Accident Investigation Board Norway

Issued October 2010

REPORT Mar 2010/10

REPORT ON INVESTIGATION OF MARINE ACCIDENT SUNDSTRAUM IMO NO 8920567 AND KAPITAN LUS IMO NO 9077551 COLLISION IN ØRESUND 3 JULY 2009

Transport Malta

Danish Maritime Authority

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Photo of ferry on the Norwegian west coast: Bente Amandussen

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NOTIFICATION OF THE ACCIDENT

At 1316 hours local time on 3 July 2009, the Norwegian vessel *Sundstraum* and the Malta-registered vessel *Kapitan Lus* collided in the Drogden Channel off Copenhagen. The accident was reported to the Sound vessel traffic service (Sound VTS), which covers the area in question. The vessel traffic service notified the Danish authorities.

The Division for Investigation of Maritime Accidents of the Danish Maritime Authority (DMA) notified the Accident Investigation Board Norway (AIBN) and the Malta Maritime Authority (MMA[1]) of the accident. The DMA immediately started investigations on board both vessels. During the evening of 3 July, it was agreed by Denmark as coastal state and Norway and Malta as flag states that the flag states should start investigations on board their respective ships. The vessels and their operators were informed, and representatives of AIBN and MMA went on board *Sundstraum* and *Kapitan Lus* on Saturday, 4 July 2009.

On Monday 6 July all parties agreed that a joint investigation should be launched with Norway as lead investigating state and Denmark and Malta as substantially interested states. It was also decided that the investigation should be carried out pursuant to Chapter 18 of the Norwegian Maritime Code and the International Maritime Organization's guidelines for conducting marine accident investigations.

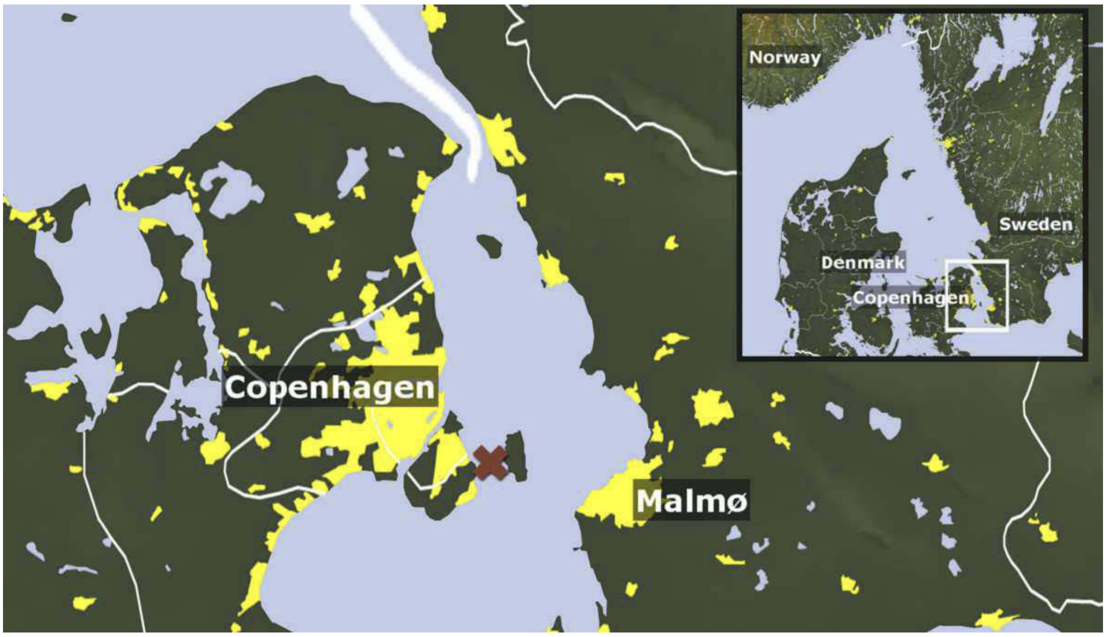


Figure 1: Map of the accident site.

[1] As from 01 January 2010, Transport Malta assumes the functions previously exercised by the Malta Maritime Authority. Transport Malta is the Authority for Transport in Malta set up by Act XV of 2009

SUMMARY

At 1316 hours local time (LT) on 3 July 2009, the Norwegian vessel *Sundstraum* and the Malta-registered vessel *Kapitan Lus* collided in the Drogden Channel off Copenhagen. *Sundstraum* was on route from Tjelbergodden in Norway to Stettin in Poland with a cargo of 3707 tonnes of methanol. The vessel was southbound in the Drogden Channel, with the officer of the watch manning the bridge. *Kapitan Lus* was on its way from St Petersburg in Russia to Le Havre in France with a cargo of 4193 tonnes of aluminium and 182 tonnes of uranium oxide. The vessel was northbound in Drogden and the bridge crew consisted of the Master, the officer of the watch, a Danish pilot and the helmsman. There was good visibility and no wind or seas worth mentioning in the area.

At about 1310 hours LT, the *Sundstraum* began to make a number of course changes to both starboard and port (oscillating movements) which just over 6 minutes later ended in a collision with *Kapitan Lus* at the northern end of the Drogden Channel. There were no injuries to personnel or damage to the environment. The *Sundstraum* only sustained minor damage, while the *Kapitan Lus* got water ingress into a cargo hold and developed a list. Both vessels were detained by the Danish authorities until the necessary investigations had been made and the necessary steps taken to safeguard Danish interests in assuring a safe onward passage for both vessels.

It was decided in a consultation between Denmark as coastal state and Norway and Malta as flag states to conduct a joint investigation with Norway as lead investigating state. The investigation was carried out pursuant to Chapter 18 of the Norwegian Maritime Code and the International Maritime Organization's guidelines for investigating marine accidents.

Interviews were conducted with the personnel involved and inspections made on board both vessels. Data from the *Sundstraum*'s Simplified Voyage Data Recorder (S-VDR) were downloaded after the accident. In addition data and information were obtained from the autopilot supplier, the rudder manufacturer and the vessel traffic service. Simulations were also performed of *Sundstraum*'s directional stability and movements at the time of the accident.

In light of the above, the vessels' movements in the period prior to the collision, the limited time and space for manoeuvre that was available, the communication between the vessels, and the manning of the bridges of the vessels, the analysis is focused on circumstances related to *Sundstraum* as this is expected to be of greatest benefit to maritime safety.

The investigation did not reveal any features of the steering or technical faults in the steering gear on board the *Sundstraum* which explain the oscillatory movement pattern that developed. However, weaknesses were revealed with respect to the operator's framework conditions for safe operation (safety management system). Two safety recommendations are made in this connection. The one concerns use of a pilot in Øresund, the other concerns practical training of the crew for scenarios that involve problems with and/or loss of steering.

1. FACTUAL INFORMATION

1.1 Details of the vessels and the accident

Details of the vessels

Name	:	**Sundstraum**	**Kapitan Lus**
Call sign	:	LIFL3	9HXI4
IMO number	:	8920567	9077551
Owner:	:	Utkilen Shipping Bergen, Norway	Shipline Two Ltd Floriana, Malta
Operator (ISM)	:	Fleet Management Europe Ltd, London	Northern Shipping Company (NSC) Arkhangelsk, Russia
Ship type	:	Chemical tanker	Dry cargo
Year / place built	:	1993 / Aarhus, Denmark	1994/ Russia
Flag state	:	Norway (NIS)	Malta
Classification society:		Det Norske Veritas	Russian Maritime Register of Shipping
Periodic inspection incl. ISM	:	DNV	Russian Maritime Register of Shipping
Home port	:	Bergen	Valletta
Hull material	:	Steel	Steel
Length o.a.	:	96.25 metres	98.20 metres
Breadth	:	15.10 metres	17.60 metres
Gross tonnage	:	3205	4998
Engine power/type	:	3000 kW / MaK 9M453C	3356 kW/6DKPH35
Propellor	:	Right-handed controllable pitch	Right-handed controllable pitch
Rudder	:	Becker	Spade rudder
Bow thruster	:	1 pc 326 KW	1 pc 360kW

Figure 2: Sundstraum.
Photo: Ole Jacob Dingen

Kapitan Lus.
Photo: DMA

Details of the accident

Time and date	:	1316 local time (LT), 3 July 2009
Place	:	Drogden Channel. Øresund, Denmark
Persons on board	:	12 crew members on board *Sundstraum* 13 crew members and a pilot on board *Kapitan Lus*
Injuries/fatalities		None
Damage to ships		*Sundstraum*: Limited damage to forepeak tank and minor damage to the bow section bulwark reinforcement plate on the starboard side. *Kapitan Lus*: Damage to the wing tank and hold no. 3, below the water-line, with subsequent ingress of water into hold no. 3.

1.2 The course of events

Sundstraum was on route from Tjelbergodden in Norway to Stettin in Poland with a cargo of 3707 tonnes of methanol. The crew had planned to sail into the Baltic Sea through the Øresund Strait. At the southern end of the strait, the crew planned to sail through the Drogden Channel, which is a dredged channel off Copenhagen. The vessel approached Drogden from the north on the morning of Friday 3 July 2009.

At the same time, the Malta-registered vessel *Kapitan Lus* was approaching Drogden from the south. *Kapitan Lus* was on its way from St Petersburg in Russia to Le Havre in France, via Rotterdam in the Netherlands, with a cargo of 4193 tonnes of aluminium and 182 tonnes of uranium oxide.

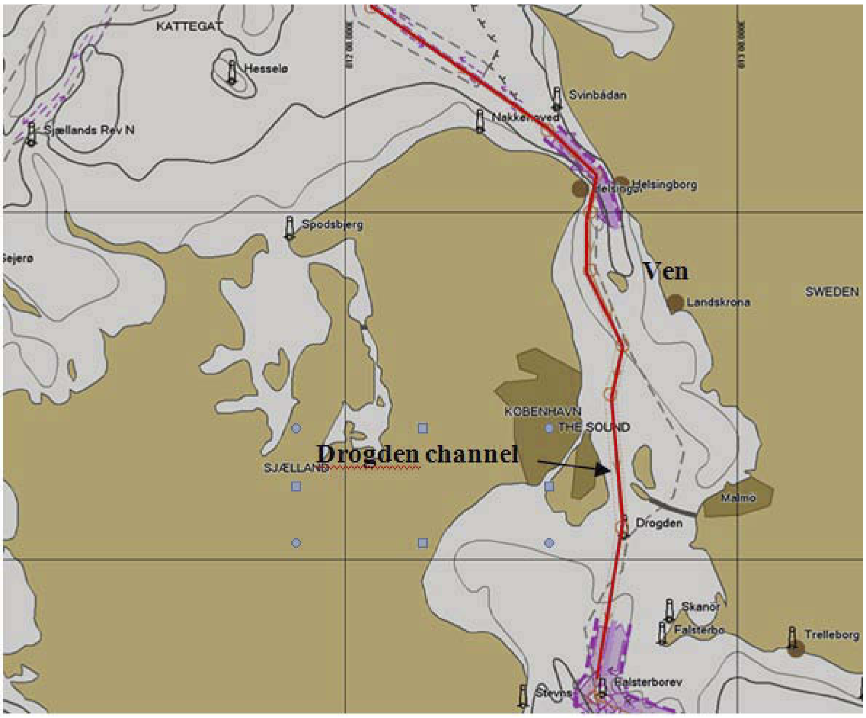


Figure 3: Section of map showing Sundstraum's planned southbound route (red) through the Øresund Strait.

Sundstraum's second officer took over the navigation watch at 1000 hours[2] UTC (1200 hours local time) when the ship was south-west of the island of Ven in Øresund Strait. At 1010 hours he reported information about the ship and planned passage to the vessel traffic service for the area (Sound VTS) and continued sailing southbound towards the Drogden Channel. At 1030 hours *Kapitan Lus* took on board at pilot at Drogden Lighthouse south of the channel, and set a northbound course at a speed of 8 knots. At approximately 1110 hours *Sundstraum* approached the northern end of the channel. The vessel had a speed of about 12 knots. At this time, *Kapitan Lus* was just south of buoy no. 6 (see Figure 4).

There was good visibility and almost no wind. The current was flowing southwards through the channel at about 0.4 knots. After *Sundstraum* had passed a meeting ship just after 1100 hours, the traffic situation at the northern end of the channel was clear, with the exception of some small leisure craft.

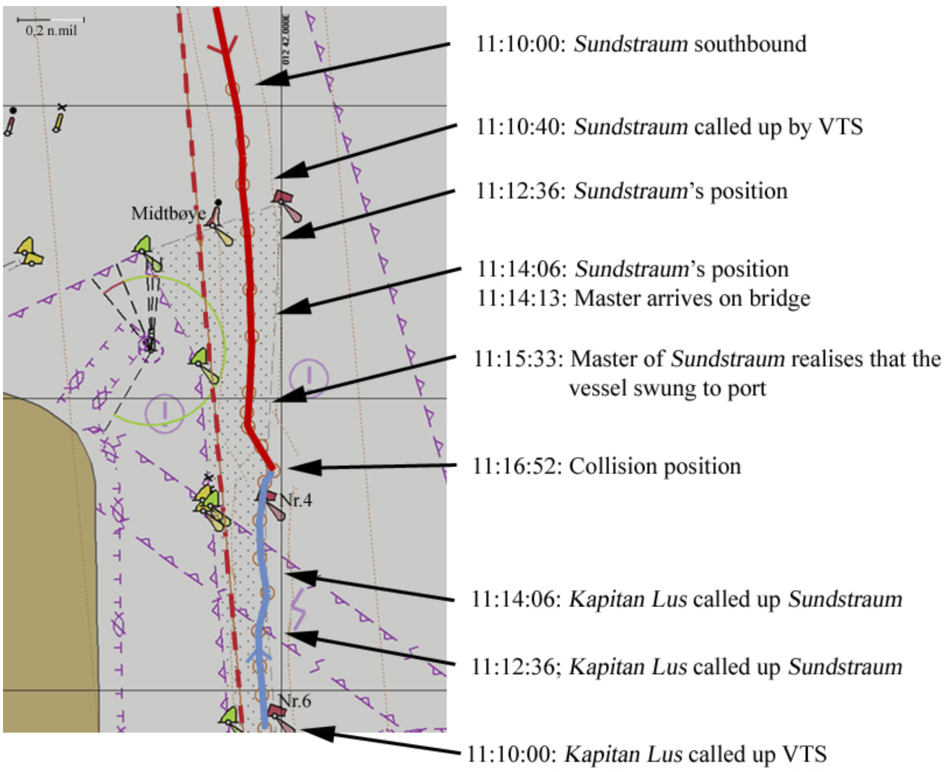


Figure 4: Map section showing a sketch of Sundstraum's passage (red solid line) and Kapitan Lus' passage (blue solid line), and Sundstraum's planned passage (red broken line).

[2] All times in UTC, based on the times from *Sundstraum*'s S-VDR and compared with the time from Sound VTS.

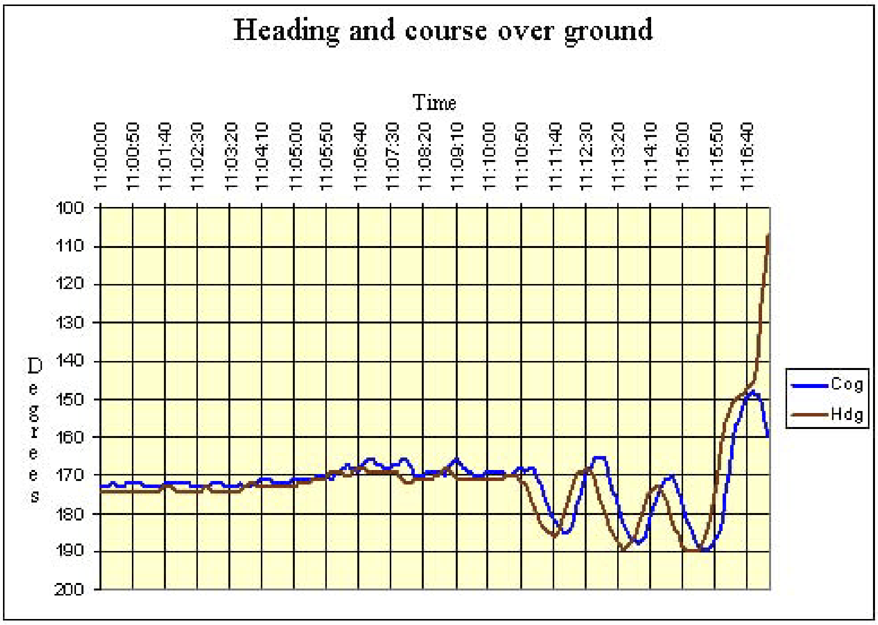


Figure 5: Diagram showing Sundstraum's course over ground (Cog) and heading (Hdg) in the last few minutes before the collision. The diagram is based on information from Sundstraum's S-VDR.

When *Kapitan Lus* was between buoys 8 and 6 at about 1105 hours, the Master on board noticed that *Sundstraum*, which was heading south, was in the eastern part of the waterway down towards the Drogden Channel. The Master drew the pilot's attention to this. On the bridge of *Kapitan Lus* were a pilot, the ship's Master, the officer of the watch and a helmsman.

At 1110 hours *Sundstraum* was located a little to the north of the Drogden Channel. The ship was sailing on the east side of the waterway with course east of the central buoy which indicates the northern boundary of the fairway (see Figure 4). At this time *Kapitan Lus* was 2.2 nautical miles south of *Sundstraum* and just south of buoy no. 6. When *Kapitan Lus* passed buoy no. 6, the pilot called the vessel traffic service and asked for identification of the southbound tanker that was approaching.

At 11.10.30 the vessel traffic service identified the vessel in question as *Sundstraum*. Immediately afterwards, the vessel traffic service called up *Sundstraum* and pointed out that it was on the wrong side of the central buoy.

The officer of the watch on *Sundstraum*, who was alone on the bridge, answered the call from the vessel traffic service and stated that he had moved to port in order to pass a leisure craft that was crossing the waterway from *Sundstraum*'s port side. The pilot on *Kapitan Lus* confirmed that there was a light leisure craft in the area at the time in question. At this time *Sundstraum* was steering 171°. At the same time as the call from the vessel traffic service was answered, *Sundstraum* started turning to starboard to a new course of 186°. After this turn to starboard, the vessel maintained the course briefly before again turning to port, ending up with a course of 168° (see Figure 5). The officer of the watch on *Sundstraum* now began calling the Master in his cabin via the telephone/PA system.

At 11:12:36 *Kapitan Lus* called up *Sundstraum* and requested that the vessels should pass port to port. The officer of the watch on *Sundstraum* answered the call and at the same time the vessel again turned to starboard to 187 before again turning back to port.

This turn to port was observed by *Kapitan Lus* and they again called up *Sundstraum*, 11.14.06, and asked *Sundstraum* to come starboard over in order to make a port to port passing.

At 11.14.13 *Sundstraum*'s Master arrived on the bridge. At this time *Sundstraum* had turned to port to 173 degrees, and was 0.81 nautical miles from *Kapitan Lus*. Shortly afterwards, *Sundstraum* again turned to starboard and was set for a port to port passing with *Kapitan Lus*. When the Master arrived on the bridge, he observed that *Sundstraum* was on the wrong side of the fairway. The officer of the watch informed him that the ship was yawing. The Master understood the officer to say that he had had to give way to a yacht, and was therefore on the wrong side of the fairway. The Master observed that *Sundstraum* was heading to starboard and towards the correct side of the fairway. As a result, the Master and the officer became caught up in discussions of how they should navigate through Drogden. This discussion was in progress when *Sundstraum* for the last time turned to port (11.15.30).

At 11.15.10 the situation, as viewed from *Kapitan Lus*' side, was again clarified, and the intention was for a port to port passing with a closest point of approach of 0.07 nautical mile (130 m) (see Figure 6). Nevertheless, the pilot and Master on board *Kapitan Lus* were uncertain of *Sundstraum*'s movements, and the pilot ordered the engine reduced to slow ahead and placed the vessel as far to starboard in the fairway as he could.

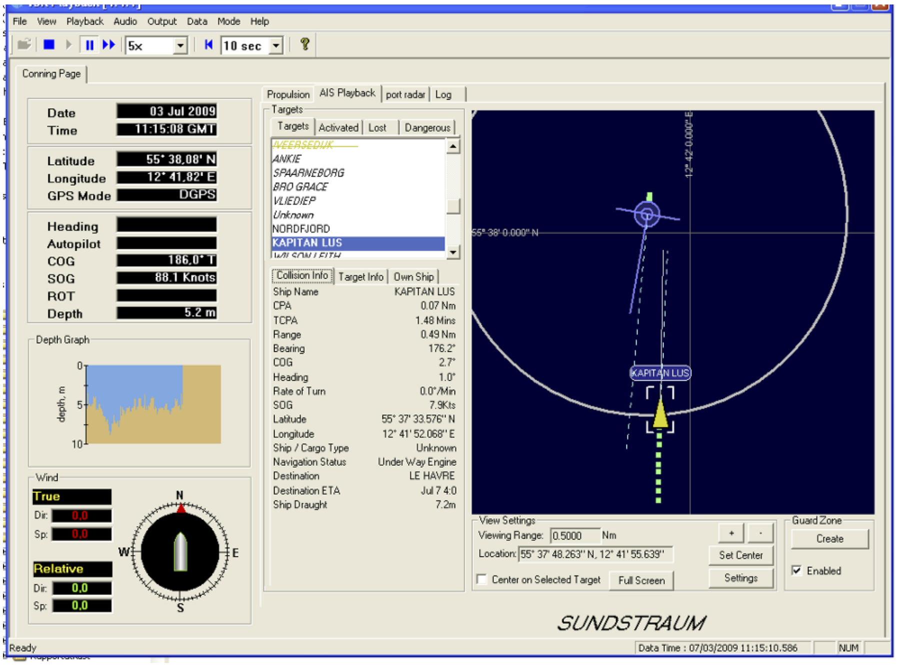


Figure 6: Picture from Sundstraum's S-VDR showing the situation at 11.15.10. The distance between the vessels at this time was 0.49 nautical miles (907 metres).

At 11.15.30 *Sundstraum* again began to turn to port. The vessel was then 0.37 nautical miles from *Kapitan Lus*. The Master of *Sundstraum* became aware of the situation, and he ordered manual steering and told the 2nd officer to put on the lights that showed that the vessel was not under command. Dialogues with those involved have not made it clear whether control actually was switched from autopilot to manual steering. The Master tried to turn the rudder to starboard with the joystick (see Figure 11), but observed that the vessel continued to turn to port. He also observed on the rudder indicator that the rudder did not move.

At the same time, the pilot on *Kapitan Lus* ordered the rudder hard to starboard and full speed ahead in order to turn the vessel away from *Sundstraum*, at the same time as 5 short blasts were given on the ship's whistle.

At 11.16.03 *Sundstraum*'s Master went to the VHF radio at the rear of the bridge and announced that the vessel was not under command. He then returned to the manoeuvre console and put the engine into reverse. The distance to *Kapitan Lus* was now 0.21 nautical miles (see Figure 7). At this time the pilot on *Kapitan Lus* realised that his turn to starboard could not prevent collision with *Sundstraum.* He then ordered the engine put hard astern in the hope that the *Sundstraum* would pass in front. The pilot soon observed that Sundstraum would not pass in front of Kapitan Lus. He then ordered full ahead and the rudder hard to port to make the vessels stern turning away from Sundstraum to reduce the impactforce of the collision.

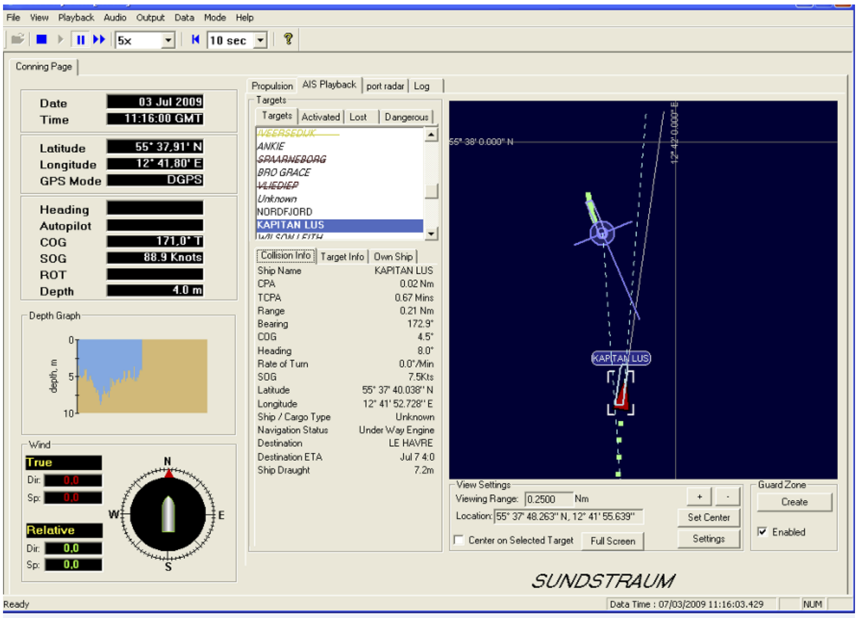


Figure 7: The situation at 11.16.03.

The Master of *Sundstraum* considered that a collision was unavoidable, and decided at this point that he would try to turn the vessel further to port in order to reduce the angle of collision. He tried to turn to port with the aid of the joystick, but the vessel did not react. *Sundstraum* and *Kapitan Lus* collided at 11.16.52. (See figure 8).

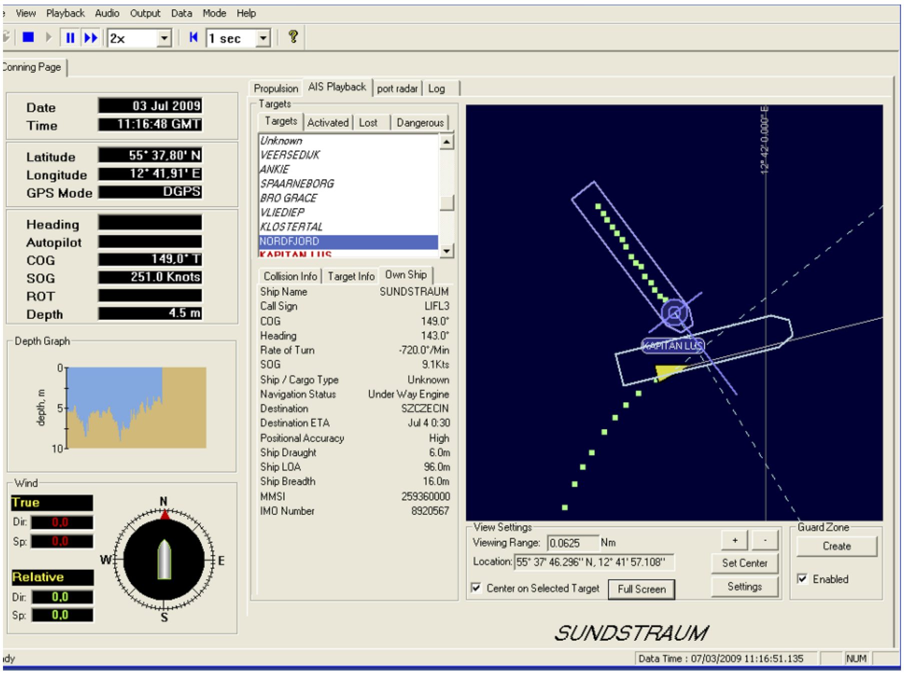


Figure 8: The situation just before the collision, 11.16.51. Sundstraum's speed had now been reduced to 9.1 knots.

After the collision, *Sundstraum* was detained by the Danish maritime authorities and anchored up in the area where the collision had taken place. *Sundstraum* had minor damage to the bows, including leakage into the forepeak tank and somewhat depressed steel in the bow section bulwark reinforcement plate on the starboard side. The vessel remained lying there until all necessary investigations had been completed and the Danish authorities released the vessel. The vessel left the area on the evening of 5 July and continued its voyage to Stettin.

Kapitan Lus sustained damage below the waterline to a wing tank on the starboard side and hold no. 3. The damage caused water ingress into hold no. 3 and the vessel rapidly developed a 10° list to port. *Kapitan Lus* was detained by the Danish maritime authorities and anchored at 1308 hours. The vessel docked in Copenhagen early in the morning of 4 July for unloading and the necessary temporary repairs. On 21 July the vessel was declared temporarily repaired and was given necessary sailing permit by the classification society. The Danish maritime authorities released the vessel and it left Copenhagen on 22 July 2009.

1.3 Sundstraum (shipowner, operator, vessel and crew)

1.3.1 Shipowner

MT Sundstraum is owned by Utkilen Shipping AS of Bergen, Norway. Operation and ISM responsibility for the vessel were outsourced to an operator company.

1.3.2 Operator (responsible for ISM)

Sundstraum was operated by Fleet Management Ltd, Hong Kong through their branch office Fleet Management Europe Ltd, London, UK (FMEL). FMEL operates a large fleet worldwide, including 48 chemical/product tankers. The Accident Investigation Board Norway has made the following summary, based on the company's website:

"The company's core area is providing ship operations such as technical operation, crew, consulting services, insurance, inspection and follow-up of newbuildings. The company's primary function is to provide shipowners with safe ship operation and optimal cost-effective performance. A great deal of emphasis is given to ship board maintenance by fully qualified and efficient crew. To achieve this, the shipping company has a well trained crew on board, qualified under the STCW Convention[3], backed up by a professional shore-based staff.

Fleet Management has established 8 manning offices, 6 located in India, 1 in the Philippines and 1 in China. Over 70% of the crews are recruited from India. FMEL has established a training institute in Mumbai, India, where short refresher and familiarization courses are held for non-certified crew, deck officers and engineers. The training institute is also equipped with a complete ship simulator for navigation and engine control room training".

1.3.3 The vessel

Sundstraum was built in 1993 at Århus Flydedok in Denmark, and has a length of 96.25 m. The ship has 13 stainless steel tanks with a total cargo capacity of 4885 m^3 and a deadweight tonnage of 4737 tonnes. *Sundstraum* is equipped with a MaK 3000 kW main engine connected to a right-handed controllable pitch propeller. The vessel is also equipped with a Becker[4] rudder and a 326 kW bow thruster. On leaving Tjelbergodden, the vessel had an aft draught of 6.0 metres and a fore draught of 5.6 metres.

Figure 9: Bridge layout on Sundstraum.

The vessel has a traditional bridge concept with a centrally located manoeuvre console. The manoeuvre console has an autopilot, manual steering, emergency steering, rudder indicator, controls for both the main engine and the bow thruster, echo sounder, internal

[3] The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers.
[4] Rudder with an extra hinged flap to increase the rudder power. When the main rudder is turned to the side, the flap turns so that the angle of the flap becomes twice as large as the angle of the main rudder.

and external communications systems. On the port side of the manoeuvre console are a Maris Ecdis 900 and an Atlas 1000 (x-band) Arpa radar system. On the starboard side of the console is an Atlas 1000 (s-band) radar system with Arpa. In the vessel's chart room are a Furuno DGSP/GPS and a Maris Ecdis 900. Two manoeuvre consoles that cover the rudder and engine controls are located on the port and starboard sides, respectively.

Figure 10: View ahead from the central manoeuvre console.

All the ship's statuatory and classification certificates were valid at the time of the accident.

Steering gear and rudder

Sundstraum is equipped with Rolls Royce/Frydenbø HS 60 D steering gear and a Becker rudder. The Accident Investigation Board has reviewed the ship's classification history with respect to the steering gear and rudder, and observes that there have previously been cases where faults of functioning have been found, but that the faults have been corrected and the equipment tested and found to be in order.

Inspection of the steering gear after the accident

As faulty steering gear was one possible cause of the collision, the vessel was detained by the Danish maritime authorities. A surveyor from the classification society arrived the vessel on the evening of 3 July and carried out an inspection of the steering gear without finding any faults. On 5 July a service technician came from the manufacturer of the steering gear and made a technical and operational review of the ship's steering gear. The review involved testing the steering gear, pumps and feedback units locally. The switches for the rudder reaction limit and the electrical steering components were tested. Alarms and steering controls were also tested. No faults or deficiencies were found in the ship's steering systems, and the service man's conclusion was that the system was well installed and well maintained.

Autopilot

Sundstraum is equipped with a Raytheon/Anschutz PilotStar D autopilot. Pilot Star D consists of a main unit located in the manoeuvre console centrally on the bridge. Coupled to this are 3 joysticks for manual control: one joystick by the central unit and one at each of the manoeuvring positions on the port and starboard sides of the ship's bridge. In the same way as with the steering gear, the Accident Investigation Board has reviewed the ship's classification history with respect to the autopilot and found that there have previously been cases where faults of functioning have been found, but that the faults have been corrected and the equipment tested and founded to be in order.

Figure 11: Autopilot located on the central manoeuvring console. A joystick can be seen at the right in the picture. A switch for changing from normal to emergency steering and buttons for emergency steering can be seen just above the autopilot consol.

The normal manual steering is linked to the autopilot and located on the right side of the panel (see Figure 11). To change from autopilot steering to manual steering, the button on the right on the panel on the right must be pressed. The switch from autopilot to manual steering is marked by three short, distinct peeps. As long as the ship is set on autopilot steering, movement of the manual joystick will not result in a change of turn. There are two ways of changing the autopilot set heading: either by turning the round knob on the autopilot panel, or by using the two arrows located next to this round knob. The arrows have two functions: pressing once will change the set heading by 1°, while holding the arrow down will change the heading by 5° (see Figure 12).

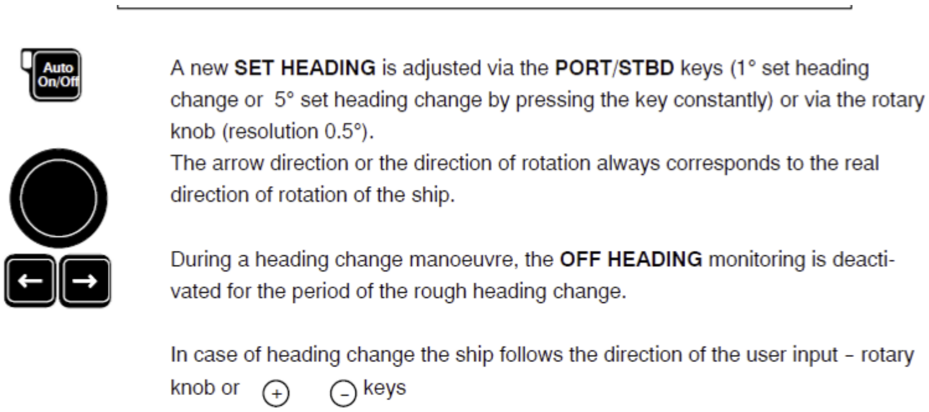


Figure 12: Excerpt from the autopilot user instructions which describe how to change the autopilot set heading.

The autopilot settings at the time of the accident were as follows[5]:

Yawing:	1
Rudder limit:	5
ROT/Min:	40
Counter Rudder:	5
Speed:	15
Off-course:	10

Inspection of the autopilot after the accident

No systematic inspection has been made of the autopilot and its functioning since the accident. According to the reading of the vessel's movements from the S-VDR and according to the crew on board, the ship was steering normally before the accident. According to the operator company, the autopilot also functioned without problems after the accident.

Other possibilities for steering the ship

There are also other possibilities for steering *Sundstraum* besides the autopilot and manual steering. The ship's emergency steering is located just above the autopilot console and includes buttons for activating and performing emergency steering. A procedure for emergency steering is located adjacent to the controls.

[5] The overview shows the autopilot settings normally made by the ship's navigators. According to the manufacturer, 'Yawing 1' is the normal setting for calm weather where the greatest possible accuracy is required to maintain set heading.
'Rudder limit 5' means that the autopilot's limit for use of the rudder is 5° to each side.
'ROT/Min 40' means that the autopilot must not swing the ship faster than 40° per minute.
'Counter rudder 5' means that the autopilot limit on rudder use to stabilise an oscillatory movement is 5°.
'Speed 15' is manual speed input.
'Off-course 10' means that the autopilot is to trigger an alarm if the difference between set heading and heading exceeds 10°.

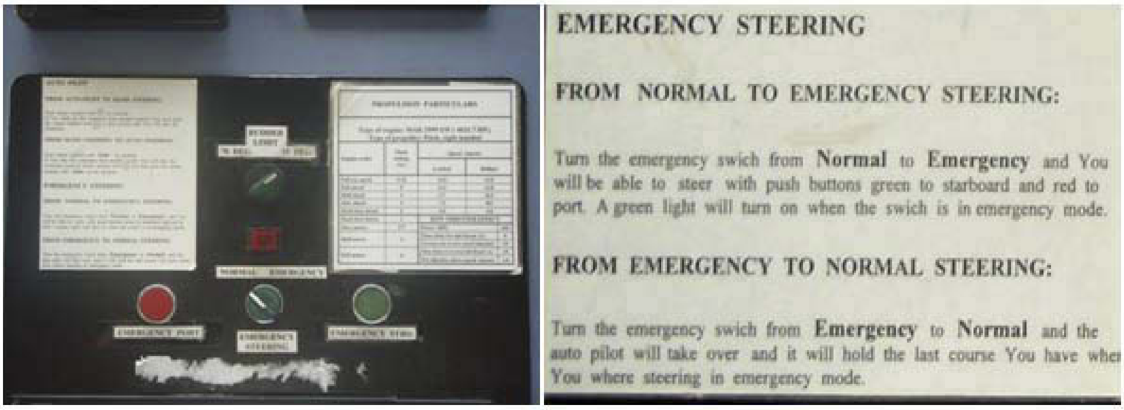


Figure 13: Emergency steering panel and procedure for emergency steering to the left. To the right, enlarged picture of emergency steering procedure.

The vessel is also equipped with the option of performing emergency steering from the steering gear room. Instructions for steering recovery are posted up in connection with the panel for manning the steering gear pumps on the central manoeuvring console on the bridge (see Figure 14).

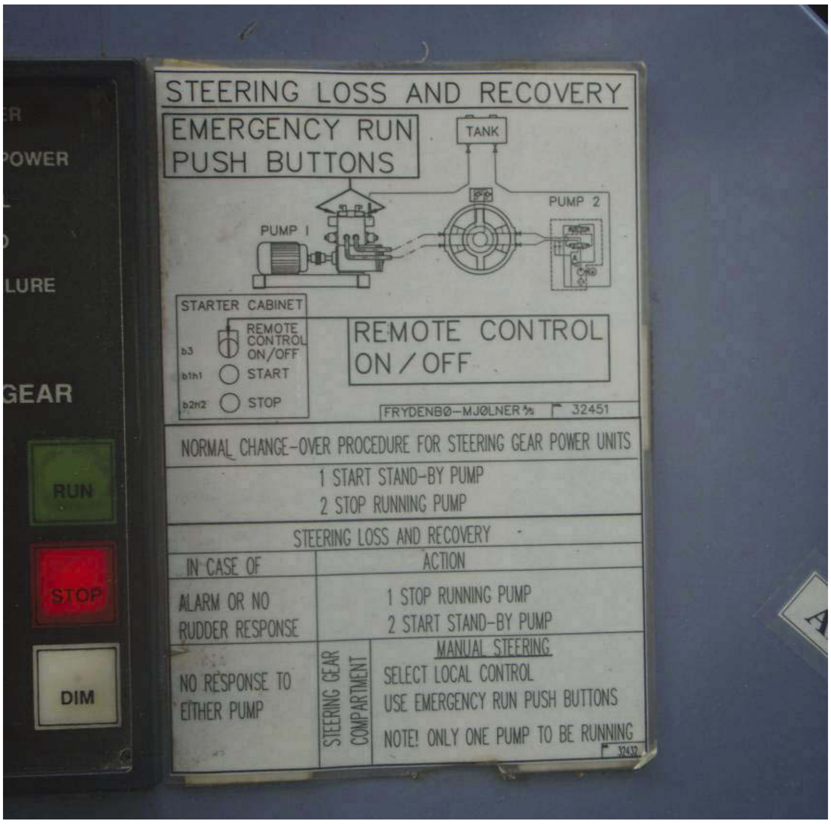


Figure 14: Instructions for handling loss of steering.

1.3.4 <u>The crew</u>

Sundstraum had a crew of 12. The deck crew consisted of a Latvian Master, three officers (one from Pakistan and two from India) and four other deck crew from India. The engineering crew consisted of a chief engineer from India, an engineer from Russia and two other engine room crew from India. The watch schedule on board for the deck department was a traditional 3-watch system with 4-hour watches followed by 8 hours free twice in a 24-hour period. The vessel was classified to sail with an unmanned engine room, which meant that the engine room crew worked largely during the day, and that the chief engineer and engineer take sleeping watches (E0) when the engine room is unmanned.

Sundstraum has used a pilot through Øresund Sound on several occasions during the period that the vessel has been operated by FMEL. During his period on *Sundstraum*, the Master who was on board at the time of the accident has sailed twice before through Øresund, both times without using a pilot.

Two of the crew members who were directly involved in the accident had the following background and responsibilities on board:

The Master was 49, and an experienced seaman. He possessed a master's certificate (Master (FG), valid until 21 February 2011) and had taken a number of STCW courses, including ARPA courses, bridge team management and ship handling courses on a simulator. As Master, he had the overall responsibility for safe navigation of the vessel. He had long experience of chemical tankers and had been sailing as Master since April 2006. His career in FMEL had lasted 6 months, and this was his second contract with the company as Master and his first as Master of the *Sundstraum*. The Master went on board the *Sundstraum* at the end of April 2009. He had previously navigated through Øresund with *Sundstraum* and a number of times with similar vessels and was comfortable about this voyage.

The second officer was the officer of the watch when the collision took place. He was 47 and had a chief mate's certificate (valid until 10 March 2014). The officer had taken several STCW courses including ARPA and a bridge resource management course. He was the vessel's navigation officer, with responsibility for planning the passage, among other things. It was his first voyage on board *Sundstraum* and his first voyage for Fleet Management. He joined the vessel on 25 April 2009. He had previously sailed as third and second officer on various chemical and product tankers, and was familiar with sailing on similar vessels through Øresund.

1.4 Kapitan Lus (shipowner, operator, vessel and crew)

1.4.1 Shipowner

Kapitan Lus is owned by Shipline Two Ltd, Cyprus, and is the shipping company's only vessel.

1.4.2 Operator (responsible for ISM)

The vessel was operated by the Russian company Northern Shipping Company (NSC) with its head office in Arkhangelsk. NSC Arkangelsk was established in 1870 and in July 2009 the company operated a fleet of 9 dry cargo ships ranging from 2200 – 14000 dwt which transport timber, general cargo, bulk cargoes and miscellaneous dangerous goods.

1.4.3 The vessel

Kapitan Lus was built in Russia in 1994 and has a length of 98.20 m. The vessel has a double hull and three holds with a total capacity of 5654 m^3 and a deadweight tonnage of 4678 tonnes. The ship is equipped with a 6DKPH35 main engine with an output of 3356 kW coupled to a right handed controllable pitch propeller. *Kapitan Lus* is equipped with a spade rudder and a 360 kW bow thruster.

Figure 15: Bridge layout.

Kapitan Lus has a traditional bridge layout with a central manoeuvring console. There are two Furuno radars on board, one of them with ARPA function. The vessel also has an electronic chart system (ECS) and Furuno GPS.

All the ship's stauatory and classification certificates were valid at the time of the accident.

1.4.4 The crew

Kapitan Lus had a crew of 13 Russians. The deck crew consisted of the Master, two officers and 4 subordinate deck crewmen. The engineering crew consisted of the chief engineer, two engineers, an electrician and two machine room crew members. During the transit through Drogden, the vessel's bridge was manned by the Master, the officer of the watch, a helmsman and a Danish pilot. All had necessary and valid certificates for their positions. *Kapitan Lus* sails regularly through Øresund, and the crew was used to the passage. The vessel uses a pilot in Øresund when they have a cargo on board which causes them to come under the IMO recommendations for use of a pilot. The vessel does not normally use a pilot when they sail with other types of cargo. Those of the crew members who were directly involved in the accident had the following background and responsibilities on board:

The Master was 59, and very experienced with ships of this type. He had been Master of the ship since 1998 and had been in the company since 1974. He had the overall responsibility for the vessel's navigation.

The second officer, who was the officer of the watch during the northbound passage through Drogden, was 49 and had been on the vessel for 3 months. He had four years of experience as second officer and had been sailing with the company since 1981.

The able seaman was 45, and functioned as helmsman during the passage through Drogden. He had been on board the vessel for 8 years and had been sailing for NSC for 21 years.

In addition to the ship's own crew there was a Danish pilot on the bridge.

The pilot was 37 and had a ship's deck officer Class I and pilot certificate. He had been a pilot in the waterway for two years and had several years of previous experience as officer on container vessels.

1.5 Passage through the Sound

The waterway between Denmark and Sweden, from Helsingborg/Helsingør in the north to Falsterbro in the south, is one of the heavily trafficked sailing routes into and out of the Baltic Sea. UNCLOS defines Øresund as an international strait where all ship's traffic enjoys the right of transit. This means that international agreements are required for restrictions to be placed on ship's traffic. Pursuant to IMO Circular SN.1/Circ. 263, 23 October 2007, ”Routing measures other than traffic separation schemes”, the use of a pilot is recommended through Øresund for laden tankers with a draught of over 7 metres, laden chemical tankers irrespective of size, and vessels with radioactive cargos.

The Drogden dredged channel is 5.5 nautical miles long and 300 m wide and is located south in the strait of Øresund, off Copenhagen, between Amager and Saltholm. The channel is marked with buoys on both sides. The depth of the channel is given as 8 metres at mean sea level. At this sea level, the Danish pilot service can pilot vessels with a draught of up to 7.70 metres through the channel. Drogden is a heavily trafficked area with approximately 30 000 ship passings annually.

Risk analysis
In 2005/2006 Danish and Swedish maritime authorities conducted an extensive analysis of navigation safety in Øresund[6] with the focus on collisions and groundings. The analysis was carried out in line with currently applicable IMO guidelines[7]. The analysis determined the risk in the various areas in Øresund and recommended a number of risk-reducing measures in the light of a cost-benefit analysis. The measures were not detailed with respect to providing a solution, since this was expected to be done later. In the case of several of the outlined measures, no assessment was made of whether these introduced new risks.

The report points to Drogden, Ven, Helsingborg/Helsingør, the Flint Channel and Copenhagen Harbour as critical areas in the Øresund Strait. The report presents the frequency of groundings and collisions in a table (see Figure 16).

In 2007, the Danish and Swedish authorities established a vessel traffic service (Sound VTS) located at Malmö as a measure to reduce the risk of collisions in Drogden and as part of the follow-up of the analysis performed to improve maritime safety in the Øresund area. The vessel traffic service's surveillance of the area is based on AIS and radar data and a voluntary reporting system (SOUNDREP). In connection with reporting to

[6] Navigational safety in the sound between Denmark and Sweden (Øresund), Rambøll Denmark, August 2006.
[7] IMO MSC/Circ.1023 “Guidelines for formal safety assessment (FSA) for use in the IMO rule-making process”

SOUNDREP, all vessels over 300 gross tonnes are urged to report the name of the vessel, call sign, draught and passage plan.

Sound VTS was established in line with currently applicable IMO guidelines[8] and the service the VTS represents comes under the category INS (information service). In accordance with these guidelines, seafarers can expect that a VTS that operates in this category will regularly, or when the VTS-operator finds it necessary, broadcast relevant information regarding safe navigation in the operational area. The crew on board can also get information on request. Safety information from the vessel traffic service may consist of position, identity and the intentions of other ship's traffic in the area, weather conditions, hazards or other factors that could conceivably affect the vessel's passage. In accordance with the agreement between Denmark and Sweden concerning Sound VTS, the purpose of the vessel traffic service is to contribute information to ship's traffic to prevent groundings and collisions and thereby to prevent environmental pollution.

Experience of SOUNDREP operations so far reveals a need for further measures to assist seafarers with information to support decision-making on board.

In spring 2010, the Danish and Swedish maritime authorities sent a proposal to the IMO's Subcommittee on Safety of Navigation that the present voluntary reporting system be made mandatory. The committee accepted the proposal autumn 2010 and final acceptance from the IMO's Maritime Safety Committee is expected Desember 2011. The proposal also implies expanding the geographical area covered by today's system.

In the follow-up of the analysis from 2005/2006 to reduce traffic through today's Drogden Channel, the Danish authorities are also working on an assessment concerning the use of a side channel to the Drogden for vessels with a lesser draught.

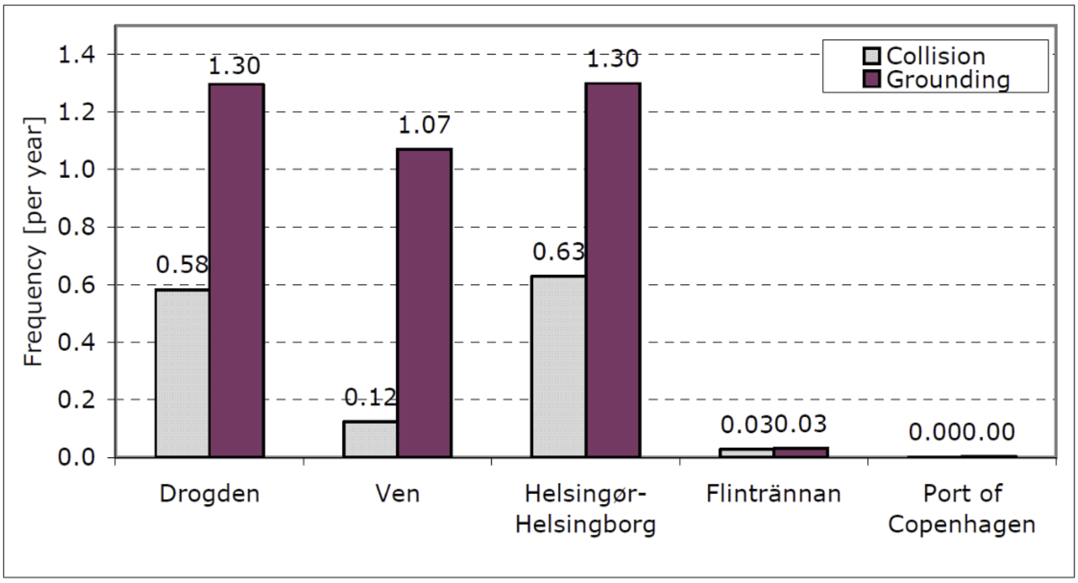


Figure 16: Groundings and collision frequency at different places in Øresund. Source: Navigational safety in the sound between Denmark and Sweden (Øresund), Rambøll Denmark, August 2006.

[8] IMO Resolution A.857(20) Guidelines for vessel traffic services

There are no international or national Danish guidelines for the sailing speeds that should be used through the area, but according to information from an experienced Danish pilot, a passage through the Hollender Deep with a draught of around 6 metres and a speed of 12-13 knots will be normal. When sailing through Drogden with this draught, the normal sailing speed will be 10 knots or less. The speed through the channel is often set depending on how the pilot feels that the ship steers. The pilot singles out the passing of the Dragør threshold and the passing of the immersed tunnel as two critical points with respect to the squat effect (dynamic draught change).

1.6 Squat effect and directional stability

Data on the ship's echo sounder have been extracted from *Sundstraum*'s S-VDR. The echo-sounder's oscillator is located forward, just behind the bow thruster tunnel, and thus reflects the water depth under the ship's bow. In the experience of the today`s operator, the echo-sounder shows the correct depths. Echo-sounder data are shown in Figure 17 and related to the ship's steered courses in the period before the collision.

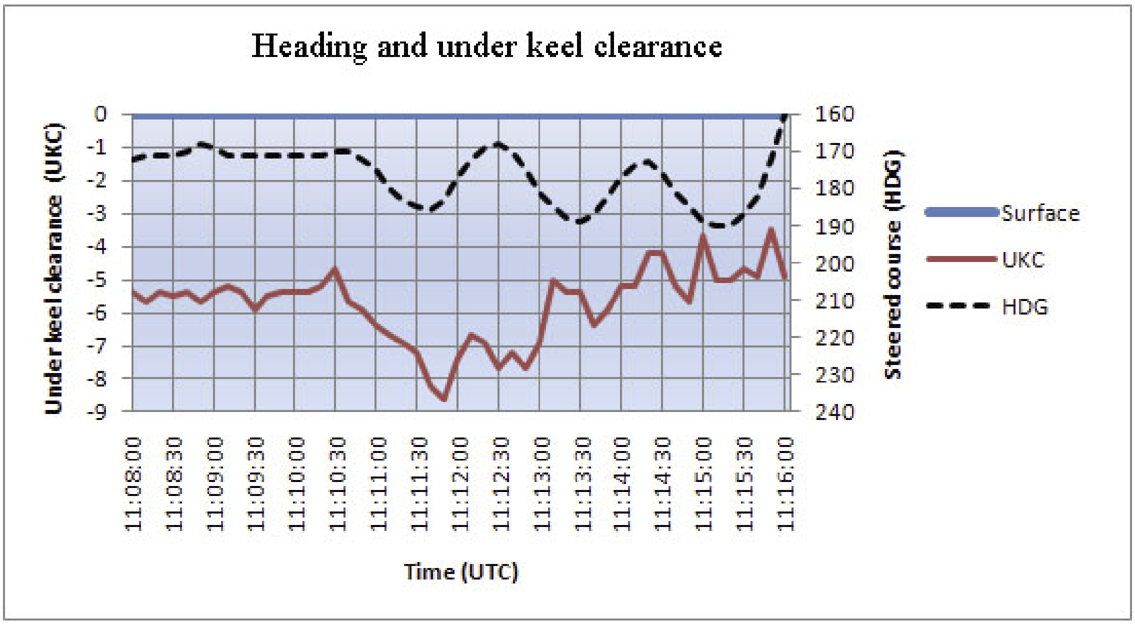


Figure 17: Sketch showing available water depth below the ship's bows and heading in the period 11.08.00 to 11.16.00.

The squat effect is due to pressure changes owing to the relative speeds of ship and water. This effect is heightened when water depth and waterway breadth are restricted. When the ship moves into shallow water, there is less space under the ship for water to pass. This causes a change in the relative speed of ship and water and hence a change in pressure (see Figure 18).

A relationship between squat effect and change in directional stability is described in the literature[9]. In other words, a combination of high speed and little water under the keel may cause a sudden and considerable change in directional stability if a vessel changes trim.

[9] TMR 4220 Naval Hydrodynamics Ship Manoeuvring, Tor Einar Berg, Department of Marine Technology, NTNU, April 2009.

By directional stability is meant the vessel's ability to follow a particular course. A sudden change in directional stability from stable to unstable will have a substantial effect on the vessel's manoeuvring capability. In such cases rudder gain could result in different oscillations from when the vessel is stable. The vessel would therefore react differently to a rudder command from what is expected.

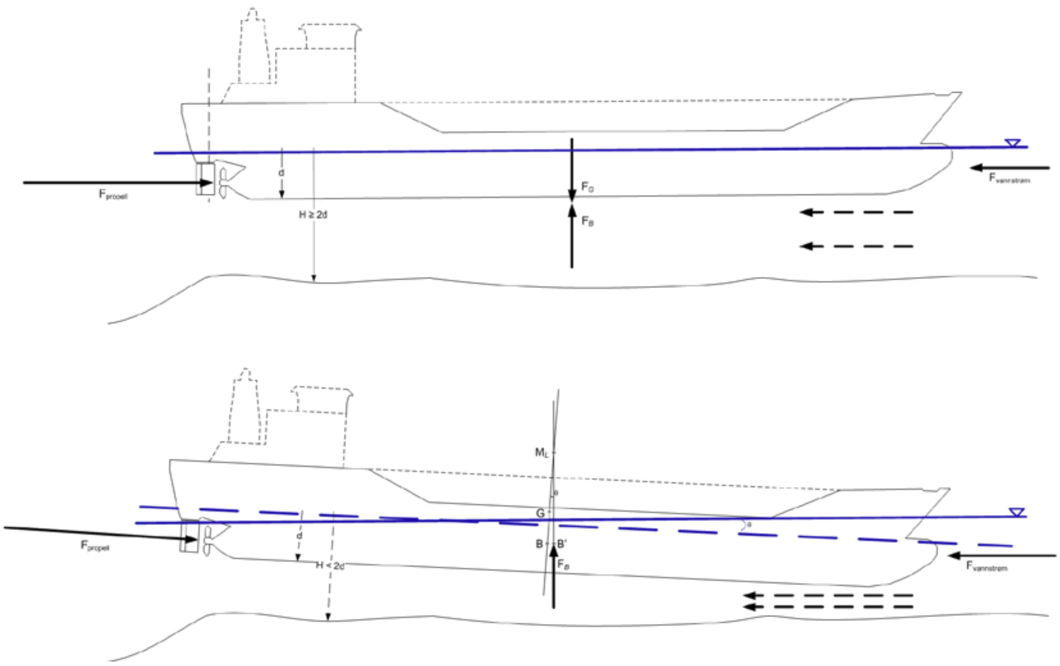


Figure 18: Two illustrations of a vessel moving forward. The uppermost illustration shows the vessel in deeper water. The lowermost illustration shows a vessel with bow trim as a result of the squat effect. This effect is the result of a combination of speed, draught and water depth.

Explanation:
G : Centre of gravity
B : Centre of buoyancy
H : Water depth
d : draught
F_G: *Gravity*
F_B: *Buoyancy*
$F_{propellor}$: *Propellor propulsion force of vessel*
$F_{water\ current}$: *Force on vessel due to water current*
The broken line arrows indicate the speed of water flow.

1.7 The operators safety management systems

Both Fleet Management and NSC Ltd had established safety management systems in accordance with the IMO's ISM Code[10]. Only the safety management system of FMEL and *Sundstraum* will be considered in this investigation. On board the *Sundstraum* there were a number of SMS[11] manuals that covered HES, the company policy and operations on board. There were also manuals that covered emergency procedures, bridge procedures, operation of chemical tankers, and loading/unloading operations.

[10] International Safety Management Code (IMO Res. A 741(18))
[11] SMS: Safety Management System

Bridge watch

Bridge watch procedures are described in the company's Bridge Procedures Manual (BPM 1.2.3). The manual makes a point of the Master's overall responsibility for decision-making with respect to safety and pollution prevention.

> *"The Master must ensure that watch keeping arrangements at all times are effective, efficient and adequate for maintaining a safe navigational watch and is also responsible for deciding the composition of the navigational bridge watch, which may include appropriate ratings and/or additional off duty officers.*
>
> *Bridge Resource Management (BRM)/Bridge Team Management (BTM) shall be implemented such that the Bridge Team:*
>
> - *Maintains the situational awareness on the Navigational bridge.*
> - *Eliminates the risk that an error on the part of one person on board the vessel may result in a disastrous situation"*

On the subject of bridge watch-keeping in densely trafficked waters (Øresund is defined as such) the company's BPM states that manning shall consist as a minimum of the master, officer of the watch, helmsman and if necessary a lookout. BPM also requires that a good lookout be kept and that the person on lookout has only this task. The roles of lookout and helmsman shall normally be kept separate, and the helmsman shall not be regarded as lookout when he is at the helm.

BPM also stresses that the Master's presence on the bridge does not exempt the officer of the watch from responsibility for navigation of the ship unless the Master has clearly stated that he is taking over the navigation. The BPM also states that the Master must be on the bridge when the vessel approaches a potentially hazardous situation and when the vessel is in trafficked waters.

Use of pilot

Masters shall use pilots when this is necessary to safeguard passage or where local regulations require the use of a pilot. In waters where pilot services are offered, but where it is not mandatory to use a pilot, the company's safety management system states that use of a pilot shall be considered by the ship's Master in the light of circumstances and the need to ensure safe navigation.

Passage planning

The requirements regarding planning of individual passages are described in BPM Section 3. According to the requirements in STCW 95, responsibility for passage planning rests with the Master, while the practical execution of the planning is carried out by the ship's second officer.

There are detailed requirements for passage planning, and it is pointed out that faults may occur in the main engine and steering gear at critical moments, and that this should not be overlooked. The planning should also include an assessment of safe speed and necessary changes in speed in light of the ship's manoeuvring capability and draught restrictions due to the squat and heel[12] effect.

[12] The vessel heels, and the draught on one side increases, for example when the vessel turns.

Navigational equipment
Section 4 of the company's BPM contains a description of responsibilities and instructions for the use of navigation and GMDSS equipment. With respect to the ship's manoeuvring control on the bridge, the BPM points out that the Master on board is responsible for ensuring that the navigators have a full understanding of the main manoeuvring system and the emergency systems. The operator has through the "Contingency planning manual" established a system for drilling different emergency scenarios, including scenarios of steering failure. In 2009 two such drills were commenced, of which the latest was on June 16th and included the crew that was on board at the time for the accident. The drills were conducted as "tabletops" were different topics was discussed.

As regards the use of autopilot, the BPM states that this shall only be used when it is safe and practical. As with the manoeuvring control system, the Master shall ensure with respect to the autopilot that the navigators are thoroughly familiar with the alternative steering methods.

Familiarization
Familiarization of crew and officers is dealt with in the Shipboard Management Manual (SMM). SMM deals with familiarization with respect to both safety on board and the individual's responsibilities and the equipment they are to use in their work. Safety familiarization shall take place within 24 hours of the crew member or officer coming on board the vessel or before the ship leaves harbour.

Familiarization with the individual's responsibilities on board and the equipment that is to be used shall take place in accordance with prepared check-lists. This familiarization applies to the ship's quality and safety documentation. For deck officers, this familiarization also includes operation of all navigational equipment. Familiarization for the officers shall be completed within 3 days, before the officer takes independent watches. After completing familiarization according to the check-lists, the officer is given 14 days to become thoroughly acquainted with all aspects of the ship's safety and operational systems.

1.8 Already implemented measures

A company investigation into the accident was carried out by Fleet Management Europe Ltd. The investigation conluded inadequate bridge manning level, unfamiliarity of the watch officer with the ship's steering system and inadequate passage planning and execution as the root causes of the accident.The operators' investigation also concludes that a peculiar design of the joystick for manual steering is a direct cause for the accident.

As corrective meassures the operator has decided to implement different control messaures to verify that the ships crew comply with the operators procedures regarding manning, planning and execution of the passage. The operator has passed a message to all vessels on the subject to make them aware of the incident, its causes and what needs to be done to prevent same. A course to be developed in the FMEL training institute focusing on this incident and the lessons learnt. The joystick for manual steering is changed to one with another design

2. ANALYSIS

2.1 Introduction

Interviews were conducted with the personnel involved, and tours of inspection made on board both vessels. Data from the *Sundstraum*'s Simplified Voyage Data Recorder (S-VDR) were downloaded after the accident. In addition data and information were obtained from the autopilot supplier, the rudder manufacturer and Sound VTS.

MARINTEK has made a study of *Sundstraum*'s manoeuvring properties and carried out simulations of *Sundstraum*'s movements on the basis of the autopilot settings.

The analysis was carried out jointly by AIBN, DMA and MMA.

In light of the interviews with the two crews, the vessels' movements in the period prior to the collision, the limited time and space for manoeuvre, the communication between the vessels and the manning of the bridges of the vessels, the analysis is focused on circumstances related to *Sundstraum* as this is expected to be of most benefit to maritime safety.

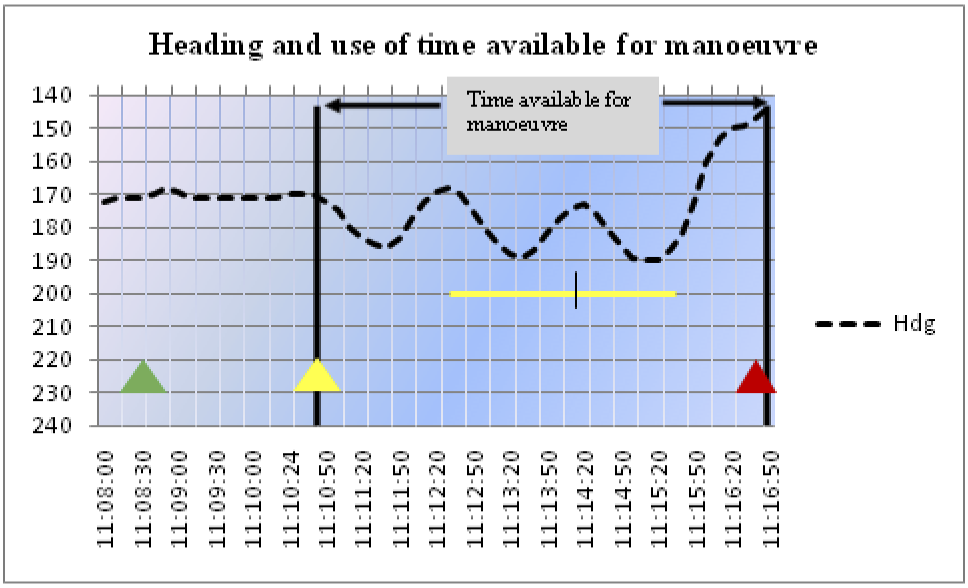


Figure 19: Shows Sundstraum's headings in the last few minutes before the collision. The period when the situation was normal is illustrated with a green triangle. The times when the movement pattern changed and when the vessels collided are illustrated with yellow and red triangles, respectively. The horizontal yellow line illustrates the period when the officer tried to contact the Master and the period when the officer and the Master discussed how to navigate in Drogden.

The analysis of the collision between the vessels is based on that fact that at about 11.10.40 *Sundstraum* started a series of movements that ended up in a collision with *Kapitan Lus* 6 minutes and 12 seconds later.

The analysis aims to find answers to why the situation changed from an apparently normal situation where *Sundstraum* was heading straight, to a situation where the vessel made several consecutive turns and the situation got out of control.

The analysis also aims to understand why the crew on *Sundstraum* handled the unexpected situation that occurred the way they did.

Against the backdrop of the fact that the crew did not regain control of the situation during the relatively long space of action time (6 minutes and 12 seconds), an analysis is made of what barriers existed that could have influenced the course of events and contributed to regaining control of the situation. The analysis also considers whether there are other barriers that could have contributed to preventing the situation from arising or could have contributed to the crew regaining control.

2.2 Why did Sundstraum's movement pattern change?

The analysis has attempted to determine why *Sundstraum* suddenly changed its steering from a stable course on autopilot to beginning to oscillate up to 20 degrees. Function tests and controls of both steering gear and autopilot after the incident revealed no faults in these units. In view of the fact that the vessel was travelling at 12 knots into an area with water depths of less than twice its draught it has been natural to consider the squat effect, bow-down effect and possible effect on the ship's directional stability.

The Accident Investigation Board has had simulations carried out to determine whether the vessel's directional stability can have changed suddenly in the period when the vessel began to oscillate up to 20 degrees. MARINTEK was assigned to carry out these simulations.

MARINTEK used a model based on information about the vessel to simulate the squat effect and change in the directional stability for various trim conditions and water depths. In addition MARINTEK carried out simulations of the vessel's movements based on the autopilot's settings during the accident period.

It is concluded from MARINTEK's simulations that the vessel probably dipped forward (bow trim) as a result of the squat effect when it moved into shallower water. It is further concluded that the directional stability was not appreciably changed as a result of the squat effect. The simulated spiral tests of the ship model show no appreciable change in shape (see Figure 20). This is explained as due to the fact that the destabilising effect of the trim influence is counteracted by the stabilising effect of reduced water depth.

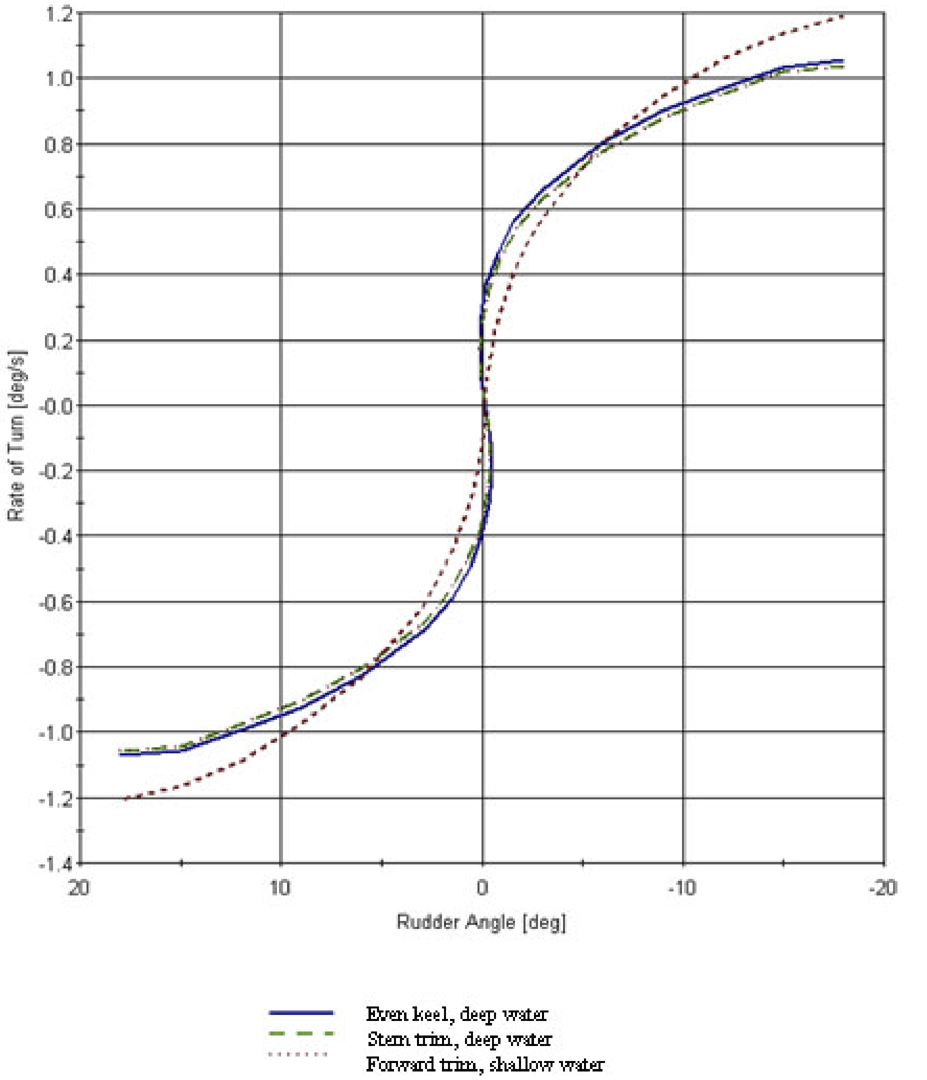
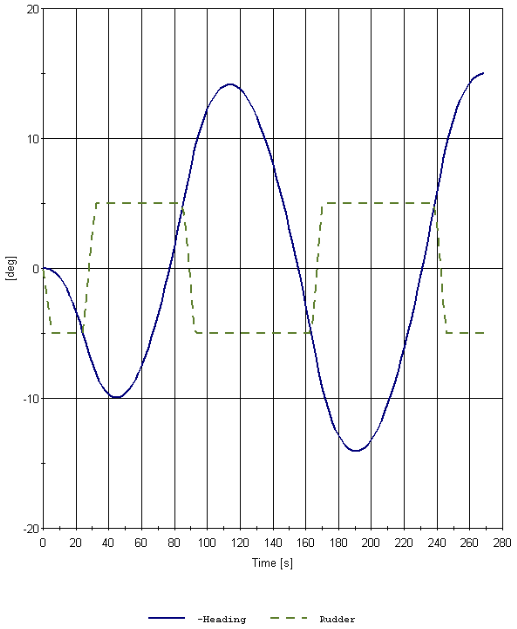


Figure 20: Shows the values that were arrived at under simulated spiral tests. The values show that the ship model is marginally stable/slightly unstable for the various conditions that were investigated.

On the basis of the autopilot settings that have been quoted, with a maximum rudder angle of 5 degrees to initiate a course change and a maximum counter rudder angle of 5 degrees to stabilise the ship on its course, calculations have been made for the ship model's movement during a forced zig-zag movement with corresponding rudder gain. The calculations were made assuming bow trim in shallow water and assume an allowed course deviation of up to5 degrees. Similar calculations were carried out for a zig-zag manoeuvre with a 5 degree rudder angle and application of counter-rudder at a 1 degree change in course. These calculations were also made assuming bow trim in shallow water. The ship model's calculated response under such a manoeuvre was plotted together with the rudder gain in Figure 21. The ship's real movements, based on information from *Sundstraum*'s S-VDR, are shown in Figure 19.



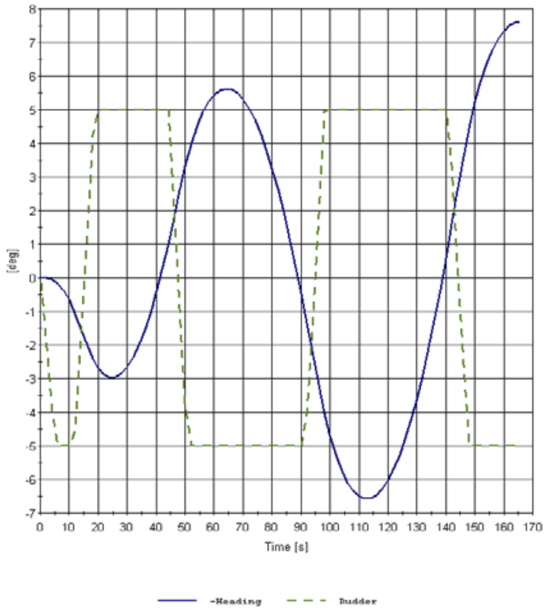


Figure 21: To the left, simulation of 5/5 zigzag test for a ship in shallow waters where counter-rudder is applied when the initial course is changed 5 degrees. To the right, a similar simulation, but now the counter-rudder is applied when the initial course is changed 1 degree.

The view of today`s operator is that a rudder limit of 5 degrees is small for navigating with autopilot in narrow waters. In view of how the ship oscillated, it is the operators view that the ship was on autopilot and that the autopilot settings have damped the heading changes and the oscillation rate. Their view is that the way the autopilot was set, and taking into account the depth conditions, the ship could have oscillated as shown in the graph in Figure 19.

An assessment of the movements arising during the simulation with a rudder gain (rudder/counter-rudder) of a maximum of 5 degrees compared with the ship's real movements indicates that the real movement pattern can be achieved with these rudder limits. The Accident Investigation Board is therefore of the view that during autopilot steering with 5 degree rudder limits the vessel had sufficient rudder force to carry out manoeuvring corresponding to the real movements.

The fact that the vessel continues the swing to port and does not swing back to starboard just before the collision (from about 11.15.50), which might be expected in view of the first oscillations, can be explained by the fact that there was now no rudder gain to starboard and that the Master put the engine into reverse, which would normally cause a swing to port for *Sundstraum*.

In the light of the factual information, the technical inspections on board, the simulations and the assessments made, the Accident Investigation Board is of the view that the vessel's steering equipment was probably normal before, during and after the accident. Nor have any changes occurred in the vessel's steering and manoeuvring properties. The Accident Inspection Board is of the opinion that the vessel was on autopilot until a short time before the collision (further reasons for this conclusion are given in Section 2.3).

The Board cannot explain conclusively what initiated and maintained the oscillations in the time from 11.10.40 until the collision was a fact.

One explanation may be that the autopilot did not function as it had done previously. Among other things, the autopilot was dependent on correct input of speed and gyro information. The speed information was set manually at 15 knots. The Board has no indications that anything was wrong with the gyro input.

Another explanation may be that the steering parameters for the autopilot were changed. AIBN has no indications that this was the case.

A third may be that the set heading the autopilot was to follow was changed a number of times by the bridge crew. An assessment of the movements that occur during the simulation with rudder gain (rudder/counter-rudder) of a maximum of 5 degrees and a course deviation of 1 degree indicates that with the set limitations the autopilot cannot carry out the ship's real movements without it being affected by changing the set heading.

Irrespective of why the oscillating movement pattern arose and continued, the Board is of the view that an unexpected situation arose for the crew. The Board is of the view that through the 6 minutes and 12 seconds before the collision, the crew had time for taking action that would have enabled them to regain control.

2.3 Why did the crew of Sundstraum handle the situation as they did?

As a result of an earlier course change to port in order to pass aft of a leisure craft that was crossing the waterway, *Sundstraum* was to the east of the channel at 11.10.40 with a course of 171°. At this time the vessel started a turn to starboard to a course of 186°. From this time and through the next 6 minutes and 12 seconds, up to the point when the collision was a fact, the vessel oscillated with heading changes of up to 20° (see Figure 19). The first turn coincides in time with the vessel being called up the first time by Sound VTS and informed that they were on the wrong side of the fairway.

After the turn to starboard, the ship turned to port. The Board is of the view that the combination of the call from Sound VTS, the leisure craft stopped up, and *Sundstraum*'s unexpected movements, led to the officer now becoming uncertain of what was happening and the loss of control started. The vessel was being steered on autopilot. The Board has not managed to establish whether the officer attempted to make a change in course with the aid of the autopilot in order to swing back to the starboard side of the fairway or to avoid the leisure craft. The officer who was on watch normally used the arrow buttons on the autopilot to change course. In the view of the Board, the possibility of initiating major course changes (5° step by holding the arrow buttons down) existed in the stressed situation in which he now found himself. The simulations carried out of the vessel's movements with the autopilot's limit of 5 degrees rudder and counter-rudder show that the movement pattern can be set up within these limits provided that the autopilot is affected by changing the set heading. The officer did not attempt to regain control by using steering possibilities other than the autopilot, but tried to contact the Master in his cabin via the ship's telephone/PA system. One reason for this choice may be that switching to manual/emergency steering would tie the officer to a position on the bridge and hence limit his possibility of carrying out other tasks. Another reason may be lack of routines/training in using alternative steering. In the Board's view, the fact that the officer was alone on the bridge put him in a difficult position when the unexpected situation arose.

Of the available time for manoeuvre of 6 minutes and 12 seconds, the officer spent 1 minute and 42 seconds from 11.12.28 in attempting to get in contact with the Master. During this period the *Sundstraum* once more turned to port, and again came onto a collision course with *Kapitan Lus*. *Kapitan Lus* called up *Sundstraum* and asked for a port to port passing. *Sundstraum* turned over to starboard yet again. The officer tried several times to reach the Master in his cabin on the telephone/PA system. No attempt was made to use other, more comprehensive alerts such as a general alert on the ship's PA system or the alarm system on board.

Just before the Master arrived on the bridge at 11.14.10, *Sundstraum* had for the second time swung over to port and was on a collision course with *Kapitan Lus*, which this time called up *Sundstraum* and asked them to turn to starboard for a port to port passing. Just after the Master reached the bridge, *Sundstraum* again started to turn to starboard. The officer informed the Master that the ship was yawing too much. The Master realised that the ship was on the east side of the fairway and understood that the officer's information, to the effect that the ship was yawing too much, was a matter of the officer giving way to a yacht and as a result ending up on the east side of the fairway. As a result of this misunderstanding, the Master and the officer spent time up to 11.15.30 discussing how to sail through Drogden.

When the Master realised at this time (11.15.33) that the ship was on autopilot and turned to port, he ordered the steering to be switched over from autopilot to manual steering. In the conversations with the persons implicated, the Board has not managed to determine whether the steering was switched over to manual, and if it was, by whom. This was a scenario that they were not trained in handling or in handling as a team. The Master has explained that he tried to change the course to starboard with the joystick by the autopilot console, but saw that he was not having any effect on the rudder. When the steering is changed from auto to manual, an alarm with three short peeps is heard. Several reruns of the sound recordings from the ship's bridge in this period have not revealed that this alarm signal was given. Inspection of the steering gear after the accident reveals no faults, the operator reports that the autopilot also functioned fine both before and after the accident.

The last 50 seconds before the collision Sundstraums speed decreases from 11,9 knots to 9,1 knots. This can be explained by the fact that the vessel was in a turn and the engine power was significally reduced. Significant reductions in the vessels power will normally cause a port turn and the effect of using the rudder is minimized.

The investigation has not clarified exactely wheter or not the ship was on automatic steering the last minute before the collision was a fact.

At 11.16.03 Sundstraum was 0,21 nautical.miles off Kapitan Lus on a collision course. Both the two on the bridge were now under strong pressure.

Besides the autopilot and normal manual steering, there are also other possibilities for steering *Sundstraum*. The ship can be steered manually by means of the emergency steering panel, and it can be steered manually from the steering gear room. Written procedures for both these options are displayed on the central control console on the bridge. As far as the Board can see, neither of these possibilities of regaining control was considered or tried. One reason for this may be lack of routines/training. This is discussed further in Section 2.4.

The vessel entered the Drogden dredged channel at almost full speed of 12 knots. Attempts were only made to reduce the speed when the Master got no response to the manual steering and considered that a collision was unavoidable. The engine was then put into reverse and at the moment of collision the speed had been reduced to 9,1 knots. In the view of the Board, reducing the speed at an earlier stage would have extended the length of time the crew had in which to take action. One reason that this was not done may, like the use of alternative steering, be due to lack of routines/training. This is discussed further in Section 2.4.

The crew of the *Sundstraum* was not prepared to handle this unexpected situation. First, there was not sufficient manning on the bridge to deal with the situation. Second, the bridge crew was not coordinated in handling the unexpected situation, and there might also have been a language problem. Third, reducing speed at an early stage of events and alternative ways of steering the vessel were not considered or tried.

2.4 Which central barriers failed and which were lacking?

The analysis aims to establish which barriers were present and could have affected the course of events and contributed to regaining control of the situation. The analysis also considers whether there are other barriers that could have contributed to preventing the situation from arising or could have contributed to the crew regaining control.

2.4.1 Planning of the passage through Drogden with respect to bridge manning

During the passage through the Hollender Deep and down to Drogden, the bridge on *Sundstraum* was manned only by the navigator of the watch. The ship's Master was on the bridge from time to time. The fact that the vessel was sailing with one man on the bridge in a narrow, shallow, densely trafficked area is not in compliance with the operator's safety management system, national and international requirements or guidelines.

The operator's safety management system BPM (Bridge Procedures Manual) clearly requires increased manning of the bridge during passage to and from harbour and in trafficked waters. The presence of Master, officer of the watch and helmsman is required, and if necessary a lookout. When it comes to the Drogden area, with dense shipping traffic, shallow waters and limited room for manoeuvre, the Board is of the view that a helmsman should be put on watch and physically steer the ship. The safety management system's bridge manning requirements are in line with national and international requirements and guidelines.

The operator's bridge procedures require that the Master consider the need for a pilot. With respect to the use of a "voluntary" pilot, BPM says that use of a pilot shall be considered by the ship's Master in the light of the prevailing conditions and the need to ensure safe navigation. The IMO's "Recommendations on navigating through the entrances to the Baltic Sea" recommend that loaded chemical tankers, irrespective of size, use a pilot through Øresund. The Master chose to sail through the area without a pilot. In the view of the Board, using a pilot as an extra navigator with local knowledge of the waterway and who would be prompt to communicate the situation that arose to the vessel traffic service and other traffic nearby would have given the bridge team good support and thereby given the bridge crew further time to take action and regain control of the unexpected situation.

Both the Master and the officer had long experience and both had sailed through the area with similar vessels earlier, and were thus comfortable with the passage. The fact that in their planning they chose to sail through the area with reduced bridge manning and without a pilot was due, in the view of the Board, not to the fact that they lacked resources, but that they both had experience with this passage and that previous passages had taken place without unforeseen events occurring. They therefore saw no reason to sail with more than the officer of the watch on the bridge.

The Board believes that the planning of the bridge manning for the passage was based on the assumption that no unexpected situation would arise. In the view of the Board, a risk assessment of the passage which reveals the possibilities of unexpected events arising can make the crew aware why it is necessary to have increased manning in this part of the passage (shallow, narrow and trafficked waterway). It may also prompt the use of a pilot.

The Board considers that the operator’s safety management system for the vessel is adequate with respect to bridge manning, except that clearer guidelines should be set for the use of a pilot where a voluntary pilot service is established. A safety recommendation is being made in this connection.

In view of the discrepancy between currently applicable procedures and actual practice, the Board is of the view that it is necessary for the operator to increase attention to this issue among its crews. The company should also use this event in its experience feedback system, among other things to motivate navigators to comply with the manning procedure. This should come in addition to the operator’s planned measures to increase internal auditing of navigation.

2.4.2 Training/familiarization and drilling

The operator’s familiarization programme allows the ship’s navigators three days to familiarize themselves with the ship’s navigational equipment before they go on independent watches. The emergency steering is defined as part of the ship's navigation equipment.
After completing familiarization according to the check-lists, the officer is given 14 days to become thoroughly acquainted with all aspects of the ship’s safety and operational systems.

Sundstraum often sails in waterways that are narrow, shallow and densely trafficked, and in the view of the Board it is important that the whole bridge crew is capable of rapidly recognising situations where steering is lost, to enable them to evaluate the situation and take the right steps to regain control.

The ship had several alternatives to steering besides the autopilot. Normal manual steering could be used. Steering could take place by means of emergency steering gear on the bridge or locally from the steering gear room. The bridge crew that was directly involved in the accident demonstrated that they were not familiar with the functioning of the equipment. This may imply that the crew’s familiarization on board is inadequate. In the view of the Board, the use of these alternative means of steering requires that there is more than one qualified person present on the bridge who has training in manual and emergency steering. The period from when the officer discovered that the vessel was oscillating until the collision took place was in the view of the Board sufficient to have been able to call further resources to the bridge to implement manual steering, or alternatively emergency steering.

It would of necessity have taken some time to establish emergency steering from the steering gear room. The event took place during the day in a period when the engine room was manned and in the view of the Board could also have been established within the time available for manoeuvre. The accident showed that the period from when the engineers realised there was risk of collision until they were at the steering gear was short.

The implementation of the aforementioned steering alternatives requires that the officer of the watch have this as a reflex reaction when something unforeseen happens. In order to achieve this, the whole bridge crew should be drilled in this type of scenario, as well as the part of the crew that is to carry out steering from the steering gear room.

When the Master arrived on the bridge at 11.14.10, a misunderstanding arose in the communication between him and the officer, which resulted in the focus being on the passage through the Drogden in general, and not on regaining control of the situation. In addition to instilling a necessary reflex reaction, training in dealing with unexpected situations could also have helped to ensure clear and unambiguous communication and that the time for manoeuvre acquired thereby was used to regain control.

The operators' management system includes, amongst others, drills on scenarios of steering failure. The drills on board are commenced as tabletop exercises and several of the drills are commenced while the ship is anchored. In the view of AIBN the drills should be carried out as practical handling of situations and the management system does not make provision for conducting such practical drills on the bridge.

The Board is accordingly of the view that the operator should focus on the work of crew familiarization. Provision should also be made for conducting regular drills during which the crew practises handling scenarios where control of the ship's steering is lost. A safety recommendation is being issued in this regard.

2.4.3 Decision-making support for the crew from the Sound VTS

During passage through areas that are covered by a vessel traffic service, information from the vessel traffic service should form a part of the basis for the ship's crew's decision-making with respect to the passage.

Sundstraum called up Sound VTS when they approached the reporting line in the north of Øresund. In response to the vessel traffic service's inquiry, the vessel reported maximum draught, destination and planned passage through Drogden. Neither at this time, nor later, did *Sundstraum* receive information from the vessel traffic service concerning other relevant shipping traffic or other special factors that could affect *Sundstraum*'s passage.

The geographical area covered by the vessel traffic service is large, and the waterway is densely trafficked. This, coupled with Sound VTS's tasks indicates that one cannot expect the individual vessel to be monitored at all times by the operators at the vessel traffic service. In the view of the Accident Investigation Board, this may explain why the vessel traffic service was not aware earlier that *Sundstraum* was heading east in the waterway down towards Drogden.

Experience of SOUNDREP operations so far reveals a need for further measures to assist seafarers with information to support decision-making on board. The Board is of the view that more active input from the vessel traffic service with respect to informing the crew of *Sundstraum* that they would be meeting vessels in Drogden could have contributed to a higher level of caution and a reconsideration of the decision to sail with one man on the bridge. An inquiry from the vessel traffic service as to whether they had a pilot on board could have enhanced this effect. The Board is of the opinion that the incident with *Sundstraum* and *Kapitan Lus* shows that there may be a need for further measures to assist mariners in the area with information to support decision-making on board. This substantiates the need for a mandatory reporting system.

3. CONCLUSION

3.1 Sundstraum's changed movement pattern

The Board cannot explain conclusively what initiated and maintained the oscillations in the time from 11.10.40 up to the time of the collision.

The vessel's directional stability probably did not change as a result of the squat effect.

The vessel was probably on autopilot until a short time before the collision.

The oscillations in the period from 11.10.40 and up to the time when the Master arrived on the bridge are probably due to the fact that attempts were made to regain control of the situation by repeated changes in the set heading on the autopilot.

Irrespective of why the oscillating movement pattern arose and continued, the Board is of the view that an unexpected situation arose for the crew.

3.2 The Sundstraum crew's handling of the situation

The crew of the *Sundstraum* was not prepared to handle the unexpected situation.

There was not an adequate bridge manning to handle the unexpected situation.

The bridge crew was not pulling as a team to handle the unexpected situation.

A speed reduction at an early stage of events, or alternative ways of steering the vessel were not considered or tried.

3.3 Bridge manning and lack of training

The passage through the Drogden, which is a shallow, narrow and trafficked waterway, requires full focus from a trained bridge crew of adequate size.

The planning of the bridge manning for the passage was based on the assumption that no unexpected situation would arise.

Compliance with the operator’s existing procedure for passage planning would have resulted in increased manning on the bridge and a greater possibility of rapidly regaining control of the unexpected situation.

The shipping company has left it up to the Master to decide whether to use an optional pilot. The Master chose to sail through the area without a pilot. Strengthening this part of the passage by including an extra navigator (pilot) would have given the bridge crew increased possibility to regain control of the situation. The IMO recommends using a pilot.

The bridge crew was probably not adequately familiarized with the vessel’s navigation equipment.

The bridge crew was not trained in handling an unexpected situation that requires cooperation, precise communication and implementing alternative ways of manoeuvring the vessel. The shipping company’s safety management system does not make provision for the crew to systematically undergo practical training for such situations. Such training would have further increased the possibility of regaining control when the unexpected situation arose.

3.4 Decision-making support for the crew from the Sound VTS

There may be a need for further measures to assist mariners in the area with information from the Sound VTS to support decision-making on board.

4. SAFETY RECOMMENDATIONS

The investigation of this accident at sea has revealed two areas where the Accident Investigation Board considers it necessary to submit safety recommendations with a view to improving safety at sea[13].

Safety recommendation Marine no. 2010/26T

Sundstraum sailed through Øresund without a pilot on board, and thereby opting out of the safety barrier represented by the pilot. In its safety management system, the operator has left the decision regarding the use of an optional pilot to the ship's Master. The Board recommends that the operator should consider using a pilot in Øresund and similar waterways in line with the IMO’s recommendations.

Safety recommendation Marine no. 2010/27T

The bridge crew's lack of training contributed to that they did not react early enough to the situation that had arisen and hence the time available for manoeuvre to regain control was not utilised. The operator’s safety management system does not make provision for the crew to practically drill scenarios where control of the ship’s steering is lost. The Board recommends that the operator should make provision for all ship’s crews to practically drill handling of scenarios where control of the ship's steering is lost.

Norwegian Accident Investigation Board
Lillestrøm, 25 October 2010

[13] The investigation report will be sent to the Norwegian Ministry of Trade and Industry which will take the necessary steps to ensure that due account is taken of the safety recommendations.

Appendix A

ABBREVIATIONS

AIBN	:	Norwegian Accident Investigation Board
DMA	:	Danish Maritime Authority
DNV	:	Det Norske Veritas
DOC	:	Document Of Compliance
IMO	:	International Maritime Organization
ISM	:	International Safety Management
kW	:	Kilowatt
MMA	:	Malta Maritime Authority
NHD	:	The Norwegian Ministry of Trade and Industry
NIS	:	Norwegian International Ship Register
PA system	:	Public announcement system
SMC	:	Safety Management Certificate
SMS	:	Safety Management System
TM	:	Transport Malta
VHF	:	Very High Frequency