“System Simulation/Emulation” As a Decision Making Tool – A Case Study

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Overview

- **Background**
- **LFE Concept**
- **Feasibility Considerations**
  - Propulsion/Braking System
  - Energy Consumption
- **Simulation Results**
- **Emulation Design**
- **Summary**

Background –
ADA Access to Transit

- **Level Boarding**
  - High-Level platforms
  - Wayside lifts
  - Vehicle-carried lifts
  - Low-Level Platforms with High Blocks
  - Low-Floor Vehicles

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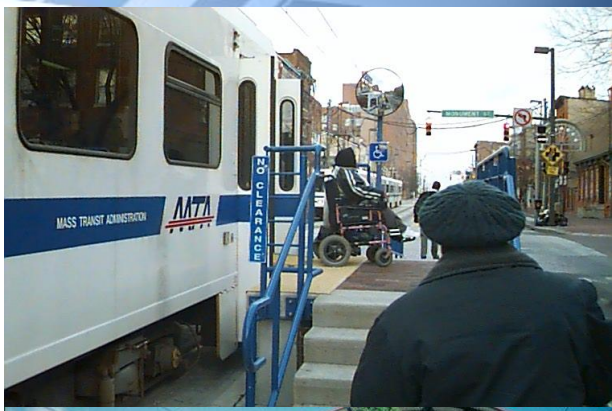
Background –
Low Platform/High Blocks & High Floor LRVs

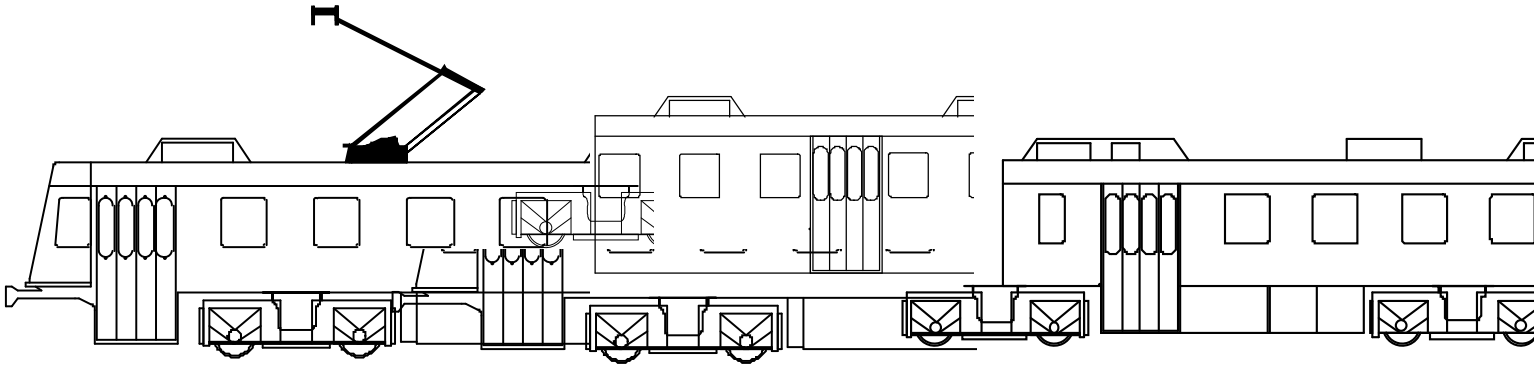
- **Floors 40 inches above top of rail.**
- **Three steps in stair wells.**
- **Dedicated ADA doorway.**
- **Separate boarding area (High blocks with ramps).**
- **Operator intervention typically required.**
- **1-5 minutes per boarding.**



Background –
Low Floor Solution

- **Potential for Improvement**
  - Eliminate high blocks.
  - Reduce operator action, dwell times, etc.
- **The "Low Floor" Solution**
  - 12-14 inches Floor height.
  - 30% - 100% interior Low Floor area.
  - Common doorway for all passengers.
  - **Low Floor LRVs (New Systems/Procurement).**
  - **Low Floor Extensions (Existing systems).**

LFE Concept



Separate existing A and B carbodies, add Low Floor section converting existing Single-Articulated LRV to Double-Articulated LRV. Middle body has low floor.

Low Floor Extension Advantages

- **Extend life of existing fleet**
  - Improve vehicle availability
  - Renew “aesthetics”
- **Increase capacity**
  - 20%-25% passengers
- **Economics**
  - Low-Floor benefits at lower cost
  - 1/3 cost of new LF LRVs
  - Minimal Propulsion modifications

LFE Conceptual Design

- **LFE body & Articulation adds 30’ length, 22,640 lbs, unpowered truck adds 9,526 lbs**
- **Same truck spacing – same clearance**
- **Adds 13 seats and 78 sq. ft. standee space**
- **Hotel load adds 10 kW**
- **AW0 142,200 lbs (empty)**
- **AW1 157,300 lbs (97 pax seated)**
- **AW2 174,300 lbs (207 pax 3ft²/pax)**
- **AW3 191,600 lbs (319 pax 1.5ft²/pax)**

LFE Effects on Existing LRV

- **Increase in Length**
  - Platform, Street running, etc.
  - Auxiliary loads (Lighting, HVAC, doors, battery, air compressor)
- **Increase in Weight (≈30%)**
  - Higher duty/reduced performance for Propulsion system
  - Effect on Braking capacity
  - Energy consumption
  - Crashworthiness

LFE Feasibility Check – System-wide Issues

- **Electrical issues**
  - Propulsion/braking system capacity
  - Energy consumption
  - HVAC/Auxiliary electric/Door controls
- **Mechanical issues**
  - Car clearance envelope (vertical curves)
  - Crashworthiness (LRV ends and new LFE)
- **Operational issues**
  - Rerailing procedure, System capacity, etc.
  - Maintenance issues, Shop limitations, etc.

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LFE Simulation

- **TPerf© Software by DCM, Inc.**
  - **Visual Basic, Windows platform**
  - **Data by spreadsheets – visual confirmation**
  - **Rapid data manipulation, "What-If" scenarios**
  - **Numerical integration using Fixed-time step**
  - **Accurate modeling of non-linear relationships**
  - **Accounts for variations in braking rate vs. speed**
  - **Account for grades, curves, train resistance, speed restrictions, propulsion/brake characteristics, etc.**
  - **Outputs include (*v, t, S, P)* for the track profile**

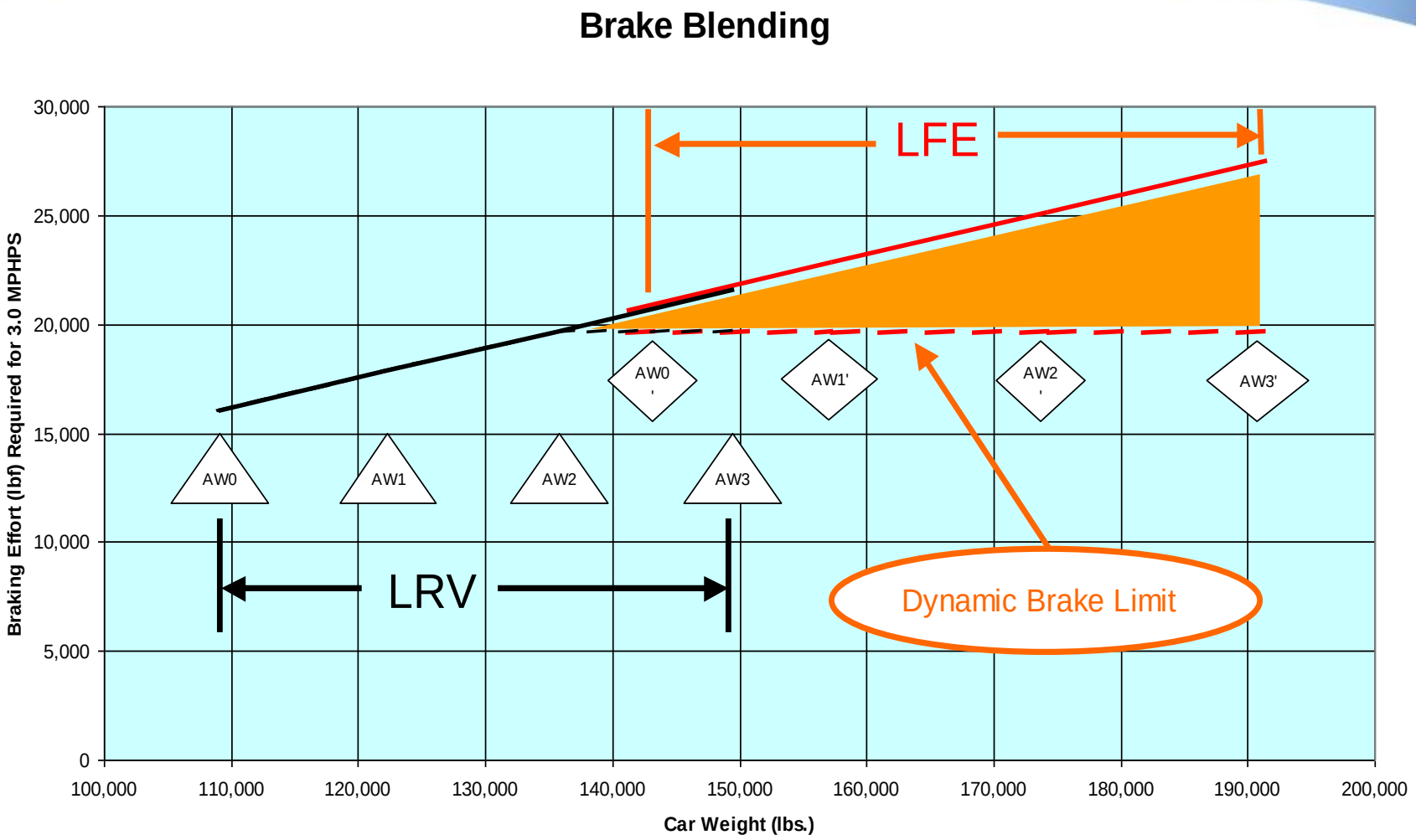
LFE Simulation

- **TPerf© setup parameters**
  - 11 mile track profile ~ *worst grade/curve*
  - Included street running
  - No regeneration ~ *worst case*
  - 30-sec station dwell time
  - Civil speed regulation:
    - Car speed always <= posted speed limits

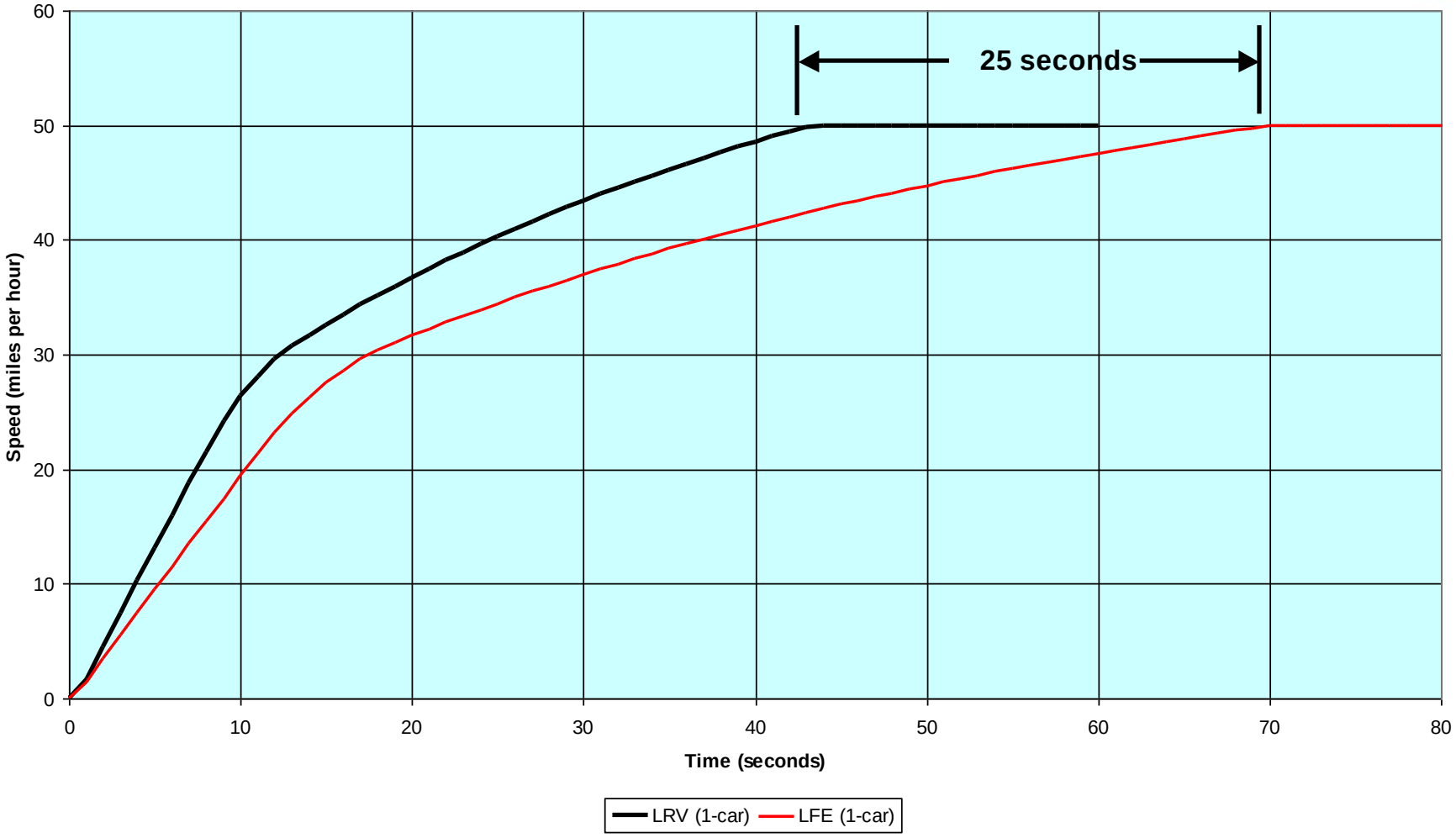
LFE Simulation - *TPerf© Input*

	LFE	LRV	
Car cross area	119	119	Sq. ft.
Car length	120	90	Ft.
Axles	8	6	
AW0	141,166	109,000	Lbs.
AW1	157,286	122,020	Lbs.
AW2	174,336	135,660	Lbs.
AW3	191,541	149,610	Lbs.
ERM	9,680	8,184	Lbs.
Initial acceleration	2.34	3.0	MPHPS
Service brake	3.0	3.0	MPHPS
Jerk limit	3.0	3.0	MPHPSPS
Top speed	50	50	MPH
Auxiliary load	50	40	kW
Line length	10.79	10.79	Miles
Stations	16	16	

LFE Simulation - *TPerf© Input*



LFE Simulation - *TPerf© Output*



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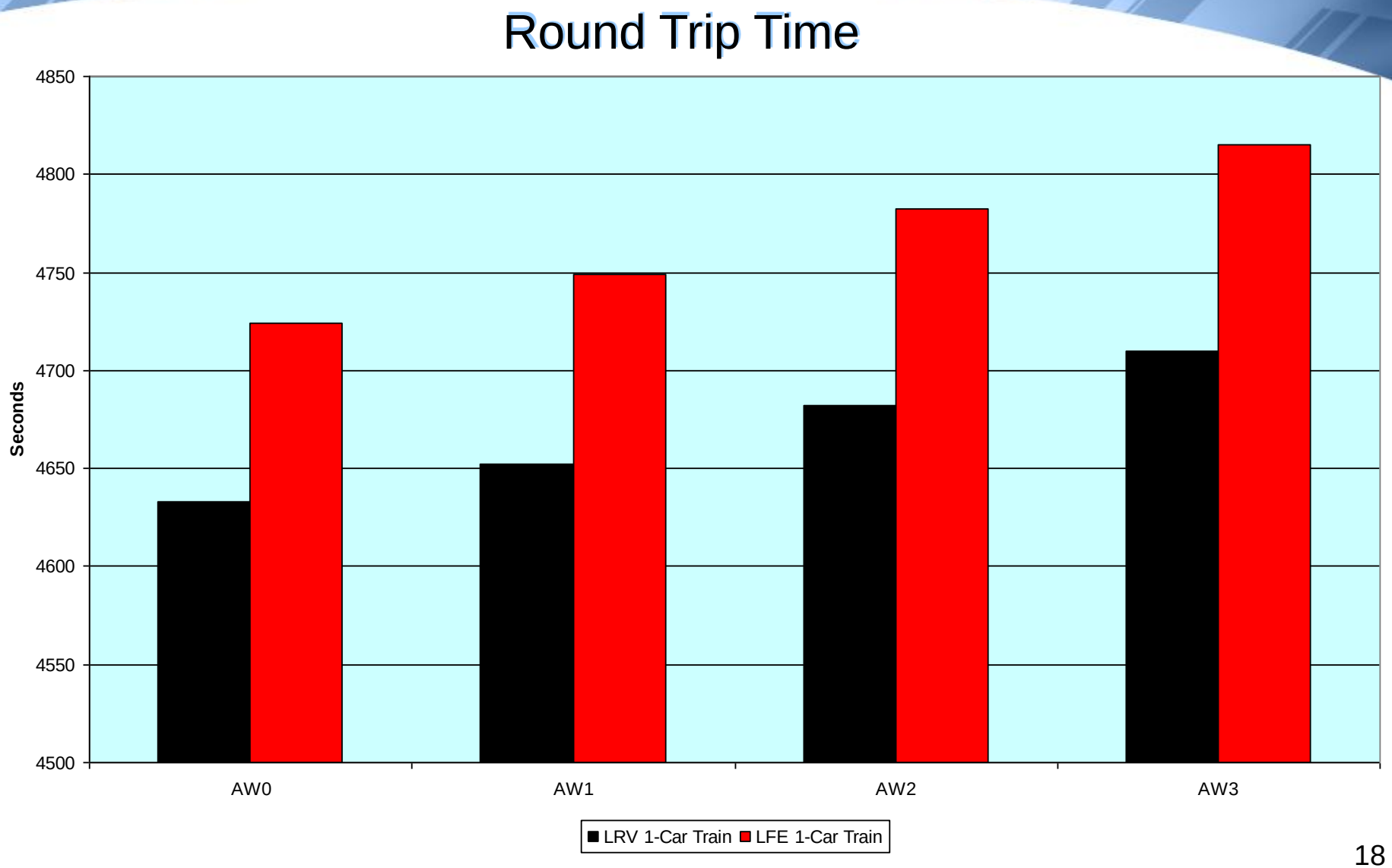
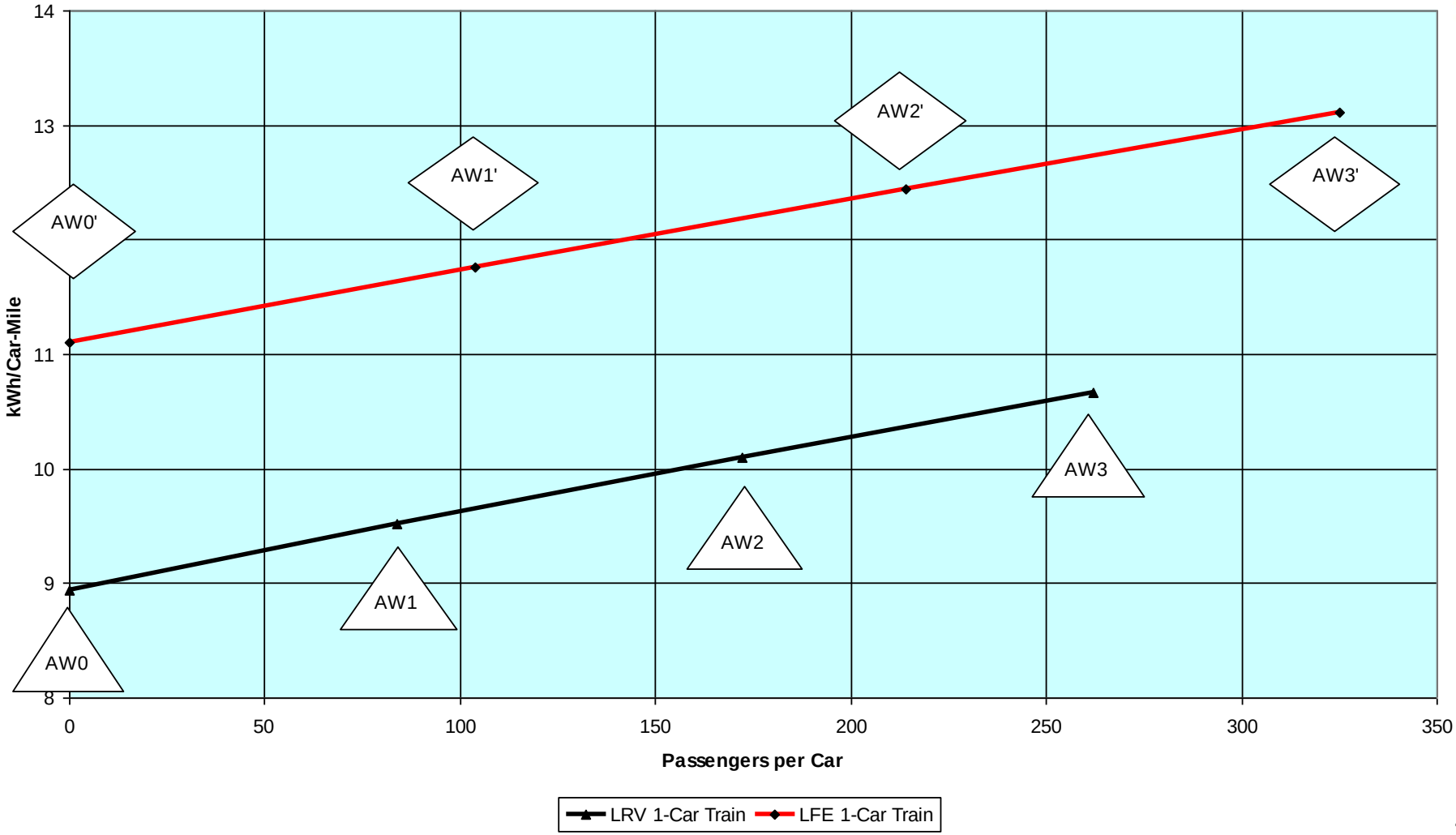


LFE Simulation - *TPerf© Output*



LFE Simulation vs. Emulation

- **Simulation «» software representation**
  - Permits rapid changes to operating conditions and vehicle design
  - Accuracy depends on model detail
- **Emulation «» physical representation**
  - Includes many factors not easily simulated
  - Subject to many uncontrolled factors
  - Provides operating “feel”
  - Lengthy and laborious to modify

LFE Emulation

- **Temporarily modified propulsion and braking response on a 3-car train:**
  - Cut out propulsion on middle car
  - Dummied in load weight signal to increase Tractive and Braking Effort by 117% in end cars
  - Reduced brake response of middle car to 66% of normal
- **Emulated LFE propulsion duty cycle for ≈AW2 (166,600)**
- **Brake rate was matched but friction duty cycle was exceeded due to limitations of test**

LFE Emulation

	Existing LRV	Concept LFE	Emulation	
Car length	90	120	270	Ft.
Axles	6	8	18	
Traction motors	4	4	8	
Weight	109,000	166,600	328,000	Lbs.
ERM	8,184	9,680	24,552	Lbs.
Accel. Mass	117,184	176,280	352,552	
TE Max	16,000	18,800	37,600	lbf
Acceleration	3.0	2.34	2.34	MPHPS
BE Max	16,000	24,100	48,200	lbf
Service brake	3.0	3.0	3.0	MPHPS

LFE Emulation

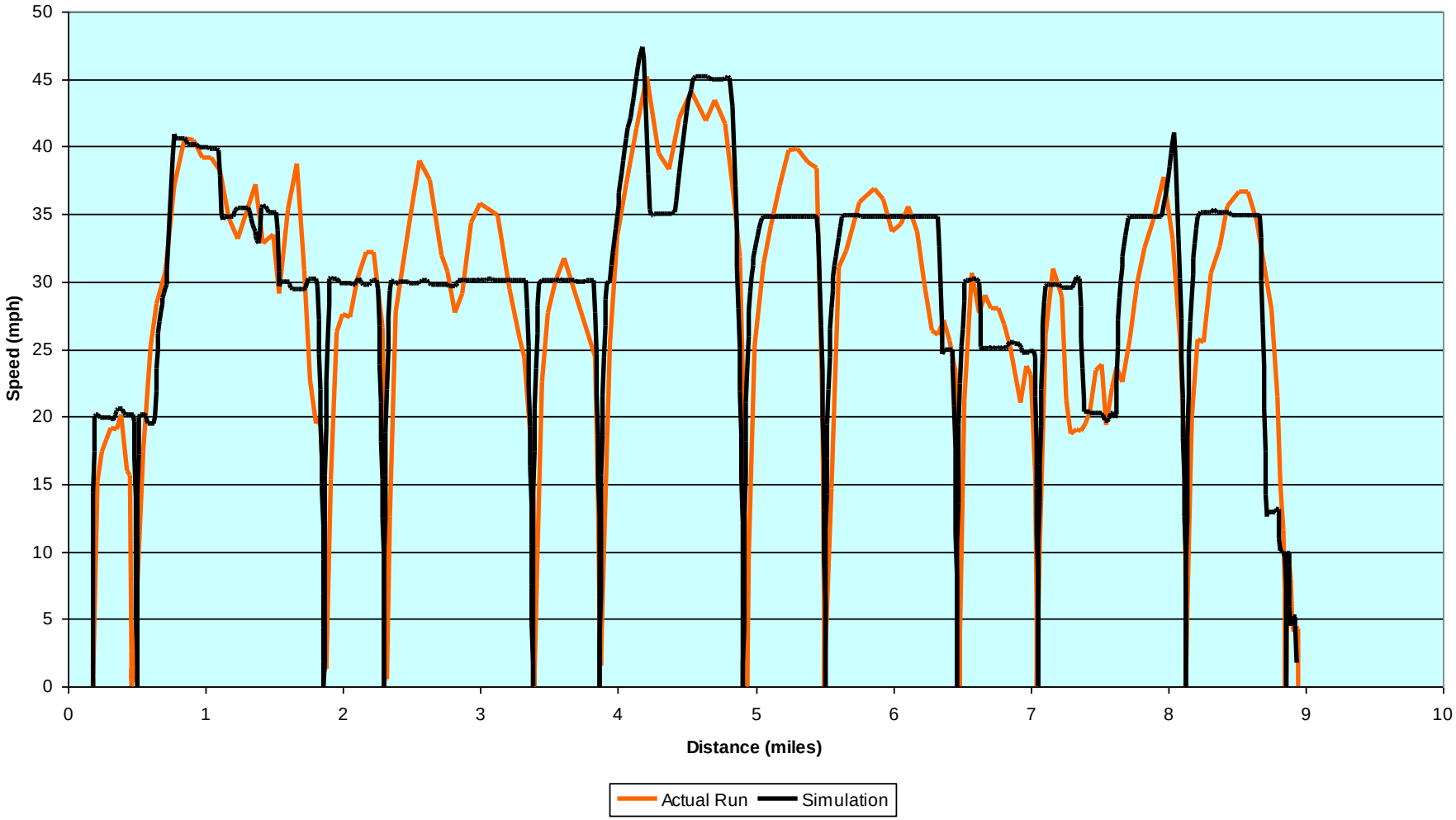
- **“Reverse engineering” to verify actual propulsion/brake response.**
- **Developed clear, detailed test procedure.**
- **Coordination with Safety and Maintenance Departments.**
- **Test train assembled from revenue cars**
- **Emulation verified on first on yard track then on nearby level track.**
- **GPS data logging supported car instrumentation.**

LFE Emulation

- **Operation proceeded smoothly on outbound trip.**
  - Street running yielded unusable data.
  - Good data collected on grade separated right of way.
  - GPS provided speed, location, and time.
- **Traction motors ran cool.**
- **Friction brakes overheated on return trip.**
- **Emulation test cancelled – data collected in normal configuration.**

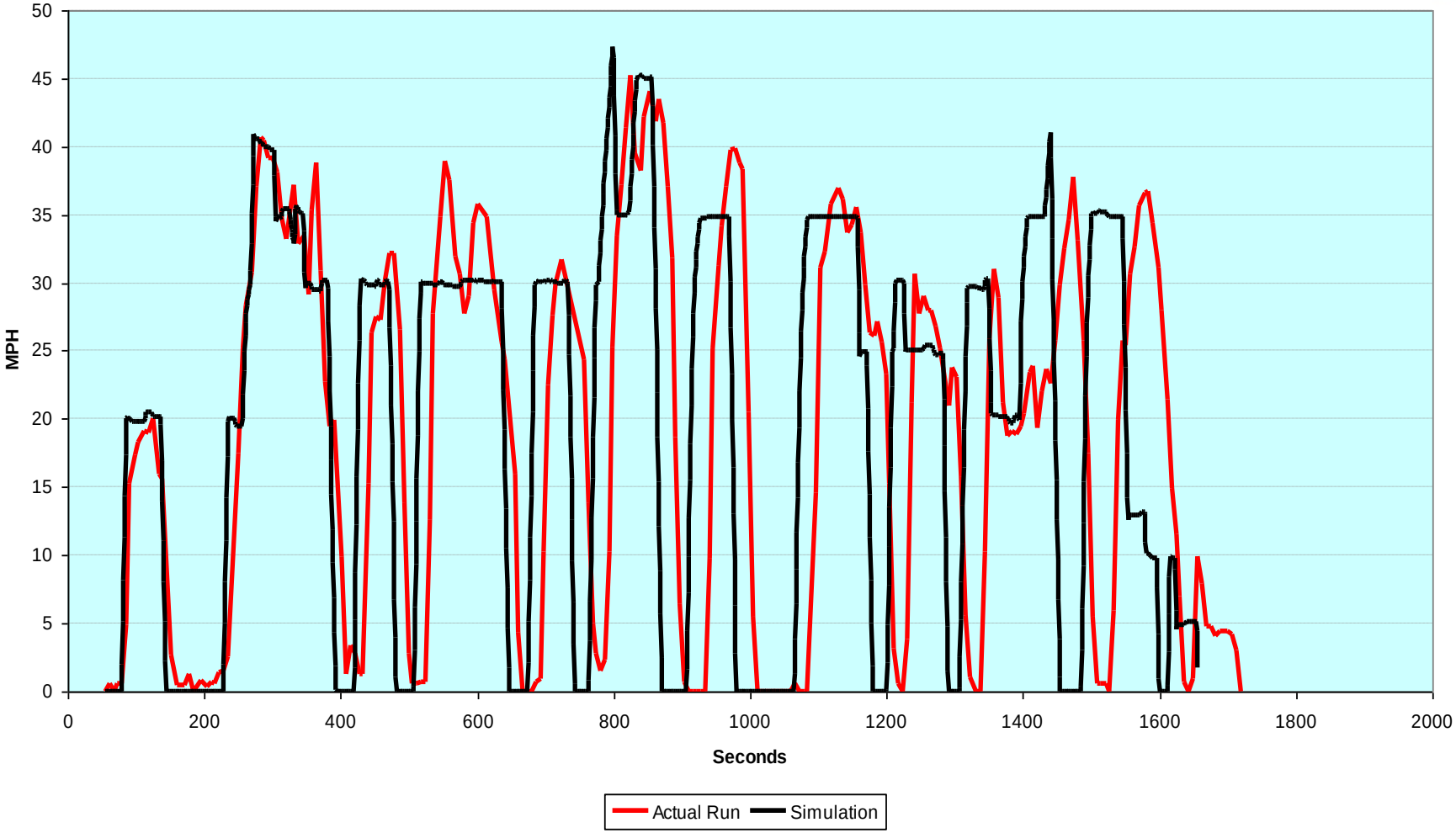
LFE Emulation

Speed versus Distance



LFE Emulation

Speed versus Time



Summary

- **Demonstrated successful use of simulation & emulation as tools in decision making.**
- **Emulation provided opportunity to better understand existing control functions.**
- **Emulation was limited by features of existing control system. Could not handle propulsion and braking in the same test setup.**
- **Simulation does not easily model human judgment.**
- **Simulation was proven accurate and flexible.**