INNOVATIVE SYSTEM APPLICATION AND INTEGRATION ENGINEERING FOR ASIA – PACIFIC

Part 1: Innovative Systems Applications using Microlok II

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Part 2: Systems Integration using modern Computerised Technology

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SUMMARY OF PART 1

Current trends in railway signalling system design and delivery are dictated by market forces and the flexibility of the products and services that are available to support them. Cost minimisation, increased system adaptability and functionality, technical innovation and engineering accountability all impact on the final system outcome and the customer's satisfaction. In Part 1 of this paper, the major factors that lead to innovative system application engineering and their impact on final system outcomes are presented and discussed

Following this, the paper reviews a number of practical examples of such outcomes that have been implemented on main line railways in the Asia - Pacific region over recent times using Union Switch & Signal's Microlok II vital programmable controller. These examples represent a few of the unique circumstances cost effective and innovative system solutions have been delivered by the supplier. There are several other examples referenced in the paper that have been implemented by the customer alone. In these cases the customer has been totally responsible for the system innovation and application choosing simply to purchase product from the supplier.

SUMMARY OF PART 2

Part 2 of this paper presents how modern computerized technology can be used to integrate Signalling and Telecommunications technologies into a state of the art Central Supervision System and focuses on two examples deployed in Hong Kong Mass Transit Railway (MTR)

The first System presented is the MTR Operations Control Centre (OCC), commissioned in 1999/2000 which provides all Signalling, Train Radio and CCTV functions at the Operator's fingertips in a single integrated system: the Signalling Indications & Control Panel (SICP). With 8 servers and 51 operator workstations, the SICP is centralizing the information from the different Signalling interlockings of 4 running lines, the Regulation System and the Radio and Video systems, constituting a highly sophisticated and one of the world's most complex control centres.

The second part describes the Station Management System (SMS) installed in 37 MTR stations in 2001. In the same approach, the SMS regroups Signalling, Communication (Train and Telephone), CCTV & Station Management (Escalators, lifts operation, electricity controls, Gates, Platform Screen Doors, etc...) in one centralized system, with the information displayed on 4 screens to the Station Operator. Integrated with a Decision Support System (DSS), it eases the work and increases the efficiency of station staffs. The SMS has 25 subsystem interfaces and over 12,000 I/O points per stations.

Part 1: Innovative Systems Applications using Microlok II

1 INTRODUCTION TO PART 1

This paper addresses innovative system application engineering as practised in the Asia - Pacific region by Ansaldo Signal NV through its regional company, Union Switch & Signal Pty Ltd, (US&S) based in Australia. The thrust of the paper is towards conventional mainline railway applications and it commences by looking at the reasons influencing innovative application engineering. These can range from cost limitations, the customer's and supplier's technical capabilities through to the configurability and flexibility of the products used to build a signalling system. This reasoning is then supported by examining a number of working examples demonstrating how innovative applications, based on Microlok II, have been realised and how they can benefit both the customer and/or the supplier. Many more examples can be found in the reference material listed in Section 6.

Before concluding, the paper also touches briefly on some new opportunities for innovations that are in the pipeline.

2 ABBREVIATIONS

ATO	Automatic Train Operation
ATP	Automatic Train Protection
CPU	Central Processing Unit
ETCS	European Train Control System
ICSS	Integrated Control & Signalling System
I/O	Input / Output
PCB	Printed Circuit Board
PBI	Processor Based Interlocking
PI	Pilbara Iron (Rail Division)
RAM	Reliability, Availability, Maintainability
WA	Western Australia

3 FACTORS FOR INNOVATIVE APPLICATION ENGINEERING

There are five evident factors that influence, drive and enable innovative system application engineering to be achieved. These are:

- customer's cost constraints;
- customer's requirements;
- customer's and/or supplier's ingenuity;
- supplier's capability; and
- configurability of the system employed.

Although these factors are certainly not unique to the Asia – Pacific region, it is the manner in which they are combined that becomes significant in determining the need for and nature of innovation. Such innovation impacts heavily on the technical and commercial success of a supplier and satisfaction of the customer.

3.1 Customer's Cost Constraints

Technologically advanced signalling systems are predominantly manufactured in Europe, Japan and North America.

Typically, a system of European origin will be predominantly designed for direct application within a significant mainline railway or metro administration of the country of origin. This is achieved through a high level of technical cooperation between the administration and the manufacturer/s concerned.

Commercially, the European customer appears prepared to pay a premium and, in return, have its expectations met in terms of system safety, performance, quality, architecture, configurability, and interface compatibility etc. in the form of a "custom built" system.

The result is a system ideally suited for purpose but expensive and not easily or economically adaptable at the application level if installed and commissioned outside its country of origin.

On the other hand, mainline railway administrations in Asia – Pacific, have not historically had the scale of funds available to pursue this European Community model but still have expectations concerning their system availability and the application of modern technology to their railways.

Even with the progress towards unified standards in Europe, there is no certainty that this will deliver the lower cost products and systems that could satisfy the cost constraints of the Asia – Pacific market at this point in time.

3.2 Customer's Requirements

Innovative solutions are frequently triggered by a change in the customer's technical requirements. Typically, these requirements are influenced by the customer's experiences with a system's operational idiosyncrasies or shortcomings that become apparent over time. However, innovation is also influenced by the need to provide new or additional functionality within a system or the desire to implement technological advancements.

Consequently, when redrafting existing specifications or preparing new specifications, the customer, quite understandably, expands and enhances the requirements by focussing on specific issues. If no remedy has been considered previously, then this situation provides the ideal impetus to seek an innovative application solution.

Providing the customer clearly sates its requirements to the supplier then there is every opportunity to work through the possibilities for finding and implementing a suitable solution. (It is important to note that this process very rarely succeeds when third parties are involved unless the third party is committed to the process and also has an innovative mindset.)

3.3 Customer's and/or Supplier's Ingenuity

An essential attribute for any customer and supplier organisation is its ability to think "outside the box". This important attribute can only be realised when it is encouraged and accepted as a normal part of the organisation's business activities and processes. Adopting this approach enables new ideas based on customer's and/or supplier's inputs to be pooled, brainstormed and once agreed and accepted, drafted into system proposals, system requirements and design specifications.

Importantly, if following this approach, the supplier must be able and willing to provide all the extra support for the customer by ensuring that development documentation, requirements specifications, safety and test plans maintenance manuals etc. are available, and all necessary training needs concerning the innovation will be met.

3.4 Supplier's Capability

Innovative application engineering can only succeed if system suppliers fully understand all the technical and functional features of the base system. One of the issues that must be considered is the impact that innovative application engineering can have on the RAMS of the base system. The supplier must also be prepared to fully and openly discuss with the customer any limitations that could result from the innovation sought as part of the development process. Such a process may need a culture shift from past practices but can be achieved when there is close cooperation and commitment between the supplier and the customer.

The issue of customer confidence in the supplier's competence will be raised on many occasions. This confidence can only be built over a period of time and will almost certainly depend on the success of the systems previously delivered. Suppliers that consistently demonstrate adherence to process and meet the customer's expectations will usually be well received when it comes to innovation.

3.5 System Configurablity

Although the fundamental railway signalling principles that are applied to the plethora of railways operating in the Asia - Pacific region are very similar, the variety of customs and practices adopted for the application of these principles within the individual railway organisations is specific and diverse.

For an equipment supplier, this situation is highly problematical as every "off-the-shelf" system and/or item of equipment requires some degree of modification to suit a particular railway's technical or functional requirements.

Unable to readily market its French and Italian signalling systems primarily for the reasons discussed in Section 2.1, US&S relies entirely on its North America signalling system, Microlok II, to provide the basis for its application solutions.

The Microlok II system is market oriented as opposed to being customer oriented. Its broad market focus requires this product to be functionally adaptable and cost effective without compromising safety or performance. Such attributes make it an attractive proposition for application throughout the Asia – Pacific region.

Microlok II is able to offer its users high levels of configurability through:

- hardware options via a broad range of purpose built I/O PCBs and associated I/O modules;
- software options via flexible application programming capabilities;
- serial communications options ranging from pole lines to Ethernets; and importantly,
- full compatibility with its predecessor products.

Consequently, this system has lent itself to innovative application engineering by forming the basic building blocks for system outcomes that vary widely in size and complexity. It is this flexibility and cost effectiveness that has been responsible for the product's wide acceptance by mainline railways in Asia - Pacific.

4 EXAMPLES OF INNOVATIVE APPLICATION ENGINEERING

Innovation is by no means new to the application design engineers at US&S P/L and has been practised over many years. References [1] [2] [3] & [4] provide earlier examples of past innovation by the company. Although the product names Microlok and Microtrax (and the new product name i-Lok) are often used interchangeably, their lineage, intended purpose and relationship are discussed in [5]. More recent innovative applications of Microlok II are presented in following examples.

4.1 A Coded Track Circuit Application

Two interlocked areas belonging to WestNet Rail, are separated by two short parallel single line sections, one standard gauge and the other narrow gauge. The two single lines cross a bridge over the River Avon in WA and were originally controlled via a now abandoned open wire route.

Figure 1 : View of the Avon Bridge

As part of its upgrading strategy, WestNet Rail elected to renew the signalling system through interlocked areas while adopting the policy of minimising the line-side cabling [6] & [8].

With the upgraded aspect sequences and approach locking requirements the controls between the two interlockings were significantly increased. This in addition to the upgraded single line controls to be implemented. WestNet Rail identified the introduction of coded track circuits to the two single line sections as the optimum method by which to implement their cabling policy across the bridge.

The coded tracks can transmit and receive very low frequency bi-polar codes (waveforms) over several kilometres with a choice of up to 21 different codes.

Although significant experience had been built up by US&S in applying coded track circuits to single line sections and intermediate block signal controls, it became clear that further innovation would be required to implement the customer's requirement.

This innovation comprised the preparation of a track coding diagram that identified the minimum number of codes to carry the optimised number of the signalling functions. These combined functions controlled the single line route locking, approach locking and aspect controls in both directions between the two adjacent interlockings.

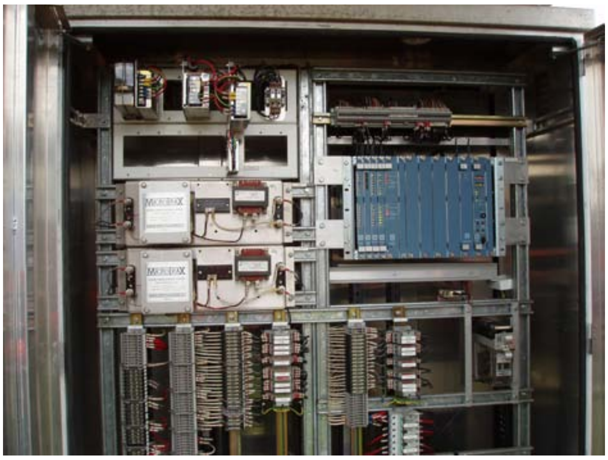


Figure 2 : Coded track circuit equipment located at the northern end of the single lines

The coding diagram formed part of the design specifications used by the design engineers to formulate the necessary logic equations and mappings between the equations and incoming and outgoing track codes at each end of the section.

4.2 A Cab-signal Application

In 1997 a new Integrated Control and Signalling System (ICSS) was commissioned for Hamersley Iron the north west of WA [4]. (This system is now operated by Pilbara Iron) The ICSS abandoned the use of conventional wayside signals and relies entirely on a cab-signalling system fully integrated with intermittent ATP. The ICSS field equipment was configured using Microtrax with a range of I/O boards to generate track codes, cab-signalling codes, conventional signal relay outputs and inputs etc.

Figure 3 : Arrangement of existing Microtrax equipment

However, with the introduction of Microlok II in 1999, [5] and Pilbara Iron's extensive expansion plans an opportunity arose to reassess and re-engineer the system configuration by replacing many of the original Microtrax cardfiles by Microlok II cardfiles thus providing significantly greater PCB slot capacity. This increased capacity has enabled additional cab-code generating PCBs to be fitted and the removal of all relays previously needed for switching the cab-code to the rails at a loop end via two shared cab-code interface panels. This is now achieved by using direct wiring from the PCBs to 3 fully utilised cab-code interface panels.

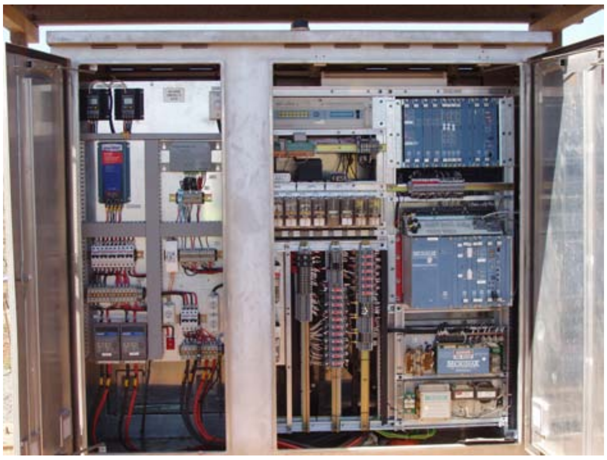


Figure 4 : Rearrangement of existing equipment to include a Microlok II cardfile

The benefits of this equipment change resulted in improved system performance due to the elimination of:

- moving parts;
- noise generating devices;
- switching breaks in the cab-code transmission to the rails; and
- short duration cab code reception times for locomotives passing over loop end points tracks.

A further innovation on new sections of duplicated track has been the by grouping all non-CPU controlled cab-coding PCBs into a single Microlok II cardfile. These PCBs are directly controlled from I/O PCBs located in a separate CPU controlled cardfile. This configuration has reduced hardware requirements through the elimination of:

- one CPU; and
- one serial data link between the two cardfiles.

4.3 A Logic Programming Tool Application

Presently all Microlok II data files are prepared by application design engineers and are based on a particular customer's signalling principles and practices. The design input information is primarily obtained from three sources:

1. the control tables (specifying the functional requirements for each interlocking);
2. the logic design specification (containing all the necessary logic structures that implement the customer's signalling principles); and
3. the system configuration plan.

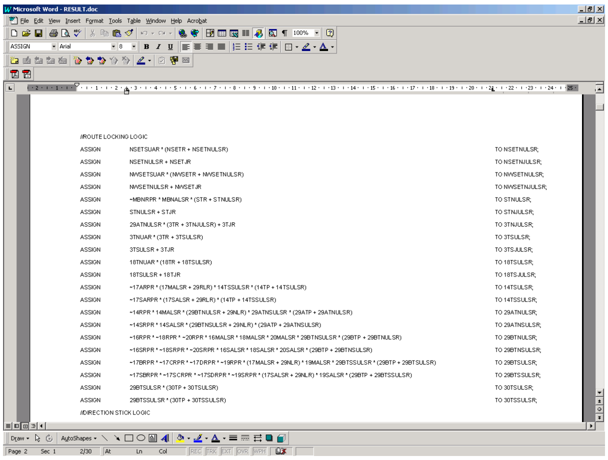
The design engineer uses these inputs to produce a data file for each interlocking controller or I/O controller. These files list the specific logic statements to achieve the desired functionality as defined in the control tables when applied to the principles defined in the logic design specification.

Figure 5 : Producing the data file automatically

Recently senior application engineers at US&S P/L have developed a software tool that generates the Microlok II data file directly from the design inputs. This is made possible because of the application engineers "freedom" to formulate the system logic contained in the data files to suit any customer's requirements. The purpose of the software tool is to very significantly reduce the design time of the project by:

- eliminating design errors;
- speeding-up the data file production; and
- reducing data file checking time.

The data design software tool produces a Microlok II data file for each controller by combining the control tables inputs with a data definition master (DDM) file containing all the logic structure for the customer concerned.



```
//ROUTE LOCKING LOGIC
ASSIGN   NSETSUAR * (NSETR + NSETNULSR)                                  TO NSETNULSR;
ASSIGN   NSETNULSR + NSETJR                                              TO NSETNJULSR;
ASSIGN   NWSETSUAR * (NWSETR + NWSETNULSR)                               TO NWSETNULSR;
ASSIGN   NWSETNULSR + NWSETJR                                            TO NWSETNJULSR;
ASSIGN   ~MBNRPR * MBNALSR * (STR + STNULSR)                             TO STNULSR;
ASSIGN   STNULSR + STJR                                                  TO STNJULSR;
ASSIGN   29ATNULSR * (3TR + 3TNJULSR) + 3TJR                             TO 3TNJULSR;
ASSIGN   3TNUAR * (3TR + 3TSULSR)                                        TO 3TSULSR;
ASSIGN   3TSULSR + 3TJR                                                  TO 3TSJULSR;
ASSIGN   18TNUAR * (18TR + 18TSULSR)                                     TO 18TSULSR;
ASSIGN   18TSULSR + 18TJR                                                TO 18TSJULSR;
ASSIGN   ~17ARPR * (17MALSR + 29RLR) * 14TSSULSR * (14TP + 14TSULSR)     TO 14TSULSR;
ASSIGN   ~17SARPR * (17SALSR + 29RLR) * (14TP + 14TSSULSR)               TO 14TSSULSR;
ASSIGN   ~14RPR * 14MALSR * (29BTNULSR + 29NLR) * 29ATNSULSR * (29ATP + 29ATNULSR)   TO 29ATNULSR;
ASSIGN   ~14SRPR * 14SALSR * (29BTNSULSR + 29NLR) * (29ATP + 29ATNSULSR)   TO 29ATNSULSR;
ASSIGN   ~16RPR * ~18RPR * ~20RPR * 16MALSR * 18MALSR * 20MALSR * 29BTNSULSR * (29BTP + 29BTNULSR)   TO 29BTNULSR;
ASSIGN   ~16SRPR * ~18SRPR * ~20SRPR * 16SALSR * 18SALSR * 20SALSR * (29BTP + 29BTNSULSR)   TO 29BTNSULSR;
ASSIGN   ~17BRPR * ~17CRPR * ~17DRPR * ~19RPR * (17MALSR + 29NLR) * 19MALSR * 29BTSSULSR * (29BTP + 29BTSULSR)   TO 29BTSULSR;
ASSIGN   ~17SBRPR * ~17SCRPR * ~17SDRPR * ~19SRPR * (17SALSR + 29NLR) * 19SALSR * (29BTP + 29BTSSULSR)   TO 29BTSSULSR;
ASSIGN   29BTSULSR * (30TP + 30TSULSR)                                   TO 30TSULSR;
ASSIGN   29BTSSULSR * (30TP + 30TSSULSR)                                 TO 30TSSULSR;
//DIRECTION STICK LOGIC
```

Figure 6 : Close-up of the Microlok II data file

Further planned developments will be the translation of signalling plan inputs directly into the software tool and gaining safety certification so removing the need for independent data file checking.

4.4 An Alternator Standby Plant Application

As part of the WestNet Rail PBI project, a Microlok II controller has been used to develop a control system for diesel alternator stand-by plants.

The alternator speed, temperature, oil pressure, circuit breaker sensing, local control switches and indications were all interfaced with the interlocking controller through an additional non-vital I/O PCB to provide a fully automatic alternator control system.

Figure 7 : Interlocking controller integrated with alternator standby plant

The mains power is monitored by the Microlok II controller and if failed for a period of 5 seconds initiates the alternator start-up. The alternator operation is fully "sensed" during the starting process and any failures detected. The alternator cannot be started if it is already sensed to be running or if the oil pressure is sensed to be normal (engine running). The system will only permit a set number of start cycles, each for a set period of time. The fuel supply is also controlled by the Microlok II.

Once the engine is sensed to be running at the correct speed over a specific duration, the electrical load is applied to the alternator. Full speed sensing takes place and should the engine speed, temperature or oil pressure be outside limits, then the electrical load will be removed and the engine stopped.

Under normal operating conditions, when the mains power has returned and proved reliable for 3 minutes, the load will be switched back to the mains supply and the engine stopped.

Figure 8 : Existing alternator standby plant rewired to operate from an interlocking controller

With the engine running normally, adjustments can be made to the load if required. This occurs if the points are swung and in this case a dummy load is turned-off and then reapplied when the points have been detected. This feature was extremely easy to implement with all signalling and alternator control written into the same Microlok II data file.

4.5 System Redundancy Applications

A recent major area of innovative system application engineering has seen the rearrangement of some Microlok II systems into warm-standby and active redundant architectures to meet different customer's requirements for availability. As the Microlok II product is not intrinsically designed for parallel operation this feature has to be implemented through the application logic design and development processes [7].

In order to achieve high system availability performance the system architecture has been structured so that the core interlocking functions of an area (e.g. a station or yard) are performed by a dedicated CPU PCB. This CPU is isolated from those associated with trackside I/O functions thereby ensuring that any system failure modes associated with I/O (object) controllers do not effect the performance of the interlocking controller.

Figure 9 : Active redundant Microlok II units in Malaysia

Once the system architecture has been finalised the hardware may be duplicated to achieve the required availability target. The functionality of the duplicated system (i.e. cold standby, warm standby or active redundant) will affect the system availability very little. However, it will reduce system reliability due to the increased hardware components and may increase the maintainability costs due to the complexity of the application logic should system alterations be required later on.

At this point it is worthwhile commenting on the need for precise RAMs specification from customer's organisations. Very few mainline railway organisations in Asia – Pacific state their RAM requirements in a sufficiently practical manner, often relying on vague generalisations such as "seem-less changeover" and "state-of-the-art". Such phrases are not helpful for quantitative engineering purposes and only precisely stated requirements can be addressed seriously.

If the customer is not prepared to state their requirements clearly then the supplier must take the initiative and stipulate the relevant specifications based on known industry standards and precedents and be prepared to justify these as appropriate and adequate for the customer's purposes.

Without establishing this RAM baseline, there may be no useful purpose in attempting to measure the performance of a system during its operational life.

Currently, active redundant Microlok II systems have been developed and designed and are operating in Australia, India and Malaysia.

5 FURTHER OPPORTUNITIES FOR INNOVATION

While this paper has focussed on innovation through the system application engineering of Microlok II, US&S is associated with other highly innovative concepts within the Asia – Pacific region, some examples being:

- Train protection and warning system (TPWS) proposed for the Northern & North Central Railway of Indian Railways based on ETCS Level 1. US&S will be responsible for developing, designing and installing the ETCS equipment that will be manufactured in India;
- Communications based advanced train management system (ATMS) for the Australian Rail Track Corporation based on North American positive train separation (PTS) concepts. This sees the entry of non-industry players into the local signalling technology market and may demand new ideas for addressing conventional practices. US&S is working closely with Lockheed Martin on this project; and
- Automatic train operation (ATO) for Pilbara Iron. This sees the high level concepts for the initial stages of a new ATO system being established and developed with the aim of overlaying ATO on ICSS. US&S will work in collaboration with PI to advance these concepts and ultimately deliver a working system.

It is expected that these concepts will stimulate the production of some very interesting papers at future conventions when the projects have materialised and come closer to fruition.

6 CONCLUSION

The nature of the market in the Asia – Pacific region is influenced by a number of key factors, the interaction of which can provide the opportunities needed to trigger innovative signalling system solutions. This market promotes the need for engineers to “think outside the box”. Suppliers that actively nurture this ability in-house, cooperate closely with their customers and offer a range of highly configurable quality products are able to survive and succeed in this dynamic market environment.

US&S has developed unique and interesting solutions for many specific applications on main line railways in Asia – Pacific as shown by the examples in the paper. The Company is continuing to develop and expand the uses of its product range and services while looking to take this knowledge and experience into the future for other new innovative opportunities.

7 REFERENCES

Several Australasian Section papers that may be of further interest to readers indicating the range of innovative applications of US&S products in Asia – Pacific are listed below.

[1] A Microlok Plus Configuration for the Antiene to Muswellbrook Resignalling – H Revell, July 1993

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[7] Botany Line Resignalling – W Allison, April 2002

[8] WestNet Rail Processor Based Interlocking Project – WA - L Costa & J Ursic, July 2003

[9] Resignalling the New South Wales (NSW) Country Network – M Lyons, November 2003

[10] Train Detection System Used on the Kuala Lumpur Monorail – Z Piper, July 2004

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Part 2: Systems Integration using modern Computerised Technology

1 INTRODUCTION TO PART 2

By providing a single point of entry to complex infrastructures, and cross-system functionality (like clicking on a train position on the line to call the Train Operator), such systems increase the efficiency and reactivity of Traffic Operators, simplify Operating procedures resulting in a smoother Railway Operation.

We will first review the context of the MTR system and the needs and requirements in terms of customized system integration, how we met these needs with the OCC and the SMS systems, their design principles and key features that could not be achieved without such integration. We will conclude with an analysis of the results we achieved, possible drawbacks and constraints of system integration and analyse the future trends in Centralized Control Systems.

2 NOTATION

AFC	Automatic Fare Collection System
ATC	Automatic Train Control
ATSS	Automatic Train Supervision System
CCR	Central Control Room
CCTV	Closed Circuit Television
CDP	Central Data Processor
CORBA	Common Object Request Broker Architecture
DSS	Decision Support System
DLTS	Direct Line Telephone System
FDDI	Fiber Distributed Data Interface
I/O	Input/Output
LC	Line Controller
MMI	Man Machine Interface (Operator Front end Graphical Interface)
MTR	MTR Corporation
OCC	Operations Control Centre
PC	Personal Computer
PIDS	Passenger Information Display System
PLC	Programmable Logic Controller
SCR	Station Control Room
SDP	Station Data Processor
SICP	Signalling Indication and Control Panel
SMS	Station Management System
SSI	Solid State Interlocking
TCP/IP	Transmission Control Protocol/ Internet Protocol
TMS	Train Mobile System (Train Radio Communication)
TSR	Train Service Regulator

3 HONG KONG MTR CONTEXT & HISTORY

Illustration 1: MTR Transportation System Map

With the opening of the Disneyland Resort Line in August 2005, the Hong Kong MTR network is composed of six lines and 52 stations interconnected by 14 interchange stations. The majority of these interchange stations allow passengers to switch trains by crossing to the adjacent platform. The MTR also operates a dedicated Airport Express Line. The MTR is characterized by its high density of passengers (more than 2.4 million passengers on a week day), its high train frequency (2 mins train interval in peak hour) and high train capacity (8 car trains, 2,500 passengers per train). In peak hours, up to 34-trains/hour can travel in each direction, which brings the capacity to 85,000 passengers/hour in each direction. This high passenger density requires a particular attention to crowd management in MTR approach, and each incident has to be handled and coordinated in the most effective manner.

This context means a series of particular needs to the MTR Traffic Operations which, while important to all Metro operators are more crucial here:

- Optimization of the train traffic: any delay in peak hour would have particularly serious consequences in terms of passengers density on platforms and in stations;
- Optimisation of passengers flow & passenger information in trains and stations; this also means a constant evolution on the station level: escalators, lifts, etc...

The Hong Kong MTR was opened in 1979 with one line and 9 stations and gradually expanded. The last major extension was the addition of the Tseung Kwan O Line (TKL) on the eastern part of the Kowloon Territory, which opened in August 2002. This gradual evolution over the years means heterogeneous technologies being used on different lines and on various portions of the same line:

- Signalling interfaces: SDP/CDP (Alstom), SSI (Alstom), ATSS (Siemens) handling;
- Various communication Systems: DLTS (Direct Line) / CCTV (Closed Circuit Television) / TMS (Train Radio) / PIDS (Passenger information), etc...
- Heterogeneous interfaces in stations: AFC / Elevators / Fire Systems / Lightning, etc...

The answer to the constraints of performance, reactivity and crowd management and the heterogeneous environment is software integration. The main idea is that traffic operators need to assess information from various sources and operate a number of different systems at once. This can be achieved with more efficiency and reactivity and minimizing the potential for human error if those system interfaces are unified in a common Man-Machine Interface.

We present in the following paragraphs how this has been done on the station level with our Station Management System and on the Operations Control Centre level with the SICP.

4 MTR OPERATIONS CONTROL CENTRE

4.1 History

With the opening of the first MTR line between Kwun Tong and Central in two phases in 1979 and 1980, a Central Control Room (CCR) was created in Kowloon Bay Depot, situated below the MTR headquarters. Line operations were based on a three-tier organisation:

- the Chief Controller is overseeing all lines;
- a Line Controller (LC) for each line is in charge of the decision making and handles Communication Systems: DLTS, CCTV, Telephone System;
- For each line, a Train Service Regulator (TSR) is executing the decision of the LC and monitors and controls the Signalling systems of the line via a hardwired panel.

Illustration 2: 1979 - KTL TSR Console view

In addition, two consoles were dedicated to Environmental and Power systems:

- Environmental System Controller
- Power System Controller

Illustration 3: 1985 - Kowloon Bay CCR

In 1995, MTR migrated the central control hierarchy from a three-tier to a two-tier organisation with the commissioning of a brand new Computerised Control System: the SICP provided by CSEE Transport.

Illustration 4: 1996 - Tsuen Wan Line Traffic Controller (left position)

The SICP brought more efficient operations and workload management:

- a Mimic Display panel would allow all actors to have a direct view of incidents, including train positions and CCTV camera feeds;
- Two Traffic Controllers share the control of a line, with modular authority assignment allowing better incident handling.

Simpler and more efficient user interface, with touchscreen technology allowed safer and more reactive user controls, alarms display, etc...

The SICP was phased in line by line starting in late 1995 and was completed in 1998.

4.2 Migration to OCC

In 2000, with the Kwun Tong Line, Tsuen Wan Line and Island Line in operation, the CCR in Kowloon Bay Depot was at its maximum capacity and could not accommodate extra lines. With the construction of the Hong Kong Airport Express and Tung Chung Line, a new control centre at Tsing Yi station was built and commissioned with sufficient capacity to incorporate all existing lines and futures extensions to be operated from a single location.

Following the commissioning of the OCC, the migration of the CCR to OCC from Kowloon Bay Depot would be done gradually on a line-by-line basis between 1999-2000. The migration would have to be done seamlessly and without interruption of traffic. Further discussion on the CCR Relocation is provided in #4.4.2.CCR Relocation from Kowloon Bay to Tsing Yi, and in Reference [2].

Simultaneous to the CCR relocation work, the integration of signalling and Telecommunication functions was on the way, with the inclusion of the TMS (Train Mobile System) and DLTS (Direct Line Telephone System) within the SICP.

4.3 System and Technologies

4.3.1 Interfaces & functions

The SICP integrates the following systems to present a unified interface to the Operators:

– Signalling Control: Point & route setting, Train hold, Fleet mode operation, Slotting function, TC Authority,
– Signalling monitoring in various locations: OCC, Backup Control room, Viewing Gallery conference room, selected Interchange Stations
– Fault handling
– Functions for ATC
– Possession Management and track access
– Communication functions: DLTS, CCTV, TMS
– Training functions
– Playback function: all events and user interactions can be retrieved and replayed by the control room operators for analysis and training purposes.

4.3.2 Hardware & Network architecture

The SICP architecture is Unix based (HP Tru64 Unix/Alpha workstations & Servers) and is composed of 8 Servers and 51 Operator workstations. The servers are working in pair, using a hot standby strategy, and are composed of:

– 2 Data Servers for data management: User modified System wide parameters, Data archiving and logging and playback function;
– 2 Line Servers for Signalling and alarms processing
– 2 Gateways link the ATR (Automatic Train Regulation System), the SICP and Signalling Interfaces. Since 2005, the ATS (Automatic Train Supervision System) has been integrated to the gateway servers. The gateways maintain basic central operation when the Line Servers are down for Maintenance during Non-Traffic hours;
– 1 Communication Server centralises CCTV, DLTS and TMS operations;
– 1 Training Server

Each Traffic controller is presented with three workstations:

– Signalling Control Screen, used to issue commands in the area of authority of the Traffic Controller: Points and route setting, fleet mode, etc. in manual mode, sequence operations and automatic mode;
– Signalling monitoring (Line Overview), which displays the train positions, Train Descriptors, routes set etc. on the four urban lines;
– Communications screen, which controls the CCTV, TMS and DLTS functions.

Servers and workstations are linked via a high speed Dual ring FDDI network and a watchdog Ethernet which ensures the automatic reconfiguration of the network in the event of equipment failures. The SICP hardware and network architecture is detailed in Appendix A.

4.3.3 SICP Software core

The SICP software is developed around Talarian SmartSockets middleware. SmartSockets is an inter-process messaging software that enables fast, reliable and secure communication across heterogeneous networks and platforms. The SICP uses a publish-subscribe communication model which is fault-tolerant and scalable. Each SmartSocket message is a formatted block of data with a logical address of destination (called subject). When another process subscribes to a subject, it can receive all the messages sent on this communication channel.

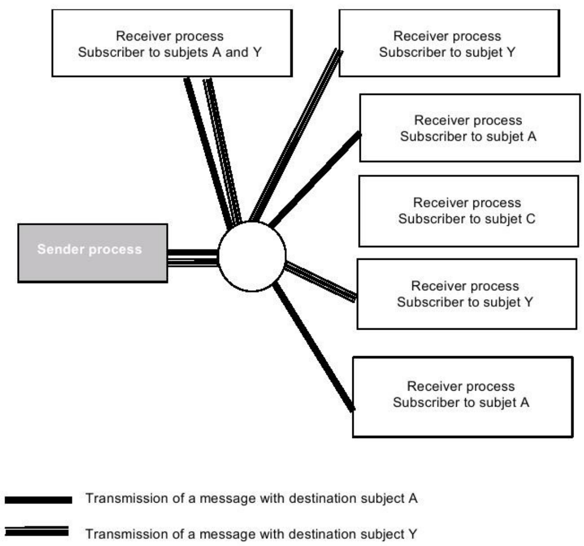

Illustration 5: SmartSockets Publish/Subscribe paradigm

Details of SICP External Interfaces are included in Appendix B.

4.4 Benefits and Special Integrated Functions

In this paragraph, we focus on key benefits provided by System Integration in the control centres such as the MTR OCC.

4.4.1 Train Mobile System

In order to optimize the work of operators, the Train radio system was integrated in the SICP in 1999-2000. The integration allows the following functionality:

– TMS Click and Call: A call to a train can be initiated simply by pressing the Train descriptor on the Line Overview MMI. Previously, the Operator had to visualize the train number and initiate the call on a separate workstation;

– Incoming calls appear on the Main Signalling screen;

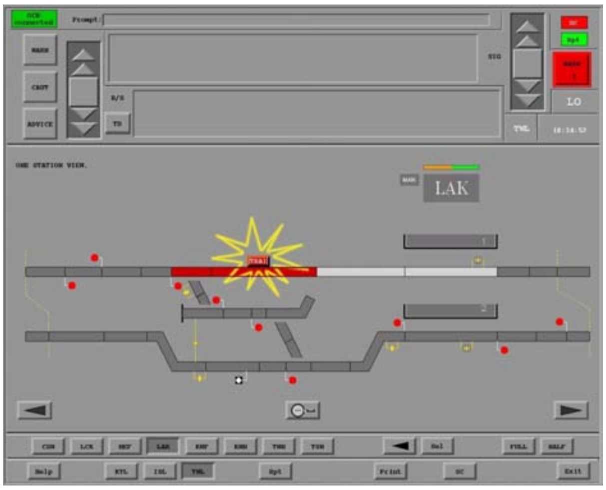

Illustration 6: Emergency TMS Incoming call (Line Overview Screen)

– Receiving a call can be done using the same methodology: press the Train descriptor of the train issung the call request.

The addition of this function to the SICP greatly enhances the Operator experience and lets him focus on his main tasks without distractions.

4.4.2 CCR Relocation

The Relocation of the MTR CCR from Kowloon Bay Depot (the old one) to Tsing Yi (the new one) in 2000 is a perfect example of how integrated computer systems are flexible and allow sophisticated functions that would not be possible without such integration.

The Relocation was done line by line in 4 phases, with a partial duplication of operating positions in Kowloon Bay Depot and Tsing Yi. The SICP was modified with a high level authority sharing mechanism between the old and new control centres allowing instantaneous function transfer between both centres, parallel operation (monitoring) and automatic fallback. This allowed a very smooth phasing in of the new Control Centre without any interruption of OCC operations.

4.4.3 Modern Control Centres

Illustration 7: Tsing Yi MTR Operations Control Centre

Illustration 8: SICP Console (view from ISL Traffic Controller position)

The MTR OCC illustrates the tremendous progress possible since the era of hardwired control panel, in terms of integration, ease of use and ergonomics The three SICP touchscreens available to the operator are:

– Signalling Control

– Signalling monitoring, integrated with Train Communication

– CCTV System: the operator is able to control every single station camera, zoom, rotate, etc from a centralised control point

5 HONG KONG STATION MANAGEMENT SYSTEM

5.1 MTR Station Control Rooms

Each MTR Station has a Station Control Room centralizing various equipment controls:

– Signalling (when in Local control mode[1]): Train Descriptors, Point operation and route setting, regulation;

1 Signalling Control can be set either to the SICP (Central Mode) or SMS (Local mode).

– Power: High and Low voltage, Traction power, auxiliaries;

– E&M equipment: Escalators, lift, security access, fire systems, etc...;

– Communications: Radio, CCTV, Public Address, Direct Line, Telephone, Passenger Information Display.

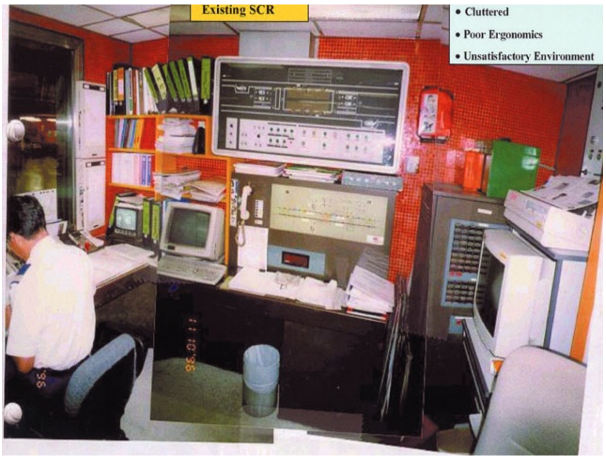

Illustration 9: Station Control Room (before refurbishment)

The abundance of systems in station lead to heterogeneous systems interfaces, cluttered Station Control rooms and poor environment. In 1998, the SMS contract was awarded to a consortium lead by CSEE Transport (with KML[2] and Logica[3]) that brought in a unified Computer interface in every station.

5.2 Requirements

The SMS Project was started in 1998 and progressed in parallel with the Station Control Rooms improvement and refurbishment works. Due to the limited space, Station Control Rooms had become cluttered over the years with heterogeneous system interfaces, and the basic requirement was to streamline all the various Control & Monitoring equipments into one single consistent Operator Interface: the SMS Software System. The SMS was to provide the operator with all station functionalities for Control and Monitoring: Signalling, CCTV, Fire detectors, lifts, escalators etc... totalling an average of 12,000 I/O points per stations through 64 discrete technical interfaces. The SMS was to be installed, commissioned and cut-in with no disruption or reduction in service quality, while it had to fit with 26 other project programmes interfaces all with different timelines, making it an overall very challenging project, technically and on an organizational level.

Ilustration 10: Station Control Room before the SMS upgrade

Illustration 11: Station Control Room after refurbishment and the SMS upgrade

5.3 SMS Technology

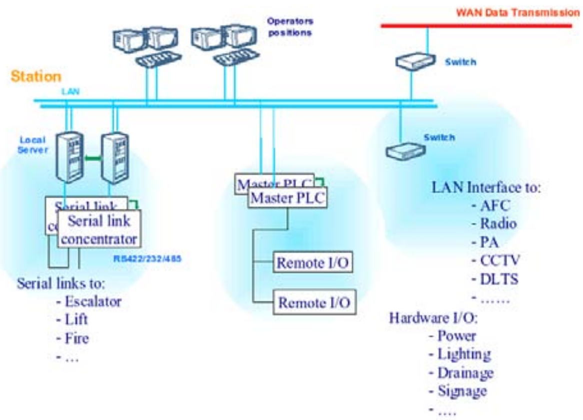

Illustration 12: SMS System Overview

5.3.1 Hardware architecture

The SMS is using a PC/Windows NT architecture for Servers and workstations. It is composed of 2 redundant servers in hot/standby configuration and 2 workstations with 4 display units with touchscreen functionality centralizing information and controls. Interfaces with external systems are done via 2 redundant serial concentrators, two redundant PLCs for digital and analog I/Os and two redundant network switches for TCP/IP interfaces.

Servers and workstations are connected to the network via dual Ethernet attachment, ensuring a full redundancy and no single point of failure throughout the system.

2 KML Engineering Limited: www.kml.com.hk

3 Logica: www.logicacmg.com

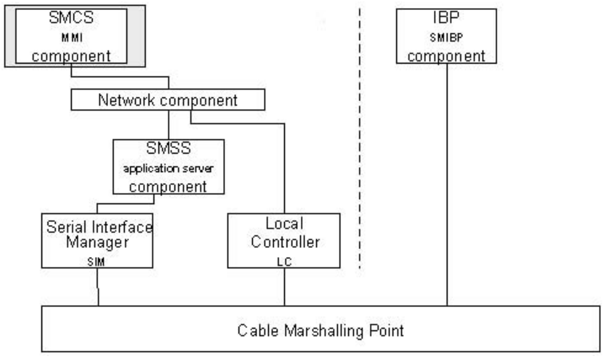

Illustration 13: SMS Overall hardware architecture

The detailed SMS hardware architecture and network interconnections is presented in Appendix C.

5.3.2 Software architecture

The SMS software is based on a fully object oriented core based on CORBA (Common Object Request Broker Architecture). The main motive for using a CORBA design is the heterogeneity of the systems to which the SMS interfaces, linked to the different history of each station. Few years span may separate stations on the same line, or even different iterations of the same equipment type within the same station: escalator logics, lights controls always differ, AFC gate signage vary from one another, or two different protocols may be used on the same type of interface.

The Object Oriented model of the SMS Software is presented in Appendix D

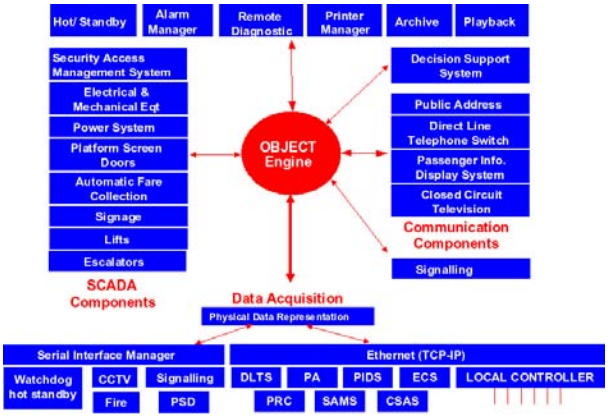

Illustration 14: SMS Software Architecture

The SMS software is based on ILOG[4] Object architecture, with servers running ILOG object broker (ILOG Server) and the workstations MMI being based on ILOG Views (fully object oriented MMI). The hot/standby functionality is based on the objects states replication between the object brokers running on the Master and Slave Server.

5.4 Benefits and Special Integrated Functions

The main benefit of an Integrated system is a unified operator interface to all station subsystems:

– Provide an improved and uniform ergonomic operating position and human interface to the various control systems within the station control room (SCR)

– Improve incidents and emergencies handling by providing integrated alarms monitoring and filtering functionality

– Integrating the monitoring and control functions within the SCR, thus overcoming the wide diversity of man-machine interfaces within the SCR and among various stations.

This mainly enhances operators efficiency and let them focus on the appropriate responses in incidents and emergency situations. It also allows an easier switch of operators from one station to another.

In addition, integration makes possible new functionalities, as for the two examples below.

5.4.1 Integrated 3D alarms display

Illustration 15: SMS Integrated 3D alarm view

This view of the SMS system is the perfect example of successful integration: the operator is presented with a list of equipment alarms, their criticality and their precise locations on a 3D map of the station. A click on the 3D point shifts to a 2D view of the object for which the alarm was raised. Its status can then be analysed more precisely by a simple click on the object representation, and corrective action be undertaken.

The benefits of such integrated views are obvious.

5.4.2 SMS Decision Support System (DSS)

Another key feature of the SMS system is its Integrated Decision Support System. In case of an incident or an emergency (typically train on fire, etc..), the operator is presented with an interactive checklist and appropriate contextual menus, thus allowing the quickest and best possible operator responses to such circumstances.

4 ILOG Software company provides the middleware components on which the SMS architecture is based: http://www.ilog.com

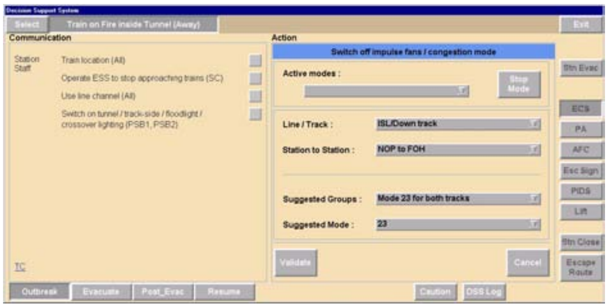

Illustration 16: SMS Decision Support view

6 CONCLUSION & FUTURE DEVELOPMENTS

6.1 Achievements

The Signalling Indication & Control Panel and the Station Management System Softwares are high performance Integrated Systems. We have seen how they meet the particular needs of the MTR Corporation: more efficient Railway Operation and response to incidents and Emergency situations in the context of a very high passenger density. Interestingly, Integration also creates a dynamic by itself, as new functions can emerge that were not intended or designed in the first place but are made possible by those Systems, like the CCR Relocation mechanism. So, is greater and greater integration the response to all Railway Operator needs?

6.2 Limits of Systems integration

Software Integration has limits. First, these systems are “custom made” and are relatively costly and difficult to finetune due to their high number of interfaces. Some interfaces are poorly documented and necessitate some reverse engineering at the lowest level, as it was the case for the TMS integration to the SICP.

They require a high technicality and design skills from us, but also from the client Engineering team to coordinate & liaise between different contractors interfaces. They also have to cope with some resistance from end-users, who are often reluctant to change their operating habits, and who have to be involved in the projects from the very early stage to the completion of the project.

A particular attention must be paid to the MMI definition and ergonomics: it would not make sense to replace a room cluttered with various equipments by a software interface unclear and cluttered with buttons and functions that would not be easier to use!

6.3 Future trends

Integration is not an end in itself. It has been the trend for several years, but in an environment of tight cost control, simpler and well-designed systems may also meet operators needs at a cheaper cost.

In the case of the SMS and SICP systems, integration has been very successful and was a way to give a modern front-end to heterogenous and often technically out-dated subsystems thus improving operations, but as these subsystems are gradually modernized and replaced, less integration may be sought, except for cases were the value added is obviously perceptible (like TMS or DSS functions).

7 REFERENCES

[1] Frederic Bernaudin, SMS Project Manager, SMS System Presentation

[2] John Chau & David Carden, IRSE Paper: Operations Control Centre Development

[3] Wikipedia articles, MTR Metro System and MTR Corporation Ltd: http://en.wikipedia.org/wiki/MTR and http://en.wikipedia.org/wiki/MTR_Corporation_Limited

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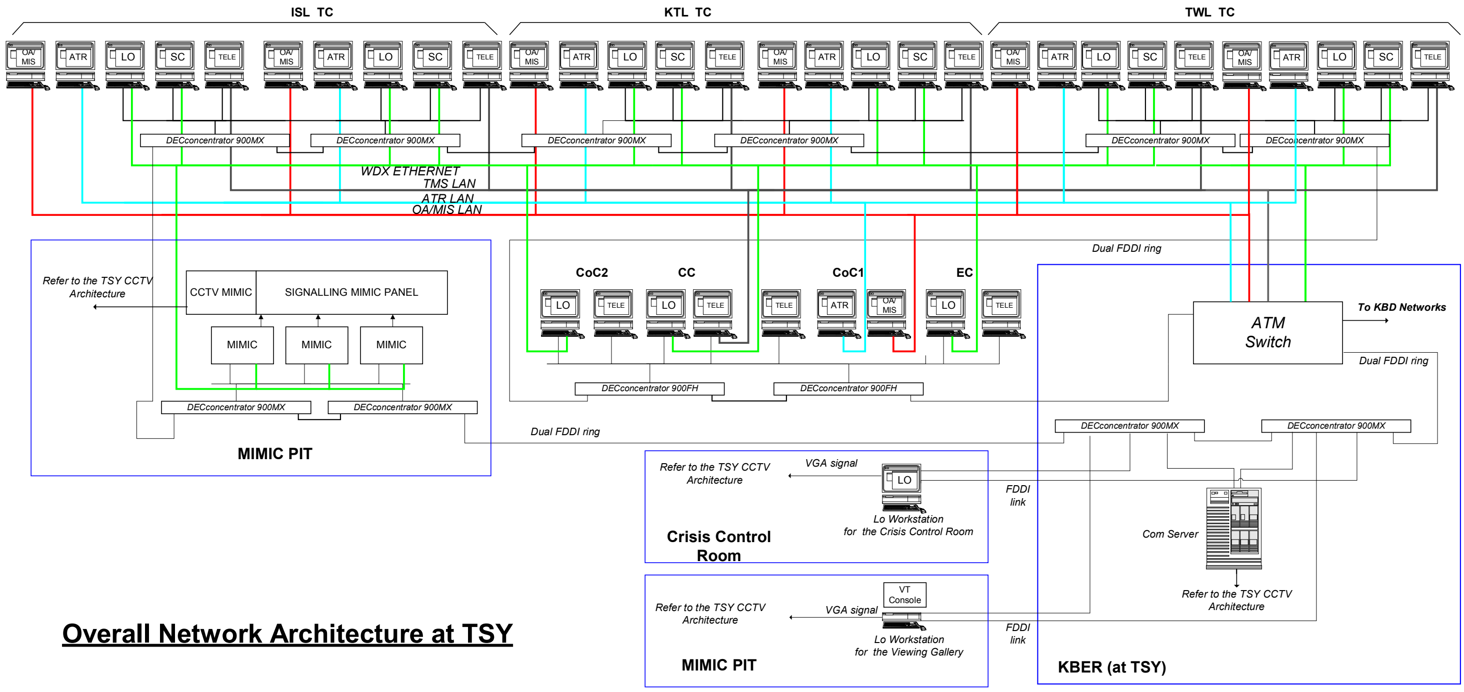
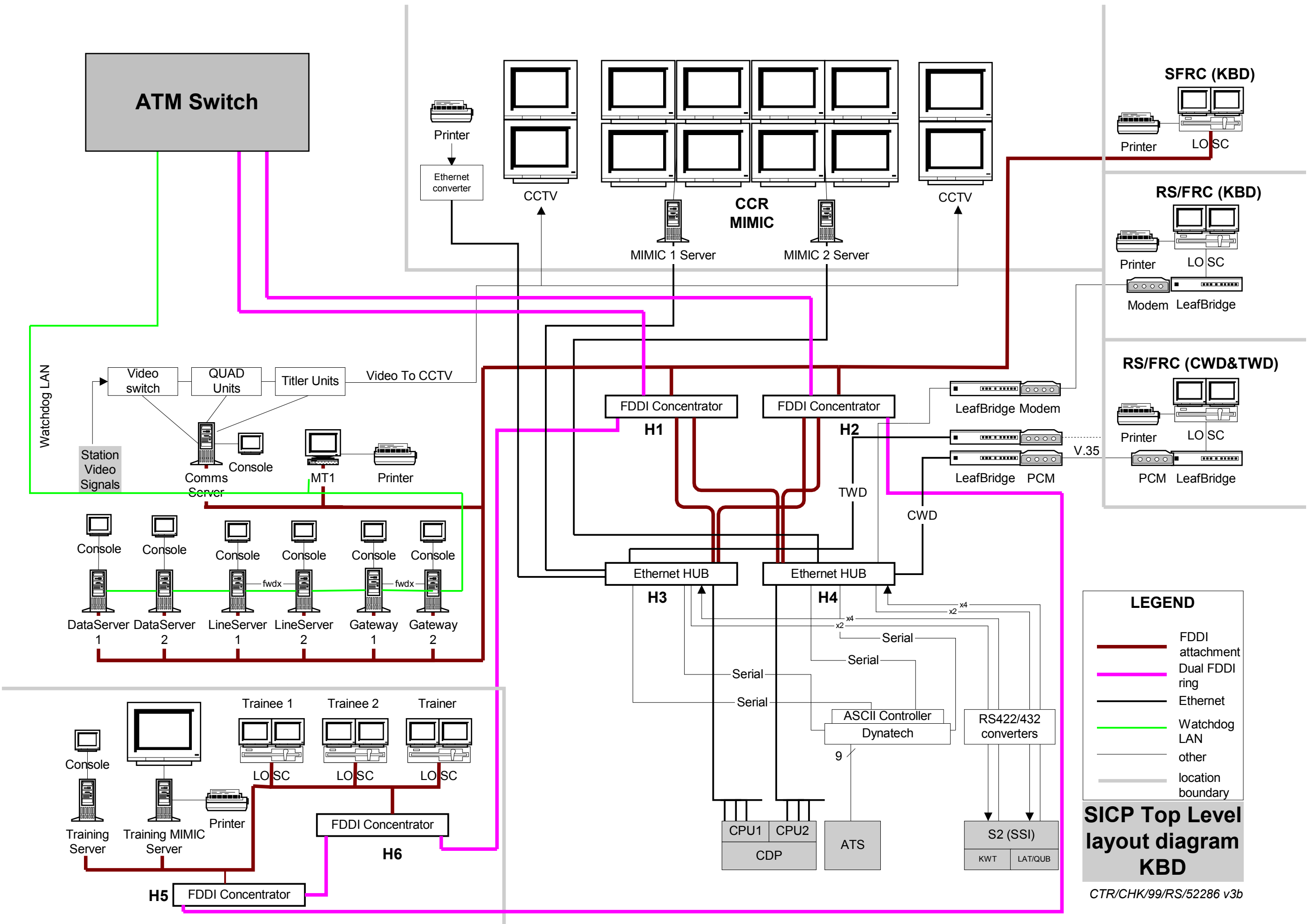
This paper has been prepared by CSEE Transport and does not necessarily reflect the views or perception of MTR Corporation Limited.

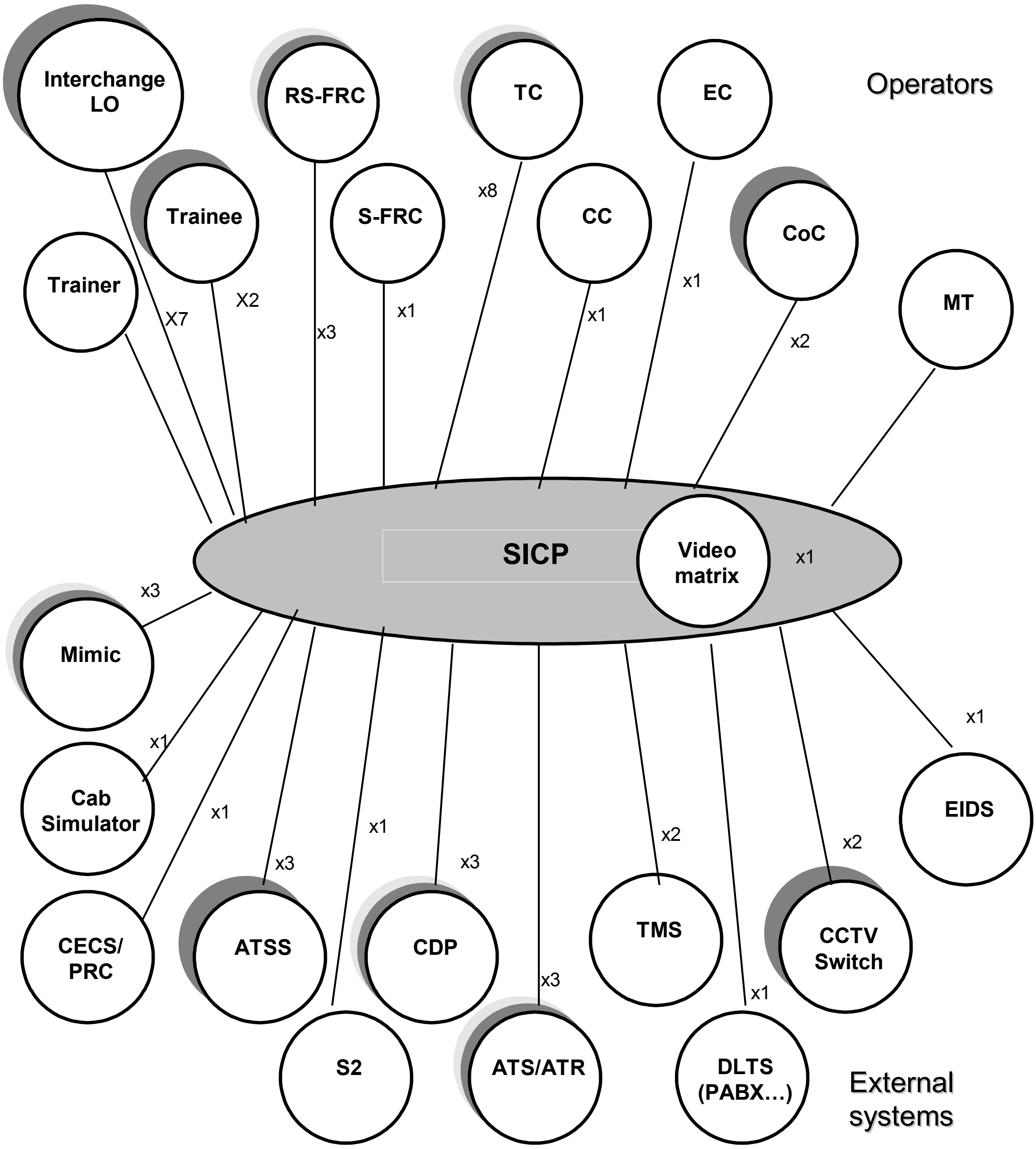
Appendix A: SICP Hardware and Network architecture



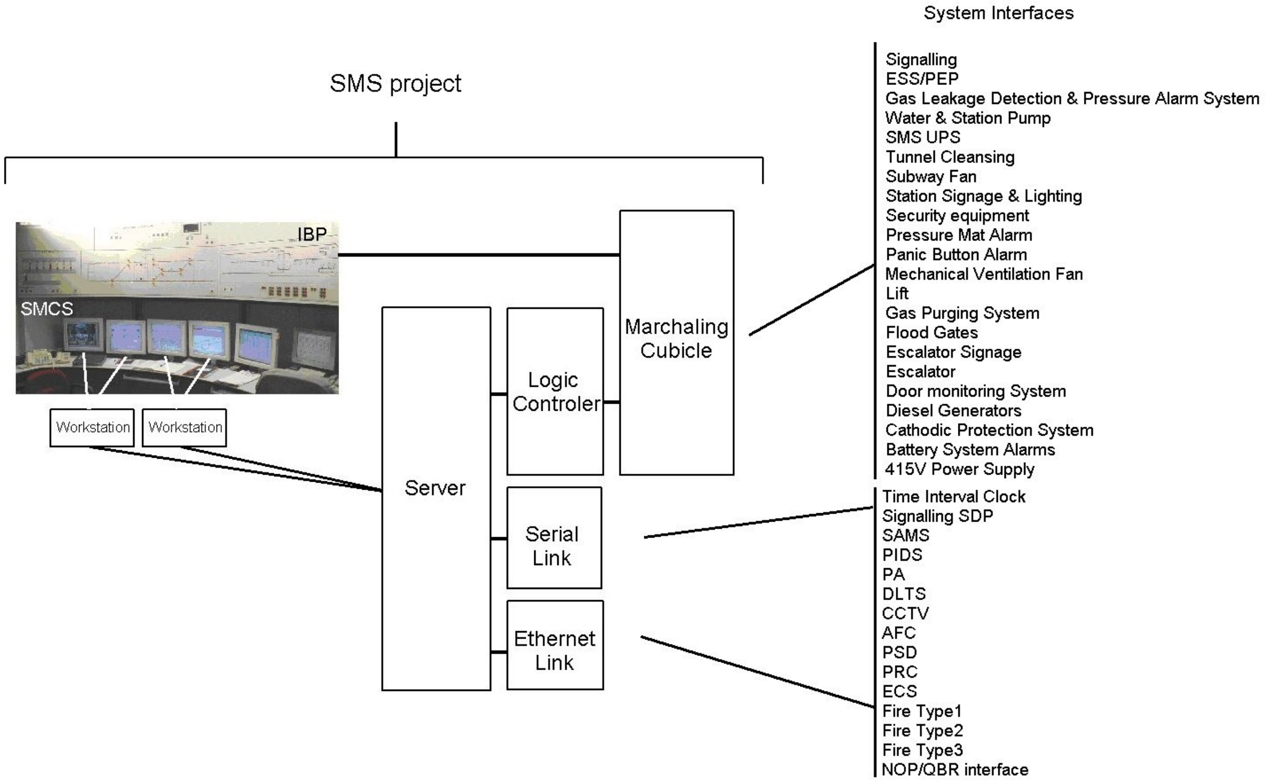
Overall Network Architecture at TSY

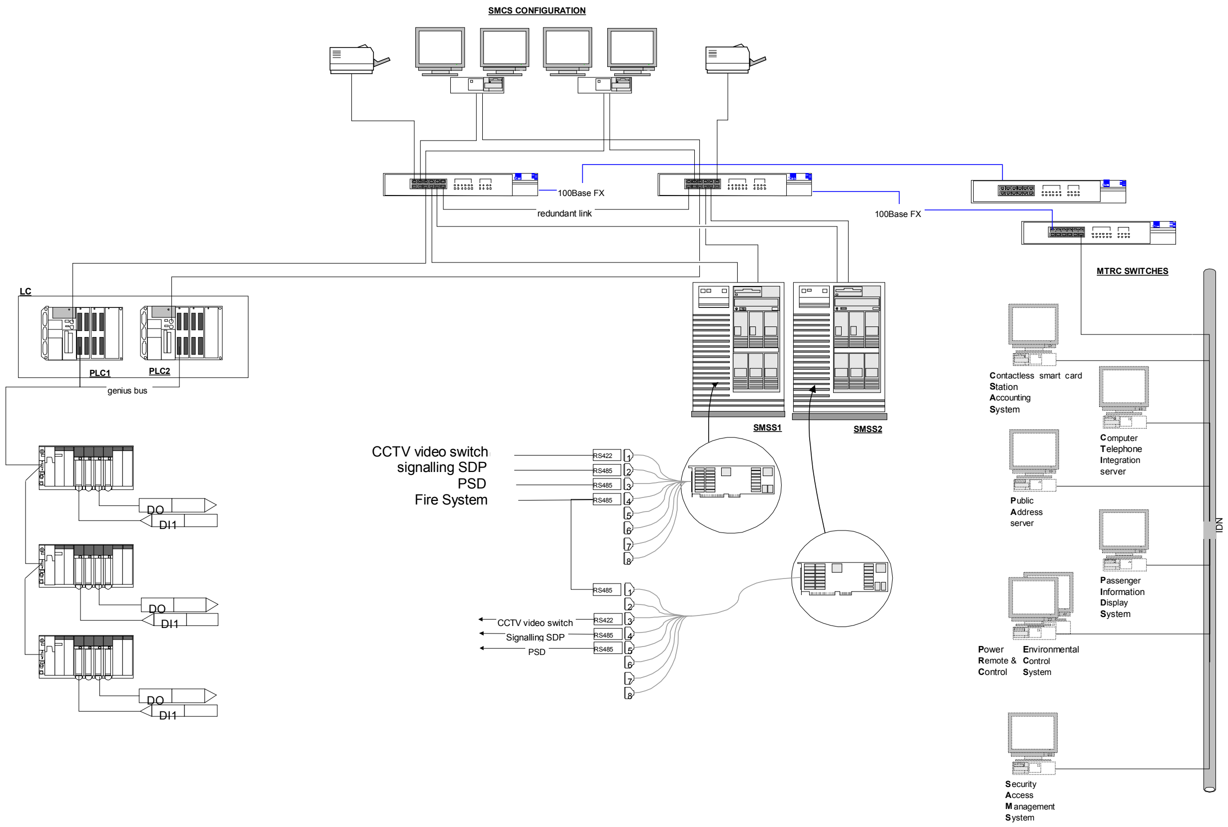


Appendix B: SICP Operators and External Interfaces



Appendix C: SMS Detailed Hardware Architecture





Appendix D: SMS Software Object Oriented Model