DMAIB

DANISH MARITIME ACCIDENT INVESTIGATION BOARD

MÆRSK BATTLER

Marine accident report on MAERSK BATTLER's loss of tow and the foundering of MÆRSK SEARCHER and MÆRSK SHIPPER on 21 and 22 December 2016

MARINE ACCIDENT REPORT ON MÆRSK BATTLER'S LOSS OF TOW ON 21 AND 22 DECEMBER 2016

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DMAIB
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Photo: MÆRSK SEARCHER and MÆRSK SHIPPER
Source: Private photo

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The investigations are carried out separately from the criminal investigation, without having used legal evidence procedures and with no other basic aim than learning about accidents with the purpose of gaining and promoting an understanding of safety. Consequently, any use of this report for other purposes may lead to erroneous or misleading interpretations.

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Board Statement

On the night between 21 and 22 December 2016, the Danish offshore supply ships MÆRSK SEARCHER and MÆRSK SHIPPER capsized and sank in the Bay of Biscay approximately 65 nm off the French coast while being towed by the offshore supply ship, MÆRSK BATTLER. The ships under tow were both unmanned during the voyage. Though no lives were at risk during the accident, the total loss of the two ships is considered a very serious accident of special concern to the potential risk of harm to the marine environment due to oil leakage. Therefore, the Danish Maritime Accident Investigation Board (DMAIB) in agreement with the French authorities initiated an investigation of the accident to establish the circumstances leading to the foundering of MÆRSK SEARCHER and MÆRSK SHIPPER.

The starting point for every investigation carried out by the DMAIB is that an accident is an unwanted event for all parties, and that the persons involved in an accident strive to achieve a successful outcome and want to contribute in a professional manner. Our core objective in this investigation is to understand why the accident happened in spite of the professional efforts made by the involved parties, because this provides a nuanced understanding of the accident.

Often, accident investigations focus on a short timeframe leading up to the accident events and focus on actions taken by persons directly involved in these events. In a case like the capsizing and foundering of MÆRSK SEARCHER and MÆRSK SHIPPER, the towing operation and voyage were preceded by nearly four months' preparation involving a large number of persons. To gain a more comprehensive understanding of the accident, the DMAIB therefore needed to broaden the investigation to include the organisational processes that took place in the shore organisation months before the accident occurred, as these are tightly coupled to the events unfolding on the night between 21 and 22 December 2016.

In other words, the DMAIB regards the foundering of MÆRSK SEARCHER and MÆRSK SHIPPER as a systemic accident. This means that local and technical circumstances unfolding on board the MÆRSK BATTLER during the voyage cannot be isolated from the preceding organisational events and circumstances taking place months earlier, but together constitute a complex system. The cause of accidents unfolding in such a complex system cannot be reduced to singular factors or root causes. Instead, accidents emerge from a unique conjunction of events and circumstances in which no single individual can have complete knowledge of the processes and predict future events emerging from these.

Thus, the investigation of the foundering of MÆRSK SEARCHER and MÆRSK SHIPPER is two-fold. It focuses on the technical circumstances leading to the foundering of the two ships and on the organisational circumstances facilitating these technical circumstances. The technical investigation describes and analyses the towing setup, the risk mitigating equipment, and the ships' stability. The organisational investigation describes and analyses risk assessments, the decision-making process, and the flow of information within the company.

Narrative

A description of the events unfolding over a period of approximatly six months leading up to the departure and the sequence of events during the voyage as they were perceived by the persons involved.

Background

The shipping company Maersk Supply Service is an independent business unit within the A.P. Moller-Maersk Group. The company provides worldwide offshore marine services to the energy sector, such as anchor handling and platform supply. Its fleet consists mainly of anchor handling tug supply ships (AHTS) and platform supply vessels (PSV). It is the company's stated objective to be a market leader and to be at the forefront of the changing offshore industry's complex marine operations. The company's operations are thus often of an explorative nature, i.e. meeting clients' specific, novel demands, rather than offering standard solutions.

As a result of a global decline in the offshore oil and gas markets, Maersk Supply Service in mid-2016 announced adjustments to its organisation, including plans to reduce its fleet by up to 20 ships within 18 months and reduce staff in the order of 400 jobs.
In July 2016, it was decided that the two anchor handling supply tugs MÆRSK SHIPPER and MÆRSK SEARCHER (figure 1; see appendix for ship particulars) were to be sold as a part of the company's divestment plans.

Both ships had been in cold lay-up (i.e. unmanned and not operative) in the Danish port of Fredericia since April and February 2016, respectively. The ships had been sold to a shipyard in Aliağa, Turkey, where they were to be recycled. In late August, preparations for towing the two S-type vessels to Turkey were initiated by Maersk Supply Service. Since towing operations were considered to be within the company's core services, the job was kept in-house.

Figure 1: MÆRSK SEARCHER and MÆRSK SHIPPER in Port of Fredericia
Source: Maersk Supply Service

Preparation of the towing operation

Deciding and preparing towing setup

In early September 2016, a Management of Change (MoC) meeting[1] was arranged as a kick-off for the planning of the MÆRSK SEARCHER and MÆRSK SHIPPER's voyage to Aliağa. The participants in the MoC meeting were individuals from several different departments, e.g. commercial, HSEQ, nautical, and operations staff, who were involved in the project management or delivered advice on the planning of the towing operation.

It had been predetermined that the transport of the ships was to be commenced as one tow by a third ship, the offshore tug MAERSK CHANCELLOR, and one of the topics for the MoC was to evaluate the different setups for carrying out this type of towing operation. The scheduled time for departing Fredericia was late September 2016.

At the MoC meeting, the participants discussed mainly two potential towing setups: 1) A double-tow where both S-type ships were individually connected to MAERSK CHANCELLOR and 2) A tow where the two ships were connected in series (figure 2).

The first setup, the double-tow, was recommended by an external towing company, but required a specific winch setup, which was not available on MAERSK CHANCELLOR, and therefore not possible. The second towing setup with the ships connected in series required the middle ship to be manned and operational in order to control the winches with the connecting wire to the last ship. A third towing setup with the S-type ships being towed side by side was also discussed, but was discarded due to some identified risks of the superstructures making contact during tow (figure 2).

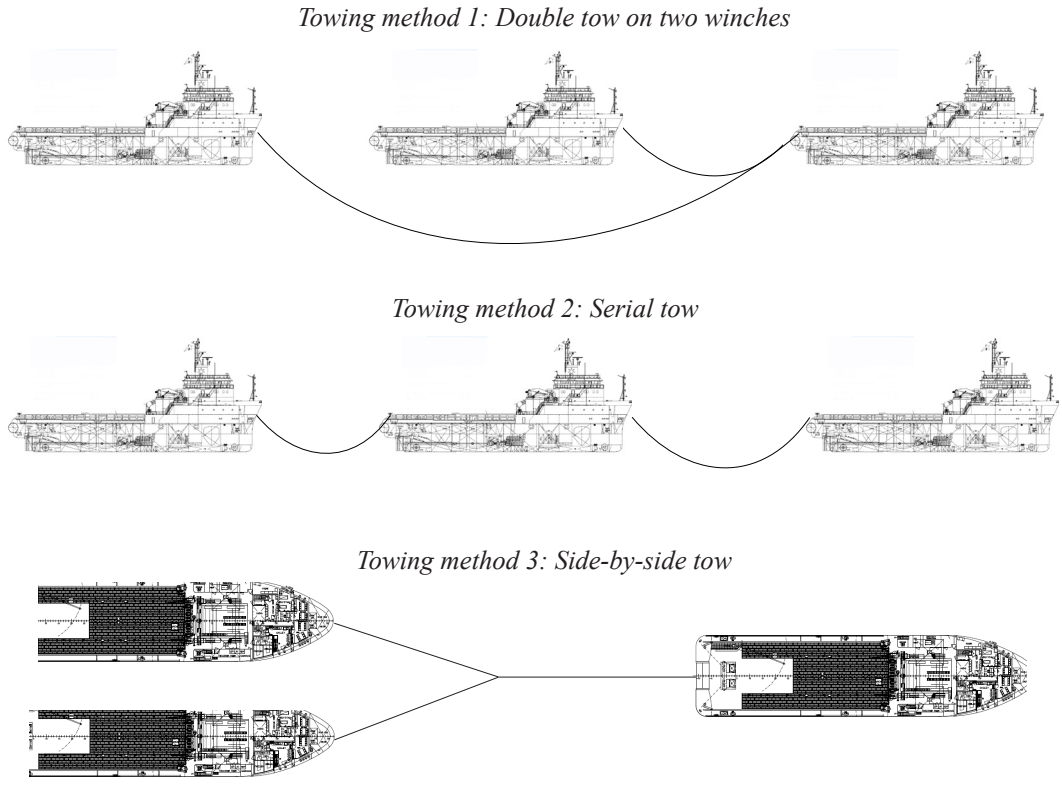


Figure 2: The three towing methods considered for the towage of MÆRSK SEARCHER and MÆRSK SHIPPER
Source: DMAIB

1 According to the company's own definition, the Management of Change meeting has the purpose of ensuring that "changes are managed and that the risk of failure is minimised without jeopardising people, the environment, our property and our organisation."

A marine superintendent had been assigned the task of preparing a towing procedure for the operation and started to prepare the setup for serial towing. During the preparation of the towing operation, it became evident that making one of the ships operational and the necessary extra crew made the serial tow an expensive solution. Therefore, the marine superintendent was encouraged by the ships' operations manager to explore alternatives to the serial tow. The superintendent agreed with other superintendents, captains and operation managers who were involved in the planning of the towing operation to examine whether the side-by-side tow could be a possible solution anyway. The side-by-side tow would fit the winch setup on MAERSK CHANCELLOR and would allow for both ships to be unmanned.

The marine superintendent set to work on a draft towing procedure for the side-by-side towage in order to assess whether this solution was feasible. The draft towing procedure consisted of, inter alia, towing arrangement, route plan and a risk assessment. While the towing procedure was being prepared and was still in draft, a demobilisation team tending to the company's laid-up vessels in Fredericia started to connect MÆRSK SHIPPER and MÆRSK SEARCHER side by side. Meanwhile, MAERSK CHANCELLOR was under way from Canada to Frederica.

The company had applied for a waste disposal certificate for MÆRSK SHIPPER and MÆRSK SEARCHER, which had to be obtained before the towage could commence. However, the certificate had not yet been issued by the authorities as MAERSK CHANCELLOR was about to reach Fredericia. As the documentation for the S-type ships would not be ready in time for the arrival of MAERSK CHANCELLOR, it was decided that MAERSK CHANCELLOR should instead engage in another towing operation with one of the company's other vessels, MÆRSK BEATER. MÆRSK BEATER was to be moved to the shipyard in Aliağa as well. In late September, the crew and the nautical inspectors put the towing operation for the S-type on stand-by and started to prepare MAERSK CHANCELLOR's new assignment.

Organisational change

In October, the company underwent significant organisational changes. The first organisational change took place in early October and consisted of a round of dismissals. The nautical inspector who had been the lead on the preparation of MÆRSK SHIPPER and MÆRSK SEARCHER's towing operation was made redundant. As a result of a management decision, the laid-off employees had to leave their workplace on the same day. The marine superintendent asked if he could hand over his current work task, but due to the organisational change process this was not possible at that time. Therefore, he could not inform his colleagues that the towing procedure was still in draft or explain the outstanding missing items.

Later in October, the company underwent a second organisational change, which imposed a large-scale rotation among the employees as a result of the merging fleet teams. As a result of the merging, the employees in the operations team managing the vessels based in Europe were moved to other sections. During late October and early November, a handover of all current affairs to the new European operations team, including the towing operation of MÆRSK SHIPPER and MÆRSK SEARCHER on standby, took place.

Preparing the towing operation with MÆRSK BATTLER

In early December, the towing operation of MÆRSK SHIPPER and MÆRSK SEARCHER was reassumed. It had been decided that the anchor handler MÆRSK BATTLER should conduct the move of MÆRSK SEARCHER and MÆRSK SHIPPER to Aliağa. Preparations for divesting MÆRSK BATTLER along with the two S-type ships were initiated, and the final decision to recycle MÆRSK BATTLER along with the other ships was taken during the voyage. On 4 December, MÆRSK BATTLER left Aberdeen and headed for Fredericia, where a crew change would take place on 8 December 2016.

The new operations team continued the preparation of the towing operation. The preparations were mainly handled by a shipping trainee, who was supervised by an operations manager. The new operations team did not evaluate the towing setup as this was considered approved months ago. At the handover during the organisational change, they had been informed that the preparation of the towing setup had been concluded and approved, and that the towing operation was ready to be executed. The operations manager and the shipping trainee were not tasked with evaluating the feasibility of the towing operation, but with facilitating the carrying out of the remaining practicalities of preparing the towage for departure. Therefore, they trusted the nautical assessment and planning carried out in September.

An MoC meeting concerning the towing operation was held on 7 December. At this meeting, the date of departure was discussed and the last outstanding items to be dealt with prior to departure were identified, such as bunkering, stores and checking the emergency towing arrangement, and a risk assessment was carried out. The participants at the

MoC meeting discussed the weather window for the voyage. The weather forecasts predicted very good weather for the season, and it was decided to take advantage of the current weather window and depart as soon as possible. The MoC participants therefore initially scheduled the towage's departure for 9 December.

On 8 December, MÆRSK BATTLER was handed over to the new crew, who immediately started to prepare for the voyage. The new crew expressed that they would like to go through all three ships and the towing arrangement prior to departure and they also needed to take fuel and change the wires on the winches. The scheduled date of departure did not render sufficient time for this, and the departure was hence postponed to 12 December.

On 9 December, the shipping trainee was in contact with an operations manager from the former operations team who mentioned that the insurers should be informed of the towing operation and have the towing documents forwarded, amongst which the towing procedure. The towing procedure was not included in the information handed over to the new operations team, and the shipping trainee was therefore not aware of its existence. The former operations manager passed the document on to the shipping trainee. The towing procedure had not been updated since the leave of the nautical inspector who prepared it, and the information still concerned MAERSK CHANCELLOR. As he was notified that the insurance issue had to be rushed, the shipping trainee forwarded the document to the insurers with a comment that this was a draft document and that the towing ship was MÆRSK BATTLER, not MAERSK CHANCELLOR. He also forwarded the towing procedure to the master of MÆRSK BATTLER and asked him to update the procedure to reflect the changes. On MÆRSK BATTLER the crew had experienced continuous problems with the internet connection on board. Therefore, the towing procedure did not reach the ship, and thus no amendments were made by the master or his crew.

During the weekend of 10-11 December, a class surveyor carried out a fitness-for-tow inspection of MÆRSK SHIPPER and MÆRSK SEARCHER and found both of them fit for towage. The crew continued their preparations of the towage, amongst other things connecting MÆRSK BATTLER to MÆRSK SHIPPER and MÆRSK SEARCHER. Handling wires and chains on the S-type ships was time consuming as no power was available on these ships and the work therefore had to be done by hand, but the crew managed to have all three ships ready for departure by 12 December (figure 3).

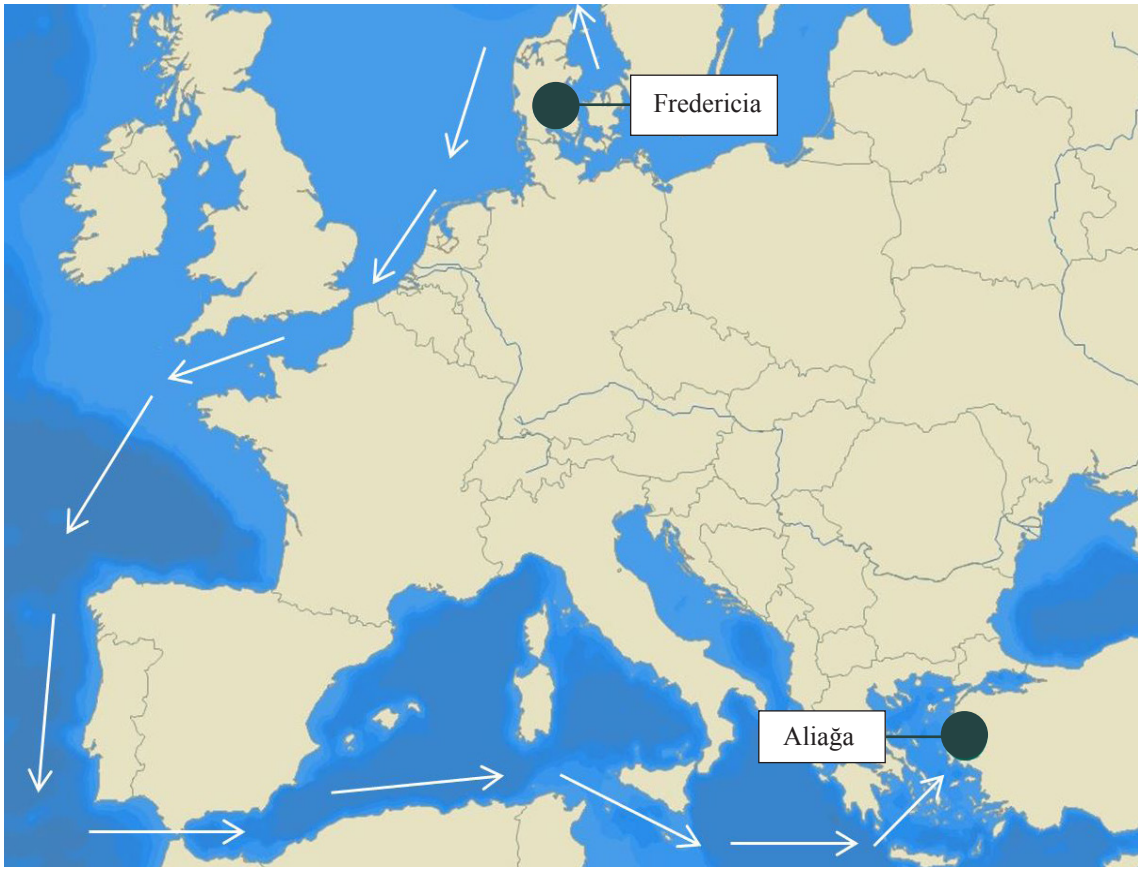


Figure 3: Planned towing route from Fredericia, Denmark to Aliağa, Turkey
Source: © Made Smart Group BV 2016, C-Map data © Jeppesen AS 2016/DMAIB

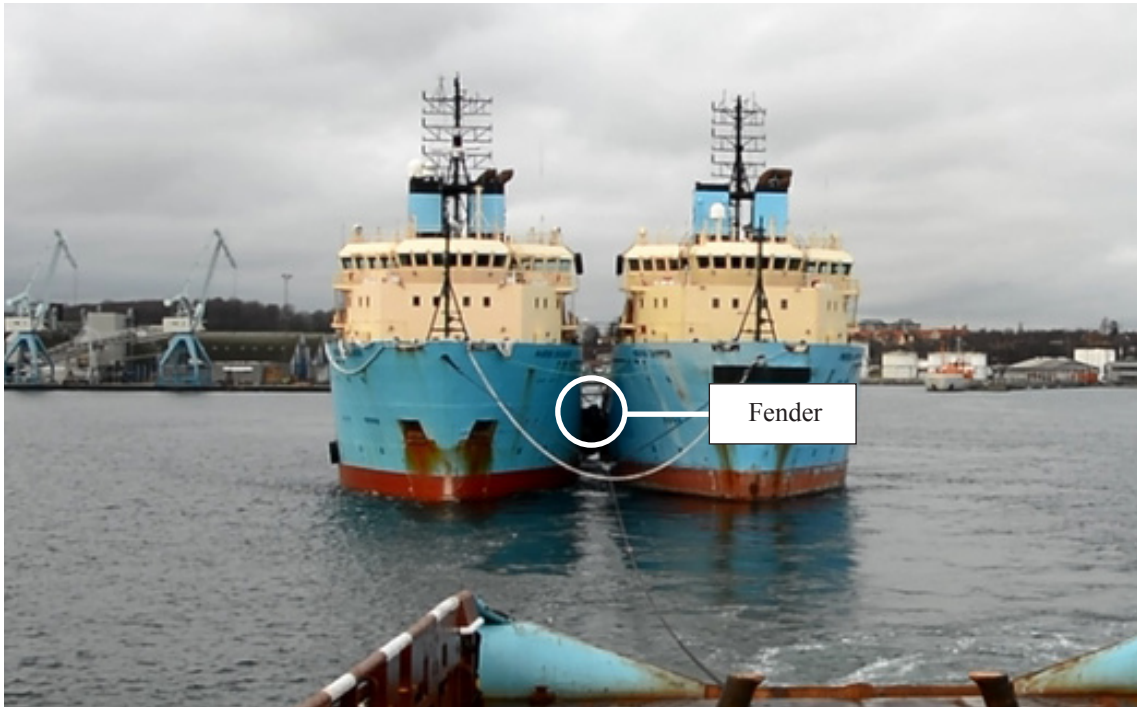


Figure 4: Towage at departure from Fredericia on 12 December 2016
Source: Private photo

The voyage

MÆRSK BATTLER departed Fredericia on 12 December 2016 at approx. 1130 (figure 4), and the towage exited the port area and proceeded to the Skaw Roads, where MÆRSK BATTLER was to take stores. The weather was clear and the two ships under tow were lying steady in the water next to each other. MÆRSK BATTLER took stores on 14 December and proceeded south through the North Sea. The crew continued to experience problems with receiving emails and updating the SPOS[2], and they therefore relied on the master retrieving weather forecasts on his personal mobile phone when the ships were within reception reach of a mobile signal.

On 20 December, the swell increased as the towage was proceeding through the English Channel. The weather conditions were not unusual for that time of year in that particular area and were not considered problematic for the towage operation. In order to adapt to the weather conditions, the main tow wire was paid out to 630 m. The crew noticed that the fenders (figure 4) keeping the towed ships apart had vanished. MAERSK SEARCHER and MÆRSK SHIPPER had direct contact, but were steady in the water (figure 5). As both vessels were to be recycled, it was not considered a problem that the ships suffered slight damage above the waterline when making contact. However, the master decided that, when the towage reached sheltered waters in the Mediterranean, some crewmembers on MÆRSK BATTLER were to board MÆRSK SEARCHER and MÆRSK SHIPPER and inspect the state of the ships. Due to the sea state in the English Channel and in the Bay of Biscay, launching the rescue boats and boarding the ships on tow imposed too great a danger to the crewmembers.

On 21 December, the weather deteriorated and the towage was affected by a westerly 4.5 m swell. At dawn, the crew could see that, during the night, both ships had suffered contact damage, primarily to the superstructures, and that the ships were no longer lying steady in the water next to each other. Both vessels rolled and showed a tendency to list towards each other, especially MÆRSK SEARCHER (figure 6).

It was not unexpected to the crew that the ships' superstructures made contact, and this event was not perceived as posing any significant risk to the towage operation. As far as the crew could observe from a distance, the damage was located above the waterline, and therefore it was not perceived to influence the watertight integrity of the ships. The ships' list towards each other was assumed to be caused by the weight of the bridle and the pull on the towing wire. Hence, the towage proceeded for the Bay of Biscay.

2 Ship Performance Optimisation System; an on-board weather routing system.

Figure 5: Towage at noon on 20 December 2016 in the English Channel. Left: MÆRSK SEARCHER.
Source: Private photo

Figure 6: Towage at noon on 21 December 2016 leaving the English Channel at the Celtic Sea.
Source: Private photo

During the morning, the master was contacted by Ushant Radio who had been informed by another ship that MÆRSK BATTLER had been involved in an incident. The master did not understand why an incident had been reported and informed Ushant Radio that no incident had occurred with MÆRSK BATTLER. In order to prevent misunderstandings and rumours spreading to the company that MÆRSK BATTLER had been involved in an accident, the master contacted a marine superintendent in the company who had been involved in the MoC meetings and gave him a status. He informed that both ships had sustained some damage above the waterline, as expected, but otherwise he thought they were doing fine. He also informed that his greatest concern was if the tow bridle was too strained and that special attention was paid to this.

On the night of 21 December, the master was on duty on the bridge along with a watch-keeping AB. The ships were acting as they had done all day, rolling and colliding with each other and having a slight list towards each other. At 2325, the AB suddenly noticed that MÆRSK SEARCHER was lying deeper in the water than before and was listing heavily. He communicated this observation to the master, who immediately realized that MÆRSK SEARCHER was about to capsize. However, the crew on MÆRSK BATTLER had no means to recover this situation. Ten minutes after the AB made this observation, MÆRSK SEARCHER capsized (figure 7).

All crewmembers were called to the bridge. It was evident that MÆRSK SEARCHER would sink and drag MÆRSK SHIPPER down as well. Saving MÆRSK SHIPPER was deemed impossible. The towing wire was shortened to 250 m after MÆRSK SEARCHER had capsized. As the water depth was approx. 155 m and the towing wire exceeded this in length, the master knew that MÆRSK BATTLER was not at risk of being pulled down by the ships under tow if they both sank.

The capsizing of MÆRSK SEARCHER occurred near the Ushant traffic separation scheme, and the master therefore made an effort to navigate the sinking towage in a westerly direction away from the traffic lane and the French coast to minimize the navigational dangers imposed by the sinking ships. MÆRSK SEARCHER sank bow first at 0022 on 22 December 2016. A few minutes later, MÆRSK SHIPPER capsized (figure 8).

The master informed the company's emergency team and the French Coast Guard of the loss of the two ships. At 0607, MÆRSK SHIPPER sank. The master decided that it was too dangerous for the crew to cut the towing wire on deck. Instead, the master carried out a controlled breakage of the main towing wire, by going forward on the main engines with a pull force greater than the wire could withstand. At 0616, MÆRSK BATTLER was free of the towage and awaited orders from the company.

The MÆRSK BATTLER continued the voyage on 22 December at 1730 and arrived in Aliağa on 5 January 2017 for recycling.

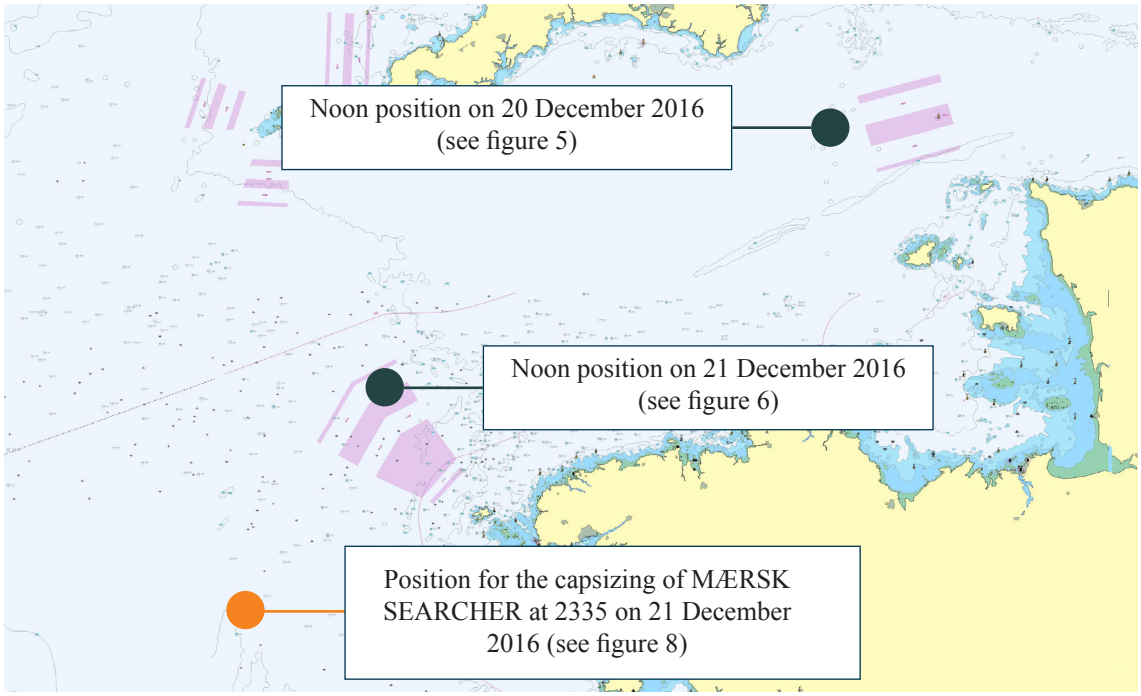


Figure 7: Position for the capsizing of MÆRSK SEARCHER.
Source: DMAIB

Figure 8: MÆRSK SEARCHER capsizing and sinking on 22 December 2016, just past midnight.
Source: Private photo

Investigation

The investigation aims to establish why MÆRSK SHIPPER and MÆRSK SEARCHER capsized and subsequently sank. The investigation focuses on the organisational circumstances preceding the accident, which concerned the preparation of the towing operation and the technical circumstances causing the foundering of the ships.

Reading note

MÆRSK BATTLER lost its tow on 21 December 2016 in the Bay of Biscay, 10 days after departure from Fredericia, Denmark. MÆRSK SEARCHER lost stability and capsized, and shortly after MÆRSK SHIPPER also capsized. Before capsizing, the ships had collided continuously for at least 36 hours.

The foundering of MÆRSK SHIPPER and MÆRSK SEARCHER is in essence a systemic and complex accident. Numerous persons have been involved over a long period of time and the technical, operational and organisational events and factors are coupled in a complex, systemic cluster. The DMAIB investigation mapped a range of factors connected to the foundering of MÆRSK SHIPPER and MÆRSK SEARCHER.

In this section, the DMAIB has narrowed these down to five investigation topics which will be expounded: the towing procedure, risk assessments, approvals, the towing setup and the foundering of the ships under tow.

These topics will be treated more or less chronologically starting from the early organisational events, such as the formation of the towing procedure, and ending with the technical circumstances of the foundering of the ships. Although many of these events overlap in actual time, this chronological sequence is intended to ease the understanding of the accident as a systemic accident where early organisational circumstances were a prerequisite for later operational and technical events.

Towing procedure

Document type
The towing procedure was a document produced as a part of the preparation of the towing operation. The document was designed for the specific towing operation with inspiration from previous operations. The procedure was not a part of the ship or company's safety management system and did not contain a description of the procedure's purpose and scope, a generic structure, or requirements for compulsory items.

When Maersk Supply Service ships were hired for anchor handling and towing operations, the costumer would prepare the towing procedure. Preparation of towing procedures within Maersk Supply Service was mainly done for towage of the company's own vessels

Towing procedure for the move of MÆRSK SEARCHER and MÆRSK SHIPPER
The towing procedure that was forwarded to MÆRSK BATTLER on 9 December 2017, but was not received on board, was marked as version 7 and with the watermark "DRAFT" on all pages. The draft towing procedure consisted of the following seven sections:

- Main particulars for MAERSK CHANCELLOR, MAERSK SEARCHER and MAERSK SHIPPER.
- A description of the towing setup and the emergency towing gear with specifications on some of the components in the towing arrangement.
- A description of where and how the hook-up between MAERSK CHANCELLOR and the twin

towage were to take place.
- Information on the manning of the ships.
- A calculation of the fuel requirement for the voyage.
- A risk assessment for the voyage.
- An appendix compiling certificates for some of the components in the towing arrangement, a voyage plan, and a letter from the Danish Maritime Authority concerning the manning of MAERSK SHIPPER and MAERSK SEARCHER.

A review of the document reveals that it can be characterized as a working paper for planning the towing operation rather than an operational procedure describing how the towage was to be carried out, as it did not contain vital characteristics of a procedure: It did not specify a scope and purpose of the procedure, and it was not stated in the procedure to whom it was directed. The procedure mostly compiled information of relevance to the preparation of the towage, and to a lesser degree described how a certain work task was to be carried out.

The towing procedure showed visible signs of not having been completed. These consisted of the draft watermark and notes about certificates that needed to be compiled. The document did not indicate whether entire chapters or sections were missing.

Workflow description for the preparation of the towing procedure

The task preparing the towing procedure was mainly performed by a superintendent from the company's marine operations team, who assisted the operations team supervising the operation of the ships with matters concerning voyage planning. During the planning and preparation, starting in late August and until the towing operation was put on standby in late September, the superintendent frequently shared the current versions of the towing procedure with other participants in the planning of the towing operation, among others the operations manager in the operations team.

In October, during the first organisational change, the marine superintendent was asked to leave his workplace, and it was not rendered possible for him to hand over the most recent version of the draft towing procedure, his list of missing items to the towing procedure, or the workflow status of the document. The towing document was in draft and was still an assessment of whether or not the towing operation was possible. It is unknown which version number the marine superintendent had last been working on, but the DMAIB obtained a version 9, and this was most likely not the latest version.

Most of the work documents were saved on the individual employee's personal work computer, and the company did not have a system in place for securing such documents during dismissals. Therefore, the knowledge of the ongoing operations possessed by the individual employee was lost.

When the towing operation with MÆRSK SEARCHER and MÆRSK SHIPPER was re-initiated on 5 December, the new operations team had received a handover from the former operations manager. The new operations manager and the shipping trainee tasked with supervising the execution of the towing operation got the impression from the handover that the planning of the towing operation had been concluded, and that only a few practical details needed to be carried out prior to departure.

Various documents concerning the towing operation had been handed over to the new operations team, but the towing procedure, in version 8, was not handed over until three days prior to departure. At this point, the towing procedure was regarded as a formal document without any practical relevance that only needed to be updated to reflect the current operational situation, i.e. replacing MAERSK CHANCELLOR's information with that of MÆRSK BATTLER.

The shipping trainee forwarded the draft towing procedure to the master on MÆRSK BATTLER; however, he never received it due to a malfunctioning internet connection and he did not need it as he believed to have sufficient information for the voyage and the towing operation. Instead, the master on MÆRSK BATTLER had received the towing procedure for the towing operation with MÆRSK BEATER carried out by the crew on MAERSK CHANCELLOR, who had conducted the same voyage, though with a different tow setup.

The nature of the towing procedure (a document describing different aspects of the towing operation and a compilation of relevant documents) as well as the use of the document during the planning and execution of the towing operation indicate that the towing procedure served different purposes to different persons in the organisation at different points in time. The marine superintendent preparing the towing procedure used and perceived the procedure as a work document with the purpose of forming a background of information for the assessment of whether the towing operation was possible. As long as the towing procedure was in draft, the superintendent did not regard the towage ready for departure or the towing setup sufficiently examined.

In the new operations team and on board the ship, the towing manual was of value only as a formal document of no practical use when carrying out the towing operation. It has not been possible for the DMAIB to fully establish how far in the workflow the towing procedure was when the nautical inspector left the company. However, at this point MÆRSK SEARCHER and MÆRSK SHIPPER had already been connected side-by-side, which suggests that the towing plan was considered to be final.

Risk assessment

Preparation of the risk assessment

The company had a risk management system in place, which was used continuously throughout the preparation of the towing operation. The system was conventionally designed and handled risk by identifying, assessing and mitigating risk. Each identified risk was assigned a certain risk value based on an assessment of its probability and the severity of consequences. This value could then be adjusted by introducing risk mitigating efforts so that the risk would be reduced to an acceptable level. If an identified risk exceeded the acceptable value, the chosen method would have been abandoned and the operation reconsidered.

In connection with the towing of MÆRSK SHIPPER and MÆRSK SEARCHER, the risk management system was in use at every MoC meeting. Furthermore, a risk assessment was carried out by the crew on MAERSK CHANCELLOR when the ship was on its way to Fredericia and this risk assessment was later followed up with risk mitigating initiatives at a MoC meeting by the shore management.

Though a risk assessment was carried out at every MoC meeting, only the risk assessment enclosed in the towing procedure has been preserved (figure 9).

Risk Assessment Form

No.	Effect	Initial Risk			Control Measure	Residual Risk			Person in Charge	Due date	Status
		Probability (A)	Consequence (B)	Risk (A * B)		Probability (A)	Consequence (B)	Residual Risk (A * B)			
1	Interaction between vessels during tow	5	4	20	Fendering between the vessels by use of yokohama fenders. Chains connecting the vessels on the aft and fwd ends. Rope moorings used.	3	2	6	Vessel		
2	Risk of loss or failure of fendering causing hull damage.	4	4	16	- Back up for fendering securing - Visual inspection	3	3	9	Vessel		
3	Tow bridle parting	4	4	16	-Tension control on tow vessel at all times. Tension to be kept under breaking load at all times. -All portions of tow bridle to be in good condition and certified. -Monitor weather and adjust speed. -Emergency tow bridle to be configured and ready to connect.	2	3	6	Vessel		
4	Tow wire parting	4	4	16	-Tension control on tow vessel at all times. Tension to be kept under breaking load at all times. -Tow wire to be inspected before tow.	2	3	6	Vessel		

Value	Probability (A):	Consequence (B):
1	Remote or unheard of in the industry	FAC / <200L Contained DtE / <10K UDS DtP
2	Highly unlikely, would require multiple failures of systems and controls	MTC or RWA / <50L Overboard > 200L Contained DtE / >10K UDS DtP
3	Unlikely, less than average i.e. easy to hypothesize an incident but unlikely	LTI / 50-10K L Overboard DtE / >50K UDS DtP
4	Possible, i.e. the event may have occurred and represents a credible scenario	FTL / 10K-30K L Overboard DtE / >200K UDS DtP
5	High, likely to occur and there is knowledge of a similar event	Multiple FTL / >30K L Overboard DtE / >1m UDS DtP

Figure 9: Excerpt from risk assessment for MAERSK CHANCELLOR's towing of MÆRSK SEARCHER and MÆRSK SHIPPER
Source: Maersk Supply Service

This means that DMAIB does not have access to the latest risk assessment from 7 December 2016 which was carried out for the towing setup with MÆRSK BATTLER. This was carried out separately from the risk assessment in the towing procedure as the procedure was not included in the documentation for the towing operation with MÆRSK BATTLER until on 9 December 2016. It is, however, relevant to study the risk assessment in the towing procedure as this reflects the perception of the risks related to the towing setup with MÆRSK SHIPPER and MÆRSK SEARCHER by the persons deciding and designing the setup. The risk assessment was prepared on 7 September 2016 and was not revised during the alterations of the towing procedure.

Risk assessment and risk mitigation for the side-by-side tow

The risk assessment of the towing procedure for the towing operation with MAERSK CHANCELLOR, MÆRSK SEARCHER and MÆRSK SHIPPER identified 15 risk factors which were listed in the risk assessment form (figure 9, previous page). These risk factors were established at an MoC meeting in September on the basis of the participants' experience and imagination of the risk scenarios. In the investigation of the loss of MÆRSK SHIPPER and MÆRSK SEARCHER, it is relevant to address three risk factors as they concern the risk of collision of the towed ships, loss of fenders and the risk of flooding on the unmanned ships under tow.

The risk of collision was given the highest risk value for probability (5) and second highest value (4) for severity in the event of interaction between the ships. As a counter measure against this risk, fendering by Yokohama fenders and a chain connection between the vessels as well as a connection by mooring ropes were put in effect. These measures were considered to reduce the residual risk to one third of the original risk value.

The probability and the severity of the event of the fenders being lost or failing were both given the second highest risk value. To mitigate this event, the control measures put in effect were to fit the fenders with back-up securing and to visually inspect the fenders. The control measures were considered to reduce the residual risk to less than half of the original risk value.

Flooding on board the unmanned towed ships was identified in the risk assessment, but this item was not given a risk value and no control measures were introduced (figure 10). The reason for the absence of a risk value and control measures might be that the risk assessment had not been concluded.

The towing procedure, including the risk assessment, was not received on MÆRSK BATTLER because of the malfunctioning satellite communication system. However, a risk assessment for MÆRSK BEATER's towing operation was delivered to the crew on MÆRSK BATTLER prior to departure. When the towage of MÆRSK SEARCHER and MÆRSK SHIPPER was put on standby, MAERSK CHANCELLOR towed the supply ship MÆRSK BEATER to Aliağa instead. The risk assessment for the towage of MAERSK BEATER was based on those carried out for the move of S-types, but also included the risk of flooding of unmanned vessels (figure 11).

The risk assessment for MÆRSK BEATER, which was sent to MÆRSK BATTLER, identified almost all the same risk factors, including the risk of floo-

7	Fire on board the towed vessel with no crew on board	2	5	10	No machinery to be running	1	5	5	Vessel
8	Flooding on board the towed vessel with no crew on board								
9	Steering gear / Rudders Failure no control of tow.	2	3	6					
10	Propeller Gear lubrication failure.	2	3	6	Proppel will be locked - no need of lubrication	1	3	3	Vessel

Figure 10: Excerpt from risk assessment for MAERSK CHANCELLOR's towing of MÆRSK SEARCHER and MÆRSK SHIPPER. Source: Maersk Supply Service

7	Fire on board the towed vessel with no crew on board	2	5	10	No machinery to be running	1	5	5	Vessel
8	Flooding on board the towed vessel with no crew on board	3	4	12	- in preparation of the vessel all doors to locked	1	4	4	Vessel
9	Steering gear / Rudders Failure no control of tow.	2	3	6	- rudders to be locked mecanical / welding	1	3	3	Vessel
10	Propeller Gear lubrication	2	3	6	Proppel will be	1	3	3	Vessel

Figure 11: Excerpt from risk assessment for MAERSK CHANCELLOR towing MÆRSK BEATER. Source: Maersk Supply Service

ding on an unmanned vessel. The risk assessment and voyage plan for MÆRSK BEATER were passed on to and applied on MÆRSK BATTLER, most likely because the operations were considered as being alike. In the risk assessment for MAERSK BEATER, the probability and consequence of this risk factor was given the risk value 12. The control measure to mitigate the risk was to close the unmanned ships' watertight/weathertight doors prior to departure. This reduced the original risk value to a residual risk of 4, with a probability value of 1, which corresponded to the definition "remote or unheard of in the industry".

The risk factors above and the established control measures are characterized by the same mitigation strategy: Each risk factor was countered by preventive control measures in isolation from the other risk factors.

Difference in risk perception
As the risk assessment prepared at the latest MoC meeting is not documented, it is not possible to study whether it differed from the risk assessment prepared in the towing procedure. However, it has been established that the crew on board MÆRSK BATTLER had a different view of the risks connected to the side-by-side tow setup than that reflected in the risk assessment prepared by the shore personnel. The crew on board expected that the fenders would fail during the tow and that the towed ships would interact, causing damage to mainly the bridge and accommodation of the ships. However, they considered this acceptable as long as the damage was above the waterline. This perception was shared by some persons in the shore organisation.

The differences between the risk assessment and mitigating initiatives prepared in September by the shore-based staff and the crew's risk perception show that the view on risk was not shared. This was also the case within the demobilisation team working on the towing setup in Fredericia, where the perception of risk ranged between the view that some of the risk mitigating equipment mounted on the ships, such as the tyre fenders on the bridge wings, were an over-reaction to the view that the ships would cause severe damage to each other when they reached the Bay of Biscay. These concerns were raised neither to the master nor at the MoC meetings as the persons holding this view did not consider themselves directly involved in the towing operation.

Approvals

During the planning of the towing operation, three types of approval processes directly connected to the tow operation were carried out: two external approvals by the Danish Maritime Authority and the classification society and one internal approval process, the MoC meetings.

Approval of unmanned tow by the Danish Maritime Authority
The operations managers and the nautical inspectors had sent the towing setup with unmanned ships to the Danish Maritime Authority (DMA) for approval. DMA informed the company by letter that there was no requirement for the ships to be manned while under tow. The operations manager and the nautical inspector interpreted the DMA letter as confirming that DMA, based on a qualified evaluation, approved the towing method and setup and that the operation was considered safe. However, DMA's approval letter only informed that an unmanned tow was in accordance with the regulations in general. The letter did not discuss, evaluate or approve the specific towing setup.

Fitness of tow survey by class
Maersk Supply Service ordered a *Fitness to be towed survey* to be carried out by the ships' classification society prior to departure. The class' definition of a *Fitness of tow survey* was strictly an assessment of the individual ship and its fitness to be towed and was mainly focused on the watertight integrity of the ship. The survey and certification process did not include factors relating to the towing setup, i.e. it did not assess the towing method, the towing ship, the towing wires, fendering, stability, weather, voyage planning, etc. However, all persons in the operations team and on board MÆRSK BATTLER were of the belief that the class inspection evaluated and approved the entire towing setup, including the towing method, fendering and voyage planning, as they would expect during an inspection carried out by a warranty surveyor, which was common practice when warranty surveyors carried out inspections on behalf of external clients.

Towing setup

Towing arrangement

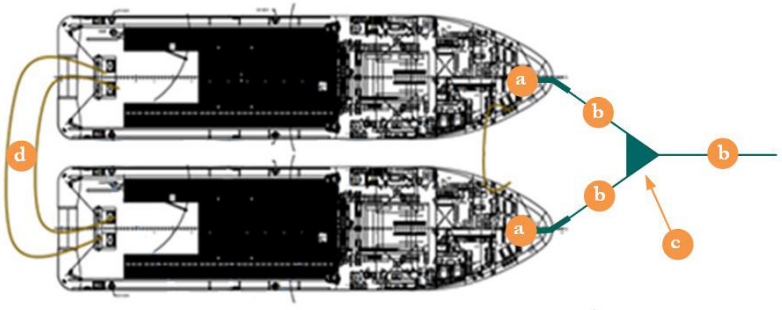
The planned arrangement for towing MÆRSK SHIPPER and MÆRSK SEARCHER to Aliağa was described in the draft towing procedure and was based on MAERSK CHANCELLOR as the towing vessel. The document described that the two S-type ships were to be arranged side by side (figure 12).

A towing wire should be fastened in a Smit bracket on each forecastle and the two towing wires would be connected in a triangular plate with a third towing wire, which would connect to MAERSK CHANCELLOR's main towing wire. Aft and fore, MÆRSK SHIPPER and MÆRSK SEARCHER were to be connected by steel chains and mooring lines forward to keep the vessels side by side.

Connecting the two ships under tow side-by-side and towing them by means of one bridle suggests that the connected ships were regarded as one single unit, similar to towing for example a drilling rig.

During the investigation, DMAIB has established that side-by-side towage of this type of vessel is mainly carried out in sheltered waters, and that it is an unconventional setup for an oceangoing tow.

The towing arrangement described in the draft towing procedure was an initial model for the connection of the ships, which was adapted to the operational circumstances by the crew in Frederica as they were working on connecting the ships. This meant that items or details not described in the towing procedure were decided or initiated by the crew in collaboration with the shore-based operations team and the marine superintendents (e.g. chain lengths), and that solutions that could not be effectuated operationally were changed on site. The towing arrangement in the draft towing procedure was not updated according to the changes carried out in practice, but the certificates for each component were compiled and enclosed as an appendix.



a) Chafing chains: No specifications

b) Towing wires: 25 m long steel towing wires with a diameter of 77 mm.

c) Towing plate: No specifications

d) Chains: Chains with a diameter of 77 mm, long enough to make a bight in the water.

Figure 12: Planned towing arrangement for MAERSK CHANCELLOR, MÆRSK SHIPPER and MÆRSK SEARCHER as described in the draft towing procedure.
Source: Maersk Supply Service/DMAIB

MÆRSK SHIPPER was placed at MÆRSK SEARCHER's port side, and the ships were ballasted so that they had a slight heel away from each other, and the rudders were locked.

It was not feasible to fasten the forward chains connecting the ships as the bollards on the forecastle were not certified for this purpose. The purpose of the chain was to ensure that the two S-type ships would not drift apart, but it was assumed by the demobilisation team in Fredericia and the shore personnel that the force of the pull on the towing bridle would keep the ships close together, and that the forward chains were therefore not necessary.

MÆRSK SHIPPER and MÆRSK SEARCHER's towing bridle was in practice fitted with three 71 mm steel wires with a MBL of 403 tonnes, and a towing plate of high tensile steel with a minimum breaking load of 425 tonnes. The towing wires were fastened to Smitt brackets on MÆRSK SHIPPER and MÆRSK SEARCHER's forecastle with an 87 mm chain tail. MÆRSK BATTLER provided a 3000 m main towing wire with a diameter of 83 mm with an MBL of 500 t.

The towing wires and fastenings performed as expected and did not show any signs of malfunction or damage during the voyage.

The towing arrangement was supplemented by equipment with the purpose of mitigating the risk of collision between MÆRSK SHIPPER and MÆRSK SEARCHER and the risk of loss of tow due to failure on the main towing wire (figures 13). The following sections will describe the setup and effect of emergency towing gear and fenders.

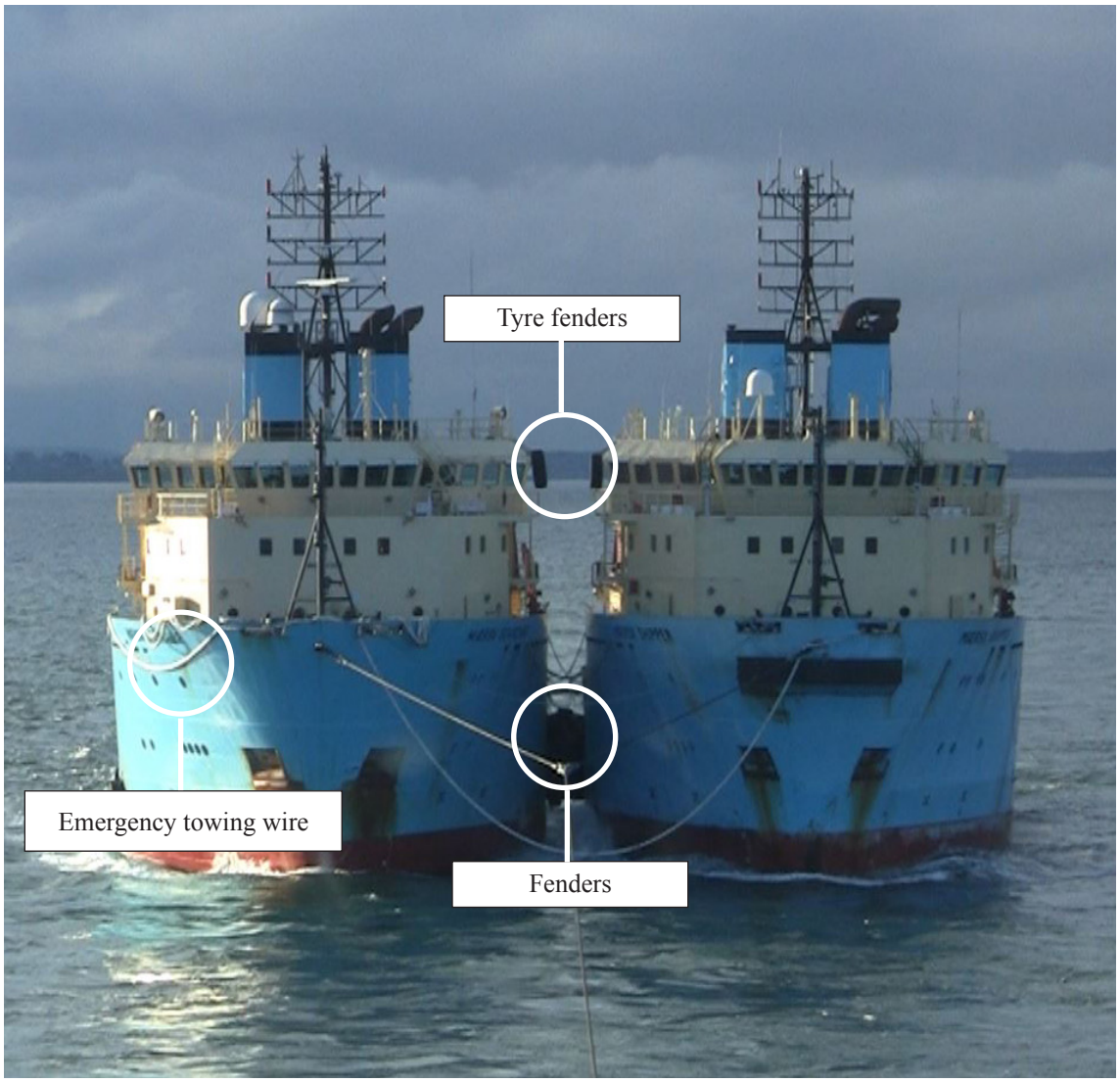


Figure 13: Risk mitigating equipment in the towing arrangement for MAERSK CHANCELLOR, MÆRSK SHIPPER and MÆRSK SEARCHER.
Source: Private photo/DMAIB

Emergency towing gear
In case of failure of the main towing wire, MÆRSK SHIPPER and MÆRSK SEARCHER were fitted with an emergency towing line. The line was fastened on the forecastle of each ship and was led aft along the starboard side of MÆRSK SEARCHER and connected to a buoy in the water. The emergency towing line could then be retrieved by picking up the buoy.

The fitting of the emergency towing gear followed the same principle as the towing arrangement: it was mounted on the tow as if the ships together formed one unit.

The use of the emergency towing gear did not become relevant in connection with the capsizing and foundering of MÆRSK SEARCHER and MÆRSK SHIPPER as the towing wire did not fail.

Procurement of Yokohama fenders
The considerations that formed the basis of the fender setup were mainly based on experience and not calculations related to the specific job. From the early versions of the towing procedure, a setup consisting of three Yokohama fenders appeared in the documents and the internal communication. As the planning progressed, the setup – consisting of three fenders – remained the same but the dimensions of the fenders varied and were reduced in later versions of the towing documents.

Originally, the departments planning the operation had identified a need for a minimum of three fenders with a diameter of no less than 3.0 m and a length of 4-5 m. Apart from the external dimensions, no other requirements were specified for the fenders. However, it was soon realised that fenders of the specified dimensions were difficult to locate and expensive to buy or rent.

One of the company's suppliers had three fenders of a smaller type available for rent, with a diameter of 2.3 m and a length of 4.0 m, at a significantly lower price than those originally requested. Some concerns were raised within the operations department as to whether the smaller fenders were acceptable, but the cheaper and smaller fender type was chosen. No recalculations or considerations were made to assess whether the reduction in fender size would have an impact on the towing setup and the risk assessments.

The draft towing plan version 3, dated 12 September 2016, as well as version 5, dated 14 September, both identified fenders with a minimum diameter of 3.0 m. From 14 to 16 September, the issue was discussed by the commercial, purchase and operations departments, and in version 8 of the towing manual, dated 27 September, the smaller fenders appeared, however described with a diameter of 2.4 m as opposed to the 2.3 m specified by the supplier.

Through the broker, the company rented the three used fenders, which were delivered to the port of Fredericia. At delivery, they showed signs of wear and appeared to be somewhat damaged, which was documented through photos (figure 14, next page).

In the process of acquiring fenders for the tow of MÆRSK SHIPPER and MÆRSK SEARCHER, the fenders were described simply as 'Yokohama fenders' with no other specifications besides approximate diameter and length. It was therefore not possible for DMAIB to determine the exact manufacturer or model of the fenders that were used for the tow.

Yokohama fender is a generic term, used for marine pneumatic rubber fenders, named after its original developer, The Yokohama Rubber Co. Ltd. Pneumatic rubber fenders basically consist of an inflatable rubber bladder and an outer protective rubber cover. Some types have netting, often with rubber tyres, mounted on the outside to protect the fender from damage. This type of fender is widely used for ship-to-ship transfers at sea as well as vessel-to-berth protection. The special property of a pneumatic fender is its ability to absorb high amounts of energy with low reaction forces. The energy absorption abilities of a pneumatic fender increase with diameter.

Other types of marine fenders, which resemble pneumatic rubber fenders, are often referred to as Yokohama fenders as well, for instance foam elastomer or foam-filled fenders. Foam elastomer fenders are manufactured with an outer skin made of polyurethane and an internal foam structure of either a closed cell core structure or an open cell core structure. Newer foam elastomer fenders usually have a closed cell structure, whereas older types often have an open cell structure.

It can be difficult to distinguish pneumatic fenders from foam-filled ones, especially if they are fitted with protective chain netting and/or tyres.

Figure 14: Photos showing details of wear and damage to the fenders upon delivery.
Source: Private photo

Figure 15: The fenders used for towing MÆRSK SHIPPER and SEARCHER, before delivery.
Source: Private photo

Description of the fenders and mounting

From photos it has been established that all three fenders were of a foam elastomer type (figure 15), and not pneumatic fenders. Two had chain/tyre protection and one had sling type protection. They were used, approx. 10-12 years old, and appeared to have some external damage and general wear and tear. Their dimensions were Ø2.3 m and a length of 4.0 m.

DMAIB has, in consultation with a manufacturer of fenders, estimated that the wear and tear in itself could have resulted in at least a 30% reduction in capacity. Depending on the internal structure and its state, their strength may have been reduced by up to 100%, i.e. they may have had no remaining capacity to withstand pressure at all. If the foam-filled fenders that were acquired for MÆRSK SHIPPER and MÆRSK SEARCHER were of an open cell structure type, as their age might indicate, the damage they had to the outer layers and protection nettings could have resulted in water penetrating and filling the interior of the fenders, which would have significantly reduced their ability to absorb energy.

The end fittings of this type of fender – both pneumatic and foam-filled ones – usually comprise a towing ring, which serves the purpose of connecting the sling or chain tyre protection net and steel eye or bracket for lifting and installation. Usually, a swivel is connected to the end fitting to allow the fender to rotate around its longitudinal axis when installed (figure 16, next page).

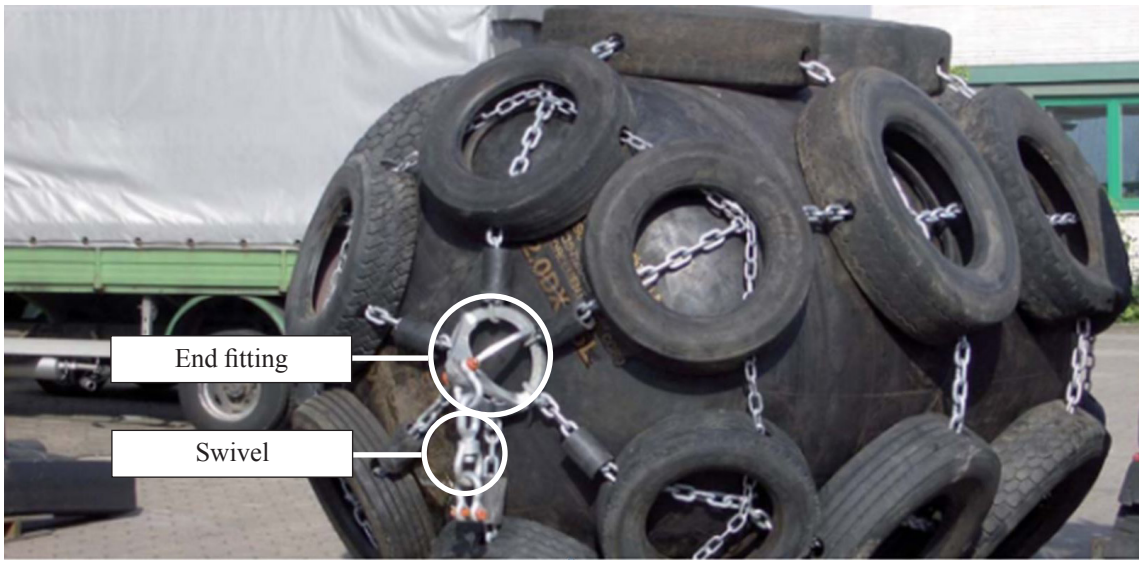


Figure 16: End fitting on a standard pneumatic fender (not related to the accident).
Source: Willbrandt Gummitechnik

In accordance with the towing manual, the three fenders were mounted on MÆRSK SEARCHER's port side. The main fixtures were steel chains at each end, attached to the towing ring and flange, and as an extra precaution, also straps or wires.

As seen in figure 17 below, the end fittings of the fenders used for the towing of MÆRSK SHIPPER and MÆRSK SEARCHER were not fitted with swivels, but instead the mounting chains were directly connected to the pin on the flange.

On the ship, the fender mounting chains were anchored to the existing structure as convenient (figure 18). As shown in the photos, some of the chains were mounted with sharp bends and/or passed over sharp steel edges, which might have contributed to their breakdown.

Figure 17: Fender from MÆRSK SEARCHER.
Source: Private photo

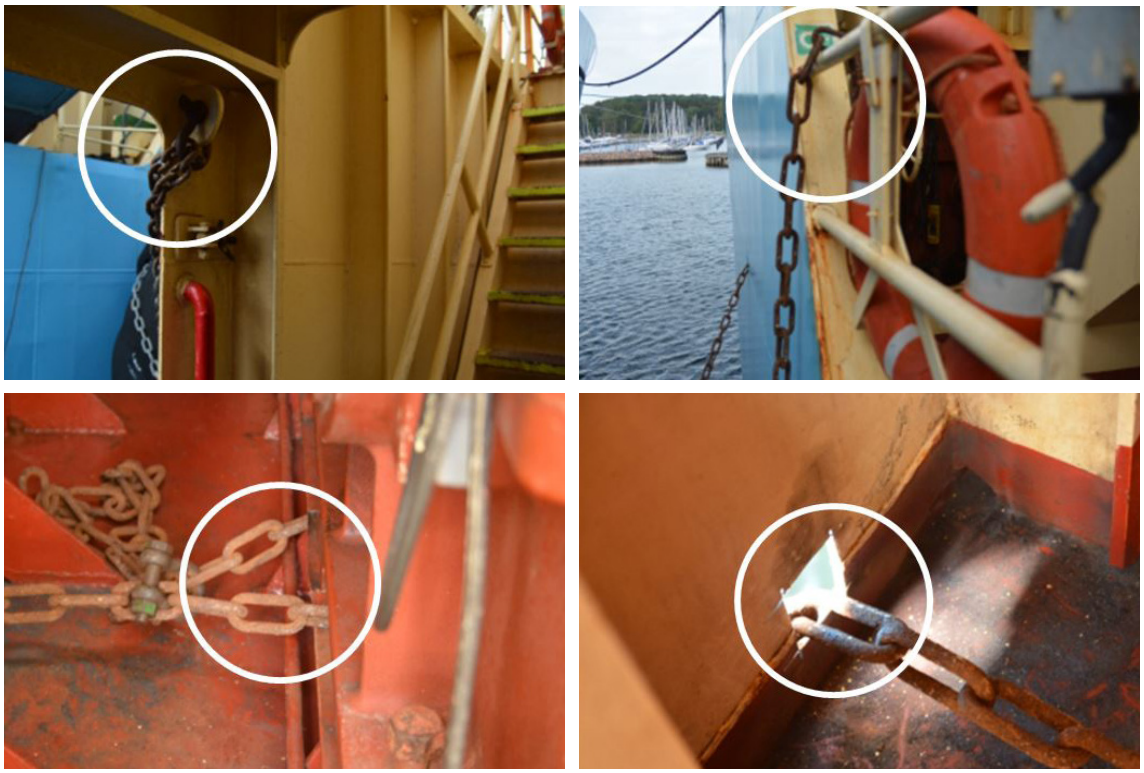


Figure 18: Connecting chains for fenders - MÆRSK SEARCHER
Source: Private photo

Loss of fenders

From the departure from Fredericia and during the voyage through the North Sea and the English Channel, the weather was calm. This meant that the two towed ships experienced only minor motions in the sea and that the resulting forces between the ships were absorbed by the fenders. When the towage entered the Bay of Biscay, the weather got more adverse and the ships' motion got larger, resulting in larger forces when the ships impacted. According to observations made by the crew, the fenders disappeared shortly after the two ships started hitting each other but it is unknown whether the fenders themselves disintegrated or if the chains broke and the fenders were lost.

There are three likely explanations for the breakdown and/or disappearance of the fenders, all of which may have contributed at the time of the accident:

1. The chains used to secure the fenders to MÆRSK SEARCHER may have broken due to the vertical and longitudinal forces acting on them when the ships collided. Due to the lack of swivels on the connections between the securing chains and the fenders, especially vertical forces acting downwards on the fenders may have caused significant loads on the securing chains.

2. The fenders may have been crushed due to the impact between the two ships because they were undersized, i.e. because the particular fender type did not have a sufficient ability to absorb energy resulting from the impact.

3. The fenders may have disintegrated because their strength was reduced due to damage and water ingress into the foam core structure.

Video recordings from the accident show that the chain and fastening from one of the the fenders are intact, but the fender had disintegrated. In the picture on next page (figure19), the remains of the fender positioned in the centre can be seen. Furthermore, the recordings show that the aft fender was intact during the same period of time indicating that the forces acting on the fenders were not evenly distributed on all three fenders. When the weather conditions worsened, the force of contact was concentrated on the forward part of the ships because of the way the towing forces acted on the ships, thereby exposing the forward fenders to excessive horizontal and vertical forces.

In addition to the fender setup discussed above, the planning process had identified a separate risk of the bridge wings colliding, causing structural damage to the superstructure. To counter this, it was decided to mount tyre fenders on the outer end of each bridge wing. When the towed ships started impacting, the bridge wings were crushed, and thus the tyre fenders did not have the desired effect (figure 20).

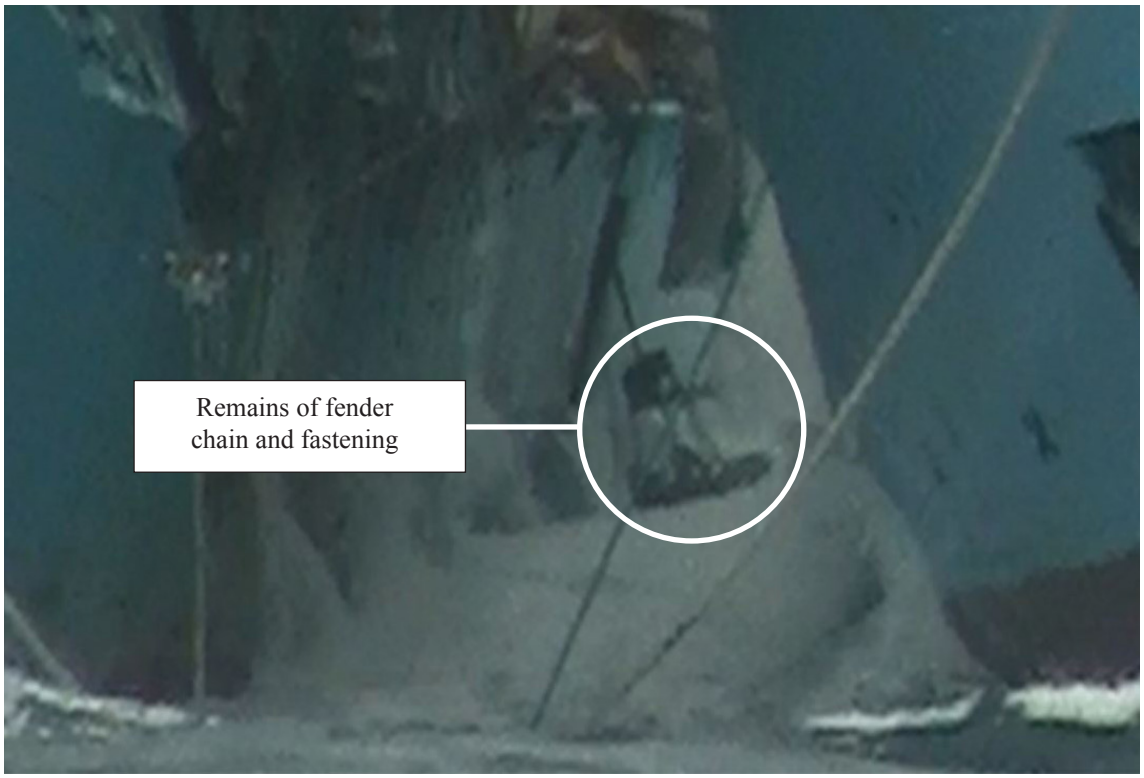


Figure 19: Remains of deteriorated fender between MÆRSK SEARCHER and MÆRSK SHIPPER.
Source: Private photo

Figure 20: Left: Tyre fenders on bridge wings Right: Bridge wings after impact.
Source: Maersk Supply Service

The ships sank at a water depth of approx. 200 m and were not salvaged. Hence, the wrecks could not be examined. However, substantial photo and video evidence was available, which shows that the ships had suffered significant structural damage while being under tow. This section contains a brief description of the ships prior to departure, followed by a description of the damage they sustained and its consequences.

Description of the ships

MÆRSK SHIPPER and MÆRSK SEARCHER were built in 1999 and were owned and operated by Maersk Supply Service. Both ships were registered in the Danish International Register of Shipping as offshore supply vessels/anchor handling tugs. They were part of a series of ships and had identical main particulars. The ships had an overall length of 82.00 m, a breadth of 18.80 m and a gross tonnage of 4013.

Figure 21 below shows the layout of the ships, which was typical for anchor handling tugs: The accommodation was placed forward, a winch garage aft of that, and the working deck aft. Below the upper deck, the engine rooms were located amidships, the aft section contained cargo tanks, and the forward section contained auxiliary machinery, chain lockers, and freshwater and dry cargo tanks. The ships were constructed with double hulls, with their side tanks used for fuel oil, diesel oil and freshwater. Under the freeboard deck, the ships had transverse watertight bulkheads at frame 28 and at frame 103 (the collision bulkhead). This meant that the ships had one large watertight compartment consisting of the major part of the underwater hull. The watertight bulkheads are indicated in figure 26 below.

MÆRSK SEARCHER had been laid up in the port of Fredericia since 28 February 2016, and MÆRSK SHIPPER since 29 April 2016. The ships were intact but were not operational, meaning that their engines and auxiliary systems were not running, and therefore there was no power on board.

In early September 2016, a team of officers was deployed in Fredericia to prepare the ships for towage. This assignment comprised three main tasks: Removing items from the ships, structurally preparing the ships for towage, and setting up the towing arrangements.

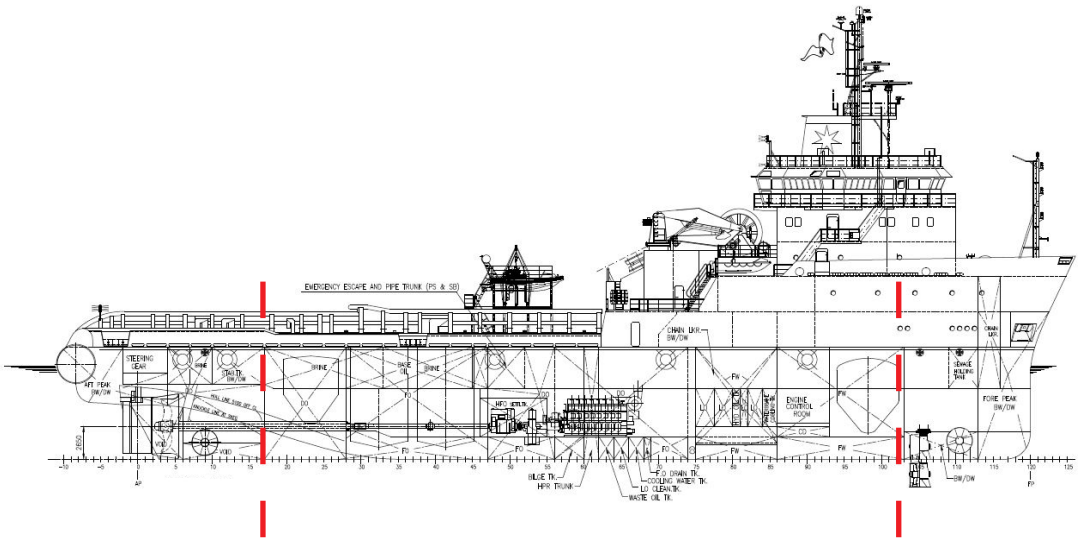


Figure 21: Excerpt of general arrangement, MÆRSK SHIPPER and MÆRSK SEARCHER. Transverse watertight bulkheads indicated.
Source: Maersk Supply Service

	MAERSK SEARCHER	MAERSK SHIPPER
Waste oil & sludge [t]	78	9
Fuel/diesel [t]	40	47
Lubricating oil [t]	22	23
Bilge [t]	12	10
Hydraulic oil [t]	6	6
Base oil (cargo) [t]	1	
Total [t]	**159**	**95**

Figure 22: Residual fluids upon departure.
Source: Maersk Supply Service/DMAIB

	MAERSK SEARCHER	MAERSK SHIPPER
Displacement [t]	5118	5053
Draft, mean [m]	5.40	5.35
Trim [m]	0.0	0.0
Heel [°]	0.9 stb	1.4 port
KMt [m]	8.69	8.71
GMt [m]	0.63	0.58
GMt req. [m]	0.39	0.39
Angle of downflooding [°]	50.6	50.9

Figure 23: Summary of departure loading conditions.
Source: Maersk Supply Service/DMAIB

The items removed from the ships were mainly documents, art, furniture etc., which were packed up and sent to the company. In addition, lubrication oil was pumped out for reuse on other ships. Ballast and freshwater pumps were removed from MÆRSK SEARCHER to be used as spare parts for other ships, as were the ships' fast rescue boats.

Figure 22 above shows a summary of the residual fluids in tanks and in machinery and pipe systems on board the two ships when they departed from Fredericia. It had been agreed with the shipyard in Aliağa that the shipyard would dispose of the residual fluids, which is common practice.

During the approximately five weeks that the team was on site preparing the ships, one of the officers from the demobilization team continuously updated the ships' loading conditions in the Loadstar software (the software used for stability calculations) to reflect the changes resulting from removing and adding weights.

When the preparations had been completed, the officer prepared a departure loading condition for each ship (figure 23 – summary of loading conditions), which he forwarded to the operations department, asking if they had any particular requirements. The operations department stated that they would prefer loading conditions with the lightest possible draught and even keel, as this would ensure the lowest fuel consumption for the towing ship. The officer suggested lightly ballasting the ships to give them a 0.5-1° heel away from each other to counter the forces from the towing bridle and avoid contact between the ships' bridge wings, which was accepted.

The departure conditions were lighter than normal operating conditions, but not significantly so. The conditions met all mandatory criteria with regards to stability, hull strength and load line requirements.

Description of damage sustained during towage

Until the ships left the English Channel and met harsher weather in the Bay of Biscay, the towed ships were apparently intact, although they may already have sustained structural damage when the fenders were lost (figure 24, next page). Photo and video recordings from 20-21 December 2016 show that both ships sustained significant structural damage to the hull, superstructure and deck appendages (figure 25, next page).

In the earlier stages of the voyage, the ships' motions were insignificant, and the ships did not make contact because the forces were absorbed by the fenders. However, when the swell increased and the ships' motions increased, the fenders were lost

and the ships started impacting. Initially, only the bridge wings seemed to be affected, but later the impact comprised the full structures of the ships hitting each other with ever increasing force.Once the fenders were no longer effective, and the ships were still tied closely together, they continuously collided, causing progressing structural damage.

The video evidence indicates that early structural damage to MÆRSK SEARCHER resulted in water ingress, which in turn caused the ship to heel more to port. It is likely that the ships also suffered damage which is not visible, e.g. below the waterline, and the effects of free water surfaces within MÆRSK SEARCHER may have contributed to the ship's movements.

The following section will focus on the damage on MÆRSK SEARCHER. Both ships sustained similar structural damage. However, MÆRSK SHIPPER appeared to retain a better stability for longer than MÆRSK SEARCHER and probably capsized mainly as a result of MÆRSK SEARCHER sinking while being connected with chains.

As the illustrations of MÆRSK SEARCHER show (figure 26, next page), the shell plating, superstructure, deck appendages and underlying structure had sustained significant damage in an area extending longitudinally from the front of the superstructure to aft of the engine room ventilation duct, just aft of the superstructure and winch garage.

Figure 24: MÆRSK SHIPPER and SEARCHER without fenders, but apparently intact.
Source: Maersk Supply Service

Figure 25: MÆRSK SHIPPER and SEARCHER with structural damage.
Source: Maersk Supply Service

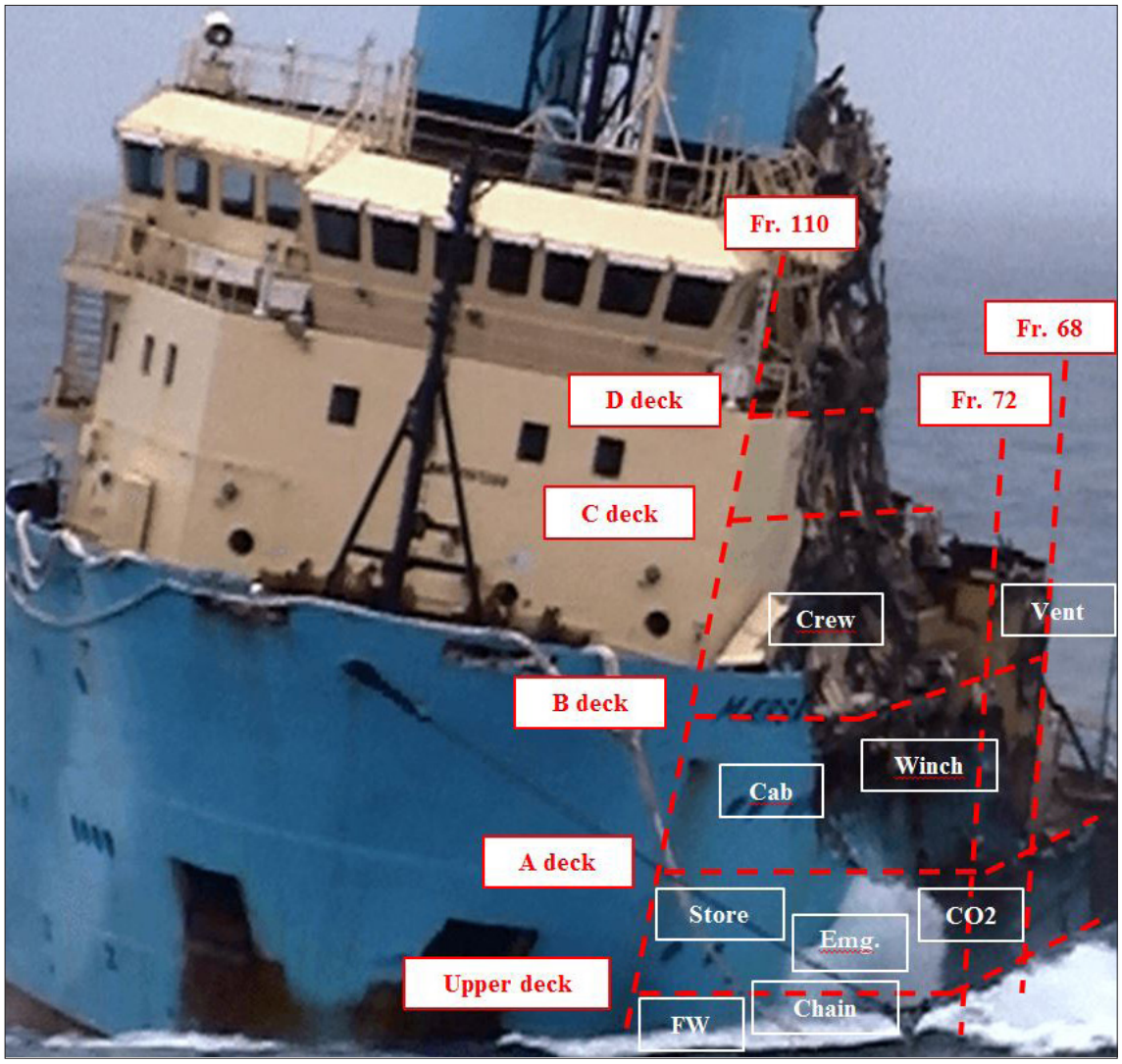


Figure 26: Extent of the visible damage on MÆRSK SEARCHER.
Source: Maersk Supply Service/DMAIB

In the transverse direction, the visible damage extended from the outermost ship side to well into the accommodation area of the superstructure. The damage in some areas extended an estimated 2-3 m into the structure (figure 27, next page).

Vertically, the photos show structural damage extending from the top of the port side funnel, extending down to around the upper deck (figures 28, next page). Longitudinally, the visible structural damage extended from the forward part of the superstructure to aft of the deck crane and engine vent.

The significant damage to the ship's structure allowed a large ingress of sea water into the internal compartments of the ship. Because the ships had one large watertight compartment below the freeboard deck, any water ingress into the major part of the hull would enter into the same watertight compartment. Figure 29 on next page shows potential flooding points and areas.

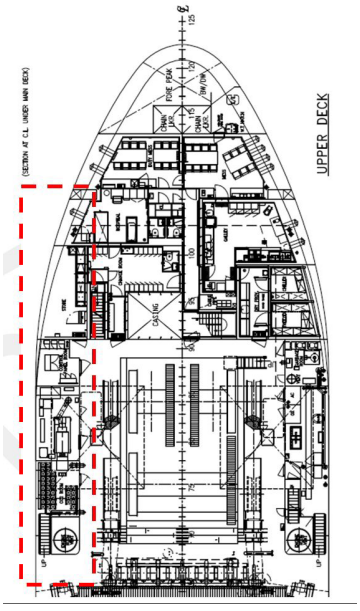


Figure 27: Extent of visible damage – top view
Source: Maersk Supply Service/DMAIB

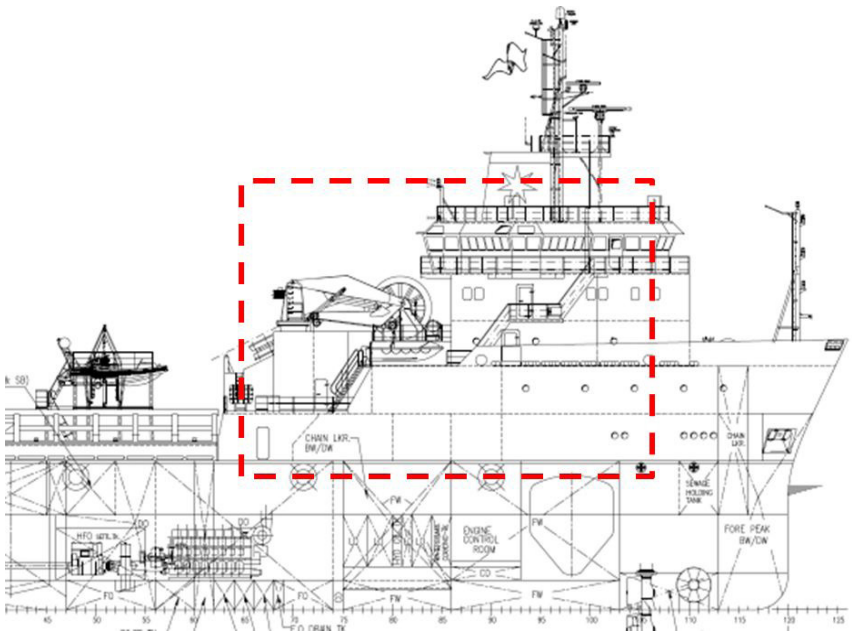


Figure 27: Extent of visible damage – starboard side view.
Source: Maersk Supply Service/DMAIB

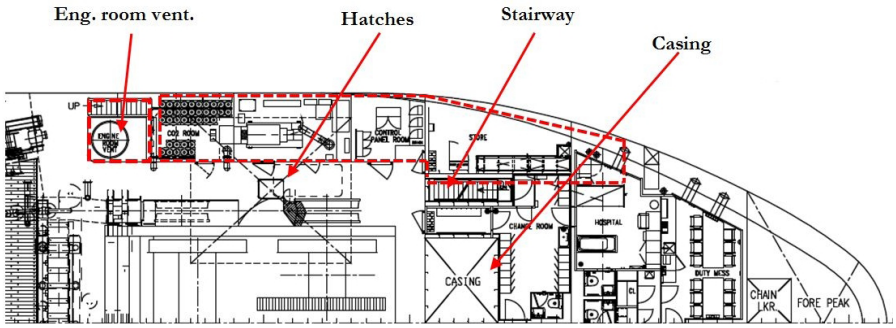


Figure 29: Potential water ingress flooding points and areas.
Source: Private photos/DMAIB

In addition to the visible hull damage, the repeated collisions between the two ships caused damage to the ships' internal structure. The forces acting on the ships' structure are likely to have led to bending and buckling of deck and bulkhead plating, fractures in weldings, warping of door frames, breaking of piping systems, etc. Therefore, it is likely that the internal watertight integrity has been compromised. It is also likely that the ships had sustained damage to the hull structure and sea connections below the upper deck.

From the flooded damaged areas and from the open deck, seawater could have entered the compartment below the upper deck through many potential entry points: Cracked weldings, deck plates, hatches, doors, cable and piping trunks, broken piping systems, staircases, damage to the underwater hull or overboard valves, etc.

Progressive flooding, i.e. where flooding leads to further heel, which leads to further flooding, of the large engine room compartment would eventually lead to the ship capsizing and later sinking.

Damage stability calculations carried out after the accident on behalf of the company showed that a water ingress of approximately 1100 tonnes into the engine room compartment would have been critical and would have caused the ship to capsize with a heel of 30°. It is likely that the structural damage to the hull and internal structure allowed significant water ingress into the engine compartments, which, in combination with the free surface effect and a list to port, caused the ship to capsize and subsequently founder.

Analysis

The aim of the analysis is to establish why MÆRSK SEARCHER and MÆRSK SHIPPER capsized and MÆRSK BATTLER had to carry out a controlled disconnection of the tow during the night between 21 and 22 December 2016. From the data presented in the accident narrative and the investigation, the analysis will focus on the organisational preconditions for the technical and operational circumstances which led to the foundering of the ships.

Reading note

Arguably, it can be questioned why the company chose an unconventional towing method for this type of towage operation and why the crew on MÆRSK BATTLER did not realise that they were on the brink of a very serious accident when they saw the extensive damage to the ships. However, the starting point of that analysis will be based on hindsight knowledge, and in accident investigation it is crucial to resist the tendency to analyse accidental events with knowledge about the outcome which the involved persons did not have prior to the accident. Therefore, DMAIB seeks to understand the involved persons' decisions and actions in the context in which they were formed with the aim of learning why the accident happened in spite of the professionalism of the organisation and the persons involved.

The foundering of MÆRSK SEARCHER and MÆRSK SHIPPER

The idea behind the side-by-side setup was that MÆRSK SHIPPER and MÆRSK SEARCHER would be connected to each other so that they would behave as one unit and reduce individual movement when being towed with a shared bridle. However, when the towage experienced increased swell in the English Channel, the ships under tow did not behave as one unit. Instead they behaved as two interacting units, exposing the fenders to forces that they could not withstand. In the absence of the fenders, the ships under tow made direct contact. The combination of two tightly connected ships in individual movement without a buffer in-between led to the ships colliding constantly for at least 36 hours, causing severe structural damage to both ships. This damage caused uncontrollable water ingress on MÆRSK SEARCHER and subsequently loss of stability, which resulted in the ship capsizing.

MÆRSK SHIPPER also suffered structural damage, but capsized as a result of water ingress and/or being dragged heavily to starboard by MÆRSK SEARCHER, as the ships were connected with chains.

Once MÆRSK SEARCHER had capsized, no contingency plan rendered it possible to save MÆRSK SHIPPER. As the ships were connected by chains and were unmanned, it was not possible to free MÆRSK SHIPPER from MÆRSK SEARCHER and to prevent the latter from pulling MÆRSK SHIPPER under. The emergency towing wire was useful only in a scenario where the towing connection was lost. This was not an issue during this towing operation; in fact, the towing wire parted with a controlled breakage.

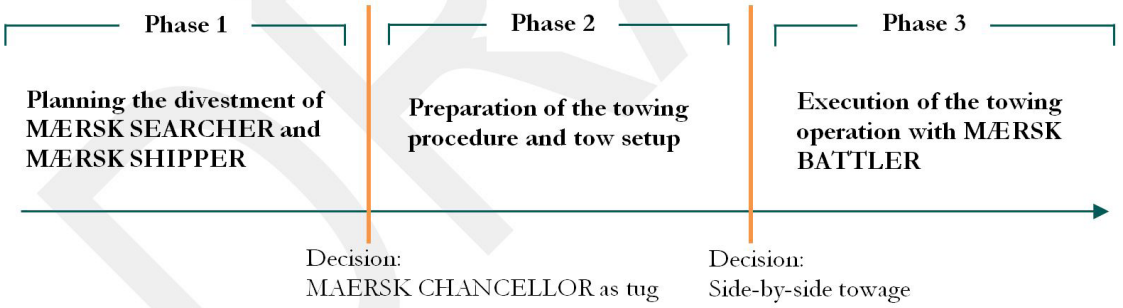
The crew on MÆRSK BATTLER did not realise that the ships were at risk of being lost due to loss of stability until 10 minutes before the capsizing of MÆRSK SEARCHER, though both ships had suffered significant structural damage. The crew were of the understanding that structural damage was to be expected with this type of setup, but that it did not pose any significant risk as long as the damage was above the waterline. The crew did not observe any damage below the waterline and had more concerns about the towing bridle. The acceptance of structural damage most likely contributed to the blurring of the line between a manageable situation and an accident. This meant that the crew did not realise that the situation was critical until MÆRSK SEARCHER had taken in a significant quantity of water and showed visible signs of losing stability, leaving no time or possibility for seeking port or sheltered waters.

Organisational preconditions for the accident

The organisational activities related to the tow of MÆRSK SEARCHER and MÆRSK SHIPPER to Aliağa can be traced back to at least four months prior to the accident. During this period of time, the company underwent organisational changes, the towing operation was postponed and the towing ship was changed, all of which caused a range of organisational factors to be in play.

To understand how the events and the decisions taken were linked to the accident, it was necessary to look at them in a historical perspective to gain an understanding of when and in which context the main decisions and events took place.

DMAIB has identified three phases which were instrumental in the preparation of the tow: 1) Planning the divestment of MÆRSK SEARCHER and MÆRSK SHIPPER, 2) Preparation of the towing procedure and towing setup 3) Execution of the towing operation of MÆRSK BATTLER. These phases were separated by two key decisions which influenced how the towage was finally to be carried out.



Phase 1

During the planning of the divestment of MÆRSK SEARCHER and MÆRSK SHIPPER, the shore management had a range of options for how to move the ships to Aliağa, e.g. they could be towed one at a time or both ships could be towed simultaneously by one ship. Once the decision was made to tow the ships simultaneously, the management was presented with a variety of options for which ships were suitable and available for that operation and what towing arrangement would be appropriate. MAERSK CHANCELLOR was chosen for mainly three reasons: The ship was deemed suitable to carry out the operation, it was available and it was convenient because the ship was to be divested as well.

The initial decision that MAERSK CHANCELLOR was to carry out the towing operation became one of the most influential decisions of the towing operation, as the limitations of its winch setup narrowed down the possible way of carrying out the towing operation. The initial choice of using MAERSK CHANCELLOR as tug hence set out a trajectory for how the planning of the towage of MÆRSK SEARCHER and MÆRSK SHIPPER was to be carried out, which is remarkable as the ship did not take part in the final towing operation.

Phase 2

During the preparation of the towing procedure, the idea of towing the ships side-by-side became relevant because MAERSK CHANCELLOR was not equipped to tow MÆRSK SEARCHER and MÆRSK SHIPPER on two separate winches, which was the towing method recommended by external towing experts. Furthermore, it was deemed too expensive to tow the ships in series because then one of the towed ships had to be manned. The decision to have MAERSK CHANCELLOR tow MÆRSK SEARCHER and MÆRSK SHIPPER simultaneously therefore left only one towing method, side-by-side towage.

During the evaluation of the possible towing methods, a superintendent in the technical department raised concern early on that the ships might collide and suffer damage during the tow. However, after having made a risk assessment of the side-by-side towage, it was deemed possible to effectively mitigate those risk factors. MÆRSK SEARCHER and MÆRSK SHIPPER were tied together even though the superintendent who had been laid off had not finalized the towing procedure and thereby the assessment of whether the side-by-side towage was feasible in practice.

During the preparation of the towage, the organisational changes took place and the marine superintendent was laid off before he had finalised the towing procedure, including the final assessment of the towing method. With the organisational changes, vital historical knowledge was lost, e.g. that another towing setup had been recommended, and though MoC meetings were held on several occasions during the planning of the towing operation, these did not ensure a flow of historical knowledge.

The organisational change and the subsequent dispersed knowledge might seem to be the organisational event of the greatest importance to the preparation of the tow because it is an out-of-the-ordinary event. However, the DMAIB finds it unlikely that the historical knowledge of the workflow status of the towing manual or the previous towing options would have been the cause for a revision of the towing setup. This is so because the side-by-side setup had already been validated as a good option by means of the risk management system, and therefore there was no reason to abort the towing setup.

Phase 3
With the ships tied together and the risk assessment being acceptable, there was no reason for either the new operations managers or the master to revise the towing method. The new operational managers who had been handed over the towing operation were of the conviction that the towage planning and the towing setup had been finalised and just needed to be executed. In other words, they were no longer in a planning mode, and their range of options was narrowed down to the side-by-side method. They trusted the assessments and decisions carried out by their former colleagues and did not have any reason to revise the setup though it was to be carried out by MÆRSK BATTLER instead of by MAERSK CHANCELLOR. Their focus was on facilitating a swift execution of the towing operation.

Once it had been decided that MÆRSK BATTLER was to replace MAERSK CHANCELLOR, it was not considered reconfiguring the towage setup though MÆRSK BATTLER had the necessary equipment. However, it is unlikely that the knowledge about an alternative towing setup would have led to a revision of the towing setup because the side-by-side option had been deemed sufficiently safe before MÆRSK BATTLER had been assigned the task.

The crew on MÆRSK BATTLER were aware that the side-by-side towing method was untraditional for this type of voyage. However, the crew strongly identified themselves with the company's image of being industry frontrunners and capable of solving difficult and novel tasks. Therefore, the crew did not question the towing method, but relied on their professionalism to manage the situation.

Risk assessment and risk management

In the risk management process preceding the towing operation, the risk of losing the fenders, the risk of collision between MÆRSK SHIPPER and MÆRSK SEARCHER, and the risk of the ships under tow being flooded were all identified. The risk factors and risk mitigating initiatives were all identified on the basis of the MoC meeting participants' experience and conceptions of what type of risk scenarios would be relevant. As no participant in the MoC meetings had experience with the side-by-side towing method, they relied solely on their ability to imagine which scenarios could occur. When observing the risk assessment and the applied risk mitigating strategies, two issues regarding the participants' risk perception can be observed:

i) Underestimation of acting forces
The forces acting between the ships under tow were underestimated. The mooring ropes mounted to keep the ships close together and the mounted tyre fenders on the bridge wings indicate that nobody had imagined that the ships were able to move individually and to interact to the extent that they did. Mooring ropes and tyre fenders are not able to withstand this type of forces. The choice of downscaling the fenders also indicates that the forces acting between the ships under tow were underestimated.

ii) Absence of mitigating strategies for acutely emerging incidents
The risk mitigation focused on preventive measures to be carried out or mounted prior to arrival. These measures were assessed to reduce the risk of the operation, but a residual risk was maintained. If these preventive measures failed, no strategies to redress the consequences were in place, which effectively left the crew without any possibility of acting on these consequences. Furthermore, as each risk factor was handled separately, the risk assessment did not address the fact that the risks could be connected, e.g. that the failing fenders could lead to collision and subsequent flooding. Hence, the preventive control measures did not correspond to the acute potential of the consequences of the residual risks coming into effect and the interaction between the risk factors.

Conclusions

DMAIB's conclusions on the loss of tow accident

MÆRSK SEARCHER and MÆRSK SHIPPER capsized and sank as a result of having suffered severe structural damage while being under tow in the Bay of Biscay on the night between 21 and 22 December 2016.

The towage was configured as a side-by-side setup where the ships under tow were connected and considered to be one unit. When the towage was confronted with swell and waves causing increased motions of the ships, they did not behave as one unit, but as two individual units interacting. The only buffer separating the ships consisted of three fenders, which were unable to withstand the force of the coupled and interacting ships and hence failed. When MÆRSK SEARCHER and MÆRSK SHIPPER had been in direct contact and had collided continuously for 36 hours, structural damage compromised the watertight integrity of MÆRSK SEARCHER. The side-by-side setup rendered no contingency to disconnect MÆRSK SHIPPER from MÆRSK SEARCHER. Hence, when MÆRSK SEARCHER capsized and sank, the crew had no option to recover MÆRSK SHIPPER, which capsized shortly after and subsequently sank.

The crew on MÆRSK BATTLER did not perceive the direct contact between MÆRSK SEARCHER and MÆRSK SHIPPER as an emergency situation. The crew expected that the fenders of the side-by-side towing setup could fail during the tow and that the ships would suffer some damage to the accommodation on each of the ships under tow, but as they were to be recycled, damage above the waterline was accepted. This perception blurred the line between a successful operation and a critical situation and therefore the emergency situation was not evident to the crew until 10 minutes before the capsizing of MÆRSK SEARCHER though both ships under tow had shown signs of significant structural damage 24 hours earlier.

The cause of the capsizing and foundering of MÆRSK SEARCHER and MÆRSK SHIPPER might seem simply to be the result of two ships being allowed to collide multiple times and a wrong choice of towing method. However, this assumption is oversimplified. Instead, this accident calls for understanding the complex circumstances of the lengthy preparation process during a period of organisational changes, which resulted in the decision to use an unconventional towing method. In this case, the choice of towing method was made on the basis of the limitations of another tug than MÆRSK BATTLER, and there was no reason to change the towing setup to the setup recommended by external experts as the risk connected to the side-by-side tow had been handled in the risk management system and was thereby reduced to an acceptable level.

The risk of loss of fenders, collision and flooding of the unmanned ships under tow was addressed in the risk assessment carried out by the shore management. The risk assessment formed the basis of the decision whether the side-by-side towing setup was feasible and was perceived as a tool which would indicate whether the operation should be aborted as being too risky. However, the logic of the risk management system was to introduce risk mitigating initiatives for each risk factor so that the risk was assumed to be reduced to an acceptable level. However, the occurrence of the accident proves that these initiatives were ineffective. DMAIB concludes that the risk mitigating strategies were mainly focused on preventing risk factors in isolation and left little or no contingency for acute interaction between the risk factors.

The risk management system used by Maersk Supply Service is one of the most common in the shipping industry and the problems connected to the risk management system which led to the insufficient risk mitigation of the towing operation are hence not out of the ordinary. The risk management system offers to handle risk as an objective value and to provide a structure for handling risk. However, there is no aid or control of what is put into the system when it comes to which risk factors are identified. The numeric risk value is based solely on how imaginative the involved persons are, and the system does not provide a structure for how to reflect on what risk mitigating strategies are applied. This means that the risk management system does not help its user to manage risk, and that the assessment of the risk reduction is highly sensitive to one or more individuals' subjective risk perception, which will be strongly influenced by the desire to make the operation possible. Thereby, the risk management system will rarely limit activities prone to risk. In fact, the risk management system instead tends to facilitate the carrying out of risk prone operations.

Preventive measures

Actions taken following the accident

DMAIB has received information from Maersk Supply Service on actions taken following the accident:

”Following the MÆRSK SHIPPER and MÆRSK SEARCHER incident in December 2016, Maersk Supply Service has been working with the French and Danish Authorities to mitigate the impact of the incident and uncover the causes of the incident. As a responsible ship owner, the safety of people, environment and assets is imperative to us. To ensure that a critical incident like this will not occur again in the future, Maersk Supply Service established an internal investigation team composed of technical experts and experienced on- and offshore personnel to thoroughly scrutinise all aspects of the event.

The investigation team has identified the following preventive measures which have been implemented in Maersk Supply Service’s procedures and operations, most of them during the spring and summer 2017. A verification process will take place later in the year to ensure that the measures are working as intended and uncover whether follow-up actions are needed.

- *Management of change training programmes*

As a follow-up to the incident, Maersk Supply Service has conducted thorough training programmes of all key personnel on- and offshore in management of change procedures. When changes to a plan occur, these need to be reflected in the entire plan and within the relevant operations. A change, such as change of vessel, time of an operation, or change of key personnel, is likely to impact other aspects of an operation.

- *Improved risk assessment procedures and mitigation actions*

Maersk Supply Service decided to upgrade its risk management system, and in addition implemented improved tools and training for on- and offshore personnel to better assess risks when they occur in operations. This includes identifying where different risks might impact each other and create a ripple effect to form an even larger risk, and ensuring that the right mitigation for potential risks is in place.

- *Review of operations by 3rd party experts*

In all operations where Maersk Supply Service is handling its own vessels, 3rd party experts are to validate the planning, processes and procedures. This is to ensure the highest standard and confirm that the plan is the best possible for the specific operation.

- *Clear responsibilities and accountability*

A revised process with updated guidelines and defined responsibilities has been implemented for when Maersk Supply Service is handling its own vessels. Every marine job where Maersk Supply Service carries the overall responsibility of the operation is to be approved by a member of the senior management team.

- *Intensive training programmes of key personnel*

To ensure a thorough understanding of the new procedures and processes across the organisation, seminars for all Captains as well as key onshore personnel have been completed. Parts of the training programmes were facilitated by Maersk Training. Maersk Supply Service continues to work closely with the Danish and French authorities. A legal notice from the French Prefecture Maritime required Maersk Supply Service to analyse and empty the contents of the vessels’ tanks. The identified task has been followed and concluded. In addition, Maersk Supply Service will inspect the wrecks and monitor any potential environmental impact twice a year until 2019.”

Appendices

Figure 30: MÆRSK BATLLER
Source: Maersk Supply Service

SHIP PARTICULARS	
Name:	MÆRSK BATTLER
Type of vessel:	Anchor handling tug/supply ship
Nationality/flag:	Denmark
Port of registry:	Frederikshavn
IMO number:	9144330
Call sign:	OYEP2
DOC company:	Maersk Supply Service A/S
IMO company no.	1045146
Year built:	1997
Shipyard/yard number:	Simek AS/92
Classification society:	Lloyd's Register
Length overall:	84.60 m
Breadth overall:	18.85 m
Gross tonnage:	4,363
Deadweight:	4,201 t
Draught max.:	7.52 m
Engine rating:	14,080 kW
Service speed:	11 knots
Hull material:	Steel
Hull design:	Single hull

Figure 31: MÆRSK SEARCHER
Source: Maersk Supply Service

SHIP PARTICLARS	
Name:	MÆRSK SEARCHER
Type of vessel:	Anchor handling tug/supply ship
Nationality/flag:	Denmark
Port of registry:	Horsens
IMO number:	9191369
Call sign:	OYQO2
DOC company:	Maersk Supply Service A/S
IMO company no.	1045146
Year built:	1999
Shipyard/yard number:	Keppel Singmarine Dockyard/233
Classification society:	Lloyd's Register
Length overall:	82.00 m
Breadth overall:	18.85 m
Gross tonnage:	4,013
Deadweight:	3,903 t
Draught max.:	7.50 m
Engine rating:	13,440 kW
Service speed:	11 knots
Hull material:	Steel
Hull design:	Single hull

Figure 32: MÆRSK SHIPPER
Source: Maersk Supply Service

SHIP PARTICULARS	
Name:	MÆRSK SEARCHER
Type of vessel:	Anchor handling tug/supply ship
Nationality/flag:	Denmark
Port of registry:	Haderslev
IMO number:	9169483
Call sign:	OYZM2
DOC company:	Maersk Supply Service A/S
IMO company no.	1045146
Year built:	1999
Shipyard/yard number:	Keppel Singmarine Dockyard/225
Classification society:	Lloyd's Register
Length overall:	82.00 m
Breadth overall:	18.85 m
Gross tonnage:	4,013
Deadweight:	3,903 t
Draught max.:	7.50 m
Engine rating:	13,440 kW
Service speed:	11 knots
Hull material:	Steel
Hull design:	Single hull

VOYAGE PARTICULARS	
Port of departure:	Frederica, Denmark
Port of call:	Aliaga, Turkey
Type of voyage:	International
Cargo information:	None
Manning:	10 crewmembers on MÆRSK BATTLER
Pilot on board:	No
Number of passengers:	None
WEATHER DATA	
Wind direction and speed:	South westerly, 3.5 m/s
Wave height:	4.5 m
Visibility;	Good
Light/dark:	Dark
MARINE CASUALTY INFORMATION	
Type of marine casualty:	Loss of towage
IMO classification:	Serious
Date, time:	21 December 2016, 2335 LT
Location:	Bay of Biscay
Position:	48° 04.21’ N – 006° 24.46’ E
Ship’s operation:	Towing
Voyage segment:	In passage
Place on board:	Over side
Human factor data:	Yes
Consequences:	MÆRSK SHIPPER and MÆRSK SEARCHER suffered a total loss.
SHORE AUTHORITY INVOLVEMENT AND EMERGENCY RESPONSE	
Involved parties:	French Coast Guard
Resources used:	None
Actions taken:	Maersk Supply Service chartered an inspection vessel which carried out an ROC examination of the tow wrecks in order to establish the risk of pollution.
Results achieved:	Immediate risk of pollution was ruled out.
RELEVANT SHIP CREW ON MÆRSK BATTLER	
Master:	STCW II/2 Master unlimited 60 years old, had served the company for 40 years and had been at sea for 44 years. Served as a master in the company since 1997, 10 weeks of which on MÆRSK BATTLER.
Chief officer:	STCW II/2 Master unlimited 34 years old and had been at sea for a total of 7 years, all of which with the company. Had served as a chief officer on MÆRSK BATTLER for 2 years.
Able seaman:	43 years old. Had served the company since 2009, approx. 7 months of which on MÆRSK BATTLER.