

# Vehicle-Track Measurement Technologies

Matthew Dick, P.E.

ENSCO Rail

June 22<sup>nd</sup>, 2022



PRINCIPLES COURSE • JUNE 22



**WRI 2022**

# Summary

**Overview of Measurement Systems**

**Detailed Evaluation of Select Technology**

**Hands-On Training**



# Overview of Measurement Systems

*There are five basic categories of measurement system.*



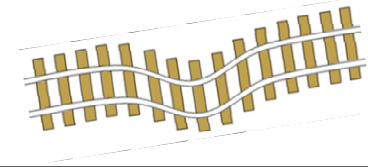
# Categories of Measurement Systems

1) Mounted on Vehicle to measure the Vehicle.



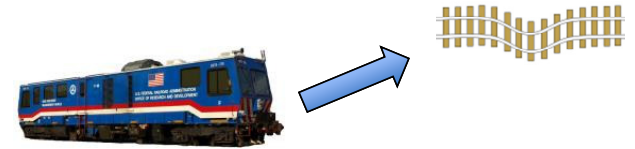
# Categories of Measurement Systems

2) Mounted on Track to measure the Track.



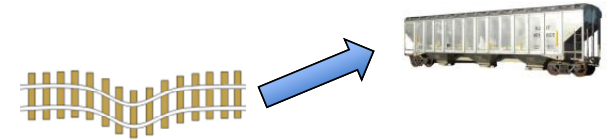
# Categories of Measurement Systems

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



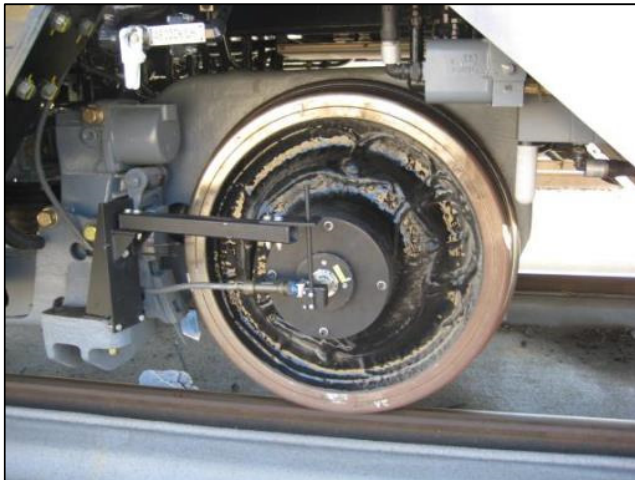
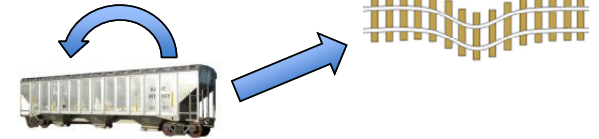
# Categories of Measurement Systems

4) Mounted on Track to measure the Vehicle.



# Categories of Measurement Systems

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





## Track Measurement

**Rail Profile Measurement System**

**Track Geometry Measurement**

**V/TI Monitor Axle Impact**

**Ultrasonic Rail Flaw Detector**

**Machine Vision**



## Vehicle Measurement

**Wheel Profile Detector**

**Truck Condition Monitor  
(TBOGI)**

**Wheel Impact Load Detector**

**Cracked Wheel Detector**

**Machine Vision**

**Instrumented Wheel Sets (IWS) &  
Truck Performance Detectors (TPD)**



## Track Measurement

## Vehicle Measurement

**Rail Profile Measurement System**



**Wheel Profile Detector**

**Track Geometry Measurement**



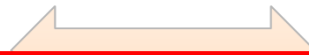
**Truck Condition Monitor  
(TBOGI)**

**V/TI Monitor Axle Impact**



**Wheel Impact Load Detector**

Ultrasonic Rail Flaw Detector



Cracked Wheel Detector

Machine Vision

Previously covered in:

**WRI 2019**

Machine Vision

Ins  
Truck Performance Detectors (TPD)



## Track Measurement

## Vehicle Measurement

Rail Profile Measurement System

Wheel Profile Detector

Track Geometry Measurement

Monitor

V/TI Monitor Axle Impact

Detector

Ultrasonic Rail Flaw Detector

Cracked Wheel Detector

**Machine Vision**

**Machine Vision**

Previously covered in:

**WRI 2021**

Instrumented Wheel Sets (IWS) &  
Truck Performance Detectors (TPD)



# Location Determination



PRINCIPLES COURSE • JUNE 22



**WRI 2022**

# 1) Global Navigation Satellite System (GNSS)

Uses all satellites, not just the USA ones (aka GPS)

More satellites means more accuracy



GPS is a single satellite system that utilizes 31 satellites

VS



GNSS utilizes 89 satellites from all 4 satellite systems

Ref: [https://www.everythingrf.com/community/what-is-the-difference-between-gnss-and-gps\\_58](https://www.everythingrf.com/community/what-is-the-difference-between-gnss-and-gps_58)



## 2) Correction Services:

“Extra stuff beyond the GNSS satellites to increase accuracy”

Correction Service Type:	Pros	Cons
Wide Area Augmentation System (WAAS)	Free	Lowest accuracy
Precise Point Positioning (PPP)	Available Worldwide Lowest Paid Service Price	
Real-Time Kinematic (RTK)	Highest Accuracy	Only available locally and base stations generally needs to be built by railway. Base stations every 10~20 kilometers
Hybrid RTK-PPP	Lower cost than RTK with base stations spread further apart	Higher cost than PPP. Lower accuracy than RTK Still requires RTK infrastructure



### 3) GNSS Accuracy

The accuracy of this...



... is the not the same on this!



Be cautious assuming a GNSS receiver's data sheet accuracy is what you would get on a railway vehicle.



## 4) Inertial Correction

Uses inertial sensors to perform “dead reckoning” in GNSS denied locations.

Fills in “gaps” of missing GNSS information in tunnels and mountain cuts.





## 5) RFID Tags

Used when no GNSS is available at all  
(like subway tunnels)

Install in track centerline

Where RFID tags are installed on the  
network is important

Use Passive instead of Active tags



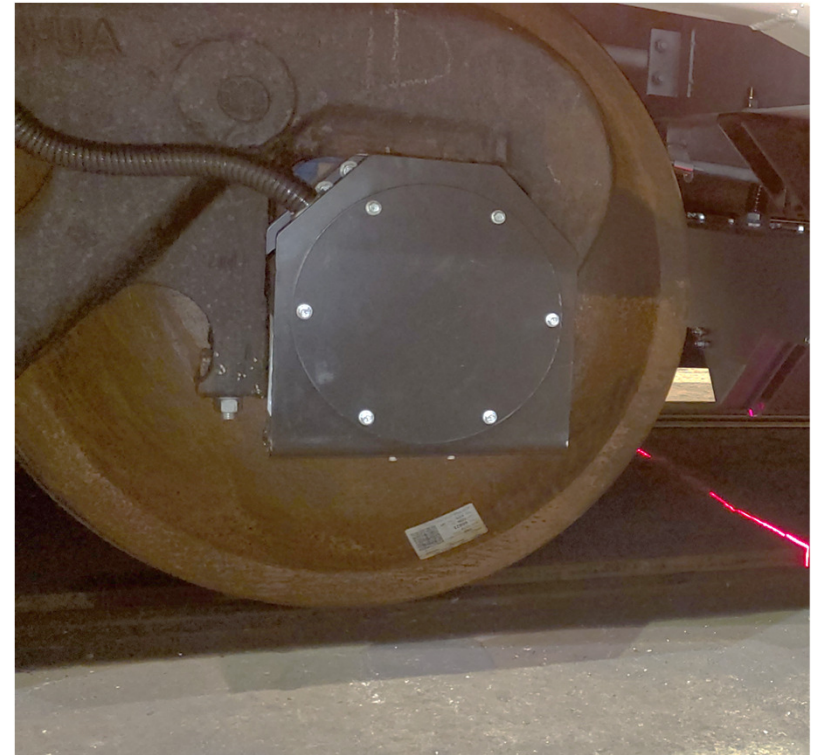
## 6) Wheel Tachometer (aka Encoder)

Backbone of location determination system.

Needs to be recalibrated whenever the wheel diameter changes, such as:

- Wheel Wear
- Wheel being turned

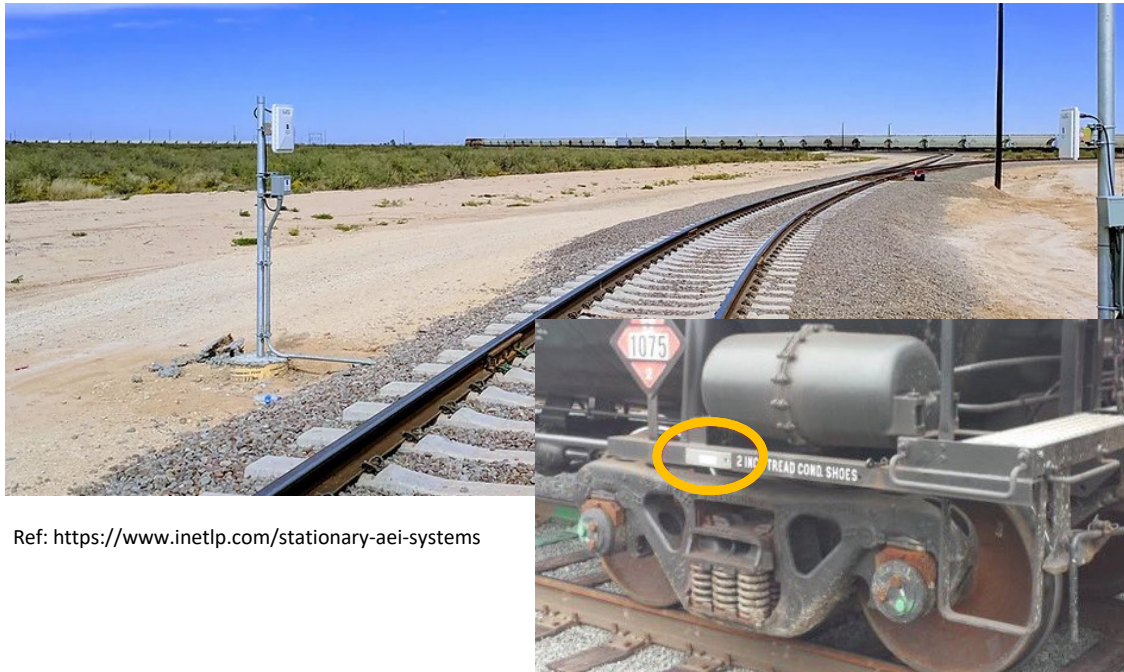
Increased focus on wheel tachometer accuracy



## 6) Positioning for Wayside Inspection Systems

### AEI Tag Reader

What car is it and which way is it oriented



Ref: <https://www.inetlp.com/stationary-aei-systems>

### Wheel Detection Sensor

Precise location of each axle



Ref: [https://www.frauscher.us/en\\_us/wheel-sensors/rsr110](https://www.frauscher.us/en_us/wheel-sensors/rsr110)



# Laser Profiling and LiDAR

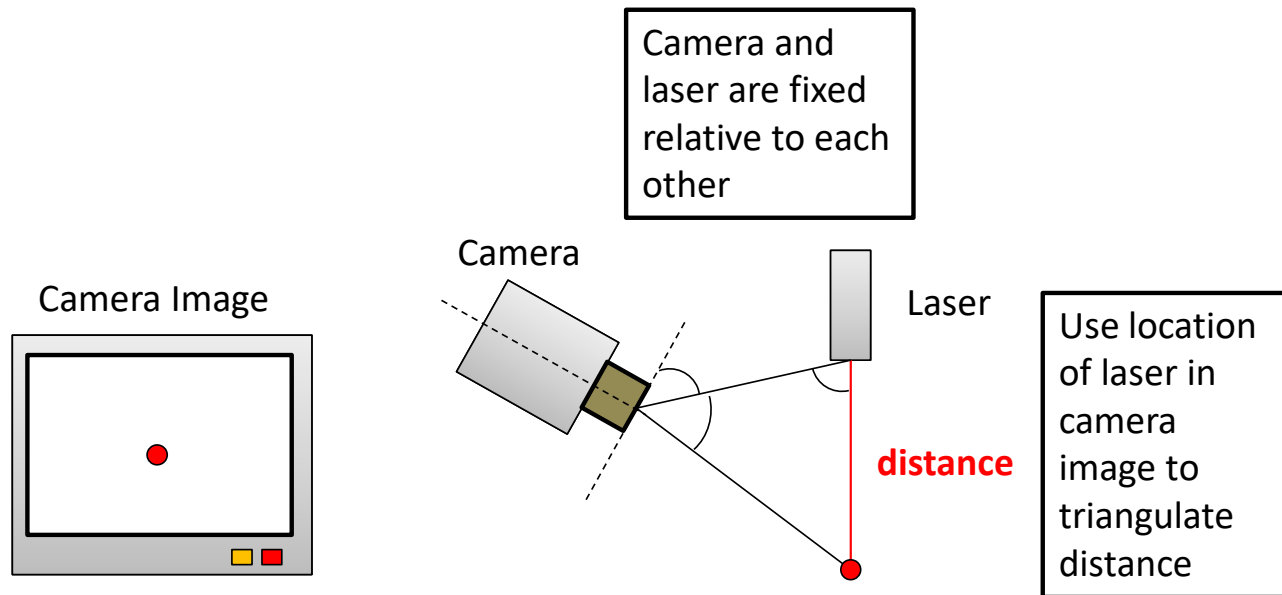


PRINCIPLES COURSE • JUNE 22

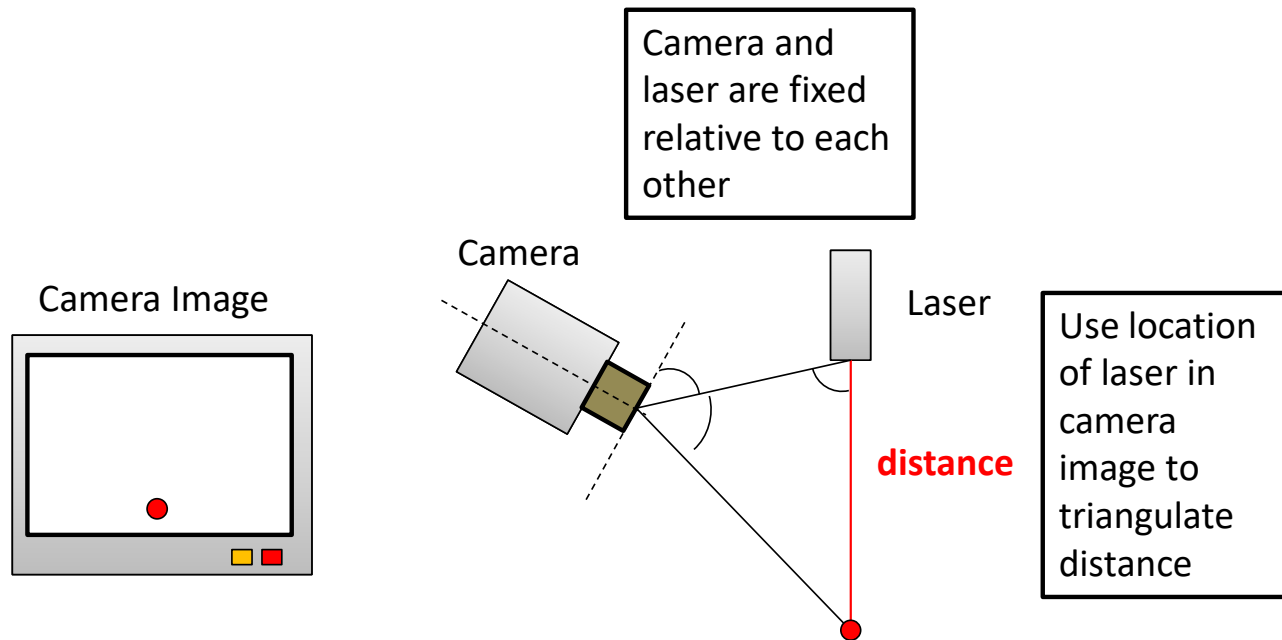


**WRI 2022**

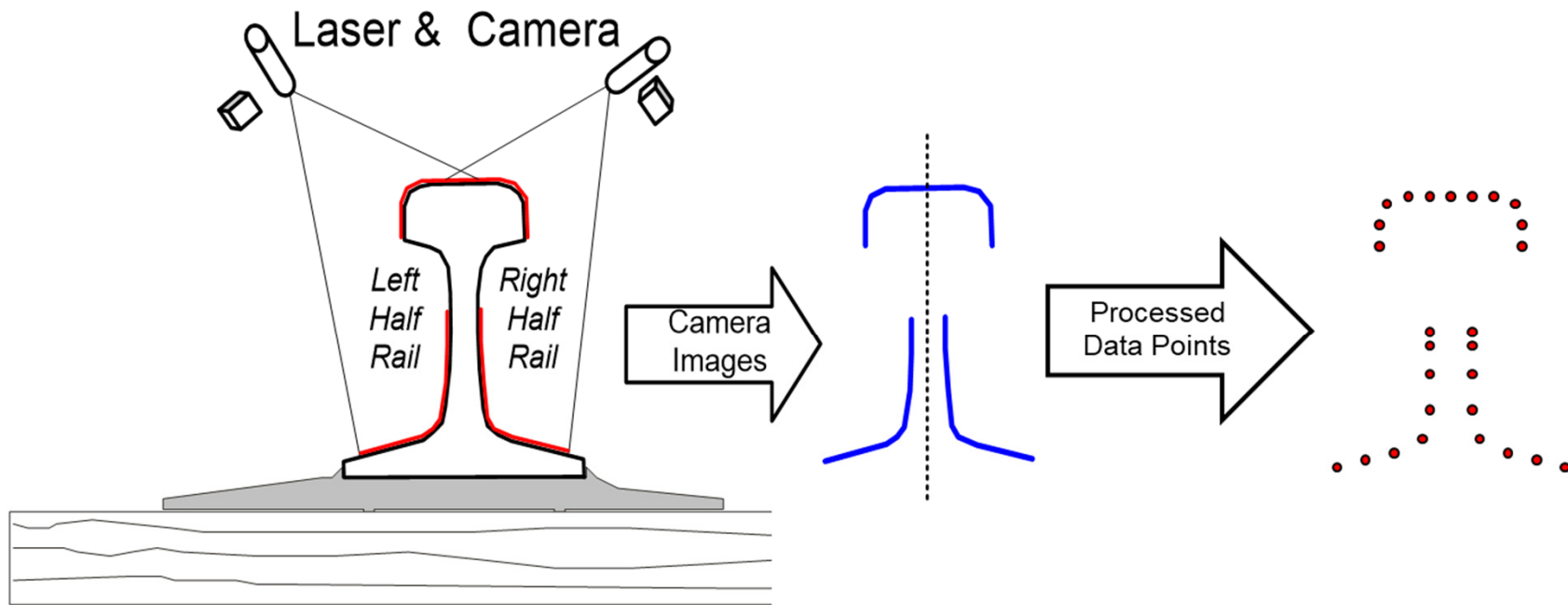
# Laser Triangulation Measurement



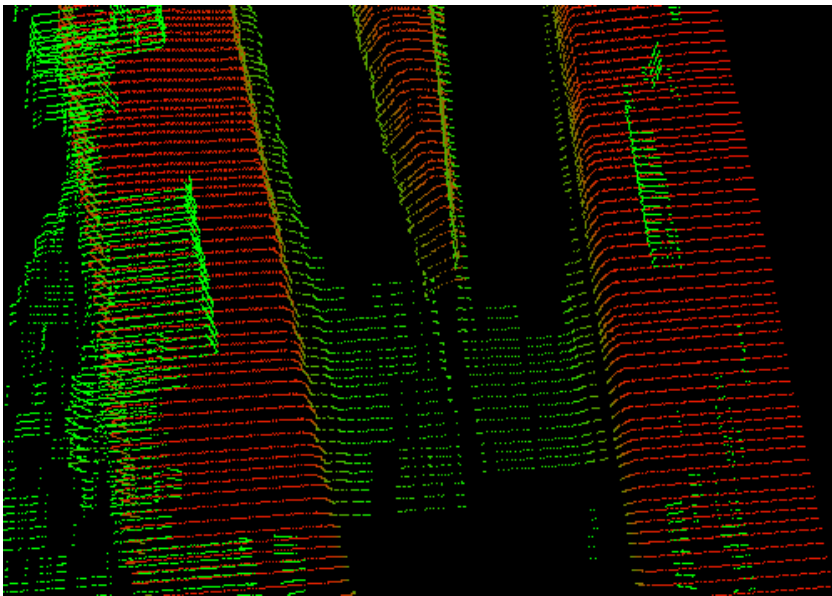
# Laser Triangulation Measurement



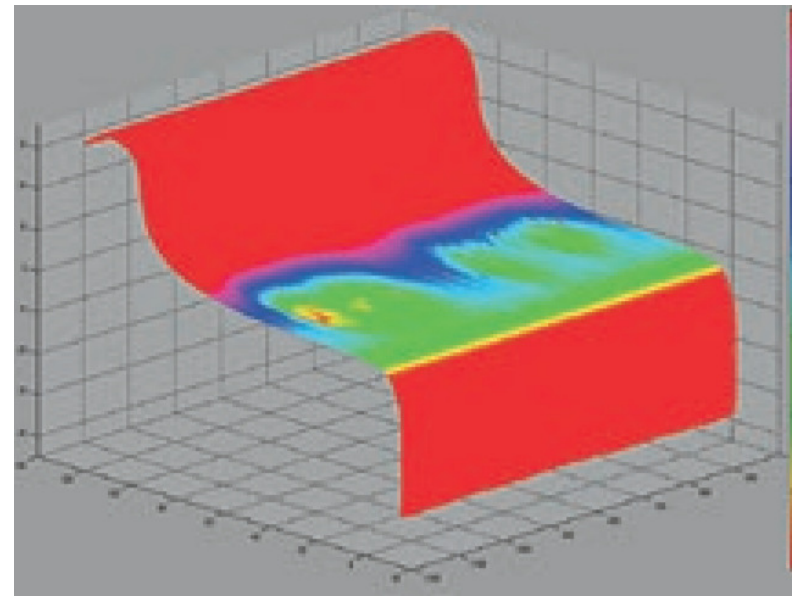
# Laser Triangulation Measurement: Rail Profile Measurement



# Laser Triangulation Measurement: 3D Profiling



High Sample Rate Scan at Frog

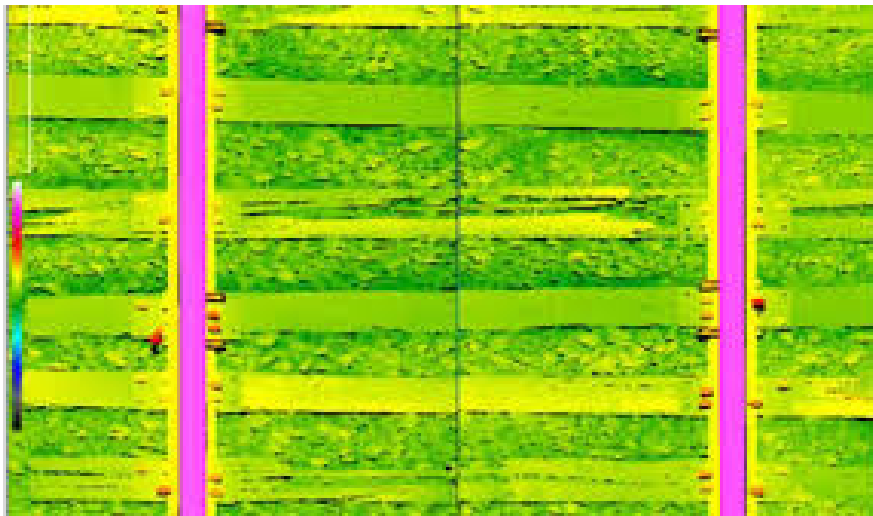


High Sample Rate Scan on Wheel Tread

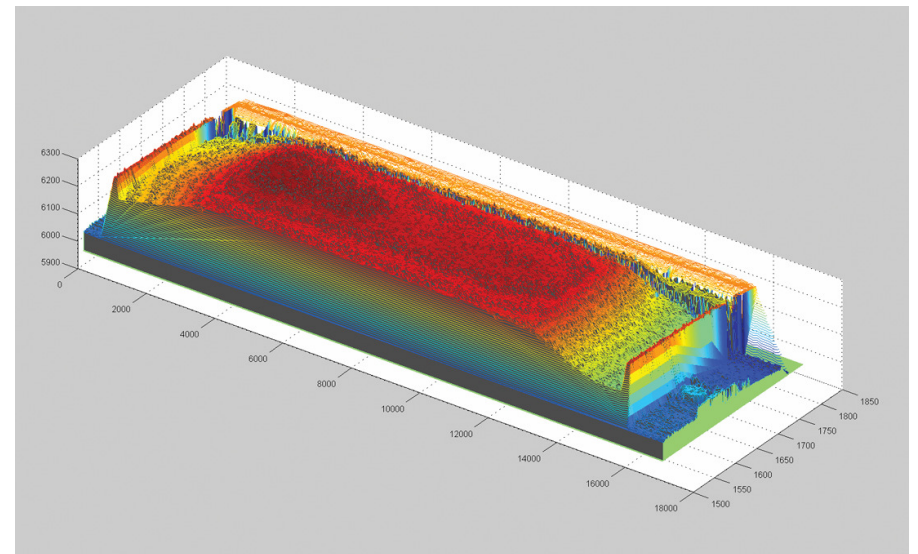




# Laser Triangulation Measurement: 3D Profiling



Track Bed 3D Laser Profile



Coal in Coal Hopper 3D Laser Profile



# LiDAR Basics



PRINCIPLES COURSE • JUNE 22



**WRI 2022**

# LiDAR Basics

Laser is emitted



PRINCIPLES COURSE • JUNE 22



**WRI 2022**

# LiDAR Basics

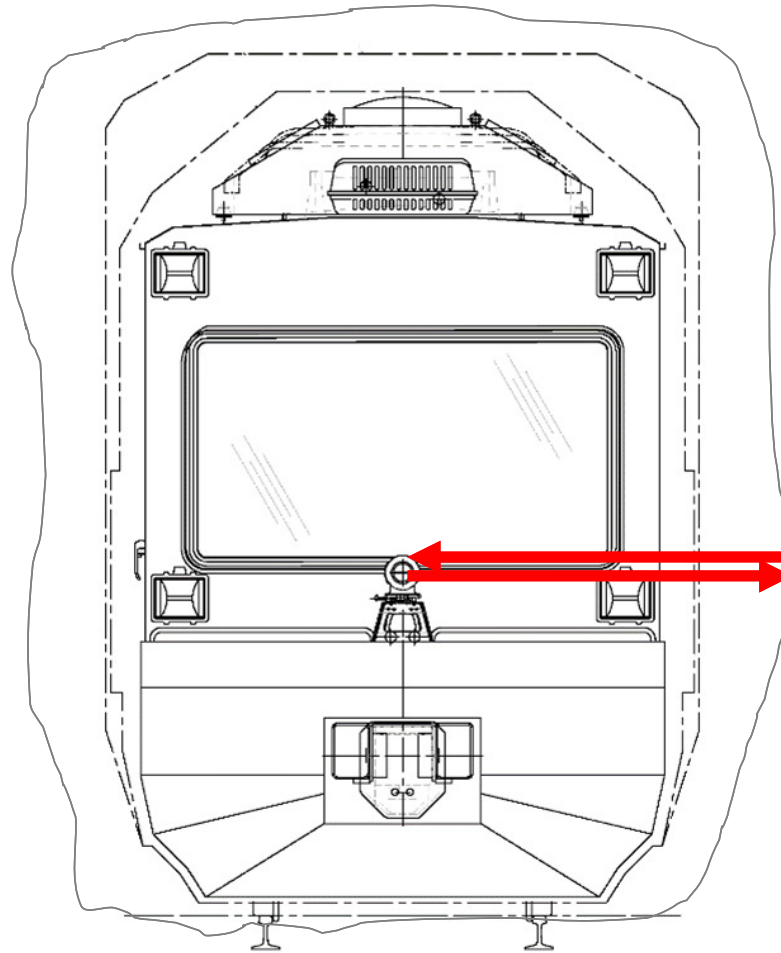
Laser is emitted

Laser bounces off surface

Travel time is measured  
and converted to distance



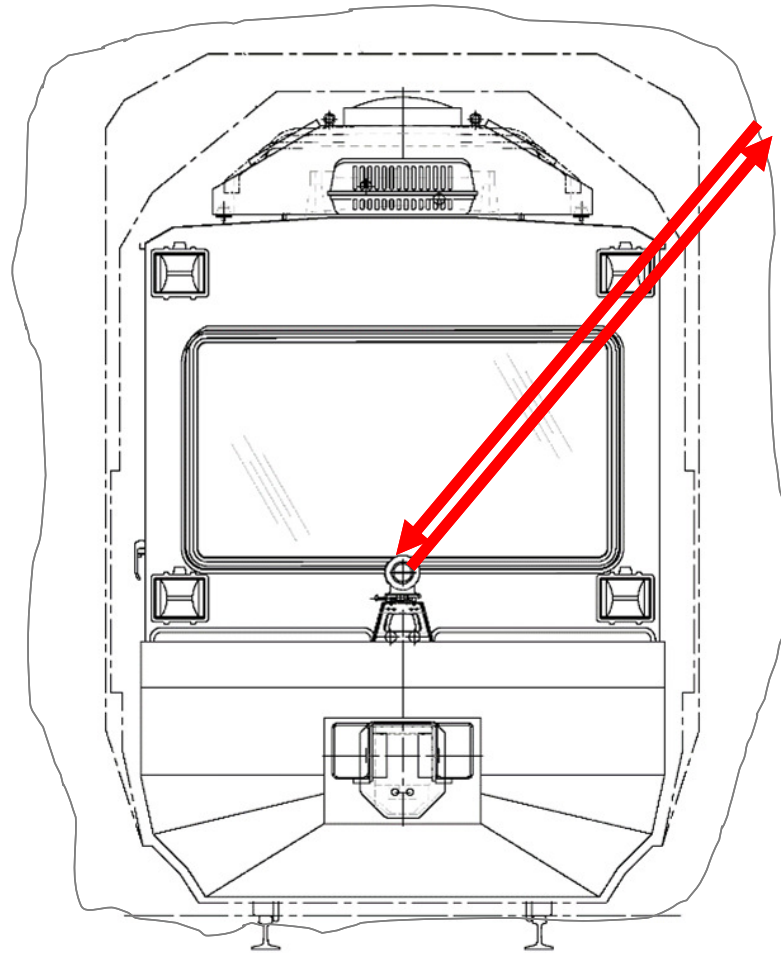
# Clearance Measurement



LiDAR works by shooting a laser point and measuring the time it takes to return.



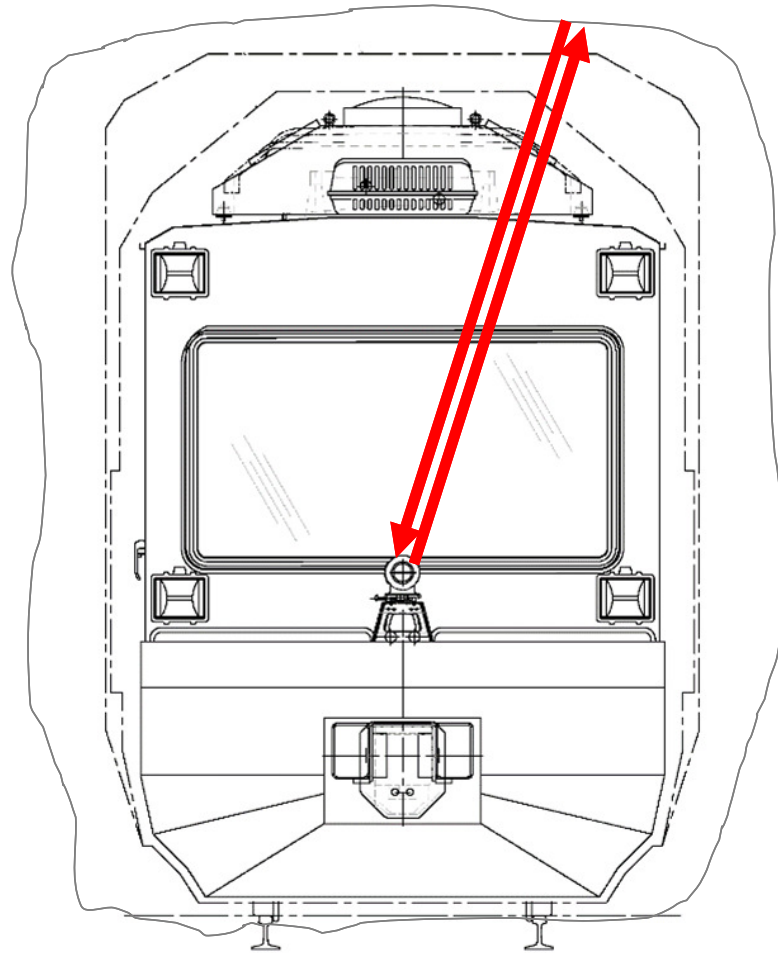
# Clearance Measurement



Rotating this laser at a fast speed allows it to measure everything around the vehicle.



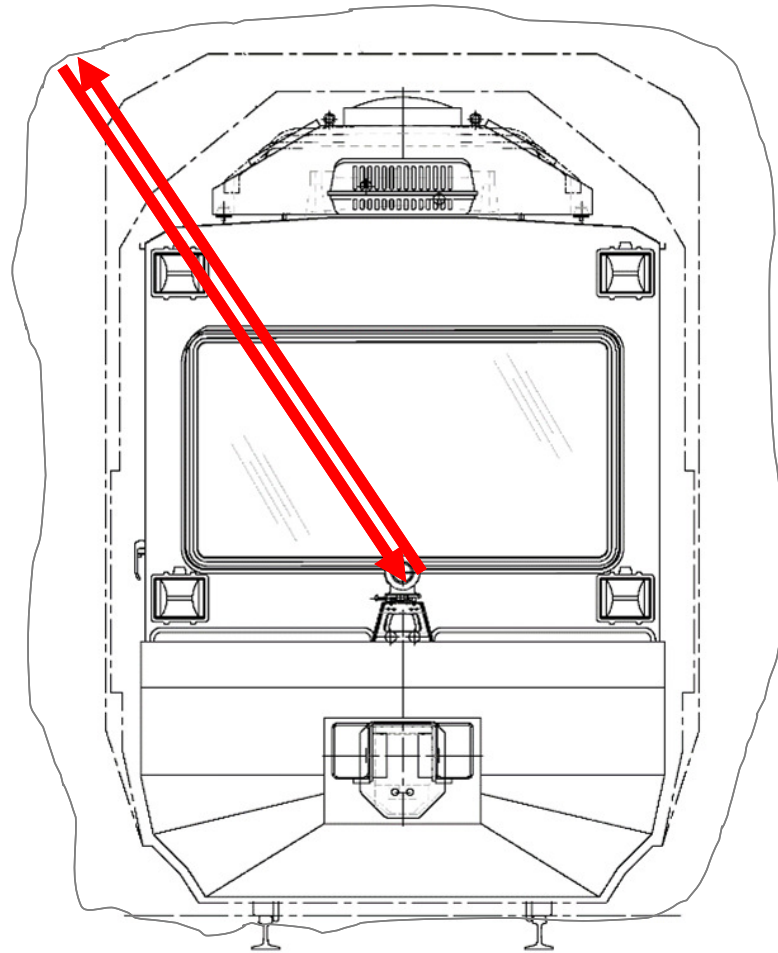
# Clearance Measurement



Rotating this laser at a fast speed allows it to measure everything around the vehicle.



# Clearance Measurement

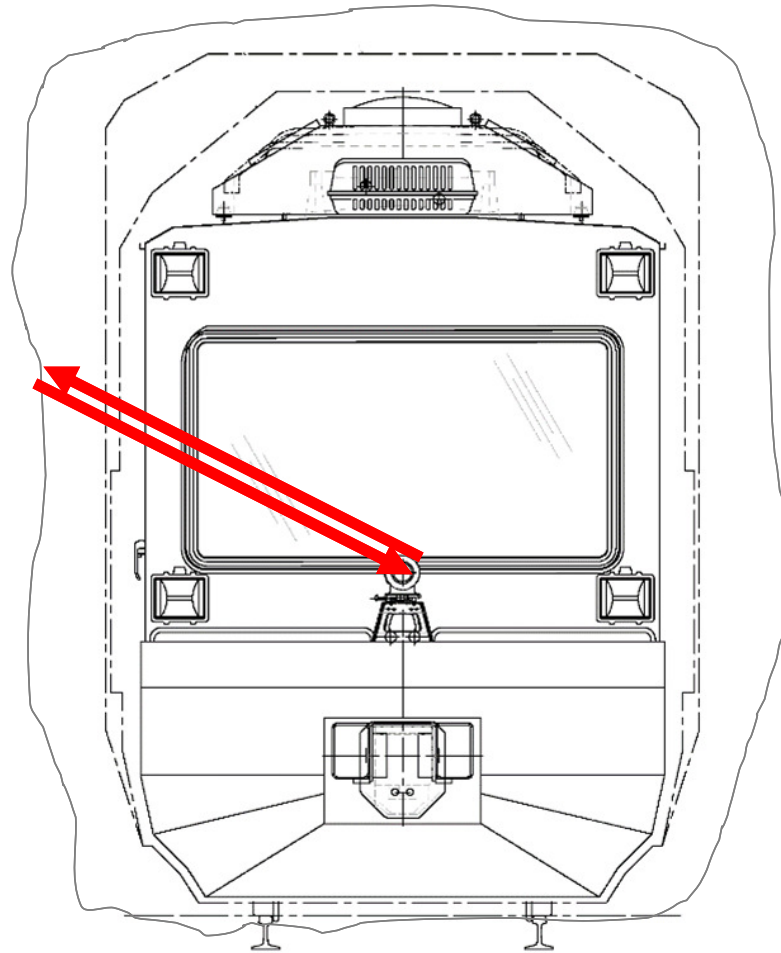


Rotating this laser at a fast speed allows it to measure everything around the vehicle.





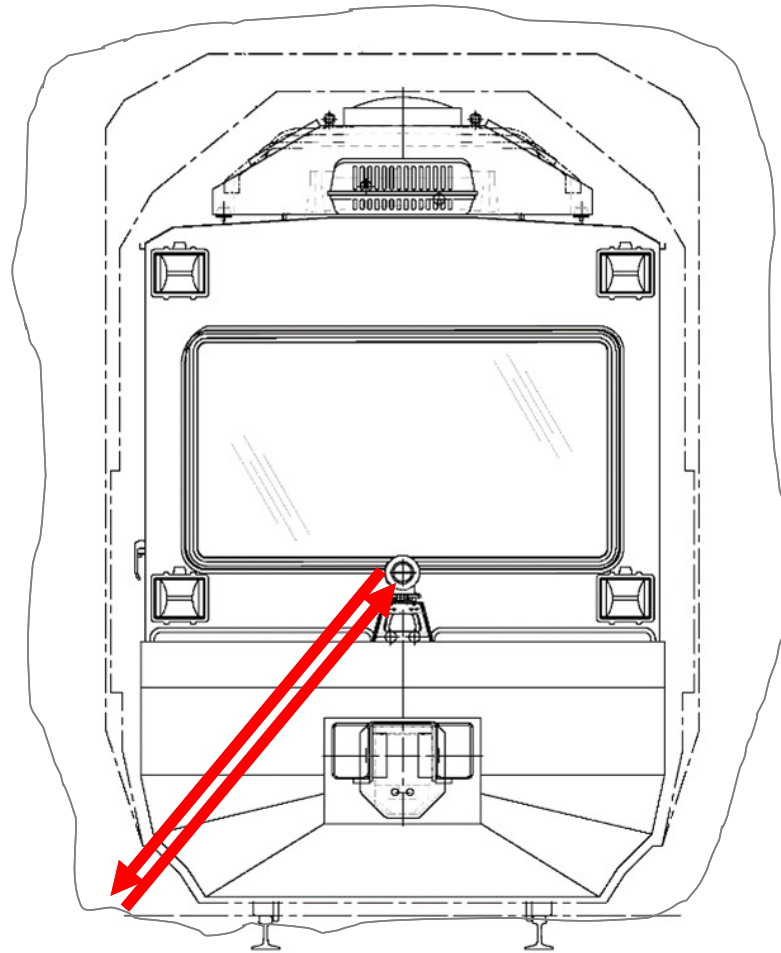
# Clearance Measurement



Rotating this laser at a fast speed allows it to measure everything around the vehicle.



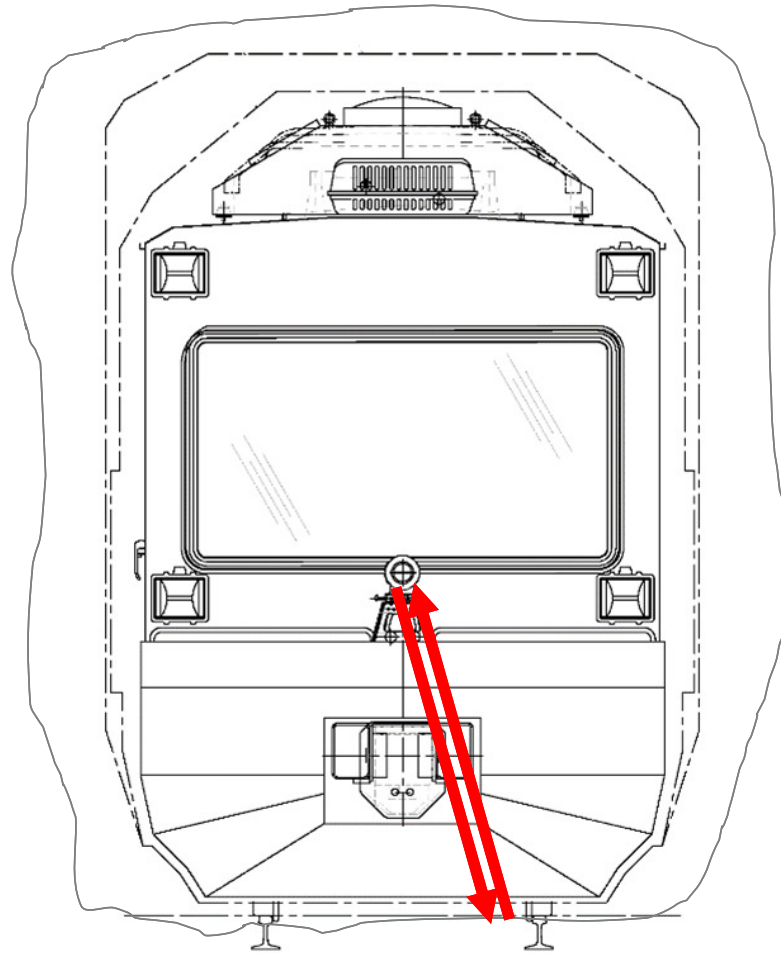
# Clearance Measurement



Rotating this laser at a fast speed allows it to measure everything around the vehicle.



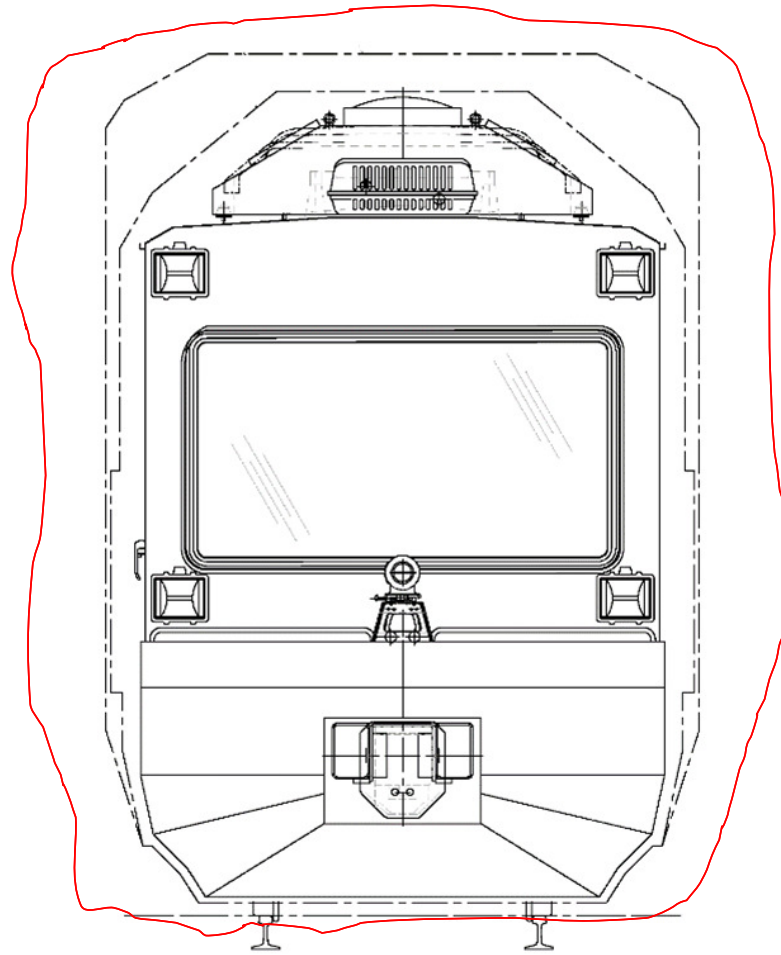
# Clearance Measurement



Rotating this laser at a fast speed allows it to measure everything around the vehicle.



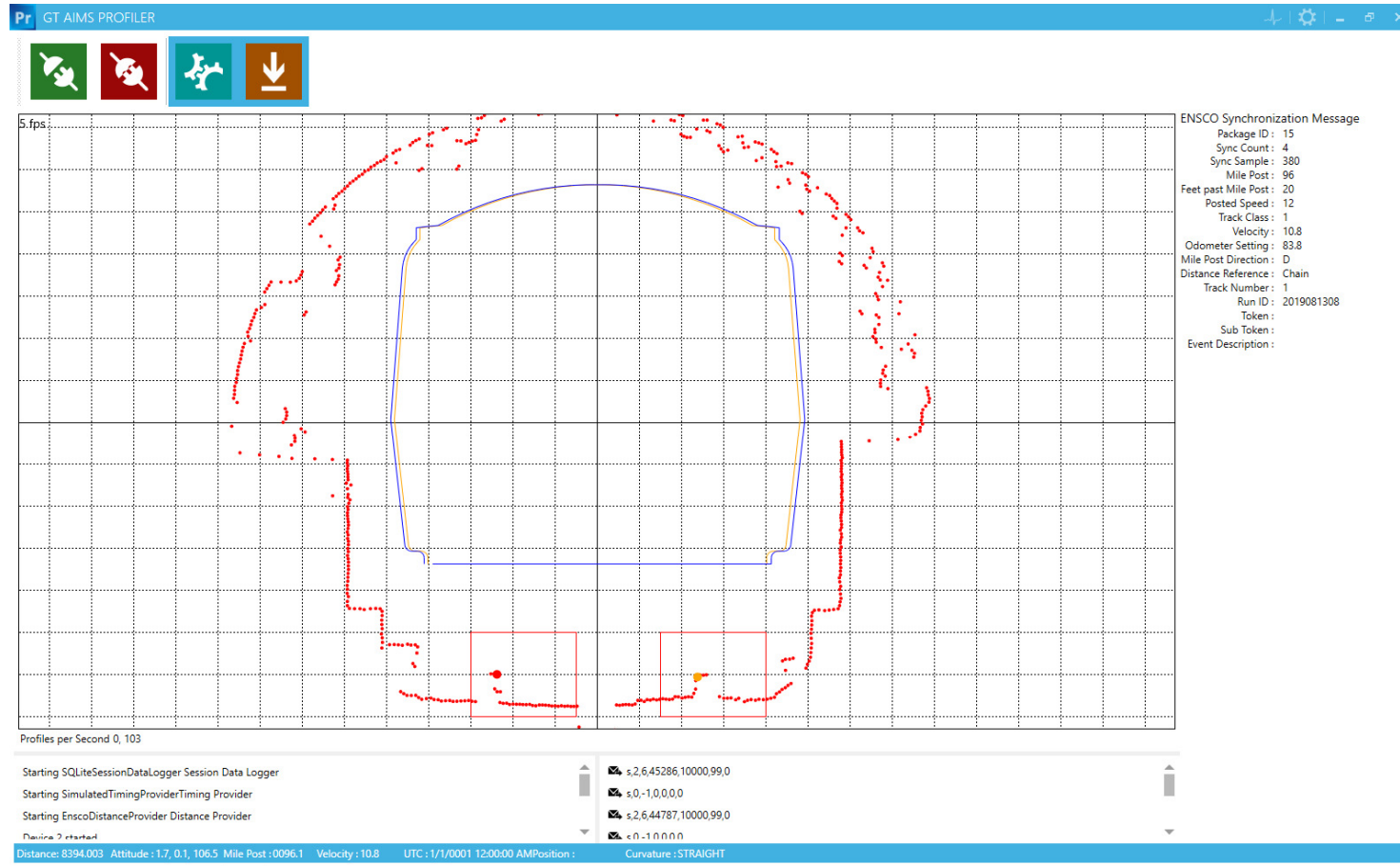
# Clearance Measurement



Rotating this laser at a fast speed allows it to measure everything around the vehicle.



# LiDAR for Clearance Measurement



# LiDAR for Clearance Measurement



# LiDAR for Right-of-Way Inspection

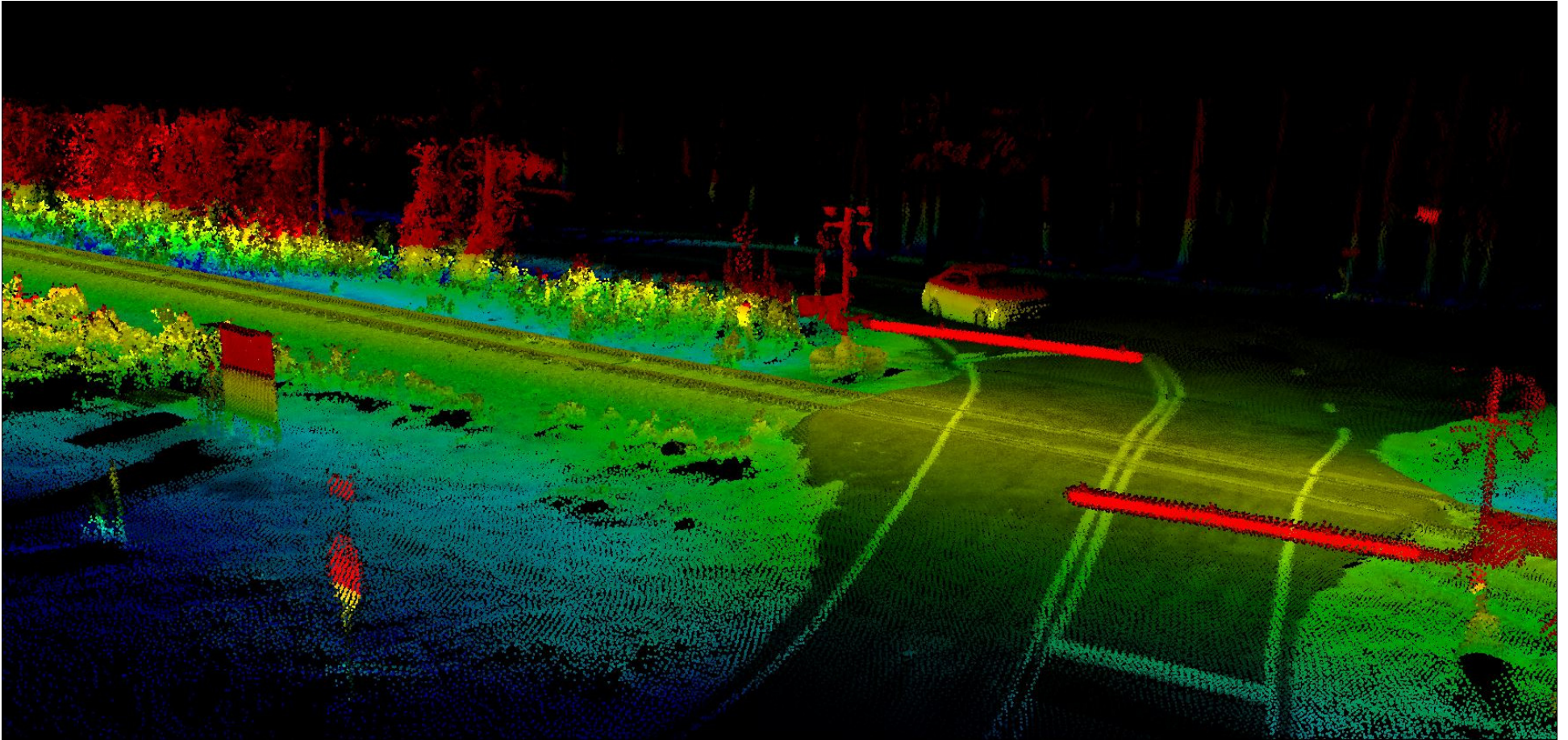


PRINCIPLES COURSE • JUNE 22



**WRI 2022**

# LiDAR for Clearance Measurement





# Ultrasonic Measurement



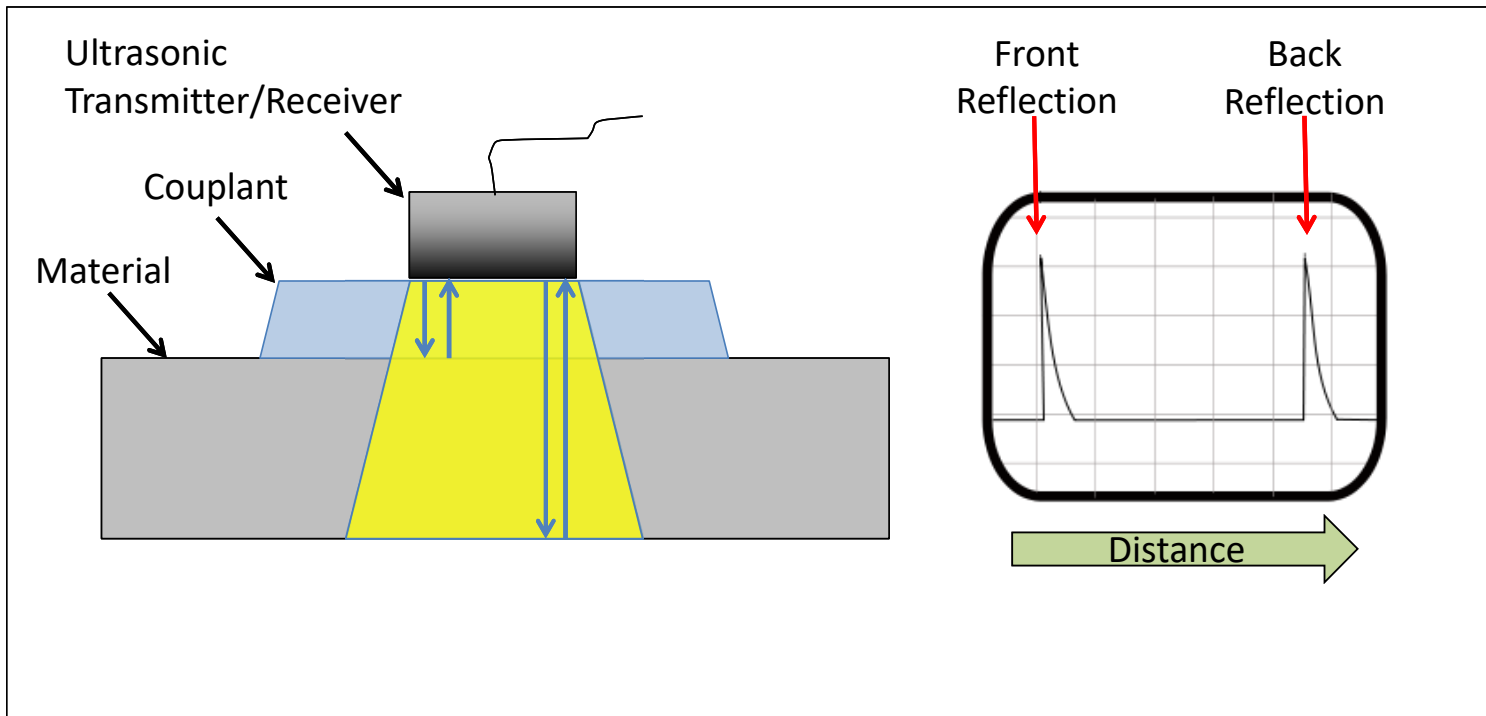
PRINCIPLES COURSE • JUNE 22



**WRI 2022**

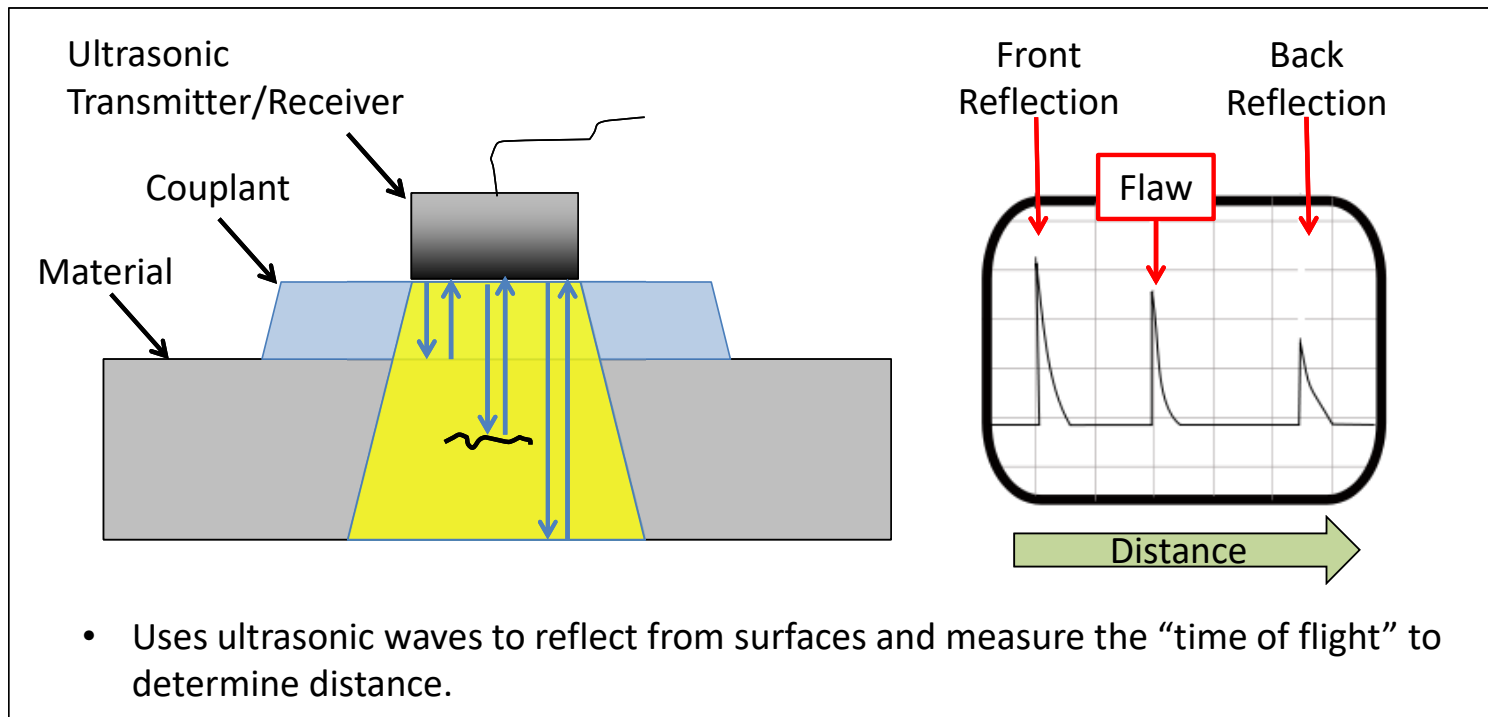
# Ultrasonic Sensors

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



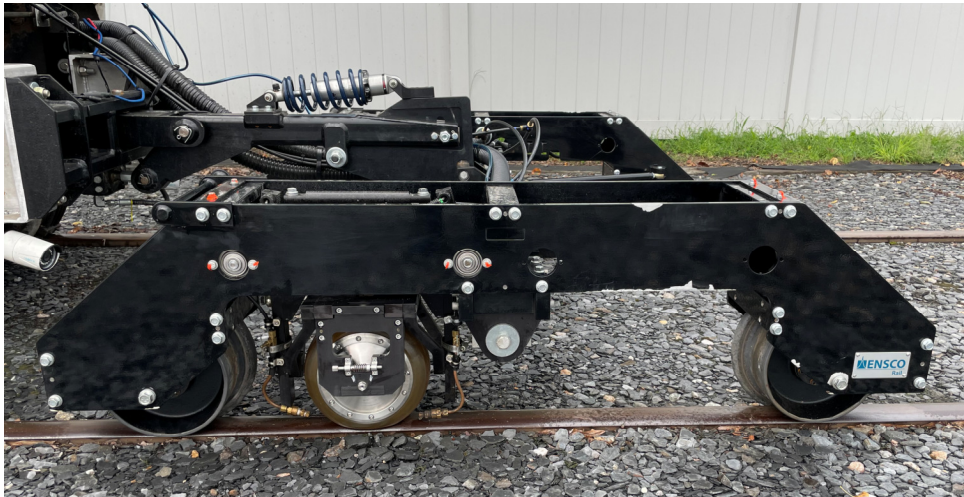
# Ultrasonic Sensors

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

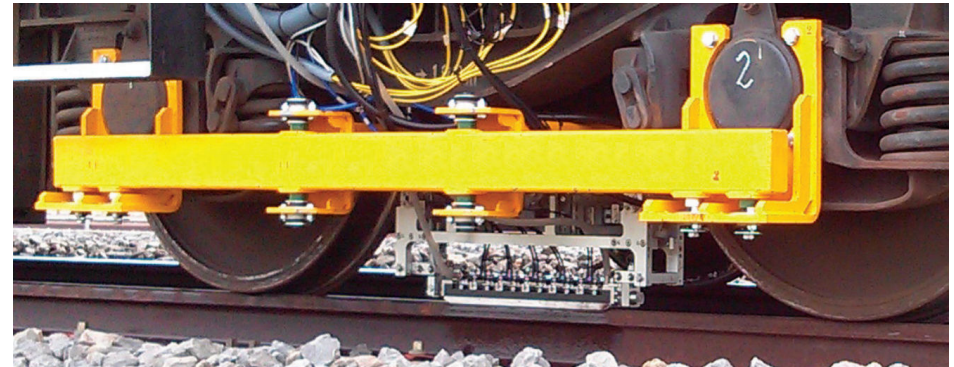


# Ultrasonic Rail Flaw Detectors

Exemplar Wheel Probe System  
(Most Commonly Used in North America)



Exemplar Sled Probe System  
(Most Commonly Used in Europe)



ScanMaster  
<http://scanmaster-irt.com/wp-content/uploads/2015/11/TrackMaster-High-Speed-brochure.pdf>



# Vehicle Platforms:



Railbound Manned



Hi-Rail Manned



ATV Manned



## A-Scan

Individual Ultrasonic Sensors



## B-Scan

Composite of multiple sensors to better visualize the flaw



# A Scan

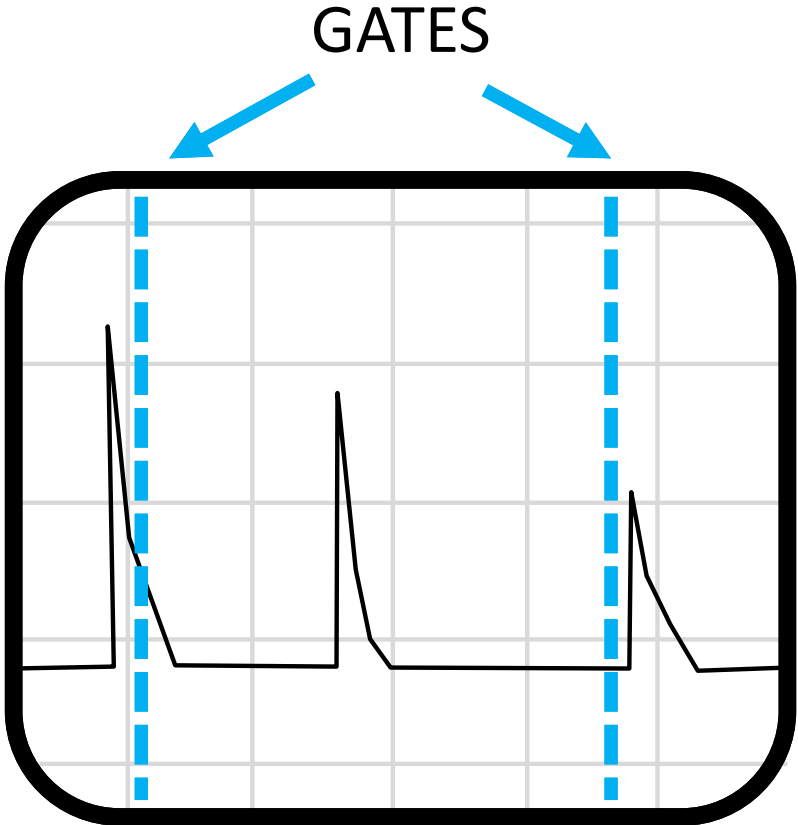
NEAR THE  
PROBE



FAR AWAY  
FROM THE  
PROBE

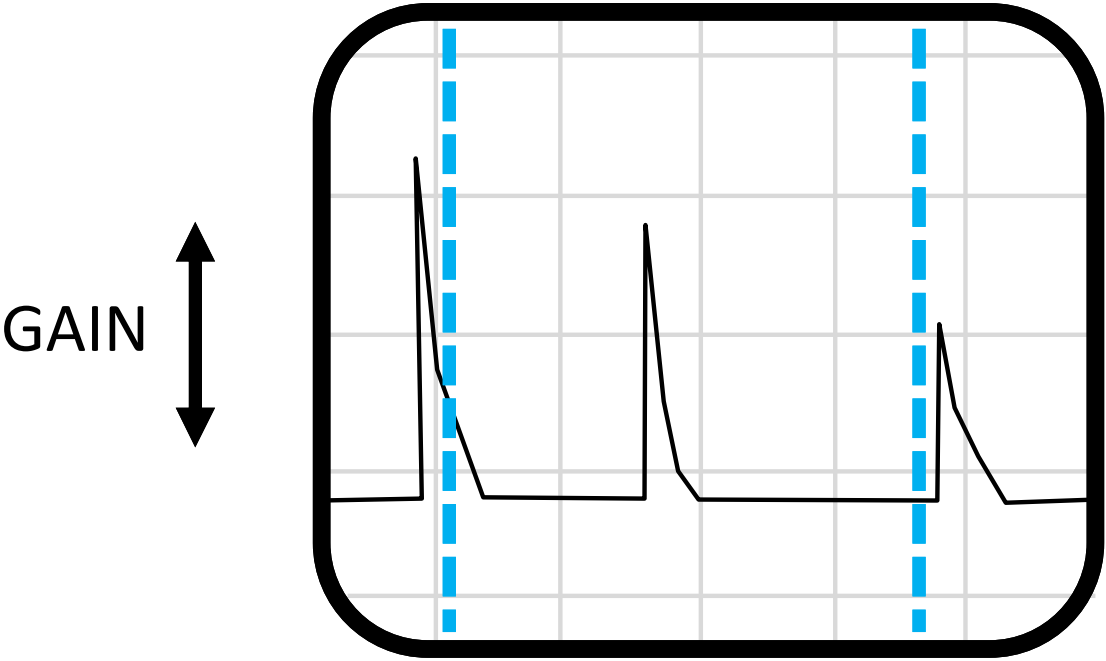


# A Scan



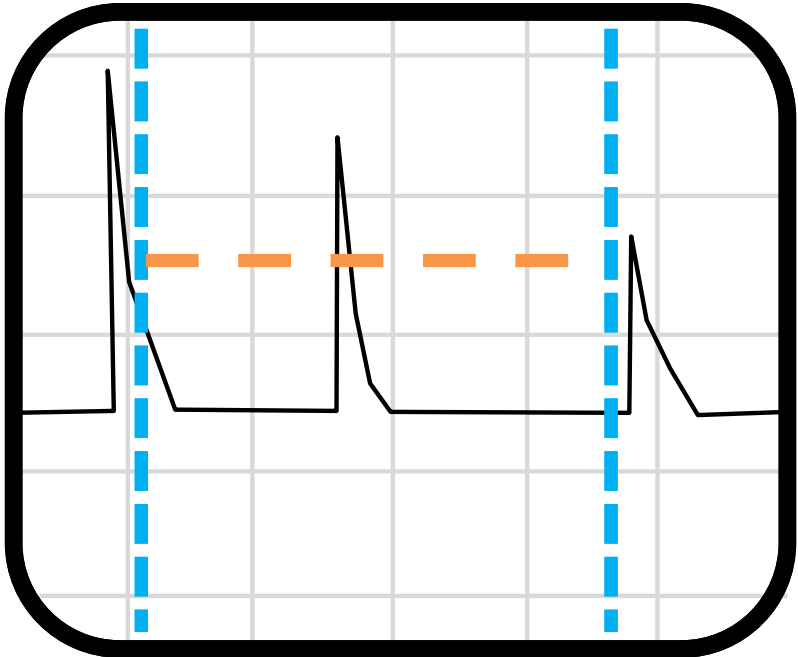


# A Scan

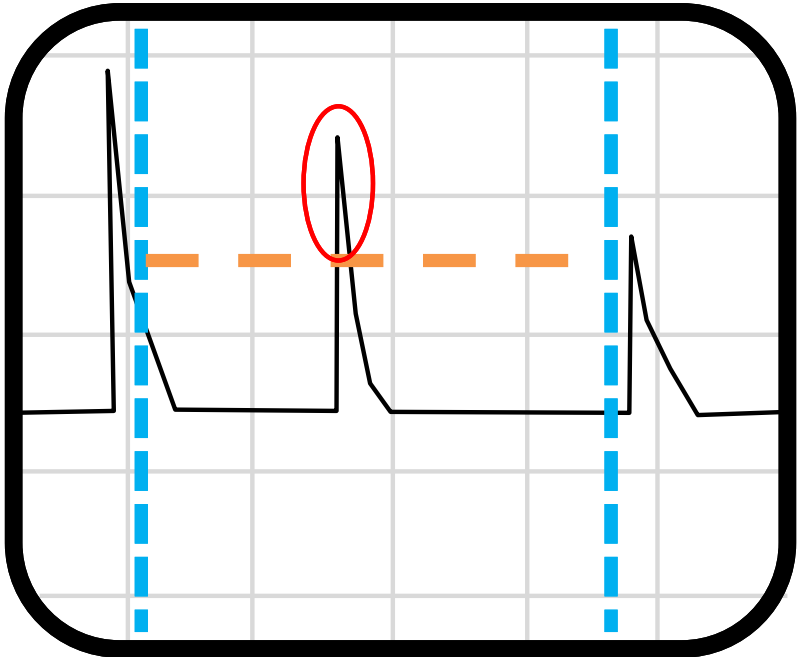


# A Scan

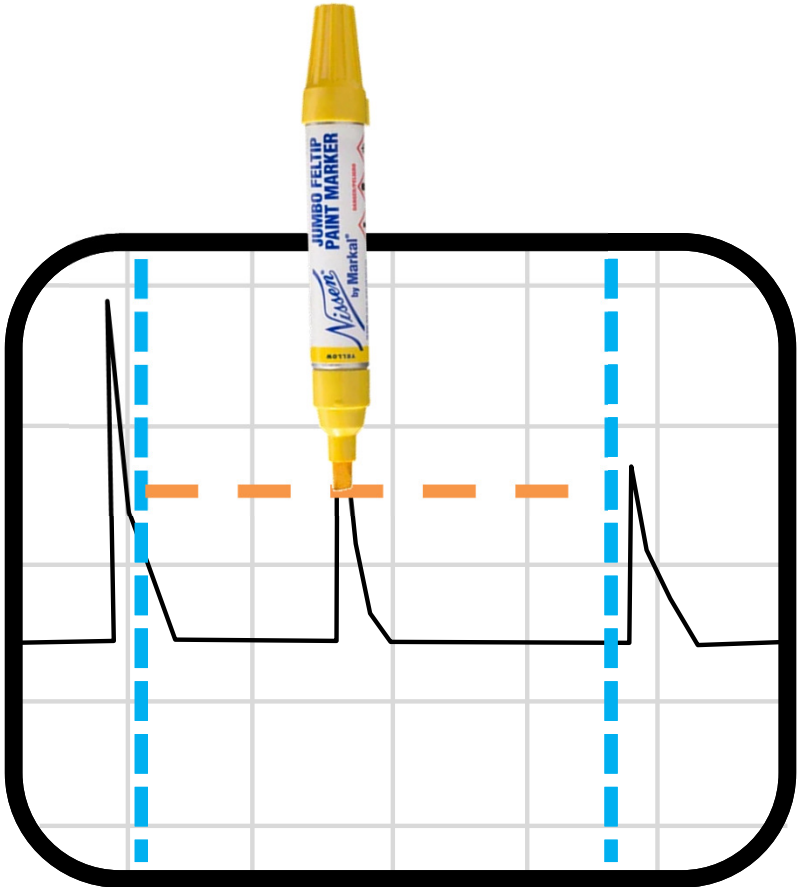
THRESHOLD



# A Scan

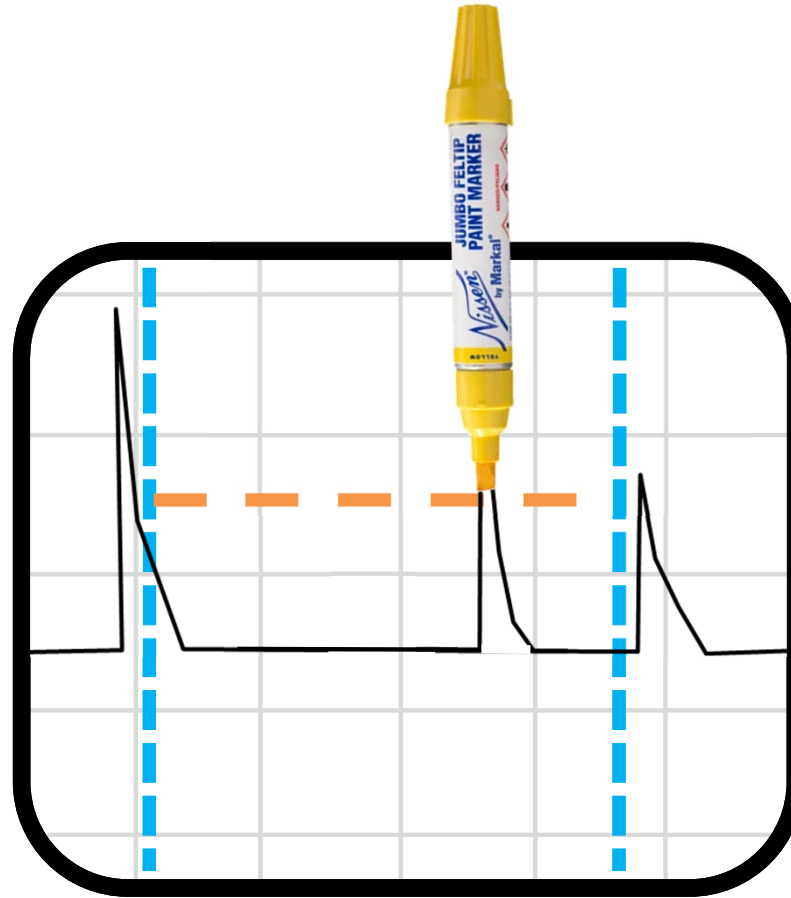


# A Scan



# A Scan

NEAR THE  
PROBE

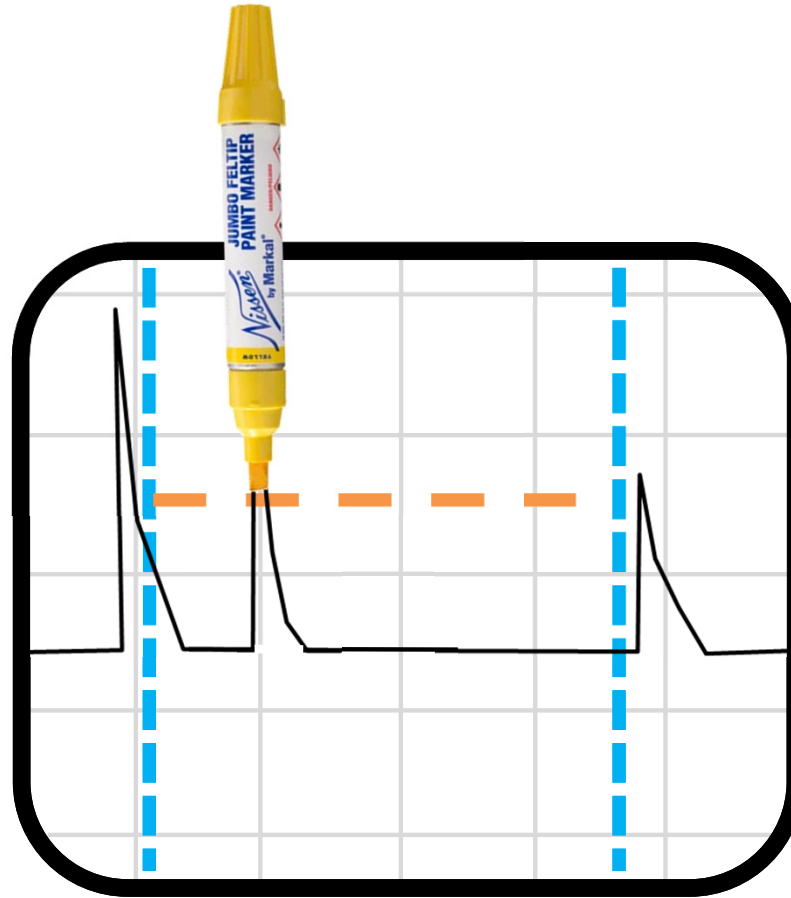


FAR AWAY  
FROM THE  
PROBE



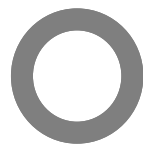
# A Scan

NEAR THE  
PROBE



FAR AWAY  
FROM THE  
PROBE



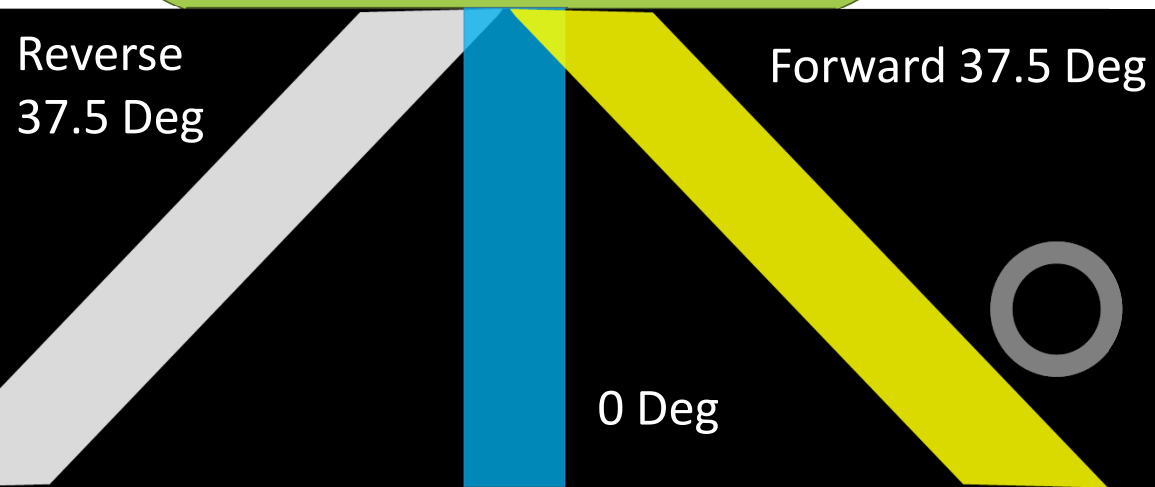


PRINCIPLES COURSE • JUNE 22



**WRI 2022**

# Wheel Probe



**B Scan**







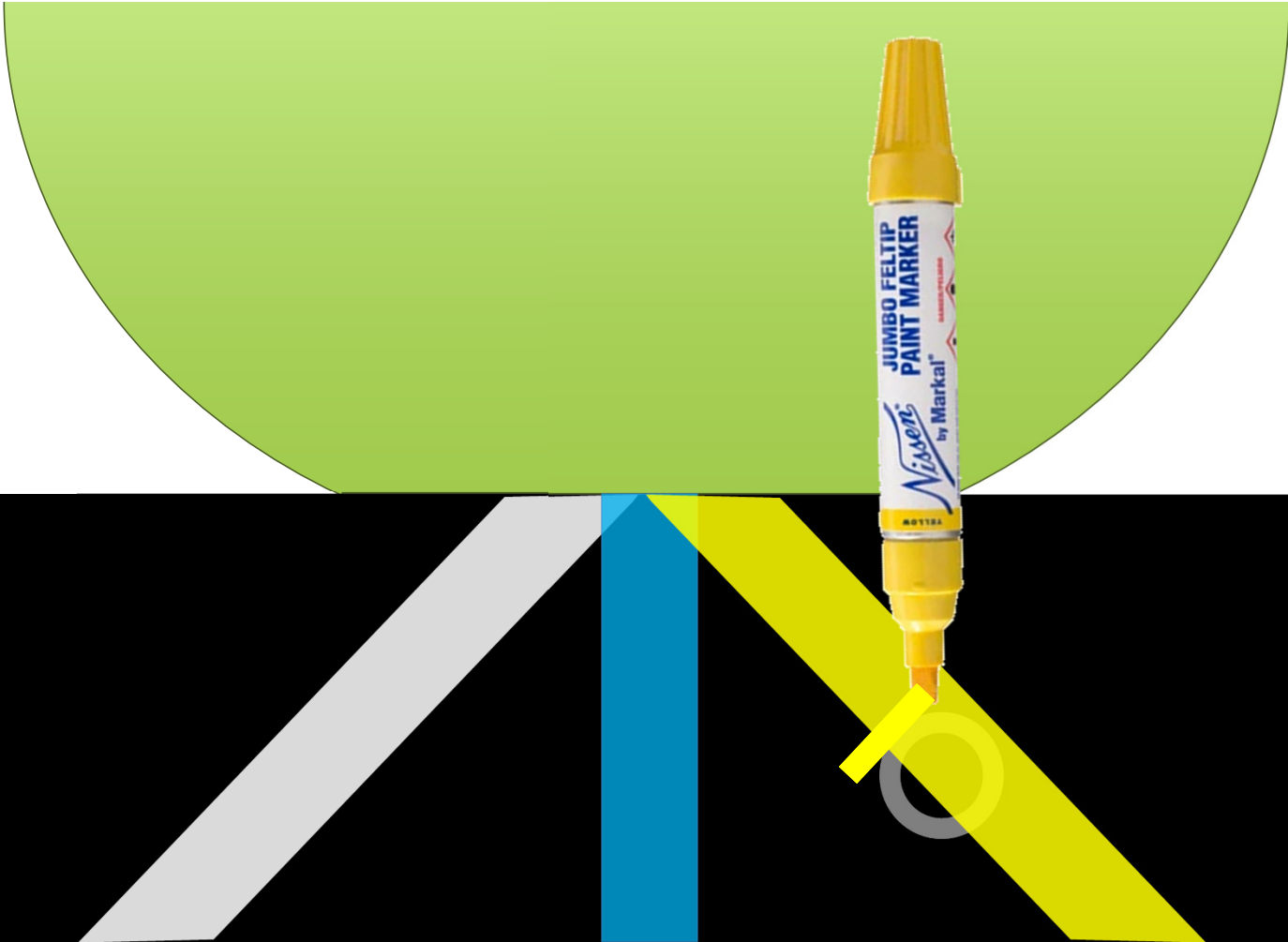
# B Scan



PRINCIPLES COURSE • JUNE 22



**WRI 2022**



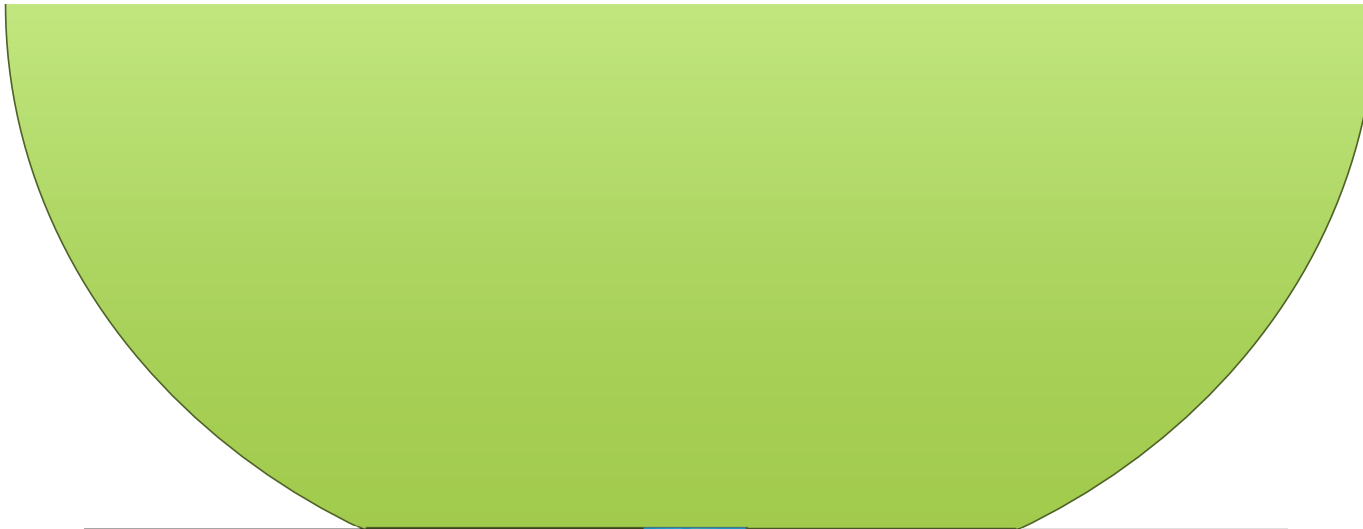
# B Scan



PRINCIPLES COURSE • JUNE 22



**WRI 2022**



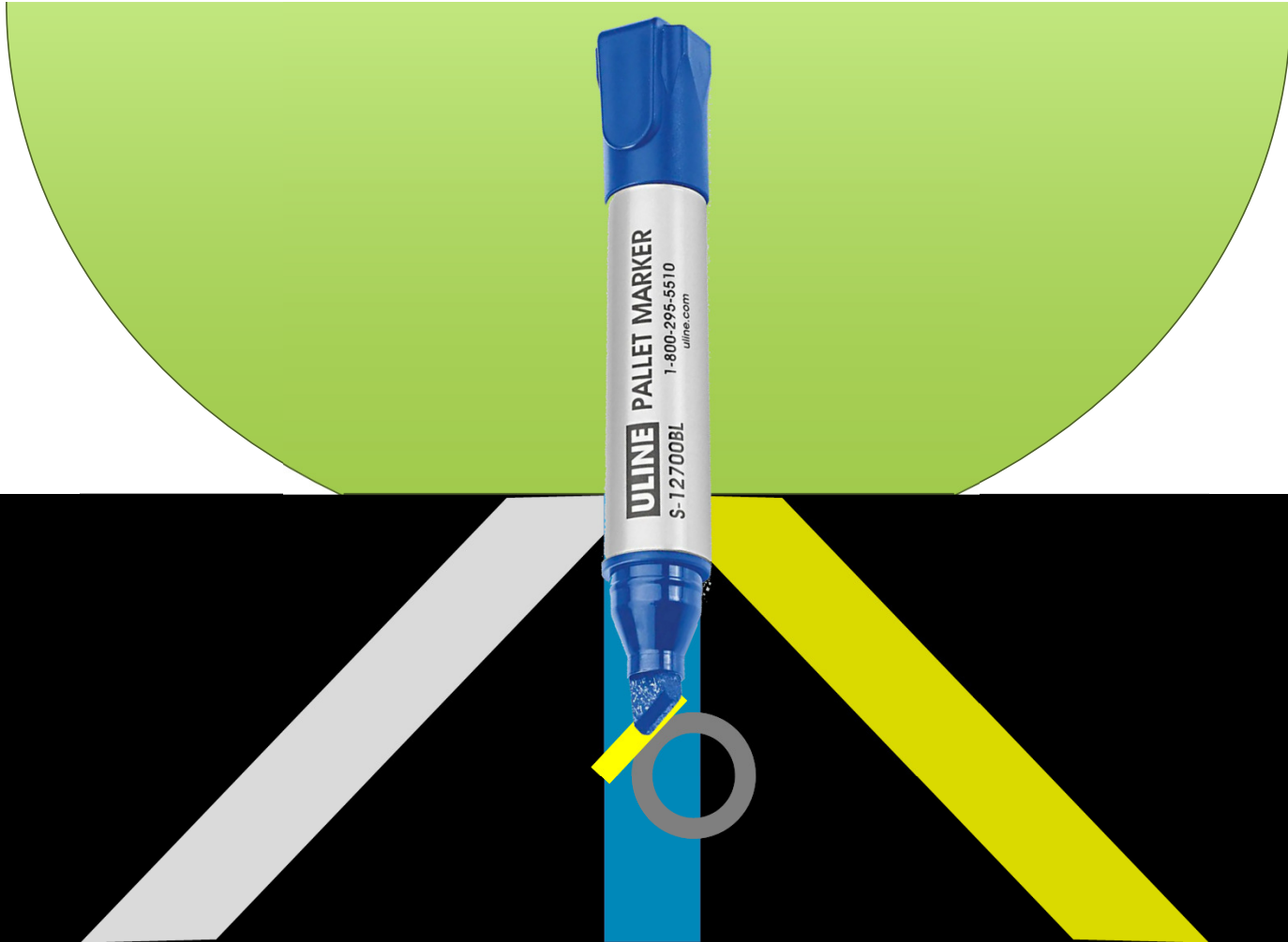
# B Scan



PRINCIPLES COURSE • JUNE 22



**WRI 2022**



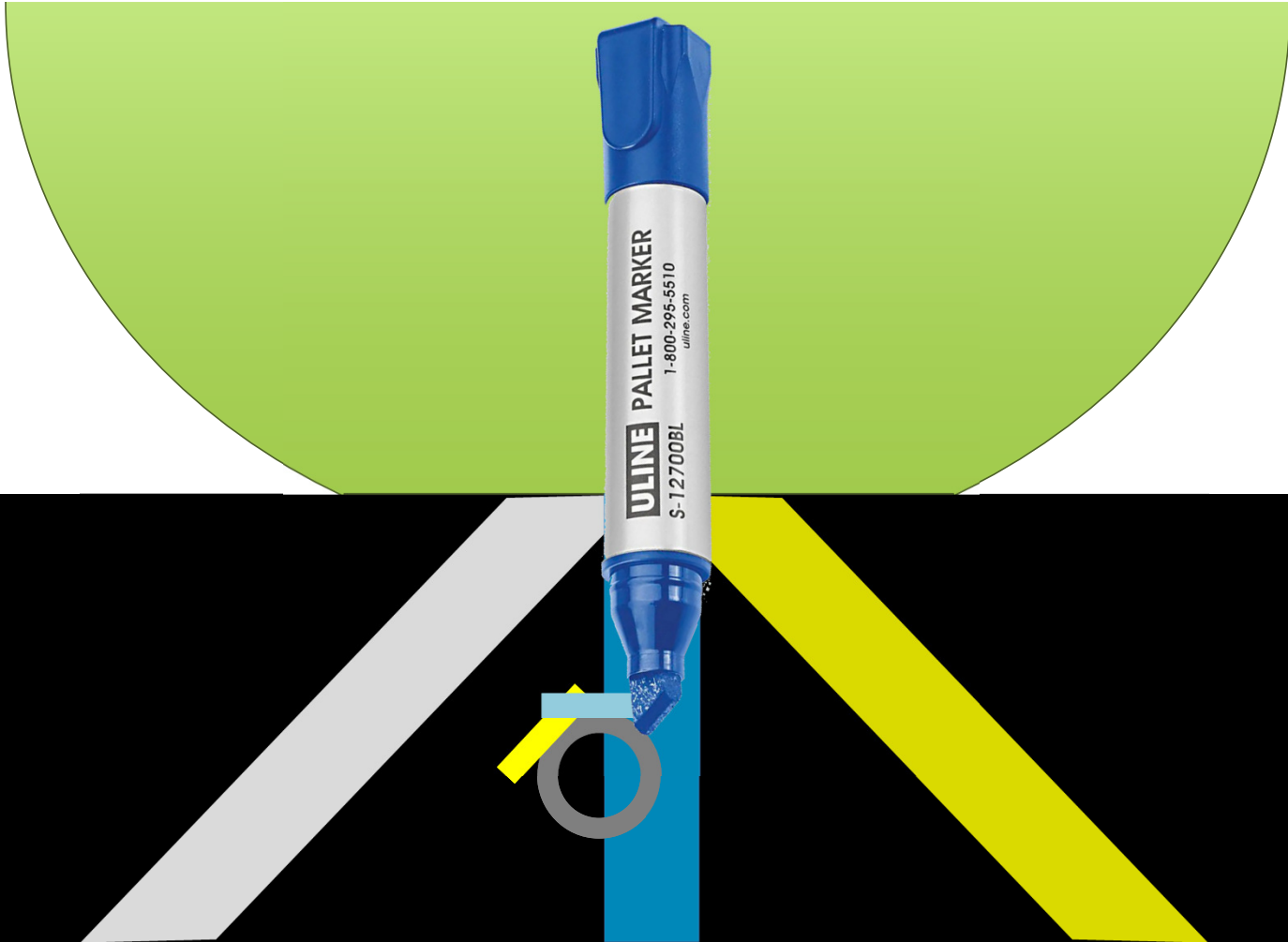
# B Scan



PRINCIPLES COURSE • JUNE 22

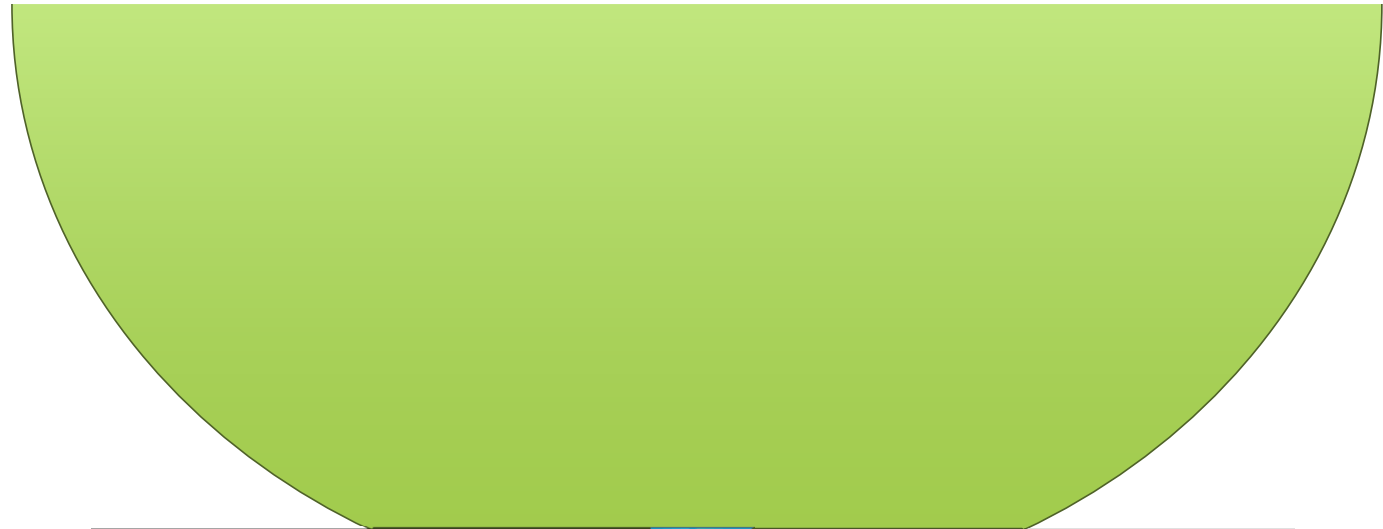


**WRI 2022**



# B Scan





**B Scan**



PRINCIPLES COURSE • JUNE 22



**WRI 2022**



B Scan



PRINCIPLES COURSE • JUNE 22



WRI 2022



B Scan

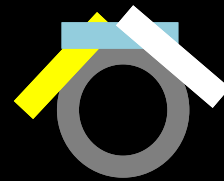


PRINCIPLES COURSE • JUNE 22



WRI 2022





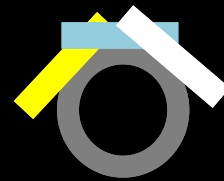
**B Scan**



PRINCIPLES COURSE • JUNE 22



**WRI 2022**



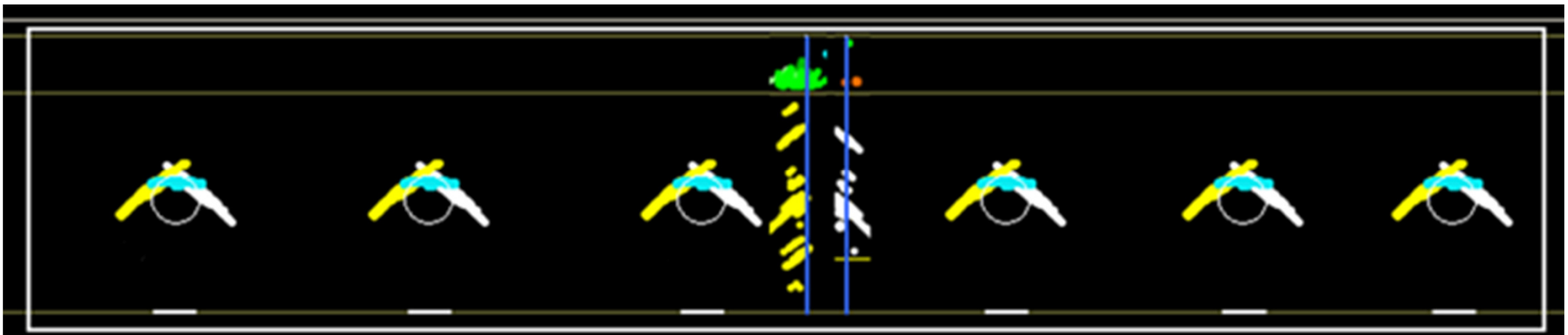
# B Scan



PRINCIPLES COURSE • JUNE 22



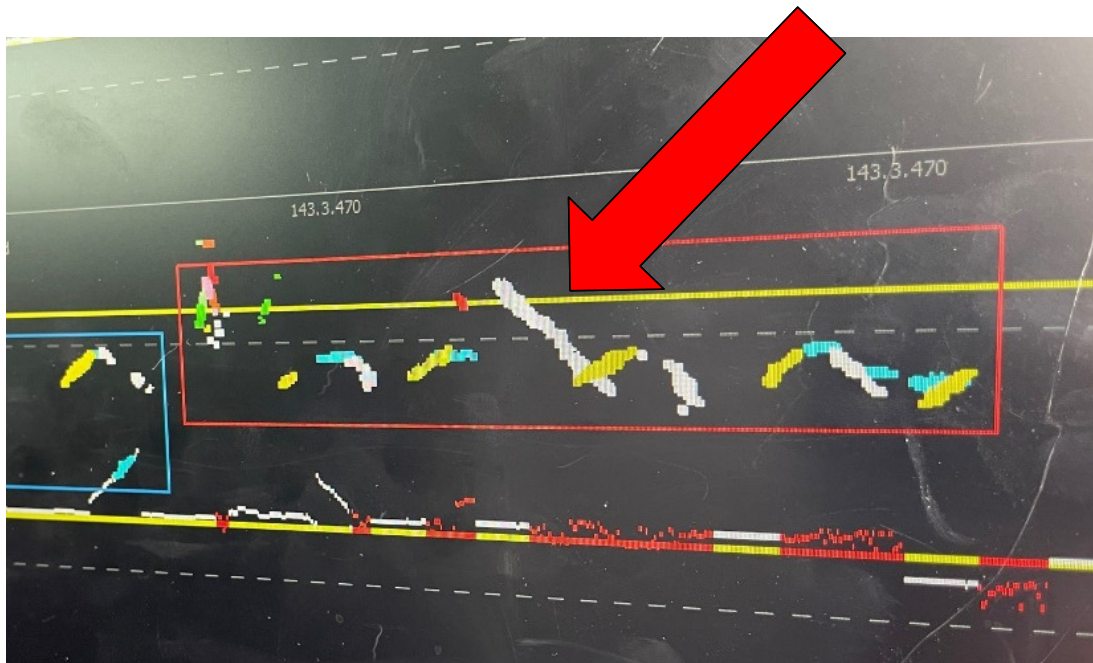
**WRI 2022**



Example B-Scan of bolt holes in joint bar



# Example Bolt Hole Crack in B-Scan

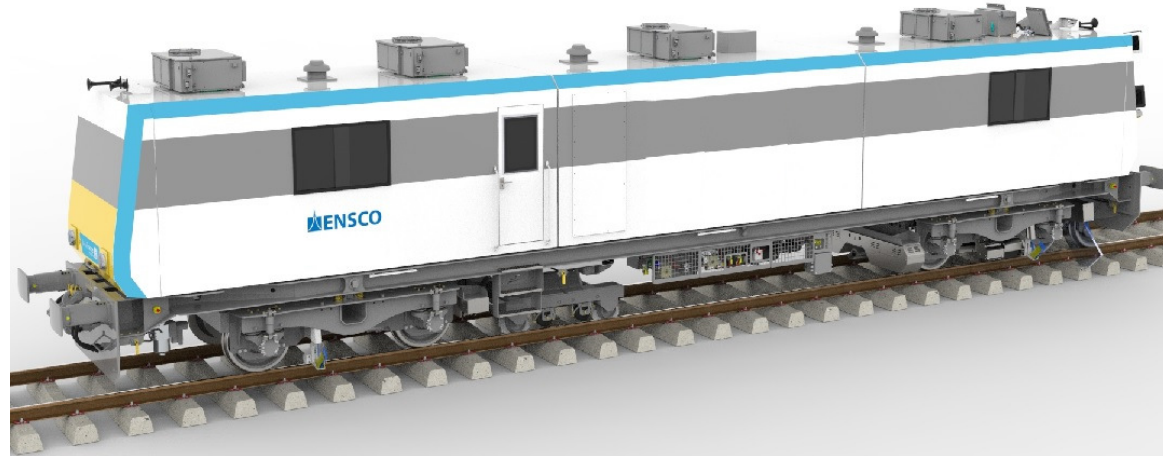


# Example Vehicles

Example Hi-Rail



Example Railbound



# Instrumented Wheel Sets (IWS) & Truck Performance Detectors (TPD)

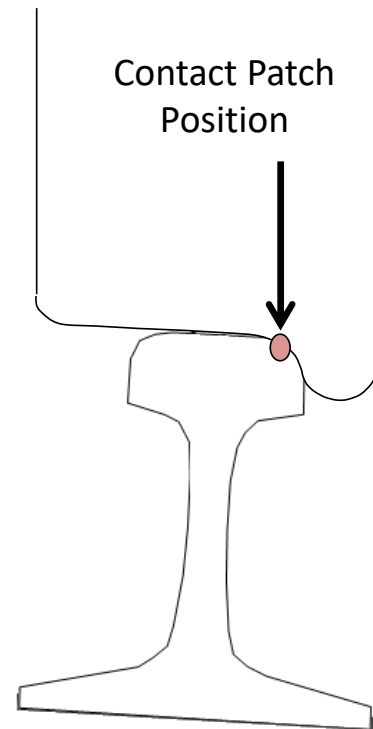
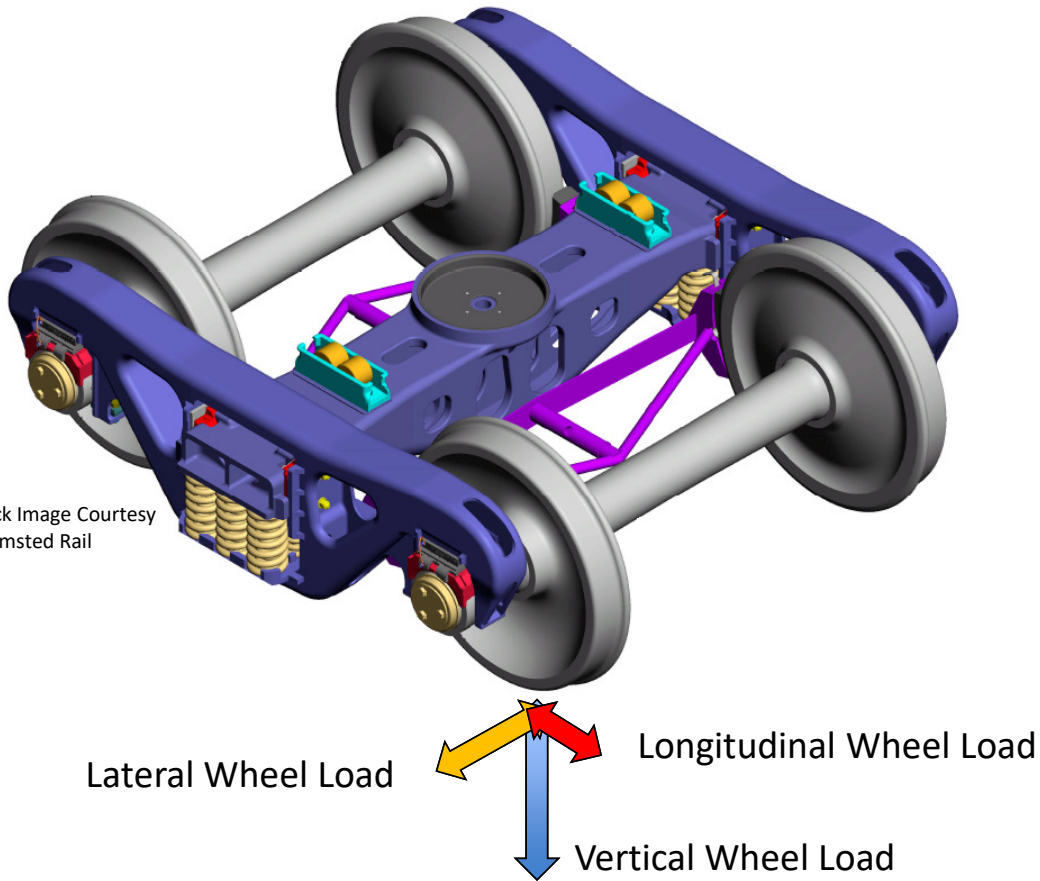


PRINCIPLES COURSE • JUNE 22



**WRI 2022**

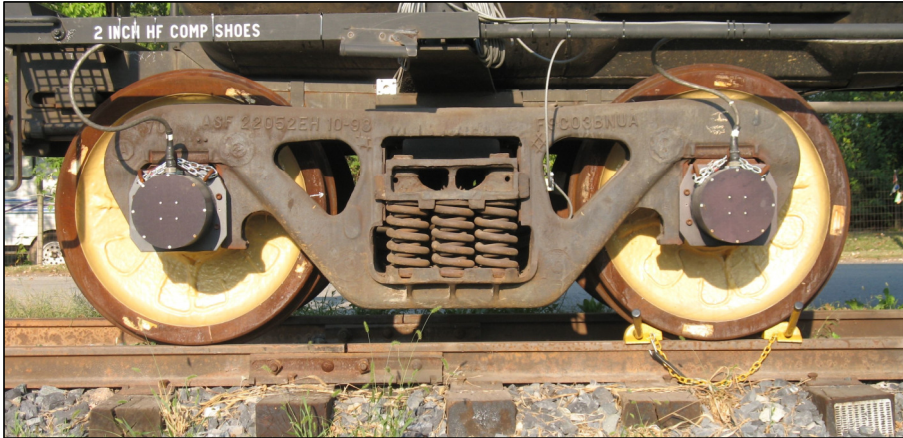
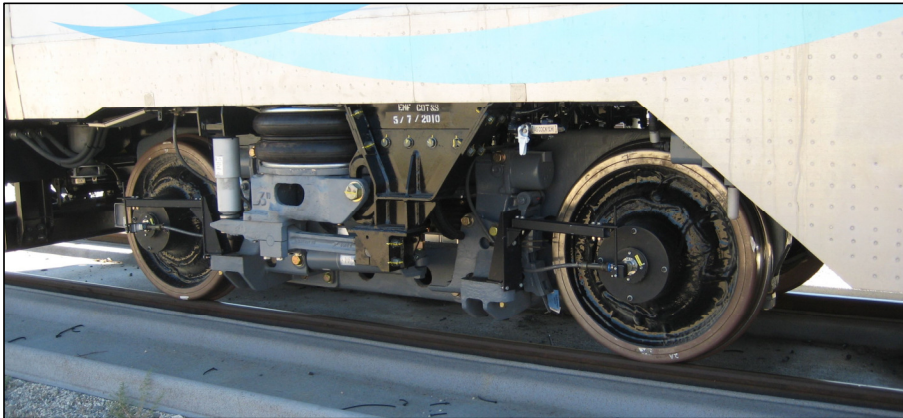
# Instrumented Wheel Sets (IWS)



- Derailment Indicators calculated from measured loads:
- Single Wheel L/V Ratio
  - Axle Sum L/V Ratio
  - Truckside L/V Ratio
  - % Wheel Unloading



# Instrumented Wheel Sets (IWS)



Strain gauges installed on wheel plate

Wired or Wireless data transmission

Manned or autonomous operation

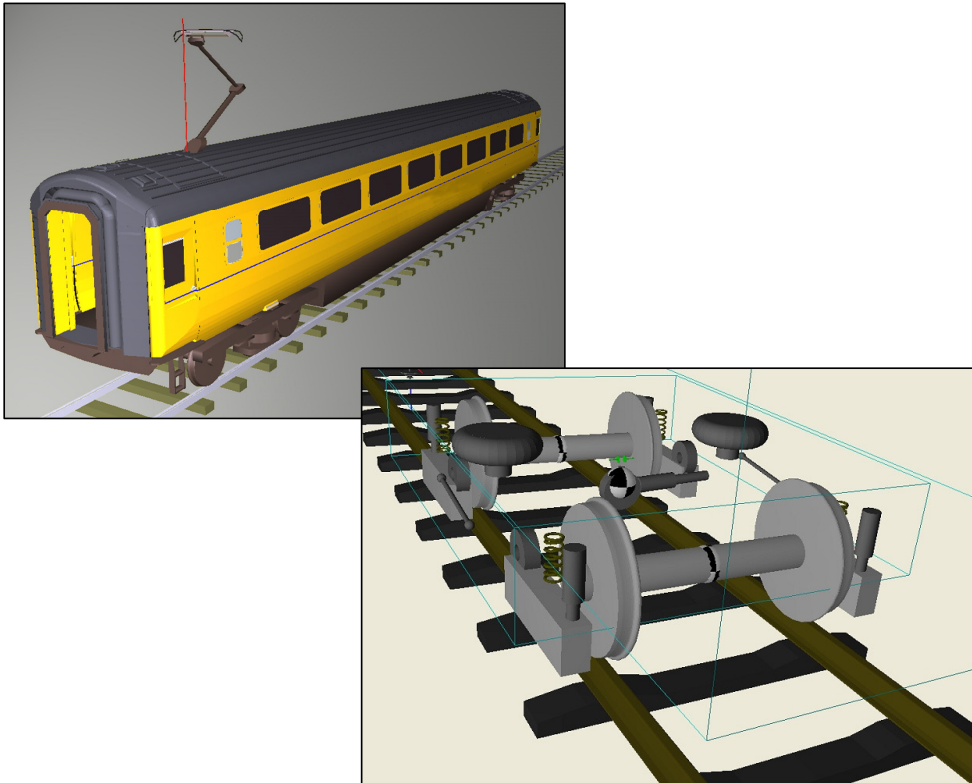
## Common Uses:

- New Vehicle Type Testing
- FRA 213.333 High Speed Track Compliance Testing
- Autonomous Continuous Monitoring





## Virtual Instrumented Wheel Sets (VIWS)



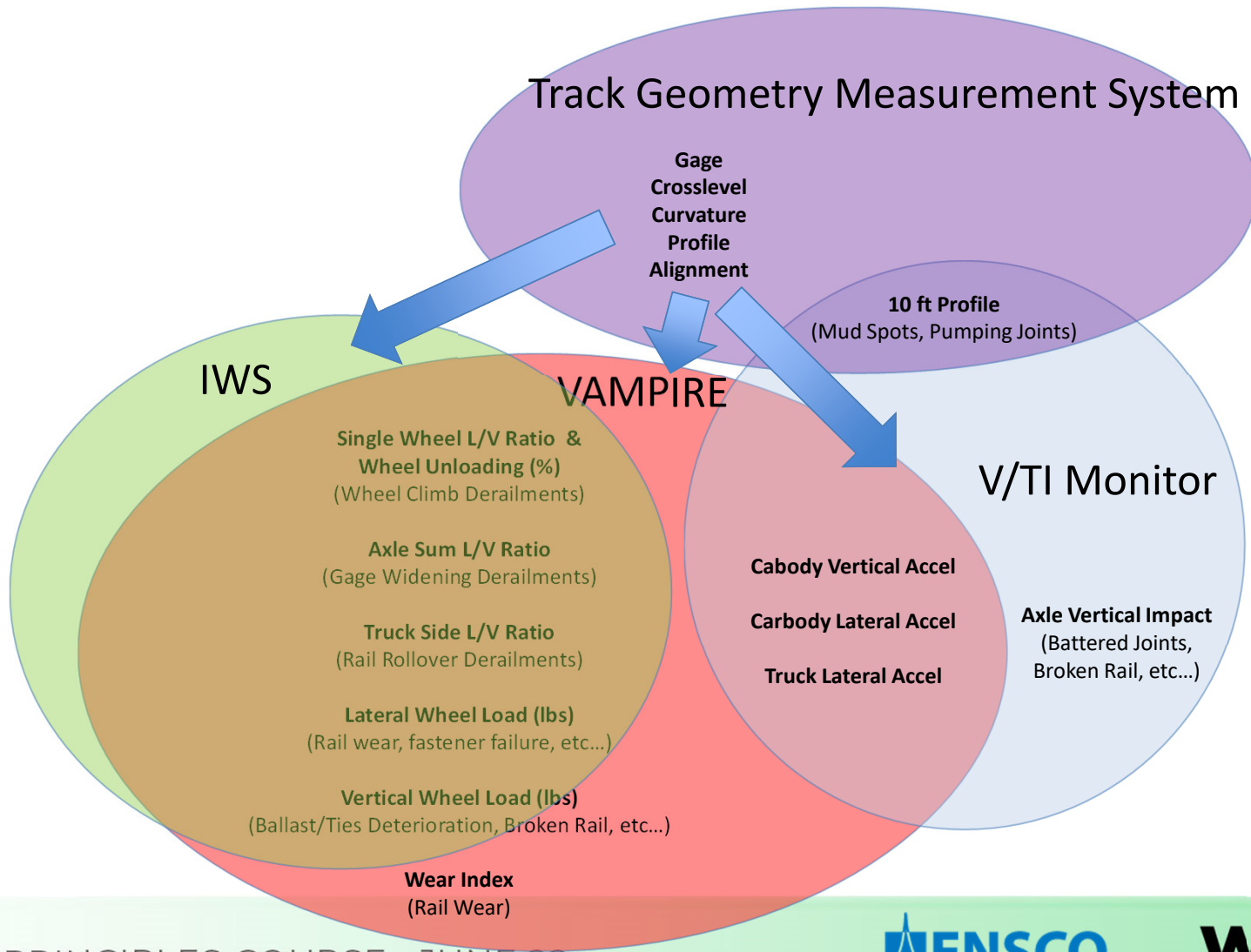
**Combined with** Autonomous or Manned  
**Track Geometry and Rail Profile**  
Measurement Systems

Makes all same measurements as a  
physical IWS, plus more

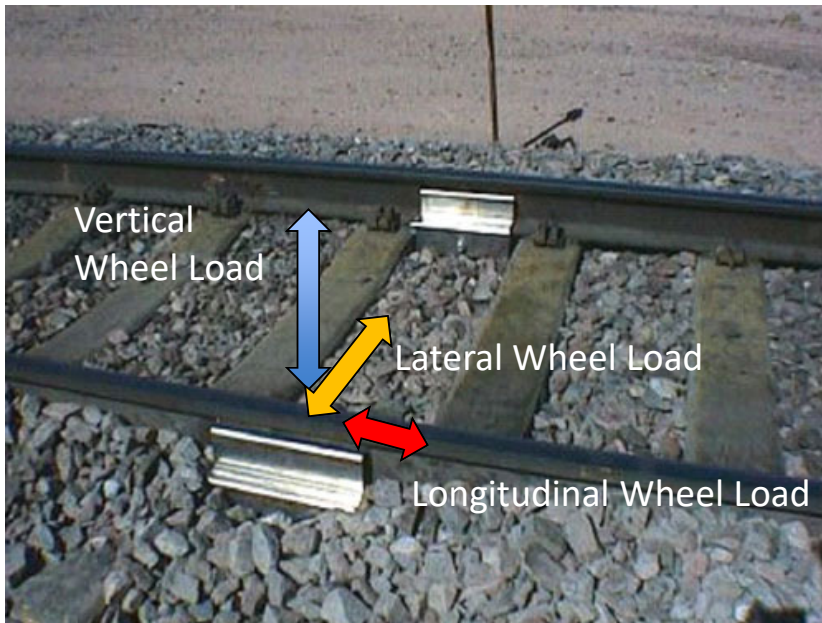
Does not require re-calibration from  
wear

Simulates multiple vehicles & multiple  
speeds





# Truck Performance Detector (TPD)



Ref: <http://international-engineering.com/en/divisions/monitoring-division/Vehicle-Steering-and-Lateral-Force-Detector.php>

Also known as “L/V Detector”

Strain gauges installed on web and base of rail

## Common Uses:

Vehicle condition monitoring  
Superelevation assessments  
New Vehicle Fleet Assessments



# Hands-On Training



PRINCIPLES COURSE • JUNE 22

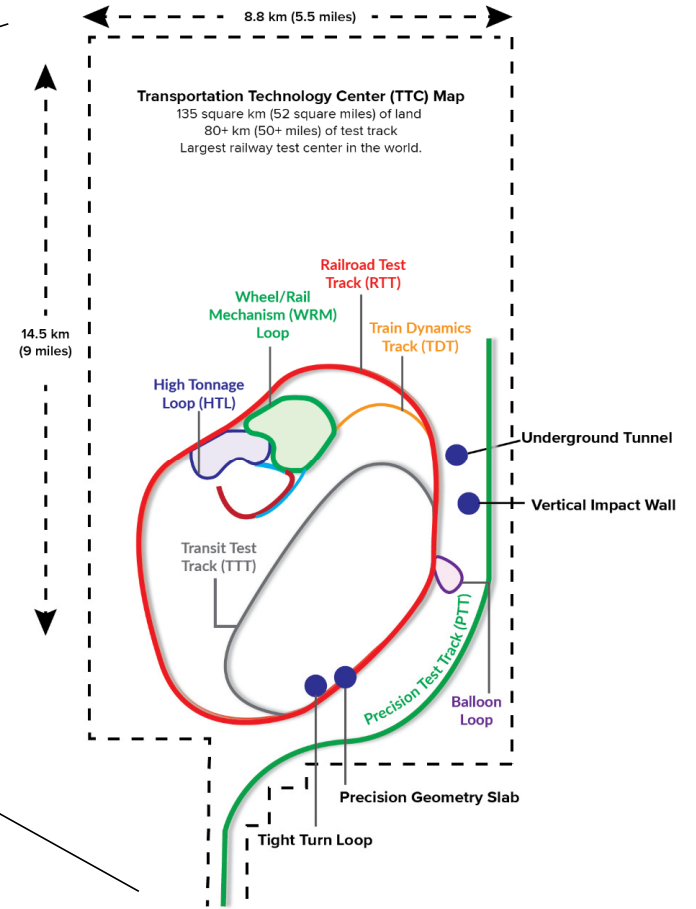
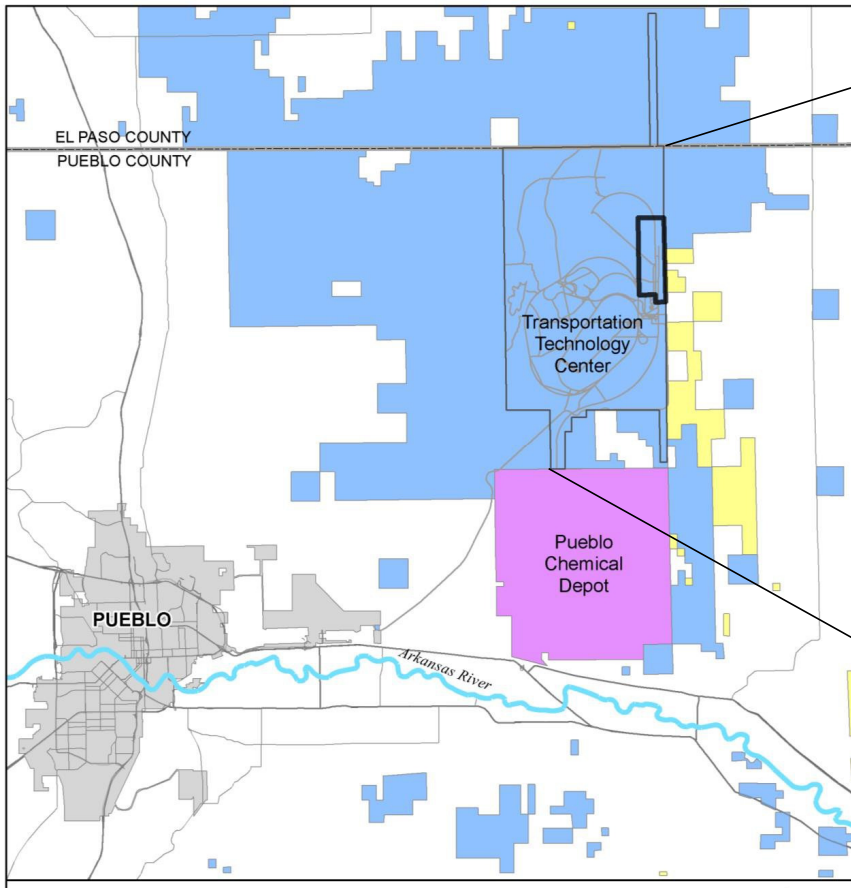


**WRI 2022**

# Hands-On Training at TTC

- The TTC will have expanded training capabilities
- Largest railway test and training center in the world!
- TTC by the Numbers:
  - 52 Square Miles
  - 50+ Miles of Test Tracks
  - 13+ Miles of Catenary Wire Track
  - 9+ Miles of Third Rail Track
  - Current maximum test speed: 165mph







### **Example Hands-On Training to Help with Technology Use:**

Run track geometry car & go find and verify the defects.

Run railcar through TPD, then disassemble, then reassemble the car and rerun through TPD.

Run V/TI Monitor through a turnout, then disassemble, then reassemble the turnout and rerun with V/TI Monitor.



# Questions?



PRINCIPLES COURSE • JUNE 22



**WRI 2022**