Allision of Liberia-Registered Fruit Juice Carrier M/V *Orange Sun* with U.S.-Registered Dredge *New York*
Newark Bay, New Jersey
January 24, 2008

Accident Report

NTSB/MAR-09/03
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National Transportation Safety Board

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Marine Accident Report

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National
Transportation
Safety Board

490 L'Enfant Plaza, SW
Washington, DC 20594

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

Abstract: This report discusses the January 24, 2008, accident in which the fruit juice carrier M/V *Orange Sun* allided with a dredge, *New York*, while the ship was outbound in Newark Bay, New Jersey. As a result of the allision, the *New York* sustained about $6 million in damage, including salvage costs, and the *Orange Sun* about $330,000. About 100 gallons of mixed oil from the dredge's machinery was released as a result of the accident. No one was injured. The safety issue identified in this accident was the actions of the *Orange Sun* crew and the pilot leading up to the allision. As a result of the investigation, one safety recommendation is issued to the *Orange Sun*'s operating company.

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Acronyms and Abbreviations

APC	alternate person in charge
BRM	bridge resource management
DNV	Det Norske Veritas
IMO	International Maritime Organization
NOAA	National Oceanic and Atmospheric Administration
RPM	revolutions per minute
STCW	Standards of Training, Certification, and Watchkeeping for Seafarers
VDR	voyage data recorder
VHF	very high frequency
VTS	vessel traffic service

Executive Summary

On January 24, 2008, about 1352,[1] the 672-foot-long, Liberia-registered fruit juice carrier M/V *Orange Sun* allided with a dredge, *New York*, while the juice carrier was outbound under pilotage in Newark Bay. About 25 minutes into the transit, the pilot ordered a 5° starboard course change from 200° to 205° and then reduced the speed to dead slow ahead as the juice carrier approached the dredge. The helmsman on board the *Orange Sun* experienced difficulty trying to steady the ship on the ordered course, and after a brief series of increasing port wheel inputs to arrest the vessel's swing to starboard, he put the wheel to midship, or zero angle. Both the helmsman and the master then made several wheel inputs to try to correct the vessel's heading, including at least three incorrect wheel inputs to starboard, which the pilot had not ordered and which were made without his knowledge. The actions of the helmsman and the master caused the ship to steer toward the dredge, with insufficient time to avoid the allision.

As a result of the allision, the *New York* sustained about $6 million in damage, including salvage costs, and the *Orange Sun* about $330,000. About 100 gallons of mixed oil from the dredge's machinery was released as a result of the accident. No one was injured.

The probable cause of the allision of the *Orange Sun* with the dredge *New York* was the master's failure to appropriately use bridge resource management and to communicate; specifically, to familiarize his bridge crew with and inform the pilot of the vessel's occasional tendency to sheer,[2] a characteristic that he had personally experienced. Contributing to the accident were the inappropriate starboard rudder movements made by both the helmsman and the master, which interfered with the pilot's ability to take appropriate action to prevent the allision. Also contributing was the second officer's failure to accomplish his primary duty as officer of the watch, which was to properly monitor the helmsman.

The National Transportation Safety Board (NTSB) identified the actions of the bridge team[3] leading up to the allision as the primary safety issue in the *Orange Sun* accident.

As a result of its investigation, the NTSB makes one recommendation to the operating company of the *Orange Sun*, Atlanship, S.A. (Atlanship).

[1] All times in this report are eastern standard time according to the 24-hour clock.

[2] In this report, "sheer" is the term for an unintentional diversion, or veering, from intended course.

[3] A bridge team is generally defined as everyone who is involved in a vessel's navigation, including the pilot. For the purpose of this report, the NTSB defines the bridge team as the pilot, the master, and the navigational crew.

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Factual Information

Vessel Information

Orange Sun

IMO No.	9342580
Type	Fruit juice carrier
Construction	Steel; 672 feet long, 33,070 gross tons
Engine	Kawasaki-Man/B&W (2 stroke diesel)
Year Built	2007
Operator	Atlanship; La Tour-de-Peilz, Switzerland
Owner	Arctic Reefer Corporation, Inc., Monrovia
Flag/Registry	Liberia
Classification	Germanischer Lloyd
Complement	22
Damage	$330,000
Injuries	None

New York

Official No.	1077537
Type	Dredge; non-self-propelled
Construction	Steel; 200 feet long, 1,485 gross tons
Year Built	1999
Operator	Great Lakes Dredge & Dock Company; Oak Brook, Illinois
Owner	Wilmington Trust Company AS TSTE
Flag/Registry	United States
Complement	7
Damage	About $6 million, including salvage costs
Injuries	None

Accident Narrative

About 1325 on January 24, 2008, the 672-foot-long fruit juice carrier M/V *Orange Sun* (figure 1) departed berth 24 in Port Newark, New Jersey. The vessel, operated by Swiss management company Atlanship, had arrived 5 days earlier from Santos, Brazil, carrying about 29,540 metric tons of concentrated orange juice, and had discharged 10,850 metric tons, or about a third of the cargo, in Port Newark. The next scheduled port call was Port Manatee, near Tampa, Florida, where the *Orange Sun* was to load additional orange juice and then transit to Europe. (More information about the shipping company appears in section "Atlanship.")

Figure 1. The *Orange Sun*. Photo by the U.S. Coast Guard.

Two tugboats, one on the bow and one on the port quarter, assisted in un-docking the *Orange Sun* from the Port Newark berth. As the ship got under way, the navigation watch consisted of the vessel master and a second officer, the latter temporarily assigned at the helm to steer until a designated able seaman would take over as helmsman after he finished with line-handling duties. A docking pilot[4] was also on board and had navigational control of the vessel. The pilot's assignment was to take the *Orange Sun* from the berth in Port Newark to an anchorage location in Upper New York Bay, where divers were to conduct an inspection of the

[4] Docking pilots specialize in docking and undocking oceangoing vessels in certain U.S. ports including Newark. Docking pilots typically pilot vessels from one berth to another and between anchorages and berths. Docking pilots regularly use tugboats to assist in maneuvering large vessels. The docking pilot on board the *Orange Sun* was a member of the Metro Pilots Association.

ship's underwater hull. During their master/pilot exchange,[5] the master explained to the pilot that he had requested the hull inspection because the *Orange Sun* had briefly touched the muddy bottom at Port Newark while berthing during low tide[6] 5 days earlier. The master had notified the vessel company, Atlanship, and requested that the hull be inspected before the ship began its transit to Florida.[7] The master told the pilot that all systems had been checked at the berth and were functioning properly. Also during the master/pilot exchange, the master informed the pilot that the juice carrier had a controllable pitch propeller and a "Becker rudder," (a flap-type rudder manufactured by Becker Marine Systems), which the pilot was familiar with from having piloted other vessels similarly equipped. (Further information about the Becker rudder can be found in the "Steering Particulars" section.)

About 5 minutes after departure the pilot released the bow tugboat and instructed the tugboat on the port quarter, the *Kimberly Turecamo*, to follow along astern in case she was needed later to assist in the tight turn around Bergen Point. The pilot notified VTS that the vessel was under way and he learned, in addition to other relevant traffic information, that a dredge, the *New York*, and associated craft were in the area preparing to begin dredging operations (figures 2 and 3).

Figure 2. The *New York* during dredging operations. Photo by Fred Wehner for Tug44.org.

[5] According to the International Maritime Organization (IMO), pilotage assignments should begin with a conference between pilot and master to share relevant information about navigation procedures, local conditions, and the ship's characteristics. The master/pilot exchange should also establish an appropriate working relationship between pilot and master.

[6] The range of the tide in Newark Bay is about 5 feet, according to the United States Coast Pilot, Vol. 2, 34th edition, page 399.

[7] The Coast Guard had not been informed that the *Orange Sun* touched bottom at Port Newark. Title 46 *Code of Federal Regulations* (CFR) Part 4.05–1 (1) states to report "an unintended grounding."

Figure 3. Aerial view of Newark Bay and Upper New York Bay. The line down Newark Bay shows the path of the *Orange Sun* leading up to the allision from the berth at Port Newark and southbound through the main shipping channel.

About 1344,[8] the able seaman assigned to the helm arrived on the bridge and assumed the helm duties from the second officer. The helmsman understood standard helm orders in English, but did not speak English. On being relieved of the helm, the second officer resumed his duties as officer of the watch. The second officer told investigators that he had not been on watch with the helmsman before and had never seen him steer. However, the second officer said that he knew that the helmsman had steered the *Orange Sun* before, as well as other ships. The second officer told investigators that he did not pay any more attention than usual to the helmsman and only checked him from time to time.

[8] The times in the following section are approximate and are based on the data extracted from the *Orange Sun*'s voyage data recorder (VDR). VDRs maintain continuous, sequential records of data relating to a ship's equipment and its command and control, and capture bridge audio from certain areas in the wheelhouse and on the bridge wings. Under regulation 20 of the International Convention for the Safety of Life at Sea 1974 (SOLAS) chapter V, all passenger ships and all cargo ships of 3,000 gross tons or more built on or after July 1, 2002, are required to carry VDRs.

(For a timeline of key events on the day of the allision, see Appendix D, and for a VDR readout of the bridge team's rudder inputs and relevant comments just before the allision, see Appendix E.)

About 1 minute after the helmsman took over the steering, the *Orange Sun* entered the main Newark Bay shipping channel, having proceeded at slow speeds and minor rudder commands in a southeasterly direction out of the branch channel. As the pilot guided the ship into the main channel, he ordered the speed increased to half ahead to expedite passing the channel buoys on the vessel's starboard side. At 1344:44, the pilot ordered the helmsman to steer course 200°, which conformed with the main shipping channel. Immediately afterwards, the pilot ordered the vessel's speed reduced from half to slow ahead.

After about 3.5 minutes on course 200° at slow ahead, the *Orange Sun* was approaching a slight right turn in the main shipping channel. According to the vessel's VDR, at 1348:36, the pilot ordered the helmsman to put the rudder to starboard 10° and gave the helmsman a course to steer of 205°. Almost immediately after the helmsman answered 205°, the pilot ordered the speed reduced to dead slow ahead. The pilot later told investigators that he ordered dead slow ahead so that the *Orange Sun* would not cause too much of a wake and thereby upset dredging operations when it passed the *New York*, which was positioned outside the main shipping channel on the juice carrier's starboard bow.

To steady the ship on the 205° course, the helmsman began slowly applying increasing amounts of wheel input to port to slow the starboard swing, which he had the discretion to do. During the next 35 seconds or so, the helmsman put the wheel to port 5°, then port 10°, port 15°, and finally, when the course was nearing 208°, the helmsman input about port 20° to counteract the starboard swing, which he described to investigators as "very fast" to starboard. He did not detect any appreciable reduction in the rate of turn to starboard.[9] With the vessel's starboard swing continuing (at a rate of turn of 9° per minute), the helmsman then brought the wheel to midship, or zero angle position, at 1349:25. The VDR recorded that a slight decrease in the rate of turn had occurred by that time, but the *Orange Sun* was still turning to starboard. The VDR also showed that the near-20° to port wheel input had been applied for less than 4 seconds before the helmsman brought the wheel back to zero. A few seconds after the helmsman put the wheel to midship, and with the vessel still turning to starboard, the pilot reiterated "two zero five" and ordered the rudder to port 20°. The helmsman responded "port ten." At this time, according to the VDR, the rudder was at port 10° but the vessel was still swinging to starboard. The helmsman repeated port 10° a second time.

At this point, the vessel was less than one third of 1 mile from the dredge and proceeding at about 10 knots. On board the *New York*, the spudding-down[10] process had been completed and the crew was preparing to start dredging. Two scows[11] and two attending tugboats were also employed in the operation. Seven people were on board the dredge.

As is often the case on ships, it was not possible for the pilot on board the *Orange Sun* to observe the wheel inputs applied by the helmsman from the pilot position forward of the bridge console (figure 4). Therefore, the pilot would from time to time monitor the vessel's rudder angle indicator, located on the overhead forward of the main navigation console (figure 5).

[9] The VDR data later showed that the counter rudder was starting to lessen the starboard swing.

[10] A spud is a heavy steel shaft used as a mooring device.

[11] Scows are barges with square-ended rakes, a flat bottom, and an open center to hold dredging spoils.

Figure 4. The bridge console on board the *Orange Sun*. The pilot was positioned forward of the console, piloting by visual cues looking out the bridge windows.

Figure 5. The *Orange Sun*'s rudder angle indicator, visible in the upper left corner.

The helmsman later told investigators that he was about to tell the pilot that he was having trouble controlling the vessel, but the pilot had already noticed that the vessel's heading was swinging past the ordered 205° course. The pilot told investigators that, when he looked at the vessel's rudder angle indicator, he expected to see that the helmsman had input some amount of port rudder to control the starboard swing. However, he saw that the rudder was about midship while the vessel's heading was still swinging past 207°, and that the rudder angles were not corresponding with his orders. At 1349:41, he said, "midship now, port twenty." The helmsman immediately responded, "port twenty," and the master urged in Croatian, "to the left, move to the left." The helmsman responded "port ten"; however, he moved the wheel to starboard 20° and then to starboard 35°, despite the pilot's order of port 20°. The pilot later told investigators that, about this time, he wanted to increase the vessel's speed to improve rudder effectiveness but, because the rudder was going to starboard, he did not increase speed.

Seconds later, the pilot ordered, "port twenty stupid," and the master again urged the helmsman in Croatian, "to the left, move to the left." The helmsman responded "midship." The pilot now urged the helmsman, "come on, get it over there. Midship. Midship." The helmsman moved the wheel from starboard 35° to midship, and a couple of seconds later put the wheel to nearly port 30°.

The pilot, watching the rudder position on the rudder angle indicator, told the master, "the rudder's off." The pilot then immediately ordered, "port twenty, hard to port." The master echoed the hard to port order and the helmsman answered hard to port. At 1349:59, the pilot questioned, "what the hell is he doing?" At this time, according to the VDR, the rudder was still slightly to starboard. (The rudder had been as far to starboard as 26°, in response to the erroneous starboard 20° and starboard 35° wheel inputs that the helmsman had entered moments before, despite the fact that the pilot had issued orders only for port rudder.) The helmsman or the master then put the wheel to port 30°, which corresponded closely to the pilot's order for hard to port. It could not be determined, based on VDR and interview information, at exactly what point the master intervened and took the wheel from the helmsman. The master told investigators that he had been standing at the front window to the right of the pilot, about 10 meters from the steering stand, and that he realized that something was wrong as the pilot "started to shout" a port command. The master said that he saw the rudder to starboard on the rudder angle indicator but did not recall the exact amount of starboard rudder. The master stated that he then rushed to the wheel, turned it to port, and also took over the control of the engine throttle. He did not recall what the wheel position was before he turned it or how much rudder he obtained on turning it. The helmsman told investigators that he did not resume steering after the master took the wheel from him.

The second officer told investigators that when the problems began, he was stationed by the chart table plotting the vessel's position. He stated that he first realized that something was wrong when the pilot said port twenty and repeated the course 205°, and the second officer noticed that the course was 207°. Later, he also saw that the rudder angle indicator showed starboard rudder, the amount of which he could not recall. The second officer stated that he could not see the reading of the wheel position because it was small and blocked by the helmsman standing in front of it. The second officer recalled that the pilot and the master both ordered hard to port, or port 35°, but he did not recall whether or not the rudder went to hard port.

At 1350:04, the pilot increased the vessel's speed, ordering "half . . . slow ahead." The master answered slow ahead. Seconds later, the pilot ordered "full to port, sixty degrees," and the master responded full to port. The rudder reached full port, or about 65°, about 5 seconds later.[12] The master, using the radio, then ordered the anchor detail on the bow to stand by the anchor. Shortly thereafter, the pilot asked the master, "Is there something wrong captain? Is the rudder responding? Captain what's wrong?" No reply from the master was recorded by the VDR. About 5 seconds after the rudder had reached port 65° the wheel was shifted from full port rudder to starboard 32°, causing the rudder to start swinging to starboard again. The master indicated to investigators that he had the helm at this point. Both the master and the helmsman told investigators that they had not moved the wheel to starboard and could not understand why the rudder went to starboard.[13]

At 1350:26, with the rudder continuing to swing to starboard, the pilot ordered, "stop engine" and "full astern," and the master repeated the pilot's orders. The pilot then radioed the tugboat *Kimberly Turecamo* that was trailing behind the juice carrier to come to the port quarter and push. The tugboat operator later confirmed that the *Kimberly Turecamo* was unable to get to the port quarter before the allision occurred.

At 1350:39, the pilot radioed the first warning to the dredge on very high frequency (VHF) channel 13. The pilot broadcast about four more warnings to the *New York*, telling the crew to brace for impact. No acknowledgement was heard from the dredge; however, the pilot told investigators that he observed activity on the *New York* that indicated that the dredge crew had received and understood the warning. Neither he nor the master sounded the vessel's whistle.[14]

The *New York*'s two onboard VHF radios were set to channel 5, which was the working channel for the dredge and the tugboats, and to channel 14, which was the channel on which vessel traffic service (VTS) would contact the vessel, if necessary. As a result, the dredge crew did not hear directly the pilot's warning on channel 13. They relied on the attending tugboats to monitor channel 13, which the tugboat crew did. The dredge's first warning broadcast came from one of the tugboat captains, the master of the *Melvin Lemmerhirt*, who heard the pilot's warning on channel 13. The tugboat master radioed the *New York* on channel 5, shouting, "watch out for that ship!" The *Melvin Lemmerhirt* also sounded the danger signal[15] on its whistle. At that moment, about four persons, including the dredge's alternate person in charge (APC), the chief engineer, and a surveyor, were in the dredge's observation room, located one deck above the main deck. At first, the APC could not see the *Orange Sun* as he was facing forward watching preparations to raise the dredge's excavator bucket. He then turned around and saw the juice

[12] At angles of about 45° to 65°, the Becker rudder can be used as a stern thruster at slow speeds through the application of propeller thrust; however, such large angles produce little turning effect without additional thrust from the ship's propeller. The Becker rudder, like other rudders, produces increased turning force up to about 35°. Beyond this angle, turning force is reduced.

[13] The VDR recorded wheel inputs and rudder response. The data revealed that the wheel had been put to starboard and that the rudder responded to the wheel inputs.

[14] Sounding the whistle was not required by regulations.

[15] Five short blasts of a vessel's horn.

carrier approaching from behind. He also saw, based on the reactions and activity on the main deck below, that the dredge crew also had seen the juice carrier. The APC told investigators that, at that point, he estimated that the ship was about 10 seconds from striking the dredge. He told investigators that he yelled for everyone in the observation room to "get on the floor and hang on," and did so himself.

The dredge operator inside the *New York*'s excavator cab told investigators that he had seen the *Orange Sun* under way for a while before the allision but had not sensed anything abnormal about the juice carrier's outbound course. As the dredge operator was getting ready to lift the excavator bucket off the deck, he heard the master of the *Melvin Lemmerhirt* on the cab radio telling him, "get out of there, get out of there." The dredge operator told investigators that he then looked up to see the *Orange Sun* approaching from port, about 10 or 15 seconds from impact, and he feared that the juice carrier's bow would strike his excavator cab. He immediately tried to raise the two forward, or "breast," spuds in the hope that when the *Orange Sun* hit the *New York*, the ship "would just shove" the dredge. The dredge operator stated that the breast spuds did start to come up but did not fully detach from the bay floor before the allision.

At 1350:44, after numerous attempts by the *Orange Sun* bridge team to correct the vessel's heading and with the distance to the dredge closing, the pilot ordered, "drop the port anchor." The deck crew on the bow dropped the port anchor and the anchor chain ran free, with the forward momentum of the vessel allowing the chain to be carried away aft.

The juice carrier's starboard side impacted the dredge's port side about 1352. The dredge crew told investigators that, on the initial impact, the dredge heeled to starboard, returned to a nearly upright position, then heeled a second time to starboard at a lesser degree as the *Orange Sun* "bounced off" and then scraped along the dredge's side. The dredge engineer, who was in the starboard-side toolroom below deck, stated that the initial impact "knocked [him] two or three feet."

A few seconds after the impact, the pilot on board the *Orange Sun* ordered the ship's anchor held. The bosun who was on the bow told investigators that he had already applied the chain brake before the pilot's order came in. The bosun had released a total of 6 shackles,[16] or 540 feet, of anchor chain. At 1352:15, the pilot ordered the *Kimberly Turecamo* to come along the starboard quarter of the juice carrier and push to stop the vessel from making further contact against the *New York*. The pilot kept the tugboat pushing the *Orange Sun*'s starboard quarter to swing the ship around to a north heading to stem the south-flowing ebb current. Once the *Orange Sun* faced north into the current the two vessels separated.

Within 1 minute of the allision, the pilot informed VTS New York that the *Orange Sun* had allided with the dredge.[17]

The allision breached the portside hull on the *New York* and shortly thereafter, the dredge's bow began to submerge. The dredge engineer proceeded up the ladder to the main deck

[16] A shackle is a measure of anchor chain length. One shackle equals 90 feet, or 15 fathoms.

[17] About 1400, VTS closed Newark Bay to commercial traffic and reopened it about 1848 with a slow bell and no-wake requirement.

where the emergency muster station was located. In the excavator cab, the operator heard bilge- and general alarms sounding before he too proceeded to the muster station, where the remaining crewmembers gathered and were accounted for. During the muster, the *New York*'s electrical power was lost. After a brief vessel survey and assessment, the crewmembers decided to abandon the dredge because, at that point, the vessel appeared to be submerging at a fairly rapid pace and flooding had reached the top of the ladder way to the storage room on the port side. The dredge crew boarded one of the attending tugboats.

After observing the *New York* for a while, the dredge crew determined that the vessel was "holding steady" and was not going to sink. They then re-boarded the dredge, opened electrical breakers to flooded spaces, and brought a previously tripped generator and a second generator on line. The crew also tied the scows which had been employed in the dredging operation to the port and starboard sides of the *New York* to provide additional buoyancy and help the dredge stay afloat. After salvage divers arrived on scene the scows were removed and the *New York* rested solely on its spuds, heeling about 1 foot to port. (For more information about the flooding, see "Damage" section in this report.)

About 1540, an additional pilot arrived on board the *Orange Sun*, but the accident pilot remained on duty. About 1550, VTS informed the *Orange Sun* that the vessel had permission to proceed to an anchorage, Bay Ridge, in Upper New York Bay. When the anchor was aweigh at 1605, the accident pilot brought the vessel to Bay Ridge anchorage under the vessel's own power, accompanied by four tugboats. The pilot told investigators that the transit was uneventful, that the *Orange Sun* handled very well, and that the tugboats never needed to be used to control the vessel. He stated that he had used 10° of rudder to navigate the vessel around Bergen Point, a location that he said sometimes required much more rudder and even tugboat assistance to get around on other vessels. At 1746, the *Orange Sun* arrived at the Bay Ridge anchorage and dropped anchor.

The pilot told investigators that the master had not mentioned that the *Orange Sun* had any sheering tendency or that any issues existed with the ship's steering system. The pilot said that after the accident, the master told him that he had previously experienced control problems with the vessel and he handed the pilot an article published by classification society Det Norske Veritas (DNV) that discussed a grounding due to loss of steering on a ship with a controllable pitch propeller and a flap-type rudder (Appendix C). The master had received the article from Atlanship, which regularly sent out articles on various maritime topics to its ships. Atlanship had instructed that the DNV article be disseminated among its bridge officers, and the master on the *Orange Sun* had had his vessel's deck officers sign it. The pilot had not seen the article before.

Investigators learned that the *Orange Sun* had also experienced reduced steering effectiveness during its inbound transit 5 days earlier, on January 19, 2008. The vessel was then approaching Port Newark with a different docking pilot and a Sandy Hook pilot on board. A different helmsman was at the wheel, and the vessel's chief officer served as the inbound officer of the watch. The master was on the bridge. The docking pilot, who had navigational control at that time, told investigators that the trip through the Kill Van Kull waterway and past the turn at Bergen Point into Newark Bay was uneventful until the vessel reached the turn into the Newark Bay branch channel leading to the assigned berth. The docking pilot ordered the vessel slowed to dead slow ahead and the course changed to port to head for the berth. The vessel was proceeding at about 2 knots and had one tugboat on the port bow and one near the stern. The docking pilot told investigators that shortly after the port rudder was applied, the vessel's bow started to swing left at a greater rate of turn than expected and the vessel continued turning beyond the desired heading. The docking pilot increased speed to improve rudder effectiveness, ordered the rudder to 65°, or "full Becker" starboard rudder, and ordered the tugboat at the bow to push on the port bow. The unexpected sheer was corrected. The docking pilot later told investigators that he was not certain which of his ordered actions had the most effect in stopping the sheer to port. He had observed that the sheer was controlled about the time he reduced the rudder from starboard 65° to about 35°.

The inbound docking pilot confirmed to investigators that after the incident, the master showed him the same signed DNV article about controllable pitch propellers and flap-type rudders that the master also showed to the outbound pilot 5 days later.

Environmental Impact

About 100 gallons of oil leaked from the dredge as a result of the allision. The oil was a mixture of lube, diesel, and hydraulic oil from the vessel's machinery and miscellaneous deck sources. No integral tanks were breached.

Toxicological Testing

While at anchorage sometime between 1400 and 1600, the chief officer on the *Orange Sun* tested the bridge crew for alcohol using the onboard AlcoMate Plus AL5000 breathalyzer. A member of the Coast Guard boarding team, who came on board the vessel following the allision, observed the testing. All crewmembers tested negative for alcohol. Later that evening, between 2210 and 2340, an outside contractor tested the master, the second officer, the helmsman, the chief engineer, the third engineer, and an electrician for illicit drugs. The results were negative. The pilot was alcohol tested about 1500 by a mate on board the tugboat *Kimberly Turecamo*, using a saliva test. The result was negative. That evening, an outside drug-testing contractor for the Metro Pilots Association collected a urine specimen from the pilot for drug testing. The result of the drug test was negative as well.

Weather

The National Oceanic and Atmospheric Administration (NOAA) indicated that at the time of the accident the wind was out of the northwest at 4 knots with slightly higher gusts. The sky was overcast and visibility was good. The air temperature was 33°F and the water temperature was 39°F. The tide was ebbing, and the pilot stated that he estimated that the current in Newark Bay was about 1 to 1.2 knots to the south.

Damage

Orange Sun. The starboard side of the *Orange Sun* sustained moderate visible damage (figures 6 –8). The repair costs totaled about $330,000.

Figure 6. Starboard-side scrapes and smudges on the *Orange Sun*.

Figure 7. Inset, puncture, and scraping to the *Orange Sun*'s bulwark on the upper starboard-side bow.

Figure 8. The scraped and dented bulbous bow on the *Orange Sun*.

New York. The *New York* sustained damage to its portside hull and framing below the waterline. Flooding occurred in the winchroom, portside transformer room, the starboard-side toolroom, and centerline storeroom, in each case to near-overhead or overhead levels. The three manual watertight doors between the flooded spaces were in the open position. Machinery, transformers, controllers, and equipment in those spaces were damaged by salt water. The main excavator's large rotational base bearing was submerged and required repair.

The port breast spud could be retracted from the bay bottom. It appeared to have suffered minimal damage, although the upper portion of it probably made contact with the *Orange Sun*. The starboard breast spud was bent about 45° and needed to be cut off under water, about 39 feet from the bay bottom, to refloat and move the dredge. The aft traveling spud was slightly bent and could not be raised. Like the starboard breast spud, it had to be cut off (figure 9).

Figure 9. The *New York* after the allision, with its submerged bow resting on the breast spuds.

The rubber wrap-around fender and supporting structure above the waterline was also damaged, at about frame 14 at the port forward corner of the trim tank. The hull shell plating was punctured on the port side at the winchroom, with a large curved vertical tear over 1 foot wide, extending about 9 feet from the chine[18] to above the water line (figure 10). All of the internal web frames of the hull's plating were severed or deformed in the damaged section.

Salvage and temporary repairs were made to the *New York* before the dredge was towed to the Brooklyn Navy Yard graving dock for permanent hull repairs. The salvage work included fitting a temporary welded plate "box" over the shell opening, securing watertight doors and pumping out the vessel, and cutting off the starboard breast and aft traveling spuds. According to a Great Lakes Dredge & Dock Company official, the cost of salvage repairs and towing totaled about $2,000,000, while the cost of drydocking and permanent repairs to steel and equipment were estimated to be an additional $4,000,000. The dredge returned to service in August 2008.

[18] The chine is a fore and aft/longitudinal hard edge where two plates meet on a hull, typically below the waterline.

Figure 10. The curved tear in the portside hull of the *New York*. Photo by Great Lakes Dredge & Dock Company.

Personnel Information

Pilot. The pilot, age 57, graduated from the State University of New York Maritime College at Fort Schuyler in June 1973. Following graduation, he worked for McAllister Towing from June 1973 to February 1978. Then he joined the Hudson River Pilots Association and piloted vessels on the Hudson River until 1992, when he joined the Metro Pilots Association as a docking pilot. He stated that he had completed required training in the Standards of Training, Certification, and Watchkeeping for Seafarers (STCW), including training in bridge resource management (BRM).

The pilot had worked the night before the accident and had slept at the Metro Pilot base on Staten Island, rising at 1100. He boarded the *Orange Sun* about 1300. The pilot stated that he had been off for two days before that. He usually went to bed about 2200, slept well, and usually got up around 0800. He stated that he felt rested on the day of the accident.

He had a physical exam by a medical doctor in September 2007, and was found fit for duty. The examination results were provided to the pilot commission. He wore reading glasses and had annual eye examinations by an optometrist. The pilot stated that he was not taking any prescription medications.

Master. The master of the *Orange Sun*, age 41, was a Croatian national and graduate of the Croatian Nautical College. He held a Republic of Liberia master's license, of any gross tonnage, issued March 16, 2004, effective until December 30, 2008. He began working for Atlanship as chief officer in August 2002, and in May 2006 began serving as master. He had worked on board four other Atlanship vessels before the *Orange Sun*, and his onboard tours ranged from 5 to 6 months in length. He first sailed as master on the *Orange Sun* on November 1, 2007, and he had been on board since that time. The master had made three round trips with the *Orange Sun* to Port Newark since coming on board as master. He also stated that he had been to Port Newark as master on other vessels, but could not remember how many times.

The master stated that he was well rested on the day of the accident. He said that, while in port, he got up at 0700 each day and went to bed at 2200 or 2300. The master stated that, because the *Orange Sun* had been in port from January 19 to 24, he had opportunity to rest. He stated that he was in good health, exercised daily, and did not take any medications. His latest physical examination was on October 24, 2006.

Records provided by Atlanship showed that the master had completed current required and recommended training. He had not taken a course specifically in BRM, which, according to Atlanship, was not required when his license was issued.

Some time after the accident, the master elected to leave his employment with Atlanship.

Second Officer. The second officer, age 35, was a Croatian national and graduated from the Rijeka College of Maritime Studies (Croatia) in 2000. He obtained a second officer license at that time, but served as a third officer for the first few years after graduating. He was on his third contract as a second officer at the time of the accident, and had served as second officer on the *Orange Sun* for a total of five and a half months. He had been on board for one and a half months when the accident occurred. He stated that he was the navigation officer, tasked with care of the navigation equipment, maintaining a portfolio of charts, and preparing passage plans. He stated that his duties as watch officer when a pilot was on board was to check the vessel's position, make sure navigation equipment operated satisfactorily, and keep the bell book. "Every once in a while" he would check the helmsman to ensure that the pilot's helm orders were carried out correctly.

The second officer stated that he got up at 0700 on the day of the accident and had gone to bed at 2300 the previous night.

Helmsman. The helmsman, age 31, was a Croatian national and had been an able seaman for 8 years. He had worked on the *Orange Sun* for 4 months, steering the vessel in and out of ports during that time. The master confirmed the helmsman's harbor steering experience on the *Orange Sun* in his interview with investigators. The helmsman's certification was issued by the Republic of Liberia's Bureau of Maritime Affairs, which certified his position as able seaman and also attested that he had the knowledge and ability to physically handle the wheel and to understand helm commands. The *Orange Sun* also had a regular weekly training regime, where all the vessel's helmsmen demonstrated their steering proficiency while supervised by an officer. At sea, the helmsman stood the 0400-to-0800 watches. During the two days preceding the accident, he had worked from 0800 to 1700. The night before the accident he had gone to bed about 1900 to prepare for standing watch from midnight to 0600. He rested from 0630 to 0700, had breakfast, and then went to work at 0800. He had lunch and then was involved in line-handling duties starting about 1230.

The master stated that the helmsman was a good worker and a reliable helmsman. The master stated, however, that the helmsman's English was not very good. During the helmsman's interview with investigators, another Croatian crewmember was present to help interpret certain questions and answers.

Atlanship

The operating company of the *Orange Sun*, Atlanship, was founded in Lausanne, Switzerland, in 1982. Atlanship operates specialized food-industry vessels; in particular, ships transporting refrigerated fruit juice in bulk. In 2009, Atlanship operated six vessels, according to the company website, and the company head office was located in La Tour-de-Peilz, Switzerland, with a representative office in Rotterdam, the Netherlands.

Steering Particulars

Controllable Pitch Propellers

The *Orange Sun* was fitted with a controllable pitch propeller (figure 11) for propulsion. In the marine industry, controllable pitch propellers are less common than fixed pitch, conventional propellers; however, their installation and use is becoming more frequent, and ship masters and pilots are increasingly experienced with them. Because of the ability to adjust the pitch, or angle, of the propeller blades, controllable pitch propellers enable quicker changes in ship speed and direction than do conventional propellers. This is an advantage over conventional propellers which alter speed by changing the revolutions per minute (RPM) of the propeller shaft. Controllable pitch propellers are especially advantageous in port or in confined waterways.

Figure 11. Controllable pitch propeller with adjustable-angle blades and main rotating shaft, similar to the one on the *Orange Sun*. Photo by Masson Marine.

Flap-Type Rudders

Flap-type rudders such as the Becker rudder (figure 12) enable more responsive steering capability on vessels under way. In port, flap-type rudders are effective as stern thrusters; by increasing the angle of the rudder to about 70°, thrust from the propeller can be directed outward at nearly 90° from the center line of the ship, allowing the operator to “push” the stern of the vessel away from or toward the dock. Flap-type rudders are considered “high performance,” and enable improved fuel economy and handling.

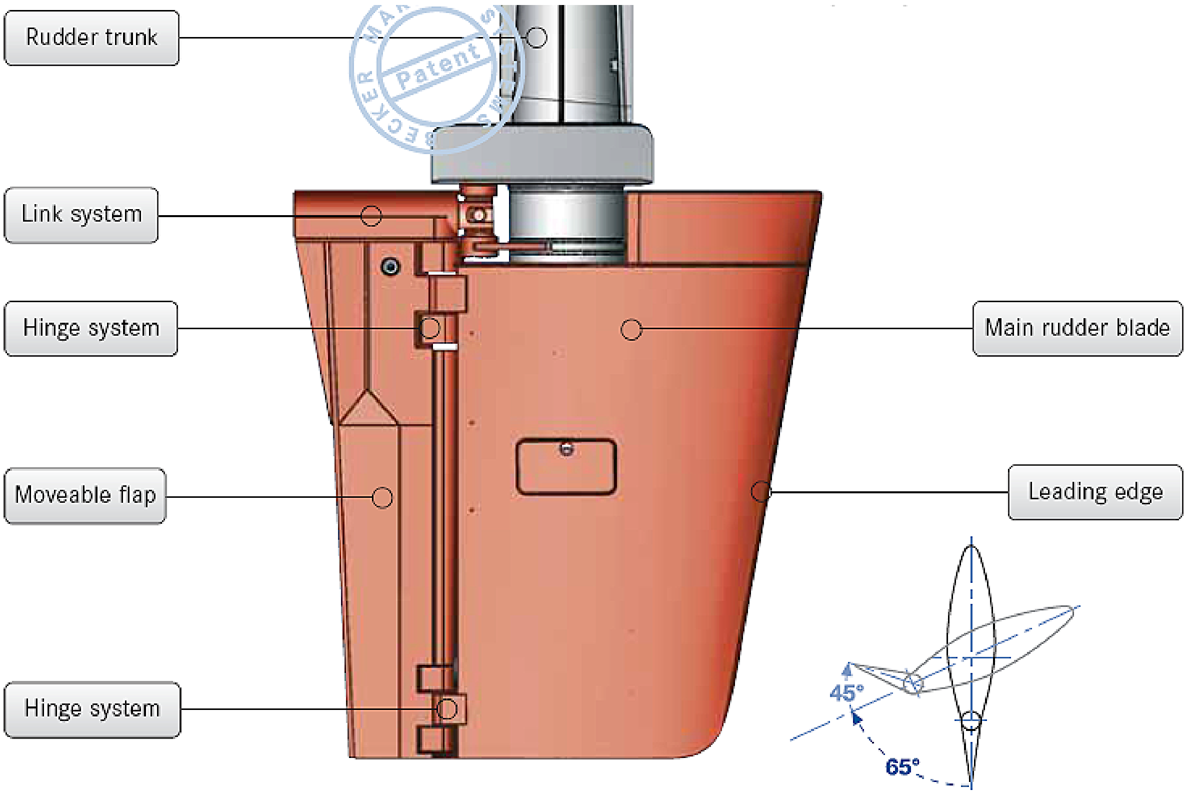

Figure 12. Becker rudder, a flap-type rudder sometimes used on single-screw, long-route ships. The rudder may be turned to very large angles (45° to 70°) and can be used as a stern thruster. Several different manufacturers make flap-type rudders. Graphic by Becker Marine Systems. (Further information about the Becker rudder can be found in Appendix B.)

Steering and Rudder Function on the *Orange Sun*

Investigators reviewed the data captured by the *Orange Sun*'s VDR, especially with regard to steering, rudder commands, and response. The results can be found in Appendix G.

Postaccident Steering Tests

While the *Orange Sun* was anchored at the accident site, Coast Guard Sector New York personnel boarded the ship and conducted a test of the steering system. The steering tested satisfactorily. While the vessel was at Bay Ridge anchorage, NTSB investigators along with Coast Guard investigators tested the steering system a second time and found that the steering operated satisfactorily. On January 28, 2008, when the *Orange Sun* left Bay Ridge anchorage for the transit to Florida, investigators rode along to the Sandy Hook pilot station, a distance of about 14 miles, to see how the vessel handled. The transit was uneventful, and the Sandy Hook pilot stated that the ship handled well. He and investigators departed the vessel at the pilot station, and the *Orange Sun* continued out to sea.

The Coast Guard in New York notified the Coast Guard in Tampa, Florida, about the *Orange Sun*'s impending arrival in Port Manatee, re-scheduled for February 2008. No assistance was needed, and the *Orange Sun* arrived and departed Port Manatee without incident.

Orange Sun's New-Build Sea Trial Tests

Investigators obtained from Atlanship the results of the *Orange Sun*'s sea trial maneuvering tests, required by international regulations, that were performed in December 2006 before the ship was delivered. The two tests were the "turning circle test," which establishes the width required to turn the vessel at various speeds, and the "zig-zag test," which tests the ability to stop a turn. The *Orange Sun* performed satisfactorily on both.

Crew and Pilot's Experiences With Steering the Ship

The second officer told investigators that, during the 10 minutes that he steered the *Orange Sun* on the day of the allision, the vessel handled properly. The second officer said that he had also steered the *Orange Sun* at sea without problem as part of onboard vessel training.

The master stated that when the *Orange Sun* was fully loaded and traveling at slow speeds of about 5 to 7 knots, the vessel had a tendency to sheer to one side or the other if speed was reduced too quickly. He said that he would prepare for this by closely monitoring the vessel's progress and be ready to increase the engine speed and to order counter rudder. The master stated that, at the time of the accident, the vessel was carrying just over half its load capacity and was ballasted down so that it handled as though it was fully loaded. The master stated that the vessel's rudder response was effective up to about a 35° input just like a standard rudder, but that a 65°, or "full Becker," rudder was not helpful in turning the vessel while under way, adding, "something happens [which] you will not like." When asked if this information should have been shared with the pilot, the master stated that he had informed the pilot that the ship had a Becker rudder and a controllable pitch propeller. He felt that this was all the information an experienced pilot should need, stating, "he's a longer pilot than I have age." The master continued by saying that it was not his intent to keep information from the pilot. He simply thought that telling an experienced pilot any more might be perceived as insulting.

The pilot told investigators that he had handled several vessels with flap-type rudders and controllable pitch propellers, and that they handled well. He stated that ships like the *Orange Sun* were sensitive enough that small course changes of about 2° or 3° of rudder were usually sufficient to give the vessel a gentle turn. He said, ". . . with a ship like this, because they're so sensitive . . . if I give him a ten-degree rudder, he's going to over-steer it. . . . you have to be careful with them a little bit when you slow them down and . . . I'm careful with them . . . that Becker rudder is – usually a ship will turn on a dime. It's amazing how much rudder effect you get with it." Later in the afternoon on the accident day, when the pilot was taking the *Orange Sun* to the Bay Ridge anchorage location, he experienced no problem whatsoever with the ship and told investigators that the vessel handled well even around the tight turn at Bergen Point.

Postaccident Action

Sandy Hook Pilots and Metro Pilots Associations

In the summer of 2009, the president of the Sandy Hook Pilots Association confirmed to investigators that no restrictions had been placed on the *Orange Sun* with respect to entering/calling on Port Newark, nor were there any plans to do so in the future. The president of the Sandy Hook Pilots Association further stated that, since the allision, the *Orange Sun* had made piloted transits in and out of Port Newark with no problems at all. The Metro Pilots Association also confirmed to investigators that that organization had not placed any restrictions on the *Orange Sun*'s transiting in and out of Port Newark.

Coast Guard

Like the Sandy Hook Pilots and Metro Pilots Associations, the Coast Guard also has placed no postaccident operating restrictions on the *Orange Sun*.

Pilot Commission Report

In November 2008, the New Jersey Maritime Pilot and Docking Commission issued its report on the *Orange Sun* allision. With regard to the pilot's reducing the vessel's speed to dead slow ahead immediately after ordering a course change, the commission stated, "the pilot should have taken into account that steering problems may occur if a ship equipped with a controllable pitch propeller is turned and slowed at or about the same time." The report recommended that "recurrent training for [New Jersey state-licensed] pilots include instruction concerning the handling characteristics of ships equipped with controllable pitch propellers." As of the date of this report, implementation has not yet been finalized.

Atlanship

After the allision and following discussions with pilots, company vessel masters, and technical personnel, Atlanship revised the pilot card for the *Orange Sun* as well as for the company's other vessels (Appendix F). According to the current master of the *Orange Sun*, the revised pilot card "fully expresses the characteristics of the vessel during maneuvering, the effects of the Becker rudder and its associated variable pitch propeller." In addition, new masters are briefed at embarkation on the vessel's handling characteristics, and in turn, masters brief the officers and helmsmen on the vessel's maneuvering equipment and its characteristics on signing on.

The current master of the *Orange Sun*, different from the accident master, stated in a November 2008 letter sent during his third stay on board the ship, that he had "not detected any abnormal tendency for the vessel to sheer off its steered course during maneuvering or during sea passage."

Previous Investigations on Bridge Resource Management

The definition of BRM is the effective use by a vessel's bridge team (officers, crew, and pilots) of all available resources—information, equipment, and personnel—to safely operate the vessel. The concept of BRM was developed to help mariners recognize and correct operational and human errors before they lead to an accident. One of the principles of BRM is that everyone on the bridge should understand his or her responsibilities and be able to freely and professionally communicate observations about the vessel's progress to others on the bridge.

Since 1974, the NTSB has investigated several accidents where breakdowns in BRM, specifically in bridge team communication, caused or contributed to the accident. In the last year, the NTSB concluded its investigation into the allisions of the *Cosco Busan*,[19] the *Axel Spirit*,[20] and the *Kition*.[21] In the *Cosco Busan* investigation, the Board determined that the master and the pilot did not adequately exchange navigational information with each other nor establish a proper working relationship before or during the transit out of Port of Oakland. The Board determined that the *Cosco Busan* pilot had relied on his pilot card to take care of most of the master/pilot exchange, instead of having a thorough discussion with the master. As a result of the findings in the *Cosco Busan* accident, the Board issued Safety Recommendation M-09-8 to the American Pilots' Association:

> Inform your members of the circumstances of this accident, remind them that a pilot card is only a supplement to a verbal master/pilot exchange, and encourage your pilots to include vessel masters and/or the officer in charge of the navigational watch in all discussions and decisions regarding vessel navigation in pilotage waters. (M-09-8)

The American Pilots' Association responded in June 2009, stating that it had publicized the results of the NTSB investigation in various member reports, encouraged each pilot to review the communication deficiencies between pilot and master described in the NTSB report, and urged its member groups to reexamine their master-pilot information exchange practices in light of the NTSB's analysis of the allision. Because of the American Pilots' Association's actions, Safety Recommendation M-09-8 is classified "Closed—Acceptable Action."

In April 2009, the NTSB completed its investigation into the allision of Bahamas-registered tankship *Axel Spirit* with Ambrose Light at the entrance to New York Harbor. The Board determined that the probable cause was "the master's failure to use all available resources to determine the vessel's position and course . . . and to adequately communicate his intentions

[19] *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: National Transportation Safety Board, 2009).

[20] *Allision of Bahamas-Registered Tankship M/T* Axel Spirit *with Ambrose Light, Entrance to New York Harbor, November 3, 2007*, Marine Accident Report NTSB/MAR-09/02 (Washington, DC: National Transportation Safety Board, 2009).

[21] *Allision of Bahamas-Registered Tankship M/V* Kition *with Interstate Highway 10 Bridge Pier, Baton Rouge, Louisiana, February 10, 2007*, Marine Accident Report NTSB/MAR-08/03 (Washington, DC: National Transportation Safety Board, 2008).

and expectations to the bridge team, which therefore prevented the bridge team from appropriately supporting the master."

In November 2008, the NTSB completed its investigation into the grounding of U.S. passenger vessel *Empress of the North* in southeast Alaska.[22] The Board determined that the master erred in assigning as night watch officer a newly licensed officer who was unfamiliar with the route and the vessel. The master himself left the bridge, and the new officer was only accompanied by a helmsman. The officer and the helmsman created a dysfunctional bridge team, with unspecified roles, responsibility, and authority. As a result of the findings, the Board issued Safety Recommendation M-08-6 to the state and federal maritime academies:

> Teach your students the circumstances of this accident, including their responsibility as newly licensed officers to prepare themselves for assigned duties and to express their concerns if placed in situations for which they are unprepared. (M-08-6)

Five of the seven maritime academies have responded and the overall recommendation is classified "Closed—Acceptable Action." It remains in an "Open—Await Response" status to the two academies who have not yet responded.

In May 2007, the NTSB completed its investigation into the grounding of Hong Kong-registered containership *New Delhi Express*[23] in the Kill Van Kull waterway in New York Harbor. The Board determined that the probable cause of the accident was "the error of the docking pilot in not using all available resources to determine the vessel's position as he navigated the Kill Van Kull waterway. Contributing to the cause of the grounding was the failure of both pilots to practice good bridge resource management." As a result of the findings, the Board issued Safety Recommendation M-07-3 to the state commissions whose harbor pilots work with docking pilots.

> Require your harbor and docking pilots to take part in recurrent joint training exercises that emphasize the concepts and procedures of bridge resource management. (M-07-3)

The recommendation is classified "Closed—Reconsidered" because the recommendation only applied to ports where harbor and docking pilots work together.

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[22] *Grounding of U.S. Passenger Vessel* Empress of the North*, Intersection of Lynn Canal and Icy Strait, Southeast Alaska, May 14, 2007*, Marine Accident Report NTSB/MAR-08/02 (Washington, DC: National Transportation Safety Board, 2009).

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

Analysis

Exclusions

The weather conditions, the vessel’s steering and propulsion system, the physical condition of the crew and the pilot, influence of alcohol or illegal drugs, and the operation of the dredge *New York* and her support vessels were neither causal nor contributory to the accident.

Breakdown in Bridge Resource Management

The NTSB’s investigation into the allision of the *Orange Sun* with the dredge *New York* indicates that effective BRM was not practiced in the events leading up to the accident. The investigation found deficiencies in four essential elements of bridge resource management, namely, the information exchange between master and pilot, clear communication among the bridge team, clear responsibilities of the bridge crew, and the bridge team’s effective use of resources. An analysis of the breakdown in these areas follows.

Master’s Errors

Incomplete Master/Pilot Exchange. During the pre-departure master/pilot exchange, when pertinent vessel and navigational information was to be discussed and agreed to, the master did not share with the pilot that, in his experience, the *Orange Sun* had an occasional tendency to sheer at slow speeds and had done so 5 days earlier during the inbound transit into Newark Bay.

The IMO Pilotage Resolution 960 (Resolution A.960 [23], December 5, 2003), Annex 2, section 5, “Master-Pilot Information Exchange,” states in part for master and pilot to discuss “any unusual ship-handling characteristics . . . that could affect the operation, handling or safe manoeuvring of the ship.” The master told investigators that he did not consider the vessel’s handling a safety issue, just a behavioral aspect of the ship. He told investigators that if the problem arose, one just needed to be focused and react in time. Given these observations, the master should have alerted the pilot to them and ensured that both the helmsman and the second officer were more vigilant about the ship’s handling. In addition, the master had recently received a DNV article from Atlanship, which discussed loss of steering and resultant grounding on a vessel with a controllable pitch propeller and a flap-type rudder. Only after, not before, the inbound incident and the outbound allision did the master mention anything about this article to the pilots or show it to them. The NTSB therefore concludes that the master of the *Orange Sun*, who was the most knowledgeable about the vessel, failed to thoroughly brief the pilot and the bridge crew about its occasional tendency to sheer.

Clear Communication and Effective Use of Resources. The master told investigators that he was well aware of the vessel’s occasional sheering tendency and would take certain precautions to prevent it. He said that he would position himself at or near the throttles so that if a sheer occurred he could immediately increase the propellers’ thrust (with either increased RPM or pitch, or both) and order counter rudder to get the heading back on course. The master told investigators that when the problem began on the day of the accident he was on the starboard side of the bridge, about 10 meters away from the helm and throttle controls. The master should have realized based on his experience with the vessel that a speed reduction to dead slow ahead might trigger the sheering. His knowledge was a resource that should have been put to precautionary use, and he should therefore have positioned himself at the throttle controls when the dead slow ahead order was given. But that day, the master did not do what he stated was his usual practice and was not near the helm when the problem began. Nor had he clearly communicated to his own bridge crew that, in his experience, the *Orange Sun* had an occasional tendency to sheer, and that, therefore, both the helmsman and the second officer needed to be more vigilant in their monitoring duties. Neither he nor the second officer, both in a supervisory capacity of the helmsman, were in a location to see the helmsman's wheel inputs. The NTSB therefore concludes that the master, who was aware of the vessel's occasional tendency to sheer, failed to prepare to respond with rudder and throttle commands.

Helmsman's Errors

Clear Communication. The steering sequence that led to the allision started with the helmsman's attempt to steady the *Orange Sun* on the ordered course of 205°. He needed to control the swing by applying some degree of port rudder, which he did in increments to almost 20° to port. However, without the starboard swing having been controlled, the helmsman then centered the wheel to zero. The correct response would have been to alert the other members of the bridge team (pilot, master, and second officer) that despite inputting nearly 20° to port the swing to starboard was not corrected. The helmsman could also have applied more than 20° port rudder in an attempt to stop the starboard swing. To bring the wheel to midship without saying a word to anyone was a critical error, both from a steering and BRM perspective. The helmsman's error and his failure to communicate about what was happening triggered a series of erratic wheel inputs by both him and the master, including at least three erroneously to starboard, which the pilot had not ordered and which were made unknown to him. The NTSB therefore concludes that the helmsman should have alerted his superiors when he felt that the counter rudder was ineffective in steadying the vessel on the 205° course, and he erred by bringing the wheel to midship, which allowed the vessel to continue its starboard swing.

Rudder Inputs. The pilot told investigators that he had been on numerous controllable pitch vessels before and that he was familiar with flap-type rudders. He stated, "because they're so sensitive . . . if I give him a ten-degree rudder, he's going to over-steer it." However, the pilot did give the helmsman a 10° rudder order to effect a 5° course change. Doing so may have been excessive on a vessel with a flap-type rudder. Nevertheless, the helmsman was responsible for steadying the vessel on the ordered 205° course by applying counter rudder as he deemed appropriate. His port wheel inputs were too small and not applied long enough to correct the starboard swing. Because the propeller pitch and RPM were reduced, the rudder was less effective—as is the case with most rudders at slow speeds, regardless of type. The rudder on the *Orange Sun* therefore needed more port rudder, applied longer, to arrest the vessel's turn to starboard. The VDR information shows that just before the helmsman brought the wheel to midship, the nearly 20° of port rudder he had applied moments before was starting to lessen, however slightly, the starboard sheer. This indicates that if more and longer port rudder had been applied the vessel's starboard swing could have been controlled. The NTSB therefore concludes that although the pilot's order of starboard 10 for a 5° course change may have been excessive on a ship with a flap-type rudder, his order should not have been difficult for the helmsman to control with appropriate counter rudder.

Second Officer's Errors

Clear Responsibilities. The underway duties of an officer of the watch when a pilot is on board are primarily to supervise the helmsman, carry out the pilot's engine orders, make appropriate log book entries (specifically the bell log book, which accounts for engine orders and navigation aids during the piloted transit) and, time-permitting, to plot the vessel's position at appropriate intervals and significant locations during the transit. The second officer, who served as officer of the watch on the day of the accident, told investigators that although the helmsman had steered the vessel many times during previous port transits, he himself had never monitored or supervised the helmsman's steering. When the helmsman relieved the second officer on the wheel about 1344 no audible exchange between the two was captured by the VDR. A proper relief of the wheel should have included the second officer informing the helmsman what the last course or rudder order was as given by the pilot. Then, once the helmsman had taken over, the second officer should have informed the pilot or the master that he had been relieved, officially alerting them that another person was now steering the ship. In any case, the VDR does not indicate that the pilot was verbally alerted to this fact. When investigators asked the second officer where he was positioned on the bridge in the minutes before the accident, he stated that he was plotting the vessel's position on the chart. Although this was one of his responsibilities as officer of the watch, his primary responsibility at that point was to ensure that the helmsman accurately executed the pilot's orders. The helm was only a few feet away from the chart table, and the rudder angle indicator (on the overhead forward of the main navigation console) was viewable from the chart table. However, the second officer should have ensured that the helmsman came right to 205° and that he applied appropriate counter rudder to steady the vessel's heading at 205° as the pilot ordered. As the vessel continued to swing past 205° it was the pilot who first noticed and verbally reminded that the order was for 205°. The second officer should have monitored the helmsman during the piloted transit and could have caught the mistake early on. Supervising the helm should have taken priority over plotting position fixes at that stage in the transit. The NTSB therefore concludes that the second officer did not monitor the helmsman appropriately and, as a result, did not identify and correct his erroneous wheel inputs.

Impact of Bridge Crew's Performance on the Pilot

Had the master or the second officer observed the helmsman's error of putting the rudder to midship as it happened, the accident could have been avoided through timely counter rudder and appropriate use of the engines. Because the pilot was positioned forward of the helm piloting by visual bearings through the bridge windows he could not actively monitor the helmsman's inputs. Nonetheless, the pilot was the first person who reacted to the vessel swinging past the ordered course. Initially, the bridge crew responded in a clear and concise manner to all of the pilot's helm and engine orders. However, when the helmsman could not achieve the heading correction he was attempting and urgency set in, the helmsman's limited understanding of English was overwhelmed, which compromised his effectiveness at the helm. Erratic wheel inputs by both the helmsman and the master ensued. The recorded data showed that the wheel had, in fact, been erroneously put to starboard at least three times, despite the master's and the helmsman's inability to recollect this. The *Orange Sun* crew response to the vessel's starboard sheer as it approached the dredge *New York* was ineffective and by the time the pilot realized what was happening and determined the need to apply a "kick" of engine power to increase flow over the rudder, the rudder was to starboard and the vessel was bearing down on the dredge. Applying increased thrust was no longer an option at that point. The NTSB concludes that, because of the bridge crew's incorrect response to the pilot's commands, the pilot was unable to take effective action to avoid the allision. The NTSB recommends that Atlanship provide its officers recurrent training in the principles of bridge resource management that encourage and emphasize correct and unambiguous communication, information management, role responsibility, and contingency planning.

Other Bridge Team Errors

The pilot radioed about five warnings to the *New York* but received no acknowledgement from the dredge. Neither he nor the master sounded the juice carrier's whistle, which they were not required to do, but which would have been good seamanship in this situation. Even though the pilot could visibly see that the dredge crew was aware of the impending allision and scrambled to get out of the way, a whistle signal such as a long continuous blast or five short blasts from the *Orange Sun* could have helped to alert some on the dredge more quickly, especially crewmembers who may have been out of earshot from the verbal warning passed from the tugboat crew. The NTSB therefore concludes that the pilot and the master of the *Orange Sun* should have sounded the vessel's whistle, which would have provided an additional warning to the dredge crew.

It might have been possible to more quickly arrest the forward momentum of the *Orange Sun* if the bridge team had dropped the anchor "under foot" by releasing less amount of anchor chain. The pilot could have ordered to stop the anchor "payout" (the amount of chain allowed out) at significantly less than what was let out. The NTSB therefore concludes that although letting go the port anchor to stop the vessel's forward movement was appropriate, not promptly setting the chain brake prevented the anchor from contributing to slowing the *Orange Sun*.

Conclusions

Findings

1. The weather conditions, the vessel's steering and propulsion system, the physical condition of the crew and the pilot, influence of alcohol or illegal drugs, and the operation of the dredge *New York* and her support vessels were neither causal nor contributory to the accident.

2. The master of the *Orange Sun*, who was the most knowledgeable about the vessel, failed to thoroughly brief the pilot and the bridge crew about its occasional tendency to sheer.

3. The master, who was aware of the vessel's occasional tendency to sheer, failed to prepare to respond with rudder and throttle commands.

4. The helmsman should have alerted his superiors when he felt that the counter rudder was ineffective in steadying the vessel on the 205° course, and he erred by bringing the wheel to midship, which allowed the vessel to continue its starboard swing.

5. Although the pilot's order of starboard 10 for a 5° course change may have been excessive on a ship with a flap-type rudder, his order should not have been difficult for the helmsman to control with appropriate counter rudder.

6. The second officer did not monitor the helmsman appropriately and, as a result, did not identify and correct his erroneous wheel inputs.

7. Because of the bridge crew's incorrect response to the pilot's commands, the pilot was unable to take effective action to avoid the allision.

8. The pilot and the master of the *Orange Sun* should have sounded the vessel's whistle, which would have provided an additional warning to the dredge crew.

9. Although letting go the port anchor to stop the vessel's forward movement was appropriate, not promptly setting the chain brake prevented the anchor from contributing to slowing the *Orange Sun*.

Probable Cause

The probable cause of the allision of the Orange Sun with the dredge New York was the master's failure to appropriately use bridge resource management and to communicate; specifically, to familiarize his bridge crew with and inform the pilot of the vessel's occasional tendency to sheer, a characteristic that he had personally experienced. Contributing to the accident were the inappropriate starboard rudder movements made by both the helmsman and the master, which interfered with the pilot's ability to take appropriate action to prevent the allision. Also contributing was the second officer's failure to accomplish his primary duty as officer of the watch, which was to properly monitor the helmsman.

Recommendation

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

To Atlanship:

> Provide your officers recurrent training in the principles of bridge resource management that encourage and emphasize correct and unambiguous communication, information management, role responsibility, and contingency planning. (M-09-18)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

DEBORAH A. P. HERSMAN
Chairman

ROBERT L. SUMWALT
Member

CHRISTOPHER A. HART
Vice Chairman

Adopted: December 2, 2009

Appendixes

Appendix A

Investigation

The NTSB learned of the allision through the news media on the afternoon of January 24, 2008, and was later notified by the Coast Guard. A team of three marine investigators, including an investigator-in-charge, a deck operations investigator, and an investigator specializing in human factors, launched to the scene. A marine engineer and two technical experts from the NTSB's research and engineering division later augmented the team. No Board member launched to the scene.

The NTSB investigated the accident under the authority of the Independent Safety Board Act of 1974, according to the Board's rules. The parties to the investigation were the U.S. Coast Guard, Atlanship, Great Lakes Dredge & Dock Company, Liberian International Ship and Corporate Registry, the New Jersey Maritime Pilot and Docking Commission, and the pilot.

Appendix B

Rudder Information Provided by the Manufacturer

becker marine systems
WAS FORMERLY WILLI BECKER INGENIEURBÜRO

Neuländer Kamp 3 - 21079 Hamburg
Telefon: + 49 (0) 40 – 2 41 99 – 0
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e-mail: info@becker-marine-systems.com
Internet: www.becker-marine-systems.com

FLAP RUDDER FULL SPADE RUDDER KORT NOZZLE STEERING GEAR MATERIAL HANDLING

General View about the Efficiency of the BECKER-High-Performance Rudder equipped to Single Screw Vessels and its Use

The main advantage of the **BECKER-rudder** is that already at smallest rudder angles a high side force is generated. The flap at the trailing edge of the rudder which executes nearly twice the angle of the main rudder blade gives an optimum profile camber which produces a maximum of side force at a minimum resistance. This characteristic is very important on straightaway course where for course-keeping or little course corrections only very small rudder angles are required which means that due to the only small resistance at small rudder angles there is hardly no loss in speed resp. a remarkable fuel saving.

The max. side force is reached at abt. 30 to 35°, whereas the flap stands at abt. 60 to 70° to ship's centre line. These rudder angles are required for big and quick course corrections where no speed loss is desired.

At rudder angles of 45° or bigger (flap over 90°) the **BECKER-rudder** can be used as stern thruster. At these angles the side force is a little less than the max. side force, but there is a minimum of residual longitudinal thrust. This effect is of a big advantage when berthing or unberthing or if manoeuvres at slow speed and smallest space are to be executed

Summarizing all the above said, the following can be established:

1.- Adjustment of the autopilot to the effect of the **BECKER-high-performance rudder**. In order to make use of all advantages, only one third of the rudder angle of conventional rudders are needed
This information has also to be given to the helmsman.

2.- When accelerating or running the ship at full speed, the helm should not be put to more than 35°, in order to attain the max. side force.

3.- Harbour manoeuvres or berthing and unberthing manoeuvres should be carried out at 45° rudder angle or more to use the **BECKER-rudder** as stern thruster.

4.- When running astern, the helm should not be put to more than 10° (flap 20°) in order not to destroy too much the water flow to the propeller. If bigger rudder angles are used, it will not be dangerous for our system, but would only have a negative effect at the astern running propeller and the desired movement of the ship is less at considerably higher vibrations.

becker marine systems

WAS FORMERLY WILLI BECKER INGENIEURBÜRO

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Internet: www.becker-marine-systems.com

FLAP RUDDER   FULL SPADE RUDDER   KORT NOZZLE   STEERING GEAR   MATERIAL HANDLING

5.- When using the rudder with propeller pitch 0, the effect of the **BECKER-rudder** and of each

other rudder as well is reduced. The propeller blades standing like a wall ahead of the rudder destroy the water flow in such a way that no effective stream to the rudder is reached.

6.- For sailing conditions with minimum manoeuvring speed, e. g. when approaching a lock or a pier,it is very important to use a minimum ahead propeller pitch to guarantee the water flow

to the rudder blade. In this condition it is also recommended to use helm angles less than 35° to get an effective water flow on the suction side of the rudder. When using rudder angles of more than 35°, you will only get turbulent waterstream without getting any side force to the ship.

7.- For reducing ship speed, it makes sense to keep the rudder in C. L. when the propeller is working astern, and than, for course correction, the rudder should be used as described under item 6.

We hope that this main guidance will be helpful to you. In case of further information please do not hesitate to contact us directly here in Hamburg again.

BECKER Marine System

Appendix C

DNV Article About Steering Issues Involving Flap-Type Rudders

C/E [redacted]
2/E [redacted]
3/E [redacted]

3/O [redacted]
2/O [redacted]
C/O [redacted]

Casualty Information

Information from DNV to the maritime industry No. 4 October 2007

Grounding due to temporary loss of steering

Ship type: Tanker Size (grt): 60,000–70,000 Year built: Any

Fig. 1: Flap rudder and CP propeller.

Course of events

Experience feedback in the past years has highlighted that a number of vessels have reported temporary loss of steering when reducing ship's speed, which has resulting in unintended changes in the ship's direction.

A fully loaded vessel approaching port under pilotage, lost steering and grounded.

Extent of damage

The vessel suffered bottom damage.

[redacted]

Probable cause

The vessel was equipped with a controllable pitch (CP) propeller and a flap rudder, see Fig. 1.

No technical malfunctions to the steering gear or rudder systems were detected during the investigation.

However, it was concluded that under certain circumstances the rudder effect may be temporarily lost, as the water flow around the rudder might change rapidly, with a resulting negative effect to the steering capability.

If the vessel is "straight line unstable" *(meaning that it will always*

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MANAGING RISK DNV

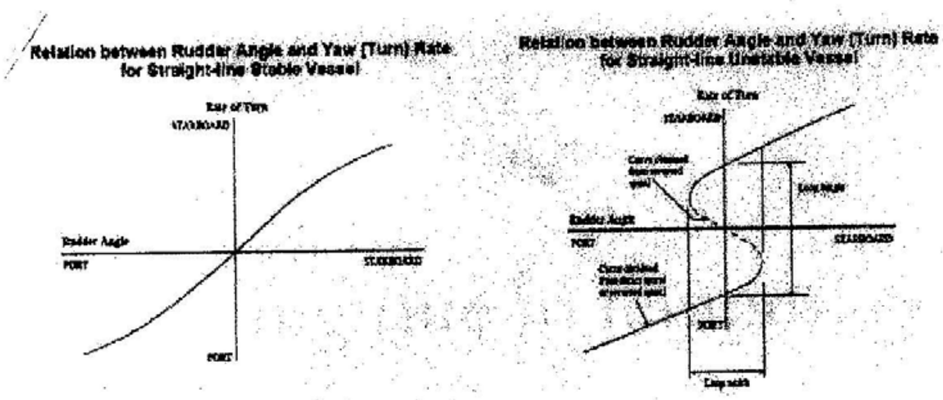

Fig. 2: Relationship between rudder angle and yaw (turn) rate for Straight-line stable/unstable vessel.

tend to turn either P or S when no rudder is applied), see Fig. 2, no rudder angle is needed to initiate a turn, while a large rudder angle is needed to check a turn *(ref. the right figure below showing the relationship between rudder angle and yaw rate (ROT) for an unstable vessel).* As larger rudder angles are needed to check a turn there is less "reserve rudder" available if the rudder force should be reduced.

It has been proven in practice, that close to zero pitch the propeller blades will form a disc which shields the rudder off from free water flow.

If the ship's speed is reduced by altering the propeller pitch the effect of the rudder (rudder force) will be reduced or possibly even temporarily lost. The unstable ship will instantly build up a yaw rate, which is not possible to check with the obtainable rudder force.

The above effect is considered to be more or less independent of the type of rudder.

Lessons to be learned

1. If available the pilot cards and ship's manoeuvring booklets should be amended to make captains, watch officers and pilots aware of a possible shielding effect of the CP-propeller to rudder.

2. To retain best possibilities for steering in restricted areas constant RPM control mode of the main engine should be avoided.

3. Any automatic ship speed control applying propeller pitch setting should be avoided in all narrow waters. In particular use of reference to ground speed increases risk for a temporary sudden loss of steering capability in case ships speed increases suddenly due to current, or errors in reference speed occurs.

4. A speed reduction well in advance of the turn will provide the possibility for a "kick ahead with propeller" to obtain proper effect of the rudder for steering.

Additional information: Casualty Information No. 5/95 "Ship manoeuvrability: Guidelines for rudder area"

We welcome your thoughts!

Casualty Information is published by DNV Maritime, Maritime Technology and Production Centre (Dept. for Ships in Operation).

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The purpose of *Casualty Information* is to provide the maritime industry with 'lessons to be learned' from incidents of ship damage and more serious accidents. In this way, Det Norske Veritas AS hopes to contribute to the prevention of similar occurrences in the future. The information included is not necessarily restricted to cover ships classed with DNV and is presented, without obligation, for information purposes only.

Queries may be directed to Det Norske Veritas AS, Maritime Technology and Production Centre (Dept. for Development, Learning&Support), NO-1322 Høvik, Norway. Fax: +47 67 57 99 11. E-mail: mtpno351@dnv.com

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MANAGING RISK DNV

Appendix D

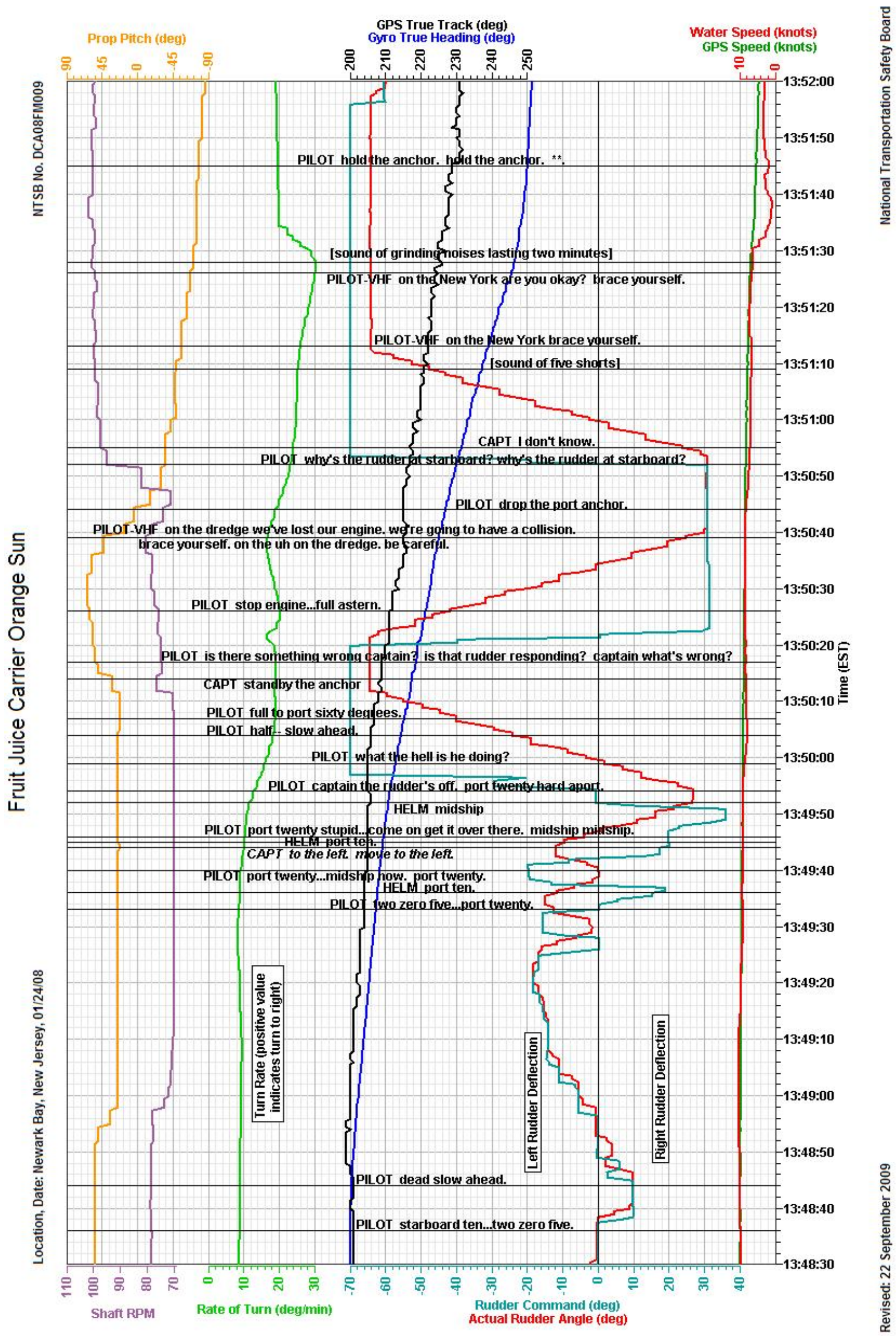
Timeline of Key Events, January 24, 2008

(Times are approximate)

Time	Action
1325	*Orange Sun* leaves the dock at Port Newark
1344	Helmsman enters the bridge and takes over steering
1345	*Orange Sun* enter the main shipping lane in Newark Bay
1348:36 – 1348:44	Pilot gives course to steer and orders dead slow ahead
1349:25	Helmsman puts the wheel to midship despite no such order by the pilot
1349:45	Helmsman's first erroneous starboard wheel input (20° starboard)
1350:04	Pilot orders speed increased to slow ahead to improve rudder control
1350:26	Pilot orders the engine stopped
1350:39	Pilot radioes the first warning to the dredge
1350:44	Pilot orders the anchor dropped
1352	Allision occurs
1352:30	Pilot notifies VTS of the allision
1400	VTS closes Newark Bay to commercial traffic
1400 – 1600	*Orange Sun* chief mate alcohol-tests entire crew; negative
1500	Pilot is alcohol-tested; negative
1848	VTS reopens Newark Bay to commercial traffic
Evening	Pilot and key crewmembers drug-tested; negative

Appendix E

Readout of VDR Data from the Moments Before the Allision



The text in this graph reflects key events and select, relevant comments uttered by the bridge team leading up to the allision.

Appendix F

Revised Pilot Card for the *Orange Sun*

FCB 03/2008

PILOT CARD

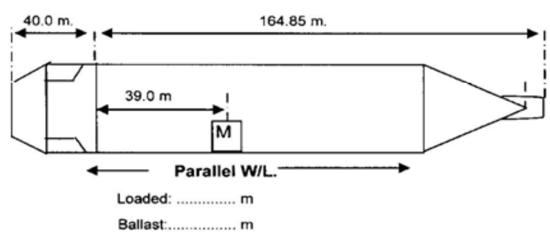
Ships name: **ORANGE SUN**
Call sign: **A8HY8**
Year built: **2007**
IMO No.: **9342580**
Draft fwd .... M aft .... m
(..........ft ....in) (..........ft ....in)

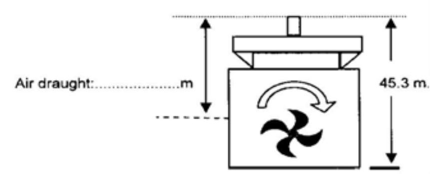
DATE: ....
Port: ....
Deadweight: .... Ts
Displacement: .... Ts

SHIP'S PARTICULARS

Gross Tonnage: 33070
L.o.a. : 204.85 m.
Breadth: 32.20 m.

Anchor chain stb.: 12 shackles
Anchor chain port: 12 shackles
1 shackle = 27.5 m / 15 fathoms





Propeller: Permanently right turning
Acting like "Left Handed"
Bow swings to PORT if pitch is set astern

Type of engine: KAWASAKI-MAN/B&W (2 strokes diesel engine)

Maximum power: 21477 BHP
15 909 kW

Speed: Combinator Mode		**CPP**: Pitch Setting	RPM
Full ahead:	17.5 kts	8	98
Half ahead:	12.7 kts	6	85
Slow ahead:	9.0 kts	4	76
D.slow ahead:	5.2 kts	2	68
Min. Speed	2.0 kts	1	66

NB: Minimum steering speed (steering very sluggish)

Steering particulars:

Type of rudder: **Becker Flap Rudder**
Hardover to Hardover time: 28 sec.
Bow/Stern Thruster's: None

Maximum rudder angle: 65°
Limited at: 35° (During sea passage only)

NB: High performance Becker rudder need about one half of conventional rudder angle to obtain the same effect.
1. It is important to reduce speed gradually, and well in advance to prevent water flow disturbance on the rudder, rapid reduction of speed or zero setting of propeller pitch may result in poor or even temporary loss of steering ability.
2. As far as possible an alteration of course and reduction of speed simultaneously shall be avoided.

Navigational Aids

Check if equipmet is operational and ready:

X-Band Radars	**yes** / no	Anchors	**yes** / no	Steering Gear	**yes** / no
S-Band Radar	**yes** / no	Whistle	**yes** / no	No.of Power Units operating:	One / Two
ARPA	**yes** / no	Echo Sounder	**yes** / no	Rudder Indicators	**yes** / no
Speed Log:	**yes** / no	Position Fixing (type: GPS)	**yes** / no	RPM Indicator	**yes** / no
E Mag Log fitted:	**yes** / no	Magnetic Compass	**yes** / no	Rate of Turn Indicator	**yes** / no
Log Indication:	**water** / ground	Gyro Compass (Fiber Optic)	**yes** / no	VHF Systems	**yes** / no
		Gyro Error: ....degrees		Engine Telegraph	**yes** / no

Equipment Operational Defects and other important Information:

Location of Lifesaving equipment for Pilot: Wheelhouse Portside

Pilot: ....

The revised pilot card has an expanded "Steering Particulars" section, which explains in greater detail the Becker rudder's characteristics.

Previous Pilot Card for the *Orange Sun*

PILOT CARD

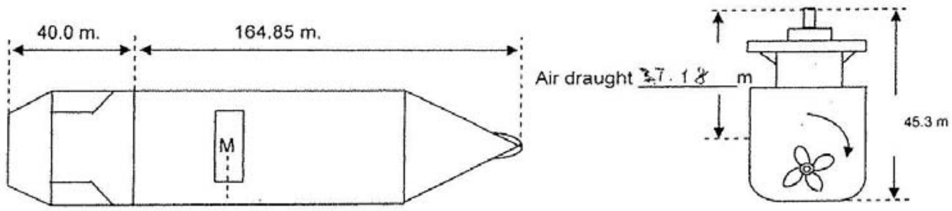
Ships name: **ORANGE SUN**
Call sign: **A8HY8**
Year built: **2007**
IMO No.: **9342580**
Draft FWD: 5.40 m AFT: 8.90 m
(____ ft ____ in) (____ ft ____ in)

Date: 24.01.2008
Deadweight: 27745
Displacement: 47326

SHIP PARTICULARS

Gross Tonage: 33070
L.O.A. :204.85 m
Breadth: 32.20 m

Anchor chain port: 12 shackles
Anchor chain stb:: 12 shackles
1 shackle = 27.5 m / 15 fathoms



Single Propeller 4 blades
Variable pitch
Right handed turning

ENGINE

Type of engine: KAWASAKI-MAN/B&W (2 strokes Diesel engine)

Maximum power: 21 477BHP
15 909 KW

Speed:	104 RPM
Full ahead	17.5 kts
Half ahead	12.7 kts
Slow ahead	9.0 kts
D. slow ahead	5.85 kts

Steering particulars:

Type of rudder: Becker Flap Rudder
Hardover/Hardover time:
Bow / Stern Thruster: NONE / NONE

Maximum angle: 65°
Limited at: 35°

Navigation Aids

Check if equipment is operational and ready

X-Band Radar	yes / no	Anchors	yes / no	Steering gear	yes / no
S-Band Radar	yes / no	Whistle	yes / no	No of Power Units operating:	2
ARPA	yes / no	Echo Sounder	yes / no	Rudder Indicator	yes / no
Speed Log	yes / no	Position fixing (GPS)	yes / no	RPM indicator	yes / no
Dopler Log fitted	yes / no	Compass	yes / no	Pitch indicator	yes / no
Log indication	water / ground	Gyro Error:	0° degrees	Rate of Turn Indicator	yes / no
VHF Systems	yes / no			Engine Telegraph	yes / no

Equipment Operational Defects and other important information:

Location of Lifesaving equipment for Pilot: **Bridge Port side.**

Pilot: [redacted]

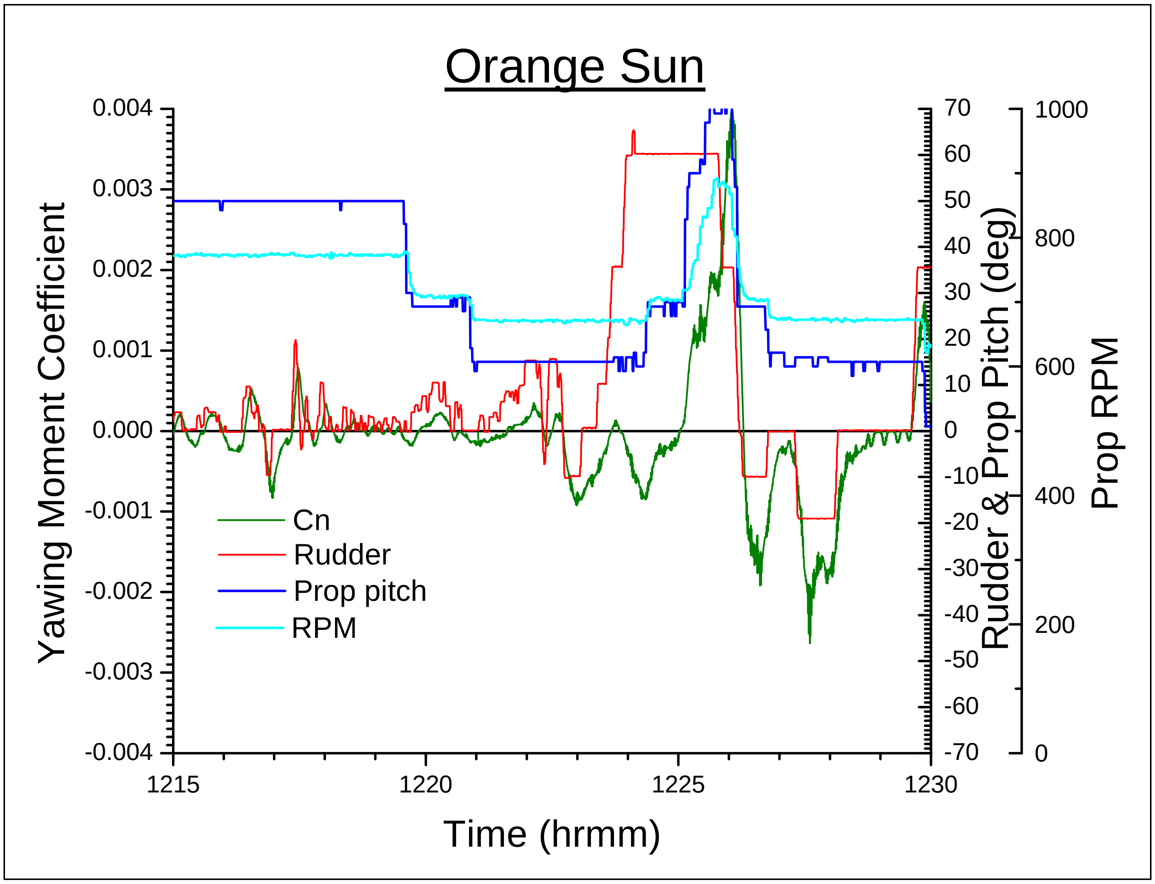
The pilot card from the day of the accident, showing the previous "Steering Particulars" section.

Appendix G

Steering and Rudder Function on the *Orange Sun*

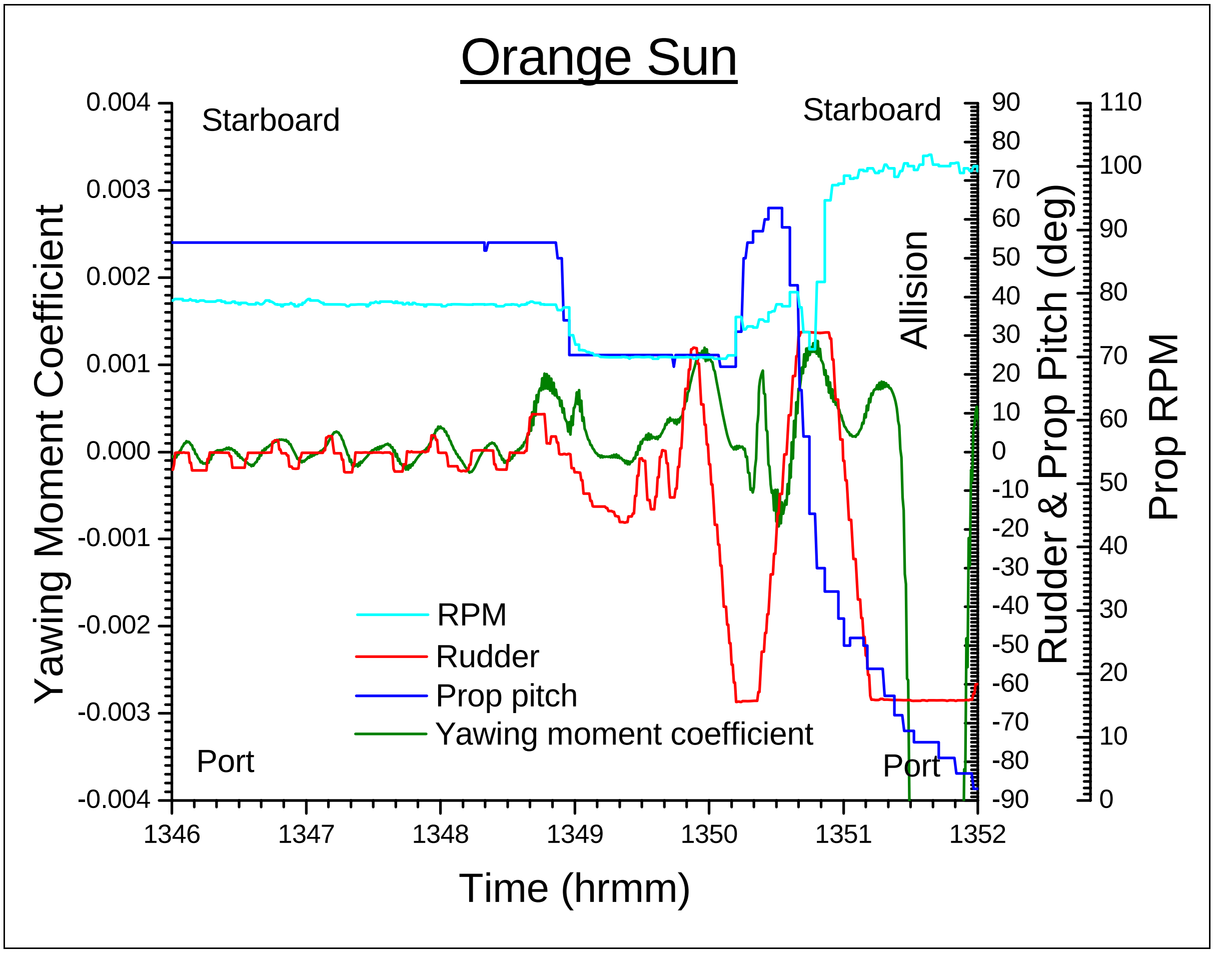
As a general rule, when a rudder's deflection is increased, the produced force increases until the smooth flow around the rudder is disrupted. After this point, continued increase in rudder deflection only decreases the rudder's force and effectiveness, resulting in "rudder stall." Rudder stall occurred both during the *Orange Sun*'s inbound incident and in the outbound accident. Rudder force is also dependent on the speed of flow around the rudder. Because the rudder is mounted directly behind the propeller, rudder force is greatly impacted by propeller pitch and RPM. This large effect by propeller pitch and RPM was seen in both the *Orange Sun*'s inbound incident and outbound accident.

According to the *Orange Sun*'s VDR data, the reduced steering effectiveness during the inbound transit on January 19 occurred between about 1215 and 1230. Investigators analyzed the data for that timeframe, extracted the vessel's yawing moment coefficient, and plotted it the first graph. Yawing moment coefficient is a term for the representation of "force" that turns the ship, and is a function of rudder deflection, propeller pitch, and RPM. As can be seen in the graph, the vessel's turning yawing moment coefficient follows, or matches, the rudder until about 1219, when the pilot reduced the propeller pitch and RPM. From that point, as indicated in the graph, the vessel's turning yawing moment coefficient trends loosely with the rudder until about 1223, when the pilot ordered 60° of rudder. The turning yawing moment does not respond to the 60° rudder deflection until about 1225, when the propeller pitch and RPM were increased. In other words, the reduction in propeller pitch and RPM significantly reduced the effectiveness of the rudder in turning the ship. In addition, the rudder was deflected well past its stall point. Note that the yawing moment doubles about 1226, when the pilot reduced the rudder deflection from 60° to 35°. Reducing the rudder deflection to below the stall point doubled the rudder's effectiveness.



Yawing moment coefficient, rudder, and power applied during the *Orange Sun*'s inbound transit on January 19, 2008, from 1215 to 1230.

The vessel's yawing moment coefficient and rudder response, together with propeller pitch and RPM during the accident on January 24, 2008, are plotted in the next graph. The yawing moment coefficient follows, or matches, the rudder until 1345:30, when the power was reduced. At 1348:55, propeller pitch and RPM were reduced and the subsequent port rudder command was followed only by a reduction of starboard yawing moment coefficient to about zero. Yawing moment coefficient does, however, appear to follow the starboard rudder input at 1349:50. Response to the 60° port rudder about 1350 was limited although propeller pitch and RPM increased during this time period. Yawing moment coefficient initially follows the starboard 30° rudder at 1350:40, but starboard yawing moment coefficient is then reduced as the propeller pitch was reversed at 1351:30, just before the allision.



Yawing moment coefficient for the accident.