Understanding Signals

April 27, 2019

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cats4ctc.org

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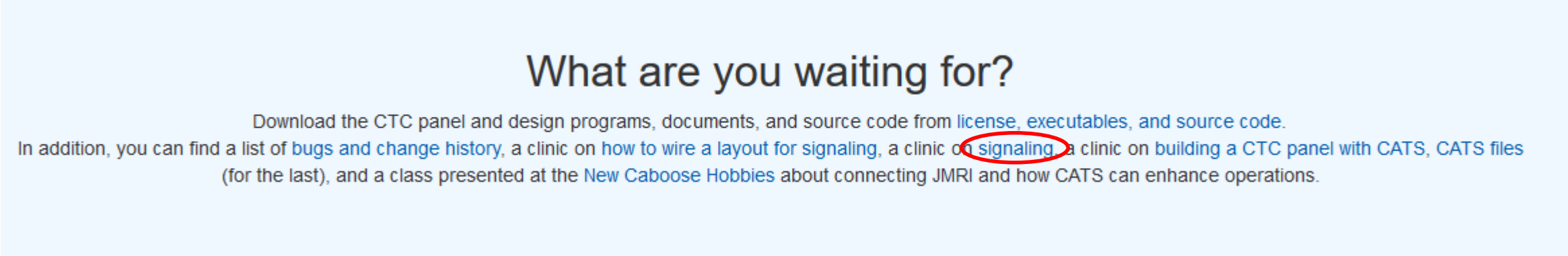


And follow the links

Outline

1. Why Signal a Layout
2. How the Prototype Uses Signals
3. Signal Placement and Control Basics
    a. Train Order Board
    b. Automatic Block Signals (ABS)
    c. Absolute Permissive Signals (APB)
    d. Centralized Traffic Control (CTC)

Disclaimer: much of this clinic is based on panel discussions from previous conventions and an excellent paper by Seth Neumann and Byron Henderson

Prototype Signals are about Safety

- Railroads make Money by economically moving things (goods, mail, people)
- A stationary train makes no money
- A train that hits something becomes a stationary train and may also stop other trains
- Because trains cannot stop in a short distance, signals are used to provide distance for a train to stop

Why Signal a Layout

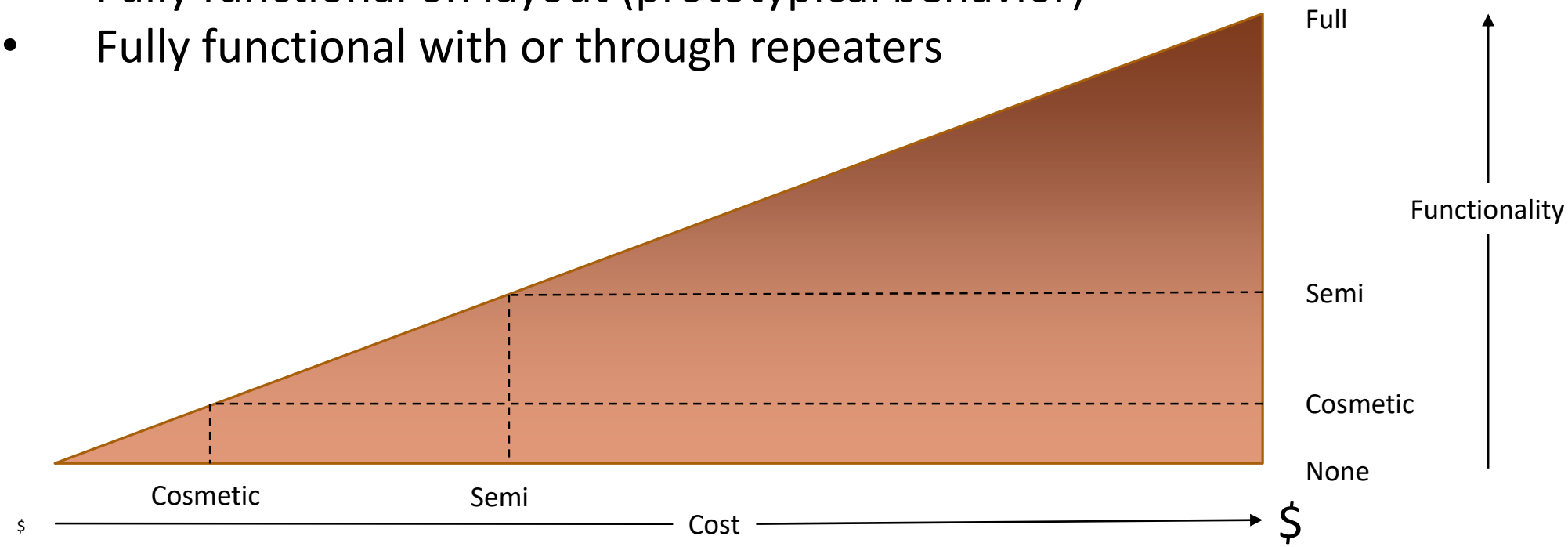
Signals add

- Color and Animation – make the layout come alive
- Realism – set the layout in time and(possibly) space
- Operating interest – mimic the prototype
- Functionality – provide safety for trains and control movement

They are cool!

Functionality Provided by Layout Signals

- Cosmetic (dummy) – static to represent signals
- Semi-functional – some animation (e.g. show turnout position)
- Fully functional on layout (prototypical behavior)
- Fully functional with or through repeaters



Balance between cost and fidelity of illusion – “I want a Sunset Valley, but can afford a time saver”.

Prototypical Signals on Layouts

Caveat: Every railroad had unique signal systems.

- Research your prototype
- If free lancing, there is probably an example
- This clinic will address generic concepts

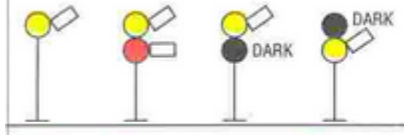
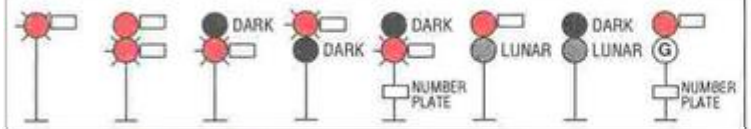
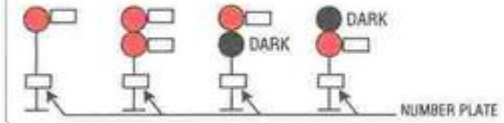
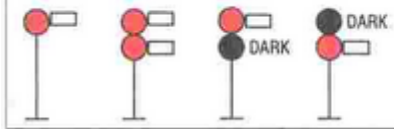
Typical Prototype Signal Usage

1. Train order boards
2. Safety overlay
3. Interlocking plants
4. Traffic control

Nomenclature

1. Aspect – how the signal appears in the field (e.g. “red”)
2. Indication – the meaning of the signal – how the crew should respond (e.g. “Proceed prepared to stop at second signal”)
3. Name – the name of the indication (e.g. “Clear”)
4. Route signals – the indication shows the path through a plant
5. Speed signals – the indication shows the safe speed for the train before the next signal

Basic Aspects and Indications

Aspect	Rule	Name	Indication
	9.50	CLEAR	Proceed.
	9.56	APPROACH	Proceed prepared to stop at next signal, trains exceeding 40 MPH immediately reduce to that speed.
	9.60	RESTRICTING	Proceed at restricted speed.
	9.61	STOP AND PROCEED	Stop, then proceed at restricted speed.
	9.62	STOP	Stop.

“permissive” stop

“absolute” stop

ATSF example

http://www.railroadsignals.us/rulebooks/cora/cora1.htm

Layout Design Considerations

- Placement
- Functionality
- Layout requirements
- Where appropriate

What is Approprate to Signal?

- Generally, mainlines, branchlines, entries to mainlines and branchlines
- Generally, not yards, industrial areas, etc.
- Except hazards (gates, highway crossings)
- Signals are expensive on the prototype
- Signals are expensive for the modeler

Train Order Boards

- Signals at manned operator stations
- Operator transcribes orders from a dispatcher, delivers them to the train crew, and reports train arrivals to the dispatcher
- The board appearances were quite unique for railroad, era, and location
- Simple on/off
- Appropriate for TT&TO

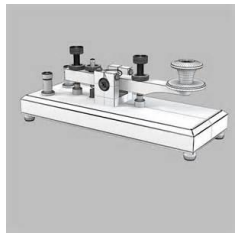
http://www.railroadsignals.us/rulebooks/ALLaspects.pdf (Todd Sestero)

Train Order Board Implementations

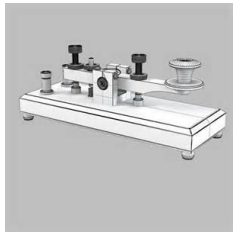
- LEDs
- Tortoises
- Servos
- Twin coils

layout

dispatcher



Orders

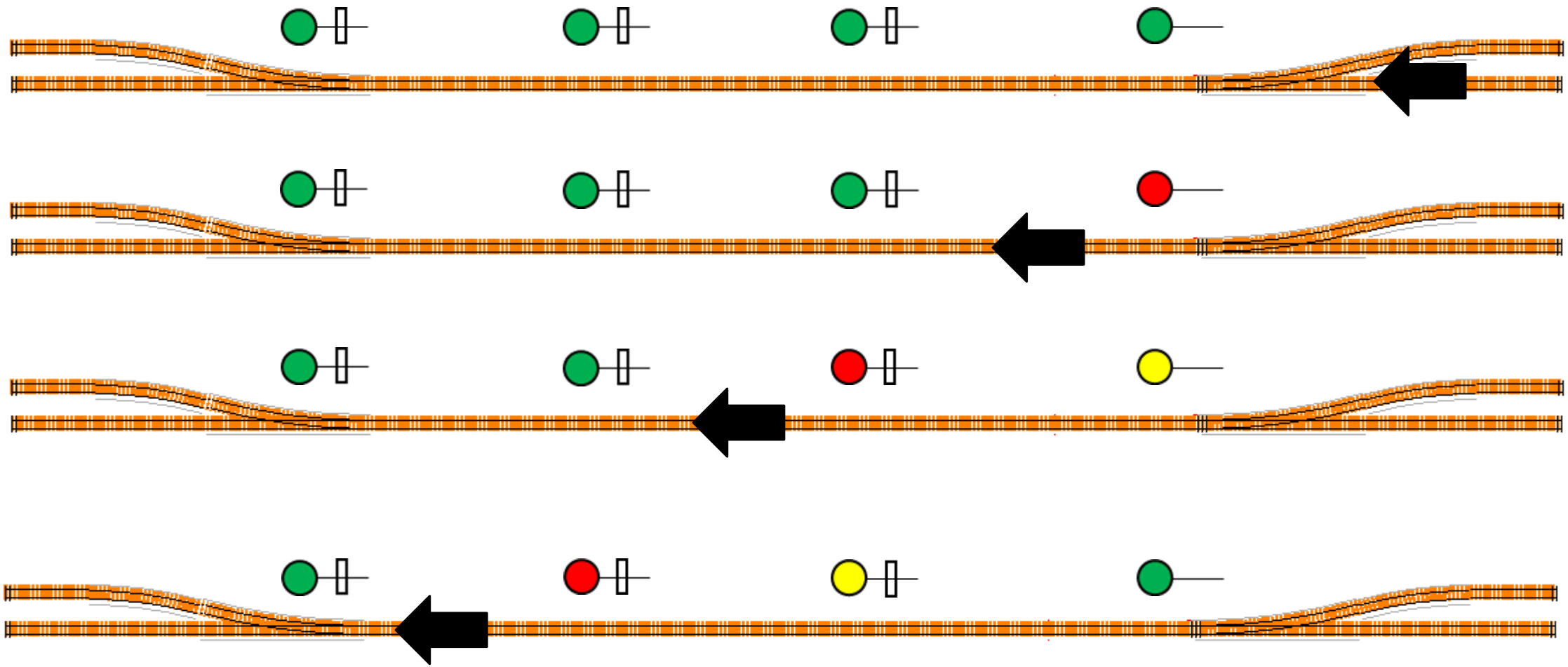


Reports

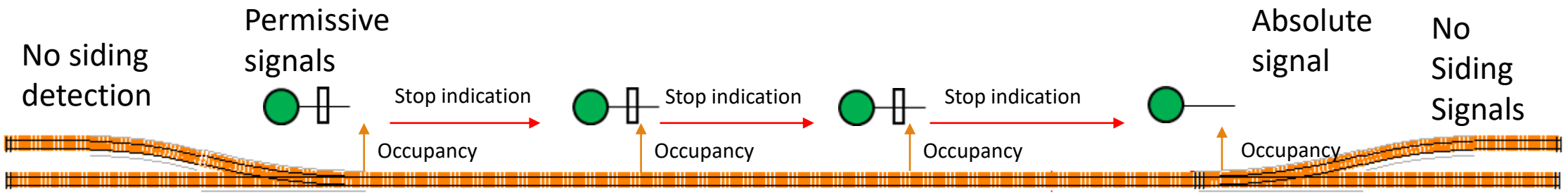
Safety Overlay (Automatic Block System)

- Electronic checking to prevent trains from running into each other
- Alternative to Rule 99 (“Flag protection required against following trains on the same track”)
- Unbonded (undetected) sidings
- Augments track occupancy authorization (except for some roads)
- Appropriate for all operating schemes (“Shout and Go”, “Mother, May I?”, TT&TO, DTC, TWC, CTC)

Safety Overlay (Automatic Block System)

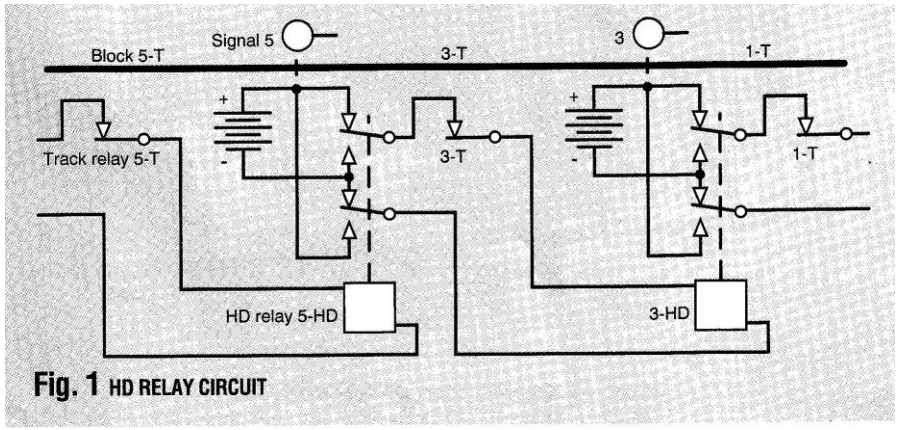


Safety Overlay (Automatic Block System)



Signals show condition of track to next signal – not authority to occupy track

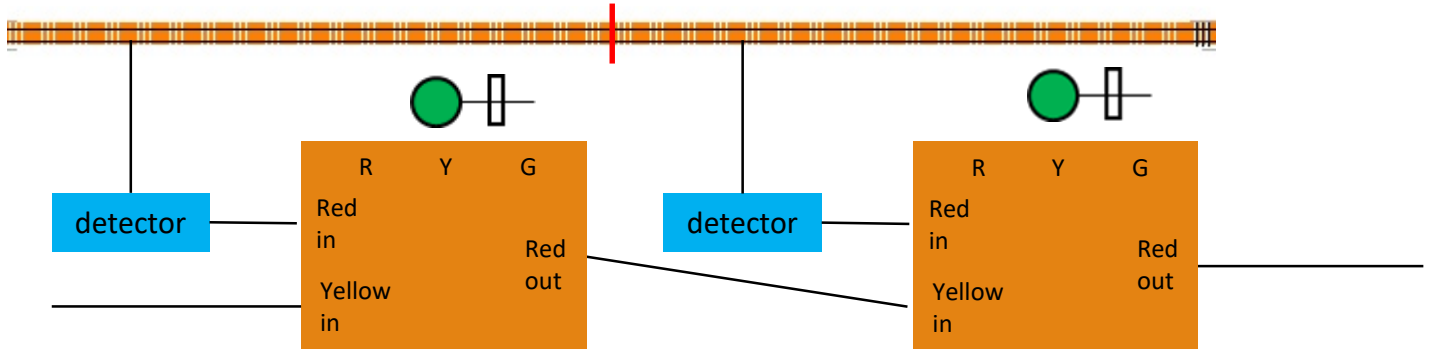
Uni-directional: Indications propagate opposite train travel direction



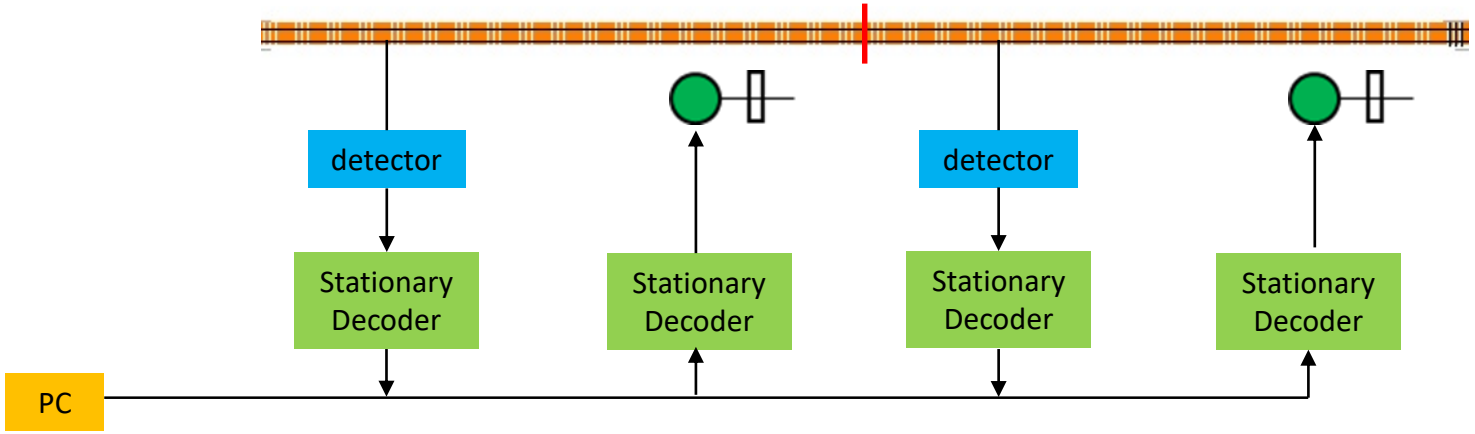
Jay S. Boggess

If block is occupied then red
Else if next signal red then yellow
Else green

Implementing ABS



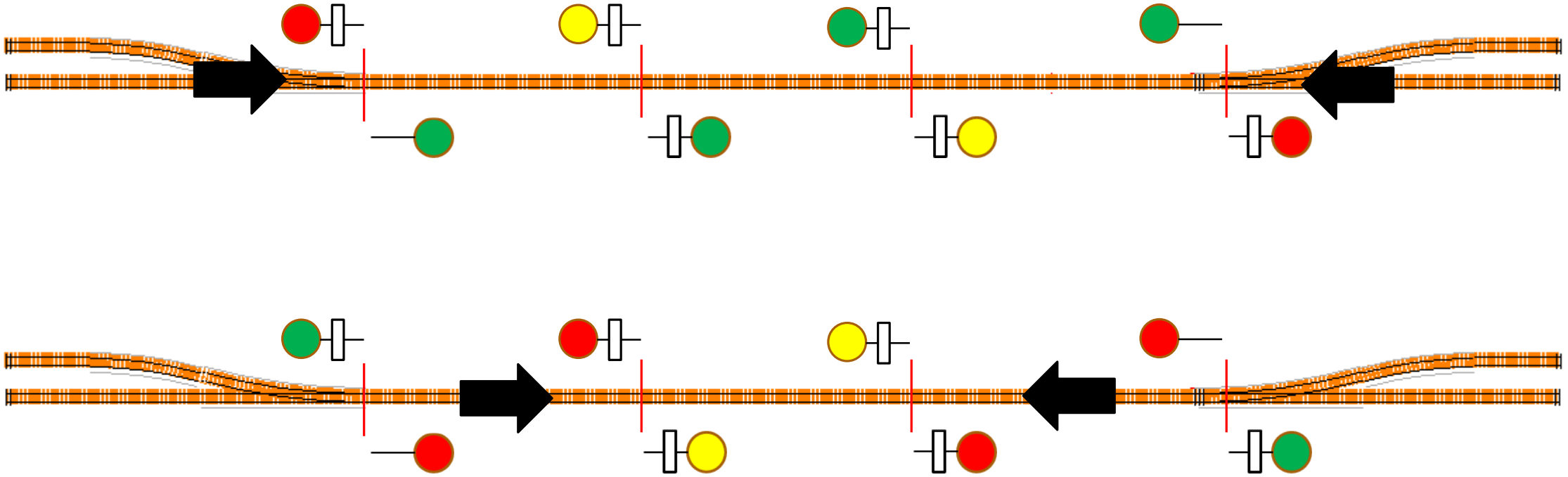
- Power not shown
- Custom boards (FPGA)
- January 1992 MR
- Arduino
- Inexpensive
- No PC
- Approach lighting?



- Power not shown
- Commercial boards
- Arduino
- Flexible
- JMRI
- Chubb (chapter 19)

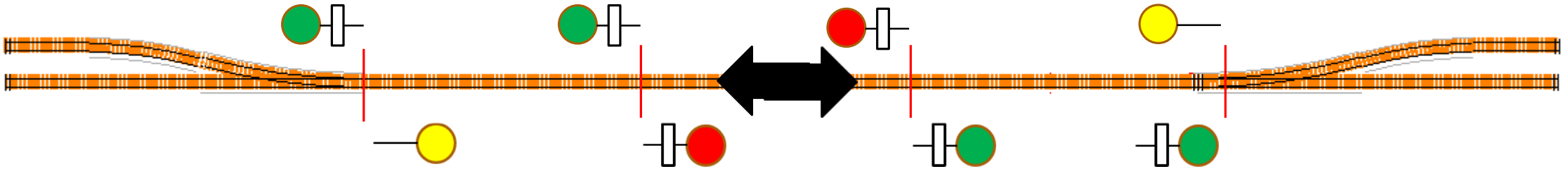
Safety Overlay (Bi-directional ABS)

Does not protect well against opposing movement

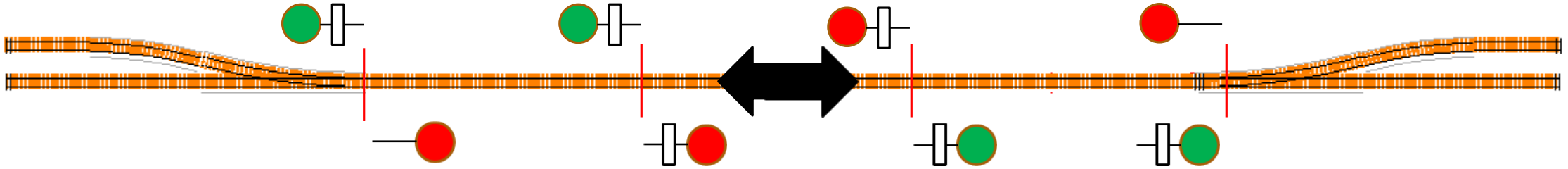


Difference Between ABS and APB

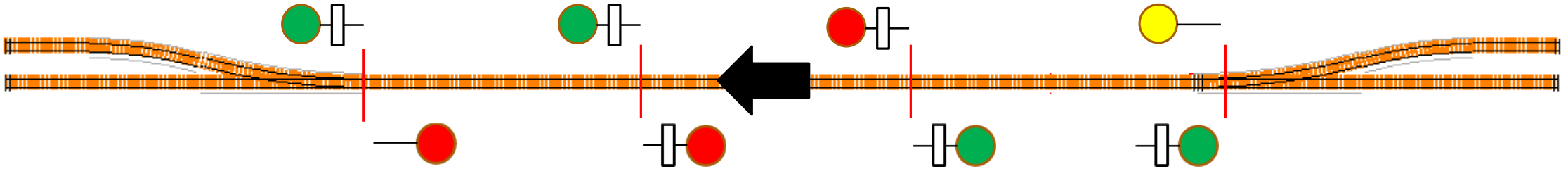
ABS



Too Limiting



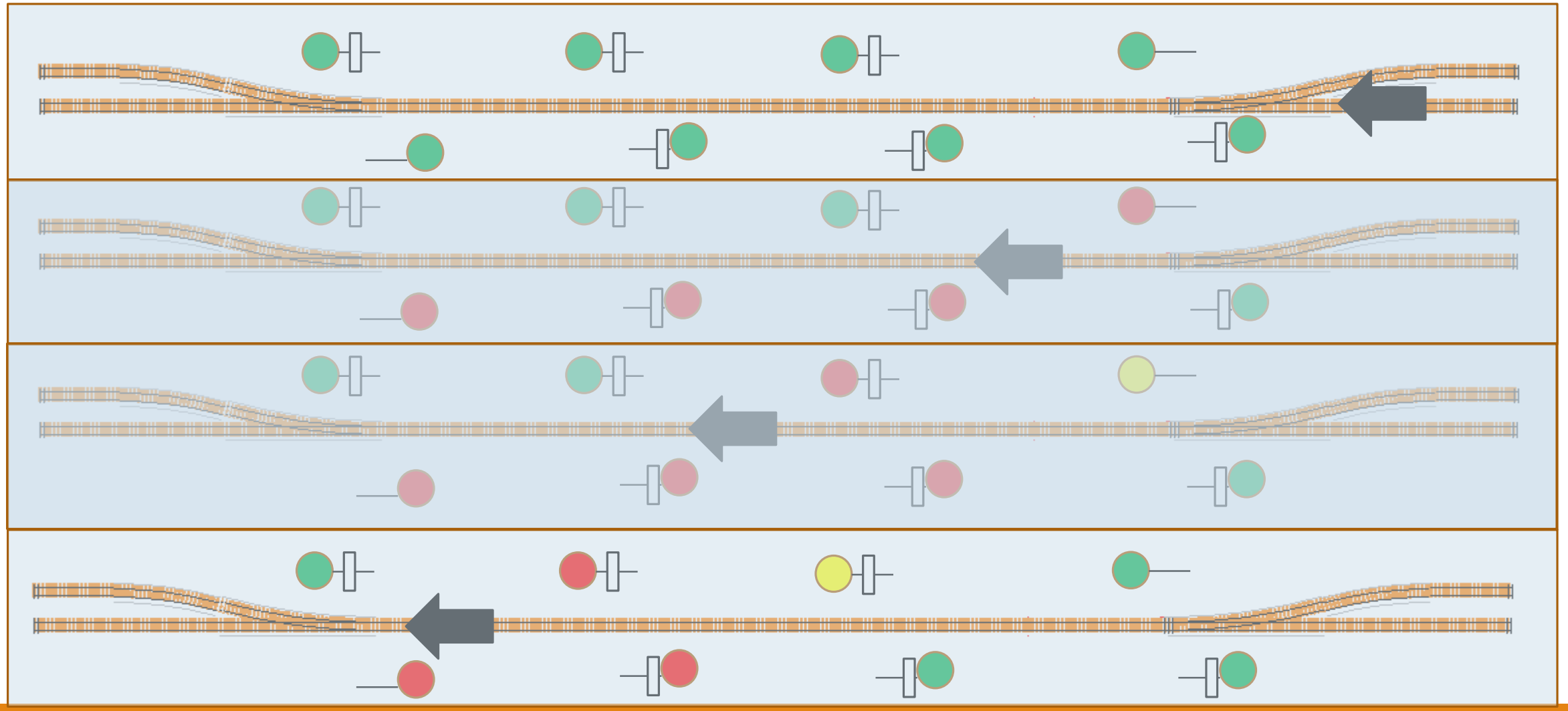
APB



Safety Overlay (Absolute Permissive Blocks)

- Electronic checking to prevent trains from running into each other – “siding to siding protection for opposing moves and signal to signal protection for following moves”
- Alternative to Rule 99 (“Flag protection required against following trains on the same track”)
- Unbonded (undetected) sidings
- Augments track occupancy authorization (except for some roads)
- Appropriate for all operating schemes (“Shout and Go”, “Mother, May I?”, TT&TO, DTC, TWC, CTC)

Safety Overlay (Absolute Permissive Blocks)



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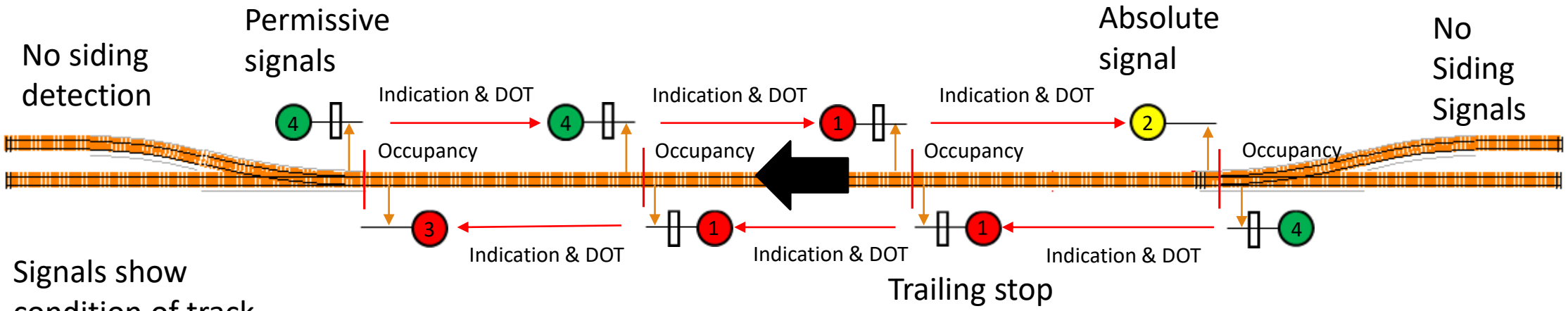


Signals show condition of track to next signal – not authority to occupy track

Indications travel opposite train direction; Tumbledown travels in train direction

DOT is Direction of Travel (Traffic Stick)

Reverse movement protection

<u>Signal determination</u>:

1 If occupied or neighbor DOT is enter then red
2 Else if next is red and next DOT is enter then yellow
3 Else if next is red and next DOT is not enter then red
4 Else green

tumbledown

<u>Occupied:</u>

If neighbor DOT is exit then DOT is enter
Else DOT is exit

<u>Unoccupied:</u>

DOT is none

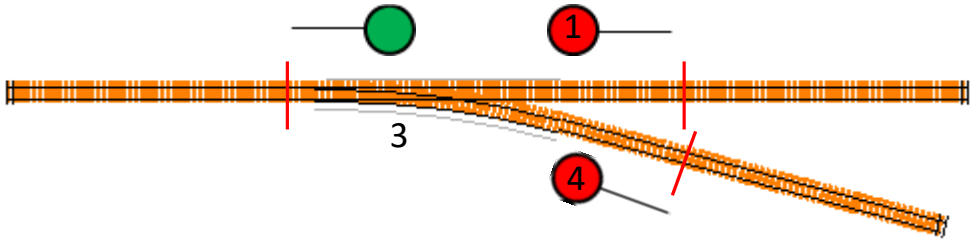
Implementation:

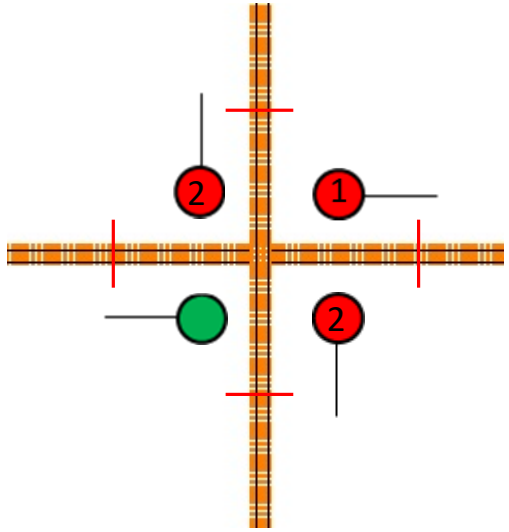
- January 1992 MR
- Chubb chapter 20
- JMRI

Interlocking Plants

- Protect crossings and junctions
- Protecting multiple routes multiplies the complexity
- Appropriate for “Shout and Go”, “Mother, May I?”, TT&TO and TWC, as well as CTC
- CTC can be as simple as remote controlled interlocking plants connected by dark territory or safety overlay*

Interlocking Plants



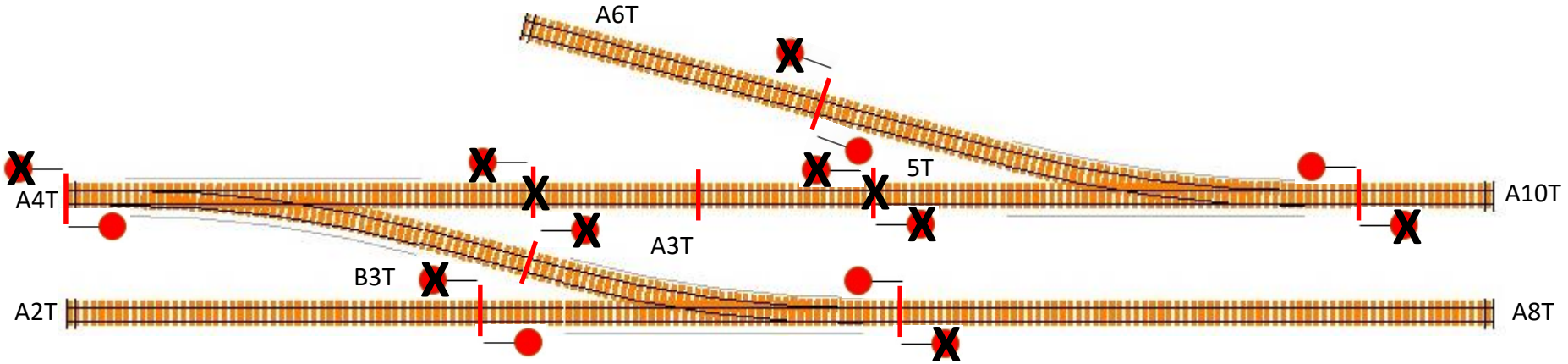


Interlocking because

1. Opposing Signal Lock – a signal cannot clear if an opposing signal is cleared
2. Conflicting Signal Lock – a signal cannot clear if a conflicting signal is cleared
3. Indication (Route) Locking – a cleared signal will lock a switch
4. Switch Indication Locking – a signal cannot clear through a fouling switch
5. Detection Locking – a switch is locked if the track circuit is occupied

Signal Placement in Interlocking Plants

1. Signals at frogs (conflicting signal lock)
2. Signals at points (opposing signal lock)
3. Pair up signals (detection)

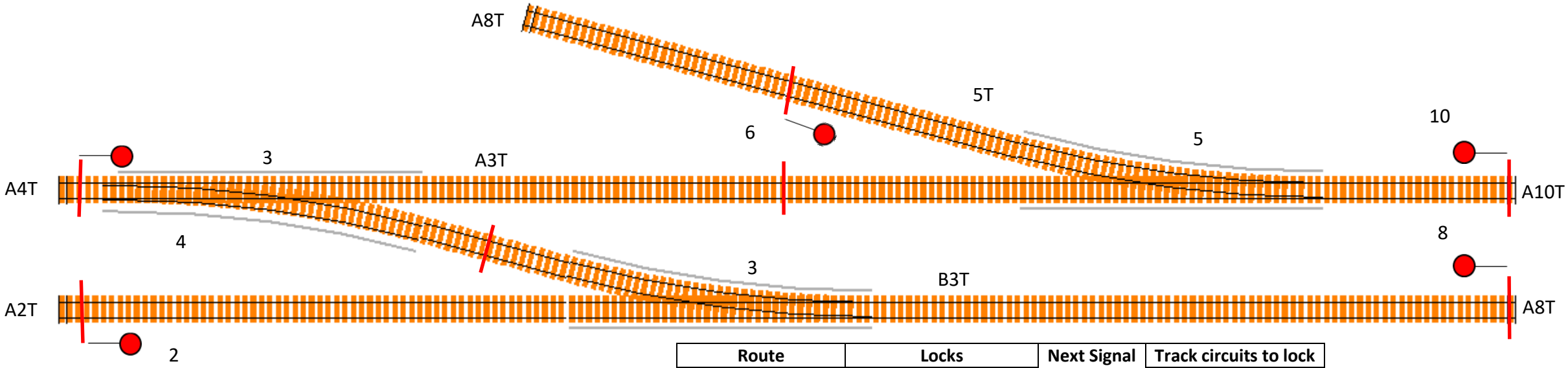


Routes

1. A2T→A8T
2. A8T→A2T
3. A4T→A10T
4. A10T→A4T
5. A4T→A3T→B3T→A8T
6. A8T→B3T→A3T→A4T
7. A6T→5T→A10T
8. A10T→5T→A6T

"Introduction to North American Railway Signaling"

Signal Placement in Interlocking Plants



Aspect or locking chart

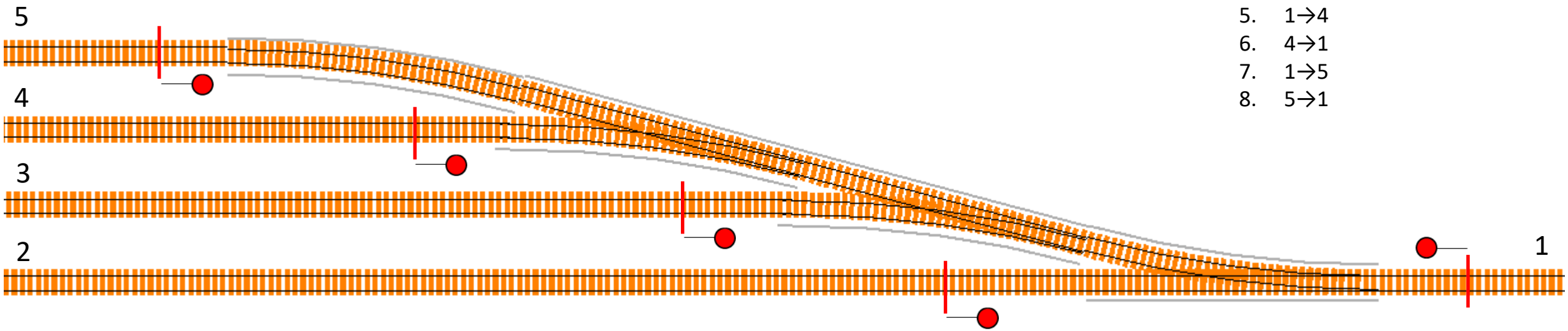
Route			Locks		Next Signal	Track circuits to lock	
From	Aspect	To	Switches	Signals		3	5
2	Y/R	8	3	8	R	B3T	-
	G/R				Y or G		
4	Y/R	10	3, 5	10, 6	R	A3T	5T
	G/R				Y or G		
4	R/Y	8	(3)	2, 8, 10 w 5	-	B3T, A3T	-
6	R/Y	10	(5)	10, 4 w 3	-	-	5T
8	Y/R	2	3	2	R	B3T	-
	G/R				Y or G		
8	R/Y	4	(3)	2, 4, 10 w 5	-	B3T, A3T	-
10	Y/R	4	3, 5	4, 6	R	A3T	5T
	G/R				Y or G		
10	R/Y	6	(5)	6, 4 w 3	-	-	5T

"Introduction to North American Railway Signaling", p. 124

Signal Placement in Interlocking Plants

Routes

1. 1→2
2. 2→1
3. 1→3
4. 3→1
5. 1→4
6. 4→1
7. 1→5
8. 5→1

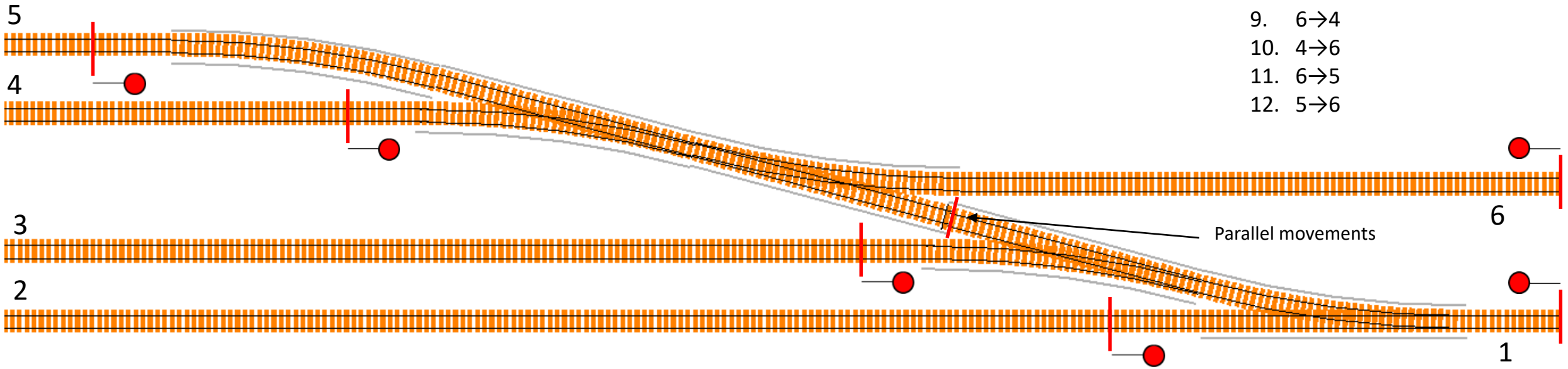


Signal Placement in Interlocking Plants

- Place signals on perimeter
- Add interior track circuits for parallel routes

Routes

1. 1→2
2. 2→1
3. 1→3
4. 3→1
5. 1→4
6. 4→1
7. 1→5
8. 5→1
9. 6→4
10. 4→6
11. 6→5
12. 5→6



Centralized Traffic Control (CTC)/ Traffic Control System (TCS)

- Eliminates manned stations
- Allows fine control (micro-managing) traffic flow
- Control points (security elements, OS sections) are like simple interlocking plants
- Control points are linked with safety overlays
- Extension of safety overlay - “Proceed on signal indication”

Example CTC Control Point

Exit Signal (Main)

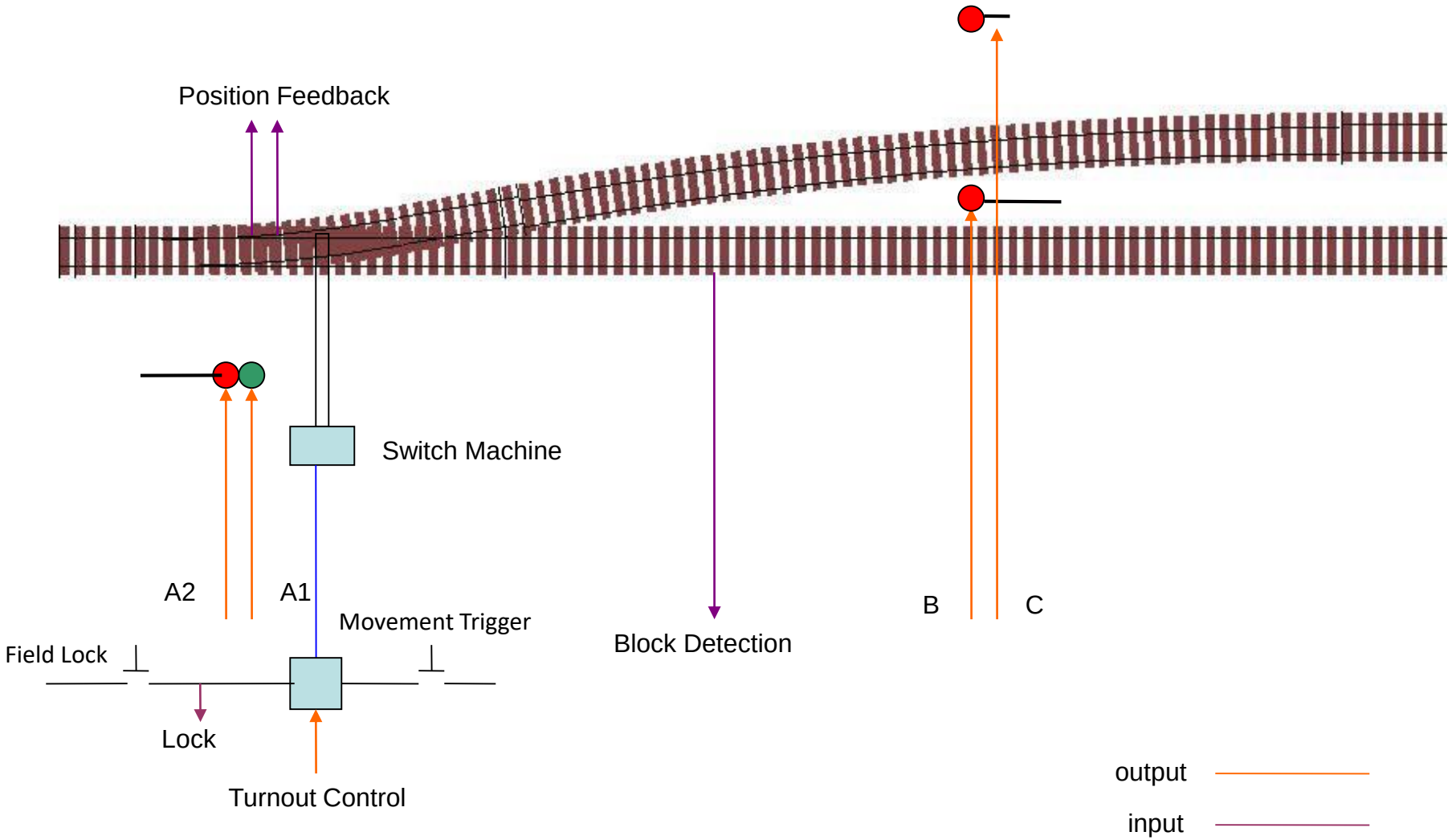
Exit Signal (Siding)

Field Equipment (Vital Logic)

Approach Signal

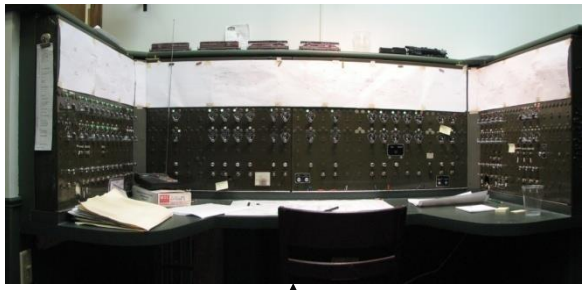
Automatic (Dual Control) Switch Machine

Control Point Schematic



Prototype CTC Architecture

Vital Logic performs the bulk of the safety checking



Telecom port

Code line

Vital Logic

Vital Logic

Vital Logic

Track circuit

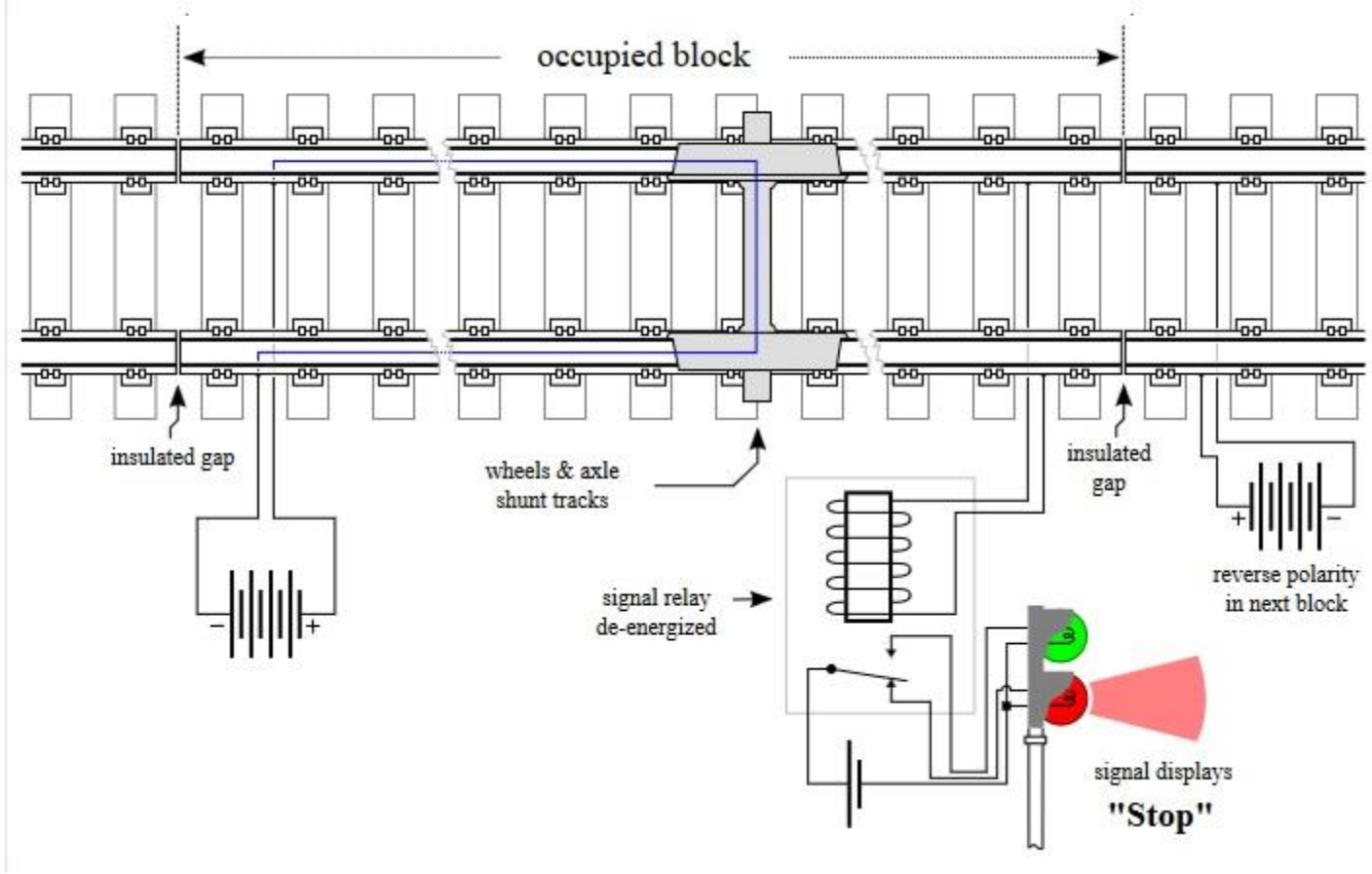
Track circuit

Advanced Train Control System

Destination	Source	#	Label	Data

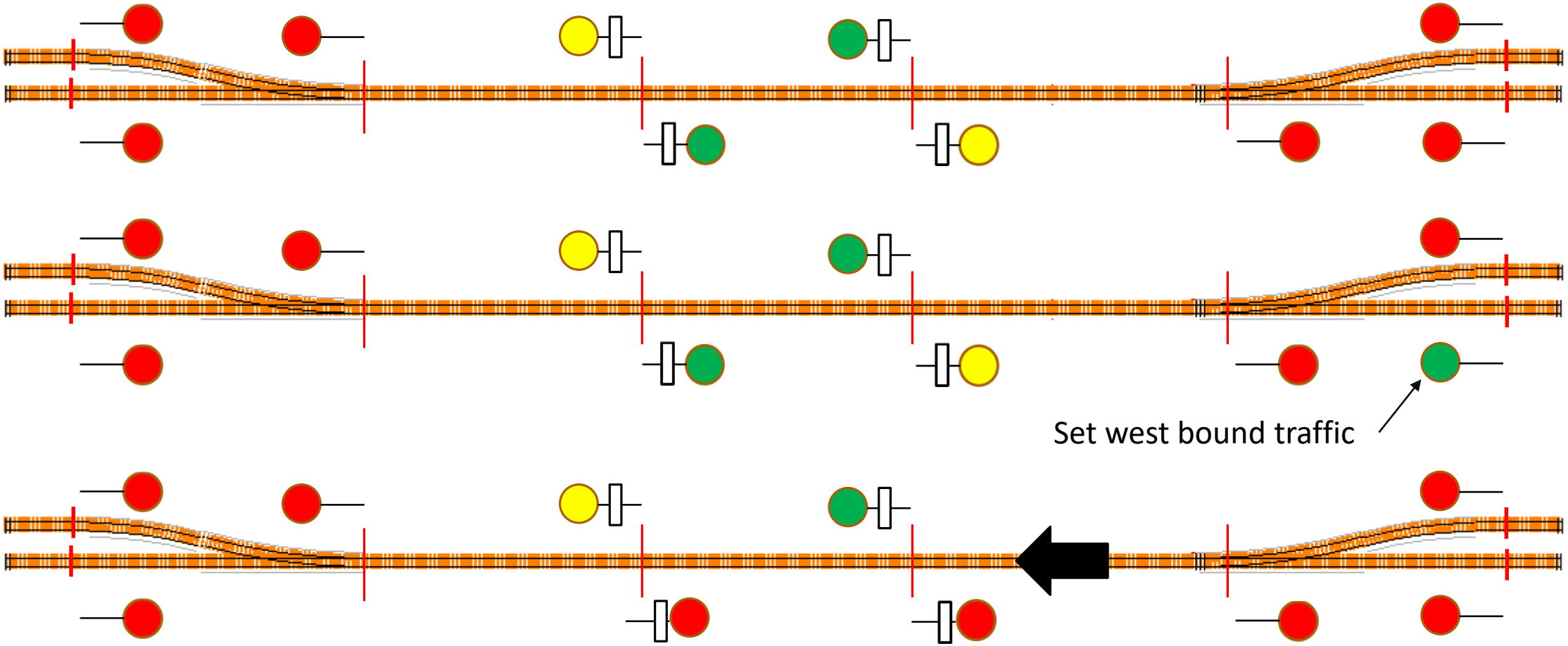
Label tends to be a request (to vital logic) or indication (to office equipment)

Prototype Track Circuit



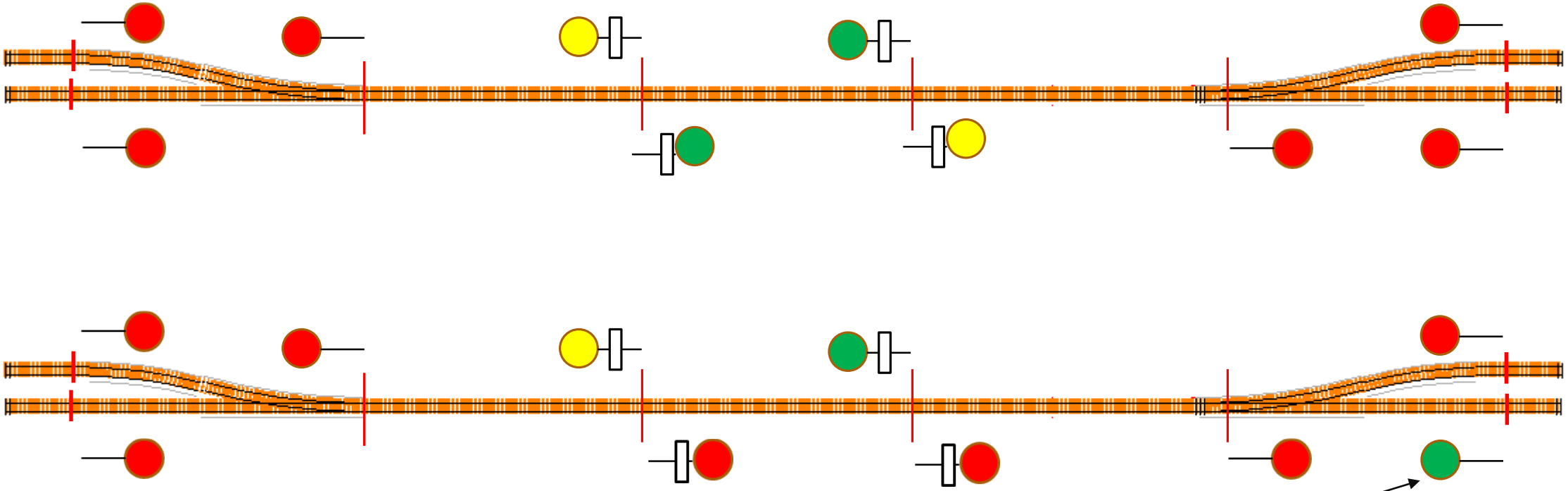
By original File: User:Mangoevector CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=19372438

Dispatcher Control with CTC (Alternative 1)



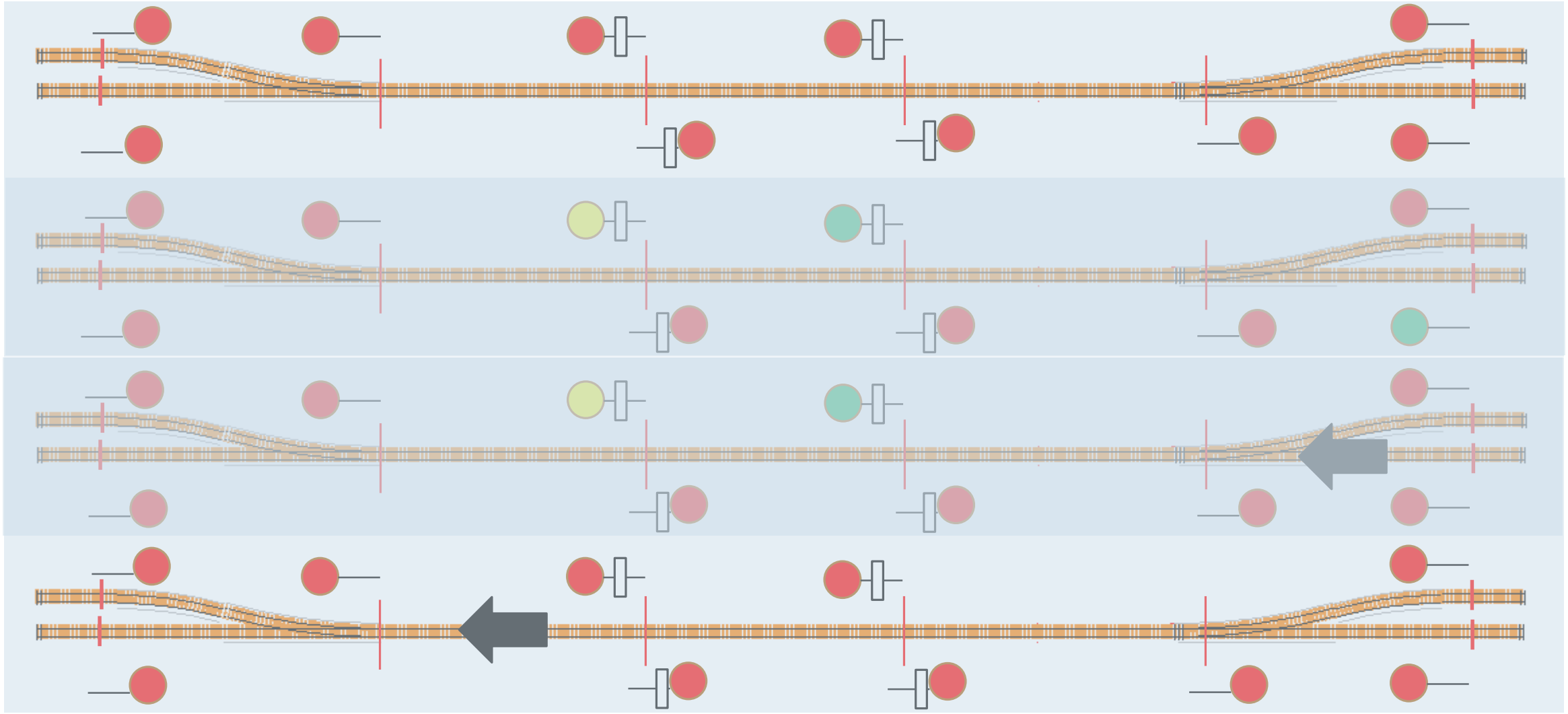
Flaw – dispatcher can set east bound traffic prior to west bound train occupying control point

Dispatcher Control with CTC (Alternative 2)



Set west bound traffic (kick in tumbledown and lock out opposing route)

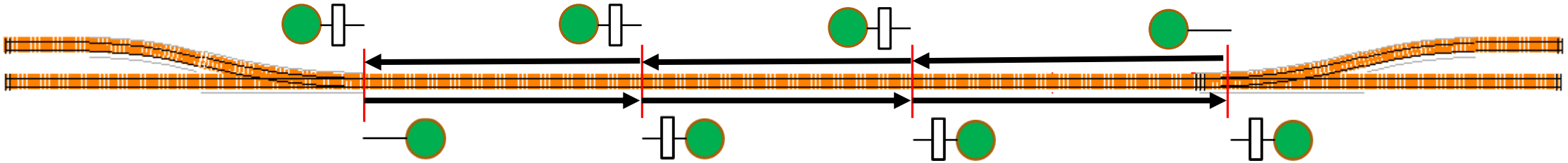
Dispatcher Control with CTC (Alternative 3)

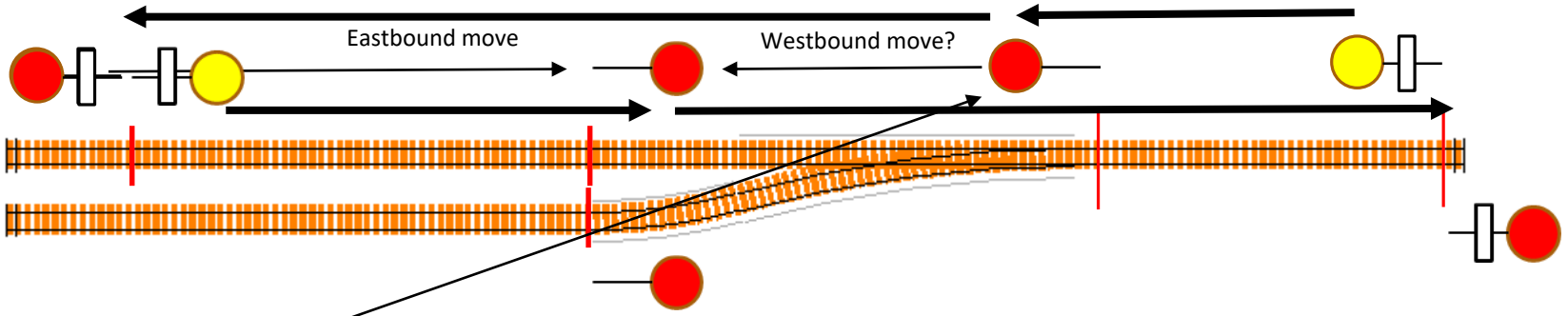


Things are getting more complicated

- What “knocks down” a signal – triggers a signal to drop to red?
  - Track occupancy
  - Other conditions
- How far does the red propagate?
  - Next signal?
  - Next absolute signal?
  - Next opposing signal?

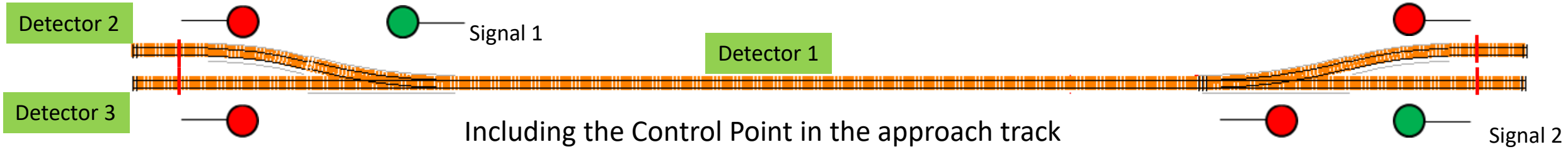
Overlapping Protection





Opposing Signal Lock propagates to first opposing signal at or after next signal in advance

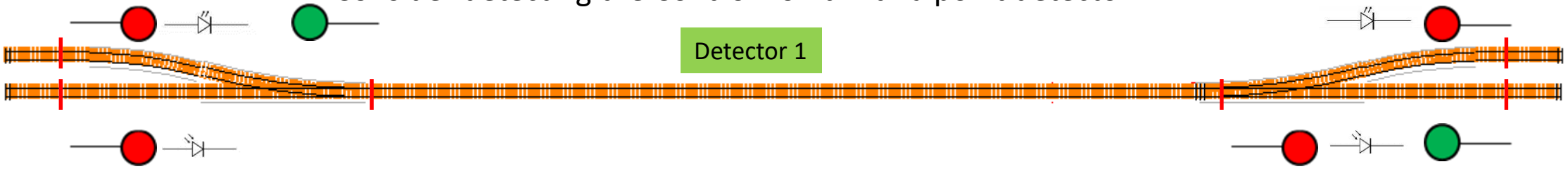
A Common Wiring Mistake



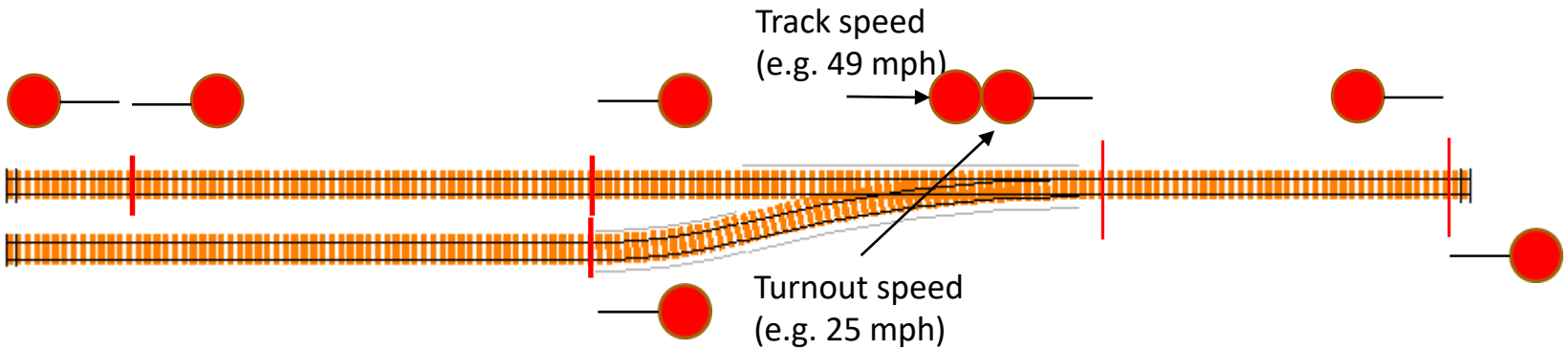
Including the Control Point in the approach track

1. Detection Locking (an occupied switch is locked) demands occupancy detection
2. What occupancy detector(s) sets Detection Locking?
   a. Not Detector 1 – not enough location resolution
   b. Either Detector 2 or Detector 3, depending upon turnout alignment
   c. The control point does not contribute to any of the triad signals (imagine a caboose stranded over the points) or to any of the signals in approach to them

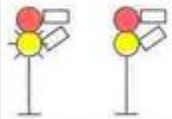
Consider detecting the Control Point with a point detector



More Complicated Indications



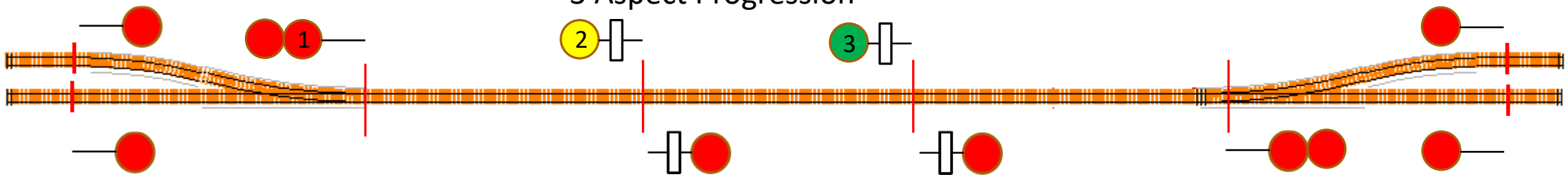
- Add second “arm” (head)
- Account for next signal being green, yellow, or red
- Excluding high speed turnouts, route based signaling is similar to speed based signaling

	9.57	DIVERGING CLEAR	Proceed on diverging route not exceeding prescribed speed through turnout.
	9.58	DIVERGING APPROACH	Proceed through diverging route; prescribed speed through turnout; approach next signal preparing to stop, if exceeding 40 MPH immediately reduce to that speed.

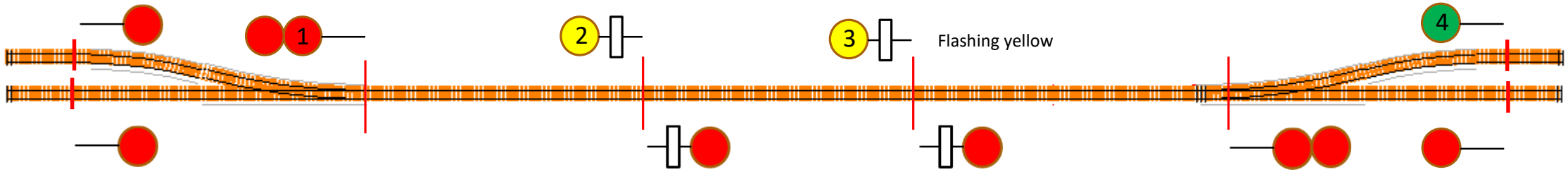
http://www.railroadsignals.us/rulebooks/cora/cora1.htm

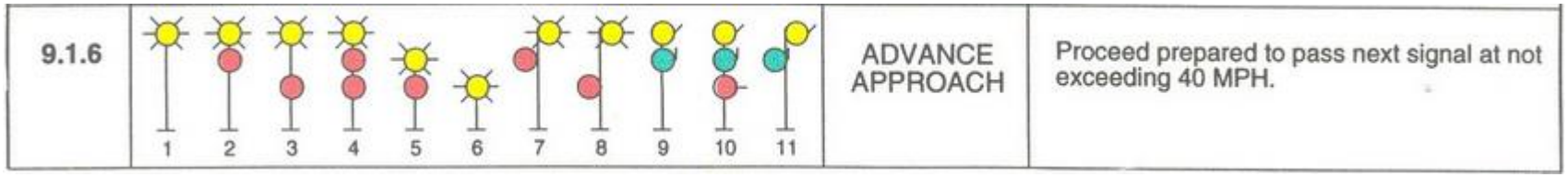
Even More Complicated Indications

3 Aspect Progression



4 Aspect Progression





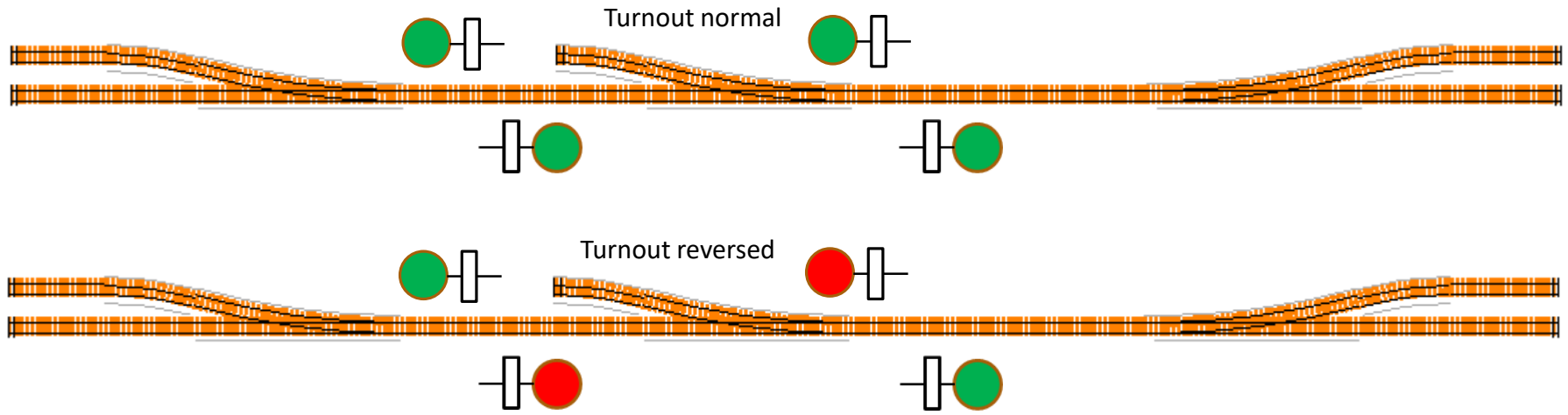
Advance signals are railroad specific!

http://www.railroadsignals.us/rulebooks/cora/cora1.htm

Turnouts (Points, Switches)

Turnout Taxonomy

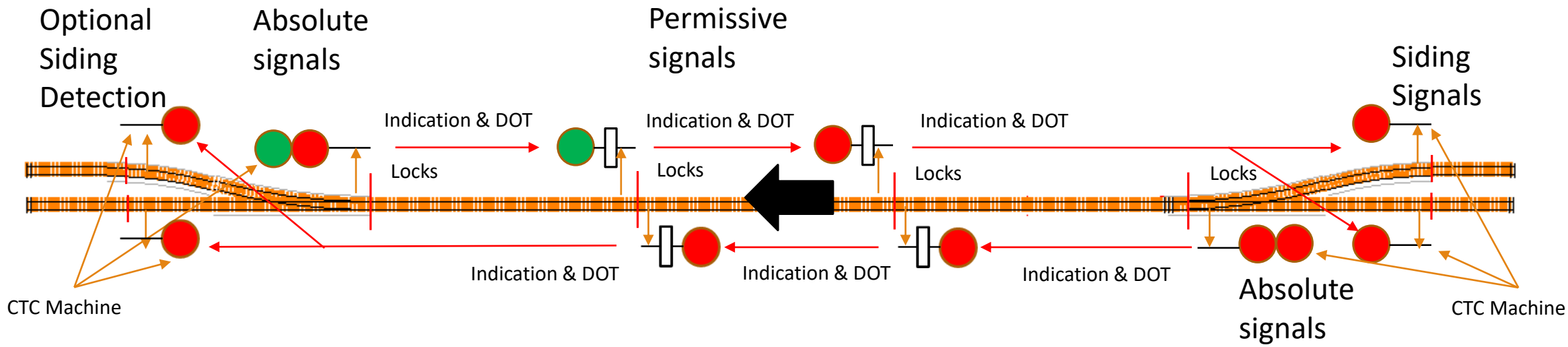
1. Manual – signals drop when points move by trainman
2. Automatic Electrical – signals drop when turnout is “unlocked” by trainman
3. Controlled Electrical – dispatcher unlocks turnout, trainman operates
4. Dual control – dispatcher can unlock and move points; trainman can move unlocked turnout
5. Powered – dispatcher only control



CTC Signal Indication Dependencies

1. Occupancy of protected track circuit(s)
2. Next (advance) signal indication in direction of travel
3. Next (advance) signal indication in opposing direction of travel
4. Conflicting signal indications
5. Alignment of protected turnouts
6. Lock/unlock status of protected turnouts
7. Occupancy of track circuits(s) in approach
8. Other things (e.g. slide fence, draw bridge)
9. Dispatcher/Towerman actions

CTC Connections



Signals show authority to occupy track

Indications travel opposite train direction; Tumbledown travels in train direction

DOT is Direction of Travel (Traffic Stick)

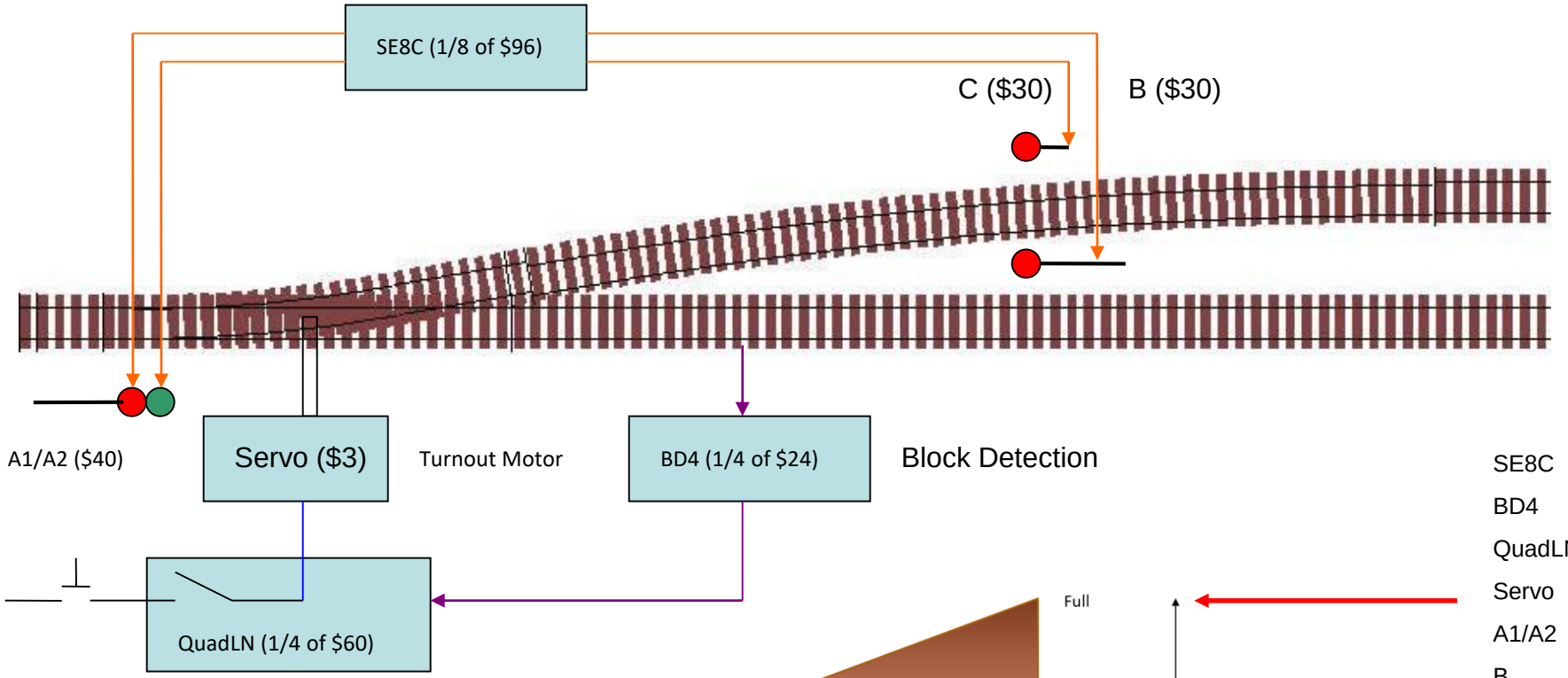
Computer is essential for dispatcher interface

Different ways of implementing intermediates

Implementation:

- Chubb chapters 21-25
- JMRI
- CATS

CTC Control Point Implementation



SE8C	$12
BD4	$6
QuadLN	$15
Servo	$3
A1/A2	$40
B	$30
C	$30
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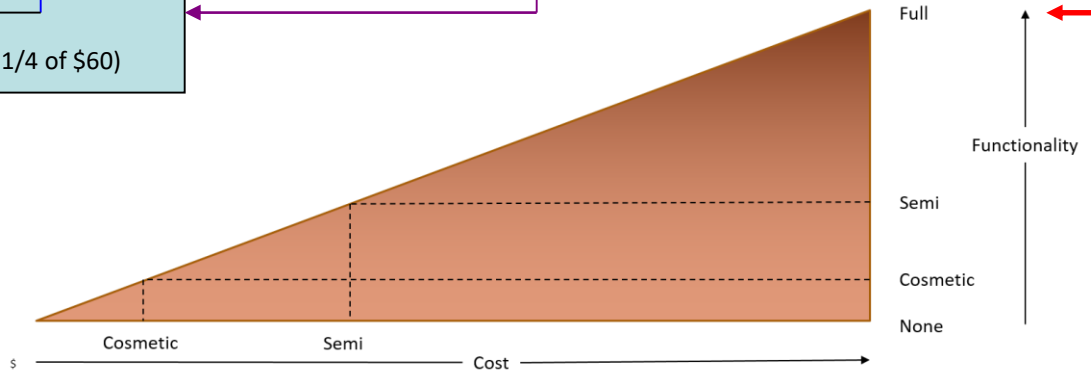
Total	$136



Could replace electronics with an Arduino

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