

# Condition Monitoring: Technology For Assessing Vehicle And Track Performance

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ENSCO Rail

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# Summary

What's inside the technology?

Overview of measurement systems.

What is the future of measurement?



# Background on Sensors



# Distance/Location Measurement



Wheel Sensor



Tachometer  
(aka Wheel Encoder)



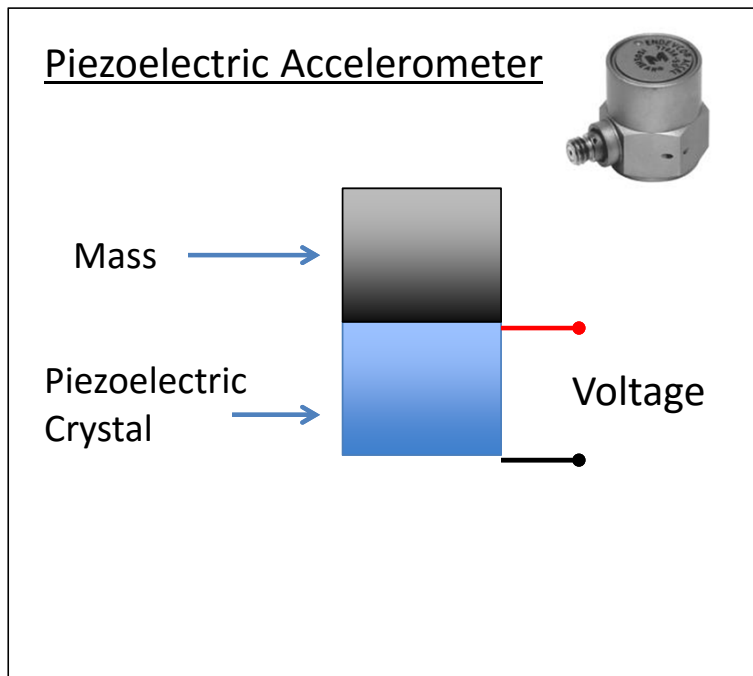
GPS Antenna  
Differential Correction  
Inertial Correction





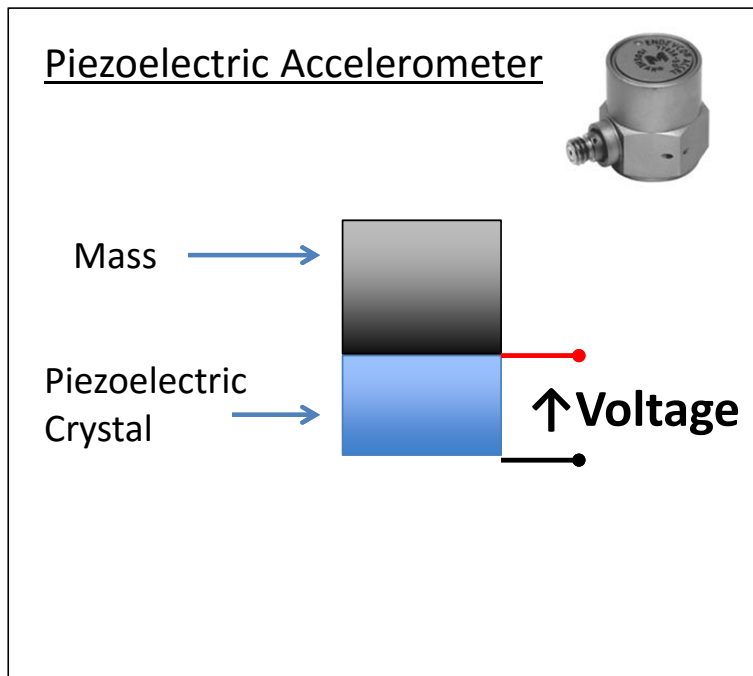
# Accelerometers

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



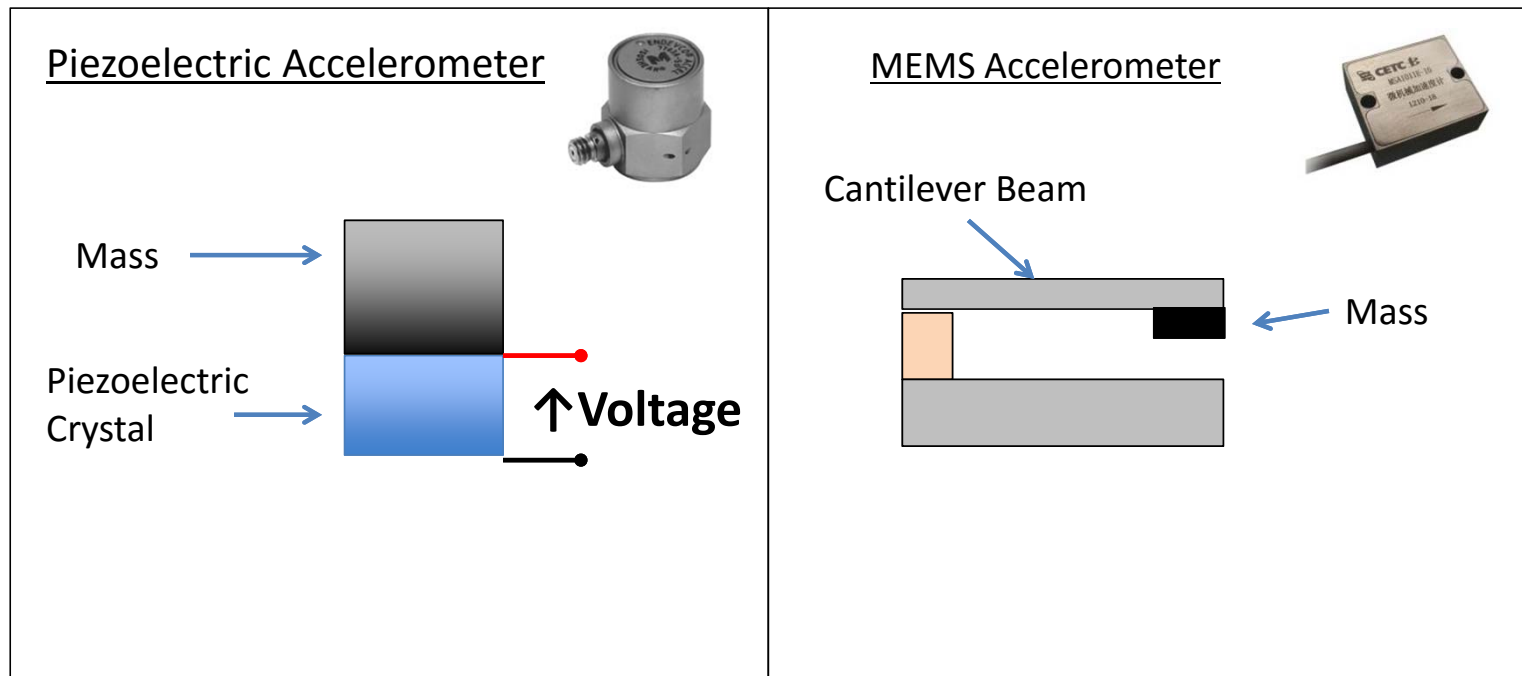
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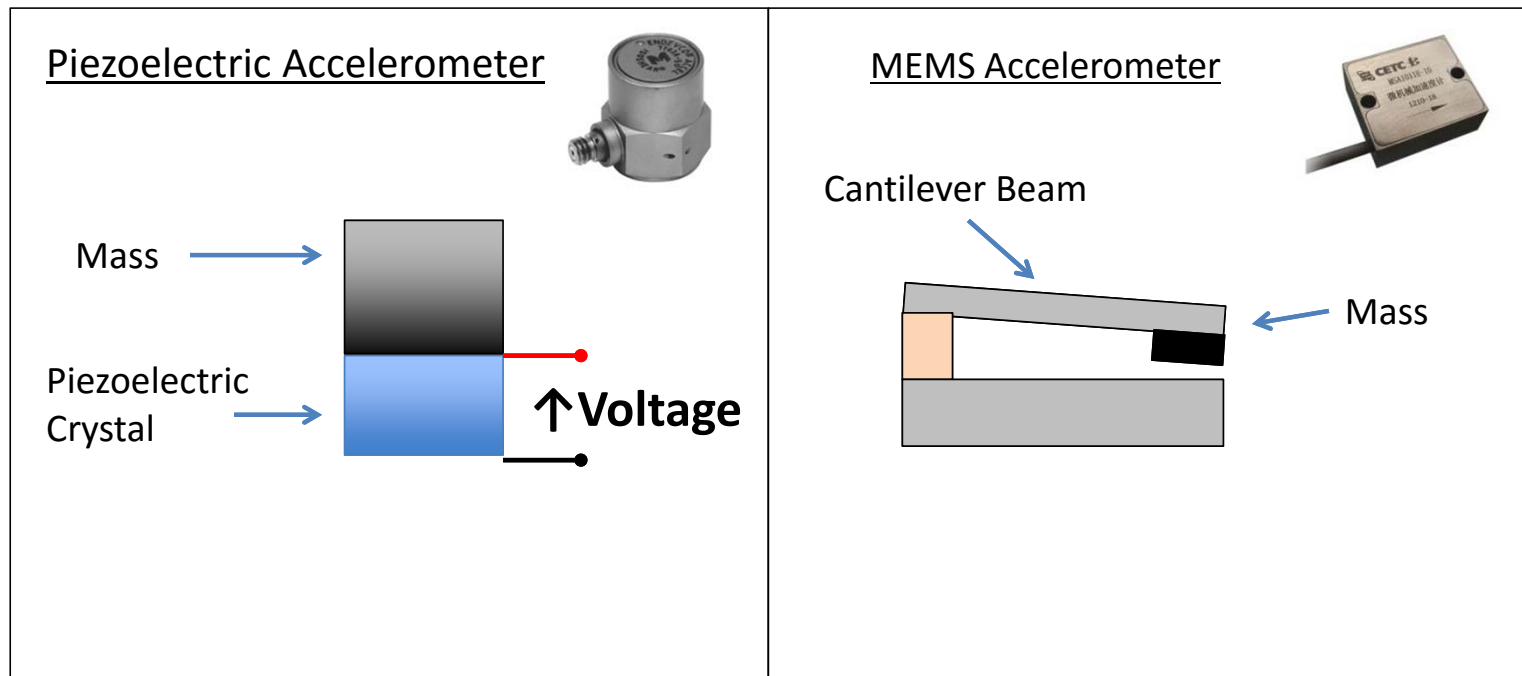
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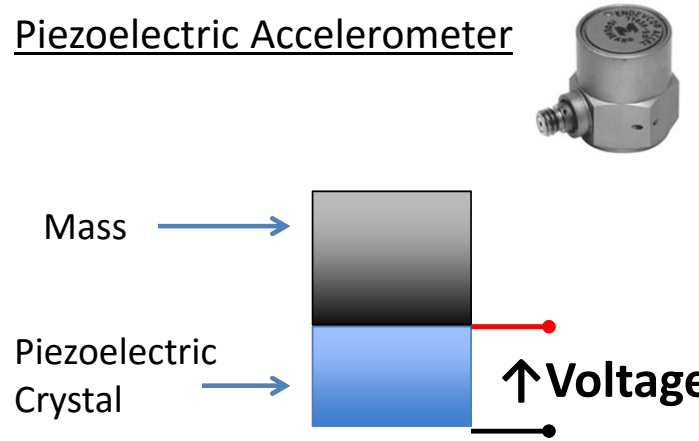
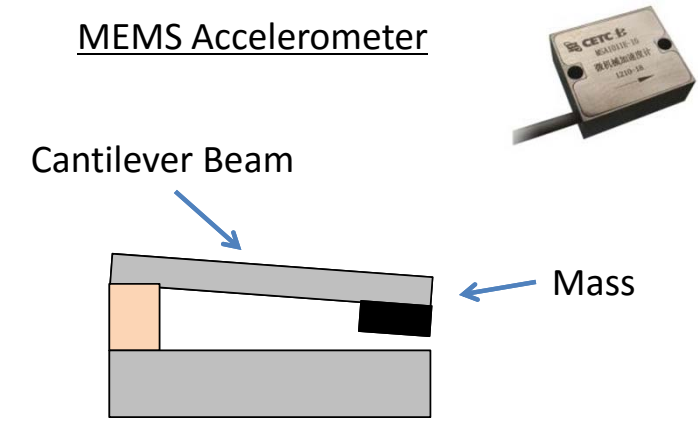
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# Accelerometers

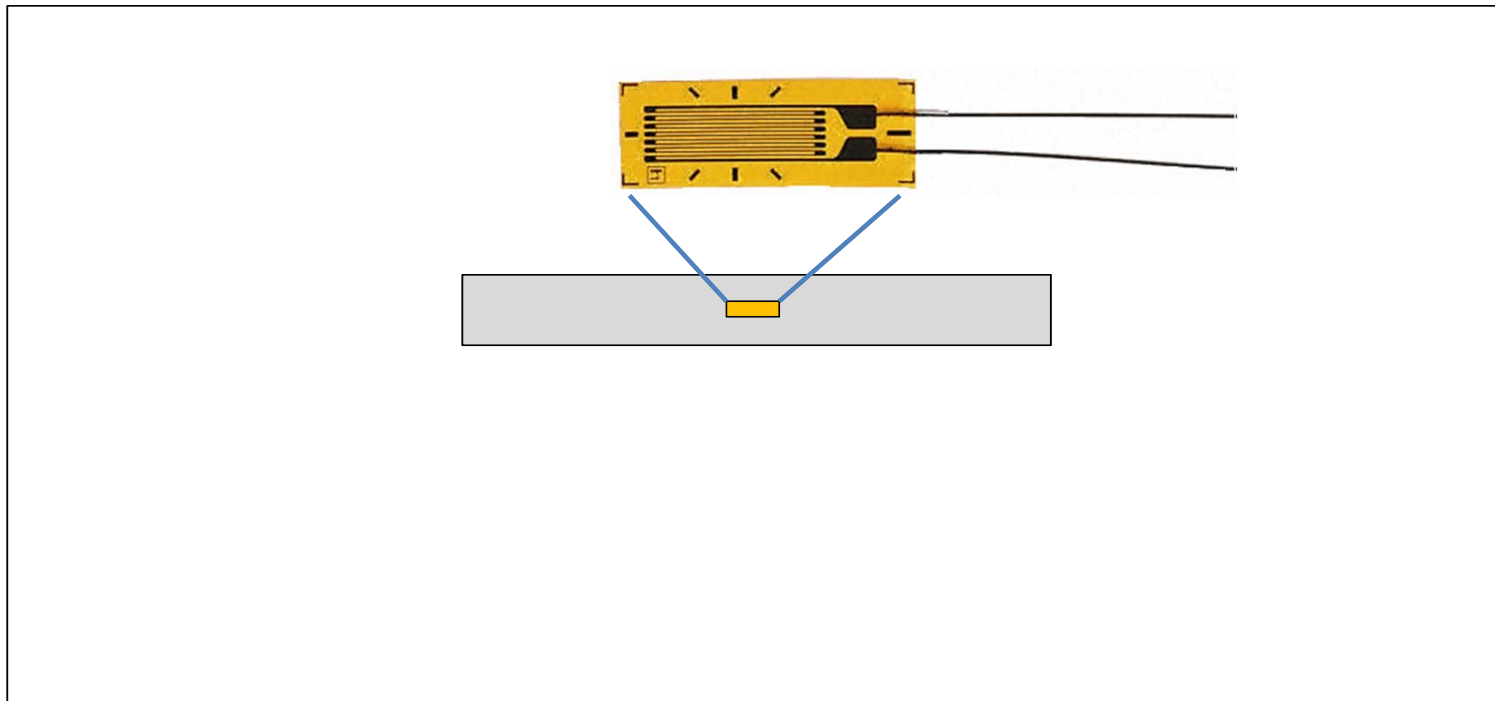
- Directly measure acceleration
- Acceleration can be converted to Velocity, Distance, and Force

<p><u>Piezoelectric Accelerometer</u></p>  <p>A diagram of a piezoelectric accelerometer. It shows a grey cylindrical component with a threaded top. Below it, a schematic shows a black rectangular block labeled 'Mass' on top of a blue rectangular block labeled 'Piezoelectric Crystal'. A red line extends from the right side of the crystal to a terminal, and a black line extends from the bottom to another terminal. An upward-pointing arrow next to the terminals is labeled 'Voltage'.</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 small rectangular component with a cable. Below it, a schematic shows a grey cantilever beam attached to a base. A black rectangular mass is attached to the end of the beam. An arrow points to the beam labeled 'Cantilever Beam', and another arrow points to the mass labeled 'Mass'.</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>
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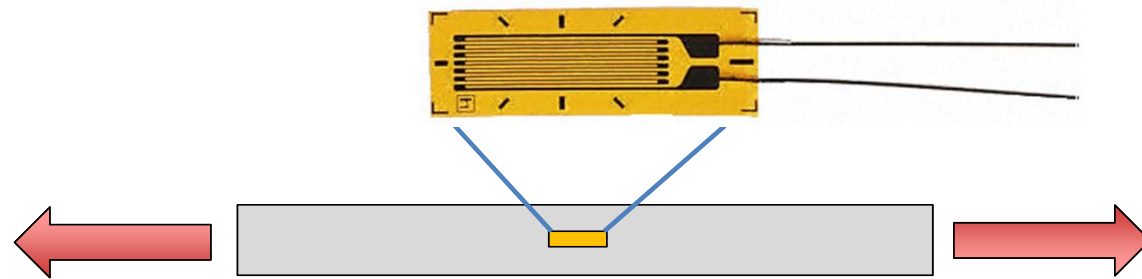
# Strain Gauges

- 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.



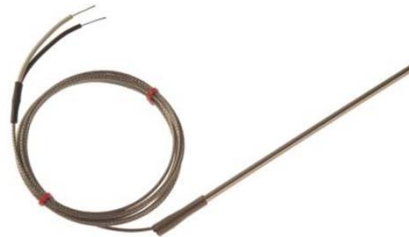
# Temperature Sensors

## Thermistors and RTDs



- Uses resistance change to measure temperature.
- Lower cost
- Lower temperature range

## Thermocouples



- Uses voltage change between dissimilar metals to measure temperature.
- Higher cost
- Higher temperature range

## Infrared Sensors



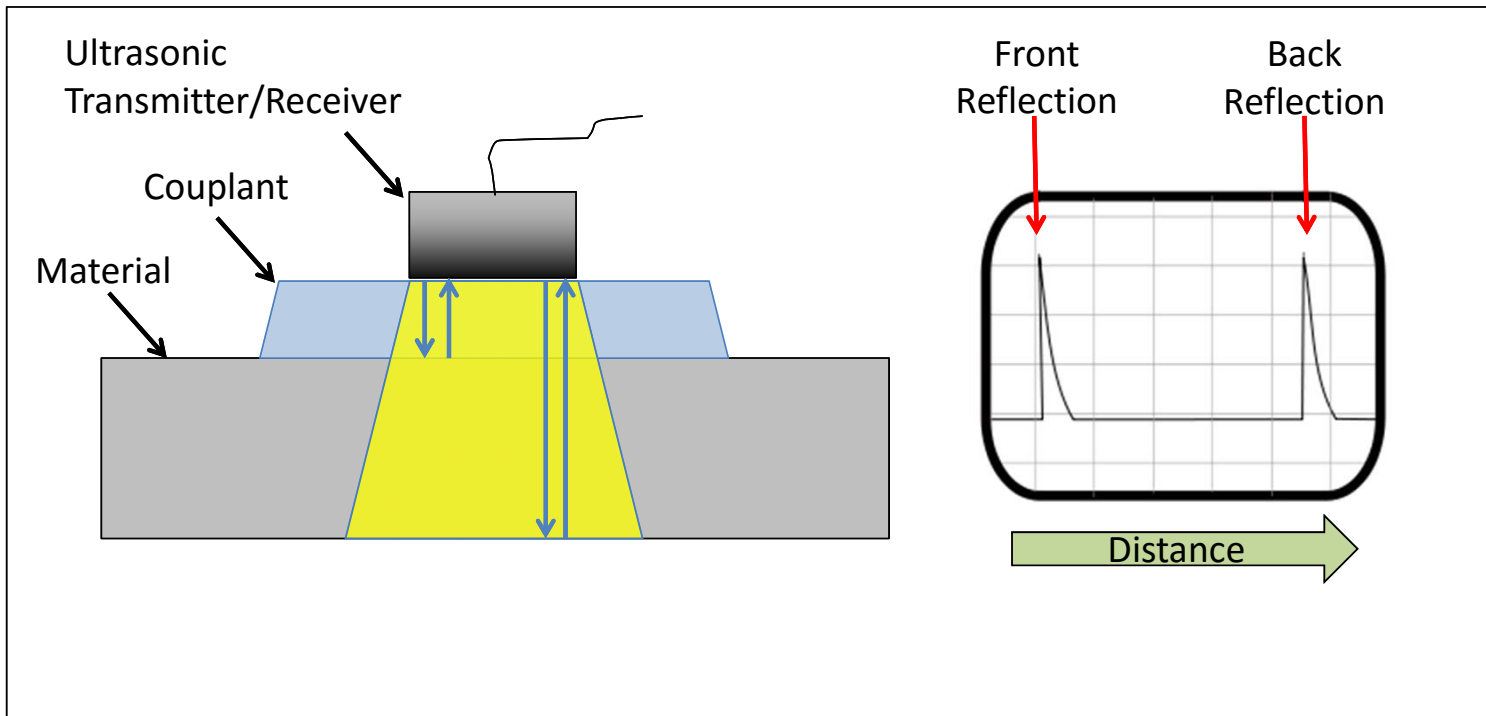
- Measures thermal radiation
- Non-contact measurement
- Sensitive to surface conditions





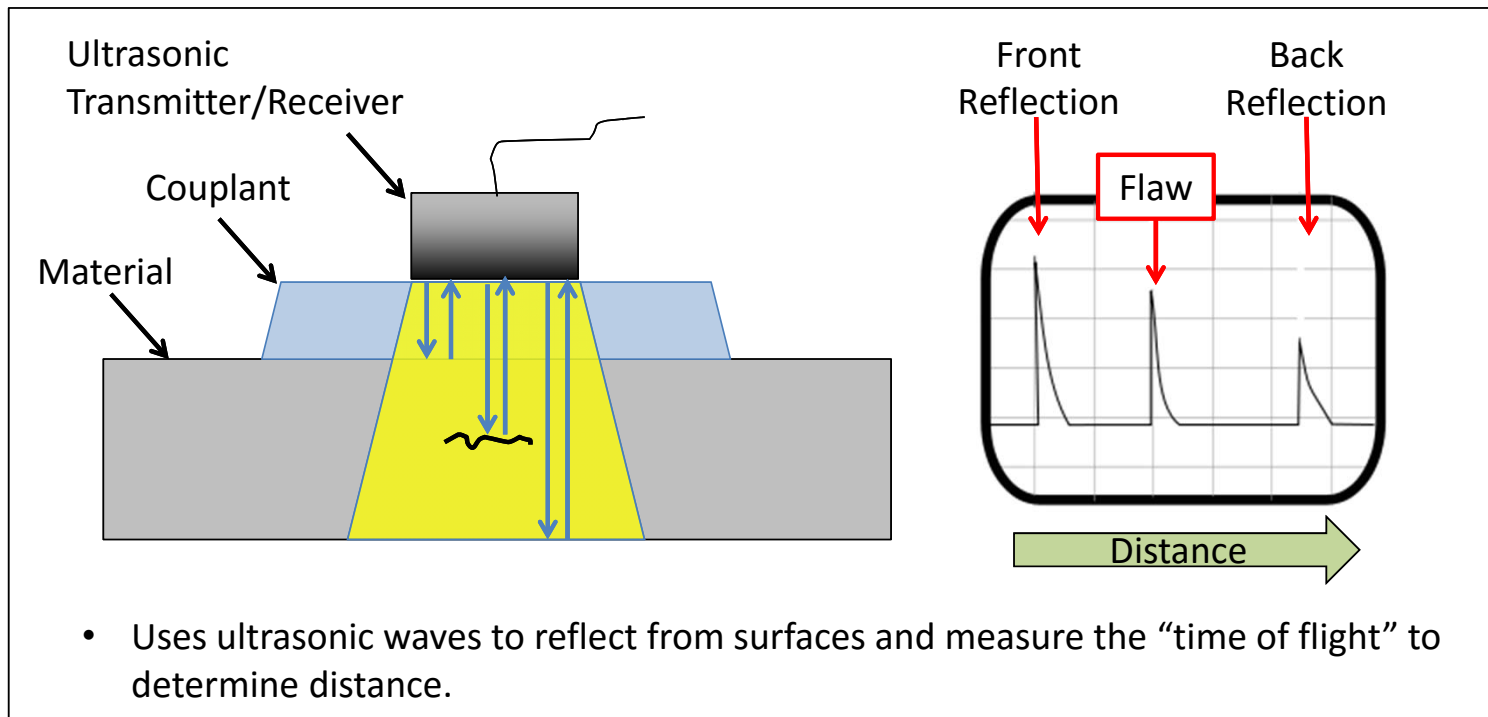
# Ultrasonic Sensors

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

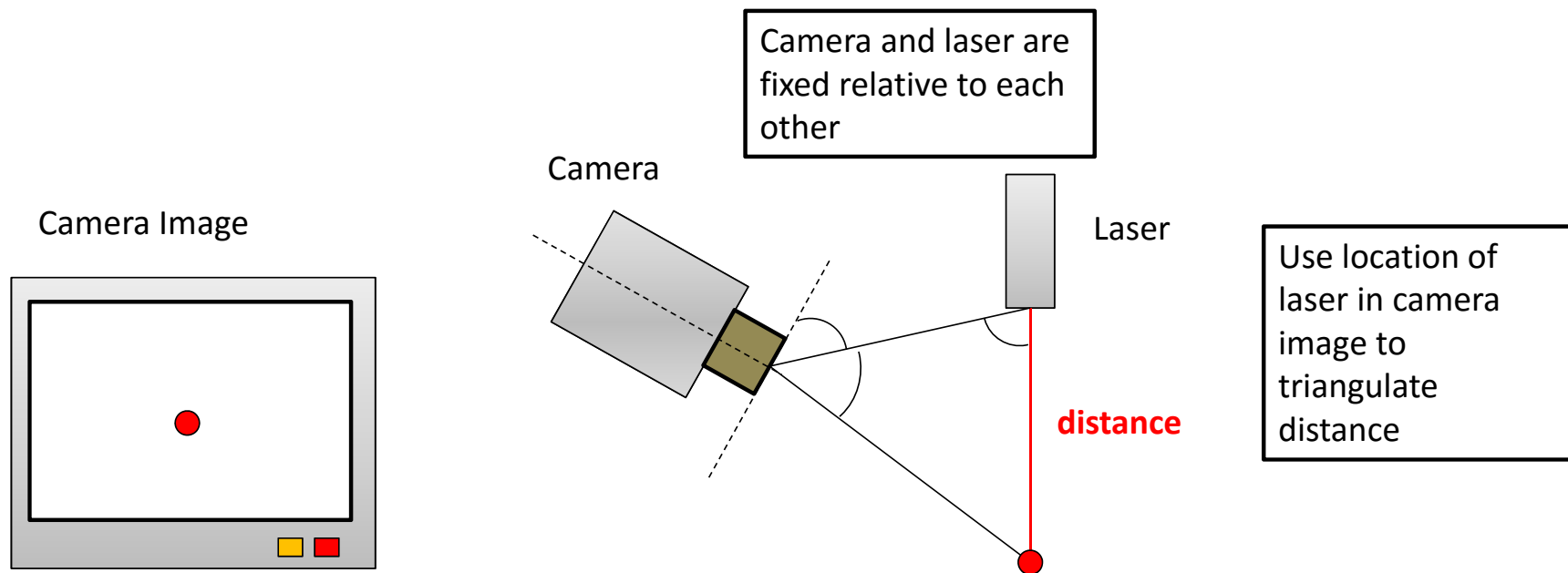


# Ultrasonic Sensors

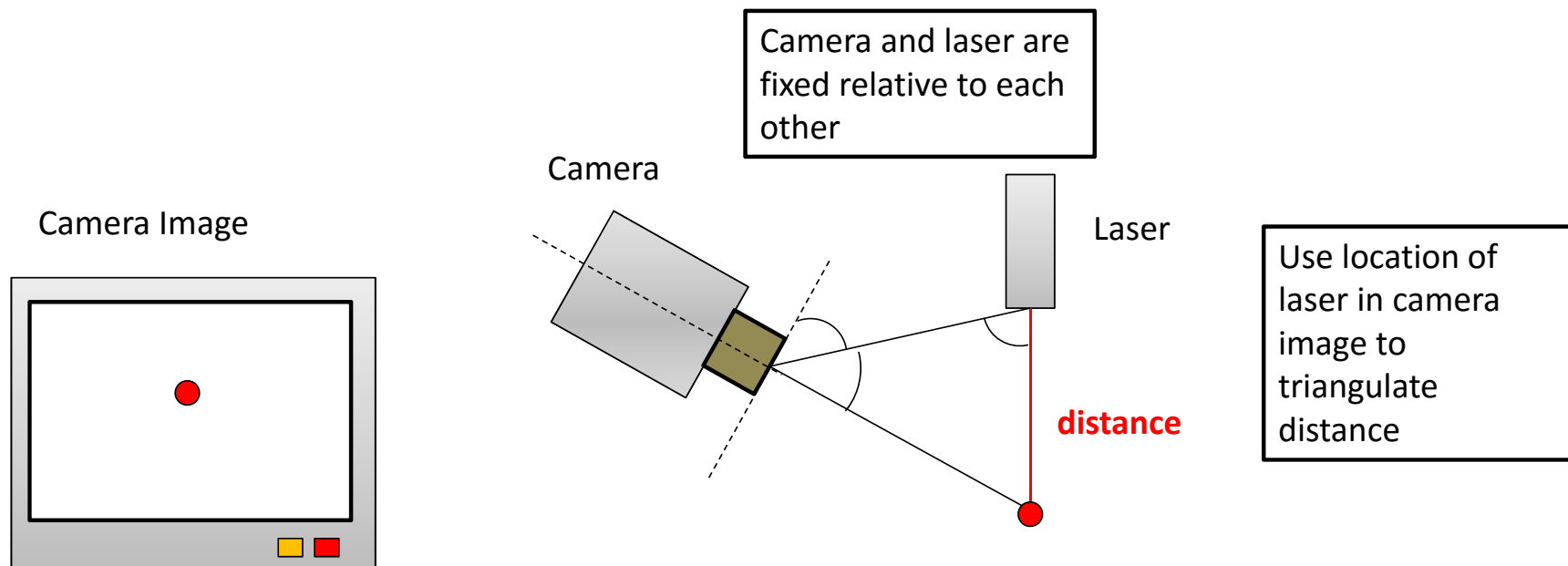
- Can measure depth, size, and orientation of internal flaws in a material



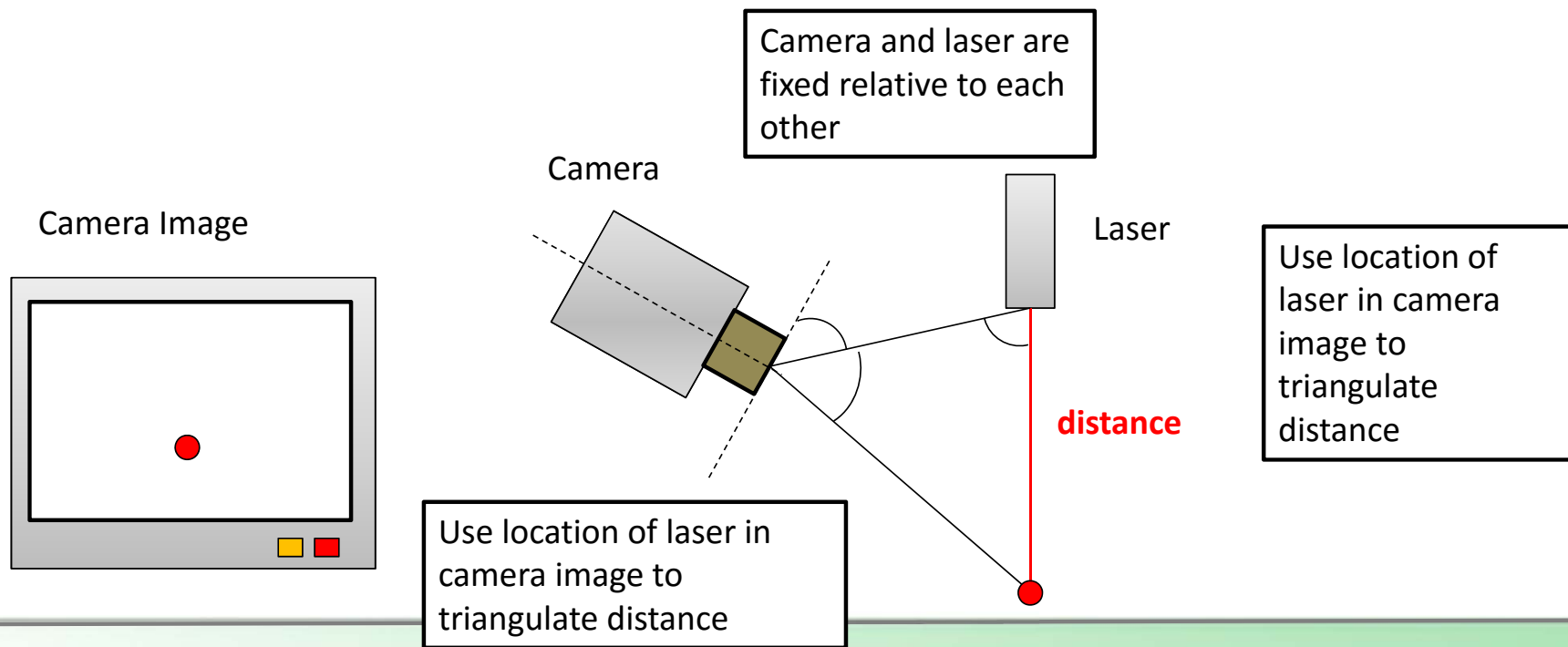
# Laser Triangulation Measurement



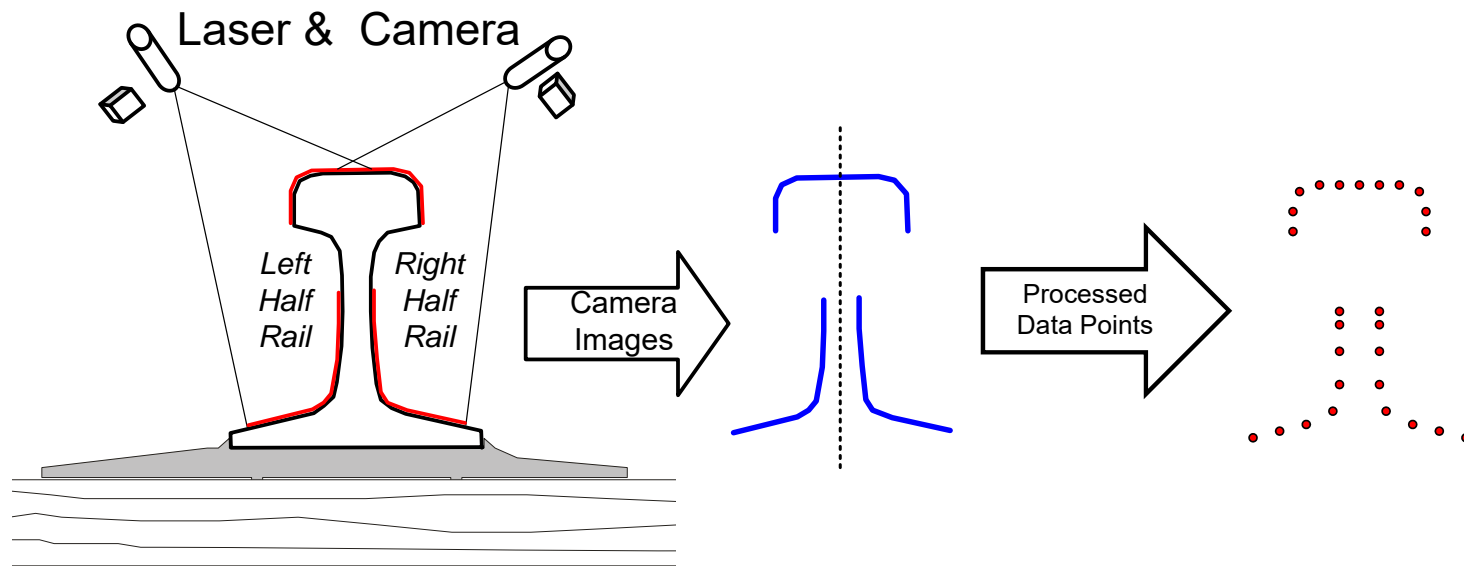
# Laser Triangulation Measurement



# Laser Triangulation Measurement



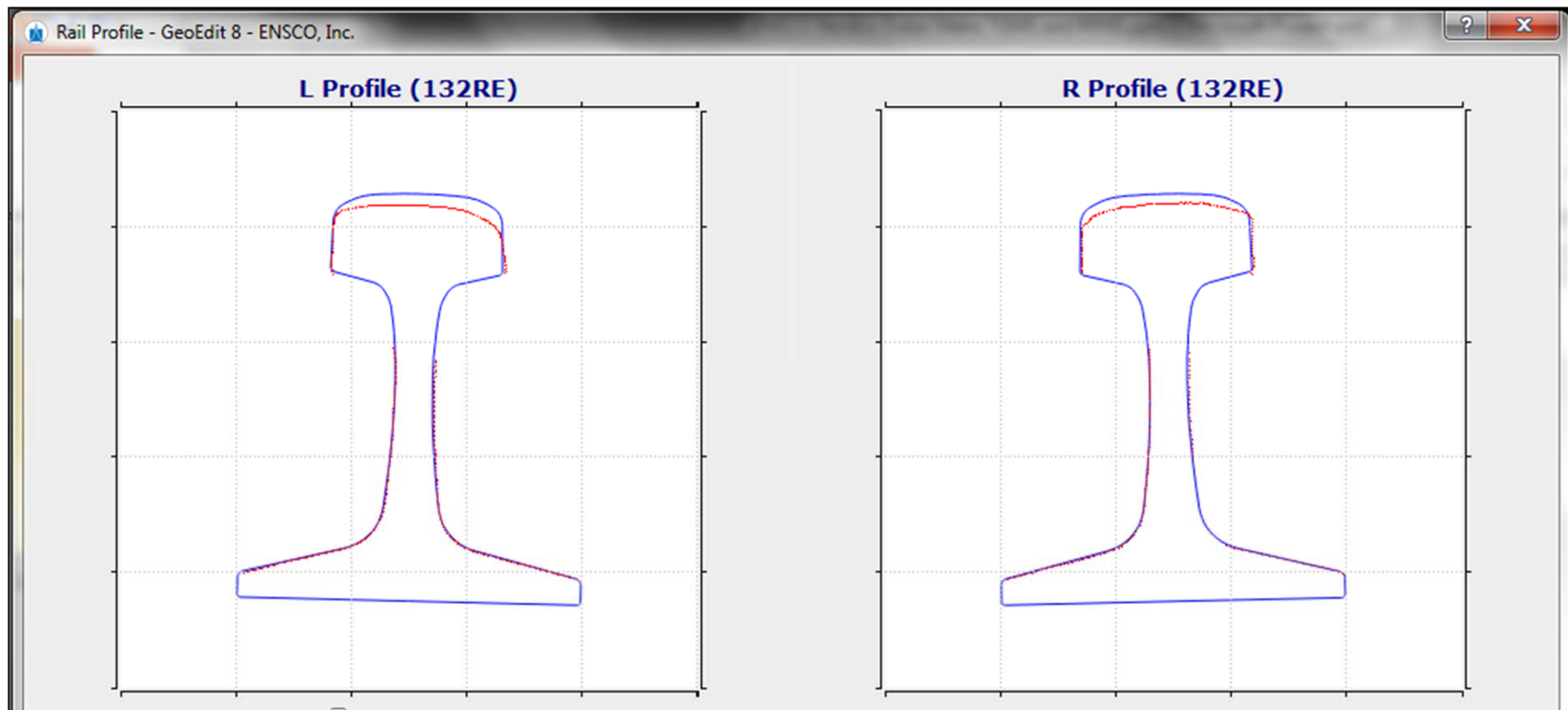
# Laser Triangulation Measurement



Ref 1



# Laser Triangulation Measurement



# Cameras

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

Works like your document scanner



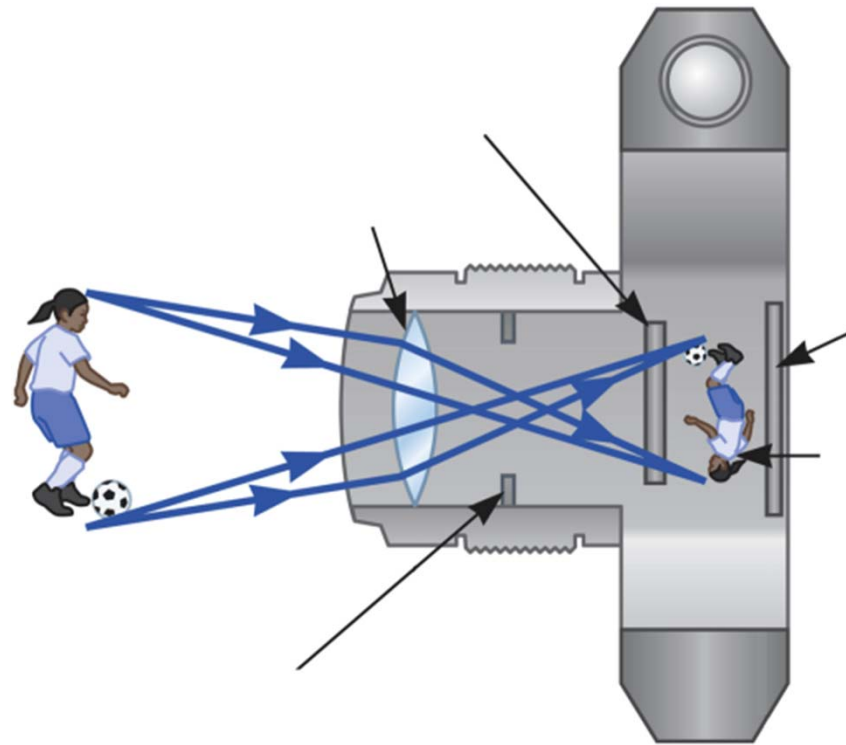
## “Area Scan” Cameras aka “Full Frame”

Works like your standard camera





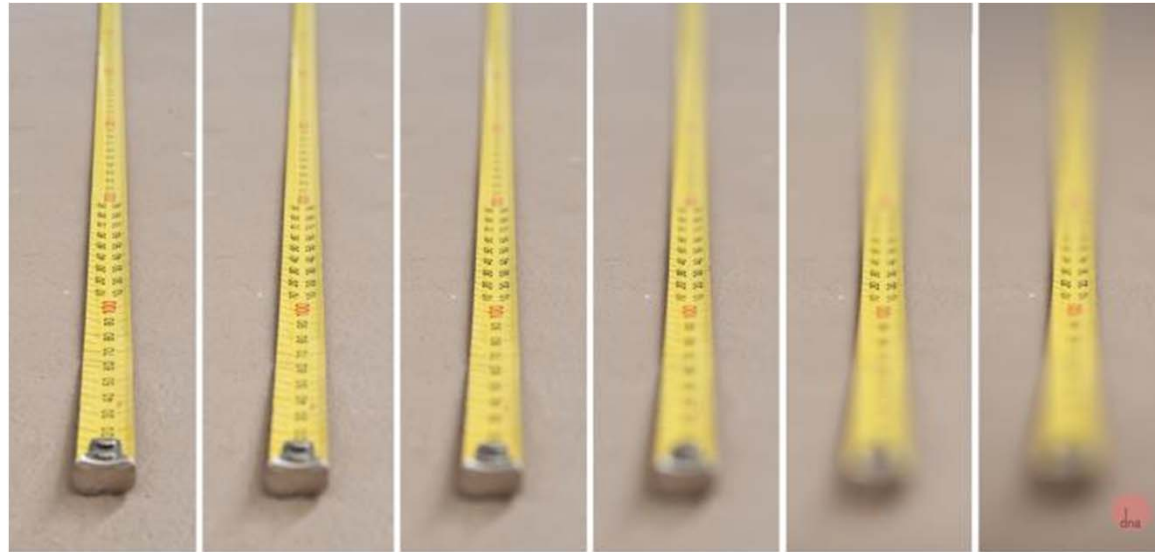
# Cameras



Ref: <http://www.physics.byu.edu/faculty/colton/courses/phy123-fall12/warmups/jitt30a.html>



# Cameras



F16



F10



F6.3



F3.5



F2



F1.4

Ref: <https://www.ormsdirect.co.za/blog/2012/05/08/what-is-aperture-desmond-louw-explains/>



# Cameras

*What is needed for a railroad application:*

Ideally want **large depth of field (small aperture)** for maximum content in focus.

Want **fast shutter speed** to capture quickly moving objects.

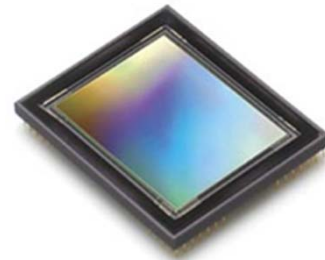
Generally **need lots of light.**



# Cameras



Line Scan Sensor



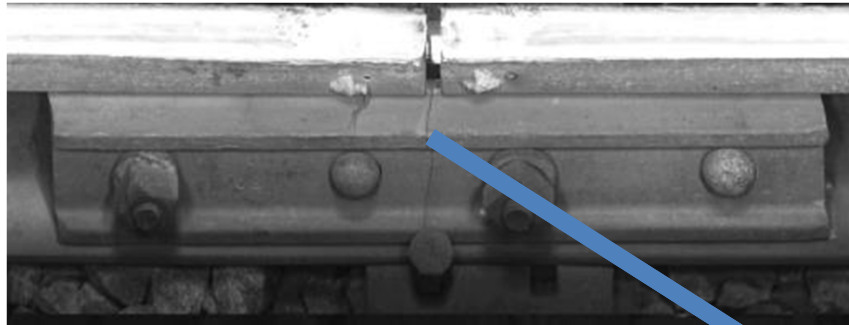
Area Scan Sensor

Light is converted to electricity similar to a solar cell.

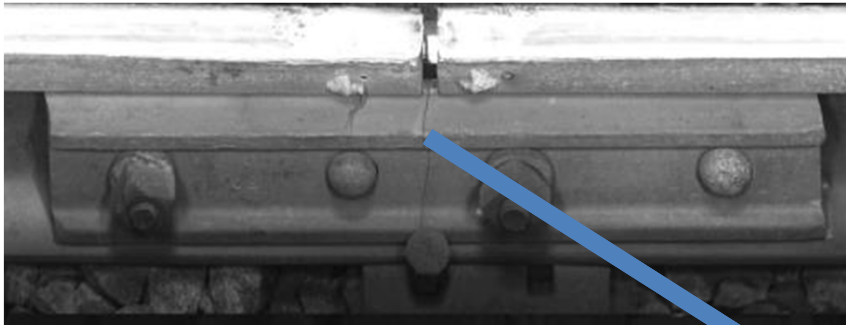
Imagery sensors are like a grid of very tiny solar cells.



# Cameras



# Cameras



169	164	161	168	113	123	138	134	134	134
176	164	155	185	118	138	154	155	138	134
153	164	126	157	117	151	159	148	134	132
115	118	106	113	97	134	135	122	113	107
101	97	97	100	84	91	90	93	91	83
97	95	97	103	76	78	86	88	90	88
97	96	98	101	83	83	96	96	97	96
97	97	100	100	95	85	96	94	97	95
97	97	101	101	95	71	98	100	99	99



# Overview of Measurement Systems

*There are five basic categories of measurement system.*



# Categories of Measurement Systems

1) Mounted on Vehicle to measure the Vehicle.





# Categories of Measurement Systems

1) Mounted on Vehicle to measure the Vehicle.

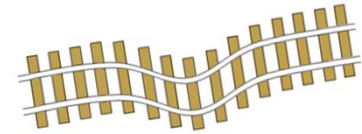


System	Accel	Strain	Temp	Ultra-sonic	Laser	Camera	Other
Event Recorder							Pressure, Throttle, etc
Locomotive Health Monitor							Pressure, Fuel
Railcar Health Monitor							



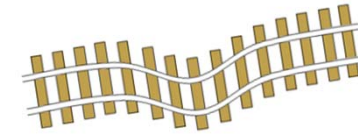
# Categories of Measurement Systems

2) Mounted on Track to measure the Track.



# Categories of Measurement Systems

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

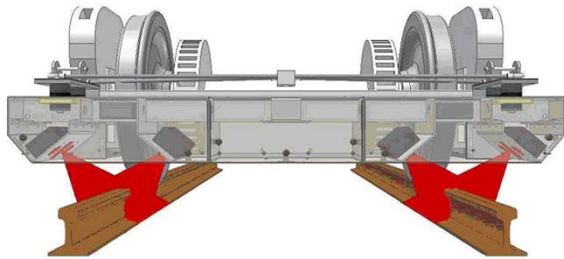
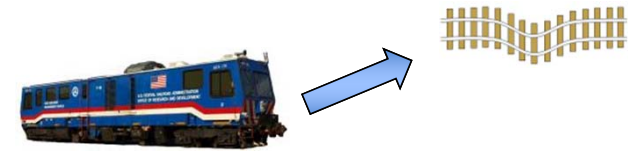


System	Accel	Strain	Temp	Ultra-sonic	Laser	Camera	Other
Rail Stress / Temp Monitor							
Bridge Monitoring							
Ballast & Formation Monitoring							Displacement
Landslip Monitoring							Displacement
Flood Monitoring							Water



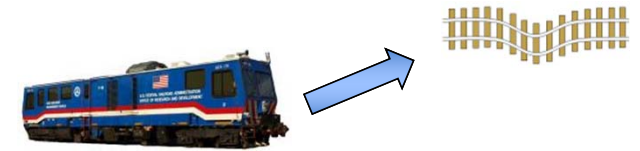
# Categories of Measurement Systems

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



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



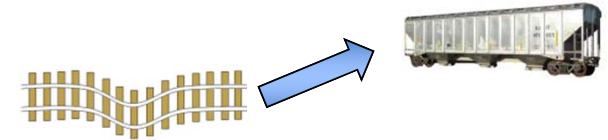
System	Accel	Strain	Temp	Ultra-sonic	Laser	Camera	Other
Track Geometry Measurement System							
Rail Profile Measurement System							
Ultrasonic Rail Flaw Detection							
Ground Penetrating Radar							Radar
Track Component, Joint Bar, & Rail Surface Machine Vision							
V/TI Monitors							
Corrugation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





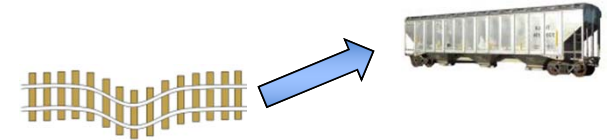
# Categories of Measurement Systems

4) Mounted on Track to measure the Vehicle.



# Categories of Measurement Systems

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

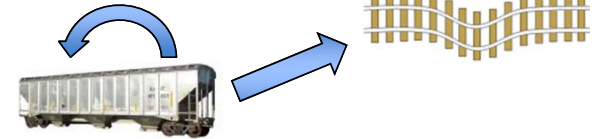


System	Accel	Strain	Temp	Ultra-sonic	Laser	Camera	Other
Dragging Equipment Detectors							Displacement
Hot Bearing & Hot/Cold Wheel Detectors							
Wheel Impact Load Detectors & Truck Performance Detectors							
Truck Condition Detector (TBOGI)							
Acoustic Bearing Detectors							Acoustic
Wheel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



# Categories of Measurement Systems

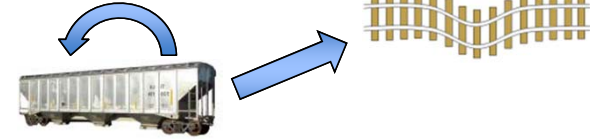
5) Mounted on Vehicle to measure the Vehicle & Track.





# 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							

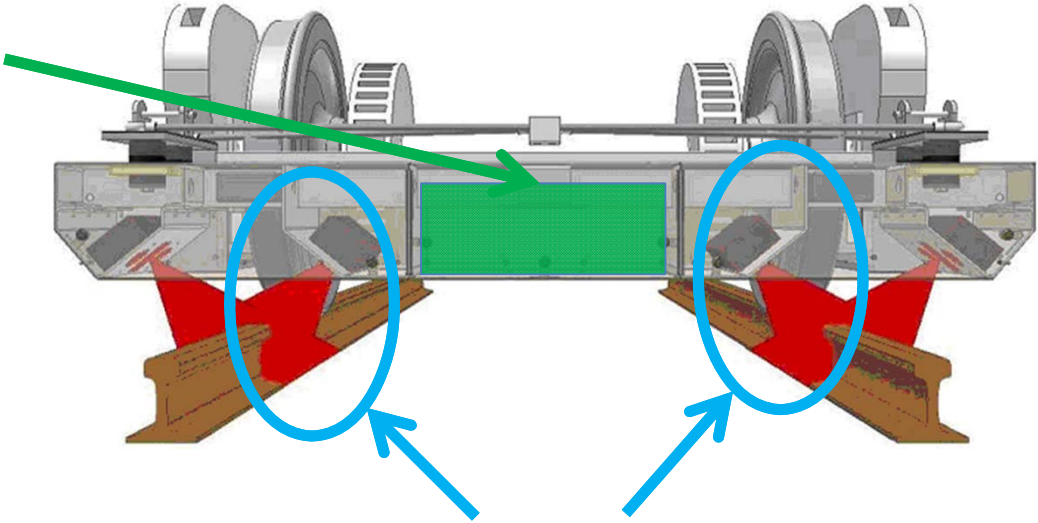


# Detailed Discussion of Measurement Systems



# How does a Track Geometry Measurement System Work?

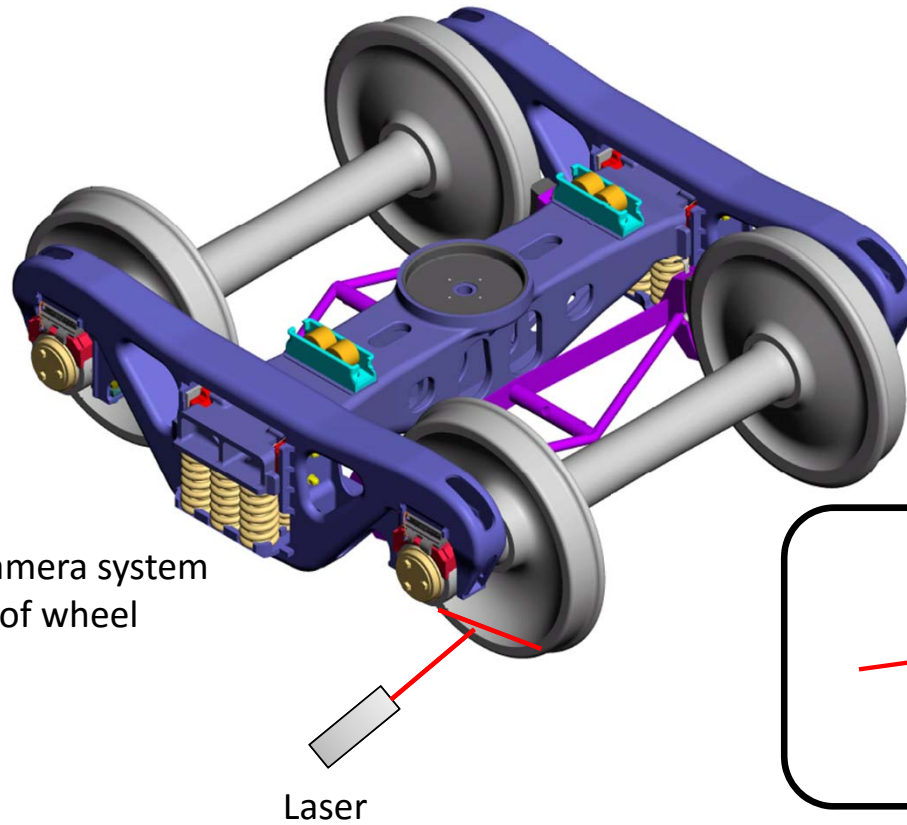
**Inertial Package**  
“Measures the beam location in three dimensional space”



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



# How does a truck condition monitor work?

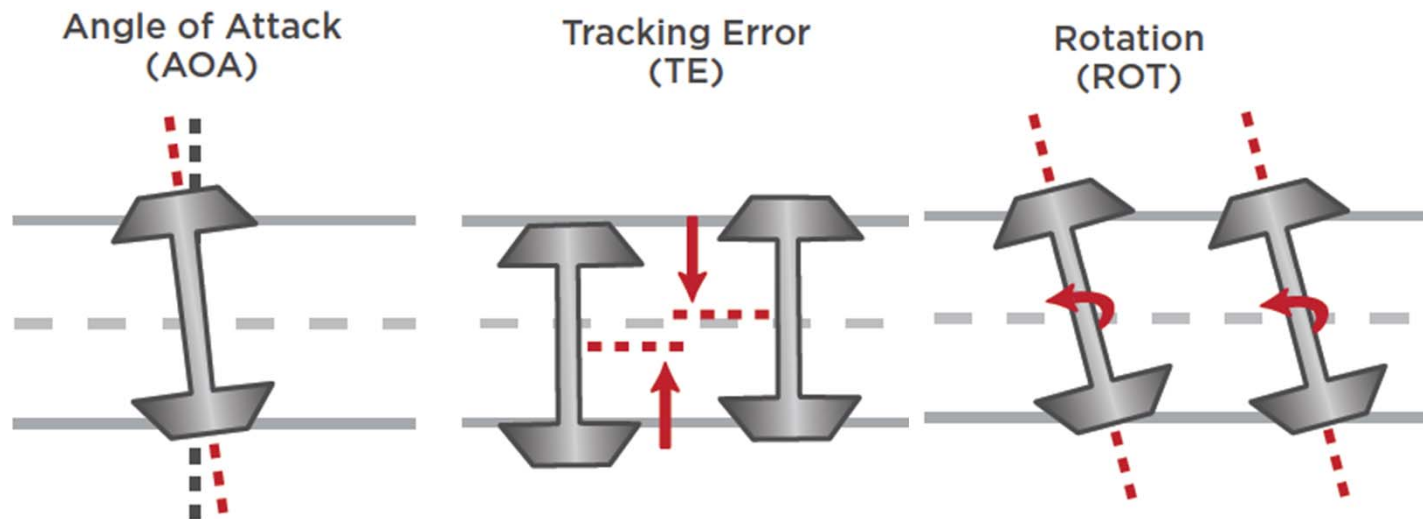


Wayside Laser/Camera system measures profile of wheel plate.

Image from Standard Car and Truck Maintenance Manual  
<http://www.sctco.com/pdf/Section1.pdf>



# How does a truck condition monitor work?



Images from Wayside Inspection Systems  
[http://wid.ca/sites/default/files/brochures/TBOGI/WID\\_TBOGI\\_Brochure\\_US.pdf](http://wid.ca/sites/default/files/brochures/TBOGI/WID_TBOGI_Brochure_US.pdf)



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# Example Camera Systems

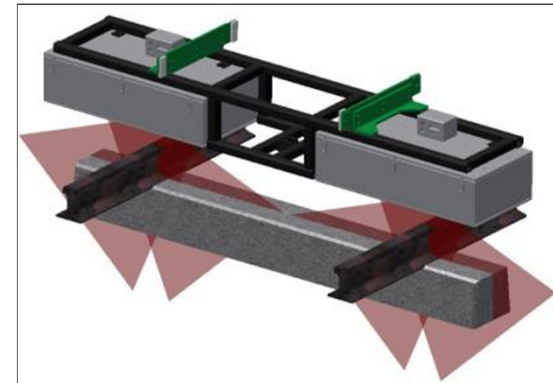


Wheel Sensor

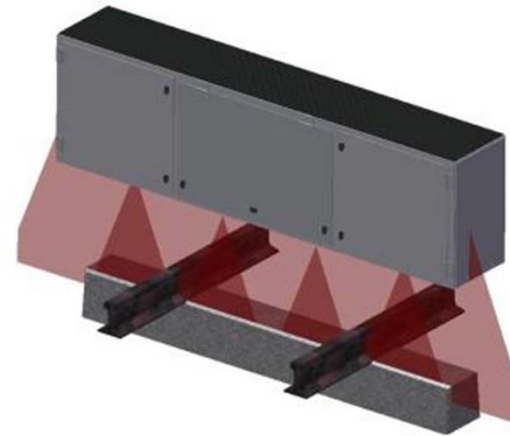




# Example Camera Systems



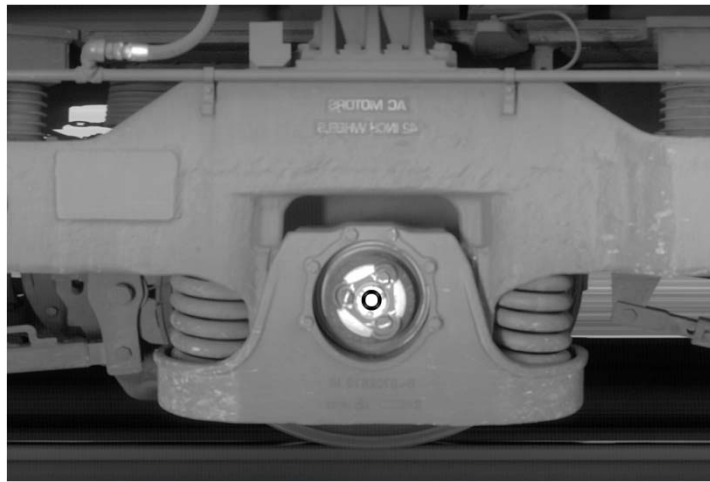
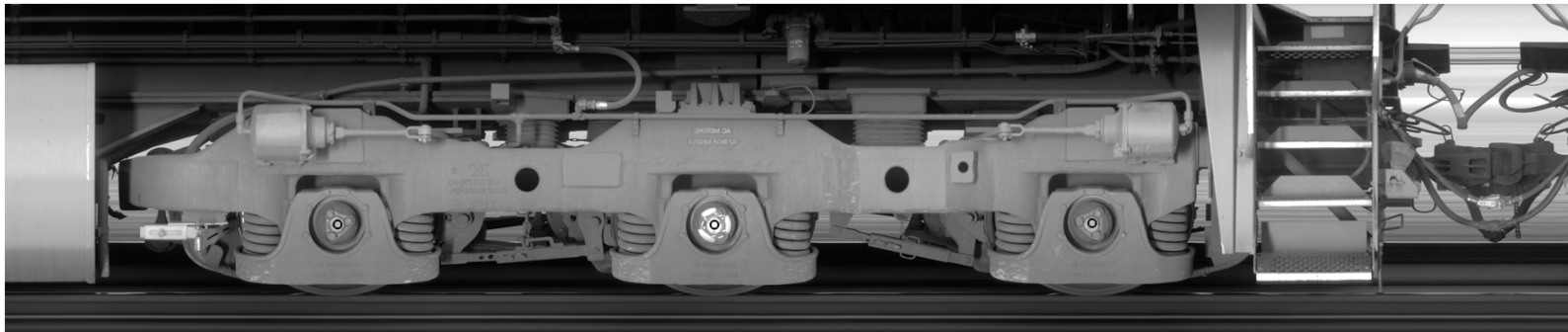
Joint Bar View



Track Bed View

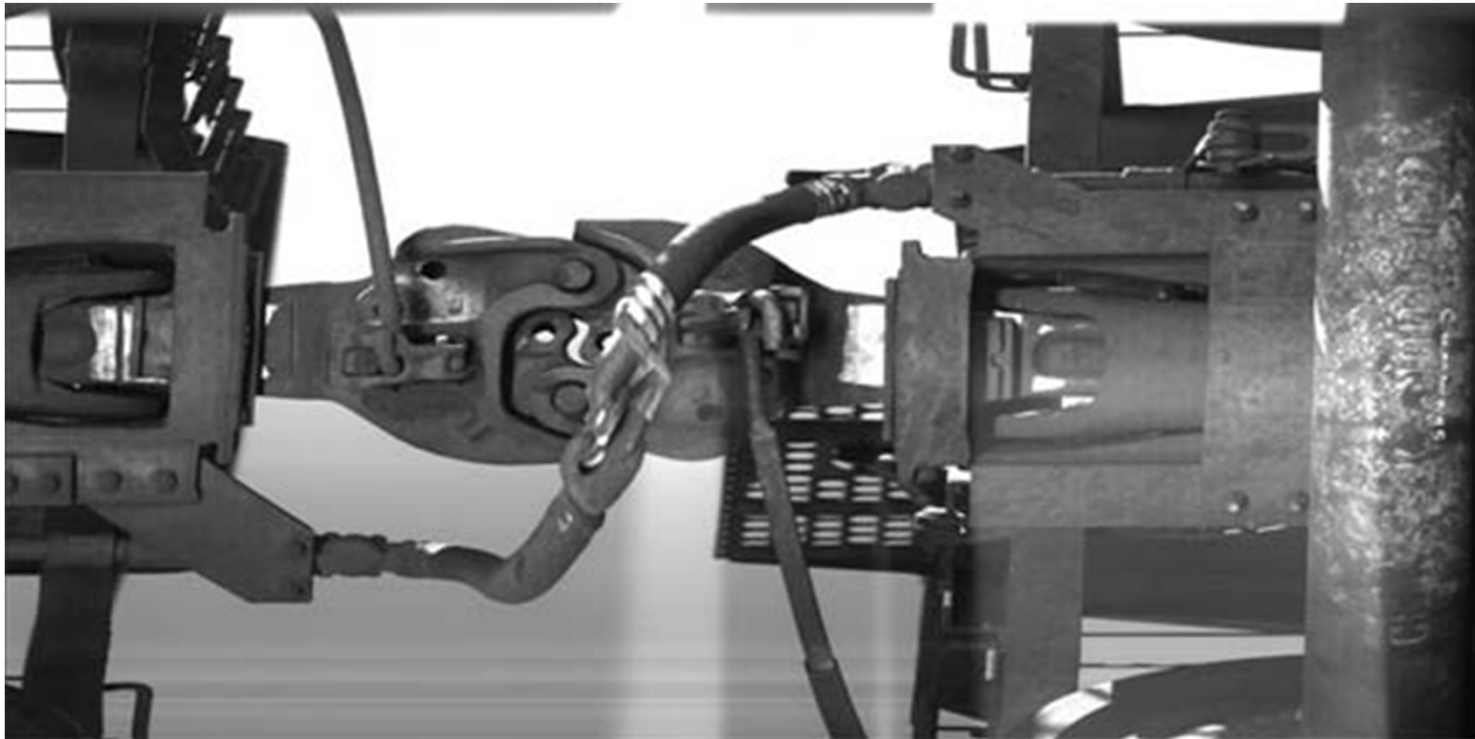


# Example Line Scan Images

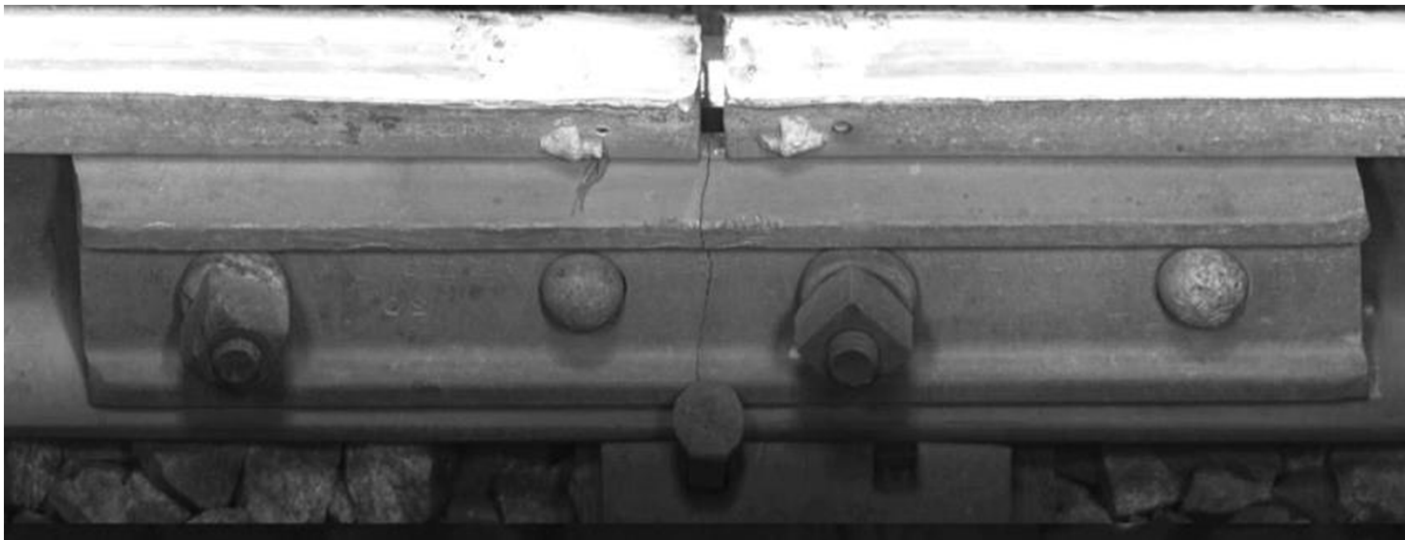




# Example Line Scan Images



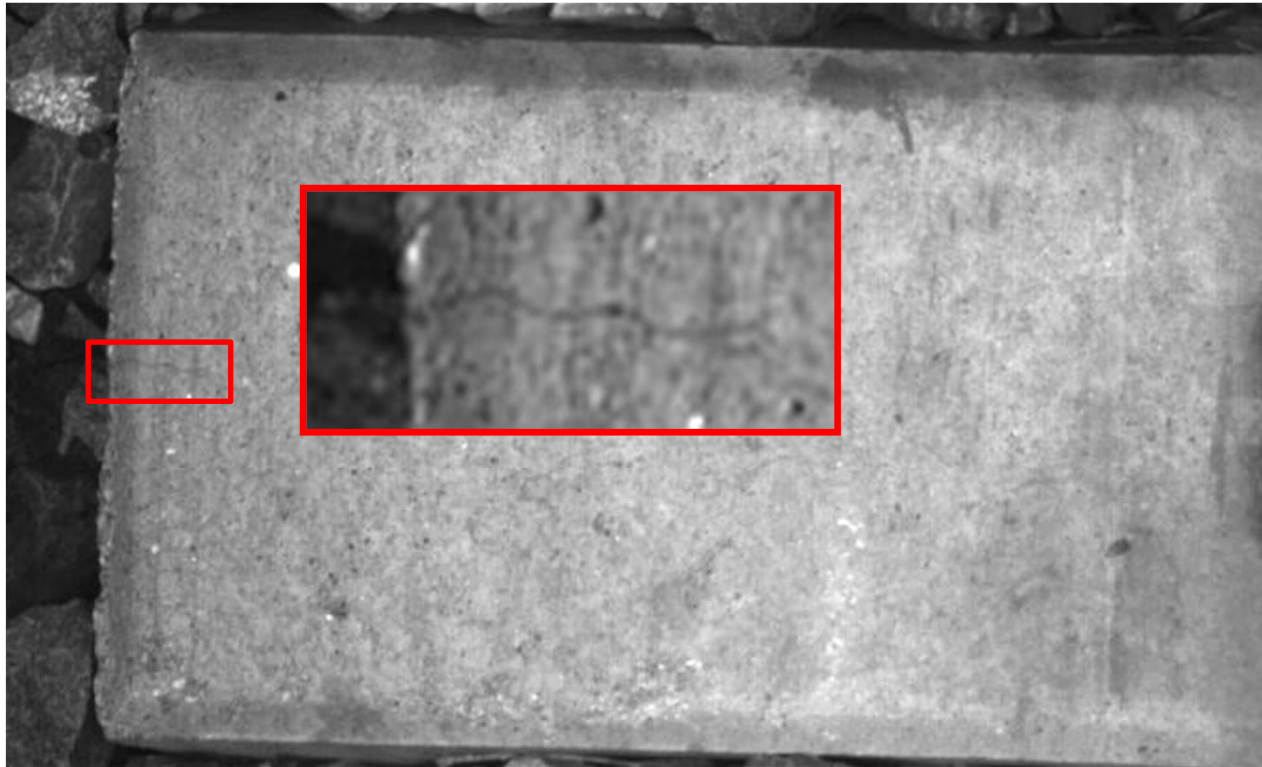
# Example Line Scan Images



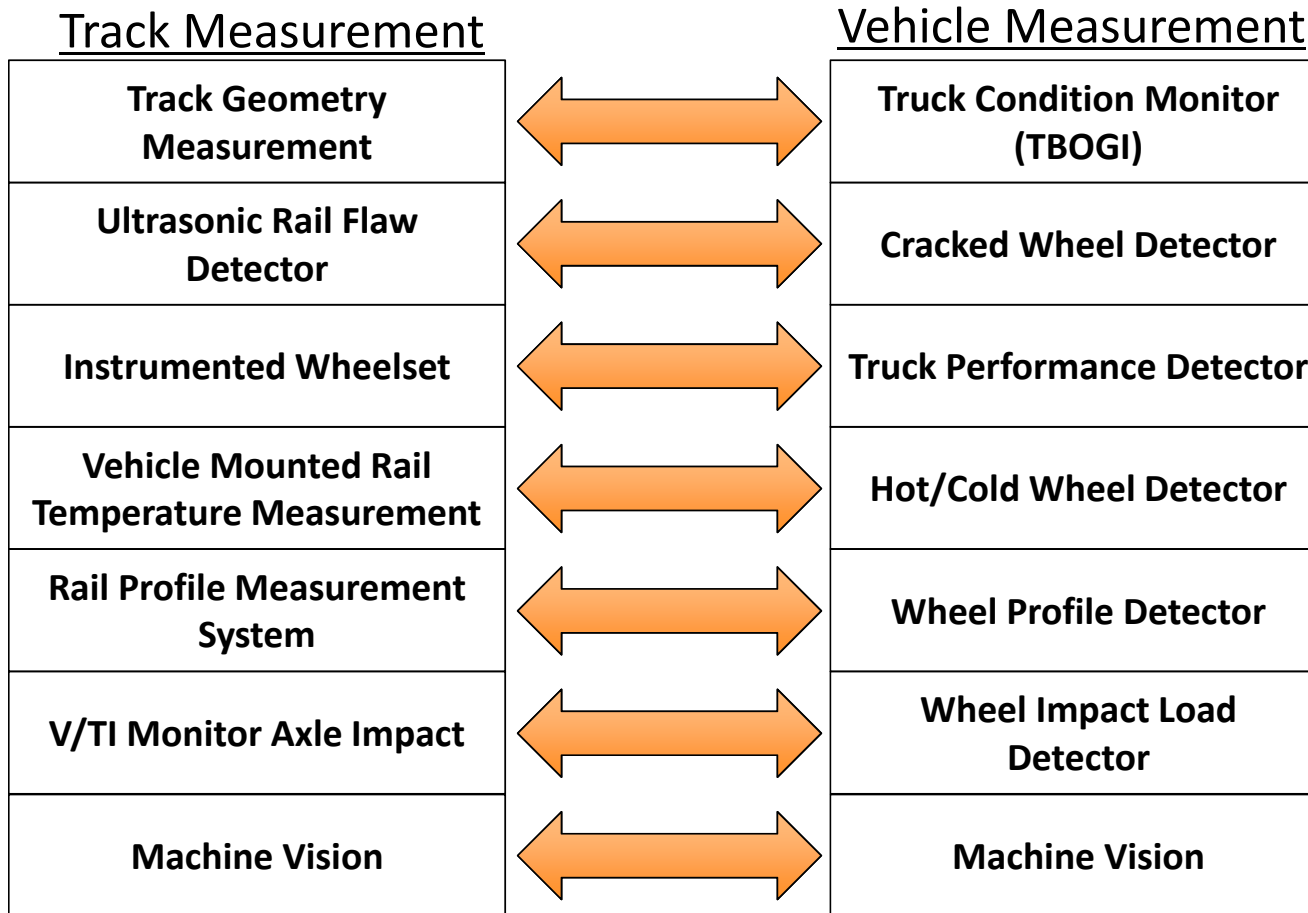
# Example Line Scan Images



# Example Line Scan Images







# What is the Future of Railway Measurement Technology?



# 1) Ultra Comprehensive Track Inspection Vehicles





**Roy Hill Mine 2015**  
**9 Inspection Systems**

Track Geometry  
Rail Profile  
Corrugation  
Ultrasonic Rail Flaw  
Ground Penetrating Radar

Track Bed Imaging  
Rail Surface Imaging  
Driver View Imaging  
Ballast/Formation Profile





## Queensland Rail 2017

### 8 Inspection Systems

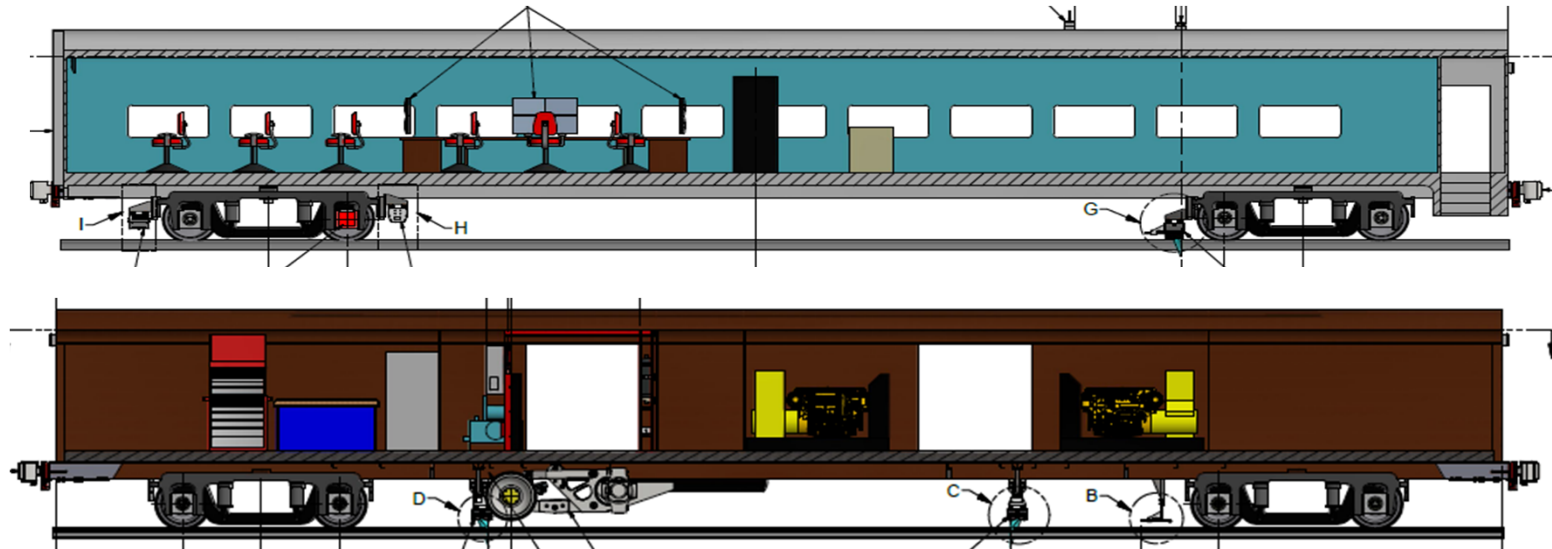
- Track Geometry
- Rail Profile
- Corrugation
- Clearance
- Overhead Wire Measurement
- Driver View Imaging
- Track Component Imaging
- Overhead Wire Imaging



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**MENSICO**  
Rail

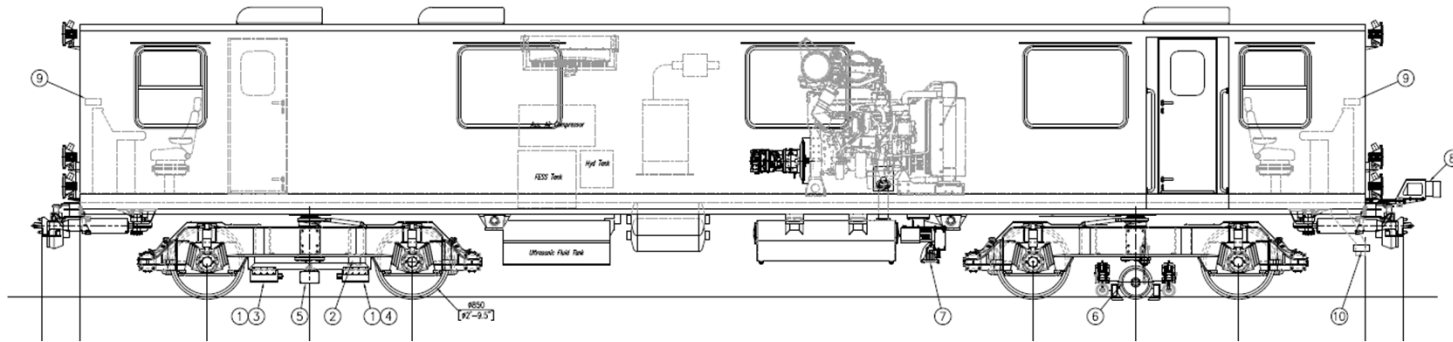
**WRI 2017**



## Canadian Pacific 2019 8 Inspection Systems

Track Geometry Measurement System (TGMS)  
 Rail Profile Measurement System (RPMS)  
 Joint Bar Inspection System (JBIS)  
 Track Component Imaging System (TCIS)  
 Driver View Imaging System (DVIS)  
 Deployable Gage Restraint Measurement System (DGRMS)  
 Loaded and Unloaded Gage  
 Grade Measurement



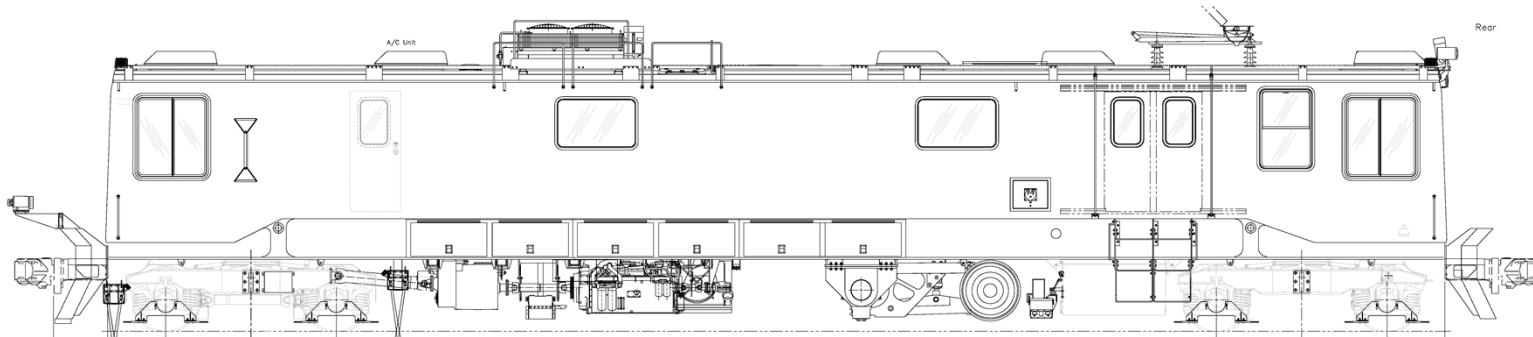


## PATH 2018

### 10 Inspection Systems

- Zero-Speed Track Geometry Measurement System (Z-TGMS)
- Rail Profile Measurement System (RPMS)
- Third Rail Measurement System (TRMS)
- Tunnel Clearance Measurement System (TCMS)
- Rail Corrugation Measurement System (RCMS)
- Driver View Imaging System (DVIS)
- Thermal Imaging System (TIS)
- Rail Surface Imaging System (RSIS)
- Tunnel Wall Imaging System (TWIS)
- Ultrasonic Rail Flaw





## Metro North Railroad 2018

### 12 Inspection Systems

- Zero-Speed Track Geometry Measurement System (Z-TGMS)
- Rail Profile Measurement System (RPMS)
- Third Rail Measurement System (TRMS)
- Tunnel Clearance Measurement System (TCMS)
- Rail Corrugation Measurement System (RCMS)
- Driver View Imaging System (DVIS)
- Overhead Wire Measurement System (OWMS)
- Deployable Gage Restraint Measurement System (DGRMS)
- Loaded and Unloaded Gage
- Signal and Communication Inspection System (SCIS)
- Joint Bar Inspection System (JBIS)
- Track Component Imaging System (TCIS)



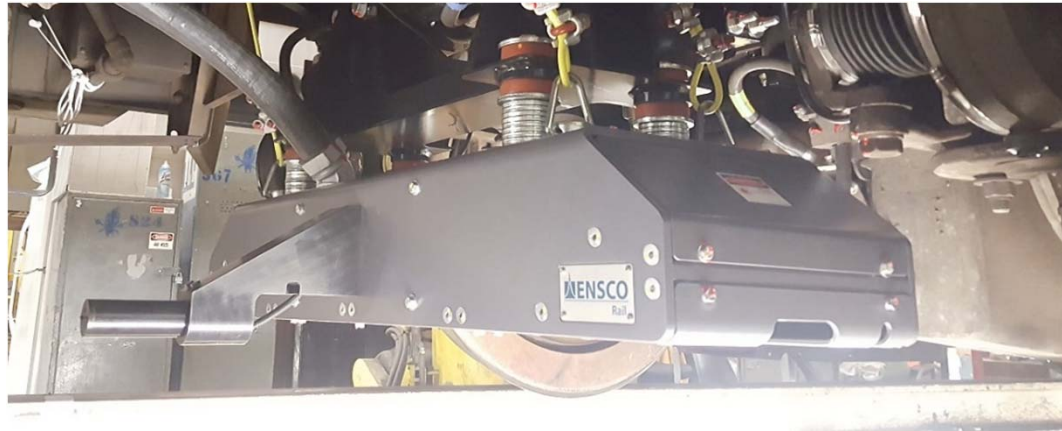
## 2) Autonomous Track Inspection from Revenue Vehicles





## 2) Autonomous Track Inspection

Metro North Railroad  
2016  
Three (3) Units



## 2) Autonomous Track Inspection

Canadian Pacific – 2013



FRA – 2016



CSX – 2016



RUMO (Brazil) – 2017



## 3) 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





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

**aka Unmanned Aerial Vehicles (UAV)**

**aka Drones**

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



# 3) Unmanned Aerial Systems (UAS)

Multi-Rotor



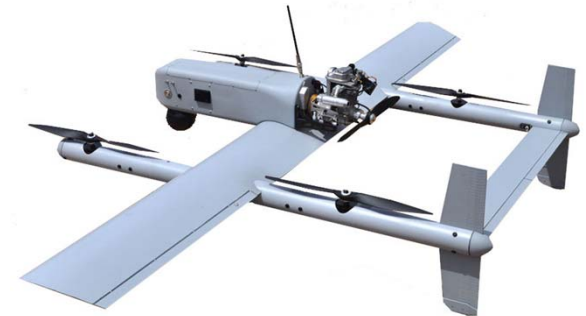
- Good maneuverability
- Relatively slow speed
- Lower altitude
- 20~40 minute flight time

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



# Questions?

