Arizona Railroad Historical Society Experience with Layout Command Control, LCC

September 27, 2019

Agenda

- Basics of DCC and LCC
- ARHS Decision Process—The agony of decision-making
- Building Blocks of LCC—An ad for RR CirKits
- Building the Hardware—How ARHS put it together
- Configuring the Cards—Slow and steady
- What we Learned—Lotsa stuff!
- Summary—LCC is the Best Decision we Ever Made!
- Demonstration—It really works!!

Arizona Railroad Historical Society, ARHS, Display at The Arizona Capitol Museum

Layout will be on tour on Saturday

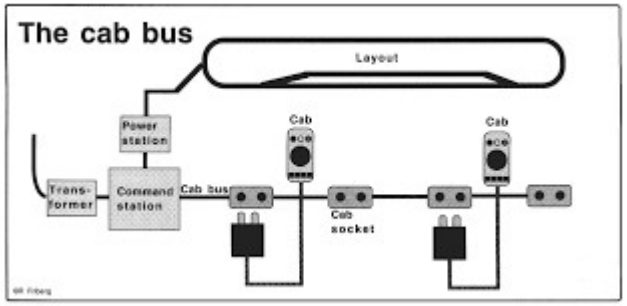
DCC Is Designed for Operating Trains

- DCC provides digital information with the power in the rails
- Command Station communicates with each throttle (or other input device)
- Command Station then sends signal to engines (or other equipment)
  - Each decoder receives all signals and reacts only to those sent to it's address
  - Does not provide feedback that it has done anything
- Sound equipped engines drive more data
- As more trains (or stationary decoders) are added, the response rate to new commands (think horn/whistle) slows

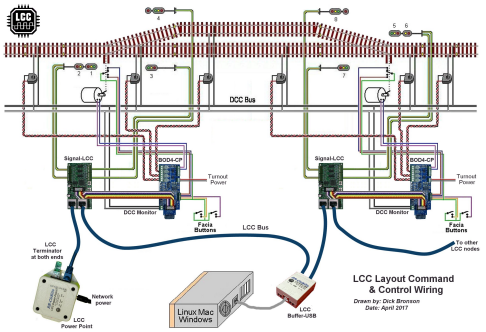
LCC Is Designed to Operate the Layout

- NMRA Definition: LCC stands for "Layout Command Control," and it's a system for controlling all the functions on your layout that don't have to do with how fast the locomotive is moving -- things like signals, or sounds, or passenger car lighting.
- Protocol is defined by NMRA standard—just like DCC
- Any manufacturers equipment will talk to any other manufacturer
- Designed for Layout functions:
  - Turnout Motors
  - Block Detection
  - Signals
  - Road Crossings
  - Building lights
  - Ambient Lights
  - Arduinos

DCC and LCC are Complimentary



- **DCC Operates the Train**
  - Powers the track
  - One-way signal to decoders
  - Each decoder is independent



- **LCC Operates the Layout**
  - No connection to track
  - Two-way communication
  - All “nodes” have all information

The LCC Bus Structure Provides All Information to All Locations

DCC sends a message to an individual location

- ***This is analogous to texting an individual in a crowded room***
- An example is "Engine 4567 turn on your headlight".

LCC announces to the "world

- ***This is analogous to a loudspeaker in an auditorium***
- An example is --A train enters Block 123 which sends a message "I am occupied"
  - All locations hear this message, and several react:
    - JMRI Panel Pro will change the color of the rail on the dispatcher panel to indicate occupancy
    - The signals in this block will change state to a "Red" aspect
    - Previous block signals will also change
    - Perhaps a turnout or other device will also activate if so directed. And the turnout will report it's actual position.

Agenda

- Basics of LCC
- ARHS Decision Process
- Building Blocks of LCC
- Building the Hardware
- Configuring the Cards
- What we Learned
- Summary—LCC is the Best Decision we Ever Made!
- Demonstration

The Decision Tree with Subsequent Charts Developing the Decision Logic

DCC
Many Suppliers

- NCE
- Digitrax
- Lenz
- CVP
- Atlas
- Bachman
- Zimo
- MRC

Layout
Three Basic Approaches

- NCE for train & Layout
- NCE + Digitrax
- NCE + LCC

LCC
One Source

- RR CirKits
- ?

These are actual charts from ARHS decision briefing

NCE is an Easy Choice for Train Control, but Layout Control is a More Complex Decision

- Train Control– (DCC)
  - Choices include: NCE, Digitrax, Lenz, CVP, Atlas, Bachman, Zimo, MRC…
  - This was an easy decision
    - Currently have NCE equipment from previous layout
    - Most members currently have and operate NCE
    - NCE is an intuitive system for operating trains
    - NCE has provided excellent support in the past
      - (although innovation is not their strong suit)
    - No sign of NCE departing the market
  - Don't reinvent the wheel—stay with NCE

- Layout Control
  - This includes:
    - As a minimum: turnout motors & block detection
    - Also desired: signaling, animation (crossings, etc) and lighting effects
  - System Choices are more Limited
    - Use NCE for Both Layout and Train Control
    - Use NCE for Train control and Supplement with:
      - Digitrax (Loconet)
      - Layout Command and Control

There Are Three Choices for "Supplemental" Layout Control

- Use Digitrax Loconet for Layout control functions
  - This approach was (and is) used by Scottsdale
  - It was not recommended for another new layout:
    - Required many "patches" to get the two systems talking
    - Sharing data and commands was difficult
- Use NCE with Auxiliary Input Unit (AIU) for Layout Control
- Use New NMRA Standard called Layout Command and Control, LCC
  - Currently only one major supplier—RR CirKits

Digitrax approached dropped based on recommendation of a club that used it

The Final Choice Came Down to NCE with an Auxiliary Input Unit Approach or LCC

NCE Advantages

1. Compatibility with existing system
2. Confidence in Company
3. Proven Past Experience
4. Interfaces to JMRI

NCE Disadvantages

1. Limited expandability
2. One way communication

LCC Advantages

1. Operates all train related functions and many layout functions
2. Expandable into the future
3. Flexible two-way bus structure
4. Easily talks to JMRI

LCC Disadvantages

1. New Company
2. Untested future support
3. Unknown-Unknowns

Total cost of either system was about the same

Risk Mitigation Plan for Implementing RR CirKits

Risk	Mitigation Plan
Single Source of Supply	•Uses NMRA sanctioned interface—so cards "should be" interchangeable—like decoders are today in DCC •Buy sufficient "spares" up front to guard against shortages.
Systems Integration	•Others are working on elements •Systems Integration—Detlef Kurpanek •Signals—Paul Davidson •Textbook—Dana Zimmerli
Unknown-Unknowns	•Received commitment from Principal developers for support •Dick Bronson—RR CirKits, President •Ken Cameron—JMRI Development Team •Balzas Racz—LCB Code Development
Obsolescence	•Common to any electronic system •Buy sufficient spares to assure parts availability through life of system
Being the first "from the Ground up" layout	•Use this to our advantage—Get publicity in MR and MRH to provide interest then the community (NMRA, Developers, Suppliers) must see that it succeeds

Agenda

- What is LCC
- ARHS Decision Process
- Building Blocks of LCC
- Building the Hardware
- Configuring the Cards
- What we Learned
- Summary—LCC is the Best Decision we Ever Made!
- Demonstraton

LCC Is Like Building with LEGO's

There are three basic building "blocks"

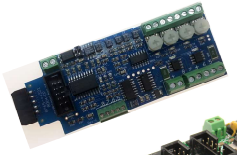
Interface

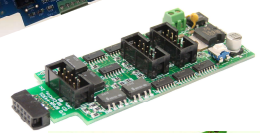
Provides interface to Computer:
- Configure LCC Cards
- Communication with JMRI
- Cat 5 Cable connects to LCC System

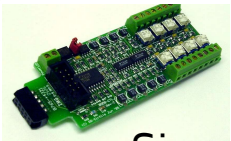
"Brains"

Tower or Signal Cards provide computation and communication daisy chain with Cat 5

Function







Functions are "Daughter Boards" to Tower or Signal Cards
Operate Turnouts, Detect Occupancy, or Auxiliary Equipment

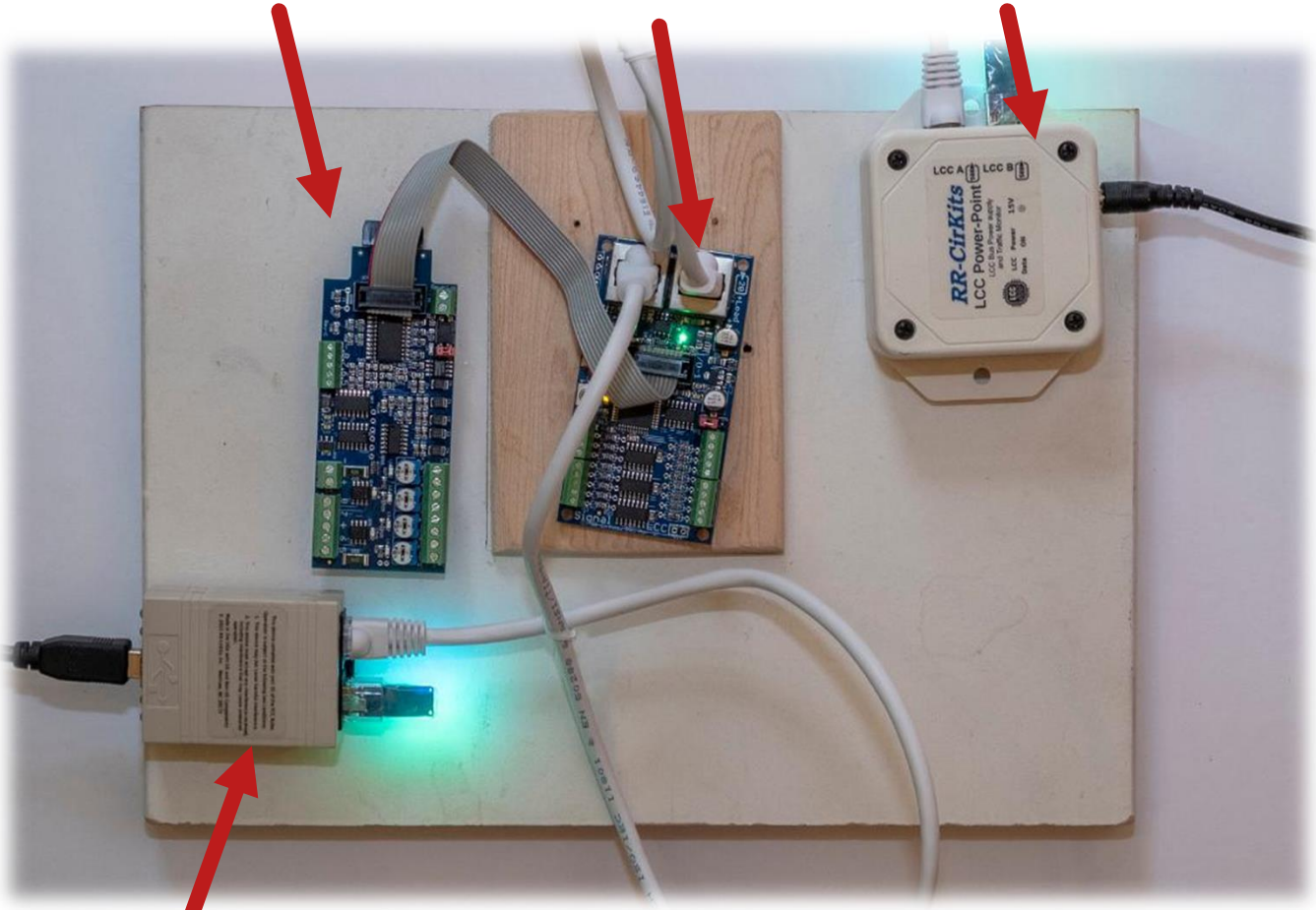
Connect with 10 wire flat cable to Tower or Signal Card

The World's Simplest LCC System

BOD4-CP

Signal LCC Card

Power Point



LCC Buffer
Computer Interface

A Computer Interface and Power are Required

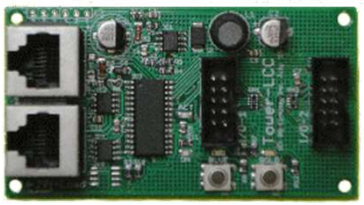
Computer Interface

NMRA CAN bus LCC® to USB interface.
2,500 Volt Digital isolation between CAN bus LCC® and USB port.
Type B USB connector for PC connection.
Dual RJ45 connectors for easy LCC® loop through connections.
4 LEDs display status. (Ready, Power, Transmit, and Receive)
Small package size. Just 1-1/2" x 2-1/4" x ¾".
Ready to run unit includes USB cable. – Nothing extra to purchase.
Standard 125,000 Baud CAN bus LCC® interface speed. – No jumpers or switches to set.
Buffered inputs and outputs for full speed error free data transmission.
Powered directly from LCC bus connections* and USB port. *
Note: Requires a powered LCC bus. [10 ma. bus load] Simplify your LCC configuration and/or use a PC based CTC. Compatible with JMRI.

Power Point

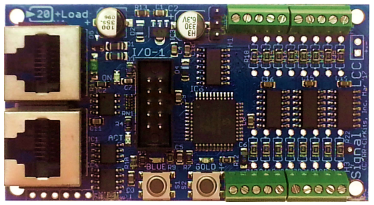
NMRA CAN bus LCC® Power Injection Unit.
•500 ma power supplied to each CAN LCC®bus jack.
•100-240VAC 15VDC 1.2 Amp Universal Switching Power Supply included.
•Internal rectifier prevents reverse polarity problems.
•Includes CAN bus data monitor for network trouble shooting.
•Dual RJ45 connectors for easy CAN LCC® loop through connections.
•2 LEDs display status. (Power, Activity)
•Small package size. Just 2-1/2" x 3-1/2" x 1". (including mounting flanges)

The "Brains" of LCC are in Two Cards



Tower LCC

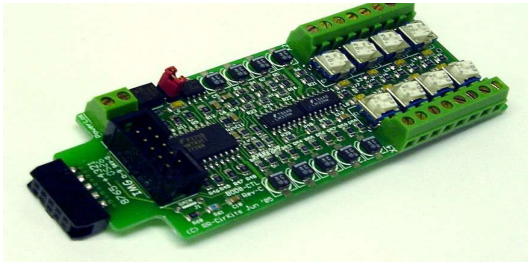
- Use this card for most applications
- 16 Line Input/output node for NMRA CAN bus LCC
  - Communicates on LCC Buss via daisy Chain Cat5 Cables
  - It will support two "daughter boards"



Signal LCC

- Use this card if you want Signals
- 16 Led drivers plus 8 line Input/Output node for NMRA CAN bus LCC®
  - Provides LED control to up to Four Signal Masts
  - It will support one "daughter board"

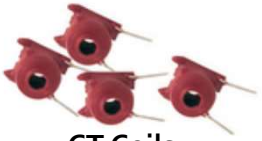
Functions Happen on "Daughter" Boards



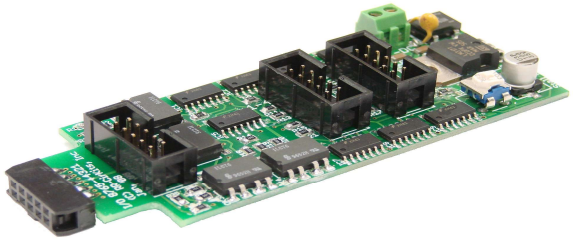
BOD8

Block Occupancy Detector

- This board operates as a DCC occupancy detector for 8 blocks using remote CT coils.
- It outputs logic levels, and has a RR-CirKits standard ribbon connector interface.
- The "Power-Lok" feature monitors the DCC bus power. A power failure latches the detection status of each block until power is restored and re-stabilized.



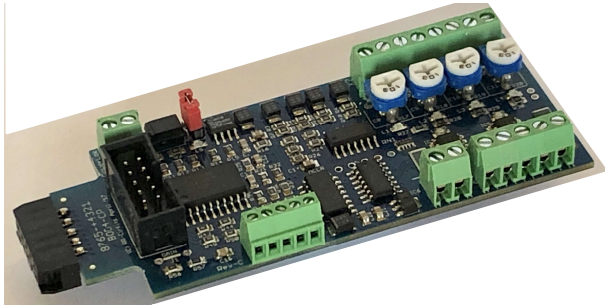
CT Coils



SMD8

Stall Motor Driver

- This 8 output, optically isolated, low current "H" bridge driver is designed for control of 8 stall motor switch machines. (E.g. Tortoises®)
- It can drive up to 100ma. per line, speed regulated output 4 to 12VDC.
- (PTC fuse limited to 200ma total per board for safety



BOD4CP

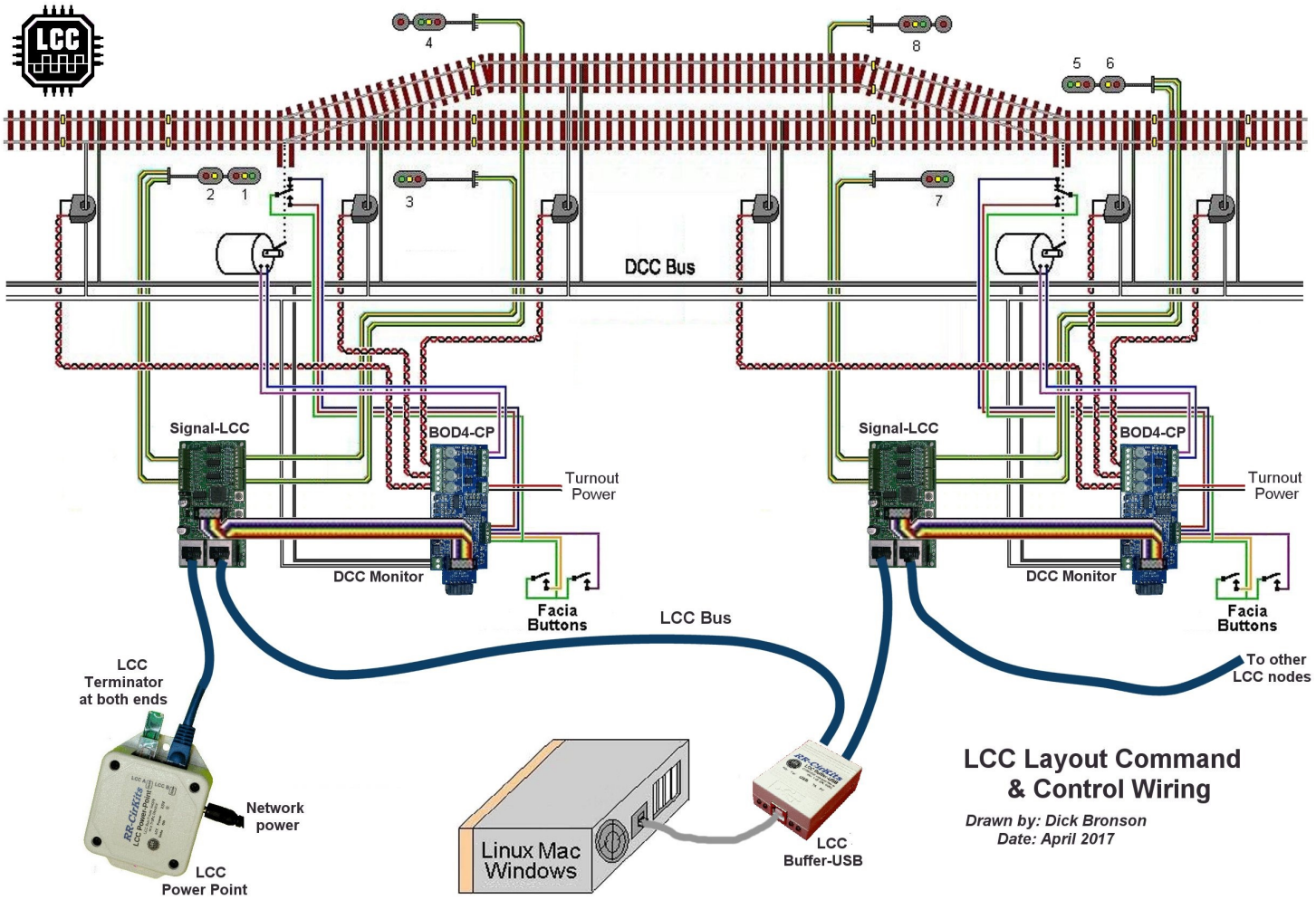
Block Occupancy Detector-4

- This board operates as a DCC occupancy detector for 4 blocks using remote CT coils.
- It outputs logic levels, and has a RR-CirKits standard ribbon connector interface.
- The "Power-Lok" feature optionally monitors the DCC bus power. A power failure latches the detection status of each block until power is restored and re-stabilized.
- The CP version also includes dual turnout drivers.
- When used with the Tower LCC or Signal LCC boards there are also 4 general purpose I/O connections.

Agenda

- What is LCC
- ARHS Decision Process
- Building Blocks of LCC
- Building the Hardware
- Configuring the Cards
- What we Learned
- Summary—LCC is the Best Decision we Ever Made!
- Demonstration

How It Works at a Single Location!



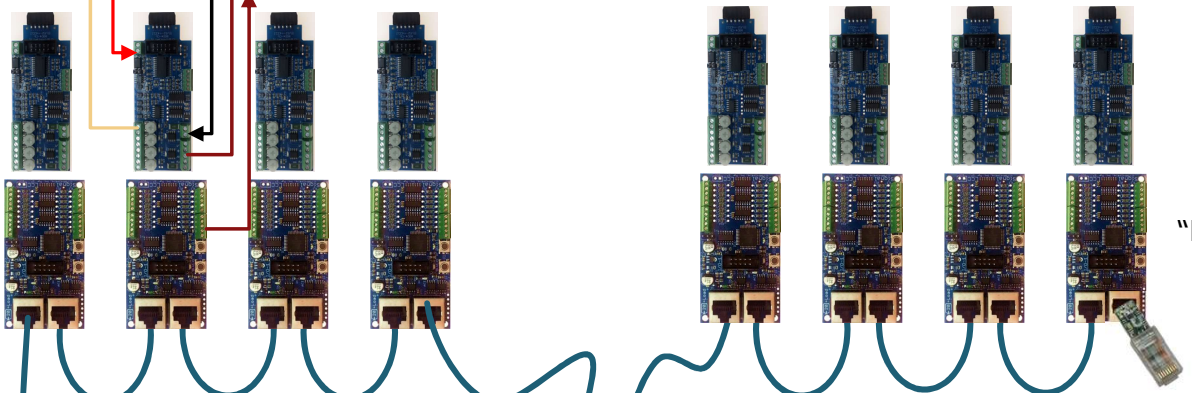
Building a System Simply Means Connecting All of the Cards

Block Detection (Up to 4 on same circuit breaker)
Track Power)from same block as above)
+12 VDC
Turnout Command (up to 2 Tortoises)
Signals (Up to 4 mast heads with 4 aspects each)

Function

"Brains"

Interface



"Last" card must contain a bus terminator

Each Power Point can power up to 8 Signal Cards
Maximum wire length 10 Feet
Each Power Point supplies up to 500 mA per channel
Power consumed by each card is about **100 mA**

- 80 mA - 4 X 20 mA per LED on a signal
- 20 mA power draw of card

Power computer and "Wall Warts" off of same "on-off" switch

To other "Nodes"

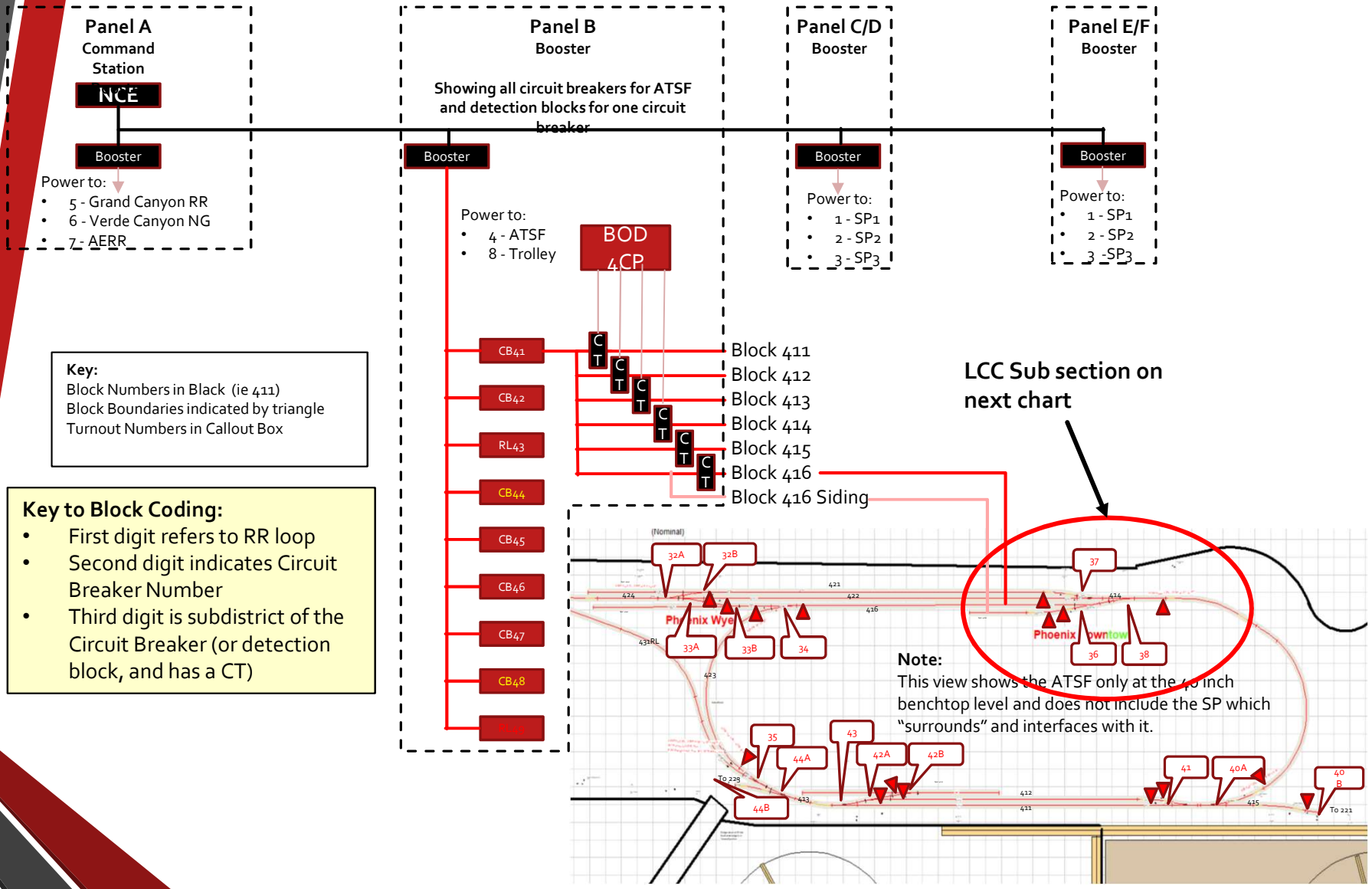
ARHS Built a "Proof of Concept" Demonstrator

Demonstrated all Functions:

- Layout
  - Block Detection
  - Turnout Control
- Control Functions from
  - NCE Throttle
  - Computer
  - Remote (Wi-Fi) Tablet
  - Phone

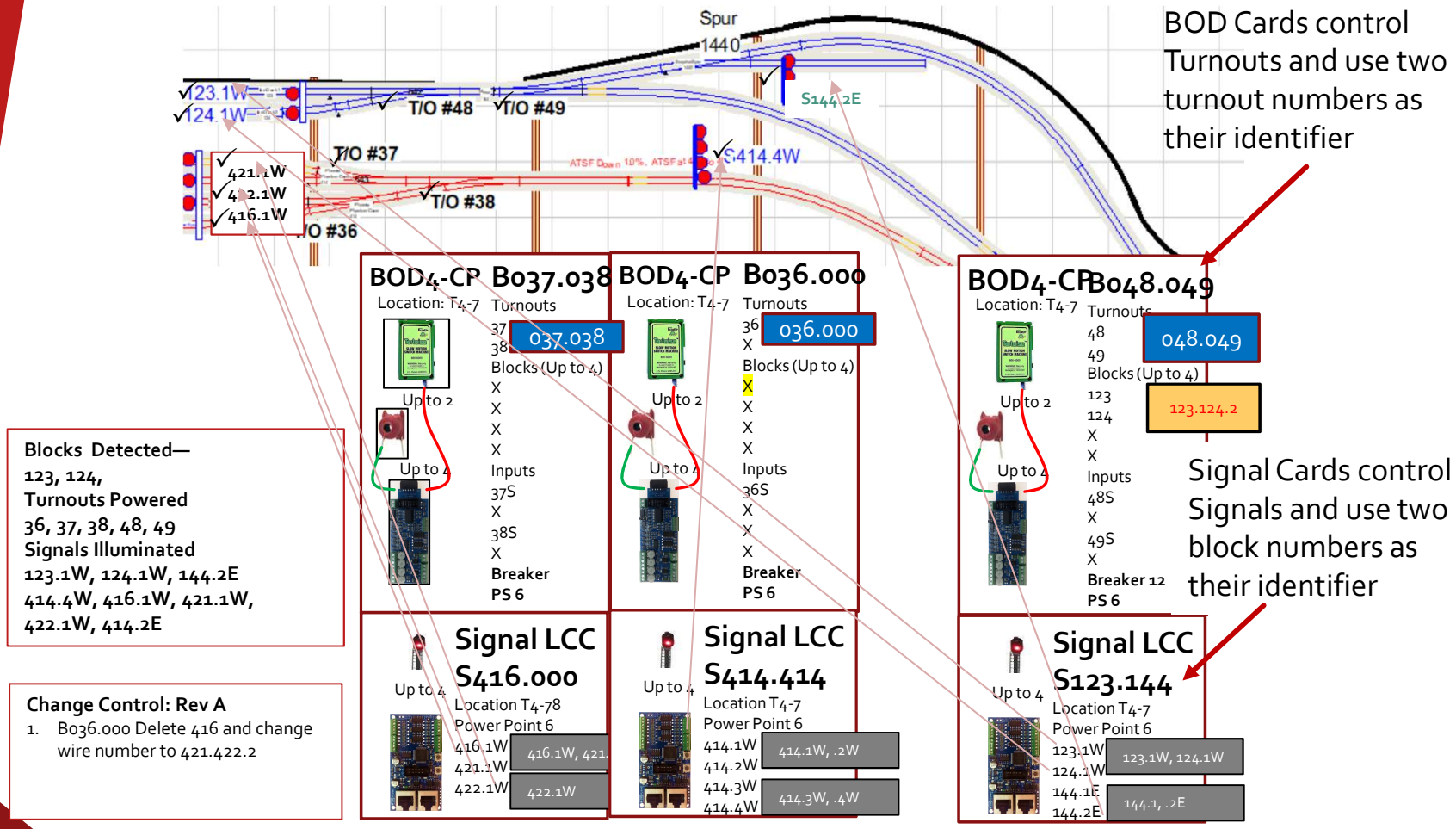
The Next Series of six slides show how the ARHS system was planned

ARHS Block Structure Showing Details of Panel B



Track Plan of ATSF on 40 inch level showing assigned Block and Turnout Numbers

Wire Connections for Each Card Were Defined



BOD Cards control Turnouts and use two turnout numbers as their identifier

Signal Cards control Signals and use two block numbers as their identifier

Blocks Detected—
123, 124,
Turnouts Powered
36, 37, 38, 48, 49
Signals Illuminated
123.1W, 124.1W, 144.2E
414.4W, 416.1W, 421.1W,
422.1W, 414.2E

Change Control: Rev A

1. B036.000 Delete 416 and change wire number to 421.422.2

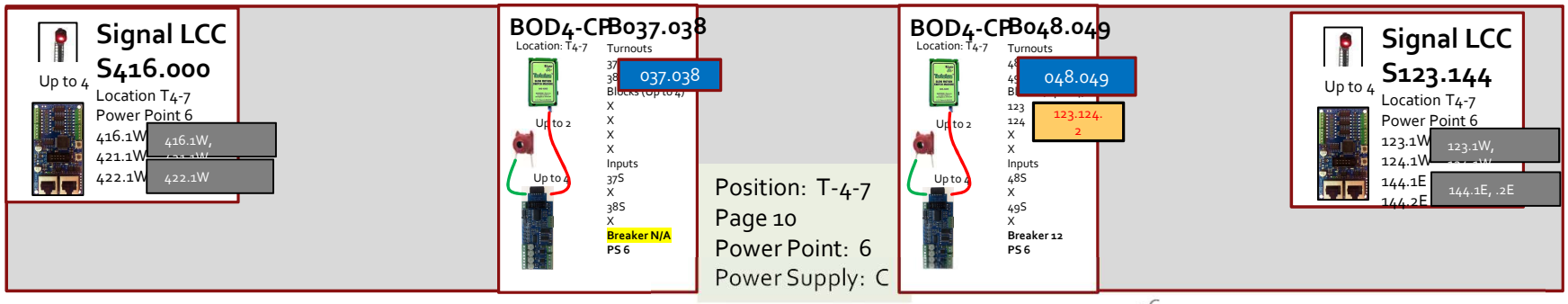
The Cards were Grouped into Panel Locations

All Critical Information for Each Signal Card is Displayed:

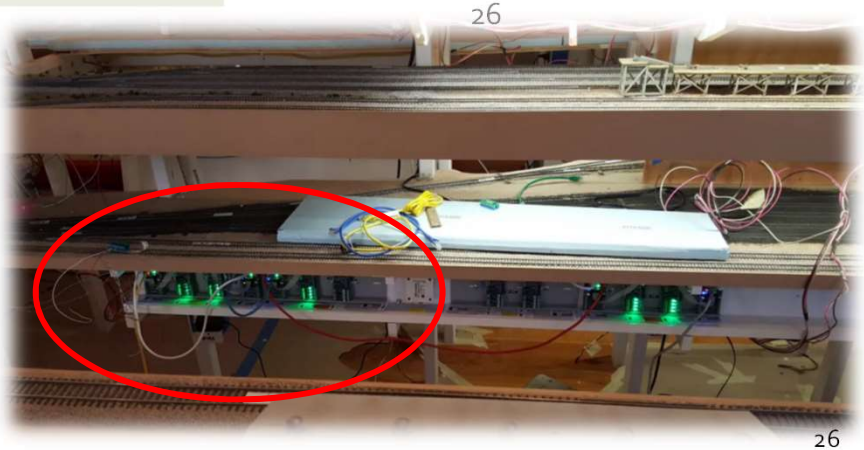
- Signal Card Name (based on signals controlled by board)
- Signals Controlled
- Wires running from card (and color)

All Critical Information for Each BOD4-CP Card is Displayed:

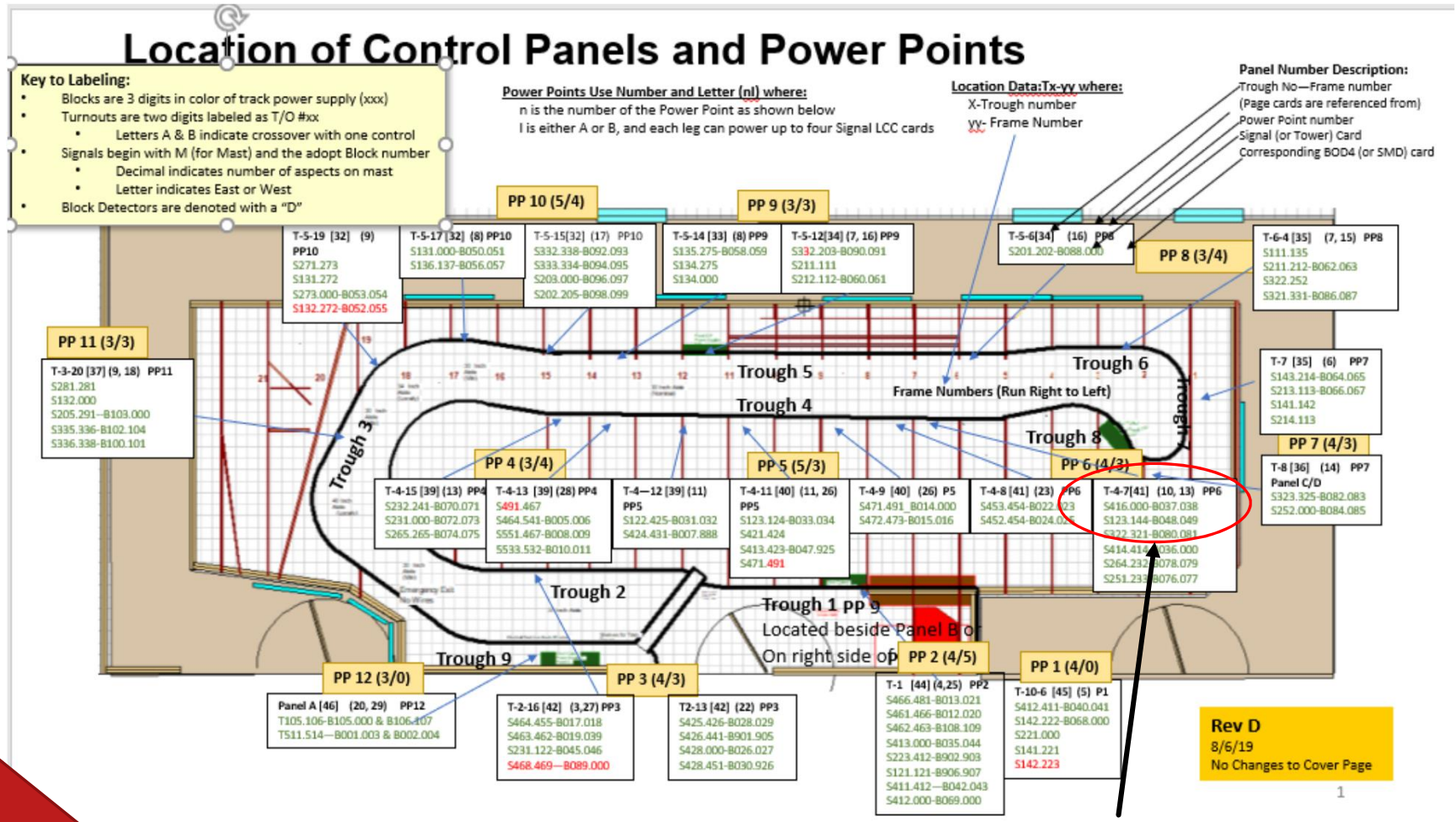
- BOD4-CP Card Name
- Controlled (based on two turnouts controlled by board)
- Wires running from card (and color) to turnouts
- Wires running from card (and color) to CT coils for block detection



The resulting installation on the layout is shown to the right



The Location of Every Panel is then located on the Layout

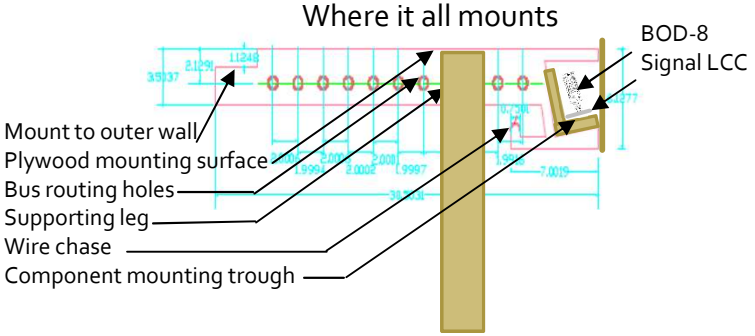


Front Mounted Components Make Installation Easy

Craig Faris installing Cards on Layout

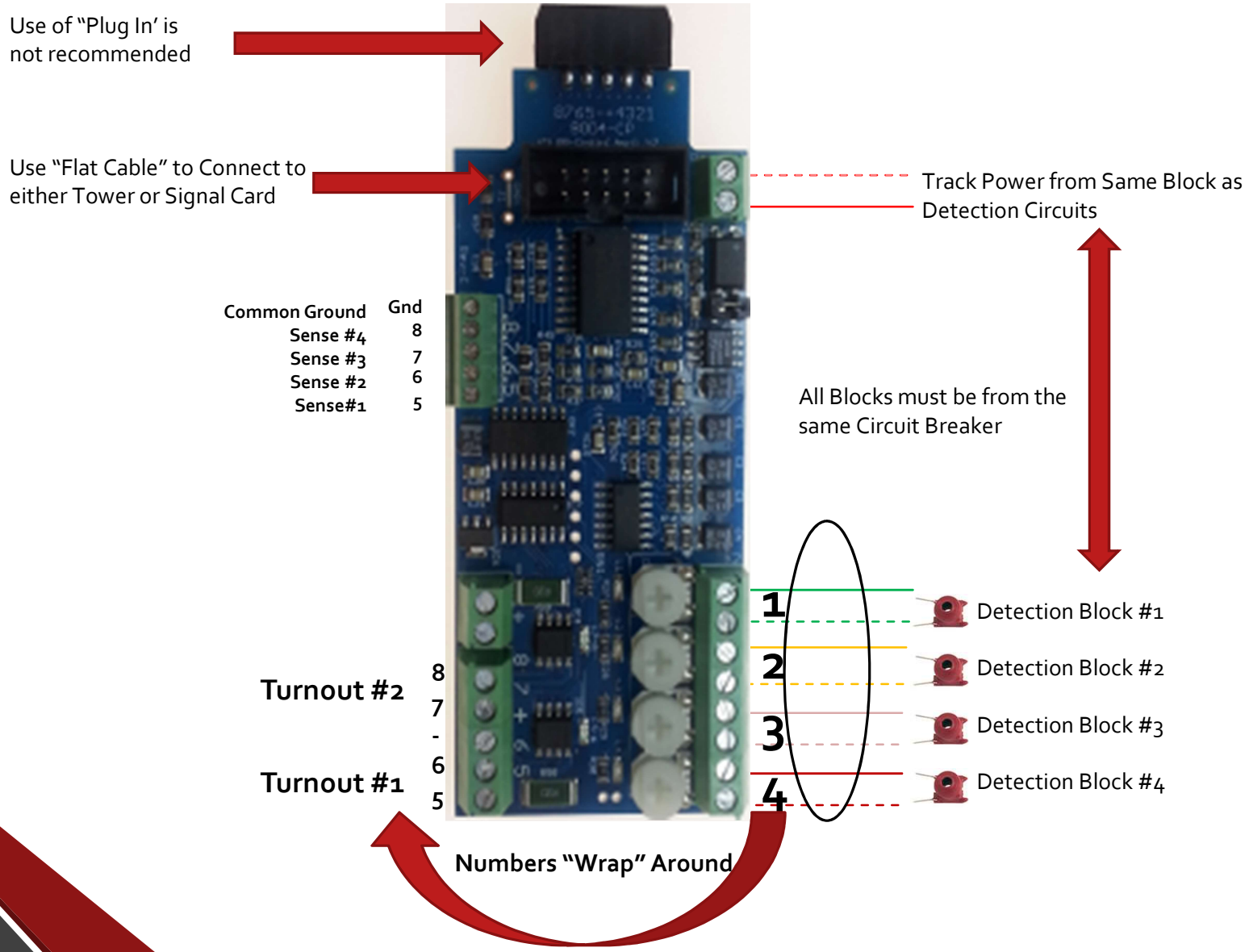
Cross-section of Stringers

Where it all mounts

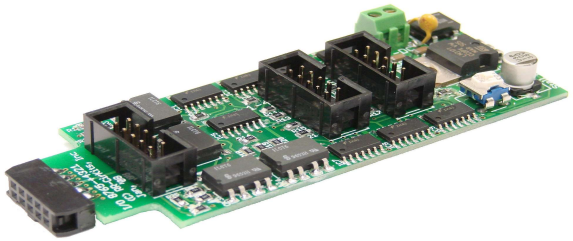


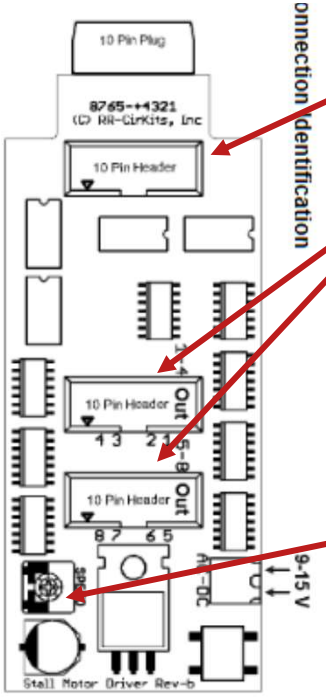
All connections on cards face outward

Pin Numbering on the BOD4-CP is Not Intuitive



SMD8 Card Can be Used for Turnouts or Other Functions





Input – 10 Wire Flat Cable from Tower or Signal Card

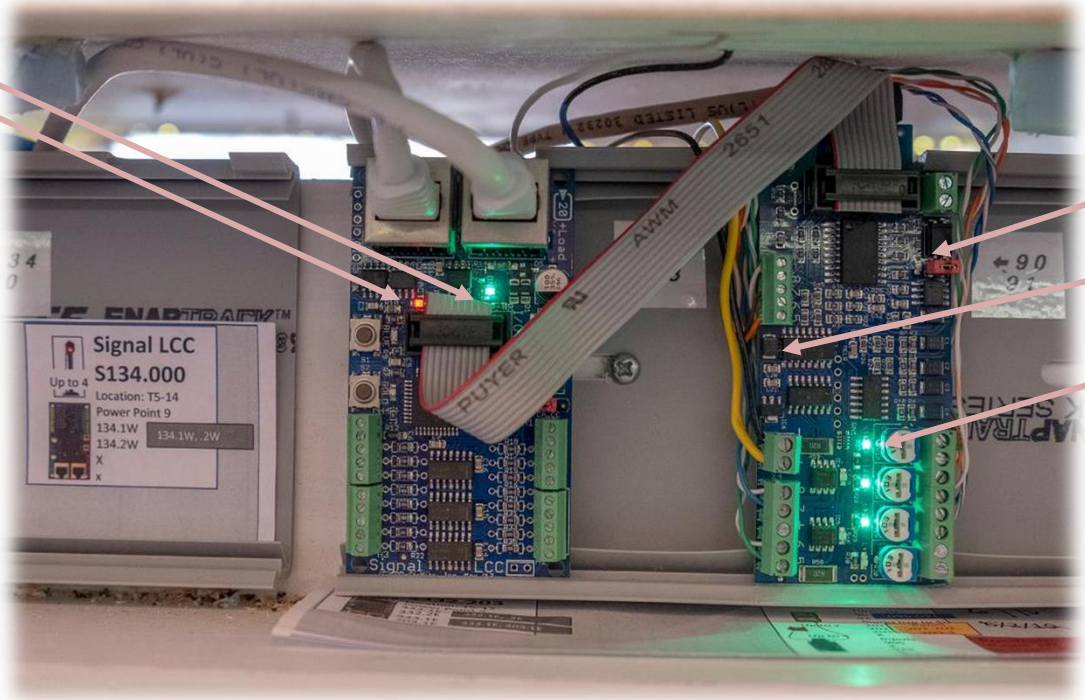
Output –2 X 10 Wire Flat Cables

- Up to 100 mA per channel
- Max of 200 mA per board
- Optimized for Tortoise Motors
- Can be used to control other functions—such as LEDs!

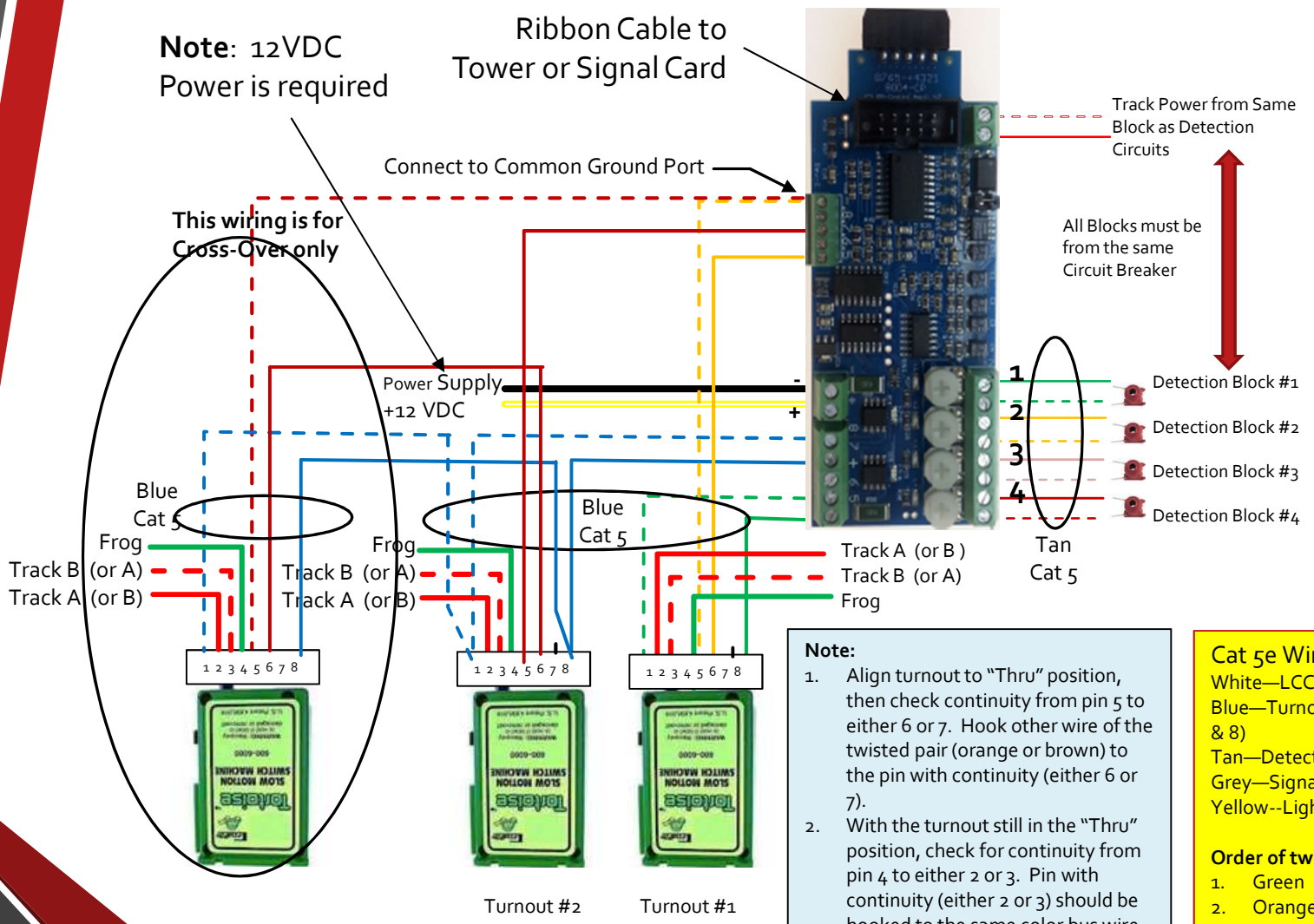
Speed Control

- Sets voltage between 4 and 12 Volts
  - Sets Tortoise rate, or
  - Input voltage to LEDs (or other auxiliary)

The "Cards" come with built-in LEDs Which Help with Diagnostics



BOD4-CP Wiring Standard used by ARHS



Note:

1. Align turnout to "Thru" position, then check continuity from pin 5 to either 6 or 7. Hook other wire of the twisted pair (orange or brown) to the pin with continuity (either 6 or 7).
2. With the turnout still in the "Thru" position, check for continuity from pin 4 to either 2 or 3. Pin with continuity (either 2 or 3) should be hooked to the same color bus wire as rail for the "thru" position.
3.

Cat 5e Wire Colors:
White—LCC Bus
Blue—Turnout Drive (Tortoise 1 & 8)
Tan—Detection (CTs)
Grey—Signaling
Yellow--Lighting

Order of twisted pair colors:

1. Green
2. Orange — Turnout #1
3. Blue
4. Brown — Turnout #2

Agenda

- What is LCC
- ARHS Decision Process
- Building Blocks of LCC
- Building the Hardware
- Configuring the Cards
- What we Learned
- Summary—LCC is the Best Decision we Ever Made!
- Demonstration

Configuring Can be Tedious at First, But Then it Becomes Cut and Paste!

- **Most Texts begin by describing in detail "Nodes", "Producers", and "Consumers"**
  - These are important concepts to software designers
  - The only thing important to the user is that a "node" is an item of hardware--It either sends (produces) a command, like a pushbutton; or It reacts (Consumes) a command, like a turnout.

Producers

Pushbutton

Auxiliary Commands

Switch

CT Coils

Both

Tortoise
DPDT Switch--Producer
Motor--Consumer

Consumers

Signal

Gate

LEDs

- **The Signal and Tower Cards are Configured—not Programmed!**
  - **The cards are preloaded with a default configuration which covers many cases**
  - **The cards contain all of the possible choices for operations which are selected from a drop-down menu**
  - **Once configured, the result can be copied to other cards as appropriate**
  - **The "daughter" boards are not configured, but work off the commands of the Signal or Tower Card**

The First Step in Configuring is to Give All "Nodes" on Your Layout a Name and Number

Examples from ARHS Layout

- Each track block has a unique name and number, and is assigned to a Signal and BOD Card.

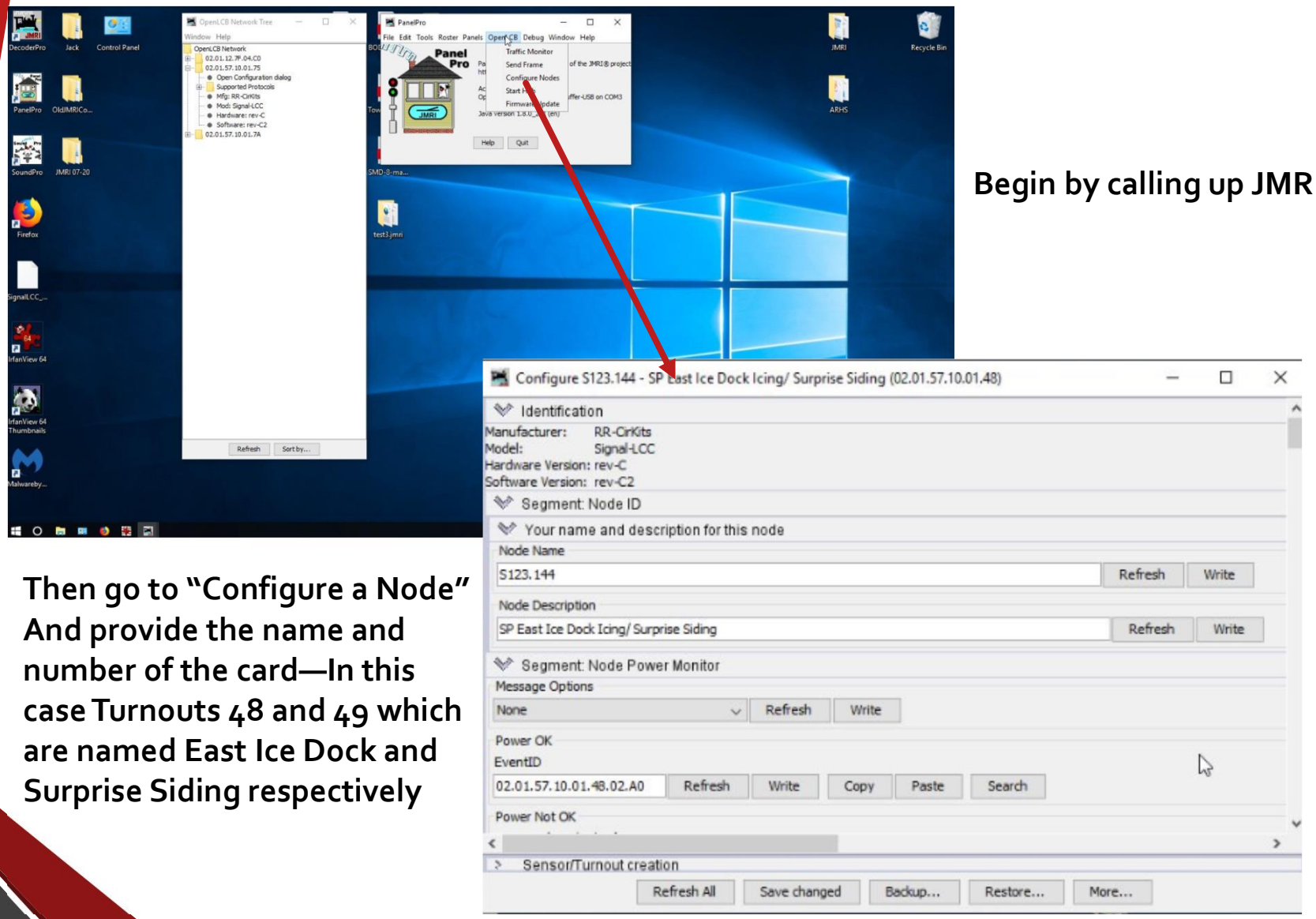
Block Name	Block	CT Location	BOD4	Signal LCC	Power Supply	Trough Location
Tempe Main (1)	111	West Wall	**B062.063**	S113.212	7	6-4
Tempe Station (2)	112	West Wall	**B062.063**	S113.212	7	6-4
Papago	113	C/D	**B064.043**	S213.113	7	7
Washington	121	So Phx	**B042.069**	S412.000	2	1
South Phoenix	122	So Phx	**B042.069**	S412.000	2	1
Ice Dock 1	123	Pen	**B048.049**	S123.144	6	4-8
Ice Dock 2	124	Pen	**B048.049**	S123.144	6	4-8
Prince	131	West Wall	**B050.051**	S136.137	10	5-16
San Xavier	132	West Wall	**B052.055**	S132.272	11	3-20
Tucson Main (1)	133	West Wall	**B052.055**	S132.272	11	3-20
Picacho	134	E/F	**B058.059**	S135.275	9	5-14
Casa Grande	135	E/F	**B050.051**	S136.137	10	5-16
Kino Siding	136	E/F	**B050.051**	S136.137	10	5-16
Kino	137	E/F	**B050.051**	S136.137	10	5-16
Sky Harbor	141	C/D	**B064.043**	S213.113	7	7
Phoenix 1	142	C/D	**B064.043**	S213.113	7	7
Coolidge (was Mesa)	143	Frame	**B062.063**	S113.212	7	6-4
Mesa	144	C/D	**B064.043**	S213.113	7	7
Surprise Spur	1440P	N/A				
Tempe Station Spur (3)	1120P	N/A				
Scrap Yard Spur	1130P	N/A				
SP Ice Dock Spur	1220P	N/A				
Tucson Industrial	1330P	N/A				

- Each Turnout has a unique name and number, and is assigned to a Signal and BOD Card

Turnout	Name	Block	BOD4	Signal	Cat 5
1	Grand Canyon Station	511	B001.003	**T511.514**	001.003
2	Grand Canyon Exit	512	B002.004	**T511.514**	002.004
3	Grand Canyon Siding	514	B001.003	**T511.514**	001.003
4	Tororeap	514	B002.004	**T511.514**	002.004
5	Supai	533	B005.006	**S464.541**	005.006
6	Esplanade Siding	532	B005.006	**S464.541**	005.006
7	Esplanade	462	B007.888	**S424.431**	7.888
8A	Williams Crossover	464	B008.009	**S551.467**	008.009
8B	Williams Crossover	533	B008.009	**S551.467**	008.009
9	Williams Station	533	B008.009	**S551.467**	008.009
10A	Bellemont Crossover	471	B010.011	**S533.532**	010.011
10B	Bellemont Crossover	471	B010.011	**S533.532**	010.011
11	Bellemont	471	B010.011	**S533.532**	010.011
12	Drake	466	B012.020	**S461.466**	12.02
13A	Eden Crossover	461	B013.021	**S466.481**	13.021
13B	Eden Crossover	466	B013.021	**S466.481**	13.021
14	Flagstaff East	475	B014.000	**S471.491**	014.000
15	Flagstaff Freight	474	B015.016	**S472.473**	15.016
16	Flagstaff West	474	B015.016	**S472.473**	15.016
17	Ash Fork Siding	464	B017.018	**S464.455**	017.018
18A	Dunbar Siding	4630	B017.018	**S464.455**	017.018
18B	Dunbar Siding	468	B017.018	**S464.455**	017.018
19A	Ash Fork Crossover	469	B019.039	**S463.462**	19.039
19B	Ash Fork Crossover	462	B019.039	**S463.462**	19.039
20A	Sunset Crossover	462	B012.020	**S461.466**	12.02
20B	Sunset Crossover	461	B012.020	**S461.466**	12.02

During the configuration process the LCC Card will assign a unique 16 digit number, but the user never needs to work with this number

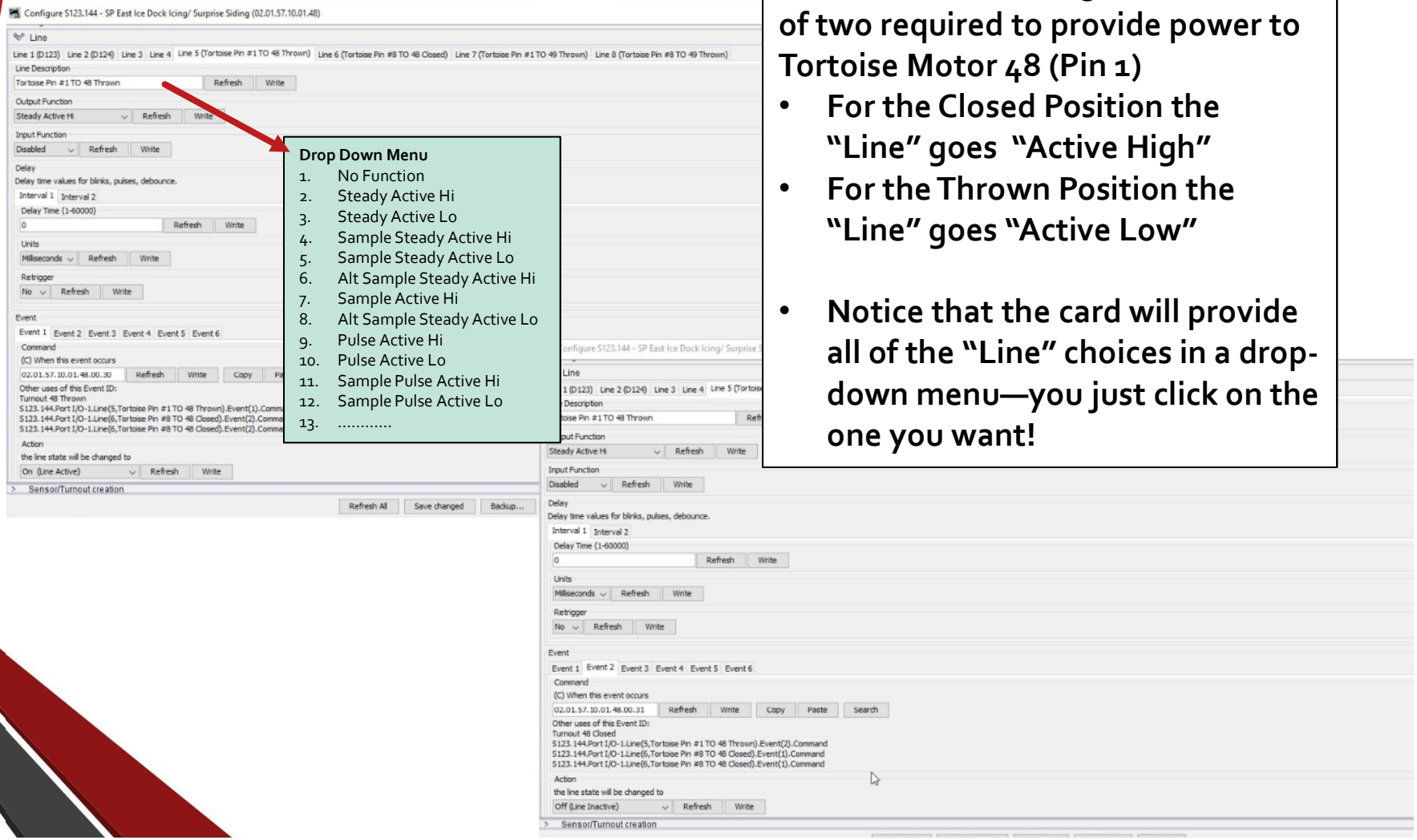
Configuring the System is Done with JMRI



Begin by calling up JMRI

Then go to "Configure a Node" And provide the name and number of the card—In this case Turnouts 48 and 49 which are named East Ice Dock and Surprise Siding respectively

Each "Line" on the Card is then Configured to React to Certain Inputs



This chart is for Line 5 which is one of two required to provide power to Tortoise Motor 48 (Pin 1)

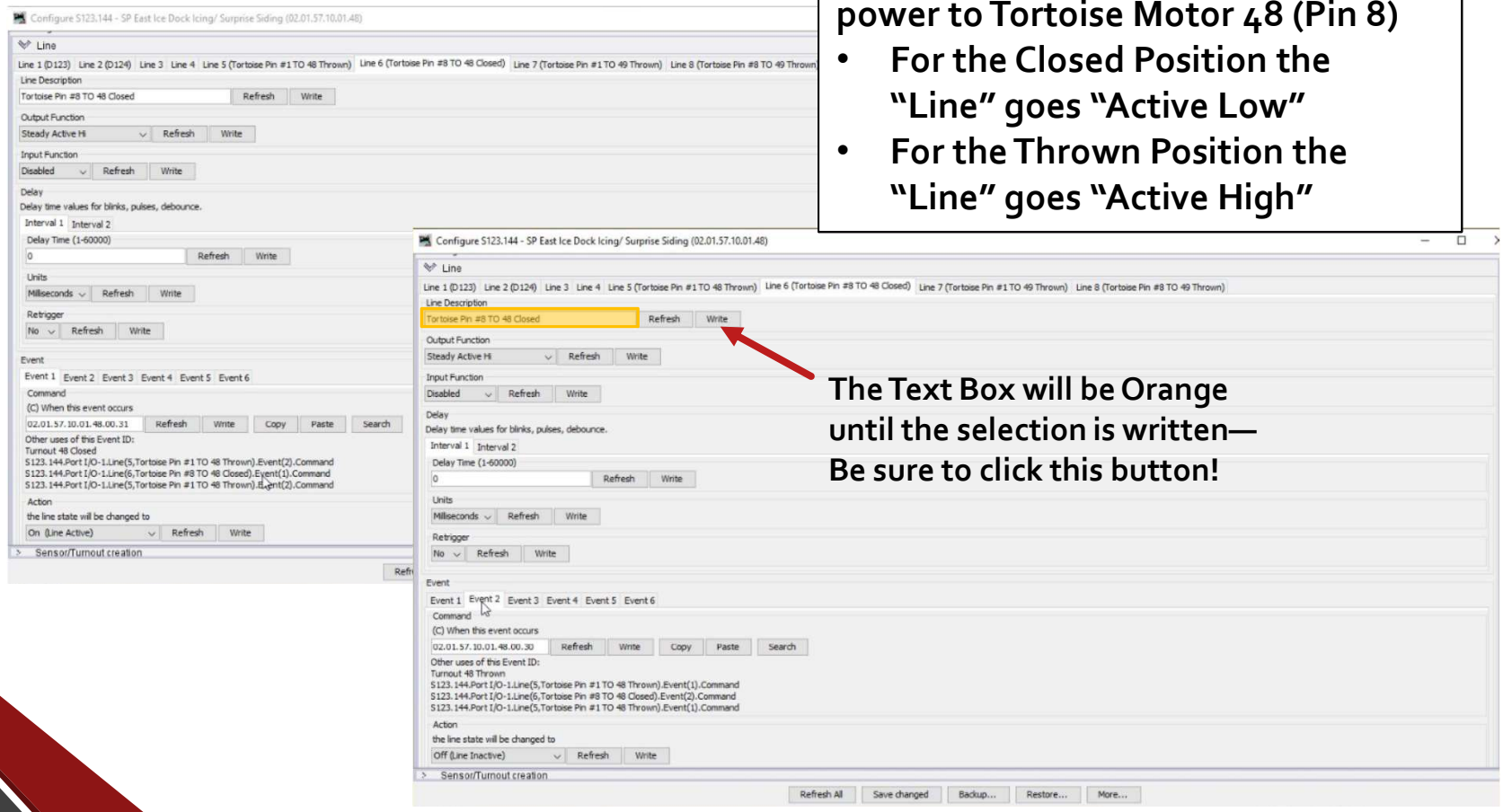
- **For the Closed Position the "Line" goes "Active High"**
- **For the Thrown Position the "Line" goes "Active Low"**

- **Notice that the card will provide all of the "Line" choices in a drop-down menu—you just click on the one you want!**

The "Other Line" to the Turnout is Configured Just the Opposite

The chart is for Line 6 which is the other of two required to provide power to Tortoise Motor 48 (Pin 8)

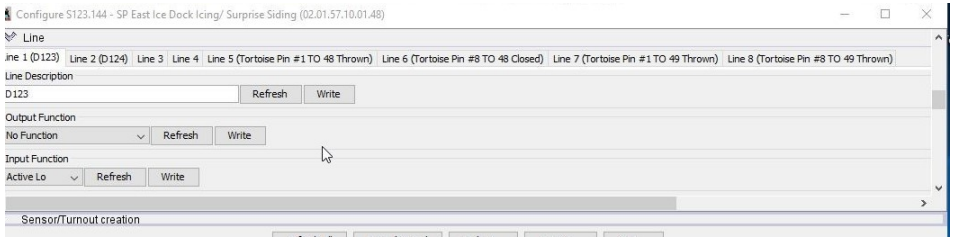
- **For the Closed Position the "Line" goes "Active Low"**
- **For the Thrown Position the "Line" goes "Active High"**



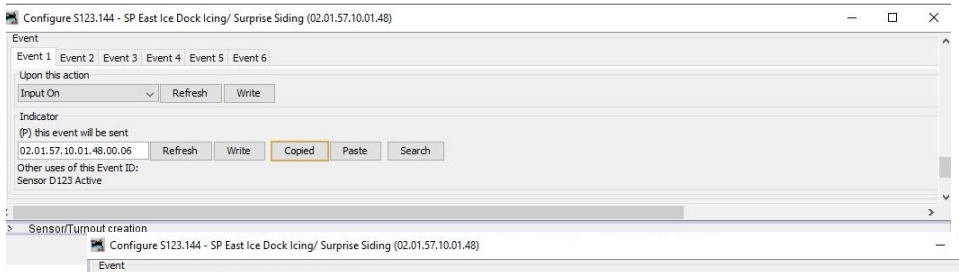
The Text Box will be Orange until the selection is written— Be sure to click this button!

Configuring for the BOD4-CP Requires Only Four Steps

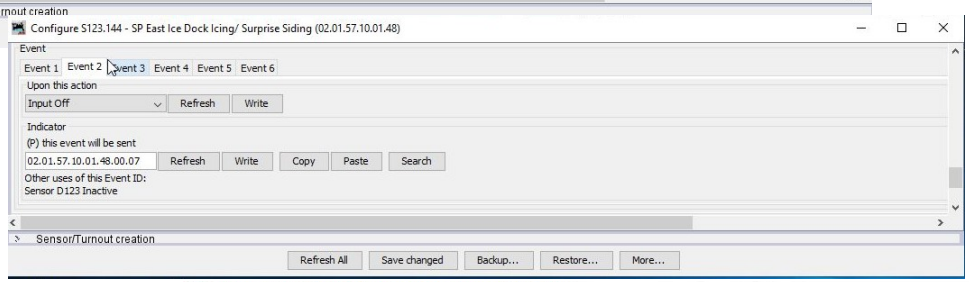
Call up Sensor by Name



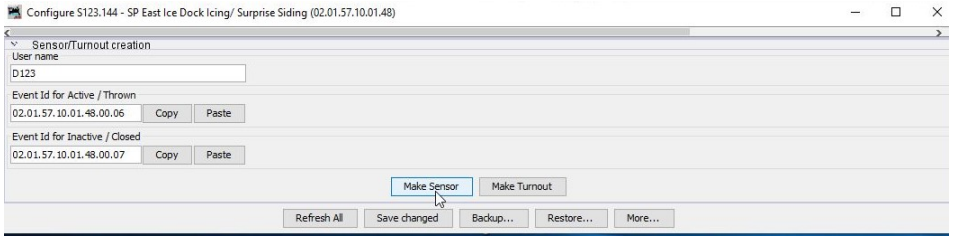
Configure "Event 1" Sensor On



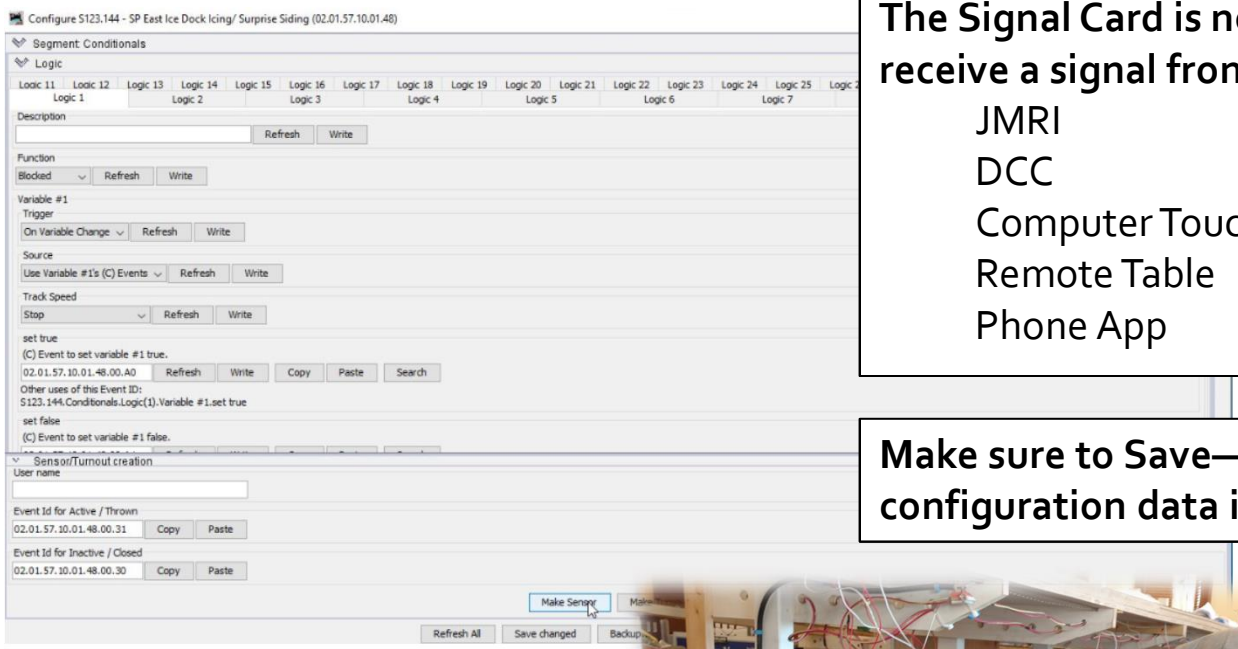
Configure "Event 2" Sensor Off



Make Sensor



Save the Configuration to the Card



The Signal Card is now ready to receive a signal from any source:

- JMRI
- DCC
- Computer Touch screen
- Remote Table
- Phone App

Make sure to Save—or all configuration data is lost!!

Throwing the first turnout on the ARHS Layout

Agenda

- What is LCC
- ARHS Decision Process
- Building Blocks of LCC
- Building the Hardware
- Configuring the Cards
- What we Learned
- Summary—LCC is the Best Decision we Ever Made!
- Demonstration

Lessons Learned: LCC configuration and JRMI Panel Pro

- **Yes, there is a Learning Curve: Take it Step by Step**
  - Creating a test bed to learn the basic building blocks was essential
- **Limited documentation to guide the beginner**
  - An Intro to Layout Command Control by Dana Zimmerli, PhD
  - LCC and JMRI user forums at Groups.io, JMRI.org
  - ARHS has gotten lots of help from manufacturers (RRCirkits) and JMRI developers
  - Don't be afraid to ask questions
- **Take it slow, once you learn the configuration process, it is repetitive for each card/node.**
- **Recommend creating all LCC-JRMI elements on the computer that will run the railroad.**
  - ARHS had different members working on separate computers and then attempting to integrate them on the main computer. This has created challenges—especially with integrating JMRI.

Lessons Learned on Planning

- **Up Front Planning is Important since this loads into all LCC Cards**
  - Pre-plan the names and numbers for all Block Locations, Turnouts and Signals
  - This seems like a big waste of time until the configuring begins, and then this becomes the most important investment of time!
- **Positioning of the Cards on the layout must be done in advance**
  - It is important to get the cards are near where the "node" located which means "scattering them around the layout—but then they must be closer together to lower voltage drop.
    - Bus must be "daisy chained"
    - Need to be close to function
    - Must inject power within 10 feet

Lessons Learned About System Design

- The "**Rule of Twos**" in LCC Design
  - All cards support 2, 4 or 8 components—having an odd number of tracks/functions makes the design logic more difficult. (A four or six track yard is easier to layout than a 3 or 5 track yard.)
- **CTs can be located either on a panel or near the point of "use" or anywhere in between**
- **Blocks must be completely isolated before the CT's work properly**.

- **A separate "sub-block" can be used for auto-throw of a turnout or activating a crossing signal etc…**
- **Future applications boggle the mind**
  - Arduinos
  - Lighting
  - Special Effects….

Agenda

- What is LCC
- ARHS Decision Process
- Building Blocks of LCC
- Building the Hardware
- Configuring the Cards
- What we Learned
- Summary—LCC is the Best Decision we Ever Made!
- Demonstration

The System Works Great!!

- **ARHS has installed 66 Signal and 55 BOD4-CP Cards without letting the "Magic Smoke" out of any of them!**
  - Over 100 Turnouts are operational
  - Occupancy Detectors are sensitive and reliable
  - Starting to experiment with Signals
  - **Would we recommend this system?—Absolutely:**

- **The National Convention in Salt Lake City convinced us that LCC was the right decision—All of the system developers were present, they were taking feedback and all suggestions for improvements very seriously**
  - "Debugging" quirks in the LCC cards—such as a power up issue
  - Working the interface to JMRI—assuring JMRI and LCC talk which is a challenge
  - Taking suggestions to improve user interface—No Push-back!!
- **LCC is good today—and is getting better…..**

Remember when DCC was new and people asked "Why would I ever convert?" That is where LCC is today!!

Agenda

- What is LCC
- ARHS Decision Process
- Building Blocks of LCC
- Building the Hardware
- Configuring the Cards
- What we Learned
- Summary—LCC is the Best Decision we Ever Made!
- Demonstration