



CHALLENGES OF IMPLEMENTING CBTC ON AN EXISTING RAILWAY

(SelTrac Comes to the London Underground)

Mark Halinaty,

Managing Director, Alcatel TAS UK

Firth Whitwam,

Director, Product Strategy, Alcatel TAS CIT

P.L. Chiu,

Business Development Manager, Alcatel Canada Inc, Transport Automation

SUMMARY

Communications-Based Train Control (CBTC) offers a variety of benefits over traditional signaling and is growing in popularity with Transit System Operators all over the world. SelTrac is a CBTC system with a proven heritage spanning more than 20 years in Automatic Train Operation (ATO) and driver-less applications, and was the choice of Tube Lines for its Jubilee and Northern Line Upgrade Programs on the London Underground. Applying this proven technology to the unique environment of the London Underground provides some interesting challenges. This paper looks at the background of the project and the innovative approaches to deal with putting SelTrac on the London Underground.

The fundamental challenge of a project such as this lies in implementing a new system on a heavily used railway without disrupting or degrading the daily service in any way. At the same time, there is a desire to achieve the operational benefits as soon as possible. The majority of the risk associated with such an ambitious project is avoided by the selection of a well proven in service system. The SelTrac system has been in service around the world for more than 20 years. The hardware platforms, software algorithms and implementation strategies are all well established. Two of the more relevant references are London's Docklands Light Railway and Hong Kong's West Rail, both of which have many similarities to the London Underground environment and operating procedures. The combination of the proven track record of the SelTrac system, good planning, staged system integration and testing approach will result in achieving the performance improvement on time with minimal disruption.

1. INTRODUCTION

Communication-Based Train Control (CBTC) offers a variety of benefits over conventional signalling systems and is growing in popularity with Transit System Operators all over the world. SelTrac^{®1} is a CBTC system with a proven heritage spanning more than 20 years and was the choice of Tube Lines Limited (TLL) as part of its Jubilee and Northern Line Upgrade Programs (JNUP) on the London Underground. Applying this proven technology to the unique environment of the London Underground provides some interesting challenges. This paper looks at the background of the project and the innovative approaches to deal with putting SelTrac on the London Underground.

1.1 The Project

Tube Lines Limited, as part of its mandate, has initiated a greater than one billion pounds sterling

Line Upgrade Programme to deliver Journey Time Capability improvements, incorporating:

- Improved Safety
- Enhanced Functionality and Reliability
- Major Performance Uplift

As part of the Line Upgrade Programme, the Train Systems Projects comprise three major project groups:

(1) Rolling Stock

- 59 New Cars for the 7 Car Train Upgrade Programme on the Jubilee Line trains
- 4 New 7 Car Trains for Jubilee Line
- New Trains for Piccadilly Line

(2) 7th Car Infrastructure

- Closed Circuit TV (CCTV) Alterations
- Platform Edge Doors Upgrade to handle 7 Car trains
- Signalling and Track Alterations

¹ SelTrac[®] is a Registered Trade-Mark of TAS Germany. Used with permission.

- Depots and Sidings
- Operations and Maintenance Facilities

(3) Signalling Upgrades

- Jubilee Line Upgrade
- Northern Line Upgrade
- Piccadilly Line Upgrade (optional)

The capability improvement goals for the Jubilee and Northern Lines are illustrated in Figures 1 and 2 (courtesy of TLL). In order to ensure that these goals are met and/or exceeded, Tube Lines Limited has selected Alcatel's proven SelTrac CBTC system for re-signalling the lines.

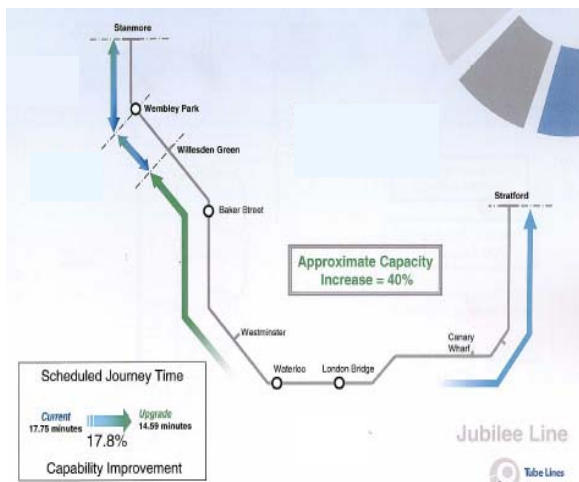


Figure 1

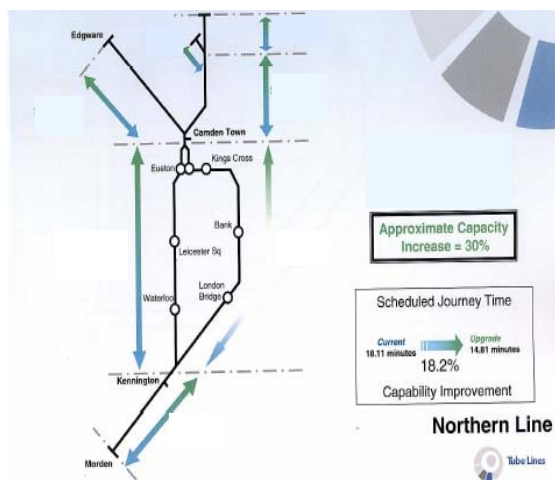


Figure 2

(Figures 1 & 2 courtesy of Tube Lines Limited)

2. THE SELTRAC SYSTEM

SelTrac is a Communication-Based Train Control (CBTC) system based on the moving block principle.

CBTC systems are characterised by the fact that the primary means of train detection is via the continuous communication between the on-board and wayside elements of the system rather than

the use of conventional track circuits. Train location is determined vitally by the on-board computer system and reported to the wayside system via a train-to-wayside communication channel. On the Jubilee and Northern Lines this will be an inductive loop system, however it may also be accomplished by a free space radio system. Independent train detection (e.g. axle counters) may be used for failure management strategies, depending on the individual operational characteristics of a particular application.

In SelTrac Moving Block system, the train separation is not associated with pre-determined fixed wayside track blocks, which are based on worst-case safe braking characteristics. Instead, safe train separation is determined by the precise location of the preceding train (or track obstacle) and the required stopping distance based on the current speed and train braking characteristics. Therefore, the separation between two trains expands and contracts based on the current conditions, allowing the system to maximise the operating performance.

These principles and the basic SelTrac architecture are illustrated in Figure 3 (at the end of the paper). The figure depicts the levels of control within the SelTrac system.

2.1 Management Level

The overall management of the automated train control system is co-ordinated by the System Management Centre (SMC). The SMC performs all of the Signalling Control and ATS functions but has no intrinsic responsibility for safety.

The SMC uses Alcatel's local area network (LAN)-based SELNET^{®2} system in conjunction with workstations to provide the following functions:

- Addition or deletion of trains to or from service;
- Assignment of routes for trains and requests for the appropriate switch settings in the field, according to pre-stored schedules or through operator input;
- Junction prioritisation through scheduling;
- Regulating trains in the system by adjusting train velocity and station dwell time;
- Regulating trains in the yard and selecting those destined for service or storage;
- Monitoring status of train performance and collection of other ATO data; and

² SELNET is a Registered Trade-Mark of Alcatel Canada Inc. Transport Automation.

- Data exchange with external systems such as Supervisory Control and Data Acquisition (SCADA) System and Passenger Information System (PIS).

2.2 Operation Level

Safe operation of the SelTrac Moving Block system is the responsibility of the Vehicle Control Centres (VCC). The VCCs ensure safe train separation throughout the system.

The VCC generates a command telegram containing a Target Point and the maximum permitted vehicle velocity, and other commands, based on the following real time information:

- Last reported train speed and position;
- Travel direction;
- Last verified position of the preceding train;
- Unlocked or unreserved switch ahead on the train's route;
- Speed restriction;
- Station stop; and
- Status of guideway devices (e.g. switch position).

2.3 Activation Level

The following components are responsible for implementing the commands from the Operations Level. The three subsystems at the Activation level are the Vehicle Onboard Controller (VOBC), inductive loops and the wayside Station Controller (STC).

The inductive loop (or radio) communication system provides the continuous two-way communication between the VCC and VOBCs.

All of the safety critical elements of the system employ proven checked redundancy principles, at various levels, to ensure the highest levels of safety. Key operational elements of the system are replicated in order to maximize system availability. The architecture of the system and characteristics of CBTC and Moving Block allow for graceful degradation and flexible failure management schemes.

2.4 The Challenges

The fundamental challenge of a project such as this lies in implementing a new system on a heavily used railway without disrupting or degrading the daily service in any way. At the same time, there is a desire to achieve the operational benefits as soon as possible.

Some of the specific risks can be summarized as follows:

- Small window for installation and

commissioning (engineering hours)

- Stringent London Underground standards and signalling principles co-existence with current systems and associated environment (e.g. Electromagnetic Compatibility (EMC) and Electromagnetic Interference (EMI))
- Mixed Mode Train Operation section on part of the Jubilee Line track (in this section track, the CBTC equipped trains and non-equipped travel at line speed under SelTrac control)
- Integration with train systems with respect to smooth control and performance optimisation
- Learning curve

3. MITIGATION STRATEGIES

The majority of the risk associated with such an ambitious project is avoided by the selection of a well proven in-service system. The SelTrac system has been in service around the world for more than 20 years. The hardware platforms, software algorithms and implementation strategies are all well established. Two of the more relevant references are the London's Docklands Light Railway and Hong Kong's West Rail, both of which have many similarities to the London Underground environment and operating procedures.

The use of a proven system means that it is not a development project and therefore the technology risk, as well as a lot of the programme risk, has been minimized. The likelihood of significant technical problems and teething pains are greatly reduced.

From this excellent starting point, further mitigation is achieved through the following steps:

- Planning
- Education and Early "Buy-In"
- Simulations
- Highgate Test Track
- Advance Demonstration
- Mainline Early Integration Testing
- Staged Cutover
- Shadow Running of Dual Fitted Areas

As with any large project, good planning is the key to success. In particular the installation and cutover strategies in this project are crucial. The planning of these elements was undertaken early on and is continually revisited to ensure new developments are captured. Risks are anticipated and tracked through a systematic risk register process. Again, the use of an established system with proven strategies allows for detailed planning early on with a high degree of confidence.

The SelTrac system, although well proven, is new to much of Tube Lines Limited and London Underground. It will certainly result in different operating and maintenance philosophies once fully in place, and will require cooperation of many entities during the implementation. Therefore, it is important to get the "buy-in" of all stakeholders as early as possible. This is achieved through an education process involving direct training, as well as thorough design reviews. Thorough understanding of the system avoids delays in design reviews and minimise the risk of unnecessary design changes caused by misunderstanding. This has been particularly useful in the detailed reviews of applicable standards and joint evaluation of signalling principles for the SelTrac Moving Block system.

The SelTrac product has an advanced set of simulation tools that are very useful in the early identification of issues and the proving of various operating strategies. Performance simulators demonstrate that the operational improvement (throughput) can be achieved and design decisions optimised long before equipment is installed on the track. Sub-system simulators provide a test bed for the proving of modifications while they are still relatively easy and inexpensive to modify. Additionally, they provide a realistic training facility to aid in the education process.

One of the most useful mitigation elements has been the establishment of a live prototype test track facility at Highgate. This has allowed us to verify the signalling and train system interfaces in order to optimise the ability to control a Jubilee Line train efficiently and smoothly. The test track has also provided a realistic environment to prove the train-to-wayside communication system, which is the backbone of a CBTC system. Interfaces with other subsystems has been evaluated and fine-tuned. This work allowed Alcatel and Tube Lines to carry out a comprehensive demonstration known as "Black Diamond", operating Jubilee Line trains in full automatic operation a mere one year into the program.

Next in the programme is the early Main Line Advance Demonstrations this year. These trackside trials will further prove the system in-situ as well as provide valuable installation risk reduction

The Dual Fitted Running Section on the Main Line will be implemented as the next step on both Jubilee Line and on Northern Line. This trial will be revenue operation that will further prove the wayside to train communication system, the on-board VOBC subsystem and will introduce the CBTC system Train Operators in revenue operation. This will provide first hand feedback for Train Operators and will be key in risk reduction for the VOBC function design and communication reliability under revenue operations.

As alluded to earlier, a staged implementation programme has been developed which installs the SelTrac system on the line one section at a time. This is done using installation procedures proved during the Main Line Trials and strategies for over and backing each night proven on previous projects. This over and backing process will allow the test team to return to the revenue service with minimum risks and in optimum time, which is key to maximising the test time during engineering hours. The use of the simulators and Highgate Test Facility, discussed earlier, also minimise the amount of testing that has to be carried out on the Main Line, again maximising the effectiveness of precious engineering hours.

As each section is implemented, it will be run in a shadow mode which will assist in train commissioning and driver training, as well as providing valuable data on system performance prior to full operation.

4. CONCLUSION

The combination of the proven track record of the SelTrac system, good planning, staged system integration and testing approach and, stakeholder cooperation will result in achieving the Jubilee and Northern Line Signalling Upgrade and performance improvement on time with minimal disruption to revenue operation.

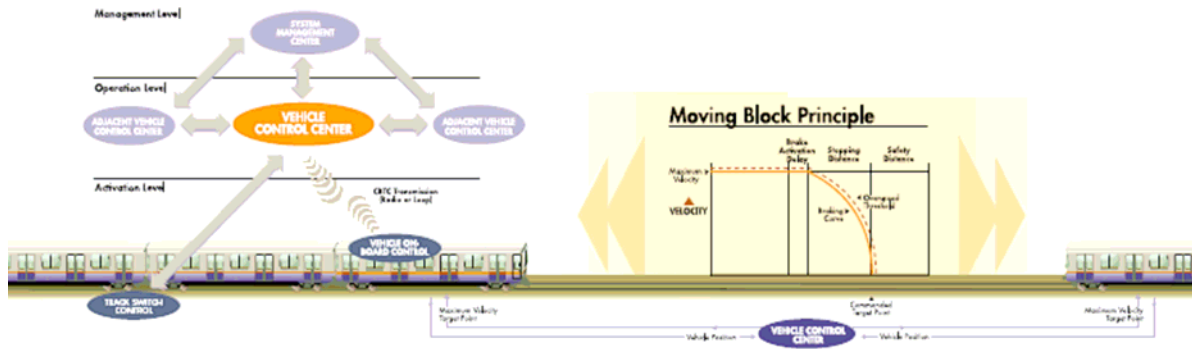


Figure 3