Reliability-Centered Maintenance Program on the ACELA Express Train sets

Amtrak ACELA Express

- Amtrak currently runs ACELA Express Service from Washington, DC to New York City and Boston.
- There are currently 34 train assignments in this current time table representing the Northeast Corridor covering every hour from 5 am to 7 pm.
- The ACELA Fleet has 20 Train sets configured with two Power Cars and six Coach Cars each.

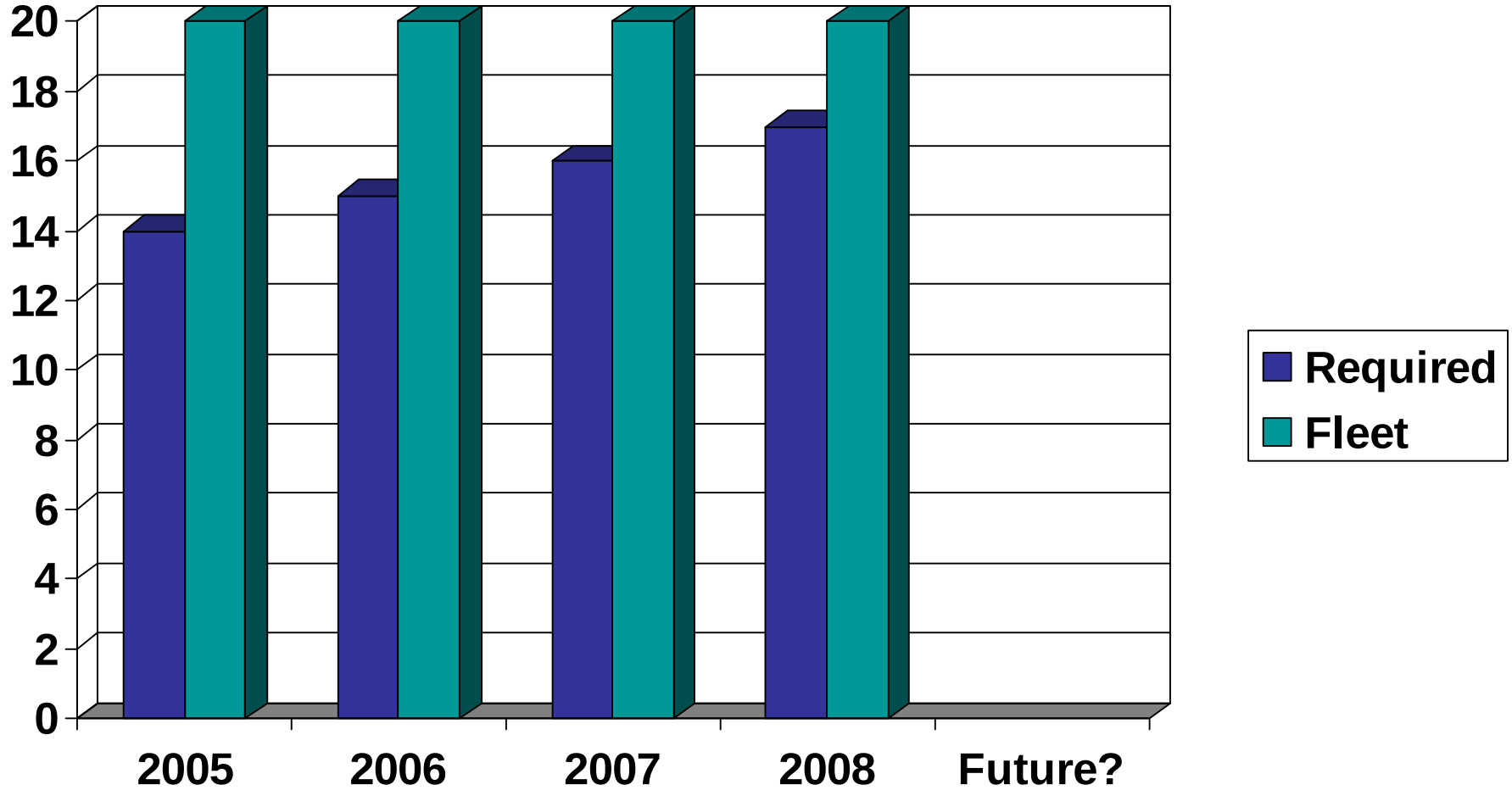
Acela Power Cars

- Continuous 4,600 kW/ 6,000 HP
- 4 asynchronous AC traction motors
- 3 GTO-Type inverters, 2 for propulsion and 1 for auxiliary power required by the power car and passenger cars.
- Top operating speed of 150mph (165mph designed)
- The Main Transformer has two primary windings connected in parallel for operating overhead AC supply of 12kV at 25Hz or 12.5kV at 60Hz and series connection when the overhead input is 25kV at 60 Hz.
- Braking system incorporates blended regenerative/rheostatic dynamic Braking

High Speed Trainset Tilting System

- Each Passenger Car is equipped with an active computer controlled and electro hydraulically activated tilting system.
- Maintains low lateral acceleration through curves at high speed.
- The curve detection is sensed by the lead power car triggering the tilt function.
- Amtrak currently operates at 7 inch cant deficiency (it is designed and tested at 9 inch cant deficiency).

ACELA Passenger Demand for Service



ACELA Passenger Demand for Service

Amtrak developed Continuous Maintenance program (CM) for Planned Maintenance (PM) to increase availability of equipment.

- PM requirements divided into manageable segments performed during Service and Inspection dwell time.
- Previous to CM two Trainsets were shopped for PM

Amtrak and RCM: Background

- Amtrak established Condition-Based Maintenance (CBM) as corporate policy in July 2006
- Amtrak reviewed and validated all Acela Train set maintenance requirements using Reliability-Centered Maintenance (RCM), per 49 CFR Part 238 Appendix E.
- Acela Level I (Daily), Level II (92Day) and Level III (Long Term) requirements were reviewed and completed in 2006.

Reliability-Centered Maintenance

Reliability-Centered Maintenance (RCM) as used by Amtrak incorporates several techniques and tasks:

- Maintenance Effectiveness Review
- Root Cause Analysis
- Condition Based Monitoring

Maintenance Effectiveness Review (MER)

Maintenance Effectiveness Review

MER analysis identify the applicability and effectiveness of maintenance tasks.

- Applicability criteria is the specific set of conditions for a given task type that must be met to improve or maintain system or equipment inherent reliability
- Effectiveness criterion judges whether a specific task would be capable of reducing the failure for its failure consequence.

✓ Task periodicities are based on evidence of need and assessment of risks.

Maintenance Effectiveness Review

Cross Functional Stakeholders

- ✓ Mechanics who perform the tasks
- ✓ Operational Management Representative
- ✓ Equipment Engineering Representative
- ✓ Operator or End User
- ✓ OEM Representative
- ✓ Facilitator

Maintenance Effectiveness Review

Task Type

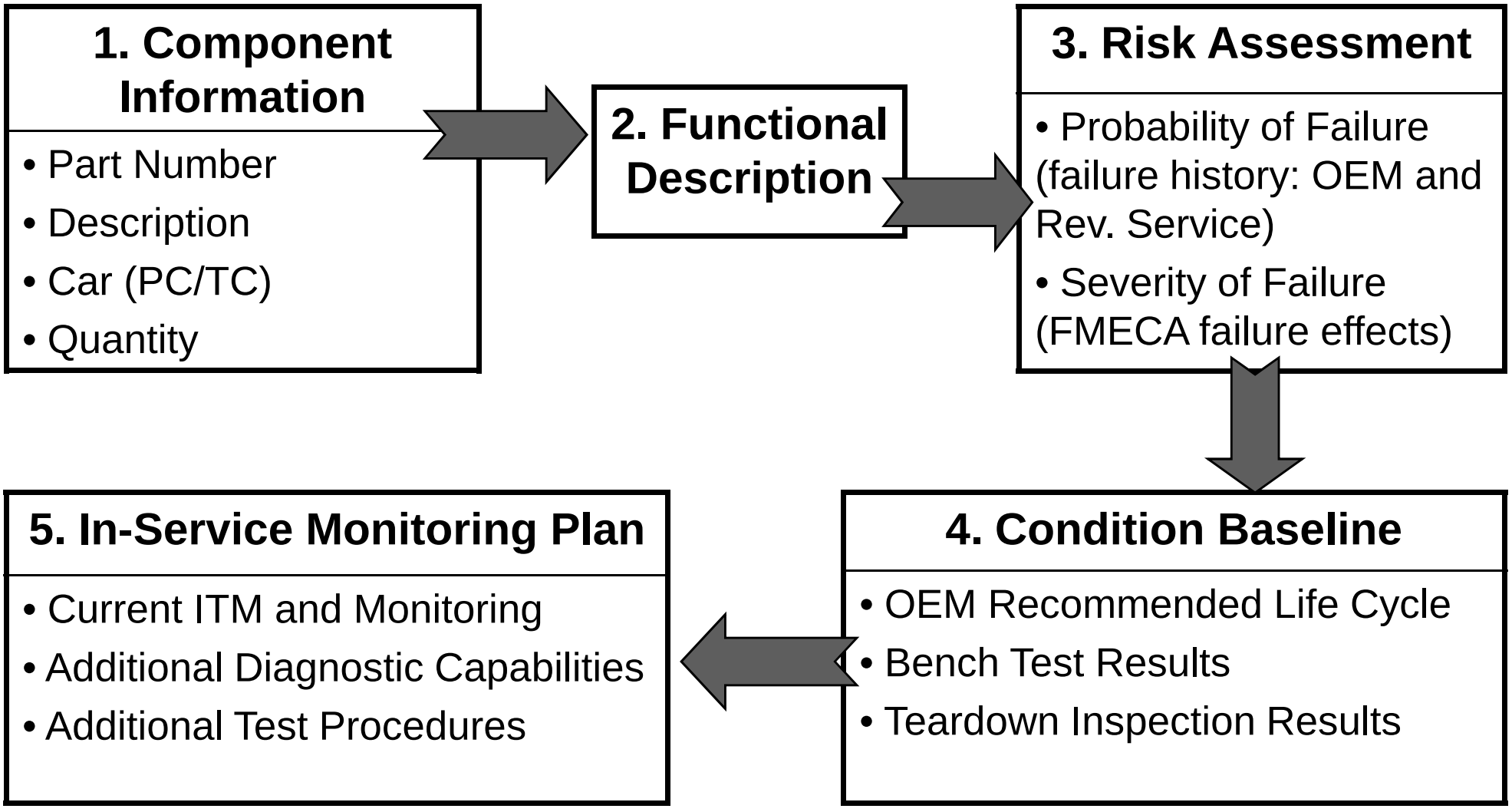
- **On Condition**, renew life based on comparison with standard, initiating action upon reaching potential failure point.
- **Age Limit**, renew life regardless of condition, taking action prior to “anticipated” failure point.
- **Failure Finding**, determine whether a hidden failure has occurred, initiating corrective action when initial failure occurs.

Maintenance Effectiveness Review

Failure Consequences

- **Safety,** functional failure results in possible loss of occupants or equipment
- **Operational**, functional failure results in indirect economic loss **plus** direct cost of repair
- **Non-operational**, functional failure results in direct cost of repair

MER Component Analysis Spreadsheet



Root Cause Analysis

Root Cause Analysis

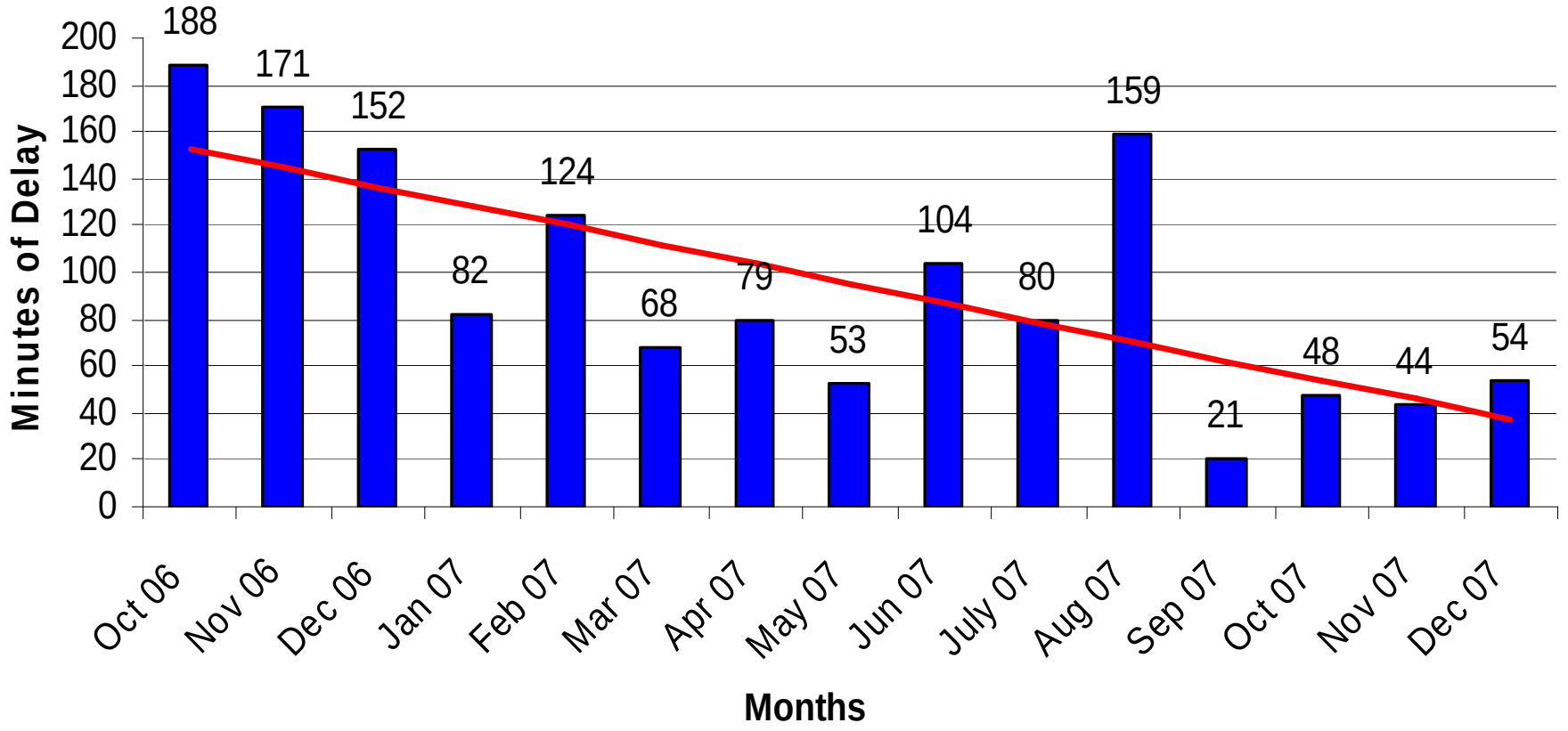
Amtrak has incorporated a standard maintenance practice on how a Root Cause Analysis session is performed. The method used is based on Reliability Center Incorporated's PROACT system.

- ✓ Preserving Event Data
- ✓ Ordering the Analysis Team
- ✓ Analyzing the Data
- ✓ Establishing Root Causes
- ✓ Communicating the Findings
- ✓ Tracking for Results

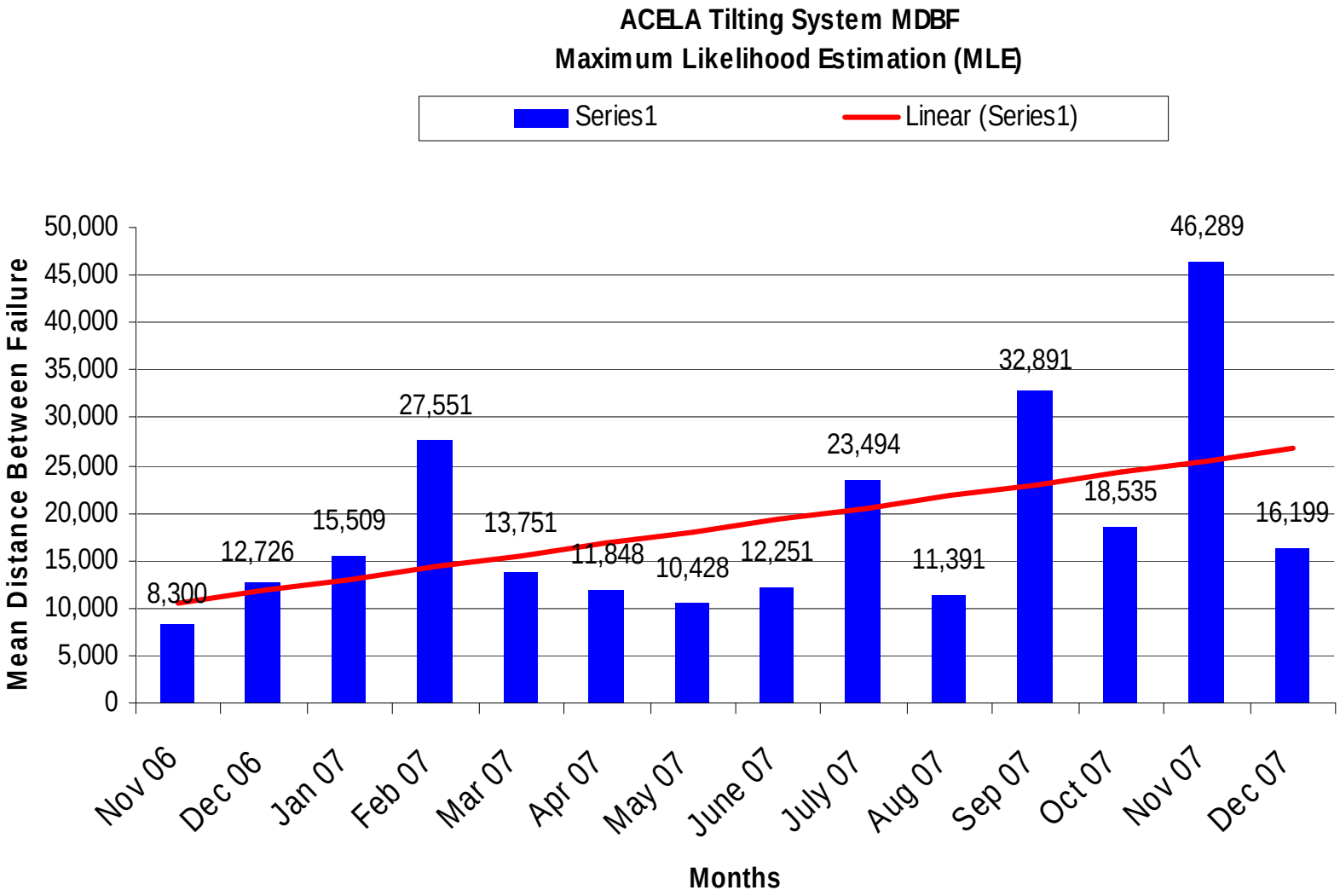
TILT SYSTEM RCA RESULTS

- Constant displacement pump and unloading circuit installation
  - Increased pump reliability and reduction in service delays
  - Improved onboard oil filtration, decreasing hydraulic oil contamination and reduction in component wear
  - Reduction in necessary periodic external filtration to maintain standard ISO level
- Minimum and centering pressure switch upgrade
  - Reduction of in service failures
- Tilting load locking valve replacement with dual pressure transducer
  - Allows for condition based monitoring and implementation of continuous maintenance tasks
  - Reduction of in service failures
- Quick connect fitting upgrade
  - Reduced external hydraulic leakage
  - Reduction of in service failures

Acela Tilting Delay Minutes



Acela Tilting System MDBF

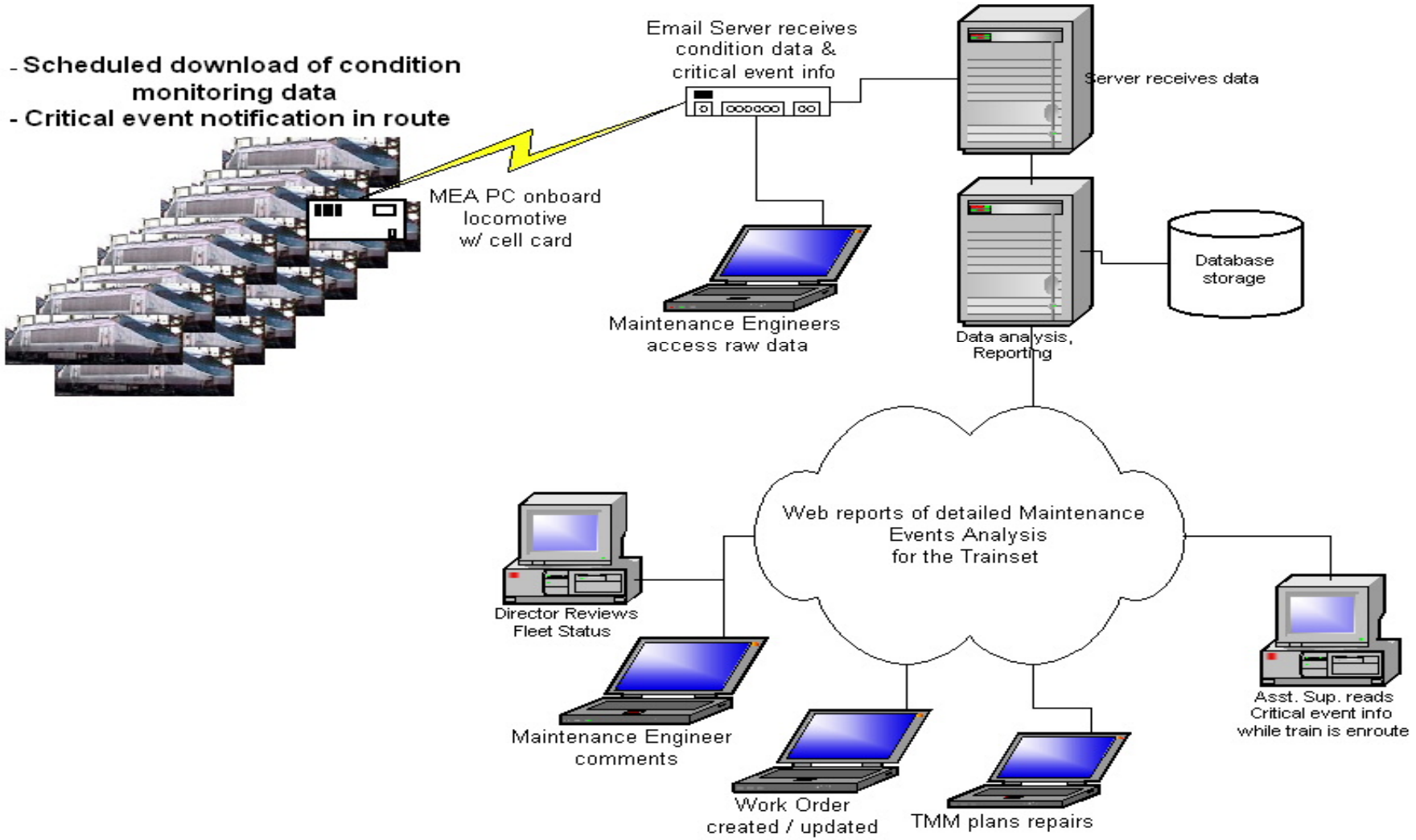


Condition Based Monitoring

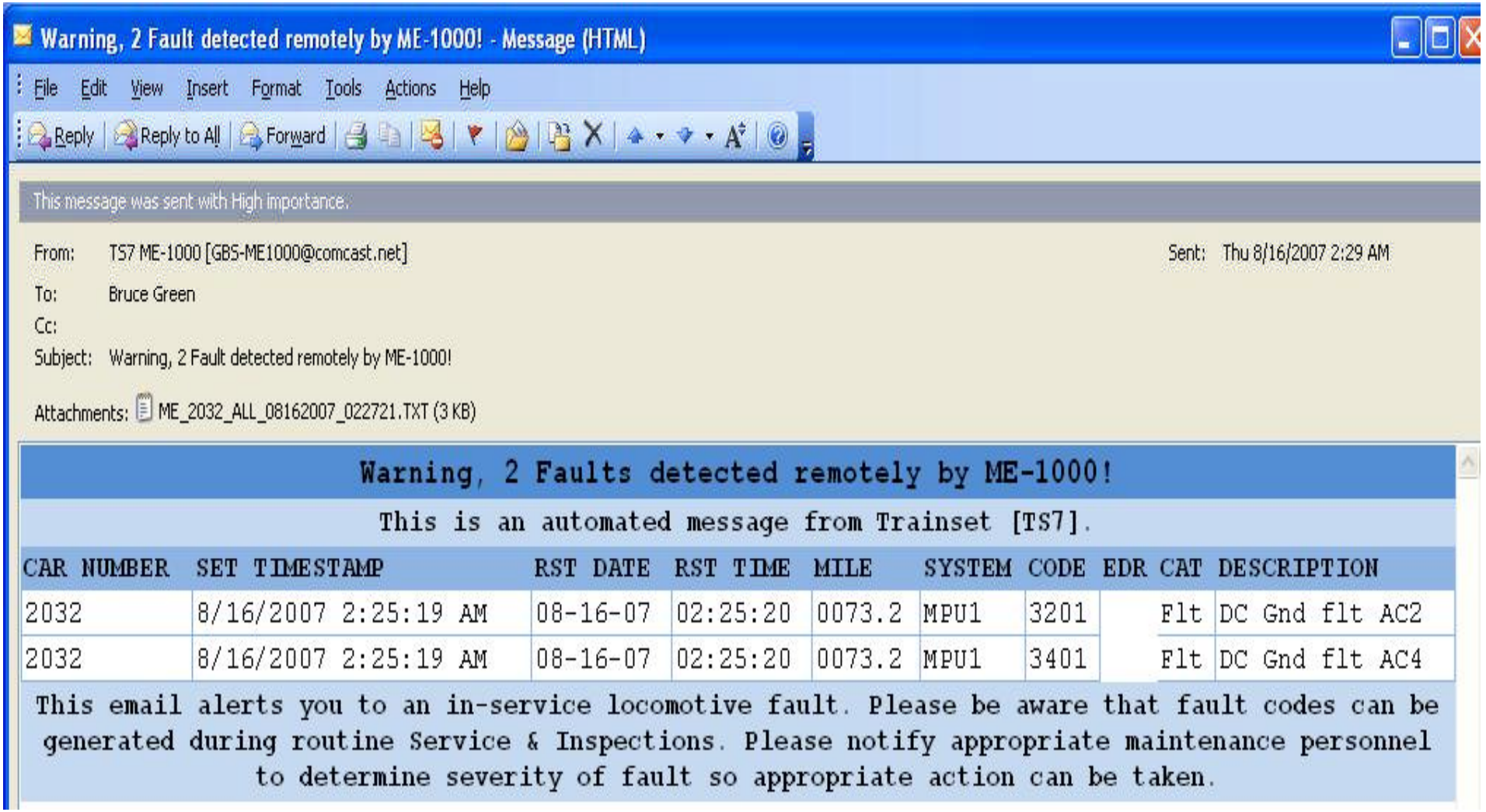
Condition-Based Monitoring

- Dynamic Monitoring detects potential failures that emit abnormal energy such as vibration or acoustical waves.
- Particle and Chemical Monitoring detects potential failures by analyzing discrete particles or traceable quantities of chemicals released in the component's operational environment.
- Physical Monitoring detects potential failures by analyzing changes in the physical structure such as cracks, wear or dimension.
- Temperature Monitoring detects potential failures by sensing temperature differentials in the component's operational environment.
- Electrical Monitoring detects potential failures that produce changes in resistance, conductivity, dielectric strength and potential.

Remote Condition Monitoring



Actual, En-route Notification of Reportable DC Ground Fault



Warning, 2 Fault detected remotely by ME-1000! - Message (HTML)

File Edit View Insert Format Tools Actions Help

Reply | Reply to All | Forward

This message was sent with High importance.

From: TS7 ME-1000 [GBS-ME1000@comcast.net] Sent: Thu 8/16/2007 2:29 AM

To: Bruce Green

Cc:

Subject: Warning, 2 Fault detected remotely by ME-1000!

Attachments: ME_2032_ALL_08162007_022721.TXT (3 KB)

Warning, 2 Faults detected remotely by ME-1000!

This is an automated message from Trainset [TS7].

CAR NUMBER	SET TIMESTAMP	RST DATE	RST TIME	MILE	SYSTEM	CODE	EDR	CAT	DESCRIPTION
2032	8/16/2007 2:25:19 AM	08-16-07	02:25:20	0073.2	MPU1	3201		Flt	DC Gnd flt AC2
2032	8/16/2007 2:25:19 AM	08-16-07	02:25:20	0073.2	MPU1	3401		Flt	DC Gnd flt AC4

This email alerts you to an in-service locomotive fault. Please be aware that fault codes can be generated during routine Service & Inspections. Please notify appropriate maintenance personnel to determine severity of fault so appropriate action can be taken.

Element of June 2007 Acela Fleet Health Analysis

HVAC Monthly Performance Evaluation
June 2007

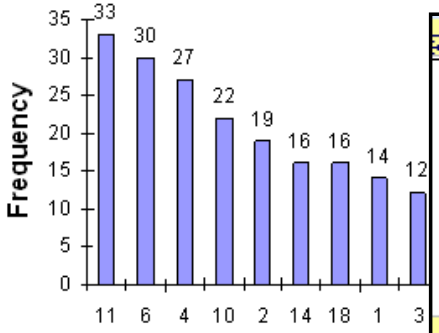
DETAILED REPORT INFORMATION

Month/Year: June 2007	Equipment Type: ACELA Express (All Cars)	Author: Wade Clark Email: wadeclark@thecbsgroup.us

MAINTENANCE EVENTS ANALYSIS DETAILS

HVAC

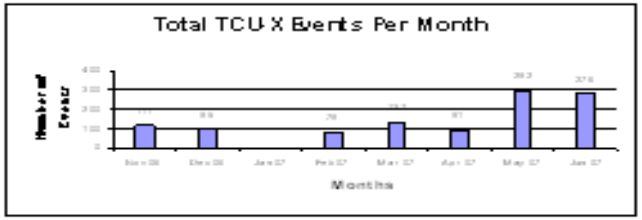
TCU-X Histogram
June 07



TCU-X Code Analysis for June 07

TCU-X Code	EVENT_DESCRIPTION	Frequency
125	Circuit Breaker Loop Open	48
130	Low Suction Pressure Flt	39
131	High Refrig. Pressure Flt	23
146	High Pressure Switch Flt.	166
	Total Faults	276

Trend of TCU-X Events



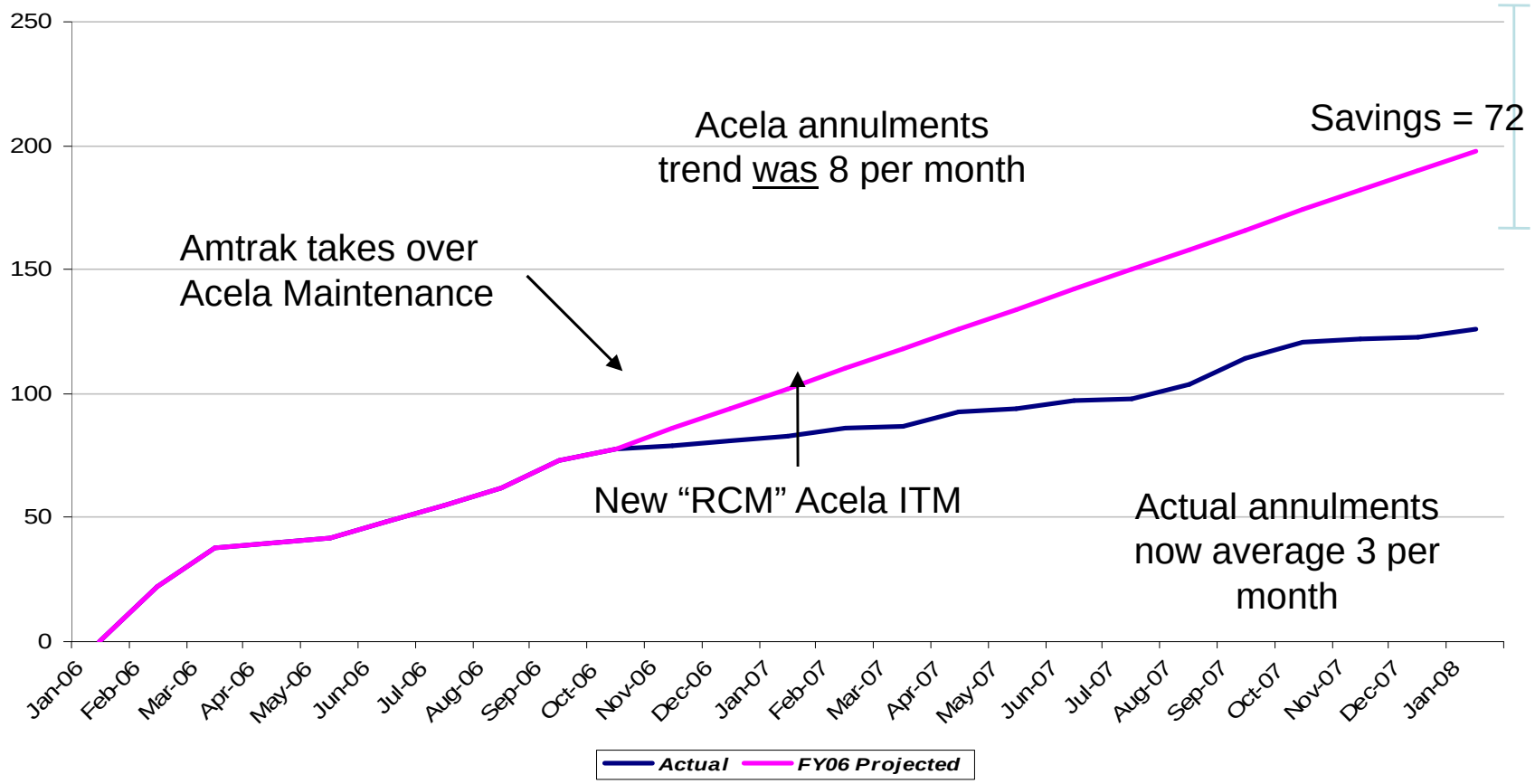
Trainset	Trend Analysis	Suggested Preventative/Corrective Action
TS-11 PC-2036	PC-2036 still generating many fault codes #146.	Fault logic: When compressor is operating the High Pressure Switch is checked once a second. IF two HPS feedback readings are low (input low) generate event #146 immediately. For troubleshooting, this switch may need to be changed out
TS-04 2001	Experienced 10 faults during the month (shut down mode #3) due to fault code #130. Last event logged May 20, this problem may have been corrected	Fault logic: When compressor is operating the Low Pressure Transducer is checked every second. If LPT < 15 psig generate event 130. When this event is logged, it typically indicates a refrigerant leak around various devices or some other location in the HVAC unit. Refrigerant leak must be located and correct
TS-10 3533	HVAC A-end experienced 3 faults during the month due to fault code #130. Last event logged on 29 June (three times).	Fault logic: When compressor is operating the Low Pressure Transducer is checked every second. If LPT < 15 psig generate event 130. When this event is logged, it typically indicates a refrigerant leak around various devices or some other location in the HVAC unit. Refrigerant leak must be located and correct

Proposed Dynamic health display to be located in Maintenance Facilities

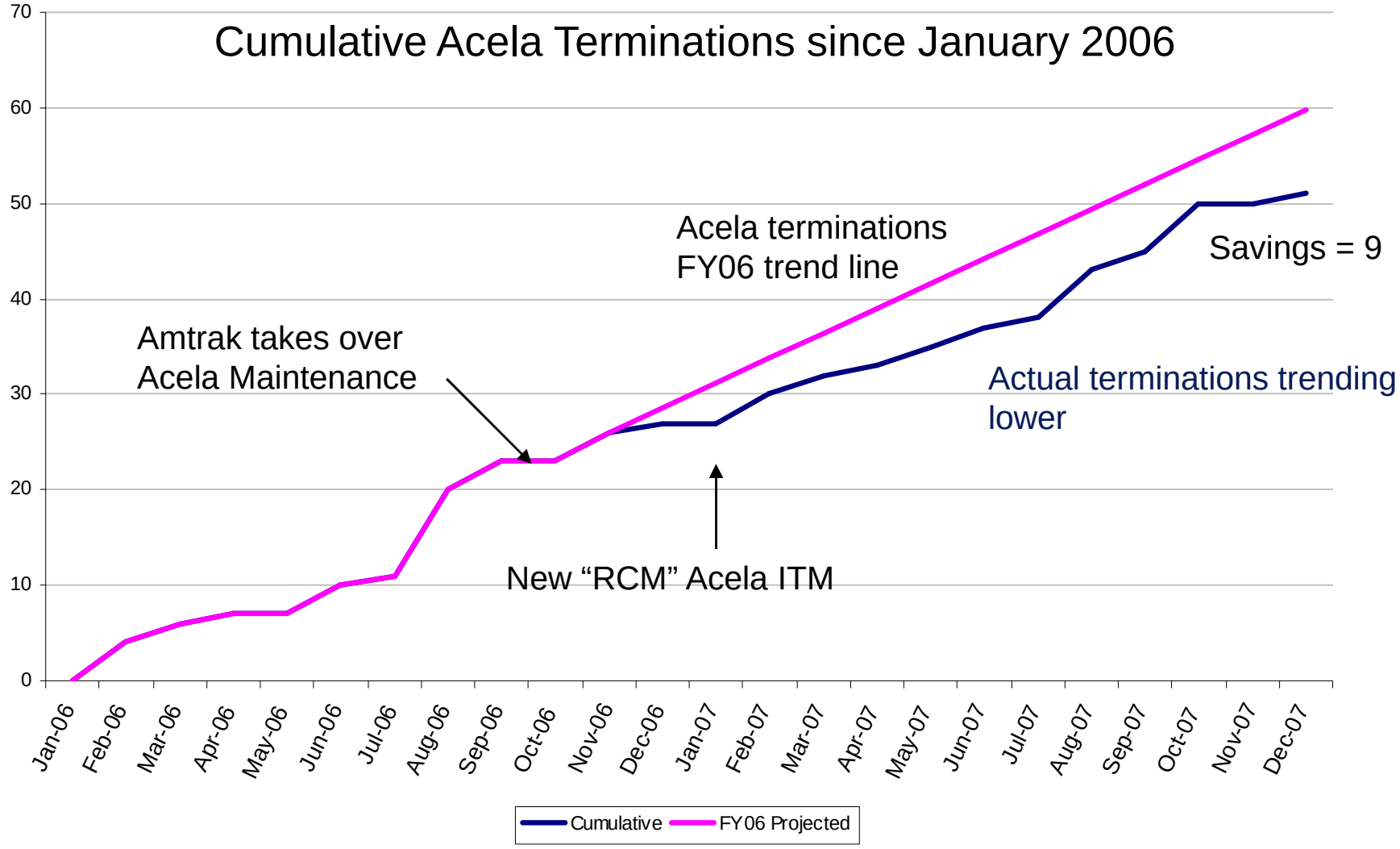
Acela Mechanical Status Board					
TS #	Location	Train #	Heading	Fault	Comments
1	Ivy City			Shop	Truck Replacement
2	Union Station	2166	Stop		
3	New York Penn	2158	Stop	Tilt	9080 Fault, reset at Turn repair during S&I
4	New York Sunnyside	2163	Stop		
5	Boston	2167	Stop		
6	MetroPark	2108	NB		
7	Wilmington	2155	SB	HVAC	Car 3216 B-End HVAC Low Suction Pressure
8	Union Station	2170	Stop		
9	Ivy City				
10	BWI	2164	NB		
11	Boston				
12	Union Station	2122	Stop		
13	Boston				
14	Newark	2117	SB		
15	New Haven	2159	SB		
16	Boston	2125	Stop		
17	Providence	2121	SB	Doors	S2 Fault
18	Marcus Hook	2110	NB		
19	Union Station	2168	Stop		
20	Baltimore	2207	SB		
			12:22 PM		

Seventy-Two (72) Annulments Have Been Avoided Since October 2006

Cumulative Acela Annulments since January 2006



Fewer Terminations



Reliability-Centered Maintenance Program on the ACELA Express Train sets