Intermediate Report of the Preliminary Assessment of MV ESTONIA

Ohutusjuurdluse Keskus

Statens haverikommission

Onnettomuustutkintakeskus

Tallinn

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In case of discrepancies between the English text and translated texts, the English text is to be considered the authoritative version.

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Glossary of Abbreviations

Abbreviation	Description
2D	Two-dimensional
3D	Three-dimensional
ADCP	Acoustic Doppler Current Profiler
CAD	Computer Aided Design
CTD	Conductivity, Temperature, Depth
DTM	Digital Terrain Model
EEZ	Exclusive Economic Zone
EGT	Geological Survey of Estonia (*Geoloogiateenistus*)
EU	European Union
HSVA	HSVA Consortium to research the sinking sequence of MV ESTONIA, led by The Hamburg Ship Model Basin (*Hamburgische Schiffbau-Versuchsanstalt GmbH*)
IMO	International Maritime Organization
JAIC	Joint Accident Investigation Commission of Estonia, Finland, and Sweden
MBES	Multi-Beam Echo Sounder
ROV	Remotely Operated Vehicle
OJK	Estonian Safety Investigation Bureau (*Ohutusjuurdluse Keskus*)
SBP	Sub-Bottom Profiler
SHK	Swedish Accident Investigation Authority (*Statens haverikommission*)
SIAF	Safety Investigation Authority, Finland (*Onnettomuustutkintakeskus* / *Olycksutredningscentralen*)
SSPA	SSPA Consortium to research the sinking sequence of MV ESTONIA, led by SSPA Sweden AB
SSS	Side Scan Sonar
SU	Stockholm University
UNCLOS	United Nations Convention on the Law of the Sea
VHS	Video Home System

Definitions

Concept	Definition
Preliminary assessment	The professional and independent assessment of all the evidence relating to an accident or serious incident in the maritime sector with the purpose of determining whether a safety investigation should be opened or re-opened.
Preliminary conclusions	The conclusions reached mid-way through a preliminary assessment.
Safety investigation	An investigation to identify the circumstances, causes, and consequences of a marine casualty or marine incident, and if necessary, to provide recommendations to prevent such marine casualty or marine incident in the future and to improve maritime safety, without appointing blame or liability.
Final conclusions	The conclusions reached at the end of a preliminary assessment or safety investigation.

Summary

The passenger ferry MV ESTONIA sank on 28 September 1994 during a voyage from Tallinn, Estonia, to Stockholm, Sweden. Of the 989 people on board, 852 died.

New video footage, not available during the Joint Accident Investigation Commission's work (1994–97), was published in September 2020 which revealed a hole in the starboard side of the hull. Based on this new evidence, the Estonian Safety Investigation Bureau initiated a Preliminary Assessment of the new information along with its counterparts in Finland and Sweden.

The objectives of the Preliminary Assessment are:

- to identify the cause of penetrating deformation(s) to the hull of MV ESTONIA, seen in the new video footage aired in September 2020 by Monster Media Group Limited;
- to assess the validity of the conclusions presented in the final report of the Joint Accident Investigation Commission of December 1997;
- to assess which new investigative measures should be taken, if any; and
- to assess whether the safety investigation of the sinking of MV ESTONIA should be re-opened.

During the Preliminary Assessment various surveys and studies have been and are conducted to meet these objectives. This Intermediate Report summarizes the main findings from all surveys completed thus far during the Preliminary Assessment. The report concludes by drawing preliminary conclusions, the most important of which are:

- The wreck of MV ESTONIA is in a poor condition with severe structural damage.
- The location of the outcropping bedrock under the hull matches the location of the deformation on the hull.
- Based on the evidence gathered so far, there is no indication of a collision with a vessel or a floating object.
- Based on the evidence gathered so far, there is no indication of an explosion in the bow area.

An assessment on seaworthiness was also conducted by SHK and OJK, the results of which are presented as Annex 2.

Chapter 1

Introduction and Background

1.1 Background

The passenger ferry MV ESTONIA sank on 28 September 1994 during a voyage from Tallinn, Estonia, to Stockholm, Sweden. Of the 989 people on board, 852 died.

In accordance with an agreement between the prime ministers of Estonia, Finland, and Sweden a Joint Accident Investigation Commission (JAIC) was formed to investigate the accident in 1994. JAIC published their final report on 3 December 1997.[1][1]

Information published since the release of the JAIC report up to 2020 is summarized as Appendix A. New video footage was published by Monster Media Group Limited in September 2020 which revealed a hole in the starboard side of the hull (Figure 1.1).

The Estonian safety investigation authority, the Estonian Safety Investigation Bureau (OJK, *Ohutusjuurdluse keskus*) initiated a Preliminary Assessment of the new information and requested assistance from its corresponding authorities in both Finland and Sweden. Both the Safety Investigation Authority, Finland (SIAF, *Onnettomuustutkintakeskus/Olycksutredningscentralen*) and the Swedish Accident Investigation Authority (SHK, *Statens haverikommission*) decided to assist OJK in carrying out the Preliminary Assessment.

The general purpose of a preliminary assessment after a maritime accident is to

[1] All citations to the JAIC report throughout this report refer to “JAIC".

FIG. 1.1: The hole that was displayed in the TV documentary in 2020 as seen in the photogrammetry during 2022. Image from photogrammetry.

consider whether a safety investigation should be initiated.

1.2 Objectives and Scope of the Preliminary Assessment

The objectives of the Preliminary Assessment are:

- to identify the cause of penetrating deformation(s) to the hull of MV ESTONIA, seen in the new video footage aired in September 2020 by Monster Media Group Limited;
- to assess whether the new information gives reason to revise the conclusions presented in the final report of the Joint Accident Investigation Commission of December 1997;
- to assess which new investigative measures should be taken, if any; and
- to assess whether the safety investigation of the sinking of MV ESTONIA should be re-opened.

The planned investigative measures were split into phases, starting with preparatory site surveys, which included a general overview of the wreck alongside environmental conditions. The purpose of these preparatory surveys was to collect data to target subsequent surveys most efficiently. Environmental data on water temperature, salinity, oxygen content, turbidity, and currents were acquired. Information on bathymetry, seabed sediments, and sub-seabed geology were acquired during marine geophysical operations. Lastly, the 3D sector scanning of the wreck together with the measurements of its exact position on seabed and preliminary video surveys of the wreck and of objects of interest in the vicinity of the wreck were also carried out.

The subsequent comprehensive wreck surveys were used to measure and photograph the hull of the wreck and its deformations. Further, the sub-seabed layers in the immediate vicinity of the wreck were imaged to better understand the stratigraphy of the sub-seabed. The comparison of the wreck's deformations and subsea geology during modelling gives knowledge of whether the deformations have arisen from the contact of the ship with the seabed and its later sliding of downslope or if the deformations may relate to other reasons.

A programme of interviews with survivors and persons associated with the catastrophe is also being carried out. These interviews are being undertaken alongside collecting, systematizing, and reviewing existing interview material.

Additional investigative measures were necessary to carry out these tasks. In addition, the carrying out of this work uncovered ancillary tasks, the completion of which enabled the Preliminary Assessment to be carried out more diligently. These are described where they relate to the main task which they supported. Secondary endeavours, including those which were carried out by other institutions during the timeframe of the Preparatory Assessment but which supported its overall goals, are described under other tasks.

1.3 Roles of Participating States

In this Preliminary Assessment, the three authorities work together under the lead of the Estonian authority. Estonia and Sweden are carrying out investigative activities while Finland, as a coastal state, facilitates access to the wreck in its Exclusive Economic Zone as well as observes the process of all work being carried out.

1.3.1 Estonia, Flag State

Article 94 of the United Nations Convention on the Law of the Sea (UNCLOS) states that the flag state is responsible for ships flying its flag in regards of, *inter alia*: construction, equipment, manning, and seaworthiness of ships. In case an accident or incident takes place, the flag state is responsible for conducting an inquiry to determine the cause(s) of the accident or incident.

Estonian Maritime Safety Act § 69[2] stipulates that the safety investigation of marine casualties and marine incidents shall be held, *inter alia*, if the ship flies the national flag of Estonia. The investigation is to be held purely with the purpose of improving maritime safety and without appointing any blame or liability.

At the time of the accident, the flag state of MV ESTONIA was the Republic of Estonia, hence the obligation to conduct an inquiry into the causes of the accident laid with Estonia. The flag state may invite other countries to participate in the inquiry who, in this case, were Finland (coastal state) and Sweden (substantially interested state).

Estonia leads the Preliminary Assessment and coordinates activities in close cooperation with Finland and Sweden.

1.3.2 Finland, Coastal State

The wreck of MV ESTONIA is located in the Finnish Exclusive Economic Zone (EEZ), outside of Finnish Territorial Waters. The United Nations Convention on the Law of the Sea (UNCLOS) is an international agreement that establishes a legal framework for all marine and maritime activities.

MV ESTONIA is considered a maritime grave site, protected by both international and national legislation. Sanctity over the site has thus been declared. The Finnish Border Guard is responsible for grave peace surveillance in the area covered by the Finnish national grave peace legislation.

Upon the decision of the flag state Estonia, underwater operations in the vicinity of MV ESTONIA were considered necessary to conduct the Preliminary Assessment.

Finland is a signatory state of the UNCLOS agreement and holds the prerogatives of a coastal state in the Preliminary Assessment. Finland's role in the Preliminary Assessment is hence to facilitate investigative activities on site. Coastal states have sovereign rights in the EEZ with respect to natural resources and certain economic activities. Coastal states also exercise jurisdiction over environmental protection, and all marine research in the EEZ is subject to the coastal state's consent.

The facilitation of the Preliminary Assessment has required expertise, cooperation, and coordination of different Finnish authorities. These include the Ministry for Foreign Affairs, the Ministry of Justice, the Ministry of the Interior, the Ministry of Defense, the Ministry of Economic Affairs and Employment, and the Ministry of Traffic and Communications.

While SIAF has participated in the Preliminary Assessment, it has not participated in underwater surveys conducted by its Estonian and Swedish counterparts.

1.3.3 Sweden, Substantially Interested State

According to the EU Directive 2009/18/EC, there is an obligation for the flag state, the coastal state, and substantially interested states to carry out a safety investigation of very serious marine casualties. The expression “substantially interested states" refers to a definition in the IMO Casualty Investigation Code. One of the alternative criteria that can be the basis for being considered as a substantially interested state is where, as a result of a marine casualty, nationals of that state lost their lives or received serious injuries.

The IMO Casualty Investigation Code as well as the mentioned EU directive came into effect after the accident.

MV ESTONIA was travelling a route between Estonia and Sweden when the accident occurred. There were 852 fatalities of 17 different nationalities. Of these a majority, 501 persons, were Swedish.

Sweden took part in the JAIC investigation, together with the flag state and the coastal state, due to the high number of lost nationals and the effects on the society of such a catastrophe—and likely also because the vessel was sailing to and from Sweden.

When the Estonian authority, OJK, representing the flag state, initiated the Preliminary Assessment in 2020 they requested assistance from their corresponding authorities in the two other states that had been involved in the JAIC investigation. SHK accepted and contributes to the surveys which are being performed.

1.4 Public Relations and the Media

Press conferences have been carried out after the achievement of milestones during the Preliminary Assessment with the primary objective of introducing interim results to the public. In addition, interviews have been given to both national and international media.

A new website[2] was designed to comprehensively detail both the original catastrophe and its subsequent investigations. Similarly, all information gathered during the Preliminary Assessment is being published on this website.

Regular meetings have been carried out with the Estonian organization Memento Mare MTÜ, which represents the catastrophe’s survivors and next-of-kin to survivors. Likewise, meetings have been held with Swedish survivors and next-of-kin.

Representatives from media as well as survivors have been present during surveys at site.

[2] The website URL is `https://estonia1994.ee/en`.

1.5 Legal Situation

1.5.1 Legal Framework

Regulation I/21 of the International Convention for the Safety of Life at Sea (SOLAS) lay down the responsibilities of flag states to conduct casualty investigations and to supply the International Maritime Organisation with relevant findings.

Article 94 of the United Nations Convention on the Law of the Sea (UNCLOS) establishes that each state shall cause an inquiry to be held by or before a suitably qualified person or persons into every marine casualty or incident of navigation on the high seas involving a ship flying its flag.

The IMO Casualty Investigation Code (Code of International Standards and Recommended Practices for a Safety Investigation into a Marine Casualty or Marine Incident) was adopted on 16 May 2008. The Code was preceded by the Code for the Investigation of Marine Casualties and Incidents adopted on 27 November 1997.

The Casualty Investigation Code establishes obligations of accident investigation authorities to investigate marine casualties (Chapter 6) as well as rights to acquire evidential material (Chapter 8).

EU Directive 2009/18/EC establishing fundamental principles governing the investigation of accidents in the maritime transport sector expresses the obligation of investigation authorities to investigate marine casualties (Article 5) as well as the right to free access to any relevant area or casualty site and to any ship or wreck (Article 8).

1.5.2 Protection of the Vessel

On 23 February 1995, the Governments of Estonia, Finland, and Sweden agreed to protect the wreck site of MV ESTONIA, as a final place of rest for victims of the disaster, from any disturbing activities.

The contracting parties stated in Article 3 of the agreement that the vessel would not be raised. In Article 4, the contracting parties undertook to institute legislation aiming at the criminalization of any activities which would disturb the peace of the final place of rest. It was explicitly stated that this criminalization should include any diving or other activities with the purpose of recovering victims or property from the wreck or the seabed.

This international agreement has been implemented in national legislations in various ways. Additional states have ratified the agreement as well. The contracting parties are Estonia, Denmark, Finland, Latvia, Lithuania, Poland, Russia, Sweden, and the United Kingdom.

1.5.3 Amendments of National Legislation

National legislation, implemented due to the international agreement to protect the wreck as a grave site, prohibited certain investigative activities. The legislation in Sweden and Finland specifically criminalized diving and other underwater activities at the accident site.

The respective accident investigation authorities requested amendments to the national legislation, which were passed by the parliaments of Sweden and Finland during 2021.

1.5.4 Legal Basis

The Casualty Investigation Code and the EU Directive 2009/18/EC were both adopted after the accident of MV ESTONIA. Neither of them contains any transitional provisions.

However, Chapter 26 of the Casualty Investigation Code establishes that each state, which has completed a marine safety investigation, should reconsider their findings and consider re-opening the investigation when new evidence is presented which may materially alter the analysis and conclusions reached. When significant new evidence relating to any marine casualty or marine incident is presented regarding a completed marine safety investigation, the evidence should be fully assessed for appropriate input.

The Preliminary Assessment has set out to examine whether these criteria are met.

Chapter 2

Preparatory Site Surveys

2.1 Overview

Preparatory site surveys were carried out from 8 July 2021 to 1 June 2022.

Table 2.1 summarizes all preparatory surveys with links to their individual reports in English.

TABLE 2.1: Overview of preparatory site surveys.

SURVEY NAME	USED SENSORS
Desk Top Study: Geotechnical Data Review [2]	*N/A*
Integrated Geophysical Survey with Appendices [3]	MBES, SSS, Midwater Sonar, ADCP, Shallow-Penetration SBP, Grab Sampler, Piston Corer, Moored ADCP, CTD, Camera
Seismo-Acoustic Profiler [4]	Medium-Penetration SBP (Boomer)
ROV Videos [5]	5x Survey Cameras + Navigation Camera
3D Sector Scanner [6]	3D Sector Scanner
Moored ADCP [7], [8]	ADCP
Seawater Turbidity [9]	Underwater Glider

2.2 Results

The following were the most significant findings regarding environmental conditions:

- Currents across the measurement site were generally weak throughout the measuring periods, but some stronger currents were also measured in the near-bottom layers with maximum speeds approaching 1 m/s.
- Turbidity was generally high in the near-bottom layers.
- The wreck is at least partially situated in anoxic conditions, but the exact depth at which conditions become anoxic changes over time.

The following were the most significant findings from the seabed imaging sensors:

- The wreck lies in ambient water depths of 71 m to 85 m.
- The shallowest water depth measured above the wreck is 58.4 m.
- Clays, till, and bedrock were interpreted on the seabed.
- Underwater slides generated by activity at the wreck during field operations in 1996 are clearly observable.

The following were the most significant findings from the sub-seabed sensors:

- Clays occur at the seabed across most of the survey area except where prominent ridges of till and/or bedrock occur.
- An upwards sloping seismic reflection, the Acoustic Basement, is shown occurring towards the centre of the wreck. This layer is not penetrated by the systems, and it is interpreted to reflect the top of glacial till and bedrock.
- The sediment layer under the wreck was interpreted to vary from less than 3.6 m to greater than 25 m. Subsequent main survey operations illustrated areas near the centre of the wreck where a retractable ROV limb was driven into the seabed with no penetration, indicating that only a veneer of sediments overlay bedrock.

The following were the most significant findings regarding the wreck:

- The wreck has a list of $133.0° \pm 0.4°$ to starboard and a forward trim relative to the sea level of $4.5° \pm 0.3°$.
- The deformations shown in new footage in 2020 were independently confirmed, with additional new deformations recorded on starboard side, port side, and stern part of the wreck.
- The bow ramp was detached from the wreck.

2.3 Desk Top Studies

2.3.1 Review of Geotechnical Data

A desk top study was undertaken to summarize the information gathered during surveys from 1994 to 1996.

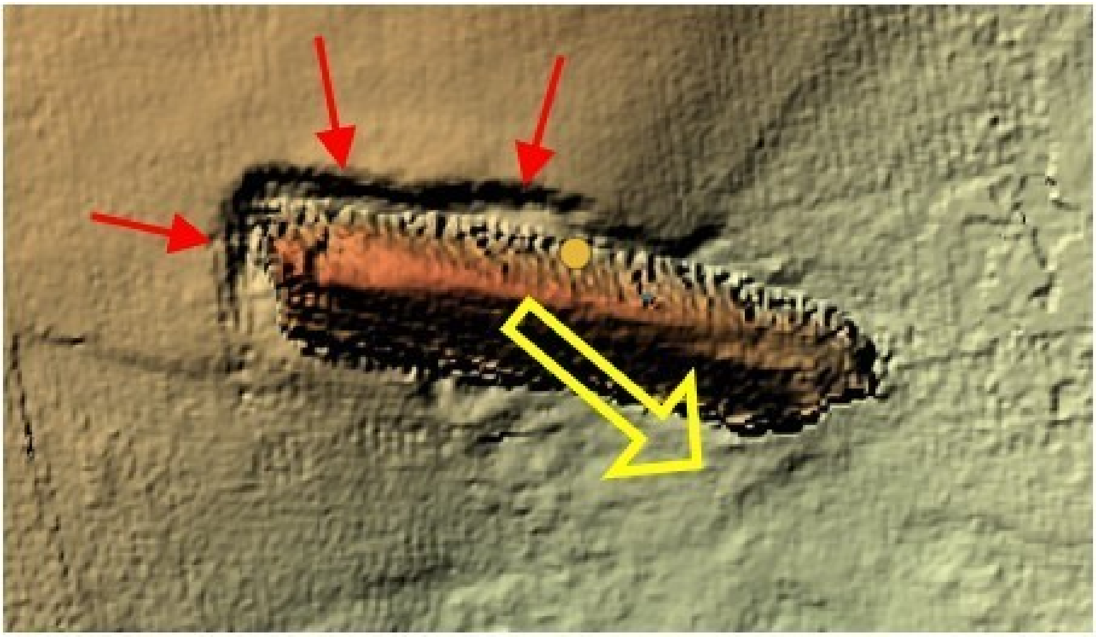

FIG. 2.1: Depression around the vessel (red arrows) and expected direction of movement of the vessel (yellow arrow), based on Traficom (2006). Image from Rudebeck and Kennedy [2].

2.4 Environmental Surveys

2.4.1 Midwater Sonar

A vessel-mounted Simrad EK80 wide-band sonar system with two split beam transducers was utilized. The Simrad ES70C transducer used frequency ranges of 45 kHz to 90 kHz. The Simrad ES200-7C transducer used frequency ranges of 160 kHz to 260 kHz. This system was used on 9 July 2021.

The following significant observations were made:

- A consistent halocline was situated between 60 m and 80 m depth.

2.4.2 Acoustic Doppler Current Profiler

A vessel-mounted Teledyne RDI ADCP with a 600 kHz transducer was used to measure horizontal and vertical ocean currents. The system used a ping rate of 3.3 Hz with 2 m depth bins ranging from approximately 6.5 m to 85.5 m depth. The manufacturer's depth range specification for this system is 50 m. This system was used on 9 July 2021.

The following significant observations were made:

- Currents in the depth interval of 6.5–40 m had a south-eastward direction with a speed of 0.1 m/s.
- Currents in the 40–55 m depth interval were generally weak and directed eastward in the west of the survey area, intensifying and turning south-southeast in the east of the survey area.

2.4.3 Moored ADCP Deployment, First Deployment

An upward-looking 400 kHz Nortek Aquadopp Acoustic Doppler Current Profiler (ADCP) was moored at 53° 23.015' N and 021° 41.272' E. The profile interval was ten minutes. The system was used to continuously measure currents during vessel-based surveys from 9 July 2021 to 14 July 2021.

The following significant observations were made:

- Currents were generally weak (typically <0.1 m/s) in the 6.5 m to 55 m depth range.
- Strong bottom currents, occasionally approaching 1 m/s, occurred between 70 m and 80 m depths. The depth interval of these bottom currents coincides with a significant turbidity peak in the hydrological data, indicating resuspension and transport of sediments with the bottom currents.

2.4.4 Moored ADCP Deployments, Second and Third Deployment

The measurements were carried out using the SeaGuard II platform, which was used to measure pressure, electrical conductivity, temperature, and oxygen.

The system was first deployed on 10 July 2021 in 74 m water depth at 59° 22.8299' N, 21° 38.8656' E and retrieved on 9 November 2021 (second measurement period). The platform, with the same setup, was deployed again on 12 December 2021 in 80 m water depth at 59° 23.0515' N, 021° 41.2294' E and retrieved on 21 March 2022 (third measurement period).

These two measurement periods allowed extending understanding of underwater currents over seasonal variations. The following significant observations were made:

- The maximum current velocities in a 20 m thick layer near the seabed during both measurement periods were 35–36 cm/s.

- The median velocity values were slightly higher under stratified conditions, i.e., 6.0 cm/s compared with the 5.3 cm/s in winter.
- The temperature, salinity and oxygen concentration measurements conducted near the seafloor over a period of seven months showed that the conditions in the area of the wreck of MV ESTONIA are highly variable: anoxic conditions and conditions with relatively high oxygen concentration alternated.
- Highly variable environmental conditions in the demersal zone in the area of the wreck of MV ESTONIA suggest that the wreck is subject to both oxidation in oxygen-rich seawater and microbiological corrosion.

2.4.5 Seawater Turbidity

A shallow-water model of the Teledyne Webb Research Slocum G2 underwater glider was used to principally measure turbidity. Turbidity is important in planning underwater camera and laser operations, with the systems being affected by poor visibility. Additionally, data on seawater temperature, salinity, oxygen concentration, chlorophyll A, and fluorescence were acquired. The sampling frequency of the above parameters was 0.5 Hz.

The glider was targeted to stay within a 300 m radius of its profiling position, 59° 22.7655' N, 021° 40.7054' E. Measurements started on 13 April 2022 and ended on 1 June 2022.

The following significant observations were made:

- Almost during the entire survey period, except for the first ten days, there was a highly turbid demersal layer of water in the area, caused by the inflow of saltier and oxygen-deficient water to the survey area.

2.5 Geophysical Surveys

2.5.1 Multi-Beam Echo Sounder

A vessel-mounted multi-beam echo sounder (MBES) Kongsberg EM2040 was used. The MBES was used in two specific configurations: firstly, a wider (less resolute) swath configuration was used (opening angle 50°-by-50°) across the whole survey area, and secondly, a more precise configuration (opening angle 25°-by-25°) was used for a survey in the immediate vicinity of the wreck. Acoustic backscatter was also acquired during MBES acquisition. This system was used on 8 July 2021.

Two Digital Terrain Models (DTMs) were generated based on these surveys: the regional DTM had a cell size of 2.0 m and the detailed wreck DTM had a cell size of 0.25 m.

The following significant observations were made:

- The wreck lies in ambient water depths of 71 m to 85 m.
- The shallowest water depth measured above the wreck is 58.4 m.
- Three transponder stations were observed on the seabed, occurring to the north and northwest of the wreck.
- Underwater slides generated by activity at the wreck during field operations in 1996 are clearly observable. The wreck has a list of $133.0° \pm 0.4°$ to starboard and a forward trim relative to the sea level of $4.5° \pm 0.3$.

2.5.2 Side Scan Sonar

A side scan sonar (SSS) survey was carried out with a Klein 5000 V2 tow fish which was operated at a frequency of 455 kHz. The side scan sonar was used to image seabed sediments as well as objects occurring on the seabed. The data is presented as a mosaic where all acquired lines are shown together. This system was used on 10 July 2021.

The SSS data are not suited to depict the wreck because of its size and metallic nature, and the data were primarily used to interpret seabed sediments, including outcropping glacial till and bedrock. The MBES DTMs and backscatter were also used during seabed sediment interpretation.

The following significant observations were made:

- Clays, till, and bedrock were interpreted on the seabed.

2.5.3 3D Sector Scanner

A 3D sector-scanning Kongsberg-Mesotech MS1000 1171 Variable Frequency High-Resolution Scanning Sonar was used. This system has two transducers, a fan beam transducer for precision imaging or imaging small areas for images and a cone beam transducer for the collection of data points. Both survey modes were utilized. This system was used from 11 July 2021 to 16 July 2021.

The following significant observations were made:

- A trench between 8 m and 1 m wide exists on the north side of the wreck.
- The ship's hull, at approximately mid-ship, seems to rest on an outcrop of bedrock.
- The bow ramp is detached from the ship and lies against the starboard side of the bow.
- The car deck seems to have a barrier of debris approximately 30 m from the entrance.

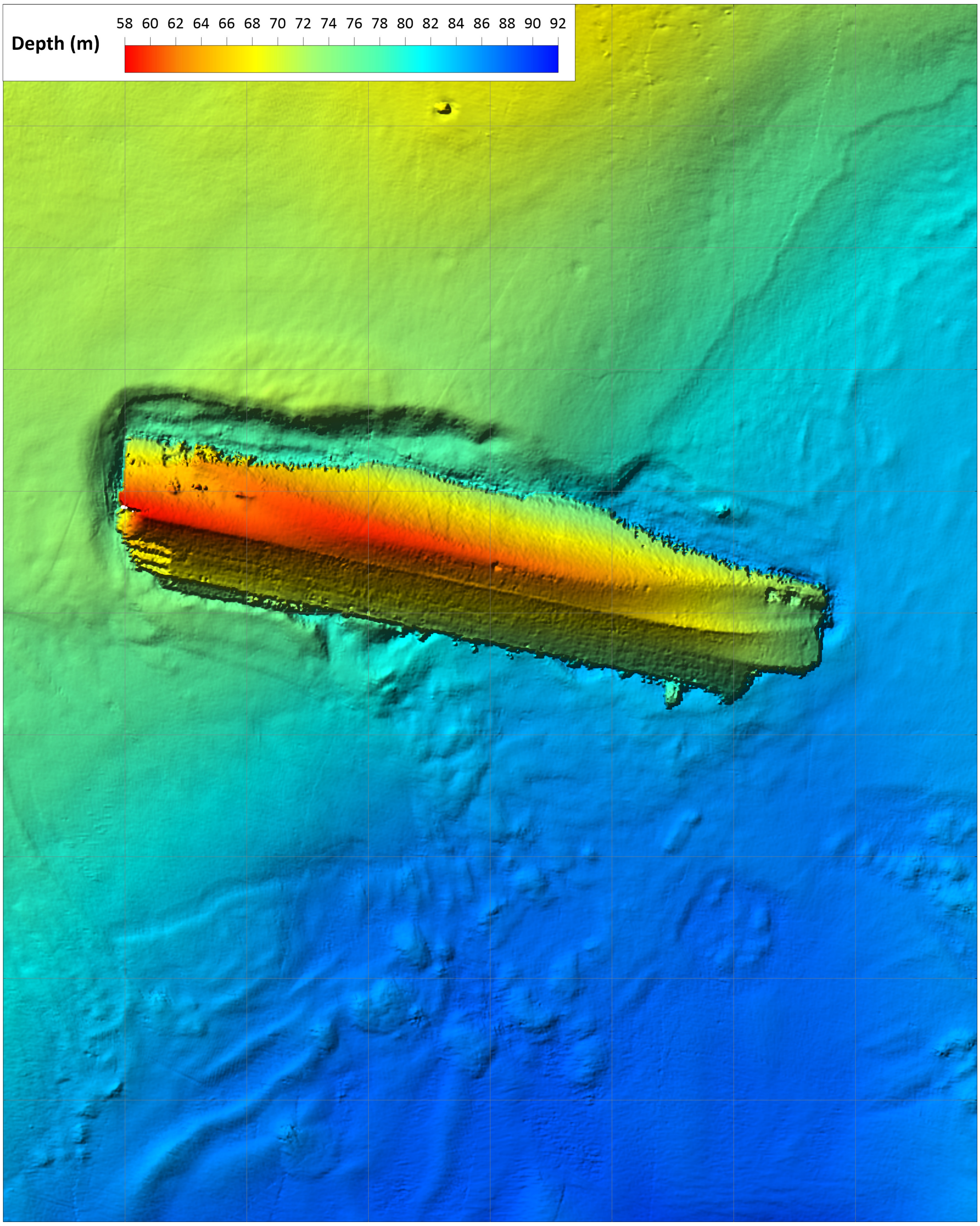

FIG. 2.2: MV ESTONIA as imaged in the 2021 MBES dataset.[3] Image by Ohutusjuurdluse Keskus.

2.5.4 Shallow-Penetration Sub-Bottom Profiler (CHIRP)

A vessel-mounted Kongsberg Topas PS40 system was used to image sediment thickness. A line spacing of 160 m was used across the survey area, with additional lines at 25–40 m spacing ran in the vicinity of the wreck. This system was used on 9 July 2021. The data were used to develop a sediment thickness model.

The horizontal resolution of SBP systems is linked to the distance of the system to the imaged seabed. Further, the wreck acted as a partial acoustic shadow, meaning that data in the vicinity of the wreck were compromised due to its presence. Therefore, a supplementary survey was carried out with a ROV-mounted SBP as part of the Main Surveys.

The following significant observations were made:

- Clays occur at the seabed across most of the survey area except where prominent ridges of till and/or bedrock occur.
- An upwards sloping seismic reflection, the Acoustic Basement, is shown occurring towards the centre of the wreck. This layer is not penetrated by the CHIRP, and it is interpreted to reflect the top of glacial till and bedrock.

2.5.5 Mid-Penetration Sub-Bottom Profiler (Seismo-Acoustic Profiler)

A SIG-France boomer with a “C-Phone” hydrophone streamer was utilized alongside the main geophysical spread as a secondary sub-bottom profiler (elsewhere called a “seismo-acoustic profiler”). The boomer complemented the shallow-penetration CHIRP system with medium-range penetration. This system was used on 9 July 2021.

The boomer system was provided and operated by the Geological Survey of Estonia (EGT). The data was utilized by Stockholm University in their integrated interpretation and report, though not specifically mentioned therein. EGT also provided a report, solely containing their interpretation of the boomer survey dataset, i.e., without reference to other acquired datasets.

The following significant observations were made:

- Clays occur at the seabed across most of the survey area except where prominent ridges of till and/or bedrock occur.
- An upwards sloping seismic reflection, the Acoustic Basement, is shown occurring towards the centre of the wreck. This layer is not penetrated by the boomer, and it is interpreted to reflect the top of glacial till and bedrock.

2.6 Geotechnical Sampling

2.6.1 Grab Sampler

A total of 13 grab samples were taken to provide information on seabed sediments. These samples were used to assist in the interpretation of seabed sediments. This system was used from 14 July 2021 to 15 July 2021.

2.6.2 Piston/Gravity Coring

Three piston cores were acquired from the area surrounding the wreck. The corer could also be used as a gravity corer. During the piston coring the core head was loaded with 473 kg. Three cores were acquired; the results were integrated into the sub-surface interpretation model. This system was used from 14 July 2021 to 15 July 2021.

The following significant observations were made:

- Two cores acquired in the vicinity of the wreck retrieved 2.34 m and 2.05 m of soft sediments before reaching a hard substrate.
- The third core, acquired over 300 m to the southwest of the wreck, retrieved 4.72 m of soft sediments.

2.7 Video Surveys

2.7.1 Bottom Filming During CTD Casts

During some conductivity, temperature, and depth (CTD) casts a GoPro Hero 7+ camera was attached to the deployment system. In addition, the camera was also deployed separately. These deployments provided visual confirmation on seabed sediments as well as allowed to identify objects that had been previously imaged on other sensors. This system was used on 8 July 2021.

2.7.2 ROV Videos

A remotely operated vehicle (ROV), or underwater robot, video survey was carried out between 14 July 2021 and 15 July 2021. The principal objective was to check images and objects which had been recorded on the sector-scanning sonar. A Seaeye Falcon ROV and a Chasing Innovation underwater drone were used with the following cameras:

- Falcon SD navigation camera;
- HD camera;
- Recording SONY a7 S3 camera 4K;
- Paralenz recording camera HD (supported SONY recordings from other angles);
- Hero7 4K recording camera;
- Hero8 4K recording camera.

The following significant observations were made:

- Stern ramps are in the closed position with no damage discovered on the outer sides of the stern ramps;
- Both rudder blades were turned standing to the starboard with no damage identified;
- Both propellers were without any visible damage with the propeller blades in neutral position;
- The starboard stabilizer fin was inside the hull (not in the extended position);
- Bow ramp was detached from the ship and rested against the starboard side of the bow with a fragment of the corner of the bow ramp detached from the bow ramp and still attached to the ship's hull;
- The second major deformation above the granite rock was discovered with the total area of the deformations being at least 22 m long in the distance which was possible to observe;
- The lugs of the hinges on ramp's portside corner were strongly deformed and the lugs of the second hinge from the left were damaged;
- Two hinges on the starboard side were missing (torn off with the corner of the ramp);
- Strong deformations and twisting of the stiffeners was seen in the directions of both sides of the central part of the bottom of the ramp,
- There are triangular indentations on the main stringers of the bow ramp on the hinge side which appear to correspond to the triangular contour of the forepeak deck;
- Numerous deformations and cracks were observed near the edge of Deck 6 on port side;
- A rupture was observed in the stern corner of Deck 6.

Chapter 3

Comprehensive Wreck Studies

3.1 Overview

Comprehensive wreck studies are being carried out with field work having commenced on 20 May 2022. In addition, the visor which was recovered from the seabed in 1994 was examined on several different occasions. Structural damage modelling commenced on 30 August 2022 and is on-going as of the publication of this report.

Table 3.1 summarizes all comprehensive wreck studies.

3.2 Results

The following were the most significant findings concerning the wreck:

TABLE 3.1: Overview of comprehensive wreck studies.

SURVEY NAME	USED SENSORS
3D Laser Scanning: Wreck (*Terminated*)	3D Laser Scanner
Photogrammetry [10]	M500 Photogrammetry ROV
High-Resolution Sub-Bottom Profiling	Innomar SES-2000
Biological Sampling	Purpose-built sampler
3D Laser Scanning: Visor	3D Laser Scanner
Structural Damage Modelling (*Ongoing*)	*N/A*

- The wreck of MV ESTONIA is in a poor condition with severe structural damage.
- No penetrating damage is observed in the hull below the water line, except for damage already known prior to the Preliminary Assessment.
- The port bridge wing, on deck 9, is pressed down towards deck 6 by several meters, implying that the part of the vessel which contains the bridge may be partially loose from the rest of the construction.
- The upper and aft part of the vessel are severely deformed.
- From astern, the upper part of the vessel is twisted to port from deck 6. This twist runs along the majority of the length of the vessel.
- An indentation was observed on the bottom of the vessel which follows the shape of at least some of the bunker tanks.

The following were the most significant findings concerning the visor:

- The visor could have floated for a limited timeframe, but only under certain ideal conditions.
- If the visor had been afloat after detachment, the bow would have pointed upwards and the hinge arms almost vertically downwards.
- Based on the evidence gathered so far, there is no indication of an explosion in the bow area.

3.3 Marine Surveys

3.3.1 3D Laser Scanning

The objective of the survey was to measure the wreck with very high accuracy focussing on all deformations and openings. A 3D model of the wreck would have been created based on these measurements which would have been compared against other models of wreck's current status.

An attempt to measure the wreck was carried out between 20 May 2022 and 28 May 2022, but the survey was stopped due to the loss of the primary ROV and its onboard equipment. No results were obtained from this survey. The contract was terminated on 31 December 2022.

3.3.2 Photogrammetry

A complete photogrammetry survey of the wreck and its immediate vicinity was conducted between 6 June 2022 and 22 June 2022. The final photogrammetric model of the wreck was provided as the result of this survey.

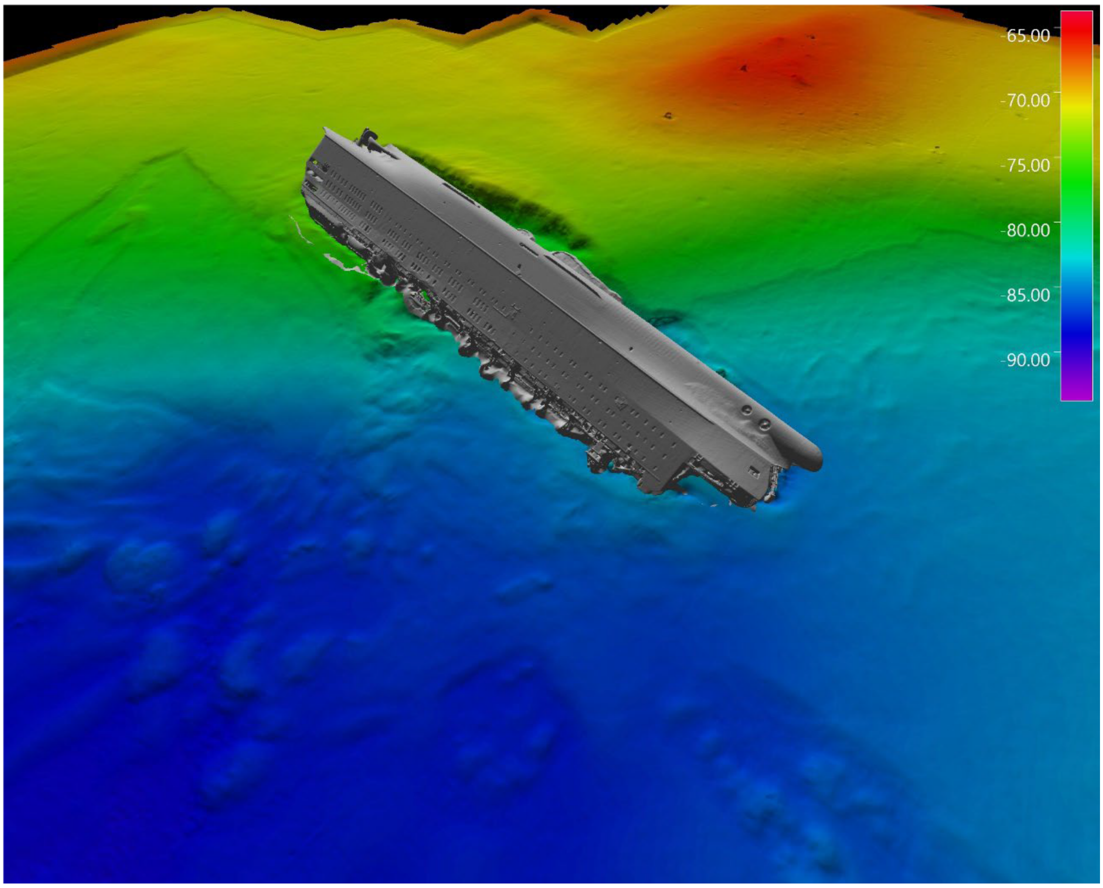

FIG. 3.1: MV ESTONIA portrayed with a mesh created at a resolution of 7 cm from the photogrammetric data; the bathymetry is represented by a 0.25 m x 0.25 m grid from the MBES survey in 2021. Visualization in QPS Fledermaus. Image by the Stockholm University.

Photogrammetry is a technique which makes digital 3D models by using many ordinary 2D photos of the object. All photos must overlap each other. The post-processing software then finds matching points on different photos and seams them all together. This means that a large number of photos must be taken to obtain a good result. Approximately 45 000 high resolution 50 megapixel photos were taken to generate the model of MV ESTONIA.

The reason for this survey was to create a 3D overview of the ship in addition to a thorough examination of the whole ship and the adjacent seabed. The 3D model gives opportunities to zoom, flip, rotate, and extract high-resolution pictures from chosen areas of the ship for more detailed studies. This technique also gives the general public an opportunity to see what the wreck actually looks like in situ. Previously, only relatively low quality video footage has been acquired which has been hard to interpret, causing misunderstandings.

The original plan was to also include up to 20 m of the surrounding seabed in the photogrammetric model along with the inside of the cargo deck. However, the surrounding seabed was not imaged successfully, and due to poor visibility some parts of the wreck could not be photographed. This mainly affected the deepest

FIG. 3.2: Port side stern of MV ESTONIA, showing a crack on deck 6. From the crack, the vessel is twisted along deck 6 and forward. Image from photogrammetry.

sections, i.e., the forward and upper decks on the starboard side of the wreck which rests against the seabed. Even though it was not possible to obtain photos with good enough quality to use for photogrammetry, many of these areas were filmed by video.

The cargo space, i.e., the car deck, suffered not only from poor visibility but also from a very large risk of entanglement (and subsequent loss) for the ROV due to the amount of internal obstacles. The most vulnerable parts of the ROV were its arms that held the lighting equipment. An option was considered whereby the arms would be removed and the lighting attached directly onto the ROV. This would have significantly reduced the risk of entanglement, but problems with visibility would have been exacerbated by this solution. Therefore, this solution was not pursued.

3.3.3 High-Resolution Sub-Bottom Profiling

A Sperre Subfighter 10K ROV system with an Innomar SES-2000 Sub-Bottom Profiler was used to conduct a high-resolution survey in the immediate vicinity of the wreck. The objective of the survey was to enhance the sub-surface model with supplementary data as close as reasonably practicable to the wreck. The survey was carried out between 6 June 2022 and 22 June 2022.

The data was used to help fine-tune the interpretation between surficial clays and underlying glacial till and/or bedrock.

No independent report detailing the results for this survey was provided, but the interpreted dataset provided inputs for structural damage modelling.

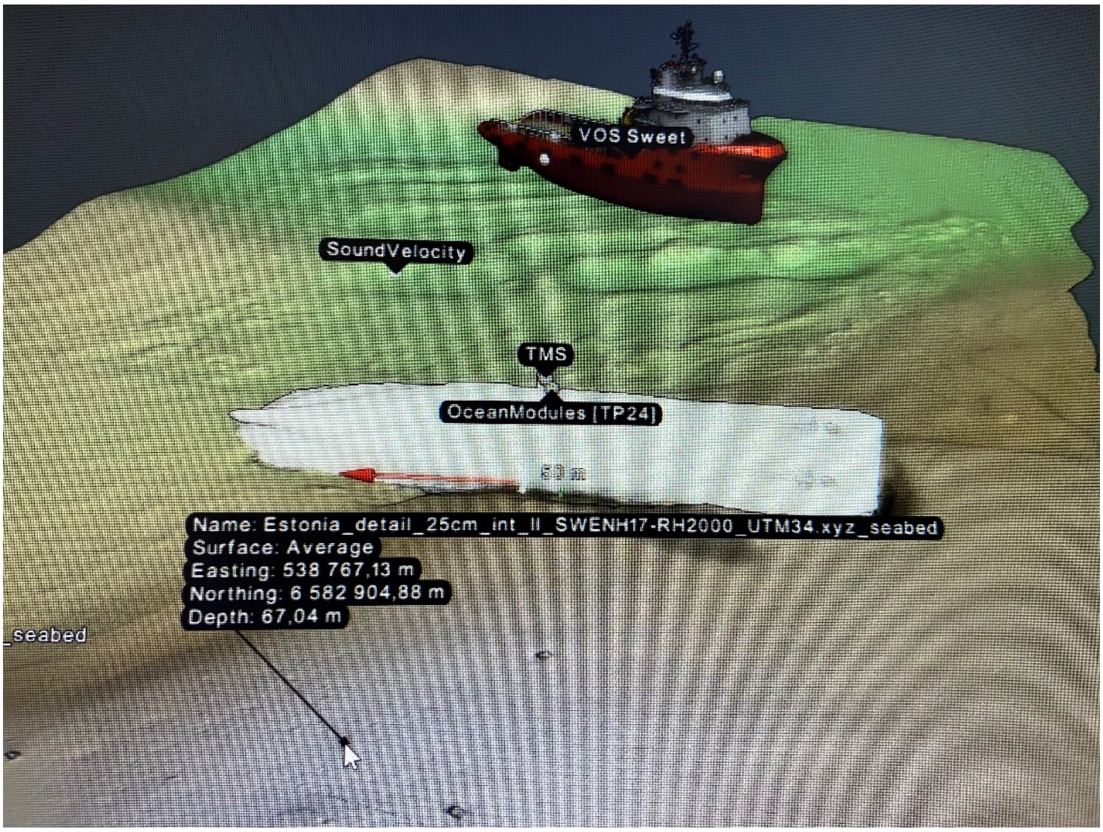

FIG. 3.3: Situational screenshot from a marine survey. Photo: SHK.

3.3.4 Biological Sampling

Mainly fracture surfaces on the wreck are covered with a black material. To obtain samples for further analysis, a tailor-made sampling equipment was manufactured in close collaboration with the Stockholm University (SU). The sampling was carried out between 6 June 2022 and 22 June 2022. Together with an on-board SU geomicrobiology specialist, the equipment was prepared and lowered to the wreck.

Unfortunately, the equipment did not work as planned. Despite several attempts, no samples could be recovered.

3.4 Visor Studies

3.4.1 Visor Stability and Weight Calculations

An estimation of the visor's buoyancy was made to determine whether the visor could have floated after it was detached from MV ESTONIA and, therefore, whether it could have also damaged the ship's hull.

The theoretical study was done on a 3D model of the visor made in NAPA software. The weight and the vertical and longitudinal centres of gravity were calculated from original drawings.

The theoretical weight of the visor was set as 64 tons. The measured weight of the visor, done after the theoretical calculations, showed it to be 65.5 tons. One of the hydraulic cylinders and other parts, e.g., both hinges, had been removed earlier. With the weight of the cut-away parts and the second hydraulic cylinder, the original weight of the visor would have been approximately 68 tons.[11] Conversely, the JAIC report states two different weights for the visor: 56 tons (JAIC 3.3.2) and 60 tons (JAIC 12.2.2) both of which did not include the hydraulic cylinders, weighing 1350 kg each. According to the original drawing of the shipyard subcontractor (from 2 October 1979), the theoretical weight of the visor was 54.5 tons.[12]

Based on the visor's centre of gravity and the volume of possible air pockets, it cannot be dismissed that the visor could have floated but only under certain ideal conditions. If the visor had been afloat after detachment, the bow would have pointed upwards and the hinge arms almost vertically downwards.

3.4.2 3D Laser Scanning

A thorough 3D laser scanning of the bow visor was done at its storage place on Muskö Naval Base, south of Stockholm. The advantage of a digital model of the visor is that it can be compared with the 3D model of the wreck to match damage. The scanning was done on the outside as well as the inside. Distance between individual sample points is approximately 2–3 mm. Overall, the point cloud consists of approximately two hundred million points, creating a 3D digital model of what the visor looked like when it was salvaged from the seabed.

Some parts, e.g., the hinges, the Atlantic lock lug, etc., were cut away during the accident investigation in the 1990s. Those parts, if still remaining, were scanned with a hand held photo scanner. The respective point clouds were joined together with the point cloud of the visor.

The resultant 3D models allow examining the visor and other imaged objects from angles that are not possible in reality without causing permanent damage to the visor.

3.4.3 Examination of Explosives in Visor

Shortly after the salvage of the bow visor in 1994, the Finnish police conducted an examination of the visor, looking for traces from explosives. The examination resulted from a possibility, first considered but later ruled out, that the accident had been caused by terrorists. However, no traces from explosives were found (JAIC 8.12).

A report published by the Norwegian University of Science and Technology in 2022 revealed the results from a number of metallurgical investigations of a plate

FIG. 3.4: Samples from the bow visor, subject of examination by Norwegian University of Science and Technology as well as Element Material Technology AB. Photo: Element Material Technology AB.

from the bow visor of MV ESTONIA. According to the report, the examined samples had been exposed to high temperatures. These temperatures may have occurred either during construction or maintenance of the vessel.

The same bow visor plate was independently examined by Element Material Technology AB who reached the same conclusions as the Norwegian report. In addition, the assessment concluded that some weldings were of very poor quality and that one of the samples had, after being exposed to high temperatures, cooled off slowly.

Based on the evidence gathered so far, there is no indication of an explosion in the bow area.

3.5 Vessel and Seabed Models

Different models have been created to assist the carrying out of the Preliminary Assessment. These models are briefly introduced below.

3.5.1 Digital and Theoretical Models

Digital Model of MV ESTONIA

The purpose of the digital model of MV ESTONIA is to provide as accurate a general overview as possible of the external appearance and the constructional and technical characteristics of the original vessel as of 27 September 1994. The model was created for the purpose of developing a physical model of the vessel and for assisting in various surveys and for demonstrating the vessel in public.

The first step in the creation of the model involved the digitisation of the original drawings: a three-dimensional (3D) drawing of the vessel was created on the basis of the shipyard's original two-dimensional (2D) drawings using computer-aided design (CAD). As the drawings were prepared during different design and construction stages of the vessel, they contain contradicting, unclear, and erroneous information. In addition, the vessel underwent various modifications and alterations during its service history and, for that reason, all kinds of photographs and videos of the vessel and wreck were used as reference during the digitisation of the drawings.

The surfaces were modelled on the basis of the 3D digital drawing of the vessel and the final spatial model of the vessel was completed.

The model features the following key modifications made after the completion of the vessel:

- Aft-most radar antenna removed due to the installation of the forward radar mast, flag gaff installed on the foundation of the aft-most radar antenna.
- Shortened forward bilge keels due to installed fin stabilisers (previous models have original double bilge keels or even single bilge keels).
- Forward radar mast with two antennas (installed in two parts in the 1980s during the Viking Line service).
- Lantern mast removed from the aft side of the funnel and masthead lights installed to the forward side of the funnel to prevent the funnel exhaust smoke from obscuring the masthead lights (installed in the 1980s during the Viking Line service).
- Cutouts made to the bulwark on both sides of the bow above the fairleads (installed in the 1990s during the Wasa Line service).
- Ducktail added to minimise the immersion of the stern (stern extension, installed in spring 1985 in Vuosaari).
- Stairway between decks 7 and 8 added to the portside near the funnel (installed in the 1990s).
- Fin stabilisers added to reduce roll (installed in January 1994 in Naantali)—these are not visible in previous models.

Digital Bathymetric Model of the Seabed and the Wreck

A digital bathymetric model was created by merging the two bathymetric surveys carried out by Stockholm University on 13 July 2021. The processed digital elevation models of the two surveys were compiled into a high-resolution grid (cell size: 0.50

m by 0.50 m). The purpose of the digital bathymetric model of the wreck and the surrounding seabed is to provide as accurate a general overview as possible of the current position of MV ESTONIA on the seabed and its surrounding bedforms.

Digital Bathymetric Model of the Seabed with the Theoretical Wreck

The digital bathymetric model was carried onwards into the next step where the bathymetric shape of the wreck was replaced by the digital model of MV ESTONIA. Bow visor, ramp, lifeboats, and life rafts have been removed from the digital model of MV ESTONIA and fin stabilisers have been retracted to replicate the ship's current situation on seabed. The ship's model was rotated and positioned according to the position of the wreck on the seabed. The purpose of this model is to provide a general overview of the current position of the wreck on the seabed with respect to the surrounding bedforms and to assist in main surveys.

3.5.2 Physical Models

Physical Model of MV ESTONIA

The purpose of the physical model of MV ESTONIA is to provide as accurate a general overview as possible of the external appearance and the constructional and technical characteristics of the original vessel as of 27 September 1994. The model (Figure 3.5) is primarily used to illustrate the sequence of the sinking of the vessel during interviews with survivors and in public.

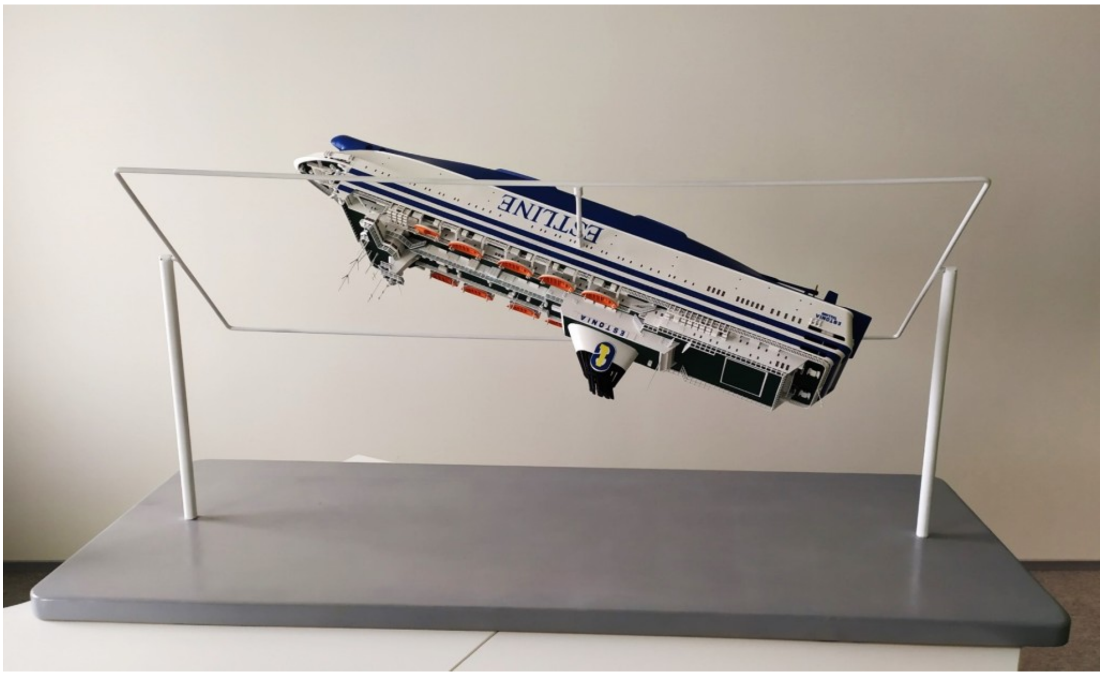

FIG. 3.5: The physical model of MV ESTONIA. Photo: Tauri Roosipuu.

The model was created on the basis of the digital model of MV ESTONIA using 3D printing technology (to achieve the most accurate result in the shortest possible time). The model is at a scale of 1:150, i.e., the dimensions of the model (length, width, and height) are 1047 mm, 207 mm, and 324 mm, respectively.

Physical Bathymetric Model of the Wreck and Seabed

The purpose of the physical bathymetric model of the wreck of MV ESTONIA and the surrounding seabed is to provide as accurate a general overview as possible of the current position of the wreck on the seabed and its surrounding bedforms. The model was primarily created for the purpose of demonstrating the position of the wreck during various surveys and in public.

The model was created on the basis of the digital bathymetric model of the wreck and seabed using 3D printing technology (to achieve the most accurate result in the shortest possible time). The model is at a scale of 1:1088, i.e., the dimensions of the model (length, width, and height) are 735.29 mm, 500.00 mm, and 51.15 mm, respectively.

3.6 Structural Damage Modelling

The objective of structural damage modelling is to determine if the deformations observed on the wreck could have been caused by the ship's collision with the seabed and by its subsequent slide downslope.

Results from the preparatory and main surveys were both necessary to ensure that modelling inputs, such as the composition of the sub-surface in the vicinity of the wreck, would correspond to reality and to verify the accuracy of modelling outputs, such as the condition of the wreck. In addition, the digital models of the ship were used as the basis for the design of the digital twin that was taken into structural damage modelling.

Structural damage modelling started on 30 August 2022. The work is on-going.

Chapter 4

Interviews

4.1 Overview

In all, 137 people survived the catastrophe. These survivors were questioned by different authorities, mainly by the police, shortly after the accident. In some cases, the same people were questioned several times.

JAIC based its decision whether to interview a survivor by reading the respective police reports. This resulted in multiple survivors who were not contacted by JAIC investigators.

The Preliminary Assessment enabled conducting interviews with all survivors to gather all possible information. This includes information which was not shared, asked, or recorded, as well as information that was misunderstood or mistranslated during earlier interrogations and interviews.

The Preliminary Assessment expanded the scope of interviews to reach out beyond the survivors of the catastrophe to other people who were involved either directly or indirectly ("associated persons").

The purpose of the interviews is to collate all possible material regarding human testimony that relates to the catastrophe.

4.2 Progress

Of the survivors, 53 survivors were identified as registered inhabitants of Sweden. Of those, eleven have passed away since the catastrophe. The remaining 42 were contacted by SHK and asked whether they would accept an interview. 28 accepted, and were thus interviewed.

The interviews were conducted on the interviewee's conditions, lasting from less than one hour to four hours for the longest interview. During the interviews, a model of the vessel and a model of the forward section of the vessel were brought along for demonstrational purposes.

In addition, a number of interviews have been conducted with associated persons.

The remaining interviews are in the process of being conducted. These concern survivors who were registered inhabitants of Estonia and other countries as well as associated persons in those countries, e.g., the relief crew and former crew members, technical personnel, and harbour personnel.

A summation of the findings from all interviews will be presented once the interview process is complete.

4.3 Process and Principles of the Interviews

The interviews are given voluntarily and all provided statements are confidential which is standard procedure in safety investigations.

The interviews are conducted where and when is most suitable for the interviewee. After acquainting themselves with the available material, such as records from previous interviews, statements, and interrogations, the interviewee is asked to tell their whole story as they remember it in their own words (the principle of free narrative). Thereafter, the interviewers ask questions to add and clarify the statement (the principle of direct examination).

During the interview, a model of the vessel as well as photographs and drawings of the ship are used to help recall as many details as possible. The interviewers also answer any questions about the on-going Preliminary Assessment to the interviewee.

The collected information is documented and systematized according to a questionnaire and data structure. The same data structure is used for all collation to allow for comparisons.

Chapter 5

Other Surveys and Studies

5.1 Wreck Oil Leak

Indications of an oil leak were observed during on-site surveys in 2021. The minor leak was located in the hull's aft section during on-site surveys conducted in 2022 (Figure 5.1). The Finnish Border Guard conducted an aerial survey and subsequently took samples of the oil for analysis.

The results of the analysis indicated that the samples mostly contained lubricating oil mixed with some fuel oil. Effective surface response activities cannot be conducted as the leakage is minimal.

The Finnish Border Guard continues to monitor the leakage.

5.2 Video Tape Digitization

The Finnish Environment Institute[1] videoed the emptying of the wreck of MV ESTONIA of oil in 1996–97. SIAF handed these video tapes over to OJK for digitization.

Altogether, there were 35 VHS tapes, 91 Hi8 Sony tapes, and 1 Scotch P5 tape. These tapes were digitized by the Film Archives of The National Archives of Estonia. The volume of digitized videos is 523 GB, the length 215 h and 55 m.

[1] *Suomen ympäristökeskus/Finlands miljöcentral*.

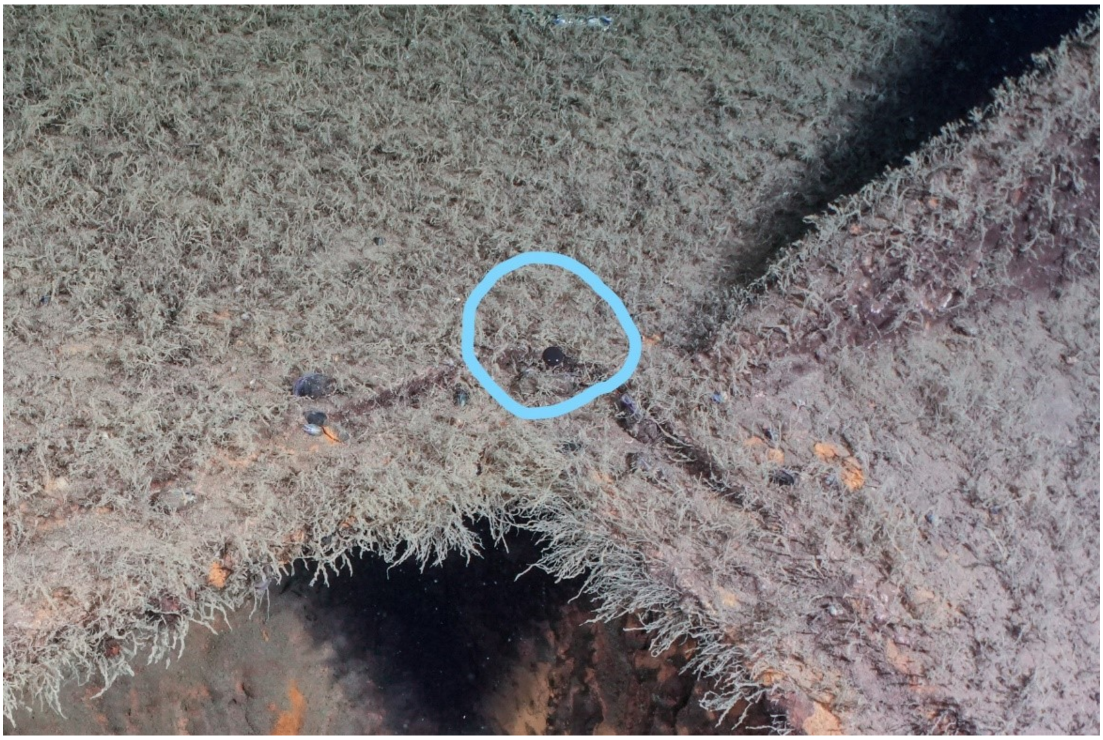

FIG. 5.1: The blue circle shows where a drop of oil is bubbling to the surface. Photo from photogrammetry.

5.3 Swedish Armed Forces Enquiry

The Preliminary Assessment made an enquiry to the Swedish Armed Forces regarding information they could provide on the sinking of MV ESTONIA, including whereabouts for Swedish submarines and the use of MV ESTONIA for shipping military equipment.

The reply of the Swedish Armed Forces stated the following:

- They did not have any sensors that could have registered when MV ESTONIA hit the seabed.
- They do not have any knowledge of vessels' movements in the area of the sinking.
- No Swedish submarine was in the area when the accident occurred.
- Electronic equipment, without connection to weapons, had been shipped on MV ESTONIA on civilian vehicles. However, on the night of the accident, no such shipment was made.

Chapter 6

JAIC Report Assessment

The JAIC report handles seaworthiness following a then-common practice, i.e., making a statement whether a vessel, involved in an investigation, was seaworthy. The explanation in the case of MV ESTONIA is that there were “no outstanding items” either from authorities or the classification society (JAIC 5.2).

The following conclusions are restated from the JAIC report:

- The bow visor was not fully built according to the approved drawings with respect to its structural members and materials.
- The ship was not built according to the SOLAS Convention with respect to the location of the bow ramp, as a collision bulkhead, and the visor.
- These deviations in construction meant that the vessel and its passenger safety certificate were not in full compliance with the SOLAS Convention, because the requirements for an upper extension of the collision bulkhead were not satisfied.

During the Preliminary Assessment, the question of MV ESTONIA’s seaworthiness was raised again. An SHK–OJK assessment of seaworthiness is presented as Appendix B.

Chapter 7

Challenges

The most modern methods have been used in the Preliminary Assessment. The level of detail that the Preliminary Assessment has sought to uncover is unprecedented for academia and industry and that has presented challenges, to which it has been necessary to find innovative solutions on an on-going basis.

The tendering environment has not been favourable to the Preliminary Assessment due to the current economic context. The general unavailability of suitable survey vessels and equipment has caused delays and price increases for conducting surveys.

7.1 Operational Challenges

Much like any open sea environment, the wreck site is open to wind and waves from every direction. High swell can be frequently encountered from S-SW and NE-E directions. Marine surveys can generally be conducted in swells of <1.5 m for smaller survey vessels and <2.5 m for larger vessels. Such conditions occur mostly during spring and summer only and, even then, it is possible that the conditions occur only for a short time.

While weather allows for surveys to be carried out during late spring and summer, surveys which require low seawater turbidity, i.e., good visibility, can be carried out from approximately the start of winter to the start of summer. Combining these criteria reduces the available survey time window to approximately four months—from

March to June. Further, even during a period of anticipated good visibility and favourable seas, real visibility at the wreck site changes continuously (almost hourly).

7.2 Technical Challenges

Marine surveys also need to balance potential dangers to the survey equipment with the requirements for acquiring best possible quality data. Hanging and floating ropes (the ones that are directed upwards due to their positive buoyancy) are attached to the wreck. With low visibility, an entanglement hazard may not be seen before it has entangled the survey equipment. Therefore, an entanglement can result in the loss of an equipment, as has happened.

Entry to the cargo deck needs to account for the wreck's trim to bow as most survey equipment needs to use an umbilical cable for communications and control. This cable must not touch the upper side of the opening to the cargo deck, as this would damage the umbilical cable. The car deck also contains floating debris, which can tangle an ROV's propellers and result in the ROV being inoperable and uncontrollable.

7.3 Working Principles

The meeting of these challenges is only possible where the survey team is responsive and has worked through relevant contingencies. Even with the best contingencies in place a single survey may not fully achieve all of its original goals. This is why in marine surveys emphasis is not on a single survey, but on the whole survey campaign: how all the surveys carried out on site complement each other. For the Preliminary Assessment, this has meant that the survey campaign has used various equipment to acquire partially overlapping datasets, which altogether ensure that the goals of the Preliminary Assessment are being met.

Chapter 8

Future Surveys and Studies

Comprehensive wreck studies and interviews are on-going as of the publication of this Interim Report. These have been detailed above.

In addition, additional surveys may be devised which would expand our understanding of the sinking. Some potential future activities are mentioned below:

- Carrying out a ferromagnetic survey of the seabed to look for ferrous items relating to MV ESTONIA. Ferrous debris can provide information to better describe the vessel's movements.
- Taking samples from the damaged area of the hull to collect material which could verify how damage arose.
- Salvage of the bow ramp which was found to be loose of the wreck; recovering it may facilitate further examination of occurred damage.
- Surveying the forward part of the wreck, now hidden by the bow ramp, by 3D laser scanning or photogrammetry.
- Surveying the trench on the starboard side by 3D laser scanning or photogrammetry.
- Surveying the cargo deck by 3D laser scanning, photogrammetry, or filming to detail the cargo, cargo securings, and any openings/deformations of the cargo deck.
- Modelling of the path of the ship based on known debris on the seabed and the status of the wreck during the sinking.
- Reviewing the Port State Control exercise held onboard MV ESTONIA the day

before the sinking, with an examination of available documentation and an assessment of the deficiencies registered during the exercise.

- Final analysis of all conclusions derived from all surveys and studies.

Chapter 9

Preliminary Conclusions

Preliminary conclusions are made during the course of a preliminary assessment, and, as such, may change once the preliminary assessment is completed.

The course of this Preliminary Assessment has allowed the reaching of the following preliminary conclusions:

- The wreck of MV ESTONIA is in a poor condition with severe structural damage.
- The location of the outcropping bedrock under the hull matches the location of the deformation on the hull.
- Based on the evidence gathered so far, there is no indication of a collision with a vessel or a floating object.
- Based on the evidence gathered so far, there is no indication of an explosion in the bow area.
- The seaworthiness of MV ESTONIA was re-assessed by SHK and OJK, based on the JAIC report, concluding that MV ESTONIA was not seaworthy.
  - An inspection of the bow parts was not performed. The related certificate should not have been issued unless such an inspection had been carried out, which means that MV ESTONIA was not seaworthy. If such an inspection, following regulations, had been carried out, the flaws of the visor construction could have been discovered, and the accident would probably not have occurred.

- The location of the bow ramp as the upper extension of the collision bulkhead was based on a practical decision for an exemption from the regulations. Such an exemption entails a condition, which must be recorded in certificates but was not. Therefore, MV ESTONIA was not seaworthy and the certificate was incorrect. If the condition had been noted in the relevant certificate, the vessel would not have been trading the Tallinn–Stockholm route.

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APPENDICES

List of Figures in Appendices

Appendix A

Facts Known Prior to the Preliminary Assessment

A.1 The History of MV ESTONIA

The ship, MV VIKING SALLY, was built in 1980 at the Jos. L. Meyer Werft shipyard in Papenburg, Germany. When the vessel sailed, it was under a Finnish flag and between Turku, Mariehamn, and Stockholm.

Ownership of the vessel changed in 1986, from the Ålandic company Rederiaktiebolaget Sally to the Swedish-Finnish group Effjohn. In 1990, she was renamed to MV SILJA STAR but continued sailing between Turku and Stockholm. In January 1991, the vessel was transferred to Wasa Line, a subsidiary of the Effjohn Group, and began sailing between Finland (Vaasa) and in Sweden (Umeå and Sundsvall) under the name MV WASA KING.

She continued sailing this route until she was sold and transferred to Estline Marine Company Limited, a Cyprus-registered company, and parallel registered in Cyprus and Estonia on 15 January 1993. Until January 1993, the vessel sailed under the Finnish flag, but she changed to an Estonian flag when she was entered into the Estonian register. This happened under the name ESTONIA on 28 January 1993, and the vessel began sailing between Tallinn and Stockholm after a delivery docking at a shipyard.

On the evening of 27 September 1994, MV ESTONIA departed from Tallinn with 989 people on board. Weather conditions were poor, deteriorating during the night. Shortly after midnight on 28 September, the vessel capsized and sank. Of those who were on board, 137 were rescued.

A.2 Organisation of Authorities at the Time of the Accident

A.2.1 Estonia

The Estonian Maritime Administration[1]) consisted of four departments in 1994, of which one was safety. A section of this department was responsible for vessel

[1] *Veeteede Amet*.

maintenance inspections. Inspections were to a large extent done by delegation to classification societies, but some parts of inspections were also performed by other institutions (e.g., elevator inspections by relevant Swedish authorities).

According to legislation from 1991, the Estonian Maritime Administration was responsible for organizing accident investigations. A manual, based on IMO documentation of official accident investigations within shipping, was adopted in 1994 by the General Director of the Administration.

A.2.2 Finland

Inspections, including Port State Control, were conducted by the Finnish Maritime Inspectorate[2]. According to superseded legislation, certain inspections could be performed by classification societies (JAIC 3.6.4). Newer legislation went into force in 1983 without mentioning any such delegation, but this praxis remained and was used in 1994 (JAIC 3.6.4).

As of 1986 effective legislation governing accident investigation has been in place in Finland stipulating that government-appointed independent commissions should investigate major accidents. The preparedness to do this was kept by the Major Accident Investigation Planning Committee[3]. This organization was replaced 1996 by the accident investigation authority (now known as Safety Investigation Authority, Finland[4]).

A.2.3 Sweden

At the time of the occurrence, the Swedish Maritime Administration[5] consisted of six departments, one of which was the Swedish Maritime Inspectorate[6]. The Swedish Maritime Inspectorate was responsible for supervisory activities within maritime transport, which includes Port State Control, and was led by a maritime safety director. This person was, with regard to the performance of their duties, independent of the rest of the Swedish Maritime Administration. This independence was manifested through the maritime safety director and their deputy being directly appointed by and directly accountable to the Government.

The accident investigation in respect of the safety investigation was within the Swedish Accident Investigation Authority's[7] area of responsibility. However, its operations within maritime transport were limited and consequently safety investigations would, in practice, be largely conducted by the Swedish Maritime Inspectorate's investigation section. In cases where there was potential doubt about the Swedish Maritime Inspectorate's impartiality, the Swedish Accident Investigation Authority took over the investigation. The Swedish Maritime Inspectorate was represented in these investigations by an observer, who was able to monitor the work of the investigation directly and could quickly ensure that the Swedish Maritime Inspectorate took relevant action without needing to wait for the investigation to be completed.

[2] *Merenkulkuhallitus/Sjöfartsstyrelsen*.

[3] *Suuronnettomuustutkinnan suunnittelukunta/Planeringskommissionen för undersökning av storolyckor*.

[4] *Onnettomuustutkintakeskus/Olycksutredningscentralen*.

[5] *Sjöfartsverket*.

[6] *Sjöfartsinspektionen*.

[7] *Statens haverikommission*.

A.3 The Previous Accident Investigation and Other Earlier Studies

Below, the previous main investigations are referred to, starting with the official Joint Accident Investigation Commission. Prior studies with their major conclusions are described below, but the assessment of these conclusions with respect to the preliminary conclusions of the Preliminary Assessment is outside of the scope of this document.

A.3.1 The Joint Accident Investigation Commission (JAIC) Investigation

Organization of the Investigation

The loss of MV ESTONIA was investigated by the Joint Accident Investigation Commission (JAIC) on the basis of an agreement between the governments of the three mainly concerned countries: Estonia, Finland, and Sweden.

Responsibilities were divided at an overarching level, with Estonia responsible for the Estonian part of the ship owner's business (operation, manning, and Estonian shore organisation), Finland responsible for search and rescue as well as radio traffic, and Sweden responsible for history, inspections, and survivors.

The commission was made up of the following:

- Estonia, chairing the commission, had three members from different institutions (government, maritime authority, and police and shipping operations), two to four experts, two administrators, and an observer from the maritime authority. The management was appointed by the government.
- Finland had three members from different institutions (the Finnish Major Accident Investigation Planning Committee, the Finnish sea rescue society, and the VTT Technical Research Centre of Finland), appointed by the government. They, in turn, appointed four experts, an administrator, and an observer from the Finnish Maritime Administration[8].
- Sweden had three members from different institutions (the Swedish Accident Investigation Authority), three experts, one administrator, appointed by the Director General of SHK, and an observer from the Swedish Maritime Inspectorate.

Weather Conditions

The JAIC report concludes that wave statistics for the vessel's various routes suggest that MV ESTONIA had been exposed to significant wave heights greater than four metres[9] against the bow for less than approximately 20 hours throughout her entire operational history. Wind and wave conditions similar to those present during the night of the accident, with a significant wave height of approximately four metres, had only occurred once or twice in the period in which she was operating on the

[8] *Merenkulkulaitos /Sjöfartsverket*.

[9] Significant wave height is the average height of the highest one third of all waves measured over a 30-minute period. The maximum wave height of individual waves can be twice as large.

Tallinn–Stockholm route. Accordingly, the JAIC establishes that "it can be concluded that the vessel had generally been protected from heavy sea conditions during her lifetime" (JAIC 13.1).

The Port State Control Exercise

The JAIC report says that a Port State Control exercise that was performed onboard on 27 September 1994 was implemented as a thorough inspection in accordance with the regulations that apply to such inspections. According to the inspectors who led the exercise, the vessel was in good condition and very well maintained, and did not have any deficiencies that would have prompted detention or other serious remarks if this had been an inspection instead of an exercise (JAIC 5.2).

However, it was noted that rubber seals for the bow visor were worn, and that watertight hatches were open and one of them showed signs indicating it was not normally closed. In addition, the officers the inspectors met during the exercise showed a lack of respect for matters related to load lines.

Seaworthiness

The JAIC reports says that MV ESTONIA was seaworthy, i.e., there were no remarks from authorities or classification societies (JAIC 5.2 and Chapter 20).

Lashing of Cargo

The JAIC reports says that equipment for lashing cargo on the cargo deck (heavy vehicles and containers) was regularly inspected and kept in stores on the same deck. All lashing took place under the supervision of the loading second officers and was conducted by the boatswain and able seamen. The applicable IMO resolution on cargo lashing was adhered to and there was a cargo securing manual on board. Before the voyage in question, the chief officer had given instructions to the effect that the heavy cargo was to be lashed carefully.

According to witness testimony referred to in the JAIC report, "all the lorries were lashed down with straps and chocks were used for the cars" (JAIC 6.2.1). Furthermore, on a subsequent round the able seaman on watch checked "the lashings which he found were in order" (JAIC 6.2.2). The chief officer's order concerning lashing was confirmed by one of the crew members from the engineering department who overheard it on the vessel's portable radio system (JAIC 6.2.3). Furthermore, two able seamen have testified that they participated in lashing down the cargo, which was conducted using four lashes on lorries and trailers. Both state they were certain that the vehicles were secured "in accordance with their instructions with the equipment to hand" (JAIC 6.3.1).

Consequently, the JAIC concludes that the cargo was lashed, even though the lashing down was not completed before the vessel had departed. To support this, the JAIC also cites the complete absence of previous claims due to inadequate lashing of cargo on this route, i.e., there had been no damage to cargo (JAIC 13.2.2).

General Information about Diving and Damage

According to information from members of the JAIC, diving inspections of the hull were conducted by performing a general sweep over the hull, before concentrating on the damage that was detected.[10] No damage to the hull, other than that which was reported, was detected during the inspection of the wreck (JAIC 8.5.1).

The interior of the vessel was extensively damaged and many areas were not accessible by divers. This was also the case for the cargo deck, which was not inspected (JAIC 8.7). The bridge was found to contain mud and an accumulation of debris and could not be inspected. It was established that the starboard side bridge wing was crushed against the seabed (JAIC 8.8).

The Forward Ramp and Bow Visor

Under the applicable rules, MV ESTONIA had to be equipped with a collision bulkhead with an upper extension on the cargo deck and at a certain distance from the forward perpendicular, which constitutes the technical calculation point. The forward boarding ramp was accepted as an extension of this type but, for practical reasons, was not located in accordance with the minimum permitted distance and was therefore closer to the bow visor. This had been accepted in accordance with the applicable rules by issuing a conditional dispensation. In order to reach land with the ramp lowered, without needing to fold the boarding ramp (which would entail a more complicated construction), it needed to be made longer than there was actually space for when it was stowed in its raised position. Consequently, a special arrangement was made in the form of a box-like housing that formed a part of the upper section of the visor. As a result, the top-most part of the ramp, when in its raised position, was inside the visor when this was lowered (JAIC 3.3.1, 3.3.2, and 10.3). With regard to maintenance requirements, the JAIC notes that a future need for maintenance of the ramp's hinges had been noted. In addition, rubber seals had been ordered.

The dives showed, among other things, that two of the ramp's four hinges were broken off and that the ramp was slightly open. The two wires that were there to prevent the ramp from falling onto the forepeak deck had detached from their attachments and there were deep indentations on the beams on the lower side of the ramp. Three of the four lugs at the locking bolts were torn open while the port side lower locking bolt was only partly extended and its mating box was undamaged (JAIC 8.5.4 and 8.6.5). In addition, the deck was torn open from the visor operating actuator openings and forward. The openings continued for some length down the front bulkhead. The deck damage was extensive with uneven fracture surfaces, whereas the opening on the port side had rather clean-cut contours (JAIC Figure 8.2).[11] The JAIC comes to the conclusion that there were no deficiencies in the ramp affecting the development of the accident (JAIC 13.2.3).

The damage to the visor was extensive and included an extensive indentation on the front of visor, located slightly starboard of the centre line (JAIC 8.5.3). Furthermore, heavy scratches with colour marks from the vessel's bottom paint were noted from the indentation along the starboard side of the visor. The bottom of the visor was also heavily distorted. With regard to the lock installations, it was noted, among other things, that all three attachment lugs for the bottom lock installation were torn off and the character of the fracture surfaces was typical of

[10] One of the commission delegates, in an Estonian documentary from May 2019.

[11] Compare to article in *Dagens Nyheter*, 18 October 1994, *"Bogvisiret slet upp hål. Haverikommissionen övertygad om vad som orsakade "Estonias" haveri - DN.SE"* [The Bow Visor Tore Open Holes. SHK convinced of what caused the loss of MV ESTONIA].

failure due to local overload, and that the welds showed signs of poor fusion and lack of penetration (JAIC 12.7.3 and Figure 8.13), while the locking bolt remained attached to the actuating cylinder piston rod (JAIC Figure 8.15). The locking bolt was salvaged and examined (JAIC 8.6.1).[12] Furthermore, the port side actuator was closed, whereas the starboard side actuator was completely extended (JAIC 8.6.4). Both actuators were still hanging from the visor hinge arms (JAIC 8.5.3) and the mounting platforms had cracks that were clearly of significance for the ultimate strength of the platform (JAIC 12.7.2).

The Bureau Veritas rules applicable at the time had no details regarding procedures for calculating loads on a bow visor. Consequently, the shipyard's contractor used general rules for calculating loads on the bow based on large vessels where the bow could not open (JAIC 3.3.1). The JAIC makes the assessment that the calculations were not sufficiently realistic and that they had "an obvious lack of logic" (JAIC 15.1.2). The visor and the attachments were made of regular mild steel, despite the fact that the lifting lugs and locking lugs should have been made of a stronger steel (JAIC 3.3.3 and 15.1.2). The JAIC also comes to the conclusion that "the locking devices [were] not … examined for approval either by Bureau Veritas or by the Finnish Maritime Administration". The investigation of the visor after the occurrence showed that the construction also differed to some extent from the drawings, e.g., two flat bars were missing from the bottom plating, some welds were defective or had not been done at all, some details had been changed using a cutting torch and the deck part of the installed hinge arrangement "differed considerably from the manufacturing drawing" (JAIC 8.12).

The previous owner, Wasa Line, had paid attention to the strength of the ramp and visor locking devices and requested a quotation for reinforcement. However, this was not rectified before the vessel was transferred under the Estonian flag (JAIC 3.3.6).

The JAIC report also describes a number of previous incidents involving similar forebody construction, including, in this respect, on the sister ship MV DIANA II. Some of this damage can be characterised as serious and was suffered by both Swedish and Finnish vessels. In a report from the supervisory authority, following an occurrence in 1974, the conclusion was drawn that "nearly all locking devices of bow doors on existing vessels are too weak". No strategic measures were implemented in order to deal with these problems (JAIC 11.2 and 15.13).

Previous Hull Surveys and Requirement for Dispensation Certificate

Surveys were conducted by the Finnish supervisory authority for as long as the vessel had a Finnish flag. However, under an exemption in an older regulation, the hull was not surveyed in conjunction with the seaworthiness inspections if the vessel had a valid classification certificate from an approved classification society (which was assumed to conduct the survey). This was the case for VIKING SALLY. A new regulation was issued in 1983 that did not retain this exemption. However, the practice of accepting the classification society's surveys was retained (JAIC 3.6.4).

The classification society Bureau Veritas conducted surveys in accordance with its own regulations and surveyed the bow and surrounding area in 1983, 1988, and

[12]The bolt was not, however, brought ashore, and was instead thrown back in the sea after being examined.

1993, in addition to the new construction survey, without any discrepancies being noted (JAIC 3.6.5). In conjunction with the change to the Estonian flag, the vessel was surveyed in accordance with the requirements that apply for a periodic survey. However, this does not include examination of the construction drawings, i.e., the location of the extension to the collision bulkhead was not considered (JAIC 3.6.3).

The Finnish Maritime Administration had issued the certificates that were required at the time the vessel was entered in the Finnish register. Nevertheless, the location of the bow ramp did not comply with the requirements for an extension of the collision bulkhead (JAIC 3.6.3 and 18.1). A dispensation for an exemption in this respect could have been issued under the international SOLAS regulations, on the condition that the vessel be permitted to sail to a maximum of 20 nautical miles from nearest land. No such dispensation was ever issued.

The Sinking of the Vessel

As the bow visor and bow ramp opened, a large opening allowed sea water to ingress into car deck. The vessel listed very quickly and water flooded into the cargo deck as well as accommodation decks through broken windows and doors. The flooding progressed and the vessel sank.

Causes of the Sinking

The JAIC report concluded that the lockings to the bow visor were too weakly built because they were based on inadequate calculations. In combination with deviations from construction drawings, the visor was unable to resist the heavy seas. A lack of detailed design requirements allowed the construction to proceed. Further, there was no control of these parts, neither by the flag state nor by the classification society.

In addition, the bow ramp was placed closer to the visor than international legislation allows without an exemption certificate. This resulted in the bow ramp having its top end in a housing of the bow visor when closed. As the visor went loose, it rested on the top of the ramp and eventually pulled the ramp open. That a certificate was never issued allowed the vessel to sail in a trade area exceeding 20 nautical miles from nearest land, which was beyond the limits of the exemption certificate (which should have been issued).

Witness Testimonies

There were 137 survivors after the accident, and of these 134 were heard. Most of them were only heard by the police. By reading the police records, JAIC chose some passengers for follow-up interviews. JAIC also interviewed a number of crew members.

The JAIC report states that some details deviate from what witnesses actually said, and some details, based on obvious mistakes, have been edited in order not to confuse readers. However, the summaries follow the witnesses' statements as closely as possible, and some of the details may therefore not necessarily correspond to facts or other findings and may consequently differ from some of the conclusions made by the JAIC.

Regulatory Changes

A panel of experts, parallel to the investigation, was set up within IMO, with the task to investigate all aspects of safety related to roll-on/roll-off passenger vessels. A number of new regulations and safety improvements have been put in force (JAIC 19).

However, some controversial proposals were rejected. Instead, a number of states agreed on specific requirements for ferries to maintain stability with water on the cargo deck (Stockholm Agreement, put into force 1 April 1997).

Additional Information

The JAIC report described the thickness of the soft clay, on which the wreck rests, as varying from 25 m (bow) to 5 m (amidship) to 15 m (stern). The vessel was also supposed to be in contact with solid boulder clay, which underlies the soft clay, at approximately amidship (JAIC 8.1).

A.3.2 SSPA

The report discusses a number of scenarios, of which the most likely is described as:

- The ramp is forced partially open by the bow visor prior to complete visor detachment from the vessel.
- Water enters the car deck through the openings at the sides of the ramp resulting in a slowly increasing starboard heel angle.
- The ramp remains partially open until the bow visor detaches from the hull.
- The ramp fully opens and crashes down onto the forepeak deck as the visor completely detaches from the vessel.
- A large amount of water enters the car deck resulting in a rapidly growing starboard heel angle up to about 35–40°.
- The ramp may swing up and down due to the interaction between waves and pitch motion.
- Water floods down to the lower decks through vents and the centre casing.
- The officer on the bridge decreases the ship's speed and starts a port turn.
- The ship's heel is still increasing after the turn, and the main engines stop.
- The heel increases and the auxiliary engines trip and stop when the heel angle is greater than 45°.
- The ship now drifts in wind, waves, and currents, and when the heel is about 80–85° the emergency generator shuts down.
- The ship capsizes, sinking with the bow up.
- The stern of the ship hits the seabed first. The foundering sequence is estimated to take about one hour.

The conclusions on the most likely sinking sequence primarily rely on three key inferences:

- The first heel resulted from water on deck flooding through forward doors, and not from flooding through any other breach of hull integrity.
- The ramp opened completely and closed due to gravity after heeling beyond 90°.

- The large side windows on the decks above the cargo deck withstood substantial pressures before breaking.

A.3.3 HSVA

The report states that water ingress most likely came from the cargo deck, and that the scenario in general is consistent with the scenario in the JAIC report.

The report also states that an explosion is not supported by available evidence, and that the visor and the ramp could have been in a not properly closed state before the accident.

A.3.4 Unauthorised Surveys and Studies

The German Group of Experts investigating the sinking of M/V ESTONIA

The German Group of Experts was formed in the beginning of February 1995 in accordance with a decision of the Managing Director of Jos. L. Meyer GmbH, the shipyard which constructed MV ESTONIA.

Their report, which was originally published before the final JAIC report, states that the technical standard of the bow visor was poor with regards to keeping water on the outside and for directing forces according to construction (instead the forces stressed components which were not designed for this purpose). Because of this, the visor lockings could not be set to closed position without using manual force, including hammers. The use of hammers is evident due to corrosion being nonexistent on the lugs to the bottom lock. The report also claims that the sensors, reading the closing status of the bottom lock, were dismounted.

The report claims that the port outer hinge bearing of the bow ramp had collapsed, causing a gap between the ramp and the corresponding part of the hull. This had been on the list to be repaired for some time without being carried out. This gap would explain the port side lower locking bolt not being in the expected, locked position. The retrieving hook on the port side cannot, according to the report, have been in the engaged position due to the misalignment of the ramp.

Other Unauthorised Surveys

In addition, there have been at least four other, unauthorised, instances involving dives or underwater activities, one of which was in conjunction with the production of the video footage aired in 2020.

A.3.5 Underwater Surveys

Video Surveys

In addition to locating the wreck and bow visor in surveys over the course of autumn 1994 (2 October and 9–10 October), the JAIC ordered dives to examine the wreck, including the bow and the bridge from 2 to 5 December 1994. The visor was located on 18 October 1994 and was salvaged on 18 November of the same year.

Some of the dives were performed partly for other purposes. Among these, specific reference can be made to dives and works on the wreck in conjunction with oil decontamination, conducted by Finnish authorities in 1996, dives by Swedish authorities in 1994 with the aim of investigating the feasibility of recovering bodies and the hull, and examinations related to the plan of covering the wreck in 1996.

During the dives, several attempts to film also inside cargo deck were carried out. However, only one may have been successful with the diver's company claiming that they entered the cargo deck for a short duration, but found it difficult to orientate.

Geophysical and Geotechnical Surveys

Several surveys of the seabed were conducted between 1994 and 1997. One of these (reference ACZ-REP-DES-034, Rev 01, 31 October 1997), conducted by Nordic Marine Contractors J.V. for the Swedish Maritime Administration, contains a plan, showing areas of the hull where damage may be expected, taking into account the composition of the seabed (Figure A.1).

The Finnish Transport and Communications Agency Traficom[13] conducted a multi-beam echo sounder survey in the general area of the wreck of MV ESTONIA in 2006.

A.4 Military Equipment

After the accident, some survivors claimed they witnessed military equipment being loaded on MV ESTONIA shortly before its departure from Tallinn.

Some years after the accident, information revealed by Swedish media confirmed that military equipment had been shipped on MV ESTONIA. The Swedish government later organized an investigation into the question of military transportation which confirmed that it had happened. However, the investigation stated that such transportation did not take place during the night of the accident.

[13] *Liikenne- ja viestintävirasto* Traficom /*Transport- och kommunikationsverket* Traficom.

Contact Area Difference chart; only penetration / deformation area shown. Lines indicate the Starboard edge of the D, E, F, G and H decks.

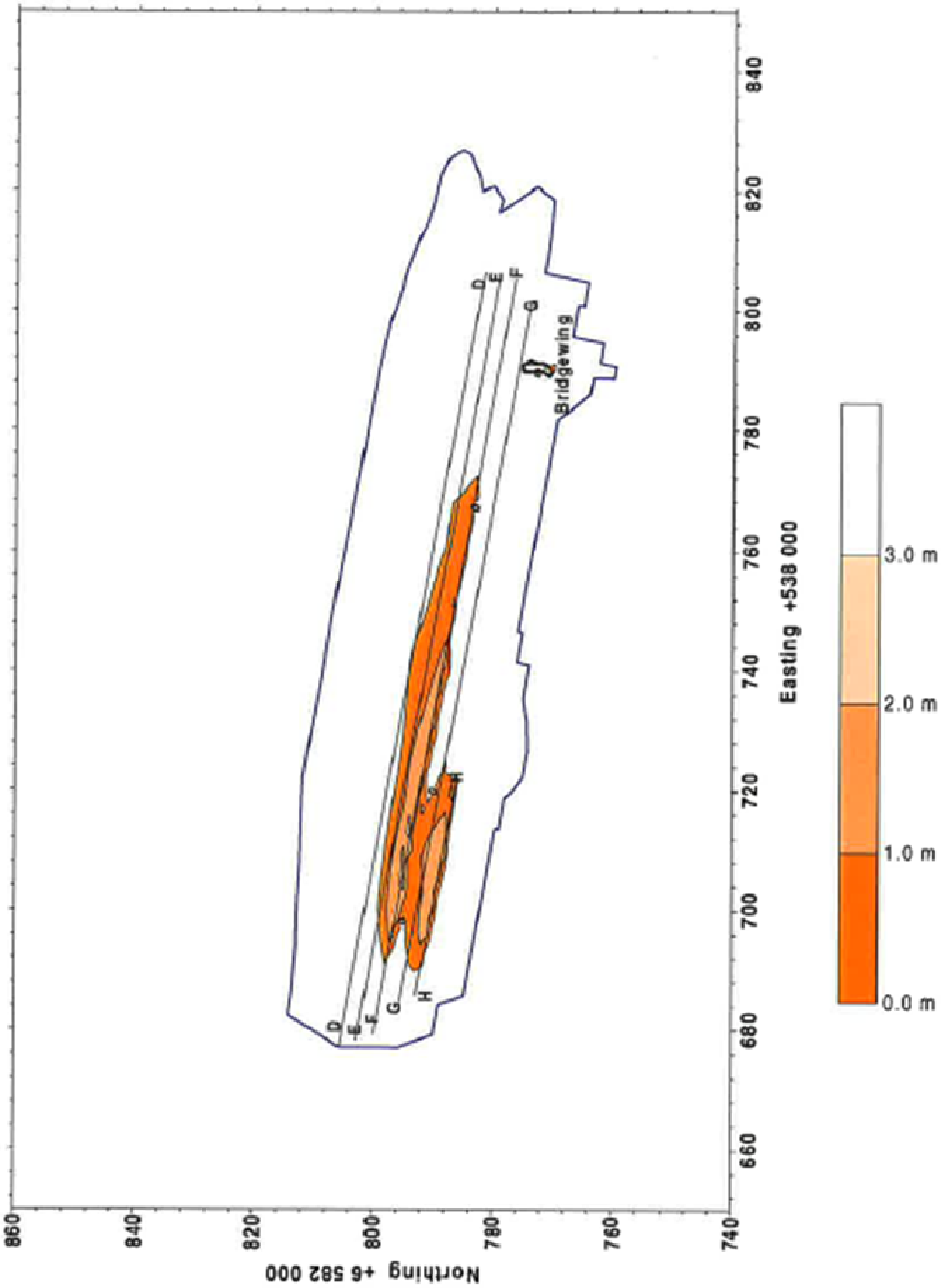


FIG. A.1: The plan shows areas of the hull where the clay layer is thinnest, i.e., where underlying layers are shallowest, based on interpretation in 1997. These areas could be expected to be the most damaged. Image from Velde [13].

Appendix B

Seaworthiness of MV ESTONIA

B.1 Background

Seaworthiness is a central concept within shipping. Nevertheless, there is no uniform international definition of this concept.

Legal aspects in shipping have historically developed on a contractual basis. The regulation of responsibilities, i.e., finding a suitable balance between ship owners' and cargo owners' responsibilities and risks, has been of interest for a long time. Therefore, there is an interest for insurers to assess risks systematically. During the last century, safety issues have developed and become an independent base for regulating shipping.

The codification of shipping on a state basis can be said to have started with the Harter Act in the United States of America in 1893 and Marine Insurance Act 1906 in the United Kingdom of Great Britain and Ireland in 1906. Thereafter, a number of international conventions were put in place, e.g., the Haag rules in 1924, the Haag–Visby rules in 1968, and the Hamburg rules in 1978 (United Nations Convention on the Carriage of Goods by Sea). These international conventions have been adopted by different states in varying degrees. Many states have also adopted national legislation that, to some degree, is based on international convention(s).

The UN International Maritime Organization, IMO, started its operation in the late 1950's, and a number of international conventions have been put in place since. One important instrument in this aspect is the International Convention for the Safety of Life at Sea (SOLAS), which originally dates to 1914, but was updated to its fifth form in 1974. SOLAS contains *inter alia* rules concerning a ship's construction, equipment, manning, and inspection.

In different regulations, seaworthiness is often mentioned as a prerequisite to avoid liability, i.e., to obtain compensation after damage. Thus, when transporting goods, the carrier guarantees that the ship which is transporting the goods is seaworthy. Further, seaworthiness is a prerequisite when inspecting or surveying the ship, for that ship to receive the relevant certificates.

However, seaworthiness is seldom defined, but some examples are highlighted. The Marine Insurance Act 1906 says that "a ship is deemed to be seaworthy when she is reasonably fit in all respects to encounter the ordinary perils of the seas of the adventure insured". The current Swedish Ship's Safety Act (2003:364) says that a vessel is seaworthy only if it is so constructed, built, equipped and maintained that it, taking into consideration its purpose and trade, gives adequate safety against accidents. The current Estonian Maritime Safety Act, in force from 2003, says that “a ship is deemed to be seaworthy or to be worthy for navigation on inland waters if it is designed, built, equipped, supplied, manned and loaded pursuant to the requirements for safe navigation at sea and good seamanship or for safe navigation on inland waters and if the technical condition of the ship conforms to the requirements for maritime safety which, when adhered to, help to prevent marine casualties, danger to human life and pollution of the marine environment or inland waters.”

The Convention of the High Seas, adopted in 1958, stated that each state shall take such measures for ships flying its flag as are necessary to ensure safety at sea with regard to the construction, equipment and seaworthiness of ships. The United Nations Convention on the Law of the Sea retained this wording on its adoption in 1982 (effective from November 1994).

Even though the principles for sharing the responsibility in different conventions and regulations somewhat vary, a consensus seems to exist in law and legal doctrine that the meaning of the expression “seaworthiness” can differ over time and depend on how the ship is used and where she is trading. This means that the concept is relative. It is also clear that the expression “seaworthiness” relates to the ship’s construction, how she is built, and the technical function with respect to her maintenance and standard. Generally, equipment is also added to the concept, but in some cases manning is also included. Other factors may be significant during the assessment of seaworthiness, e.g., how the ship’s Safety Management System is implemented is more and more important.

Ships are to be surveyed regularly. Dependent on how the ship is used and where she is trading, different certification and documentation is needed. Different forms of inspections are performed. The background circumstances are normally not controlled, if a valid certificate exists within a certain field. This can be said to be a formal control of the ship’s seaworthiness. Under other circumstances, a physical inspection is made, e.g., when issuing a new certificate or updating an old one. In this case, an actual control of the ship’s seaworthiness is taking place.

MV ESTONIA was originally built for passenger traffic in the Baltic Sea and she flew the Finnish flag during her first thirteen years. At the time of the accident she was parallel registered on Cyprus (primary register) as well as in Estonia (secondary register); she flew the Estonian flag.

B.2 Matters to Consider when Assessing Seaworthiness

Though there is no single definition of seaworthiness, a number of requirements are generally to be fulfilled to entitle a vessel to be called safe. All necessary certificates have to be valid, and the vessel has to be constructed, built, maintained, equipped, supplied, manned, and used in a trade for which she is approved. If any of these conditions is not fulfilled, the vessel is, per se, not seaworthy, and thus not allowed to sail.

It may also be concluded that seaworthiness can be expressed from an operational aspect as well as from a certification or approval aspect. This is in line with different parties’ responsibility for a vessel’s safety: the ship’s owner and their representative, the master, on one hand, and the certifying institutions, the flag state, and the classification society on the other.

B.2.1 Operational Aspect

Owner and Master

The vessel owner (i.e., the company) and the master, being the owner's representative, are responsible for the safety of the vessel and hence they have to make certain that the vessel is seaworthy. This should be assessed continuously and, at least, before each departure.

However, the ability for the owner and the master to assess all aspects may be restricted (e.g., construction and how the vessel was built) since there is no reasonable way for them to control this. This leads to the conclusion that their responsibility for seaworthiness may be restricted to circumstances that they can control, i.e., certification, maintenance, equipment, supplies, manning and trade.

Authorities

In order to complete the owner's assessment, relevant authorities may also perform relevant and recurrent inspections from an operational point of view. Such an inspection may be performed as a Port State Control (PSC), and can consist mainly of controlling certificates. The inspection may also be expanded to include an overview assessment of the vessel, including an operational exercise. However, a PSC is not very thorough and cannot be considered to substitute or replace the owner's and master's continuous assessment, even though some of the relevant circumstances may be a subject of control, e.g., manning, supplies and trade.

B.2.2 Certification or Approval Aspect

The relevant institutions for approval of a vessel is primarily the flag state, accompanied by the classification society. The relation in responsibility between these may differ from flag to flag, depending on national legislation and agreements with the classification society. These institutions perform control through regular inspections, surveys (scheduled and additional), and audits. Certificates are issued to verify these control methods. Certificates are thus updated following certain time limits, e.g., every year or every fifth year. The degree of how meticulously the inspection is performed depends on the time frame of the certificate.

The possibility to inspect and verify each detail continuously is limited due to practical reasons (e.g., construction details). It is therefore obvious that in some aspects the control function at construction and building stage is of outmost importance. Whatever is accepted and approved while the vessel was constructed and built will in many cases not be subject to later regular control.

Therefore, the initial inspections and approval, manifested in initial certificates, may in some aspects follow the vessel through its lifetime without being questioned.

B.3 The JAIC Assessment

The JAIC report handles seaworthiness following a then-common practice, i.e., making a statement whether a vessel, involved in an investigation, was seaworthy. The explanation in the case of MV ESTONIA is that there were "no outstanding items" either from authorities or the classification society (JAIC 5.2).

There is no other substantial support for the conclusion in the report and there is no analysis of the matter. This is an operational assessment of the seaworthiness of MV ESTONIA, considering the possibility for the master (as the owner's representative) to make their routine decisions, based on the information available to them at that time. In this context, the JAIC report does not question certification, equipment, supplies, and manning.

JAIC does note that there was a need for future maintenance (JAIC 3.3.6), but not to such a degree that it would affect seaworthiness. Likewise, the fact that the bow-ramp port side lower locking was not fully extended (JAIC 8.6.5, 15.8 and 13.4) has not been considered as a reason to question the vessel's seaworthiness, most likely due to the possibility that the locking piston had moved inwards during the process of the ramp being breaking up (JAIC 13.2.3).

FIG. B.1: The picture is from diving operations in 1994 and shows the bow-ramp port side lower locking, hull part, which was not in a fully extended position. The diver estimated the degree of extension to "1.5 inches" (some 3 cm) instead of the full length, about 15 cm. If this was the circumstance when leaving Tallinn, a green light would not have shown on the indication panel on the bridge at departure.

FIG. B.2: An image from the photogrammetry acquired in 2022. The lower red circle displays the same locking as Figure B.1, i.e., the port side lower bow ramp locking.

B.4 Opinion on Seaworthiness

The Preliminary Assessment again raised the question of seaworthiness and the validation of MV ESTONIA's status of seaworthiness, presented as an assessment of the question. This opinion is based on the facts that were presented in the JAIC report in 1997 and the results from discussions held with IMO officials and relates to the regulations in SOLAS 1974 which were valid at the time of the accident. The assessment takes into account both the operational aspect as well as the certifying and approval aspect.

B.4.1 Operational Aspect and JAIC Assessment

The conclusion JAIC made regarding MV ESTONIA being seaworthy as she left Tallinn is well-reasoned, taking into account that it solely considers the operational aspect and is based on facts known at the time. Even though the possibility that the bow-ramp port side lower locking was not in position may call for some concern, the assessment by JAIC has to be regarded as justified.

During the on-going Preliminary Assessment, there have been circumstances indicating a pertinent concern with regards to whether the cargo was secured to the cargo deck or not. However, these concerns have not been confirmed, and there is not enough evidence at this stage to question the JAIC assessment that, from an operational point of view, MV ESTONIA was seaworthy.

B.4.2 Certification or Approval Aspect

In the JAIC report, there are many references and findings that relate to the safety of the vessel. Some of them can be directly connected to seaworthiness. The following section refers to a number of these findings and analysis their potential impact on seaworthiness. These findings are connected to the initial approval and the certification of the vessel.

Construction

The Bureau Veritas (BV) rules, valid at the time of construction of the bow visor, did not contain any details on how loads should be calculated. Therefore, instructions, originally used for determining the loads of large ships, were used (JAIC 3.3.1). The conclusion in the JAIC report is that the procedure used had “an obvious lack of logic” (JAIC 15.1.2).

Further, due to the fact that the flag state, Finland, did not have to carry out a hull survey if the class certificate was issued by a classification society no examinations for the approval of the calculations of the design of the attachment points for the locking devices were ever performed (JAIC 15.1.2). This is exacerbated by the lack of requirements for the Classification Society, BV, to make a detailed survey of the visor attachments. Thus, the initial certification was based on an approval procedure, which contained compulsory but non-existing elements. This led to the vessel having unknown flaws throughout all her existence and the certification being based on lacking information.

The conclusion is that MV ESTONIA was not seaworthy in this aspect even though the certification, as such, was in place.

Building

The construction of the bow visor deviated from the drawings, with two missing flat bars and related brackets and no signs that they had ever been there. The deck part of the installed hinge arrangement differed considerably from the manufacturing drawings (JAIC 3.3.3 and 8.12). The bow visor, including attachment devices, was built of grade A mild carbon steel (JAIC 3.3.2) instead of the requirement for the lifting lugs, the bottom lock visor lug, and the side lock lugs to be made of St52-3 steel (high-tensile strength steel to cold toughness class 3) (JAIC 3.3.3).

Consequently, it has been noted that all three lugs of the bottom lock installation failed and that the lug fractures showed patterns typical of good-quality ductile plate that failed due to local overloads. It was also noted that the fillet welds attaching the housing and the lock bushing showed signs of poor fusion and lack of penetration (JAIC 12.7.3).

The conclusion is that the building of these parts of MV ESTONIA deviated to such a degree that the vessel was not seaworthy in this aspect.

Trading Area, Exemptions, and Limitations

The SOLAS Convention requires a collision bulkhead with a certain distance from the forward perpendicular (a technically defined longitudinal position for each individual vessel). On MV ESTONIA the collision bulkhead was represented by the bow ramp. She was built with an exemption from the SOLAS Convention requirement in regards to the placement of the collision bulkhead. Such an exemption is conditioned with a limitation in trade, i.e., the vessel is not allowed to trade an area

FIG. B.3: The locking bolt for the bottom lock, filmed on the wreck. The bolt was salvaged and examined by investigators, but was not saved. To the left bottom of the picture, the remains from the three broken attachment lugs are seen. The image is from the JAIC report, Figure 8.15, and is turned upside-down (to compensate for the vessel lying effectively upside-down when filmed).

further than 20 nautical miles from nearest land . This limitation must be noted in a vessel's certificate .

Such an exemption was never noted in the certificates of MV ESTONIA. Initially there was a separate decision of the flag state that the vessel was not allowed to travel further from land than 20 nautical miles (JAIC 3.6.1). The fact that the content of the decision was not noted in the certificate led to the knowledge of her trade limitations being lost during the years, and instead the classification notations indicated "no restriction regarding areas or conditions of operation" (JAIC 3.1.2).

This means that the safe operation of the vessel was seriously affected, and that the vessel was not seaworthy.

B.5 Conclusions

There are at least two aspects from which seaworthiness for vessel safety could be assessed, depending on which party or institution is involved or concerned. These are the operational aspect and the certification or approval aspect.

B.5.1 Operational Aspect

Given the facts available for the master at the time of MV ESTONIA's departure on the late afternoon of 27 September 1994, the vessel is to be regarded as seaworthy. The doubts presented above are not enough to question the JAIC assessment.

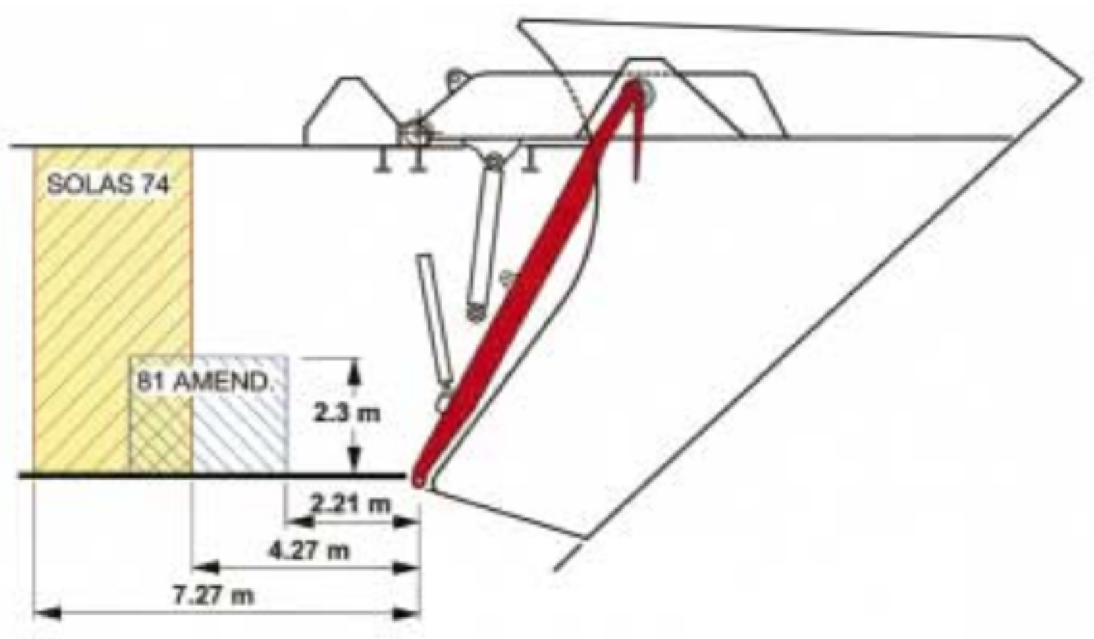


FIG. B.4: Placing of the collision bulkhead in accordance with the SOLAS Convention. The bow ramp (marked red) was more than 2 m fore of accepted placing. In addition, it towered above the forecastle deck, thus requiring to be housed partially inside the visor. This meant, that when the visor came loose, it was hanging on the bow ramp. Reproduced from the JAIC report, Fig. 3.13.

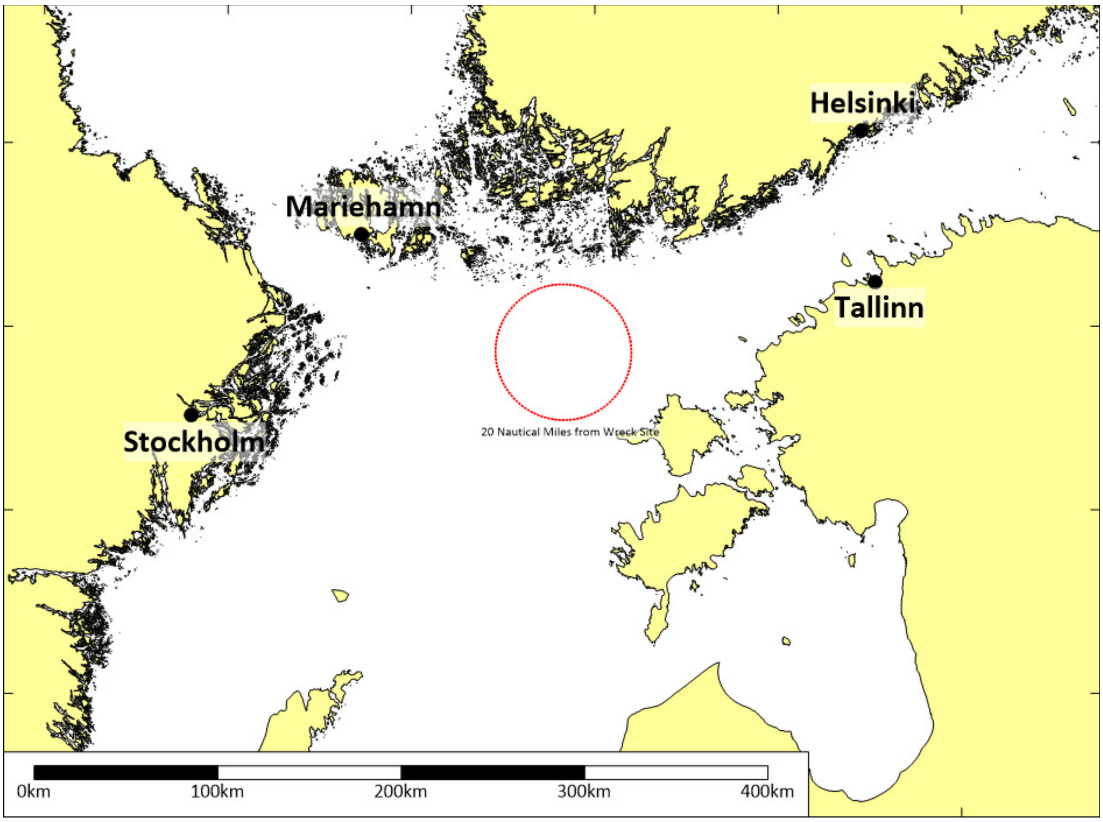
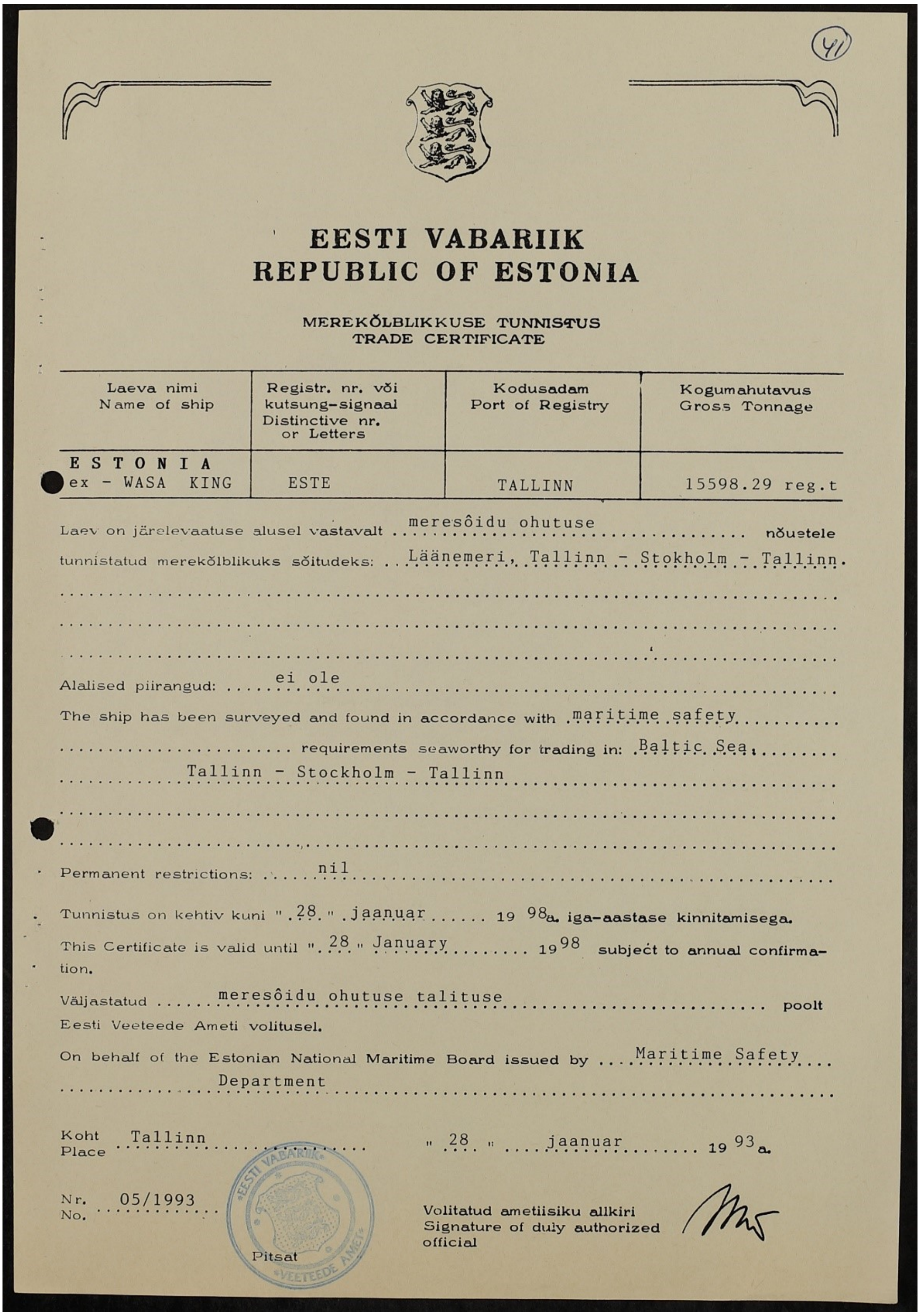


FIG. B.5: Map showing the limit of 20 nautical miles from the wreck site of MV ESTONIA. The position of the wreck is marked with a red cross.



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EESTI VABARIIK
REPUBLIC OF ESTONIA

MEREKÕLBLIKKUSE TUNNISTUS
TRADE CERTIFICATE

Laeva nimi Name of ship	Registr. nr. või kutsung-signaal Distinctive nr. or Letters	Kodusadam Port of Registry	Kogumahutavus Gross Tonnage
E S T O N I A ex - WASA KING	ESTE	TALLINN	15598.29 reg.t

Laev on järelevaatuse alusel vastavalt meresõidu ohutuse nõuetele tunnistatud merekõlblikuks sõitudeks: Läänemeri, Tallinn - Stokholm - Tallinn.

Alalised piirangud: ei ole

The ship has been surveyed and found in accordance with maritime safety requirements seaworthy for trading in: Baltic Sea, Tallinn - Stockholm - Tallinn

Permanent restrictions: nil

Tunnistus on kehtiv kuni "28." jaanuar 1998a. iga-aastase kinnitamisega.

This Certificate is valid until "28" January 1998 subject to annual confirmation.

Väljastatud meresõidu ohutuse talituse poolt Eesti Veeteede Ameti volitusel.

On behalf of the Estonian National Maritime Board issued by Maritime Safety Department

Koht / Place Tallinn "28" jaanuar 1993a.

Nr. / No. 05/1993

Pitsat

EESTI VABARIIK VEETEEDE AMET

Volitatud ametiisiku allkiri
Signature of duly authorized official

FIG. B.6: Certificate of Seaworthiness of MV ESTONIA from 28 January 1993. Source: *Laevatoimik nr A-014, ERA.5414.1.560*.

B.5.2 Certification and Approval Aspect

The facts, as presented by the JAIC report, clearly define that MV ESTONIA was never seaworthy (even from her delivery). A lack of rules and realistic calculations, in combination with non-existing elements in the approval procedure, resulted in certification based on limited and/or lacking information. Severe deviations from drawings during the building stage and the absence of conditions in the certificate made the certification both wrong but also based on incorrect information.

The following conclusions are restated from the JAIC report:

- The bow visor was not fully built according to the approved drawings with respect to its structural members and materials.
- The ship was not built according to the SOLAS Convention with respect to the location of the bow ramp, as a collision bulkhead, and the visor.
- These deviations in construction meant that the vessel and its passenger safety certificate were not in full compliance with the SOLAS Convention, because the requirements for an upper extension of the collision bulkhead were not satisfied.

The following conclusions are drawn:

- An inspection of the bow parts was not performed. The related certificate should not have been issued unless such an inspection had been carried out, which means that MV ESTONIA was not seaworthy. If such an inspection, following regulations, had been carried out, the flaws of the visor construction could have been discovered, and the accident would probably not have occurred.
- The location of the bow ramp as the upper extension of the collision bulkhead was based on a practical decision for an exemption from the regulations. Such an exemption entails a condition, which must be recorded in certificates but was not. Therefore, MV ESTONIA was not seaworthy and the certificate was incorrect. If the condition had been noted in the relevant certificate, the vessel would not have been trading the Tallinn–Stockholm route.