FIGURE 6: Train passes over 'mid-section magnet', driver acknowledges alarm

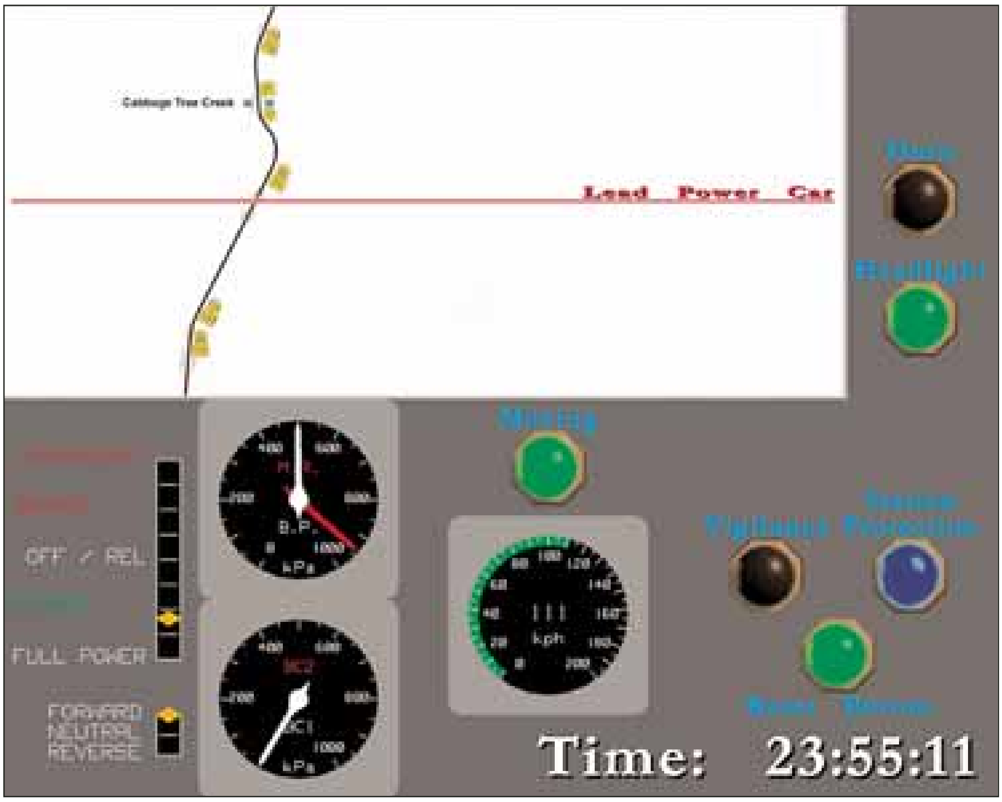


FIGURE 7: Power/Brake Controller in full emergency brake position, train travelling at 112 km/h

The train rapidly decelerated as the leading power car rolled to the right, leaving the tracks and dragging the remaining trailer cars off the track (Fig. 8, 9 & 10). During the derailment sequence the train collided with three overhead power support poles. From all available evidence, VCQ5 derailed 419.493 km from Brisbane (Roma Street) on the first of the 60 km/h curves in advance of Cabbage Tree Creek travelling at a recorded speed of 112 km/h.

The power car skidded on its right side coming to a stop 108m from the point of derailment. Car ‘A’ came to rest parallel to the track. Car ‘B’ slewed so that it was at an angle of about 40 degrees to the line of travel. Cars ‘C’ and ‘D’ jack-knifed and were virtually at right angles to the track. Car ‘E’ came to rest parallel to the track but displaced by between 15m and 20m, probably as a result of the derailing dynamics of the cars in front and behind. Car ‘F’ was also at right angles to the track, while car ‘G’ was to the left side of the track. The trailing power car came to a stop aligned slightly to the left of the direction of travel with its leading bogie derailed. With the exception of cars ‘A’ and ‘B’ all cars became detached and the trailing power car was the only part of the train to remain upright.

FIGURE 8: **Aerial photograph of accident site, showing relative position of power car and trailer cars**

At 2357 the Electrical Control Operator (ECO) Rockhampton contacted North Coast Control by telephone when an electrical circuit breaker tripped on the 25kv AC traction power system. The trip was reported as having occurred at approximately 419 km from Brisbane. North Coast Control immediately identified this site as the geographic location through which VCQ5 was travelling, but did not associate the circuit breaker trip with the possibility of the train’s derailment. However, the Controller did endeavour to contact VCQ5 on several occasions but to no avail. At about the same time a passenger onboard VCQ5 managed to phone through to the emergency services, using his mobile phone, and alerted them regarding the derailment.

This information was relayed back through to North Coast Control and by 0002, seven minutes after the derailment, there was then immediate recognition along with the cues from the ECO Rockhampton that a major accident had occurred. The emergency services were despatched and recovery strategies put in place.

FIGURE 9: Laser survey scan, showing relative position of power cars and trailer cars

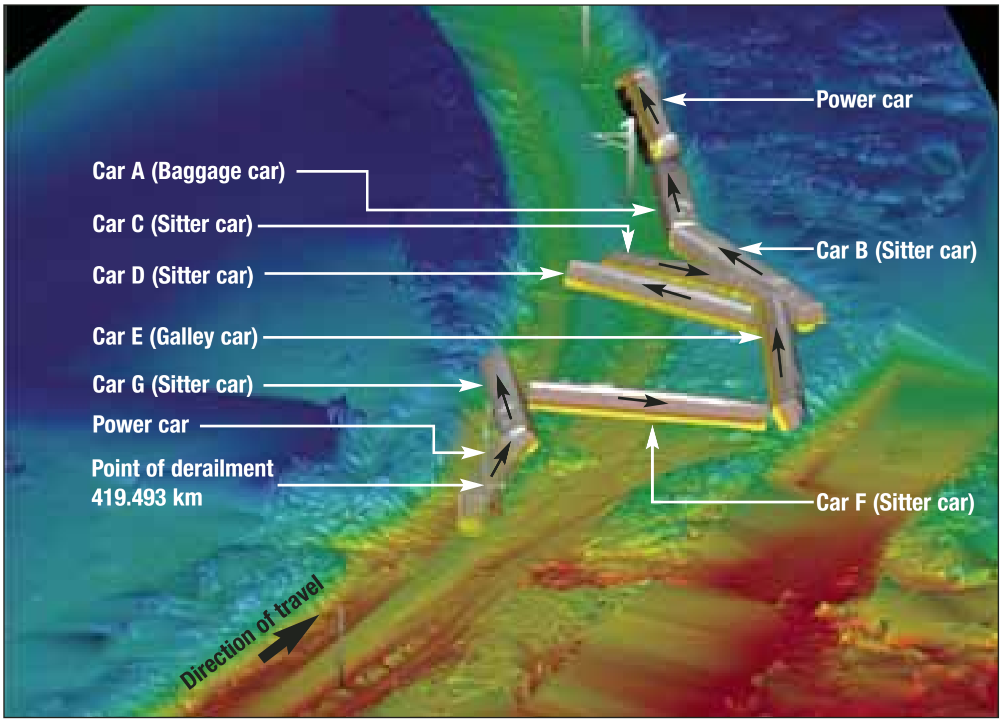
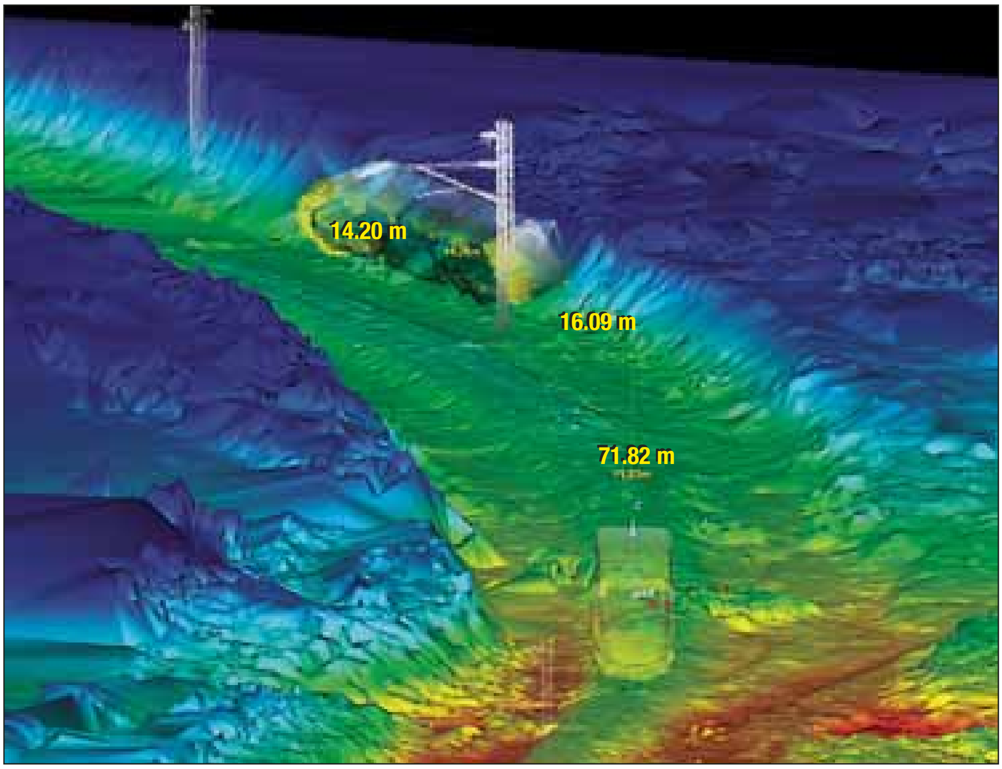


FIGURE 10: Laser survey scan, showing general skid line of power car 5403



Police arrived at the scene by 0044 followed by emergency services personnel and QR recovery teams. Passengers were evacuated from the train and treated on site before being transported to local area hospitals on a priority basis, dependent on injury type and severity.

Those with severe injuries had been evacuated by 0228. All remaining passengers and crew had been evacuated to Bundaberg by 0555. Given the extent of the derailment, its remote locality and time of night it is concluded that the Police, Emergency Services and QR recovery teams were effective and efficient in their handling of the accident.

1.3 Environmental factors

The derailment occurred on Monday 15 November 2004 at 2355. The moon had set four and a half hours earlier at 1923 and was 26 degrees below the horizon which meant the accident site was in complete darkness.

Information obtained from the Bureau of Meteorology (BoM) as detailed in Table 1 and from witnesses has established that at the time of the accident the weather in the vicinity of Berajondo was fine. Berajondo is approximately 63 km north of Bundaberg.

Table 1: Weather Details for Bundaberg on 15/16 Nov 2004 (Source BoM)

Local Time	*Wind Direction (degrees from true north)*	*Wind Speed (km/h)*	*Maximum Wind Gust (km/h)*	*Temp. (degrees Celsius)*	*Relative Humidity (%)*	*Cumulative Rainfall (mm) from 9am*
2300	040	13	17	24.5	85	0
0001	050	11	17	24.6	86	0

At the time of the accident, the temperature was approximately 24.5 degrees Celsius, wind speed was low and visibility was good. There was no discernible rainfall.

1.4 Loss or damage

1.4.1 The train

Damage to the rollingstock was extensive but indications are that all cars are repairable.

1.4.2 Damage to infrastructure

Approximately 120m of track sleepers and ballast was damaged, three overhead traction support poles and associated overhead wiring was destroyed and required replacement.

1.4.3 Cost

The direct costs of the accident including investigation is estimated at $35.5m.

1.5 Train, general information

The Cairns Tilt Trains were built by EDI Rail, Maryborough, Queensland and started service in June 2003. Each train set is 196.8m in length and comprises two high speed diesel power cars, without tilt capability, operating in a push-pull configuration with seven air-conditioned trailer cars, with tilt capability. Each power car is driven by two 12 cylinder turbo charged diesel engines (1350kW) driving through a hydrodynamic transmission and axle drive gearbox combination.

For this ‘down’ journey train VCQ5 was configured so that car ‘A’, a luggage/staff car was immediately behind the lead power car. Cars ‘B’, ‘C’ and ‘D’, behind the luggage car, were passenger cars that could each accommodate up to 39 seated passengers.

Car ‘E’ was a galley/club car followed by two further passenger cars, ‘F’ and ‘G’ each with a capacity of 28 seated passengers.

Timetabled services were based on a maximum permissible/scheduled[4] service speed of up to 160 km/h, track permitting. The train meets current Australian design standards that set high standards of crashworthiness and includes strict fire protection requirements to minimise risk of fire in the event of an accident/collision. Overall, it is concluded that the train offers high levels of safety for the protection of passengers and crew.

As an indirect safety feature, the Cairns Tilt Train is fitted with a locomotive data logger; the information derived from this unit was used to assist with the drawing of conclusions as to the nature of the derailment. The locomotive data logger is a highly valuable diagnostic tool and is also extremely valuable in undertaking accident investigations. The ATSB believes that the universal fitment of locomotive data loggers should be considered by all organisations with locomotives operating on main lines and sidings, subject to an appropriate risk assessment.

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[4] Acceptance tests undertaken by QR on the diesel tilt train were based on an allowance of 10% above the maximum service speed of 160km/h, that is 176km/h.

2 COMMENT AND ANALYSIS (Operational Conditions)

2.1 Introduction

In coming to an understanding of the nature of this accident it is valuable to examine some of the principal mechanisms that may give rise to a derailment, which include:

- Track failure
- Vehicle failure
- Flange climb
- Vehicle roll-over (capsizing).

2.2 Risk assessment

'Accredited Rail Operators' are required to demonstrate safe operations by the submission of a comprehensive safety management system incorporating a comprehensive risk assessment strategy. All risks should be identified and measures taken to remove or reduce those risks to a level that is as low as reasonably practicable (ALARP). Measures to mitigate risk include proper track and infrastructure design, vehicle design, associated maintenance, driver training and measures to control train speed.

In the process of introducing electric tilt train operations in 1998, a comprehensive risk assessment was undertaken by QR to determine whether its infrastructure was fit for purpose. This included the development of a fully documented safety case and an examination of the track as to whether it could safely accommodate the higher speeds associated with tilt train operations. These studies established that the main line from Bundaberg to Gladstone was suitable for tilt train operations.

Following on from this review a maximum operating speed of 160 km/h was designated for tilt train operations. In areas of speed restrictions on curved sections an increase in speed of up to 25 per cent was approved for tilt train operations over the standard speed board limits. The increase in operating speed was determined to be consistent with safe operations given the gauge and other features of the track. New maintenance standards were adopted to ensure high levels of track integrity. Testing of the electric and diesel tilt trains validated that they were capable of sustained and safe operations of up to 160 km/h and could in fact safely operate beyond this limit.

The review undertaken by QR also examined a range of 'Human Performance' issues associated with the running of 'Tilt Train' services. Three primary areas of threat were identified and included:

- Signals Passed at Danger (a driver passing a STOP signal at danger)
- Speed (a driver over speeding) and

- Incapacitation (a driver failing to respond to external stimuli, for example distraction, collapsing due to a medical condition, etc).

Based on its previous operational experience, QR developed a series of strategies to mitigate the risk associated with these threats, which included:

- *Two Driver Operation* (the built in redundancy of having a second observer/driver, to avoid single person error)
- *Vigilance System* (an on board/train system that periodically tests the driver for alertness and applies an automatic brake application if he/she fails to respond to stimuli)
- *Station Protection System* (a track based sensor system for warning a driver when he/she approaches a station area where more alertness is required)
- *Speed Boards* (signage that indicates the safe track speed)
- *Training* (ensuring that a driver is competent to undertake assigned duties including sound Route Knowledge of the track. Training includes checking/monitoring driver performance for Route Knowledge and safety breaches – for example, exceeding mandated speed limits, signals passed at danger (SPADs), etc).

2.3 Track

The section of track from Bundaberg through to Gladstone comprises single line 1067mm narrow gauge with a combination of 47kg/metre and 50kg/metre continuous welded rail (CWR) fastened to prestressed 28 tonne axle load concrete sleepers with Pandrol clips. Sleepers are nominally spaced at 670mm and supported by 250mm of grade 'A' ballast.

The track standards used by QR, STD/0077/TEC, differ from those for the Australian Code of Practice (ACoP) for the Defined Interstate Rail Network (DIRN) in as much as QR operates on a different and narrower gauge, 1067mm, compared to the standard gauge, 1435mm, to which the ACoP apply. A review of the two standards has established that the design assumptions and maintenance standards used by QR throughout this area are safe and fit for purpose. The QR standard provides for levels of safety consistent with that used throughout Australia.

The track through this section was laid and maintained in accordance with QR design standard STD/0077/TEC. The track was regularly examined through a combination of:

- Walking inspections
- Riding on train inspections
- Hi-rail patrol (Road rail vehicle)/inspections
- Track stability inspections
- Concrete sleeper testing
- Track Recording Car inspections and
- Ultrasonic Rail Flaw testing.

The *City of Townsville* derailed on a curve with a radius of 235m and a cant of 51mm. Pre-derailment site data indicated that the track was in good condition. Post-derailment site measurements and inspection data also support this conclusion.

The post accident examination of the track ruled out track buckling and/or track failure due to breakage and/or fatigue. From the information available, it is apparent that the track conformed to QR standards at the time of the accident.

The track through the accident site was laid on concrete sleepers, consistent with QR standards and was suitable for 60 km/h tilt train operations and 50 km/h normal train track speed.

A review of the track including pre-derailment maintenance records and post-maintenance condition has established that there was no design deficiency or defect that directly contributed to the derailment of the VCQ5 on the night of the 15 November 2004. It is also concluded that the track was fit and suitable for tilt train operations up to the design limits established by QR.

2.4 Speed boards, speed control and warnings

Speed boards on the North Coast line should be erected in accordance with QR standard SAF/STD/0015/CIV. At the 419.410 km site, the style and location of the speed board is as gazetted in QR Weekly Notices 44/98 and 45/98. It designates a limit of 50 km/h for normal trains (circular disk), on top of a 60 km/h limit for tilt trains (rectangular board), see Figure 11.

FIGURE 11: 'Speed Board' at 419.410 km

Trains are required to be at or below the prescribed speed limit before passing the board/entering the curve.

QR standard SAF/STD/0015/CIV also provides guidelines for the placement of advance warning signs on the QR network. These signs are intended to give prior warning of a speed reduction of greater than 40 km/h, but were not part of the original design criteria for tilt train operations. Before reaching 419.410 km a tilt train must reduce from a maximum permitted speed of 150 km/h to 60 km/h, a reduction of 90 km/h.

The approach to the curve at 419.411 km was not marked by an advance warning board and such boards are not universally installed on the North Coast Line. At the time of the derailment a QR internal ‘risk review’ was being undertaken with a view to erecting advance warning signs at appropriate sites.

Current QR custom and practice for tilt train operation, relies heavily on driver ‘Route Knowledge’ in recognising geographic position and managing speed accordingly. This practice is common with many rail organisations, both in Australia and overseas. Provided that there is an ongoing program for validating driver ‘Route Knowledge’ and ‘Competency’, the practice as it exists in QR can be regarded as an effective strategy. One of its weaknesses is that under conditions of darkness landmarks are lost, the field of vision is limited and an individual’s spatial awareness may be compromised.

There are technological defences such as ‘station protection magnets’ and Automatic Train Protection (ATP). A ‘mid-section magnet’ is located 415m in advance of the curve at 419.411 km. The train’s data logger shows the alarm as annunciating and being cancelled 13 seconds before the derailment as the drivers’ cab passed over the magnet. The alarm apparently did not alert the driver to the possibility that his spatial awareness was compromised.

Other automatic or semi automatic train management systems are available as operational defences to prevent trains over speeding or colliding. There are significant costs associated with such systems and whether or not such systems are adopted is a matter of the cost benefit such equipment provides or whether alternative strategies reduce the risk to an acceptable level.

2.5 Vehicle (mechanical examination of train)

Following the accident and the collection of on site evidence, the Cairns Tilt Train (CTT) was transported to the EDI Workshops at Maryborough, Queensland. The train was then impounded for further independent examination, before being released to Queensland Rail.

The mechanical examination included:

a) An examination of all rollingstock involved in the accident, with a particular focus on the wheel profiles, suspension, bogies, tilt mechanism and braking systems. No items were identified that would have had any direct or indirect causal affect on the derailment.

b) A review of maintenance and inspection records. This review found some very minor non-safety related procedural and quality control issues, none of these items would have had any direct or indirect causal affect on the derailment.

c) An examination of the general condition of the train through visual inspection of running gear components; including bogies, braking system, structure, etc. No items were identified that would have had any direct or indirect causal affect on the derailment.

d) An independent assessment of the crashworthiness and structural performance of the train found that it performed very well in maintaining the integrity of the passenger compartments. For most of the cars, the body structure stayed relatively intact with only minimum penetration of the passenger compartments. Overall, the damage to the vehicles involved in the derailment showed a high resistance to collapse with only the Power Car 5403 showing major structural damage.

e) A metallurgical inspection of the trailing arms (swing arms) on the leading axle of the lead power car, front bogie (No. M52003) see Figure 12 & 13. During preliminary inspections, site investigators noted that both trailing arms had fractured. Initial concern resulted in the temporary withdrawal from service of the remaining CTT.

The bogie arms were inspected for potential fatigue failure and subsequently cleared. The remaining train was returned to service accordingly.

Metallurgical examination of the fractures on Power Car 5403 has established that:

- The fractures of both leading axle trailing arms from bogie M52003 were typical of a brittle fracture mechanism induced by rapidly applied overload conditions.
- The orientation of the fractures on the arms was consistent with the likely forces sustained by the bogie and axle assembly during the derailment event.
- Neither trailing arms showed any evidence of prior or pre-existing cracking or other physical defects that may have predisposed the arms to failure in the manner sustained.
- Neither trailing arms showed any evidence of having failed or being defective prior to the derailment event.
- The arm material met the mechanical and chemical requirements specified by the manufacturer and is considered fit for purpose.

FIGURE 12: Power Car 5403 bogie M52003

FIGURE 13: Fractured trailing arm – leading axle, left side

It was therefore concluded that the fractures occurred as a consequence of the derailment, that is as a result of the accident and did not contribute in causing the accident.

One factor related to the train equipment that is a possible contributing factor is that of the train headlight. Although the train's headlights were reported to be working as prescribed, a review of internal QR correspondence highlighted complaints from drivers regarding the strength and quality of the lights on the CTT. This was in part related to deterioration in the quality of the headlight covers as a result of normal wear and some minor damage, possibly caused by products used to clean the covers. A review of QR records established that the headlight covers were replaced prior to the derailment on 15 November 2004. Further, an examination of the current Railways of Australia, Code of Practice for Rollingstock, indicates that the headlights on the CTT meet current industry standards, for this type of operation.

In conclusion, a review of the rollingstock including pre-derailment maintenance records and post maintenance condition of the vehicles has established that it is highly improbable that there were defective items or deficiencies with the CTT that either directly or indirectly contributed to the derailment.

From a crash worthiness perspective, the train performed very well. Damage sustained to the vehicles involved in the derailment clearly showed a high resistance to collapse with only the Power Car 5403 subject to major structural damage. Overall the body structure of the cars protected the passengers from major intrusions and this is reflected in the overall survivability of passengers who were on board the train at the time of the accident. The environment of the accident site at Berajondo, with its lack of significant vegetation (large trees) and the nature of the cutting (soft earth embankments) was also probably a factor in the minimising of damage, intrusion into the passenger cars and associated injuries.

2.6 Derailment modelling

Having ruled out vehicle and track failure as possible contributing factors, derailment as a result of 'flange climb[5]' and/or 'roll-over[6]' were theorised as the most likely cause of the accident. Derailment due to 'flange climb' and 'roll-over' can be calculated/modelled where the geometric characteristics of the rollingstock and track are known along with the train speed. In the case of VCQ5 this information was readily available through well documented vehicle/track information, maintenance data and train speed information that were extracted from the train's locomotive data logger.

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[5] Flange climb – In most conventional derailments involving 'flange climb' on a curve, the train wheel will mount the gauge face of the high rail then traverse all or part of the rail head before dropping off onto the field side of the rail. The wheels then generally ride across the sleepers and ballast for some distance before finally coming to rest. With this type of derailment the markings on the rail head and associated track structure are quite distinctive. The rail head will exhibit scoring along all or part of its length and the wheels exhibit damage that is consistent with running over the sleepers and ballast. The sleepers and ballast will generally exhibit damage reflective of wheel set scoring.

[6] Roll-over – In the case of derailment by roll-over, damage at the 'point of derailment' (POD) tends to be absent along with limited damage to the wheels. In the case of the derailment of VCQ5, the absence of damage to the wheels on the leading bogie was initially a strong indicator that the mechanism of derailment was as a result of roll-over (capsizing), thereby suggesting over speed. In addition, the wheel tread in a rollover event often displays distinctive spiral markings that are not found in a flange climb derailment, however these markings were not evident on this occasion.

Calculations for the ratio of lateral over vertical (L/V) wheel/rail forces were made to determine whether a derailment by 'flange-climb' was likely to have occurred. These values were found to be small, such that derailment by this mode was most unlikely.

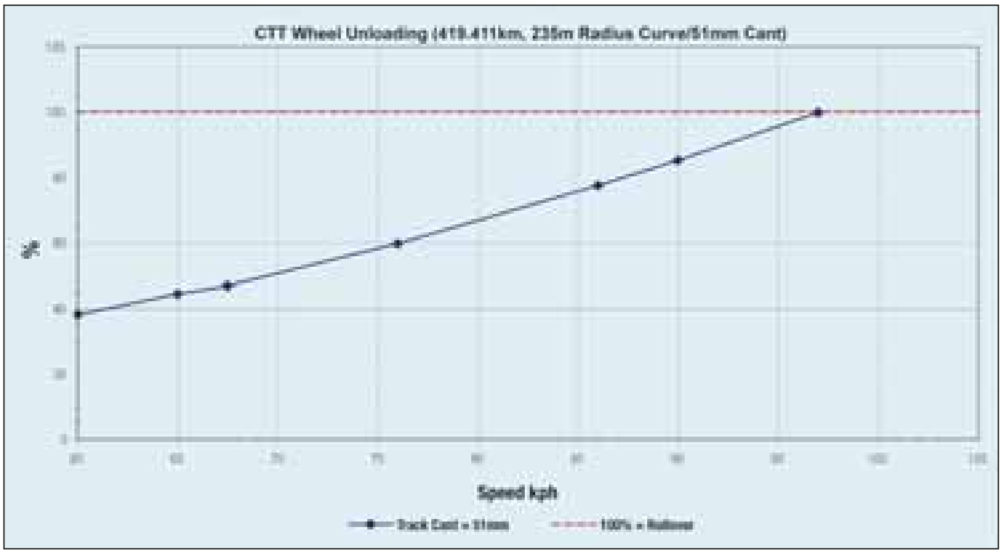
Subsequent modelling concentrated on 'roll-over' as the likely mechanism. Two principal analysis techniques were used in the evaluation, force-balance equation and Vampire[7] modelling.

As a general rule, roll-over will occur when the centre of gravity of the train acts just beyond the vertical of the outer running rail. The Vampire modelling established that 100 per cent wheel unloading for the lead power car through the first 60 km/h curve occurred at 97 km/h.

The modelling, supported by force-balance calculations and field observations, has led to the conclusion that the lead power car rolled and then dragged the remaining trailer cars off the track before all units came to rest. Figure 14 below is a graph of 'wheel unloading, (front left)' vs 'speed' for the CTT on a 235m radius curve with 51mm cant.

As there was no evidence to suggest that there was a malfunction in the rollingstock or infrastructure, the evidence points to excessive train speed as the most likely cause of the derailment.

FIGURE 14: Wheel Unloading vs Speed



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[7] Vampire' is the name of a commercially available railway vehicle dynamics computer simulation program. Simulations undertaken using Vampire include the full vehicle suspension characteristics, so the effect of the vehicle body moving laterally and in roll is included in calculations. 100% wheel unloading represents theoretical commencement of rollover.

2.7 The drivers – training and qualification

Driver training and safety policies/procedures are primary defences against unwanted errors. Drivers engaged in tilt train operations are trained in accordance with QR safety policies/procedures and monitored for acceptable performance. As part of the performance monitoring process, drivers are required to demonstrate to 'tutor drivers' that they have a detailed knowledge of the train and route over which they operate, in this case the CTT and the Brisbane to Rockhampton route respectively. The CTT training course is designed to bridge experienced drivers in the operation of the tilt train and comprises:

- 2.5 days of theory and a half day examination.
- 1 day of static on board training, covering powering up/shutting down, towing the train, etc and a half day examination.

In addition drivers undertake a minimum of two full journeys accompanied by a 'tutor driver' who observes and instructs the driver as required.

Table 2: Driver & Co-driver details

Driver Details	*Driver*	*Co-driver*
Gender	Male	Male
Qualifications	Driver Class II	Driver Class II
Experience	Extensive	Extensive
Trained/Re-trained	Yes to QR Standards	Yes to QR Standards
Medical Status	Fit to QR Standards	Fit to QR Standards
Medical Restrictions	None	None
Tests (Drug/Alcohol)	Negative	Not Tested
Fatigue Analysis	No issues identified	No issues identified

Records (summarised at Table 2) indicate that the driver of VCQ5 was appropriately trained and qualified and that he had extensive experience driving a variety of train types including the diesel tilt train. He qualified in the operation of the electric tilt train in November 2000 and the diesel tilt train in February 2003. He transferred from the Coal and Freight Services Group of QR to commence duties with the Passenger Services Group in March 2004. He had worked the Bundaberg area for approximately five years and therefore should have had sound 'route knowledge'. During the previous months he had worked the CTT over the Bundaberg to Mackay section on three occasions.

However, it was noted from an examination of his personal records that he had been involved in three safety performance issues, notably Signals Passed at Danger (SPAD). These events occurred on 28 May 2000, 31 May 2000 and 1 December 2003. Two of the three SPADs occurred while he was working in single driver mode, that is he was the only driver in the cab at the time of the incident. The QR investigations into these incidents concluded that he was responsible. In accordance with QR's Safety Management System, he had undergone re-training/re-evaluation by 'tutor drivers' and was successfully returned to work but was subject to ongoing monitoring.

During the investigation, it was also noted that where a driver is subject to reassessment following an accident or breach of procedures, the use of a 'tutor driver' from the same depot to monitor the fitness and competency of a driver's return to full duties was common practice and poses certain risks to the system. The independent judgement of 'tutor drivers' from the same depot could be tested by their personal knowledge of a direct colleague where judgement may be influenced by hostility or friendship. The tutoring and auditing/testing role should be separated.

The co-driver of VQC5 started service with QR as an Electrical Apprentice in 1968 and other than a short period in 1976 has had continuous service with QR. He started as a trainee driver in 1997 and was appointed as a qualified driver in 2000. Since that time he has principally worked at Roma and Bundaberg depots.

2.8 Train management

All evidence indicates that the train derailed because the driver did not slow the train for the curve at 419.411 km and therefore could not safely negotiate it. The train passed through Berajondo three minutes ahead of schedule and the driver was maintaining the train speed below the maximum line speed up until 419.410 km. It is unlikely that the driver was attempting to drive 'to the limit' and simply misjudged his braking.

The locomotive data logger shows that the driver was actively using the throttle and responding to the station protection magnet alarms from the time of leaving Bundaberg to the point of derailment. The locomotive data logger also shows that the throttle was moved rapidly to the emergency braking position while the train was travelling at 113 km/h, one second before train VCQ5 derailed. Some person was therefore at or adjacent to the controls and apparently conscious.

On 15 November 2004 the driver had complained about the quality of the beverage that had been on offer in Bundaberg. On clearing Berajondo, the co-driver left his seat and entered the adjacent vestibule area to make a 'brew' for the driver, this was three or four minutes before the derailment. He was in the adjacent vestibule when the train derailed. He was therefore not in a position to observe the speed boards at 415.663 km, 416.480 km, 417.783 km and the critical speed for 419.410 km and intervene as may have become necessary.

The driver was interviewed on two occasions by the investigation team. On neither occasion did the driver recall any of the events in the minutes leading up to the derailment. He did recall becoming conscious, being outside the train and being assisted by the co-driver.

There is no evidence to suggest that the driver intended that the train should derail. There is no evidence to suggest that the driver deliberately drove in excess of the speed limits or deliberately ignored the speed restriction. The information from the locomotive data logger shows that in the minutes leading up to the derailment the train was being driven consistently below the posted speed limits.

The passenger service staff were in cars 'A' and 'E', the co-driver was in the adjacent vestibule of the power car. The driver was alone in the drivers' cab for between three and four minutes before the derailment. There is no witness to indicate what the driver was doing or what may have caused him to fail to react to the required speed reduction.

The possibility that the driver experienced a short sleep episode or an even shorter ‘micro sleep’ cannot be totally excluded, but either event seems unlikely given the evidence that the driver was actively controlling the train speed and responded to the mid section magnet alarm. It is also worth noting that a ‘micro sleep’ is generally considered to be of the order of a second or so in duration. The driving of a train requires significant advance planning and the driver would need to commence braking at or near the mid section magnet to bring the train under effective control. This occurred some 13 seconds from the curve and well exceeds what is generally considered to be a ‘micro sleep’.

It is therefore reasonable to surmise that the driver was not incapacitated to an extent that he did not know what was going on. The throttle/brake controller was being operated and he clearly responded to the mid-section magnet at 418.995 km. The mid-section magnet should have alerted the driver that he was approaching Cabbage Tree Creek and, based on his track knowledge, he should have been aware that he was approaching a 60 km/h speed restricted curve. A real possibility is that the driver suffered an initial lapse of concentration and thought that he was on the section of track, approaching Baffle some 5 km further on where a similar left hand curve is 110 km/h for the tilt train and 90 km/h for freight trains. Surrounded by darkness and with the headlight providing the only source of illumination may have sustained the driver’s initial disorientation. The possibility that that the driver thought that the train was approaching Baffle is supported by a statement given to the police in which the driver responds to a question by saying:

Police Question: “*Can you recall what the speed sign is for this bend?*”

Driver Answer: “*I thought the sign indicated 110 over 90. 110 for the tilt train and 90 for the freight train.*”

The countryside was in darkness. The train headlight was on, and in the absence of any moonlight, was the only form of illumination to show the track ahead. The distance from the mid-section magnet to the speed board at 419.410 km was over 415m. Travelling at 31.4 m/sec the train was 13 seconds from the speed board. The driver reset the mid-section magnet alarm at 2355:11. At this time the train’s headlight would only provide limited visual detail of a distant speed board or curve transition. Train drivers must plan ahead and any action to slow the train should have already commenced.

Other than the light from the instrumentation, the drivers’ cab was in darkness. No radio messages were recorded as having been transmitted or received by VCQ5. On that night the driver had left his mobile phone with his wife and there is no evidence of any mobile phone traffic to either driver. The probability of any external distraction is therefore remote.

It is possible that having become disorientated and then resetting the alarm, the driver believed he had passed the critical curve at 419.411 km. Following this he may have decided to access his bag and/or get some food from the mini fridge located directly behind the co-driver's position. It is known that the driver was anticipating a 'brew'. It is natural for food and beverage to go together and it is quite possible that the association caused the driver to desire a food pack. He could not access his bag and/or the food pack without leaving the driving seat. If the driver left the seat for sufficient time, just a few seconds and resumed his driving position the train would have been very close to the 60 km/h curve. The finding of two loose packets of 'ham and tasty cheese' sandwiches and a bottle of water in the driver's cab during examination of the accident scene lends some weight to this possibility (Fig. 15)

FIGURE 15: Photograph showing two sandwich packages and bottled water in drivers' cab

Normally, the co-driver sits in the right hand seat, adjacent to the driver. His/her main task is to ensure that the driver is driving the train safely this includes a requirement that they independently observe the route ahead and 'call' signals, which the driver acknowledges. If the driver does not react appropriately the co-driver can intervene. Prior to the 15 November 2004 QR operational procedures did not require drivers to call critical changes in speed limits and did not preclude the co-driver from leaving the drivers' cab to enter the adjacent vestibule area to make beverages, etc.

A review of all environmental factors has not established any environmental factors, other than the darkness that either directly or indirectly contributed to the derailment of VCQ5 on the 15 November 2004.

2.9 Communications

Train to base radio communication is available through QR's Mt Watalgan microwave radio repeater. This site incorporates Train Control Radio, Maintenance Radio and Trunked Radio facilities.

The Train Control Radio is the principal mechanism for train to Control Centre communications. It is an open channel system and provides direct access to Brisbane's Far North Control.

QR staff are provided with fixed and portable radios as necessary, with access to the train control channels and can communicate with controllers and each other, coverage permitting.

Deficiencies in emergency communications at this site were revealed as a result of the derailment. It was noted that as a result of damage to the lead power car and injuries sustained by the driver and co-driver, neither was able to use the train's radio system to alert Far North Control to the accident. Similarly, the customer services supervisor was unable to contact Far North Control using the portable train radio. Neither was the train manager able to communicate using the on board mobile telephone or satellite telephone. Fortunately, a passenger on board the CTT had a mobile telephone with access to an alternative service provider which had coverage at this location. This passenger was able to contact the emergency services and raise the alarm; this coupled with clues that Far North Control had received from the ECO, resulted in an effective response to the emergency.

A possible solution to the loss of communication in the event of an accident, particularly in remote areas is the use of electronic position indicator radio beacons (EPIRB).

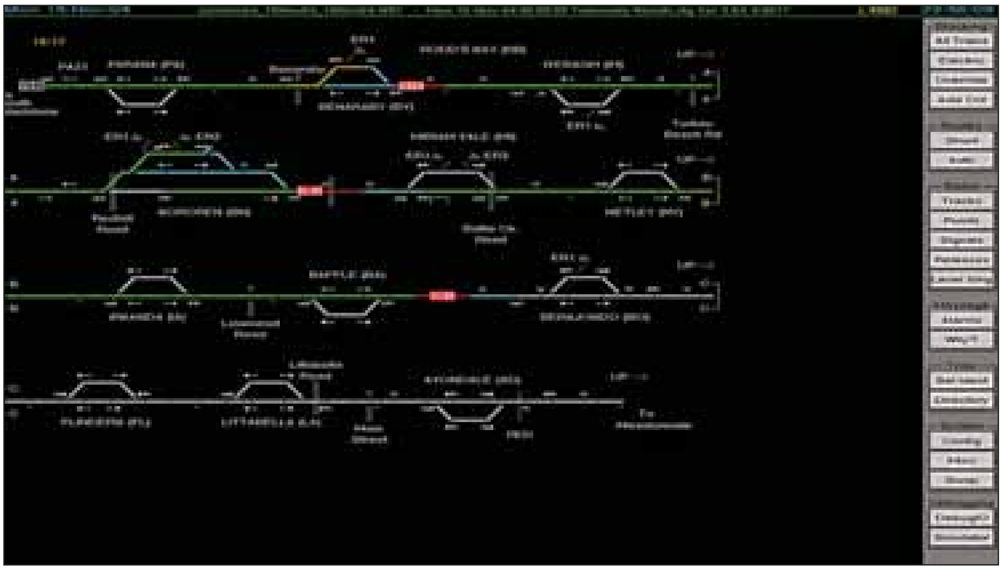
Once alarmed, an EPIRB is detected by geostationary satellites and also provides position location information. The benefit of the EPIRB is that it generally works anywhere on the globe, can be easily installed, for example in a train carriage, and is relatively inexpensive. When armed it provides an immediate indication of distress.

2.10 Train control

2.10.1 Universal Train Control (UTC)

At the time of the derailment, VCQ5 was under the direction of QR's Train Control located in Brisbane. The section of track between Baffle and Berajondo including the 'passing loops' are remotely controlled by UTC workstation 1 (Graphics Overview, Figure 16.). Signal, points, track and train movement data is recorded and can be replayed in the event of an incident.

FIGURE 16: Graphics Overview, UTC Workstation 1 – Replay Screen, 2356:09



The replay files pertinent to this derailment were extracted from UTC workstation 1 with relevant information being analysed to identify whether there were any unusual occurrences in the lead-up to or during the accident. A review of this data has established that there were no abnormal events.

2.10.2 Audio recording

Similar to the signal, points, track and train movement data, voice communications between the control centre and train(s) is recorded and can be replayed in the event of an incident. The relevant audio files from 2300 on 15 November 2004 through to 0100 on 16 November 2004 were downloaded for the channels as listed below:

- RC1 03 Far North Console Speaker
- RC1 09 Far North Handset
- RC l 17 Far North Trunk Radio
- RC1 28 Far North UHF 1
- RC1 29 Control Supervisor Meridian Handset
- RC1 47 Control Supervisor 81-1662
- RC1 48 Control Supervisor 81-3779.

A review of the data from these files has established that there were no abnormal events in the lead up to or during the derailment.

This same data helped establish that at 2358 the ECO Rockhampton contacted North Coast Control by telephone regarding an electrical circuit breaker trip on the 25kV AC traction power system.

There is no evidence from the recordings of what may have caused the derailment.

2.11 Overhead wiring

The section of track from Brisbane to Rockhampton is electrified at 25 kV AC; with the running rail providing earth return. The 25 kV AC system provides traction power for electric rollingstock, it is not required for diesel tilt train operations. However, isolation of the overhead power supply is a critical issue during maintenance and emergency events. On the night of the accident, the electrical circuit breaker protecting the Berajondo to Baffle section tripped, this 'isolated' the 25 kV AC. An attempt was made by the ECO to remotely re-close the 25 kV AC circuit breaker. When this failed he notified North Coast Control of the fault and that the overhead had been 'isolated' until an on site inspection could identify/rectify the fault. At about this time, 0002, North Coast Control became aware that the CTT had derailed and a major accident had occurred. Emergency services were despatched and recovery strategies put in place. On site confirmation was received at 0044 from the Queensland Police that the CTT train had derailed.

A QR incident manager arrived at 0110. The immediate site was electrically isolated and the overhead lines were strapped to earth to provide additional protection, this occurred by 0150 following which the emergency services were cleared to commence evacuation.

Although QR employees are instructed in the hazards associated with the 25V AC traction system and are required to regard the site as 'live' until it is declared safe (the issue of a 'C' form Safety Certificate) it was apparent that during the period immediately following the derailment through to 0150 the crew of the CTT, passengers and the emergency response team(s) were unsure of the status of the 25 kV AC system, that is, whether it was alive or isolated. This created anxiety and hindered the evacuation process. It is considered that QR should refine its emergency procedures to better communicate the status of the 25 kV AC system to site personnel and conduct a risk assessment that identifies the hazards associated with train evacuation in situations where electrical equipment may be live. Evacuation strategies must also consider circumstances where communication systems have failed.

2.12 Fatigue

The Australian Macquarie Dictionary defines fatigue as '*weariness from bodily or mental exertion*'. Simply, people who are fatigued are tired. A person suffering from fatigue is likely to have slowed responses and associated loss of functional capacity; this can have a significant affect on their work performance and the ability to stay alert/awake on the job. Fatigue can be traced back to various causes such as:

- Lifestyle
- Workplace and
- Psychological.

It is a well recognised fact that the human body is designed to be awake during daylight hours and sleep during the night. A shift worker disturbs this cycle (circadian clock) by working when their body should really be asleep.

Sleeping during the day is particularly difficult, because a person tends to be in a 'wakefulness' mode. Fatigue in shift workers can be further compounded if the worker endeavours to undertake extra activities, during what should be rest periods, that is, they end up 'burning the candle at both ends'. The effects of fatigue have long been associated with shift working and in the transport industry, which has high levels of shift workers, this has been an area of ongoing concern.

Most transport companies now recognise this problem and while they do not have control of what an employee does while not at work, the more responsible organisations such as Queensland Rail, have employed computer modelling techniques to ensure that shift rosters minimise levels of fatigue and also brief their employees regarding the risk of chronic fatigue.

Queensland Rail use FAID, a commercially available computer program to predict the effects of fatigue resulting from shiftwork, and models its rosters to minimise the impact of fatigue. However like many companies, it does not actively readjust the model for actual hours worked. Work-related fatigue is estimated within the FAID program by considering the duration and timing of work, work history, etc. Using hours of work as an input, the program enables an assessment of rostering practices by providing a FAID score.

Exceedence of set 'fatigue limits' are flagged and should result in the re-rostering of employees where necessary to minimise fatigue. An examination of the rosters and actual worked by both the driver and co-driver would suggest that fatigue levels should not have been a contributory factor in this accident. When questioned, the driver did indicate that he had adequate sleep leading up to the rostered shift for the evening of the 15 November 2004.

2.13 Medical and toxicology information

The scope and frequency of medical examination, for QR train drivers, is as prescribed in QR's '*Fitness to Work - Medical Standards for Traincrew*' SAF/STD/0021/WHS. The frequency of examination is age dependent and is superior in frequency to that prescribed in the new 'National Standard for Health Assessment of Rail Safety Workers'.

During the process of the investigation, both the QR Resident Medical Officer and driver's General Practitioner were consulted regarding the driver's physical and psychological health. A review of the driver's personal records established that he was medically examined on 1 September 2004 by the QR Resident Medical Officer, based in Bundaberg. His records clearly indicate that he was fit and had passed all QR medical requirements. He was due for his next medical examination on 30 September 2006.

The medical investigation established that:

- He was medically current for train crew under the Train Crew Medical Fitness Standards contained in Standard STD/0021/WHS.
- He was not suffering from any known medical or psychological condition(s) that had the capacity to distract him or to cause acute or subtle incapacitation prior to, or at the time of the accident.
- He was not taking any prescribed medication nor is it believed that he was taking any over-the-counter preparations.

- He was well-adjusted and in excellent health, with no known medical conditions of any significance, either past or recent.
- His colour vision was normal and he had good unaided distance visual acuity.
- He did suffer with a mild right-sided hearing loss attributed to industrial noise exposure, but the degree of hearing loss was not considered to be significant or relevant in the context of the derailment.
- There is no evidence to indicate that he was cognitively impaired prior to, or at the time of the derailment.

It is considered that there were no identified issues that could have either directly or indirectly contributed to the accident as a result of the driver's physical or psychological health.

The driver of VCQ5 provided blood samples, voluntarily, for the purpose of toxicology tests. This was done on the 16 November 2004 approximately 7 hours after the accident. The results of this test were negative.

An examination of the co-driver's medical records established that he had last been medically examined on 7 August 2003. He was medically current for train crew under the Train Crew Medical Fitness Standards contained in Standard STD/0021/WHS. He was due for his next medical review on 30 August 2005.

It is considered that there were no issues identified that could have either directly or indirectly contributed to the accident that were as a result of the co-driver's physical or psychological health.

2.14 Passenger questionnaire

Following on from the accident, a passenger questionnaire was developed jointly by the ATSB and QT in trying to come to an understanding of the various events as seen/perceived by passengers in the lead-up to, during, and post accident.

Questions focused on broad issues covering:

- Passenger Perception – passenger experience on the journey up until the derailment, including safety/evacuation processes. Any warning of impending derailment. Passenger experience during the actual derailment and post derailment. Evacuation response, how was the evacuation handled, through windows, doors, any specific problems. Was lighting adequate, were there any physical impediments, how did passengers get down from the train, etc.
- Response by Passenger Service Staff, Emergency Services, evacuation from the scene, etc.
- Passenger Injuries – injury type/severity, passenger position in train.
- Any other issues.

Based on the outcome of these questions, investigators were able to determine whether there were any clues that might help in understanding the mode of derailment, why the derailment occurred, how the train performed during the derailment, emergency evacuation and response planning strategies. After reviewing all passenger responses, it is considered that the information has been useful in isolating the mechanism of derailment and understanding evacuation difficulties.

Appreciation of these issues will assist in developing future strategies to improve evacuation performance.

Of the 150 passengers on board the train, a total of 75 per cent responded to the questionnaire. This is an excellent response and is a sound basis for developing statistical conclusions. Of those who responded, 98 per cent indicated that English was their primary language. Eighty one per cent of all respondents were over 50 years of age.

Respondents were asked whether, prior to the derailment, they knew where their nearest emergency exit was located. Seventy three per cent indicated that they did know. Sixty four per cent of respondents had read the emergency evacuation card which was generally found to be useful.

Forty eight per cent of respondents indicated that they had previously travelled on the tilt train. Most of these (87 per cent) indicated that the trip, up until the derailment, was similar to previous trips.

2.14.1 Physical Injuries

Of the passengers who responded, 86 per cent indicated that they sustained some form of physical injury during the derailment or while evacuating from the train and/or moving to a safe area. Some passengers advised that they subsequently developed physical symptoms after the event, such as deep bruising, soreness, stiffness and swelling.

Over 85 per cent of responding passengers advised that they were sent to hospital for examination. Of these 36 were admitted for treatment, assessment or further observation. Based on predicted recovery time, physical injuries were classed as severe, moderate or minor:

- Sixteen passengers suffered severe physical injuries with a predicted recovery time greater than three months;
- Ten passengers suffered moderate physical injuries with a predicted recovery time between one and three months; and
- Seventy one passengers suffered minor physical injuries with a predicted recovery time under one month.
- The driver suffered severe physical injuries.
- The co-driver suffered minor physical injuries.
- Of the on board staff, one female member suffered severe burns/scalding.

The remaining staff members sustained minor physical injuries.

2.14.2 Crashworthiness from a passenger perspective

The driver and co-driver sustained severe and minor physical injuries respectively. Three of the passenger service staff were located in car ‘A’, immediately behind the power car; two were seated and one was lying down. The passenger services supervisor experienced minor bruising and abrasions. The remaining two staff members were in car ‘E’ where the galley was located. A female staff member experienced severe burning when very hot liquid from a coffee machine spilled on to her legs and arms resulting in second degree burns.

She also suffered cuts and bruising and a fractured bone in her foot, probably caused while escaping from the car. The remaining staff member sustained minor physical injuries.

Train VCQ5 had a capacity of 167 seated passengers. Cars ‘B’, ‘C’ and ‘D’ were of identical layout each with a capacity of 39 seated passengers, car ‘E’ was the catering car and cars ‘F’ and ‘G’ had a capacity of 28. Leaving Bundaberg the train had 150 passengers; 35 in car ‘B’, 37 in car ‘C’ and 34 in car ‘D’. Cars ‘F’ and ‘G’ had 24 and 20 passengers respectively.

Of the 35 passengers in car ‘B’ three suffered severe injury and a further one sustained moderate physical injuries. Cars ‘C’ and ‘D’ ‘jack-knifed’ and came to rest parallel to each other. Eight of the 37 occupants of car ‘C’ experienced severe physical injuries and five moderate physical injuries while the 34 occupants of car ‘D’ experienced five severe physical injuries and four moderate physical injuries.

No severe or moderate physical injuries were reported in cars ‘F’ and ‘G’.

Eighty passengers were dislodged from their seats, four of whom were propelled through a window finding themselves outside the train. Thirty five passengers collided with another individual. Given that no seats were dislodged from their mountings some form of passenger restraint system may have been beneficial in preventing some of the physical injuries.

The train withstood the dynamics of the derailment with minimum distortion to the structure of the cars. Although some passengers reported that the armrests had broken and tray tables had dislodged, inspection of the cars showed that no seats had actually separated from the floor mounting.

Despite the general robustness of the cars, some emergency doors were distorted in the derailment and either could not open, or were difficult to open. Sixteen passengers in car ‘D’ indicated that the emergency doors did not work, four in both cars ‘B’ and ‘C’, three in car ‘G’, and one in car ‘F’. In car ‘A’ an electrical panel in the ceiling of the car became dislodged and blocked access to the rear emergency door and the first-aid kit. Passengers reported 11 ceiling/light panels coming loose and partially blocking escape routes, which may have contributed to some passenger injury.

Four passengers were ejected from the train by the dynamics of the derailment and found themselves outside the train. The passenger services supervisor and his co-worker managed to leave the train and started to render assistance. Most passengers were assisted from the carriages by personnel from the emergency services, who gained access to the interior of the train through emergency exits (doors and windows) and non-emergency windows.

The passenger survey would indicate that QR should review the effectiveness of emergency exits. Six passengers attempted to operate designated emergency exits, doors and windows without success. Other passengers either did not know or could not locate the hammer to break emergency windows. Unaided escape by passengers was hampered by the angle of some carriages and concerns of live wires outside the train.

The passenger service supervisor in car 'A' had to force the forward door so there was sufficient space for him to squeeze through. Five external doors were successfully opened from inside the carriages and two opened automatically. From the passenger survey it was identified that there were at least 28 unsuccessful attempts to open external doors with only five instances where emergency doors were operated by someone internal to the carriage.

Twenty-six passengers escaped from the train through designated emergency windows, some of which were broken from the outside by the passenger services supervisor, emergency crews or were broken due to the accident. Forty passengers are reported to have left the train through the non-emergency windows, which had been broken in the accident or as an alternative to emergency exit windows. A small number of passengers reported that the glass in these windows shattered and left exposed shards of glass which caused some physical injuries.

The train interior lighting, including emergency lighting[8] was lost in all but one car (car 'G') as the train derailed with passengers being left in total darkness. This failure along with the loss of the train's public address system, hindered escape efforts. The effectiveness of the passenger services staff would have been enhanced if these systems were available.

Conclusions from the passenger questionnaire:

Passenger safety/emergency evacuation briefings had been read/viewed by the majority of passengers who responded to the survey. However, the message contained in the video presentation is dependent upon the passengers using head sets to listen to the instructional dialogue. The briefing of passengers joining at intermediate stations, often in the middle of the night, raises particular problems if train staff is to ensure they are made aware of critical safety information. Some procedure needs to be developed to ensure that passengers, including those who join at intermediate stations, are fully briefed by passenger service staff or by some other means.

The journey on VCQ5 on the night of the 15 November 2005, up until the derailment was consistent with previous journeys.

Evacuation of passengers was hampered by the failure of the various 'Emergency Evacuation Exits' but more importantly the 'Emergency Evacuation Lighting' which failed in all but car 'G', and the status of the 25 kV AC traction power supply system, hindered escape efforts, and created unnecessary anxiety for passengers.

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[8] Emergency lighting was lost on all but car 'G', as a result of the emergency/backup batteries located on the underside of each of the sitter cars being torn off during the derailment.

3 CONCLUSIONS

3.1 Major factors

1. Prima facie the principal cause of the derailment was excessive speed. At 2355:27 the lead power car No. 5403 of the *City of Townsville*, VCQ5, rolled over at 112 km/h, on a curve 419.493 kms from Brisbane's Roma Street Station and then dragged the remaining trailer cars off the track before all units came to rest.
   Recommendation 10, 11
   Observation 1

2. The driver did not reduce the train to a safe speed before entering the curve at 419.411 km. However, there is no evidence to suggest that the driver intended that the train should derail or that the driver deliberately drove in excess of the speed limits or deliberately ignored the speed restriction.
   Recommendation 10
   Observation 1

3. The train was in steady power virtually up to the time of the derailment. The train brakes were not applied until very late into the accident sequence.
   Recommendation 10
   Observation 1

4. It is possible that the driver became disorientated and/or distracted from his principal task in the section leading into the curve at 419.411 kms and subsequently failed to recognise geographic proximity along the track.
   Recommendation 10
   Observation 1

5. There is no technical system on the CTT that detects very short periods of driver inactivity/distraction.
   Recommendation 1
   Observation 1

3.2 Underlying factors

1. At 417.783 km (approx 2354:26) the posted speed for 'Tilt Train Operations' increases to 150 km/h.

2. It is possible that the driver mistook the 'mid-section' alarm to be the 'station protection' magnet located in advance of Baffle.
   Recommendation 4

3. It is possible that the driver momentarily left the driving position, either shortly before or after passing over the mid-section magnet, to get some food from his carry bag/mini fridge, thinking it was safe to do so. By the time he orientated himself, the train speed was too high and efforts to apply emergency braking were too late.
   Recommendation 1
   Observation 1

4. The safe driving of the CTT largely depended on the driver responding to external prompts (speed boards, vigilance system warnings and the station magnet system), track knowledge and competency and a 'two-driver' mode of operation.
   Recommendation 1, 2
   Observation 1

5. The co-driver was absent from his seat. He had entered the adjacent vestibule area and was not in a position to check the driver's actions or inactions thus removing an important defence against one person error. QR operational procedures did not preclude the co-driver from leaving the drivers' cab.
   Recommendation 3, 10

6. The train's headlight would only have provided limited visual detail of a distant speed board or curve transition at the 'mid-section magnet' to alert the driver to the train's true position. Train drivers must plan well ahead in controlling a train's acceleration/deceleration.
   Recommendation 2

7. The external darkness may have contributed to any loss of geographical awareness by the driver.
   Recommendation 2, 3

8. The 'mid-section magnet' is primarily used for providing tilt train geographic reference information but could also provide a prompt for extra driver alertness. It provides no indication of location or the next speed limit. A driver who incorrectly assumes the position location of a train along the track is not aided by the alarm.
   Recommendation 4

9. Monitoring of a driver's return to full duties following an accident or disciplinary occurrence by 'tutor drivers' from the same depot could be tested by their personal knowledge of a direct colleague where judgement may be affected by hostility or friendship.
   Recommendation 10

3.3 Other issues

1. QR's North Coast Control did not immediately realise that VCQ5 had derailed; it was through external cues (circuit breaker trip, no radio contact with VCQ5, passenger calling emergency services) that they came to appreciate that a derailment had occurred. This response took approximately seven minutes.
   Recommendation 5

2. North Coast Control acted promptly as soon as they recognised that a derailment was a possibility, this was followed up by an appropriate Emergency Response Strategy.
   Observation 2

3. The passenger service staff responded effectively to the emergency, given the constraints, that is the loss of 'Emergency Evacuation Lighting' and the train's PA system.
   Recommendation 5, 6
   Observation 2, 3

4. Emergency Services and QR recovery teams responded effectively and efficiently, particularly recognising the scale of the accident, its remote locality and time of night.
   Observation 2

5. Evacuation through windows and doors was hindered by a failure of some of the 'Emergency Exit Doors' and some passengers who could not locate or use glass hammers to break emergency windows.
   Recommendation 7, 8
   Observation 3

6. Evacuation and passenger welfare was adversely affected by the loss of the 'Emergency Evacuation Lighting' which failed in all but car 'G'.
   Recommendation 8
   Observation 3

7. Evacuation and safety advice was adversely affected by the loss of the PA system.
   Recommendation 8

8. The train vehicles, bogies and structure were in good condition, properly maintained and did not contribute to the derailment.

9. The track and signalling infrastructure, up to the time of the collision, were in good condition, capable of supporting tilt train operations up to the design limits established by QR and did not contribute to the accident.

10. Emergency communications coverage in this locality was patchy with the existence of 'dead spots'. It is conceivable that given a different set of circumstances, response to the derailment could have taken longer.
    Recommendation 5

11. During the period immediately following the derailment through to 0150 the crew of the CTT, passengers and the emergency response team(s) were not fully aware of the status of the 25 kv AC power system, this hindered evacuation.
    Recommendation 6

12. The Cairns Tilt Train is fitted with a locomotive data logger, the information derived from this unit was invaluable for investigators in coming to conclusions regarding the nature of this derailment.

13. The fixed time based Vigilance system as installed on VCQ5 was ineffective in preventing driver distraction and promoting driver alertness. No Automatic Train Protection system was operating to reduce the risks of human error.
    Recommendation 1
    Observation 1

14. Advance warning boards may have helped in alerting the driver to the approaching curve at 419.411 kms.
    Recommendation 2

15. The 'crash worthiness' of the tilt train was of a high standard. In the context of the accident site and the dynamics of the roll-over, it provided a high degree of protection to the majority of the passengers. However as 80 passengers were dislodged from their seats, some form of passenger restraint system may have been beneficial.
    Recommendation 9
    Observation 3

4 RECOMMENDATIONS

4.1 Safety actions already initiated

1. The second of the two diesel tilt trains, the *City of Cairns*, was temporarily withdrawn from service on Friday 19 November 2004 as a precautionary measure to examine bogies for potential stress cracking. The train was returned to service the following Monday, 22 November 2004 as no issues were identified. The investigation has established that cracking found on the *City of Townsville* was as a result of the accident, and that there was no evidence indicative of fatigue cracking.
2. The speed of the tilt trains (two electric and the one remaining diesel) have been limited to 100 km/h with incremental speed increases to be subject to risk assessment and QT approval.
3. QR has provided train crews with a list of speed critical curves where there is a changeover from high speed to medium speed. Both drivers are to remain in the drivers' cab while the train is traversing these curves and the curve speed is to be called between the drivers prior to entering the curve.

4.2 Recommended safety actions

(Not in order of priority)

1. QR should review the use of vigilance systems to determine whether a random time based system or similar would improve the train operating risk profile.
   Major factors 5
   Underlying factors 3, 4, 5, 6
   Other issues 13
2. QR should report on its findings and proposed future strategy with respect to its review of the use of 'Advance' speed warning boards.
   Underlying factors 4, 6, 7
   Other issues 14
3. QR should conduct a thorough risk assessment into the procedures that permit a co-driver vacating the co-driver position.
   Underlying factors 5, 7
4. QR should explore the possibility and advisability of providing differentiation or specific identification of individual station magnets.
   Underlying factors 2, 8
5. QR should review the effectiveness of emergency communication strategies[9] on the North Coast Line and/or consider alternative communication strategies that provide enhanced coverage in the event of an accident/incident.
   Other issues 1, 3, 10
6. QR should review the risks associated with train evacuation in any location where electrical equipment may be live.
   Other issues 3,11

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[9] This may for example include provision of an 'Electronic Position Indicator Radio Beacon' (EPIRB) system or equivalent. QR should give consideration to consulting with the State Emergency Services when developing strategies to enhance its emergency communication capabilities.

7. QR should review the effectiveness of 'Safety Briefings' given to passengers on joining 'Tilt Train' services, particularly in mid-sections, where it may be difficult to provide information to the extent necessary.
   Other issues 5
8. QR should review the crash survivability of the current 'Emergency Exit' systems installed on the 'Tilt Train' including emergency lighting and the ability to communicate with passengers during an emergency.
   Other issues 5, 6, 7
9. QR should review and undertake a risk assessment regarding the benefits of a passenger restraint system on tilt train services.
   Other issues 15
10. QR should review its monitoring and ongoing training of drivers that have been involved in nonconforming situations in the operation of trains. Strategies[10] that enhance driver performance should be investigated and implemented.
    Major factors 1, 2, 3, 4
    Underlying factors 5, 9
11. Following the publication of this report, QR should provide QT with a response to this report, as relates to tilt train services, outlining all proposed risk mitigation strategies including time frames for implementation. The Rail Safety Unit of Queensland Transport should regularly review this plan and report its status to the Director-General of Queensland Transport.
    Major factors 1

Observation:

1. During the early stage of the investigation it was noted that QR intended to expand the use of its Automatic Train Protection (ATP) for tilt train services. The use of ATP for tilt train services was being progressively worked through and further tests were prescribed/underway at the time of the derailment. These tests are continuing. This strategy is supported with the proviso that if the present system cannot be effectively modified/used a further review should be undertaken to determine additional mechanisms to enhance/enforce driver vigilance, including the use of alternative positive train control systems.
   Major factors 1, 2, 3, 4, 5
   Underlying factors 3, 4, 5, 6
   Other issues 13
2. All personnel who responded to the emergency, including local residents, QR passenger service staff, emergency services personnel and QR response teams should be commended for their prompt response and post accident management of this derailment.
   Other issues 2, 3, 4
3. Information provided by passengers who were involved in the derailment is acknowledged. This information was extremely useful, constructive and enhanced the value of the final report.
   Other issues 3, 5, 6

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[10] Strategies should be developed in consultation with employee and union groups to ensure that high risk employees are identified and effectively managed. To assist with this strategy, it is considered that it may be beneficial for QT to work with the other State Rail Regulators in developing a nationally consistent approach for the monitoring and handling of safeworking breaches.

5 SUBMISSIONS

A review of this report occurred on 24 and 25 August 2005 with the Directly Involved Parties (DIPs). All comments have been considered and where appropriate included within the report without changing the general thrust or conclusions and recommendations. All comments were considered to be of constructive value and enhanced the readability of the final document.

6 APPENDICIES

6.1 Railway signalling & automatic train protection (ATP)

The fundamentals of railway signalling (Fig. 17) have not substantially changed with time and are intended to:

- Regulate train movements, that is, satisfy a timetable demand/traffic pattern
- Maintain a safe distance between train movements and
- Safeguard trains movements at/through junctions and crossings.

Today, most traditional railway signalling systems comprise:

- Multiple-Aspect Colour Light Signals, (similar to road traffic light signals) that provide a simple and clear indication to train drivers regarding the status of the line ahead.
- Train Detection Systems, that is, geographic train location systems, for the purpose of positive train detection to ensure that the position of trains on a running line is known and that a train is not undetected.
- Interlocking Plant, for ensuring effective interlocking between conflicting train routes and thereby ensure the safe passage of train movements.

In most cases, information regarding the status of the line/track ahead as provided by a signalling system is quite basic. It comes in the form of information communicated through the signal indication. This information is essential to a driver in ensuring effective control of a train which due its speed and heavy mass may take many kilometres to stop.

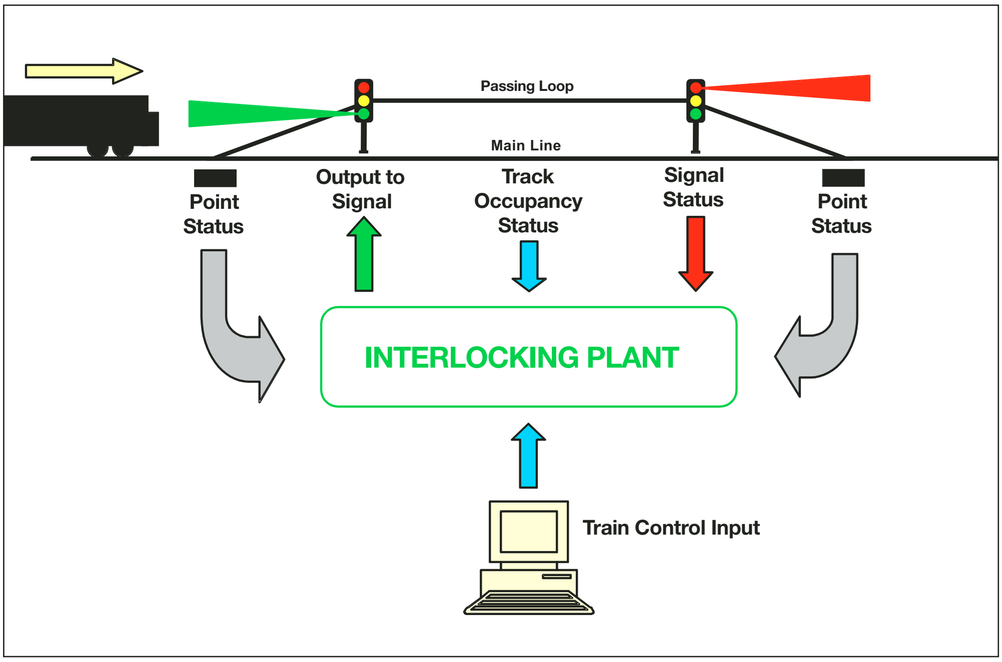
Railway signalling systems in their most basic form, however, do not provide 'Positive Train Control', that is, they do not directly control train speed or braking. Controlling the train is often totally dependent on the train driver(s) who must respond to visual cues provided by the signal indications and other external stimuli, such as 'Speed Boards', curves, level crossings, etc.

As with most safety critical systems, railway signalling is designed to be inherently safe and with this invariably comes a high price tag. Over the years, rail safety has dramatically improved as technology and engineering solutions have eliminated many of the early railway operational risks, however one of the primary risks that still remain is a reliance on the train driver to respond correctly to external stimuli. In recent years, 'Positive Train Control' systems, like ATP have evolved and are increasingly being used by railway administrations. In many cases, ATP systems are now fairly mature technologies but may introduce initial operational difficulties where introduced on rail systems that have mixed traffic, like QR. ATP systems are fundamentally designed to enforce train speed/braking in the event that a train driver has failed to correctly respond to external stimuli, eg a stop signal, curve speed restriction, etc. However it should be noted that ATP cannot protect against all scenarios, for example a level crossing fouled by motor vehicles. Most modern ATP systems have an onboard electronic map of the entire train route which includes any permanent or temporary speed restrictions that might be in existence.

ATP systems also actively update the status of any advance signal indication. Most ATP systems are an adjunct to existing signalling and do not provide the first level of safety afforded by the core signalling system.

As ATP is expensive and is technologically complex to implement which can adversely impact on operational capacity and reliability its adoption is invariably debated at length by railway administrations and the decision to adopt ATP may be based on emotive, sometimes social/philosophical principles rather than a rational economic business case.

FIGURE 17: Elements of Railway Signalling Plant



Signalling systems are highly complex as is ATP, so when a railway administration decides to add ATP to an existing signalling system, it is not unusual to encounter technical and operational difficulties in bringing these systems into service.

From a railway administration perspective, it can become a delicate balance in ensuring that at the time of commissioning the ATP system is fit for purpose and does not adversely affect safety or operational performance.

In addition to 'Positive Train Control' systems like ATP, there is a suite of lesser 'Driver Supervisory Systems' such as 'Train Stops' and 'Automatic Warning Systems' (AWS) that provide some level of train braking and speed enforcement.

The signalling system used by Queensland Rail, on the North Coast Line, between Bundaberg and Gladstone in principal comprises a contemporary three-aspect colour light route signalling system. QR employs a centralised control system, called Universal Traffic Control (UTC) that provides for the real time monitoring and control of field hardware, such as signals, points, track circuits and the associated real time management of all train movements operating over the network.

ATP was confined to freight operations on QR's North Coast Line at the time of the accident. Since its introduction, the system has had various technical problems, particularly with respect to reliability which directly affects operational performance and indirectly, safety performance. In the original risk assessments undertaken by QR, ATP was to be installed on 'Tilt Train' services, however this had not occurred as a result of the various technical issues. These technical issues were being progressively worked through prior to the accident and further tests were prescribed/underway at the time of the accident. Testing/installation is continuing.

At the time of the accident, train protection on the tilt train solely comprised a philosophy of having a combination of driver/co-driver supported by the 'Vigilance' and 'Station Protection' systems.

6.2 Tilt train technology

When a vehicle is driven around a curve at speed, any occupant will feel a lateral/centrifugal force. The philosophy behind 'Tilt Train Technology' is to reduce the lateral component of this force and convert this into a vertical component. Generally, people are more tolerant of vertical forces (gravity) than lateral/centrifugal forces and accordingly if passengers can be made to feel more comfortable they can travel around curves at higher speeds, provided the design limits of the train/infrastructure are not exceeded.

Cant is the cross level angle of track on a curve. It is used to compensate for the lateral/centrifugal forces generated by a train as it passes through a curve. For mixed traffic railways (a combination of freight and passenger services) the degree of cant is often a compromise between the slowest and fastest train types and rarely compensates fully for centrifugal loads. The difference between the equilibrium cant, that is the theoretical value of cant that will fully compensate for the centrifugal load, and the actual track cant is known as cant deficiency.

As centrifugal force is proportional to vehicle speed, and if not fully compensated by track cant, passengers will begin to experience a lateral/centrifugal force, which in the extreme becomes uncomfortable. In most cases, passenger discomfort arising from cant deficiency is the limiting factor precluding the running of passenger trains through curves at higher speeds, rather than the safety considerations imposed by the train/infrastructure design. This often implies that there is scope for increasing the speed of a train through curves without compromising on safety.

Tilt train technology, takes advantage of this phenomenon by providing higher levels of passenger comfort by tilting the train body. The technology does not have any significant affect on rail forces or safety. That is to say, for two identical trains one with tilt train technology and one without each can generally traverse a curve at the same speed, it is only passenger comfort that becomes the real issue. This is evident in the design of the CTT in which the diesel power car is not equipped with tilt capability whereas the trailer/passenger cars are.

So why does a tilt train have a quicker journey time than a conventional train? The acceleration and deceleration of trains is relatively slow. For example, it can take several minutes for a train to get to its top speed. If there are frequent speed restrictions as a result of curves, and the train speed is slower through curves than technically necessary, for passenger comfort reasons, then the train is rarely going to approach its top speed capability. As tilt trains can travel around curves at a higher speed than conventional trains without causing passenger discomfort then it stands to reason that the train can maintain a higher average speed over the entire journey and thereby reduce the overall journey time. What must be recognised is that it is the engineering design standards that generally dictate the safe speed that a train can traverse a track. Generally these standards are quite conservative as is the case with the 'Cairns Tilt Train'.

6.3 Locomotive data logger

FIGURE 18: Power Car CPU Rack – Data Download

Both power cars 5403 and 5404 are provided with an EKE-Electronics Ltd train management system (TMS). One function of this system is to record train data/events. Data is stored on removable electronic cards contained within the TMS system.

These cards were extracted and transported in the presence of Queensland Police to Brisbane for analysis. On arrival in Brisbane, the data cards were inserted into a 'Power Car CPU Rack' to enable downloading (Fig. 18) and subsequent analysis.

Information extracted from both sets of electronic cards has been used in re-constructing the events leading up to the derailment as described in this report.

6.4 Emergency Position Indicating Radio Beacon (EPIRB)

Historically, EPIRBs have been used in maritime and aviation applications. There are now three types of EPIRB, one type transmits an analogue signal on 121.5MHz and is being progressively phased out. The second transmits a digital identification code on 406MHz and a low-power 'homing' signal on 121.5MHz. The 406MHz EPIRBs need to be programmed with the user data, but provide for user identification in case of an alert. The latest is the Inmarsat system.

The 406MHz EPIRBs are divided into two categories:

- Category I EPIRBs are activated either manually or automatically. The automatic activation is triggered when the EPIRB is released from its bracket.
- Category II EPIRBs are manual activation only units.

Once alarmed, the 406MHz EPIRB is immediately detected by geostationary satellites and also provides position location information.

The benefit of the EPIRB is that it generally works anywhere on the globe, can be easily installed, for example in train carriage and is relatively inexpensive. When armed it provides an immediate distress signal that can be acted on independently of terrestrial based communication systems.

The Inmarsat system has 667 channels available for its distress system. This allows for future expansion with nearly no frequency limitation. Inmarsat satellites are geostationary satellites and provide for fast alarm forwarding without any unwanted delay. Inmarsat EPIRBs transmit the position in case of an emergency as part of the message and do not need programming because they transmit a unique system code.

Derailment of Cairns Tilt Train VCQ5, North of Berajondo, Queensland, 15 November 2004

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