# Strategies for Train Control Within Queensland Rail

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Abstract:

This paper looks at two recent developments in Queensland Rail for different types of Train Control, namely:-

UTC (Universal Traffic Control) for controlling trains in signalled areas

DTC (Direct Traffic Control) for controlling trains in non-signalled areas

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## 1. *Introduction*

This paper looks briefly at the latest Train Control Systems developed in-house by Queensland Rail. These include Universal Traffic Control (UTC) for operation in power signalled areas, and Direct Traffic Control (DTC) for operation in un-signalled or dark territory areas.

## 2. *The Urban Train Control Challenge*

In 1979, Queensland Rail centralised numerous local cabins into Brisbane's Mayne Control Centre as part of the electrification program.

The centre-piece of this control system consists of a large mimic diagram controlled by Signalmen pushing signal buttons in a one-signal-at-a-time entrance-exit mode. All non-vital logic for this system was originally achieved by using miniature relays. A Train Describer computer was added purely for the train information role.

The opportunity to develop an enhanced train control system to cater for the urban environment was the result of a number of inter-related factors:

* The original train describer and mimic diagram systems at Mayne had reached their capacity.

* Management and operations staff were increasingly under pressure to improve the on-time running performance of the Citytrain network.

* There was an increasing need for the automated recording and reporting of all train movements, fault and untoward operating events.

* The existing control centre and telemetry equipment was a patchwork of differing equipment and design methodologies as a result of the many and various extensions to the electrified network.

* Major alterations to the network were planned including duplication of the Beenleigh line and extension of this line to the Gold Coast, the new inner-city tunnels and associated quadruplication works, and the more recent extension of dual gauge track from Acacia Ridge to the Port of Brisbane at Fisherman Islands.

After an initial feasibility study and investigation of possible alternatives, the in-house development of an urban train control system was accepted as best meeting QR's short and long term objectives. This project was started in earnest in mid-1990 and achieved its first milestone on 26 January 1992 when the original train describer was de-commissioned. The first section of UTC based control was introduced with the commencement of the Kuraby to Beenleigh duplication in March 1992.

To date 15 urban signalling interlockings and 4 CTC interlockings have been commissioned on what is now called QR's universal traffic control system (UTC).

## 3. *Universal Traffic Control - The Details*

### *UTC System Concepts*

The UTC system provides a simple user interface, the power of detailed control, and is expandable in a modular, industry standard and distributed manner. In addition, a substantial amount of redundancy is provided for this mission critical application to protect against hardware or software failures.

The UTC system has its various software tasks spread over a number of different networked PCs. This was done so that the amount of processing required by each PC was kept to a minimum, thereby providing the potential for much larger areas of control to be accommodated. In addition, if there are any application software problems, then these will be isolated to an individual WorkStation PC, thereby insulating the total UTC system from single mode failure.

All PCs other than the Operator WorkStations are duplicated with automatic hot changeover from one side to the other. As well as providing a greater degree of redundancy, this hardware arrangement also simplifies software modification and updating process which is all done off-line in the UTC environment.

The PCs communicate via a star wired twisted pair EtherNet LAN. The LAN itself is duplicated with two LAN cables connected to each PC. A separate LAN interface card is used for each LAN connection, each card having its own Protocol Stack.

### *Non-Operator PC Functions*

Telemetry Processors (2):

These processors communicate with the duplicated telemetry master stations or front end processors. This latter equipment then provides for secure communications via a bearer network with the telemetry field station equipment (in the case of a conventional relay interlocking) or directly with the field equipment (in the case of a solid state interlocking).

Train Describer processors (2):

These processors receive track and signal status from the LAN (telemetry processors) in order to track the location of every train within the suburban area.

Message PostBox PCs (2):

The function of these PCs is as a LAN Message PostBox, simplifying message passing between PCs. Every message from one PC to another goes via this Message PostBox. This means that each PC other than the Message PostBox PC has to have only one software LAN connection, that being between itself and the Message PostBox. In addition, if a single message has to go to several destinations, then the PC only has to send this message to the Message PostBox once which will then copy this message for dispatch to all the required destinations. The postbox approach therefore helps to reduce the amount of processing done by each PC, simplifies the software connections, and creates a common point where all messages pass which can assist in maintenance.

Maintenance PCs (2):

These WorkStation PCs are used by the technical staff to monitor the operation of the system. A number of on-line facilities are provided to monitor telemetry error rates and bit displays, LAN activity, LAN connections, etc. In addition, any warning messages that the Operators are issued with are also brought to the attention of the Maintenance Staff. These Warnings include Telemetry Failures, Trains going past Red signals, etc. This WorkStation PC is also responsible for providing the equivalent of the CTC Event and Fault logs.

The Townsville UTC system, because of the lower amount of traffic, has combined the Telemetry Processor and Message PostBox functions onto one pair of duplicated PCs. However, the applications software being fully multi-tasked is precisely the same.

### *Operator WorkStation PCs*

Mouse Control:

To keep the user interface simple, it was decided to restrict the type of mouse control to just a single click of either the Left or Right Hand Buttons, i.e. double clicking and dragging are not used. This made the user interface more consistent and reduced the learning curve. In addition the need for a keyboard has been completely dispensed with.

The majority of user actions are done by clicking with the Left Mouse Button. This includes calling Routes, swinging Points, giving Releases, answering Prompts, and obtaining information on device status, outstanding alarms, and train running information.
The Right Mouse Button is reserved for Restoring of Signals, Blocking of Tracks and Locking of Points, i.e. restrictive type moves.

Screen Layout:

Each operator's workstation (which can be up to a maximum of three) displays a layout of the area under his/her control. When there is no activity, the entire layout is shown in a dull grey, however where activity occurs these areas are shown in a bright colour depending on the activity. This selective highlighting makes activity areas stand out to the Operator.

Typically, the active parts of the display are shown in a non flashing colour. However, when something happens that requires the attention of the Operator, these elements will flash. This flashing tends to get the attention of the Operator without having to bring up a message telling him what to do. For instance, when a train first appears on the system its unknown identity will flash indicating that a train ID is required to be entered. If this flashing is ignored, then the system will bring up a text message prompt after a predetermined time depending on the nature of the problem.

Prompts are also produced when the system detects faults and dangerous incidents. For instance, the system will immediately report when it detects that a train has gone past a red signal. All of these messages are colour coded Red indicating Faults and Incidents, whereas Green is used to indicate Recoveries, and Yellow for general information. Any Urgent (Red) messages are also brought to the attention of the Operator before other messages.

Urgent messages waiting to be acknowledged will sound a warning beep every 1 second whereas it will sound only every 8 seconds if only non-urgent messages are waiting.

To reduce the amount of information on the graphics display, track names, signal names, points numbers, level crossing names, etc, are not normally displayed. This reduces the amount of clutter and allows the Operator to concentrate on train movements. Similarly, only those signals which are part of a set or queued route are displayed, again reducing the amount of data to be displayed.

Anything that is displayed as steady purple represents a failed object. Such objects include signals, points and releases. If the station itself has failed then the station name will be shown in purple.

Signals:

A route is set by first clicking on the source or origin track. This track will then begin to flash to give visual feedback that the correct track was selected. The colour of this flashing indicates the type of route that is about to be set - green for a Main route and yellow for a Shunt Route. The destination track is then selected by clicking on it with the Left Mouse Button.

The system will then determine if it is possible to set a route between the two points, and if so it will then call the signals and points to make the desired route. While the route is being called, the tracks are indicated as brown, and when cleared will be shown in a colour to match the type of route (i.e. yellow or green).

If the system determines that it is not currently possible to call the route then it will determine if it is possible to queue the route so that it can be subsequently called when field conditions become favourable. Once queued the route will be displayed as cyan. If the route cannot be queued then warning beeps are given.

When determining if a route is available, the system will always use the same path. For instance, if the system determines that the route is unavailable due to one of the tracks being Blocked, it will not try to find an alternate path to take the train around this blocked track. This is left up to the Operator to decide how the train is to be re-routed.

Although it would have been quite easy to let the system determine an alternate route, this would have meant that the Operator would always need to check before setting a route to determine how the system would attempt to set it. The concept here is one of system consistency.

Points:

A set of points are swung simply by clicking on the curved arm (not necessarily the reverse arm) of the set of points. This will cause the points to be called in the opposite direction to the current lie. While the points are being called, the points icon will be represented by flashing the arm of the required lie in yellow. Once the points have swung to the required direction and have been detected the flashing will stop and the points will be shown in steady grey.

The points can be locked into their detected position by clicking on the curved arm of the points with the Right Mouse Button. This will be indicated by flashing the non detected arm red.

Releases:

A release is given by simply clicking on the release icon. The release will flash yellow until it is taken. At this time the icon lever will flip over and the release will be displayed as steady yellow. When the release is given back to control the icon will again flash yellow. If the Operator ignores this visual prompt, then a text prompt will be issued after 15 seconds informing the operator that the release can be taken back.

Menu Buttons:

Along the Right Hand side of the display is a set of soft buttons. These provide additional facilities not directly available by clicking onto the screen layout. These buttons were chosen rather than the traditional pull down menus as buttons can be highlighted to show when a particular function is activated.

The function of these buttons are as follows:

Blocking to All Trains:

Clicking on this button allows the user to Block Tracks by clicking on them with the Right Hand Mouse Button. Both straight tracks and points tracks can be blocked in this manner. Clicking on tracks which are already blocked removes the block. The Block Setting function is terminated by again clicking on the 'Block to All Trains' button, or by clicking on any track with the Left Mouse Button (e.g. when a route is attempted to be called).

When a track is Blocked the system will stop any routes being called across this track and it is indicated by flashing the track icon red.

Blocking to Electric Trains:

Similar to the 'All Trains' Block, this function only stops a route being called across a track if the route is for an electric train. This is particularly useful when the overhead is unavailable, thereby stopping electric trains from using the track, but still allows Diesel hauled trains to use it. The train type is determined from the first character of the train ID. Any unknown train is assumed to be an electric.

If a route is set through an 'Electric Blocked' track, and there is no train to determine if it is for an electric train, then the route will be automatically queued until an approaching train is detected. At this stage the system will determine whether to call (for a diesel train) or cancel the route (in the case of an approaching electric train). At no time will a clear signal be restored in the face of an approaching train. An 'Electric Blocked' track is indicated by a flashing purple track.

Shunt, Call-On, and Warner moves:

By default, whenever the Operator sets a route the system will call this as a Main Route, unless the only route available is a Shunt Route, in which case it will call it as a shunt route. However, if one of the other special types of signalling move is required (e.g. as a warner or call-on move), then the Operator must first click on corresponding menu button first. This special operation is one-shot in that the system will revert back to using the default mode after the signal is called. Note that when a long Warner Route is selected, then only the very last signal is placed into this restricted mode.

Information Displays:

Signal Positions:

When this button is pressed, all signals are displayed, not just the active ones. Signals which are red and not part of a route are shown in the dull grey to avoid distraction.

Level Crossings:

When this button is pressed, all Level Crossings and their names are displayed, not just the ones which are in an alarm state.

Status of Tracks, Points, Signals, and Releases:

These buttons allow the Operator to obtain the dynamic field status, including the object's identity. After clicking on one of these buttons, the Operator can either click on the object of interest, or click on the station name to get a list of all such objects at that station - after which one is selected.

When in this status display mode, the Operator can continue to select another similar objects to determine their individual status. This function remains in operation until the Menu Button is de-selected.

Why? Button:

Whenever the Operator makes a mistake, or a route is attempted to be set that is either illegal or can only be queued, then the system prepares a message indicating the cause. This message however is not brought to the attention of the Operator because in most cases the cause will be quite obvious (e.g. Route had to be queued because there was a train in the way). However, if the Operator wishes to know the cause of the above, then clicking on the Why? button will display the cause as a detailed and meaningful message.

Alarms:

Whenever an Alarm or Prompt Message is produced, an Alarm Box showing the Alarm Message is displayed. After displaying the alarm the Acknowledge Button within this Alarm Box is clicked and the next alarm message is displayed if one is waiting. When no more alarms are to be displayed, the Alarm Box is automatically removed from the screen.

If the Operator prefers to keep the Alarms Box displayed, or if it is required to check on an old alarm (the Alarms Box holds the last 100 alarms), clicking on the Alarms Button will redisplay the Alarms Box.

Set Train ID:

When a train enters the system it may be necessary for the Operator to enter its identity. This is not required if the train has come from another operator's territory, or from territory monitored by the Train Describer as its identity will be automatically passed from another WorkStation. The train's identity is set by the operator by first clicking on the 'Set Train ID' button, and then onto the required train. This process will bring up a list of known trains in the expected direction of travel. If the train is in the list then it can be selected. If however the train's identity is not in the list, then the Operator can click on the Keypad Button which brings up an alphanumeric keypad for entering the train identity. This identity will then be added to the train list for future selection.

Train identities remain in this train list unless they are not selected for one month after which time they will be removed from the list. This keeps the train list to a workable minimum by only holding the most frequent trains.

As well as renaming trains, the Operator can also preset a train identity by selecting an unoccupied track rather than a train. When a train subsequently occupies this track it will pick up the new identity. This feature is often used where trains are due to turn back at terminal stations or balloon loops.

Train Directory:

The system keeps a record of the time that each train reaches predetermined recording points. The resulting train run information can be displayed by clicking onto the Directory Button which brings up a list of all trains in the system (not just trains in the operator's territory). The Operator can either select one of the trains from the list, or can directly click onto the train icon from the screen layout to bring up a train run Directory Listing.

This train run Directory Listing is dynamic and will be updated as the train records arrival and departure times. Five of these train directory reports can be displayed simultaneously.

Event Replay:

All operator actions and all messages received by the operator's workstation (as received from the LAN), are logged to disk together with time of day information. Over time, this replay file builds up a complete history of what is happening on a particular WorkStation. One Replay File is maintained for each day, each file being kept on-line by the system for one month[6].

When required this Replay File can be replayed back in graphical mode and/or text mode onto another (off or on-site) PC to see exactly what sequence of events took place. This is of immense benefit in the case of both operational incidents and technical faults. This facility has been used extensively in the Brisbane UTC system as previously no automatic capture of incidents was possible.

The Replay Controller allows the user to search up to a particular time or event, playing at normal or accelerated speeds, single stepping through events, and decoding of each individual event as required.

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[6] These replay files can be kept indefinitely off-line as required.

### 4. *Direct Traffic Control Requirements*

QR DTC is a method of rail traffic control via voice radio for non-signalled or Dark Territory operations. It is a cost effective way of controlling trains in Dark Territory when compared with a system such as ATCS level 10, which is too expensive and too complex for controlling large, remote areas as in Queensland Rail's case. It is also easier to use than Train Order which gets complicated when altering authorities involving crossings with other trains.

QR DTC is based on DTC (Direct Traffic Control) as implemented in 1984 by the Southern Pacific RailRoad in the USA. It has been modified and semi-automated to run on PC's and also to concur with QR rules and regulations regarding Dark Territory working. It embodies the principles of CTC with wayside signals replaced by Control Points (Block Limit Boards) and avoids the complexity and inflexibility of Train Order which has been traditionally used in areas of Dark Territory.

One of the cornerstones of DTC is in the direct communication (or transmission of authorities) between train controller and driver. No intermediate communications are necessary as is generally the case in train order working. The direct communications is augmented by the fact that DTC authorities are kept simple - there are no explicit crossing, passing, or permissive working authorities. These fundamentals ensure DTC operations are kept fast, reliable, and highly flexible in meeting the needs of traffic staff.

The need for direct Control to Train communications also necessitates the provision of dedicated and reliable radio systems designed for saturation coverage along the length of the DTC territory.

The office equipment consists of an IBM compatible PC with a VGA colour monitor and mouse running under DOS. An 80 column printer is also used as an event logger for hard copy of significant events. In addition, logging to a disk file is used to continuously record all valid and invalid operator actions.

The on-train equipment consists of a driver's terminal (an IBM compatible Laptop PC) which is used to decode and display the Authorities, and the train radio. The driver's terminal is a conventional, off the shelf laptop PC which is enclosed in a 'Cradle' packed with foam rubber to ensure that most vibrations and shocks are absorbed.

Control to train communications are typically via a dedicated UHF radio system, with on-board VHF radio and WaySide Telephones as backup.

It is important to note that both the DTC hardware and software are non-vital in a Signalling sense and safety is vested in the Train Controller and Driver by virtue of the QR DTC procedures.

## 5. *Characteristics of QR DTC*

### *General*

The safety of QR DTC operation is the responsibility of the Train Controller and Driver rather than interlocking equipment and is assisted by the secure transfer and ownership of authorities to use or release absolute block sections of track between the Train Controller and driver and vice versa. This transfer is done in three steps by radio communications. It involves the exchanging of 8 digit codes generated by the software in the Train Controller's PC and the driver's terminal in the locomotive of the relevant train.

### *Field Equipment and Layout*

In QR DTC an Absolute Block is defined to be from 'Starter' to 'Home' and similarly from 'Home' to 'Starter'. Many such blocks can be chained together in the one DTC proceed authority. The Field equipment consists of reflectorised signs (Block Limit Boards (BLB's)). For consistency the BLB numbering is identical to that used for signal numbers in simple CTC Crossing Loops, i.e.

- Down BLB numbers are Odd,
- Up BLB numbers are Even,
- BLB's 16 and 25 are always on the Main or Straight Road
- BLB's 18 and 23 are always on the Loop or Offset Road

### *Train Controller's PC*

The Train Controller's PC presents a graphical layout of all DTC stations in the relevant area of control with a menu of all the valid commands in the right margin. The options on the menu will change depending on what valid moves are available to the Train Controller when a particular Train is selected from the screen.

A Train Controller can put a Train onto QR DTC Territory in one of two ways:

1. In the case of a Train which is fitted with a driver's terminal the driver will pass to the Train Controller a Start-up Code which when entered into the Controllers PC will create a train at the Station Specified by the Start-up code.

2. If a Train is not equipped with a driver's terminal and needs to enter QR DTC Territory then the Train Controller can simply place a train on his area of Control by selecting a train from a screen based menu of valid train numbers. A similar menu is used to select the driver of the particular train.

If a train requires to go from Station A to Station B then the Train Controller is required to Click his Mouse on the Head of the Train and then Click the mouse on the proposed Destination of that Train. The Software will then generate a Command Code and the following steps are taken to inform the driver of their Destination:

1. The Train Controller will issue the 'Command Code' to the driver over the radio.

2. Once the driver enters the Command Code into the driver's terminal, it generates a 'Drivers Code' which is given to the Train Controller over the radio.

3. After validation by the train controller's PC that the driver code belongs to the correct train at the correct location, it generates a 'Display Code', which is given to the driver, thus causing the authority to be displayed on the laptop in the Train Cab.

The Codes being passed contain information about the Driver, the Train Number, the Station the Train is at, and the Block Limit Board that the train is facing at that station. If at any time the codes do not match, the operator (the Train Controller or the driver, depending on which code is found to be erroneous), is prompted to re-enter the code.

It is to be noted that the Authority is only Displayed to the driver after the third Step, by which time the software at both the control centre and the Train have determined that the authority belongs to the right driver and the right train at the correct location.

***Driver's Terminal***

When a Train is about to enter QR DTC Territory, the driver turns on the laptop PC in the locomotive. Once the laptop boots up, it prompts the driver to confirm the date and time with the Train Controller to ensure that the driver's terminal has the same date and time as the controller's PC. Once the date and time have been entered, the driver is prompted to select his/her name, train number, Station the train is at, and the Block Limit Board that the train is facing. The driver's terminal then generates a Start-up Code, which the driver relays to control. The controller then enters this code into the train controller's PC to create a new train. The driver's terminal also uses this information to create a Text Graphic representation for the driver's benefit.

The release of absolute blocks is the responsibility of the driver and can be done in one of two ways:

1. The blocks may be released verbally over the radio by the relevant driver informing control that the train is facing a particular Block Limit Board at a nominated station.

2. A driver can generate a 'Release Code' by using the driver's terminal to indicate where the train is currently located. This 'Release Code' is then passed to control.

For the forthcoming QR DTC trial, the method used will be up to the mutual agreement of the train controller and the driver. In both situations, the train controller will update the train information to indicate the current location of the train.

## *6. Development of QR DTC*

QR DTC has been developed over approximately three years with a significant input from the client (QR's Freight Group), the Safeworking Manager and staff, the signalling section, and the Training & Development Division. Train Controllers have also had continuous input into the design and implementation of the method of working and the types of authorities to be used.

Trials of the driver's terminal have taken place at the Acacia Ridge Freight Terminal to ensure that the Laptop PC can withstand the rigours of the locomotive environment. It has been found that the cradle arrangement is acceptable for the trial period, but design improvements will undoubtedly be incorporated into future installations.

## 7. *Advantages of PC Operation*

Each proposed authority is automatically cross checked against all existing authorities prior to issue and rejected if in error. Each proposed authority, release or reduction of block authority is displayed in text form on the screen of both the Train Controller's PC and driver's terminal, resulting in a highly formalised yet straight forward transfer of authorities between the controller and the driver.

All current authorities, train locations and blocked sections of track are displayed in a graphical track layout form on the Train Controller's PC, thus providing the controller with a 'Dark Diagram' display of activity in his/her territory.

The provision of a PC for each locomotive as well as for the train controller permits the generation and validation of message codes for the block authorities and releases. These can be transmitted quickly and securely by voice communications between train controller and train crews. If warranted, alternative forms of data transmission, for example DTMF tones over-layed onto the train radio system, are also possible - but care must be taken so that the total system availability is not reduced.

The provision of a PC in the locomotive ensures the current authority is displayed all times, thus reducing the possibility of Driver error in relation to the extent of his/her authority.

With the use of a mouse in conjunction with the train controller's PC, very little typed input is required. Basically, for normal movement authorities, only one set of codes has to be typed per authority. All other aspects of movements, authorities, and maintenance are carried out via the mouse and screen based menus.

Password access is necessary to permit special authorities which permit a train to enter an obstructed single line block, or one containing a failed or divided train. The train control supervisor has access to such passwords and therefore provides an additional check in those potentially dangerous moves. Special authorities usually involve the authorisation of two trains into the same block as is required to assist a disabled train or divided train.

A printed event log is produced showing all block authorities issued by the Train Controller and all Block releases given by the driver. A file is also kept on disk showing all controller activity. A separate file is produced for each day.

A disk file replay facility is available for both the train controller's PC and the driver's terminal. This replay file records all input to the DTC equipment and allows for off-line analysis of incidents.

## 8. *Conclusions*

The success of the QR UTC system within the Brisbane Urban area has seen this system become the strategic control system for operation of all power signalled areas throughout the state.

When testing of DTC is completed, it is expected that this system will become the strategic control system for operation of all non-signalled areas throughout the state.