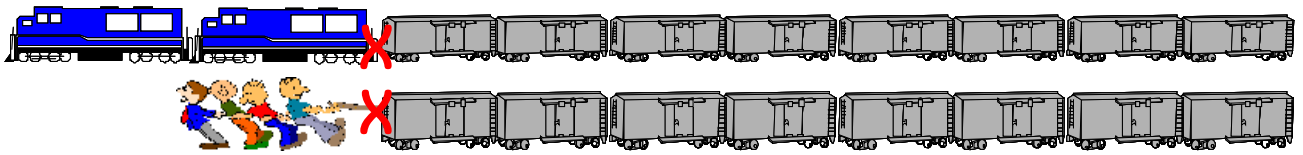
Distributed Power and Wheel/Rail Wear

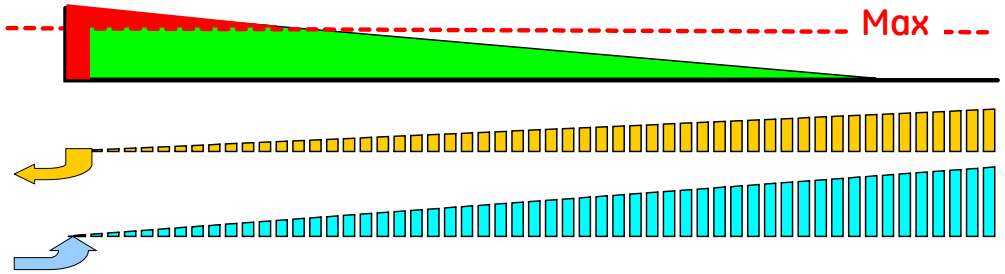
David Peltz
Chief, Advanced Technology
GE Transportation

DP: Basic Concept…

Distribute Locomotives to improve performance

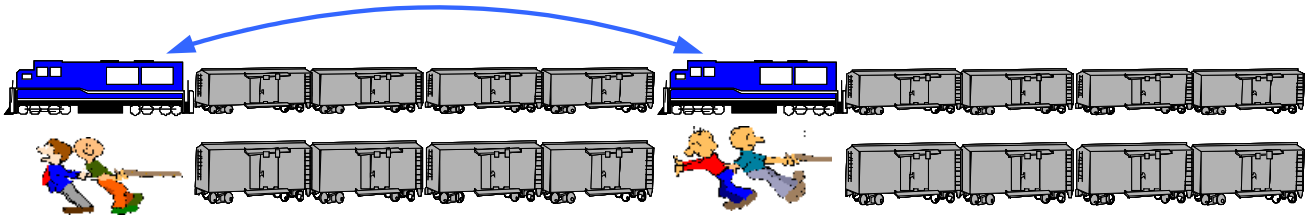
Head-End:

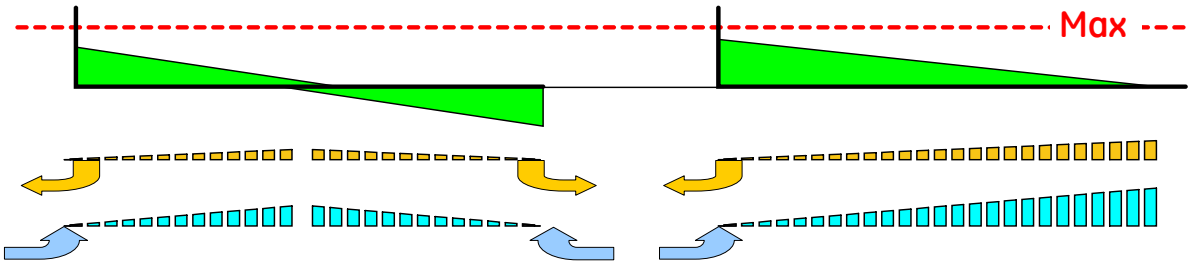




- High Forces:
  (Coupler, Curve friction, slack action)
- Slow Brakes:
  Air Vented at lead only
- Slow Release:
  Air filled at lead only

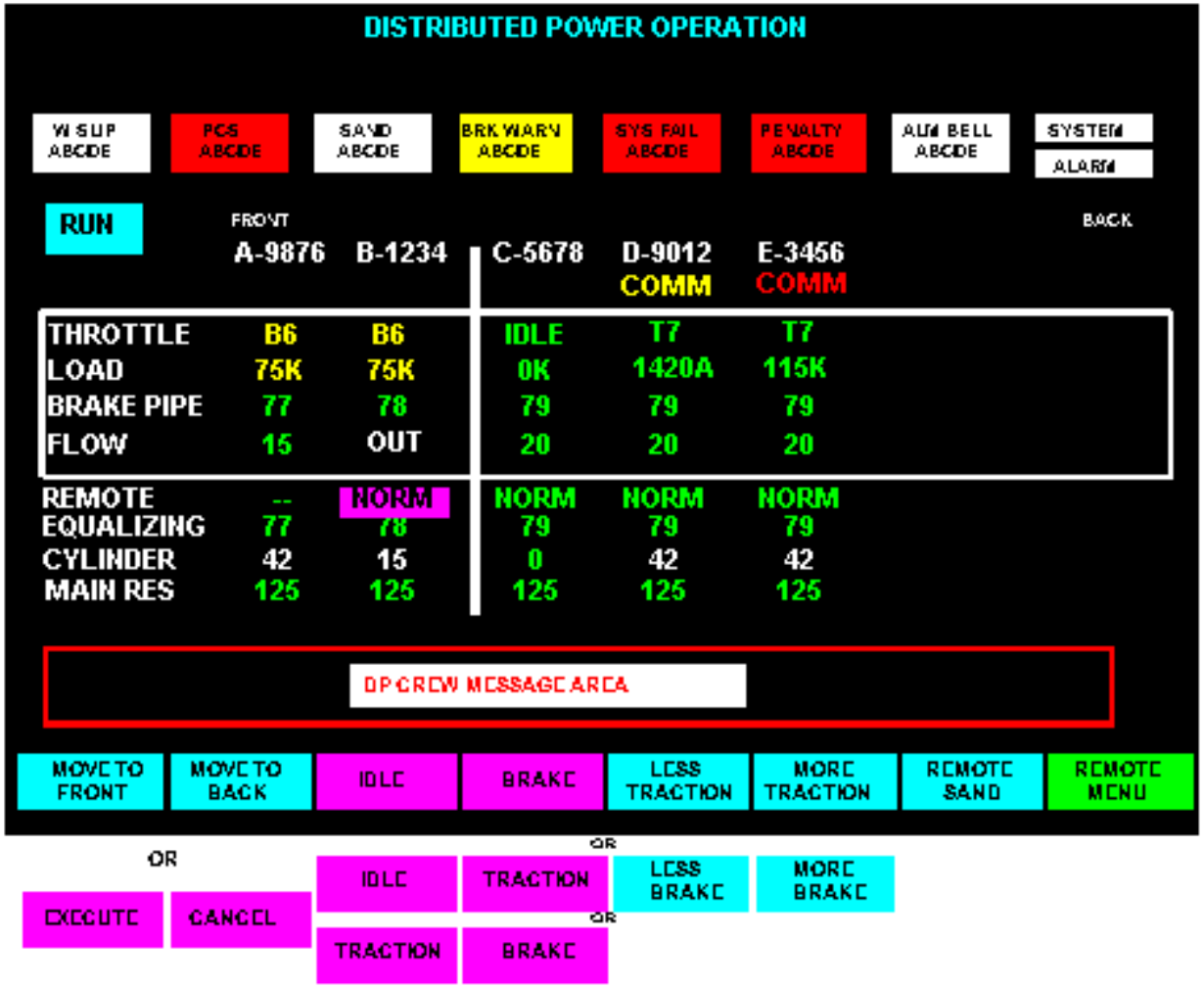
LOCOTROL DP:





- Low Coupler Force:
- Fast Brakes:
  Air Vented at multiple places
- Fast Release:
  Air filled at multiple places

DP: Basic Equipment/HMI…



2011: Long DP trains

99,732 tons, 682 ore cars
2x168x2x168x2x168x1x178x1
BP segments: 5,800'

~42,000 tons, 342 ore cars
2x114x2x114x4x114x1
BP segments 3,740'

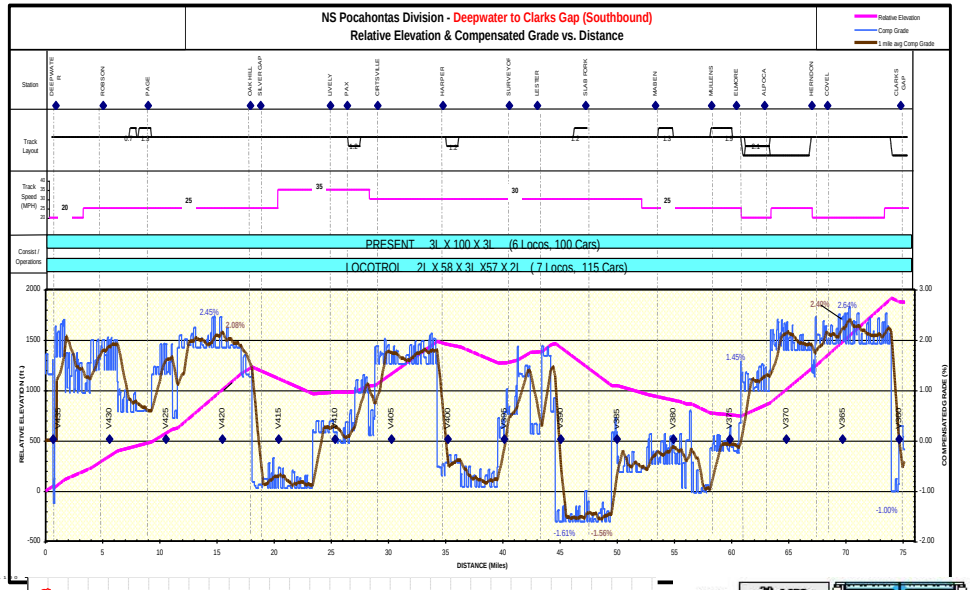
~45,000 tons, 336 ore cars
2x112x2x112x2x112
BP segments 3,608'

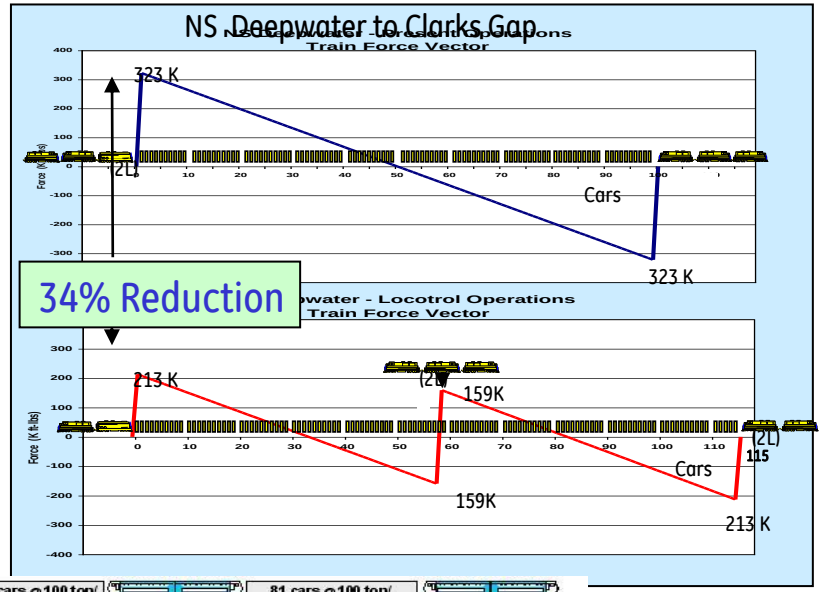
~10,000 tons, 179 wells
5x170x1 typ.
BP segment 10,000'

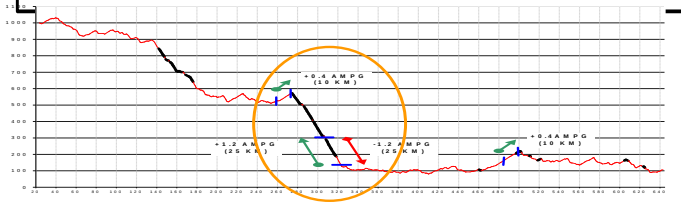
~16,000 tons, 306 wells
3x102x2x102x2x102x2
BP segment 6,000'

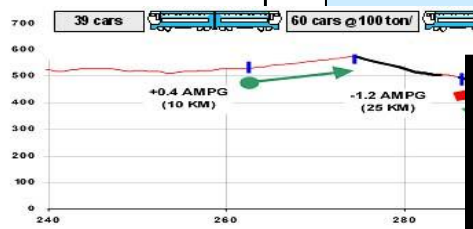
15,000 tons, 130 cars
1x74x1x74x1
BP segments 6000'
High Flow (90 CFM Rule Change)

DP Elements: Operations Analysis…









In-house modeling for in-train forces and optimizing train configuration for various operations and territory

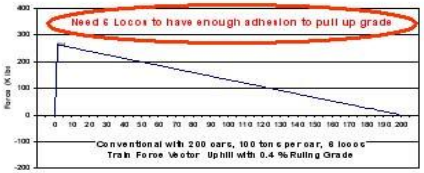
Configuration	Downhill Tractive Effort /Adhesion needed	1st Car Downhill Buff Force needed	Brakepipe Recharge time	Uphill Speed MPH	Uphill Return with Empties Speed MPH	Car to loco ratio	Comments
1 x 60	1.28	78	Good	67	61	30	OK
1 x 120	0.65	152	Marginal	34	32	60	Marginal Handling
2 x 120	1.28	152	Marginal	67	61	30	OK
2 x 180	0.87	230	Poor	45	42	45	Poor BP recharge
1 x 80 x1 x 40	1.28	76	Good	67	61	30	OK
1 x 120 x1 x 60	0.87	115	Good	45	42	45	2nd Best Choice
1 x 133 x 1 x 67	0.78	127	Marginal	41	38	50	3rd Best Choice
1 x 160 x 1 x 80	0.65	152	Marginal	34	32	60	Marginal Handling
1x80x1x80x1x80	0.97	152	Good	45	42	40	Best Choice

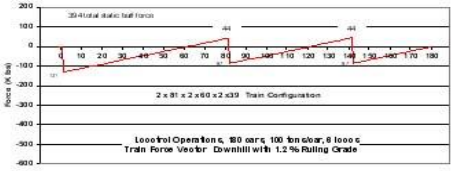
Configuration	Downhill Tractive Effort /Adhesion needed	1st Car Downhill Buff Force needed	Brakepipe Recharge time	Uphill Speed MPH	Uphill Return with Empties Speed MPH	Car to loco ratio	Comments
1 x 60	0.76	131	Good	41	61	30	OK
1 x 120	0.38	259	Marginal	0	32	60	Can't go Uphill / slow downhill
2 x 120	0.76	259	Marginal	40	61	30	OK
2 x 240	0.38	518	Poor	0	32	60	Can't go Uphill / slow downhill
1 x 80 x 1 x 40	0.76	130	Good	40	61	30	2nd Best Choice
1 x 120 x 1 x 60	0.51	195	Good	0	42	45	Can't go Uphill / slow downhill
1x81x1x60x1x39	0.76	130	Good	40	61	30	Best Choice
1 x 133 x 1 x 67	0.46	217	Good	0	38	50	Can't go Uphill / slow downhill
1x89x1x67x1x44	0.68	144	Good	36	55	33	3rd Best Choice
1 x 160 x 1 x 80	0.38	259	Good	0	32	60	Can't go Uphill / slow downhill
1x107x1x80x1x53	0.57	173	Good	45	47	40	OK

2 Locos @92 ton/8582 HP each, 5224ton train

LCOTROL Up Loaded 60 cars 84 ton per	Grade	Needed TE @ grade (klbs)	Available TE @27% Adhesion	Speed
AMPG				
Max Grade				

84 ton per	Grade	(klbs)	Adhesion	TE ratio
Max Grade DB only				
AMPG				
Max Grade				

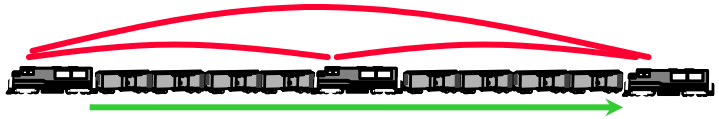




DP Elements: Communications…

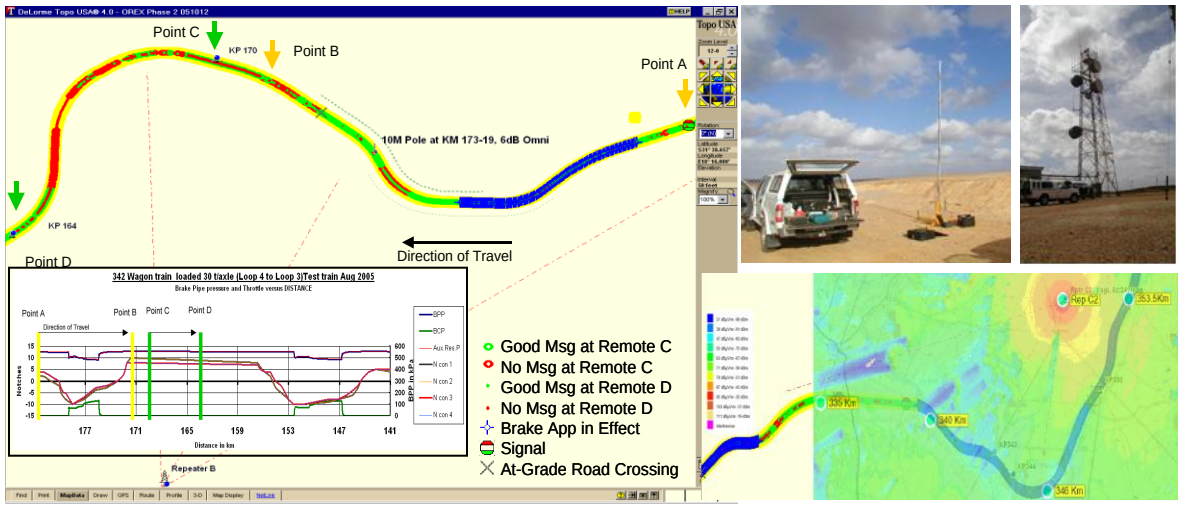
LOCOTROL Distributed Power uses two means of communication:

- Radio/Wire (main)
- Brake Pipe (back-up)

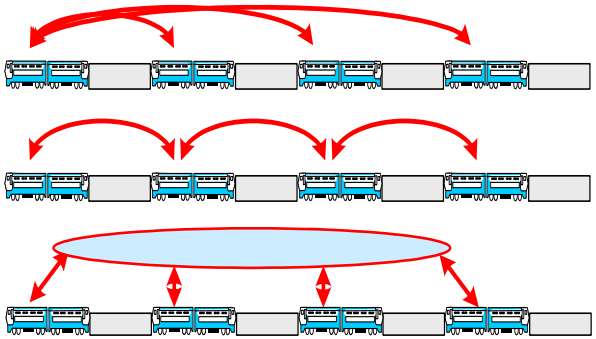


Radio commands:

- Sent upon control, or every 20 seconds
- Designed to work through random comm losses
- Persistent; last command stays in effect during comm loss, **(unless detects braking commanded)**

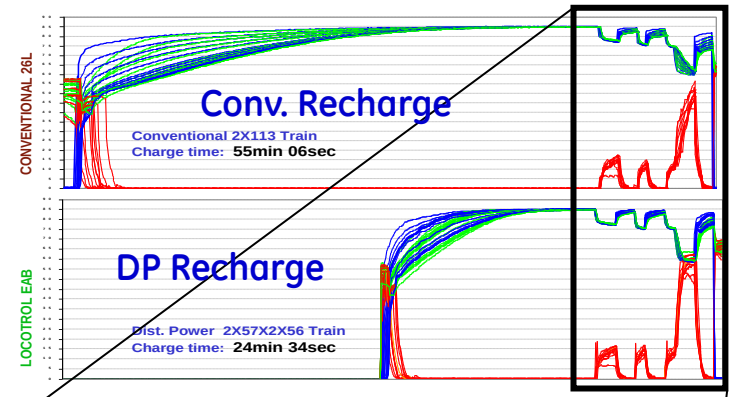


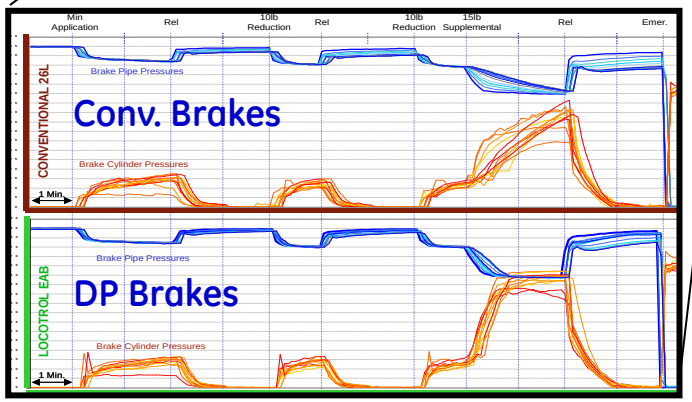
Radio Comm taylored to *operations*: Surveys, repeaters, Redundancy, Comm options..

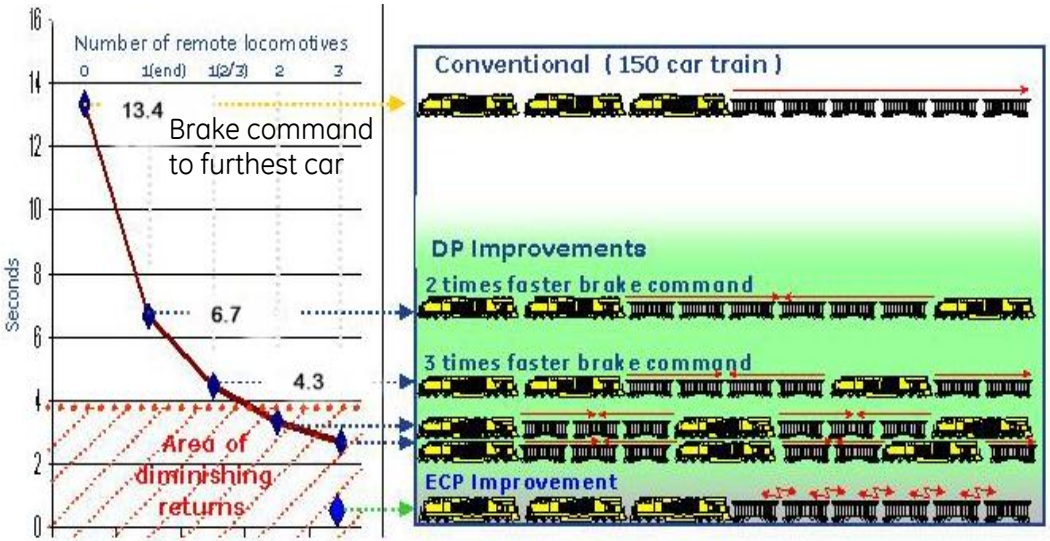


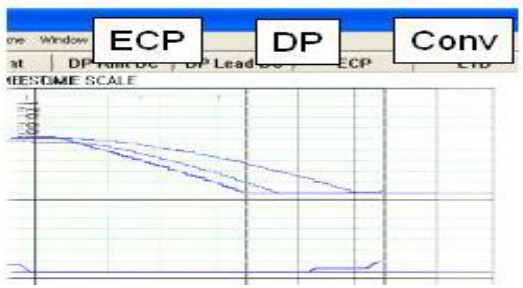
DP Elements: Air Brakes

- With just one remote
  - Less than half the train charge time
  - 30% faster Applications, 100% faster releases
  - Less slack action
- With multiple remotes, significantly better performance …









50 mph Full Service
-0.4% dwn grade
DP: 2016' better vs 2839'= 71%
Train momentum dominant

DP: 71%

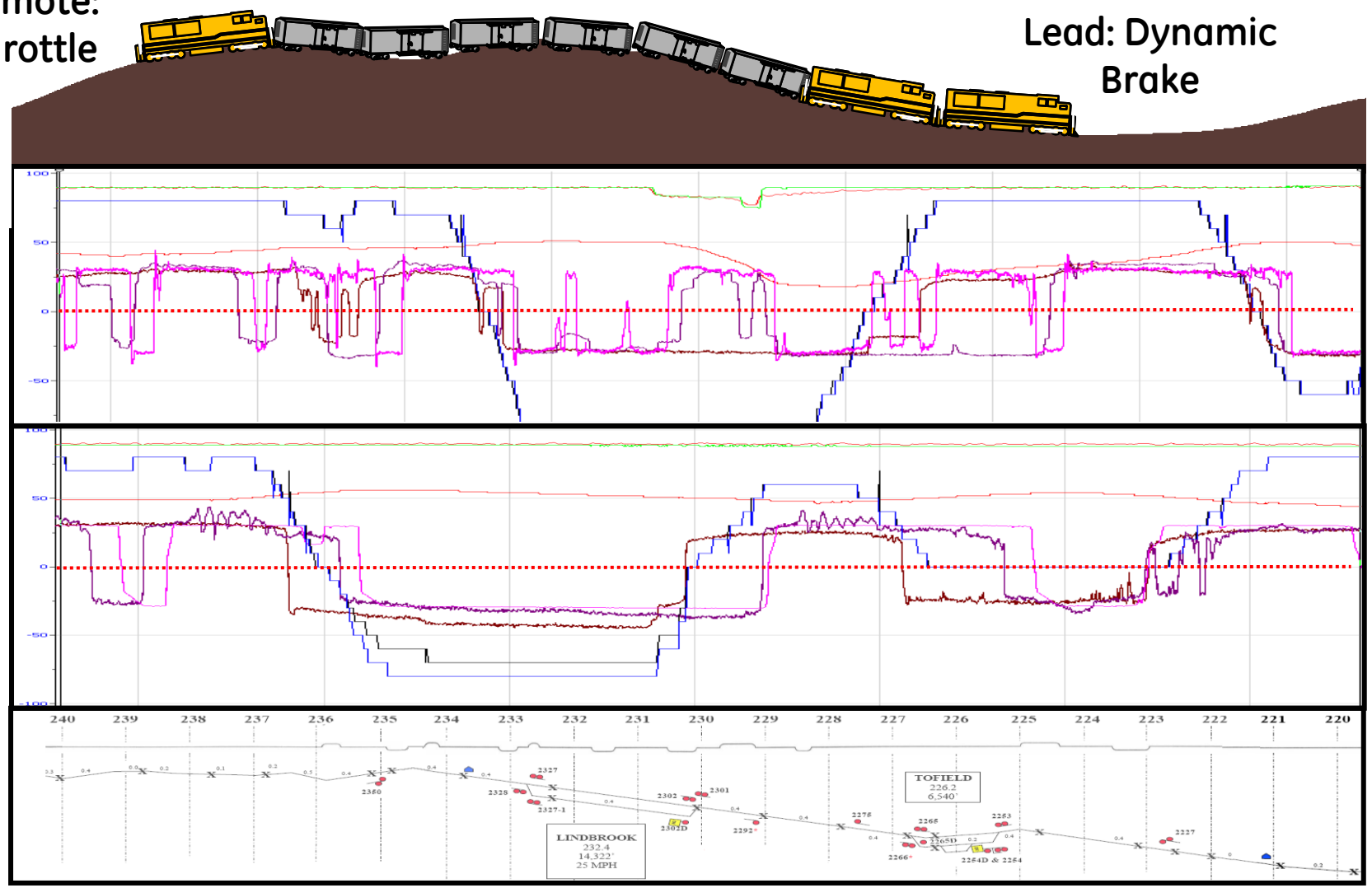
Stop distance of ECP

DP Elements: Independent Control

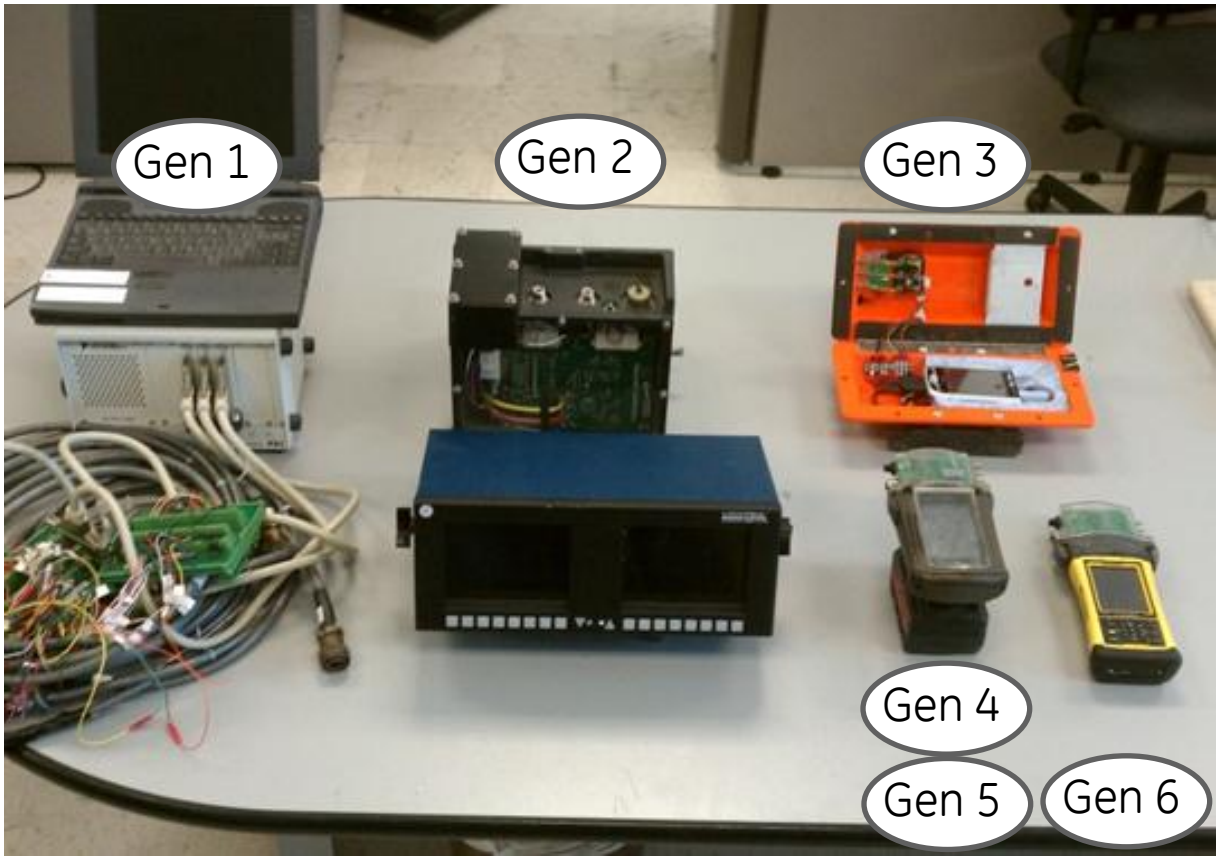
Minimize in-train forces:

Remote: Throttle

Lead: Dynamic Brake



In-Train Instrumentation



Gen 1: Single location
8ch, 100 S/sec, 8hrs, 15lb

Gen 2: Multi (radio) locations
4ch, 0.5 S/sec, 4hr, 30lb

Gen 3: Multi locations
4ch, 10 S/sec, 6hr, 15lb

Gen 4: Multi location waterproof
4ch, 10 S/sec, 10hr, 8lb

Gen 5: Multi location waterproof
4ch, 50 S/sec, 8hr, 8lb

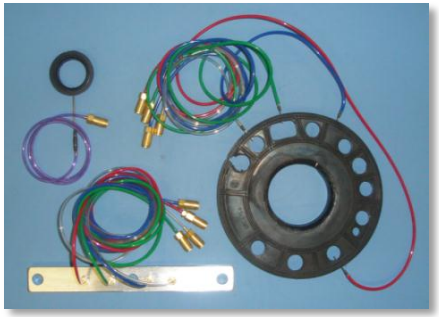
Gen 6: Multi Location waterproof
4ch, 100 S/sec, 96hr 9lb

Innovation and system Improvement can only be as good as the visibility into the situation…

In-Train Instrumentation

PPC-Daq R6
4 Channel
Pressure/0-5V selectable
50 Sample/Sec
30hr logging max (8 hr/battery)
0.25 psi, 0.1", 0.1CFM

PPC-Daq R7
4 Channel + GPS
Pressure/0-5V selectable
100 Sample/Sec
86hr logging max (12hr/battery)
0.01 psi, 0.01", 0.01CFM



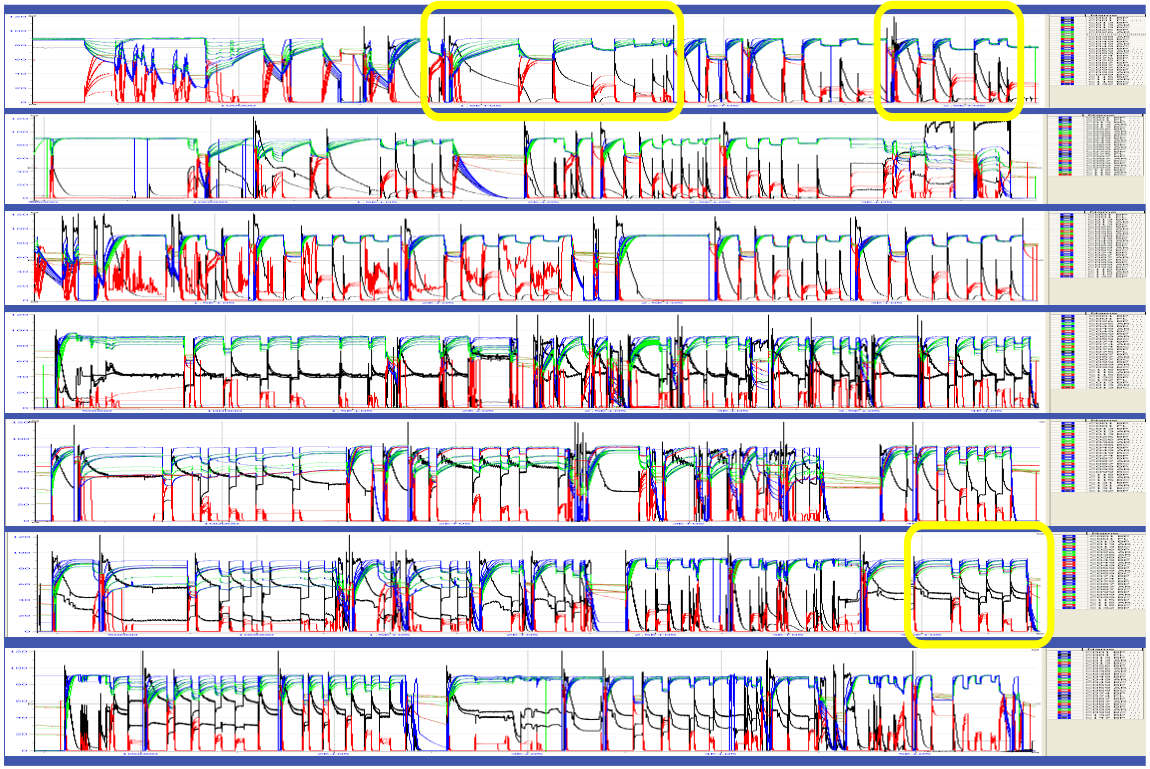
Pressure Interfaces
3/32" tubing/valve quick disconnects
- Glad-hand gasket
- Single Car Test Port
- Service Portion Gasket

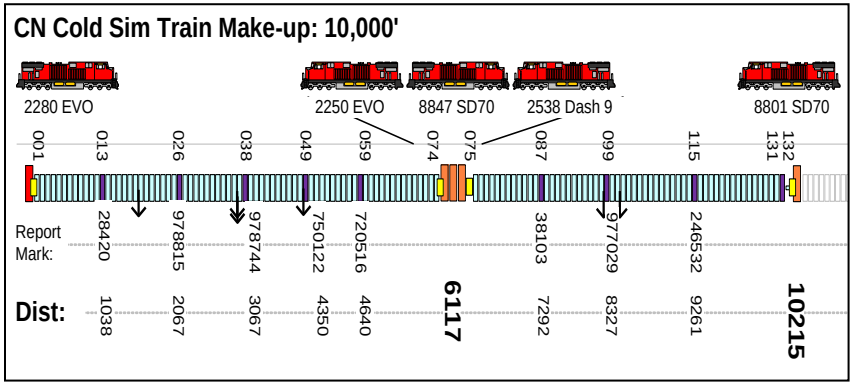
0-5V Interfaces
- 0 to 200 CFM high precision flow meter
- 36" travel string pot for slack measure

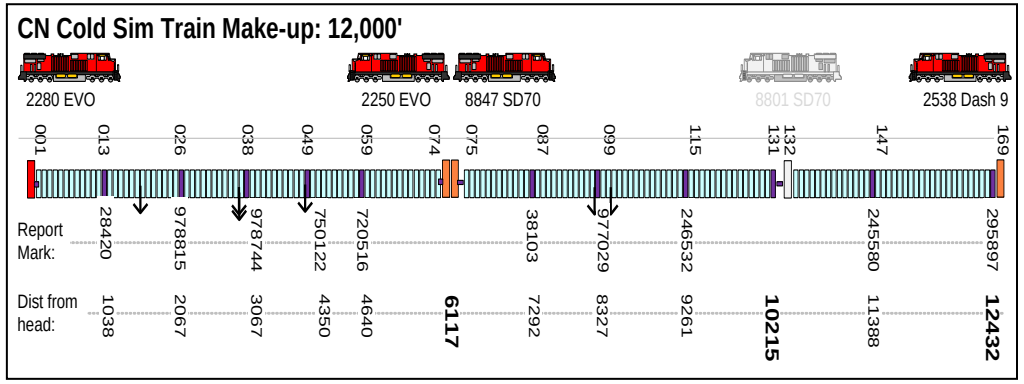
MU connector
converts throttle TLs to stepped voltage for single channel of Notch Cmds

90 CFM Departure Rule Change for DP

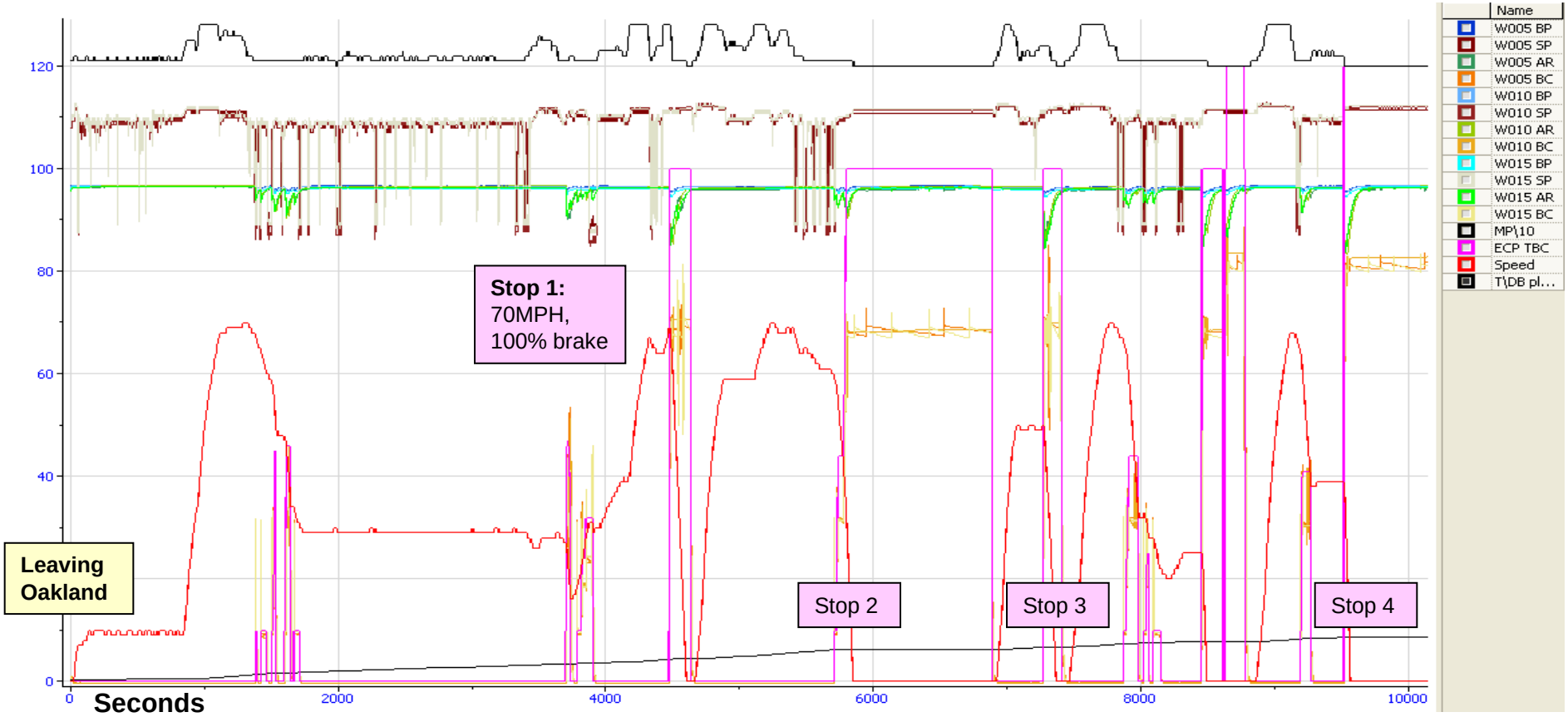
- 23 different 10,000' combos:
  - 1x0, 1x0x1, 1x1x1 trains
  - Leakages: tight, 60/60, 60,90,60
  - various single unit mid types
  - Various multiple unit mid consists
- 2 different 12,000' combos:
  - 1x0x1, 1x1x1 trains
  - Leakage: tight, 60/60, 60,90,60
  - various single unit mid remotes
- Six continuous days of testing
  - 135 Application and Releases
  - 65 configuration/setup tests
  - > 700 Million samples taken





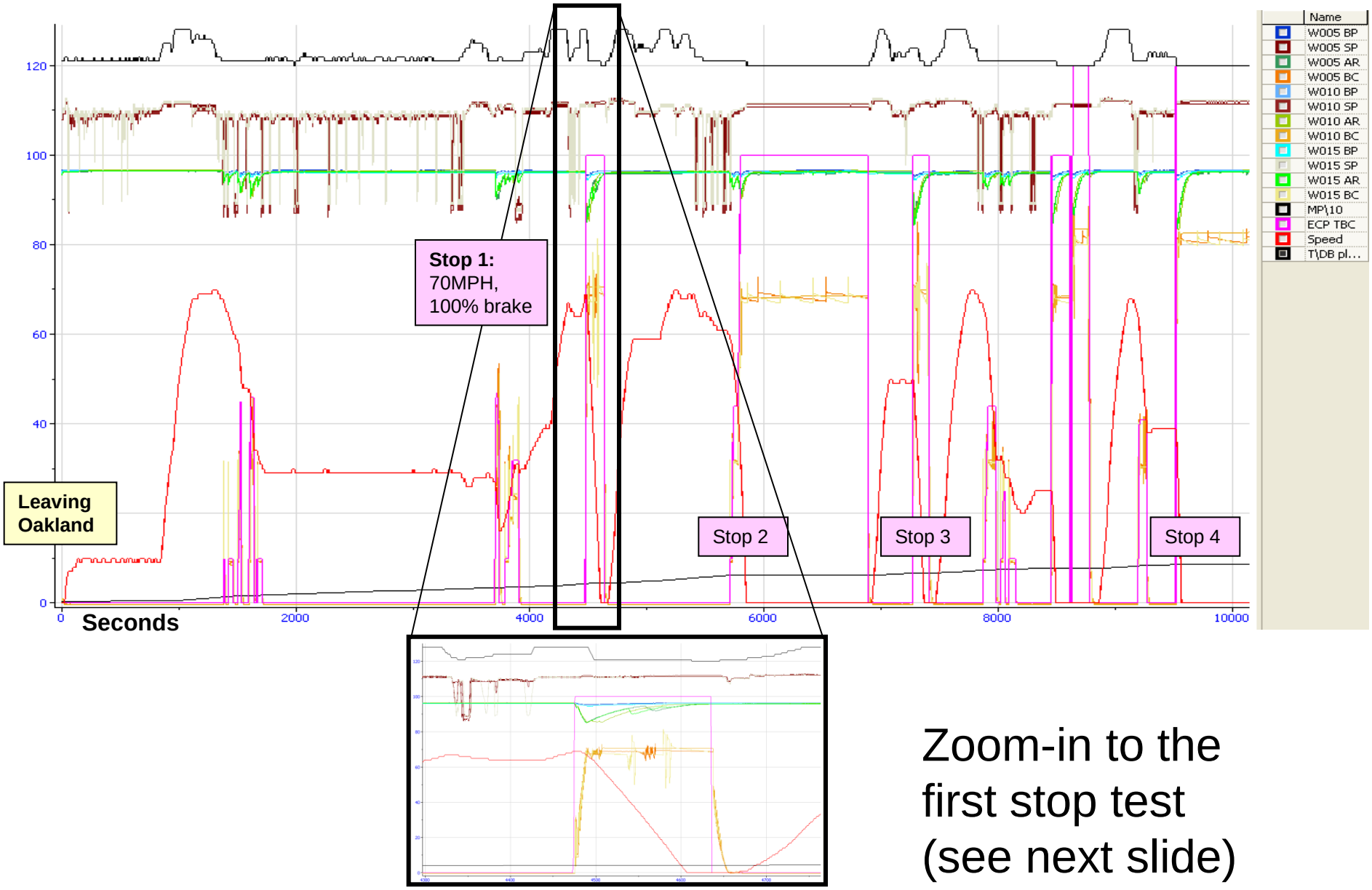


ECP Stop Test…



First Four Stops

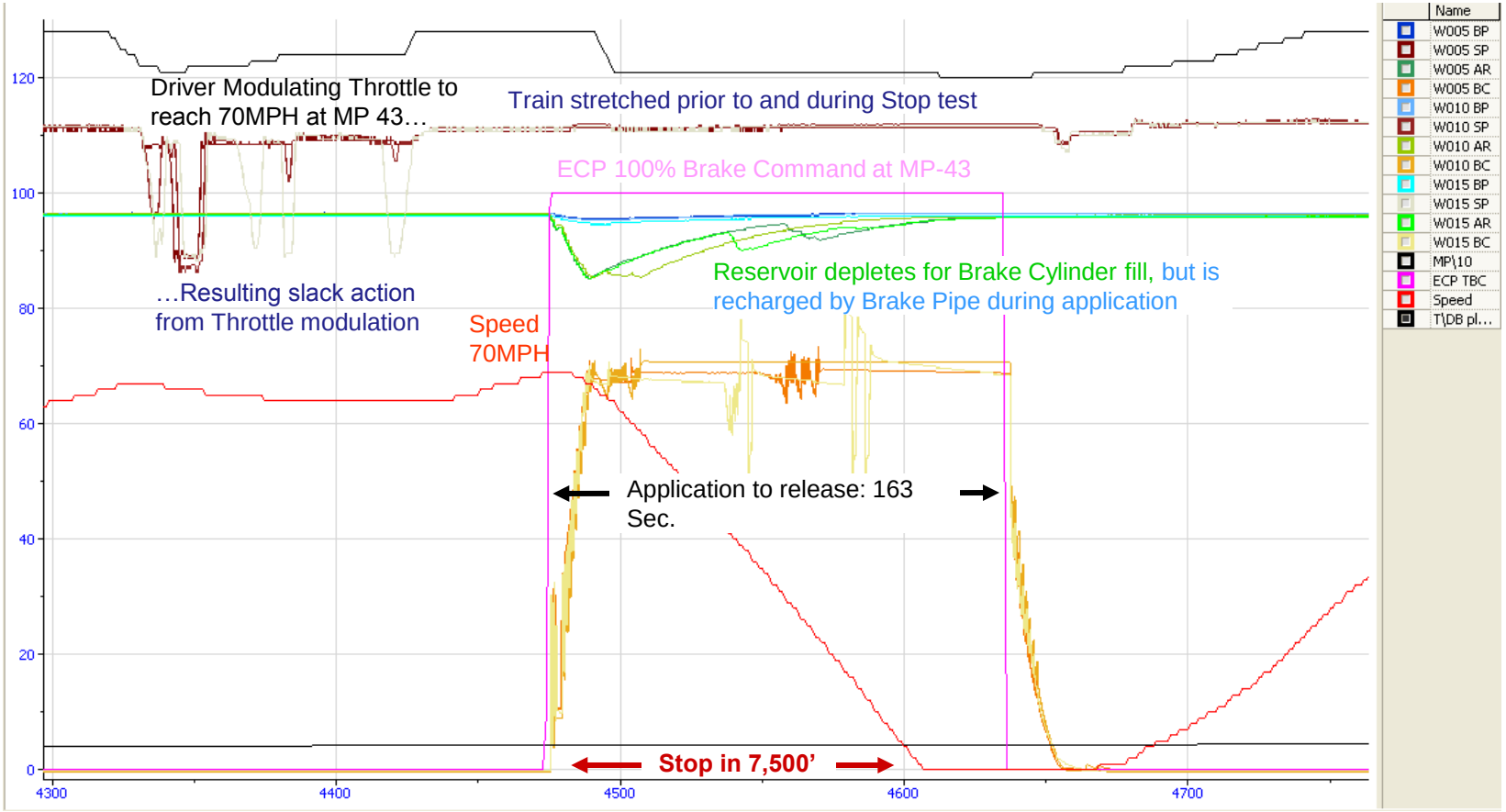
Pneumatic Data



Zoom-in to the first stop test (see next slide)

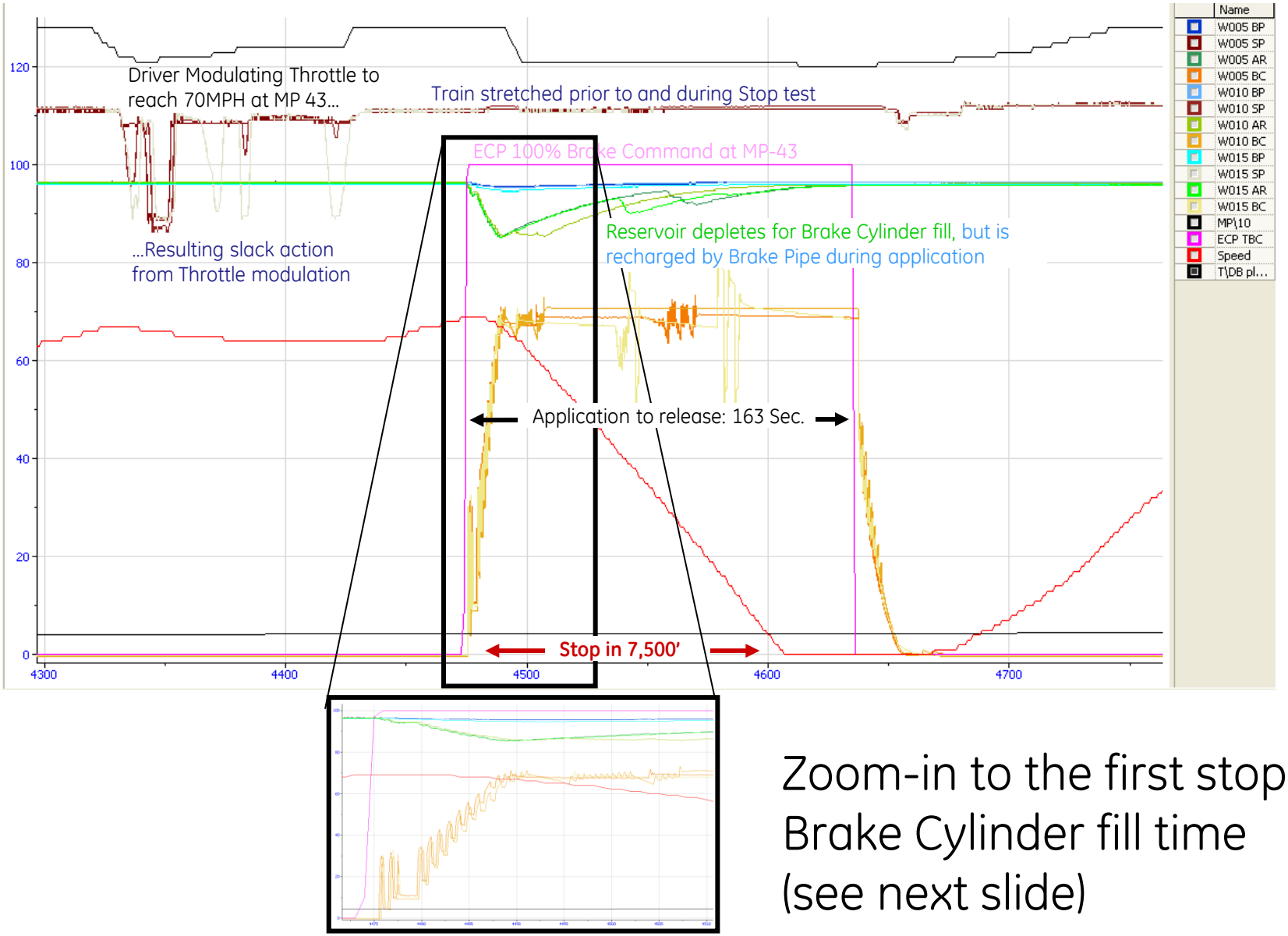
First Stop

Pneumatic Data



First ECP Stop

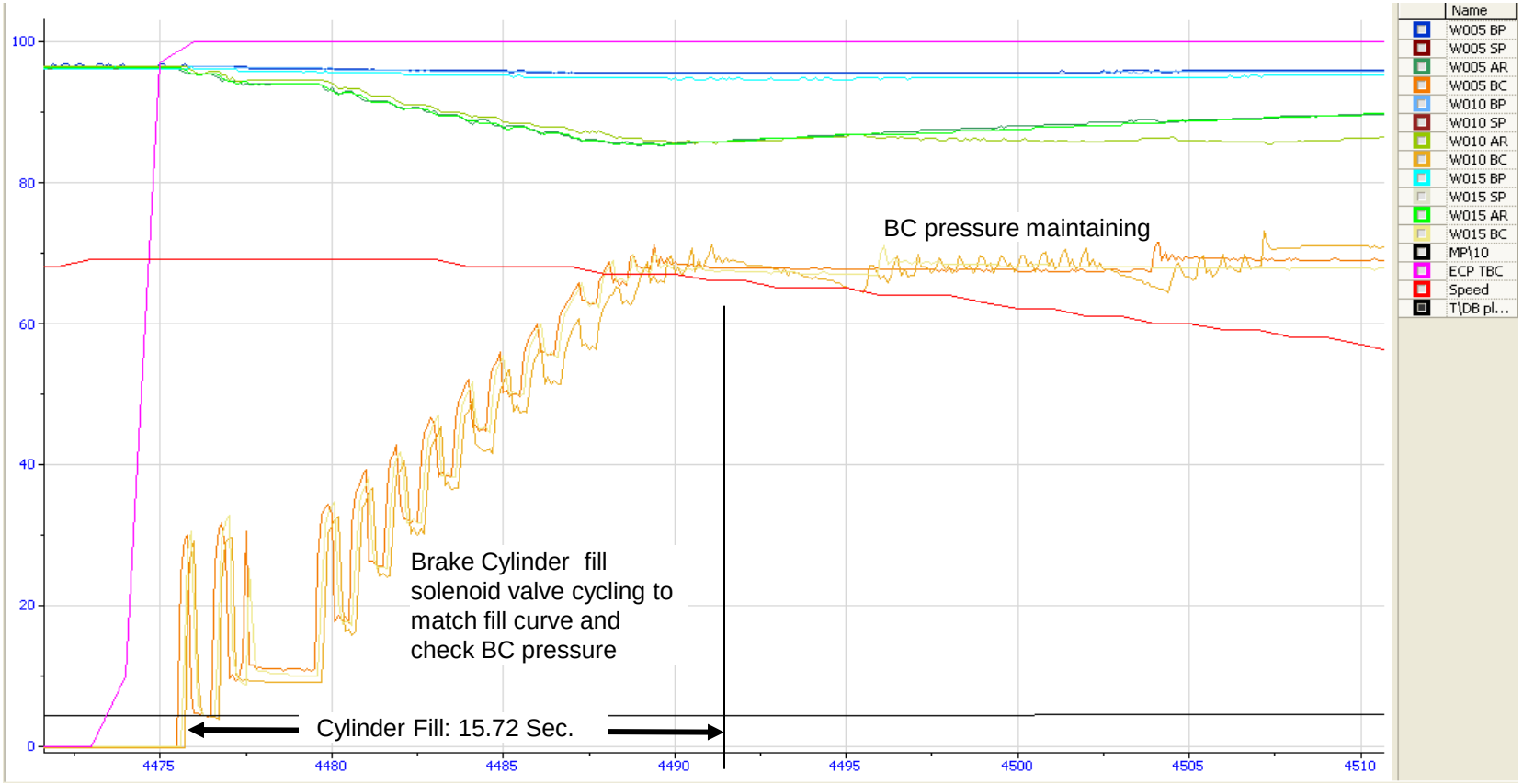
Pneumatic Data



Zoom-in to the first stop Brake Cylinder fill time (see next slide)

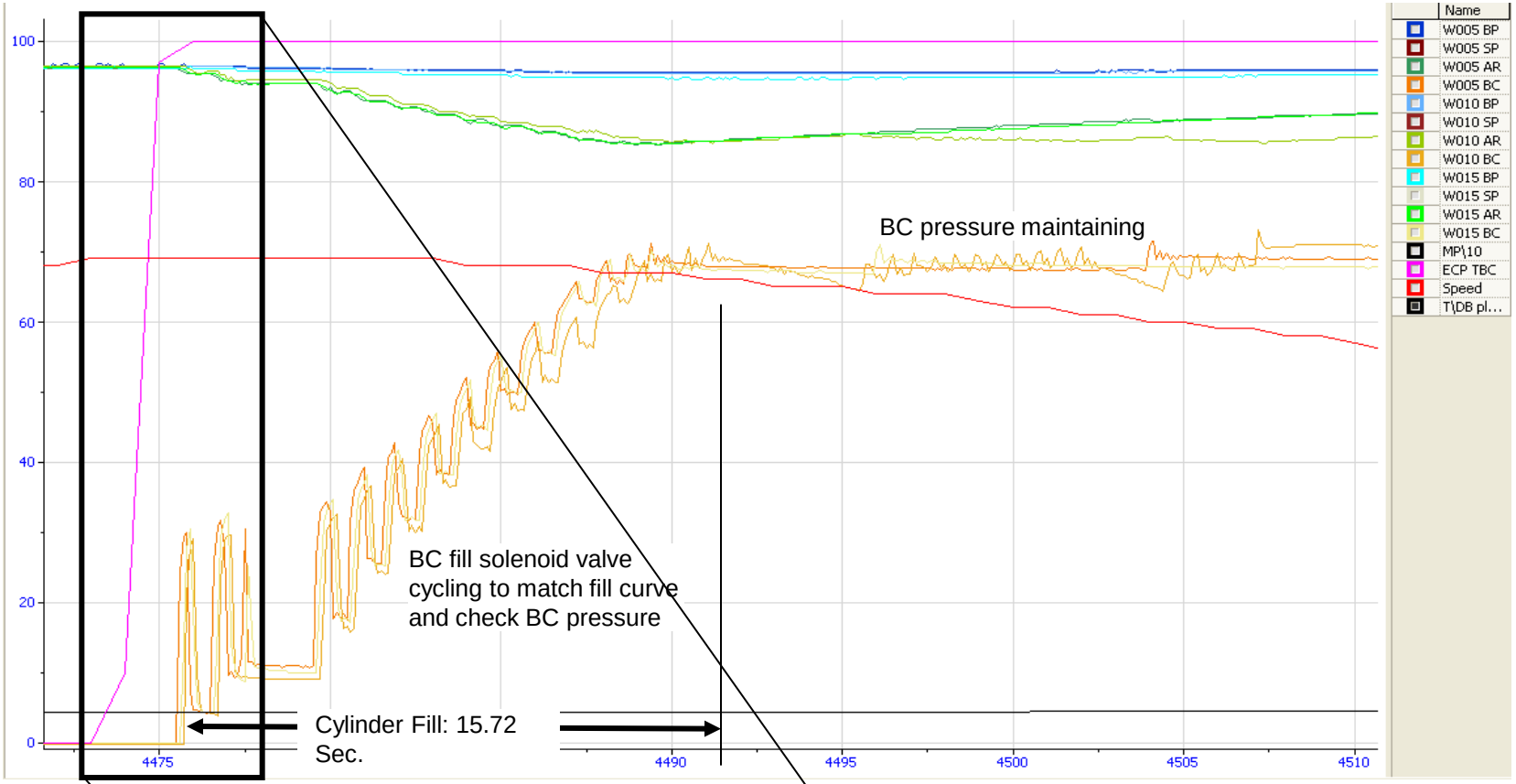
First Stop, ECP Brake Cylinder fill time

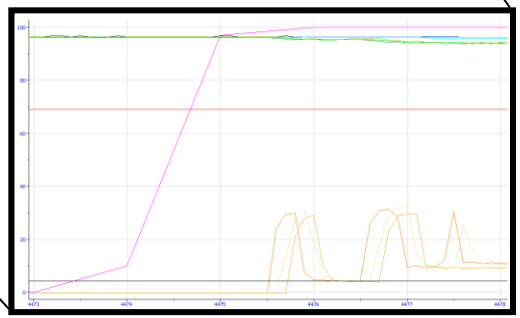
Pneumatic Data



First Stop, Brake Cylinder fill time

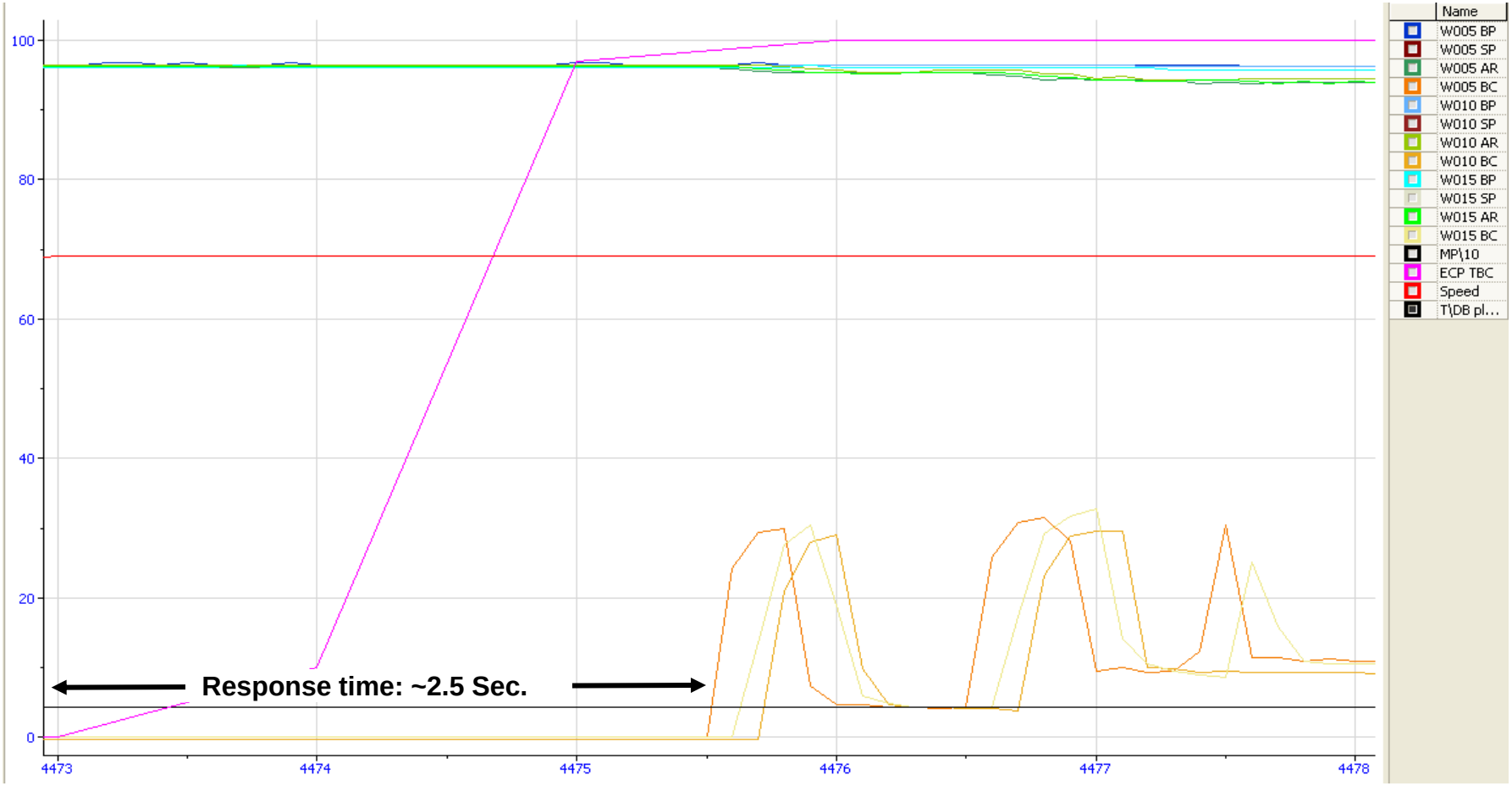
Pneumatic Data



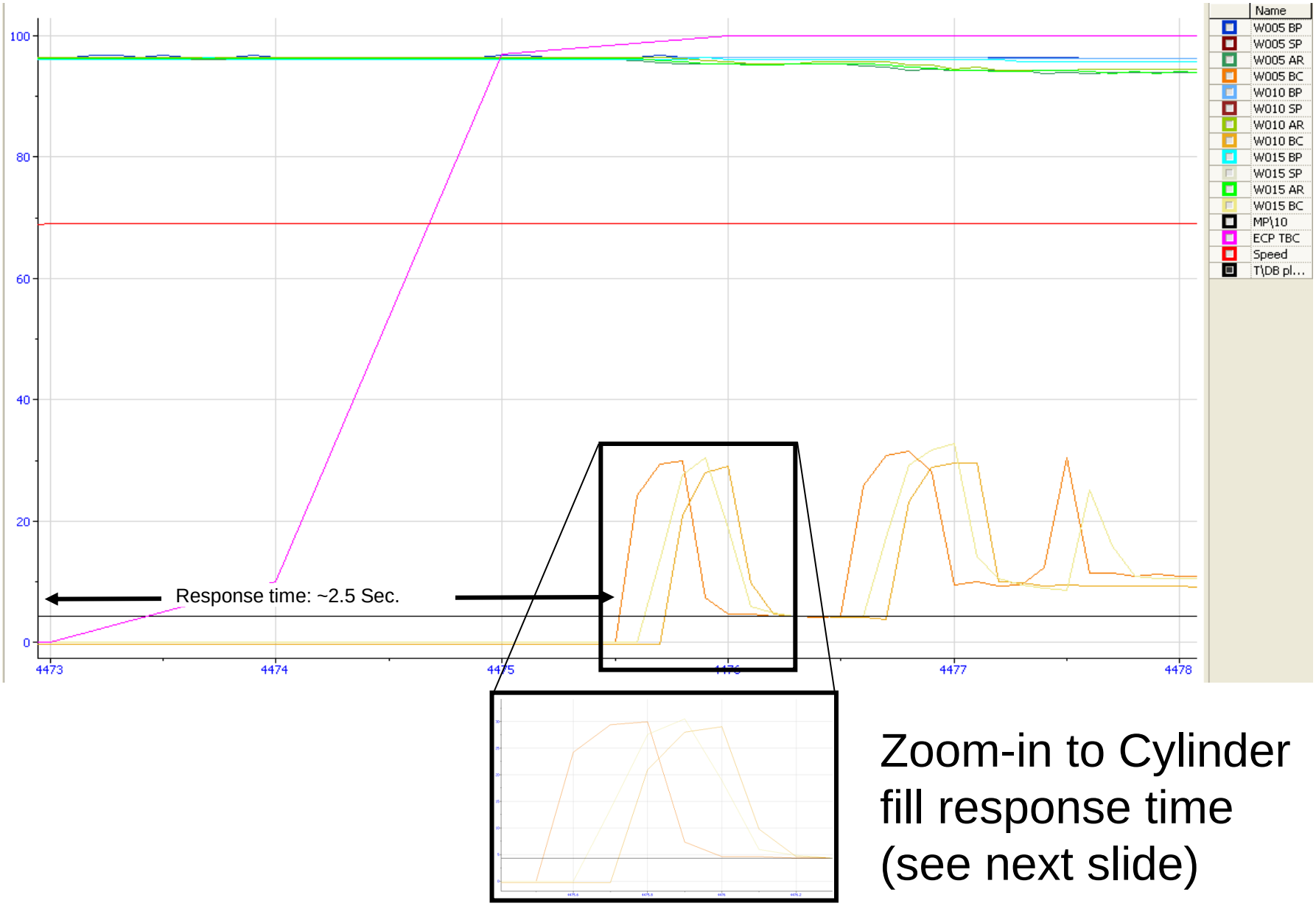


Zoom-in to the first stop Brake Command to Cylinder fill response time (see next slide)

Brake Command to Cylinder fill Response time: Pneumatic Data



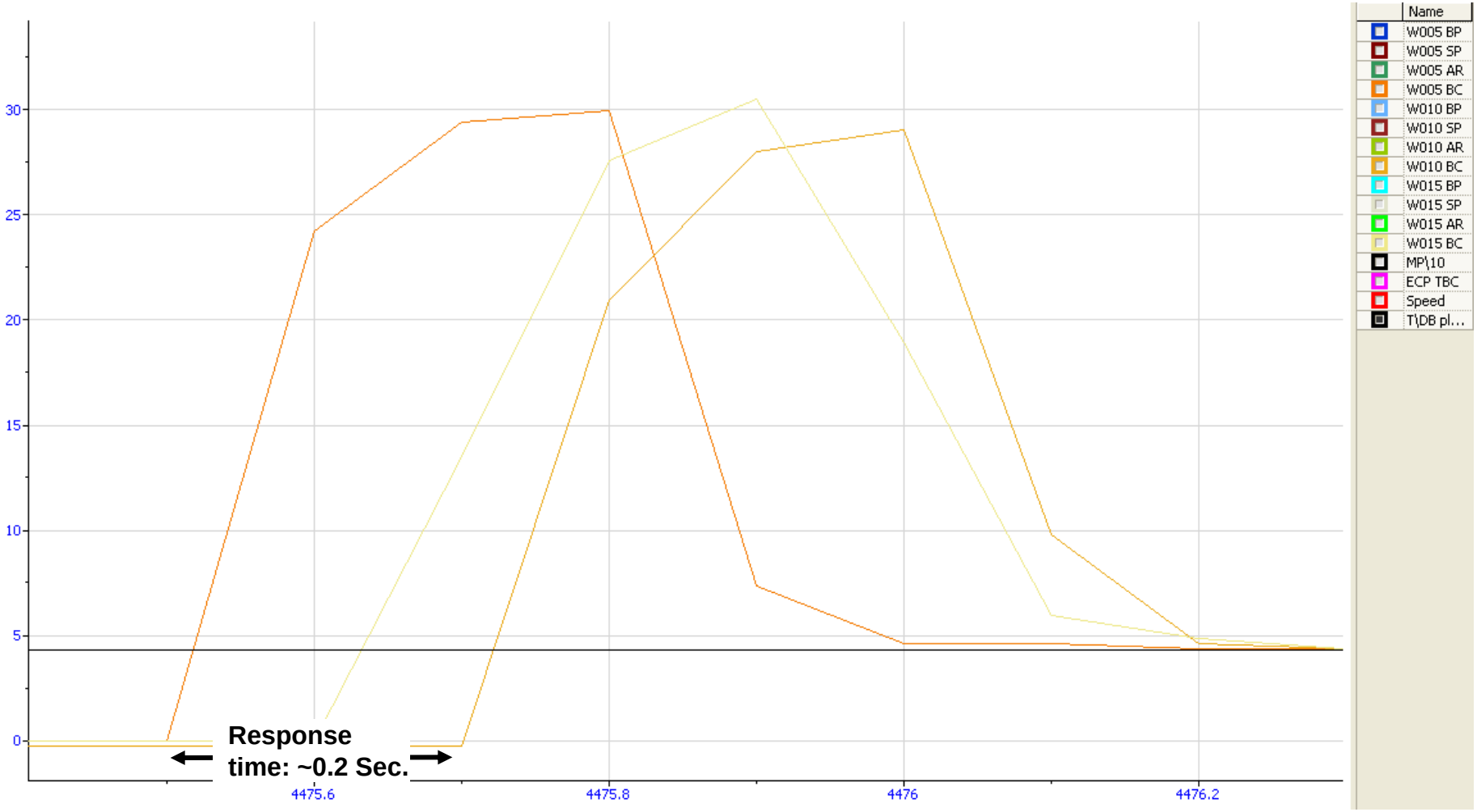
Brake Command to Cylinder fill Response time Pneumatic Data



Zoom-in to Cylinder fill response time (see next slide)

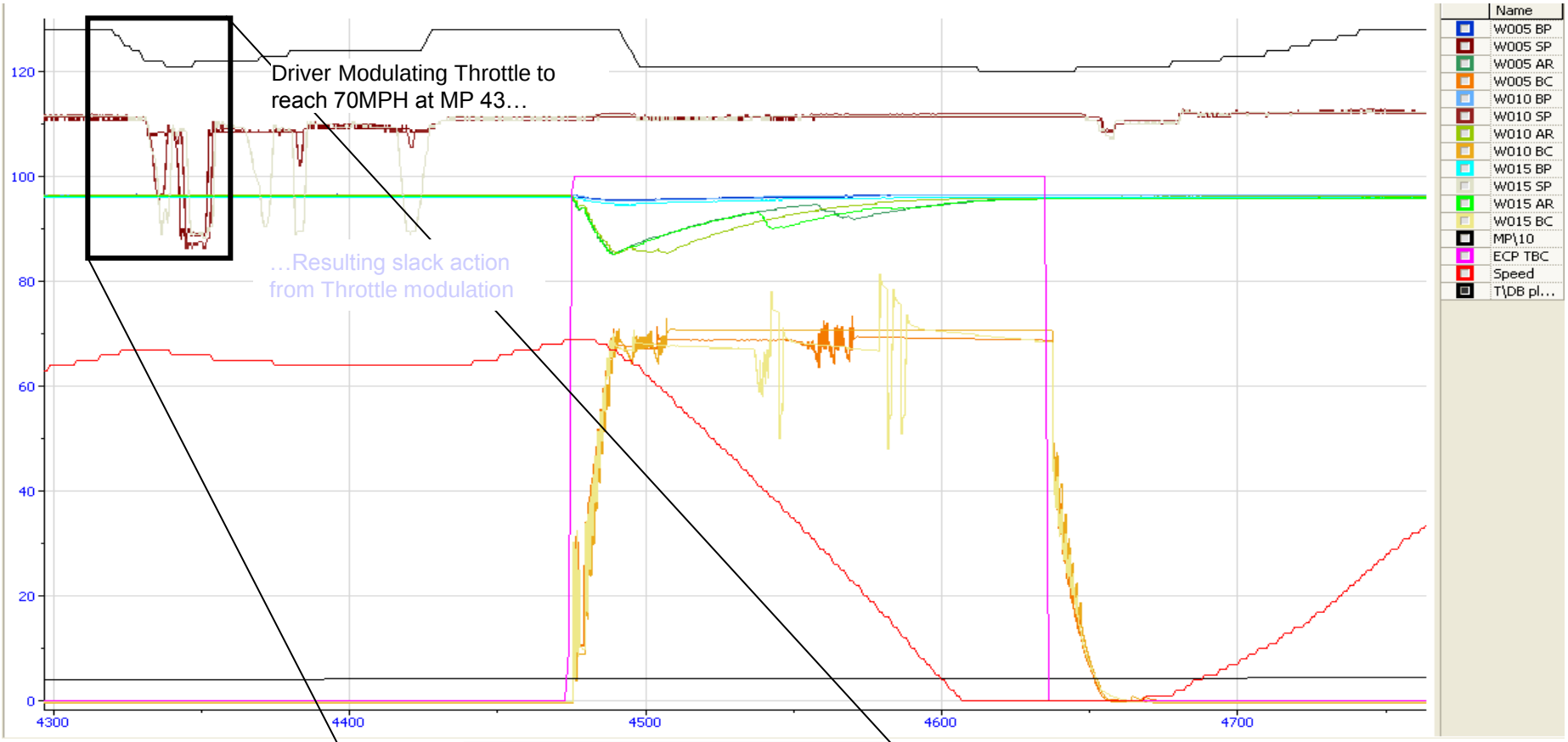
Cylinder fill Response time

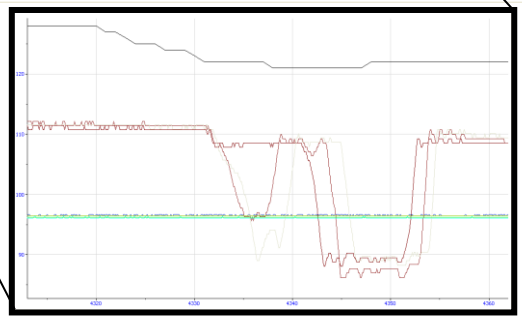
Pneumatic Data



First Stop

Slack Data

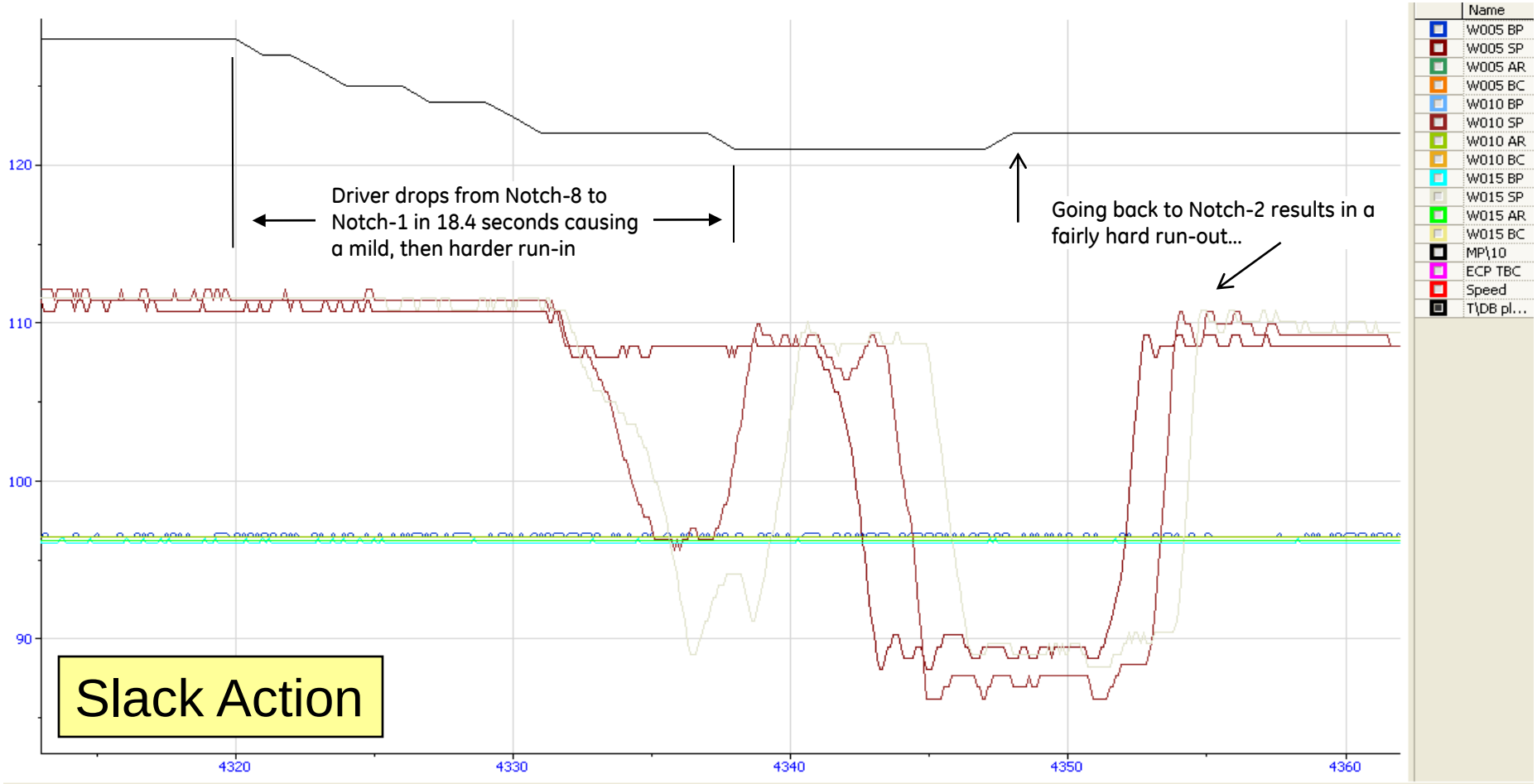




Zoom-in to Slack Action prior to 1st stop (see next slide)

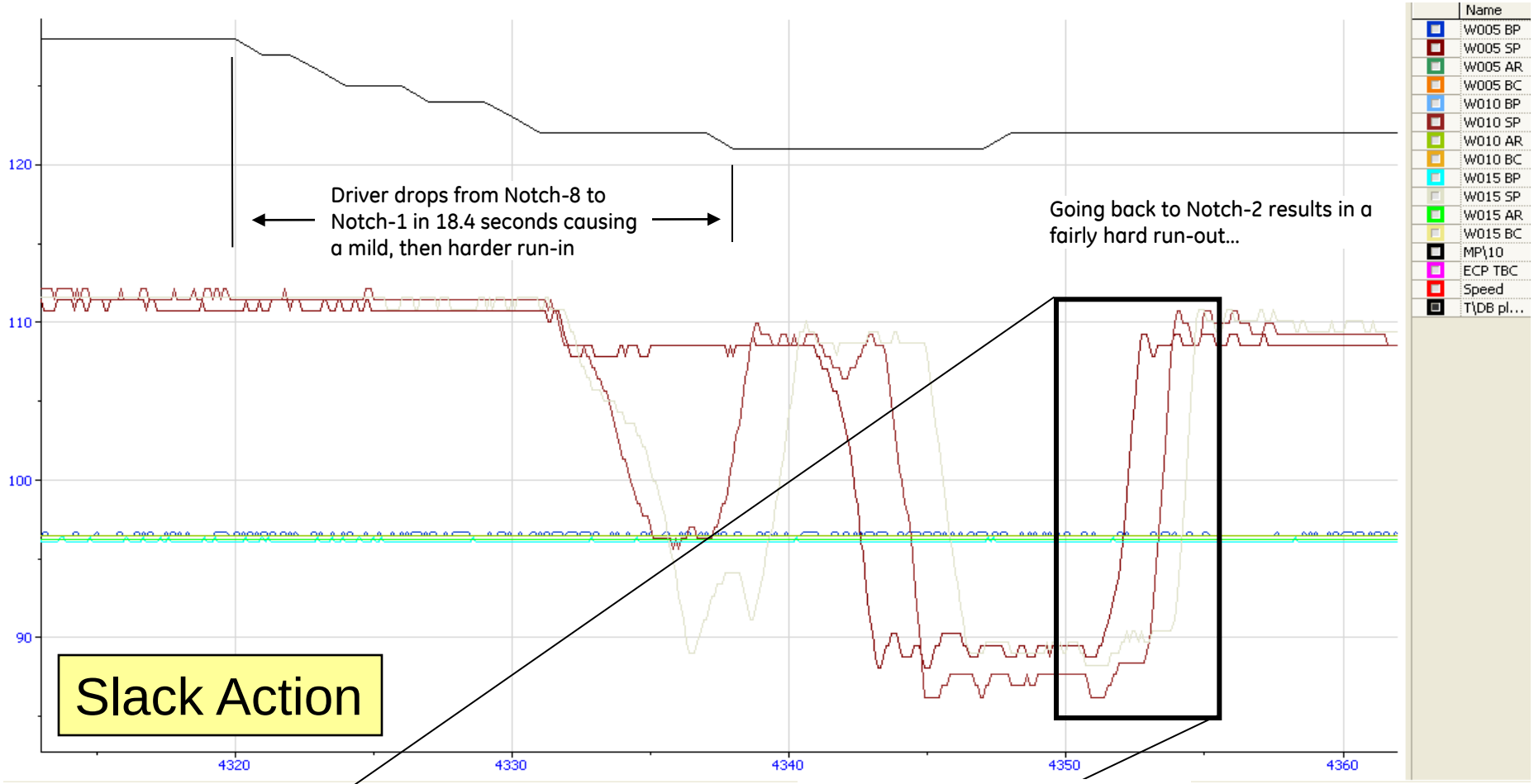
Slack Action Prior to 1st Stop

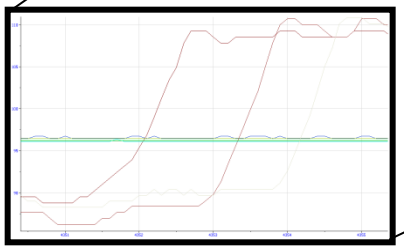
Slack Data



Slack Action Prior to 1st Stop

Slack Data

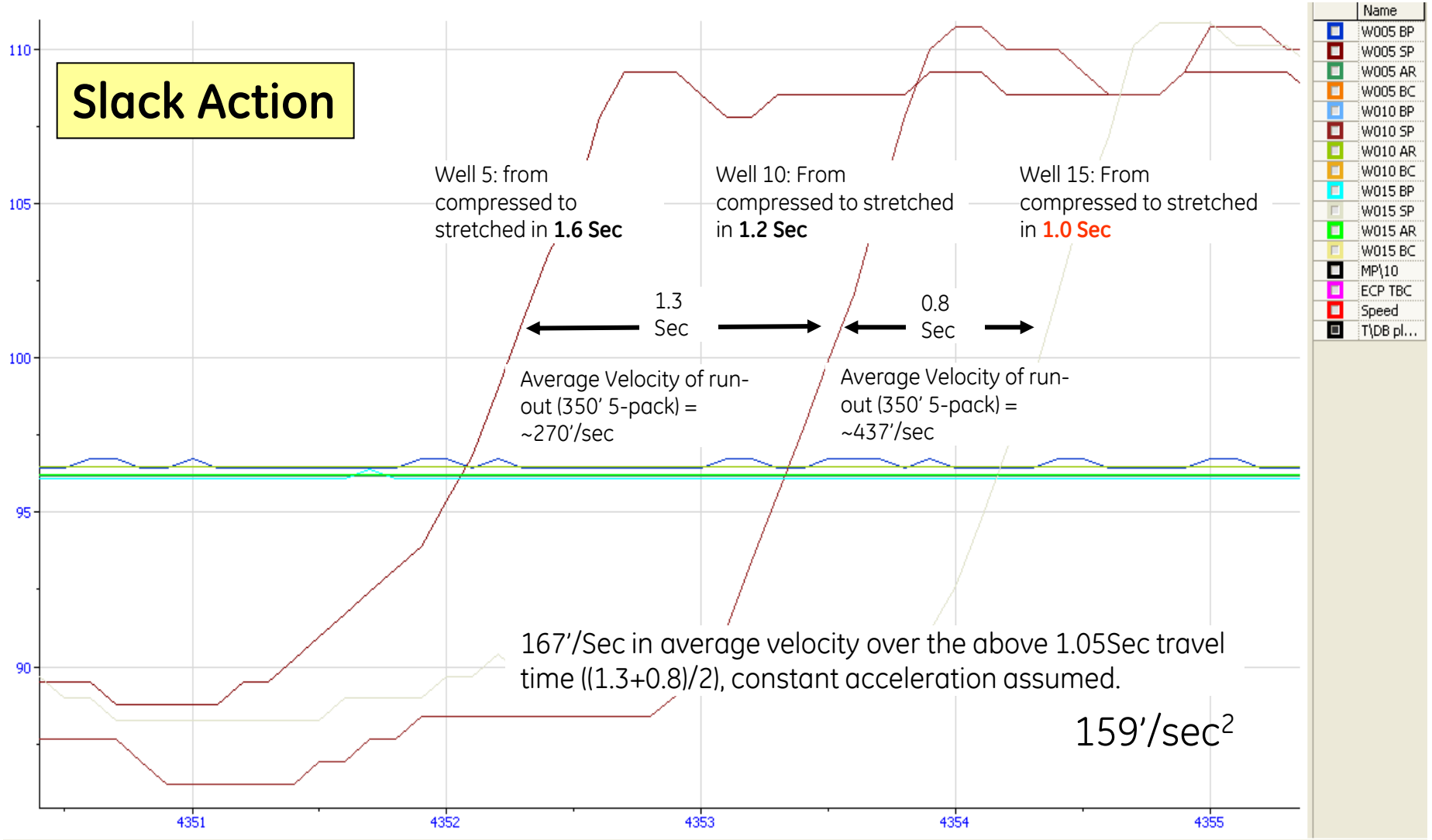




Zoom-in to Run-out (see next slide)

Slack Action Prior to 1st Stop

Slack Data



Speed/severity of slack increasing toward back of train

DP with GE's Trip Optimizer

Automated Energy Management with automatic control of Independent Distributed Power

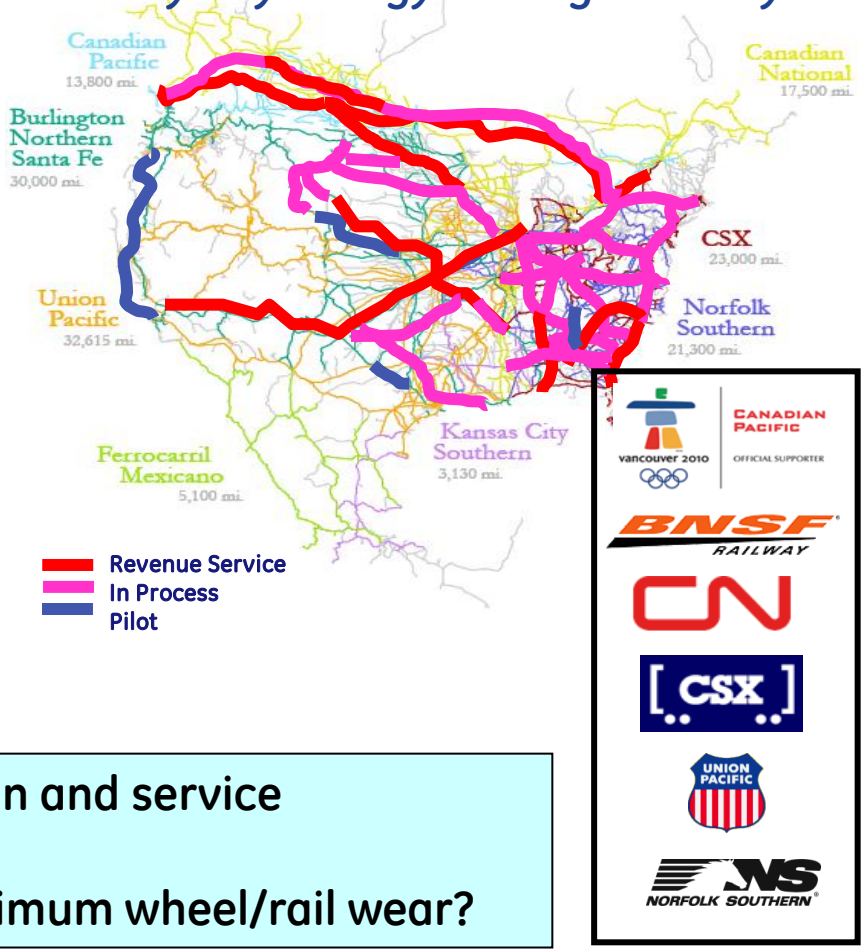
GE's Trip Optimizer

Operating in Revenue Service on Six Class 1 RRs

Trip Optimizer Deployment Status

Railroad	BNSF, CP, CSX, CN
# Unique Track Miles Operated	>30,000 Miles
Revenue Operating Miles	+18 Million Auto Control +32 Million Total
Varying Terrain	Mountains/Prairies/Mines/ Undulating
Train Starts	+188,000
Locomotives	+2183(contract for 2722)
Tonnage Range	500 – 24,000 Tons
Train Types	Intermodal, Manifest, Bulk, High EOC

Most Diverse Terrain and Train Types tested by any energy management system

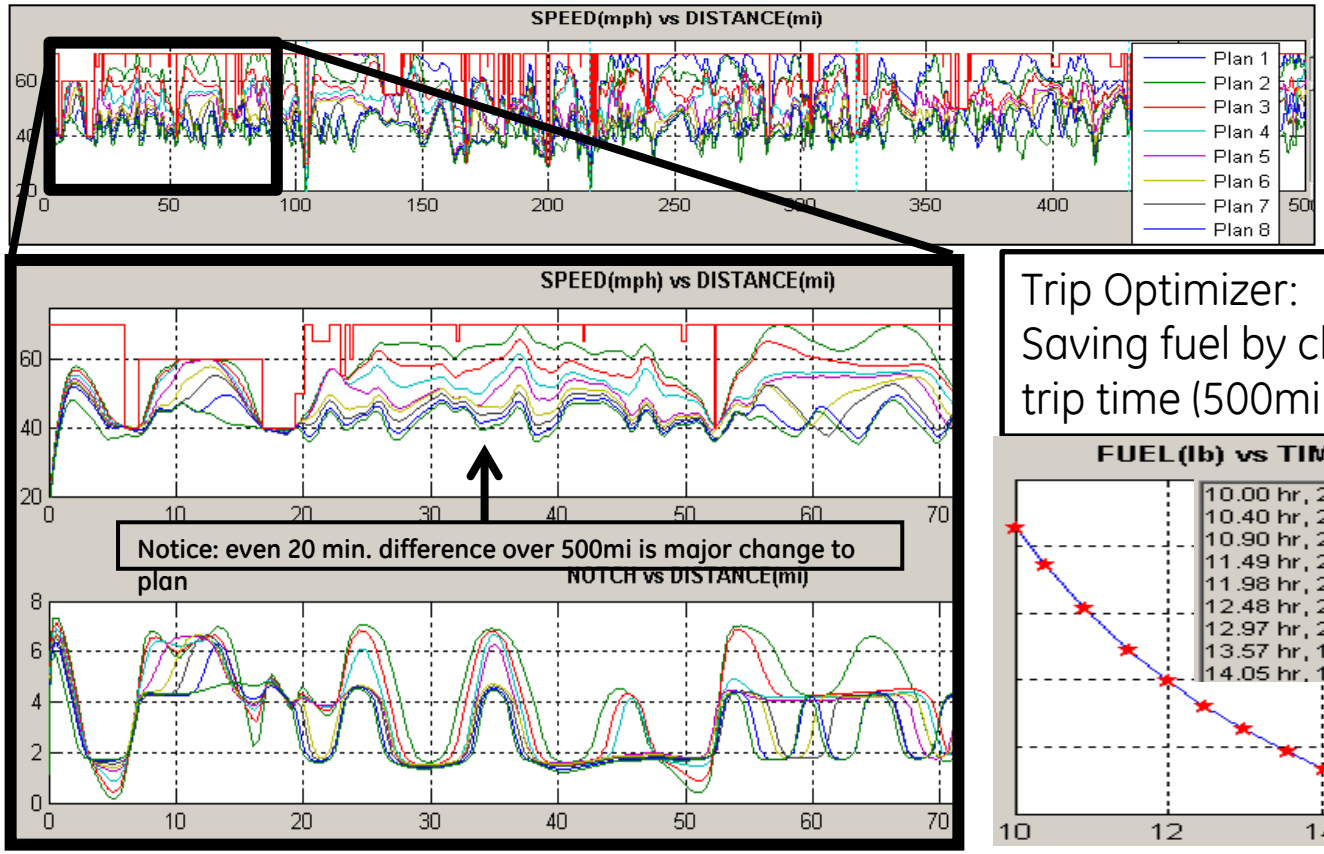


- Fuel Savings of 3-17% depending on terrain and service
- No velocity impact
- Precision Train Handling (Optimize for minimum wheel/rail wear?

GE's Trip Optimizer

Optimization: Physics dictates only one optimized trip for a given set of constraints.

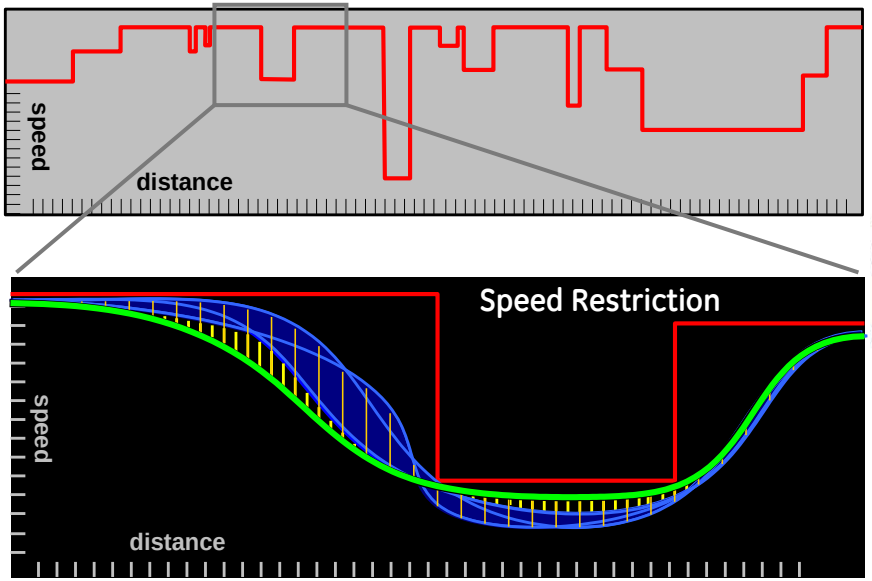
TO plans *optimum* operation (can create a family of curves for the entire run for changes to a single parameter):

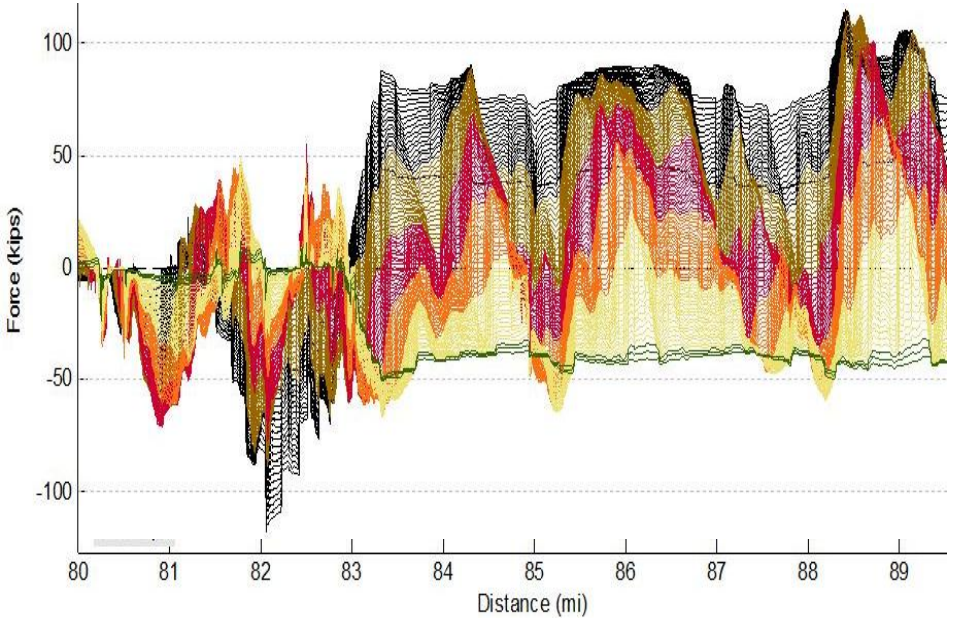


Trip Optimizer:
Saving fuel by changing just trip time (500mi run)

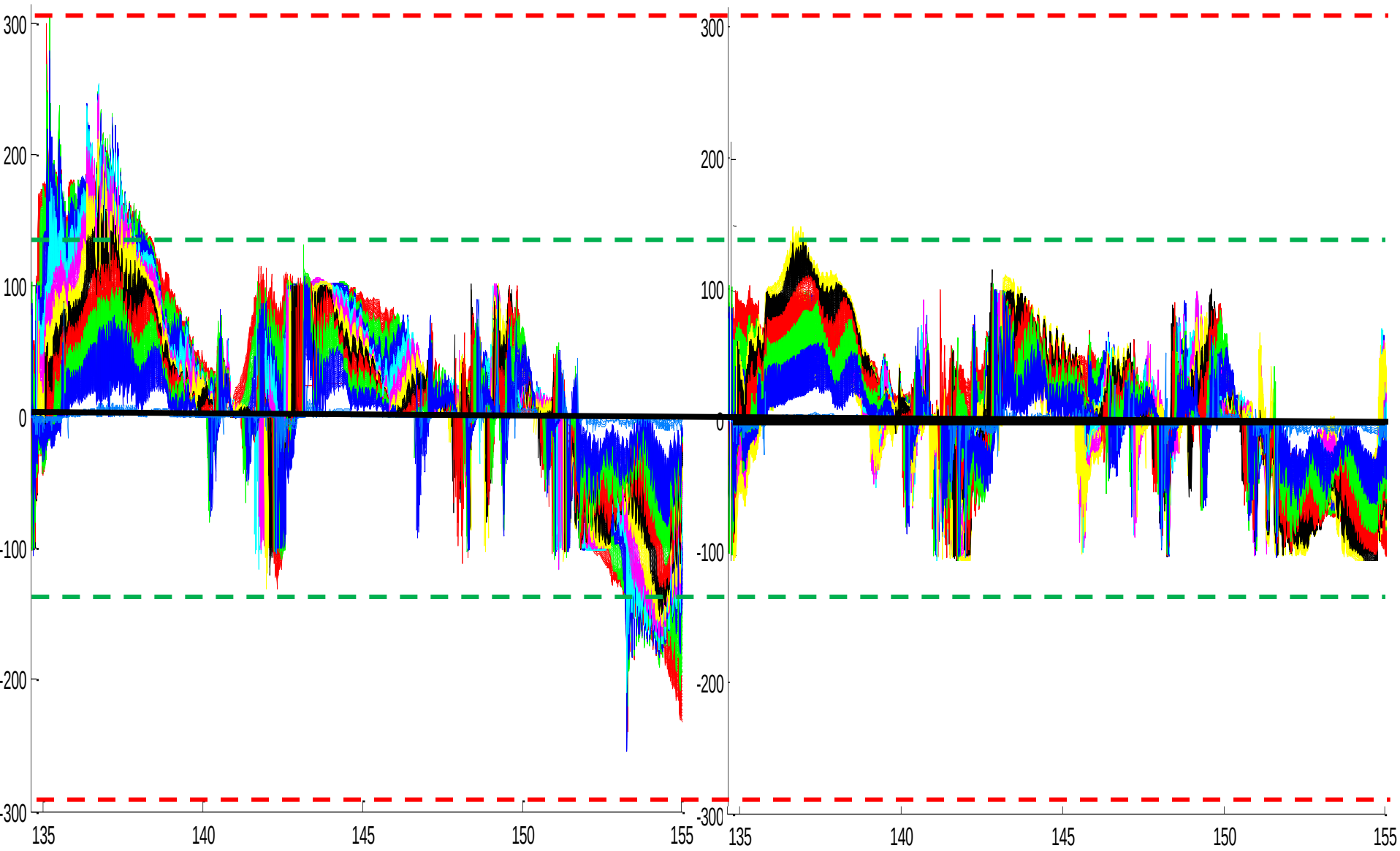
GE's Trip Optimizer

- **Real Time Train control performed by the RTE** (Regulator, Tran handling, Estimator)
  - Drives to the plan – accurately
  - Fast, closed loop, feedback control system – learns variations for re-plan
  - Continuously calculates car-by-car (rope model), forces ten miles ahead
  - Uses appropriate train handling for the real situation in-train forces

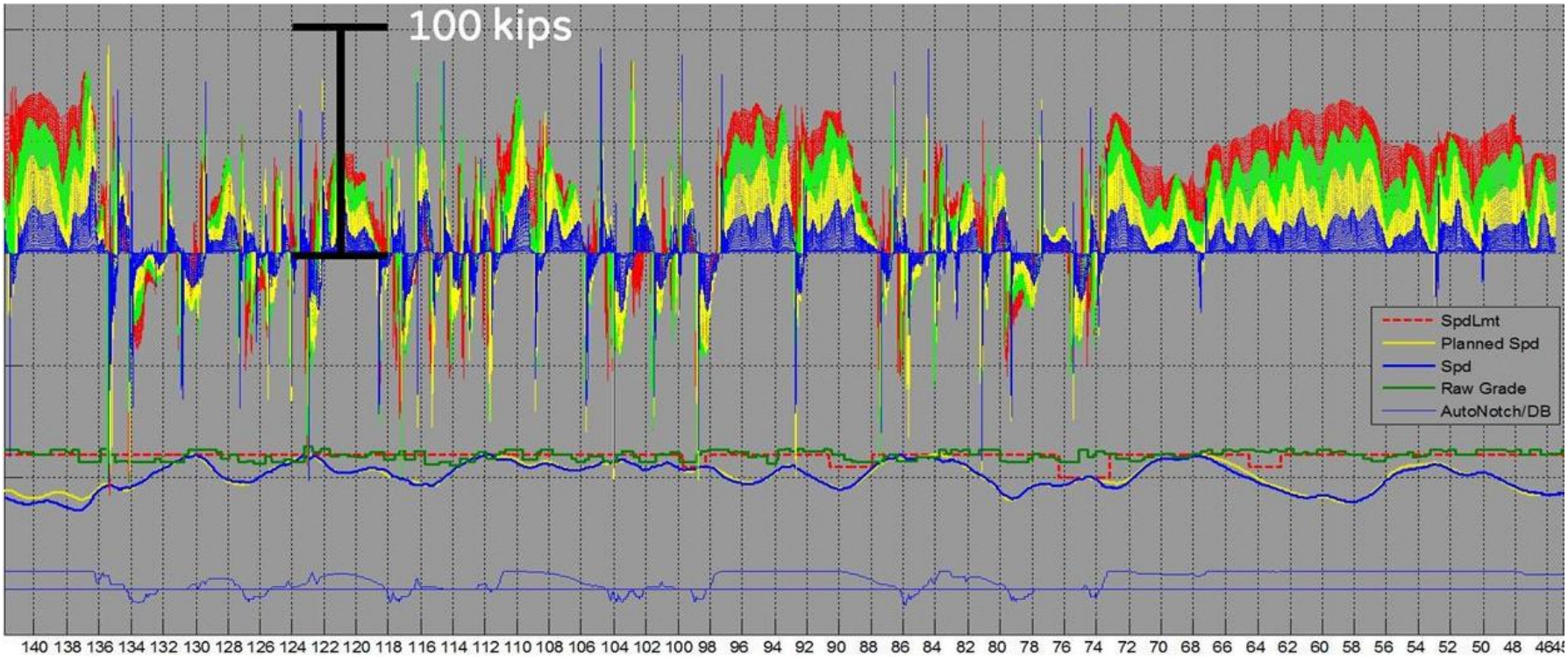




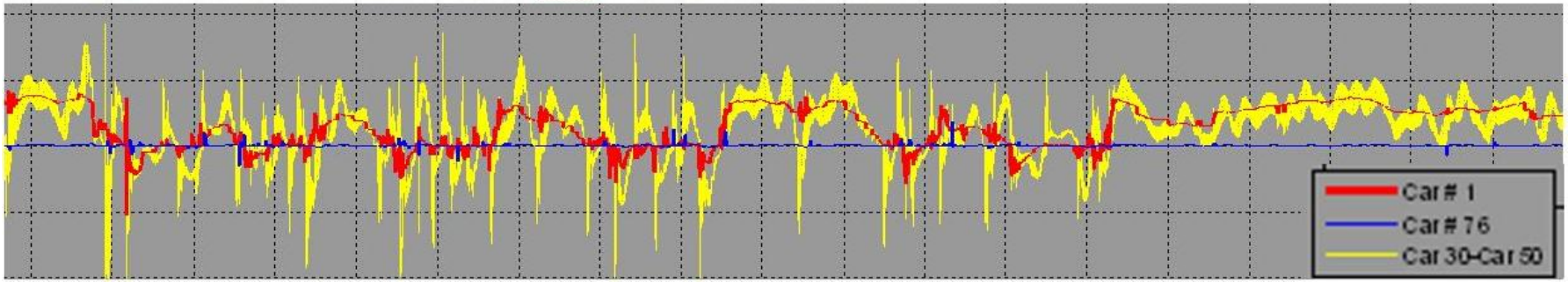
Longitudinal Force Sim: DP Synch vs. Independent



Longitudinal Force Sim: DP Synch vs. Independent



What the Driver feels vs rest of train:



Simulation Validation

Slack detection:
Data systems every 11 cars
100 Sample/Sec
0.1” Resolution

Measured slack data from MP143-135:

GE Simulation force data for MP143-135:

Combined data: Excellent Correlation

LOCOTROL User's Experience: Indications of significantly less Wheel/Rail Wear

Union Pacific: 5% Fuel Savings
Fewer break-in-two's

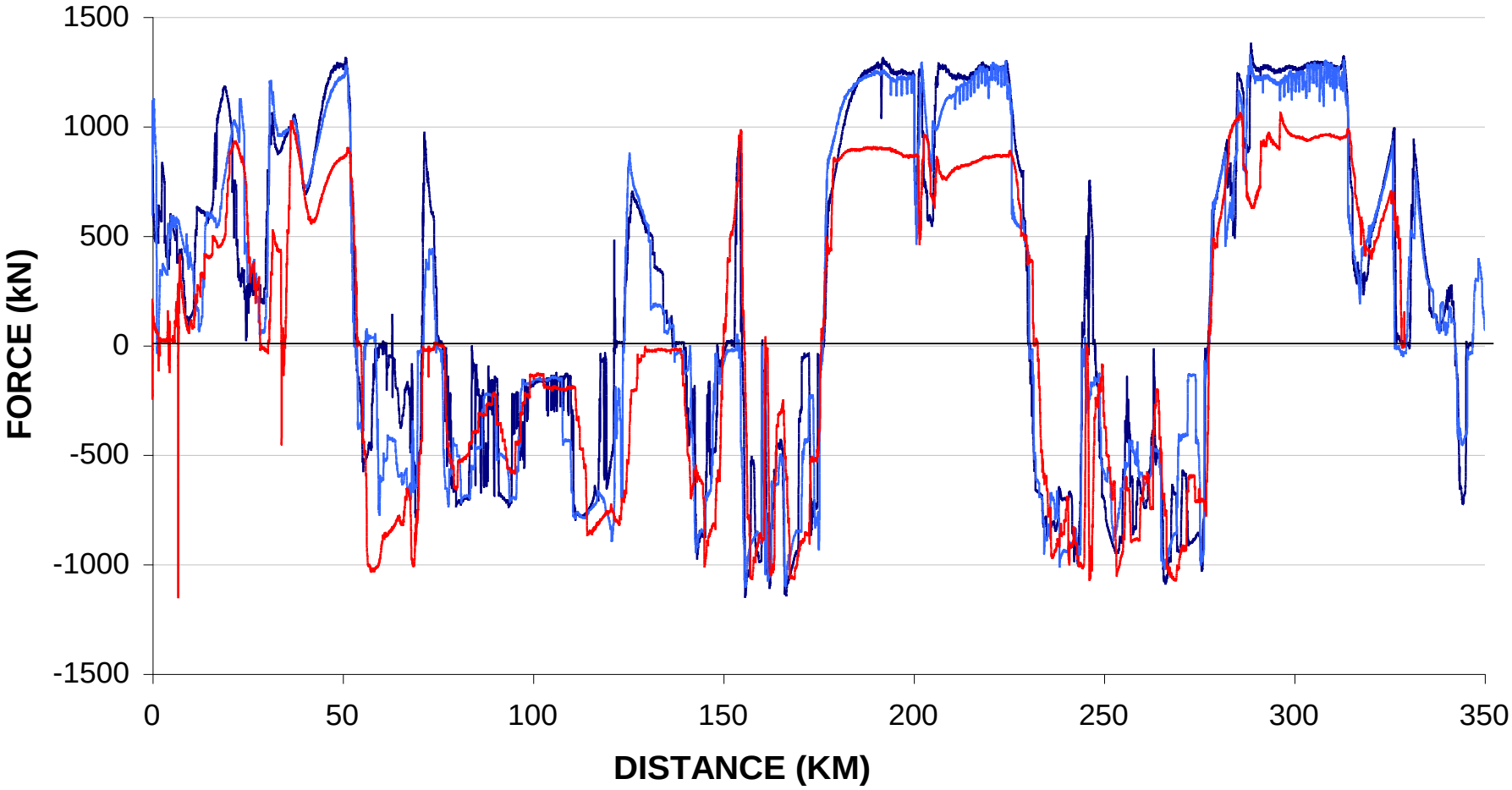
BNSF: 10,000' Intermodal trains - Same Productivity with 2/3 the train starts

CNRR: Running full length trains at -35 C
Eliminate extreme cold delays with 90CFM rule change

CPRR: 6% Fuel Savings
10% Improvement in overall tonnage
11% Improvement in fewer train starts

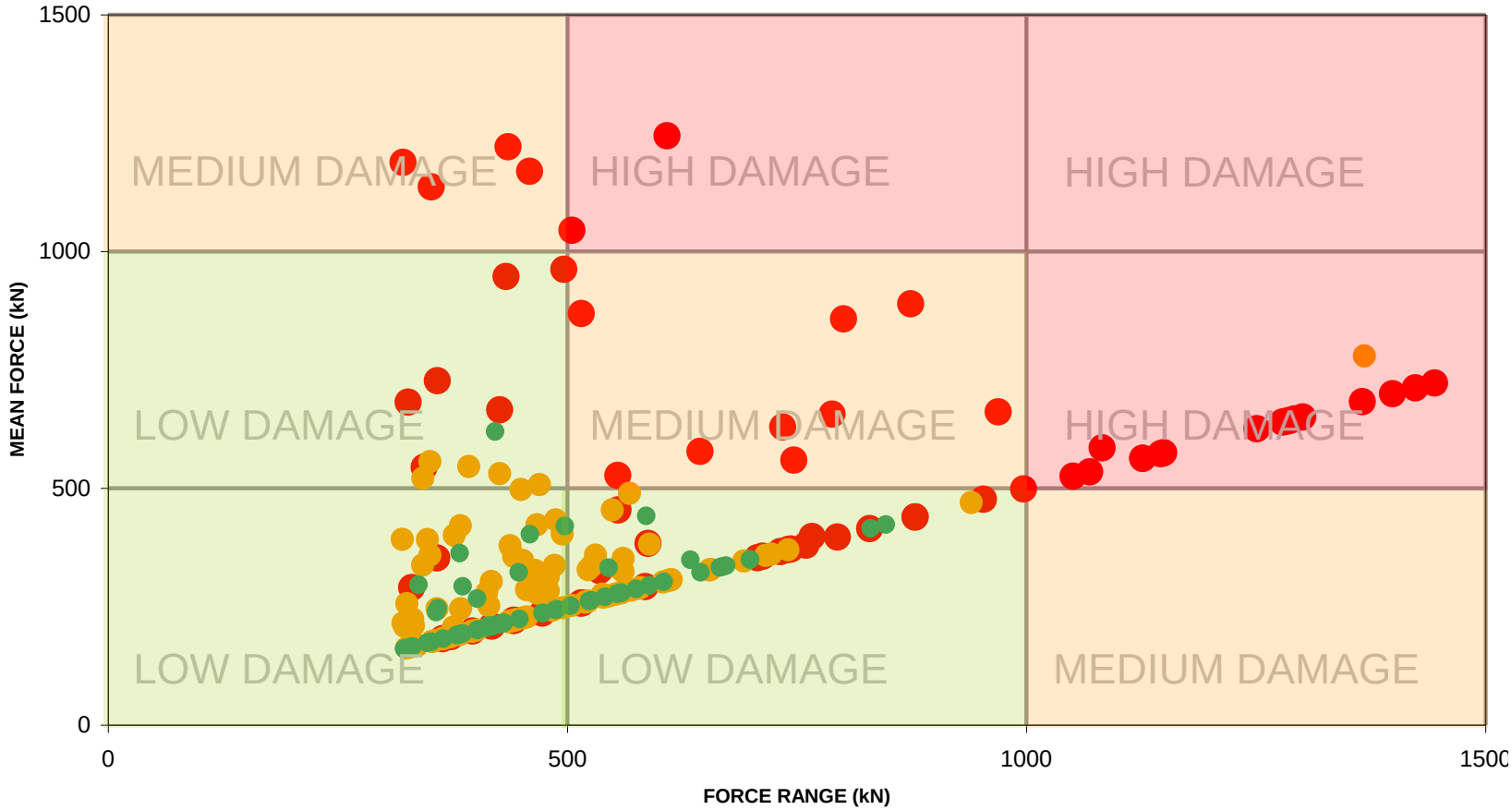
DP: Less Coupler Force (fatigue/break-in-twos)

Head-end Train
DP Train
} (Same train length, mass)

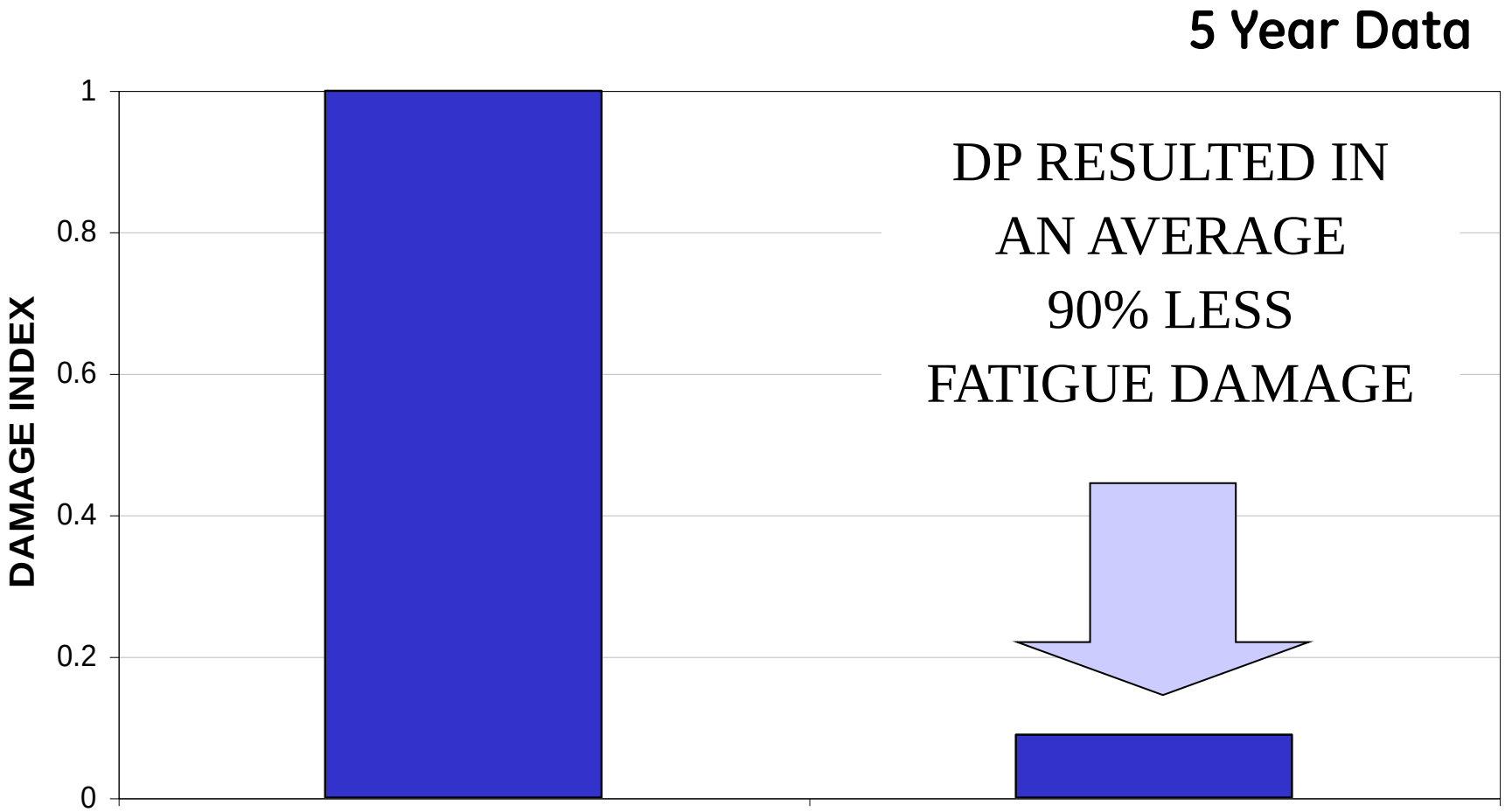


DP: Less Coupler Force (fatigue/break-in-twos)

- Head-end Train
- DP Train
- DP Train with Handling Training (Independent Mode)

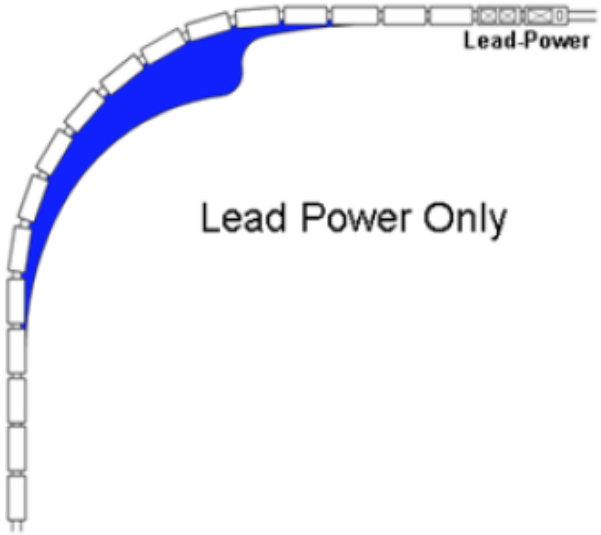


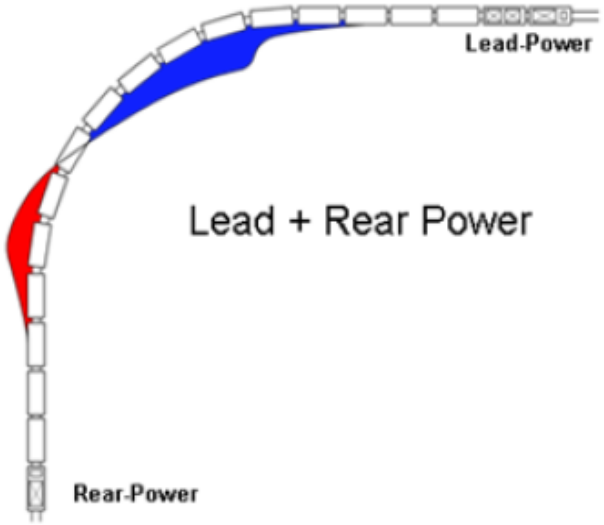
Less Longitudinal Force, Less Coupler Damage

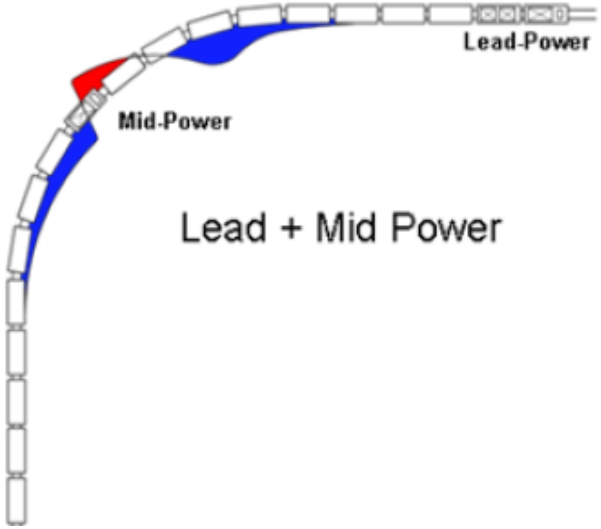


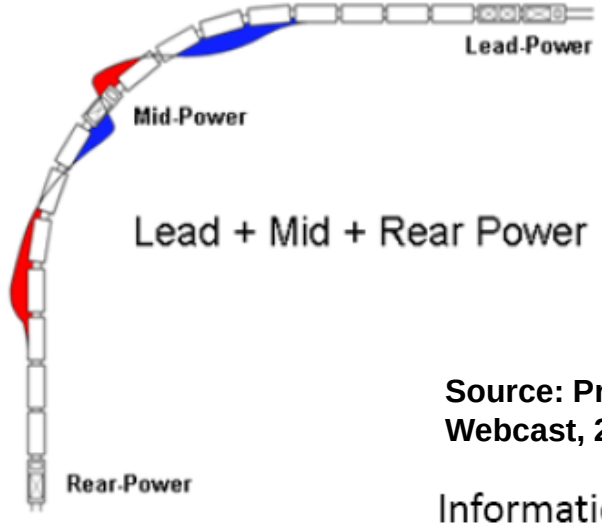
Why Here?

Less Longitudinal Force, less Lateral Force









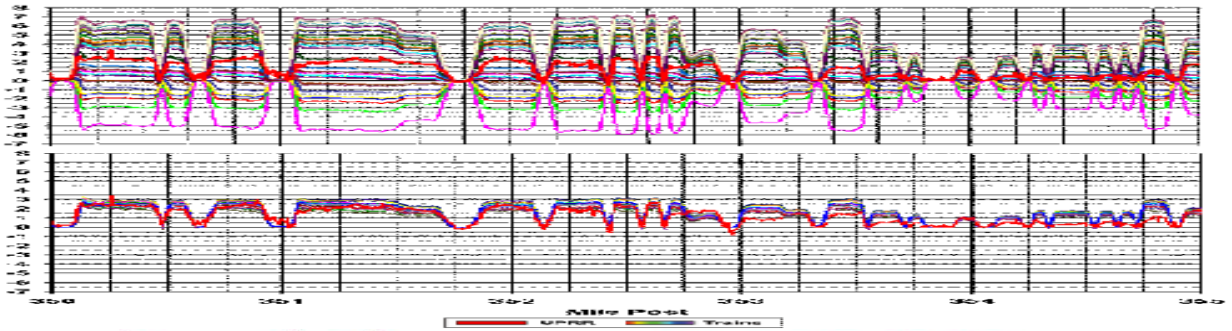
Source: Progressive Railroading Webcast, 28 July 2010

Information on Slide from ARRT

DP and Wheel/Rail Wear

Super elevation range without DP

Super elevation range with DP



Results of Changes @ MP 342

Before

The rail installed in Oct. 2004 and replaced in May 2005.

- The extreme rail wear was seen after only 7 months.

After

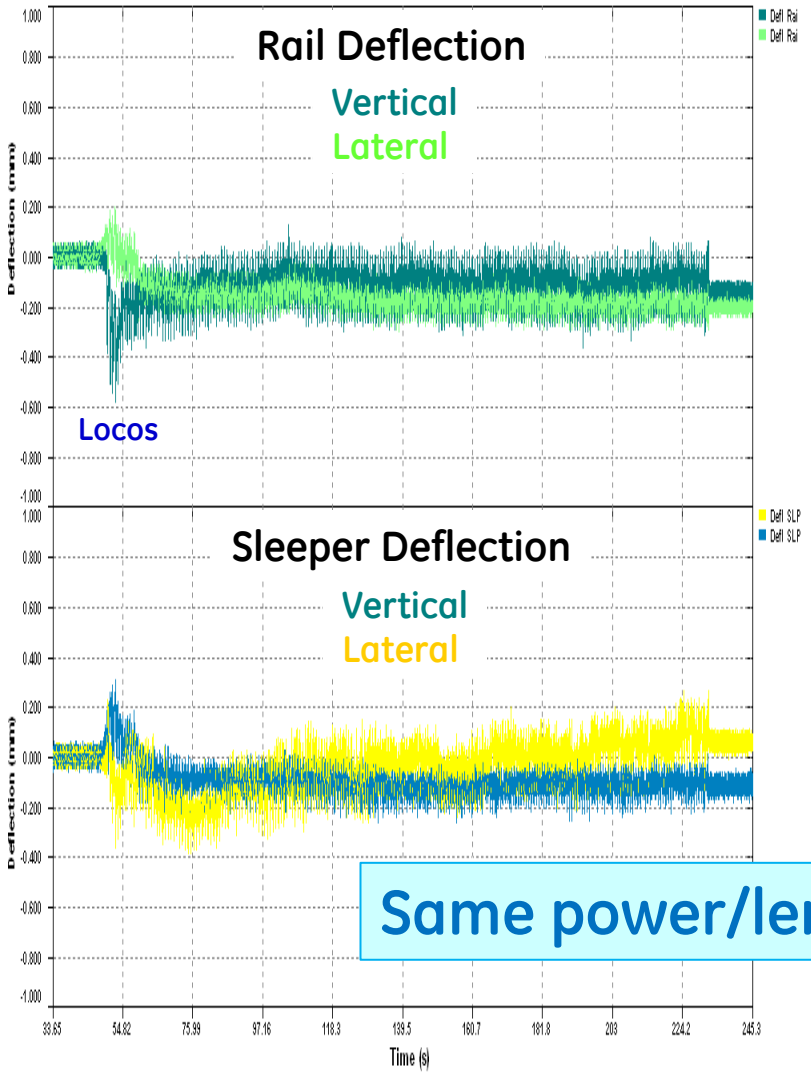
After installation in May of 2005, which is 7 months, the curve rail wear was between 1/32 to 2/32.

- This is a major improvement.
- Rail Life extended from one year to five years.

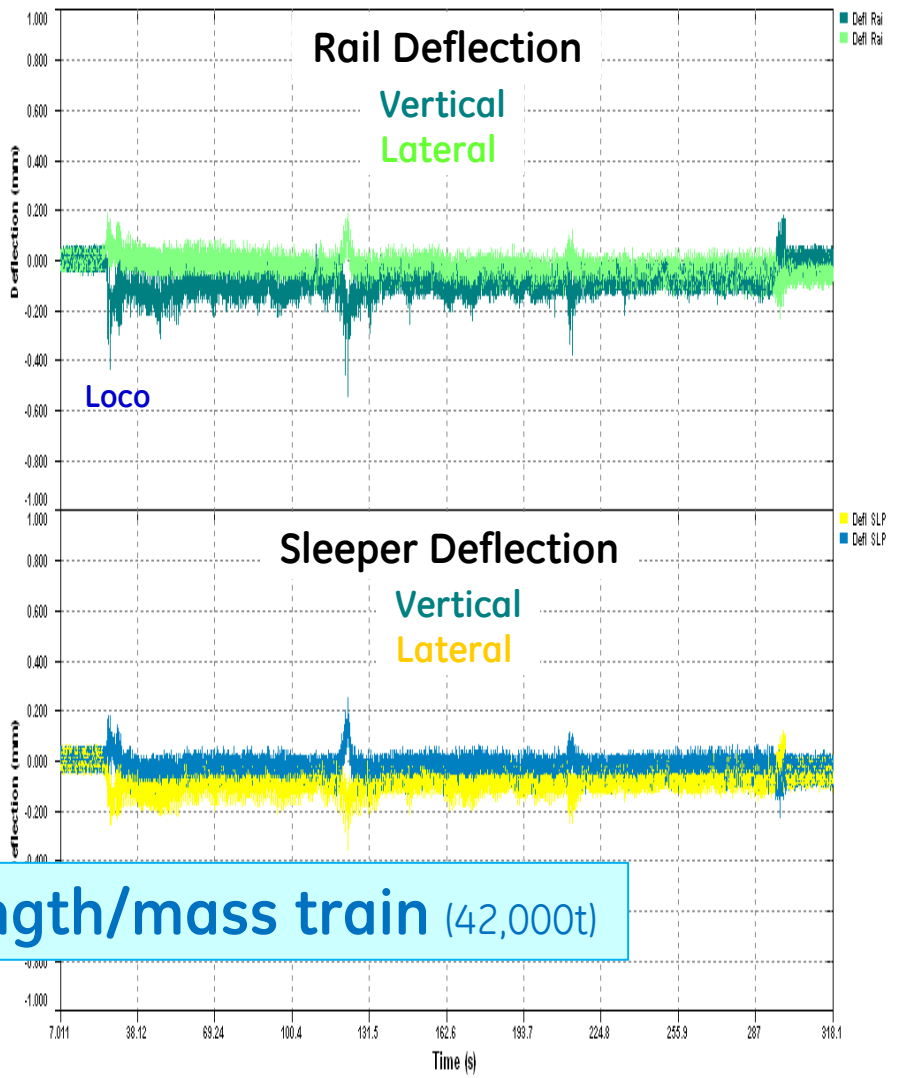
Source: Progressive Railroading webcast , 28 July 2010

DP: Less Infrastructure Damage

Head-end Train



DP Train

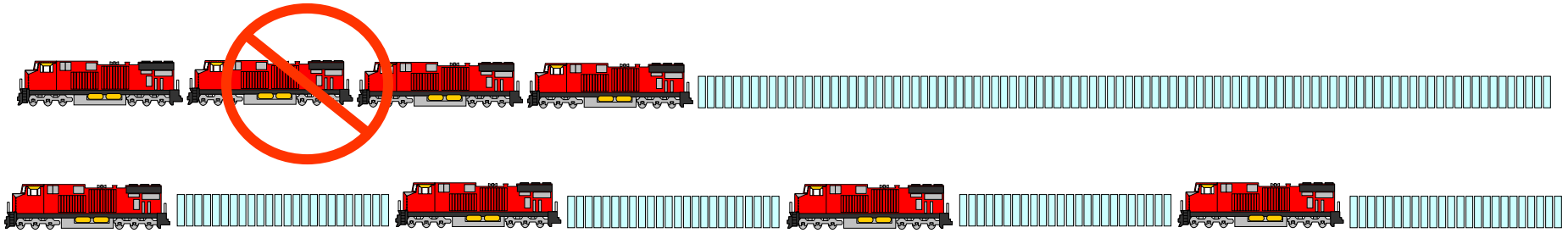


Same power/length/mass train (42,000t)

DP Controls Longitudinal Force

Minimizes damage to train and infrastructure

- Couplers, wheels, boggies?
- Rail, sleepers, road-bed



Why not?

Operational Logistics of distributing locomotive

Action:

Show the benefits

imagination at work