DELIVERING COMPLEX OPERATIONAL CHANGE ACROSS MULTIPLE BOUNDARIES

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SUMMARY

A major part of the works on Regional Rail Link – City to Maribyrnong River (CMR) work package was the reconfiguring of the approaches to Southern Cross Station to allow services from the new RRL lines to come across the refurbished North Melbourne flyover over the suburban lines into platforms 1-8 of Southern Cross Station. This included substantial reconfiguring of the track layout and replacement of the signalling and train control systems for the regional lines and adjustments to the existing signalling and train control for the suburban network.

The work took place in two major stages and crossed the boundaries between three Rail Infrastructure Managers – Metro Trains Melbourne (MTM), V/Line and ARTC, their respective train control centres at Metrol, Centrol & No 1 Box and Mile End and across nine different interlockings ranging from new CBI to free wired and geographic relay interlockings.

An earlier CMR commissioning across the MTM and V/Line boundary at South Kensington was a technical success but train delays occurred due to train controller unfamiliarity with the new cross-boundary movements.

This paper highlights some of the key learnings picked up over the life of the CMR project and how they were implemented in planning and delivering the complex Southern Cross approach works.

1 INTRODUCTION

Southern Cross Station is both the regional and interstate passenger terminus and a major suburban station, handling over 1400 train movements and 60,000 passengers a day.

The Regional Rail Link project provided a new pair of tracks to carry regional passenger services from the west and north of Melbourne to Southern Cross, requiring a major reconfiguration of the approaches. This work was undertaken in two major stages.

The majority of the track reconfiguration was completed in January 2014 (occupation E45) with alterations to the existing signalling to allow operation with a slightly reduced functionality.

The remaining track work was completed, all connections reinstated and the new signalling and train control was commissioned in July 2014 in occupation E48.

The approaches to Southern Cross lie at the boundaries of the MTM, V/Line and ARTC rail systems and cover a mix of old and new signalling, telemetry and train control systems. In addition to the various systems needing a seamless interface, the train controllers all need to have a common, thorough understanding of the operation of the system.

2 NOTATION

The following terms and acronyms are used in this paper:

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>CBI</td>
<td>Computer Based Interlocking</td>
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<tr>
<td>Centrol</td>
<td>V/Line regional train control centre</td>
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<tr>
<td>CMR</td>
<td>City to Maribyrnong River</td>
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<tr>
<td>Geographic Interlocking</td>
<td>An interlocking of standard pre-assembled modules arranged and electrically connected in a geographical manner. Now outdated and all but life expired.</td>
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<tr>
<td>Interlocking</td>
<td>An arrangement of signal apparatus controlling signals and points to prevent conflicting movements or unsafe conditions</td>
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<tr>
<td>JZA</td>
<td>Telemetry system connecting the Metrol train control system to the interlockings</td>
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<td>Metrol</td>
<td>Metropolitan train control centre</td>
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<td>No 2 Box</td>
<td>Southern Cross No 2 interlocking</td>
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<td>RRL</td>
<td>Regional Rail Link</td>
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Term | Definition
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SigMAP | The telemetry interface to the V/Line train control system
Smartlock | Alstom supplied proprietary CBI
SSI | Solid State Interlocking
T&C | Testing and commissioning

3 SYSTEM INTERFACES

Early risk assessment of the proposed works indicated that the most significant risks were related to the physical works in the Southern Cross No 2 Box and the Franklin Street Box geographic relay interlockings, the technical interfaces between the systems and the human interfaces between the train controllers.

Geographic interlockings are a system once commonly used in Victoria, whose intricacies are now fully understood by only a few designers and construction personnel. They consist of standard modules related to signals, turnouts and crossovers connected in a manner that mirrors the physical layout and plug coupled together.

The major risks in working inside a geographical interlocking are disturbance and damage to the ageing plug couplers and the chance of encountering undocumented modifications within the wiring.

An exercise to define all of the technical interfaces was undertaken to ensure that all of the interfaces between the various systems were clearly understood and could be easily communicated to team members and stakeholders.

The simplest way to communicate the complex nature of the system was using a system interface diagram (Figure 1) showing the nine interlockings and three train control systems and all of the communications linking them together.

The technical interfaces between the systems involve connecting various legacy systems, including the geographical interlockings, the metropolitan JZA telemetry system and train describer system and integrating them with the new interlockings and train control systems.

The newer systems are easily connected for simulation purposes but the interface with the legacy systems introduces the potential for complications that will not be found until during commissioning.

The changes required to three train control systems and changes to the operational layout on the boundaries between the MTM, V/Line and ARTC systems also introduced the potential for...
confusion for train drivers and train controllers alike.

The changed arrangements for train drivers can be dealt with through simulation, driver training runs, and the use of pilots. Train controller training has traditionally been done in classroom mode, with assistance from operational supervisors during the initial running period.

4 LESSONS LEARNT

In planning the works, the Alliance sought to understand the lessons learnt from recent occupations and commissioning events where some of the risks we had identified had been encountered. This included a review of the January 2014 occupation and covered all of the normal risks involved in shutting down a railway for a defined period, ripping it apart and putting it back together.

Two events were singled out for particular relevance to the proposed works, being the ANZAC Day occupation and the South Kensington CBI Split.

4.1 ANZAC Day

Works planned and delivered at Southern Cross for the ANZAC Day long weekend in 2013 included commissioning of a new Smartlock interlocking to partially replace No 2 Box, requiring substantial modifications within the geographic interlocking.

Figure 2 – Southern Cross No 2 Box

The occupation on the Through Suburban lines commenced after the last train on Wednesday 24th April and over-ran by 24 hours as the commissioning was unable to be completed prior to the AM peak on Monday 29th April. Due to the number of trains, commissioning was not completed until Monday night.

A full report on the causes of the overrun was completed and released to the industry with the aim of preventing repeat occurrences. Some of the major lessons and recommendations adopted from the report include:

- All correlation of existing equipment and scheduled pre-construction activities must be completed ahead of the start of the main occupation;
- The working time allowed per drawing sheet for wiring works in No 2 Box was insufficient;
- Progress reporting was ineffective and should have identified issues earlier;
- T&C team presence in Metrol should be implemented, with an interface person who has detailed knowledge of the works;
- Contingency planning for occupation overrun scenarios are to be completed and progress review points defined in the program and Occupation Works Guide;
- Separate roles should be defined for a Tester in Charge, Commissioning Manager and Event Manager (Project Manager) for occupations with major commissioning activities;
- The fault teams from the installation and testing teams should be separate teams;
- Lines of communication should be kept clear when senior rail operator representatives are seeking updates on progress. Multiple enquires direct to the T&C team can lead to conflicting information and unnecessarily distract the team.

Following these works there was a greater emphasis from MTM on assessment of works readiness and adherence to the “T-minus” Works Readiness Procedure, including independent peer reviews on the progress of design and physical works.

All of the lessons from ANZAC Day were applied to the planning of the Southern Cross commissioning, including open engagement with the MTM peer reviewers.

4.2 South Kensington CBI Split

The South Kensington CBI split, delivered as part of the CMR works took place in November 2013. The junction at South Kensington between the new RRL tracks (controlled by V/Line) and the existing MTM network is primarily intended for operational flexibility during abnormal operations. As part of the overall RRL staging it allowed early access to platforms 15 & 16 at Southern Cross, offsetting some of the functionality that would be lost following the works in January 2014 and was intended to be used for
timetabled moves until the completion of the RRL tracks.

This work involved installing additional crossing work, splitting the existing interlocking to provide the cross-boundary moves and removing these from the existing SSI CBI into the new Smartlock CBI.

There were some technical issues with the signalling works, resulting in faults being reported after commissioning, but the major in-service issue was that the train controllers on both the V/Line and MTM sides of the boundary did not fully understand how to respond to any faults that occurred or changes to the agreed sequence of train movements and how to alter routes that had been set. This created an unacceptable level of train delays.

4.2.1 Cross-Boundary Operation and Maintenance

The major lesson learnt from the South Kensington split was around the requirement to train both train controllers and maintainers on how to respond to abnormal situations on the cross-boundary interface. During the lead-up to this event, the train controllers were trained on the new interface with a PowerPoint presentation, where the trainer effectively ran through the panel indications and sequence of events required to operate the interface.

While fault recovery and removal (cancellation) of cross-boundary routes were covered in the training, under the pressure of operating the railway when things did not go according to the plan, the training was revealed to be inadequate. This resulted in some significant train delays.

The training provided to the maintainers was also found to be lacking, such that whenever an issue arose, the cross-boundary points were simply locked until the fault could be resolved. To assist with rectification of these issues after the commissioning, an on-call arrangement for the design team was established so that the signalling fault centre would have a point of contact to speed resolution of the issues.

The following lessons were applied to occupation E48:

- Training of train controllers is to be more hands-on and have a focus on fault recovery;
- Training is to be provided to signal maintenance staff;
- Post-commissioning support from designers and rail operators is to be defined and agreed in advance;
- As a last-resort backup, point clipping plans are to be provided with point clips and padlocks available.

4.2.2 Management of Testing & Commissioning

As the commissioning weekend progressed, there was uncertainty as to the exact progress made on the principles and interface testing of the new signalling systems, with conflicting reports of the current status and time to complete and hence the uncertainty of achieving the required handback time. It was agreed that there should be more focus on improving visibility of this aspect of the works.

5 OCCUPATION READINESS

Occupation readiness refers to the preparedness of the delivery and commissioning teams to complete the works in the allotted time. Ordinarily this includes risk assessment of the works to plan for various foreseeable events and an assessment of the state of all the necessary preparatory works.

Starting the process early, allowed enough time to develop and follow through with key initiatives including additional confidence testing, detailed works planning and staging and independent peer reviews to ensure readiness to complete commissioning and hand back of the occupation on time.

5.1 Confidence Testing

Confidence testing is pre-testing of the interlockings to provide a degree of confidence that the design is fundamentally correct and will operate as expected in the field.

Where CBIs are used and the interface is only to other CBIs, it is possible to completely test the interlockings on a simulator, complete the principles testing and have 100% confidence that the interlocking will perform in the field. In these cases it is only necessary to function test and correspond the field equipment following installation, resulting in a quick commissioning.

When CBIs interface to existing relay based interlockings (including geographic interlockings) it is only possible to emulate the relay interlocking with a model in the simulator. This introduces the possibilities that the emulator may not correctly mimic the intended relay interlocking function or the interface between the CBI and relay interlocking.
In interfacing with legacy technology, this was seen as a significant risk, both due to the likelihood of encountering a problem and the time required to investigate the cause and to design and implement a solution.

To counter this, a multi-layered approach was developed (Figure 3) which included additional bespoke simulations of specific interfaces to provide confidence that the systems would work together.

**Figure 3 – Confidence testing methods**

Each of the confidence testing methods progressively tested the various components and then how they interfaced together. These methods started with business as usual activities with Method 1 and culminated in fully bespoke physical simulation in Method 3.

**5.1.1 Method 1 – Data testing**

Method 1 tested each system in isolation to ensure it behaved as expected and included the usual principles testing of the interlocking data for the Smartlock CBI and independent checking of the geographic interlocking.

**5.1.2 Method 2A – Interlocking to interlocking (data)**

Method 2A tested that the Smartlock interlocking and the emulated geographic interlocking together behaved as expected.

**5.1.3 Method 2B – Train control to interlocking (data)**

Method 2B introduced another layer to ensure that the interlockings correctly interfaced with both the telemetry systems (Sigmap and JZA); the existing train describer system; and the train control systems, which were being developed by the RRL Rail Systems work package.

This included simulating train control screens and commands and connecting the Alstom Smartlock interlocking being used for development and testing to the train control systems being developed at another site. This setup was also used for train controller training as described in Section 6.1.

**5.1.4 Method 3 – Interlocking data to circuits**

In order to test that the CBI connection to the geographic interlocking worked, a test rack was designed and constructed, which consisted of the interface circuits and geographic modules for part of the interfacing junction.

This was connected to the Smartlock interlocking and operated by the principles testing team. The test rack and mimic panel is shown in Figure 4.

**Figure 4 – Method 3 test rack**

The method 3 testing provided a great deal of confidence that the interface between the two technologies had been correctly designed and would be correctly implemented by the project team.

**5.1.5 Confidence testing results**

Methods 1, 2A and 2B are normal practice in testing and commissioning, however using the simulator for method 3 was an additional step taken to suit the critical nature of the interfaces. The construction of the overall system also allowed the simulator to be used to assist with training of the train controllers.

The net effect of this testing was the early identification and resolution of 48 train describer system issues which would have resulted in test logs being raised during final commissioning. These may have resulted in delays to the commissioning or post-commissioning fixes, potentially with operational restrictions.
5.2 Construction Methodology and Staging

An early strategic decision was the split of scope between occupations E45 and E48 to meet timings & create certainty of delivery.

This enabled the team to be able to plan the commissionings early and lock in the strategy to allow sequencing of works and occupations and determine where additional time was required outside train running hours for works or interfaces outside the occupation boundaries.

Significant expenditure on correlation in Southern Cross No2 Box and Franklin St geographic relay rooms equipped designers and constructors with the best possible information.

A focus on completing all the pre-works and not taking any works into the occupation that could have been reasonably completed beforehand enabled more confidence entering into the occupation.

An MTM Officer In Charge was arranged in geographic locations around the clock while works were underway.

5.3 Peer reviews

The peer reviews confirmed that construction works were as ready as could be but raised some concerns on the proposed work method for alterations to the geographic interlockings at No 2 Box and Franklin St.

6 OPERATIONAL READINESS

Following the lessons from the commissioning of South Kensington, there was a significant focus on ensuring the smooth operation of the new signalling system immediately following commissioning as any delays at Southern Cross would quickly spread throughout both the MTM and V/Line networks.

A completion and handover strategy was developed for the commissioning, which included planning for various contingencies of delays to the final commissioning, with a staged commissioning and handover of assets.

The team placed a significant focus on the impacts to the train control function for MTM and V/Line, including:

- Training of train controllers with a focus on what happens when a planned move needs to be changed or if a fault occurs
- Using simulation training on cross-boundary moves for operators as well as traditional PowerPoint methods
- Using validation trains to test that the actual system worked as anticipated by the simulator
- Mentoring of train controllers during operations immediately after the occupation until enough controllers were familiar with the system

Driver training was undertaken using different methods tailored to the requirements of each rail operator, including videos, walk throughs, driver training trains and the use of pilots.

Training for signal maintainers on the new equipment was developed, with a specific focus on how to resolve faults and reset moves with the train controllers.

Operational change briefings detailing operations before and after the occupations, including route availability, train describer system adjustments and control screen changes for occupation E45 and again for occupation E48.

6.1 Train Controller Training and Mentoring

A major issue identified following the South Kensington CBI split was the lack of understanding between the train controllers on both the MTM and V/Line sides of the new interface. They did not know how to respond to changes in the routes that had been established when the sequence changes or equipment errors prevented the proposed route being set.

![Figure 5 – Metrol northern group panel](image)

To counter this, a former senior train controller was engaged to assist MTM and V/Line in the development of training materials and remove some workload from the current MTM and V/Line train control trainers.

This training consisted of PowerPoint style classroom sessions (Figure 6), followed up by use of the simulator developed for confidence testing to allow hands-on training of the train controllers, allowing them to get the feel of how the system worked and allowing the trainers to observe and confirm a level of competence in the operation of the system.
The training covered the correct procedure for operating both sides of the interface with a particular focus on changing routes once they had been set and recovering from faults that may occur.

Following resumption of operations, mentoring of both V/Line and MTM train controllers with the trainers was planned for the first two weeks of operation, however the MTM roster meant that this did not give coverage to enough controllers to be rotated through the northern panel and this duration was extended.

The result of this effort was that the changeover to the new system was seamless with no delays attributed to train controller unfamiliarity with the system.

### 6.2 Operational Validation

Operational validation was conducted by the rail operators to provide an independent level of assurance that the cross-boundary (MTM to V/Line and vice versa) interfaces operated as intended and that the train controller training had been effective.

Two V/Line test trains were arranged for each shift in a combination of broad and standard gauge configurations and the set of required moves were established and documented, along with a proposed sequencing of the moves. A signoff sheet and test log & comment register were established.

A total of 52 sequences of operations were to be undertaken during the last days of the planned commissioning. These were to be undertaken after commissioning was complete and the occupations handed back but prior to resumption of revenue train services.

Progress reports were given at the daily phone hook-up between the project team and rail operators. The major issue was the delay in commissioning certain parts of the system which meant that the trains had to operate within the occupations in specific parts of the signalling system, under the authorisation of the Tester In Charge, under safe-working circulars issued to allow this to occur.

The outcome of the testing program was confirmation that the cross-boundary interfaces performed as designed and that the training of the train controllers was valid. An additional benefit was that 33% of the Metro train controllers were given experience in the live operation of the system before operating revenue services.

### 7 THE UNEXPECTED

In spite of all the planning and crystal ball gazing, several issues arose during the occupation.

Testing of the overall system involved principles testing that extended well into the existing interlockings and revealed significant non-compliances to modern signalling principles. These were raised in fault logs which were not immediately attended to and took time to resolve with the relevant authority within the rail operators.

Planning of the geographic changeovers was done on the basis of a documented methodology proposed to MTM. This allowed works to proceed in areas that were far enough away from the operational parts of the interlocking, to proceed with trains running, on the assumption this would be acceptable to MTM.

However, following the peer reviews, MTM only permitted some of the works to take place with no trains running. In Southern Cross No 2 Box it was only with the assistance of Metrol running trains around the potentially affected area after the PM peak that the works were able to be completed in the required time, albeit 24hrs behind the construction program. This was something that should have been picked up and addressed earlier.

The specific changeover methodology adopted in No 2 Box resulted in the inadvertent removal of jumper cables connecting two pins within the same plug coupler when the plug coupler connection was modified. When this error was discovered it caused a delay to the commissioning program as all plug couplers with jumper cables were checked to ensure that none were missing.

### 8 RESULTS

#### 8.1 Successes

Occupation E48 and the Southern Cross commissioning were considered to be an outstanding success.

The confidence testing program gave MTM and V/Line confidence that there were no integration issues between the design packages or between the new and old technologies and allowed early resolution of some 48 issues which would have become
test logs during commissioning either requiring resolution before or during the nights after commissioning.

The train controller training was considered very successful and provides a new model which can be applied for future major system changes.

The validation trains enabled 33% of the train controllers to use the new system to make cross-boundary moves.

8.2 Opportunities for Further Improvement

There are always opportunities for improvement and in this regard, the peer reviews of work methodology should have been completed earlier.

Principles testing of geographic interlocking control tables (in unchanged areas) should be conducted prior to the commissioning to validate the control tables, simplify testing at commissioning and allow for resolution of any issues. Guidance should be provided to the principles testers on what could be encountered and how to deal with them should be provided prior to commissioning.

Test logs need to be more closely monitored and managed. Management intervention should take place where the log is not closed out within a reasonable period following a response from the designer to allow quicker escalation of issues requiring ARO approval or resolution.

Validation methods (including pre-testing) should be examined to see where issues with train describer number propagation can be uncovered in advance of the works.

9 CONCLUSION

The initiatives developed for this commissioning were based on lessons learnt from other recent and similar commissionings. This clearly assisted in delivering a successful outcome at Southern Cross.

The focus on the cross-boundary interfaces and training of the train controllers saw the commissioning as an operational success.

All of the lessons used here can be applied in future commissionings, and the team also identified further opportunities for future improvement.

10 ACKNOWLEDGEMENTS

The planning and execution of the commissioning was a huge team effort. Special acknowledgements are given to:

Chris Gordon from the CMR team for defining the system interfaces and creating Figure 1 and for developing the detailed commissioning strategy.

Rob Vaughan, Dean Higginbotham, Calvin Li and Howard Twigg from MTM for development of the training and assistance in resolving the issues that arose during the commissioning.

The CMR signalling team led by Jeff Russell and the commissioning team led by Rod Johns.