London Underground's Designer Trains

Roger Ford on 1986 Tube Stock

EXPERIENCE over the past two decades has taught that prototypes of new railway equipment are of dubious value. Businesses under pressure need the benefits of new equipment as early as possible. Even if the procurement time-scale does not rule out the construction of a prototype, it rarely allows significant service running experience to be achieved — and certainly not enough to disclose the majority of potential faults. There is also a good chance that a new locomotive or train will offer more performance than the stock it is replacing. As a result, trial running is under the operating conditions of yester-day's railway.

In the aircraft industry, which has a long history of innovative jargon, 'prototype' nowadays generally refers to the first of the batch of development aircraft, sometimes also known as 'pre-series'. What would popularly be considered a prototype is now a 'technology demonstrator'. In railway terms, the prototype 'Deltic' was really a technology demonstrator, as was the Experimental Advanced Passenger Train. The prototype High Speed Train and APT-P were pre-series development units.

On this basis, we need to watch the terminology when considering the London Underground 1986 Tube Stock. While it is convenient to label the trains as 'proto-types', they are classic examples of the 'demonstrator' concept. In fact, London Underground Limited (LU) has taken the idea to its logical extremes and used the three trains to demonstrate not just new technology, but also procurement practice and aesthetic design. This refreshingly logical approach has already proved an undoubted success. It remains to be seen whether LU engineers can maintain disci-pline and keep the trains from becoming prototypes.

Future renewal strategy

By 1985, LU had completed the pro-gramme to replace all pre-1939 rolling stock. With the majority of the replacement stock built since 1959, and a nominal service life of 36 years, LU faced the prospect of a pause in train procurement. Logically, the next fleets needing replacement would be the 1959 Tube Stock on the Northern Line and then the 1962 Tube Stock on the Central Line. Using the 36-year service life, this gave replacement dates of 1995 and 1998 respectively.

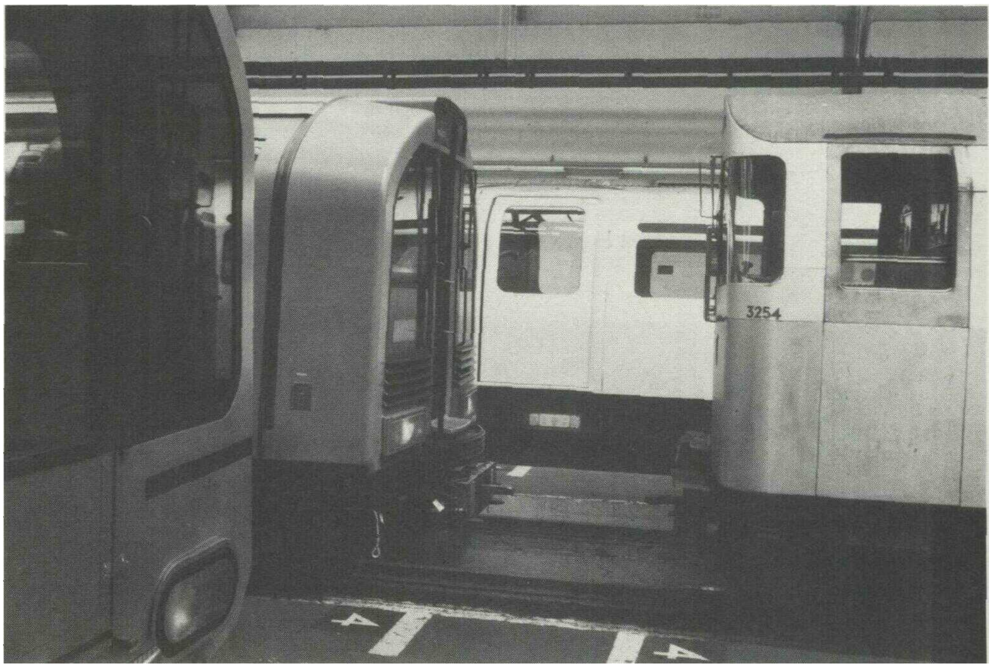
Budgets and manufacturing processes prefer steady flows to big bulges so, in 1978, a plan was produced which 'smoothed' these renewal requirements. It was decided to bring forward Central Line rolling stock renewal to 1990 and cascade the 1962 Tube stock to the Northern Line.

A key factor behind this plan was the need to resignal all the Central Line at the end of the 1980s. Unusually, the line had been resignalled all at once in the past. This provided the opportunity to introduce changes, such as automatic train control, which would be uneconomic if it meant premature replacement of existing equipment.

There was thus the prospect of re-equipping the Central Line as a single integrated project. At one time, LU was considering putting this £400 million project out to tender as a turnkey project, Docklands Light Railway style. Perhaps regrettably, this imaginative concept now seems less popular. However, the Under-ground remains committed to procurement by performance specification, with the contractor being responsible for managing the contract, as with the 1986 stock.

Philosophy

With Central Line re-equipment planned for the early 1990s, LU had time for a relatively prolonged consideration of the type of trains which would be needed to take its services through into the 21st century. With so many developments in technology, plus the opportunities for a fresh look at aesthetic (as opposed to engineering) design, LU decided to build a small number of trains to demonstrate what might be on offer for the definitive 1990 Tube Stock. Thus, instead of talking of 1990 Tube Stock prototypes, the



Above right:
1986 Tube Stock faces a train of 1972 Mk 2 Tube Stock, a derivative of the 1967 Tube Stock style first seen on the Victoria Line. ***Roger Ford***

Right:
Interior of BREL 'B' train.

demonstrators became the 1986 Tube Stock in their own right.

Since the formulation of the 1990s renewal strategy in 1978, LU had been studying developments in vehicle construction and traction technology. In parallel, DCA Design Consultants of Warwick had been working with LU on external and internal styling and colour schemes for future trains. Finally, Underground procurement policy underwent a major change. Traditionally, LU had retained overall project management for each train contract. It ordered the vehicles and traction equipment separately and was responsible for interfacing, bringing them together at the vehicle manufacturer's works.

Now, this has all changed. With the second, extended, batch of 1983 stock, LU went over to the main-contractor concept. Barring political changes, this is likely to be the basis of all future procurement. Its corollary is that the manufacturer designs the train to a performance specification. The 1986 Tube Stock provided an opportunity to give this form of procurement a dry run. The new trains also gave the opportunity to break the Metro-Cammell 'monopoly'. This company has built all Underground trains since 1962: for the new policy of procurement by competitive tender to be effective, there has to be competition.

Innovation

London Underground identified a number of developments needing evaluation. While all-aluminium rolling stock had been in service on the Underground's surface lines since 1949, Tube Stock, with its steel underframe and aluminium body, was small but heavier. With new methods of body-shell construction, particularly the use of seam-welded large aluminium extruded sections, studies showed that an all-aluminium Tube train would save around 1.25 tonnes on the bodyshell, with consequent energy savings, and be cheaper to manufacture.

Two innovations in running gear to be evaluated were steering bogies and motor-mounted disc brakes. Steering promises to reduce wheel wear and thus maintenance costs. Separating the brakes from the wheels offers the prospect of smaller wheels which can fit beneath the underframe. Present wheel-size takes up above-floor space beneath the seats.

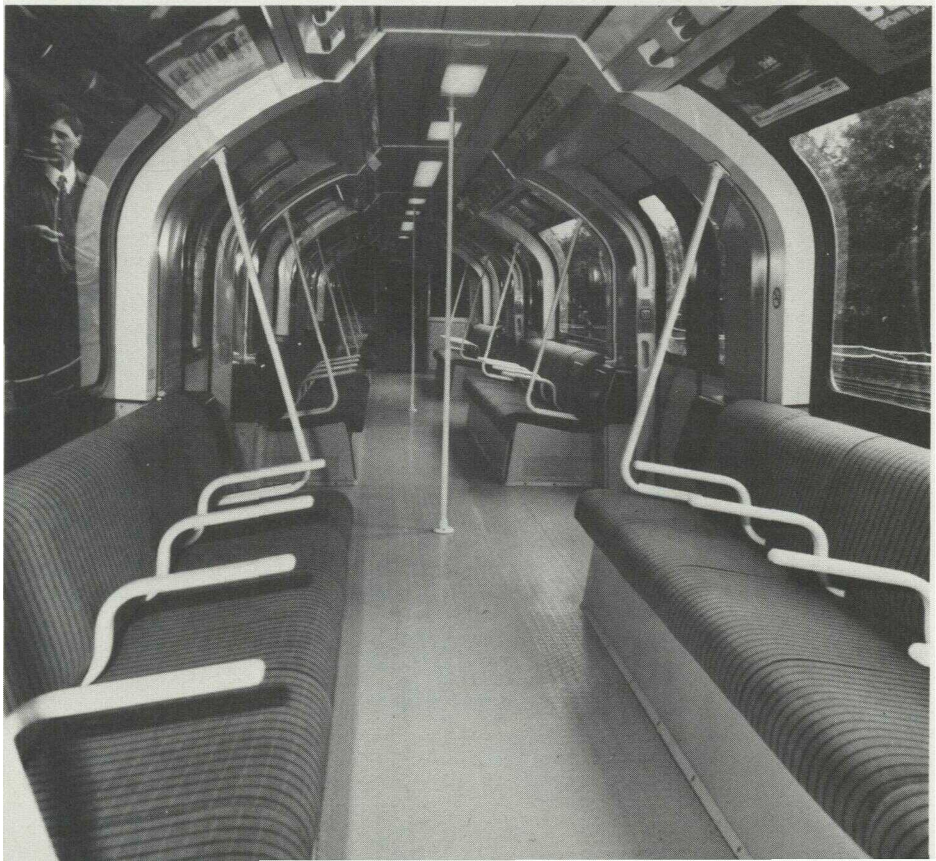
An obvious area to explore, but an innovation only as far as the Underground was concerned, was traction control using solid-state power devices. With its unusual traction current supply system — the earth-current return is through a fourth rail rather than the running rails-LU has had problems in getting to grips with direct current 'chopper' control. The Experimental Tube Trains of the 1970s were never very happy in terms of traction-current interference with signalling and telecommunications systems, and came to nothing.

Since then, chopper technology has advanced considerably, as has the technology of frequency monitoring. This is necessary because the Signalling & Telecommunications engineers give the Traction specialists certain frequencies at which the power electronics can 'chop' without interfering with the Underground's alternating current track circuits.

Safety then depends on the chopper not operating outside its frequency band. Hence the need for the monitoring equipment which not only checks for correct chopping frequency but also watches for other frequencies which may be generated by the chopper equipment, for example through resonance. If a malfunction is detected, the equipment is shut down.

Partly because of what an LU engineer described as the 'unknown but very intensive electrical environment of the Underground, three-phase alternating-current drive is not being considered for the 1990 Tube Stock. Personally, I find this surprising. On the other hand, it would mean choosing between expensive first generation equipment or buying second generation equipment, at present under development and based on gate-turn-off (GTO) thyristors, on the basis of limited service experience with a few prototypes.

The 1986 trains offer a choice of chopper philosophies. Brush for the BREL 'B' train



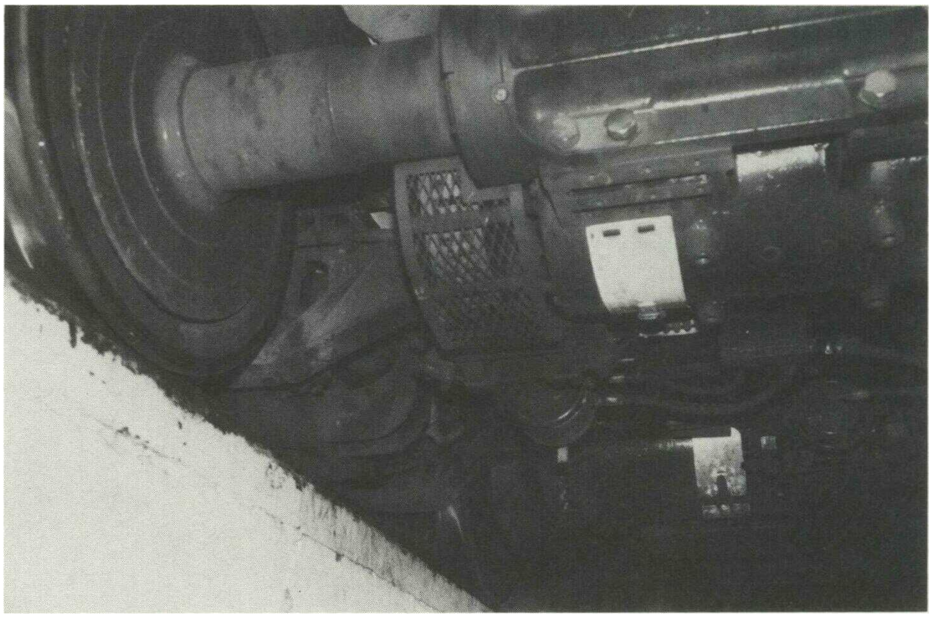
Above left:
Interior of Metro-Cammell 'A' train.

Left:
Interior of Metro-Cammell 'C' train.

London Underground's prototype Tube trains line up for the camera. From left to right, Metro Cammell's 'A' train, British Rail Engineering's 'B' and Metro Cammell's 'C'.
London Underground

Right:
Underneath the BREL 'B' train, the ventilated disc brake is visible in the 'cage' at the end of the traction motor. *Roger Ford*

Far right:
Hand-held driving unit plugged into console at cab-less end of a 1986 Tube Stock train.
Roger Ford



have supplied a 'classic' chopper, while the GEC and Brown Boveri (BBC) equipments in the A and C trains are GTO based. BBC has a four-phase chopper with a single GTO thyristor driving each pair of motors. This is claimed to give finer control of tractive effort and lower ripple on the traction supply. GEC has a two-phase chopper based on equipments in service with the Seoul Subway and Dublin DART trains. This has two main GTOs in place of conventional thyristors feeding four parallel strings of four motors.

Already in service on LU, but offering great potential, is the use of multiplexing to transmit control and indication data. The underframe of an existing Underground car looks like part of a spaghetti factory, thanks to the steady increase in the amount of wiring needed to link the growing number of equipments and control and communications systems. Multiplexing allows a large number of separate signals to be transmitted and received over a single pair of wires.

A central microprocessor can address, individually, microprocessor units controlling and monitoring train equipments and connected to a data highway running down the train. Thus, the braking system, air compressor and doorgear each have their own intelligent control unit connected to the data-highway. Messages between these intelligent units and the master controller are coded so that messages go only to the intended unit. Multiplex systems both reduce the volume and cost of wiring in a train and also provide the basic reporting system needed for modern fault monitoring, diagnostic and reporting systems.

Finally, there is visual and ergonomic design. Modern materials, production techniques and new technologies offer the designer a much wider choice in a many features, ranging from floor finishes to the size of windows. Before the specification for the trains was put out to tender, DCA of Warwick had conducted an initial aesthetic design exercise for the Underground. The resulting styles and colour-schemes were made part of the specification.

Procurement

To run the 'prototype' trains in revenue-earning service an eight-car formation would be required. Bearing in mind the likely availability for service of prototypes, LU wanted to have four spare cars. Financially, 12 cars were affordable and this number equated to three four-car trains, each of two two-car units. Four companies were invited to put in bids — BREL, Metro-Cammell, CIMT of France and Waggon Union of Berlin. The UK firms were successful, with BREL building one train and Metro-Cammell two. While the Metro-Cammell trains are apparently quite different from each other, this is achieved through variations on a basically-common bodyshell. Power equipments were ordered from Brush and GEC in the UK and from Brown Boveri of Germany.

Performance

The three new trains are very much 'GT' models. Intensive services in the central area of the Underground dictate minimum headways. At present, 30 trains per hour are run on the Central Line during the peaks. Future requirements are likely to be for even shorter headways, placing the emphasis on high-performance rolling stock. Higher acceleration and braking rates also mean that a given level of service can be provided by a smaller number of trains.

Emergency braking rate, at 1.34m/sec^2, is the same as other recent LU stock and the service rate is only slightly less. In practice, braking rates are limited by the adhesion which can realistically be guaranteed and the comfort of standing passengers. However, trials with the disc-braked 'B' train have already shown the highest ever emergency braking rates achieved by LU.

With all-axles motored, electric service braking is also maximised. The traction equipments are designed for regenerative braking which is expected to show energy savings between 15% and 25%, with an overall reduction in traction current consumption of 10%. The introduction of separately-excited traction motors as part of the chopper control schemes should improve the effectiveness of the electric braking, as the braking effect is established faster and more reliably and full brake force is sustained to a much lower speed.

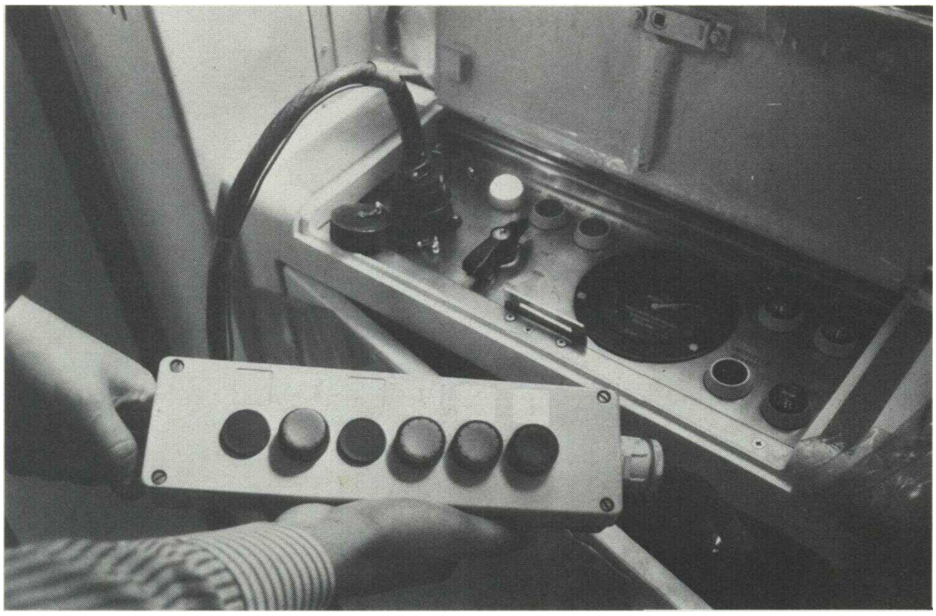
Having all axles motored also gives the trains the GT performance referred to earlier. I understand that during commissioning runs on the dedicated test track at Ealing, the drivers had a lot of fun giving service trains on the adjacent line a start and then 'outdragging' them. The chopper systems allow the trains to have two characteristics. In 'out of town' mode, the trains run with high acceleration to high speed followed by coasting and regenerative braking. Computer simulation showed that by having two seconds coasting per kilometre, the round trip from West Ruislip to Epping and back would take 18 minutes less than the present schedule of 177 minutes and use only 9% more energy. The 'in town' characteristic is similar to the performance of existing stock but with higher acceleration to the lower speed. This extra performance will allow 75 of the new trains to replace the existing 85-train Central Line fleet. On the other hand LU may well be able to make the case for providing extra capacity as well, pushing the peak hour flow from 30 to 33-34 trains an hour. In this event, more trains would be required.

The 'A' train (Red)

This was built by Metro-Cammell with bogies by Duwag of Germany and GTO thyristor chopper equipment by GEC Transportation Projects. It was the last of the trains to be delivered and was full of workers and test equipment when I previewed it. The 'A' train shares a common body shell with the 'C' train *(see centrespread photo).* In common with the 'C' train, it has windows which follow the bodyside curve up into the roof line, although they also start at a higher level than in existing stock. Externally, the main impression is of neat detailing. For example, there are grooved panels around the door-open buttons to provide a tactile guide for visually handicapped travellers.

Internally, the design seems less happy — but reaction to design is, of course, subjective *(See photos, page 420).* The vertical grab poles beside each doorway and the longitudinal grab rails above the seats have been made continuous. Readers will have their own perception, but I did not like the effect of a bright-red cage around the seating area.

It also seems perverse, given the large high-level windows, to run a thick horizon-



tal bar across the window at the eye level of a seated passenger of average height — particularly as passengers will need to read platform signs at night on the over-ground sections of the Central Line. Other internal detailing shows signs of thought — for example, the recessed grabs in the door surrounds.

Despite the window bar, the overriding impression is of lightness. This is aided by the windows in the non-cabbed ends of the cars which allow a clear view the length of the train. Apart from the aesthetic appeal, this also gives a greater sense of security, as passengers feel less cut-off from the rest of the train.

The 'C' Train (green)

Taking the trains out of alphabetical sequence simplifies the comparison, because the 'A' and 'C' vehicles share the same body-shell. The 'C' train was described to me by LU staff as 'Pure DCA' — and it shows. It is at once the most adventurous, the 'cleanest' in terms of detailing and the most functional from the point of view of seating.

Dominating both the exterior and interior are the large single windows in each of the three bays created by the door-areas. The impression of size is enchanced by the windows wrapping-upward into the roof line. The vertical grab-rails are conventional, although angled away from a standee in the aisle. The horizontal grab-rails are in recesses in the ceiling coving.

As with the 'A' train, there are recessed hand holds in the door surrounds. Also in the stand-back area beside each door are the perch seats. Given the varying height of the human posterior above ground level, a perch seat must inevitably be a compromise. I think that you are meant to lean against the inclined back, with friction taking some weight off the legs, but tall people will be able to perch on the flat top surface.

A feature of all the trains is the equipment crammed into all available spaces. For example, the doors have roof-mounted actuators rather than the classic under-seat mounted rotary actuator. Living in the space where the rotary actuator would have gone is the pressure ventilation equipment. While trying to perch, I asked what was inside the plastic housing which forms the seat. For a moment, there was elation among LU engineers at the thought of unused space being discovered in one of their tight-packed trains. Then, the lid was lifted — to reveal the brake isolating equipment.

The normal seats in the 'C' train are likely to be a source of controversy as they have expanded plastic foam cushions on a baseboard. The result is best described as 'firm'. The seats in the other two trains all have spring interiors with either natural hair/fibre or foam padding. All seats are covered with 85% wool/15% nylon moquette.

Underneath the 'A' and 'C' trains, there are several innovations in addition to the chopper equipments. The traction motors are mounted on the transoms of the H-frame bogies (built by Hunslet in the 'C' train) and drive the wheelsets through an axle-hung gearbox, nose-suspended from the bogie frame. The GEC equipment uses a splined flexible drive whereas the BBC equipment has rubber units.

Both cars also have solid-state inverters to provide auxiliary power in place of the traditional motor alternator set. This should reduce noise levels, as should the Hydrovane rotary air compressors fitted to the Metro-Cammell cars.

The 'B' train (blue)

The BREL train is structurally the most conventional of the three. Internally, the most striking feature is the use of single transverse seats in a 1+1 configuration in the centre bay. The aim of this is to provide more space for standing passengers inside the car rather than around the door areas. In theory, it should be possible to accommodate two rows of standing passengers along the car. To meet this requirement there are vertical grab poles between each pair of back-to-back seats and a continuous grab rail.

Because of the 'conventional' window layout, BREL has been able, with difficulty, to use overhead ducts and vents for the pressure ventilation system. In the Metro-Cammell cars the size and height of the windows prevents this, and the air is blown into the saloon through grilles behind the seats. In all trains, the heating and ventilating packs are installed beneath the seats.

Assessing trains in the open, or even in a depot, on a fine day does not give a true impression of the ambience created by the lighting when running underground. Subjectively, the sulptured, carefully-detailed ceilings of the 'A' and 'C' trains look the best in daylight, but I suspect that the more 'old fashioned' fluorescent panels in the 'B' trains may be best in the dark.

Beneath the floor, the 'B' train has its share of innovation. As already mentioned, the train runs on steering bogies. Unlike the BREL cross-braced bogie, where the wheelsets take up radial attitudes on curves automatically, the cross-bracing is assisted by a steering beam, connected to the body by links, which physically 'steers' the wheelsets into correct alignment.

With this configuration, the motor is connected to the axle with a conventional suspension tube and the motor is nose-suspended on a beam running between the bogie side frames. Because the axles can move, tread braking is difficult to,provide, there is not room for an axle-mounted disc brake, hence the small disc brake, ventilated for high thermal capacity, is mounted on the free end of the traction motor shaft.

Communications

All three trains give a foretaste of what microprocessor technology has to offer both the passenger and operator. Public address announcements are made automatically by digitally recorded speech systems. Separate announcements will be made when approaching and in stations, and a tone will indicate when doors are about to open or close. Internal 25-character visual displays at both ends of each saloon will show the destination of the train, until triggered by a transponder at the approach to a station, when the station name will alternate with the destination. On the front of the train, a similar display will show the destination. A microphone beside each alarm button allows a passenger using it to speak to the driver. The driver can speak to the whole train or an individually-selected car in reply.

Completing the outfit of the 'smart' train is the fault-annunciation system. Through the multiplexing system, this keeps track of the train's equipment and reports faults in plain text. LU engineers describe this facility as 'super', on the basis of its value during commissioning. Also using the multiplexing system, a hand-held unit can be plugged into a console at the cabless end of a unit allowing the unit to be shunted.

Below:
BREL's 'B' train.

Metro-Cammell's 'A' train.

Metro-Cammell's 'C' train.