YOU CAN GET LONELY OUT THERE!

John Aitken

BE AMIRSE

Aitken & Partners

SUMMARY

"You can get lonely out there!" sighed the track inspector. He had described working alone on some of the most remote rail track in Australia, travelling vast distances far from the highway. Radio often is his only contact with others.

Even when close to population centres railway lines can be remote or relatively inaccessible, with only train radio for communication. It would seem reasonable to expect that train radio systems would provide a robust and reliable link for people working in such environments.

Is this expectation realised? To test this we review a number of incidents and the performance of train radio and communication systems in these incidents. Some design decisions are discussed and their hidden features and risks are explored. It is evident that to not make a design decision is in fact to make a decision, but with an unpredictable outcome.

Incidents are usually the result of the failure of multiple defences against error: communication systems may be the last line of defence against disaster. As the last defence, the non-vital communication system can become very important. The communication system can be as important after the incident, for reporting and recovery.

Since incidents are relatively rare, it is essential that the communication system designer have a very comprehensive understanding of the requirements for all modes of operation. We advocate the adoption of international standards for railway communications. These standards benefit from the experience of many railways and are continually tested on a much larger scale than could ever be achieved in Australia alone.

INTRODUCTION

Train radio systems in Australia are "bespoke" – made to a customer's specifications. Bespoke is a word commonly used to describe tailoring, bringing the image of a suit designed to fit just one wearer. An exact fit, taking into account the peculiarities of that person. Definitely not designed to be used by another.

There is no single standard for communications, no common thread of functionality and performance in Australia[1]. (Queensland is the only state to claim to have a single train radio system for all their operations and that is a recent achievement.) We commence with a discussion of the requirements for radio communication systems, discussing some of the considerations for a robust and reliable system. There are obviously some significant differences between high traffic urban operations and remote lines with "one train in steam".

Australia has not had very many railway accidents where communications have been significant. Of these, some have been investigated and reported in the public domain, however, most have been the subject of internal investigations with no publicly released findings. Our assessment of the effectiveness of train radio therefore includes a review of accident investigation reports from New Zealand and Canada, as well as the available Australian documents.

THE FUNDAMENTALS

There are at least two parties interested in communicating by train radio. The first is a person on the train, usually the driver. The second is the person who has responsibility for authorising the movement of the train, usually a signaller or train controller. If there is more than one train, the driver of the second train will have some interest in communicating with the first.

All railways need maintenance and inspection so our track inspector will be there somewhere, needing to communicate with the train drivers and with the controller. The track inspector or maintenance supervisor will need to speak directly with the train driver as the train passes through a work site or area of defective track.

On suburban trains there may be a guard; on country passenger trains a conductor may be responsible for the passengers. Each of these people has a need to communicate, often in different ways; sometimes all must communicate at once, unambiguously.

Of course, a railway that is running correctly has little need of radio communications. There is a timetable, there are procedures and there are telephones. It is only when something goes wrong that radio communication becomes important – though never "vital". Will the system cope in these circumstances? Or will those on the train and trackside be left feeling very lonely?

RELIABILITY

1. Importance

Reliability is normally placed at the end of the list of requirements for a system. It is a given, not something to worry about unduly. We believe that reliability is the most critical aspect of train radio.

Reliability has a special meaning to an engineer. The engineer discriminates between reliability and availability, takes into account the maintenance intervals, the mean time between failures and other parameters. The user of a radio system does not make such distinctions. To paraphrase the "Cocky's Lament"[2]:

> *I want a radio.*
>
> *I want a radio that works.*
>
> *I want a radio that works all the time.*

Users of a train radio or other communication system will have one of two views of the radio system. They will either see it as one that works all the time; or as one that sometimes works. The first view results in a confidence in the system that is sometimes misplaced. The second results in a lack of confidence that can have tragic consequences.

Of course, it is easy to dwell on the deficiencies and ignore the many occasions when systems work well. Often there are further factors to consider, such as public address systems or contact from road vehicles. There is a moral in each of the following examples.

2. Well Placed Confidence

A review of investigation reports shows some incidents where confidence in the communication system was well placed.

Canada[3]
A train crew used incorrect braking techniques on a steep incline, resulting in derailment and a runaway portion of the train. The crew made an emergency call and no other trains were involved in the incident.

Manitoba[4]
Freight trains were passing each other when the crew of train 472 noticed that wagons of the other train were derailed and leaning toward their train. They made an emergency radio call to train 471 and took cover on the floor of the cab. After the collision, the locomotive radio on 472 did not work. The portable radio was used to re-establish communication.

Conrad[5]
A washout had undermined the track near Conrad. The CTC system displayed normal indications, as the track circuits were continuous. A train passed onto the washout and was derailed with fatal consequences for the crew. The train controller observed a CTC malfunction and tried unsuccessfully to contact the crew. A nearby train confirmed that the crew had not passed and a search was launched.

Pointe au Baril[6]
The circumstances here were similar. The train derailed but the crew were able to exit the cab and contact the train controller with a portable radio to obtain assistance.

Bowmanville[7]
A freight train struck an abandoned tractor-trailer at a farm level crossing. The freight train derailed and dragged the trainer approximately 700 metres along the track. An emergency radio call made by the crew of the freight train alerted the crew of a passenger train, approaching on an adjacent track. After hearing the radio call the crew of the passenger train reduced speed and thereby lessened the severity of impact. The passenger train struck the debris and derailed, just before the freight train came to a halt.

The truck driver had a Citizens' Band radio and a cellular telephone. He was under the impression that the cellular phone was only capable of contacting the dispatch office and did not know that the 911 emergency telephone number tied in with the railway emergency officers. He did not make an emergency call on either system while he was stuck on the crossing or after the derailment. (A recommendation of the investigation was that signs be placed at level crossings detailing emergency communication numbers.)

A similar incident has occurred in Australia but the details have not been released.

Blue River[8]
The second locomotive and all cars of a passenger train derailed. The crew made an emergency broadcast call to alert other trains and then reported the situation to train control. Protection and assistance was provided. The extrication of passengers was made difficult as the public address system did not have external speakers and relied on the locomotive power source, which had been disconnected in the derailed locomotive.

Ashburton[9]
Train control cleared a signal that authorised a train to enter a section of track already occupied by a hi-rail vehicle. The driver of the hi-rail

overheard conversation between the train controller and driver and interrupted to advise that he was still in the section.

3. Misplaced Confidence

Radio system designers work to some confidence level that any particular portion of the track will have coverage and to some other confidence level that the equipment serving that portion of the track will be working at any instant (availability). The coverage criterion may be 95% or better (as found in NSW terrestrial coverage areas) or much less, as found in much of Victoria.

The availability criterion is less clearly defined, usually because the radio portion is considered in isolation from the other components of the overall system. An availability of at least 99% of the time is probably realistic. However, there is no statement of when the other 1% of the time occurs. It may be as a period of nearly four consecutive days or it may be in ten-minute periods over the year.

The radio engineer does not usually consider the user interface and human factors. Such matters do not appear in the undergraduate courses and are often dismissed in somewhat caustic terms by equipment and system designers. However, the human interface is a part of the overall system and must be counted in the calculation of reliability.

Error tolerance is a part of system design[10], either by omission or commission. It is routinely included for data transmission calculations and is no less a part of the user interface performance.

Of course, these issues do not trouble our track inspector, who is confident that the system works very well and will therefore work when required. Sometimes that confidence is misplaced.

Hexham[11]
At Hexham signal box in NSW the signallers were often said to ignore radio transmissions. The problem was not that they were ignoring the transmissions. The signallers simply did not hear certain radio broadcasts. Nor did they hear the responses to their own transmissions. The cause of these allegations was discovered in an accident investigation. The radio system interface that the signallers were using was obtuse and misunderstood. The signallers circumvented this by using a portable radio, inadvertently thereby reducing the coverage of the system. In addition, the signallers were exposed to continuous irrelevant chatter on the system. The radio was therefore turned down, so that the chatter would not be heard. The signallers believed that they were operating the radio appropriately. Their confidence was misplaced.

Toronto[12]
Commuter cars operating in Toronto were required to make a standard shunting move, driving out from one platform and then back to another. The difference for the particular crew on the particular occasion was that they drove out of the first platform and then propelled back into the destination platform. The driver and guard had not worked in this manner previously and did not have an established protocol. The guard in the rear cab told the driver at the front of the train that the signal had changed after the forward move and the driver commenced propelling into the platform. The conductor observed a train standing at the platform and tried to tell the driver to stop, using the intercom. (There was a lot of radio traffic in the station). However, the intercom worked only through the handset earpiece, rather than the cab speakers and the guard forgot to alert the driver with the call button. The handset was on hook and could not be heard. The driver was unaware of the hazard and the trains collided.

Armstrong[13]
Two hi-rail vehicles collided head-on on a curve near Armstrong, Ontario. The rules required that on territories where there are curves, every five miles and at every station, a broadcast announcement must be made on the engineering radio system and repeated, identifying the type of track unit, location and direction of travel. The operators of each of the hi-rail vehicles made the required radio transmissions. However, none of the operators heard these transmissions, although the radio equipment was operating as designed. It was concluded that the rugged terrain blocked radio transmission, rendering it useless in locations where it could be most beneficial.

4. Expectations of Failure

An even more dangerous situation arises when the users expect that the system will fail. Any aberration in operations or lack of response is then assumed to be a problem in the communications system.

Ellerslie[14]
Two diesel multiple unit trains collided head-on on the up main line between Penrose and Ellerslie. Prior to the accident, one had become disabled at Ellerslie and the series of miscommunications that followed the discovery of a mechanical fault in that train lead to the collision. The train controller "unknowingly" authorised the trains to run on the same line, in opposite directions.

Each of the trains was equipped with portable radios. As they were portable, the train controller did not know which radio was on which train, unless told by the train driver. The inquiry report found that "the collision occurred primarily due to poor communication; equally missing was the intent to communicate and the ability to do so". "The ongoing poor performance of the portable radios was well known and the continued difficulties experienced by the train controller and crews probably discouraged communication between them. "

Glenbrook[15]

The Glenbrook collision involved the Indian Pacific loco hauled passenger train and an electric multiple unit commuter train. The Indian Pacific was stationary at a failed signal when the commuter train that was following collided with it.

There were many aspects to this accident. One was the known incompatibility of the radio systems on the locomotive and the commuter train (they could not communicate). A second aspect was a set of rules that prescribed that only certain methods of communication could be used, even if there were other methods available that were no less secure. The third aspect was the known unreliability of the signal post telephones. When stopped at the signal, the locomotive driver was unable to communicate with the telephone. He assumed that the phone was not working and was unaware that the method of telephone operation had been changed.

Three working and available communications systems were not used and the collision occurred.

5. Interference

Interference can take many forms. The radio engineer would normally consider interference as a source of noise; calculate a signal to noise ratio, increase the signal as necessary to obtain the required ration and move on to the next problem. It can be subtler.

Notch Hill[16]

A freight train was operating in CTC territory where radio communication normally was not required. However, in this instance the crew were governed by a rule requiring them to continuously monitor the standby channel, in order to be aware of other trains in their vicinity. The crew were required to call the signals to each other but the noise level in the cab was such that their words were unintelligible. The train came around a bend and the crew saw another train 140 metres away. The trains collided. The investigation revealed that the crews were commonly not calling the signals, as they knew they could not be heard.

HUMAN FACTORS

Human factors will be present in any communication system, whether allowed for in the design or not. One defence against human error is the development and maintenance of communication protocols.

1. Protocols

Communication protocols are important in any railway. A well thought out and disciplined protocol ensures consistent and effective communication. The better systems successfully operate on these protocols and do so consistently. However, there must be provision for the unexpected. The Glenbrook[15] incident is a frequently cited example of flawed protocols and procedures. In this case the problems preceded the incident. They can follow.

Biggar[17]

A passenger train derailed after fracture of the lead axle on the trailing locomotive. The train public address system continued to operate (from the carriage emergency supplies) after the derailment. The public address system provided one-way communication and was of limited value for co-ordination of disaster recovery. Both train and passenger services (OTS) crew had portable two-way radios with the train-working and OTS channels. The policy of the railway precluded the train and OTS crews from communicating with each other and the policy made no provision for an emergency. Policy also required that the passenger service manager and other OTS employees remain on the OTS channel at all times. The conductor maintained his radio on the train stand-by channel and did not use the OTS channel. The crew had to walk to each other to communicate.

Campbellville[18]

A freight train struck two stationary track units (a small crane and lorry). The track crew foreman had instructed the crew to proceed on the north track. The crew repeated “main track” instead of “north track” and the foreman did not detect the error and verified the repeat as correct. The railway depends on strict adherence by employees to the procedures and rules as defences against communication errors. Although the procedures were “roughly” followed, the necessary structured approach to the language used was not maintained. There was no requirement for the train crew to apprise the foreman of the track on which they were approaching.

2. Human Error

Human error is evident in many forms. Shock is significant and can result in actions that are unintended or the failure of intended actions.

Dalhousie Mills[19]

A freight train derailed and spilled 1900 litres of hydrogen peroxide. The crew made an emergency call on the stand-by radio channel to alert other trains. The crew were unable to contact train control on the radio call-in channel and then radioed a nearby track maintenance person. The track person advised the driver by cellular phone that train control was attempting to contact the train. Communication with train control was then effective. No defects were found in the radio system and no emergency calls from the train were logged. It was concluded that the crew members had become excited when they realised that both main lines were blocked and used incorrect radio procedures.

Greely[20]

Fatigue affected the crew of a train that failed to stop at signals and collided with an oncoming train. The other crew misunderstood an emergency call from the fatigued crew. The inquiry recommended fatigue management actions, including the installation of locomotive cab audio systems, using headsets for music and intercom.

FLEXIBILITY AND COMPATIBILITY

In the past, train radio and communication systems have been inflexible in their design. This was not necessarily due to any lack of vision in the designers; it was simply a limitation of the available technology. With a modern technology such as GSM-R, these limitations do not apply.

Glenbrook, discussed above, is a prime example of incompatible and inflexible train radio and telephone systems. The Hexham incident, also mentioned earlier, is another example of the confusion, lack of communication and error that can be introduced through inflexibility and incompatibility.

Waterfall[21]
At Waterfall the train derailed in a deep cutting, well away from population. The only radio services in the area were the Metronet train radio, accessible only to train crews and a few others and the Government Radio Network. Initial reports of the accident were made through cellular telephone calls to the emergency "000" number. As rescuers and others arrived, the Government Radio Network's very limited capacity was quickly swamped. There will be more detail on this in the final report of the Waterfall Special Commission of Inquiry.

Chiltern[22]
The report on this accident has yet to be released. A V/Line Passenger service from Albury to Melbourne collided with the wreckage of a Pacific National freight train that had derailed near Chiltern in Victoria. The derailment occurred on the standard gauge track. The passenger train was travelling on the parallel broad gauge track. The standard gauge track is controlled by ARTC, while the broad gauge track is controlled by Freight Australia. The tracks have different radio channels and the controllers are in different cities.

Spencer Street[23]
A train ran away from Broadmeadows station and stopped only when it crashed into another train at Spencer Street. The inquiry report notes that there is no open channel radio system in the Melbourne suburban rail network. Therefore, there was no way in which urgent 'broadcast' messages could be made over the rail network.

RESCUE THE PERISHING

Perhaps too blunt a caption but the issue is most important. Our track inspector rolls his vehicle. The locomotive derails and overturns. How do we know that it has happened or where it happened? There is inexpensive technology for tracking trains and some Australian systems incorporate GPS tracking (eg QR, Countrynet, AWARE).

Some (and only some) of the locomotives and track vehicles operating in isolated areas carry Emergency Position Indicating Radio Beacons (EPIRBs) or Personal Locator Beacons. A beacon transmitter should, in the author's view, be fitted to each cab of each locomotive with an external antenna and tilt switch. The more severe accidents that are most likely to disable the crew involve derailments and rolled locomotives. With a tilt switch the emergency alarm would be initiated as the locomotive rolled, well before any fire or other damage. There is a simple and well managed international response mechanism for location beacon alarms[24].

New Zealand[25]
A freight train driver fell asleep on curved track in rugged terrain. The train exceeded the design speed for the track, derailed and the locomotives rolled into the valley beside the track. It was some hours before the train controller realised that the train was overdue. Many hours passed before the search commenced and many more before the train was found. During all this time the seriously injured second person was trapped in the cab of the locomotive with the deceased driver. One of the searching crews in a hi-rail vehicle collided with the rear of the train. The radio system had provided vital clues about the location of the derailed train (through base station site names). However, the train controllers did not know the names of the sites and their position relative to the track. The search period could have been significantly reduced had this information been usable.

Waterfall[21]
It took quite some time for the fact of the Waterfall accident to be realised and even longer for the rescue crews to determine the location of the train and means of access to it. A tracking device would have given greater precision than the track circuits and would have been independent of their operation. The Metronet system that was used provides a position indication only when the train passes a transponder. There is no further indication of position until the next transponder is passed, usually at the boundary of the next signaller area.

Hexham[11]
This incident, mentioned earlier, is one where GPS tracking was available to accurately position the derailed freight train. Unfortunately, the train controller did not take advantage of the information that was displayed on the Countrynet screen. The passenger trains in the area only had portable radios and were therefore not tracked in the same manner. The collision with the passenger train may have been averted had the train positions been positively identified.

DESIGNER'S DILEMMA

Where does this leave the system designer? How can such a vast scope be covered in any specification or solution? There is no comprehensive communication system design manual for Australian railways. Indeed, there is not even a defined approach to risk analysis or a checklist of considerations. Each new system and each material change is assessed on the basis of the experience of a few individuals, usually on the basis of their experience in a single railway.

1 EIRENE

There is good news: Australian railway operations are really no different from those in other parts of the world. All the requirements discussed in this paper appear in every railway (although they may not have been acknowledged). There is no need for any railway or country to work alone, to attempt to develop individual standards. An international approach offers the benefits of world-wide experience and a world-wide market.

European railways have documented train radio and communication requirements very thoroughly when formulating their specifications for EIRENE[26]. This set of requirements specifications lead to a railway specific version of GSM cellular telephony. (The railway specific enhanced version of GSM is known as GSM-R.)

EIRENE provides rapid call connection for emergency calls (a key consideration). It can operate as both an open channel system with press-to-talk and as a discrete telephone connection. More powerfully, it can operate in both modes simultaneously in a given base station area. The individual call connections are defined by the railway in an "access matrix" and in the SIM card for the user's telephone.

Position reporting is an inherent function in EIRENE and can be driven by GPS, transponders or other systems. Since the GSM implementation of EIRENE is a superset of GSM features, the GSM-R EIERENE compliant mobiles can also work on standard GSM. (There is a loss of EIRENE functionality but full GSM functionality). The ability for mobiles to "roam" onto other networks provides an independent alternative system should the GSM-R system fail or be damaged (subject to coverage and roaming agreements).

Flexible re-configuration of the system is provided through the network access matrix. Network operators can have dynamic or predetermined emergency configurations that reallocate the system resources to respond to any incident. This level of flexibility is not available in existing train communication systems.

Disaster recovery has often been impeded by the inability of emergency and rescue crews to communicate. (Much time was lost at Waterfall due to lack of communication.) The standalone, bespoke communication systems that have been used by railways have no capacity for expansion or adaptation in time of emergency and disaster recovery.

If a system conforming to the EIRENE specifications is used, disaster recovery can be managed by reallocating access privileges for particular telephones. The initial report of an incident can be made from any GSM telephone as the GSM-R system will accept an emergency call (dialled to 000) if there is no other GSM system in the area.

During the recovery period sites can be expanded in capacity without reprogramming mobiles and without impact on the existing services. One need only look at the paucity of communications at Cowan Bank[27] when the interurban train collided with a steam-hauled train to see how limited communications can be, even very close to a major city. Thirteen years later, the situation at Waterfall was similar.

2 The Wide, Open Spaces

While Australian railway operations are not unique, the wide, open spaces and low traffic density are rather different from the high-speed international routes envisaged by the EIRENE specification writers.

GSM-R was introduced for high-speed railways in high population density areas. Its deployment on the major freight routes (the Defined Interstate Rail Network) is appropriate and can be facilitated by suitable commercial models. However, it is improbable that GSM-R would ever be utilised over the length of the Tarcoola to Darwin railway or on many of the seasonal grain lines. Australia is therefore always likely to have a mix of radio communication systems; the blend being determined by traffic levels and location.

We would argue that this situation is not a reason for ignoring the international standard. Rather, it is a reason for working as closely as possible with the international standard, applying it without compromise over the DIRN and all metropolitan networks.

An extension to the specification is needed for low traffic lines. This is well understood by the developers of the EIRENE specification, as there are low traffic lines in many countries. Work is in progress on a low cost, compatible specification for such areas. This specification has its genesis in the UIC Locoprol[28] project. The Locoprol approach is particularly aimed at satellite location but has obvious connections to the communication network. It would be more appropriate for Australia to join in the development of low traffic, low cost expansions of the international specification than to develop another set of bespoke solutions.

CONCLUSION

Railway crews and operations need reliable radio and telephone communication. A reliable system is not just one that does not break down. It is a system that is always available; has consistent coverage and provides clear, intelligible communication.

The communication system will be used by humans and must be designed accordingly. In moments of stress the users will make mistakes so the system must be designed to accommodate mistakes and to minimise their consequences.

The incident experience of any single railway will not provide a comprehensive database and knowledge base for system design. International standards are built on the experience and knowledge of many railways, with a wide variety of operation styles and needs. These standards are consistently tested and are reviewed systematically. They should be adopted and applied in Australia. Both EIRENE and Locoprol should be considered.

Flexibility is an essential characteristic as the railway's requirements after an incident are vastly different from those for normal operations. Emergency configurations should be built into the system, ready for activation at a moment's notice.

Redundant layers of communication increase the reliability and robustness of the communication link. Emergency beacons and tracking devices that operate independently provide a layer of protection. In particular, an emergency beacon can operate after locomotives have derailed or rolled over, even if the crew of the train are incapacitated.

Communication systems are often considered as optional components of a railway. We would argue that they are essential to a safe, modern railway. Unless there is robust, reliable communication system, our track inspector will, indeed, be lonely out there.

---

[1] John Aitken, *Australia Wide Communications System for Rail Operators*. IRSE Technical Convention, Adelaide, 14 March 2003.

[2] *The Cocky's Lament* originated during Telecom Australia investigations into telephony in country Australia late last century. In this context, the users wanted a telephone, a telephone that worked , a telephone that worked all the time.

[3] Transportation Safety Bureau of Canada, Report R97C1047, 1997. *Runaway/Derailment, Canadian Pacific Railway. Train No. 353-946 Laggan Subdivision Field, British Columbia,* 2 December 1997

[4] Transportation Safety Bureau of Canada, Report R999W0231. *Derailment and Collision, Canadian Pacific Railway, Near Poplar Point, Manitoba.* 1 November 1999.

[5] Transportation Safety Board of Canada, Report No R97V0063. *Derailment Canadian National Train No Q-101-51-26. Conrad, British Columbia.* 26 March 1997.

[6] Transportation Safety Board of Canada. *Subgrade Failure, Canadian Pacific Railway, Train No 935-08, Pointe au Baril, Ontario*. 7 April 1997.

[7] Transportation Safety Board of Canada, Report No R99T0298. *Crossing Accident and Derailment. Bowmanville, Ontario* 23 November 1999.

[8] Transportation Safety Board of Canada. Report No R95V0089. *Derailment Via Rail Canada Inc Passenger Train. Blue River, British Columbia.* 22 April 1995

[9] Transport Accident Investigation Commission New Zealand. Report 02-129. *Train Control Incidents – trains authorised to enter sections of track already occupied by hi-rail vehicles and work groups. Various locations.* 29 August 2002 – 4 December 2002.

[10] John Aitken, *Error Tolerant Communication Systems*, Rail Safety 2004, Sydney, 10 February 2004.

[11] Transport NSW, *Incident Investigation. Passenger Train Collision with a Derailed Coal Train at Hexham NSW. 12 July 2002, Final Report.*

[12] Transportation Safety Bureau of Canada, Report R97T0299 – Rail 1997. *Collision of commuter trains at Union Station, Toronto, Ontario, Canada.*

[13] Transportation Safety Board of Canada, Report No R96T0008. *Collision, Canadian National, Two Hi-Rail vehicles, Armstrong Ontario.* 11 January 1996.

[14] Transport Accident Investigation Commission, New Zealand. Report 00-123. *Diesel Multiple Units, Trains 3131 and 3134, collision, Ellerslie, 28 December 2000.*

[15] The Honourable Peter Aloysius McInerney, *Special Commission of Inquiry Into the Glenbrook Rail Accident, Final Report*, April 2001

[16] Transportation Safety Bureau of Canada, Report R98V0148 Railway Investigation Report, *Rear-end Train Collision, Canadian Pacific Railway. Train No. 839-020 and Train No. 463-11. Mile 78.0, Shuswap Subdivision, Notch Hill, British Columbia* 11 August 1998.

[17] Transportation Safety Board of Canada. Report R97H0009. *Derailment, Via Canada Passenger Train No 2, Mile 7.5, near Biggar Saskatchewan.* 3 September 1997.

[18] Transportation Safety Board of Canada. Report No R98T0141. *Collision St Lawrence & Hudson Railway Campbellville Ontario.* 17 June 1998.

[19] Transportation Safety Board of Canada. Report No R96H0021. *Derailment St Lawrence & Hudson*

Railway, Dalhousie Mills, Quebec. 29 August 1996.

[20] Transportation Safety Board of Canada. Report No R95V0218. *Collision between Canadian Pacific Limited trains.* Greely, British Columbia. 1 October 1995.

[21] The Honourable Peter Aloysius McInerney QC *Special Commission of Inquiry into the Waterfall Rail Accident. Interim Report* January 2004

[22] Railway Digest, April 2003

[23] Australian Transport Safety Bureau. Rail Investigation Report No 2003/001. *Runaway of Suburban Electric Passenger Train 5264 and collision with Diesel Electric Hauled Passenger Train 8141. Spencer Street Station, Victoria.* February 2003.

[24] http://www.cospas-sarsat.org/ describes the international response system. Further information is available at http://beacons.amsa.gov.au/What_is/index.asp

[25] New Zealand Transport Accident Investigation Commission. Report No 02-116. *Express freight Train 533, derailment, near Te Wera.* 26 July 2002

[26] *European Integrated Railway radio Enhanced NEtwork:* UIC Project to develop the specifications for and to facilitate the standardisation of the GSM-R railway radio communication system. www.gsm-r.uic.asso.fr

[27] A Sydney bound interurban train collided with the rear of a tour train hauled by steam locomotive 3801 on 6/5/1990. There were very limited communication facilities and there was no train radio.

[28] The LOCOPROL project intends to develop an innovative cost-effective satellite based vital fail-safe train location system as the core of a train protection, control and command system. The proposed innovations are planned for short-term applications for low-density traffic railway lines, with significant reduction in costs. www.locoprol.org