National Transportation Safety Board

Sinking of the US Cargo Vessel *El Faro*

Illustrated Digest

This digest of the National Transportation Safety Board's (NTSB's) Marine Accident Report **NTSB/MAR-17/01** contains a description of the accident and safety issues, and summarizes some of the safety recommendations intended to prevent such an accident from happening again. The full report and docket can be found at **www.ntsb.gov**.

NTSB | National Transportation Safety Board

SPC-18-01

The accident

September 29

On the evening of September 29, 2015, the US-flagged cargo ship *El Faro* cast off from Jacksonville, Florida, bound for San Juan, Puerto Rico, with crew of 33 and a cargo of vehicles and shipping containers. The vessel was operated by TOTE Services, Inc. (TOTE), which, until 2 weeks before the accident, was known as Sea Star Line, LLC. Hundreds of miles southeast, Tropical Storm Joaquin moved toward the Bahamas. At the time of the ship's departure, *El Faro*'s captain was aware of the weather and planned to remain south of the storm. Before meeting the storm, the vessel's speed was about 20 knots.

***El Faro* under way** Photo: Capt. William Hoey

Tropical Storm Joaquin at 1410 on September 29, 2015
Photo: NASA

September 30

On September 30, 2015, at about **0600**, the captain and chief mate discussed the storm's route, referring to one of the ship's onboard weather programs, Bon Voyage System (BVS).[1] BVS files were sent to the captain's e-mail address. However, tropical cyclone information in the BVS files (when sent) typically lagged what was found in other weather sources by 6 hours. In addition, there was another lag until the captain downloaded each file. Another source of weather information, Sat-C, delivered text broadcasts of National Hurricane Center (NHC) weather products to the vessel's bridge.[2] The captain favored BVS throughout the voyage, seemingly not considering the latency associated with the tropical cyclone information contained in the BVS files.[3]

At **0624**, the captain shifted *El Faro*'s course slightly southward. At **0625**, the Sat-C terminal received an urgent high seas forecast for Tropical Storm Joaquin of maximum sustained winds of 75 knots (hurricane strength) with gusts to 90 knots within 24 hours.

The captain and the chief mate discussed that any further course change would be drastic and wasn't warranted "for a 40-knot wind."[4]

At **0711**, the captain was heard on the voyage data recorder (VDR) saying, "Needless to say, we'll be watching the weather deteriorate today." A few minutes later, he indicated his doubts that the ship's anemometer[5] was working properly.

At **0739**, the NHC announced in an intermediate advisory that Joaquin had become a hurricane; however, intermediate advisories weren't broadcast via Sat-C and were not available via e-mailed BVS files.

1 *El Faro*'s voyage data recorder (VDR) captured both conversations and parametric data. However, only the voice of the person speaking on the bridge was captured in a two-way conversation with another person who was not on the bridge.

2 Sat-C is short for Inmarsat Satellite's channel C. The Sat-C terminal provided timely weather information from the National Weather Service (NWS), including the National Hurricane Center (NHC).

3 The BVS vendor could also send e-mail updates, which provided current tropical cyclone information, if a user specifically requested them. During the accident voyage, however, *El Faro*'s captain did not request any.

4 The captain and crew expected to encounter winds of about this strength (later, they refer to "45-knot winds") as a product of both the expected intensity of the storm and their expected position relative to it.

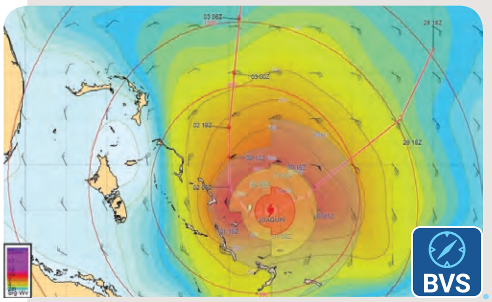
5 An anemometer provides wind speed and direction. Over 99 percent of the anemometer data samples captured on *El Faro*'s VDR during the accident voyage indicated a relative wind direction of between 180° and 193°.

Although the captain discussed alternate routes through the Northwest Providence Channel and the Old Bahama Channel (*see* The accident voyage, *p. 8*), he did not choose these routes.[6] Throughout the day, crewmembers were directed to prepare the vessel for rough weather.

At **1943**, the third mate arrived on the bridge for the watch change and said, "I just hope it's not worse than what this [BVS] is saying because . . . Weather Underground . . . they're saying it's—more like 85—not 50 . . . wind." At **2305**, he made the first of two calls to the captain. On his second call, the third mate suggested diverting to the south, but the captain did not authorize a course change. Later, the third mate told the able seaman on watch that the captain thought they would be south of the storm. The second mate arrived for the 0000 watch at **2345**.

6 Although he did not divert to the Old Bahama Channel, the captain did arrange with personnel ashore to make the return trip via the Old Bahama Channel.

El Faro's weather data sources



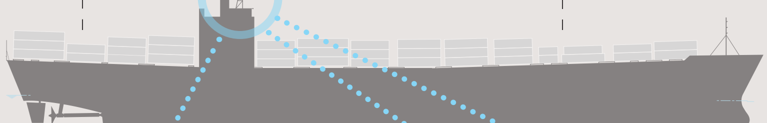
BVS

BVS presented processed tropical cyclone data in a graphical desktop program. Its advantage was that route and storm information could be plotted on screen. Its disadvantage was that the tropical cyclone information was typically 6 hours old when delivered. BVS files were sent only to the captain's e-mail address on *El Faro*.

NWS via Sat-C terminal

When the NWS and associated entities (such as the NHC) made tropical cyclone information available, the information normally arrived on *El Faro*'s bridge via Sat-C terminal with limited delay. However, see *Sources not used*, at right.

Exemplar Sat-C terminal printout



The Weather Channel

One crewmember made repeated references to The Weather Channel. Although he consistently deferred to the captain, tropical cyclone information on The Weather Channel was more timely than the tropical cyclone information available via BVS.

Broadcasts from USCG aircraft

US Coast Guard aircraft broadcast hurricane watch and warning information, adding "mariners use extreme caution" on September 30. *El Faro*'s captain and second mate both responded, "Wow." About 24 minutes later, USCG aircraft repeated the "extreme caution" message.

Satellite radio

Satellite radio broadcasts heard on the bridge provided information about the position and increasing intensity of the hurricane. One broadcast said that Joaquin had increased in intensity from category 2 to category 3 just prior to the second mate's call to the captain on October 1 at 0120.

El Yunque

As *El Faro* sailed toward San Juan, a similar TOTE ship, *El Yunque,* was returning from San Juan to Jacksonville. The captains and chief mates talked by radio, and the captains exchanged e-mails, about the storm.

Sources not used

NHC products

El Faro did not receive intermediate advisories from the NHC because intermediate advisories were not broadcast via Sat-C. There is no evidence that *El Faro*'s crew procured these advisories on Hurricane Joaquin, even though they were likely readily available by e-mail via FTPmail.

NAVTEX

The NWS also provides weather information in Navigational Telex (NAVTEX) messages that print out on a ship's dedicated receiver. The third mate reported trouble with the NAVTEX receiver, and there is no evidence that *El Faro* received NAVTEX weather messages.

The accident (continued)

October 1

At **0120** on October 1, after hearing satellite radio reports of the strengthening hurricane, the second mate also called the captain and suggested that they change to a more southerly route at **0200** instead of the earlier-planned east-southeast-erly route. Again, the captain did not authorize the change. Instead, he directed her to "run it," which meant resume the earlier-planned route.

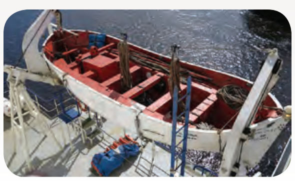
As the seas became higher and the winds intensified, *El Faro*'s speed slowly decreased. At **0340**, the second mate adjusted course to steer further to the north to compensate for the wind pushing the ship to the south, and the second engineer began "blowing tubes."[7] The ship was heeling to starboard from the increasing wind on its port side, a condition called windheel. The vessel's speed was about 16.8 knots at **0340**. It dropped sharply thereafter.

When the chief mate's watch began at **0345**, the second mate told him that the engineers were blowing tubes. The chief mate adjusted course to nearly due east, further into the

7 Using high-pressure steam to remove soot from the boiler tubes. During this process, a a steam-powered ship like *El Faro* would temporarily lose some propulsion power, and therefore a few knots.

El Faro in departure condition

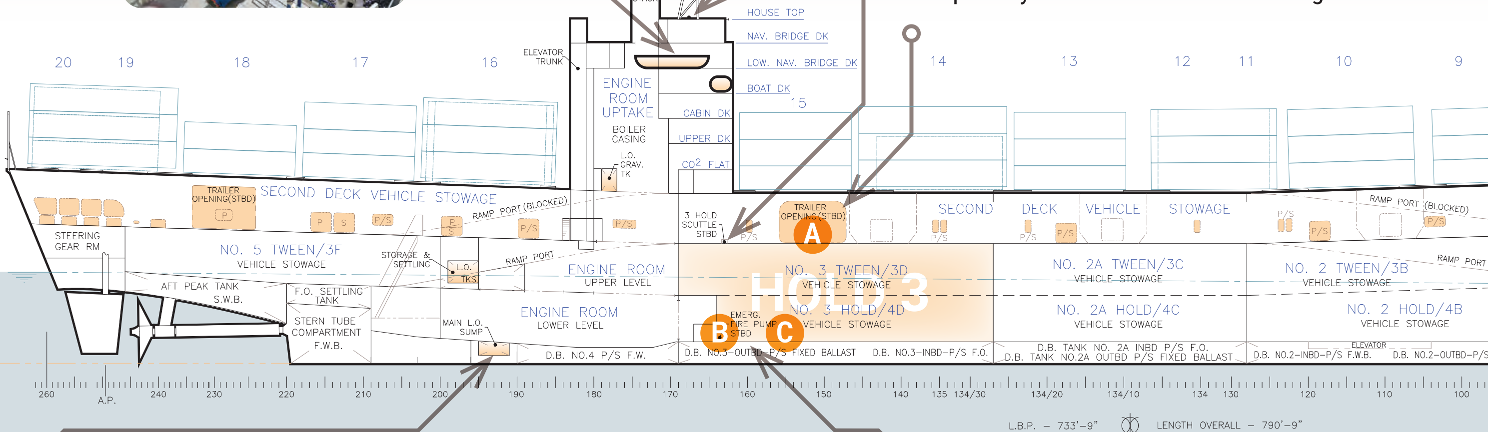
Open lifeboats and 25-person liferafts were stowed on the boat deck. Open lifeboats such as *El Faro*'s have not been allowed on new vessels since the 1990s, but *El Faro* was built much earlier *(see* Recommendations, *p. 13)*.



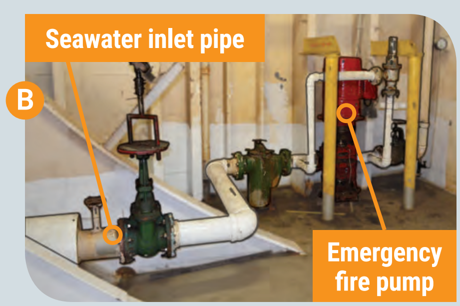
Scuttles are small hatches that allow crewmembers to transit between decks. However, the scuttles on the weather deck (second deck) had to be securely fastened to ensure the ship's watertight integrity. *El Faro* did not have remote open/close indicators for its scuttles *(see* Recommendations, *p. 13)*.

Voice data recorder (VDR) attached to mast

Seawater could flow onto *El Faro*'s second deck through openings, including large openings in the starboard side **A** through which trailers were loaded. The deck was partially enclosed, so seawater could temporarily accumulate before draining off.



According to logbook entries, the level of lube oil in the sump had been kept at 25 or 26 inches for most of the 2 years before the accident. In rough seas, this could lead to loss of propulsion *(see* Loss of lube oil suction, *p. 7)*.



Cargo hold 3 housed the emergency fire pump, which was connected to a seawater inlet pipe **B** (photo at left is of *El Yunque*'s emergency fire pump and unprotected inlet piping). Similar components, although arranged differently, made up the corresponding system on board *El Faro*. Hold 3 was also used for vehicle stowage. **C** wind. The vessel's speed was now about 13.8 knots. At **0409**, the captain arrived on the bridge, shortly thereafter telling the chief mate that the only way to correct the starboard list was to transfer water to the port side ramp tank.[8]

At **0440**, the chief mate called the captain over the electric telephone. He said, "The chief engineer just called . . . something about the list and oil levels." He might have tried to gauge the list with a clinometer ("can't even see the [level/bubble]").[9]

At **0443**, the captain said to put the vessel into hand steering so it could be steered into the wind to try "to take the list off."

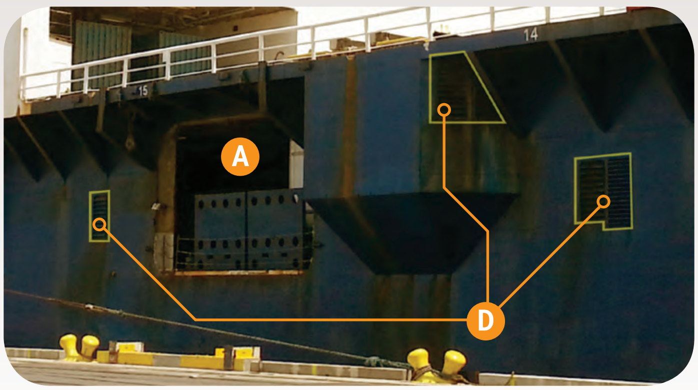
The chief mate turned the vessel northward to 65°. The captain took the conn and ordered a further change to 50° (farther into the wind). The vessel's speed dropped to 7.5 knots.

At **0445**, the captain downloaded a BVS weather file that was available at 2304 the night before. Its position and forecast information for Joaquin was consistent with an NHC advisory delivered to the ship via Sat-C almost 12 hours before.

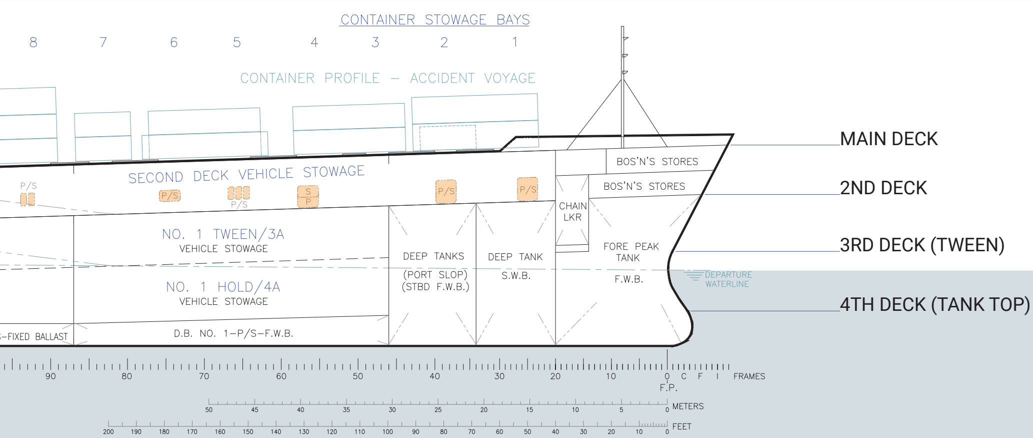
Less than 2 minutes later, *El Faro*'s Sat-C terminal received an NHC advisory with up-to-date position, wind speed, and storm track information. At **0503**, the captain, comparing

8 The ramp tanks were intended to counter the effects of loading or unloading cargo in port. They could correct a list of about 3°.

9 On the VDR transcript, uncertain phrases, words, or partial words are placed inside parentheses. Here, parentheses within parentheses are rendered as brackets.



Louvered openings in the hull D allowed air to flow in and out of the cargo holds via ventilation ducts. These were required to be opened under way, but could have been shut in heavy weather. Pictured at left is the starboard side of *El Faro,* just above hold 3. Louvered vents are outlined in yellow and a large trailer opening A is also visible.



Instead of each automobile being secured to the deck at each corner, they were secured to a long chain across the width of the ship E (photo at left is from a similar lashing arrangement on board *El Yunque*). As the ship encountered heavy weather, vessel motion increased and lashings would have failed more easily as the deck became wet and the ship rolled *(see* How the water got in*, p. 6)*.

NTSB

The accident (continued)

the updated Sat-C weather information with his most recent download of BVS, said he was getting “conflicting reports as to where the center of the storm is.” At that time, another BVS weather file became available, but the captain did not download it until an hour later (0609). Beginning at **0510**, the captain and the riding gang supervisor—an off-duty chief engineer—discussed the extent of the starboard list, and the captain asked how the list was affecting “operations as far as lube oil(s).”

At **0514**, shortly after the captain said their speed was maintaining at 11 knots, he turned the ship into the wind again. By **0518**, the vessel’s speed had dropped to 5.8 knots. It was now moving with a pronounced starboard list; in hurricane-force wind, rain, and waves; with zero visibility and an untrustworthy anemometer.

At **0543**, the captain received a call from the chief engineer that there was a problem in cargo hold 3. He told the chief mate to go to the hold and start pumping. The crew continuously pumped the hold 3 bilges from this point onward.

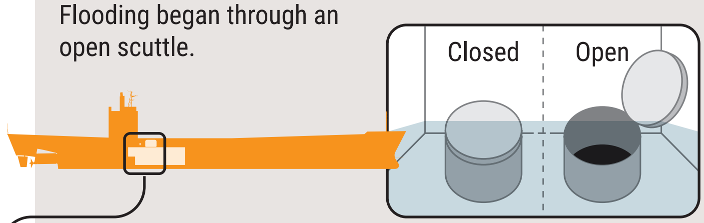
At **0544**, the captain was heard on the VDR saying “We got cars loose,” likely referring to automobiles that had broken free from their lashings. The automobile-lashing arrangement did not meet the requirements of the vessel’s approved cargo-securing manual, making automobiles more likely to shift in heavy weather.

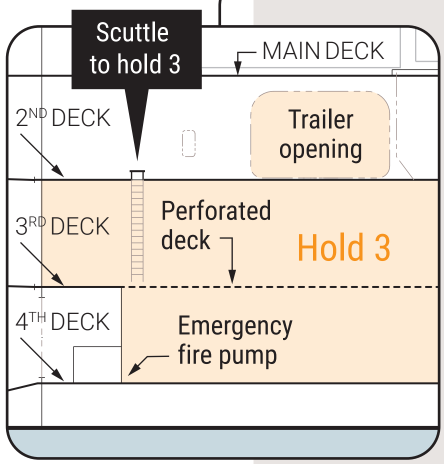
The crew found that a scuttle (small watertight hatch) on the second deck, starboard side, was open and seawater on deck was flowing over it and down into cargo hold 3. The ship’s list to starboard was causing seawater to pool near the scuttle located on the starboard side. The captain told an engineer to begin transferring ballast water from the starboard ramp tank to the port ramp tank.

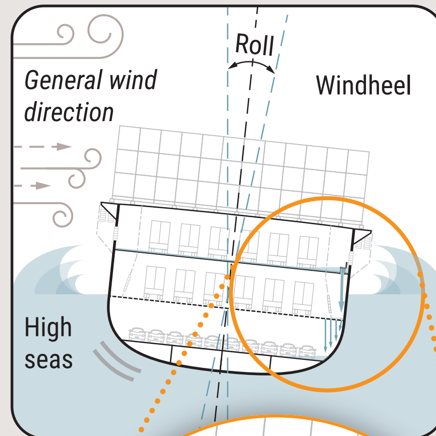
Second deck scuttle to hold 2A, similar to hold 3 scuttle
Photo: Herbert Engineering

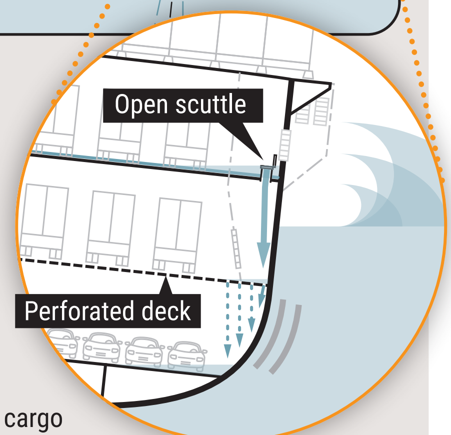
How the water got in

El Faro’s partially enclosed second deck had a number of scuttles that had to be closed and fastened (“dogged”). Flooding began through an open scuttle.



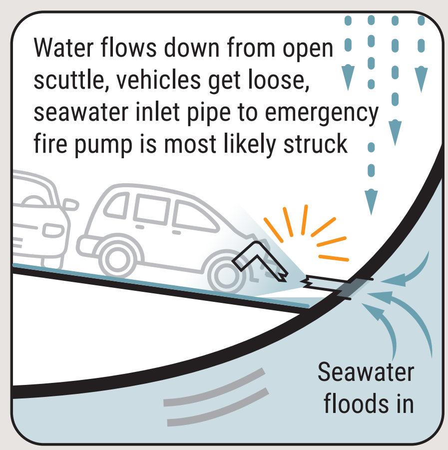






Once the deck became wet in hold 3, automobiles were more likely to break free of their lashings. An automobile likely struck the intake piping leading to the emergency fire pump. Seawater piping to the emergency fire pump in cargo hold 3 was inadequately protected from such impact.

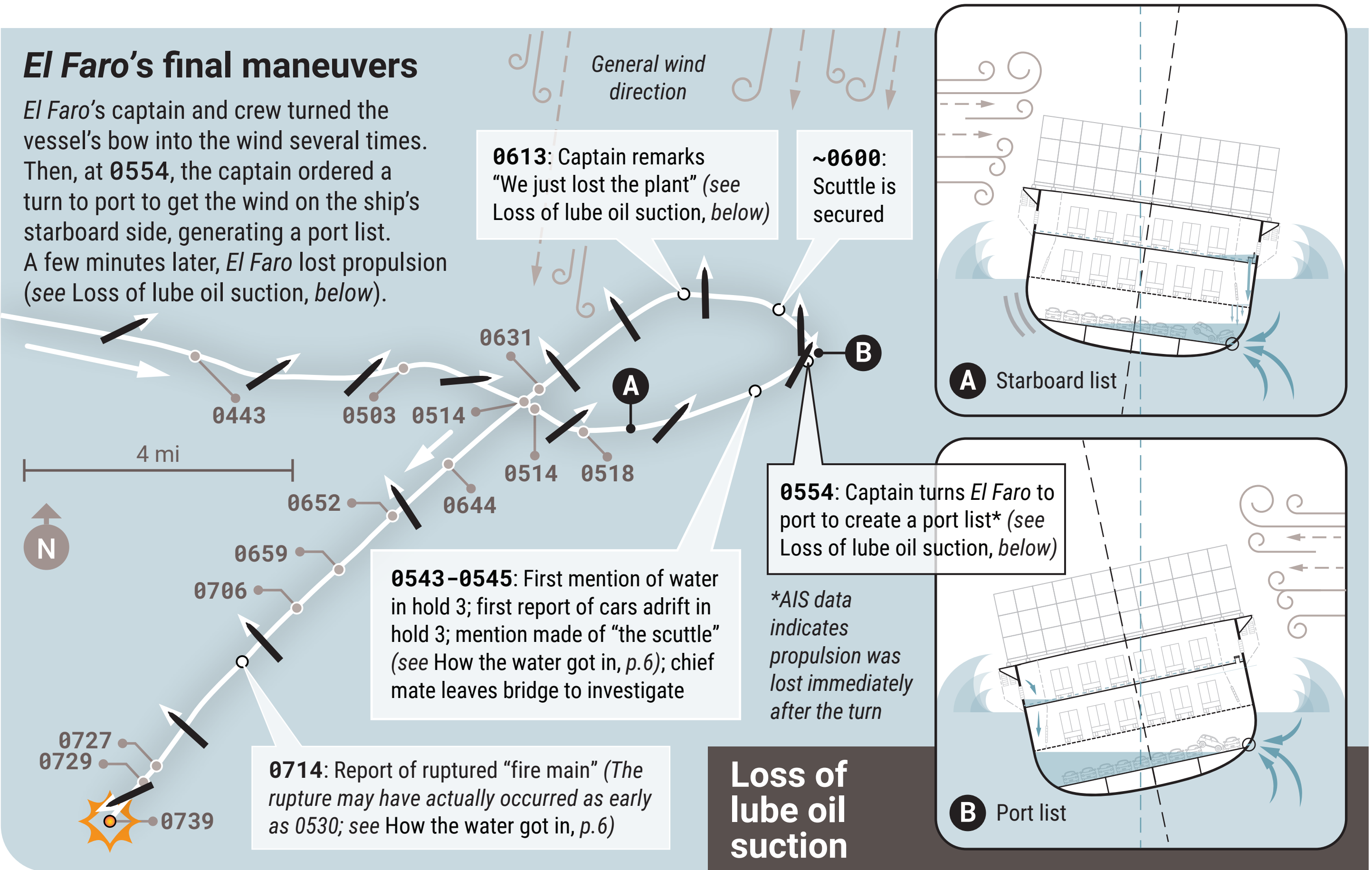
With a severe breach of the intake piping, water would have flowed into hold 3 under seawater head pressure. Bilge pumps could not keep up with flooding through the fire main.



As the ship’s permanent angle to the sea (sustained list) increased past 15 degrees, the high seas would have allowed water to enter the hull through ventilation openings.

El Faro's final maneuvers

El Faro's captain and crew turned the vessel's bow into the wind several times. Then, at **0554**, the captain ordered a turn to port to get the wind on the ship's starboard side, generating a port list. A few minutes later, *El Faro* lost propulsion (*see* Loss of lube oil suction, *below*).



At **0554**, the captain ordered a turn to port to put the wind on the ship's starboard side, thereby generating a port list so the crew could better investigate the source of the flooding in cargo hold 3. This was also the most aggressive of several turns that followed the first conversation about oil levels at about 0440.

Shortly after the turn to port, the chief mate reported that they had secured the scuttle on the starboard side of the second deck. The vessel was now listing to port and its speed was 2.8 knots.

At **0602**, the second mate said she heard alarms sound in the engine room. At **0609**, the captain downloaded the BVS weather file, which was sent at 0502, whose information about the hurricane (position, forecast track, and intensity) was consistent with an NHC advisory the ship had received via SAT-C about 7 hours before. He ordered the engineers to transfer bilge water back to the starboard ramp tank, saying "I'm not liking this list."

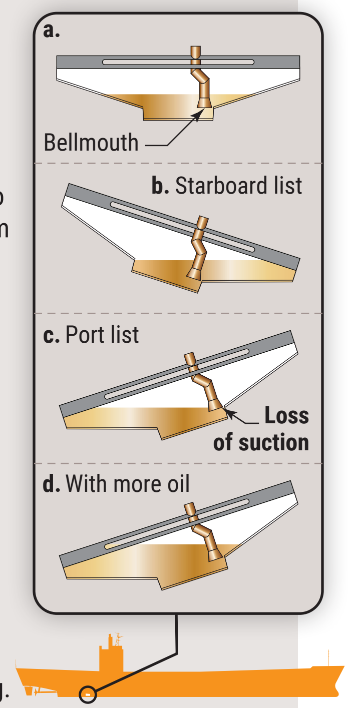
Cargo hold 3 continued to take on water and the ship continued to lose speed, despite continuous bilge pumping efforts by the crew.

At **0613**, the captain said he thought that the vessel had lost propulsion.

Loss of lube oil suction

Because the bellmouth (intake) for the main propulsion engine lube oil pump was located toward the starboard side, it mattered whether the ship was listing to port or starboard. (The trim of the ship also affected the oil suction; forward trim was worse). It also mattered how much lube oil was in the sump.

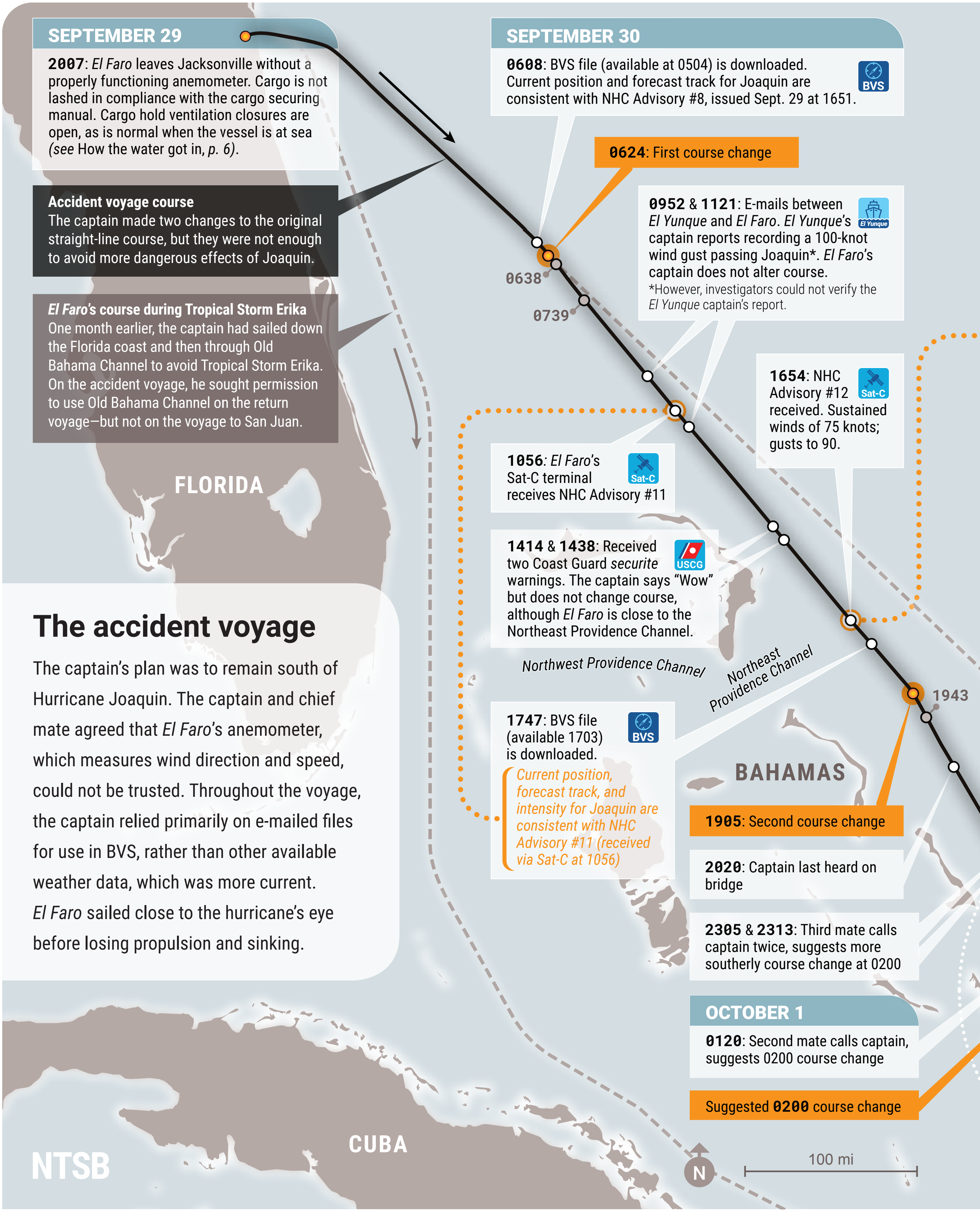
Log books indicated no more than 26 inches of oil in the sump in the months before the accident (**a**). With this oil level, the bellmouth would not take in air (lose suction) with an 18-degree list to starboard (**b**), but would lose suction with an equivalent list to port (**c**). With 32 inches of oil in the sump, the bellmouth would continue to take in oil with the same 18-degree list to port (**d**) allowing normal functioning.

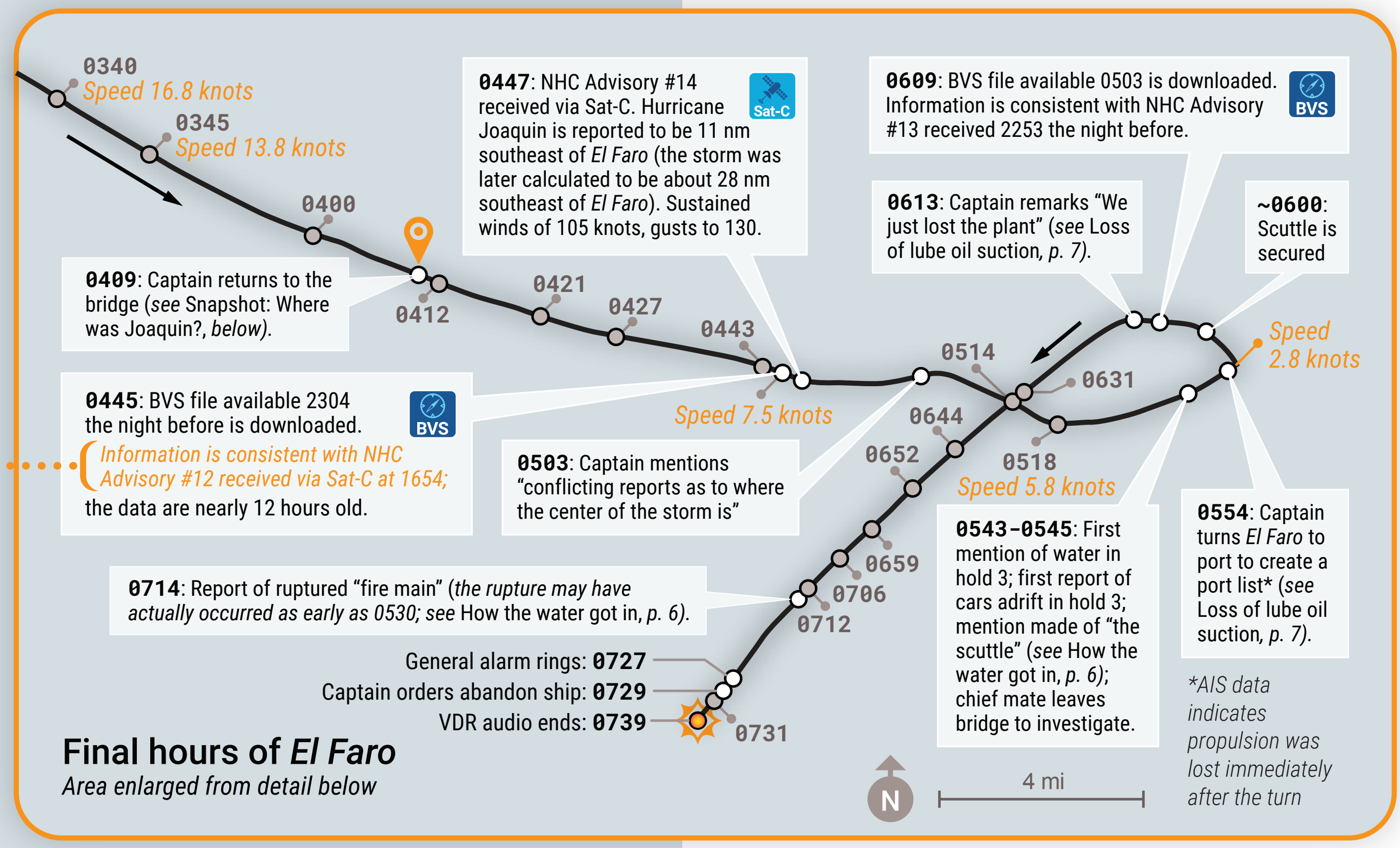


The loss of lube oil pressure would have triggered a protective device, the low lube oil pressure switch, which would have shut off the flow of steam to the main engine. (However, steam continued to flow to turbogenerators for lights and other systems.) To reset the switch, lube oil pressure would have to be restored. Without propulsion, *El Faro* could not maneuver and was at the mercy of the storm.

The accident voyage

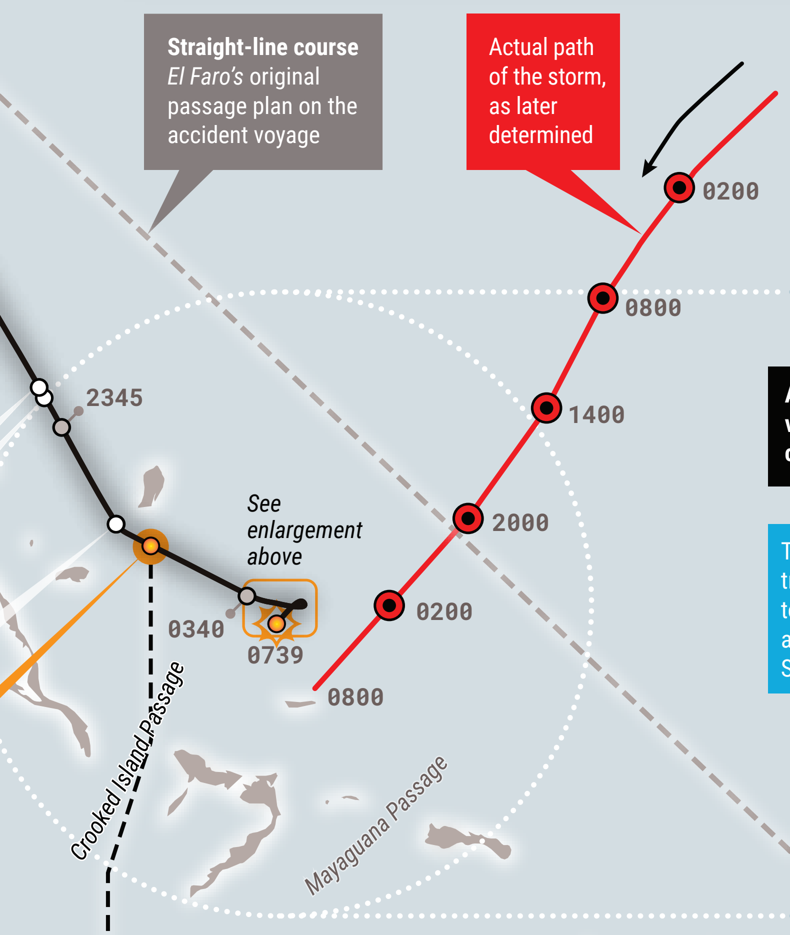
The captain's plan was to remain south of Hurricane Joaquin. The captain and chief mate agreed that *El Faro*'s anemometer, which measures wind direction and speed, could not be trusted. Throughout the voyage, the captain relied primarily on e-mailed files for use in BVS, rather than other available weather data, which was more current. *El Faro* sailed close to the hurricane's eye before losing propulsion and sinking.





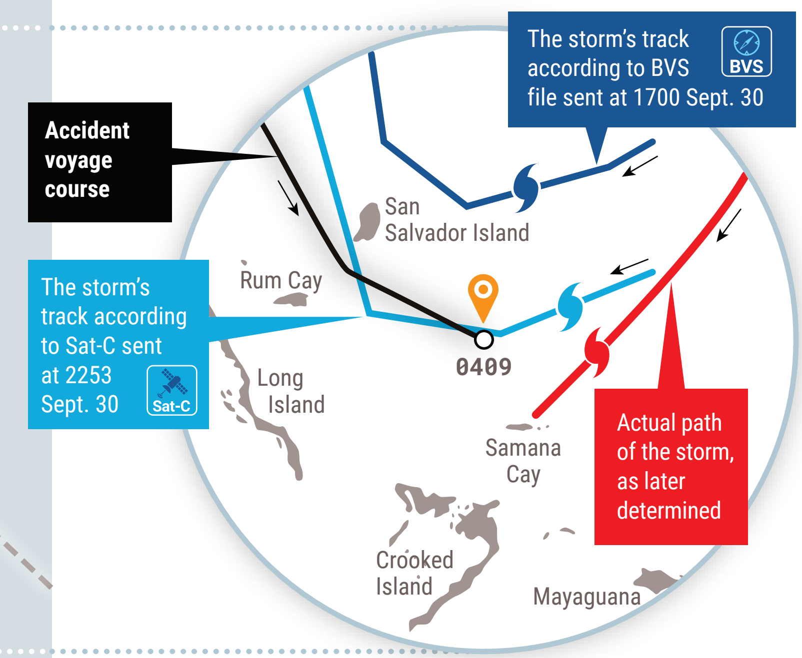
Final hours of *El Faro*

Area enlarged from detail below



Snapshot: Where was Joaquin?

At **0409** the captain returned to the bridge. He discussed the weather with the crew, apparently relying on the BVS file sent at 1700 the evening before. The captain thought they were on the "back side" of the storm, meaning the less dangerous quadrant. In reality, the storm was east, not north, of *El Faro*.



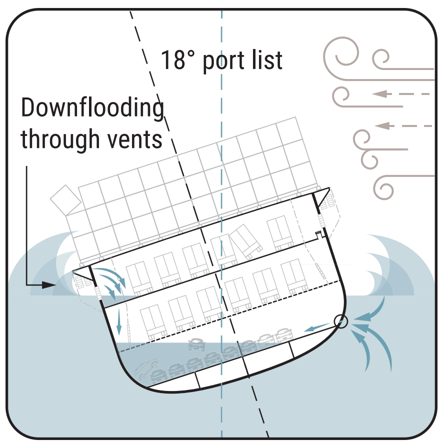
The accident (continued)

At **0616**, the engine room called. Although the conversation from the engine room was not recorded on the VDR, the captain asked, “so . . . is there any chance of gettin’ it back online?” It is likely that a suction pipe leading to the lube oil service pump had taken in air instead of oil *(see* Loss of lube oil suction, *p. 7)*. The port list, coupled with the vessel’s motion, resulted in a loss of oil pressure that caused the main engine to shut down.[10] Once propulsion was permanently lost, *El Faro* was pushed sideways by the wind and waves.

At **0631**, the captain said he wanted “everybody up.” He had the second mate compose, but not send, a distress message.

By **0644**, *El Faro*’s bow was pointed not into the wind, but perpendicular to it. Minutes later, the captain mentioned “significant” flooding in hold 3, but said that he did not intend to abandon ship, saying there was “no need to ring the general alarm yet.”

At **0659** the captain called a designated person (DP) ashore and left a message. Seven minutes later, the captain was connected to the DP and reported a marine emergency. When the call ended at **0712**, the captain had the second mate send the distress message.



The increasingly large induced list to port from wind and increasing flood water levels in hold 3, combined with the vessel’s rolling in the storm seas, likely caused seawater to enter cargo hold ventilation openings in the hull. It was possible to close these openings, but they were left open during the event; they were not considered downflooding points in any available guidance documents. Seawater poured into hold 3 and then into hold 2A and 2. At **0714**, the chief mate told the captain that the chief engineer had said that, “something hit the fire main, got it ruptured, hard” *(see* How the water got in, *p. 6)*.

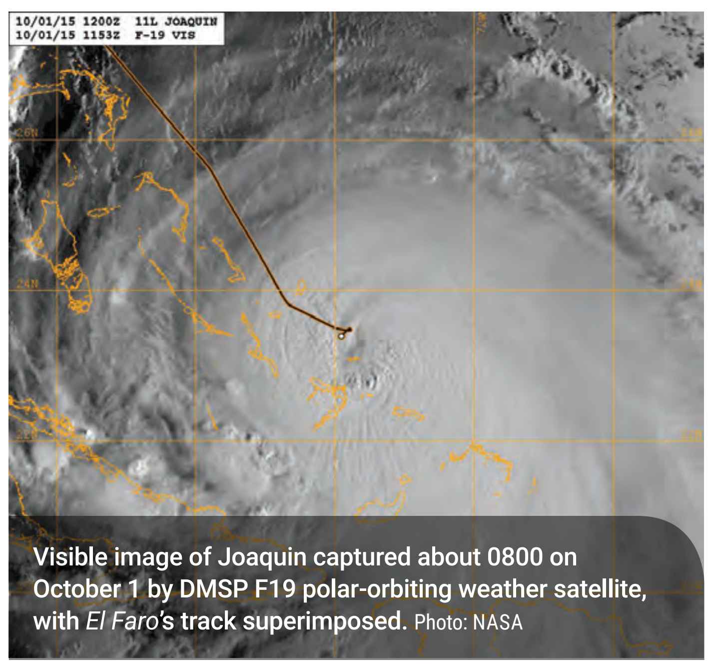
One or more of the vehicles in hold 3 had likely struck the emergency fire pump, or “fire main” piping, at the starboard side of hold 3. The inlet piping to the fire main system was designed to supply seawater to the suction side of the emergency fire pump. With a severe breach, seawater would have flowed into hold 3 at a rate that would inevitably overwhelm the capabilities of *El Faro*’s bilge pumps. It is likely that the piping was breached earlier than 0714, based on the continued flooding of hold 3 after the scuttle was secured and the hold was being dewatered by bilge pumps. (Vehicles had likely been adrift at

El Faro **computer rendering in static surface water showing list to port of 18° with departure trim 5.8 feet by the stern due to flooding of hold 3 estimated at 20% and windheel.**
Illustration: USCG Marine Safety Center

least as early as 0544, when the captain reported “cars loose.”)

Rather than mustering the entire crew, the captain and a few officers continued efforts to diagnose the problem, though they made no reference to consulting a damage control plan or booklet. Finally, at **0727**, the captain ordered ringing of the general alarm. A minute later, the chief mate advised the captain over the radio that the crew was mustering on the starboard side, and at **0729**, the captain ordered the crew to abandon ship. He ordered the liferafts thrown overboard at **0731** and told everyone to get into their rafts and stay together.

The recording ended at **0739**.



Visible image of Joaquin captured about 0800 on October 1 by DMSP F19 polar-orbiting weather satellite, with *El Faro*’s track superimposed. Photo: NASA

10 A shutdown device stopped the main engine from running without lube oil, by design. However, the ship’s boilers and electrical generators continued to operate, and the ship had electrical power.

About 3 minutes after *El Faro*’s VDR stopped recording, a reconnaissance aircraft estimated a 10-second average surface wind speed of 117 knots about 21 nautical miles south of *El Faro*’s last known position. At **0800**, Joaquin’s center was estimated to be about 22 nautical miles south-southeast of *El Faro*’s last known position, according to an NHC post-storm assessment.

Artist’s rendering of *El Faro* at final rest
based on data collected during search and recovery missions

Safety issues

The NTSB investigated many issues to find out what happened, why it happened, and what needs to be done to prevent it from happening again.

***El Faro*'s bridge**

Captain's actions

From early in the voyage, the captain made decisions that put his vessel and crew at risk, including making only minor course corrections to avoid Joaquin; relying on outdated weather sources; declining to change course or return to the bridge, even after receiving three calls from deck officers when he was not on the bridge; and introducing a port heel to shift water on the weather deck from starboard to port.

Use of noncurrent weather information

The captain continually referred to hours-old weather information from BVS. The watchstanders on the bridge were routinely getting more current information from the Sat-C terminal and from programs on satellite radio and The Weather Channel *(see* El Faro's weather data sources, *p. 3).*

Late decision to muster the crew

After *El Faro* lost propulsion, the captain continued to voice his expectation that main propulsion would be restored. Although the captain did say he wanted "everybody up" at 0631, the general alarm didn't ring until 0727, and the captain did not muster the crew until 0728.

Ineffective bridge resource management

Two members of the bridge team suggested or hinted that they disagreed with the captain's decisions, but the captain disregarded their concerns. For their part, the bridge crew deferred to the captain's authority and experience, rather than acting more assertively. Regardless, when the crew did voice concerns, the captain chose not to listen. The suggestions of not only one but two of his officers should have prompted him to at least return to the bridge and review the weather information.

Although bridge resource management (BRM) stresses assertiveness, traditional maritime culture emphasizes the captain's authority onboard and responsibility for the vessel. TOTE had not effectively implemented BRM, which involves modernizing centuries-old roles and including the bridge team in discussions pertaining to the safe navigation of the vessel.

Inadequate company oversight

TOTE regarded captains as the primary nautical experts. According to one TOTE executive, "There is no one in the company that formally provides oversight for nautical." Lack of training in BRM was one area in which company oversight failed. The company also failed to formally train crewmembers to use BVS, or on the damage-control module of a cargo-loading program called CargoMax. In addition, TOTE failed to track the vessel's position relative to the storm and support the captain during the accident voyage.

Company's safety management system

The company's safety management system did not provide the officers and crew with the necessary procedures to ensure safe passage, watertight integrity, heavy-weather preparations, and emergency response during heavy-weather conditions.

Flooding in cargo holds

Water initially flooded into the cargo holds through an open scuttle. This lowered deck friction coefficients and likely contributed to loose vehicles in hold 3, which likely damaged the emergency fire pump piping in the hold, allowing seawater to flood the hold faster than the bilge pumps could remove it. The continued hold flooding and increasing list in heavy seas allowed seawater to downflood through the cargo hold ventilation system *(see* How the water got in, *p. 6).*

Loss of propulsion

The sequence of events leading to the ship's loss of propulsion began with a sustained starboard list from beam winds and later flooding of a cargo hold. The captain acted to shift the starboard heel to a port heel. The port heel, in combination with momentary roll, likely allowed air into the lube oil system's pump, which triggered a shutdown of the main propulsion engine *(see* Loss of lube oil suction, *p. 7).*

Downflooding through ventilation closures

El Faro's certificate of inspection required that cargo hold ventilation closures be kept open at sea when the vessel was transporting vehicles with fuel tanks. In rough weather with a threat of downflooding, it was critical that crewmembers understood that such closures must be secured to prevent flooding *(see* How the water got in, *p. 6).*

Need for damage control plan

There is no evidence on the VDR that the captain or crew consulted a plan or procedure for damage control during the heeling, propulsion loss, and flooding sequence. Investigators determined that the vessel had no damage control plan or booklet.

***El Faro*'s starboard lifeboat on arrival at Coast Guard Air Station Miami**

Lack of suitable survival craft

El Faro carried only open (not modern, enclosed) lifeboats. In addition, by the time the crew was abandoning ship, the severe weather, combined with *El Faro*'s list, made it unlikely that the side-mounted lifeboats could be boarded or launched.

Exemplar enclosed freefall lifeboat in launch position on a slipway

Recommendations

We issued 10 early safety recommendations, followed later by 53 more recommendations in our accident report. Some of the results that these recommendations are intended to bring about are summarized here. To read the full findings and recommendations, see the report (MAR-1701) at www.ntsb.gov.

- Better tropical cyclone forecasting, storm advisories, and weather dissemination systems to improve the accessibility and quality of forecasts and advisories for planners and mariners
- Engines and other critical machinery that work at greater angles of inclination (i.e., despite more listing)
- Lifeboats that can be launched at still greater angles of inclination, so that they can be launched even if engines or other machinery fail
- Enclosed, not open, lifeboats
- Protected seawater supply piping in cargo holds
- Remote open/close indicators for watertight doors and hatches
- Guidance that actions intended to correct a list can be dangerous with cargo adrift
- Class-approved damage-control plans/booklets onboard all vessels, regardless of build date
- Review of the inspection program and improved oversight for vessel inspections
- Lifesaving appliances updated at least every 20 years
- Personal locator beacons for crewmembers
- Better VDRs and VDR testing
- Weather reporting by ships to global authorities every 6 hours at fixed times, using the automatic identification system
- Appropriate and recurrent BRM and meteorology training for all deck officers
- Improved processes, procedures, documentation, training, and shoreside support at TOTE
- External audit of TOTE's safety management system
- Functioning weather instruments on TOTE ships
- Heavy-weather procedures on TOTE ships that address oil levels in critical machinery

Recipients

In many cases, we issued companion recommendations to more than one entity with a single result in mind. In other cases, such as recommendations to TOTE, the hoped-for results were narrower and could be achieved by a single recipient. The recommendation recipients are:

US Coast Guard

Federal Communications Commission

National Oceanic and Atmospheric Administration

International Association of Classification Societies

American Bureau of Shipping

Furuno Electric Company, Ltd.

TOTE Services, Inc.

The search for *El Faro* and the VDR

The *Atlantis* under way

Data recorders are among the most powerful tools investigators have for determining what happened in an accident and to prevent it from happening again. The search for the wreckage of *El Faro* and recovery of its voyage data recorder (VDR) took three voyages, and resources from several organizations.

First voyage

OCT 23 2015 The Navy ship *Apache*, with three underwater assets, arrived at the site of the sinking

Towed ping locator. Investigators listened for the VDR acoustic beacon but heard nothing.

Towed side-scan sonar (ORION). ORION was launched on October 27, and, after 4 days of searching, located a large target of interest.

Remotely operated vehicle (ROV) CURV-21. Team members navigated the CURV-21 through the debris field, aided by a video feed.

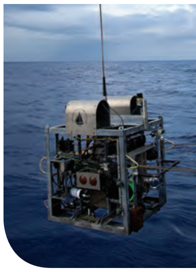
On the ROV's second dive, investigators spotted the wreckage, but the decks containing the navigation bridge, mast, and VDR were missing. Finally, on November 11, CURV-21 located the missing decks but not the mast or the VDR.

NTSB investigators analyzed video footage of the hull and debris field and calculated object trajectories to identify where the mast and VDR might have come to rest. A second voyage was planned in consultation with SUPSALV, NSF, and WHOI *(see* Organizations Involved in the Search, *next page).*

Second voyage

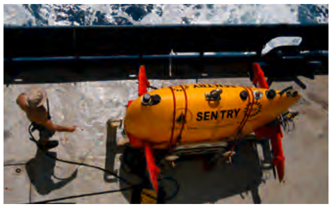
A vessel equipped with dynamic positioning was needed for the second voyage (dynamic positioning allows a vessel hosting underwater search vehicles to remain on station even during bad weather). The *Atlantis* (pictured above) became available in April 2016.

APR 21 2016 *Atlantis* arrived at the site of the sinking, equipped with the AUV (autonomous underwater vehicle) *Sentry* and an additional observation vehicle.



Atlantis surveyed site with multibeam sonar, verifying main hull wreck location and overall bottom bathymetry (depths and topography).

Sentry, programmed to search wide areas with different sonar frequencies or cameras, identified more than 200 targets of interest.



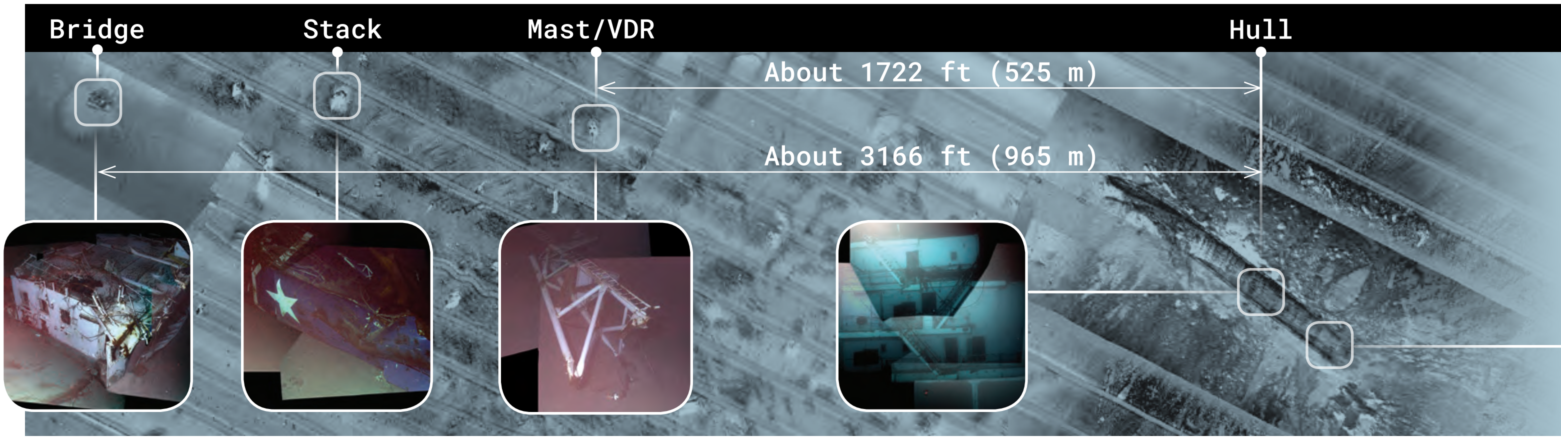
Observation vehicle obtained high-definition video and photos of *El Faro*'s hull, and interrogated the detected targets—one of which was the *El Faro*'s mast, with the VDR capsule attached.

The VDR is found directly at mast, and likely attached (remaining bolted) to the mast with obstructions, precluding a simple recovery.

A final recovery mission was launched in August 2016.

Second voyage photos: WHOI

Sentry **side-scan sonar survey of debris field**



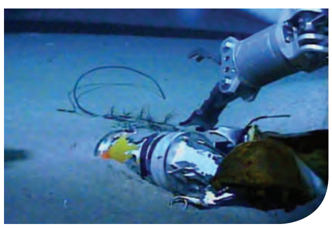
USNS *Apache* in the Atlantic Ocean
Photo: US Navy

Third voyage

AUG 08 2016

The ROV CURV-21 arrived at the site of the sinking, again hosted on board the Navy ship Apache. At 1950, CURV-21 successfully freed the VDR capsule from the partly buried mast and brought it to the surface.

The documentation of wreckage, together with the data and audio downloaded from the vessel's VDR, provided invaluable information to determine the circumstances of the sinking.



SEA LEVEL

PHOTIC ZONE
About 650 ft
Where sunlight hits

TWILIGHT ZONE
Less than 1 percent of surface light reaches here

THE DEEP SEA
About 3,000 ft
Completely dark

Empire State Building 1,454 ft

Burj Khalifa 2,722 ft

5,000 ft

3 miles to the bottom

The voice and data recordings were located on a chip smaller than a credit card contained in a capsule about the size of a basketball, 15,000 feet beneath the ocean surface.

10,000 ft

9,800 ft
Deepest recorded dive by a sperm whale (picture not to scale); underwater pressure is about 1.6 tons per square inch

12,500 ft
Wreck of the RMS *Titanic* rests under 2.8 tons per square inch of water pressure

El Faro's main hull at depth of 15,400 ft; pressure is nearly 3.5 tons per square inch

15,000 ft

ORGANIZATIONS INVOLVED IN THE SEARCH

The Department of the Navy's Superintendent of Salvage and Diving (SUPSALV) SUPSALV often supports NTSB investigations under a memorandum of understanding between the agencies

Woods Hole Oceanographic Institution (WHOI) From the planning of the second voyage on, investigators utilized WHOI's oceanographic assets and expertise

National Science Foundation (NSF) Provided use of the vessel Atlantis

University of Rhode Island's Inner Space Center Provided real-time transfer of large volumes of video and data between Atlantis and NTSB headquarters

NTSB

Reviewing the VDR

The entire 26-hour recording was reviewed many times, with some statements reviewed more than 100 times by the VDR audio transcript group to ensure they understood what was being said in the recording.

About 10 hours of audio was determined to be relevant to the investigation and therefore transcribed by the VDR audio transcript group. The transcript required more than 1,100 work hours to complete. The transcript report is more than 500 pages and is the longest transcript ever produced by the NTSB.

Parties to the investigation

US Coast Guard

TOTE Services, Inc.

American Bureau of Shipping

National Weather Service

Harding Safety USA (Palfinger)

Herbert Engineering