log: M-427C

National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: MAY 14 2001

In reply refer to: M-01-7 through -10

Cruise Line Companies
(List attached)

The National Transportation Safety Board is an independent Federal agency charged by Congress with investigating transportation accidents, determining their probable cause, and making recommendations to prevent similar accidents from occurring. We are providing the following information to urge your organization to take action on the safety recommendations in this letter. The Safety Board is vitally interested in these recommendations because they are designed to prevent accidents and save lives.

These recommendations address the following safety issues: adequacy of fire protection systems, adequacy of passenger and crew safety, and adequacy of engineering systems design. The recommendations are derived from the Safety Board's investigation of the fire on board the Liberian Passenger Ship *Ecstasy* near Miami, Florida, on July 20, 1998, and are consistent with the evidence we found and the analysis we performed.[1] As a result of this investigation, the Safety Board has issued twelve safety recommendations, four of which are addressed to the cruise line companies listed on the attachment. Information supporting the recommendations is discussed below. The Safety Board would appreciate a response from you within 90 days addressing the actions you have taken or intend to take to implement our recommendations.

The fire on board the *Ecstasy* started in the main laundry and migrated through the ventilation system to the aft mooring deck, where mooring lines ignited, creating intense heat and large amounts of smoke that damaged several deck areas in the aft two main vertical zones of the ship. The affected areas included the stern thruster room, an air conditioning room, an electrical equipment room, and the steering gear room. In addition, some passenger staterooms and crew cabins on decks No. 2, 4, 5, and 6 sustained heat and smoke damage. The *Ecstasy* subsequently lost propulsive power and most steering and had to be towed back to Miami. During the on-board emergency, all passengers evacuated safely from the affected areas; however, two crewmembers became trapped in their accommodations area, and firefighting teams had to rescue them. Nine passengers were treated for injuries resulting from pre-existing conditions or smoke inhalation, and 14 crewmembers sustained minor injuries from firefighting activities and/or smoke inhalation.

[1] For further information, read: National Transportation Safety Board, *Fire On Board the Liberian Passenger Ship* Ecstasy, *Miami, Florida, July 20, 1998*, Marine Accident Report NTSB/MAR-01/01 (Washington, DC: NTSB, 2001).

From its examination and tests of damaged ship areas on the *Ecstasy* and from interviews with witnesses, the Safety Board determined that the probable cause of fire aboard the *Ecstasy* was the unauthorized welding by crewmembers in the main laundry that ignited a large accumulation of lint in the ventilation system and the failure of Carnival Cruise Lines to maintain the laundry exhaust ducts in a fire-safe condition. Contributing to the extensive fire damage on the ship was the lack of an automatic fire suppression system on the aft mooring deck and the lack of an automatic means of mitigating the spread of smoke and fire through the ventilation ducts.

The *Ecstasy's* main laundry ventilation ducts, which served as a conduit for the fire, had fail-safe fire dampers, which closed in the event that the ventilation system lost power. If conditions warranted that the dampers be closed while the ventilation system was operating, someone present in the laundry area or someone on the bridge had to shut the dampers. In this accident, if the fire in the overhead had triggered the closure of the laundry fire dampers, the shutdown would have occurred several minutes before the bridge personnel secured the ventilation system, which would have resulted in appreciably less heat, smoke, and flame escaping from the main laundry and spreading to the mooring deck.

A passive means for actuating the closure of fire dampers in certain areas is required by various interpretations of the *International Convention for the Safety of Life at Sea* (SOLAS), including U.S. Coast Guard (Coast Guard) regulations.[2] The most commonly required passive closure mechanism is a weight- or spring-activated fusible link that melts at a given temperature, allowing the fire damper to close. A fusible link can be designed to actuate at various temperatures, depending on the metal used in the mechanism. It potentially offers a more fail-proof method of closure and, consequently, a greater margin of fire safety because an external power source is not needed to drive the damper.

While automatic fire dampers with passive actuating mechanisms are one way to effectively stem the spread of smoke and fire through ventilation systems in high-risk areas, such dampers are not the only method of mitigating the danger. The Board considers the individual cruise ship companies best qualified to analyze their vessels' design arrangements and devise measures for dealing with the problem. The Safety Board believes that cruise ship companies should, for existing vessels with ventilation system arrangements similar to Carnival Cruise Lines' Fantasy Class ships, engineer, design, and implement system modifications to mitigate the spread of smoke and fire from the laundry rooms through the ventilation ducts to other areas of the vessel.

The *Ecstasy's* mooring station, where the major fire occurred, was categorized as an open deck, which meant that the area was not required to have smoke detectors or sprinklers. The mooring station had been equipped with 11 mooring lines, each measuring 220-meters and weighing about 900 pounds. The fire that migrated to the mooring deck ignited lint that had been exhausted from the laundry and imbedded in the mooring lines. The burning lint, in turn, ignited the lines. Based on postaccident tests that determined the heat of combustion generated by the mooring line, the Safety Board estimated that the consumption of the polypropylene line on the mooring station could have yielded as much as 150 million Btu (British thermal units) of heat.

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[2] *Navigation and Vessel Inspection Circular* No. 09-97.

If sprinklers had been installed and had activated on the mooring deck, the water might have extinguished the ignited lint before the mooring line caught fire. At the least, water from activated sprinklers would have knocked down the flames of the fire, which probably would have enabled shipboard firefighters to enter the mooring station and combat the fire.

In the past, cruise ships typically were designed with mooring decks having either no overhead or an overhead and large permanent openings in the vessel's side shell. Because the mooring deck area was open to the weather elements, the risk of fire was low; therefore, SOLAS did not require mooring decks to have fire protection. Modern cruise ship designs, such as that of Carnival Cruise Lines' Fantasy Class vessels, typically incorporate the mooring station into the superstructure, often below accommodation and service spaces. Many mooring stations have openings that can be closed with hatches or covers. Despite this loss of openness, SOLAS still categorizes these mooring stations as open decks that are not required to have fire protection systems. Some newer ship designs also place ventilation inlets and outlets on the mooring decks. The Coast Guard, recognizing the safety issues inherent in the design arrangement, has proposed that the International Maritime Organization (IMO) clarify the category for mooring decks such as the type on the *Ecstasy*. The Coast Guard has recommended that, for all new construction, a partially covered mooring deck be categorized as an auxiliary machinery space. This categorization would not only require fire protection systems (detection and suppression) but also prohibit using the space as a ventilation terminus. The status of the Coast Guard's proposal at IMO is pending.

Regardless of whether the IMO does or does not agree to categorize mooring decks as recommended by the Coast Guard, any action taken by the IMO will not take effect immediately and may affect only certain cruise ships. The Safety Board is convinced that all efforts should be made without delay to minimize the potential for fire on mooring decks that are incorporated into the vessel structure, such as the mooring decks on the Fantasy Class cruise ships. The Board recognizes that some mooring decks are used to store only anchors or small combustibles or both and, thus, might not warrant fire protection. To optimize safety, cruise ship companies need to examine their mooring stations for fire risk and determine the need for detection and suppression systems. The Safety Board, therefore, believes that cruise ship companies should, for existing vessels having mooring deck arrangements similar to Carnival Cruise Lines' Fantasy Class ships, install automatic fire suppression systems on mooring decks that contain high fire loads and presently have no automatic fire protection.

The *Ecstasy* had been built to Lloyds Register of Shipping (LR) regulations, which stipulate the need to provide independent and isolated power supplies to essential components of the vessels engineering systems, such as propulsion. The *Ecstasy's* propulsion system had many redundant features and isolated components designed to provide reliability. However, the auxiliary voltage to the high-speed breakers for the starboard and the port propulsion systems was routed through the same distribution panel, which was in an electrical equipment room on the deck above the mooring station. The auxiliary voltage was essential to the operation of both propulsion systems. When the distribution panel sustained heat damage, both systems failed.

The propulsion system was designed and manufactured by ABB, a subcontractor to Kvaerner Masa, the shipbuilder. The integration of the propulsion system into the ship's other systems, notably the electrical distribution system, was the responsibility of Kvaerner Masa's

designers. ABB's specifications to the shipbuilder list the required voltage and current supplying the propulsion system. The specifications do not indicate that the voltage supply should be provided by independent sources. Kvaerner Masa routed the auxiliary voltage for both high-speed breakers through a single external interface.

As part of the agency's investigation, Safety Board staff contacted ABB regarding the reviews and examinations of the propulsion system that were conducted before and during the construction of the *Ecstasy*. ABB officials stated that they did not do a qualitative failure analysis of the propulsion system for the Fantasy class ships, including the *Ecstasy*, because it was not required by SOLAS standards and LR regulations. In addition, the ship owner did not require that a system failure analysis be conducted.

A qualitative failure analysis can identify potential failures and rank them according to the probability of occurrence, the severity of effects, and the probability of detection. System failure analyses are widely used in many other industries as part of the overall movement toward quality improvement in processes and products. In addition, IMO now requires that a failure analysis be performed during the design of navigation equipment and bridge systems. The Coast Guard has required the use qualitative failure analysis techniques in evaluating the reliability and safety of vital system automation on U.S. flag vessels since 1988. In proposing the regulatory requirement that designers, manufacturers, and/or shipyards perform and submit system failure analysis, the Coast Guard stated that the use of advanced automation technologies such as electronics and microprocessors made it increasingly difficult, "at times impossible, for the Coast Guard, ship owners/operators, and classification societies to evaluate safety."

The Safety Board is convinced that a qualitative failure analysis can be an important technique to maximize the reliability and safety of a system before it is built, when changes can be easily made. The Safety Board believes that, in the construction of new passenger ships, cruise line companies should use qualitative failure analysis techniques to identify system components whose failure might cause a complete loss of propulsive power and take action to mitigate identified problems.

As mentioned earlier, two crewmembers became trapped by smoke in this accident. They could not notify anyone of their predicament because the crew accommodations areas lack a means of signaling for help, such as a call system. The crewmembers' inability to signal for help demonstrates that existing SOLAS requirements for emergency communication are not adequate. The *Ecstasy's* passageways had telephones; however, using them to call for help depended upon a person being able to reach a telephone. In this accident, the cabin steward who first smelled and saw smoke tried to alert crewmembers in nearby cabins of the fire. Conditions worsened considerably during the brief time that he knocked on cabins doors, and dense, suffocating smoke prevented his and another crewmember's escape. The men did not have the option to walk to or spend time on a corridor telephone.

In previous reports that addressed the need for a means of emergency communication in cabins, the Safety Board discussed the simple call button system used to summon flight attendants on commercial airlines. Hospitals and nursing facilities employ a similar system to enable patients to signal for nursing assistance. The Safety Board believes that cruise ship

companies should install emergency call systems in passenger staterooms and crew cabins so that people trapped during a fire emergency will have a means of signaling their location.

In summary, the National Transportation Safety Board makes the following recommendations to the cruise line companies, including their subsidiary operating cruise lines, where applicable:

> For existing vessels with ventilation system arrangements similar to Carnival Cruise Lines' Fantasy Class ships, install an automatic method or system to mitigate the spread of smoke and fire from laundry spaces through the ventilation ducts to other vessel areas. (M-01-7)
>
> For existing vessels with mooring deck design arrangements similar to Carnival Cruise Lines' Fantasy Class ships, install fire detection and suppression systems on mooring decks that carry high fire loads and presently have no automatic fire protection. (M-01-8)
>
> In the construction of new passenger ships, use qualitative failure analysis techniques to identify system components whose failure might cause a complete loss of propulsive power and take action to mitigate identified problems. (M-01-9)
>
> Install emergency call systems in passenger staterooms and crew cabins so that people trapped during a fire emergency will have a means of signaling their location. (M-01-10)

The Safety Board also issued safety recommendations to the U.S. Coast Guard, Carnival Corporation, Carnival Cruise Lines, ABB, Inc., and the International Association of Classification Societies. In your response to the recommendations in this letter, please refer to M-01-7 through -10. If you need additional information, you may call (202) 314-6607.

Acting Chairman CARMODY and Members HAMMERSCHMIDT, GOGLIA, and BLACK concurred in these recommendations.

Carol J. Carmody

By: Carol J. Carmody
Acting Chairman

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* Subsidiary operating companies include The Delta Queen Steamboat Company, Delta Coastal Voyages, United States Lines, and American Hawaii Cruises.

** Subsidiary operating companies include Royal Caribbean International and Celebrity Cruises.

Log: M-427A

National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: MAY 14 2001

In reply refer to: M-01-2 and -3 and
M-01-7 through -10

Mr. Micky Arison
Chairman and CEO
Carnival Corporation, Inc.
3566 NW 87th Avenue
Miami, Florida 33178

The National Transportation Safety Board is an independent Federal agency charged by Congress with investigating transportation accidents, determining their probable cause, and making recommendations to prevent similar accidents from occurring. We are providing the following information to urge your organization to take action on the safety recommendations in this letter. The Safety Board is vitally interested in these recommendations because they are designed to prevent accidents and save lives.

These recommendations address the following safety issues: adequacy of management safety oversight, adequacy of fire protection systems, adequacy of passenger and crew safety, and adequacy of engineering systems design. The recommendations are derived from the Safety Board's investigation of the fire on board the Liberian Passenger Ship *Ecstasy* near Miami, Florida, on July 20, 1998, and are consistent with the evidence we found and the analysis we performed.[1] As a result of this investigation, the Safety Board has issued twelve safety recommendations, six of which ask Carnival Corporation to implement changes for the fleets of its operating companies, including Carnival Cruise Lines, Costa Crociere, S.p.A., Cunard Line, Holland America Line, Seaborne Cruise Line, and Windstar Cruises. Information supporting the recommendations is discussed below. The Safety Board would appreciate a response from you within 90 days addressing the actions you have taken or intend to take to implement our recommendations.

The fire on the *Ecstasy* started in the main laundry and migrated through the ventilation system to the aft mooring station where mooring lines ignited, creating intense heat and large amounts of smoke that damaged several deck areas in the aft two main vertical zones (MVZs) of the ship. Damaged areas included the stern thruster room, an air conditioning room, an electrical equipment room, and the steering gear room. In addition, some passenger staterooms and crew cabins on decks No. 2, 4, 5, and 6 sustained heat and smoke damage. The *Ecstasy* subsequently lost propulsive power and most steering and had to be towed back to Miami. During the on-board emergency, all passengers evacuated safely from the affected areas; however, two

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crewmen became trapped on deck No. 2, and firefighting teams had to rescue them. Nine passengers were treated for injuries resulting from pre-existing conditions or smoke inhalation, and 14 crewmembers sustained minor injuries from firefighting activities and/or smoke inhalation.

From its examination and tests of damaged ship areas on the *Ecstasy* and from interviews with witnesses, the Safety Board determined that the probable cause of fire aboard the *Ecstasy* was the unauthorized welding by crewmembers in the main laundry that ignited a large accumulation of lint in the ventilation system and the failure of Carnival Cruise Lines to maintain the laundry exhaust ducts in a fire-safe condition. Contributing to the extensive fire damage on the ship was the lack of an automatic fire suppression system on the aft mooring deck and the lack of an automatic means of mitigating the spread of smoke and fire through the ventilation ducts.

At the time of the fire, Carnival Cruise Lines' Safety Management System (SMS) manual contained numerous safety procedures for workers performing welding operations, including a prohibition against undertaking welding "unless the requirements of the 'Hot Work Permit' are satisfied." The permit requirements for welding included applying in writing to the duty engineering officer, who, before approving the application, must assess the intended work area for hazards and either eliminate them or take precautions to control the risk, such as posting a fire guard. Neither fitter followed the hot work permit procedures. They both testified that they were aware of the requirement to obtain a hot work permit and that they intended to apply for one after setting up the welding equipment. They also admitted that, when they energized the welding machine, they were not following proper welding procedures that they learned in welding school or during their service on Carnival's vessels.

Following this accident, Carnival Cruise Lines revised its SMS to require that engineering supervisors secure all portable welding machines to prevent employees from circumventing required safety procedures. Now, the welding machines are not released to fitters until a hot work permit is issued.

Carnival Cruise Lines is one of several subsidiaries of Carnival Corporation. The Safety Board is concerned that the SMS procedures and manuals for the other vessels in the fleets of Carnival Corporation's other operating companies may not contain processes to prevent employees from performing unauthorized hot work. The Safety Board believes that, for the ships in its fleets, Carnival Corporation should revise the SMS to include processes for preventing unauthorized flame cutting, grinding, or other activities that might ignite a fire.

The *Ecstasy's* main laundry ventilation ducts, which served as a conduit for the fire, had fail-safe fire dampers that closed in the event that the ventilation system lost power. If conditions warranted closing the dampers while the ventilation systems was operating, someone present in the laundry area or someone on the bridge had to shut the dampers. In this accident, if the fire in the overhead had triggered the closure of the laundry fire dampers, the shutdown would have occurred several minutes before the bridge personnel secured the ventilation system, which would have resulted in appreciably less heat, smoke, and flame escaping from the main laundry and spreading to the mooring deck.

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While automatic fire dampers with passive actuating mechanisms are one way to effectively stem the spread of smoke and fire through ventilation systems in high-risk areas, such dampers are not the only method of mitigating the danger. The Board considers the individual cruise ship companies best qualified to analyze their vessels' design arrangements and devise measures for dealing with the problem. The Safety Board believes that Carnival Corporation should, for existing vessels with ventilation system arrangements similar to the Fantasy Class ships, engineer, design, and implement system modifications to mitigate the spread of smoke and fire from the laundry rooms through the ventilation ducts to other areas of the vessel.

The *Ecstasy's* mooring station, where the major fire occurred, was categorized as an open deck, which meant that the area was not required to have smoke detectors or sprinklers. The mooring station had been equipped with 11 mooring lines, each measuring 220-meters and weighing about 900 pounds. The fire that migrated to the mooring deck ignited lint that had been exhausted from the laundry and imbedded in the mooring lines. The burning lint, in turn, ignited the lines. Based on postaccident tests that determined the heat of combustion generated by the mooring line, the Safety Board estimated that the consumption of the polypropylene line on the mooring station could have yielded as much as 150 million Btu (British thermal units) of heat.

If sprinklers had been installed and had activated on the mooring deck, the water might have extinguished the ignited lint before the mooring line caught fire. At the least, water from activated sprinklers would have knocked down the flames, which probably would have enabled shipboard firefighters to enter the mooring station and combat the fire earlier.

In the past, cruise ships typically were designed with mooring decks having either no overhead or an overhead and large permanent openings in the vessel's side shell. Because the mooring deck area was open to the weather, the risk of fire was low; therefore, SOLAS did not require mooring decks to have fire protection. Modern cruise ship designs, such as that of the Fantasy Class vessels, typically incorporate the mooring station into the superstructure, often below accommodation and service spaces. Many mooring stations have openings that can be closed with hatches or covers. Despite this loss of openness, SOLAS still categorizes these mooring stations as open decks that are not required to have fire protection systems. Some newer ship designs also place ventilation inlets and outlets on the mooring decks. The Coast Guard, recognizing the safety issues inherent in the design arrangement, has proposed that the International Maritime Organization (IMO) clarify the category for mooring decks such as the type on the *Ecstasy*. The Coast Guard has recommended that, for all new construction, a partially covered mooring deck be categorized as an auxiliary machinery space. This categorization would

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[2] *Navigation and Vessel Inspection Circular* No. 09-97.

not only require fire protection systems (detection and suppression) but also prohibit using the space as a ventilation terminus. The status of the Coast Guard's proposal at IMO is pending.

Regardless of whether the IMO agrees to categorize mooring decks as recommended by the Coast Guard, any action taken by the IMO will not take effect immediately and may affect only certain cruise ships. All efforts should be made without delay to minimize the potential for fire on mooring decks that are incorporated into the vessel structure. The Board recognizes that some mooring decks are used to store only anchors or small combustibles or both and, thus, might not warrant fire protection. To optimize safety, cruise ship companies need to examine their mooring stations for fire risk and determine the need for detection and suppression systems. The Safety Board, therefore, believes that Carnival Corporation should, for existing vessels having mooring deck arrangements similar to the Fantasy Class ships, install automatic fire suppression systems on mooring decks that contain high fire loads and presently have no automatic fire protection.

Although no one was seriously hurt in the *Ecstasy* accident, the Safety Board identified several improvements needed in the area of passenger and crew safety, including accounting for all personnel on board.

Carnival Cruise Lines conducted an emergency drill for the *Ecstasy's* passengers before the vessel sailed. Of the 126 passengers who responded to a postaccident survey conducted by the Safety Board, a number of respondents who mustered on an outer deck said that they had to move to a different station because of smoke.[3] In this accident, three MVZs were closed, forcing passengers to go to different muster stations than those to which they were assigned.

During the emergency, two crewmen were unable to exit their deck because of heavy smoke. They initially sought refuge in a crew cabin. They were following survival techniques in a shower when one of the men panicked because of worsening smoke conditions. He left the toilet facility and began feeling his way along the bulkhead of the smoke-filled passageway. The other crewman followed the first man to try and convince him to return to the safety of the shower. The severity of the smoke-inhalation injuries that they sustained was limited only because fire team members searching the area happened upon the crewmembers. In addition, one passenger stated that a crewmember told her not to retrieve her lifejacket from her stateroom and, later, another crewmember told her to get her lifejacket from her cabin. She said that when she attempted to do so, she could not reach her stateroom because of the smoke.

The passenger's attempted return through a smoke-filled corridor to her stateroom and the short entrapment of two crewmen in their accommodations area raised questions about the two methods used by the *Ecstasy's* shipboard personnel to account for passengers and crewmembers during the emergency muster. At the muster stations, the crewmembers noted the letters imprinted on the lifejackets worn by passengers to ensure that they had reported to the correct station. The muster station crews did not have a list, by name, of passengers assigned to the respective stations. In the accommodation areas, crewmembers checked each room to determine whether it was empty. They then wrapped a towel around the doorknob to show other

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[3] The Safety Board mailed questionnaires to 300 *Ecstasy* passengers asking about the muster drill and whether they encountered any problems during the actual emergency.

searchers that the room had been checked. Neither of these procedures provides assurance that the vessel has accounted for everyone on board.

SOLAS leaves the method of devising procedures to account for passengers and crew during an emergency up to the companies. The International Safety Management Code presently stipulates the need for cruise ship companies to account for passengers and crewmembers. Courses developed by the Coast Guard and the marine industry to meet the emergency preparedness requirements contained in amendments to the *International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers* stipulate that the preferred method of accounting for people at muster stations is by name so that rescue crews can employ more systematic methods of searching for missing persons.

The Safety Board is aware that the *Ecstasy* maintained an electronic manifest of all passengers. When passengers boarded the ship, their names were entered into a computer and they were issued magnetic cards that tracked their purchases and their debarkations and embarkations at travel stops. Given the advancements in computer technology, magnetic cards or other computer-based devices and equipment could be used to quickly determine who has not mustered during an emergency.

Because even short delays in identifying missing people can have fatal consequences, it is essential for companies to have systematic procedures to account for people by name. Moreover, the *Ecstasy* accident demonstrates that the accounting procedures must address different emergency scenarios. Depending on the time of the alarm and the location of passengers and crewmembers, several hundred people might be forced to report to an alternate muster station if an MVZ is secured to isolate a fire.

Holland-America, another subsidiary of Carnival Corporation, accounts for its passengers by taking roll at muster stations. The Safety Board is convinced that, during a fire emergency, an accurate accounting by name is essential for passenger and crew safety. The accounting methods used on a ship should be incorporated into the SMS procedures presently required by SOLAS. The Safety Board believes that, for the ships in its fleets, Carnival Corporation should develop plans to account for all passengers in common emergency scenarios, in particular, a situation involving the inaccessibility of one or more MVZs and/or muster stations.

The two crewmen who were trapped by smoke in a toilet facility on their deck could not notify anyone of their predicament because their accommodations area lacked a means of signaling for help, such as a call system. The crewmembers' inability to signal for help demonstrates again that existing SOLAS requirements for emergency communication are not adequate. The *Ecstasy's* passageways had telephones; however, using one of them to call for help depended upon a person being able to reach a telephone. In this accident, the cabin steward who first smelled and saw smoke tried to alert crewmembers in nearby cabins of the fire. Conditions worsened considerably during the brief time that he knocked on cabins doors, and dense, suffocating smoke prevented his and another crewmember's escape. The men did not have the option to walk to or spend time on a corridor telephone.

A similar situation occurred in the *Universe Explorer* accident,[4] but with fatal consequences. Rescuers found three dead crewmembers in the passageway and two dead crewmembers in their cabins. If they did not have the time and opportunity to reach an emergency exit, it is unlikely that they had time and opportunity to locate a corridor telephone to let someone know they needed immediate help. In its report on the *Universe Explorer* accident, the Safety Board discussed the simple call button system used to summon flight attendants on commercial airlines. Hospitals and nursing facilities employ a similar system to enable patients to signal for nursing assistance. The Safety Board believes that Carnival Corporation should install emergency call systems in passenger staterooms and crew cabins so that people trapped during a fire emergency will have a means of signaling their location.

The *Ecstasy* had been built to Lloyds Register of Shipping (LR) regulations, which stipulate the need to provide independent and isolated power supplies to essential components of the vessels engineering systems, such as propulsion. The *Ecstasy's* propulsion system had many redundant features and isolated components designed to provide reliability. However, the auxiliary voltage to the high-speed breakers for the starboard and the port propulsion systems was routed through the same distribution panel, which was in an electrical equipment room on the deck above the mooring station. The auxiliary voltage was essential to the operation of both propulsion systems. When the distribution panel sustained heat damage, both systems failed.

The propulsion system was designed and manufactured by ABB, a subcontractor to Kvaerner Masa, the shipbuilder. The integration of the propulsion system into the ship's other systems, notably the electrical distribution system, was the responsibility of Kvaerner Masa's designers. ABB's specifications to the shipbuilder list the required voltage and current supplying the propulsion system. The specifications do not indicate that the voltage supply should be provided by independent sources. Kvaerner Masa routed the auxiliary voltage for both high-speed breakers through a single external interface.

As part of the agency's investigation, Safety Board staff contacted ABB regarding the reviews and examinations of the propulsion system that were conducted before and during the construction of the *Ecstasy*. ABB officials stated that they did not do a qualitative failure analysis of the propulsion system for the Fantasy Class ships, including the *Ecstasy*, because it was not required by SOLAS standards and LR regulations. In addition, the ship owner did not require a system failure analysis.

A qualitative failure analysis can identify potential failures and rank them according to the probability of occurrence, the severity of effects, and the probability of detection. System failure analyses are widely used in many other industries as part of the overall movement toward quality improvement in processes and products. In addition, IMO now requires that a failure analysis be performed during the design of navigation equipment and bridge systems. The Coast Guard has required the use qualitative failure analysis techniques in evaluating the reliability and safety of vital system automation on U.S. flag vessels since 1988. In proposing the regulatory requirement that designers, manufacturers, and/or shipyards perform and submit system failure

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[4] National Transportation Safety Board, *Fire on Board the Panamanian Passenger Ship* Universe Explorer *in the Lynn Canal Near Juneau, Alaska, July 27, 1996,* Marine Accident Report NTSB/MAR-98/02 (Washington, DC: NTSB, 1998).

analyses, the Coast Guard stated that the use of advanced automation technologies such as electronics and microprocessors made it increasingly difficult, "at times impossible, for the Coast Guard, ship owners/operators, and classification societies to evaluate safety."

The Safety Board is convinced that a qualitative failure analysis can be an important technique to maximize the reliability and safety of a system before it is built, when changes can be easily made. The Safety Board believes that, in the construction of new passenger ships, Carnival Corporation should use qualitative failure analysis techniques to identify system components whose failure might cause a complete loss of propulsive power and take action to mitigate identified problems.

In summary, the National Transportation Safety Board makes the following recommendations to Carnival Corporation:

> For the ships in your fleets, revise the safety management system to include processes for preventing unauthorized flame cutting, grinding, or other activities that might ignite a fire. (M-01-2)
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> For the ships in your fleets, develop plans to account for passengers and crewmembers in common emergency scenarios, in particular, a situation involving the inaccessibility of one or more main vertical zones and/or muster stations. (M-01-3)
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> For existing vessels with ventilation system arrangements similar to Carnival Cruise Lines' Fantasy Class ships, install an automatic method or system to mitigate the spread of smoke and fire from laundry spaces through the ventilation ducts to other vessel areas. (M-01-7)
>
> For existing vessels with mooring deck design arrangements similar to Carnival Cruise Lines' Fantasy Class ships, install fire detection and suppression systems on mooring decks that carry high fire loads and presently have no automatic fire protection. (M-01-8)
>
> In the construction of new passenger ships, use qualitative failure analysis techniques to identify system components whose failure might cause a complete loss of propulsive power and take action to mitigate identified problems. (M-01-9)
>
> Install emergency call systems in passenger staterooms and crew cabins so that people trapped during a fire emergency will have a means of signaling their location. (M-01-10)

The Safety Board also issued safety recommendations to the U.S. Coast Guard, American Classic Voyages, Carnival Cruise Lines, Crystal Cruises, Disney Cruise Line, Norwegian Cruise Line, Orient Lines, P&O Princess Cruises International, Ltd., Radisson Seven Seas Cruises, Regal Cruises, Renaissance Cruises, Inc., Royal Olympic Cruises, Royal Caribbean Cruise Lines, and Silversea Cruises, Ltd., ABB, Inc., and the International Association of Classification Societies. In your response to the recommendations in this letter, please refer to M-01-2 and –3 and M-01-7 through -10. If you need additional information, you may call (202) 314-6607.

Acting Chairman CARMODY and Members HAMMERSCHMIDT, GOGLIA, and BLACK concurred in these recommendations.

By: Carol J. Carmody
Acting Chairman