ACCIDENT REPORT

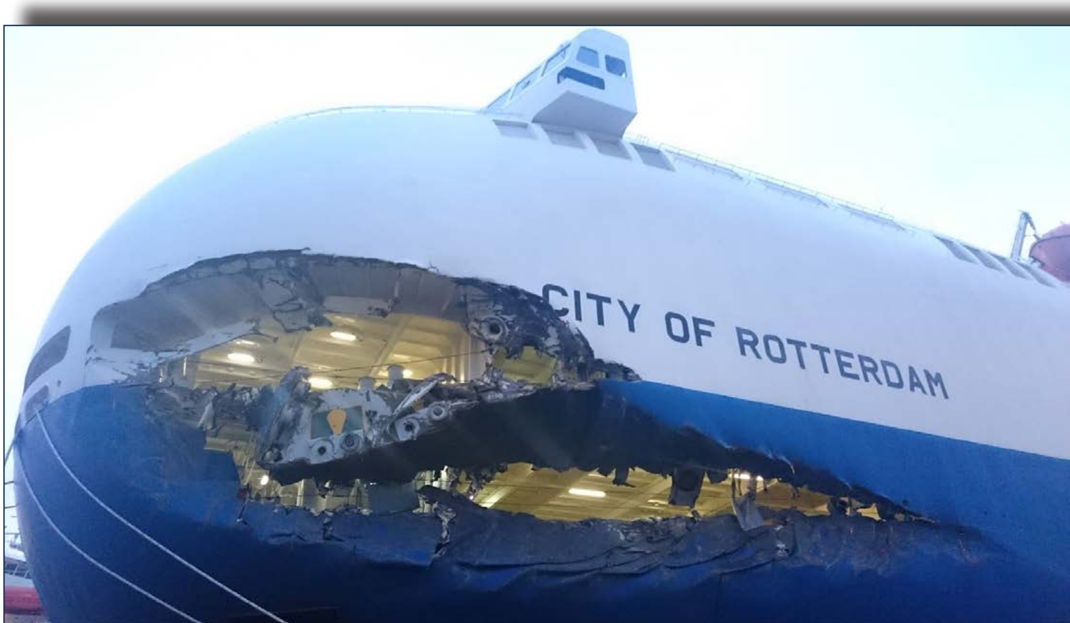
MAIB

MARINE ACCIDENT INVESTIGATION BRANCH

Report on the investigation of the collision between the pure car carrier *City of Rotterdam* and the ro-ro freight ferry *Primula Seaways*

River Humber, United Kingdom

3 December 2015



VERY SERIOUS MARINE CASUALTY   REPORT NO 3/2017   FEBRUARY 2017

Extract from

The United Kingdom Merchant Shipping

(Accident Reporting and Investigation)

Regulations 2012 – Regulation 5:

"The sole objective of the investigation of an accident under the Merchant Shipping (Accident Reporting and Investigation) Regulations 2012 shall be the prevention of future accidents through the ascertainment of its causes and circumstances. It shall not be the purpose of an investigation to determine liability nor, except so far as is necessary to achieve its objective, to apportion blame."

NOTE

This report is not written with litigation in mind and, pursuant to Regulation 14(14) of the Merchant Shipping (Accident Reporting and Investigation) Regulations 2012, shall be inadmissible in any judicial proceedings whose purpose, or one of whose purposes is to attribute or apportion liability or blame.

Front cover photograph of *Primula Seaways* courtesy of Peter Ward

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GLOSSARY OF ABBREVIATIONS AND ACRONYMS

AB	-	Able Seaman
ABP	-	Associated British Ports
AIS	-	Automatic Identification System
BDEAP	-	Bridge Design, Equipment Arrangement and Procedures
BRM	-	Bridge Resource Management
BV	-	Bureau Veritas
COLREGS	-	International Regulations for Preventing Collisions at Sea 1972 (as amended)
DFDS	-	DFDS Seaways AB
ECDIS	-	Electronic Chart Display and Information System
ECS	-	Electronic Chart System
EML	-	Euro Marine Logistics
HES	-	Humber Estuary Services
IACS	-	International Association of Classification Societies
IALA	-	International Association of Marine Aids to Navigation and Lighthouse Authorities
IMO	-	International Maritime Organization
ISM Code	-	International Safety Management Code
kW	-	kilowatt
LEDs	-	light emitting diodes
LR	-	Lloyd's Register
m	-	metre
MCA	-	Maritime and Coastguard Agency
MGN	-	Marine Guidance Note
MSC	-	Maritime Safety Committee
nm	-	nautical mile
NMCC	-	Nissan Motor Car Carrier Company Limited

PEC	-	Pilotage Exemption Certificate
PMSC	-	Port Marine Safety Code
RO	-	Recognised Organization
SMS	-	Safety Management System
SOLAS	-	International Convention for the Safety of Life at Sea 1974, as amended
STCW	-	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers 1978, as amended
TOS	-	Traffic Organisation Service
UI	-	Unified Interpretation
UK	-	United Kingdom
UTC	-	Universal Co-ordinated Time
VDR	-	Voyage Data Recorder
VHF	-	Very High Frequency
VTS	-	Vessel Traffic Services

TIMES: all times used in this report are UTC unless stated otherwise.

Image courtesy of Tomas Østberg-Jacobsen

City of Rotterdam

Image courtesy of Bo Randstedt, wikimedia

Primula Seaways

SYNOPSIS

On 3 December 2015, the Panama registered pure car carrier *City of Rotterdam* collided with the Danish registered ro-ro ferry *Primula Seaways* on the River Humber, UK. Both vessels were damaged but made their way to Immingham without assistance. There was no pollution and there were no serious injuries.

The MAIB investigation identified that the outbound *City of Rotterdam* had been set to the northern side of the navigable channel and into the path of the inbound ferry, but this had not been corrected because the pilot on board had become disoriented after looking through an off-axis window on the semi-circular shaped bridge. The car carrier was of an unconventional design and his disorientation was due to 'relative motion illusion', which caused the pilot to think that the vessel was travelling in the direction in which he was looking. Consequently, the pilot's actions, which were designed to manoeuvre the car carrier towards the south side of the channel, were ineffective.

That the pilot's error was allowed to escalate the developing close quarters situation to the point of collision was due to: intervention by *City of Rotterdam*'s master was too late, and the challenges to the pilot's actions by *Primula Seaways*' bridge team and the Humber Vessel Traffic Service being insufficiently robust. Although *Primula Seaways* started to reduce speed about 2 minutes before the collision, a more substantial reduction in speed was warranted.

Following the accident, and an early MAIB recommendation, action has been taken by Fairmont Shipping (Canada) Limited, *City of Rotterdam*'s managers, to reduce the likelihood of relative motion illusion and to improve the bridge resource management of its deck officers. Action has also been taken by Associated British Ports, the harbour authority for the River Humber, to confirm the competency of the pilot and the suitability of *Primula Seaways*' master to hold a pilotage exemption certificate.

Bureau Veritas, *City of Rotterdam*'s classification society, has been recommended to propose measures to the International Association of Classification Societies that are aimed at raising the awareness of relative motion illusion and promoting the need for naval architects and shipbuilders to adhere to internationally accepted ergonomic principles for bridge design.

SECTION 1 - FACTUAL INFORMATION

1.1 PARTICULARS OF *CITY OF ROTTERDAM*, *PRIMULA SEAWAYS* AND ACCIDENT

SHIP PARTICULARS		
Vessel's name	*City of Rotterdam*	*Primula Seaways*
Flag	Panama	Denmark (Int.Register)
Classification society	Bureau Veritas	Lloyd's Register
IMO number/fishing numbers	9473468	9259513
Type	Pure car carrier	Ro-ro freight ferry
Registered owner	Picer Marine S.A.	DFDS Seaways AB
Manager(s)	Fairmont Shipping (Canada) Ltd.	DFDS
Construction	Steel	Steel
Year of build	2011	2004
Length overall	139.99m	200.00m
Gross tonnage	21143	32289
Minimum safe manning	14	11
Authorised cargo	Vehicles	Ro-ro freight
Draught (Max)	6.3m	7.2m
VOYAGE PARTICULARS		
Port of departure	Immingham, UK	Gothenburg, Sweden
Port of arrival	Newcastle, UK	Immingham, UK
Type of voyage	Coastal	International
Cargo information	In ballast	Ro-ro freight
Manning	18	19
MARINE CASUALTY INFORMATION		
Date and time	3 December 2015 at 2040 UTC	
Type of marine casualty or incident	Serious Marine Casualty	
Location of incident	River Humber, UK 53°35.1N, 000°02.6E	
Place on board	Bow/forecastle	Bow/forecastle
Injuries/fatalities	None	None
Damage/environmental impact	Damage to bow, forecastle, port shoulder, port bilge keel and ballast tank.	Damage to bow and forecastle.
Ship operation	On passage	On passage
Voyage segment	Transit	Transit
External & internal environment	Wind: south-south-west gusting to 40kts. It was dark with clear skies. The visibility was good and the tidal stream was flooding at about 1.5kts	
Persons on board	18 crew	19 crew 6 passengers

Courtesy of ABP

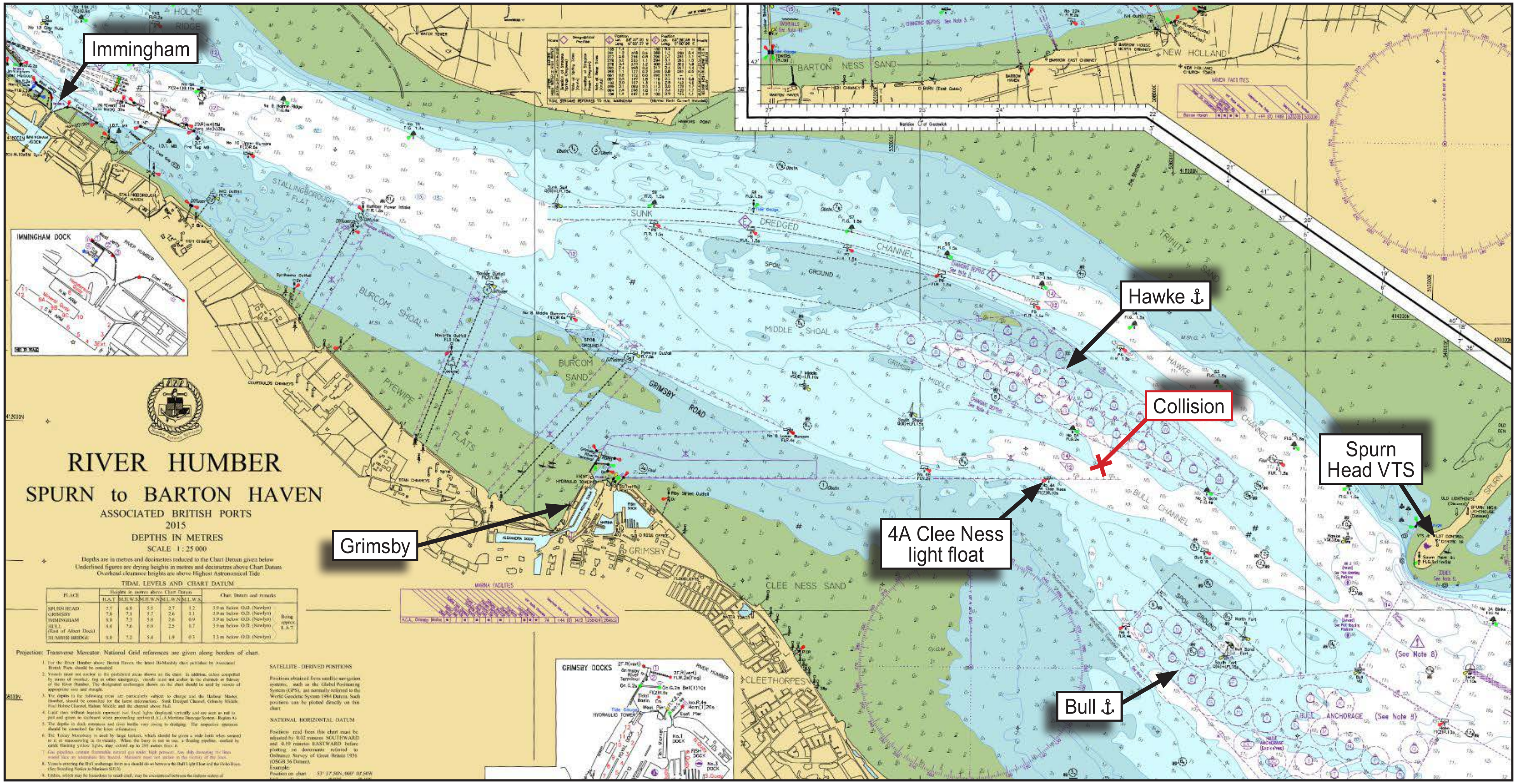

Figure 1: Extract of ABP chart of Humber

1.2 NARRATIVE

1.2.1 Events leading up to the collision

On 3 December 2015, the Panama registered pure car carrier *City of Rotterdam* was preparing to depart Immingham Dock, UK **(Figure 1)**. On the bridge were the master, the third officer, an able seaman (AB) helmsman and a pilot. The master and the pilot discussed the departure with reference to the vessel's pilot information card and the pilot's passage plan.

During the exchange, the master advised the pilot to stand at either the forward centreline conning station or behind the navigation workstation **(Figure 2)**. He also pointed out to the pilot a length of cord on the centre window that indicated the vessel's centreline. The master and the pilot also discussed the potential effects of the wind. The vessel was high-sided and in ballast, and the wind was gusting up to 40 knots from the south-south-west. The pilot anticipated that the vessel would experience a high drift rate throughout its passage, but more so once passed Grimsby where it was more exposed and the effect of the tidal stream would be more pronounced.

At 1858, *City of Rotterdam* sailed from its berth and the pilot conned the vessel in to Immingham lock. By 1959, the vessel had cleared the lock, released the attending tugs and was passing 9A buoy in the main navigation channel in the River Humber **(Figure 3)**. The vessel was on a south-easterly heading in manual steering at a

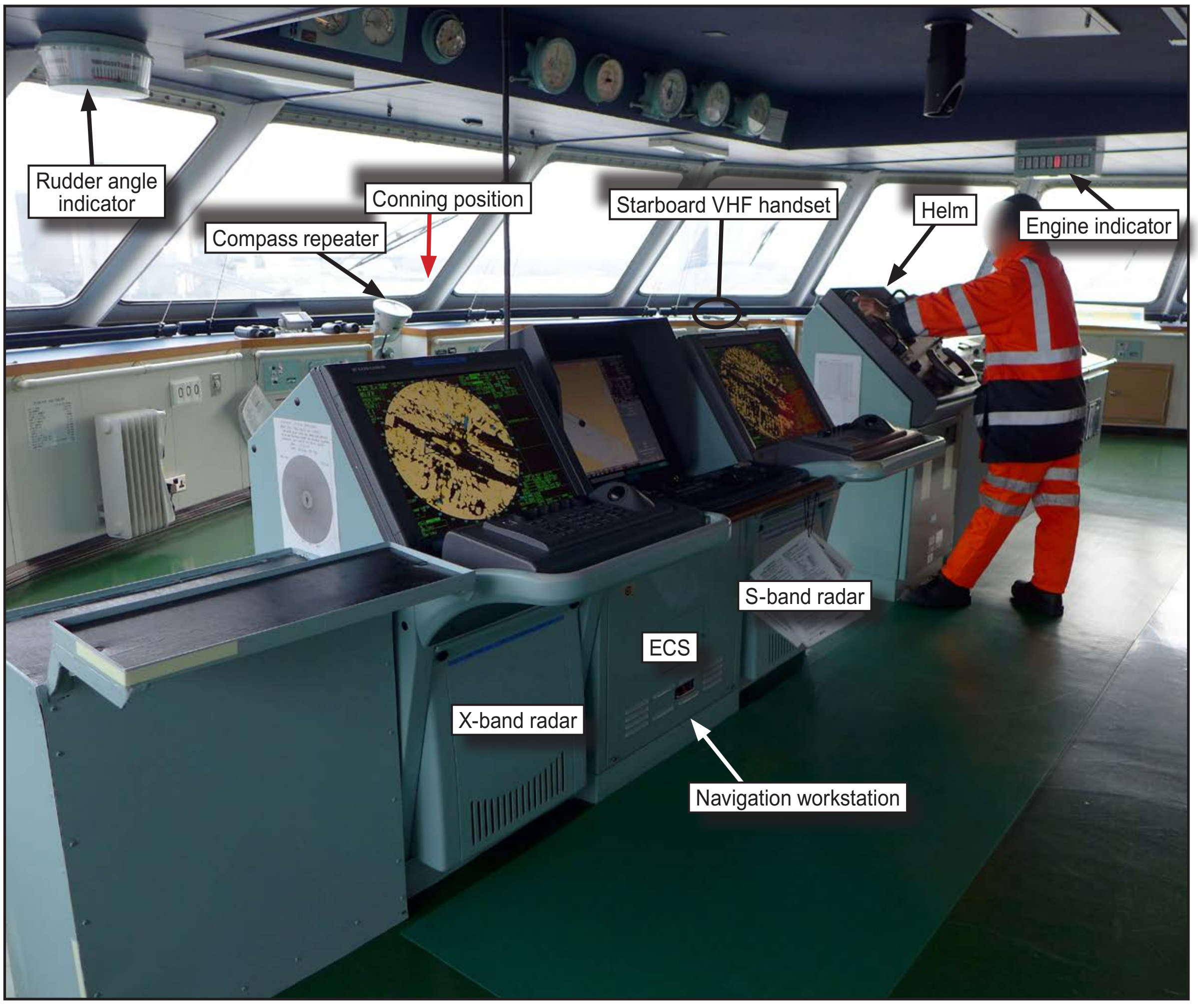

Figure 2: *City of Rotterdam* - bridge (from port side)

speed of 12kts[1]. The tidal stream was flooding at a rate of about 1.5kts. On passing 9A buoy, the pilot reported the vessel's position to Humber Vessel Traffic Service (VTS) via very high frequency (VHF) radio channel 12[2]. As *City of Rotterdam* continued on passage down the main navigation channel, the pilot primarily monitored the vessel's position by eye but he also used the electronic chart system (ECS) and the port radar display **(Figure 2)** (the starboard radar display was on standby).

At 2027, *City of Rotterdam* passed the Grimsby Middle buoy on a heading of 125° **(Figure 4)**. At that time, the Denmark registered ro-ro freight ferry *Primula Seaways* was in the outer approaches of the River Humber, inbound for Immingham. The ferry was on a trackpilot controlled heading of 291° at 20kts and was overtaking the Malta registered bulk carrier *Seferis*. On the ferry's bridge were the master, second officer and an AB. The second officer was seated in the chair to starboard of the central conning station **(Figure 5)**. He was monitoring the ferry's position on the Electronic Chart Display and Information System (ECDIS) and by radar. The master had the control of navigation and was seated in the chair on the central console's port side.

Between 2027 and 2032, *City of Rotterdam*'s pilot altered the vessel's heading from 125° to 095° in 5° increments **(Figure 6)**. The vessel was to the north of the intended track and the pilot informed the master that he would try and manoeuvre the ship further to the south. By that time, *Primula Seaways* was in clear sight and the pilot informed the master that the vessels would pass port to port.

Meanwhile, the VTS operator monitoring VHF channel 12 had reported *City of Rotterdam*'s northerly position to the watch manager. However, the watch manager was not concerned as the pilot had sufficient time to take corrective action.

At 2034, *Primula Seaways*' master called VTS on VHF channel 12 **(Table 1)**.

Primula Seaways (master)	*VTS Humber Primula Seaways*
VTS Humber Channel 12 operator	*Primula Seaways VTS Humber*
Primula Seaways (master)	*Yeah, good evening just a question. City of Rotterdam is he going for the Hawke anchorage?*
VTS (Channel 12 operator)	*Primula Seaways VTS negative. The City of Rotterdam is proceeding outward with pilot.*
Primula Seaways (master)	*He's proceeding outward* [pause] *OK.*

Table 1: VHF radio exchange between *Primula Seaways* and Humber VTS between 2034 and 2035

City of Rotterdam and *Primula Seaways* were 2.8nm apart. The car carrier was now heading 105° at 12.2kts and *Primula Seaways* was heading 295° at 16.5kts **(Figure 7)**. The ferry's speed had been reduced in order to meet its scheduled arrival time. At 2035:44, *City of Rotterdam*'s pilot reported the vessel's position to VTS on VHF

1 All speeds are speed over the ground

2 See paragraphs 1.4.5 and 1.15.4

Image courtesy of ABP

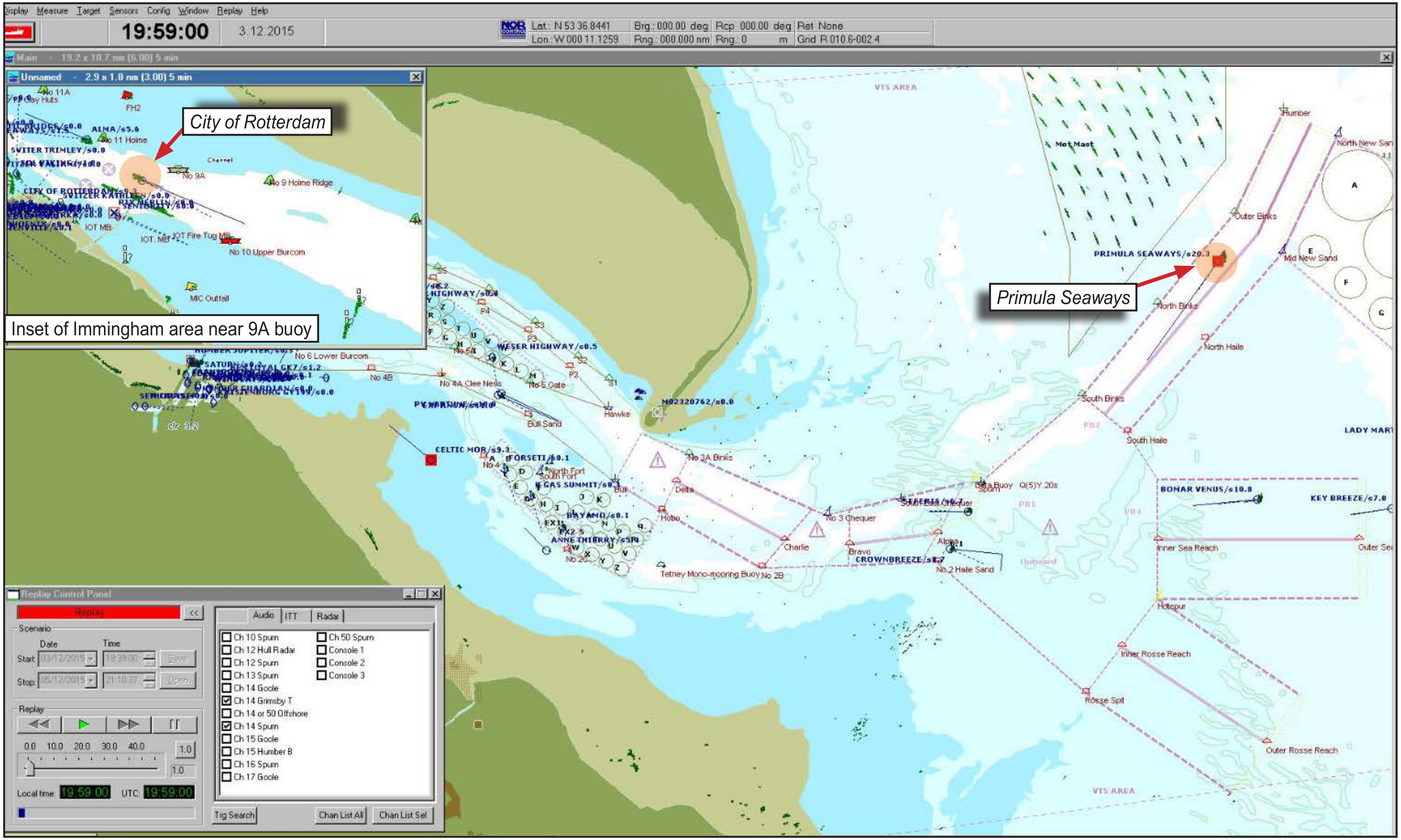

Figure 3: Vessels' position at 1959

Image courtesy of ABP

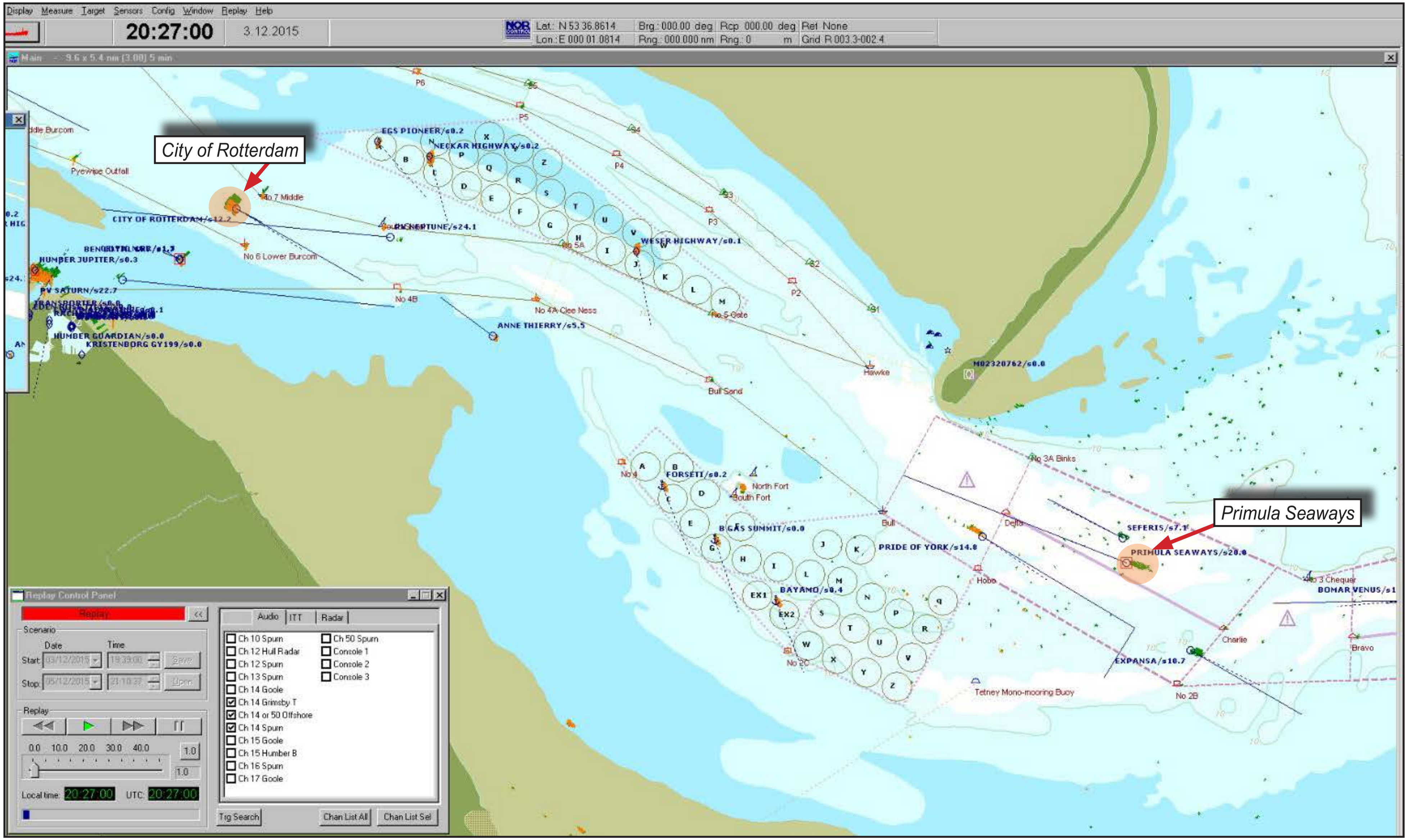

Figure 4: Vessels' position at 2027

Image courtesy of ABP

Figure 5: *Primula Seaways* - bridge

channel 14 **(Table 2)** as it approached 4A Clee Ness light float. The pilot used the VHF radio sited at the front of the bridge to starboard of the centreline **(Figure 2)** and had to wait for up to 20 seconds for VTS to complete a VHF exchange with another vessel before he could start his transmission.

Pilot	*VTS the City of Rotterdam*
VTS (Channel 14 operator)	*City of Rotterdam VTS*
City of Rotterdam (pilot)	*Yeah, good evening sir, I'm Clee Ness out and New Sand Hole*[3]
VTS (Channel 14 operator)	*Clee Ness New Sand Hole, thank you City of Rotterdam, tide gauge Spurn Head four decimal six five* [pause] *launch this evening the Saturn* [pause] *the Saturn has three boardings to do at alpha whisky two*[4] *and then she'll follow you outwards*
City of Rotterdam (Pilot)	*Roger that, thanks*

Table 2: VHF radio exchange between *City of Rotterdam* and Humber VTS between 2035:44 and 2036:17

[3] New Sand Hole is a reference to the route to be taken by the vessel once it has passed the Alpha buoy. There are three channels: New Sand Hole (NE), Sea Reach (E) and Ross Reach (SE).

[4] AW2 is a pilot boarding point used in adverse weather.

Image courtesy of ABP

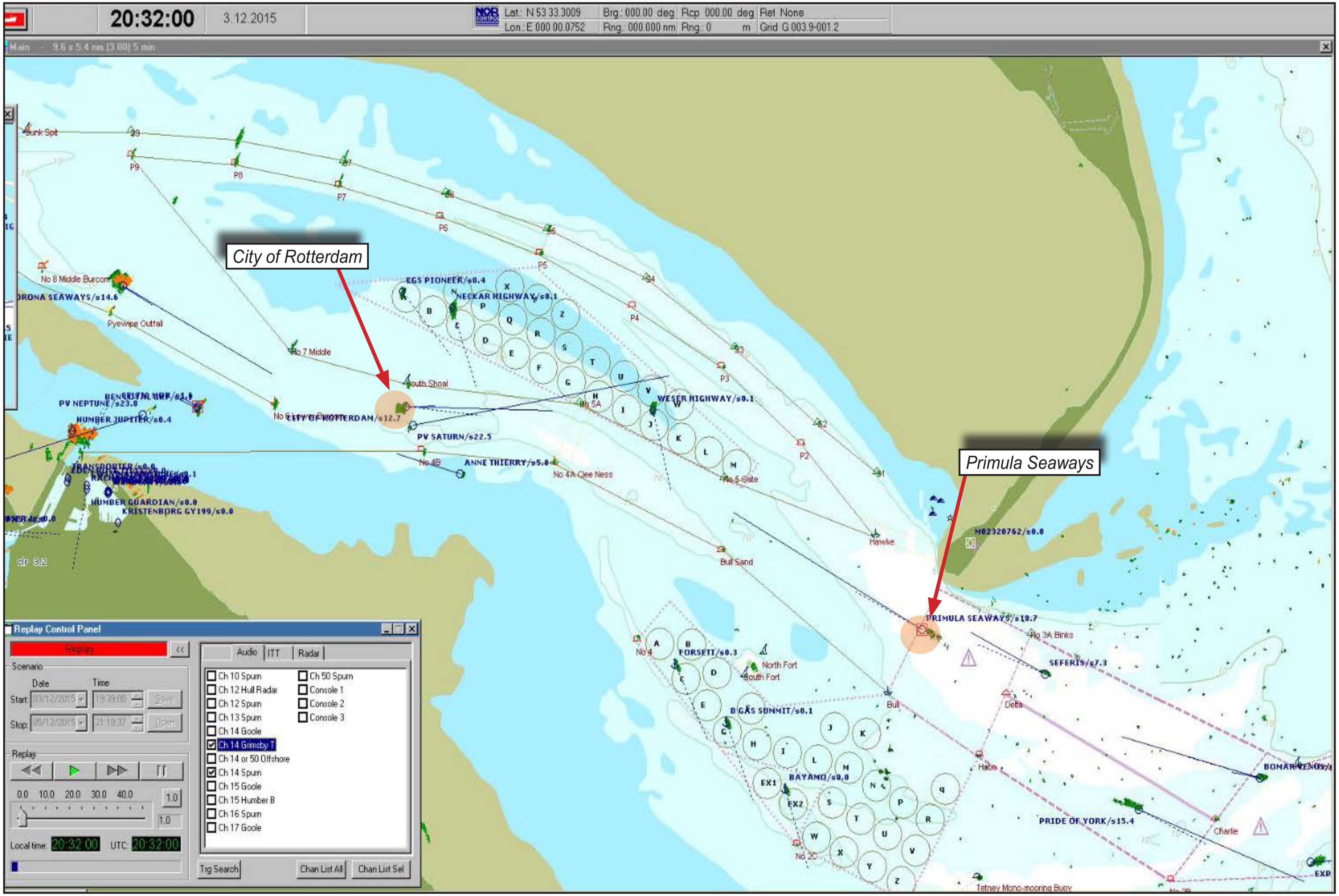

Figure 6: Vessels' positions at 2032

Image courtesy of ABP

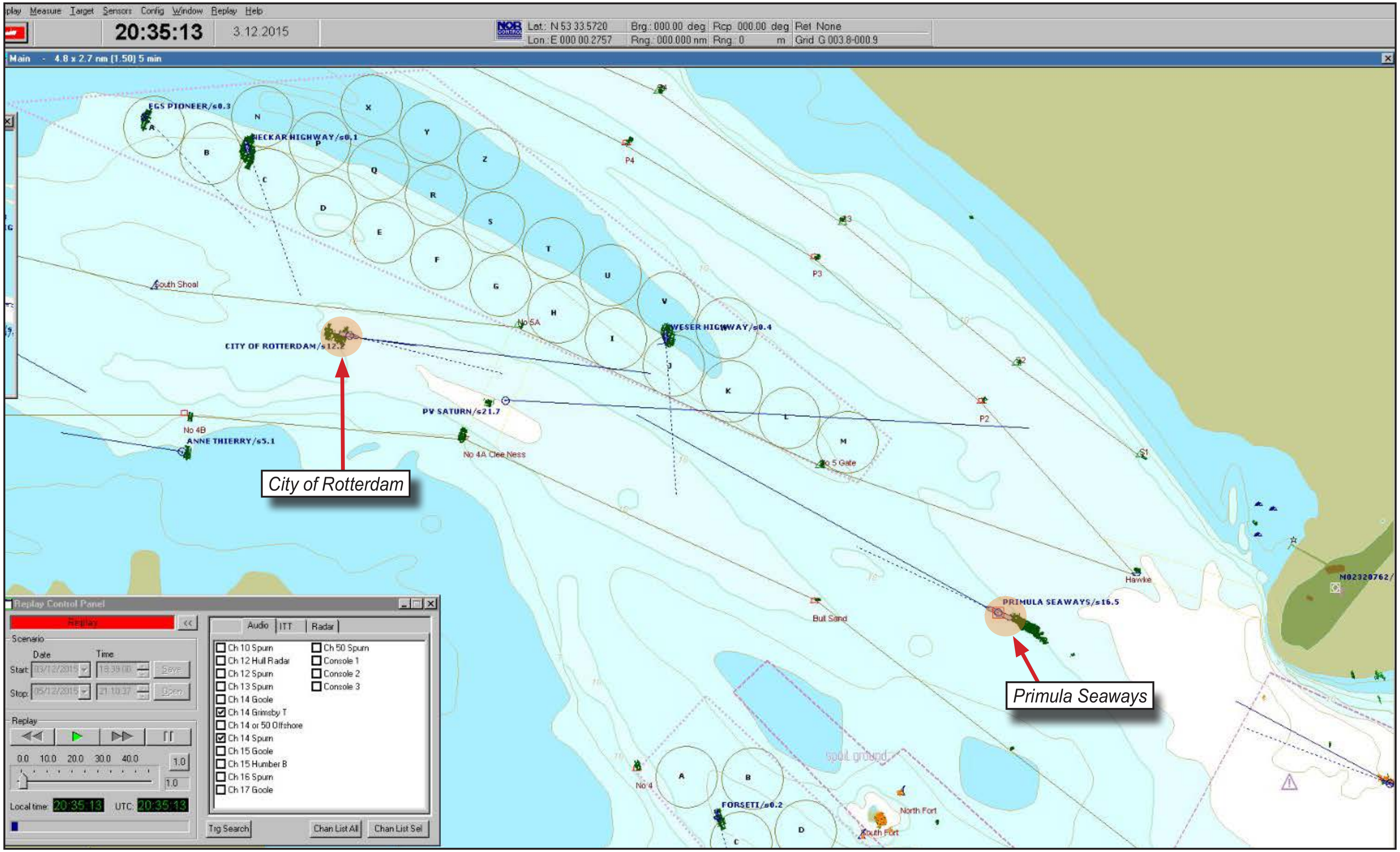

Figure 7: Vessels' positions at 2035

Primula Seaways' master and second officer continued to be concerned that *City of Rotterdam* remained on the northern side of the channel and did not appear to be altering course. The VTS watch manager was now also concerned, and he and *Primula Seaways*' second officer called the car carrier in quick succession on VHF channel 14 at 2037 **(Table 3)**. The pilot replied, again using the VHF radio on the starboard side of the bridge front.

VTS	*City of Rotterdam, VTS*
Primula Seaways (second officer)	*City of Rotterdam City of Rotterdam, Primula Seaways Primula Seaways*
City of Rotterdam (pilot)	*Station calling City of Rotterdam thirteen please*
Primula Seaways (second officer)	*One three*
Primula Seaways (second officer)	*City of Rotterdam Primula Seaways*
City of Rotterdam (pilot)	*Loud and clear good evening sir go ahead I'm trying to drop her down to the south as much as possible is that you on my port bow?*
Primula Seaways (second officer)	*Yeah that's right, we're just coming up to Clee Ness now*
City of Rotterdam (pilot)	*Yeah I'm trying to bring her as far to the south as the wind will allow me but er* [pause] *yeah I'll keep coming down to the south more positive*
Primula Seaways (second officer)	*I'd be obliged for that ok back to fourteen*

Table 3: VHF radio exchange between *Primula Seaways* and *City of Rotterdam* between 2037:09 and 2038:02

1.2.2 The collision

At 2038, the distance between *City of Rotterdam* and *Primula Seaways* was 0.97nm. The ferry continued on a heading of 295° **(Figure 8)** and its port and starboard sidelights were visible to *City of Rotterdam*'s bridge team. *City of Rotterdam*'s pilot confirmed with the helmsman that the vessel's heading was now 110°. He then ordered the helmsman to steer 115°.

Image courtesy of ABP

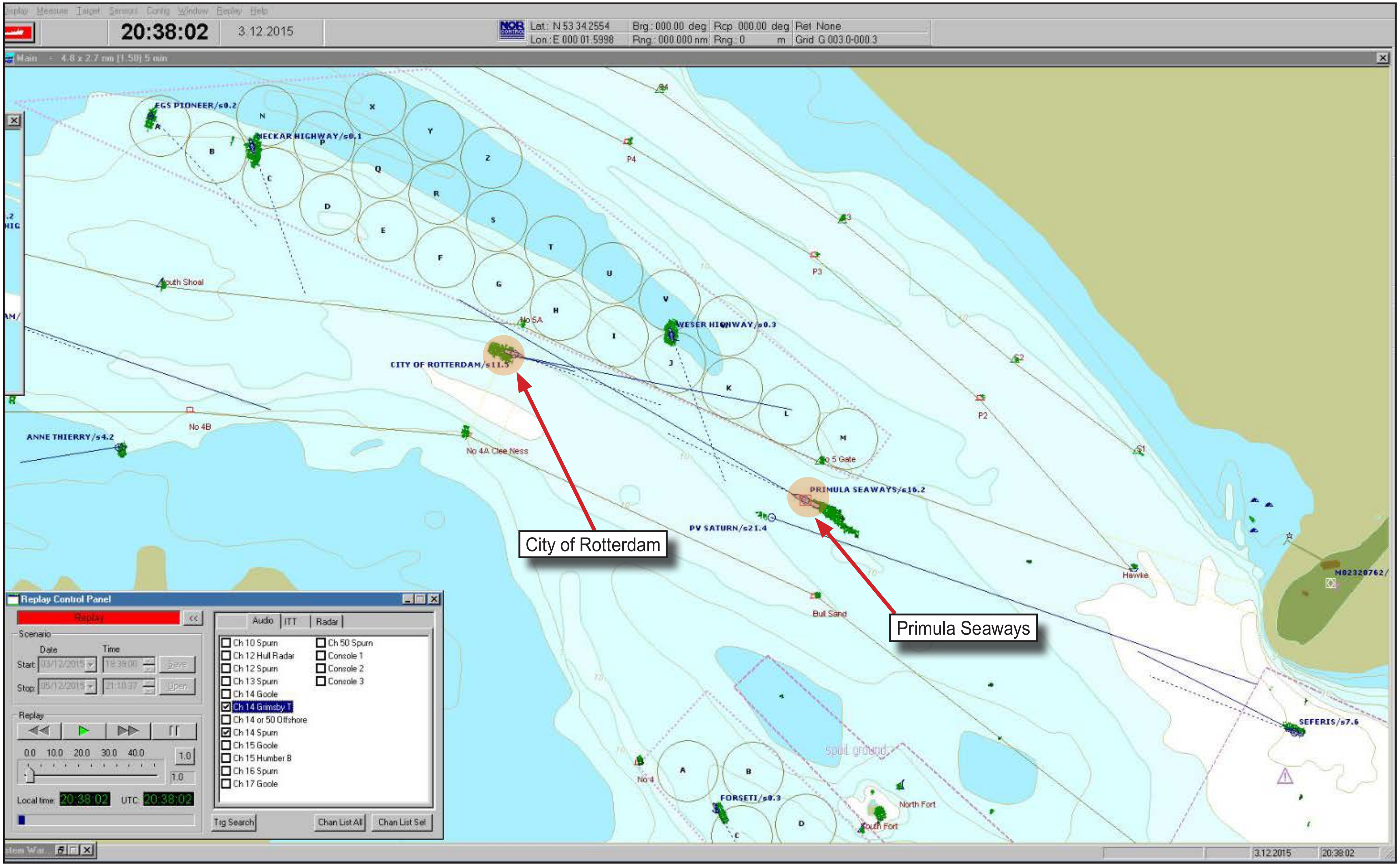

Figure 8: Vessels' positions at 2038

At 2038:25, the VTS watch manager called *City of Rotterdam* on VHF channel 14 **(Table 4)**. *Seferis* initially responded, but the VTS watch manager continued with his message.

VTS (watch manager)	*City of Rotterdam City of Rotterdam VTS*
Seferis	*Seferis* replying
VTS (watch manager)	*Yeah City of Rotterdam VTS from my equipment you're tracking to the north… tracking into the Hawke anchorage at the moment*
City of Rotterdam (pilot)	*Yeah we're on full speed and heading nearly south but we're going to try and bring her as far down as possible*
VTS (watch manager)	*Yeah you're entering the Hawke anchorage now* [pilot's name], *the Primula Seaways is right to the north of the channel, you might struggle to get south of him now*
City of Rotterdam (pilot)	*Yeah I'm on full speed and heading right down south*

Table 4: VHF radio exchange between VTS Humber and *City of Rotterdam* at 2038:25 and 2039:15

During the VHF exchange, *Primula Seaways*' master reduced the ferry's engine telegraph to 'half ahead', which equated to a speed through the water of 9.4kts.

City of Rotterdam's pilot ordered "*starboard 20*". As the car carrier's heading reached 125° the pilot ordered "*midships*" then "*135°*". Accordingly, the helmsman arrested the vessel's swing to starboard in order to steady the vessel as ordered. The car carrier's master expressed concern over the developing situation and the pilot explained to him that both vessels were experiencing drift.

At 2039:27, *Primula Seaways'* bridge team realised that *City of Rotterdam* was not turning to starboard as quickly as they expected. Manual steering was selected and full starboard helm was applied. The engine was also set to 'full astern'.

At 2039:57, *City of Rotterdam*'s pilot ordered "*150°*" and the helmsman applied 5° of starboard helm. Five seconds later, the master shouted "*what is he doing?*" The two vessels were now 0.27nm apart. *City of Rotterdam*'s speed was 12kts and *Primula Seaways*' speed was 14.3kts.

The VTS watch manager called *Primula Seaways* on VHF channel 14 **(Table 5)**.

VTS (watch manager)	*Primula Seaways VTS*
Primula Seaways (second officer)	*VTS Primula Seaways go ahead*
VTS (watch manager)	*Yes sir, warning, it appears that the City of Rotterdam is unable to bring it down further to the south* [pause] *from my equipment it appears there is a risk of collision*
Primula Seaways (second officer)	*Er* [unintelligible] *we can't do much now we're coming hard a starboard but I think we're going to collide* [pause] *yep*
VTS (watch manager)	*City of Rotterdam VTS did you receive?*

Table 5: VHF radio exchange between VTS Humber and Primula Seaways at 2040

City of Rotterdam did not reply. At 2040:23, the vessel's master shouted "*go to starboard*". He then ordered "*midships*" followed by "*hard to port*". Fourteen seconds later*, Primula Seaways* and *City of Rotterdam* collided, port bow to port bow **(Figure 9)**, on headings of 288° and 163° respectively.

1.2.3 Post-collision actions

Primula Seaways

Primula Seaways' second officer reported the collision to the VTS while the master turned the ferry back to its intended heading at slow speed. The general alarm was not sounded but the master made a public address system announcement to advise the vessel's crew and six passengers of the situation. The chief engineer and chief officer conducted a damage assessment of the vessel. On completion, the master reported to the VTS that there was "*no apparent damage*" and the VTS permitted the ferry to continue its passage to Immingham. The information that had been recorded on the vessel's voyage data recorder (VDR) was saved.

City of Rotterdam

On impact, *City of Rotterdam* heeled to starboard. The master and pilot fell to the deck but they were not injured. The pilot reported the collision to the VTS and the car carrier was manoeuvred towards the Bull anchorage at slow speed. The general alarm was not sounded. The chief and second officers went to the bridge immediately. The chief officer then went forward to assess the damage while the on-watch engineers checked for damage in the machinery spaces.

City of Rotterdam's forward hydraulic system was badly damaged so the vessel was unable to anchor. As soon as it was confirmed that there had been no breach in the car carrier's watertight integrity, the VTS authorised the vessel to return to Immingham. The VDR data was saved, but no radar information was recorded due to the starboard radar display being on standby.

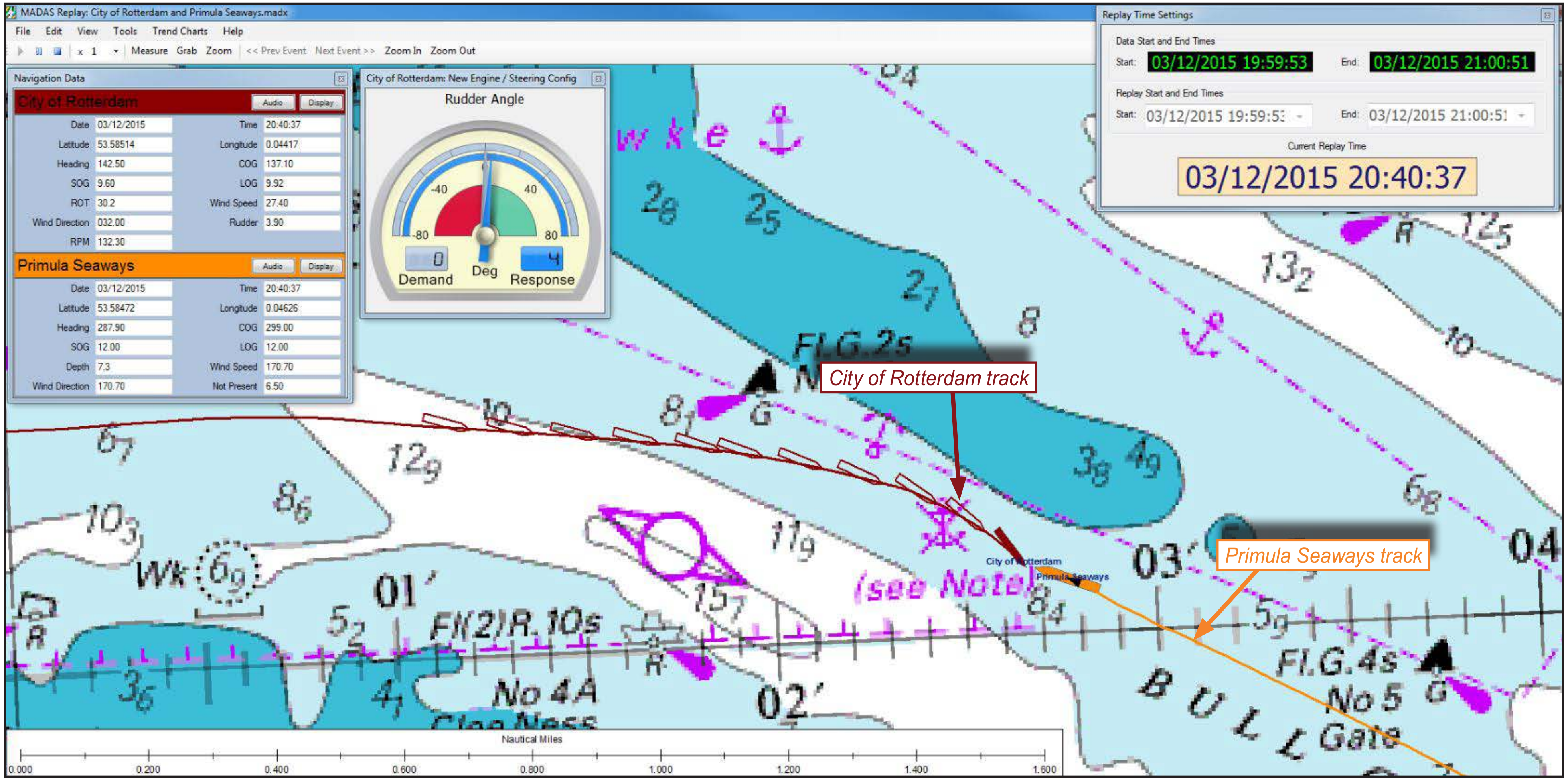

Figure 9: Vessels' positions at 2040

1.3 DAMAGE

Primula Seaways suffered damage to its bow above the waterline **(Figure 10)**. *City of Rotterdam*'s bow was damaged in way of the forward mooring deck, the forward hydraulic room, and car decks 5 and 6 **(Figure 11)**. The port side bilge keel and plating was also depressed and damaged, which resulted in water ingress to number 4 port ballast tank. The vessels were surveyed by classification society and Maritime and Coastguard Agency (MCA) surveyors. Following temporary repairs

Figure 10: *Primula Seaways* damage

in Immingham, both vessels proceeded to a ship repair yard on the River Tyne for permanent repair. The estimated cost of returning *Primula Seaways* to service was US$3 million. *City of Rotterdam* spent 2 months in dry dock, but the cost of the vessel's repair was not disclosed.

Figure 11: *City of Rotterdam* damage

1.4 BRIDGE AND VTS PERSONNEL

1.4.1 Certification, rest and alcohol

The members of *City of Rotterdam*'s and *Primula Seaways'* bridge teams held the STCW[5] certificates of competency required for their positions on board and met the Convention's requirements concerning hours of work and rest. With the exception of the car carrier's master, local police tested all bridge personnel for alcohol when the vessels arrived in Immingham. The tests were negative. *City of Rotterdam*'s master was not tested because after the vessel berthed he was taken to hospital following the sudden onset of a medical condition.

1.4.2 Primula Seaways

Primula Seaways' master was 53 years of age and a Swedish national. He had served as master for 7 years and had held a Class A pilotage exemption certificate (PEC)[6] for the River Humber since July 2011. The master also held a PEC for Gothenburg, Sweden. He had previously been master of *Fresia Seaways* and joined *Primula Seaways* 3 days before the accident.

The second officer was 64 years of age and a UK national. He had been a regular crew member on board the ferry for 3½ years and had not visited the River Humber for 2½ years.

The AB was 58 years of age and a Danish national. He had worked on board *Primula Seaways* for 11 years.

1.4.3 *City of Rotterdam*

City of Rotterdam's master was 62 years of age and a Bulgarian national. He had been a regular master on board the vessel for 2 years but he did not hold any PECs. The master had completed 20 days of a 2-month contract.

The third officer was 34 years of age and a Filipino national. He had been on board the vessel for 4 months and it was his second contract on board.

The helmsman was 33 years of age and a Filipino national. He had been on board the vessel for 6 weeks. It was the helmsman's second contract on board.

1.4.4 The pilot

The pilot on board *City of Rotterdam* was 61 years of age and a UK national. He held an STCW II/2 (master) certificate of competency and had been a 'VLS'[7] Humber pilot for 14 years. The pilot had last been assessed during an act of pilotage in November 2014, but no issues regarding his competency were identified. He had started his duty cycle on 1 December 2015 when he worked for 8 hours. The pilot did not work the following day.

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5 International Convention on Standards of Training, Certification and Watchkeeping for Seafarers 1978, as amended

6 A Class A PEC was required for vessels 100 metres or more in length and was valid for all DFDS 'Flower Class' ferries - *Begonia*, *Freesia*, *Ficaria*, *Magnolia*, *Primula* and *Petunia*.

7 'VLS' - Very Large Ship is the highest grade of pilot on the River Humber.

1.4.5 VTS

The duty VTS operators were all British nationals. The watch manager was 33 years of age and had been a VTS operator for 7 years. He had completed the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) standard V103/1 Operator training in January 2009, V103/1 refresher training in March 2012 and V103/2 supervisor training in November 2014. He had been a watch manager since August 2015.

The VHF channel 12 operator was 57 years of age and had been a VTS operator for 4½ years. He had completed V103/1 operator training in June 2011, V103/1 refresher training in February 2014 and the V103/4 'On The Job Instructor' course in March 2015.

The VHF channel 14 operator was 48 years of age and had been a VTS operator for almost 5 years. He had previously been a Class 3 Humber pilot[8]. He had completed his V103/1 operator training in March 2011, V103/1 refresher training in February 2014 and the V103/4 'On The Job Instructor' course in March 2015.

1.5 VESSEL MANAGEMENT AND OPERATION

1.5.1 *Primula Seaways*

Primula Seaways was owned and operated by DFDS Seaways AB (DFDS). The ferry usually operated between Gothenburg and Ghent, Belgium, but it was rescheduled on 1 December 2015 to operate on the Gothenburg-Immingham route. The vessel's last external and internal audits under the International Safety Management Code (ISM Code) were conducted in December 2014 and April 2015 respectively. Neither audit identified any non-conformities or made any observations concerning navigation or bridge procedures.

1.5.2 *City of Rotterdam*

City of Rotterdam was owned by Picer Marine S.A. and was on long-term time charter to Nissan Motor Car Carrier Co.Ltd. (NMCC), Japan. NMCC time chartered the vessel to Euro Marine Logistics (EML), which used it to transport cars between the UK and ports in Belgium, Sweden, Russia, Finland and Germany. EML was a joint venture between Mitsui OSK Lines and Hoegh Autoliners and operated 15 vessels.

Fairmont Shipping (Canada) Limited was *City of Rotterdam*'s marine and technical manager. It was also the ISM document of compliance holder.

City of Rotterdam's last internal audit was in March 2015, and identified only minor non-conformities. The audit was conducted by a company superintendent during a sea voyage. The vessel's last external audit was conducted by Lloyd's Register in April 2015, which raised only one observation. Neither the non-conformities identified in the internal audit nor the observation made in the external audit concerned navigation or bridge procedures.

[8] Class 3 authorises a pilot to conduct pilotage on vessels up to 7m draught and 10,000 tonnes deadweight.

1.6 NAVIGATION AND BRIDGE PROCEDURES

1.6.1 *Primula Seaways*

ECDIS was the primary means of navigation on board *Primula Seaways,* but the intended tracks for the ferry's entry into Immingham were also input into the radar displays. Checklists for arrival, passage planning and post-accident were all completed. Trackpilot steering was routinely used in open and pilotage waters.

1.6.2 *City of Rotterdam*

City of Rotterdam's primary means of navigation was paper charts, but the intended tracks for the vessel's departure from Immingham had also been input into the ECS. The tracks followed the axis of the buoyed channel and were generally equidistant from the port and starboard marks. During the passage in the Bull Channel, the third officer monitored the vessel's position on the ECS, but he had also periodically plotted positions on the chart **(Figure 12)**.

With regard to responsibilities when a pilot is embarked, the Safety Management System Manual (SMS) on board *City of Rotterdam* stated:

> *The Master's responsibility for the vessel is not diminished when a pilot or mooring Master is on board. For this reason, the OOW shall monitor the passage and advise the Master of any deviation from the agreed plan.*

1.7 UNCONVENTIONAL BRIDGE DESIGN

City of Rotterdam's hemispherical bow **(Figure 11)** was designed to reduce wind resistance and carbon emissions and to provide better fuel economy. A consequence of the bow's shape was that the vessel's bridge was of unconventional design **(Figure 13)**. Only the front window on the centreline was perpendicular to the vessel's fore and aft axis. The angular difference between the centre window and the off-axis windows[9] above the VHF radios mounted on the forward bulkhead was 33° **(Figures 14** and **15)**. The windows also sloped inwards from the bottom at an angle of 55°.

None of the vessel's bow canopy was visible from the bridge, so to provide a visual reference of the vessel's centreline a length of black cord had been positioned down the middle of the centre window **(Figure 14)** with two green light emitting diodes (LEDs) at its base. A compass repeater, an automatic identification system (AIS) transceiver and a pilot plug were positioned by the centreline window **(Figures 2**, **13** and **16)**.

The steering stand was on the centreline, 3m aft of the forward bulkhead. A workstation to port of the steering stand was fitted with an ECS and 'X' and 'S' band radar displays. A workstation to starboard of the steering stand was fitted with propulsion controls and internal communications systems. A clock and indicators showing relative wind speed and direction, rate of turn, heel, rudder angle, main engine speed and log speed were mounted along the deck head between the steering stand and the forward bulkhead **(Figure 16)**.

Chart and communication workstations were located at the rear of the bridge. Manoeuvring workstations with engine, rudder and bow thruster controls were located at each enclosed bridge wing. The bridge wing consoles were also fitted with a VHF radio.

[9] Windows that are not perpendicular to the vessel's centreline.

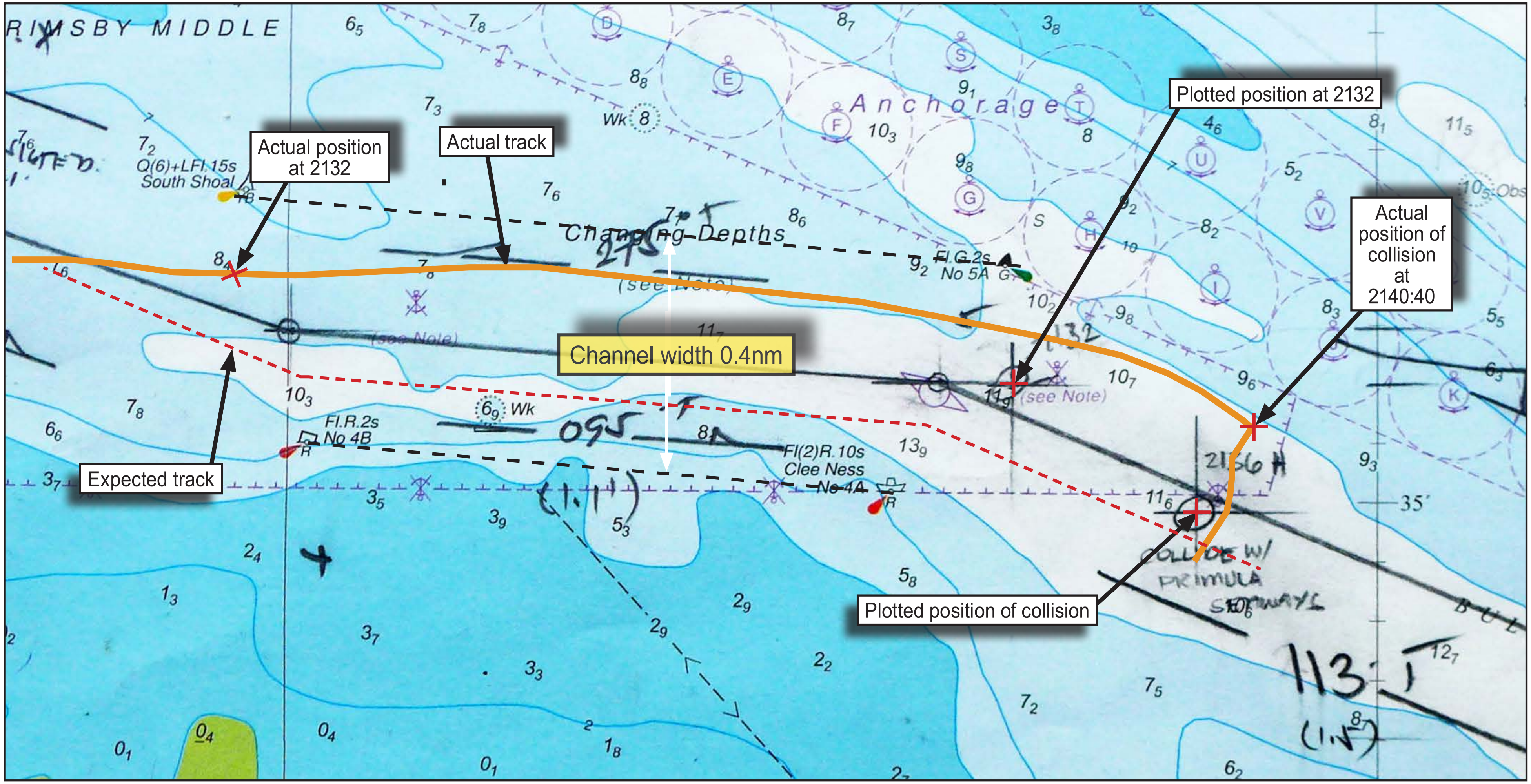

Figure 12: *City of Rotterdam* - extract of chart in use (with overlays)
Note: times on this chart are UTC (+1)

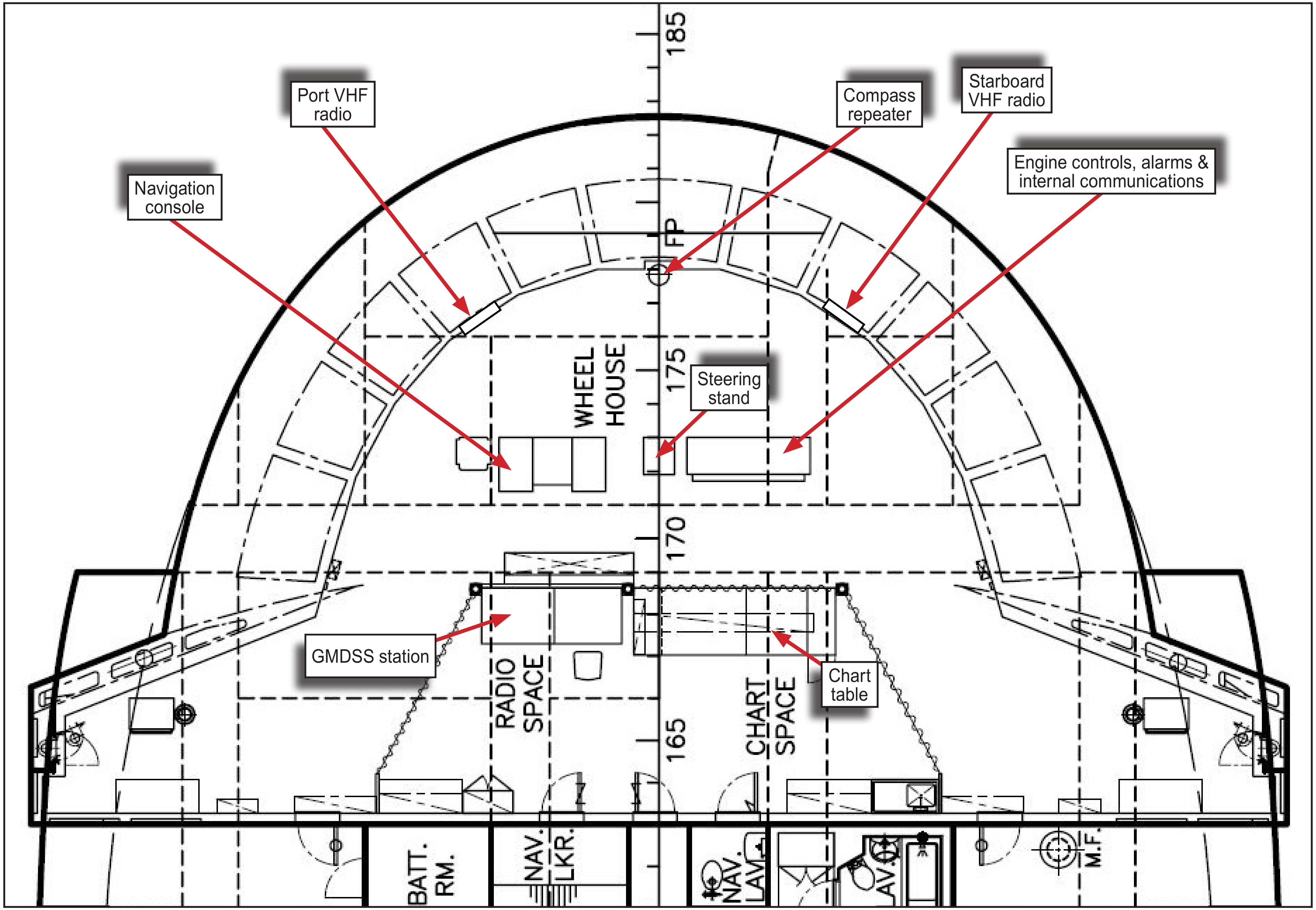

Figure 13: *City of Rotterdam* - Bridge arrangement

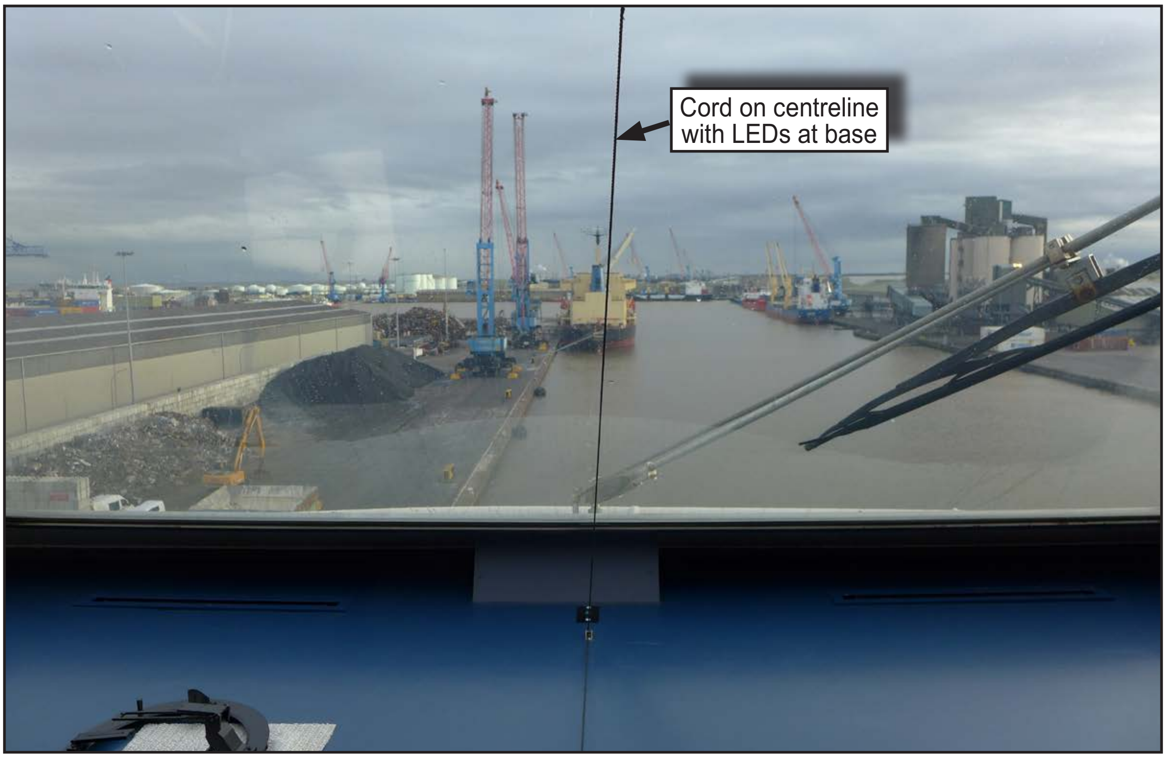

Figure 14: *City of Rotterdam* - view from centre window

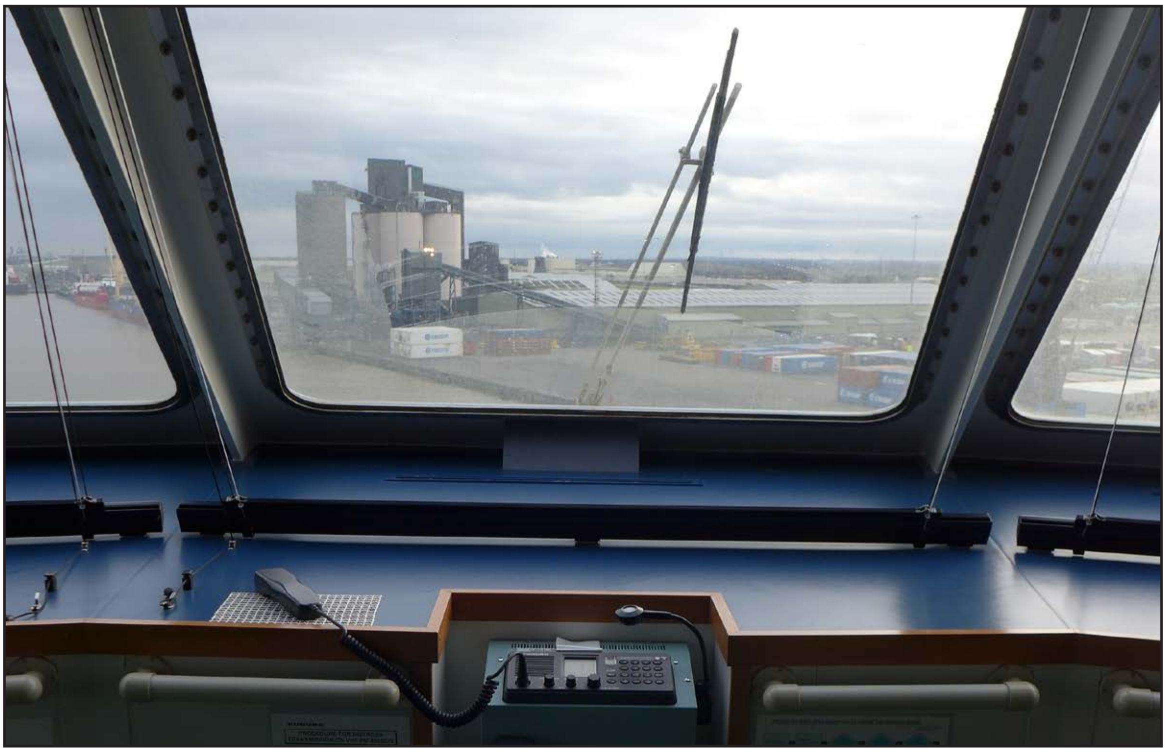

Figure 15: *City of Rotterdam* - same view, from off-axis window (starboard VHF)

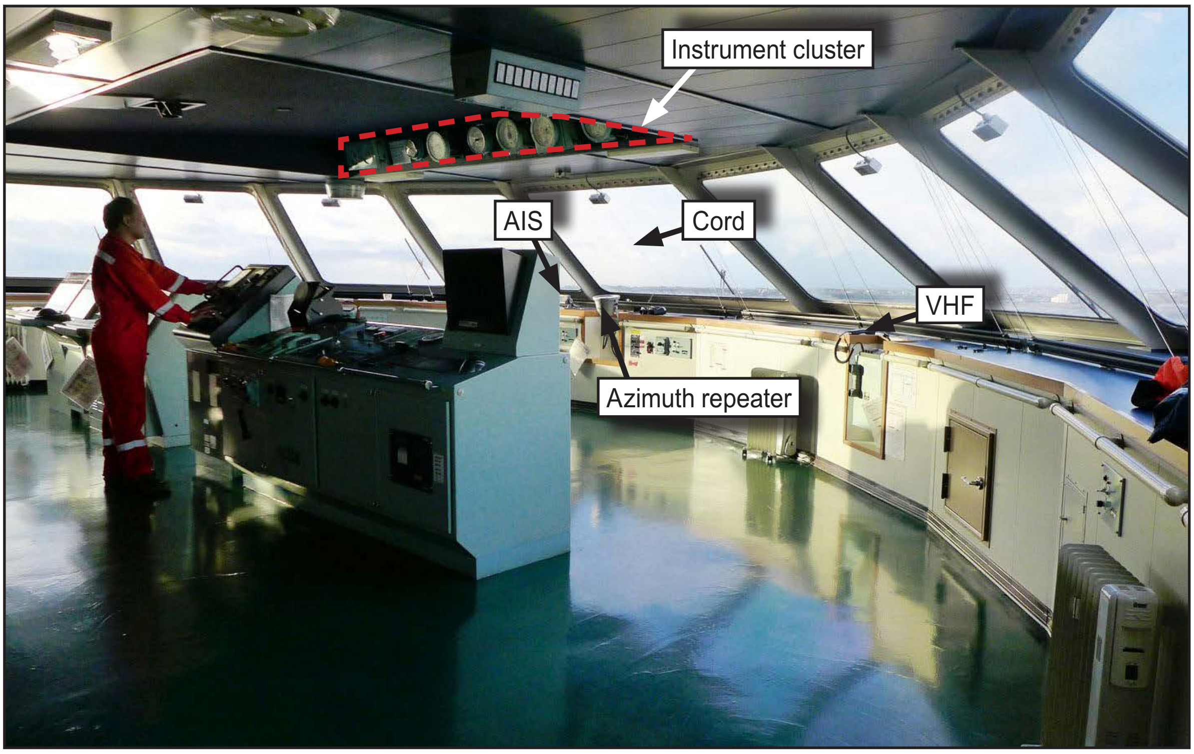

Figure 16: *City of Rotterdam* - bridge from starboard side

1.8 BRIDGE DESIGN APPROVAL

City of Rotterdam and its sister vessel, *City of St Petersburg*, were built by Kyokuyo Shipbuilding Corporation, Japan. While the vessels were under construction they were registered with the Panama Maritime Authority (PMA), which nominated Bureau Veritas (BV) as the 'recognised organization' (RO)[10]. BV was also the vessels' classification society.

In March 2010, the Kyokuyo Shipbuilding Corporation conducted a practical test in accordance with SOLAS V/22.3 **(Annex A)** to demonstrate that the design of the vessels' bridge windows was able to achieve, as close as practical, the visibility requirements detailed in SOLAS V/22.1.9.1. The SOLAS regulation required that all front windows shall be inclined from the vertical plane, top out, at an angle of between 10° and 25° in order to minimise reflections.

The test report was submitted to the PMA, which accepted its findings. The PMA issued certificates exempting *City of St Petersburg* and *City of Rotterdam* from the requirements of SOLAS V/22.1.9.1 on 27 December 2010 and 21 April 2011 respectively.

[10] The RO is responsible and accountable to the Flag administration for the work that is carried out on its behalf. It also verifies that a ship is built in compliance with applicable requirements based on the relevant national laws, which in turn are based on International Conventions to which the Flag administration's government is a signatory, together with additional instructions that may be issued by the Flag administration.

1.9 PILOTS' FEEDBACK

Feedback from a number of pilots based in several ports frequently visited by *City of Rotterdam* and *City of St Petersburg* indicated that they found piloting the vessels 'disconcerting' or 'uncomfortable'. The pilots had developed strategies to cope with the challenges resulting from the bridge layout. These included:

- Mainly standing behind the centreline compass repeater or the helmsman.
- Limiting time at the navigation workstation.
- Using hand-held VHF radios.

When manoeuvring near a berth, the pilots expressed concern that the ships' sides could only be viewed by one person from the bridge wing side windows and that a ship's side could not be viewed at the same time as operating the helm, engine and bow thruster controls.

1.10 ERGONOMIC ASSESSMENT

In view of *City of Rotterdam*'s unconventional bridge design and the pilots' feedback, Process Contracting Ltd. was commissioned to explore the potential effects of the off-axis window on perception. A comparison of aspects of the bridge design against current regulations and good practice was also undertaken. During the study, an ergonomist from Process Contracting Ltd. visited *City of Rotterdam* while the vessel was in dry dock. He also accompanied MAIB inspectors on board *City of St Petersburg* during pilotage transits in daylight and in darkness on the River Tyne. During these transits, it was observed that the lead attached to one of the VHF radios at the front of the bridge had been extended to enable the radio to be used while standing on the centreline.

A key finding of the ergonomist's report **(Annex B)** was the potential for relative motion illusion (also known as vection illusion) to develop when looking through an off-axis window. This illusion refers to perceived self-motion in relation to the real motion of another object. This frequently occurs when in a stationary vehicle at traffic lights and an adjacent car edges forward. In such situations, individuals occasionally sense that they are rolling backwards. The report states:

> *The effect of standing at an off-axis window is that the observer loses all sense of orientation relative to the ship. Objects in the scene are positioned relative to the observer (an egocentric frame of reference[11]), including relative motion. The consequence of this for navigation is that objects are considered to move as though the ship were headed in the direction of the window.*

The report explains:

- How an observer's field of view is framed by the window framing and that any items of the ship's structure that are in view do not give any indication of orientation.

[11] MAIB note – An egocentric frame of reference is based on an individual's own location within the environment (as when giving direction as 'right' rather than 'north').

- That an egocentric frame of reference is more dominant than an exocentric[12] one as this is the frame of reference usually used when looking out of the window for ship control and manoeuvring.

- There is a cognitive cost of translating between egocentric and exocentric frames of reference.

- The nature of relative motion illusions is such that they return immediately after being broken, even with regular reminders.

- With regard to *City of Rotterdam*'s bridge design's compliance with regulatory requirements and adherence to good practice, the report identified apparent deficiencies in bridge visibility, the bridge arrangement (particularly the radio installation) and the design and approval of unconventional designs[13]. Particular concern was raised over the bridge radio installation, and the bridge design's effect on the needs of the pilot and the interaction between the bridge team and the pilot.

1.11 SIMULATION

In order to explore the potential for relative motion illusion on *City of Rotterdam*'s bridge, and its effects, the collision between *City of Rotterdam* and *Primula Seaways* was simulated at the South Tyneside Nautical College using VDR data, including voice recordings. In addition to gaining a better insight into the pilot's perception, the simulation was also used to examine the events leading up to the collision from the perspective of *Primula Seaways*' bridge team.

To simulate the view of *City of Rotterdam*'s pilot from the forward bridge window above the starboard VHF radio, the view from the centre window in the bridge simulator was offset 33° to the right. Two of the simulation runs were conducted with different Humber pilots providing commentaries. The key findings of the simulations were:

- At 2037, when *City of Rotterdam*'s pilot first stated that he was trying to "*bring her as far to the south as the wind will allow me*" **(Table 3)**, he was looking towards the Bull anchorage on a bearing of 138° while the vessel's heading was 105° **(Figure 17)**. One minute later, when he informed VTS that he was "*heading nearly south*" **(Table 4)** he was looking towards the Bull anchorage on a bearing of about 148° while the vessel's heading was 115°.

- During the simulation runs with the Humber pilots, neither of the pilots recognised that the view ahead was offset. Instead, they both accepted that the vessel was heading in the direction of view and attributed the vessel's apparent movement to significant set or drift.

---

[12] An exocentric or allocentric frame of reference specifies location and orientation with respect to elements and features of the environment and independent of an individual's location in it.

[13] It should be noted that the PMA had exempted *City of Rotterdam* from the requirements of SOLAS V/22.1.9.1 and its bridge design had been accepted by BV. In addition, no deficiencies in the bridge installation had been identified during either internal or external audits or inspections. However, a number of the principles of the applicable regulations and good practice (see Paragraphs 1.13 and 1.14) are open to interpretation and therefore opinions on the compliance or otherwise of bridge designs may differ. The deficiencies highlighted in **Annex B** are based on the interpretations of Process Contracting Ltd.

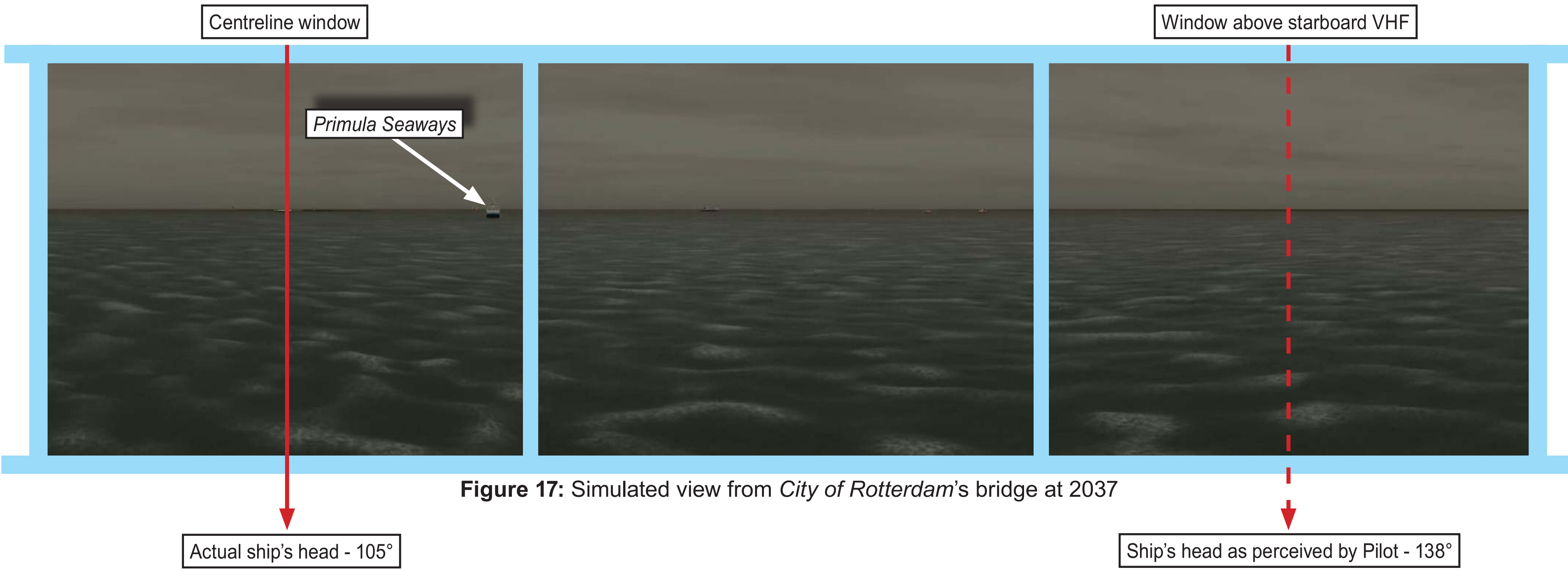

Figure 17: Simulated view from *City of Rotterdam*'s bridge at 2037

- When *Primula Seaways* started to reduce speed to 'half ahead' at 2038:25, *City of Rotterdam* was within 1nm **(Figure 18)**. The car carrier's pilot had informed the ferry's master several times that he was manoeuvring to the south, yet there was no sign of the vessel doing so. From the simulations, it was evident that a course alteration to starboard would have caused the ferry to cross *City of Rotterdam*'s bow while an alteration to port would have exacerbated the close quarters situation that was developing if the car carrier did turn more to the south as the pilot had indicated.

Figure 18: Simulated night-time view from *Primula Seaways* at 2038:25, *City of Rotterdam* is showing its two masthead lights and green sidelight

Figures 19 and **20** show the respective simulated views from *City of Rotterdam* and *Primula Seaways* at 2039:27 when the ferry's engine was put to 'full astern' and full starboard helm was applied.

1.12 SIMILAR BRIDGE DESIGNS

A number of modern vessels are constructed with bridges that are semi-circular, with off-axis windows. In all such vessels identified, the bridges were fitted with integrated navigation systems and fixed seats at the conning positions **(Figure 21)**. It is noted that *NS Savannah*, which was launched in 1959, had off-axis windows and, against the convention of the time, the bridge's main workstation was located on the centreline at the bridge front **(Figure 22)**. In 2015, the Kyokuyo Shipyard launched the container ship *Natori* **(Figure 23)**, another ship with a hemispherical bow. However, on the direction of the vessel's Flag administration (Japan), the bridge was fitted with sloping windows that were compliant with SOLAS V/22.1.9.1.

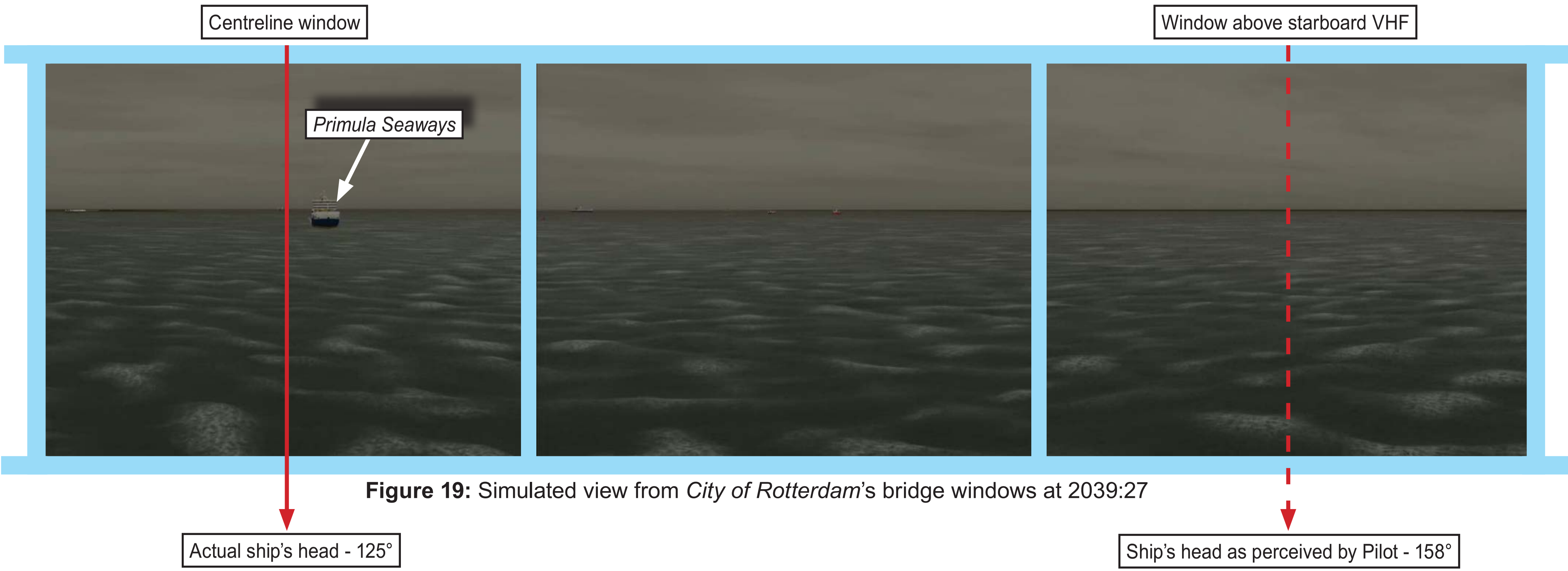

Figure 19: Simulated view from *City of Rotterdam*'s bridge windows at 2039:27

Figure 20: Simulated night-time view from P*rimula Seaways* at 2039:27, *City of Rotterdam* is showing its two masthead lights and green sidelight

Image courtesy of Ulstein

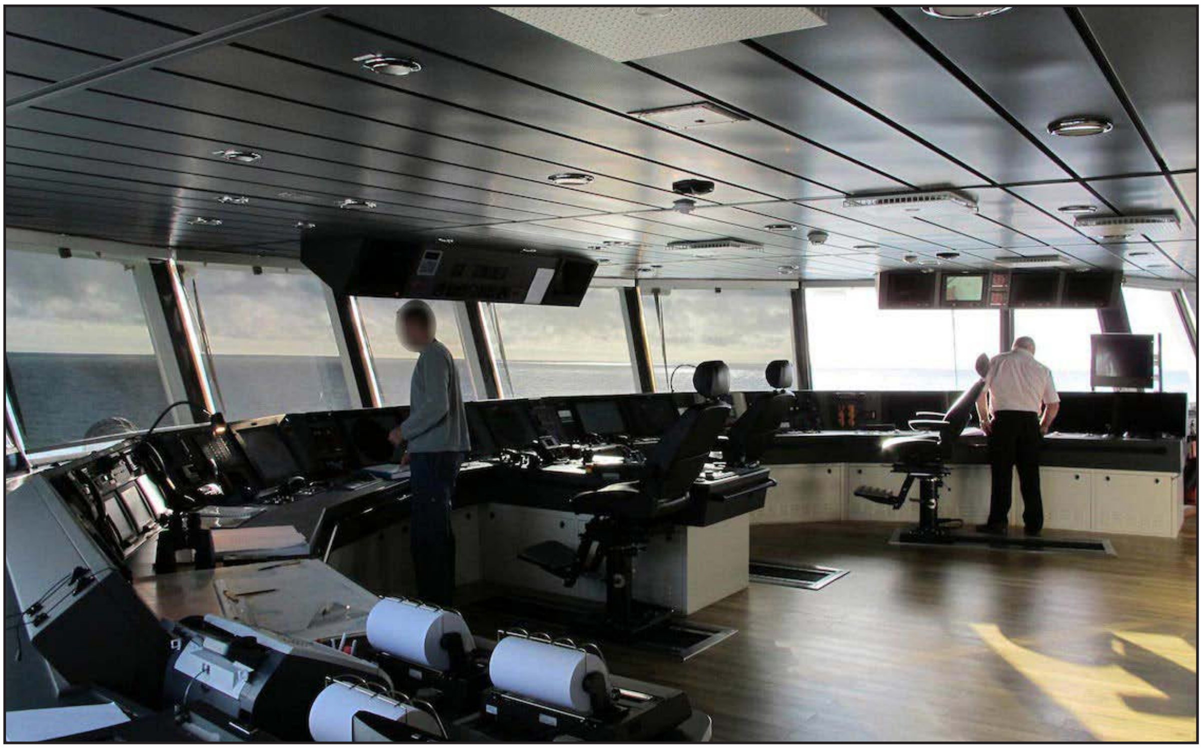

Figure 21: Example of another bridge with off-axis windows

Image courtesy of Wikimedia

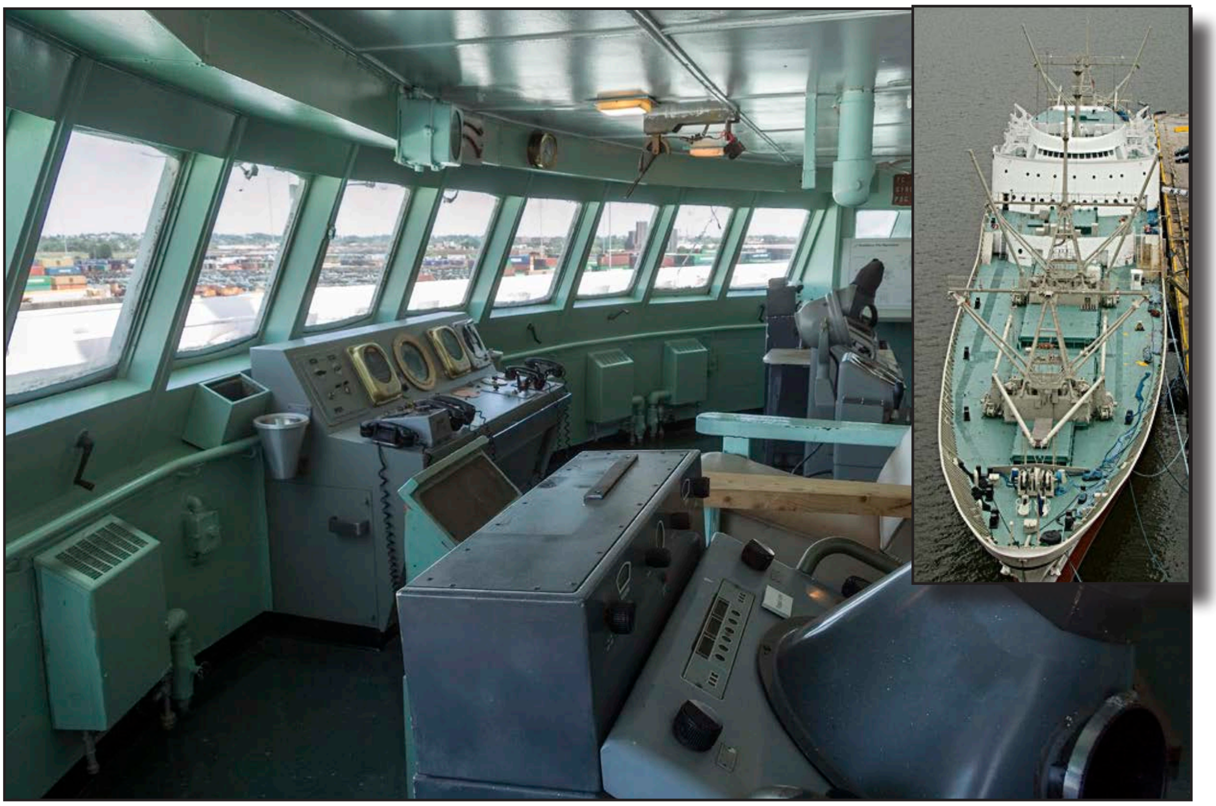

Figure 22: The bridge on board *NS Savannah*

Image courtesy of Andreas Schlatterer, www.shipspotting.com

Figure 23: The container ship *Natori*

1.13 BRIDGE DESIGN REGULATIONS

1.13.1 SOLAS V Regulation 15 (SOLAS V/15)

SOLAS V/15 – *Principles relating to bridge design, design and arrangement of navigational systems and equipment and bridge procedures* requires owners, naval architects, manufacturers and administrations to ensure compliance with specific ergonomic principles. It also requires owners and masters to ensure that bridge procedures, which take ergonomic criteria into consideration, are adopted. The Regulation states:

All decisions which are made for the purpose of applying the requirements of regulations 19, 22, 24, 25, 27 and 28 and which affect bridge design, the design and arrangement of navigational systems and equipment on the bridge and bridge procedures shall be taken with the aim of:

1.1	*facilitating the tasks to be performed by the bridge team and the pilot in making full appraisal of the situation and in navigating the ship safely under all operational conditions;*
1.2	*promoting effective and safe bridge resource management;*
1.3	*enabling the bridge team and the pilot to have convenient and continuous access to essential information which is presented in a clear and unambiguous manner, using standardized symbols and coding systems for controls and displays;*
1.4	*indicating the operational status of automated functions and integrated components, systems and/or sub-systems;*
1.5	*allowing for expeditious, continuous and effective information processing and decision-making by the bridge team and the pilot;*
1.6	*preventing or minimizing excessive or unnecessary work and any conditions or distractions on the bridge which may cause fatigue or interfere with the vigilance of the bridge team and the pilot; and*
1.7	*minimizing the risk of human error and detecting such error if it occurs, through monitoring and alarm systems, in time for the bridge team and the pilot to take appropriate action.*

1.13.2 SOLAS V Regulation 22 (SOLAS V/22)

SOLAS V/22 – *Navigation Bridge Visibility* **(Annex B)** details minimum design specifications to ensure good visibility. It also allows administrations discretion concerning ships of unconventional design. The Regulation states:

On ships of unconventional design which, in the opinion of the Administration, cannot comply with this regulation, arrangements shall be provided to achieve a level of visibility that is as near as practical to that prescribed in this regulation.

1.13.3 SOLAS IV – Regulation 6 (SOLAS IV/6)

SOLAS IV/6 – *Radio Installations* states that every radio installation shall, among other things:

> *Be so located as to ensure the greatest possible degree of safety and operational availability*

and

> *Control of the VHF radiotelephone channels, required for navigational safety, shall be immediately available on the navigation bridge convenient to the conning position and, where necessary, facilities should be available to permit radiocommunications from the wings of the navigation bridge. Portable VHF equipment may be used to meet the latter provision.*

1.14 BRIDGE DESIGN GUIDANCE

1.14.1 Maritime Safety Committee guidelines

In December 2000, the International Maritime Organization (IMO) Maritime Safety Committee (MSC) issued MSC/Circ.982 – *Guidelines on ergonomic criteria for bridge equipment and layout*. The purpose of the guidelines was to:

> *Provide ergonomic requirements for the bridge equipment and layout to render assistance to enable consistent, reliable and efficient bridge operation.*

With regard to workstations, the Circular defines a *workstation for navigating and manoeuvring* as:

> *Main workstation for ship's handling conceived for working in seated/standing position with optimum visibility and integrated presentation of information and operating equipment to control and consider ship's movement. It should be possible from this place to operate the ship safely, in particular when a fast sequence of actions is required.*

The Circular indicates that the navigating and manoeuvring workstation should be sited close to the centreline and be equipped, among other things, with indications for propeller revolutions, rudder angle, rate of turn, compass heading, water depth, wind direction and speed and time.

The Circular also provides definitions for other workstation types for monitoring, manual steering, docking (bridge wing), planning and documentation, communication and safety. It does not provide a definition for 'conning position'.

1.14.2 IACS guidelines

At MSC 78 in June 2004, the Human Element working group considered the International Association of Classification Societies (IACS)[14] Unified Interpretation (UI)[15] (SC 181) regarding bridge design. The working group was appreciative of IACS' work but considered that the development of a UI that could be used to demonstrate compliance with SOLAS V/15 was not necessary. UI SC 181 was withdrawn pending further development.

In 2007, IACS issued Recommendation No 95[16], *Recommendation for the Application of SOLAS Regulation V/15 – Bridge Design, Equipment Arrangement and Procedures* (BDEAP). The recommendation was based on the international regulatory regime and IMO conventions and instruments.

The definitions detailed in BDEAP include:

> *A 5.7 Commanding view: View without obstructions which could interfere with the ability of the officer of the watch and the pilot to perform their main tasks, providing at least the field of vision required for the safe performance of collision avoidance functions, requiring that the view of the sea surface forward of the bow to 10° on either side is not obscured by more than two ship lengths (2xLOA), or 500m, whichever is less, and that a horizontal field of vision extends over an arc of not less than 225° - that is from right ahead to not less than 22.5° abaft the beam on either side of the ship. Ref. SOLAS V/22, 1.1, 1.2 and 1.3.*
>
> *A5.9 Conning station or position: Place in the wheelhouse arranged and located for monitoring and directing the ship's movement in narrow waters and buoy lanes by visual observations, providing a commanding view (A 5.7), close view of the sea surface (A 5.8) and the required information for conning (SOLAS regulation V/19)17.*
>
> *A 5.91 Additional conning station: Workstation used for navigation, including conning, providing a commanding view with access to radar and navigational chart in addition to information required for conning by Reg. V/19, which may serve as an alternative conning station for the pilot when required.*
>
> ***Note:*** *Both the conning station/position (A 5.9) and the workstation that may serve as additional conning station (A 5.9.1) need to provide a commanding view. The difference is that the commanding view in the first occurrence is provided at a position which also allows a close view of the sea surface, while*

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[14] IACS develops, reviews and promotes minimum technical requirements in relation to the design, construction, maintenance and survey of ships. The association comprises the 12 leading classification societies for shipping, including BV, which was a founder member.

[15] Unified Interpretations are adopted resolutions on matters arising from implementing the requirements of IMO Conventions or Recommendations. Such adopted resolutions can involve uniform interpretations of Convention Regulations or IMO Resolutions on those matters which, in the Convention, are left to the satisfaction of the Administration or vaguely worded. IACS UIs are applied by IACS members to ships whose Flag administrations have not issued definite instructions on the interpretation of the IMO regulations concerned, in the course of statutory certification on behalf of those Flag administrations.

[16] IACS produces recommendations and guidelines related to adopted resolutions that are not necessarily matters of class but which IACS considers would be helpful to offer some advice to the marine industry.

[17] MAIB Note – SOLAS V/19.2.5.4 requires all ships of 500 gross tonnes and over to have rudder, propeller, thrust, pitch and operational mode indicators, or other means, to be readable from the conning position.

the additional conning station provides additional information from instruments (radar/chart) and the commanding view from the working position at the radar, without necessarily providing a close view of the sea surface.

A 5 17.2 Workstation for navigating and manoeuvring: A workstation with a commanding view used by navigators when carrying out route monitoring, traffic surveillance, course alterations and speed changes, and which enables monitoring of the safety state of the ship.

The conning functions are tabulated in BDEAP as follows:

Conning Functions	**Equipment to be operated**	**Information to be viewed**	**Remarks**
Determine & direct course and speed in relation to waters and traffic			
Monitor:			
heading		Gyro repeater	May be digital
rudder angle		Rudder angle	
rate of turn		RoT indicator	>50 000grt
propulsion		RPM/Pitch	
speed		Speed log	
water depth		Echo sounder display	Anchoring
Give sound signals	Whistle control button		
Effect communication	VHF		Available
Documentation	Log-book or equivalent		Manual or electronic – Legal!

Table 6: Extract from the IACS Bridge Design and Equipment Arrangement Procedures

1.15 RIVER HUMBER

1.15.1 Governance

The River Humber is the busiest ports complex in the UK, with about 30,000 ship movements annually. Associated British Ports (ABP) is the statutory and competent harbour authority[18], but the harbour authority's operational roles are delegated to ABP Humber Estuary Services (HES). ABP operates 22 UK ports and complies with the Port Marine Safety Code[19].

1.15.2 The Bull Channel

The Bull Channel **(Figure 1)** was at its narrowest between the South Shoal Buoy and the 4A Clee Ness buoy, when it was about 4 cables wide. There was no speed limit in the channel but the Humber Byelaws included:

> *Nothing in these Byelaws shall affect the operation of the Collision Regulations or the duty upon the master of a vessel to comply therewith.*

and

> *The master of a vessel shall navigate the vessel with due care and caution and at a speed and in a manner which shall not endanger the safety of any person or any other vessel or cause damage thereto or to a floating navigational mark or mooring or other property.*

The North Sea (West) Pilot[20] advises mariners:

> *the flood stream sets strongly to the north in the Bull Channel (53°35'N 0°03'E) which can carry vessels out of the fairway. It is reported (1994) that vessels have frequently collided with No.5 Gate Buoy which marks the N side of the channel.*

1.15.3 Pilotage

Pilotage was compulsory in the Humber for all vessels 60m or over in length. ABP employed approximately 120 pilots, who were authorised following their successful completion of training and oral and practical examinations. The pilots were re-assessed at intervals not exceeding 5 years.

Masters and chief officers of vessels navigating the Humber pilotage area could apply for a PEC. Applicants had to satisfy the harbour authority that they had a suitable level of skill, experience and local knowledge to navigate safely in the harbour area. PECs were required to be re-validated every 12 months (based on achieving the required minimum number of trips), and PEC holders were re-assessed every 5 years.

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[18] A competent harbour authority in the UK has statutory powers relating to the provision of pilotage in its waters.

[19] The Port Marine Safety Code is the UK standard for every aspect of port marine safety. It applies to all harbour authorities in the UK that have statutory powers and duties. Continued compliance with the Code is required to be confirmed to the MCA every 3 years.

[20] Admiralty Sailing Directions North Sea (West) Pilot NP54.

1.15.4 VTS Humber

VTS Humber provided a traffic organisation service (TOS)[21] east of the Humber Bridge, which included the area between Immingham and the eastern port limit. It operated to international standards detailed in IMO Resolution A857(20) and the IALA VTS Manual. All of the VTS operators were familiar with and regularly used message markers[22] during VHF radio communications.

The VTS station was located on Spurn Head **(Figure 1)** and was equipped with VHF radio, a bespoke VTS chart display system with radar and AIS overlays, land-based closed circuit television coverage at critical points and weather monitoring equipment. Operators were also able to access ABP's port and vessel information system to assist with the planning and monitoring of all significant traffic in the area.

The VTS station operated continuously with three duty operators, a VHF channel 12 operator (west of the 4A Clee Ness Buoy), a VHF channel 14 operator (east of the 4A Clee Ness Buoy) and a watch manager who operated VHF channel 15 (upper Humber). The VHF channel 12 operator was generally the least experienced and the watch manager the most experienced. The VTS operators followed an 8 hours on/8 hours off routine for a period of 4 or 6 days. They lived on site as access to the station was generally only achievable by boat.

1.15.5 Previous accidents

The MAIB has investigated three collisions in the Humber since 2005:

- In January 2005, the oil products tanker *Amenity* and a ro-ro cargo vessel *Tor Dania* collided between the Grimsby Middle and South Shoal buoys. Among the safety issues identified in the MAIB investigation report (MAIB 20/2005) were the training and assessment of PEC holders and bridge manning.

- In June 2006, the general cargo ship *Skagern* and container vessel *Samskip Courier* collided. Both vessels were under pilotage in restricted visibility near the Saltend jetties east of Hull docks. The investigation report (MAIB 6/2007) identified that the masters of both vessels had been over-reliant on the pilots and that the interaction and communication among the bridge teams was poor. Following the accident, the MAIB recommended:

The Port Marine Safety Code Steering Group, to:

2007/122 Promulgate to Port Authorities the need for pilots to maintain dialogue with the bridge team regarding the conduct and execution of the passage plan, thus ensuring the team is kept fully involved, and informed, at all times.

[21] See Paragraph 1.16.

[22] The IALA VTS manual lists eight message markers (Instruction, Advice, Warning, Information, Question, Answer, Request and Intention) which can be used at the start of VHF communications to increase the probability of a message being understood.

The International Chamber of Shipping, to:

2007/125 Through its member organisations, emphasise the need for shipowners to ensure masters are given clear guidelines that detail the importance of effective dialogue with pilots, and identifies the need for masters to challenge or question decisions or actions taken by pilots at an early stage so that, when required, effective corrective action can be taken to prevent accidents.

- In April 2007, the products tanker *Audacity* and general cargo ship *Leonis* collided in the precautionary area east of Spurn Head. Among the contributing factors identified in the MAIB investigation report (MAIB 2/2008) were that the pilots and bridge teams did not make a full assessment of the risk of collision and that VTS procedures for managing traffic in the precautionary area were insufficient. As a result of the accident, ABP HES took several actions to, among other things, improve the performance of the VTS and its pilots.

1.16 VESSEL TRAFFIC SERVICES

Three levels of VTS are available: an information service (INS), a traffic organisation service (TOS), and a navigation assistance service (NAS). Authorities can operate one, two or three services from the same VTS station.

The type of service provided by VTS in the UK is detailed in Marine Guidance Note (MGN) 401 (M+F) - *Navigation: Vessel Traffic Services (VTS) and Local Port Services (LPS) in the United Kingdom*. With reference to a TOS, the MGN states:

> *This service type provides essential and timely information to assist the onboard decision-making process. It may involve the provision of information, advice and instructions. TOS concerns the forward planning of movements to maintain vessel safety and to achieve efficiency. This service may involve:*
>
> - *The allocation of water space;*
> - *The mandatory reporting of movements;*
> - *The position, identity, intention and destination of vessels;*
> - *Specific information, such as traffic congestion and advice about vessels with VTS sailing / route plans;*
> - *Information such as meteorological and hydrological conditions, notices to mariners, status of aids to navigation;*
> - *Amendments and changes in promulgated information concerning the VTS area such as boundaries, procedures, radio frequencies, reporting points;*
> - *Establishing routes to be followed and speed limits to be observed and such other measures as may be considered necessary and appropriate by the VTS;*
> - *Establishing and operating a system of traffic clearances - all or certain classes of vessels may be required to participate in this service and shall not proceed without clearance;*
> - *Specific information such as traffic congestion and special vessels with limited manoeuvrability which may impose restrictions on the navigation of other vessels or any other potential hindrances.*

SECTION 2 - ANALYSIS

2.1 AIM

The purpose of the analysis is to determine the contributory causes and circumstances of the accident as a basis for making recommendations to prevent similar accidents occurring in the future.

2.2 THE COLLISION

The collision between *Primula Seaways* and *City of Rotterdam* stemmed from the latter being set to the northern side of the Bull Channel by the wind and the tidal stream, followed by the distortion of its pilot's spatial awareness due to a 'relative motion illusion'. The pilot was aware that the car carrier was to the north of its intended track but he perceived the action he was taking to head to the southern side of the buoyed channel was as substantial as the navigational constraints allowed. The pilot was under the impression that the vessel was heading to the south, whereas its heading was not altered significantly beyond the axis of the channel **(Figure 12)** until collision was imminent. Consequently, *City of Rotterdam* remained on the northern side of the buoyed channel and in the path of the inbound *Primula Seaways*.

The bridge teams on board both *City of Rotterdam* and *Primula Seaways* and the VTS operators were appropriately qualified and experienced. However, the interventions made by VTS were not sufficiently robust to make the pilot appreciate that more aggressive action was required to avoid the developing collision situation. Moreover, the absence of any challenge or intervention by *City of Rotterdam*'s bridge team until collision was imminent indicates an over-reliance on the pilot and a breakdown in the bridge resource management on that vessel. In addition, although *Primula Seaways*' bridge team had identified the risk of collision and had taken action to clarify the pilot's intentions, substantial action to avoid the collision was taken too late to be effective.

2.3 RELATIVE MOTION ILLUSION

City of Rotterdam's pilot's spatial awareness was distorted during the 5 minutes preceding the vessel's collision with *Primula Seaways*. During this period, he had been drawn to the bridge window located directly above the starboard VHF radio that was angled off the perpendicular to the vessel's centreline. As a result, the pilot experienced a relative motion illusion in which the vessel appeared to be heading in the direction in which he was looking. The likelihood of the pilot experiencing this illusion has been confirmed through an analysis of the information recorded on the vessel's VDR, simulation (paragraph 1.12), the experiences of pilots who have worked on board either *City of Rotterdam* or *City of St Petersburg* (paragraph 1.10), and the experiences of MAIB inspectors and an ergonomist during pilotage transits in and out of Newcastle, UK (paragraph 1.11).

During the passage along the Bull Channel, *City of Rotterdam*'s pilot had moved between the navigation workstation and the forward conning position as he monitored the vessel's position by eye, radar and ECS. The pilot had recognised that the car carrier had been set to the north of its intended track by the wind. He had also realised that he needed to manoeuvre the vessel further to the south in order to pass *Primula Seaways* port to port. However, between the pilot calling the VTS at 2035 and the collision, it is likely that he would have spent much of the time looking through the window above the starboard VHF radio.

Relative motion illusion deceives a viewer into thinking that the observed view is the direction of travel. In this case, the pilot was looking through the window above the starboard VHF radio, which was 33° off-axis from the centreline. As it was dark, the inward slope of the window removed all objects in the periphery, and there were no visual clues, such as a forward structure or bow tip, the illusion would have been compelling.

Consequently, when during the VHF exchange with *Primula Seaways* at 2037 **(Table 3)** the pilot stated that "*I'm trying to drop her down to the south as much as possible is that you on my port bow?"* and "*I'm trying to bring her as far to the south as the wind will allow me but er* [pause] *yeah I'll keep coming down to the south more positive*", the pilot perceived that the vessel was moving towards the Bull anchorage, which was on a bearing of 138°, whereas the vessel was actually on a heading of 105°. In addition, *Primula Seaways* was on the starboard bow, but from the pilot's perspective the ferry was on the left hand side of the window and would have appeared to have been on the car carrier's port bow. That *Primula Seaways*' second officer erroneously confirmed that the ferry was on the car carrier's port bow would have reinforced the pilot's illusion.

The pilot's illusion remained during the VHF exchange with the VTS watch manager at 2038 **(Table 4)** when he stated "*we're on full speed and heading nearly south but we're going to try and bring her as far down as possible*" and "*I'm on full speed and heading right down south*." At the time, the pilot was looking toward the Bull anchorage on a bearing of 148° whereas *City of Rotterdam* was heading 115° **(Figure 17)**. The pilot had adjusted the vessel's heading from 095° but he clearly was not cognisant of the difference between the heading he had steadied the ship, or a heading that he would typically have steered on passing 4A Clee Ness light float **(Figures 8** and **12)**, and his perceived direction of travel.

As explained in the ergonomist's report **(Annex B)**, the pilot's ability to reconcile the headings he had ordered with his perceived direction of travel was probably hindered by the fact that when navigating predominantly by eye, his egocentric frame of evidence would have been dominant. In short, he would have believed what he saw. It was also probably hindered by the cognitive cost when transferring between egocentric and exocentric frames of reference, and that a relative motion illusion is likely to return after being broken, even with regular reminders.

2.4 OVER-RELIANCE ON THE PILOT

Pilots trade on their reputation as ship handling experts with the local knowledge to ensure a vessel's safe entry and departure from ports. Many masters rely heavily on them, defer to their knowledge and, in many cases, leave them to navigate the vessel without interference or supervision. The collision between the general cargo ship *Skagern* and the container vessel *Samskip Courier*, which resulted in MAIB recommendations (paragraph 1.15.5) is one of many similar accidents where ships' crews' over-reliance on pilots has been a contributing factor.

In this case, that neither *City of Rotterdam*'s master nor the third officer challenged the pilot's actions until seconds before the collision was pivotal to the accident. The master and the pilot had discussed the departure plan before *City of Rotterdam* sailed from Immingham. Both were aware of the likely effect of the wind on the high-sided vessel that was in ballast and the potential for disorientation when conning from a position away from the centreline or the navigation workstation. In such circumstances, the need for the bridge team to remain vigilant and to support, monitor and challenge the pilot's actions was compelling.

However, the master and the third officer left the responsibility for *City of Rotterdam*'s safe passage predominantly to the pilot soon after the vessel entered the main navigation channel. Although the third officer periodically plotted the vessel's position on the paper chart, **Figure 12** shows that these plots were inaccurate. Therefore, it is likely that the third officer's action was solely procedural, and that he was relying more on the ECS than the paper charts to monitor *City of Rotterdam*'s position. Nonetheless, neither he nor the master queried the pilot's course alteration to 095° at 2032 **(Figure 6)**. Had the pilot's actions been closely monitored, it would have been apparent that, as 095° was the intended course to make good **(Figure 12)**, the pilot had not taken into account the wind and tidal stream, which he had warned would have most effect in this area.

The master and the third officer also readily accepted the pilot's corrective actions to regain track, despite the challenges to *City of Rotterdam*'s position and movement by *Primula Seaways* at 2037 **(Table 3)** and by the VTS at 2038 **(Table 4)**. That neither of these external challenges prompted a challenge from the master, even though *City of Rotterdam*'s position in the channel was contrary to the requirements of Rule 9 of the COLREGS, and the vessel was in the way of the inbound ferry, indicates that the bridge team had placed total reliance and trust on the pilot's ability to conn the vessel. Indeed, the master's comment at 2040:02 regarding *Primula Seaways* of "*what's he doing?*" suggests that the master had not kept abreast of the developing situation. Consequently, his direct intervention 14 seconds before the collision was far too late to be effective.

The ability of individuals to challenge decisions not forming part of an agreed plan is a fundamental aspect of bridge resource management, which is included in STCW training requirements. However, it is evident that the principles of such training, which also include the continuous monitoring of a vessel's progress to maintain safe passage, were not followed on this occasion. The applicable requirements of the onboard SMS manual (paragraph 1.6.2) with regard to the master's and third officer's responsibilities when the vessel was under pilotage, were also not met.

2.5 ACTION ON BOARD *PRIMULA SEAWAYS*

Primula Seaways' bridge team noticed that *City of Rotterdam* was on the northern side of the Bull Channel between the South Shoal buoy and 4A Clee Ness light float. The car carrier was on the 'wrong' side of the channel. Therefore, the master's query to the VTS at 2034 **(Table 1)** regarding the car carrier's intended movement was timely and appropriate. The vessels were about 3nm apart and the ferry's speed had been reduced to 16.5kts.

It is apparent from *Primula Seaways'* second officer's VHF call to *City of Rotterdam* at 2037 **(Table 3)** that the ferry's bridge team had continued to monitor *City of Rotterdam* and were concerned that the vessel was still on the northern side of the Bull Channel. However, the pilot assured the second officer that he was manoeuvring the car carrier to the south, an action that the pilot reiterated shortly after being advised by the VTS that *City of Rotterdam* was heading into the Hawke anchorage. Nonetheless, *Primula Seaways*' master remained sufficiently concerned to set the ferry's engines to 'half ahead'.

The simulations of the accident (paragraph 1.11) showed that, when the ferry's speed was reduced at 2038:25, a course alteration to starboard would have caused the ferry to cross *City of Rotterdam*'s bow while an alteration to port would have exacerbated the situation if the pilot manoeuvred the car carrier as stated **(Figures 8** and **18)**. Doubt clearly existed and, as the vessels were only 1nm apart and closing at a speed of 28.5kts, a more substantial reduction in speed was warranted. By the time full starboard helm was applied and the engine was set to 'full astern' at 2039:37, the vessels' closing speed was still 26kts and they were only 0.5nm apart **(Figures 19** and **20)**.

2.6 VTS INTERVENTION

City of Rotterdam's progress in the Bull Channel was closely monitored by the VTS and the vessel's northerly position after it had rounded the South Shoal buoy was quickly detected. The VHF channel 12 operator communicated his concern to the watch manager and the situation continued to be monitored. In the circumstances, the watch manager's assessment that there was sufficient time to correct the situation was appropriate.

Nonetheless, an opportunity to raise concern at the vessel's position with the pilot and to highlight the approach of *Primula Seaways* when the pilot reported on passing 4A Clee Ness light float at 2035 **(Table 2)**, was not taken. Although this was an opportunity missed, particularly as the call from the ferry to the VTS 1 minute earlier **(Table 1)** queried the route taken by *City of Rotterdam*, such a 'soft' challenge was unlikely to have broken the pilot's illusion. The illusion was not even broken by the VTS watch manager's intervention at 2038 **(Table 4)** when he advised the pilot that the vessel was entering the Hawke anchorage.

In hindsight, however, the watch manager's intervention could have been more effective had it been prefixed with a 'warning' message marker and had the watch manager not referred to the pilot by name. A 'warning' message to *City of Rotterdam* would have been more likely to have prompted the master to take more interest and challenge the pilot's actions. It would have also highlighted the VTS's concerns to *Primula Seaways*, which might have prompted an earlier and more substantial speed reduction on board the ferry. By the time the VTS warned *Primula Seaways* of the risk of collision, it was too late for further avoiding action to be taken.

2.7 CONSEQUENCES OF BRIDGE DESIGN

The aerodynamic shape of *City of Rotterdam*'s bow impacted on the design of the vessel's bridge, particularly with regard to the bridge windows. The inward sloping windows were contrary to the requirements of SOLAS V/22 1.9.1, but this was recognised by the shipbuilder. The precaution of moving sources of light away from the windows in order to reduce the likelihood of reflections, met the intent of the regulation, which enabled the PMA to issue exemptions.

However, the bridge shape, the mitigation measures taken to reduce reflections, and the equipment layout had consequences. In particular, although the centreline conning position had a 'commanding view', a close view of the sea surface (IACS

Recommendation 95) and it was possible to sight the azimuth repeater and the rudder angle indicator. However, the propulsion, wind and speed indicators on the deck head in front of the helmsman **(Figure 16)** were set back and were not readable as required by SOLAS V/19.2.5.4.

More significantly, with respect to the requirements of SOLAS IV/6 for radio installations, the VHF radios at the front of the bridge were "*convenient*" to the forward conning position, in that there was easy and unobstructed access to them. However, their location by the off-axis windows did not "*ensure the greatest possible degree of safety*" due to the potential for relative motion illusion. In this case, *City of Rotterdam*'s pilot's relative motion illusion occurred as a result of him having to move away from the centreline window to use the starboard VHF radio.

The MAIB is not aware of relative motion illusion occurring on board other vessels with semi-circular shaped bridges, although these tend to be fitted with integrated navigation systems (paragraph 1.12). Therefore, it is understandable why the potential for the illusion was not foreseen and taken into account during the design of *City of St Petersburg* and *City of Rotterdam*. However, the need to learn from this accident and recognise the potential for the illusion to develop by off-axis windows in future designs is compelling. That *City of Rotterdam* and *City of St Petersburg* had operated for 5 years without navigational accidents, was largely due to the measures adopted on board the vessels such as the cord on the centreline window, the extended lead on the VHF radio (*City of St Petersburg*) and the coping strategies adopted by the ship's crew and by the pilots (paragraph 1.9).

2.8 REGULATION OF INNOVATIVE DESIGNS

Innovations in ship and bridge design have the potential to make positive contributions to vessel safety and the environment. As such, they are to be encouraged, and it is inevitable that exemptions to particular criteria will be necessary to enable unconventional designs to enter into service. However, the circumstances of this case and the departures from good practice highlighted in the ergonomic assessment (paragraph 1.10 and **Annex B**) indicate that a stricter adherence to the ergonomic principles of bridge design detailed in SOLAS V/15 could reduce the likelihood of human error.

IACS Recommendation 95 (paragraph 1.14.2) provides important guidance on the implementation of international regulations and instruments related to bridge design. It also explains key terms such as 'conning position', which are referred to in SOLAS IV and SOLAS V but are not defined. However, like the guidelines in MSC.Circ. 982 (paragraph 1.14.1), the recommendations are not binding. Consequently, the ergonomic principles detailed in SOLAS V/15 are open to interpretation.

The IMO's MSC decided in 2004 that the development of a UI that could be used to demonstrate compliance with SOLAS V/15 was not necessary. However, the freedom of interpretation and discretion this decision afforded to naval architects in the application of good practice increases the potential for innovative designs to have unintended consequences on human performance. Therefore, the need for an IACS UI on the interpretation of the ergonomic principles of bridge design warrants reconsideration.

SECTION 3 - CONCLUSIONS

3.1 SAFETY ISSUES DIRECTLY CONTRIBUTING TO THE ACCIDENT THAT HAVE BEEN ADDRESSED OR RESULTED IN RECOMMENDATIONS

1. The collision stemmed from *City of Rotterdam* being set to the northern side of the Bull Channel by the wind and the tidal stream followed by the distortion of its pilot's spatial awareness due to a 'relative motion illusion'. [2.2]

2. *City of Rotterdam*'s pilot's relative motion illusion deceived him into thinking that his view from the window above the starboard VHF radio, which was 33° off the vessel's centreline axis, was the vessel's direction of travel. [2.3]

3. As it was dark, the inward slope of the window removed all objects in the pilot's periphery, and there were no visual clues such as a forward structure or bow tip, the illusion would have been compelling. [2.3]

4. The pilot's ability to reconcile the headings he had ordered with his perceived direction of travel was probably hindered by further psychological effects of the relative motion illusion, such as the cognitive costs of transferring between different frames of reference. [2.3]

5. Soon after *City of Rotterdam* entered the main navigation channel, the master and the third officer left the responsibility for the vessel's safe passage predominantly to the pilot. [2.4]

6. *City of Rotterdam*'s master and third officer did not challenge the pilot's actions despite concern at the vessel's position being expressed by *Primula Seaways* and the VTS. The master's intervention, 14 seconds before the collision, was far too late to be effective. [2.4]

7. *City of Rotterdam*'s bridge team's over reliance on the pilot, and its lack of effective monitoring of the vessel's progress, were evidence of ineffective bridge resource management. [2.4]

8. Although *Primula Seaways*' engines were reduced to 'half ahead' 2 minutes before the collision, a more substantial reduction of speed was warranted in view of the doubt concerning *City of Rotterdam*'s movement. [2.5]

9. The VTS intervention at 2038 could have been more effective in alerting the bridge teams on board both vessels to its concerns had it been prefixed with a 'warning' message marker and it had not referred to the pilot by name. [2.6]

10. The location of the VHF radios by the off-axis windows on board *City of Rotterdam* increased the potential for relative motion illusion. [2.7]

11. The potential for relative motion illusion was unforeseen and therefore not taken into account during the design of *City of St Petersburg* and *City of Rotterdam*. [2.7]

12. Stricter adherence to the ergonomic principles of bridge design detailed in SOLAS V/15 would reduce the likelihood of human error. Therefore, the need for an IACS UI on the interpretation of the ergonomic principles of bridge design warrants reconsideration. [2.8]

SECTION 4 - ACTION TAKEN

4.1 MAIB ACTIONS

On 11 February 2016, the MAIB recommended Fairmont Shipping (Canada) Ltd to:

2016/104 Take action to reduce the likelihood of distorted spatial awareness on the bridges of *City of Rotterdam* and *City of St Petersburg*, taking into account, inter alia:

- The importance of emphasising to crew and embarked pilots the risk of spatial distortion occurring on these bridges.
- The increased risk of distorted spatial awareness when standing away from the centreline or a navigation station, including when using the fixed VHF radios.
- The need to monitor pilots' actions at all times and to challenge when appropriate.

4.2 ACTIONS TAKEN BY OTHER ORGANISATIONS

4.2.1 Fairmont Shipping (Canada) Ltd

Fairmont Shipping (Canada) Ltd in response to MAIB recommendation 2016/04 has:

- Installed a bow tip marker on the centreline immediately ahead of the centre bridge window to provide a reference point from any position on the bridge.
- Increased the length of the VHF handset wires to enable the radios to be used from the forward centreline conning position.
- Posted notices by the forward VHF radios, on the bridge deck head and in the chart room warning of relative motion illusion. The notices state:

• CAUTION
• ERRORS IN JUDGEMENT FROM 'RELATIVE MOTION ILLUSION' MAY OCCUR IF OBJECTS ARE VIEWED THROUGH SIDE WINDOWS ON THE CURVED SECTION OF THIS WHEELHOUSE. • 'RELATIVE MOTION ILLUSION' IS A PHENOMENON IN WHICH OBJECTS APPEAR TO MOVE AS THOUGH THE SHIP WAS HEADING IN THE DIRECTION OF VIEW THROUGH THE WINDOW. IT IS MORE LIKELY TO OCCUR DURING PERIODS OF DARKNESS

- Incorporated into the safety management system and the pilot information card references to spatial awareness and relative motion illusion.

The ship manager also conducted an investigation into the collision. The investigation report **(Annex C)** identified measures to prevent a similar accident in the future. These included additional internal audits to monitor bridge teams during pilotage and coastal navigation, and refresher bridge resource management training for all masters and deck officers.

4.2.2 DFDS A/S

DFDS A/S has:

- Re-affirmed to its masters and navigating officers the importance of good bridge resource management and continued to enrol them on its MCA approved 'Maritime Resource Management Course'.

4.2.3 Associated British Ports

ABP has:

- Reassessed the pilot's competency and re-authorised him for pilotage duties.
- Reassessed and re-authorised Primula Seaways' master's PEC.
- Reviewed its risk assessment for traffic in the vicinity of the Clee Ness VTS reporting point.
- Reinforced the importance of using message markers when conducting VTS communications.

SECTION 5 - RECOMMENDATIONS

Bureau Veritas is recommended to:

2017/104 Propose to the International Association of Classification Societies that Recommendation 95 "Recommendation for the Application of SOLAS Regulation V/15 Bridge Design, Equipment Arrangement and Procedures (BDEAP)" is revised to:

- Improve the definition of conning position(s), taking into account the equipment that is required to be at, viewable from, and convenient to the position.
- Raise the awareness of the dangers of navigating from off-axis windows and the effect of relative motion illusion.

2017/105 Propose to the International Association of Classification Societies that the status of Recommendation 95 is raised to a Unified Interpretation.

Safety recommendations shall in no case create a presumption of blame or liability

Marine Accident Report

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