

# Condition Monitoring: Technology For Assessing Vehicle And Track Performance

Matthew Dick, P.E.

ENSCO Rail

May 3<sup>rd</sup> 2016



# Summary

What's inside the technology?

Overview of measurement systems.

What is the future of measurement?



# Background on Sensors



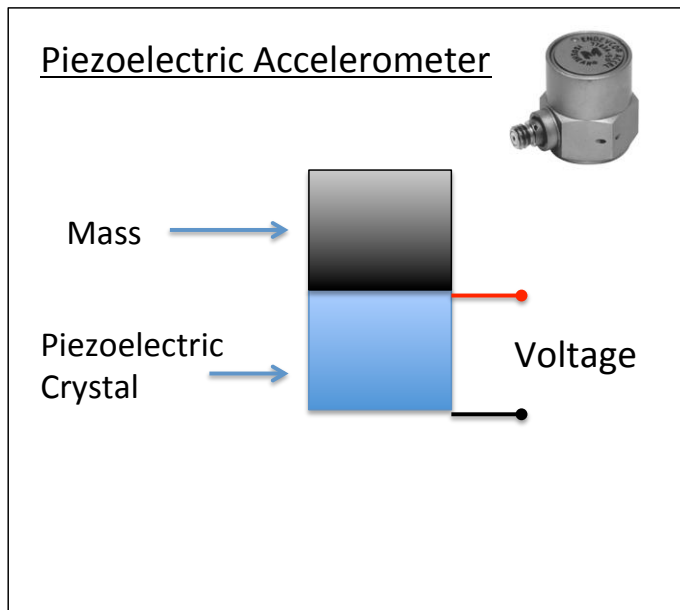
PRINCIPLES COURSE • MAY 3, 2016



**WRI 2016**

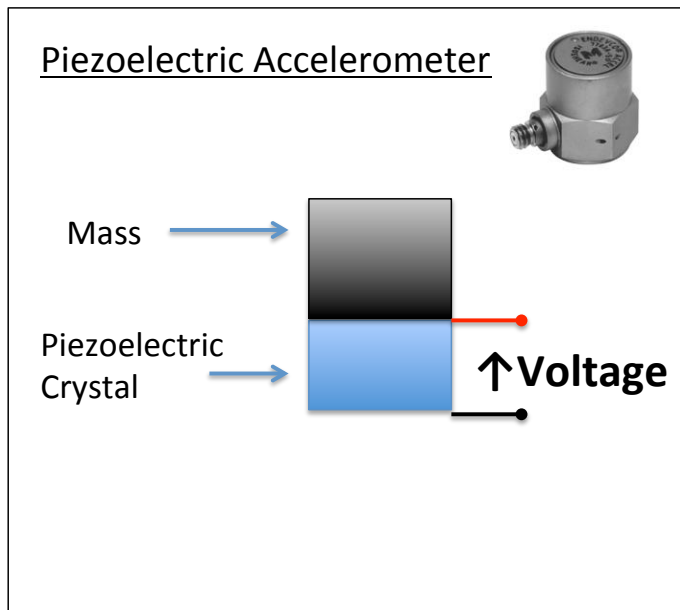
# Accelerometers

- Directly measure acceleration
- Acceleration can be converted to Velocity, Distance, and Force



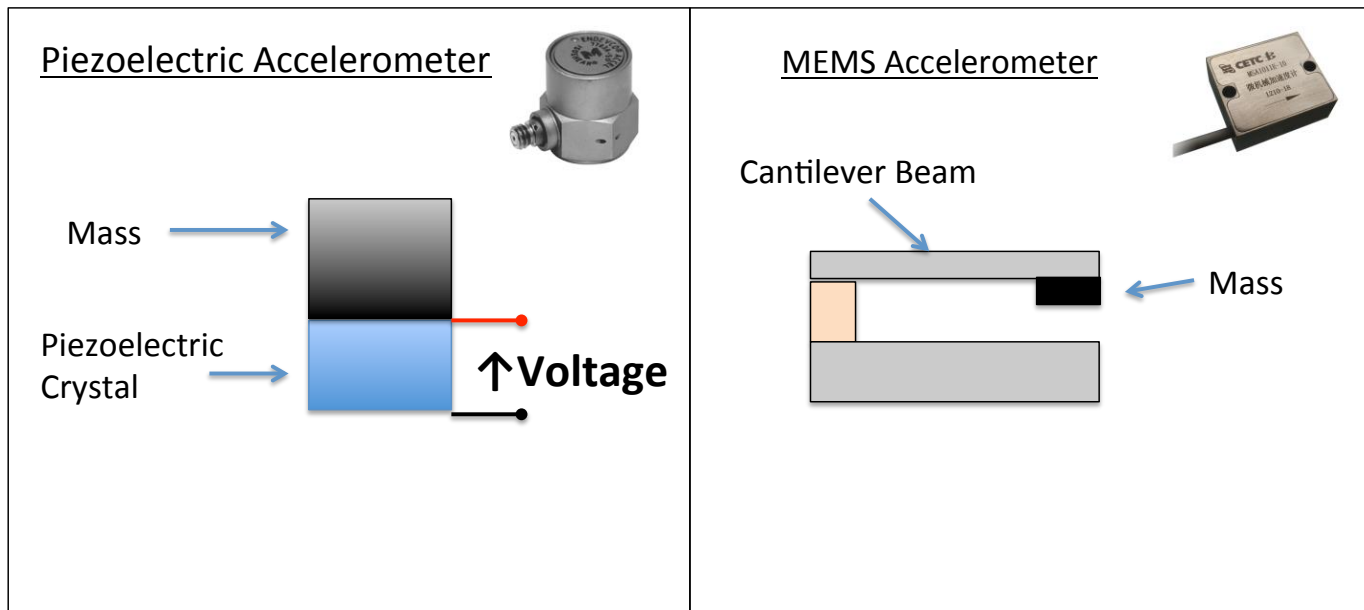
# Accelerometers

- Directly measure acceleration
- Acceleration can be converted to Velocity, Distance, and Force



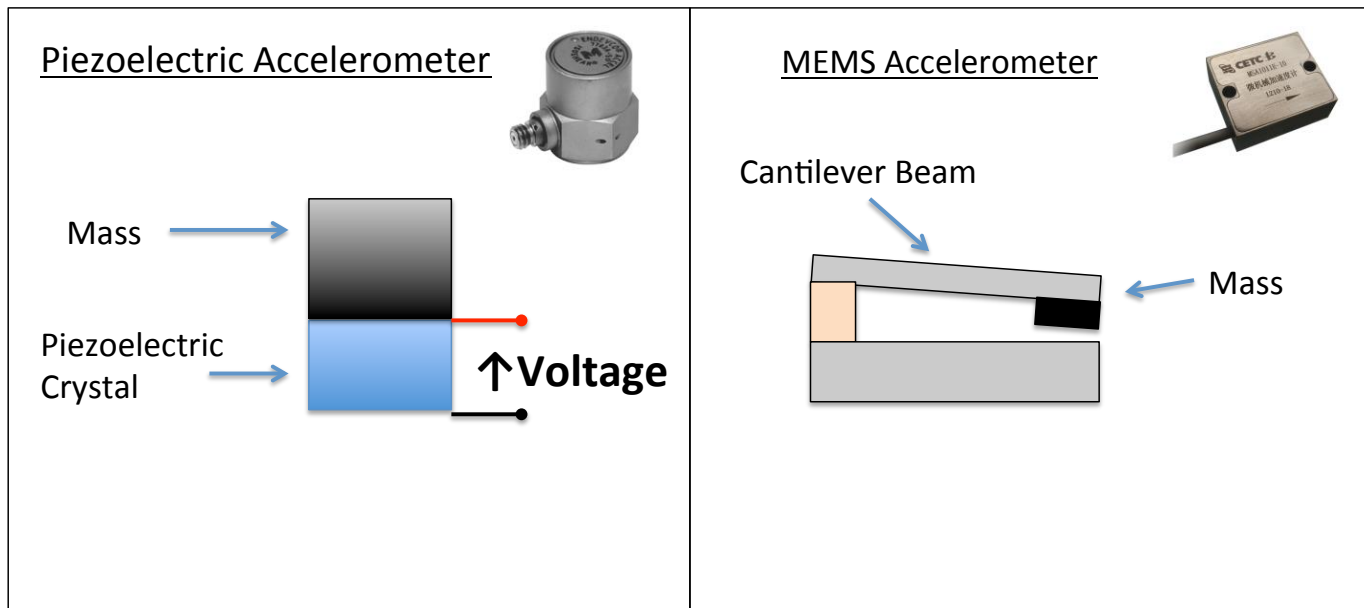
# Accelerometers

- Directly measure acceleration
- Acceleration can be converted to Velocity, Distance, and Force



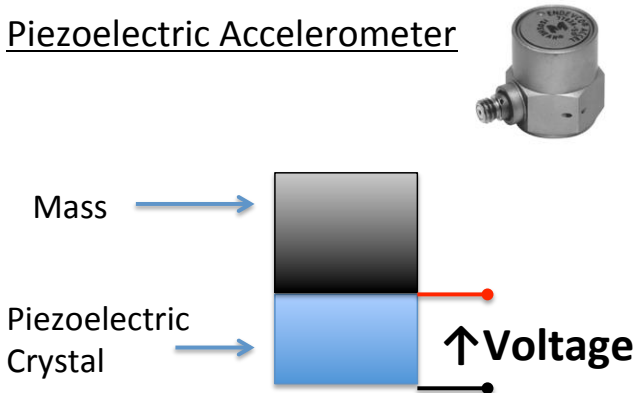
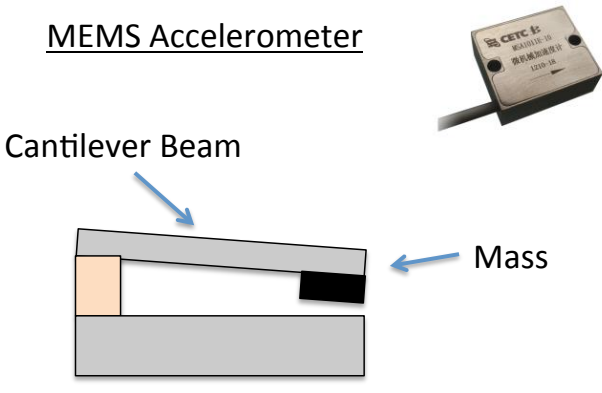
# Accelerometers

- Directly measure acceleration
- Acceleration can be converted to Velocity, Distance, and Force



# Accelerometers

- Directly measure acceleration
- Acceleration can be converted to Velocity, Distance, and Force

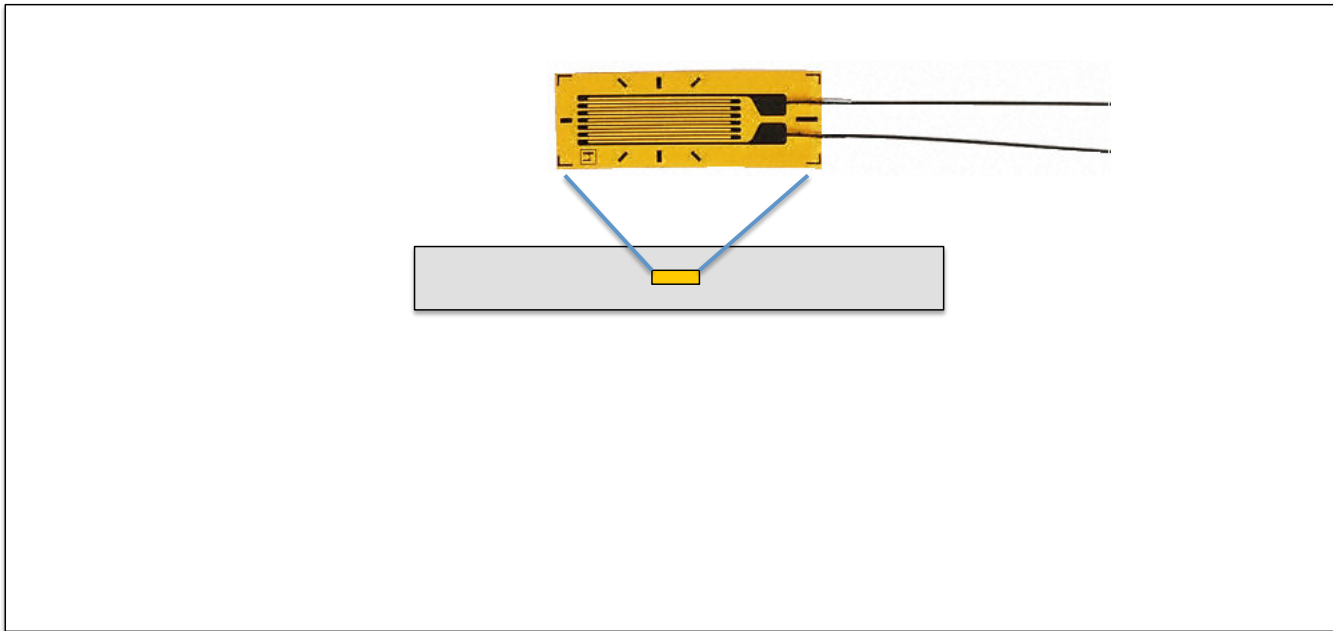
<p><u>Piezoelectric Accelerometer</u></p>  <p>A diagram of a piezoelectric accelerometer. It shows a black rectangular mass on top of a blue rectangular piezoelectric crystal. A blue arrow labeled 'Mass' points to the black mass. Another blue arrow labeled 'Piezoelectric Crystal' points to the blue crystal. To the right of the crystal, there are two electrical terminals, one red and one black, with an upward-pointing arrow labeled 'Voltage' between them. Above the diagram is a photograph of a cylindrical piezoelectric accelerometer.</p> <ul style="list-style-type: none"><li>• Used for higher acceleration</li><li>• Used for higher frequency vibration</li></ul>	<p><u>MEMS Accelerometer</u></p>  <p>A diagram of a MEMS accelerometer. It shows a cantilever beam fixed to a substrate on the left. A mass is attached to the free end of the beam on the right. A blue arrow labeled 'Cantilever Beam' points to the beam. Another blue arrow labeled 'Mass' points to the mass. Above the diagram is a photograph of a small, rectangular MEMS accelerometer with a wire extending from it.</p> <ul style="list-style-type: none"><li>• Used for lower acceleration</li><li>• Used for lower frequency vibration</li><li>• Can measure "DC Response"</li></ul>
---	--





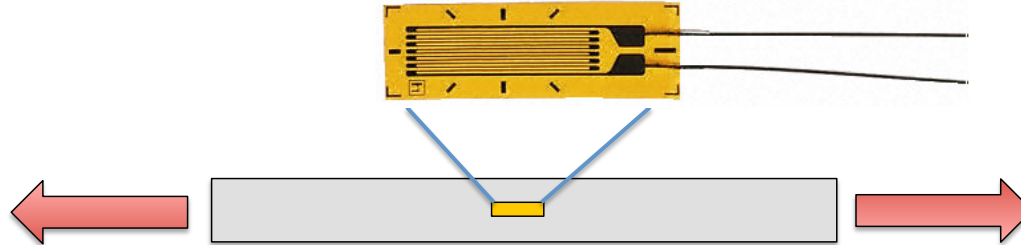
# Strain Gauges

- Directly measures strain, which can be converted to stress.



# Strain Gauges




- Directly measures strain, which can be converted to stress.



- Voltage change can be measured due to the strain gauge resistance change.
- There are various types and installation patterns of strain gauges.



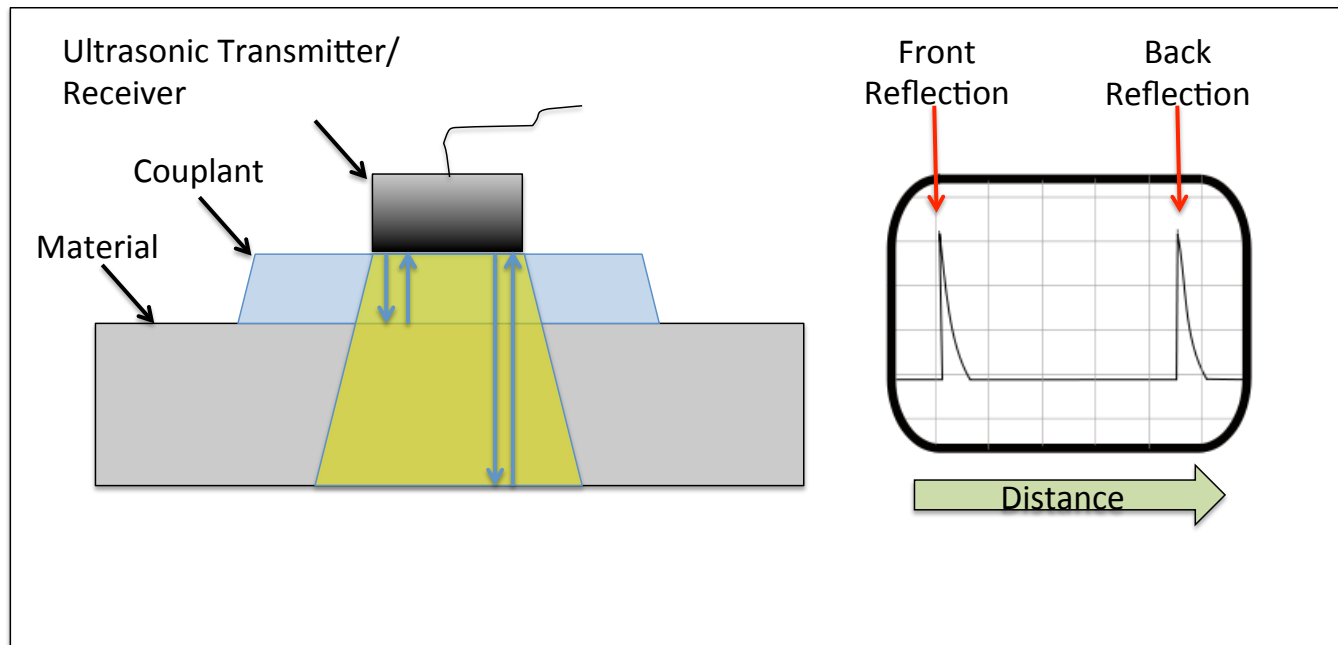
# Temperature Sensors

<u>Thermistors and RTDs</u>	<u>Thermocouples</u>	<u>Infrared Sensors</u>
 <ul style="list-style-type: none"><li>• Uses resistance change to measure temperature.</li><li>• Lower cost</li><li>• Lower temperature range</li></ul>	 <ul style="list-style-type: none"><li>• Uses voltage change between dissimilar metals to measure temperature.</li><li>• Higher cost</li><li>• Higher temperature range</li></ul>	 <ul style="list-style-type: none"><li>• Measures thermal radiation</li><li>• Non-contact measurement</li><li>• Sensitive to surface conditions</li></ul>



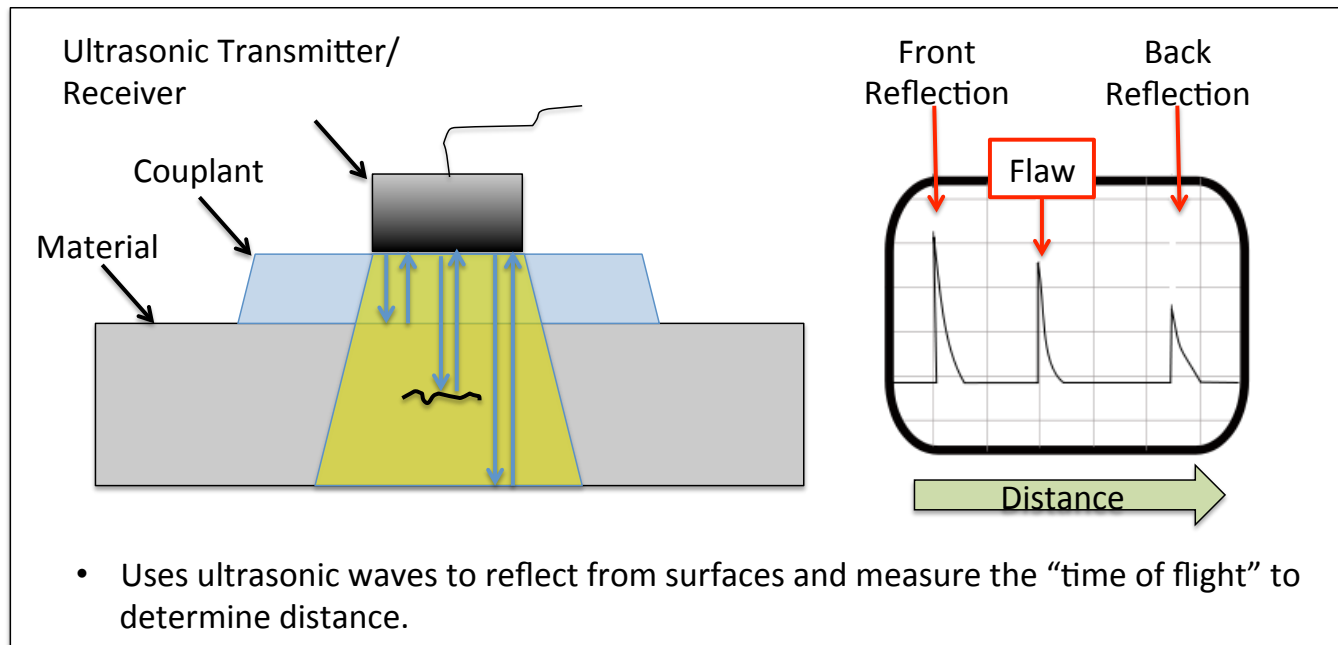
# Ultrasonic Sensors

- Can measure depth, size, and orientation of internal flaws in a material

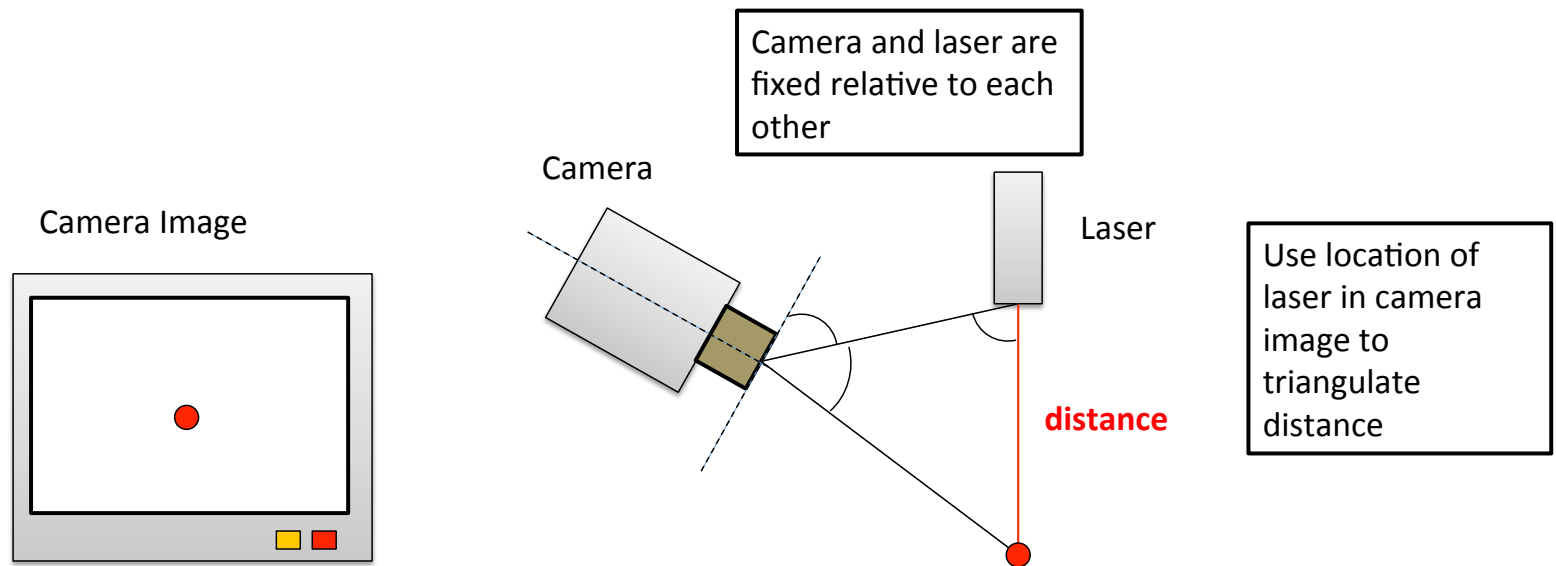


# Ultrasonic Sensors

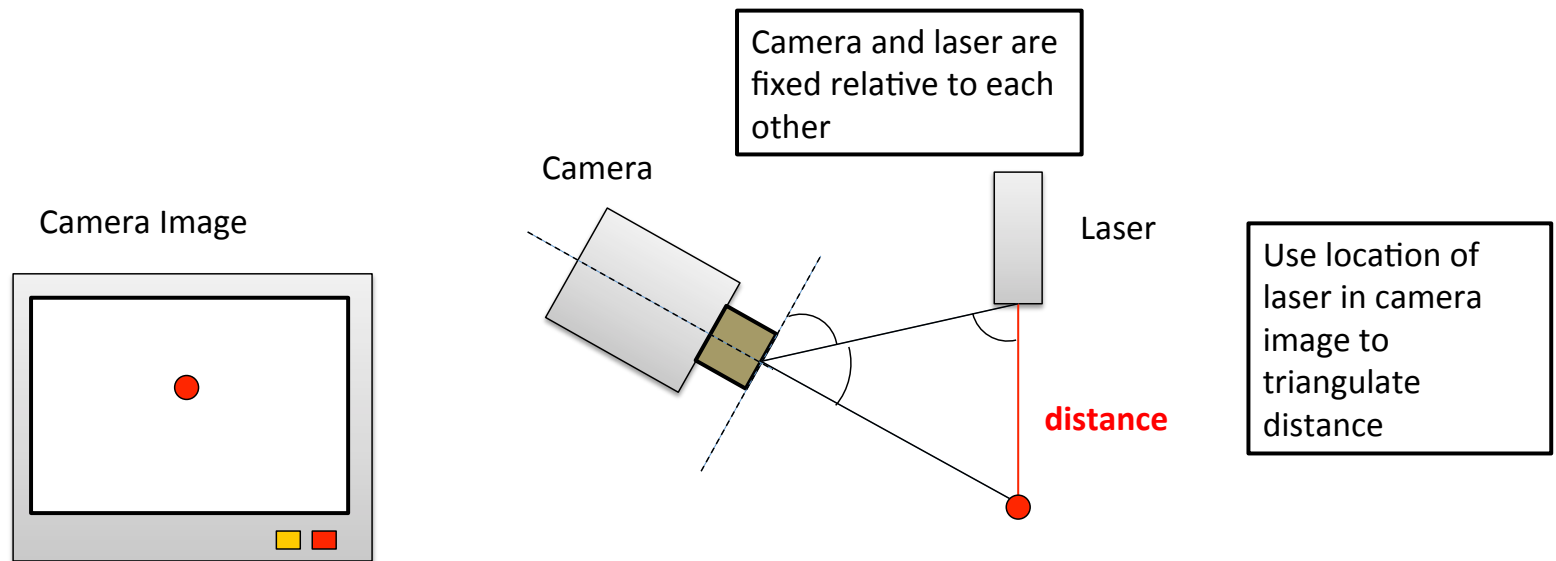
- Can measure depth, size, and orientation of internal flaws in a material



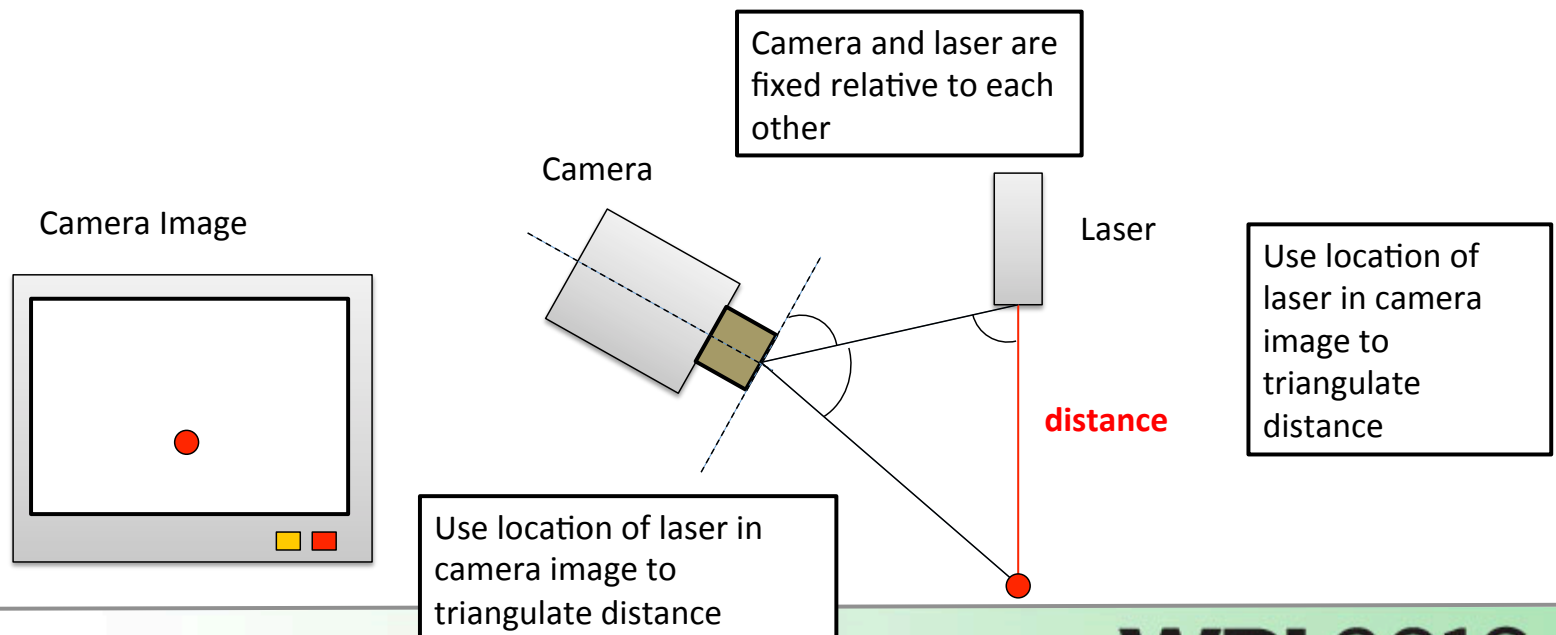
# Laser Triangulation Measurement



# Laser Triangulation Measurement

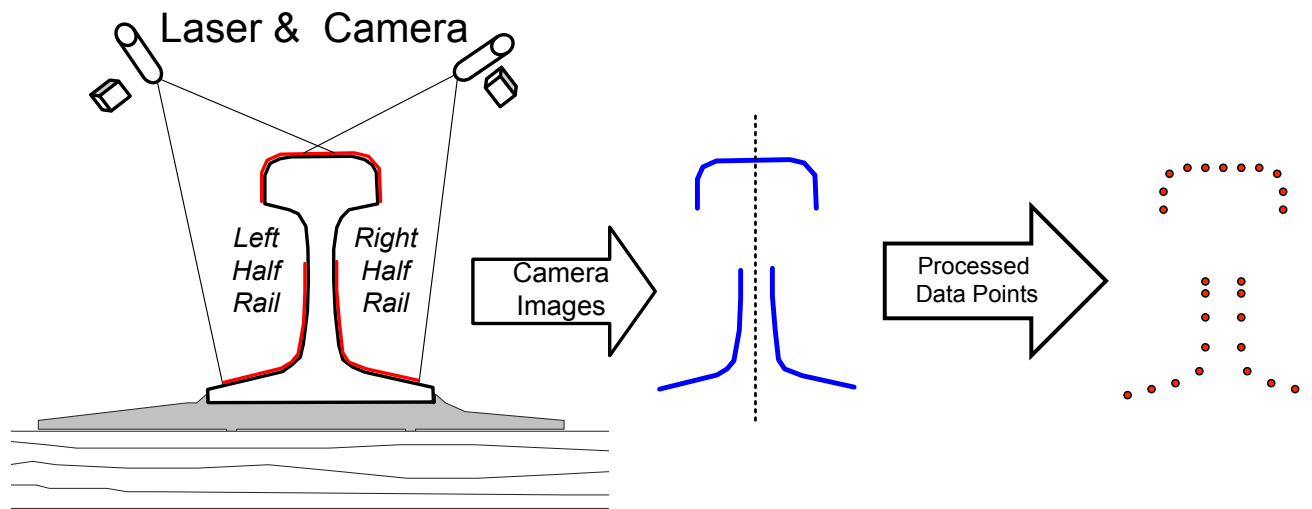


# Laser Triangulation Measurement





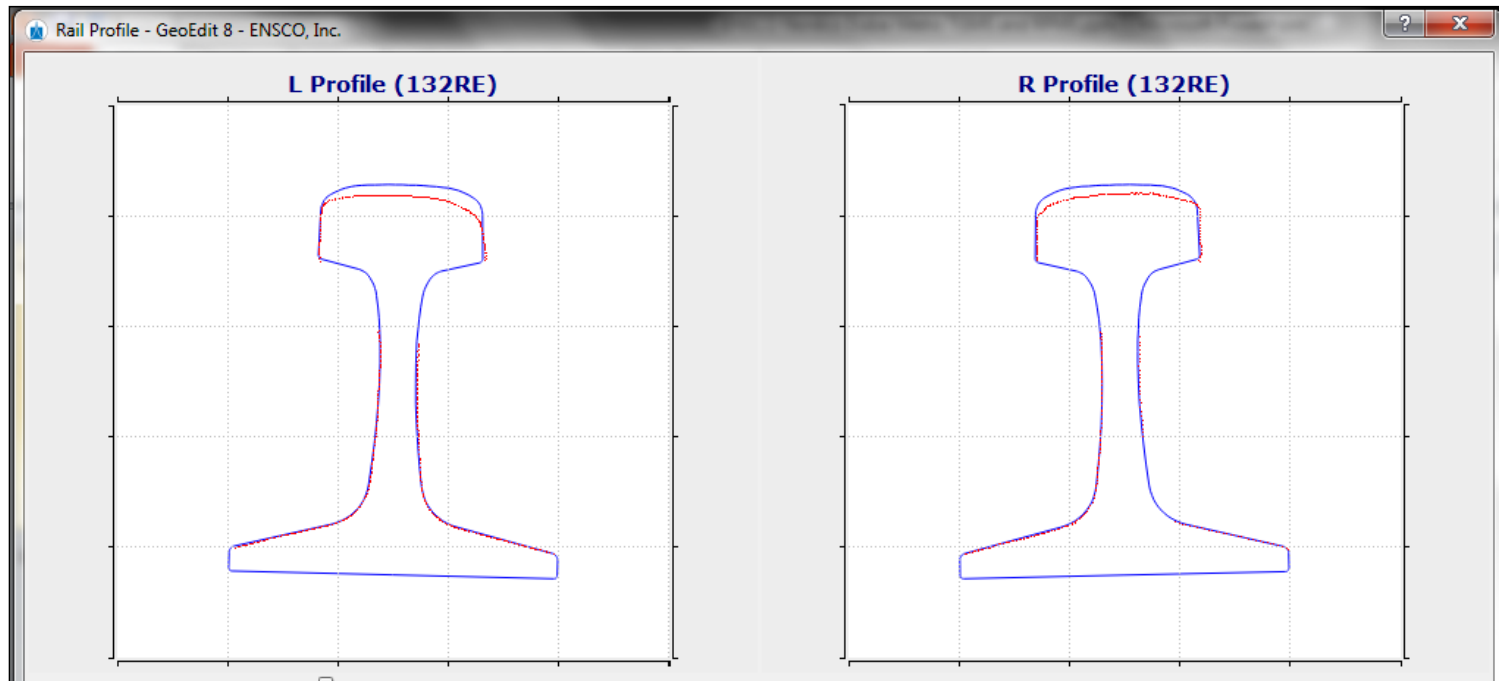
# Laser Triangulation Measurement



Ref 1



# Laser Triangulation Measurement



# Cameras

## “Line Scan” Cameras aka “Slit Scan”

Works like your document scanner



## “Area Scan” Cameras aka “Full Frame”

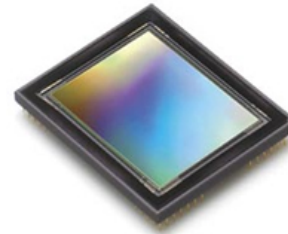
Works like your standard camera



# Cameras



Line Scan Sensor



Area Scan Sensor

Light is converted to electricity similar to a solar cell.

Imagery sensors are like a grid of very tiny solar cells.



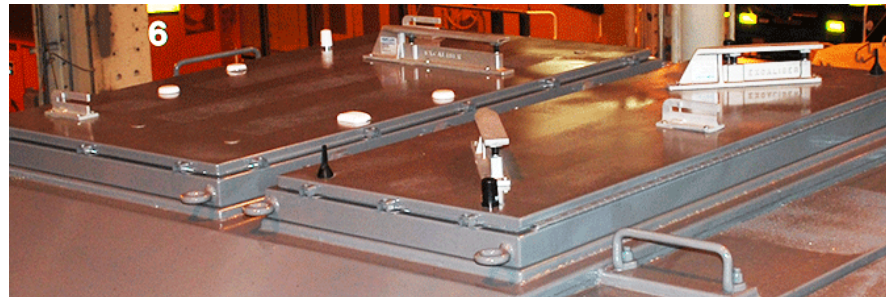
# Distance/Location Measurement



Wheel Sensor



Tachometer



GPS Antenna



# Overview of Measurement Systems

*There are five basic categories of measurement system.*



# Categories of Measurement Systems

## 1) Mounted on Vehicle to measure the Vehicle.

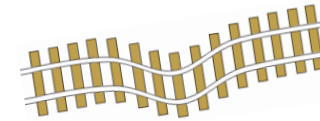


System	Accel	Strain	Temp	Ultra-sonic	Laser	Camera	Other
Event Recorder							Pressure, Throttle, etc
Locomotive Health Monitor							Pressure, Fuel
Railcar Health Monitor							



# Categories of Measurement Systems

## 2) Mounted on Track to measure the Track.



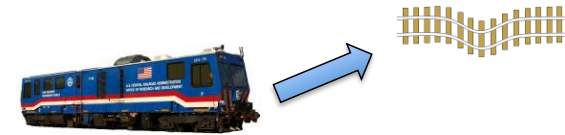
System	Accel	Strain	Temp	Ultra-sonic	Laser	Camera	Other
Rail Stress / Temp Monitor							
Bridge Monitoring							
Landslip Monitoring							Displacement
Flood Monitoring							Water





# Categories of Measurement Systems

## 3) Mounted on Vehicle to measure the Track. (Manned, Unmanned, and Autonomous)

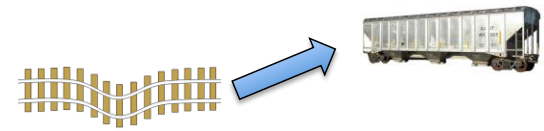


System	Accel	Strain	Temp	Ultra-sonic	Laser	Camera	Other
Track Geometry Measurement System							
Rail Profile Measurement System							
Ultrasonic Rail Flaw Detection							
Ground Penetrating Radar							Radar
Track Component, Joint Bar, & Rail Surface Machine Vision							
V/TI Monitors							
Corrugation Measurement							
Clearance Measurement & 3D Scanning							



# Categories of Measurement Systems

## 4) Mounted on Track to measure the Vehicle.

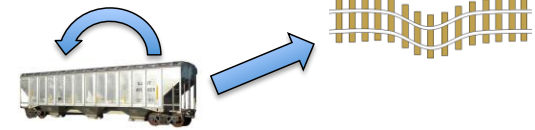


System	Accel	Strain	Temp	Ultra-sonic	Laser	Camera	Other
Dragging Equipment Detectors							Displacement
Hot Bearing & Hot/Cold Wheel Detectors							
Wheel Impact Load Detectors & Truck Performance Detectors							
Truck Condition Detector (TBOGI)							
Acoustic Bearing Detectors							Acoustic
Wheel Profile Detectors							
Cracked Wheel Detectors							
Machine Vision Systems							



# Categories of Measurement Systems

5) Mounted on Vehicle to measure the Vehicle & Track.



System	Accel	Strain	Temp	Ultra-sonic	Laser	Camera	Other
V/TI Monitors							
Instrumented Wheelsets							



# Detailed Discussion of Measurement Systems



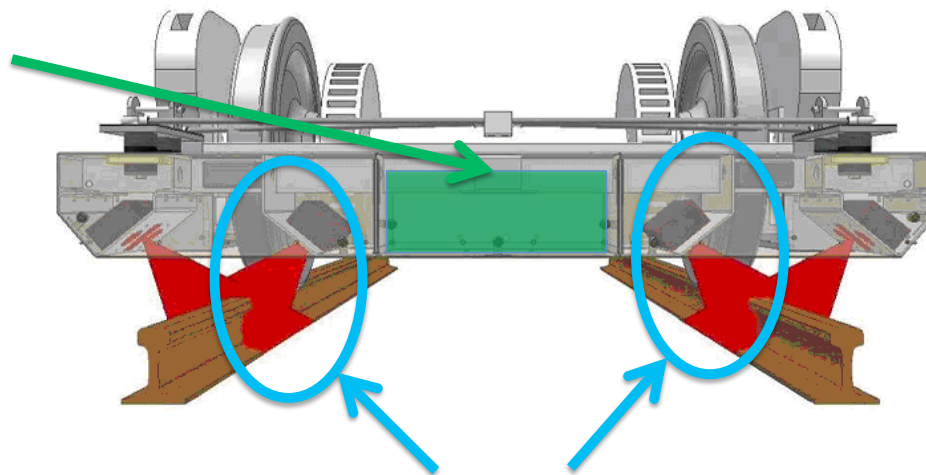
PRINCIPLES COURSE • MAY 3, 2016



**WRI 2016**

## How does a Track Geometry Measurement System Work?

**Inertial Package**  
“Measures the beam location in three dimensional space”



**Laser/Cameras**  
“Measures the relative positions between the rails and the beam”



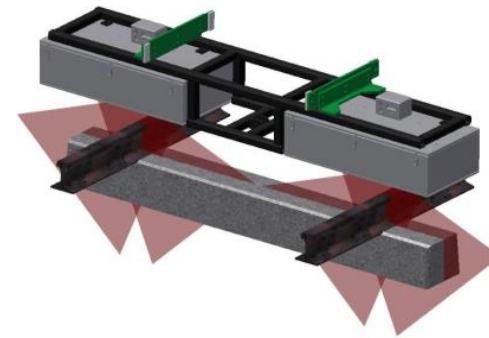
# Example Camera Systems



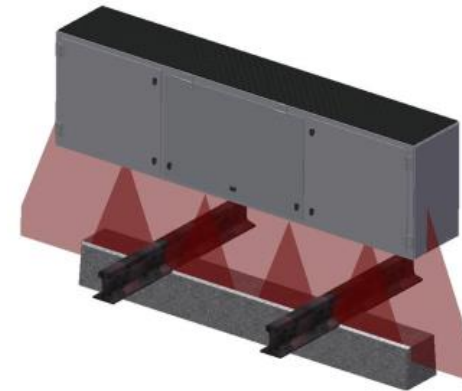
Wheel Sensor



# Example Camera Systems



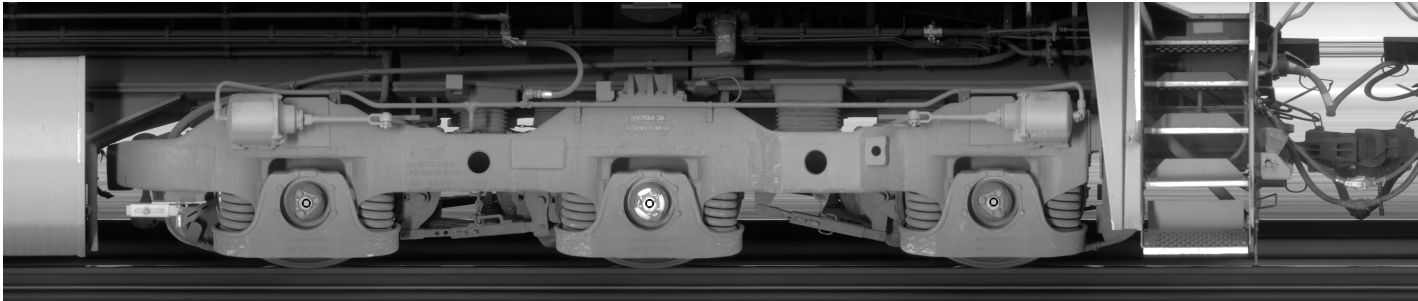
Joint Bar  
View



Track Bed  
View

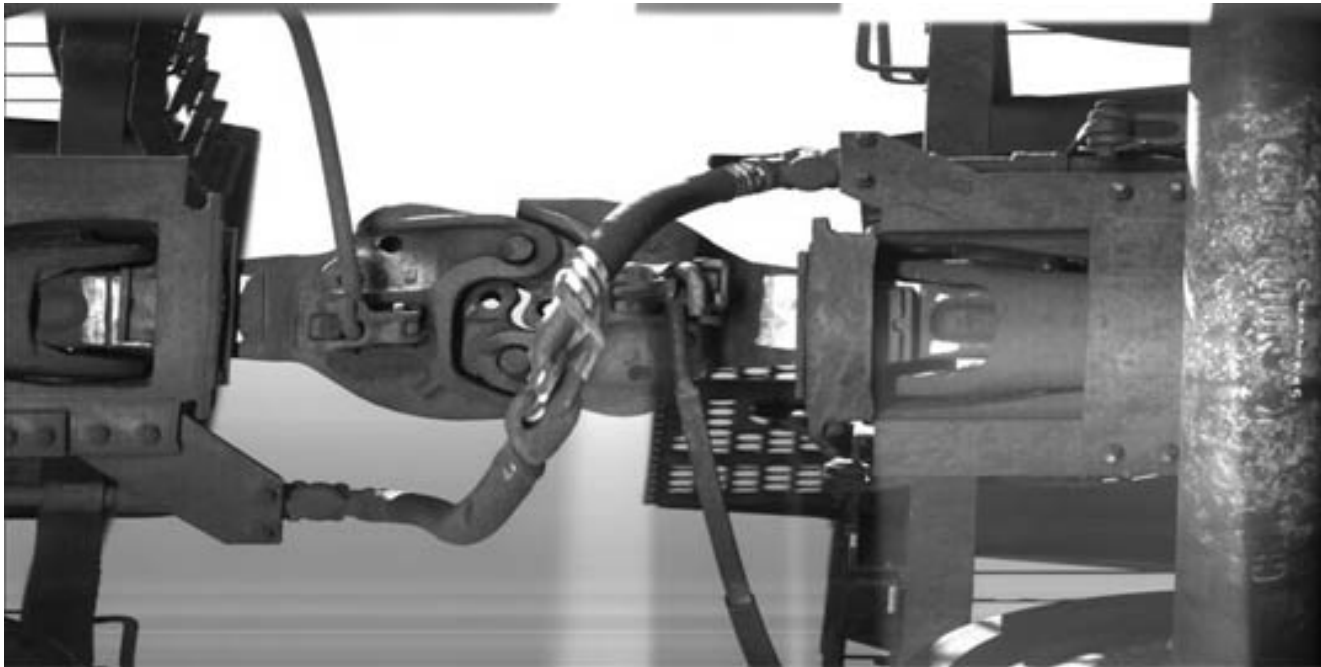


# Example Line Scan Images

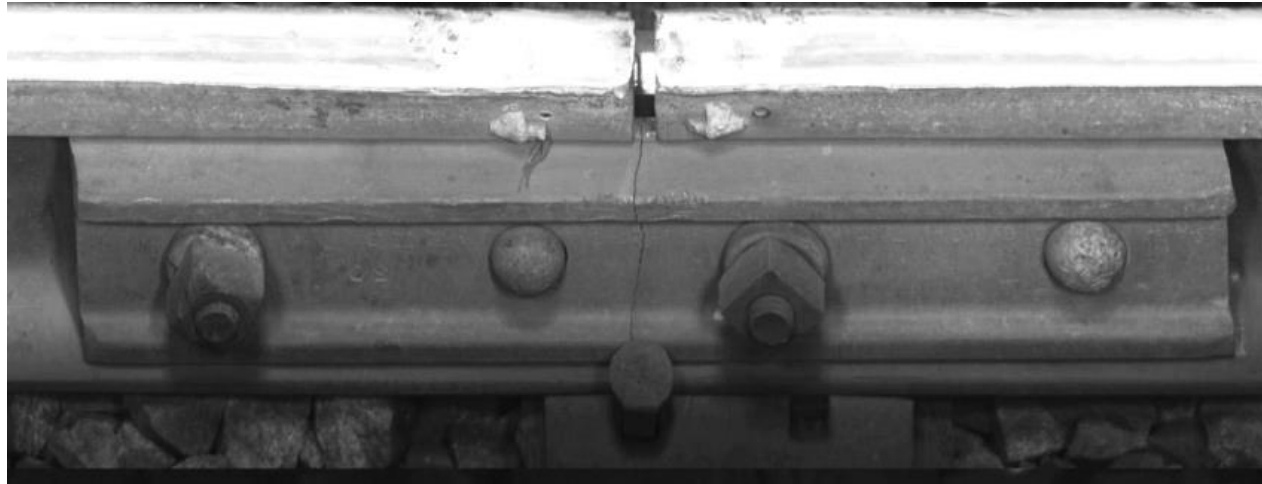




## Example Line Scan Images



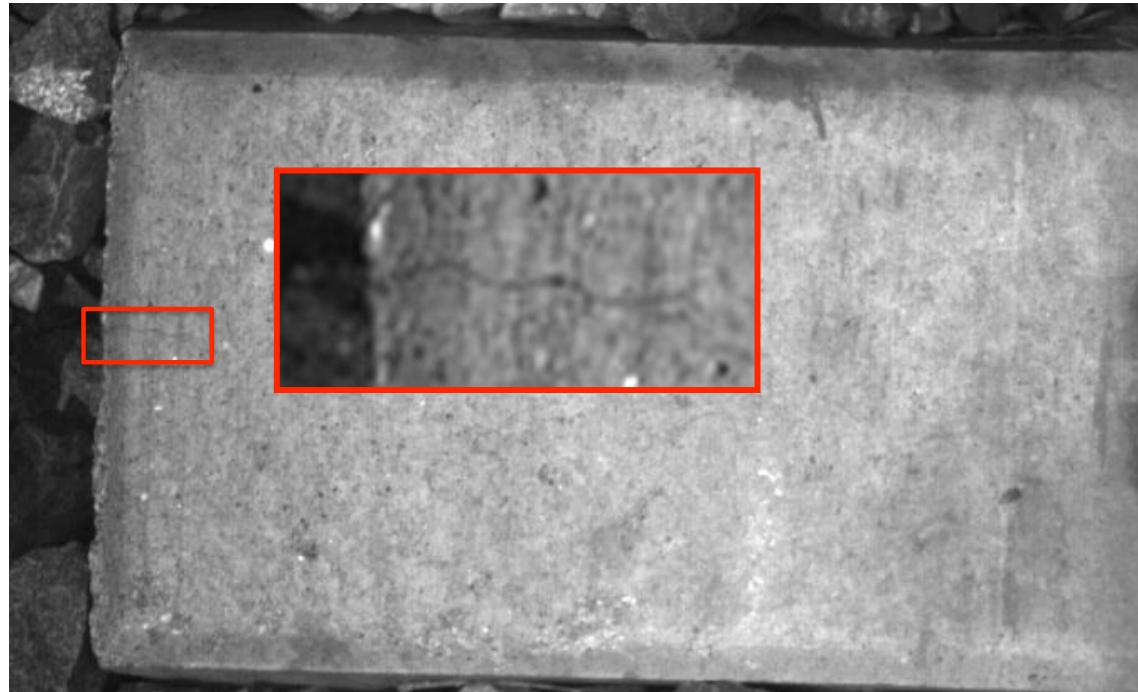
# Example Line Scan Images

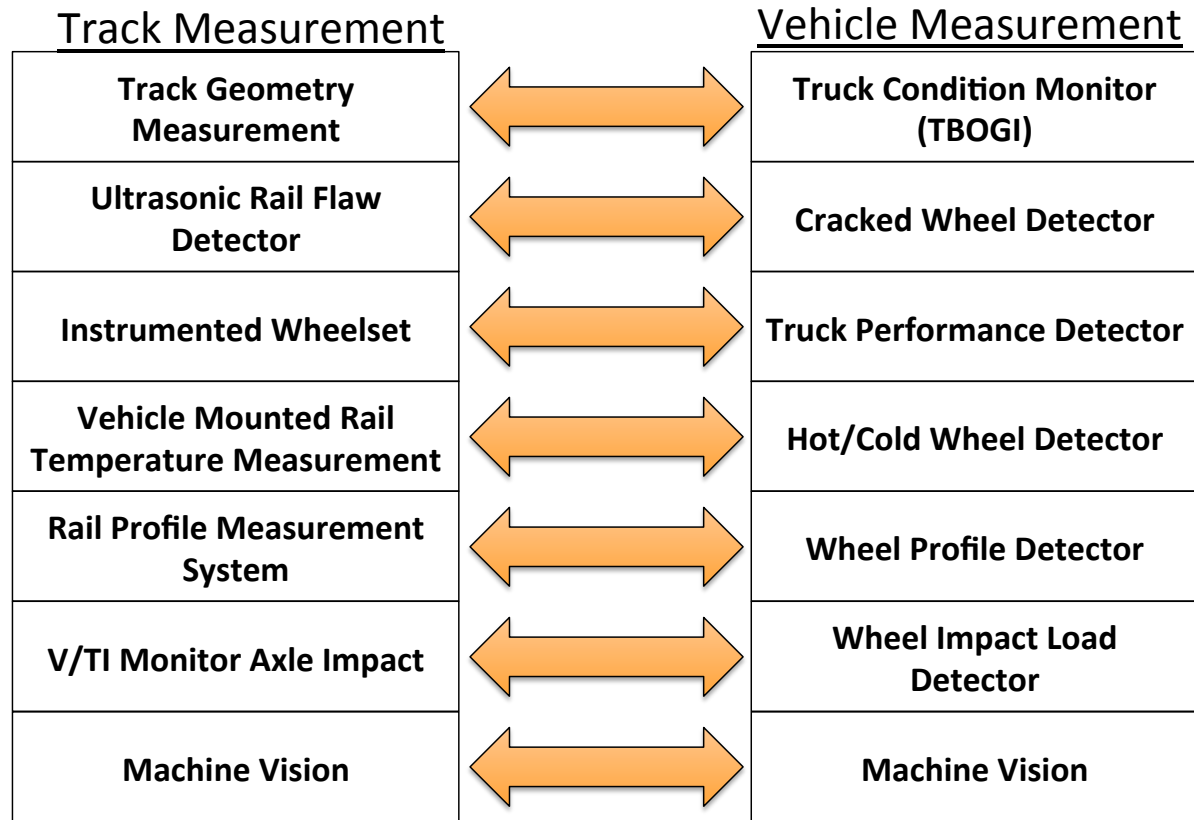


# Example Line Scan Images



# Example Line Scan Images





# What is the Future of Railway Measurement Technology?



PRINCIPLES COURSE • MAY 3, 2016

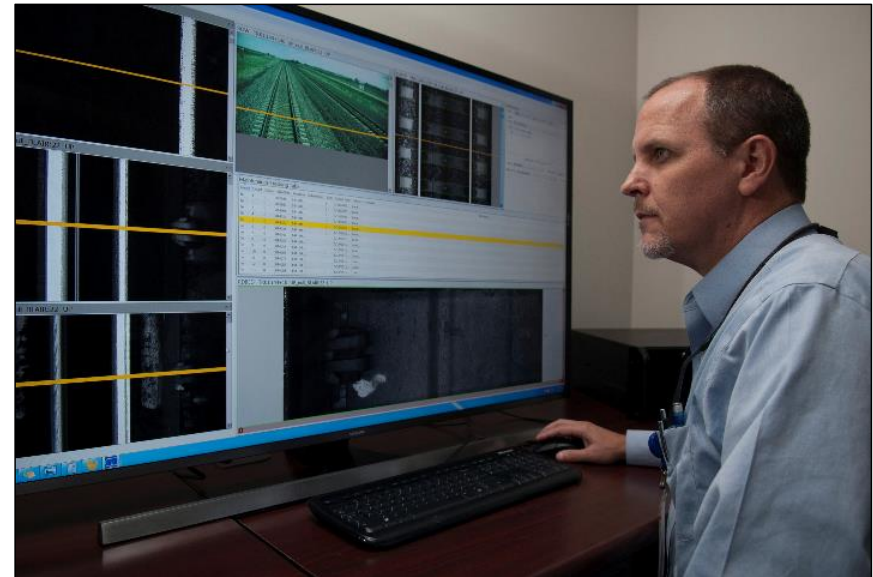


**WRI 2016**

# 1) Field Inspections in the Office

- Increased safety
- Increased productivity and savings
- Additional increased savings from unmanned and autonomous systems on revenue vehicles

Virtual Track Walk Software



## **2) Unmanned Aerial Systems (UAS)**

**aka Unmanned Aerial Vehicles (UAV)**

**aka Drones**

**(But don't call them Drones)**





### 3) Unmanned Aerial Systems (UAS)

#### Multi-Rotor



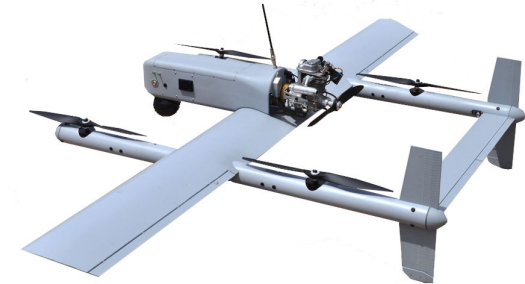
- Good maneuverability
- Relatively slow speed
- Lower altitude
- 20~40 minute flight time

#### Fixed Wing



- Good for flying long paths
- Relatively fast speed
- Higher altitude
- Several hours flight time

#### Vertical Take-Off and Landing (VTOL)



- Hybrid of multi-rotor and fixed wing



## 2) Unmanned Aerial Systems (UAS)

### USA Regulatory Items:

- FAA regulates UAS operations, not the FRA
- Currently no one can fly beyond-visual-line-of-sight (except BNSF)
- Businesses require FAA Section 333 Exception and Certificate of Authorization (COA)
  - Below 400' altitude and line-of-sight operation
  - 500' from non-participants
  - 5 miles from airports with exceptions
  - Currently 5,114 Section 333 exceptions have been granted (including 3 railroads)
- BNSF is on the FAA Pathfinder Program to help define beyond line-of-sight operation for the US.
- **The first commercial beyond line-of-sight flight in the USA was by BNSF in October 2015!**



# Questions?

