Beyond Levels - Addressing the variable traffic density needs of rail networks with the scalable ATLAS train control solution

Vincent PASSAU, Alstom Transport

SUMMARY

The ERTMS train control solution was developed to meet a number of different infrastructure configurations. The Level 1 and Level 1 Limited Supervision (LS) allow overlay over existing infrastructure, the Level 2 cab signalling has been extensively deployed on new (often high speed) lines while the addition of STMs for operation with legacy system, allows operation of fitted trains over non-upgraded lines. The recent worldwide success of ERTMS, the planned national roll-outs and the development of Baseline 3 make it a good time to reconsider how solutions should be developed to best suit the needs of train operators (railway undertakings) and infrastructure managers.

In addition the presently deployed Level 1 and Level 2 are based on an “implicit” signalling solution consisting of interlockings and secondary detection. This ETCS deployment did not change the essential overall architecture with its known procedures for management of degraded modes. For example the successful deployment in 2005 of ERTMS Level 2 on the Rome-Naples high speed line demonstrated that having a centralised architecture with RBCs and a GSM-R network did not create any particular difficulties compared with a traditional high speed lines with track circuit transmission and distributed interlockings. However the ERTMS system will enable Level 3 functionality, and use of this feature forces a reconsideration of what is the overall solution and the procedure for degraded modes.

For reconsideration of train control solutions, it is proposed that, if one does abstraction of the different needed infrastructure configurations and focuses on the train control system of the future, then the key variable customer need for train control is that of traffic density. Railways have a very wide variety of operating densities going from around 6 trains per day on low density lines, to 40 trains per day on saturated single track lines, to busy lines of a hundred or so trains per day and finally to some extremely busy suburban lines with over 600 trains per day. As traffic density increases, so does the availability requirements increase and also the requirements on degraded modes.

To meet these varying needs, it is argued that there are benefits in proposing a scalable ERTMS solution that is adaptable to the whole range of traffic needs giving an optimised CAPEX and OPEX at each step up in the scale, meeting the operating and user needs of all sorts of railways. In this way the ATLAS scalable solution goes beyond the levels of ERTMS to address the different operating scales of train and infrastructure operators.

1 INTRODUCTION

This paper looks at three interrelated aspects: firstly the technological and contextual trends affecting the ERTMS standard; secondly the railways operator’s basic and evolving requirements; and thirdly the solutions for addressing trends and requirements. It is argued that it is necessary to deploy ERTMS solutions that are configurable rather than to deploy one out of the three levels: Level 1, Level 2 or Level 3.

Going “Beyond Levels” to the configurable ATLAS solution on a future-proof Baseline 3 standard allows meeting the conflicting constraints of standardised systems, evolving technology, and changing network needs and configurations.
2 THE PRESENT DEFINITION OF LEVELS

The ERTMS train control solution was developed to meet a number of different infrastructure configurations. The Level 1 meets the need of overlaying over existing infrastructure. The Lineside Electronic Unit (LEU) and connected Eurobalise take the signal information and translate to a common ERTMS language for transmission to the train. The driver still looks at the signal but he is under Full Supervision of the SIL4 ATP. This Level 1 design was chosen for two reasons. Firstly the wide experience in Europe of Eurobalise type solutions and secondly the flexibility of the approach that allows all the needed signal, distance, speed and gradient information to be transmitted to the train, whatever the signalling system.

The Level 2 design comes from the successful experience of many years of high speed rail operations where the high speed of trains means that signals cannot be reliably seen by the driver. These high speed lines therefore required an in-cab signalling and a Full Supervision ATP. Only minimal signalling was required as many lines had little mixed traffic, only some works trains (exceptions include Germany and Italy). The ERTMS Level 2 is therefore a cab signalling system. The choice was made to share the transmission system with the voice radio function to reduce the cost of the system and to propose a system that could evolve to a solution with no track circuits or any other conventional train detection. The Level 2 cab signalling has been extensively deployed on new (often high speed) lines while the addition of STMs (Specific Transmission Modules for operation with legacy system) allowing operation of ETCS-fitted trains over non-upgraded lines.

The ERTMS Level 2 system is now widely proven in operation. In fact the Alstom ATLAS ERTMS Level 2 was the first to be put in operation and is approaching its 10th birthday having been put in service in 2005 on the Rome-Naples High Speed Line. In addition the ATLAS system has nearly a decade of in-service experience on the Betuweroute Freight Line and on the Mattstetten - Rothrist mixed traffic line that carry respectively >100 and >200 trains per day.

So the ERTMS standard with its combination of flexible overlay with Level 1, the variable traffic types managed in Level 2 with no lineside signals and a future solution with Level 3 has naturally become a worldwide standard.

3 SIGNALING STANDARDS : STABLE OR EVOLVING ?

3.1 The challenge of developing and using Standards

The first public railway opened in September 1825 and many railways still use the same standard track gauge, but not all standards are so stable.

For example, by 2020 it is estimated that 80% of the world’s adult population will be using Smartphones. Since 2007, Smartphones have been going through a succession of standard evolutions with 2G, 3G, 4G and soon 5G. This is roughly one generation of the standard every 5 years but the industry and users are adapting to the situation.

In both the case of the stable railway track gauge standard and the rapidly changing telecommunications, standards bring huge benefits and open competition. Standards need to protect investments, but must also support evolution of needs.

3.2 Signalling standards need to evolve

Signalling standards have stable aspects:

- Core needs are linked to safety needs,
- Rail infrastructure technology evolves slowly,
- Rail networks are fairly stable once built.
However, signalling standards face pressures to change due to:

- Interfacing to changing telecommunications systems,
- Evolving functionality in software based functions,
- Interfacing to evolving software systems such as:
  - Safety topics both in new hardware and control software,
  - Traffic management,
  - Assets management,
  - Passenger information systems,
  - Security systems,
  - Monitoring and maintenance systems.

### 3.3 ERTMS timelines

So a compromise is required for the evolution of signalling standards that specify software-based signalling systems. A stable standard, like railway gauges, is not feasible, nor is it possible to have a standard that changes every 5 years.

The ERTMS standard was first worked on in early 1990 and 20 years later the system has been through a full cycle of deployment and feedback and changing technological contexts (see Figure 1).

![Figure 1: The ERTMS timeline](source)

So a new baseline has now been specified, which is Baseline 3.
3.4 A future-proof baseline

The objective of Baseline 3 is to have an interoperable standard core (see Figure 2) that also maintains backward compatibility. The modular add-ons address a range of new needs such as ATO, satellite-based positioning, key management, moving block and train integrity.

Figure 2: Baseline 3

The second important feature of Baseline 3 is that of “bearer independence” with the upgrade of the communications interface to IP-based protocols. This ensures compatibility to both alternative and future telecommunications standards. In particular it gives flexibility to choose different radios when the standard GSM-R frequency range is not available e.g. outside of Europe.

Baseline 3 is therefore the future-proof evolution of the ERTMS standard. It addresses the difficult problem of evolution of a standard that was initially conceived in the early 1990s, that needs to adapt to new demands but that has demonstrated its flexibility in interfacing to different national signalling systems in Level 1 and in operating in the different environments of high speed lines, freight lines and mixed traffic lines with Level 2.

The question is then how should Solutions, that are based on the new Baseline 3 standard, themselves evolve to best meet the requirements of railway operators?
4 THE BASIC NEEDS OF RAILWAY OPERATORS

4.1 Technical configurations versus Operating requirements

The objectives of the ERTMS are very ambitions. The long term aim is that the ERTMS system should be the natural solution to replace all existing signalling systems in Europe (see Figure 3).

The initial concepts of levels in ERTMS meet the three basic configurations required by infrastructure operators:

- Level 1: Overlay on existing Signals,

Figure 3: The ambition of ERTMS
• Level 2: No signals (ideally),
• Level 3: No signals and no conventional train detection.

But this does not address the operators operational requirements. As already mentioned, railways have a very wide variety of operating densities going from around 6 to 600 trains per day and as traffic density increases, availability requirements increase as well as the requirements on degraded modes.

4.2 Network configurations in Suburban and Regional contexts

The configuration of rail networks is complex. For example in the lines that approach cities, the traffic density requirements increase rapidly. A low density regional line can merge onto a service branch of a suburban line that itself converges with other lines to go through the city. So traffic densities can increase from one train per hour to 30 trains per hour over a relatively short distance. The notion of having separate signalling systems for different traffic densities is not ideal. It can be better to have a configurable system.

In addition, many cities have, or are constructing long tunnels to go through the city centre. Our studies show that these are generally between 3 to 10 kilometres long. There are only a small number of exceptions where the central suburban rail tunnel or section is 20 km or more and can justify a specific (“metro-like”) signalling system. These types of suburban lines with short central sections have long branches, so the requirement is to have both a good traffic regulation and an appropriate signalling system on the branch lines. Without a good regulation system, trains will come into conflict as they approach the central converging junction.

Alstom has simulation results comparing ATO driving with manual driving on suburban lines. The results are shown in Figure 4. The horizontal axis shows the ATO and different drivers doing a regional train run. The vertical axis shows the arrival time in seconds compared to the planned Timetable.

![Figure 4: ATO versus Manual Driving](image)

The results show that drivers can match in the precision of an ATO in some cases but will often arrive either too early or too late. In the context of optimising the flow of traffic through junctions, ATO driven systems will present a greater advantage, especially since in practice there are also perturbations where rapid adjustments will be needed and an ATO will also react faster as well as more reliably.
4.3 Evolving traffic needs

Traffic needs must not only be looked at in static terms. Signalling systems are deployed for at least a thirty year investment cycle. There are many examples that show that traffic operational requirements can change very significantly. An example is the London Overground where disused circular tracks around London are being transformed into an efficient suburban service.

This phenomenon of evolving requirements is not just an urban phenomenon. The creation of transcontinental freight lines rapidly lead to saturation. The main single track line going through Mongolia is now saturated and new passing loops and new signalling is required.

4.4 Sustainable operations with ATO

The benefits of ATO are not just in enhancing performance and reduced train headways. The driving simulation studies mentioned in the previous section also looked at the energy saving differences between ATO and manual driving (see Figure 5).

![Figure 5: ATO energy-saving benefits](image)

The graph shows the difference in energy efficiency in % compared to the ATO Driving. The results indicate a significant benefit of the ATO. A driver can drive in an energy-efficient way but not while respecting the timetable. The driver who had good energy saving was also the one whose train arrived very late.

This raises the issue of what can be the key benefit of ATO operation, that of meeting multiple constraints:

- respecting the timetable,
- driving in an energy-efficient way,
- adjusting to traffic regulation orders,
- giving time to the driver to undertake other duties.
4.5 Whole-life requirements and alternative architectures

The presently deployed Level 1 and Level 2 systems are based on an “implicit” signalling solution consisting of
interlockings with secondary train detection.

This deployment of ETCS did not change the essential overall architecture with its known procedures for
management of degraded modes. For example the successful deployment in 2005 of ERTMS Level 2 on the
Rome-Naples high speed lines demonstrated that having a centralised architecture with Radio Block Centers
(RBCs) and a GSM-R network did not create any particular difficulties compared with a traditional high speed line
with track circuit transmission and distributed interlockings. In such a case the degraded mode procedures in case
of an RBC or interlocking failure or reset of a track circuit failure are very similar. There is an objective from the
infrastructure controllers to reduce trackside equipment to reduce capital costs, maintenance and the possibilities
of thefts. The experience from metro CBTC systems is that except in the simpler smaller lines, some train detection
equipment has been useful for detecting entry of vehicles and avoiding cascading of the effect of failures between
line sections.

It is expected that the same situation will occur in mainlines. Some isolated low density lines will be operated with
no train detection equipment as envisaged by the ERTMS Level 3. But in the more general case some detection
equipment will be needed to manage the various operation modes, both nominal and degraded, and the
requirements of mixed traffic. So rather than consider Level 2 as being a system with train detection and Level 3
with no train detection, it is better to consider the full range of configurations required:

- Level 2,
- Level 2 with virtual sub-blocks,
- Level 3 with some train detection,
- Level 3.

4.6 Operator needs

Railway operators have networks that by nature have multiple requirements that vary both in place and time. These
requirements and constraints do fall neatly into the pre-defined (and otherwise very useful) ERTMS levels.

However, they are expecting to have a signalling solution providing the right level of performance at the right place
and at the right time over the full lifecycle.

5 BEYOND LEVELS

5.1 More or fewer levels

As operator needs do not really match onto the present pre-defined ERTMS Levels, a first possible approach is
to add more levels. One can add a CBTC level for very high density traffic and a new level for the other end of
the scale, for very low density isolated lines.
ERTMS Levels have many sub-divisions and overlap as is shown in Table 1.

<table>
<thead>
<tr>
<th>Levels</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L1-LS</td>
<td>Level 2 with backup legacy system</td>
<td>Level 3 in low density isolated line</td>
</tr>
<tr>
<td></td>
<td>L1</td>
<td>Level 2</td>
<td>Level 3 with some degraded mode train detection</td>
</tr>
<tr>
<td></td>
<td>L1 with Infill</td>
<td>Level 2 with ATO</td>
<td>Level 3 with ATO and with some degraded mode train detection</td>
</tr>
<tr>
<td></td>
<td>L1 with continuous Radio infill</td>
<td>Level with virtual Subblocks</td>
<td>Level 3 with Satellite positioning instead of Eurobalises</td>
</tr>
</tbody>
</table>

Table 1: ERTMS Levels in detail

In addition, based on the previous sections, it is argued that solutions must be configurable. So a configurable Level2/Level 3 system will meet the needs of the operators by reducing rather than increasing the number of levels.

5.2 Solutions beyond levels

To meet the varying network needs, it is argued that there are benefits in proposing a scalable or configurable ERTMS solution that is adaptable to the whole range of traffic needs. This gives an optimised CAPEX, OPEX and performance at each step up in the scale while meeting the user needs. In this way Alstom’s ATLAS scalable or configurable solution goes beyond the levels of ERTMS to address the different and changeable operating scales of train and infrastructure operators.

6 CONFIGURABLE SOLUTIONS

The configurable ATLAS™ solution developed around the new Baseline 3 is at present proposed in the core ATLAS 200 version and with two other configurations, ATLAS 400 for low density sections and ATLAS 500 for high density ones.
6.1 ATLAS 400

The ATLAS 400 minimises infrastructure and maintenance costs by reduction in trackside equipment (see Figure 6).

![Figure 6: ATLAS 400](image)

ATLAS 400 features include:

- Compliant with ERTMS Level 3 and ERTMS Regional,
- Positive train detection, virtual blocks, control of crossing loops and simple stations,
- Allow for partial GSM-R coverage, and other bearers (TETRA),
- No signals required.

6.2 ATLAS 500

The ATLAS 500 solution is proposed for high density sections or for just reducing the headway an an existing line with an overlay arrangement. Its main feature is optimised train operations by use of an ATO (see figure 7).

![Figure 7: ATLAS 500](image)
ATLAS 500 features include:

- Compliant with ERTMS Level 2 or Level 3,
- Continuous radio communications between trains and the RBC is performed through GSM-R or GPRS for higher capacity,
- Scalable and interoperable ATO, for higher capacity, with no infrastructure map on board the train,
- Ecodriving and energy saving features,
- Metro-like operational features (including platform screen door management).
- Advanced traffic management system with traffic regulation, conflict detection and resolution.

7 DEPLOYING A CONFIGURABLE SOLUTION IN DENMARK

The new Baseline 3 ATLAS solution is being deployed in Denmark with planned operation in 2016. This major project features trackside and trainborne contracts for complete roll-out by 2021 and maintenance for up to 25 years.

For the trackside east area contract deployment of ERTMS Level 2 will be on:

- 9 lines,
- 634 km,
- 76 stations.

For the trainborne contract there are 668 Train Vehicles of 27 types to be equipped plus 111 other vehicles used for works and maintenance.

This is a configurable system where ATO can be deployed as an option for energy saving or improved regulations needs.

8 CONCLUSION

The ERTMS standard was first conceived in the early 1990s and has been a worldwide success adopted by over 40 countries, many outside Europe. The standard has to evolve to stay in line with new technologies and evolving needs. The new Baseline 3 has been specified as a future-proof version with a modular approach around core requirements and around telecommunications interfaces that are bearer independent.

To meet the present and future needs of railway operators it is proposed that, rather than having solutions that add new Levels, products for Baseline 3 should be provided with a reduction in the number of Levels through a configurable Level 2/Level 3 with planned maintenance releases for technology and functional evolutions, while maintaining Interoperability. This includes such systems as shown in the ATLAS range of products.