ARTC

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ATMS Equipped Train Braking Standard

ESD-32-02

Applicability

ARTC Network Wide

Publication Requirement

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1.0	19 Jun 20	Development & Engineering Manager - ATMS	Stakeholders	Manager Signalling Standards	General Manager Technical Standards 19/06/2020

Amendment Record

Amendment Version #	Date Reviewed	Clause	Description of Amendment
1.0	19 Jun 20	All	First issue of standard to support NESA-S038 ATMS IS1 - Type Approval.

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1 Purpose

The purpose of this Standard is to specify the train braking parameters agreed between ARTC and Train Operators to ensure the performance of the ATMS brake algorithm is acceptable for safe operation of ATMS Equipped Trains under the Advanced Train Management System of safe working within the territories defined in Appendix A.

Appendix C provides an overview of the process to be followed in deriving and specifying ATMS train braking parameters for changing or adding ARTC approved ATMS equipped train types and Locomotive classes.

1.1 Scope

This Standard is applicable to:

- Locomotive classes that have been approved by ARTC for fitment and operation of the ATMS Trainborne equipment.
- ATMS train types that have been approved by ARTC for operation as an ATMS equipped train under the Advanced Train Management System of safe working.
- ARTC Rail Network corridors that have been approved by ARTC for operation as an ATMS equipped train under the Advanced Train Management System of safe working.

1.2 Document Owner

General Manager Technical Standards is the document owner. Queries should be directed to standards@artc.com.au in the first instance.

1.3 Responsibilities

The **ATMS Product Support Manager** is responsible for the implementation of this Standard in any new ATMS deployments and/or additions of ATMS approved locomotive classes and train types or ARTC rail network corridors for operation of ATMS equipped trains.

Train operating companies are responsible for:

a. Operating trains in accordance with this Standard;

b. Confirmation that this Standard appropriately characterises train braking performance for use by the ATMS brake algorithm in calculating predictive stopping distances for the ATMS Equipped train types specified in Appendix A;

c. Notifying ARTC within a reasonable timeframe of any material changes to ATMS Equipped Train types specified in this Standard.

1.4 Definitions

The following terms and acronyms are used within this document:

Term or acronym	Description
AMS	Authority Management Server
ARP	Auxiliary Reservoir Pressure
ARTC	Australian Rail Track Corporation
ATMS	Advanced Train Management System
ATMS Equipped Train	Locomotive fitted with the ATMS Trainborne equipment
ATMS Equipped Train Type	A train types approved to operate ATMS under this Standard (per Appendix A)
ATMS OEM	The ATMS Original Equipment Manufacturer
ATP	Automatic Train Protection
BPP	Brake Pipe Pressure
Braking Axle	The point at which a brake is applied on a rolling stock wagon
CPN	Configurable Parameter Name
EAS-ATMS	Electronic Authority System – Advanced Train Management System
LDS	Location Determination (sub) System
NCC	Network Control Centre
Platform	A rolling stock wagon with the number of braking axles as specified in Parameter 1. Note: A “multi-pack” consist comprising multiple wagons, should be broken into each wagon for purposes of parameter calculation. For example, in deriving platform lengths, a ‘3-pack’ rolling stock wagon with 12 braking axles and total length of 36m should be treated as 3 platforms each with 4 braking axles and length 12m.
TC&D	Train Control & Display (sub-system)
TCS	Train Control System
TDB	Track Database
TIU	Trackside Interface Unit
Short Train	A train with less than the platforms specified in Appendix A. It is assumed that the driver will not bail off the locomotive brakes on a short train under ATMS-initiated braking.
Train Operator	An operator of rolling stock utilising the ARTC network

1.5 Reference Documents

Ref	Document Number	Document Title
[1]	NESA-S038	ATMS IS1 Type Approval Report
[2]	ATMS-2014-13-0024	ATMS Specific Application Safety Case Port Augusta to Whyalla
[3]	ESD-05-03	Train Braking Application Design
[4]	ESD-32-01	Signalling Rolling Stock Interface

2 ATMS Overview

The ATMS is an advanced communication based safe-working system developed by Lockheed Martin Australia (LMA) in collaboration with Australian Rail Track Corporation (ARTC) under the ATMS Implementation Stage 1 (IS1) Project. The ATMS comprises of multiple subsystems:

- The ATMS Train Control System (TCS) is responsible for initiating authority, route settings, train path requests, and other controls. ATMS TCS is based on the Phoenix train control system customised with enhanced security and safety capabilities.
- The ATMS Authority Management System (AMS) manages and safely issues authorities.
- The ATMS Trackside Interface Unit (TIU) monitors and manages points position and monitors track circuits.
- The ATMS Trainborne System is equipment installed on Rail Traffic that provides situational awareness to Rail Traffic Crew and provide train position determination for ATMS AMS.
- The ATMS Track Database (TDB), describes the layout and location of the track centreline and associated features along the track, both physical and logical (e.g., points, km posts, civil speed limits, electronic block boundaries)
- The ATMS Communications Systems provides the required data and voice connectivity between the subsystems.

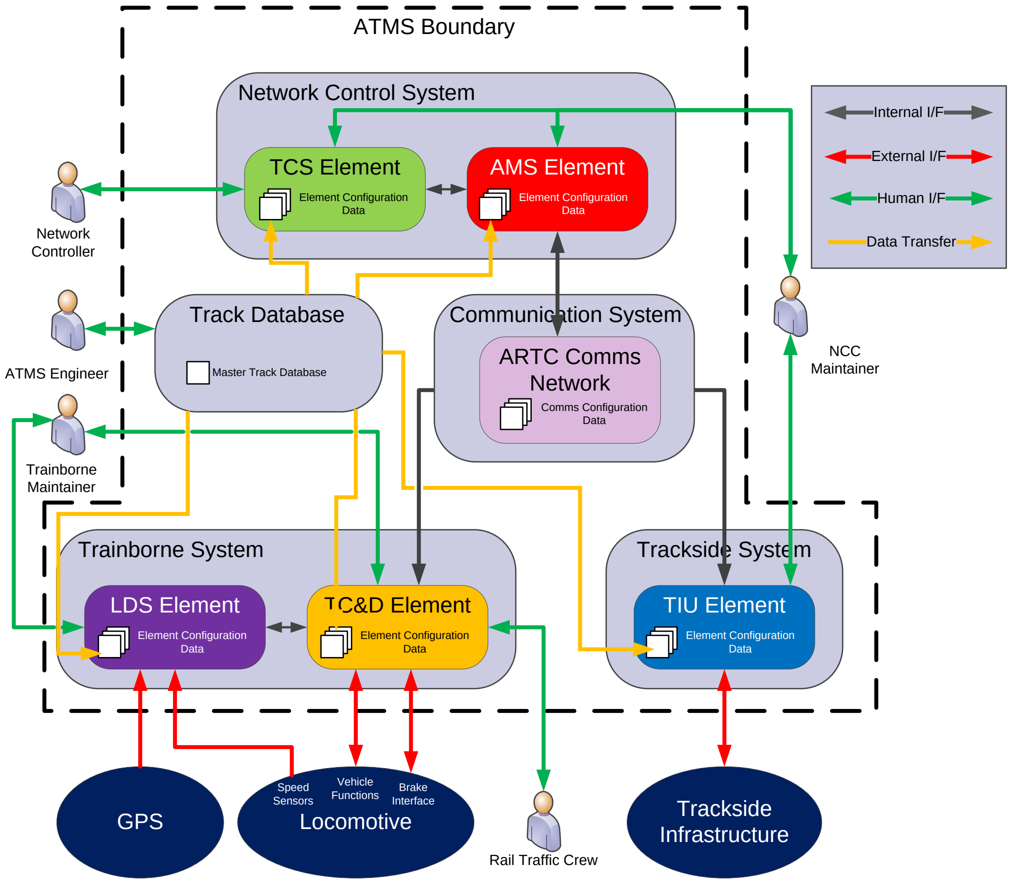

Figure 1: ATMS System Overview

2.1 ATMS Brake Algorithm Overview

ATMS provides an Automatic Train Protection (ATP) capability that continuously monitors train speed and authority limits of ATMS equipped trains to prevent overspeed and exceeding an authority limit. ATP is achieved using a Brake Algorithm that periodically and frequently calculates a predictive braking profile for the train which characterises the maximum distance the train may travel before the application of brakes is required. This information is used by the trainborne system to:

- determine if it should automatically apply the brakes; and
- generate warnings and alerts to the driver
- automatically apply the brakes when the profile determines the train is operating at an unsafe speed or is predicted to overshoot a limit of authority.

ATMS equipped trains operate with predictive and reactive braking enforcement. Reactive braking enforcement occurs when a stop target has been overshot or if the train speed is greater than the permitted speed (by a configurable amount). Predictive braking utilises an algorithm that enforces braking (predictively) to ensure a train stops safely prior to a stop target without driver intervention. ATMS will also stop the train safely when the train exceeds the permitted speed or if predicted to be moving faster than an upcoming lower speed. To do this, the predictive braking algorithm must assume a level of train braking performance available on the class of train. This performance is expressed as a set of train dynamic inputs and braking parameters defined for each class of rolling stock.

The predictive braking profile is based on:

- Dynamic inputs that include: train speed and location, the status of the train's air brake system, and the gradient of track;
- Braking parameters that include: static configuration data such as the length of the train, the mass of the train, and the types of locomotives and wagons within the train. For each rolling stock class, the Train Operator has specified the parameter values, and where appropriate, reviewed the ATMS brake algorithm performance through simulated test results and braking field tests.

For each time period, the braking profile predicts the future relationship between train speed and distance travelled should an application of the train's penalty brake be initiated within that time period. The trainborne system compares this with each braking target to determine if any braking target might be violated should the train continue at its current speed. If this is the case, the trainborne system initiates a penalty brake application to ensure the braking target is respected.

These concepts are illustrated in Figure 2, below.

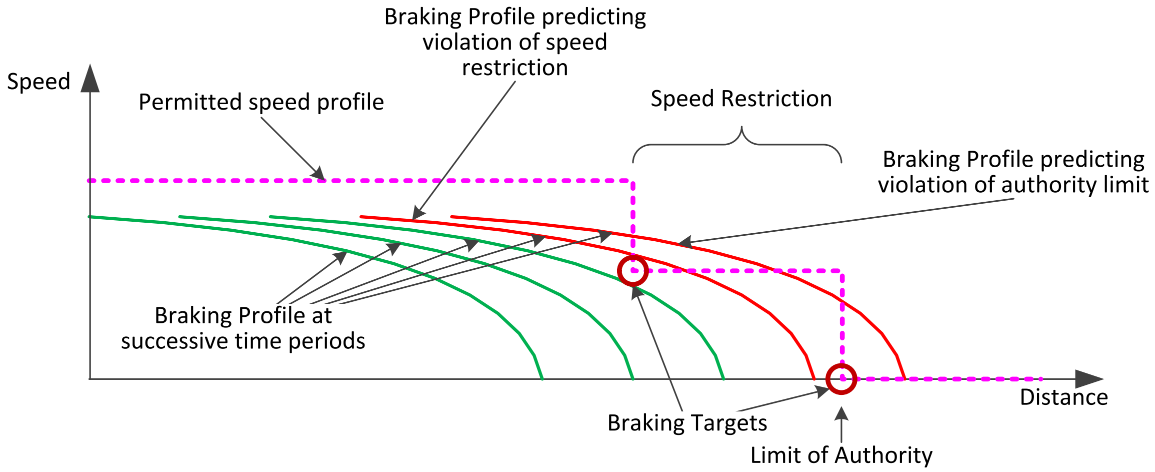

Figure 2: Braking Profile Concepts

3 Appendix A – Approved ATMS Equipped Train Types

This Appendix specifies the train braking parameters that rolling stock must comply with for operation as an ATMS equipped trains under the Advanced Train Management System of safe working.

Where a Train Operator chooses to operate a train that does not comply with this Standard, the train must be operated as an ATMS unequipped train.

3.1 Train Type 1– Pacific National Reference (NR) Steel Train

This section specifies the ATMS train braking parameters, lead locomotive class(es) and assumptions/restrictions that are configured in the ATMS Brake Algorithm for the purposes of predictive train braking for the train types within the ARTC Network Territory specified below. Where applicable, details of the simulation test range are also provided (refer Appendix C for information on the simulation process).

ATMS Equipped Train Lead Locomotive Class(es):

1. Pacific National NR Class locomotive.

ARTC Rail Network Territory

2. ATMS safe working system in operation between Spencer Junction (exclusive) and Whyalla (exclusive) in South Australia.

Train Consist Assumptions/Restrictions

1. Locomotives are marshalled at the front of train, distributed power is not used.
2. Conventional pneumatic braking systems (only) are used.
3. Throttle power is automatically disengaged if a full-service brake application is applied, i.e. (1) the cut-out mechanism is vital; and (2) there is negligible delay between the BPP starting to drop and the throttle being cut-out.
4. Train braking system will be effective and work within its specified performance when ATMS enforces.

3.1.1 Train Parameters

The following parameters are used to characterise the train type within the Braking Algorithm. The Algorithm has been tested and confirmed to stop the train safely within ranges below;

ID	Parameter Name	Value
1	Number of Axles	Per Platform = 4 Per Locomotive = 6
2	Number of Locomotives in the consist	Min = 1 Max = 4
3	Standard Platform TARE Weight Maximum Weighted Average Loaded Platform Mass (MWALPM)	Weight = 20.8 tonnes ± 5% MWALPM = 78.1 tonnes ± 5%
4	Average Platform Length	17.96m ± 2.44 m
5	Minimum and Maximum Train Length	Min Train Length: 22 metres Max Train Length: 1800 metres
6	Minimum and Maximum Train Weight	Min Train Mass: 132 tonnes Max Train Mass: 10,000 tonnes
7	Number of platforms with inoperative brakes	10% of Number of Platforms
8	Number of platforms in a Short Train	Max of 10 Platforms
9	Average Platform brake shoe force	Weighted average empty platform brake force = 53002N ± 3% @ 357 kPa Weighted average loaded platform brake force = 117972N ± 3% @ 357 kPa
10	Average Locomotive brake shoe force	2943 – 3335 N/tonne
11	Coefficient of friction between brake shoe and wheel	0.255 + 0.11*exp(-0.0434959835*v) ± 20% where v = speed in km/h

ID	Parameter Name	Value
12	Service Brake Application time	(0.03904 * Length(m) + 9.7094) - (Adjustment_Factor * (-0.00000920177 * Length(m) + 0.8494612)) seconds Where Adjustment Factor = 0
13	Quick Service Brake application time	0.23333 x Service Brake Application Time + 4.0314 seconds
14	ARP equalization	357.5 kPa
15	ARP recharge rate	Initial charge rate = 33.52 sec + 0.27 sec per platform Final charge rate = 90.96 sec + 6.16 sec per platform + 0.03164 sec x sq (number of platforms)
16	Aerodynamic coefficients	Per Locomotive (K_{Loco}) = 0.294 Per Platform ($K_{Platform}$) = 0.07
17	Average rate of BPP reduction	-8kPa per second
18	Maximum BPP differential	35kPa

4 Appendix B - Additional Parameter Information

4.1 Number of Axles

This parameter defines the exact number of axles on a platform and a locomotive. It assumes there is no variance within platforms or locomotives.

Related variables: <BRK_NUM_AXLES_PER_PLATFORM>, <BRK_NUM_AXLES_PER_LOCOMOTIVE>

4.2 Number of Locomotives

This parameter defines the exact number of locomotives in a consist. Entered by the train driver whenever the consist materially changes.

Related variables: <BRK_NUM_LOCOS>

4.3 Standard Platform TARE Average/Max Weight

These parameter values are used in combination pre-configured values for:

- Total Train weight (driver entered)
- Weighted Average TARE
- Weighted Average Max
- Percentage Load factor

to derive the number of Empty and Loaded Platforms.

Related variables: <BRK_WEIGHTED_AVE_TARE>, <BRK_WEIGHTED_AVE_MAX>

4.4 Average Platform Length

This parameter is used with train length entered by the driver to derive the Number of Platforms in the Consist as follows:

$$Number\ of\ Platforms = \frac{Total\ Train\ Lengh - Length\ of\ Locomotive(s)}{Average\ Platform\ Length\ per\ platform}$$

Related variables: <BRK_LENGTH_PLATFORM>

4.5 Min/Max Train Length

Fixed values for the minimum and maximum length of a consist.

4.6 Min/Max Train Weight

Fixed values for the minimum and maximum weight of a consist.

4.7 Number of Platforms with Inoperative Brakes

Fixed values for the average percentage of platforms with inoperative brakes.

Related variables: <BRK_PLATFORM_IOB_PERCENTAGE>

4.8 No of Platforms in a Short Train

This parameter is used by the ATMS Brake Algorithm to determine if the brake algorithm should consider locomotive brake force when performing predictive stopping distance calculations. This is based on train length entered by the Rail Traffic Crew and the Average Platform Length.

For Short Trains, the brake algorithm assumes that locomotive brakes would be used by the Rail Traffic Crew in stopping the train, and thus includes available locomotive brake force in stopping distance calculations. For long trains, the brake algorithm assumes that locomotive brakes may be 'bailed off' (not used by the Rail Traffic Crew in stopping the train), and thus does not include any available locomotive brake force in stopping distance calculations.

Related variables: <BRK_NUM_SHORT>

4.9 Average Platform brake shoe force

Fixed values for the shoe force applied at a platform axle. During initialisation, a check is performed to determine if the platform is defined as loaded or empty. Values are converted so that all vehicles are modelled as equipped with high friction brake shoes.

Related variables: <BRK_FB_PLATFORM_EMPTY>, <BRK_FB_PLATFORM_LOADED>

4.10 Average Locomotive brake shoe force

Fixed values for the shoe force applied at a locomotive axle.

Related variables: <BRK_FB_AVG_LOCS>

4.11 Coefficient of friction

Each locomotive and platform in a train has an average coefficient of friction between its brake shoes and wheels. This coefficient varies with speed.

Related Variables: <BRK_SHOE_WHEEL_COEFF1>, <BRK_SHOE_WHEEL_COEFF2>, <BRK_SHOE_WHEEL_COEFF3>

4.12 Service Brake Application Time

The time, in seconds, for the average auxiliary reservoir pressure to reach equalization pressure following a service brake application from a fully charged brake pipe pressure.

Related variables: <BRK_TAPPLY_COEFF1>, <BRK_TAPPLY_COEFF2>, <BRK_TAPPLY_COEFF3>, <BRK_TAPPLY_COEFF4>, <BRKADJUSTMENT_FACTOR_PERCENTAGE>

4.13 Quick Service Brake Application Time

The time, in seconds, for the quick service portion of the brake application to reduce the auxiliary reservoir pressure.

Related variables: <BRK_TAPPLY_QUICKSERV_COEFF1>, <BRK_TAPPLY_QUICKSERV_COEFF2>, <BRK_TAPPLY_QUICKSERV_REDUCTION>

4.14 Aux Reservoir Pressure (ARP) Equalization

A fixed value for equalization pressure.

The simulation test range models variation of brake cylinder piston stroke of each platform. Nominal value 7.5", full distribution between 5.32" and 10.12. This variation will result in the brake cylinder equalization changing for each platform based on the value selected.

Related variables: <BRK_ARP_EQU_RATIO>, <BRK_ARP_FULLY_CHARGED>

4.15 Aux Reservoir Pressure (ARP) Recharge Rate

A value that varies by the distance between a platform and the recharge generator.

Related variables: <BRK_INITIAL_RECHARGE_COEFF1>, <BRK_INITIAL_RECHARGE_COEFF2>, <BRK_FINAL_RECHARGE_COEFF1>, <BRK_FINAL_RECHARGE_COEFF2, <BRK_FINAL_RECHARGE_COEFF3>

4.16 Aerodynamic coefficients

Fixed values for both the locomotive and platform defining their aerodynamic efficiency.

Related variables: <BRK_AERODYNAMIC_LOCOMOTIVE>, <BRK_AERODYNAMIC_PLATFORM>)

4.17 Average rate of BPP reduction

The average rate of reduction in the brake pipe pressure following application of service brakes. Note if the actual BPP reduction rate is faster than -103 kPa per second then the Brake Algorithm will assume an emergency brake application. The typical application rate is around 21-28kPa for the first couple of seconds and then the rate starts to taper off as the application continues.

The simulation test range models brake pipe pressure drop from the locomotive based on locomotive brake setup, brake pipe pressure leakage, ambient pressure and temperature, and overall train length. At the beginning of a brake application the rate of reduction will be closer to the 28kPa and the rate of reduction will taper off as it gets closer to the full reduction made.

Related variables: <BRK_BPP_AVE_RATE_REDUCTION>

4.18 Maximum BPP differential

This is the worst-case difference between the BPP at the rear of the train and the BPP at the front of the train. The BPP differential will depend on this leakage rate and the length of the train. The longer the train the higher possible BPP differential.

The simulation test range models variation of brake pipe leakage from 0.689 kPa/minute to 34.47 kPa/minute.

Related variables: <BRK_BPP_DIFF_MAX>

4.19 Target Offset

The Target Offset (TO) dynamically varies and is based on the train speed, the average percent grade over the stopping distance, the train weight and Braking Safety Margin. The Braking Safety Margin is a configurable value used in the Enforcement Algorithm to provide a safety buffer to the target offset calculation. This ensures the train will stop short of the target within the required confidence interval.

5 Appendix C - Parameter Derivation Process

This Appendix provides an overview of the process to derive ATMS train braking parameter values. This process is managed by the ATMS OEM in consultation with ARTC, train operating companies and third-party providers of train simulation and modelling capabilities.

Step 1: Gather train type Consist Configuration and Rolling Stock Class Specification Data

This requires consulting with the train operating company for provision of consist and rolling stock configuration data for the train type for which the train braking parameters are applicable to. This is to support building a model of the train type in the simulation test environment to support the simulation testing component of the process.

Step 2: Build Train Model in Simulation Test Environment

Using data gathered in Step 1, a train model of the train type is configured within a simulation test environment. This shall model the braking performance of the train type under various scenarios. An example of the types of rollingstock data typically required is listed in Appendix B.

Step 3: Derive Parameter Values for Simulation Testing

Based on data gathered in Step 1, and on input from the train operating company, an initial parameter value is derived for each Train braking parameter specified in Appendix A. In addition, where applicable, a simulation test range is specified for which the actual value of the parameter will be varied during the testing process.

Step 4: Develop Simulation and On-Track Test Plan

The ATMS OEM in consultation with ARTC, train operating companies and third-party train simulation and modelling providers, will establish a test plan for conduct of laboratory-based simulation testing and on-track testing if required. This includes a set of test cases necessary to demonstrate safe and operationally acceptable performance of the ATMS brake algorithm for the specified train type.

Step 5: Conduct Testing and Tuning of Brake Algorithm Parameters

The train simulation and modelling provider will conduct simulation testing, and the ATMS OEM, ARTC and train operating companies the on-track testing where required. The test results will be analysed to determine performance of the brake algorithm.

Depending on the test results, the brake algorithm performance may be ‘tuned’ to provide either a conservative predictive behaviour in specific scenarios or all braking scenarios. This will be done in consultation with the ATMS OEM, ARTC and train operating companies. This may result in adjustment of the parameter values. Where changes are made, regression testing is undertaken as required.

Step 6: Baseline Brake Algorithm Parameter Values for train type

At the conclusion of Step 5, the train braking parameters for the specific train type have been tested and demonstrated to appropriately characterise train braking performance for use by the ATMS brake algorithm in calculating predictive stopping distances. This is confirmed through the ATMS Specific Application Safety Case [2] for the specified ATMS Equipped train type, and issuance of an ARTC Type Approval [1] for Locomotive Class and train type.

The specific parameters for the train type are then documented in this Standard.