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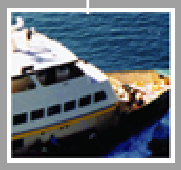


# FERRY SAFETY INVESTIGATION REPORT

## COLLISION OF THE MANLY FERRY *COLLAROY* NUMBER 3 WEST WHARF, CIRCULAR QUAY

4 MARCH 2005

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**OTSI File Ref: 03545**

**25 November 2005**

**The Office of Transport Safety Investigations**
**Level 21, 201 Elizabeth Street**
**Sydney NSW 2000**

The Office of Transport Safety Investigations (OTSI) is an independent NSW agency whose purpose is to improve transport safety through the investigation of accidents and incidents in the rail, bus and ferry industries.

Established on 1 January 2004 by the *Transport Administration Act 1988*, the Office is responsible for determining the causes and contributing factors of accidents and to make recommendations for the implementation of remedial safety action to prevent recurrence.

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Information about OTSI is available on its website or from its offices at:

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The Office of Transport Safety Investigations also provides a Confidential Safety Information Reporting facility for rail, bus and ferry industry employees. The CSIRS reporting telephone number is 1800 180 828.

# TABLE OF CONTENTS

# TABLE OF FIGURES

# GLOSSARY OF TERMS AND ABBREVIATIONS

| | |
|---|---|
| Backboards | Timber buffers comprising heavy beams set on frames supported by piles driven into the seabed, adjacent to dead end berths, used to arrest vessels in the event that they overrun their intending berthing point. |
| Bow | Front area of vessel |
| BHP | Brake Horse Power. An engine power output rating, as distinct from Shaft Horse Power SHP |
| CCTV | Closed Circuit Television |
| CPP | A Controllable Pitch Propeller has the thrust resulting from its constant rotation varied ahead or astern by pitch adjustment from a remote location, such as a vessel's bridge control console |
| CRM | Crew Resource Management. Training designed to ensure the use of all available resources to achieve safe and efficient operations by enhancing communication, teamwork and the capacity to respond to emergencies. |
| CVAG | The Commercial Vessel Advisory Group is a body sponsored by the NSW Maritime Authority to propose safety improvements |
| Ebb | Periodic seawater level falling due to decreasing tidal forces |
| EPA | Environmental Protection Agency |
| Evolutions | Ferry crew training drills and procedures undertaken by SFC as programs forming part of its safety management system (SMS) |
| FAID | Fatigue Audit InterDyne™ is the name given to a range of fatigue risk management software, developed by InterDynamics Pty Ltd |
| Ferry | A vessel which carries more than 8 adult persons, as defined by the *Passenger Transport Act 1990* (NSW) |
| GPH | A General Purpose Hand, or Deckhand, is a duly qualified crewmember not engaged in navigational or engineering duties |
| ICAM | Incident Cause Analysis Method |
| ISM Code | International Safety Management Code .The purpose of this Code is to provide an international standard for the safe management and operation of ships and for prevention of pollution at sea. Promulgated by the International Maritime Organisation (IMO). |
| ITSRR | The Independent Transport Safety & Reliability Regulator NSW |
| Knot | Unit of speed - one nautical mile per hour - about 1.85 km/h. |
| kW | Kilowatt |

| | |
|---|---|
| Lloyds | One of the international ship classification societies. Ship Classification is a system for safeguarding life, property and the environment at sea. Society approval entails verification of a vessel's criteria against a set of requirements during its design, construction and operation for purposes such as insurance. |
| MCR | Machinery Control Room (a manned space below deck adjoining the vessel's engine room) |
| NMSC | National Maritime Safety Committee |
| NSW | New South Wales |
| OTSI | The Office of Transport Safety Investigations |
| PTA | *Passenger Transport Act 1990* (NSW) |
| ProCon | Programmable Logic Controller |
| Port | The left-hand side when facing forward on board a vessel |
| Public Passenger Service | The carriage of passengers for a fare or other consideration by means of a vessel within New South Wales waterways |
| RPM | Revolutions, of running equipment and machinery, Per Minute |
| RTA | The NSW Roads and Traffic Authority |
| SOPs | Standard Operating Procedures that are intended to standardise operations within and/or between organisations |
| Starboard | The right-hand side when facing forward on board a vessel |
| Stern | Rear area of vessel |
| SMS | Safety Management System |
| | |
| SFC | Sydney Ferries Corporation |
| TAA | *Transport Administration Act 1988* |
| Taylor Report | A report commissioned by the Minister for Transport in 2001 and prepared by the then Waterways Authority, entitled "Independent Review of the Operations of Sydney Ferries" |
| USL Code | Uniform Shipping Laws Code. The current maritime standard applied throughout Australia in respect of safety matters and specifically vessel construction, equipment, crewing and operation |
| VOM | Vessel Operations Manual. The prime reference, issued by Sydney Ferries Corporation, containing technical information and operating instructions, for each class of ferries. |
| 'X-Y Lever' | Ferry propulsion control devices, fitted at each navigational station console, that set propeller and rudders to provide longitudinal and transverse thrust as ordered by the vessel's master |

# EXECUTIVE SUMMARY

## The Accident

At 6.38AM on Friday 4 March 2005, the vessel *Collaroy*, a "Freshwater" class Manly ferry operated by Sydney Ferries Corporation (SFC), over-ran its berth on approach to the Southern end of No. 3 West Wharf at Circular Quay, in Sydney Cove, and struck the safety backboards. There were no passengers embarked at the time and the crew was not injured in the collision. There was little damage to the *Collaroy* as a result of the collision but the backboards were extensively damaged.

## Findings

As a result of its investigation OTSI finds:

a. In the matter of **causation**, that:

   i. The collision occurred when the *Collaroy* failed to respond to the master's handling instructions and a number of back-up features also failed.

   ii. The *Collaroy* failed to respond to the master's handling instructions when one of four control units, upon which he was relying to convert his instructions into an altered pitch setting on the No.1 propeller, was rendered inoperative by a faulty electrical circuit in a logic card.

   iii. The failure of warning and back-up systems, which should have been activated when the control unit failed, was a consequence of human error. These 'defences' were dependent on all four control units being switched-on at the time and they were not.

b. In the matter of the **appropriateness of the emergency response**, that:

   i. The master of the vessel, confronted with a loss of control, and automatic warning alarms and an automatic back-up system that did not activate, had limited options available to him in the confines of Sydney Cove.

ii. The extent and nature of communication between the *Collaroy*'s master and engineer on the morning of, and during, the incident was not consistent with effective Crew Resource Management.

iii. Sydney Ferries' expectation is that there will be a helmsman present on the bridge of "Freshwater" class vessels whenever they are in operation. However, there is no formal statement/policy requiring this to occur and, in this instance, the master was alone on the bridge both prior to and during the incident.

iv. While the master did initiate a prolonged sounding of the *Collaroy*'s horn to alert others of his predicament, he did not activate a pre-recorded warning message for the benefit of those on board, in this case, the crew. This has been a recurring omission across a number of accidents reviewed by OTSI and it has been reported that masters do not regard the current facility as being particularly useful.

v. Duty personnel at Circular Quay from both Sydney Harbour Control and SFC acted quickly and efficiently to assist *Collaroy*'s crew to secure the vessel, minimise the prospects of environmental damage, cordon the area and to alert the necessary response agencies, including the NSW Maritime Authority and OTSI. Those contacted also responded quickly and efficiently.

vi. One of *Collaroy*'s five deckhands was not subjected to drug testing following the incident.

c. In the matter of **whether the accident could have been anticipated and the effectiveness of the risk management strategies adopted by the SFC**, that:

i. Sydney Ferries operates 31 vessels, but their operation is made more complex by the fact that these vessels fall into seven different vessel classes, and even within classes there are differences between vessels. While Sydney Ferries is aware of this complexity, its current risk management procedures do not take sufficient account of it, as evidenced by the absence of specific references to

the uniqueness of the *Collaroy*'s "Kamome" propulsion control system in the "Freshwater" class Vessel Operations Manual (VOM), and the absence of specific drills for emergencies that might arise as a consequence of this uniqueness. OTSI notes that Sydney Ferries has since developed a VOM specifically for the *Collaroy* but that this publication has yet to be issued.

ii. For several months, *Collaroy* had been experiencing problems with the propulsion control system on start-up and a modified starting procedure had been adopted by engineers to overcome the problem. However, there was no evidence to suggest that any formal risk assessment had been applied to address these problems, their potential consequences or the risks associated with the modified procedures.

d. In the matter of **any other matters arising from the investigation that would enhance the safety of ferry operations**, that:

i. All ferry operators had been required under Section 53D of the *Passenger Transport Act 1990* (Schedule 3, Clause 23) to have a Safety Management System (SMS) in place by 1 January 2005; that this date was extended by Regulation to 1 July 2005, and that the NSW Maritime Authority first commenced to audit Sydney Ferries' SMS on 4 October 2005.

ii. Sydney Ferries were obliged to advise the NSW Maritime Authority of the problems it had been experiencing on the *Collaroy* and of the modified procedures. However, because the problems and interim solutions were not managed in accordance with the relevant procedures in their SMS, Sydney Ferries did not identify the need to advise the NSW Maritime Authority of the related issues.

iii. There is an absence of safety backboards at No. 6 Wharf, Circular Quay and at the Southern end of Manly Wharf.

iv. CCTV coverage of vessels approaching and berthing at Circular Quay is neither comprehensive, nor reliable.

## Recommendations

Notwithstanding the initiatives announced by the NSW Minister for Transport on 11 October 2005 which make provision for, amongst other initiatives: an upgrade of the *Collaroy*'s control system; the installation of Global Positional Systems across Sydney Ferries' fleet and the upgrading of onboard data recording systems on "Freshwater" and "Supercat" vessels, the following recommendations are made to:

### a. Sydney Ferries Corporation

i. Undertake a thorough risk assessment in order to determine whether it should continue to operate the *Collaroy* in its current configuration.

ii. As long as the *Collaroy* continues to remain unique in its class, take action to ensure its uniqueness is fully understood by all personnel required to either operate or maintain the vessel.

iii. Ensure that future changes to operating instructions are underpinned by proper risk assessments and, be they interim or otherwise, are formally communicated throughout the Corporation.

iv. Require all propulsion control units to be tested on all vessels as part of start-up procedures.

v. Act to reinforce CRM throughout its organisation and in particular require safety critical issues during start-up and emergency procedures to be the subject of specific communication between masters and engineers.

vi. Issue a formal policy requiring a helmsman to be present on the bridge of "Freshwater" class vessels from the commencement of start-up procedures through to the completion of shut-down procedures.

vii. Review the utility of its extant pre-recorded emergency broadcast messages.

**b. NSW Maritime Authority**

i. Review any risk assessment/s undertaken by Sydney Ferries in respect of the *Collaroy*.

ii. Take action to upgrade safety backboard/buffer arrangements at No.6 Wharf, Circular Quay and at the Southern end of Manly Wharf.

iii. Take action to ensure the provision of a reliable, high-resolution CCTV video system capable of recording all vessels moving into and out of Sydney Cove from at least two cross-referenced points.

# PART 1 INTRODUCTION

## Notification and Response

1.1 At 07.15AM on 4 March 2005, the Office of Transport Safety Investigations (OTSI) Duty Officer was notified by Sydney Ferries Corporation (SFC) that one of its Manly ferries, the *Collaroy*, had collided with No.3 Wharf at Circular Quay at approximately 06.38AM.

1.2 Based on the information provided by the reporter, the Chief Investigator directed the deployment of OTSI Investigating Officers to the incident site.

## Initiation of Investigation

1.3 As a result of the primary evidence collected by the OTSI Investigating Officers at the incident site, the Chief Investigator determined that the incident constituted a Category 2 accident and initiated a Ferry Safety Investigation in accordance with s46BA of the *Passenger Transport Act 1990.*

1.4 On 7 March, the Chief Investigator notified all Directly Involved Parties (DIP) that OTSI was investigating the collision and requested that an officer be nominated in each organisation to act as the point of contact for all inquiries made by the appointed OTSI Investigator in Charge. The Terms of Reference for the Investigation were provided to the DIPs with this notification.

## Terms of Reference

1.5 The Chief Investigator established the following Terms of Reference to determine why the accident had occurred and what to do to prevent recurrence:

a. identify the factors, both primary and contributory, which caused the accident;

b. identify whether the accident might have been anticipated and assess the effectiveness of any strategies that were in place to manage the related risk/s;
c. assess the effectiveness of emergency actions in response to the accident, and
d. advise on any matters arising from the investigation that would enhance the safety of ferry operations.

**Interim Factual Statement**

1.6 An Interim Factual Statement notifying OTSI's investigation and describing the incident in terms of what had happened was published on the OTSI website on 15 March 2005.

**Methodology**

1.7 The methodology adopted for this investigation is based on the Incident Cause Analysis Method (ICAM) and involves the process of:

a. Collection of primary physical evidence at incident site;
b. Collection of witness evidence;
c. Collection of documentary evidence;
d. Collection of other relevant and/or corroborating evidence, including results of technical inspections and/or test results;
e. Analysis and interpretation of evidence;
f. Determination of those factors which:
    i. contributed directly to accident causation;
    ii. contributed indirectly to accident causation, and
    iii. are relevant safety issues but did not contribute to accident causation;
g. Establishing the cause of the accident, and
h. Determining recommendations to improve safety and prevent recurrence.

1.8 The underlying feature of the methodology is the Just Culture principle with its focus on safety outcomes rather than the attribution of blame or liability.

## Consultation

1.9 On 19 October, a copy of the investigation Draft Report was forwarded to the Sydney Ferries Corporation, the NSW Maritime Authority and the Independent Transport Safety and Reliability Regulator (ITSRR). The purpose was to provide all DIPs with the opportunity to contribute to the compilation of this Final Report by verifying the factual information, scrutinising the analysis, findings and recommendations, and providing any commentary that would enhance the structure, substance, integrity and resilience of the Investigation Report. DIPs were requested to submit their comments by 4 November. Submissions were received from all three parties.

1.10 The Chief Investigator considered all representations made by DIPs and where appropriate, reflected their advice in this Final Report. On 16 November, the Chief Investigator informed DIPs which matters from their submissions had been incorporated in this Final Report and where any proposal was not included, the reasons for not doing so.

## Investigation Report

1.11 This report describes the collision which occurred at No 3 West Wharf at Circular Quay on 4 March 2005 and explains why it occurred. The recommendations that are made are designed to contribute to the maintenance of safe ferry operations and to minimise the potential for a recurrence of this type of accident.

# PART 2 FACTUAL INFORMATION

## Before the Collision

2.1 At 6.20AM on Friday 4 March 2005, the "Freshwater" class Manly ferry *Collaroy* departed the Sydney Ferries Corporation (SFC) Balmain shipyard facility at Mort Bay, enroute to Circular Quay, in preparation for the commencement of its daily scheduled passenger service to Manly. The approximate course of the *Collaroy* is shown at Figure 1. The crew consisted of the master, an engineer and in this instance, five, rather than the usual four, general-purpose deckhands (GPHs).

2.2 Shortly after leaving the Balmain facility and before entering Sydney Cove, the master successfully completed a routine equipment and machinery manoeuvring control test in preparation for berthing. The master was alone on the vessel's bridge and was standing at the main control console as he approached Sydney Cove. The engineer was supervising the systems monitoring console in the Machine Control Room (MCR) in accordance with Sydney Ferries' standard operating procedures. The master advises that he kept the *Collaroy's* propulsion control system in manoeuvring mode and that he committed the vessel to a normal approach to its berth. Data from the onboard Honeywell Monitoring System confirmed that the *Collaroy* was travelling at below the permitted limit of eight knots (14.8 kph) at this time and that the transit, to this point, had been uneventful.

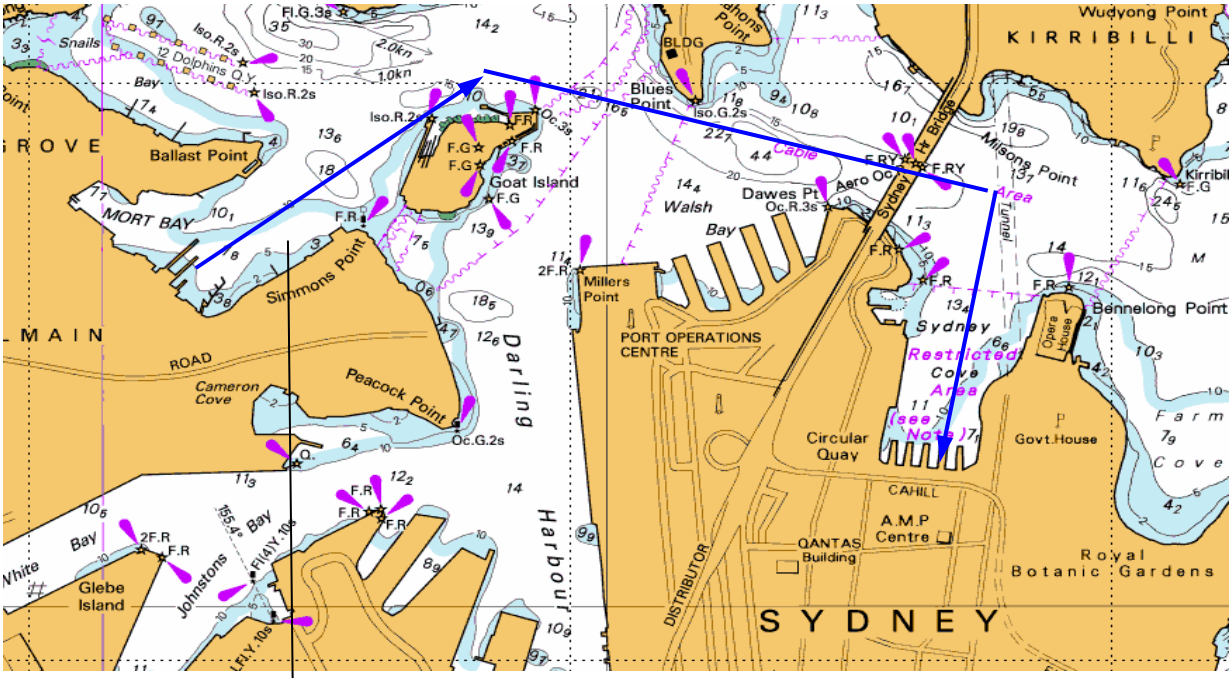


**Figure 1: Extract from chart Aus 202**

Approximate track of the *Collaroy* from the Balmain facility to No. 3W Circular Quay

## Collision Sequence

2.3 The master reported that he was less than a vessel length (69.5 metres) from his intended berth when he noticed that *Collaroy's* speed was increasing, rather than decreasing, in response to his ordered control setting. He attempted to regain propulsion control by repeating the required setting several times, but the ferry did not respond and subsequently collided with the timber backboards or 'buffers' at the end of the berth. The backboards absorbed the force of the collision before collapsing against the promenade breastwork. Figure 2 shows the impact damage.

2.4 According to the master, the primary propulsion control system then spontaneously self-corrected, at which time he regained control and secured the ferry at its berth.

**Figure 2: Damage to the Backboard at No. 3 West Wharf**

## After the Collision

### Emergency Response

2.5 Immediately after the vessel berthed, the ferry crew, assisted by Sydney Ferries' duty personnel at Circular Quay, who had been alerted by the activation of the *Collaroy's* horn, commenced a series of checks to establish the extent of damage and to ensure the vessel's safety and security. At the same time, Sydney Ferries informed Harbour Control, relevant emergency services, OTSI and the NSW Maritime Authority of the incident.

### Medical and Toxicology Information

2.6 NSW Water Police breath-tested all crew members and all tests returned negative results. Six of the seven crew members were also drug tested in accordance with Sydney Ferries' Drug Testing Procedure and the results were again negative. The one member who was not drug tested was a supernumerary deckhand undergoing training as a Greaser. The fact that he was not drug tested is discussed in Part 3 of this report.

## Damage

2.7 The *Collaroy* sustained minor scrapings to the above and underwater painted surfaces around its bow area and a zinc anode was torn off. Underwater divers confirmed that there was no visible distortion to the bow propeller or rudderstock. A section of the timber buffer was extensively damaged. Sydney Ferries' operations were affected by the *Collaroy's* withdrawal from service and the closure of No.3 West Wharf for one and three weeks respectively.

## Location Description

2.8 Circular Quay is Sydney's busiest wharf facility. It is sited at the Southern end of Sydney Cove and comprises five, 78.5 metres long, pile-supported piers and pontoon wharves, aligned North-South, providing both access and egress to ferry and charter vessel passengers. More than ten vessel movements may occur in Sydney Cove concurrently and in recent years, there has been an increase both in traffic frequency and the size of vessels operating therein. Significantly, Circular Quay is less than 300 metres wide at its Southern end. The facility's layout, showing *Collaroy's* final position, is shown at Figure 3.

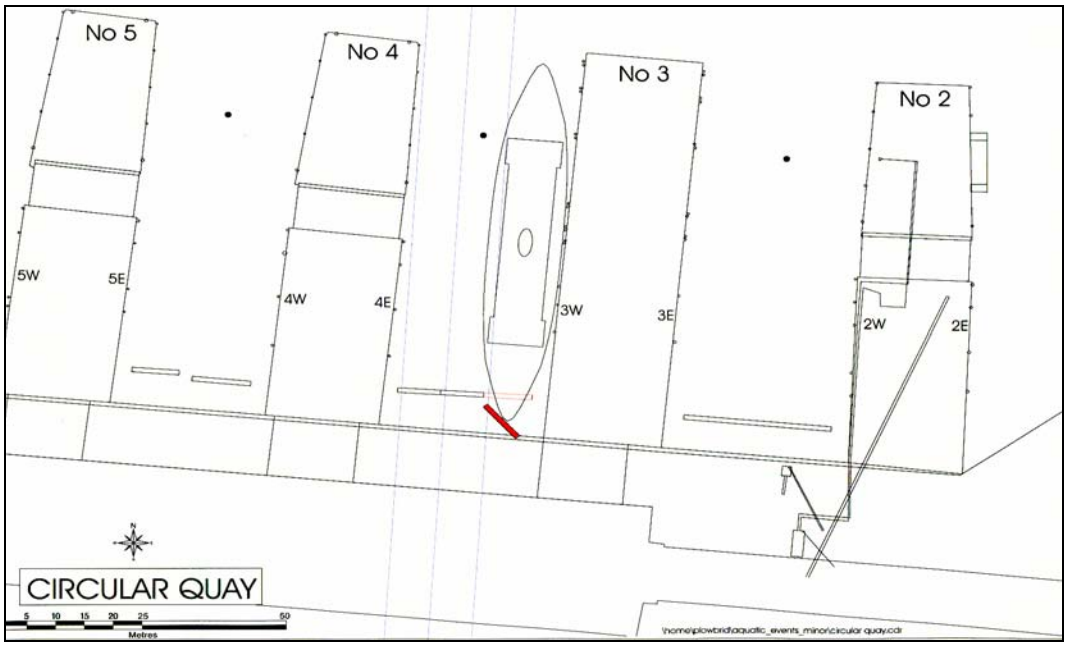


**Figure 3: Location Diagram (Courtesy NSW Maritime Authority)**

## Vessel Information

2.9 *Collaroy* is one of four "Freshwater" class vessels operated by Sydney Ferries Corporation. It is 69.5 metres long and 13 metres in beam. *Collaroy* has a 'double-ended' configuration, with a centre-line propeller and rudder fitted at both ends, allowing the ferry to be operated on return trips from Sydney to Manly without having to turn around. *Collaroy* is propelled by two 2238kW (3000BHP) Daihatsu marine diesel engines, only one of which is normally in use during routine service. Its normal service speed is 14 knots; it has a displacement of 1140 tonnes and has a maximum carrying capacity of 1100 passengers. A schematic of the vessel is shown at Figure 4.

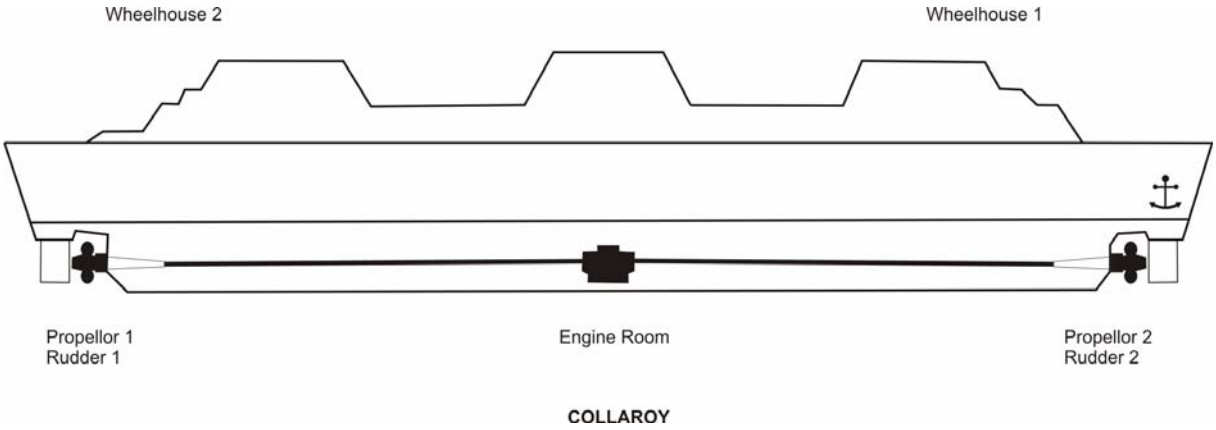


**Figure 4: Diagrammatic Representation of the *Collaroy***

2.10 *Collaroy* is the last of the four "Freshwater" class vessels acquired by Sydney Ferries, coming into service in 1988. Despite being the newest vessel of its class, *Collaroy's* propulsion control system is now the most dated. The other three ferries in the "Freshwater" class were brought into service with a "Lips" propulsion control system, manufactured in Holland. However, *Collaroy* was commissioned with a "Kamome" propulsion control system, manufactured in Japan. At the time, this system was regarded as technologically superior to the "Lips" system. Consequently, the *Collaroy* was, and remains, unique within its class.

2.11 Sydney Ferries commenced to upgrade the "Lips" system as fitted to the other three "Freshwater" class vessels, commencing in the late 1990s. This action was initiated as a result of the fact that the "Lips" manufacturer was no longer prepared to support what it considered to be a dated system. The upgrade to the "Lips" system incorporated technologies that were then, and continue to be, considered by many of Sydney Ferries' masters and engineers to be superior to the "Kamome" system. However, Sydney Ferries decided to retain the "Kamome" system on the *Collaroy* as the manufacturer was prepared to continue to support the system, and because of funding considerations. To upgrade the *Collaroy's* propulsion control system was then estimated to cost $1 Million.[1] Because the *Collaroy* is unique within the "Freshwater" fleet, Sydney Ferries' policy is to utilise it on the Manly service only when one of the other "Freshwater" vessels is off-line.

2.12 *Collaroy's* Master controls and navigates the vessel from one of two identical enclosed bridges on the ferry's superstructure. Each control console is fitted with external bridge wing control stations, i.e., the master can exercise control from three stations at either end of the ferry. The centre console station is shown at Figure 5 *overleaf*.

2.13 Like its sister vessels in the class, *Collaroy* is akin to a small sea-going ship and has a separate Machinery Control Room (MCR) that is controlled by an engineer. The master may direct control of the propulsion settings through the engineer located in the MCR. A part of the MCR is shown at Figure 6 *overleaf*.

[1] The recent (11 October 2005) announcement to upgrade the *Collaroy's* propulsion system provides $1 Million for this project.

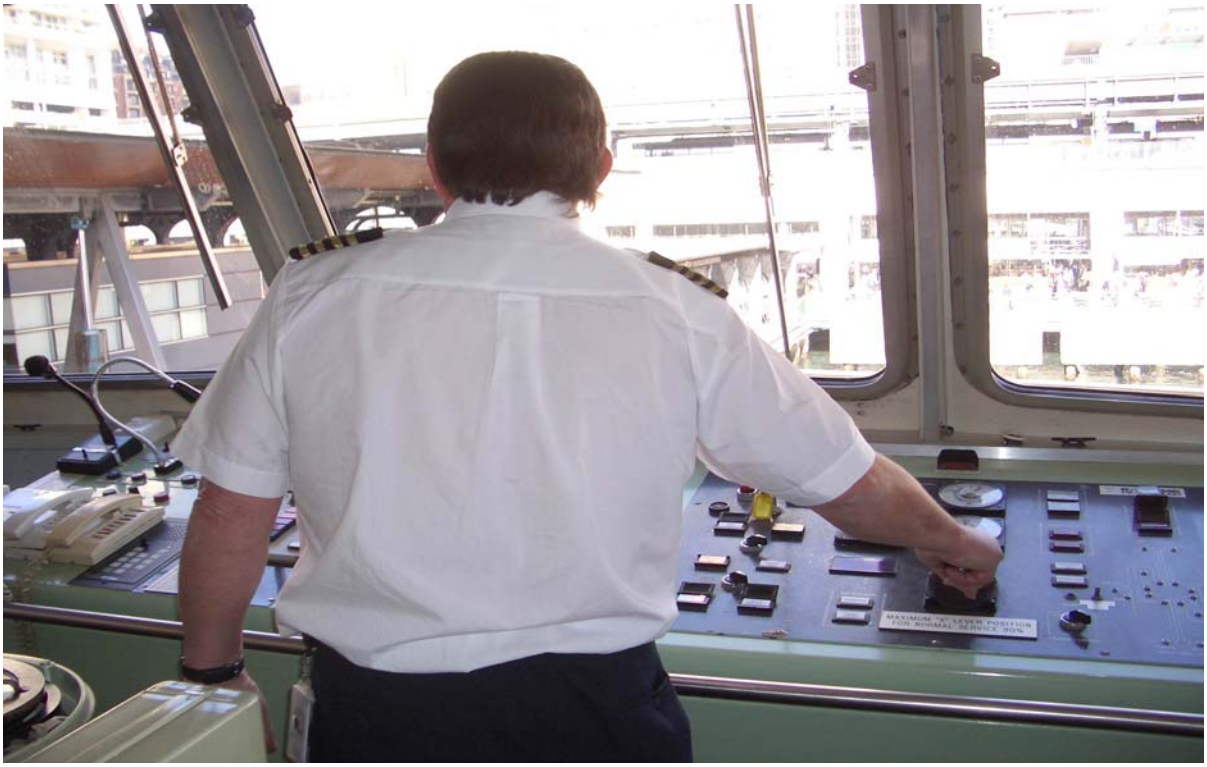

**Figure 5: A master at the No. 2 Bridge centre control console**


**Figure 6: The Machinery Control Room (MCR) Mimic Panel and Data Logger Console**

## Crew Information

2.14 Each member of the *Collaroy's* crew was appropriately qualified and held the relevant certificates of competency. As is the usual case, the master was the only person on board holding a Uniform Shipping Laws (USL) Master Class Four qualification, entitling him to exercise navigational command of the vessel. As required under the *Pilotage Licensing Act (1996*) for masters of large vessels, *Collaroy's* master held a valid local knowledge certificate.

2.15 *Collaroy's* engineer held a qualification as a Marine Engineer Class 1 which exceeds the minimum requirement for an Engineer certificate of competency of USL Class Two or higher.

2.16 GPHs or 'deckhands' do not require a marine certificate of competency, but must qualify for a Pre-Sea Safety Certificate in order to obtain an endorsement issued by the NSW Maritime Authority. *Collaroy's* deckhands had been appropriately endorsed.

## Meteorological & Environmental Information

2.17 The height of the tide was approximately one metre at the time of the incident, with low water predicted at 9.45AM local time. Sunrise was at 6.45AM and the master advised that he enjoyed unrestricted visibility and that his handling of the *Collaroy* was unaffected by the current or wind.

# PART 3 ANALYSIS

## Berthing Procedures and Master's Actions

3.1 Manly ferry masters navigate by eye and draw upon their experience, judgement and developed motor skills to manoeuvre their vessels into and out of wharves. The Freshwater class ferries have control systems and handling characteristics that are more complex than other vessels operated by Sydney Ferries. The master uses a control, known as the X-Y lever, to adjust the vessel's advance towards its position opposite the embarkation ramps at the dead-end berths. The X-Y lever is shown at Figure 7.


**Figure 7: Showing the X-Y lever and Emergency Control Switch**

3.2 Lateral direction and motion in manoeuvring mode is achieved by the vessel's rudders being offset to deflect the thrust from each propeller as required. Masters usually remain at the centre console until they have stopped the vessel just short of its final position, then relocate to the bridge wing on the side closest to the wharf to complete the berthing procedure.

3.3 The other aids to propulsion, steering and navigation available to the master of the *Collaroy* are radar and the bridge instrument console which houses the propulsion and steering control gauges that indicate each of the vessel's rudder and propeller pitch settings. There is no analogue or GPS speed indicator to confirm the master's visual estimation of his vessel's closing rate towards the berth. The pitch setting gauges are shown at Figure 8.


**Figure 8: Gauges, available to a master, indicating pitch settings**

3.4 The master advised that, on realising that he was gaining speed rather than slowing, he manipulated the X-Y control lever several times to regain control and obtain full astern propulsion. Approximately one minute elapsed between the onset of the failure he described and the subsequent collision, during which time he did not attempt to communicate with, or effect control through, the engineer located in the MCR. Nor did he attempt to utilise the alternative Emergency Control back-up propulsion system fitted to the vessel, activate a pre-recorded audio warning message or deploy an anchor, on the basis that there was insufficient time to do so. However, he did initiate a prolonged warning blast on the ferry's whistle to alert his crew and personnel ashore.

3.5 The key aspects of the master's description of events were corroborated by the information contained in the recordings of the *Collaroy*'s data loggers. They show that during the final approach phase, the pitch setting of the bow propeller, known as No.1, did not respond to a series of commands from the master. Further, instead of slowing the vessel, the No.1 propeller set to a pitch that drove the vessel ahead. After a delay of 28 seconds, during which the master repeated his original command a number of times, the No.1 propeller began to provide the reverse braking thrust ordered by the master. A further 22 seconds elapsed before No.1 propeller assumed the 30-degree blade pitch setting needed for full reverse thrust. During this time the ferry struck the backboard.

**Propulsion Control System**

3.6 *Collaroy* uses two modes of propulsion, known as 'sailing' and 'manoeuvring' modes, during its passenger services between Sydney and Manly. In sailing mode, for passages in open waters, the vessel is propelled conventionally by way of a stern propeller and steered by a rudder. Manoeuvring mode is a configuration used to move the vessel in proximity to its berth. It involves the use of the X-Y lever and the other propeller and rudder fitted at the bow, to provide the additional longitudinal and transverse thrust needed to slow the ferry and move it sideways into position. This provides for increased manoeuvrability and removes the need to turn such a large passenger ferry around in confined waters after each passage.

3.7 Significantly, forward or astern propulsion in manoeuvring mode is effected via adjustment of the controllable pitch of propeller blades, rather than by the more conventional means which change the direction of rotation of the propeller shafts via a gearbox and altering engine RPM. This configuration also allows the vessel's engines to run at a constant speed, reducing wear and tear on machinery and transmission gear. The master manoeuvres the ferry using the X-Y

lever which converts fore, aft and transverse thrust commands into electrical signals, via a potentiometer.

3.8 In order to understand the extent of the challenge facing the master when it malfunctioned, OTSI examined the *Collaroy*'s propulsion control system in detail.

3.9 *Collaroy* is fitted with a "Kamome" propulsion control system and relies on four electronic logic units, known as Programmable Logic Controllers (ProCons). The units are designated 1A, 1B, 2A and 2B and are housed in a cabinet as shown in Figure 9 *overleaf.* Two ProCon units are assigned to each propeller, so that at any time the vessel is in operation, each propeller has one of these units on-line and the other in stand-by mode. Normally, ProCon units 1A and 2A are used as the on-line operating controllers and units 1B and 2B are in stand-by mode.

3.10 The ProCons convert the master's ordered commands, via the X-Y lever, from analogue electrical signals into digital settings that adjust the hydraulic valves in the pitch propeller system. The pitch of the propeller's blades is altered, for ahead or astern thrust, as ordered. Upon sensing a malfunction, the control system is designed to automatically revert to the ProCon unit on stand-by, as well as initiating an alarm signal on the bridge and MCR to alert both the master and the engineer. The system is complex, as exemplified by components including more than 600 electrical relays. Part of the "Kamome" propulsion control circuitry is shown at Figure 10 *overleaf*. It is also sensitive to incorrect inputs because they may trigger a variety of 'reset' functions, some of which can take a considerable amount of time to be effected.


Figure 9: ProCon Cabinet

Figure 10: Part of the Kamome propulsion control circuitry

## What Went Wrong?

3.11 Following the accident, experts from, or on behalf of, the manufacturers of the *Collaroy*'s data logger, engines' governors and propeller pitch control systems, together with independent specialists in propulsion control systems, joined technical staff from Sydney Ferries to determine whether there had in fact been a loss of control and, if so, those factors that may have contributed to it. Sydney Ferries also engaged the services of a marine surveyor to provide an assessment that was independent of those being proffered by the various manufacturers or their agents. OTSI investigators were present throughout the majority of the testing and simulations, as were officers from the NSW Maritime Authority, and subsequently accessed the various inspection reports.

3.12 Downloaded data confirmed that the master had been confronted with a loss of control and that alarm and back-up systems that should have automatically activated, failed. They also confirmed that the fault later self-rectified. A variety of examinations and tests eliminated the governors, the CCP propellers and related control valves and hydraulics as the source of the loss of control. The focus then shifted to the electronics at the heart of the "Kamome" propulsion control system.

3.13 Initially, simulations and a sea trail failed to replicate a loss of control similar to that which occurred on 4 March 2005 and system engineers were subsequently forced to work their way through the entire Kamome system, using a process of elimination. Whilst a number of electrical control relays were found to have high resistances, none could be positively identified as initiating the failure. Detailed analysis of recordings on the data logger identified that the active propeller's pitch gradually increased even though the X-Y lever remained at the zero position.

3.14 Eventually, a simulation which fed false inputs into the ProCon system, did replicate the 4 March failure and revealed that ProCon unit 1B had failed. The logic cards, in effect circuit boards, in the ProCon were subsequently replaced with new cards. *Collaroy* was then subjected to a series of sea trials which were completed without fault. Further analysis established that at the time of the malfunction, ProCon units 1B and 2A were being employed by the master, instead of the normally used 1A and 2A units. More significantly, it was also established that ProCon units 1A and 2B were not switched on. This meant that when unit 1B failed, there was no prospect of the master receiving an audible warning alarm, or of a back-up ProCon unit being automatically brought on-line.

3.15 Sydney Ferries advised OTSI that they had been experiencing thermally-induced faults in the ProCon's electronic logic-card circuitry over a period of several months and that Sydney Ferries' technical support staff were aware of the situation. The problem, believed to be caused by the ProCon units being subjected to repeated cycles of heating and cooling after being switched on and off on a daily basis, was usually only apparent during morning start-ups whilst the propulsion control system warmed-up. Loud warning alarms would sound in the vessel's MCR each time a unit malfunctioned. The problem would typically self-correct before vessels left the Balmain Yard. A senior engineer, on his own initiative, issued a Memo to guide fellow engineers in a modified start-up procedure which, amongst other things, was intended to compensate for the problems that were being experienced within the ProCon units during start-up. Part of the instructions read:

**"SWITCH ON THE PRONCONS IN THE KAMOME CABINET. At the time of writing 2A & 1B procons will be in error first thing in the morning but will settle down after @20 minutes or so".**

3.16 On the day of the accident, *Collaroy*'s engineer recalls implementing the modified procedure but thought that he only had three functioning ProCons as the vessel left Balmain and that another unit, 1A, might have "slipped off" as the berthing approach was commenced. The master had no recollection of being informed by the engineer that there were any irregularities before the *Collaroy* departed the Balmain Yard. In reviewing the communication between the master and the engineer during the start-up procedures, it became apparent to OTSI that it could not be likened to that which might occur between an airline pilot and co-pilot, for instance. Whilst the engineer was required to undertake a series of specific checks, the accepted practice is that the results of such checks are communicated to a master by 'exception', i.e., the engineer is expected to only identify faults or to provide an 'all clear'. This contrasts with the start-up procedures employed by pilots and co-pilots where the result of every item is communicated and

acknowledged. In making this comparison, OTSI acknowledges that the situation between a pilot and a co-pilot and that of the master and the engineer are not analogous, however the outcome of pre-flight and pre-sailing check processes should be the same, i.e., there should be a clear and common understanding of the condition of the aircraft/vessel and a journey should not commence if there are reservations about the functionality of key systems.

**Master's Emergency Actions**

3.17 Confronted by a loss of control, the master responded by repeating his command instructions several times via the X-Y lever. This response action would have been conditioned by previous instances where loss of control had been known to self-correct, and by the fact that he had not been alerted to an alarm which was designed to inform him of a malfunctioning ProCon unit. However, OTSI notes that instrumentation on the control panel would have provided such an indication. The master would also have expected a standby ProCon unit to be automatically available to him. When this didn't happen, the master concluded that there was little he could do, other than to initiate a prolonged warning blast on the ferry's whistle to alert his crew and personnel ashore. The master advised that he did not consider it feasible to deploy an anchor or to use the separate Emergency Control system available to him on the *Collaroy*, believing that there was insufficient time for such manoeuvres to have the desired effect. OTSI notes that the process of deploying an anchor requires both time and space that were not available to the master in this instance.

3.18 While the emergency mode comes on-line immediately a master switches the Emergency Control Switch to 'on', the initial effect of such an action is to bring the on-line propulsion engine up to 600 rpm very quickly. However, propeller pitch settings remain as they were immediately prior to the selection of Emergency Control. This option would have had to have been exercised by the master almost immediately after the onset of the failure to have had the desired effect

because the initial effect of engaging the emergency system would have been an increase in propulsion towards the backboards. Additional time would also have been required in this instance to have altered the pitch settings that remained in an orientation that assisted rather than retarded movement. Such a manoeuvre would also have required communication with the engineer, and this was something that did not happen throughout the period of approximately one minute between the onset of the malfunction and the subsequent collision.

3.19 The master might also have activated a pre-recorded audio emergency message, but OTSI notes that masters in general have expressed limited confidence in this facility, believing the message to be too lengthy and not sufficiently compelling.

**Organisational Issues – CRM**

3.20 While all of the crew were appropriately qualified, a check of training records established that not all of the crew had participated in recent emergency training. Sydney Ferries requires that crew members participate in such training on a monthly basis. Its training records indicate that this requirement was not being met in all cases. The deckhands last participated in emergency training in February 2005 and/or March 2005 and the master in October 2004. There was no record of the engineer having participated in emergency training throughout 2004 or in the period 1 January 2005 – 4 March 2005.

3.21 The extent and nature of communication between the master and the engineer before the *Collaroy* left the Balmain Yard and during the emergency was not reflective of good CRM. OTSI believes that there should be a formal requirement for masters and engineers to communicate during start-up procedures and in any emergency.

3.22 OTSI noted that the master was the only person on the bridge as the vessel entered Sydney Cove. Sydney Ferries' expectation is that a helmsman will be on the bridge of "Freshwater" class vessels at all times during operations. OTSI was advised that in practice, helmsmen are generally present when passengers are on board but that it is not uncommon for the master to be alone on the bridge when "Freshwater" class vessels are transiting from Balmain prior to the commencement of passenger operations. OTSI has two concerns in relation to this aspect of crewing. The first is that such a matter was the subject of 'expectation' rather than being a formally stated requirement. The second is that there would seem to be a view amongst some crew, including the masters, that the services of a helmsman are only necessary once passengers are embarked. Clearly, there is a prospect that a master might suffer from illness; be required to cope with an onboard emergency, or would benefit from having an additional pair of eyes on lookout irrespective of whether passengers are on board.

3.23 During the examination of Sydney Ferries' approach to emergency training, it became apparent that there is a degree of Union dissatisfaction with the programming of such training and its design, delivery and evaluation. OTSI did not pursue this matter, but will do so in the context of a systemic investigation into collisions across the "Freshwater" class that it has subsequently commenced.

**Organisational Issues – Fatigue & Impairment**

3.24 Having examined rosters and work sheets, there was nothing to suggest that fatigue was at issue. Both the master and the engineer returned negative results to drug and alcohol testing, as did the four deckhands tested for both drugs and alcohol. One deckhand was tested for alcohol, and returned a negative result, but was not tested for drugs. Sydney Ferries has drawn OTSI's attention to the fact that its drug testing procedure specifies that an employee who has been involved in an accident or irregular incident while carrying out transport

safety work **may** be, rather than **must** be, required to undergo drug testing and that this is consistent with Section 9 of the *Passenger Transport (Drug and Alcohol Testing) Regulation 2004 (NSW)*. Sydney Ferries also advised OTSI that their procedure is under review because they do not believe it provides sufficient guidance to require a trainee to be tested, given that they do not have a designated line of work, or set of transport safety worker responsibilities, relevant to the safe passage of the vessel.

3.25 Notwithstanding the ambiguity surrounding the status of trainees in Sydney Ferries' drug testing procedure, OTSI was provided reliable advice which indicated that the failure to test one of the deckhands was the consequence of an oversight. "Freshwater" class vessels are normally crewed by six personnel: a master, an engineer and four GPHs. In this instance, there were five GPHs on board, albeit one was undergoing training. OTSI understands that immediately prior to the drug testing, crew were in a variety of locations being individually interviewed and debriefed and that during this process Sydney Ferries lost sight of the fact that there were seven, not six, crew that might have required testing. OTSI notes that Sydney Ferries now requires that there be a reconciliation of the actual crew and crew names entered onto the vessel's log before testing occurs and that the master assist in this process. This should reduce the prospect of a crew member not being considered for testing because of an oversight.

**Organisational Issues – Maintenance**

3.26 Sydney Ferries had been aware of ongoing problems with the "Kamome" propulsion control system over several months. Whilst a modified start-up procedure had been adopted as an interim means of addressing these problems, Sydney Ferries did not implement any longer term strategies to resolve the problems. OTSI noted the propulsion control system was not included in any in-house inspection schedule or any routine preventive maintenance program. Instead,

Sydney Ferries relied upon a contractor to provide technical support when the system malfunctioned.

**Organisational Issues - Risk Management**

3.27 All Sydney Ferries' vessels are subject to an annual survey under arrangements directed and controlled by the NSW Maritime Authority. The vessels may also be subjected to additional inspection by the Maritime Authority if it deems that necessary. *Collaroy* is also subjected to Lloyds Classification Society's inspection requirements, for insurance purposes, on an annual basis. The NSW Maritime Authority accepts Lloyd's certification as evidence that the survey requirement for the hull and machinery has been satisfied. The *Collaroy*'s Certificate of Survey was issued by the NSW Maritime Authority in August 2004 and its Certificate of Class was issued by Lloyd's Register in July 2004, and both were current at the time of the accident.

3.28 Ferry operators were required under Section 53D of the *Passenger Transport Act 1990* (Schedule 3, Clause 23) to have a Safety Management System (SMS) in place by 1 January 2005. However, this deadline was extended by Regulation to 1 July 2005. Implicit in such a requirement is the obligation to systematically identify, analyse and treat risk.

3.29 Sydney Ferries was aware of ongoing problems with the *Collaroy*'s propulsion control system. One of its engineers had promulgated a modified start-up procedure intended to encourage a consistent approach by engineers in the face of such problems. However, this procedure had not been the subject of any formal risk assessment as was required under Sydney Ferries' SMS, nor was there any evidence of actions taken to ensure that the entire crew had a common understanding of the interim procedures. Had this important step been observed, Sydney Ferries might also have seen fit to notify the NSW Maritime Authority of these on-going problems and the proposed

solution as also required by its SMS. In making this point, OTSI acknowledges that such arrangements are recent and evolving. The NSW Maritime Authority commenced its first audit of Sydney Ferries' SMS on 4 October 2005 and it is expected that such activity will reinforce the observance of such requirements.

3.30 As previously noted, *Collaroy* is different to the other "Freshwater" class vessels operated by Sydney Ferries. Sydney Ferries had attempted to minimise the potential for masters to be confused by such differences by aligning the *Collaroy*'s procedures and instrumentation where possible with those of its sister vessels. The only formally documented operating procedures at the time were those contained in the generic Freshwater class VOM. Sydney Ferries acknowledged that some of the information contained in this VOM contained matters that were either irrelevant or erroneous in the context of the *Collaroy*'s configuration or operations. Significantly, the VOM made no reference to the *Collaroy*'s unique Kamome propulsion control system. Similarly, there was no specific reference in the list of response procedures that might be adopted in a range of emergency situations, to matters that might arise as a consequence of the *Collaroy*'s uniqueness.

3.31 Sydney Ferries acknowledged that aspects of its risk management require reinforcement and advised OTSI that it has initiated a "Big Boat Project" which will:

a. assess the risks associated with the operation of "Freshwater" class vessels;
b. review crewing arrangements and qualifications in the light of assessed risks;
c. review the roles and responsibilities of all crew members, including the processes for selection and appointment for the roles and the opportunities for career pathways and skills enhancement;
d. review the engineering history across the class and the related maintenance and audit processes;

e. include broader areas such as security, CRM and contingency planning including the use of other classes on services to and from Manly, and

f. introduce, on a trial basis and in consultation with unions, a Mate IV or Master Class V onboard “Freshwater” class vessels.

## Emergency Response

3.32 The emergency response to this incident was satisfactory, with the exception of the fact that 37 minutes elapsed before Sydney Ferries notified OTSI of the collision. The management of the incident was relatively straight-forward in the absence of injuries and any extensive collateral damage.

# PART 4 FINDINGS

4.1 **In respect of causation, OTSI finds that**:

a. The collision occurred when the *Collaroy* failed to respond to the master's handling instructions and a number of back-up features also failed.

b. The *Collaroy* failed to respond to the master's handling instructions when one of four control units, upon which he was relying to convert his instructions into an altered pitch setting on the No.1 propeller, was rendered inoperative by a faulty electrical circuit in a logic card.

c. The failure of warning and back-up systems, which should have been activated when the control unit failed, was a consequence of human error. These 'defences' were dependent on all four control units being switched-on at the time and they were not.

4.2 **In the matter of appropriateness of the emergency response, OTSI finds that:**

a. The master of the vessel, confronted with a loss of control, and automatic warning alarms and an automatic back-up system that did not activate, had limited options available to him in the confines of Sydney Cove.

b. The extent and nature of communication between the *Collaroy's* master and engineer on the morning of, and during, the incident was not consistent with effective Crew Resource Management.

c. Sydney Ferries' expectation is that there will be a helmsman present on the bridge of "Freshwater" class vessels whenever they are in operation. However, there is no formal statement/policy requiring this to occur and, in this instance, the master was alone on the bridge both prior to and during the incident.

d. While the master did initiate a prolonged sounding of the *Collaroy's* horn to alert others of his predicament, he did not activate a pre-recorded warning message for the benefit of those

on board, in this case, the crew. This has been a recurring omission across a number of accidents reviewed by OTSI and it has been reported that masters do not regard the current facility as being particularly useful.

e. Duty personnel at Circular Quay from both Sydney Harbour Control and SFC acted quickly and efficiently to assist *Collaroy's* crew to secure the vessel, minimise the prospects of environmental damage, cordon the area and to alert the necessary response agencies, including the NSW Maritime Authority and OTSI. Those contacted also responded quickly and efficiently.

f. One of *Collaroy's* five deckhands was not subjected to drug testing following the incident.

4.3 **In the matter of whether the accident could have been anticipated and the effectiveness of the risk management strategies adopted by the SFC, OTSI finds that:**

a. Sydney Ferries operates 31 vessels, but their operation is made more complex by the fact that these vessels fall into seven different vessel classes, and even within classes there are differences between vessels. While Sydney Ferries is aware of this complexity, its current risk management procedures do not take sufficient account of it, as evidenced by the absence of specific references to the uniqueness of the *Collaroy's* "Kamome" propulsion control system in the "Freshwater" class Vessel Operations Manual (VOM), and the absence of specific drills for emergencies that might arise as a consequence of this uniqueness. OTSI notes that Sydney Ferries has since developed a VOM specifically for the *Collaroy* but that this publication has yet to be issued.

b. For several months, *Collaroy* had been experiencing problems with the propulsion control system on start-up and a modified starting procedure had been implemented by engineers to overcome the problem. However, there was no evidence to

suggest that any formal risk assessment had been applied to address these problems, their potential consequence or the risks associated with the modified procedures.

4.4 **In the matter of any other matters arising from the investigation that would enhance the safety of ferry operations, that:**

a. All ferry operators had been required under Section 53D of the *Passenger Transport Act 1990* (Schedule 3, Clause 23) to have a Safety Management System (SMS) in place by 1 January 2005; that this date was extended by Regulation to 1 July 2005, and that the NSW Maritime Authority first commenced to audit Sydney Ferries' SMS on 4 October 2005.

b. Sydney Ferries were obliged to advise the NSW Maritime Authority of the problems it had been experiencing on the *Collaroy* and of the modified procedures. However, because the problems and interim solutions were not managed in accordance with the relevant procedures in their SMS, Sydney Ferries did not identify the need to advise the NSW Maritime Authority of the related issues.

c. There is an absence of safety backboards at No. 6 Wharf, Circular Quay and at the Southern end of Manly Wharf.

d. CCTV coverage of vessels approaching and berthing at Circular Quay is neither comprehensive, nor reliable.

# PART 5 OTHER MATTERS THAT MIGHT ENHANCE THE SAFETY OF FERRY OPERATIONS

## On-board Data Loggers/Event Recorders

5.1 *Collaroy* was fitted with an on-board data logger which provided detailed information about many of the key operational functions of the vessel at the time of this incident. However, OTSI noted that none of Sydney Ferries' vessels have what might be considered a comprehensive suite of event recorders, i.e., the facility to monitor and record mechanical, electrical and navigational functions. Nine of the 31 vessels operated by Sydney Ferries do not have an event recorder of any type. Whilst there is currently no mandated requirement for event recorders on ferries in NSW, or anywhere else in Australia, OTSI notes that the fitment of event recorders is mandated in the air and rail industries throughout Australia and that bus operators providing regular passenger services in NSW were provided with an incentive to fit onboard cameras, by the then NSW Department of Transport in 1998/9. The NSW Government recently amended the bus services regulation to make installation of an approved security camera system on all Sydney metropolitan and outer metropolitan buses a statutory obligation. This will take effect from 1 July 2006. Similar provision for ferries warrants consideration.

## CCTV Coverage at Circular Quay

5.2 CCTV coverage from and at Circular Quay is limited and OTSI has noted, in the context of other investigations, that it is not always reliable. In this instance, OTSI was unable to be provided with CCTV footage from two cameras because they were unserviceable. OTSI notes, however, that the in-situ cameras have been provided by Sydney Ferries to meet their own needs. Given that Sydney Ferries is

not the only user of Circular Quay, OTSI does not consider it appropriate that they be expected to be the sole provider of such a capability. This responsibility should more appropriately rest with the NSW Maritime Authority.

## Backboards

5.3 Whilst the backboard at No. 3 West Wharf arrested the momentum of the *Collaroy*, no such facility exists at the southern end of No. 6 Wharf where large passenger-carrying vessels berth in proximity to a busy pedestrian thoroughfare. This situation is depicted in the photograph at Figure 11.

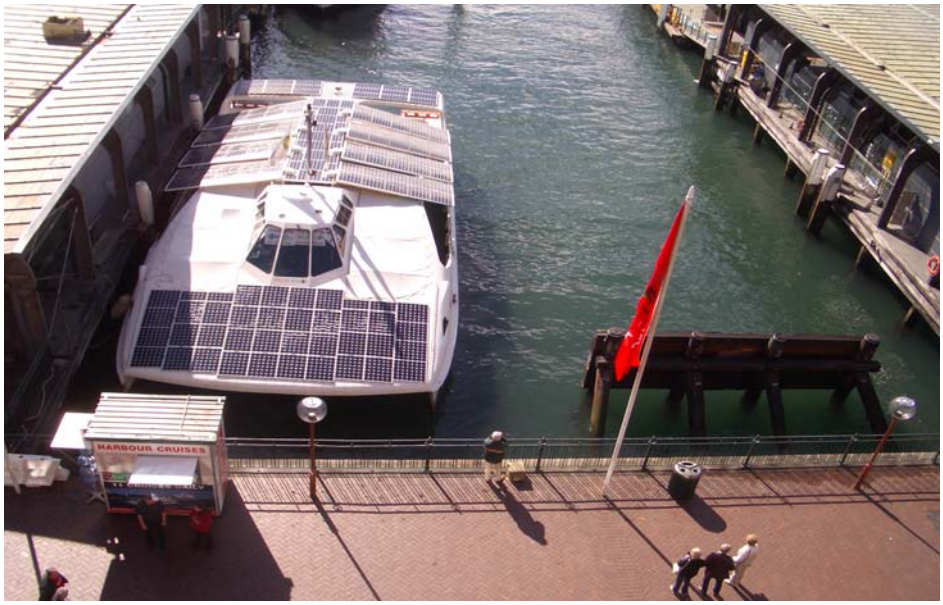


**Figure 11: Absence of Backboards at No. 6 East Wharf**

5.4 OTSI also noted that backboards, or some alternate form of protection, are not provided at the Southern end of Manly Wharf. OTSI has been advised by the Maritime Authority, however, that backboards are due to be fitted to No. 6 Wharf in the financial year 2006/2007 and that a semi-rigid energy absorbing buffer system will be installed at the Southern end of Manly Wharf in the near term as part of a major refurbishment program. It was further advised that consideration is being given to the installation of semi-rigid pontoons to provide shock absorption at the end of each finger wharf/jetty at Circular Quay.

# PART 6 RECOMMENDATIONS

**6.1** Notwithstanding the initiatives announced by the NSW Minister for Transport on 11 October 2005 which make provision for, amongst other initiatives: an upgrade of the *Collaroy*'s control system; the installation of Global Positional Systems across Sydney Ferries' fleet and the upgrading of onboard Data Recording Systems on "Freshwater" and "Supercat" vessels, the following recommendations are made to:

### 6.1.1. Sydney Ferries Corporation

a. Undertake a thorough risk assessment in order to determine whether it should continue to operate the *Collaroy* in its current configuration.

b. As long as the *Collaroy* continues to remain unique in its class, take action to ensure its uniqueness is fully understood by all personnel required to either operate or maintain the vessel.

c. Ensure that future changes to operating instructions are underpinned by proper risk assessments and, be they interim or otherwise, are formally communicated throughout the Corporation.

d. Require all propulsion control units to be tested on all vessels as part of start-up procedures.

e. Act to reinforce CRM throughout its organisation and in particular require safety critical issues during start-up and emergency procedures to be the subject of specific communication between masters and engineers.

f. Issue a formal policy requiring a helmsman to be present on the bridge of "Freshwater" class vessels from the commencement of start-up procedures through to the completion of shut-down procedures.

g. Review the utility of its extant pre-recorded emergency broadcast messages.

### 6.1.2 NSW Maritime Authority

a. Review any risk assessment/s undertaken by Sydney Ferries in respect of the *Collaroy*.

b. Take action to upgrade safety backboard/buffer arrangements at No.6 Wharf, Circular Quay and at the Southern end of Manly Wharf.

c. Take action to ensure the provision of a reliable, high-resolution CCTV video system capable of recording all vessels moving into and out of Sydney Cove from at least two cross-referenced points.