Analysis of the Royal Majesty Grounding Using SOL

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Overview

- Introduction
- Accident overview
- Points of note about the accident
- Post accident testing revelations
- Analysis using SOL
- Comparison with NTSB & WBA investigations
- Conclusions

Introduction

- SOL - Safety through Organizational Learning
- Developed by Babette Fahlbruch and Bernhard Wilpert at TU Berlin.
- SOL looks at an organization as a set of five subsystems - technical, individual, team, organization and environment.
- Contributing factors from each subsystem can lead to the occurrence of an accident.

Introduction

- SOL takes each subsystem in turn, and attempts to identify directly and indirectly contributing factors for each.
- This approach helps to prevent contributing factors from being overlooked, and helps prevent mono-causal thinking.

Accident Overview

- Case Study: The grounding of the Royal Majesty Cruise Ship on Rose and Crown Shoal near Nantucket, Massachusetts, on June 10th, 1995.
- Information taken from the NTSB report of this accident, available from: http://www.ntsb.gov/publictn/1997/mar9701.pdf
- WBA information taken from “WBA of the Royal Majesty Accident” presented at the 2nd Bieleschweig Workshop, Braunschweig, July 2003.

Accident Overview

- The Royal Majesty Cruise Ship before the accident.

Accident Overview

- On June 9th, at approximately 1200, the Royal Majesty left St. George's, Bermuda, bound for Boston, Massachusetts.
- The first 24 hours or so of the trip were uneventful. The ship followed its programmed track, as displayed on the automatic radar plotting aid (ARPA).
- At about 1840 on June 10th, the ship was near the southern entrance to the Boston traffic lanes, which was marked by a BA buoy.

Accident Overview

- The Chief Officer on watch identified an object he believed to be the BA buoy on radar at 1845. He could not visually confirm the identity of the BA buoy, as there was a glare on the ocean surface from the rays of the setting sun.
- At 2030, the port Quartermaster reported the sighting of a yellow light off the ship's port side to the Second Officer, who was now on watch. According to the Quartermaster, the Second Officer acknowledged the report, but took no further action.

Accident Overview

- Shortly after this, the port and starboard Quartermasters reported the sighting of several high red lights off the ship's port side to the Second Officer. Again, the Second Officer acknowledged the reports, but took no further action.
- At 2145, the Second Officer told the Master that he had seen the BB buoy, the next marker in the Boston traffic lane, although he hadn't confirmed the buoy on radar or visually.

Accident Overview

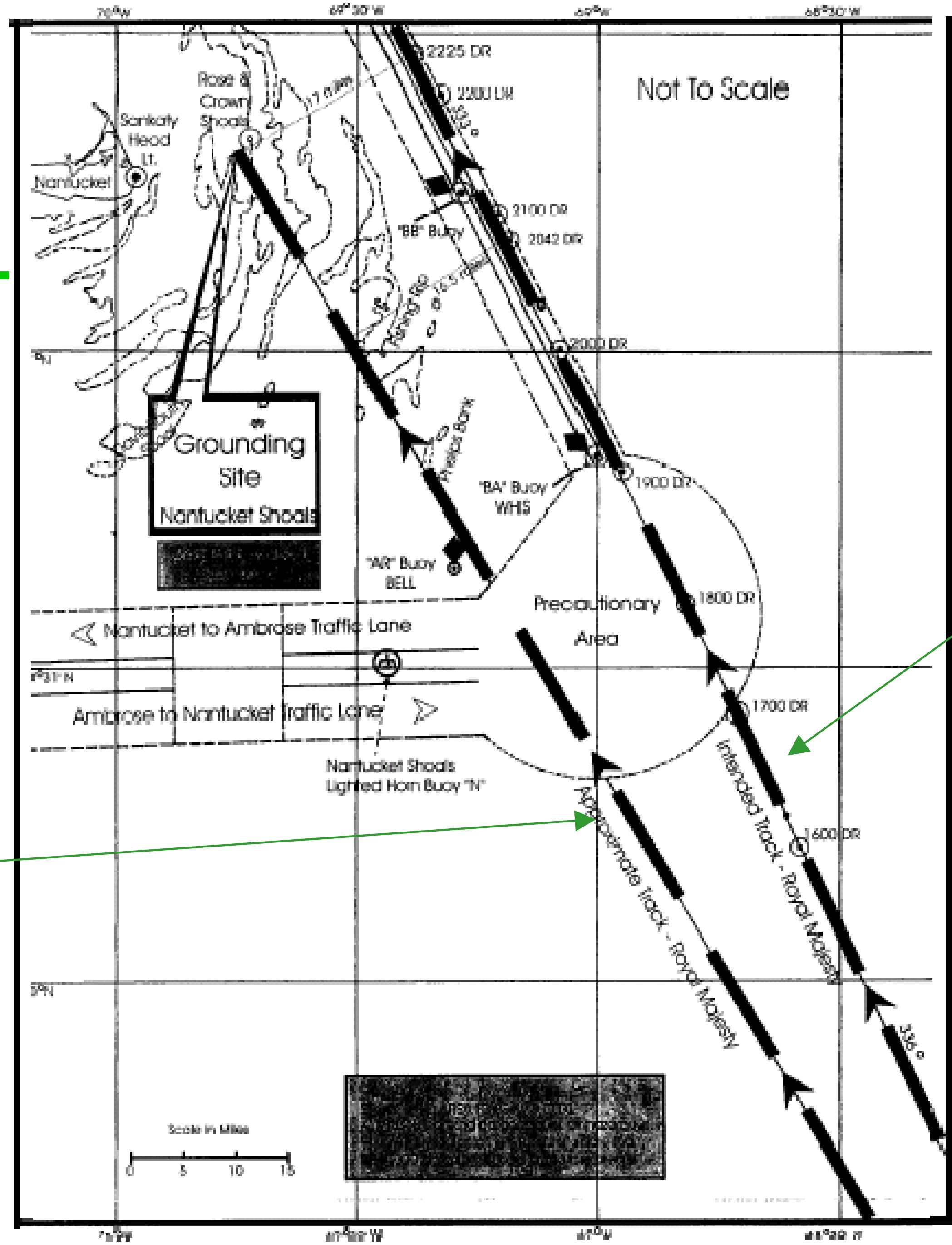
- At about 2215, the port Quartermaster reported the sighting of blue and white water dead ahead to the Second Officer. According to the Quartermaster, the Second Officer acknowledged receiving the information, but he did not discuss it, or take any further action.
- Shortly after this, the ship unexpectedly veered to port, then sharply to starboard, and then heeled to port.

Accident Overview

- The Master ran to the bridge, and found the Second Officer manually steering the ship. The Second Officer had become alarmed when the ship suddenly heeled to port, and had switched off the autopilot.
- The Master ordered a lookout to take over the helm, and he switched on the starboard radar, to the 12-mile range. He noticed that Nantucket was less than 10 miles away.
- He ordered the helmsman to apply hard right rudder, but before he could respond, the ship grounded on the shoal.

Accident Overview

- The Master then had the GPS and Loran-C navigation aids checked, and realized for the first time that the GPS position data was in error by at least 15 miles.
- The ship had actually grounded 17 miles away from its programmed track.



Intended track

Actual track

The Cost of the Accident

- There were no injuries resulting from the accident, but damage to the ship was estimated at $2 million, and loss of revenue for the time the ship was out of service was estimated at $5 million.

Points of Note

- The navigation systems used were part of an Integrated Bridge System (IBS).
- Some of the navigational aids in this IBS were as follows:
  - GPS - a satellite-based radio navigation system designed to provide continuous and accurate position data under all weather and sea conditions.
  - Loran-C - a radio-based navigation system designed to provide position data along the coasts of the United States.

Points of Note

  - NACOS 25 - when set on NAV mode, this system's autopilot automatically corrected for the effect of set and drift, caused by wind, sea and current to keep the vessel within a preset distance of its programmed track.
- Hourly position fixes were plotted on a chart by the officer on watch, as required by both the Operations Manual, and by the Master.
- Neither states how the ship's position is to be checked, nor do they require that the GPS data and Loran-C data be compared.

Points of Note

- The ship was fitted with a fathometer with a digital readout. The fathometer indicates water depth below the bottom hull plating, and was normally set to go off when the water beneath the hull was less than 3 meters deep.

Points of Note

- The ship also had a port and a starboard radar.
- According to the Master, the starboard radar was typically turned off during good weather. When he used the starboard radar, he normally set it to the 12-mile range.
- He further stated that there was no procedure prescribed for the radar scale to use, and that is was the option of the watch officer on duty.

Post Accident

- Post accident testing revealed that the fathometer was set to 0 meters. This is the normal setting when the vessel is in port or in a harbour, to prevent the alarm from being continuously sounded.
- The Master, Chief Officer and Second Officer all testified that they did not recall seeing or hearing the fathometer alarm before the grounding.
- The Chief Officer, the Navigator and the Second Officer all testified that the fathometer was turned on before the accident.

Post Accident

- Post accident testing of the GPS revealed that the GPS antenna cable had separated from the factory connection at the antenna, approximately 52 minutes after the ship left St. George's.
- The cable showed no signs of physical damage, other than having been separated from the connection.
- The GPS cable was not secured to the roof or protected from someone tripping over it, kicking it, or otherwise damaging it and the nearby antenna connector.

Post Accident

- Because the antenna cable was separated from the connection, the GPS receiver transmitted DR-derived position data instead of satellite-derived position data to the NACOS 25 autopilot.

A SOL Analysis

- SOL comprises a number of steps:
  - Identify the events that occurred during the accident
  - Organise these events into Event Building Blocks
  - Arrange the Event Building Blocks into a Time-Actor Diagram - a timeline of the accident
  - Identify directly and indirectly contributing factors for each Event Building Block in the Time-Actor Diagram.

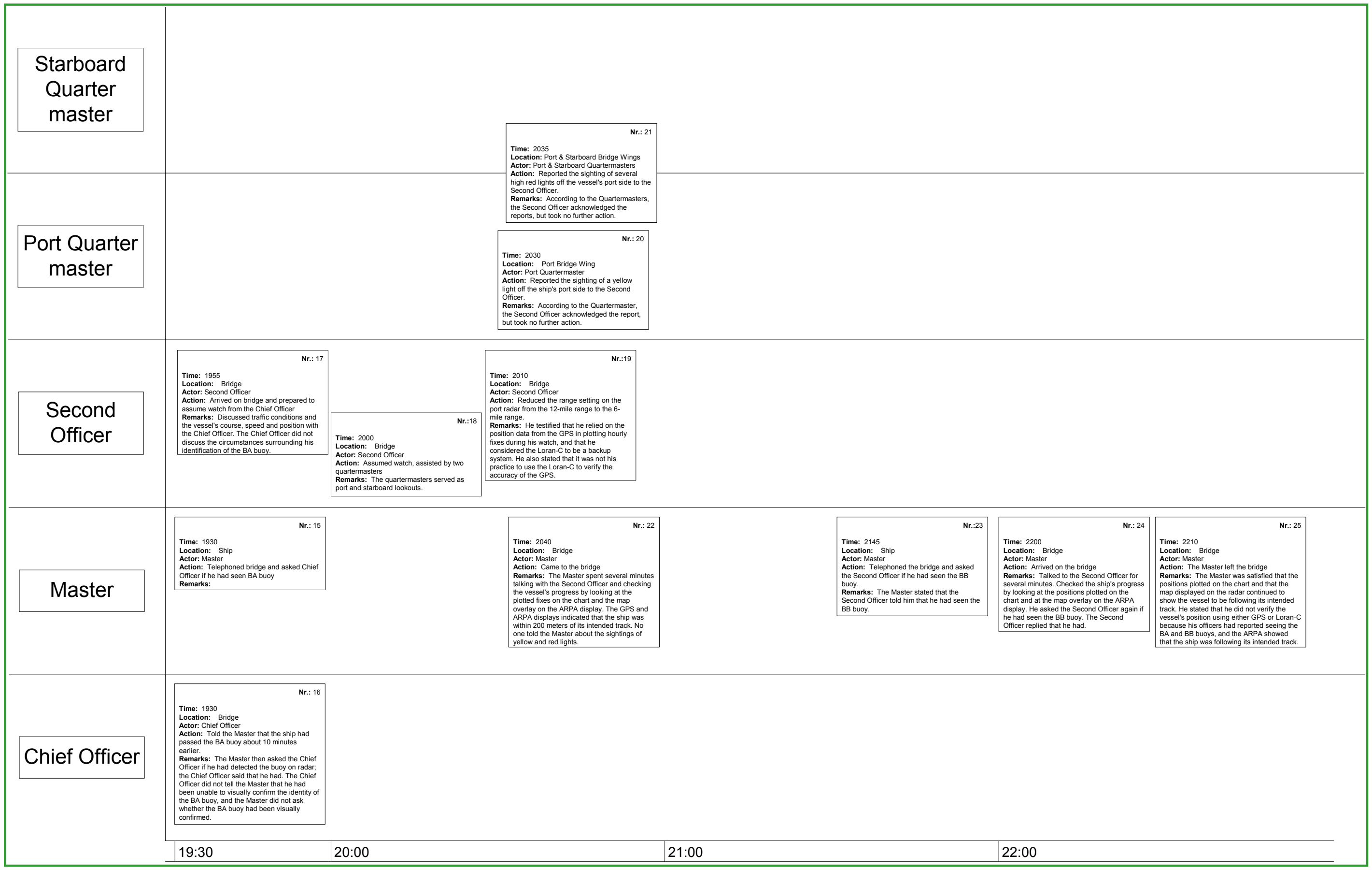
Event Building Blocks

- The Event Building Blocks record, for each event, the time, location, actor(s) involved, the action(s) that took place and any other remarks that may be relevant.

Nr.: 24

Time: 2030
Location: Port
Actor: Quartermaster 3
Action: Saw a yellow light off port side
Remarks: Reported sighting to Second Officer, as yellow light not normally observed in the traffic lane

Time-Actor Diagram



A timeline of the accident is constructed using the Event Building Blocks.

The timeline for this accident is too large to show here.

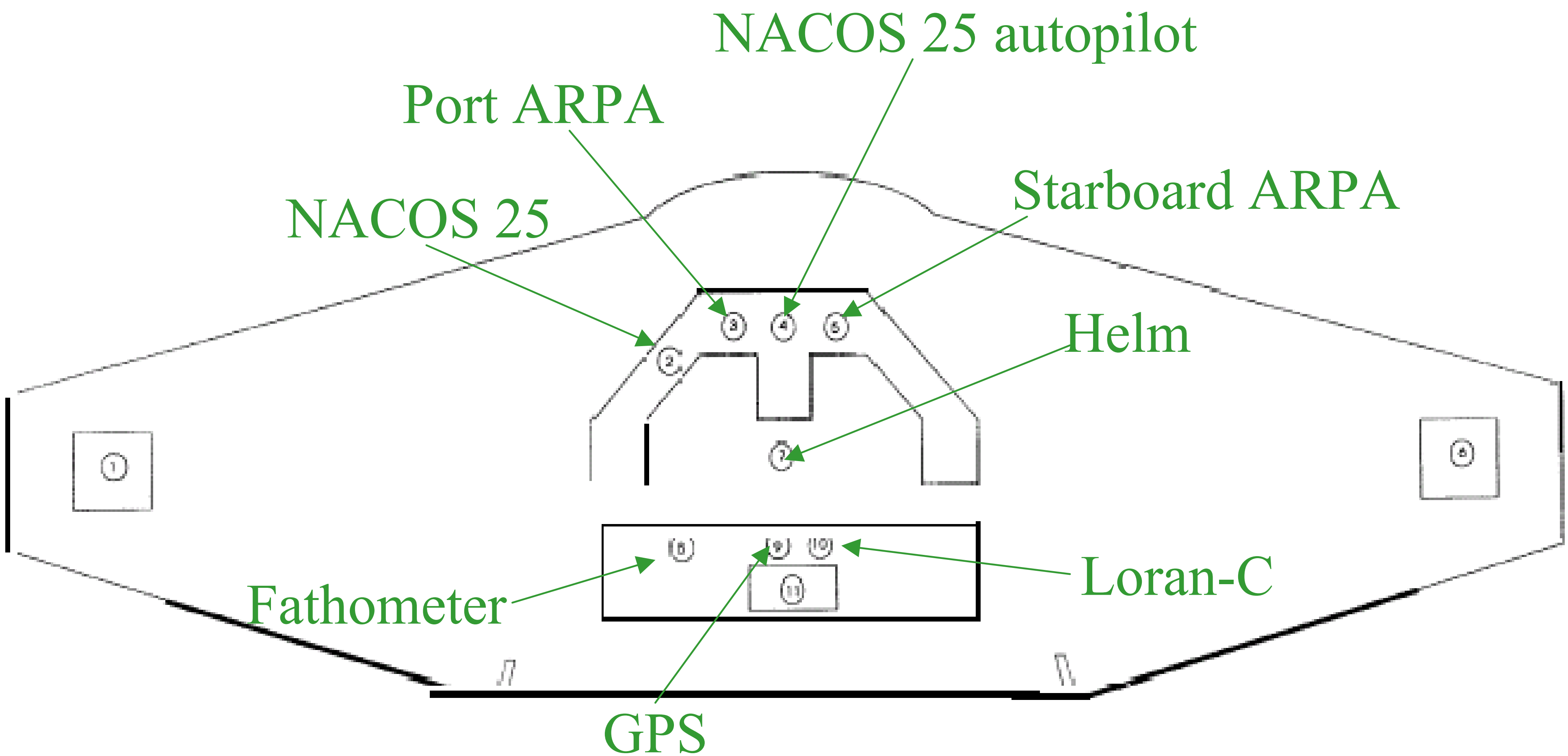
Contributing Factors

- Each Event Building Block is then analysed, individually, to identify directly and indirectly contributing factors.
- The contributing factors identified for this accident are as follows:

Directly Contributing Factors

- Representation of Information
  – The position of the GPS and Loran-C displays, in relation to the helm.
  – The displays are also relatively small.
  – The displays could be out of earshot, meaning that alarms would be difficult to hear if they sounded.

Directly Contributing Factors



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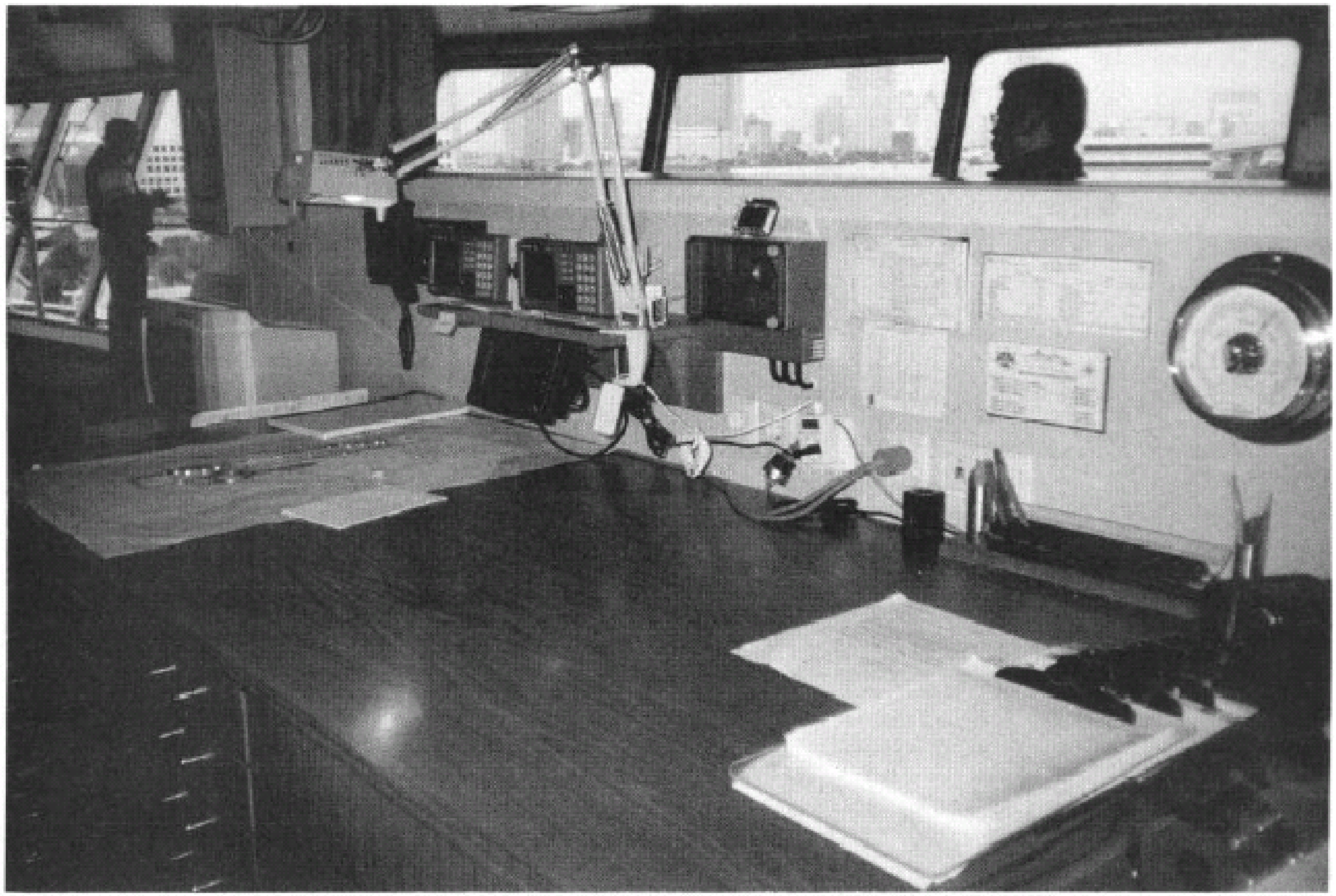

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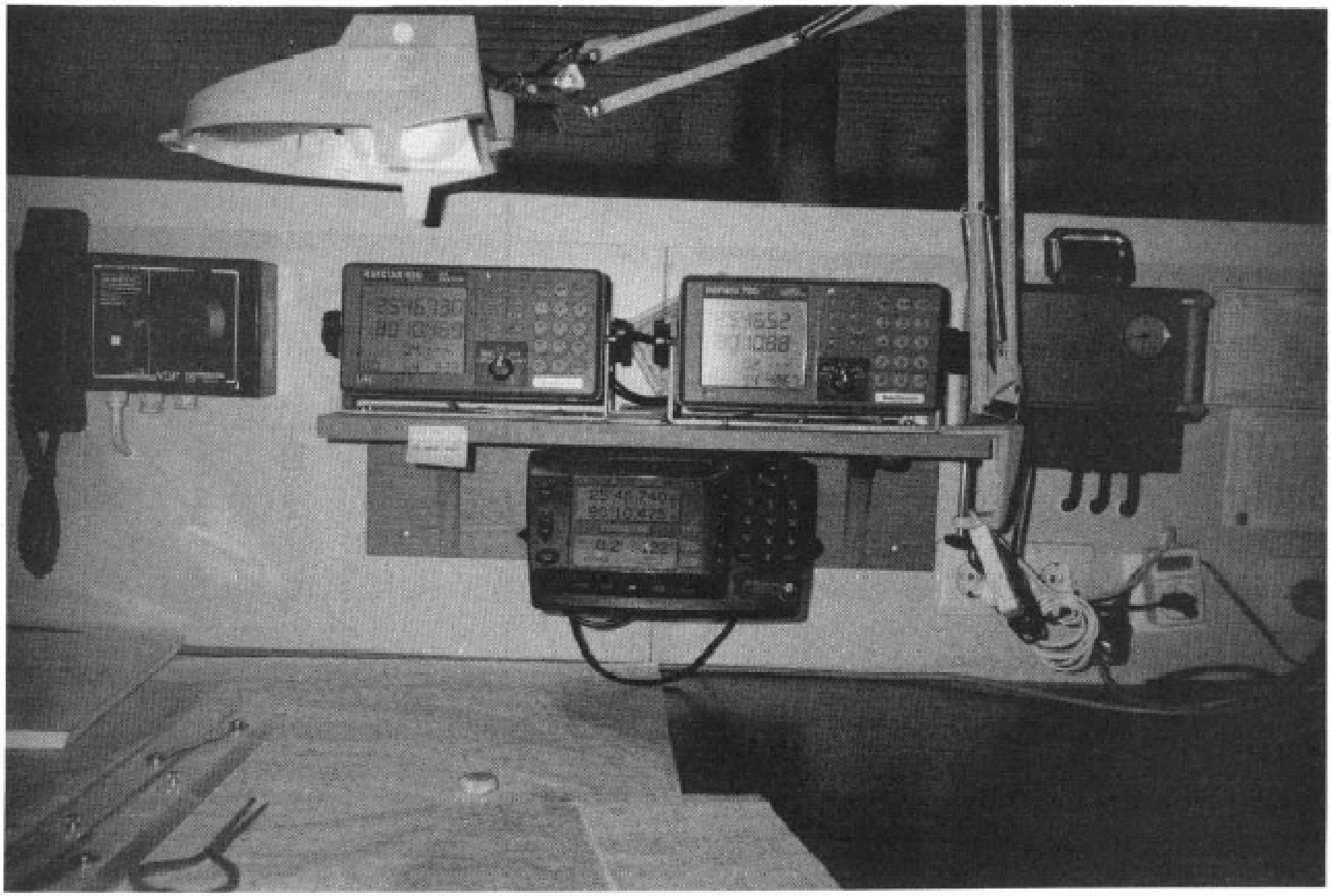
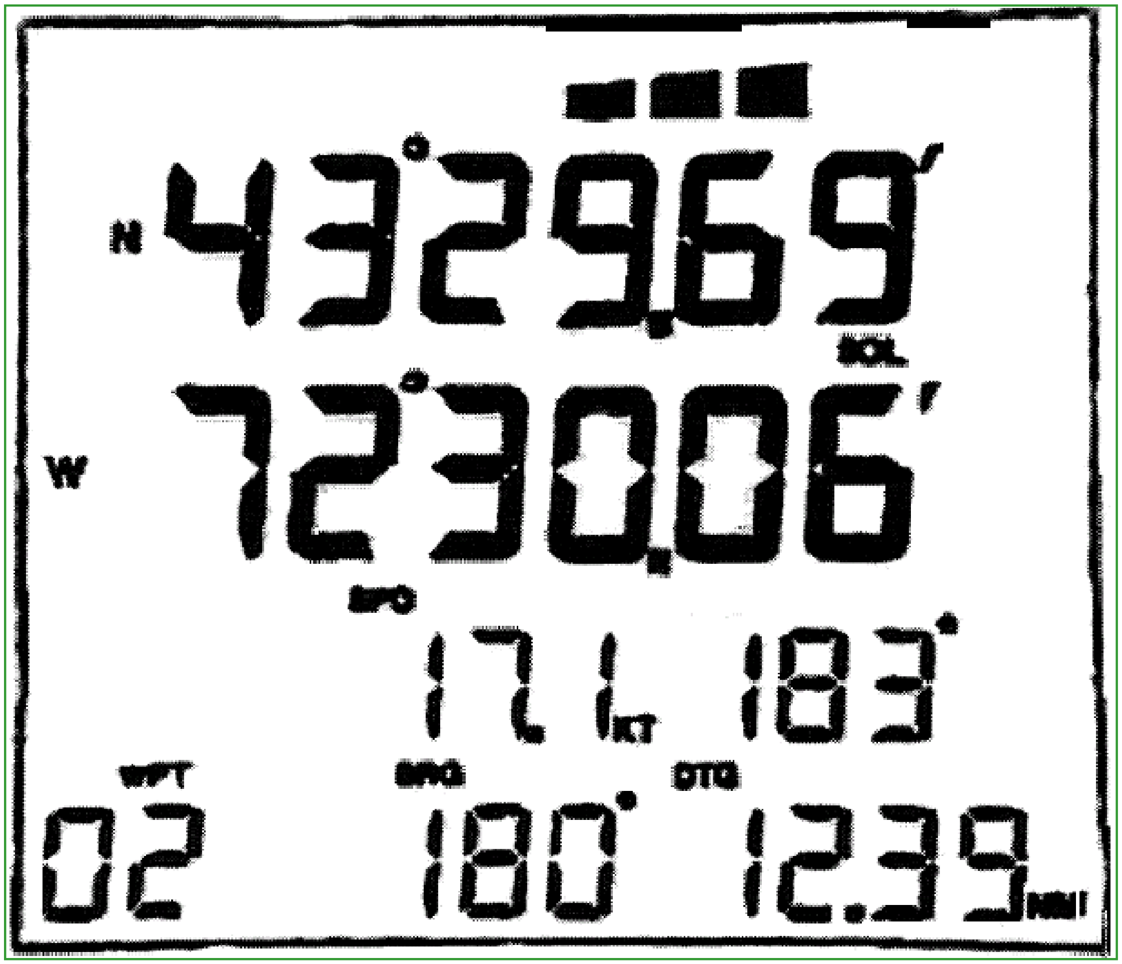


Directly Contributing Factors



Directly Contributing Factors

- Communication
  - Missing communication
    - The events surrounding the identification of the BA and BB buoys.
    - The events surrounding the sightings of yellow and red lights, and blue and white water
  - Insufficient communication
    - No standard procedure for use of radars.
    - No standard procedure for plotting hourly fixes.

Directly Contributing Factors

- Working Conditions
  - Environmental influence (indirectly contributing factor)
  - Glare of the sun on the ocean surface prevented the visual confirmation of the BA buoy.
  - Numerous mentions of “because of the good weather…”
    - Perhaps the crew were slightly off guard or slightly more relaxed about duties because of the good weather, and because the voyage was largely uneventful?
  - Over reliance on satellite system
    - Not using the Loran-C to verify GPS position data.

Directly Contributing Factors

- Personal Performance
  - Insufficient performance
    - Chief Officer concluded that he had identified the BA buoy because it was about the time he expected to see it.
  - Not using requisite working procedures
    - Using the Loran-C only as a backup system. However, all the watch officers, except the Second Officer, did at some point compare the GPS position data with the Loran-C position data.

Directly Contributing Factors

- Violation
  - Non compliance with regulations
    - Not specifically stated, but the impression is given that buoys should be identified both visually and by radar.
    - The Second Officer should have investigated, or at least reported, the sightings of lights and shallow water, as these are unusual circumstances.
    - The Second Officer lied to the Master about seeing the BB buoy.

Directly Contributing Factors

- Technical Components
  - The GPS antenna had separated from the cable, and was sending incorrect position data to the NACOS 25 autopilot.
  - No backup warning system to tell them that they were too close to shore.
    - The existing warning system on GPS either didn't work or was ineffective. All officers and the Master testified that they didn't see or hear any warning signal.

Indirectly Contributing Factors

- Operation Scheduling
  - Ambiguously formulated tasks
    - The ship's position must be plotted every 30 minutes at least, according to the Operations Manual.
    - It doesn't state how the ship's position is to be checked, nor does it states that GPS and Loran-C position data be compared.
    - The Master testified that he requires the watch officer to plot the ship's position on an hourly basis, but does not state how this should be done.

Indirectly Contributing Factors

- Rules, procedures and documents
  - Lack of written rules/procedures regarding the number of radars to use while on watch, and what range they should be set to.
    - The Master stated that it is up to the officer on watch to determine how many radars should be used, and what range they should be set to.
  - Lack of written rules/procedures regarding how to plot ship's position, and regarding comparison of GPS position data with Loran-C position data.

Indirectly Contributing Factors

- Responsibility
  - The Master did not compare the GPS position data with the Loran-C position data at any stage.
    - He stated that he did not check the position data from the two navigational systems because his officers had reported seeing the BA and BB buoys, and the ARPA showed that the ship was following its intended track.
  - The lookouts did not report their unusual sightings to the Master, even though they knew the Second Officer had not reported them.

Indirectly Contributing Factors

- Control and Supervision
  - The Master did not notice himself that the GPS data was in error.
  - He did not ask the Chief Officer if the BA buoy was confirmed visually.
  - He did not ask the Second Officer if the BB buoy had been confirmed either visually or on radar.

Indirectly Contributing Factors

- Group Influence
  - The lookouts didn't tell the Master about their unusual sightings
    - Is this because they didn't want to go behind the Second Officer's back?

Indirectly Contributing Factors

- Qualification
  - The Royal Majesty was the first ship the Second Officer had worked on with an Integrated Bridge System.
  - There is no reason given as to why the Second Officer reduced the port radar range to 6-mile range.
    - All the other watch officers used 12-mile range.
  - The Second Officer didn’t report any of the unusual sightings to the Master
    - Perhaps he didn’t realise that these were unusual circumstances?

Indirectly Contributing Factors

- The Second Officer panicked when the ship suddenly veered to port and then to starboard
    - It seems that he didn't know what to do – had never experienced this, or had not been given proper training.

Indirectly Contributing Factors

- Training
  - The Second Officer had received three weeks on-the-job training aboard the Royal Majesty
    - His attitude towards the navigational equipment (radar and Loran-C) suggests that either the training was inadequate, or that it wasn't covered.
  - The Second Officer didn't know what to do when the ship suddenly veered to port and then to starboard
    - He started trying to manually steer the ship, suggesting again that he wasn't trained in how to deal with this situation.

Indirectly Contributing Factors

- Safety Principles
  - Missing warning systems
    - The watch officers and the Master all testified that they hadn't seen or heard any warning signal from the GPS to indicate that the antenna had separated from the cable, and that it was transmitting incorrect data.
    - Either the warning system failed, or it is inadequate to warn the crew.

Indirectly Contributing Factors

- Maintenance
  - The GPS antenna had been moved to improve the signal.
    - It had been openly routed on the roof of the bridge and had been painted over at least twice.
    - The cable was not secured to the roof or protected from someone tripping over it, kicking it, or otherwise damaging it and the nearby antenna connector.

Comparisons

- NTSB conclusions:
  - Over reliance of the watch officers' on the automated features of the integrated bridge system.
  - Majesty Cruise Lines failed to ensure that its watch officers were adequately trained in the automated features of the IBS.
  - Second Officer's failure to take corrective action after several cues indicated that the vessel was off course.
  - Inadequate testing of IBS aboard vessels.

Comparisons

- Comments on NTSB conclusions:
  - The weather was a factor - it prevented the BA buoy from being confirmed visually, and it may have made the crew complacent.
  - There were no procedures specifying how the watch officers should monitor the ship's position.
  - The Master took for granted what his crew told him, and didn't perform any checks of his own.

Comparisons

- WBA conclusions:
  - The ship grounded because the autopilot put it there.
  - The autopilot did this because it was receiving incorrect data from the GPS, because the GPS cable had separated from its connector.
  - The crew should have checked GPS against the Loran-C.
  - The fathometer alarm should have been set to 3m.
  - The crew should have identified the buoys accurately, and should have paid attention to the unusual sightings.

Comparisons

- The crew were not adequately trained in the operation of the IBS.
- The crew may have been over reliant on the automated navigation equipment.
- The design of the IBS left something to be desired.

Conclusions

- SOL identifies some factors that were not identified, or not explored fully, by the official NTSB report.
- SOL and WBA analyses were, on the whole, similar.
  - WBA identified “physical causes”.
  - SOL puts more of a focus on organizational aspects.

The End!

- Questions or Comments?