Signaling with CATS & JMRI

Dick Johannes
& the HUB Division Signal Committee
May 2016
The HUB Division
Signal Committee Members
Hoosac, Upton & Boston RR

- Now over 65 members
- Dick Ball is the current Superintendent
- Very large setups including the annual Amherst Railway Society Show & our New England Model Train Expo
- Annual displays at Children’s Hospital Boston & the National Heritage Museum in Lexington, MA
- Shown internationally: Canada, Germany, Netherlands
- Very early adopter of DCC (after all, Stan and Debbie Ames are members) Has always been Lenz driven
- 1st Place awards at NMRA Nationals both in individual modules and modular railroad categories.
Goals & Rationale

- Increase the knowledge and curiosity in signaling within HUB Division members
- Add a new level of operating interest to the modular layout
- Enhance the viewing experience for spectators of the layout
- Sounded like fun!!
Key historical events

- 1840: Ball signals: LTC Rolt
- 1841: Semaphore – Charles Gregory
- 1851: Telegraph – Chas Minot
- 1870: Track Circuit – William Robinson
- 1871: Disk (Banjo) Signal – Thomas Hall
- 1904: Color light signals – William Churchill
- 1915: Position-light signals – Arthur Rudd
- 1924: Color Position signals – Frank Patenall
- 1925: Tri-color (G type) signals - GRS
Two types of “regions”

Interlockings (Junctions & Sidings)

Linear Blocks
The Distinctions

• Linear blocks
  – Unsupervised (e.g. totally automated)
  – Default is “clear” or “green”
  – ABS (Automatic Block Signaling)
  – APB (Absolute Permissive Block)

• Interlockings (Junctions & Sidings)
  – Supervised (e.g. human controlled)
  – Default is “stop” or “red”
  – Mechanical interlocks
  – US&S panels
  – Computerized CTC
Aspects: NORAC*

Rule: 281
Name: Clear
Indication: Proceed not exceeding Normal Speed

Rule: 281a
Name: Cab Speed
Indication: Proceed in accordance with cab signal indication

Rule: 281b
Name: Approach Limited
Indication: Proceed approaching the next signal at Limited Speed

Rule: 281c
Name: Limited Clear
Indication: Proceed at Limited Speed until entire train clears all interlocking or spring switches

Rule: 282
Name: Approach Medium
Indication: Proceed approaching the next signal at Medium Speed

Rule: 282a
Name: Advance Approach
Indication: Proceed prepared to stop at the second signal. Trains exceeding Limited Speed must reduce to Limited Speed as engine passed the signal


- Flashing
Rule: 283
Name: Medium-Clear
Indication: Proceed at Medium Speed until entire train clears all interlocking or spring switches, then proceed at Normal Speed

Rule: 283a
Name: Medium Approach Medium
Indication: Proceed at Medium Speed until entire train clears all interlocking or spring switches, then approach next signal at Medium Speed

Rule: 284
Name: Approach Slow
Indication: Proceed approaching the next signal at Slow Speed

Rule: 285
Name: Approach
Indication: Proceed prepared to stop at the next signal. Reduce to Medium Speed as engine passes signal

Rule: 286
Name: Medium Approach
Indication: Proceed prepared to stop at the next signal. Reduce to Medium Speed as soon as signal is clearly visible

Rule: 287
Name: Slow Clear
Indication: Proceed at Slow Speed until entire train clears all interlocking or spring switches, then proceed at Normal Speed

  - Flashing
We Built 5 “Test” Modules

- Two were “passive” (e.g. do not have a signaling card)
  - No detection
  - No signals
  - These represented unchanged modules

- Three were “active” modules (e.g. have a signaling card)
  - These 3 modules all contained signals
  - Each module used a different type of signal
    - 1 used G-type, 1 used Searchlight, 1 used D-type
    - All wired as common anode
  - NCE AIU & DB20s used for detection, Oaktree signal boards

- Wiring strategy:
  - Inner main supplies power & detection to the left
  - Outer main supplies power & detection to the right
The Test Modules

Three “Active Modules

OS Module

Crossover Module

Straight Module
The Six Permutations

Order #1

Order #2

Order #3

Order #4

Order #5

Order #6
Permutation of Module Order
US&S CTC Panels

Screen shot from Dick Bronson’s Hartford National Clinics
But There Was Interest in a Modern CRT-based Panel

- We looked at the Layout Editor
- Using the JMRI Website, we found CATS (Computer Automated Traffic System)
- Open Source JAVA software layered atop PanelPro
- Written by Rodney Black. Like JMRI, it has an online user forum
- Based upon prototype Digicon system
CATS Suite is 3 Programs

- **DESIGNER**
  - Used to describe the panel (e.g. track, turnouts & signals)
  - Creates a permanent stored XML file
  - Detector and signal definitions & address mapping
  - Many display options

- **CATS**
  - The runtime application
  - Many runtime controls and display options

- **TRAINSTAT**
  - Tool to allow documenting train location and time (either real time or fast clock)
  - Can be stored to file for archiving
CATS

• Several outstanding features
  – Uses all the debugging tools in JMRI
  – Great benefits even without signals
  – Signaling based on 4 track speed / 2 or 3 block rules
  – “Pre-programmed” signal logic
  – CTC signals are visible whereas intermediate signals can be invisible on the dispatcher panel
  – Can grant track authority
  – Can take track out of service
  – Allows train tracking by train symbol or locomotive #
  – Well written online manuals
CATS & Arbitrary Module Order

- How does one swap module order and preserve signal logic?
- The File → Import function
  - File→Import reads in a saved layout (a library) without erasing any existing work. It is a way to merge multiple layouts together, add some pre-canned design elements to the existing layout, insert existing signal definitions, etc. When a file is selected, designer will grab the track plan from the file and insert the upper grid corner of the trackplan at the grid cursor location. It will expand the layout in the horizontal and vertical directions as needed. Note that the library is not inserted, but replaces existing track; thus, preserving any track not overlaid.
  - Tracks, information associated with tracks (e.g. Block definitions), Stations, Signals, etc. will be added to the existing work. File→Import will also merge any Devices (Section 8) defined in the file, but not any Appearances (Section 14.1), Trains (Section 10), Crew (Section 12), or Jobs (Section 11). “Merging” is defined as “if something in the file does not exist in the current trackplan, it is added”. This means that things in the library file will not replace things with the same name in the trackplan.
Insertion Demonstration
Screenshot: the Digicon Prototype
CATS Rendering of the Prototype
Locks

- **Route Locking**: Prevents realigning a turnout while a selected route is occupied
- **Indication Locking**: Prevents realigning a turnout or clearing a conflicting signal when a signal for entry into the route has been cleared
- **Time Locking**: Prevents realigning a turnout or clearing a conflicting signal for a period of time after the dispatcher has “knocked down” a cleared signal
Speed

1. Maximum authorized (Normal)
2. Limited – 45 mph
3. Medium – 30 mph
4. Slow – 20 mph

<table>
<thead>
<tr>
<th>Prototypical Frog Number</th>
<th>Typical Model Frog Number</th>
<th>Typical Usage – model &amp; prototype</th>
<th>Typical Prescribed speed for model (scale mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>4</td>
<td>Tight yard &amp; industrial tracks</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>5</td>
<td>Moderate yards &amp; industrial tracks</td>
<td>15</td>
</tr>
<tr>
<td>12</td>
<td>6</td>
<td>Broad yard, branch lines &amp; Main track – slow speed turnout</td>
<td>20</td>
</tr>
<tr>
<td>16</td>
<td>8</td>
<td>Main track – medium speed turnout</td>
<td>30</td>
</tr>
<tr>
<td>20</td>
<td>10</td>
<td>Main track – limited speed turnout</td>
<td>45</td>
</tr>
</tbody>
</table>
Fundamentally, there are two different schools of thought regarding how prototype signal aspects should be used for controlling train movements through interlocking controlled turnouts. The first, called “Speed Signaling,” uses aspects to define the specific speed that a train may travel through an interlocking plant. The second, called “Route Signaling,” simply uses aspects to define that a train is set up to take the diverging route through the interlocking plant.

-Dr. Bruce Chubb, MRC February 2016
The Signal Template (Defaults)
Define Your Signal Rules

<table>
<thead>
<tr>
<th>Rule</th>
<th>Aspect</th>
<th>Name</th>
<th>Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>281b</td>
<td></td>
<td>APPROACH LIMITED</td>
<td>Proceed approaching the next signal at Limited Speed.</td>
</tr>
<tr>
<td>281c</td>
<td></td>
<td>LIMITED CLEAR</td>
<td>Proceed at Limited Speed until train clears all interlocking or spring switches. Then proceed at Normal speed.</td>
</tr>
<tr>
<td>282</td>
<td></td>
<td>APPROACH MEDIUM</td>
<td>Proceed approaching the next signal at Medium Speed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SLOW APPROACH</td>
<td>Proceed approaching the next signal at Limited Speed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RESTRICTING</td>
<td>Proceed at Restricted Speed until the entire train has cleared all interlocking and spring switches of signal or an interlocking or CP signal and the leading wheels have:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1. Passed a more favorable signal or</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2. Entered next signal DSS territory.</td>
</tr>
</tbody>
</table>

In CSS territory, trains with operators cab signals must increase speed until the train has run one train length or 500 feet whichever distance is greater, past a location where a more favorable cab signal was received.
The Signal Template (HUB Edited)
References (Books)

• **Railroad Signaling.** Brian Soloman, MBI Publishing 2003.
• **Railroader's C/MRI Applications Handbook V3.0** (Volumes 1,2,&3 Especially Vol 2). Bruce Chubb. Available through JLC Enterprises.
• **Railroad Operation and Railway Signaling.** Edmund J Phillips. Simmons-Boardman 1942
• **All About Signals.** John Armstrong, Kalmbach, 1967.
• **34 New Electronic Projects for Model Railroaders.** Peter J Thorne, Kalmbach, 1982.
References (Journals)

• Operating signals with software. Model Railroader, October 2007, page 50.


• Where to place trackside signals. Model Railroader, October 2007, page 52.


• Absolute-Permissive Block Signals (3 part article). Model Railroader, November 1991 page 128.

• Centralized traffic control for the Cat Mountain Line. Model Railroader, May 1984, page 74.
References (Web Sites)

- Carsten Lundstens site: http://www.lundsten.dk/us_signaling/index.html
- Norac Simulator: http://raildata.railfan.net/java/DivRte/NORAC.htm
- Railroad Signals: http://www.railroadsignals.net/
- Railroad Signals of the US: http://www.railroadsignals.us/
- JMRI: http://jmri.sourceforge.net/
- CATS: http://cats4ctc.wikidot.com/
- CMRI: http://www.jlcenterprises.net/
- Custom Signals: http://www.customsignals.com/
- ISS: http://www.integratedsignalsystems.com/
- Signals by Spreadsheet: http://www.signalsbyspreadsheet.com/
- Railroad Circuits: http://rr-cirkits.com/
- Logic Rail: http://www.logicrailtech.com/
New Challenges

- Detection sensitivity & universal use of resisted wheelsets
- Compatibility with other modular groups
- Discipline of Dispatcher Control
- Approaches to removable signals
- Track complexity
  - Wiring track power
  - The bridge module has become the “draw bridge” module
  - Linearize the signal bus
HUB Division Website

http://www.hubdiv.org/signalComm.htm

The NMRA HUB Division
Modular Railroad Signal Committee

Committee Origins & Goals
Discussions on signaling the HUB Modular Railroad began in the spring of 2010. At the 75th NMRA convention that summer, the project started to take root when Dick Johannes, Jeff Gerow and Stan Ames attended a Signal Seminar at the convention. In addition, Dick attended any and every session on signals on model railroads he could find, with the other two members attending many of them alongside him. They returned to Boston energized with the concept that signals could be done on a modular railroad. The problem was how, since signal systems are designed for static layouts. Additional members of the HUB Division joined the effort, which evolved into the HUB Modular Railroad Signal Committee as we know it today.

At present, Dick Johannes is the Chairman, and the committee members are (in alphabetical order) Stan Ames, Ken Belovarac, Gerry Covino, Manny Escobar, Jeff Gerow, David "Shack" Haralambou, Mark Harlow, Bill Powers and Peter Watson.

The goal of the HUB’s Signal Committee was to research, design and build a true modular signaling approach for the HUB’s modular railroad. Signaling had previously been done on other modular railroads, but the solutions required a specific set of modules arranged in a specific order. This approach was not adequate for the HUB, due to the variety of layout shapes and sizes that we display at our shows each year. An additional complexity was the fact that the same set of modules are not always displayed together, because the combined total number of modules owned by modular group members is more than can be used in any one show. So our Module Coordinator routinely rotates through the available modules to ensure that all members have an opportunity to show their module(s) at least a couple times a year.
The Testing Environment

1. JMRI (simulator)
2. CATS Runtime
3. JMRI Sensor Table
4. JMRI Signal Head Table
5. The System Monitor
THANK YOU!

johannes4@comcast.net
Wiring Scheme
Current MU-ing

Existing
- Outer Main Power
- Inner Main Power
- Third Track Power
- 18v A/C Power
- Accessory DCC

Newly Added
- Active Module Outer Main Power
- Active Module Inner Main Power
- Ground
- Spare (Unused)

5/15/2016
Terminal Strip Color Conventions

Wiring Harness Diagram (11-17-13)

Remove Jumper Wires for Active Module
Wiring scheme

Active Module

Detection Required As module to the left may be passive

Rail Cut Point

Detection Required As module to the right may be passive

NO Detection Required Belongs to leftmost block of module to the right

UNinsulated Joiner Tracks

NO Detection Required Belongs to rightmost block of module to the left

Rail Cut Point

DCCOD

UNinsulated Joiner Tracks

WEST

EAST
Mainline Wiring

Active Module Outside Main

Active Module Inside Main

Passive Module Outside Main

Passive Module Inside Main

5/15/2016
Active Module Outside Main

1. PASSIVE End Segment
2. INTERMEDIATE TRACK
3. ACTIVE End Segment

WEST  EAST
Simple Oval
“Splicing” in Active Modules
Turnout Wiring

Viewed From Fulcrum Side

1. Tortoise Power In
2. Position
3. Power Out
4. Ground
5. Track Power In

Motor

Tortoise Switch Machine

Tortoise Wiring Proposal July 2013

Frog Power

Point Position

Motor Power

5/15/2016
New Kids on the Block

**cpNode**

- Arduino based
- 16 Configurable ports
- Configurable node address
- Configurable baud rate
- Behaves like an SMINI
- Small: 3 x 2 ½ inches
- Low cost
- Built-in Turnout control
- Expandable

5/15/2016
Summary

• Signaling a modular layouts can be done without constraining either the sequence of modules or limiting the function of the signaling system
• Can run with or without a dispatcher
• Pre-setup: Create linear list of modules “importing” the layout plan for that particular setup into CATS
• Setup = 1) Link the physical modules 2) Load the CATS equivalent 3) Run
• HUB modular railroad uses:
  1. Lenz DCC with a LAN-USB connection
  2. C/MRI SMINI boards + (cpNodes & SMicros)
  3. C/MRI DCCOD occupancy detectors
  4. JMRI & CATS software
Clearance Form “A”

- This is the form that makes a train a train.
- We use it to fill in the needed info for train tracking.

<table>
<thead>
<tr>
<th>CLEARANCE FORM “A”</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>STATION</td>
<td>UPTON YARD</td>
</tr>
<tr>
<td>CONDUCTOR AND ENGINEER</td>
<td><strong>Dick Johannes</strong></td>
</tr>
<tr>
<td>ORDERS (If no orders, indorse “NONE”)</td>
<td></td>
</tr>
<tr>
<td>OK AT (Time)</td>
<td>11:00 AM</td>
</tr>
<tr>
<td>CHIEF DISPATCHER</td>
<td><strong>Shake Hand and bow</strong></td>
</tr>
<tr>
<td>DO NOT LEAVE BEFORE (Fill in when necessary to comply with rule 221)</td>
<td></td>
</tr>
<tr>
<td>TRAIN NAME</td>
<td>EPO</td>
</tr>
<tr>
<td>BLOCK (Fill in only when operating under Manual Block System)</td>
<td></td>
</tr>
<tr>
<td>LEAD LOCOMOTIVE</td>
<td># 510</td>
</tr>
<tr>
<td># CARS (At Origination)</td>
<td>14</td>
</tr>
</tbody>
</table>

Conductor and engineer must have a copy and see that their train is correctly designated in the above form, also that the numbers of all train orders received correspond with numbers inserted above.

DA FORM 4091-R, 1 May 93
REPLACES DA FORM 55-200
1 Jan 90 WHICH IS OBSOLETE
## HUB CATS File Development Documentation

### Upton Yard Signal
#### Program file
#### East Module
##### Signal Block Definitions

<table>
<thead>
<tr>
<th>Block Name</th>
<th>Signal Discipline</th>
<th>Address</th>
<th>Block Location on Module</th>
<th>Define Signal</th>
<th>Actual Head</th>
<th>Details/Signal Head Definitions</th>
<th>Address</th>
<th>Aspect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upton Yard OWE TS2</td>
<td>CTC</td>
<td>7004</td>
<td>Outer Main</td>
<td>Upright, Left</td>
<td>Top, Head0</td>
<td>Red</td>
<td>7001</td>
<td>Yellow 7002, Green 7003, Red 7004, Yellow 7005, Green 7006, Yellow 7007, Green 7008, Green 7009</td>
</tr>
<tr>
<td>Upton Yard IWE TS1</td>
<td>CTC</td>
<td>7001</td>
<td>Inner Main</td>
<td>Upright, Left</td>
<td>Top, Head0</td>
<td>Red</td>
<td>7011</td>
<td>Yellow 7012, Green 7013, Red 7014, Yellow 7015, Green 7016, Yellow 7017, Yellow 7018, Green 7019</td>
</tr>
<tr>
<td>Upton Yard LET TS1</td>
<td>CTC</td>
<td>7011</td>
<td>Local</td>
<td>Upright, Left</td>
<td>Top, Head0</td>
<td>Red</td>
<td>7021</td>
<td>Yellow 7022, Green 7023, Red 7024, Yellow 7025, Green 7026, Yellow 7027, Green 7028</td>
</tr>
<tr>
<td>Upton Yard LTL TS3b</td>
<td>CTC</td>
<td>7010</td>
<td>Yard Side</td>
<td>Right, Bottom</td>
<td>Top, Head0</td>
<td>Red</td>
<td>7037</td>
<td>Yellow 7038, Green 7039, Red 7040, Yellow 7041, Green 7042, Red 7043, Yellow 7044, Green 7045</td>
</tr>
<tr>
<td>Location</td>
<td>Name</td>
<td>Head Name</td>
<td>Software Flashing</td>
<td>Color</td>
<td>Prefix</td>
<td>Address</td>
<td>Action</td>
<td>Off Command</td>
</tr>
<tr>
<td>----------------</td>
<td>-------------</td>
<td>-------------------</td>
<td>-------------------</td>
<td>-------</td>
<td>--------</td>
<td>---------</td>
<td>--------</td>
<td>-------------</td>
</tr>
<tr>
<td>Column 5 Row 1</td>
<td>RSJ SL3</td>
<td>Undefined</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Column 5 Row 2</td>
<td>RSJ SL2</td>
<td>Stony Brk North Upper</td>
<td>green</td>
<td>CT</td>
<td>13026</td>
<td>throw</td>
<td>TRUE</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>yellow</td>
<td>CT</td>
<td>13027</td>
<td>throw</td>
<td>TRUE</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>red</td>
<td>CT</td>
<td>13025</td>
<td>throw</td>
<td>TRUE</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stony Brk N Lower</td>
<td>TRUE</td>
<td>red</td>
<td>CT</td>
<td>13028</td>
<td>throw</td>
<td>TRUE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>flashing green</td>
<td>CT</td>
<td>13029</td>
<td>throw</td>
<td>TRUE</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>yellow</td>
<td>CT</td>
<td>13030</td>
<td>throw</td>
<td>TRUE</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>green</td>
<td>CT</td>
<td>13030</td>
<td>throw</td>
<td>TRUE</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>flashing yellow</td>
<td>CT</td>
<td>13030</td>
<td>throw</td>
<td>TRUE</td>
<td></td>
</tr>
<tr>
<td>Column 3 Row 1</td>
<td>RSJ SL3</td>
<td>NewtonJct IM West Upper</td>
<td>green</td>
<td>CT</td>
<td>13032</td>
<td>throw</td>
<td>TRUE</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>yellow</td>
<td>CT</td>
<td>13033</td>
<td>throw</td>
<td>TRUE</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>red</td>
<td>CT</td>
<td>13031</td>
<td>throw</td>
<td>TRUE</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Newton Jct IM West Middle</td>
<td>TRUE</td>
<td>red</td>
<td>CT</td>
<td>13034</td>
<td>throw</td>
<td>TRUE</td>
</tr>
</tbody>
</table>
CHUBB to HUB
# Aspect Combinatorics & (NORAC)

<table>
<thead>
<tr>
<th>UPPER HEAD</th>
<th>LOWER HEAD</th>
<th>Signal</th>
<th>RULE (Aspect)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GREEN</td>
<td>GREEN</td>
<td><img src="green" alt="Green Green" /></td>
<td><img src="rule-281" alt="Rule 281" /></td>
</tr>
<tr>
<td>GREEN</td>
<td>YELLOW</td>
<td><img src="yellow" alt="Green Yellow" /></td>
<td><img src="rule-282" alt="Rule 282" /></td>
</tr>
<tr>
<td>GREEN</td>
<td>RED</td>
<td><img src="red" alt="Green Red" /></td>
<td><img src="rule-283" alt="Rule 283" /></td>
</tr>
<tr>
<td>YELLOW</td>
<td>GREEN</td>
<td><img src="green" alt="Yellow Green" /></td>
<td><img src="rule-284" alt="Rule 284" /></td>
</tr>
<tr>
<td>YELLOW</td>
<td>YELLOW</td>
<td><img src="yellow" alt="Yellow Yellow" /></td>
<td><img src="rule-285" alt="Rule 285" /></td>
</tr>
<tr>
<td>YELLOW</td>
<td>RED</td>
<td><img src="red" alt="Yellow Red" /></td>
<td><img src="rule-290" alt="Rule 290" /></td>
</tr>
<tr>
<td>RED</td>
<td>GREEN</td>
<td><img src="green" alt="Red Green" /></td>
<td><img src="rule-281" alt="Rule 281" /></td>
</tr>
<tr>
<td>RED</td>
<td>YELLOW</td>
<td><img src="yellow" alt="Red Yellow" /></td>
<td><img src="rule-291" alt="Rule 291" /></td>
</tr>
<tr>
<td>RED</td>
<td>RED</td>
<td><img src="red" alt="Red Red" /></td>
<td></td>
</tr>
</tbody>
</table>

*Note: The above table represents the aspect combinatorics and rules as per the NORAC system.*