0530 on January 23, 2010, a pilot from the Sabine Pilots Association boarded the *Eagle Otome* at the Sabine Fairway anchorage off the coast of Texas to begin the transit up the Sabine-Neches Waterway to Beaumont. About 0750, a second Sabine pilot boarded the tankship, as called for by the Sabine Pilots Association, which had established a two-pilot guideline in the waterway for vessels greater than 120 feet in width. The transit was uneventful for about the next hour and a half. About 0910, the *Eagle Otome* entered a section of the waterway called the Sabine-Neches Canal, where the waterway narrowed to about 400 feet. About 0922, the tankship needed to complete about a 32-degree turn to starboard at a location referred to as Missouri Bend. The first pilot, who had the conn, was on the radio speaking with the master of the towboat *Dixie Vengeance*, which was outbound in the canal about 2.6 miles north of the *Eagle Otome* and would be meeting the tankship near the Port of Port Arthur. When the radio exchange ended about 0923, the *Eagle Otome* had entered Missouri Bend but the first pilot had not yet ordered the starboard turn. At 0923:54, the first pilot ordered "hard to starboard," and the tankship began to make its way through Missouri Bend. At 0924:11, the first pilot gave rudder orders to ease the turn. However, the *Eagle Otome* continued the starboard motion despite the pilot's easing the rudder. The first pilot characterized this starboard motion as the first of four sheering events. When the tankship's starboard bow came in close proximity to the east bank of the canal, it turned back toward the center of the canal, sheering to port this time, despite the first pilot's rudder orders to counteract it. The *Eagle Otome* sheered toward the west bank of the canal and, about 0929, passed close to the west foundation of the Dr. Martin Luther King, Jr. Memorial Bridge in Port Arthur. As the *Eagle Otome* approached the west bank of the canal, the cushion of water at the bow forced the ship to starboard, sheering toward the east bank of the canal despite the first pilot's rudder orders to counteract it. The first pilot again attempted to prevent the bow from turning back when it began to interact with the east bank. However, a final sheering event occurred, forcing the *Eagle Otome* toward the west bank of the canal, where the general cargo vessel *Gull Arrow* was berthed at the Port of Port Arthur. About 0935, the *Eagle Otome*'s bow collided with the *Gull Arrow*'s starboard side. Seconds later, the forward of the two barges that were being pushed by the *Dixie Vengeance* collided with the starboard side of the *Eagle Otome*. The second pilot and the master on the *Eagle Otome*, as well as the *Dixie Vengeance* master, all reported the accident to the Coast Guard.

Following the accident, NTSB investigators tested the mechanical systems on both the *Eagle Otome* and the *Dixie Vengeance*, and all inspected systems were found to be in proper working order. Postaccident toxicological testing, which was performed on all the pertinent crewmembers on the three accident vessels as well as on the VTS watchstander and the VTS supervisor, was negative for the presence of alcohol or illegal drugs. The weather at the time of the accident was calm and clear with light winds and visibility of about 6 miles. Nothing in the weather conditions would have encumbered navigation. The NTSB therefore concludes that weather, mechanical failure, and illegal drug or alcohol use were not factors in the accident.

The area of the Sabine-Neches Canal where the *Eagle Otome* and the *Dixie Vengeance* were going to meet each other was narrow, about 400 feet wide. Transiting and meeting in this area required considerable vigilance. However, safe meeting and passing of vessels the size of the *Eagle Otome* with smaller vessels can be—and is—accomplished on a near-daily basis in the Sabine-Neches Canal. Postaccident photos of the accident location clearly show that the *Dixie Vengeance* was keeping to the right of the center of the canal. The towboat master did so to allow the *Eagle Otome* as much space as possible to transit on the towboat's port side. The *Dixie Vengeance* master was navigating as agreed to by radio communication with the first pilot. The NTSB therefore concludes that the vessel meeting arrangement agreed to by the towboat master and the first pilot was appropriate and was not a factor in the accident.

The watchstanding personnel at VTS Port Arthur had AIS and radar imagery available to monitor the Sabine-Neches Waterway and provide guidance to marine operators. However, the accident area was displayed only as a small portion of the total area shown on the VTS watchstanders' screens. Therefore, the sheering of the *Eagle Otome* that began after Missouri Bend would have been nearly imperceptible on the VTS screens unless the watchstanders considerably enlarged the display of that section of the canal. From the watchstanders' perspective, there was no reason to do so. Also, because of the nature of AIS transmission, the information available to VTS watchstanders was delayed by several seconds. Although VTS monitored the waterway, the watchstanders could not have prevented or mitigated the results of the accident because the information available to them did not indicate a problem with the movement of the *Eagle Otome*. The NTSB therefore concludes that personnel at VTS Port Arthur played no role in the accident.

2.2 Navigation

About 0914, as the *Eagle Otome* was approaching the Texas Island Intersection, the first pilot made a security call inquiring about any outbound traffic near the bridge at the Port of Port Arthur. The *Dixie Vengeance* master promptly responded and stated that his towboat was about 3 miles from the bridge. The two pilots were conversing with each other at the time, and neither acknowledged the call from the *Dixie Vengeance*.

The navigational sequence of events that led to the accident began at Missouri Bend. At this turn in the Sabine-Neches Canal, the *Eagle Otome* needed to make about a 32-degree turn to starboard. As the tankship approached Missouri Bend about 0923, the first pilot who had navigational control was on the radio with the master of the towboat *Dixie Vengeance* discussing meeting arrangements. He had not yet given the order to turn the *Eagle Otome*, and the tankship's rudder was still at midship when he responded to the *Dixie Vengeance* master's radio call announcing his location. The piloting guidelines established by the Sabine Pilots Association stated that radio communication and other miscellaneous tasks should be handled by "pilot no. 2"—in this case, the second pilot—so that the pilot with the conn could focus on navigation. Nevertheless, the first pilot was conducting the radio calls during the transit, and he did not give the rudder order at Missouri Bend until after he had concluded the 45-second radio conversation with the *Dixie Vengeance* master. The NTSB therefore concludes that, contrary to pilot association guidelines, the first pilot on the *Eagle Otome* was conducting a radio call at a critical point in the waterway, and the radio call interfered with his ability to fully focus on conning the vessel.

When the first pilot finished the call with the towboat master, he ordered “hard to starboard” to commence the turn. A hard rudder order when maneuvering Aframax tankships is not uncommon in and of itself. However, the turn at Missouri Bend is only about 32 degrees, and hard to starboard is a large rudder order for such a relatively mild turn. Moreover, the first pilot had initiated all of his previous turns that morning with a maximum rudder order of 20 degrees, as opposed to hard rudder, even though some of those earlier turns in the waterway necessitate larger course changes than Missouri Bend. Postaccident analysis of the *Eagle Otome*’s S-VDR data revealed that bank effect at Missouri Bend had already begun the bow’s movement to starboard before the first pilot’s rudder order had taken effect. The hard to starboard rudder order—which was excessive at that point—therefore likely indicated the first pilot’s realization that the *Eagle Otome* was “too deep into the bend.” Although the tankship exited Missouri Bend without incident, a sheering sequence had begun, which the first pilot was unable to correct. From this point forward in the transit, his efforts to arrest the sheering were ineffective (also see section “2.4 Fatigue”). The NTSB therefore concludes that the first pilot’s failure to correct the sheering motions that began after his late turn initiation at Missouri Bend led to the accident.

When the second sheering event occurred while the vessel was approaching the Dr. Martin Luther King, Jr. Memorial Bridge, causing the *Eagle Otome* to cross the canal from the east bank to the west, the pilots’ comments indicated that they both were aware of the sheering problem: At 0928:13, the first pilot asked the second pilot, “Is she gonna come back?” Six seconds later, the second pilot answered, “Might.” At this point, the two pilots could have alerted the *Dixie Vengeance* of the increasing danger that the sheering posed to vessels upriver, as several minutes remained before the *Eagle Otome* was to meet them. However, the pilots did not do so.

In the radio conversation between the first pilot and the towboat master about 5 minutes earlier, the *Dixie Vengeance* master offered to facilitate the meeting, stating, at 0923:42, “If I need to speed up or slow down to make it easy on both of us, let me know.” Still, despite the two pilots’ realization that they did not have full control of the *Eagle Otome* and despite knowing that the *Dixie Vengeance* master was willing to do what he could to facilitate the meeting if asked, neither pilot alerted him of the situation. At 0933:14, a full 5 minutes after the two pilots likely recognized the sheering problem, the first pilot finally said to the second pilot, “Will you talk to this next tow?” Eleven seconds later, at 0933:25, the second pilot answered, “What do you want me to tell them? Just one whistle or look out here we come?” The first pilot answered, “One, yeah, look out, the one there is *Vengeance*.” Yet despite the first pilot’s instruction that the second pilot alert the *Dixie Vengeance*, the second pilot did not make the radio call. Almost 1 minute later, at 0934:16, the *Dixie Vengeance* master radioed asking, “Inbound ship lookin’ okay?” Despite his inquiry, the towboat master received no response, and the first definitive sign that the *Eagle Otome* was experiencing problems came from his seeing the tankship’s anchor drop. At that point, it was too late for him to stop the towboat and avoid the tankship. Had the *Dixie Vengeance* master received a radio warning when the *Eagle Otome* was sheering near the bridge or shortly thereafter, which was about 5 minutes before the accident, he could have reacted sooner. As it was, he was able to reduce the towboat’s speed by only about 2 knots in the

1 minute from when he saw the tankship's anchor drop to the time of the collision. The NTSB therefore concludes that, had the *Eagle Otome* pilots alerted the *Dixie Vengeance* master of the sheering problem, the force of the collision between the *Eagle Otome* and the *Dixie Vengeance* tow would have been lessened or the collision might have been avoided altogether.

2.3 Division of Piloting Duties; Breakdown in Bridge Resource Management

To enhance safety in the Sabine-Neches Waterway as tankship sizes increased, SETWAC established a ship traffic protocol in the early 1980s which, in part, called for two onboard pilots on large ships in the waterway. The Sabine Pilots Association also established guidelines regarding the duties and responsibilities of its pilots, including who should have the conn in what segment of the waterway. The piloting guidelines were detailed in a printed document called "Guidelines Governing Aboard Vessels Requiring Two Pilots When Transiting the Sabine-Neches Waterway." The intent of the piloting guidelines seemed to be that the Sabine Pilots Association wanted its pilots to form navigation teams. This intent was commendable; the use of teams in operating complex systems, such as navigating large vessels in narrow waterways, is preferable to using single operators. Researchers have noted the following:[106]

> Teams have become the strategy of choice when organizations are confronted with complex and difficult tasks. Teams are used when errors lead to severe consequences; when the task complexity exceeds the capacity of an individual; when the task environment is ill-defined, ambiguous, and stressful; when multiple and quick decisions are needed; and when the lives of others depend on the collective insight of individual members [p. 540].

The use of two operators to navigate large vessels on the Sabine-Neches Waterway is consistent with human factors principles. That is, given the complexity of the task, the use of teams on the waterway would enable pilots to share navigation-related tasks so that one pilot does not become overloaded. For example, while one pilot focuses on vessel navigation tasks, the other pilot communicates with nearby vessels. Teams also enable pilots to monitor each other's performance to reduce errors and their consequences, which is consistent with good BRM practice. However, at the time the *Eagle Otome* accident occurred, the Sabine pilots were not consistently applying the piloting guidelines in their operations. As a result, the first pilot had the conn in the accident area when the second pilot should have. More significantly, when the first pilot should have been focusing on the upcoming turn at Missouri Bend at about 0923, he—not the second pilot, as should have been the case when the first pilot had the conn—was conducting the radio call with the *Dixie Vengeance* master. When the second pilot was needed to assist the first pilot after the radio communication, he was not prepared to do so because he had not been sufficiently engaged in the navigation. The two pilots had both attended BRM training; however, their most recent training before the accident was in the late 1990s. Leading up to the accident, neither pilot appeared to take full advantage of having an experienced and equal colleague on the bridge. The second pilot allowed himself to lose situational awareness by reading the newspaper and disengaging from performing radio and miscellaneous duties specified in the piloting

[106] E. Salas, N.J. Cooke, and M.A. Rosen, "On Teams, Teamwork, and Team Performance: Discoveries and Developments," *Human Factors*, vol. 50 (2008), pp. 540–547.

guidelines. The first pilot chose to conduct both the conning and miscellaneous duties by himself, and thus did not use all of the resources that were available to him. The NTSB concludes that although both pilots completed BRM training, they failed to apply the team performance aspects of BRM to this operation. The NTSB therefore recommends that governors of states and territories in which state and local pilots operate require local pilot oversight organizations that have not already done so to implement initial and recurring BRM training requirements.

According to the president of the Sabine Pilots Association, individual variation on the piloting guidelines was permissible and, in his opinion, may even have improved the pilotage in the Sabine-Neches Waterway. However, adhering to the Sabine Pilots Association guidelines that non-conning pilots handle radio and miscellaneous tasks could have allowed the first pilot to focus exclusively on navigation. The NTSB concludes that the *Eagle Otome* pilots did not follow Sabine Pilots Association guidelines with respect to division of duties while under way. The NTSB therefore recommends that the Sabine Pilots Association take action to ensure that its member pilots follow its guidelines with respect to division of duties and responsibilities of pilots.

In the Coast Guard's hearing on the accident, the chairman of the Jefferson and Orange County Board of Pilot Commissioners stated that the commission's duties included, in part, establishing the number of pilots necessary for safe pilotage in the area and establishing rules for the pilots to follow. However, the commission chairman was unaware of the piloting guidelines that the Sabine Pilots Association had had in place for about 20 years. To ensure the highest levels of safety, the commission should have been aware of best practices in the waterway, ensured that the practices were documented, and ensured that the local pilots' duties and behaviors met the intent of the documented guidelines (see section "2.4 Fatigue").

2.4 Fatigue

The totality of the evidence indicates that, at the time of the accident, the first pilot was subject to the fatiguing effects of insufficient sleep from a combination of untreated OSA, extended wakefulness, and disrupted circadian rhythms. Throughout the series of sheers that began at Missouri Bend, the first pilot's engine and helm orders were either insufficient or not applied preemptively enough to counter and stop the sheering. In other words, during the sheering events, he was "behind," rather than ahead of, the tankship's motions; quicker and more aggressive rudder and engine inputs were needed.

The ability to correct the sheering required the very cognitive skills most susceptible to the adverse effects of fatigue: vigilance, perception, judgment, and reaction time, among others. These cognitive skills were needed to enable the first pilot to determine not only what was happening to the ship he was navigating, but to predict the effects of his commands on the vessel's future path in the waterway. His failure to properly interpret and project the *Eagle Otome*'s path based on his steering and engine commands can be directly attributed to fatigue. Therefore, the NTSB concludes that the first pilot's fatigue adversely affected his ability to predict and stop the *Eagle Otome*'s sheering.

The first pilot had been diagnosed with moderate to severe OSA following a polysomnography in 2008 and was subsequently prescribed a CPAP device to treat the condition. However, he found the CPAP uncomfortable and did not use it consistently, testifying that he had not used it in at least the 4 days before the accident. Given the severity of his diagnosed sleep disorder, not using the CPAP would have led to his being fatigued.

In addition to untreated OSA, the first pilot maintained a fatigue-inducing schedule in the 2 days before the accident. Although the Sabine Pilots Association sought to reduce the effects of fatigue by establishing a rest period policy, the policy itself was insufficient to prevent fatigue among the pilots. It did not address (1) circadian rhythms, (2) time on task, or (3) extended wakefulness, all factors well-documented to be fatigue-inducing.

Sabine Pilots Association members, like those of other pilot associations, can work at any hour during a 2-week duty period, after which they are allotted 2 weeks off duty. During their on-duty periods, the association assigns piloting jobs in order, so that after a pilot completes one rotation, that pilot is then the last to be assigned until all other pilots ahead of him or her in the rotation have been assigned piloting jobs. As a result, pilots working less than 12 hours can be called to report for duty any time in a 24-hour period. Further, by this policy, a pilot can report for duty less than 8 hours after completing a transit as long as the first transit took place on board a vessel with a draft of less than 33 feet and lasted less than 12 hours.

Because it does not consider time of day, the Sabine Pilots Association rest period policy allows pilots to be assigned piloting jobs at any hour, day or night, during their 2-week duty period. Further, the policy does not fully address time on task or periods of extended wakefulness. Thus, as was true with the first pilot on the *Eagle Otome*, a pilot can complete an 8-hour+ transit on a relatively shallow-draft vessel and then be called for a 10-hour+ commitment only 3 hours after completing the first. In short, the rest period policy of the Sabine Pilots Association, although well intended, does not prevent fatigue.

The first pilot had maintained a day-awake, night-asleep schedule for at least 3 days during the week before the accident. Two days before the accident, he awoke about 0700, reported for duty about 1000, and was off duty at 1852. Just over 3 hours later, about 2200, he was called for another piloting assignment that he began shortly after midnight and finished at 0813 the day before the accident. These consecutive piloting assignments resulted in extended wakefulness, insufficient sleep, and disruption to circadian rhythm because the first pilot (1) was awake continuously for at least 27 hours, receiving no sleep when he should have slept 8 hours, and (2) worked through the night when his circadian rhythms were used to sleeping.

After completing the second consecutive piloting assignment the day before the accident, the first pilot then went to bed about 1015, rose about 1700, and remained awake but off duty until 2100 when he went to bed. Although he was in bed for much of the day before the accident, the quality of the sleep he received would almost certainly have been poor because (1) he did not treat his OSA and (2) he was attempting to sleep during a period when he had ordinarily been awake. Even if he had used the CPAP that day, his circadian rhythms, which were consistent with being awake in this period, would likely have prevented him from accruing a full 6 hours and 45 minutes of restorative sleep during the period he was in bed (1015 to 1700). As noted, he went to bed again at 2100 but was called at 0230 the morning of the accident and reported for duty at 0530, where he continued on duty until the accident.

The first pilot was therefore awake during a period when his circadian rhythms corresponded to times of lower performance, times when he would ordinarily have been in his deepest sleep. In the 48 hours before the accident, the schedule that he maintained was in and of itself fatigue-inducing. As a result, the first pilot was subject to fatigue from multiple sources: untreated OSA, circadian disruption, and extended wakefulness, making him highly susceptible to the adverse effects of fatigue on his cognitive performance and at higher risk of involvement in an accident. In effect, none of the three fundamental parameters of fatigue prevention was in place in this accident. The first pilot's sleep disorder was not treated, he was not given formal training on the adverse effects of fatigue, and no effective hours of service rules were in place to prevent fatigue-inducing schedules. Therefore, the NTSB concludes that the combination of untreated OSA, disruption to his circadian rhythms, and extended periods of wakefulness that resulted from his work schedule caused the first pilot to be fatigued at the time of the accident.

The Sabine Pilots Association's rest period policy was intended to prevent pilot fatigue; however, because it had shortcomings, the policy was nevertheless ineffective. Further, no regulatory body with pilot oversight authority had rules or regulations in place that could have precluded the adverse effects of fatigue-inducing scheduling practices from impairing the very cognitive skills that the pilots needed most to effectively navigate vessels through the Sabine-Neches Canal. Therefore, the NTSB concludes that no effective hours of service rules were in place that would have prevented the Sabine pilots from being fatigued by the schedules that they maintained.

The Jefferson and Orange County Board of Pilot Commissioners asserted that its authority only extended to pilot licensing and pilot training. The commission's lack of scheduling rules created a void that permitted fatigued pilots to perform safety-critical duties in a busy, challenging waterway. Such a void in a complex transportation system poses a threat to property, ecosystems, and the lives of those in and near the waterway. Researchers have suggested criteria—such as time of day, circadian rhythms, duration of opportunity for sleep, sleep quality, predictability, sleep debt, time on task, and short breaks—to evaluate the efficacy of hours of service rules.[107] Although it can be argued that not all of the criteria are appropriate to a fatigue mitigation and prevention regulatory scheme, these criteria can be used as a standard of comparison against which regulations can be assessed, and most hours of service rules in place today meet at least several of these criteria. However, because no regulatory body had established effective hours of service rules that Sabine pilots were required to follow, the pilots were at risk for fatigue in all of the suggested criteria, highlighting the safety hazard posed by the regulatory vacuum that existed. Without effective hours of service rules and education in fatigue management, there was little to mitigate the effects of fatigue among the Sabine pilots except for Coast Guard medical oversight of mariner sleep disorders. Therefore, the NTSB concludes that the absence of an effective fatigue mitigation and prevention program among the pilots operating under the authority of the Jefferson and Orange County Board of Pilot Commissioners created a threat to the safety of the waterway, its users, and those nearby.

[107] C.B. Jones and others, "Working Hours Regulations and Fatigue in Transportation: A Comparative Analysis," *Safety Science*, vol. 43 (2005), pp. 225–252.

The circumstances of this accident illustrate the important role that hours of service rules play in preventing fatigue in transportation. The NTSB's concern about effective hours of service rules led it to issue Safety Recommendation M-99-1 to the Coast Guard calling for it to upgrade its hours of service rules to reflect advances in the science of sleep. The NTSB has been disappointed with the Coast Guard's response to M-99-1, particularly in light of the extensive research demonstrating the adverse effects of fatigue that has been gathered since the NTSB issued the recommendation. Other Federal transportation regulators, such as the FAA, have made considerable progress toward preventing fatigue by establishing or initiating scientifically based hours of service rules. The NTSB has consistently disagreed with the Coast Guard's position that mariner education and medical oversight are sufficient to prevent mariner fatigue because this position is not based on research in general and research in transportation safety in particular.

At this time, a sufficient amount of experience has been gained to provide regulators with knowledge about the benefits of an FRMS to prevent fatigue-inducing scheduling practices. A recent study provides several illustrations of the application of FRMSs to transportation settings.[108] The FAA has stated that this approach would meet the intent of its proposed rulemaking changes to implement effective, scientifically based hours of service programs to prevent schedule-induced fatigue, and the NTSB has supported this approach. Pilot commissions and the Coast Guard may consider this method as an acceptable means of implementing hours of service rules effective in preventing fatigue.

The statement by the Jefferson and Orange County Board of Pilot Commissioners—that it deals primarily with pilot training and pilot re-commissioning—appears to meet the letter, but not the spirit, of its regulatory responsibilities. As Kirchner and Diamond note, "State pilotage systems not only license pilots and oversee their professional activities (as the Coast Guard does for Federal pilots), they also seek to ensure that each port in the state has a reliable, expert pilot operation … ."[109] The commission's charter calls for it to "adopt rules and issue orders to pilots and vessels when necessary to secure efficient pilot services," a responsibility that gives the commission the authority to regulate the safety of pilot actions and performance. Pilot oversight organizations should use the power that the governors of their states and territories have given them to fully regulate practices that enhance the safety of their waterways. To enhance safety in the Sabine-Neches Waterway, the commission could have been aware of and enforced the intent of the two-pilot guidelines that the Sabine Pilots Association developed for piloting large vessels through the Sabine-Neches Waterway and played an active role in SETWAC. The commission could also have implemented a fatigue mitigation and prevention program to educate pilots about fatigue and require that fatigue-preventing hours of service rules govern pilot schedules. The commission's lack of familiarity with the Sabine Pilots Association's two-pilot guidelines further illustrates that the commission did not take an active role to ensure waterway safety through establishing safety rules and piloting oversight. Therefore, the NTSB concludes that the Jefferson and Orange County Board of Pilot Commissioners should have more fully exercised its authority over pilot operations on the Sabine-Neches Waterway by becoming aware of and enforcing the Sabine Pilots Association's two-pilot guidelines and implementing a fatigue mitigation and

[108] P. Gander and others, "Fatigue Risk Management: Organizational Factors at the Regulatory and Industry/Company Level," *Accident Analysis and Prevention,* vol. 43 (2011), pp. 573–590.

[109] Kirchner and Diamond, pp. 168–205.

prevention program among the Sabine pilots. The NTSB therefore recommends that the Jefferson and Orange County Board of Pilot Commissioners develop and implement (1) a system to monitor its state-licensed pilots so that the commission can verify the execution of policies, procedures, and/or guidelines necessary for safe navigation, and (2) a fatigue mitigation and prevention program among the Sabine pilots.

The NTSB is concerned that other pilot oversight organizations, like the Jefferson and Orange County Board of Pilot Commissioners, may not be exercising their authority to ensure the safety of our nation's waterways by effectively overseeing the activities and work schedules of local pilots. In the interests of safety, therefore, organizations that oversee pilots must ensure that sufficient regulations are in place so that pilots follow best practices for safety. Because most pilots are required to have Coast Guard licenses, Coast Guard oversight of mariner medical standards is already in place to reduce the risk of fatigue from sleep disorders. However, the circumstances of this accident suggest that pilot oversight organizations may lack regulations that promote the highest level of safe practices among their pilots, including hours of service rules that prevent fatigue-inducing scheduling. Therefore, the NTSB recommends that governors of states and territories in which state and local pilots operate ensure that local pilot oversight organizations effectively monitor and, through their rules and regulations, oversee the practices of their pilots to promote and ensure the highest level of safety. In addition, the NTSB recommends that governors of states and territories in which state and local pilots operate require local pilot oversight organizations that have not already done so to implement fatigue mitigation and prevention programs that (1) regularly inform mariners of the hazards of fatigue and effective strategies to prevent it, and (2) promulgate hours of service rules that prevent fatigue resulting from extended hours of service, insufficient rest within a 24-hour period, and disruption of circadian rhythms.

The circumstances of this accident also suggest that pilot oversight organizations differ in their awareness of the fatiguing effects of poor scheduling practices. In the *Cosco Busan* investigation, where it was evident that pilot oversight organizations did not systematically and regularly communicate with each other and did not have the ability to readily access a database of pilot incidents and accidents, the NTSB concluded that regular meetings of oversight organizations and a regularly accessible database would enhance the oversight effectiveness of these organizations.

No mechanism is currently in place for pilot oversight organizations to regularly communicate with each other to learn of safety issues that their colleagues are encountering and of ways to address those issues. In addition, pilot oversight organizations that maintain databases of pilot incidents and accidents have access only to their own pilots' activities. These databases provide insufficient sample sizes to portray the true picture of safety trends that would be available in a nationwide database. The Coast Guard does maintain a database of marine accidents and incidents, but it (1) is not restricted to pilots but includes all mariners, (2) is only available by request to the Coast Guard and a response to a database request necessitates extensive Coast Guard effort due to manpower and resource limitations, and (3) requires considerable expertise and database knowledge to fully exploit. Because of these limitations, the NTSB issued Safety Recommendation M-09-5 to the Coast Guard in the belief that only the Coast Guard had the resources and the objective commitment to marine safety to establish a nationwide communication mechanism. However, the Coast Guard declined to act on the recommendation, stating that (1) pilot oversight organizations have not expressed a need for such suggestions and (2) the APA "provides sufficient mechanisms of information exchange among pilot organizations."

This accident indicates that a need exists for both regular communication and a readily accessible database of nationwide pilot incidents and accidents that could reveal to pilot oversight organizations particular hazards—for example, fatigue-inducing scheduling—that jeopardize the safety of the waterways they oversee and allow them to discuss with each other these safety hazards and methods to address them. Moreover, the association that the Coast Guard identifies as best suited to carry out the intent of Safety Recommendation M-09-5, the APA, is not a pilot oversight organization and represents the interests of only one segment of U.S. marine operations, pilots on local waterways. The APA does not represent the interests of vessel operators, vessel owners, vessel flag states, classification societies, the IMO, other waterway users, the waterway ecosystems, or the neighbors of the waterways. By contrast, the Coast Guard, as a U.S. government agency, oversees civilian marine operations to ensure the safety of our nation's waterways and to protect the marine environment. Therefore, the NTSB concludes that the Coast Guard is the organization with the resources, capabilities, and expertise best suited to (1) enhance communication among pilot oversight organizations and (2) establish an easy-to-use and readily available database of pilot incidents and accidents. Given the Coast Guard's response, the NTSB classifies Safety Recommendation M-09-5 "Closed—Unacceptable Action/Superseded." The NTSB recommends that the Coast Guard facilitate and promote regular meetings for representatives of pilot oversight organizations to communicate information regarding pilot oversight and piloting best practices. In addition, the NTSB recommends that the Coast Guard establish a database of publicly available pilot incidents and accidents and make the database easy to use and readily available to all pilot oversight organizations.

2.5 Medical Oversight

The first pilot did not report his OSA diagnosis on his subsequent 719K form, dated February 2009, nor was he required to do so because the version of the form in effect at that time did not specifically ask about the diagnosis of sleep disorders. The Coast Guard's subsequent version of the 719K form, released in November 2009, does inquire about sleep disorders, and the first pilot disclosed his OSA diagnosis during his subsequent medical certification in February 2010. The Coast Guard requires mariners with OSA waivers to annually submit evidence of compliance with their treatment plans. The NTSB is pleased with the changes that the Coast Guard has made in its medical oversight system of mariners. As currently implemented and practiced, the system should prevent mariners with diagnosed sleeping disorders from performing safety-related duties without demonstrating that they are effectively treating their disorders.

In 2009, the NTSB issued Safety Recommendation M-09-4, which would require mariners to report to the Coast Guard any significant medical changes that occur between mandatory medical evaluations. Had M-09-4 been implemented, the first pilot on the *Eagle Otome* would have been required to promptly notify the Coast Guard of his OSA diagnosis in 2008, but he ultimately did not report it until nearly 2 years later, after the accident. Because of the loophole that currently exists in the Coast Guard's medical reporting system, the NTSB reiterates M-09-4 in this report.

2.6 Whistle Alert and General Alarm

Leading up to and at the time of the accident, the master of the berthed *Gull Arrow* was on the bridge checking on the installation of a new radar. He heard several blasts of the *Eagle Otome*'s whistle, sounded by the first pilot, which made him aware of the impending collision. The *Dixie Vengeance* master also heard the tankship's whistle blasts. At that point, the *Gull Arrow* master sounded his ship's general alarm. Doing so was prudent and facilitated alerting crewmembers and longshoremen, who were offloading cargo from the ship, about the danger. Security video footage from the dock where the *Gull Arrow* was berthed shows the personnel reacting to the warning.

In the NTSB's investigation of the January 24, 2008, allision of the fruit juice carrier M/V *Orange Sun* with the dredge *New York*,[110] the NTSB concluded that the pilot and the master on board the juice carrier should have sounded the ship's whistle to attempt to warn the *New York* crew of the impending accident. The pilot had made five radio calls on VHF channel 13 to attempt to warn the *New York* crew but had received no acknowledgement that the crew had heard his calls. The NTSB concluded that sounding the *Orange Sun* whistle would have been prudent in using all available resources to alert people in harm's way. Because the first pilot on the *Eagle Otome* did sound 12 blasts of the tankship's whistle, which were heard and acted on, the NTSB concludes that the first pilot's sounding the *Eagle Otome*'s whistle and the *Gull Arrow* master's sounding the cargo vessel's general alarm were prudent and effective.

2.7 Oil Spill Response

Within minutes of the accident and resulting oil spill, boat crews with MSU Port Arthur established a safety zone around the three vessels, and VTS Port Arthur broadcasted an alert to mariners that the canal in that area was closed. About 1 hour after the accident, the Coast Guard established a safety zone along a 12-mile section of the Sabine-Neches Waterway. Local police and fire department assets notified residents and businesses in the affected area of the accident and also went door-to-door to ensure their safe evacuation. The *Eagle Otome*'s vessel response plan was also enacted efficiently. The Coast Guard quickly assembled an on-scene unified command, and oil spill response organizations formed an effective joint team to tackle the spill. The numbers of contracted oil spill response resources that the ship owner deployed to the accident scene were in accordance with the assets identified in the vessel response plan. The NTSB therefore concludes that the accident response and oil spill recovery efforts were timely and effective.

2.8 Waterway Risk Analysis

More than 11 years have passed since the last PAWSA was conducted for the Port of Port Arthur. Because of the evolving and increasing traffic density in the Sabine-Neches Waterway, a new PAWSA could help identify new or changed risk factors and assess how VTS may have influenced conditions since its establishment.

[110] *Allision of Liberia-Registered Fruit Juice Carrier M/V* Orange Sun *with U.S.-Registered Dredge* New York, *Newark Bay, New Jersey, January 24, 2008*, Marine Accident Report NTSB/MAR-09/03 (Washington, DC: National Transportation Safety Board, 2009).

Moreover, NTSB investigators' initial calculations that assessed the channel width at Missouri Bend together with the *Eagle Otome*'s dimensions indicate that the Sabine-Neches Canal is narrower at Missouri Bend than what the Corps' preliminary guidelines stipulate for channel width and vessels of that length and beam. The Corps has made clear that its guidelines, on which NTSB investigators based their calculations, are conservative, that the width guidance can usually be reduced, and that many channels in the United States are narrower than the guidelines suggest. The Corps uses simulation studies to aid in determining final channel configuration. Although a simulation study was conducted in the Sabine-Neches Waterway in 2002, the Corps did not conduct such a study of Missouri Bend, and according to a Corps director, it is not clear what effect the results of a simulation study of Missouri Bend would have had on the channel width in that location.

The circumstances of this accident suggest that the margin of safety in the Sabine-Neches Waterway—particularly in its narrow sections, such as the Sabine-Neches Canal where the accident occurred—may be insufficient, and the NTSB is concerned that the turn dimensions at Missouri Bend may be inadequate for large ships. Moreover, as indicated in an NTSB kinematics parameter extraction study, the hydrodynamic forces in the area of Missouri Bend and the Port of Port Arthur can become excessive, and the channel dimensions leave little margin for operator error. Given the hazardous substances carried on board some of the vessels in the waterway, any increased risk of collision is of concern. The risk could be mitigated by certain strategies. For example, greater restriction on meeting arrangements could be applied. Another example would be for large ships to employ tugboats when transiting in narrow sections of the waterway (as the *Eagle Otome* operating company AET chose to do following the accident). Although large vessels have been transiting the waterway for years without incident, the NTSB nevertheless concludes that the dimensions of the Sabine-Neches Waterway may pose an unacceptable risk, given the size and number of vessels transiting the waterway. The NTSB therefore recommends that the Coast Guard conduct a PAWSA for the Sabine-Neches Waterway, determine from that whether the risk is unacceptable, and if so, develop risk mitigation strategies.

2.9 Control Design

The master of the *Eagle Otome* tried to increase the tankship's propulsion from 65 to a total of 90 rpm, or from full ahead to navigational full ahead, in an attempt to avoid striking the *Gull Arrow*. However, when the master attempted to press the button that would have enabled him to do this, he inadvertently pressed an adjacent button—the "manual emergency stop" button—in the group of identically shaped buttons on the engine control console. As a result, instead of increasing the propulsive power, the opposite occurred: the engine stop order reduced rather than increased the engine rpm. NTSB investigators determined that the master's error did not contribute to the accident because, at the same time, the first pilot ordered the anchor dropped to try to stop the vessel anyway. Without the help of the anchor, the *Eagle Otome* would have needed about 2,625 feet to come to a stop, and less than 500 feet separated the *Eagle Otome* and the *Gull Arrow* at that point.

Although the engine stop order did not lead to the accident, the master's error was a common one in which the operator intends to accomplish one action but instead causes another, an error referred to as a "slip."[111] This type of error, which includes such common ones as typographical errors, is highly influenced by the design of the particular control. The NTSB has long been interested in control design in transportation and its relationship to operator errors that lead to accidents.[112] Although commonly accepted human factors guidelines for control design have been available for several decades to reduce the incidence of design-induced errors, and although such guidelines are required to be applied to aircraft control design, vessel designers continue to design critical component controls without employing these guidelines.

For example, one standard human factors reference[113] lists six different ways controls can differ: location, shape, size, color, labeling, and mode of operation. The greater the difference among controls in at least the first three of these factors, the less likely an operator in a stressful situation will be to inadvertently command the wrong action by activating the wrong control. The buttons on the *Eagle Otome*'s engine control console were not required to meet commonly accepted human factors design principles. In fact, they were located adjacent to each other and were the same size and shape, contrary to standard human factors design principles.

The IMO took action on this issue in 1998, when its Maritime Safety Committee issued MSC Circular 834, "Guidelines for Engine-Room Layout, Design and Arrangement." However, these guidelines were advisory only. Similarly, the vessel classification society American Bureau of Shipping has developed guidelines for the design of critical vessel controls and displays and has distributed these guidelines to its customers and the marine community. However, the American Bureau of Shipping does not mandate its guidelines in the vessels it surveys. The potential safety issue illustrated by the error made by the *Eagle Otome* master stems not from a dearth of information about the need for human factors guidance in control design or from a lack of such guidance itself. Rather, it stems from the absence of a requirement to apply such guidelines in the design and manufacturing of critical vessel controls. The NTSB therefore concludes that commonly accepted human factors principles were not applied to the design of the *Eagle Otome*'s engine control console, which increased the likelihood of error in the use of the controls. The NTSB therefore recommends that the Coast Guard work through the IMO to encourage the application of human factors design principles to the design and manufacture of critical vessel controls.

2.10 Use of Vessel Name in Radio Communication

During the NTSB's investigation of the *Cosco Busan* accident in San Francisco, California, investigators confirmed that at no point during the underway radio communication between the pilot and VTS was the ship referred to by its name. Instead, the pilot and VTS simply used the pilot's designator, "Romeo," as identification. The *Cosco Busan*'s master and bridge crew were Chinese, and the master later told investigators that he was uncertain as to what ship the radio communication was referring. He said that without hearing his vessel's name

[111] D.A. Norman, *The Design of Everyday Things* (New York: Doubleday, 1988).

[112] See, for example, *Design Induced Landing Gear Retraction Accidents in Beechcraft Baron, Bonanza, and Other Light Aircraft*, Aviation Special Study NTSB/SR-80/01 (Washington, DC: National Transportation Safety Board, 1980).

[113] M. Helander, *A Guide to Human Factors and Ergonomics* (2nd edition) (Boca Raton, Florida: CRC Press, 2006).

during radio communication, it was difficult to discern whether the exchange was "private conversation" as opposed to operational and vessel-specific, and hearing the vessel name would have clarified that the communication pertained to him. During the *Cosco Busan* investigation, the NTSB also confirmed that in most U.S. ports, VTS uses the vessel's name in radio communication, but that in a few ports—including the Port of Oakland, from which the *Cosco Busan* departed—VTS and the pilots used the pilot designator or other terms as identification. As a result of this finding, the NTSB issued Safety Recommendation M-09-2 to the Coast Guard:

> Revise your vessel traffic service policies to ensure that vessel traffic service communications identify the vessel, not only the pilot, when vessels operate in pilotage waters.

In a July 2009 response, the Coast Guard responded that it concurred with the intent of the recommendation and that it would review VTS's radiotelephone practices to determine whether nationwide communication protocols should be developed. As a result, the NTSB classified Safety Recommendation M-09-2 "Open—Acceptable Response" in November 2009.

Following the *Eagle Otome* accident, the VTS Port Arthur supervisor confirmed to NTSB investigators that VTS Port Arthur uses the vessel name when communicating by radio. However, the first pilot on board the *Eagle Otome* did not refer to the ship by name in his radio communication with the *Dixie Vengeance* master. According to the Federal Communications Commission's "Bridge-to-Bridge Communication Procedure" at 47 CFR 80.331, the vessel name should be used in radio communication that takes place on designated navigational frequencies. The *Dixie Vengeance* master referred to his vessel by name but did not ask the first pilot for the name of the tankship. During the radio communication leading up to the accident, the *Dixie Vengeance* master referred to the *Eagle Otome* only as "inbound ship." This was similar to the way in which the first pilot had referred to the ship in his earlier radio communication with the towboat master ("first of two inbound tankers").

As the Chinese master of the *Cosco Busan* indicated, radio communication in a foreign language may be difficult for a bridge crew to comprehend, especially if the crew is not specifically concentrating on it. Considerable radio exchange can take place during the course of a long transit (between pilot and dispatcher, pilot to pilot, and general vessel-to-vessel communication) and frequently does not pertain to the navigation of that specific vessel at that exact moment. A bridge crew is therefore more likely to heed and take action when its vessel's name is called out. Had the *Eagle Otome* master and bridge crew heard the *Dixie Vengeance* master ask, "*Eagle Otome* lookin' okay?" as opposed to "Inbound ship lookin' okay?" they might have questioned the pilots about the call or answered the towboat master themselves when the pilots did not. The *Eagle Otome* master, an Indian national, did not indicate in postaccident interviews that he was uncertain whether the radio communication pertained to his vessel, nor does evidence indicate that the first pilot's not using the vessel's name was a factor in the accident. Nevertheless, the NTSB concludes that consistent use of a vessel's name in radio communication can help avoid confusion and enhance bridge team coordination. The NTSB recommends that the American Pilots' Association advise its members to consistently identify vessels by name in bridge-to-bridge radio communication, as required by the Federal Communications Commission.

3. Conclusions

3.1 Findings

Note: The order in which these findings are listed below is different from their order in the analysis section. This is intentional.

1. Weather, mechanical failure, and illegal drug or alcohol use were not factors in the accident.

2. The vessel meeting arrangement agreed to by the towboat master and the first pilot was appropriate and was not a factor in the accident.

3. Personnel at Vessel Traffic Service Port Arthur played no role in the accident.

4. The *Eagle Otome* pilots did not follow Sabine Pilots Association guidelines with respect to division of duties while under way.

5. Although both pilots completed bridge resource management training, they failed to apply the team performance aspects of bridge resource management to this operation.

6. Contrary to pilot association guidelines, the first pilot on the *Eagle Otome* was conducting a radio call at a critical point in the waterway, and the radio call interfered with his ability to fully focus on conning the vessel.

7. Had the *Eagle Otome* pilots alerted the *Dixie Vengeance* master of the sheering problem, the force of the collision between the *Eagle Otome* and the *Dixie Vengeance* tow would have been lessened or the collision might have been avoided altogether.

8. The combination of untreated obstructive sleep apnea, disruption to his circadian rhythms, and extended periods of wakefulness that resulted from his work schedule caused the first pilot to be fatigued at the time of the accident.

9. The first pilot's failure to correct the sheering motions that began after his late turn initiation at Missouri Bend led to the accident.

10. The first pilot's fatigue adversely affected his ability to predict and stop the *Eagle Otome*'s sheering.

11. No effective hours of service rules were in place that would have prevented the Sabine pilots from being fatigued by the schedules that they maintained.

12. The absence of an effective fatigue mitigation and prevention program among the pilots operating under the authority of the Jefferson and Orange County Board of Pilot Commissioners created a threat to the safety of the waterway, its users, and those nearby.

13. The Jefferson and Orange County Board of Pilot Commissioners should have more fully exercised its authority over pilot operations on the Sabine-Neches Waterway by becoming

aware of and enforcing the Sabine Pilots Association's two-pilot guidelines and implementing a fatigue mitigation and prevention program among the Sabine pilots.

14. The Coast Guard is the organization with the resources, capabilities, and expertise best suited to (1) enhance communication among pilot oversight organizations and (2) establish an easy-to-use and readily available database of pilot incidents and accidents.

15. The first pilot's sounding the *Eagle Otome*'s whistle and the *Gull Arrow* master's sounding the cargo vessel's general alarm were prudent and effective.

16. The accident response and oil spill recovery efforts were timely and effective.

17. The dimensions of the Sabine-Neches Waterway may pose an unacceptable risk, given the size and number of vessels transiting the waterway.

18. Commonly accepted human factors principles were not applied to the design of the *Eagle Otome*'s engine control console, which increased the likelihood of error in the use of the controls.

19. Consistent use of a vessel's name in radio communication can help avoid confusion and enhance bridge team coordination.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the collision of tankship *Eagle Otome* with cargo vessel *Gull Arrow* and the subsequent collision with the *Dixie Vengeance* tow was the failure of the first pilot, who had navigational control of the *Eagle Otome*, to correct the sheering motions that began as a result of the late initiation of a turn at a mild bend in the waterway. Contributing to the accident was the first pilot's fatigue, caused by his untreated obstructive sleep apnea and his work schedule, which did not permit adequate sleep; his distraction from conducting a radio call, which the second pilot should have conducted in accordance with guidelines; and the lack of effective bridge resource management by both pilots. Also contributing was the lack of oversight by the Jefferson and Orange County Board of Pilot Commissioners.

4. Recommendations

4.1 New Recommendations

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

To the U.S. Coast Guard:

Conduct a ports and waterways safety assessment for the Sabine-Neches Waterway, determine from that whether the risk is unacceptable, and if so, develop risk mitigation strategies. (M-11-13)

Work through the International Maritime Organization to encourage the application of human factors design principles to the design and manufacture of critical vessel controls. (M-11-14)

Facilitate and promote regular meetings for representatives of pilot oversight organizations to communicate information regarding pilot oversight and piloting best practices. (M-11-15)

Establish a database of publicly available pilot incidents and accidents and make the database easy to use and readily available to all pilot oversight organizations. (M-11-16)

To the Jefferson and Orange County Board of Pilot Commissioners:

Develop and implement (1) a system to monitor your state-licensed pilots so that your commission can verify the execution of policies, procedures, and/or guidelines necessary for safe navigation, and (2) a fatigue mitigation and prevention program among the Sabine pilots. (M-11-17)

To the Sabine Pilots Association:

Take action to ensure that your member pilots follow your guidelines with respect to division of duties and responsibilities of pilots. (M-11-18)

To governors of states and territories in which state and local pilots operate:

Ensure that local pilot oversight organizations effectively monitor and, through their rules and regulations, oversee the practices of their pilots to promote and ensure the highest level of safety. (M-11-19)

Require local pilot oversight organizations that have not already done so to implement fatigue mitigation and prevention programs that (1) regularly inform mariners of the hazards of fatigue and effective strategies to prevent it, and (2) promulgate hours of service rules that prevent fatigue resulting from extended hours of service, insufficient rest within a 24-hour period, and disruption of circadian rhythms. (M-11-20)

Require local pilot oversight organizations that have not already done so to implement initial and recurring bridge resource management training requirements. (M-11-21)

To the American Pilots' Association:

Advise your members to consistently identify vessels by name in bridge-to-bridge radio communication, as required by the Federal Communications Commission. (M-11-22)

4.2 Previous Recommendations Reiterated in This Report

To the U.S. Coast Guard:

Require mariners to report to the Coast Guard, in a timely manner, any substantive changes in their medical status or medication use that occur between required medical evaluations. (M-09-4)

4.3 Previously Issued Recommendation Classified in This Report

To the U.S. Coast Guard:

Establish a mechanism through which representatives of pilot oversight organizations collect and regularly communicate pilot performance data and information regarding pilot oversight and best practices. (M-09-5)

Safety Recommendation M-09-5 (previously classified "Open—Unacceptable Response") is classified "Closed—Unacceptable Response/Superseded" by M-11-15 and M-11-16 in section "2.4 Fatigue" of this report.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

DEBORAH A.P. HERSMAN
Chairman

ROBERT L. SUMWALT
Member

CHRISTOPHER A. HART
Vice Chairman

MARK R. ROSEKIND
Member

EARL F. WEENER
Member

Adopted: September 27, 2011

Member Sumwalt filed the following concurring statement on October 3, 2011. He was joined by Chairman Hersman, Vice Chairman Hart, and Members Rosekind and Weener.

Member Sumwalt, Concurring:

For vessels traversing the Sabine-Neches Canal with a beam width of 120 feet or greater, there is a local requirement for two pilots to be on board. This requirement was put in place a number of years ago, ostensibly to provide an extra margin of safety, by having one pilot backing up and assisting the other pilot.

According to Sabine Pilots Association guidelines, "both pilots shall be on the navigation bridge of the vessel and either shall be ready, willing and able to assume command of navigation of the vessel at all times."

Piloting a ship is very much a cognitive task – the pilot issues orders to the helmsman, then monitors to see that those orders are properly carried out, and finally, watches to ensure the ship responds as desired. It is an iterative process that involves active monitoring of orders, inputs, and response.

In order for the inactive pilot to be "ready, willing and able to assume command of navigation of the vessel at all times," that pilot would need to be actively engaged by listening, monitoring, and watching. Instead, the second pilot on board the *Eagle Otome* was resting and reading the newspaper during the *Eagle Otome*'s passage through the Sabine-Neches Canal. He told investigators that his first indication of a potential problem was when the first pilot asked, "Is she gonna come back?"

I firmly believe that if the second pilot had been more actively engaged in backing up and assisting the first pilot with pilotage duties instead of conducting non-pertinent activities, he could have provided valuable input which may have prevented the accident.

Those entrenched in the marine piloting profession may retort that this practice of doing non-pertinent activities such as reading is "just the way it is done" when two pilots are on board. Perhaps so, but I rhetorically ask: Just because it is always done, does this mean it is acceptable? Is it professional? Shipping companies pay large sums of money to have two pilots on board. That requirement is founded on the basis of safety; it is not for the purpose of allowing one pilot to read the newspaper while navigating a narrow channel.

I urge those who defend this practice to rethink your position. Generally speaking, the pilots of U.S. ports and waterways do an outstanding job; that said, is it time to raise the bar to an even higher level?

5. Appendixes

Appendix A

The Coast Guard notified the NTSB's communications center of the accident about 1130 eastern standard time on January 23. On January 25, three NTSB investigators arrived on scene about 1800 central standard time. The accident investigation was led by the Coast Guard with the NTSB participating. The NTSB's on-scene investigation concluded on February 3, 2010. No NTSB Board Member launched to the accident site.

The NTSB's investigator-in-charge returned to Port Arthur for the Coast Guard's public hearing on the accident, which took place March 9 through 11, 2010.

Appendix B

The ship traffic operating protocol, developed by SETWAC, in effect at the time of the accident:

SHIP TRAFFIC OPERATING PROTOCOL FOR THE SABINE-NECHES WATERWAY

THIS VOLUNTARY SHIP TRAFFIC OPERATING PROTOCOL (the "Protocol"), is made and entered into as of November 20, 2009, by and between the Southeast Texas Waterways Advisory Council (SETWAC) and the Sabine Pilots Association, collectively, the "Parties".

WITNESSETH:

WHEREAS, the Texas Transportation Code sets forth the compulsory Pilotage requirements in those waterways encompassing the Sabine-Neches waterway;

WHEREAS, Chapter 25 of Title 33 U.S. Code (Ports and Waterways Safety Program) and the regulations set forth in Title 33 of the Code of Federal Regulations endows the U.S. Coast Guard Captain of the Port with the authority to manage those navigable waterways of the United States within that Captain of the Port's defined boundaries;

WHEREAS, the charter of the Southeast Texas Waterways Advisory Council (SETWAC) allows regional stakeholders including but not limited to Port Authorities, shipping agents, marine terminals and the Sabine Pilots Association to develop policies and procedures for the safe and secure movement of commerce in the Sabine and Neches rivers and their approaches; and

WHEREAS, the aforementioned authorities permit stakeholders to provide advice and guidance to the applicable regulatory authorities – consistent with the Federal Advisory Committee Act – and the following protocol is intended to enhance navigation safety, define best practices and establish an equitable and fair approach to vessel traffic management consistent in accordance with the goals and intent of the Port and Waterways Safety Act:

NOW THEREFORE, in consideration of the mutual agreement of the shipping industry, waterway stakeholders, and with support of the U. S. Coast Guard and SETWAC, the following Protocol shall be administered by the Sabine Pilots Association.

VESSEL TRAFFIC COORDINATION

For vessels requiring or requesting a State Pilot, the Sabine Pilots will coordinate vessel movements in the waterway utilizing best vessel dispatch procedures consistent with overall efficiency and safety of the waterway. This shall include the coordination of such efforts with Vessel Traffic Service (VTS) Port Arthur as set forth in the VTS Port Arthur User Manual. In order for the Pilot Dispatch Office to do this, it is very important that the Pilot Office be kept well informed of expected vessel arrival and sailing times.

- The following procedure should be followed as closely as possible to enable the Pilot Office to make the most efficient use of the waterway in an effort to reduce delays. Advise the Pilot office as far in advance as possible but not less than four hours of any vessel's ETA and destination, along with its deep fresh water draft, air draft, length, beam, and DWT.
- Keep the pilot office abreast of any changes in ETA.
- When a vessel is in port, give notice as soon as possible, but not less than two hours of the vessel's ETS and deep fresh water draft.

The Pilots have agreed to, upon reasonable request, make available information to all impacted stakeholders as to the expected traffic schedule and any events that might cause delays.

NOTHING IN THIS AGREEMENT SHALL BE CONSTRUED AS LIMITING THE EXERCISE OF A PILOT'S GOOD JUDGMENT.

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TURNING BASINS

In order for the limitations on vessel movements to be kept at a minimum, it was agreed to utilize the turning basins at FINA and SUN OIL for the meeting of two vessels when circumstances make it unsafe for the vessels to meet. Based upon the pilots' discretion and vessel traffic flow, and in coordination with the Vessel Traffic Service, the inbound or outbound vessel will utilize the basins and allow the other vessel(s) passage. It is understood that tugs will be required to hold the vessel in the turning basins during this operation. The Pilot office will advise interests involved as to times vessels can be handled in these situations. If these basins are utilized properly, while perhaps causing a temporary delay in some cases, time on the inbound or outbound vessels can be gained. It is agreed that designated turning basins normally will not be used for anchorage. Vessels will vacate the basins as soon as possible.

VESSEL MOVEMENT AND MEETING LIMITATIONS

Vessels with any of the following criteria will move during daylight hours only above TEXAS ISLAND intersection.

- Vessels with a deadweight of 85,000 metric tons or greater
- Vessels with a LOA of 875 feet or longer
- Vessels with a beam of 125 feet or greater

Vessels with any of the above criteria may be shifted at any time to a nearby anchorage or adjacent dock at the discretion of the Pilot Office.

Vessels with a combined beam that equals or exceeds one-half the channel width will not meet day or night.

Vessels 85,000 metric deadweight tons or more will not meet vessels of either 30,000 metric deadweight tons or more, or 25 foot draft or more above TEXAS ISLAND intersection.

Vessels 85,000 metric deadweight tons or more will not meet vessels of 30,000 metric deadweight tons or more with a draft of 30 feet or more, above buoys 29 and 30.

Vessels 48,000 metric tons or more with a draft of 30 feet or more will not meet above buoys 29 and 30.

Vessels with a combined draft of 70 feet or more will not meet between the Neches River intersection and daybeacon #40 (Smith's Bluff) at night. Vessels with a combined draft of 65 feet or more will not meet above daybeacon #40 at night.

Meeting in bends should be avoided whenever possible or practical.

Vessels with a beam equal to or greater than one-half the width of the channel will move during daylight hours only in the Sabine River (200' wide Federal Channel leading to Orange).

DRAFT LIMITATIONS

The Federal waterway project depth currently allows vessels to transit with a maximum 40 foot draft. However, the most recent US Army Corp of Engineer's Hydrographic report, prevailing weather, and tidal conditions will govern the Sabine Pilot policy on maximum draft limitations.

NOTHING IN THIS AGREEMENT SHALL BE CONSTRUED AS LIMITING THE EXERCISE OF A PILOT'S GOOD JUDGMENT.

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CHECK POINTS

Notwithstanding VTS reporting points as set forth in the VTS Users Manual, vessels shall report to the Pilot Office at the below listed check points as well as upon departure from a berth or anchorage. The dispatcher will use this information to ensure compliance with the above provisions of this agreement.

1. Sabine Bank Buoy, "SB", Lat 29-25N Long 93-40W;
2. Buoys 29 and 30: Lat 29-36N Long 93-48W;
3. Daybeacon #40 on Sabine-Neches Canal; Mesquite Point;
4. Port Arthur turning basin;
5. Daybeacon #65; Neches River Intersection;
6. Daybeacon #40 in the Neches River.
7. Daybeacon #22 on the Sabine River at Orange Cut.

GENERAL GUIDELINES FOR VESSELS REQUIRING TWO PILOTS

Definitions: A Two Pilot Vessel is any vessel that meets either or both of the following criteria:

- Length Over All (LOA) of 860 feet or more.
- Beam of 120 feet or more.

Certain non-descript vessels, drill rigs, dead tows, etc. shall be considered by the Pilots on an individual basis to determine if two pilots are necessary.

In witness whereof, this agreement is executed the date first set forth herein.

SETWAC REP

[redacted]

Chairman-SETWAC

SABINE PILOTS ASSOC. REP

[redacted]

President-Sabine Pilots Assoc.

NOTHING IN THIS AGREEMENT SHALL BE CONSTRUED AS LIMITING THE EXERCISE OF A PILOT'S GOOD JUDGMENT.

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Appendix C

The Sabine Pilots Association guidelines in effect at the time of the accident:

GUIDELINES
GOVERNING ABOARD VESSELS REQUIRING TWO PILOTS WHEN TRANSITING THE SABINE-NECHES WATERWAY

DEFINITIONS:

Conning means the pilot is in charge of piloting the vessel:

a) By directing the helmsman to turn the ship's rudder for steering, altering the course or maneuvering the vessel as, in his judgement, the existing circumstances and conditions dictate.

b) By directing the engines to operate in a way, so that, safe speeds are maintained at all times, as the vessel transits the waterway.

c) At times of reduced visibility he (the conning pilot) determines actions to be taken under the existing circumstances and conditions.

Radio Communications means the pilot must listen and handle all the radio communications relating to traffic, safety and position reporting established requirements, as the vessel transits the waterway.

Miscellaneous means:

a) Assist the pilot conning the vessel per his request.

b) Assist by providing information whenever dense traffic conditions prevail. Watch for clearance of traffic or other objects been obstructed by vessel's size or construction.

c) Inspect ship's particulars, arrange for tugs, brief the Captain of mooring arrangements. Provide any other assistance to the conning pilot and the master of the ship as requested.

INBOUND FROM SEA
DUTIES AND RESPONSIBILITIES OF PILOTS

PILOTING AREA	PILOT NO. 1	PILOT NO. 2
a) From Boarding Station to Beacon #40 (Port Arthur Canal)	Conning	Radio/Miscellaneous
b) From Beacon #40 (Port Arthur Canal) to School House (Chk. Pt. #3)	Radio/Misc.	Conning
c) From School House to Beacon #20 (FINA Highlines)	Conning	Radio/Misc
d) From Beacon #20 (FINA Highlines) to SUN Terminal #5 included	Radio/Misc	Conning & Docking
e) From SUN Terminal #5 to any destination above SUN #5	Conning & Docking	Radio/Misc.

OUTBOUND FOR SEA
DUTIES AND RESPONSIBILITIES OF PILOTS

PILOTING AREA	PILOT NO. 1	PILOT NO. 2
a) From Beaumont to SUN Terminal #5 (Chk. Pt. #5)	Radio/Misc.	Undock/Turn/Conn
b) From SUN Terminal #5 to Neches River Intersection	Undock/Turn/Conn	Radio/Misc.
c) From Neches River Intersection to Texas Island Intersection	Radio/Misc.	Undock/Turn/Conn
d) From Texas Island Intersection to Pilot Station	Undock/Turn/Conn	Radio/Misc.

Both pilots shall be on the navigation bridge of the vessel and either one shall be ready, willing and able to assume command of navigation of the vessel at all times.
The above guidelines as set by the Sabine Pilots should not be construed as limiting the assigned pilots in the exercise of their good judgement.

Appendix D

Timeline of events on the day of the accident and section of navigation chart 11342 showing the times of certain commands leading up to the accident, as recorded by the *Eagle Otome*'s S-VDR:

0524 The first pilot boards the *Eagle Otome* and takes the conn at the Sabine Fairway anchorage in the Gulf of Mexico.

0750 The second pilot boards the *Eagle Otome* at Sabine Pass in the Sabine-Neches Waterway.

0800 The second pilot takes the conn.

0904 The first pilot takes the conn.

0910 The *Eagle Otome* enters the Texas Island Intersection, a 38-degree turn to starboard, with a rudder order of starboard 20.

0914:34 The first pilot initiates a security call via VHF radio, announcing the *Eagle Otome*'s location and inquiring about outbound traffic near the bridge in Port Arthur.

0914:56 The *Dixie Vengeance* master answers the first pilot's security call, announcing that he is outbound with two loads about 3 miles north of the bridge.

0923:05 The *Dixie Vengeance* master announces his location (about 2 miles north of the bridge) via VHF radio, and he and the first pilot on the *Eagle Otome* engage in a 45-second conversation.

0923 The *Eagle Otome* enters Missouri Bend, a 32-degree turn to starboard, with the rudder at midship.

0923:54 The first pilot orders "hard to starboard" to initiate the turn at Missouri Bend.

0925 The *Eagle Otome* exits Missouri Bend, and the first sheering event occurs (to starboard, with the *Eagle Otome* near the east bank).

0928 The second sheering event occurs (to port, near the bridge, with the *Eagle Otome* close to the bridge's westside foundation).

0933 The third sheering event occurs (to starboard, with the *Eagle Otome* close to the east bank).

0933:35 The first pilot orders full ahead.

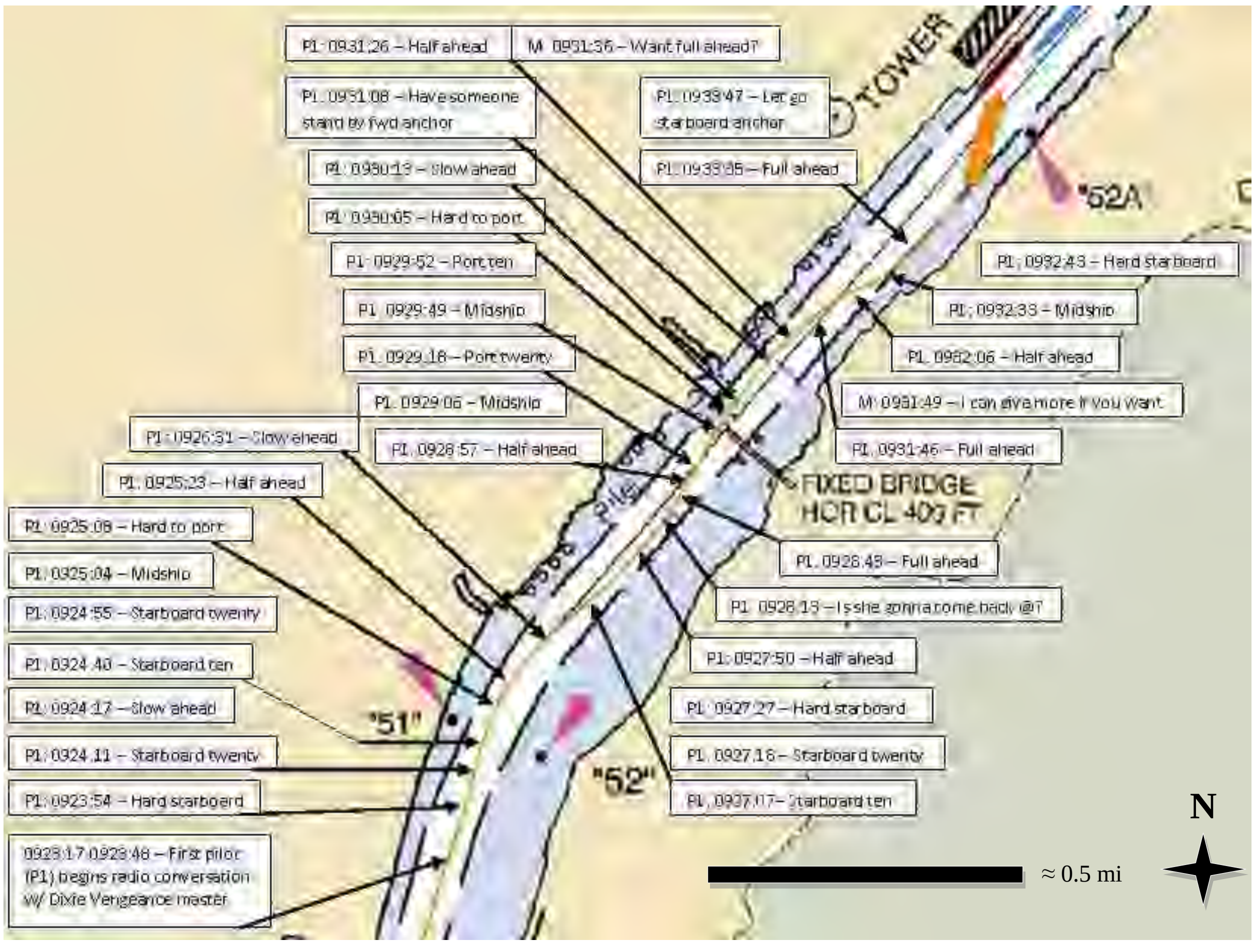
0933:46 The master tries to activate "navigational full ahead" and inadvertently presses the "manual emergency stop" button. (The master is able to restart the engine about 45 seconds later, and, as directed by the first pilot, then puts the engine full astern.)

0933:47 The first pilot orders the starboard anchor dropped.

0934 The fourth sheering event occurs (to port, toward the *Gull Arrow*, berthed at the Port of Port Arthur).

0934:20–25 The *Dixie Vengeance* master sees the *Eagle Otome*'s anchor drop and hears warning blasts from its whistle (sounded by the first pilot). He puts his engines full astern and sounds the towboat's emergency alarm.

0935 The *Eagle Otome* strikes the *Gull Arrow*; seconds later, the forward of the two barges pushed by the *Dixie Vengeance* strikes the *Eagle Otome*.



P1: First pilot

M: *Eagle Otome* master

National Transportation Safety Board

Marine Accident Brief

Collision of Bulk Carrier *Yochow* with Articulated Tug and Barge *OSG Independence/OSG 243*

Accident type	Collision	**No.** DCA18FM026
Vessel names	*Yochow*, *OSG Independence/OSG 243*	
Location	Houston Ship Channel, Houston, Texas 29°43.12' N, 095°14.46' W	
Date	June 13, 2018	
Time	0250 central daylight time (coordinated universal time – 5 hours)	
Injuries	None	
Property damage	$21,338,000 est.	
Environmental damage	None	
Weather	Clear visibility, winds southeast <10 knots, slack current, air temperature 77°F, water temperature 88°F	
Waterway information	The Houston Ship Channel extends 44 miles from Galveston across Galveston Bay to the city of Houston.[1] It is 500 feet wide with a controlled depth of 30–38 feet at Sims Bayou Turning Basin.	

At 0250 local time on June 13, 2018, the inbound bulk carrier *Yochow* collided with the articulated tug and barge *OSG Independence/OSG 243*, which was moored at the TPC Group, Inc. facility on the Houston Ship Channel in Houston, Texas. *OSG 243*'s tanks were empty and awaiting a cargo of methyl tert-butyl ether (MTBE). As a result of the collision, two of the barge's tanks and *Yochow*'s bulbous bow were holed, and the facility suffered extensive structural damage. There were no injuries among the crew of 18 on the *Yochow* or the 8 aboard the tug *OSG Independence*, nor was any pollution reported. Damage to the facility ($20 million), the barge ($1 million), and the bulk carrier ($338,000) amounted to an estimated $21,338,000.

Bulk carrier *Yochow* under way.

[1] All miles in this report are nautical miles.

Location where *Yochow* collided with *OSG Independence*'s barge, *OSG 243*, in the Houston Ship Channel. (Satellite image from Google Earth Pro)

Background

The Hong Kong-flagged *Yochow*, built in 2015, was a 590-foot-long bulk carrier of typical design operated by Beikun Shipping (Tianjin) Co., Ltd. The vessel had a flat-bottomed hull, a bulbous bow, and a single propeller driven by a slow-speed diesel engine. On arrival at the pilot station on June 12, the bulk carrier was carrying a partial load of steel coil and pipe, after having discharged cargo in Veracruz, Mexico, 2 days prior. Houston was its first US port call on this voyage, and it had no documented history of detentions or casualties. *Yochow*'s 18 crewmembers were of mixed nationality. At the time of the accident, the pilot, the master, the second mate, and a helmsman were on the bridge.

The *OSG Independence/OSG 243* was an articulated tug and barge (ATB), a unit consisting of a barge with a notch in the stern for an accompanying tug to make fast with mechanical pins. It was flagged in the United States and operated by OSG Ship Management, Inc., with the *OSG Independence* accompanying the *OSG 243* in the notch. Built in 1982 as the *Ocean 211*, the tank barge was reconfigured with a double hull in 2006.[2] The tug and barge were moored at the "A" dock at the TPC Group facility when the collision occurred. The barge's tanks were inerted and waiting for a cargo of MTBE to load.

[2] The *Oil Pollution Act of 1990* phased in a requirement for petroleum to be transported in double-hull tank vessels and tank barges. See Public Law 101-380.

The TPC facility was located on the south side of the Houston Ship Channel, west of the Sims Bayou Turning Basin. Just before the turning basin, the channel was about 300 feet wide with a controlled depth between 30 and 38 feet. Inbound vessels must negotiate a 70-degree turn to starboard just past the facility.

Accident Events

On June 12, the *OSG Independence/OSG 243* arrived at the TPC facility and moored starboard-side to in order to load a cargo of MTBE.[3] Connections were made with the shoreside cargo-loading arm and vapor-recovery hose, but cargo operations had not yet commenced.

A Houston pilot boarded the *Yochow* outside of Galveston at the pilot station. Interviews and documentation indicated that all the vessel's systems, including steering and bridge equipment, were functioning properly. The pilot described the ship's handling characteristics as typical for its age and design, with a tendency to "slide" due to a flat bottom, suggesting that the vessel would advance along its original course even as the heading changed. The bulk carrier was trimmed close to even keel after allowance for freshwater. Given that *Yochow*'s bridge had been darkened for night vision, a rudder angle indicator was lit and easily seen from the pilot's position, and the second mate told investigators that he could still see the helmsman's movements in the dark. The engine remained in engine room control with three engineers on duty. The vessel had no bow thruster.

The pilot conned the *Yochow* from the centerline windows. The helmsman was directly behind him, with the mate near the engine order telegraph just to the helmsman's left. While on the bridge, the master would station himself near the electronic chart display and information system (ECDIS) console to the right of the helm.

The *Yochow* passage from the pilot station through Galveston Bay to Lynchburg Landing was uneventful. The second mate and a helmsman relieved the watch at midnight. This helmsman manually steered from the time he came on watch at 2345 until several hours later—without relief. The weather on the morning of June 13 was clear, wind negligible, and current slack.

The channel makes an approximate 100-degree turn to port at Lynchburg Landing near San Jacinto State Park. Upon reaching this area at 0115, the pilot gave a port 20-degree command to start the turn. The helmsman answered, "Port 20," but put the helm 20 degrees to starboard. In catching the error, the pilot ordered, "Midships," 11 seconds later, then repeated the port-20 order 2 seconds later. Using a full-ahead bell, the bridge team was able to stop the vessel's swing to starboard about 38 seconds after the original command to port and regain the channel.

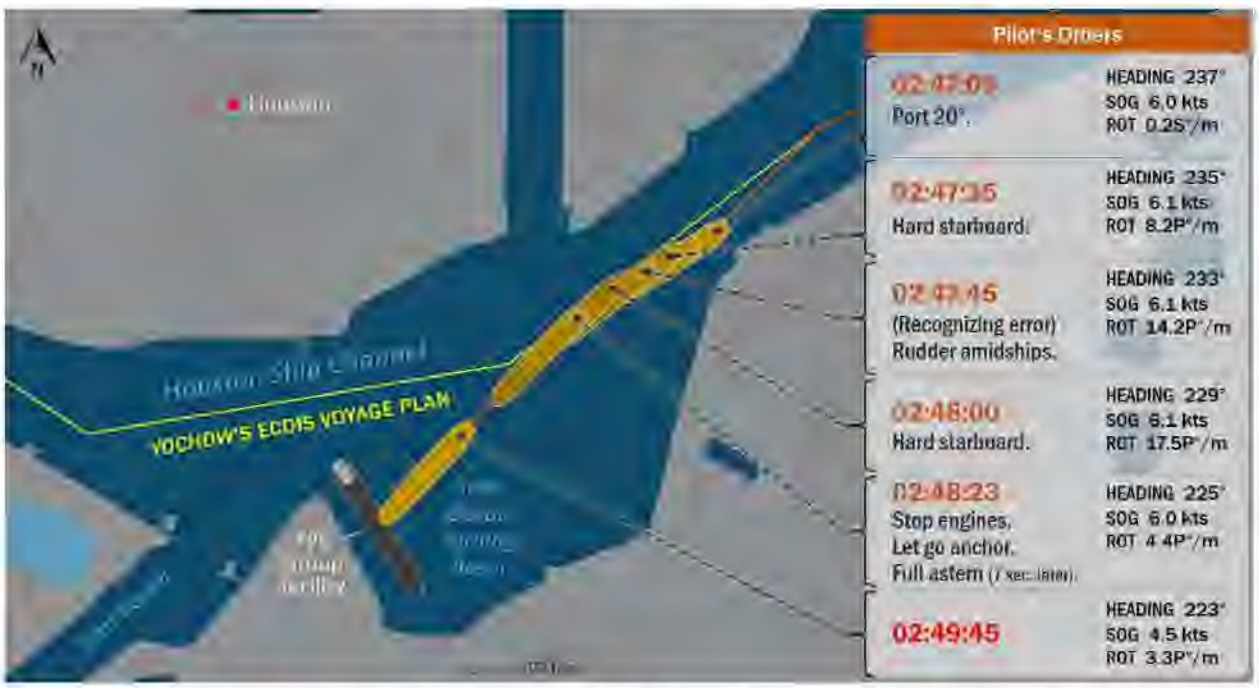
Following the helmsman's error and recovery, the pilot and second mate had a brief conversation about the mate's duty to watch the helmsman. The second mate agreed to double-check the helmsman with each command. The master was not on the bridge at the time; the mate offered to call him, but the pilot declined. Although the second mate did not understand conversational English, he told investigators he understood the pilot's orders.

[3] MTBE is a flammable additive in unleaded gasoline that reduces carbon monoxide and volatile organic compound emissions and enchances the octane content. TPC Group, Inc. is one of the leading North American producers of MTBE, primarily for export.

The *Yochow* approached the turn at Sims Bayou about 90 minutes later at a slow bell. Prior to the approach, the pilot checked in with vessel traffic service (VTS), who informed him of the dredge *MBI 05* operating in the channel just past the turn. He requested that his office contact the dredge's crew to inform them of *Yochow*'s approach. The pilot planned to turn wide at Sims Bayou, intending to stay to the south side of the channel to pass the dredge. On the voyage data recorder (VDR), the master can be heard on the bridge at this time, although there was no conversation between the master and pilot about negotiating either the upcoming turn or meeting the dredge. The pilot gave a port 20-degree command to bring the ship slightly left, ahead of the turn, and the helmsman answered accordingly. His next order 24 seconds later (at 02:47:35) was "hard starboard" to make the turn. The helmsman repeated the pilot's order but immediately put the rudder hard to port.

Ten seconds later, the pilot recognized the error and ordered midships while tapping with his fingers on the rudder angle indicator above his head to get the helmsman's attention. It took the steering gear 15 seconds to shift from hard port to midships, and then the pilot repeated his original hard-starboard order. The rudder reached hard starboard 12 seconds later, although the ship's heading was still falling to port at about 12 degrees per minute.

When the *Yochow* was about one ship's length away from the *OSG Independence/OSG 243*, the pilot ordered at 02:48:23, "Stop engines. Let go anchor," 48 seconds after his original order to starboard. He followed this order with full astern 7 seconds later and then ordered the whistle sounded. At this point the *Yochow* was making 6 knots, and its heading was still falling to port. The pilot told investigators that increasing the engine speed to power through the turn, as he had done earlier, would risk hitting the tug, which likely had a sleeping crew on board. He chose instead to attempt to stop the vessel and risk hitting the barge ahead of it.



According to electronic data, last 10 minutes of *Yochow*'s trackline leading up to accident based on pilot's orders. (Background from Google Earth)

RSP_006972

With the port anchor and two shots of chain deployed, the *Yochow* collided at approximately 4.5 knots with the port side of the tank barge *OSG 243* amidships at 02:49:45. The crew sounded the bulk carrier's whistle just before, in an attempt to warn the crew aboard the ATB.

Yochow's bulbous bow penetrated the moored barge's no. 5P ballast tank from 4 feet above the waterline to the turn of the bilge and inboard along 22 feet of the bottom plating, damaging piping, framing, and reach rods. The length of the breach was 7 feet 4 inches, and the deepest penetration was approximately 10 feet. The inner hull (nos. 5P and 6P cargo tanks) was inset but not holed by the bulbous bow; however, the bow holed tank no. 6P at the top, allowing inert gas to escape. The vessel's starboard anchor also damaged 30 feet of handrail, a cantilever deck, chocks, and fish plate on the barge's port side. In addition, *OSG 243*'s starboard side, which was lying against the facility fendering, sustained indented side shell as well as damage to the framing in nos. 5S and 6S ballast tanks, the main deck, a cantilever deck, handrails, and nearby valves and deck grating. Additionally, several mooring lines parted. The tug *OSG Independence* was undamaged.

The impact of the barge against the wharf damaged the structure's pilings and walkways of the TPC facility. The barge moved approximately 70 to 100 feet forward on contact, ripping off the vapor recovery hose and causing the loading arm to fail at the ship's reducer just outboard of the manifold.

The *Yochow*'s bulbous bow was holed, and the forepeak was flooded to the waterline. The bow at the main deck was damaged where it contacted the barge's upper deck.

Damage to *OSG 243*, port side. Yellow circles identify, *at top*, cantilever deck damaged by *Yochow*'s bow rake and, *at bottom*, side shell at waterline in no. 5P ballast tank penetrated by bulk carrier's bulbous bow.

TPC facility on Houston Ship Channel. The impact pushed the pedestrian bridge off its support, crushing conduit below. (Photo by Coast Guard)

Yochow's **bow showing, *at left*, holed bulbous bow and depth of penetration and, *at right*, damaged upper starboard bow.**

Additional Information

Houston was the master's first American port call of the voyage. His work/rest log indicated that he had been working since 0900 the day before the accident. When the collision occurred, the master had been working for nearly 18 hours, although the *International Convention on Standards of Training, Certification and Watchkeeping for Seafarers* (STCW) requires a minimum of 10 hours of rest within a 24-hour period. According to the pilot and master's statements to investigators, the master would leave the bridge occasionally during the passage to briefly refresh. Per the pilot's request, the master kept a radio with him; however, no conversation between the officer on watch and the master was heard on the VDR at any time he was off the bridge during the passage.

The work/rest log for the helmsman on watch at the time of the accident showed only 8 hours of watch the previous day. His only documented work outside of watches was a drill on June 11 and an unmooring in Veracruz the previous day. However, in a later deposition, the helmsman stated he also worked on deck from 0800 to 1730 (with a 2-hour lunch), which was not reflected in the log; in that case he did not meet the minimum of 10 hours of rest within a 24-hour period.

Analysis

The Houston Ship Channel above Lynchburg Landing is a meandering and narrow waterway with facilities lining both banks for several miles. Much of the channel before the accident site is less than 500 feet wide, with minimal room for error in shiphandling. The pilot indicated, and electronic data showed, that the bridge team was able to successfully navigate the channel and meet traffic with an understanding of the ship's handling characteristics and the prevailing conditions, without an assist tug. Investigators found no deficiencies with the steering gear or other engineering or bridge equipment.

Twice during the transit, including just prior to the accident, the pilot gave a rudder order that the helmsman correctly repeated, yet he turned the wheel in the opposite direction. In both cases, the pilot—not the watch officer—noted the error and took action to direct the helmsman to correct the rudder. Bridge procedures provided by *Yochow's* operator were silent on the duties of the mate on watch in restricted waters, including watching the helm. The second mate told investigators though that "one of my duties as the officer on duty is to monitor the helmsman." The master's standing orders stated as follows: "Cross Check the bridge team member's action and communicate freely and openly on concerns you may have to avoid 'One Man Error'. Instruct the lookout and helmsman also to communicate freely and openly without hesitation or holding back." The pilot told investigators that it is not an uncommon scenario to have helm orders improperly executed and that pilots learn to watch for it. Giving the command midships will grab the helmsman's attention quicker than just repeating the original command.

Bridge resource management (BRM) is an industry standard for using all available technical and human resources to safely execute a vessel's passage plan. It requires all involved to maintain situational awareness and share information freely to address contingencies. Included in this concept is the expectation for the officer of the watch to check the rudder angle indicator with each helm order and the rpm indicator with each ordered change of speed. The mate on watch, who was standing next to the helm, did not notice or correct the helmsman during the two steering errors.

According to their logs, the mate and helmsman each stood 8 hours of watch per day and met *STCW* rest requirements. However, the helmsman stated that he performed work that was not reflected in the log, which the investigation found meant that he would not have met work/rest requirements. Failure to adhere to work/rest guidelines can lead to fatigue and thereby can impair a crewmember's alertness and ability to safely operate a vessel or perform safety-related duties. Further, at the time of the accident the helmsman had been at the wheel continuously for almost 3 hours, at night, without relief, and was likely fatigued.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the collision of the bulk carrier *Yochow* with the tank barge of the articulated tug and barge *OSG Independence/OSG 243* was the mate's failure to effectively monitor the helmsman, contrary to the principles of good bridge resource management. Contributing to the accident was the lack of company and shipboard oversight to ensure crewmembers adhered to work/rest guidelines, resulting in fatigue of the helmsman.

Managing Fatigue

Fatigue impacts every aspect of human performance, including decision-making, reaction time, and comprehension, all of which affect seafarers' ability to safely navigate. Having fatigued crewmembers in critical positions when navigating a busy channel increases the probability of errors that lead to incidents. Companies should include fatigue management procedures in their safety management systems and ensure compliance with applicable work/rest requirements.

Vessel Particulars

Vessel	*Yochow*	*OSG 243*
Owner/operator	Grand Famous Shipping, LTD / Beikun Shipping Co., LTD.	Maritrans Operating Partners LP/ OSG Ship Management, Inc.
Port of registry	Hong Kong	Wilmington, Delaware
Flag	Hong Kong	United States
Type	Bulk carrier	Tank barge
Year built	2015	1982; reconfigured to double hull in 2006
Official number (US)	Not applicable	646669
IMO number	9728394	None
Classification society	NK	ABS
Construction	Welded steel	Welded steel
Length	590 ft (180 m)	557.3 ft (169.9m) (w/o ATB)
Draft	32.2 ft (9.8 m)	31.5 ft (9.6 m)
Beam/width	98 ft (30 m)	83 ft (25.3 m)
Gross and/or ITC tonnage	21,538 ITC	14,513 GRT / 16,286 ITC
Engine power; manufacturer	7,067 hp (5,720 kW); MAN-B&W 6S46ME-B8.3	Not applicable
Persons on board	18	0

NTSB investigators worked closely with our counterparts from Coast Guard Sector Houston/Galveston throughout this investigation.

For more details about this accident, visit www.ntsb.gov and search for NTSB accident ID DCA18FM026.

Issued: April 23, 2019

The NTSB has authority to investigate and establish the probable cause of any major marine casualty or any marine casualty involving both public and nonpublic vessels under Title 49 *United States Code*, Section 1131(b)(1). This report is based on factual information either gathered by NTSB investigators or provided by the Coast Guard from its informal investigation of the accident.

The NTSB does not assign fault or blame for a marine casualty; rather, as specified by NTSB regulation, "[NTSB] investigations are fact-finding proceedings with no formal issues and no adverse parties . . . and are not conducted for the purpose of determining the rights or liabilities of any person." Title 49 *Code of Federal Regulations*, Section 831.4.

Assignment of fault or legal liability is not relevant to the NTSB's statutory mission to improve transportation safety by conducting investigations and issuing safety recommendations. In addition, statutory language prohibits the admission into evidence or use of any part of an NTSB report related to an accident in a civil action for damages resulting from a matter mentioned in the report. Title 49 *United States Code*, Section 1154(b).

Allision of Hong Kong-Registered Containership M/V *Cosco Busan* with the Delta Tower of the San Francisco–Oakland Bay Bridge San Francisco, California November 7, 2007

Accident Report

NTSB/MAR-09/01
PB2009-916401

National Transportation Safety Board

Notation 7976B/C
Adopted February 18, 2009

Marine Accident Report

Allision of Hong Kong-Registered Containership M/V *Cosco Busan* with the Delta Tower of the San Francisco–Oakland Bay Bridge San Francisco, California November 7, 2007

National Transportation Safety Board

490 L'Enfant Plaza, SW
Washington, DC 20594

National Transportation Safety Board. 2009. ***Allision of Hong Kong-Registered Containership M/V* Cosco Busan *with the Delta Tower of the San Francisco–Oakland Bay Bridge, San Francisco, California, November 7, 2007.* Marine Accident Report NTSB/MAR-09/01. Washington, DC.**

Abstract: On November 7, 2007, the Hong Kong-registered, 901-foot-long containership M/V *Cosco Busan* allided with the fendering system at the base of the Delta tower of the San Francisco–Oakland Bay Bridge. Contact with the bridge tower created a 212-foot-long by 10-foot-high by 8-foot-deep gash in the forward port side of the ship and breached the Nos. 3 and 4 port fuel tanks and the No. 2 port ballast tank. As a result of the breached fuel tanks, about 53,500 gallons of fuel oil were released into San Francisco Bay. No injuries or fatalities resulted from the accident, but the fuel spill contaminated about 26 miles of shoreline, killed more than 2,500 birds of about 50 species, temporarily closed a fishery on the bay, and delayed the start of the crab-fishing season. Total monetary damages were estimated to be $2.1 million for the ship, $1.5 million for the bridge, and more than $70 million for environmental cleanup.

The safety issues identified during this accident investigation include medical oversight of the *Cosco Busan* pilot, medical oversight of mariners in general, guidance for vessel traffic service operators in exercising authority to manage traffic, procedures for improving the assessment of oil spills in California waters; and training and oversight of the *Cosco Busan* crew. As a result of its investigation of this accident, the Safety Board makes safety recommendations to the U.S. Coast Guard, the American Pilots' Association, and Fleet Management Ltd.

The National Transportation Safety Board is an independent Federal agency dedicated to promoting aviation, railroad, highway, marine, pipeline, and hazardous materials safety. Established in 1967, the agency is mandated by Congress through the Independent Safety Board Act of 1974 to investigate transportation accidents, determine the probable causes of the accidents, issue safety recommendations, study transportation safety issues, and evaluate the safety effectiveness of government agencies involved in transportation. The Safety Board makes public its actions and decisions through accident reports, safety studies, special investigation reports, safety recommendations, and statistical reviews.

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Acronyms and Abbreviations

AASHO	American Association of State Highway Officials (predecessor to AASHTO)
AASHTO	American Association of State Highway and Transportation Officials (successor to AASHO)
ACP	area contingency plan
AIS	automatic identification system
ALCOAST	All Coast Guard (message)
ARPA	automatic radar plotting aid
Bay Bridge	San Francisco–Oakland Bay Bridge
Caltrans	California Department of Transportation
CFR	*Code of Federal Regulations*
CGMTA	Coast Guard and Maritime Transportation Act
CGVTS	Coast Guard Vessel Traffic System
CPAP	continuous positive airway pressure
DAPI	Coast Guard Drug and Alcohol Program Inspector
DFG–OSPR	California Department of Fish and Game–Office of Spill Prevention and Response
ECDIS	electronic chart display and information system
ECS	electronic chart system
FHWA	Federal Highway Administration
Fleet Management	Fleet Management Ltd.
FOSC	Federal on-scene coordinator
FOSC-R	Federal on-scene coordinator representative
GPS	global positioning system
HSC	Harbor Safety Committee of the San Francisco Bay region
HSP	Harbor Safety Plan

ICS	Incident Command System
IFO or IFO-380	heavy fuel oil carried on board the *Cosco Busan*
IHO	International Hydrographic Organization
IMO	International Maritime Organization
ISPR	U.S. Coast Guard incident-specific preparedness review
MARPOL 73/78	International Maritime Organization's *International Convention for the Prevention of Marine Pollution from Ships*
MDO	marine diesel oil
MLLW	mean lower low water
MSRC	Marine Spill Response Corporation
N-PREP	National Preparedness for Response Exercise Program
NCP	National Contingency Plan
NIDA	National Institute on Drug Abuse
NIMS	National Incident Management System
NMC	National Maritime Center
NRCES	NRC Environmental Services
NSC	National Safety Compliance
NSOP	National Standard Operating Policy
NVIC	navigation and vessel inspection circular
OES	California Office of Emergency Services
OIG	Office of the [Department of Homeland Security] Inspector General
PAWSS	Port and Waterways Safety System
pilot commission	Board of Pilot Commissioners for the Bays of San Francisco, San Pablo, and Suisun
PSAP	public safety answering point
PWSA	Port and Waterways Safety Act of 1972
QI	qualified individual
RACON	RAdar beaCON navigation aid

RCP	Regional Contingency Plan
SCC	sector command center
SMS	safety management system
SOLAS	International Convention for the Safety of Life at Sea
SOPEP	Shipboard Oil Pollution Emergency Plans
SOSC	state on-scene coordinator
UTDC	universal track data card
VDR	voyage data recorder
VMRS	vessel movement reporting system
VMS	voyage management system
VPIC	VTS–Pilots Issue Committee
VRM	variable range marker
VTC	vessel traffic center
VTS	vessel traffic service

Executive Summary

On Wednesday, November 7, 2007, about 0830 Pacific standard time, the Hong Kong-registered, 901-foot-long containership M/V *Cosco Busan* allided with the fendering system at the base of the Delta tower of the San Francisco–Oakland Bay Bridge. The ship was outbound from berth 56 in the Port of Oakland, California, and was destined for Busan, South Korea. Contact with the bridge tower created a 212-foot-long by 10-foot-high by 8-foot-deep gash in the forward port side of the ship and breached the Nos. 3 and 4 port fuel tanks and the No. 2 port ballast tank. As a result of the breached fuel tanks, about 53,500 gallons of fuel oil were released into San Francisco Bay. No injuries or fatalities resulted from the accident, but the fuel spill contaminated about 26 miles of shoreline, killed more than 2,500 birds of about 50 species, temporarily closed a fishery on the bay, and delayed the start of the crab-fishing season. Total monetary damages were estimated to be $2.1 million for the ship, $1.5 million for the bridge, and more than $70 million for environmental cleanup.

The National Transportation Safety Board determines that the probable cause of the allision of the *Cosco Busan* with the San Francisco–Oakland Bay Bridge was the failure to safely navigate the vessel in restricted visibility as a result of (1) the pilot's degraded cognitive performance from his use of impairing prescription medications, (2) the absence of a comprehensive pre-departure master/pilot exchange and a lack of effective communication between the pilot and the master during the accident voyage, and (3) the master's ineffective oversight of the pilot's performance and the vessel's progress. Contributing to the accident was the failure of Fleet Management Ltd. to adequately train the *Cosco Busan* crewmembers before their initial voyage on the vessel, which included a failure to ensure that the crew understood and complied with the company's safety management system. Also contributing to the accident was the U.S. Coast Guard's failure to provide adequate medical oversight of the pilot in view of the medical and medication information that the pilot had reported to the Coast Guard.

The following safety issues were identified during this accident investigation:

- Medical oversight of the *Cosco Busan* pilot;
- Medical oversight of mariners in general;
- Guidance for vessel traffic service operators in exercising authority to manage traffic;
- Procedures for improving the assessment of oil spills in California waters; and
- Training and oversight of the *Cosco Busan* crew.

As a result of its investigation of this accident, the Safety Board makes safety recommendations to the U.S. Coast Guard, the American Pilots' Association, and Fleet Management Ltd.

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Factual Information

Accident Synopsis

On Wednesday, November 7, 2007, about 0830 Pacific standard time, the Hong Kong-registered, 901-foot-long containership M/V *Cosco Busan* allided with the fendering system at the base of the Delta tower of the San Francisco–Oakland Bay Bridge. The ship was outbound from berth 56 in the Port of Oakland, California, and was destined for Busan, South Korea. Contact with the bridge tower created a 212-foot-long by 10-foot-high by 8-foot-deep gash in the forward port side of the ship and breached the Nos. 3 and 4 port fuel tanks and the No. 2 port ballast tank. As a result of the breached fuel tanks, about 53,500 gallons of fuel oil were released into San Francisco Bay. No injuries or fatalities resulted from the accident, but the fuel spill contaminated about 26 miles of shoreline, killed more than 2,500 birds of about 50 species, temporarily closed a fishery on the bay, and delayed the start of the crab-fishing season. Total monetary damages were estimated to be $2.1 million for the ship, $1.5 million for the bridge, and more than $70 million for environmental cleanup.

Accident Narrative[1]

The *Cosco Busan* (figure 1) was scheduled to depart its berth at pier 56 in the Port of Oakland at 0700 on November 7, 2007, with an all-Chinese crew. Cargo operations had begun the previous evening, and about 0600 on November 7 the longshoremen had loaded the last container on the vessel. The ship was carrying 2,529 containers and was destined for Busan, South Korea. A pilot from the San Francisco Bar Pilots Association was assigned to navigate the vessel from the time it left the berth until it exited the bay.

Dense fog was restricting visibility in the bay when the pilot boarded the *Cosco Busan* about 0620. When he arrived on the bridge, he introduced himself to the ship's master[2] and handed him a San Francisco Bar Pilots pilot card.[3] The master asked the pilot, "…can go?" to which the pilot replied that they would "take a look at things" and see how the visibility developed. The bridge watch officer provided the pilot with the vessel's pilot card, which contained ship characteristics and ship maneuvering performance data. The pilot acknowledged receipt of this information by signing the document, noting "rec'd only" next to his signature and citing the name of the assist tug to be used, *Revolution*, just below his signature. This same pilot card had a checklist for the crew to use before departing to verify that the ship's vital navigation, steering, and mooring gear had been tested and was operational.

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[1] Information in this section was obtained from Fleet Management Ltd. (which provided the ship's crew and technical management), from VTS [vessel traffic service] San Francisco (see footnote 6), from the shipboard voyage data recorder (see footnote 5) and voyage management system, and from postaccident interviews with the *Cosco Busan* pilot.

[2] In the maritime industry, the terms "master" and "captain" both refer to the highest-ranking officer on the ship and the one with overall responsibility for the vessel's operation and safety. In this report, the two terms refer to the same individual.

[3] The pilot's pilot card contained harbor information such as radio frequency channels, local distances, and procedures of instruction while the pilot is on board.

Figure 1. The *Hanjin Cairo*, which would later (in November 2006) be renamed *Cosco Busan*.

According to the notations on the form, at 0630, the third officer completed another required navigational safety form[4] titled "Bridge Checklist 4 – Master/Pilot Exchange." Checkmarks on the form indicated that the pilot had been provided with the vessel's pilot card and that the pilot and the master had discussed and agreed on the proposed passage plan, weather conditions, un-berthing procedures, and use of the assist tug. The checklist also indicated that the progress of the ship and the execution of orders would be monitored by the master and the officer of the watch. This checklist was signed by the third officer and the master. The onboard voyage data recorder (VDR)[5] did not capture any conversations with regard to the issues noted on the various checklists.

[4] The form was required by the vessel's safety management system, which is discussed in detail elsewhere in this report.

[5] VDRs, which are similar to flight data and cockpit voice recorders on aircraft, maintain continuous, sequential records of data relating to a ship's equipment and its command and control, and capture bridge audio from certain areas in the wheelhouse and on the bridge wings. Under regulation 20 of the International Convention for the Safety of Life at Sea 1974 (SOLAS) chapter V, all passenger ships and all cargo ships of 3,000 gross tons or more built on or after July 1, 2002, are required to carry VDRs. Under July 1, 2006, amendments to the regulations, cargo ships of the *Cosco Busan*'s size built before July 1, 2002, must be equipped with the devices during the first dry-docking after July 2006 but not later than July 2009. The *Cosco Busan* was equipped with a simplified VDR (S-VDR), which is not required to capture all of the parameters of a standard VDR but is permissible under the July 2006 amendment to SOLAS.

About 0637, the pilot, as required, contacted vessel traffic service (VTS)[6] and informed the VTS operator that he planned to depart berth 56 and pass through the "Delta–Echo" span (the 2,200-foot-long span between bridge towers/piers D and E) of the Bay Bridge, and then to the deep water traffic lane. He inquired about visibility "around Alcatraz and the Golden Gate Bridge" and was told that visibility was 1/8 to 1/4 nautical mile all the way to the Golden Gate Bridge.

By this time, the pilot had begun working with the master and the third officer to adjust (tune) the ship's two radars with regard to picture display. The men tested the target acquisition of the automatic radar plotting aid (ARPA) until the pilot was satisfied that the radars were performing acceptably. The discussions that took place between the pilot and crewmembers while these adjustments were being made were recorded by the VDR (and later transcribed for this accident investigation). The ship was also equipped with an automatic identification system (AIS) and an electronic chart system (figure 2). (See the "Vessel Information–Navigation Equipment and Charts" section of this report for more detailed information about these and other navigation system components and their capabilities.)

According to the VDR transcript, about 0650, the pilot said to the master:

> So, Captain, there's a . . . tug and a barge coming in. We let them come in first and then—cause you can see the other side now, and there's no more traffic—this looks good. The current's not very strong. It's coming this way, so I think we'll be able to go as soon as [the tug and the barge go] past us.

The master responded, "yeah, yeah, yeah."

About 1 minute later, the pilot told the master, "As [soon as the] tug gets by, you can single up."[7] About 1 minute after that, the pilot called VTS and said, "We're going to wait until the [barge] *William R* gets past us, and we're still finishing up a little paperwork."

About 0721, the pilot said to the master, "You can single up, Captain, if you want." The master responded, "OK, single up." About 0730, the pilot estimated that visibility was about 1/4 mile. The pilot later told Safety Board investigators that he consulted with the master about whether it was safe to depart, and the two agreed to commence the voyage. If such a discussion took place, it was not recorded by the VDR.

About 0745, the pilot and the master went outside onto the bridge wing where the pilot said they would stay "for now, until we get a ways out, then we'll go in [to the wheelhouse]." The bridge wing audio channel of the VDR recorded the pilot giving instructions to the tug *Revolution* and informing the tug master that he planned to shift the tug to the center stern chock[8] when they reached the middle of the channel "just for insurance." The pilot also told the *Cosco*

[6] VTS is operated by the U.S. Coast Guard and provides active monitoring and navigational advice for vessels in especially confined and busy waterways. Traffic in the San Francisco Bay area is managed by VTS San Francisco, which operates out of the Vessel Traffic Center on Yerba Buena Island. The VTS will be discussed in more detail later in this report.

[7] Single up means to reduce the number of mooring lines to a minimum in preparation for getting under way.

[8] A chock is a reinforced opening in the steel bulwark through which a line may be run to a set of bitts.

Busan master of his plans to shift the tug to the stern. The pilot commented to the master that the loaded vessel had a deep draft that was unusual for ships leaving Oakland because most ships left the port "all empty."

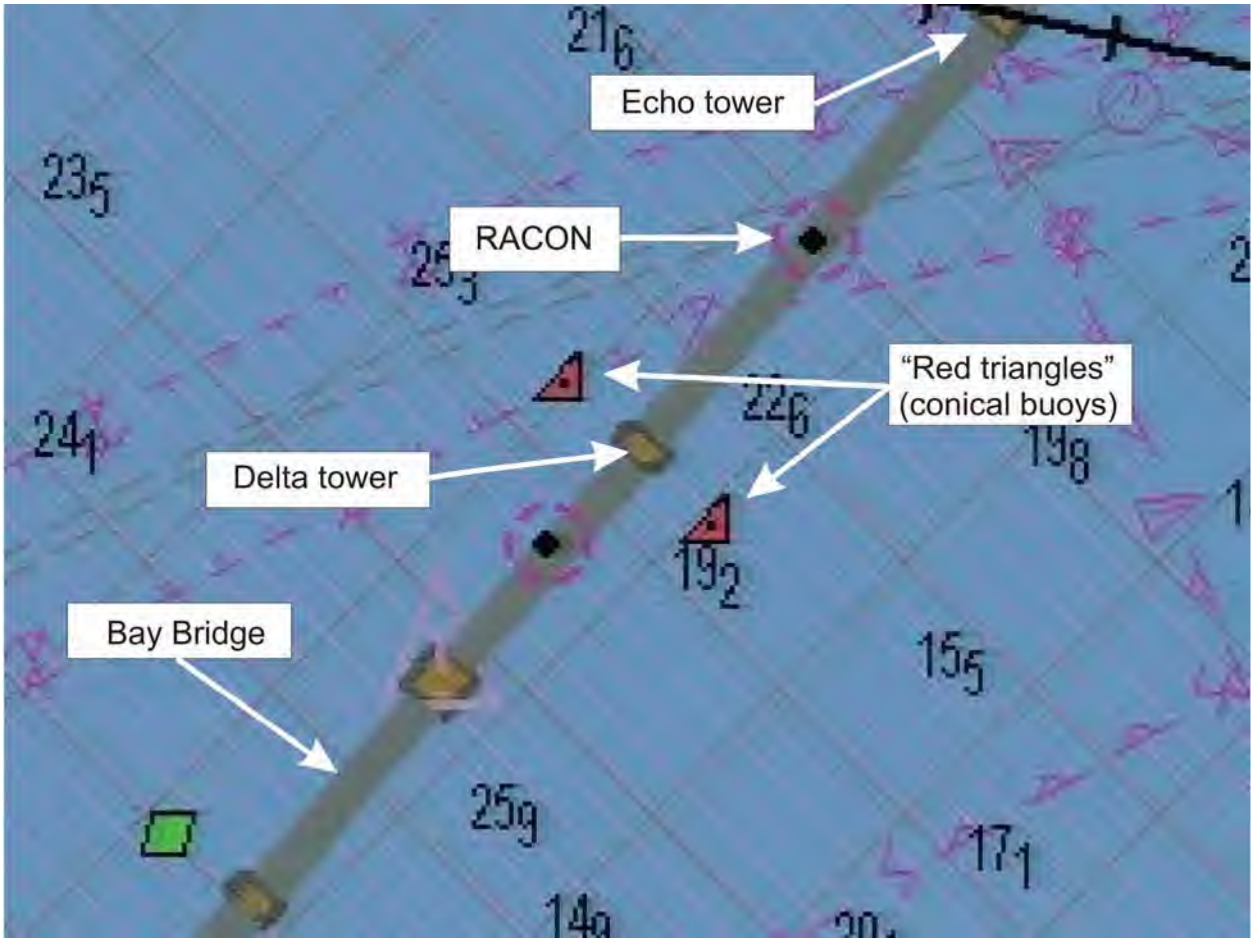

Figure 2. An enlarged section of the electronic chart on board the *Cosco Busan*. Two conical buoys, positioned on either side of the Delta tower, are displayed as red triangles on the electronic chart.

About 0800, the vessel moved away from berth 56 with the aid of the tractor tug *Revolution* on the port quarter pulling with one line while the ship used its 2,700-horsepower bow thruster. About this time, the VDR recorded the voice of a crewmember saying, in Mandarin,[9] " . . . American ships under such conditions, they would not be under way."

About 0805, the pilot and the master came in from the bridge wing. At that time, the bridge navigation crew consisted of the master, the third officer, a helmsman, and the pilot. The ship's bosun[10] was on the bow, and the second officer was on the stern. After the vessel eased off the dock, the pilot had the tug shift to the stern as had been planned. The pilot told investigators that the ship handled reasonably well except for perhaps being a little sluggish because of its

[9] Mandarin Chinese, which is spoken in Beijing and across most of northern and southwestern China.

[10] The bosun is the highest ranking member of the unlicensed deck crew.

deep draft. The pilot card for the ship indicated a forward draft of 39 feet 9 inches and an aft draft of 40 feet 1 inch.

About 0810, with the tug trailing behind on about 100 feet of slack line, the *Cosco Busan* started making headway out of the Inner Harbor Entrance Channel on a heading[11] of about 288°.[12] The trip would take the vessel northwest out of the entrance channel directly toward the southeast tip of Yerba Buena Island and into the Bar Channel. Once in the Bar Channel, the vessel would turn left toward the southwest to clear Yerba Buena Island, and then turn right to the northwest to cross under the Bay Bridge using the Delta–Echo span (figure 3). According to the chart, the approximate course out of the entrance channel was 286° true followed by a left turn to an approximate course of 272° through the Bar Channel, then a right turn to line up for a course of approximately 310° true to pass under the Delta–Echo span of the bridge.

About 0808, the pilot called the master of the tug *Revolution* by VHF radio and informed him of his intention to keep the tug trailing behind the *Cosco Busan* until the containership had gotten through the Bar Channel. The pilot asked the tug's master about his work schedule and was told that the tug's next assignment was at 0830.

The vessel proceeded outbound on a slow bell[13] until 0820 when the pilot ordered "half ahead," which would increase the ship's speed. The pilot stated that as the *Cosco Busan* continued to make its way out of the Inner Harbor Entrance Channel, he could see the Nos. 6 and 4 buoys pass by on the port side and noted that their flashing lights were visible. He kept the vessel to the high side (north side) of the channel as he departed the entrance channel in anticipation of the flood current (water flowing into the harbor with the rising tide) that he would encounter. He stated that the visibility again diminished and that he did not see the No. 1 buoy marking the northern boundary of the entrance to the Bar Channel as the ship passed it.

As the pilot later told investigators was his usual practice, he set the radar's variable range marker (VRM)[14] at 0.33 nautical mile as a reference for his approach to the Bay Bridge. He stated " . . . I usually . . . put the ring on there, and it just keeps the ring on the island as you go through the bridge, and that brings you to the center of the bridge."

According to the VDR, about 0822, the pilot, referring to the electronic chart, said (to the master), "What are these… ah… red [unintelligible]?" The master responded, "This is on bridge." The pilot then said to the master, "I couldn't figure out what the red light… red… red triangle was."

[11] Heading refers to the direction in which the bow of the ship is pointing. Depending on wind, current, and other factors, the heading may or may not coincide with the vessel's actual track, or course, over ground.

[12] All heading and course-over-ground references in this section reflect degrees true and are taken from the radar display images captured by the ship's VDR.

[13] A slow bell engine order on the *Cosco Busan* would have equated to 35 rpm on the main engine and a speed of about 9 knots with the vessel loaded. A half ahead bell would have equated to 50 rpm on the main engine and a speed of about 13 knots with the vessel loaded.

[14] The VRM superimposes a circle, or "ring," of the specified radius around the ship on the radar display.

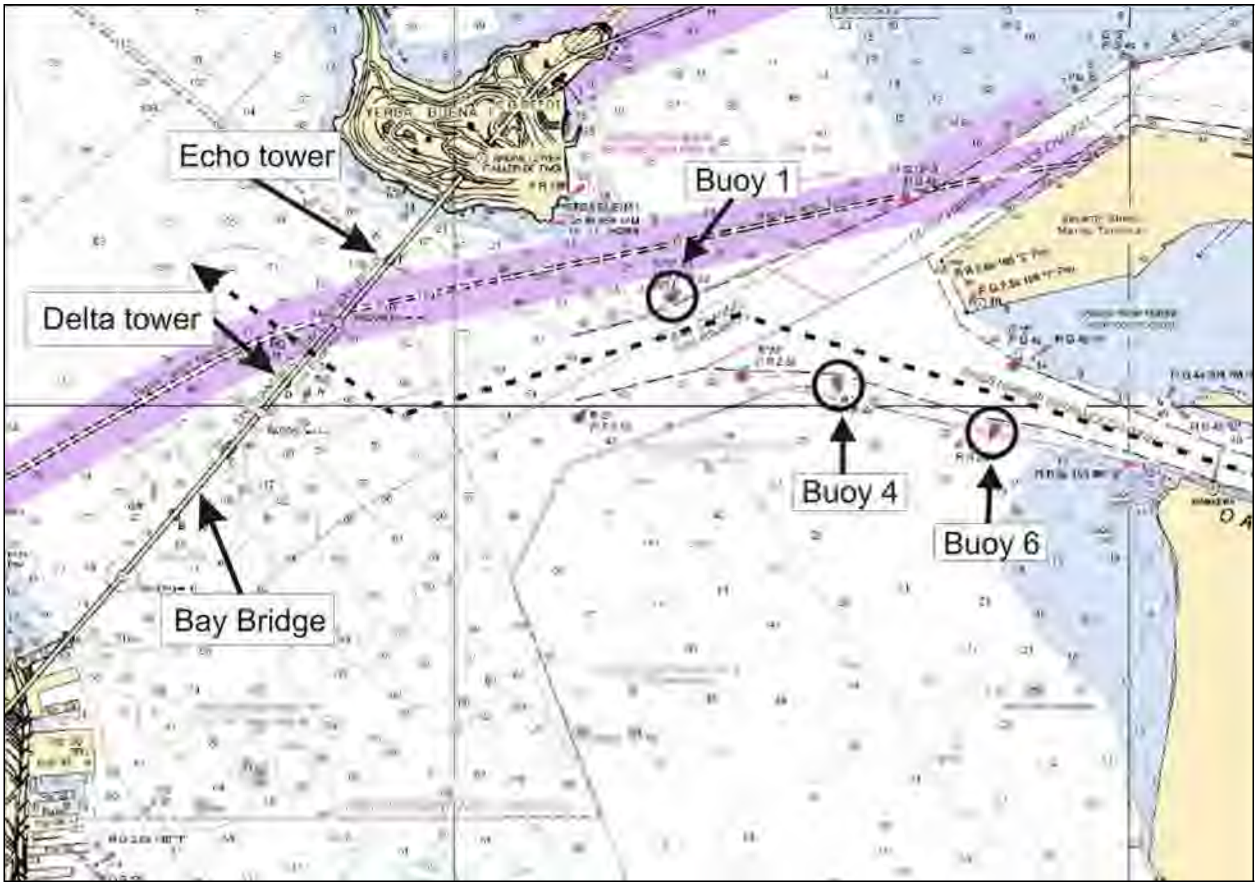

Figure 3. Navigation chart of the accident area with the approximate intended course of the *Cosco Busan* shown by the black dotted line.

About 0823, the pilot began a left turn to the southwest by ordering 10° port rudder. Radar data indicate that the ship at this time was on a heading of 282° and was traveling about 10 knots. A radar image from about 0825 showed that the VRM ring, which the pilot indicated he would normally attempt to keep positioned along the southern edge of Yerba Buena Island, had overlapped the edge of the island.

Although the pilot would later tell investigators that the radars were not performing properly, the VDR did not record the pilot making any comment to this effect during the voyage. The pilot stated that when he made the turn to port, he was where he wanted to be, but because of a deterioration in the radar display, he decided to use the electronic chart and "aim for" the location (identified on the chart by the red triangles) that the master "had pointed [out as] the center of the bridge." At this point, the vessel was about 1 mile from the Bay Bridge.

About 0825, the vessel had reached a heading of 253°, and the pilot ordered rudder to mid-ships (centered) before then asking for a heading of 250°, followed by 245°. Less than 1 minute later, the pilot ordered 10° starboard rudder, then starboard 20° and the engine to full ahead.[15] According to the VDR capture of the ship's radar display, at that time, the ship's

[15] A full-ahead engine order can be used to increase thrust over the rudder and achieve greater maneuverability, as the pilot did at 0825. On the *Cosco Busan*, a full-ahead engine order would have equated to 65 rpm on the main engine and an eventual speed of about 17 knots with the vessel loaded.

heading was 241° (almost parallel with the bridge) and its course over ground was 255°. When starboard rudder was applied and the ship's heading began to move toward the northwest, the ship's course over ground continued southwest. About 0827, the ship's heading was 247° while its course over ground was 236°. A few seconds later, the heading had increased to 261°, but the course over ground was 235°. The speed had remained constant at about 10 knots.

About this time, when the *Cosco Busan* was about 1/3 nautical mile from the bridge, a VTS operator who was monitoring traffic in the Central Bay Sector, including the progress of the *Cosco Busan*, noticed that the vessel appeared to be deviating from its intended route and was out of position to make an approach to the bridge's Delta–Echo span. The VTS operator radioed the pilot addressing him by his pilot designator name, "Romeo." The VTS operator and the pilot referred to VTS as "traffic." The following exchange occurred, as recorded by the vessel's VDR and captured on audio recordings provided by VTS:

Speaker	Time	Transcript of communication
VTS	08:27:24	Unit Romeo, Traffic.
Unit Romeo	08:27:29	Traffic, Romeo.
Unit Romeo	08:27:45	Traffic, Romeo, did you call?
VTS	08:27:48	Unit Romeo, Traffic. AIS shows you on a 235 heading.[16] What are your intentions? Over.
Unit Romeo	08:27:57	Well, I'm coming around; I'm steering 280 right now.
VTS	08:28:04	Roger, understand you still intend the Delta–Echo span. Over.
Unit Romeo	08:28:15	Yeah, we're still Delta–Echo.
VTS	08:28:21	Uh, roger, Captain.

The VDR showed that when the pilot reported to VTS that he was "steering 280," the ship's actual heading was 262°. The VTS operator did not further communicate with the pilot.

VDR voice recordings indicate that during his conversation with the VTS operator, about 08:28:08, the pilot asked, "This [apparently referring to a point on the electronic chart] is the center of the bridge, right?" The master answered, "Yeah."

Over the next 2 minutes, the pilot gave rudder orders of hard starboard, mid-ships, starboard 20, and hard starboard. At 0829, the bosun used his radio to report, in Mandarin, "The bridge column. The bridge column." The master replied (in Mandarin), "Oh, I see it. I see it." The pilot then said, "Yeah, I see it." About 10 seconds later, the pilot ordered the rudder (which had been at hard starboard) to mid-ships. After another 5 seconds, the pilot ordered hard port rudder.

The forward port side of the vessel struck the corner of the fendering system at the base of the Delta tower at 0830. (It would later be determined that contact with the bridge had breached the ship's No. 2 water ballast tank and the Nos. 3 and 4 port fuel tanks. The response to

[16] The VTS operator's display showed the course over ground of the vessel, not its heading.

the oil spill is discussed in the section titled "Incident Response and Spill Estimate.") About 30 seconds later, after being reminded by the crew that the rudder was still hard to port, the pilot ordered the rudder to mid-ships and the engine to dead slow ahead. At that point, the vessel was past the bridge tower.

The pilot contacted the VTS operators by VHF radio and informed them that his ship had "touched the Delta span" and that he was proceeding to anchorage 7 (just west of Treasure Island, about 2 miles away) where he planned to anchor the vessel. At that point, the *Cosco Busan* chief officer reported to the master, in Mandarin, that the ship was leaking. The pilot asked if the ship was all right, and the master answered, "No, no, no, it's leaking." The pilot then said, "OK, dead slow ahead. We're going to anchor."

As the ship proceeded toward the anchorage, the pilot had the following exchange with the master (from the VDR transcript, intervening helm commands deleted):

Pilot: [unintelligible] you said this was the center of the bridge.

Master: Yes.

Pilot: No, this is the center. That's the tower. This is the tower. That's why we hit it. I thought that was the center.

Master: It's a buoy. [unintelligible] the chart.

Pilot: Yeah, see. No, this is the tower. I asked you if that was [unintelligible]. . . . Captain, you said it was the center.

Master: Cen… cen… cen… center.

Pilot: Yeah, that's the bridge pier [expletive]. I thought it was the center.

Shortly after this conversation, the master can be heard saying, in Mandarin, "He should have known—this is the center of the bridge, not the center of the channel."

Postaccident Interview with the Pilot

In his postaccident interview with Safety Board investigators, the pilot stated that when he was tuning the vessel's radars and testing the ARPA before departure, he also examined the electronic chart and noticed that "the symbols on the . . . electronic chart didn't look similar to me to the symbols that are on paper charts." He stated:

> So I asked the captain, 'Where's the center of Delta–Echo span [of the Bay Bridge] on this electronic chart?' So he pointed to a position on the chart, and it had two red triangles on either side of the bridge. So I said, 'Well, what are these?' And he said, 'Oh, those are to mark the lengths for the center of the span.'

The pilot told investigators, "I see probably 10 different ECDIS[17] during a week" but "I have never seen a red triangle on any piece of navigation information, electronic, paper or

[17] ECDIS (electronic chart display and information system) refers to a specific form of computer-based navigation information system that complies with International Maritime Organization (IMO) regulations. A

otherwise. . . . That's why I asked him, I said, 'What does this mean?'" The conversation that the pilot described was not recorded by the onboard VDR.

The pilot further told investigators that about 0825, when the *Cosco Busan* was making the turn to port in its approach to the Bay Bridge, the onboard radars became distorted:

> As I made the turn . . . the radar picture of the bridge got distorted. It got wider. The bridge got wider. The RACON[[18]] never appeared. And I couldn't see the bridge piers or the buoys south of the span. I couldn't pick it up on the radar. So at that point, I figured that the electronic chart would be more accurate because . . . I wasn't comfortable with the [radar] display[s].

The pilot further stated that he was confused by the VTS communication at 08:27 in which VTS stated that it showed the vessel on a heading of 235:

> And I'm standing at the radar, and the radar and the electronic chart are right next to each other, and . . . I said my heading flasher[[19]] is on 280. . . . I was nowhere near 235. I mean it's not even a course you use to get to the bridge. I never go left of 250. When I leave the Bar Channel generally, I steer towards the tower or somewhere between 250 and 260, depending on the current. So I mean that really stunned me. I was really confused by that. I couldn't understand how they could have me at 235 and I had me at 280. . . . the heading flasher showed that I had already cleared what the captain had indicated was the center of the bridge. The heading flasher was to the right of it, and we were still coming right . . . from the electronic chart, it looked to me like I was already past the center and I was . . . a little concerned about going too far to the starboard.

Postaccident Interviews with the Master and Other Ship's Officers

Just over a year after the accident, Safety Board investigators collected sworn testimony from the master and the second and third officers after they had been given immunity from prosecution by Federal law enforcement officials.

Master

Decision to Depart. The master told investigators that, in his view, the fact that the port was not closed and that the pilot was willing to sail in the existing visibility conditions left the master with limited reason to object to departing. He said that he understood that the responsibility for the vessel's safe operation ultimately rested with him as the master. He noted:

> It is not [for] me to decide whether to set sail or not under such condition. Basically, I have to follow his [the pilot's] direction. Even though I realize that the master has full

certified ECDIS can be used in lieu of paper navigation charts for primary navigation. As will be discussed later in this report, the electronic chart system on board the *Cosco Busan* was not a certified ECDIS system.

[18] A RACON (RAdar BeaCON) is a navigation aid that responds to radar interrogation by displaying its Morse code identifier on the radar screen. A RACON was in place at the center of the Delta-Echo span of the Bay Bridge at the time of the allision, and postaccident reviews of radar images recorded by the VDR showed that the RACON was functioning and periodically displaying its signature on the *Cosco Busan*'s 3-cm radar.

[19] Heading flasher refers to an illuminated radial line on the radar that shows the ship's heading.

> authority, but under such a condition, when we have the pilot on board, I have never encountered any times that, that the captain would overrule the pilot in even both shipboard safety and environment.

The master also stated that the fact that the port was not closed indicated to him that vessels were expected to sail. As he testified, “the decision [to sail came] from the Port Authority.”

Monitoring the Accident Voyage. The master stated that the pilot did not tell him of his intention to proceed through the Delta–Echo span of the Bay Bridge, nor did the master ask the pilot about his intentions. The master stated that he did not have any conversation with any of the ship’s deck officers concerning the planning for the transit from the berth in Oakland to the San Francisco pilot station or a discussion of any potential hazards along the route, such as the Bay Bridge. The master said that during the accident voyage he was monitoring the ship’s radar. He said that he observed the radar signature of the RACON marking the center of the Delta–Echo span, but the ship’s VDR recorded no comment by the master or other crewmember about the RACON display.

Master/Pilot Information Exchange. Before the vessel got under way, neither the master nor the second officer briefed the bridge team members on the outbound voyage. The master stated that he did not want to make the pilot “feel uncomfortable or unwelcome,” so he chose not to engage the pilot in a discussion of his plans with regard to the outbound voyage.

Pilot’s Question About the “Red Triangles.” The master told investigators that he thought that the pilot asked about the red triangles on the electronic chart because “he was curious and want[ed] to know what that was.” The master said he felt that the pilot should have known what the symbols meant. The master told investigators that when he responded to the pilot’s question about the “center,” he meant the center of the entire bridge and not necessarily the center of the Delta–Echo span. The master later stated in a deposition that when he answered the pilot’s question about the buoys, he “was just guessing,” and he did not realize it was a “serious question.”

Pilot/VTS Radio Conversation. According to the master, the VTS San Francisco practice of using the name or designator name of the pilot rather than the name of the vessel made it difficult initially to monitor VTS communications with the vessel. As the master told investigators:

> [VTS at] another port normally would call the ship’s name. If the VTS called the pilot’s or the person’s name, maybe private conversation. If for working, I think it’s best way to call ship’s name, because you call the ship’s name, not only pilot would understand that, even the captain understands.[[20]]

[20] No international standard governs the type of designator to be used by VTS when communicating with vessel bridge teams.

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Other Ship's Officers

The chief officer and the third officer both stated that, before the accident voyage, they had not received any training from Fleet Management on the master's standing orders, on passage planning, or on bridge team management. The chief officer also stated that he had never before worked on a ship with an electronic chart system. The second officer stated that, before the voyage, neither the ship's master nor Fleet Management superintendents had provided him with any training, instruction, or guidance on the master's standing orders or on Fleet Management's *Bridge Procedures Manual*. He said he had not prepared a berth-to-berth passage plan when the vessel departed Busan, Long Beach, or Oakland. The third mate stated that, in contrast to his experience sailing with other technical management companies, he and fellow crewmembers were given limited opportunity to meet with the off-going *Cosco Busan* crewmembers and had little time to become acquainted with the ship and to review Fleet Management's policies and procedures before they undertook their first voyage on the vessel.

Postaccident Activities

On being notified of the allision at 0830, the VTS watch supervisor contacted the Coast Guard Sector San Francisco Command Center Situation Unit controller via telephone about 0832 to report the information that the pilot had provided regarding the incident. The report initiated the situation unit response to the incident. At 0834, the VTS watch supervisor notified the California Department of Transportation (Caltrans) of the incident involving the bridge.

Also at 0834, according to the VDR transcript, the pilot used his cell phone to report the incident to the San Francisco Bar Pilots Association office. He said that his ship had struck the bridge tower, stating:

> Well it was a… I'd like to call it a glancing blow, but… there's definitely damage. . . . there was… confusion [about] the electronic chart. What I thought they said was the center of the bridge was actually the tower, so I thought I had it made [but], uh, we didn't . . . .

The pilot office notified the pilot port agent (who was also president of the San Francisco Bar Pilots Association), who in turn notified the commander of Coast Guard Sector San Francisco.

At 0836, also using his cell phone, the pilot followed up on his VHF report to VTS regarding the allision and provided additional information, including his preliminary assessment of damage to the fender of the Delta tower. During this call, a VTS watch supervisor asked the pilot, "As far as the ship goes right now, [have] they conducted soundings[21] on the ship and everything's fine, or…?" The pilot responded, "Well… we're just going to anchor now. I don't—ah—they have to go check. I just wanted to let you guys know right away."

[21] Sounding is the act of using a measuring tape or rod to determine the depth of liquid in a tank.

As soon as this call ended, the pilot asked the master to have his crew check the ship for damage. He also told the master that the Coast Guard wanted the tanks sounded, "to make sure there's no holes or anything."

Meanwhile, the pilot port agent embarked on the pilot boat *Golden Gate*, along with three other pilots and the boat's crew, to assess damage to the Delta tower. Arriving in the vicinity of the tower, the pilot port agent reported to VTS via his cell phone about 0847 that debris was in the water and that the *Cosco Busan*'s fuel tank had been ruptured. He asked the VTS operator to notify the Corps of Engineers that "there's going to be debris floating around down at the anchorage."

That telephone call ended about 0848. About 0850, the pilot on the *Cosco Busan* contacted VTS via VHF radio to report the vessel's arrival at anchorage 7 and of his intention to deploy the vessel's anchor. Meanwhile, the *Golden Gate* had arrived on scene, and the pilot port agent had seen "substantial oil coming out of the hull." At 0853, the pilot port agent contacted the VTS watch supervisor via cell phone and reported this information, saying:

> . . . we need to… get the spill responder going. This guy's dumping fuel into the water . . . It's not a ton of fuel, but quite a bit. There's a lot of damage to the ship as well . . .

The call ended at 0854. About 0855, the pilot on board the *Cosco Busan* contacted VTS, this time by cell phone, and informed operators that he suspected that one of the vessel's fuel tanks had been ruptured and that an oil slick was forming around the vessel. In his postaccident interview, the pilot said that this was the first time he had noticed the oil in the water but that he had not previously looked for it. About 0900, the pilot released the tug *Revolution*, which had remained tethered to the vessel's stern by 100 to 400 feet of line from the time the containership left the inner harbor channel until it reached the anchorage. In his postaccident interview, the pilot stated that he had forgotten about the tug until he arrived at the anchorage.

Also about 0900, one of the San Francisco Bar pilots who had arrived on the *Golden Gate* reported to the vessel bridge to relieve the accident pilot. Shortly thereafter, another one of the pilots who had arrived on the *Golden Gate* came on board and witnessed the accident pilot self-test for alcohol using a saliva strip that the accident pilot carried as part of his personal gear. This pilot told Safety Board investigators that the test was negative. The accident pilot then departed the ship and was taken on board the pilot boat *Drake* to the pilot association office for mandatory drug and alcohol testing. These tests were negative. (See the "Medical and Toxicological Information" section of this report for more detail about these tests.)

About 1002, because of the ebbing tide and the relief pilot's concern over the vessel's draft and the water depth at anchorage 7, the *Cosco Busan* heaved anchor and shifted to anchorage 9, a deeper anchorage just south of the Bay Bridge.

Organizations/Agencies Involved in the Spill Response

A number of public and private agencies and organizations were involved in the response to the *Cosco Busan* allision. The following is a brief description of each of these organizations and its role in the response, the details of which will be discussed in the next section of this report.

U.S. Coast Guard

The U.S. Coast Guard (Coast Guard), an element of the U.S. Department of Homeland Security, is organized into two areas, Atlantic and Pacific, and nine districts. Headquarters for the Pacific Area are in Alameda, California, as are headquarters for Coast Guard 11th District, which encompasses the states of California, Arizona, Nevada, and Utah. Coast Guard District 11 includes three sectors (San Francisco, Los Angeles/Long Beach, and San Diego) and one group (Humboldt Bay). The *Cosco Busan* allision occurred in the area under the authority of Coast Guard Sector San Francisco, located on Yerba Buena Island. The commander of Coast Guard Sector San Francisco was the Federal on-scene coordinator (FOSC) for the response. The FOSC holds the ultimate authority for all decision-making related to the response and is responsible for directing Federal response efforts and coordinating other Federal efforts at the scene of a discharge or release. In the event of a marine oil spill, the FOSC is responsible for overseeing the response effort and, if it is determined that the effort is not being properly conducted, to assume control of the response.

California Office of Emergency Services

The California Office of Emergency Services (OES), an element of the governor’s office, coordinates overall state agency response to major disasters in support of local government. The office is responsible for assisting local governments in their emergency preparedness, response, and recovery efforts. The OES Warning Center is staffed around the clock. OES maintains a 24-hour toll-free toxic release hotline and relays spill reports to a number of other state and Federal response and regulatory agencies, as well as local governments.

California Department of Fish and Game–Office of Spill Prevention and Response

The California Department of Fish and Game–Office of Spill Prevention and Response (DFG–OSPR) is responsible for preventing, preparing for, and responding to spills of oil and other hazardous materials. A DFG–OSPR First Response Team, which included an oil spill prevention specialist, was dispatched to the *Cosco Busan* on the day of the allision to quantify the amount of fuel lost. The lieutenant (state warden) supervisor of DFG-OSPR was the state on-scene coordinator (SOSC) for the response.

Fleet Management Ltd.

Fleet Management Ltd. (Fleet Management) of Hong Kong was responsible for the technical management of the *Cosco Busan* on behalf of Regal Stone Ltd. of Hong Kong, the vessel’s owner. Fleet Management recruited the ship’s crew and was responsible for the crew’s training and overall operation and maintenance of the ship and its equipment. The company was also responsible for maintaining approved port state and Federal vessel response plans on board the vessel.

The O'Brien's Group/Qualified Individual

Under the Oil Pollution Act of 1990 and the Coast Guard and Maritime Transportation Act of 2004, all ships that call upon U.S. ports must have a vessel response plan that identifies a qualified individual (QI) who is to be notified in the case of an oil spill and who will manage the response effort on behalf of the ship owner or operator. Fleet Management had contracted with the O'Brien's Group to act as the QI in the event of a spill involving the *Cosco Busan*.

Oil Spill Response Organizations

The vessel response plan on board the *Cosco Busan* identified two oil spill response organizations, the Marine Spill Response Corporation (MSRC) and NRC Environmental Services (NRCES), that were to be contacted in the event of a spill involving the vessel. MSRC is a non-profit national spill response company that was founded in 1990 and is funded by companies engaged in petroleum exploration, production, refining, marketing, and transportation. NRC Environmental Services, Inc., is an independent wholly-owned subsidiary of National Response Corporation. The company provides hazardous and nonhazardous waste management and emergency response services to private industrial and government clients on the West Coast.

Incident Response and Spill Estimate

The first Coast Guard response unit to be notified of the allision was Coast Guard Sector Command Center (SCC) Situation Unit, which received notification by VTS about 0832. At 0836, the SCC issued a marine safety information bulletin warning vessels in the area to stay at least 100 yards away from the *Cosco Busan* and to transit the area with caution. Personnel from the SCC briefed the Coast Guard marine casualty investigating officer and the District 11 bridge administrator at 0837 and 0840, respectively.

At 0846, the SCC arranged for a Coast Guard utility boat to transport a pollution investigation team, consisting of two Coast Guard petty officers, that was to assess the damage to the bridge and to the *Cosco Busan* and find out how much oil had spilled from the ship. While en route, the team contacted the SCC via cell phone and reported observing a 3-foot-wide oil slick on the water leading from the bridge to anchorage 7. The team arrived at the vessel about 0930 and used a cell phone to transmit a photo of the damage to the SCC. The team estimated the damage area to be about 100 feet long and about 10 feet wide.

The first estimate of the amount of fuel oil that had been released into the bay came from the pilot who had relieved the accident pilot on board the *Cosco Busan*. According to VDR transcripts, the relief pilot was aware shortly after he arrived on board that oil had been transferred from the breached tanks to other tanks on the ship, and he believed the flow of oil had been stopped. About 0913, the relief pilot asked the ship's master if he had any estimate of "how much bunker [oil][22] went into the water." After speaking briefly with the chief engineer about the

[22] Oil used to fuel a ship's engines is referred to as bunker oil to distinguish it from oil carried as cargo. The tanks used to store the fuel oil are sometimes referred to as bunker tanks.

transfer of oil, the master spoke by satellite phone to the O'Brien's Group command center and reported, "The damage to the ship is forward, but how much oil spilled I cannot give you the feedback." About 0917, the relief pilot contacted MSRC by cell phone and stated that the fuel loss had been stopped and the fuel lost " . . . could be 10 barrels [about 400 gallons] . . . I don't know." MSRC was one of the two oil spill response organizations listed in the *Cosco Busan*'s vessel response plan to be notified in the event of a spill. The second organization listed was NRCES. NRCES was not notified at this time, but NRCES representatives told Safety Board investigators that the company had learned of the spill through VHF radio traffic about 0910 and was already in the process of mobilizing.

After being notified of the spill by the *Cosco Busan*'s master about 0915, the O'Brien's Group command center in Slidell, Louisiana, notified the California (OES) Warning Center (at 0942) and the National Response Center (at 0949).[23] About 0950, the command center contacted the O'Brien's Group manager of consulting services, who was in Ventura, California, at the time, and directed him to go to San Francisco to serve as incident commander.[24] The manager of consulting services officially confirmed activation of the *Cosco Busan*'s two oil spill response organizations—MSRC and NRCES—at 0951 and 1041, respectively. He activated MSRC before departing for San Francisco by car; he activated NRCES while en route.

In the absence of a firm estimate of the amount of oil spilled, the response organizations were required by California regulations to respond to the "reasonable worst-case" scenario, which would have been based on the capacity of the vessel's largest fuel tank.[25] For the *Cosco Busan*, this was 5,874 barrels, or about 250,000 gallons.[26] NRCES began mobilizing about 0910 and MSRC began mobilizing about 0940, ahead of receiving the official activation from the QI, as previously noted. Both companies would continue to deploy assets to the San Francisco Bay throughout the first day.

About 0930, a virtual brief via conference call was conducted between the Coast Guard deputy commanding officer and the sector commander and members of his staff, including the chiefs of response and prevention, the acting chief of the Incident Management Division and division personnel, and the command duty officer.[27] At 0945, the off-going command duty officer initiated a critical incident communication, or CIC, to Coast Guard Headquarters, Pacific Area Command, and to 11th District informing all parties of the allision, the limited visibility conditions, the reports of a 3-foot wide oil slick extending from the Bay Bridge to the vessel, the damage to the vessel, the relief pilot's unverified 10-barrel fuel loss estimate, and the high media

[23] The National Response Center is an interagency organization that is the sole Federal point of contact for the reporting of oil or chemical spills in the United States and its territories.

[24] The QI for this incident was the O'Brien's Group, and the company's manager of consulting services would be acting as incident commander under the QI's direction and representing the QI on scene.

[25] Reasonable worst-case spill is defined in 14 *California Code of Regulations* Section 827.02

[26] Both the Coast Guard and the oil spill response organizations would have access to this information through the vessel's approved nontank vessel response plan, which will be discussed later in this report.

[27] The three most senior officers assigned to the Incident Management Division were away from the SCC on the day of the spill, and their responsibilities during the accident response were carried out by lower-ranking personnel within the division.

interest. The situation was not seen as a potential critical incident and thus was to be managed at the sector level.

Also about 0945, a Unified Command was established at the Sector Command Center on Yerba Buena Island. The Unified Command (discussed in the next section of this report) initially consisted of representatives from Sector San Francisco and the California Department of Fish and Game. Later in the day, it would consist of the commander of Coast Guard Sector San Francisco (who served as the FOSC), the lieutenant supervisor with the DFG-OSPR (who was the SOSC), and the incident commander from the O'Brien's Group (who was driving up from Southern California and would not arrive until about 1800).

The Coast Guard pollution investigation team boarded the *Cosco Busan* about 0947 after taking photographs of the damage to the ship and transmitting them to the SCC via cell phone. Shortly after boarding the vessel, the pollution investigation team began attempting to determine the amount of fuel oil that had been released. Up until this point, the only estimate of the size of the spill was the 10-barrel/400-gallon "guess" that had been offered by the relief pilot about 0918. The pollution investigation team interviewed the chief engineer, who told them he was unsure whether portside tanks 3 or 4, or both, were punctured.[28] A review of the vessel's oil records revealed that, at departure, the Nos. 3 and 4 port tanks had held 80.4 and 742.5 metric tons, respectively. Based on this initial amount (the amount the chief engineer said had been transferred from tanks 3 and 4 to double-bottom bunker tanks, and the amount that remained in the tanks), the team estimated a loss of about 0.4 metric tons, which they later calculated to be about 146 gallons. Shortly after 1030, the team reported this amount to the SCC but cautioned that the figure might not be accurate because of the reliance on imprecise float gauges and the inability to sound all the tanks. The team also reported some difficulty in communicating with the Chinese chief engineer[29] and suggested that another spill estimate should be made based on the 2-mile-long, 3-foot-wide trail of thick oil they had previously reported. In addition to conveying the fuel spill estimate, the team also informed the Incident Management Division of the capacities of the two tanks suspected of being damaged and the documented quantity of fuel in each at departure. This information was not provided to the FOSC, nor did he ask for it. The 146-gallon estimate was not provided directly to the oil spill response organizations or to the QI but was made public by the FOSC at a noon press conference.

About 1205, an oil spill prevention specialist from the DFG-OSPR, accompanied by a warden from the California Department of Fish and Game and a Coast Guard investigator, departed Yerba Buena Island for the *Cosco Busan* to conduct a detailed analysis of the fuel tank volumes and to calculate the amount of fuel that had spilled into the bay. The specialist said he had not been aware of earlier loss estimates either of 10 barrels or 146 gallons. The specialist told investigators he and the warden had arrived at the island about 0935 but had been unable to secure a Coast Guard boat to take them to the vessel until about noon. At the public hearing on the accident convened by the Safety Board at its headquarters in Washington, D.C., on April 8

[28] Portside tank No. 2 was also breached, but this tank contained only ballast water.

[29] Under the *International Convention on Standards of Training, Certification and Watchkeeping for Seafarers 1978* (STCW 78) as revised in 1995 (STCW 95) crewmembers responsible for vessel navigation and engineering must be sufficiently proficient in written and spoken English to perform their jobs safely in a multilingual environment.

and 9, 2008, the then-commander of Coast Guard Sector San Francisco (since retired) stated that he had not been aware of the specialist's presence on the island or his need for transportation until about 1130. The oil spill prevention specialist acknowledged during the public hearing that he had not coordinated his movements with the Coast Guard and had attempted on his own to secure transportation to and from the *Cosco Busan*.

The oil spill prevention specialist said that after arriving on board the *Cosco Busan* about 1230, he spoke briefly with the master before going below with the vessel's chief engineer to sound the Nos. 3, 4, and 5 port fuel tanks, as well as the tanks to which oil had been transferred. The specialist said he had no difficulty communicating with the chief engineer because the two spoke in English using technical terminology that the engineer easily understood. Because of damage to the sounding tube in the No. 3 tank, the float gauge had to be used to determine the remaining oil in this tank. Tank Nos. 4 and 5 were sounded, with the soundings indicating that the No. 5 tank had not been breached. The soundings were completed by about 1315.

The specialist then calculated the size of the spill by subtracting the amount of oil remaining in the tanks (including the tanks to which oil had been transferred) from the amount of oil the ship was known to have had on board when it left the berth. By about 1335, he had concluded his calculations, which indicated that the ship had lost about 219 cubic meters, or 58,020 gallons, of heavy fuel oil (designated IFO-380). At that time, the ship was down slightly by the head and had a slight list because of the lost oil. (The specialist returned the next day, when the ship was on a more even keel, and re-measured the oil levels, recalculating the loss as about 203 cubic meters, or 53,500 gallons.)

The Coast Guard attempted to arrange for a helicopter to take the FOSC over the bay to assess the scope of the spill. When the helicopter experienced an in-flight malfunction at 1455 and had to return to base, the FOSC went out on a Coast Guard small boat about 1455 to assess the scene.

By this time, the oil spill prevention specialist on board the *Cosco Busan* had completed his calculations of the magnitude of the spill, but he did not immediately report his findings. Instead, he waited until he could return to the command center and brief the SOSC in person. At the April 2008 public hearing on this accident, the specialist stated:

> If you give it [the spill quantity] to the wrong parties . . . it can get leaked to the press and it can get exaggerated [or] exploded out of proportion. . . . [So you] funnel it up through your SOSC, who then takes it to the Unified Command, and then they're the ones who release it to the public . . . .

He also stated that he preferred to convey the information in person because:

> You want to go in there, explain to SOSC how you got the figure, the methodology, your calculations, your figures, you want to put it all down in front of him . . . so that he knows that this is what he can run with.

The SOSC, who also testified at the public hearing, confirmed that, in a case such as this, he preferred to get the information directly. He stated:

> Usually . . . a warden will manage a response, but if it gets kicked up to a level where it's going to be of economic sensitivity, you know, high environmental or political [sensitivity], then I step in. And . . . I want an accurate figure. I don't want to have to go back and explain why we messed up. So [the oil spill prevention specialist] knows that I want [the information given] personally to me. . . . so I can ask questions as a check and balance before it goes out to the Unified Command.

As a result of this practice and the fact that the oil spill prevention specialist again had to await transportation, this time from the vessel back to Yerba Buena Island, the SOSC was not made aware of the actual magnitude of the spill until about 1600 when the specialist arrived back at the incident command center. About 1700, the SOSC provided the Unified Command with the updated figure, which was then conveyed to the DFG-OSPR deputy administrator about 1715 and to the state OES about 1717.

About 1730, on-water oil spill recovery operations were suspended for the day because of darkness. About 2100, the state OES conducted a conference call with local jurisdiction emergency services and with the counties surrounding San Francisco Bay informing them of the 58,000-gallon quantification.

At the April 2008 public hearing on this accident, the Safety Board asked parties involved in the response to the incident whether their efforts had been hampered by the delay in accurately quantifying the spill.

The O'Brien's Group incident commander stated:

> I don't think the response was hampered. As far as the technical response and the equipment deployed, we responded quickly with a very large quantity of equipment for a reasonable worst case. I think the fact that we recovered 33 percent of the volume on water with skimming equipment in the first 4 days is remarkable . . . .

When asked if the Coast Guard response would have been different had the pollution investigation team initially reported that 58,000 gallons, rather than 146 gallons, of fuel oil had been lost, the then-commander of Coast Guard Sector San Francisco stated:

> It wouldn't have been much different except that maybe I would have called out the Pacific Strike Team sooner. We ended up calling the Pacific Strike Team[[30]] out at the end of the day when we had the 58,000-gallon number. So other than that, all the resources were rolling out in San Francisco as fast as they could be rolled out.

He said that the Pacific Strike Team could have helped with staffing the Unified Command and that, though the team had response resources, "since the [oil spill response organizations were] moving all of their equipment into place immediately, [those resources] wouldn't have been necessary right away."

[30] The Pacific Strike Team is one of three special teams that, along with the Atlantic Strike Team and the Gulf Strike Team, make up the National Strike Force. These teams comprise specially trained Coast Guard personnel who maintain and respond with specialized equipment and incident management skills in the event of an oil discharge, a hazardous substance release, or other emergency.

Asked if the state's response would have been different if the size of the spill had been known sooner, the SOSC said, "No, not at all, no." He also said that the state's response was a worst-case approach that was based on the capacity of the largest fuel tank on board and that, while he did not know that capacity, "I know it's a 900-foot oceangoing vessel that crosses the Pacific. I know it's a lot of oil."

He went on to say:

> It didn't matter whether I got [the amount] at 6:00, 7:00, [or] 8:00 at night; we were still out there and . . . we got it done, we really did. . . . We're responding like it's a worst case anyway.

Representatives of the San Francisco Department of Emergency Management within the Division of Emergency Services first learned of the true amount of the spill about 2100 when they participated in the conference call initiated by the state OES. The manager of plans and operations for the Department of Emergency Management said this was the first time anyone with the city of San Francisco became aware that the spill involved much more oil than originally believed and that he "wondered why it took that long to get that information out to us about the scope of the spill."

The manager said:

> Had we been told that it was a 900-foot ship, 200-foot gash, potential for lots of oil in the water, regardless of the exact number, we would've responded differently.

But he also said he couldn't be sure because, "this was our first oil spill." He said the city had no oil recovery equipment but that:

> We probably would have offered up our emergency operations center right off the bat, at least as an initial place to be until we could find something more permanent . . . . We can offer indirect support, just as we did the following day, on the 8th, when we were in the command post.

The manager said that on the day after the allision, the city provided equipment such as telephones, audiotape, and printers to the command center and arranged for communications vans to provide Internet access. The city also provided a mobile command post. The manager said that these assets could have been offered earlier if the city had been aware of the scope of the spill.

Communication Within the Unified Command

The Unified Command System operates on the principle of shared command response authorities on the Federal and state level. In this accident, the Unified Command consisted of the FOSC, the SOSC, and the incident commander/QI. The commander of Coast Guard Sector San Francisco filled the role of FOSC and acted as the Federal incident commander. The FOSC holds the ultimate authority for all decision-making related to the response and is responsible for coordinating and directing Federal response efforts. In the event of a marine oil spill, the FOSC is responsible for overseeing and ensuring the adequacy of the response actions and has the authority to take over, or federalize, the response if it is not being properly conducted.

The SOSC and state incident commander in this accident was the lieutenant supervisor from DFG-OSPR. The SOSC told investigators that, until later in the day, he worked primarily with the FOSC's representatives and had little interaction with the FOSC himself, who was getting updates from his representatives and was involved in preparing for upcoming press briefings, trying to arrange for a helicopter overflight, and assessing the situation by boat.

The final member of the Unified Command for this accident was the incident commander from the O'Brien's Group. The incident commander said that, while en route to San Francisco from Ventura, California, he maintained contact with the O'Brien's Group command center and with the oil spill response organizations, from whom he received periodic updates about resources deployed and the progress of the response effort. He said he also had hourly contact with a Coast Guard command duty officer, to whom he relayed the information he was receiving from the field. Postaccident interviews with participants indicated that little if any information from the oil spill response organizations found its way to the FOSC, who indicated at the public hearing on this accident that he had relied on his representatives in the Unified Command and on Incident Management Division personnel to assess the oil spill response.

Notification of Local Jurisdictions

When the California OES Warning Center received the 0942 telephone report from the O'Brien's Group advising of an unknown quantity of fuel oil spilled from the *Cosco Busan* into San Francisco Bay, the incident location was reported as Oakland, Alameda County. Based on that information, the Warning Center, in accordance with its *Standard Operating Procedure for Hazardous Materials Incidents* in place at the time of the incident, notified only the Oakland Fire Department and the Alameda County Department of Environmental Health that a spill had occurred.

At 1028, the Warning Center received an e-mail from the DFG-OSPR deputy administrator advising that the breech of the vessel hull appeared to have released 10 barrels of oil into the bay. The Warning Center received a situation update at 1515 when a fisherman reported a 1-mile oil slick. Again, the only local government agencies notified of this report were the Oakland Fire Department and Alameda County Department of Environmental Health. The situation update was also forwarded to the Coast Guard and state Office of Spill Prevention and Response. The estimated spill volume remained about 10 barrels, or 400 gallons. At 1740, the Office of Spill Prevention and Response deputy administrator informed the OES Warning Center of the recently completed quantification, which he conveyed as 1,840 barrels.[31] Again, the only local jurisdictions made aware of the updated quantification were the Oakland Fire Department and the Alameda County Department of Environmental Health.

[31] This quantification was contained in an e-mail from the Department of Fish and Game deputy administrator. It was an incorrect amount that was not cited elsewhere. It could not be determined why the amount was incorrectly reported.

Since this accident, the California OES has revised its *Standard Operating Procedure for Hazardous Materials Incidents*. The revised procedure requires the Warning Center to notify the appropriate county public safety answering point(s) (PSAP) in the event of a known or potential release of one barrel or more of petroleum product. Notifications are to be made both orally and by fax. Identification of the PSAPs to be notified is based on whether the spill occurs in the ocean, a river, stream, or in a bay area. In the event of a bay-area spill, as was the case with the *Cosco Busan*, all surrounding county PSAPs are to receive notification. The plan uses the San Francisco Bay as an example and lists the required notifications as Alameda, Contra Costa, Marin, Napa, San Mateo, Santa Clara, Solano, Sonoma, and San Francisco.

Oil Recovery Response

Title 33 *United States Code* 1321(j)(5)(D) requires that owner/operators of nontank vessels[32] of 400 gross tons or more that carry fuel for main propulsion and that operate in U.S. waters have a nontank vessel response plan that has been submitted to the Coast Guard and that is carried on board the vessel.[33] Additionally, some states, including California,[34] have their own requirement for nontank spill response contingency plans, which they require the subject vessels to carry when operating in those states' waters.

The *Cosco Busan* carried a California-approved Nontank Vessel Contingency Plan (as required in 14 *California Code of Regulations* Section 827.02). Under the plan, the owner, operator, or agent of a vessel involved in an oil spill must, no more than 30 minutes after discovery of the discharge, contact the National Response Center, the designated oil spill response organizations, the QI, and the California OES.

Section H of the vessel's California-approved Nontank Vessel Contingency Plan contained a table (table H-2) summarizing the required response times and skimming capacities for reasonable worst-case spills occurring at various California coastal locations. Section H states that the response times and skimming capacities contained in the plan are in accordance with the nontank vessel plan regulations found in 14 *California Code of Regulations* Section 827.02(h)(2)(A)&(B), "Containment Booming and On-Water Recovery." The California code specified that nontank vessels transiting the San Francisco Harbor shall have "the on-water recovery capability to address the nontank vessel's reasonable worst-case spill volume at the scene of the spill within six hours." The regulations defined "reasonable worst-case spill" as the total volume of the largest fuel tank on the nontank vessel. For the *Cosco Busan*, the response standard for the reasonable worst-case spill would have been 5,874 barrels, or 246,708 gallons.

The first oil spill response organization to respond to the incident was NRCES, which responded after being alerted of the spill by radio traffic about 0910. MSRC began mobilizing about 0940. When the incident commander was contacted by the O'Brien's Group command

[32] Nontank vessels are defined as self-propelled vessels of 400 tons or greater, other than tank vessels, that carry oil or any kind of fuel for main propulsion and that are vessels of the United States or that operate on U.S. waters.

[33] At the time of the *Cosco Busan* allision, the Coast Guard was not enforcing this requirement. See the "Other Information" section of this report for details.

[34] Other states with state-specific nontank vessel response plans are Alaska, Washington, Oregon, and Texas.

center about 0950, he was told that MSRC had already been notified and had mobilized skimmers. He was advised to contact MSRC and NRCES regarding activation of resources and to let them know that he would be directing their activities. He contacted MSRC at 0951 and NRCES at 1041.

According to MSRC and NRCES records, both spill response organizations mobilized all of their response resources positioned in the San Francisco Bay area. MSRC activated all of its mobile skimming and boom boats in the San Francisco and Richmond areas, and NRCES deployed all of its resources from Alameda. Additional MSRC resources were positioned about 15 to 20 nautical miles away in Crockett and Martinez, California, and the remaining 25 percent of NRCES's assets were positioned in Benicia, California, also 15 to 20 miles away. Both organizations estimated that about 3 hours were needed to organize and mobilize additional crews to respond from these locations.

MSRC and NRCES records indicated that, as of 0950, about 1 hour and 20 minutes after the allision, the two companies had 8,588 barrels per day of skimming capacity, or estimated daily recovery capacity (EDRC),[35] on site, with two skimming vessels at the *Cosco Busan*. This equipment package also included 5,000 feet of boom. About 2 hours after the allision, an additional 31,888 barrels per day of skimming capacity was on-scene with another four vessels and 8,000 feet of boom, bringing the total to 40,476 barrels per day. About 6 hours after the allision, an additional 34,567 barrels per day of skimming capacity had arrived on scene, bringing the total on-site skimming capacity to 75,043 barrels per day. At the end of recovery operations on the first day, a total of eight on-water skimming vessels with 20 support vessels, 19,000 feet of boom, and about 160 personnel from various Federal, state and local agencies and contact personnel were on scene.

Because of the difficulty of locating and assessing the magnitude of an oil spill from the surface, oil spill response professionals generally rely on visual observation from aircraft to determine the scope of the spill, to direct recovery assets, and to forecast subsequent oil movements. In this incident, the effective use of aircraft to assess the extent of the fuel oil spill was limited throughout most of the day by poor visibility due to fog. The first helicopter to get airborne was an MSRC-contracted flight that surveyed the scene between about 1336 and 1448. A second MSRC overflight using the same aircraft launched about 1506 and landed about 1547. The third overflight of the day (and the first by the Coast Guard) was a Coast Guard aircraft that took off about 1641.

During the two overflights chartered by MSRC, oil spill response specialists noted an oil sheen but no large pockets of oil forming anywhere on the bay, indicating that the oil had separated and spread. Based on these observations, MSRC and NRCES personnel used their local knowledge of the bay currents and tides to position their recovery assets.

Although most of the recovered oil was retrieved within 2 weeks of the incident, response efforts continued for several months. As of November 3, 2008, a total of 22,991.5 gallons, or almost 43 percent, of the total amount of oil spilled was recovered from the water and land.

[35] EDRC is the amount of oil that can be recovered in a 24-hour period based solely on the pumping capacity of the device. EDRC includes a de-rating factor to account for the fact that 80 percent of the liquid being pumped is water.

Shoreline remediation continued for some time after completion of the on-water recovery portion of the response.

Meteorological Information

Weather at the time of the accident was dense fog, with visibility forecast as 1/4 mile or less from Oakland out to the Golden Gate Bridge. The wind was calm. The temperature was about 52° F, and relative humidity was 98 percent. Barometric pressure was 30.10 inches. At the time of the accident, the current was flooding at 168° true at approximately 1.25 knots. High water at Yerba Buena Island was predicted for 0958 local time on the day of the allision. The high water measurement at that time was calculated to be 6.1 feet above mean tide level.

Damage

Cosco Busan

Damage to the *Cosco Busan* from its allision with the Bay Bridge was confined to the port side of the vessel, forward of the superstructure, above the waterline (figure 4) The Nos. 3 and 4 port fuel tanks were breached, as was the No. 2 port water ballast tank.

The *Cosco Busan*'s classification society, Germanischer Lloyd,[36] surveyed the vessel's damage on November 13, 2007. The forward-most point of the damage was about 237 feet aft of the ship's bow and extended along the port side of the vessel for about 212 feet. This damage area extended about 10 feet vertically up the hull side. The hull's shell plating[37] was torn open along the entire length of the damaged area. All the internal web frames in the damage area were deformed to some extent. Pipes, ladders, handrails, and gratings associated with all three of the damaged tanks were damaged or destroyed. Internal damage to the vessel did not extend past the inboard boundaries of the three breached tanks.

At the time of the allision, according to sounding tables from the day before the accident, the No. 3 port fuel tank was about 10 percent full. This placed the fuel level below the breach in the hull, and none of the fuel was released in the accident. Conversely, from the same day's soundings tables, the No. 4 port fuel tank was at 87 percent capacity, a level above that of the hull's postaccident portside damage.

The *Cosco Busan* remained in the San Francisco Bay area for 30 days after the allision while temporary repairs were made to the vessel hull. The repairs consisted of fitting a plate over the shell opening. According to a Fleet Management official, the cost of the temporary repairs

[36] Germanischer Lloyd is one of 10 major classification societies worldwide that establish and apply technical standards (rules) regarding the design, construction, and survey of marine-related facilities, including ships and offshore structures. A vessel that has been designed and built to the appropriate rules of a society may apply for a certificate of classification from that society. Such a certificate does not warrant that the vessel is safe or seaworthy, only that it is in compliance with the standards that have been developed and published by the society issuing the certificate.

[37] Shell plating is a ship's external steel skin or sheathing.

Figure 4. Damage to the forward port side of the *Cosco Busan* after the allision with the bridge tower.

totaled $1,239,792. After completion of the temporary repairs, the vessel transited to China for permanent repairs. The damaged tanks were not used to carry fuel on that voyage. The vessel's temporary repairs were made to the outside shell plating, not the actual inner bunker fuel tank boundaries. The final repairs were completed in 13 days and cost an additional $812,000. On January 11, 2008, the vessel was renamed *Hanjin Venezia*.

Bay Bridge

The Caltrans monitoring system on the Bay Bridge immediately detected the allision of the *Cosco Busan* with the bridge pier fendering system. Caltrans was quickly able to conclude that the event was an allision (not an earthquake) and to determine where the allision had occurred.

About 0900, the Caltrans chief of the Office of Structures Maintenance and Investigations (Toll Bridges) received a phone call from the Caltrans toll bridge maintenance operations manager asking that an engineer accompany the maintenance crew on a boat to the incident site. About 0910, a senior Caltrans bridge engineer, an area bridge maintenance engineer, and a state transportation engineer inspected the pier. They found that about 100 feet of the fendering and skirt at the southeast corner of the Delta pier had been damaged (see figures 5 and 6), but they found no damage to the pier itself or to any other part of the bridge structure.

Cost to repair the damage was $1.5 million. By 0950, Caltrans engineers had completed their inspection and found no damage that would compromise the structural integrity of the bridge.

Figure 5. Damaged fendering system at the base of the Bay Bridge Delta tower.

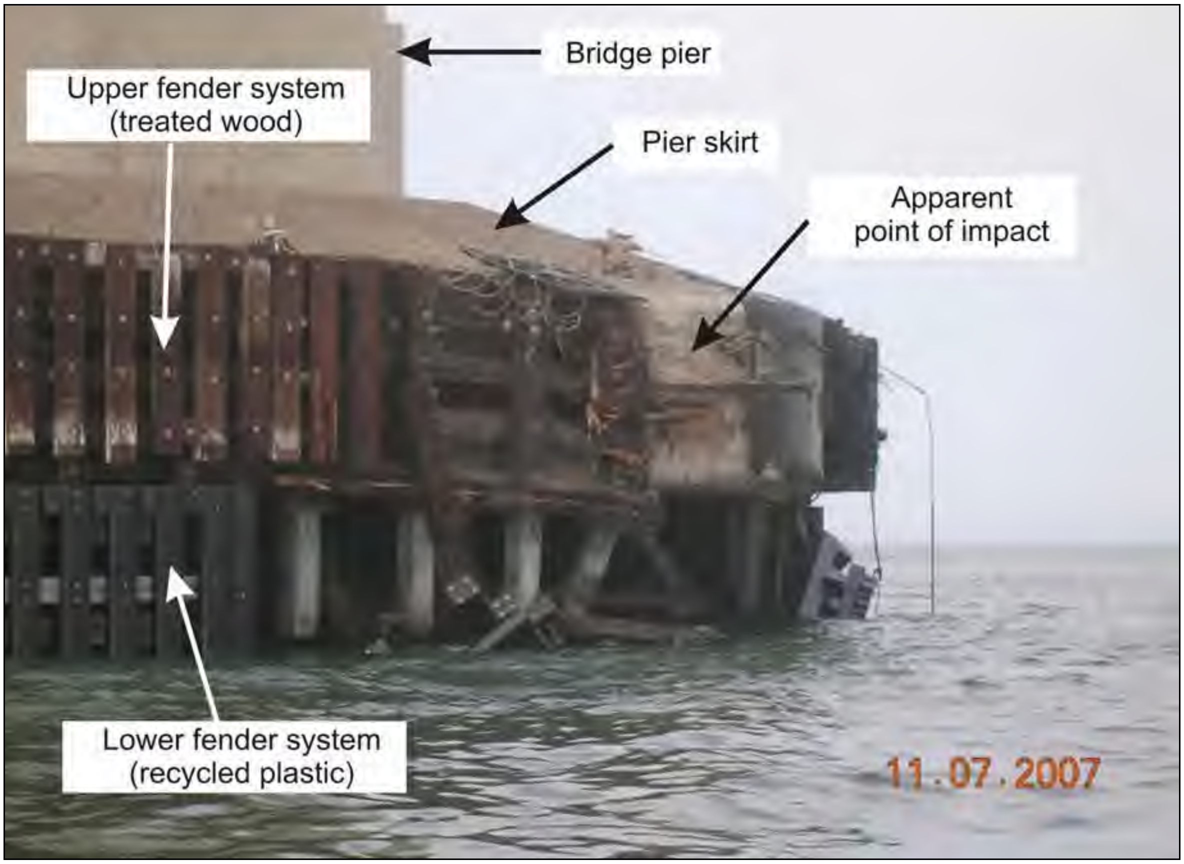

Figure 6. Close-up view of the fendering system at the base of the Delta tower showing the likely point of impact and a portion of the 100-foot-long damage area.

Environmental Impact

The oil spill resulting from the *Cosco Busan* allision affected environmentally sensitive sites in several jurisdictions in the San Francisco Bay area, including San Francisco, Marin, Contra Costa, Alameda and San Mateo Counties. A total of more than 26 miles of shoreline were affected by oil to varying degrees, with San Francisco, Marin and Alameda Counties receiving the bulk of the contamination. At one point, authorities closed 27 public beaches. Of the substrates affected, about 85 percent were rip-rap (piles of large rocks or chunks of concrete), seawall, and sand.

The spill resulted in a fishery closure of the bay and a delay to the start of the Dungeness crab season. The California Department of Fish and Game collected samples of representative fish and wildlife species to evaluate the impact of the contamination on the local fauna and lifted the fishery suspension on November 29, 2007.

As of November 2008, a total of 2,938 birds of over 50 species, including some threatened and endangered species, were collected live and dead from affected bodies of water and associated shoreline habitats. Of the 1,084 birds found alive, 418 were cleaned and released. More than 2,500 birds died as a result of the oil spill. A total of seven mammals died as a result of the pollution.

Vessel Information

Ownership

The *Cosco Busan* was built in 2001 by Hyundai Heavy Industries Company at Ulsan, South Korea. The vessel left the Hyundai shipyard under the ownership of Conti Cairo (M.I.) Shipping Ltd. of Buxtehude, Germany, and under technical management of another German entity, Niederelbe Shiffahrtsgesellschaft GmbH & Company. In December 2001, the vessel was placed under long-term charter to Hanjin Shipping Co. Ltd. of Seoul, South Korea. Hanjin Shipping Co. entered the vessel into its main pendulum service[38] as the *Hanjin Cairo* with Republic of the Marshall Islands registry. In this service, the vessel called on various ports of Europe, Asia, and along the West Coast of the United States, specifically the Ports of Long Beach and Oakland, California.

The *Hanjin Cairo* made its first call to the Port of Long Beach on February 25, 2002, and it continued operations in this pendulum trade route until March 14, 2003, making a total of 10 port calls in the Port of Long Beach and 9 port calls in the Port of Oakland. On March 18, 2003, the vessel's owners changed the vessel's registry to the flag of Germany, and the vessel did not call on U.S. ports for several years.

In November 2006, the vessel ownership renamed the vessel *Cosco Busan* and returned it to the established Europe, Asia, and west coast pendulum trade route. After a 3-year absence from U.S. ports, the *Cosco Busan* called upon the Port of Long Beach on December 29, 2006.

On October 24, 2007, the vessel was sold to Regal Stone Ltd. of Hong Kong and was reflagged to the national flag of Hong Kong. The *Cosco Busan*'s new owners contracted with Fleet Management to supply an all-Chinese crew and to manage the technical operation of the ship on the owner's behalf.

Throughout the changes in flag, ownership, and managing operator, the *Cosco Busan* remained under charter to Hanjin Shipping Company. From the time the vessel resumed trade in the United States on December 29, 2006, until the casualty on November 7, 2007, the vessel had made a total of 13 calls in the Port of Long Beach and was outbound from its 9th call in the Port of Oakland. In total, the vessel had made 17 previous calls in the Port of Oakland with no recorded casualties or mishaps.

Operations–Fleet Management Ltd.

General Services. As of the date of this report, Fleet Management is the fourth largest ship management company in the world[39] with its headquarters in Hong Kong. The company also has offices in Singapore, Mumbai, London, Cyprus, and Houston, with several branch offices primarily in India and the Philippines. According to Fleet Management's general

[38] Pendulum service is a term used in the international shipping trade to describe a rigidly structured trade route from one continent to another that involves regular service to certain ports.

[39] Lloyd's List, November 2008.

manager of operations, the company manages about 190 vessels. These include 60 bulk carriers, 36 container vessels, 28 chemical tankers, 28 refrigerated cargo tankers, 21 oil tankers, and other types of vessels.

Fleet Management Hiring of Crew. One of the general services provided by Fleet Management is technical management of vessels for vessel owners. This includes selecting and training licensed and qualified crew, implementing safety management systems (or SMS,[40] which is discussed later in this report) for vessel operations, and day-to-day operation and oversight of the vessels. According to Fleet Management's general manager of operations, at the time of the accident, about 71 percent of its overall crewmembers were Indian, 13 percent were Chinese, and 9 percent were Filipino. When crewmembers from different nationalities serve on board the same vessel, the working language is English. Because the crewmembers on the *Cosco Busan* were Chinese, the working language was Mandarin, with English being the language used when interacting with non-crewmembers.

The general manager of operations stated that to hire the crew for the *Cosco Busan*, Fleet Management had relied on a manning agency in China. Fleet Management then examined the crewmembers' records and licenses and verified their suitability for the vessel based on crewmembers' experience, ratings, and licenses. In their interviews with investigators, the second and third officers confirmed that they had been hired through the manning agency and that Fleet Management interviewed them by telephone in English before hiring them for the *Cosco Busan*. The master stated that he could not recall whether Fleet Management interviewed him.[41]

Fleet Management Training of Crew. The International Safety Management (ISM) Code[42] requires that a vessel's management:

> . . . establish procedures to ensure that new personnel and personnel transferred to new assignments related to safety and protection of the environment are given proper familiarization with their duties. Instructions which are essential to be provided prior to sailing should be identified, documented and given.

As specified by the company SMS on board the *Cosco Busan*, Fleet Management's procedures for fulfilling the ISM requirement established three stages in the training of new personnel. The first training to occur was called "Safety Familiarization," which required all new personnel joining the ship to become familiar with the lifesaving and firefighting appliances on board the vessel within 24 hours of joining the vessel or before sailing, whichever came first. Completion of this training was to be documented and captured on a company "QMS 11" checklist. Second, department heads were required to instruct their new personnel in "Shipboard Familiarization with Duties & Equipment." This instruction was to cover the specific shipboard

[40] An SMS is a structured and documented system designed to enable company personnel (in this case, Fleet Management personnel) to effectively implement the company's safety and environmental protection policy, as well as the International Safety Management Code.

[41] Fleet Management documents indicate that the master was interviewed by telephone on February 10, 2007.

[42] The ISM Code was enacted as "International Management Code for the Safe Operation of Ships and for Pollution Prevention," SOLAS, Chapter IX, in 1998 for passenger ships, high-speed craft, and oil and chemical carriers and in 2002 for cargo ships such as the *Cosco Busan*.

duties and responsibilities of the mariner's position, as well as give direction for the safe use and operation of all machinery and equipment the individual was likely to handle. Because of the scope and depth of this training, licensed officers were allowed 3 days to complete it; other crewmembers were allowed 2 days. In all cases, the training had to be completed before the individual could be assigned to an independent watch on board. Completion of this training was to be recorded on company checklist "QMS 13."

Once these two stages of training were completed, new personnel were allowed 2 weeks to complete a third, more in-depth training called "Officer's Familiarization" or "Ratings Familiarization." Through this training, the mariner was expected to become thoroughly familiar with all aspects of the vessel's safety and operational systems for his/her grade, which included reading all company manuals. Completion of this training was required to be documented on company checklist "QMS 12."

According to the company website,[43] technical superintendents from the company visited the vessels every 3 months to "to ensure a very close follow-up of shipboard activities." Fleet Management's general manager of operations told investigators that the company also relied on regular internal and external SMS audits to ensure that its crewmembers properly followed its operations procedures. The third officer, who had worked on a vessel operated by Fleet Management for 6 months before joining the *Cosco Busan*, told investigators that the company did carry out such oversight, whereas other companies he had worked for did not. He said that during those 6 months, Fleet Management sent several superintendents and one auditor to the vessel he worked on. He estimated that the longest period that a superintendent remained on board was 20 days, during which time the representative observed vessel operations. On the first 2 vessels he served on, which were not operated by Fleet Management, a company representative "basically came on board, [took] a quick look, and then left."

In addition, Fleet Management's website provided information on the crew training that the company stated it offered its customers:

> Fleet Management has trained and experienced staff who specialize in the preparation of in house training films.
>
> These ship specific and company specific films are shot onboard our vessels and edited at a studio in Mumbai, India. In addition to ship specific familiarization films which we prepare for each of our vessels, we also have training films covering critical and specialized operations such as:
>
> Chemical Tanker Operations
> Great Lakes Operations
> Log Loading
> Container Loading/Discharging
> Reefer Vessel Operations

[43] <http://www.fleetship.com/services/index.html> accessed on October 22, 2008.

Bunkering Operations
Work Permit System

Further titles are under production.

The company website also listed recent seminars that the company had conducted around the world addressing various topics concerning vessel operation, safety, and crew interactions. The company also conducted training and developed training films and videos at its training center in Mumbai, India.

The company stated that it had developed an internal training program for crewmembers of multinational crews. The program, using videos and role-playing, addressed what the general manager described as “power gradient.” As the general manager described it:

> This is a problem or this is an identified weakness that can happen with nationalities when they train internationally. That means that they will be overpowered by someone coming on board the ship who is more aggressive than them. This is also a problem which we like to address. We hold seminars and we do play acting [to address the topic].

Because the *Cosco Busan* crewmembers were of the same nationality and because they were new to the vessel, they had not yet been introduced to this program.

Training and Duties of the *Cosco Busan* Crew. Fleet Management’s general manager of operations told investigators that, about a month before the accident, on September 27, 2007, a company port captain and an observing chief engineer boarded the *Cosco Busan* in Busan to observe the operation of the vessel and its engineering system. This was done in advance of the vessel’s first trip (from Busan to Long Beach, then to San Francisco) for which Fleet Management would serve as the ship’s technical management company. The observing chief engineer became the vessel’s chief engineer once the new crew took over operation of the ship, and he was on board at the time of the accident.

According to Fleet Management’s policy, if the crewmembers were new to the company, as was the case with most of the crew of the *Cosco Busan*, Fleet Management would send a training officer on the crewmembers’ first voyage to train them on company procedures. Therefore, the company port captain (who had boarded the vessel on September 27) was assigned to accompany and train the crewmembers during the trip to California. A superintendent engineer also joined the *Cosco Busan* before departure to train the crew and to observe operations during the voyage from Busan to Long Beach, then to San Francisco. The general manager of operations indicated that the company port captain trained the crew in the vessel’s systems and the company SMS during the 2-week voyage and that he would have remained on board longer if he believed that additional training was necessary. Training was reportedly conducted through training videos and one-on-one instruction, after which the crew was checked for mastery of the material, in accordance with company policy.

On the day of the ownership transfer, October 24, 2007, the chief engineer and the crewmembers who had been recruited by Fleet Management reported for duty in the evening for the ocean transit to Long Beach. All of the crewmembers were new to the vessel and (except for the chief engineer, the third engineer, and the third officer) new to Fleet Management. Most of the crewmembers had traveled together from Beijing, China, to the dock in Busan. On arrival, they had about an hour and a half to converse with the vessel's off-going crew, and, after that, the new crew went to work. Documentation provided to the Safety Board by Fleet Management stated that the crewmembers then began training in Fleet Management's SMS and the ship's security plan. Under the supervision of the company port captain and the superintendent engineer, the crewmembers also began training in the operations and procedures specific to the vessel's vital systems and equipment. The initial training of the new crew occurred simultaneously with cargo operations and with a visit from three representatives of Germanischer Lloyd, the vessel's class society. The representatives audited both the vessel's SMS and security plan and also conducted a survey of the material condition of the ship to verify compliance with the International Convention for Safety of Life at Sea (SOLAS), 1974, and other international treaties. Just after midnight on October 24, 2007, the vessel was issued a provisional or interim certificate, valid for 6 months, indicating (1) that all components of the company SMS and supporting documents were on board in a language understood by the crew, (2) that the documents included key elements of the ISM Code, (3) that the master and ship's officers were familiar with the company SMS and the planned arrangement for its implementation on board, (4) that instructions identified as essential were on board and provided to the crew before sailing, and (5) that the company was planning to audit the ship within the next 3 months.

According to records in the required SMS checklists, the crewmembers began their training on October 24, 2007, the date of their arrival on board. The SMS checklists QMS 11 and QMS 13 initially provided to the Safety Board indicated that each crewmember completed the mandated "Safety Familiarization" and "Shipboard Familiarization with Duties & Equipment" training on October 25, 2007, before the vessel departed Busan. Checklist QMS 12 that was provided to the Safety Board for each crewmember indicated that the "Officer's Familiarization" or "Ratings Familiarization" training was completed on November 4, 2007. However, the chief officer later testified to Federal law enforcement officials that he did not receive any training before the vessel got under way in Busan. His training on the vessel's electronic chart system, radar, master's standing orders, bridge procedures, SMS, and so on, took place during the transit to California. The boatswain testified to Federal law enforcement officials that he recalled watching a 3-hour video about crew and fire safety at the manning agency before leaving Beijing. The other interviewed crewmembers generally concurred that, with the exception of several SOLAS-required emergency drills, the crew did not receive training in under way responsibilities until the vessel had departed Busan.

Fleet Management's general manager told investigators that the company intended to conduct additional training and check-up of the crew following the initial training that was conducted on the Busan–California voyage. The general manager noted:

> We continue to train and then maybe after 45 days, we will do an internal audit to check that the system has been implemented correctly, and then we'll call in for an external auditor to come and do a full audit. So by the end of three months, we have a certificate and we are confident that the whole system is in place. In this case, [the company port captain] was doing the indoctrination of the crew [on the trip from Busan to California].

On October 25, 2007, about 0845 local time, the *Cosco Busan* departed Busan for the Port of Long Beach under the control of a new master and crew. The crew consisted of 4 deck officers, 5 engine officers, 14 crewmen, and 1 cadet. The company port captain and the superintendent engineer remained on board to continue the safety drills and training of the new crew. The chief engineer also remained on board. The vessel arrived at the Port of Long Beach on November 3, 2007. The vessel conducted cargo operations at Long Beach for the next 2 days before departing for the Port of Oakland. The *Cosco Busan* arrived at berth 56 on November 6, 2007, and began cargo operations shortly after 1900. About 0600 on the day of the allision, the longshoremen had loaded the final containers on the vessel. Shortly thereafter, about 0630, the company port captain and the superintendent engineer disembarked the vessel.

In their interviews with Safety Board investigators, the master and the second and third officers stated that during the 2-week voyage from Busan to Long Beach, training was conducted concurrently with vessel operations. During this period, the company port captain also conducted regular drills in various required aspects of vessel safety, including firefighting and lifesaving. All three crewmembers described some difficulty with training because the entire crew was new to the vessel. As a result, they had only the company port captain, the superintendent engineer, and the chief engineer to turn to with questions about the ship. In addition, the need to learn company procedures, practice necessary drills, and locate or assemble vessel documentation allowed little time to focus on training exclusively. The third officer noted:

> Yes, on board the Cosco Busan, at that time, the whole crew was changed over and there were a lot of new things to learn all over again and what we did was we worked while we learned and then we tried to create – and then, of course, when we first came on board, the ship had just changed ownership, so there were a lot of other manuals that belonged to the former ownership and the manual or document was not complete as a set, but they change little by little."

According to the master and the second and third officers, they did not receive training in company or vessel operations and procedures before boarding the *Cosco Busan*. The third officer did recall watching a DVD about onboard vessel safety before leaving Beijing, where the crew had been based. Both the second and third officers indicated that they did not receive instruction in the SMS but that they read the SMS manual pertaining to their respective duties and responsibilities when they had time during the 2-week voyage. All three men confirmed that the company port captain trained the deck officers in using the vessel's navigation equipment. The master confirmed that the company port captain had personally trained him in the vessel SMS and that, through this training, the master believed, "certainly we had to comply with the SMS." (For more information about the vessel's SMS, see section "*Cosco Busan* Safety Management System and Navigation Safety.")

Vessel Description

The *Cosco Busan* was one of four containerships of the same design and the same capacity (5,500 TEU)[44] built at the Hyundai shipyard between 2001 and 2002. The vessel was 900.9 feet long, 131.2 feet wide, and 79.3 feet deep. It had a maximum draft of 46 feet 6 inches.

[44] Container capacity is often expressed in twenty-foot-equivalent units, or TEU. The 20-foot container is a common container worldwide and is 20 feet long and 8 feet wide. The height varies depending on container type.

The vessel was propelled by one main engine, a MAN B&W model 10K98MC-C manufactured by Hyundai. This was a 10-cylinder, 2-cycle, direct-reversible, crosshead turbocharged diesel engine driving a single propeller. It produced a maximum 77,600 horsepower and was capable of propelling the ship to an approximate top speed of 25 knots. The vessel also had a 2,700-horsepower tunnel bow thruster located about 75 feet aft of the bow to assist the vessel during slow-speed maneuvering and docking.

The forward 600 feet of the ship was used for cargo containers, which were carried below deck as well as stacked on the main deck. Just aft of this forward deck was the superstructure. In addition to housing the bridge on the upper deck and the lifeboats on its exterior, the superstructure also contained the crew's berthing and recreational areas, galley, office areas, and the vessel's fuel and ballast control room. The vessel's engineering spaces, which housed the main and auxiliary engines, power generation equipment, and all associated engineering systems, occupied the four decks below the main deck under the superstructure.

Aft of the superstructure and engineering spaces, the vessel extended for another 240 feet to the stern. This part of the ship accommodated additional cargo containers. Also located in this area were steering gear and line-handling winches and equipment.

Fuel and Fuel Storage

The *Cosco Busan* carried and burned two types of fuel oil for its main engine: marine diesel oil (MDO) and heavy fuel oil, designated IFO-380 (IFO). MDO is the less viscous and cleaner-burning of the two fuels. The MDO fuel oil was used during the vessel's transits into and out of ports because of its lower emissions, whereas the IFO was consumed while the vessel was at sea because of its higher heat content and lower cost.

The *Cosco Busan* had an aggregate fuel capacity of 7,833.6 metric tons (~2,069,400 gallons) of IFO and 405.1 metric tons (~107,000 gallons) of MDO. According to tank sounding sheets obtained from the vessel, the last soundings of the IFO tanks before the allision were taken at 0900 on November 6, 2007. Those soundings indicated that the *Cosco Busan* had a total of 4,098.9 metric tons (1,082,806 gallons) of IFO-380 on board.

The IFO was stored in eight large storage tanks, four along each side of the vessel. The tanks were designated No. 3 port and No. 3 starboard, No. 4 port and No. 4 starboard, No. 5 port and No. 5 starboard, and No. 6 port and No. 6 starboard.[45] The forward-most IFO tanks, Nos. 3 port and starboard, were 290 feet from the bow. Nos. 4 and 5 tanks were aft of the No. 3 tanks along each side of the hull, ending just forward of the superstructure. Collectively, these 6 tanks ran a distance of 281 feet along each side of the hull. The forward ends of the Nos. 6 port and starboard tanks were 62 feet aft of the superstructure and ran along the hull for about 47 feet, ending about 140 feet from the stern. All of the IFO storage tanks contained steam heating coils to reduce the oil's viscosity in colder weather. Analog gauges reflected the quantity of fuel oil in each tank. Each tank also had a sounding tube to manually measure the tanks liquid level.

[45] Tanks No. 2 port and starboard, which were forward of tanks No. 3, were water ballast tanks. The vessel had no side shell tanks designated No. 1.

Navigation Equipment and Charts

The *Cosco Busan* was equipped with a Sperry Marine Vision 2100 voyage management system (VMS). This was a three-node (navigation station, planning station, and conning station) integrated bridge management system in which the vessel's major navigation components communicated with one another to allow crewmembers to view, on one display, navigation data gathered from a variety of sources. The VMS recorded information every 30 seconds and retained a record of these data going back 30 days, including the track of the ship, the electronic charts in use, and any radar or AIS targets identified during the voyage. Using these records, accident investigators were able to recreate the images being displayed at 30-second intervals at the VMS workstations.[46]

The primary components of the VMS were two radars, an electronic chart system, and a conning information display (figure 7), as described below, as well as an AIS.[47]

Radars. The *Cosco Busan* had two BridgeMaster E ARPA radars manufactured by Sperry Marine. One radar operated on the X band (3-centimeter wavelength); the other on the S band (10-centimeter wavelength).[48] The ship had a display screen for each radar, but information from either antenna could be shown on either or both displays. The radar displays could also be superimposed onto the electronic chart along with any vessel identification, speed, and track information acquired by the AIS. Also, if the vessel's voyage plan had been entered into the VMS, this proposed vessel track could be superimposed onto the radar screen. The VDR captured and stored radar images from the 3-centimeter radar at 15-second intervals.

On July 17, 2007, while the vessel was in port at Long Beach, Sperry Marine technicians replaced a magnetron in the 10-centimeter radar. While performing this work, the technicians determined that a new radar receiver was also needed. A new receiver was installed on July 17, 2007. The equipment was determined to be working normally after these replacements. On November 5, 2007, while the vessel was again in port at Long Beach, a Sperry Marine service engineer replaced the magnetron and the modulator in the 3-centimeter radar. Afterward, the radar was tested and was determined to be operating properly.

[46] Safety Board investigators reviewed the recorded data using Sperry Marine's proprietary replay software and, using a hardware device installed in the video data stream, captured screen images during the replay. Because the VMS data at the time of the accident was recorded only every 30 seconds, some adjacent images captured during replay did not indicate movement of the ship's position on the recreated electronic chart presentation.

[47] The VMS also included an automatic navigation and track-keeping system (ANTS) module. According to Sperry Marine product information, the ANTS determines the ship's present position, monitors the advance against the planned track, and determines the heading and speed orders needed to keep the ship on the prescribed track. The ANTS interfaces directly with the autopilot and speed control systems. According to Sperry Marine, the integration of the ANTS with the VMS had been disabled on the *Cosco Busan* some time before the accident.

[48] A 3-centimeter radar detects smaller targets in more detail at smaller range scales; a 10-centimeter radar is preferred for detecting targets at longer ranges. A 10-centimeter radar is less susceptible than the 3-centimeter radar to image degradation due to precipitation. Both radars are required on ships of the same class as the *Cosco Busan*.

Figure 7. The bridge of the *Cosco Busan* showing primary navigation displays.

Electronic Chart System (ECS). The Vision 2100 VMS system included an electronic chart system (ECS). The ECS had 3 components: hardware, operating software, and chart database. Although the system was capable of performing as an electronic chart display and information system (ECDIS), it was an ECS rather than a certified ECDIS because of the way it was configured and the type of electronic charts that were being used on board the *Cosco Busan*. As an ECS, the system was permitted to be used as a navigation aid only; paper charts were required for primary navigation.

The *Cosco Busan*'s ECS used C-Map CM-93 charts (figure 8). Such charts are in widespread use, but the versions of the charts that were on board the *Cosco Busan* were not ECDIS-certified. Because CM-93 charts are vector charts,[49] the ship's crew had significant control over the amount and type of information displayed. For example, crewmembers could choose to display chart symbols in either traditional or simplified format or could choose different colors for different water depths. Also, using a query function, crewmembers could perform a "spatial query"[50] to obtain any available information contained within the database about specific objects, such as an aid to navigation, displayed on the screen. A number of

[49] Vector charts are digital images generated from a computer database. Raster charts are scanned images and are simply electronic versions of paper charts.

[50] The spatial query could be executed by using the system's pointing device to first select the query button on the main menu, then selecting an object on the chart.

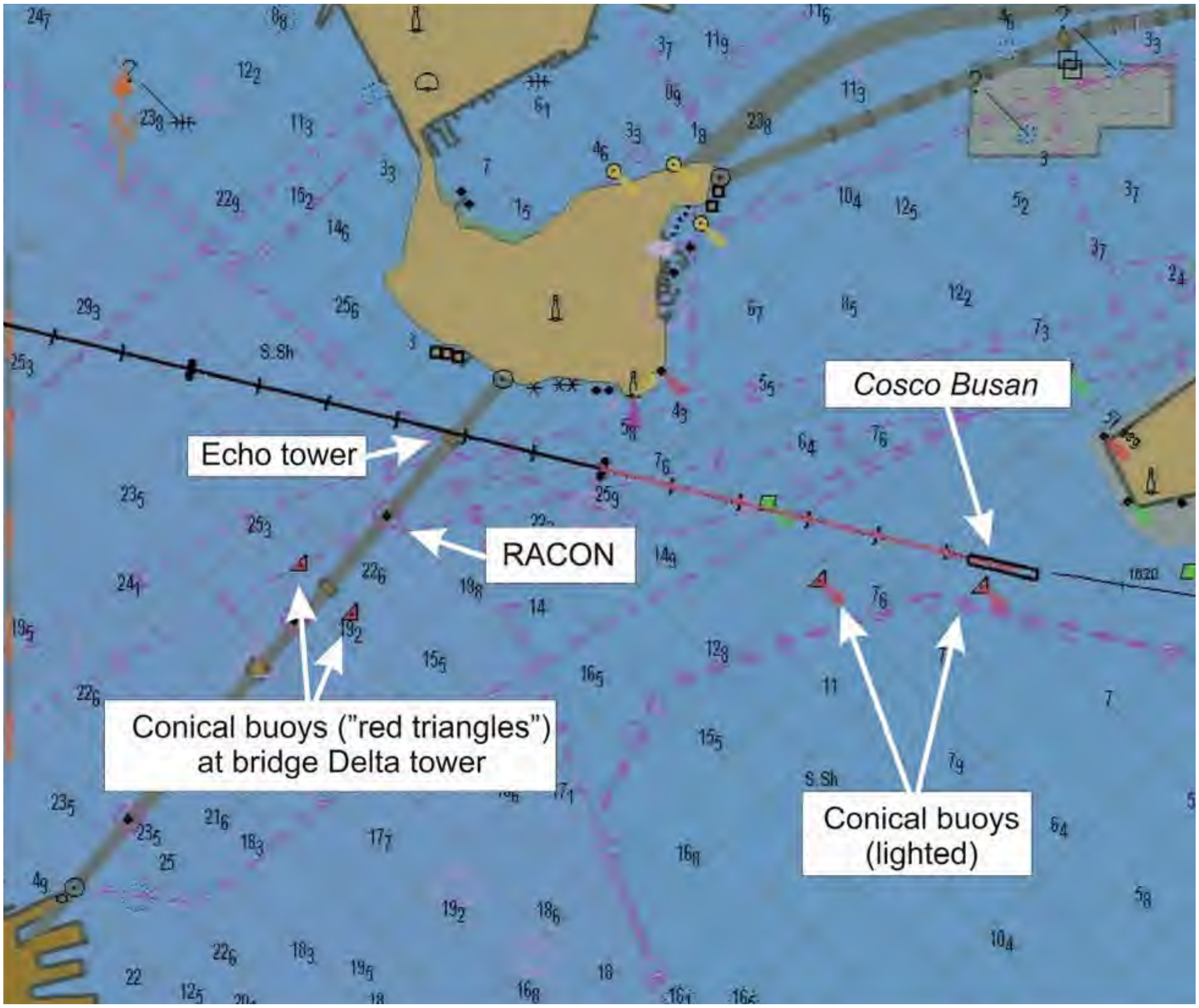

Figure 8. The Bay Bridge as displayed on the electronic chart on board the *Cosco Busan*. The chart display is from 0821:51, the approximate time the pilot questioned the ship's master about the meaning of the red triangles at the bridge.

primary and secondary sensors provided a real-time plot of the ship's movement on the electronic chart with time markers at 5-minute intervals (figure 9).

Automatic Identification System. The ship was fitted with an AIS as required by international regulations. The AIS comprises a transmitter (which acts like a transponder operating in the VHF maritime band) and two receivers. At 2- to 12-second intervals on a moving vessel, the AIS broadcasts the vessel's identification number, rate of turn, speed over ground, position, course over ground, heading, and a date/time stamp. For vessels at anchor, this same information is transmitted at 3-minute intervals. Every 6 minutes, the system broadcasts the vessel's International Maritime Organization (IMO) number, radio call sign, name, ship type, ship dimensions, type of position-fixing device used, draft, destination, and estimated time of arrival at the destination. The AIS signal may be received and displayed on board other AIS-equipped ships or ashore at VTS centers.

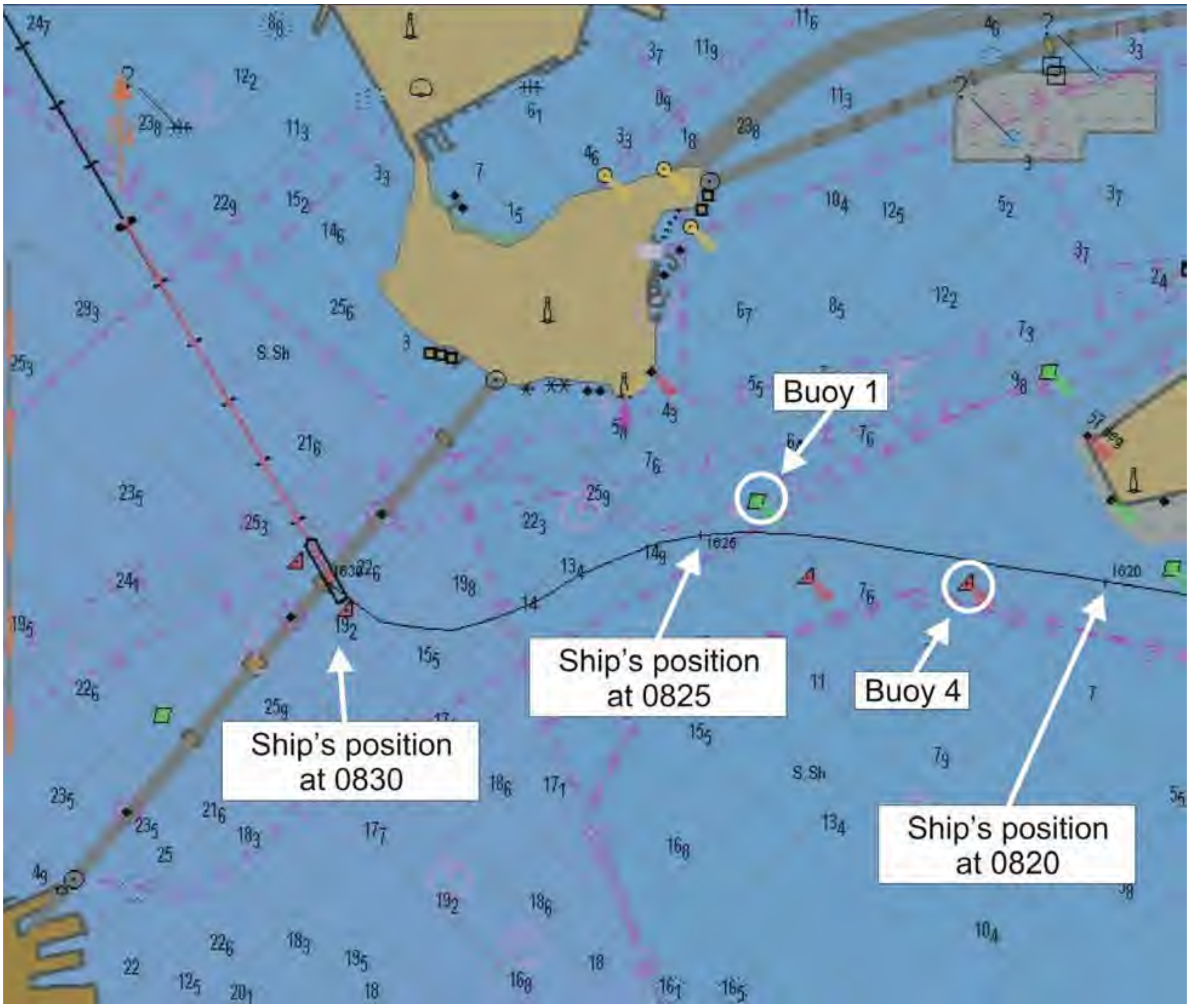

Figure 9. Electronic chart from the *Cosco Busan* showing the vessel's track from the entrance channel to the bridge during the accident voyage. The ship's position was marked on the chart at 5-minute intervals.

Paper Chart. The paper chart on the chart table on the morning of the allision was British Admiralty chart No. 588, Edition 5, dated November 29, 2001 (corrected through Notice to Mariners No. 38/07). A crewmember had drawn a single course line on the chart indicating the planned route through the Delta–Echo span of the Bay Bridge to and from berth 56 (figure 10).

PSP_007028

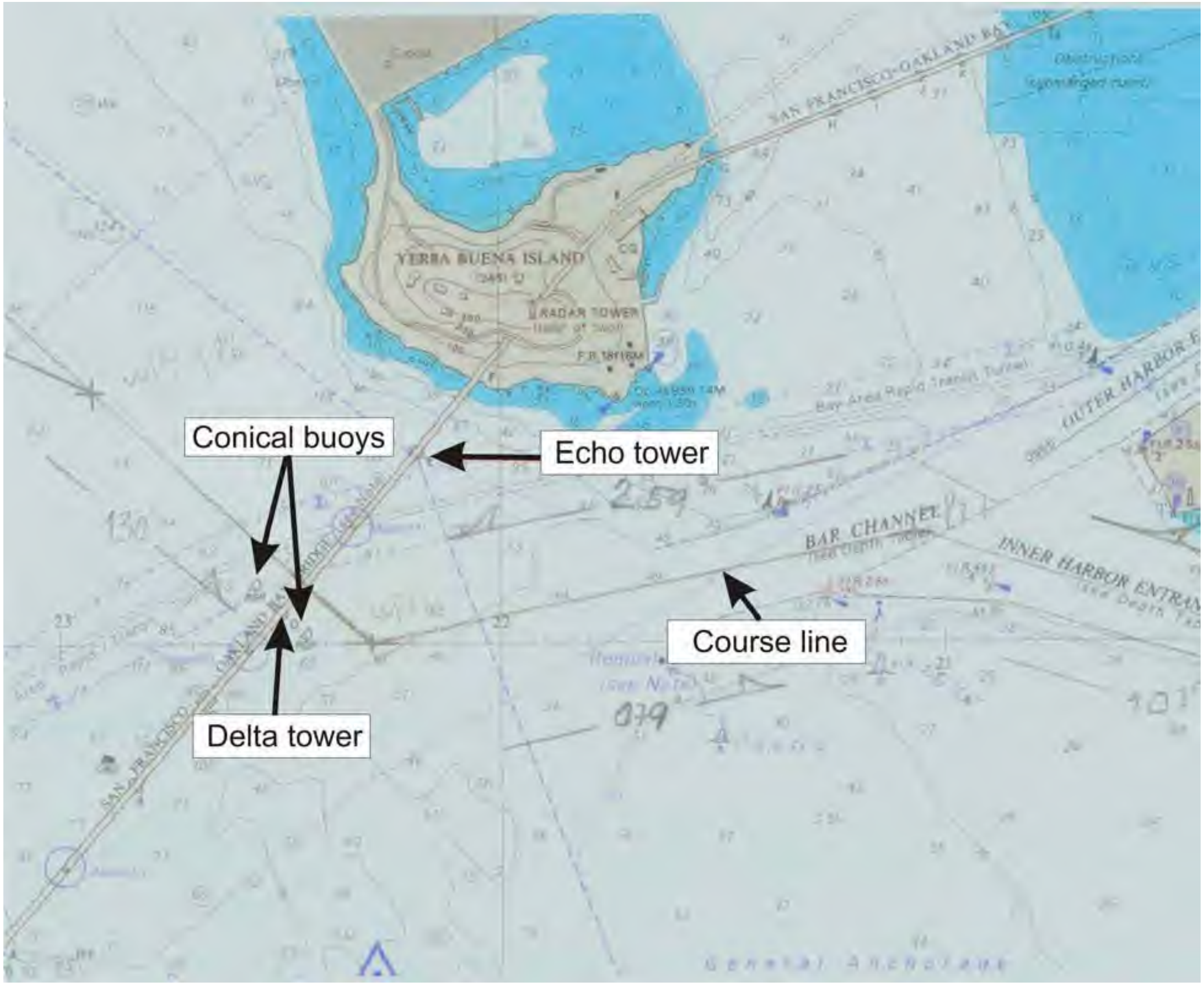

Figure 10. A portion of the paper chart that was on the chart table on the bridge of the *Cosco Busan* at the time of the allision. The course line, with in- and outbound headings, had been plotted and added to the chart by the ship's crew.

Waterway Information

The *Cosco Busan* departed from berth 56 at the Oakland Marine Terminal. As of the date of this report, the Inner Harbor Entrance Channel has a controlling depth of about 40 feet, on average, measured at mean lower low water (MLLW).[51] For a length of about 1 nautical mile, from the terminal to the end of the entrance channel, the channel is about 275 yards, or 0.14 nautical mile, wide. The navigable channel in the center of the entrance channel is about 180 yards wide. The approximate course out of the channel is 286° true and then a course to the left of 286° (as per pilot instruction through the Bar Channel) to line up for a course to pass under the span of the Bay Bridge between the Delta and Echo towers. The span of navigable water between the Delta and Echo towers is about 2,200 feet. The fendering system of the Delta

[51] MLLW is the average height of the lower low waters over a 19-year period.

tower is about 50 feet wide. On either side of the Delta tower are red-over-green conical ("nun") buoys marking the preferred channel.[52] A RACON at the center of the Delta–Echo span displays the Morse code symbol "Y" (dash–dot–dash–dash) on the radar screen of a vessel whose radar has interrogated it. Review of radar images from the *Cosco Busan* (as discussed in the "Review of Radar Images" section of this report) showed that the RACON was functioning on the day of the allision.

According to *U.S. Coast Pilot No. 7,* 2008, vessels transiting the area of the Bay Bridge inbound on a southerly course should proceed through the northeast side of the Alpha–Bravo span. Outbound vessels or those on a northerly course should proceed through the southwest side of the Delta–Echo span. The course that had been drawn on the paper chart was appropriate for an outbound voyage as recommended in *U.S. Coast Pilot.*

Bay Bridge Information

General

The Bay Bridge, which carries Interstate 80 (I-80) across San Francisco Bay, is owned, operated, and maintained by Caltrans. The bridge consists of two major spans connecting each shore with Yerba Buena Island, a natural island located mid-bay (figure 11). The western crossing, from San Francisco to the island, consists of two suspension bridges end-to-end with an anchorage, plus three shorter truss spans connecting the San Francisco landing to the western cable anchorage on Rincon Hill. The western bridge span at the site of the allision is double-decked, with westbound traffic using the upper deck and eastbound traffic the lower. At the time of the accident, average daily traffic across the bridge was more than 280,000 vehicles. Caltrans continuous traffic data sensors on the bridge showed that about 1,100 to 1,300 vehicles were on the west span at the time of the allision. The impact occurred at the bridge tower designated by Caltrans as pier W-5 (because it was the fifth pier west of the San Francisco end of the bridge) and designated on Coast Guard and other maritime charts as pier Delta. According to Caltrans records, the bridge was opened to traffic on November 12, 1936.

Bridge Tower Fendering System

The Bay Bridge carries a portion of I-80, making the bridge a part of the Interstate Highway System and placing it under the purview of the Federal Highway Administration (FHWA). Although the FHWA has oversight of this and similar bridges, the specifications and rules by which highway bridges are designed are distributed by the American Association of State and Highway Transportation Officials (AASHTO).

At the time the Bay Bridge was designed and constructed, the applicable design guide was the American Association of State Highway Officials (AASHO[53]) *Standard Specifications for Highway Bridges and Incidental Structure, July 1, 1927*. A review of that document revealed

[52] The red topmark color of the buoys on both sides of the Bay Bridge Delta tower indicates that the preferred channel for both inbound and outbound vessel traffic is the Delta–Echo span.

[53] AASHO became AASHTO in 1973.

that it contained no guidance with regard to protecting the bridge structure against allisions. The only mention in the document of potential impacts with the highway bridge structures referenced floating debris and ice. However, a bridge tower fendering system was installed as part of the original Bay Bridge construction. The bridge final design report described the fendering system as follows:

> [A] robust system consisting of a concrete skirt and timber walers and sheathing. Since the size of the pier precludes any possibility of damage to it by a colliding ship, the fenders were designed so as to inflict a minimum of damage on the ship. The timber work on the outside would ward off any ordinary blow. Should the ship crash through this and strike the concrete with enough force to puncture the hull, the hole would be above the water line and there would be less danger of it sinking.

Figure 11. The western crossing of the San Francisco–Oakland Bay Bridge looking east.

According to Caltrans, the Bay Bridge fendering system has changed little over the past 70 years except for the periodic replacement of timbers and changes in the nature of the “sacrificial” materials used in the fenders. At the time of the allision, the fendering system of the Delta tower consisted of Portland cement concrete, wood timbers, recycled plastic, and other frangible materials intended to adsorb energy. The most recent work on the system involved replacing the wood timbers with recycled plastic lumber. The upper fendering system of the Delta tower consisted of five layers of timbers, but the wood timbers of the lower system had been replaced with recycled plastic in 2006. Caltrans provided the Safety Board with diagrams of the fender structures but, because of security concerns, was unable to share detailed information about the structural integrity of either the fendering system or the piers. The actual bridge design plans and specifications, and their revisions, are classified “confidential” by Caltrans and the U.S. Department of Homeland Security.

While stating that the fendering system has changed little, Caltrans officials also said that the actual bridge piers, along with the rest of the structure, have undergone an extensive seismic retrofit over the past decade. The officials stated that when Caltrans engineers mathematically modeled the western span of the Bay Bridge during the seismic retrofit, they used peak spectral accelerations as high as 1.4 g and analyzed pier displacements in the 18- to 24-inch range. The officials stated that the bridge is now considered capable of withstanding an 8.0-magnitude earthquake with minimal damage.

After the loss of several Caltrans bridges in the 1989 Loma Prieta and 1994 Northridge earthquakes, Caltrans equipped the Bay Bridge (and others in the state of California) with seismometers and other instrumentation to detect and measure bridge movement. According to Caltrans, this instrumentation on the Bay Bridge detected the allision of the *Cosco Busan* with the bridge pier. The sensors indicated that the impact lasted for about 16 seconds and moved the bottom of the pier 0.117 centimeter, or about 0.046 inch (just under 3/64 inch). The top of the steel tower moved 0.17 centimeter, or 0.066 inch. Sensors recorded that the allision resulted in a maximum lateral acceleration of 0.018 g at the tower leg base and 0.058 g at the top of the tower.

Caltrans officials characterized this amount of movement as insignificant and equal to the movement that the tower might regularly experience on a windy day. They determined these movements to be too small to warrant closing the bridge. Caltrans structure maintenance and investigations engineers performed a postaccident visual inspection of the bridge pier and determined that the damage was confined to the fendering system.

Caltrans officials stated that even though the postaccident visual inspection of the fendering system confirmed that it had performed as intended, the agency is reevaluating the fendering system and will be considering new fender designs that might better protect the bridge and its elements. The officials stated that the agency is in contact with the Coast Guard, the U.S. Navy, the FHWA, and several other states’ departments of transportation regarding their practices and the status of any ongoing fender system research. The current applicable design guide is the 1991 *AASHTO Guide Specification and Commentary for Vessel Collision Design of Highway Bridges*. This document was intended to correct problems in bridge design that were identified in the 1980 collapse of the Sunshine Skyway Bridge in St. Petersburg, Florida. Caltrans officials stated that Caltrans engineers had analyzed the Bay Bridge fenders and piers and had determined that the design of the fendering system at the Delta tower was consistent with the design specified in the AASHTO guide.

Accident History

Repair records by Caltrans documented seven occasions when vessel strikes necessitated repairs to the fendering system of one of the Bay Bridge piers. In each case, the damage was only to the wood sheathing, with repair costs ranging from $10,000 to $50,000. Two of these strikes involved the Delta tower. The first strike to the tower involved the *USS Gardiners Bay*, a 2592-ton Barnegat class small seaplane tender that allided with the tower on February 14, 1957. The second strike, which was the last strike before the *Cosco Busan* allision, involved the vessel

Brilliant Star in February 1980 and resulted in damage to the fender's wood sheathing. No information was found on the size of that vessel or the circumstances of that incident nor the one involving the *USS Gardiners Bay*. Other strikes to other bridge piers included a tugboat, a barge, and other vessels that were not identified.

Risk Assessment

Caltrans officials told the Safety Board that, until the 1990s, the agency based its vessel collision risk management of the Bay Bridge on the large navigational channel (2,200 feet) between the Delta and Echo towers and on the preventive measures in place, including navigation lights, radar guidance provided by the RACON in the centerline of the channel, the presence of the Coast Guard VTS, and the required use of qualified harbor pilots.

Since about 1991, Caltrans has used Method II from the 1991 AASHTO *Guide Specification and Commentary for Vessel Collision Design*, which, according to Caltrans, is a more complicated probability-based procedure for analyzing and evaluating possible vessel collisions. Method II categorizes the collision risk for bridges as either "critical" or "regular" and assigns a probability for a collision within a given time frame. Among other factors, the method considers the width of the waterway and the number of pier and span elements within the waterway, or within a certain distance on each side of the inbound and outbound vessel transit paths. This results in an acceptable risk criterion for each pier and span element of the total bridge.

Personnel Information

San Francisco Bar Pilot

Experience and Training. At the time of the allision, the *Cosco Busan* pilot, age 59, had been a pilot for 26 years. After graduating from high school, he joined a maritime union and first went to sea in 1966. He made various trips on the West Coast and then enrolled in the California Maritime Academy in 1967. After graduating in 1972, he worked overseas until 1977, when he returned and started working on harbor and oceangoing tugs with the goal of becoming a pilot. He became a member of the San Francisco Bar Pilots Association on February 1, 1981. He told investigators he had made "thousands" of trips under the Bay Bridge. He said it was not uncommon to operate in fog and that outbound voyages were more likely than inbound to proceed in limited visibility.

The pilot told investigators that he had received training in simulators every 3 years and in manned model ship-handling every 5 years. Records showed that the pilot had most recently completed simulator training, a 7-day course required[54] every 3 years, at the Maritime Institute of Technology & Graduate Studies near Baltimore, Maryland, in June 2005. He had previously received this training from Marine Safety International and California Maritime Academy. The

[54] Training requirements for bar pilots were established by the Board of Pilot Commissioners for the Bays of San Francisco, San Pablo, and Suisun, as discussed elsewhere in this report.

pilot last attended ship handling training (required every 5 years) at Port Revel, France, in August 2003. He attended ship-handling training in Poland in August 1993 and July 1998.

Work-Rest Schedule. The Safety Board interviewed the pilot, examined his work schedule in the days before the accident, and reviewed the record of his use of a continuous positive airway pressure (CPAP) machine for the treatment of sleep apnea[55] to roughly determine when the pilot went to sleep and awoke in the days before the accident.

San Francisco Bar Pilots Association pilots employ a schedule of 1 week on and 1 week off. During their week on duty, pilots can work at any time of day or night, regardless of other times they worked while on call. On October 31, 2007, the accident pilot reported to a vessel at 2100 and went off duty at 0300. He was off the next day, November 1. On November 2, he reported for duty at 0300 and went off duty at 1000; on November 3, he reported at 1600 and went off duty at 2130. He was off November 4. On November 5, 6, and 7 (the day of the accident), the pilot reported for duty at 0330 (off at 1315), 0630 (off at 1030), and 0500 (off at 1000), respectively.

Data from the record of the pilot's CPAP device indicated that on November 4, which was 3 nights before the accident, he used the CPAP for 4 hours 6 minutes. On November 5, he used the CPAP for 6 hours 13 minutes, and, on the night before the accident, he used it for 6 hours 10 minutes. The pilot estimated that he received about 7 hours of sleep the night before the accident.

Medical History. Review of the pilot's pharmacy and insurance records revealed that the pilot had received regular prescriptions of multiple psychoactive medications (medications that can alter mood, anxiety, behavior, and cognitive processes), including multiple narcotics since at least 1997 and multiple benzodiazepines and antidepressants since at least 1999. Most of these were prescribed by the pilot's main primary care physician. In his postaccident interview with Safety Board investigators, the pilot said that he used a CPAP machine because of sleep apnea and that he was taking two drugs: Synthroid (levothyroxine) to treat a thyroid condition and Provigil (modafinil) to help him stay awake and combat the fatigue effects of sleep apnea.

In the 60 days preceding the accident, the pilot filled prescriptions as follows: 180 lorazepam[56] 1 mg tablets, 120 diazepam[57] 5 mg tablets, 50 prochlorperazine[58] 10 mg tablets, 190 propoxyphene[59] 65 mg tablets, 200 hydrocodone[60]/acetaminophen[61] 10/325 mg tablets,

[55] Obstructive sleep apnea is a medical condition in which an individual's airway becomes obstructed, causing the individual to stop breathing and partially awaken many times while sleeping. The condition is associated with fatigue, significant cognitive and psychomotor deficits, and an increased risk of accidents. These adverse effects can be partially reversed with the use of a CPAP, which is a device worn while sleeping that delivers continuous air pressure to keep the airway open and promote uninterrupted sleep.

[56] A prescription antianxiety medication in the drug class of benzodiazepines that is often known by the trade name Ativan.

[57] A prescription antianxiety medication in the drug class of benzodiazepines that is often known by the trade name Valium.

[58] A prescription medication often known by the (now discontinued) trade name Compazine primarily used for the control of nausea and vomiting.

[59] A prescription opiate painkiller often known by the trade name Darvon.

50 pentazocine[62]/naloxone[63] tablets, 100 diphenoxylate[64]/atropine[65] 2.5/0.025 mg tablets, 27 sumatriptan[66] 50 mg tablets, 90 modafinil[67] 200 mg tablets, and 90 sertraline[68] 50 mg tablets (figure 12).

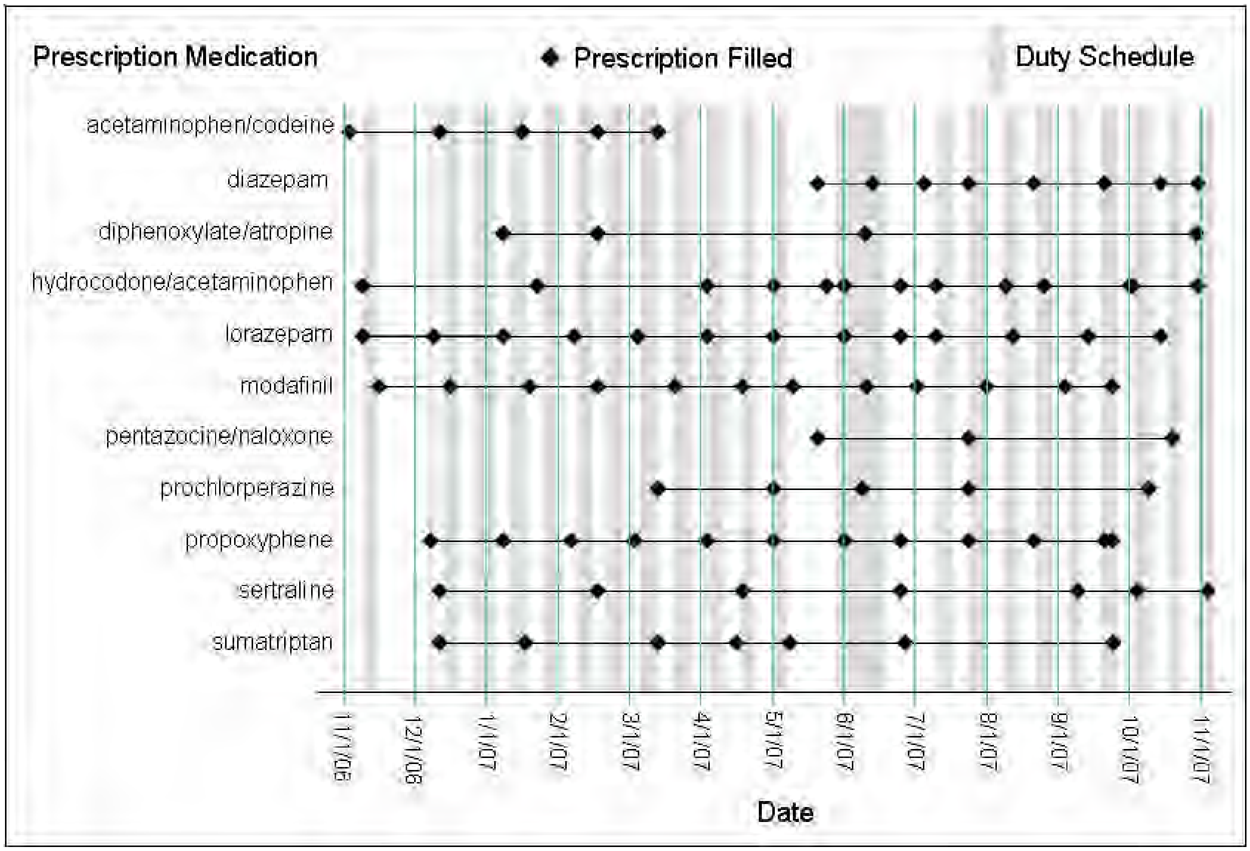

Figure 12. Graphical display of the *Cosco Busan* pilot's prescription history and duty schedule for the year preceding the allision. Each diamond denotes the filling of a prescription for the medication indicated.

60 A prescription opiate painkiller used for the control of moderate to moderately severe pain and often known by the trade names Vicodin, Lortab, or Norco when combined with acetaminophen.

61 An over-the-counter painkiller often known by the trade name Tylenol.

62 A short-acting prescription opiate painkiller used for the relief of moderate-to-severe pain and often known by the trade name Talwin when combined with naloxone.

63 A prescription medication that blocks the effects of opiates when injected intravenously. It is included in the tablet formulation of pentazocine to prevent pentazocine misuse and abuse.

64 A prescription opiate medication often known by the trade name Lomotil when combined with atropine.

65 A prescription medication that is added to diphenoxylate in small quantities to discourage deliberate abuse or overdosage.

66 A prescription antimigraine medication often known by the trade name Imitrex.

67 A prescription wakefulness-promoting medication also known by the trade name Provigil and indicated for the treatment of narcolepsy and of fatigue associated with obstructive sleep apnea and circadian disruption.

68 A prescription antidepressant often known by the trade name Zoloft.

In that 60-day period, and for at least several months preceding it, all prescriptions except for one had been filled by the same pharmacy. On October 2, 2007, about 1 month before the accident, a supermarket pharmacy filled a prescription for the pilot from a dental surgeon for 24 hydrocodone/acetaminophen 5/500 mg tablets. The following day, the pilot's usual pharmacy filled a prescription from a primary care provider for 100 hydrocodone/acetaminophen 10/325 mg tablets.

Review of the pilot's personal medical records for the 10 years preceding the accident revealed that the pilot's main primary care physician had made a total of 10 (handwritten) entries in the pilot's medical records between September 1998 and the date of the accident. These entries did not clearly indicate the indications, names, dosages, or dates of order for a substantial portion of these medications. Records from that physician and from a variety of other physicians who attended the pilot noted a long history of kidney stones, pancreatic disease, headaches, depression, abdominal pain, and back pain. The records noted inpatient treatment for alcoholism (alcohol dependence) in 1999 and subsequent abstinence from alcohol. Records from two primary care providers and a psychiatrist noted a history of alcoholism and subsequent treatment with opiate and benzodiazepine medications.

Records from the pilot's gastroenterologist noted difficulty achieving adequate anesthesia for a gastroenterological procedure that the pilot had in June 2005, after the medical staff had administered a typically adequate dose of a benzodiazepine and a narcotic medication. Records from one primary care provider noted a diagnosis of lorazepam withdrawal after lorazepam had been temporarily discontinued in August 2005. The records showed no indication that the pilot had undergone any formal evaluation for substance dependence following inpatient treatment for alcoholism.

The pilot's medical records documented visits to a sleep medicine clinic since 2004, with a diagnosis in 2005 of obstructive sleep apnea and successful treatment with a CPAP device. CPAP use was documented for more than 6 hours on each of the 2 nights preceding the accident, and modafinil was prescribed to support alertness during shift work. With the exception of an oral surgeon, each of the providers from whom records were obtained had documentation reflecting the pilot's occupation. Nothing in the records indicated that the providers at the sleep medicine clinic were aware of the pilot's regular use of multiple opiate and benzodiazepine medications. Two providers, the pilot's gastroenterologist and a psychiatrist whom the pilot had previously seen, had made notes in their records about restricting the pilot from working in 1999. Investigators found no other notes regarding work restriction in the medical records that they reviewed.

After the accident, the Coast Guard reviewed the medical information that the pilot had previously submitted to the Coast Guard (discussed in detail in the "Medical and Toxicological Information" section of this report). The Coast Guard determined that the medications and conditions that the pilot had listed could interfere with the safe performance of his duties and that he was therefore "not physically competent to maintain the license." As a result of this finding, the pilot was asked to voluntarily deposit his Federal pilot's license with the Coast Guard until such time as he "present(s) a report from a third-party independent licensed physician which states that (he) is fully fit, in all respects, to perform his duties." The pilot deposited his Federal license with the Coast Guard in December 2007. While not in possession of his Federal license, he could not exercise the privileges of his California state pilot's license.

Master

The master of the *Cosco Busan* was born in China in 1960. He studied at the Maritime University in Dalian, China, beginning in 1978 and had been sailing since 1982. In 1988, his first license (as a third officer) was issued by the Liaoning Maritime Safety Administration of the Peoples Republic of China. He held a Chinese master's license for ships of 3,000 gross tons or more and first sailed as a master in 1998. The accident trip was the master's first time sailing with Fleet Management and his first trip into San Francisco Bay. He had previously sailed on at least three ships that were larger (in gross tonnage) than the *Cosco Busan*. He had boarded the *Cosco Busan* on October 24, 2007.

Chief Officer

The chief officer, who was on the bow of the *Cosco Busan* just before the allision, was born in China in 1972 and had been sailing since July 1997. He was trained at Shanghai Maritime University and was issued his first license (as a third officer) in 1999 by the Shanghai Maritime Safety Administration. He held a license as chief officer on ships of 3,000 gross tons or more. He first sailed as a chief officer in September 2005 and had sailed on one other vessel similar in size to the *Cosco Busan*. He had been on board a ship in San Francisco Bay about 1999, but his vessel stayed at anchorage and never docked. He had boarded the *Cosco Busan* on October 24, 2007.

Second Officer

The second officer was born in China in 1980 and had been sailing since 2003. He was trained at Wu Han University of Technology. About 2004, he received a third officer certificate from Tianjin Maritime Safety Administration, the Peoples Republic of China. He held a Chinese license as second officer on ships of 3,000 gross tons or more, and he began sailing as second officer in July 2006. This was his first voyage on the *Cosco Busan*, and he had not worked on a ship similar to the *Cosco Busan*. The second officer had never been to San Francisco Bay before this voyage. He had boarded the *Cosco Busan* on October 24, 2007.

Third Officer

The third officer, who was on the bridge at the time of the allision, was born in China in 1977 and had been sailing since 2003. He was trained at Wu Han University of Technology. He received his first license (as a third officer) from Tianjin Maritime Safety Administration in December 2005. He held a Chinese license as second officer on ships of 3,000 gross tons or more. The third officer first sailed with Fleet Management in September 2006. This was his first trip with the assigned master. He had never sailed on a vessel the size of the *Cosco Busan*, and this was his first time in San Francisco Bay. He had boarded the *Cosco Busan* on October 24, 2007.

Helmsman

The AB (able seaman) who was at the helm when the *Cosco Busan* allided with the bridge tower, was born in China in 1978, and had been sailing for about 10 years. He received his maritime training at the Nan Ton Navigation Academy in the Gan Su Province. He had never been on a ship similar to the *Cosco Busan* and he had never been to San Francisco. He received his seagoing certification or documentation from the Tianjin Maritime Administration. He had boarded the *Cosco Busan* on October 24, 2007.

Bosun

The bosun had been sailing since 1992. He received his maritime training at the Guang Zhou Maritime School. He received his marine credentials from the Guang Zhou Maritime Safety Administration. He entered employment with Fleet Management on October 24, 2007. He had no previous experience on vessels similar to the *Cosco Busan*. The bosun had made his first trip into San Francisco Bay in or around 2000.

Medical and Toxicological Information

Postaccident Drug and Alcohol Testing of Mariners

In 1988, the Coast Guard developed and promulgated the regulations found in 46 *Code of Federal Regulations* (CFR) Parts 4 and 16 governing drug and alcohol testing requirements for the merchant marine industry. The maritime regulations are predominately applicable to U.S. marine employers and mariners holding either a license, Certificate of Registry, or Merchant Mariner's Document as a condition of employment on board a U.S. vessel. In the case of a "Serious Marine Incident"[69] or "Operating a Vessel While Under the Influence of Alcohol or a Dangerous Drug," the testing requirements (contained in 46 CFR 4.06, 2007, and 33 CFR Part 95, 2007) are applicable to personnel on board foreign flag vessels.

Testing guidelines and processes are established by the Substance Abuse and Mental Health Services Administration, formerly under the direction of the National Institute on Drug Abuse (NIDA). The drug-testing regulations specifically target marijuana, cocaine, certain opiates (codeine and morphine), amphetamines, and phencyclidine. Testing for these drugs, which are often referred to as the "NIDA 5," is conducted through the collection of urine specimens. Breath, blood, or saliva may be used to test for alcohol.

In the case of a serious marine incident, 46 CFR 4.06 mandates that a marine employer "take all practicable steps" to have each individual directly involved in an incident tested for

[69] Serious marine incident is defined, in part, in 46 CFR 4.03-2 as a marine casualty or accident that results in one or more deaths, damage to property in excess of $100,000, an actual or constructive total loss of any vessel subject to inspection, an actual or constructive total loss of any self propelled vessel not subject to inspection of a 100 gross tons or more, a discharge of oil of 10,000 gallons or more, a discharge of a reportable quantity of a hazardous material into the waters or a hazardous substance into the environment, an injury to a crewmember, passenger, or other person that requires professional medical treatment beyond first aid, and, in the case of a person employed on board a vessel in commercial service, that renders the individual unfit to perform routine vessel duties.

evidence of drug and alcohol use.[70] Alcohol testing must be conducted within 2 hours of the incident, and a drug-test specimen must be collected within 32 hours of the incident unless these actions are precluded by other safety concerns directly related to the incident. Title 46 CFR 4.06-3 stipulates that if more than 8 hours has elapsed from the time of the incident, alcohol testing is not required; however, drug-test specimens must be collected even if the 32-hour targeted window for collection has passed.

Drug and Alcohol Testing of the *Cosco Busan* Pilot

On the morning of the allision, the *Cosco Busan* reached the anchorage about 0841. The relief pilot (who had arrived on board the *Golden Gate* with two other pilots and the pilot port agent) reached the ship's bridge at 0858. Soon thereafter, the relief pilot called one of the other pilots on board the *Golden Gate* and asked him to come on board the vessel. When the second pilot arrived on the bridge about 0905, the accident pilot asked him to witness the administration of an Alco Screen O2 saliva screening test.[71] According to audio captured by the vessel's VDR, the accident pilot self-administered the saliva strip test about 0908. About 2 minutes later, the second pilot and the accident pilot examined the surface of the reactive pad. During postaccident interviews, the second pilot and the accident pilot told investigators that the test result was negative and that immediately after the test, the accident pilot placed the expended test strip back in the foil packaging.

After administration of the saliva test, the accident pilot and the second pilot boarded the pilot vessel *Drake* for transportation back to the pilot station. About 1015, the *Drake* arrived at the pilot station where the accident pilot remained to await drug and alcohol testing. At 1029, a representative of Global Drug & Alcohol Testing of Oakland, California, performed an alcohol breathalyzer test on the pilot using a Draeger Alcotest 7410 Plus DOT system.[72] That test result showed that the pilot had a .000 blood alcohol content. At 1035, the same representative obtained a urine specimen from the pilot that was released to Quest Diagnostics Laboratory for testing. On November 8, 2007, the drug screening results were reported as negative for the presence of marijuana, cocaine, opiates, amphetamines, and phencyclidine.

Drug and Alcohol Testing of the *Cosco Busan* Crew

About 0840, some 10 minutes after the allision, the Coast Guard duty investigator telephoned the port agent[73] representing Fleet Management and asked that arrangements be made

[70] In this accident, the tug master was not tested because he was not deemed to be directly involved.

[71] The Alco Screen O2 is a qualitative testing device approved by the Department of Transportation and used for alcohol testing in the field. The device consists of a test strip with a pad designed to display a distinct colored line when exposed to the saliva from a person whose blood-alcohol concentration is 0.02 percent or greater. The instructions on the packet and in the manufacturer's data sheet indicate the test device is designed and calibrated to be interpreted 4 minutes after saturation of the reactive pad and that the test subject should not have placed anything in the mouth for 15 minutes before taking the test.

[72] Draeger Alcotest 7410 Plus DOT is a portable breath alcohol screening instrument designed specifically for the Department of Transportation workplace testing program.

[73] A port agent assists vessel owners and operators by providing logistical and other support to vessels while in port. The port agent performs such duties as arranging for government approval for vessels to enter the United States, arranging for berth or terminal assignments, arranging for cargo loading and unloading, and serving as an intermediary between the vessel owner/operator and local and Federal authorities.

for the drug and alcohol testing of the *Cosco Busan* crewmembers directly involved in the casualty. After completing this call, the Coast Guard duty investigator went to the office of the San Francisco Bar Pilots Association to interview the pilot and to make sure the pilot would be properly tested for drugs and alcohol. A second Coast Guard investigator departed for the vessel to begin the Coast Guard's investigation and to conduct initial alcohol screening of the involved crew.

At 1102, a Fleet Management official in London e-mailed the company port agent asking that the agency "arrange for a drug and alcohol test for all the crew members on board." The company port agent contacted National Safety Compliance, Inc. (NSC),[74] to request that a specimen collector attend the *Cosco Busan*. According to the NSC employee who took the call, the company port agent specified that only the master was to be tested for drugs and that the remainder of the crew were to be screened for alcohol. The NSC employee who was dispatched to the vessel to make the collections told investigators that he also contacted the company port agent while on board the vessel and confirmed that drug testing would be limited to the master. In a June 16, 2008, letter to the Safety Board, a representative of the company port agent stated that, even though the agency had been initially instructed by Fleet Management to have all crewmembers tested for drugs and alcohol, "Due to the sheer volume of phone calls, e-mails, and other messages [between the agency and Fleet Management], the general understanding was that only the Captain was to be tested [for drugs]."

About 1056, a team of Coast Guard personnel boarded the *Cosco Busan* to interview the crew, conduct alcohol testing, assess damage, and perform other marine safety and investigative functions. This team included the second Coast Guard investigator who, about 1124, began performing alcohol breathalyzer tests of crewmembers using an Alco-Sensor IV system. The second Coast Guard investigator conducted alcohol screening of the master, the chief engineer, the third officer, and the helmsman. These tests were concluded by 1130, with all crewmembers recording a .000 blood-alcohol concentration. Meanwhile, the Coast Guard duty investigator had gone to the offices of the San Francisco Bar Pilots Association and was satisfied that the pilot had been properly chemically tested. He attempted to interview the pilot, but the pilot said he preferred not to be interviewed without his attorney present. He left the association office and arrived at the *Cosco Busan* about 1315, where he began examining the data collected by the second investigator and other members of the Coast Guard boarding team.

About 1445, a specimen collector from NSC arrived on board to conduct alcohol screening and to collect a urine specimen from the master. The Coast Guard duty investigator later stated that the NSC collector had arrived on board carrying "six or seven" urine collection bottles. The investigator said he thought the entire bridge crew would be tested, but he did not confirm it with the collector.

After witnessing the first stages of the specimen collection process for the master, the Coast Guard duty investigator said he gave the specimen collector his business card and asked that copies of the chain-of-custody forms for all urine specimens collected be forwarded to the

[74] National Safety Compliance, Inc., is a U.S. Department of Transportation-certified agency that conducts a variety of transportation-related inspection services, including conducting drug and alcohol testing. According to the port agency, the company was contacted because it was well positioned to provide a timely response.

Sector San Francisco Investigations Department. He then left the area to continue the investigation.

At 0700 on November 9, 2007, the Coast Guard duty investigator contacted the vessel agent to follow up on the request for copies of the chain-of-custody forms. It was then that he learned that the NSC collector had not obtained urine specimens from any crewmembers except the master. The duty investigator stated that he asked the company port agent for the telephone number for NSC and that he contacted the company directly to ask that a second collector be sent to the vessel to collect urine specimens from the remaining crewmembers. About 1341 on November 9, 2007, another NSC specimen collector began obtaining urine specimens from the chief officer, the bosun, the second engineer, the chief engineer, the third officer, and the helmsmen. The urine specimens from the master and the crew were received by Quest Diagnostics Laboratory for testing on November 12, 2007. On November 12, 2007, these tests were reported negative for the presence of marijuana, cocaine, opiates, amphetamines and phencyclidine.

Drug and Alcohol Testing of VTS San Francisco Watchstanders

Under the Coast Guard substance abuse prevention program found in the agency's *Personnel Manual*, the active duty and reserve military members of VTS San Francisco are subject to the random, probable cause, and postaccident alcohol and chemical testing. Additionally, through its *Safety and Environmental Health Manual*, the Coast Guard has established a policy of investigating unplanned, unexpected, or undesirable events or mishaps that have caused injury, death, or property damage in an effort to learn from those events and prevent a recurrence. The manual states that, in the case of "high-potential events," which the manual defines as "near mishaps, lessons learned events or other events with a high potential for injury, damage or Coast Guard wide implications," the commanding officer should order testing of each military member involved to determine whether the member is fit for duty.

Because civilian personnel serving at VTS San Francisco are performing safety-sensitive functions related to vessel traffic control, those individuals are subject to the provisions of the U.S. Department of Transportation Order 3910.1C, *Drug and Alcohol-Free Departmental Workplace*. This guidance provides policy on random, pre-employment, probable cause and postaccident testing. Under that policy, when the commanding officer determines that an incident has occurred that meets the criteria for postaccident testing, alcohol testing should be conducted within 2 hours of the incident, and drug testing should occur within 4 hours of the incident.

In the case of the *Cosco Busan* allision, the Coast Guard Sector San Francisco commanding officer did not direct that the one military and two civilian VTS controllers or the civilian watch supervisor on duty at the time of the incident submit urine, blood, or breath specimens for testing. At the April 2008 public hearing on this accident, the then-commander of Coast Guard Sector San Francisco said that he did not order that VTS watchstanders on duty at the time of the allision be tested for drugs and alcohol because "I had no reason to even think that they . . . did anything wrong."

Medical Requirements for Merchant Mariners

The Coast Guard is responsible for the medical certification of more than 210,000 U.S. mariners. Applicants for the licensed and qualified ratings (other than pilots of vessels of 1,600 gross tons or more) must have a physical examination every 5 years. Any pilot of a vessel of 1,600 gross tons or more must have a physical examination every year. Other than the frequency of examinations, the medical examination and certification requirements for Federal pilots is the same as for other licensed and qualified ratings.

Merchant mariner physical examinations may be performed by any state-licensed health care provider (physician, physician assistant, or nurse practitioner) using guidelines that, at the time of the accident, were contained in Navigation and Vessel Inspection Circular (NVIC[75]) 02-98, "Physical Examination Guidelines for Merchant Mariner's Documents and Licenses."[76] These guidelines provided general direction to the examiner in assessing the applicant's ability to perform the shipboard job for which a license was being sought. The guidelines were intended to help the practitioner ensure that the mariner:

- Is of sound health;
- Has no physical limitations that would hinder or prevent performance of duties;
- Is physically and mentally able to stay alert for 4- to 6-hour shifts; and
- Is free from any medical conditions that pose a risk of sudden incapacitation that would affect operating or working on vessels.

The examining practitioner completes (or the mariner completes and the practitioner signs) a form CG-719K, "Merchant Mariner Physical Examination Report," which mariners other than pilots normally forward to the appropriate Coast Guard regional examination center[77] at the time of their initial licensing or at the time their license is up for renewal (every 5 years). Until 2006, Federal pilots were not required to submit their annual physical examination reports to the Coast Guard but were required to have them available for review on request. Since 2006, the Coast Guard has required that Federal pilots forward their annual physical examination reports to their regional examination centers.[78]

[75] The Coast Guard uses NVICs to disseminate information or policy to the marine industry. Although the guidance in a NVIC is not enforceable, the industry usually makes an effort to comply with it. NVICs are sometimes used to disseminate information that will subsequently be proposed as regulations.

[76] NVIC 02-98 has since been replaced by NVIC 04-08, ''Medical and Physical Evaluation Guidelines for Merchant Mariner Credentials," which became effective October 29, 2008.

[77] The Coast Guard maintains 17 regional examination centers to serve mariners nationwide. License documentation for mariners in the San Francisco Bay area is processed through the regional examination center in Oakland.

[78] The Coast Guard established this requirement as part of its response to Safety Recommendation M-05-04, which was issued by the Safety Board to the Coast Guard as a result of the Safety Board's investigation of the

The Coast Guard does not require that a mariner report a change in physical condition that may occur between required physical examinations unless the mariner has previously been granted a medical waiver stipulating that such a change be reported. In these cases, only the condition specifically related to the waiver must be reported; the mariner is not required to report an unrelated condition.

(The medical oversight of the Board of Pilot Commissioners for the Bays of San Francisco, San Pablo, and Suisun, [henceforth referred to in this report as the "pilot commission"] under whose license the *Cosco Busan* pilot was operating, is described later in this report.)

Review of Pilot's Coast Guard Medical Reporting Forms

The pilot's Coast Guard records, obtained from the regional examination center in Oakland, included 719K forms dated December 5, 1989; February 10, 1994; July 26, 1999; January 13, 2004; January 18, 2006; and January 19, 2007.[79] The records included notations of driving under the influence (DUI) offences in 1971 and 1998 and the completion of a 30-day alcohol and chemical recovery program in March 1999. In a July 1999 letter to the Coast Guard, the pilot's psychiatrist documented the pilot's treatment for depression and indicated that the pilot was "fit for duty." The letter did not address alcohol use or prescription medication.

The July 1999 form 719K noted, in part, a history of pancreatitis, treatment for depression with the prescription antidepressant bupropion, and treatment for "alcohol use." No other medication use was noted. Additional records dated between July 26, 1999, and November 30, 1999, included documentation of completion of a court-ordered first-offender DUI program, documentation of almost 9 months of court-ordered attendance at Alcoholics Anonymous (AA) meetings through November 8, 1999, a letter from a gastroenterologist documenting resolution of pancreatitis, and letters of reference.

An e-mail from the National Maritime Center (NMC) "Medical Waivers" staff on November 30, 1999, noted, in its entirety, "A waiver is granted for [the pilot's] condition. Please include a waiver statement on his license when it is issued." A Coast Guard memorandum "To: File" dated November 30, 1999, with the subject "License Renewal Package for [the pilot]" indicated that the pilot:

> . . . has taken great efforts to shorten his assessment period such as regular AA attendance, completion of a rehab program, steady employment, and letters of reference as outlined in Title 46 C.F.R. 10.201(j). . . . It was agreed that the time period between November 21, 1999, and January 04, 2000, would serve as a suspension period of his license for his DUI conviction on February 05, 1999.

October 15, 2003, allision of the ferry *Andrew J. Barberi* at Staten Island, New York. See the "Other Information" section of this report for details.

[79] As previously noted, although pilots were required to have a medical evaluation every year, they were only required to submit the resulting 719K to the Coast Guard when their license was due for renewal (every 5 years). Beginning in 2006, pilots were required to submit a 719K form every year.

A "U.S. Coast Guard License to U.S. Merchant Marine Officer" issued January 4, 2000, certified the pilot without any indication of medical conditions or waiver.

The pilot's most recent form 719K (January 19, 2007)[80] noted, in part, a history of: pancreatitis in 1998, passage of 10 kidney stones ("no stone for 10 years") treated with potassium citrate, alcohol abuse and current AA attendance, depression, "occasional" headaches treated with sumatriptan, chronic esophagitis treated with daily rabeprazole,[81] sleep apnea diagnosed 1 year previously and treated with a CPAP device and daily use of modafinil "if needed," "occasional abdominal pain" treated with propoxyphene, a 4-year history of glaucoma treated with brimonidine[82] eye drops, and "occasional use of 1 mg lorazepam at bedtime for sleep." No other medication use was noted.

At the bottom of each of the 719K forms noted above was the printed statement:

> Considering the findings in this examination and noting the duties to be performed by the applicant aboard a merchant vessel of the United States of America, I consider the applicant (**please check one**)

This statement was followed by checkboxes indicating "Competent," "Not competent," and "Needing further review." In each case, the box for "Competent" was checked.

The pilot's signature appears on each of the 719K forms below the statement "I certify that all information provided by me is complete and true to the best of my knowledge." The Coast Guard records do not include any further documentation of specialist treatment or diagnostic testing. The examining physician also certified to the pilot commission, in a letter, that the pilot was fit for duty.

About 2 months after the accident, Coast Guard personnel interviewed the physician who had performed the pilot's January 19, 2007, evaluation and his three prior evaluations.[83] The physician was one of the four physicians that the pilot commission retained to perform pilot physical examinations and determine whether San Francisco pilots were "fit for duty." The physician was a primary care physician with no training in occupational medicine. He performed the physical examinations for the pilot commission and also completed the 719K forms that he provided to the Coast Guard but not to the commission. He said he obtained guidance for the Coast Guard evaluation from the form itself. The pilot commission provided guidelines on medical oversight of pilots,[84] but the physician said he was not familiar with them.

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[80] This form 719K was submitted in response to the requirement that pilots of vessels of 1,600 gross tons or more have a physical examination annually and provide the form 719K to the Coast Guard. The pilot's license was not due for renewal at that time.

[81] An anti-acid medication often known by the trade name Aciphex and indicated for the treatment of gastroesophageal reflux disease, esophagitis, and ulcers.

[82] A medication often known by the trade name Alphagan and indicated for the treatment of glaucoma.

[83] The three prior evaluations occurred on July 26, 1999; January 13, 2004; and January 18, 2006.

[84] These were Seafarers Health Improvement Program, or SHIP, guidelines, developed with the support of the U.S. Maritime Administration in 1985.

The physician said he had been performing mariner medical evaluations for the commission for about 15 to 20 years, averaging about 10 to 20 pilot medical evaluations yearly. He told Coast Guard investigators that during that time he had judged four pilots not fit for duty because of "heart problems." He said he had performed physical examinations to qualify drivers for a commercial driver's license but that he had not performed other transportation-related medical evaluations, such as airman physical examinations for the Federal Aviation Administration. He said that he was familiar with the duties of a San Francisco Bar pilot, but he was not familiar with Coast Guard NVIC 02-98. He also told the Coast Guard that he did not know how to consider diagnoses of sleep apnea and alcohol dependence when determining a pilot's fitness for duty.

The physician characterized the January 19, 2007, medical evaluation of the *Cosco Busan* pilot as "adversarial" in a way that he had not previously experienced in evaluating pilots for the pilot commission. He recalled that the pilot became "very agitated" when asked if he had been hospitalized for treatment of depression. He said the pilot left the office during the medical exam, stating that he needed to consult with his attorney. The pilot returned to complete the physical later that same day. According to the physician, he "very pointedly warned" the pilot that he could not serve as a pilot within 24 hours of using the medications modafinil, propoxyphene, or lorazepam. The pilot told him that he only used the medications "sporadically" and that he did not use these medications within 24 hours of working as a pilot. After the Safety Board's April 2008 public hearing on this accident, the commission temporarily suspended use of this physician for medically evaluating pilots pending completion of its investigation into the accident.

NVIC 02-98 listed a number of conditions that were potentially disqualifying for a license or license renewal but for which the NMC could grant a waiver if recommended by the chief of the regional examination center. These conditions were categorized in the NVIC under "Eyes, Hearing, Speech, Cardiac, Pulmonary, Gastrointestinal, Genitourinary, Orthopedic, Endocrine/Metabolic, Diabetes Mellitus, Hematologic/Oncologic, Neurologic, Psychiatric, Allergies, Infectious Diseases, Medications, HIV/AIDS, and miscellaneous."

Under "Gastrointestinal" in the NVIC was listed (in addition to other conditions) "Chronic/recurrent pancreatitis." Under "Psychiatric" were listed "Any condition requiring the use of psychotropic medication(s)," and "Current or chronic alcohol abuse/alcohol dependence/alcoholism." Under "Medications" were listed "Anticoagulants (Warfarin, Coumadin)," "Systemic corticosteroids," "Psychotropic medications," and "Medication side effects—see MISCELLANEOUS below."

Under "Miscellaneous" was listed:

> Any other disease, constitutional defect, medication (side effects), sleep disorders or therapy which would result in gradual deterioration of performance of duties, sudden incapacitation or otherwise compromise shipboard safety, including required response in an emergency situation.

Safety Board investigators interviewed the chief of the Oakland regional examination center (who was not required to, and did not, have medical training), who cited two reasons why the 719K form for 2007 would not have been sent for further medical review. First, NVIC 02-98 was in the process of being revised, and the revision was expected to include a list of specifically prohibited medications. In the meantime, he said that he interpreted Coast Guard guidance to be that, until the new circular was issued, regional examination centers were to “continue to use the old NVIC,” that is, the “old” system of reviewing the results of medical evaluation forms. He stated that the then-current (“old”) NVIC did not identify any medication that, if listed on the 719K form, would automatically require additional Coast Guard review. He said that, secondly, because a waiver had been granted to the pilot in the 1999 review of his 719K form and because he (the chief of the regional examination center) did not believe that the information on the form had changed substantially between 1999 and 2007, it was his view that the waiver was still valid and that additional review was unnecessary.

At the April 2008 public hearing on this accident, one of the witnesses was the chief of the Coast Guard’s merchant mariner medical evaluation branch. He stated that the most likely reason the Oakland center did not forward the pilot’s 719K form to the NMC was the perceived ambiguity in the Coast Guard policy on whether those personnel reviewing mariner documents should adhere to the “revised” or the prevailing NVIC 02-98. He stated, “The policy was unclear at that point. Many of the [regional centers] knew that we were working on the NVIC, that we were internally using the information and moving in that direction, but there had been no official changes.” Since that time, he noted, the head of the NMC issued “several memorandums” that communicated Coast Guard policy on NMC review of merchant mariner medical information. In any case, the branch chief noted that he interpreted the existing medical NVIC as calling for NMC review of merchant mariner medical information that listed the use of certain medications and medications with side effects that could affect a mariner’s performance.

Centralization of Mariner Medical Review

At the time of the accident, the Coast Guard was in the process of restructuring and centralizing its marine licensing and documentation programs. As part of the restructuring and centralization process, some functions that had previously been performed at the regional examination centers, such as reviewing physical examination reports and issuing mariner credentials, were being moved to the NMC at its new facility in Martinsburg, West Virginia.

Under the new system, which as of the date of this report has been implemented, all applications for licenses or renewals are submitted to the NMC (after a review for completeness by the regional examination center) where personnel who report to the agency’s senior medical officer review all 719K forms. The medical evaluation personnel, who include a licensed physician, physician assistants, and others with medical training, review each mariner’s physical examination report to determine whether applicants are physically and medically competent to be issued a credential. At the time of the accident, some examination centers had already transitioned to the new centralized process, but the center in Oakland had not. That center began transitioning in April 2008 with transition completed in August 2008.

According to testimony at the public hearing on the accident, the NMC, under the previous system, would review about 2,000 physical evaluation forms per year. Under the restructured system, the NMC medical staff is responsible for reviewing about 60,000 forms annually.

Oversight of San Francisco Bar Pilots

San Francisco Bar Pilots Association

General. The pilot on board the *Cosco Busan* at the time of the allision was working through the offices of the San Francisco Bar Pilots Association, which provides dispatch services and promotes the business interests of its membership of about 60 pilots.

The San Francisco port agent told the Safety Board that his role as port agent for the San Francisco Bar Pilots Association includes general oversight of the pilots of the association and serving as the association's point of contact with the pilot commission, which is responsible for pilot oversight in the San Francisco Bay area, including Sacramento, Stockton, and Monterey Bay. He stated that, in his role as port agent, he provides business oversight of association pilots and reports to the pilot commission whenever association pilots are involved in incidents or accidents. He also reports to the commission any pilot he suspects may be incapable of piloting for any reason.

The port agent said that in the 5 nonconsecutive years he had served in that capacity, he had reported two pilots to the commission—one who had age-related performance issues and another who had behavioral issues. The pilot reported for behavioral issues was the pilot of the *Cosco Busan* for his role in an October 9, 2004, incident (discussed later in this report) that occurred while he was the assigned pilot for the U.S. Navy vessel *Tarawa*.

According to the port agent, the pilots association works with the pilot commission to implement the commission's policies. For example, the commission mandates the experience level required of pilots before they can pilot vessels of certain gross tonnage, and the association maintains records of pilot experience so that pilots can provide evidence to the pilot commission that they have met the commission's requirements. The commission also establishes training requirements for pilot trainees, and the association facilitates the training.

The association provides guidance, but not written requirements, to its members on operating practices, sometimes using lessons learned from pilot-related mishaps. For example, it encourages, but does not require, that pilots engage masters in master/pilot exchanges. As the port agent explained, " . . . if you have a written policy, then you probably shouldn't vary from it much, and it all depends on the conditions and the number of arrivals and the directions and everything else." Further, he added that " . . . part of the reason the ship hires a pilot is for his . . . expertise on board the vessel. And we don't tell him how to pilot on board that vessel . . . once he's on there."

The association had no policy prohibiting departures from the dock during poor visibility conditions, although the port agent noted that the San Francisco Harbor Safety Committee (discussed later in this report) recommends against departures when visibility is less than half a mile. As he explained, such "blanket regulations" could be difficult to implement, " . . . because we deal with summer fog constantly and, frankly, it would shut all the ports down if you just had a blanket regulation."

With regard to the conditions that were prevailing at the time of the accident, the port agent noted that it would be difficult to say what he would have done on the day in question. However, he added that, " . . . from what I heard about the conditions, I would not have departed."

Drug Testing of Pilots. Federal regulations and regulations of the pilot commission require that pilots participate in a random drug-testing program. The San Francisco Bar Pilots Association does not consider itself the employer of its member pilots for purposes of the Federal regulations, but it does maintain a drug abatement program that includes a random drug-testing program for pilots, as well as for pilot boat crewmembers (who are association employees). All pilots are participants in the random testing program. The association contracts with several collection agents (because of the large geographic area served by the association) who collect specimens, preserve chain of custody, and send the specimens to an approved facility for analysis. According to the port agent, half or more of the random testing program participants are tested each year, in accordance with Federal requirements. Every pilot must participate in either the association's or another random testing program that meets Federal requirements in order to be eligible to be dispatched to piloting assignments by the association. According to the American Pilot's Association (APA), the San Francisco Bar Pilots Association is not alone in overseeing its own drug-testing program as other associations do so as well. In other instances, associations delegate all aspects of the program to a third party, as the San Francisco Bar Pilots Association has done after the accident, while, in other instances, the pilot oversight organization oversees the pilot drug-testing program.

Between 1989 and 2008, the San Francisco Bar Pilots Association's drug-testing program[85] was managed by a Drug Abatement Committee comprising three members of the association elected by and from association membership. The committee was chaired by its longest-serving member.

The responsibilities of the Drug Abatement Committee included maintaining all records associated with the drug-testing program, appointing a medical review officer, designating a medical facility to act as a collection site, acting as a liaison between the pilots and the medical review officer, establishing and maintaining random drug-testing procedures, to include the process by which pilots were selected for testing, and issuing certificates to each participant in the program who had not failed or refused to take a test in the previous 12 months.

San Francisco Bar Pilot records indicate that the accident pilot had been tested three times: on September 4, 2002, and February 27, 2006, both random tests, and on November 7, 2007, which was a postaccident test. The results in all cases were negative. The association's drug-testing program called for random selection of 50 percent of the pilots annually, in accordance with Coast Guard requirements. Selection of pilots for random testing, and notification of such selection, was overseen by a subcommittee of the association, the Selection Board for Random Testing. One member of the association's Drug Abatement Committee served

[85] In addition to random drug testing, the program also included pre-employment testing, voluntary periodic testing, postaccident testing, reasonable-cause testing, and rehabilitation testing (for persons who had once tested positive).

on this board, along with two other association pilots. Association records did not indicate the name of the Drug Abatement Committee member who served on the Selection Board.

On January 29, 2008, the association issued the latest revision of its "San Francisco Bar Pilots Drug Free Workplace Policy for Pilots," which does not mention the Drug Abatement Committee and instead assigns to the association and the port agent the functions formerly performed by the committee. An association representative told the Safety Board that the association had determined that its needs would best be served by contracting with an outside provider to implement and maintain the association's drug-testing program. In October 2008, the association joined the American Maritime Safety, Inc. (AMS) consortium. AMS is a maritime trade association with the largest drug and alcohol-testing program in the United States.

In 1995, the Coast Guard established a Drug and Alcohol Program Inspector (DAPI) in each district office with the goal of increasing the level of compliance with the drug and alcohol-testing regulations throughout the marine industry. Most DAPI functions fall into the categories of either education and assistance or enforcement. In the educational and assistance role, the DAPI will make site visits to marine employers to help them develop drug-testing programs. In the enforcement role, the DAPI will make site visits to vessels and marine employers to examine and review all aspects of the specific chemical testing programs that are in place.

The San Francisco Bar Pilots Association provided documentation indicating that it had, in 1992 and again in 1994, requested a Coast Guard review of the association's drug-testing program to determine whether the program was in compliance with Federal regulations. No record exists of what the Coast Guard response, if any, was to the request, or why the association did not pursue the matter after the Coast Guard established its DAPI program in 1995. The Coast Guard did not perform its first audit of the program until after the *Cosco Busan*'s allision with the Bay Bridge. On December 13, 2007, the Coast Guard 11th District DAPI conducted an audit of the association's chemical testing program and, according to the report of that audit, found that the association's program was not in compliance with the applicable regulations. Specifically, the audit found discrepancies in five distinct areas noted on the audit form. The areas with noted shortcomings were *General Program Review*, *Pre-Employment Testing*, *Random Testing*, *Employee Assistance Program*, and *Management Information System*. The DAPI noted these deficiencies and allowed the association 30 days to resolve them.

On February 1, 2008, the DAPI conducted a second audit of the association's chemical testing program and found that deficiencies had been corrected in four of the five areas identified as deficient in the earlier audit. The association still did not meet the regulatory requirements governing the *Employee Assistance Program* area and was deemed noncompliant with the regulations. The association was given another 30 days to bring this program area into compliance. On May 15, 2008, the DAPI reported to the Safety Board that the San Francisco Bar Pilot's Association was still not compliant with the *Employee Assistance Program* section of the chemical testing requirements, noting that 28 of the 56 licensed state pilots and 10 of the association's 15 marine employees still had not reviewed a drug awareness training video that was a required part of a compliant employee assistance program. This required training has since been completed, and on July 22, 2008, the DAPI sent an e-mail to the association confirming compliance with the applicable regulations.

Board of Pilot Commissioners

Federal law, in 46 *United States Code* Sections 8501 and 8502, requires U.S.-flagged vessels not sailing under register (that is, sailing between U.S. ports) to use federally licensed pilots when operating in U.S. ports and harbors. Foreign-flagged vessels and U.S.-flagged vessels sailing under register use the services of state or locally licensed pilots while operating in U.S. ports, except for vessels operating in the Great Lakes or selected local ports.

General. According to its executive director, the Board of Pilot Commissioners for the Bays of San Francisco, San Pablo, and Suisun was established by the state of California to oversee the performance of state-licensed pilots in the San Francisco Bay area and, since 1984, a group of inland pilots. The pilot commission, which at the time of the accident reported to the governor of California,[86] establishes the selection and training standards of the pilots, investigates pilot-related incidents through its Incident Review Committee, and recommends corrective action at the completion of its investigations. The executive director indicated that he is in regular contact with the association's port agent and speaks with him "multiple times during a week" on commission matters.

Medical Standards. The executive director said that the pilot commission does not establish medical standards for the pilots; rather, it adheres to Coast Guard medical standards and requires its pilots to be medically evaluated by one of four specified physicians. The physician will certify to the commission whether a pilot is medically fit for duty based on Coast Guard standards and those in 1984 guidelines, known as SHIPS, or the Seafarers Health Improvement Program. The commission has no additional reporting requirements for medication use or change in medical condition beyond those established by the Coast Guard. The physician only provides the commission with his or her determination of medical fitness for duty. Information from the medical evaluation, provided on the Coast Guard 719K form, is sent to the Coast Guard.

In September 2008, the governor of California signed into law legislation upgrading the medical standards of the commission, to take effect in January 2009. Among other provisions of the new law, pilots and pilot trainees are now required to submit to the examining physician, which the commission selects, a list of all medications taken in the 30 days before the examination. In addition, under the new law, pilots are required to report to the commission-selected examining physician, within 10 days, any changes to the dosage of the medications previously reported, or any new medication prescribed. The examining physician is then to determine and report to the commission if the dosage change or newly prescribed medication adversely affected the pilot's or pilot trainee's fitness for duty.

Accident/Incident Investigations. The commission's Incident Review Committee is composed of the commission executive director and a public member of the commission. The Incident Review Committee's responsibilities include investigating all reports of misconduct or navigational incidents involving a vessel piloted by a pilot licensed by the commission and reporting the results of that investigation to the full pilot commission. The procedures to be followed by the Incident Review Committee when investigating piloting incidents were

[86] Under legislation signed by the governor of California on September 29, 2008, the pilot commission, beginning in January 2009, will not report directly to the governor but instead will be placed under the State Business, Transportation, and Housing Agency.

established by statute in 1993. The regulations require the assigned pilot or inland pilot on board a vessel involved in a navigational incident to report that incident to the commission. According to the regulations, navigational incidents include, but are not limited to, “all incidents involving the grounding of a vessel, the striking of any object or injury or damage to persons or property.”

The pilot commission’s regulations require the Incident Review Committee to include in its report “a summary of the investigations of any prior incidents, misconduct or other matters involving the pilot” and, in determining corrective action, to consider “the number and frequency of prior incidents involving pilot error, the length of time the pilot has been licensed, and the prior corrective action imposed upon the pilot.” On completion of the investigation and the consideration of the findings of the investigation, the results of the investigation are made public and given to the San Francisco Bar Pilot Association for distribution to its member pilots.

Before 1993, piloting incidents were investigated by one of the commission members. According to representatives of the pilot commission, the investigations were less structured and the results were generally reported orally to the commission, “leaving a relatively sparse record.” The commission had no statutory or regulatory provisions or written guidelines for determining appropriate corrective action, and no clear determination of whether an incident involved pilot error unless a party filed an accusation seeking suspension or revocation of a pilot’s license. Commission representatives told the Safety Board that, for incidents that did not result in the filing of an accusation, most were closed with the notation “pilot counseled, case closed.”

The pilot commission executive director said that “ . . . the number of incidents is relatively small. In some years we have as few as six.” The most investigations the executive director remembered conducting in a single year was 19. The commission relies on the port agent to inform it of any problems with a pilot and also receives occasional reports from ship or terminal operators regarding a pilot’s ship handling or a vessel interaction.

At the conclusion of an investigation, the commission will, if necessary, take remedial or punitive action against a pilot. Action may involve additional training or, if the error was sufficiently great, license suspension or revocation. The executive director recalled that the most recent incident in which the Incident Review Committee recommended action against a pilot occurred in 2003 when the commission sought the suspension of a pilot’s license. The pilot retired before a hearing was held. The executive director indicated that the most severe action he remembered the commission taking was in 1997 when a pilot’s license was revoked, an action that was reduced to a 6-month license suspension and subsequent probation. The director noted that the commission called for ”at least a dozen” suspensions. Some were 2-month suspensions with a “pretty fair number” of 2-week suspensions.

In response to the *Cosco Busan* incident, the commission suspended the accident pilot’s state license on November 30, 2007. On December 6, 2007, based on its investigation of the incident, the commission, through its Incident Review Committee, filed charges alleging that the *Cosco Busan* pilot (1) had reason to doubt whether the ship could safely proceed under the prevailing circumstances, (2) proceeded with insufficient information about the level of visibility along his intended route, (3) proceeded at a speed that was excessive for the circumstances and (4) failed to make full use of all available resources to determine the vessel’s position. A hearing on the charges was scheduled for September 2008 but was cancelled when the pilot retired effective October 1, 2008.

On October 23, 2008, the pilot commission released its Incident Review Committee report on the role of the pilot in the *Cosco Busan* incident.[87] The report did not evaluate the actions of the master. The "Executive Summary" of the report summarized the findings of the investigation as follows:

> (1) That, prior to getting underway, [the pilot] failed to utilize all available resources to determine visibility conditions along his intended route when it was obvious that he would have to make the transit to sea in significantly reduced visibility;
>
> (2) That [the pilot] had exhibited significant concerns about the condition of the ship's radar and a lack of familiarity with the ship's electronic chart system, but then failed to properly take those concerns into account in deciding to proceed;
>
> (3) That, considering the circumstances of reduced visibility and what [the pilot] did and did not know about the ship and the conditions along his intended route, he failed to exercise sound judgment in deciding to get underway;
>
> (4) That [the pilot] failed to ensure that his plans for the transit and how to deal with the conditions of reduced visibility had been clearly communicated and discussed with the master;
>
> (5) That, once underway, [the pilot] proceeded at an unsafe speed for the conditions of visibility;
>
> (6) That, when [the pilot] began making his approach to the Bay Bridge, he noted further reduced visibility and then reportedly lost confidence with the ship's radar. While he could have turned south to safe anchorage to await improved visibility or to determine what, if anything was wrong with the radar, [the pilot] failed to exercise sound judgment and instead continued on the intended transit of the M/V *Cosco Busan*, relying solely on an electronic chart system with which he was unfamiliar; and
>
> (7) That [the pilot] failed to utilize all available resources to determine his position before committing the ship to its transit under the Bay Bridge.

Pilot Qualification and Training. The executive director said that the commission works with the Coast Guard to maintain safety by providing "the best trained pilots" it can. If an individual is unable to maintain his or her Coast Guard license for any reason, that individual cannot perform as a state-licensed pilot.

According to information provided by the pilot commission, pilots are required to attend two specified courses on a recurring basis. The "3-year course" is a 7-day course that is required of all pilots every 3 years. The "5-year course" is a manned model ship-handling course and is required of all pilots every 5 years.

[87] Board of Pilot Commissioners for the Bays of San Francisco, San Pablo and Suisun, Incident Review Committee Report: *November 7, 2007 Allision With the San Francisco–Oakland Bay Bridge* (Presented October 23, 2008).

According to the Maritime Institute of Technology & Graduate Studies "course framework" document provided to the Safety Board by the pilot commission, the scope of the 7-day "3-year course" provided to the accident pilot in 2005 was as follows:

> This training program is designed to afford pilots an opportunity to gain knowledge and understanding of the principles and procedures of Azipod and Kamewa systems, Advances in Electronic Navigation, Emergency Medical Response and Emergency Shiphandling and Bridge Resource Management.

The 2-day "advances in electronic navigation" module of the course had the following scope:

> This training program is designed to afford pilots an opportunity to gain basic knowledge and understanding of the principals and procedures of Electronic Charting Display and Information Systems (ECDIS), Integrated Bridge Systems (IBSs) and Automatic Identification Systems (AIS). The program has been designed using the guidelines provided in the International Maritime Organization's (IMO) Model Course 1.27 for ECDIS. The AIS portion of the seminar has been developed using manufacturer and government technical data. Practical applications ("hands-on" training) can be provided through the use of MITAGS simulator systems.

Communication With Other Pilot Commissions. No formal method exists by which state or local pilot oversight and regulatory bodies maintain contact with other pilot oversight organizations, although, as the executive director of the California pilot commission noted, he maintained "informal contacts" with colleagues in Washington state and Oregon. He noted that in the early 1990s, commissioners in Florida hosted two "Pilot Commission Symposia" for state or local pilot oversight and regulatory bodies, with a third one held later in New Orleans. The programs, which he described as "fairly informal," " . . . gave us an opportunity to talk about what our programs were like, and it was, it was mostly looking at each other's training. We [also] talked about our incident investigation process." Since the symposium in New Orleans, no additional meetings of pilot oversight organizations have been conducted.

Representatives of the pilot commission told the Safety Board that, both before and after the public hearing on this accident, the commission initiated a number of contacts with other pilot commissions on the West Coast and in Alaska to explore ways in which the groups could share lessons learned.

Pilot's Incident Record

The *Cosco Busan* pilot's personnel file maintained by the pilot commission showed that the pilot had been involved in 13 pilot-related incidents during his 26-year career. These incidents are summarized below.

M/V *Pioneer*: On February 20, 2006, the motor vessel *Pioneer* grounded while being piloted by the *Cosco Busan* pilot. There was no damage to the vessel or to the environment. The commission faulted the pilot because he " . . . had not realized [that] the vessel was going off track and did nothing to prevent it" and attributed the accident to the pilot's "lack of situational awareness." On July 14, 2006, the commission issued a letter of reprimand to the pilot for his role in the incident and counseled him to "maintain better situational awareness." The Coast Guard also investigated the incident and, based on its findings, issued the pilot a letter of warning stating that "As the pilot of the M/V PIONEER, you failed to safely navigate the vessel in accordance with the vessel maneuvering characteristics and published local weather conditions, which resulted in the grounding of the vessel."

USS Tarawa: On October 9, 2004, the *Cosco Busan* pilot reportedly became "enraged" when boarding a U.S. Navy vessel at the offshore pilot station because the pilot ladder was equipped with tag lines used to hoist the ship's ladder when not in use (which he considered a potential safety hazard). The pilot cut off the tag lines and used "offensive and derogatory language" to the vessel's officers and crewmembers. On October 14, 2004, the association port agent reported the incident to the commission, indicating that the association would remove the pilot from the duty rotation until the commission completed its investigation.

The commission, with the Coast Guard, investigated the incident. The commission treated the incident as a medical issue and retained a psychiatrist to conduct an independent evaluation of the pilot to determine his ability to fulfill his duties. The psychiatrist was not aware of the pilot's use of prescription drugs nor was he given access to the records of the pilot's primary care physician. On February 7, 2005, the psychiatrist reported to the commission that, based on his evaluation, the pilot was not, nor had he ever been, psychotic and had not been experiencing a psychiatric disorder at the time of the incident. The psychiatrist also reported that the pilot indicated that he was taking "Wellbutrin [bupropion, an antidepressant] as prescribed" and not mixing it with other drugs, prescribed or illicit, or with alcohol that "could render any individual unfit to perform his duties." The psychiatrist concluded that he could arrive at "no valid medical/psychiatric explanation [for the pilot's behavior during the *Tarawa* incident] [that] is pathologic." The psychiatrist added that "this incident is most likely an outgrowth of his personality which is ordinarily in better control."

Based on this evaluation, the commission, in March 2005, allowed the pilot to return to duty under additional monitoring and oversight, as recommended by the examining psychiatrist. In closing its investigation, the commission sent a letter to the pilot dated August 8, 2005, noting that despite the pilot's anger and reported behavior, he piloted the vessel safely "under challenging environmental conditions." The letter, which was to be included in the pilot's file with the commission, noted that his "unprofessional conduct . . . had the potential of distracting the bridge team[[88]] from the safe navigation of the vessel."

M/V *Ginga Kite*: On October 6, 2002, the chemical tanker *Ginga Kite* interacted[89] with another tanker, which was moored to its dock, as the vessel was being piloted to a terminal in Pittsburg, California. The commission was notified of the incident by a terminal representative 2 days after the event, by which time both vessels had departed the area.

[88] A bridge team is generally defined as everyone who is involved in a vessel's navigation. However, the APA does not consider pilots to be part of the bridge team. For the purpose of this report, the Safety Board defines the bridge team as the pilot, the master, and the navigational crew.

[89] The term "vessel interaction" refers to the hydraulic effect on a moored vessel caused by the displacement of water as another vessel passes nearby. It does not involve any contact between the two vessels.

The commission's investigation was limited as a consequence of the departure of the vessels and their crews. It relied on statements of the pilot and representatives of the two vessels for incident-related information. Because of the insufficient information available to the commission, it closed the investigation with the finding "no attributable pilot error." It concluded that, "regardless of causes in this incident, pilots should pay close attention to potential vessel interaction situations and proceed at minimum speeds consistent with good vessel maneuverability."

M/V *Chimborazo*: On July 16, 2002, the motor vessel *Chimborazo* allided with a wharf while the *Cosco Busan* pilot was serving as the pilot. The commission concluded that the pilot ". . . had the vessel well under control" and that, rather than any performance deficiency on the part of the pilot, the allision was caused by a spring line that snagged on a section of the dock. The Incident Review Committee finding was "no pilot error," and the case was closed.

M/V *Mare Caspium*: On April 23, 1997, with the *Cosco Busan* pilot overseeing the performance of a pilot trainee on the bridge, the motor vessel *Mare Caspium* allided with a container gantry, causing minor damage to the vessel and the gantry. The commission attributed the incident to "minor pilot error," and no further action was taken.

Incidents Occurring Before 1993. According to pilot commission records, the *Cosco Busan* pilot was involved in eight incidents that primarily involved minor damage between his licensing in 1981 and the 1993 establishment of the Incident Review Committee (and the subsequent conduct of more thorough and well-documented accident investigations). One incident occurred in 1983, three in 1986, one in 1987, two in 1990, and one in 1991. After a 1986 incident in which a vessel struck a submerged object, notice was sent to all pilots to remain 200 feet away from Potrero Point, the site of the incident and of an apparently uncharted underwater obstruction. As a result of six of the remaining seven incidents, the commission counseled the pilot. The records were insufficient to determine whether a finding of pilot error had been made in any of these incidents.

When asked about the 13 pilot-related incidents in the records of the *Cosco Busan* pilot, the executive director of the pilot commission said that he would expect to see "some but not many" incidents in the record of a pilot with 26 years of experience, such as the *Cosco Busan* pilot had accrued. The executive director characterized the pilot's number of incidents as "more than average in number but not by much." He also indicated that the record of the pilot's incidents, which date back to 1983, makes it difficult to compare the pilot's earlier performance with his later performance because "the system of investigation wasn't as sophisticated as it is now . . . ." As noted above, the commission considered the *Tarawa* incident as a medical one and the other incidents involving the pilot as performance-related.

Cosco Busan Safety Management System and Navigation Safety

The SMS in place on board the *Cosco Busan* provided several risk-mitigation checklists and specified the shipboard practices that were to be followed by the master and crew to enhance navigational safety.[90] These risk-mitigation procedures and checklists were found in the

[90] U.S. and international regulations also specify the responsibilities of master and pilot in navigating a vessel.

company's *Bridge Procedures Manual*. They included requirements for developing, monitoring, and executing a berth-to-berth passage plan; procedures for monitoring and overseeing a pilot's actions; and guidance addressing the company's expectation for navigation at safe speeds during periods of restricted visibility. The SMS and all associated checklists were printed in English only.[91]

Both the second and third officers said that, while they tried to follow all SMS procedures, it was not possible in some instances. As the third officer testified:

> It's not quite possible to follow it [the SMS manual] to the letter. I would read some parts related to safety issues. However, sometimes what's written in there, in reality it's impossible to follow, and so I would try my best to follow the procedure. What I mean is these minute details, if you follow every detail—all the detail procedures, it's just impossible for you to navigate the ship.

Similarly, the master told investigators that, while he would try to follow all SMS procedures, "sometimes it is unpractical or impossible to follow all the regulation there."

Passage Planning

The concept of passage planning applies to all vessels and is essential for the safety of life at sea, efficiency of navigation, and protection of the marine environment. Passage planning involves detailed planning of the entire contemplated voyage berth-to-berth, execution of the plan, and under-way monitoring of the vessel in the implementation of the plan.

Safety Board investigators were initially provided with a copy of the *Cosco Busan*'s berth-to-berth passage plan from Oakland to Busan that appeared to have been signed and acknowledged on the morning of the allision by all members of the vessel's navigation team, including the master. The passage plan identified 30 waypoints along the vessel's intended track and provided the bridge navigation team with detailed navigational information for each waypoint. This navigational information included a latitude and longitude for each waypoint, course to steer from each waypoint, distance of travel between each waypoint, remaining distance to go from each waypoint, under-keel clearance calculations, tidal information, and the minimum intervals and means for obtaining a position fix.

The passage plan could have been entered into the vessel's VMS, which had the capability of superimposing the vessel's intended track and the waypoints onto the radar screens. Such a track and waypoints were not shown on the radar screen images captured by the vessel's VDR, indicating that the *Cosco Busan*'s crew had not entered the plan into the system (nor were they required to do so).

Fleet Management's SMS stated with respect to monitoring and executing the passage plan, "close and continuous monitoring of the ship's progress along the pre-planned track is essential for the safe conduct of the passage." The plan also stated:

[91] According to ISM Code, *Resources and Personnel*, 6.6, "The company should establish procedures by which the ship's personnel receive relevant information on the safety management system in a working language or languages understood by them."

> It will be important for the Master to consider whether any particular circumstance, such as the forecasted restricted visibility in an area, where position fixing by visual means at a critical point is an essential feature of the navigation plan, introduces unacceptable hazard to the safe conduct of the passage and thus, whether that section of the passage should be attempted under the conditions prevailing, or not.

In June 2008, information came to light from Fleet Management indicating that the original passage plan for the Oakland–Busan voyage that the second officer had prepared for November 7, 2007, was not berth-to-berth but was pilot-station-to-pilot-station. The berth-to-berth plan that had been provided to investigators was actually prepared after the accident.

Pilot Oversight

The vessel's SMS also addressed the need to ensure that a pilot had been properly provided with the ship's particulars and that the pilot and the master had discussed and agreed on the proposed passage plan and the pilot's intended course of action.

The SMS stated that the pilot "acts only as an advisor" and that, "should the Master consider the Pilot to be endangering the ship or contravening any law, rule or regulation, he shall reject the Pilot's advice and relieve him of his duties and assume control of the ship himself."

Safe Speed in Restricted Visibility

In regard to operating in restricted visibility, the *Cosco Busan*'s SMS stated the following:

> The Company does not wish their ships unduly delayed, but still less do they wish them to be damaged. A few hours gained will not compensate for weeks of repair work. The Company relies on their Masters to navigate prudently in restricted visibility. In fog or other conditions of restricted visibility, Master should ensure that the vessel proceeds at SAFE SPEED.

On the morning of departure, the second officer completed a form, "Bridge Checklist 10 – Restricted Visibility," indicating that proper lookouts had been posted and that the Convention on the International Regulations for Preventing Collisions, 1972, were being complied with, "particularly with regard to proceeding at a safe speed." According to the AIS data from the vessel, as recorded by VTS San Francisco, when the vessel allided with the Delta tower, its speed over ground was about 10.1 knots, which was consistent with the GPS data captured on the vessel's VDR.

Master/Pilot Information Exchange

An effective master/pilot exchange includes discussion of the vessel's navigational equipment, any limitations of maneuverability, available engine speeds, un-berthing maneuvers, intended course and speed through the waterway, anticipated hazards along the route, weather conditions, composition of the bridge team and deck crew both forward and aft including bow lookout, and so on.[92] Fleet Management's policy on master/pilot exchanges states, in part,

> . . . after his arrival onboard, in addition to being advised by the Master for its present condition of loading, the pilot should be clearly consulted on the Passage Plan to be followed. The general aim of the Master should be to ensure that the expertise of the Pilot is fully supported by the ship's Bridge Team.

The APA's guidance with respect to master/pilot exchanges states that each pilotage assignment should begin with a conference between pilot and master to share not only the information that each needs, but to also establish an appropriate working relationship, and that pilot cards or similar documents should "supplement, not substitute for, the master/pilot information exchange."[93] In a postaccident interview, the pilot told investigators that when he arrived on board the *Cosco Busan* on the morning of the allision, he gave the master a copy of the harbor pilots' pilot card:

> I handed him the document, and he took it, and I think he read it, but I don't recall him discussing it with the mates or the helmsman. . . . I handed it to him and was expecting him to read it. It says right on it, if you have any questions, ask.

The VDR did not record any conversation between the master and the pilot about the vessel's passage plan or the vessel speed or route that the pilot planned from the berth to deep water. The pilot did inform the VTS of his plan to proceed through the Delta–Echo span of the bridge, but investigators could not verify that the master was aware of this plan.

Before arriving in Oakland, a crewmember re-traced the previous crew's erased course line on the paper chart indicating the planned inbound route through the Delta–Echo span of the Bay Bridge to berth 56 (figure 10). The paper chart did not have a separate course line for the outbound route, but reciprocal headings on the single course line indicated that the same course could be used on the return to sea. Neither of the two VDR microphones in the area just to the left and right of the chart table picked up any conversation regarding the paper chart before the allision. Specifically, the pilot and the master were never heard talking about or referencing the paper chart until after the allision. Nor did the VDR capture any other conversation between the pilot and any other member of the bridge team referencing the intended route through the Delta–Echo span. In his postaccident interview, the pilot stated that he had not seen the paper chart.

According to the master, he did not feel comfortable questioning the pilot. His "frustration" with the pilot began as soon as he met him. The master told investigators:

> Normally as a captain I would welcome the pilot with my open arms, enthusiastic, and I would show my hospitality in offering him if he need any food or coffee or tea, et cetera. And then [this] pilot came on board with a very cold face. Some of them just don't want to pay attention on us and some of them would not like to talk with us . . . it seems the

[92] George A. Quick, "Bridge Resource Management for Maritime Pilots, III." April 2002.

[93] American Pilots' Association, "The Master-Pilot Information Exchange: Best Practices Summary." Adopted October 8, 1997 (Washington, DC: APA, 1997).

> pilot coming on board was with cold face, doesn't want to talk. I don't know if he had a hard day before or because he was unhappy because I was a Chinese.

The master said that he did not question the pilot, and the pilot did not discuss with the master the plan to navigate the vessel from the berth to the pilot station. The master said that he became concerned about the safety of the voyage when VTS called the pilot after the vessel was under way. As a result, the master stated that he "observed [the pilot] very carefully to see if there was any mistake."

VTS San Francisco

On the Day of the Accident. The VTS controller responsible for vessel traffic in the Central Bay sector on the day of the allision said that he began to be concerned about the position of the *Cosco Busan* about 0827 because of his "perception of where the vessel was at in relation to the Delta–Echo span" of the Bay Bridge. This concern prompted the VTS operator to radio the pilot, incorrectly informing him that AIS showed the vessel on a "heading" of 235° and asking if he still intended to use the Delta–Echo span. The pilot responded that he was bringing the ship around and steering 280° and that he still intended to use the Delta–Echo span. No further communication occurred between VTS personnel and the pilot on board the *Cosco Busan* before the vessel's allision with the bridge support tower.

The on-duty VTS watch supervisor reported in postaccident interviews that, based on the pilot's "calm" demeanor and the known time lag in the display of a ship's position on the VTS operator's screen, VTS personnel did not question the pilot further. At that point, both active VTS operators and the VTS watch supervisor focused their attention on the Central Bay area to monitor the progress of the *Cosco Busan*. The VTS watch supervisor stated:

> On my display, I was able to zoom in to kind of follow his track. And it was apparent to us, I mean to me, that [it] was extremely close. But, again, not having that kind of definition, you really couldn't tell whether he had actually hit the bridge or not. The next call we got was from [the pilot] indicating that he had touched the bridge and that he would… proceed to the anchorage.

At 0901, VTS began broadcasting Sector San Francisco's first safety-related radio transmission, or *Securite* broadcast.[94] This radio broadcast established a minimum wake zone and wide berth around the *Cosco Busan* while it was at anchor in anchorage 7. Additionally, the relief pilot reported to VTS via VHF radio that he was on board the *Cosco Busan* and would remain there for the duration of the incident. No further communication relevant to the incident occurred between the accident pilot and VTS San Francisco personnel at that time. Multiple VHF radio communications and telephone calls regarding oil sightings and the locations of oil accumulation along various portions of the waterway continued to come into the VTS center throughout the morning hours and into the early afternoon.

[94] A *Securite* radio call is used to alert stations and vessels that important safety information is about to be transmitted.

Traffic Monitoring. At the time of the accident, VTS San Francisco monitored and managed marine traffic using Coast Guard Vessel Traffic System (CGVTS) equipment and a partial deployment of the Marine Traffic Management (MTM-200) system developed by Lockheed Martin Corporation. Together, this equipment and software integrates a variety of sensors and communications devices (such as radar, closed-circuit television, VHF radio, and AIS data) to provide VTS operators with a visual representation of vessel traffic in their areas of responsibility.

When CGVTS was developed and deployed in the early 1990s, it did not incorporate AIS data. In 1996, the Coast Guard launched the Port and Waterways Safety System (PAWSS) VTS Improvement and Standardization Project with a principal goal of incorporating AIS data into the VTS system while relying as much as possible on commercially produced and readily available equipment. To that end, the Coast Guard selected a Windows-based, full version of the MTM-200 system, which not only integrated AIS into the VTS system but also provided decision-support functions for VTS operators. These functions included the ability to replay multiple vessel tracks and to alert vessel operators if vessels violated waterway rules (such as speed restrictions).

Because of funding constraints in the early 2000s,[95] only six of the eight larger VTS locations received the full version of the MTM-200 system. VTS San Francisco and VTS Puget Sound were outfitted with only the AIS portion of the MTM-200 system, which integrated AIS into the CGVTS equipment but did not provide the additional decision-support functions. Even though AIS broadcasts a ship's heading at regular intervals, the CGVTS in use by VTS San Francisco at the time of the accident could not be configured to display heading information to VTS operators.

In addition to using sensors, equipment, and software, VTS San Francisco and other VTSs use a regulatory Vessel Movement Reporting System (VMRS) to monitor and track vessel movement. VTS waterway users are required to provide sailing plan reports, position reports, sailing plan deviation/amplification reports, and final reports to VTS. The sailing plan, which must be provided to VTS via VHF radio 15 minutes before a vessel enters VTS waters, must include the vessel name, vessel type, current position, time and point of entry into VTS-controlled waters, vessel destination, intended route of travel, estimated time of arrival at destination or exit from VTS-controlled waters, and any dangerous cargo.

The position report is required on a vessel's entry into VTS-controlled waters, at designated points within the VTS area, and as directed by VTS operators. A sailing plan deviation or amplification report is required when a vessel intends to deviate from previously reported intentions (a change in route or bridge span intentions, for example), or when needed to provide additional information to VTS. The final report is required on a vessel's arrival at its destination or when leaving the VTS area, and it must include the vessel's name and position. Although VTS regulations afford certain exemptions for vessels on published routes or vessels that operate within a small nautical area, vessel participation in the VMRS is mandatory for all

[95] CDR B. Tetreault, USCG, *Systems and Equipment in Use at U.S. Coast Guard Vessel Traffic Services*, U.S. Coast Guard Professional Paper, U.S. Coast Guard, December 11, 2007.

power-driven vessels of 40 meters or more, all towing vessels of 8 meters, and all passenger vessels carrying 50 or more passengers.

The information provided from a vessel to VTS is entered into an electronic form called a universal track data card, or UTDC. The data card can be retrieved or displayed by VTS controllers as the vessel transits the coverage area. VTS controllers will routinely "read back" the data card information to the vessel, primarily to verify that VTS has accurately captured the vessel's intentions, and also to re-broadcast the vessel's intentions using the powerful vessel traffic center (VTC) radio transmitter. In addition, VTS controllers will provide the vessel operator with advisories, marine event information, potential hazards, or other hindrances to the vessel's safe transit. Communications from shore to ship, and ship to shore, are made using the English language and commonly accepted, standard marine communication phrases.[96]

During periods of restricted visibility, VTS controllers also provide vessel operators with all radar targets that may affect transit. The UTDC provides VTS operators with static information, such as a vessel's name, type, length, beam, gross tonnage, call sign and identification number, point of entry or departure, final destination, and any onboard pilot's alpha/numeric designation. The UTDC also provides VTS operators with continuously updated information, such as vessel speed over ground, course over ground, latitude, and longitude.

Traffic Control. The Coast Guard authorizes VTS operators to exert four levels of control over vessel movements. These control levels, from lowest to highest, are *monitor*, *inform*, *recommend*, and *direct*. At the *monitor* level, VTS operators use the sensors and VHF radio to track vessel movement in the waterway and to identify potential risks. At the *inform* level, a VTS operator may provide vessels with navigational information. At the *recommend* level, the VTS operator, based on data from the VTS system that may not be available on board a vessel, may offer navigational suggestions or alternatives for consideration by the vessel's master or pilot. The decision whether or not to take a specific action remains with the master or the pilot. At the *direct* level of control, a VTS operator who has determined that a certain vessel action is "necessary to enhance navigation and vessel safety and protect the environment" may direct that a ship's master or pilot take specific actions to mitigate the risk. The directions from VTS may include "imposing vessel operating requirements," but do not include specific vessel operational orders such as helm or rudder commands. In times of restricted visibility, 33 CFR 161.11(b) stipulates that VTS may "control, supervise, or otherwise manage traffic, by specifying times of entry, movement or departure to, from, or within a VTS area."

In the VTS *Operational Policies Manual*, VTS personnel are instructed to use either a VTS *recommendation* or a VTS *direction* as needed to address incidents that are perceived to "have the potential to drastically affect the transit of one or more vessels, cause damage to property and the environment, or cause injury or loss of life." The VTS San Francisco *User's Manual*, 2005, which is provided to the public and waterway users, describes this level of authority as follows:

[96] IMO Resolution A.918(22), *IMO Standard Marine Communication Phrases*, dated January 22, 2002, provides for recommended standardization of language and terminology to enhance the safety of navigation and to support compliance with the standards of competence as required by STCW Code, Table A-II/1.

> On rare occasions (and during heightened security conditions) VTS will direct movement or actions of a participant. Direction would be given in cases when [VTS] observes obvious violations of regulation or an obvious and immediately dangerous condition of which the participant is not or does not seem to be aware.

Vessel Name Versus Pilot Designator in VTS Communication. The *Cosco Busan* master told investigators that, in his experience, VTS in overseas ports gave explicit warnings, using the vessel's name, if ships were in potential danger. He said that, on past occasions, VTSs had explicitly warned him of vessels that were close to his. He said that in those situations, VTS would instruct, "I determine you close to this buoy or this vessel or this boat. You should change your present course." The master said that he did not hear such explicit warnings in this case, nor did VTS and the pilot use the vessel's name in their conversation.

Investigators asked the Coast Guard to determine how many U.S. VTS locations use the vessel name when contacting ships and how many typically use the pilot's name or pilot designator. As conveyed in a December 2008 e-mail, the Coast Guard estimated that, of the 12 VTS locations in the United States, 8 use the vessel name or the vessel's call sign almost exclusively. The remaining four VTS locations (San Francisco, Houston-Galveston, Port Arthur, and Lower Mississippi River) use the vessel name and the pilot designator on initial check-in and, once reliable communications have been established, they use the pilot designator for most communications.

Location, Mission, and Personnel. VTS San Francisco is a branch of the Coast Guard Sector San Francisco and is staffed around the clock by a mixed civilian and military crew (about 70 percent civilian and 30 percent military). VTS San Francisco operates from the VTC, which is located on the highest point of Yerba Buena Island. The mission of VTS San Francisco is to ensure "safe, secure and efficient transit of vessels in San Francisco Bay, including its approaches and tributaries . . . ." Local waterways monitored by VTS San Francisco include the waters south of the Mare Island Causeway Bridge and the entrance markers of the Petaluma River, the San Joaquin River as far east as the Port of Stockton, the Sacramento River as far north as Sacramento, and all seaward approaches to the San Francisco Bay area. Because the area subject to VTS control is so large, it is divided into three sectors: the Offshore/Approaches sector, the Central Bay sector, and the Inland/Delta sector. Watch sections normally consist of three VTS controllers and a VTS watch supervisor. The three controllers rotate every 80 minutes through two control positions (one for the Offshore/Approaches and Inland/Delta sectors and one for the Central Bay sector) as well as through a third position, known as watch assistant, with the entire watch section being rotated every 8 hours.

According to the Coast Guard chief of the Waterways Management Division, the average length of employment for its VTS watchstanders is about 7 years. Coast Guard active duty members serve 3-year tours of duty, while civilian employee service is not bound by any particular tour length. (For information about the history of VTS, see Appendix B.)

Tests and Research

Propulsion and Steering System Evaluations

According to ship documents, the *Cosco Busan* crew conducted forward and astern main engine propulsion tests before departing the dock on the morning of the allision and recorded the engine as operating satisfactorily. The pilot who had taken the *Cosco Busan* out of Long Beach 2 days before the allision told Safety Board investigators that he had had no problems maneuvering the ship and that all equipment functioned normally. The pilot on board the *Cosco Busan* when the allision occurred also told investigators that he was not aware of any propulsion or steering problems with the vessel.

The steering gear system on the *Cosco Busan* was an electro-hydraulic twin ram design. Investigators tested the steering gear dockside on November 14, 2007, as part of the documentation of wheelhouse equipment. As a test of the steering gear functionality and its compliance with SOLAS requirements, investigators had the helmsman, at the wheelhouse steering station, enter a command for a hard-port-to-hard-starboard rudder movement. The rudder moved from hard-over port to hard-over starboard in 19 seconds, which was well within the maximum 28 seconds allowed under SOLAS.

SOLAS additionally requires that a vessel's steering gear be tested for proper operation no less than 12 hours before departure. According to ship's documents, the crew tested the steering gear at 0620 the morning of November 7, 2007, about 1.5 hour before getting under way and slightly more than 2 hours before the allision. The test result was logged as satisfactory.

A review of the *Cosco Busan*'s engineroom logbook from November 1 through 7, 2007, the week before the accident, revealed no indications of steering, propulsion, or engineering equipment failure or abnormalities. All rounds of the engine and steering spaces were reported as normal, and all tests of the propulsion and steering equipment during this period were documented as satisfactory.

The *Cosco Busan*'s engineroom electronic alarm logger was on the main operator's console in the engine control room. Investigators retrieved the alarms pages of the times surrounding the allision, and nothing on the records indicated a propulsion or steering malfunction.

Safety Board investigators reviewed the *Cosco Busan*'s chief engineer's night orders written between October 29 and November 7, 2007. (Night orders provide daily written instructions for engineroom watchstanders in regard to any problems or concerns the chief engineer might have about the operation of the engineering plant.) None of the night orders written during the week before the allision mentioned any significant problems regarding propulsion, steering, or machinery on board the vessel.

Radar Functionality and Testing

The VDR on board the *Cosco Busan* captured images from the 3-centimeter radar at about 15-second intervals. The recorded images allowed investigators to evaluate the radar's performance throughout the vessel's voyage on November 7, 2007, from the time the pilot and crew began tuning the radars shortly after the pilot arrived on board until the vessel allided with the bridge tower.

The images show that the ship's crew made numerous adjustments to the radar's range (from 0.75 to 3.0 nautical miles) and gain[97] settings over a period of about 1.5 hour before the ship sailed. During the April 2008, public hearing on the accident, the manager of product support and training for Sperry Marine was asked to comment on the radar adjustments. He said that, based on the radar settings as shown on the screen captures, the radar's sea and rain clutter adjustments were set to automatic and never changed while the radar was being tuned. Because the ship was at the dock, the radar was receiving strong signals from the shore that were being automatically dampened by the sea clutter feature. Thus, when *Cosco Busan* crewmembers increased the gain, they were attempting to enhance the radar returns at the same time the sea clutter feature was suppressing them. The result was a gain setting that was "really higher than it should be" according to the Sperry representative, who also said:

> While this [the high gain setting] never impacts the [radar's] ability to give a good picture, it does . . . give much more return on the display. What you'd see is things get a little larger, a little more clutter because the gain is up so high.

The Sperry representative said the normal procedure would be to turn the rain and sea filters all the way down before making any gain adjustments. Once these adjustments were made, the rain and sea filters could be restored if necessary. He stated that Sperry had no records indicating that the crewmembers of the *Cosco Busan* had been trained by Sperry in the proper use of the Vision 2100 VMS but that they could have been trained by a third-party vendor.

On November 12, 2007, Safety Board investigators arranged for the testing of the radar systems by a Sperry Marine service engineer. Among the tests done were a qualitative evaluation of the radar picture, a test of the radars' ability to acquire and track targets, the ability to display the proper bearing and range to targets, the ability to display the RACON on the Bay Bridge, and the quality of the gyro heading data. The magnetron current and power supply voltages were also tested. According to the service engineer, all the test results were normal, and the radars were operating correctly at the time of the testing.

Tests of the Electronic Chart System

In conjunction with the testing of the radar systems, the Safety Board requested that a Sperry Marine service engineer test the operation of the electronic chart system. According to the service report dated November 12, 2007, the correct chart was displayed by the VMS, and the three network nodes all had good data. The service report also stated that both gyro data and GPS data were available and selectable, that the VMS was providing the radar with good position data, and that all sensors were working. The service report concluded that the VMS was fully operational.

[97] The radar's *gain* may be compared to the volume control on audio equipment. Increasing the gain increases the visibility of radar returns, but too much gain can distort the images of targets that are large or close to the ship and can add confusing clutter to the display.

Review and Evaluation of Radar Images

The *Cosco Busan* pilot told investigators that about the time the vessel began its initial turn to port (about 0823), "the radar picture of the bridge got distorted. It got wider. The bridge got wider. The RACON never appeared." Investigators reviewed the radar images captured by the VDR and assessed the quality and consistency of the images that were displayed during the accident voyage (figure 13). This review revealed that the radar returns from the Bay Bridge did not change significantly from the time the bridge first became visible on the display about 0819 until about 0826 when the upper end of the bridge appeared to widen. The upper portion of the bridge appeared to widen on the radar image for about 1 minute before beginning to return to normal.

During the public hearing on this accident, the Sperry manager of product support and training reviewed the image and attributed the change in the bridge's appearance to the *Cosco Busan* being almost abeam of the bridge at that point, with the top section of the bridge providing a much stronger radar return because the radar was "shooting . . . [radiofrequency] energy directly into the girders . . . ." Figure 14 shows the radar image that was being displayed on the *Cosco Busan* at the time the radar image of the Bay Bridge became, in the words of the pilot, "distorted." After about 2 minutes, the entire bridge began to appear thinner on the radar screen as the ship approached the bridge and more of its radar waves passed beneath the bridge instead of being reflected back. The signature of the RACON transponder at the midpoint of the Delta–Echo span also appeared on the radar screen at regular intervals throughout the voyage.

Figure 13. (Top) Radar image displayed on the bridge of the *Cosco Busan* at 0822:44, just before the vessel turned to port, and (bottom) the radar image at 0826:14, just after the vessel made the turn to port. In the bottom image, note the identifier for the RACON at the center of the Delta–Echo span of the bridge.

PSP_007066

Figure 14. Radar image on board the *Cosco Busan* at 0827:14. According to investigators, 0827:14 was the time at which the upper portion of the bridge appeared the most enlarged on the radar image before returning to normal.

Chart Symbols

In a postaccident interview, the *Cosco Busan* pilot told investigators that, even though he typically saw as many as 10 different ECDIS systems during a work week, he had "never seen a red triangle on any piece of navigation information, electronic, paper or otherwise." The red triangles to which the pilot referred were the conical ("nun") buoys on either side of the Bay Bridge Delta tower.

The electronic charts in use on the *Cosco Busan* were C-Map CM-93 vector charts. Although the vessel's electronic chart system was not a certified ECDIS, the symbols used to signify conical buoys on the CM-93 charts were similar, if not identical, to the symbol for these buoys shown in the International Hydrographic Organization's (IHO's) *Presentation Library for ECDIS, Publication S-52, Appendix 2, Annex A*. The paper charts in use on the vessel also displayed conical buoys that appeared identical to those in the presentation library. Figure 15 shows the standard symbols for conical buoys used on IHO-compliant paper charts and on the CM-93 electronic charts (as well as on all ECDIS-certified S-57 charts).[98]

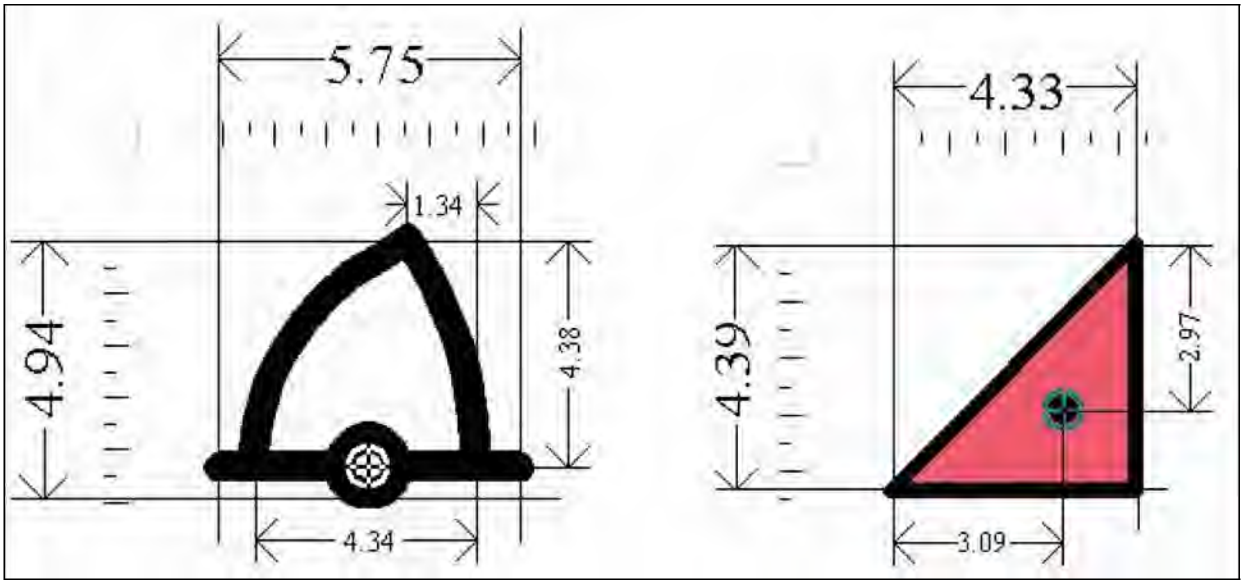

Figure 15. The International Hydrographic Organization (IHO) symbol used to represent conical buoys on paper charts (left) and the simplified symbol for the same buoys as represented, in red, on IHO S-57 electronic navigation charts (right).

Other Information

Postaccident Actions Involving the Board of Pilot Commissioners

Following the *Cosco Busan* allision, the Board of Pilot Commissioners for the Bays of San Francisco, San Pablo, and Suisun began a review of its medical oversight system. As of the date of this report, that assessment was still in progress. The pilot commission also examined its policy on pilot use of personal navigation devices (such as laptops) and recommended that all pilots be supplied with such equipment. The pilot commission also reviewed its training contract to assess whether to include enhanced training in advanced electronic navigation instruments, which, as of the date of this report, had not yet been determined. In November 2008, the pilot commission sponsored a meeting with other West Coast pilot oversight entities to discuss best practices and other issues related to pilot oversight.

Postaccident Actions Involving VTS

After the *Cosco Busan* incident, the Coast Guard's chief of Vessel Traffic Services, Office of Shore Forces, accelerated the formulation of "VTS National Standard Operating Procedures," or VTS NSOP, which are designed to standardize operations, personnel training

[98] Certified ECDIS charts must conform to *IHO Transfer Standard for Digital Hydrographic Data Edition 3.0–March 1996, Special Publication No 57* and to the symbol representations specified in the IHO S-52 presentation library. Charts that are in compliance with these standards are known as S-57 charts.

and certification, unit operation evaluation, and policy implementation at all VTCs operated by the Coast Guard. According to the Coast Guard's April 4, 2008, response to a report on the *Cosco Busan* allision by the Office of the Inspector General within the Department of Homeland Security,[99] the NSOP is now in final draft with adoption expected in the first quarter of 2009. When adopted, the NSOP will be distributed to the field for implementation.

Also after the accident, the San Francisco Bay Area Harbor Safety Committee (discussed in the next section), working in conjunction with the San Francisco Bar Pilots Association and the Coast Guard, developed updated low-visibility navigation guidelines. The enhanced "Restricted Visibility Guideline" was then incorporated into the local Harbor Safety Plan (HSP). Based on the new guidelines, VTS San Francisco developed a "low-visibility enforcement procedure" and a "low-visibility staffing policy." The low visibility enforcement procedure provides VTS operators with decision criteria and procedures for enforcing the local Harbor Safety Plan guidelines (discussed in the next section) governing vessel movement during restricted visibility. The policy identifies several "critical maneuvering areas" within the San Francisco Bay area in which the transit of any power-driven vessel of 1,600 gross tons or more or of any tug with a tow of 1,600 gross tons or more is restricted or controlled when visibility is reported to be less than 0.5 nautical mile.

According to senior VTS San Francisco personnel, the low visibility staffing policy was designed to complement the implementation of the low visibility enforcement procedure. The staffing policy redefined the role of the watch assistant from an administrative function to one that more effectively augments the Central Bay sector operator, the Ocean/Approaches and Inland/Delta sector operator, and the watch supervisor position. The policy has the watch assistant acting as operator or traffic manager for the area with low visibility, including adjusting radar range, re-scaling chart areas, and adjusting track vectors to optimize the traffic manager's view of the low-visibility area. The two new procedures were implemented at VTS San Francisco on March 28, 2008. VTS officials said these local procedures will not be incorporated in the VTS NSOP because each VTS develops its own procedures based on local conditions and in partnership with its respective port stakeholders.

VTS officials told the Safety Board that at the same time these low visibility procedures were implemented, VTS San Francisco increased its training focus in regard to elevating levels of traffic control, with specific emphasis on teaching operators how to migrate from the lower modes of traffic management (*monitoring* and *informing*) to, if needed, the more assertive levels of control (*recommending* and *directing*, which require watch supervisor approval). A separate requalification and recertification training program, implemented in September 2008, was developed to ensure that veteran VTS operators maintain their skill, including effective shore-to-ship communication, and their proficiency in all program and local policy guidance.

On September 18, 2008, the Coast Guard issued notice CG COMDTNOTE 5102 titled, "Vessel Traffic Service and Sector Command Center Watchstander Post Accident Drug Testing Policy." This notice requires that sector commanders, VTS directors, and SCC supervisors ensure that VTS and SCC personnel are subjected to drug testing if there is any reason to believe that

[99] Department of Homeland Security, Office of the Inspector General, *Allision of the M/V* Cosco Busan *with the San Francisco–Oakland Bay Bridge*, Report OIG 08-38, April 2008 (Washington, DC: 2008).

their performance could have been a contributing factor in an accident. The notice also mandates training to ensure that all personnel are aware of these requirements.

Harbor Safety Committee of the San Francisco Bay Region

History and Background. Spurred by the large oil spill off Huntington Beach, California, on February 7, 1990, when the tankship *American Trader* ruptured its hull with its own anchor, the California legislature enacted the Lempert–Keene–Seastrand Oil Spill Prevention and Response Act of 1990. The act mandated the creation of a Harbor Safety Committee (HSC) in the San Francisco Bay area and in other harbors within the state of California, with the stated purpose of developing recommendations "for the safe navigation and operation of tankers, barges, and other vessels within each harbor." The membership of the HSC of San Francisco Bay Region comprises key maritime stakeholders from both the public and private sectors who meet regularly, usually monthly, in a public forum. Maritime safety recommendations from the HSC and other guidance are captured in an HSP, which must be reviewed annually and submitted to the administrator of the DFG-OSPR for comment and acceptance.

Recommendations found in the HSP are considered "best practices" by all port stakeholders and are not enforceable unless such recommendations become either Federal or state regulations through the respective regulatory processes. All Federal regulations cited in the HSP are enforced by the Coast Guard, and all *California Code of Regulations* cited in the HSP are enforced by either the California State Lands Commission or the California DFG.

The HSC of the San Francisco Bay Region held its first meeting on September 18, 1991, and produced its first approved HSP on August 13, 1992. In accordance with state law, the HSC administrator is required to appoint a "representative of the pilot organizations within the harbor" and a "designee of the Captain of the Port from the United States Coast Guard, the United States Army Corps of Engineers, the National Oceanic and Atmospheric Administration (NOAA), and the United States Navy to the extent that each consents to participate on the committee."

Harbor Safety Plan for 2007. The HSP in place at the time of the allision was approved on June 14, 2007, and covered the San Francisco, San Pablo, and Suisun Bays. The HSP addressed various risks commonly encountered on the local waterways, including adverse weather. A section titled "Safety Considerations in Adverse Weather Conditions" included the following guidance:

> Reduced visibility during periods of fog requires that mariners observe caution. During reduced visibility, vessels may remain docked, reduce speed if underway or anchor in or near a channel to await improved conditions. Extra vigilance must be used in reduced visibility, particularly in or near navigation channels. Vessels within the Bay at a dock or at a safe anchorage should not commence movement if visibility is less than .5 nautical mile throughout the intended route, unless the operator's assessment of all variables is that the vessel can proceed safely. The operator's local knowledge should include an understanding of historic weather patterns during that time of year, current weather reports, and checking with reporting stations along the route. This guideline acknowledges that the Bay region is a series of bays and rivers, in-Bay distances are long and that there is not a single Bay region climate, but a series of microclimates with

variable fog. The Captain of the Port has the authority to prohibit movement of vessels within all or portions of the Bay during adverse weather conditions.

The HSP also outlined various outreach and partnership programs within the maritime community as a way of sharing "professional information in order to foster a team approach to the issue of navigation safety within the San Francisco Bay Area." One such effort was the VTS–Pilots Issue Committee, or VPIC. This committee, which comprises the VTS San Francisco operations director, Operations Center supervisor, training coordinator, and members of the San Francisco Bar Pilot Association, meets periodically to discuss how VTS and the pilots can better serve one another. HSC officials have credited the VPIC meetings, which serve as a forum in which both groups can review interactions from their respective points of view, with automating the exchange of information about vessel arrivals and departures and refining and enhancing the reports provided to mariners that pertain to construction in the San Francisco Bay area that may affect vessel movement.

National Contingency Plan

The Federal government's blueprint for responding to both oil spills and hazardous substance releases is the National Oil and Hazardous Substances Pollution Contingency Plan, or National Contingency Plan (NCP). The purpose of the NCP is to provide the organizational structure and procedures for preparing for and responding to discharges of oil into or on the navigable waters of the United States and to the releases of hazardous substances, pollutants, and contaminants that may endanger public health or threaten the welfare of the United States. The NCP was originally published in 1968 as a result of the country's efforts to develop a national response capability and promote overall coordination among the hierarchy of responders and contingency plans. The plan was revised in 1994 to reflect the oil spill provisions of the Oil Pollution Act of 1990 (OPA 90).

Regional Contingency Plans

Regional Contingency Plans (RCPs) are guidance documents implemented in conjunction with the NCP for government agencies and non-government organizations that respond jointly to oil spill emergencies. In the states of Arizona, California, and Nevada, and the 146 tribal nations, the Federal Region 9 RCP is the reference guide for coordinating responses to hazardous materials releases, including oil spills, as mandated by Section 300.205 of the NCP. It is intended for use by local, tribal, state, and Federal emergency response personnel as a tool for obtaining the resources necessary to respond to an oil or hazardous materials incident. It outlines the response mechanisms that would be activated among the various levels of the response community in the event of an emergency situation. It is intended to coordinate with local plans and build on the mechanisms set forth in state emergency response plans.

According to the RCP, the national standard for incident management adopted by the Coast Guard is the National Incident Management System (NIMS) Incident Command System (ICS). The ICS includes five management functions: incident command, operations, planning, logistics, and finance, not all of which may be necessary for a particular incident. In the event that multiple agencies have jurisdictional responsibility for an incident, a Unified Command, representing joint decision-making authority, is incorporated into the ICS to allow these agencies to work together to develop a common set of objectives and strategies and to manage the incident. According to Appendix VII (B) of the RCP, which discusses the California State Response System specifically, the Unified Command would consist of the Coast Guard, DFG-OSPR, and the responsible party's representative who serves the role of incident commander.

Section 2002 of the RCP describes the Unified Command structure as one that brings Federal and state agencies and the responsible party together to achieve an effective and efficient response. Within this structure, the FOSC holds the ultimate authority for all decision-making related to the response and has responsibility for worker health and safety. Section 2004 of the RCP explains the shared command response authorities on the Federal and state level. Pursuant to the NCP and OPA 90, for all responses under their jurisdiction, the FOSC assumes the role of the Federal incident commander. On the state level, the plan discusses the roles of California DFG and OES and indicates that DFG shall serve as the state incident commander or SOSC when natural resources are at risk.

The responsibilities of the FOSC are discussed in detail in Section 2005 of the RCP. The plan explains the role of the FOSC as directing Federal response efforts and coordinating other Federal efforts at the scene of a discharge or release, ensuring adequate oversight of response actions, and, if the FOSC determines that the response is not timely and effective, to take over, or federalize, the response. The RCP lists 10 specific FOSC responsibilities. These responsibilities include notifying appropriate state and Federal agencies, determining whether appropriate response actions have been initiated, collecting information concerning the discharge or release, coordinating efforts with appropriate Federal, state and local agencies, consulting with and informing Regional Response Team members via pollution reports, implementing community relations activities, and addressing worker health and safety issues both before and during the response. The RCP does not discuss the specific responsibilities of the state incident commander and the responsible party.

Area Contingency Plans

Area Contingency Plans (ACPs) are guidance documents implemented in conjunction with the NCP and RCP for government agencies and non-government organizations that respond jointly to oil spill emergencies. Area committees comprising representatives from Federal, state, and local agencies develop their area-specific ACP for response to a discharge of oil or hazardous substance in their areas under the direction of the FOSC and in accordance with Section 4202 of OPA 90. The Coast Guard is responsible for designating areas, appointing area committee members, determining the information to be included in the ACP, and approving the final plan.

The state of California has six area committees, each of which is responsible for developing its own ACP. The San Francisco and Delta Bay Area Committee is responsible for an area of the bay designated as ACP-2.

ACP-2 references the parallel command sections of the RCP discussed above for guidance. As mentioned, the plan identifies the Unified Command structure and provides guidance for setting immediate response objectives. It also provides guidance for recovering released substances and addresses emergency response operations, including overflights and staging areas for response equipment. The plan also addresses Coast Guard communications capabilities and the use of the Coast Guard Safety Support Center and Pacific Strike Team.

National Preparedness for Response Exercise

The National Preparedness for Response Exercise Program (N-PREP) was developed to establish a workable exercise program that meets the intent of Section 4202(a) of OPA 90 and to satisfy the exercise requirements of the Coast Guard, the Environmental Protection Agency (EPA), the Pipeline and Hazardous Materials Safety Administration, and the Minerals Management Service. ACP holders are required to follow N-PREP guidelines, which establish a minimum level of response preparedness. The N-PREP requires that every 3 years, all components of ACP, including Federal, state, local government, and industry, participate in an exercise to observe the response infrastructure and assess the ability of the entire response community to effectively conduct a spill response.

The most recent area exercise conducted before the *Cosco Busan* allision was the Safe Seas 2006 exercise held between July 10 and August 10, 2006. This multi-agency effort included ICS training and a tabletop exercise, short courses, and a full-scale exercise and field deployment, and focused on a simulated oil spill resulting from a hypothetical marine casualty. Among the key objectives of Safe Seas 2006 were to evaluate the ability to make the notifications identified in the ACP before establishing the Unified Command and to evaluate the ability to establish a Unified Command and complete the planning cycle through the planning meeting. Other major objectives were to demonstrate the ability to conduct initial vessel assessments and develop appropriate plans, to conduct initial environmental assessments and develop appropriate plans, to deploy equipment, to assess environmental conditions, to protect environmentally sensitive areas, and to treat spilled oil.

Several participants in the *Cosco Busan* response, including the Coast Guard, DFG–OSPR, and MSRC, attended the Safe Seas 2006 exercise. The only local agencies that chose to participate in the exercise were the San Francisco Office of Emergency Services and the Alameda County Sheriff's Department. The exercise participants reported several positive outcomes, including good interagency coordination, cooperation, and communications. However, Coast Guard Sector San Francisco observed that, with regard to the Unified Command, some disagreement arose during the exercise regarding the inclusion in the Unified Command of jurisdictional authorities beyond the FOSC, the state of California, and the responsible party. The disagreement stemmed from conflicting interpretations of plans and/or conflicting guidance and the RCP. Both NOAA and the U.S. Department of the Interior asked to participate in the Unified Command because of their jurisdictional authority and because of their perception that they were not getting sufficient information during the exercise. In response to this issue, Sector San Francisco made the following recommendation to the Regional Response Team:

> The Regional Response Team (RRT) should continue to examine guidance from the Department of Homeland Security and the National Response Team regarding the composition of the Unified Command to determine if the ACP or RCP require revision. Prior to implementing Unified Command composition changes to these plans, the RRT should consult with the Area Committees and EPA and USCG FOSCs to ensure that their

> concerns are addressed. If this is also an issue for other regions, the RRT should consult with the National Response Teams and/or NIMS Integration Center for clarification and alignment. The role of jurisdictional authorities in the Unified Command should be included in ICS training classes and materials.

When interviewed by Safety Board investigators, some local county emergency service organizations expressed concern that a similar issue resurfaced on the second day of the response to the *Cosco Busan* oil spill when the counties failed to receive adequate information. The counties requested to become members of the Unified Command, but they were ultimately not included.

California Local Jurisdiction Response Plans

In 1993, the Office of Spill Prevention and Response of the California DFG instituted a grant program that allowed California counties that are adjacent to marine waters to apply for funding to be used in the development and maintenance of local oil spill contingency plans. The objective of this voluntary program was to "encourage local governments to complete, update or revise an oil spill contingency plan element and to help provide a coordinated response and cleanup effort between local governments and state and Federal officials in order to provide the best achievable protection of the California Coast." Counties that applied for grant funding were initially awarded $50,000 to be used in developing the plan, with an additional $5,000 to be made available annually to offset expenses associated with participation in planning activities and keeping the plan up to date. The plans were required to be updated at least every 3 years.

The San Francisco Bay area encompasses portions of Marin, Sonoma, Napa, Solano, Sacramento, San Joaquin, Contra Costa, Alameda, Santa Clara, San Mateo, and San Francisco counties. According to DFG–OSPR, with the exception of Napa, Sacramento, Santa Clara, and San Joaquin, each of the counties applied for and received $50,000 to develop a local oil spill contingency plan. San Joaquin County attempted to participate in the program in 2000, but the plan it submitted did not meet requirements and was not approved. The county made no further attempt to submit a plan. According to DFG–OSPR, several of the counties that originally applied for the $50,000 grant have not since applied for funding to maintain the plans.

The local government grant coordinator for DFG–OSPR said that San Francisco, Marin, Solano, and Sonoma counties have the most current oil spill contingency plans in the San Francisco Bay and Delta area, meaning that they have been updated in the last 3 years. Alameda, Contra Costa, and San Mateo counties have not updated their local plans since their initial development in 1995-96.

Postaccident Actions of California DFG–OSPR

Representatives of the California DFG–OSPR informed the Safety Board of a number of actions the agency has taken since the *Cosco Busan* allision. Those actions are summarized below.

Response. DFG–OSPR is beginning the process of changing the oil spill response time regulations for vessels operating in high-traffic ports (San Francisco Bay and Los Angeles/Long

Beach). The current response time of 6 hours will be shortened. Oil spill response organizations will have to show that they can meet the updated standard.

Notifications. The California OES changed its protocol for notification of local governments potentially affected by an oil spill. Counties adjacent to an oil spill are now notified. DFG–OSPR is working with the OES to ensure that the most current and accurate spill information is provided to the Warning Center for dissemination to local government responders.

Spill Quantification. DFG–OSPR hired an additional oil spill prevention specialist who has extensive experience in gauging marine vessel tanks and quantifying oil spills. The office is also developing a joint protocol and memorandum of understanding with the Coast Guard outlining their respective roles in quantifying spills during emergency response. In conjunction with its regular vessel boardings and inspections, DFG–OSPR has been ensuring that vessel masters and chief engineers are cognizant of spill quantification and reporting procedures as required by California *Code of Regulations*.

Planning. Changes to the San Francisco ACP were presented for adoption at the Area Committee meeting on July 15, 2008. The Area Committee is co-chaired by DFG-OSPR and the Coast Guard. The changes included pre-identifying incident command posts in the San Francisco Bay area, using volunteers, updating sensitive site-protection strategies, and updating inventory of response equipment/resources in the San Francisco Bay area.

Postaccident Actions of U.S. Coast Guard and Department of Homeland Security

On November 19, 2007, the Coast Guard issued ALCOAST[100] 541/07, “Coast Guard Environmental Incident Response Doctrine,” as a result of the *Cosco Busan* accident. ALCOAST 541/07 addresses the initiation of an incident-specific preparedness review (ISPR) and several aspects of environmental response doctrine, including local preparedness and response policies. The “Initial Response and Investigation Actions” section of ALCOAST 541/07 states that the FOSC/incident commander should plan and execute initial response actions based on the maximum potential spill volume, which, for a vessel, would be the entire cargo/fuel capacity of the damaged tank(s). According to the chief of the Marine Investigation Division at Coast Guard headquarters, this guidance will eventually be included in the Coast Guard’s *Incident Management Manual*; until then, the ALCOAST remains in effect.

As addressed in ALCOAST 541/07, the Coast Guard chartered a postaccident ISPR to examine the Unified Command’s response to the *Cosco Busan* accident. The review team consisted of representatives of Federal, state, and local agencies; environmental organizations; the shipping industry; and a non-government major stakeholder in oil spill preparedness and response.[101] The review team identified 33 preparedness and 57 response focus issues that

[100] ALCOAST (All Coast Guard) messages are a subset of general messages that are dispatched electronically through the Coast Guard messaging service. They are rapid-response information vehicles that can, as with ALCOAST 541/07, contain policy guidance.

[101] United States Coast Guard, Incident Specific Preparedness Review (ISPR): M/V Cosco Busan *Oil Spill in San Francisco Bay*, *Report on Initial Response Phase*, January 11, 2008, and Part 2 and *Final Report*, May 7, 2008. The review team charter members included representatives of the Coast Guard, NOAA, state of California OSPR, Pacific States/British Columbia Oil Spill Task Force, California Coastkeeper Alliance, San Francisco Baykeeper, Pacific Merchant Shipping Association, and the San Francisco Department of Emergency Management.

covered a range of topics, many of which were beyond the scope of the Safety Board's investigation into this accident, such as the use of volunteers to clean beaches, locating the incident command post, and the rescue of oiled wildlife.

The team examined event logs and prepared a timeline for the first 24 hours of the response. The team interviewed members of the Unified Command, oil spill response organizations, and other Federal and state personnel who participated in the response. The review team issued its initial response phase report on January 11, 2008, and its final report on May 7, 2008, along with 190 recommendations that were directed to Federal, state, and local agencies. The Coast Guard chief of staff directed headquarters offices to consider the recommendations, the lessons learned, and to advise on implementation strategies.[102]

A major theme of the report was the need to improve interagency partnership and communication. Many of the team's recommendations related to local participation in area contingency planning and better coordination and integration of local resources in appropriate ICS positions for future spill response incidents. The team also made five recommendations relating to spill volume quantification, including the need for professional spill quantification personnel and responder training and for ensuring that the FOSC is aware of the most current spill quantity estimates.

The Office of the Inspector General (OIG) of the Department of Homeland Security, in its investigation of this accident also reviewed the performance of the Coast Guard's marine casualty and pollution investigation and the response activities during the first 24 hours after the accident. The report of that investigation (released in April 2008) made nine recommendations to improve the effectiveness of VTS operations, post-casualty investigations, and ACPs. The report recommended that the Coast Guard clarify its role and responsibility and employ experts or upgrade its investigator training in quantifying the volume of pollutants resulting from marine casualties or pollution mishaps. The Coast Guard concurred with the recommendation in part, acknowledging the need for updated spill quantification training; however, the Coast Guard believed that it should update contingency plans to ensure that qualified persons are available to assist in quantifying the volume of oil spilled. The OIG responded that the Coast Guard's suggested change to the recommendation does not require the Coast Guard to clarify its role and responsibility, and therefore the OIG did not revise its recommendation.

The OIG further recommended in its report that the Coast Guard ensure that its quick response checklists are current and accurately reflect the ACP and that watchstanders and supervisors receive recurrent training in the use of the checklists. Although the Coast Guard watchstanders made the required notifications on the day of the accident, these events were not documented on a checklist.

[102] Coast Guard Chief of Staff VADM Robert Papp, ALCOAST message 045/08, regarding *Cosco Busan* ISPR results, January 28, 2008.

Nontank Vessel Response Plans

The Coast Guard and Maritime Transportation Acts of 2004 and 2006 (CGMTA 2004 and 2006) amended 33 *United States Code* 1321(a) and (j)[103] to require owners and operators of nontank vessels to prepare and submit to the Coast Guard plans for responding to a worst-case oil discharge, or to a substantial threat of such a discharge, from their vessels. The 2004 act mandated that the Coast Guard issue regulations requiring that nontank vessel response plans be prepared and submitted to the Coast Guard by August 8, 2005 (1 year after enactment of CGMTA 2004).

To assist the maritime industry in preparing the plans and complying with the deadline for submission, the Coast Guard, on February 4, 2005, published NVIC No. 01-05, “Interim Guidance for the Development of Response Plans for Nontank Vessels,” which provided guidance for ship owners/operators who wished to voluntarily submit their plans before the regulations requiring them took effect. The NVIC was not itself enforceable.

In the regulatory area, the Coast Guard published “Nontank Vessel Oil Response Plans Notice and Request for Comments” in the *Federal Register* on June 17, 2005 (70 FR 36649). Because of the length of time needed to receive and consider public comment on the proposed regulations, the Coast Guard anticipated that final regulations would not be in place by the August 8, 2005, deadline. Consequently, the Coast Guard determined that it would not enforce the 2004 act until regulations were issued and in effect.[104]

With the continued absence of nontank vessel response plan regulations, the Coast Guard, on January 13, 2006, published NVIC No. 01-05 Change-1. The revised guidance provided that vessels that were required to have a Shipboard Oil Pollution Emergency Plan (SOPEP) could combine those plans with their nontank vessel response plan.[105] Also, owners or operators of vessels that were already required to have approved vessel response plans (tank vessels) could add their nontank vessels to those plans as long as the information in NVIC 01-05 is provided. The revised guidance suggests that planning for high-volume ports, such as the Port of San Francisco, should account for response equipment necessary to address a worst-case discharge.[106] The guidance dictates that response equipment should be capable of arriving on scene within 12 hours and should be en route to the scene of a discharge within 2 hours of notification.

In accordance with NVIC 01-05, on October 15, 2007, Fleet Management added the *Cosco Busan* to its nontank vessel response plan, which has been on file with the Coast Guard since February 15, 2005. In addition to the *Cosco Busan*, this plan included 76 other vessels operated by the company.

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[103] Federal Water Pollution Control Act.

[104] United States Coast Guard, Commandant Message to All Coast Guard (ALCOAST 398/05), August 1, 2005.

[105] In general, all oil tankers over 150 gross tons and all other ships over 400 gross tons must carry an approved SOPEP.

[106] Worst-case discharge is defined in 33 CFR 155 as a discharge in adverse weather conditions of a vessel’s entire fuel capacity.

On August 21, 2008, the Coast Guard issued Marine Safety Information Bulletin 71-08, stating that the Coast Guard would, effective August 22, 2008, begin enforcing the requirement for nontank vessel owners and operators to prepare and submit plans for responding to a worst-case oil spill from their vessels:

> Effective August 22, should a nontank vessel be found operating in a U.S. port or waterway without a properly submitted response plan, the cognizant Coast Guard Captain of the Port will exercise authority under the Ports and Waterways Safety Act of 1972 and impose operational controls, as necessary, on the vessel to safeguard the port.

IMO Initiatives Regarding Bunker Fuels

MARPOL 73/78. The IMO, headquartered in London, is a United Nations agency that promulgates international regulations directed toward the safety and security of shipping and the prevention of marine pollution caused by ships. The IMO exists to develop conventions, codes, and guidance to be used or implemented or to be overseen by maritime regulators or by its member states.

The IMO's *International Convention for the Prevention of Marine Pollution from Ships* is referred to as MARPOL 73/78. The original MARPOL convention was signed in 1973 but never took effect. It was later incorporated into a subsequent convention, adopted in February 1978, that became known as MARPOL 73/78. After ratification, MARPOL 73/78 became effective on October 2, 1983.

MARPOL 73/78 now comprises six annexes addressing the various types of pollution caused by ships:

Annex I - Oil
Annex II - Noxious Liquid Substances carried in Bulk
Annex III - Harmful Substances carried in Packaged Form
Annex IV - Sewage
Annex V - Garbage
Annex VI - Air Pollution

Until recently, Annex I, covering oil pollution, had not regulated the location of fuel (bunker) tanks on cargo vessels so as to protect them from external damage. An amendment to MARPOL Annex I addressing this issue was adopted in October 2004 and, after ratification, took effect in January 2007.

The amendment consists of the new regulation 12A in Annex I, which applies to all ships with an aggregate fuel oil capacity of 600 cubic meters (158,500 gallons) or more. "Fuel oil" in the regulation is defined as "any oil used as fuel in connection with the propulsion and auxiliary machinery of the ship in which such oil is carried." "Bunker tanks" are defined as tanks "in which fuel is carried, but excludes those tanks which would not contain fuel in normal operations, such as overflow tanks." The regulation does not apply to bunker tanks with a capacity of less than 30 cubic meters (7,925 gallons).

Under the regulation, no one bunker tank can exceed 2,500 cubic meters (660,425 gallons) in capacity. The regulation also contains language for the protection of valves and piping to and from bunker tanks.

Regulation 12A offers ship designers two alternatives for locating a ship's bunker tanks to comply with its requirements. The first option calls for double-hull protection for the bunker tanks regardless of whether the tank is located on the side or bottom of the ship. The regulation stipulates how far inboard of the shell plating each bunker tank boundary must be located to keep it from being damaged during a vessel casualty.

The second alternative is performance-based and calls for the ship's design to "comply with the accidental oil fuel outflow performance standard" specified in the regulation. Using this standard, ship designers should locate a bunker tank in the ship's hull based on the probability that the tank will be holed if the ship is involved in a grounding, collision, or allision. The formulae used in this alternative take into account such parameters as fuel oil density, the volume of fuel in the tank, and the tank's location in the hull. From these calculations, both the probability of the tank's being breached and the probability of its further leaking fuel are accounted for. According to testimony given by an American Bureau of Shipping spokesperson during a U.S. Senate hearing before a subcommittee of the Committee on Commerce, Science and Transportation on March 4, 2008, the IMO developed the second alternative "in order to give designers the freedom to optimize fuel tank arrangements and to deal with the design constraints encountered in different ship types."

Regulation 12A affects ships delivered on or after August 1, 2010, and those under contract on or after August 1, 2007. While the regulation is not retroactive and does not require existing ships to protect their bunker tanks, existing ships will have to comply if they undergo a "major conversion" as defined in the regulation. As with new ships, the regulation will apply to vessels under contract for a major conversion after August 1, 2007, or having a conversion completion date after August 1, 2010.

Bunker Convention Covering Pollution Damage Liabilities. No IMO treaties cover liability and compensation for pollution damage caused by bunker oil from ships other than tankers. This changed when the IMO's *International Convention on Civil Liability for Bunker Oil Pollution Damage*, adopted in 2001, took effect on November 21, 2008.

The *International Convention on Civil Liability for Bunker Oil Pollution Damage* makes insurance compulsory for ships greater than 1,000 registered tons. Such vessels will "be required to maintain insurance or other financial security, such as the guarantee of a bank or similar financial institution, to cover the liability of the registered owner for pollution damage . . . ." Limits of liabilities are defined in the text of the convention. Under the requirements of the convention, ships will be required to carry a certificate attesting to their holding insurance or other financial security that meets the provisions of the convention.

The convention will make the ship owner liable for compensating damage caused by spilled bunker oil as well as post-spill measures necessary to minimize or prevent the pollution damage. The term "ship owner" in the convention is defined as "the owner, including the registered owner, bareboat charterer, manager and operator of the ship."

Previous Safety Board Action Regarding Mariner Medical Review

On October 15, 2003, the Staten Island Ferry *Andrew J. Barberi* allided with a maintenance pier as the ship completed a regularly scheduled trip from Manhattan to Staten Island. Eighty-one passengers and crew were injured in the accident, 11 of them fatally.[107] As a result of the accident, which the Safety Board attributed primarily to the unexplained incapacitation of the assistant captain, the Board made the following safety recommendations to the Coast Guard:

> M-05-4
> Revise regulation 46 CFR 10.709 to require that the results of all physical examinations be reported to the Coast Guard, and provide guidance to mariners, employers, and mariner medical examiners on the specific actions required to comply with these regulations.
>
> M-05-5
> In formal consultation with experts in the field of occupational medicine, review your medical oversight process and take actions to address, at a minimum, the lack of tracking of performed examinations; the potential for inconsistent interpretations and evaluations between medical practitioners; deficiencies in the system of storing medical data; the absence of requirements for mariners or others to report changes in medical condition between examinations; and the limited ability of the Coast Guard to review medical evaluations made by personal health care providers.

On May 18, 2005, the Coast Guard responded that, while it did not commit to revising 46 CFR 10.709, it did agree to review its medical oversight process, “focusing on those areas identified by the Board.” The Coast Guard expressed its support for Safety Recommendation M-05-4 and indicated that it would analyze the needs and resources required to implement the recommended rule change. It added that it anticipated providing guidance “on any new medical review requirements . . . through an [NVIC].” Based on this response, the Safety Board classified Safety Recommendations M-05-4 and -5 “Open—Acceptable Response” on August 24, 2005.

The Safety Board next received written communication from the Coast Guard regarding Safety Recommendations M-05-4 and -5 after the Board wrote to the Coast Guard commandant on May 23, 2008, formally requesting an update of the Coast Guard’s plans to address the recommendations. In a June 20, 2008, e-mail, the Coast Guard informed the Board that it had taken the following action with regard to M-05-4:

> . . . we published a notice in the *Federal Register* (71 FR 56999) through which we exercised the existing authority in 46 CFR 10.709 to require all first class pilots on vessels greater than 1600 gross registered tons (GRT), and other individuals who “serve as” pilots on certain types of vessels greater than 1600 GRT, to provide a copy of their

[107] One passenger died more than 30 days after the accident from injuries received in the accident. Her death is included among the 11 killed in the accident. See National Transportation Safety Board, *Allision of Staten Island Ferry* Andrew J. Barberi*, St. George, Staten Island, New York, October 15, 2003,* Marine Accident Report NTSB/MAR-05/01 (Washington, DC: NTSB, 2005).

> annual physical examination to the Coast Guard. Included in the notice were specific instructions for the submission of the reports of physical examination to be followed to comply with the regulations.

The Coast Guard had also indicated in its May 18, 2005, letter that it had already implemented several changes in its mariner medical oversight system. A review of the Coast Guard's medical oversight system was led by its senior medical officer, trained in occupational medicine, in consultation with industry through the Merchant Marine Personnel Advisory Committee (MERPAC). The Safety Board, at the Coast Guard's invitation, sent investigators to observe MERPAC meetings in which proposed changes to its medical review system were discussed. At the time of the *Cosco Busan* allision, the Coast Guard's review had not been completed, although, as discussed earlier in this report, the Coast Guard was in the process of centralizing its medical license review process, which was one of the improvements made in response to Safety Recommendation M-05-5. Other improvements, including listing medications and medical conditions that call for additional documentation and medical review, were to be included in a new NVIC, which had not been completed at the time of the *Cosco Busan* accident.

On September 15, 2008, the Coast Guard released the new NVIC, numbered 04-08, which became effective on October 29, 2008. The new NVIC provides more medical information to health practitioners performing mariner medical evaluations than was contained in NVIC 02-98 and specifically lists numerous medical conditions that call for additional information and medical review. Enclosure 4 of the new NVIC also contains the following information regarding medication use:

> Credential applicants who are required to complete a general medical exam are required to report all prescription medications prescribed, filled or refilled and/or taken within 30 days prior to the date the applicant signs the CG-719K or approved equivalent form. In addition, all prescription medications, and all non-prescription (over-the-counter) medications including dietary supplements and vitamins, that were used for a period of 30 or more days within the last 90 days prior to the date that the applicant signs the CG-719K or approved equivalent form, must also be reported.
>
> Use of certain medications is considered disqualifying for issuance of credentials. The underlying cause or need for use of these medications and potential side effects may result in denial of a credential application or require a waiver.

NVIC 04-08 does not call for mariners to report to the Coast Guard changes in their medications or conditions between examinations. With regard to the centralization of the review of mariner medical evaluations under the supervision of a physician trained in occupational medicine, the Coast Guard has reported that the final regional examination center completed the transition to the centralized review in April 2008.

Analysis

This analysis begins with a summary of the accident sequence, followed by a discussion of those factors that were found to be neither causal nor contributory to the accident. The balance of the analysis will address the accident sequence and pre- and postaccident events, with emphasis on the following safety issues:

- Medical oversight of the *Cosco Busan* pilot;
- Medical oversight of mariners in general;
- Guidance for VTS operators in exercising authority to manage traffic;
- Procedures for improving the assessment of oil spills in California waters; and
- Training and oversight of the *Cosco Busan* crew.

The Accident

The *Cosco Busan* was scheduled to depart berth 56 in the Port of Oakland at 0700 on November 7, 2007. About 0620, the San Francisco Bar pilot who was assigned to navigate the vessel from the berth to the sea reported on board and within a few minutes was greeted by the master. The harbor was experiencing dense fog at the time, and the master immediately asked the pilot if the ship would be able to depart. The pilot answered that they would talk about it and see how the visibility developed.

The pilot handed the master a San Francisco Bar Pilots pilot card and received from a crewmember a copy of the vessel's pilot card. He then began working with members of the bridge team to adjust the vessel's radars with regard to scale and target acquisition. As the pilot stated was his usual practice, he set the radar's VRM at 0.33 nautical mile as a reference for his approach to the Bay Bridge. He said that maneuvering the vessel to keep the VRM ring on the edge of Yerba Buena Island would bring the ship to the center of the bridge span.

About 0650, after testing the ability of the radars to track vessels in the harbor, the pilot told the master that they would wait until an incoming tug and barge had cleared the channel, then "we should be able to go." About a minute later, he told the master to stand by and be prepared to "single up" (reduce the number of mooring lines in preparation for getting under way) as soon as the other vessels cleared the channel. The pilot then contacted VTS and informed the VTS operator of his plans to depart as soon as an incoming barge had passed and some paperwork was finished.

About 0721, the pilot told the master that he could single up if he wished, and the master agreed. After some additional pre-departure activities, the vessel moved away from berth 56 about 0800 with the aid of the tractor tug *Revolution* on the port quarter pulling with one line while the ship used its bow thruster. Once away from the dock, the pilot, as he had planned, had the *Revolution* shift to the stern where it would trail the *Cosco Busan* on a slack line "just for insurance" until the containership had exited the entrance channel and was through the Bar Channel.

Except for the fog at the time of departure, the transit from letting go of the lines at the dock to entering the Bar Channel, a distance of about 1.5 nautical miles, was uneventful. The path out of the entrance channel was essentially a course down the middle of the channel, which was charted as 286° true. About 0820, with the vessel making good a course of 280°, the pilot ordered an increase in engine speed to half ahead. The speed and steering course at that time were appropriate to account for the 1-knot flood current that the pilot had anticipated and that would affect the ship after it left the entrance channel.

According to the VDR transcript, about 0822, the pilot asked the master about the "red triangles"—as he referred to them—on the electronic chart display of the vessel's transit area. Though the pilot said later that he had never seen such symbols, the red triangles were standard representations of the navigation buoys on either side of the Delta tower of the Bay Bridge. When asked about the meaning of the red triangles, the master said, "this is on bridge." This was the first conversation that the VDR recorded having to do with the red triangles.

About this time, the pilot would have been expected, based on his arrangement with the tug master, to release the tug *Revolution*. The containership had successfully cleared the entrance channel and the Bar Channel, so the assistance of the tug was no longer required. Also, the pilot was aware that the tug master had another assignment at 0830. But the pilot did not release the *Revolution* at that time and, in a postaccident interview, acknowledged having forgotten all about the tug during the voyage. The tug was finally released after the *Cosco Busan* reached the anchorage shortly after the allision.

About 0823, the pilot began a left turn to the southwest by ordering 10° port rudder. This was an appropriate order as the vessel needed to jog slightly to the south and west in order to shape up for its next turn to the right, which would take it through the Delta–Echo span of the Bay Bridge. But based on the radar image of the VRM ring, which the pilot said he used to help maintain his ship's position in relation to the bridge, the vessel was too far north, and the port 10° port rudder may not have been enough to swing it sufficiently left to allow it to set up properly for the next turn.

The pilot said that, as the vessel made this turn, the radar image became "distorted" to the extent that he could not identify the bridge piers. The pilot also said that he did not see on the radar display the signature of the RACON at the center of the Delta–Echo span. The accident investigation later determined that the RACON was working and that its identifier was being displayed regularly. The pilot said that he decided the radars were not reliable. Instead, he would use the electronic chart and "aim" for the "red triangles" that he and the master had discussed earlier.

About 0825, the pilot ordered the rudder to mid-ships as the vessel was swinging to port, and he ordered the helmsman to steer 245°. Less than a minute later, the pilot ordered 10° starboard rudder, then starboard 20. He ordered the engine to full ahead. At that point, the entire starboard side of the vessel would have been exposed to the flood current, which could have been setting the vessel with greater force to the south than the pilot realized, especially considering that his normal visual references were obscured by fog.

About 0827, the VTS operator who was monitoring traffic in the Central Bay Sector noticed on his display that the *Cosco Busan* had moved farther to the south than would be expected and that the vessel appeared to be out of position to make a transit through the Delta–Echo span. The VTS operator radioed the pilot and informed him that the VTS display was showing the *Cosco Busan* on a “heading” of 235°. During this transmission, but before being informed of his apparent heading, the pilot ordered the rudder eased to 10°. The operator asked the pilot if he still intended to use the Delta–Echo span. The pilot answered in the affirmative, but he later acknowledged having been confused by the call from VTS. He had given helm commands that were turning the vessel to starboard to a heading of 280° (according to the VDR, the ship’s heading at that time was, in fact, 262°), and he could not understand the VTS report that his vessel was on a heading of 235°. In fact, VTS was reporting the vessel’s course over ground, not its heading. While on the radio with VTS, the pilot again ordered the rudder to starboard 20. After confirming with a crewmember, probably the master, that the red triangles indicated the “center of the bridge,” he then ordered hard starboard.

During the next 1.5 minutes, the pilot made rudder orders for mid-ships, starboard 20, and hard starboard. When the Delta tower of the bridge came into view through the fog, the pilot ordered the rudder to mid-ships, then hard port. The order for hard port rudder was likely made in an attempt to avoid the allision or reduce its severity by moving the stern away from the bridge tower. After the vessel allided with the tower fendering system, the pilot immediately called VTS by VHF radio and informed operators of the allision and that he was proceeding to anchorage 7.

As the vessel was on its way to the anchorage, the VDR recorded a discussion between the pilot and the master about the red triangles. It is clear from this conversation that the pilot had believed that the red triangles marked the center of the Delta–Echo span when they were actually the nun buoys on either side of the Delta tower.

Exclusions

A few days after the accident, Safety Board investigators boarded the *Cosco Busan* at anchor and examined and tested the steering gear, the engine order telegraph, and associated equipment. All were found to be working satisfactorily, and a review of the equipment logs and records showed no indication of a previous defect that might have affected the *Cosco Busan* on the day of the allision. Safety Board investigators arranged for the testing of the radar systems by a Sperry Marine service engineer who determined that all the test results were normal, indicating that the radars were operating as designed at the time of the testing. In conjunction with the testing of the radar systems, the Safety Board had a Sperry Marine service engineer test the operation vessel’s VMS, which included a test of the electronic chart system. According to the service report, the correct chart was displayed by the VMS, and the three network nodes all had good data. The service report also stated that both gyro data and GPS data were available and selectable, that the VMS was providing the radar with good position data, and that all sensors were working. The service report concluded that the VMS was fully operational.

According to the VDR data and audio recordings, all steering and engine orders given by the pilot to members of the bridge team were answered and carried out accurately and in a timely manner. VDR data also showed that the pilot had waited to depart until all tug and barge traffic had safely passed his position in the entrance channel and that the *Cosco Busan* encountered no harbor traffic from the time it departed the berth until it allided with the tower.

Examination of radar images captured by the VDR showed that the RACON positioned at the midspan of the Bay Bridge between the Delta and Echo towers was broadcasting the correct Morse code designator before and after the allision. Before the allision, neither the Coast Guard nor Caltrans had received reports of a malfunction of the RACON, and postaccident inspection confirmed that the RACON was operating properly.

The wind was calm at the time the *Cosco Busan* departed its berth, as is often the case in conditions of dense fog. As the vessel left the dock, it was sailing out into the last of the flood stage of the tide and would be stemming into (running against) about a 1-knot current.

While under way from the berth and through the transit until the allision, the vessel's bosun was maintaining lookout on the bow. He communicated with the navigation bridge using a handheld radio and was available to respond in the event the anchors were needed. The first alert recorded by the VDR of the close approach to the Delta tower came from the bosun.

The pilot assigned to the *Cosco Busan* was one of the most experienced of the San Francisco Bar pilots. During his 26 years of service, he had made thousands of successful trips, navigating a variety of vessels in a variety of weather and sea conditions in San Francisco Bay. He had successfully completed all of the training required of San Francisco Bar pilots, training that addressed the skills and the knowledge appropriate for San Francisco Bar pilots.

VTS San Francisco was outfitted with Coast Guard Vessel Traffic System (CGVTS) equipment and a partial deployment of the more recent Lockheed Martin Marine Traffic Management (MTM-200) system. Together, these systems integrated a variety of sensors to display a traffic image that could be used by VTS operators to evaluate developing traffic situations and make decisions regarding the management of vessel traffic in the VTS area. The configuration met all international guidelines. The Coast Guard conducted operational evaluations of VTS San Francisco before the *Cosco Busan* incident, on November 9, 2006, and after the incident, on February 29, 2008. In each case, VTS San Francisco was found to be a functional, properly equipped, and well-operated unit with no mission-limiting discrepancies.

The Safety Board therefore concludes that the following were neither causal nor contributory to the accident: wind and current; the vessel propulsion and steering systems; the bridge navigation systems; bridge team response to orders; vessel harbor traffic; navigation aids, including the RACON at the center of the Delta–Echo span; maintenance of a proper lookout; pilot training and experience; and VTS equipment and operational capability.

Bay Bridge Damage and Response

Within minutes of the allision, Caltrans, using seismometers and other instrumentation, was able to assess the significance of the impact and determine where it had occurred, that the event was an allision, not an earthquake, and that it was not of sufficient magnitude to justify stopping bridge traffic. California Highway Patrol vehicles were immediately dispatched to make a preliminary inspection of the bridge, and within 1 hour, Caltrans engineers had completed an initial inspection and assessment of the damage. They determined that the fendering system and skirt of the Delta pier had sustained about 100 feet of damage as a result of the allision but that neither the bridge pier nor any other part of the bridge structure was affected. The Safety Board therefore concludes that Caltrans' assessment of damage to the Bay Bridge following the allision was timely and appropriate.

Caltrans estimates that about 1,100 to 1,300 vehicles were on the bridge at the time of the allision; however, no motor vehicles were involved in this accident. Given the limited visibility due to fog and the low magnitude of bridge movement registered by the bridge sensors, it is likely that few, if any, of the motorists on the bridge were aware of the allision. In fact, Caltrans characterized the amount and velocity of the bridge movement as similar to what the bridge might experience on a windy day. The Safety Board therefore concludes that Caltrans' decision to allow the bridge to remain open to traffic after the allision was appropriate.

According to Caltrans, the design of the accident fender system for the W-5 (Delta) pier appeared to be essentially the same as the design shown in the current AASHTO 1991 Guide, and the bridge itself has been retrofitted to a much higher standard than required due to concerns about earthquakes. For security reasons, Caltrans was unable to share detailed information about the structural integrity of either the fendering system or the piers. The actual bridge design plans, specifications, and their revisions are classified "confidential" by Caltrans and the U.S. Department of Homeland Security. The Safety Board concludes that in this accident, the bridge tower fendering system worked as intended to protect the pier structure and to limit damage to the striking vessel to the area above the waterline.

Responsibilities of the Master and the Pilot

A ship's master bears primary responsibility for the safe passage of the ship.[108] The presence of a pilot, even if required, does not absolve the master of responsibility for overseeing the safe navigation of his ship to and from port. It is now an accepted maritime rule that a pilot is on board to provide assistance, a service, to a ship's master and is not there to take command of the vessel. Nonetheless, a pilot does bear significant responsibility for the safe passage of the vessel to which he is providing navigational assistance.

The pilot is retained by the ship to provide local knowledge of the harbor, familiarity with the unique tides and currents in that body of water, understanding of local procedures, and a thorough knowledge of the topography of both the coastline and the harbor bottom. The pilot

[108] The responsibilities of the master are established in both U.S. and international regulations. U.S. navigation safety rules at 33 CFR 164.11 require that the master or person in charge of a vessel shall ensure that the wheelhouse is constantly manned by competent persons who control and direct the movement of the vessel and fix its position. International regulations at STCW Code Section A-VIII/2, part 3-1 states, in part, that despite the duties and obligations of pilots, their presence on board does not relieve the master or officer in charge of the navigational watch from his/her duties and obligations for the safety of the ship. The master and the pilot shall exchange information regarding navigation procedures, local conditions and the ship's characteristics. The master and/or the officer in charge of the navigational watch shall cooperate closely with the pilot and maintain an accurate check on the ship's position and movement.

usually operates by issuing maneuvering instructions (such as heading, rudder angle orders in degrees either to port or starboard, and speed orders via the engine order telegraph) to the crew under the supervision of the master or the officer in charge of the navigation watch (mate), or both.

The master is ultimately responsible for ensuring that the instructions and operations of the pilot result in the safe passage of the vessel through the harbor and to or from a berth. The master must be prepared to act if the pilot, or any crewmember for that matter, endangers the ship or places at risk any other vessels or property along the ship's intended route.

The master's responsibilities in a harbor begin before the vessel departs or enters the port. Specifically, the ship's master is expected to be familiar with both the controls and the navigation equipment on board the vessel. Particularly in the modern era marked by an increasingly sophisticated complement of onboard electronic navigation equipment, the master must affirmatively seek to learn the critical operational aspects of the equipment so that the master may (1) navigate in those circumstances where no pilot is on board, (2) effectively assist a pilot who may not be familiar with the type of equipment on board the master's vessel, (3) properly oversee the performance of the pilot to ensure a safe passage, and (4) assume on short notice the navigational control of the ship should the master lose confidence in the pilot or if the pilot becomes incapacitated. Unless a master knows what should be happening at any given time, he " . . . is in a poor position to question the pilot regarding the progress of the ship or its situation at any moment . . . ."[109]

Next, a master is expected to monitor the pilot's performance through attention to all available navigational equipment. Under clear conditions and no known hazards to navigation, the master may largely rely on visual cues. While operating in a port with numerous hazards or under severely restricted visibility, the master may need to pay particularly close attention to the navigational equipment and frequently monitor the ship's position.

The Safety Board considered if, or how well, the *Cosco Busan* pilot and master fulfilled their respective responsibilities on the day of the allision. Those assessments are discussed in the sections that follow.

Performance of the San Francisco Bar Pilot

On the day of the accident, the pilot was experiencing difficulty in interpreting at least some of the data presented visually on the radar and electronic chart displays. For example, he experienced some problems in getting the radars adjusted to his satisfaction shortly after he boarded the vessel. Evidence later suggested that the radar settings may have been inappropriate for the types of adjustments that were being made. Although these inappropriate settings were never corrected, the pilot was eventually able to track AIS targets on the display. During this time, however, the ship was still secured to the dock, and the pilot was able to focus all of his attention on the task at hand.

[109] Captain A. J. Swift, *Bridge Team Management: A Practical Guide*, 2nd Edition (London: The Nautical Institute, 2004), pg. 56.

The movement of the vessel out of the entrance channel and into the Bar Channel was not particularly challenging, with the vessel essentially maintaining its current heading. Also, in the channel, the lights along the dock, even in fog, may have been dimly visible and may have served to orient the pilot. In his postaccident interview, the pilot said he remembered seeing two lighted buoys pass on the port side as he exited the entrance channel. But he said that the visibility then diminished and he did not see the No. 1 buoy marking the northern boundary of the Bar Channel.

At that point, navigation aids were few and visibility was restricted by heavy fog. The pilot therefore had to exclusively use electronic navigation aids at a time when he also had to devote attention to his physical maneuvering of the ship. His performance suggests that he did not have the capacity to do both. If he had been correctly interpreting the radar images before making the first turn to port, he should have noticed from the VRM ring that he was proceeding slightly farther north before making the turn than was his usual practice.

During this part of the voyage, the pilot asked the master about the red triangles on the electronic chart. Although the electronic chart being used on the *Cosco Busan* on the day of the allision was not an ECDIS-certified chart, it was a standard, widely used chart with buoy representations that were the same as those used on ECDIS–certified S-57 charts, with which the pilot should have been familiar. Given the limited number of standard symbols used to represent buoys on navigation charts, and given the pilot's waterway experience, the Safety Board does not find it credible that the pilot would never have seen these particular symbols.

Further, the chart described an area with which the pilot was intimately familiar. The major features on the chart, principally Yerba Buena Island and the Bay Bridge, would have been recognizable to even the most inexperienced mariner. The pilot knew that red-over-green buoys were stationed on either side of the Delta tower of the bridge, and by location alone he should have immediately recognized them on the chart, even if they had been represented by nonstandard symbols he had never seen and even if he was unfamiliar with this particular electronic chart system. The master, who was making his first trip to the San Francisco Bay area, recognized the bridge on the chart and understood the meaning of the red triangles even if he did not know of their physical presence from his own experience. The VDR transcript documents that, when he was first asked about the red triangles, the master responded that they were "on bridge." This was far from a precise response and, based on subsequent events, the pilot apparently interpreted this as "center of the bridge" or, more significantly, "center of the span."

In a postaccident interview, the pilot said that before sailing he had asked the master about the meaning of the red triangles and was told that they marked the center of the Delta–Echo span. Though this conversation probably would have taken place near the electronic chart where other pilot-crew interactions were recorded by the VDR, it was not recorded, leading the Safety Board to conclude that the conversation did not take place as the pilot described it. If it had occurred, it still would have raised the question of why an experienced pilot was asking the ship's master for help in interpreting a standard navigation chart of the pilot's home waters. The fact that the pilot appeared confused by a common tool of his trade indicates that his ability to interpret visual data while functioning in a dynamic environment was compromised.

This degraded cognitive performance of the pilot was also evident with regard to the ship's radars. The pilot said that when he began turning the *Cosco Busan* toward the southwest, the radar image became "distorted" and that he could not distinguish the bridge piers or the buoys south of the span (these would have been the buoys represented by the red triangles on the electronic chart). He also said he did not see the RACON Morse code signature marking the center of the Delta–Echo span. But a postaccident review of the radar images showed that the RACON was indeed functioning and marking the center of the span. Likely the result of stronger radar returns from the bridge structure, the upper portion of the bridge did briefly become fractionally wider on the radar display as the vessel made its turn, but its position on the screen in relation to Yerba Buena Island or the *Cosco Busan* did not change except to reflect movement of the vessel. If the pilot had been using the radar displays before this time, nothing occurred that would have prevented his continuing to use them. The fact that he could not do so suggests that his ability to interpret this display of information, especially when his attention was divided, was not what would normally have been expected.

The pilot said in his postaccident interview that he became concerned about the reliability of the ship's radars and decided to use the electronic chart. A more likely explanation is that his ability to effectively understand and apply the complex information that the radar was displaying was diminished, and he chose instead to refer to the relatively simpler display on the electronic chart. On the electronic chart, the bridge and the red triangles showed clearly, and the pilot decided to aim for the red triangles that he incorrectly believed indicated the intended bridge span. This, of course, would have made his aim point not the center of the 2,200-foot-wide span but the 50-foot-wide Delta tower fendering system.

The pilot was making good his course for the red triangles when, about 3 minutes before the allision, VTS radioed the pilot, asking his intentions. The pilot was confused because he believed he was on a course for the center of the span. He could not reconcile the "heading" (actually "course over ground") reported by VTS with where he believed he was in relation to the bridge span. A manifestation of the pilot's confusion was a series of rudder commands he ordered over the next 1.5 minutes. With no visual references and with VTS information that conflicted with his perception of his position (heading toward the red triangles and thus the intended bridge span), he was clearly unsure of his vessel's position. He also forgot to release the tug *Revolution*.

None of the confusion exhibited by the pilot on the day of the allision would have been expected of any pilot with effective cognitive and perceptual functioning. The Safety Board therefore concludes that the *Cosco Busan* pilot, at the time of the allision, experienced reduced cognitive function that affected his ability to interpret data and that degraded his ability to safely pilot the ship under the prevailing conditions, as evidenced by a number of navigational errors that he committed.

The Safety Board notes that though the pilot's degraded cognitive performance was manifested by his inability to correctly interpret information presented graphically, he did not exhibit a similar degradation in lower-level cognitive performance associated with long-practiced and ingrained tasks. For example, while the pilot's perception of the course he needed to steer to safely clear the Bay Bridge was clearly in error, he performed adequately in maneuvering the vessel in terms of the rudder commands needed to steer that course. For example, once he decided to steer toward the red triangles, he gave commands appropriate to that end. And after becoming aware that the *Cosco Busan* was at risk of striking the bridge fendering system, he immediately and correctly ordered hard port rudder to swing the stern of the vessel away from the tower to prevent further damage. Under visibility conditions less severe than those on the day of the allision, when the bridge itself would have been visible, the pilot would likely have been able to complete the voyage safely despite his reduced cognitive function. The Safety Board concludes that the pilot's order for hard port rudder at the time of the allision was appropriate and possibly limited the damage to the vessel and the bridge fendering system.

Potential Influences on the Pilot's Performance

The Safety Board considered factors that may have contributed to the pilot's diminished cognitive performance on the day of the accident, as discussed below.

Fatigue

The Safety Board examined the pilot's work-rest schedule and the record of his use of a CPAP (continuous positive airway pressure) machine for treatment of obstructive sleep apnea, to determine whether his performance at the time of the accident may have been degraded by fatigue or sleep deprivation.

San Francisco Bar Pilots Association pilots employ a schedule of 1 week on and 1 week off duty. During their on-duty weeks, pilots work at any time of day, regardless of the time they worked the previous day. The accident pilot had a fairly regular report time in the 3 days before the accident—0330 on November 5, 0630 on November 6, and 0500 on November 7, the day of the accident. However, on October 31, his report time was 2100; on November 2, it was 0300; and on November 3, it was 1600. A schedule that alternates daytime work with nighttime work in the same week is detrimental to optimum performance in that it is difficult for someone to compensate for the sleep deprivation that has resulted from working at a time when one is typically sleeping.[110]

Although the pilot reported for duty at early hours in the 3 days before the accident, the regularity of his schedule would have compensated, to some extent, for the disruption to his circadian rhythms on the night that he worked late (October 31) and the day he reported to work in the afternoon (November 3), provided that he obtained sufficient rest on the nights that he reported for work early in the day. Data from the record of his CPAP device indicate that on November 4, three nights before the accident, he used the CPAP for 4 hours 6 minutes. On November 5, he used the CPAP for 6 hours 13 minutes, and on the night before the accident, he

[110] For example, see (a) S. M. Jay, D. Dawson, and N. Lamond, "Train Drivers' Sleep Quality and Quantity During Extended Relay Operations," *Chronobiology International* 23 (2006): 1241-1252. (b) J. J. Pilcher and M. K. Coplens, "Work/Rest Cycles in Railroad Operations: Effects of Shorter than 24-Hour Shift Work Schedules and On-Call Schedules on Sleep," *Ergonomics* 43 (2000): 573-588. (c) J. Dorrian, C. Tolley, N. Lamond, C. van den Heuvel, J. Pincombe, A. E. Rogers, and D. Dawson, "Sleep and Errors in a Group of Australian Hospital Nurses at Work and During the Commute," *Applied Ergonomics* 39 (2008): 605-613. (d) S. W. Lockley, J. W. Cronin, E. E. Evans, B. E. Cade, C. J. Lee, C. P. Landrigan, J. M. Rothschild, J. T. Katz, C. M. Lilly, P, H. Stone, D. Aeschbach, C. A. Czeisle, "Harvard Work Hours, Health and Safety Group. Effect of Reducing Interns' Weekly Work Hours on Sleep and Attentional Failures," *New England Journal of Medicine* 351 (2004): 1829-1837.

used it for 6 hours and 10 minutes. The pilot himself estimated that he received about 7 hours of sleep the night before the accident, an amount fairly consistent with the CPAP use record. It is possible that he slept after he stopped using the CPAP device or that he was not asleep while using it. However, the fact that he used the machines for over 6 hours each of the 2 nights before the accident, while maintaining a regular schedule in the 3 days before the accident, would argue against a sleep deficit sufficient to cause substantially reduced cognitive performance. Also, the record of his prescription drug use (discussed in more detail below) indicates that he regularly used modafinil, a drug prescribed to counteract the impairing effects of sleep deprivation.

In short, the evidence with regard to the pilot's fatigue, or lack of it, at the time of the accident is mixed. His work schedule was relatively consistent in the 48 hours before the accident, but not in the week before. He used the CPAP for only 4 hours 6 minutes 3 nights before the accident, but he used it for more than 6 hours in each of the subsequent 2 nights. The evidence was insufficient to indicate whether he had slept sufficiently on those nights to compensate for any sleep deprivation that may have accrued previous nights. He also routinely used a drug that can compensate, at least partially, for the impairing effects of fatigue. The Safety Board therefore concludes that although the pilot had been diagnosed with sleep apnea, he was being treated for the condition, and there was no evidence that he was sleep-deprived at the time of the accident.

Medical Conditions

The pilot had reported suffering a variety of medical conditions during his career, and he was undergoing treatment for several conditions at the time of the accident. The conditions reported by the pilot included a long history of kidney stones, pancreatic disease, digestive difficulties, headaches, depression, abdominal pain, and back pain. He had been diagnosed with obstructive sleep apnea in 2005 and had been successfully using a CPAP device to treat the disorder. He had undergone inpatient treatment for alcoholism in 1999, with documentation of attendance at subsequent AA meetings.

Any of these conditions could have resulted in distraction, impairment, or incapacitation; but, except for sleep apnea (which could have resulted in fatigue) or alcohol use, none of them would likely have resulted in the type of perceptual difficulties that the pilot demonstrated on the day of the allision.

Medications and Medication Side Effects

The pilot had continuously and regularly been prescribed multiple medications to treat his various conditions. Prescription records for the 60 days preceding the accident reflected quantities that are consistent with the pilot's having used the prescribed medications approximately as follows: twice weekly use of 50 mg sumatriptan; daily use of one dose each of pentazocine/naloxone, 10 mg prochlorperazine, 50 mg sertraline, and 200 mg modafinil; twice daily use of 2.5/0.025 mg diphenoxylate/atropine[111] and 5 mg diazepam; and 3 times daily use of 65 mg propoxyphene, 1 mg lorazepam, and 10/325 mg hydrocodone/acetaminophen.

Sumatriptan is a prescription antimigraine medication often known by the trade name Imitrex.[112] A typical prescription calls for 25 to 100 mg to be taken every 2 hours up to a maximum of 200 mg per day. It is not known to cause cognitive performance degradation,[113] although other serious adverse side effects have, on rare occasions, been reported. The pilot's average use of two doses of 50 mg per week, as indicated by his prescription records, suggests that he was using Sumatriptan to treat headaches twice a week, or he may have had less frequent headaches that required more medication.

Pentazocine is a short-acting prescription opiate painkiller used for the relief of moderate to severe pain. The tablet formulation of pentazocine (often known by the trade name Talwin) is combined with naloxone to prevent pentazocine misuse and abuse (naloxone blocks the effects of opiates when injected intravenously). The typical prescription calls for one to two tablets to be taken every 3 to 4 hours up to a maximum of 12 tablets per day. Because its use may lead to psychological dependence, it is contraindicated in patients with active substance abuse or dependence on opiate medications. Testing performed using healthy volunteers has shown that single doses of pentazocine can cause drowsiness and measurable degradation on cognitive performance in tasks involving tracking, information processing, and divided attention. With higher doses, these effects can last for up to 12 hours.[114] The pilot's average daily use of the medication, as indicated by his prescription records, suggests that he may have been using it to treat ongoing symptoms of a regular intermittent painful condition.

Prochlorperazine is a prescription medication often known by the (now discontinued) trade name Compazine. Used primarily for the control of nausea and vomiting, it is also indicated to control anxiety or as a treatment for a psychiatric condition. A typical prescription is 5 to 10 mg to be taken 3 to 4 times per day. As shown in tests involving healthy volunteers, single oral doses cause measurable degradation on cognitive performance for up to 7 hours in tasks involving choice reaction time and tracking. Repeated oral doses cause significant degradation of driving abilities 2 hours after administration.[115] Drowsiness is also commonly seen in laboratory studies. The pilot's average daily use of a single dose of 10 mg of prochlorperazine, as indicated by his prescription records, suggests that he was using it to treat frequent nausea.

Sertraline is a prescription antidepressant often known by the trade name Zoloft. It is also used for a variety of other conditions. It is typically prescribed to be used 25 to 200 mg once per

[111] The designation 2.5/0.025 mg of diphenoxylate/atropine means a single tablet combining 2.5 mg of diphenoxylate with 0.025 mg of atropine.

[112] Information regarding the clinical use of the drugs noted in this report comes from Clinical Pharmacology [online database]. Gold Standard, Inc., Tampa, Florida. 2008. <http://www.clinicalpharmacology.com>.

[113] See, for example, S. Evers, J. Rüschenschmidt, A. Frese, S. Rahmann, and I. W. Husstedt. "Impact of Antimigraine Compounds on Cognitive Processing: A Placebo-controlled Crossover Study," *Headache* 43(10) November-December (2003): 1102-8.

[114] See, for example, R. C. Baselt. *Drug Effects on Psychomotor Performance* (Foster City, California: Biomedical Publications, 2001).

[115] Baselt.

day. Controlled studies have not shown any significant sedation or interference with cognitive performance at recommended doses, and the medication appears to improve performance in depressed patients.[116] However, no studies presently exist on Sertraline's impact on or interaction with the other medications that the pilot was using.

Modafinil is a prescription wakefulness-promoting medication also known by the trade name Provigil. It is used to treat narcolepsy as well as fatigue associated with obstructive sleep apnea and circadian disruption. It is typically prescribed to be used 200 to 400 mg once per day. It has not been shown to cause cognitive performance degradation, and test subjects using the medication have shown substantial preservation of some aspects of cognitive performance during extended periods without sleep.[117] While physiological dependence is not typical, it is possible, and patients with a history of substance abuse should be closely monitored. The pilot's apparent average daily use of a single dose of 200 mg of modafinil, as indicated by his prescription records, suggests that he was using it to treat symptoms of persistent fatigue or drowsiness.

Diphenoxylate, also known by the trade name Lomotil, is a prescription opiate medication that is used to treat a gastrointestinal disorder and that is combined with atropine (a prescription medication that discourages deliberate abuse or overdose). It is normally not intended to be used for more than 10 days. When prescribed for a chronic condition, a typical prescription is for 2.5 mg to be taken 2 to 3 times per day. Symptoms of dependence have not been reported in patients receiving therapeutic dosages of diphenoxylate, but patients using higher dosages may suffer withdrawal when treatment ends. For that reason, research suggests that the drug should be prescribed cautiously to patients with a history of opiate substance abuse. The pilot's average twice-daily use of 2.5/0.025 mg of diphenoxylate/atropine, as indicated by his prescription records, suggests that he was using it to treat symptoms of chronic gastrointestinal disorder.

Diazepam, also known by the trade name Valium, is a prescription antianxiety medication in the drug class of benzodiazepines that is also used to treat muscle spasm and alcohol withdrawal. A typical diazepam prescription calls for 2 to 10 mg to be taken 2 to 3 times a day for anxiety and 3 to 4 times per day for muscle spasm. It can cause both physical and psychological dependence and should be used with extreme caution in patients with a known or suspected history of substance abuse. Single oral doses of 5 mg or more have been shown to cause drowsiness and to significantly impair cognitive performance on tests of simple reaction time, choice reaction time, vigilance, recall, arithmetic, and information processing for up to 6 hours, and the degree of performance degradation generally increases with repeated use.[118] The pilot's average twice-daily use of 5 mg of diazepam, as indicated by his prescription records, suggests that he was using it to treat symptoms of chronic anxiety or muscle spasm.

[116] See, for example: (a) W. Bondareff, M. Alpert, A. J. Friedhoff, E. M. Richter, C. M. Clary, E. Batzar. "Comparison of Sertraline and Nortriptyline in the Treatment of Major Depressive Disorder in Late Life," *American Journal of Psychiatry* 157(5) (2000): 729-36; (b) M. Siepmann, J. Grossmann, M. Muck-Weymann, W. Kirch. "Effects of Sertraline on Autonomic and Cognitive Functions in Healthy Volunteers," *Psychopharmacology* 168(3) July (2003): 293-8.

[117] See, for example, W. D. Killgore, T. L. Rupp, N. L. Grugle, R. M. Reichardt, E. L. Lipizzi, T. J. Balkin. "Effects of Dextroamphetamine, Caffeine and Modafinil on Psychomotor Vigilance Test Performance after 44 h of Continuous Wakefulness" *Journal of Sleep Research*. June 2 (2008).

[118] Baselt.

Propoxyphene is a prescription opiate painkiller, also known by the trade name Darvon, which is used for the control of mild to moderate pain. It is typically prescribed to be used 65 mg every 3 to 4 hours, as needed, to a maximum dose of 390 mg per day. Use of propoxyphene may lead to psychological dependence, thus the medication should not be prescribed for patients with a history of substance abuse or dependence. Single oral doses of 130 mg have been shown to cause drowsiness and performance degradation for up to 6 hours on tests of reaction time, divided attention, and certain aspects of vision in healthy volunteers and arthritis patients.[119] The pilot's average three-times-daily use of 65 mg of propoxyphene, as indicated by his prescription records, suggests that he was using it to treat chronic pain.

Lorazepam, also known by the trade name Ativan, is a prescription antianxiety medication in the drug class of benzodiazepines. It is typically prescribed to be used in doses of 2 to 6 mg per day, given in two or three divided doses. Use of lorazepam can cause physical and psychological dependence, and it should be used with extreme caution in patients with a known or suspected history of substance abuse. Single or repeated doses of 1 mg or more have been shown in laboratory studies and in actual driving experiments to cause drowsiness and to adversely affect cognitive performance for up to 10 hours on tests of visual acuity, tracking, simple reaction time, choice reaction time, information processing, recall, divided attention, and vigilance.[120] The pilot's average three-times-daily use of 1 mg lorazepam, as indicated by his prescription records, suggests that he was using it to treat symptoms of chronic anxiety.

Hydrocodone is a prescription opiate painkiller used for the control of moderate to moderately severe pain. It is often combined with acetaminophen (an over-the-counter painkiller often known by the trade name Tylenol). In such combination products, it is often known by the trade names Vicodin, Lortab, or Norco. A typical prescription calls for 10 mg of hydrocodone to be taken every 4 to 6 hours as necessary for pain, to a maximum of 60 mg of hydrocodone or 4 g of acetaminophen in 24 hours. Use of the medication may lead to physical and psychological dependence, and individuals with a previous history of substance abuse may be at increased risk of relapse. Repeated doses of 7.5 mg hydrocodone with ibuprofen (an over-the-counter painkiller often known by the trade name Motrin) have been shown to adversely affect cognitive performance for at least 6 hours in tests of simple reaction time and tracking.[121] Single doses of 10 mg or 20 mg hydrocodone with homatropine (a medication that is added to hydrocodone in sub-therapeutic doses to discourage abuse) have been shown to cause drowsiness for at least 5 hours; the higher dose also demonstrated adverse effects on information processing tests for at least 4 hours and on logical reasoning tests for 5 hours.[122] The pilot's average three-times-daily use of the 10 mg hydrocodone preparation, as indicated by his prescription records, suggests that he was using it to treat chronic pain.

[119] Baselt.

[120] Baselt.

[121] G. J. Allen, T. L. Hartl, S. Duffany, et.al. "Cognitive and Motor Function after Administration of Hydrocodone Bitartrate Plus Ibuprofen, Ibuprofen Alone, or Placebo in Healthy Subjects With Exercise-induced Muscle Damage: a Randomized, Repeated-dose, Placebo-controlled Study," *Psychopharmacology* 166(3) March (2003): 228-33.

[122] J. P. Zacny, "Characterizing the Subjective, Psychomotor, and Physiological Effects of a Hydrocodone Combination Product (Hycodan) in Non-drug-abusing Volunteers," *Psychopharmacology* 165(2) January (2003): 146-56.

The pilot had thus been regularly prescribed—almost exclusively by a single physician who was familiar with the pilot's occupation—at least six medications with demonstrated potential for cognitive performance degradation. The pilot had received prescriptions for each of the medications, and no evidence was found that he had not followed the physician's instructions with regard to each medication. Many of these medications, and others prescribed for the pilot, can interfere with the metabolism of other medications taken in combination or otherwise adversely interact.[123] Though no studies have been performed on individuals simultaneously using all of the medications prescribed for the pilot, it is likely that their use together would allow at least some of the substances to accumulate in the pilot's system over time or to exacerbate potential side effects and potentially increase or prolong any performance decrement associated with their use.

The pilot's apparent daily use of multiple medications that degrade cognitive performance makes it likely that he was typically experiencing some performance degradation from the combined use of those medications, even had he built up a significant tolerance to their effects. The pilot may not have been aware of such degradation, and it may only have been apparent when he was presented with complex stimuli and tasks. While the possibility exists that the pilot temporarily discontinued the use of these medications while on duty, his medical records showed no indication that he was ever instructed to do so, and his prescription record indicates that he had likely not done so before the accident. If he had discontinued taking such medications, he likely would have experienced withdrawal symptoms (potentially including nausea, diarrhea, profuse sweating, depression, anxiety, and diffuse body pain, among others) that may have been even more degrading of cognitive performance than the medications themselves; such withdrawal symptoms were noted by one provider when the pilot had temporarily discontinued the use of lorazepam. Some of the pilot's other diagnoses (such as depression and gastrointestinal difficulties) may have actually been related to intermittent manifestations of withdrawal symptoms. Given the pilot's medical history and his documented prescription patterns over time in general and in the weeks preceding the accident in particular, the Safety Board concludes that, as evidenced by his prescription history and duty schedule, the pilot was most likely taking a number of medications, the types and dosages of which would be expected to degrade cognitive performance, and these effects were present while the pilot was performing piloting duties, including on the day of the accident.

The pilot's cognitive performance degradation was not such that it would have been obvious to those with whom he associated, nor would it necessarily have always led to degraded job performance. The effects of any performance decrement could have varied each day based on types or amounts of medications in his system or the magnitude of withdrawal he might have been experiencing from medications he had stopped taking.

But whatever his level of cognitive performance degradation on any given day, the probability that the decrement would lead to errors increased in the presence of external complicating factors. For example, poor visibility limited the external cues available to him, making it more likely that he would commit errors. On a day with good visibility and favorable

[123] As examples: prochlorperazine may interfere with the metabolism of propoxyphene; modafanil and diazepam are metabolized by similar enzyme pathways and may therefore prolong the activity of one another; and sumatriptan and sertraline may interact to cause increased levels of certain chemicals in the brain, resulting in possible agitation or confusion, among other symptoms.

sea conditions, his medication use would likely not affect his ability to safely navigate a vessel because considerable additional cues, providing much additional information, would be available, and these cues would have required less cognitive effort to comprehend. Similarly, with a vessel crew playing a more active role in vessel navigation, the pilot's reliance on his own cognitive abilities to interpret and act on the available electronic data would have been reduced. However, with a decrease in visibility or in the role of the vessel crew, he would have to rely on electronic displays without assistance from other crewmembers, and the higher-level cognitive effort and perceptual skills necessary to effectively interpret those displays were precisely those capabilities that would have been degraded by the combined medications he was taking.

Performance of the *Cosco Busan* Master

Before Getting Under Way

According to the notations on the form, at 0630, the third officer completed the vessel's "Bridge Checklist 4 – Master/Pilot Exchange" form, which indicated that the pilot had been provided with the vessel's pilot card and that the pilot and the master had engaged in a master/pilot exchange, that is, that they had discussed and agreed to the proposed passage plan, weather conditions, un-berthing procedures, and use of the assist tug. The form also indicated that the progress of the ship and the execution of orders would be monitored by the master and the officer of the watch. The third officer and the master signed this checklist.

However, the notations on the form with regard to a formal master/pilot exchange were not confirmed by the VDR recording. Immediately after the pilot arrived on board, the master asked if the vessel would be able to depart, and the pilot replied that they would "talk about it." The VDR audio recordings did not document the exchange of the pilot cards (the San Francisco Bar Pilots pilot card from the pilot and the vessel's pilot card from the crew). During interviews the pilot told investigators, "I handed him [the master] the document, and he took it. I think he read it, but I don't recall him discussing it with the mates or the helmsman. . . . I handed it to him and was expecting him to read it. It says right on it, if you have any questions, ask." The pilot said that the master had no questions. Even if the brief exchange of cards had occurred exactly as described by the pilot, this master/pilot exchange would have failed to satisfy several components expected in a well-managed exchange of information between master and pilot. At no time did the VDR transcript provide evidence that a more formal meeting between the pilot, the master, and the rest of the bridge team took place with regard to visibility, un-berthing, or the details of the proposed passage.

The pilot told the master of his plan to have the tug shift to the stern before they started out of the entrance channel, but this was part of a conversation on the bridge wing that was not specifically related to voyage planning. No discussion was documented about the challenges associated with the severely limited visibility or the guidance that the master might be operating under with regard to the company's SMS.

The pilot did not inform the master, and the master did not ask, about the pilot's planned maneuvers during un-berthing, his planned route of travel, his anticipated heading changes, concerns over any anticipated obstacles or hazards, or the speed at which they would likely proceed. They did not discuss the ship's suite of electronic navigation equipment, any known malfunctions, or how to use the bridge crew during the harbor passage. Further, the pilot did not inform the master of his plan to release the tug once the vessel had departed the Bar Channel. As discussed more fully elsewhere in this report, the master believed that the pilot discouraged an exchange about the navigation plan and thus, because the master did not insist on a thorough master/pilot exchange, he was unaware of how the pilot intended to proceed with the *Cosco Busan*.

Rather than "talking" with the master about the visibility, as he had indicated he would, the pilot, at 0650, told the master that a tug and a barge were coming down the entrance channel and suggested that visibility was improving because "you can see the other side now, and there's no more traffic—this looks good." The pilot told the master that he thought they would be able to depart as soon as the barge passed, to which the master responded "yeah, yeah, yeah."

About 1 minute later, the pilot advised the master that he could "single up" as soon as the tug passed. This was a clear indication that the pilot intended to proceed to sea under the existing conditions and was only waiting for traffic to clear. If either the master or the rest of the bridge team had any reservations about departing the berth in the current conditions, this was the time to make them known, but nobody did. The VDR transcript documents one of the *Cosco Busan* crewmembers commenting, "For American ships under such conditions, they would not be under way," clearly indicating that at least one among the bridge crew was concerned about the fog.

Given the minimal visibility prevailing at the time, the master, at a minimum, should have questioned the pilot more carefully about the decision to depart the dock. As the vessel master, he was ultimately responsible for the vessel and its safety, and the limited visibility at the time should have been sufficient to have raised questions about the safety of the passage under those conditions. The visibility was so poor that the bow of the ship could not always be seen from the ship's bridge. A prudent master would have questioned the pilot fully about the advisability of departing the dock under such conditions. Once the master did agree to sail, he should have sought additional information from the pilot about the actions that the pilot intended to take to ensure a safe passage. The master did neither, and the pilot did not assist by volunteering any information.

About 0721, the pilot told the master, "single up, if you want." The master then gave orders to single up, thereby again tacitly agreeing to depart without ever having engaged in a discussion about whether departing under those conditions was prudent.

The master told investigators that he believed that he had little input into the decision to depart in the restricted visibility conditions. His previous experience led him to assume that controlling authorities would close ports in the type of weather conditions that existed at the time. The absence of such closure in San Francisco led him to conclude, erroneously, that vessel operations were approved by that authority—in this instance, the Coast Guard. He appears to have been unaware of the fact that, unless the port is closed, it is the vessel master and not the port authority that ultimately decides whether a vessel can depart. Further, the master deferred to the pilot without questioning him on the wisdom of sailing or the pilot's navigation plan. For a variety of reasons, including his previous port experiences that influenced his decision-making, the master exerted no authority in the decision to sail in the existing conditions.

The master interpreted from the pilot's demeanor that the pilot would not be particularly communicative with him, even discouraging communication regarding the pilot's navigation plan. Although the pilot may not have intended such a perception, the master believed that the pilot's displaying a "cold face," as he told investigators, discouraged discussion of critical navigational issues. In addition, although the master may have incorrectly perceived the pilot's attitude and though the master should have exercised his authority and firmly requested information regarding the pilot's navigation plan, the pilot's history of adversarial conduct with persons in positions of authority lends credence to the master's interpretation of the pilot's attitude. In the incident involving the *USS Tarawa*, the pilot was accused of cursing U.S. Naval officers. The physician who conducted the pilot's medical evaluation in January 2007 described the evaluation as "adversarial" and stated that, in decades of medical practice, he had not witnessed behavior during an examination as that which the pilot exhibited.

Further, the attitude implicit in the pilot's postaccident statement concerning his providing the master with his pilot card after he boarded the vessel supports the master's perception. The pilot told investigators, "I handed [the pilot card] to him and was expecting him to read it. It says right on it, if you have any questions, ask." This statement suggests a belief that providing his pilot card to the master was comparable to engaging the master in a master/pilot exchange. By simply handing the master the pilot card and expecting him to ask any questions he may have had, rather than inviting the master to discuss the matter, the pilot accepted no responsibility for determining whether the master understood and agreed to the pilot's navigation plan. Such an attitude is not only counter to the APA's view of the role of pilot cards (that is, to "supplement, not substitute for, the master/pilot information exchange"), but also to the most fundamental precept of vessel safety—that the master and the pilot together will use all available bridge resources to maximize vessel safety. Pilots are integral members of the bridge team, and to discourage communication limits not only their effectiveness but that of the master and other crewmembers as well. Such actions create dysfunctional bridge teams with limited effectiveness in maintaining safe vessel operations, as appears to have happened on the *Cosco Busan*. Therefore, the Safety Board concludes that the pilot and the master of the *Cosco Busan* failed to engage in a comprehensive master/pilot information exchange before the ship departed the dock and failed to establish and maintain effective communication during the accident voyage, with the result that they were unable to effectively carry out their respective navigation and command responsibilities. The Safety Board therefore recommends that the APA inform its members of the circumstances of this accident, remind them that a pilot card is only a supplement to a verbal master/pilot exchange, and encourage its pilots to include vessel masters and/or the officer in charge of the navigational watch in all discussions and decisions regarding vessel navigation in pilotage waters.

The Master's Role During the Accident Voyage

Having failed to participate in a comprehensive and effective master/pilot exchange, the master was limited in his ability to monitor the pilot's adherence to the pilot's own intended plan once the vessel departed the dock. Even if the pilot had deviated by a wide margin from his intended route (which did not occur in this accident), the master would have had little ability to detect such deviation and thus would not have been in a position to question the pilot's performance. If nothing else, an effective master/pilot exchange in this instance would have aided the master in assuming control of vessel navigation should the pilot have, for whatever reason, become incapacitated. However, because the master did not insist on a thorough master/pilot exchange, he was unprepared for such an eventuality.

Even so, as the vessel progressed, the master had a clue that something might be wrong when the pilot asked the master about the meaning of the red triangles on the electronic chart. Assuming that the master fully understood the pilot's question (despite the language difference), he may have been surprised by the pilot's apparent inability to comprehend a standard navigation symbol on a chart of the San Francisco Bay area. If so, the master's surprise should probably have put some doubt in his mind about the competence of the pilot to whom he had entrusted the navigation of his ship. At the very least, it should have prompted the master to become more involved in tracking the vessel's progress, because in addition, a master is supposed to support the pilot. The VDR did not capture any comments or questions by the master concerning the *Cosco Busan*'s navigation while the ship was under way.

The master may not have been aware of the exact route the pilot planned to take through the Bay Bridge; however, the master had the opportunity, after the pilot's question about the red triangles, to query the pilot about his plans and to have him, at a minimum, confirm the intended route on the chart. The pilot apparently decided that the red triangles marked the center of the span. If the pilot had pointed this out to the master or made any attempt to communicate his plans, the master may have inferred that something was wrong. But the master did not ask, and the pilot did not offer, and the vessel continued on a route toward the Delta tower.

Another indication to the master of a possible problem with the pilot's performance came just minutes before the allision, when VTS contacted the pilot with regard to the vessel's course. The master may not have fully understood the importance of the call, but the differences in "headings" reported by VTS (235º) and the pilot (280º) and their variance from the ship's actual heading at the time (262º), which the master should have known, should have prompted the master to query the pilot about the progress of the ship and the pilot's intentions. At that time, it may have been too late for the master to safely intervene, although he still maintained responsibility for the safe operation and navigation of his ship.

The Master's Implementation of the Safety Management System (SMS)

The objective of the "International Safety Management (ISM) Code for the Safe Operation of Ships and for Pollution Prevention," is to require a company to develop and implement a set of procedures to mitigate risk and ensure that activities that affect safety and environmental protection, both afloat and ashore, are managed, organized, and executed in accordance with the applicable regulatory parameters and with company policy. At the time of this accident, Fleet Management had been issued a valid document of compliance indicating the company's SMS met the requirements of the ISM Code. It is just as important, however, that each vessel operated under the company's document of compliance have a master and officers on board who are familiar with that SMS and who implement it on the vessel.

The master on the *Cosco Busan* was new to Fleet Management and at the time of the incident had been with the company only 2 weeks. He had not served on board the *Cosco Busan* previously, and the handover and vessel familiarization process that he had undergone had not been provided by the previous master but rather by the company port captain. Only a day after the master had taken command, a representative from the vessel's classification society had performed a pre-audit of the SMS and issued the vessel an interim safety management certificate, which was valid for 6 months. By design, this audit was a narrowly focused examination to ensure (1) that all components of the company's SMS and supporting documents were on board in a language understood by the crew, (2) that the documents included key elements of the ISM Code, (3) that the master and ship's officers were familiar with the company's SMS and the planned arrangement for its implementation on board, (4) that instructions identified as essential were on board and provided to the crew before sailing, and (5) that the company was planning to audit the ship in the next 3 months. The master had ultimate responsibility for implementing the safety and environmental policy of the company and for verifying that the various onboard procedures and instructions were complied with during day-to-day operations.

Fleet Management's SMS included several navigational safety procedures which, if properly executed either alone or in harmony with one other, provided adequate safeguards to reduce the potential for an incident such as an allision with a bridge. Per the SMS, the *Cosco Busan* crew was required to produce an outbound, berth-to-berth passage plan for the passage from Oakland to Busan. The investigation determined that such a passage plan had not been prepared before the vessel departed Oakland's berth 56 on the morning of November 7. The passage plan that was produced by Fleet Management and put forth as having been on the vessel on the day of the accident was later found to have been prepared after the accident. The master's failure to ensure that the instructions in the company SMS regarding passage planning had been properly followed was suggestive of an ineffective implementation and oversight of the SMS procedures.

When the pilot arrived on the bridge of the *Cosco Busan* to perform pilotage duties for the outbound voyage, the third officer completed the safety management form, "Bridge Checklist 4 – Master/Pilot Information Exchange" and the second officer completed the safety management form "Bridge Checklist 10 – Restricted Visibility," both of which were reportedly signed by the master before departure.

These checklists were intended to reinforce the company SMS requirements for the completion of certain navigational safety functions and also to remind the navigational officers of the need to ensure that the pilot had been briefed on the vessel's passage plan, of the need to monitor the progress of the ship and the execution of the pilot's orders, and of the need to ensure that the vessel's transit speed was appropriate for the restricted visibility.

Although the 2007 Harbor Safety Plan recommended that vessels safely moored at a dock within the bay not commence movement if visibility was less than 0.5 nautical mile throughout the intended route, the pilot made the decision to get under way in visibility that VTS had reported to him as between 1/8 and 1/4 nautical mile all the way through to Alcatraz Island. The VDR captured no conversation between the pilot and the master regarding this decision. Contrary to Fleet Management's *Bridge Procedures Manual* regarding safe execution of the passage plan, the master did not exercise his authority to question the pilot's decision to attempt this passage under the prevailing conditions. The restricted visibility presented a risk to safe navigation that could have been avoided simply by delaying the vessel's departure until the visibility improved.

Prudent navigational and watch-keeping practices require that navigation teams effectively communicate, act in close coordination with others on the watch, and use all available tools to detect a developing risk of collision with another vessel or allision with a fixed object, such as the Delta tower of the Bay Bridge. This includes the continuous gathering, interpreting, and applying of information to formulate a timely, proper execution of the relevant elements of SMS procedures governing safe navigation in all conditions and the appropriate response to developing situations. This was not the case on the bridge of the *Cosco Busan*, as communications between the master and the pilot were limited, at best, and neither the master nor the pilot demonstrated an appropriate level of situation awareness regarding the position of the vessel during a time of restricted visibility.

Because the master had ultimate responsibility for implementing the SMS on the vessel, the Safety Board concludes that the master of the *Cosco Busan* did not implement several procedures found in the company SMS related to safe vessel operations, which placed the vessel, the crew, and the environment at risk.

Potential Influences on the Master's Performance

Experience Navigating in the Bay Area

Masters are in command of their vessels at all times, even when the vessel is under the navigational control of a harbor pilot. Therefore, regardless of any differences in experience, training, or knowledge, masters have the responsibility and authority to make all final decisions with regard to how their vessels should be operated. Such a clearly delineated and defined structure is critical to the effectiveness of individuals in multi-operator teams—that is, systems controlled by more than one operator working together—whether on the *Cosco Busan* or on any large seagoing vessel.

In this incident, however, the master and the pilot, although ostensibly superior and subordinate respectively, differed considerably in their experience in San Francisco Bay. No one on the bridge of the *Cosco Busan* on the day of the accident was more skilled or better trained in navigating the vessel out of the harbor than the San Francisco Bar pilot. The pilot had 26 years of experience operating vessels exclusively in this waterway. This disparity in experience, likely less significant in conditions of good visibility, had considerable influence on the bridge team dynamics in the restricted visibility that existed at the time. The master, because of his limited experience with the vessel, his unfamiliarity with the area, and his inability to visually confirm the vessel's path along the waterway, relied to a greater degree than would otherwise have been the case on the expertise of the pilot.

Differences in experience and perceived expertise that contrast with ostensible lines of authority have been found to adversely affect team structure and resultant team performance among multi-operator teams and have played a role in both aviation[124] and marine accidents.[125]

[124] See, for example, National Transportation Safety Board, *Northwest Airlines, Inc., Flights 1482 and 299 Runway Incursion and Collision, Detroit Metropolitan/Wayne County Airport, Romulus, Michigan, December 3, 1990,* Aviation Accident Report NTSB/AAR-91/05 (Washington, DC: NTSB, 1991).

Thus, the differences in the experience of the master and the pilot, differences that were magnified by the restricted visual conditions prevailing at the time, diminished the nominal superior-subordinate relationship between the two and may have adversely influenced the master's oversight of the pilot on the day of the allision.

Cultural Differences

The Safety Board evaluated to what extent cultural factors may have made the master hesitant about questioning the authority of the pilot with regard to vessel navigation. Research first conducted among workers in the same multinational corporation and then in safety-critical systems showed that individuals behaved differently in ways that could largely be explained by their particular nationality or culture.[126] Among the characteristics measured was the extent to which individuals deferred to figures in authority, referred to as "power distance." People from Asian cultures were found, in general, to be more likely to defer to people in authority than were people from Western societies.

For example, the pilot involved in this accident had, in the past, demonstrated an assertive presence with individuals who were nominally his superior in either authority or education, such as the examining physician and the naval officers on the *USS Tarawa*. The pilot's assertive demeanor may have made the master even more reluctant to challenge him, even with regard to the conduct of a formal master/pilot exchange.

In addition, although sufficiently competent with English to be deemed qualified for his position, the master was not a native English speaker. Therefore, to engage the pilot in a discussion of departure issues, although within the master's ability, would have been more difficult for him than for someone with native English-speaking ability.

Because of experiential, language, and cultural differences between the pilot, the master, and the remainder of the bridge team, and the perceived attitude of the pilot, the lines of authority on the *Cosco Busan* bridge became blurred to the point that the master deferred to the pilot for all decisions regarding vessel navigation, from the decision to depart up to and including the time of the allision. Although these factors did not relieve the master of the authority and responsibility for asserting his command when navigation of the vessel became questionable, they may explain why the master did not assert his authority and why the bridge team proved ineffective in preventing the allision. Therefore, the Safety Board concludes that the interactions between the pilot and the master on the day of the allision were likely influenced by a disparity in experience between the pilot and the master in navigating the San Francisco Bay and by cultural differences that made the master reluctant to assert authority over the pilot.

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[125] See, for example, National Transportation Safety Board, *Grounding of the U.S. Passenger Vessel* Empress of the North, *Intersection of Lynn Canal and Icy Strait, Southeast Alaska, May 14, 2007,* Marine Accident Report NTSB/MAR-03/08 (Washington, DC: NTSB, 2008).

[126] (a) G. Hofstede, *Culture's Consequences: International Differences in Work-Related Values* (Beverly Hills, California: Sage, 1980); (b) G. Hofstede, *Cultures and Organizations: Software of the Mind* (New York: McGraw-Hill, 1991); (c) R. L. Helmreich, J. A. Wilhelm, J. R. Klinect, and A. C. Merritt, "Culture, Error, and Crew Resource Management" in E. Salas, C. A. Bowers, and E. Edens (Eds.), *Improving Teamwork in Organizations: Applications of Resource Management Training* (Mahwah, New Jersey: Lawrence Erlbaum Associates, 2001) 305-331.

Although bridge resource management has become a standard part of mariner curricula, the circumstances of this accident suggest the need for specific mariner training in power distance and other cultural factors, especially in light of the fact that in the marine industry, unlike commercial aviation, multicultural crews are common. The Safety Board therefore recommends that the Coast Guard propose to the IMO that it include a segment on cultural and language differences and their possible influence on mariner performance in its bridge resource management curricula.

Postaccident Drug Testing of Master and Bridge Crew

Of the crewmembers on the bridge at the time of the accident, only the master was tested for illegal drug use within the 32-hour period that the Coast Guard established in regulation. The testing omission was largely the result of a breakdown in communication between Fleet Management and its port agent, and between the port agent and a Coast Guard duty investigator. The results of the master's drug test were negative. No evidence suggests that any of the crew was affected by illegal drug use at the time of the accident; however, the failure to properly test the crew prevents a conclusive determination on the issue. The Safety Board therefore concludes that because the *Cosco Busan* master was the only crewmember to have been drug tested in a timely manner, no conclusive evidence exists as to whether the use of illegal drugs by the other crewmembers played a role in the accident.

Performance of VTS San Francisco

When, about 0806, the pilot on board the *Cosco Busan* informed VTS San Francisco that he was under way, the VTS operator accepted the pilot's information and initiated the vessel's transit tracking process. This was a routine function that the VTS operator had performed many times. It involved ensuring that the vessel's movements were consistent with its sailing plan and projecting its position along its intended route to prevent the development of an unsafe or hazardous condition. At that time, the VTS operator was functioning at the *monitoring* level of control, the lowest and most common level of control in the traffic management continuum.

When the pilot decided to get under way, he was aware that visibility through the intended route was less than half a nautical mile, but he elected to proceed with the outbound transit relying on his local knowledge, his previous experience, and the vessel's navigation systems. At the time the pilot notified VTS San Francisco via radio that he was under way, VTS San Francisco was operating under low-visibility procedures, and the VTS operator was aware that visibility throughout the entire bay area was less than 1/4 nautical mile. The VTS operator did not challenge the pilot's decision to get the *Cosco Busan* under way in such poor visibility, nor did he exercise any level of vessel control authority.

VTS San Francisco's low-visibility reporting procedures were the predominant tool used by the unit to mitigate the increased risks posed by vessel movement during restricted visibility. The procedure was enacted when visibility was 1 nautical mile or less and required VTS operators, in addition to the data they would normally report, to "read back" or report all radar targets that may affect a vessel's transit. Although the additional information regarding radar contacts would be helpful to mariners choosing to operate in fog or inclement weather, the low-visibility procedures left the responsibility for risk-assessment and for making the decision to get under way entirely to the master or pilot. Given the extremely limited visibility in the early morning throughout the bay area on the day of the accident, VTS San Francisco had the authority to restrict the movement of all vessels over a specified tonnage that were safely moored at berth or at anchorage until such time as the visibility improved.

Once under way, the *Cosco Busan* passed through the Bar Channel and made its port turn to start a slight southwesterly track. The vessel then remained on a southwesterly course over ground that exceeded the VTS operator's expectations and that placed the vessel to the south of the anticipated track line for a passage through the Delta–Echo span. To the VTS operator, the vessel appeared to be deviating from the sailing plan. Per VTS San Francisco's standard operating procedures, the operator appropriately escalated the level of control over the *Cosco Busan* to the next level within the traffic management continuum—the *informing* level. At this level, VTS personnel provide mariners with information that may be beyond the ability of the vessel's navigational team to acquire. In this case, however, the VTS operator's attempt to alert the pilot to the developing situation actually added to the pilot's confusion.

About 3 minutes before the vessel allided with the Delta tower, the VTS operator radioed the pilot and stated, incorrectly, "AIS shows you on a 235 heading." The system at VTS San Francisco was configured to display the vessel's course over ground, not its heading. The pilot responded in a somewhat confused manner, "Um, I'm coming around. I'm steering 280° right now." In fact, the ship was on a heading of about 262°. The pilot then ordered the helmsman to increase the rudder angle from 10° starboard, to 20° starboard. When the VTS operator responded back to the pilot to ask if he still intended to use the Delta–Echo span, he provided no amplifying information to the pilot with regard to the vessel's proximity to the bridge support tower or to the vessel's position, which was well over 1,000 feet south of the vessel's expected track. Either of these critical pieces of information might have served to alert the pilot to the risk of allision.

Having been asked by the VTS operator only to verify his route intentions, the pilot attempted to get reassurance that the vessel was on the intended route by asking the master again, "This is the center of the bridge, right?" while referring to the electronic chart display. When the master responded, "yeah, yeah," the pilot ordered the helmsman to increase the rudder angle from 20° starboard to hard starboard and responded back to VTS, "Yeah, we're still Delta–Echo." With that navigational order, the *Cosco Busan* was proceeding toward the Delta tower at a speed of more than 10 knots. The Safety Board therefore concludes that VTS San Francisco personnel, in the minutes before the allision, provided the pilot with incorrect navigational information that may have confused him about the vessel's heading.

In a postaccident interview, the on-duty VTS watch supervisor stated that, because of the pilots "calm" demeanor and the known time lag in the display of a ship's position on the VTS operator's screen, VTS personnel did not question the pilot further. After the exchange between VTS and the pilot, the *Cosco Busan* was about one ship length from the Delta tower and less than 1 minute from the allision. The VTS watch supervisor and the Central Bay operator adjusted the scale of their visual displays to the highest level of definition so that they could closely monitor the situation, and they knew that the vessel would pass perilously close to the bridge tower. However, because they thought that the pilot was aware of and in control of the situation, neither individual attempted to provide the pilot with this information or to otherwise alert him to the potential danger.

When communicating with a pilot or a vessel master over the VHF radio, the VTS operator must strike a balance between brevity and conveying sufficient unambiguous information to help the pilot avoid danger. The operator must also use discretion in the timing of a communication so as to avoid disrupting the navigation team during critical phases of vessel maneuvering. However, guidance from the IMO on recommended standardization of language and terminology used in marine communication provides suggested phrases for VTS operators to use in these instances, including "Your present course is too close to . . . " and "You are running into danger."[127] This was the type of explicit VTS guidance that the master told investigators that he had heard being used in other VTS locations, and the absence of such explicit warnings suggests that the master did not immediately recognize from the VTS conversation with the pilot that the vessel was getting dangerously close to the Delta tower.

According to the master, VTS San Francisco's use of a pilot designator, "Romeo," rather than the vessel name, *Cosco Busan*, created initial uncertainty and delay on the part of the master with regard to VTS's intentions. After all, vessel masters and crew will likely note their own vessel's name or designator rather than one referring to "Romeo." To recognize the latter, the master would have to recognize (1) that "Romeo" was the designator of a pilot, and (2) that the pilot "Romeo" was the pilot on board that vessel. Identifying the vehicle directly, as is done by most U.S. and overseas VTSs and by air traffic control systems worldwide, would eliminate these cognitive steps and consequently hasten crew comprehension of the object of the communication. Therefore, the Safety Board concludes that VTS communications that identify the vessel, not only the pilot, would enhance the ability of vessel masters and crew to monitor and comprehend VTS communications. The Safety Board therefore recommends that the Coast Guard revise its VTS policies to ensure that VTS communications identify the vessel, not only the pilot, when vessels operate in pilotage waters.

The Safety Board notes that the in-house VTS recertification and requalification training implemented in September 2008 includes a module that promotes preventative measures through the use of concise communications. In this accident, although more explicit communications on the part of VTS may have better alerted the pilot and the master to the hazard, the Safety Board cannot determine whether even explicit language would have prevented the allision. Such language may have more clearly alerted the pilot to the risk, but the time available to take action was short, and the specific actions needed would not have been obvious. The pilot might have been able to take action that would have prevented or reduced the severity of the accident, but he could have been just as likely to have taken actions that would have had the opposite effect. The Safety Board therefore concludes that, although VTS San Francisco personnel should have provided the pilot and the master with unambiguous information about the vessel's proximity to the Delta tower, the Safety Board could not determine whether such information, had it been provided, would have prevented the allision.

[127] IMO Resolution A.918(22), *IMO Standard Marine Communications Phrases,* A1/6.2.3.5 *Vessel Traffic Service (VTS) Standard Phrases, Avoiding Dangerous Situations, Providing Safe Movements.*

Potential Influences on the Performance of VTS San Francisco

The role of VTS is to improve the safety of navigation, protect the marine environment, and reduce the risk of injury or death upon the waterways. Although VTSs have the authority to direct and control vessel movement, they predominately act in an advisory or informational capacity, providing vessel masters and operators with information that might not otherwise be available. The waterways subject to VTS control may be used by recreational boats, fishing vessels, personal watercraft, and other types of vessels that are not required to report to the VTS, may not show up on radar, and may not be monitored. In addition, VTS operators have limited information about many of the factors affecting the safe navigation of a vessel, such as wind, current, or unreported debris in the water. The VTS also lacks real-time data sufficient to safely control a vessel's movements. Therefore, any direction or exertion of operational control by a VTS operator to a vessel would be outcome-based or general in nature and would not include specific helm, rudder, or speed orders.

The authority of the VTS operator to direct the operation, movement, and anchorage of a vessel is discussed in general terms in applicable portions of the *Code of Federal Regulations* and Coast Guard *Marine Safety Manual*. There is, however, no program-wide policy or instruction that specifically tells VTS operators how or when to exercise their authority or when to elevate the level of control along the control continuum. At VTS San Francisco, the captain of the port did not issue a clear and concise local policy on his expectations of the use of VTS authority during times of restricted visibility, although it was addressed broadly in several local forms of guidance used by the VTS operators, including the unit's standard operating procedures, the *Operational Policy Manual*, and the *Training Guide*.

As previously noted, VTS had the authority to hold the *Cosco Busan* in its berth until visibility improved. But, in fact, the VTS operator lacked clear and distinct guidance on which to base such an order or impose such a restriction during periods of reduced visibility. Because this guidance did not exist, the VTS operator and watch supervisor would have had concerns about exceeding the level of authority associated with their positions. Moreover, with potential significant cost to maritime industry by delaying the ship's departure, a restriction on the ship's movement would not be implemented at the VTS operator level without direction from higher authority. Existing direction, policy, and instruction at both the Sector San Francisco and at the headquarter levels of authority did not clearly convey command expectations to VTS personnel for use of this authority. Therefore, this extremely valuable waterways management tool was not implemented by VTS San Francisco personnel, nor was it considered a feasible option. The Safety Board therefore concludes that the lack of Coast Guard guidance on the use of VTS authority limited the ability of VTS San Francisco personnel to exercise their authority to control or direct vessel movement to minimize risk. The Safety Board therefore recommends that the Coast Guard provide Coast Guard-wide guidance to VTS personnel that clearly defines expectations for the use of existing authority to direct or control vessel movement when such action is justified in the interest of safety.

Following the accident, the San Francisco Bay Area Harbor Safety Committee, working in conjunction with the San Francisco Bar Pilots Association and the Coast Guard, developed updated low-visibility navigation guidelines. Based on the new guidelines, VTS San Francisco, on March 28, 2008, implemented a "low-visibility enforcement procedure" and a "low-visibility staffing policy." The low-visibility enforcement procedure provides VTS operators with decision criteria and procedures for enforcing the guidelines found in the HSP governing vessel movement during periods of restricted visibility. The policy identifies several "critical maneuvering areas" within the Bay area in which the transit of any power-driven vessel of 1,600 gross tons or more, and tugs with tows of 1,600 gross tons or more, is restricted or controlled when visibility is reported as being less than 0.5 nautical mile. Per the procedure, VTS controllers will either direct the vessel to remain moored, remain anchored, or, if the vessel is under way, to proceed to anchor unless other navigational options (such as holding position or slowing vessel speed) provide an equivalent level of safety. The low-visibility staffing policy redefined the role of the watch assistant to act as a controller or traffic manager for the area with low visibility, including adjusting radar ranges, re-scaling chart areas, and adjusting track vectors to optimize the traffic manager's view of the low visibility area. These actions should clarify the expected use of VTS authority to control vessel traffic during periods of restricted visibility. These local procedures will not be incorporated in the VTS NSOP because each VTS develops its own similar procedures based on local conditions and in partnership with port stakeholders.

While the failure to properly test the VTS watchstanders for alcohol and illegal drug use is contrary to Coast Guard policy, no evidence suggests that any of the watchstanders were affected by alcohol or illegal drug use at the time of the accident. However, the Coast Guard's failure to collect toxicological specimens from VTS watchstanders prevented conclusively determining whether or not use of alcohol or illegal drugs had influenced the watchstanders' performance. After the *Cosco Busan* allision, the Coast Guard's dissemination of written policy clarified postaccident drug and alcohol testing of operational VTS and SCC watchstanders and also mandated training to ensure that all personnel are aware of these requirements.

Medical Oversight of the *Cosco Busan* Pilot

Personal Physician

The pilot's occupation was such that many of the medications he was using should have been prescribed cautiously, if at all. Also, the pilot had several conditions that should have called into question the ongoing, regular prescription of multiple psychoactive medications. The physician who prescribed the majority of these medications had so poorly documented the indications for their use, or even the most basic information about the names and dosages of the medications or the dates that he prescribed them, that the Safety Board was unable to determine precisely why each had been prescribed. In the absence of such documentation, it would not have been possible for the physician himself to accurately assess the appropriateness of each of the medications prescribed on the various occasions when they were prescribed. In some cases, the pilot's conditions may have been exacerbated, or even caused, by such medications. Even so, no evidence was found that this physician, who was prescribing the majority of the pilot's medications and who was aware of the pilot's occupation, ever conducted any comprehensive formal review of the pilot's medication use or ever considered the discontinuation of medications that may have been inappropriate.

The pilot had a history of alcohol dependence. Studies have shown that alcohol-dependent individuals are substantially more likely than the general population to become dependent on prescription medications.[128] Thus, the pilot's routine prescriptions for four different opiate and two different benzodiazepine medications, each with the potential for abuse and/or dependence, were medically inappropriate. The pilot had, in fact, experienced symptoms consistent with dependence on opiate and benzodiazepine medications: he exhibited substantial tolerance to the effects of such medications during a procedure in June 2005, and, 2 months later (in August 2005), he exhibited withdrawal symptoms while trying to discontinue lorazepam. These incidents were documented by other physicians, and this documentation was included in the pilot's medical record that the pilot's primary physician maintained.

Information in the pilot's medical and medication records suggest that he probably also suffered medication-overuse headaches that can occur when pain medications are used too frequently over a long period of time to control intermittent migraine or tension headaches.[129] Gastrointestinal symptoms (particularly constipation) are quite common with opiate medications, and the pilot's regular use of the medications may have obscured other potential causes of his abdominal pain.

Benzodiazepines such as lorazepam and diazepam are typically contraindicated for patients with obstructive sleep apnea, as they can relax the throat and worsen the apnea.[130] Narcotic medications can also contribute to sleep apnea. In one study, 50 percent of patients chronically using such medications were found to have moderate to severe sleep apnea, with increased severity when benzodiazepines were also being used.[131] It is entirely possible, then, that the pilot's sleep apnea was at least partially a result of his medication use. Also, the pilot's use of multiple medications with sedative side effects may have caused persistent sleepiness even if his sleep apnea was being effectively treated. Such sleepiness may have led to his taking daily doses of modafinil to increase his alertness.

The Safety Board therefore concludes that even though the pilot's personal physician, who prescribed the majority of medications to the pilot, was aware of the pilot's occupation and his medical history, including his documented history of alcohol dependence, he continued to inappropriately prescribe medications that, either individually or in concert, had a high likelihood of adversely affecting the pilot's job performance.

Examining Physician

Regardless of their possible role in the accident and despite the pilot's failure to report them all, many of the medical conditions and medications the pilot made known to the physician who performed his January 2007 medical examination (as well as his three previous examinations) should have triggered a more detailed evaluation of his ability to safely pilot a

[128] See, for example, B. A. Johansson, M. Berglund, M. Hanson, C. Pöhlén, and I. Persson. "Dependence on Legal Psychotropic Drugs Among Alcoholics," *Alcohol*. 38(6) Nov-Dec (2003): 613-8.

[129] 16: Related Articles: Z. Links, R. Katsarava, and R. Jensen. "Medication-overuse Headache: Where Are We Now?" *Current Opinion in Neurology* 20(3) June (2007):326-30.

[130] J. C. Leiter, S. L. Knuth, R. C. Krol, D. Bartlett Jr. "The Effect of Diazepam on Genioglossal Muscle Activity in Normal Human Subjects," *American Review of Respiratory Diseases* 132 (1985): 216-9.

[131] L. R. Webster, Y. Choi, H. Desai, L. Webster, B. J. Grant. "Sleep-disordered Breathing and Chronic Opioid Therapy" *Pain Medicine* 9(4) May-June (2008): 425-32.

vessel. In particular, the pilot had noted on his most recent form 719K a history of kidney stones, headaches, digestive problems, obstructive sleep apnea, depression, alcohol abuse, and glaucoma. He had reported his use of rabeprazole (a prescription stomach-acid-reducing medication that is not typically expected to result in performance degradation but that may interfere with the metabolism of other medications), potassium citrate (a prescription medication used to prevent the recurrence of kidney stones, not typically expected to result in performance degradation), and of sumatriptan, lorazepam, modafinil, and propoxyphene (all discussed previously).

The physician's statement that he warned the pilot not to use propoxyphene, modafinil, or lorazepam within 24 hours of serving as a pilot indicates that he was aware of potential adverse effects of drugs on safe performance, but he nevertheless took no positive steps to learn why, how, or when these medications were being used. The fact that the pilot was using these medications in combination should have been sufficient justification for the examining physician to deny the pilot's medical certification or, as a minimum, to require the pilot to provide additional information or undergo formal evaluation by other medical specialists. Without requesting or receiving any additional information about the pilot's conditions or medications, the examining physician reported—to the pilot commission by letter and to the Coast Guard through the form 719K—that he found the pilot competent for mariner duties, despite the fact that he warned the pilot not to use several medications listed on his 719K within 24 hours before serving as a pilot. Given the pilot's reported conditions and use of potentially impairing medications, this assessment was clearly in error. The Safety Board therefore concludes that although the pilot did not disclose to the physician who conducted his January 2007 medical evaluation all of his medical conditions or medication use, as he was required to do, the physician exercised poor medical oversight on behalf of the California Board of Pilot Commissioners by finding the pilot fit for duty despite having collected sufficient information regarding his multiple medical conditions and medications to call into question his ability to perform his piloting duties safely.

Pilot's Knowledge of His Medication Use

The pilot himself may have been aware that his use of multiple medications was inappropriate, particularly in view of his duties as a San Francisco Bar pilot. About 1 month before the accident, he had filled two almost identical prescriptions from two different providers on consecutive days at two different pharmacies, perhaps suggesting that he was aware that his use of the medication might have been challenged had he filled the prescriptions at the same pharmacy. The pilot had not informed his other physicians, including the physician who had performed his most recent medical evaluation for the pilot commission (and who completed the Coast Guard form 719K associated with that evaluation), of the full extent of his medication use. The pilot had signed the form 719K attesting to its accuracy and completeness even though he had not reported his use of four of the six medications that he had been prescribed (and was using at the time) that had the potential for abuse (hydrocodone, pentazocine, diazepam, and diphenoxylate), and these medications were not listed on the form. This omission provides additional evidence suggesting that the pilot was aware that the use of such medications might have been disqualifying for his position. Further, according to the examining physician, when the pilot was questioned about whether he had been hospitalized for treatment of depression, he left the examination before it was completed, explaining that he needed to consult with his attorney. The physician indicated that the pilot returned several hours later, and the examination was then completed.

Board of Pilot Commissioners

The physician who conducted the pilot's January 2007 medical examination was one of four physicians designated by the pilot commission to perform medical evaluations associated with the licensing and certification of San Francisco harbor pilots. The pilot commission requires the selected physicians to evaluate pilots using guidelines, referred to as SHIP guidelines, that were developed in 1985. The physicians are required to document the evaluation on the form 719K and forward the form to the Coast Guard. The examining physicians certify pilots' fitness for duty to the pilot commission, but the commission does not receive a copy of the 719K.

This medical oversight system is, in one important way, superior to the Coast Guard oversight system. By requiring that pilots be evaluated by one of four specified physicians, the commission eliminates the possibility that a pilot with a potentially disqualifying medical condition will "doctor shop," that is, seek evaluations from a number of practitioners until finding one that might overlook or fail to document the condition. Although the Safety Board is aware of no evidence that such doctor-shopping occurs under the Coast Guard system or that, with effective medical review by its medical staff, it would adversely affect the medical oversight of mariners, the possibility cannot be excluded.

Also, the Coast Guard permits mariners to be evaluated by nurse practitioners and physician's assistants—individuals who, while medically competent, have less medical training than physicians. As long as the physician designated by the commission is experienced and appropriately trained to exercise proper medical oversight of pilots, this system should be effective. Unfortunately, in the case of the accident pilot, the examining physician that the pilot commission had designated did not appear to be appropriately trained and qualified.

The Safety Board notes that, after the accident, the pilot commission temporarily suspended its use of the physician who had conducted the most recent examination of the *Cosco Busan* pilot, preventing him from conducting further pilot evaluations. The commission has also undertaken a complete review of its medical oversight program. The Safety Board finds the commission's efforts to improve its medical oversight system commendable. However, in its discussion with other state and local pilot government oversight entities, the Safety Board did not find any whose medical oversight system went beyond that of the Coast Guard. Given the depth of resources available to the Coast Guard and its expertise in the area of medical oversight, it is appropriate that state and local pilot oversight entities rely on the Coast Guard's medical oversight system to oversee the fitness of their own pilots. This should not, however, preclude those entities from applying their own medical fitness standards that exceed those of the Coast Guard, a practice that would enhance the safety of our waterways.

Coast Guard

Even though the pilot's examining physician had certified that the pilot was medically qualified, the Coast Guard, which was the final approval authority regarding the mariner's qualifications, was under no obligation to accept that assessment. At the time of the pilot's last medical evaluation, in January 2007, the Coast Guard had begun to centralize its review of merchant mariner medical documents at the National Maritime Center. But at that time, merchant mariner documents in the San Francisco Bay area were still being received and reviewed by the Coast Guard's San Francisco regional examination center in Oakland. Only those medical documents judged to require further review were forwarded to the National Maritime Center.

The information that the pilot reported on his form 719K, even though incomplete, should have been sufficient to cause the regional examination center to, at a minimum, forward the form to the National Maritime Center for further medical review. Instead, the regional examination center took no action with regard to the information on the pilot's form 719K, which permitted the pilot to continue his duties as a San Francisco Bar pilot with no medical restrictions.

The chief of the San Francisco regional examination center told Safety Board investigators that he did not have his staff send the pilot's 2007 (as well as the 2004 and 2006) form(s) 719K to the National Maritime Center for additional review because (1) he interpreted Coast Guard guidance (in the form of an e-mail message to a senior inspector of personnel) as directing examination centers to continue using the NVIC 02-98, which he said contained no guidance on the medications and medical conditions listed on the pilot's form and was being revised, and (2) a waiver had been granted to the pilot in the 1999 review of his 719K and, believing the information on the form had not changed substantially since 1999, the chief considered the waiver to still be valid, making a medical review unnecessary.

With regard to the first stated reason for not forwarding the pilot's documents for further medical review, the chief of the Medical Evaluation Branch of the National Maritime Center stated, during the April 2008 public hearing on this accident, that the medical condition and impairing medications listed on the pilot's form 719K did justify a medical review and would have done so under the prevailing NVIC 02-98, as well as under the enhanced guidance of NVIC 04-08. The second stated reason, that the pilot's medical condition had not changed since the granting of the waiver in 1999, was simply incorrect. The form listed the pilot as being treated for sleep apnea, a sleep disorder not listed on the 1999 form. Also, two medications, lorazepam and propoxyphene, listed on the form called for additional review because of their potentially impairing effects on the pilot's decision-making, cognitive performance, and ability to perceive complex inputs. The Safety Board therefore concludes that although the pilot did not disclose to the Coast Guard and the California Board of Pilot Commissioners all of his medical conditions or medication use, as he was required to do, the information he did provide should have been sufficient to prompt the Coast Guard, at a minimum, to conduct additional review of the pilot's fitness for duty.

Additionally, in 1999, the pilot had undergone evaluation by the Coast Guard following a second DUI conviction. He had been diagnosed with alcohol dependence, undergone a 30-day inpatient treatment at an alcohol rehabilitation center, and had documented regular attendance at AA meetings for several months. Alcohol dependence is a medical condition that, because of its lifelong nature, should have called for frequent Coast Guard review to verify that the pilot was functioning acceptably. Instead, the regional examination center asked for no further information about his treatment following the 1999 waiver. That waiver lacked, among other information, an explanation of its basis, the medical condition and/or use of impairing medication being waived, the documentation supporting it, and even the identity of the medical professional, if any, who authorized the waiver. It thus provided little or no information to guide future Coast Guard actions regarding the pilot. Nonetheless, the presence of the waiver was one of the reasons cited for the regional examination center's failure to submit the pilot's medical documents for further review.

After the accident, the Coast Guard reviewed the information reported by the pilot on his most recent form 719K and, on that information alone, determined that he was not physically competent to maintain his license. Coast Guard records indicate that this was the first time information on his forms 719K had ever been reviewed by a qualified physician. Even based on the limited information the pilot provided on the form about his medical conditions and medication use, the Coast Guard physician found this information sufficient to question his medical fitness for duty as a pilot. Had the Coast Guard performed that same review earlier and come to the same determination, the pilot would not have been on board the *Cosco Busan* on the day of the accident. The Safety Board therefore concludes that the Coast Guard, which had the ultimate responsibility for determining the pilot's medical qualification for retaining his merchant mariner's license, should not have allowed the pilot to continue his duties because the pilot was not medically fit.

Coast Guard Medical Oversight of Mariners

The Safety Board first identified shortcomings in the Coast Guard's system of mariner medical oversight in its investigation of the 2003 allision of the *Andrew J. Barberi*. In its investigation of that accident the Safety Board wrote:

> In attempting to determine the medical status of the assistant captain, the Safety Board found additional shortcomings in the Coast Guard's system of medical oversight of mariners. For example, headquarters Coast Guard personnel overseeing the medical evaluation process knew little about the quality of regional [examination center] reviews of medical evaluations—the initial, and for most mariners, the final evaluator of the results of medical examinations. Consequently, differences between regions in their reviews and determination of fitness may be present and undetected, potentially having an adverse effect on the reliability of the medical oversight system.

To address the shortcomings identified in the Coast Guard's system of medical oversight of mariners, the Safety Board issued, to the U.S. Coast Guard, the following safety recommendations:

> <u>M-05-4</u>
> Revise regulation 46 CFR 10.709 to require that the results of all physical examinations be reported to the Coast Guard, and provide guidance to mariners, employers, and mariner medical examiners on the specific actions required to comply with these regulations.

M-05-5
In formal consultation with experts in the field of occupational medicine, review your medical oversight process and take actions to address, at a minimum, the lack of tracking of performed examinations; the potential for inconsistent interpretations and evaluations between medical practitioners; deficiencies in the system of storing medical data; the absence of requirements for mariners or others to report changes in medical condition between examinations; and the limited ability of the Coast Guard to review medical evaluations made by personal health care providers.

The Coast Guard agreed with both recommendations and has made progress in addressing the deficiencies identified in the *Andrew J. Barberi* accident investigation. For example, it has centralized the initial review of mariner medical documents and has employed a physician qualified in occupational medicine to oversee its medical review of merchant mariners.

The Safety Board believes that "Exercise of Authority" that the Coast Guard initiated through the *Federal Register* in response to Safety Recommendation M-05-4 has achieved the desired goal of requiring pilots to report the results of their annual medical evaluations. An example of the positive effects of this recommendation is the fact that reports of pilot physicals are now being submitted to the Coast Guard annually. Without this requirement, the pilot's 2007 form 719K would not have been submitted to the Coast Guard, and important information about the pilot's fitness for duty would not have been available to Coast Guard reviewers (even though in this case, that information was not appropriately acted on). Because of the Coast Guard's response to the recommendation, the Safety Board reclassifies Safety Recommendation M-05-4 "Closed—Acceptable Alternate Action."

The Safety Board has reviewed NVIC 04-08 and has found it responsive to much of what the Safety Board called for in Safety Recommendation M-05-5. Further, the Coast Guard, by centralizing its review of mariner medical evaluation results under the supervision of a physician trained in occupational medicine, has eliminated inconsistencies that the Safety Board found among Coast Guard reviewers and has made it possible to track the results of medical evaluations.

The Coast Guard has not, however, taken action with regard to one deficiency noted in Safety Recommendation M-05-5, that is, the lack of a requirement for mariners to report changes in their medical condition between examinations. The Coast Guard has given no indication that it intends to implement such a requirement. The period between medical evaluations for non-pilot mariners is 5 years, during which considerable changes in a mariner's medical status or medication use can take place. Even pilots, who are required to be medically evaluated annually, can experience significant medical changes or be prescribed medications with potentially impairing side effects between required medical evaluations. The absence of a requirement mandating the reporting of substantive changes in medical condition or medication use can thus allow a mariner with a known potential for cognitive or physical performance degradation to serve in a safety-critical position on a vessel in any U.S. waterway.

The Safety Board therefore concludes that the Coast Guard's system of medical oversight of mariners continues to be deficient in that it lacks a requirement for mariners to report changes in their medical status between medical evaluations. The Safety Board recommends that the Coast Guard require mariners to report to the Coast Guard, in a timely manner, any substantive changes in their medical status or medication use that occur between required medical evaluations. Because this recommendation addresses the only element of Safety Recommendation M-05-5 that has not been met, that recommendation is reclassified "Closed—Acceptable Action—Superseded."

Role of Fleet Management

The Safety Board examined the policies and practices of the *Cosco Busan* operator, Fleet Management, in an attempt to determine what role, if any, the company may have played in this accident. The Safety Board's assessment of Fleet Management was limited by its inability to re-interview the company port captain who had trained the *Cosco Busan* crew during the transit from Busan to Long Beach and Oakland and to interview or re-interview other company officials as well.

As the vessel's management company, Fleet Management was responsible for selecting the crew, training them in ship operations, establishing the SMS and associated operating procedures, and ensuring that the crew complied with the SMS. The company selected crewmembers to serve on the *Cosco Busan* from crew recruited by a manning agency in China. Fleet Management then examined the crew's qualifications and matched them with the needs of the vessel. Based on the evidence available to the Safety Board, Fleet Management appears to have selected properly qualified and certificated mariners to crew the *Cosco Busan*.

Fleet Management sent the company port captain and the chief engineer to observe vessel operations for 30 days before the new crew arrived to take over the ship in Busan. When the ship departed Busan with its new crew, the company port captain and the chief engineer remained on board, and an additional Fleet Management superintendent engineer traveled with the vessel and crew to Long Beach and on to Oakland to oversee operations and train the crewmembers. Dispatching the company port captain and chief engineer to the vessel a month before the new crew took over vessel operations was a prudent course of action.

Except for the third officer, all of the vessel's deck officers were new to Fleet Management. In addition, the crewmembers had not previously worked together, and almost all were new to the vessel. To safely operate the ship, the crewmembers had to both learn about the vessel and about the way Fleet Management expected them to operate it. This was especially important because, not knowing the other crewmembers, they did not know how each performed, thus placing even more importance on the need to learn vessel operating procedures and the assignments of each within their respective purviews. According to the *Cosco Busan* deck officers that the Safety Board interviewed, on the voyage from Busan to Long Beach, deck crew referred their questions almost exclusively to the company port captain because, as noted, the other crewmembers, including the master, were themselves attempting to learn about the vessel and about company procedures. Unlike situations in which only a few new crewmembers join a vessel, nearly the entire *Cosco Busan* crew was new and thus could not turn to fellow crewmembers for information and assistance. The crewmembers were expected to learn the vessel and company procedures while at the same time carrying out vessel operations. Given the tasks that Fleet Management expected the *Cosco Busan* crew to perform on the voyage from

Busan to Long Beach, the conditions under which onboard training was carried out were not optimal.

At the time they left Busan, the crewmembers were unprepared to safely operate the vessel without additional training from the company. During their brief time at the dock in Busan, the crew performed several critical drills related to vessel safety, and the limited amount of time that the crew spent on board the vessel before departing Busan was insufficient to have enabled them to learn both about the vessel and how to operate it safely. Additionally, the *Cosco Busan* chief officer and second and third officers stated that Fleet Management, before the accident voyage, had not provided them with training in such areas as master's standing orders, passage planning, and bridge team management.

The deficient performance of the master and other members of the *Cosco Busan* bridge crew on the day of the accident can be directly tied to the failure of Fleet Management, before the accident voyage, to properly prepare the crew to operate the vessel safely and in accordance with the company's SMS. The second officer did not prepare a berth-to-berth passage plan before the vessel departed Busan, Long Beach, or Oakland, even though such plans were required by Fleet Management and even though a Fleet Management superintendent was on board for the first two departures.

At no time did the bridge crewmembers, as a team, discuss the planned outbound voyage and the respective roles to be taken by each crewmember in that voyage. As a result, no one on the bridge was able to adequately monitor the performance of the pilot and help ensure that the proposed route was being followed. This tacit delegation of authority from the bridge team to the pilot with regard to navigation was in violation of Fleet Management's SMS as well as of IMO policies and procedures.

Neither the master nor any other bridge officer took full advantage of the capabilities of the electronic chart system. An effective response by the master to the question from the pilot about the "red triangles" would have been to use the chart system's query function to call up data about the buoys. Such data may have alerted the pilot, even in his diminished cognitive state, that the red triangles marked an obstacle to be avoided, not a target to be aimed for. The fact that the master did not avail himself of this chart function suggests either that he had not been adequately trained in its use or that he had not been provided sufficient time to fully familiarize himself with its functionality.

The Safety Board therefore concludes that Fleet Management had failed to adequately train the *Cosco Busan* crewmembers, who were new to the vessel, who had not worked together previously, and who for the most part were new to the company, and this failure contributed to deficient bridge team performance on the day of the accident. The Safety Board recommends that Fleet Management Ltd., when assigning a new crew to a vessel, ensure that all crewmembers are thoroughly familiar with vessel operations and company safety procedures before the vessel departs the port.

The master and the second and third officers told investigators that, while they believed that it was important to follow SMS procedures, it was impossible to follow them all under the circumstances. It is likely that their beliefs were established before they joined Fleet

Management, given that two of them had only been with the company for about 2 weeks before the accident. Because of the importance attributed to SMS in maintaining safety, the Safety Board is concerned by the crewmembers' view that it was not necessary to follow all aspects of SMS. Though the master confirmed to investigators that the company port captain personally trained him in the SMS and that crewmembers "certainly . . . had to comply with SMS," Fleet Management could have conducted more extensive training and more strongly emphasized the importance of following all SMS procedures.

Because the working language of the vessel was Mandarin and because the onboard SMS manual was available only in English, only those crewmembers skilled in English could read and understand it. The master and the deck officers could do so, but at least some of the other crew reportedly could not. Thus, crew ability to review the SMS and follow the procedures in it was limited. The Safety Board concludes that providing an SMS manual to the *Cosco Busan* crew only in English and not also in the vessel's working language limited the crewmembers' ability to review and follow the SMS. Therefore, the Safety Board recommends that Fleet Management provide SMS manuals that are in the working language of a vessel's crew.

It is likely that had the company conducted training under more ideal circumstances, in which crewmembers were not distracted by the need to operate the vessel about which they were attempting to learn, the company could have better presented its view of the role of SMS in safe vessel operations and the importance of following the SMS. Such training was especially needed given the crewmembers' beliefs regarding the impossibility of following all SMS procedures. These beliefs had not been altered when the Safety Board interviewed several deck officers over a year after the accident. Therefore, the Safety Board concludes that Fleet Management had not successfully instilled in the *Cosco Busan* master and crew the importance of following all company SMS procedures.

Fleet Management conducts both internal and external SMS audits of its vessels, as required under the ISM Code. In addition, according to its website, it sends out a company representative every 3 months on its vessels to observe vessel operations, an action that was confirmed by the third officer who had worked for Fleet Management before joining the *Cosco Busan*. This program exceeds international requirements and provides the company with relatively current information about vessel operations and crew performance. Because the *Cosco Busan* was new to the company, it had not yet been subject to such observation.

Fleet Management also conducted training that was not required by governmental regulation. The company website stated that Fleet Management conducted training in recognizing and addressing power gradient issues. This training, according to the director of operations, was conducted when needed for crews of mixed nationality. Cultural factors influence how people of different backgrounds interpret and respond to people according to perceived stature in a particular hierarchy, and thus training in this topic can enhance the ability of crews of mixed nationalities to work together effectively. Being a single nationality crew, the *Cosco Busan* crew did not receive this training.

Based on the evidence, Fleet Management appears to have performed some aspects of vessel and crew oversight effectively and some ineffectively. The company screened and interviewed crewmembers nominated by the manning agency, observed operations, and conducted training on power gradients. However, with regard to the *Cosco Busan*, Fleet Management attempted to train a newly employed crew that was also new to the vessel, while that crew was also operating the vessel. While the crew sailed the vessel successfully to Long Beach and Oakland under the observation of the Fleet Management port captain, chief engineer, and superintendent engineer, the evidence also indicates that the training did not alter the crewmembers' belief that they would be unable to follow all aspects of the SMS.

Environmental Response

Actions Taken to Quantify the Amount of Oil Released

On the morning of the *Cosco Busan* allision, both the Coast Guard and the DFG-OSPR sent investigators to the vessel at the anchorage to determine the quantity of fuel oil that had been released. The Coast Guard pollution investigation team boarded the vessel about 0947. About 1030, after conversing with the ship's chief engineer and reviewing the oil record book and ship schematics, the team reported a net fuel oil loss of 0.4 metric tons, or about 146 gallons. The team's report went first to the Sector Command Center, then to the Unified Command.

Because of a lack of communication between the DFG-OSPR and Coast Guard Sector San Francisco officials, the DFG-OSPR oil spill prevention specialist who had arrived at Yerba Buena Island about 0930 did not secure Coast Guard transportation to the *Cosco Busan* until about 1130, boarding the vessel about 1230. Once on board, he consulted with the chief engineer and conducted tank soundings and measurements to arrive at a calculated fuel oil loss of 219 cubic meters, or 58,020 gallons. The specialist concluded his calculation as early as 1335, but he chose to wait to report the quantification until he could discuss it with the SOSC in person. Because the specialist had not previously arranged for transportation and had to wait for a boat to take him from the ship back to Yerba Buena Island, the SOSC did not receive this information until about 1600. The Unified Command was not advised until 1700, more than 7 hours after the spill response organizations had mobilized to recover the spilled oil.

Fortunately, the oil spill response organizations, absent an immediate quantification of the spill, had responded to the potential worst-case spill. In this case, that would have been the capacity of the *Cosco Busan*'s largest fuel tank, or about 250,000 gallons. In fact, the Coast Guard pollution investigation team's inaccurate 146-gallon quantification was not provided to either the QI or the oil spill response organizations on the day of the accident, thus it did not affect the level of response resource mobilization. Further, because the Unified Command did not direct the deployment of oil spill response organization resources on the day of the accident, the failure of the DFG-OSPR oil spill prevention specialist to quickly relay the accurate 58,020-gallon quantification to the Unified Command did not affect the level of response. The oil spill response organizations indicated that had they received the 58,020-gallon spill quantification figure as soon as it was determined, at 1335, the information would have likely aided only in the setup of assets for the following day because on-water recovery operations ceased a few hours later, at nightfall.

In this case, however, the oil spill response organizations arrived quickly because of their proximity to the site of the spill. This proximity also allowed them the flexibility to deploy more assets as needed throughout the day. The Safety Board therefore concludes that the failure of the Coast Guard and the DFG-OSPR to quickly quantify and relay an accurate estimate of the quantity of oil spilled to the Unified Command did not affect the overall on-water recovery effort in this accident.

Accurate and timely oil spill estimates serve not only to facilitate maximum containment and recovery of the oil, they also enable the members of the Unified Command, particularly the FOSC and SOSC, to make sound judgments about the resources that are being deployed and to accurately inform the public of events affecting their communities. In this accident, neither the FOSC nor the SOSC pursued this information with a sense of urgency. The FOSC did not question the 146-gallon loss estimate even though the precise nature of this estimate should have aroused his suspicion—especially in light of the reported 2-mile-long, 3-foot-wide oil slick and the reported damage to the vessel. The SOSC did not direct the oil spill prevention specialist to notify him as soon as the specialist had completed his calculations, and he apparently did not contact the specialist during the 4 hours that he was either on board the vessel or en route back to Yerba Buena Island.

Since this accident, DFG-OSPR hired an additional oil spill prevention specialist with expertise in tank gauging, thereby doubling its staff of trained quantification experts. DFG-OSPR is also developing protocols with the Coast Guard outlining roles and procedures for quantifying oil spills during pollution responses. DFG-OSPR reports that the Coast Guard is considering whether to institute these protocols district-wide or nationwide. DFG-OSPR has begun conducting quantification and reporting exercises during its regular vessel boarding inspections to ensure competency of masters and chief engineers in quantifying and reporting spills. DFG-OSPR is placing vessel masters on notice of its regulatory requirement that spill quantities be reported to the state within 30 minutes after a release is discovered.

Both the Coast Guard ISPR team and the Department of Homeland Security OIG addressed the issue of spill quantification in their respective reports. The ISPR team made five recommendations relating to spill volume quantification, including the need for professional spill quantification personnel and responder training and for ensuring that the FOSC is aware of the most current spill quantity estimates. The OIG report recommended that the Coast Guard clarify its role and responsibility and employ experts or upgrade its investigator training for quantifying the spill volumes of pollutants resulting from marine casualty or pollution mishaps.

In addition, ALCOAST 541/07, published following the *Cosco Busan* accident, provides guidance to the FOSC/incident commander to plan and execute initial response actions based on the maximum potential spill volume, that is, the entire cargo/fuel capacity of the damaged tank(s). In the view of the Safety Board, the guidance to base initial estimates on the maximum potential spill is both prudent and appropriate. Had it been in place at the time of the accident, the FOSC would have been better equipped to make sound judgments about the adequacy of resources deployed and about informing the public of the potential effect of the spill. Because of this guidance and the ISPR team and OIG recommendations, the Safety Board is not issuing a recommendation to address spill quantification.

FOSC Evaluation of Response

The Unified Command system operates on the principle of shared command response by the appropriate Federal, state, and local authorities and the involved private entities, such as spill response companies and transporters and shippers of oil and hazardous materials. The FOSC holds the ultimate authority for all decision-making related to the response and is responsible for directing Federal response efforts and coordinating other Federal efforts at the scene of a discharge or release.

In the event of a marine oil spill, the FOSC is responsible for overseeing the response effort and, if it is determined that the effort is not being properly conducted, to assume control of the response. An accurate and timely oil spill quantification is essential if the FOSC is to effectively carry out this responsibility.

The Coast Guard pollution investigation team included in its initial report from the *Cosco Busan* not only the 0.4-metric ton/146-gallon figure, but also the tank capacities and the pre-allision fuel tank quantities for the two portside fuel tanks suspected of being damaged. Despite having been provided this information, the FOSC's representative (FOSC-R), a Coast Guard officer assigned to Sector San Francisco, did not communicate either the maximum potential spill or the reasonable worst-case spill to the FOSC, nor did the FOSC ask for either of these quantities. As a result, the only spill estimate included in briefings to the FOSC, and later released by the FOSC during a noon press conference, was the 146-gallon estimate.

The incident commander from the O'Brien's Group maintained hourly communications with a Coast Guard command duty officer at Sector San Francisco on the day of the accident, during which he relayed information as he was receiving it from the command center and the oil spill response organizations working in the bay. The duty officer relayed this information to the FOSC-R and SOSC in the Unified Command, but little, if any, of this information was relayed to the FOSC, who relied on the FOSC-R and the Incident Management Division to assess and act on response organization reports.

Because the FOSC initially acted on the 146-gallon spill estimate rather than a reasonable worst-case spill and did not actively pursue updates about spill response efforts, he was not in a position to assess those efforts. The Safety Board therefore concludes that the FOSC failed to aggressively use the resources available to him to obtain timely and accurate information about the extent of the spill in order to fulfill his responsibilities.

Notification of Local Jurisdictions

In California, the responsibility for notifying jurisdictions in the event of an oil spill lies with the California OES Warning Center. When the OES was informed by the O'Brien's Group that an unknown quantity of fuel oil had spilled from the *Cosco Busan* into the San Francisco Bay, the only local agencies it notified were the Oakland Fire Department and the Alameda County Department of Environmental Health. The standard operating procedure for local notification at the time called for all spills to be reported to the local administrative agency. Because the spill location was identified as Oakland, Alameda County, the OES made the appropriate notifications. However, in this incident, several other counties situated along San

Francisco Bay could have been, and in some cases were, affected by the spill. While none of these jurisdictions had spill response personnel or equipment other than some limited booming material and would not have been able to assist in the containment of the spill and recovery of the oil, they nonetheless should have been notified of the incident.

After the accident, the California OES revised its notification procedures for hazardous materials incidents. The most notable change was to require that the OES notify the appropriate county Public Safety Answering Point(s) (PSAP) in the event of a petroleum product release of 1-barrel or potentially 1-barrel. Had these revised notification requirements been in effect and followed at the time of the *Cosco Busan* accident, all of the counties in the San Francisco Bay area would have been alerted to the oil spill within about 2 hours.

Actions of the Vessel Crew and Qualified Individual

Under California's nontank vessel contingency plan regulations, a vessel experiencing an oil spill is required to contact the oil spill response organizations identified in the vessel's response plan within 30 minutes of discovery of the discharge. According to VTS transcripts, the pilot of the *Cosco Busan* first contacted VTS regarding oil in the water at 0857. The relief pilot notified one of the contracted oil spill response organizations at 0917, 20 minutes after the vessel's first report of oil in the water.

The California regulations also require that the owner/operator or a designee contact the QI, the California OES, and the National Response Center immediately, but no more than 30 minutes after discovery of discharge. The master of the *Cosco Busan* notified the QI identified in the vessel's nontank vessel contingency plan, the O'Brien's Group, at 0915, about 45 minutes after the allision occurred and 18 minutes after the vessel first reported oil in the water. The O'Brien's Group notified the California OES of the allision at 0942, which was 45 minutes after the vessel reported oil in the water, and the National Response Center at 0949, 52 minutes after report of oil in the water. The SOSC did not consider this delay in notification to be significant because state representatives were already on scene at the beginning of this incident, and the primary concern on board the *Cosco Busan* was safely anchoring and securing the vessel. The incident commander maintained contact with the QI and the oil spill response organizations, receiving periodic updates about resources deployed and the progress of the response effort. The Safety Board therefore concludes that effective communication regarding response activities was established and maintained between the oil spill response organizations, the QI, and the Coast Guard on the day of the accident.

Timeliness and Effectiveness of Oil Spill Response Organizations' Efforts

On the day of the *Cosco Busan* allision, both MSRC and NRCES began mobilizing their response resources positioned in the San Francisco Bay area within minutes of the allision. By 0950 (about 1 hour and 20 minutes after the allision), 8,588 barrels per day of skimming capacity was on scene. About 40 minutes later, 40,476 barrels per day of skimming capacity was on scene, and 6 hours after the allision, the total on-site skimming capacity was 75,043 barrels per day. This far exceeded the state of California's worst-case scenario requirement that 5,874 barrels per day of skimming capacity to be on site within 6 hours. Thus, despite the grossly underestimated 146-gallon oil spill quantification figure and the significantly delayed 58,020-gallon accurate spill assessment, the combined effort of the two oil spill response organizations identified in the *Cosco Busan*'s California Nontank Vessel Contingency Plan significantly exceeded the requirements of the plan and California's 6-hour nontank vessel response capability standard for on-water oil recovery capacity and containment booming. The Safety Board therefore concludes that the designated oil spill response organizations' level of response to the *Cosco Busan* fuel oil spill was timely and effective.

Nontank Vessel Response Plans

Under the Coast Guard and Maritime Transportation Act of 2004, Congress mandated that the Coast Guard issue regulations requiring owner/operators of nontank vessels to develop oil spill response plans for those vessels and to submit those plans to the Coast Guard for review and approval by August 2005. The Coast Guard was not, however, able to issue the necessary regulations and guidance in time for vessel owners to develop and submit their plans by the statutory due date. Therefore, on February 16, 2005, the Coast Guard published interim guidance in the form of NVIC 01-05, which implemented a voluntary process by which owners/operators of nontank vessels could develop response plans and submit them for Coast Guard approval.

With the continued absence of nontank vessel response plan regulations, the Coast Guard, on February 14, 2006, announced the availability of revised interim guidance in NVIC 01-05 CH-1. Although the revised guidance closely parallels existing regulations for tank vessel response plans found in 33 CFR Part 155, the revised NVIC merely provides guidance to owners/operators of nontank vessels and is not itself enforceable by the Coast Guard.

In response to the *Cosco Busan* allision, the Coast Guard-chartered incident-specific preparedness review, on January 11, 2008, recommended that the Coast Guard expedite rulemaking for nontank vessel response plans. On June 23, 2008, the Coast Guard published a notice in the *Federal Register* of a new policy regarding the nontank vessel response plan provisions mandated under the 2004 act. The new policy, which became effective August 22, 2008, encourages owners and operators of nontank vessels to submit plans in accordance with NVIC 01-05 Change-1.

The Coast Guard also stated in the notice that until such time that regulations were issued and take effect, the Coast Guard would continue issuing interim operating authorization letters for those plans meeting the requirements of the 2004 act. Because this new policy is only applicable to vessels exceeding 1,600 gross tons, which the Coast Guard considers to pose the greatest threat, it falls short of the 400 gross tons threshold as specified in the act. Further, the Coast Guard states in NVIC 01-05 Change-1 that it may initiate vessel operational controls against owners and operators with deficient plans, but it does not indicate what action, if any, will be taken against vessels that have no plans at all. The Safety Board recognizes that the Coast Guard's actions have been interim measures until regulatory action mandated by the 2004 act can be completed. The Coast Guard Nontank Vessel Response Plan Program informed the Safety Board that rulemaking is in progress as of October 21, 2008, but program officials do not know when a rulemaking notice will be forthcoming. Because the Coast Guard has an existing and appropriate statutory mandate to require nontank vessel response plans and has issued administrative procedures providing interim guidance, the Safety Board is not issuing a recommendation in this area; however, the Safety Board urges the Coast Guard to draft regulations satisfying its statutory mandate.

Local Planning

When the DFG–OSPR introduced the local government grant program to California in 1993 to encourage local governments to develop and maintain oil spill contingency plans, only 7 of the 11 counties situated in the San Francisco Bay and Delta area[132] applied for and received the $50,000 grants. Since that time, annual grants of $5,000 have been available for plan maintenance; however, only four of these counties had up-to-date plans at the time of the *Cosco Busan* accident. The other three counties had not updated their plans since their development. In addition to plan maintenance, grants can be used to cover expenses associated with participation in Area Committee planning and exercises. While participation in the grant program is voluntary, the DFG–OSPR requires those counties opting for contingency plans to update them every 3 years in order to continue receiving funds.

The purpose of establishing the local government grant program was to encourage plan development and to foster a coordinated response effort between local governments and Federal and state officials in the event of an oil spill. One advantage of having a local plan is that it indicates who should be contacted in a given situation, as well as identifies what local resources are available and how they can be acquired. In order to be effective and useful, such information must be current.

Local government representatives who participate in area committee planning have the opportunity to become familiar with personnel who could potentially be involved in a response, pollution response doctrine, and the function of the ICS. Before the *Cosco Busan* accident, the Coast Guard and the California DFG–OSPR had repeatedly invited local jurisdictions to participate in area planning and various drills and exercises. Despite these invitations, DFG–OSPR indicated that the level of participation by the counties in the San Francisco and Delta Bay area was sporadic. Since the accident however, DFG–OSPR reported that counties have expressed a high level of interest in future participation in these types of events.

Communications Among Pilot Oversight Organizations

The Safety Board also learned during its investigation of this accident that no formal mechanism exists by which any pilot oversight jurisdiction may easily engage in formal discussions or information exchanges with any other pilot oversight organization. Although one pilot oversight organization did sponsor such an exchange of national pilot oversight bodies in the 1990s, this local effort by one oversight entity was not repeated after two meetings. Regular meetings of pilot oversight organizations would provide a means for those organizations to discuss and learn of common issues and to develop and evaluate innovative ways of addressing common challenges. The Safety Board concludes that a mechanism for the collection and regular communication among pilot oversight organizations of pilot-related performance data and

[132] These counties are as follows: Alameda, Contra Costa, Marin, San Francisco, San Mateo, Solano, and Sonoma counties.

information regarding pilot oversight and best practices would enhance the ability of those organizations to effectively oversee pilots.

Unfortunately, for a local jurisdiction, the resources needed to sponsor even one such meeting would be a challenge in itself. Not only would it have to contact and determine the availability of each of the other jurisdictions, it would also have to arrange for a meeting site, organize an agenda, and deal with myriad logistical details. The resources needed to organize a single meeting likely exceeds those available to all but a few pilot oversight entities; yet, for the benefits of such an effort to be realized, meetings should be held regularly. Again, the Coast Guard, with more than 40,000 employees nationwide and a specific responsibility for harbor and port safety, has the expertise and resources to coordinate such meetings. The Safety Board therefore recommends that the Coast Guard establish a mechanism through which representatives of pilot oversight organizations collect and regularly communicate pilot performance data and information regarding pilot oversight and best practices.

Prevention of Fuel Oil Spills

The most serious threats to the environment from an oil spill are posed by tanker ships carrying massive amounts of oil as cargo. But, as shown by the *Cosco Busan* incident, even spills of fuel oil from nontank vessels can have serious and long-lasting effects on the environment. Until recently, the IMO had no regulations requiring that fuel (bunker) tanks of cargo vessels be located deep inside a ship so as to protect them from external damage. However, in January 2007, an amendment to Annex I of MARPOL 73/78 went into effect that addresses possible spills of bunker oil. The amendment applies to all ships with an aggregate fuel oil capacity of 600 cubic meters (158,500 gallons) or more. Under the regulation, no one bunker tank can exceed 2,500 cubic meters (660,425 gallons) in capacity. Further, the regulation requires that, in addition to the tanks themselves, the valves and piping to and from bunker tanks be protected from damage. As for the tanks, they must either be given double-hull protection or incorporated into the design of the ship in a way that minimizes the risk of a fuel spill.

The regulation affects ships delivered on or after August 1, 2010, and those under contract on or after August 1, 2007. The regulation is not retroactive and does not require existing ships to protect their bunker tanks; however, existing ships will have to comply if they undergo a major conversion. As with new ships, the regulation will apply to vessels under contract for a major conversion after August 1, 2007, or having a conversion completion date after August 1, 2010.

No IMO treaties currently in effect cover liability and compensation for pollution damage caused by bunker oil from ships other than tankers. This changed when IMO's *International Convention on Civil Liability for Bunker Oil Pollution Damage*, adopted in 2001, took effect on November 21, 2008. The convention requires that ships greater than 1,000 registered tons carry insurance or other financial security guarantee to cover damages from a potential bunker oil spill. Liability will extend to the immediate damage, as well as to the post-spill activities necessary to minimize damage to the environment. The Safety Board therefore concludes that recently implemented international regulations with regard to the protection of fuel oil tanks on nontank vessels will, over time, reduce the likelihood of oil spills in mishaps such as occurred with the *Cosco Busan*.

Conclusions

Findings

1. The following were neither causal nor contributory to the accident: wind and current; the vessel propulsion and steering systems; the bridge navigation systems; bridge team response to orders; vessel harbor traffic; navigation aids, including the RACON at the center of the Delta–Echo span; maintenance of a proper lookout; pilot training and experience; and vessel traffic service equipment and operational capability.

2. The California Department of Transportation's assessment of damage to the San Francisco–Oakland Bay Bridge following the allision was timely and appropriate.

3. The California Department of Transportation's decision to allow the bridge to remain open to traffic after the allision was appropriate.

4. In this accident, the bridge tower fendering system worked as intended to protect the pier structure and to limit damage to the striking vessel to the area above the waterline.

5. The pilot's order for hard port rudder at the time of the allision was appropriate and possibly limited the damage to the vessel and the bridge fendering system.

6. Although the pilot had been diagnosed with sleep apnea, he was being treated for the condition, and there was no evidence that he was sleep-deprived at the time of the accident.

7. As evidenced by his prescription history and duty schedule, the pilot was most likely taking a number of medications, the types and dosages of which would be expected to degrade cognitive performance, and these effects were present while the pilot was performing piloting duties, including on the day of the accident.

8. The *Cosco Busan* pilot, at the time of the allision, experienced reduced cognitive function that affected his ability to interpret data and that degraded his ability to safely pilot the ship under the prevailing conditions, as evidenced by a number of navigational errors that he committed.

9. The pilot and the master of the *Cosco Busan* failed to engage in a comprehensive master/pilot information exchange before the ship departed the dock and failed to establish and maintain effective communication during the accident voyage, with the result that they were unable to effectively carry out their respective navigation and command responsibilities.

10. The master of the *Cosco Busan* did not implement several procedures found in the company safety management system related to safe vessel operations, which placed the vessel, the crew, and the environment at risk.

11. The interactions between the pilot and the master on the day of the allision were likely influenced by a disparity in experience between the pilot and the master in navigating the San

Francisco Bay and by cultural differences that made the master reluctant to assert authority over the pilot.

12. Because the *Cosco Busan* master was the only crewmember to have been drug tested in a timely manner, no conclusive evidence exists as to whether the use of illegal drugs by the other crewmembers played a role in the accident.

13. Vessel Traffic Service San Francisco personnel, in the minutes before the allision, provided the pilot with incorrect navigational information that may have confused him about the vessel's heading.

14. Vessel traffic service communications that identify the vessel, not only the pilot, would enhance the ability of vessel masters and crew to monitor and comprehend vessel traffic service communications.

15. Although Vessel Traffic Service San Francisco personnel should have provided the pilot and the master with unambiguous information about the vessel's proximity to the Delta tower, the Safety Board could not determine whether such information, had it been provided, would have prevented the allision.

16. The lack of U.S. Coast Guard guidance on the use of vessel traffic service authority limited the ability of Vessel Traffic Service San Francisco personnel to exercise their authority to control or direct vessel movement to minimize risk.

17. Even though the pilot's personal physician, who prescribed the majority of medications to the pilot, was aware of the pilot's occupation and his medical history, including his documented history of alcohol dependence, he continued to inappropriately prescribe medications that, either individually or in concert, had a high likelihood of adversely affecting the pilot's job performance.

18. Although the pilot did not disclose to the physician who conducted his January 2007 medical evaluation all of his medical conditions or medication use, as he was required to do, the physician exercised poor medical oversight on behalf of the California Board of Pilot Commissioners by finding the pilot fit for duty despite having collected sufficient information regarding his multiple medical conditions and medications to call into question his ability to perform his piloting duties safely.

19. Although the pilot did not disclose to the U.S. Coast Guard and the California Board of Pilot Commissioners all of his medical conditions or medication use, as he was required to do, the information he did provide should have been sufficient to prompt the Coast Guard, at a minimum, to conduct additional review of the pilot's fitness for duty.

20. The U.S. Coast Guard, which had the ultimate responsibility for determining the pilot's medical qualification for retaining his merchant mariner's license, should not have allowed the pilot to continue his duties because the pilot was not medically fit.

21. The U.S. Coast Guard's system of medical oversight of mariners continues to be deficient in that it lacks a requirement for mariners to report changes in their medical status between medical evaluations.

22. Fleet Management Ltd. had failed to adequately train the *Cosco Busan* crewmembers, who were new to the vessel, who had not worked together previously, and who for the most part were new to the company, and this failure contributed to deficient bridge team performance on the day of the accident.

23. Providing a safety management system manual to the *Cosco Busan* crew only in English and not also in the vessel's working language limited the crewmembers' ability to review and follow the SMS.

24. Fleet Management had not successfully instilled in the *Cosco Busan* master and crew the importance of following all company safety management system procedures.

25. The failure of the U.S. Coast Guard and the California Department of Fish and Game's Office of Spill Prevention and Response to quickly quantify and relay an accurate estimate of the quantity of oil spilled to the Unified Command did not affect the overall on-water recovery effort in this accident.

26. The Federal on-scene coordinator failed to aggressively use the resources available to him to obtain timely and accurate information about the extent of the spill in order to fulfill his responsibilities.

27. Effective communication regarding response activities was established and maintained between the oil spill response organizations, the qualified individual, the U.S. Coast Guard, and the Unified Command on the day of the accident.

28. The designated oil spill response organizations' level of response to the *Cosco Busan* fuel oil spill was timely and effective.

29. A mechanism for the collection and regular communication among pilot oversight organizations of pilot-related performance data and information regarding pilot oversight and best practices would enhance the ability of those organizations to effectively oversee pilots.

30. Recently implemented international regulations with regard to the protection of fuel oil tanks on nontank vessels will, over time, reduce the likelihood of oil spills in mishaps such as occurred with the *Cosco Busan*.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the allision of the *Cosco Busan* with the San Francisco–Oakland Bay Bridge was the failure to safely navigate the vessel in restricted visibility as a result of (1) the pilot's degraded cognitive performance from his use of impairing prescription medications, (2) the absence of a comprehensive pre-departure master/pilot exchange and a lack of effective communication between the pilot and the master during the accident voyage, and (3) the master's ineffective oversight of the pilot's performance and the vessel's progress. Contributing to the accident was the failure of Fleet Management Ltd. to adequately train the *Cosco Busan* crewmembers before the accident voyage, which included a failure to ensure that the crew understood and complied with the company's safety management system. Also contributing to the accident was the U.S. Coast Guard's failure to provide adequate medical oversight of the pilot in view of the medical and medication information that the pilot had reported to the Coast Guard.

Recommendations

New Recommendations

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

To the U.S. Coast Guard:

Propose to the International Maritime Organization that it include a segment on cultural and language differences and their possible influence on mariner performance in its bridge resource management curricula. (M-09-1)

Revise your vessel traffic service policies to ensure that vessel traffic service communications identify the vessel, not only the pilot, when vessels operate in pilotage waters. (M-09-2)

Provide Coast Guard-wide guidance to vessel traffic service personnel that clearly defines expectations for the use of existing authority to direct or control vessel movement when such action is justified in the interest of safety. (M-09-3)

Require mariners to report to the Coast Guard, in a timely manner, any substantive changes in their medical status or medication use that occur between required medical evaluations. (M-09-4) Supersedes M-05-5

Establish a mechanism through which representatives of pilot oversight organizations collect and regularly communicate pilot performance data and information regarding pilot oversight and best practices. (M-09-5)

To Fleet Management Ltd.:

When assigning a new crew to a vessel, ensure that all crewmembers are thoroughly familiar with vessel operations and company safety procedures before the vessel departs the port. (M-09-6)

Provide safety management system manuals that are in the working language of a vessel's crew. (M-09-7)

To the American Pilots' Association:

Inform your members of the circumstances of this accident, remind them that a pilot card is only a supplement to a verbal master/pilot exchange, and encourage your pilots to include vessel masters and/or the officer in charge of the navigational watch in all discussions and decisions regarding vessel navigation in pilotage waters. (M-09-8)

Previously Issued Recommendations Reclassified in This Report

To the U.S. Coast Guard:

M-05-4
Revise regulation 46 CFR 10.709 to require that the results of all physical examinations be reported to the Coast Guard, and provide guidance to mariners, employers, and mariner medical examiners on the specific actions required to comply with these regulations.

Safety Recommendation M-05-4, previously classified "Open—Acceptable Response," is reclassified "Closed—Acceptable Alternate Action" in the "Coast Guard Medical Oversight of Mariners" section of this report.

M-05-5
In formal consultation with experts in the field of occupational medicine, review your medical oversight process and take actions to address, at a minimum, the lack of tracking of performed examinations; the potential for inconsistent interpretations and evaluations between medical practitioners; deficiencies in the system of storing medical data; the absence of requirements for mariners or others to report changes in medical condition between examinations; and the limited ability of the Coast Guard to review medical evaluations made by personal health care providers.

Safety Recommendation M-05-5, previously classified "Open—Acceptable Response," is reclassified "Closed—Acceptable Action—Superseded" in the "Coast Guard Medical Oversight of Mariners" section of this report.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

MARK V. ROSENKER
Acting Chairman

ROBERT L. SUMWALT
Member

KATHRYN O'LEARY HIGGINS
Member

Adopted: February 18, 2009

Member Deborah A. P. Hersman voted to disapprove this report and filed the following dissenting statement on February 25, 2009.

Board Member Statement

Member Deborah A. P. Hersman, dissenting:

From the initial hours of our arrival in San Francisco, it was clear that this accident was rife with issues. Throughout the investigation, the NTSB team has struggled deciding which issues deserved attention and which ones did not. As in all complex situations, reasonable people can look hard at the same set of facts and come to different conclusions. That is the case here. Our own staff of marine experts was so divided about certain issues in this investigation that a group of them submitted to the Board their own dissent to the final draft report. As a Board member, I have my own disagreement about certain aspects of this accident report, to the point that I have taken the unusual step of voting against it. In the following dissent, I explain why I believe the report does not satisfactorily explore a number of important issues, why I disagree with elevating the master's role with that of the pilot as the proximate cause of the accident, and why I believe that the probable cause should include a contributing factor identifying the failure of the Vessel Traffic Service (VTS) to warn the pilot of the ship's dangerous proximity to the Bay Bridge.

Vessel Traffic Service

The genesis of the Vessel Traffic Service we know today began over 40 years ago with the Harbor Advisory Radar Project (HARP) whose purpose was to evaluate land-based radar in maritime traffic control. San Francisco was selected as the site of the first HARP project in 1969. HARP was a voluntary system of vessel movement reports, but no authority was granted to direct vessel movements. Following the collision of two oil tankers in low visibility on January 18, 1971 which resulted in an 800,000-gallon oil spill directly underneath the Golden Gate bridge, Congress passed the Ports and Waterways Safety Act of 1972 granting Coast Guard the authority to establish VTSs. After the *Argo Merchant* ran aground and broke apart, releasing 7.7 million gallons of oil off the coast of Nantucket, Congress passed the Port and Tanker Safety Act in 1978 giving the Coast Guard the authority to order any vessel to operate or anchor if weather, visibility, sea conditions, port congestion, or other hazardous circumstances justified such a directive in the interest of safety. Following the *Exxon Valdez* spill, Congress passed the Oil Pollution Act of 1990 making participation in VTS mandatory for certain classes of vessels, and in the mid-90s, the Coast Guard extended this compulsory participation to additional vessels when it issued National VTS Regulations.[133]

Each of these tragic accidents led to crucial steps that enhanced safety by strengthening areas of VTS control. In the past 30 years VTS operations have been upgraded to become more technologically sophisticated, but with those developments have come a commensurate expectation of more effective intervention when unsafe situations arise. In the 1971 collision in San Francisco Bay, the HARP watchstanders could only observe helplessly as the *Arizona Standard* and the *Oregon Standard* collided. By contrast, the watchstanders on duty the morning

[133] 33 CFR Part 161.

of November 7, 2007, had the opportunity, the ability, the authority, and ultimately the obligation, to intervene when they saw an unsafe situation developing with the *Cosco Busan*.

According to Coast Guard, VTS operators are authorized to exercise four different levels of control over vessel movements depending on the potential risk: monitor, inform, direct, and control. On the morning of the allision, the VTS watchstanders observed the *Cosco Busan* move 1,000 feet past the point where it should have turned to successfully navigate through the Delta/Echo span. Although it came perilously close to the Delta tower and the level of risk rose very quickly, neither the watchstander nor the supervisor, both of whom were closely monitoring the vessel, made an effort to escalate the control level.

This inaction was at cross-purposes with International Maritime Organization (IMO) Guidelines for Vessel Traffic Services, Resolution A-857(20), which state:

> The efficiency of a VTS will depend on the reliability and continuity of communications and on the ability to provide good and unambiguous information. The quality of accident prevention measures will depend on the system's capability of detecting a developing dangerous situation and on the ability to give timely warning of such dangers.

During the Board meeting, Board members and staff discussed some information that was presented in the draft report that may not appear in the final version of the report.[134] This information included an account of a radio exchange initiated by the VTS operator with the pilot approximately three minutes prior to the allision because the *Cosco Busan* appeared to be 1,000 feet south of the track to turn and pass through the Delta-Echo bridge span. In that exchange, the VTS operator asked the pilot if he still intended to use the 2200-foot span between the Delta and Echo towers to transit the bridge. The pilot responded affirmatively. After this cryptic exchange, there was no more communication between VTS and the pilot, although the VTS watchstander and the Central Bay operator both adjusted the scale of their visual displays to the highest definition so that they could more closely monitor the vessel's further movement. In an interview with one of our investigators, the VTS supervisor said that as the watchstanders observed the vessel's progress, they "predicted that they would hit the bridge."

The draft report discussed in the Board meeting states, "The fact that the Central Bay operator and the watch supervisor focused so much attention on the *Cosco Busan*'s progress at that point indicated that, despite their determination that no further interaction with the pilot was required, they knew that the vessel would pass perilously close to the bridge tower. Even though ample time existed to pass further information to the pilot regarding the vessel's proximity to the bridge support tower or the vessel's position with regard to its intended route, neither individual attempted to provide the pilot with this information or to otherwise alert him to the potential danger."

[134] One of the VTS conclusions states, "Although Vessel Traffic Service San Francisco personnel should have provided the pilot and the master with unambiguous information about the vessel's proximity to the Delta tower, the Safety Board could not determine whether such information, had it been provided, would have prevented the allision." Near the end of the Board meeting, it was determined that this conclusion was not supported by the language in the report. It was further determined that, rather than modify the conclusion to reflect the factual and analysis portions of the report, staff would modify the report to support the conclusion. Therefore, this language from the *draft* report approved by the Board may be revised and not present in the final report.

The report goes on to say:

> When communicating with a pilot or a vessel over the VHF radio, the VTS operator must strike a balance between brevity and conveying sufficient unambiguous information to help the pilot avoid danger. The operator must also use discretion in the timing of a communication so as to avoid disrupting the navigation team during critical phases of vessel maneuvering. However, guidance from IMO on recommended standardization of language and terminology used in marine communication provides suggested phrases for VTS operators to use in these instances, including "Your present course is to close to…" and "You are running into danger."… An explicit warning might have enabled the pilot to recognize the vessel's dangerous proximity to the Delta tower in time to take evasive action….

The Coast Guard and the VTS exist to protect the public interest by checking unsafe actions or unsafe operators. The taxpayers support 35 employees at VTS San Francisco to provide this protection and enforce discipline in an industry of safe professionals who may be imprudently influenced by economic pressures and who may occasionally make mistakes. VTS San Francisco's stated purpose is to facilitate the safe and efficient transit of vessel traffic in an effort to prevent collisions, rammings, groundings, and the associated loss of life and damage to property and the environment. By not naming VTS as a contributing factor in the probable cause, the Board turned a blind eye to the public's strongest safety advocate in the San Francisco Bay.

<u>The role of the master</u>

The master should have been cited as a contributing cause rather than as one of the probable causes, as my colleagues voted. I believe the outcome the Board has elected insinuates that the master's culpability in the allision was as great as that of the compulsory local pilot who actually steered the vessel into the bridge. Moreover, it is a clear departure from past Board actions when we pinned the blame of accidents involving navigational error of piloted vessels squarely on the pilot without even a mention of the vessel's master in the probable cause.[135]

Just one year ago, the same five members of this Board voted on the accident report of the *Kiteon*'s allision with the Interstate Highway 10 bridge over the Mississippi River at Baton Rouge.[136] Cited as the probable cause of that accident was the pilot's attempt to execute the high-risk maneuver of turning at the dock immediately above the bridge rather than moving the vessel downriver through the bridge before turning or taking it upriver and then turning. The report indicated that the pilot had a habit of not informing masters of his navigation plans unless they

[135] K*ition* allision with the Interstate Highway 10 bridge at Baton Rouge (MAR-08-03); *New Delhi Express* grounding in the Kill Van Kull waterway (MAB-07-02); Collision of the containership *Ever Grade* and US Coast Guard buoy tender *Cowslip* on the Columbia River near Astoria, WA (MAB-99-01); Grounding of the Liberian passenger ship *Star Princess* on Poundstone Rock, Lynn Canal, Alaska (MAR-97-02); Ramming of the Maltese bulk carrier *Mont Fort* by the British tankship *Maersk Neptune* in Upper New York Bay (MAR-88-09); Ramming of the Sidney Lanier Bridge by the bulk container *Ziemia Bialstocka* near Brunswick, GA (MAR-88-03); Collision of the *Petersfield* bulk carrier and *Bayou Boeuf* towboat and tows on the Mississippi River in New Orleans (MAR-88-01); Collision of the *Palm Pride* with the *Sioux City* and New Orleans Barge Fleet in the Mississippi River near the Luling-Destrehan Bridge (MAR-87-03).

[136] NTSB/MAR-08/03.

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asked, a practice that is patently contrary to the principles of good bridge communication and resource management. Although the master did not attempt to intervene in the allision, he was not named in the probable cause.

Almost two years ago, this same Board cited as the probable cause of the grounding of the *New Delhi Express* in New York the docking pilot's failure to use all available resources to determine the vessel's position as he navigated the Kill Van Kull waterway.[137] The Board cited as a contributing cause the failure of the pilot and the docking pilot to practice good bridge resource management. The report noted that the passage plan and information exchange between the master and the pilots were inadequate, much like in the *Cosco Busan* event. Although the master made no attempt to intervene with the pilots' actions, he was not mentioned in the probable cause.

In deliberating on this report, my colleagues on the Board strenuously argued that the master of the ship should retain all responsibility for the navigation of the vessel even when it is out of the master's hands. I agree that the master remains ultimately responsible for the vessel, and I would have been comfortable naming the master as a contributing cause because of his failure to 1) communicate with the pilot about their limited visibility departure and planned route, and 2) show appropriate concern when the pilot repeatedly queried him about the symbology on the electronic chart. My greater concern is the Board's inconsistency with probable causes determined fairly recently in accidents of similar circumstances.[138] I am not opposed to the Board taking a new direction in any regard if the intent is to improve safety. However, if that is what the Board is doing in this case, we should clearly say so and why. Furthermore, I would expect that such a shift would also be reflected in our recommendations, taking this new direction to the broader maritime community. I don't believe an adequate explanation of this departure from past decisions is part of this report.

Coast Guard failures

Coast Guard Sector San Francisco made a number of mistakes in the early response to this accident which I believe should have been more clearly explored in the report and included in the report's findings. First, the spill response team that was dispatched to the ship immediately following the allision arrived at a grossly inaccurate figure of 146 gallons for the oil spill. Then, in the face of overwhelming evidence contradicting this estimate, the Coast Guard failed to revise the original estimate for eight hours. It was not until the California state oil prevention specialist produced different calculations that the spill estimate was revised upwards to 58,000 gallons. While the assets responding to the spill may have assumed a worst-case scenario, the Coast Guard did little to accurately assess the spill in a timely manner. Their inaccurate estimates

[137] NTSB/MAB-07/02.

[138] The *Empress of the North* accident (NTSB/MAR-08/02), mentioned by my colleagues during the Board meeting, is not a comparable outcome. In that accident, we cited the master of the ship because he selected from his own crew a relative greenhorn to navigate the vessel through a narrow strait during the night. The master, who could have turned the vessel over to a more experienced crewmember or taken shift himself, chose instead to appoint the task to an inexperienced junior officer who was not qualified to pilot the vessel in the local waters. After making that assignment, the master went to bed. This was a clear case of active mismanagement by the master, circumstances that were quite different from those that led to the allision involving the *Cosco Busan* at the hands of a veteran pilot.

did not instill confidence in the public that the disaster was being managed appropriately, nor did it convey the magnitude of the disaster to the community in the critical early hours post-allision. Finally, the erroneous initial estimate created ripple effects by deterring the response of other local, state and federal entities, including the NTSB.

Further investigation by NTSB and other entities also was hampered by critical errors by the Coast Guard marine casualty investigators in their post-accident response.

- The investigators failed to secure and test critical equipment on the bridge of the vessel compromising the chain of custody in the investigation.

- They did not recognize that the *Cosco Busan* had a VDR, nor did they ask for a copy of the VDR information, jeopardizing the retention of critical evidence in the accident investigation. It was not until NTSB investigators arrived four days post-accident and asked Fleet Management about the VDR was that information retrieved and secured.

- They did not supervise the drug testing of the crew. Consequently, only the master was tested, but this error was not recognized during the 32-hour window for post-accident testing. The remainder of the crew was tested some 53 hours after the accident.

- They failed to initiate post-accident drug and alcohol testing of the VTS watchstanders.

- They conducted very limited initial interviews with the crew.

A subsequent investigation and report by the Department of Homeland Security Inspector General (OIG-08-38, April, 2008) found that the level of training and experience of the marine casualty investigators, as well as the inadequate job aids supplied to them by the Coast Guard, "contributed to the deficiencies in collecting and preserving the evidence related to the mishap."

It cannot be stressed enough that the Coast Guard's initial inaccurate assessment of the magnitude of the spill, which delayed bringing the NTSB into the investigation, had a deleterious effect on this investigation. Opportunities to establish certain facts were lost. The Coast Guard's failure to carry out its post-accident responsibilities in a timely and thorough fashion made the NTSB investigators' job much more difficult and the results less than satisfying. There is an important lesson here for future marine accidents in which we share a response with the Coast Guard. I believe that our report, by not reaching some of these findings about Coast Guard's failures in this accident response, is missing a golden opportunity to make future marine investigations more productive.

Other Possible Findings

Other aspects of this report caused me concern to a lesser extent. While these issues, on their own merits, would not have inspired me to write a separate statement, I believe this dissent provides me an excellent opportunity to nevertheless point them out.

The report should include findings regarding the adequacy of the guidelines on visibility that were in place on the day of the accident and whether an appropriate risk assessment was performed by the pilot, the master and VTS prior to departure. In recent reports such as the

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capsizing of the *Taki Too*,[139] we have cited the go/no-go decisions of the vessel operators, focusing on whether the decision was faulty, how the decision was made, who should have questioned it, and if guidance was lacking. In their submissions, virtually every party to the accident investigation of the *Cosco Busan* allision (the California Department of Fish and Game's Office of Oil Spill Prevention and Response, the Coast Guard, the Board of Pilot Commissioners for the Bays of San Francisco, San Pablo and Suisan, the American Pilots' Association, and Fleet Management, Ltd.) cited the decision to get underway in conditions of limited visibility as causal or contributory to the accident.

The report also should include a finding regarding whether the *Cosco Busan* was moving too fast for the conditions, as was cited in submissions by local experts, such as the Board of Pilot Commissioners ("speed that was excessive for the circumstances") and the Coast Guard ("unsafe speed in near zero visibility").

The report should have included a finding regarding the sloppy oversight of the random drug and alcohol testing program for the San Francisco pilots. The San Francisco Bar Pilots Association maintains a drug abatement program that includes random drug and alcohol testing for 50 percent of the pilots annually (about 30 pilots). Between 1989 and 2008, the selection of pilots for random testing was overseen by the Drug Abatement Committee, comprised of three members of the association. The report did not note that the accident pilot served as Chairman of the Drug Abatement Committee during part of this time, despite his DUI conviction in 1998. Although the *Cosco Busan* pilot was a long-time member of the association (beginning in 1981), he was selected for random testing only twice prior to the accident (September 4, 2002 and February 27, 2006). Furthermore, under the Drug and Alcohol Program Inspector (DAPI), established in 1995, the Coast Guard is to make site visits to vessels and marine employers to examine their drug testing programs with the goal of increasing the level of compliance with the drug and alcohol-testing regulations. Although the San Francisco Bar Pilots Association had requested Coast Guard to review its drug abatement program twice prior to the establishment of the DAPI, these reviews apparently were never made. The DAPI did not perform any audit of the program until after the *Cosco Busan* allision, when it was determined that the pilot association's program was not in compliance with the applicable regulations. I understand that illicit drugs played no role in this accident. However, because the investigation uncovered this glaring weakness in the safety oversight of the pilots, our findings should have noted the deficiencies of the in-house drug and alcohol program and the inadequate Coast Guard oversight of the program.

Finally, to dispel any confusion by non-mariners about the job of tug operators, the report should more fully explain the tug's role in this accident and whether tug operations can be conducted in a way that could prevent another accident like this.

Conclusion

Three issues in this investigation motivated me to vote against the final report and file this dissent: the absence of VTS from the probable cause, the prominence of the master in the probable cause, and the myriad of errors by Coast Guard San Francisco. Although I accept that my single vote against the final report will not prevent its issuance by the Board, I will continue

[139] NTSB/MAR-05/02

to view the report as a regrettable missed opportunity to thoroughly address marine safety issues that I expect we will see again.

Appendixes

Appendix A

Investigation and Public Hearing

Notification

The National Transportation Safety Board was notified of the *Cosco Busan* allision by the U.S. Coast Guard about 1400 on November 7, 2007. Initially, based on the low estimates of the amount of oil released and the reports from the Coast Guard indicating only minor damage to the ship and bridge, the Board did not launch an immediate investigation. By November 10, however, the widespread publicity about the spill and criticisms of the Coast Guard's response to the incident led the Board to confer with the Coast Guard on the conduct of the investigation. The Safety Board subsequently assumed lead of the investigation and launched a go-team of six investigators to San Francisco. The investigative team arrived on scene on the evening of November 10.

The Safety Board's investigation focused on all aspects of the accident, including equipment, personnel, training, bridge resource management, damages sustained by the ship and bridge, notification of the accident (timeliness and quality of information), and the actions taken immediately after the accident to limit, contain, and initiate cleanup of the spill. The initial on-scene investigation was completed on November 20. Member Deborah Hersman was the Board Member on scene. Safety Board investigators returned to the San Francisco Bay area for follow-on investigative activities during January, February, and March 2008.

Parties to the Investigation

Parties to the investigation were the U.S. Coast Guard; the California Department of Fish and Game–Office of Spill Prevention and Response; the Board of Pilot Commissioners for the Bays of San Francisco, San Pablo, and Suisun; Fleet Management Ltd.; the San Francisco Bar Pilots Association; the American Pilots' Association, and Sperry Marine. In addition, the Safety Board invited Hong Kong's accident investigation agency to participate in the on-scene activities, and a representative of Hong Kong joined the team during the later part of the on-scene portion of the investigation. The representative from Hong Kong also participated in the development voyage data recorder audio transcription.

Public Hearing

The Safety Board held a public hearing on the *Cosco Busan* accident on April 8 and 9, 2008, at the Board's headquarters in Washington, D.C.

Appendix B

Vessel Traffic Service Information

The Port of Liverpool, England, is generally credited with being the first port to use shore-side radar to manage ship movements, having used it as early as 1949.[140] In the United States, this concept was first instituted by the Coast Guard in 1968 in the San Francisco Bay area as a research and development project known as the Harbor Advisory Radar Project, or HARP. Participation in this early system was voluntary, and not all vessels transiting the waters of San Francisco Bay participated. The circumstances surrounding the January 18, 1971, collision of the tankship *Arizona Standard* with the tankship *Oregon Standard* under the Golden Gate Bridge spurred the development and passage of two Federal laws designed to enhance overall maritime safety.[141] The first law, the Bridge to Bridge Radiotelephone Act of 1971 (codified in 33 *United States Code* Chapter 24), required positive means by which the operators of approaching vessels could communicate their intentions to one another through voice radio. The second law, called the Port and Waterways Safety Act of 1972 or PWSA (codified in 33 *United States Code* Chapter 25), was signed on July 10, 1972, and gave the Coast Guard the authority to construct, maintain, and operate VTSs in waters subject to U.S. jurisdiction. Shortly after Congress passed the PWSA in 1972, the Coast Guard established both VTS San Francisco and VTS Puget Sound.[142] The Coast Guard currently operates or participates in 12 VTSs.[143]

The purpose of VTS is to provide active monitoring and navigational advice for vessels in particularly confined and busy waterways. VTS may be surveilled or non-surveilled. Surveilled systems consist of one or more land-based sensors such as radar, AIS, or closed-circuit television sites, which output their signals to a central location where operators monitor and manage vessel traffic movement. Non-surveilled systems consist of one or more reporting points at which ships are required to report their identity, course, speed, and other data to the monitoring authority. Non-surveilled systems encompass a wide range of techniques and capabilities aimed at preventing vessel collisions, allisions, and groundings in the harbor, harbor approach, and on inland waterways. Non-surveilled systems are designed to expedite ship movement, increase transportation system efficiency, and improve all-weather operating capability.[144]

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140 Source: <http://www.uscg.mil/hq/g-cp/comrel/factfile/factcards/VTS.html>

141 See U.S. Department of Transportation, *Marine Casualty Report: Collision Involving the* SS Arizona Standard *and* SS Oregon Standard *at the Entrance to San Francisco Bay on January 18, 1971* (Washington, DC: DOT, 1971).

142 Source: <http://www.uscg.mil/d11/vtssf/history.htm>

143 VTSs are currently in operation at Valdez, Alaska; Seattle, Washington; San Francisco, California; Los Angeles, California; Houston, Texas; Port Arthur, Texas; Morgan City, Louisiana; New Orleans, Louisiana; Tampa, Florida; Louisville, Kentucky; Sault Ste. Marie, Michigan; and New York, New York.

144 Source: <http://www.navcen.uscg.gov/mwv/vts/vts_home.htm>.