SUMMARY

KiwiRail Network, the New Zealand railways infrastructure owner/operator, is currently overseeing a major upgrade of the Auckland metropolitan rail network which will culminate in the delivery of a high capacity, double track, electrified railway, complemented with a state of the art signalling and train control system.

This paper is a technical descriptive overview covering all aspects of the new signalling system which is being commissioned over the next 18 months. The new signalling system replaces nearly all of the existing signalling equipment including; signals, train detection, point machines, interlockings, communications infrastructure and control systems. In addition, a comprehensive Automatic Train Protection (ATP) system is being installed, including the onboard ATP fitment of the new fleet of EMUs using the European Train Control System (ETCS) Level 1.

The Asia Pacific division of Invensys Rail, formally known as Westinghouse Rail Systems Australia was awarded a contract in 2009 to complete all of the signalling works described in this paper. The project is due for completion by late 2011. Small parts of the project have been delivered already but the majority is in the design or construction phase at the time of writing this paper. Therefore this paper is primarily a preview of what will be delivered by the completed Auckland Metropolitan Resignalling Project (AMRP) system at the end of the project.

1 INTRODUCTION

The infrastructure of the Auckland metropolitan rail network has been steadily changing over the last few years as a result of the ongoing Project DART works which have included redevelopment of the key Newmarket Junction, duplication of 24kms of the Western Line, some extensions such as the Onehunga branch line and soon the Manukau Rail Link. The next major stage in Auckland’s rail upgrade is the electrification of all passenger lines with the 25kVac overhead electric traction system. Unfortunately much of the existing signalling equipment employed is not compatible with alternating current traction system because it is not designed to be immune to unwanted interference or wrong side failure caused by stray earth or induced currents originating from the traction power. This combined with much of the equipment being life expired and a need for large scale capacity improvements led to the decision to re-signal the entire Auckland network.

Invensys Rail are providing a new signalling system that provides traction immunity, headways of up to 24 trains per hour and an important improvement in safety with the introduction of modern equipment and significantly Automatic Train Protection (ATP).

The introduction of so much new and interesting signalling equipment in one project, covering an entire city’s rail system, is an exciting prospect and the aim of the paper is to give an overview of what is currently being engineered and how it will operate when completed.

2 NOTATION

The following acronyms and abbreviations are used in this paper:

AMRP  Auckland Metropolitan Resignalling Project
ARS   Automatic Route Setting
ATP   Automatic Train Protection
EMU   Electric Multiple Unit
ERTMS  European Rail Traffic Management System
ETCS  European Train Control System
GCP   Grade Crossing Predictor
LEU   Lineside Electronic Unit
LOM   Lamp Output Module
NTCC  National Train Control Centre
PIM   Parallel Input Module
PM    Processor Module
ROM   Relay Output Module
SIMBIDS SIMplified Bi-Directional Signalling
SIL   Safety Integrity Level
SP    Separable Portion
3 AUCKLAND OVERVIEW
The Auckland network can be summarised as a central station, Britomart, which feeds south to the North Island Main Trunk (Southern Line) passing through Westfield and Papakura to exit the Auckland metropolitan area. The other main line in the metropolitan area is the North Auckland Line (Western Line) which starts at Westfield and runs north to Newmarket and then west to Swanson and Waitakere. There is also an important link between Britomart and Newmarket. A branch line to Onehunga is in the process of being commissioned as an upgrade to an existing freight only line. Another new branch line to Manukau City will complete the network in mid 2011. As such, the AMRP is bounded by Papakura to the south and Waitakere to the west.

The incumbent signalling systems within the project area comprise of an interesting array of signalling equipment which originates from the 20th century. The plain line sections are all signalled as ‘double line automatic’ and although supervised by the National Train Control Centre (NTCCC) in Wellington are mostly ‘dark territory’ with no controls and few indications available to the signaller. The junctions (interlocked areas) are controlled by a variety of technologies with relay and geographical interlockings remotely controlled from the NTCCC being the most common. Three Westinghouse Brake & Signal company style ‘L’ electrically locked power frames are still in use at Wiri (normally switched out), Papakura and Otahuhu which were installed in 1931, 1939 and 1942 respectively. Britomart and Quay Park have been relatively recently re-signalled with electronic VPI interlockings controlled from a VDU based control system at Britomart.

4 SIGNALLING DEVELOPMENT
As the AMRP is a complete resignalling, the opportunity was taken at the beginning of the project to review the relevant New Zealand signalling standards and update parts of them to ensure that the best performance and safety levels were achieved for the Auckland system. Following this, new signalling arrangement plans were produced in collaboration with the KiwiRail Network project team and operators.

4.1 Principles
An early deliverable for the AMRP was the production of a comprehensive signalling principles specification. The principles combined all existing KiwiRail signalling principles documents and updated them to describe the system KiwiRail desired for Auckland. This included some new concepts such as route setting system KiwiRail desired for Auckland. This included some new concepts such as route setting (as opposed to unit lever) and SIMplified Bi-directional Signalling (SMBIDS). Completed through a series of workshops between customer and client, the signalling principles now form the primary functional specification for the signalling sub-system. Some of the key principles and features of the new signalling system are listed below, many of which are covered in more detail later in this paper:

Signals: Standard New Zealand signal aspects are used so as to ensure compatibility with the many trains that only use the network for a small part of their journey. The overall signal density is increased to meet the capacity requirements and as a result the mostly three aspect existing system is replaced with four aspect signalling throughout. These signals are spaced to allow passenger trains to operate at full speed under a preliminary caution aspect (flashing yellow over red) and only commence braking at the caution aspect (yellow over red). Freight trains which also regularly operate over this busy mixed traffic railway are able to operate safely at the same speeds, as the flashing yellow gives sufficient warning required for their extended braking distances.

Overlaps: Standard safety overlaps of 150m beyond all signals (some longer where required by
high speed or steep grade) are provided. This brings significant safety benefits for non ATP fitted trains and also results in good performance of the ATP system in general.

Subsidiary Aspects: All signals on the network are arranged as stop and stay signals, even those in the block section which work automatically. Every main signal is also fitted with a subsidiary aspect. Controlled signals are all fitted with a 'Low Speed' aspect which allows permissive moves and the signal to be cleared in some failure conditions. Automatic signals are provided with 'A' lights which when illuminated allow the driver to consider the signal as passable. The 'A' light can be activated by the signaller, but also automatically illuminates should the associated object controller lose communication with the main interlocking and the block was previously set in the direction to which the automatic signal applies. Each automatic signal is also provided with an emergency replacement control from the Train Control centre.

Lockouts: The whole network as been split into 64 work site protection lockout zones which can be activated by the train controllers to prevent train movements into a specific lockout area. They can also be taken co-operatively by trackside staff using new switchboxes which can be secured in the locked position using a padlock to ensure worksite protection for unplanned track works or access into dangerous locations. A feature like this is even more valuable when bi-directional signalling and therefore less predictable train movements are introduced.

Warner Routes: The introduction of overlaps on all signals can cause severe operational constraints on historical track layouts that were designed without overlaps in mind. To alleviate this problem a new 'Warner' class of route has been added to the KiwiRail signalling principles. This allows a signal to be cleared with only a limited overlap of at least 50m available beyond the signal at the end of the route. This is mitigated by the use of delay clearing combined with a "20" km/h dynamic speed indicator on the entry signal.

4.2 Scheme Design

The AMRP is a design and construction project which means that the next stage of the design, after specifications such as principles were agreed upon, was to complete the signalling arrangement plans. For each SP area one or more scheme plans are produced. These provided a high level view of the signalling layout with key information such as signal spacing, types, positions, numbering, overlaps, ATP provision, etc. These are then sent to an external 3rd party for capacity modelling to make sure the signal spacing delivers the required headway. Simultaneously scheme plans are circulated for internal approval by KiwiRail Network such that all key stakeholders and end users of the signalling system can have input into the system they will have to operate for the next few decades. In tandem with the production of scheme plans, detailed ‘hand sketches’ are produced which provide full details of the signalling scheme showing every detail including all axle counter heads and gradient changes along with all the dimensioning information required for construction. The approval of key designs such as these and aspect sequence charts are instrumental in allowing detailed design to progress. They are also important controlled designs which provide part of the interface specification between separate sub systems such as signalling, train control and ETCS design which is all being completed by separate teams.

5 SYSTEM ARCHITECTURE

Before taking a closer look in detail at some of the components, an overview of the complete system to be installed from a generic system integration standpoint is worth consideration. A simple diagram is provided in figure 2 which shows the basic relationships between the control centre, interlockings and the object controllers. All the interlockings for the entire Auckland network are co-located in a single 19” rack in a centralised signalling equipment room specially provided at the heart of the network near Westfield, which is also the location of the signalling maintenance team for the area. The object controllers use the same interlocking hardware as the central interlockings but with the addition of input/output cards. Nearly all the logic processing is handled by the interlockings with the object controllers mostly acting as dumb distributed terminals for the collection and output of discrete indications and controls respectively. Each signalling location case is provided with an object controller.

![Figure 2: Overview of the basic interlocking/control system architecture](image)

In figure 3 a more complete overview of the system is provided which shows one example of all of the major components that make up the signalling and train control system, including the on-train equipment for ETCS. In all locations except for Britomart, modular locations cases are
provided which use a small object controller connected to pre-wired modules to interface with the trackside. The whole system is designed to be extremely resilient to potential failure modes and as such all communication links are duplicated or ringed, the control centre is replicated with a back-up system in Auckland and the centralised interlocking site has a disaster recovery twin at Newmarket to protect against a catastrophic failure (such as fire) at the primary site. A changeover mechanism is provided for the signalers at Wellington in the event that the main interlocking site has failed. This allows a switch to the back-up interlocking site to be instigated safely and with a loss of service less than 5 minutes.

Auckland network as well as the NTCC in Wellington and the back-up train control location at Britomart Transport Centre in Auckland.

The architecture of the communications network has been kept as simple as possible. The core backbone is provided by a fibre optic cable which calls at every location. (Interestingly this means

**Figure 3: A logical (simplified) overview of the AMRP integrated systems architecture.**

### 5.1 Communications

As the signalling, train control and ETCS trackside systems are all based around a centralised ‘brain’ with dumb terminals/object controllers architecture, a high capacity, reliable and redundant communications network is required. To meet these requirements an Ethernet network has been designed covering every new location on the Auckland network as well as the NTCC in Wellington and the back-up train control location at Britomart Transport Centre in Auckland.

The architecture of the communications network has been kept as simple as possible. The core backbone is provided by a fibre optic cable which calls at every location. (Interestingly this means...
that the AMRP will be the first project in Auckland to deliver ‘fibre to the door’ of every location, and to think the telecom industry generally considers railway telecoms as old fashioned!)

A feature of the AMRP system architecture that brings material and installation cost efficiency is that the only inter-location cabling is fibre optic and 400Vac power. This is also important for electromagnetic compatibility with the traction supply and when combined with the provision of approximately 150 new locations cases means that all tail cables to signalling objects can be kept as short as possible.

6 INTERLOCKINGS
The project sees the introduction of new interlockings for all areas of the Auckland network.

The WESTRACE interlocking family has been used at a number of installations in New Zealand previously and has been installed in hundreds of sites worldwide in the past 20 years. The WESTRACE interlocking is an electronic interlocking arranged as a number of cards. A decision was taken to use the new WESTRACE MkII interlocking range for AMRP as it offers vastly increased logic processing capabilities as well as better efficiencies when utilised in a large number of small installations as object controllers. It also ensures the latest and therefore most obsolescence proof technology is being installed.

The WESTRACE MkII interlocking comprises of 4 cards. To help explain how the interlocking system is built up, an explanation of the basic function of each card is provided below:

Processor Module (PM) – This card is responsible for all logic processing (ladder logic identical to WESTRACE MkI), communications (all Ethernet based using WNC vital protocol and WSA-S2 for non-vital control centre links). Data is stored on the module’s permanent backplane which means should a card need replacing that the new card does not need to be manually programmed with the application logic for that site.

Parallel Input Module (PIM) – This card provides the method for collecting vital discrete inputs in the field. It provides 12 x 48Vdc voltage sensing inputs. It is used for detecting the state (including correct polarity) of incoming line circuits which in the AMRP are normally limited to level crossing, Train Ready To Start and worksite protection lockout switch inputs.

Relay Output Module (ROM) – This card has 8 double cut discrete 48Vdc outputs. The main use for this card on AMRP is to drive the high current point contactor relays.

Lamp Output Module (LOM) – The LOM provides 6 separate 110Vac outputs suitable for driving a large range of LED and incandescent signals. Each output has the ability to display a steady or flashing aspect and also has inbuilt current proving to detect failed aspects.

6.1 Interlocking Arrangement
The central interlockings only use the PM cards. Object controllers in each signalling location use one PM card and any combination the PIM, ROM and LOM cards as required.

Each of the WSTRACE MkII modules is fully enclosed within its own aluminium case which means that safe handling without electrostatic protection can be achieved. One of the most important improvements of WSTRACE MkII over the previous generation of WSTRACE interlockings is that if a single card detects a critical failure it only shuts itself down rather than the whole system. Add to this, that the cards can be hot swapped without affecting the rest of the system, this results in large availability gains for the new Auckland system.

As discussed in chapter 5, the interlockings are centralised. At the primary interlocking site 2 PMs are provided for each interlocking area which are set-up in a hot-standby configuration. As all equipment in the central interlocking sites is duplicated for availability, including power supplies and networking equipment, the failure of any one component does not affect system availability and almost all equipment can be repaired or replaced while the system is live.

After careful consideration it has been decided that the most efficient means of interlocking data testing is to have one interlocking for each sub-phase (note some SP areas have multiple commissioning dates because of their size/complexity.) This results in 9 interlockings in total. Each interlocking on average has about 30 object controllers well within the maximum permitted of 128 as well as a large amount of spare data processing capacity for future expansion.

7 TRACKSIDE OBJECTS
Not only is the AMRP providing all new interlockings, the majority of the trackside signalling objects; the signals, point machines, train detection devices, etc, are also being replaced or supplemented with new equipment.

7.1 Signals and Points
As a complete resignalling project (Quay Park and Britomart excluded) most existing signals are relocated and supplemented as required to provide the necessary headway. Most signals are mounted on new signal posts and provided with LED heads for main and subsidiary aspects as well as route and dynamic speed indicators where required.
A new folding mast signal post product has been developed specifically for this project to allow signals to be constructed without the need for ladders, landings or complex traction staff protection cages. The top part of these signals pivot around a hinge around 4ft above the base to allow the signal to be lowered for maintenance by a sole technician, without the need to go near the overheads or work at height.

The majority of existing point machines used on the Auckland network are being replaced as part of this project. Invensys Westinghouse M23A machines with 120Vdc motors are being used wherever whole machine replacement is required. Some of the existing point machines are relatively new so are being retained, however they require motor changes to DC motors to make them AC traction immune.

7.2 Train Detection
The AMRP sees a fundamental shift in train detection technology for Auckland. Previously track circuits were the only technology used for this purpose in Auckland with the exception of a few axle counters at Britomart. The AMRP changes this as axle counters are now to be the main method of train detection. The only use of track circuits is for the island track section of a road level crossing. This is an important design feature as it allows a road-rail (hi-rail) vehicle to enter or exit the axle counter system without causing a miscount. The axle counter system used is provided by Frauscher of Austria. The axle counter system is configured in a distributed fashion. Typically up to 12 axle counter section evaluators are provided in any one location case to serve the tracks within the area the location controls. The axle counter heads are shared among the sections as required. For the track sections on the fringe between two location areas two evaluators are provided, one at one location and the other at the next neighbouring location up the line. These evaluators are configured as in a slave/master relationship and communicate using RS232 of which up to 4 sections are multiplexed down a single pair of fibres to the next location.

Figure 5: A Westinghouse M23A point machine installed at Newmarket. Just visible on the right hand side are the integral manual control handles

Figure 4: Tilting masts get complicated when route indicators have to be at the bottom of signals! This is, strictly speaking, a swivelling/tilting mast as before the signal can be lowered (the pivot is just above the route indicator) the route indicator must be swivelled out of the way on its own movable mounting.

Photo: David Brown, KiwiRail.

Figure 6: A Frauscher axle counter head. The Frauscher heads have proved very robust and work well even in areas where there is a lot of metal work close to the head as pictured here.

Photo: David Brown, KiwiRail.

One of the most important features of an axle counter and how it is integrated into a signalling system is the way resets are performed in the
event of a miscount or component failure. This was given careful consideration during the early design phase of the project as this is the first time that such a large scale application of axle counters has been used in New Zealand. The result is that there are two different types of reset which are available in different scenarios. In the most serious failure conditions which typically are when the equipment has suffered a component failure or the last count was an "in" count, the section needs a local reset by a maintainer. Following this a remote reset by the train controller is also required which is actioned through the train control and interlocking systems. Should the failure be limited to a less serious fault such where the last count was "out" of the section, then a remote reset alone is sufficient.

In either case, after the Frauscher equipment has been reset, the interlocking ‘aspect restricts’ all signalled routes over the affected section. This aspect restriction means that the signal can only be cleared to a Low Speed or ‘A’ light aspect which provides an automated and enforced protection against a section being incorrectly reset with an obstruction still present. After a train has successfully traversed the section under aspect restriction conditions, the interlocking automatically removes the aspect restriction control.

In certain critical locations such as the entrance crossovers to Britomart terminus and Newmarket triangle, some axle counter heads are duplicated to provide a level of redundancy against a single failure that could lock up a whole junction.

Site trials were conducted in 2009 as part of the type approval process to enable Frauscher axle counters to be used in New Zealand. The opportunity was also taken to identify the best head and mounting arrangement to ensure the system would detect all vehicles used by KiwiRail including road rail vehicles.

7.3 Going Modular

Probably the most unique feature of this project is the method used for populating the traditional signalling location cases. On traditional signalling schemes which use an object controller architecture (be it WESTRACE, SSI or similar), the object controllers are housed in small locations along the track but require considerable free wired design and construction effort to provide power, communications and most complex of all; the interface and protection required to the external trackside equipment.

A new type of location design has been used for the first time on this project in the form of Invensys Rail’s Modular Signalling System. This allows locations to be designed by the simple application of a number of pre-wired and pre-tested basic building blocks in the form of WESTRACE Interface Modules. These modules are connected by pre-configured plug coupled cables.

Each location has a power module which takes the incoming 110Vac supply and converts it into all the voltages required to power the various equipment in the location, which includes 120Vdc for point machines, 24Vdc for the WESTRACE Object Controller and 48Vdc for point detection circuits and ETCS equipment, as well as providing the 110Vac required for signal lighting. The power module also has integral Earth Leakage Detectors for 110Vac, 120Vdc and 48Vdc.

Other modules which can be present in a modular location are:

**WOC Modules:** Up to three of these WESTRACE Object Controller modules can be fitted per location and are all connected, each with 5 WESTRACE MkII module slots. Only one PM is required per location which allows up to 14 i/o cards per site.

**Signal Module:** Contains an isolation transformer, connection to WESTRACE MkII LOM card and surge protection which also act as outgoing links for tail cable termination.

**Point Module:** Contains the only relays used on the project outside the level crossing locations. Two relays are provided for the normal and reverse point drive contacts. The module also includes a DC-DC converter to isolate the point detection supply. A maximum of four point modules can be accommodated in one location. All four modules are daisy chained together and

![Figure 7: Two Axle Counter WESTRACE Interface Modules (top) and associated Frauscher Axle Counter evaluators, interface cards and surge arrestors](image-url)
share one ROM card for point commands and one PIM card for point detection. Different point module models are available to allow control of different point machine types.

**Axle Counter Module:** This module provides the power required by the Frauscher evaluators. It also contains the interface circuits to allow the reset commands and track occupied, track clear indications from four Frauscher axle counter sections to be interfaced to a ROM and PIM card respectively.

**General Purpose Input Module:** Provides 12 surge protected voltage sensing inputs for 48Vdc line circuits.

**General Purpose Output Module:** Provides 8 miscellaneous vital 48Vdc vital double cut outputs, usually used for level crossing controls.

**Communications Module:** Three different types of this module are available depending on the communications requirements at specific sites. The module can contain high availability Ethernet switches (and optionally a router) as well as duplicated power supply with seamless changeover. The networking equipment all has fibre optic line drivers for external connection. Up to three RS232-over-fibre media converters are also provided which allow for a maximum of 12 fringe axle counter sections per location.

**ETCS Module:** The ETCS module houses either one or two Lineside Electronic Units (LEUs) which allow control of up to 8 signal balise groups from one location.

All the modules are factory tested for continuity and functionality by a semi automated process which means that they can be treated as ‘plug and play’ on site. This means no location functional testing is required onsite except standard through testing for each input and output to ensure the external equipment is wired and operating correctly. All modules are fitted with windows in the front door to allow maintainers fast access to view the state of all indicator fuses and surge arrestor modules to aid fault finding.

Power is fed to the modular locations via a 400Vac distribution system fed in turn from a number of 230Vac street supplies around the network. Each location has a 400-110Vac power box mounted externally.

The modular locations are designed to meet the project’s requirement for 24 hours back-up power by providing their own local battery backed up supply. Each location has four large batteries to provide back-up which is sufficient to power all equipment in the area of the location (including point machines) for at least one day. This local back up rather than ring fed or adjacent site reticulation removes the need for heavier cabling or permanent back up generators at every power feed point.

**Figure 8: The rear of 3 signal modules. The 2 small plug connectors on the left side of each module are the multi-power bus ‘in’ and ‘out’ connectors which provides 24Vdc, 48Vdc and 110Vac to all modules on a rack via a daisy chain. The large plug coupler on each module is the link to a WESTRACE MkII Lamp Output Card (LOM).**

### 7.4 Level Crossings

The work at level crossings on the AMRP does not include any particularly novel nor new technology, however they are worthy of mention as there are in excess of 50 within the project scope which means they form a significant portion of the works. Some of these level crossings have recently been upgraded as part of the Project DART works but around 50% are being renewed completely by AMRP. All level crossings have new barrier and warning light control circuits with the crossing command logic performed by the local WESTRACE object controller using the local axle counters on the approaches to detect approaching trains. All level crossings have their own 12v battery backed up supply and are fitted with solid state flasher units with a small number of relays to control the barrier and light sequence. All crossings are fitted with lights, bells and half barriers. Some crossings may require special ‘super’ controls where controlled signals are very close to them.

### 8 AUTOMATIC TRAIN PROTECTION

Core objectives of the ongoing Auckland rail upgrades are to achieve significant increases in both system capacity and safety. However
capacity and safety tend to have an inverse relationship because as one rises so do adverse affects on the other. For example, if signalled capacity is doubled this leads to a probable doubling of the likelihood of a SPAD on any given day (assuming twice as many signals are now being passed by trains each day). Conversely, often increases in signalling safety, such as increasing overlap lengths, can reduce capacity. There is no magic solution to this problem, but the one way to comprehensively increase safety at the same time preserving or even improving capacity is to fit the whole network with a common continuous ATP system rather than applying ever increasingly complex controls to the existing signalling in the quest for risk reduction.

The European Rail Traffic Management System / European Train Control System (ERTMS/ETCS) level 1 system that is being commissioned in Auckland ensures no dangerous SPADs can occur at any signals to a fitted train. It also provides continuous speed supervision to ensure fitted trains are driven within the safe line speed profile. A full explanation of the operation of ETCS and its application to Auckland is covered in another paper at this conference. Therefore this paper limits the description to the trackside and onboard hardware being employed and the core features of the system.

8.1 Trackside Fitment
The trackside ATP infrastructure for Auckland is being provided by the installation of the Invensys Rail FUTUR 1300 ETCS Level 1 system. The system consists of two main pieces of hardware, the EuroBalise and Lineside Electronic Unit.

Figure 9: A controlled EuroBalise. Note the tail cable from LEU on the right to allow the telegram to be reprogrammed in real time.

The balise is a non powered transponder device that is fixed to the sleeps midway between the rails. A train’s ETCS antenna provides a powering frequency which the balise then returns, modulated with an encoded message. Each balise can hold 1024 bits of data. There are two types of balise; fixed and controlled. Only the controlled balise has a tail cable which is connected to the LEU in the nearest location. The controlled balise is re-programmed in real time by the LEU to reflect the state of the signalling system. Fixed balises are used for static data which does not change based on the signal aspect such as line speed and gradient in a plain line section.

The Lineside Electronic Unit (LEU) is the ATP encoder used by ETCS level 1. The LEUs provided for AMRP have the ability to drive 4 separate balise groups. The LEUs have a vital serial connection to the interlocking utilising the common railway signalling Ethernet based WNC protocol. This serial link allows the LEU access to information from a very wide area, which means it can give the train additional information compared to that available from the signal aspect alone. This feature is used in Auckland to provide the driver with longer movement authorities than the 4 aspect signalling provides on its own. This will allow line speeds to be increased in the future for ETCS fitted trains with no need to change the signalling infrastructure; it also improves the performance of the ETCS system if a single balise group fails.

Figure 10: A serial Lineside Electronic Unit (LEU). The three cards are, Power Supply Unit (PSU), Logic Module (LM) – this decides which telegram to programme each balise with based on state of interlocking, and Balise Output Card (BOC) – which can drive up to four controlled balise.
8.2 Onboard Fitment
Not only does the AMRP involve fitment of ETCS to all mainline tracks in the Auckland area, but there is also provision in the contract for the fitment of ETCS equipment to the first 35 new Electric Multiple Units and six existing locomotives (76 cabs in total). The system to be fitted onboard is the Invensys FUTUR 3000 ETCS Level 1 system which can be upgraded to ETCS level 2 in the future with the simple addition of the necessary radio equipment.

Unfortunately the new electric trains will not be delivered until after the trackside portion of the resignalling project is completed. Therefore it will be some time before Auckland has a truly ATP protected rail system. In the interim some cabs are being fitted (SA driving van trailers to begin with) for trialling of the ETCS system. The first test runs will be run on the Onehunga branch line later this year.

9 CONTROL SYSTEM

9.1 Introducing Route Setting
The AMRP interlocking logic is based around a route setting core. This brings a large change in train control user interface for KiwiRail Network where previously unit lever operation has prevailed. Route setting allows the signaller to set up complex routes which just two inputs (at the entrance and exit of the route). A good demonstration of the benefits of this shift will be demonstrated at Newmarket where an early stage of the AMRP has already installed a new WESTRACE interlocking in a very complex layout, currently this interfaces to the existing Auckland unit lever VDU control system at Britomart. Some routes today involve (in the worst case) between 10-20 mouse clicks for the signaller, which of course all eats into precious capacity on this important section of the network. With route setting (which will be commissioned for Newmarket at the end of 2010) these same routes will set in the time it takes the operator to make two mouse clicks.

9.2 SystematICS and WESTROL
The new train control system is based around the Invensys SystematICS platform. This is a modular and highly available SIL2 platform designed for mission critical system such as train control and SCADA. The SystematICS platform consists of two hot standby redundant servers which are co-located with the two centralised interlocking sites. All parts of the system are at least duplicated so in the event of any failure the redundant equipment can continue without loss of service. However SystematICS only provides the data management and interface functions of the Train Control system (somewhat like an operating system to a computer). The actual train control functionality is provided by the train control application which is called WESTROL and provides user interfaces for the signallers on workstations connected to the SystematICS servers.

WESTROL is an advanced VDU based train control platform and because of its generic platform/workstation architecture is both more complex and powerful than the more common 1st generation VDU control centres which were essentially designed as computer replacements/replicas of physical signalling panels or lever frames. Of course the downside of the additional complexity is that the train control component has now become a complicated system in itself with a large amount of configuration and integration required. In the Auckland resignalling project WESTROL is being used not only provide basic control of the signalling system but also to provide advanced tools to enable the signallers to extract the most capacity and performance from the network. Probably the most prominent of these is the introduction of Automatic Route Setting (ARS) to the network. ARS allows the train control system to set routes automatically and operate...
autonomously based on timetable data with the signallers performing a supervisory role. Signallers are able to choose which trains or areas are under ARS control which allows them to focus their attention on areas where it is needed (such as a failed train situation). ARS functionality will be added when enough of the network is under the control of the new signalling system as the ARS’s timetable and predictive algorithms and work most effectively when it can take a holistic view of the network.

10 MANAGING THE NEW TECHNOLOGY
This chapter explores one of the key new technologies used on the project and looks in detail at how risks are mitigated when introducing newly developed or unknown products into a complex and important project such as AMRP.

10.1 Case Study: WESTRACE MkII
Probably the most critical piece of new technology being used on the AMRP is the WESTRACE MkII product range. The AMRP sees the first non-trial/pilot application of this technology anywhere in the world, which means that type approval and interlocking system proving are of the highest importance for the project. With any product developed to CENELEC SIL4 standards, safety can be proved by reference to the rigorous documentation and V&V required in such a development. However, a bigger problem is proving the operational reliability of such equipment as well as providing some physical evidence of its safety credentials. A number of risk mitigation activities have therefore been planned for the WESTRACE MkII equipment before it sees operational service in Auckland with no fallback system. They are:

Shadow Mode Trial: A full shadow trial has been running at a station called Pitis in Madrid, Spain where a WESTRACE MkII interlocking has been loaded with the same data as the WESTRACE MkI interlocking already in service. The MkII receives the same trackside inputs and controls from the train control system as the real interlocking. A third WESTRACE systems (MkI) is provided as an arbitrator which compares the outputs of the WESTRACE MkI to the field with those the MkII would output if it was connected. The Pitis trial has been running for over a year now with no mis-comparisons or other issues.

Wellington Distant Junction Trial: A pair of WESTRACE MkII Processor Modules (PMs) in hot-standby configuration on trial at Distant Junction. Figure 12: A pair of WESTRACE MkII Processor Modules (PMs) in hot-standby configuration on trial at Distant Junction.

Wellington Distant Junction Trial: A pair of WESTRACE MkII PMs were installed in the relay room at Distant Junction in Wellington earlier this year. The first stage of the Wellington trial has seen the PMs prove they can handle the KiwiRail environment (specifically DC traction) with the cards running test data for 3 months without any failures or problems. The health of the MkII system is monitored by the commissioned MkI system in the same relay room. The next stage of the trial planned for later in the year, pending KiwiRail Network interim type approval of the WESTRACE MkII cards, which involves porting the Distant Junction WESTRACE MkI interlocking logic onto the PMs and putting them into vital service as the interlocking processor for the area. In this configuration, should any reliability issues arise the system can be configured back to MkI control in less than 10 minutes.

Onehunga Pilot: The final and most comprehensive demonstration and proving of the WESTRACE MkII components is as part of the Onehunga Pilot as detailed further in section 10.3 of this paper. This sees the final configuration of MkII interlockings and object controllers commissioned (but not in service) for the whole line a number of months prior to the first main commissioning.

10.2 Type Approvals
Approximately 160 new products are used on the AMRP which have not previously been commissioned in New Zealand. These range from the small and relatively simple, such as surge arrestors, to SIL4 ATP systems. Regardless, they all have to go through the process of KiwiRail Type Approval and achieve approved status before commissioning. A number of methods are used such as cross acceptance or documentary analysis as well as operational trials for some of the more critical components. This is a sometimes tedious and often time-consuming activity for both the contractor and customer but is an important
10.3 Onehunga Pilot

Part of Project DART sees the relaying and opening to passenger traffic of the Onehunga Branch line. This 3km stretch of ex-industrial branch line crosses the public highway no less than 8 times. To avoid unnecessary rework and to facilitate the branch’s opening it was decided to incorporate the necessary signalling works to bring the line into operation as part of the AMRP.

To enable this work to progress ahead of the AMRP resignalling schedule as required for a 2010 opening, an interim signalling system using axle counters and Grade Crossing Predictors (GCPs) is being installed by Invensys Rail. Although the GCPs will be removed upon commissioning of the final interlocking on the line it is hoped to retain one in shadow mode to allow trials of its operation in a 25kVac traction environment.

The opportunity of a green-field site such as Onehunga is also being captured for greater use as part of the AMRP. At the same time as installing the interim signalling to enable passenger operations in 2010, the final signalling equipment including WESTRACE MkII and ETCS Level 1 equipment is being installed as an overlay. This final system is available for testing when the line is not required for passenger trains and facilitates the proving of various new technologies in a large scale application as well as providing the test site for the first test runs of ETCS in New Zealand. The Onehunga pilot provides KiwiRail Network with invaluable information and confidence before commissioning of the first main stage of AMRP in the heart of the Auckland network without putting at risk the initial commissioning of the line in 2010.

11 PROJECT IMPLEMENTATION

This last section of the paper provides a brief overview of the work completed to date, work that is currently in hand and some of the strategies in place to ensure technical success, as well as those required to commission such a complex system in a live environment.

11.1 Newmarket

Newmarket station is an important junction just outside central Auckland. As part of Project DART the station and track layout have been totally rebuilt and remodelled to provide greatly increased flexibility. Rather than install a temporary signalling system that would be decommissioned one year later, it was decided to add this work to the AMRP contract. Following this decision the new layout at Newmarket was commissioned at Christmas 2009 using as much of the final AMRP equipment as possible. It saw the first implementation of modular signalling and Frauscher axle counters as well as new point machines and signals (with tilting masts!) provided throughout.

![Figure 13: Modular Signalling rack at Newmarket, note spare slots reserved along top row for final WESTRACE MkII object controllers.](image)

11.2 Staging

As shown in figure 1 at the start of the paper, the project has been split into 5 distinct Separable Portions (SPs). These have been scoped such that each stage is manageable and can be commissioned over a short block of line (typically one weekend). One of the advantages of the latest generation of computer based interlockings is their immense data capacity compared to some of the original electronic and computer based interlockings. This is an invaluable tool to the project’s implementation as it allows interlockings to be designed such that their boundaries can be in the most simple automatic section location as possible rather than, as was often the case with smaller capacity interlockings, in the middle of a complex junction because an arbitrary data limit had been reached.

SP1 is arguably the most complex stage of the project not only because it is the first. To help de-risk this crucial stage it is split into 2 commissionings, the first at the end of November 2010 will bring the section of line from Morningside to Grafton into use. This will be followed over the Christmas/New Year break by the re-interlocking and alterations at Quay Park and Britomart which introduces reduced headway and bi-directional signalling capability. This first stage will result in
the final signalling being available between Auckland and Kingsland to enable a very high frequency timetable to operate between the Rugby World Cup stadium at Kingsland and the centre of Auckland.

The SP2 commissioning follows at Easter. SP4 will probably be commissioned next so as to ensure the new Manukau City Rail Link is brought into operation well in advance of the Rugby World Cup. SP3 and SP5 will then be completed throughout the remainder of the year.

11.3 Design and Construction
At the time of producing this paper the high level design required for the first 2 stages of the project has been completed and approved. Soon the detailed design for modular signalling, interlocking data, train control software and ETCS data preparation will also be completed for the first stage. The first civil construction works have begun on stage 1 which will rapidly accelerate to a rolling program of construction and installation that will continue for the next 12 months.

11.4 Commissioning Strategy
Given the inevitable operational constraints of trying to resignal an existing rail network for a whole major city, the new signalling system has been purposely designed to eliminate the need for long shut downs for the commissioning of each stage. As a totally independent new 400Vac signalling power supply system is being provided as part of the resignalling works along with a new communications network, this allows the new locations to be powered up well in advance of the final commissioning. As nearly all equipment provided is new, most of the AMRP system can be through tested and pre-commissioned well in advance of the actual commissioning date. Upon entering a commissioning weekend, all axle counters will have been pre-commissioned and soak tested, new signals will have been through tested and bagged, train control software corresponded to all interlocking i/o and all interlocking equipment thoroughly tested. Even the ETCS trackside equipment can be fully commissioned prior to the old signalling being decommissioned. At the actual commissioning weekend the only work that will need to be focused on is the changeover of point machines (some of which may be done in advance where possible), level crossings changeovers, fringe connections and associated principles testing.

12 CONCLUSION
The intention of this paper was to give an overview of all the major components that are being implemented for the Auckland Metropolitan Resignalling Project as well as the way they integrate together.

The completed system will deliver large increases in capacity and an important leap in rail safety. At the time of writing construction is just beginning on the core of the project so this really is only the beginning of the story. The introduction of many new technologies, not to mention the move to cab signalling equipment, will all bring with them their own challenges and lessons but that is for a future paper.

The paper has demonstrated that although many of the technologies used on this project are exciting on their own they are mostly not unique nor world-firsts, however when viewed as a complete system there are not many other signalling projects which comprehensively provide such a level of new technology and exciting features.

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REFERENCES
My role as Project Integration Manager for the AMRP means that I am fortunate enough to be involved with all technical aspects of this exciting project on a daily basis, hence no external publications were used in the production of this paper. I must admit however that the one historical fact in this paper was extracted from John Francis’ informative text ‘Westinghouse – The Style ‘L’ Power Frame’ 1989, ISBN 0951463608.