Massachusetts Bay Transportation Authority

Green Line Transformation Program: Future Capacity Study Update

Fiscal & Management Control Board

May 7, 2018

Green Line Transformation Program

Today's Presentations:

1. Future Capacity Study
   - Year Long study focused on identifying opportunities to increase Green Line Customer Capacity
   - Multiphase program has been identified to modernize and increase capacity of the Green Line
2. Green Line Transformation Program
   - Establish a program that integrates safety and reliability needs of today and modernization planning for tomorrow into a single, coordinated capital investment program
   - Current $950m+ of Green Line SGR projects identified in the CIP
3. Award of Program Management & Construction Management team to support this program

Green Line Future Capacity Study Overview

- Goal: To evaluate practical concepts to increase customer carrying capacity on the Green Line
  - Define Infrastructure Constraints
  - Explore Vehicle Configurations
- Recommended path to achieve greater Green Line capacity
- Next Steps we are taking to get there

FOCUS 40
The 2040 Investment Plan for the MBTA

Challenges and Constraints

Infrastructure

- Accessibility
- Curves, Crests and Sags, Tunnels
- Platform Size and Locations
- Maintenance Facilities and Yards
- Bridge Load Ratings
- Power Distribution
- Signals (including GLTPS)
- No Train Operator Simulator

Vehicles

- Duty Cycle (intensity of service)
- Service Reliability
- Infrastructure
- Accessibility
- Fare Collection
- Crash Worthiness
- Vehicle Performance (Acceleration & Braking)
- Design Availability (Can it be built)

Operations

- Schedule
- Platform Crowding
- Peak Period Demand
- Maintenance Requirements
- Bunching and Double Berthing
- Operator Training
- Station Dwell Time
- Onboard Fare Collection

Relationship between Infrastructure and Vehicle Design

- Legacy infrastructure has always influenced vehicle design
  - Lechmere Inner Loop, circa 1920, has been a significant influence on multiple generations of Green Line vehicles and is going away with the GLX
  - The Lechmere Viaduct circa 1905, restricts vehicle loading
  - The diameter of the Park Street Loop defined circa 1895
  - The track spacing and platform layout along Beacon Street in Brookline (C Branch) determined circa 1887
- Front door fare collection constrained door and cab design, going away with AFC 2.0

Identifying Constraining Infrastructure

- A comprehensive review of the Green Line was conducted
- All infrastructure constraints that impact vehicle design and capacity have been identified
  - Bridges and Structures
  - Restrictive Curves
    - Lechmere Inner Loop
    - Lake St Yard and Boston College Station
    - Reservoir Yard
  - Park Street Loop
  - Station and Platform Lengths
  - Vehicle Maintenance Facilities and Storage
  - Power & Signals
  - Track State of Good Repair

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Bridges and Structures

- Restrictive Curves
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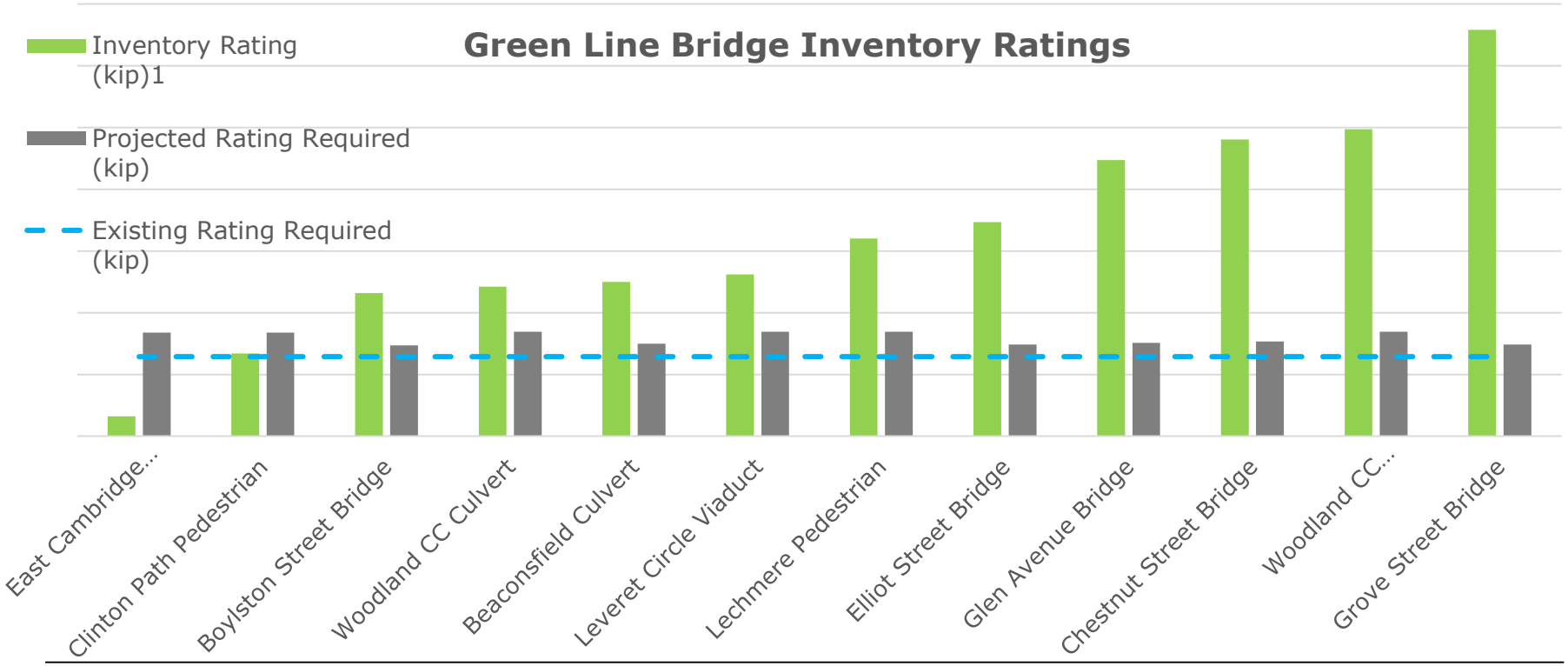
Bridges and Structures

- Longer and heavier cars with different axle spacing will load bridges differently than existing cars

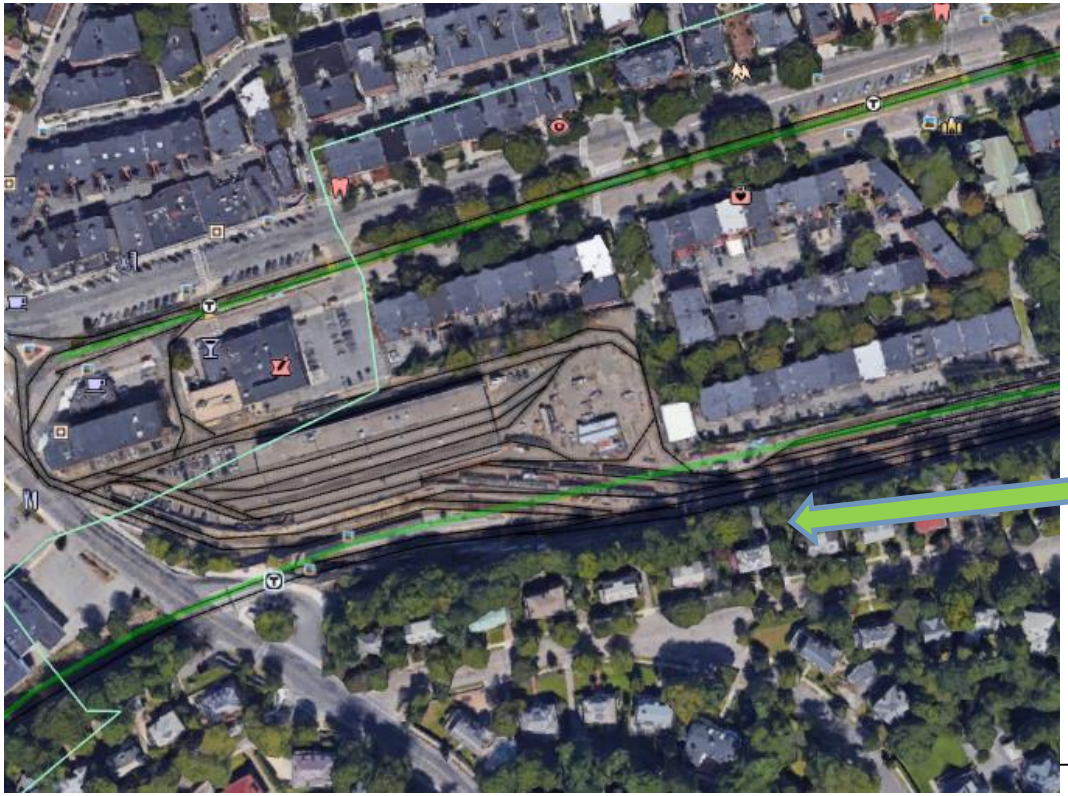


Bridges and Structures - Lechmere Viaduct

- Landmark Bridge between Boston and Cambridge.
- Modernization required because the condition of the bridge restricts current operations to low speeds and limits the number of trains in each direction at any time.

Bridges and Structures - Clinton Path Underpass

- Pedestrian Underpass near Reservoir Station
- Minor upgrades will be needed to support a longer vehicle



Identifying Constraining Infrastructure

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Restrictive Curves

  - Lechmere Inner Loop
  - Lake St Yard and Boston College Station
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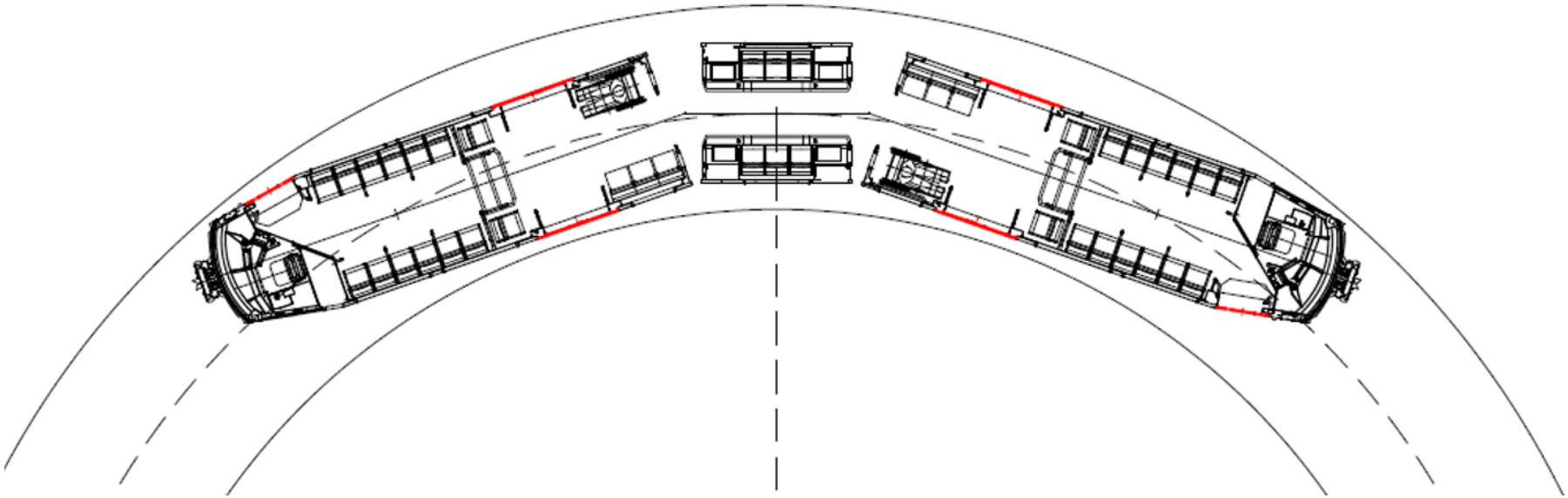
Restrictive Curves

- Tight Curves restrict vehicle design and operations

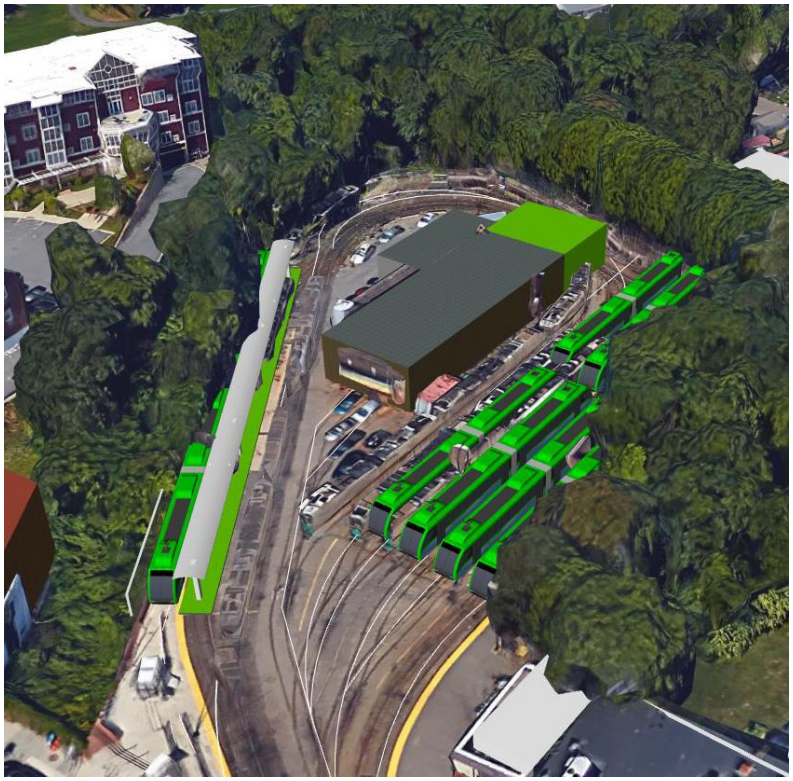


Restrictive Curves

- The 42 ft. Lechmere Inner Loop curve has influenced the design of Green Line vehicles for 96 years and is being removed as part of the GLX project.
- The remaining Tightest Curves Shown Below:

Radius	Location	Name
45	*Reservoir Yard*	*West Wye Curve 97*
45	*Lake St Yard*	*Curve 16*
45	*Lake St Yard*	*Inner Loop*
46	*Lake St Yard*	*Curve 13*
47	Park St	Park St Loop
49	Government Center	Brattle Loop

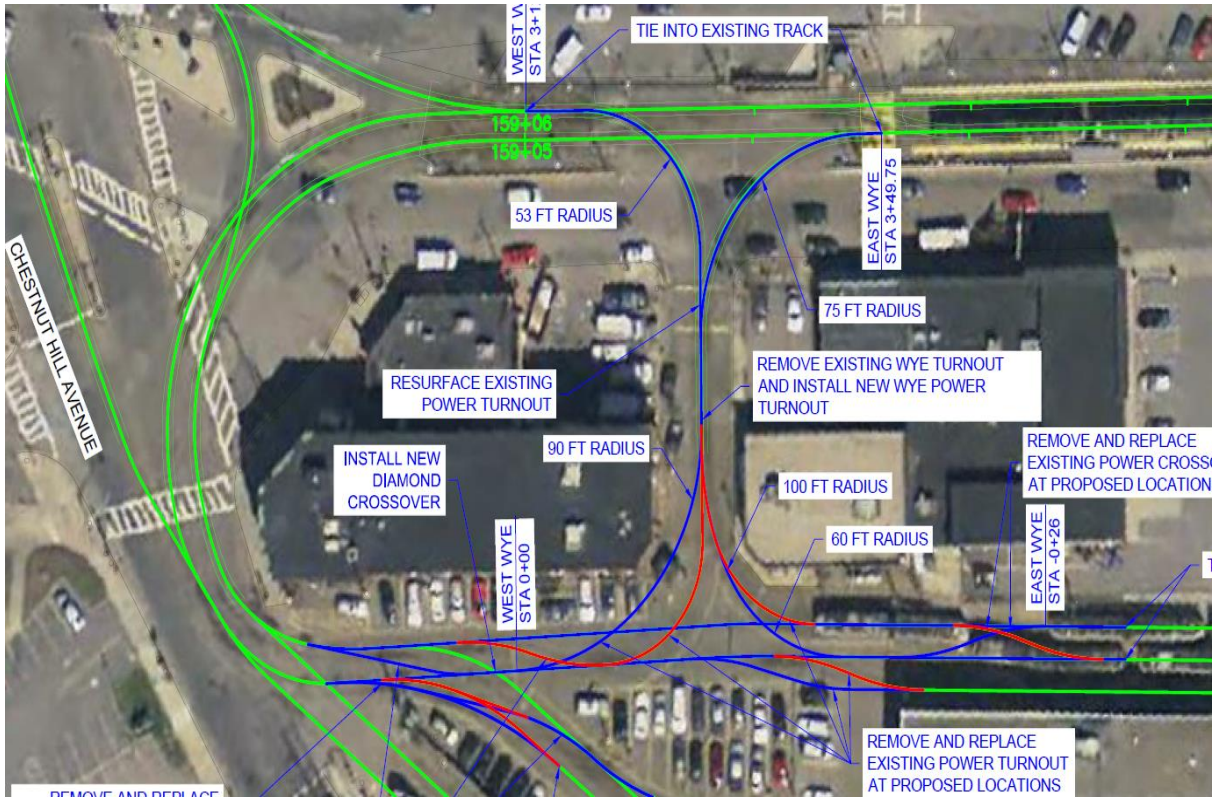
Restrictive Curves - Lake St Yard & BC Station



- Lake Street Yard Loops are 45ft. curves that will be the tightest curves in the system after GLX opens
- Inbound and Outbound platforms are separated and both platforms are on curves and too short
- Expanding the yard by eliminating the loop will provide more vehicle storage and a better BC Station

Restrictive Curves - Reservoir Yard

- Reservoir yard also has 45 foot curve that will be the tightest in the system.
- A proposed plan is shown below.



Existing Track to Remain, Existing Track to be Removed, New Track to be Installed

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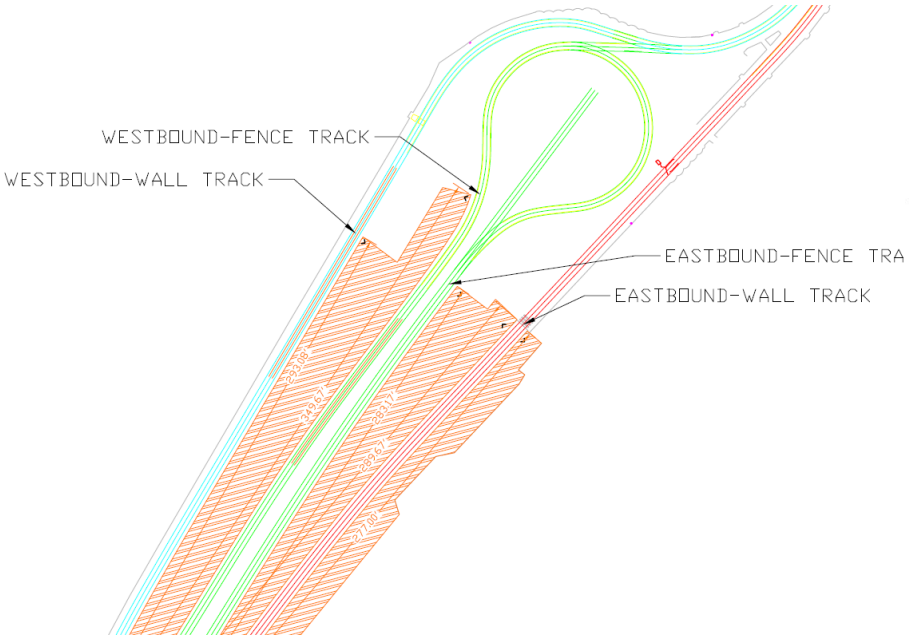
Park Street Loop

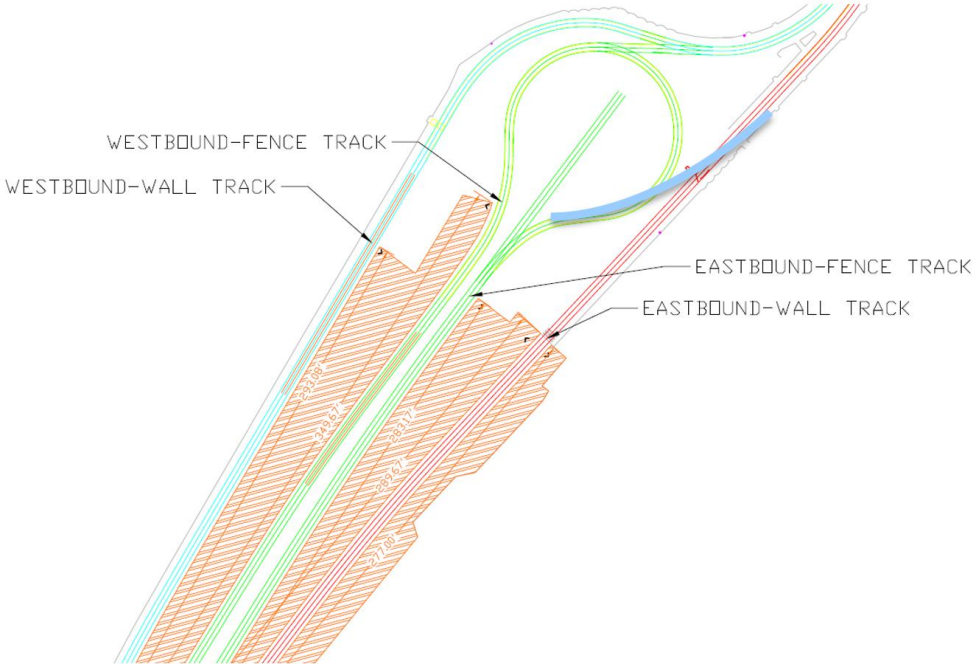
  - Station and Platform Lengths
  - Vehicle Maintenance Facilities and Storage
  - Power & Signals
  - Track State of Good Repair

Park Street Loop

Existing



Proposed



- The Park Street Loop at 47 ft. is needed to maintain operational flexibility
- A new cross over will be necessary to efficiently utilize both platforms

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Station and Platform Lengths

- Vehicle Maintenance Facilities and Storage
- Power & Signals
- Track State of Good Repair

Stations and Platforms

- 34 Platforms are Under 225 Feet
- 225 feet is the length required to fully berth current vehicles as three car trains

Central Subway

Platform	(ft.)
Boylston (EB)	210
Science Park (EB)	220
Science Park (WB)	222

D-Line

Platform	(ft.)
Brookline Hills (EB)	214
Fenway (WB)	223
Reservoir (WB)	223

E-Line

Platform	(ft.)
Heath Street (EB)	131

C-Line

Platform	(ft.)
Cleveland Circle (EB)	113
Cleveland Circle (WB)	136
St. Paul Street (EB)	195
Washington Square (WB)	200
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B-Line

Platform	(ft.)
Boston College (EB)	130
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Blandford Street (EB)	197
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Vehicle Maintenance Facilities and Storage

  - Power & Signals
  - Track State of Good Repair

Vehicle Maintenance Facilities and Storage

- Shop equipment such as lifts and roof access mezzanines are positioned to maintain the existing fleets of 75 foot cars with three trucks
  - Riverside, Reservoir, Lake Street & GLX
- Longer vehicles with more trucks will require new lifts and new storage strategies

Power and Signals

Signals: Legacy Signals limit vehicle operations

- Continue our $350M+ Green Line signals modernization program
- New Vehicles must operate with Green Line Train Protection (GLTP) System

Power: Running more trains requires more electrical current which puts more stress on our distribution network

- Power Capacity analysis is planned to define what cable and wiring upgrades are needed now and for the future

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Track State of Good Repair

Track State of Good Repair

- **Track conditions can limit operations of a fully accessible vehicle**
  - Continue investments of $150M+ currently dedicated to SGR of Green line track
  - Additional track upgrades are anticipated to be need to return all Green Line track to good condition

Concept Vehicles

- New Vehicle Goals
- Concept Vehicles Reviewed
- Evaluation Criteria
- Recommended Concept Vehicle
- Detailed Conceptual Analysis Examples
- System Operational Modeling

Concept Vehicles

New Vehicle Goals

- Concept Vehicles Reviewed
- Evaluation Criteria
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New Concept Vehicle Goals

- Availability from multiple vehicle manufactures
- 100% Low Floor and Accessible
- Provide a full width operating Cab
- Maximize passenger capacity
- Maximize door openings and boarding efficiency
- Ability to negotiate curves, crests, sags, clearances and grades
- Limit axle loads to minimize impacts on track and structures
- Meet duty cycle and operational tempo needed for GL operations
- Minimize operating and maintenance resources

Concept Vehicles

- New Vehicle Goals

Concept Vehicles Reviewed

- Evaluation Criteria
- Recommended Concept Vehicle
- Detailed Conceptual Analysis Examples
- System Operational Modeling

Concept Vehicles

Concept A

Concept C

Concept D

Concept E

Concept F

Type 8/9

Concept H

Concept I

Concept Vehicles

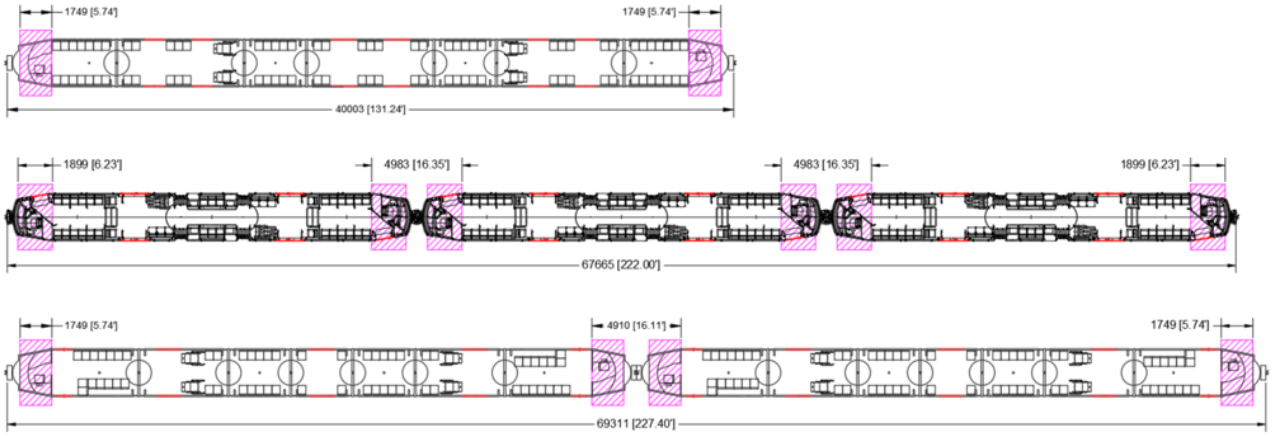
- New Vehicle Goals
- Concept Vehicles Reviewed
- Recommended Concept Vehicle

Evaluation Criteria

- Detailed Conceptual Analysis
- System Operational Modeling

Evaluation Criteria

- Infrastructure Changes
- Future Capacity
- Dwell Time Impacts
- Fleet Maintenance Costs
- Fleet Operating Costs
- Predicted Reliability
- Operating Impact on Infrastructure
- Fleet Procurement Costs
- Procurement Risk
- Technical Risk
- Industry Standards
- Interoperability



Concept Vehicles

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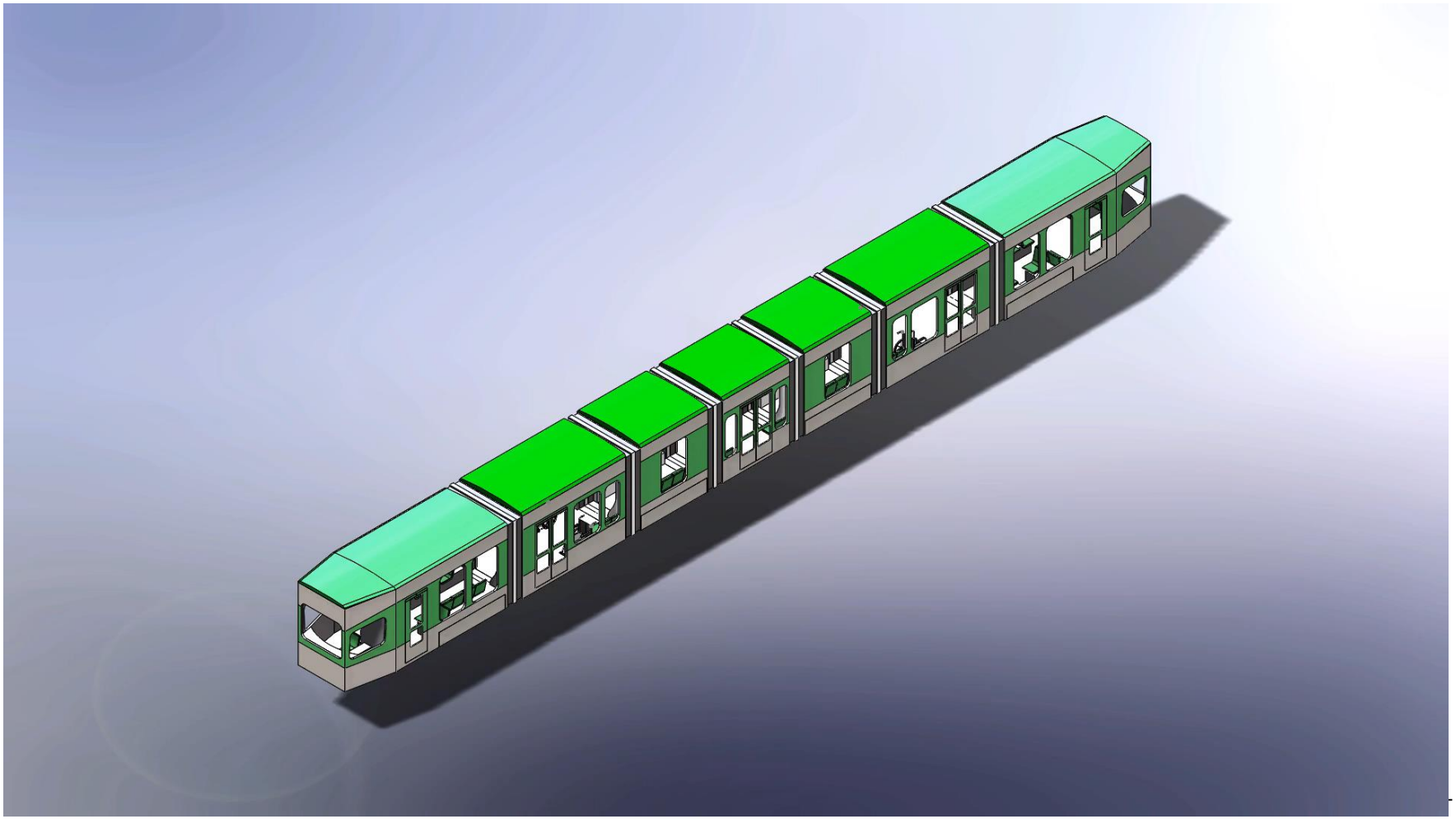
Recommended Concept Vehicle

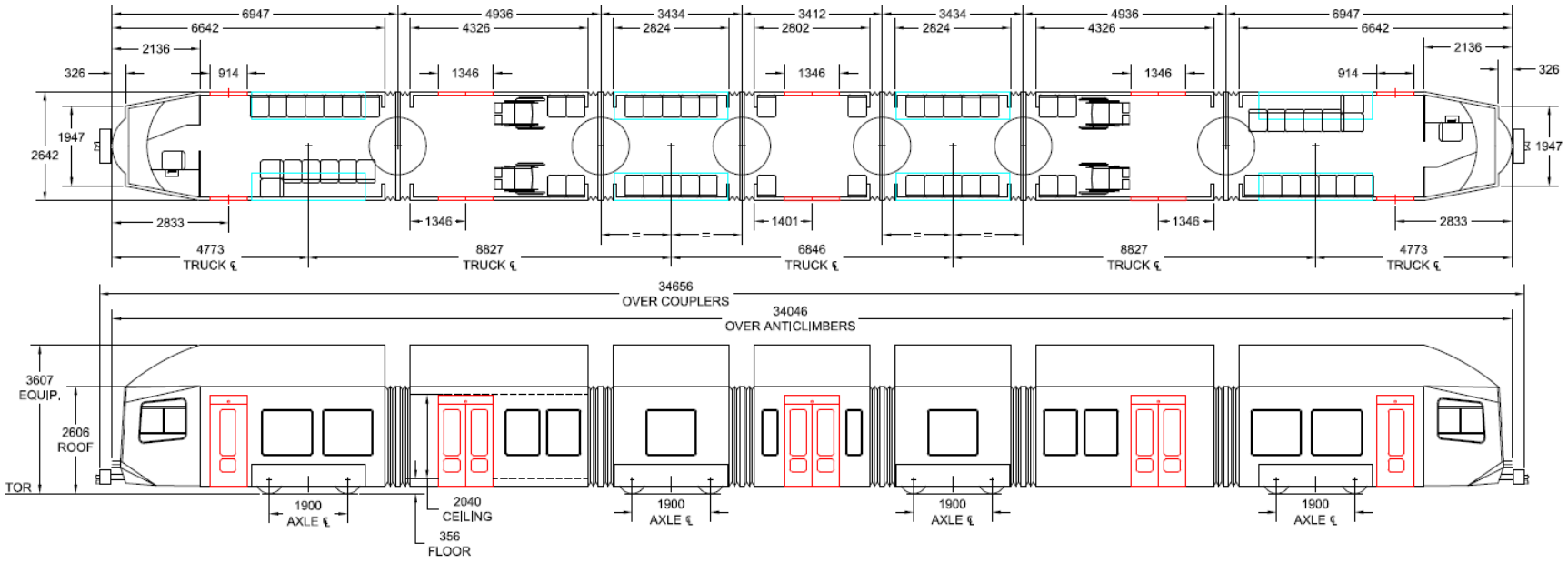
- Detailed Conceptual Analysis
- System Operational Modeling

Recommended Concept Vehicle - Concept D



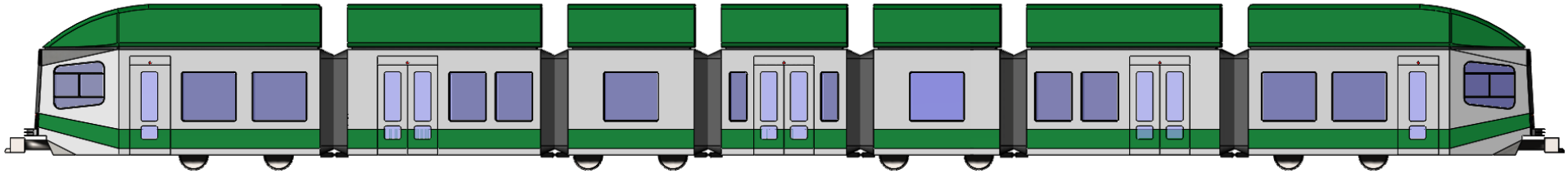
Recommended Concept Vehicle - Details

- **Fully Accessible 100% Low Floor, no stairs**
- **Same Passenger Capacity as a two car Type 8/9 train**
- 7 Sections with 4 Powered Trucks
- 5 Door Openings per side
- Full Width Cab at each end



Recommended Concept Vehicle- Industry Lineage

Rail vehicle manufactures offer modular designs like recommended concept vehicle



Concept Vehicles

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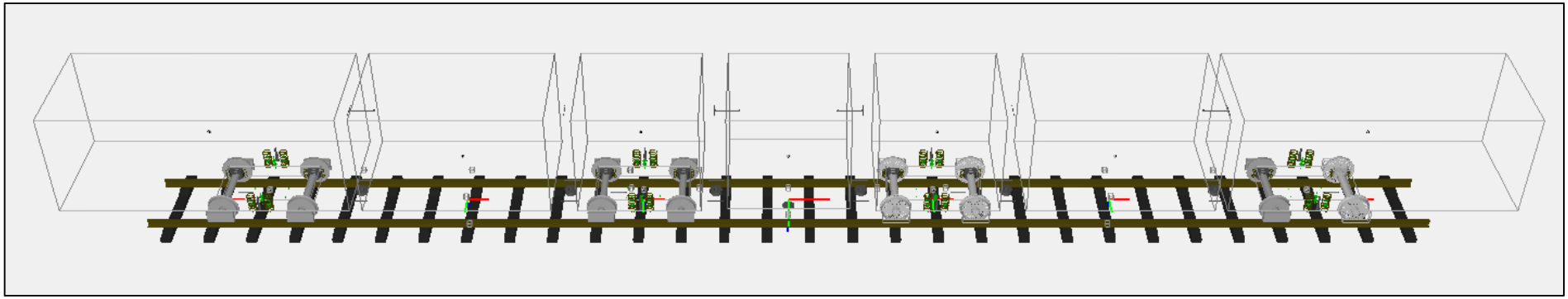
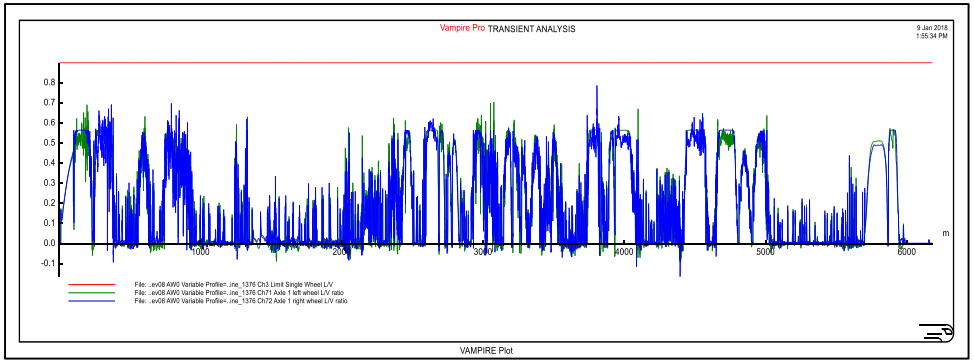
Detailed Conceptual Analysis Examples

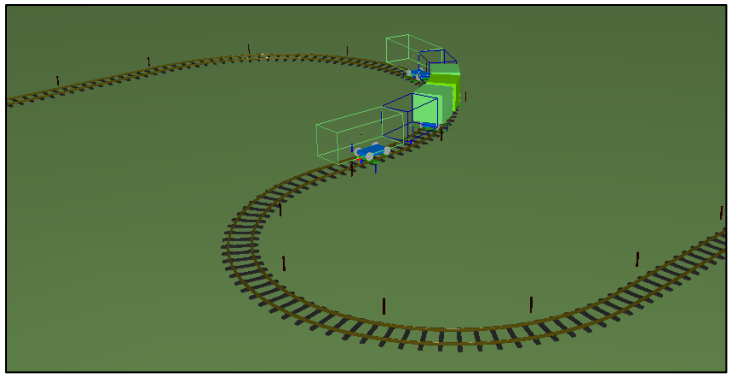
- System Operational Modeling

Detailed Conceptual Analysis – Dynamic Modeling

- Dynamic simulations were conducted
- Simulations included carious track conditions including curving and stability
- Simulations demonstrated that Concept D is viable in the MBTA Green Line operating environment

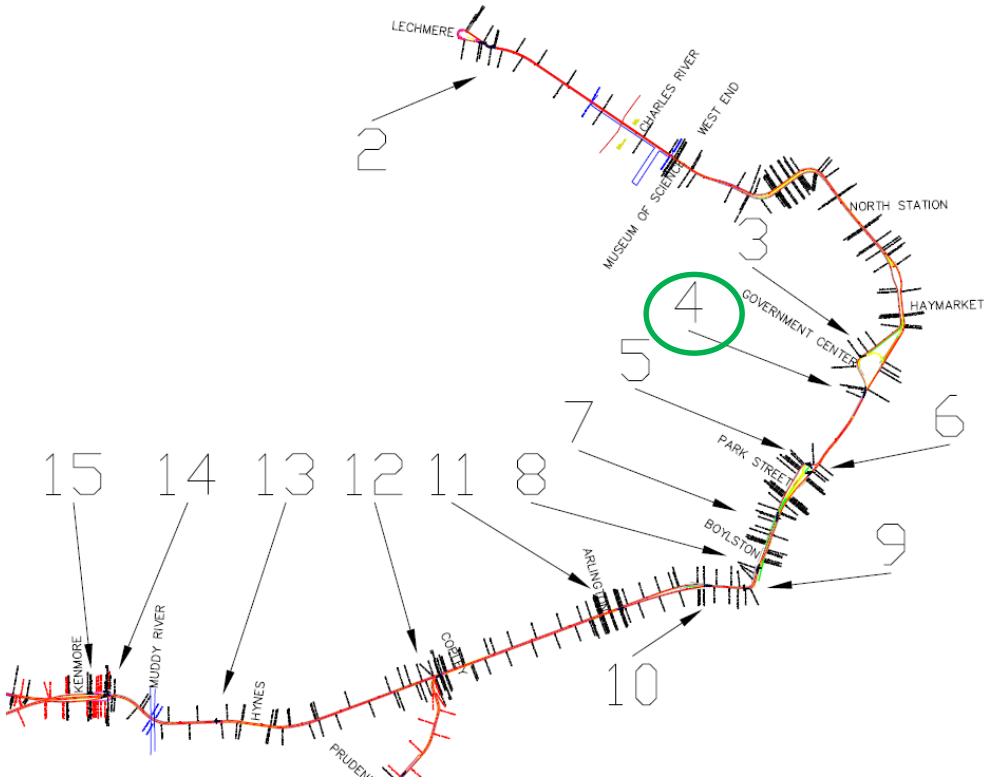


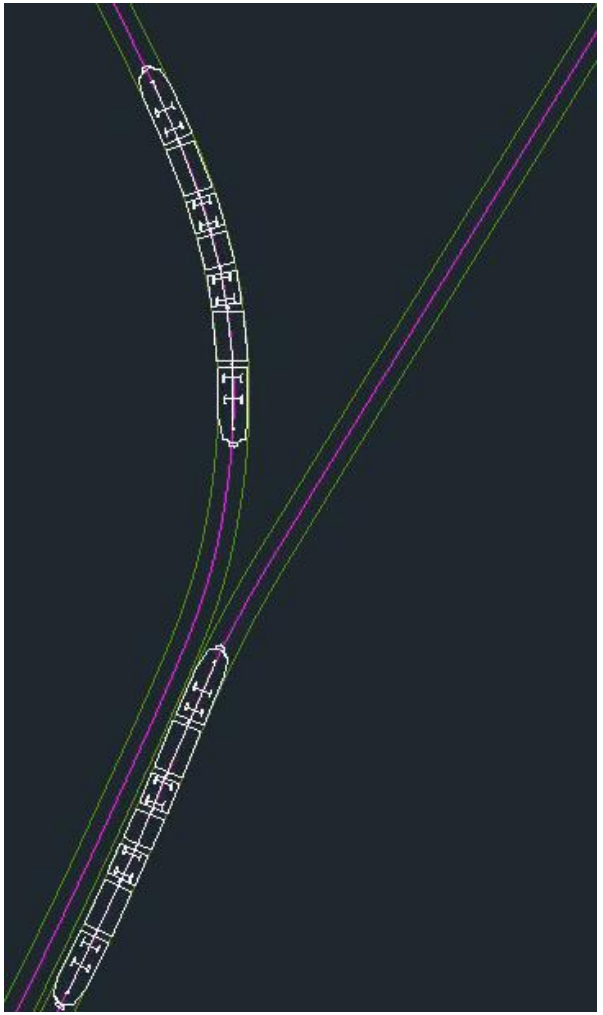




Detailed Conceptual Analysis - Clearance

- Two Concept D vehicles operating west of Government Center through cloud of Park Street

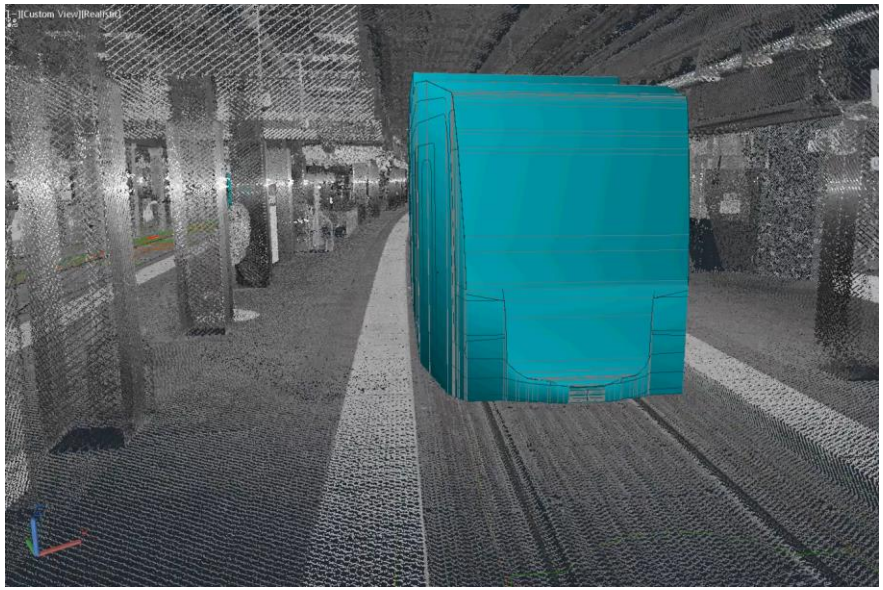


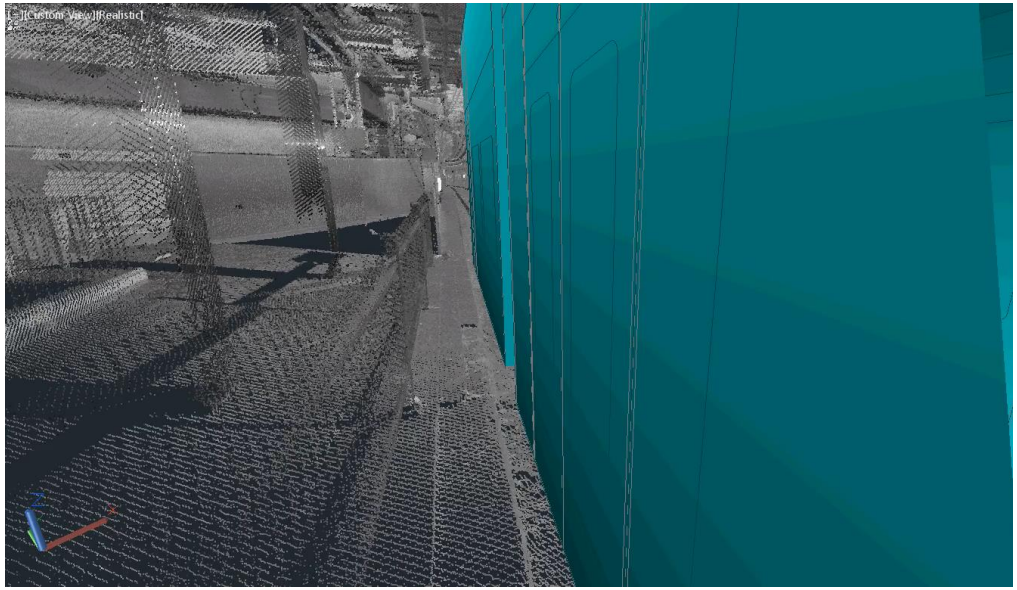


West of Government Center Station
Location 4

Detailed Conceptual Analysis - Park Street

- Concept D operating through actual MBTA collected LIDAR point cloud of Park Street

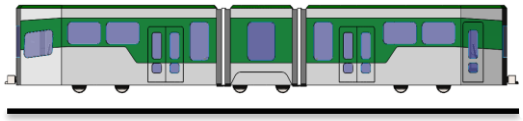




Detailed Conceptual Analysis – Platforms

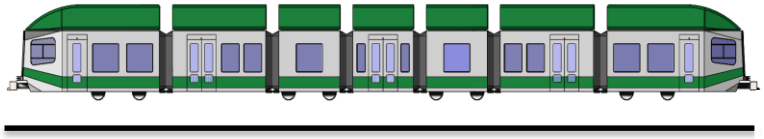
- Analysis of current platforms was conducted to determine impact of concept vehicles on stations

Type 8/9

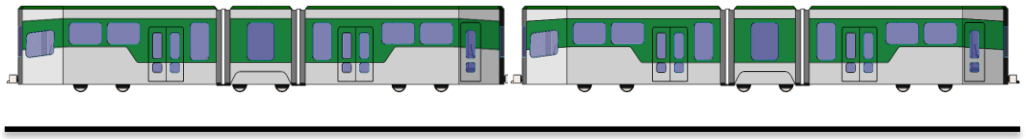


74 ft.

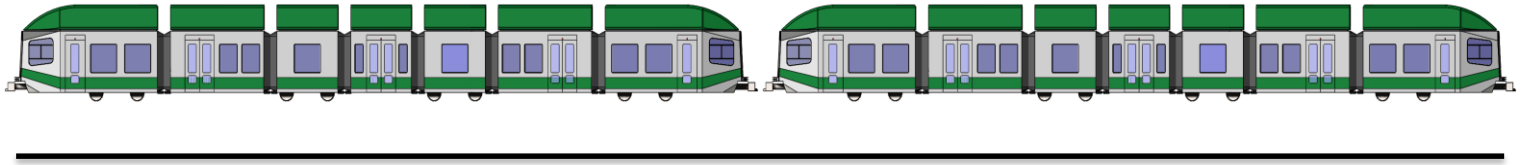
Concept D



112 ft.



148 ft.



225 ft.

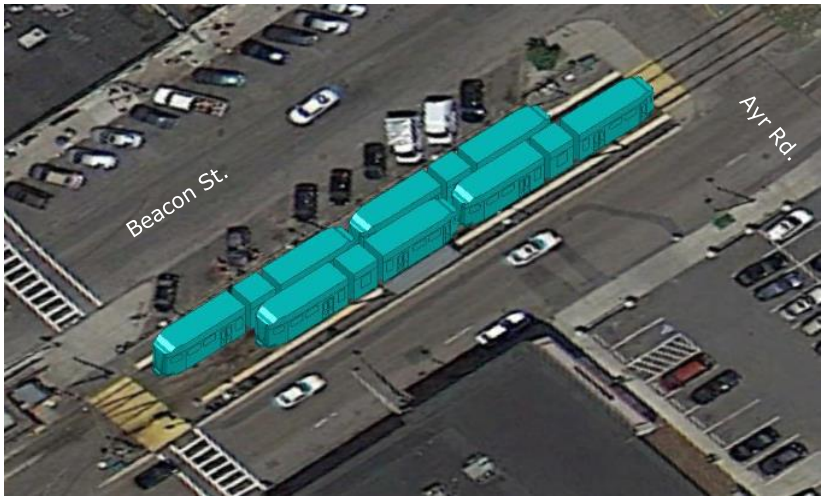
Detailed Conceptual Analysis - Newton Center Platform

3 car Type 8/9 can berth at platform

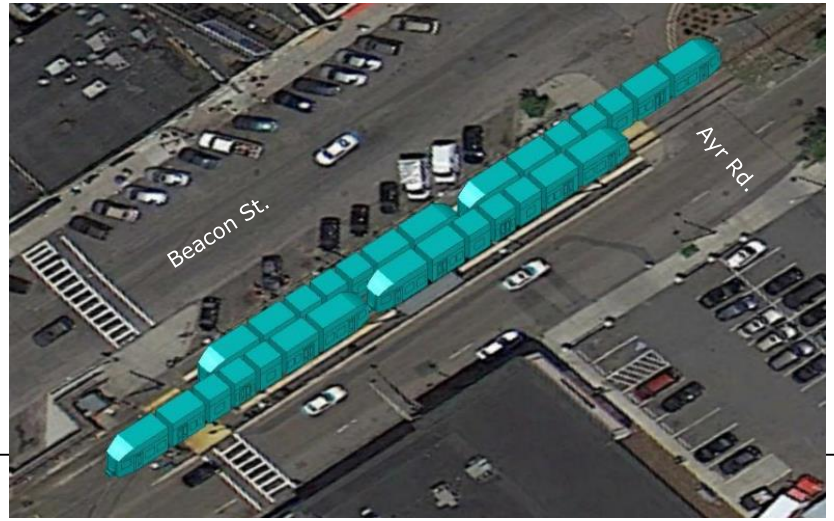
2 Car Concept D can berth at the platform

Detailed Conceptual Analysis – Platforms C Line

2 Type 8/9 can berth at platform



1 Concept D can berth at platform



2 Concept D cars cannot

Cleveland Circle

Detailed Conceptual Analysis – Platforms D & E Lines

- Three Platforms Require work to run longer trains on the for D & E Lines
- 225 feet is optimally required platform length

D-Line	
Platform	**(ft.)**
Brookline Hills (EB)	214

E-Line	
Platform	**(ft.)**
Heath Street	131

Central Subway	
Platform	**(ft.)**
Boylston (EB)	210

Detailed Conceptual Analysis – Platforms B & C Lines

27 Platforms listed below must be extended to allow 2 Concept D's to berth the B & C lines

B-Line	
Platform	**(ft.)**
Boston College (EB)	130*
Boston College (WB)	138*
Blandford Street (EB)	197
Sutherland Road (WB)	207
Blandford Street (WB)	207
Allston Street (WB)	218
Allston Street (EB)	219
Griggs Street (WB)	220
Griggs Street (EB)	221
Sutherland Road (EB)	224

C-Line	
Platform	**(ft.)**
Cleveland Circle (EB)	113
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St. Mary's Street (EB)	210
St. Mary's Street (WB)	210
Kent Street (WB)	214
Kent Street (EB)	216
Brandon Hall (WB)	216
Summit Avenue (EB)	219
St. Paul Street (WB)	220
Hawes Street (WB)	223
Brandon Hall (EB)	224

* BC Station Requires changes due to Lake street Yard Changes

Concept Vehicles

- New Vehicle Goals
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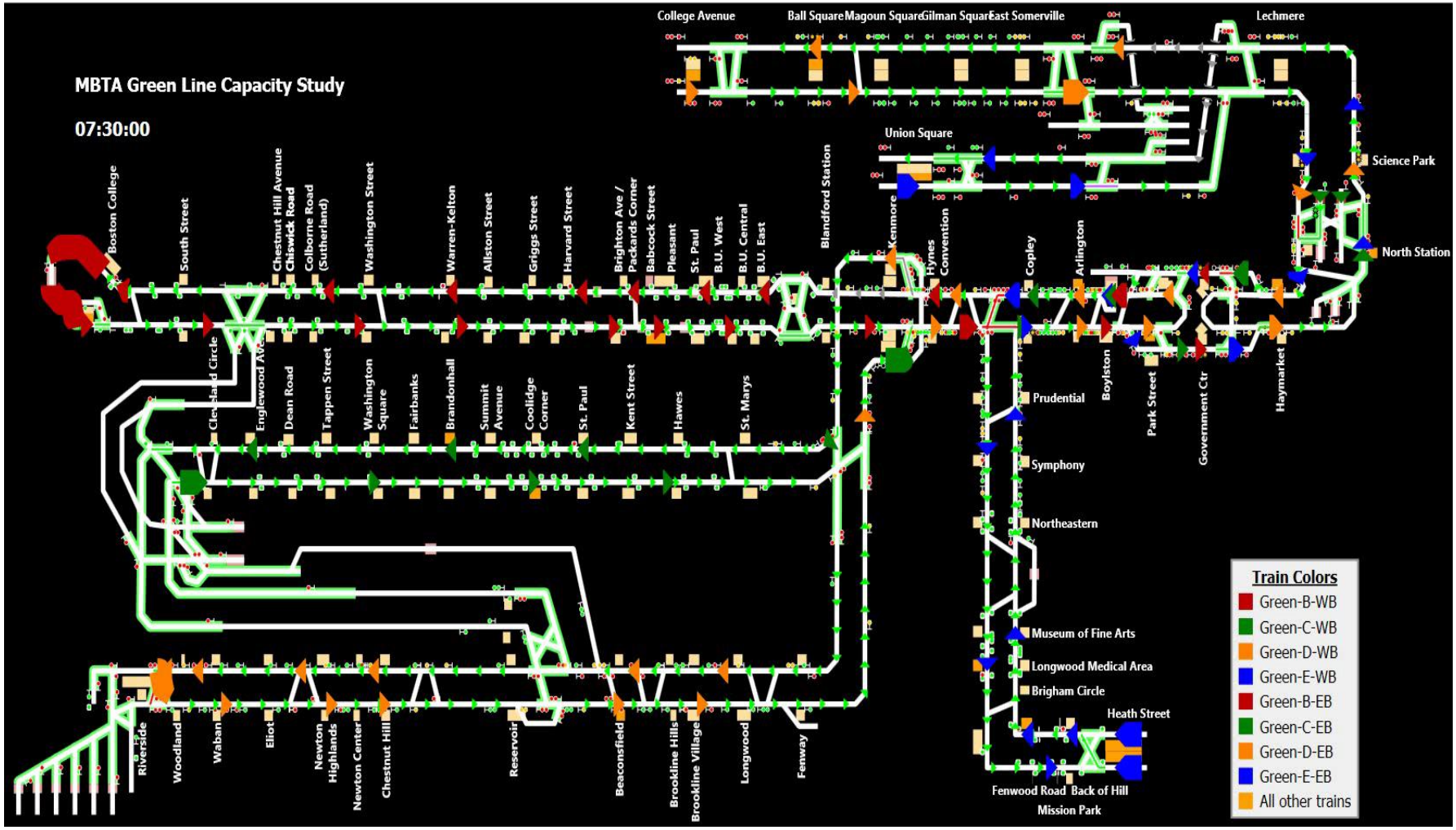
- Evaluation Criteria
- Recommended Concept Vehicle
- Detailed Conceptual Analysis Examples

System Operational Modeling

Detailed Conceptual Analysis – Operational Modeling

- A complete operational model of the Green Line was developed
- Multiple operational simulations were run to identify the best combination of concept vehicles and infrastructure needs.
- The model confirms recommended Concept D will improve Green Line operations

Detailed Conceptual Analysis - Operational Simulation



Phased Implementation

- Multi-phased program proposed that will transition the Authority to a modern 100% accessible high capacity car and necessary system improvements
  - Phase I: Near term projects currently identified in FY19-23 Draft CIP totaling $950M+
  - Phase II: Procurement of a new modern fleet of Green Line vehicles and completion of necessary infrastructure changes to operate them as single units
  - Phase III: Completion of necessary infrastructure changes to operate new vehicles as 2 car units on the D & E Lines.
  - Phase IV: Long term possibility, completion of infrastructure changes to operate new vehicles as 2 car units on B & C Lines.

Phased Implementation – Phase I

- Projects Currently Identified in draft FY19-23 CIP $963.7M
  - $739.9M Programmed in current draft CIP
  - The remaining program costs will be programmed in the outlying yeas of the CIP
  - Many Projects identified are currently underway

- Projects address urgent SGR needs and necessary system reliability improvements
  - Track
  - Power
  - Signals
  - Current Vehicles
  - Infrastructure

- Will be discussed further in following presentation
- Continue project funding of $223.8M will be programmed in next CIPs

Phased Implementation – Phase II

- Operate New Trains as Single Cars on the Green Line – All Lines

- Increase weekday peak trains operating
  - Current: 73 Trains
  - Proposed: 94 Trains
  - **Capacity Gain: 15%**

- Necessary Projects
  - Complete Phase I Programs
  - Vehicle Procurement
  - Reconditioning of Lechmere Viaduct
  - Installation of a Park Street Loop Crossover
  - Expand Vehicle Maintenance Facilities
  - Reconfigure Lake St. and Reservoir Yards
  - Reconfigure BC Station

- Rough estimated cost: $1.5-$2 Billion

Phased Implementation – Phase III

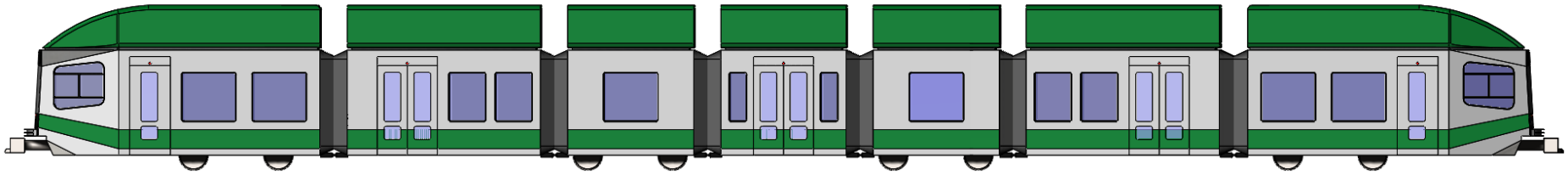
- Operate New Trains as Single Cars on the B & C and Operate New Trains as two car trains on the D & E lines
- Increase weekday peak trains operating
  - Current: 73 Trains
  - Proposed: 94 Trains
  - **Capacity Gain: 50%+**
- Necessary Projects
  - Complete Phase I Programs
  - Complete Phase II Programs
  - Reconfigure Heath Street Station
  - Extend Brookline Hills- East Bound Platform
  - Clear obstruction on Boylston Station East Bound
  - Upgrade Power Distribution
  - Retirement of the Type 7 & 8 Cars
- Rough estimated cost: $500 million

Phased Implementation – Phase IV (Long Term Possibility)

- Operate New Trains as two car trains on all lines
  - If ridership growth requires more capacity than programed two car trains could be operated on all lines
- Increase weekday peak trains operating
  - Current: 73 Trains
  - Proposed: 94 Trains
  - **Capacity Gain: 100%+**
- Necessary Projects
  - Complete Phase I Programs
  - Complete Phase II Programs
  - Complete Phase III Program
  - Extend or reconfigure 27 stations on the B & C Lines
  - Procure additional Type 10 vehicles
  - Expand vehicle storage to accommodate a larger fleet
- Rough estimated cost: TBD

Program Next Steps

- Award PM/CM Team For Green Line Transition – Today
- Finalize Concept Vehicle Design Specifications & Award Vehicle Engineering & PM Contract
- Prepare detailed cost estimates for Phase II & III
- Complete Alternative program funding analysis



Thank you