NXSYS Subway Signalling Simulator

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NXSYS is a signalling and NX/UR Interlocking simulator application designed to the signalling and circuit styles and standards used in the New York City Transit System throughout the second half of the twentieth century. It facilitates learning about classic relay-based signalling and switching by actually controlling moderately complex (simulated) arrangements of tracks and signals the way they are controlled in real life. **NXSYS** facilitates analysis and observation of, and experimentation with, signalling behavior right down to the level of individual electrical relays. This document contains not just usage details of this application, but extensive information on all types of signals and related concepts as employed on the New York system (and, generally, many other rapid transit systems and other railroads).

NXSYS is currently available in two versions:

- **Version 2 for Microsoft™ Windows™**, (2016, 2022–). Version 2 features arbitrary two-dimensional track geometry and two real New York interlockings in addition to ports of the Version 1 didactic ones. There is a Track Layout editor (**TLEdit**), but no logic compiler. Version 2 (either implementation) also includes several new interlocking features (e.g., traffic levers).
- **Version 2 for the Apple™ Macintosh™/OS X**, "**NXSYS/Mac**", (2014–). Compatible with Version 2 for Windows, including **TLEdit**. **NXSYS/Mac** features a couple of additional frills, such as a new style of Full-Signal Displays, and has its own help document (describing differences only) in its **Help** menu.

Version 1 is no longer available and no longer supported. Its interlocking sources are not supported. Its attractive Cab View feature is not available in Version 2, because the problem of simulating an arbitrary 3-D world credibly and attractively is too large. There is no more relay compiler; modern processors are fast enough to obviate it.

The OLE scripting (NXCTL/NXScript) system has been retired. No one, including the author, ever expressed enthusiasm for it, and it is difficult to test and maintain.

There are three relevant World Wide Web pages:

- https://BernardGreenberg.com/Subway on my personal site. This is the official page, and where important news and new versions will be announced. This is currently the official download site. There are YouTube demo videos cited there.
- https://github.com/BernardGreenberg.com/NXSYS, the now-official source repository for both versions, promised to be buildable and runnable on both systems. I don't know right now if I will post executables there. This site is most likely to survive me.
- https://www.nycsubway.org/wiki/NXSYS,_Signalling_and_Interlocking_Simulator on nycsubway.org, which was the first download home of this software.

Please also visit Subway Signals: A Complete Guide, by this author, for an alternative introduction to (classic) New York City Transit signalling, part of the vast, wonderful nycsubway.org of David Pirmann (with many other contributors).

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Note that **Command** is used on the Mac almost everywhere **control** is written below (the default assumption being MS-Windows), as is common on Windows applications ported to the Mac.

Note that azure text can be hovered over to pop up definitions of the terms so highlighted.

1. Introduction

An **interlocking** is a collection of railroad (or subway) tracks and signals (what are called "traffic lights" for automobiles) that work together with a person controlling them to effect safe train movement. It is so called because the controls of these items are so interlocked that only safe sequences of moves and states are possible. The controls appear on a "panel" or "interlocking machine" in a **tower,** operated by a human **tower operator** (formerly "towerman"). The panel looks like a model of the tracks being controlled with buttons, switch keys and lights on it. In earlier times, a mechanical frame with actual mechanical levers, physically interlocked, was employed. In modern interlockings, the physical buttons and switch keys are not mechanically interlocked, but their effects and operation are restricted to safe moves by electrical logic.

Interlocking is a kind of counterpoint for subway tracks; each track adds about as much complexity as a line of a fugue. The game is to sufficiently understand the complex interactions between signals, switches, and trains, as must a real tower operator, to be able to operate the the interlocking at all.

This application, **NXSYS,** simulates entire interlockings, not just the panel, but all the logic implemented in electromechanical relays, relay by relay. Relays are still used in many interlockings worldwide as well as in New York. Before the twenty-first century, all interlocking logic in New York was relay logic, and most remains so.

What you will see when you read in a file is the "panel" of a moderate-size interlocking under your control, representing hundreds (or thousands) of feet of an imaginary (or real, in some scenarios) subway line.

The track board is designed to be as similar as possible to a real "NX/UR" panel, the kind in use in New York City since the 1950s and still being installed, an object of the author's intense intellectual concentration during his youth. You can move imaginary trains around with the mouse, control the "traffic lights" (i.e., signals) and track routes, and see how they all interact.

NXSYS does not simulate any particular interlocking, but rather, "runs" simulations of particular interlockings read in from files defining them. Currently, five such sample interlockings are supplied. These files define the track and signal layout of the interlocking, and all its logic as traditional relay-logic circuitry.

A major reward of **NXSYS** is much like that of flight simulators: learning the rules of interlocking hands-on without worsening transportation chaos in New York City or entering upon tracks or other dangerous terrain. The interlockings implemented in **NXSYS**, like any other NX interlockings, also provide the additional reward of watching them figure out how to work themselves in a safe order in response to your routing requests.

NX stands for "entrance-exit," the generic technique of selecting routes by choosing their endpoints, invented in 1937 (and a trademark of General Railway Signal, Inc., present-day successor Alstom Corp.) which is what NXSYS implements. **UR** is "Union Route," the trademark of the Union Switch and Signal company (which signaled the IRT) for their NX interlocking implementation, which is slightly different than the GRS (BMT) "NX" implementation.

As the further use non-technical language such as "traffic lights" is undesirable, please proceed to Definitions at once. You do not have to understand them all at once. Many critical definitions are available as hyperlinks throughout the document. Use ordinary browser controls to navigate it.

1.1 Definitions

As these terms are used throughout, it is important that you learn them. These are standard railroad signalling terms, not terms peculiar to New York or **NXSYS.** Some of the more critical and non-obvious ones are available as hypertext links like this throughout the text. The terms are not listed alphabetically, but in order of importance.

Signal	A "Subway traffic light." Formally, an array of colored lamps whose configuration (or **aspect**) (different colors being lit or dark) convey information about routes and the safety of the track ahead (or **indication**, i.e., the meaning of the aspect)to train operators. See The Purpose of Signals for a detailed consideration.
Switch	A track device by which a train can go from one track to another; the place where two tracks join. Non-technical people sometimes call it a "switch-track", and technical people a "turnout." In the United Kingdom, they say "points", although in the US, that refers only to the tips of the moveable part.
Track Section	(or track circuit) A length of track between, more or less, two signals (actually two insulated joints.) All signal-controlled track is divided into track sections.
Interlocking	A collection of signals and switches, with associated track and their control equipment, so interlocked with each other as to be operable only in safe and logical sequences of operations.

IJ ⟶ Traffic IJ

Track Section o Track Section o Track Section
Signal   Signal

IJ = "Insulated Joint" in track.

Tower	A room or building at a given interlocking with the control apparatus for it, from which the tower operator controls it. Usually, the relevant track is visible from the tower.
Tower Operator	The person in the tower controlling the interlocking.
NX	For "e**N**trance-e**X**it." A type of interlocking control where routes are specified by identifying their endpoints. See Basic NX Operation.
Called	(or Requested) A signal is called, or requested, if the tower operator allows it to be other than red.
Clear	A signal is "clear" when it is not red, and permits movement.
Occupied	A track section is "occupied" if there is any portion of a train in any of it. The opposite is "vacant."
Home Signal	A two-headed signal under control of the interlocking/tower operator as well as track occupancy and other conditions. See Types of Signals. Home signals are said to be *absolute* because their stops cannot be driven down by automatic key-by.
Automatic Signal	A signal controlled only by train movement, i.e., not under the control of the interlocking and tower operator. See the discussion under "Types of Signals"
Approach Signal	A single-headed under control of the interlocking, as well as by track occupancy and other conditions. Unlike a home signal, it never protects a switch or potential conflicting movement. See Signal Types and Approach locking.
Dwarf Signal	A low, interlocked signal with only red and yellow lenses. Dwarf signals are used to direct low-speed reverse and yard movements. See the discussion under "Types of Signals" and the section on control lengths.
Marker Signal	A signal with only red lights, more or less the subway equivalent of a "Do not enter" sign.
GK Light	(for siGnal indiKator) — the symbol on the panel representing a signal.
Insulated Joint (IJ)	A small section of an insulating substance, now usually fiberglass or fiber, electrically separating two track sections from each other.
Station number	A number indicating physical location of a signal or IJ, in 100's of feet from an arbitrary-selected reference point.
Lever number	A number used within the context of an interlocking to talk about a switch or signal under its control. See lever.
Diverging route	A path diverging from a main track via a switch, i.e., when a switch "has been thrown."
Main route or	normal route The opposite of diverging route, the "not thrown" path.
Points	The very tippy-toes of a switch that swing back and forth against the main track when the switch moves. On the interlocking panel, where the switch intersects the main track.
Lever	A control for a switch or signal, in former times an actual, physical lever. The lever for a signal normally forces it to be red, and can only *permit* (request) it to be otherwise, that is, clear, if operated. In an NX interlocking such as **NXSYS**, levers are imaginary and simulated by relay logic.
Trailing-point	switch A switch, when viewed from a certain track in a certain direction, which merges movement into that track in that same direction. If approached in the opposite direction on the same track, it would be a facing-point switch.
	switch A switch, when viewed from a certain track in a certain direction, which allows a choice of

Facing-point	tracks for movement in that same direction. If approached in the opposite direction on the same track, it would be a trailing-point switch.
Control length	of a signal. That length of track beyond the signal, starting at it, which "controls" the signal. That is, if there is a part of a train anywhere within it, the signal will be red. See the section on control lengths.
Overlap	(of control length). Control lengths often (always, in New York) extend from the signal to which they belong up to and beyond the next signal. The portion beyond the next signal, which coincides with the near end of that signal's control length, is called "overlap."
Route	A cleared path for a train over an interlocking, from an entrance point to an exit point. See Basic NX Operation.
Entrance	The location (actually always that of a signal) at the beginning of a route. The route is initiated by the tower operator by pressing the button at (in **NXSYS**, mousing) the GK Light of the signal there.
Exit	The location at the end of a route. Routes in an NX (eNtrance-eXit) interlocking are selected by choosing an entrance and an exit. There is always a signal at an exit.
Exit Light	A white light on the interlocking panel that lights up at each potential exit when an entrance is selected (a route is initiated). Initiation at signal 22 offers exits at signals 32 & 34
Initiate	To begin the process of selecting a route by choosing the signal at its entrance (by mouse, in **NXSYS**). See Basic NX Operation.
Entrance Light	A white light on the interlocking panel that looks just like an exit light, which lights up at the point of initiation when an exit has been selected and the route is determined.
Complete	To finish the process of selecting a route by choosing the point of its exit (by mouse, in **NXSYS**).
Cancel	To dis-establish an initiation or route or restore the lever of a signal to normal, forcing the signal red, all the same operation in an NX interlocking, accomplished in **NXSYS** by clicking left on the initiating signal.
Grade Time (GT)	A signal which is normally red, and is cleared by trains approaching it sufficiently slowly. See the section Time Signals.
Station Time (ST)	A signal which, when approached sufficiently slowly, "cuts back" its control length, allowing trains to close in on each other. See the section on Station Time.
Approach locking	A technique whereby the interlocking does not "believe" that a signal is not a potential dangerous source of trains, even if cancelled, when there is a train in front of it. See the later section on approach locking.
Time locking	A technique where approach locking is released after a long time interval has passed. See the later section on approach locking.
Auto-cancel	The automatic cancellation of a signal and a route by train motion past it. See Auto-cancel and Fleeting
Fleet	To effect a signal initiation such that subsequent train motion does not cancel it or its route. See Auto-cancel and Fleeting
End-to-end	(or "through routing") A feature where by several signals may be initiated and their routes completed by initiating the first and completing the last. See Basic NX Operation.
Train Stop	(or stop or trip) A trackside device associated with a signal whose function is to trip a train if the latter tries to pass the former when it is red. Stops are (optionally) represented by little red (or yellow) triangles in **NXSYS**, and can be seen in caricature in the Full Signal Display. See Train Stops.
Trip	What a raised stop does to a train, causing a full emergency brake application, hopefully bringing the train to a screeching halt. As a noun, same as train stop.
	A feature of automatic signals and approach signals that allows a train operator who brings the
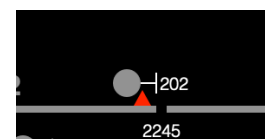
Automatic Key-By (AK)	train to a creeping halt to pass a red signal: the train passing the signal at creeping speed drives the stop down.
UR Exit Feature	(Not a standard term, but a standard UR feature) Being able to choose a route by choosing entrance and exit signal buttons, with no need for special exit buttons, or in the case of **NXSYS,** clicking on exit lights. In fact, General Railway Signal's "NX" (as opposed to UR) panels have used this feature for some years now.
Relay	An electromechanical logic element consisting a set of electrical switches (or "contacts") operated simultaneously by an electromagnet. See the full discussion for more information.
Call-on	A manoeuver where the tower operator offers a special indication for a train to close in on another train and pass a red home signal. The tower operator must take special action, a special indication on the signal is given, and the train operator must press a button on the signal to lower the stop. See call-on.
Off-side	Refers to a train stop intended for a train moving in the other direction than a movement under discussion. Such stops have to be cleared for movements in the direction under discussion.
Auxiliary Switch keys	(or "Switch test keys") Miniature levers on the interlocking panel which allow direct, manual call of switches. See the section on them.

1.2 Getting Started

Starting up the simulator from Windows leaves you with a black board and one meaningful command option. You must read in the definition of an interlocking, which includes track and signal layout and control logic, from files. We supply the definitions of five interlockings with **NXSYS.** Please see Supplied Interlocking Scenarios for a discussion of them. We recommend Progman St. for those new to this program or new to the subject matter.

Read in the **progman.trk** file using the **File|Open** command on the menu bar. (You may also place its pathname as a command argument on the Windows command line in a start up icon for **NXSYS** for automatic startup of a given layout.) It loads whatever other files it needs from its folder.

Now you will see the control panel for Progman St. Interlocking. Proceed with caution to What you see before you.

If you have not seen the demo system, try opening **demo1-Progman.xdo** from the **Demo** item of the **File** menu. See Demo System for more information on this.

1.3 What you see before you

Once you have read in the root file **Progman.trk**, you will see the interlocking panel for "Progman St.", a medium-sized interlocking. The gray lines represent the tracks — there are no trains when you start. North is to your right. The little circle-with-pedestal symbols, some of whose circles may be lit, are called GK Lights, and represent **signals,** the "traffic lights" of the subway.
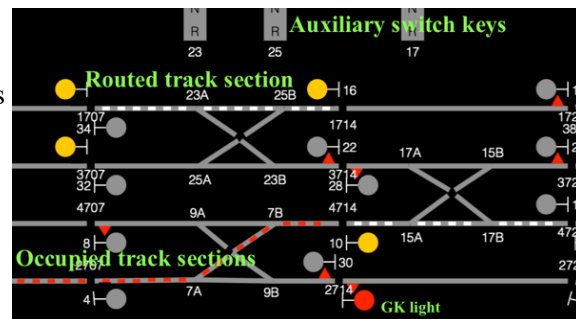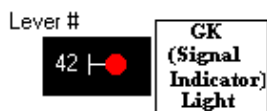
The tracks are divided into track sections — you can see the little gaps between the sections, known as IJ's, or Insulated Joints. You can see one where every signal appears. The IJ's, and the signals at them, have numbers called station numbers, which are measured in hundreds of feet along the route from some
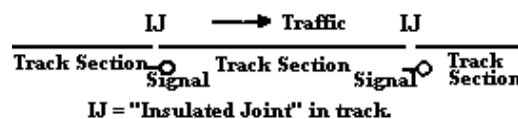
arbitrarily-chosen reference point, often the origin of the particular subway line or its construction contract. In the current default track layout, these are all in the 700's — that is what the numbers in the 700's mean.

The signals can have one or two numbers associated with them, the station number, already discussed, and a Lever Number, always even, which, in the default layout, is a small number. The station number refers to the physical location of the signal, the lever number is that by which the interlocking defines the signal. The lever number appears next to the signal head (the round part of the GK light.

The switches have lever numbers, too, which are always odd. As the two ends of a switch are controlled by the same "lever", they are typically numbered A and B with the same number. That is what the numbers at the points of the switch mean.

Aux. switch keys & lock lights

Under the track model you will see a number of auxiliary switch keys . Written under each is the number of the switch it controls. Normally, you do not need to use these, but you can determine switch locking by observing them.

There is a horizontal scroll bar at the bottom of the window. Only the tabs on the end are active - the thumbscroll and the page left-right bars are not enabled. You can scroll a little bit to see all of large interlockings. You can also use the arrow and PageUp/PageDown keys to scroll. Real interlocking panels are much bigger than a computer screen.

1.4 What the various lit-up things mean

Track sections are normally dark (gray). When a track section is lit up as a line of red dots, that means it is occupied, i.e., a train or portion of a train is in it. When it is lit up in white dots, that means that a route is lined up over it, i.e., it is ready for train movement.

The pieces of track being and representing switches are divided in half, between the two track sections which they connect, and will indicate red or white or dark along with those sections when the switch is set to a diverging route. A switch which is lit up in **blue** is thrown (set to diverging route), but neither occupied nor part of a route. This is a non-standard feature not present in real interlockings — this is because it is sometimes interesting to know switch position in these cases, even though there is no necessity to know it. Also, this feature was useful before full NX control was implemented in NXSYS.
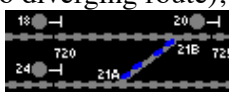
Switch 21 set for movement from 20 to 24 (Diverging route)
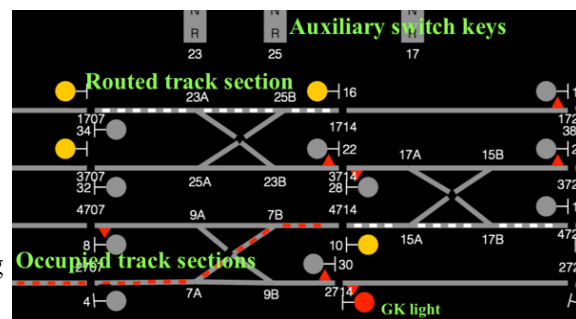
When a switch is moving (changing position), the switch reverse position on the interlocking panel flashes red. This takes several seconds, and other things may be going on simultaneously. If the auxiliary switch keys are calling for a switch, it will light steady white in the position to which it has been called.

GK lights represent signals. Although on real NYCT interlocking panel automatic signals have no GK lights, **NXSYS** supplies them anyway for your edification. In short, the GK light reports the signal's aspect: yellow means "clear" (i.e., the actual aspect is yellow or green), and red means "red". However, if the represented signal is *not* an automatic signal, i.e., *is* under the control of the interlocking, the GK will be *dark* unless the signal is called, or an initiation has been punched at that signal. (If the GK light is dark, and the signal is not called, it is a certainty that the actual signal will be red.) A home or approach signal may also be fleeted, in which case a little green triangle appears on the GK light. See Auto-cancel and Fleeting for more about that.
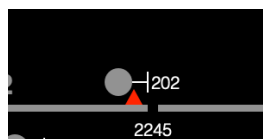
Some signals will have little red triangles sitting on the track sections next to them. These are the symbol for train stops, which are devices that cause trains attempting to pass red signals to grind to a halt. See train stops for more information on this.

It is possible to see what the actual signal looks like, and watch it change in real time, by popping up the Full Signal Display.

When a route is initiated, that is, the beginning of a path over the interlocking is selected, a bright white exit light will light up in the track section at each exit allowable at that time. By selecting the exit with the mouse, the tower operator selects and completes the route. That is the basic theory of NX interlocking.

Under the track model are the auxiliary switch keys . These are not used in normal operation. See the section about them for more information.

Aux. switch keys & lock lights

1.5 Using the Mouse to Control the Interlocking

There are five kinds of mouse-sensitive objects in **NXSYS:** track sections, switches, signals, exit lights and auxiliary switch keys. The mouse is used instead of the metal or plastic buttons on a real interlocking panel. The left and right mouse buttons effect the most common operations on each type of object; clicks with modifier keys (**shift** or **control**) are used for less common operations. Finally, **control click-right** on any object (except exit lights) offers a so-called context menu of all possible operations on the object, elementary and advanced, although its use is rarely necessary (documentation of this may be found below).

Clicks on Signals

Clicking **left on a signal's** GK light has an effect which is different for different types of signals (See Types of Signals), and differs depending upon the state of the signal. The basic idea is to toggle the signal's requested (or called) state, i.e., work towards clearing it if it is not clear, and *vice-versa*. More specifically, clicking left on the GK light for a(n)

1. **automatic signal** or **marker signal** has no effect.
2. **approach signal** attempts to call (and clear) it if it is not called, and unconditionally "cancels" it, i.e., de-routes it, if it is.
3. **home signal** or **dwarf signal** initiates a route, if possible, at that signal if it is not initiated or called, and unconditionally "cancels" a route or initiation from that signal otherwise, forcing the signal to "red," although route locking might hold the route in spite of this.

Note that calling or initiating a signal will not necessarily clear it; for a home or dwarf signal, it is guaranteed not to until an exit is selected and all switches have fully moved, and its control length is clear of trains.

Note also that the interlocking might refuse to initiate at a given signal if it believes that no routes from it are possible at that time. Note yet more the UR exit feature, which allows you to click on the *signal* at a lit exit light instead of that exit light to choose that exit.

Shift-click-left on a signal turns its fleeted status on or off. See Auto-cancel and Fleeting for more info. **Control-click-left** on the GK light of a home signal offers a call-on if appropriate conditions are met.

Click **right on a signal,** more specifically its GK light, to pop up a Full Signal Display for that signal (on the Mac, there is a **Preferences** option to assign **click-right on a signal** to its context menu, and **control-click right** to the full signal display, although this breaks demo scripts.).

Clicks on Track Sections

Click **left** on a track section, any portion of it, to toggle its "occupied" status, i.e., move a train into it or out of it. Normal train movement can be simulated by occupying several successive sections (a normal train is ten cars of sixty-one feet), occupying sections ahead and cleaning up behind. Of course, you can lift trains off the track with the mouse by simply clearing occupied sections in a non-real manner. That is, click left drops a train on the tracks at the point you click, or removes it if there is one. This, of course, is an NXSYS feature only, and not a feature of real interlockings (although mice

and rats do occasionally drop in on rights-of-ways). While this is the best way to learn the effect of train movement on the interlocking, it is not "realistic" or "fun": for that you need autonomous (auto, no mouse) simulated trains, which are provided by the train system.

To determine the circuit ID/section number of a track section, call up its context menu (**control-right**), select **Query Relay**, merely observe the number displayed, and dismiss the relay query dialog.

Clicks on Switches

Clicking **right on a switch,** its points or arms, will attempt to move that switch (change its position). The switch will flash red as it moves. This is *not the correct way* to move switches, though: the correct way is to select routes and enjoy watching the interlocking identify and move the switches correctly: see Basic NX Operation. This capability is provided only for debugging and playing around, i.e., deliberately annoying the interlocking for the pleasure of later watching it move the switches at route-setup: you should never legitimately need to move switches this way. This is an **NXSYS** shortcut for the operation normally performed by manipulating the auxiliary switch keys.

Note that switches that are in the reverse position ("thrown" in sloppy, non-technical terminology), but not lit in red or white are lit in blue dots — this is a non-standard feature, again, to facilitate learning. Note that the switch *will not move* if the interlocking does not permit it — this is a major goal of interlockings. See interlocking features.

Clicks on Exit Lights

Clicking **left on an exit light** selects that exit, and attempts to complete the route between the initiated entrance and that exit. Other lit exits will be "knocked down", switches moved, and the appropriate track sections made part of the route, all in the correct sequence.

There is always a signal at an exit light, and one may, if one chooses, use the UR exit feature and click on that signal instead of the exit light to select the exit. The relevant signal at an exit is usually the one *opposing* the direction of traffic, unless, of course, there is only one in the other direction. See Basic NX Operation.

At times, you may see GK lights and switch points flash (the latter in white) in unison when you attempt to initiate some other signal. This indicates a conflict in routes that you must resolve. See Locking conflicts.

Clicks on Auxiliary Switch Keys

Click **left on an auxiliary switch key** calls for the switch to move normal or reverse, depending upon which half is clicked. The call remains in effect as long as the mouse button is held.

Click **right on an auxiliary switch key** calls for the switch as does click left, but the call remains in effect even after the mouse button is released; the call can be cancelled by clicking on it again, the switch locking, or use of the menu item **Interlocking|Clear all aux switch keys.**

Auxiliary switch keys are not the standard way to operate switches. This capability is provided only for debugging and playing around, i.e., deliberately annoying the interlocking for the pleasure of later watching it move the switches at route-setup, as well as esoteric needs discussed under that rubric.. Use the NX route selection mechanism to move switches in normal usage.

Context Menu (control-right click)

Clicking **control-right** (that is, clicking **right** while holding the **control** key down on any track section, switch, signal, or auxiliary switch key offers (as per Windows convention) a "context menu", a list of possible operations upon the object on which you clicked, including both "interlocking" operations simulating various pushes, pulls, and turns of buttons on real panels, and "simulator" operations, such as popping up full signal windows or examining the circuitry associated with that signal or other object. All of the operations available by other clicks appear on the context menu, as well as some operations (such as the call-on stop release key and approach locking release) not available elsewhere.

1.6 Full Signal Display (Aspect windows)

Click right on the GK light of any signal and a window with a full drawing of what that signal actually looks like will be popped up. These signal images reflect the signal state dynamically. The windows can be moved around at will, and are child windows of the track board. They can be closed individually with their individual system menus, or all flushed from the screen with the **Other|Flush Sig Wins** menu item. The title bar of a full signal display gives the most common nomenclature for the signal, which is the lever number for interlocked signals and the station number for automatic signals.
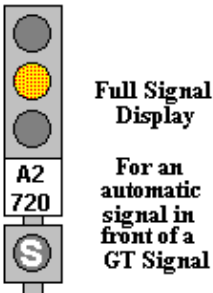
The full signal display window will pop up right under the signal icon on the control panel; you should then pick it up with the mouse, grabbing it by its title bar, and place it where you want. On the Mac, there is a **Preferences** option to show the Full Signal Displays without backing windows — the signals just hover. On Windows, the little windows have "close (X)" in their title bars to close/hide them. **On the Mac, you double-click on a full signal display, with little window or without, to close/hide**.

These signals are implemented according to the "new" (BMT/IND) convention (new since 1935, all new NYCT signals today). Red means stop, Green means that not only may you proceed, but the next signal is clear, as well, and yellow means proceed with caution: usually, but not always, the next signal will be red.

When there is more than one head (vertical box of one to three lights), the upper one means as above, and the lower one indicates green for straight, yellow for diverging route . Sometimes there will be two-headed signals where they do not seem necessary — we cannot go into that here.

At the bottom of the Full Signal Display (except for dwarf signals), a little to the right of the signal, you will see a depiction of the signal's train stop. (On the BMT and IND, it is to the left of the track, on the IRT, it is to the right). The yellow head of the stop will be on the bottom of the window if the stop is down (passable), or up on its black stem if the stop is up (tripping, impassable). The stop goes up and down, visibly, in the time it takes a real stop to do so. Please see stops.

2. Menu Commands

As the point of this system is to simulate another, already-defined interface, most control is accomplished by that means, not Windows menus. Nevertheless, here are the known commands. Most are disabled if no interlocking is loaded.

2.0 Top-level (application) menu

tr>

NXSYSMac		Mac only; expectable application-scope operations. Always available. Other operations besides these (not **NXSYS**-specific) appear as well.
	About	Pops up a display of authorship, copyright, and version information.
	Preferences	Pops up a dialog allowing you to configure stop display policy, full-signal display style, and the meaning of **right-click** versus **control-right-click** on signals. Preferences are retained between application invocations.
	Quit	Closes down and exits the application, stranding passengers in existential limbo.

File	**Open**	Reads in the definition of an interlocking from an interlocking definition file, usual suffix **.trk**. Each interlocking in is own folder (interlockings comprise many source files). See the Interlocking Scenarios for the correct names of files for each version, but you don't have to know that if you use the **Interlocking Library** command below.
	Reload	Asks for confirmation, and re-initializes the currently-loaded interlocking from the current interlocking definition file. This resets its state to "as it was in the beginning". This can also be used to debug changes to interlocking definitions or simply to reset the layout. See also **1 (Last interlocking pathname)** below on this menu to reattempt to load an interlocking that has failed to load.
	File Info	Displays a small dialog with statistical information about the content of the interlocking, viz., the pathname of the top-level definition file, the count of signals, switches, relays, etc.
	Interlocking Library...	Pops up a "submenu" of interlocking scenarios supplied with the application. Selecting any loads it. It is driven by a simple XML file in the application's directory (or its Resources directory on the Mac).
	Recent Files...	Pops up a "submenu" of recently-visited interlockings in most-to-least-recently-used order, with single-digit accelerators on Windows. Selecting any loads it. On both systems you can clear the list (or menu, as the Mac calls it.)
	Demo	brings up a file dialog for interlocking demo (**.xdo**) files, and runs the demo you select. See the Demo System section.
	Print Logic	(**Windows only**) offers a Printer Dialog and prints a set of electric schematic diagrams for all the relays in the interlocking, sorted in name order, along with comprehensive indexes in the traditional style at the end of the set. The state of the contacts will reflect the state of the relays at the time it is invoked. Works only if an interpreted (**.trk**) interlocking is loaded. See **Print Logic File.**
	Exit	Closes down the application. Passengers are left stranded in the tunnels without power or Windows resources. Use **Quit** on the **NXSYSMac** menu on the Mac.
	1 (Last interlocking pathname)	Tries to reload the last interlocking definition successfully loaded. You cannot use **Reload** if no interlocking is loaded; this is useful to reload an interlocking being debugged which has failed to load.

Interlocking		These commands perform various auxiliary functions controlling the interlocking. They have no counterparts at real interlockings (although there is an "emergency switch release", but **NXSYS** and its interlockings do not now implement it — **Release all approach locking** is the closest to it. They are to facilitate experimentation.
	Clear all track	is not an interlocking function at all. Lifts all trains into the sky, clearing all occupied track sections. Obviously, there is no real-life parallel. This is not the same as killing all trains.
	Cancel all signals	does just that, cancelling all initiations and routes as well, making all home, approach, and dwarf signals red, dropping all routes, and cancelling all fleeting. Routes might still be shown lit, though, due to approach locking and route locking.
	Release all approach locking	See the discussion of approach locking for the need for and explanation of this. Please note that it also releases all route locking. Typing **Control-A** at any time invokes this command.
	Clear all aux switch keys	Restores all auxiliary switch keys to their neutral position, i.e., not calling for any switch in any direction, extinguishing yellow and green "hold" lights. **Normal all switches** will, of course, not normal any switches held called reverse by auxiliary switch keys.
	Normal all switches	calls all switches to move to the normal (main route) position, not by magic, but by "operating their levers." Thus, only switches which are neither locked (see Switch locking) nor called reverse by auxiliary keys or established routes will move. The switches will all move in parallel and take the usual amount of time, and indicate as such.
	All the above	clears all track, cancels all signals and routes, releases approach locking, and normals all switches, in that order, which is guaranteed to work if there are no bugs. If there are no bugs, this is a faster and more "correct" way of resetting an interlocking to its initial state than **File|Reload.** This command interposes a 1.5 second delay before attempting to **Normal all switches** to assure that all train stops have returned to their tripping position, without which some switches to be called normal might be locked.
	Bobble all Signal repeaters	simulates a 3-second failure of track electrical power to all "red signal repeater (**RGP**) relays", causing false indication to appear at the interlocking, if the latter is programmed for this feature (Progman St. currently is, Islington is not). This sometimes happens in real life, and activating this menu item (which requires confirmation) tests if the interlocking

		is properly designed to handle this contingency.
	Automatic Operation	For interlockings that have this feature, enables the pop-up of route selector "boxes" and operation of the interlocking by means of them. See Automatic operation.
Trains		These commands create and manage trains. See that section for a description of that feature.
	New	Asks you to choose a track, with the mouse or by typing a digit, and creates a new train, popping up its train dialog. The train will be in the "Observant" state, and will slow down and stop outside the limits of the interlocking if you have not cleared a route for it.
	New (stopped)	Same as **New**, except the train will be created in the stopped state ("Free will" mode, 0 fps). The train will not move until you advance its throttle or place it into "Observant mode" and clear signals in front of it.
	Halt all	halts all trains in their tracks, immediately, with infinite deceleration. You will have to move individual speed controls on the train dialogs to restart them.
	Kill all	makes all trains and their dialogs disappear instantly.
	Minimize all	minimizes all train dialogs, reducing them to numbered icons at the desktop bottom. They can be restored individually (as any iconized window), or *en masse* with **Show all.** You can minimize any train dialog by clicking its minimize control; train motion will not be affected. This feature is not available on the Macintosh.
	Show all	restores all minimized train dialogs to visibility. This feature is not available on the Macintosh.
Relays		These commands facilitate debugging or observation of the relay logic implementing each interlocking. They are intended for the "signal maintainer," not the tower operator. See Chapter 5, "Relays".
	Query	puts up a dialog asking for the name of a relay, such as **4707NS**. The state of that relay will be reported via a second dialog, which will also display a list of all relays whose state depends upon the state of the relay selected. Double-clicking on any one of those starts anew at that relay. This works in interpreted as well as compiled interlockings, in which latter case it is the only logic probing tool available. In an interpreted interlocking, drawing the circuit of the selected relay is also offered. The last 40 relays requested are offered in a combo-box drop-down.

	Trace	pops up a tall, thin window in which all simulated relay transitions are reported. In true Lisp fashion, transitions of compiled relays are reported as effortlessly as those of interpreted ones. If the window is already up, this command hides it (making keyboard use (**Alt+R T**) very convenient). See [Relay Trace Window](#).
	Show Circuit	prompts for the name of a relay, like **Query,** and the pops up a window drawing the circuit of that relay in traditional Transit Authority notation. "Interpreted" (**expr**) interlocking code (**.trk**) must be loaded. If you click left on any relay contact, the circuit for that relay will then be displayed. Unlike traditional drawings, however, **NXSYS** drawings respond in real-time to relay state changes and update accordingly! For fun, start by displaying the circuit for 10PBS or 10XS at [Progman St.](#) and set up some end-to-end routes involving signal 10 and then explore. 24PBS is impressive, too. The last 40 relays requested are offered in a combo-box drop-down. See [Relays.](#)
Other	**Flush Sig Wins**	removes all [Full Signal Displays](#) from the screen. See there, and the [Mouse usage info](#).
	Show Stops	offers a dialog with three radio buttons controlling the conditions under which [train stops](#) are displayed on the panel. You may choose to display stops only when they are in the "stop" position (the default,) at all times, in which case they will be displayed yellow when "clear" and red when at "stop", or not at all, which is the case on a real NX/UR panel. On the Mac, this is the **Stop Policy** tab on the **Preferences** dialog callable from the **NXSYSMac** menu.
	Scale Display	offers a dialog which accepts a number, default 1, which zooms or shrinks the display scale by that factor from its default. By setting this to .8, .7 or .5 or so, large layouts can be made to fit on screen. As the display becomes smaller, label numbers are discarded and other numbers are condensed. This feature is not needed on the Macintosh; use native magnification gestures.
Help	**Usage/Help**	You must know about this already if you are reading this. Gets you into this document.
	About	Displays system authorship and copyright information. On the **NXSYSMac** menu on the Macintosh.
	(Scenario-specific help)	Help about the specific [scenario](#) (specific interlocking) you have loaded is made available on the **Help** menu. The text can come from this helpfile or the interlocking definition.

2.1 Demos and the Demo System

NXSYS is more than willing to demo its capabilities by running automated scripts. These scripts consists of instructions to "press" (that is, click on) the buttons of the interlocking panel, comment upon what it's doing, and wait between commands. A sample demo script, **demo1-Progman.xdo,** is provided, both as a model and as a learning tool for **NXSYS.** You may have to change the **Progman.trk** pathname in it to account for file structure on your system.

Demos are called up from the **Demo** item of the **File** menu, which puts up a File Dialog allowing you to select a demo file. Alternatively, you can (on Windows only) specify

> **-demo** *demo-script-pathname*

when you invoke **NXSYS**, to get that file loaded and run automatically. The selected file is then "run" via timer events: that means that as the demo is going on, the interlocking and all of its commands, menus, and controls are usable, as well as those of other Windows programs. You can actually interact and interfere with the demo as it is going on, or play in another portion of the interlocking, without fear of creating an unsafe situation. Relay Interlockings are highly parallel real-time systems.

If you are using a Windows screen-saver, do not be surprised if it is invoked or the screen is blacked out due to inactivity while watching the demo.

If you are on the Mac, you must disable the **Right-click on signals is menu** option if you have enabled it, because **mouseright** in demo scripts assumes full-signal display. This is a shortcoming in the demo user-interface interaction design that may be remedied in the future.

You can pause or end the demo at any time while it is active: typing a **space** pauses the demo or resumes it if it is paused, and typing the **ESCAPE** key ends an active demo. One can, of course, simply exit **NXSYS** from the **File** menu while the demo is active, and that will end it, too.

The forms in the demo script are simple Lisp forms (if you don't know what that means, ignore this description) that name signals, track sections, and exit lights by number, provide strings to display, and time intervals in milliseconds to wait. Most forms take an optional comment which is displayed in a window at the bottom of the app's window.

A form naming a **track** section, **signal**, or **switch** is a request to click left on that object. If the first element of the form is **mouseright**, mouse right will be used instead, and the remainder of the form is the "real form". **mouseleftshift** or **fleet** works the same way for click left with shift, used for fleeting signals.

You can create and schedule trains with the demo system, providing a constant flow of traffic for you to route. You have to pick a unique train number (currently 1 to 15) for each active train. The second number in the **create** form is a track number. The known **train** keywords are **create, halt, reverse, kill, freewill, observant, callon, minimize, restore. callon** presses the call-on button, **minimize** and **restore** minimize and restore the train dialog.

(train *n* **create** *where {...options...}*) allows several parameters to be specified (optionally, perhaps multiply) for trains at creation time: **hidedialog** causes the train dialog to be hidden, **minimizedialog** causes it to be minimized, and **halted** causes the train to be created halted, in "free will" mode (the default is "observant"). Starting a demo destroys all trains extant at that time.

where is a track number in Version 1, direction determined by that track number. In Version 2, including the Mac, *where* is the ID of an insulated joint at the extremities of the scenario, where a train will enter in the only possible direction.

The form **(options** ...*options*...**)** controls global behavior. Currently recognized are **noxes**, which disables (for this demo) the big yellow "X" which simulates the mouse, **maximize**, which maximizes **NXSYS**'s window immediately, and **nostops, showstops,** and **showstopsred**, which automate the stop-policy control (see Show Stops). These options are intended to provide for lifelike simulation. The demo legend window does not appear until the first time a form comment or **say** is used, so if you do not use any form comments, the demo legend will never appear.

There is also a newer scripting system, only available on Windows, **NXScript**, which is more oriented towards creating realistic scenarios and organized testing, and has many more capabilities. Please see Scripting and OLE Automation.

Here is some typical demo scripting with trains. See also the supplied demo **demo1-Progman.xdo**.

```
(train 1 create 2606 minimizedialog) ;create train 1 at IJ 2606, minimized dlg
(signal 24 "Let's initiate a route at signal 24!")
(wait 1000)
(exitlight 8 "Now when we choose the exit light at signal 8...")
(say 1200 "Switches 21 and 15 move,")
(wait 2000)
(train 1 speed 50.5) ;set speed — sim feet/seconds
(wait 180000) ;wait 3 minutes for next train
(train 2 create 1606)
(fleet signal 26 "Now let's initiate at 26, fleeted")
(train 2 minimize) ; can minimize it afterwards, too...
```

2.2 Trains and the Train System

NXSYS is not unlike flight simulators in that it implements the simulation of a real-world transportation system. With flight simulators and car simulators the goal of the "game" is to master the driving of complex vehicles through passive media: the air and roads do little more than sit there. In **NXSYS,** however, you control and learn a complex reactive environment through which vehicles may run; it does not simulate, but actually *is* an NX interlocking. The goal is not to learn the piloting of trains, but the controlling of interlockings which themselves restrict the movement of trains.

With that in mind, the most instructive mode of usage of **NXSYS** is to control switches and signals and occupy and vacate track sections one-by-one, using mouse-left on track sections, carefully observing what happens when each becomes occupied and becomes vacant. This is the equivalent of dropping and removing axles from the tracks to see the effect on the interlocking.

While instructive, this is not as much fun as having real trains obey the signals and move through the interlocking. While **NXSYS** cannot create real trains in a simulated world, it can, however, simulate them. But like many a real tower operator, the only evidence of the "trains" that you will see on the panel is a line of red (occupied) lights.

You create a train by choosing the **Trains|New** or **Trains|New (stopped)** menu item; choose between them as according to whether you want the train to start out moving (automatically) or stopped. You will be asked to choose a track either with the mouse or by typing the track number (1 is Southbound Local, 2 Northbound Local, etc, as numbered on the model). A **Train Dialog** will pop up at that time, one for each train. The train will enter at the South end of a Northbound track and vice-versa. The train dialog will show, dynamically, the position of the front of the train, its speed, and the next and last signals seen. The train dialog may be minimized, or the train "killed" (made to disappear) or halted at any time by pressing buttons on the dialog. There is also a scroll bar which is the speed control. When a train vanishes off the other end of the interlocking, its train dialog will disappear.

There are two modes of train behavior, **Observant** (the default) and **Free Will.** An "observant" train acts as though under the control of a competent "tower operator" who is indeed watching the signals. It will slow down and speed up as signals change, and slow to a halt at red signals. It will start up automatically when stopped before a signal which you clear. If you create a train (all of which start out observant) without having set up any routes for it, it will grind to a halt off the limits of the interlocking, waiting for you to clear a route for it.

Free Will (which may be chosen with the radio buttons in the train dialog) trains do not obey the signals — they obey you; they think they have free will, but little do they know that their thoughts are coming from a higher power. You can use the "Speed" slider scroll bar and "Halt" buttons to control their speed.

Even if you are a **Free Will** , you may not defy the interlocking. If you try to run a red signal, you will be tripped (forcibly stopped_ by the train stop of that signal, forced to a halt, chastized, and your train "killed." This will also happen if you, as tower operator, cancel a signal in the face of an oncoming train without giving it enough time to slow down. Thus, it is theoretically impossible to orchestrate an unsafe train movement: that is the whole *point* of interlocking. Note that dwarf

signals are intrinsically unsafe, as it is possible to pass them in unsafe circumstances, as they lack stops, but the Train System does not help you with reverse-direction train moves (**note also that the train system does NOT (currently) detect and trip on raised off-side stops — see "Stops".**).

Free Will trains may, however, pass automatic signals and approach signals at crawl-speed, even if the stops are up via a maneuver known as automatic key-by. See Train Stops.

Free Will trains can even pass home signals at stop if the tower operator offers a call-on. In this case, the yellow light at the bottom of a home signal facing a train of the train system will be lit (R R Y will appear in the train dialog), and a "call on" button will appear automagically in the train dialog; The train should crawl up to that signal in **Free Will** mode: the button will not be obeyed unless the train is within 10 sim-feet of the signal! Pressing that button will lower the train stop and cause the button to disappear, at which point the **Free Will** train operator can creep up on the back of another train, with the tower operator's cooperation. Please see the call-on section for more information on this.

You may switch between **Observant** and **Free Will** behavior at any time by operating the radio buttons on the train dialog. The initial state of a newly-created train is chosen as **Observerant** or **Free Will** by virtue of its having been created with **Trains|New** or **Trains|New (stopped)** respectively.

There are three buttons always present on the train dialog, **Halt, Kill,** and **Rev**(erse). **Halt** stops the train immediately, and throws it into **Free Will** mode — you must then click **Observant** to restart it, if you wish it to run automatically. **Kill** immediately destroys the train and lifts it off the tracks. **Rev** is only enabled when the train is stopped, either having ground to its own stop or having been **Halt**ed. When pressed, the train operator moves to the other end of the train, and if the train is "observant", it will obey signals facing its other end and move in the other direction — it "turns the train around".

There are main menu commands to minimize and restore all train dialogs, halt all trains, and kill (make disappear) all trains.

With the train system, it is easy to set up one-time routes, watch a train move over them, bring in the next train, hold trains at signals, turn trains around at terminals, and so on, all in parallel, just like at a real tower.

Cab View and OLE sections removed here.

3. Signalling and Interlocking Features

This section describes standard signalling and interlocking concepts, both in general and as they are implemented in **NXSYS** and its sample interlockings. These are not only the fundamentals of signal function, but the various features that facilitate switch and signal operation and constrain it to be safe.

If, when Using the Mouse to Control the Interlocking, you find that signals will not clear and switches will not move on your demand, that is why. That is the whole purpose and meaning of interlocking, to enforce operation in the proper order.

With an NX interlocking, you do not move switches or attempt to clear signals directly, but instead, let the "system" do it as a consequence of route selection (see Basic NX Operation.) Nevertheless, the "system" goes through the same moves as would a "manual" tower operator in an old-style interlocking, and is subject to the exact same constraints and cross-locks as in that case. These are described in the subsequent sections of this chapter.

The following sections are presented in the order in which they must be understood. The section Control Length — the Purpose of Signals underlies and determines the entire philosophy and implementation of the signal system, is thus first. Please proceed, prepared to stop at the next section.

3.1 Control Length — the Purpose of Signals

The charter of rapid transit is evident in its name: to move people safely as rapidly as possible. While trains, motors, and

propulsion power are responsible for the rapidity, signals are responsible for the safety.

A rapid transit signal's job is to keep trains at a safe distance from dangers, including each other, via three closely-related functions,

- To indicate to train operators whether the track ahead is clear,
- To instruct the train operator to proceed (green), proceed prepared to stop at the next signal (yellow), or to stop (red), accordingly, and
- To forcibly stop a train via its train stop should that train fail to comply with an indication of "stop."

An extent of track being "clear" means that it is proven free of hazards such as other trains, trailing-point switches set the wrong way, open drawbridges, conflicting routes from other signals, and so on. The extent of track ahead of a given signal for which it makes this check, which is different for different signals, is called its **control length,** as it controls the signal's indication. If, at a given time, any of these hazards appear within any portion of a signal's control length, that signal is required and designed to display an indication of "stop". A "clear" indication confirms the proven absence of hazards within a signal's control length.

Signals are placed regularly along a track, at insulated joints, subject to considerations to be discussed. Each signal's indication instructs the train operator what to do *up to the next signal*. An indication of "proceed", or "proceed prepared to stop at next signal" is only valid up until the next signal, when that signal's indication assumes validity.

Consider the following "single line" signalling diagram. As per standard, the lines under the track starting in little circles at signals and ending in arrows represent those signals' control lengths. The "lazy house" shaped object represents a stopped train. The big arrow indicates the direction of traffic. The signals here are 200' apart.


Kids: DO NOT try this at home!!
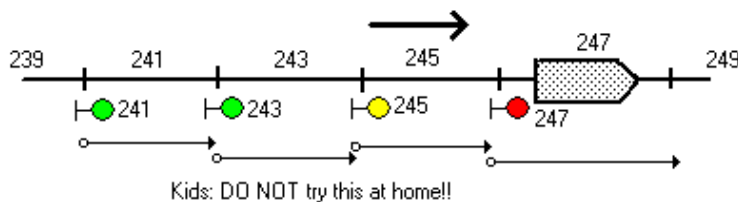
Here, each signal is controlled solely by the occupancy of the "block" in front of it, extending to the next signal (that is, whether it is clear or not. 245 is yellow because 247 is red). Assuming that 245 is visible early enough for the operator of an approaching train to observe and obey it and slow down, and posted speed restrictions are being obeyed, that train will stop before arriving at the red signal 247, and the rear of the stopped train, and this scenario is adequate.

But in real life, this will not do: an oncoming train might not be operating within the posted speed limit, and the train operator might be temporarily or permanently physically, mentally, or morally incapacitated, in which case the signal system, via its train stops, must forcibly stop the train. In these cases, the yellow aspect (indicating "prepare to stop at next signal") might be ignored, and a train going at the fastest possible speed will arrive at signal 247 at speed.

Assuming signal 247 had a train stop that acted as expected (assumed "tripping" position when the end of a train passed it, although this not quite the case in reality, see train stops), and the oncoming train's brakes were fully applied automatically by it, a collision would still result, because trains moving at 60 or 70 miles per hour cannot "stop on a dime:" typically, hundreds of feet are required for a train moving at full speed to come to a halt via a brake application. On this account, a train must be commanded to stop hundreds of feet *before* an obstruction *at* which it *must* stop. This distance is called the **worst-case (or "safe") braking distance,** and is a function of the maximum speed of trains, the terrain, the weather conditions, and so on. It is called "worst-case" because it must take into account brakes in the worst condition (short of total failure), trains going at the maximum achievable, impermissible, speed, tracks at maximum slipperiness, and so on.

It can be seen that simply increasing the block length to the worst-case braking distance, or many times it, does not improve the situation — a train approaching another train at the near end of a block at speed will not have enough space to stop, even if "tripped", no matter how long the block. In track-circuit based signalling, train position can be reckoned only in terms of which track circuits the train occupies. The solution to this problem is overlap of control lengths, that is, having each track circuit (section) control not one but several signals behind it — were there only one red signal behind a train, the situation is always possible in which it is too close behind the train for safe braking. Consider the following far more

realistic scenario:

Overlapped signal control lengths
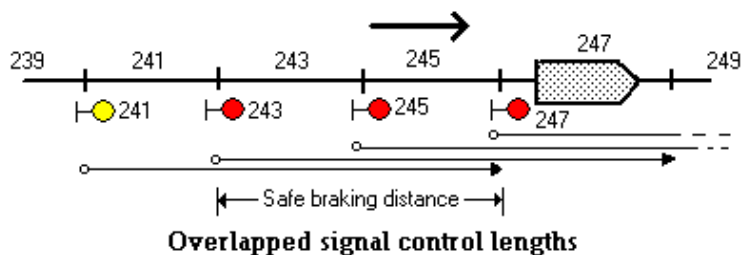
Here, the control lengths of all signals are overlapped. 243, 245, and 247 indicate "stop", and 241 indicates "prepare to stop at next signal" (yellow aspect). The worst-case braking distance here is somewhere between 200 and 400 feet. An oncoming train barreling ahead at full speed ignoring signal 241 will be tripped by 243, and come to a halt within the safe braking distance indicated, that is, short of block 247 and the train it contains. From this it can be seen that the key to safety is a control length overlap at least equal to the worst-case braking distance.

The key to understanding this is to think (in this case) about signal 241, not 243. By giving a "clear" (albeit "prepare to stop at next") indication, signal 241 has asserted that should a train accept its indication, the track which is encompassed in its control length is safe, in particular, such that **if the *next* signal (i.e., 243) within that control length indicates "stop", and that indication is obeyed or enforced via a train stop, that train will stop within that control length (i.e., before IJ 247) and clear of any danger.** In other words, the 241 asserts by its clear indication that its control length is safe, even if you are forcibly stopped within it.

From the above it can be seen that a signal must have a control length of at least one safe braking distance beyond *the next signal*, i.e., its overlap. Because of this design, and the use of train stops, the signal system ensures that trains are kept a safe distance from each other and from other, transient, dangers. (Note that this has very definite implications for interlockings: an interlocking cannot allow a dangerous condition to be thrown in the path of a train which has already accepted a signal which has spoken for the absence of such conditions in its control length. See approach locking.).

In the above scenario, it is assumed that the operator of an oncoming train will see the yellow aspect of 241 and begin to brake sufficiently soon to be able to stop the train before reaching 243, lest it train be tripped. Given that the distance from 241 to 243 is markedly less than the worst-case braking distance, we can assume that the distance from the place where 241 can first be seen to 243 must be the expectable braking distance at the posted operating speed. A train obeying 241 under these conditions will not be tripped at 243. If 241 is not clearly visible far back enough, either inter-signal spacing should be longer, or more than one signal back should display yellow ("prepare to stop at next signal") if 243 is red (a feature known as **overlapped distant control.**) Another common technique used at interlockings and places where closely-spaced signals are needed is the employment of signals that have only yellow and red aspects, i.e., always, when clear, indicate "prepare to stop at next signal."

Note that if one can "prove" that a train is going at reduced speed, required braking distance will be less, and the enforced separation between trains, and hence signal control lengths, would be less. This is the idea underlying station time signals, described in the referenced section.

In much "routine" automatic signal territory, inter-signal spacings are equal to or greater than one safe braking distance, and control lengths two track circuits (two safe braking distances). Closer signals allow for finer control, especially when combined with the station time feature.

The situation is slightly different for Dwarf Signals and home signal call-on. The control lengths of such signals and moves do *not* check for trains, but do check for switches, conflicting routes, etc. (See Types of Signals.). In these cases, what trainmen (like pilots) call "visual rules" apply: trains must operate at very low speed, prepared to stop within vision.

Since a signal being clear indicates that there are no hazards in its control length, it must also be so that no two signals not in the same direction on the same track may clear movement into the same track section. This is one of the fundamental principles of interlocking, and is enforced by disallowing the calling of a signal (via its lever, in NX/UR interlockings an abstraction implemented in relays rather than a physical lever) when the levers of other signals are now so set that clearing this signal would create such a situation. Even below the level of the levers, the relay circuitry of the signals prohibits opposing and conflicting signals from being clear simultaneously.

The selection of the spacing and control lengths of signals is an exceedingly complicated subject, and involves not only considerations of safety, but the expected headway between trains, curves, grades, and other conditions affecting train speed and braking distances, and many other factors that must be balanced to preserve safety while maximizing the number of people who can be transported per unit time.

3.2 Types of Signals

There are five basic categories of signals used in the subway, whose distinctions must be understood if one is to be a train operator, let alone a tower operator! While some attributes, such as being a time signal, are applicable to several of them, these distinctions between these categories underlie the notion of interlocking.

The most fundamental kind of signal is an **automatic signal.** They look like the illustration at right. Note that it has one head with two or three lenses, at least one of which is not red. An automatic signal is not controlled by an interlocking, for, by definition, its state does not affect the interlocking. Therefore, an automatic signal is controlled only by track occupancy (i.e., the presence, absence, and movement of trains in its control length), including timers dependent on track occupancy, as with time signals. Automatic signals are the only kind present in the vast majority of the subway system, that is, between interlockings. When represented on an interlocking panel, automatic signals do not have lever numbers (or, in real life, GK lights, but in **NXSYS** they do). Automatic signals and approach signals implement automatic key-by (AK).
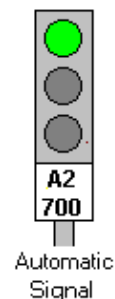
The second most fundamental kind of signal is a **home signal.** A home signal is always controlled by a lever of an interlocking, in addition to track occupancy and possible timers. Here is an illustration of one. The signal's lever number appears on its lower head. A home signal always has more than one multi-lens head. The upper head has the same meaning as with an automatic signal (proceed, proceed prepared to stop at next signal, stop). The lower head tells whether a normal or diverging route is set, yellow being the latter. Red always appears together in both heads. A home signal is used whenever a switch is protected, facing or trailing, including all cases of a choice of routes, or potential conflicting movements are involved. When a home signal indicates double-red, the indication is "stop and stay:" there is never any Automatic Key-by to clear the train stop of a home signal. There is, however, call-on, which is indicated by the single yellow light at the bottom of the signal, which allows the train stop to be cleared by cooperation of the train operator and the tower operator in highly restricted circumstances (see the call-on description for details).
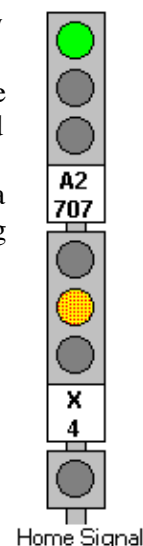
The third most common kind of signal is an **approach signal.** An approach signal looks just like an automatic signal (the illustration above is actually the former!); there is no easy way for a train operator to tell the difference (although in New York, approach signals have their interlocking number plates on their sides), but that is not a problem, as the meaning of either to him or her, and the behavior of their stops, is the same. Approach signals are controlled by interlocking levers (actually pushbuttons on an NX panel), and can be forced red by being cancelled by the tower operator at any time. Approach signals never actually protect switches or govern conflicting routes, but their control lengths frequently encompass trailing-point switches or interlocking exits. Calling an approach signal can move a switch; cancelling an approach signal may be necessary before certain routes can be set up. Although to a train operator an approach signal appears the same as an automatic signal, to the tower operator it is represented in the same way as a home signal, that is as a GK light with a lever number. Approach signals play an important role in approach locking. Approach signals are sometimes combined with Station Time (ST) timing for a particularly complicated behavior described elsewhere.

The two remaining kinds of signals are fairly rare. **Dwarf signals** are interlocked signals with only red and yellow lights, low on the ground, intended to govern low-speed, rare train movements, usually in the reverse direction or in or toward yards. Dwarf signals are obsolete; they are not used in new interlockings. They are inferior because they are hard to see, do not indicate which of a possible selection of routes has been cleared, and perhaps worst of all, lack train stops. Yet, they are traditional, and the author owns one (K3-343 from East New York Tower 3 Interlocking). A dwarf signal's control length does not check for track occupancy, and it may lack a train stop. As with a call-on, a train operator accepting a "proceed" indication from a dwarf signal must be prepared to stop within vision.
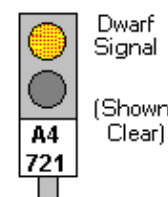
Marker signals, such as 30 and 38 at Progman St., are dummies that are always red, and are there to forbid movement unconditionally and serve as placeholders in the interlocking. They are extremely uninteresting because they never change state. Marker signals may or may not have train stops.

Marker Signal
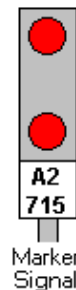
3.3 Basic NX Interlocking Operation

The basic idea of an NX ("E**N**trance-E**X**it") interlocking is to route trains over the interlocking by specifying the starting point (entrance) and ending point (exit) of each such path. On a real NX interlocking panel, buttons are pressed at the points representing the entrance and the exit; in **NXSYS,** the points are moused, signal GK lights for the entrances, and the exit lights that subsequently light up for the exits.

When you initiate a route at a home signal (or dwarf) by clicking left on its GK light, such as Signal 22 shown here, the interlocking will respond by lighting the GK light red. It will send out seeking-tendrils over all routes in that direction emanating from that point, and offer a choice of exits by displaying exit lights at each possible exit. Every possible consideration of switches that are locked and conflicting routes, i.e., the current situation, as described by other sections in this chapter, will be factored into the choice of which exits are offered. If no exits are possible, the interlocking will (usually) not let you initiate at all (the GK light will not turn red, and no exit lights will light up).

Initiation at signal 22
offers exits at signals 32 & 34

At that point you can click on one of the exit lights: this is called route **completion,** and causes electrical tendrils to spread out from the exit to seek the tendrils of the initiating signal: when they meet, they will enwrap each other, cancel all other exit lights, and turn on the entrance light (which looks just like an exit light) at the point of initiation, so you know that this has happened. At this point, the interlocking will cause all switches to move and all encompassed train stops to be lowered such that that route is actually set up and the initiating signal to be called and probably cleared. This is called "route selection," and is the basic operation of an NX/UR interlocking.

Instead of clicking on the exit light at a signal, you may also click on the GK Light for the signal itself; this feature was pioneered by the IRT, and Union Switch & Signal, hence it is called here the **UR exit feature.** The interlocking will determine that the signal is being selected as an exit, even if soon it will be an entrance, too. (Normally, the signal in the *direction opposite to traffic* is the one to select for an exit, unless there is none such, such as at Signals 10 and 24 at Progman St., when it is said that "the entrance and exit are in the same direction", and the signal is both at once. Try clicking slowly on 8, 10, 10, 14, then cancel, then 8, 14 to see this.)

At that point, when the route is all set up, white lines of light will indicate the track sections which form the route. You may play with trains, or cancel the route at any time by clicking on the GK light of the initiating signal. (You can cancel the initiation at any time in this way, even before completion.)

The NX interlocking takes it upon itself to operate the imaginary levers of the switches and signals in the route in the proper order. However, you might find, when initiating a route, that not all the exits you expected are offered: you will then have to figure out why (after having read the rest of this chapter), and cancel conflicting routes and/or move trains out, as would a real tower operator.

When you initiate a route, you may see the GK lights of other signals, or the some switches on the panel, begin flashing in unison. This indicates that they are preventing some routes and exits from being offered that otherwise would be. See Locking Conflict panel indications for more information on this.

Both supplied interlockings implement a features called end-to-end route selection (or, more recently, "through routing"), whereby NX selection over successive sub-networks, such as the diamond crossovers, relay initiations and completions from one to the next. Thus (at Progman St.) when one initiates a route at 4, one will see not only 30 and 10 as exits, but 14, 20, and 24 as well. If one selects one of the latter as exits, not only are other offered exits cancelled, but ultimately signal

10 is called in the middle of the route as though it itself had been the initiator. If, however, you wish to cancel an end-to-end route once it has been set up, you must do so signal-by-signal (or use the heavy hammer of the menu item **Interlocking|Cancel all signals.**)

For a *tour-de-force* of NXSYS/Progman St. power, initiate at 20 and complete at 34 in the upper left corner. Now cancel 16, 18, and 20 , deposit a train in A1-720 (the track section between 16 and 18 on track A1), and try the experiment again. NX/UR interlocking through-routing must choose the best of all possible paths when several are available between a given entrance and exit.

3.4 Signal Calling (Requesting)

Signals that can potentially affect each other and be affected by switches must be controlled by the interlocking such that their interactions be safe. Each signal is conceptually associated with a lever, which in earlier interlockings was an actual lever, controlled by the tower operator. In an "all relay" interlocking such as **NXSYS,** the lever is imaginary, and its effect is simulated by logic. If the lever is in its normal position ("cancelled"), the associated signal is guaranteed to be red. Only when the lever is moved to its other, called, position, is the signal able to clear in response to train movement.

Therefore, the levers controlling signals are interlocked with each other — they could not be moved out of their normal (signal may not clear) position unless other levers controlling other, conflicting signals are in their normal position. Of course, exactly which signals conflict is highly dependent upon switch position, which is in turn constrained by signals and so on.

In an NX interlocking implementation such as **NXSYS,** signal levers are not operated directly, but are controlled automatically by the route selection mechanism (see Basic NX Operation). It is possible to "cancel" any signal, though, that is, move its lever to the "normal" position simply by clicking left on the GK light of the signal you want to cancel.

Levers for approach signals are more or less controlled directly by clicking on the GK light: clicking on one which is not called attempts to call it (succeeding if and only if clearing the signal would be safe), and clearing it when permissible; clicking on a called signal, clear or not, cancels it.

Note that the GK light for a home signal will come on (red) when a route is initiated there; you can tell that it is not really called yet, i.e., the route not yet set up, by the possible presence of exit lights and the absence of white lines of light, indicating routes successfully set up.

A called signal will not clear until certain conditions are met. These conditions are the lack of trains (except for call-on) along the signal's control length and perhaps timers and certain complexities involving stops. Other conflicts would have prohibited it from being called in the first place.

3.5 Auto-cancel and Signal Fleeting

At active interlockings, it is quite common to set up a different route for every train, that is, very few successive trains take the same route. In these cases, it is convenient for a train could "cancel its own route," that is, clean up behind itself to facilitate subsequent setup for the next train, reducing the possibility that the following train will accept the same route by virtue of inaction. In other cases, especially at inactive interlockings, it is more convenient to establish routes and leave them set indefinitely for many successive trains.

NX/UR interlockings provide both modes of operation. The default is **auto-cancel:** when a train passes a home or approach signal, the signal will be cancelled and the GK light on the panel will go dark. Although the first track section beyond the signal will show red (occupied), subsequent sections will still show white and remain part of the route, lit up in white, held by route locking until the train passes through.

To cause a signal to remain called, it must be **fleeted.** (The term comes from the letting 'the fleet' pass through.) On a real NX panel, this is done by turning the signal button (which is normally pushed) in the direction of traffic. This turning operation also pushes it. When the signal is fleeted, the call for the signal, will not be cancelled by the track occupancy

resulting from train motion. Dwarf signals may not be fleeted, approach and home signals may.

NXSYS simulates the fleeting control with Shift-Mouse-left, that is, clicking left on a GK light while holding the **Shift** key down. The rules are a bit tricky, but fairly natural once used and mastered. Clicking shift-left on a signal (home or approach GK light) which is not initiated (shows blank) initiates and fleets it. The fleeted status in **NXSYS** is shown by a little green arrow on the stem of the signal. Clicking shift-left on a fleeted signal un-fleets it, but does not cancel it. Clicking left *without* shift on a fleeted signal, however, both un-fleets and cancels it simultaneously.

Multiple home or approach signals in a route created by end-to-end selection (see Basic NX Operation) must be fleeted individually.

3.6 Switch Locking

Moving the points of a switch while a train is on that switch, or about to hit it, is, obviously, extremely unsafe, and guaranteed to cause an accident.. Switch movement must be inhibited when the track sections of a switch are occupied, or a route is set up (or "lined") permitting train movement over it.

Interlockings provide a facility called "switch locking" which permits the movement of the switch only when the proper set of conditions prevails. When the switch may not be moved, it is said to be "locked;" it may only be moved when "unlocked." In **NXSYS,** if you click right on a switch (see Using the Mouse to Control the Interlocking), and it does not respond by flashing red and changing state, that is because (assuming you have clicked accurately) it is locked.

If you see a line of red lights (see What the various lit-up things mean) on the switch or any part of its track sections, that is a train, and that is why it is locked. This type of locking is called "detector locking." The switch will be unlocked only when that train clears the switch track section limits, if all else is OK. If you see a line of white lights, that means a route is set up by some signal further back along the white lights, or already in progress (see Route Locking), in which case the switch will not be unlocked until the train is gone.

If the switch still will not move, it may be because it is within the far extent overlap the control length of some signal further back, and the proposed movement would set a trailing-point switch against that signal. In this case, you must cancel that signal, which locks the switch, before attempting to move it. The interlocking will usually flash the GK light of that signal and the points of the switch in the position they are locked when you try to initiate: see Locking Conflict panel indications for more on this.

Switches are also locked by the train stops of all signals around them. No matter what the excuse, all surrounding stops must be up, that is, in "tripping" position, before a switch may be moved. For this reason, the interlocking will often a hold a signal at the exit of a sub-section red, so that its stop will not lock switches in approach to it. To see this in action at Progman St., try clearing a route from 10 to 14 both with a route from 8 to 10 and without. 10 will not clear, nor its stop, if there is neither a route nor a train (perhaps reversing) in approach to it.

In **NXSYS,** interlockings, as well as many real ones, you can tell by inspection if a switch is locked by looking at its switch lock indicator light. Associated with a switch's auxiliary key, the switch lock indicator lights the key in dark red when the switch is locked. When switches are free to move (not locked), they can be moved demonstrably via the auxiliary switch keys.

Again, in an NX interlocking, one does not usually move switches explicitly, but via route selection (see Basic NX Operation). Nevertheless, the route selection mechanism might refuse to offer certain exits because the switches that would have to be moved to line up a route route to that exit are locked, and may not be moved to the required position.

3.7 Approach and Time Locking

Approach locking and time locking are consequences of the fact that trains are big and heavy and, when moving fast, take a long distance and time to come to a halt, no matter how hard the brakes are applied.

Consider the following schematic scenario:
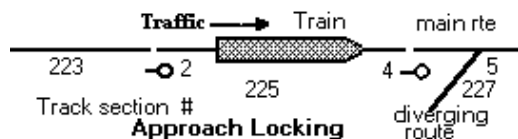
Imagine that switch 5 is set to a diverging route. By all that should now be understood, this means that signals 2 and 4 must be red (of course, 2 must be red because of the train), and cannot even be called.

Now suppose that switch 5 was set to the normal route, and both signals were clear. Suppose a train on 225 as shown were moving rapidly, and as the train approached signal 4 and the switch, the tower operator cancelled signal 4 in the face of the moving train, making it (or both?) red, and then caused the switch (5) to move, while the train was still barrelling towards 4 and 5. Nothing so far would prevent this — the train would indeed be tripped by the stop and signal at 4, but would take a long distance to slow down, and would doubtless run the trailing point switch and damage it and/or be derailed.

Cancelling a signal *at any time* cannot be made impermissible or prevented — it is a safety feature that a train may be stopped at any time. But telling the interlocking that "all is OK, 4 is safe at stop" (and hence, switch 5 may be thrown) when there is a train coming at it is not satisfactory.

The solution to this problem is **approach locking.** When a train is approaching a home signal, and it is cancelled by the tower, the route will drop and the signal will go red, but the rest of the interlocking will not "believe" the cancellation: the route will lock out other routes and hold switches locked via route locking.

Of course, it might be so that the train has been sitting there for a while, and is not moving rapidly. As just explained, approach locking would make it impossible for the tower operator to change his or her mind with a train facing a signal. The solution to this is **time locking.** Approach locking will release after a sufficiently long period of time, 9 or 10 seconds in **NXSYS.** If this is too long for you, the menu item **Interlocking|Release all approach locking** will release all approach timers immediately. Approach locking will also "quick release" as soon as a train gets into the route ("accepts" it), so that route locking can take over. Time locking in non-rapid-transit railroads is sometimes measured in *minutes*.

The approach locking of approach signals is one of the chief reasons for their existence. Consider again this illustration:
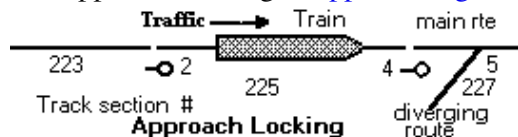
Imagine that the train is not there, that signal 2 has been clear for a long time, and 4 has been in the cancelled state for a long time, and the switch is set for the main route (but no route is set up over it). The interlocking has "believed" that 4 has been cancelled (approach locking has been satisfied) for a long time. Again, 2 was called a long time ago, and is clear.

Although in this state, signal 2 would have to be yellow because 4 is red, imagine that a train is coming along at high speed and fails to observe the yellow signal, and continues through 2 at high speed. As soon as it passes 2, the tower operator cancels 2 (if fleeted, or lets it auto-cancel) and moves the switch. Nothing now prevents the train from tripping at 4 and derailing at high speed.

The solution to this is approach locking for the approach signal 2. The interlocking will not "believe" that 2 has really been cancelled if there is a train *past* it, i.e., in section 225, at the time it is cancelled, until time-locking for 2 expires. Time locking timing starts when a signal is cancelled.

Thus, it would be impossible for the switch to be moved or a conflicting route to be set up unless 2 was either cancelled for "a long time" or there was no train in the "approach section." The problem stops there— the train cannot pass 2 without coming to a full stop, and thus, its speed at 4 would be limited.å

(In fact, there is a small "window of opportunity" between the time 2 is cancelled and 2's stop gets to come up that could allow 2's approach locking to release without tripping the train at 2 if misfortune lines up "just right": for this reason,

section 223 must also be part of 2's approach section. For consistency, the standard design would add 223 to 4's approach limits, too.)

To see approach locking in action at Progman St., drop a train in section A2-700 (between 2 and 4). Set up a route from 4 to 10. Cancel the route by clicking on 4. The white lights will not go out for 9 seconds (unless the train is removed). You can observe that during this interval, not only will switches 7 and 9 be locked, but 17 as well.

A signal's approach locking is released by one of three occurrences: (1) The signal is cancelled when there is no train within its approach limits (2) The time-locking time has run to completion since the signal was cancelled, or (3) so-called **quick release,** often omitted for dwarf and other rarely-called signals, which occurs when a train occupies the track section that would lock the switch that the signal is protecting (here 227): when the train enters that section, the signal's approach locking is no longer needed. Furthermore, approach locking cannot be released (or the timer even start) unless the signal is "verified to be red" (in older time, semaphores verified in position) and the signal's stop is verified to be in its tripping position.

The above grows in complexity when a home signal such as 8 at Progman St. locks a switch that it does not immediately protect, i.e., a switch in the overlap of its control length, (in this case, 17 at Progman St.). In this case, the home signal (8) is acting as an approach signal to signal 10 and switch 17 in addition to being a home signal protecting its immediate switch network. Thus, the quick release of 8 cannot occur until the train has touched the detector track sections of that distant switch (17, i.e., track 4714) and the local switch (7/9, 4707) simultaneously, and the sections between the signal and the distant switch it locks must be part of its approach section.

Approach locking timeouts in both New York and Toronto are normally 30 seconds; **NXSYS** interlockings have shorter timeouts to forestall boredom. In **NXSYS**, any signal's approach locking can be reset individually from its context menu before it has rightly timed out, and **all** approach locking can be prematurely timed out by the **Interlocking** menu or typing **Control-A**; both of these operations have no analogue in real interlockings, are patently (railroadwise) unsafe, and are there for debugging and simulation convenience only.

"If this sounds complicated, that's because it is."

3.8 Route Locking

Route locking is an interlocking feature which allows all the effects of a routing to continue to hold once a train has entered ("accepted") the route, even if the signals are, as is usual, cancelled shortly thereafter. It is a technique for semipermanently associating a train with a given route in a given direction and an intent to follow that route: it ensures that a train which has accepted a route is "just as bad" as the cleared signal it accepted, as far as the locking of switches (see Switch Locking) in the route and potential conflicting movements (see Signal Control Length)are concerned.

Route locking can be demonstrated at Progman St. Interlocking (in its default state) by setting up a route from 24 all the way to 4 on the Northbound Local track (click left on signal 24, then click left on the exit light which will appear at signal 4). Once switches move, the route should be cleared and lit in white. Now cancel 24 by another click on its GK light, and the route vanishes. Now set up that route again, but this time move a train in off the right edge of the map into track A3, and then past signal 24: the signal will auto-cancel, but the route will still being held and lit up in white. As the train moves southward, the route will still be held (preventing routing of 6 or 2, for instance). But as the back of the train clears track sections, you will see them go dark, as the route locking drops out.

Route locking is also frequently used at interlockings of more than one "network", or "sub-interlocking". In the layout below, there are two networks, one consisting of signals 2, 4, 6, and 8 and switches 5 and 7, and the other the remaining switches and signals (10, 12, 14, 16, and 18, switches 13 and 15).

Interlocking of two networks (sub-interlockings)
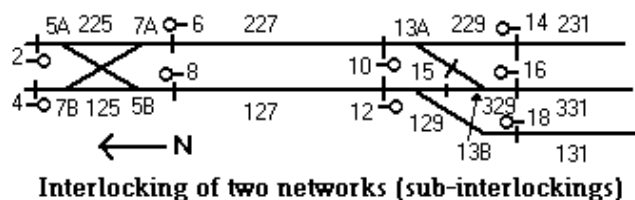
In the above diagram, route locking would usually be provided for track sections 127 and 227, to ensure that a train exiting one network toward the other prevents the establishment of an exit facing its motion as long as that train occupies the trackage between them. For example, if a southbound route were established from 4 to 6, and a train accepted the route, southbound route locking of section 227 would prevent an exit at 10 (i.e., northbound, from an entrance at 14 or 16) from being selected as long as that train occupied any track on the route between 4 and 10. In this case, route locking serves as an automatic replacement (i.e., requiring no tower operator intervention) for traffic control between the sub-interlockings.

Route locking is one of the criteria used in Switch Locking.

The **Release All Approach Locking** menu command also releases all route locking.

3.9 Time Signals

Sometimes, in addition to the performing the functions discussed under Control Lengths, signals are equipped with timers to restrict the speed of trains. These &;dquo;time controls" can be used with any type of signal (except dwarf or marker), and add a new facet of functionality. Time control occurs in two forms, **Grade Time (GT),** which restricts the speed of trains unconditionally, and **Station Time (ST),** which allows a signal to shorten its control length if a train approaches it at restricted speed. GT is easier to understand, and will be explained first. ST will be explained subsequently..

Grade Time (GT) Signals

GT (Grade Time) signals are so called because they are used on grades (slopes) and around curves. They operate by not clearing until the a train has spent a sufficient number of seconds in the track sections in front of the signal to be evidence of low enough speed.

In Progman St. Interlocking, the signals A2-725, A4-720 and A4-727 on the northbound tracks are GT signals; that is why they come up red. They will not clear until a train has been in track sections A2-714, A2-720 long enough, or more complicated conditions on the Northbound Express track. Deposit a train in A2-720 (between 720 and 725) and wait five seconds to see A2-725 clear. See the description of Islington for a list of GT signals there.

The simplest kind of GT signal is the "one shot" GT, which, in New York, has a single bright white ("lunar white") lens, which, when it is displayed with red (and it is displayed no other time) indicates that although it is red, the only reason is that the GT timer has not "timed out", or run its full course, and if the signal is approached sufficiently slowly, it will clear. This is called a "one-shot&rddquo; GT signal. The lunar white indication is used slightly differently in Toronto: there, it is on the signal *before* a GT signal, and indicates that the latter has not cleared because of time alone.

Automatic signal displaying Lunar White (GT) aspect
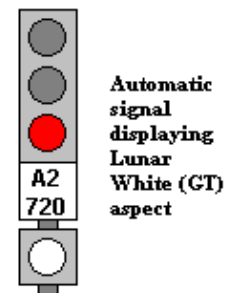
Sometimes more than one track section in front of a GT signal can be used to time and clear it. In that case, the signal in between the train and the GT signal will go from yellow to green at the same time the train times out the GT signal. To see this at Progman St., bring up Full Signal Displays of all the signals on the A4 track, route signals 8 and 10, and move a train very slowly northward, section by section. The idea here is that the train operator gets two chances to achieve the right speed, and need not fear being tripped if he or she should fail the first time. This is called a "2-shot (or 2-try) GT signal": it has two independent timing sections, the latter of which is run if and only if the first is not satisfied (unless it is shared with the next signal in a series of 2-shot GT signals).

The GT timeouts on Progman St. Interlocking are defined by the "US relays" in **progman.trk,** and are 4, 5, or 6 seconds as appropriate. (Normally, the time constant is calculated as would be expected, i.e., the quotient of the track circuit length

and the desired speed, but as **NXSYS** train kinematics still leave room for improvement, these fairly arbitrary numbers have been chosen).

When a 2-shot GT signal is red for **only** the reason that its timer has not timed out yet, that is, traffic or interlocking reasons are not holding it red, and the signal before it is clear, that latter, nearer signal will not only indicate Yellow (prepare to stop), but have a lit-up "S" under the first head. This can best be seen on signal 10 (A4-714) at Progman St. Set up a route from 8 to 14, and click right on signal 10 to watch it. The "S" will be present on 10. Putting a train in section 727 will negate this condition, and cause the "S"; light to go off. The "S" light tells the train operator that by his or her going slowly enough the next signal (i.e., the one after the one with the "S" light) will clear.

Full Signal Display

For an automatic signal in front of a GT Signal
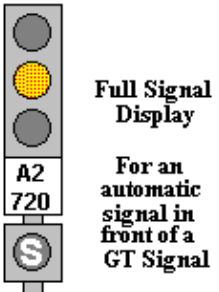
Station Time (ST) Signals

Although Station Time (ST) signals are extremely common in New York, there are none at the fictitious Progman St. There are three fairly complex ones (X48, X20, X18) at Islington Interlocking, and at Atlantic and Myrtle Aves. in Version 2. Station Time facilitates trains "closing in" on stations to keep them moving, albeit slower, when trains are stopped ahead in a station. Here is the canonical situation:
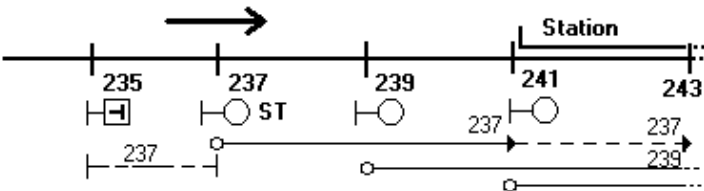

Illustration of ST (Station Time) signal timing

The control length of signal 237 is shown as extending from the signal itself downtrack to IJ 243. That is, if any portion of a train appears between insulated joints 237 and 243, 237 will display a red, "stop" indication to oncoming traffic. Referring to the earlier discussion of control length, it can be seen that these 600' control lengths imply a safe braking distance between 200 and 400 feet.

If there is a train, or portion of a train occupying the "dotted portion of the control length", that is, between 241 and 243, but no portion of any train in the "solid portion of the control length" between 237 and 241 (that is, the end of a train is in the station), a new condition obtains: a second train approaching 237 sufficiently slowly to "time out" the section between 235 and 237 will cause signal 237 to "cut back" its control length to the solid portion, effectively ignoring the train in the dotted portion. Of course, this is not unsafe, because signal 239 will still enforce a separation (with the normal policy of stops for automatic and approach signals, 241 will not). If the train is going slow enough to cause 237 to cut back its control length, it would be able to brake in the 200' between 239 and 241. This reduces the minimum separation between trains in approach to stations.

An ST signal allows trains to "close in" on each other by acting like a GT signal if only the dotted portion of its control length is occupied. Some signals are GT and ST at the same time; the ST timing must obviously be slower than the GT timing if this is to be meaningful. A yellow sign with a "T" on it (and often the ST speed limit) indicates the start of a timing section for ST. Often, several ST signals occur in sequence to coordinate this situation.

The signal at right displays the standard New York aspect for an automatic ST signal in the "ST" state, that is, a train occupies only the dotted portion of its control length. The "20" indicates that the signal must be approached at 20 miles per hour to time out its ST: it is only lit when the the signal is red, but actually *will* clear if approached sufficiently slowly. In older New York signalling, and at Islington, the ST signal has no special indication for its ST state.

Automatic Signal displaying Station Time (ST) aspect
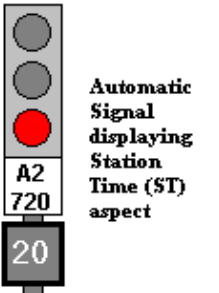
Interlocked Station-Time Signals

Station Time (ST) explodes in complexity when combined with interlocking. When the dotted portion of an interlocked signal's control length encompasses trailing-point switches and possible conflicting routes, the conditional nature of the signal's control of that region of track has implications throughout the interlocking. Some interlocked ST signals actually cause conflicting switches and routes to be cut out of the control line when the latter is cut back. The policy

employed with the three ST signals at [Islington] is that of the NYCT standard in this case, as follows. This is quite complex; please read it carefully.

When an attempt is made to route an interlocked ST signal with this feature, a determination is made as to whether the "dotted portion" contains conflicting routes or trailing-point switches thrown against the route that cannot be moved now ("bad switches"). If there are no conflicting routes or non-movable "bad" switches in the dotted portion, the signal is called "wholesale", and such bad switches in the dotted portion that need be moved are — it then behaves as above over its route, and locks those switches and fully governs the section. If there are conflicting routes in the non-dotted portion, the signal cannot be called. But if there are conflicting routes or non-movable bad switches in the dotted portion and only the dotted portion, the signal routes and clears in a "restricted form", whereby it does *not* move the switches, but displays an ST aspect (in New York), and requires ST timing to clear at all. If the "bad switches" subsequently move to a non-conflicting state (but *not merely unlock*) by virtue of some other manipulation while the signal is in this state, the signal advances automatically to the "wholesale called" state, and clears.

In short, when an attempt is made to route an interlocked ST signal of this kind, if a conflicting situation in the dotted portion of the control length can be cleared at that time, it will be, but if not, the signal will be called but not cleared, and will only clear on station time. If and when the conflicting situation in the dotted portion is resolved by other action, the signal will clear.

This model is implemented in full for signals X48, X20, and X18 at [Islington,] and may be investigated there.

3.10 (Automatic Train) Stops

Unlike street traffic lights, subway signals can force disobedient traffic to stop. Next to each signal (except some dwarfs) at track level lies a T- or hammer-shaped apparatus, controlled by motors on the BMT/IND and air on the IRT, which rises (via a counterweight, for safety reasons, when not actively held down) to an upright position more or less when the associated signal is "red," and wants trains to stop. This **trip,** or **train stop,** will engage a brake valve on the underside of a passing train and **trip** it, i.e., cause the train to screech to an emergency halt.

The "more or less" is due to the fact that a signal turns red as soon as the front of the first car of the train passes it, and care must be taken not to trip the rest of that very train. Also, trips for signals that are being passed backwards, such as at interlockings, must be carefully cleared (put "down", i.e., not "tripping") when routes are cleared over them, and restored when the train is passed or the route cancelled, lest they trip the train by hitting the brake valve in the wrong direction (this is known as **off-side tripping.**)

It is important to be able to see the state of train stops in a world where you are both train operator and tower operator. On a real NX panel, stops are not shown. **NXSYS** displays train stops as little triangles on the right of the track (seen in the relevant direction of motion), as per IRT convention, but also creating a visual association with the correct signal. By default, the triangle is shown red when the stop is in the tripping position, and not shown at all when it is clear. Via the menu item **Other|Show Stops** you can elect to show them this way, at all times, in which case they will be yellow when clear, or never, as on a real panel. They are also fun to watch, especially as they come up behind the ends of trains, proving that the interlocking is indeed working correctly. They are especially interesting in the case of reverse-direction routes.
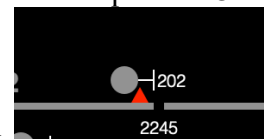
Unless you have chosen never to see stops on the panel (as on a real NX/UR panel), the little stop triangles will flash rapidly when the stop is in motion, flashing red when the stop is moving to tripping position, and flashing yellow when clearing. As in real life, it takes about a second to move the stop. A signal will not clear until its stop is fully cleared (although its GK light will indicate "clear" before the stop begins to clear). If you have a full signal display up, an animated graphic of the stop moving will be visible.

All signals except some dwarf signals and some marker signals have stops.

Automatic and approach signals implement a feature called **automatic key-by,** ("AK") whose use, has in recent years been forbidden in New York, unless explicit permission is given by radio, due to accidents resulting from abuse. But it is implemented in the wiring, so **NXSYS** signals implement it. This feature allows you to pass a red automatic or approach signal if you creep up to it extremely slowly: the relative placements of the train wheel, trip valve, IJ and stop are sufficiently carefully worked out that if a train crawls past the IJ of such a signal, the stop will drive (go down). To do this

on **NXSYS,** you must be in **Free Will** mode on such a train (track sections occupied or vacated by the "mouse from Heaven" are not trains, and thus not subject to train stops!), and perform this maneuver at a speed of less than 5 "sim units" per second, which requires, intentionally, extreme care. As in the real world, you may not, and will not be allowed to, "key by" a home signal.

Because the standard implementation of AK optimizes the use of the same track relay contact to support reverse-direction motion, you may observe that the stops for automatic signals do not come up immediately behind a train, but at a distance of one track section behind the train. For this reason, overlap of control length is critical if stops for automatic signals are to have any efficacy. Yet another advantage of this technique is the saving in lengthy and expensive copper wiring in automatic signal territory, where checking the section in approach to the signal and stop would require an additional wire back to the previous signal.

In most recent (2016) New York signalling, an explicit timer (**UK**, nomenclature, not Britain) is involved in automatic key-by; **NXSYS** scenarios don't have this.

There is also the call-on feature, which allows a "manual key-by" past home signals in certain very special circumstances. The train operator and the tower operator can cooperate to lower the stop of a home signal when the appropriate circumstances obtain: Please read that section for details.

In the real subway, stops may be "hooked" by being forced down by foot pressure and latched into a "clear" position. This is an emergency procedure that is employed when signals are malfunctioning. Although **NXSYS** currently provides no means to simulate that procedure, its interlockings do make all the checks of stop action that are often motivated by its use.

Stops are also involved in an automatic behavior called "cycle check." A signal will not clear, nor clear its stop, unless it can prove that the latter has actually been in the tripping position. This verifies that the stop is working properly, has not been "hooked," and has the ability to trip.

Signals set for normal traffic movement also check off-side stops before clearing. Stops are also directly involved in switch locking. Please see that section and back-to-back signals.

3.11 (Home Signal) Call-On

Call-on is a feature used in very special circumstances which allows trains to pass red home signals by means of close cooperation between the tower operator and the train operator.

The idea of call-on is to allow trains to close in on each other past home signals, just like with automatic key-by on automatic and approach signals, except that both the tower operator and train operator must cooperate via taking special explicit action: if the circumstances are acceptable for call-on, the tower operator displays a call-on indication on a home signal, and the train operator creeps up to the signal and **accepts** the call-on by pressing a special button that causes the train stop to be lowered, and holding it until the stop drives (comes down). He or she may then pass the signal prepared to stop within vision. The call-on "aspect" (the way it looks) of a home signal is red over red over yellow; there is special yellow light at the bottom of each home signal reserved for this purpose.

The conditions which must obtain to permit a call-on are easy to describe, namely, all the necessary conditions for clearing a "high signal" (i.e., a normal clear signal, not a call-on), absent the necessity of there being no train in the home signal's control length. That is, the route must be initiated and completed, all switches in the correct position, and no conflicting routes. What is more, the track section in front of the signal, the "approach section," must be occupied — a train must be at the signal. To "clear the call-on," the tower operator sets up the route as usual, but at some time after initiating, presses the **call-on button** for that signal. In **NXSYS** this is done by clicking **control-left** on the signal, not when initiating, but as a separate, second gesture after initiation: one can do this even when the signal is already called and the signal is red (but a train *must* be in its approach section). When the call-on is cleared, the GK Light will blink yellow, and the call-on indication will be displayed. At that time, the "call on is being offered," as a full signal display will reveal. The signal, as always, can be cancelled at any time by clicking on it.

The train operator **accepts** the call-on by pressing a button actually attached to the signal — in **NXSYS** this can be done

via a button in the train system, which see, or via the signal's context menu, which also see. At that time, the train stop will drive (go down), as the full signal display will reveal, and the GK Light will go to steady yellow. The call-on will be ended when the approach section is vacated; whether the signal is cancelled then, too, depends on whether it is fleeted, as in the non-call-on case.

In real interlockings, the call-on can be set by the tower operator pressing the call-on button when the signal is already called, but red, or by holding the call-on button while initiating (even if a high signal can be cleared), a train being necessary in the approach section in ether case. Since one only has one "hand" with **NXSYS**, the latter method is achieved in **NXSYS** by initiating, and *then* clicking control-left on the signal.

In Toronto Interlockings (such as Islington), some home signals are equipped with "automatic call-on." Such signals display a call on aspect automatically if one could be displayed after a train sits for a significant length of time in front of the signal; the stop clears automatically, without need for the train operator to operate the call-on button.

3.12 Auxiliary Switch (Test) Keys

Auxiliary switch keys, also known as switch test keys, are miniature levers on all-relay interlocking panels (i.e., including NX/UR) that allow direct call for switches when such manipulation is safe. When such calls are not safe, manipulation of the auxiliary keys is ignored.

Auxiliary switch keys are not employed in normal operation, and typically find use in the following circumstances:

- To test the switch controllers and motors to verify that they are functional, i.e., during maintenance, adverse weather conditions, etc., without actually setting up routes and perhaps misdirecting trains. Obviously, in **NXSYS,** such testing is not an issue, although experimentation becomes a possibility.

- To operate the switches under emergency conditions. Again, this is not an issue in **NXSYS.**

- To experiment with the effect of various constraints on the route-selection mechanism of the interlocking. This is a possibility in **NXSYS.**

- To test, i.e., verify the proper function of, the interlocking. This, too, is certainly a possibility in **NXSYS.**

- To "force the hand" of the preferred/alternate end-to-end route selection mechanism of the interlocking, i.e., to force it to choose a specific route of many possible between two points, when that route is not the one it would choose by default. This is the main reason why they are supported by **NXSYS.**

The auxiliary switch keys on real interlocking panels are miniature levers about an inch high, with three positions. Each is associated with one switch or crossover, i.e., one conceptual switch lever. Unlike a lever on a traditional interlocking machine, auxiliary switch keys are not mechanically constrained; their manipulation is simply ignored when unsafe. When moved to the left, the switch is called to move normal; when moved to the right, reverse. The key can be operated momentarily and returned to center, submitting a call for the switch, or simply moved, submitting and sustaining a call for the switch.

In **NXSYS,** the switch keys are lighted buttons with two halves, the top half for the "normal" call and the bottom for "reverse." When not active, they are grey. **Click left on either half** issues a call for the switch to move to the corresponding position. The half-keys light up, yellow for reverse, green for normal, as long as the mouse button is held down.

Aux. switch keys & lock lights

To submit a momentary call for a switch, click left on the top (normal) or reverse (bottom) half of the button, which will flash when clicked on. To submit and sustain ("stick") a call for a switch, click right on the appropriate half. To release the call, click left on it. The command menu item **Interlocking|Clear all aux switch keys** can be used to release all calls at once.

The call for a switch, whether generated by the switch keys or the normal mechanism, will not be honored if the switch is

locked. A call can be submitted and stuck, but (in general) the call will not be honored when the switch becomes unlocked (preconditioning); as a matter of fact, in this switch the switch will *remain* locked until the call is removed.

When a switch successfully moves on sustained call from the switch keys, the points of the switch, normal or reverse as appropriate, light up in steady white (similar to a route) to indicate that this call is in effect —— that lit portion will be included in routes over the switch.

Switch Lock Indicator Lights

On some interlocking machines, NX/UR and otherwise, panel lights are provided to indicate when a switch is locked. This feature has been added to **NXSYS** because it is quite instructive to watch, study, and understand the locking of the various switches of the interlockings as routes are set up, accepted, and released, and as trains move through.

When a switch is locked, a red light above its auxiliary key (in **NXSYS**) will light up; that is the **switch lock indicator light**.

As befits the semantics of switch locking, clicks on the auxiliary key will be ignored when the switch is locked (i.e., the lock light is lit).

Note that calling for a switch is not the same as locking it: while calling for a switch to move reverse may cause it to move reverse and cause calls for it to move normal to be ignored, that does *not* constitute locking as far as the interlocking is concerned. The switch is only locked when a route is set up over it, or any of the other diverse conditions discussed under switch locking and elsewhere hold.

Click right on a switch is an older **NXSYS** shortcut for auxiliary switch key operation.

It is extremely instructive to initiate routes, especially long end-to-end ones, and, before completion, experiment with the auxiliary switch keys to observe the effect on the choice of exits offered.

Controlling alternate end-to-end routes with switch keys

To force an end-to-end route path with auxiliary switch keys, click right on the auxiliary switch keys for one or more critical switches in the route to be set up to call them to the positions you want. Of course, these switches must be unlocked for this to work. Then initiate the end-to-end route. The selection circuitry, forced to respect the switches you have called, will set up an end-to-end path through them, if possible. The white lights lit over the switch points by the auxiliary keys will be incorporated into the route chosen.

3.13 Locking Conflict panel indications

An NX/UR interlocking has the ability to tell you why it refuses to set up a route that you ask it to. Normally, this is because either an exit you want is looking into a cleared (or approach-locked) route in the opposite direction, or a switch that must be moved to establish that route is locked in the wrong position for any of the reasons discussed below. The former case can usually be discerned easily by inspection. The latter case is equally easy to discern when the track section containing the switch is occupied nor part of a route — lit up in red or white, the reason why the switch will not move is shown plainly.

When a switch is locked by the overlap of the control length of a signal it is neither part of a route nor its track section occupied, and it is usually not clear by inspection why the switch is locked. In this case, when you try to initiate a route that but for a switch being locked in this way would extend out over that switch, the interlocking will flash the points of the switch (on the interlocking panel) in white and the GK light of the signal that is locking it in unison. You then can cancel the signal so identified, or the initiation, for that matter, or ignore this information and set up some route which is not locked out.

To see this in action at Progman St., route approach signal 2 by clicking on it, and then try to initiate at signal 8 by clicking

on it, in turn. The GK light for signal 2 and the normal-position points of switch 9 will begin flashing, signifying that signal 2 is locking switch 9 normal, and that is why no exit at signal 30 via 9 reverse is being offered. Cancelling 2 at this point (by clicking on it) stops the flashing and offers the additional exit. Selecting the exit at 10 (or elsewhere), or cancelling the initiation at 8, also stops the flashing conflict indication.

It is possible for a switch to flash in this way without any GK flashing. This occurs when the a signal is no longer called, but its approach locking has not yet timed out and is locking the switch. Obviously, you cannot cancel the signal — you must either give up, wait for the approach locking to time out, or cancel all approach locking via the command menu.

There is also one case where a switch and the signal locking it will continue to flash even though an exit has been chosen. This is the case of facing point overlap, which see.

3.14 Advanced Locking Scenarios

(For the intensely curious and dedicated only — beginners may ignore this.)

In order to maintain all the rules already stated, switches and signals have to interlock in very subtle ways that are not at all obvious upon first inspection. This section discusses several situations that occur in real interlockings, and are dealt with by the 733-33 standard. They all occur at Islington Interlocking, but not at Progman St. They occur frequently in the Advanced New York scenarios. The following diagram will be referred to in the rest of this section:

Complex conditional and crosslocking situations
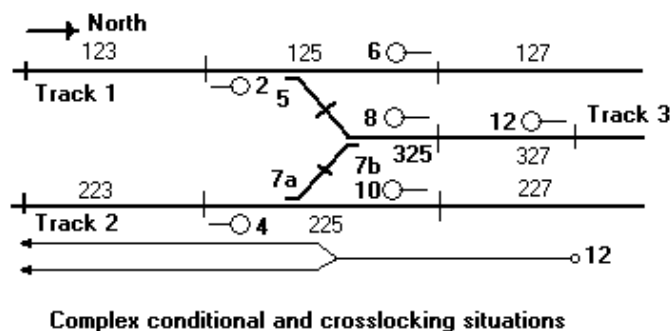
The above is known as a "crotch layout", and is exceedingly common in all railroads, the New York subways not excepted. As can be seen, it is the termination of a third mainline or siding track to running tracks. Although the above example is fully signalled for all possible moves, often signals 2 and 10 might be omitted, or be marker signals. The three switches are controlled as one crossover (7) and one singleton switch (5). There is an approach signal on the center track (12), and, as can be seen, its control line extends past the home-signal-protected area out to track sections 123 and 223.

The first issue is a railroading practice concerning the effect of switch 5 on routes over switch 7 reverse. If a route is to be set up from signal 4 to signal 8, or vice versa, which would be over 7 reverse, the position of switch 5 is theoretically of no consequence, as it is not involved. However, good railroading practice demands that in the case such a route, 5 be set normal. It can be seen that a northbound train on track 1 has less chance of causing damage, broadsiding the train on 7 reverse, if 5 is ensured normal. The interlocking must, therefore, ensure that 5 is capable of being set normal, and moving it so, when any route over 7 reverse is set up. Any situation which locks 5 reverse (but somehow does not lock 7) will lock out a move over 7 reverse. This is referred to as the "crotch layout" case in the literature.

The second issue is called **conditional crosslock**, and involves signal 12, an approach signal, and its interaction with the state of switches 7 and 5. It can be seen that if 7 is normal, 12 cannot clear unless 5 is reverse — with 7 normal, 5 is a trailing-point switch in the control length of 12. Either one of 7 and 5 must be reverse for 12 to be able to clear. Now, as described above, when a route is laid out from 8 to 2 or 4, switches 5 and 7 must both be moved such that only one is ultimately in the reverse position.

In detail, assuming no route is set up over 5 and 7, clearing signal 12 must force either 5 reverse and 7 normal or 7 reverse and 5 normal. Assume no route over 5 and 7, but 5 reversed, and 12 is clear (over 5 reverse to 123). Assume we then wish to set up a route from 8 to 4 over 7 reverse in this condition. As stated above, 5 must be normal before a route over 7 reverse can clear. But if 5 is set normal before 7 is fully moved, the control length of 12 will see switch 5 set against it, and

will turn red ("be kicked off"), perhaps in the face of an oncoming train, which is impermissible. Thus, the interlocking, in this case, must move switch 7 *first,* then switch 5, so that at no time is signal 12 kicked off. This is done automatically by the interlocking; it is not something the tower operator must concern him or herself with. Switches 27 and 29 at Islington have this relationship, and this behavior can be observed. When there is an exit at 44, 27 and 29 can be moved by hand (right click), but only one at a time and never through the state where both are normal.

Note that it must be permissible for 7 and 5 to be reverse simultaneously with 12 clear (but, presumably 8 not (yet) clear). Were this not so, it would be impossible to call and clear 8 to an exit at 4 with 12 already clear over 5 reverse and 7 normal.

The third issue is called **facing point overlap.** Again, this involves signal 12 above, and manipulating switches 5 and 7 in a situation where 12 is already clear under such constraints that the signal is not kicked off as a side-effect. Consider switch 5 reverse, 7 normal, approach signal 12 clear over 5 reverse into section 125 and 123. As can be seen from the diagram, its control length extends out through 123. Suppose, in this situation, that section 223 were occupied, and an attempt were made, even under all the constraints above, to move switch 7 reverse, perhaps to clear up a call-on on 8 into the train at 223. Even though the route is valid and permissible, a side-effect would be to "throw the train" into the control length of 12, which will kick it off as soon as the switch is moved, which is impermissible.
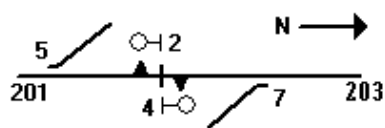
In this case, switch 7 is said to be "locked by the overlap of 12". A properly-designed interlocking will not permit 7 to be reversed in this case. However, a very special allowance is made in this case. The route from 8 to 4 can indeed be set up, but the switch will not move until the train leaves 223, at which point the switches will move and the route will complete its setup automatically. This is called **preconditioning** the switch, i.e., setting up a situation where a later event causes a manipulation attempted earlier to take effect, and the only case where it is permitted. The switch and signal 12 will flash on the interlocking panel (see Locking Conflicts) with entrance and exit lights showing in this state.

In all of the above scenarios, "signal 12 is clear" is shorthand for "signal 12 is clear, or its approach locking has not reset." Please see Approach Locking for a discussion of this.

All of these situations can and do occur simultaneously. They all occur simultaneously over switches 27 and 29 at Islington, where the complexity is further enhanced by the interaction of these three situations with station time (ST) signals. They occur frequently at the advanced version 2 real NYC scenarios.

3.15 Back-to-back signals

Two signals in opposite directions at the same location (the same insulated joint) present many interesting issues. Consider the following two signals and associated switches and track: Note that each of the signals 2 and 4, which must be home signals, has a stop. Every signal (except some dwarfs and markers) has a stop, and is prepared to stop a train. When two signals are at the same location, their stops are at the same location, but on opposite sides of the track. A stop in the wrong direction in the tripping position can indeed trip a train, but it is not designed to. Thus, no matter what other rationale can be brought to bear, it is not meaningful for two stops at the same location to disagree, i.e., one be tripping and one be clear. Thus, the two stops at 2 and 4 are controlled (and sometimes even constructed) as one mechanism. This is the case in **NXSYS.**

Back-to-Back Home Signals

This raises issues about how the two signals interact to clear the stop. Clearly, if either one is clear, the stop must drive (go down), and when a train passes the pair of signals in either direction, the stop must come up behind the train.

An additional complexity is introduced by the fact that stops lock switches. That is, a switch cannot be moved until all stops protecting it are in the tripping position. Thus, for switch 5 to move, 2's stop must be tripping, which, of course, is no surprise, as 2 must not be called. But since 2's stop is 4's stop, 4's stop must be at tripping, and thus, 4 must be at stop. Therefore, unless 4 is at stop, 5 cannot be moved, which is not obvious. If 4 were clear, there is little sense in clearing 2, as no trains can be between two signals at the same point. But clearing a route with an *exit* at 2, i.e., entering at the left of the diagram, would be impossible if 4, and thus 2's stop, were clear. Thus, interlockings (including in **NXSYS**) require a home signal in this case to be red unless there is a route lined up *toward it.*

There is an exception to this case: if a train moving southward passes completely past 2/4, and wants to reverse, it would be impossible to clear 4 under these conditions. Therefore, the rule above is short-circuited, as it were, if there is a train in 201 — occupancy of 201, or north routing through 201, permits 4 to clear.

Note that all signals check their stops, and do not clear unless and until their stops are clear; the shared stop being in the tripping position forces both its signals red.

Lengthy bidirectional tracks between interlockings feature back-to-back automatic signals at each insulated joint. Such tracks are always under traffic control, whose consistent state chooses between the control of the two signals for the shared stop or stops.

This situation becomes even more complex when the back-to-back signals are of different types, e.g., one is an automatic and the other is a home signal or marker signal. In this case, the automatic-key-by feature of the automatic signal would totally defeat the stop of the home signal unless great ingenuity is applied to the management of the shared stop. It turns out that the standards used by NYCT consider the idea of a home (or marker) signal's stop being driven down by another signal's AK, no matter what the rationale, less acceptable than decoupling the two stops, and that is the policy currently in force at marker 30 and automatic A2-714 at Progman St. (for example) and elsewhere in the **NXSYS** interlockings. It is the establishment of a northbound route from signals 4 or 8 exiting at 30 which drives 30's stop (the **VS relay**) and allows automatic A2-714 to clear at all.

The practice of operating the two stops of back-to-back signals from the same motor ("shared stop machine") was once common on the BMT, but is no longer employed.

3.16 Traffic Control and Traffic Levers

Traffic control is a technique used to coordinate the direction of traffic on a single run of track (henceforth, "the extent"), usually lengthy, connecting two interlockings (i.e., with none other between them). **Traffic levers** are operator controls at those interlockings (actual levers in classic frames, or equivalent knobs at newer ones, including NX/UR) employed to operate this. When mutually consistent, they designate the containing interlocking as either the entrance to the extent or exit from it. In traditional lever-frame interlockings, levers are physically locked, i.e., cannot be moved, unless appropriate conditions obtain. In "all-relay" interlockings, including NX/UR, these controls are not physically locked, but (as elsewhere) have no effect unless appropriate conditions obtain: the white arrow-marked directional lights surrounding the "traffic lever" knob show red when it is logically locked.

Routes cannot be lined to allow trains into a traffic-controlled extent unless the traffic levers at both ends agree about which is the entrance and which is the exit. To change traffic direction, the interlocking desiring to be the new exit must first so declare itself, and only then can the interlocking desiring to be the new entrance concur, and so declare itself, whereupon the new direction is finally established. The conditions which must be met that permit either action are as follows:

The interlocking desiring to declare itself the exit of the extent (the end receiving trains from it) cannot so set its traffic lever unless

- **Exit conflict** — No routes are set up whose exit is *to* the extent; no such routes previously set up are are active on account of approach locking or route locking.
- **Compliance** — All approach or home signals under the control of this interlocking actually on the extent governing movement away from it have been cancelled and their approach locking released, i.e., all those that cannot be called once the exit is established.
- **Vacancy** — The extent is presently fully unoccupied.

The interlocking desiring to declare itself the entrance to the extent (the end supplying trains into it) cannot so set its traffic lever unless

- **Concord** — The distant interlocking has successfully set itself up (i.e., moved its lever) to be the exit, validating the above conditions.
- **Compliance** — All approach or home signals under the control of this interlocking actually on the extent governing movement towards it have been cancelled and their approach locking released, i.e., all those that cannot be called once the entrance is established.

- **Vacancy** — The extent is presently fully unoccupied (yes, it's implicit in the above).

Note that traffic direction cannot be changed if there are trains, portions of trains, or even faults falsely indicating trains, in any portion of the controlled extent (**Vacancy**). Of course, the whole purpose of this mechanism is to subsequently admit trains into it from the "entrance" end.

Traffic-controlled extents between two distant interlockings always contain automatic signals in both directions, most often back-to-back pairs sharing an insulated joint and (on old BMT) a stop machine. The concurring traffic levers determine which signal of each pair is functional, how the shared stop should function, or which unshared stops should function and which "lay low". Home and approach signals conflicting with the proposed traffic direction cannot be called once it is established; hence, the need to cancel them before the change can be effected (**Compliance**).

There are no supplied interlockings with **NXSYS** containing multiple sub-interlockings (although some such **NXSYS** scenarios do exist!). Therefore, there is no real need for traffic levers in the supplied ones. However, the real interlockings they model do involve traffic levers, such as Atlantic Avenue, where the northern ends of the local tracks become the Seventh Avenue IRT, and face Wall St. Interlocking with traffic levers at each end. The **NXSYS** interlockings thus supply a traffic lever which is not coordinated with any distant traffic lever; such "singleton" traffic levers are only subject to the conditions other than **Concord** listed above. "Singleton" traffic levers are not unheard of "in real life" in large interlockings with discrete "sections" controlled from one panel. (Deep insight — route locking by and large accomplishes the same thing in a one-interlocking context.)

An **NXSYS** traffic lever, comprising a knob and the two directional lights, looks like this. Clicking on any part of it at all "flips" it the other way, but doing so will have no effect if either light is red (i.e., the lever is logically locked by the conditions above not being met.).
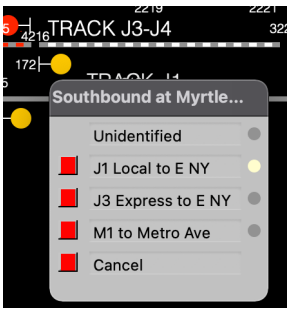

3.17 Train Operator Route Selectors and Automatic Operation

Since time immemorial in the twentieth century, New York Subways have included "route selector" push-button boxes for Train Operators (previously called "motormen"; many are now women) to "punch", from their cab windows, to identify their trains and destinations to inform the the Tower Operator, usually at the next station, of their intent, and in some places (e.g., DeKalb Avenue, Brooklyn), inform passengers on the platform. In the twenty-first century, the latter function, at least, has been obsoleted by radio communications and "arrival prediction" digital displays in many cities, including many places in New York.

The author of this application, while bidding a bittersweet farewell to this ingenious system which even fifty years ago implemented a "queue of trains" without chips or computers, but just wickedly clever relay logic (deeply remeniscent of Route Locking), nonetheless offers it in Version 2 **NXSYS**. Some supplied interlocking scenarios (e.g., Myrtle Avenue) have this feature.

When this feature is enabled for an interlocking, the **Automatic Operation** item on the **Interlocking** menu is enabled, and you must check it to turn the feature on. When Automatic Operation is enabled, occupation of certain track sections (often at the limits of the scenario, or at station platforms) where, "in real life" Route Selector boxes appear (including when an NXSYS train occupies it) causes a very similarly styled **NXSYS** "Route Selector menu" to pop up there. Here is what one looks like on the Mac (the Windows version is a Windows-styled (as opposed to trackside-styled) multiple-choice menu):

Southbound at Myrtle...

Unidentified	○
▪ J1 Local to E NY	○
▪ J3 Express to E NY	○
▪ M1 to Metro Ave	○
▪ Cancel	

The actual button box appearing in the subway system is more or less a menu, thus it is not surprising that a menu should represent it. You (the **NXSYS** user) take on the identity of the Train Operator, not the Tower Operator, when you "punch in" your train identification on the buttons at the left of the box; the circles on the right of the box are lights that identify your choice, which is initially **Unidentified**. The **Cancel** button at the bottom of all such boxes, as "in real life", reverts you to that state.

When you choose such a route by "punching" one of the other (than **Cancel**) buttons, your choice is transmitted, cascaded, through relays associated with each track section ahead of you to the nearer of the back of the next train (ahead in space, preceding in time) or a similar box at the switch whose setting you are trying to choose (and forges ahead as the next train vacates sections — I've just given away its "real life" implementation secret). When your train arrives at that place, the Automatic Operation logic will actually press signal and exit buttons and set up ("line") the requested route! If, at that place and time, you, the Train Operator, press **Cancel**, the lined route will *not* be cancelled, and you, the Tower Operator, must cancel it yourself. When a train setting a route this way accepts the lined route, it will (modulo bugs) cancel it by the normal auto-cancellation.

4. Interlocking Scenarios

NXSYS comes supplied with two sample interlockings, Progman St., a four-track setup with three double crossovers, not unlike Brighton Beach or 57th St. (Broadway/7th Avenue) (those old enough to remember the Brighton Express will recognize and appreciate the symmetry) with a single crossover added, and Islington, a two-track setup with a double crossover and a siding, the latter not unlike Lefferts Ave. on the IND Fulton St. line or Court Square on the IND Crosstown. In Version 2, including the Mac version, two additional, real NYC interlockings are also supplied (click on that).

Islington is the more recent addition to **NXSYS**, and was designed from actual Toronto signal charts. Progman St., on the other hand, contains many simplifying assumptions, such as the lack of station time signals and facing point overlap. Progman St. is much better for learning the rudiments of NX/UR operation, while Islington goes full bore to all the complexities of a live scenario. In order to really operate Islington, it is necessary to comprehend even the Advanced Locking Scenarios described in this document; for Progman St., it is not.

Designing your own scenarios is difficult.

4.1 Progman St. Interlocking

The fictitious **Progman St.** is an interlocking very much like several 4-track terminals on the New York system where the station "pockets" on the center (express) tracks are used for holding and reversing trains coming from either the express or local (outside) tracks. 57th St. (Broadway/7th Avenue BMT), and Brighton Beach (Brighton Beach line, BMT) are typical of such. Progman St. is a little more and a little less, to introduce variety for didactic purposes. The equivalent of switch 21 appears at neither of the named interlockings, and is there only to add to the fun with the availability of multiple routes between signals 20 and 32 and 34.

The interlocking definition files for Progman St. interlocking is **progman.trk**.

Please refer to the **NXSYS** display of Progman St. interlocking for the following discussion. It is conventional, when explaining a given interlocking, to present a track map with all control lines and time signal timing sections shown — it is

hard to operate or understand the interlocking without this knowledge.

Progman St., while usable as such a terminal, is signalled in a style that indicates such use is envisioned in rare circumstances only. This is evident in the fact that signal 14 is a dwarf signal (used for rare moves), not a full home signal, and the fact that there is no northbound (to the right, that is) signal opposite 24, controlling moves into the pocket on A3 track. This is deliberate, to produce a more interesting interlocking. The most recent NYCT interlockings I have seen are very heavily signalled in all directions.

Progman St. also supports "reverse" moves into normal running track — trains entering on the right from A1, A3, or A4 tracks can exit to the left on any of the four tracks, and trains entering from the left on any track can exit to the right on any track — there are signals provided to govern all these moves. Yet, Progman St. only supports these moves "lightly" — they are very lightly signalled, and entrance at 32 and 34 is expected to be rare, as these are dwarf signals (click right on them to see).

Progman St. supports end-to-end routes (or "through-routing", see Basic NX Operation) from any entrance to any possible exit. Moves between 4 and 20 are the most expansive.

An interesting feature of Progman St. is the overlap of the home signal control lines. For instance, If 8 is the entrance of a route to 10, and 26 begins a route to 24, switch 15 must be normal, or the routes would conflict in the overlaps of the control lengths of 24 and 8. If this setup is attempted with 15 reverse, you will actually see 15 move normal. To see this, route 8 to 26, cancel 10 after setup, then route 26 to 24. Cancel 8 in this condition and attempt to initiate at 14, and you will see switch 17 flash and signal 26 complain by flashing, indicating a locking conflict with the overlap of 26. Similarly, if a northbound train (as per route-locking) sits facing signal 28, but 32/34's approach locking has expired, lining a route from 26 to 24 will require and force 15 reverse before 26 clears; these situations are categorically known as **facing-point push.**

Progman St. also contains three Grade Time (GT) signals, the northbound automatics A2-725, A4-720, and A4-727; that is why they are red at startup. Please see the discussion of time signals for a description of this feature.

Progman St. Safety Warning!!!

Because of its didactic intent, safety at Progman St. has been compromised in one serious way which could not occur at any real interlocking — it allows "wrong-direction" trains to enter the tracks on the lower left and upper right, without any protection against trains coming in in the correct direction from the "great void" outside of the screen. In a real interlocking (e.g., 57th St) such moves would be outright forbidden ("No moves to track 2"), or traffic control coordinated with a remote interlocking and/or "holdout" signalling would be employed. Any of these techniques would either extend the panel off the screen in both directions, mysteriously halting simulated trains off the screen and totally befuddling beginners, or otherwise reduce the didactic value of Progman St.

Furthermore, the dwarf signals are unsafe against impermissible wrong-direction moves, as they have no stops. This is as per reality in older interlockings; as discussed under that heading, newer interlockings do not employ dwarf signals on revenue trackage for that reason.

4.2 Islington Interlocking (Toronto)

NXSYS now supplies a very complete and accurate implementation of Islington Interlocking on Toronto's Bloor-Danforth line. The signalling principles and panel operation are identical to those in New York City, although the signal aspects for time signals are a little different.

This interlocking was chosen because even though it is smaller than Progman St., and involves fewer tracks, it involves a fair number of complexities not present there.

The interlocking file for Islington interlocking is:

islingtn.trk   Relay-language source-code for the interlocking

Please read **Islington.html** in its folder for more information about its particulars and Toronto conventions.

4.3 Myrtle and Atlantic Avenues — Advanced "Real Life" NYCT scenarios

Supplied with Version 2 are two operative scenarios for actual New York City interlockings, in their own folders, loadable from **atlantic.trk** and **myrtle.trk** in the similarly named folders (directories). While the track, signal, and switch identifications (and signal control lines) are from real life, the circuitry is *not the actual circuitry* at these sites, although it is designed to the same spec, but "less well".

These two fair-sized interlockings operate identically on the Windows and Macintosh implementations of Version 2 **NXSYS**, and include traffic levers, automatic operation, double and single slip switches, countless overlap- and crosslocks and other advanced and interesting features. As they both include extensive scenario-specific documentation on their respective contributions to the **NXSYS Help** menu, they will not be described further here; both should be visited.

New York (BMT) Broadway-Myrtle Interlocking in Version 2 NXSYS
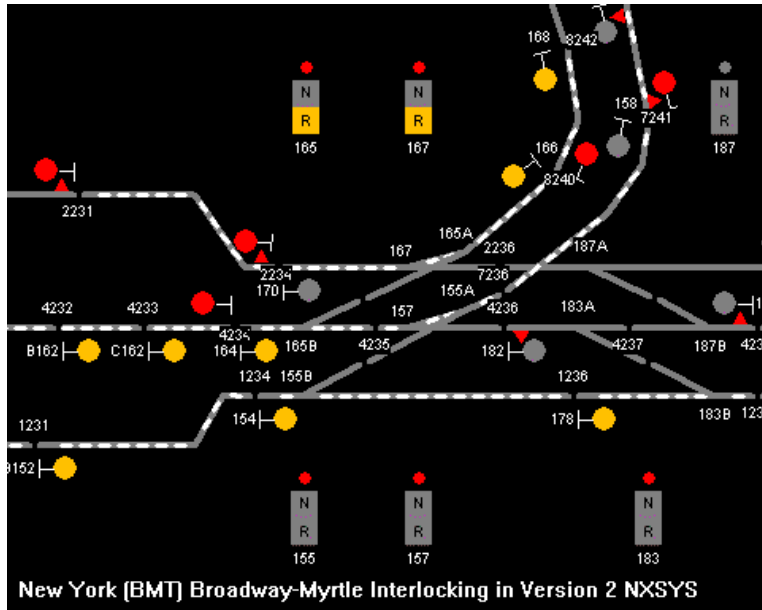
4.4 240th St Broadway Line
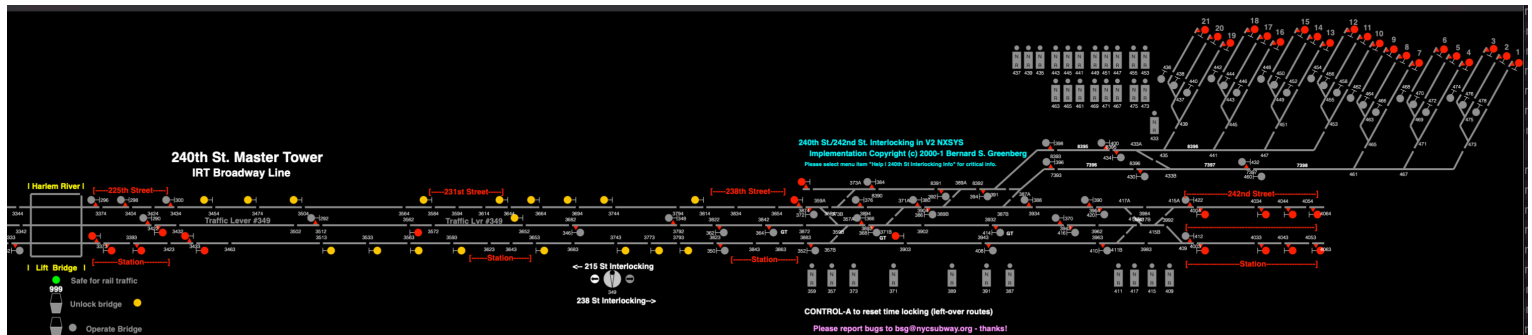
The NXSYS scenario for 240th St. Master Tower was begun by Henry Sundermayer and myself about 2000, and continued and upgraded by me continually since. It represents all the trackage from 215th St. north (but not the 207th St. Yard connection.). There is operative middle-track (single-control) traffic control. It is quite complex, and demonstrates many, many complex locking features. See the incorporated help text for details.

4.5 Duckburg design tutorial
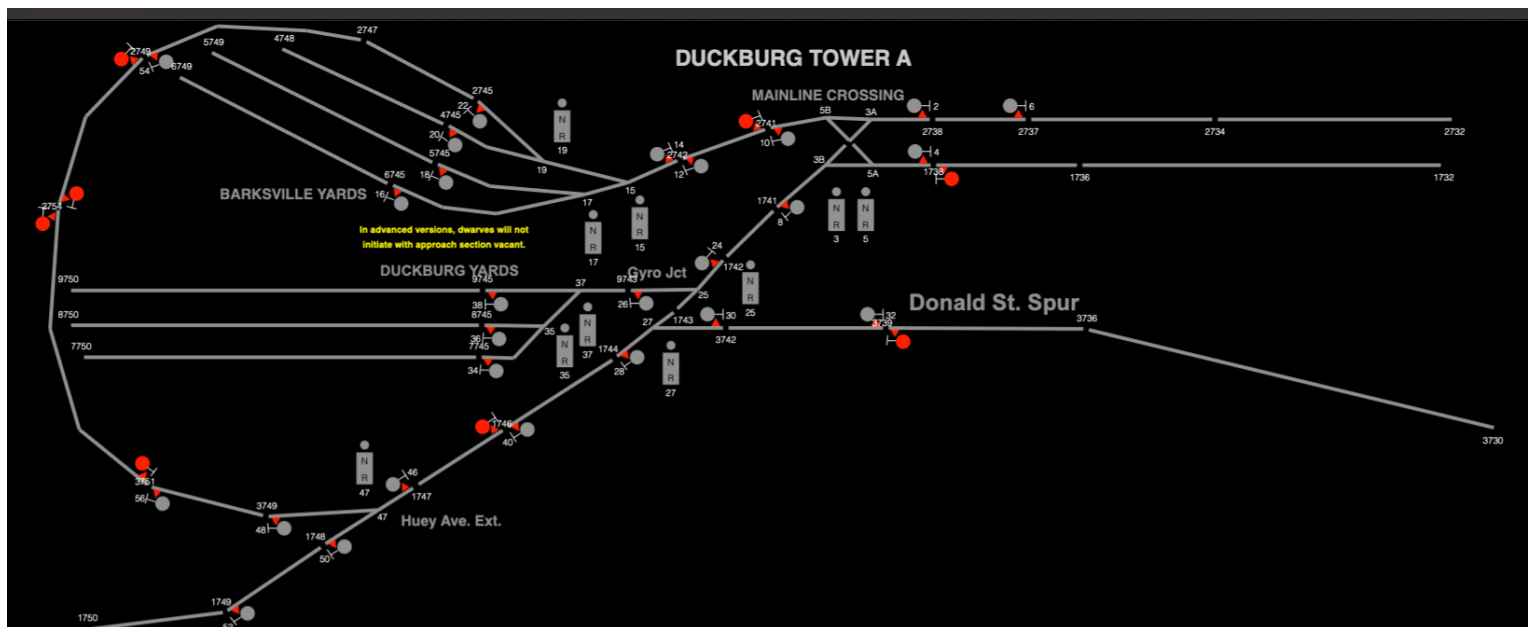
This layout is an imaginary yard with "railroad-like" design. What is interesting here is that the interlocking is supplied in seven files, explaining (in source comments) seven stages of implementing the interlocking logic from scratch to a fully-functional tower. File **db1.trk** can only select routes, but no signals, locking, etc., and **db7.trk** is a fully-functional interlocking. See the file **README.md** in the interlocking's eponymous folder.

4.6 Designing your own scenarios

Designing your own scenarios is not easy! As **NXSYS** is an interlocking simulator, not an interlocking implementation, designing and creating the track layout consists not only of designing and expressing the track and signal plan, but all the relay circuitry which implements the interlocking. The latter is the lion's share of the work (and the fun), but requires substantial understanding of the New York (or other) prototype circuits. It is probably possible to learn a lot of this subject matter by watching the relays in action with **NXSYS.** Rather than an accident, a bug, poor design choice, or cop-out, this is the reason **NXSYS** came to be in the first place.

As of this writing (17 February 2021), I have supplied a document teaching the basics of relay-based rapid transit interlocking circuit design. It is downloaded with this application, and should be at this link. This is no simple matter, but feel free to study that if it interests you.

The NXSYS paradigm, does, however, offer the advantage that you have the "source code" for several supplied interlockings; in the time-honored tradition of computer programmers, you can modify the supplied interlockings in layout, behavior, or implementation, without restriction, if you wish to experiment or learn without crashing any real trains. You do not need the source code for **NXSYS** to do this, or to know any programming language, at all. The *real* pleasure in **NXSYS** is not so much playing with an operative interlocking, but interactively designing and debugging it in the manner of a computer program.

If you have the required expertise in signal engineering, or are trying to acquire it, **NXSYS** is an ideal tool to create, experiment with, and debug relay circuit designs.

TLEdit, the "track layout editor", is also supplied. **TLEdit** allows you to create actual layouts, i.e., the display of tracks, switches, signals, etc., but only you can create the logic which gives it life and makes it responsive. It is self-documenting.

5. Relays and Relay Logic

You can safely ignore this section. But if you wish to understand the internal workings of **NXSYS** interlockings, or debug them, or you are so idle and/or well off that you wish to attempt to design your own interlockings, read on.

A **relay** is an electromechanical switch (not a "switch" as in a piece of track), a set of switches operated together by an electromagnet. Electricity flowing through the switches can be used to control any electrical apparatus, or, more relays. Relays are neurons, and form "logic networks" implementing complex functionality. Although relays as logic elements have largely been obsoleted by computer technology, the earliest electrical computers, including phone switches, were built of relays, and railroad signalling and interlocking is still (largely) implemented in relays today. This is because their modes of failure, unlike those of software, can be fully enumerated and designed around.

As of now (2016), digital and semiconductor circuitry is slowly but inexorably pushing out the now antiquated relay technology, more rapidly in new systems, but certainly in New York, too. However, the vast bulk of the system still relies on relay interlockings dating from all times of the twentieth century, and even the newer solid-state and digital technology must interface to it. Alas, relay technology is obsolescent, but still ... .

Relays sport two types of switches, or "contacts," those that allow electricity to flow through them when the "coil" (electromagnet) is energized and not when not, and those that allow current to flow when the coil is *not* energized, and not when it *is*. In railroad terminology, the former are called **front contacts,** and the latter **back contacts.** A contact is said to be **closed** when electricity can flow through it, and **open** when not. A typical railroad signalling relay might have a dozen contacts total, some front, some back. Railroad signalling relays are of extremely high quality, rugged, and quite expensive.

NXSYS interlockings are implemented as simulated relays; the actual names (*nomenclature*) of the relays and the way the contacts are interconnected are defined in the **.trk** file. All of the logic of the interlocking described in Chapter 3 of this documentation are implemented not in C or C++, but in simulated relays, using traditional New York circuit nomenclature and designs.

NXSYS allows you to actually see the circuits for any and all relays it is managing and simulating. You can display the circuits on the screen, several at a time, or create a set of hardcopy circuit drawings suitable for study and analysis. The relays and their logic circuits are displayed in traditional New York Subway relay logic notation, which is extremely clear

and intuitive: the coil of a relay is a little box sitting on a wire, and a contact is a little triangle and a dot — triangles "balancing" above the wire are front contacts, and triangles sitting under it are back contacts. Each coil or contact is labelled with the name of the relay of which it is part.
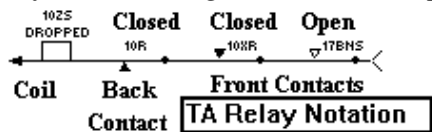
A relay is said to have a **state** at any time: it is said to be **picked** or **up** if the coil is energized (and front contacts closed and back contacts open), or **dropped** or **down** if the coil is not energized, front contacts open, and back contacts closed.

The "definition of" or "circuit for" a relay is the wiring diagram for its coil, the network of contacts of other relays (or even that relay) which control when it is up and when it is down. You may view the circuit for any relay, and even observe its state dynamically. See NXSYS Relay Graphics.

A typical relay name comprises a number identifying a switch, signal, or track section, and a **nomenclature** indicating function. For instance, **24R** is the "Route Check" (called) relay for Signal 24, which is picked when it is called and dropped when not.

5.1 Vital and nonvital relays

Relays, by function (i.e., nomenclature), in real-world interlockings divide into two classes, "vital" and "nonvital". Vital relays, as the name suggests, are those ultimately responsible for the safety of life and limb: those that directly operate or report signals, stops, and switches, and others directly responsible for their safety. While it may seem that *all* relays in an interlocking are thus, that is not strictly so: many, typically those that record panel-board actions and implement (some) panel indications, and those which implement the ingenious entrance-exit route selection, are *not* critical to safety, and are therefore "nonvital". Categorically, by careful design, the failure, failure to pick, failure to drop, failure to operate properly or consistently, of a nonvital relay, while capable of creating a transportation tie-up, cannot create unsafe conditions. Failure of vital relays can, although they cross-check each other (quite literally) up and down, coming and going, to minimize these possibilities. Vital and nonvital relays are markedly different in construction and cost: while nonvital relays resemble those available at do-it-yourself parts stores, vital relays are huge, hyper-rugged, plastic-encased complex instruments each costing (at least) hundreds of dollars.

For example, if the entire routing network of nonvital **PBS**, **XS** and **ANN, ANS** etc. relays were to call for bogus signal and

switch movements, the circuits of the vital **H, AS, LS, etc.** relays would not permit these orders to be carried out. Vital relays that assert, for safety checking, that something is *not so* (e.g., signal not clear, track not occupied, northbound route not active in this section, etc.) always are designed such that the relay's being picked is the positive assertion of the *absence* of the undesired (more unsafe) condition, even though this requires the relay being energized around the clock year round.

Vital relays check only each other. They even check that they are not lying to each other — for example, the circuit of an **H** relay, the vital relay that clears a signal and stop, checks that not only the **AS** relays of conflicting/opposing signals are picked (approach locking released), but that its *own AS relay* (which will symmetrically inhibit those very signals) is, in fact, dropped out to do so (and similarly for route locking).

While the vital/nonvital distinction is key to the paradigm of the circuitry, vital and nonvital relays are not distinguished in **NXSYS**; their logical operation is identical. Nonetheless, the apportionment of function over relays in **NXSYS** interlockings continues to maintain this model, and correct design must diligently comply. Nonvital networks can safely be replaced by software; they are "relay software"; they tell the vital ones what to do.

In traditional lever interlockings, there are few, if any, nonvital relays. The interlocked levers serve both control and checking functions simultaneously. For instance (say on the BMT where levers used to go "in and out" from the frame), a signal lever pushed all the way in is "reset" and does not inhibit other levers from motion, while countless other levers in concert potentially prevent it from being moved from this position. But once it can be and has been pulled out, it calls its signal, and locks other levers. However, although it can be pushed in *a little* to cancel its signal at any time, it cannot be pushed *all the way in* unless its signal's approach locking has released (i.e., unlocked that far by its so-called "indication magnet", "**M**", forebear of the **AS** relay), and thus, does not unlock other levers until this happens and it is then pushed fully in.

5.2 Important NY-style Relay Nomenclatures

Here are the key nomenclatures used in **NXSYS** and New York and Toronto (and probably many other places) interlockings (the second column indicates vital or nonvital function). "Stick" designates a relay that "sticks" picked, i.e., becomes "stuck" via a "feedback contact" as long as some appropriate condition obtains. It is thus a memory element equivalent to the digital flip-flop.

See actual circuits in the supplied interlockings (with the relay graphics tools) for examples.

The amorphous term "actually" as abused below means "directly, in a hardware sense, with no intervening logic". For instance, "**HV** directly clears the signal" means that the signal's actual, physical lamps (in this case, the red lamp and a contact of **D** or **DV** selecting between green and yellow lamps) are connected to contacts of this relay. "Is actually clear" means connected to contacts on the actual device (e.g., a stop) verifying its physical position. As this is not possible with color-light signals, **RGP** checks the relays **H** and **HV**, but in semaphore-signalling (visible on the extremities of the IRT through at least the 1960's), the actual, physical position of the semaphore is indeed checked.

Signals and **Stops**, (i.e., relays associated with them)

H	V	"Home" relay — clears the signal and stop. Checks every condition necessary for this, including track vacancy, switches switches locked and in correspondence, route locking, approach locking (both safe opposite the signal's direction and dropped out (unsafe) in its own direction), offside stops clear, traffic locking, etc.
D, DV	V	"Distant" relay — displays "distant" (a green aspect) when this signal and the next are clear. **DV**, not used for home signals, is so-called because it implements stop cycle-check when the signal is not clear, checking its own operation as well.
V	V	The stop itself (from "valve" on electropneumatic, e.g., IRT). Note that signal clearing (**H**) checks stops on the off-side through the control length (see **VS**).
HV		Actually clears the signal when both **H** calls for it and the stop (**V**) is

	V	actually clear.
HY	V	Home signal "slotting". Checks all the track conditions necessary for a signal to clear (display a "high" aspect) but not necessary for a call-on, i.e., vacancy of the control length.
CO	V	Home signal call-on. Clears the signal's call-on aspect, and conditions the stop to clear when the train operator presses the button. Contains all the checks and terms of **H**, with the exception of all those in **HY**, and the non-vital contact of the **COS** (panel call-on control) relay.
U	V	Time/approach locking timer; see below.
RGP	V	"Red siGnal rePeater" — picked when all of **HV**, **H**, and **CO** attest that the signal is red.
NVP	V	"Normal stop repeater" — picked when the train stop is actually in its normal (tripping) position.
RVP	V	"Reverse stop repeater" — picked when the train stop is proven clear (driven down).
AS	V	"Approach stick" — picked when approach locking is fully satisfied and released — this is the relay that other interlocking functions check to ensure the safety of a conflicting signal.
VS	V	Off-side (reverse motion) stop driver/route locking. Drives down (clears) the stop of a signal in the opposite direction to a lined route. Picked by **R** at entrance and held down ("stick") by route locking relays approaching the signal (backwards).
R	NV	"Route check" relay — the virtual signal lever; calls for the signal.
PBS	NV	"Push Button Stick" — initiation. When interlocked station-time signals that permit their clearing in spite of a trailing-point switch are involved, this function is split into **APBS** and **BPBS** depending on whether the initiation exploits this feature or not. For an approach signal, this is the "virtual lever" that calls for the signal.
XS	NV	"Exit Stick" — picked when an offered exit has been selected.
XR, ZS	NV	Ingenious relays used to couple networks to implement end-to-end route setup. They drop away once the routes are lined.

Switches

LS	V	"Lock Stick" — picked when switch is unlocked, i.e., safe to move.
NWP, RWP	V	Normal and reverse switch repeaters — repeat (in the tower) actual contacts on the switch that indicate its actual position.
NWZ, RWZ	V	Normal and Reverse switch control — actually operate the switch motor or valves when called for by **NLP/RLP** and permitted by **LS**. One of the two is always picked.
NWC, RWC	V	"Normal and reverse sWitch Correspondence — Actual switch position agrees with last valid call.
NLP,	NV	"Normal" and "reverse" lever repeaters — call for switch to move normal, or reverse. Operated by auxiliary keys, the selection network

RLP		(see below), and more.
ANN, BNN, ANS,BNS, RN, RS	NV	"Switch selection" — potential intention to move a part of a switch a given way. The "tendrils" at the heart of NX magic, operated by **PBS, XS** and each other. Example: **ANS** = **A** half, **N**ormal, **S**outh.
NWK, RWK	NV	Normal and reverse "switch indicator" relays, used in route-selection logic and panel indication, but not critical control of switches or signals. An indicator relay picks when the switch is both in the position of the relay's name (**NWC/RWC**), and is either locked or called for in that position, i.e., when there is no possibility of moving it to the other position. These indicator relays rule out such calls non-vitally; **LS** prohibits them vitally.

Track (relays for each track section)

T	V	Track relay — picked when the track section is clear (it is *not* occupied).
TP	V	Track relay repeater — picked when **T** asserts that the section is clear.
NS, SS	V	North, South ("stick") route locking relays, picked when *no* route or in-progress motion in that direction is established, i.e., their being picked attests to the *absence* of such a route or train motion.

Multiple types of apparatus

U	V	Timer; does not pick until designated time after energized. The letter **U** appears alone or otherwise (e.g., **US** and **UK**, nomenclatures, not nations) in different uses of timers for different types of apparatus (i.e., signals, track sections, stops in newest installations). The unadorned timer nomenclature for a signal is used for its time approach locking timer; for a track section, it is the GT timer.

There are many others, and they are left as a tantalizing exercise for the reader. This information can be quite interesting — you can look into a functioning brain with it. For instance, if clicking on a signal does not cause it to initiate, you might want to look at the **PBS** circuit for that signal and see which contacts are closed and which are open, i.e., where the path is broken. One can then track down those relays, by merely clicking on the contact, until the situation is figured out. By choosing a good selection of relays to watch at once, and observing contacts as a train goes through or a route is set up and cancelled, one can actually watch the interlocking think.

Important!
There are relays that are operated by NXSYS when you press buttons or click on track representations or other controls, and other relays which, when operated by the relays you code, cause "switches" to move, signals to clear, track sections to turn red or white or flash, etc. These are the logical inputs and outputs of your relay system, and, corresponding, the outputs and inputs of the NXSYS application. The identities and contracts (not *contacts*) of these relays are discussed in the Relay Language document at this link.

5.3 NXSYS relay graphics and other tools

To see the definition (circuit) of any relay, select **Relays|Show Circuit** and type the nomenclature (e.g., **244PBS**) of the relay you want to see. The circuit will be displayed in a window called the "Relay Draftsman" on Windows and "Relay Draftsperson" on the Mac. The present state of the relay (picked or dropped) will be displayed with the coil, and the state of each contact will be displayed as open or closed — a white triangle is open, black is closed. If relay and contact states

change while you are looking at the drawing, it will be updated as you watch. If you click on any contact, the circuit for that relay, reflecting current state, will be displayed as well. On Windows, when the page fills up, it will be cleared, or you can clear it from its local menu; on the Mac, it scrolls.

You may also click right on any object (track circuit, signal, switch, or other), and select **Draw Circuit** to be offered a menu of relays associated with that object; select one to draw its circuit.

Relays may be interrogated with **Relays|Query.** This command will prompt for a relay name and show its state, and, if you wish, its "dependents," that is, the list of all relays who depend upon this relay in their own circuits (its "outputs", if you will).

The relay graphics window can be resized: making it narrower makes the symbols smaller, too — there are a fixed number of contacts on each line — but doing so also allows more to fit in a given vertical space.

One can (on Windows only) print, on a printer, all the circuits for all the relays in the interlocking from the **File|Print Logic**. It is best to restore the interlocking to "canonical state", i.e., all track sections clear, all signals cancelled, all switches normal (use **Interlocking|All the above** if you wish) before printing, so that contact states will reflect the "normal" state of these relays, which is defined in this way, and is the original intent and traditional usage of the black/white triangle distinction.

Some relays will appear to have "missing circuits", or coil wires that go nowhere, or are disconnected. Most of these relays are "Quisling relays", operated directly by the user via the mouse (i.e., puppets operated by a foreign power), such as by clicking on a signal or track section, providing the "inputs" to the relay system. Bear in mind, too, that other relays are observed directly by the user interface (such as **H, T, V**) to control the states of the symbols it displays. Both are enumerated in the [Relay Language document](#).

The Relay Draftsperson may also be used to access the pseudo-Lisp source for a relay via a click on a coil or contact representation, to facilitate editing of relays under development. This feature is not trivial to set up, but is quite useful when running. Do read [this document about it.](#)

Relay Trace Window

One can trace relay activity, in a compiled or interpreted interlocking, with the **Relay Trace window**, which is activated from **Relays|Trace.** Each time a relay is picked or dropped its name and which (pick or drop) is reported to the trace window. The trace window, of course, makes the interlocking substantially slower — hiding it restores interlocking speed.

Enable **More** on the trace window's menu (or use the toolbar, selecting the "moron" to turn "More" on) to cause the trace (and the interlocking simulation) to pause at the end of each screenful. Typing space or pressing the **M** tool allows the trace and simulation to resume. But typing **Q** or pressing the "Stop" tool aborts the simulation, the only way to get out of a loop in an logic-bug-induced emergency. At that point, you will be offered exiting **NXSYS**, reloading the interlocking, or return to top level with no interlocking loaded.

The trace window can be cleared, a frequent need, from its own menu, or the first tool on its toolbar.

6. Credits and Conditions of Use

NXSYS was conceived, designed, and written by [Bernard S. Greenberg, of Boston, Mass., USA,](#) on his own time, not using any non-redistributable copyrighted or owned components, or developed on anyone else's paid time. This software is offered as-is. Although this software is thought to be relatively bug-free, bug reports and suggestions will be fielded, but no response in any given time promised. No representations, warranties, guarantees, or claims about correctness, operability or suitability of this software and/or documentation for any purpose are made or implied. Please check the website listed below regularly for notice of bug fixes and changes.

This software is intended for educational, demonstrative, and entertainment purposes only, and is not suitable for use for control of actual railroads or other life-critical missions. The circuit designs, in particular, occasionally employ shortcuts

and simplifications not appropriate for real railroad signalling, and are not suitable for use as prototypes for systems to control real life-critical systems. The author assumes no responsibility for any damage or harm resulting from use or misuse. The author assumes no responsibility for errors resulting from corruption of the distribution media or files. Compliance with any extant copyrights, patents, or other rights potentially infringed by the commercial use, in spite of this warning, of information provided in this software or documentation, is your responsibility alone.

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NXSYS is implemented in C++, currently at the C++17 (2017) language level, exploiting STL. The Microsoft Windows versions are presently (2022) 64-bit, in Microsoft Visual C(++) 2022, the Macintosh version in Apple **clang LLVM** C++, 64 bit, with the user interface in Objective C++ (see the Mac-specific help for more detail). An original Lisp implementation (originally including an original compiler) forms a part of it. The Windows versions are intended for use in modern Windows environments, currently pretty much Windows 10 or 11. The 32-bit versions, which are obsolete, will work on older Windows platforms. NXSYS 1 is gone. This help text was born in original Microsoft Help Compiler source, transmuted through Python scripting to HTML, and is now maintained in XCode on the Macintosh.

This software employs the pugixml portable XML library (http://pugixml.org). pugixml is Copyright ©2006-2018 Arseny Kapoulkine.

NXSYS is based upon ideas and designs from the June 1, 1958 New York City Transit Authority drawings, *NX & UR Interlockings, Typical Circuits (733-33),* which was one of the central formative documents of the author's career. A recent gift of a 1994 733-33 has been most helpful, too. The relay-logic interlockings implemented by **NXSYS** straightforwardly implement most, but not all, of these ideas. Neither this software nor this documentation has been authorized, approved, or verified by the New York City Transit Authority or its successors.

The author conceived the ideas in the relay logic simulator/interpreter and compiler which form a large part of **NXSYS** when he was in the employ of Symbolics, Inc., in the early 1980's. Implementation of (16-bit Windows) NXSYS was begun on 29 May 1994. Version 2, permitting arbitrary 2-dimensional track geometry and topology, was begun (on 32-bit Windows) early in 1997, but not released. The Macintosh Version was birthed in the Fall of 2014. The releaseable Version 2.1 for Windows was effected, benefiting from many improvements in the Mac version, in the Winter of 2016.

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The system icon is the noble visage of the Type D "Triplex" cars, who reigned over the BMT express runs for forty years ending in 1964.

The World Wide Web site for **NXSYS**, containing the latest versions, interlockings, and modification info, as of this writing, is

https://www.nycsubway.org/wiki/NXSYS,_Signalling_and_Interlocking_Simulator

You can contact the author at the Signal section of nycsubway.org.

6.1 About the Author, and other contributors

Bernard Greenberg, the author of this program, its interlockings, and documentation, grew up in Brooklyn, NY, in the heyday of the subways, the 1950's and 1960's. Like most New Yorkers of the time, he rode them everywhere, and, through the kindness of helpful motormen, towermen (they were all male then) and the like, became an avid and knowledgeable railfan before he was old enough to ride alone. He finally made contact, as it were, with the NYCTA in 1962, and for a couple of years regularly received boxloads of documents, maps, plans, and answers from a railfan employee, Martin

Schachne. In love with the subways, after being shown the DeKalb Avenue NX panel he soon combined this passion with his then-largest "hobby", "electronics" (an old name for a precursor of computation), and increasingly zeroed in on NYCTA signalling, culminating in a 1966 study of 733-33, the typical circuits for NX/UR interlockings and subsequent design of a complete UR interlocking for Atlantic Avenue (IRT) "for the fun of it". Abandoning New York, the New York Subways, and signals for graduate study, he grew up to be a successful computerist specializing in operating system design and implementation. Creating **NXSYS** has finally allowed him to realize his boyhood dream of design, debugging, and experimenting with NX/UR interlockings and signal circuitry. The Internet user community of this program has fulfilled another, namely, finding others who share his passion for this subject matter.

Two signal engineers formerly, but not at the time, in the employ of the New York TA, Dave Rosenthal and Norm Ishler, contacted (as it were) me not long after Version 1 was posted. Both were exceedingly generous in their critiques, corrections, and supplementation of my imperfect knowledge, finding and fixing all the parallel fifths and unresolved suspensions in my subway scores, and I wish to relay my enduring gratitude here

Special mention and credit is due New York's Dave Barraza, who, with this application (prerelease Windows Version 2), not only found a continuing professional career in signal engineering, and has tested and used and critiqued both versions of this software extensively, but has designed, with his professional signal engineering skills now far superior to my amateur skills, a number of massive, master-tower multi-interlockings within it, including several of the "masterpieces" of the New York systems, some 10 or 20 times the extent of the none-too-simple sample interlockings supplied here, and has continued to be the prime tester of the Mac version.

Enjoy!