APTA STREETCAR SUBCOMMITTEE

BOMBARDIER FLEXITY FLEET

Sunday June 23, 2019

Agenda

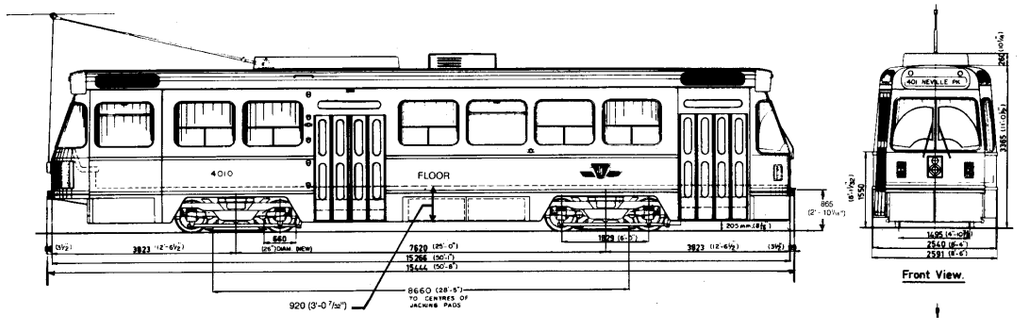
1. LEGACY FLEET
2. FLEXITY VEHICLE
   - **Design Features**
   - **Design Challenges**
   - **Maintenance Challenges**
3. INFRASTRUCTURE
   - **Infrastructure Changes**
   - **Pole To Pantograph**
   - **Challenges**
4. OPERATIONS
   - **Changes To Operations**
5. LESSONS LEARNED

LEGACY FLEET

LEGACY FLEET

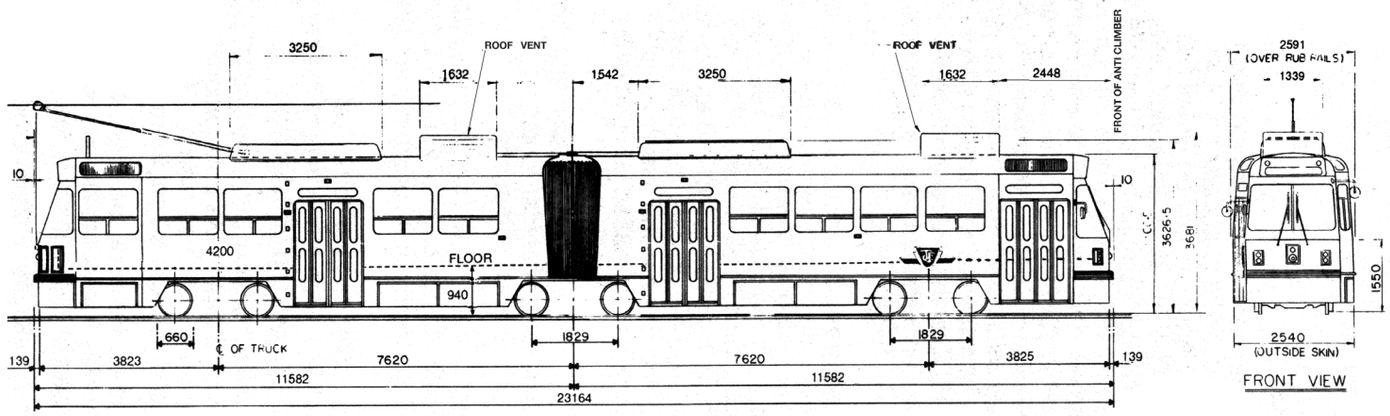
Canadian Light Rail Vehicle (CLRV)

- Commissioned: 1979
- Manufacturer: UTDC
- Total Purchased: 196
- Total Length: 40 Ft
- Total Capacity: 102 Passengers
- Mid-Life Overhaul: None
- Motorized Trucks: 2/2



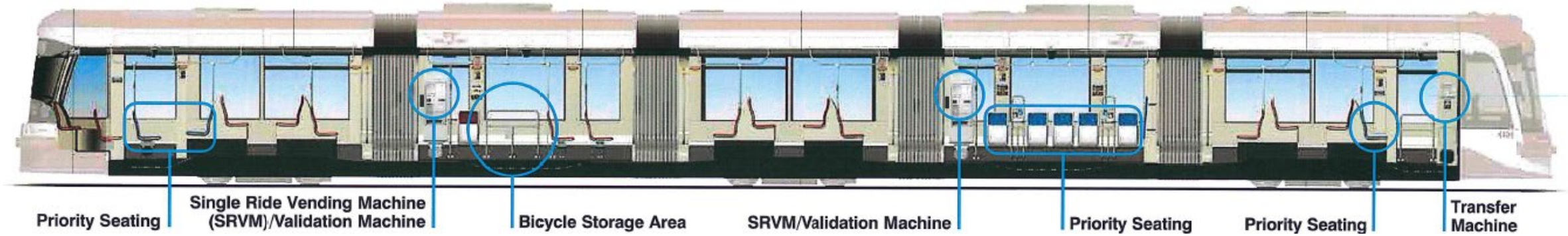
Articulated Light Rail Vehicle (ALRV)

- Commissioned: 1988
- Manufacturer: UTDC
- Total Purchased: 52
- Total Length: 75 Ft
- Total Capacity: 155 Passengers
- Mid-Life Overhaul: None
- Motorized Trucks: 2/3

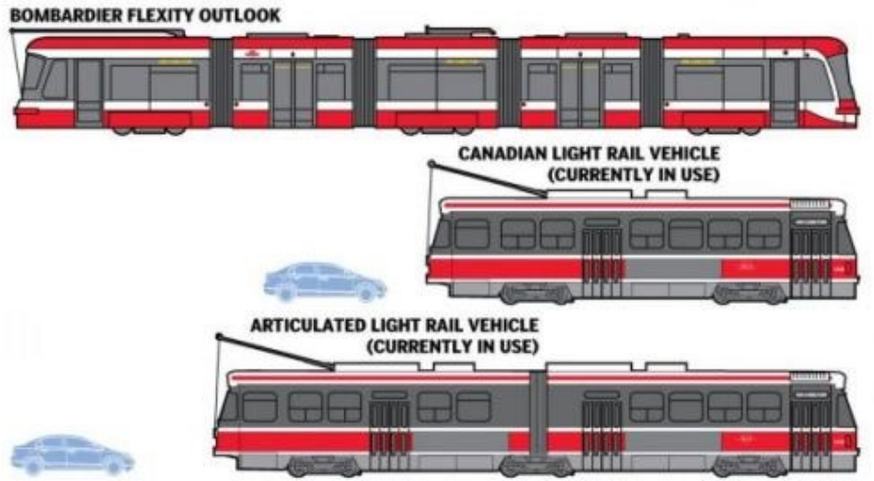


FLEXITY VEHICLE

BOMBARDIER FLEXITY LFLRV



- Commissioned: 2014
- Manufacturer: Bombardier Transportation
- Total Purchased: 204
- Total On Property: 154 (June 1, 2019)
- Total Length: 100 Ft
- Total Capacity: 251 Passengers
- Total Articulation: 4
- Motorized Trucks: 3/3



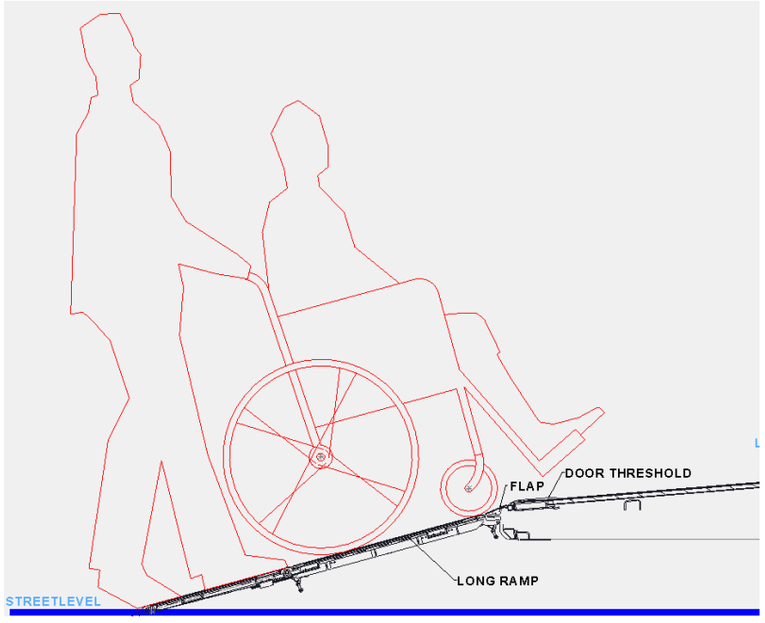
VEHICLE NETWORK INTEGRATION

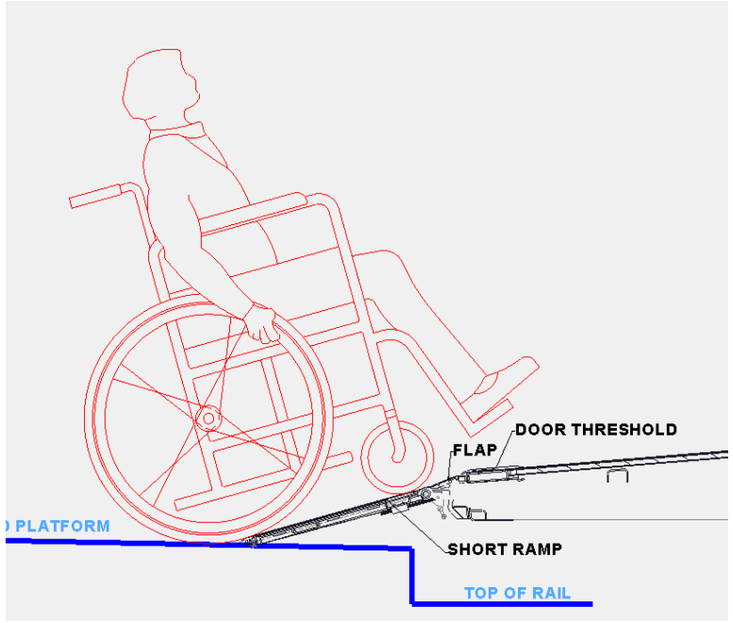
- Minimum horizontal curves: 11.1m inside rail radius
- Maximum Gradients: 8%
- Interoperability with Legacy fleet
- Mix traffic

ACCESSIBILITY

AODA Regulation (Accessibility for Ontarians with Disabilities Act)

- Public Announcements
- 2-stage Ramp





PASSENGER & OPERATOR COMFORT

Passenger comfort

- HVAC
- Wide windows, bright lighting
- Bicycle rack

Operator’s Features

- Transition from pedals to hand Master Controller
- HVAC
- Door cameras & Rear view cameras

IMPROVED PERFORMANCE

- Propulsion & Hydraulic Braking
  - Redundancy (3 motorized/braking bogies)
  - Spin slide correction
- Reduced noise and vibration
- Reduced loading & off-loading time

RELIABILITY CHALLENGES

Braking equipment

Traditionally electric-pneumatics

LFLRV – Hydraulic system

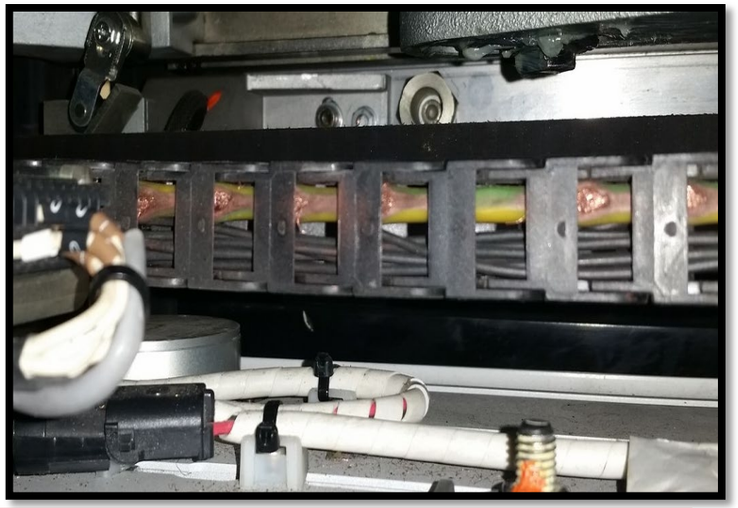
- Oil Leakages
- Loose hardware
- Premature component failures

Door System

Traditionally pneumatic activated

LFLRV - Belt pulley activated

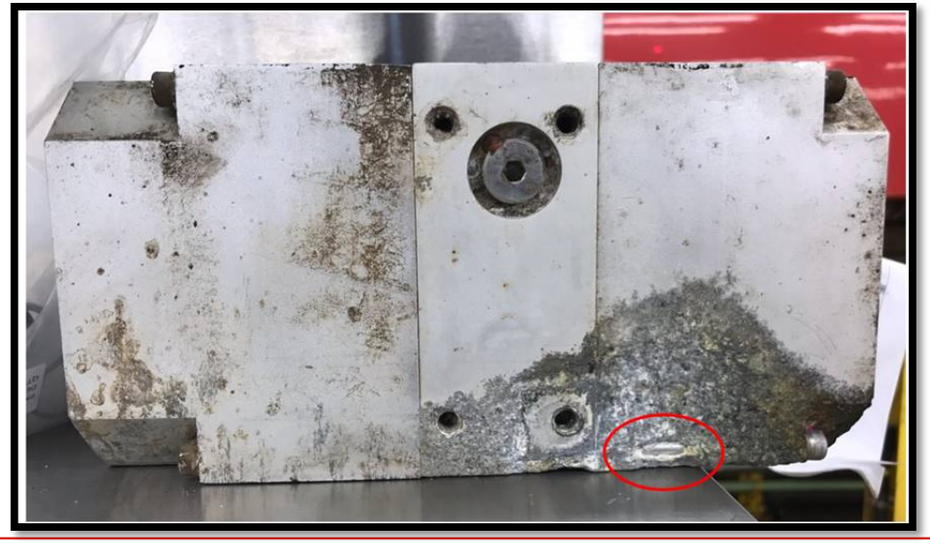
- Wire damages due to fatigue
- Grease flushed out
- Adjustment parameters at installation

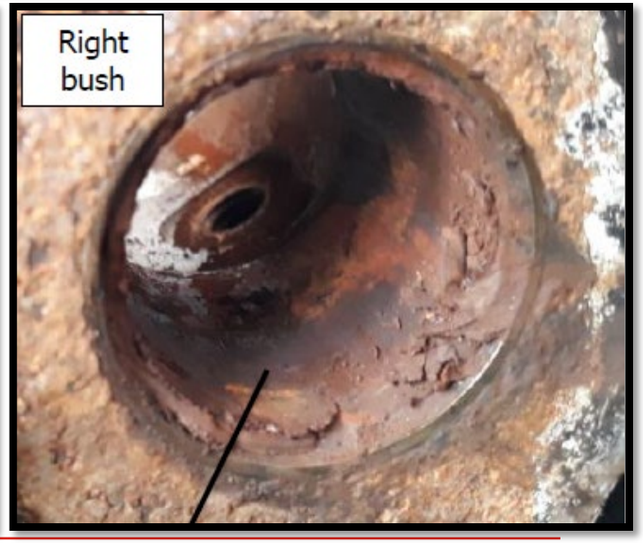


ENVIRONMENT

- **Snow, Salt, Slush, Dirt**
  - Articulation bearings
  - Ramp mobile part

- **Corrosion**
  - Bogie mounted equipment
  - Roof mounted





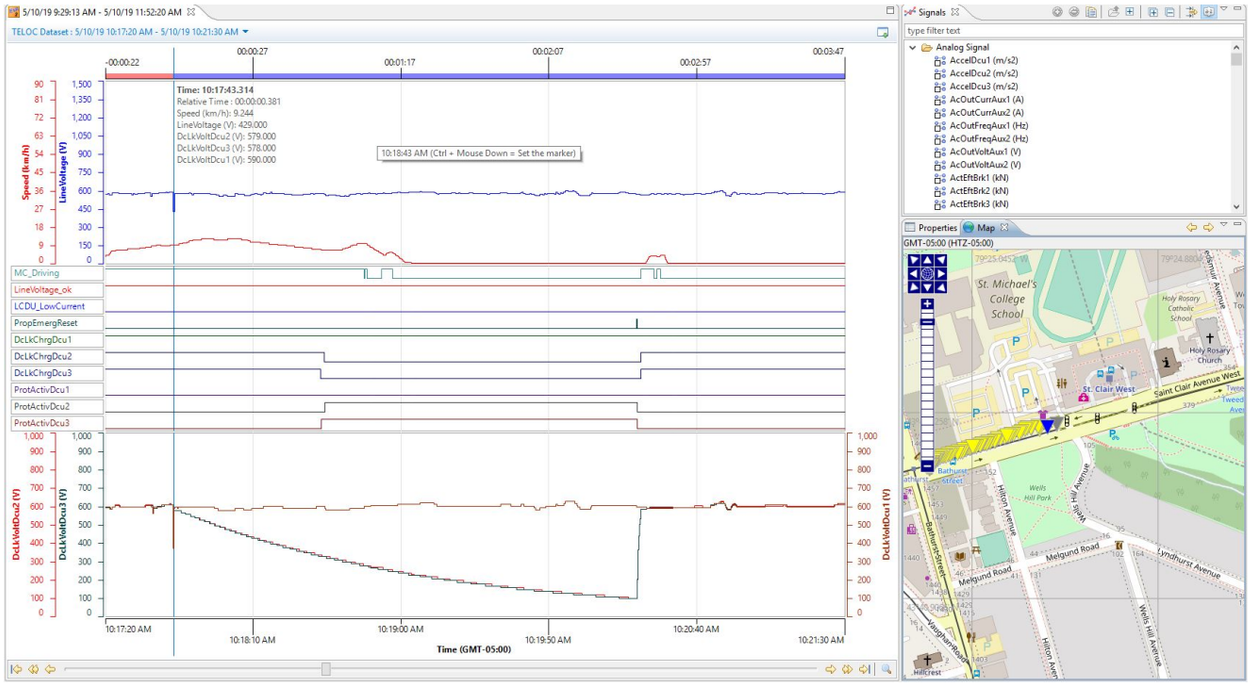
MAINTENANCE CHALLENGES

Design modifications (6th MOD program)

- Maintenance Instructions, troubleshooting procedures
- Training material
- Logistics: Parts, space, availability of cars

New technology

- Fault logs
- Signal/Event logs



INFRASTRUCTURE

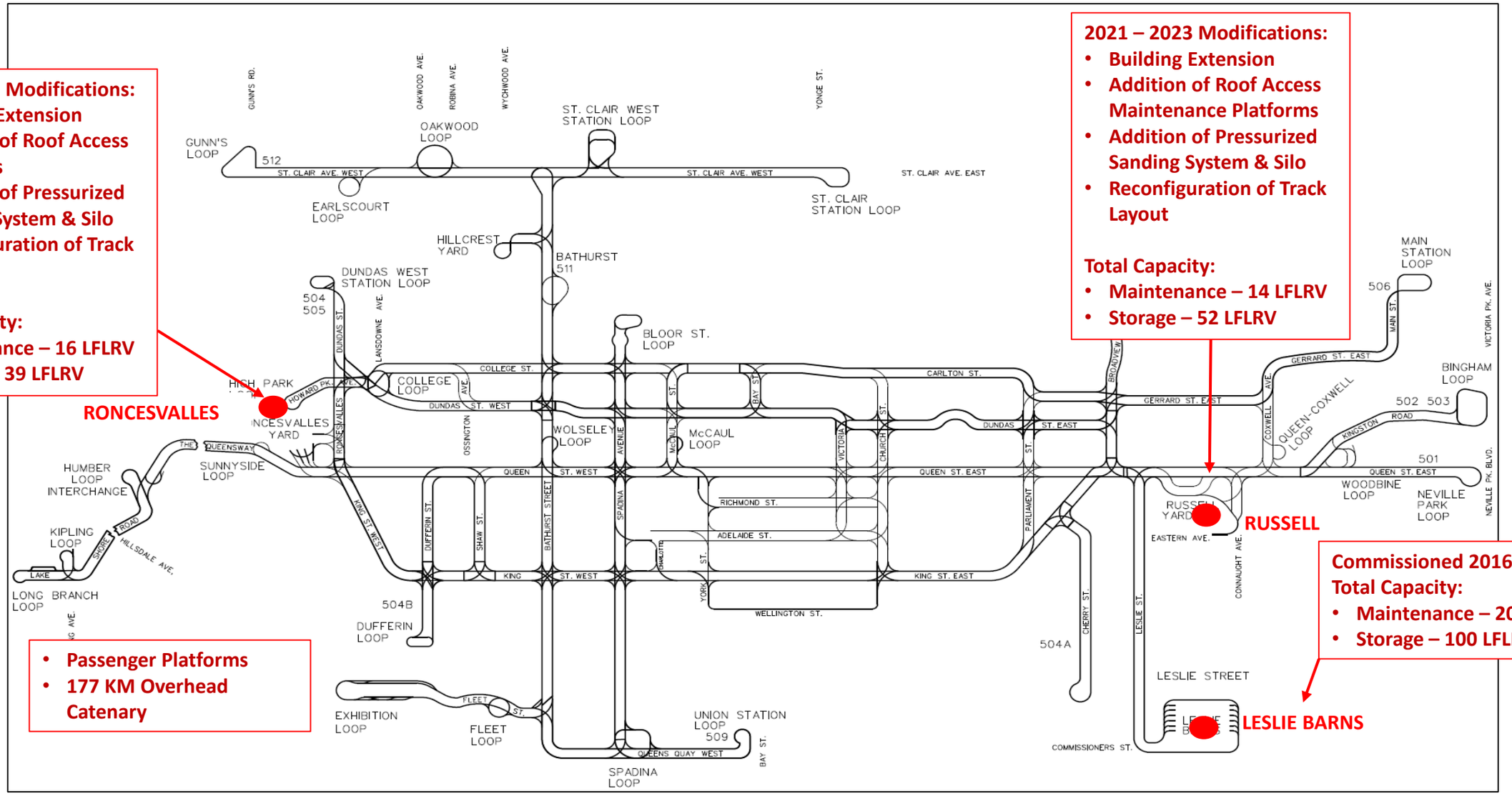
CHANGES TO INFRASTRUCTURE

2018 – 2020 Modifications:
- Building Extension
- Addition of Roof Access Platforms
- Addition of Pressurized Sanding System & Silo
- Reconfiguration of Track Layout

Total Capacity:
- Maintenance – 16 LFLRV
- Storage – 39 LFLRV

2021 – 2023 Modifications:
- Building Extension
- Addition of Roof Access Maintenance Platforms
- Addition of Pressurized Sanding System & Silo
- Reconfiguration of Track Layout

Total Capacity:
- Maintenance – 14 LFLRV
- Storage – 52 LFLRV



- Passenger Platforms
- 177 KM Overhead Catenary

Commissioned 2016
Total Capacity:
- Maintenance – 20 LFLRV
- Storage – 100 LFLRV

POLE TO PANTOGRAPH CONVERSION

Pole → Hybrid → Pantograph

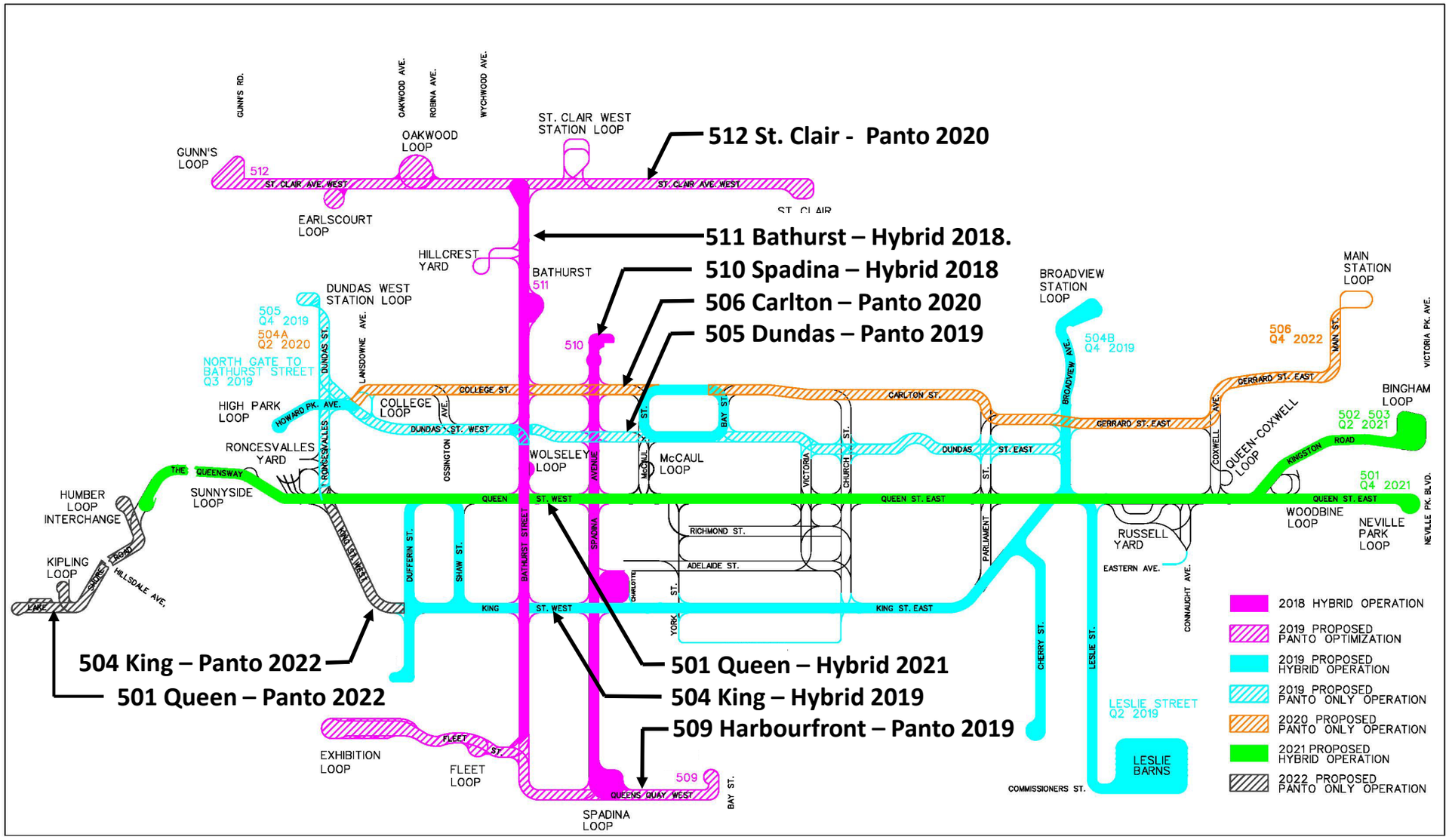
POLE TO PANTOGRAPH CONVERSION

- Conversion scheduled in 3 stages
  - Stage 1: LFLRV Pole Operation Only
  - Stage 2: LFLRV Pole & Pantograph Operation (Allows For Legacy Vehicle Operation)
  - Stage 3: LFLRV Pantograph Operation Only

- Conversion Strategy
  - Smallest to Largest Route (According to Fleet Requirements)
  - Least to Most Complex (According to no. of Intersections)
  - Opportunity to couple conversion with planned city projects

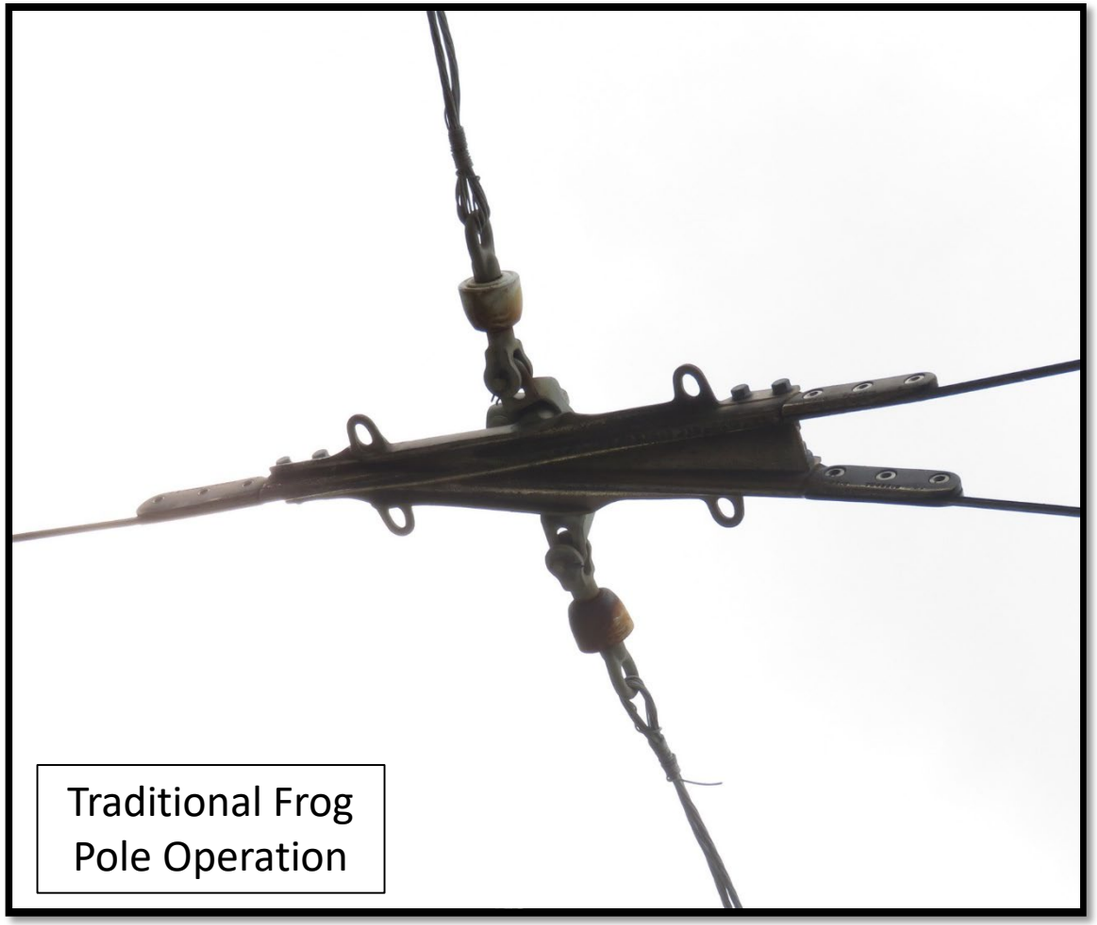
- Network is currently 50% in Hybrid mode & is expected to be 100% Hybrid by Q1 2022
- Full pantograph conversion is expected by 2025

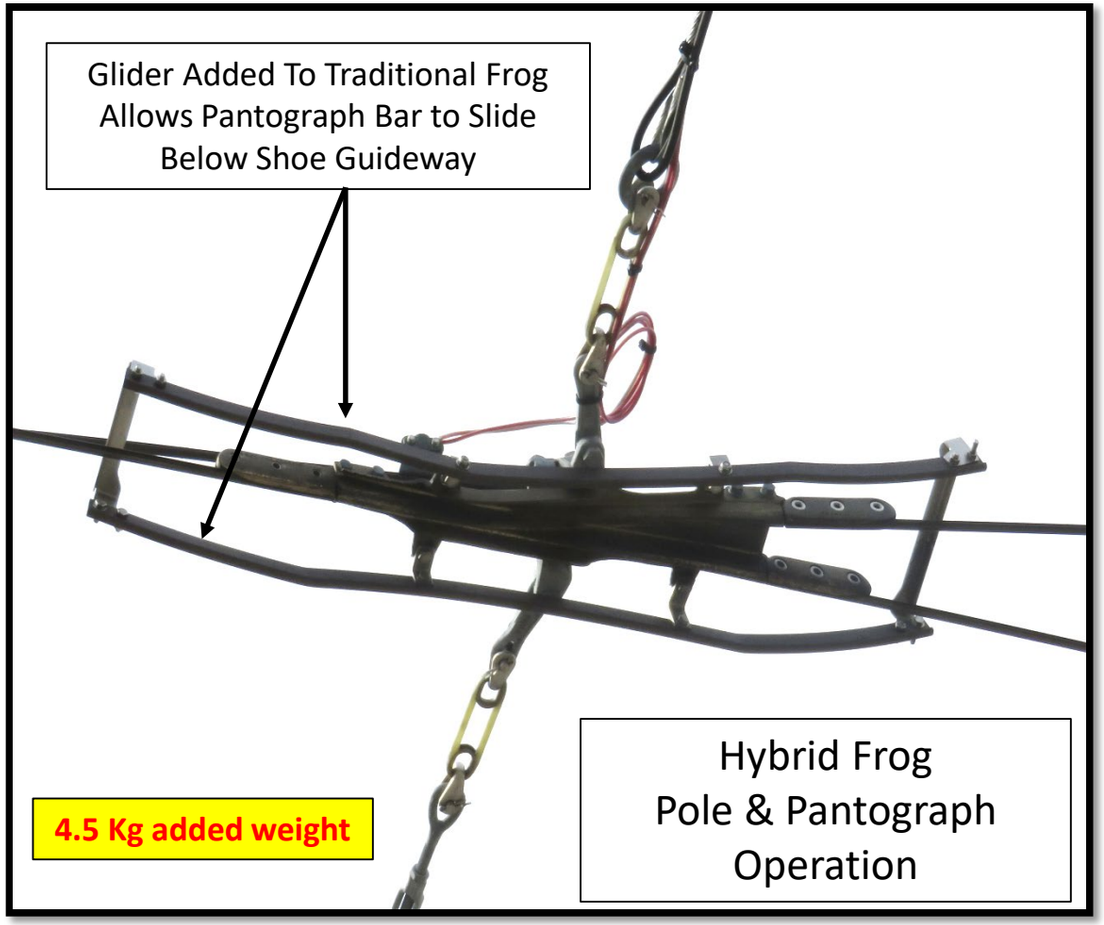
POLE TO PANTOGRAPH CONVERSION SCHEDULE



HYBRID CATENARY

FROGS

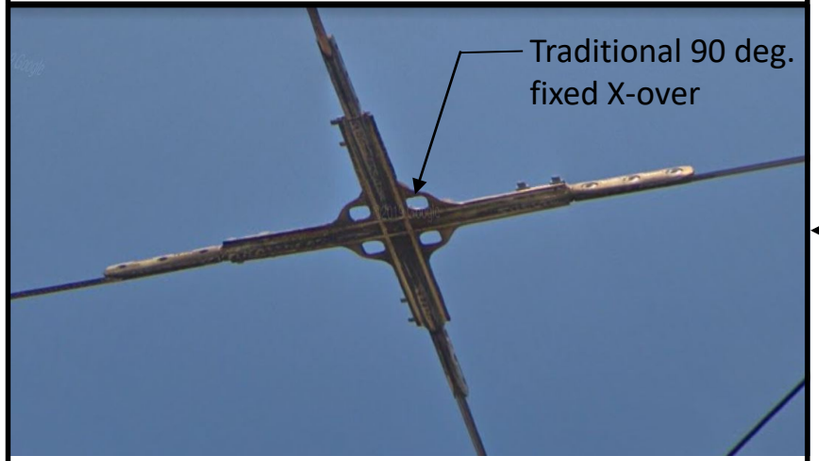




HYBRID CATENARY

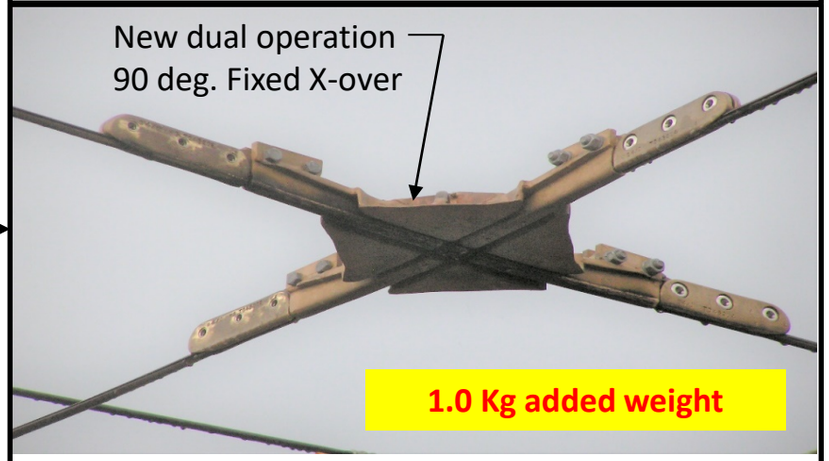
CROSSOVERS

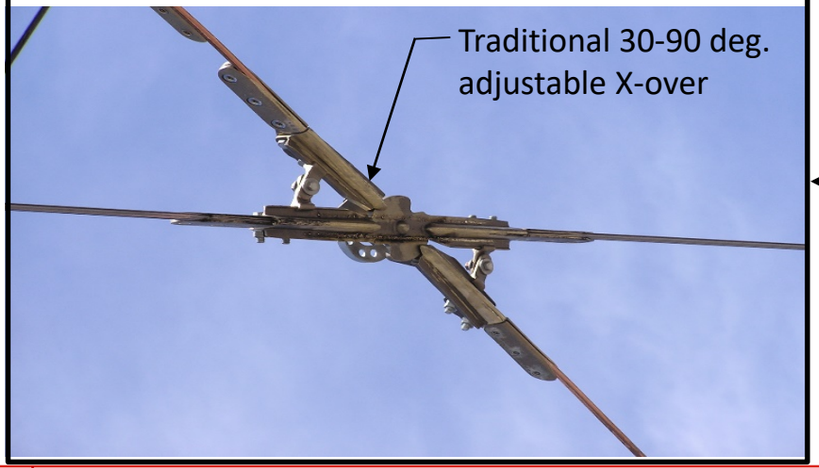
Pole Operation



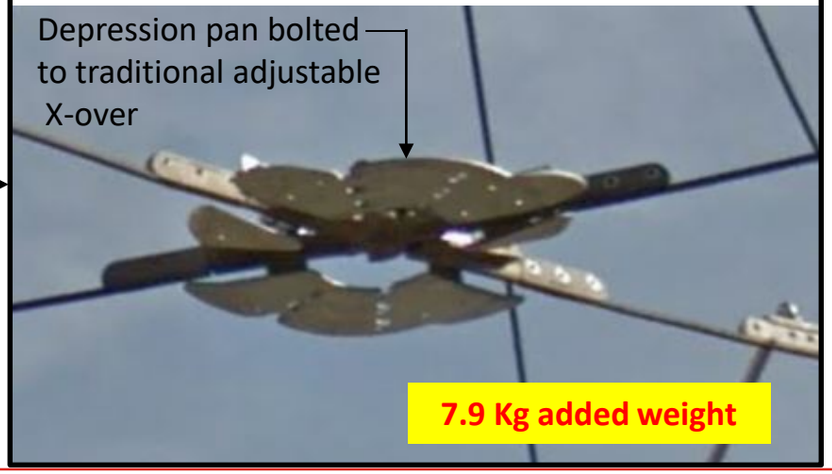
Fixed 90 Degree Crossovers

Pole & Pantograph Hybrid Operation





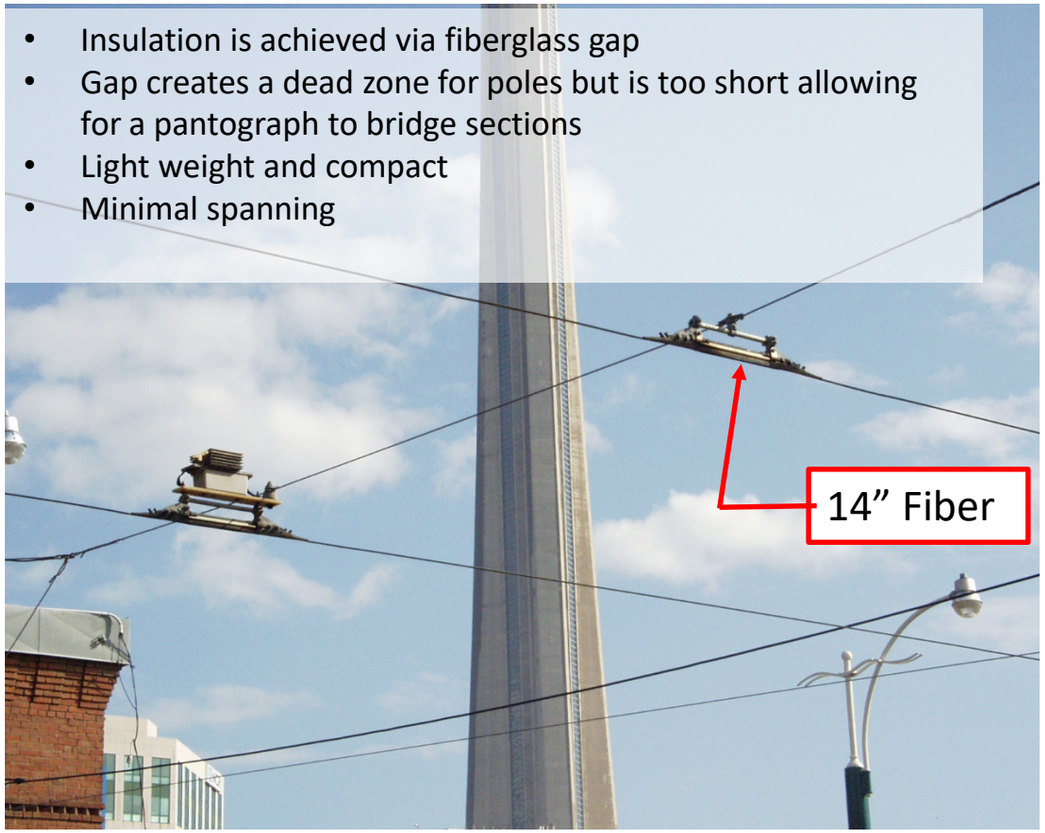
Adjustable Crossovers



HYBRID CATENARY

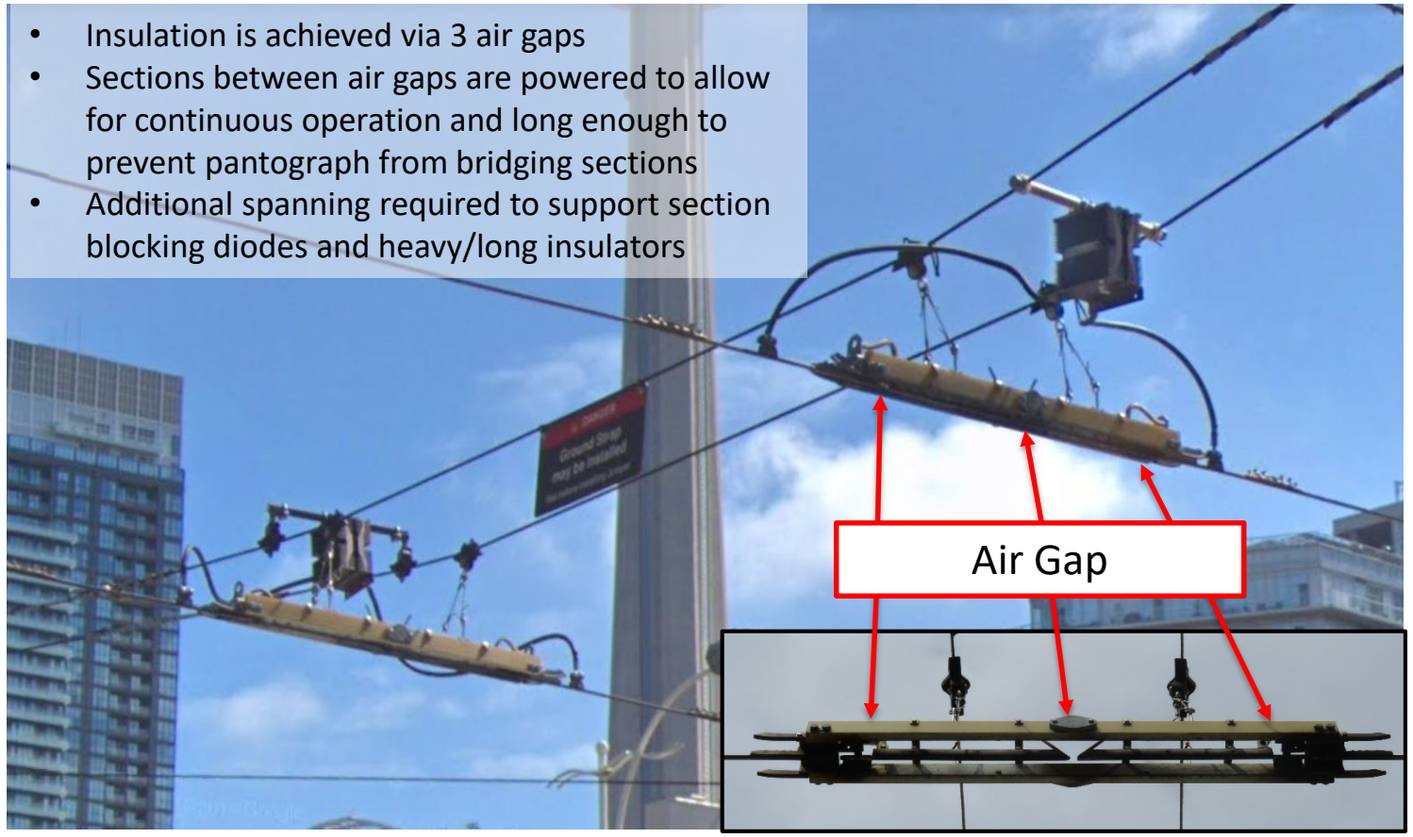
Section Insulators

- Insulation is achieved via fiberglass gap
- Gap creates a dead zone for poles but is too short allowing for a pantograph to bridge sections
- Light weight and compact
- Minimal spanning



Pole Only Operation

- Insulation is achieved via 3 air gaps
- Sections between air gaps are powered to allow for continuous operation and long enough to prevent pantograph from bridging sections
- Additional spanning required to support section blocking diodes and heavy/long insulators



Pole & Pantograph Operation

POLE TO PANTOGRAPH CONVERSION CHALLENGES

Challenges:

- Weight of hardware – increased risk of sag
- Pole, pantograph and wire interface – increased risk of interference
  - Pole and Pantograph snags & damage
  - Down overhead
- Increased maintenance efforts of hybrid system
- Accelerated wear of pantograph carbon strip without full stagger
- Conversion of network while trying to maintain service levels

Lessons Learned:

- Installation of anti-trap deflector bars required to mitigate snagging of de-wired poles
- Installation of constant tension devices to mitigate sag
- Earlier conversion of routes to full stagger to mitigate localized carbon wear

OPERATIONS

CHANGES TO OPERATIONS

PRE-SERVICE

Manual Sand Fill System

Pressurized Sand Fill System

Challenges:

- Increased Yard Movements
- Pinch Point
- Balancing Service Requirements with Realistic Throughput
- Reliability of Sand Pump

Benefits:

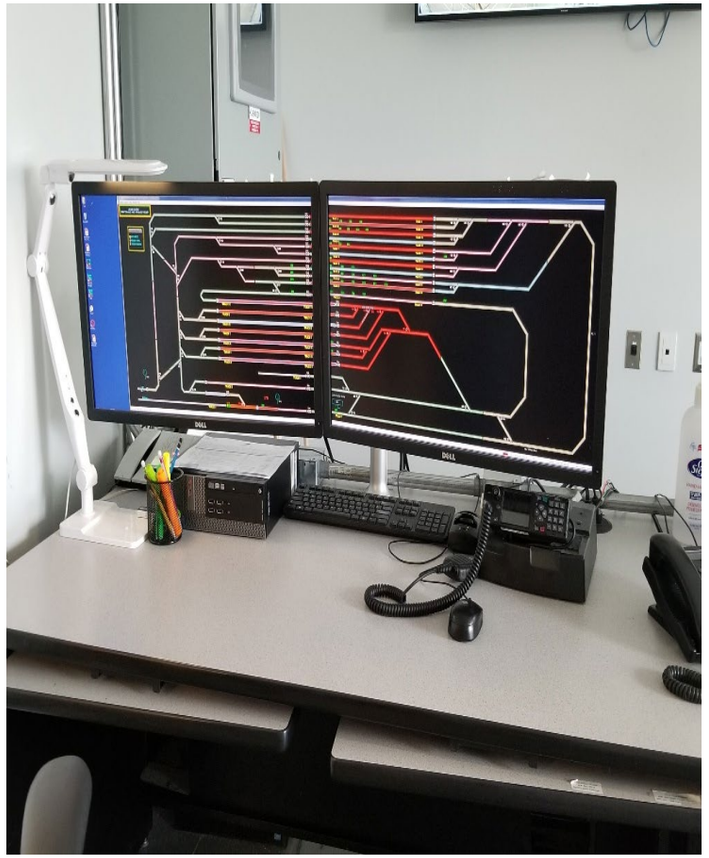
- Elimination of Moisture
- Reduced Sand Consumption

CHANGES TO OPERATIONS

YARD CONTROL

Manual Switch System

Automated Switch System



Challenges:

- Switch & Software Reliability
- Operator Pick Up vs Hostler Delivery

CHANGES TO OPERATIONS

ASSET MANAGEMENT AND TRAINING

- ‘Fix On Fail’
- In-House Maintenance Work Order System (SMS)
- In-House Technical & Vehicle Training & Qualification

- Predictive Maintenance
- Enterprise Asset Maintenance Work Order System (MAXIMO)
- Technical Degree from College/University with In-House Vehicle Familiarization, Training and Qualification

LESSONS LEARNED

LESSONS LEARNED

1. Program vs Project Management Oversight

2. Catenary Conversion Plan
    - Bus Substitution & Closures

Q&A?

APPENDIX

CHANGES TO OPERATIONS

MAINTENANCE – YARD VS FACILITY PRE-SERVICING

Manual Sand Fill System

Pros:

- ✓ Flexibility of Pre-Servicing
- ✓ Minimizes Yard Movements
- ✓ Faster Pre-Servicing

Cons:

- × Exposure To Inclement Weather
- × Susceptible To Slip, Trips, Fall & Strains
- × Open System – Subject To Moisture
- × Cleanliness & Wastage

Pressurized Sand Fill System

Pros:

- ✓ Eliminates Exposure To Inclement Weather
- ✓ Reduces Slips, Trips, Falls & Strains
- ✓ Improves Cleanliness & Reduces Wastage
- ✓ Enclosed System – Eliminates Moisture
- ✓ Frees Up Resources

Cons:

- × Increases Yard Movement
- × Sand System – Pinch Point

CHANGES TO OPERATIONS

MAINTENANCE – MANUAL VS AUTOMATED SWITCH SYSTEM

Manual System

Pros:

✓ More Robust Switches

Cons:

× Exposure To Inclement Weather
× Susceptible To Slip, Trips, Fall & Strains

Automated System

Pros:

✓ Eliminates Exposure To Inclement Weather
✓ Reduces Slips, Trips, Falls & Strains

Cons:

× Increased Maintenance – Electrical & Software System

CHANGES TO OPERATIONS

Updated_CP

MAINTENANCE

- Pre-Service
  - Sanding Inside (no longer can do outside)
  - Panto – Cut Power and Roof Access Inside
  - Longer Pre-Servicing Time 15min x 3 ppl
  - More Yard Movements & Through Put in the Carhouse
  - Re-railing – more difficult but front/back trucks – pull back on fast

PD Inspection – move from 30 to 60 days
More Diagnostic tooling required
On Board Health Monitoring System
No more pneumatics – hydraulics contract out repairs/overhaul
Introduction of ramp and HVAC systems
Modular composite panels vs large steel plates – faster turn around
Redundancy – less RCCO
No Ice Cutters but Slider Prototype and Glycol Spray

CHANGES TO OPERATIONS

TRANSPORTATION

King Street Pilot

Pole To Panto

POLE TO PANTOGRAPH CONVERSION

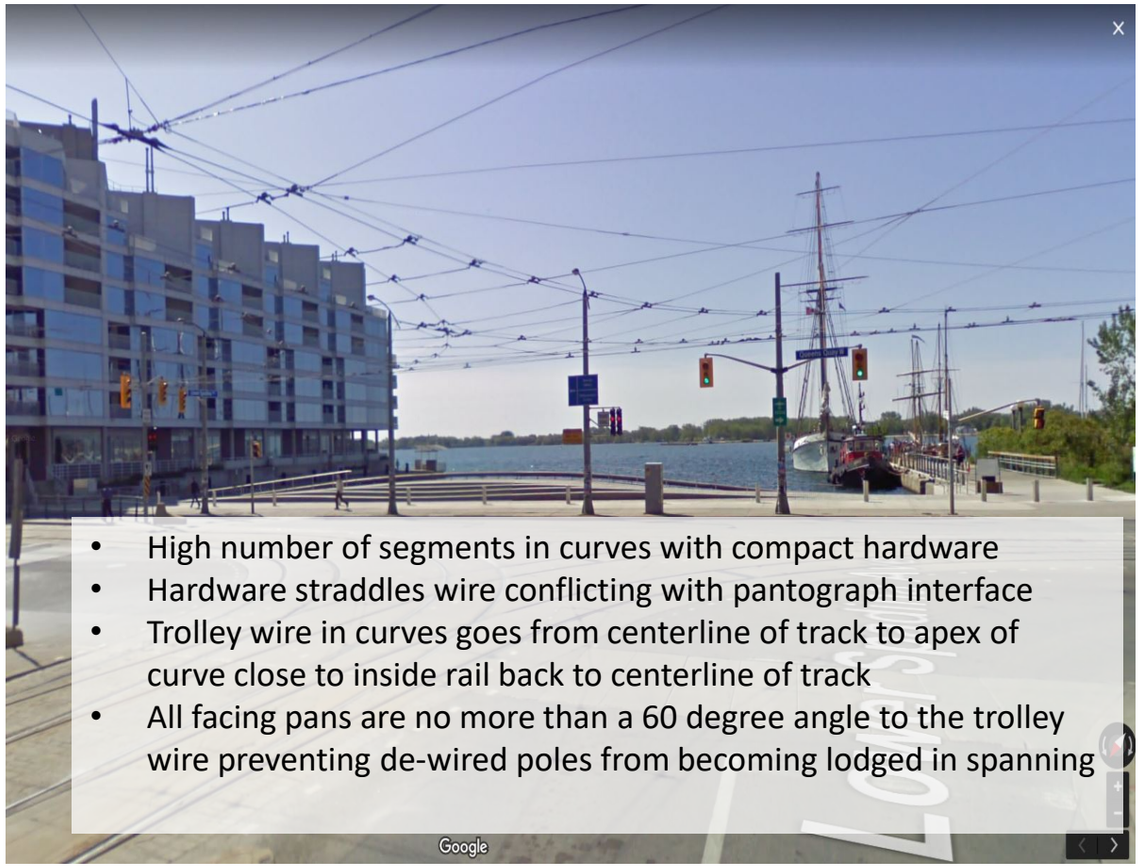
CHRONOLOGY

2009 – Bombardier Flexity Vehicle order placed to replace existing fleet of CLRV and ALRV streetcars
– New vehicles to be outfitted with both pole and pantograph current collection systems
2010 – Hybrid parts prototyping and test installations begin on St Clair, Fleet Street and Roncesvalles
2013 – Testing with pantograph begins on Queen and St. Clair
2014 – First revenue service vehicle operates on Spadina with pole operation
– First deployment of pantograph operation in Hillcrest Yard exclusively
– Pantograph testing continues on St. Clair, Fleet and Queens Quay
2015 – Pantograph snags OCS on St Clair during testing resulting in delayed revenue service deployment
2016 – Pantograph operation begins in Leslie Barns
2017 – Hybrid Pole/Pantograph operation begins on the 509 Harbourfront route
2018 – Hybrid Pole/Pantograph operation begins on the 510 Spadina route
2019 – Pantograph only operation begins on 512 St. Clair route

POLE TO PANTOGRAPH CONVERSION

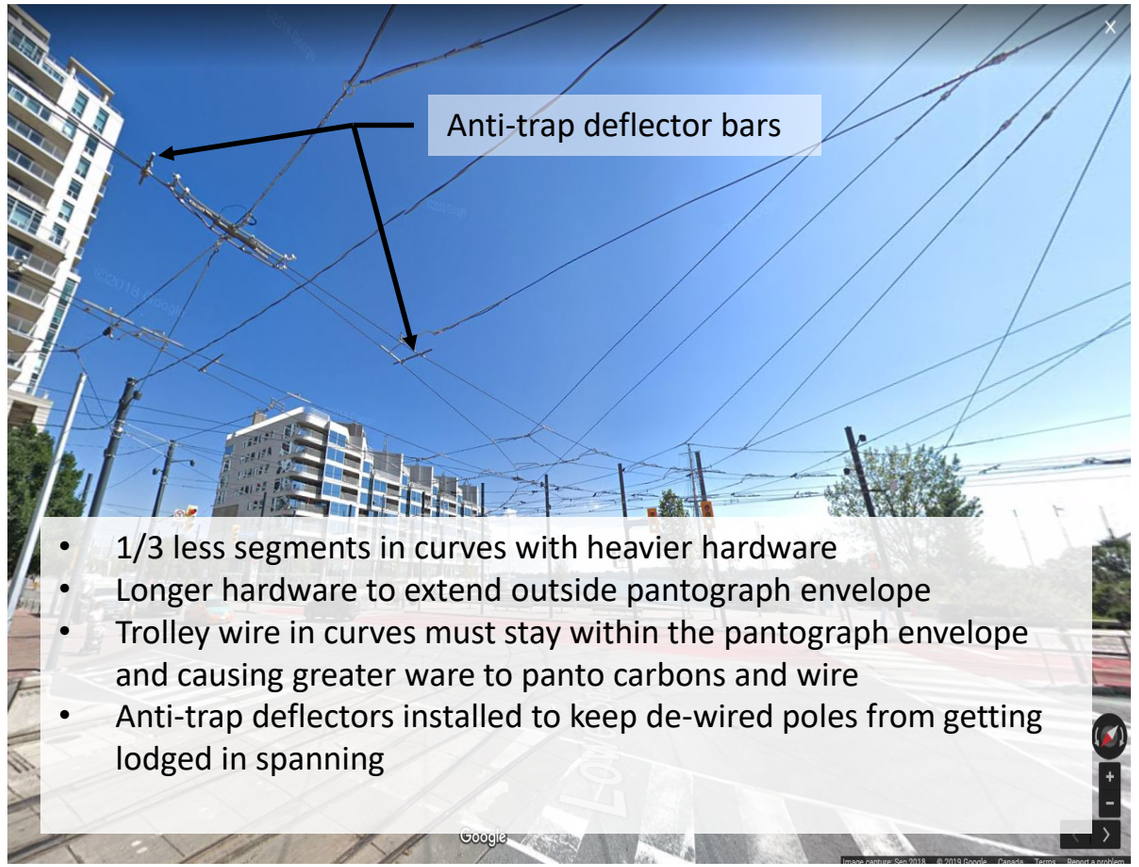
Lower Spadina & Queens Quay

Pole → Hybrid



- High number of segments in curves with compact hardware
- Hardware straddles wire conflicting with pantograph interface
- Trolley wire in curves goes from centerline of track to apex of curve close to inside rail back to centerline of track
- All facing pans are no more than a 60 degree angle to the trolley wire preventing de-wired poles from becoming lodged in spanning

Pole Only Operation



- 1/3 less segments in curves with heavier hardware
- Longer hardware to extend outside pantograph envelope
- Trolley wire in curves must stay within the pantograph envelope and causing greater ware to panto carbons and wire
- Anti-trap deflectors installed to keep de-wired poles from getting lodged in spanning

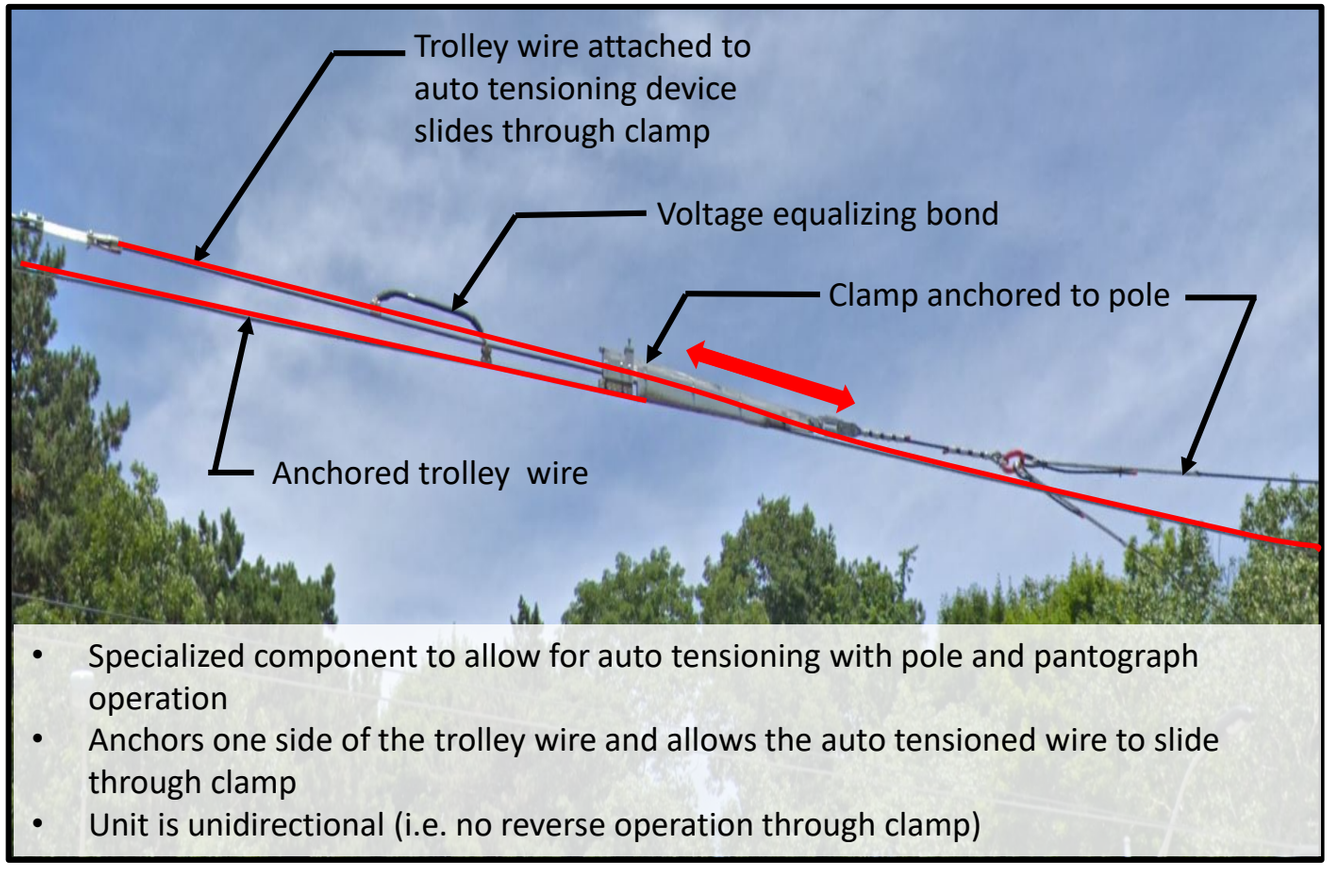
Pole & Pantograph Operation

POLE TO PANTOGRAPH CONVERSION

Hybrid Auto Tensioning

- Compact design allows for installation on shared poles
- Tensioning device location is out of reach of the public
- 500m tension length with 2000 lbs. of constant tension from -40°C to +40°C

Cam/Spiral – Constant Tensioning Device



- Specialized component to allow for auto tensioning with pole and pantograph operation
- Anchors one side of the trolley wire and allows the auto tensioned wire to slide through clamp
- Unit is unidirectional (i.e. no reverse operation through clamp)

Pole & Pantograph Compatible Overlap Transition Clamp

CHANGES TO OPERATIONS

New facility - Design and delivery of new Assets

- **Wheel lathe**
- **Lifting units - Hoist**
- **Sanding Units**
- **Automatic wheel profiling**
- **Flushing carts**

CHANGES TO OPERATIONS

MAINTENANCE – POLE VS PANTOGRAPH SYSTEM

Pole System

Pros:

- ✓ Flexibility of Pre-Servicing
- ✓ Minimizes Yard Movements
- ✓ Faster Pre-Servicing

Cons:

- × Exposure To Inclement Weather
- × Susceptible To Slip, Trips, Fall & Strains
- × 1-2 Day Frequency – Carbon Replacement

Pantograph System

Pros:

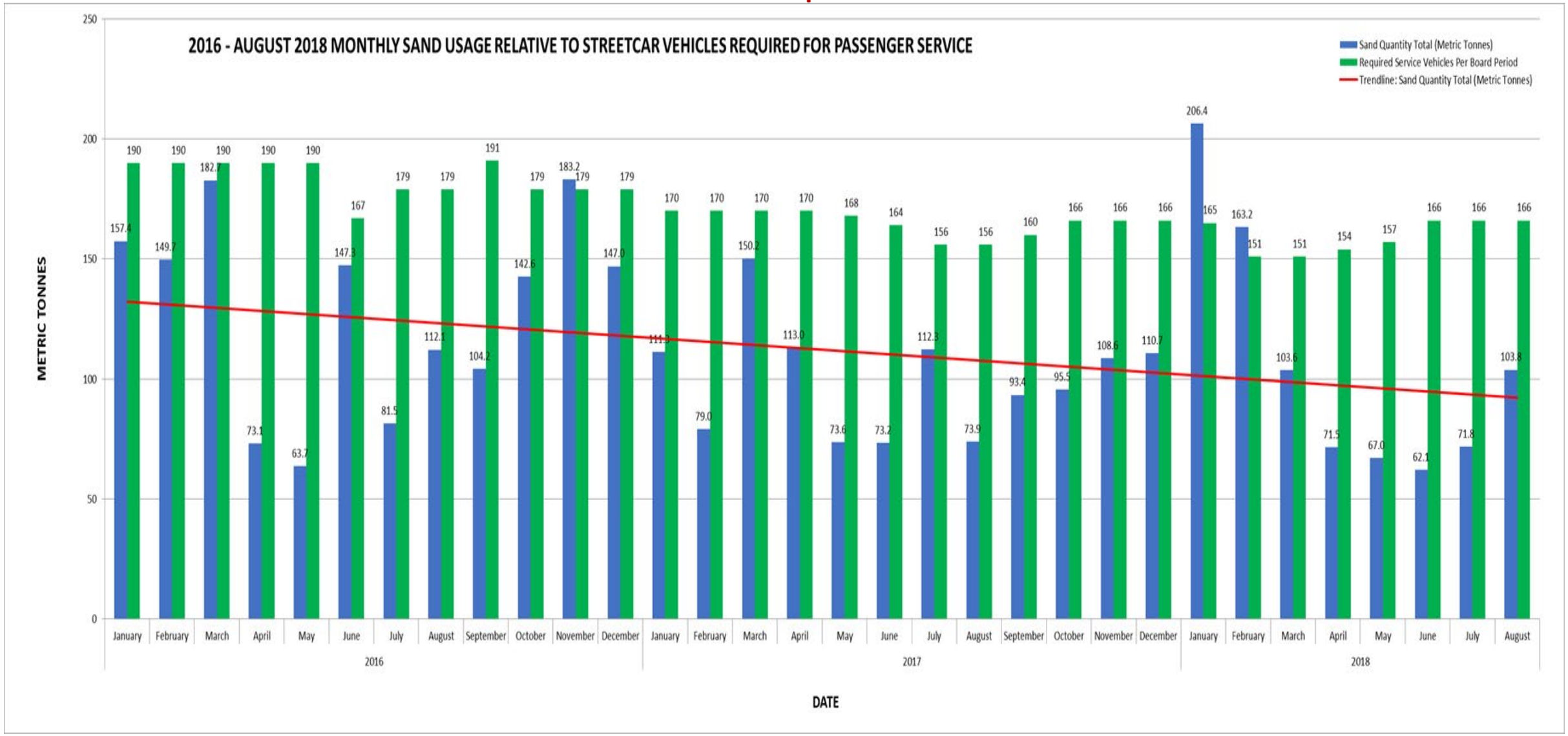
- ✓ Eliminates Exposure To Inclement Weather
- ✓ Reduces Slips, Trips, Falls & Strains
- ✓ 2 Month Frequency – Carbon Replacement

Cons:

- × Increases Yard Movement
- × Increases Servicing Time – Power Cut

CHANGES TO OPERATIONS

Sand Consumption

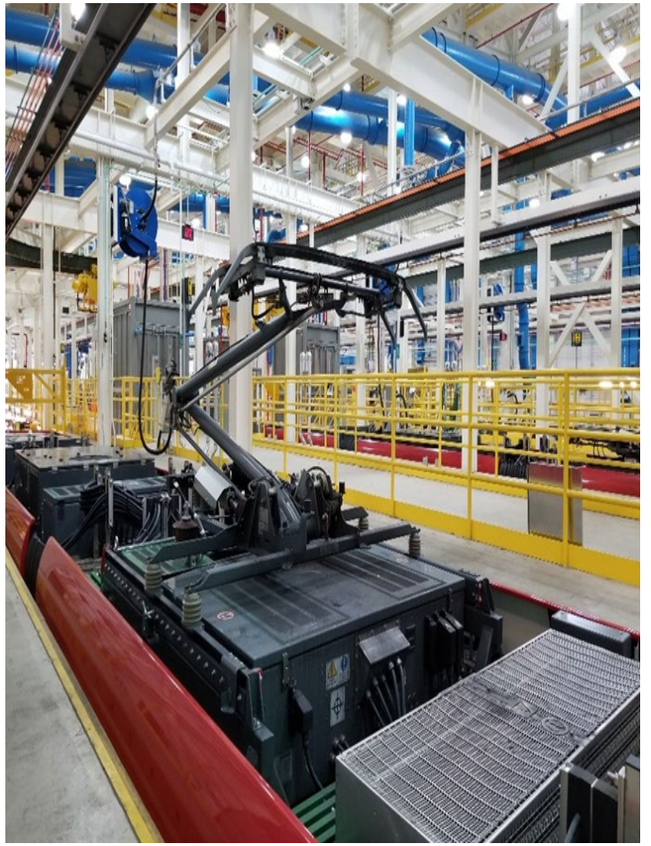


CHANGES TO OPERATIONS

POLE VS PANTOGRAPH

Pole System

Pantograph System



Challenges:

- Maintenance of 2 Systems
- Pole/Panto/Overhead Interface
- Panto Drops Damage & Inventory Supply

Benefits After Conversion:

- 2month inspection vs. daily

OPERATIONS CHALLENGES

Challenges

- Customer Education
  - Passenger Activated Doors

- Operator Discipline
  - All Doors Boarding
  - Pole & Pantograph Areas
  - Operating Speeds At Intersections and Under Passes