FMCSA Tire Pressure Monitoring
Field Operational Test Results

Tampa, FL
February 8, 2011
Agenda

- Introduction
- Background
- TPMS Field Operational Test Plan
- Field Operational Test Findings
Introduction

- In October 2006, Booz Allen was awarded a contract with the US DOT to install tire pressure monitoring systems (TPMS) and automatic tire inflation systems (ATIS) on commercial vehicles (CMV) in revenue generating service for a year long field test.

- Assignment builds on previous work evaluating sensors on a closed course test track at the Transportation Research Center (TRC) in East Liberty, Ohio and on transit buses in revenue service.

- US DOT interested in performing study with commercial vehicles to provide vital cost and benefit information for TPMS implementation.

- Program goal: Determine whether systems can influence maintenance intervals and practices, and improve performance and safety.
Background
In 2003, a study found inadequate tire pressure maintenance...

- In a survey of CMVs,
  - ~50% of tires were within 5 psi of the recommended pressure
  - 1 out of 14 tires were 20+ psi underinflated
  - ~20% of dual-tire assemblies have tire pressures that differ by more than 5 psi

- The financial implications of improper tire pressure maintenance include:
  - Tire procurement costs increased by 10 to 13%
  - Fuel economy losses of 0.6%
  - Accounts for one road call per year
  - Total operating costs increased by $600 - $800

...has severe financial implications.
Further, the study outlined the economic benefits of TPMS and ATIS installation.

- An economics analysis of tire-related costs and TPMS found:
  - Tire-related costs are the single largest maintenance item for commercial vehicle fleet operators (1.9¢ per mile)
  - Automatic inflation systems reduce operator’s time spent checking tire pressures
  - Operators can expect a return-on-investment within 1 to 2 years (based on a $1,000 system)
  - Lack of system penetration based on concerns of system reliability, maintenance costs, and initial system costs

- This initial study set in motion additional research on TPMS, including equipment durability, equipment reliability, and overall costs and benefits.
In 2006, the overall performance of TPMS and ATIS equipment was analyzed on a closed-circuit test track.

- **Automatic Inflation Systems:**
  - Are limited by rate of flow to tires.
  - Are able to maintain pressure during heavy braking AND induced tire leak.
  - Protected intact tires from deflating during catastrophic failure of a single tire in system.

- **Dual Pressure Tire Equalizers**
  - Effectively balanced tire pressure between tires
  - Isolated tires during an incident.

- **Tire Pressure Monitoring Systems:**
  - Accurately reported values within 2 to 3 psi of measure value.
  - Accurately warned of low pressure within 2 to 3 psi of expected threshold.
  - Valve-stem mounted sensors are susceptible to theft and loss.
  - Rim mounted sensors are susceptible to damage during tire mounting and dismounting.
In 2007, the performance and durability of TPMS was examined in a field test using transit buses.

- Evaluated TPMS ability to accurately detect tire pressure, tire temperatures, and tire leakage rates in revenue service.

- TPMS equipment installed on fleet included:
  - Wabco IVTM (Valve-Stem Mounted)
  - Tire SafeGuard (Rim-Mounted)
  - Michelin eTire (Tire-Mounted)

- The study found:
  - TPMS equipment provided accurate tire inflation pressure data.
  - TPMS sensors consistently and reliably reported tire inflation pressures.
  - Valve-stem mounted systems were preferred due to ease of system installation and tire replacement.
  - TPMS-equipped buses did not experience increased average tire pressure due to diligent tire pressure maintenance.
  - TPMS display location is essential to impact tire maintenance practices, fuel economy, and tire life.
TPMS Field Test Plan
The field test aimed to prove the following hypotheses...

- TPMS or ATIS use will increase the life of equipped tires.
- TPMS or ATIS use will reduce fuel consumption of equipped tractor-trailers.
- TPMS or ATIS use will reduce road calls for damaged/flat tires of equipped tractor-trailers.
- TPMS or ATIS correctly measures the tire pressure of equipped tractor-trailers.
- TPMS or ATIS use will not introduce unscheduled maintenance that adversely affects day-to-day fleet operations.
... through the collection of data during vehicle operation.

The following was collected at each scheduled preventative maintenance and inspections by the technicians:
- Vehicle mileage & Inspection Date
- Tire pressures (Manual and System)
- Low pressure indicator status
- Tire replacements
- Tread depth

In case of a failure, reports were generated by the driver (if in service) and/or by the technician, including:
- Vehicle Mileage & Failure Date
- Failure Location
- Failure Type (System, Tire, etc)

### Example Data Collection Schedule

<table>
<thead>
<tr>
<th></th>
<th>Scheduled Inspection</th>
<th>Monthly</th>
<th>As Needed</th>
<th>Yearly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle Mileage</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Fuel Consumption</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>System Status</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual Tire Inspection</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tire Pressure Check</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tread Depth</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tire Failures</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>In-Service Failures</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>System Failures</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Tire Replacements</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>System Maintenance</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Driver / Technician Surveys</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tire Maintenance Records</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>
Two fleets were selected...

- **Sheetz**
  - Headquartered in Claysburg, PA
  - Tanker fleet terminal in Altoona, PA
  - Operates 24 married tractor-tankers
  - Uses wide-based tires on tractor drive axles and tanker axles
  - Return daily to Altoona Terminal
  - Maintenance performed by Fox & James

- **Gordon Food Services (GFS)**
  - Headquartered in Grand Rapids, MI
  - Maintenance terminal in Grand Rapids
  - Test encompassed tractors, refrigerated pup trailers, and standard 50’ trailers
  - Return daily to home terminal
  - Maintenance performed in-house
... to represent a diverse set of equipment and operating environments.

**Sheetz**

- **Type of Operation**
  - Outbound trips operate fully loaded tankers
  - Inbound trips operate empty tankers
  - Drive and trailer axles use wide-based single tires

- **Equipment tested:**
  - Freightliner’s Columbia daycabs, manufactured between 2006 and 2009.
  - Six tractors (1 test / 5 control) upgraded from 2002/3 model years to 2009 model years in November 2008.
  - Heil’s 406 Tankers

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**GFS**

- **Type of Operation**
  - Equipment operates on city streets and highways
  - Tires experience frequent curb hits and tire scrubbing due to maneuverability during deliveries

- **Equipment tested:**
  - Volvo’s VNM and IHC 8600A daycabs, manufactured between 2007 and 2009.
  - 28 foot Great Dane refrigerated pup trailers
  - 50 foot Great Dane straight trailers
Three technologies were evaluated.

- **Inflation Systems:**
  - Automatically adds air to tires if tire pressure drops below preset pressure setting.
  - On-unit air system maintains tire pressure.
  - **System Installed:** Meritor Tire Inflation System (MTIS) by PSI

- **Wheel Mounted TPMS**
  - Monitors tire pressure, warning driver of low tire pressures.
  - Tire sensors strapped to tire rim
  - **System Installed:** Tire-SafeGuard Monitoring System

- **Valve Stem Mounted TPMS:**
  - Monitors tire pressure, warning driver of low tire pressures.
  - Tire sensors mounted to wheel lugs and connected to existing valve stem
  - **System Installed:** Integrated Vehicle Tire Monitoring System (IVTM)
Meritor Tire Inflation System by PSI

- Designed by PSI, distributed by Arvin Meritor
- Trailer-mounted system only.
- Maintains preset pressure at each of the tire locations.
- Display – External light monitors flow of air to tires. Light illuminates to alert the driver of air being added to the tire.

<table>
<thead>
<tr>
<th>System</th>
<th>Sheetz Tractors</th>
<th>Sheetz Tankers</th>
<th>GFS Tractors</th>
<th>GFS Trailers</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTIS</td>
<td></td>
<td>10</td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>Tire-SafeGuard</td>
<td></td>
<td>12</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>IVTM</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Manufacturer Participants…

**Tire-SafeGuard Monitoring System**

- Designed & Manufactured by HCI Corporation
- Monitors both tractor and trailer
  - Tractor and trailer not required to be married pair. Tractor system automatically detects trailer equipment.
- Uses wheel, valve-stem, and rim mounted sensors.
  - Tested system using wheel-mounted sensors.
- Display: In-cab display monitors tire pressure and tire temperature. Audible and visual warnings are provided to the driver.

<table>
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<td>Tire-SafeGuard</td>
<td></td>
<td>12</td>
<td>12</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Manufacturer Participants…

Integrated Vehicle Tire Monitoring System (IVTM)

- Manufactured by Wabco Automotive, distributed by Michelin
- Capable of monitoring both tractors and trailers.
  - Tested only on tractors.
- Uses valve-stem mounted sensors
- Display: In-cab display monitors individual tire pressures and compares to remaining tires on the vehicle.

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<th>Sheetz Tankers</th>
<th>GFS Tractors</th>
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</tr>
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<td></td>
<td>10</td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>Tire-SafeGuard</td>
<td></td>
<td></td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>IVTM</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Field Test Findings

- Fuel Economy
- Tire Wear
- Tire Incidents
- System Discrepancies
- Feedback
The fuel and tire findings from the 12 months of testing at Sheetz shows...

- The fleet operated over 3,856,337 miles, consuming 632,870 gallons of diesel fuel.
  - Units averaged 14,000 miles per month

- The technicians conducted 324 inspections to measure tread depth and verify system operation.

- Sheetz replaced 160 tires for tire wear...
  - 102 tires on the test fleet
  - 58 tires on the control fleet

- ... and identified 38 tire incidents.
  - 27 tires on the test fleet
  - 11 tires on the control fleet
During the 18 months of testing at GFS, fewer miles were traveled per vehicle, but more tires were replaced...

- The tractors operated over 3,406,570 miles, consuming 520,547 gallons of diesel fuel.
  - Tractors averaged 7,900 miles per month

- The trailers operated approximately 5,461,159 miles.
  - Trailers averaged 4,300 miles per month

- GFS replaced 278 tires for tire wear...
  - 110 tires on the test fleet
  - 168 tires on the control fleet

- ...and identified 77 tire incidents.
  - 44 tires on the test fleet
  - 33 tires on the control fleet
At Sheetz, the test tractors had the higher fuel economy.
Similar results were observed during the GFS testing.

Average fuel economy spread of 1.4% between test and control fleets

Field Test Start June 2009

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Trends in tread wear were identified in the Sheetz test fleet.
The Sheetz control fleet had similar tread wear rates.
Between the Sheetz fleets, the test fleet had slower wear rates.
Tire replacement rates due to wear were calculated at GFS

- Tread depth measurements were insufficient to define rate of wear.
  - Low mileage resulted in less than one tire wear cycle during the field test.
  - The rate of tires replaced due to tread wear were examined.
The Sheetz test fleet had 27 tire incidents during the field test.

<table>
<thead>
<tr>
<th>Incident</th>
<th>No. of Events</th>
<th>System Warning</th>
<th>Drove to Garage</th>
<th>Road Call</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Air</td>
<td>3</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leaking Valve Stem</td>
<td>2</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foreign Object Detected</td>
<td>5</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>Drivers identified screwdriver, bolts, and nails.</td>
</tr>
<tr>
<td>Pre-trip Inspection</td>
<td>3</td>
<td>✓</td>
<td></td>
<td></td>
<td>Identified prior to trip. Included a broken belt, an air leak, and torn tread</td>
</tr>
<tr>
<td>Tire Failure</td>
<td>3</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>Reports on only 2 incidents: @ service station, nail in tire. @ truck scale, faulty tire valve</td>
</tr>
<tr>
<td>Foreign Object Detected</td>
<td>8</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>Drivers identified screws, nails, and bolts. System maintained air.</td>
</tr>
<tr>
<td>Pre-trip Inspection</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>Drivers identified tire separation and nail during pre-trip inspection. Identified prior to failure. Fixed prior to shift.</td>
</tr>
<tr>
<td>Tire Failure</td>
<td>3</td>
<td></td>
<td></td>
<td>✓</td>
<td>Tire blow-out. System could not maintain air.</td>
</tr>
</tbody>
</table>

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The Sheetz control fleet experienced 11 tire incidents.

<table>
<thead>
<tr>
<th>Incident</th>
<th>No. of Events</th>
<th>System Warning</th>
<th>Drove to Garage</th>
<th>Road Call</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tractor Events</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foreign Object Detected</td>
<td>2</td>
<td></td>
<td></td>
<td>✓</td>
<td>Drivers identified a bolt in the tread.</td>
</tr>
<tr>
<td>Pre-trip Inspection</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>Drivers identified a tire bulge and a tire leak (due to a slice on the inner sidewall).</td>
</tr>
<tr>
<td>Tire Failure</td>
<td>2</td>
<td></td>
<td></td>
<td>✓</td>
<td>Report of tire blow-out and nail in tire.</td>
</tr>
<tr>
<td>Trailer Events</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Air</td>
<td>2</td>
<td></td>
<td></td>
<td>✓</td>
<td>Identified by driver.</td>
</tr>
<tr>
<td>Foreign Object Detected</td>
<td>2</td>
<td></td>
<td></td>
<td>✓</td>
<td>Drivers identified a nail and a bolt in the tread.</td>
</tr>
<tr>
<td>Pre-trip Inspection</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>Driver identified a slice in the sidewall.</td>
</tr>
</tbody>
</table>
The GFS test fleet had 44 tire incidents during the field test.

<table>
<thead>
<tr>
<th>Incident</th>
<th>No. of Events</th>
<th>Road Call</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tractor Events</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Foreign Object Detected</td>
<td>4</td>
<td>All tires replaced.</td>
</tr>
<tr>
<td>Tire Damage</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Air Leak</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Tire Failure</td>
<td>1</td>
<td>✓ Night service call in yard.</td>
</tr>
<tr>
<td>Trailer Events</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat</td>
<td>8</td>
<td>Drivers identified screws, nails, and bolts.</td>
</tr>
</tbody>
</table>
| Foreign Object Detected   | 20            | Tires repaired – 7  
Tires replaced – 13 |
| Tire Damage               | 1             | Cut in sidewall identified. |
| Air Leak                  | 1             |                            |
| Tire Failure              | 7             | ✓ Tire failures on pup trailer – 2  
Tire failures on 50’ trailer – 5 |
The GFS control fleet experienced 33 tire incidents.

<table>
<thead>
<tr>
<th>Incident</th>
<th>No. of Events</th>
<th>Road Call</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Foreign Object Detected</td>
<td>5</td>
<td>All tires replaced.</td>
</tr>
<tr>
<td>Tire Damage</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Air Leak</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Tire Failure</td>
<td>2</td>
<td>One steer tire failure caused progressive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>damage to surrounding equipment.</td>
</tr>
<tr>
<td>Flat</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Foreign Object Detected</td>
<td>5</td>
<td>All tires repaired.</td>
</tr>
<tr>
<td>Tire Damage</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Air Leak</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Tire Failure</td>
<td>9</td>
<td>One tire failure involved the catastrophic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>failure of two inner tires on a pup trailer.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tire failures on pup trailers — 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tire failures on 50’ Trailers — 3</td>
</tr>
</tbody>
</table>
During the field test, Sheetz reported few issues…

- Initial IVTM sensors lost communication with the in-cab display
  - Sensors returned to manufacturer for analysis. No trend identified.
  - No issues with replacement sensors.

- Loose hose connections caused air leaks during first phases of test.
  - Air hoses inspected and tightened as appropriate.
  - Maintenance procedures improved as test progressed, reducing air leaks.
  - Loose hoses did not disable any tractor-tankers.

- Over-filled hubs created appearance of oil leaks
  - On equipped trailers, oil seeps through vents on overfilled hubs.
  - Technicians adjusted the oil level as required.
  - Additional oil seepage from the hub vents did not occur.
GFS reported several minor issues during the test...

- PSI equipped trailer experienced overheated wheel end due to stuck brake valve
  - PSI confirmed safety valve properly isolated system to eliminate use of trailer air during a low-air condition.

- Inflation system frequently exceeded target pressure of 95 psi.
  - Technicians released air during inspections.

- Tire-SafeGuard wire harness failed
  - Trailer wiring harness overheated and failed.
  - Source of failure unknown.

- Slow communication between tractor and trailers
  - Tractor system must recognize sensors in trailer and hold ID.
  - System took several minutes after vehicles began driving to display trailer pressures.

- Trailers with monitoring systems could only communicate when recognized by tractor, after equipment was driving down road.
TPMS and ATIS installations were well-received by Sheetz management and personnel.

- Inflation systems warned drivers of air leaks in the tanker tires.
- Inflation systems maintained tire pressure, allowing vehicles to return to the terminal.
- Monitoring systems warned drivers of air leaks, preventing road-side breakdowns.
- Drivers monitored in-cab displays during tire pressure loss, enabling service at maintenance facility.
- Technicians and managers had confidence in the systems’ ability to reliably detect tire failures and provide accurate tire pressure measurements.
- Drivers requested management to equip entire fleet with TPMS and ATIS at FOT conclusion.
Interviews with GFS management and personnel identified the following:

- Drivers preferred the inflation system.
- Monitoring systems provided accurate tire pressure readings.
- Driver and technicians desired improvement in communication of monitoring system between trailer and tractor (faster response time).
- Tire personnel were able to track wheel sensors during tire changes.
  - Wheel modules were returned to proper positions after tire changes without excessive work.
Conclusions
In conclusion, the field test proved the following:

<table>
<thead>
<tr>
<th>Sheetz</th>
<th>GFS</th>
<th>Hypothesis</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>🟢</td>
<td>🟢</td>
<td>TPMS or ATIS use will increase the life of equipped tires.</td>
<td>GFS tire wear data points toward increased tire life.</td>
</tr>
<tr>
<td>🟢</td>
<td>🟢</td>
<td>TPMS or ATIS use will reduce fuel consumption of equipped tractor-trailers.</td>
<td>Fleets saw a 1.4% improvement in fuel economy.</td>
</tr>
<tr>
<td>🟢</td>
<td>🟢</td>
<td>TPMS or ATIS use will reduce road calls for damaged/flat tires of equipped tractor-trailers.</td>
<td>Test fleets experienced fewer road calls.</td>
</tr>
<tr>
<td>🟢</td>
<td>🟢</td>
<td>TPMS or ATIS correctly measures the tire pressure of equipped tractor-trailers.</td>
<td>Minor issues were identified in each fleet.</td>
</tr>
<tr>
<td>🟢</td>
<td>🟢</td>
<td>TPMS or ATIS use will not introduce unscheduled maintenance that adversely affects day-to-day fleet operations.</td>
<td>Technicians did not report altered work habits due to TPMS equipment.</td>
</tr>
</tbody>
</table>

- 🟢 Valid
- 🟢 Inconclusive
- 🔴 Invalid

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Questions

- Final report expected by Summer 2011
Contact Information

Chris Flanigan
*USDOT, FMCSA*
- Phone: (202) 385-2384
- Email: chris.flanigan@dot.gov

Deborah Van Order
*Booz Allen Hamilton*
- Phone: (703) 377-7779
- Email: van_order_deborah@bah.com

Steve Brady
*Booz Allen Hamilton*
- Phone: (703) 917-2096
- Email: brady_stephen@bah.com

Asa Sharp
- Phone: (330) 283-3227
- Email: asasharp@aol.com