MV Estonia, a Plausible Sinking Scenario

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ABSTRACT

This paper shows how the assertion, set forth by the German group of experts, that MV Estonia was leak may make perfect sense. A possible similarity between the MV Estonia the MV Al Salam Boccaccio 98 cases is established and the paper may give essential erudition to two major disasters costing the life of nearly 2000 seafarers. Though not a point by itself the paper hints how an imprudent investigation may lead naval architectural analyses astray.

KEYWORDS

MV Estonia, MV Al Salam Boccaccio 98, Ro-Ro Pax, Pilot doors, disaster, capsizing, foundering.

INTRODUCTION

The official approach to the Estonia sinking has been that water flowed into the garage by an open bow-ramp. However, a German group of experts early pointed that the ship was leak. This assertion, which was regarded as physical impossible by the investigating specialists at the MV Estonia workshop in May 2007, is analyzed in this paper.

A central point is why Estonia sunk by stern when the German group of experts maintains water was up-flooding fairly far ahead. Use of ballast as well as drainage of bilge is suggested to explain how trim caused by the forward inflow might have been controlled by pumps prior to the ship suffering energy black-out.

In the aftermath of The Herald of Free Enterprise disaster even the most fearless masters must be expected to be very anxious about water accumulating at car-deck. Consequently one may not rule out that masters, at time of emergency, attempt to improve the insufficient drainage of these ships. Furthermore, since the scenario of water penetrating Estonia by the bow-ramp only, has

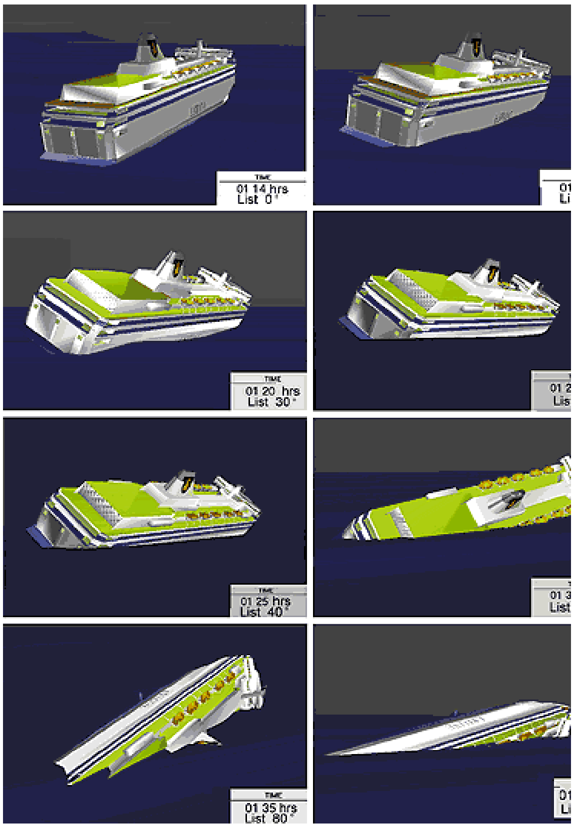

Figure 1: Computer generated scenario by JAIC. The author presumes these pictures are based on testemony by survivors rather than by simulation of any scenario [1, Fig. 13.3].

never been properly established, I early got the sensation that water might have penetrated the hull by some of the starboard side doors. Unfortunately, my hunch, that ship commands could consider such means, at time of emergency, was later highlighted in the Al Salam Boccaccio 98 disaster, in 2006, where 1069 seafarer lost their life.

For Estonia as well as Al Salam Boccaccio 98 one has to explain how the buoyancy represented by the freeboard as well as the car-deck was lost. While a leak bow-ramp might have been contributing in the MV Estonia case a similar scenario is not plausible for Al Salam Boccaccio 98. She had a fixed bow and her collision bulkhead was extended up to the forecastle deck in front of the garage. Furthermore, her initial water flooding was due to the fire fighting rather than water penetration of the hull.

A missing video from the official Estonia investigation, which might have thrown some light about an alleged artificial sand-heap covering one of the pilot doors as well as the leakage, has been central for this article. Though I have used much effort on this topic no information has been gained. I have, however, learned that the technical information regarding the Swedish attempt to protect the wreck from divers is missing as well.

THE DISASTER AND THE INVESTIGATION

MV Estonia foundered in bad, but not extreme, weather September 28th 1994 and 852 seafarers lost their lives while 137 were rescued. Shortly after the disaster governors of Sweden, Finland and Estonia decided, based on purely ethical reasons that one should not search for and bring up the 757 bodies still missing. The approx 130 bodies already sighted were left inside the wreck. Though the biggest underwater entrepreneur, experienced from the Alexander Kielland disaster, recommended rapid search and rescue for bodies surrounding the wreck such search was never carried out [1].

When the governors defined the site of the wreck as a sea tomb, relevant laws were issued in all the tree countries to prevent divers from entering it. The Swedish government took upon them to cover the wreck by concrete sheets but they were forced to abandon the project due to public resistance.

The official investigation was performed by a Joint Accident Investigation Committee (JAIC) consisting of Sweden, Finland and Estonia [2]. A German group of experts made their own investigation on behalf of the shipyard and these experts were so alarmed by the proceedings of JAIC that they published their 1st report prior to the JAIC report and another one some years later [3& 4].

In 2005 Swedish authorities initialized a project headed by Swedish Ship Research Centre (SSPA) to analyze the disaster. The project should start from the recent JAIC studies and it should analyze all known evidence to obtain a better understanding of the sinking. The project seems impeded by the tomb protection laws as new surveys have been shut out by authorities [5]. This seems strange since the tomb covering was aborted to uphold the needs of future investigations. [6]

In 2006 Swedish authorities started a criminal technological investigation of some of the videos taken from the seabed. The mandate was extended a year later to include the first video surveys as well. The criminal technological investigation did, however, not include investigation of an alleged artificial sand heap [7].

In May 2007 a Swedish financed workshop regarding the Estonia disaster took place in Glasgow. The technical presentations indicate that variations of the JAIC scenario were still being focused on though this time improved simulation models were used. The original JAIC scenario may shortly be summarized:

> **MV Estonia lost her visor and her bow-ramp was forced open after which she maintained full speed heading up against the foul weather thus flooding her car-deck. During the foundering process, when Estonia sank, stern first, upside down, the ramp is expected to have closed itself.**

The scenario of the German Group of Experts, which so far has been rejected by specialists as physically impossible, may be summarized:

> **MV Estonia forced her way against hard weather with a weakened bow visor and ramp. The ship suffered a minor leakage which flooded the pool compartment. Simultaneously water cascaded into the garage by leakages at the side of the bow ramp.**

OBSERVATIONS AND OTHER FACTS

The survivors' observations:

Water cascading in beside the bow-ramp had been observed at the engine control monitor for considerable time prior to disaster [5]. A similar monitor was located in the chart-room adjacent to the coning-position.

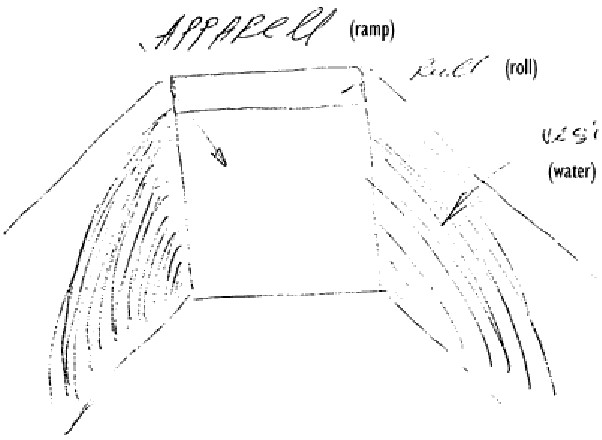

Figure 2: The water inflow observed at the engine control monitor [2, Fig. 6.1].

- The bow visor was observed flexing prior to disaster and water was observed cascading up between the hinges of the visor [8, p65]. Though one could not see the visor from the coning-position a lookout would have been able to study it from the forward staircases [2, $3.2.7].

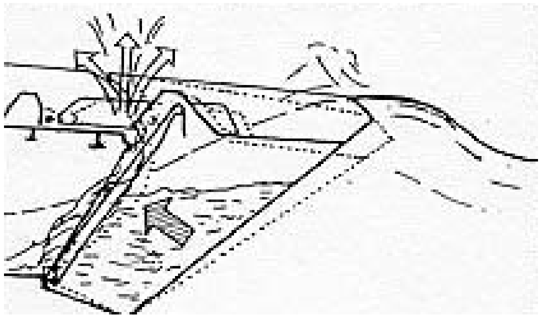

Figure 3: Observed water cascading up behind the visor [4, $31].

- The disaster was pre-warned by passengers who noticed water up-flooding from the pool compartment. This fact was disputed at the workshop, but my impression is that many sided with the German group of experts in this matter [3, p35]. NOTE: I have no personal opinion whether there was up-flooding or not, I merely analyze the situation if it was.
- The bilge pump was started prior to disaster [8, p71].
- A tentative MayDay was noticed by another ship at this time, but it was weak and as it was not repeated; nobody took any notice [4, $22.1].
- The disaster was initiated by huge roll and pitch [3, p36].
- A strong bang which experts at the workshop considered to be made by slamming, rather than explosion, was heard.
- MV Estonia was observed to have turned shortly after the huge roll & pitch [8, p225].
- The bow-visor was observed to be attached to the wreck when Estonia foundered by 6 survivors [8, p118].
- The bow-ramp had been observed to be closed shortly prior to foundering by survivors walking on it [5].

- The ship is reported to have done a banana-turn. That is; the ship command reduced speed and initiated a turn to starboard then huge heel forced an uncontrolled turn to port [8, p. 225].

Other facts

- The time domain scenario by JAIC (Fig 1) seems to be more or less agreed on.
- Concerning a harbor control exercise performed shortly prior to departure the JAIC report states: *The Swedish inspectors leading the exercise have been interrogated by the Commission and have stated that the vessel was in good condition and very well maintained*. This has been highly disputed and 2 Swedish journalists have written an interesting, though alarming, book on the subject [9]. They assert the Swedish inspector in charge wanted to prevent the ship from sailing and that he called his superiors in this respect. The journalists further pointed that a Swedish commission member withdrew from the commission when he was deprived of his right to write a divergent opinion regarding the seaworthiness. The commission member, a psychologist, interpreted the statement by the Swedish chief inspector to be about the finery of the ship, rather than the seaworthiness.
- The rear-ramp was observed to be slightly open. The German group of experts has suggested it might have been opened deliberately to drain water from the car-deck [4, $31].

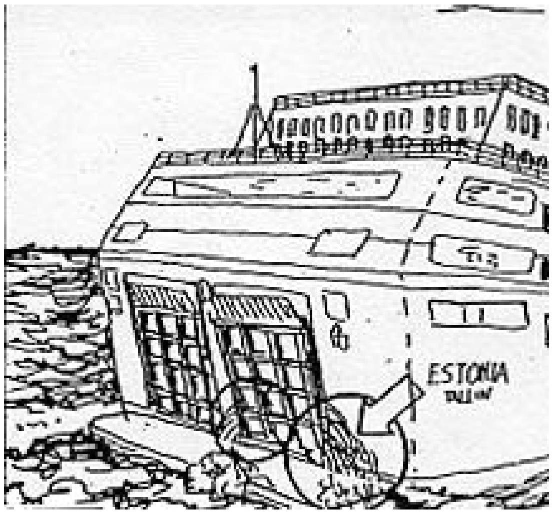

Figure 4: The German group of experts has suggested the rear ramp was opened to drain out the water that flowed in by the bow ramp [4, $31].

- Radio-logs by the Swedish high command may have been lost [8, p169].
- The bow-ramp was found slightly open and marks on the underside prove it must have been knocked against the fore peak at least once. While JAIC as well as present investigation groups seem to believe the bow-ramp stayed open for considerable time and closed itself when the ship foundered, others have suggested it might have been forced open after the foundering. The damage might as well be of earlier date.
- The bow-visor was found far west of the wreck, in a position that Dr Valanto at the workshop considered natural if the ship turned shortly after loosing her visor.
    - Since the German group of experts thinks the location of the visor contradicts observations by survivors the group has suggested the bow visor was dislocated shortly after the foundering.
    - The finish radar-plot is missing. The master of Silja Europe pointed at the interrogation that the plot by JAIC was obviously wrong [8, p213]. Dr. Valanto of HSVA seems to agree on this because the elapsed route does not

comply with the drift he estimates the ship might have had. The opinion of the master should of course carry much weight, when the surveillance plots were not to find; the master was designated On the Scene Commander (OSC) [2, $7.1].

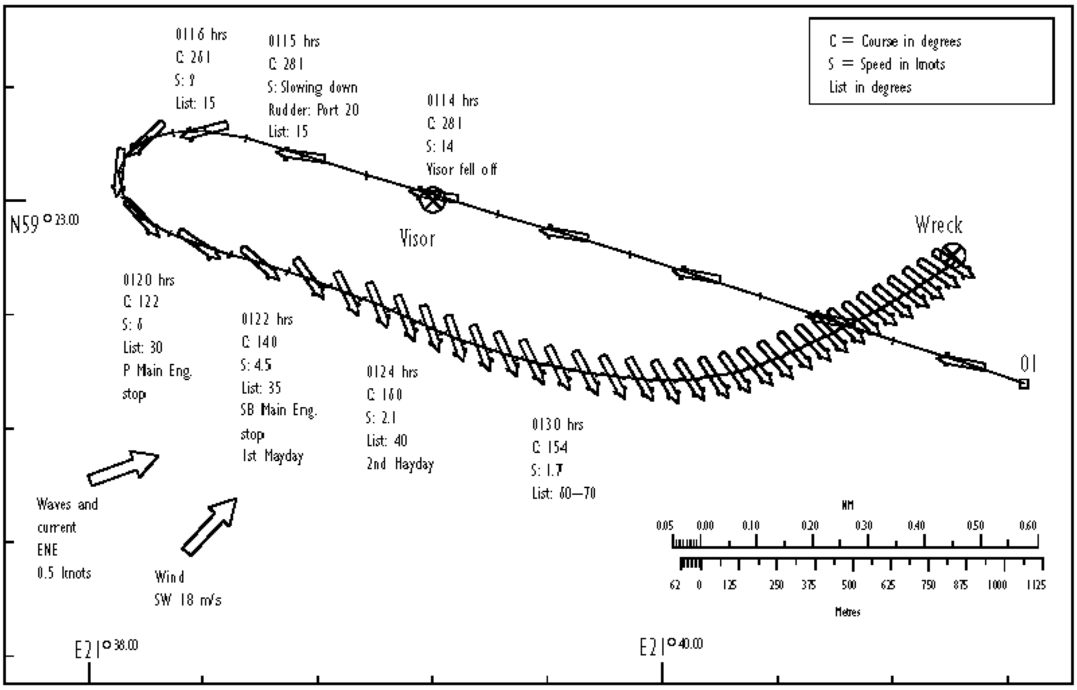

Figure 5: The JAIC plot shows how they expect the ship headed up against foul weather after the visor has been lost [2, Fig 13.2].

- Though present stability analyzes make use of better simulation software than the previous, no scenarios so far analyzed, seem to have been found physically possible by simulations.
- The doors separating the car-deck from the stairways were fire-resistant but not watertight. The aft most of these doors was, according to the German group of experts, very wide and had no threshold in order to facilitate easy transport of storage.
- The port heel tank is expected to have been full and the starboard empty at departure [2, $5.3]. The workshop was told that the cross-over valve separating these tanks would open automatically if the watertight doors should be closed. Consequently, such ballasting could heel the ship in all damage situations, port side damages exempted.
- The fore peak is expected to have been full. [2, $5.3]
- Model tests presented by SSPA at the workshop indicate the bow ramp would have bounced wildly up and down if the ship encountered the waves with full speed. Unfortunately SSPA refuses to hand out a copy of this very interesting video.

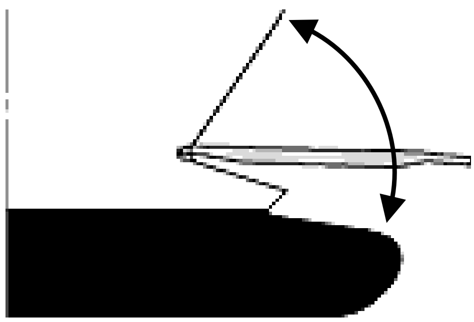

Figure 6: Model tests shows the bow-ramp would bounce wildly and close itself for the oncoming waves [2, Fig 10.2].

- SSPA informed at the workshop that the rip off forces acting on the hinges have never been analyzed. Though the question was repeatedly raised, none of the experts suggested that strength analyzes of the hinges might prove the open ramp scenario to be physically possible. Later Swedish authorities strangely argued that it has not been within the mandate of SSPA to take the strength of the hinges into account. Though the call for bid actually points that the JAIC description of the sinking process should be used as starting point it was hopefully not the authorities' intention to duplicate the JAIC work. NOTE: Neither the call for bid, nor the bid itself, indicate model test and simulations, were not to take prudent consideration to the natural laws of science.

- Anders Björkman states: *The forward starboard pilot door is situated in that area (at frame 122) and should thus have been visible on the mudline video. However, the video films of both 1 October (seabed survey) and 2 December (mud line survey) have been edited in just that area, i.e. the films have been cut and the superstructure side and the pilot door cannot be seen!* [10, $1.16].

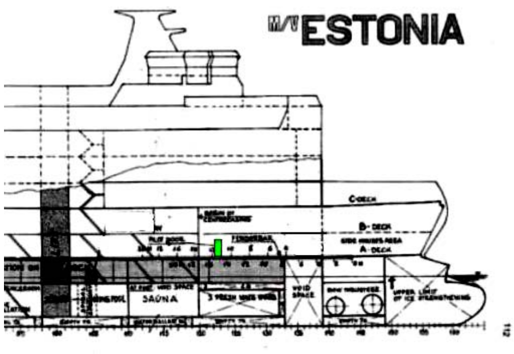

Figure 7: The figure shows how the mud level was expected to be at the site of the forward starboard pilot door [10, Fig 1.16.4].

- Anders Björkman further states: *The Gregg Bemis dive expedition 2.24 inspected the area (Section D) in 2000 and found that the superstructure side was covered by sand (!) up to the level of the fender between hull and superstructure that didn't match the seabed mud, i.e. sand had been deposited against the wreck to change/raise the mud line and to cover the superstructure side and the pilot door. The whole area below the wreck - where you could have seen the superstructure side in 1994 - was filled with sand in 2000! It can hardly have been swept in by, say currents.* [10, $1.16]
    - The assistant director of prosecutions of Estonia could not give any information at the workshop regarding the alleged artificial sand-heap.
    - Later Swedish authorities have informed that their archive does not hold any technical information regarding the aborted protection of the wreck. The only documentation received is the governmental decree which orders the work immediately stopped with one exemption; the pressure banks could be completed. I have learned from NCC that these pressure banks should support the concrete sheets rather than the ship. Furthermore they should not be located close to the wreck. When NCC and the salvage company Smidt were released from the contract no sand-filling had been done close to the wreck and they do not know anything about the alleged sand-heap. The only remaining contractor, the gravel-covering specialist Van Oord, has not responded to questions in this regard.

About the observations highlighted in this paper

The observations selected for this paper are those which I have found explanatory to the leak scenario I am presenting. To my knowledge the scenario is not contradicted by other observations.

The Swedish historian Knut Carlquist who, by profession, should be expected to be able to analyze statements, seems to back the observations collected by the German group of experts.

NUMERIC SIMULATIONS

At the workshop two different approaches to the simulations were presented.

- HSVA (Hamburg Ship Model Basin) uses a fluid-mechanical model.
- SSRC (Ship Stability Research Centre) seems to use a more traditional hydrostatic model.

If my understanding of these models is correct, than the first of them may have the highest theoretic potential while the last requires less calculation. At the workshop Dr. Valanto of HSVA informed that their model, in contrast to the more traditional ones, indicate that water will stay quite flush with the deck when ships are moving in waves. Consequently more water would accumulate in rough weather by this model, prior to the low frequency instability of the trapped water becomes overwhelming. At that moment one may assume that the initial roll may be quite huge as the trapped water moves from the unstable 0 heel to one of the two relatively large low frequency lurching angles. This partly explains the big roll & pitch. Furthermore, and generally speaking, one may assume water to accumulate at passenger ships' freeboard decks for many damage scenarios where one at present, assumes water will drain off!

While the behavior of ships and inflow of water through openings in the hull is well known, the Estonia simulations are sensitive to down-flooding trough various openings from the car-deck. Since these are not statically submerged one has to simulate the flow under, beside, in front of, and abaft the trucks due to roll and pitch of the ship itself. This is hardly an easy task and it is far from obvious that the simulations will produce unambiguous results. This was emphasized at the workshop when professor Vassalos, responding to question, pointed that they considered their SSRC-simulator to handle this problem conservatively. However, engineering history proves calculus considered to be conservative, frequently have been far too optimistic. Another question is what is to be considered conservative in a situation like this. Conservative while ruling out a scenario is quite another thing than being conservative proving a scenario to be possible. Consequently various down-flooding models may be needed.

To put above reasoning in other words: When the simulation-model is uncertain one may crudely categorized the results:

1) Despite uncertainties the simulations proves that the ship would sink by the scenario
2) Despite uncertainties the simulations indicates that the ship might sink by the scenario
3) The Simulations of the scenario give no indication
4) Despite uncertainties the simulations indicates that the ship might not sink by the scenario
5) Despite uncertainties the simulations proves that the ship would not sink by the scenario

Scenarios fitting well with observations should fall into category 5 to be ruled out while scenarios fitting badly with observations should be categorized as 1, maybe 2, to be taken into consideration. In my view, based hydrostatic logics as well as rude estimates by an offshore simulator, I will categorize the scenario here presented as category 2.

THE PROPOSED PLAUSIBLE SCENARIO:

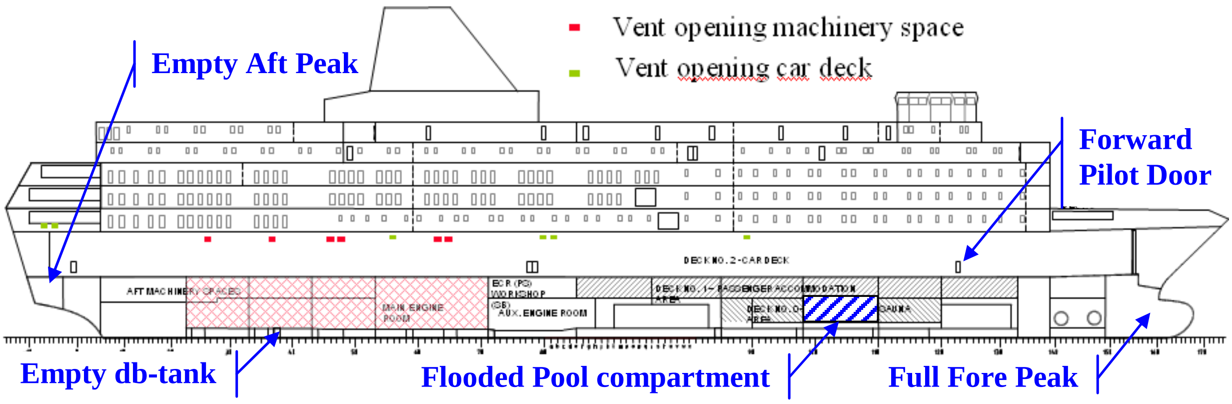

Figure 8: Inflow points according to Chalmers University at the workshop and ballast distribution according to JAIC

The only scenario I find to comply with above observations is as follows: Sometimes during the evening of disaster, the pool-compartment, situated forward at the lover deck, started to leak. Additionally, the leakage beside the bow-ramp seems to have been more predominant on her last voyage (Fig. 2). The sketch by the engineer on duty indicates that the water-level in front of the ramp may have been approx 6m above CWL and the flow seems to have been rather constant [5]. Such flow fits with the observation that the visor was flexing as one may expect the visor was forced open by the wave impact; otherwise closing.

Flooding of the pool compartment would of course make the bow work harder and the pressure on the ramp would be higher than normal. As long as the trim was by stern, the ship could drain water from the car-deck by opening the rear ramp as suggested by the German group of experts. However, sooner or later the ship would be likely to trim by head. Due to starboard heel and the gradient of the car-deck the starboard pilot door would become the lowest point of the car-deck and it would be the best option for additional drainage.

Flooding of the pool-compartment would cause the ship to trim forward entailing the bow to work harder and the inflow beside the bow-ramp to increase. Under such circumstances it seems quite likely that the ship command would discharge ballast from the full fore peak to reduce the pressure on the bow. Though one should have checked the keel for leakage if the water on the car-deck stowed ahead, one may hardly blame the command if they, unknowing of the leakage, attempted to raise the bow by emptying the fore peak and filling the db-tank to reduce strain on the bow. If they really felt they were in hurry they might have ballasted the aft peak as well though this would cause rather great free surface moment.

As previously mentioned the German group of experts has suggested that the forward starboard pilot door was opened to discharge suspect cargo. I find it more likely the door might have been opened to drain water and save the ship. We know, from the Al Salam Boccaccio 98 disaster that such use was at least mentioned [11 & 12].

When the ship command of Estonia learned that water flowed up from the pool-compartment, they must be expected to have started the bilge pump. Though bilge pumps are rather small it is far from obvious it might not have checked such a small leakage as advocated by the German group of experts.

If the leakage was small and ballast as well as bilge pumps were running the ship could have been altering trim by stern thus bringing the water at the car-deck to be distributed over a greater area. Consequently the longitudinal as well as the transversal stability would deteriorate. Simultaneously the bow was weighted down by water inside the visor and, to some extent, water on the forecastle deck. If this water was released during a short period of time, the longitudinal equilibrium could falter and provoke an internal monster wave which would dislocate cargo longitudinally as well as transversally. The centre-casing would combine roll and pitch movements caused by internal water flow on the car-deck because the water had to circumvent the centre-casing.

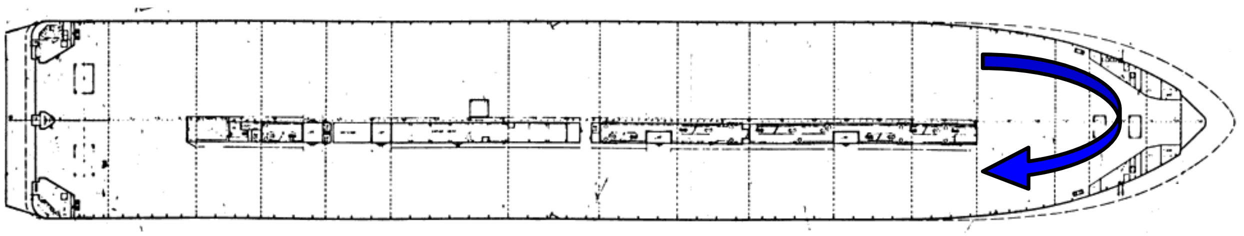

Figure 9: Car-deck & centre-casing. The centre-casing may very well create circular water-flow thus combining the roll & pitch.

A turn, to port, might have been initiated by a wheel order causing the big roll and pitch and subsequent starboard list. However, it might have been the other way around as well. The underlying instability finally initiated the big roll and pitch where after the starboard list initiated the turn to port. The reduced speed and the banana turn indicate that something of the sort happened [8, p. 225]. Reduced speed might have reduced the anti-heel effect and induced roll! It might have brought about pitch as well [3, p36]. How the rudder actually was used is difficult to say as only observations of the wake will indicate the rudder angle. A starboard turn might have been initiated and then, if the ship preferred to go starboard due to heel, the rudder may have been turned by the ship command.

Down-flooding of water from the garage to the lower decks would be by the stairways through the fire-doors which one may presume had been knocked of during the huge roll and pitch. The aft most of these doors had been made flush with the car-deck and very wide in order to facilitate carts to enter the elevator. Consequently down-flooding by this door must be expected to be much higher than by the other doors.

If any pilot doors were open, one may expect that inflow by them and down-flooding from car deck eventually could heel the ship some 40º. Then the ventilators penetrating the hull at the top of the garage would be submerged and inflow would increase (Fig 8). The down flooding of engine-compartments could very well be faster than down-flooding as well as inflow through the hole forward. This could submerge the aft part of the centre-casing with its ventilator shaft and staircases. Consequently the down-flooding rate of engine rooms would increase considerably.

Though some air would be trapped in the engine-rooms this would not necessarily be sufficient to prevent the ship from foundering when the forward part was flooded from the garage and air escaped by the hole in the pool-compartment.

If one is to believe the observations of 6 survivors that the visor was attached when Estonia foundered; somebody dislocated the visor afterwards. The direction and distance of the dislocation seem reasonable if the intention was to make it look like MV Estonia foundered when she tried to escape the weather with open bow. If the bow visor was deliberately dislocated it seems reasonable to believe attempts were done to rip off the bow-ramp and dislocate that as well. This might explain the damage to the bow-ramp. If the pilot doors were open at time of disaster salvage of the ship would surely uncover this.

Very accurate numeric simultaneous or model test might prove the scenario here suggested to bee physically impossible. However, there is hardly any reason to state, by a mere glance at the problem that Estonia could not sink the way she did, due to a rather small forward hole.

Some second thoughts about the proposed scenario.

The scenario above suggested is the one best complying with the information from the German group of experts. However, the suggested sinking scenario is independent of the whereabouts of bow visor and the ramp. Consequently a modification could be suggested:

> **MV Estonia headed up against rough weather at full speed with her bow visor flexing and her ramp leaking severely. Some of her pilot doors at leeward were kept open to drain water from her car-deck and ballast as well as bilge pump was used to trim her by stern. The bow-ramp was never lowered and the damage below the ramp was due to cargo operations prior to the voyage. The visor might have been knocked off causing the ship command to turn the ship or it might have been the other way around. The ship command, knowing about the leakage, was forced to turn and the turn itself started the huge heel and the visor was knocked partly off by wave forces combined with huge roll & pitch.**

The lack of a reasonable sinking scenario combined with the general distrust of the investigation seems to have nurtured many speculations regarding manipulation of the wreck. Most of these are unimportant to the international ship stability expertise and should not be included in this paper. However, if sand was filled below the forward part of the ship to hide evidence and prevent erudition this should concern us.

THE HUMAN FACTOR

JAIC assumed that Estonia maintained course and speed up against the weather when ship command should be able to observe at the monitor that the bow-ramp was totally open. I am not convinced this is the only plausible hypothesis regarding the course of action. I find it more likely that ballast might have been used and that a pilot door might have been opened. Another fair presumption, if the situation developed slowly, is that ship command telephoned superiors for advice.[1] If this was the case we should expect it happened no later then the bilge pumps were started and a weak, tentative MayDay was heard. Radio-logs of coastal and satellite radios should be able to indicate the answer to this question. Unfortunately, radio-logs by the Swedish high command may have been lost [8, p169].

Human factors might as well have influenced the examination of the scene of disaster itself since it could not follow any national structure of investigation. The Swedish historian Knut Carlquist describes the Estonia investigation as rather strongly influenced by political control [8, $5].

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[1] As far back as 1978 the captain of Amoco Cadiz realized the utility of modern communication when he requested the company whether or not he could engage tugs.

- At the evening of disaster the Swedish government decided that the word salvage should not be used as it could be interpreted as salvaging the ship [8, p166]. Furthermore the prime minister indicated bow failure might have been the cause. The Swedish director of maritime safety pointed that Sweden was not ruled by ministers and he called attention to the importance of the independence of the authorities [9, p. 63]. He further argued that the ship had to be salvaged; *700 persons are still there and it would be remarkable if they are to find their final rest in the ocean* [8, p 174]. According to Knut Carlquist the prime minister let a former public prosecutor hang the director and the director was transformed to a non-person over night.
- Since the prime minister to become promised to salvage the ship above decision should not have been of any importance (the sitting government lost the election shortly prior to the disaster) [5]. However, when taking office the new prime minister appointed an Ethical Board as an alibi in the salvage conflict [8, p. 183].
- Shortly afterwards the director of maritime safety was squeezed to resign his commission.

Apart from the influence of political command the naval architects investigating the disaster might as well have been somewhat predetermined as they surely should have foreseen another Herald of Free Enterprise disaster. That is; the Swedish / Finish deviation from international rules invited for such a disaster and it had been forewarned by the DIANA-II incident [2 $11.3]. Though the investigators might not have known about the DIANA-II incident prior to the Estonia disaster they definitely did so during the investigation. Self-acting remorse by the Swedish Finish naval architectural community is surely understandable, but the investigation might have been severely hampered if design rather than observations were put at focus. The lack of correlation between proposed naval architectural scenarios and observations has later been noted of by the Estonian Assistant Director of Prosecutions [5]. Similar problems seem to have burdened the MV Rocknes investigation as well [13].

CONCLUSION

1) The scenario here presented seems to be in harmony with most witness observations and it should be considered plausible until it has been proven impossible by detailed simulations.
2) Important evidence could have been secured if the ship had been salvaged.
3) Seafaring authorities are advised to act precautionary and to do their outmost to inform mariners of the potential hazards of drainage by pilot doors [14].
4) The recommendation of the Egyptian Technical Committee that drainage systems of car-decks should not be based on gravity only seems well motivated [15].
5) Relevant authorities are advised to investigate if huge amounts of sand have been filled under the wreck.

AUTHORS' BIOGRAPHIES

Rolf C. Imstøl, a former merchant officer, holds the current position of head of the marine technical department at Bergen University College. Furthermore, he acts as marine technical & nautical consultant for solicitors working on behalf of many bereaved as well as some survivors in the Al Salam Boccaccio 98 and Rocknes cases. He has previously published a set of articles regarding the Rocknes capsize as well as a harbinger to this article; Accidents Involving Passenger Ship Stability [13 & 16].

REFERENCES

Communication between Swedish Authorities and Stolt Comex Seaway (Norwegian /Swedish), The Swedish Public

Record Office.

Joint Accident Investigation Committee, Final Report, Estonia 1997.

The German group of experts, Investigation Report #1 (Swedish), Ahlers & Vogel, Hamburg 1997.

The German group of experts, Investigation Report #2, http://www.estonia.xprimo.de/estonia/index.html

Lars Borgnäs, The truth at 80m depth (Swedish), Swedish National Broadcasting, Stockholm 2007

Swedish Governmental Decree, June 19th 1996.

Håkan Bergstedt, Swedish Criminal Technological Laboratory, March 22 2007.

Knut Carlquist, the Silent Game (Swedish), Stockholm 2001.

Mats Holm & Susanna Popova, the Protocol (Swedish), Finland 2003.

Ander Björkman, Disaster Investigation, July 2007: http://heiwaco.tripod.com/ekatastrofkurs.htm

Voices from beyond the grave echo doomed Red Sea ferry's final hours, Lloyds List 24th of July 2006

Black box transcript reveals four hours of confusion and fear as ferry sank, Lloyds List 24th of July 2006

Rolf Imstøl, The capsize of MV Rocknes, Norwegian Technical Review, Oslo 2005

UNESCO, The Precautionary Principle, March 2005

The International Technical Committee formed to Investigate and Analyze the causes for the sinking of the Ferry ASSALAM BOCCACCIO 98 in the Red Sea in February 2006, Technical Report, Egypt 2006.

Rolf Imstøl, Accidents Involving Passenger Ship Stability, The Design and Operation of Passenger Ships conference, London 2007

Link to the authors Estonia home-site

http://home.hib.no/ansatte/rci/Estonia