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National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: APR 10 1997

In reply refer to: M-97-21 through -26

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On June 10, 1995, the Panamanian passenger ship *Royal Majesty* grounded on Rose and Crown Shoal about 10 miles east of Nantucket Island, Massachusetts, and about 17 miles from where the watch officers thought the vessel was. The vessel, with 1,509 persons on board, was en route from St. George's, Bermuda, to Boston, Massachusetts. There were no deaths or injuries as a result of this accident. Damage to the vessel and lost revenue, however, were estimated at about $7 million.[1]

The National Transportation Safety Board determines that the probable cause of the grounding of the *Royal Majesty* was the watch officers' overreliance on the automated features of the integrated bridge system, Majesty Cruise Line's failure to ensure that its officers were adequately trained in the automated features of the integrated bridge system and in the implications of this automation for bridge resource management, the deficiencies in the design and implementation of the integrated bridge system and in the procedures for its operation, and the second officer's failure to take corrective action after several cues indicated the vessel was off course.

Contributing factors were the inadequacy of international training standards for watchstanders aboard vessels equipped with electronic navigation systems and integrated bridge systems and the inadequacy of international standards for the design, installation, and testing of integrated bridge systems aboard vessels.

About 52 minutes after the *Royal Majesty* left St. George's, the antenna cable connection for the global positioning system (GPS) receiver had separated enough that the GPS switched to the dead-reckoning (DR) mode, and the autopilot, not programmed to detect the mode change and invalid status bits, no longer corrected for the effects of wind, current, or sea. Over time, the

[1] For more information, read Marine Accident Report—*Grounding of the Panamanian Passenger Ship* Royal Majesty *on Rose and Crown Shoal near Nantucket, Massachusetts, June 10, 1995* (NTSB/MAR-97/01).

effects of the east-northeasterly wind and sea set the *Royal Majesty* in a west-southwesterly direction and away from its intended track, resulting in the vessel straying more than 17 miles off course.

The Safety Board's investigation determined that the GPS antenna, which was originally installed on the radar mast, had been moved several months before the grounding. An examination of the GPS antenna cable indicated that it was routed in such a way that it could be kicked or tripped over, which could induce separating stress at the antenna cable connection, and that it had been painted on at least two occasions. However, precisely when the painting was done was not known. In short, it could not be determined whether the GPS antenna failed as a result of crewmembers' inadvertently damaging it while they were doing routine maintenance, as a result of crewmembers' tripping over the cable, or as a result of other unknown factors. Nevertheless, the Safety Board concludes that openly routing the GPS antenna cable in an area where someone occasionally walked increased the risk of damage to the cable and related connectors. The Safety Board believes, therefore, that the International Council of Cruise Lines (ICCL) should recommend that its members eliminate the practice of openly routing navigation equipment cable to decrease the risk of damage.

The investigation determined that although the manufacturer of the navigation and command system autopilot, STN Atlas, had classroom and simulator training available to purchasers of the system, the owner of the *Royal Majesty* had not purchased any training. When the vessel was placed in service, the manufacturer provided an orientation during sea trials to the first complement of officers assigned to the ship; however, of the officers on the *Royal Majesty* at the time of the grounding, only the chief officer had been a part of that complement.

The investigation determined that although the watch officers on the *Royal Majesty* during the grounding were familiar with the basic operation of the automated navigation equipment, no one, with the possible exception of the navigator, appeared to be fully proficient with the system, as evidenced by the lack of knowledge about the GPS receiver's DR mode capability. The crew's automated navigation equipment training consisted primarily of on-the-job training, the type of training on which the marine industry has historically relied. For example, the second officer's preparation to operate the automated navigation system was described as his reading the equipment manuals acquired with the system installation, observing bridge operations by the other officers, and using the equipment under their supervision. Because the second officer's introduction to the system consisted of watching others or operating the system himself during routine conditions, he probably had very little experience in recognizing and coping with system malfunctions. The Safety Board has long supported on-the-job training as an important aspect of an operator's training. However, with the implementation of sophisticated, automated navigational equipment, the Safety Board believes that on-the-job training alone may not be sufficient. The Safety Board is particularly concerned that there were no procedures for the officers to determine their proficiency in operating the automated navigation system, including the navigator who, according to his testimony, was responsible for all instruments on the bridge and the orientation and training of new officers. The Safety Board concludes that the on-the-job training program employed by Majesty Cruise Line to train the *Royal Majesty*'s watch officers in the operation of the integrated bridge system did not adequately prepare the officers to identify and respond to system malfunctions. Therefore, the Safety Board believes that the ICCL should

recommend that its members provide initial and recurrent formal training on essential technical information, equipment functions, and system operating procedures to all bridge watchstanding personnel on all of their ships that are equipped with integrated bridge systems.

Although the officers' inadequate monitoring led to the errant track and was a serious deviation from acceptable methods of operating automated equipment, the grounding itself could have been avoided had the chief officer and the second officer followed longstanding good watchkeeping practices when approaching land. During the 1600-to-2000 watch preceding the accident, the chief officer did not visually identify the buoy he saw on the radar about 1900 and apparently assumed that it was the BA buoy, which marked the entrance to the traffic lanes. The target that he probably observed was the AR buoy, which marked a shoal about 17 miles west of the traffic lanes, and it was probably coincidental that he detected it when and where he anticipated seeing the BA buoy. He later explained that he was not concerned about confirming that the target was the BA buoy because the information displayed at the time on the central console showed it was not necessary.

When the second officer assumed the following watch, he did not see the next buoy in the traffic lanes, the BB buoy, when it was expected. Contrary to standing orders from the master, he failed to report that he had not seen the BB buoy; and when the master called the bridge asking the second officer whether he had observed the buoy, the second officer stated that he had.

The second officer continued to miss opportunities to avoid the grounding when the lookouts reported sighting tower lights (later determined to be on Nantucket Island), sighting a flashing red light on the port bow, and sighting blue and white water ahead of the *Royal Majesty*. He acknowledged these observations, but he failed to take any action.

The second officer's response to these sightings should have been deliberate and straightforward. He should haye been concerned as soon as the BB buoy was not sighted and then again when the lookouts sighted red lights. Had he then increased the radar range from 6 miles to 12 miles on the one radar in use or turned on the second radar and set it to the 12-mile range, he would have detected Nantucket Island. He would also have seen that the radar pictures did not conform to the radar maps exhibited on the display of the automatic radar plotting aid. In addition, had he checked a chart of the area for the source of the flashing red light, he would have learned that the nearest flashing red light was the Rose and Crown Shoal buoy and, thus, would have been warned that the ship was not in the traffic lanes, as he believed it was. The chart would also have shown him that if the ship were in the inbound traffic lane, as he apparently believed it was, there should have been no shallow water where the lookout sighted blue and white water.

Additionally, the second officer should have checked the Loran-C to crosscheck his position, as he knew the Loran-C to be accurate in this area. Had he still been uncertain about the position of the *Royal Majesty* after checking the Loran-C, he should have called the master and the navigator to the bridge for assistance. The Safety Board concludes that the sighting of lights not normally observed in this area and the second officer's inability to confirm the presence of the BB buoy should have taken precedence over the automation display on the central console and compelled the second officer to promptly use all available means to verify his position.

Fundamental seamanship practices caution against exclusive reliance on any one source of position information for navigation. When a watch officer finds visually sighted navigation aids that conflict with a position determined by automated instrumentation, he should promptly verify the vessel's position by using proper procedures. The Safety Board concludes that the chief officer and the second officer did not observe good watchkeeping practices or act with heightened awareness of precautions that are needed when a vessel approaches the Boston traffic lanes and landfall. Consequently, in view of the actions of the watch officers on the *Royal Majesty*, the Safety Board believes that the ICCL should recommend that its members review and revise as necessary the bridge watchstanding practices on all their vessels to ensure that all watch officers adhere to sound watchstanding practices and procedures, including using landmarks and navigational aids to verify a vessel's position, relying on more than one source for position information, and reporting to the master the failure to see navigational aids. The Safety Board further believes that the ICCL should recommend that its members periodically review the performance of all officers on board their vessels.

The performance of the watch officers during the voyage and the circumstances leading to the grounding were linked to several error-inducing deficiencies in the design of the equipment and to an inefficient layout of system displays on the bridge.

Although the *Royal Majesty* was equipped with multiple position receivers, the navigation and command system (NACOS) 25 autopilot was not configured to compare position data from multiple independent position receivers such as Raytheon's 920 GPS and 780 Loran-C receivers. Given the *Royal Majesty*'s frequent proximity to land and the expected reasonable accuracy of the Loran-C in that area, the NACOS 25 could have recognized the large discrepancy between the GPS and the Loran-C positions as the vessel approached Nantucket Shoals had it been able to compare them. The Safety Board concludes that had the autopilot been configured to compare position data from multiple independent position receivers and had a corresponding alarm been installed that activated when discrepancies were detected, the accident may have been avoided. The safety benefits associated with the redundancy of such critical systems as position receivers would help prevent such single-point catastrophic failures as occurred on the *Royal Majesty*.

The NACOS 25 central console provided efficient access and display of most information needed to conduct a passage when the GPS was fully operational. However, where various sources of position information were possible (i.e., GPS, Loran-C, or DR), as with the NACOS 25 autopilot, it was important to delineate clearly which mode was in use. On the *Royal Majesty*, because the NACOS 25 could not detect the GPS's change to DR mode, the central console display switched from GPS to DR-derived positions without changing its display in any perceivable way or notifying the crew. The integrated bridge system, as configured, did not indicate to the officers at the central console that the navigation system had defaulted to the DR navigation mode.

Of particular concern was the alarm system for the GPS. The internal aural alarm for the GPS lasted 1 second, despite its critical function. Neither the brief aural alarm nor the visual alarm, in

the form of very small *DR* and *SOL*[2] characters on the GPS receiver's screen, could be easily seen or heard at the command console. Rather, the GPS receiver was in the chart room behind the console on the bridge. The remoteness of the location probably precluded the *Royal Majesty*'s watch officers' hearing the GPS receiver's brief aural alarm or initially noticing the *DR* and *SOL* indications when the GPS defaulted to the DR mode. Further, the integrated bridge system installer did not connect the GPS receiver's external alarm switch to a loud and continuous external alarm, even though one was available. Had the GPS external alarm been installed or had its internal aural alarm required user action to silence it, the officers would have been alerted to the GPS antenna problem shortly after leaving St. George's. Consequently, the Safety Board concludes that the Raytheon 920 GPS receiver's brief aural alarm, the remoteness of the receiver's location, and the failure of the installer to connect the GPS external alarm resulted in the inadequacy of the aural warning sent to the crew when the GPS defaulted to the DR mode. In view of the foregoing, the Safety Board believes that the ICCL should recommend to its members that they ensure that integrated bridge systems installed on their vessels provide critical aural alarms that are continuous and require the user to take action to silence them.

The failure of the GPS antenna connection and the subsequent failure of the NACOS 25 autopilot to recognize the GPS data as invalid and to sound an alarm resulted in a single-point, "silent" failure mode. Aeronautical and aerospace design safety practices typically require the analysis of potential failure modes via failure modes and effects analyses (FMEAs). FMEAs of the *Royal Majesty*'s integrated bridge system could have highlighted the need for multiple independent comparisons of positioning systems for discrepancies between systems, the need for removal of the DR input to the Raytheon 920 GPS receiver, and the need for interrogation of the National Marine Electronics Association 0183 *valid/invalid* position data bits by the NACOS 25. The Safety Board concludes that FMEAs of the Royal Majesty's integrated bridge system would probably have disclosed the shortcomings of the system's components. Consequently, the Safety Board believes that the ICCL should recommend that each of its members ensure that their existing and new integrated bridge systems incorporate the following:

- multiple independent position receiver inputs;
- monitoring position receiver data for failures/invalid data and subsequent positive annunciation to the crew;
- comparing position receiver data for significant discrepancies between position receivers, and subsequent positive annunciation to the crew; and
- FMEAs on existing systems, during the design process for new systems, and whenever peripheral devices or equipment details change.

Therefore, the National Transportation Safety Board recommends that the International Council of Cruise Lines:

[2] *SOL* is meant to indicate that the GPS satellite position solution is invalid or not available. According to the Raystar 920 operation manual, *SOL* means the unit can not calculate its lat/long position.

Recommend that its members provide initial and recurrent formal training on essential technical information, equipment functions, and system operating procedures to all bridge watchstanding personnel on their ships that are equipped with integrated bridge systems. (M-97-21)

Recommend that its members review the bridge watchstanding practices on all their vessels, and revise as necessary to ensure that all watch officers adhere to sound watchstanding practices and procedures, including using landmarks, soundings, and navigational aids to verify a vessel's position, relying on more than one source for position information, and reporting to the master any failure to see navigational aids. (M-97-22)

Recommend that its members periodically review the performance of all officers on board their vessels. (M-97-23)

Recommend that its members eliminate the practice of openly routing navigation equipment cable to decrease the risk of damage. (M-97-24)

Recommend to its members that they ensure that integrated bridge systems installed on their vessels provide critical aural alarms that are continuous and require the user to take action to silence them. (M-97-25)

Recommend that its members ensure that their existing and new integrated bridge systems incorporate the following:

- multiple independent position receiver inputs;
- monitoring position receiver data for failures/invalid data and subsequent positive annunciation to the crew;
- comparing position receiver data for significant discrepancies between position receivers, and subsequent positive annunciation to the crew; and
- failure modes and effects analyses on existing systems, during the design process for new systems, and whenever peripheral devices or equipment details change. (M-97-26)

The Safety Board also issued Safety Recommendations M-97-1 through -4 to Majesty Cruise Line; M-97-5 through -11 to the U.S. Coast Guard; M-97-12 and -13 to STN Atlas Electronik GmbH; M-97-14 and -15 to Raytheon Marine; M-97-16 through -18 to the National Marine Electronics Association; M-97-19 and -20 to the International Electrotechnical Commission; and M-97-27 and -28 to the International Chamber of Shipping and to the International Association of Independent Tanker Owners. The Safety Board also reiterated Safety Recommendations M-93-18 and -19 to the U.S. Coast Guard.

The National Transportation Safety Board is an independent Federal agency with the statutory responsibility "to promote transportation safety by conducting independent accident

investigations and by formulating safety improvement recommendations" (Public Law 93-633). The Safety Board is interested in any action taken as a result of its safety recommendations. Therefore, it would appreciate a response from you regarding action taken or contemplated with respect to the recommendations in this letter. Please refer to Safety Recommendations M-97-21 through -26. If you need additional information, you may call (202) 314-6450.

Chairman HALL, Vice Chairman FRANCIS, and Members HAMMERSCHMIDT, GOGLIA, and BLACK concurred in these recommendations.

By: Jim Hall
Chairman