LONDON UNDERGROUND SIGNALLING
A HISTORY
by Piers Connor
39. THE CENTRAL LINE PROJECT

A NEW APPROACH

Last month, we looked at the Central Line ATC[1] system devised and installed by Westinghouse Rail Systems (now absorbed into the Siemens empire), which they developed from the original Victoria Line system of the 1960s, via further developments in Singapore and Madrid. This was the first major signalling and train control installation project contracted by the Underground as a package and the first to be based on a whole line approach. It was a bold step and, in some respects, it could be said to have been a step too bold at the time. The Underground wasn't ready for it and it showed very early on that everyone was in for a difficult time.

Figure 1: A 1992 Tube Stock train about to depart from the EB platform at Leytonstone, the starting signal showing the 3-aspect signals used to provide proceed indications for both manually driven and automatic trains, like those on the Victoria Line. The Central Line upgrade project of 1990-2005 included the 1992 Tube Stock and new ATC signalling installed by Westinghouse. Note the new style of route indicator introduced on this line with an illuminated arrow indicating each direction rather than three while lights being shown only for diverging routes. The arrow seen here indicates the route straight ahead. Unlike the older route lights, these new indications were not required to be proved. Photo: Phil Wimbush.

London Underground originally assumed that the Central Line ATC system would be designed as a development of the system installed by Westinghouse in Singapore. Westinghouse would design and deliver the system components while the Underground's signalling department would do the installation. However, when it was decided in 1989 to go for a competitively tendered procurement process, the whole balance of the project shifted[2]. The spec had to be rewritten to allow other signalling companies to bid. Apparently only Westinghouse and Alcatel (offering SelTrac) did bid and, in the end, Westinghouse got the job anyway. However, apart from the usual supply of equipment, the tender included design and installation as well, things the Underground had not outsourced before[3]. This change in approach did not go down well with the Chief Signal Engineer's department, since they had always done their own design and installation. As they had to liaise closely with Westinghouse in order to get the work done to their own exacting standards and they had to provide facilities and advice on the site conditions, there was inevitably some friction. There were other issues too, largely to do with organisation.

REORGANISATION

Following the King's Cross fire of 1987, London Underground underwent a reorganisation in both its approach to safety and in its engineering organisations. A new Managing Director, Denis (now Lord) Tunnicliffe, who was from the airline industry and had no railway experience, and a new Engineering Director, the late Brian Mellitt, a former academic, were brought in to develop this. They set up a

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1 I am going to call it ATC (Automatic Train Control) from now on because ATC is the combination of ATO (the operation of the train) and ATP (the safety bits).

2 The competitive procurement process was, by this time, a requirement of the EU. Although many EU countries didn't always bother to follow the rule, Britain decided it had to.

3 They did the same for the rolling stock and it too did not go well. The contract went to ABB, who had taken over the old British Rail Engineering Ltd. site at Derby. The design was horrible and the construction was poor. The fleet is currently undergoing a complete refurbishment so it can limp on for another 10-15 years.

separate project management organisation which was supposed to manage the projects. Projects were to be technically specified by a 'professional services' engineering organisation within the Underground. The internal 'client' was to be the development directorate, what we would today call 'the sponsor', who were supposed to define the scope and develop a business case. At first, very little focus was directed towards the Operating Department.

The new arrangements were foisted upon the unsuspecting management and engineering organisations, who suddenly found themselves without departmental heads within their own expertise. Part of this re-organisation was enshrined in a 'Company Plan' that was a thinly disguised staff shedding exercise. It generated a 20% reduction in staff within three years and 100% demoralisation of those who were left. It also caused an acute shortage of expertise, as many long-serving people took generous 'voluntary severance' opportunities, left and went to work for consultants. The Underground then had to go to these consultants to get the expertise they'd recently paid to give away.

In parallel with all this, because of the fallout from the King's Cross fire, everyone was running around looking for anything they could find that looked unsafe, whether it was or not. It was a huge distraction. Whilst there is no doubt change was needed, it was being done by a leadership with no railway experience and at a time when they were starting a huge line conversion project and, at the same time, looking to eliminate everything unsafe on the Underground. Of course there was trouble.

CONVERSION PLAN

The Central Line project was tackled as a whole line project covering the new ATC system, the introduction of 85 new trains (the 1992 Tube Stock), a new central control centre, new communications, improvements to depot facilities, some new track and new power supplies. The cost in 1992 was expected to be £717 million, over £2.1 billion in today's money. The ATC system had to cover 49 stations and 19 interlockings over 73 kms of route[4]. To manage the project, London Underground employed a huge project team of around 200 people, mostly body-shopped from the above mentioned consulting companies[5].

The consultant project manager chosen for the project was a civil engineer by training and experience and had little understanding of the complexities of a signalling project of the scale required and he was, at times, critical of the insistence on the safety and integrity requirements of the Underground's signal engineers and their perceived lack of understanding of the system integration requirements. He was also openly critical of the Underground's safety culture. He suggested that signal engineers were unaware of their total effect on system performance, assuring safety in signalling equipment by increasing complexity to the detriment of reliability, hence actually producing a loss of system safety. He instanced trap points, which obviously have a measurable effect on reliability, when examination of other features of the whole system, such as safe systems on trains, could make them unnecessary[6]. In his apparent lack of railway experience, he had obviously not considered a loose vehicle running away.

WESTRACE

The original intention had been to install relay interlockings at all the local sites along the line, with control being based on a new control centre to be built at Wood Lane. However, very early on, the project team began reviewing the original requirements. Changes were made to take advantage of new techniques and technologies. Some of these we have seen in earlier articles in this series like fibre optic shunt signals and electro-hydraulic point drives, but one of the biggest was the decision to change, mid-project, from relay interlockings to a solid state interlocking known as Westrace.

The name Westrace came from the title 'Westinghouse Train Radio and Advanced Control Equipment', first developed under the group who then owned Westinghouse, Hawker Siddeley. The work was shared by companies in Britain, Spain and Australia. Westrace was originally developed for use on small locations like plain line station areas but further development had persuaded people that it was going to be suitable for even the large area interlockings on the Central Line like White City. A substantial benefit of Westrace was its ability to monitor equipment condition from a central point and to

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4 Rodgers, S (2002), '*Central Line Automatic Train Operation*', Signal & Electrical Engineers' Technical Society, London 5 March 2002.

5 T. Humphrey, C. Brown, J. Crisp, K. Dodsworth, 'Central Line Resignalling', Proc. Inst. Railway Signal Engineers, 1994-95, Pp.39-48.

6 Discussion, Humphrey et al, ibid. The friction within the project participants was evident from several comments made in the discussion after this paper. Your author was thrown into the middle of this as the 'client' for the project for a while.

self-diagnose faults. The mid-project change meant that, of the 49 station and junction areas on the Central Line, the first 25 had relay-based equipment and the rest, all those from Liverpool Street eastwards, had Westrace interlockings. It was later decided to install Westrace in place of some of the relay interlockings already installed and this started at West Ruislip in 1998.

PROGRESS

Not surprisingly, installing a new ATC system on a working railway proved very challenging. New FS2500 coded track circuits were to replace all existing track circuits and new lineside signals were to be provided plus new interlockings and a new control system. As the new 1992 Tube Stock trains had chopper-controlled invertors capable of causing interference with the existing signalling circuits in some areas, new circuits, immune to these issues, had to be installed before the new trains could run[7]. The first 1992 Stock train entered service on 7 April 1993.

The plan for the signalling replacement programme was to start at West Ruislip and work east, doing each interlocking in turn. At West Ruislip, an additional project to renew the track and pointwork was included on top of the resignalling. This was not a wise decision. Although such an approach was not uncommon on the railways, this was the first time anyone had tried to put in new signalling with a contracted workforce not familiar with the work nor with the railway. Initially, the project team asked for a 5-week long possession to carry out the work. Most of us expected something like a long weekend would be sufficient so this came as a bit of a shock. I recall suggesting at the meeting when this bombshell was dropped that the press would have a field day if we announced that we were closing the two-track terminus at West Ruislip for over a month for resignalling when British Rail resignalled much of their large terminus at Liverpool Street in a 4-day weekend. After some lengthy negotiations, we persuaded them to accept (reluctantly) a 9-day closure from 24 August 1991. Little did we know.

The work soon ran into serious problems. Although we knew it would be difficult, none of us had realised just how difficult it would be to convert a manually operated railway to an automatic one, installing new signalling equipment and keeping the manual operation in use during conversion. It was worse than we imagined. West Ruislip was a nightmare. Apart from the installation difficulties, the worst problems were when wrong side failures appeared during initial commissioning work, resulting in the operators refusing to accept the system. This resulted in the work at West Ruislip turning from a 9-day possession into a 3-month horror show that wasn't finally completed until 10 December 1991.

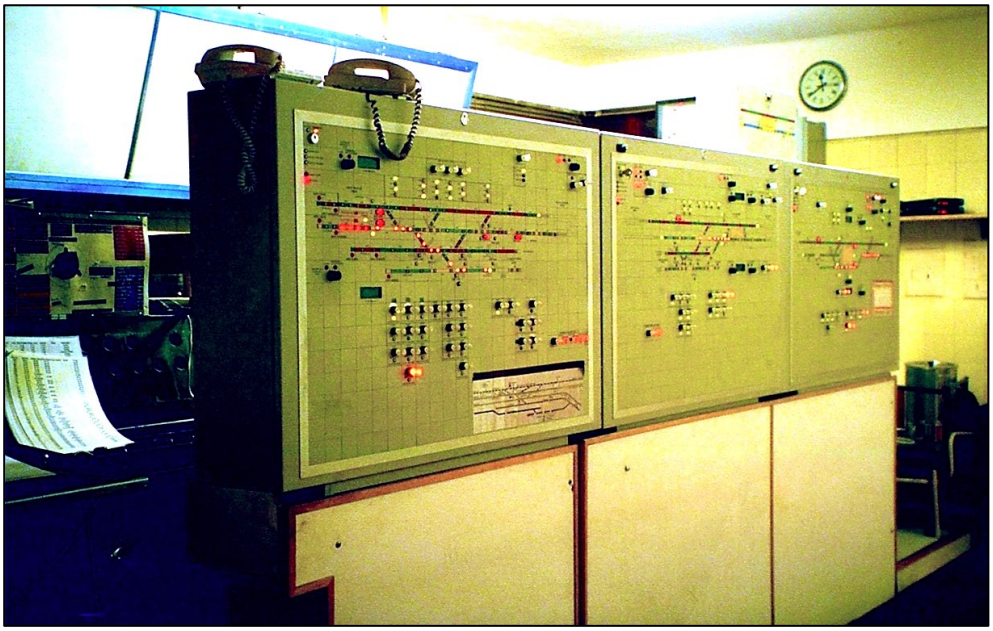

Figure 2: The emergency local control panels installed inside the original signal cabin at West Ruislip for the Central Line resignalling and conversion to ATC. They were provided in case control is lost from the line control centre at Wood Lane. Each panel controls a separate area. From left to right is West Ruislip, Ruislip Gardens and Northolt. The small box on top is for South Ruislip. Later, the individual units were relocated in their own stations so they could be accessed by the local supervisor if necessary, Photo: Phil Wimbush.

Further progress along the line was very slow. The next controlled area to be commissioned was Northolt on 9 November 1992, almost a year after West Ruislip. Contrary to the original plan, it missed out Ruislip Gardens. Ruislip Gardens was resignalled, with temporary control from West Ruislip cabin, on 8 January 1993. It then took until the end of 1997 for all sites to be converted for the new signalling, progress being slowed down by the introduction of Westrace interlockings half way through. In the meantime, the new 1992 Tube Stock trains were being introduced in manual mode using trainstops and tripcocks, like the trains they

[7] The Ealing Broadway branch was the only area running 33⅓Hz track circuits and 1992 Tube Stock was initially prohibited from the branch. The (by now usual) replacement of 10kHz Delta circuits was done across the line.

replaced. On 17 February 1995, the last 1962 Tube Stock train ran in public service so that the whole line could be operated by the new stock under ATP when it was ready and work could start on conversion to ATO.

Although the new trains were introduced under the standard Underground trainstop/tripcock protection system, there had been an expectation that the new signalling would be operational before their delivery and that the new trains would enter service under ATP. This didn't happen, so the new trains had to be fitted with tripcocks that they were not designed for. It was not a happy modification and there was a high rate of failures.

The switchover to automatic protection and operation was carried out in two stages. The first was the change from trainstop protection to ATP, with the driver driving the train using the target speed shown in the cab. This was called 'coded manual' (CM), as I described last month. The switchover was commissioned in sections, with trains changing over from a trainstop section to an ATP section mid trip. There were some failures to switch over from time to time. The conversion to ATP also involved altering many of the track circuits to allow better train performance and, although this was planned for completion in October 1997, the alterations and changeover to ATP, with the decommissioning of all the trainstops, wasn't finished until November 1998.

ATO CONVERSION

Following the completion of the change to ATP and Coded Manual driving, conversion to ATO followed, also in steps. It was rather tentative to begin with, with the short section from Gants Hill to Wanstead being changed over first on 16 December 1999. This was the time leading up to the change from the 1990s to the year 2000 and there was widespread angst over the effects on computer software. This was because dates in programs had always used two digits to indicate the year. It was thought this would affect how computers would behave when they year 2000 started. Much effort was expended on modifying software to avoid risks. I wonder if this affected the approach to the ATO conversion, which might explain why it was started on such a short, simple plain line section. The next stage was converted on 12 February 2000 between Mile End and Liverpool Street. The last section done was from West Acton to Ealing Broadway on 16 June 2004.

After it was first installed at Ealing Broadway, it was found that the ATO stopping tolerances in Ealing Broadway platforms were such that the last set of doors could be off the platform if the train stopped short of the stopping position but still within tolerance. This caused a withdrawal of the ATO into the station while they sorted out a solution. In the end, they had to build a short platform extension to get over it and ATO was then reinstated. It took over two years, the work being complicated by the start of the PPP (Public Private Partnership) contracts.

ATO INTRODUCTION DATES

Gants Hill to Wanstead	16 Dec.1999
Mile End to Liverpool Street	2 Dec 2000
Liverpool Street to Bond Street	22 Mar 2000
Bond Street – Shepherd's Bush	5 April 2000
Wanstead to Mile End	17 July 2000
Shepherd's Bush to West Ruislip	7 March 2001
North Acton to West Acton	7 March 2001
Ealing Broadway to West Acton EB	7 March 2001
West Acton to Ealing Broadway WB	4 Mar 2002
Withdrawn	11 Mar 2002
Reinstated	16 June 2004
Epping to Leytonstone and Woodford to Gants Hill via Hainault	1 May 2001
Woodford bay platform	16 Nov 2001

The ATO rollout was not without other problems. There were particular issues with the changeover from manual to ATO at the boundaries between sections and with poor stopping accuracy in platforms. There were issues with the correct side door enable operating too slowly and with trains refusing to start from platforms in ATO mode. The particular problem that did cause the most problems with delays to the train service were overruns of both platforms and signals at danger. It took over a year to get these problems under control[8]. Then there was a further tranche of ATO modifications at nine locations in 2005.

WET RAILS

The Central Line has long sections in the open, west of White City and east of Leytonstone. There had always been some concern about how trains would perform under ATC when running over open sections in poor rail conditions. Drivers on manually operated lines could use their training and experience to adjust control of their train according to the rail conditions but this was not possible in ATO. Although it was acknowledged that the braking rate deployed in open sections should be less

[8] Rodgers, (2002) ibid

than what was used in tunnels, doubts about managing ATO in wet rail conditions persisted. In 1997, rather late in the day, some ideas about adding tram-style magnetic braking to the trains were bandied about[9] but this didn't happen. Aside from the expense, there was hardly the room for them under the train. Brake rates were originally set to a maximum of 1.15m/s^2 for tunnel sections and 0.75 m/s^2 for open sections but later, around 2011, a lower, poor adhesion rate of 0.55m/s^2 was made available in the control centre for use when necessary.

In the following years, the Underground worked on a system known as ACCAT (Adhesion Controller's Condition Assessment Tool) to determine whether trains on the open sections of the Central Line could operate under Automatic Train Operation (ATO) at the 'normal' ATO outdoor brake rate or whether the reduced ATO brake rate (0.55m/s^2) should be implemented.

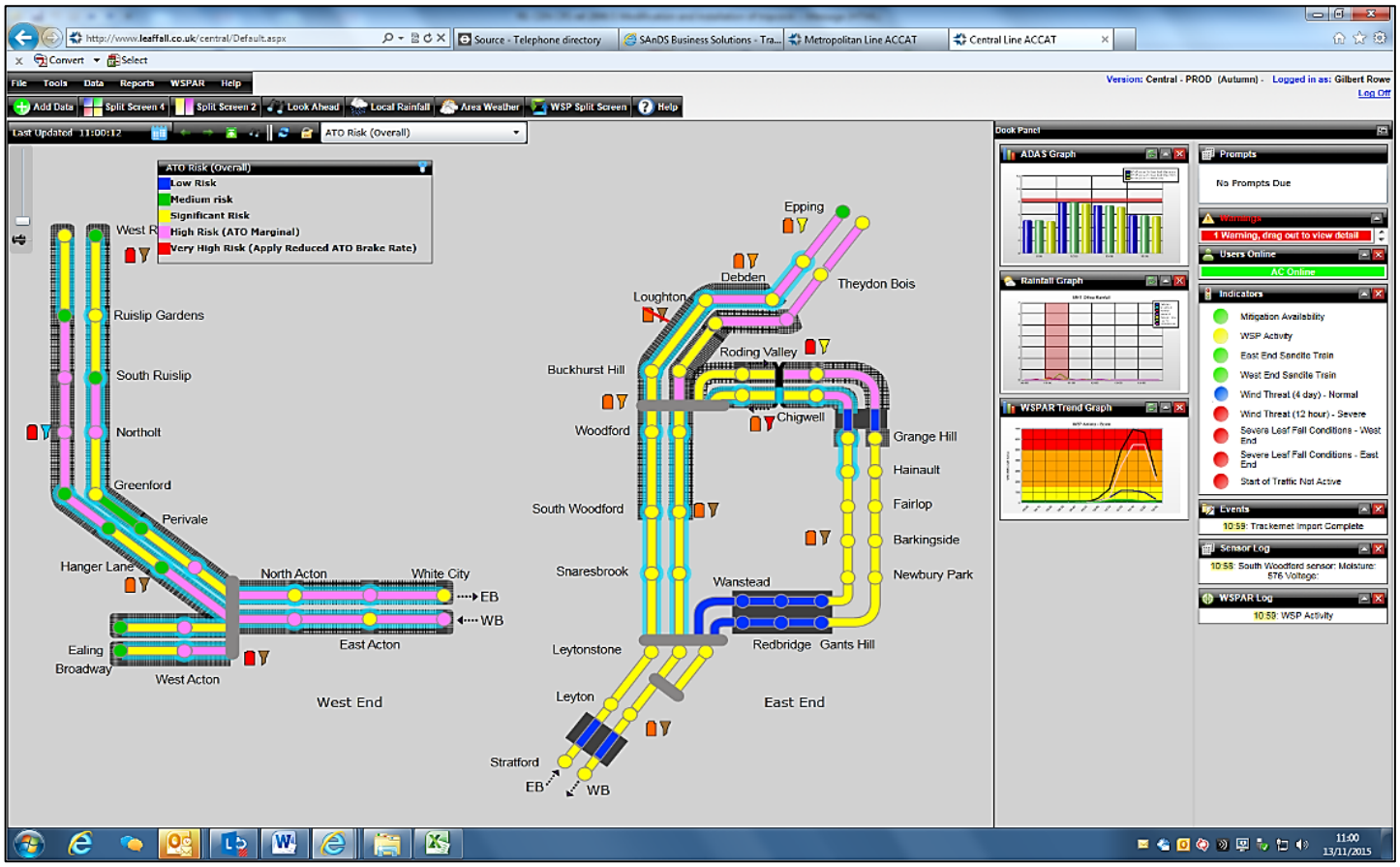

Figure 3: A screenshot of the Central Line ACCAT weather monitoring program. The western end of the line is shown on the left and the eastern end in the middle. The coloured sections show the weather risks to correct ATO operation. The yellow sections indicate 'significant risk' while the purple sections indicate 'High Risk, ATO marginal'. Photo: Collection P. Connor.

The ACCAT system is a computer based program using a range of information from various sources to assess the risk of contamination (Figure 3). It is largely based on leaf fall prediction, rainfall information and moisture presence using railhead moisture sensors. The screen shows, by different colours, the level of risk which indicates the likelihood of an adhesion problem. ACCAT also has a look-ahead capability to predict what the conditions will be up to six hours ahead. The ACCAT can produce prompts for the Controller regarding ATO brake rate changes that need to be implemented. Other measures taken to reduce adhesion problems now include targeted lineside vegetation management, running Sandite trains (one for each end of the line) and some trackside teams who help with hand sanding and giving feedback on railhead conditions.

NEW SIGNS AND SIGNALS

With the new signalling came new lineside signals and signs. Some of them were derived from the original Victoria Line versions and updated for the Central Line. The photos and illustrations below show some of the new Central Line signs and signals.

[9] Thorogood, R (1997), 'Central Line Project – Operational Experience', Proc. IRSE, 1997-98, Pp. 39-46.

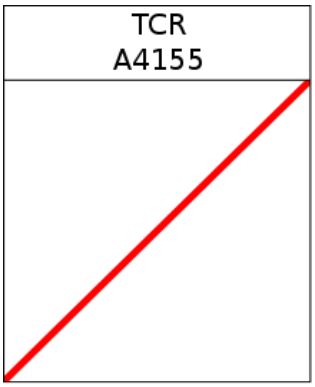

Figure 4 (left): A Block Marker Board (BMB) as used on the Central Line. This performs the same function as the Headway Post on the old Victoria Line system and this new form has since replaced the headway posts on that line too. The 3-letter code refers to the SER that controls the area and is normally related to a station name. TCR is Tottenham Court Road. The number refers to the track circuit it is located on. BMBs are not externally illuminated. With bright marker lights available on the front of trains, it is considered sufficient to use reflective plates for lineside signs. The earliest date for mention I can find for reflective signs is 1989 when they appeared on the Victoria Line.

Figure 5 (above right): A signal identification plate for an automatic visual signal on the Central Line. The code letters refer to the area, in this case, South Ruislip. The signal is the westbound home.

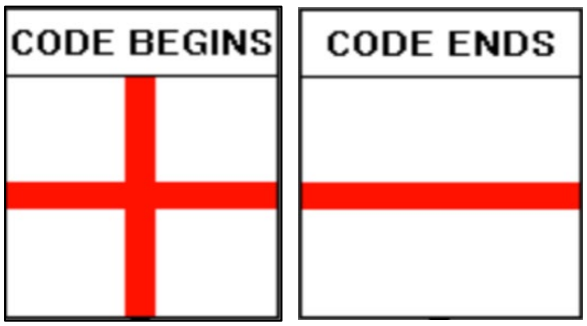

Figure 6: Depots on the Central Line do not use the ATC system so a fixed reflective sign is provided at the entrance to each depot to denote "code ends". In the same logic, each depot exit road is provided with a sign "code begins". Trains using sidings for reversing or outstabling are driven in and out of the siding manually, using the 'coded manual' mode of the ATC system. The same procedure is used on the Victoria Line.

Figure 7: An example of a 3-aspect signal on the Central Line at White City. It has its aspects arranged from the top as Green, White and Red. The white aspect is shown for the departing train, which is in ATO mode. Trains in coded manual are not permitted to pass the signal unless a green aspect is shown. Below the signal is the 'Route Secure' sign and below this is the square sign where a shunt signal is displayed if required. The signal number is on a small rectangular plate, showing WHC 2665. Below that is a triangular rail gap indicator. Photo: Still from YouTube video by x2k9.

PAIN

The Central Line went through almost ten years of pain in its conversion from manual operation to ATC. When the project started, as we've seen, the basis for the Westinghouse ATC system ordered by LU was what they had installed in Singapore. The Underground should, perhaps, have accepted that and allowed the system to be designed to that specification but, as usual, they required a number of alterations, particularly in the way the central control was set up. The Underground went its own way and decided, according to Bob Thorogood, the Central Line's former operating manager in a lecture to the IEE in 1997[10], "to make a large number of modifications to those on an already working system to get the improvements and extra capacity and robustness required to operate on our system". His view was that the Underground should have left well enough alone. Interestingly, he also stated that many of the problems already experienced with the Singapore system were replicated on the Central Line.

Thorogood thought that to order an existing system and then ask for a large number of modifications is fraught with danger and, of course, he is right. It's impossible to appreciate the effect that the modifications will have on the overall system and it's equally difficult for the contractor who was asked to provide a bespoke system but subsequently finds that this is a very different animal from what is

[10] Thorogood ibid.

actually required. It is better to take a tried and trusted system and accept that system completely as it stands and not fiddle with it. Regrettably, the Underground didn't heed his warnings and has continued to demand all sorts of additional features and changes to proprietary ATC systems subsequently ordered for other lines.

To be continued …