ATMS/ETCS INTEROPERABILITY OPTIONS

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1. INTRODUCTION

This paper looks at the issue of interoperability between different rail traffic management systems. It examines the matter of interoperability generally, and the objective of achieving a framework for national interoperability between present and future train control and protection systems, across all rail networks in Australia. It examines interoperability specifically in reference to the interface between ARTC’s Advanced Train Management System (ATMS) and RailCorp’s implementation of the European Train Control System (ETCS).

The paper discusses a variety of ways in which interoperability can be achieved, in ways that depend on the relative architectures of the respective systems, and the implications of each method.

It concludes that interoperability is achievable, with minimal duplication of equipment and functions, with any translations needed between systems kept ‘under the covers’ and transparent to the operators.
2. NOTATION

AMS  Vital Authority Management Server in ATMS.
ARTC  Australian Rail Track Corporation.
ATMS  ARTC’s Advanced Train Management System.
ATP  Automatic Train Protection.
Balise  French word for beacon, or radio transponder.
ETCS  European Train Control System.
IEEE  Institute of Electrical and Electronic Engineers.
GSM-R  Global System for Mobile Communication - Rail.
LDS  Location Determination System in ATMS.
LEU  Lineside Electronic Unit in ETCS.
NCC  Network Control Centre.
NextG  Telstra’s 3rd Generation mobile phone system.
OBC  Onboard Computer.
RBC  Radio Block Centre in ETCS.
TCS  Non-vital Train Control System in ATMS.
TIU  Trackside Interface Unit in ATMS.

3. DEFINITION OF INTEROPERABILITY

A formal definition of interoperability has been given as:

“The ability of two or more systems or components to exchange information and to use the information that has been exchanged.”[1]

In the railway context this might be expressed as:

“The ability of a train to operate across multiple jurisdictions and operate successfully in each control environment.”

4. STAKEHOLDERS IN INTEROPERABILITY

Network Managers, Train Operating Companies and Rolling Stock Suppliers all have a big stake in interoperability, through the potential to improve safety and operations, and to lower costs. However, it must be recognised that Australian rail transport has widely varying operating and risk environments and that one uniform control solution is unlikely to be suitable for all networks. Therefore, the problem must be seen as how to get different systems talking to each other, rather than how to get agreement on one system.

5. DESIRABLE CHARACTERISTICS FOR INTEROPERABILITY

The following characteristics are desirable of an interoperability solution:

• No reduction in rail safety.
• No reduction in reliability.
• One interface to the train driver.
• Trains do not have to slow when crossing the boundary between systems.
• Any differences between systems are ‘under the covers’ and transparent to operators, except for display differences warranted by the need to advise drivers of changes in control environments.
• Optimal whole of life cost for whole industry.
• No barriers to supplier competition.
• Support national and local operating rules.
• No constraint on future network capacity improvements.

In addition to those above, the following characteristics are also desirable of an interoperability solution:

• A framework that caters for future yet to be invented control systems, and future system functionality.
• A framework that has national applicability.
• A framework that allows for jurisdictional independence in relation to the choice of systems.

6. INTERNATIONAL TRAVELLERS

For the sake of comparison consider the process that occurs when an international traveller crosses a national border.

• The national borders carry some form of identification, usually signs and some form of checkpoint.
• A traveller must approach this border and identify themself, usually by presenting a passport. This also identifies the language that the traveller speaks.
• Authority to enter usually involves the presentation of a form in the language of the traveller, or at least in one of the major world languages, completion of that form, and endorsement by the authorities.
• Any restrictions to entry, such as time allowed or places that are off limits are noted on the form.
• The traveller proceeds into the foreign country.

7. GENERIC TRANSITION PROCESS
In general the following process needs to occur at control system boundaries.

• The boundaries are identified.
• If necessary, the train is identified when approaching a boundary.
• The train is advised of authority to proceed.
• The train is advised of the limits of the issued authority.
• If the train has authority enforcement, it must have a means of determining its location.

8. ATMS AND ETCS ARCHITECTURE

8.1 ATMS Architecture

The Advanced Train Management System (ATMS) architecture is highly centralised with minimal field equipment and includes the following features:

• Separate non-vital Train Control System (TCS) in the Network Control Centre that handles the interface with the Network Controller, accepting commands from the Controller, driving displays, and conducting a degree of automation such as authority stacking and automatic route setting.
• Safety critical (vital) Authority Management Server (AMS) in the Network Control Centre, managing the validating of authority requests from the Controller, setting switches in accordance with these requests, issuing of validated authorities, and rolling up of fulfilled authorities.
• Communications system based on the Telstra NextG system.
• Trackside Interface Unit (TIU) managing control of switches and interfacing with a switch track control circuit.
• Train borne system including locomotive computer, drivers’ display, Location Determination System (LDS), brake interface, and communications equipment.

Compared to existing signalling systems the key differences are that the wayside signals have been replaced by a digital display in the cabin, and the field interlocking has been replaced by the AMS in the Control Centre.

The locomotive based location determination capability allows the ATMS system to know accurately the location and speed of all of the equipped trains at any time. A consequence of this is that a number of the design principles associated with current signalling systems (such as approach locking) are no longer required, as they are predicated on imprecise knowledge of train location and speed.

8.2 ETCS Level 1 Architecture

A typical implementation of the European Train Control System (ETCS) at Level 1 and includes the following features:

• Separate non vital TCS, accepting commands, driving displays, and conducting a degree of automations such as automatic route setting, with non-vital signal commands transmitted to the field.
• Separate field interlocking equipment to manage safe separation of trains and non-conflicting signal state commands sent to trackside signals.
• A Lineside Electronic Unit (LEU) that takes electrical signals from the field interlocking equipment on signal states, converts these into a data message, and sends it to the track mounted balises (beacon or transponder) or infill loops.
Controlled and fixed balises, mounted within the track structure that contain information on signal states from the LEU, and fixed information such as balise location, track gradients and track speed.

Infill loops that provide advance information on signal aspects (not shown on this diagram).

Train borne system including balise reader, onboard computer, drivers’ display, tachometers/RADAR, brake interface, and communications equipment.

ETCS Level 1 provides supervision of train speed and enforcement of movement authorities as an overlay on existing signalling systems. ETCS Level 1 provides information to the driver on the supervision applied as well as other information useful in managing the train via an in cabin display.

ETCS Level 2 is a development of ETCS Level 1, with the wayside signals (optionally) removed, although the wayside interlocking that provided information on signal states is retained. The state of the ‘virtual’ signals is picked up from field interlocking equipment in a similar fashion to Level 1, but the data messages are transmitted to the train by radio from the wayside radio block centres rather than through track mounted balises. Consequently the infill loops are not required as updates can be continuously transmitted to the trains. The balises do not carry authority information at Level 2, but fixed information on balise location.

ETCS Level 3 is a further development of ETCS level 2 with the field interlocking removed, and replaced by centralised interlocking contained within the radio block centres. The functionality provided by ETCS Level 3 is comparable with that provided by ATMS. Note that whilst ETCS Level 3 has been specified it has not yet been implemented on any railway.

9. SPECIFIC TRANSITION PROCESSES

Although there are many different control systems, for the purposes of this discussion we will examine three classes of control system as follows:

- Voice based (train order).
- Wayside systems (usually based on signals).
- Electronic authority systems (eg ATMS and ETCS).

The entry of a train into one of these three classes of control system follows a specific process.

9.1 Voice authority system

- The boundaries are identified by wayside signage, usually located at braking distance from the boundary, utilising driver route knowledge.
- The train is identified when approaching a boundary by an exchange between the respective Controllers, and the driver calling the Network Controller and advising approach and train ID.
- The train is advised of authority to proceed, when safe to do so, by the issue of a voice train order.
- The train is advised of the limits of the issued authority, by the limits being specified in the train order.

9.2 Wayside signal system

- The boundaries are identified by signage and approach signals usually located at braking distance from the boundary, utilising driver route knowledge.
- The train is identified when approaching a boundary by an exchange between the respective Controllers, and partly when the train occupies approach track circuits. This may be automated by means of an exchange between control systems that present the identity of the train to the operator.
- The train is advised of authority to proceed, when safe to do so, by the Controller clearing the relevant signals.
The train is advised of the limits of the issued authority by the signal aspects, including green for no imminent limit, yellow for an approaching limit, and red for the actual limit.

If the train has authority enforcement, it must have a means of determining its location. In signalling systems, where enforcement is provided, it is usually by track circuits and enforcement by ground based mechanical train stops.

9.3 Electronic authority system

• The boundaries are identified by wayside signage (possibly) and display to the train driver.
• The train is identified when approaching a boundary, either by exchange between the respective Controllers or by electronic advice between the adjacent control systems.
• The train is advised of authority to proceed by issue of an electronically generated and transmitted movement authority.
• The train is advised of the limits of the issued authority via the parameters of the electronic movement authority.
• If the train has authority enforcement, it must have a means of determining its location. Usually this will be by a system based on a combination of global coordinates, inertial navigation and wayside checks and logic.

9.4 Implications

The implications for a train to enter each class of control system are as follows:

• For the transition to a voice based control area, either the trains must have compatible radio systems with the network or the network must be able to select the appropriate communication media to suit the incoming train. This is historically achieved by trains carrying multiple radio equipment, or more recently by control centres having intelligent multiple media handling capability.
• For the transition to a signalled area, drivers simply have to observe and obey line side signals.
• For the transition to an electronic authority area, either the train must be able to read and interpret commands sent by the electronic authority system, or the electronic authority system must first translate the commands that are sent to the incoming train.

For example, for an ATMS fitted train to enter an ETCS area, either

• The train must be able to read and interpret ETCS commands received via the track mounted balises (level 1) and via radio block centres using GSM-R (level 2), or
• The track side must be able to translate ETCS commands to ATMS commands and send these to the train via the NextG network. For ETCS level 1 this requires the train to advise its position to the trackside so that movement authorities can be issued at the point in time when the train would have read the balise corresponding to each signal.

Likewise, for an ETCS fitted train to enter an ATMS area, either

• The train must be able to read and interpret ATMS commands received via the NextG network, or
• The track side must be able to translate ATMS commands to ETCS commands and send these to the train via the NextG network.

Both the ATMS and ETCS fitted train would need to have radio equipment installed to receive information via a medium compatible with it and the trackside system.

It is important to distinguish here between the communications medium and the data message protocols. It is possible that data messages with either ATMS or ETCS protocols be transmitted over NextG or GSM-R communications systems. The use of track mounted balises and train mounted balise readers is a third method of transmitting data messages to the trains.

10. OPTIONS FOR SYSTEM INTERFACE

There are a range of options for the interface between adjacent but different control systems, and the options vary depending on the architecture of the two systems. For simplicity, we shall compare ARTC’s Advanced Train Management System (ATMS) with RailCorp’s European Train Control System (ETCS). Note that other Australian cities have Automatic Train Protection (ATP) systems that are architecturally similar to ETCS Level 1 but that these are usually proprietary systems.

11. OPTIONS FOR LOCATION OF INTERFACE BETWEEN TWO SYSTEMS

There are a number of locations where the interface between two systems could be located as described in the following sections.
11.1 Within the driver’s head

The interface could be handled by train drivers who have the ability to interpret information received from different systems and ‘translate’ them into the allowed movement authority. For example, on the transition from an ATMS area to a signalled area the driver can cease to refer to the computer screen and instead refer to the wayside signals. This makes the drivers ‘bilingual’ in the sense that they can talk two control system ‘languages’ but this does not support enforcement of movement authorities.

Fig 5: Interface by driver

11.2 Within the onboard equipment

The onboard system could be provided with the hardware and software to ‘read’ movement authority information from two different kinds of wayside systems.

For example, on transition from ATMS to ETCS, the onboard equipment can cease to ‘listen’ to the ATMS radio signals, and instead ‘listen’ to the information transmitted from track mounted balises or from radio block centres. This would require radio equipment as well as balise readers to be installed on trains (note that radio equipment will already be installed to support voice communications), and software to switch between and handle the two different forms of information. This makes each train bilingual.

Note that if balises are not installed in an ATMS area then an ETCS fitted train would also need equipment installed to determine its location by some other means.

Fig 6: Interface within onboard systems.

11.3 Within wayside equipment

The wayside equipment could be provided with the hardware and software to ‘send’ movement authority information to two different kinds of onboard systems.

For example, for an ATMS fitted train in an ETCS area the onboard equipment can continue to ‘listen’ to what it perceives are ATMS radio signals generated by the wayside. This would require equipment installed on the wayside to receive and transmit information, and software to handle the two different forms of information. That is, each signal becomes bilingual.

For an ETCS fitted train in an ATMS area it can continue to ‘listen’ to what it perceives are ETCS radio signals generated by the wayside. This would require equipment and software installed on the wayside to handle the two different forms of information. That is, ATMS must become bilingual.

Note that if balises are not fitted in the ATMS area then the ETCS fitted train would also require radio equipment installed on the train to receive ETCS information via ATMS radio signals (note that radio equipment will already be installed to support voice communications), and equipment to determine its location by some other means.

Fig 7: Interface within wayside equipment

11.4 Within the control centre

If movement authorities are generated at the control centre, then they can be sent to trains in whatever language the train understands. This would necessitate the control centres knowing what language each train uses, and selecting the appropriate data message protocol and compatible communications medium. Thus, the control centres become bilingual.
12. INTEROPERABILITY OPTIONS

The possibilities for ATMS and ETCS interoperability across ARTC and RailCorp territory are now described in more detail.

12.1 ATMS / ETCS Level 1 (signals retained)

Note that ETCS Level 1 is RailCorp’s proposed implementation.

12.1.1 Driver Manages Translation Between Systems

In this scenario, the driver manages the translation between systems and all communication and control are done with existing radio based processes and by visual sighting of signals.

This would replicate existing control methods, and would represent neither an improvement nor a degradation of safety. This is undesirable as RailCorp’s intent in introducing ETCS is to increase safety on the network. However, given that one of ARTC’s objectives is to remove wayside signals, it would also be less than optimal to retain reliance on visual sighting of signals or voice based authorities. Any such trains would be severely limited in terms of their access to congested time slots.

This is the Base Case, shown in Fig 9, with no technology utilised to support the transition between networks, although a procedural handover would occur between adjacent Network Controllers and the drivers would no doubt communicate with the Controller of the network that is being entered.

12.1.2 Onboard Manages Translation Between Systems

In this scenario, the onboard manages the translation between systems with the required hardware and software to interpret information exchanged with the wayside systems encountered.

For ATMS fitted trains, this would mean installation of balise readers (and similar equipment for other metropolitan networks), and for RailCorp trains it would mean installation of NextG equipment (or other compatible medium) as well as equipment to determine the location of the train in lieu of balises.

Each train would have core supervision hardware and software with separate software to allow each train, whether fitted with ATMS or ETCS, to talk to the ATMS system in ARTC territory or to the ETCS system in RailCorp territory. In other words, the interface between the ETCS and ATMS systems is managed within the onboard equipment.

It is feasible for the ATMS and RailCorp’s signalling systems to be interconnected in such a way that the network from which the train is departing enforces a stop unless the receiving network has given authority to enter. Thus RailCorp entry signal state would be fed into the ATMS system, and the trains enforced to stop at the boundary unless entry signals were clear. Conversely, the ATMS system would transmit to the signalling system information about the authority status for the entering train, and this would be used to allow departure signals to clear.

At present, the ATMS concept does not contemplate any technological connection between the two systems, but manages the handover by procedure. However, ATMS will enforce a departing train to a stop at the boundary unless the driver acknowledges (by soft key pushbutton) that entry authority has been granted. For a train entering ATMS territory, ATMS can enforce a train to a stop prior to the boundary unless it has a valid authority to enter.

Fig 8: Interface within control centre

Fig 9: Driver translation between systems

Fig 10: ATMS fitted trains have movement authority enforced at RailCorp boundary
12.1.3 Wayside Manages Translation Between Systems

In this scenario, the wayside manages the translation between systems with the required hardware and software to translate information for the kinds of onboard systems encountered.

For the RailCorp network this would mean installation of NextG equipment (or other compatible medium), and the hardware and software to translate and send ETCS LEU commands in ATMS format for ATMS fitted trains at a point in time when the train was determined to be over the corresponding balise location.

For the ATMS network this would mean the installation of hardware and software to translate and send ATMS commands in ETCS format for ETCS fitted trains. For an ETCS fitted train in an ATMS area, this would also mean the installation of radio equipment to receive commands via the NextG network (or other compatible medium) as well as equipment to determine the location of the train in lieu of balises.

12.2 ATMS – ETCS Level 2 (signals removed)

Note that RailCorp does not plan to implement ETCS Level 2 at this stage.

12.2.1 Onboard manages translation between systems

In this scenario, the onboard manages the translation between systems with the same hardware and software as per ‘ATMS / ETCS Level 1 – Onboard Manages Translation Between Systems’ with the exception that GSM-R communication is supported in addition to reading balises.

12.2.2 Wayside manages translation between systems

In this scenario, the wayside manages the translation between systems with the same hardware and software as per ‘ATMS / ETCS Level 1 - Wayside Manages Translation Between Systems’ except that this would now be per radio block centre and communication would be via NextG or GSM-R.

Note that visual sighting by train crews is no longer an option, as signals are removed.
12.3 ATMS – ETCS Level 3 (signals and interlocking removed)

Note that RailCorp does not plan to implement ETCS Level 3 at this stage.

12.3.1 Train manages translation between systems

In this scenario, centrally generated movement authorities would be transmitted in ATMS protocols using NextG (or other compatible medium) in an ATMS area and ETCS protocols in an ETCS area using GSM-R (or other compatible medium).

For ATMS fitted trains in an ETCS area the ETCS commands received would be translated into ATMS style commands. For ETCS fitted trains in an ATMS area the ATMS commands received would be translated in ETCS style commands. That is, the train becomes ‘bilingual’

12.3.2 Control centre manages translation between systems

In this scenario, centrally generated movement authorities would be transmitted in ATMS protocol via NextG or ETCS protocol via GSM-R specific to each the train and the equipment fitted. That is, the Control Centre becomes ‘bilingual’.

13. CONCLUSIONS

Interoperability should be seen as the ability of different systems to work together to allow trains to efficiently transit across rail network borders. It is not necessarily the same as related concepts of uniformity, equipment compatibility, or an open systems supplier market.
There are some fundamental requirements when people or equipment passes across an administrative boundary. These include boundary identification, approaching vehicle identification, language in which procedures are conducted, and authority to enter. These processes are remarkably similar regardless of whether it is people crossing a national border, or trains crossing a rail network boundary.

A control system similar to ETCS Level 3 or ATMS, with its centralised architecture allows ready interface with other systems, as protocol and communications media conversions can occur at the control centre. When both the ETCS Level 3 and ATMS systems are developed, whether trains are proceeding into RailCorp territory or into ARTC territory, arrangements can be readily put in place where the control system can communicate using the protocol of the incoming trains and the prevailing and most convenient communications system. This translation could just as well occur onboard the train.

There are a number of methods by which interoperability can be achieved within the Australian rail industry. The choice depends on the levels at which ETCS or similar systems are implemented and considerations about the best location for interfaces and any equipment or software required to interface the systems.

There is a certain amount of additional hardware and software required to make ATMS and ETCS interoperable regardless of what level of ETCS is implemented.

However, interoperability can be achieved with any translations or additional equipment or software kept ‘under the covers’ and without burdening the train driver with more than one screen and set of controls.

14. REFERENCES

What do we want from interoperability?

- The ability of trains to operate across multiple jurisdictions so that:
  - Safety and reliability are maintained
  - There is a seamless transition between systems
  - Differences in operation are confined to the driver display
  - Optimal whole of life cost is achieved
  - National and local operating rules are supported
  - There are no constraints on improvement to increase capacity
- Within a framework that:
  - Allows for future systems
  - Has national applicability
  - Allows for jurisdictional independence
What is ATMS?

- Safety critical authority management system
- Communications over NextG network
- Trackside systems to control switches
- Onboard train supervision

What is ETCS?

- ETCS level 1
  - Trackside interlocking retained
  - Communications via balises
  - Onboard train supervision

- ETCS level 2
  - Trackside interlocking retained
  - Continuous updates via GSM-R
  - Onboard train supervision

- ETCS level 3 – moving block with train integrity checking done on the train
ATMS – ETCS interoperability options

- The driver manages the translation between ATMS and ETCS through observance of line side signals
- The onboard manages the translation between ATMS and ETCS commands received from the wayside
- The wayside manages the translation between ATMS and ETCS commands sent to the onboard
- The control centre manages the translation between ATMS and ETCS commands sent to the onboard

ATMS – ETCS interoperability by driver

- ATMS train supervised by ATMS or by driver following signals
- ETCS train supervised by ETCS or by driver following signals
ATMS – ETCS interoperability by onboard

- ATMS train translates ETCS commands from ETCS wayside
- ETCS train translates ATMS commands from ATMS wayside
- Onboard provides compatible communication medium
- Onboard driver display reflects any changes in supervision

ATMS – ETCS interoperability by wayside

- ATMS train receives ATMS commands from ETCS wayside
- ETCS train receives ETCS commands from ATMS wayside
- Wayside provides compatible communication medium
- Onboard driver display reflects any changes in supervision
ATMS – ETCS interoperability by network control centre

- ATMS train receives ATMS commands from ETCS NCC
- ETCS train receives ETCS commands from ATMS NCC
- NCC provides compatible communication medium
- Onboard driver display reflects any changes in supervision

Questions?