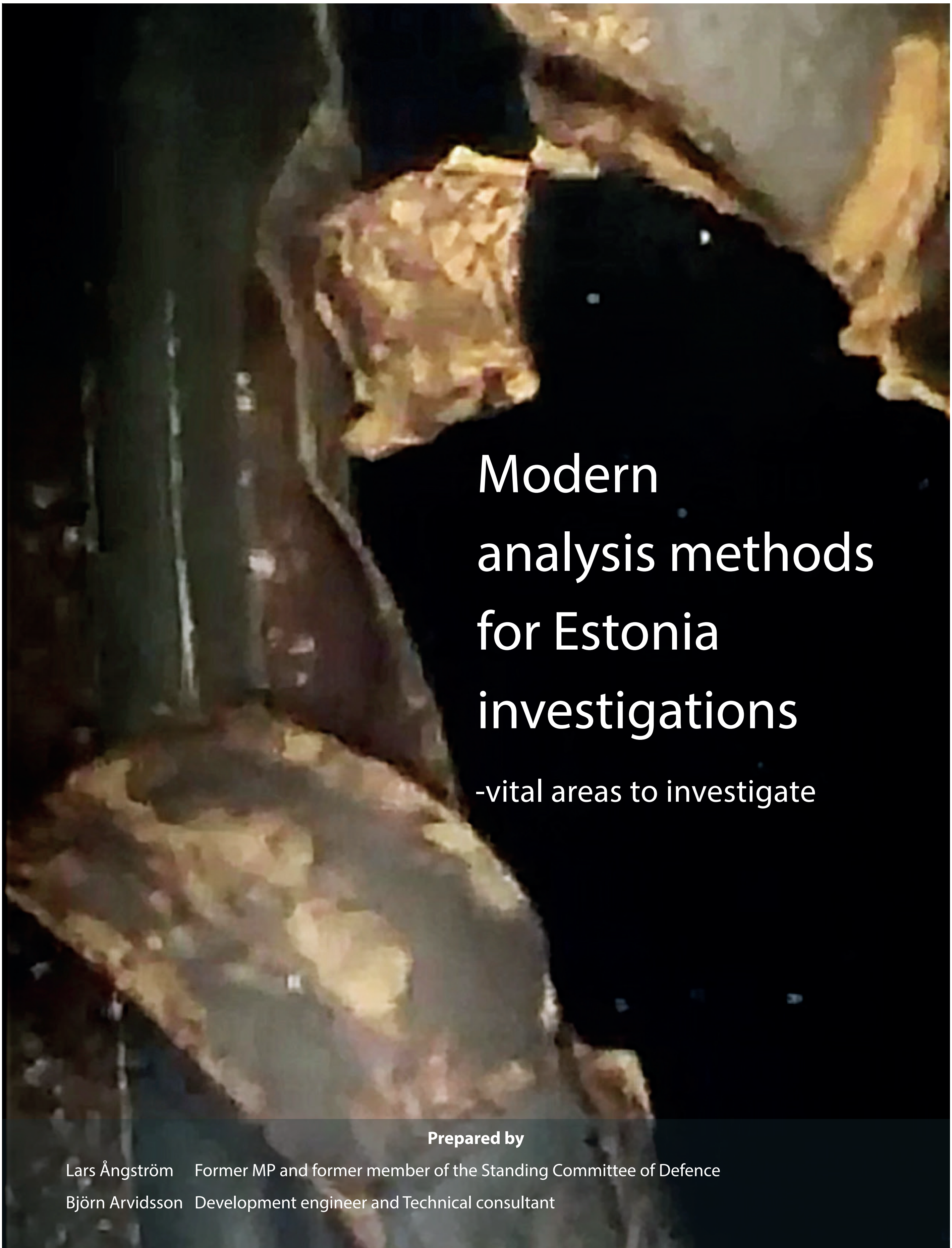


Modern analysis methods for Estonia investigations

-vital areas to investigate

Prepared by

Lars Ångström Former MP and former member of the Standing Committee of Defence

Björn Arvidsson Development engineer and Technical consultant

It is only by acquiring complete and unambiguous knowledge of the cause of a disaster that proper measures can be taken to prevent it from happening again.

We dedicate this report to those who lost their life in the Estonia disaster on the 28th of September 1994.

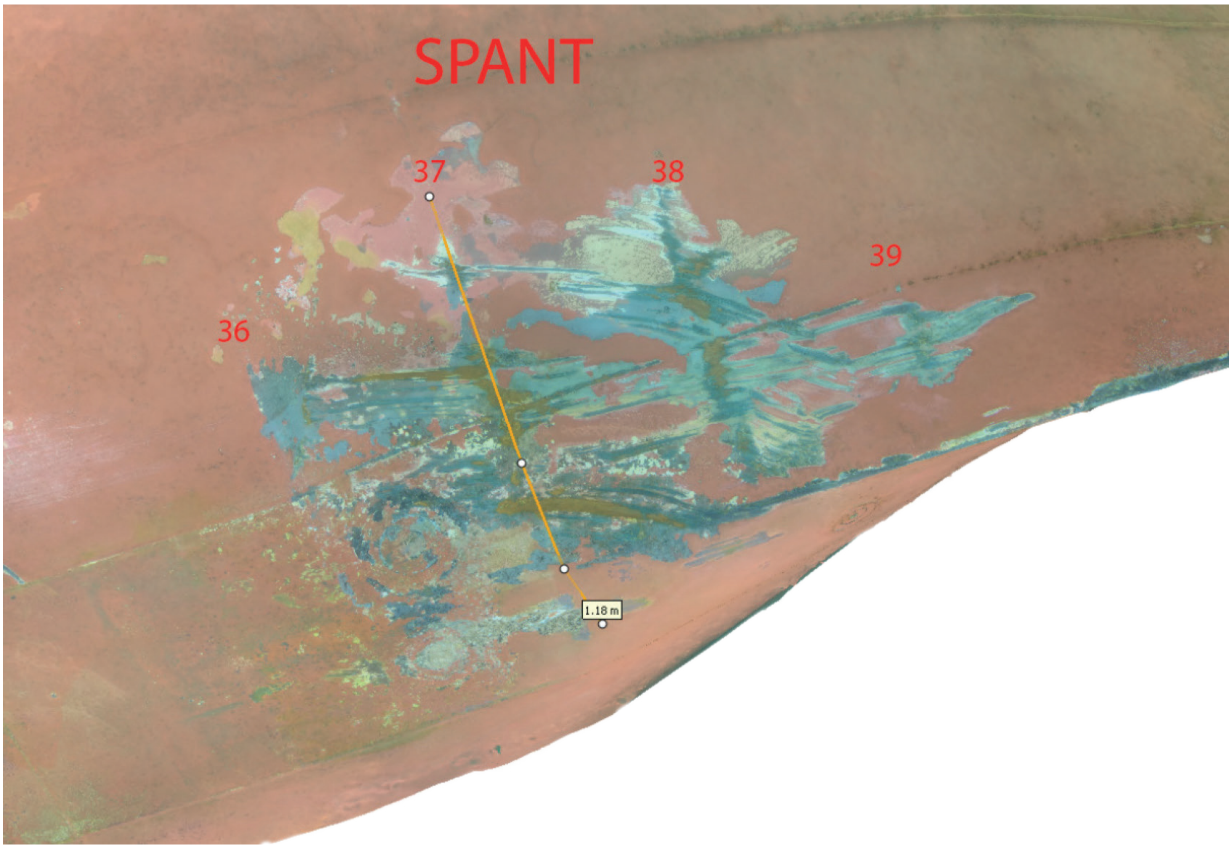
Front page picture showing damage on the front bulkhead of the Estonia.

Modern analysis methods for Estonia investigations

-vital areas to investigate

Introduction

In this report we have listed five different investigations that can bring clarity to the Estonia disaster and we strongly believe that modern technology can clarify all aspects of this catastrophic event. Photogrammetry is the ultimate tool in a technology that can acquire substantially detailed information. Several external experts from various professions have been consulted several times during the preparation of this report.



Photogrammetric example with a damaged hull in millimeter resolution (not Estonia):
Linus Andersson LA Survey

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Lars Ångström Former MP and former member of the Standing Committee of Defence

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Foreword

This report will be sent to the Estonian Government and the Estonian Safety Investigation Bureau. It will also be sent to the Swedish public prosecutor / RÅ, Riksåklagarmyndigheten, The Swedish Accident Investgation Authority / SHK Statens Haverikommission and to OTKES, The Safety Investigation Authority of Finland.

ITSA (The International Transport Safety Association) and IMO (The International Maritime Organization) will receive a copy of this report which also is a request for a determination whether a new upcoming investigation - based on current Swedish legislation and instructions – can be considered as independent in accordance with regulations stipulated by these organizations.

We believe that these organizations will handle this information with due attention and that it is their obligation to seek the truth. That will only be achieved by opening a new public and independent investigation to clarify the events surrounding the Estonia's last journey.

The Swedish SHK and OTKES from Finland, as members of ITSA must follow international regulations without limitations from government legislation, when new important information has been obtained. This is the case with major newly discovered probable impact damage on the Estonia.

There is a history of two Estonia reports with completely different conclusions from the JAIC investigation and German Group of Experts. JAIC or Joint Accident Investigation Commission was the Investigating commission from Sweden, Finland, and Estonia. The German Group of Experts or GGE was a group of research institutes and independent experts from Germany, Finland, Sweden, Switzerland and the UK. They were organized by the law firm Ahlers & Vogel and worked for the shipyard Meyer Werft who built the Estonia. There is also a lack of proper raw evidence material in combination with the newly discovered holes in the hull that were not accounted for in any investigations. Finally, the shipments of Russian military equipment weeks before the sinking were not accounted for in any investigations and the statements from passengers who saw military trucks driving onboard the Estonia on the last journey were not commented in the JAIC investigation.

Any new investigations should be run as ITSA and IMO find suitable considering this history. We conclude that a SIA (Safety Investigation Authority) from independent third party country like Japan or the Netherlands could run or at least lead any new investigation due to the history with substantial error in earlier investigations and strong indications of shipment of military hardware from Russia.

Contents

1 Some comments on the Estonia disaster

1.1 The discovered damage on the starboard side

New filming of the Estonia wreck has provided us with new evidence showing one major hole on the starboard side and also one smaller hole. The images of the bigger hole point in the direction of impact damage[1] according to the Norwegian explosions expert Frank Børressen and other naval experts interviewed in the new documentary Estonia – fyndet som förändrar allt from Monster Media.

The new information in the documentary, directed by Henrik Evertsson, needs to be examined closely. A combination of catastrophic impact damage on the starboard side and an almost simultaneous loss of the bow visor in heavy weather is not a conclusion that can or should be accepted as a coincidence.

1.2 The possibility of damage being caused by collision with the sea floor

There have been some preliminary suggestions presented that the big damage on the starboard side might be explained by collision[2] with the sea floor during the sinking of the Estonia. One fact contradicting this theory is demolished parts of the steel hull actually standing out from the damaged area. This could be a part of the fender bar which is a strong steel beam along the sides of the ship. All other parts of this damaged area are impacted and pressed into the ship.

There is also an absence of a major stone formation as we conclude that such a formation would have penetrated approx. 1 meter inside the ship over a large area, several meters high and several meters long. Such stone formation would be possible to observe as the ship only moved from an angle of 120° list after the sinking to the current 132° list. This change in ships list over the years corresponds to a movement of the ship by approx. 3 meters. The supposed rock formation should today be clearly visible approx. 2 meters from the wreck protruding from the surrounding sea floor. No such stone formation is evidenced in the documentary and the sea floor is documented to consist of clay.

In fact, Svenska Sjöfartsverket / Swedish Maritime Administration conducted an investigation of the sea floor around the Estonia following the decision to cover the wreck with a construction in concrete. They concluded that the sea floor was a 10-20 meters thick layer of soft clay and silt. The sea floor was documented on video by Sjöfartsverket. That video material can confirm absence of any rock formations.

The Rockwater survey report also shows that there are no stones or rock formations on the sea floor. They made an investigation by drilling up to 15 meters below the sea floor. If doubted there may be a call for further investigations.

1.3 The possibility of damage being caused by collision with the visor

One conjecture suggests that the big damage on the side of the ship could be the result of a collision with the fallen off visor. Such collision would involve an impact at slow speed. Assuming sufficient floating capacity, the visor would have been floating in the sea for approx. 6-8 seconds with the Estonia passing by at a speed of 7 m/sec. Some pointed part of the visor would then penetrate approx. 10 mm of steel hull and somehow become attached to the ship. A sufficiently strong attachment would, without losing the grip, manage to accelerate the entire 55 ton visor up to ships speed despite the drag from surrounding water and the visor would be able to project a force of 500 ton onto the hull. The visor would make a rotating movement to push an area of the hull approx. 1 meter inwards and then push out a part of the steel hull. That part in the damaged area is in the forward part (closest to the bow) which make these events a bit difficult to explain. It would be easier to imagine this if the part was in the portion of the damaged area that was furthest aft. The visor would then bend these parts as the visor was mechanically released and rotated out and away from the ship´s side.

This event also occurs in rather slow speed which makes it difficult to explain the demolished steel parts that stand out sharply. The documentary shows that these parts of the hull have been blackened, twisted and fractured. It is however important to investigate the possibility of visor collision further with 3D simulations and FEM analysis. Professor emeritus Anders Ulvarsson has simulated this event[3] and concludes that it could be possible.

1.4 The possibility of damage being caused by collision with foreign objects

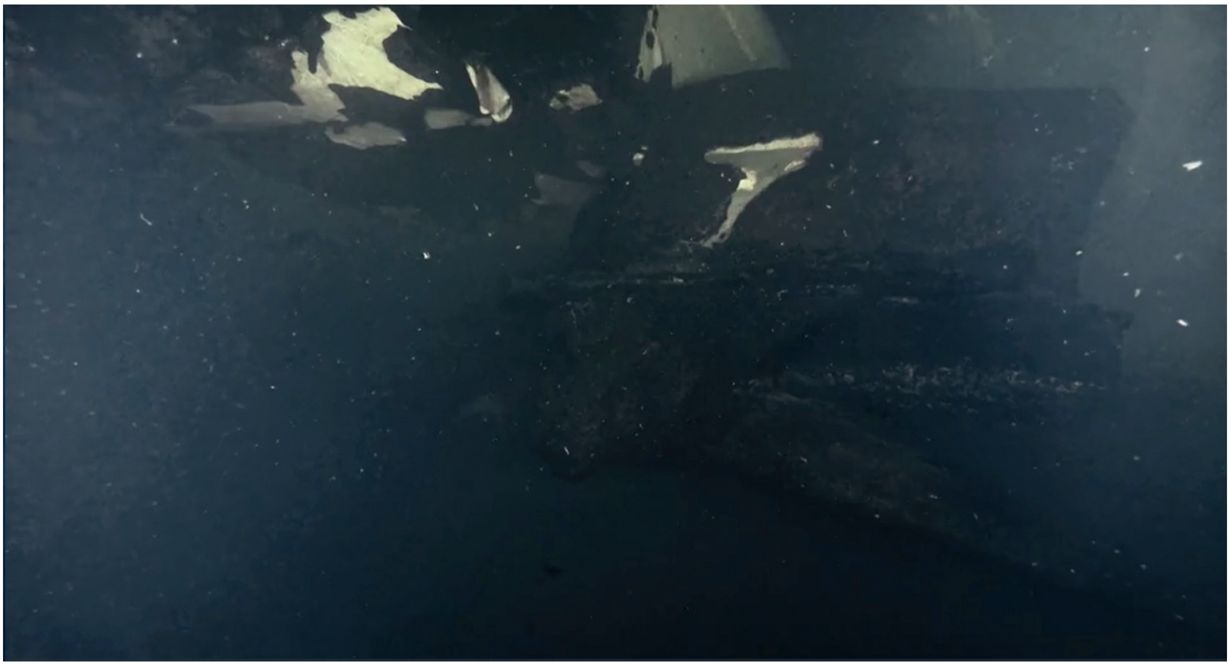
A new investigation needs to conduct FEM analysis to simulate possible reasons for the parts standing out. New 3D simulation could try and create the same damage. This can be simulated by hitting this area of the ship in a 3D model data environment with objects of various speed, weight and various total energy content from 1-4 Megajoule. The energy calculated by Norwegian professor Jørgen Amdahl in the Estonia documentary is 2 Megajoule[4]. The impacting object should also be simulated with different diameter and front shape. The impact point and angle on the ship side should also differ in simulations. The impact angle of a foreign object could be from behind at approx. 45° as the Estonian investigators[5] actually conclude in their preliminary memo after seeing the documentary even though they find any kind of collision and especially from that angle from behind highly unlikely.

Estonia film by Monster: Fyndet som ändrar allt, 5 Part: Demolished fender bar in damaged area on starboard side with the white painted surface to the right and a blackened surface to the left.

It is important for investigators to simulate a direct hit on the fender bar just behind the original position of the protruding steel parts. It could be the case that a foreign object hit the Estonia from somewhere to the rear of this impact point on the fender bar. The object forced the steel part out from the ship. The object simultaneously knocking, by the impact force, the rest of the fender bar and the side of the hull inwards 1,2 meters.
Such an event could explain the total twisted demolishment and the blackened surface. A new investigation needs to explain these demolished parts and why these surfaces are blackened.

1.5 The statements made by ROV operator during filming

In the documentary the ROV operator and specialist Linus Andersson comments on the fender[6]: “Här är fendern helt ihopmosad”. (The fender is totally crushed here.) He also comments on the steel parts like this: ”Skrovet är helt utfläkt här – pekar utåt en stor metallbit här” (The hull is totally torn open here– a big piece of metal is sticking out here).



Estonia film by Monster: Fyndet som ändrar allt, 5 Part: Demolished steel part standing out in damaged area on starboard side. Almost all paint is missing except for a small section in the middle.

1.6 The conditions during filming

It is important to recognize that filming was difficult due to strong current and limited space between the sea floor and the hull, according to the ROV operator Linus Andersson, LA Survey. There was also the steel part sticking out from the ship. Therefore, there is a lack of clear pictures or films detailing the damage. A photogrammetric investigation is needed in order to draw proper conclusions regarding cause and origin of the part sticking-out and the damaged area in general. It is clear that some force has demolished and/or accelerated parts out from the hull and in a forward direction (towards the bow). There could also be other parts, than the one in the picture above, standing out from the hull.

1.7 The possible consequences of the damage

It is necessary for investigators to analyze if the damage on starboard side created a connection for any water to flow down from the car deck to deck 1 below. This could be the water that surviving passengers see on deck 1 in the beginning of the sinking. This could increase the list at the start of the event. Later as the list increased, the sea water could enter through this damage on the side of the ship as waves struck the side of the hull. Some witness reports state that a rushing sound of water comes and goes after some metallic bangs in the beginning of the sinking. Finally, the list got so great that water could fill the ship through the big starboard damage constantly if the damage occurred at the beginning of the sinking. This damage is a bit above the water line and might have played a bigger role as the list increased. It should also be analyzed if this hole in the hull could also play a part in releasing trapped air during the final stages of the sinking.

1.8 Recalculating the sinking scenario with added healing angle caused by wind forces

The damage on the starboard side of the ship could also have played a bigger role in the events from the very beginning.

First, the Estonia had 1° healing angle to starboard when the ship left Tallinn according to the JAIC. This lowers the starboard side towards the sea level by approx. 0,2 meter. The trim tank on port side with 183 m^3 capacity was full of water to try and balance the ship but this was not enough. A new investigation should analyze the reason for these circumstances.

Any water entering the car deck through a leaking visor and ramp would end up on the starboard side from the beginning of the event. This water would increase list even further if larger volumes entered the car deck that couldn't be evacuated through the scuppers.

Second, the forces from winds hitting the Estonia from south west at an angle of about 45° with an average speed of 20 m/s would add healing angle of 7° to starboard. This angle has been calculated by Professor emeritus Anders Ulfvarson[7]. This force alone and the healing angle that Estonia already had at departure could have reached 8° in total. This lowers the center of damaged areas on starboard 1,7 meters to slightly below water line. Every wave top would almost cover the big damage with water at these conditions. JAIC summarizes wave conditions to be approx. 4 meters significant wave height. The damaged area is 4 meters high and up to 1,5 meters wide according to the documentary and it would add major contributions of sea water on deck 1. The ship was also rolling in the sea which could have added to the healing angle and lowered the starboard side further down at the exact moment when this damage occurred, if the damage happened in the beginning of the event.

It is impossible to exactly calculate the list, the exact average wind speed and the forces from winds in the beginning of the sinking but the damage on the starboard side could play a very significant role in the sinking and this scenario needs to be investigated.

Any attempt to remedy the ever-increasing list with the trim tanks was useless since the ship had left port with a full trim tank on the port side. There was no empty tank volume left on port side to counter the list to starboard. The only option left would be to alter the course of the ship in time and have the wind hitting the starboard side of Estonia before the list became impossible to handle.

1.9 The consequences of the forward trim

The forward trim of the ship also needs to be better analyzed. A witness points this out that it could have been the wrong trim with water running on the floor in cabins towards the bow. Water in the visor and perhaps the late loading of military trucks could add to the forward trim of the ship. This could cause up to nearly 1-meter lower position of the bow if the visor was full of water according to a simulation by Professor Anders Ulfvarson. With a scenario that starts with the newly discovered hole in the starboard side of the ship this could increase to 1,3 meters in about 15 minutes by inflow of water and down-flooding to deck 0. This would add more stress to the visor and add more water on the car deck through a broken leaking visor and ramp. This also means that the bow could have been lower in the water when forces creating metallic bangs struck the visor.

Investigators should once more analyze the final maneuvers before the sinking and simulate how that could affect the list and any possible early water entry through damage on starboard side. This also includes investigation of the conditions of watertight doors on the lower decks and the time of closing.

The ramp in the stern on starboard side should also be investigated. It is also slightly open on the wreck and the ramp could have been used to help evacuate water from the car deck. When the healing angle increases and the forward trim increases this slightly opened ramp in the stern could have had a reverse function that added more water inside the ship which could have added to the sinking.

1.10 The statements from surviving passengers

It is also important to acknowledge and investigate statements from the surviving passengers on board confirming that there was a severe list to starboard from the beginning of the sinking. This list came quickly, it got better for a few seconds but then the list got worse again and it never stopped. It got gradually worse at a rapid pace. The sinking sequence seems to start with some metallic sounding bangs. Witness reports from passengers and crew members state that the Estonia almost seems to stop in the water from one of the bangs and that it did not feel like a big wave. The survivor Carl Eric Reintamm is staying in his cabin on deck 1 very close to the newly discovered big damage on starboard side. He experiences a very loud and heavy bang that results in his action to immediately leave his cabin. He sees water that is 0,3-meter-high towards one of the walls in the corridor and this water is rushing along the wall. He runs straight up the stairs from deck 1 which is below car deck and out onto the deck 7 with the lifeboats and thereafter the list increase dramatically according to Mr. Reintamm.

The survivor Carl Övberg experienced a heavy bang and then 30-40 seconds later another bang. The last bang throws him towards the wall in his cabin on deck 1 as if something hit the bow of the ship. He runs out and sees water coming up from the goosenecks connected with deck 0 below. This water comes up before the big heal to starboard. Övberg runs up the stairs and reach car deck when the first big heel comes at min. 45°. He is standing on the wall now and he is holding on to the rails. Mr. Reintamm is already up on deck 7 at this specific moment. Then the Estonia comes back to almost upright position and he continue to run up the stairs. When he reached deck 6 it was only possible to walk further up when the Estonia rolled back in the up position. When the ship rolled deep to starboard, he had to stop and hold on to the rails. These statements cannot be found in the JAIC report.

The GGE, The German Group of Experts reach the conclusion[8] that there was extensive damage to the shell- and bottom plating of the ship. They try to prove this with several pictures in chapter 29 of their report by showing damage and holes caused by corrosion. They also show sharper holes that are not caused by corrosion. The vessel must have had 200 ton extra weight on the starboard side according to the GGE. This could have been caused by uneven loading of heavy trucks but the GGE are of the opinion that the Estonia left port in Tallinn with one or several of the ballast tanks, water tanks and perhaps the trim tank on starboard side broken and open to the sea. They conclude that water enters the ship on deck 0 in the beginning of the sinking which would lead up to the statement by Övberg who see water coming up under pressure through goosenecks in the corridor on deck 1 from deck 0. This is before the big heel according to Mr. Övberg. A possible reason for any water entry from deck 0 needs to be investigated and it could be the result of holes in the hull in the beginning of the sinking when the bangs occur. The reason for the corrosion and the lost possibility to counter the heeling with the port side trim tanks during the sinking could be a lack of measures to protect the tanks with coating and/or anode protection according to the GGE.

The conclusion is that a new investigation needs to carefully listen to all survivors this time to better analyze the starting sequence of the sinking in more detail all the way from the departure on the last voyage. If the list came as quickly as many passengers' state and the damage was present on the starboard side from the beginning, then the holes in the damaged area or areas would quickly be completely under water causing massive water volumes to enter inside the ship. There could also be other holes in the shell- and bottom plating and the entire ship needs to be thoroughly investigated. A new investigation should also investigate if any holes present during the sinking could add flooding of deck 0 and 1 which might explain why the ship did not turn over 180° and capsized. There is sand covering parts of the hull on the starboard side near the bow. This sand needs to be removed according to ROV operator Linus Andersson, LA Survey and this area needs to be examined.

2 Necessary investigations

2.1 General comments

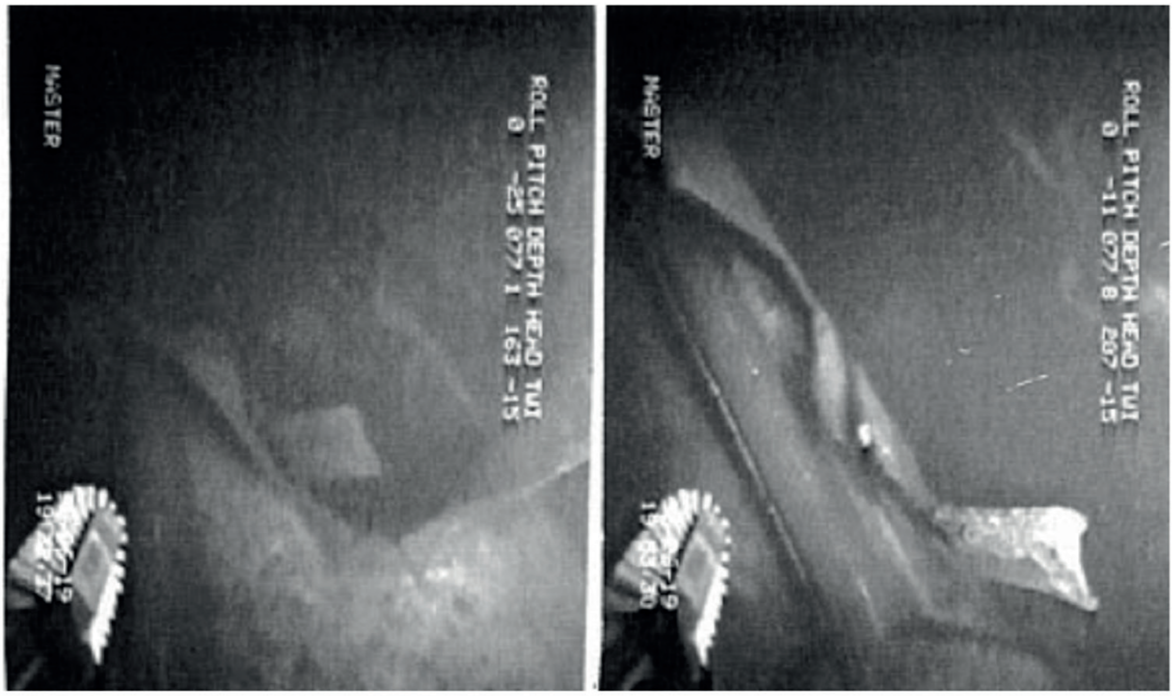
We have analyzed new film material, previous reports and gathered information from experts. We suggest five different investigations to better analyze the Estonia sinking. The first three parts do not need any diving operations or changing of sanctuary protection by law and is therefore easy to conduct without any further delay. The necessary investigations are listed below:

- Independent analysis of films and pictures.
- Independent analysis of reports created by external expertise.
- Independent investigation of bow visor at Muskö naval base.
- Photogrammetric under water examination of the Estonia.
- Examination of the sea floor around the Estonia and other areas.

3 Independent analysis of films and pictures.

3.1 Statements from experts and investigators

An independent analysis of films and pictures needs to confirm or reject evidence of explosions in the bow of Estonia. According to the investigation made by GGE, The German Group of Experts and analyses by IFG, The Independent Fact Group, as well as internationally recognized military expertise on underwater blasting, there are several instances of blast damage in the bow of the Estonia. These are in the bulkheads around the lifting cylinders, locks for the visor and the car ramp. The damage is documented in the official Swedish film material from 1996 and in material filmed during the Bemis/Rabe diving expedition in 2000. The following material needs to be investigated:



Photos: Swedish film material presented in The GGE Report 32.2 Findings[9]

3.2 Swedish film material

Swedish official film material shows petal shaped holes in the starboard- and port side bulkheads close to the lifting cylinders for the visor along with several other instances of damage. The shape of the damage with petals was never commented on by the JAIC. (The JAIC report denies any investigation on car deck.)

Film material also show yellow rectangular packages[10] in the bow area that the British underwater explosives expert Brian Braidwood positively identified as unexploded devices. These findings were never investigated or commented by JAIC.

Film material show damage on bulbous bow. There are several instances of damage visible in the film material. This suggests collision with an object that could have been quite strong considering the very strong construction of the bulbous bow according to the GGE report. Compare this material with reports from earlier incidents that could have caused damage to the bulbous bow. This damage was never investigated or commented by JAIC.

It is also important for a new investigation to analyze the video tapes filmed at the bow, midships and at the stern to confirm or reject if the hull up to 1 meter below the fender bar was visible before the rocks were dropped on this position. Then it should have been possible to detect the big damage on starboard side if divers or ROVs covered all of the ship with their filming.

Photos below from film sequences show the railings on the car ramp that have been detached from the closed ramp sometime between the 28th of September and the 2nd of October. As clearly visible on film these railings are standing on the sea floor next to the Estonia which has been confirmed by analysis of the Swedish SKL, Statens kriminaltekniska laboratorium.

The Swedish military and Finnish investigators were the only authorities who knew about the position of the Estonia wreck until the 4th of December and Swedish armed forces were responsible for the surveillance of the area. How, when and why were these railings removed? JAIC never investigated or commented on these facts.

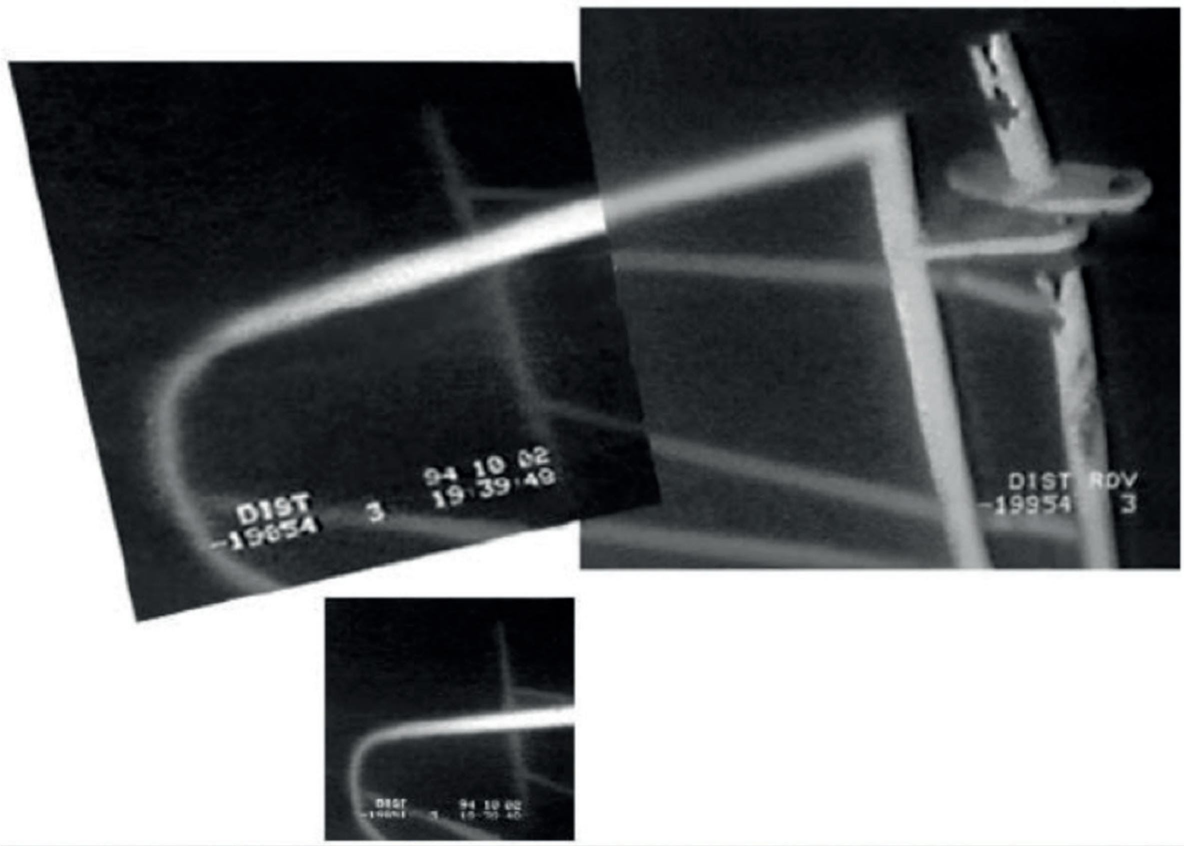


Photo: The railings from the closed ramp standing on the bottom outside the wreck filmed by a ROV camera 2nd of October. Collage by Independent Fact Group[11]

3.3 German film material

Films from Bemis/Rabe expedition showing the front bulkhead with big holes. Fractured/ blown open plates with petals are shown 13 minutes into the film. The quality of this film material is very good compared to the earlier Swedish film material. This film material was produced in 2000.

Film sequence[12] at 13 minutes 29 seconds with what the German group of experts say is a bigger hole from an explosion in a bulkhead. From Documentary: Estonia Jutta Rabe.

https://www.youtube.com/watch?v=4oLYxqjokSs

3.4 Sonar pictures

Analysis of the sonar pictures taken of the wreck. The picture shows a big object[13] with the same size and shape as the visor attached to / very close to / on top of the bow of the ship.

The AgnEf organization received a drawing from Sjöfartsverket where a sonar image of the wreck had been copied onto a map of the sea floor (creating a working material for the planned covering of the wreck). This explains why the level curves from the sea floor are visible through ship and visor. The level curves (1 m) of the object correlate with the size of the visor. The angle of the object in relation to the sea floor is the same as between the wreck and sea floor. Even the damage to the visor can be seen on the sonar picture. This image has given rise to argumentation. GGE, the German group of experts and IFG, the Independent Fact Group both claim that the bow visor was still attached to the ship as she sank. In support of that claim they refer to witness by survivors. Also, to a fax communication[14] between Finland and Sweden which shows that the visor was found and filmed very early and not the 18th of October as claimed by JAIC.

According to IFG the visor was actually taken up from its position at/on the wreck and not 1 nautical mile away, as claimed by JAIC. The picture needs to be analyzed to confirm or reject the scenario suggested in the final JAIC report, which has no mention of this sonar picture or any investigation of the matter.

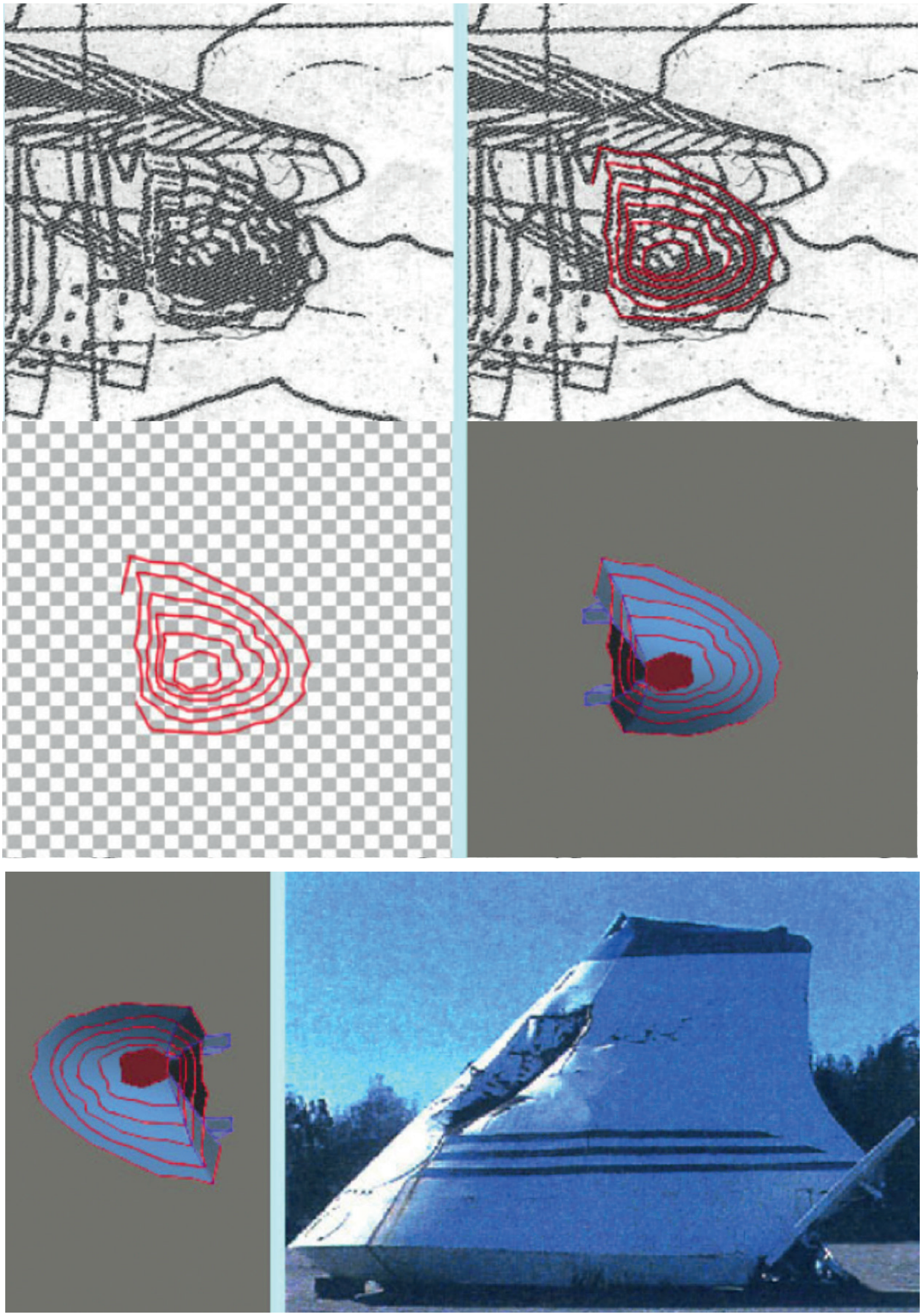
The original of this picture needs to be found to confirm or reject alternative theories on where the visor was found and recovered. According to Sjöfartsverket the original picture would be at the Finnish part of JAIC.

Graphics: Independent Fact Group

If the visor was positioned at the bow of the Estonia during the first days after the sinking, why was it later reported found 1 nautical mile away from the Estonia?

If the visor, as shown in the sonar image, was at the bow of the wreck the investigation must explain how and why it could end up in that position?

Was the visor attached in any way when the Estonia sank and how was the visor later removed from the ship?



Graphics: Independent Fact Group

The sonar picture above also serves to illustrate the damage to the starboard side of the visor, Heavy impact through collision with the bulbous bow or alternative? The picture above also shows a damage on the starboard side that is not present on the sonar picture to the left. A big part of the steel hull has been bent outwards from the visor. This damage needs to be analyzed and also the force needed to bend this part of the visor with FEM analysis. A new investigation needs to clarify when this damage occurred.

4 Independent analysis of reports created by external expertise

4.1 General comments

New findings on the wreck, in particular the hole midships, and a renewed investigation may result in a need to ascertain whether any part of the wreck had been subjected to explosion. In 2000 samples were taken from a damaged part in the front bulkhead showing petals.

A number of experts and materials research institutes were consulted at the time and the findings in their examinations of the samples should be reexamined and considered by new external experts on underwater explosions for an updated opinion on the matter.

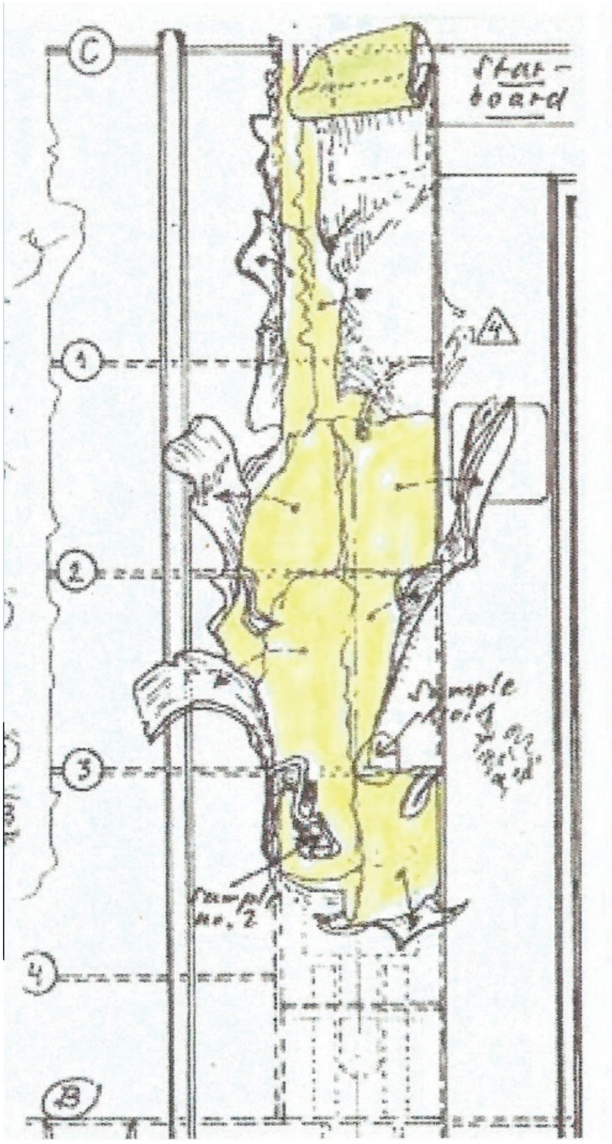
4.2 Reports by Brian Braidwood

Brian Braidwood was such an expert; he had spent twenty-five years as an Explosive Ordnance Disposal specialist with the British Navy. He wrote several reports[15] for the German Group of Experts and had explanations to the various instances of damage, documented both in films and on the recovered visor.

Brian was seconded to the New Zealand Government by the British Ministry of Defense to help investigate the attack on the Greenpeace ship Rainbow Warrior in 1985. That sinking was conducted with two limpet mines and the second delayed mine explosion killed the photographer Fernando Pereira in the Port of Auckland. Braidwood's reports on the Estonia deserve a respectful analysis by new independent experts.

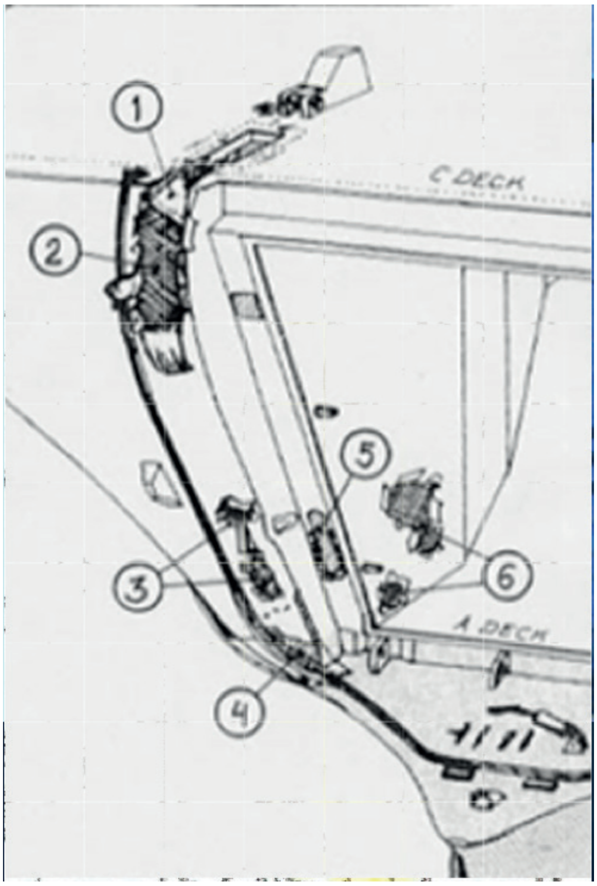
4.3 Reports made by international research institutes

Several materials research institutes analyzed the steel plate samples from the damaged front bulkhead. The samples were cut off by divers in the Bemis/Rabe expedition in 2000.



Graphics: Rabe

Hole in front bulkhead



Graphics: GGE

As the JAIC report had no mention at all about the matter of an explosion on the Estonia, their reports must now be taken into account and carefully analyzed.

There are six reports in total:

- Materialprüfungsanstalt Brandenburg examined the samples and concluded that they had been exposed to an explosion. The plastic deformation in some areas of the steel samples indicate very strong shock effect. This is a typical example of the effects caused by an explosion.

- The American Southwest Research Institute did a similar examination and came to the same conclusion.

- BAM, Bundesanstalt für Materialforschung und -prüfung assert in their report that there were no traces of explosion. The report was criticized for not having examined the side of the steel plates facing the explosion and maintained that the surface changes on the steel plate samples were due to the material having been steel ball blasted. This in spite of previous information from The Meyer Werft shipyard that all steel plates in the ship had been sand blasted.

- Cranfield Military University in the UK did the last examination of the samples and found evidence of an explosion.

- Institute fur Masterialprufung und Werkstofftechnik conclude that changes in the material of the samples were caused by explosion or a projectile.

- RCMS Royal Military College of Science in England concluded that the metal samples from Estonia's bulkhead showed traces of explosions.

If the conclusions, stating that there was an explosion/indication of detonative force are correct, the investigation needs to identify the purpose of such action, at what time the event occurred, and which party was responsible for the action.

5 Independent investigation of bow visor at Muskö naval base

5.1 The need to investigate the visor.

Based on interviews with passengers it is important to investigate the visor more thoroughly. Some witnesses give statements in which the Estonia hits something and it feels almost like the ship stops in the water. The sudden stop of the ship and the metallic bangs[16] they describe were very different from the ongoing sounds and movements from the rough sea. They describe noises as if the Estonia was passing through ice or as if Estonia had collided with something that also passed alongside or under the ship. These noises could partly also have been caused by cavitation and/or vibration created from steel parts standing out from the ship below water level at approx. 14 knots speed.

This investigation can be performed on land at a very low cost. It is easy to do since the visoris kept at the Muskö naval base near Stockholm.

Photo: Knut Carlqvist

This investigation should include outside as well as the inside inspection of the bow visor. Here are the main steps of an investigation:

5.2 3D Scanning of visor

Outside 3D scanning of damage on both upper starboard side and upper port side of the visor.

5.3 3D analysis of visor and bulbous bow

Analyze the damaged areas of visor and the shape of the bulb in a 3D simulation to confirm or reject if it is possible to explain damage by collision between visor and the bulbous bow on the ship. This is achieved with the use of a portable 3D scanner and that information is imported into a 3D model covering both the damaged visor and a 3D model of the bulb in the bow.

5.4 Analysis of visor damage prior to the last journey

Analyze the state of damage to the visor prior to the last journey. Did the visor have extensive damage before the last journey and what were the conditions of the locking devices?

5.5 Force simulation of damage

Simulation with FEM analysis in a 3D model to simulate what forces caused damage on the visor. This analysis will show what amount of energy impact with foreign objects, that is needed to cause the damage to starboard and port sides of the visor. A similar analysis is performed on the big hole in the starboard side in the new Discovery documentary by Monster Media.

5.6 Analysis of surfaces of visor

The surfaces of the visor need to be investigated in order to find possible traces of collision with foreign object. Material like titanium, aluminum alloys or steel may be present on the surfaces. Several areas of the starboard side and port side of the visor needs to be examined.

On the starboard side of the visor there is a very sharp straight edge between an area without paint and an area below with the white paint still intact. This sharp edge needs to be analyzed. The other edges of the area without paint also need to be analyzed. The shape of the paint at the edges could indicate if the surface has been burnt when the damage occurred or if the paint has been removed by mechanic deformation during collision with foreign object or collision with the bulbous bow.

5.7 Damage on the lower inside of visor

Inspection of damage to the lower inside part of the visor to establish if the damage was caused by explosion or other force. This particularly on areas around the side lock and bulkheads on the starboard side.

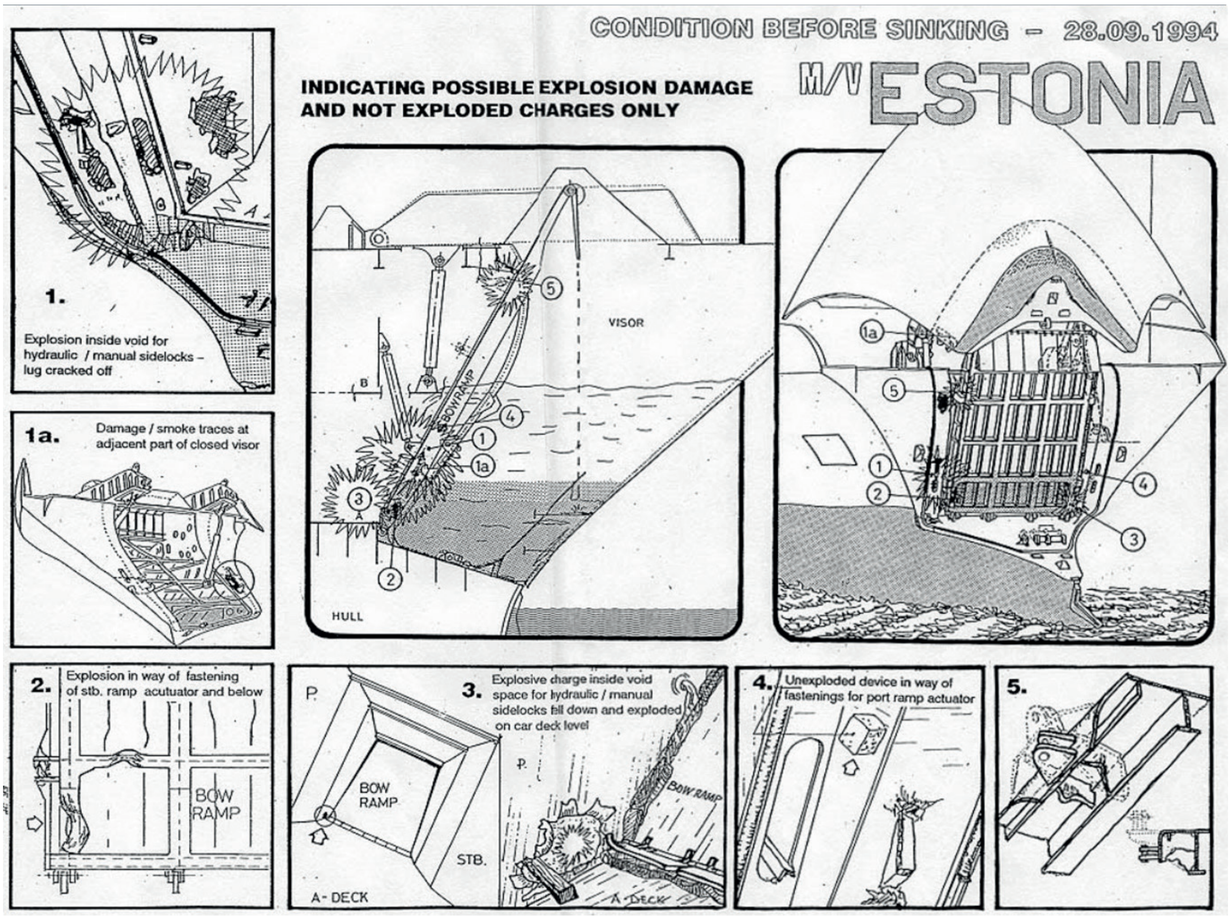
5.8 Analysis of visor lifting cylinders

Inspection of damage to starboard and port side hydraulic visor lifting cylinder. That includes cylinder surfaces, attachments and hydraulic fittings.

5.9 Analysis of the German GGE report concerning visor and bow area.

The GGE report made a comprehensive analysis of the damage to various areas: to the visor, to the damage to the bulkheads and to the locking devices on the car deck. Each picture below has a short text presenting the explosion damage found in five different places according to the GGE investigation. Numbers in the picture below are not connected with the numbered points in this chapter, they refer to points in the GGE report.

It is the area shown in picture 1a below that needs to be investigated at Muskö. A new 3D model of the visor should be made by using a 3D scanner. Is it possible to explain this damage inside the visor with mechanical collision with metallic parts from the bow of the ship in a digital 3D model or is that damage the result of an explosion?



Graphic presentation of documented explosions from the GGE investigation

These graphics also show the positions in the bow and on car deck of the wreck that need to be scanned with photogrammetry to create a 3D model with a minimum 3 mm resolution. Modern tools for analysis, that can calculate the exact forces causing deformations, will be needed to investigate this damage. There are conclusions in the GGE report[17] and in the JAIC report[18] that need to be confirmed or rejected by thorough scanning and 3D analysis.

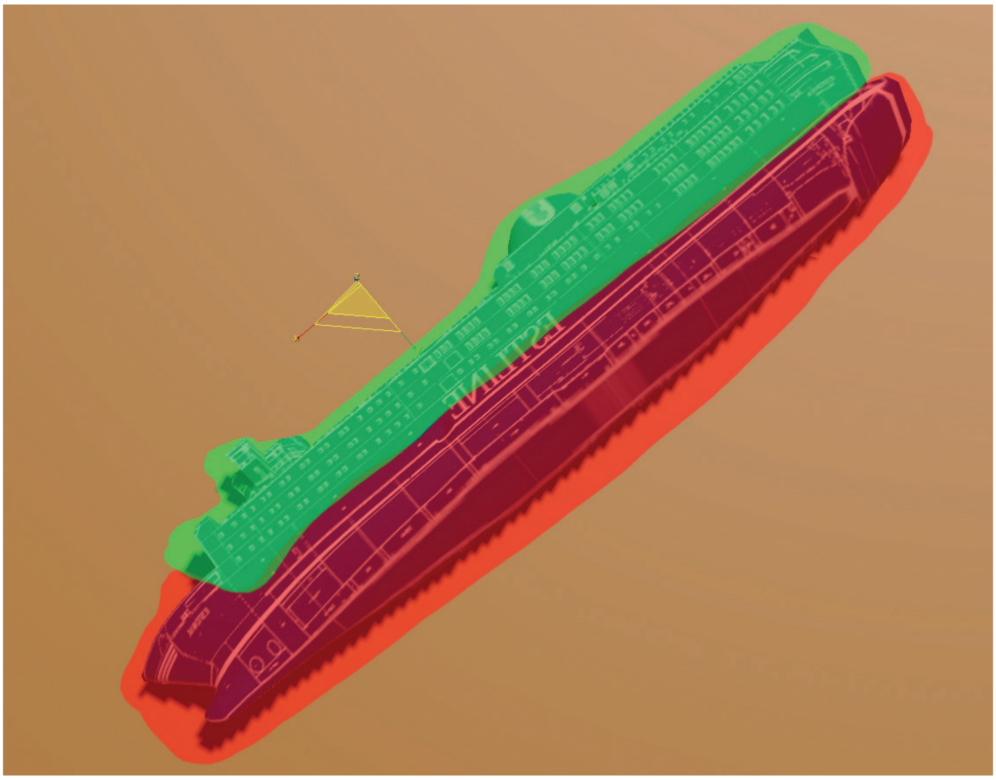
6 Photogrammetric underwater examination of the Estonia.

6.1 Modern 3D scanning technology

Several modern technologies have evolved over the last 26 years since the accident that can add much needed clarity to the Estonia investigation. This part of a new investigation can help to mitigate all possible conspiracy ideas with 3D models that will have millimeter precision.

Linus Andersson, LA Survey,[19] has provided us with photogrammetric pictures from other surveys (not the Estonia) and he describes that there are several different methods ranging from textured point clouds with 3 mm resolution to 2D composition of still pictures with 1 mm resolution. The entire ship can be scanned in detail. The recommendation from Linus Andersson is to use photogrammetry covering the sea floor out to some meters from the wreck and then cover the entire area up to some meters above the fender bar on the ship, shown in red below. This will secure a complete picture of the entire ship below the fender bar. There could be more damage in the red area that have not been discovered yet.

Photogrammetry of the red area below is an easy operation to perform with mostly smooth surfaces. Photogrammetry of the green surface is more difficult to perform but could still be useful to create a picture of all upper parts of the ship that are not covered under the sea floor.



Graphic presentation Linus Andersson LA Survey

It is also possible to use Side scan sonar 500x500 meter around the ship to capture findings on the sea floor that can be analyzed later by photogrammetry. Penetrating side scan sonar can also be used to see what is under the sea floor. These can be a very important tools to find objects hidden under the surface and important parts from the ship. Parts of the ship interior are spread on the sea floor and they can tell us how the ship moved during the sinking.

These are the main areas of an investigation:

6.2 Photogrammetric investigation of the bulbous bow, shell- and bottom plating

This information will be used to analyze any damage to bow of the ship. This will be transformed into a FEM analysis to rule out if any foreign object has hit this part of the ship. This will also answer the question of what force and energy content would be needed to cause any damage.

Photogrammetric investigation of the shell- and bottom plating will answer the question if some water tanks were open to the sea which could have added to the sinking sequence.

6.3 Photogrammetric investigation of bulkheads to rooms for lifting cylinders

Photogrammetric investigation with ROV covering the bulkheads to the rooms for lifting cylinders on starboard and port sides. Detailed 3D pictures will rule out if damage to bulkheads was caused by explosions or not. Naval experts will be able to clarify this type of damage by analyzing the shape of holes in the damaged area in a 3D model. It will be possible to see if the damaged areas have the petal shape that only explosions can cause. Any conclusion that there is clear evidence of explosion in the photogrammetric material should lead to further metallurgic investigations.

6.4 Photogrammetric investigation of flaps on car deck

Photogrammetric investigation with ROV covering the last flap[20] between car deck and ramp on the starboard side. This flap seems to be jammed in a position between two torn out steel plates that is difficult explain. The flap is oriented as if it was in a 120° position when this event occurred. This flap is shown on a picture in the GGE investigation and has been analyzed by The Independent Fact Group.

Their analysis points in the direction that an explosion occurred when the Estonia was on the sea floor, lying at a 120° angle. otherwise the flap would not have been jammed between plates in this position. The flap should have been aligned with the car deck at 0° angle if an explosion took place on the sea surface and tore out these steel plates. That would not leave the flap jammed at 120° angle.

6.5 Photogrammetric investigation of railings on the bow ramp

Photogrammetric investigation with ROV covering the railings on the car ramp This includes any railings still attached to the ramp as well as the railings that have been detached. That also includes metallurgical examination of any parts of the railings that remain attached to the ramp to conclude how the railing was detached. Samples may need to be removed to carry out this investigation.

6.6 Photogrammetric investigation of the big damage on the starboard side

Photogrammetric investigation with ROV covering the big damage on the starboard side. This investigation will provide a much more detailed 3D view of the damage. This model could answer the important question of why parts of the hull are standing out from the ship´s side in this damaged area. Some parts that are twisted, bent and heavily fractured by some kind of extreme force could be a part of the fender bar.

Photogrammetric investigation of the cabins adjacent to the cabin that was hit by this impact with damage close to the ceiling. Further damage inside these cabins and a possible penetration of cabin walls would indicate that the impact damage was caused by a smaller object at higher speed.

An impact damage by a bigger object or smaller ship at low speed will not cause any more damage than the 1,2 meters penetration through the hull of Estonia that has been discovered. Splinters of a highspeed object might bounce on the rugged bulkhead next to these cabins. This bulkhead runs through the ship acting like a watertight wall between compartments. The vertical 4 meters long crack with the broken weld is formed along this strong bulkhead.

This part of an investigation should also involve the car deck which seems to be at the center of the damage. The totally demolished fender bar, which could be the contact zone of the impact damage is at the same level as lower parts of the car deck. Parts of a penetrating object could therefore be found on the car deck.

Damage could be found on vehicles parked on the car deck in the area of this probable impact. There could also be parts of a foreign object attached to vehicles or even found inside vehicles after a collision.

The ROV should also scan the 4-meter long crack further down towards the keel and verify if the possibly empty ballast tank positioned under this damaged area was hit in a way that led to sea water filling the tank. A sudden filling of this trim tank would have added to the list if the tank was empty. The ROV should also scan for the possibility of sea water entry to other parts of deck 0 through this crack.

6.7 Photogrammetric investigation of the small damage on starboard side

Photogrammetric investigation with ROV covering the smaller damage on the starboard side further towards the stern of the ship. This damage has not been shown to the public yet and it is supposed to be of a different kind. The shape of this damage should be analyzed with an open mind.

The edges of the steel plate and the direction of the distortion will give clarity to the reason for the damage. It is also important to conclude if all parts of the steel hull are still present in the damaged area or if any parts are missing. The internal parts of the ship at this location also needs to be documented by ROV. Steel plates in the damaged area that are bent inwards could be an indication of another impact.

This should be considered and lead to an internal investigation of the ship's engine room and car deck with ROV to confirm or reject such a scenario. Parts of foreign objects could still be present inside these parts of the ship. It is also possible that some object bounced against the hull in this position.

This smaller damaged area further back on the ship could also have played a part in the sequence of events where the ship sank on the stern. That is possible if this damage was present during the sinking. The damage could also be a consequence of something happening when the ship hit the sea floor.

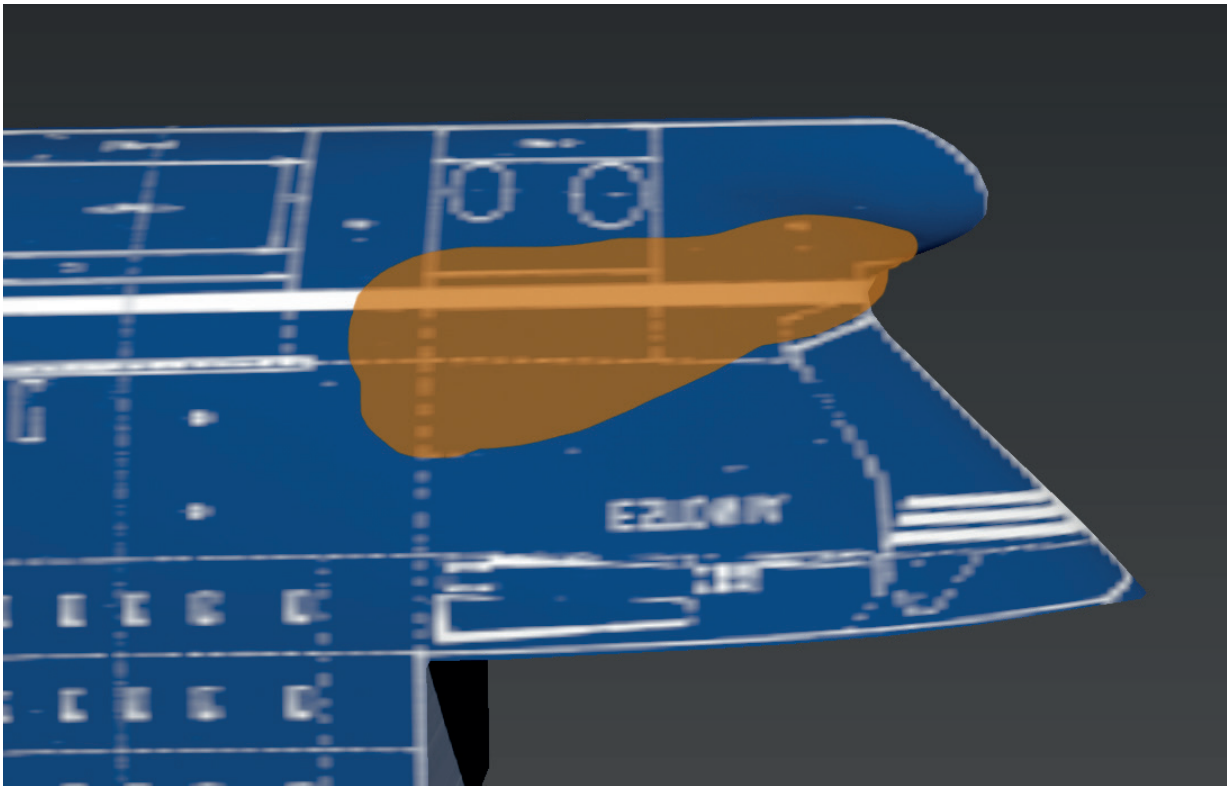
6.8 Photogrammetric investigation of the car deck

Photogrammetric investigation with ROV covering the car deck. The primary reason for this investigation is to establish if there are military trucks onboard as stated by several witnesses. These trucks were among the last vehicles to enter the ship. They tilted to the side when the ship tilted to starboard and were later further turned when the ship sank in almost upside-down position. The military trucks could be found on top of other trucks and cars as all unsecured vehicles on the car deck tumbled towards the stern.

It is also important to examine if they still have their cargo in case these trucks are found. Linus Andersson LA Survey recommend that any investigation should start with a video investigation to conclude what parts of the car deck should be investigated with photogrammetry. This is due to the risk involving a ROV for photogrammetry in this part of the ship with piles of demolished vehicles and other debris.

6.9 Removal of sand and photogrammetric investigation of the bow area.

Parts of the bow area are covered with sand as shown below by Linus Andersson, LA Survey. This sand needs to be flushed away to be able to cover the entire ship with photogrammetry.

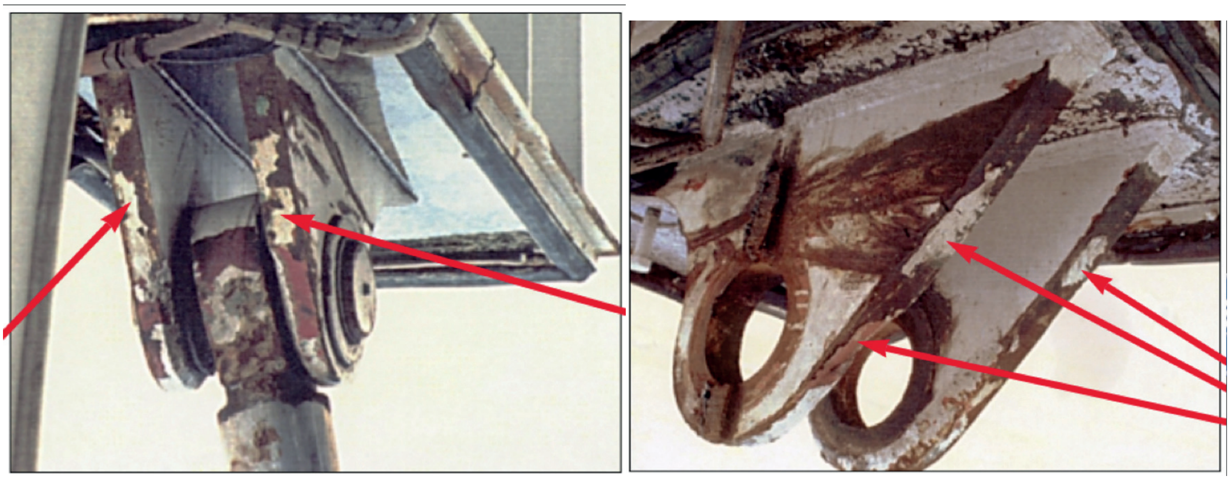


Graphic presentation Linus Andersson LA Survey showing area with sand covering parts of the hull near the bow.

6.10 Photogrammetric investigation of the deck beam

This investigation can clarify if the lugs, attaching the lifting cylinder to visor arm/hinge beam, have been torn off on both sides by the movements of the visor. This is the scenario presented but not proven by JAIC and it needs to be confirmed if this event is even possible and whether that is what occurred. The white paint on the surfaces of these lugs was still in place which indicates that this explanation might not be correct. There are alternative ways to explain the loss of visor other than the visor arm lugs cutting through the transverse deck beam.

A modern FEM simulation or a practical experiment with hydraulic cylinder/actuator would show how many enacted 'wave' movements it would take to cut through a similar beam with such lugs. This could present investigators with a rough estimate of the time it would have taken Estonia to hit that number of waves. The time needed can be calculated based on the wave period at 4-meters significant wave height and the speed and direction of the Estonia. Indications of an explosion close to the lifting cylinder could be another way to explain the loss of the visor, as found in the GGE and IFG investigations.



Photos: Independent Fact Group, Report Impossible visor scenario[21]

Pictures above show the recovered port- and starboard lugs with paint still in place on surfaces that were said to have cut through a thick beam according to the JAIC investigation. This needs to be confirmed or rejected by a new investigation.

One area that needs to be documented with photogrammetry is the upper part of the bow of the Estonia. A new investigation needs to investigate the hole on the screen shot below. This film material comes from the Bemis/Rabe dive 19-31st of August in 2000 and uploaded to Youtube by Slawek Packo. The quality of this film material is very good compared to the material released earlier from the Swedish authorities.

This steel plate below has been rolled up and this needs to be analyzed by underwater blasting experts to conclude or reject if this steel plate has been ripped up by an explosion along the welds on the sides or if other forces can create this roll up. This plate of the ship also needs to be removed and metallurgically analyzed by explosions experts.

Screen shot from Youtube video: Slawek Packo wreck of Estonia ferry - YouTube

6.11 Photogrammetric investigation of the preventer wires with lugs securing the car ramp

According to the JAIC investigation the visor fell off and the ramp was forced by the visor to fully open position. The wires for car ramp were detached during this event according to the JAIC. A new investigation needs to establish in what shape these parts are. JAIC says they were torn off. Film material from the official investigation show that at least the starboard preventer wire and both preventer wire lugs are intact. Video RW/SEMI1/EST/D/014, at recorded time 01.13, shows that the starboard preventer wire is complete with shackle and shackle bolt in place. Video SHK B 40c at 0.59.35 shows starboard lug and at 1.30.40 shows portside lug. Both lugs are intact.

6.12 Photogrammetric investigation of hoses and piping inside the ship for lifting cylinders.

The IFG have made a report[22] recently regarding the hoses and piping by analyzing the conditions of these hydraulic parts when the visor was lifted from the sea floor. They reach the conclusion that there is final proof that the visor was removed from the ship after the sinking. The presence and condition of these parts in the wreck needs to be examined.

7 Examination of the sea floor around the Estonia and other areas.

7.1 Modern technology for sea floor scanning

The sea floor surrounding the wreck of the Estonia needs to be examined as well as other parts of the sea floor that the Estonia passed over in the latest stages of the catastrophic event. Linus Anderson LA Survey recommend search technology that uses a marine transverse Gradiometer. The technology is used to secure a sea floor before laying out electric sea cables and it is used on sites for windmill exploration. These surveys are mapping the sea floor with an array of scans. Debris from the Estonia and other parts such as the locking bolt from the Atlantic lock are buried today in the sea floor but can be found with this technology.

7.2 Scanning the sea floor around the Estonia and salvaging objects

This investigation needs to clarify what objects may be present there by scanning for and salvaging any important object found on the sea floor. Several objects from the visor locking devices which could confirm or reject if any explosion occurred, were initially recovered but later left at the wreck. Parts of the Atlantic lock were salvaged but later thrown back into the sea. Such objects could bring new important information to the investigation. The position of the ramp railings also needs to be examined; they were found standing on the sea floor close to the Estonia as shown on films from 2nd of October 1994.

In case any explosion did occur with the ship at the bottom, as claimed by the Independent Fact Group, traces, splinters etc. of such explosion with the wreck on the sea floor, might be possible to find with penetrating side scan sonar. It is important to also remove and investigate all the remaining parts of pipes, fittings and hoses from lifting cylinders after a photogrammetric investigation has been conducted.

The sea floor in the area at the position where the first metallic bangs first occurred, needs to be scanned as well. It is possible to detect any foreign object or parts of objects that could have collided with the Estonia. There are several different interpretations of the Estonia's position at shortly after 24.00 hours when witnesses reported the first metallic bangs. This means that several areas need to be scanned including the position[23] at 24.00 given by The Independent Fact Group who made a detailed survey of the route of the last journey and reached a very different conclusion as compared to the one given by JAIC.

8 Summary and conclusion

8.1 A new investigation should use the best available technology

A new investigation using modern scanning technology is needed for increased knowledge to better explain this disaster. The possibility to create a digital 3D replica of the Estonia has never been better. This investigation will be able to conclude what happened with the Estonia on her last journey and perhaps why it happened.

8.2 A new investigation need to follow international regulations

Neither Swedish public opinion, relatives of deceased victims nor Swedish legislation can override international law regarding independent investigation of any public disaster with human casualties with any type of vessel in any international waters. This is a disaster on a vessel for public transport and the lessons learned from this disaster shall be used to improve public transport and mitigate risks on future sea travel on similar types of ships.

The work in a new investigation needs to be conducted with a new independent team this time in accordance with regulations from IMO (The International Maritime Organization) and ITSA (The International Transport Safety Association).

IMO Casualty Investigation Code, Resolution MSC.255(84) Article 26.1: „Marine safety investigating State(s) which have 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."

ITSA have regulations for its members called SIA (Safety Investigation Authorities). The requirements established by ITSA are intended to protect the SIA from undue intervention into an investigation from the government (or other body.). Some of the most important regulations that concerns the current Estonia situation are listed below:

The SIA is empowered to decide at its own discretion what occurrences to investigate, unless statutory law specifies such criteria.

The SIA shall have the powers necessary to initiate and fully carry out a safety investigation independently and separately from any other form of investigation into the same occurrence.

The SIA shall have the right to freely publish investigation reports, including any conclusions and safety recommendations it deems relevant, without the need for consent from any other body, including any branch of government.

The SIA is recognized by its peers as a world leader in its field as demonstrated through the successful completion of major investigations involving multiple countries, the implementation of recommendations that result in major safety improvements in multiple countries, and/or the development of new investigation tools and techniques adopted by other countries.

8.3 Transparency

It is important that a new investigation is transparent and that every move is open to the public. This needs to be conducted with transparent handling of filming, analysis and information gathering. This involves planning and international independent observers as well as observers from organizations like SEA and the Estonia group in the Swedish parliament being given access. This is the only way to build trust in a new investigation. This is the only way to put the regrettable consequences of previous failures behind us.

A Swedish policeman stopped the Estonian representative onboard the survey ship in 1994 when he tried to enter the room where they were filming the damage to the Estonia with a ROV and showing it on video screens. These kinds of actions cannot be allowed to happen again.

The old JAIC investigation was heavily criticized by the German Group of Experts in their final report in almost all aspects for missing video tapes, systematic cuts in video tapes showing the starboard side, handling of statements from survivors, their conclusions and several other pieces of evidence that were lost or not made available. The GGE did not agree with the conclusions from JAIC regarding the car ramp. There were no statements from the crew looking at video screens that the car ramp was fully opened which would be caused by the visor falling off as stated by JAIC.

Several other international organizations and experts also criticized the JAIC conclusions and concluded that the Estonia would have turned upside down and capsized immediately during these conditions with enormous amounts of sea water entering a fully opened car deck and with not enough water entering below car deck in time to balance the ship.

8.4 Investigations inside the wreck of the Estonia.

To ensure the quality of a full investigation It will be required to scan some internal parts of the ship with photogrammetry and conduct diving. Car deck, engine room, bow area and a few cabins closest to the damaged area need to be documented or the investigation will be not be able to reach a full clarification of what happened with MS Estonia.

8.5 The expected behavior of the Swedish government

The Swedish government cannot try and continue to control what parts of the Estonia will be examined in the light of new extreme damage found on the ship. This is a breach of international regulations. Sanctuary protection cannot be used to prevent independent investigations when new critically important facts have emerged. Any instructions from the Swedish government to SHK should be made public and there should be no more contacts on a regular basis between the Swedish government and SHK in this matter.

SHK should know the meaning of the word independent and act accordingly without limitations. SHK should at least advice the Swedish Government to add a SIA from an independent third-party country as the new head of any new investigation. The Swedish government cannot narrow down the investigation to only make an inspection of the big damage on the starboard side while maintaining complete trust in the old JAIC investigation as they do now. A new investigation is needed to fully establish what caused this accident with the death of min. 852 people.

We end this report by asking the Swedish government and authorities what margins do we have on a modern ferry today with RORO capacity? What margins do we have if a ferry is hit by an impact damage with the same energy content midships near the water line in a storm and the crew is slow to respond due to a lack of awareness? What have we learned from this disaster?

Lars Ångström Former MP and former member of the Standing Committee of Defence

Björn Arvidsson Development engineer and Technical consultant

End notes

[1]Estonia film by Monster: Fyndet som ändrar allt, 5 Part, Interview with naval expert Frank Børressen regarding possibillity of explosion at 37 minutes

[2]Estonian investigators Viewing of the ROV video to MS Estonia page 4
https://www.valitsus.ee/sites/default/files/2020-09-19_observations_from_the_rov_video_to_ms_estonia_18th_september_2020.pdf

[3]TV interview with Anders Ulfvarson on Swebbtv
https://www.youtube.com/watch?v=OdP4bkacbyo

[4]Estonia film by Monster: Fyndet som ändrar allt, 5 Part, Interview with professor Jørgen Amdahl regarding energy content at 45 minutes with examples of possible weight and speed.

[5]Estonian investigators Viewing of the ROV video to MS Estonia page 4
https://www.valitsus.ee/sites/default/files/2020-09-19_observations_from_the_rov_video_to_ms_estonia_18th_september_2020.pdf

[6]Estonia film by Monster: Fyndet som ändrar allt, 5 Part, ROV filming at 20 minutes.

[7]TV interview with Anders Ulfvarson on Swebbtv
https://www.youtube.com/watch?v=OdP4bkacbyo

[8]GGE report with pictures of damage 29 The shell Plating and Bottom Plating 29.5 the shell plating and bottom plating (estoniaferrydisaster.net)

[9]GGE report with pictures of explosion damage 32.2 Findings
https://www.estoniaferrydisaster.net/estonia%20final%20report/32.2.htm

[10]Package that could be Unexploded material
https://www.estoniaferrydisaster.net/estonia%20final%20report/chapter32.htm

[11]ROV camera collage by Independent Fact Group

[12]Film sequence Documentary: Estonia Jutta Rabe 1994. at 13 minutes 29 seconds with probable blast hole in a bulkhead

https://www.youtube.com/watch?v=4oLYxqjokSs

[13]The Independent Fact Group presentation with manipulated sonar pictures
http://privat.bahnhof.se/wb576311/factgroup/est/riddlese.html

[14]Fax communication 19941010 from Tuomo Karppinen to Börje Stenström at SHK. Document ES-NR:SE/SPF/1/ES/2/F1HA/256/1

[15]Brian Braidwood Supplementary Investigation report
https://www.estoniaferrydisaster.net/estonia%20final%20report/enclosures%20HTM/enc%20 4/34.7.435.1.htm

[16]Metallic bangs as later testified by engineer Henrik Sillaste from the engine control room
https://www.estoniaferrydisaster.net/estonia%20final%20report/21.2.4.htm

[17]The German Group of Experts, report
https://www.estoniaferrydisaster.net/estonia%20final%20report/Contents.htm

[18]JAIC report in Swedish
http://www.estoniasamlingen.se/textfiles/JAIC-haverirapport.pdf

[19]LA Survey and Linus Andersson on photogrammetry
http://www.la-survey.se/fotogrammetri

[20]The Independent Fact Group, Report on the jammed flap
http://privat.bahnhof.se/wb576311/factgroup/est/cardeck.html

[21]The Independent Fact Group, Report The impossible visor scenario
http://privat.bahnhof.se/wb576311/factgroup/est/visor.pdf

[22]The Independent Fact Group, Report regarding the final proof that the visor was detached from the ship after the sinking of Estonia *Final Visor.pdf (factgroup.uk)*

[23]The Independent Fact Group, Report on navigation and route on the last voyage
http://privat.bahnhof.se/wb576311/factgroup/est/route.html