New York City Transit
Car-Borne Maintenance: Present & Future

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Vice President & Chief Mechanical Officer
New York City Transit
Car Equipment - Department of Subways
AGENDA

- Introduction to New York City Transit (NYCT)

- NYCT Current Maintenance Practices
  - Scheduled Inspections
  - Corrective Maintenance
  - Scheduled Maintenance System (SMS) Program

- Condition Based Maintenance (CBM) Principles

- NYCT Future Maintenance Practices with CBM

- NYCT CBM Efforts Under Way
NYCT - Division of Car Equipment (DCE)

Responsible for:

- Car Inspections, Repairs and Maintenance
- Scheduled Maintenance System Program
- Purchase and support of all revenue and non-revenue vehicles
- Engineering
- Emergency Response
- Quality Assurance
- Customer Accidents & Investigations
- Facility Maintenance
NYCT - Division of Car Equipment (DCE)

- 4,800+ Employees
  - Managers ~ 3%
  - Professional/Technical ~ 4%
  - Supervisory ~ 10%
  - Hourly ~ 83%

- 24-hour / 7-day Operation

- Fleet Size:
  - > 6,500 Revenue Railcars
  - > 550 Non-Revenue (Work) Equipment
NYCT - Division of Car Equipment (DCE)

Support Facilities:

- **13 Fleet Maintenance Facilities**
  - Performing scheduled maintenance and repairs, lay-ups during off-hours

- **2 Major Overhaul Facilities**
  - Performing scheduled overhauls in addition to car body and truck repairs
  - Dedicated Component Shops:

- **2 Work Vehicle Maintenance Facilities**
  - Performing scheduled maintenance and repairs
MTA NYCT: Quick Facts

- Ridership:
  - Average weekday subway ridership: 5.6 million
  - Annual ridership: > 1.7 billion

- Number of Stations: 472 (The largest number of public transit subway stations of any system in the world).

- Number of Lines: 24

- Miles of Track: 665 mainline track miles / 840 miles including non-revenue (4’8.5” gauge)

- Number of Weekday Train Trips: 8,200

- Subway Annual Car mileage: Fleet traveled 358 million miles

- Miles traveled by an average subway car between repairs: > 120,000
Overall Fleet Age (As of 2nd Quarter 2019): 23 Years
KPI: Mean Distance Between Failure (MDBF)

- Key indicator for fleet performance.
- Measures car reliability as it relates to its on-time performance.

\[
MDBF = \frac{\text{TOTAL MILES OPERATED}}{\text{TOTAL NUMBER OF MECHANICAL FAILURES}}
\]

**Total Miles Operated:** Actual number miles traveled in revenue service (excluding deadhead, training and maintenance)

**Mechanical Failures:** Service delays greater than five minutes, including cancelations and terminations
Scheduled Maintenance Inspection

The Scheduled Maintenance Inspection (SMI) Program verifies that cars are mechanically and electrically reliable, ensuring safe operation with adequate number of trains available for daily service.
Scheduled Maintenance Inspections (SMI) Program

- There are four SMI Cycles (SM1 through SM4).
- Inspection criteria: 68-76 days or 10,000 to 12,000 miles, whichever comes first.
- All systems are checked in each cycle
- “Regular” or “Heavy” inspections are performed, based upon the OEM recommendations and lessons learned
- Components with longer lifetimes are given extended service (“Heavy Inspection”) on a rotating basis over the four cycles.
- Larger components with longer lifetimes are addressed in the SMS Program.
## Scheduled Maintenance Inspections (SMI)

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<tr>
<th>INSPECTION FUNCTION</th>
<th>INSPECTION SCHEDULE</th>
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<td>TRIP VALVES</td>
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<td>MISC UNDER CAR</td>
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**TRACTION INVERTER**
- Propulsion Self Test
- Inspection, Exterior
- Inspect Inductor Assembly
- Inspection, Interior
- Inspect Line Breaker & Overload Relay
- Inspect Line Charging & Brake Contactor
- Inspect Emergency Relay
- Inspect High-performance Relay
- Inspect Inverter / Dynamic Brake Assembly
- Inspect Logic Assembly
- Inspect High Performance Enabling Relay
- Inspect COMC
- Inspect Rail Gap Detector Assembly
- Cleaning
- Power Self Test
NYCT Maintenance Practices

Corrective Maintenance

Corrective Maintenance is performed upon detection of a failure (either while the car is in service, during the daily pre-trip inspection or at the scheduled inspection interval).
Repair action is designed to return the subway car to a state of operational readiness as quickly as possible, without compromising safety.

In the late 1980s, the technical specifications redefined car-borne maintenance philosophy, incorporating the concept of Line Replaceable Unit (LRU) and Lower Level Replaceable Unit (LLRU) into the design approach.

- **Level 1 Operational Level Maintenance: Car-borne level**
  - LRU
  - Portable Test Equipment (PTE)

- **Level 2 Intermediate Level Maintenance: Dedicated Repair Shops**
  - LLRU
  - Bench Test Equipment (BTE)

- **Level 3 Intermediate Level Maintenance: Dedicated Repair Shops**
  - Sub- components
  - Bench Test Equipment (BTE)
Present Level 1 Corrective Maintenance: Car-borne LRU Isolation

1. Upon detection of a failure in service (or during inspection), trouble-shooting is performed.
2. Defective LRU is identified and removed from the car.
3. Functional LRU is removed from inventory stock and installed on the vehicle.
4. Train placed back into service

Faulty LRU

Good LRU

Electronics Repair Shop
Pneumatics Shop
Electro-Mechanical Shop

Bench Test Equipment (BTE)
Level 2 Corrective Maintenance: LRU Testing to LLRU Isolation

LRU

Bench Test Equipment

END OF PROGRAM.
LRU IS GOOD.

OR

END OF PROGRAM

LRU IS FAULTY.

SUSPECTED PCBS:
1. PCB “A”
2. PCB “B”
3. PCB “C”

LLRU
END OF PROGRAM.

PCB IS GOOD.

OR

END OF PROGRAM

PCB IS FAULTY.

SUSPECTED COMPONENTS:
1. IC1
2. IC2
3. IC3
4. C1
5. R1
NYCT Maintenance Practices

- **Scheduled Maintenance System (SMS)**
  - Compliments the Scheduled Inspection program and is the cornerstone of NYCT’s fleet maintenance program.
  - SMS is a preventative maintenance program based on the planned replacement of key components and systems to sustain a state of good repair (SOGR) and optimize performance through the vehicle’s lifecycle.
Three distinct SMS Overhaul (O/H) cycles, based upon anticipated breakdown date:

- **4 Year O/H** - air brake operating unit valves, load sensor valve, cab emergency magnet valve, battery reconditioning

- **6 Year O/H** – truck, brake valve, coupler/electric, HVAC, propulsion cards, magnet valves, Air Compressors

- **12 Year O/H** – all 4 and 6 year work plus car body, draft gear, flooring, door operators/control, master controller, propulsion, electronic signs, auxiliary electric/electronic units
Car repair line

30% work

Components for repair / refurbishment

Dedicated MTA repair shops

70% work

External Vendors Electric Motor Electric Component Pneumatic HVAC Wheel / Axle Truck Battery Plant Maintenance

Store room Kits for parts repair

Suppliers

Replacement parts

Repairs parts

Parts for assembly

Repairs / refurbished components

Suppliers
<table>
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<tr>
<th>System</th>
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Challenges: Scheduled Maintenance System (SMS)

- Existing Scheduled Maintenance Intervals and SMS Programs are based upon ridership history and current car technologies.
- Fleet Mileage is increasing faster than originally anticipated when SMS Program was derived.
- Increases in electronic systems impacting scope of work for inspections being performed at scheduled maintenance intervals
Where do we go from here?

Condition-based Maintenance (CBM)
Future: Condition-Based Maintenance (CBM)

- CBM is based on using real-time data to monitor and determine the overall health of the system.
- CBM recommends a maintenance action based upon decisions from the information collected through condition monitoring.
- The CBM process can be divided into three steps:
  - Data Capture
  - Data Processing
  - Recommended Maintenance Action
Future: Condition-Based Maintenance (CBM)

- **Data Capture**
  On board data from subsystem health and diagnosis is transmitted at key locations (terminal stations, layup locations, etc.) to a central workstation.

- **Data Processing**
  Data and analyzed to determine next course of action.

- **Recommended Maintenance Action**
  When an established “Impending Failure” go/no-go criteria has been reached, vehicle is sent to the maintenance shop after completion of scheduled service.

  - Level 1 actions (troubleshooting & repair)
  - Level 2 (LRU) and Level 3 (LLRU) maintenance remains unchanged.
Future: Condition-Based Maintenance (CBM)

- Types of systems that are candidates for CBM:

  - **DOORS**
    - Motor Current
    - Door opening / closing times
  
  - **PROPULSION**
    - Traction Motor Current
    - Vibration
  
  - **BRAKING**
    - Cylinder Pressure Status
    - Valve Status
  
  - **HVAC**
    - Inlet Air Temperature vs. Car Temperature
    - Inverter Status
Future: Level 1 Maintenance; Car-borne LRU Isolation with CBM

1. Real-time data transmitted to Car Maintenance Facility prior to failure.

2. CBM download identifies potential faulty LRU(s).

3. Maintenance action request to be performed post-service.

1. After completing service, train is sent to maintenance shop to perform follow-up predictive maintenance actions.

2. Isolation and removal of LRUs that are identified as approaching “failure” condition.

3. Minimized turnaround time in trouble-shooting results in faster train availability.
**Present: Corrective Maintenance Timeline**

- **T0 - T1:** Development of Fault Condition
- **T1:** Failure Occurs
- **T1 - T2:** Service Disruption; Train removed from service & travels to shop
- **T2 - T3:** Level 1 Troubleshooting
- **T3 - T4:** Spare part(s) retrieval
- **T4 - T5:** Repair Action:
  - Remove/Replace part
  - Test
- **T5 +:** Train returns to service
Future: Condition-Based Maintenance Timeline

T0 - T1: DEVELOPMENT OF FAULT CONDITION

T1: CBM DIAGNOSTICS

T1-T2: TRAIN COMPLETES SERVICE

T2-T3: DATA ASSESSMENT - SPARE PARTS RETRIEVED

T3-T4: TRAIN TRAVELS TO SHOP

T4-T5: TROUBLE-SHOOTING

T5-T6: REPAIR ACTION - REMOVE/REPLACE PART - TEST

T6 +: TRAIN RETURNS TO SERVICE

SAVINGS ! ! !

POTENTIAL SAVINGS

POTENTIAL FAULT CONDITION
Improved Vehicle Availability with CBM

PRESENT

FUTURE

TRAIN RETURNED TO SERVICE
Future: Condition-Based Maintenance (CBM)

Advantages

- Improved system reliability and overall performance
- Decreased maintenance costs
- Increased inspection intervals
- Reduced number of unplanned failures and maintenance operations
- Reduction of human interaction with carborne system components
- Increased asset life
- Increased turnaround vehicle availability
- Reduced overall maintenance costs
- Increased efficiency of maintenance management
- Potential extension of the subsystem overhaul intervals
- Potential in redefined scheduled overhaul scope of work
Future: Condition-Based Maintenance (CBM)

- Disadvantages:
  - Increase initial investment for monitoring equipment
  - Requires investment for additional training of personnel
  - Increased additional maintenance due to increase in hardware
  - Increased installation costs
  - GO/NOGO critical level and monitoring intervals (sampling rate) often established in a cost prohibitive fashion.
Future: Condition-Based Maintenance (CBM)

Challenges

- Collection of adequate amount of “near real-time” data in order to establish optimal “GO/NO-GO” threshold
- Streamlined analysis of collected data and update of carborne monitoring software
- Quality of sensor data
- Cyber-security
- Lack of standard of data communication
- Assessment of component failure modes
- Statistics for determining failure root cause
- Accuracy of historical data.
Future: Scheduled Maintenance Inspections w/ CBM

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<tr>
<th>INSPECTION FUNCTION</th>
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• **INSPECTION CYCLES MAY HAVE THE OPPORTUNITY TO BE LENGTHENED**
  • 72 days → 90 days?

• **INSPECTION STEPS COULD BE STREAMLINED OR ALTERNATED BETWEEN CYCLES**
Future: Scheduled Maintenance System with CBM

- With the ability to perform condition-based maintenance (CBM) at the maintenance shop level, the next generation SMS Overhaul cycle will be driven by the carborne system that possesses the weakest link (shortest cycle).
- Time interval may remain the same or potentially increase
- Scope of Work should be reduced as a result of CBM scheme
## Future: Scheduled Maintenance System with CBM

### Current

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<th>6 Year</th>
<th>12 Year</th>
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<td>Air Brake valves</td>
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### Future

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<td>HVAC</td>
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<td>Propulson Controls</td>
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<td>Door Operators / Controls</td>
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NYCT CBM Efforts Under Way

Many of the condition-monitoring systems for railway vehicles are focused on the wheel and truck interfaces as these subsystems have the largest impact on the performance and maintenance costs.

- **R188 Fleet: # 7 Line**
  - Wheel Wear Wireless Sensors
  - Traction Motor Vibration Sensors via Energy Harvesters
NYCT CBM Efforts Under Way

- R211 New Fleet Procurement: Maintenance & Diagnostic System Status
  - Propulsion
  - Braking
  - Doors
  - HVAC
NYCT CBM Efforts Under Discussion

- Car Borne Monitoring & Diagnostics Interface with Wayside CBTC
  - R188 Fleet MDS Status (CBTC Vendor: Thales)
  - R160 Fleet MDS Status (CBTC Vendor: Siemens)
- R142 Fleet Enhancements: MDS Car Status using VPN Interface
  - Doors
  - HVAC
  - Propulsion / Braking
Examples of Suppliers Offering CBM Solutions

- **Rail / Signals**
  - Alstom - HealthHub
  - Bombardier – INTERFFLO & CITYFLO
  - Knorr Bremse – Intelligent Condition Oriented Maintenance (iCOM)
  - CAF – LeadMind Digital Platform
  - Siemens – Railigent

- **Bus**
  - Allied - SMARTCBM
  - Samasara - Telematics Fleet Management Solution
  - Trapeze – Intelligent Condition Oriented Maintenance (iCOM); Rail

- **General Designers for Corrective / Predictive Maintenance**
  - PERPETUUM
  - TRAPEZE
  - GEOTAB
  - DEEPVIEW
Thank you.