






# TECHNICAL DIRECTORATE

## C160 Rolling Stock Great Western ATP Report

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## 1 Introduction

Crossrail Class 345 trains are currently fitted with three train signalling and protection systems, standard UK AWS/TPWS, Central Section CBTC train control and train protection and ETCS train protection. The AWS/TPWS and ETCS systems are provided by Bombardier and are fully integrated with the AWS/TPWS functionality being a sub set of the ETCS equipment and functionality. CBTC is in theory a standalone system but is integrated within the Crossrail ETCS control system, and control of which train protection / control system is active is managed by the overall train control and ETCS system. Driver displays and controls relating to the train protection systems are fully integrated into the train DMI screens and speedometer display.

The current train design can therefore be judged as “fully integrated” in terms of train control and signalling systems, with no specific actions required by the driver to switch on / change between the different systems as the train travels across routes equipped with different systems.

## 2 Background

This review has been provided to explore possible options with regards to short term modifications to the basic Crossrail train design to facilitate the use of the legacy train protection system known as Great Western ATP (GW-ATP). The temporary fitment of GW-ATP is a possible option to mitigate issues associated with the programme for demonstrating correct ETCS operation on the train, required for operation on the Heathrow Branch and the Great Western mainline.

Both the Heathrow Branch and Great Western mainline are fitted with both the legacy GW-ATP system and the recent ETCS system, and therefore the possibility of operating on those routes under GW-ATP control is being explored.

## 3 What is the equipment

To provide context to the following sections a basic overview of the items of train borne equipment associated with GW-ATP is provided below:

- The main control cubicle (computer) which has dimensions of approximately 570x600x410mm (excluding cable exits, etc.). One such control cubicle is required to be installed on each driving vehicle. The control cubicle performs the power and control aspects of the ATP system (as well as manipulation of the axle end speed sensor data to provide speed signals and drive the speedometer).



- A driver's speedometer / ATP indication display unit 175x287 mm installed on each cab desk. This provides the train speed indication, the indication of maximum ATP speed (illuminated green LEDs), and general instructions on mode of train protection (3-digit display in the lower centre), plus indication lights and driver switches.



Data Entry Panel - 2<sup>nd</sup> mans desk



- A data entry unit approximately 300x140mm installed in the cab. The data entry unit is used at the beginning of each journey (cab activation) to input specific characteristics of the train which are used in the calculation of acceptable speeds and ATP intervention points (train length, brake defects).

- An antenna approximately 400x115x110mm installed on the leading bogie. The antenna is the method by which data in the lineside ATP balises is read and passed to the main control cubicle. Its location in terms of relative position, height above rail and area of "metal free zone" are all critical to its ability to correctly and reliably read the balises.

Antenna - Underframe



Speed Probe - bogie



- An axle end speed sensor, preferably installed on a non-powered wheelset (to maintain odometry and positional accuracy). The speed sensor confirms train actual speed used in the calculation of ATP intervention.

The equipment was supplied by Alstom Signalling Solutions and had its origins from the late 1980s, when it was selected by the then British Railways Board as one of two extensive Automatic Train Protection (ATP) trials (one on the Great Western railway and one on the Chiltern railway). The GW-ATP system was originally fitted to the High-Speed Train (HST) power cars which operated on the Great Western during the early 1990s.

Following its fitment on the Great Western the system was then fitted to the newly constructed Heathrow branch as the only form of train protection on that route (1998) and consequently was fitted to the new Heathrow Express trains. Subsequent fitment to new trains has been limited to the Alstom Class 180 Adelante which were intended to operate on the Great Western routes but were subsequently re-deployed to other routes within the UK, and the very recent Hitachi Intercity Express Programme (IEP) trains currently operating on the Great Western. In addition, it is understood the small fleet of Heathrow Connect vehicles are also fitted to allow operation to Heathrow.

As of 2018 the HSTs have been withdrawn from operation on the Great Western and are being re-deployed on other routes where GW-ATP is not required. It is understood the HSTs have retained the GW-ATP equipment as the driver's speedometer display has been retained and much of the other equipment is required to power the speedometer.

The Alstom Class 180s are also deployed on alternate routes to the Great Western where GW-ATP is not required, however it is believed they all retain the fitment of the GW-ATP equipment, albeit in effect isolated and non-operational.

The Heathrow Express units are still in operation between Paddington High Level and Heathrow Airport and as such are still fitted with fully functional GW-ATP equipment which is required for operation on their current routes.

The relatively new Hitachi IEPs are fitted with fully functional GW-ATP equipment which is currently a requirement for operation on their Great Western routes. It should be noted that the train borne equipment on the IEPs is of the same design as that fitted in the early 1990s and was supplied new to Hitachi circa 2014. Current understanding is that Alstom Signalling Solutions has committed to support the equipment (both train borne and trackside until circa 2021).

## 4 How many GW-ATP sets and availability

To permit Crossrail trains to operate between Paddington High Level and Heathrow and stations on the Great Western routes it is credible that a small sub-fleet could be conceived fitted with the necessary GW-ATP equipment. Costs associated with the necessary design, modification and basic equipment are likely to be high and as the reason for fitment is a short-term action to permit operation on the Great Western and Heathrow Branch prior to the completion of ETCS fitment and commissioning, full Crossrail fleet fitment appears unnecessary.

For this investigation it has been assumed that 10 Crossrail units would need GW-ATP fitted, which is 20 sets of equipment (one set per driving vehicle / cab).

As the GW-ATP equipment is in effect a legacy system which is not of a modern design and with no credible future commercial market, the desire for the original equipment supplier (Alstom Signalling Solutions) to provide new equipment in any quantity is likely to be extremely limited. For the IEP contract the quantities and presumably the commercial price agreed were agreeable to Alstom Signalling Solutions to produce new equipment, this is unlikely to be the case in 2018 for a relatively small quantity of equipment.

On the presumption that 20 sets of equipment are required then there are several theoretical options available to obtaining the equipment, these are:

- Approach Alstom Signalling Solutions to procure 20 new sets of equipment (plus a potential addition 2 spare sets). Costs are likely to be high (please refer to projected cost section), lead times are likely to be very long unless the supplier already has sufficient numbers available and in storage. An approach to Alstom Signalling Solutions would establish the above.
- An approach to the owners of the previous Great Western HST power cars could be made to establish whether it would be possible to purchase 22 sets of GW-ATP equipment in effect as second hand equipment, with a view to having the equipment inspected and overhauled as necessary prior to fitment to the Crossrail sub fleet. Modifications would be required to replace the GW-ATP speedometer with a suitable replacement, however this may be attractive to the owners as it would remove the reliance on the relatively old GW-ATP equipment. Details of HST power car availability is provided at <http://www.hst-info.co.uk/>. Discussions with the respective train owners would establish the above.
- An approach to the owners of the previous Great Western Class 180 Adelante fleet (Angel Trains) to explore whether it would be credible to remove the equipment from the Class 180s, and possible timescales and costs associated with such a strategy.

In theory the above options would make available the required number of GW-ATP sets for the proposed approach.



## 5 Options, Integration and Installation

Considering the options outlined and discussed within the Crossrail meeting of the 5<sup>th</sup> November “Stage 2 Phase 2 Signalling Options”, the following comments are made with regards to the options identified by Crossrail, the “option numbering” referred to below adopts that used within the Crossrail meeting.

### Option 1b: Just ETCS.

There is no need to have bespoke TCMS or branches in the software for ‘Just ETCS’ (without CBTC) as CBTC could be disabled by isolating it or powering it down (using mcb’s). It is believed that the current Crossrail design has the ability to operate in this isolated state for when CBTC fails and needs to be isolated. The ETCS/AWS/TPWS should be capable of operating without CBTC. Bombardier could continue developing TCMS software with the CBTC aspects unable to operate when it is isolated. However, if ETCS functionality and reliability is the main cause of issues then such an approach would not fundamentally address the issue.

### Option 3a: GW-ATP and AWS/TPWS.

For GW-ATP to be included the various items of equipment associated with GW-ATP would be required. If AWS/TPWS was also to be retained, then the current design uses the cab DMI to display all speed indications and also AWS / TPWS indications. Therefore, if AWS / TPWS is required the cab desk DMI would need to be retained (for that system) and in addition the GW-ATP speed indication unit would need to be located in an appropriate location on the desk. This is judged as being extremely difficult to achieve, the cab desk is limited in terms of available space, mounting of the GW-ATP speed unit on the upper surfaces of the cab desk are unlikely to be acceptable in terms of impact on drivers sightlines, other approaches which required whole scale re-design and layout of the cab desk are extremely unlikely to be credible in practical timescales.

In terms of modifications to TCMS, there would be no need for significant TCMS rework as ETCS/CBTC would need to be disabled but still providing speed data for TCMS related speed functions. The TPWS system would remain functional and displayed on the signalling DMI and the GW-ATP system would be a standalone system, on the presumption the speed display unit could be fitted.

### Option 3b: GW-ATP standalone.

An approach where all train signalling and protection systems other than GW-ATP were disabled but ETCS is still providing speed data for TCMS related speed functions. This would result in a train which could only operate on the routes fully fitted with GW-ATP and operational implications of this would need to be assessed. In theory the ability to not need a working ETCS / AWS/TPWS or CBTC system would allow the possibility of removing the signalling DMI from the cab desk and using the vacant space for the GW-ATP speed indication unit. The train would be able to operate from Paddington to Reading and Heathrow on the assumption that the route is fully fitted with GW-ATP and that a case could be constructed for the non-fitment of AWS/TPWS.

Further specific discussion on the implications of the fitment of GW-ATP equipment are provided below.

## GW-ATP Speed probe.

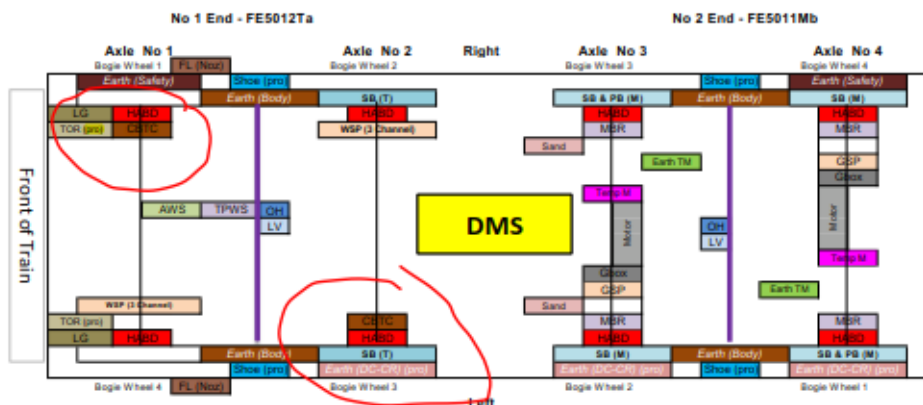
For GW-ATP to operate speed and distance data is required, a single speed probe input provides this, ideally from a non-motored wheelset (to avoid odometry errors linked to traction wheel spin) and preferably in the case of Crossrail an un-braked axle to avoid errors during wheel slide. Currently CBTC speed probes are fitted to axles 1 and 2 of the leading bogie on Crossrail units.

The GW-ATP only requires one speed probe, so a possible solution could be to use the CBTC probe / or its location. This approach is predicated by the assumption that removal of the CBTC equipment is acceptable, if it were not then other axle locations (further away from the driving cab) would need to be investigated and the implications of routing the speed probe cabling back to the driving cab explored. It is possible that the CBTC probe may have a compatible output to GW-ATP, but this would need to be investigated further. The mechanical interface and the nature of the associated speed probe toothed wheel would also need to be confirmed to establish whether the proposed approach is possible.

Speed Probe - bogie



CBTC probe locations on Crossrail DMS vehicle: -



## ATP Speedometer and control panel.

From a driver's perspective the GW-ATP speed indication unit is the key interface / control and as such must be in a prominent position with acceptable sightlines and supporting human factor assessment. The unit must therefore be fitted to the cab desk. There are two possible approaches to including a GW-ATP speed indication unit onto the Crossrail driver's desk, these are:

- Develop a bespoke system which permits the use of the standard GW-ATP control system but permits the equivalent functionality of the GW-ATP speed indication unit onto



the existing Bombardier signalling DMI – thus using the DMI as the single driver interface. Considering the age and design of the GW-ATP control system it is judged as impossible for it (the GW-ATP control system) to directly interface to the modern Bombardier signalling DMI screen, which is in effect a computer style display screen. To pursue this option would require the development of some form of interface module between the existing GW-ATP system and the signalling DMI and for Bombardier to further develop the necessary software to represent the GW-ATP display on the DMI screen. The development of such a bespoke system is judged as being significant in terms of both cost and engineering resource from Bombardier, is highly bespoke and unproven. As such this approach is judged as not being credible.

- Modify the existing Crossrail cab desk in terms of alterations to the existing DMI mounting panel. If it were accepted that CBTC and ETCS and AWS/TPWS could be removed for the period required to support operation to Heathrow and on the Great Western using only GW-ATP a possible approach would be to remove the existing signalling DMI and mount the GW-ATP speed unit in that space.



Figure 1 Crossrail DMI Desk Panel

Equipment shown with “red strike outs” could be removed, the new panel with the ATP speedometer panel is comparable with the face dimensions of the removed items. The depth would have to be checked. The approximate size of the GW-ATP speed unit is shown on the following diagram by the red area. A modified desk panel could be produced which retained the location and spacing of those controls not shown as “red strike outs” and include the GW-ATP speed unit. With the caveat regarding depth of the available space, the option presented here looks possible in terms of minimum change to the cab desk layout and inclusion of the GW-ATP speed unit in an acceptable position.



Figure 2 Crossrail DMI Desk Panel – GW-ATP Speedo Overlay

Other possible options for mounting the GW-ATP speed unit look to present difficulties in terms of lack of clear space on the main driver's desk, especially in the area which would be judged as his primary vision area. The possibility of trying to mount the speed unit on the top side of the desk (e.g. without having to disturb the existing desk layout) look challenging due to the size of the speed unit and the probability that if mounted in such a location it would impinge upon driver's sightlines. A simple CAD simulation or practical mock up with a representative speed unit and a range of driver heights would confirm whether this approach has any possibility.

### ATP data entry unit.

The GW-ATP data entry unit needs to be accessed by the driver on unit start up, however it does not need to be accessed while driving the train and as such could be located on the non-driver side of the cab desk or the cab back wall, as close as possible to the main control unit to minimise wiring installation. The dimensions of this are 300mm x 140mm. In reality its location is not critical and space could be found for it within the Crossrail cab.

Data Entry Panel – 2<sup>nd</sup> mans desk



## ATP Electronic Rack (main computer module)

The main control unit associated with the GW-ATP system is a 12U 19-inch rack (534mm \* 483mm), with necessary allowances for cable / wiring access. The module is provided in a small metal enclosure. Ideally this needs to be located within or very close to the driving cab to minimise cable installation distances between the module, the cab desk display, and data entry unit and the GW-ATP antenna. On the Crossrail train there is not significant available space within the cab area for additional electronic equipment modules. Mounting within the passenger saloon immediately behind the cab back wall would be possible but would require the removal of seats and the introduction of some form of secure (non-accessible to members of the public) equipment cabinet. Similar designs have historically been implemented when older trains had OTMR data recorders fitted, as such an approach of mounting either within the cab or within the saloon is judged as possible.

Again, if the approach of removing the CBTC equipment is accepted it is possible (subject to inspection and detailed measurements) that the GW-ATP module may fit in the space envelope used by the equivalent CBTC module within the cab back wall. If this were possible then it would be the preferred approach in terms of least design effort, time, and cost. Mounting of the GW-ATP module within the passenger saloon area would represent the greatest time and cost solution and also present greater challenges in terms of cable / wiring installation and access.

Initial details regarding the dimensions of the CBTC equipment, provided below suggest that replacement of the CBTC module with the GW-ATP module would be possible.

12U 19" Electronic Rack – cab cubicle



Removal of the CBTC equipment in the cab back wall could give the space required for this equipment. The interface specification for CBTC equipment quoted the following dimensions: -

- *CBTC onboard computers, a maximum of 15U. The Train Carried S&CS onboard computer shall weigh no more than 25Kg.*
- *CBTC interface control unit, a maximum of 6U. The Train Carried S&CS interface control unit shall weigh no more than 10Kg.*
- *CBTC data radio, a maximum of 6U. The Train Carried S&CS data radio shall weigh no more than 10Kg.*

## ATP Transponder Antenna

The GW-ATP antenna must be mounted within certain controlled limits relative to rail level and track centreline to ensure it reliably reads the data from the track-based element of GW-ATP. To this end it will need to be mounted on the bogie or possibly the underframe. In addition to physical location it is understood that there are other specific criteria regarding “metal free zone” areas adjacent to the antenna.

Mott MacDonald are not in possession of the installation rules, but one supposes these could be relatively quickly obtained from either the GW-ATP equipment supplier or by measuring typical existing installations which have been shown to function (e.g. the location of an HST power car or Heathrow Express unit). The antenna is relatively large and is 400x115x110mm It weights approx. 60kg.

Antenna - Underframe



Approximate weight 50-70kg per cab end

Due to the size and likely positional requirements of the GW-ATP antenna the most credible option again would be to remove the existing CBTC antenna and develop a suitable mounting arrangement to use that space envelope for the GW-ATP equipment. Considering the space available under the DMS leading bogie, combined with its inherent inside frame design, it is judged as extremely unlikely that the antenna could be fitted to the bogie.

It is thought possible that it could be mounted from the underframe in a location just behind the leading bogie. A location for the antenna looks credible subject to confirmation that underframe rather than bogie mounted is acceptable.

## ATP Power Supply

The GW-ATP will need an electrical power supply, it should be possible to simply re-use the CBTC power supplies and associated train wiring and protection mcbs as the power supply requirements between GW-ATP and CBTC are believed to be similar. ATP requires 1kW of power per cab. It is also understood that the Crossrail auxiliary power system is designed with contingency for additional electrical loads in the future (notional 10% contingency) and as such power supply for the GW-ATP equipment is not considered a problem.

## Brake System Integration

The ATP brake output would need integrating into the emergency brakes circuit. In addition to this an ATP Isolation/Control switch would be required (possibly re-using the CBTC isolation switch on cab back wall) for the following two options: -

- ATP standalone: The ATP Isolation switch would be capable of isolating a faulty ATP system which would otherwise immobilise the train.
- ATP with another Signalling system (e.g. AWS/TPWS). The switch would allow either the ATP or the TPWS/AWS systems to control the trains brakes. If the trains were to operate between these 2 signalling systems this would require manual operation of the switch whilst stationary defined boundary locations.

## OTDR.

In addition to the above items of equipment it is likely that the status of the GW-ATP system will need to be recorded on an OTMR / OTDR, for the GW-ATP system the interface is a RS232 which is unlikely to directly connect to the existing OTDR and as such an additional OTDR will be required. This is considered possible as the unit should be able to be mounted somewhere within the cab rear wall.

## 6 Projected Costs

Given the fact that ATP equipment is supplied by a monopoly supplier which has previously announced that it is no longer manufacturing the product, the cost is likely to be significant. The figure previously quoted in C160-MMD-R1-RCT-CR001-00009 of £1.4m per train is considered to remain realistic although it should be noted that given the monopoly supplier, cost is very difficult to anticipate and depends on political rather than engineering issues.

The costs originally presented in C160-MMD-R1-RCT-CR001-00009 were established by using benchmark costs being discussed with the Department for Transport (DfT) in circa 2012, which were judged as being acceptable for indicative costings. Within the calculation, allowances were made for design costs, the actual equipment, fitment, testing and associated approvals. A nominal 20% cost assumption was allocated to the development and approvals aspects – leaving 80% associated with the equipment, fitment and testing.

The 80% figure was projected to be £1.12M for two sets of equipment – i.e. £560,000 per cab. For this investigation Mott MacDonald have made no approach to the supplier to explore possible costs and as such the previous projected costs have been retained. It is understood that Crossrail may be approaching the supplier for updated indicative costs.

To set these costs in context details provided within the HSE publication Research Report 066 “Train Protection – Review of Economic aspects of the work of the ERTMS Programme Team 2002” included the following costs for GW-ATP fitment.

- 1994 British Railways ATP Report cost per cab £50,000
- 1997 Review of costs study cost per cab £70,000
- 2002 Costs supplied to support HSE Report cost per cab £ 352,000 (note 2002 prices)



**Table 2** ATP installation costs (supply and fit), £2002 prices

		<i>1993/94 BR-ATP Report</i>	<i>1997 review</i>		<i>April 2002 (supplied by EPT)</i>	
		<i>£'000</i>	<i>£'000</i>	<i>Rise from 1993/94</i>	<i>£'000</i>	<i>Rise from 1997</i>
GW: Retrofit - 1 cab per vehicle	Train/cab*	50	80	68%	352	340%
	Track/signal	10	15	41%	72	380%
Chiltern: New – 2 cabs per vehicle	Train/cab*	30	56	83%	272	386%
	Track/signal	6	17	169%	72	324%

*\* The cost of a complete new multiple unit vehicle is about £750k (Modern Railways, September 2002, page 18).*

**Extract HSE Research Report 066**

If the 2002 figures quoted are used and a notional allowance for inflation between 2002 and 2018 is included a 2018 projected cost of £550,000 per cab would be the result. It would therefore appear reasonable to conclude that costs per cab are likely to be in the region of £500,000 plus / minus 20%.

With regards to possible costs for second hand equipment this is difficult to quantify as the costs could be minimal for the equipment, but there would be costs associated with the removal of the equipment from the existing vehicle, costs for any design work required, costs associated with any replacement equipment required and some costs associated with the documentation of the changes and any approvals required. However, the costs of the “second hand” option will be less than those of new equipment. Without initial discussions with the existing vehicle owners it is not possible to predict the costs.

## 7 Testing and Validation

Fitment of GW-ATP to the Crossrail trains will need to include appropriate testing to verify both the correct installation and integration into the associated train systems, confirmation tests to confirm correct functionality of the advisory and protection aspects of the system and validation tests to confirm the required braking performance required as one of the key parameters of the control computer.

It is envisaged that a series of static function tests will be required to confirm basic correct functional behaviour and integration in the first instance, followed by dynamic track testing to validate the actual functionality – this will only be possible on routes which are fitted with the GW-ATP system. Testing of the system is likely to require several weeks to confirm full functionality and be confident that sufficient testing has been performed to demonstrate both correct operation and reliable operation. However, as the basic GW-ATP equipment being fitted to the train is already proven there should be no extensive testing required to demonstrate the basic correct functionality of the GW-ATP system itself.

If the GW-ATP system were to be integrated into the DMI and ETCS / CBTC retained, then it is likely that testing time would be greater due to the inclusion of additional interface modules between TCMS and ATP and the need to confirm their correct functionality and responses.

Brake performance data which is required to set the GW-ATP parameters would normally require a series of braking tests to be performed to establish the required performance



parameters (deceleration rates at various speeds and loads). However, one presumes that it may be possible to use the braking performance data already gathered by Bombardier and Siemens as part of the type testing required to validate the braking performance for both ETCS and the CBTC system.

## 8 Timescales

Timescales for procurement of new equipment from Alstom Signalling Solutions is difficult to predict, historically timescales of up to 9 months have been indicated. For this investigation the assumption has been made that procurement of new equipment could take between 3 months at best or longer based upon past evidence, however this could only be confirmed with discussions with the supplier.

Considering the element of vehicle design which would be required for the Crossrail vehicle installation, if it is assumed that there is minimal system integration required (which appears the only credible option) and that the approach of “isolate ETCS/CBTC and AWS/TPWS” is adopted there is likely to be some work required to address this at a TCMS software level. Additional design work would be required for the change to include the speed display unit into the cab desk, and mounting the antenna, control module and speed probe. An approximation of between 2 and 3 months for this work would seem credible with some overlap with the procurement times being possible. This of course requires Bombardier to be able to suitably resource the activity without compromising other Crossrail development activities.

To support the changes to the Crossrail vehicle there will need to be some form of supporting safety / modification papers as part of the overall “safety case”. An element of this could be produced in parallel with the design development an approximation of 2 months to produce supporting justification is judged as typical.

Approvals work will be required to support the change of signalling protection and to support the changes made to the existing Crossrail vehicle design, this is likely to include the development of a formal modification instruction, supporting high level Human Factors assessment, confirmation of changes to TCMS and driver fault reporting alarms, changes to the Train Operating Manual and how to address defects and failures, maintenance and testing prior to entry into service. Timescales for such activities are unlikely to be less than 2 months, with some overlap possible.

Vehicle system integration testing and dynamic testing will be required to confirm correct functionality and correct train performance. Read across of braking performance results may be possible from previous brake tests and if this is assumed to be the case testing could be undertaken in a timescale of circa 1 month (including review of test results by necessary parties).

Driver Training will be required prior to use of the GW-ATP and the assumption has been made that this could be performed in circa 2 weeks, this may be optimistic and confirmation of typical driver training timescales from the Operator should be sought.

Overall the likely best-case timescales could be composed of; 3 months to obtain the equipment, 2 to 3 months for the supporting design (assume 1 month overlap with procurement), 2 months supporting papers (1 month overlap) 2 months approvals (1 month overlap), testing 1 month, driver training 2 weeks. Considering the unknown aspects to the above assumed timescales a minimum project timescale of circa 7 to 8 months is thought “best case” and in reality, the lead time associated with procuring the equipment could be / is likely to be significantly longer, possibly by as much as an additional 6 months.

If an approach of obtaining “second hand” equipment was possible, it is thought likely that the timescales would be similar to above, the equipment would in theory be available sooner but the allowances for the necessary design work likely to support its removal would need to be

factored in plus negotiations with the existing vehicle owners and any possible requirement to have the equipment “overhauled” due to its age. An assumption of circa 7 to 8 months is considered possible.

## 9 Conclusions

Integration of GW-ATP into the existing Bombardier train control and in particular the signalling DMI display is considered impractical due to the technical difference between the systems and the likely workload in terms of engineering involvement from Bombardier in the critical areas of signalling and TCMS.

Installation of the main GW-ATP driver speed display unit onto a suitable location of the Crossrail cab is considered very difficult due to its size and the relative lack of space in the key cab desk area immediately in front of the driver. Significant re-design of the cab desk in terms of moving existing controls is considered impractical due to timescales.

Removal of the signalling system DMI from the cab desk would permit in theory the GW-ATP speed display unit to be positioned in a suitable location from a driver interaction perspective. However, removal of the existing signalling system DMI would by default necessitate isolation of both CBTC, ETCS and AWS/TPWS. Such an approach while possible would result in a train which could only operate on GW-ATP fitted routes, which may not be operationally acceptable.

Retention of AWS/TPWS functionality is not possible if the signalling system DMI is removed due to the approach of signalling system integration adopted by Bombardier. The DMI screen is used to mimic / represent the traditional AWS and TPWS displays and controls and as such the AWS/TPWS system relies on the DMI. An approach where “traditional” AWS and TPWS controls and displays is added to the cab layout has the same space and positional constraints as the inclusion of the GW-ATP speed display unit. For these reasons retention of AWS/TPWS is judged impractical.

Installation of the other key GW-ATP items of equipment (e.g. speed probe, control module, data entry panel and antenna) appear to have feasible options, subject to a more detailed physical inspection of the space envelopes, however conceptually the installation looks credible.

If new equipment is required, the costs from Alstom Signalling Solutions are likely to be high. Without being able to directly approach the supplier or liaise with train builders who may have recently procured such equipment (Hitachi) the costs discussed in the original C160-MMD-R1-RCT-CR001-00009 and re-visited in this report are considered valid. A single cab's worth of equipment is expected to cost £500,000 plus / minus 20%. The costs are believed to reflect equipment costs only and would not include any additional costs charged by Bombardier for subsequent design work. The costs may prove impractical for Crossrail.

No specific enquiries have been made regarding lead times for new equipment, but from previous experience on the DfT's projects it is likely that lead times could be in the order of many months and assumed overall timescales look to be at best circa 8 months and are likely to be greater possibly in excess of 12 months. These timescales are likely to prove impractical for Crossrail.

Redundant GW-ATP equipment may be available in limited numbers from combinations of withdrawn / re-deployed former Great Western HST power cars, or possibly re-deployed Alstom Class 180 units. Discussions and enquiries would need to be made with the respective vehicle owners to explore this option further, however this may prove credible as a source of the required GW-ATP equipment.

Bombardier engineering resource input will be required to support the fitment of GW-ATP. Without detailed discussions it is not possible to comment on whether Bombardier have the necessary resource available to undertake this activity in acceptable timescales. However, one

could suppose that in the specialist areas of signalling integration and TCMS software development and implementation Bombardier may already be fully committed both to Crossrail and other strategic new build Aventura train projects. It is therefore highly probable that Bombardier will not have the available resource to support timely development of the more complex fully integrated options, indeed they may not be able to support even the simplest of changes.

Overall timescales are at best considered to be circa 8 months from starting the process of acquiring the GW-ATP equipment to concluding the necessary driver training, these timescales are considered to be the shortest / "best case" which could be achieved with the assumptions listed and with all parties involved fully co-operating.

## 10 Summary

Equipment availability is unknown and historically the lead times from placing orders to equipment being available have been significant, as such lead time of equipment is likely to be critical in terms of whether credible timescales are achievable. It is unlikely that the lead time will be less than 3 to 4 months and could be longer. An approach to the equipment supplier would be required to confirm lead times.

Second-hand equipment availability may be an option, with equipment being removed from vehicles which have previously operated with GW-ATP. However, before this approach can be shown as credible an approach to the vehicle owners would be required and further understanding of the implications in terms of any engineering work required on the vehicles to support removal and the possible need to overhaul / refresh of recovered equipment. Timescales may again be considerable and prove unacceptable.

Costs for new are likely to be very high with prices possibly as high as circa £500,000, however this figure would need to be confirmed with the equipment supplier as it is possible that the costs could be less.

Costs for second-hand equipment is unknown and in reality, could be relatively low, however the costs would need to include design costs for any subsequent modifications, approvals and testing of changes required to the existing vehicles as a consequence of removal of the GW-ATP equipment. On the HST power cars it is understood that the only speedometer display fitted is the GW-ATP one, driven via the GW-ATP axle end probe and elements of the GW-ATP control module. It would therefore be necessary to develop and replace those speedometers with a replacement system (presumably the same design as deployed on non-GW-ATP fitted HST power cars). Discussions with the vehicle owners would be required to confirm agreement and costs of this approach.

Overall timescales for the various approaches are significant (circa 7 to 8 months at best with 12 months plus being credible) and unlikely to support a solution within acceptable times for Crossrail, however this cannot categorically be confirmed until further detailed discussions with the identified parties is performed.