

WBA of the Royal Majesty Accident

Derived from NTSB Report NTSB/MAR-97/01

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Acknowledgements

- The construction of the List of Facts from the NTSB Report was performed by Heidieker, Hoffmann, Husemann, Paller, Sanders, Stuphorn and Vangerow
 - with a little help from the man in the corner
- The WBA was performed by the same team
 - with much less help from the man in the corner
- Husemann and Stuphorn used credit to draw the graphs
 - with a lot of help from the man no longer in the corner

The Royal Majesty, as she was



Planned and Actual Course

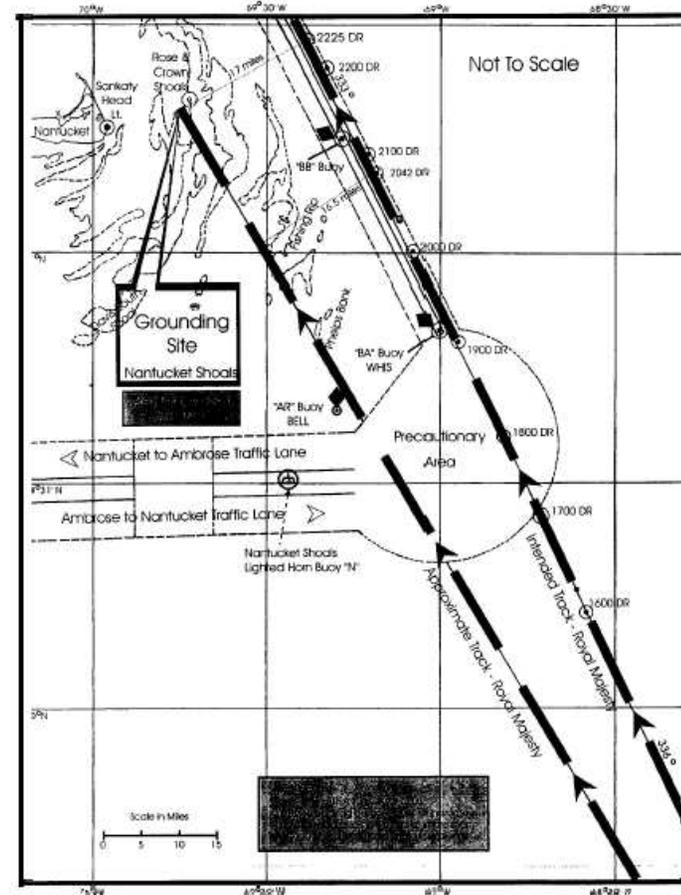
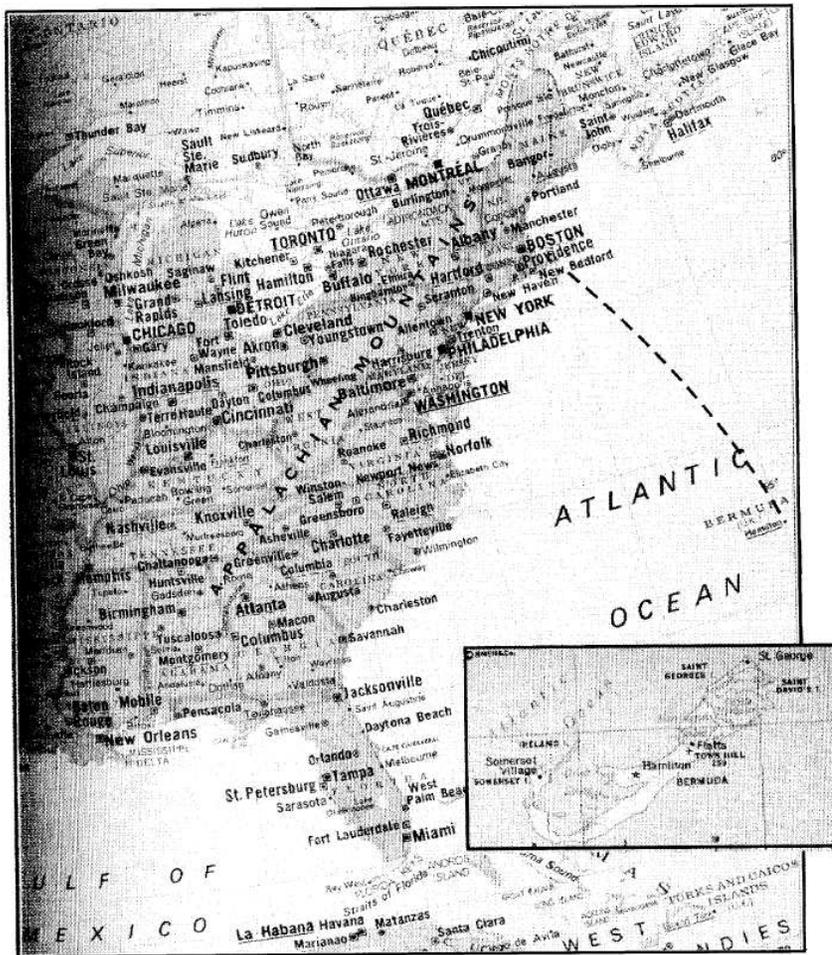


Figure 5-intended track and approximately actual track.

What Happened

- Cruise ship Royal Majesty left St. George's, Bermuda on June 9, 1995 ~12:00 en route for Boston, MA
- GPS antenna cable separated from antenna shortly after departure
- Ship under control of autopilot NACOS 25 for the voyage
- GPS delivered dead-reckoning data throughout, which was followed by the autopilot
- Fathometer alarm had been left at 0m instead of standard 3m

What happened

- Ship ran aground some 34 hours later, at 22:25 on June 10, on the Nantucket shoals, some of the most dangerous water for general shipping in the world, some 17 miles west of course

What Else Happened

- The autopilot was expecting either no data, „nulled“ data, or unchanging data, when the GPS was not functioning properly
- The GPS, though, set the *valid/invalid* bits in the data stream to indicate invalid data
- It was procedure to check GPS against Loran-C data hourly. No one appears to have noticed the presumed discrepancy of up to 17 miles
- Buoy passage was incorrectly reported
- Traditional watch anomalies were ignored („blue and white water“, later, fixed lights where none should have been)

Royal Majesty high and dry



List of Facts

- Derived directly from the body of the NTSB report
- Additional points were added, through
 - Logical inference (ConsInf)
 - Structural construction, as in classification (ConsStruct)
- ~100 individual facts listed

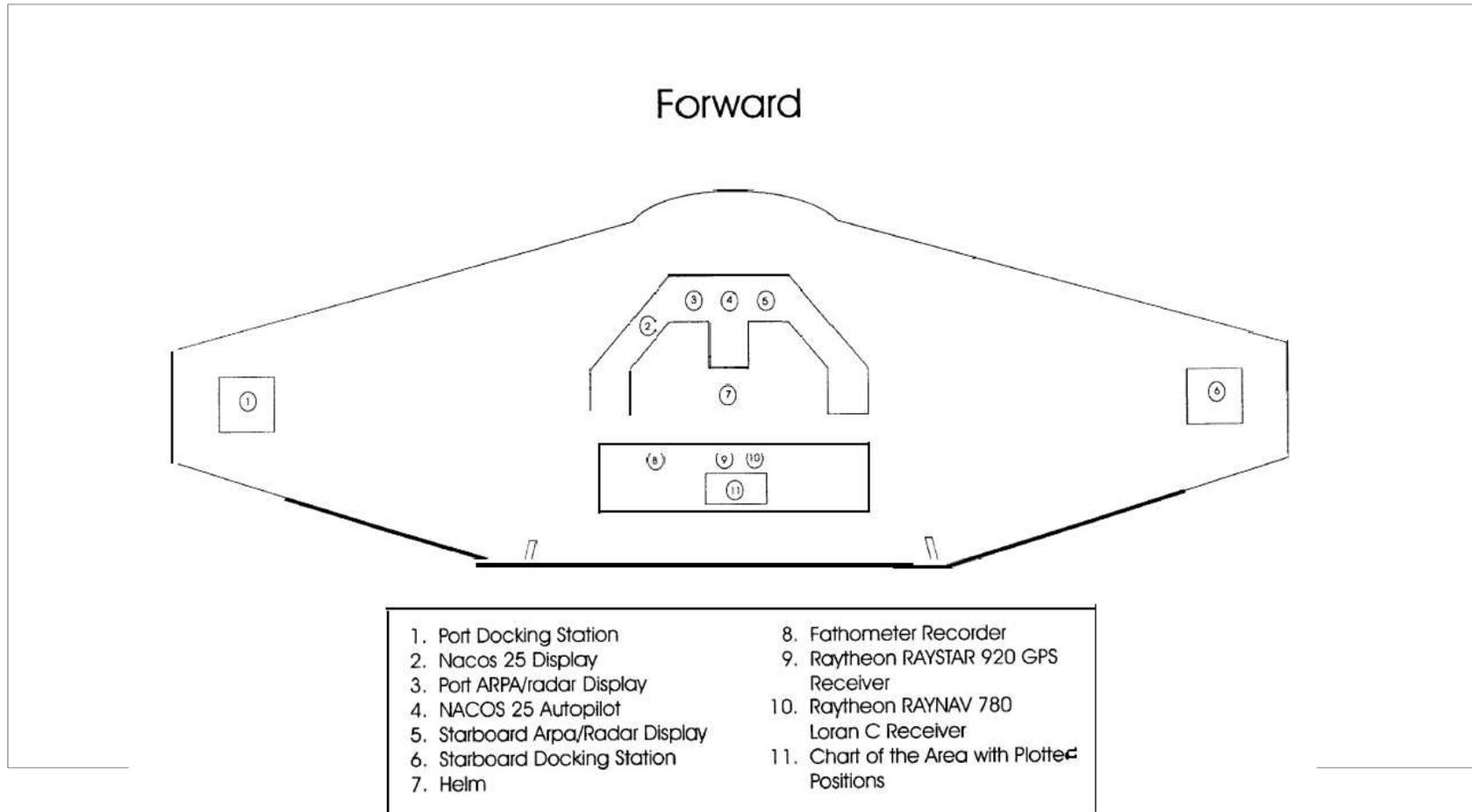
WB-Graph

- 67 nodes (medium to large)
- Divided into 6 subgraphs with „connectors“
- Performed graph reduction
 - Select a partition of the graph
 - Change paths to edges (edge relation becomes that of Lewisian „cause“ rather than that of Lewisian „causal factor“)
- Attempted reduction to match NTSB statement of Probable Cause

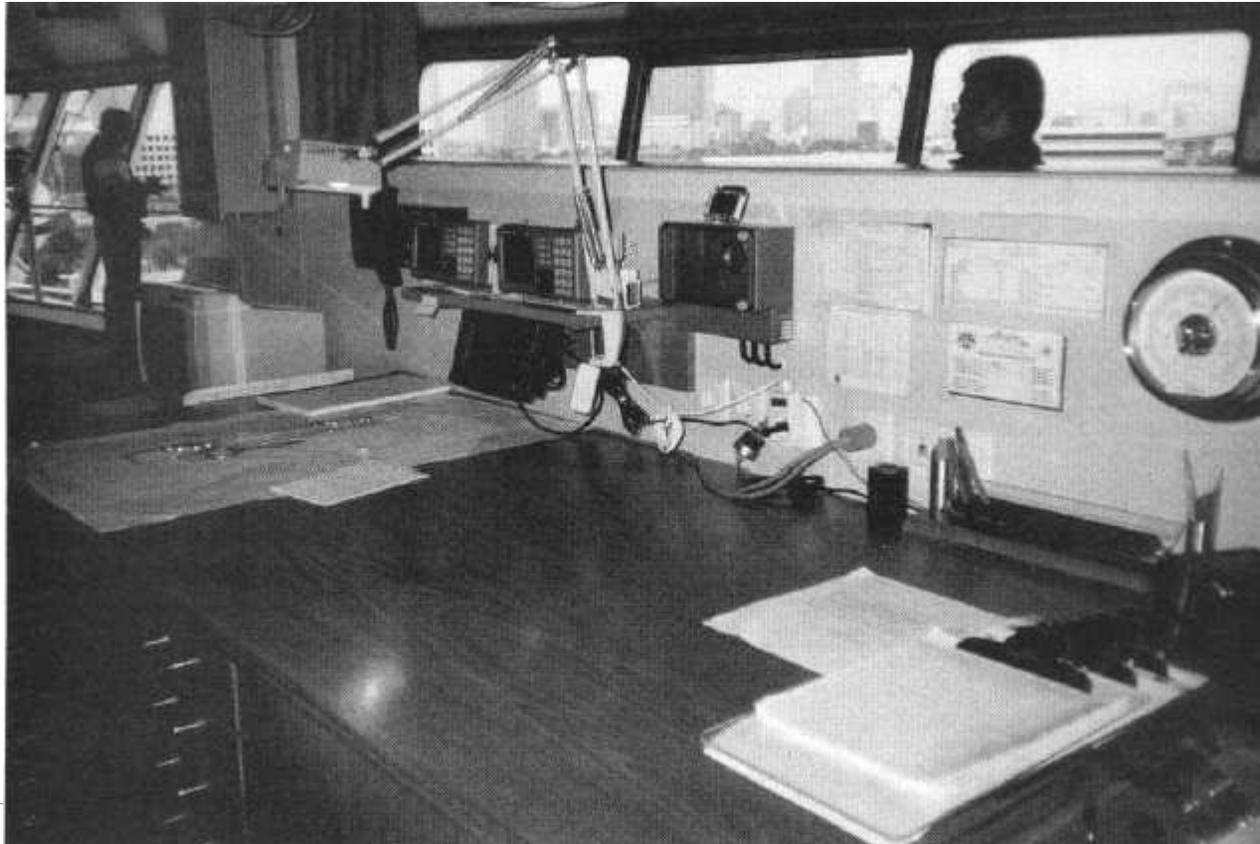
WB-Graph

- Found two discrepancies
 - Incomplete data-transfer specification (NMEA 0183) for IBS
 - Faulty setting of fathometer alarm was a causal factor but not enumerated

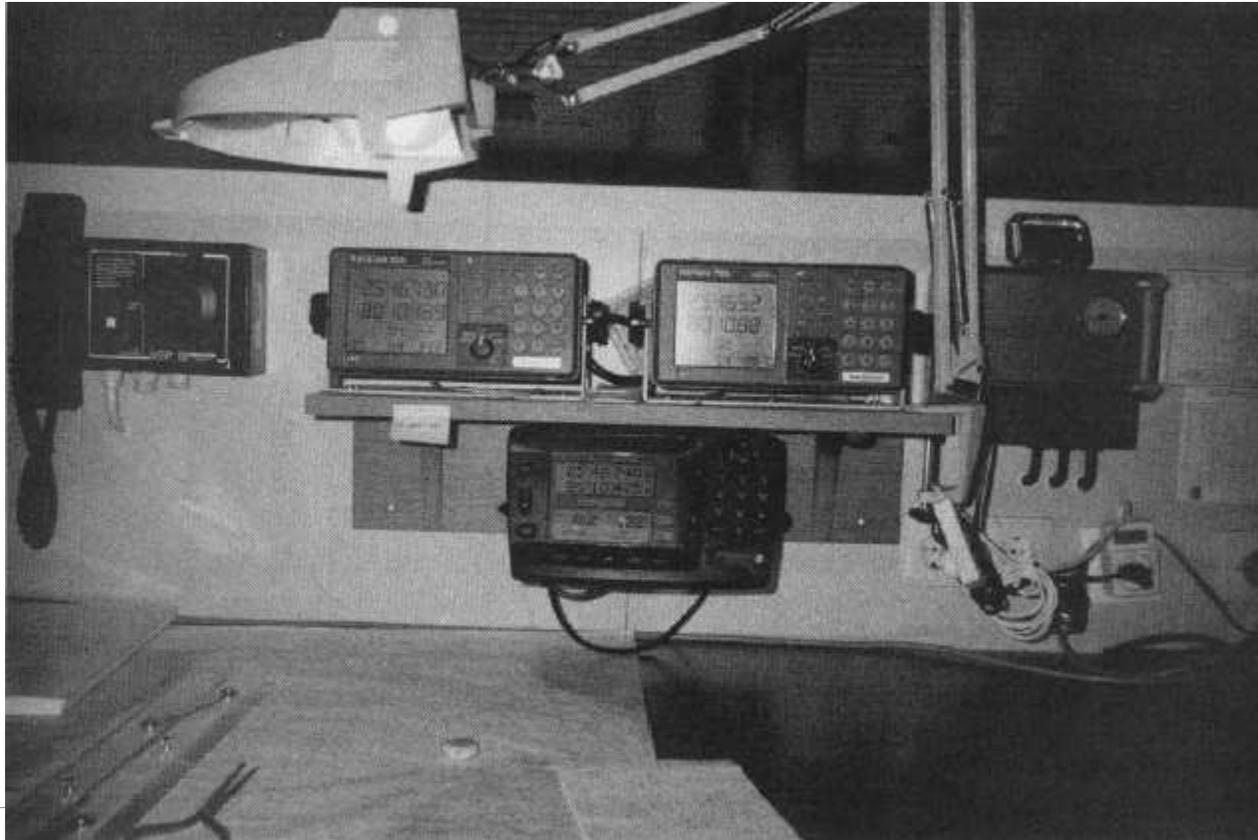
The Bridge Layout



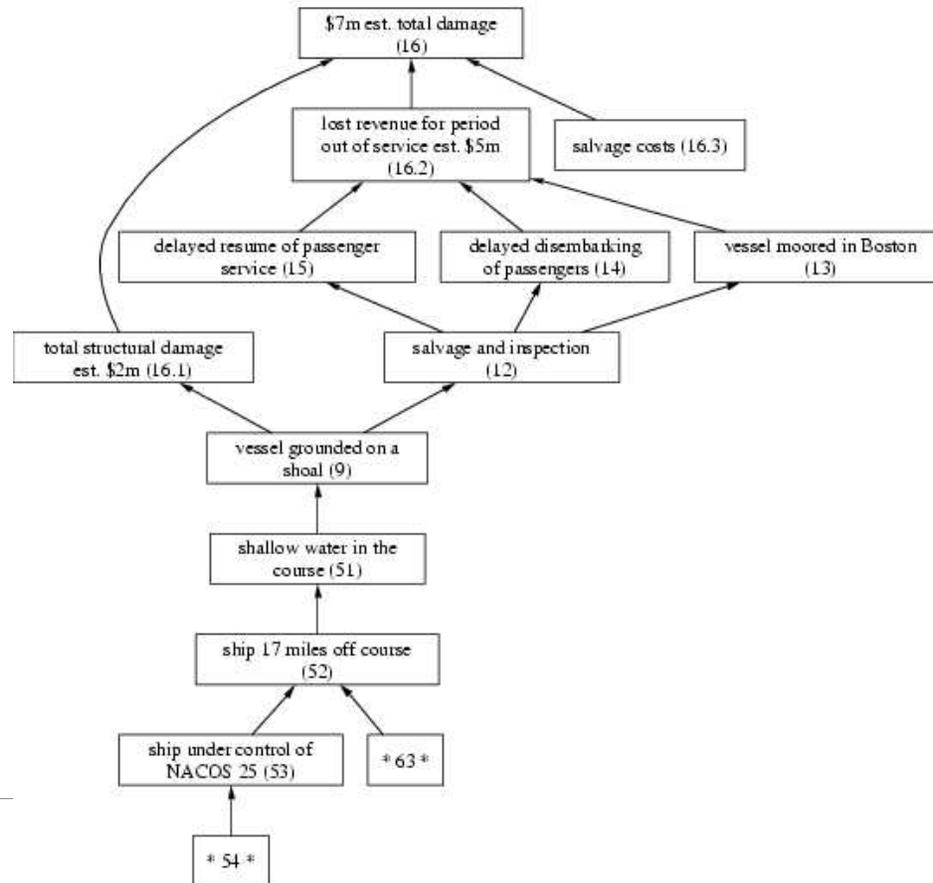
The Bridge, from the Chart Room



Integrated Bridge System displays in Chart Room



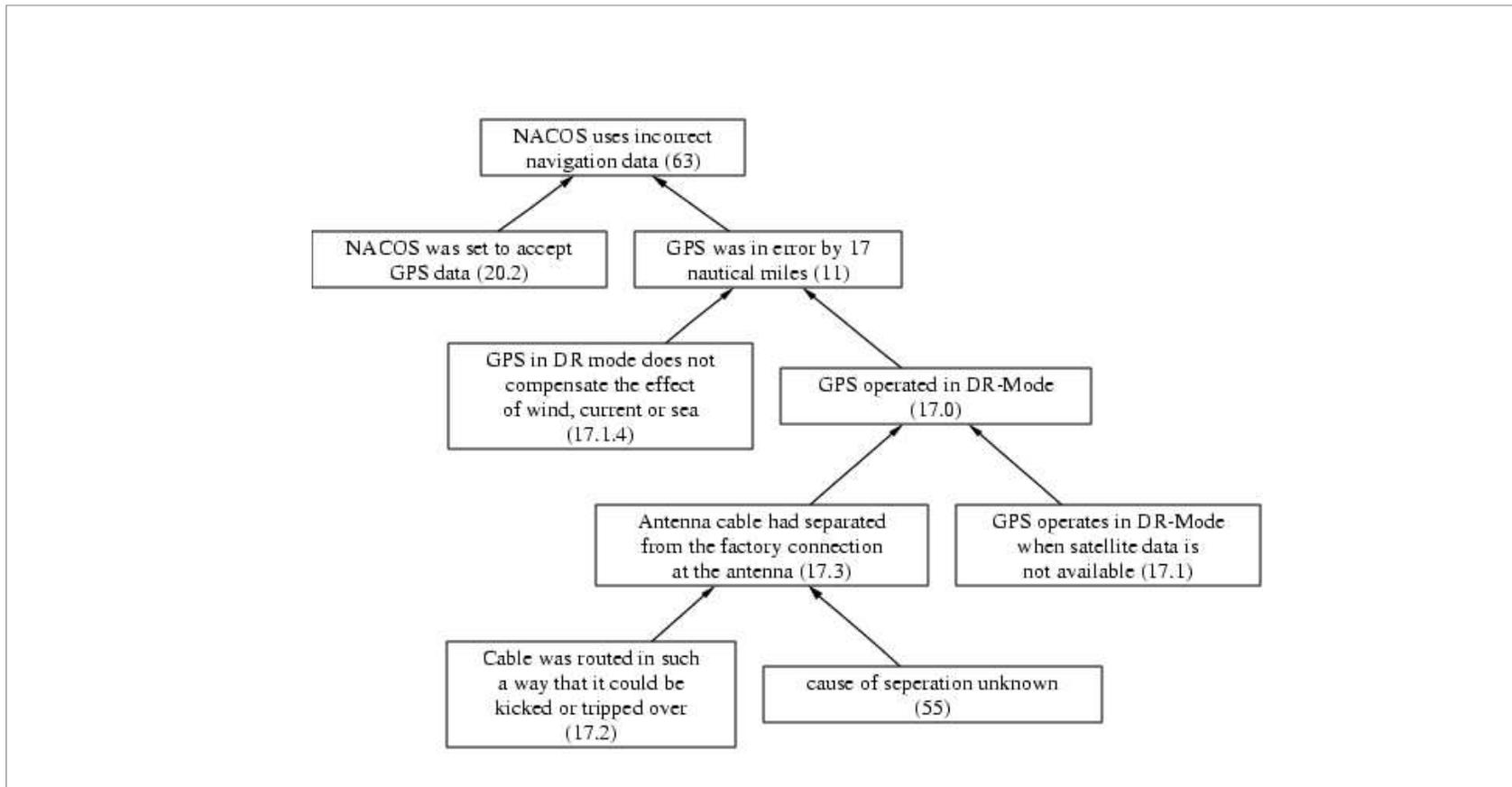
The WBG



The WBG – Commentary

- The top level of the WBG is fairly self-explanatory
 - The formal definition of why it was an accident
 - Costs incurred through salvage and loss of revenue
 - The proximate reason why it occurred
 - Ship was off course
 - The proximate reason of the proximate reason
 - Ship was under control of the autopilot
 - Autopilot receiving inappropriate nav data

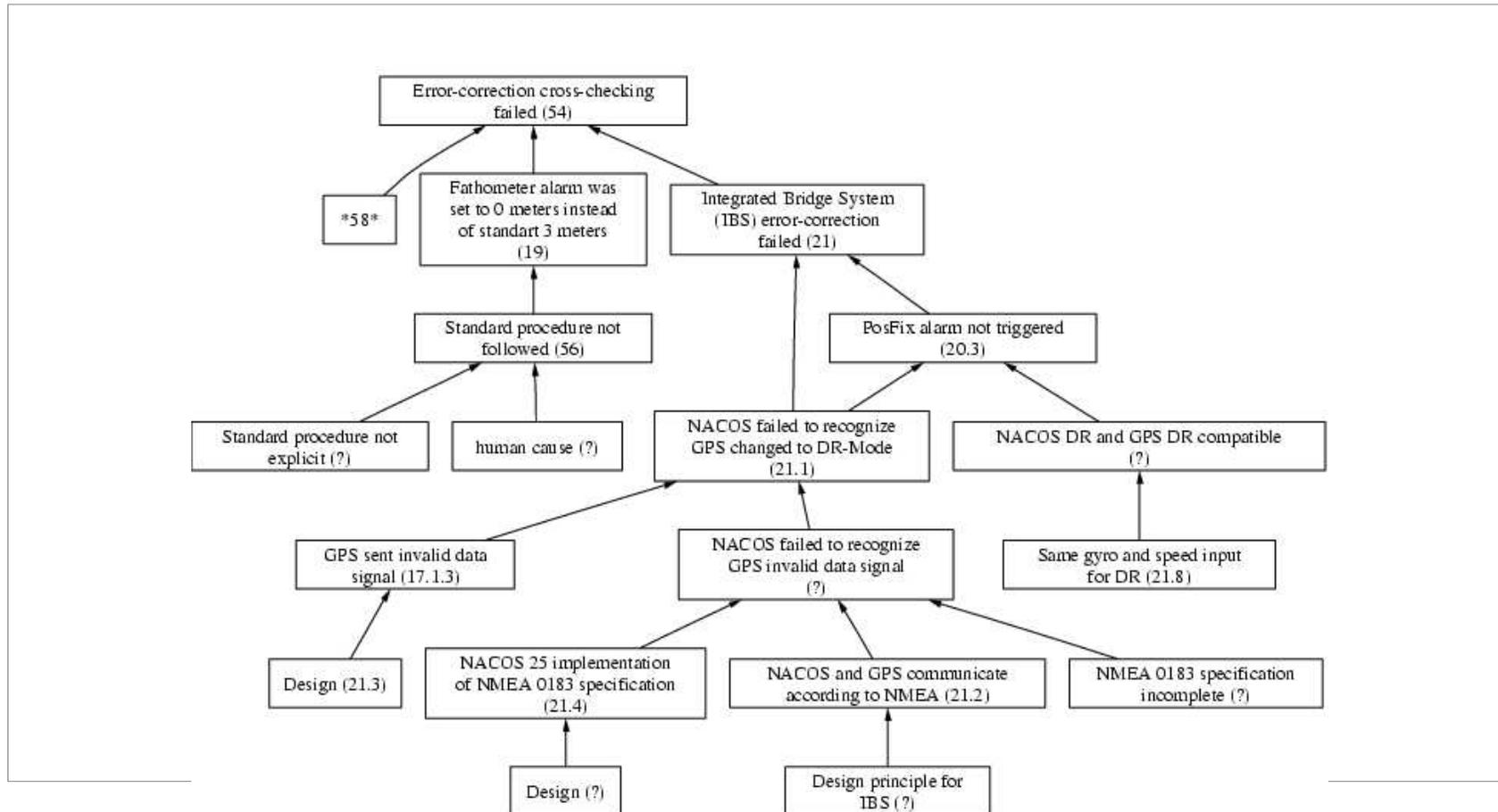
The WBG, Subgraph from Node 63



WBG Node 63 Subgraph – Commentary

- Also mostly self-explanatory
 - The autopilot was getting inappropriate data because it was listening to GPS and GPS data was faulty
 - Note that the failure to check by the crew does not appear here. Should it?
- GPS data was faulty because GPS was operating in dead reckoning mode and this mode does not compensate for various physical effects (wind, current, sea)
 - It is presumed that such effects pertained. In any case, that the dead reckoning data were so far off the actual position was not felt to need further explanation.

The WBG Subgraph from Node 54



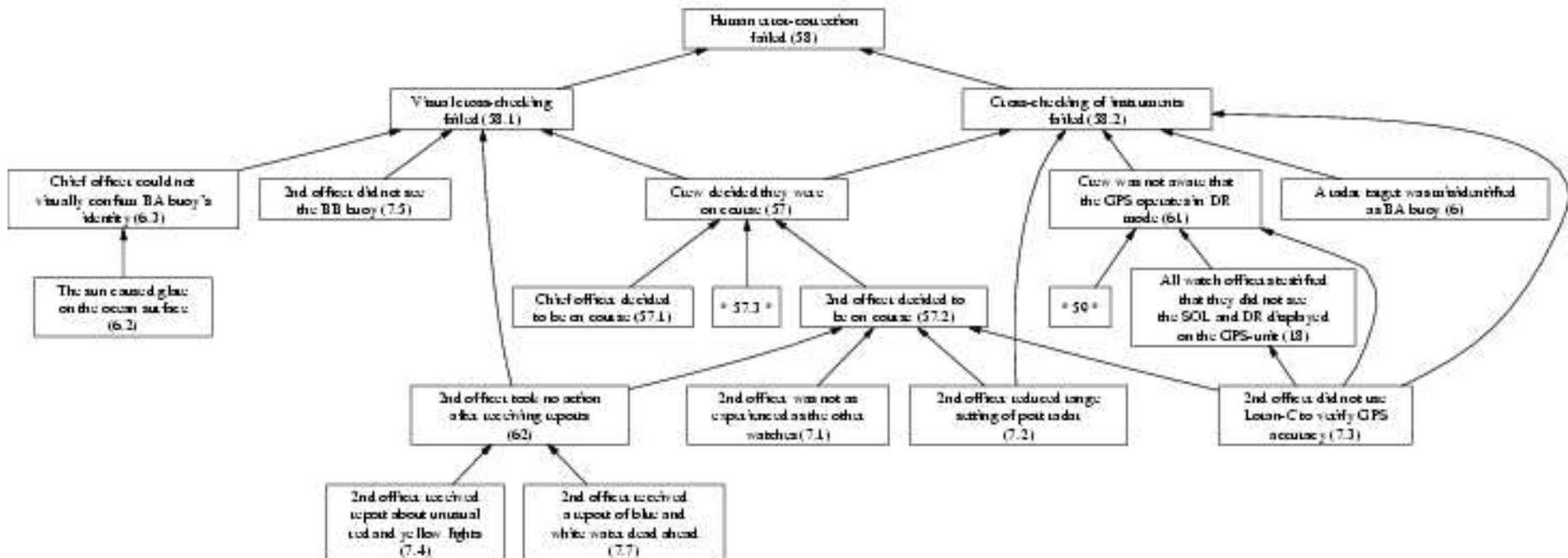
The WBG Node 54 Subgraph – Commentary

- The error cross-checking is both human-operator and digital
 - They involve separate mechanisms so are split
- The digital checks failed because the NACOS 25 and GPS were not communicating compatibly
 - GPS was sending data and signalling invalidity on special bits according to specification NMEA 0183
 - NACOS 25 was not listening to those bits
 - It was expected „bad data“ to mean: no data, or nulled data fields, or constant data
 - The NMEA 0183 specification apparently allowed this situation to pertain

The WBG Node 54 Subgraph – Further Commentary

- The fathometer alarm was left at 0m (the setting for port, to prevent nuisance alarms) and not set to the under-way value of 3m
 - Had it been so, the ship would have had plenty of warning that it was entering shallow water, instead of being in the deep channel
 - The NTSB believes this warning would have been sufficient to avoid the grounding
- There was also a failure of traditional seamanship and of human cross-checking of the automation (Node 58)

The WBG Subgraph from Node 58



The WBG Subgraph Node 58 – Commentary

- Two specific actions of the 2nd officer seem to have significant causal effect on a lot of nodes
- How the 2nd officer decided they were on course receives a lot of attention. However, how the chief officer decided they were on course does not appear to be further investigated
 - The 2nd officer was the watch officer at the time of the grounding
 - It may have to do with the fact that the NTSB decided the 2nd officer was lying:
 - he cannot have seen any buoy which could have corresponded to the BB buoy, which he reported as having passed.
 - He claimed to have checked the GPS (against Loran) and found it „on track“

The WBG Subgraph Node 54 – Further Commentary

- The 2nd officer was lying
- He was also „less experienced“ than the others
- He was disciplined. He was the only person obviously disciplined
- However, the previous watch officer (chief officer) had also failed to check GPS hourly, as per procedures
- The chief officer had also incorrectly identified the BA buoy (it was sighted against the setting sun and there was glare on the water – but he must have known this lowered the chances of identifying properly)

The WBG Subgraph Node 54 – Further Commentary

- None of the crew was aware that the GPS was operating in DR mode
 - It was in the chart room and the display was out of sight
 - The „DR“ mode indication on the display was tiny
 - The DR mode aural alarm sounds only for a brief time and is in the chart room, not on the bridge central console where the watch officer stands
 - Still, cross-checking against the Loran is required, and was evidently not performed
 - It is presumed the Loran was indicating accurately; the area where they were is very well covered by Loran signals

The GPS Display

- A challenge:
 - Find the „DR“ notification

The GPS display

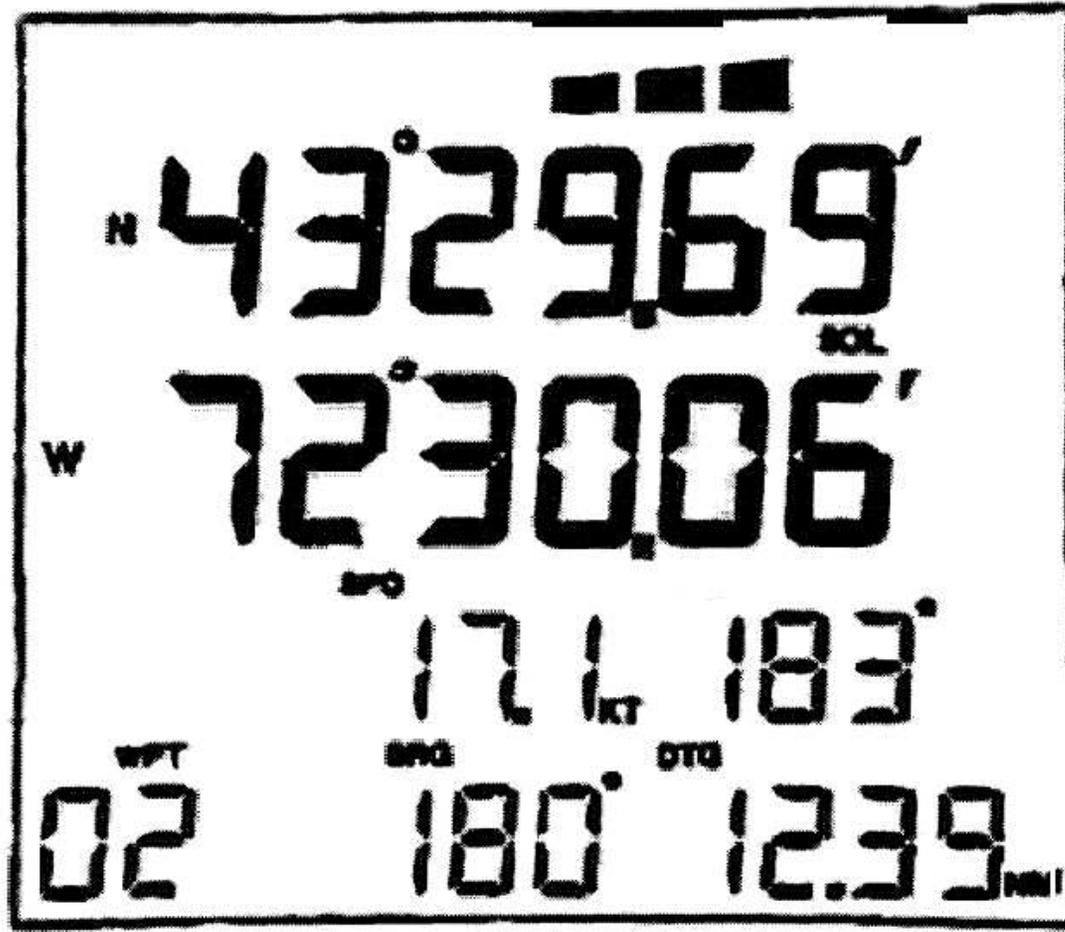
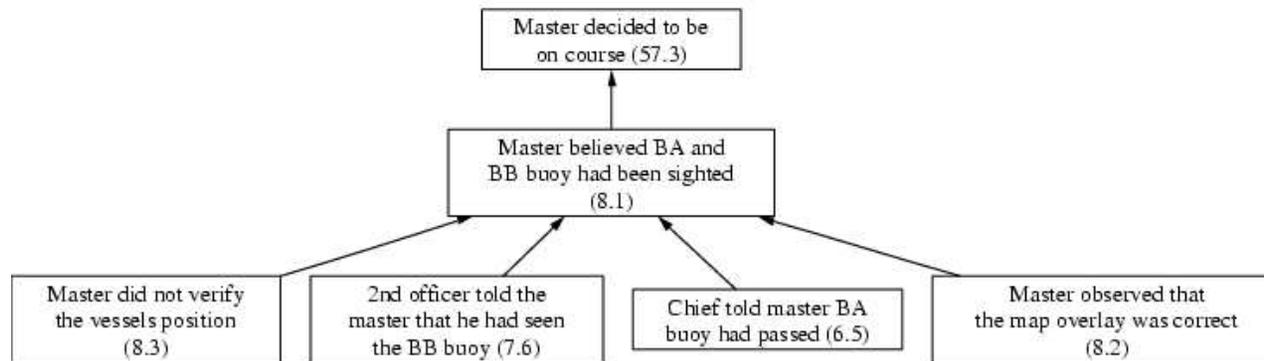


Figure 8—GPS display showing SOL and DR.

The WBG Subgraph from Node 57.3



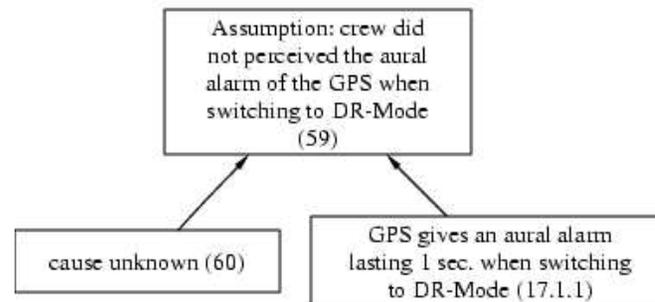
The WBG Subgraph Node 57.3 – Commentary

- The master just listened to what he was being told by his watch officers
- He did not himself perform anything other than cursory checks
- However, many of the clues that the IBS was not operating as desired were available to him also
 - He had no way of knowing that the buoy sightings were deficient
 - He had no way of knowing of the visual anomalies except through the 2nd officer reporting them, as procedures say he should

Procedures for the Watch Officer

DUTIES OF THE OFFICER ON WATCH	OPS	3
<ol style="list-style-type: none"> 1. The paper work required during the watch is to be done on the bridge done in the bridge, never in the chartroom. When you need to go to the chartroom you should be brief. 2. Smoking in the chartroom is not allowed. 3. One quartermaster is to always be on the lookout position. 4. Check the compasses during your watch twice, and enter the readings in the relevant book. Check the course, the position, navigation lights, traffic in the area, course and distance of ships in the vicinity before you take over the watch. 5. Check the compass error at least once during your watch (weather condition permitting) and enter the readings in the relevant book. 6. Check the ship's position as often as conditions and circumstances allow, but never longer than 30 minute intervals. 7. You summon the Master to the bridge when: <ol style="list-style-type: none"> a) The visibility is less than 5 miles. b) The wind changed direction, which could cause drifting from course. c) Another ship is crossing the bow and the bearings are steady. d) You have doubts about the position. e) Traffic is congested or ship is about to pass dangerous areas. 8. If the Master is not in his office and cannot be found immediately, use the P.A. system by saying "THIS IS THE BRIDGE" Never say "THE CAPTAIN IS REQUESTED ON THE BRIDGE." 9. In case of fog, after you have summoned the Master to the bridge, do the following: <ol style="list-style-type: none"> a) Engines on "stand by." b) Radar "on." c) Whistle "on." d) Switch from auto pilot to hand steering. e) Close the watertight doors. f) One quartermaster on the "lookout" position on the bridge and one AB at the bow. g) Plot the course, position, and speed of all ships in the vicinity. h) When the fog has cleared, recall all above actions. 10. Never pass another ship, land, or any other object less than 1.5 miles distance. 11. Start maneuvering the ship to avoid a collision, never less than 3 miles distance. 12. Close all the portholes and headlights during bad weather conditions. 13. One radar is to always be "ON" if the conditions require so. Relevant entry is to be made in the radar book. 14. Never leave your position before you are relieved by the Officer of the next watch. 15. Always be alert during your watch. 	CIRCULAR NO. 9 PAGE 3	
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The WBG Subgraph from Node 59



NTSB Conclusions

- 22 conclusions overall, non-exclusively classified as follows:
 - 6 are a conjunction of WBG nodes
 - 11 are assertions of causality, including subgraphs of the WBG
 - 3 are inferences from the List of Facts or from the WBG
 - 1 refers to faulty or faultily-executed procedures
 - 1 is an assumption
 - 2 are design recommendations
 - 8 are deontic assertions
 - 2 are epistemic assertions

Deontic Assertions

- 7 conclusions are deontic assertions
 - These are not statements of causality alone
- The goal of an NTSB investigation is to make recommendations to be followed in the future
 - it is natural that these be based on deontic judgements
- A WBA is purely a causal analysis
 - Deontic judgements do not obviously follow from purely causal judgements

Probable Cause (NTSB)

- Watch officers' overreliance on the automated features of the IBS
- The implications of this automation for bridge resource management
- Deficiencies in design and implementation of the IBS
- Deficiencies in procedures for operation of the IBS
- 2nd officer's failure to take corrective action on report of anomalies

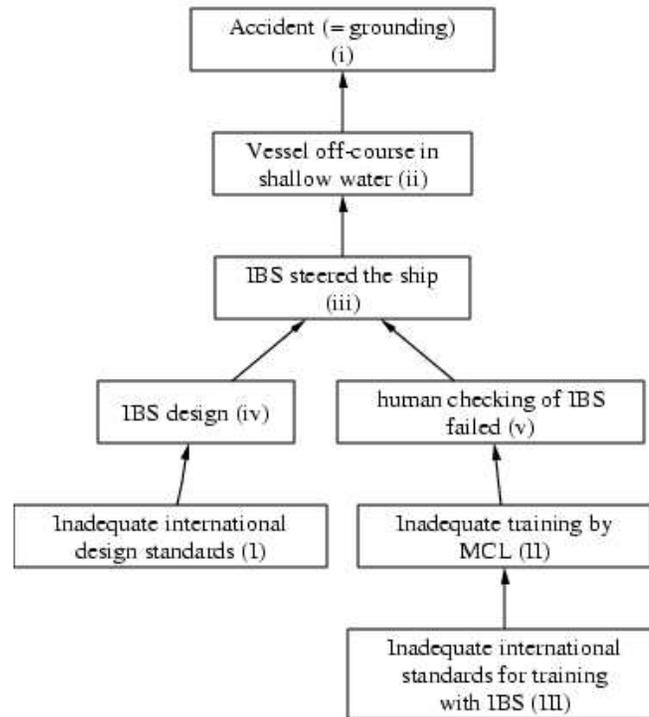
Contributing Factors (NTSB)

- Inadequacy of international training standards for watchstanders aboard IBS-equipped vessels
- Inadequacy of international standards for the design, installation and testing of IBS's

Comments

- Contributing Factors are two statements
 - One found in the Conclusions, but not in the body of the report
 - One found neither in the Conclusions nor in the body of the report
- A causal factor of the grounding, that the fathometer alarm was inappropriately set, appears nowhere in the Probable Cause, nor is it subsumed therein
- A necessary cause, that the NMEA 0183 specification is incomplete in certain essential respects, is not subsumed in the Probable Cause
- These observations follow by WBG-reduction and comparison

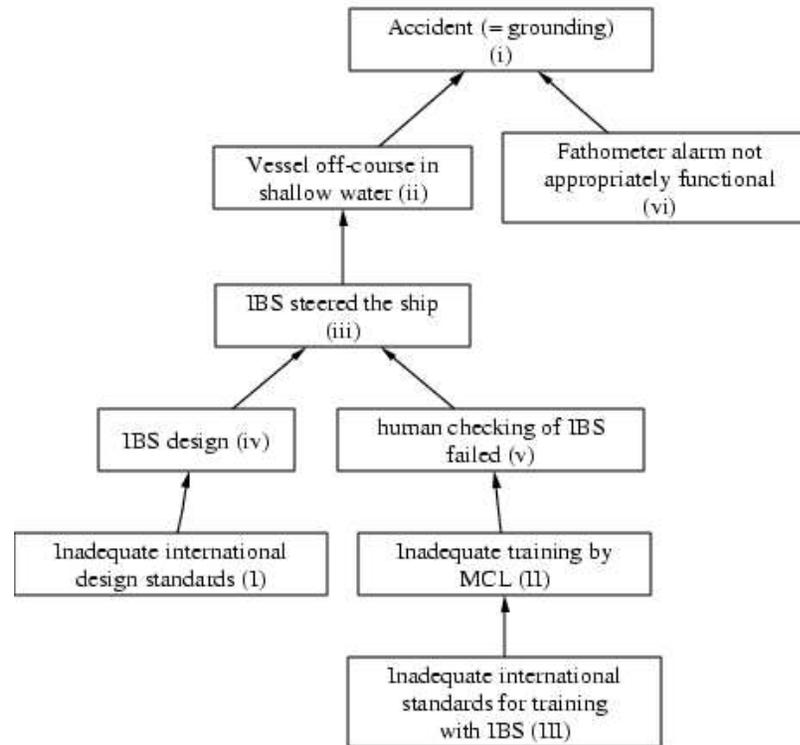
The WBG according to the NTSB



The NTSB WBG – Commentary

- Some of these nodes appear for the first time here (they are not in the report body; they are not in the Conclusions)
 - It may be appropriate to require that any fact appearing in the Conclusions is contained in the report body (under Analysis, for example)
 - It may be appropriate to require that any fact appearing in the statement of Probable Cause appear in the Conclusions
- Besides that, there is a mistake. A factor is omitted

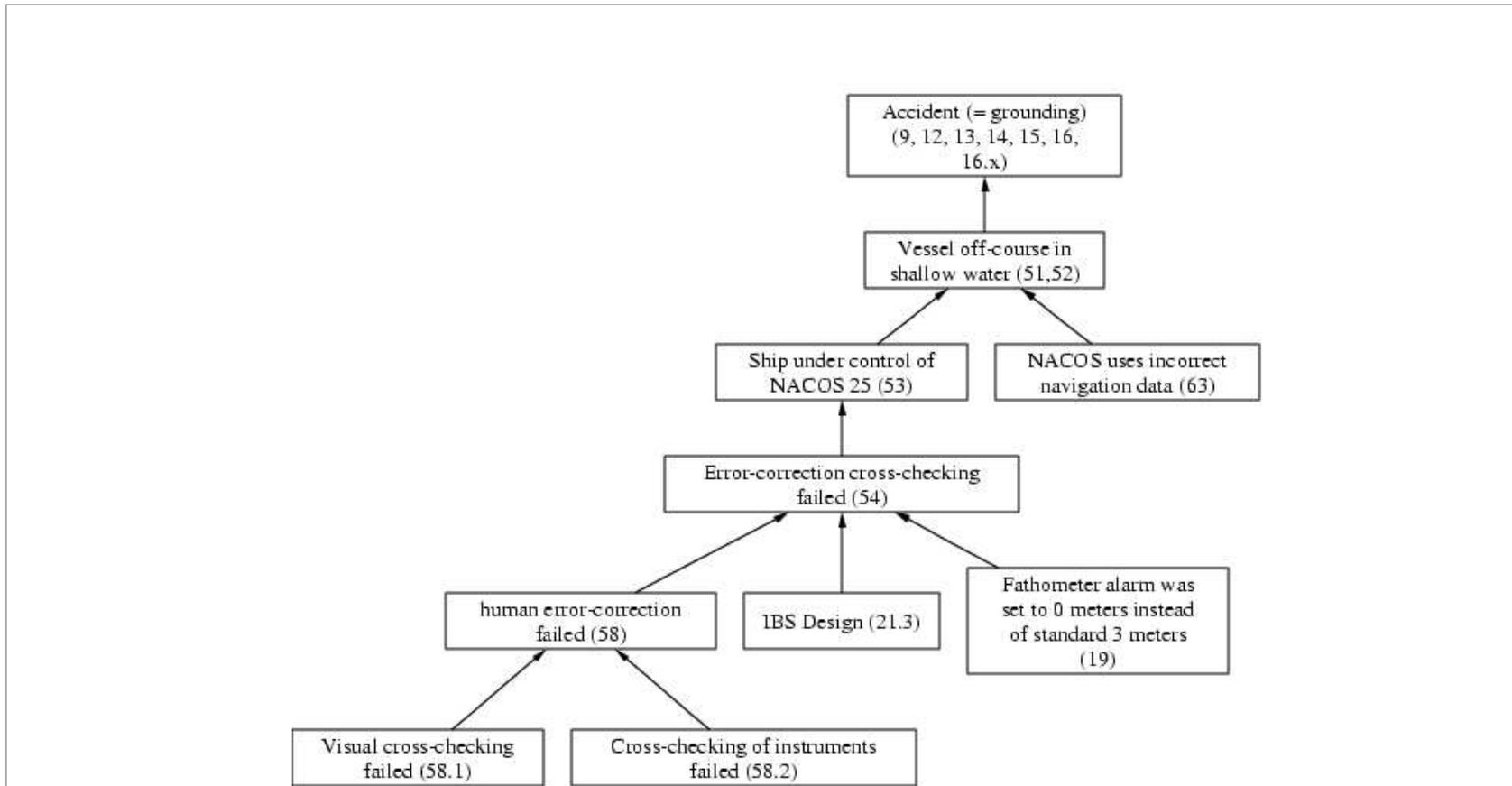
A Plausible WBG Reduction With the Extra Nodes



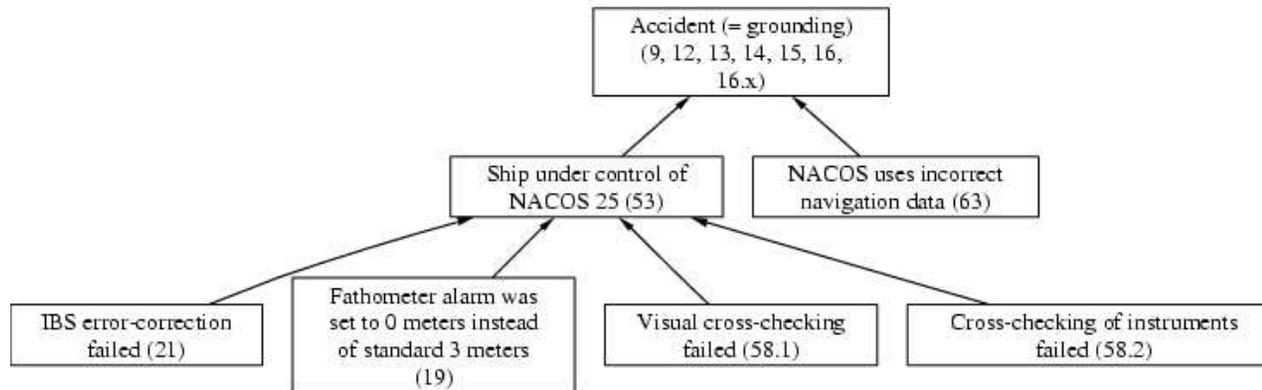
Plausible Reduction – Commentary

- That the inappropriate functionality of the fathometer alarm was a causal factor in the grounding is determined directly through the Counterfactual Test
 - Had the alarm been set to 3m, warning would have been given in adequate time to take evasive action
- However, this is not the assertion concerning the fathometer alarm that appears in the report body or Conclusions
 - It appears their positively: it was set to 0m
- Positive and negative formulations of the same „fact“ have different causal relations!

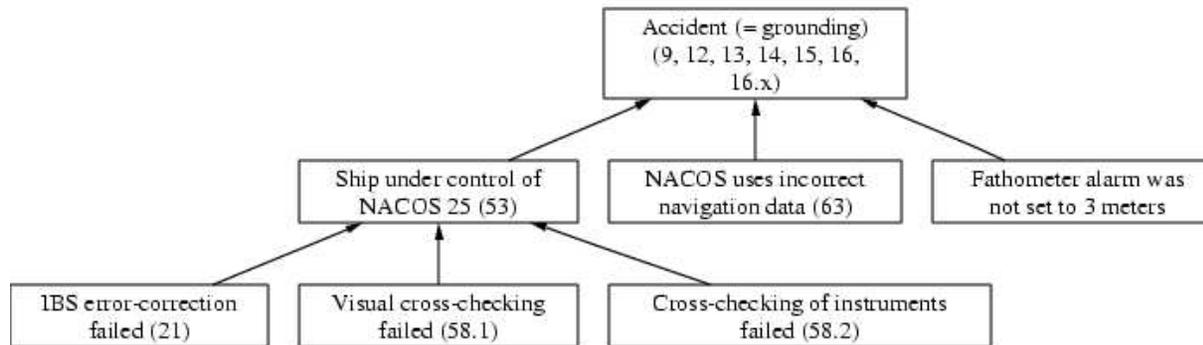
A WBG Reduction



A Further WBG Reduction



The WBG Reduction with „Negative“ FathAlarm



Remaining Questions

- A reduction is a removal of nodes
 - In the reduction, edges represent paths in the original WBG
 - The reduced graph must partition the original WBG; that is, every causal path through the original WBG must pass through some node in the reduction
 - These „key nodes“ must be chosen somehow
- Do any of these reductions appear to be a plausible summary of the WBG?
- If so, how, formally, is the reduction generated?

More Observations: the Physical Cause

- Neither the NTSB Probable Cause nor the (reduced) WBG correspond directly to an intuitive assignment of cause:
 - The ship grounded because the autopilot put it there
 - The autopilot put it there because of inappropriate use of data
 - The data did not indicate the correct position because the GPS antenna was uncoupled

More Observations: Human Contributions

- Additionally, there are things that „should have happened but didn't“
 - The crew should have cross-checked the equipment: GPS against Loran at least hourly
 - The fathometer alarm should have been set at 3m
 - The crew should have identified the buoys accurately (or at all!)
 - The crew should have paid attention to visual anomalies traditionally indicating that the vessel was potentially off-course

More Observations: Indirect Human Contributions

- Some „off-line“ or indirect human failings were
 - That the crew were not adequately trained in the intended operation of the IBS
 - That the crew may well have suffered from „automation complacency“
 - NMEA 0183 specification was inadequate, and inadequately implemented
 - System integration left, um, something to be desired