SCATS

As a computer–based area traffic management system, SCATS[1] is a complete package that includes hardware, software, and a unique control philosophy.

The system operates in real–time, adjusting signal timings in response to variations in traffic demand and system capacity.

The purpose of SCATS, as with any area traffic control system, is to control traffic on an area basis rather than on an individual, uncoordinated intersection basis.

New Generation

SCATS is constantly improved and enhanced as new technologies become available. In response to customer needs, the Roads and Traffic Authority of NSW (RTA) has released the newest version of SCATS. This newest version, SCATS 6, provides far more flexibility for the decision maker, the Traffic Engineer, and most importantly the accountant.

Major enhancements include:

- Moving to a personal computer platform.
- Increasing the number of intersections that can be connected to one computer.
- Improving data collection resources and reporting facilities.
- Improving management and monitoring methods.

SCATS 6 is available in different configurations to suit specific needs and budgets. These configurations include:

- Full Real Time Traffic Adaptive.
- Fixed–time Plans.
- Dial–In, Dial–Out, which offers unique remote access to sites in outlying areas that need monitoring on a daily basis. This configuration reduces the need for constant visits to check operations.

Improvements to the new version are too substantial to describe in this booklet. However, details are available from the contacts listed on the back page.

SCATS has always been a real time adaptive traffic management system. Nothing has changed except the recognition of the variety of systems required by traffic engineers around the world, each with their own diverse traffic conditions.

This booklet describes SCATS in its most functional role, that of a real–time, responsive, adaptive traffic management system. Details of fixed–time plans, and Dial–In, Dial–Out configurations are available on request.

[1] Sydney Coordinated Adaptive Traffic System

RTA tyco Integrated Systems

Adaptive System Copes with Unusual Demand

Adaptive SCATS, unlike 'fixed-time' or 'semi-responsive' systems, requires no pre-calculations of composite signal timing plans. Logic and algorithms in the system's controllers and traffic control computer analyse real–time traffic data from vehicle detectors to produce signal timings that are suitable for the prevailing traffic conditions.

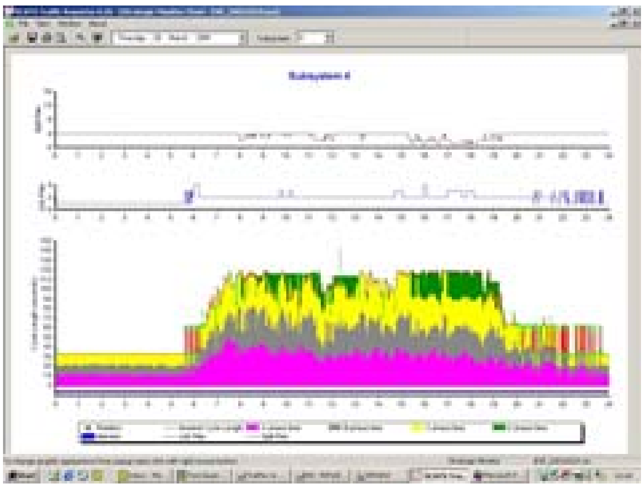
Many other area traffic control systems manage signals on a 'fixed–time' basis in which a series of signal timing plans are brought into operation at certain times of the day. Each plan determines the timing of individual signals, and the time relationship between signals is pre–calculated based on previously surveyed traffic conditions.

A 'fixed–time' system is generally unable to cope with unpredicted traffic conditions. SCATS 6 addresses this problem by improving decision–making capabilities built into the FTP system to compensate for this deficiency in fixed–time operation.

No Need to Update Timing Plans

Furthermore, as traffic conditions change with the passage of time, fixed–time plans become outdated. This requires resurveying the area and new signal timing plans calculated every few years. Experience has shown this procedure to be expensive and to require resources that are not always readily available.

As a result, either the development of new plans is deferred beyond the useful life of the old plans or 'ad hoc' changes are made to the plans and timetables, usually resulting in sub–optimum performance.



Adaptive alteration of Cycle Lengths and Splits over 24 hours .

More Responsive Control Method Required

The problems of 'fixed–time' systems suggest that a technique responsive to changing traffic conditions would be more appropriate as well as more acceptable to the motoring public.

SCATS Offers Real–Time Responsiveness

The implementation of a fully responsive system does not mean that the careful design of each intersection can be avoided. The present state of technology only allows for the real–time variation of signal timings at the intersections that have been designed to suit known or anticipated traffic requirements.

A degree of adaptability of the local design to varying traffic requirements is accommodated by a system such as SCATS. This is achieved by providing a variable sequence of stages and the ability to omit stages or movements from the sequence on a cycle–by–cycle basis, whenever there is no demand.

Four Modes of Operation

SCATS manages signals in the system using four operations modes:

- Masterlink
- Flexilink
- Isolated
- Flashing Yellow

The adaptive mode, known as Masterlink, provides the integrated traffic responsive operation.

In the event of failure of a regional computer or loss of communications, the local controllers can revert to a form of time–based coordination known as Flexilink. In this mode, adjacent signals are synchronised by reference to the power mains frequency or an accurate crystal–controlled clock, and signal timing plans are selected by time of day. Local vehicle actuation facilities are operational in this mode.

Signals may also operate in an Isolated mode with local vehicle actuation being the sole operating strategy.

The fourth mode is Flashing Yellow in which the normal signal display is replaced by flashing yellow displays on all approaches or flashing yellow and flashing red to different approaches.

Any Mode Can be Used

Provided communications are functional, signal operation can still be centrally monitored in Flexilink, Isolated, and Flashing Yellow modes. Any signal may be set to any of the four modes either by time of day or an operator using a SCATS workstation.

Volumes data is collected from all lanes at all junctions 24 hours a day.

Two Levels of Control

SCATS control of traffic is effected at two levels that determine the three principle signal timing parameters of traffic signal coordination; stage split, cycle length and offset.

These two levels are referred to as ‘Strategic Control’ and ‘Tactical Control’.

Strategic Control

Strategic Control is the top level of control that is impressed on a network of coordinated signals by the regional computer. Using flow and occupancy data collected from loop detectors in the road by the local controllers, the strategic algorithms determine, on an area basis, the optimum cycle length, stage splits and offsets to suit the prevailing average traffic conditions. This is carried out for adjacent groups of signals (usually one to ten in size), which are known as subsystems.

Subsystems

The subsystem in SCATS is the basic unit of strategic control. Each subsystem consists of one or more intersections and contains only one critical intersection that requires accurate and variable stage splits. The intersections in a subsystem form a separate group that are always coordinated together and share a common cycle length, inter–related split, and offset selection.

Stage splits for minor intersections in the subsystem are, by definition, non critical and are therefore either non–variable or selected by a matching process which selects splits that are compatible with the splits in operation at the critical intersection.

Subgroup Linking

To coordinate larger groups of signals, subsystems can link together to form larger systems, operating on a common cycle length. These links, which determine the offsets between the subsystems, may be permanent, or may link and unlink as needed.

This ensures that where traffic flow between subsystems is sufficient to warrant coordination the link is enforced but when one or more subsystems can operate more efficiently at a lower cycle time, the link is broken.

Degree of Saturation

The basic traffic measurement used by SCATS for strategic control is the degree of saturation on each approach or, more accurately, a measure analogous to degree of saturation. Inductive loop vehicle detectors placed in important approach lanes at the stop line of the critical intersections (and some detectors at other intersections) are defined in the regional computer database as strategic detectors.

The local controller collects flow and occupancy data during the green of the approach and, after pre–processing, it is sent to the regional computer and used (together with automatically self–calibrated saturation flow data for each detector) to calculate the SCATS ‘degree of saturation’, or DS.

The degree of saturation is defined as the ratio of the effectively used green time to the total available green time on the approach. The effectively used green time is the length of green which would be just sufficient to pass the same platoon of vehicles had they been travelling at optimum headways as in saturation flow conditions.

The algorithm is capable of producing values of DS greater than unity in congested conditions, enabling SCATS to deal effectively with over saturated traffic.

Effect on Cycle Time

Cycle time is increased or decreased to maintain the degree of saturation around 0.9 (user–definable) on the lane with the greatest degree of saturation. A lower limit for cycle time (usually 30–40 seconds) and an upper limit (usually 100–150 seconds) are specified by the user. Cycle time can vary by up to 21 seconds each cycle but this limit is substantially reduced unless a strong trend is recognised.

Effect on Stage Splits

Stage splits are varied by a few percent each cycle in such a way as to maintain equal degrees of saturation on competing approaches, thus minimising delay. The minimum split that can be allocated to a stage is either a user–definable minimum or, more usually, a value determined from the local controller's minimum stage length. The current cycle time and the minimum requirements of the other stages limit the maximum split, which can be allocated to a stage.

Offsets

Offsets are selected for each subsystem (i.e., the offsets between intersections within the subsystem) and between subsystems that are linked together based on traffic flow. In this way, the best offsets are selected for the high flow movements. Other links carrying lower flows may not receive good coordination if the cycle time is inappropriate. However, when traffic conditions permit the use of a cycle time that can provide good offsets on a majority of links, the system tends to maintain this cycle time even though a smaller cycle time would provide sufficient capacity. Optimal offsets on the heavy flow links minimise the total number of stops in the system, reducing fuel consumption and increasing capacity of the system.

Tactical Control

Tactical Control is the lower level of control that is undertaken by the local controllers at each intersection. Tactical control operates under the strategic umbrella provided by the regional computer but provides local flexibility to meet the cyclic variation in demand at each intersection.

Tactics essentially terminate green stages earlier whenever the demand for the stage is less than the average demand, and to omit stages entirely from the sequence if there is no demand.

Conditional signal group introduction is also provided. The local controller bases its tactical decisions on information from the vehicle detector loops at the intersection, some or all of which may also be strategic detectors.

Tactical Control is the Responsibility of the Controller

The tactical level of control is carried out in the local controller using exactly the same operational techniques as described for isolated operation for a local controller.

The degree to which tactical control is able to modify the signal operation is entirely under the control of the regional computer.

Tactical Control different to Isolated

A basic difference from isolated operation is that one stage, usually the main road stage, cannot skip and cannot terminate early by action of gap and waste timers.

This is because all controllers in a linked group must share a common cycle time to achieve coordination. Any time saved during the cycle because of other stages terminating early or being skipped may be used by subsequent stages or is added on to the main stage to maintain each local controller at the system cycle length.

Strategic and Tactical Control Together Equals Efficiency on the Street

The combination of strategic control, which varies the split, cycle time and offsets in response to gradual changes in traffic demand patterns, together with tactical control, which handles the rapid but smaller changes in demand cycle by cycle, results in a very efficient operation of the signals on the street.

Operator Control

SCATS provides the operator with a range of manual functions to override the normal automatic operation. These functions allow:

– Manual control of signal lamps to 'on', 'flash', or 'off'.

– Manual selection of link mode to Masterlink, Flexilink, or Isolated mode.

– Manual selection or alteration of split, cycle time or offset, either on an individual intersection or for a whole subsystem. (A group of intersections is typically 2–4 junctions.)
– A dwell facility that allows any signal to be held on a nominated green stage for as long as required.

A dwell manually forces the controller to the nominated stage via the shortest possible path, subject to all safety constraints being met and to remain there for a fixed period.

Variation by Timetable

SCATS also allows system operation to be varied by a timetable. Almost any function that can be executed manually can also be set up to occur at specified times on specified days. For example, in a central business district, pedestrian walks may be automatically introduced on business days, late shopping nights and other periods of high pedestrian activity.

Special Routines

A range of special routines is also available in SCATS that allows the user to define special operations to occur under special conditions. These routines are used to address requirements not covered by the general operation of SCATS. Features of this type enable every detail of signal operation to be tailored to meet the operational needs of each individual intersection. SCATS is the only system to offer such a feature.

Capacity

The capacity of a SCATS regional computer is 250 intersections.

Software is available in a variety of increments as follows:

– 0–16 intersections
– 17–32 intersections
– Subsequent increases in multiples of 32 intersections

For larger systems, a series of regional computers are networked under the control of a SCATS Central Manager computer.

Fallback Operation

Automatic Fallback

In the event of regional computer failure, loss of communications between the computer and any local controller, failure of all strategic detectors, or certain other local malfunctions, the affected intersections will 'fallback' to a user–defined mode of operation which may be either Flexilink (time–based coordination) or Isolated operation.

Coordination Maintained during Fallback

If specified by the user, fallback at one intersection will also cause other intersections in the subsystem to fall back and, optionally, intersections in adjacent linked subsystems. In this way, if Flexilink is specified as the fallback mode, coordination can be maintained between intersections affected by the failure.

The Controller is the Key

All data necessary for fallback operation is held in the local controller, i.e., local signal timings for Isolated operation and plans and schedules for Flexilink operation. A copy of this data is held in the regional computer so that it may be downloaded from the regional computer to the local controller in the event of it being lost. The clocks in the local controllers are periodically checked by the regional computer and adjusted as necessary.

Controller information data form.

System Hardware

Computer Platform

Distributed, Hierarchical System

SCATS is designed in a modular configuration to suit the varying needs of small, medium, and large cities. Personal Computers are used. In its simplest form, a single regional computer can control signals at up to 250 intersections.

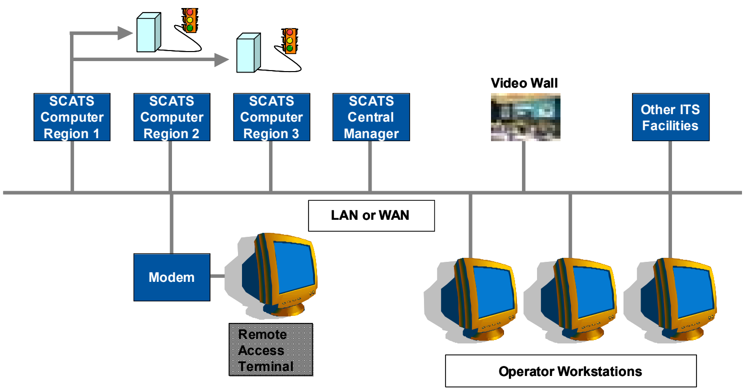
Expansion of the system is achieved by installing additional regional computers. For large systems, it is common to add a Central Management Computer to provide centralised access for data input, monitoring and traffic data collection, improved system management support, data analysis, data backup, fault logging and analysis and a system inventory.

These features ease the logistic burden of managing larger systems. A typical large system SCATS computer configuration is shown below.

Regional Server Computers

SCATS Regional Server operates on standard Windows NT computers. Asynchronous serial (multi–port) interfaces and modems (one channel per controller) connect the Regional Computer to the intersection communications lines.

Regional computers are usually located near the centre of the group of signals it controls to minimise the cost of communications lines.



A typical large system SCATS computer configuration.

Central Manager Computer

SCATS Central Manager operates on Windows NT using a standard personal computer. Communications with regional computers and workstations is via an Ethernet LAN or WAN. The Central Manager software can reside on the same computer as the Regional Server software.

User Interfaces

The Operator interface to SCATS is normally by personal computer acting as a workstation terminal and running RTA interface software.

Minimum requirement is 486DX or better with a 32–bit operating system (Windows 95 or Windows NT4). The graphical user interface requires a minimum screen resolution of 800 x 600 (Super VGA).

Computer workstations operate in the following modes:

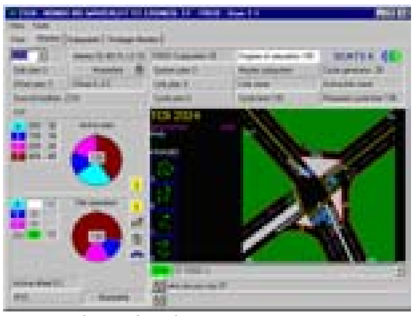
– Local mode, as a freestanding computer.
– Local network mode (accessing any computer on the LAN).
– SCATS workstation, providing access to the traffic control system and management subsystems provided by the Central Management Computer.
– Workstations may be connected via the LAN (e.g. thin wire Ethernet), via a terminal server, or direct to a regional computer.
– Field terminals (e.g. laptop) connected to a local controller.

Monitoring and Control Facilities

The full range of operator commands and monitoring functions is available from all workstations subject to the security access afforded to each operator as defined in the database. Passwords are provided for security purposes.

These facilities are provided from workstations at the control centre, any regional computer, and any intersection controller or remotely via modem. The information displayed includes:

For Intersections:	For Subsystems:
Lamps ON/OFF/FLASHING	Current splits
Current stage demands	Current offset plan
Detectors occupied	System cycle length
Cycle length	System detector data
Operational mode	
Alarms	
Stage running	
Time in stage	



Main Window displaying an intersection operation.

Graphical User Interface

A graphical user interface (GUI) replaces the earlier character–based screen. The main window, the intersection monitoring window, is illustrated above.

Data is entered in using forms, an example of which is illustrated below..

The Split Plan Editor is used to view or modify the split plans and related data or to lock, unlock or trim the active split plan.

Data is entered into the Split Plan Editor.

Graphics

The workstations support full colour graphics in a sizeable window.

Regional display

The Regional Display shows a map of the selected regional area with current traffic flow conditions.

Roads display with five different colours representing conditions from very light to heavily congested traffic.

Subsystem display

The Subsystem Display shows the selected subsystem layout together with an on–line graphical bar chart.

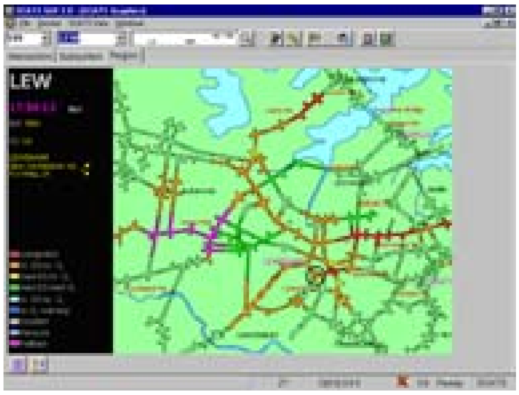
The chart represents traffic flow and traffic density as measured by strategic detectors.

Intersection display

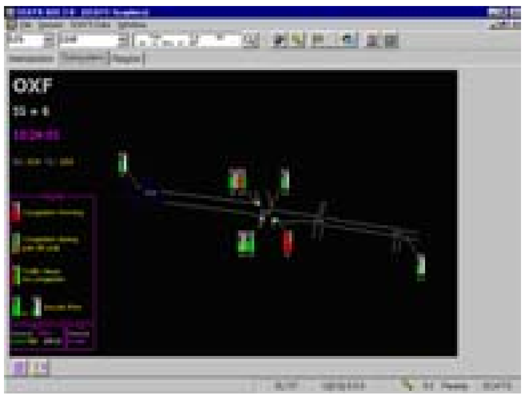
Intersection Display shows the intersection layout and stage design with real–time display of detector operation and stage greens.

On–Line Control

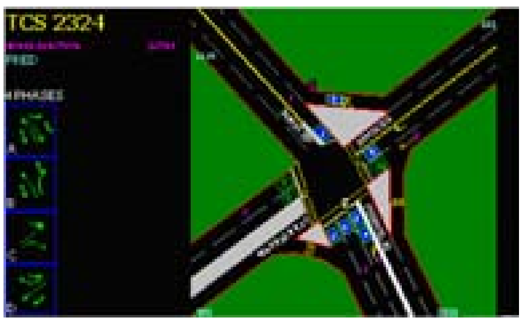
It is possible to display and change all adaptive control parameters from any system workstation while the regional computer is on–line, both by operator command and automatically by time of day. There is no need to take the regional computer off–line when altering data or re–configuring the dimensions of any data array. Manual control of any intersection is also possible from any system workstation.



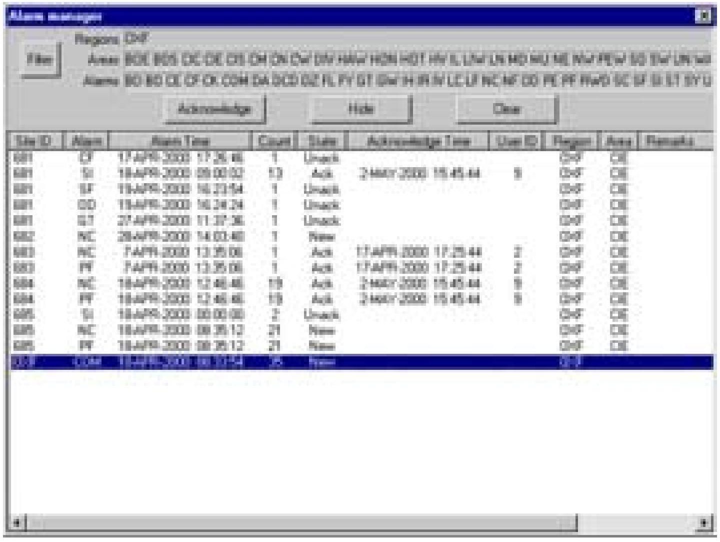
Regional Display.



Subsystem Display.



Intersection Display.



The Alarm Manager monitors system events and alarms.

Alarm Conditions

The system provides a comprehensive set of alarm conditions to warn the operator of all unusual or fault conditions.

These alarms are logged automatically on occurrence and clearance and can be queried at any time. Alarms are also provided for congested traffic conditions in each subsystem.

Local Controllers

Four Controller Modes

SCATS local controllers can operate in four modes. These modes can be invoked manually or automatically by the regional computer or at the local controller.

Masterlink Mode

In Masterlink (adaptive) mode, the regional computer determines the stage sequence and the maximum duration of each state and the duration of walk displays.

The local controller may terminate any stage under the control of the local vehicle actuation timers or skip an undemanded stage, unless prohibited by instruction from the regional computer.

The regional computer controls the stage transition points in the local controller subject to the local controller safety interval times being satisfied (e.g. minimum green, pedestrian clearance, etc.).

On completion of the transition to a new stage, the local controller times the minimum green and minimum walk intervals and then waits for a stage termination command from the regional computer.

On receipt of the command to move to the next stage, the local controller then independently times the necessary clearance intervals (eg. yellow, all–red) for the stage termination.

Communications errors or faulty operation of the traffic control computer cannot cause the local controller to produce dangerous signal displays such as short greens, short pedestrian clearances, short yellows or short reds as would be the case if the local controller depended on the regional computer for the timing of all intervals.

The termination of pedestrian walk signals is also under the control of the regional computer to allow the walk timing to be varied to match prevailing traffic conditions.

The duration of the walk signal cannot be less than the prescribed minimum walk.

Flexilink Mode

In Flexilink (time–based coordination) mode the stage sequence and the maximum duration of each stage and the duration of walk signal displays is determined by the current plan.

The local controller may terminate any stage under the control of the local vehicle actuation timers (gap, headway, and waste) or skip an undemanded stage unless prohibited by instruction within the plan. Flexilink is the usual fallback mode of operation.

Isolated Mode

In Isolated mode the state sequence and the maximum duration of each stage is as specified in the local controller time–settings.

The local controller may terminate any stage under the control of the local vehicle actuation timers (gap, headway, and waste) or skip an undemanded stage unless prohibited by the local controller personality. Isolated mode may be specified as the fallback mode of operation.

Flashing Yellow Mode

In Flashing Yellow mode the signals display flashing yellow to all approaches. Other flashing displays can available, e.g. flashing red/yellow.

Stage Sequencing

The signal cycle is divided into stages called A, B, C, etc., and these can be introduced in any defined sequence (eg. A–B–C–A).

Any stage can be skipped if no vehicle is waiting for a green on that stage (eg. if no vehicle is waiting for stage B, the sequence would be A–C–A).

In Isolated and Flexilink modes, the sequence is as defined in the local controller personality. In Masterlink mode, the sequence is determined by the regional computer.

Detection

Stop Line Detection

All detectors (both strategic and tactical) are normally located at or near the stop line (one in each lane).

The calculation of the degree of saturation (DS) relies on the detector being of sufficient length in the direction of traffic flow to ensure that large values of space are not measured under conditions of slow moving, closely spaced traffic (which would appear to be the same as light traffic widely spaced).

The detector must not be too long, however, as it would not measure any spaces when traffic moves freely. Research has shown the optimum length of the detection zone is between 3.5m–4.5m (11.48ft–14.76ft) depending on local traffic behaviour.

Strategic Detectors

Strategic detectors are located at the stop line in order to enable measurement of the use made of the green time by traffic at a point at which the traffic is controlled by the signal.

If the strategic detectors were placed remotely from the stop line, assumptions would have to be made about the flow rate actually achieved during the green period.

At any time when these assumptions were not valid, an incorrect green time would be allocated to the approach.

Tactical Detectors

Tactical detectors located at the stop line differentiate between the left turn, straight ahead and right turn movements at the intersection both by knowledge of the lane usage in lanes of exclusive use and by speed differential in lane shared by two or more movements.

If the detectors were remote from the stop line, it would not be possible to identify the intended movement (direction) of detected vehicles due to subsequent lane changing.

Additional detectors may be installed in advance of the stop line but, in general, this has been found unnecessary.

Detector Requirements

Tactical detectors should be provided on all lanes of an approach (or movement) that will benefit from tactical control, the minor movements being the most suitable.

It can be seen that approaches most requiring strategic detection are those least requiring tactical detection and vice–versa, resulting in the need for detection on most approaches.

In general, the approach lanes that can be left undetected are lightly used curb lanes on approaches which otherwise require strategic detection and at minor intersections on the 'main road' approaches which are not immediately upstream of a major intersection.

Detection is normally loop–based but newer SCATS systems have used video imaging detection.

The numbered boxes represent the vehicle detectors, coloured according state.

Communications

Data Links

The local controllers are connected to SCATS by standard voice–grade telephone lines or a dedicated cable network. In both point–to–point and multi–drop configurations, a single pair of wires is required.

Alternatively, fibre networks including ATM networks are often used.

Communications Mode

Messages are sent to, and a reply message received from, each intersection controller, every second.

In point to point mode data is transmitted varying speeds as low as at 300 bps full duplex where poor communications are encountered. The low speed rate required for SCATS communications allows for a high degree of tolerance in the reliability of the local communications network.

GUI Display

The following images demonstrate a few of the operator workstation screens.

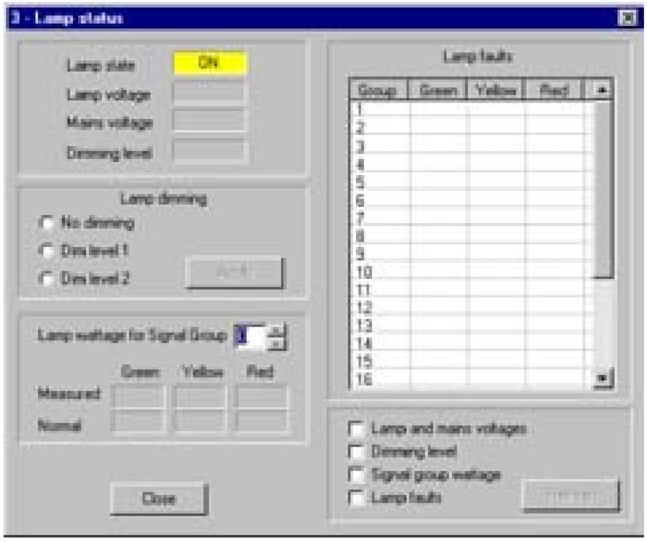
Main window

The Main Window allows operational data to be viewed or changed. Up to ten monitor windows may be open at the same time.

Main Window displaying an intersection operation.

Lamp Status Window

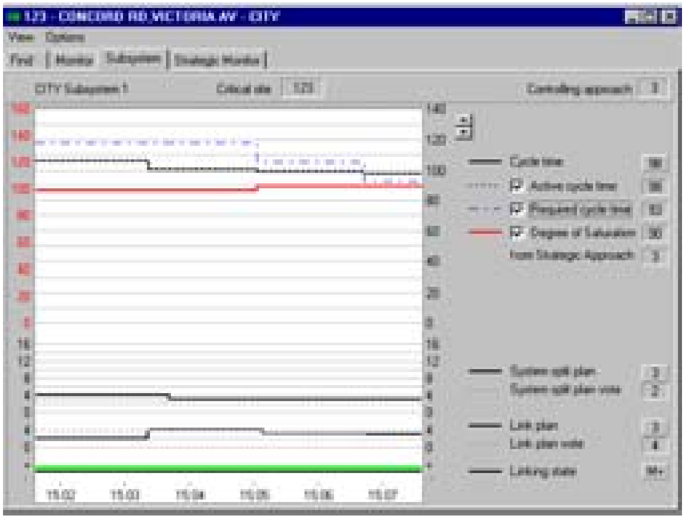
The Lamp Status window gives access to all conditions relating to the lamps.



Lamp Status Window.

Subsystem

The Subsystem window accesses the subsystem window, allowing the operation of the subsystem to be monitored.



Subsystem window.

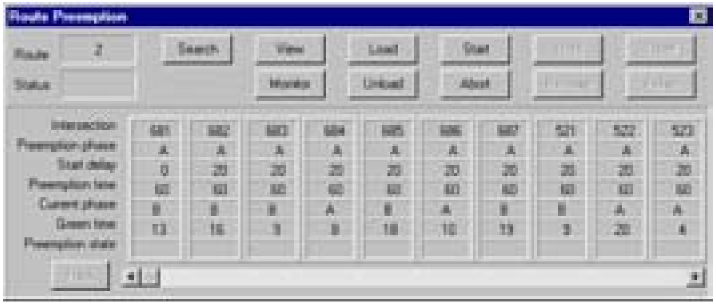
Password Maintenance

Provided the old password is known, a new password can be allocated.

Change Passwords easily.

Route Pre–emption

The View/Route Pre–emption menu item displays the Route Pre–emption window. Route Pre–emption is the sequential timed introduction of a green window along a route.



Route Pre–emption window.

Typical Capacities of SCATS

The table below lists the typical capacities of a SCATS system in Masterlink (adaptive) mode.

Options

– Database & support software.

– Automatic network travel time (VIS) system.

– Controller personality production software.

– Variable message signs.

– Congestion/Incident Reporting.

UTC Masterlink Mode
(per regional computer)

Signalised Locations	250
Stages per intersection	7
Sub systems	250
Occupancy detectors	4,000
Tactical/counting detectors	4,072
Adaptive Cycle Length range	20 > 190 sec
Adaptive Stage Split range	5% > 95%
Adaptive Offset range	–127–+127 sec
Special Facility Flags (per intersection)	22
Timetabled routines	250
Fallback plans	11
Fallback schedules	20
VIP and Emergency Vehicle Pre–emption	
Fault Logging	
Event Management	

List of UTC SCATS Systems

	Regions	Junctions
Australia		
RTA, Sydney, NSW	32	2449
VicRoads, Melbourne, VIC	25	2078
DRT, Adelaide, SA	12	560
Adelaide City, SA	1	104
Perth, WA	7	560
Canberra, ACT	3	169
Darwin, NT	3	50
Hobart, TAS	3	88
New Zealand		
Auckland City	3	183
Manukau City	2	95
North Shore City	1	65
Waitakere City	1	37
Dunedin	1	51
Wellington	1	97
Christchurch	3	230
Whangarei	1	16
Hamilton	1	36
New Plymouth	1	12
Nelson	1	12
Palmerston North	1	16
Rotorua	1	4
Timaru	1	12
Total Australia/New Zealand	105	6,924

	Regions	Junctions
International		
Guangzhou, China	1	40
Hangzhou, China	1	25
Pudong, China	1	6
Shanghai, China	8	800
Shenyang, China	2	98
Shijiazhuang, China	1	7
Suzhou, China	1	115
Tianjin, China	1	72
Yichang, China	1	22
Kowloon, NT, Hong Kong	8	607
Sha Tin, Hong Kong	1	75
Victoria Island, Hong Kong	1	70
Bandung, Indonesia	2	117
Jakarta, Indonesia	1	45
Kuala Lumpur, Malaysia	1	98
Sandakan, Malaysia	1	11
Seremban, Malaysia	1	40
Cebu, Philippines	1	93
Manila, Philippines	4	404
Singapore	16	1525
Dublin, Ireland	2	301
Tehran, Iran	1	50
Mexico City, Mexico	1	310
Delaware, USA	4	45
Detroit, CA, USA	6	401
Durham, NC, USA	1	20
Minneapolis, MN, USA	1	65
Suva, Fiji	1	12
Total International	71	5,474

Further information about SCATS, Tyco, or any of our products; please visit our web site at www.tycoint.com or contact:

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Worldwide Totals

Cities:	50
Regions:	176
Junctions:	12,398

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SCATS