

Report on the investigation of heavy weather
encountered by the cruise ship

Pacific Sun

200 miles north north east of North Cape, New Zealand

on 30 July 2008

resulting in injuries to 77 passengers and crew

Marine Accident Investigation Branch
Carlton House
Carlton Place
Southampton
United Kingdom

Report No 14/2009
June 2009

The MAIB has investigated this accident pursuant to the IMO Code for the Investigation of Marine Casualties and Incidents (Resolution A.849(20)).

MAIB gratefully acknowledges and appreciates the generous assistance provided by New Zealand's Transport Accident Investigation Commission during this investigation.

Extract from
The United Kingdom Merchant Shipping
(Accident Reporting and Investigation)
Regulations 2005 – Regulation 5:

“The sole objective of the investigation of an accident under the Merchant Shipping (Accident Reporting and Investigation) Regulations 2005 shall be the prevention of future accidents through the ascertainment of its causes and circumstances. It shall not be the purpose of an investigation to determine liability nor, except so far as is necessary to achieve its objective, to apportion blame.”

NOTE

This report is not written with litigation in mind and, pursuant to Regulation 13(9) of the Merchant Shipping (Accident Reporting and Investigation) Regulations 2005, shall be inadmissible in any judicial proceedings whose purpose, or one of whose purposes is to attribute or apportion liability or blame.

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GLOSSARY OF ABBREVIATIONS AND ACRONYMS

CCTV	-	Closed Circuit Television
CDEM	-	Civil Defence and Emergency Management
CLIA	-	Cruise Lines International Association
ERC	-	Emergency Response Center (Princess Cruises)
ERO	-	Emergency Response Organisation
ETA	-	Estimated time of arrival
EU	-	European Union
GES	-	General Emergency Signal
GM	-	Metacentric Height
GMDSS	-	Global Maritime Distress and Safety System
HF	-	High Frequency
IACS	-	International Association of Classification Societies
IMO	-	International Maritime Organization
kW	-	Kilowatt
LR	-	Lloyd's Register
LT	-	Local Time
m	-	metres
MCA	-	Maritime and Coastguard Agency
Medivac	-	Medical Evacuation
Metservice	-	Meteorological Service of New Zealand
MSL	-	Mean Sea Level
MTN	-	Marine Telecommunications Network
nm	-	nautical miles
NTSB	-	National Transportation Safety Board
OOW	-	Officer of the Watch
PA	-	Public Address System

PSA	-	Passenger Ship Association
PSD	-	Passenger Services Director
s	-	seconds
SERS	-	Ship Emergency Response Service (LR)
SMC	-	Safety Management Certificate
SOLAS	-	Safety of Life at Sea Convention 1974, and its Protocol of 1988 as amended
t	-	tonnes
TAIC	-	New Zealand Transport Accident Investigation Commission
UTC	-	Universal Co-ordinated Time
VSAT	-	Very Small Aperture Terminal
WRI	-	Weather Routing, Inc.
Z	-	Zulu Time, alternative nomenclature used by some authorities instead of UTC

Times: Between 0200 on 26 July and 0200 on 29 July times are UTC+11 hours, all other times are UTC+12 hours.



Pacific Sun

SYNOPSIS

During the evening of 30 July 2008 the cruise ship *Pacific Sun* rolled heavily in gale force winds and high seas while returning to Auckland on the final leg of an 8-day cruise of the South Pacific. Of the 1730 passengers and 671 crew on board, 77 were injured, with seven sustaining major injuries.

The motion of the ship had increased during the day, and at sunset the master had hove to into wind and swell, in doing so reducing the vessel's speed to below that at which the one working stabiliser was effective. Two hours later, the ship rolled heavily three times, to an estimated angle of heel of 31°, as the master was attempting to reduce her motion by altering course.

Many of the injuries sustained by the passengers and crew were caused by falls and contact with unsecured furnishings and loose objects in the busy public rooms, including those designated as passenger emergency muster stations. Following the accident, the moving furniture and debris made many of the public rooms unusable, and the master instructed the passengers to return to their cabins for their own safety.

Had *Pacific Sun's* furnishings and fittings been sufficiently secured so as to resist moving when she heeled, the number of injuries would have been greatly reduced.

As a consequence of this accident, Princess Cruises has taken action to: supply its bridge teams with night vision glasses; improve deck officers' training in the risks associated with heavy weather; and review the securing arrangements for its vessels' satellite communications equipment.

Princess Cruises has been recommended to: review the role of active stabilisers in ensuring passenger safety; review the risk of injury from moving furnishings and objects, and develop suitable means of securing such items for heavy weather; develop a standard for securing furnishings and equipment in public spaces; and develop its heavy weather guidance and instructions to include actions to reduce the risk of injury to personnel.

MAIB has recommended that the Cruise Lines International Association and the Passenger Shipping Association develop a guide on industry best practice based on Princess Cruises' standard for securing furnishings. The trade associations have also been recommended to promulgate the lessons learned from this accident to their members.

SECTION 1 - FACTUAL INFORMATION

1.1 Particulars of *Pacific Sun* and accident

Vessel details

Registered owner:	:	Carnival PLC (trading as P & O Cruises Australia)
Manager	:	Princess Cruises
Operator	:	P&O Australia
Port of registry	:	London
IMO Number	:	8314122
Flag	:	UK
Type	:	Passenger cruise ship
Built:	:	July 1985
Construction:	:	Steel
Length overall:	:	223.36m
Gross tonnage:	:	47,546

Accident details

Date & Time:	:	30 July 2008, 1945 LT UTC+12
Location of incident:	:	200 miles NNE North Cape, New Zealand
Persons on board:		1730 passengers and 671 crew
Injuries/fatalities:		77 injuries to passengers and crew, including 7 major injuries
Damage/pollution:		Substantial damage to internal furnishings. No pollution

1.2 NARRATIVE

1.2.1 Background

Pacific Sun, operated by P&O Australia, was engaged in a series of cruises from Auckland to the Pacific Islands to the north, taking the passengers to warmer weather during the southern hemisphere winter. The accident happened during an 8-day “Summer Daydream” cruise (**Figure 1**). The itinerary stated that after departure from Auckland on 23 July 2008, 2 days were to be spent at sea followed by port calls at Lifou, Port Vila and Mystery Island. There would then follow a 2 day return passage to Auckland, arriving on 31 July.

Figure 1



Extract from the P&O Cruises
“South Pacific - Queensland - Asia 2007-2009” brochure

1.2.2 Pre-departure

At 1630 on 23 July, *Pacific Sun*'s master made a public address (PA) announcement to the passengers stating that the vessel would depart late due to strong winds on the berth. He warned that they would be heading into rough weather overnight, which might cause the vessel to pitch and roll, and advised that they take care when moving around the vessel.

Prior to departure, the staff captain notified the department heads by email of the forecast heavy weather and advised them that equipment should be secured. The deadlights¹ on decks 3 and 4 were confirmed as secure before departure.

Sailing with the ship were two technicians: one employed to check the condition of the starboard stabiliser and to identify a long-standing fault with the port stabiliser; and one from the manufacturer of the ship's satellite communications system.

1.2.3 The cruise

At 2210 on 23 July, *Pacific Sun* departed Princess Wharf, Auckland assisted by tugs in 20 knot westerly winds. Due to the late departure, the speed required to arrive at the first port of call of Lifou had increased from the scheduled 17.1 knots to 18.9 knots, the vessel's maximum speed in light winds and low swell conditions.

Early the following afternoon, with the ship making good a speed of 17 knots in strong headwinds and heavy swell, the master advised the passengers that the itinerary would be amended. He informed them that *Pacific Sun* would not call at Lifou, and that they would head directly to Port Vila, arriving as early as possible depending on the weather conditions. The next 2 days were spent heading northward during which the rolling and pitching of the ship gradually moderated.

During the passage, the Global Maritime Distress and Safety System (GMDSS) High Frequency (HF) transmitter failed. This was recorded in the GMDSS log and a request was made for a technician to attend during the vessel's next call in Auckland.

Pacific Sun arrived alongside in Port Vila slightly early on the morning of 27 July. However, the vessel's departure was delayed for a medivac of a sick passenger who was landed ashore at 0228 the next day, and *Pacific Sun* sailed from Port Vila shortly afterwards.

At 0720 on 28 July, the master received the first weather routing information (**Annex 1**) by email from Weather Routing, Inc. (WRI)². The weather forecast predicted that a storm would form over the South Coral Sea overnight, then drift

¹ Steel covers for glass portholes

² Weather Routing, Inc. provides meteorological consulting, including forecasts and route planning for commercial fleets and private yachts.

south easterly and develop to give gale force winds later. The master was advised by WRI to: *Modify course / speed as needed for best handling in this unavoidable heavy weather.* The winds were forecast to be force 8-9 gusting 10 from the west north west, with the sea building to 6.5m.

The late departure from Port Vila meant that, despite setting an increased speed, *Pacific Sun* arrived at Mystery Island³ at 1430 on 28 July, 6½ hours later than scheduled. At Mystery Island *Pacific Sun* anchored and the passengers were ferried ashore. Because of the time this took, the master decided to delay *Pacific Sun's* departure from 1600 to 1815 so that the passengers could spend longer ashore.

1.2.4 The passage

Pacific Sun's passage from Mystery Island to Auckland had been planned on the basis that the vessel would proceed at 17.3 knots. However, because of the vessel's later departure from Mystery Island, her speed was increased to 17.9 knots to meet the scheduled arrival time at Auckland.

WRI weather update No.2 (**Annex 1**) was received at 0900 on 29 July and informed that the developing storm would gradually move south; with the wind forecast to be force 9 from the west north west gusting force 10, with wave heights up to 6.5m. The advice to the master was:

Route valid, as able. Adjust course / speed as needed in unavoidable heavy weather.

At 1830 the master made a PA announcement, warning passengers of the expected heavy weather, and the staff captain sent an email to the department heads instructing them to check that their departmental areas were secure.

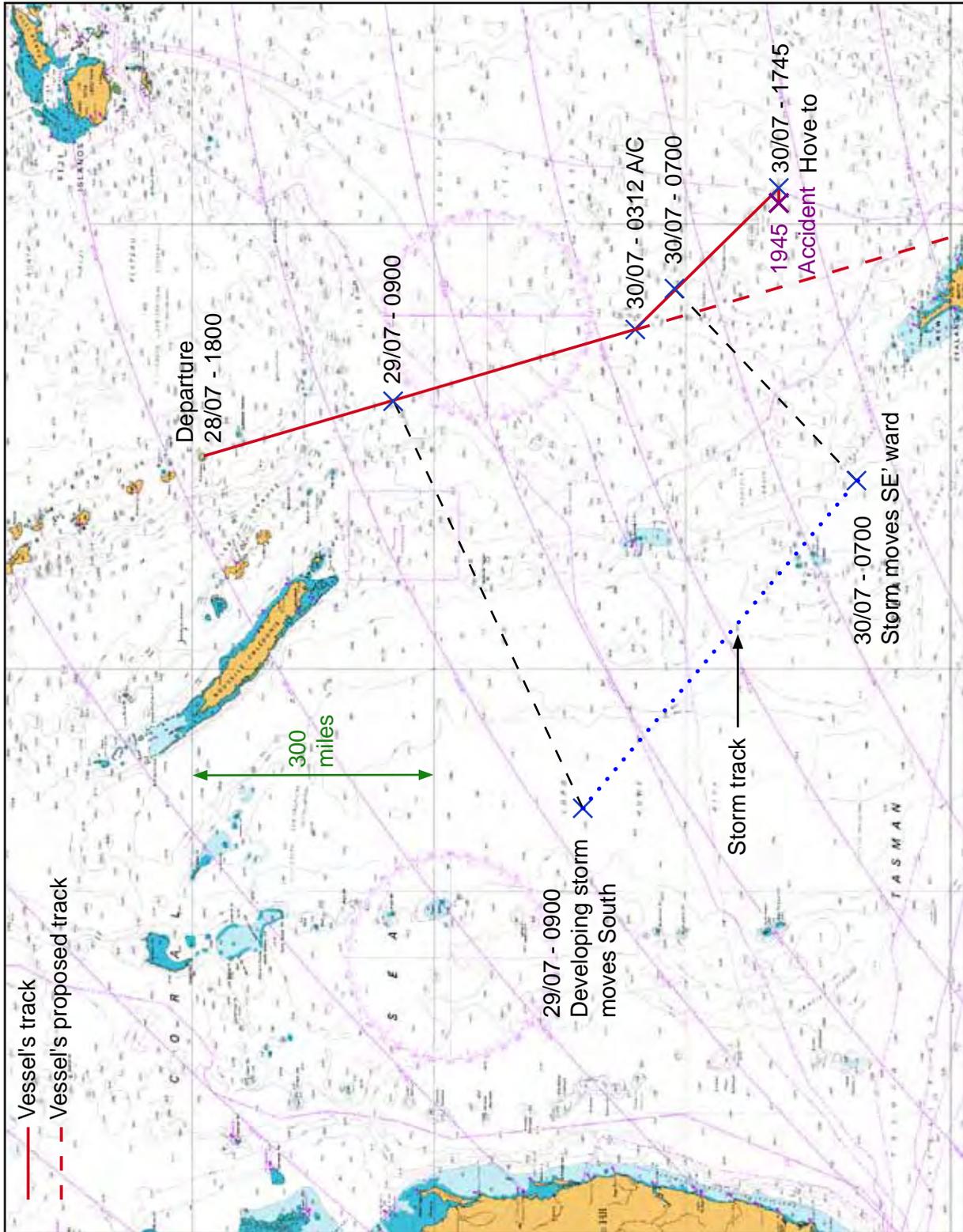
Overnight the weather deteriorated, with the wind and sea increasing from the north west, and the rolling and pitching also increased. At 0312 on 30 July, the master altered course to 136° and reduced the speed by 2 knots to place the sea and swell on the starboard quarter and reduce the vessel's rolling. At 0400 the Officer of the Watch (OOV) recorded that *Pacific Sun* was rolling heavily and pitching due to rough seas and a 5m north westerly swell.

At 0700, the weather routing forecast No.3 (**Annex 1**) was received from WRI. The storm centre had moved in a south easterly direction overnight rather than the predicted southerly track (**Figure 2**). The master was again advised that:

As able route valid. Modify course / speed as needed for best handling in unavoidable gale to storm force W-NW winds and large W-NW swells associated with the aforementioned storm.

³ Mystery Island is also known as Anatom Island or, more correctly, Aneityum Island, the most southerly island of the Vanuatu archipelago.

Figure 2



Plot of Pacific Sun and the storm centre

At 0900 the master advised the Director of Nautical Operations in the Carnival Office in Sydney of his situation, and gave a revised estimated time of arrival (ETA) of 1200 on 31 July, 5 hours later than expected.

At 1735, shortly before sunset, *Pacific Sun* was recorded as pitching moderately and rolling to a maximum angle of 10°. The starboard stabiliser was confirmed as extended and working, while the port stabiliser was housed with a known fault. With sunset approaching, overcast skies, and virtually no moon, the master was aware that the seas would soon become indiscernible. He therefore decided to turn from a heading of 135° degrees to 270° to heave to into the wind and swell.

The master announced to the passengers and crew that the vessel might roll as she turned. The turn commenced at 1740 in hand steering and, at 1745, it was complete. The speed was reduced to 4.5 knots over the ground, around 6 knots through the water, and the roll severity moderated to a maximum of 5-6° at times. At this speed, the master considered that the one stabiliser had 30-40% the effect of both stabilisers at full speed. The master advised the OOW to alter course if necessary to reduce rolling and to make the motion as comfortable as possible, while he divided his time between his cabin and the bridge.

At 1826 the master made a further PA announcement to the passengers advising them to take care as they moved around the ship during the evening, and to use handrails wherever possible.

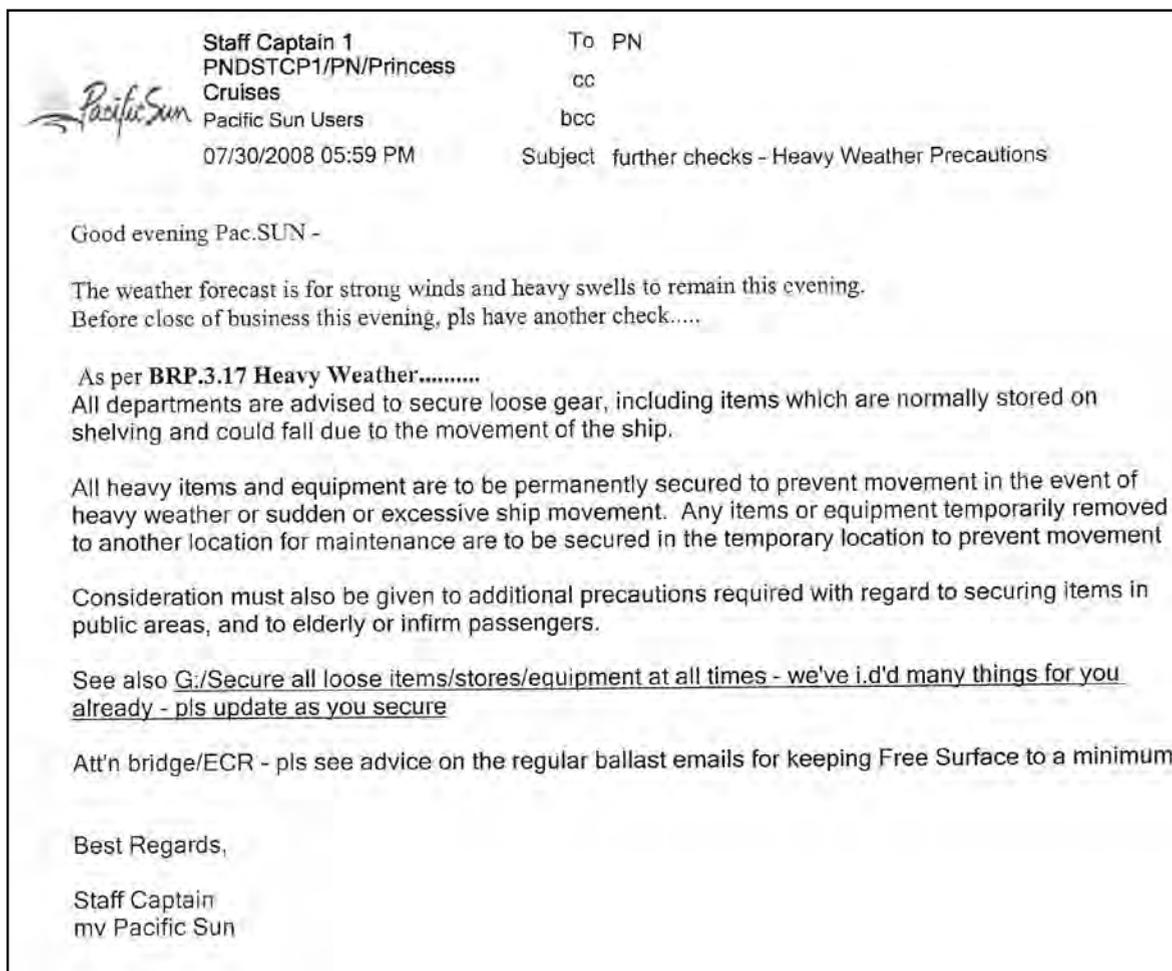
At 1900 the staff captain sent an email to the heads of department, stating: *the weather forecast is for strong winds and heavy swells to remain this evening. Before close of business this evening, pls have another check.* The instruction was followed by the company's "Heavy Weather Precautions" (**Figure 3**).

1.2.5 The accident

At 1935 the vessel rolled more heavily, to around 14°, on a heading of between 265° and 275°. When the master arrived on the bridge, the OOW was altering the heading to 280° in an attempt to reduce the severity of the roll. The master tried to, but he could not, establish the direction of the sea and swell by looking out of the bridge windows into the darkness.

At 1937 the master used the PA system to announce to the passengers that he was about to turn the vessel to reduce the rolling. He warned that this might result in her rolling and pitching. The master took over the conduct of the ship from the OOW and, at 1938, ordered 10° port rudder. As he did so, but before the rudder had been applied, the ship started to pitch moderately and rolled heavily to starboard to around 23°. The ship continued to roll heavily three times; the final and largest roll heeled *Pacific Sun* to an estimated 31° to starboard as the heading was altered to 260°.

Figure 3



Email sent by the staff captain to department heads at 1900 on 30 July 2008

At 1938 the staff captain ordered the fore peak tank to be de-ballasted to reduce the free surface effect and increase the metacentric height (GM) and trim the bow up.

The heavy rolling caused passengers and crew, together with unsecured and insufficiently secured furniture, to move across the ship. The greatest disruption was in the upper deck large public rooms and restaurants where the majority of passengers were located. The accident caused fear and great anxiety among many of the passengers.

The effect of the roll is shown in the sequence from the CCTV footage in **(Figure 4)**.



Legends Bar, Deck 9, prior to the three large rolls



Legends Bar, Deck 9, following the three large rolls

1.2.6 Post accident events

The master turned the ship to starboard, and initially steadied her on a heading of 280° with a speed over the ground of 3.5 knots.

The medical staff started to muster at the hospital on deck 3, aware that a mass casualty incident was likely.

At 1949, the master altered course to 290° as *Pacific Sun* continued to pitch moderately and roll to a maximum of 10°. At this time, the first six casualties were reported to the bridge by radio, and the master then made a PA announcement for injured passengers to go to the medical centre on deck 3. At 1953, following a request from the senior doctor, the master announced that the secondary medical centre had transferred from the Outback Bar and Grill, which had been badly affected by debris and was unusable, to the Oz Night Club, he also requested medically trained passengers to volunteer to assist.

At 1954 the master instructed the communications officer to contact Princess Cruises to establish the company's Emergency Response Center (ERC) in California. The satellite C communications system, the usual method of communicating with the shore, was inoperative and communications were instead established by one of the satellite B telephones.

At 1956 the Stretcher Party was mustered, and the first serious injury - of a passenger with severe bleeding - was reported to the bridge.

At 2000, as reports of more casualties continued to be received, the master sounded the Crew Alert signal. This required that crew return to their cabins, collect their lifejackets and report to their crew alert stations. The master announced that all passengers should immediately return to their cabins unless they were in need of medical assistance. Of the four muster stations, all located on the upper passenger decks, stations B and C were relocated due to "damage and safety issues". Most of the crew dealing directly with the injured passengers remained with them initially until they felt able to carry out their emergency duty.

The staff captain contacted the Lloyd's Register (LR) Ship Emergency Response Service (SERS) by satellite B telephone to request assistance in calculating the ship's stability condition. With the satellite C system defective following the large rolls, the information could not be sent automatically and the data was transferred orally via the satellite B system.

At 2009, the master contacted the Princess Cruises ERC team, headed by the Senior Vice President Marine.

At 2012 the master increased speed to 6 knots, maintaining a course of 290° to try to further reduce the ship's motion.

Under the direction of the staff captain, the Search and Rescue party started a thorough search of the ship to ensure that all injured passengers and crew had been identified and were receiving care. A further announcement was made for the passengers to return to their cabins.

At 2019, the master was informed that the starboard stabiliser fin was not working, and he requested the Chief Technical Officer to investigate the failure.

The master was advised that several passengers continued to arrive at their allocated muster stations, that some were uncomfortable in their cabins and some were concerned at the sight of the crew wearing lifejackets.

By 2026 all the onboard emergency parties had mustered, accounting for all crew on board, and the required parties were assisting with the injured.

At 2110 the crew, except the passenger muster personnel, were stood down from Crew Alert and the operation to clear debris and clean the ship started.

The passenger muster personnel continued to account for the passengers who were located mainly in their cabins, at one of the two medical centres, or at their muster stations. However, several of the passengers had congregated in cabins of friends or relatives, adding to the time taken to account for them. All of the 1730 passengers had been accounted for by 2350.

1.2.7 Recovery phase

Overnight the passengers remained in their cabins while the crew continued to replace furnishings, remove obstructions, make temporary repairs and clean the ship (**Figures 5a, 5b, 5c and 5d**). The satellite B phone line was maintained between the bridge and the company ERC throughout the night.

At morning twilight the combined sea and swell was observed to be from the west with a height of 8m. An occasional secondary swell from the north west was also seen, which was noted as being a higher and steeper swell than the predominant swell. The logbook recorded *Pacific Sun* as pitching and rolling moderately at times.

The fault with the starboard stabiliser could not be identified so it was housed, but then extended later that morning to act as a bilge keel in resisting the rolling of the vessel. It was not possible to extend the failed port stabiliser to produce a similar effect.

During the morning of 31 July the passengers were served breakfast in their cabins while the ship's officers made an assessment of the damage. At 1030, the master announced to the passengers that they could now leave their cabins,

Figure 5a



Public rooms condition following the accident - Outlook Bar and Grill,
Deck 10, Muster Station C

Figure 5b



Legends Bar, Deck 9, Muster Station B

Figure 5c



Speak Easy Piano Bar, Deck 8

Figure 5d



Duty-free shop, Deck 8

but advised them to take care around the ship. He also informed them that some areas remained out of bounds while the crew continued to clear up the debris.

Late in the morning the inoperative starboard stabiliser was housed for repair, which was successful, and at 1347 it was extended and returned to service in angle control mode.

During the day discussions between the ERC and the master continued in order to confirm the status of all tanks. Particular attention was paid to the status of ballast, black and grey water tanks to confirm the ship's calculated stability condition.

At 1430 the master updated the New Zealand Maritime Rescue and Co-ordination Centre of their situation and of the status of the injured passengers and crew.

Prior to altering *Pacific Sun's* course to 148°, towards Auckland, the master instructed all passengers to return to their cabins as a precaution. The vessel rolled and pitched moderately throughout the turn.

At 1313 on 1 August, *Pacific Sun* arrived alongside in Auckland where the three most seriously injured people were disembarked to awaiting ambulances.

1.3 THE THREE INSTANCES OF HEAVY ROLLING

The angle of heel was not recorded on board *Pacific Sun*; crew and passenger accounts of the extent of the vessel's motion vary widely. However, CCTV recordings showed the movement of pictures in the art gallery (**Figure 6**), which were suspended by light wires and able to move freely away from the bulkhead as the ship rolled to starboard. This footage allowed estimates to be made of the angles of heel achieved as the ship rolled, and the roll period.

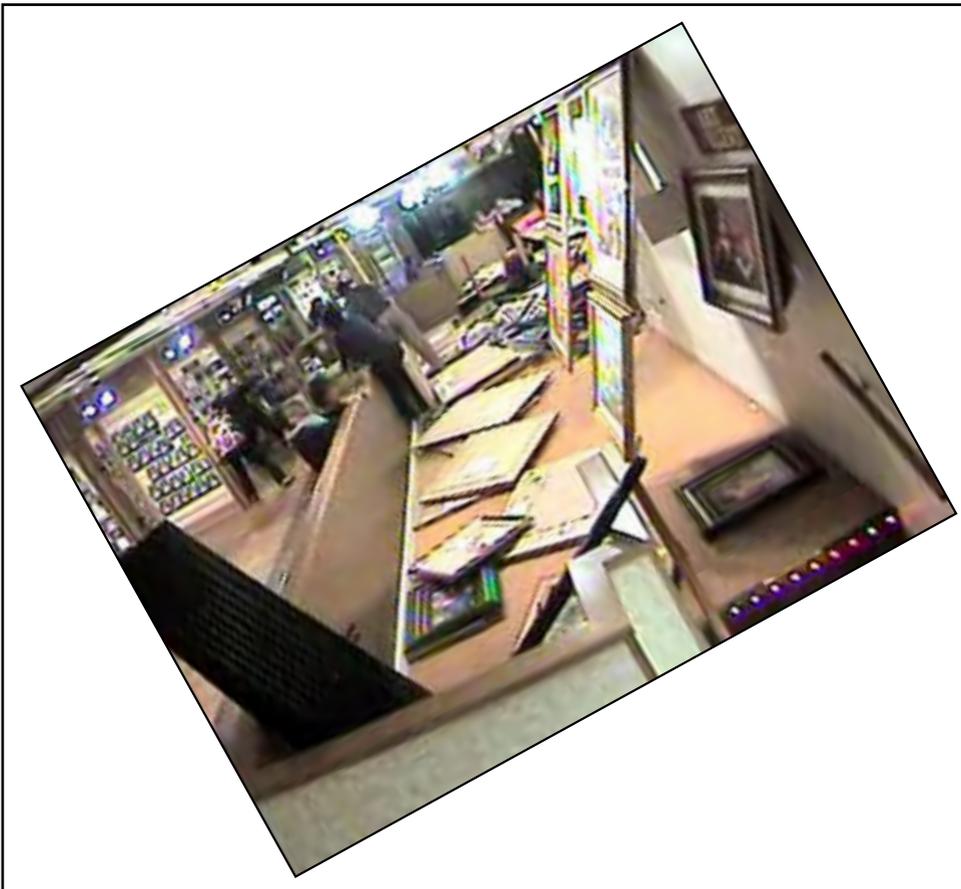
The heeling angles to starboard of the three large rolls were measured as 23°, 26° and 31° respectively. The extent of the heeling angles to port is not known, but CCTV footage of activity on board indicates the heels to port were similar in magnitude to the heeling angles to starboard.

1.4 TIMING OF THE ACCIDENT

The accident occurred at 1940, when most of the passengers were either at dinner or in the public rooms. The main passenger entertainment for the evening, in the Atlantis Showlounge, had been postponed due to the heavy weather. However, dinner was being served in the two main restaurants, and the Outback Bar and Grill, as normal, with their galleys providing a full service. All the bars on decks 8, 9 and 10 were open.



Art Gallery and Photo Gallery, Deck 9, at the largest recorded roll angle



How the vessel would have appeared at 31°

1.5 INJURIES TO PASSENGERS AND CREW

Of the 1730 passengers and 671 crew on board, 80 passengers and 11 crew injuries were initially recorded by the medical staff. The figures were later revised to 69 passengers and 8 crew injuries, due to the apparent duplication of records. Most of these were bruise and laceration injuries caused by contact with furnishings, and falls as they were thrown across the vessel. Several other passengers and crew sustained minor injuries that did not require medical assistance, were self-treated, or became apparent after the passengers disembarked. The list of injuries does not include the distress and anxiety caused to passengers, which reportedly led to several panic attacks.

Three of the injured required immediate hospital treatment on arrival in Auckland. These major injuries included: a pelvic fracture; rib injury with splenic injury; and extensive bruising. Seven fractures and a partial finger amputation were also recorded. A list of the recorded injuries is attached at **Annex 2**.

None of the passengers or crew was considered to be in the most serious “red” triage category. Three of the injuries to two passengers and one crew member were considered to be “yellow” within the triage system. A summary of the triage system is at **Annex 3**.

1.6 DAMAGE

1.6.1 Mapping of injuries by location

Pacific Sun sustained no structural damage during the accident. However, damage to internal furnishings, fixtures and equipment was extensive.

The locations where passengers sustained injuries, in so far as these could be identified, are shown at **Figure 7**. The majority of injuries occurred on the busy upper decks, in the public spaces, bars and restaurants with all the serious injuries occurring on decks 8, 9 and 10.

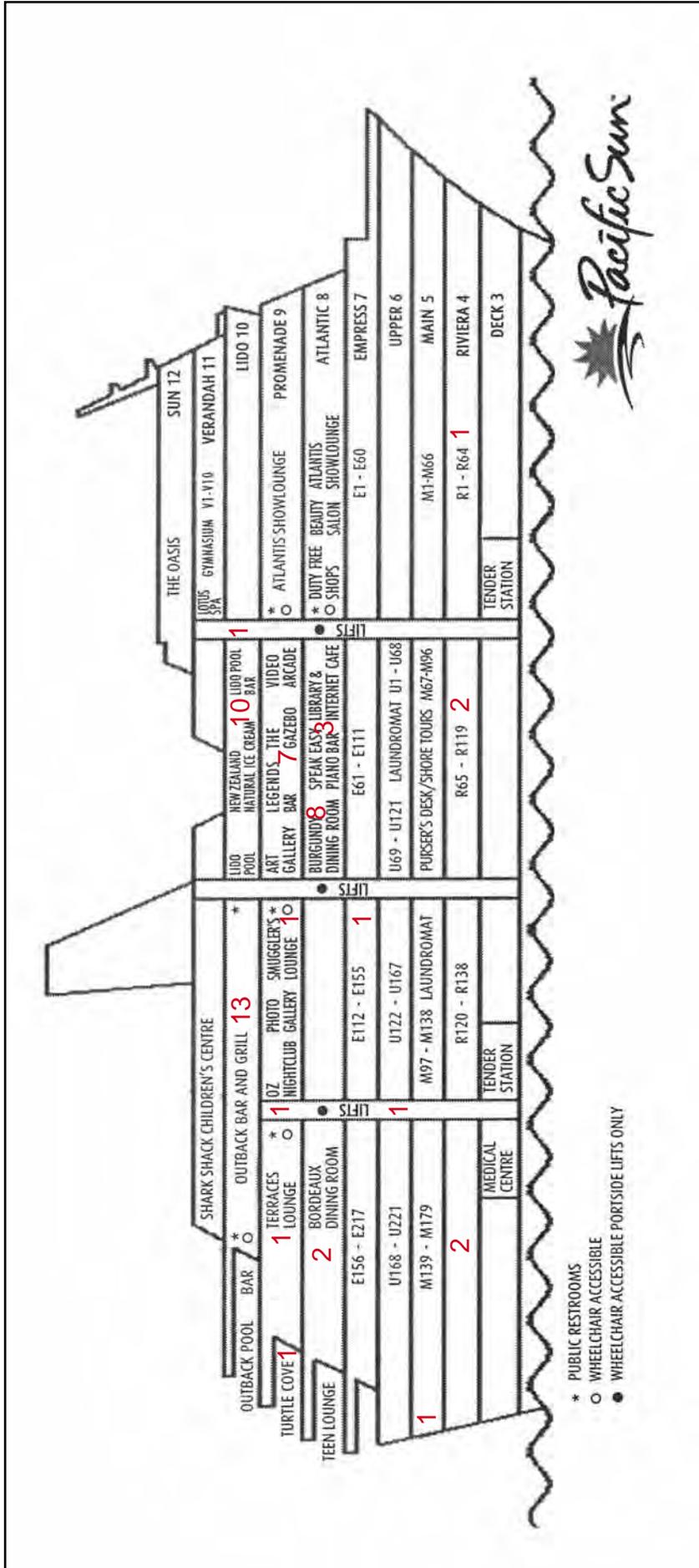
1.6.2 Muster stations

Four emergency muster stations, A, B, C and D, were provided on board (**Figure 8**) to congregate and account for the passengers in an emergency.

- Muster Station A (Deck 8 & 9) - Atlantis Showlounge

The deck 8 furniture consisted mainly of banquette seating and secured tables and chairs that remained secure with the exception of one fixed table that broke free. Only a few passengers were in this room at the time, and no major injuries were reported.

Figure 7



Location of injuries to passengers and crew - where known



Location of injuries, where known, and Muster Station locations

- Muster Station B (Deck 9) - Casino and Legends Bar

This muster station combined two areas of deck 9. The effect of the rolling in the casino area caused large secured items to move, including a bank of gaming machines to fall from the bulkhead (**Figure 9**). Some passengers only avoided injury because the adjacent chairs prevented the gaming machines from collapsing directly on to the deck. The electronic poker machine (**Figure 10**) came adrift and travelled across the casino deck, causing several reported injuries.

Figure 9



Collapsed casino gaming machines, Casino, Deck 9



Poker Pro machine, released from mountings, Deck 9

In the Legends Bar, where bar service was being provided, the effect of the roll can be seen in the 'before' and 'after' pictures at **Figure 4**. The settees, tables and chairs were all able to move freely, and the CCTV footage showed passengers attempting to regain their balance by grabbing at heavy unsecured tables and other unsecured furnishings as they were thrown and fell across the deck. The broken glass, liquids and fallen plant pots added to the hazards the passengers and crew faced, and at least seven injuries were reported from this area.

- Muster Station C (Deck 10) - Outback Bar and Grill

The highest number of injuries occurred in the Outback Bar and Grill where at least 13 passengers and crew were injured. The effect of the rolling in this restaurant can be seen in **Figure 11** where several passengers and crew were injured either by the moving objects or cut by the glass and crockery.

As the ship heeled, the unsecured tables and chairs slid across the full width of the room. Passengers, unable to hold on, fell and slid across the room with the debris, some crossing the deck several times.

- Muster Station D (Deck 9) – Terraces Lounge

The Terraces Lounge room extends the full width of the ship, and was in use at the time of the accident, with a band playing. This room contained a large number of heavy chairs and portable tables. One passenger was injured in this room.



Outlook Bar and Grill - Deck 10, Muster Station C, during the large rolls

1.6.3 Restaurants

Both the Burgundy and the Bordeaux main passenger restaurants on deck 8 were busy providing dinner when the accident occurred. Ten passengers and crew were injured by falling, or sustained cuts from the broken glass and crockery. Many passengers fell back from their chairs as the ship rolled, but most were able to hold on to the large secured dining tables.

1.6.4 Other public rooms and spaces

A grand piano located forward of the casino in the Tivoli Square slid across the deck and damaged an adjacent bulkhead.

One passenger in the Speak Easy Bar (deck 8) and one in the Smugglers Lounge (deck 9) sustained serious injury.

Passengers had started to put out their luggage in the passenger cabin alleyways in anticipation of the hotel crew taking the luggage to deck 3, ready for offloading the following day. This luggage fell and partially blocked the passenger alleyways.

1.6.5 Crew and working areas

In the officers, staff and crew mess rooms (**Figure 12**), all of which were in use at the time of the accident, no tables or chairs were secured to the deck and all of these moved as the ship rolled.

Figure 12



Damage to crew mess room, Deck 3

The stores handling area on deck 3 was a busy thoroughfare and served as a storage area for engineering equipment and baggage handling cages. As the ship rolled, a forklift truck which was stowed in this area, several heavy pipes and a number of storage boxes were able to move across the full width of the deck (**Figure 13**). In addition, at the extremities of the rolls the deck 3 shell doors were partly submerged and, as these were not watertight, seawater entered the deck, making it slippery.

Figure 13



Deck 3 handling area and crew main access, before and after the large rolls

In preparation for arrival in Auckland the next day, the crew had started to place on deck 3 the garbage and other equipment for landing, and some of these stows collapsed, blocking alleyways (**Figure 14**).

Figure 14



Deck 3 - main crew alleyway after accident

Under normal conditions, the preferred route to the medical centre from the forward part of the ship for stretcher parties was via the main crew alleyway. However, the obstructions in the store handling area and main crew alleyway on deck 3, along with the wet decks, made passage through this area extremely difficult.

1.6.6 Open decks

Many of the passengers were on deck 10 by the Lido pool bar. As the vessel rolled, the passengers, most sitting in plastic chairs, slid across the open deck and at least 10 were injured.

The two whirlpool spa pools on deck 11 were full with a total of 4.3t of water, most of which emptied as the ship rolled and flowed down to deck 10, making it slippery and hazardous for the passengers on that deck. The public address on decks 10 and 11 was compromised by the background noise from the wind. Consequently, some passengers could only partially hear the announcements made by the master.

1.6.7 Communications equipment

As the vessel rolled, the MTN⁴ satellite communications system in the communications office on deck 11 ripped from its securing arrangement and fell over, tearing out connections and disabling the unit (**Figure 15**).

Figure 15



Electro Technical Office after the accident

⁴ In May 2006, SeaMobile acquired Maritime Telecommunications Network (MTN), the industry leader in delivering global VSAT satellite communications to the maritime industry

1.7 ENVIRONMENTAL CONDITIONS

1.7.1 Weather forecast

Weather route forecast from WRI. Update #1, 27 July 2000Z (0800LT on 28 July) stated:

A ridge of high pressure from New Caledonia s'ward to 30S and e'ward to the International dateline, will move ese'ward next 1-2 days. Low center will form over the South Coral Sea during tonight, then drift ese-ward and deepen to gale later tonight / early 29th, before moving se-ward and deepening to storm later 29th thru 30th, reaching central New Zealand late 30th.

Recommend as conditions permit direct routing to Auckland. Note that the aforementioned Gale/storm in place, unavoidable gale to storm force w-nw winds and large w-nw swells are likely beginning on 29th, continuing farther south toward Auckland. Modify course / speed as needed for best handling in this unavoidable heavy weather.

Weather route forecast from WRI. #2 sent 28 July 2100Z (0900LT on 29 July) stated:

Developing storm near 28S / 162E will gradually move s'ward towards 41S 168E through morning of 31st with "tail end" of frontal boundary remaining across the port Villa area.....Ridging associated with series of high pressure systems will build around developing storm through 31st.

Route valid, as able. Adjust course / speed as needed in unavoidable heavy weather.

29/12-00z nw-w Force 8-9 swell wnw-nnw 4.0-6.5 swells build, gusts force 10

30/00-12z w-nw Force 8-9 wnw -nnw 6.5-5.5 gusts force 10

Weather route forecast from WRI .#3 sent 29 July 1900Z (0700LT on 30 July) stated:

Storm centred near 33s 169e, will drift ese-se'ward through 01st with center of system reaching /crossing central south island on 01st. meanwhile ridge of high pressure will build e'ward in the wake of the storm and into/across much of the s'rn Coral and n'rn Tasman seas over next 2-3 days.

As able, route valid. Modify course/speed as needed for best handling in unavoidable gale to storm force w-nw winds and large w-nw swells associated with the aforementioned storm.

29/19-00z wind w-nw F8-9 swell nnw-nw 4.5-6.5 periods F10.

30/00-12 w-nw F8-9 swell wnw-nnw 6.0-8.0 periods F10.

1.7.2 Sunset and twilight

Sunset on 30 July was at 1741LT and civil twilight at 1806LT. There was 5% moonlight, although the sky was overcast.

1.7.3 Weather hindcast from the Meteorological Service of New Zealand

The Meteorological Service of New Zealand (MetService) prepared a report at the request of the New Zealand Transport Accident Investigation Commission (TAIC). The report (**Annex 4**) concluded that:

From 0000 UTC on 29 July 2008 gale and storm warnings, and the Marine Weather Bulletin for Subtropic clearly indicated that northwesterly gales and heavy swells could be expected to affect the planned route of the “Pacific Sun” between Aneityum in Vanuatu and Auckland. The sequence of MSL⁵ analysis charts show that the gale and storm warnings and the Marine Weather Bulletins correctly described the wind and wave conditions that were experienced by the ship during the voyage. The computed wind wave and swell wave product showed that the time of highest combined wave height at the position of “Pacific Sun” coincided approximately with the time of the heavy weather incident at 0740 UTC 30 July 2008.

MetService predicted that the expected combined sea and swell height in the area at the time of the accident were in the region of 7m from the west with a period of around 11s (**Figure 16**).

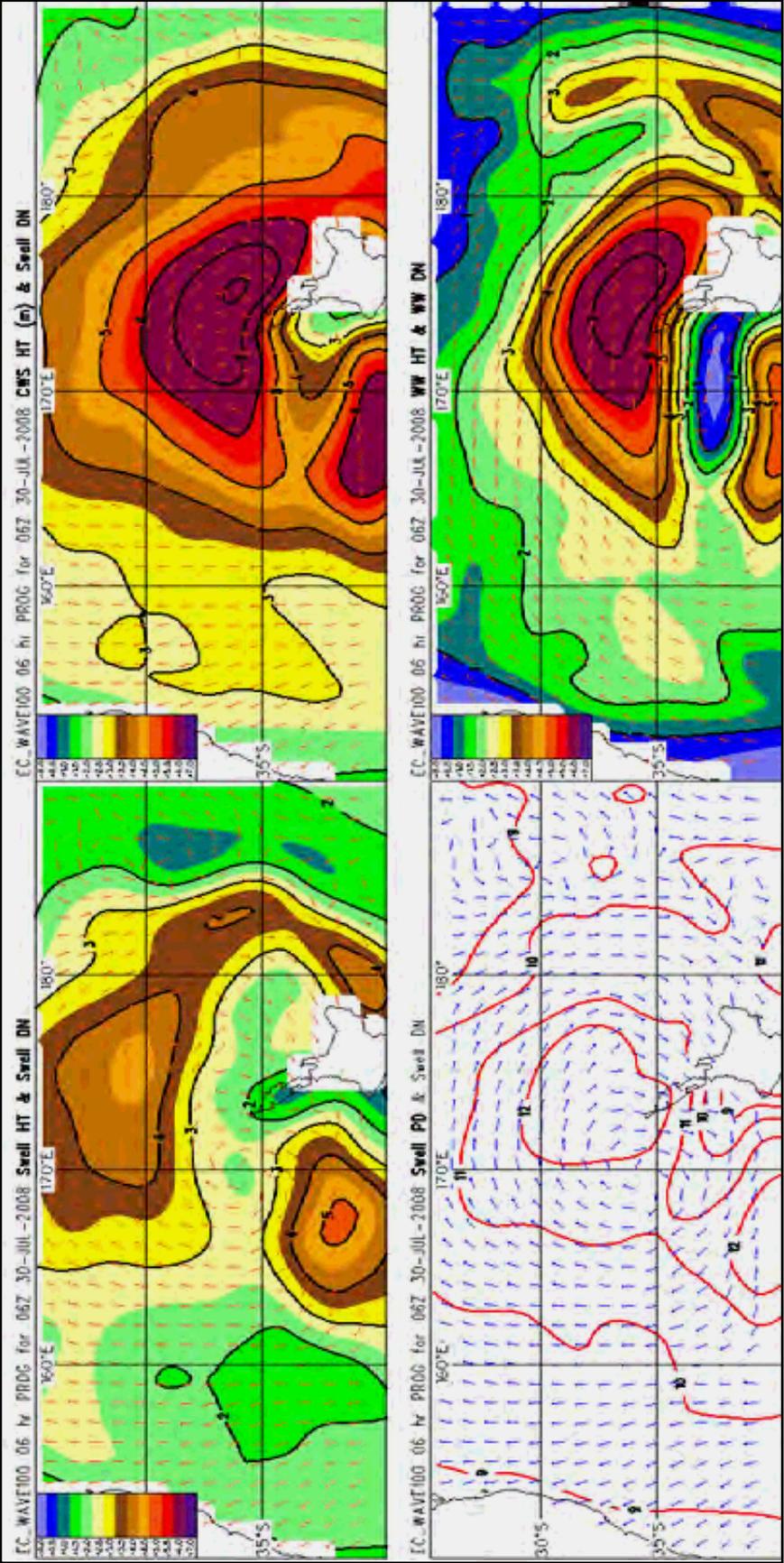
1.7.4 Effect of the storm on New Zealand

The mainland of New Zealand was buffeted by the weather system encountered by *Pacific Sun*, which locally disrupted road, rail, and air travel, and electricity and water supplies on 30 and 31 July. People were advised to avoid unnecessary travel in the affected areas and to listen to local radio for updates from the Ministry of Civil Defence & Emergency Management (CDEM). CDEM reported that:

Marlborough CDEM Group declared a state of local emergency in the Picton area at 3pm [30 June] due to flooding and the need to evacuate some people.

There were widespread reports of landslips, flooding, and damage to trees, buildings and roads in many regions of New Zealand during the storm.

⁵ Mean Sea Level



MetService wave analysis for 0600Z (1800 ship's time) 30 July 2008

1.8 SHIP MOTION INFLUENCES

1.8.1 Abnormal waves

The mariner's handbook notes that:

A well found ship properly handled is designed to withstand the longest and highest waves she is likely to encounter as long as they retain their original shape. But when waves are distorted by meeting shoal water, a strong opposing tidal stream or current, or another wave system, abnormal steep fronted waves must be expected. Abnormal waves may occur anywhere in the world where appropriate conditions arise. In places where waves are normally large, abnormal waves may be massive and capable of wreaking severe structural damage on the largest of ships, or even causing them to founder.

The Maxwave project⁶, undertaken by the European Union, showed that abnormal waves occur much more frequently than had been previously believed.

MetService notes in its report (**Annex 4**) that:

Individual waves may be much higher than this representative [significant wave height] measure; approximately 1 in 100 waves will be twice the significant wave height.

It is possible, therefore, that the waves experienced by *Pacific Sun* at the time of the three large rolls could have been exacerbated and steepened into abnormal waves due to the presence of the secondary wave pattern, which was observed by the master at daybreak the following morning.

1.8.2 Synchronous rolling

Synchronous rolling is an example of resonance. Large rolling motions may be excited when the natural roll period of a ship coincides with the encountered wave period.

MAIB studied *Pacific Sun*'s vulnerability to synchronous rolling (**Annex 5**). The calculated encounter periods were not coincident with *Pacific Sun*'s predicted natural roll period, therefore synchronous rolling is thought an unlikely contributor in this case.

⁶ Maxwave, full title 'Rogue Waves – Forecast and impact on marine structures' Dec 2000 to Dec 2003 was a sub programme of EU Programme FP5-EESD-1999, Sustainable marine ecosystems, Operational forecasting of environmental constraints of offshore activities.

1.8.3 Parametric rolling

Parametric rolling can be a particular problem on ships designed or modified with a flat transom and large bow flare. This is a common design, found particularly on many modern container ships, which maximises deck cargo capacity while minimising hull resistance with fine hull lines. Cruise ship hull forms like *Pacific Sun* can be considered not dissimilar to that of a container vessel.

The parametric rolling phenomenon occurs as a result of the transverse stability alternating between being "stiff"⁷ and "tender"⁸ as a wave passes along the length of the hull, leading to a rhythmical increase of any slight angle of heel that may have been initially present. Ships are particularly vulnerable to parametric rolling when the encountered wave period is half the vessel's natural roll period, and the wave length is roughly equal to the ship's length.

The study at **Annex 5** examined different wave periods at various ship headings, corresponding to a ship speed of 6 knots through the water to establish if the criteria for parametric rolling were met. It was found that in head seas and near head seas with a wave period of 11s, the wave length was roughly equal to *Pacific Sun's* hull length, and the encountered wave period was half that of the ship's predicted natural roll period of 17.3s.

The wave period from analysis and prediction from the MetService report (**Annex 4**) shows a significant wave height of 7m, from the north west with a wave period of around 11s, less than 2 hours before the accident (**Figure 16**).

Parametric rolling cannot, therefore, be discounted as a contributing factor to the accident. However this cannot be confirmed without much greater study and analysis to establish the susceptibility of *Pacific Sun's* hull form to this phenomenon.

1.9 *PACIFIC SUN'S* RESILIENCE TO ROLLING

In compliance with SOLAS requirements, *Pacific Sun's* main propulsion machinery and all auxiliary machinery was designed to operate when rolling up to an angle of 22.5° to port and starboard while simultaneously pitching up to 7.5° by the head or stern.

⁷ Said of a vessel when she offers exceptional resistance to forces tending to list her.

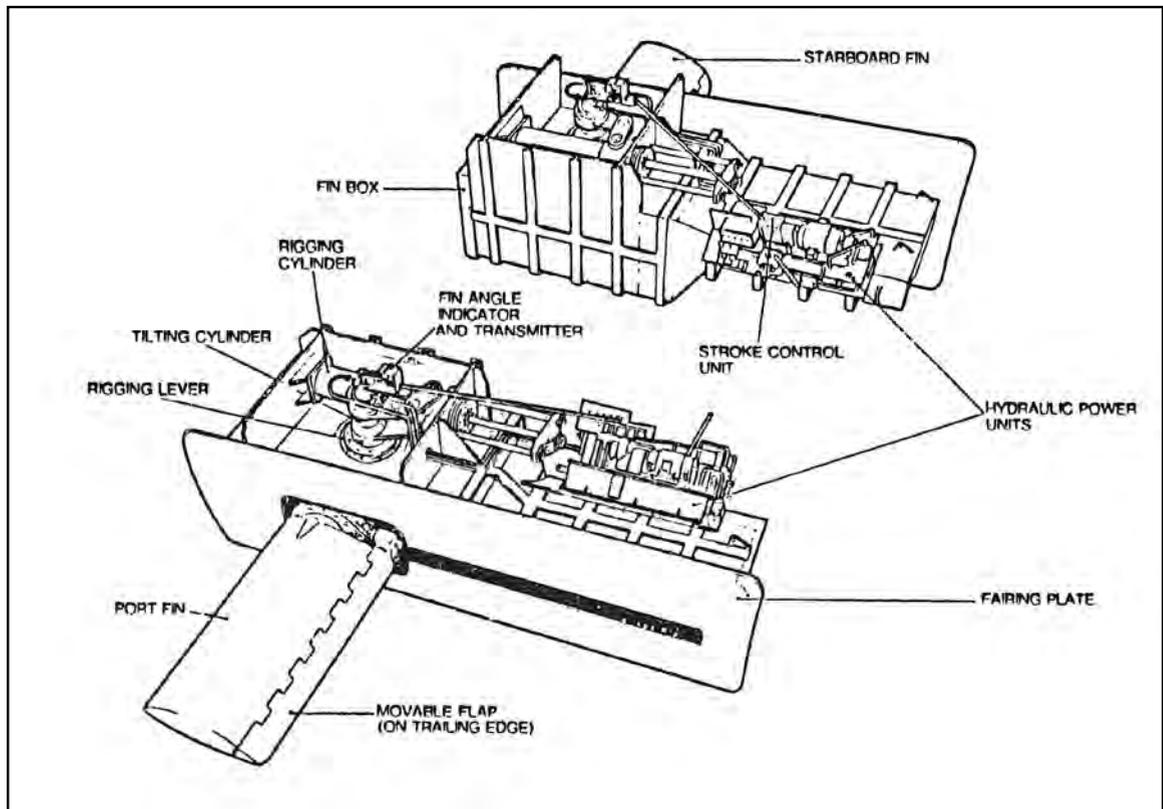
⁸ Said of a vessel having a small righting moment; so being easily moved from her position of equilibrium, and slow returning to it.

Dictionary of Nautical Words and Terms, C.W.T Layton.

1.10 THE STABILISERS

Pacific Sun was fitted with a pair of Sperry Marine Gyrofin roll stabilisers. In calm conditions the stabilisers were housed within the ship's hull. When required one, or both, is extended hydraulically depending on the extent of the rolling (**Figure 17**). Stabilisers have no effect in reducing a ship's pitching motion.

Figure 17



Typical stabiliser machinery unit as fitted to *Pacific Sun*

The control surfaces on stabilising fins work in the same way as aircraft wing ailerons. When tilted down, they deflect the water flow downwards and, in doing so generate lift. Similarly an upwards tilt produces a downward pressure. A gyro sensor will detect rolling torque and so move the fin control surface to oppose a roll before the ship has started to heel over. Active gyro fin stabilisers are operated in either the angle control or lift control modes, the lift control mode producing maximum fin efficiency. The operation of the stabilisers could be seen from a panel located on the bridge (**Figure 18**), but no audible alarm was fitted to indicate that an operating stabiliser had failed.



Bridge Gyrofin control unit

Pacific Sun's port stabiliser was inoperative because parts of the system were heavily worn and could not be replaced until the next period in dry dock. Her starboard stabiliser was operating in angle control mode due to a failure of the lift transducers required for the lift control mode. This was caused by salt water entering the transducer compartment. An overhaul of both the stabilisers had been scheduled for the vessel's previous dry dock maintenance period, in Brisbane in 2004. However, Brisbane's dry dock was insufficiently wide for the stabilisers to be withdrawn, and the overhaul was postponed to the forthcoming 2008 dry dock.

A single stabiliser will produce around 60% of the effect of two. Active stabilisers become ineffective at speeds of around less than half their design speed, in *Pacific Sun's* case at speeds through the water of less than 10 knots. The speed through the water at the time of the accident was around 6 knots,

and this would have produced no lift effect from the stabiliser. However, the extended starboard fin would have generated some resistance to the vessel's rolling, producing an effect similar to that provided by a bilge keel.

There is no statutory requirement for stabilisers to be fitted to seagoing vessels. However, stabilisers have become a standard item on cruise vessels for passenger comfort. Their condition is monitored by Classification Societies only to ensure the watertight integrity of the units.

1.11 STABILITY

At 0700 on 30 July, routine calculation of *Pacific Sun's* stability showed a metacentric height (GM) of 1.45m when corrected for free surface effect. The vessel was trimmed 0.37m by the stern. At the time of the accident, *Pacific Sun* comfortably complied with the statutory 'intact' and 'damaged' stability requirements.

1.12 MASTER AND OFFICERS

Master

The master had been employed mainly with Princess Cruises since 1993, and he was promoted to the position of master in April 2007. He joined *Pacific Sun* on 18 April 2008 for the first time, and was appropriately qualified including an STCW II/2 certificate.

Staff Captain

The staff captain had been at sea for 20 years, the last 10 years of which had been with P&O Australia. He held an STCW II/ 2 certificate and had been a staff captain for 4 years. He had been on board *Pacific Sun* for 5 weeks.

Officer of the watch

The on-watch first officer had been employed on Princess Cruises' vessels for several years. He held an STCW II/2 certificate, and had been on board for 1 month prior to the accident.

Passenger Services Director

The passenger services director (PSD), in charge of the passenger muster personnel, had been at sea for 21 years. She had first joined *Pacific Sun* 18 months before the accident, for the first of her 4 month appointments. She was promoted to PSD in May 2008.

Senior Doctor

The senior of two doctors on board had been qualified for 20 years, initially as an anaesthetist, and she had subsequently worked as an accident and emergency doctor trained in triage procedures. She had worked on several company vessels for 2 years.

1.13 PACIFIC SUN – BACKGROUND AND MANAGEMENT

1.13.1 Management

Pacific Sun, originally named *Jubilee*, was one of three “Holiday Class” ships constructed for Carnival Cruise Lines by Kockums Varv, Malmo, Sweden. She commenced operation in 1986. At build, her two Sulzer 11755kW main engines provided a maximum speed of 21.5 knots, however *Pacific Sun*’s achievable speed was about 19 knots at the time of the accident.

In 2004, *Jubilee* was renamed *Pacific Sun*, flagged into the British Registry, and traded under the banner of P&O Cruises Australia, managed by Princess Cruises. The vessel has remained with Lloyd’s Register Classification Society throughout her service life.

As part of an internal realignment of management responsibilities, management of *Pacific Sun* transferred to P&O Cruises UK in September 2008.

1.13.2 Itinerary planning

P&O Australia has operated cruise ships from Australia and New Zealand for several decades, the cruise routes being developed with ships originally built as passenger liners.

Pacific Sun was engaged on a series of winter cruises from Auckland to the Pacific islands, mainly Fiji, New Caledonia, and the Vanuatu archipelago with occasional longer cruises. The “Summer Daydream” cruise was a regularly repeated itinerary, which was operated at various times of the year by P&O Australia’s fleet. As this was a tried and tested itinerary, it did not require additional management consideration on this occasion.

1.13.3 Heavy weather guidance

The heavy weather checklist was reviewed throughout the voyage; it was referred to frequently as the conditions worsened and also following the accident. Guidance to the master about the required actions in heavy weather was provided within the fleet regulations and is shown at **(Annex 6)**.

1.13.4 Emergency procedures

In an emergency, the Crew Alert Signal was usually sounded prior to the General Emergency Signal (GES) to ensure that the stairwells, evacuation routes and muster stations were manned in anticipation of the passengers going to their muster stations and therefore prevent the congestion of passengers and crew in stairwells and alleyways. Once the crew were in position the GES would be sounded if required and passengers, having first collected their lifejackets and warm clothing from their cabins, would go to their muster stations.

On this occasion the passengers were instructed by the master to return to their cabins at the same time as the crew were ordered to their Crew Alert positions.

1.13.5 Mass casualty response

Two mass casualty exercises had been held recently on board *Pacific Sun*. The first, held in December 2007 at the company's behest, had been to develop the company-wide triage and mass casualty response system. The second, a ship-board drill in April 2008, had identified the Oz Nightclub as the preferred secondary medical centre and this arrangement was expected to be formally adopted once approval had been received from the vessel's managers.

1.14 EXTERNAL INSPECTION

The Maritime and Coastguard Agency (MCA) issued *Pacific Sun's* Safety Management Certificate (SMC) on 12 December 2006 and the Passenger Ship Safety Certificate in September 2007. The last Port state control was carried out in May 2008.

1.15 IMO REGULATION

The Safety of Life at Sea Convention (SOLAS), regulation II-2 Part B Reg 5. 3.3 Furniture in stairway enclosures of passenger ships, states:

Furniture in stairway enclosures shall be limited to seating. It shall be fixed, limited to six seats on each deck in each stairway enclosure, be of restricted fire risk determined in accordance with the Fire Test Procedure Code, and shall not restrict the passenger escape route. The Administration may permit additional seating in the main reception area within a stairway enclosure if it is fixed, non-combustible and does not restrict the passenger escape route. Furniture shall not be permitted in passenger and crew corridors forming escape routes in cabin areas. In addition to the above, lockers of non-combustible material, providing storage for non-hazardous safety equipment required by these regulations, may be permitted. Drinking water dispensers and ice cube machines may be permitted in corridors provided they are fixed and do not restrict the width of the escape routes. This applies as well to decorative flower or plant arrangements, statues or other objects of art such as paintings and tapestries in corridors and stairways.

SOLAS also states:

Muster stations shall be provided close to the embarkation stations. Each muster station shall have sufficient clear deck space to accommodate all persons assigned to that muster station, but at least 0.35m² per person.

There are no requirements for furnishing within muster stations to be secured, as there are for escape routes.

1.16 PASSENGER QUESTIONNAIRE

MAIB passenger questionnaires⁹ were sent to the home addresses of all the passengers on board who were older than 18. A total of 310 responses were received.

1.17 PREVIOUS ACCIDENTS

1.17.1 *Crown Princess*

The following is an extract from The National Transportation Safety Board (NTSB) report on its investigation into a heeling accident on M/V *Crown Princess*, Atlantic Ocean off Port Canaveral, Florida July 18, 2006.

On July 18, 2006, the cruise ship Crown Princess, which had been in service about a month, departed Port Canaveral, Florida, for Brooklyn, New York, its last port on a 10 day round-trip voyage to the Caribbean. Slightly more than an hour after departing, while on a heading to intersect its track to Brooklyn, the vessel's automatic steering system began a turn to port. In an effort to counter the effects of a perceived high rate of turn, the second officer, the senior watch officer on the bridge, disengaged the automatic steering mode of the vessel's integrated navigation system and took manual control of the steering. The second officer turned the wheel first to port and then from port to starboard several times, eventually causing the vessel to heel at a maximum angle of about 24° to starboard.

The heeling caused people to be thrown about or struck by unsecured objects, resulting in 14 serious and 284 minor injuries to passengers and crewmembers.

The vessel incurred no damage to its structure but sustained considerable damage to unsecured interior components and to cabinets and their contents.

The National Transportation Safety Board determines that the probable cause of the Crown Princess accident was the second officer's incorrect wheel commands, executed first to counter an unanticipated high rate of turn and then to counter the vessel's heeling.

The Safety Board's investigation of the accident identified the following safety issues: [not inclusive]

- *Reporting of heeling incidents and accidents.*
- *Emergency response following severe incidents.*

As a result of its investigation, the Safety Board makes recommendations to the U.S. Coast Guard, to the Cruise Lines International Association, and to SAM Electronics and Sperry Marine (manufacturers of integrated navigation systems).

⁹ Facilitated by New Zealand Transport Accident Investigation Commission (TAIC).

The report commented on the effect of the heeling on the passenger areas, stating:

Further, given the debris on the vessel after the accident, including water from the pools, broken glass, and displaced and overturned furniture, directing passengers to their muster stations could have exposed them to hazards of slips, falls, and blunt or lacerating injury. In addition, the number of injured passengers and crew and the severity of their injuries were uncertain. Having passengers report to muster stations could have delayed treatment of the injured. Therefore, the Safety Board concludes that the captain's decision not to order passengers to their muster stations after the accident was appropriate.

Following the accident, in August 2006, the Senior Vice President of Princess Cruises sent an instruction to the masters of each vessel, including *Pacific Sun* instructing them to review the securing arrangements to prevent items, especially heavy objects, from moving in heavy weather or if the vessel is subject to large angles of heel (**Figure 19**).

1.17.2 Pacific Star

Pacific Star sailed from Auckland, New Zealand, in the late afternoon of 10 July 2007 on Summer Daydream cruise, the same cruise itinerary as *Pacific Sun*. Overnight the ship experienced easterly winds in excess of 90 knots, and a swell height of more than 5m. As a result, she suffered damage to internal fittings and to a number of windows in cabins and public spaces, as well as structural damage to the forecastle bulwark and the loss of a satellite communications dome. Significantly, the rough weather also exacerbated pre-existing corrosion damage causing the ship to take water through small holes in her side. Following an underwater survey at her next port of call, Port Vila, Vanuatu, she was instructed by the MCA to proceed directly to a dry dock repair facility, without passengers.

The subsequent MAIB investigation focussed on the shell plating weakened by corrosion, and why this had not been detected during survey.

Dear Captains

Securing Arrangements

As a matter of some urgency we would like all ships to review the securing arrangements of all items throughout the ship to prevent items, especially heavy ones, from moving in heavy weather or if the vessel is subject to a large heel or roll.

Through the Executive Committee we request that a survey of the ship is made highlighting areas on the ship where additional securing is required. We request this information to be sent to [REDACTED], Fleet Technical Project Manager by Monday 14th August. [2006]

Attached is a list of areas where items moved during a recent incident in one of our ships, to provide some guidance. The children's and teen area should also be included in this list.

Before any onboard action is taken we would like to review these lists, with the exception of any safes (not stateroom safes), and heavy items out of passenger sight which ship's staff can secure immediately. Please also consider when securing items they should be flush to the bulkhead or a space provided for cleaning purposes.

We understand that there are many items which will require outside assistance to secure and we would like to ensure continuity throughout the Fleet.

Areas of concerns are;

- Pianos
- Photocopiers
- Televisions
- Luggage racks
- Hospital Items
- Gym Equipment
- Boutiques
- Casino

Please liaise with [REDACTED] reference the securing of Televisions in Public Areas.

Best regards
[REDACTED]

10/12/2008

Email sent to Princess Cruises Masters following the *Crown Prince* accident in 2006

SECTION 2 - ANALYSIS

2.1 AIM

The purpose of the analysis is to determine the contributory causes and circumstances of the accident as a basis for making recommendations to prevent similar accidents occurring in the future.

2.2 FATIGUE

All personnel directly involved in this accident were well rested, and there is no evidence that fatigue contributed to this accident.

2.3 ITINERARY PLANNING

Pacific Sun was on a routine “Summer Daydream” cruise to the Pacific islands to the north of New Zealand that formed part of the company’s programme during the summer and winter months. P&O Australia accepted that modifications would be required to several cruises each year, particularly during the winter months. The cruise planning process did not address this cruise particularly as it had been completed on numerous occasions in the past.

The cruise started and finished with two lengthy ocean passages, and the vessel’s itinerary required these to be made at between 17 and 18 knots. At the time of the accident *Pacific Sun* had a maximum speed of 19 knots, rather than the 21 knots she could achieve after each period in dry dock. The schedule therefore allowed the master very little flexibility to make up time lost due to the effects of bad weather or if the ship’s departure was delayed.

The passengers’ cruise experience was initially diminished when the first port of Lifou was missed due to the late departure from Auckland and poor weather en route, and *Pacific Sun* headed directly to Port Vila. The delayed departure from Port Vila led to a greatly reduced call at Mystery Island, which reduced their enjoyment of the cruise further.

While the master delayed his departure from Mystery Island for as long as possible, his decision meant that the speed required on the return leg, of almost 18 knots into forecast bad weather, made it highly improbable that the ship would arrive in Auckland on time.

The master was fully aware of the consequences of arriving late at the turnaround port. Revised travel arrangements could be required for passengers leaving the ship; those joining for the following cruise could have had to be accommodated until it arrived; and storing and bunkering operations had to be re-scheduled. Although the master was not put under any pressure to arrive in Auckland sooner than was safe, the schedule had placed him in a difficult situation and it would have been natural for him to make every effort to arrive at the turnaround port on time or to limit the delay to a minimum.

Had allowances been made during the itinerary planning stage for the reductions in the ship's achievable speed and the greater probability of rough weather in the winter months, the master would have had greater flexibility to achieve the outward and return passages on schedule.

2.4 DECISIONS ON PASSAGE

2.4.1 Mystery Island

As *Pacific Sun* sailed late from Mystery Island, her master was aware that it was unlikely that she would arrive in Auckland on schedule given the worsening weather forecast. With the benefit of hindsight, had he decided to miss out the visit to Mystery Island and instead proceed directly from Port Vila for Auckland, it is possible that he would have passed ahead of the forecast storm and arrived alongside early. This would have had an impact on only one cruise; the subsequent cruise could potentially then have departed on time.

It would have been a very robust decision for the master to recommend to the company that the visit to Mystery Island be cancelled. The visit to one of the three ports on the itinerary had already been cancelled due to poor weather, and to cancel a second would have heavily impacted on the overall cruise. Further, he was looking at the 48 hours ahead weather forecast, which indicated nothing substantially worse than he and *Pacific Sun* had encountered many times before. Therefore while, in hindsight, it would have been better to have cancelled the visit to Mystery Island, the master's decision to continue with the visit was understandable.

2.4.2 Decision to heave to

Having left Mystery Island, the weather routing information from WRI advised the master to set a direct route to Auckland and modify courses and speeds as necessary in the prevailing conditions. At the start of the passage the storm was forecast to move south. However, it moved south east over the following 24 hours, converging on *Pacific Sun's* route. As the weather conditions deteriorated, the master altered course and speed to make the movement of the ship as comfortable as possible by placing the sea and swell on her starboard quarter.

The master did not consider heaving to until just before sunset, when he realised that he would be unable to see the sea and swell in the ensuing darkness. In hindsight, had he decided to heave to earlier in the day, the depression would have passed further to the south of *Pacific Sun*, and she would have encountered lesser winds and smaller waves.

By deciding to run parallel to the predicted path of the storm for as long as possible, and only to heave to at sunset, the master inadvertently placed *Pacific Sun* in the area of the worst sea conditions, where she was most vulnerable to the wind and seas because her one operational stabiliser was ineffective at slow speed.

2.4.3 Ability to observe the seas

On 30 July it was a dark, overcast night, with virtually no moon, and neither the OOW nor the master was able to identify the direction of the sea and swell. A better view of the sea could have enabled them to identify the best heading for the ship when hove to, to reduce the rolling, and to time any course alterations so as to avoid particularly large waves.

Portable night vision glasses are now commercially available and are not prohibitively expensive. In this case, had the bridge team had access to night vision glasses they would have gained a better understanding of the sea conditions they faced, and might have been provided with some warning of the approach of any abnormally large waves.

2.5 ROLL MECHANISM

2.5.1 Effect of synchronous rolling, parametric rolling and abnormal waves

Whether *Pacific Sun* rolled to large angles due to the presence of an abnormal wave or waves, or was subjected to the effects of parametric rolling cannot be stated with any certainty.

MAIB's calculations into the ship's vulnerability to synchronous rolling or parametric rolling (**Annex 5**) have indicated that while synchronous rolling is unlikely, parametric rolling was possible if *Pacific Sun's* hull form was susceptible to this behaviour. However, the lack of a steady build up to the three large roll angles experienced does conflict with normal parametric rolling behaviour.

It is more likely that the large sea and swell, possibly combined with the second more northerly swell identified the following morning, produced a series of large steep sided abnormal waves. These abnormal waves, unseen in the dark, would have most likely been the cause for *Pacific Sun* rolling so heavily.

2.5.2 Stabilisers

Both stabilisers were due to be extensively overhauled during the dry dock maintenance period scheduled for a few weeks after the accident. With only one stabiliser working, *Pacific Sun's* ability to dampen her roll was reduced, and the potential for the remaining stabiliser to fail, leaving the vessel without active stabilisers, increased as the time since the system's last major overhaul increased.

Shore managers and the ship's officers understood the critical nature of the stabilisers, particularly for schedules in the South Pacific winter, and remedial maintenance was provided immediately prior to the cruise. However it was not possible, or expected, to bring the defective port stabiliser back into service before the next dry dock period, and it was considered acceptable for the vessel to continue to operate with only one working stabiliser.

Had both stabilisers been maintained, as originally intended, during the vessel's previous dry dock period in 2004, it is likely that both would have been available for the cruise. By deferring that maintenance, the likelihood increased that *Pacific Sun* would, at some point, be left without working stabilisers during a winter storm, as occurred on this occasion.

The malfunctioning port stabiliser did not directly contribute to the accident. However, *Pacific Sun's* master would have been better able to handle the rolling of the ship throughout the cruise if both stabilisers had been working.

It is not possible to determine whether the remaining stabiliser failed prior to, during, or after the large rolls because no alarm sounded (or was required to sound), and the failure was not noticed until around 30 minutes after the accident. The master and officers were therefore unaware that the stabiliser had failed and was not providing the roll reduction they anticipated.

When the ship was hove to, she was already vulnerable to the effect of the forecast seas and swell. At 10 knots or more, had one, or both stabilisers been operational, they would have moderated *Pacific Sun's* heavy rolling. However this speed would also have resulted in increased pitching. To avoid heavy pitching, the master reduced *Pacific Sun's* speed to 6 knots, 4.5 knots through the water. At this speed, he believed that the starboard stabiliser would be partially effective in the active mode. In reality, at that speed the stabiliser was only effective as a bilge keel.

2.5.3 Guidance to masters

Pacific Sun's master was not aware that at speeds of less than 10 knots the active stabilising effect was lost completely and the stabilisers, if extended, would only be acting as bilge keels. Neither did he have any information on *Pacific Sun's* vulnerability to either synchronous or parametric rolling in certain conditions, particularly when operating at speeds when the active stabilisers were ineffective. No such ship specific guidance or training in these risks is provided to the masters of ships within the Carnival group of companies.

Carnival Group should consider making an assessment for each of its ships of their vulnerability to synchronous and parametric rolling and other handling characteristics, for example stabiliser effectiveness, to provide its masters with vessel specific guidance on ship handling in rough weather.

2.6 EFFECT OF HEAVY ROLLING

2.6.1 Preparations for heavy weather

Before encountering and during the heavy weather, the staff captain sent routine e-mails to all heads of department instructing them to secure their areas, and referred them to the relevant fleet instruction. All departments secured their equipment in their normal manner. While this level of securing was effective

during the passage north from Auckland, it was ineffective for the conditions experienced on the return leg when many items were insufficiently secured to withstand the severe rolling.

Had the severity of the weather conditions experienced by *Pacific Sun* after sailing from Mystery Island been anticipated, the senior officers could have taken a number of actions to mitigate the effects of extreme ship motion. These could, for example, have included:

- A further review of the securing arrangements for all moveable objects.
- Postponing the preparations for arrival, including delaying the collection of passenger baggage and the pre-positioning of stores, garbage and equipment in alleyways and handling areas ready for landing.
- Restricting passenger movement and activity.
- Other actions, such as emptying the spa baths and modifying menus to reduce the hazards present in the galleys during cooking.

These actions could impact on the passengers' enjoyment of the cruise, and therefore would not be adopted lightly. To guide ship's staff, a methodology is needed to identify when such steps are appropriate.

2.6.2 Securing moveable items

The officers and crew believed that they were prepared for heavy weather, but were hampered by physical limitations. For example, few items of heavy furniture had securing points as part of their design, and the decks did not have suitable fittings for these heavy items to be secured to. In the large public areas, heavy items were able to move unrestricted during the rolling, posing a significant hazard to passengers and crew and causing many of the reported injuries.

Had the vessel been provided with additional means of securing for bad weather, then ship's staff could have secured these heavy objects more thoroughly.

2.6.3 Securing of fixed items

A number of items that were, in theory, permanently fixed broke free of their securing arrangements. These included such items as a grand piano, a bank of gaming machines in the casino, and heavy office equipment such as photocopiers, many of which were being used by passengers to steady themselves against the motion. It was pure good fortune that some passengers and crew were not more seriously injured or killed by the unexpected movement of supposedly fixed heavy items.

Attempts to identify and secure items, and especially heavy objects, on Princess Cruises' vessels following the *Crown Princess* accident in July 2006 were not successful in preventing similar items from breaking free on *Pacific Sun*. In the absence of an industry standard, Princess Cruises should develop a company standard for securing fixed items on board its vessels and apply it across its fleet as soon as practicable.

2.6.4 Effect on muster stations

Muster stations are allocated to provide protection for passengers and to congregate them away from potential danger in an emergency. The muster stations on board *Pacific Sun*, all in public areas, could have been required to assemble the passengers had the situation deteriorated further.

On this occasion, due to the quantity of loose items and debris, and the continued risk of further heavy rolling, two and possibly three of the four muster stations would have been unable to safely accommodate the numbers of passengers they were required to hold. This would have left the master and PSD with the difficult task of accounting for, and managing, all the passengers on board without using the nominated or alternative muster stations.

In the fourth muster station, Muster Station Alpha, the Atlantis Showlounge, all furniture, including rotating chairs, was secured. Although one table released from its mounting, the impact of the rolling on this room was minimal and no injuries were reported there. This is in striking contrast to the condition of the three other muster stations with mainly unsecured tables and chairs where significant numbers of injuries occurred.

Had all the muster stations been secured to the same standard as Muster Station Alpha, the number of injuries sustained due to moving furniture would have been greatly reduced.

Pacific Sun temporarily heeled to an estimated angle of 31°, yet her machinery was only required to operate to an angle of 22.5°. In the worst case, the vessel could have lost engine power and then lain beam to the seas and rolling heavily until power was restored. In these circumstances, the master might well have sounded the GES, sending the passengers to their muster stations as part of his emergency response. In such an event, passenger safety would have depended on the tenability of the muster stations.

There are no SOLAS regulations to ensure that furnishings and equipment on board passenger ships' muster stations are secured, and that no extraneous objects are placed there. The onus therefore lies with the operating company to decide on the appropriate degree to which furniture and other objects are secured in public areas on passenger vessels which have been designated as muster stations.

2.7 EMERGENCY RESPONSE

2.7.1 Passenger muster

It took the crew almost 4 hours to account for all the passengers following the master's instruction for them to return to their cabins. With no established system to account for the passengers in their cabins, the existing system of mustering passengers had to be adapted. Accounting for passengers was made more difficult because some passengers were in the Medical Centre and Secondary Medical Centre, and a number had chosen to go to their muster stations or had joined friends in other cabins.

In previous accidents on Princess Cruises' vessels the passengers had been instructed to return to their cabins as part of the emergency response. However, the opportunity had not been taken to formalise the process, and *Pacific Sun's* ERO did not provide for a suitable system of accounting for passengers once they had returned to their cabins. Had such a system been established, and the crew trained in its use, the time taken to ensure all passengers were accounted for would have been much reduced.

2.7.2 Crew alert

The sight of crew in lifejackets caused concern to many passengers. The system of Crew Alert normally preceding General Emergency meant that the crew were in possession of their lifejackets and the passengers were not.

Had the master not sounded the Crew Alert Signal, he would have been unable quickly to account for the crew and would not have had emergency teams, such as the fire parties and the passenger assistance party, in place had the situation deteriorated. The master therefore made the most appropriate decision in responding to his current problems and anticipating the possibility that the situation could deteriorate further.

Sounding of the Crew Alert Signal during the initial confusion of an actual emergency will always have a negative impact on some passengers, regardless of announcements that may be made to reassure them. This situation exists extensively throughout the cruise industry and better solutions have yet to be found.

2.7.3 Communications equipment

The collapse of the main satellite C communications system reduced the master's ability to communicate effectively with external organisations and with the Princess Cruises ERC.

The failure of the GMDSS HF and MF system prior to the accident also limited the vessel's ability to communicate effectively and might have had a detrimental effect had the situation deteriorated and further external communications been necessary.

Although not part of the GMDSS equipment, the loss of the satellite C system meant the vessel was not able to link into the company's ERC's computerised emergency management system. Had consideration been given to the system's importance, the satellite C equipment could have been more effectively secured, or additional redundancy provided in the form of an "emergency only" satellite communication system.

2.8 SIMILAR ACCIDENTS

The NTSB report into the heeling accident on board *Crown Princess*, and the MAIB's report into the *Pacific Star* accident, have shown that large passenger vessels heel and roll for numerous reasons. Such reasons can include heavy weather, mechanical fault, such as a steering gear failure, or human error, and the resultant heeling might, or might not, be predictable. Regardless of the cause of the large angles of heel, cruise vessels should be able to withstand such accidents without endangering the passengers and crew through unsecured or insufficiently secured furnishings and equipment breaking loose.

This accident demonstrates that the actions taken by Princess Cruises had not ensured that procedures for securing furnishings on board its vessels were sufficiently robust to remove the risk of injury to its passengers and crew in the event of future heeling accidents, however caused.

SECTION 3 - CONCLUSIONS

3.1 SAFETY ISSUES DIRECTLY CONTRIBUTING TO THE ACCIDENT WHICH HAVE RESULTED IN RECOMMENDATIONS

1. Had both stabilisers been maintained, as originally intended, during the vessel's previous dry dock period in 2004, it is likely that both would have been available for the cruise. By deferring the maintenance, the likelihood increased that *Pacific Sun* would, at some point, be left without working stabilisers during a winter storm, as occurred on this occasion. [2.5.2]
2. It was not possible to determine whether the one working stabiliser failed prior to, during, or after the large rolls because no alarm sounded, and the failure was not noticed until 30 minutes after the accident. [2.5.2]
3. Had the severity of the conditions been anticipated, the senior officers could have taken a number of actions to mitigate the effects of extreme ship motion. These could have included, for example: a further review of the securing arrangements; postponing the preparations for arrival; restricting passenger activity; and modifying menus to reduce the hazards present in the galleys during cooking. [2.6.1]
4. Had the ship's staff been provided with additional means of securing for bad weather they could have secured moveable objects more thoroughly. [2.6.2]
5. A number of items that were, in theory, permanently fixed broke free of their securing arrangements. [2.6.3]
6. Attempts to identify and secure items, and especially heavy objects, on Princess Cruises' vessels following the *Crown Princess* accident in July 2006 were not successful in preventing similar items from breaking free on *Pacific Sun*. [2.6.3, 2.8]
7. There are no IMO SOLAS regulations to ensure that furnishings and equipment are secured, and that no extraneous objects are placed in the muster stations of passenger ships. [2.6.4]
8. The collapse of the main satellite C communications system reduced the officer's ability to communicate effectively with external organisations and with Princess Cruises. [2.7.3]

3.2 OTHER SAFETY ISSUES IDENTIFIED DURING THE INVESTIGATION ALSO LEADING TO RECOMMENDATIONS

1. Passenger vessels can experience large angles of heel for a number of reasons including: heavy weather; mechanical fault, such as steering gear failure; or human error, and the resulting heel angles can be unpredictable. Regardless of the cause of the large angles of heel, cruise vessels should be able to withstand such incidents without endangering passengers through unsecured and insufficiently secured furnishings and equipment breaking loose. [2.8]

3.3 SAFETY ISSUES IDENTIFIED DURING THE INVESTIGATION WHICH HAVE NOT RESULTED IN RECOMMENDATIONS BUT HAVE BEEN ADDRESSED

1. Had allowances been made during the itinerary planning stage for the reductions in the ship's achievable speed and the greater probability of rough weather in the winter months, the master would have had greater flexibility to achieve the outward and return passages on schedule. [2.3]
2. Had the bridge team had access to night vision glasses, they would have better understood the sea conditions they faced, and might have had some warning of any abnormal waves approaching. [2.4.3]
3. The ship's emergency response organisation did not provide for a suitable system for accounting for passengers once they had returned to their cabins. Had one been established, and the crew trained in its use, the time taken to ensure all passengers were accounted for would have been much reduced. [2.7.1]
4. The sight of crew in lifejackets caused concern to many passengers. The dual system of Crew Alert and General Emergency meant that the crew were in possession of their lifejackets before the passengers. [2.7.2]
5. *Pacific Sun's* master was not aware that at speeds of less than 10 knots the active stabilising effect was lost completely and the stabilisers, if extended, would only be acting as bilge keels. Neither did he have any information on *Pacific Sun's* vulnerability to either synchronous or parametric rolling at speeds when the active stabilisers were ineffective. [2.5.3]

SECTION 4 - ACTIONS TAKEN

Princess Cruises has:

- Introduced night vision equipment to assist bridge teams.
- Provided additional training and guidance to masters and deck officers in the effective handling of its vessels in heavy weather.
- Undertaken a technical review of critical emergency and communications equipment, and the provision of additional redundancy in portable satellite communications to ensure effective emergency response.
- Reviewed its itinerary planning process.

Carnival PLC has:

- Carried out a trial muster of passengers in their cabins, instead of their muster stations, and will amend the fleet's onboard emergency response plans accordingly.

Cruise Lines International Association (CLIA) has:

- Agreed to discuss at the CLIA Committee on Technical and Safety Matters the potential negative impact on passengers of crew mustering in lifejackets prior to any formal announcement of emergency stations and explore possible alternative arrangements.

SECTION 5 - RECOMMENDATIONS

2009/138 Princess Cruises is recommended to:

- Review the role of active stabilisers in ensuring passenger safety. The review should include system redundancy, planned maintenance, and the need to fit suitable alarms to warn of system degradation or failure.
- Carry out a fleet-wide assessment of the risk of injury from moving furnishings and objects following large angles of heel. This should include the calculation of the forces involved and identify suitable means of securing objects both routinely, and for heavy weather.
- Develop a standard for securing furnishings and equipment in public spaces, particularly in muster stations and their access routes.
- Develop its heavy weather guidance and instructions to include actions to reduce the risk of injury.

2009/139 Cruise Lines International Association and the **Passenger Shipping Association** are recommended to:

- Use the Princess Cruises' standard for securing furnishings and equipment in passenger vessels (once completed) as a basis for developing a guide on industry best practice.
- Disseminate the safety issues, actions taken and lessons learnt following this accident to their members.

Marine Accident Investigation Branch
June 2009

Safety recommendations shall in no case create a presumption of blame or liability