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The Hon Michael Costa MLC
Minister for Transport Services
Parliament House
SYDNEY NSW 2000

Dear Minister

Please find attached the Ministry of Transport's Report into the rail accident at Waterfall on 31 January 2003.

The then Minister for Transport directed the Director General of the Department of Transport to undertake an investigation into the incident under section 58(4) of the *Rail Safety Act* (1993). The Direction and terms of reference for this investigation are attached.

The then Director General delegated authority to investigate to the Rail Safety Regulator. This is consistent with the requirements of the *Rail Safety Act* (2002) which came into effect on 8 February 2003.

The Rail Safety Regulator convened and chaired an investigation panel. The investigation was conducted jointly by the NSW Police and the Rail Safety Regulator with participation by officers from State Rail Authority, Rail Infrastructure Corporation and advised by a number of expert consultants.

Consistent with the then Minister for Transport's direction, the Rail Safety Regulator has cooperated with the Special Commission of Inquiry, under the Hon. Peter McInerney. In some cases evidence from the Commission has been used in this Report.

The methodology and management of the investigation is set out in Section 2 of the Report. Consistent with section 67 of the *Rail Safety Act* 2002, this is on a "no blame" basis, and as such refers to organisations in general rather than to individuals in particular. Also, the methodology relates to the situation as existed on the date of the incident.

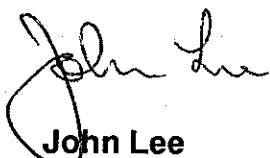
From the commencement of this investigation a number of important changes have occurred or been flagged in relation to the rail industry in NSW, including:

- Creation of the Transport Services portfolio
- Establishment of the Ministry of Transport

- Creation of an Independent Transport Safety and Reliability Regulator from 1 January 2004.
- Merging the State Rail Authority and Rail Infrastructure Corporation from 1 January 2004

Finally, we are advised that a number of matters, which are the subject of recommendations in the Report, have been or are being progressed by the relevant organisations.

Yours sincerely



John Lee
Director General

24 DEC 2003



Kent Donaldson
Executive Director
Transport Safety & Rail
Safety Regulation



MINISTRY OF TRANSPORT



WATERFALL

31 January 2003

Railway Safety Investigation

FINAL REPORT

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Report released in conjunction with the Special Commission Report into Waterfall.

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1.0 EXECUTIVE SUMMARY

At approximately 0714 on 31 January 2003, State Rail Authority (SRA) passenger train service C311, a scheduled service from Sydney to Port Kembla, overturned at high speed and collided with stanchions and a rock cutting approximately 2 km south of Waterfall NSW.

The train was carrying 47 passengers and two crew. As a result of the accident, the driver and six passengers were killed. The four-car Tangara train, identified as G7, was extensively damaged.

The investigation found there was a high probability that the driver became incapacitated at the controls as a result of a pre-existing medical condition, shortly after departing Waterfall Station. The train then continued to accelerate, out of control, with maximum power applied.

The deadman system and the guard were the designated risk controls against driver incapacitation. Both controls failed to intervene as intended and C311 overturned on a curve while travelling at approximately 117 km/h.

The train continued on its side for a short distance until it collided with stanchions and a rock cutting. The first and second carriages were righted by the collision. The driver and six passengers were ejected from the train as a result of the accident.

The immediate cause of the accident was the train exceeding the overturning speed for the curve. The systemic causes of the accident were the simultaneous failures of risk controls in the areas of medical standards, deadman system and training.

Although G7 was fitted with two data loggers, they had not been commissioned. Extensive investigation was therefore required, including computer simulation, to provide an understanding of the conditions that preceded the accident and the crash sequence.

An underdeveloped safety culture had resulted in failures in the application of the published SRA Safety Management System by line management.

SRA had insufficient safety and risk management expertise and had not systematically identified hazards to its operations or effectively controlled all the risks that had been identified. It had a reliance on accident trends to identify risks that needed to be controlled which demonstrated a reactive approach to risk management.

The Rail Safety Regulator had been inadequately resourced to develop an effective rail safety regulatory regime, and consequently had not identified the risk management deficiencies that existed at SRA.

The investigation has made a number of performance-based recommendations to address the systemic safety deficiencies identified in this report.

2.0 METHODOLOGY

The investigation was conducted according to Australian Standard AS 5022-2001, Guidelines for Railway Safety Investigation.

The terms of reference were to report upon:

1. the causes of the railway accident at Waterfall on 31 January 2003 and the factors that contributed to it
2. the adequacy of the safety management systems applicable to the circumstances of the railway accident.

The following sub-groups were established to manage the primary components of the investigation:

1. rolling stock
2. infrastructure
3. human factors and train operations
4. modelling
5. emergency response.

Investigators and sub-group members included NSW Police, officers from the Rail Safety Regulator, SRA and RIC, and a number of specialist consultants including a medical adviser.

A systemic investigation approach was adopted to identify both human and organisational issues. The investigation group has identified and analysed the issues relevant to the terms of reference and has recommended a number of safety actions.

Some of the issues identified during the investigation revealed that further investigation was warranted, but was beyond the scope of this investigation. Where necessary, recommendations have been made to undertake further investigation work.

The format adopted by this report is to present the factual information surrounding the accident, the analysis of those facts and the conclusions reached.

The objective of the investigation was to determine the circumstances surrounding the accident and to recommend corrective actions that, if implemented, would minimise the risk of similar events occurring.

The information in this report is provided to promote rail safety and in no case is it intended to imply blame or liability on the part of any individual or organisation. However, the report must include sufficient factual information to support its analysis and conclusions. Some information may reflect on the performance of individuals and organisations, and how their actions may have contributed to the outcomes of the matter under investigation.

Every endeavour was made to balance the use of information that may imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

3.0 FACTUAL INFORMATION

3.1 Background information

The train service was identified as run C311. It was a scheduled service operating from Sydney's Central Station to Port Kembla Station in the 'Down' direction¹. The train was crewed by a driver and a guard from Wollongong depot, both of whom had conducted the same run on the previous day.

The journey was scheduled to depart Sydney at 0624 on 31 January 2003 and arrive at Port Kembla at 0817. The stopping pattern was Hurstville, then all stations to Helensburgh, Stanwell Park, Austinmer and then all stations to Port Kembla. C311 was the only service operated by Wollongong train crews that had that particular stopping pattern.

In addition to the crew of two, there were 47 passengers on board when C311 departed Waterfall.

3.2 History of the journey

The crew arrived together at No.14 platform Central Station from the crew room at 0617 and entered their respective cabs at either end of the train. The driver 'cut in' (activated) his controls and logged on to the Metronet train radio network and then the crew conducted a 'continuity test'. This test established that bell communication existed between the driver and the guard, that the guard's emergency brake cock was working and that the air brake was continuous throughout the train.

C311 departed Central Station on time at 0624. The 47-minute journey to Waterfall was uneventful but because of signal delays before Hurstville, the train ran between one and a half and two minutes behind the scheduled times.

Several trains travelling in the opposite direction passed C311 between Central and Waterfall and no abnormalities in the train's operation or the performance of the crew were noted. There were no radio calls logged to or from the train before it arrived at Waterfall. Examination of enhanced closed circuit television (CCTV) images provided no reliable evidence about the driver's posture or fitness.

At six of the 11 stations before the accident, the train stopped at least 5 m past the designated four-car stopping marker. At Heathcote Station, immediately prior to Waterfall, the train stopped 22 m (nearly a full car length) past the marker and at Waterfall it stopped 15 m past the marker. However in all cases, the train had stopped within the platform.

The following table shows the times of arrival and departure at each station on 30 January 2003 and 31 January 2003, and the stopping position of the train at each platform where it could be determined from the CCTV image.

¹ 'Down' direction trains travel away from Sydney. 'Up' direction trains travel to Sydney.

C311 Journey		30 January 2003			31 January 2003		
Station	Scheduled departure time	Actual departure time	Dwell time (secs)	Stop position relative to 4-car marker	Actual departure time	Dwell time (secs)	Stop position relative to 4-car marker
Sydney	0624	0624:51	N/A	N/A	0624:53	NA	NA
Hurstville	0642	0642:27	26	NK	0644:10	26	7 m past
Penshurst	0644	0644:45	20	5 m past	0646:14	22	7 m past
Mortdale	0646	0646:43	23	5 m past	0647:55	31	5 m past
Oatley	0648	0649:04	16	NK	0650:00	21	NK
Como	0651	0652:06	19	NK	0653:01	17	NK
Jannali	0654	0655:07	16	NK	0655:43	18	NK
Sutherland	0656	0657:33	23	4 m past	0658:17	23	NK
Loftus	0659	0659:57	16	NK	0700:35	20	NK
Engadine	0703	0704:15	19	4 m past	0704:45	22	6 m past
Heathcote	0706	0707:16	23	3 m past	0707:23	24	22 m past
Waterfall	0712	0713:49	20	0 m past	0712:51	22	15 m past

Table 1: The data in this table was derived from CCTV images. The dwell times indicate the duration the train was seen to be stationary at each station. The stopping positions are estimations based on CCTV images and may be subject to viewing angle error. Note: NK= not known, NA= not applicable.

The CCTV recordings from Waterfall Station indicated that the train departed Waterfall at 0712:51. Calculations based on movement out of the station, as recorded on CCTV, indicated that the train probably departed with the Master Controller (power lever) in notch two or three out of a possible four notches (see Section 6: Train Operations for further discussion).



Picture 1: Aerial view of accident site and access tracks.

Automated signal data logs enabled calculations to be made about the train's movement after leaving Waterfall platform. (No information was available from the train's data logger, as it was not commissioned.) The calculations indicated that the train continued to accelerate as it traversed the track away from Waterfall Station. When the train entered a left curve approximately 1,930 m beyond the Waterfall platform, all four carriages rolled over to the right onto the adjacent Up track. Approximately 88 seconds had elapsed between leaving the station at Waterfall and reaching the 775 signal near the accident site.



Picture 2: *View of accident site from where the train left the Down track.*

An Up passenger train with approximately 800 passengers on board, C412, had departed Helensburgh two minutes late at about 0713. C412 was stopped approximately 4 km from the accident site by the 770 signal, which had returned to STOP as a result of the accident interfering with the circuits on the Up track.

Independent simulations and analyses were carried out based on the observed status of the track and probable configuration of the train. These indicated that the train was travelling at a speed of approximately 117 km/h when the roll-over sequence began. Many of the passengers interviewed by police indicated that after Waterfall Station the train had travelled a lot faster than normal as it approached the left curve. Many passengers also

commented that there was no noticeable deceleration, or braking, before the train rolled over.

Shortly after rolling over, the leading carriage hit stanchion SW40+805, which supported overhead wires. It then impacted the face of a rock cutting. The leading carriage separated from the train and was righted by the impact, coming to a stop on its wheels approximately 60 m beyond the stanchion footing.



Picture 3: *Impact damage to the first carriage.*

The second carriage also impacted the rock cutting and was also righted onto its wheels. The third and fourth carriages remained on their side with the roof of the fourth carriage impacting and collapsing stanchion SW40+773.

3.3 Injuries

The following table lists the injuries from C311.

Table 2: Injuries			
	Fatal	Injured	Total
Crew	1	1	2
Passengers	6	41	47
Total	7	42	49

3.4 Train details

C311 consisted of four Outer Suburban Tangara double-deck electric carriages operating in a permanently coupled set identified as G7². The cars were individually identified in the direction of travel as: 6831 (control car), 5816 (motor car), 5866 (motor car with toilet) and 6832 (control car).

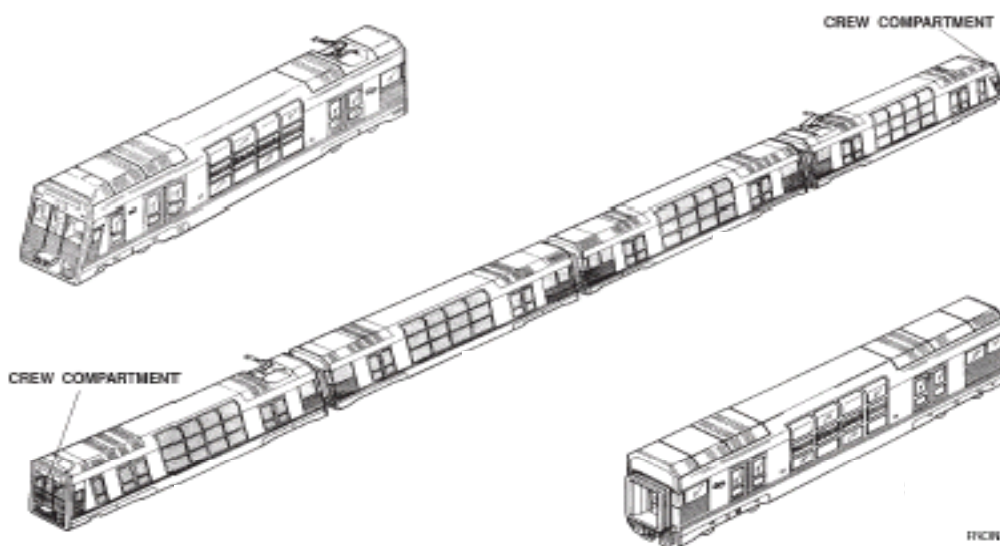


Figure 1: Outer Suburban Tangara G-set configuration.

G7 weighed approximately 185 tonnes and had seating capacity for 406 passengers. It would have been at approximately that weight because of the light passenger load. The train had a total length of 81 m and was built by A. Goninan & Co Ltd in Newcastle NSW. G7 was accepted into revenue service on 27 October 1995 and was the last G-set supplied to SRA. It differed from other Tangaras in that it was fitted with an AC traction power system, which allowed SRA to compare AC traction performance with that of the DC traction-powered Tangaras.

3.5 Environmental conditions

First light at Waterfall on 31 January 2003 was at 0548, with official sunrise about an hour before the accident, at 0615. The position of the sun at Waterfall at the time of the accident was azimuth 104°14'29" (True), or about 092 degrees magnetic (East) and an altitude of 10°34'07" above the horizon.

The weather was fine with a temperature of around 21°C. The wind was southerly at about 30 km/h with gusts up to 40 km/h and some light, high cloud (1-2 OKTAS) above 10,000 feet.

There was no indication that weather or environmental factors contributed to the accident.

² There were two variants of Tangara trains: T-sets configured for suburban operations and G-sets configured for outer suburban operations.

3.6 Site information

The accident occurred on the Illawarra line approximately 40.7 km south of Sydney. The accident site was in a two-track area approximately 1,930 m south of Waterfall station.

The site was on one of a number of curves where the track wound down off the southern escarpment towards Wollongong. On the southern side of the curve was an embankment and cutting face. The accident site was preceded by a straight portion of track, which was approximately 700m long and passed 430m through a deep cutting. The designated track speed on this portion was 75 km/h.

The line was double track with a designation class of 1XC, the highest class of track used in NSW.

The accident was on a 1:80 downhill grade and the left bend had a 239 m radius. The posted track speed limit on the curve at the accident site was 60 km/h and this decreased a short distance later to 50 km/h in preparation for a sharper right curve with a radius of 203 m.

3.7 Infrastructure

The investigation examined the railway infrastructure in detail and found it did not contribute to the cause of the accident.

The investigation of infrastructure identified that the placement of speed boards and the associated construction of SRA timetables required further investigation. These issues are discussed in Section 11 of this report.



Picture 4: *Driver's view approaching the accident curve.*

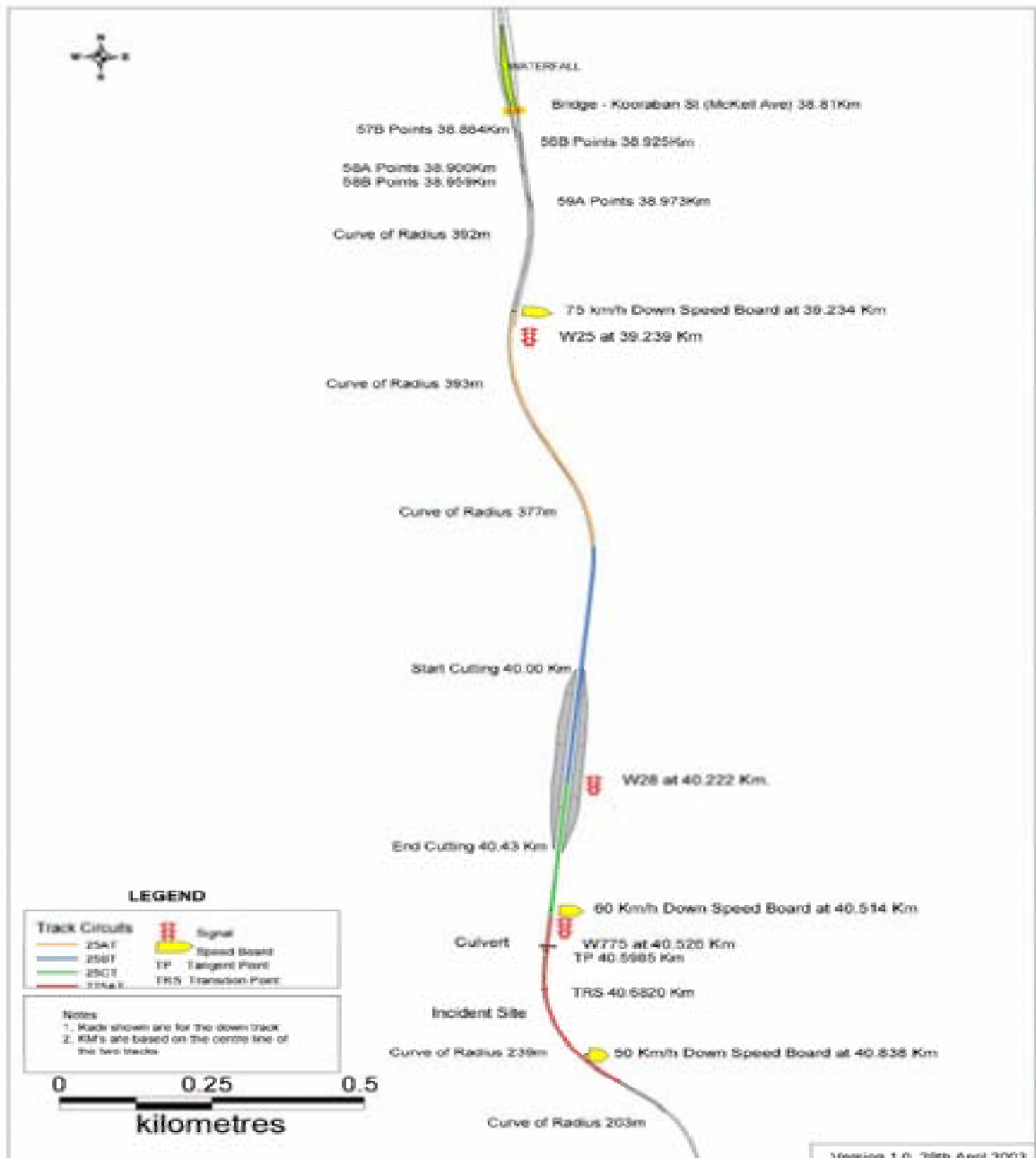


Figure 2: Configuration of track and infrastructure between Waterfall and the accident site.

3.8 Rolling stock

A rolling stock investigation was undertaken by SRA and supervised by a group that included Special Commission of Inquiry independent experts, NSW Police and the Rail Safety Regulator.

An extensive program of testing and examination of train equipment and systems concluded that there was no evidence that electrical or mechanical failure, or the AC traction equipment, had contributed to the accident.

Deadman system deficiencies are reported in Section 7 of this report.

3.8.1 History of brake failures and ‘surging’

The investigation obtained information through interviews and Special Commission evidence that some drivers had reported a history of brake failures and ‘surging’ in Tangara trains. An independent consultant was retained to examine the drivers’ reports. The consultant concluded that drivers’ perception of surging and brake failure was generally due to a characteristic of the brake system that resulted in a transient reduction in the deceleration rate due to regenerative brake ‘drop out’, or as a result of the wheel slide protection system.

3.8.2 Master controller (power controller)

The master controller of the leading carriage was damaged during the crash. Forensic metallurgical examination of markings determined that the master controller handle was most likely in between power notches three and four (i.e. in transit) when the damage occurred.

It could not be determined when in the accident sequence the marks were created. However, as the speed analysis demonstrated that the train had been accelerating at full power prior to the accident, it was probable that the master controller moved away from notch four (the rearmost position of the handle) due to the high rate of deceleration during the accident sequence.

3.8.3 Brake controller

The brake controller of the leading carriage was also damaged during the crash. Forensic examination identified that the brake controller had been significantly displaced rearwards from its normal location and position, with the brake handle in the rearmost position (the “Release” position) after the incident.

3.8.4 Data loggers

Two data loggers were installed in G7: one in each control trailer car (6831 and 6832). The data loggers were not switched on at the time of the accident. However, the supplier downloaded the devices to identify any data that may have been inadvertently recorded. This did not provide any fault conditions or information concerning the accident.

The data loggers were not switched on because the commissioning process had not been completed.

SRA had proposed to use data logger information primarily for incident investigation and maintenance purposes. SRA did not have a program to use data logger information for monitoring driver performance and quality control.



Picture 5: *Relatively undamaged data logger in the wreckage of car 6831.*

3.9 Recorded information

3.9.1 Signal log speed analysis

Records were obtained from the Wollongong signal box data logs. The time for travel on each track circuit was extracted from the recorded data and applied to the length of the appropriate piece of track. The investigation was able to calculate that C311 had travelled at speeds considerably in excess of the authorised speeds over a large part of the journey from Waterfall to the point of derailment.

The speed analysis indicated C311 entered the 239 m radius left curve travelling at between 114 km/h and 120 km/h. A calculation extending the Newtonian mechanics principles indicated that the train may not have overturned on that curve travelling at up to 110 km/h (although it may have derailed on the next curve). NUCARS analysis and Vampire³ analysis supported this finding independently of the signal log data.

The data indicated that other trains had travelled in excess of the authorised speed limits over the same section of track. The 25ABC⁴ track was 1280m in length. It included 40 and 75 km/h speed limits and a requirement to slow for the nearby 60 km/h speed limit. The maximum average speed that a four car train could attain over that portion of track without exceeding the speed limit was 69 km/h.

Between 24 and 31 January 2003, of 209 trains that had traversed the 25ABC track, 77 (37%) had travelled in excess of the 69 km/h average speed, with the highest exceedance being 89 km/h average speed. This analysis was extended to the entire month of January 2003 with about the same proportion of speed exceedance indicated.

Of the 77 trains that had excessive average speeds, 26 had average speeds greater than 75 km/h, which indicates a peak speed considerably in excess of the 75 km/h maximum track speed in that area.

3.9.2 Closed circuit television (CCTV)

Footage from the CCTV cameras on each of the stations along the route of C311 on the day of the accident and the previous day was reviewed in detail.

On much of the footage, there was no conclusive information about the train driver. This was because of the glare from the sun and the positioning of the cameras, which were angled to capture events on the platforms and not to observe events on the train. However, the footage did confirm that the guard watched his train into and out of most stations, including Waterfall.

Other information obtained from the CCTV footage was that the guard and driver walked together to train C311 at platform 14 from the crew room of Central Station at 0617. The driver was visible entering the cab of C311 at 0618.38 and the train departed Central Platform 14 at 0624.53.

³ NUCARS and Vampire are computer software packages for examining the behaviour of rolling stock under various track configurations.

⁴ The track circuits from signal W25 to signal 775

3.10 Tests and research

3.10.1 G-set acceleration tests

On 11 March 2003, tests were conducted to determine longitudinal acceleration rates when travelling on track with grades similar to those of the track near the Waterfall accident. A four-car train, G4, was used for the tests, which took place between Mt Druitt and St Marys. A number of acceleration scenarios were tested and the results of the tests were used to determine the likely speed profile of C311 after it departed Waterfall Station.

The speed analysis and simulation work, using these results, concluded that C311 must have been in notch four from about the crossovers, at 58 points, to at least the 775 signal.

3.10.2 Guard's emergency cock – car 6832

A station assistant at Central Station gave evidence that the crew of C311 had conducted a continuity test before departure. This evidence was consistent with normal train operations and indicated the guard's emergency cock was intact and operational when the train started its journey. No evidence was obtained to suggest that damage was sustained to the cock between the time C311 departed Sydney and the time that it departed Waterfall. The emergency cock should therefore have been operational and available for the guard to stop the train.

The guard's emergency cock handle separated from its valve during the accident. The separation was consistent with the damage sustained around the valve in the crew cabin of car 6832 during the accident, due to the roof impacting the stanchion.

The guard gave evidence at the Special Commission of Inquiry that he had not activated the emergency cock. Subsequent detailed forensic examination of the emergency brake cock determined it was still in the closed position and had not moved during the accident sequence.

3.10.3 Finite Element Analysis

Extensive analysis of the derailment and crash sequence was undertaken using the finite element analysis (FEA) technique, which involved numerical simulation of complex geometric and material models.

A 3D-computer model using laser mapping was created, encompassing the train carriages, tracks, surrounding landscape, stanchions, overhead wiring and the rock cutting surfaces. The model was verified by comparison of the simulation results with photographs showing the final resting location of the train and structural damage to the carriages.

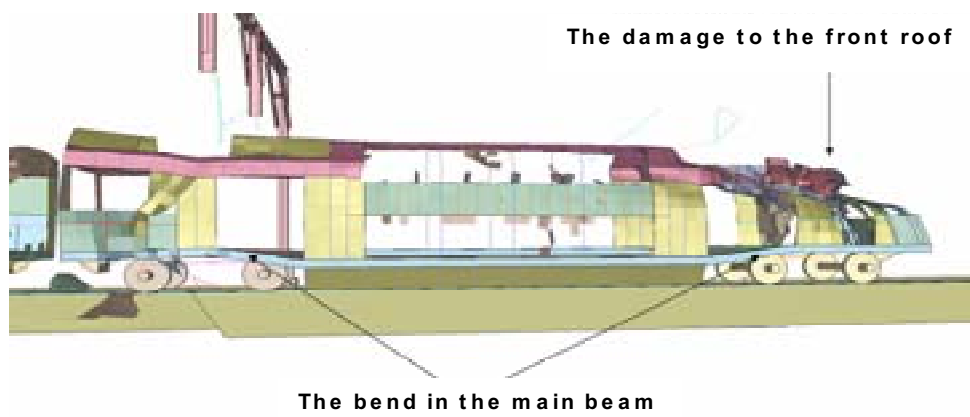
This work examined aspects such as the impact mode at the stanchions, how the rock face righted the carriages and the mode of damage incurred by the train components. It provided information on the overturning speed, timing and crash sequence, and crash dynamics.



Figure 3: *View of FEA analysis showing concrete footing separating from Stanchion SW40+805 during the accident sequence.*



Picture 6 and Figure 4: *Demonstrate the correlation between the FEA analysis and the actual damage sustained.*



3.11 Joiner rights

A practice known as 'joiner rights' existed at SRA. This permitted train crews to commence duty at a location other than their rostered sign-on location. Management had issued written instructions on how to apply the practice. The driver of C311 used joiner rights to begin his shift on 31 January 2003 and did not report to the station manager at Wollongong.

One of the purposes of the train crew sign-on process was to apply a number of safety-related management controls to crews who were about to commence safety-critical work. Those controls were not applied at a remote sign-on location to crews commencing duty under joiner rights.

The investigation noted that when using joiner rights:

- crews were not observed and assessed by a designated sign-on officer as being fit for safety-critical duties before commencing work
- the system did not ensure crews could receive or acknowledge safety documentation or advice of conditions affecting the network during the shift they were about to commence
- an accurate record of crew work hours was not available to facilitate an accurate assessment of individual fatigue levels, as measured through their FAID⁵ score.

The C311 driver was not observed and assessed by a supervisor or manager for medical and operational fitness on the morning of 31 January 2003, as he joined his roster at Port Kembla. In addition, because he commenced duty at a station away from his home depot, he was not provided with operational or safety documents relevant to his duties for the day.

3.12 Secondary employment

SRA maintained a secondary employment policy that required drivers to seek approval for secondary employment, including self-employment and voluntary work. The driver of C311 operated a hobby business that produced videos of weddings. Information from the driver's wife indicated that he may have produced two or three of these videos per month, which included up to 12 hours of work on the day of a wedding plus editing time. Local management provided information that they were aware of this activity, although no record of application or approval of this secondary employment was discovered during examination of SRA documents.

⁵ FAID: Fatigue Audit InterDyne™, an occupational fatigue assessment tool. See Appendix B.

4.0 CREW DETAILS – DRIVER

4.1 General

The driver was a 53-year-old male who began work in the rail industry in 1965. He was a qualified train driver based at the Wollongong depot. He had been a driver for nearly 27 years, after first qualifying as a freight train driver in May 1976 and moving onto passenger trains in 1987.

The driver's wife indicated during interviews that his immediate family was a major focus in his life and he concentrated a lot of his attention on planning activities and holidays for them. She said that he loved his job, but generally did not socialise with work colleagues. She described her husband as a happy, active person who carried out physical activities around the houses of his family members.

4.2 Driver's preceding activities

The driver returned to work early in the morning of 30 January 2003, after a five-week break for a period of leave. He spent the early part of this leave on the south coast water-skiing with his family.

During the week before the accident the driver did not participate in any strenuous activities. Over the Australia Day long weekend, he socialised with family members and worked on wedding videos. On Tuesday 28 January, he did further work on a wedding video and non-strenuous household errands.

Wednesday 29 January was the day before the driver was due to resume work. He spent the day visiting family, shopping and continued work on a wedding video. He had an early dinner at home with his wife before retiring to bed between 1800 and 1830.

On Thursday 30 January, the driver's roster required him to sign on at 0112 at Wollongong then start work at 0147 at Port Kembla. His wife remembered the alarm ringing between 0015 and 0030, and having to nudge her husband to wake. She recalled that the phone rang some time later and her husband answered it. He reported for duty two and a quarter hours late, although his time sheet indicated that he signed on at the rostered time of 0112.

After completing work on 30 January at 0845, the driver went home. During the day he went shopping, watched television and ate dinner with his wife about 1750 before retiring to bed by 1830. He did not mention any illness or health problems to his wife.

Friday 31 January: as his roster was the same as for 30 January, his planned wake-up time would have been the same as the previous night. The driver's wife said that when she went to bed at around 2300, he was asleep and she did not hear him leave for work.

4.3 Driver's medical history

The driver last underwent an SRA periodic medical examination (PME) on 2 May 2001. This examination was conducted by an SRA-appointed general

practitioner (ME). During that examination, the ME found the driver to be fit for duty according to the SRA 'Medical Practices and Procedures' document published in December 1995. The examination focused on the driver's medical condition at that time and did not incorporate predictive elements to detect sub-clinical conditions. Of note was that the driver's weight was 116 kg, which gave him a body mass index (BMI) of 34.3 (although there was no requirement for this calculation to be determined as part of the examination). The driver reported on 2 May 2001 that he had no adverse health effects and that he considered himself fit for his position. He did not disclose his long-standing history of hyperlipidaemia⁶.

In 1984, the driver's family general practitioner (GP) referred him to a cardiologist due to his suffering from viral pericarditis, a condition concerned with the outer lining of the heart. This condition gradually resolved. The driver presented again in August 1986 with similar symptoms to the 1984 infection. The driver declined to have the symptoms further investigated, but accepted a prescription for the 'Indocid' medication that had proven effective previously. In evidence provided since the accident, the GP noted that the driver did not present with the same symptoms again.

The GP reported that on 11 March 2002 the driver's cholesterol level was measured at 6.76 mmol/l⁷, which was elevated compared with the recommended upper limit of 5.5 mmol/l. The last documented check of the driver's cholesterol level was in September 2002 and it was recorded as being 7.9. His history of elevated cholesterol levels dated back to 1994. They were recorded as having peaked in July 1999 at 8.6. The family GP had prescribed various dosages of Lipitor, a cholesterol-lowering medication, and this had helped lower the cholesterol to more acceptable levels. However, the driver had not maintained the medication program and restarted on several occasions, when re-prescribed by the GP.

The driver was last seen by his GP on 24 August 2002 for a sore neck. The GP's records did not indicate any systemic health problems apart from the elevated cholesterol.

4.4 Driver's injuries

The driver sustained fatal injuries in the accident.

A report from the NSW forensic pathologist indicated that the driver sustained multiple traumatic injuries during the accident. Post-mortem examination of the heart showed extensive (up to 90 per cent) atherosclerotic occlusion of the left anterior descending coronary artery and minor atherosclerotic changes in other coronary arteries. The pericardial sac had been obliterated by fibrosis. In addition, a large xanthoma (cholesterol deposit) was evident above the right eyelid.

The cause of death was given by the forensic pathologist as brain stem disruption in association with coronary artery disease.

The presence in the driver of severe focal atherosclerosis of the left anterior descending coronary artery made him a high risk of a major clinical cardiac

⁶ The presence of excess fat or lipids in the blood.

⁷ Millimoles per litre.

event, assessed at a probability of 85 percent over the next five years. The forensic pathologist who performed the autopsy on the driver agreed with the following proposition when it was put to him at the Special Commission of Inquiry into the Waterfall Rail Accident:

“The state of his heart was such that if he had been brought in without the trauma – in other words, had he collapsed in the street and been brought in without the multiple trauma brought about by the accident itself – the state of his heart would have led you to conclude that that was the likely cause of death.”

There were no pulmonary emboli noted at the driver’s autopsy and despite extensive investigation, his blood was not detected in the driving cab or at any point between the first impact and where his body was discovered. On-site examination provided evidence of minimal bleeding around the site of the driver’s body. The condition of the driver’s blood and its lack of distribution indicated that there might have been no circulation at the time of impact.

The physical evidence gathered from the train wreckage and the crash site gave investigators no further insight into the way in which the driver’s injuries were sustained.

4.5 Driver’s work history

The driver’s personnel records indicated that he had been the subject of 24 reported disciplinary events during his career. Most of these incidents were related to absences from duty or late reporting for duty. The majority occurred between 1965 and 1969. Eight incidents were recorded over the ensuing 33 years.

He had been involved in eight reported safety incidents during his career over which disciplinary action was taken. Three of these were classified by SRA as major offences and involved passing signals at danger.

The inspector who conducted the driver’s last performance assessment on 4 December 2002 recorded that he had competently demonstrated the knowledge and skills required of a train driver.

The records indicated that the driver had taken a significantly increased amount of sick leave during the four calendar years preceding the accident (from a career average of 1.56 days per annum to an average during the preceding four years of 12 days per annum). As such, he was identified as a candidate for an SRA ‘absence control program’ in October 2002. The program required the driver to provide a doctor’s certificate for any further sick leave that was taken. The driver’s medical records did not indicate any chronic complaints or illnesses experienced over that period of time, with the exception of the elevated cholesterol.

Despite this record, the driver’s peers regarded him as a professional and conservative passenger train driver.

4.6 Driver’s roster details

After returning to work from his holiday break, the driver was rostered to work Wollongong diagram 954 on both 30 and 31 January 2003. This was part of

his normal roster, which required him to sign on at 0112 at Wollongong and then travel to Port Kembla by SRA-supplied taxi to prepare and take a train to Sydney on run C302, which was scheduled to depart Port Kembla at 0333. After a one-hour break in Sydney, his next task was to take run C311 to Port Kembla and then sign off on return to Wollongong at 0854.

The driver's wife indicated that the driver was fully aware that he was due to begin duty from 0112 on the morning of 30 January 2003, after completing his annual leave.

	No. 954	
	Sign on 0112 WOLLONGONG (With 953 Driver)	
	Wollongong	Port Kembla
	0127.....Taxi	0142
	Prepare 4 DO cars and work:	
	Sydney	Port Kembla
	0525	C302.....0333
	Secure Train.	
	CRIS	
	Relieve C304 due 0605 No. 956 (MO) 957 (MS)	
	Driver	
	Sydney	Port Kembla
	0624.....C311	0817
	Wollongong	
	0839	C322.....0827
	Relieved by No. 948 Driver	
	Dust Allowance: 2'31"	
	Time off duty : 0854	
	Total Shift : 7'42"	
	187.798Zn	DCI 18/11/03

Figure 5: Copy of the driver's work schedule, diagram 954, for the day of the accident.

4.7 Driver's fatigue level

Having completed an extended period of leave two days before the accident, it was likely that the driver became fully adapted to a sleep cycle appropriate to being on holidays. He then returned to work on early morning shifts, with start times displaced by about nine hours from his holiday routine.

This roster pattern would have significantly disrupted the circadian rhythms established during his extended period of leave. (See Appendix B for a pictorial presentation.) In the 48 hours before the accident the driver made an effective 'time zone' shift similar to that experienced when flying from Sydney to London. He then had to wake abruptly and work as if he was fully adapted to a new time zone. Such considerable circadian disruption is known to have significant detrimental effects on important aspects of individual performance such as vigilance, concentration and reaction time.

The driver was reported to have experienced difficulty in waking for his shift on 30 January, after which he reported late for work.

The SRA published a 'Stable Rostering Code' booklet in October 1987 which contained guidelines on rostering practices for intercity drivers. Section 10.5.2 of this document contained information about the practices to be applied when a driver returned to work after a period of leave. It stated that if a driver applied for leave and did not submit specific requests about the

timings to be applied upon returning to work, the assumption was to be made by rostering clerks that the person would be available to be rostered from 0001 on the day after the leave period finished. The driver was to confirm availability by midnight of the day prior to the date of resumption.

According to the FAID system, the driver's roster pattern for his brief return to work before the accident indicated that his fatigue levels should have been in an acceptable range for the performance of his duties. Calculations indicated that he had a FAID score of 14.7 at the end of his shift on 30 January and a projected score of 37.9 for the end of his shift on 31 January, both below the average level of 40. However, it is believed that this score fails to consider the considerable potential acute fatigue effects of the circadian disruption experienced by this driver as detailed above, since FAID only considers the effects of the driver's work activities.

See Appendix B for further information on fatigue.

4.8 Summary of driver information

The driver presented as a well-balanced individual with a stable job and family life. There was no evidence that any domestic or employment issues were troubling him in the days before the accident and it was likely that he returned to work from holiday on 30 January 2003 in a relaxed and content frame of mind. His history of employment indicated that he was a generally reliable employee and a proficient and conservative train driver. There was no evidence to suggest that he had any intention to harm himself or any other persons on the day of the accident.

The driver's roster on his return from leave (commencing with two early morning shifts) would have significantly disrupted the circadian rhythms established during his extended leave period. It was likely that he would have experienced considerable difficulty in readapting to his early morning shift roster after his holiday. He was reported to have experienced difficulty in waking for his first shift back on 30 January, after which he reported late for work and would almost certainly have experienced some symptoms of acute fatigue during that morning and the following morning of 31 January. In such circumstances, the onset of hypovigilance (diminished vigilance) and microsleep⁸ episodes were a distinct possibility.

The medical and post mortem examination of the driver, and his history, identified that he had severe atherosclerotic occlusion of the left anterior descending coronary artery, which posed a high risk of a major cardiac event. In light of the occlusion, together with the possible absence of circulation, the probability that the driver was medically incapacitated at the time of impact was high. The injuries he sustained would have been fatal without the cardiac pathology aspects and were consistent with him being ejected from the train.

⁸ Microsleeps are brief, unintended episodes of loss of attention characterised by events such as blank stare, head snapping, prolonged eye closure, etc. Microsleeps typically occur when an individual is fatigued but is trying to stay awake to perform a constant monotonous task, such as operating a vehicle or monitoring a screen-based display. Microsleeps intrude upon wakeful activity and typically last between two and 30 seconds, but can stretch to several minutes. While experiencing a microsleep, individuals are unable to respond to subtle external stimuli.

5.0 CREW DETAILS – GUARD

5.1 General

The guard was a 39-year-old male who began work in the rail industry in 1982 and had completed 21 years of continuous service with SRA. After his initial employment as a station assistant, he commenced duty as a train Guard Class 1 in July 1988. At the date of the accident he was working as a train guard based at the Wollongong Depot.

The guard's personnel records supplied by SRA contained minimal detail of his employment history.

5.2 Guard's preceding activities

Although the guard gave evidence at the Special Commission, he was unavailable for interview by this investigation due to his post-accident medical condition. No information was obtained about his activities outside rostered work hours.

5.3 Guard's roster details

The day of the accident was the second successive day that the guard and driver had worked C311 together. The guard was working his fifth shift in a block of nine early morning shifts with start times ranging from 0323 to 0547. This followed an earlier eight-day roster with three days off in between. Of the next four days of rostered duties after 31 January, the first three had the guard start before 0600 and the last day had a rostered start time of 0825.

5.4 Guard's medical history

The guard's last SRA periodic medical examination (PME) was on 15 March 2002. No restrictions were noted, although only his vision, colour sense and hearing were tested. He did not undergo a full medical examination as required by Section 1.5 of the SRA 'Medical Practices and Procedures'. Investigations could not identify the source of this interpretive anomaly, however SRA had introduced full medical examinations for guards in mid January 2003. His next PME was due on 15 March 2007.

The guard's medical history detailed slightly elevated serum cholesterol in association with obesity (BMI greater than 30) in December 2000 and a history of psychological health issues, some of which were related to his employment as a train guard. His private records, obtained by the Special Commission, indicated that he received extensive psychological care from November 1995 to November 1996. The records indicated that coincidentally, the guard used the same medical practice for his private health care and for his periodic medical examinations. There appeared to be no obligation on his treating doctor to disclose to SRA the fact that he had suffered psychological issues for a period of at least one year, and there was no evidence that SRA had been apprised of this.

5.5 Guard's injuries

The guard sustained a wedge fracture of the eleventh thoracic vertebra and minor soft tissue injuries during the accident. His right shoulder was also dislocated. As a result of the accident, the guard experienced severe post-traumatic stress disorder with other associated complications that required extensive treatment.

5.6 Guard's work history

There was no disciplinary history recorded by SRA for the guard. He had been commended in 1997 for his dealing with an intoxicated passenger.

He was put on an absence control program in October 2002 as a result of having taken more than six days sick leave without a medical certificate during the preceding year. As with the driver, the guard was required to provide a doctor's certificate for any further sick leave. The guard's medical records did not indicate any chronic complaints or illnesses experienced over that period of time.

5.7 Guard's work incidents

There were no indications in the guard's employment records that he had been involved in any reported safety incidents during his career. There was reference to a trespasser fatality involving the guard's train on 28 August 1991. There were no further details available.

The Special Commission of Inquiry hearings revealed the guard had been involved in an incident at Bellambi in July 1994 where his train had allegedly overshot the platform, which allegedly resulted in injuries to passengers who had detrained onto the tracks. The Special Commission indicated this incident was the catalyst for some of his psychological health issues.

5.8 Guard's fatigue level

The guard's work roster indicated that the accident occurred on his fifth consecutive duty day and on his third consecutive early morning shift. The FAID score at the end of his shift on 31 January 2003 would have been 90.8, which was below the score of 100 that SRA had chosen to use as a trigger for action to reduce the fatigue level of an employee. According to the FAID model, a normal person with a score of 90.8 would be likely to experience a level of fatigue in excess of 200 per cent of the level of fatigue associated with the average working week. There was a high probability that such a level of fatigue would have considerably impaired the performance of the guard.

Applying the FAID model to the guard's next four work shifts after the accident, his FAID score would have risen to 99 on day three and then dropped to 68 for the last day. A FAID score of 99 equals a level of fatigue approximating 250 per cent of that associated with the average working week.

The roster that the guard was working was constructed according to the fatigue management principles established by SRA in order to avoid the accumulation of high levels of fatigue.

See Appendix B for further information on fatigue.

5.9 Summary of guard information

Development of the guard's profile was difficult due to the lack of detail in the supplied documents. It was likely that he was subjected to high levels of cumulative fatigue at the time of this accident and it was noted that he had experienced some psychological difficulties. The same medical practice appeared to have provided care to the guard for many years. The doctors at this practice had undertaken his periodic medical examinations for the SRA. In spite of this, there was no evidence that SRA had been appraised of his diagnosis by the medical practitioner of psychological issues, although local managers were aware of his problems.

It is noted that submissions received from solicitors for the guard expressed the view that there was a high probability that the guard's level of fatigue had induced a micro-sleep. Although the guard disclaimed the possibility of sleep in his own evidence to the Special Commission, this may not be conclusive. The solicitors also submitted that there was no evidence that the guard's psychological history had contributed to the accident.

6.0 TRAIN OPERATIONS

6.1 Train control

The accident site was located in a bi-directional, double-line, Rail Vehicle Detection area, meaning the signalling system was automatically controlled by trains passing over track circuits. Being an automatic signalling area, there were no points in the vicinity. The nearest controlled signalling areas were Waterfall to the north and Helensburgh (controlled remotely from Wollongong) to the south. Illawarra Train Control provided overall train control services and was co-located with Sydney Operations Control at the Rail Management Centre (RMC) at Central station.

6.2 Signalling

Examination of the signalling logs indicated that at the time of the accident, the automatic signals for C311 south of Waterfall were indicating 'full clear' and bi-directional operations were not in progress.

The logs demonstrated that the accident caused the track circuit of the adjacent Up line to indicate 'occupied'. This had the effect of returning the Up direction signals to STOP. As a result of these signals showing STOP, the C412 train approaching from the opposite direction was stopped south of the accident site.

A short time after C311 departed Waterfall, the signaller at Waterfall observed on his track diagram that the Up line track was displaying an 'occupied' indication. As he knew that C412 had not yet arrived at that location and there were no other Up direction trains in the section, he initially responded to the indication on the basis that a track failure had occurred.

It was while the signaller's assistant was reporting the perceived track failure to the train controller that the signaller received notification of the accident through a series of broken mobile telephone calls from the guard of C311.

6.3 Metronet train radio

The Metronet train radio was available to train drivers but not guards, and was used for communications between the drivers and controllers and/or signallers. The system recorded both activity (log-ons, calls placed and unanswered calls) and actual voice communications. The driver of C311 had logged-on to the Metronet system prior to departing Sydney, however, no calls were placed to or from C311 between the log-on and the accident. A number of unanswered calls were recorded as being placed to C311 by the Wollongong signaller after the accident.

A design difficulty existed in the Metronet train radio system in that trains within the automatic signalling area south of Waterfall were within the radio jurisdiction of Wollongong signal box and not contactable by Waterfall. As a consequence, when the signaller at Waterfall became concerned about C311, he was required to telephone Wollongong signal box and ask for a radio call to be placed to C311 and the result reported back to him.

6.4 C311 driver's technique

The CCTV recording from Waterfall Station indicated that C311 left the station at an acceleration rate consistent with the driver using notch two or three on the master controller. This acceleration rate was consistent with normal train handling technique for departing Waterfall Station, where the speed was limited to 40 km/h.

Speed analysis used the recorded signal system data to derive time intervals, in conjunction with Tangara acceleration rate data. It revealed that after clearing Waterfall Station, C311 accelerated at maximum power (notch four) and remained at maximum power until at least the 775 signal (south of the southern end of the cutting along the straight).

6.5 Normal train driving technique

6.5.1 Sutherland to Waterfall

This part of the journey had five station stops over a distance of approximately 14 km. The schedule specified 14 minutes to cover it. The track speeds in the area were high, with a maximum of 115 km/h.

It would have been normal for a driver to apply full power (notch four) to start the train from each station. Due to the predominantly uphill grade, full power would have been applied for a major part of the distance between most stations until braking began for the next station stop. However, the uphill grade crested approximately 1,400 m before Waterfall, resulting in a long period of coasting to that station.

6.5.2 Waterfall to Helensburgh

The journey from Waterfall to Helensburgh was predominantly downhill with a much lower average speed than the previous section. After accelerating to track speed, the entire journey in this section would normally have been undertaken with alternating braking and coasting as the driver regulated the speed against the effect of gravity.

A typical driver technique for departing Waterfall Station would be the application of medium power to get the train moving through to the end of the 40 km/h area, a distance of approximately 440 m past the end of the Waterfall platform. The driver could then either apply full power for a short time to accelerate to the track speed of 75 km/h or allow the downhill gradient to gradually accelerate the train.

At the completion of the acceleration, the driver would normally shut off the master controller and allow the train to coast until the brake was applied at about the southern end of the deep cutting, to slow for the sign-posted 60 km/h left-hand bend at 40.7-kmh.

6.6 Speed compliance

Signal log data revealed that other trains had exceeded the 75 km/h speed limit approaching the accident site, however, these trains had braked and slowed to a speed suitable for the curve.

Some drivers gave evidence that, in general, they drove according to the weather and track conditions prevailing at the time, which may have resulted in them exceeding posted speed limits.

In the past, drivers had operated electric trains without speedometers and had developed the ability to drive at a safe speed based on the condition of the track and their estimation of speed. A number of other factors influenced drivers when deciding how fast to travel. These included unrealistic sectional running times, lack of supervision, errors in posted speed boards or doubts as to the appropriateness of posted speed boards. *See Section 11: Speed Boards and Timetabling.*



Picture 7: *A typical 60 km/h speed board.*

6.7 Crew cooperation

The crew operated at opposite ends of the train and their normal, routine communication was limited to the bell signals used in station work and to an intercom for voice communication. There were additional bell signals for use in non-normal situations, such as passing signals set at STOP or to tell the driver to stop immediately. A crew could complete an uneventful journey without face-to-face contact or voice communication and without even knowing who the other crew member was. It was not uncommon for drivers and guards to change trains mid-journey for rostering purposes and there was no requirement for contact before or after such a change.

Guards had been assigned the broad responsibility for the safety of the train. However, there were no defined requirements or training in relation to guards monitoring drivers' health and alertness, or the speed of travel.

Evidence given in train crew statements and informal discussions indicated that there was an element of cultural animosity between some drivers and guards, which could have discouraged guards from intervening in the operation of the train by doing something such as applying emergency brakes.

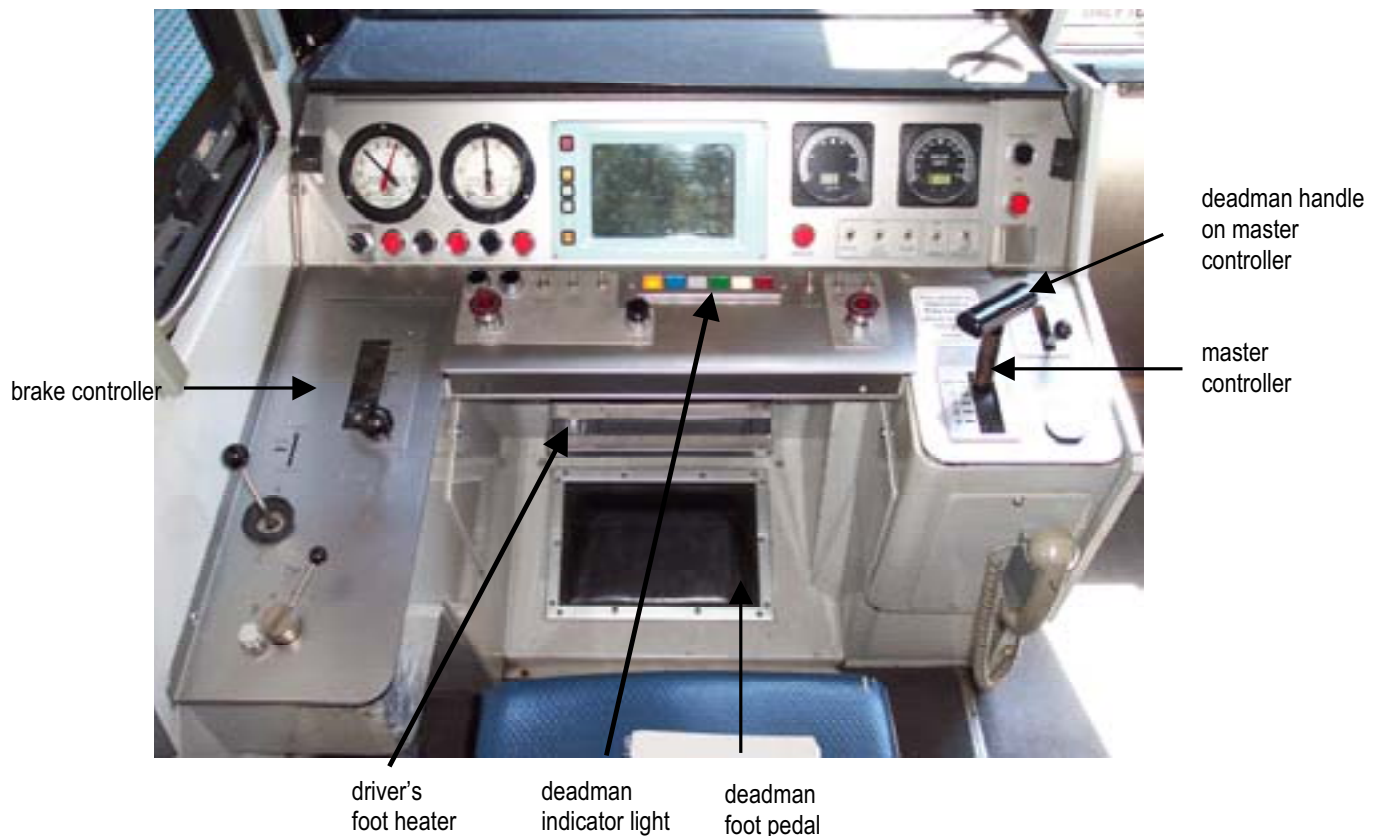
7.0 DEADMAN SYSTEM (DMS)

7.1 Background

The purpose of the Tangara deadman system was to apply the emergency braking on the train in the event of the driver becoming incapacitated or leaving the controls in an emergency. Two of the primary components of this system were the deadman foot pedal and the master controller T-bar handle which interfaced directly with the driver as shown in the photograph below. The driver could use either or both and the system relied on a mechanical input from either source to determine whether the driver was in control.

The deadman foot pedal relied on the driver placing either or both feet on the pedal to hold it in the central engaged position. Too much or too little pressure would trigger emergency braking and cut off power. The master controller T bar handle required the driver to twist the handle and keep it in the twisted position. If the driver released the T-bar and did not have a foot on the pedal in the correct position, emergency braking would be applied immediately and traction power would be cut off.

The deadman system components of G7 were tested satisfactorily for correct functioning after the accident.



Picture 8: Tangara G-Set driver's console (not from G7).

7.2 History

Documents supplied by SRA were examined to determine the history of the Tangara's deadman system (DMS) since the train's introduction to service in 1988.

Tangara trains were manufactured to SRA specification and Goninan design, and were fitted with a DMS that could be engaged by master controller twist-grip or by deadman foot pedal. A clear intent of this system was to act as a defence against partial or total incapacitation of train drivers. The most basic function of the system was to bring a train to a stand, in the shortest possible time, by applying brakes and cutting off power in the event of driver incapacitation. The integrity of a number of related risk management processes, such as the SRA 'Medical Practices and Procedures', was predicated on the assumption that the DMS would act in this manner and that it was infallible.

Documentation examined as part of the investigation indicated that the DMS was not designed to defend against lapses in driver attention or vigilance.

In November 1988 an instructor at SRA's Procedural Training Unit submitted an internal memorandum to SRA's Tangara Project Manager, noting that:

"I find that if I place my feet at the front of the plate, the weight of my legs will hold the deadman during motoring."



Picture 9: *View of deadman system being operated, without effort, by the weight of a seated driver's leg. Note: this train was under way at the time of the photo. Also note proximity of the heater to the top of the driver's foot.*

The instructor further noted that:

“This can also be achieved by jamming your feet under the heater.”

In the two years following this notification, correspondence within SRA and between SRA and the manufacturer attempted to address the problem. This correspondence included a December 1990 letter from Goninan & Co indicating that it could not replicate the circumvention of the DMS described by the instructor. Following further correspondence from SRA, a March 1991 letter from Goninan & Co indicated that:

“Theoretically, it is possible for a person to hold the pedal in the set position by the weight of their legs alone.”

“It can be shown that for such an event to occur, the driver would have to weigh greater than 115 kg.”

In the 12 years before the accident in January 2003, details of safety deficiencies in the Tangara DMS were documented in a considerable number of letters and papers. Included in this documentation were risk assessments, studies and analysis for the addition of a vigilance control system to the Tangara fleet and proposed ergonomic upgrades. There were comments about Occupational Health and Safety (OHS) issues as well as observations from drivers about difficulties in using the deadman system, specifically in relation to injuries similar to Repetitive Strain Injury (RSI). However, the investigation found no evidence that the safety functioning of the DMS had been improved, apart from an OHS-driven change to the direction that the Master Controller T-bar handle twisted.

At the time of his death, the driver of C311 weighed about 118 kg and he may have been incapacitated with the master controller set at the full power position before the train derailed.

Further documents examined related to the SRA’s reaction to an incident report dated 5 February 2003, in which a driver claimed it was possible to override the deadman system by wedging his foot under a heater above the pedal. All the documents examined about this recent event appeared to be predicated on SRA having no previous knowledge of the possibility that a shoe wedged under the heater could nullify the designed safety features of the deadman system.

There was no evidence that those in SRA who knew about the well-documented expert opinion on the deficiencies of the deadman system had adequately assessed the identified risk.

If a coordinated hazard and risk register had existed, it should have revealed the identified risk to the organisation and applied an assessment process that would have been recorded.

<p>It is noted that solicitors for the manufacturer submitted that it is not possible to design a “deadman” foot pedal without limitations and that the specification supplied by SRA did not require this to be attempted.</p>

7.3 Deadman system maintenance

The deadman system was a critical safety component of Tangara trains and was subject to daily tests by drivers during their preparation before taking the train out at the start of the day's operations. These tests were confined to verifying the basic operation.

SRA Passenger Fleet Maintenance did not provide a scheduled preventative maintenance regimen on the Tangara deadman foot control system. It considered the number of failures to be insignificant. The scheduled train maintenance inspection every 90 days included a functionality test of the foot control. Documentation was not available to indicate any testing process other than the engineer placing a foot over the pedal and pressing it downwards until the panel indicator light illuminated.

There was no calibration standard available in maintenance manuals or similar documents to test the forces required to activate or release the foot pedal function.

The only evidence of forces required to set or trip the system was obtained from SRA Drawing 003-677. This specified a 'force to activate' of 73N (minimum) and a 'force to deactivate' of 101N (maximum). However, this drawing only referred to cars up to and including D6242. The drawing was marked with a caption: "For new and retro-fit cars see drawing B. 14838". Inspection of that drawing did not reveal any comments about pedal forces.

No standard has been developed to calibrate the twisting force required at the T-handle to suppress brake activation. (Transducer measurements taken from a number of master controller handsets to prove simulator fidelity at Petersham were in the range of 3.5 to 4.5N.)

7.4 Deadman system functionality

As part of the physical examination of the G7 deadman system after the accident, the forces required to activate and deactivate the deadman function were measured. For comparison, the forces were measured on five other Tangara deadman systems to determine the consistency of force required. The data indicated that a range of forces, from 83.8 to 95.6N, were required to initially set the foot control, which was well above the minimum specified force of 73N. It was significant that after applying an initial force, the force could be reduced significantly, to a release force of between 39.4 to 54.4N. However there was no specified minimum release force.

7.5 Deliberate circumvention of the DMS

During discussions with drivers regarding the ways they used the deadman system, some displayed direct or indirect knowledge that some drivers wedged one of the red flags from the cabin between the driver's desk and the deadman foot pedal. The purpose of using the flag in this manner was to override the deadman device by applying appropriate pressure to the pedal to lock it into the centre position.

Examination of the underside of the driver's console from the rear car of G7 (car 6832) revealed marks in the corner between the side panel and the

underside of the desktop that were consistent with the use of a flag handle in the manner described above. When a flag was placed against the marks, a good fit was seen (see photos below). Further examination of a random sample of 29 cars from Tangara trains, including a G-set bound for Port Kembla, revealed similar wear marks on each occasion, some more pronounced than others. All wear marks were consistent with repeated insertion and removal of a wedged, round wooden peg.

A variation to the wear marks was observed in eight of the cars. In these cases a gum-like substance was placed in the upper areas of the foot well. In one case, there were sufficient markings in the gum to indicate the recent presence of a timber pole. The substance appeared to have been placed to provide grip sufficient to hold a pole in place to circumvent the foot pedal function.

There was anecdotal evidence to suggest that some unofficial train maintenance practices may have utilised the flag or a similar device in a manner that would leave the observed witness marks under any of the driver's desks.

The investigation team received anecdotal and witness observations about elastic bands and various weighted objects, such as bags, used to circumvent the twist-grip deadman device on the master controller.



Pictures 10 and 11: Car 6832 foot well with flagstick.

7.6 Vigilance control systems

Vigilance control systems are designed to apply the brakes of a train if a driver fails to carry out certain tasks or acknowledge the system within a specified period of time. Modern systems are task-linked and speed-sensitive. As at January 2003, vigilance control systems in their various forms were fitted to locomotives, XPT, Endeavour, Xplorer, Millennium trains and the recently modified Double Deck Inter City (DDIC) fleet as standard.

Vigilance control systems typically have a four-part cycle of waiting, visual warning, audible warning and finally a penalty brake application. Only task-linked and speed-sensitive systems could complete the cycle in less than 60 seconds.

Neither Tangara trains nor any other suburban trains were fitted with a vigilance control. The journey of C311 from Waterfall to the 775 signal lasted approximately 88 seconds. The last task probably performed by the driver was the application of full power in the vicinity of the crossovers (at 59A points). There was approximately 68 seconds between that action and passing the 775 signal.

A report commissioned by the Special Commission⁹ examined the effect that a vigilance control, with the same operating characteristics as that of DDIC trains, would have had on C311 given the speed and timing on the day of the accident. The report concluded that such a vigilance control would have prevented this accident by applying the emergency brakes to reduce the speed to below overturning speed.

Due to infinite combinations of train performance and geography, the conditions for a roll over could develop in a shorter period than was demonstrated in this accident, and possibly in less time than the shortest vigilance control cycles. Therefore vigilance control cannot be regarded as a completely reliable substitute or back-up for a deadman system.

⁹ *Revised Examination of Vigilance System Stopping Opportunities Prior to the Waterfall Accident.*

8.0 INCAPACITATION SIMULATION

8.1 Background

Evidence gathered in the early stages of the investigation suggested that incapacitation of the driver may have been a contributing factor to the accident. To test this supposition, the investigation requested access to the Tangara simulator at the Australian Rail Training Centre at Petersham NSW. Investigators sought to examine a number of possible issues through a series of structured driver and guard operational simulations.

The simulation group developed a number of scenarios to be simulated, and sought to identify how the safety devices may have operated.

8.2 Methodology

The simulations were conducted using a scientific methodology and the testing group made a number of assumptions that were recorded as part of the methodology. The group produced task instructions which were ratified between stakeholders before the simulations began.

Three volunteers from the NSW Police were selected to play the part of train drivers in scenarios. They were selected solely because they had a body mass and height equal to that of the deceased driver (no previous rail experience was required).

Principal among the initial scenarios was a plan to simulate a sleeping or incapacitated driver to determine the likelihood of a driver being able to suppress the deadman foot control or master controller handle while in such a non-responsive state. The configuration of the simulator included placement of the driver foot heater in the same place that it was fitted to G7.

All simulations were witnessed, documented and professionally filmed with two synchronised cameras. Particular attention was focused on the location and movement of feet in relation to the deadman pedal.

8.3 Results

Simulator test results were verified by reproducing some of the scenarios in the non-driving cab of a live G-set Tangara train operating under similar conditions to C311 south of Waterfall. These used volunteer certified drivers and volunteers from the NSW Police. The dynamic testing confirmed that the scenarios tested in the simulators were representative of what would happen on a real train.

The simulator incapacitation tests determined that:

1. A driver with a body mass exceeding 110 kg, with *both feet* on the deadman pedal and with *feet forward* to the foot well wall was able to circumvent the deadman function involuntarily. This was due solely to the weight of the driver's legs on the pedal and was achieved with or without the wedging of knees or shoes on any part of the cabin structure.

2. A driver with an equivalent body mass to the C311 driver was able to circumvent the function of the deadman foot control involuntarily with just *one* foot, in a *forward* position on the deadman pedal, using a legs crossed posture. To achieve this result without discomfort, a driver with a height of 184 cm needed to place the seat in a rearward position. This result was achieved without wedging knees or shoes on any part of the cabin structure.
3. A driver with an equivalent body mass to the C311 driver was able to circumvent the deadman foot control involuntarily by wedging either one or both knees between the underside of the driver's console and the deadman pedal.
4. A driver with an equivalent body mass to the C311 driver was able to circumvent the deadman foot control involuntarily by wedging either one or both feet between the foot heater unit and the deadman pedal on the G7 set.
5. It was possible for an incapacitated driver to retain the master controller twist grip handle in the set position, but the test results could not be reliably repeated.



Picture 12: *Driver feigning incapacitation with both feet on the deadman pedal. Note arrowed light indicating that the deadman system was suppressed in these conditions.*

9.0 TRAINING

9.1 Background

SRA considered guards to be part of the protection built into train operations to control the risk of driver incapacitation. SRA stated in the 'Guard's Duties Field Week – Trainee Workbook ART 2002' that:

"The guard is responsible for the safety of all passengers on the train and must be prepared to stop a train immediately if an emergency situation arises."

SRA had adopted the principles of risk management through its safety management system. This should have identified specific training that was needed to mitigate identified risks.

The investigation examined the training that guards underwent to ascertain the extent to which they were capable of fulfilling this risk control role.

9.2 Structure

There were two components to guards' training, initial and recurrent training.

The Glenbrook Inquiry had resulted in a review of the recurrent training regime for crews, which led to the development of the *Safety Management System* (SMS) training concept.

The SMS training was defined by SRA Safety Standard 6.005 as "...refresher or re-certification training, which is delivered to all rail safety workers who work under the Rail Safety Act (1993)". It required all rail safety staff to attend a minimum of three formal training courses each year and completion of these courses became part of the re-certification requirements.

The Glenbrook Inquiry had recommended a re-write of the Safeworking rules by the Rail Infrastructure Corporation. A major focus of the SMS training had been ensuring SRA staff were trained in the application of the new rules.

The SMS training program included non-safety related elements and although it was a part of SRA's Safety Management System, it was actually recurrent operational training, rather than training in or about Safety Management Systems. The label of SMS training was therefore a misnomer and was potentially misleading.

9.3 Findings

There was no evidence to indicate that the guards' training program provided them with critical decision-making skills, for ensuring they would reliably interpret an emergency situation and react appropriately. The skills to recognise a speeding train and initiate the appropriate action to stop the train did not appear in the guards' training.

Although drivers and guards had attended SMS training together, there was no evidence that training had conditioned drivers and guards to operate effectively together as a team, or had otherwise adopted the principles of

crew resource management (CRM)¹⁰. Informal discussions with a number of drivers and guards on the metropolitan network confirmed that many saw their roles as individual and not as part of a team.

CRM teaches operational crews (similar to train drivers and train guards) to use all available resources including information, people and equipment to prevent accidents through improved coordination and communication. It focuses on the development of cognitive and interpersonal skills.

Discussions with some junior guards revealed a strong perception of an authority gradient between drivers and guards. This situation manifested itself in an apparent reluctance for some guards to challenge drivers on any issue.

Investigators received evidence that drivers would generally not expect guards to use the emergency cock (also known as ‘pull the tail’) without first attempting to communicate with them by intercom or by the electric bell (see also Section 6.7).

9.4 Regulator audit of training

An audit of Australian Rail Training (ART) by the Regulator indicated that the auditors conducted only a general assessment of the overall training provided by ART and mainly focused on existing Safeworking requirements and their delivery. The report indicated that the audit was process-based and did not examine the integration of all the parts of training and their application to everyday train operations.

¹⁰ In 1999 the Royal Aeronautical Society described CRM as:

“CRM encompasses a wide range of knowledge, skills and attitudes including communications, situational awareness, problem solving, decision making, and teamwork...”

10.0 CREW CERTIFICATION

10.1 Background

The *Rail Safety Act 1993* imposed requirements on rail operators in relation to certificates of competency for rail safety workers. One principle of the Act was to provide confidence in the competency of individuals involved in rail operations.

10.2 State Rail certification processes

In NSW, rail operators were required to adopt a systematic approach to certify their employees' competency. Certification for drivers and guards consisted of three parts:

1. Candidates were required to complete a total of six SMS training modules within the two-year period of certificate currency.
2. They had to be medically fit according to the SRA 'Medical Practices and Procedures' document (1995).
3. They had to pass 'on-road performance assessments' to be conducted at intervals not exceeding 12 months.

10.3 Certification issues

The NSW Rail Safety Regulator sampled the operational performance of individuals but did not conduct rigorous audits of the certification process and relied on operator assurances that crews were competent.

It could not be determined whether any driver or guard had actually failed an on-road performance assessment, because the SRA database that held this information did not have a field to accept a performance grading or assessment result.

Evidence indicated that some train crews did exceed their assessment intervals. A derailment investigation in 2001 found that the SRA driver involved had not had a performance assessment for two years. That investigation had recommended that SRA provide an assurance that drivers with expired certification would not be rostered for operational duties until their certification was renewed. That recommendation had not been implemented.

10.4 Certification of C311 guard

Comparison of the guard's on-road assessment with the driver's did not provide any measurement indicators or activity that might help assess how they functioned together as a team or unit.

SRA maintained two different databases on crew certification; one indicated that the guard's certification had expired. However, this contradiction was found to be an administrative error and the guard was found to have been correctly certified.

11.0 SPEED BOARDS AND TIMETABLING

11.1 Background

The speed analysis carried out in relation to C311 identified that other trains had traversed the section south of Waterfall at speeds in excess of the posted track speed. Some drivers gave evidence that the timetable could not be complied with unless they exceeded track speed, while others stated that there was a perception that some track speeds were too low in relation to the physical environment.

11.2 Speed boards

Permanent speed boards in NSW were located beside the line to indicate to the train driver the maximum speed at which the train was permitted to travel between that and the next speed board. Permanent speed boards had black numbers on a yellow background. The Rail Infrastructure Corporation was responsible for determining the positioning, placement and maintenance of speed boards. Other types of speed boards included temporary and turnout speed boards and black-on-white XPT speed boards.

As part of the investigation, the actual position of speed boards was compared to the specifications in the Train Operating Conditions Manual in the Sydney to Port Kembla section. The review identified that a number of speed boards, particularly on the Up line, were incorrectly positioned.

11.3 Overturning speed

Posted speed limits were determined by engineers using complex geometric calculations designed to achieve equilibrium speed (equal wheel loading) when a train negotiated a curve. The calculations were dependent on factors such as curve radius, track superelevation and rolling stock centre of gravity.

A function of this geometry was that the overturning speed was always higher than the equilibrium speed, so a margin of safety existed over the posted speed limits. In the case of this accident, while the posted track speed was 60 km/h, the overturning speed for G7 on that curve was approximately 110 km/h.

11.4 Network Rules applicable to train speed

Rule SWU 904, which had applied until November 2001, stated that “when a speed board indicates that the speed of a train can be increased, the driver may do so as soon as the front of the train reaches the speed board”.

The new rule NSG 604 stated that “drivers and track vehicle operators must make sure that the front of the train or track vehicle passes a speed sign at or below the speed given by the sign. If speed signs allow increase, drivers and track vehicle operators must not increase speed until the rear of the train or track vehicle has passed the speed sign”.

The new rule was consistent with the National Codes of Practice.

The Rail Infrastructure Corporation had not applied its 'configuration change control' process to this rule change, so engineers had not reviewed speed board positions. Some speed boards had remained positioned according to SWU 904, with a redundant 300 m offset (see 11.5 below).

There was no evidence that the timetable had been reviewed by SRA as a result of the change in rules.

11.5 Positioning of speed boards in reference to SWU 904

Where speed limits reduced, the speed board was placed at the beginning of the section of track requiring the reduced speed (e.g. at the beginning of a curve). Where speed increased, speed boards were located 300 m (an arbitrary train length) beyond the section of track to which the previous lower speed applied.

The SWU 904 methodology gave rise to issues that included:

- Trains longer than the nominal 300 m, with a high acceleration rate, could significantly exceed that speed limit when the front of the train began to accelerate to the next authorised speed limit.
- At locations with critical permanent speed restrictions, additional speed boards were required to ensure longer trains did not exceed the speed limit.
- The 300 m offset could result in speed boards that did not align with track features such as curves.
- The rules for responding to permanent speed boards were different from those for temporary speed boards and turnout speed boards, where the driver was expected to apply an offset equivalent to the actual length of the train.

11.6 Positioning of speed boards in reference to NSG 604

The new rule required the driver of a train to increase speed only after the whole of the train had passed the speed board. With the introduction of this rule, the issues in relation to placement of the speed boards identified for SWU 904 had essentially been eliminated because the length of the train was no longer relevant in determining the position of a speed board.

However, as the 300 m offset was no longer relevant, many speed boards were left misplaced which potentially increased sectional running times.

11.7 Independent timetable analysis

The investigation sought to independently verify the adequacy of timetabled running times. The timetable for C311 was analysed using the M-Train¹¹ simulator.

Using M-Train it was possible to predict train movement by reference to stations in hours, minutes and seconds. The analysis of the timetable for run

¹¹ M-Train is a train performance analysis tool.

C311 was prepared using both rules SWU 904 and NSG 604 and the two results compared.

The existing timetable provided a running time of one hour and 53 minutes from Sydney to Port Kembla. Using the M-Train simulation, the total time required for a theoretically perfect run was calculated at one hour and 49 minutes and 22 seconds under SWU 904, and 1 hour and 50 minutes and 23 seconds under NSG 604. The new rule required an additional one minute and one second for the entire route, however both results indicated the total running time was theoretically adequate under ideal conditions.

There were however, sections of the journey where the running time was not adequate between stations.

11.8 Basic running time calculations – Waterfall to Stanwell Park

Simple calculations using distances and track speeds indicated inadequate sectional running times from Waterfall to Stanwell Park, with 19 minutes provided in the timetable and about 20 minutes thirty seconds actually required.

Although there was some recovery time or 'slack' built into the timetable, it was apparent that in some cases the slack could be contradicted by inadequate sectional running times.

With small margins available to account for delays, drivers would easily have been exposed to the pressure of maintaining on-time running.

A further running time anomaly can be seen in the 'CityRail Working Timetable, Book 3' instruction pages, which specified that a through (non-stopping) train should be allowed nine minutes between Waterfall and Helensburgh, but a stopping train was only allowed eight minutes (including platform time at Helensburgh). Clearly a stopping train would take longer than a through train.

Collectively, these issues indicate that on balance, timetabling was not managed to avoid the potential to create operational risks.

12.0 CRASH EFFECTS AND SURVIVABILITY

12.1 General

The driver and six passengers were ejected from the train during the accident sequence. All but one of those ejected received fatal injuries. One deceased passenger was found under the second carriage, while the other ejected passengers were found between the train and the cutting. One fatally injured passenger was retained in the wreckage of the first carriage upper deck.

According to the FEA crash simulation, the passengers and crew were subjected to a maximum deceleration force of 7g during the overturning and impact with the cutting. This was a survivable rate of deceleration.

The significant structural damage to the first carriage upper deck caused the destruction of the windows and roof on the right side, which permitted the ejection of five passengers during the left rolling motion after impact with the cutting. Three other passengers were retained in the upper deck, one fatally injured and another critically injured.

The windows of the first carriage lower deck and rear vestibule remained largely intact. The five passengers in these parts of the train were retained in the carriage and survived.

The front of the second carriage was significantly damaged. The windows of the right side of the upper deck were destroyed but with less structural damage than the first carriage. One of the eight passengers seated in this area was ejected but survived. The windows of the second carriage lower deck and the remainder of the train remained largely intact. All passengers travelling in these areas survived.

The guard's cabin was not significantly structurally deformed, however the emergency equipment that was stored in the compartment under the guard's seat was ejected as a result of the accident. Some of this equipment caused injuries to the guard.

12.2 Driver

Fragments of windscreen glass were found embedded in the driver's seat back and the right armrest was broken off. This suggested the driver was not in his seat at the time of impact and was consistent with him being thrown from his seat when the rolling motion stopped just prior to impacting the stanchion. The driver's body was found against the cutting near the rear of the first carriage with a marker light box and a static inverter transformer nearby. The driver's bag was found under the first carriage, indicating it had arrived there before the carriage. The driver's body differed from the bodies of the other deceased in that there was more debris, including ballast, vegetation and wreckage, on top of the body.

13.0 EMERGENCY ACCESS AND EGRESS

13.1 Background assumptions

'Evacuation' is a supervised activity conducted by train staff. 'Escape' is when passengers act to rescue themselves. The need to evacuate or escape from a train would arise after an accident and/or when the hazards of remaining onboard, such as fire, fumes or submersion, become life threatening.

13.2 Escape from the wreckage

There was no Australian standard on train access and egress and there was no internal emergency door release (EDR) on Tangara trains. Emergency access and egress was intended to be via the side and/or end doors and to be supervised by train crew. External EDR push buttons were provided and relied on the availability of a compressed air supply to operate.

With the driver deceased and the guard incapacitated by his injuries, there was no train crew to conduct an evacuation or release doors. With no internal EDR available, passengers were unable to quickly escape the wreckage except where the structure had been opened by the crash.

Tangara trains were the only trains in the SRA fleet to have multi-layer polycarbonate windows. However, some passengers made their escape by breaking and kicking out windows.

Emergency services workers could not open some doors using the external EDR push buttons. This was possibly due to the weight of the plugging doors and little or no stored air being available. There was little understanding of this at the time, despite this being the fourth Tangara to have had ended on its side in a derailment¹².

There were no immediate hazards to the passengers who remained inside the train and there was no evidence that delays to first aid contributed to any death or further injury.

SRA had adopted the policy of not making internal EDR available to passengers. This policy was influenced by reliability and vandalism concerns and the potential for passengers to escape onto an adjacent line into the path of a moving train.

A study initiated by SRA after the accident¹³ found that in relation to Tangara, this policy was not consistent with the approach taken in countries such as the United States. Conversely, the study suggested that while the multi-layer polycarbonate windows had hampered access and egress, their strength had helped to retain passengers inside the train during the roll-over.

¹² Other Tangara roll-overs occurred at Wentworthville, Concord West and Kingsgrove.

¹³ Tangara Access and Egress Design Study, July 2003.

14.0 EMERGENCY RESPONSE

14.1 SRA Incident Management Plan

The SRA emergency response policies were documented in the Incident Management Plan. The plan outlined roles and responsibilities of staff and included policies on a range of issues such as police liaison and car parking. The plan did not clearly define the requirements for information gathering, assessment and emergency response activation.

This plan indicated that train controllers at the Rail Management Centre (RMC) were responsible for receiving information and initiating emergency procedures.

14.2 'First 5 Minute Response' documents

There were a series of SRA documents titled 'First 5 Minute Response'. There was a version of the document for staff positions ranging from guard to operations control supervisor. The documents contained checklists of actions to be taken. There were no assessment criteria to identify the occurrence of an emergency. Controllers were not trained in emergency response procedures for rail accidents on the scale of Waterfall.

There was a checklist for the Rail Commander at an accident site. There was no requirement on this checklist for the Rail Commander to report to the Site Controller or to advise police on train access or rescue. Rail Commanders were not trained to apply these procedures to a rail accident.

14.3 Identification of the emergency

The first information the RMC received about the accident was at 0716, when the Electrical Operations Centre (EOC) advised that there was no electrical supply in the Waterfall area. This was followed at 0717 by an unsuccessful attempt by the RMC to contact the driver of C311. At 0718 the RMC was advised by Waterfall Station of a possible track circuit failure.

The train describer system in the Waterfall signal box showed the location of C311 in relation to signals and track circuits.

Police were first notified of the emergency at 0720, when a passenger made a mobile phone call to 000.

The guard of C311 used his mobile phone to call Waterfall Station on its public number, but the reception was poor and several attempts were required. At 0730, Waterfall Station advised the RMC that C311's guard had reported the derailment.

Six people in the RMC were receiving and making calls about the accident. Police first sought information from the RMC at 0728 and again at other times. The police found these communications confusing because they spoke to a different person each time. RMC staff were not coordinated and no one person took on the role of being a single point of contact.

The RMC received detailed information about the accident from police and other information from rail sources including Waterfall Station, indicating that a serious accident had occurred. However, the recorded voice logs indicate the RMC was reluctant to acknowledge that an emergency existed until it received confirmation from someone at the site.

14.4 Identification of the accident location

The RMC could have identified where the accident occurred within a distance of less than one kilometre by collecting and analysing several sources of information. This could have been done in just a few minutes. An RIC person was available in the RMC who could have helped establish the location of C311.

For reasons unknown, the location of the accident was initially inaccurately given as 100 m south of Waterfall. This location would have been visible to Waterfall Station staff, however no-one in the RMC sought verification of this fact. It was not until police ran almost 2 km along the track from Waterfall that the location was determined.

14.5 Emergency access

Police and emergency services did not have maps or other information about access points to railway land and did not have ready access to boundary gate keys. A network of tracks led to the accident site, which was in a remote area and was difficult to access.

A Waterfall Station assistant, using his own knowledge of the access tracks, went with police to unlock the boundary gate and guide the search for the accident site.

14.6 Electrical power supply

The EOC made one automatic and four manual attempts to restore the overhead power supply between the time of the accident and 0729, when Waterfall Station advised the EOC that a derailment had occurred. The EOC isolated the power supply to both tracks at 0750, after on-site electrical personnel advised the EOC that a serious accident had occurred.

14.7 Evacuation and rescue

Both the passengers and emergency services found access to and egress from the train difficult. The doors of the train were locked and emergency services had no knowledge of the external EDR buttons. Ambulance rescue personnel discovered that windows could be removed after removing the rubber seal.

14.8 Site control and rail representatives

The accident site was declared a crime scene. A NSW Police 'Site Controller' was in control of the accident site and had expected the Rail Commander to

become part of the site control team to advise on rescue matters and to provide rail expertise, and a link with the rail industry.

An SRA Rail Commander who was experienced in derailments attended the accident site. However the Rail Commander's training had not prepared him for participation in serious rail accidents and he did not remain at site control as part of the site control team. Police were therefore required to deal with many rail people, some of whom did not have the information required, nor the authority to make decisions or take action.

The Rail Commander perceived that he had no role in the rescue operations and, with the best of intentions, occupied himself during this time with securing evidence.

Many rail staff, without a role to play in the rescue operation, self-responded and accessed the accident site, which added to congestion and had the potential to contaminate evidence.

14.9 Accident Investigation

The Rail Safety Regulator had an obligation under the Rail Safety Act to investigate rail accidents. The Regulator was not prepared or resourced for an investigation on the scale of the Waterfall accident. There were no investigation procedures and no critical incident response team.

The Regulator did not assume full control of the site at the transition from emergency response to investigation phase. Some evidence was not obtained from the accident site, which added to the cost and duration of the investigation.



Picture 13: *Rescue operations taking place.*

15.0 SAFETY SCIENCE

The management of safety in the workplace, both in an operational and in an occupational health sense, has developed as a science discipline, with an expectation that practitioners be appropriately qualified. Tertiary courses in safety science are available. These courses cover key components of safety management including topics such as hazard analysis, risk management, safety management systems and human factors.

Information about safety management can be found in a number of organisations outside academia that can provide guidance on the training, skills and experience required of a recognised 'safety practitioner'.

The investigation identified that the NSW rail industry was still maturing in terms of safety science at the time of the Waterfall accident. There was no definition for a 'rail safety specialist' and both the Regulator and SRA had an insufficient number of skilled safety specialists, ie people with the education, skills and experience that would have been required of a safety specialist in some other industries, working in safety management positions.

With insufficient safety expertise, both the Regulator and SRA had, at an organisational level, struggled to stay abreast of contemporary safety science principles.

By comparison, some industries had given more thought to the competence of people whose position affects safety. For example, in the occupational health and safety industry, Australian Standard AS4804 for OHS management systems defines the required skills for an "occupational health and safety professional".

In civil aviation, CASA has been consulting with the industry on the introduction of regulation that will define the safety-critical positions of some aviation operators. This regulation will require appointments to safety-critical positions to be approved by CASA, and will specify the training and experience required of people in certain positions, such as a safety manager.

In more general terms, the requirements for membership of the Safety Institute of Australia (which are consistent with the examples above) could be generally taken as the recognised standard of expertise required of a professional safety practitioner.

16.0 SAFETY CULTURE

16.1 Background

The term *safety culture* first appeared in literature after it was defined by the International Nuclear Safety Advisory Group (INSAG) in 1986 following a review of the Chernobyl nuclear power plant accident.¹⁴ It has come into increasing use over the past 15 years or so to help explain why some organisations are 'safer' than others. The premise is that safety health results from two elements: the quality of the systems and processes implemented to deal with risk and safety related information (the Safety Management System), and the safety culture, defined as people's shared values, beliefs and attitudes about safety. These two elements combine to define how people behave in their organisation, the 'behavioural norms'. The best Safety Management System (SMS) will be ineffective if the safety culture is characterised by counterproductive attitudes and behaviour. Conversely, organisations without a sophisticated SMS can achieve high levels of safety and efficiency via the right blend of attitudes and behaviour, which form a positive safety culture.

16.2 Definition

Reason (1997)¹⁵ and Hudson (2003)¹⁶ suggest an organisation's safety culture is defined by the extent to which it is:

- Informed: Managers know what is going on in their organisation and the workforce is willing to report their own errors and near misses.
- Wary: The organisation as a whole and individual employees are on the lookout for unexpected events, and maintain a high degree of vigilance.
- Just: The organisation has a 'no blame' approach to errors, but applies appropriate penalties to unacceptable actions (violations).
- Flexible: Such organisations reflect changes in demand, providing both high tempo and routine modes of operation.
- Learning: Organisations are ready to learn, and have the will to implement reforms when they are required.

¹⁴ International Nuclear Safety Advisory Group. (1986). *Summary Report on the Post-Accident Review Meeting on the Chernobyl Accident. Safety Series No. 75-INSAG-1*. Vienna: IAEA.

¹⁵ Reason, J. (1997). *Managing the risks of organizational accidents*. Aldershot, UK: Ashgate.

¹⁶ Hudson, P. (2003). Achieving a safety culture for aviation. *Journal of Aviation Management* 2003, 27-47. Singapore: CAAS.

16.3 Safety culture observations

The concept of safety culture must consider the critical importance of the collective values, beliefs and behaviour of *management*. This point is neatly summarised by Hopkins, who states:

“It is *management* culture rather than the culture of the workforce in general which is most relevant here. If culture is understood as mindset, what is required is a *management* mindset that every major hazard will be identified and controlled and a *management* commitment to make available whatever resources are necessary to ensure that the workplace is safe.”¹⁷

The investigation gathered a range of evidence indicating the existence of attitudes within SRA that were not consistent with a positive safety culture. There was a perception by some that railways were inherently safe, and that Waterfall was an unforeseeable accident. This argument was used to support a conclusion that everything that could have been done to prevent it had been.

There was evidence that at the senior level, safety was thought of as somebody else’s responsibility, such as the safety department’s.

SRA employees confirmed a lack of motivation to report hazards, believing that nothing would be done. Most critically, the investigation did not find any evidence of the existence of a combined risk and hazard register, contrary to the SRA SMS statement that such a register was being periodically reviewed to ensure that risks to safety were identified and managed.

There were remnants of a blame culture, which discouraged employees from being open about near misses and other hazardous conditions. This restricted the organisation from learning.

There was a well-developed short-cut mentality among frontline workers to the extent, for example, that some believed avoiding the sign-on process was not only permitted but was a ‘right’.

In parts of SRA, a flawed approach to the management of on-time running had been applied in that it had not avoided the potential to compromise safety.

Some evidence was obtained of some employees being pressured to compromise safety to avoid delaying trains.

¹⁷ Hopkins, A. (2002). *Safety Culture, Mindfulness and Safe Behaviour: Converging ideas?* National Research Centre for Occupational Health and Safety Regulation, Working Paper 7.

16.4 Pro-activity

Being *wary* involves sensitivity to circumstances or events that could reduce the safety envelope. Examples of minimal alertness to such situations within the SRA included:

- Employee FAID score limits adopted by SRA could be exceeded, due to lack of ongoing monitoring of daily rosters.
- Some trains travelled in excess of authorised speeds.
- Incompatibility between speed boards and timetabling.
- The deadman system was being circumvented by a variety of driver violations. This risk was not reported or detected by supervisors.
- Scenarios in which effective crew resource management behaviours would enhance safety do not appear to have been anticipated by SRA, and thus training to prepare crews for these eventualities was not commissioned. This training, like other CRM courses, would need to have taken into consideration known barriers to effective teamwork and communication between drivers and guards. These barriers were in themselves another threat to safety that went unaddressed.

Learning organisations pay attention to information and even ‘weak signals’ about hazards, evaluate what they mean and take action. They do this before, not just because, an accident occurs. There is clear evidence that some SRA managers repeatedly did not act over a number of years on reputable, documented evidence that there were serious defects in the Tangara deadman system (see Section 7.2 above).

The explanation for this lies partly in a defective safety management system, but also in the fact that people did not act on the information provided.

Learning organisations also ensure that knowledge gathered centrally is disseminated to those with a need to know, through formal and informal processes. It was not apparent that programs such as the so-called Safety Management System training were addressing the full range of topics known in other domains to provide frontline crews with essential non-technical skills to identify and manage everyday threats to safety (see Section 9 above). Lessons from the Glenbrook Special Commission of Inquiry, particularly in relation to ‘situational awareness’ and emergency response did not have a sufficiently high focus in ART training.

In regard to learning, SRA did not appear to have insight into its own culture, or operational risks, this appears to be partly due to insufficient input from operational areas to ensure a ‘needs based’ approach to training outcomes.

17.0 SAFETY MANAGEMENT SYSTEMS

17.1 Background

A safety management system (SMS) is a documented and integrated set of procedures that forms a component part of the organisation's overall management system. The purpose of a SMS is to identify, assess and control risks. Four major imperatives that should be included in safety management systems are management commitment, a hazard reporting and identification program, a risk management program, and a process to monitor and review.

17.2 SRA safety management system

The SRA safety management system had been developed around 15 elements, which in turn were based on various legislative requirements and Australian Standards.

The system was last reviewed in 1999-2000 in preparation for an accreditation application in 2001. The resultant system encompassed environmental, occupational health and safety, and operational safety issues.

17.3 Investigation document search

Sufficient anecdotal and other evidence was obtained of unidentified hazards and uncontrolled risks to justify an overview examination of SRA's safety management system to test the significance of the evidence gathered. However the investigation was not able to conduct an extensive review of the system due to time constraints and the size of the task.

Investigators examined the documentation submitted with the SRA accreditation applications of 2001 and 2002. Objectives and implementation processes accompanied the 15 elements of the safety management system, which appeared to be logical and written in simple language. However, an examination of the SRA self-assessment suggested that there was a strong occupational health and safety influence to the system and a lesser focus on operations and human factors issues.

Some anecdotal evidence indicated that the concepts of a safety management system had not cascaded down from the senior management level to the frontline employee. Formal and informal interviews of SRA employees in less senior positions provided investigators with the following impressions of their views of the safety management system. They ranged from no knowledge, to cynicism about the intention of its introduction, to a feeling that it was another fad, to a recognition by some of the importance of such a system. Evidence from the Special Commission of Inquiry revealed some senior managers had a superficial understanding of safety management systems.

Evidence indicated that it was not uncommon for those administering and applying the system to be appointed to their positions without safety management experience or qualifications. The evidence also indicated that

the safety management system assigned responsibilities to people who did not understand how to discharge them or were unwilling to accept and/or discharge them.

17.4 Deficiencies in the SRA SMS

The following points summarise the deficiencies noted by the investigation in the SRA safety management system:

1. Fatigue: SRA had applied a fatigue rostering program only to the master roster (see Appendix B), and had used a maximum fatigue management index of 100, which was a higher level than research could assure was safe. The program was not applied dynamically to daily rosters, so roster variations could cause a driver's fatigue index to exceed 100. At the time of the Waterfall accident, SRA was on its own assessment fully compliant with Element 12 of the SMS: "*Fitness for work is defined and maintained, including such areas as... Fatigue...*". A statement in support of SRA's accreditation application under Element 12 stated that dynamic fatigue rostering would be introduced in 2003.

2. Deadman system: The investigation identified that information had been available to some SRA management regarding the deficiencies in the deadman pedal installed on the Tangara trains for approximately 14 years prior to the Waterfall accident. Element 4 of the SMS dealt with Hazard Identification, Risk Assessment and Control. SRA had self-assessed that its operations were mostly fully compliant with the SMS's measurement of success under this element.

The investigation gathered evidence from SRA documents indicating that known risks existed in connection with the deadman system fitted to the Tangara. That no action was taken to address these risks contradicted SRA's assessment of the efficacy of this element.

3. Risk and hazard logs: Element 4 of the SRA SMS described hazard and risk registers and stated that "*the hazard and risk register is periodically reviewed to ensure it is kept up to date*". The investigation found no evidence of individual registers or of a combined risk and hazard register. The safety management system documentation included with the 2002 accreditation application contained a page titled "2002 State Rail Safety Action Program" and described the 2002 State Rail Priority Hazard List (which was not a risk register). Significantly, this list did not include any mention of the risks previously identified as associated with the deadman system installed on the Tangara trains.

SRA advised in writing on 22 May 2003, in response to a request for more information about the risk register, that "*work is currently under way to review and revise State Rail's approach to risk management including the formal development of a risk register*".

4. Train scheduling: The Rail Infrastructure Corporation introduced new network rules in 2002. As previously described (see Section 11), the new rules resulted in an increase in running times for trains over some sections. The SRA safety management system stipulated processes that should have identified that the new rules regarding train operations may have introduced new risks. The investigation did not find evidence to suggest that this possibility was considered or assessed.

5. Joiner rights: Evidence obtained by the investigation indicated that *joiner rights* was an accepted practice among SRA train crews (see Section 3.11). The evidence indicated that SRA management permitted the practice, but there was no evidence presented to indicate that the audit program (Element 15 of the safety management system) had highlighted the practice as presenting a possible risk to operations.

6. Training: A number of training issues were highlighted as a result of the Waterfall investigation (see Section 9). Element 6 of the SRA SMS addressed selection, training and competence and this element had the objective *“to ensure that all personnel are able to perform their work activities competently and safely.”* An examination of the parameters that SRA used to measure success in this element did not include a range of contemporary human factors that were relevant to the accident, for example, the application of crew resource management (CRM) principles, critical decision making or a general awareness of the risk-based approach that SRA professed to employ.

7. Incident reporting: The investigation received extensive information during both formal and informal interviews and discussions with drivers about their lack of motivation to report hazards or anything other than significant incidents. One reason stated for this was their perception that nothing would be done about such reports. The written objective for Element 7 of the safety management system was *“To ensure that all incidents and injuries (including ‘near misses’) are reported, investigated and the causes rectified to prevent similar occurrences.”* SRA had self-assessed that it was fully compliant with the following nominated measures of success: that *“all incidents and injuries are reported”* and *“All incidents and injuries are investigated to identify immediate and basic causes, and corrective actions are assigned to mitigate these.”* Evidence was presented at the Special Commission of Inquiry about reports that were submitted and apparently not adequately acted upon. An examination of SRA’s Incident Information Management System (IIMS) indicated that about 1,000 reports were submitted each month. However few, if any, of these reports were voluntary reports of safety incidents that had not otherwise come under notice

17.5 Rail Safety Regulator assessment

When the revised SRA safety management system was submitted to the Rail Safety Regulator as part of its 2001 accreditation application, officers from the Regulator examined the documents and assessed them as sufficient to support the application. These officers had not been provided with safety management system training nor did they have sufficient resources available to call on others to provide expert opinion about topics on which they did not have first-hand knowledge or expertise.

In the 2001 audit of SRA by the Rail Safety Regulator, the auditors identified issues relating to the safety management system which required action. There was no apparent correlation between these identified issues and the Rail Safety Regulator's audit of SRA in 2002.

SRA attached a summary of its safety management system to its 2002 accreditation application and this was again accepted by the Rail Safety Regulator. Although the safety management system formed a major substantiating document in support of SRA's accreditation application, the investigation team discovered no evidence indicating that the Regulator conducted a targeted audit of the safety management system. Nor was evidence obtained that indicated that any extra emphasis was focused on the SMS as part of the annual audit in 2002. However, following the 2002 audit, deficiencies in the area of fault reporting and handling in relation to rolling stock were identified. The result of this discovery was a follow-up audit focused on SRA's compliance with its accreditation application and therefore its safety management system. This audit exposed a number of deficiencies in the system, which resulted in issuance of a non-conformance notice.

The audit and investigation sections of the Rail Safety Regulator, which were responsible for assessment of the SRA safety management system, were stretched due to a lack of resources. This was exacerbated by an escalating workload with the number of investigations increasing at a rate higher than others were being concluded and cleared. More auditor positions were created, but these had not been filled. In addition, officers performing accreditation and audit activities had minimal training or professional development in contemporary safety science or risk management theory.

18.0 RAIL SAFETY REGULATION

Until the 1990's, the rail system in NSW was dominated by an integrated, government owned SRA which was effectively self-regulated. With the introduction of competition and new entrants coming into the rail market it became necessary to put independent safety regulatory arrangements in place.

With the introduction of the Rail Safety Act in 1993, the regulatory model adopted was co-regulation, where industry operators determined the standards by which they would operate, and presented those standards to the Regulator to accredit them as safe.

The Rail Safety Regulator had a history of being under resourced and under skilled, resulting in it being unable to effectively scrutinise accreditation applications. It therefore took a passive approach to regulation, ie was not prescriptive where necessary.

SRA had therefore been permitted to operate to its own safety agenda, and to apply its own interpretation of regulations.

The various safety deficiencies identified throughout this report demonstrate that effective safety and risk management had not yet been assured by the regulatory process and that the Rail Safety Regulator clearly had a need to be better resourced.

19.0 ANALYSIS

19.1 The accident

C311's operations on 31 January 2003 were normal until a short time after it left Waterfall Station. Nothing indicated that the crew and the train were not fully operational. Although C311 stopped away from the four-car marker at several of the stations on the journey from Central Station, no significance could be attached to this, with the available evidence.

The driver was known as a fairly conservative driver and his employment history did not show a predisposition to speeding. On 31 January 2003, there was no imperative to speed, as the train departed Waterfall on scheduled time. Evidence from the previous day, when the driver drove the same run, indicated that he operated within the speed limit along the section of track south of Waterfall.

The evidence indicated that the train departed Waterfall Station in a manner consistent with normal driving technique. Testing and information analysis supported the notion that to achieve the elapsed times between Waterfall Station and the 775 signal, full power must have been applied near the crossovers and remained applied with little or no braking for the rest of the 1,930 m, 88-second journey. The analysis also suggested that the train was performing as it was being directed and it entered the curve travelling at a speed of approximately 117 km/h, which was in excess of the overturning speed for that curve.

Despite extensive investigation and analysis, no connection was established between the infrastructure or the rolling stock and the accident, and no evidence was discovered to show that the brakes were applied prior to the accident.

Post-accident medical evidence indicated a high probability that the driver was medically incapacitated at the time of initial impact. The medical evidence was more convincing than fatigue-related theories, with the forensic pathologist providing evidence of severe atherosclerotic occlusion that he would have ascribed as the cause of death had the driver's body not also demonstrated traumatic injuries.

Therefore, it is probable that the driver became totally incapacitated some time after departing Waterfall Station and was not capable of controlling the train as it approached the left curve south of Waterfall. The investigation was not able to determine whether the driver applied full power before becoming incapacitated or whether the power was applied by the driver while becoming incapacitated.

19.2 Data loggers

The investigation was not able to use data downloaded from the data loggers installed on G7, as they had not been commissioned and switched ON. This deprived the investigation of valuable data that could have obviated the need for deductive investigation to determine the train's operating parameters after it left Waterfall Station.

Because the data loggers were not operating, SRA had no access to accident and incident information and was also deprived of valuable trend information on the performance of trains and their operators. If SRA had a program of data monitoring from these recorders, it may have seen that during January, at least 37% of trains had exceeded the speed limit down the portion of track south of Waterfall Station leading to the left curve on which C311 overturned. Thus an opportunity was missed to identify deficiencies in operations that could be addressed in a pro-active sense.

19.3 Post-crash aspects

The investigation was not able to determine the dynamics of the driver's motion after the train overturned. His injuries and the disposition of his body in relation to other wreckage, including his bag, suggested he had been thrown from his seat and was then ejected forward from the cab. That is, he had not escaped from the driver's cab into the vestibule or passenger cabin before the roll-over and impact.

19.4 Medical standards

The driver had a history of hyperlipidaemia and obesity that should have been identified through a thorough periodic medical examination. The investigation identified that the standards SRA medical examiners used were inadequate and did not ensure that safety-critical personnel were appropriately assessed. Had more rigorous standards been implemented and appropriately trained occupational medicine practitioners been employed to conduct the driver's previous periodic medical examination, it was highly probable that his risk indicators of high BMI, hyperlipidaemia, age and medical history would have alerted the medical practitioner to make further investigative examinations. The outcome of such examinations should have been withdrawal of the driver's medical certificate until his risk factors were managed to acceptable levels.

It was likely there were other drivers presenting a similarly high risk profile and therefore a need to expedite the application of improved medical standards.

19.5 Deadman system

One of the defences installed in G-set Tangara trains to stop the train should the driver become incapacitated, was the deadman system. The investigation showed that this defence failed in its prime function and did not operate when C311's driver became incapacitated.

SRA had known for more than 14 years that the deadman system could be inadvertently circumvented when a driver of a certain weight was incapacitated and that it could also be deliberately over-ridden. While the deficiencies were examined in a number of risk assessments conducted after the problem was first identified, the deficiencies had not been corrected, and the system defences against driver incapacitation and deliberate circumvention had not been strengthened.

The investigation clearly demonstrated that a person weighing more than 110 kg slumped at the driving desk of a G-set Tangara could hold the deadman foot pedal in the set position by the weight of his or her legs alone. The same result could be achieved by wedging a foot or leg under the desk structure or a foot under the heater.

There was no suggestion or evidence that the driver of C311 normally circumvented the deadman system or that he deliberately circumvented the system on 31 January 2003. However, as he weighed approximately 118 kg on the day of the accident, it is probable that after becoming incapacitated the weight of his legs caused the deadman pedal to remain suppressed and prevent brake application.

The long-term existence of the deadman system deficiencies was an archetypal “latent condition”¹⁸ in terms of Reason’s model of organisational accident causation (Reason, 1990, 1991, 1997; Reason & Hobbs, 2003).¹⁹ In organisational terms, SRA did not adequately manage the risk associated with this identified latent condition.

Although there was a suggestion that maintenance people had also wedged flags under the driver’s desk, the extent of the witness marks and the gum deposits that were found were more likely to have been the result of deliberate circumvention by some drivers.

19.6 Vigilance control

The time interval between the application of full power and the train overturning was in the order of 70 seconds.

A task-linked and speed-sensitive vigilance control system such as that fitted to the DDIC fleet could have prevented the accident at this location by applying emergency brakes and reducing the train speed by at least 10 km/h, in under 70 seconds.

¹⁸ “Latent condition”: A term introduced by Professor James Reason (1990, 1991, 1997) to refer to a workplace condition which usually originates from a decision or action taken or not taken (by designers, manufacturers, managers, etc.) at a time and place remote from the accident site. This condition usually lies dormant within a system for considerable time, until activated by operational personnel.

¹⁹ Reason, J. (1990). *Human error*. New York: Cambridge University Press.

Reason, J. (1991). Identifying the latent causes of aircraft accidents before and after the event. *Proceedings of the 22nd ISASI Annual Air Safety Seminar*, Canberra, Australia. Sterling, VA: ISASI.

Reason, J. (1997). *Managing the risks of organizational accidents*. Aldershot, UK: Ashgate.

Reason, J., & Hobbs, A. (2003). *Managing maintenance error: A practical guide*. Aldershot, UK: Ashgate.

SRA had not fitted a vigilance control system to the Tangara G-set and thus such a system was not available to mitigate for the known limitations in the deadman system.

19.7 Non Intervention by guard

The guard, as a member of the crew operating C311 on 31 January 2003, had the opportunity to prevent this accident by taking action to slow the train before it negotiated the curve. Three primary courses of action were essentially available to him: intercom communication with the driver, bell communication with the driver or application of the emergency brakes.

For the guard to have intervened early enough to prevent the accident, he would have had to detect and identify the problem, review his options, decide to take action, probably attempt communication with the driver, wait for a response and then act to apply the emergency brakes. The brakes would then have to reduce the speed sufficiently to allow the train to safely traverse the curve.

The first obstacle to overcome would have been the recognition that the train was speeding and was not likely to slow before the curve. The train had been operating at high speed for the previous 15 minutes over the sections between Sutherland and Waterfall and the guard would possibly have become desensitised to the sensation of travelling fast. The evidence that a number of drivers exceeded the 75 km/h speed limit down the straight approaching the left curve may have further desensitised the guard from recognising that the train was speeding. It was possible, from the evidence gathered throughout the investigation, that guards were conditioned to travelling at speeds up to 90 km/h along this portion of track.

The guard had known and travelled with the C311 driver previously and would have been aware of his conservative approach to driving and his professional capabilities with respect to handling the train. This, along with the guard's significant cumulative fatigue levels, the hour of the day and the opportunity to relax for several minutes between stations, may have resulted in him being less alert to external stimuli such as the train's speed.

The guard had not been trained to develop the critical decision-making skills needed to intervene if a train were speeding. He had not been trained to identify when trains were out of control, how to make his own interpretation of the situation, or how to decide on the appropriate reaction. His training also did not include practised, conditioned responses to defined critical events. He admitted that he did not identify that the train was out of control until braking did not occur at the usual location, but by then it was too late to prevent the accident.

The authority gradient between drivers and guards discouraged some guards from challenging a driver, even on matters of safety. This was a fundamental systemic communication deficiency that may have resulted in conditioning that discouraged the guard from taking timely action.

Some psychological issues were identified in relation to the guard, but no definitive link was established between these issues and his actions or inaction during this accident sequence.

The guard therefore had an opportunity to take action to slow the train before entering the curve, but a number of factors probably combined to limit his perception of a problem until it was too late to intervene.

19.8 Fatigue-related incapacitation

If the evidence supporting the likelihood of a medical incapacitation of the driver were disregarded, strong evidence would remain to support the possibility that the driver was affected by circadian disruption with a consequent degradation in performance and possible microsleeps. His sudden switch from holiday routine to early morning shift work would have severely disrupted his circadian rhythms, and he would almost certainly have experienced some symptoms of acute fatigue during the two mornings that he worked after his extended period of leave. This was supported in part by his late arrival for work on the first morning. In such circumstances, the onset of hypovigilance and microsleep episodes was probable during times of maximal sleepiness. The possibility of hypovigilance may also explain the previously inconclusive evidence of inconsistency of the stopping position of C311 at Heathcote and Waterfall.

The 1987 Stable Rostering Code permitted the driver to be rostered to return to work in the early hours of the morning after a five-week holiday. The rostering practices in that code did not allow for an acclimatisation period in returning workers to shift work and probably exposed the driver to acute fatigue symptoms.

The FAID program had only been implemented at the strategic overview level and did not take into account issues associated with circadian disruption or other fatigue elements at the micro levels. Thus, there was no formal mechanism that enabled SRA management to proactively deal with potential roster or work-induced fatigue in periodic and daily roster management.

The guard was probably highly fatigued, which would have impaired his performance. This is another probable reason why the guard did not intervene to prevent the train speeding into the curve.

19.9 Training

ART was unable to demonstrate conclusively that guards were specifically trained to recognise a speeding train and initiate the appropriate action to stop the train. This was confirmed by a general vagueness about guards' interpretation and reaction to emergencies. This meant there could be no certainty about how guards would react to an over-speed situation.

These findings indicate that guards did not have a capacity to reliably fulfil their role as a defence against the risk of driver incapacitation.

The investigation also found that training had been directed at the driver and the guard operating mostly in isolation from each other. Given that drivers and guards worked trains as a crew, it followed that they should have been trained to operate as a crew.

Their training was an opportunity not only to promote effective teamwork, but also to combat the adverse elements in the workplace culture, such as the

authority gradient between drivers and guards. However, the investigation has demonstrated that this opportunity was not taken through training.

SRA stated that it was using a risk-based approach to curriculum development. Had this been applied, SRA should have identified the hazards needing to be addressed through training, such as the authority gradient and critical decision making. The lack of such training indicated that SRA's risk-based approach to training was not effective.

As the ART facility was a hub for safety education, it was vital that the Rail Safety Regulator conducted audits focused on safety-critical training objectives. The Regulator had not developed and applied audit criteria that were capable of identifying systemic deficiencies in safety-critical areas such as the risk-based approach to training and auditors were unable to call on expertise to conduct in-depth training-focused audits.

19.10 Crew certification

SRA used the training system at ART to evaluate the competence and certification of drivers and guards. Although one of the requirements for certification was an annual 'on-road assessment', the certification assurance process adopted by SRA did not record the performance assessment renewal or result. It was therefore possible that a driver or guard could lose their entitlement to certification between training commitments at ART but continue to do rail safety work because there was no link or checking process between the certification and rostering systems that would automatically result in the withdrawal of certification.

Despite an investigation recommending SRA address this anomaly in 2001, it took no action. The investigation identified that two SRA certification databases could provide conflicting information regarding the certification status of individual drivers or guards.

19.11 Emergency response

By 0718 on 31 January the RMC knew that there was no overhead power in the Waterfall area, that there had been a track failure, and that the driver of C311 was not contactable. There was sufficient information to raise alarm about the status of C311, and to identify its location. However there was no criterion for train controllers to assess information coming into the RMC.

Controllers were not trained in applying the 'First 5 Minute Response' checklist in response to a train accident. Six people became involved in communications about the accident at the RMC, and without clear procedures for responding to a train accident, no one took a lead role in the emergency response. The emergency was not fully acknowledged at an early stage, the checklist was not followed, and consequently the accident location was not identified by the RMC.

Due to the delay in the RMC recognising the emergency, the EOC followed normal procedures for a loss of power supply, attempting to restore power to the downed overhead wires while passengers were escaping the wreckage.

Site safety and rescue operations were further compromised by the delayed isolation of the power supply.

The SRA procedures for the Rail Commander were not applicable to a major accident that involved a multi-agency response. Although the Rail Commander was very experienced in derailment incidents, neither SRA procedures nor his training led him to play a rail liaison role at Site Control.

19.12 Tangara crashworthiness

With the exception of the first two carriage upper deck areas, the fact that there was little deformation to the train, and the passengers in these other areas were retained in the train and survived, suggests the train performed well in terms of crashworthiness.

That this was the fourth Tangara to have overturned during a derailment naturally brings the Tangara's resistance to overturning into question.

However it was beyond the capacity of this investigation to make an informed analysis of Tangara crashworthiness and resistance to overturning, and recommendations have been made to reflect this.

19.13 Speed boards and timetabling

There were numerous issues, ambiguities and contradictions surrounding timetabling, which indicated that timetables were not optimised. This condition had the potential to confuse drivers in terms of how they interpreted speed boards.

Too little or too much time in the timetable would both have been detrimental. Insufficient time created the potential to induce speeding and excessive time potentially brought the efficacy of speed board values into question.

These issues indicated there was a need to have a development protocol for ensuring the timetable did not contain incompatible goals, that it was achievable and that configuration changes resulted in timetable changes where necessary.

19.14 Safety Management Systems

The investigation examined the SRA safety management system because of the quantity of evidence gathered that indicated that the system might have been deficient.

As part of the organisation's accreditation, SRA had undertaken a risk management approach to its business. The risk management approach imposed the principles of prospective hazard control, i.e. a proactive, not reactive, approach. However, the investigation demonstrated that the SRA was largely reactive in managing risks that were outside the Priority Hazard List.

The evidence also suggested that some of the administrators and managers of the system possessed only a rudimentary understanding of the concepts underpinning such a system and many of the success indicators appeared to

have had their genesis in occupational health and safety. It was possible that had there been a deeper emphasis on operational and human factors in the safety management system, some factors contributing to the Waterfall crash may have been eliminated before the accident occurred.

SRA's self-assessment in the documentation supporting its accreditation applications for 2001 and 2002 highlighted the disparity between senior management perception of the status of the safety system and the application of the system.

Without appropriate expertise or resources, the Rail Safety Regulator officers were unable to effectively scrutinise the SRA safety management system in terms of both accreditation applications and audits. Consequently, many of the weaknesses in the application of the safety management system remained hidden.

19.15 Safety expertise

Operators were not required by the Regulator to demonstrate, through the accreditation process, that their safety specialists were appropriately skilled to provide the strategic leadership needed by the board, senior and line managers to manage safety in their area.

There was a demonstrable lack of safety expertise in some areas which resulted not only in the application of invalid and unreliable safety solutions, as evidenced by the various uncontrolled risks identified by this investigation, but also in an inability to recognise the organisational shortcomings in this area.

The dilution of the safety management system into a reactive system rather than a risk management tool, and the related issue of poor safety culture, may not have evolved had there been a wider organisational knowledge of safety management principles, and strategic risk management.

19.16 Safety culture

A comprehensive analysis of SRA's safety culture was beyond the scope of this investigation. However, it became apparent during the course of the investigation that aspects of SRA's operational methods adversely influenced safety in general and contributed significantly to the accident.

Although SRA had a safety management system that espoused many best-practice concepts and processes, the application of those processes and concepts by some line managers at the operational level was not visible to the investigators. Analysis of evidence gathered throughout the investigation indicated that the main imperative driving the organisational culture, or the 'way things were done' in SRA, appeared to be 'on-time running' (see next section for discussion).

The investigation revealed that within SRA there was not a collective and consistent *management mindset* that every major hazard was to be identified. In addition, the general mindset among many people spoken to during the investigation was that the rail system was safe and that Waterfall was an unfortunate accident. Safety professionals would immediately

identify the danger signals of such an institutionalised attitude towards safety, knowing that complacency within a corporate culture often resulted in shortcuts and other unsafe practices, which have been identified through this report.

Safety conscious line managers, supported by safety professionals use risk management and other safety tools to promote accident prevention by actively seeking hazards and putting processes in place to prevent the hazards from escalating into accidents. One way of achieving this is to manoeuvre the organisational safety focus towards a sense of 'chronic unease'²⁰, where everyone is constantly nervous that an accident is about to happen and actively searches for the causes so that they can be neutralised before an accident occurs. SRA had not established an environment similar to a sense of chronic unease about safety. The evidence pointed to a sense of relaxation at management level because of a belief that a solid safety management system was in place and enough had been done.

As defined by the International Atomic Energy Agency,²¹ safety culture is *"that assembly of characteristics and attitudes in organisations and individuals which establishes that as an over-riding priority ... safety issues receive the attention warranted by their significance."* It cannot be concluded from evidence about the attitudes of some individuals nor SRA as a whole that safety was an over-riding priority.

An independent safety culture survey by SRA would help to identify where the problems are and how to address them.

19.17 On-time running

It appeared the dominant mindset at SRA had become on-time running. This factor was relevant to its core business as an operator of passenger trains, however it had evolved to be applied in a manner that was often contradictory instead of complementary to safety.

It was possible that the pursuit of reduced running times had resulted in the timetable becoming difficult to reliably achieve, at least in some areas. In conjunction with the timetabling issues discussed earlier, other factors such as high performance standards and rostering restrictions could have contributed to an overall difficulty in reliably achieving on-time running expectations.

A consequence of this would have been that line managers would have diverted much of their time to managing on-time running issues.

The imbalance between safety and on-time running had become a cultural norm, which had influenced decision making, which had led to many of the issues identified in this report.

This analysis indicates that improved safety could be achieved by relieving the on-time running pressure, by having timetables that can be reasonably achieved, but at no time compromising the safety of operations.

²⁰ Reason, J. (1997). *Managing the risks of organizational accidents*. Aldershot, UK: Ashgate

²¹ International Nuclear Safety Advisory Group. (1991). *Safety Culture. Safety Series No. 75-INSAG-4*. Vienna: IAEA.

20.0 FINDINGS

1. The driver and the guard of C311 were correctly certified.
2. The journey of C311 progressed uneventfully from Central to Waterfall.
3. C311 departed Waterfall on time at 0712:51.
4. Departure from Waterfall was normal, probably with notch two or three selected on the master controller and the driver probably using the deadman foot pedal.
5. Full power was applied a short time after the train cleared Waterfall platform, earlier than it should have been, but was not shut off in the area where normal driving technique would dictate it should have been.
6. The driver was not known as a person who regularly exceeded the speed board limits.
7. The deadman system could be circumvented.
8. The driver's weight and position at the controls probably coincided with the conditions that could cause inadvertent circumvention of the deadman system.
9. It was highly probable the driver suffered some form of incapacitation, possibly related to his cardiac function.
10. The guard was not adequately trained or conditioned to intervene in an over-speed condition and made no attempt to contact the driver or apply the emergency brake.
11. C311 continued to accelerate out of control down the straight portion of track, achieving a maximum speed of about 117 km/h.
12. C311 overturned about 1,930 m south of Waterfall, after entering a left-hand curve where the overturning speed was about 110 km/h.

See Section 21.5 for additional findings.

21.0 CONTRIBUTING FACTORS

Reason's model of accident causation (Reason, 1990, 1991, 1997)²² suggests that serious industrial accidents are best understood by analysing the complex interrelationship between organisational processes, local task and environmental conditions, and the actions of the people directly involved. The model describes how latent organisational deficiencies allow or create conditions that predispose errors or violations, and how unsafe acts combine with local triggering events to produce a potential accident. However, an accident only occurs when the defences designed to prevent such an occurrence are inadequate. Reason's model can be applied to provide a structured framework for sorting, simplifying and mapping the dynamic relationship between the contributing factors in an accident or incident.

21.1 Absent or failed defences

Defences are the 'last minute' measures designed to prevent an accident or its consequences in the face of preceding technical or human failures. They include technology, such as detection or control systems, work processes or procedures, or human awareness of and/or response to a threat. The absent or failed defences (AFDs) identified in this investigation are:

- The deadman system failed to operate as intended to stop the train (AFD-1).
- The guard did not recognise the onset of a potentially hazardous situation (AFD-2).
- There was no warning system of alert the guard of excessive train speed (AFD-3).
- No vigilance protection system was installed. (AFD-4)
- No speed envelope limitation system was installed. (AFD-5)
- Emergency door releases were not accessible by passengers (AFD-6)

²² Reason, J. (1990). *Human error*. New York: Cambridge University Press.

Reason, J. (1991). Identifying the latent causes of aircraft accidents before and after the event. *Proceedings of the 22nd ISASI Annual Air Safety Seminar*, Canberra, Australia. Sterling, VA: ISASI.

Reason, J. (1997). *Managing the risks of organizational accidents*. Aldershot, UK: Ashgate.

21.2 Individual and team actions

Individual and team actions are the things that people did or failed to do – usually errors or violations – that triggered the accident. They are a normal part of everyday operations in all industries, and result from natural human limitations in combination with conditions inherent in the task or workplace.

The actions by an individual or team that contributed to this accident were:

- The driver became unable to control the speed of the train because of incapacitation (involuntary action).
- The guard failed to attempt communication with the driver or apply the emergency brake in his compartment after identifying that the train was travelling at excessive speed (lapse or mistake²³).

21.3 Task, environmental and human conditions

The conditions existing immediately prior to an accident or incident influence how people act, frequently increasing the likelihood of an error or violation being committed. These conditions involve the task itself (for example, complexity, workload), the environment (for example, temperature, lighting, noise), people's physical or mental states, and social, cultural or life circumstances.

A multitude of task, environmental and human conditions can be identified following any accident. It is important to distinguish between those that contributed to the event and those that may be otherwise interesting, but were not part of the accident chain. Relevant conditions in this accident are:

- The driver had a potentially incapacitating medical condition that was not detected and addressed.
- The driver was working his second day of early morning shift after returning from extended period of leave and was likely to have been affected by fatigue resulting from circadian disruption.
- The deadman pedal system was ineffective as a defence against driver incapacitation as a driver weighing more than 110 kg could depress the deadman pedal without conscious effort.
- Deadman system deficiencies, first observed soon after the Tangara was introduced into service in 1988, remained uncorrected at the time of the accident.
- An authority gradient existed between SRA drivers and guards, which may have inhibited the development of effective teamwork within train crews.
- SRA guards were not required to demonstrate competence in effective communication and critical decision making in emergency situations.

²³ A lapse is defined as the failure to carry out an action, typically involving memory failure (e.g. forgetting) or attentional control (e.g. being distracted). A mistake is defined as a failure in judgement or knowledge that results in the action taken (or not taken) failing to produce the desired outcome.

- The concept of joint crew responsibility for train safety was not well understood or practised.
- Violations of posted track speeds by some drivers occurred frequently on that portion of track.
- The guard's performance could have been impaired by fatigue.

21.4 Organisational factors

Organisational factors influence the conditions under which people work. They result from management decisions, systems, processes and cultural influences. They in turn produce task and environmental conditions, which may lie dormant and undetected for many years before combining with local conditions and human actions (errors and/or violations) to breach the system's defences.

The investigation identified that the following organisational factors contributed to this accident.

- The SRA medical standards were inadequate in that they did not anticipate and manage the risk of potentially incapacitating illnesses in safety-critical personnel (ORG-1).
- The design of the Tangara deadman system was defective, potentially allowing inadvertent or deliberate circumvention (ORG-2).
- Accountability for rectifying a known deficiency in a primary defence against driver incapacitation was not clearly allocated, monitored or enforced (ORG-3).
- The SRA safety management system did not bring to notice and correct known deficiencies in the Tangara deadman system (ORG-4).
- SRA safety culture was deficient in that known hazards and unsafe practices were not addressed (ORG-5).
- SRA rostering practices allowed a possibility of fatigue-induced performance impairment (ORG-6).
- The SRA fatigue management program did not assess the daily fatigue potential of its safety-critical personnel on the basis of actual time worked (ORG-7).
- SRA rostering practices did not consider the potential for fatigue or circadian disruption among crew returning to work after leave (ORG-8).
- SRA had not adequately identified risk management strategies to deal with driver incapacitation (ORG-9).
- Crew responsibilities and operational procedures in an emergency were not clearly documented (ORG-10).
- SRA had not applied a risk-based approach to training curriculum development (ORG-11).
- SRA did not provide dedicated training in crew resource management techniques or human factors principles (ORG-12).

- SRA did not provide crews with effective training in communication and critical decision making or action in emergency situations (ORG-13).
- The performance assessment regime did not ensure that drivers and guards were competent in dealing with emergency or other high risk situations (ORG-14).
- The Regulator did not identify that SRA did not have a risk-based approach to training (ORG-15).
- The Regulator did not ensure appropriate fatigue management and rostering practices within SRA (ORG-16).
- Regulatory oversight of SRA crew certification and competency was ineffective (ORG-17).
- Regulatory oversight had not ensured that defences within SRA against driver incapacitation were effective in principle and in practice (ORG-18).
- The Regulator was inadequately resourced to effectively audit crew training and rail operations, and to investigate safety occurrences (ORG-19).
- The Regulator had not developed effective regulatory oversight of SRA (ORG-20).

21.5 Additional findings

This section lists findings on additional system deficiencies that, while not contributing directly to this accident, are nonetheless significant and in need of corrective action (see Section 22.2).

- The deadman system was susceptible to intentional circumvention through a variety of methods.
- Some drivers had intentionally circumvented the operation of the deadman system.
- There were weaknesses in the SRA certification regime, which could result in an uncertified person being rostered to do rail safety work.
- The Regulator had not required operators to specify and validate standards for professional qualifications and competence of rail safety specialists as part of the accreditation process.
- Some individuals in safety specialist positions in the rail industry did not have the equivalent professional education, skills and experience that would be expected of a safety practitioner in other safety-critical industries.
- The design position of speed boards was not consistent with Network Rule NSG 604.
- The actual position of speed boards was not always consistent with the design position.
- The overall timetable for C311 was theoretically achievable but only by perfect train and driver performance. There were certain sections over which the timetable could not be achieved under any circumstances while complying with the speed boards.
- Network Rule NSG 604, introduced in November 2001, had fundamentally changed the interpretation of speed boards but neither the physical position of the speed boards nor the timetable had been reviewed to account for this change.
- Two separate databases could be accessed to provide the same training information relating to crew certification, but provided different results on the certification status of the guard.
- The emergency equipment that was stored under the guard's seat was not secure in a roll-over accident.
- No record of application or approval of the driver's secondary employment was discovered during examination of SRA documents.
- The SRA approach to 'joiner rights' circumvented some of the safety-related controls that were part of the train crew sign-on process.

22.0 RECOMMENDATIONS

The recommendations below are divided into two sections, the first covering those related to factors that directly contributed to the accident and the second to those addressing other system deficiencies that came to light in the course of the investigation.

22.1 Recommendations related to contributing factors

1. *That the board of SRA prepare a strategic plan to bridge the gap between existing safety and risk management practices and best practices in these areas, which clearly sets out;*
 - *Plans to improve the organisational safety culture*
 - *Identified target dates*
 - *The provision of appropriate safety and performance measures to test the efficacy of the strategy*
 - *The embedding of skilled safety specialists in operational areas*
 - *Demonstration to the Regulator that there is individual accountability for safety at all levels*

The SRA board should report quarterly to the Regulator on the implementation and success of this plan.

2. *That the SRA internal safety auditor should report directly to the SRA board.*
3. *That pending the adoption of a national standard through the National Transport Commission (NTC) process, the Rail Safety Regulator mandate medical standards for train crews and other railway safety workers to provide for predictive and preventive management of potentially incapacitating medical conditions, with due regard for functional-based risk assessment of each category of worker. Such standards should make provision for psychiatric conditions as well as the more traditional medical conditions.*
4. *That the medical standards mandated by the Rail Safety Regulator have disqualification provisions for individuals with potentially incapacitating medical or psychiatric conditions, particularly for single driver operations.*
5. *That the Rail Safety Regulator prepare a set of guidelines in relation to the application of medical standards in the rail industry for use by medical examiners who conduct periodic medical examinations of safety-critical rail personnel. The guidelines should:*
 - *Set out the minimum qualifications required of a medical examiner conducting examinations;*
 - *Refer the examiner to the mandated standards required of personnel in the rail industry;*
 - *Provide a plain English explanation of the work functions of each category of rail safety worker , so that Examiners can consider this in assessing rail personnel*

6. *That the medical standards mandated by the Rail Safety Regulator prescribe a process of regular review to ensure that the standards are maintained at a level of best practice in medical and occupational health aspects.*
7. *That all operators expedite the application of the revised medical standards to rail safety workers by applying risk profiling to identify and prioritise potentially high-risk individuals.*
8. *That all accredited operators take immediate action to ensure that no cab-based equipment could be deliberately or inadvertently used to circumvent the deadman system or any other safety device.*
9. *That SRA address as a matter of urgency the latent technical deficiencies identified in the deadman system fitted to the Tangara (and other) trains, particularly in relation to deadman foot pedals and the risk associated with drivers with a body mass greater than 110kg.*
10. *That the Rail Safety Regulator commissions an appropriately funded project to research options available to integrate contemporary technology with existing and developing deadman, vigilance and speed-envelope systems. The research should include risk assessments of each option. In particular, the research should examine tamper-proof processes in which driver alertness and/or vigilance and incapacitation can be continuously monitored and managed.*
11. *That the Rail Safety Regulator use the results of the study into deadman systems to define guidelines against which deadman systems will be assessed and audited.*
12. *That rail operators ensure that the progressive FAID scores (or the equivalent) for individuals are assessed on both master rosters and actual hours worked, as part of the fatigue management program.*
13. *That rail operators immediately review and, if necessary, update rostering policies to accommodate an acclimatisation period for rail safety workers returning to shift work after an absence or leave.*
14. *That the Rail Safety Regulator in conjunction with industry undertake a research project to identify appropriate standards in rostering practices for shift workers returning to work from leave.*
15. *That rail safety workers returning to work from leave be provided with a familiarisation period to allow for a review of safety documentation that was issued during the leave and an update on configuration changes that may have occurred during the absence. Local managers should be accountable for verifying and recording that crews have been provided with and understood this information.*
16. *That the Rail Safety Regulator collaborate with SRA and other operators to develop a guideline for fatigue management across NSW, including a risk based determination of the upper acceptable fatigue limit for train crews and other rail safety workers. A transitional period should be defined for the adoption of these guidelines.*
17. *That all NSW rail operators develop awareness campaigns and formal training programs to educate safety-critical workers on strategies that can*

assist in minimising the effects that fatigue might have on their operational performance.

- 18. That SRA have a formal Safety Culture Survey independently undertaken, with particular emphasis on identifying ALL of the factors that had an adverse effect on safety culture. The survey should include but not be confined to, various managers' interpretation of on-time running imperatives, and the regulator should be consulted on the survey methodology.*
- 19. That SRA clearly specify crew responsibilities and expected crew behaviours in emergency situations.*
- 20. That SRA expedite the integration of "crew concept" values and activities into initial and recurrent training programs associated with train drivers and train guards. This integration should seek to maximise the potential for drivers and guards to operate as interdependent crewmembers who are supportive and cooperative of each other during train operations.*
- 21. That SRA incorporate a risk-based approach to training course design, to ensure that, where appropriate, identifiable hazards are treated by the provision of suitable training.*
- 22. That the Rail Safety Regulator develop and apply audit criteria to assess the effectiveness of SRA's risk based approach to training.*
- 23. That auditors of safety critical training be conversant with the principles of contemporary risk management and have access to expertise in training and development.*
- 24. That SRA nominate a position to be accountable for developing an integrated certification regime, that will ensure rail safety workers in all categories remain competent and correctly certified and cannot be rostered or signed-on for rail safety work without holding correct and current certification.*
- 25. That SRA review and amend the train crew performance assessment process to ensure it effectively assesses and records against all identifiable performance requirements and is accountable.*
- 26. That SRA conduct and provide to the Rail Safety Regulator, a systematic risk analysis which provides a full and complete understanding of whether not providing internal Emergency Door Releases presents an increased or decreased risk to passengers.*
- 27. That the Rail Safety Regulator investigate performance based rollingstock evacuation procedures and equipment and mandate an appropriate standard for all rail operators.*
- 28. That SRA conduct testing to determine if the existing Tangara external Emergency Door Releases will function as intended under all foreseeable conditions, including when a carriage is on its side and a secondary means of activation. Corrective action should be taken if recommended by these tests.*
- 29. That officers of the Rail Safety Regulator who are involved in accreditation and audit, be trained in Safety Management Systems and Risk Management.*

30. *That the Rail Safety Regulator expand the existing audit regime to include specific Safety Management Systems audits of accredited operators.*
31. *That the Rail Safety Regulator be provided with all appropriate resources to fulfil its accreditation, audit and investigation responsibilities.*
32. *That SRA amend its Safety Management System to include a dynamic hazard register and reporting system, that is applied across all divisions and recorded centrally, and that the Rail Safety Regulator include this in its Safety Management System audits.*
33. *That SRA initiate a program to ensure that employees at every level of the organisation understand and carry out their responsibilities under the Safety Management System.*
34. *That SRA conducts a formal review of how the Tangara performed in this accident in relation to crashworthiness. The results of this assessment are to be presented to the Regulator.*
35. *That SRA further assess the dynamic performance of Tangara to identify any factor that may promote overturning.*

22.2 Recommendations related to additional findings

36. *That the Rail Safety Regulator require all accredited rail organisations in NSW to ensure that any risks associated with configuration changes are managed by the application of a configuration change control process.*
37. *That the Rail Safety Regulator develops and applies an audit function specifically to the staff certification records of operators.*
38. *That the Rail Safety Regulator develop and implement a capacity to randomly and regularly sample that rail safety workers are carrying the correct and current certification.*
39. *That the Rail Safety Regulator develop a guideline for a standard form of recording the certification details of individuals.*
40. *That the Rail Safety Regulator has continuous access to the certification databases that are maintained by operators. Field staff conducting safety inspections should have ready access to certification information.*
41. *That RIC review the design position of all speed boards, to ensure consistency with NSG 604.*
42. *That RIC have a continuous program to review the actual position of all speed boards, to ensure consistency with design position, and that an accountable person certify the accuracy of speed boards.*
43. *That SRA provide the Regulator with a program to appoint an accountable person to review its timetable, using a risk based approach, and eliminate any conditions where the timetable cannot be achieved while maintaining compliance with the track speed, stopping pattern and other operational safety requirements, and that the accountable person certify the timetable as free of incompatible goals.*

44. That SRA maintain evidence of an ongoing program for an accountable person to review its timetable, using a risk based approach, and certify that it is free of incompatible goals. This will be particularly relevant to configuration changes that may occur.
45. That the Rail Safety Regulator issue a guideline on the demonstrable competencies required of a 'rail safety specialist' that is consistent with the definition of a qualified safety professional as it appears in the safety industry.
46. That the Rail Safety Regulator require that any safety specialist within the rail industry not in possession of adequate qualifications, commence a professional development program to be completed within a nominated time, to achieve the skills consistent with the definition of a 'rail safety specialist' as a condition of retaining their position.
47. That SRA implement a train operations quality assurance program, based on routine datalogger surveillance, which will support training and other programs designed to ensure safe driver behaviour.
48. That SRA secure all cab based features and equipment so that they cannot become projectiles during a derailment or roll-over.
49. That SRA rename the crew competency training program to accurately reflect its objective.
50. That emergency procedures within the Rail Management Centre be reviewed and developed so as to enable the most expeditious identification, evaluation and response to emergency situations, and to ensure unambiguous and coordinated communication within the Rail Management Centre and with external contacts, including stations, signal boxes and emergency services.
51. That Rail Management Centre staff be trained in the evaluation of information and implementation of emergency procedures, with the procedures validated through exercises.
52. That train guards be provided with effective and reliable communications equipment for use in emergencies, with regard to the potential for one or both crewmembers becoming incapacitated.
53. That the emergency plans of RIC/SRA make provision for facilitating as fully as possible, the provision of information to emergency services, and their access to all railway property.
54. That the SRA emergency plan clearly state the role of the Rail Commander at major accident sites. This should include immediate actions, site control liaison, decision-making authority, site safety, site security and the training required to fulfil this role.
55. That a definition and procedures be developed for providing a form of interim electrical system isolation, that provides accident site safety and permits rescue operations to commence, before full isolation procedures have been completed.
56. That Rail Management Centre emergency plans require the Electrical Operations Centre to implement the procedure mentioned in No. 55, whenever information indicates that a derailment or other major incident

has occurred on a main line, until it can be established that no hazard exists.

- 57. That the emergency plans of SRA, RIC and other operators reflect the investigative obligations of the Rail Safety Regulator, under the Rail Safety Act 2002, and the requirement to preserve evidence.*
- 58. That the Rail Safety Regulator develop a critical response capability and accident investigation procedures applicable to its role in transport accidents.*
- 59. That a Memorandum of Understanding, or other protocol, be developed between the Rail Safety Regulator and the NSW Police regarding rail accident investigation in NSW, with provision to extend this protocol to other transportation modes for which the Regulator is responsible.*
- 60. That the infrastructure owner conduct regular emergency procedures exercises involving the rail industry and emergency services, to be held in the various regions.*
- 61. That SRA provide local managers with criteria against which secondary employment applications can be assessed. These criteria should include opportunities to assess fatigue through FAID.*
- 62. That SRA introduce robust controls in relation to the enforcement of the crew secondary employment policy.*
- 63. That SRA impose robust controls upon the provision of safety documentation to rail safety workers commencing work.*
- 64. That the Regulator and SRA jointly investigate 'joiner rights' to identify all the risks associated with the practice and to identify any controls that may be applied to the identified risks.*
- 65. That the Rail Safety Regulator be appropriately resourced and skilled to fulfil its role.*
- 66. That the Rail Safety Regulator and SRA meet so that the Regulator can provide any clarification which SRA requires in the interpretation of these recommendations and so that the Regulator and SRA can agree on the implementation actions required. SRA should produce implementation plans, including timescales, for each recommendation, which are acceptable to the Regulator, and report quarterly to the Regulator on the implementation of these plans.*

23.0 ACKNOWLEDGEMENTS

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- University of Sydney
- University of NSW
- Unisearch Limited
- LEAP Australia
- New Dawn 3D

24.0 APPENDIX A – MEDICAL STANDARDS FOR TRAIN CREWS

24.1 General

The medical standards for SRA train crews in January 2003, including medical examination standards and the intervals at which they were to be carried out, were contained in a document titled 'Medical Practices and Procedures', fifth edition December 1995, published by the State Rail Authority of NSW. The Rail Safety Regulator accepted the predecessor of this document when it was offered by SRA in support of an accreditation application in 1994. The basis for acceptance was historical usage and the absence of any statistical data on incidents to suggest that the practices were not appropriate. The Regulator did not have standards to compare the document against and did not consult medical experts for advice on the acceptability of the document's contents. Subsequent accreditation applications referring to the 1995 document were accepted on the same basis. No documentation has so far been identified to indicate that the Regulator assessed or analysed the 1995 document in relation to subsequent accreditation applications.

The NSW Regulator, as chair of the Australian Regulators (State jurisdictions), instigated a review of medical standards in conjunction with Victoria and the National Road Transport Commission in September 2002.

Expert witnesses at the Special Commission of Inquiry into the Waterfall accident testified that medical knowledge had advanced significantly since the SRA document was developed in 1995, but the SRA standards did not advance with them. These witnesses also indicated that SRA management had been alerted to the fact that the SRA procedures were deficient and needed to be reviewed and updated to keep them in line with best practice.

SRA advised that its 1995 document was reviewed in October 2001 and actions were initiated in February 2002 to replace it. By September 2002, SRA had commenced a program of functional analysis and risk assessment of various safety-critical roles as a prelude to the adaptation of the revised Victorian medical standards to its own requirements. SRA plans to fully implement the new standards for drivers, guards and track-side workers by December 2004. Until this implementation program has been completed, SRA plans to retain the use of the 1995 procedures.

The investigation team included an occupational medical practitioner who assessed the SRA 'Medical Practices and Procedures' document against contemporary medical standards and practices for transport safety workers. The comparable documents included:

- 'Guidelines for Health Assessment for Work'. Australasian Faculty of Occupational Medicine, Royal Australasian College of Physicians. Oct. 1998;
- 'Designated Aviation Medical Examiners Handbook'. Civil Aviation Safety Authority (CASA). Feb. 2003;
- 'Draft National Medical Guidelines for Rail Organisations'. June 2000;

- ‘Medical Examination Guidelines for Authorised Practitioners’. Public Transport Corporation (Victoria). July 1997; and
- ‘Annex to the Code of Practice. Guidelines for Health Professionals Conducting Assessments for Rail Safety Workers’. (Version 6 – draft replacement document for Victorian guidelines above.) 10 April 2003.

24.2 Background

The SRA medical standards provided general and essentially limited guidelines in relation to determining medical fitness for work for specific categories of employees. The standards did not contain sufficient information to ensure that examining medical practitioners were made familiar with the nature and medical requirements of the work performed by employees being examined. There was no obvious direction for the selection and authorisation of medical practitioners to undertake SRA occupational medicine assessments. The medical standards did not require practitioners to be assessed for their skills in occupational medicine history-taking and examinations. In this context, and with the possible exception of specific hearing and vision-related activities, there was no guarantee that the application of the standards would have resulted in adequate SRA occupational assessments being conducted.

Additionally, the lists of medical conditions requiring careful assessment for safety purposes were incomplete and, in a number of instances, lacked detail on particular levels or standards. Few procedures were included to provide assessors with guidance on actions to be undertaken in the event that they identified significant medical conditions. The frequency of assessments was significantly less than those of the annual requirements specified for aviation medicine examinations.

24.3 Medical aspects

In regard to the driver of C311’s identified medical conditions, namely hyperlipidaemia and obesity, the SRA document was largely silent. Of note was that, in addition to these two conditions, the driver had age, inactivity and maleness as positive cardiac risk factors. It was stated in the SRA standards document in regard to pre-employment examinations that: *“Applicants with a Body Mass Index >30 are not generally found to be medically fit. However, if the examining doctor regards the person as fit for the job, the person may be considered medically fit.”* No guidelines for existing employees were provided in regard to obesity, although this condition was referred to in the introductory paragraph of Section 3. There were also no guidelines, either pre- or post-employment, for hyperlipidaemia. Thus, although the driver’s BMI was 34.3, bordering on morbid obesity, and he had significant hyperlipidaemia with other cardiac risk factors, he was declared fit at the time of the periodic medical examination (PME) in May 2001. This situation was inconsistent with the comparative requirements of CASA.

The requirement in Section 3 of the SRA document to have a resting electrocardiogram (ECG) as part of the PME was consistent with occupational medicine and, specifically, aviation medicine practice. However, as resting ECGs may have limited diagnostic value, CASA

additionally required the estimation of serum lipids and, for individuals who scored 15 or more points on the American Heart Association Coronary Heart Disease Risk Factor Prediction Chart, five-yearly stress ECGs to age 60. The intent of this requirement was to identify individuals who had an annual risk of an adverse cardiovascular event that was greater than one per cent. The negative predictive value of this process (i.e.: the proportion of individuals who pass the stress ECG test and who do not have cardiac disease) has been stated as being greater than 99 per cent. The score on this chart for the driver of C311 was 20 points. Had he been a commercial or airline transport pilot, he would have been subjected to stress ECG and other testing, and his underlying coronary artery disease would most likely have been detected, resulting in licence withdrawal.

The SRA document contained a statement in the section on PME that: *“Employees should be removed from driving duties if they suffer from a medical condition which the examining doctor considers would put them at risk of sudden loss of consciousness”*. The statement was followed by a brief mention about the fitting of deadman devices and, in some instances, vigilance control devices. There was no clarification or discussion as to the potential relationship between loss of consciousness and the activation or non-activation of such devices, which may have given assessors a false sense of security. Indeed, paragraph 3.7.1 reinforced the trust placed in these devices as it suggested that a driver with diagnosed cardiac ischaemia or previous infarction may continue driving if a deadman device was fitted. Nonetheless, Section 3.8, Medical Restrictions, may have been in conflict with 3.7.1, as it gave medical examiners the option to specify work restrictions for employees with uncontrolled cardiac conditions.

The draft ‘National Medical Guidelines’ proposed annual periodic medical assessments for individuals over 50 years of age. Enhanced job task analysis was also addressed to assist with determining fitness for employment, along with significantly increased detail in relation to guidance and procedures following identification of significant medical conditions. For individuals whose BMI exceeded 30, a practical anthropometric assessment only was proposed. No predictive assessments for cardiovascular disease were incorporated.

The draft ‘Guidelines for Health Professionals’ (Victoria 2003) provided comprehensive guidelines and procedures, based on evidence and risk management principles. In many respects, this was similar to the CASA handbook. In particular, occupational medicine and industry knowledge requirements were stated for examining medical practitioners, significant safety-related medical conditions were fully addressed and the use of the Coronary Heart Disease Risk Factor Prediction Chart was stipulated. However, there were some voluntary aspects relating to examiner competencies and the provision of key information (such as sick leave, workers compensation and incident records) to examiners. The latter was used to support a reduced frequency of assessment (five-yearly to age 55). An annual risk of an adverse cardiovascular event which was greater than two per cent was applied as the threshold for undertaking a stress ECG. Additionally, the Victorian draft guidelines expressed specific reliance on deadman and vigilance devices.

24.4 Psychological and psychiatric aspects

In regard to the guard's principal identified medical conditions, namely anxiety and depression, the SRA 'Medical Practices and Procedures' document stated, at Section 2 (Pre-employment Examinations), that applicants were generally considered to be unfit if they suffered from major psychosis. It did not specifically refer to anxiety and depression. However, Section 2.3.8 stated that the regular use of antidepressants "*should be viewed with caution*". Section 3, Periodic Medical Examinations, applicable to current employees, referred to "psychological conditions" in the preamble. No guidelines were subsequently provided for psychiatric or psychological conditions or how to assess them.

The various documents referring to medical standards that were reviewed as part of the assessment of the SRA 'Medical Practices and Procedures' document incorporated medical standards and guidelines in respect of psychiatric conditions, including anxiety and depression, to varying degrees. The CASA DAME Handbook was extensively detailed in this regard and included specific elements on mental status assessment and post-diagnosis procedures. The current Victorian document had mental health as a question in the pre-examination questionnaire and the proposed national rail guidelines had a section on a range of psychiatric conditions. The proposed Victorian guidelines were comprehensive and incorporated the formal requirement for a psychological screening questionnaire.

24.5 Driver and pilot medical standards

The CASA standards were designed to ensure the medical fitness of pilots who could exercise all the privileges of their licences as they related to transporting passengers in aircraft. Train drivers operate trains for the mass transport of passengers, sometimes more than 1,500 people in a train at a time. It is noteworthy that an aircraft carrying a large number of passengers would be crewed by both a pilot and a co-pilot who, unlike the guard of a train, either pilot would be physically able to see the person flying and would have available a set of controls with which to take over in the event of that person's incapacity. The medical standards for train drivers should ensure that those drivers are medically fit to perform all tasks possible under their certifications, as is the case for pilots. The standards should also ensure that the efficacy of the medical standards is not reduced because of the expectation that a deadman or vigilance system will compensate for lower levels of risk management.

24.6 Conclusions

The comparative analysis of the various documents containing medical standards and procedures led to the following conclusions in relation to the 1995 SRA 'Medical Practices and Procedures' document:

1. The SRA document was inadequate in ensuring that appropriate occupational health assessments were conducted for SRA safety-critical personnel, in particular regard to examiner competencies and task knowledge.

2. Medical examiners were provided insufficient guidance on required standards and actions to be taken following identification of significant medical conditions.
3. Periodic medical examinations were undertaken at significantly lower frequencies than those stipulated for safety-critical personnel in the aviation industry and were also less frequent than those required for comparable rail employees in Victoria.
4. The SRA document indicated significant reliance on deadman and vigilance devices in the presence of medical conditions which predisposed to sudden loss of consciousness. The investigation medical adviser considered this a highly questionable practice, as these devices represented the last line of defence.
5. The guard's PME in March 2002 did not meet the requirements of the SRA document in respect of train guards in that it was not a full medical examination.
6. The SRA document lacked predictive risk elements and did not meet best practice standards for occupational health assessment guidelines.
7. Neither the medical examination guidelines applicable to Victorian rail personnel (1997) nor those proposed for national adoption offered significant advantage over the SRA document.
8. The draft Victorian (2003) guidelines offered remedies to many of the deficiencies in the SRA document. Nonetheless, the proposed extended assessment frequencies, raised threshold for action on cardiac risk and a reliance on deadman and vigilance devices were potentially problematic.

25.0 APPENDIX B – FATIGUE

25.1 General

There has been a global imperative to research fatigue and its effects because of the negative impact fatigue has been demonstrated to have on human performance and safety in industrial settings. Fatigue particularly affects cognitive functioning, motor skills, situational awareness and general performance.²⁴

In October 2000 the Australian House of Representatives Standing Committee on Communications, Transport and the Arts published a report of its extensive inquiry into managing fatigue in transport.²⁵ This report identified the main causes and impacts of human fatigue in the Australian transport industry, discussed how fatigue was being addressed, and considered new strategies for effectively managing fatigue in the transport industry.

This 'Midnight Oil' report underscored the fact that fatigue was recognised as a serious safety concern in all modes of transport and many other productive industries. Fatigue posed a serious threat to competent operator performance and increased the potential for human error. Human error continues to contribute to the vast majority of transport accidents.

The effects of fatigue include decreased vigilance, inability to concentrate, forgetfulness, apathy, poor judgement and acceptance of degraded performance. Fatigued workers find it increasingly hard to concentrate, have difficulty with decision making and may have to recheck information several times as a result of impaired memory or an inability to process information. Alertness is decreased and reaction times are increased.

Increased drowsiness and episodes of microsleep can be experienced by fatigued individuals. Evidence suggests that microsleeps are responsible for a large proportion of motor vehicle accidents where drivers lose control of their vehicles.

The onset of fatigue is insidious; individuals cannot readily discern the initial effects. A fatigued individual may not be aware of the gradual and cumulative effects of fatigue and consequently may be unaware that their own performance has become degraded.

The main causes of fatigue are a lack of recent sleep or continuous wakefulness (acute fatigue), cumulative sleep loss over a period of days (chronic fatigue) and the disruption of circadian rhythms. Acute fatigue can result from recent sustained periods without adequate sleep and/or intense physical or mental activity. Chronic fatigue develops progressively over longer periods of time, when several periods of contiguous acute fatigue are experienced without adequate opportunity for the body to recover through

²⁴ Åkerstedt, T., Czeisler, C., Dinges, D. F., & Horne, J. A. (1994). Accidents and sleepiness: a consensus statement from the International Conference on work hours, sleepiness and accidents, Stockholm. *Journal of Sleep Research*, 3: 195.

²⁵ House of Representatives Standing Committee on Communications, Transport and the Arts. (2000). *Burning the Midnight Oil*. Canberra.

restorative sleep. Shift workers and long-haul airline crews are among those commonly affected by circadian rhythm disruption.

25.2 Circadian disruption

Parts of the transport industry frequently maintain a continuous 24-hour, seven-day-a-week schedule. Their human workers, however, operate on an alternating work-rest schedule, under the control of the body's various circadian rhythms. Shift work requires people to adopt a work-rest routine that conflicts with the body's natural cycles. This clash of schedules results in circadian disruption that affects individual performance capabilities, behaviour and attitudes.

The circadian biological clock is located in a small area of the brain called the suprachiasmatic nucleus²⁶, found within the hypothalamus. This centre effectively programs people to sleep at night and to be awake during the day. It co-ordinates the daily rhythms that exist in the diversity of physiological and behavioural functions of the body and is itself synchronised by time cues from the environment, notably sunlight, work schedules and social factors. The quality and duration of sleep each depend on when sleep takes place in an individual's circadian cycle.

Research into circadian disruption experienced due to travel between different time zones (commonly referred to as 'jet lag') indicates that an individual's bodily rhythms take about one day to adjust to every hour of time zone change. For example, if an individual travels from Sydney to Paris, which is a difference of nine time zone hours, it will then take about eight or nine days for that person's bodily rhythms to fully adapt to the new time zone. Circadian disruption experienced due to such jet lag has many similarities with that resulting from shift work, where parallels can be drawn with the theoretical time required for complete adaptation to a new shift cycle. This phenomenon has been referred to as 'industrial jet lag'.

It should be noted that this does not mean that international travellers or shift workers will necessarily feel jet-lagged for more than a week after making respective large time zone or shift changes. The most conspicuous symptoms of the fatigue produced by this state (for example, drowsiness, decreased vigilance, inability to concentrate, apathy, etc.) will be most evident within the first few days within the new time zone or shift cycle. After that time the effects on an individual's bodily rhythms are subtler and more difficult to detect.

Any industry that involves 24-hour operations will require part of its workforce to try to override the basic diurnal orientation dictated by the circadian clock. This sets up a situation where the circadian clock receives conflicting time cues from the environment.²⁷

²⁶ A discrete brain region lying within the hypothalamus and responsible for the generation of circadian oscillations.

²⁷ Gander, P.H., Gregory, K.B., Connell, L.J., Miller, D.L., Graeber, R.C., & Rosekind, M.R. (1996). *Crew factors in flight operations, VII: Psychophysiological responses to overnight cargo operations*. Moffett Field, California: NASA Ames Research Center.

Night work, for example, tends to draw the body clock around to a reversed schedule (the need to sleep during the daytime). However, the night worker is still aware of the normal day and night cycle and the daylight orientation of the rest of the world, and these cues tend to draw his or her circadian clock back to its preferred orientation for night-time sleep. In addition, most shift-workers revert to night-time sleep on their days off and those working rotating shifts change their work schedules every few days or weeks. For many shift-workers, therefore, their circadian clock never fully adapts to any one schedule.²⁸

Those returning to shift work following an extended break or period of leave can experience considerable adaptation problems. During such absences from work most individuals completely adapt to the 'normal' sleep and activity pattern of the rest of society. In fact many individuals over-adapt while on leave, choosing to sleep in and reduce physical activity levels to recuperate from the demands of modern life and work schedules. Readapting to shift work after such absences can thus be even more difficult than making the adjustments required after a routine shift rotation.

Train drivers working a backwards rotating shift (starting earlier each day) have been demonstrated to experience sleep-debt resulting in progressive decreases in subjective alertness and progressive degraded performance in several aspects of their work, including safety-sensitive tasks.²⁹ Extrapolating the results of this research, a driver returning to work from extended period of leave and commencing duty with a series of early morning shifts (requiring him or her to wake eight to nine hours earlier than while on leave) could be expected to suffer considerable performance decrements in the first few days after return to work.

Incomplete adaptation of the circadian clock to a work schedule can degrade productivity and safety in two ways. First, sleep quality and quantity can be compromised if sleep is displaced to part of the circadian cycle when, physiologically, the individual is programmed to be awake. Shorter, less-recuperative sleep increases the likelihood of making errors at work. Second, there are marked fluctuations in the capacity for physical and mental performance across the circadian cycle.³⁰

While the time of peak human performance varies with the nature of the task, impaired performance consistently occurs around the time of maximal sleepiness, which coincides with the low-point in an individual's circadian temperature cycle. This is between 3 am and 5 am for most people on a stable 24-hour routine with most sleep occurring at night. Trying to work through this circadian trough increases the likelihood of hypovigilance and making errors.

²⁸ Smolensky, M.H., & Reinburg, A. (1990). Clinical chronobiology: relevance and application to the practice of occupational medicine. In A.J. Scott (Ed.). *Shiftwork: Occupational Medicine: State of the art reviews*, 5(2), 239-272.

²⁹ Thomas, G.R., Raslear, T.G., & Kuehn, G.I. (1997). *The effects of work schedule on train handling performance and sleep of locomotive engineers: A simulator study*. Washington DC: Federal Railroad Administration, US DOT.

³⁰ Monk, T.H. (1990). Shift-worker performance. In A.J. Scott (Ed.). *Shiftwork: Occupational Medicine: State of the art reviews*, 5(2), 183-198.

It is well established that some individuals are 'morning people', preferring to wake early and go to bed early, while others are 'night people', preferring the opposite. It is likely that an individual who maintains a routine of going to bed late and sleeping in will experience a period of maximal sleepiness later in the morning than the norm of 3 am to 5 am. In this case, the impaired performance associated with maximal sleepiness is also likely to occur later in the morning, for example, between 5 am and 7 am.

25.3 FAID™

The Centre for Sleep Research at the University of South Australia (CFSR) has been researching the determinants and effects of industrial fatigue for the past decade and is the Australian leader in sleep and shiftwork research.³¹ The centre has conducted applied research as a member of the Australian Rail Industry Shiftwork and Workload Consortium since 1994. SRA used a fatigue modelling computer program based on CFSR research findings, FAID (Fatigue Audit InterDyne™), as a tool to assist with the management of work-roster-induced fatigue.

FAID predicted work-related fatigue by taking into account the duration and timing of work periods, work history and the biological components of sleep. FAID also provided indications of levels of performance impairment due to fatigue by modelling against equivalent impairment levels produced via blood alcohol levels. The progressive adoption of FAID across SRA depots for roster management began in the second half of 2002 and commenced at Wollongong depot on 26 January 2003.

The major output of the FAID program was a numerical score between 0 and 140 that provided an indication of the level of fatigue likely to be experienced by an individual working a particular roster. FAID could also be used to retrospectively determine the likely level of fatigue of an individual who has been involved in an occurrence.

As an indication, a FAID score of 40 would be characteristic of a level of fatigue that a normal person working 0900 to 1700 Monday to Friday would be likely to experience at the end of a working week. At a score of 80, the normal person would be likely to experience a level of fatigue approximately equivalent to 200 per cent of that experienced in the average working week. A FAID score of 100 would equate to about 250 per cent of the fatigue experienced in the average working week and a score of 120 would equate to about 300 per cent. Thus as the FAID score rises, the fatigue level experienced and the associated performance degradation likely to be observed will also rise.

³¹ See, for example:

Dawson, D., & Reid, K. (1997). Fatigue and alcohol intoxication have similar effects on performance. *Nature*, 38, p 235.

Dawson, D., & Reid, K. (2000). Fatigue management in aviation: Similarities between the effects of fatigue and alcohol on performance impairment. In B.J. Hayward & A.R. Lowe (eds.), *Aviation resource management, Volume 1*. Aldershot, UK: Ashgate.

Dawson, D., & Fletcher, A. (2001). Quantitative model of work-related fatigue: Background and definition. *Ergonomics*, 44(2), pp 144–163.

From the numerous validations performed by CFJR to date,³² it can be stated that a score below 80 FAID points is consistent with a safe system of work from the perspective of hours-of-work contributing to work-related fatigue. Scores above 100 points have been shown to be consistently associated with performance impairment comparable to that seen in individuals with a blood alcohol concentration (BAC) of 0.05 per cent or greater. When FAID scores are between 80 and 100 points, the degree to which a score is associated with impairment comparable to 0.05 per cent BAC or greater depends on the performance measure used. That is, tests that are particularly sensitive to the effects of fatigue will indicate this comparison with scores closer to 80. Tests that are less sensitive to fatigue will indicate this comparison with scores closer to 100.

A three-day workshop was held in December 2000 to discuss standards and guidelines for fatigue management within SRA (attended by representatives of CFJR, occupational health and safety workers, service unions and train crew management). Following this, SRA adopted a FAID score of 100 as the catalyst for initiating changes to the master roster. While other organisations had adopted lower maximum FAID scores, this was regarded as an achievable and positive first step, to be augmented by a strategy to ultimately and incrementally reduce the threshold for initiating roster changes to a score of 80. The workshop attendees emphasised that the adoption of FAID was intended to manage fatigue and not to limit shift swaps and overtime or reduce wages, and that this concept was to be presented to depot staff at separate workshops.

When they adopted the FAID system, SRA decided to apply it only to the 12-monthly master roster and not to the periodic or daily rosters which more accurately reflect the hours actually worked by employees. The effect of this decision was that there was no realistic ongoing analysis of any individual's progressive FAID score as it might vary from the initial roster plan as a result of factors such as overtime, shift swaps, sick leave and other unplanned activities. The application of FAID to the master roster resulted in individual FAID scores being limited to less than 100 at the time these rosters were compiled. However, in the absence of a process to allow contemporaneous oversight of ongoing roster changes, SRA was unable to monitor or reconcile any elevation of individual FAID scores that may be produced by shift swaps and other modifications to the master roster. Thus, it was possible for individual FAID scores to exceed 100 without managers or employees being aware of the score and the associated increased risk.

SRA have advised that an agreement with the relevant service unions and various administrative resource limitations prevented manual application of the FAID program to the periodic and daily rosters. There were plans for SRA to amalgamate FAID into the periodic roster at the same time that an automated rostering system called OPCREW was to be implemented. This was planned to occur in the fourth quarter of 2003, however OPCREW implementation had been deferred numerous times.

³² Fletcher, A. (2000). *Comparison of performance impairment due to alcohol intoxication and predicted fatigue scores using a range of validated tests*. A report produced for members of the Australian Rail Consortium, March 2000. Adelaide: Centre for Sleep Research, University of South Australia.

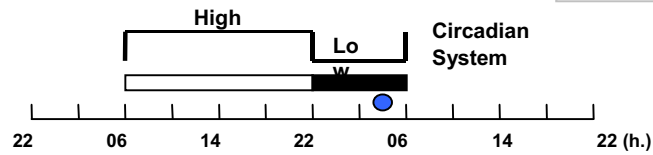
A limitation of the FAID system was that it did not account for individual differences. These differences could include such factors as individual tolerance to fatigue (some people need more or less sleep than others); individual activities outside work hours (such as a second job); the specific demands of individual tasks (for example, driving a train or administrative tasks), etc. However, FAID has been adopted by a number of organisations in a range of industries as a predictive indicator of fatigue-inducing rostering practices and an integral component of fatigue risk management systems.

Driver Circadian Disruption

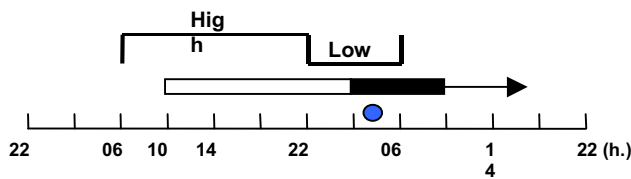
Key

- Activity (white bar)
- Rest/Sleep (black bar)
- Work (hatched bar)
- Circadian temperature low-point (blue dot)

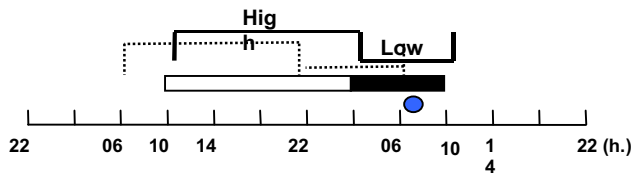
Performance for monitoring/vigilance tasks



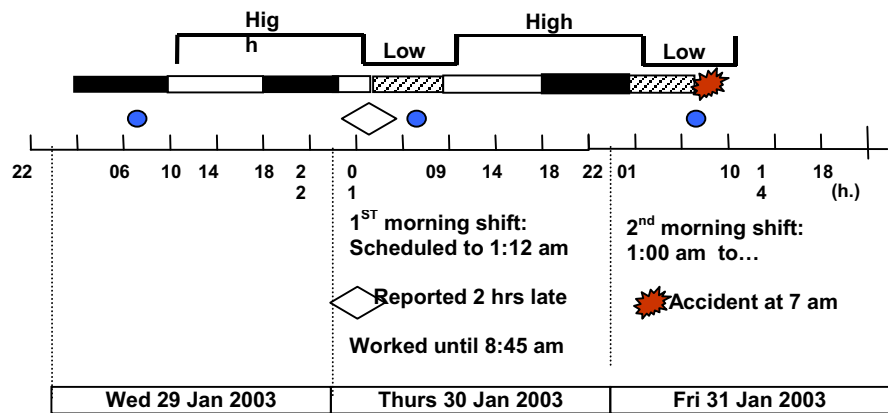
1 Reference: activity /rest cycle adjusted to day/night alternation.



2 Sleep pattern – first days of holidays: Delay of bedtime awakening.



3 After five weeks holidays: Circadian rhythms fully adapted to the new pattern, delayed compared to the reference.



4 Morning shift imposes a new activity/rest pattern: It creates a sudden disruption in circadian rhythms.

1

Reference:

Activity/rest cycle adjusted to day/night alternation.

- Low-point in an individual's circadian temperature cycle is between 3 am and 5 am for most people
This low-point marks a peak of drowsiness and low performance for monitoring/vigilance tasks.

2

Sleep pattern – first days of holidays:

This delay of the activity/rest cycle corresponds to the driver's profile. He and prefers an average of eight hours sleep per night.

3

After five weeks holiday:

Circadian rhythms fully adapted to the new pattern, delayed by several hours compared to the reference.

- Circadian temperature low-point is delayed. The maximum drowsiness and minimum performance time has shifted until around 7 am / 8 am.

4

Return to work on morning shift imposes a new activity/rest pattern:

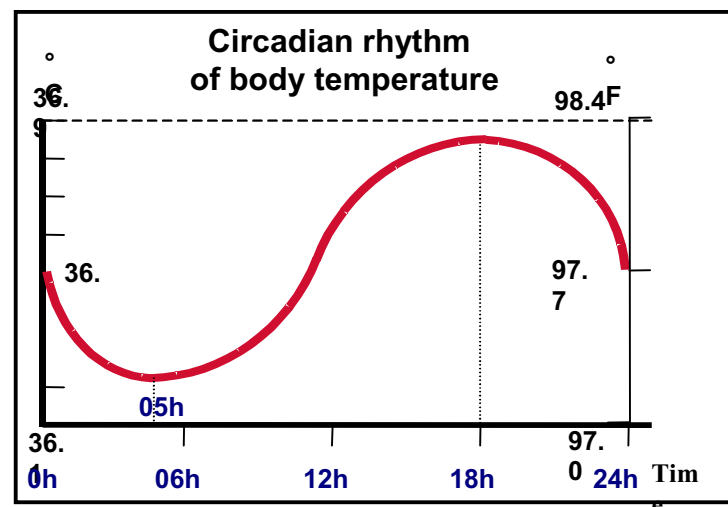
- It creates a sudden disruption in circadian rhythms: it implies going to bed and getting up at much earlier times.
- It draws the body clock around to a reversed schedule (advancing bedtime and awakening). As a result, it creates an internal dissociation – loss of harmony in circadian system.
- The effort required to advance these times is even greater due to the delayed circadian rhythms established during the driver's period of leave. Moreover, a morning shift is harder for a 'night-type' person than a 'morning-type' person.
- Due to its inertia, the biological clock does not immediately adjust to the new activity/rest pattern. Thus the maximum efficiency coincides with the period the driver is supposed to sleep, hence a bad sleep in quantity and quality. The minimum efficiency coincides with the period the driver is working.
- The maximum peak of drowsiness (thermal temperature low point) still occurs around 7 am / 8 am according to the circadian system of the driver.
- Additionally, the circadian disruption causes sleep loss.
- This sleep loss aggravates the drowsiness occurring during the work period (morning shift).
- **The second morning shift** follows the same pattern, sleep loss being accumulated and the resulting fatigue even more increased.

Theoretical Background

The circadian regulation of bodily functions tends to optimise human functional capabilities during the day and decrease them during the night.

The body core temperature rhythm is often used as a standard reference rhythm and is a very good marker of the biological clock. It follows a circadian cycle (a period of slightly more than 24 hours) with a maximum in the evening (36.9°C) and a minimum at about dawn (36.2°C around 5 am), as shown opposite.

The sleep/wake cycle also follows the circadian clock. The duration of sleep as well as its latency and composition are closely related to the body temperature cycle: spontaneous sleep onset starts near the maximum temperature (when body core temperature is declining) between about 10 pm and 1 am (10 pm for morning type people and 1 am for evening type people); sleep taken at this time will have a normal architecture and be longer than sleep taken in the early morning near the thermal minimal around 5 am (when body core temperature starts to increase).



Source: BRIEFINGS 2000, Reference Manual. "A Human Factors Course for Pilots and Aviation Professionals". Edited by Dédale SA and IFSA: September 2000.

