# Collision between Bulk Carrier *Conti Peridot* and Tanker *Carla Maersk*
## Houston Ship Channel near Morgan's Point, Texas
## March 9, 2015


**Marine Accident Report**

NTSB/MAR-16/01
PB2016-103277

**National Transportation Safety Board**

NTSB/MAR-16/01
PB2016-103277
Notation 8707A
Adopted June 20, 2016

# Marine Accident Report

Collision between Bulk Carrier *Conti Peridot* and Tanker *Carla Maersk*
Houston Ship Channel near Morgan's Point, Texas
March 9, 2015

National
Transportation
Safety Board

490 L'Enfant Plaza, SW
Washington, DC 20594

**National Transportation Safety Board. 2016.** ***Collision between Bulk Carrier* Conti Peridot *and Tanker* Carla Maersk, *Houston Ship Channel near Morgan's Point, Texas, March 9, 2015*. Marine Accident Report NTSB/MAR-16/01. Washington, DC.**

**Abstract:** This report discusses the March 9, 2015, collision between bulk carrier *Conti Peridot* and tanker *Carla Maersk* in the Houston Ship Channel near Morgan's Point, Texas. The collision occurred in restricted visibility after the pilot on the *Conti Peridot* was unable to control the heading fluctuations that the bulk carrier was experiencing during the transit. As a result, the *Conti Peridot* crossed the channel into the path of the *Carla Maersk*. No one was injured in the collision, but an estimated 2,100 barrels (88,200 gallons) of methyl tert-butyl ether spilled from the *Carla Maersk*, and the two vessels sustained about $8.2 million in total damage.

The report identifies the following safety issues: Inadequate bridge resource management, insufficient pilot communications, and lack of predetermined ship movement strategies during restricted visibility in the Houston Ship Channel.

As a result of this investigation, the National Transportation Safety Board makes new safety recommendations to the *Conti Peridot* operating company (Bremer Bereederungsgesellschaft mbH & Co.), the Houston Pilots Association, and the Lone Star Harbor Safety Committee.



**National Transportation Safety Board**
**Records Management Division, CIO-40**
**490 L'Enfant Plaza, SW**
**Washington, DC 20594**
**(800) 877-6799 or (202) 314-6551**

NTSB publications may be purchased from the National Technical Information Service. To purchase this publication, order product number PB2016-103277 from:

**National Technical Information Service**
**5301 Shawnee Rd**
**Alexandria, VA 22312**
**(800) 553-6847 or (703) 605-6000**
**www.ntis.gov**

# Contents

**Figures** ..... iv

**Acronyms and Abbreviations** ..... v

**Executive Summary** ..... vi

**1. The Accident** ..... 1
1.1 Background ..... 1
1.2 Injuries ..... 11
1.3 Toxicological Testing ..... 12
1.4 Damage ..... 12
1.5 Emergency Response ..... 14
1.6 MTBE Information ..... 17
1.7 Personnel Information ..... 17
1.8 Waterway Information ..... 19
1.9 Weather Information ..... 20
1.10 VTS Houston/Galveston ..... 20

**2. Investigation and Analysis** ..... 22
2.1 Inadequate Bridge Resource Management ..... 22
2.2 Insufficient Pilot Communications ..... 23
2.3 Cognitive Workload in Restricted Visibility ..... 24
2.4 Ship Information in AIS ..... 25
2.5 VTS Houston/Galveston Procedures in Restricted Visibility ..... 25
2.6 Lack of Predetermined Ship Movement Strategies during Restricted Visibility in the Houston Ship Channel ..... 26

**3. Conclusions** ..... 28
3.1 Findings ..... 28
3.2 Probable Cause ..... 29

**4. Recommendations** ..... 30

**Board Member Statement** ..... 31

**Appendixes** ..... 32

# Figures

**Figure 1.** Bulk carrier *Conti Peridot* ........ 1

**Figure 2.** Satellite image of the Houston Ship Channel ........ 3

**Figure 3.** Chemical tanker *Carla Maersk*........ 3

**Figure 4.** Animation image of the *Conti Peridot* trackline ........ 6

**Figure 5.** Satellite image of the area near Morgan's Point........ 7

**Figure 6.** *Carla Maersk* navigation bridge........ 8

**Figure 7.** *Conti Peridot* navigation bridge........ 9

**Figure 8.** Animation image of the vessels leading up to the collision ........ 10

**Figure 9.** The two vessels moments after the collision ........ 11

**Figure 10.** Damaged port side of the *Carla Maersk* ........ 12

**Figure 11.** Portside damage to the *Carla Maersk* ........ 13

**Figure 12.** Damaged bow of the *Conti Peridot* ........ 13

**Figure 13.** Sheen on the water near the *Carla Maersk* ........ 15

**Figure 14.** Map of the safety zone and air monitoring stations........ 16

**Figure 15.** Cross-sectional view of the Houston Ship Channel ........ 20

**Figure 16.** Layout of the VTS Houston/Galveston vessel traffic center ........ 21

# Acronyms and Abbreviations

| | |
|---|---|
| AIS | automatic identification system |
| *CFR* | *Code of Federal Regulations* |
| ECDIS | electronic chart display and information system |
| LPG | liquefied petroleum gas |
| MTBE | methyl tert-butyl ether |
| NOAA | National Oceanographic and Atmospheric Administration |
| NTSB | National Transportation Safety Board |
| PAWSS | Ports and Waterways Safety System (used by Coast Guard vessel traffic service) |
| PPU | portable pilot unit |
| SOLAS | International Convention for the Safety of Life at Sea |
| VDR | voyage data recorder |
| VHF | very high frequency |
| VTS | vessel traffic service (Coast Guard) |

# Executive Summary

On March 9, 2015, at 1230 central daylight time, the inbound bulk carrier *Conti Peridot* collided with the outbound tanker *Carla Maersk* in the Houston Ship Channel near Morgan's Point, Texas. The collision occurred in restricted visibility after the pilot on the *Conti Peridot* was unable to control the heading fluctuations that the bulk carrier was experiencing during the transit. As a result, the *Conti Peridot* crossed the channel into the path of the *Carla Maersk*. No one on board either ship was injured in the collision, but an estimated 2,100 barrels (88,200 gallons) of methyl tert-butyl ether spilled from the *Carla Maersk*, and the two vessels sustained about $8.2 million in total damage.

The National Transportation Safety Board determines that the probable cause of the collision between bulk carrier *Conti Peridot* and tanker *Carla Maersk* in the Houston Ship Channel was the inability of the pilot on the *Conti Peridot* to respond appropriately to hydrodynamic forces after meeting another vessel during restricted visibility, and his lack of communication with other vessels about this handling difficulty. Contributing to the circumstances that resulted in the collision was the inadequate bridge resource management between the master and the pilot on the *Conti Peridot*.

Safety issues identified in this accident include the following:

- **Inadequate bridge resource management:** Despite the pilot's difficulty controlling the *Conti Peridot*'s heading leading up to the collision, he and the master did not work together to solve the problem. The pilot did not involve the master because he was unsure whether the master could do anything to help; the master said nothing because he was likely unaware of the vessel's heading fluctuations and may have been generally reluctant to question the pilot.

- **Insufficient pilot communications:** Although the pilot on the *Conti Peridot* was having difficulty controlling the vessel and had an earlier near-miss meeting with an oncoming ship, he did not alert the pilots on subsequent oncoming vessels, including the *Carla Maersk*.

- **Lack of predetermined ship movement strategies during restricted visibility in the Houston Ship Channel:** On the day of the accident, local pilot associations determined that the increasing fog was significant enough to suspend pilot boardings of inbound ships. However, piloted vessels already under way continued the transit in the fog. Investigators found no existing predetermined ship movement strategy for piloted vessels already under way at the onset of hazardous weather conditions.

As a result of this investigation, the National Transportation Safety Board makes new recommendations to the *Conti Peridot* operating company (Bremer Bereederungsgesellschaft mbH & Co.), the Houston Pilots Association, and the Lone Star Harbor Safety Committee.

# 1. The Accident

## 1.1 Background

The 623-foot-long bulk carrier *Conti Peridot* (figure 1) arrived at the outer fairway anchorage to the Port of Houston on March 4, 2015. The ship had departed Manzanillo, Mexico, with a cargo of steel rolls and transited through the Panama Canal. Because of fog and berth logistics in the Houston area, the *Conti Peridot* remained at anchor until March 9, when the master was notified of an available berth and provided with a pilot boarding time.[1]


**Figure 1.** Bulk carrier *Conti Peridot*. (Photo by G. Dorofeyev, www.marinetraffic.com)

About 0730 that morning, the *Conti Peridot* master ordered the anchor heaved and got under way toward the nearby pilot boarding area.[2] A pilot with the Houston Pilots Association boarded the bulk carrier at 0932 outside the entrance to Galveston Bay (near buoys 1 and 2) and conducted a master/pilot exchange with the master on the navigation bridge.[3] Also on the bridge were a mate and a helmsman. The pilot told investigators that he checked the weather forecast both the previous night and while on the pilot boat before boarding the *Conti Peridot*,

[1] A state pilot is mandatory and retained by the ship to provide local knowledge of the waterway, familiarity with tides and currents in the area, understanding of local procedures, and a thorough knowledge of the topography of the waterway. Pilots usually operate by issuing maneuvering instructions (such as heading, rudder angle orders in degrees to port or starboard, and speed orders) to the crew under the supervision of the master or the officer in charge of the navigation watch, 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 waterway and to or from a berth.

[2] Unless otherwise noted, all times in this report are central daylight time (coordinated universal time – 5 hours), based on the 24-hour clock.

[3] A *master/pilot exchange* is required at the start of pilot transits and includes discussion of the vessel's navigational equipment, any limitations of maneuverability, available engine speeds, 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. For more detail, see for example "Bridge Resource Management for Maritime Pilots, III" by George A. Quick, April 2002.

and that neither time did the forecast mention fog. There was a 100 percent chance of rain that day, but the pilot told investigators that the visibility was unlimited when he boarded the *Conti Peridot*.

As part of his piloting assignment, the pilot reviewed ship notes about the *Conti Peridot*.[4] The notes included input from another local pilot (a colleague of the current pilot), who had navigated the *Conti Peridot* in the Houston Ship Channel 2 years earlier. Based on that piloting assignment, the previous pilot recommended that the next time the *Conti Peridot* transited the Houston Ship Channel, the bulk carrier ought to be trimmed 1 foot to 1.5 feet by the stern and possibly use an escort tugboat. On the morning of the accident, the *Conti Peridot* had a draft of 31 feet 3 inches forward and 31 feet 4 inches aft (or about 9.5 meters); essentially, a near-even keel.[5] The pilot told investigators that he did not know how much difference a 1.5-foot trim by the stern would have made in the vessel's handling characteristics. He therefore elected not to change the trim (which would have taken at least a couple of hours) nor use an escort tugboat.

The pilot on the *Conti Peridot* told investigators that certain ships or classes of ships, such as bulk carriers of similar dimensions as the *Conti Peridot*, handle poorly in shallow water and narrow channels like the Houston Ship Channel. (The master also told investigators that, compared to other ships he had worked on as master, the *Conti Peridot* reacted slowly.) Accordingly, the pilot said that he judged the bulk carrier's handling ability during the first couple of turns and determined that he could handle the ship for the transit. The two initial turns were completed at the south end of Galveston Bay near buoy 8 and then near buoy 10 (figure 2). The pilot told investigators that, at that time, about 1000, visibility was still clear. About 25 minutes later, as the *Conti Peridot* continued the inbound transit, the tanker *Nave Capella* overtook the bulk carrier (after agreement by both pilots) at a turn in the channel near buoy 16. Again, the pilot on the *Conti Peridot* observed no handling difficulty with the bulk carrier. He also told investigators that the crewmembers carried out his orders promptly and appropriately. The *Conti Peridot* master told investigators that he could sense that the pilot was very responsible, and the master felt comfortable with him.

---

[4] Ship notes are informal notes about the performance and characteristics of the vessel, written by other pilots who have previously piloted the vessel and who want to share helpful information with other pilots to aid them during future transits. Ship notes are not required by the pilot association. The pilot on the *Conti Peridot* reviewed the bulk carrier's ship notes while on the pilot boat en route to boarding the vessel.

[5] *Draft* is the depth to which a vessel's hull sinks into the water. During the *Conti Peridot*'s transit in the Houston Ship Channel 2 years earlier, referred to in the ship notes, the *Conti Peridot* had a draft of 35 feet.

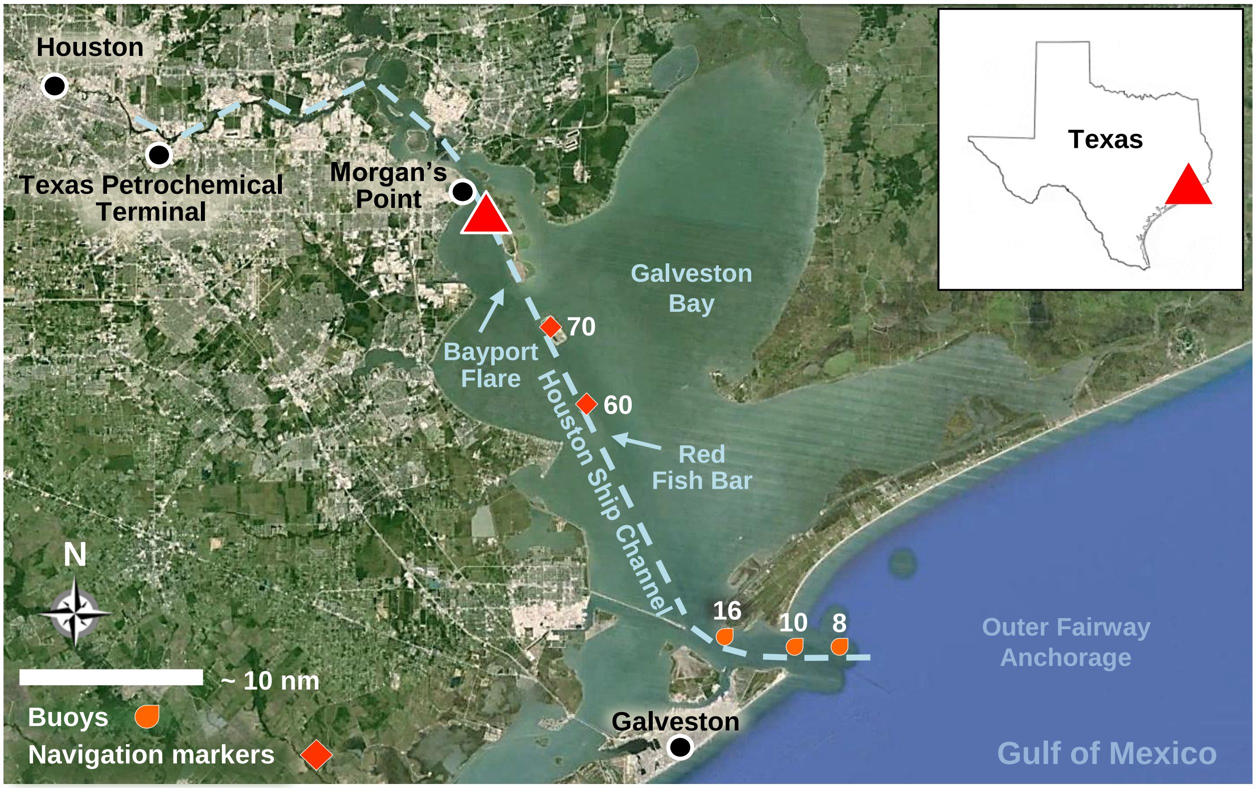


**Figure 2.** Satellite image of the Houston Ship Channel. The overlaid red triangle denotes the collision site. (Background by Google Earth)

At 0953, in the northern section of the Houston Ship Channel, the 600-foot-long tanker *Carla Maersk* (figure 3) departed its berth at Texas Petrochemical Terminal with the aid of two tugboats.


**Figure 3.** Chemical tanker *Carla Maersk*. (Photo by Roland Delhaxhe, [www.marinetraffic.com](http://www.marinetraffic.com))

The *Carla Maersk* was carrying 216,049 net barrels (9,074,058 gallons) of methyl tert-butyl ether (MTBE; also see section "1.6 MTBE Information"), shipped by Lukoil Pan

Americas to Petroleos de Venezuela. All cargo tanks, except port and starboard tanks nos. 1, 2, and 10, were loaded with MTBE. On the navigation bridge were a pilot from the Houston Pilots Association, the master, a mate, and a helmsman. The pilot and the vessel master conducted the master/pilot exchange and discussed the various vessel traffic under way in the channel. Their discussion also included the weather conditions, which at the time featured light rain with a low cloud ceiling. The pilot and the master did not discuss fog. Once the pilot was comfortable with the *Carla Maersk*'s steering, he released the two tugboats, and the tanker continued the outbound transit unassisted.

The *Carla Maersk* was on an even keel with a draft of 10.2 meters (about 33.5 feet) forward and aft. The pilot told investigators that he observed no problems with either the tanker or the crew during unberthing and the transit. He said that all his steering and engine orders were carried out correctly.

The *Carla Maersk* was transiting at a speed of about 9 knots, about 1 mile to a mile and a half behind the outbound vehicle carrier *Gaia Leader*. According to pilots whom investigators interviewed, this spacing is common for deep-draft vessels transiting in the same direction in the Houston Ship Channel.[6] The pilots stated that the spacing allows enough room for reacting in an emergency and for maneuvering around an oncoming vessel when the vessels are meeting head-on in the channel. The spacing also allows for ample time to prepare for the next vessel meeting.[7]

About 1115, farther south in the channel, the inbound *Conti Peridot* approached and met liquefied petroleum gas (LPG) carrier *BW Kyoto*. The pilot on the *Conti Peridot* told investigators that, once again, the bulk carrier handled very well and that he had no problem getting the ship back to the centerline after meeting and passing the *BW Kyoto*.

The visibility in the waterway was starting to deteriorate (also see section "1.9 Weather Information"). About 1120, after receiving reports of increasing fog, pilots with the Houston Pilots Association suspended boardings of inbound deep-draft vessels at the sea buoy. About 1135, the Galveston–Texas City Pilots also decided to suspend pilot boardings.[8] The US Coast Guard vessel traffic service (VTS) was notified.[9] Inbound deep-draft vessels already under way (such as the *Conti*

[6] The term *deep-draft* describes vessels that must transit in the main ship channels (unlike smaller vessels, such as towing and fishing vessels, which can operate in shallower water outside the main ship channels).

[7] The meeting maneuver, colloquially known as the *Texas chicken* or the *Texas 3-step*, is used by mariners navigating large vessels in the Houston Ship Channel and is also used in similar narrow waterways when large vessels meet. Two vessels approach each other head-on in a meeting arrangement. When the vessels are about 0.6 mile from each other, and if the pilots have agreed to a port-to-port meeting, each pilot applies slight starboard rudder of about 3 to 6 degrees. The water that is being displaced by the vessels' bows (known as *bow cushion*) then helps push the ships away from each other and away from the channel's centerline during the meeting. After the ships pass each other, the suction of the displaced water flowing back in behind them naturally pulls the vessels back toward the center of the waterway.

[8] Pilots often refer to suspension of pilot boardings as "closing the bar."

[9] VTS Houston/Galveston is co-located with Coast Guard Sector Houston/Galveston at Ellington Field in Houston and is staffed by both military and civilian personnel. About 70 miles of navigable waterways fall under VTS Houston/Galveston's coverage area, 55 miles of which is the Houston Ship Channel. A description of the VTS Houston/Galveston area can be found in Title 33 *Code of Federal Regulations* (*CFR*) 161.35(a). Coast Guard regulations governing VTS operations in the United States require certain vessels transiting the waterways to check in with VTS both before entering the area and at designated reporting points once inside. Their crews must provide a sailing plan, position report, sailing plan deviation/amplification report, and final report to VTS (see Title 33 *CFR* 161, subpart B; and www.uscg.mil/vtshouston/). Also see sections "1.10 VTS Houston/Galveston" and "2.5 VTS Houston/Galveston Procedures in Restricted Visibility" in this report.

*Peridot*) continued their transit up the Houston Ship Channel, and the suspension did not apply to out/southbound vessels.

By about 1121, when the *Conti Peridot* was nearing Red Fish Bar (about 12 miles south of the collision site), visibility had decreased to about 2 miles.[10] The pilot told investigators that he had just taken the *Conti Peridot* through a 10-degree turn and, again, experienced no handling difficulty with the bulk carrier. At 1126, he reported his location and the prevailing visibility to VTS, telling the VTS watchstander that the fog was "closing in pretty quickly." The pilot also requested and received a report of all outbound vessel traffic at that time, which included the *Carla Maersk*.

By 1135, the pilot on the *Conti Peridot* had lined up the bulk carrier to meet LPG carrier *Karoline N*. At this point, the visibility had deteriorated to "zero" according to the pilot, but as a measureable distance, he estimated the visibility to be 800 to 900 feet when he met and passed the *Karoline N* at navigation marker 60. The pilot told investigators that, after meeting the *Karoline N*, the *Conti Peridot* "dove to the left" as a result of the displaced water behind the *Karoline N*. The pilot told investigators that the bulk carrier then began reacting to bank effect and that he was "doing everything [he] could to control her."[11] He said that, once the *Conti Peridot* entered "zero" visibility, he had difficulty handling the bulk carrier because "you couldn't see your reference points to give you a better idea of the true head[ing] of the vessel."

A replay of the pilot's portable pilot unit (PPU) confirmed that, after the *Conti Peridot* dove to the left, bank effect off the main channel's left bank (in relation to the travel direction of the vessel) forced the bulk carrier's bow toward the right bank.[12] According to his postaccident interview, before meeting the next vessel, tanker *Stolt Span*, the pilot on the *Conti Peridot* felt that the bulk carrier's sheer toward the right bank was cause for concern.[13] He said that the visibility at the time was an estimated 400 to 600 feet, and that he could barely see the bow of his ship. He radioed the pilot on the *Stolt Span*, saying, "pay attention, watch me, I'm coming off the bank." A review of the bridge audio recording from the *Conti Peridot*'s voyage data recorder (VDR) revealed that the pilot on the *Stolt Span* asked, "You all right?"[14] No intelligible response can be heard on the VDR. About 1140, as the vessels met, the *Stolt Span* was forced to the far right side of the channel (in relation to the travel direction of the *Stolt Span)* as the *Conti Peridot* sheered to the left, crossing the center of the channel. The pilot on the *Conti Peridot* told investigators that for a distance of about 2 miles during meeting and passing the *Karoline N* and the *Stolt Span*, he was struggling to get the bulk carrier under control, including for about half a mile after passing the *Stolt Span* (figure 4). He said that although his PPU was helpful, he really needed to see the "head" of the ship and its true motion to have good situation awareness.

[10] Red Fish Bar is a small channel that connects the main Houston Ship Channel and Galveston Bay, and is used mostly by smaller craft. Red Fish Bar is also a mandatory VTS call-in point (see Title 33 *CFR* 161.35[c]).

[11] *Bank effect* is a common hydrodynamic phenomenon caused by water pressure between the ship's bow and the near bank of the waterway. The water pressure creates a cushion, which can force the bow to deflect away from the bank, back toward the center of the waterway. Pilots and experienced mariners regularly use bank effect to their benefit when maneuvering vessels in narrow waterways.

[12] A *portable pilot unit* is a compact laptop computer with electronic navigation and charting software that pilots use for navigation (in addition to the vessel's own navigation equipment).

[13] *Sheering* is a hydrodynamic phenomenon that involves sudden change in the direction of a ship's head and temporary loss of steering control.

[14] VDRs maintain continuous, sequential records of data relating to a ship's equipment and its command and control. VDRs also capture audio from certain areas on the navigation bridge 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. Investigators retrieve and analyze VDR data as part of accident investigations.

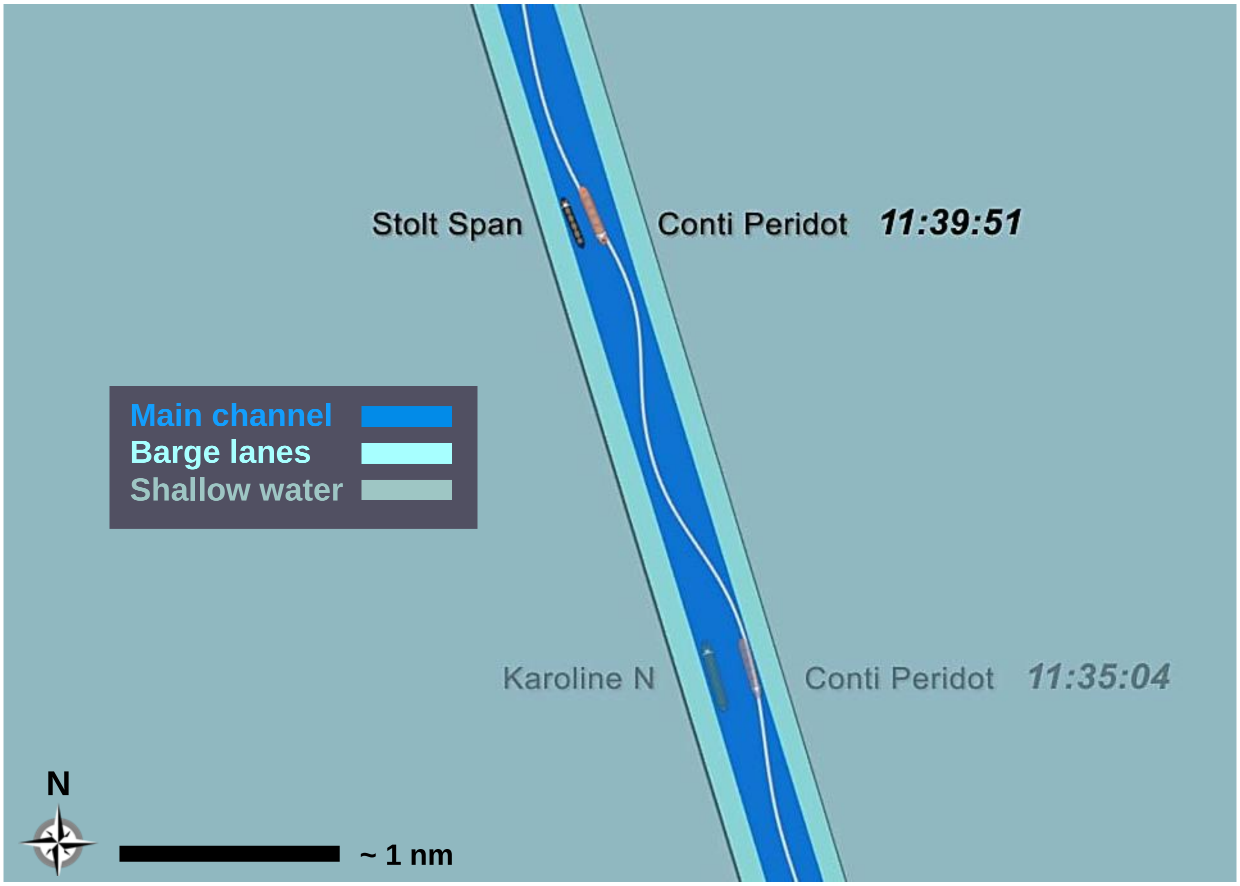


**Figure 4.** Animation image showing the oscillating trackline of the *Conti Peridot* after the bulk carrier passed the *Karoline N* and before meeting the *Stolt Span*, about 1 hour before the collision. Image compiled using automatic identification system (AIS) and VDR data.[15]

After passing closely astern of the *Stolt Span*, the *Conti Peridot* sheered toward the left bank. Eventually, the pilot on the *Conti Peridot* regained heading control and brought the bulk carrier past navigation markers 70 through 74. The pilot told investigators that the visibility was less than the ship's length and that he was unable to see the bow. About 1206, the *Conti Peridot* passed the south end of the Bayport Flare. About 1210, north of the Bayport Flare and passing navigation marker 78, the pilot on the *Conti Peridot* assessed the outbound traffic he would be meeting. Looking ahead on his display, he recalled seeing three vessels lined up to meet him; the *Carla Maersk* was the second of the three vessels. He noted that they were all about a mile and a half apart, and he thought "this is the same scenario" similar to the previous meetings with the *Karoline N* and the *Stolt Span*. He also assessed the position of a northbound towing vessel, the *Lincoln L*, which was transiting ahead of the *Conti Peridot* in the starboard-side barge lane pushing one barge. The pilot told investigators that he decided to slow down and allow the *Lincoln L* to move farther ahead, so that the *Conti Peridot* would not meet deep-draft vessels while simultaneously having a tow alongside. Accordingly, at 1217, the pilot ordered the speed

[15] AIS is a maritime navigation safety communications system. At 2- to 12-second intervals on a moving vessel, the AIS automatically transmits vessel information, including the vessel's name, type, position, course, speed, navigational status, and other safety-related information, to appropriately equipped shore stations, other vessels, and aircraft. The rate at which the AIS information is updated depends on vessel speed and whether the vessel is changing course. AIS also automatically receives information from similarly equipped vessels. Coast Guard regulations require AIS in waterways governed by vessel traffic control (Title 33 *CFR* Part 164).

reduced from full ahead (about 11 knots, the speed at which the *Conti Peridot* had transited for part of the voyage) to half ahead (about 8.5 knots).[16]

On board the outbound *Carla Maersk* a few minutes earlier (1207, about 24 minutes before the collision), the pilot and the master were discussing the decreasing visibility and the ships they would have to meet as the tanker proceeded. The pilot on the *Carla Maersk* expressed hesitation about continuing the transit in the fog. He told the master that, given the decreasing visibility, he did not want to meet any inbound ships. He and the master continued to discuss the pros and cons of the situation as the tanker continued south at half-ahead speed of about 9 knots. They discussed the possibility of entering Barbours Cut north of Morgan's Point with or without the aid of tugboats and anchoring in the turning basin there to wait out the fog and/or inbound traffic (figure 5). The discussion continued until about 1221 when the pilot said, "It's too late now. We gotta go." Neither the pilot nor the master on the *Carla Maersk* knew that the pilot on the *Conti Peridot*—which their vessel was about to meet—had experienced difficulty controlling the bulk carrier.

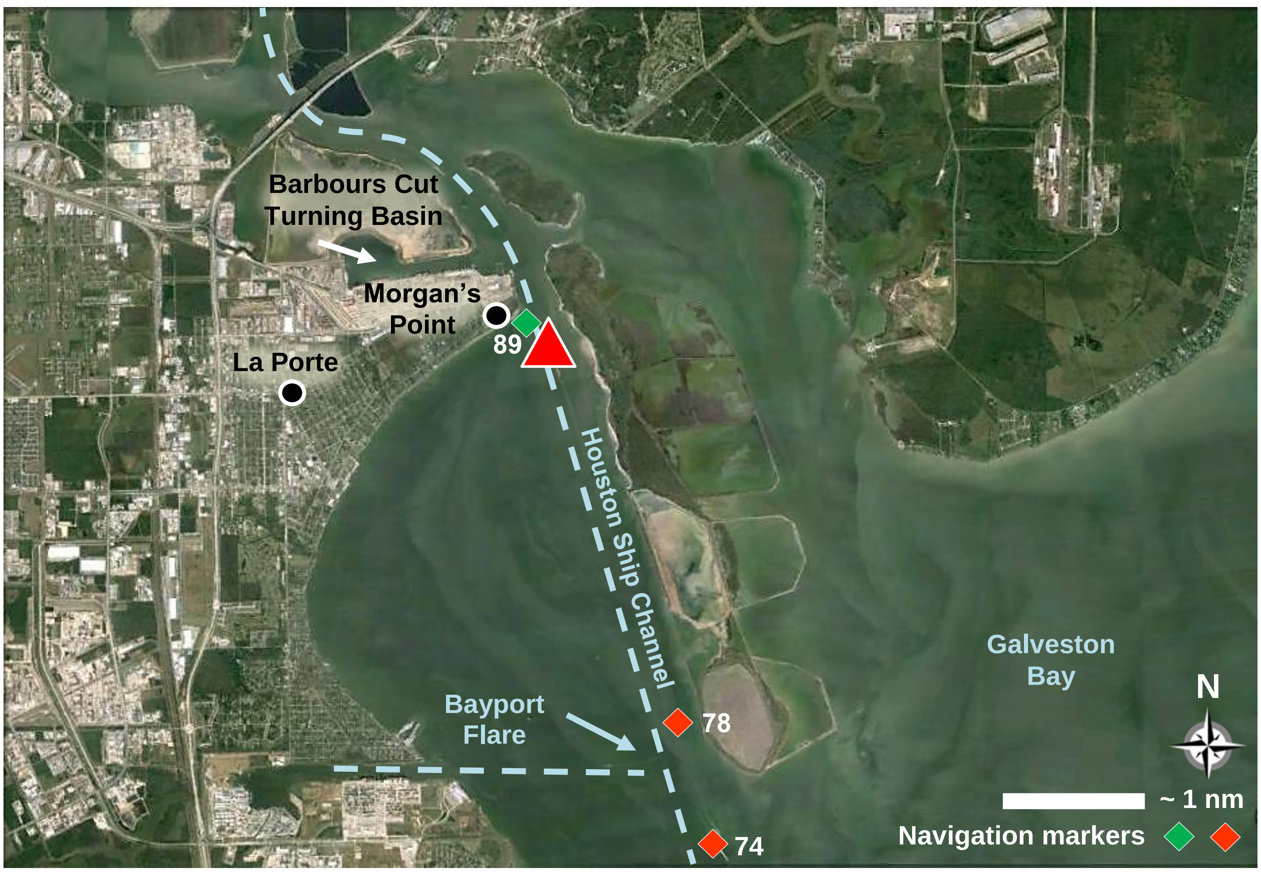


**Figure 5.** Satellite image of the area near Morgan's Point, including the Barbours Cut turning basin and the city of La Porte. The collision site near navigation marker 89 is overlaid by a red triangle.

---

[16] According to the *Conti Peridot*'s pilot card, which is an informational card about the ship's particulars that the master presented to the pilot during the master/pilot exchange, full-ahead speed equaled 105 rpm on the bulk carrier's main propulsion engine. Due to perceived excessive vibration at 105 rpm, the master decided to allow a maximum of 100 rpm (5 fewer rpm than stated on the pilot card) during full-ahead engine orders. The master did not inform the pilot of this minor difference in engine rpm, nor did the pilot express a problem with the engine during any part of the transit or in his postaccident interview. (Also see section "2.1 Inadequate Bridge Resource Management.")

Given the increasing fog, the *Carla Maersk* bridge team added an additional bow lookout from the crew.[17] The pilot also asked the mate to change the radar scale from 3 miles to 1.5 miles for greater detail. The pilot then repositioned himself on the bridge, away from the front windows and aft to the radar (figure 6), placing his PPU next to it. The bridge team also began sounding the fog signal on the *Carla Maersk.*

**Figure 6.** The *Carla Maersk* navigation bridge, shown from port to starboard. Consoles are equipped with radars, electronic chart display and information system (ECDIS), steering controls, and engine telegraph and communications equipment.

About 1216, some 15 minutes before the collision, the pilot on the *Conti Peridot* contacted the pilot on the next vessel he was about to meet, the *Gaia Leader*, and initiated a port-to-port meeting arrangement.[18] He continued to keep the *Conti Peridot* in the center of the channel to prepare for the meeting, anticipating that the bulk carrier was "going to take a run off that bank" (that is, sheering after encountering bank effect). The two vessels met and passed each other about 1224, each transiting at a speed of about 9.5 knots, with nothing out of the ordinary heard on the radio or recorded by the *Conti Peridot* VDR. The pilot on the *Conti Peridot* told investigators that, after

[17] A *bridge team* is generally defined as everyone who is involved in a vessel's navigation. This report defines the bridge team as the pilot, the master, and the navigational/bridge crew.

[18] *Port-to-port* meeting arrangements are the standard, although starboard-to-starboard meetings do occur and are not considered abnormal.

passing the *Gaia Leader* and sensing that vessel's large displacement of water, the *Conti Peridot*, as expected, "[dove] into the void" behind the vehicle carrier (similar to what happened with the *Stolt Span* about 1 hour earlier). The pilot said that the *Conti Peridot* was then "off to the races," describing the bulk carrier's uncontrolled motion from bank to bank. He did not communicate the continued handling difficulty to the bridge crew nor anyone else. When investigators asked the pilot what the *Conti Peridot* master was doing during this time, the pilot said that he did not think the master (or bridge crew) knew what was happening. The pilot said that the master and bridge crew "didn't know we were going bank to bank" and that no one questioned him as to what was going on with the vessel (figure 7).

At this point, the *Carla Maersk* was about 2 miles north of the *Conti Peridot*, and, because of the fog, its bridge team could not visually sight the meeting between the *Gaia Leader* and the *Conti Peridot*.

**Figure 7.** The *Conti Peridot* navigation bridge, shown from port to starboard. Consoles are equipped with radars, ECDIS, steering controls, and engine telegraph and communications equipment.

About 1226, shortly after the *Conti Peridot* and *Gaia Leader* passed each other, the pilot on the *Conti Peridot* radioed the pilot on the *Carla Maersk* and again requested a port-to-port meeting arrangement. The pilot on the *Carla Maersk* acknowledged the request. The pilot on the *Conti Peridot* now attempted to line up the vessel for meeting the *Carla Maersk*, but he said nothing to the pilot on the *Carla Maersk* about his ongoing difficulty controlling the *Conti Peridot*.

The pilot on the *Conti Peridot* told investigators that, as the meeting with the *Carla Maersk* approached, the *Conti Peridot* sheered toward the left bank. The pilot applied counter (starboard) rudder to try to slow the rate of turn to port. At some point, after sheering to the left, the *Conti Peridot* sheered back toward the right bank. The pilot then applied counter (port) rudder to arrest the starboard sheer and continued applying the port rudder as he came off the right bank. When he then saw that the *Conti Peridot*'s speed had decreased, he realized that he needed more "wheel wash," or thrust over the rudder, to improve rudder effectiveness. He shifted the rudder to hard starboard and, to achieve a better rudder response to this starboard command, ordered the engine to full-ahead speed.[19] But despite the full-ahead and starboard orders, the *Conti Peridot* continued sheering to port, toward the *Carla Maersk*.

At this point, about 1229, the pilot on the *Conti Peridot* did warn the pilot on the *Carla Maersk* via radio, saying in part, "Try to miss me, coming across the channel." He also asked the other pilot to come left with the *Carla Maersk* in the waterway. This requested direction was counter to the port-to-port meeting arrangement to which the pilots had previously agreed, but the pilot on the *Conti Peridot* explained to investigators that, because the bulk carrier was sheering to the left (toward the *Carla Maersk*), he was hoping that the pilot on the *Carla Maersk* could come left to avoid the collision. The pilot on the *Carla Maersk* replied that he could not come left as he had already committed to moving to starboard in preparation for the meeting (figure 8).

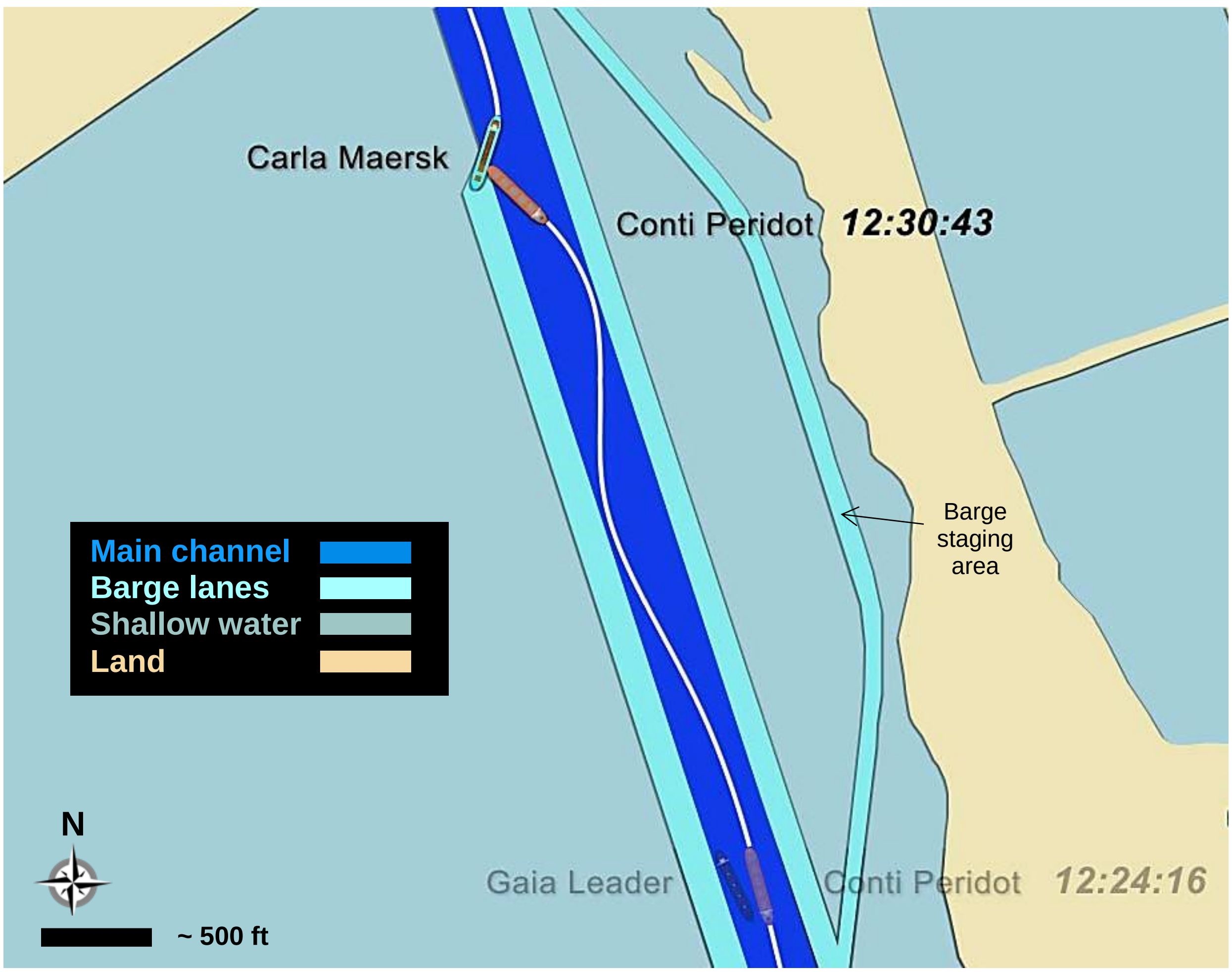


**Figure 8.** Animation image of the *Conti Peridot*'s oscillating trackline after the bulk carrier passed the *Gaia Leader* and as it approached the meeting with the *Carla Maersk*. Image compiled using AIS and VDR data.

[19] A *hard* rudder command is a maximum rudder input to port or starboard, usually about 35 degrees. A temporary order of *full ahead* is often used in maneuvering situations to increase water flow across the rudder and thereby enhance the turning effect of the rudder.

As the *Conti Peridot* continued sheering to the left and the vessels came closer to one another, the *Carla Maersk* bridge team could see the bow of the *Conti Peridot* emerging from the fog and crossing the channel toward the tanker. Just seconds before the collision, the *Conti Peridot* began turning to starboard. The pilot on the *Carla Maersk* ordered the rudder hard right (toward the right bank of the channel in relation to the travel direction of the *Carla Maersk*) and the engine to full-ahead speed in order to turn as quickly as possible from the oncoming bow of the *Conti Peridot*. The *Carla Maersk* grounded during the collision sequence.

At 1230, the bow of the *Conti Peridot* struck the port side of the double-hulled *Carla Maersk* just forward of midship (figure 9). The collision damaged several ballast tanks and cargo tanks on the *Carla Maersk*, including breaching cargo tank no. 4, and damaged the bow on the *Conti Peridot* (also see sections "1.4 Damage," "1.5 Emergency Response," and "1.6 MTBE Information"). The vessels separated shortly after the collision and anchored in the vicinity.


**Figure 9.** The two vessels moments after the collision. (Photo by *Carla Maersk* crewmember)

## 1.2 Injuries

None of the crewmembers on either the *Conti Peridot* or the *Carla Maersk* reported sustaining injuries in the collision.

## 1.3 Toxicological Testing

Testing for alcohol and other drugs was conducted on relevant crewmembers from both vessels, the pilots, and relevant VTS watchstanders in accordance with regulations.[20] Urine analysis was conducted on the crew and pilots; in addition, breath tests were conducted on both pilots. All results were negative.

## 1.4 Damage

***Carla Maersk*.** The damage to the *Carla Maersk* totaled $5.6 million, according to the vessel's classification society Det Norske Veritas-Germanischer Lloyd.[21] The initial impact point was the port side forward of midship, between frames 69 and 78. Portside cargo tank no. 4 was breached, and portside cargo tank no. 3 was damaged (figures 10 and 11). Portside ballast tanks nos. 2 and 3 port were breached as well.


**Figure 10.** The damaged port side of the *Carla Maersk*. (Photo by the Port of Houston Authority Fire Department)

[20] In accordance with Title 46 *CFR* 4.06-3, postaccident alcohol testing must be conducted within 2 hours and other drug testing must be completed within 32 hours of a serious marine accident, unless precluded by safety concerns directly related to the accident.

[21] Classification societies are nongovernmental organizations that establish and maintain standards for shipbuilding and operation, and they are authorized to perform vessel inspection and certification functions delegated by the Coast Guard.

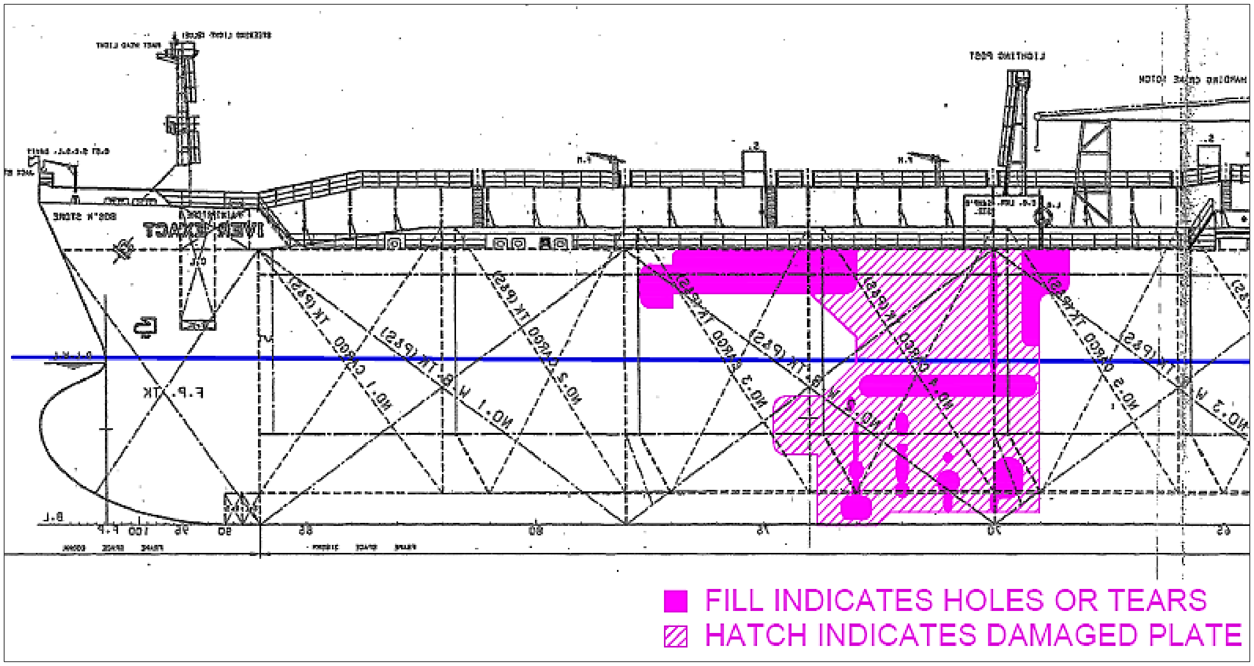


**Figure 11.** The portside damage to the *Carla Maersk* highlighted in magenta. (Image provided by Titan-Svitzer Salvage; reverse mirror image drawing)

***Conti Peridot*.** The damage to the *Conti Peridot* totaled $2.6 million, according to the damage survey conducted by the bulk carrier's classification society, the American Bureau of Shipping. The bow was scraped and inset in an area about 30 feet high and 15 feet wide, and the portside anchor was lost in the collision (figure 12).


**Figure 12.** The damaged bow of the *Conti Peridot*. (Photo by Port of Houston Authority Fire Department)

## 1.5 Emergency Response

Immediately after the collision, both vessels anchored in place until it could be determined whether they could transit safely and until suitable lay berths were identified for each. The *Carla Maersk* was equipped with an inert gas system, which supplied the cargo tanks with nitrogen gas to create an oxygen-deficient environment so that combustion could not occur inside the tanks.[22]

Within 10 minutes of the collision, about 1240, the Coast Guard closed a nearly 3-mile section of the Houston Ship Channel between an area just north of Morgan's Point and navigation marker 86 to the south.[23]

During the first 10 to 15 minutes after the collision, the *Carla Maersk* began listing to port, eventually reaching a list angle of about 10 degrees. The master told investigators that he assumed that the list resulted from the breached ballast tanks nos. 2 and 3 filling with water. Because the master knew that several cargo tanks on the starboard side were empty and able to receive product, he instructed the chief engineer to move cargo and ballast water to try to balance the ship. He also alerted everyone on board to report to the muster stations. The crew began the process of transferring cargo from portside cargo tank no. 3 to starboard-side cargo tank no. 2; about 45 minutes after the collision, the *Carla Maersk* was no longer listing. The master also initiated the required notifications.[24]

A Coast Guard team that boarded the *Carla Maersk* after the accident reported that three ballast tanks and two cargo tanks were ruptured on the port side. An oil sheen about 1 mile long by one-half mile wide and an odor were reported in the vicinity of the *Carla Maersk* (figure 13).

[22] The *Carla Maersk* was equipped with an inert gas system because the tanker's deadweight tonnage exceeded 20,000 tons. However, the International Bulk Chemical Code does not require MTBE to be inerted (MARPOL Annex II Cargoes with Flash Point <60°C, Flash Point of MTBE -18°F [-27.8°C]). The *Carla Maersk* owner/operator, A.P. Moller–Maersk A/S, voluntarily uses the inert gas system as a safety precaution on its tankers carrying MTBE.

[23] That section of the Houston Ship Channel was reopened for traffic 3 days later, on March 12.

[24] In accordance with the Oil Pollution Act of 1990, the *Carla Maersk* master initiated emergency response procedures described in the vessel's spill response plan. These procedures included contacting the onshore qualified individual, who is a person designated to be notified in the event of a cargo spill and who manages the response effort on behalf of the ship owner or operator. In this case, the qualified individual was a representative of Gallagher Marine Systems who acted on behalf of A.P. Moller–Maersk A/S.


**Figure 13.** Sheen on the water near the *Carla Maersk*. (Photo by the Coast Guard)

The emergency response guidance for MTBE advises responders to isolate the spill for at least 1,000 feet in all directions, which responders did. Air monitoring stations were promptly established (figure 14). A fireboat, dispatched by the Port of Houston Authority Fire Department and carrying an assistant fire chief, was on scene next to the *Carla Maersk* within 25 minutes of the collision. The *Carla Maersk* crew was also monitoring the air in several locations inside the ship. Initial readings detected high levels of volatile organic chemical vapor, both on board and near the ship. Personnel were wearing appropriate personal protective equipment while conducting air monitoring. About 1309, due to increasing reports of odor, a modified shelter-in-place order was put into effect for the Barbours Cut terminal; the order was subsequently extended to include the city of Morgan's Point. About 1415, the local fire department ordered that the Barbours Cut terminal be evacuated. About 1500, some 2.5 hours after the collision, a unified command was established at the La Porte Emergency Operations Center, near Morgan's Point.[25] About 1600 that same afternoon, the shelter-in-place order was

[25] 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 (in accordance with the National Incident Management System, which strives to guide governmental and nongovernmental entities to work together seamlessly and manage incidents involving threats and hazards). In this case, the qualified individual (of Gallagher Marine Systems) served as incident commander. The Coast Guard captain of the port, who was also the commanding officer of Coast Guard Sector Houston/Galveston, served as the federal on-scene coordinator. The Texas Commission on Environmental Quality served as the state on-scene coordinator. A representative from the city of La Porte Emergency Management and a representative from the Port of Houston Authority served as the two local on-scene coordinators. In addition, staff from the National Oceanographic and Atmospheric Administration, Wildlife Response Services LLC, the

lifted after continuous air monitoring showed that the readings were not at elevated levels. Vapor was still detected near the *Carla Maersk*, but levels kept decreasing during the afternoon and evening. At 1100 the next morning, March 10, air monitoring equipment on board a local fire department boat adjacent to the tanker detected no vapor.

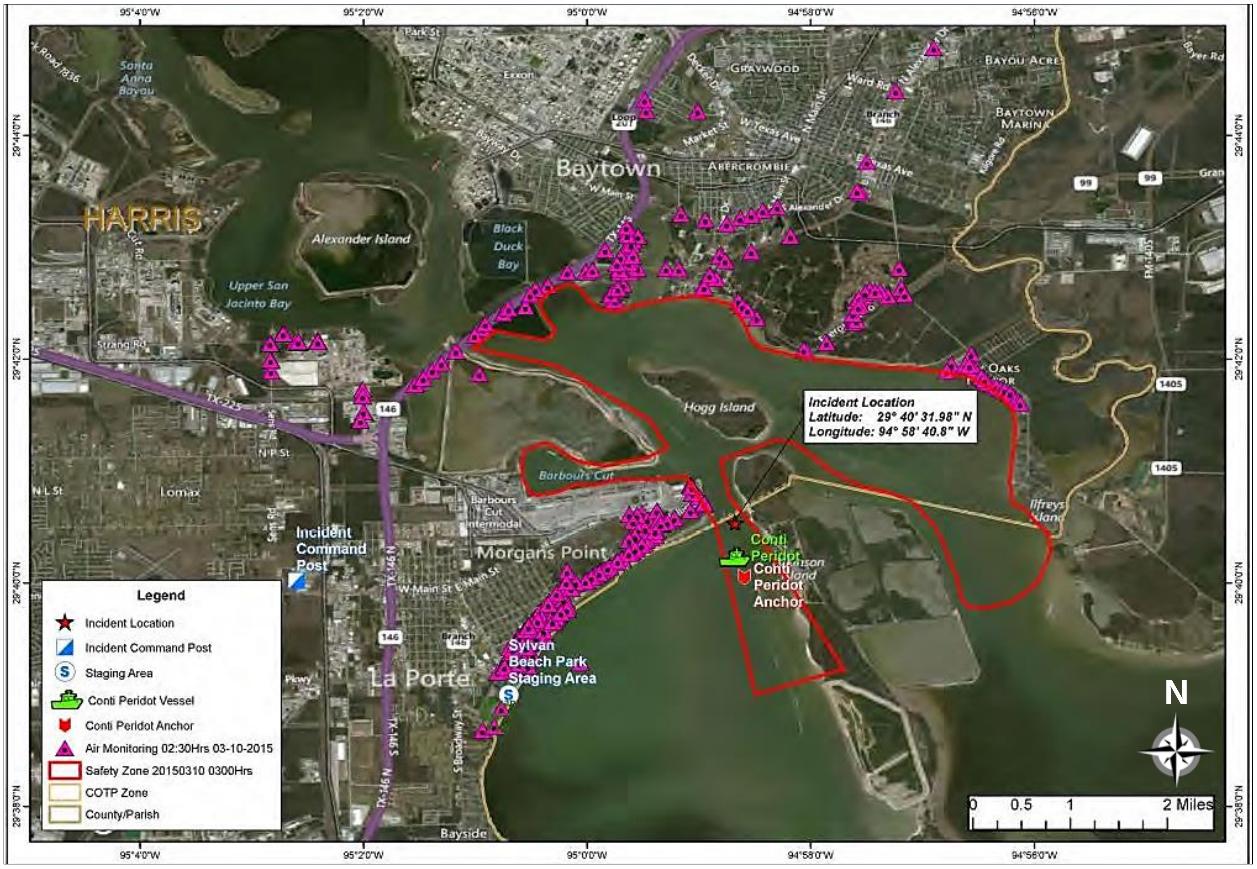


**Figure 14.** Map of the safety zone and air monitoring stations on the morning after the collision.

The unified command estimated that about 2,100 barrels (88,200 gallons) of MTBE were lost in the collision, with a large portion probably spilling into the *Carla Maersk*'s onboard ballast water.[26] Nevertheless, the unified command used a "worst-case" discharge scenario (three punctured cargo tanks, or 42,000 barrels/1.76 million gallons) for its response, even though it was known that the *Carla Maersk*'s breached cargo tanks were not fully loaded.

On March 12, 2015, when the Houston Ship Channel was reopened to traffic, the *Carla Maersk* was moved out of the channel and anchored in the Barbours Cut turning basin. Lightering activities began there on March 14.[27] On March 17, after lightering concluded, the *Carla Maersk* was moved to a nearby facility to offload the remaining cargo.

Center for Toxicology and Environmental Health, Horizon Environmental, and Titan-Svitzer Salvage assisted the unified command.

[26] This is the amount of MTBE that, based on a review of onboard cargo loading, was unaccounted for after the accident. However, because MTBE easily blends with water, the amount could not be confirmed.

[27] *Lightering* is the process of discharging a cargo from one vessel to another vessel or barge to decrease the vessel's draft. In this case, lightering was done to remove MTBE from the breached tanks to mitigate the spill into the environment.

The Coast Guard provided response documentation after the National Transportation Safety Board (NTSB) on-scene investigation, which indicated that the local, state, and federal response actions followed generally accepted practice for an MTBE release.

## 1.6 MTBE Information

MTBE is a volatile, flammable, and colorless liquid with a distinctive anesthetic-like or turpentine-like odor. Vapors are flammable, heavier than air, and may travel some distance to a source of ignition. MTBE is slightly soluble in water. Studies have shown that when released to surface waters, MTBE evaporates relatively quickly. Since 1979, MTBE has been used as an octane enhancement additive for gasoline motor fuel. Due to environmental and health concerns, MTBE use has been phased out in the United States; however, it is still used in gasoline in other countries.

The Environmental Protection Agency has concluded that available data are not adequate to estimate the potential health risks of MTBE at low exposure levels, but the information supports the conclusion that MTBE is a potential human carcinogen at high doses.[28]

According to the National Oceanographic and Atmospheric Administration (NOAA), only limited aquatic toxicity data are available for MTBE. Although the effect of the release on the aquatic environment in the Houston Ship Channel was not well understood, the NOAA scientific support coordinator predicted the potential for localized fish kills given the size of the release.[29] None was reported.

## 1.7 Personnel Information

**Pilot on the *Conti Peridot*.** The pilot, age 63, was a 1975 graduate of Texas A&M Maritime Academy in Galveston. After graduating, he joined Sabine Towing and Transportation, where he worked his way up from able seaman quartermaster to master (he obtained his mariner credential as master, unlimited, in 1982). He left Sabine in 1991 to become a pilot with the Houston Pilots Association, training for 2 years as deputy pilot and becoming a full pilot in 1993.[30] As pilot, he had handled more than 4,900 ships.

The pilot on the *Conti Peridot* told investigators that, on the day of the accident, he was well-rested and had slept sufficiently. The day before the accident, he took three naps totaling more than 7 hours. The first nap took place on board the pilot boat while en route to another piloting assignment, where he was the no. 2, or backup, pilot on board. The second nap took place on board that ship shortly after he boarded (with a 15-minute break to complete paperwork). His third nap took place between about 1630 and 1830. Later that evening (the night before the accident), he went to bed at 2300 and slept until 0600, or about 7 hours. Review of his

[28] Information obtained from the Environmental Protection Agency website. Methyl Tertiary Butyl Ether Overview, https://archive.epa.gov/mtbe/web/html/faq.html (accessed April 7, 2016).

[29] The NOAA scientific support coordinator provides guidance to the federal on-scene coordinator, such as predicting MTBE movement and identifying risks to sensitive environmental resources. The fish kill prediction was based on a worst-case discharge of 42,000 barrels.

[30] The deputy pilot program commences after the pilot board accepts a pilot's application. For the first 6 months, the deputy pilot rides along with a senior pilot, who critiques and assesses the trainee's ability. The training starts with vessels of smaller tonnage, length, and draft. As the new pilot progresses through the program, the ship sizes increase accordingly.

cell phone records showed that he did not make any phone calls or send any text messages during periods marked as "sleeping" on his work/rest log. He had been awake for about 6.5 hours when the accident occurred.

The pilot on the *Conti Peridot* wore glasses only for reading and did not otherwise need corrective lenses. He stated that no medical issues affected his job or license. Before this accident, he had never been in a collision.

The pilot on the *Conti Peridot* provided his training records to investigators. He completed a 16-hour course in bridge resource management in February 2015, the month before the accident.[31] Other training in the last 5 years included the following: Restricted Visibility Navigation for Pilots (2014); Collision Regulations for Pilots (2013); Pilot Incident Management (2013); Raven Electronics Navigation Systems Training (2013); Error Detection and Application of Advanced Radar Techniques in Confined Waters (2012); Bridge Resource Management for Marine Pilots–Renewal (2012); Fatigue, Sleep and Medications (2010); 1-Day Radar Observer Recertification Course (2012); General Shiphandling (2011); Legal Aspects of Piloting, and Ship Simulator Course (2010).

***Conti Peridot* Master.** The *Conti Peridot* master, age 53, was of Filipino nationality. He graduated from the Philippine Merchant Marine Academy in 1983. He had a Liberia-issued credential as master, unlimited tonnage. He had sailed worldwide as master since 2004, and this was his second voyage as master of the *Conti Peridot*.

The *Conti Peridot* master completed the following relevant training in the last 5 years: Basic Training (2014); Furuno Type Specific ECDIS (2014); and ECDIS (2012).

According to his work/rest log, during the week leading up to the accident, the *Conti Peridot* master worked 10 hours per day for 4 days, with a 1-hour lunch break each day. The day of the accident, the master had worked about 6.5 hours when the collision occurred. The master's work/rest log did not distinguish between rest and sleep hours.

**Pilot on the *Carla Maersk*.** The pilot, age 56, started working on harbor tugboats after graduating high school in 1976. About 3 years later, he obtained an endorsement as able seaman and started working for Exxon, where for the next 2 years he towed oil barges. All his maritime training before applying for a pilot's position with the Houston Pilots Association was experience gained through working in the marine industry as mariner. He had completed thousands of transits on vessels of all sizes after becoming a full pilot.

The pilot completed a 16-hour course of instruction, Bridge Resource Management for Pilots, in September 2013. Other training in the last 5 years included Collision Regulations for Pilots (2013), Pilot Incident Management (2013), Bayport Flare Turn Using Manned Model (2014), Legal Aspects of Piloting (2012), and 1-day Radar Observer Recertification (2010).

According to the pilot's work/rest log, he worked two single shifts and one double shift during the week leading up to the accident. He averaged 9.9 hours of sleep per every 24-hour period during the 96 hours before the accident. The night before the accident, the pilot went to bed at 2230 and slept until 0600 on the morning of the accident (about 7.5 hours of sleep). He

[31] *Bridge resource management* is the effective use of all available resources—information, equipment, and personnel—by a vessel's bridge team (masters, pilots, officers, and crew) to safely operate the vessel.

had been awake for about 6.5 hours when the accident occurred. Review of his cell phone records showed no activity during the times that the pilot reported as having slept.

***Carla Maersk* Master.** The *Carla Maersk* master, age 43, was of Swedish nationality. He started sailing in 1988 as ordinary seaman and later as able seaman. He enrolled at the Swedish Maritime Academy in Kalmar in 1999 and, after graduating, started working as a licensed deck officer in 2002. He obtained his master's credential in 2009 and worked exclusively as master after that, transiting only on chemical tankers such as the *Carla Maersk*, which he first came on board in August 2012. He had transited in the Houston Ship Channel about two dozen times previously and was very familiar with its ship meeting arrangements; he stated that the waterway was challenging. He had not previously worked with the pilot assigned to the *Carla Maersk* on the day of the accident.

The *Carla Maersk* master had most recently completed bridge resource management training in May 2013. Other relevant training courses in the last 5 years included ECDIS-TRANSAS (2015), Environmental Management and Compliance (2014), Safety Culture (2011), Working Environment (2011), and Incident Investigation (2011).

The master told investigators that no cell phones were used on the bridge either by the pilot or anyone of the bridge team around the time of the accident. He estimated obtaining about 8 hours of sleep per night during the 3 previous nights while the *Carla Maersk* crew loaded cargo in port, and stated that he felt well-rested on the morning of departure.

## 1.8 Waterway Information

The Port of Houston is one of the busiest ports in the world in terms of cargo tonnage.[32] The Coast Guard reported that, in 2015, the average daily traffic along the Houston Ship Channel totaled about 765 vessel transits (including tankers, freighters, tows, and ferries, among others), with nearly 80 ships docked in port.[33]

The Houston Ship Channel is about 55 nautical miles in length from the sea buoy offshore from Galveston (where pilots usually board inbound deep-draft vessels) to the turning basin at the Port of Houston. In 2005, the US Army Corps of Engineers completed a major upgrade of the Houston Ship Channel, which included adding dedicated barge lanes for towing vessels and deepening and widening the main channel. The main Houston Ship Channel in the area of the accident is 530 feet wide with a project depth of 45 feet. The barge lanes located on both sides of the main channel are each 235 feet wide with a project depth of 12 feet (figure 15).

---

[32] Statistics and rankings are compiled by organizations including port authorities, local and national governments, marine industry groups, and business and economic analysts.

[33] *State of the Waterway 2016*, available at www.uscg.mil/vtshouston/ (accessed April 7, 2016).

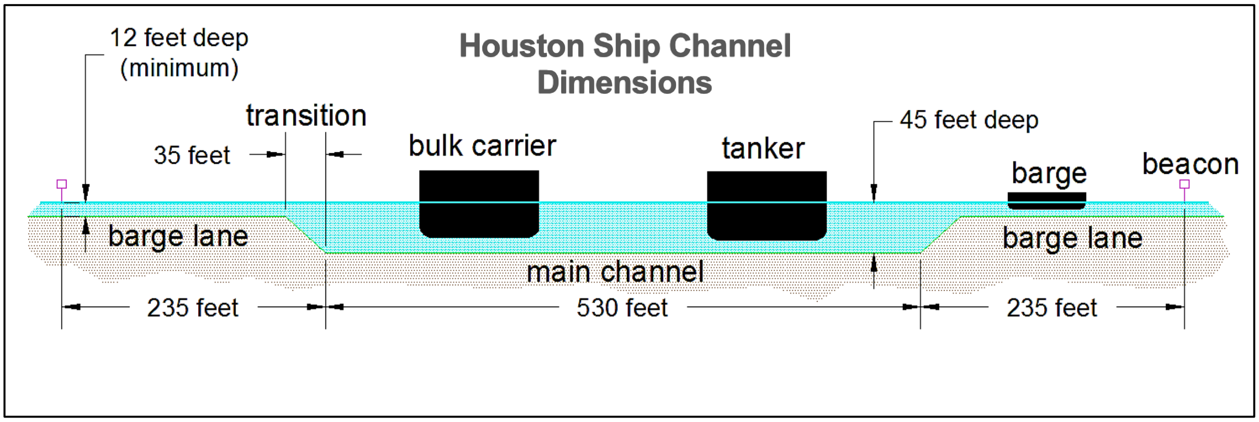


**Figure 15.** Cross-sectional view of the Houston Ship Channel in the accident area. (Modified image; original provided by the Houston Pilots Association)

## 1.9 Weather Information

At 1230, the time of the collision, winds were light at 10 knots or less from the east. Both the air and water temperature was 54 degrees F and the barometer was 1023.4 mb.[34] Tidal current predictions showed slack water (negligible force of the waterway current) at the accident time and location. Visibility in the collision area was restricted due to fog.

According to a 2009 safety assessment of the Houston Ship Channel conducted by the Coast Guard, heavy seasonal fog is common in the spring and fall. However, the onset and dissipation of the fog can be hard to predict. Fog, of varying degree of intensity, may also be localized to specific parts of the channel. On the morning of the accident, the National Weather Service forecasted the possibility of sea fog developing by the afternoon/evening.

## 1.10 VTS Houston/Galveston

According to the VTS Houston/Galveston watch log, the VTS watch was staffed by a supervisor, an assistant supervisor, and six watchstanders at the time of the accident. About 44 vessels were in the VTS Houston/Galveston coverage area, which was divided into a southern zone (known as "Sector I & II") and a northern zone (known as "Sector III"), with one watchstander per zone.[35] Of the personnel on duty, the watch supervisor had the highest level of authority and overall responsibility for the watch.

At the VTS watch desk for Sector I & II (figure 16) in which the accident occurred, an active-duty watchstander took the watch at 1030 that morning, beginning a 2-hour shift. When asked by investigators about his preferred display settings, the watchstander said that he did not like using the track history setting on the display (a function that displays a vessel's course over ground on the screen for a defined period of time), because he felt that this setting "just clutters up the screen."[36] He did use the track vector setting, a function that displays both a

[34] Temperature information provided by a NOAA buoy at Morgan's Point, about half a mile west of the collision site.

[35] In April 2015, about 1 month after the accident, VTS Houston/Galveston split the southern zone (Sector I & II) into two separate zones and added a watchstander. Each of the three watch sectors in VTS Houston/Galveston coverage area (I, II, and III) is now individually monitored by a watchstander.

[36] VTS Houston/Galveston is equipped with software called Ports and Waterways Safety System (PAWSS), which collects, processes, and disseminates information on the marine operating environment and vessel traffic. PAWSS

vessel's current heading and the projected immediate future direction of travel. The watchstander set that function to a range of 2 to 3 minutes.

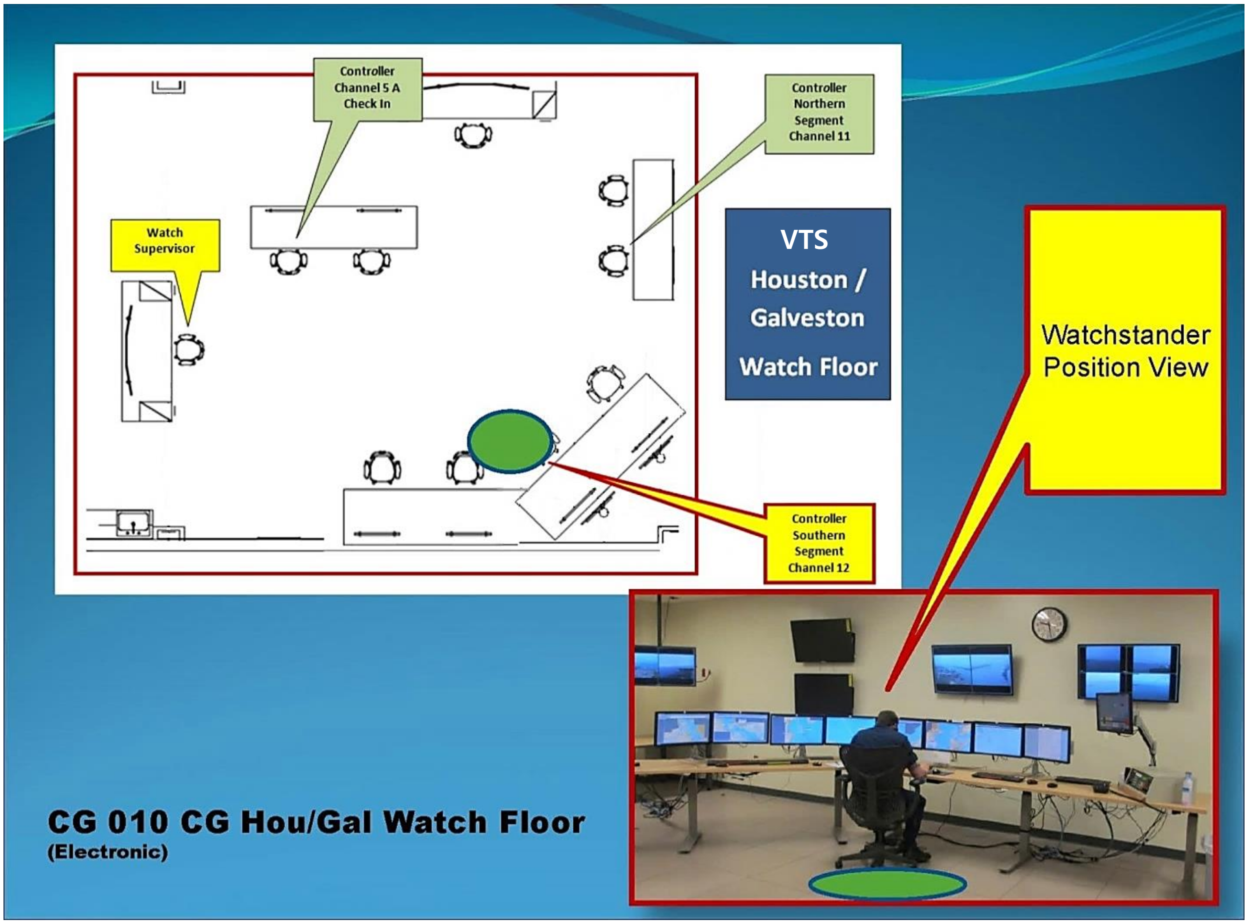


**Figure 16.** The top drawing shows the layout of VTS Houston/Galveston's vessel traffic center. The bottom photo shows a watchstander monitoring the displays for southern Sector I & II.

After VTS was notified of the suspended pilot boardings of inbound vessels (the Houston Pilots Association at 1120 and the Galveston–Texas City Pilots at 1135), the VTS watch supervisor contacted the director of VTS Houston/Galveston about any potential actions that the director might consider taking, such as broadcasting a fog advisory. About the same time, the VTS assistant watch supervisor received a call from a local representative of the National Weather Service about the deteriorating visibility in the Houston Ship Channel and Galveston Bay. The VTS watch supervisor decided to broadcast a dense fog advisory to vessels in the VTS coverage area, which would include informing mariners of locations where the fog was the heaviest. He conveyed the directive to the respective VTS watchstanders, who began including this information in the radio broadcast to vessels. The watchstanders also began a "roll call," which was an attempt to contact individually each vessel inside the respective sector to alert mariners about the fog. (Also see section "2.5 VTS Houston/Galveston Procedures in Restricted Visibility.")

receives vessel movement data from AIS, three radars, and 26 closed-circuit television cameras. In addition, PAWSS collects meteorological and hydrological data from NOAA's Physical Oceanographic Real-Time System.

# 2. Investigation and Analysis

Neither pilot reported any problem with his PPU or the bridge navigation equipment. In addition, investigators assessed the engine and preventive maintenance records for both ships and found no anomalies with the propulsion and steering systems. Further, toxicological testing was negative for the presence of alcohol and other drugs. Investigators also obtained and reviewed available work and sleep records for the pertinent individuals in this accident, as well as assessed their medical histories and medications. Finally, review of available cell phone records (such as for both accident pilots) showed no evidence that personal use of electronic devices leading up to the accident played a role. The NTSB therefore concludes that navigation equipment, vessel propulsion and steering systems, alcohol and other drug use, fatigue, medical conditions and medication use, and distraction from personal use of electronic devices were not factors in this accident.

## 2.1 Inadequate Bridge Resource Management

Although the pilot on the *Conti Peridot* was growing concerned about how the bulk carrier was handling, he did not communicate these concerns to the bridge crew. When investigators asked the pilot why he did not consult with the *Conti Peridot* master about the handling difficulties, he stated, "I didn't know if he could have addressed them . . . or if he could have helped me correct them." The pilot did acknowledge that the master was entitled to know about the handling difficulties, but the pilot said that he simply did not believe that it would have helped the situation at that time. When investigators asked the pilot where the *Conti Peridot* master was standing during the majority of the voyage, he could not recall exactly, but he mentioned that the master may have been spending a majority of the time over on the port side of the bridge near the communications table and desk.

The *Conti Peridot* master told investigators that he was standing in front of the ECDIS and radar from time to time. For the length of the VDR bridge audio recording that investigators reviewed, the master and the pilot could not be heard discussing the vessel's navigation leading up to the collision. The master did not engage, such as by asking the pilot if everything was all right or suggesting to slow down or call the oncoming ship, most likely because he was unaware of the vessel's heading fluctuations. In his interview, the master stated that when he first saw the *Carla Maersk* appearing out of the fog just before the collision, he thought the *Carla Maersk* was positioned perpendicular to the channel. In actuality, it was the *Conti Peridot* that was crossing the channel into the path of the *Carla Maersk*. Even if the master had been fully aware of the *Conti Peridot*'s heading fluctuations, he may have been reluctant to speak up about them. Cultural factors can contribute to such hesitation; in fact, the pilot on the *Conti Peridot* stated that, in his experience, certain cultures tended to be more deferential and would not challenge a pilot. Scientific research also indicates that culture can play a role in bridge resource management.[37] Effective bridge resource management training addresses cultural factors.

Further, the *Conti Peridot* master did not inform the pilot that, due to perceived excessive engine vibration at full-ahead speed, he allowed a maximum of 100 rpm on the main propulsion engine. The *Conti Peridot* pilot card that the pilot reviewed at the start of the voyage stated that

[37] See, for example, research cited on page 111 of NTSB 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.* Marine Accident Report NTSB/MAR-09/01. Washington, DC.

full-ahead speed equaled 105 rpm on the bulk carrier's engine. The difference was minor and not a factor in the accident, nor did the pilot express a problem with the engine's performance during any part of the transit or in his postaccident interview. Nevertheless, the master should have brought to the pilot's attention the difference between stated and actual rpm as part of effective bridge resource management. The NTSB concludes that the lack of communication between the master and the pilot on the *Conti Peridot* and the lack of situation awareness exhibited by the master demonstrate inadequate bridge resource management, which reduced the effectiveness of the *Conti Peridot* bridge team.

The NTSB has a long history of advocating for effective bridge resource management and clear, unambiguous communication in the marine industry.[38] Due in part to this advocacy, training in bridge resource management has become standard in mariner curricula, both for pilots and ship officers. Good bridge resource management should encompass all bridge operations, including when pilots are on board. Companies should have audit procedures to ensure that policies related to bridge resource management are, in fact, being adhered to. Accordingly, the NTSB recommends that the *Conti Peridot* operating company inform its personnel about the circumstances of this accident, and require training and audit procedures to ensure that bridge resource management is practiced during all operations.

## 2.2 Insufficient Pilot Communications

After the close-quarters meeting with the *Stolt Span*, the pilot on the *Conti Peridot* eventually regained heading control. However, about 30 minutes later, he saw on his PPU a similar meeting scenario developing, which he told investigators concerned him. Despite this lineup, the pilot gave no advance warning to either the pilot on the outbound *Gaia Leader* or the *Carla Maersk*. From the bridge audio recording on board the outbound *Carla Maersk*, it is evident that the pilot on the *Carla Maersk* was concerned about the decreasing visibility and the challenge of meeting inbound traffic farther down the channel. The pilot on the *Carla Maersk* discussed this matter at length with the *Carla Maersk* master, including possible options, but ultimately, no change was made and the outbound voyage continued until the collision with the *Conti Peridot*. When investigators asked the pilot on the *Carla Maersk* what other actions he might have taken in the minutes leading up to the accident, the pilot responded, "if only I had known [about the handling difficulties on board the inbound *Conti Peridot*] or if he [the pilot on the *Conti Peridot*] had told me he was having trouble, we could have done something differently." The pilot on the *Carla Maersk* mentioned that, had he known about the handling difficulties on the *Conti Peridot*, he might have approached the meeting by staying in the center of the channel. Then, once he saw which way the *Conti Peridot* was turning, he could have input

[38] See for example (a) Safety Recommendation M-97-52 to Princess Cruise Lines for its bridge watch officers to undergo joint bridge resource management training with Alaska pilots, and (b) Safety Recommendation M-09-18 to ship operating company Atlanship for training emphasizing unambiguous communication, role responsibility, and contingency planning. Both recommendations are classified "Closed—Acceptable Action." See also (c) Safety Recommendation M-07-3 to state pilot commissions nationwide about improved pilot-to-pilot communication (d) Safety Recommendation M-09-8 to the American Pilots' Association about including vessel masters in all navigation discussions, and (e) Safety Recommendation M-11-21 to governors of states and territories in which state and local pilots operate to ensure that local pilot oversight organizations implement initial and recurring bridge resource management training requirements. Safety Recommendations M-07-3 and M-09-8 are classified "Closed—Acceptable Action." As of the date of this report, the overall status of Safety Recommendation M-11-21, which was sent to 31 pilot commissions, is "Open—Await Response," with the following breakdown: 15 "Closed—Reconsidered," 11 "Open—Await Response," 3 "Closed—Acceptable Action," 1 "Open—Unacceptable Response," and 1 initial response.

appropriate rudder orders on the *Carla Maersk* (for example, passing on the starboard side instead of attempting the port-to-port meeting). Instead, the lack of communication from the *Conti Peridot* prevented the pilot on the *Carla Maersk*, who was already hesitant about continuing the outbound transit in restricted visibility, from taking alternative action beyond turning further toward the right bank to avoid the collision. The NTSB concludes that the pilot on the *Conti Peridot* should have informed the *Conti Peridot* master and the pilots on the outbound vessels about the handling difficulty he was experiencing with the bulk carrier. The NTSB recommends that the Houston Pilots Association inform its members about this accident and the need for effective bridge resource management and timely communication between pilots when circumstances could impact the safety of vessel operations.

## 2.3 Cognitive Workload in Restricted Visibility

Vessel operators often rely on visual cues in their environment during navigation. Fog can hinder an operator's ability to see external references, such as aids to navigation and channel banks. When external visual references are unavailable, judgment of distance and speed may be affected, leading to disorientation. In dense fog, operators' obscured vision can lead to disorientation by which an operator fails to sense accurately the direction of motion in relation to external visual cues, thus, adversely affecting the operator's performance.

Typically, on the bridge of a ship there are two primary forms of information being provided to operators: Processed information is provided by the electronic navigation equipment (PPU, ECDIS, etc.), while unprocessed information is accessible through the operator's perception of the actual (outside) environment. If unprocessed (outside) information is not available, due to adverse weather conditions such as heavy fog, the operator no longer has that redundancy.

In this accident, the restricted visibility prevented the pilot on the *Conti Peridot* from using external cues to aid his navigation. In fact, his difficulty handling the bulk carrier began only when the visibility deteriorated. Given the dense fog, he could rely only on electronic navigation equipment for the information he needed (the pilot told investigators that, on several occasions, he could not see beyond the bow of the ship). This reliance only on processed information demanded the pilot's full concentration and increased his cognitive workload.

Increased cognitive workload affects the ability to ascertain situation awareness; the human attentional system has limits to what it can process. Once an operator reaches that limit of attentional resources, attention can no longer be divided between the tasks but will instead focus singularly on one task, a phenomenon also known as cognitive anchoring (Matlin 2013). When workload is high, due to factors (in this case) such as close-quarter passing, poor weather conditions, and difficulty handling the vessel, cognitive anchoring may impede the pilot's ability to consider alternative solutions. When the demand of tasks exceeds an operator's available attentional resources, timesharing efficiency drops and performance begins to deteriorate. For example, communication between pilot, master, and crew may also be adversely affected. The VDR from the *Conti Peridot* clearly exhibits a quiet bridge, where, leading up to the accident, there were no discussions about the handling of the vessel or explanations as to why the pilot was rapidly changing rudder commands.

The burden of navigating the *Conti Peridot* fell solely on the pilot. He received no input from the bridge crew. The communication between them consisted only of the pilot's orders to the crew and their responses. The pilot told investigators that trying to get the bulk carrier back on a steady course was very difficult given his loss of visual bearings (as noted in section "2.1 Inadequate Bridge Resource Management," the *Conti Peridot* master indicated that the fog initially confused him as to which vessel was misaligned in the channel just before the collision). The pilot's intense concentration on controlling the vessel, as he worked essentially independently of the bridge crew, taxed his cognitive abilities. He was simultaneously preoccupied with radioing outbound ships to set up the next suitable meeting arrangement. Additionally, according to their interviews, at no point during the transit did the pilot or the master on the *Conti Peridot* commence sounding the fog signal or even have a discussion about it. About 1221, the pilot on the *Conti Peridot* began giving rudder orders in a rapid manner, not waiting for the rudder to fully respond in the direction ordered before calling out additional orders in the opposite direction. As he began getting closer to the oncoming vessel, the frequency of his orders continued to increase. The loss of visual references likely led the pilot on the *Conti Peridot* to overcompensate by giving progressively more frequent steering commands. The NTSB concludes that the dense fog led to loss of external visual cues and increased the cognitive workload for the pilot on the *Conti Peridot*, which affected his ability to control the bulk carrier.

## 2.4 Ship Information in AIS

Investigators noted after the accident that the AIS position data being transmitted by the *Carla Maersk* were offset by about 500 feet. As a result, when AIS subsequently depicted the *Carla Maersk* as an electronic symbol on vessel navigation software displays (such as the VTS PAWSS software and other vessels' ECDIS), the *Carla Maersk* appeared to be about 500 feet farther back in the channel than the tanker actually was.[39] The AIS offset was not a factor in the collision because the *Carla Maersk* position data were unrelated to the handling difficulty that the pilot on the *Conti Peridot* was experiencing with the bulk carrier, nor did the pilot express a problem with the position of the *Carla Maersk*. However, as outlined in Title 33 *CFR* 164.46(b), "accurate input and upkeep of AIS data fields" is mandatory.[40]

## 2.5 VTS Houston/Galveston Procedures in Restricted Visibility

VTS is intended to be an active navigational aid to waterway safety. VTS personnel have the authority to assess the safety of waterway situations; call attention to particular hazards; recommend that mariners take or avoid certain actions; and, if necessary, direct vessels to perform or not perform certain maneuvers or movements. However, the exercise of this authority requires that VTS watchstanders maintain a vigilant watch, actually detect situations where danger is imminent, and then implement appropriate traffic management measures to reduce risk.

Adding extra watchstanders is specifically noted in the VTS internal operating procedures during periods of restricted visibility to ensure positive tracking of each vessel and thus further limit the risk of collision. Despite this procedure, the VTS watch supervisor, who was specifically charged with monitoring the workload of individual watchstanders and making adjustments as necessary to maintain optimum performance, did not add additional watchstanders to either Sector I & II or Sector III. Additional watchstanders would have

[39] The *Carla Maersk* position offset was corrected in figure 8 in this report.

[40] The NTSB previously noted the importance of consistently entering complete and accurate AIS data in its report on the March 22, 2014, collision between bulk carrier *Summer Wind* and the *Miss Susan* tow in the Houston Ship Channel. In that report (NTSB/MAR-15/01, available at www.ntsb.gov), the NTSB concluded that [broadcasting complete and accurate AIS data] "would alleviate misinterpretation and possible confusion from inaccurate information, and thus enhance safety."

improved the active monitoring of vessel traffic. The fact that the watchstander for Sector I & II, which was the area in which the *Conti Peridot* and the *Carla Maersk* collided, did not actually observe the collision on his traffic image screen indicates that the internal operating procedures requirement for positive tracking of all vessels in the VTS system was not adhered to, at least not for the *Conti Peridot* or the *Carla Maersk*. Further, despite internal operating procedures, VTS Houston/Galveston did not maintain an active listening watch of VHF radio channel 13, which is the main vessel-to-vessel communication channel. As a result, VTS watchstanders were unaware of the collision until a towing vessel operator radioed them about the accident.[41] The NTSB concludes that VTS Houston/Galveston did not effectively monitor vessel traffic to identify the developing risk of collision during restricted visibility.

## 2.6 Lack of Predetermined Ship Movement Strategies during Restricted Visibility in the Houston Ship Channel

The NTSB has investigated several accidents in or near the Houston Ship Channel (see, for example, NTSB 2012, 2015, and 2016). Investigators expressed concern about this trend when meeting with local waterway stakeholders. Moreover, the collision between the *Conti Peridot* and the *Carla Maersk* is the third accident the NTSB has investigated since 2011 that illustrates the hazards associated with operating large vessels in the Houston Ship Channel. Each case involved pilots who lost control of their vessels due to hydrodynamic forces of ship-to-ship interaction and bank effect. As seen in this collision, it is particularly difficult to respond to destabilizing forces during restricted visibility.

The Coast Guard captain of the port has the ultimate authority to stop vessel traffic in the Houston Ship Channel, a decision that can be made at any time, for any reason. However, complete shutdowns are very rare and for true emergency situations only (such as during hurricanes). In most cases, decisions about whether to get under way are made by the local pilots and ship masters, based on prevailing conditions.[42] Both the Coast Guard captain of the port and the VTS director told investigators that, in their individual opinions of the circumstances of this accident, the pilots are in the best position to decide whether to stop operating.

When the *Conti Peridot* and the *Carla Maersk* got under way on the morning of the accident, the visibility was clear. However, fog developed during the transit, which increased the complexity of their transits. The pilot on the *Conti Peridot* told investigators that, in the past on a densely foggy day, pilots would have chosen to temporarily hold up in the waterway until the visibility improved. However, he remarked that pilots nowadays, with the availability of increasingly sophisticated electronic equipment (ECDIS, AIS, and PPUs), may be trying to do too much during restricted visibility. There is also commercial pressure (on pilots, masters, vessel terminals, and shipping companies) to continue operations. The pilots prefer not to be the first in line to stop operations, knowing that they will then be stacking up all the other vessels behind them. So those factors influence operators' decisions to continue the transit to avoid interfering with commerce and traffic movement.

---

[41] The NTSB previously noted the lack of an active VTS listening watch in its report on the March 22, 2014, collision between bulk carrier *Summer Wind* and the *Miss Susan* tow in the Houston Ship Channel. For more detail, see marine accident report NTSB/MAR-15/01, available at www.ntsb.gov.

[42] Vessel masters are responsible for ensuring the safety of the ship during each transit. In accordance with their company's safety management systems, masters will adhere to local rules and regulations.

Members of the Houston Pilots Association told investigators that, on certain previous occasions, the decision had been made to stop traffic in one direction only and thereby let either the outbound or inbound vessels continue until the visibility improved. The *Carla Maersk* master told investigators that he believed one-way traffic would be safer during restricted visibility.

When the accident pilots were asked about procedures for stopping operations in restricted visibility, they both stated that decisions whether to anchor in the channel or suspend pilot boardings of deep-draft vessels were left to the discretion of the pilots themselves. Both accident pilots indicated that it was difficult to anchor in the channel due to coordination between the various pilots and the time and distance necessary to come to a controlled stop. Specific ship movement strategies are not currently in place for vessels already under way in the channel when hazardous conditions develop.

Accordingly, local waterway stakeholders, such as the members of the Lone Star Harbor Safety Committee, need to assess the circumstances of this accident and develop policies and procedures that standardize the decision-making process for certain events that impact ship movement in the waterway (such as fog, high winds, storms, and so on).[43] A standardized decision-making process is especially important for vessels already under way when hazardous conditions develop, such as on the day of the accident when several deep-draft vessels (including the *Conti Peridot* and the *Carla Maersk*) had already begun their transits in the channel when inbound pilot boardings were suspended. The process should identify who makes the decision regarding matters affecting vessels already under way, the risk assessment parameters on which the decision is made, what measures should be considered, and how the information is disseminated to operators. The NTSB concludes that predetermined ship movement strategies would enhance safety for vessels under way in the Houston Ship Channel during restricted visibility. The NTSB therefore recommends that the Lone Star Harbor Safety Committee develop predetermined ship movement strategies (considering options such as increased vessel separation, one-way traffic, and/or anchoring) to be implemented before or at the onset of hazardous weather conditions to enhance safety for vessels under way in the Houston Ship Channel.

[43] The Lone Star Harbor Safety Committee is composed of stakeholders with vested interests in a wide range of issues relevant to the ports of Houston, Galveston, Texas City, and Freeport, including the associated waterways of the Gulf Intracoastal Waterway. Lone Star members include (but are not limited to) representatives from the Coast Guard, the Houston Pilots Association, the Port of Houston Authority, and the Board of Pilot Commissioners for Harris County Ports. Lone Star subcommittees address specific aspects of the waterway system and areas of concern, such as vessel operation; maritime security; and waterway safety, maintenance, and improvement.

# 3. Conclusions

## 3.1 Findings

1. Navigation equipment, vessel propulsion and steering systems, alcohol and other drug use, fatigue, medical conditions and medication use, and distraction from personal use of electronic devices were not factors in this accident.

2. The lack of communication between the master and the pilot on the *Conti Peridot* and the lack of situation awareness exhibited by the master demonstrate inadequate bridge resource management, which reduced the effectiveness of the *Conti Peridot* bridge team.

3. The pilot on the *Conti Peridot* should have informed the *Conti Peridot* master and the pilots on the outbound vessels about the handling difficulty he was experiencing with the bulk carrier.

4. The dense fog led to loss of external visual cues and increased the cognitive workload for the pilot on the *Conti Peridot*, which affected his ability to control the bulk carrier.

5. Vessel Traffic Service Houston/Galveston did not effectively monitor vessel traffic to identify the developing risk of collision during restricted visibility.

6. Predetermined ship movement strategies would enhance safety for vessels under way in the Houston Ship Channel during restricted visibility.

## 3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the collision between bulk carrier *Conti Peridot* and tanker *Carla Maersk* in the Houston Ship Channel was the inability of the pilot on the *Conti Peridot* to respond appropriately to hydrodynamic forces after meeting another vessel during restricted visibility, and his lack of communication with other vessels about this handling difficulty. Contributing to the circumstances that resulted in the collision was the inadequate bridge resource management between the master and the pilot on the *Conti Peridot*.

# 4. Recommendations

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

**To BBG (Bremer Bereederungsgesellschaft mbH & Co., the *Conti Peridot*'s operating company):**

Inform your personnel about the circumstances of this accident, and require training and audit procedures to ensure that bridge resource management is practiced during all operations. (M-16-1)

**To the Houston Pilots Association:**

Inform your members about this accident and the need for effective bridge resource management and timely communication between pilots when circumstances could impact the safety of vessel operations. (M-16-2)

**To the Lone Star Harbor Safety Committee:**

Develop predetermined ship movement strategies (considering options such as increased vessel separation, one-way traffic, and/or anchoring) to be implemented before or at the onset of hazardous weather conditions to enhance safety for vessels under way in the Houston Ship Channel. (M-16-3)

## BY THE NATIONAL TRANSPORTATION SAFETY BOARD

**CHRISTOPHER A. HART**
Chairman

**ROBERT L. SUMWALT**
Member

**T. BELLA DINH-ZARR**
Vice Chairman

**EARL F. WEENER**
Member

**Adopted: June 20, 2016**

# Board Member Statement

**Chairman Christopher A. Hart filed the following concurring statement on June 13, 2016:**

I agree with the findings, probable cause, and recommendations in this report, but I wonder whether the time is right to take better advantage of existing technologies to address the problem of operating in tight quarters in low visibility.

This investigation demonstrated that in very low visibility, it is difficult even for the most seasoned mariner to arrest low-frequency, long-period lateral oscillations, even with the assistance of a sensitive yaw rate indicator. In fact, it would appear that in many circumstances, pilot-induced lateral oscillations, to use the aviation term, are likely in very low visibility, especially in the presence of the hydrodynamic forces of ships meeting and passing each other.

A crucial part of arresting such oscillations is the ability to see—immediately—very minute lateral movements of the bow. That requires the ability to see the bow against distant landmarks because the lateral motion of a compass—even an electronically stabilized compass—or of a moving map would be so slow as to be imperceptible. When the visibility is so low that even the bow is barely visible, as occurred here, precise lateral control becomes very difficult.

In aviation, when the industry added more “highways in the sky” by reducing the minimum vertical separation of opposite direction traffic at higher cruising altitudes (above 29,000 feet in the mainland United States) from 2,000 feet to 1,000 feet, the industry collectively decided that such close passage of opposite direction traffic would not be sufficiently reliable under human control. Although the likelihood of a mid-air collision is very small even with reduced vertical separation, the consequences are usually very high, i.e., often fatal to everyone in both airplanes. Consequently, automatic pilots are mandatory in order for aircraft to take advantage of the reduced minimum vertical separation.

I am aware that minute precision is not so important for most marine autopilots because they are largely used at open sea, but existing technologies would easily enable the development of very precise marine autopilots, with lateral accuracy measured in feet, even in the presence of the hydrodynamic forces of passing ships and the banks. Query whether consideration should be given to using available technologies in the marine world to further improve safety in the Houston Ship Channel.

Member Robert L. Sumwalt joined in this statement.

# Appendixes

## Appendix A – Investigation Information

The NTSB launched a team of investigators and a Board Member to the accident scene on March 10, 2015. While on scene, investigators interviewed crewmembers from both accident vessels, as well as watchstanders and supervisors from VTS Houston/Galveston. In addition, investigators documented both vessels' characteristics and damage, and they retrieved and reviewed recorded data from the vessels' VDRs and from VTS Houston/Galveston's command center.

## Appendix B – Vessel Information

| Vessels | *Conti Peridot* | *Carla Maersk* |
|---|---|---|
| **Owner** | Schiffarthrts-GmbH & Co. | A.P. Moller–Maersk A/S |
| **Operator** | BBG (Bremer Bereederungsgesellschaft mbH & Co.) | A.P. Moller–Maersk A/S |
| **Port of registry** | Monrovia | Copenhagen |
| **Flag** | Liberia | Denmark |
| **Type** | Bulk carrier | Chemical tanker |
| **Year built** | 2011 | 1999 |
| **IMO number** | 9452634 | 9171503 |
| **Construction** | Steel | Steel |
| **Length** | 623 ft (190 m) | 600 ft (183 m) |
| **Draft** | About 31 ft (9.5 m) | About 33.5 ft (10.2 m) |
| **Beam/width** | 106 ft (32 m) | 106 ft (32 m) |
| **Tonnage** | 33,036 gross tons | 29,289 gross tons |
| **Engine power; manufacturer** | STX MAN-B&W, 6S50MC-C7, 9,480 kW (12,707 hp) at 127 rpm, single-speed 6-cylinder diesel engine | Hyundai MAN-B&W, 6S50MC-MK6, 8,561 kW (10,480 hp) at 123 rpm, single-speed 6-cylinder diesel engine |
| **Persons on board** | 24 crew; 1 pilot | 26 crew; 1 pilot |

## References

Matlin, Margaret W. 2013. *Cognition* (8th ed.) Wiley. ISBN 978-1-118-14896-9.

NTSB. 2012. *Collision of Tugboat/Barge* Alliance/MMI 3024 *with Tankship* Naticina, *Texas City Channel and Gulf Intracoastal Waterway*. NTSB/MAB-12/01. Washington, DC: NTSB.

NTSB. 2012. *Collision of the Tankship* Elka Apollon *with the Containership* MSC Nederland, *Houston Ship Channel, Upper Galveston Bay, Texas, October 29, 2011*. NTSB/MAR-12/02. Washington, DC: NTSB.

NTSB. 2015. *Collision between Bulk Carrier* Summer Wind *and the* Miss Susan *Tow, Houston Ship Channel, Lower Galveston Bay, Texas, March 22, 2014*. NTSB/MAR-15/01. Washington, DC: NTSB.

NTSB. 2016. *Collision between Tanker* Chembulk Houston *and Container Ship* Monte Alegre, *March 5, 2015*. NTSB/MAB-16/04. Washington, DC: NTSB.