

1996 tube stock arriving at Stratford in CBTC mode with conventional signals 'bagged' on the left. Kim Rennie



London Underground gets more automated

Piers Connor reviews LU's resignalling policy

This summer, the London tube passenger should see better train services – on two lines at least. Two stages in the long and painful slog to bring the ageing system up to modern standards are close to completion. One is on the Victoria Line with the replacement of the last of its 1967 tube stock trains and its old-style automatic operation. The other is on the Jubilee, with the completion of its conversion to Automatic Train Control (ATC).

Both projects started back in 2003, under the now defunct Public Private Partnership (PPP) and today, despite the collapse of the whole PPP structure and eight fraught years of design, planning and implementation, signs are obvious on the ground that new things are happening.

The Victoria Line

On the Victoria Line, the original trains, the iconic 1967 stock, have been replaced by new 2009 stock sets built in Derby by Bombardier. This month sees the last of the old trains removed from service so that the line can adopt the regenerative capabilities of the new trains and start reducing the heat dumped into the tunnels during braking – good publicity for the

summer. While the effect for individual passengers will hardly be noticed, at least a start will have been made in containing the rise in temperatures underground.

The removal of the old trains will also allow the full implementation of a new ATC system, the Invensys (formerly Westinghouse) Distance To Go – Radio (DTG-R) product. The equipment has been installed in overlay mode on top of the original Westinghouse ATC and the new trains are using it but, as long as the old trains were in use, the original ATC train separation had to be retained. Now a start has been made on stripping out the original system and introducing the upgraded DTG-R capability to reduce the train separation distances. The first changeover took place between Walthamstow Central and Tottenham Hale on 31 May and the remainder of the line will follow in stages over the next year.

The Jubilee

In parallel with the Victoria Line, the Jubilee Line has been going through its own publically traumatic conversion to ATC, with several years of frequent weekend closures for installation and

testing and a couple of lengthy in-service failures during the subsequent shakedown period. So far restricted to the line south of Dollis Hill, the new system was due to be fully operational all the way to the northern terminus at Stanmore from 27 June. The Jubilee uses the Thales (formerly Alcatel) SelTrac S40 system, similar to that on the Docklands Light Railway, but it is substantially different from the Victoria Line's DTG-R.

For a start, DTG-R retains track circuit train detection. Track circuit occupancy and interlocking status information is sent to each train, using radio transmission, to form the basis of its DTG calculations with its on-board route map, so that the train knows its permitted speed and the distance to its limit of movement authority. This allows it to approach the preceding train more closely than was possible under the fixed overlap system used by the original ATC system.

S40 doesn't have on-board maps, radio or track circuits. The transmission system uses track-mounted loops, crossed every 25m to provide fixed location markers. A 'vehicle on-board computer' (VOBC) is used to determine



train location. Each train calculates its progress along the line and continuously transmits this to the Vehicle Control Computer (VCC) for the area. The VCC can control up to 40 trains at a time, although the LU installations will not need more than 20 under normal conditions. The Jubilee Line has five VCCs and the Northern Line, which is now being equipped with the same system, will get six.

A feature of the UK version of the S40 system is the use of axle counters as a secondary means

of train detection or for 'non-equipped' trains. Docklands had them imposed on them, so it was a foregone conclusion that LU would have to have them too. They are also used to confirm route occupation for point locking.

PPP collapse

Back in 1968 when London Underground (LU) opened the initial section of the Victoria Line, it was the first metro in the world to build a new line fully equipped with ATC. This year, LU goes for the triple crown – the first metro in the world to adopt three different ATC systems on three different lines, two of which share part of the same route and one of which shares it with trains that will not be equipped with ATC.

Now the conversion to ATC of an existing, high capacity, urban railway, running trains every two to three minutes, isn't for the faint-hearted, especially if your political masters have tied one of your hands behind your back by imposing serious interface problems on you from the start.

On the Jubilee Line, which shares 4½ miles of its route between Finchley Road and Wembley Park with the Metropolitan Line, the PPP organisation drove a wedge between the infrastructure owners of the two lines. London Underground watched, seemingly helpless, as the two infrastructure contractors, Metronet for the Metropolitan Line and Tube Lines for the Jubilee, chose different train control systems – Westinghouse DTG-R for the Metropolitan and other sub-surface lines (SSL) and S40 for the Jubilee. Giving a paper to the Institution of Railway Signalling Engineers some years later, one project engineer described it, rather tactfully, as 'unfortunate'. He was being generous. It was ridiculous.

Further weaknesses of the PPP structure led to the collapse of Metronet in 2007 and LU managers quickly dumped the Westinghouse SSL contract as too expensive. Bearing in mind that the price per km was 35% more than SelTrac's, who could blame them? However, I doubt the two-year overrun on the Jubilee Line

implementation and all the technical problems the installation and testing has brought on will have allowed Thales to keep to its original cost base.

Tube Lines absorbed

Then, in June 2010, Tube Lines was purchased by Transport for London (TfL) and the PPP was finally dead. It was hailed as a wonderful opportunity to overcome the signalling interface issues and get a sensible, railway-orientated approach to resignalling the jointly operated parts of the system. The purchase was greeted by Kulveer Ranger, Mayor Boris Johnson's transport adviser at the time, as ending the ridiculous situation on the Metropolitan/Jubilee route. 'So now we have that bit of track, we can actually procure a contract that meets that requirement,' he said. 'It means the contractor can actually deliver what's required, rather than two contractors having two different systems on the same part of track.' Oh really?

Just over a year later, in June 2011, a completely new and untried contractor was confirmed as the supplier for the SSL resignalling and Mr Ranger was shunted into TfL's 'Environment and Digital London' departmental siding. The new contractor is Bombardier and the new system is that company's 'Cityflo 650' product. This will cover the Metropolitan, Circle and District Lines and, the word is, the contract contains an option to resignal the Piccadilly Line. If this happens, it will take the interface risk out of two more difficult areas – the Rayners Lane to Uxbridge section shared with the Metropolitan and the joint District/Piccadilly section between Barons Court and Hanger Lane Junction, near North Ealing.

Most strangely, when it announced the choice of Bombardier, TfL said of the original Westinghouse offer, 'It would also have left LU with the legacy of a signalling system not compatible with others across the tube network'. No, I couldn't see what they meant either.

Acronyms

- **ATC:** Originally the Great Western Railway's 'Automatic Train Control' system, which was the forerunner of Automatic Warning System (AWS). Now, ATC is a catch-all term for an integrated ATS, ATP and ATO system. In the UK, we sometimes use ATO to mean ATC.
- **ATP:** Automatic Train Protection – the basic safety system that prevents over-speeding and train collisions without having to rely on the driver to do it.
- **ATO:** Automatic Train Operation – does the driving and braking without driver participation. Sits on top of ATP.
- **ATS:** Automatic Train Supervision – a system which can, if properly designed, help controllers and signallers make the right choices in train service management. Usually works better if the controllers and signallers don't fiddle with it. Sits on top of ATP and ATO.
- **CBTC:** Communications Based Train Control – generally agreed as a system that doesn't use track circuit coding to control the trains. Rather, it uses separate transmission cables or aerials and induction or radio.
- **TBTC:** Transmission Based Train Control – the same as CBTC. It just depends on who's describing it.



Far left: Under the SelTrac S40 CBTC system on the Jubilee Line, a Stanmore train is standing just 90m in rear of another stationary train in the platform at Willesden Green. Under the old, fixed block system, at this location, the separation between the two trains would have been 376m. A Metropolitan Line (right) train passes on the next track, operating under the old fixed block system. Richard Griffin

Left: The Victoria Line was resignalled north of Seven Sisters over the 28-30 May bank holiday weekend for Distance To Go signalling. As a result, 1967 tube stock was no longer able to work between Seven Sisters and Walthamstow Central. A northbound 1967 tube stock service calls at King's Cross St Pancras on the evening of Friday 27 May 2011, the last day such trains could run to Walthamstow Central. Kim Rennie

Right: Jubilee Line CBTC signalling 'Ready to Depart' platform indicator. These are provided now that conventional station starting signals and platform repeaters have been removed. Kim Rennie



Radio

So why did LU, with every opportunity to adopt a mature, accepted and now proven, signalling system across the jointly-operated parts of their network, choose yet another supplier and dig itself a huge new interface hole that's going to be even bigger than the one it is still deeply into? Cityflo 650 isn't proven in the UK and it has to go through the trauma of getting accepted by LU, whose safety elves would scare the paint off the hardest garden gnome, as well as Network Rail's equally Tolkienesque acceptance processes to let it work over the Richmond and Wimbledon branches. And it has to slot into S40 on the Jubilee Line, the Metropolitan's existing system, the new signalling currently being installed in Neasden depot (yes, of course it's different from all the others, need you ask?) and whatever Network Rail has on its bits of track used by Underground trains.

Well, the clue to our question is in a comment by a senior LU engineer who remarked to me, 'I don't want any more of that b****y cable lying around on my railway'. Apparently, the S40 transmission system isn't too popular with certain sections of the Underground hierarchy. The major difference between Cityflo and S40 is that the train to wayside transmission system for Cityflo is radio. The dreaded track-mounted cables are not needed. I haven't been able to get anyone to tell me why the cable system was chosen with SelTrac when Thales already had a radio transmission system available but I suspect it was regarded as 'not sufficiently proven' back in 2003.

Spanish seduction

It seems as if the Cityflo choice has come as a result of a careful seduction campaign by Bombardier, which has used its Spanish connections with the Madrid metro, where it has recently installed its Cityflo 650 system without the long weekend closures that we've had to get used to in London. The hope, apparently, is to ride on the back of track and station upgrade

closures so that no one will notice the new signalling going in.

How this will work while on-line testing of the system – the really difficult part of the business – is being done, is anyone's guess. The architecture of the Cityflo system is very similar to the Jubilee's S40's and one of the reasons for the long drawn-out testing regime was the need to take over long sections of the Jubilee so that the VCCs could be validated. For the Cityflo system, the control areas are known as 'Regions'.

Bombardier has a huge task ahead of it. Its signal engineers will not be familiar with the complex LU engineering philosophy and its rigid operating procedures and LU doesn't know the 'Ebilock' interlocking technology (remember the aborted Horsham installation?) nor the train control system. The latter has its origins in the American Westinghouse airport people-mover system, like the one at Gatwick Airport, where little, four-wheeled shuttle cars trundle up and down between terminals. Transferring that technology onto complex junctions like Earl's Court or Harrow-on-the-Hill will be just as 'challenging' as the S40 has been.

That said, LU now has hard-won experience of upgrading two lines and there are lessons to be learned from Madrid, so hopes are that the Cityflo conversion will be rather less traumatic than the Jubilee Line changeover. The spin from Bombardier was that there was a high level of co-operation between operator and supplier in Madrid and that there was a carefully-staged overlay programme. Like London's Victoria Line project, old and new systems operated together throughout the upgrade. We can only wait and watch.

Vic vs Jub?

There is a perception that the Victoria Line upgrade has gone better than the Jubilee's. This may not be entirely fair. Time-wise, they have almost run in parallel, with the Jubilee actually ahead for completion this year. Both have had rolling stock changes – the Victoria getting all

new trains and the Jubilee increasing its stock length from six-car to seven-car sets – and both have had weekend closures. The Victoria Line also used early evening closures to provide more installation time at night.

Perhaps the real difference has been that the Victoria Line is a self-contained railway with few signalling interfaces, whereas the Jubilee has a complex set of interfaces with the Metropolitan, particularly at Neasden and Wembley Park. For some possessions, it was necessary to close the Met as well as the Jubilee.

The differences between the two systems had a part to play. The distributed architecture of the Victoria Line's DTG-R system allowed staged implementation and single trains could be tested while old trains were still running. Training was also staged as the new trains went into service mixed with old trains. The old and new ATC systems could operate in passenger service together.

The Jubilee couldn't do this, as all trains and staff had to be in place for the new system to go live. There were also considerable technical difficulties interfacing the S40 systems with the original Westinghouse equipment, whereas both Victoria Line systems were Westinghouse-based.

Back-up

A big question for the discerning ATC buyer is whether or not to have a backup system. Good question, since some systems do and some don't. Even within LU, the Jubilee Line's S40 does but the Victoria Line's DTG-R system doesn't. You might ask why this is, since all ATC systems incorporate ATP and trains will stop if something goes wrong.

After all, the traditional, fixed block, colour-light system we all know and love doesn't have a back-up system, apart from the rule book, and neither does TPWS. Why should metro ATC systems be different?

The answer lies in our love affair with the track circuit. Most operators just can't wrench themselves away from the traditional form of

train detection provided by the track circuit. Anything else seems too reliant on shaky transmission systems like radio or induction loops. If you lose the communications, they say, how do you know where your trains are and, more importantly, once you've lost them, how can you find them again?

Both S40 and Cityflo use fully redundant computer systems to run large areas of their transmission-based train detection systems but, if an area control falls over, up to 20 trains can be wiped off the computerised memory map. Of course, the system is designed to stop all the lost trains immediately but, to recover, it then has to poll each train to find out where it is and which way it is facing and then calculate the relationships with other trains before it can restart the system. This effectively shuts down the whole line.

In a recent incident on the Jubilee Line, a VCC glitch required it to be 'rebooted' to clear its memory of a virtual train. This meant clearing the area under its control of real trains too. This took half an hour. After rebooting, a test train had to be sent through the area to test the system and reset the axle counters used in the back-up system. This took another hour.

Cityflo attempts to get over this with its 'Train Registry System', which independently tracks train movements and can then be used to update the 'Regions' if one falls over.

Having a back-up system may make the operator feel comfortable at the contract signing stage but there is little evidence that, in the heat of battle, it provides anything more than a slow speed train detection system that is no better than the restricted manual speed of 10mph provided by the ATP. Not only that but, if the back-up system fails, it rebounds on the main system, causing restricted movement through the area. In the end, it costs more to provide, it costs more to maintain, it adds another failure risk and it offers no tangible improvement in service recovery. So, why have it at all?

Benefits

The Underground's upgrades are already showing benefits, with the new trains on the Victoria Line providing a reduction in dwell times. Their faster operating systems allow door opening and closing times to be reduced and the lag between doors proved closed and wheel start to be shortened.

More benefits will come. Now all the old trains have gone, the long overlaps can be removed and the old interlockings disconnected. Within a year, the new track circuits and Westrace interlockings will have total control and it will be possible to reduce headways.

A big benefit of ATC is in train service consistency and recovery. Just eliminating 'defensive driving' and variable braking techniques on a manually-operated route will give an extra 2.5 trains per hour (tph). If you can shorten the distances between trains too, using ATP systems like DTG-R or S40, you can get another train or two per hour.

On the S40 system, a train can stop as close as 80m behind the one in front, something impossible with the old, trainstop-based system.

This ability provides for rapid recovery from minor delays and, combined with the ATS, allows a better balance of trains along the route.

On the Jubilee Line, with the new ATC in place, the ATS adjusts the speed of trains to even out the service or lets trains recover time. The anomalies of manual driving are eliminated and train speeds are adjusted to the circumstances detected by the central computers. Already this is very apparent, as some trains appear to move quite gently along the line, while others perform up to their full limits. It just depends on the status of the route at the time. The same sort of service adjustment can be applied to the Victoria Line.

Under good conditions, the manually-operated Underground routes can manage 24-28 trains per hour (tph) depending on the existing signalling and the terminal arrangements. If all goes according to plan, the Jubilee Line will get a new timetable in July that will offer a step up from 24 to 27tph. Once the system has fully bedded in, it will be possible to increase this. On

the Victoria Line, once the asset replacement programme is completed in a year's time, another 2-3tph can be added to the timetable.

Naturally, this pragmatic approach to performance improvement has been spun out of control by the TfL press office which says, 'the overall SSL upgrade programme will increase capacity on the District Line by 24% to 50,000 passengers/hr, on the Metropolitan Line by 27% to 44,500 passengers/hr and on the Circle and Hammersmith & City Lines by 65% to 43,500 passengers/hr'.

Since the official maximum capacity for a brand new seven-car 'S' stock train is 1,194, to get 50,000 passengers/hr on the District, you would need 42 trains per hour. I doubt Bombardier has signed up for that. **MR**

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Dollis Hill on the Jubilee in the southbound direction, where CBTC takes over from the old signalling. Original automatic station starting signal A 171 is covered over and out of use. Below is new signal WIG 002 which marks the 'migration point' between conventional and CBTC signalled areas. This displays either a red (stop) or blue (proceed in TBTC) aspect. Kim Rennie