Vehicle-Track Measurement Technologies

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ENSCO Rail
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Summary

Overview of Measurement Systems

Detailed Evaluation of Select Technology

The Future is Here

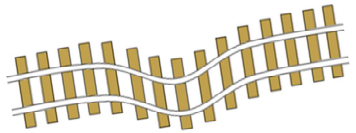
Overview of Measurement Systems

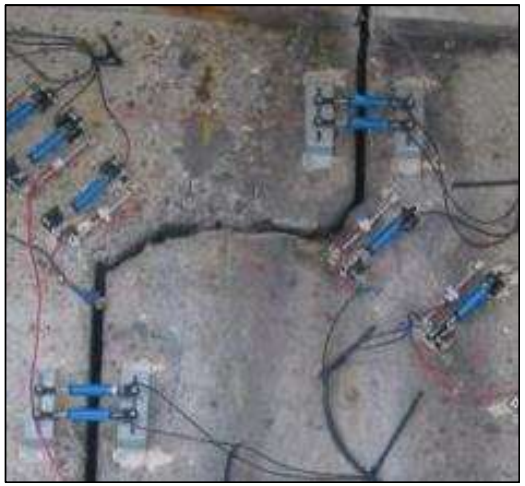
There are five basic categories of measurement system.

Categories of Measurement Systems

1) Mounted on <u>Vehicle</u> to measure the <u>Vehicle.</u>	

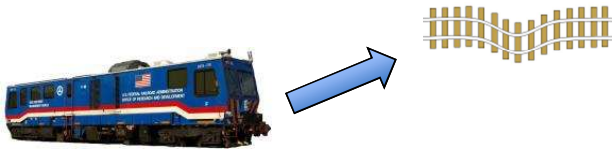
Categories of Measurement Systems

2) Mounted on <u>Track</u> to measure the <u>Track.</u>	



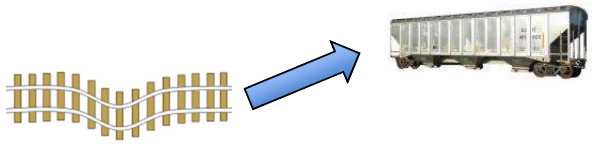
Categories of Measurement Systems

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

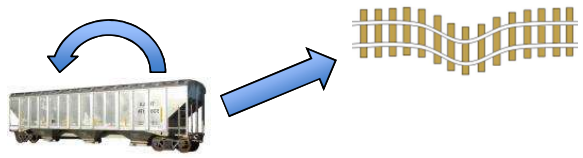


Categories of Measurement Systems

4) Mounted on Track to measure the Vehicle.



Categories of Measurement Systems

5) Mounted on <u>Vehicle</u> to measure the <u>Vehicle & Track.</u>	

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	⟷	Machine Vision

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 D[illegible]ct		[illegible]ked Wheel Detector
Machine Vision		Machine Vision

Previously covered in:

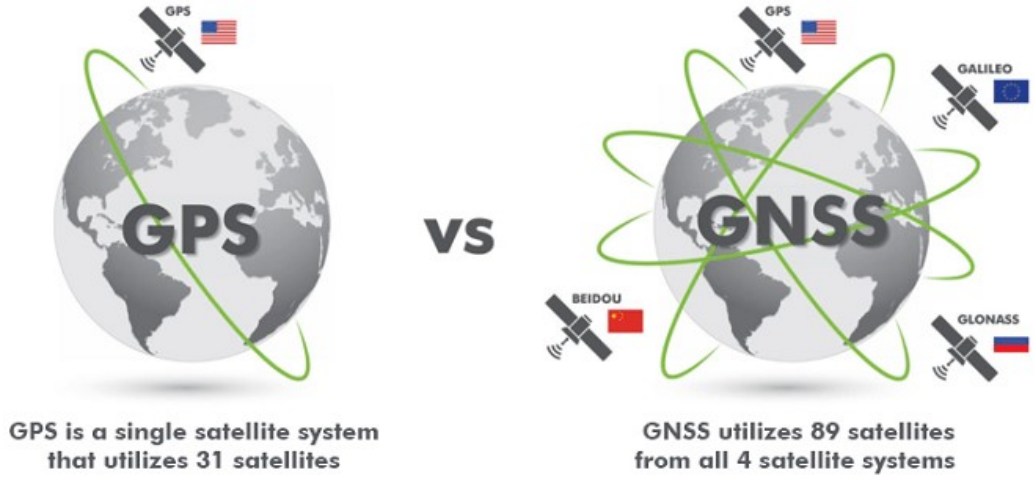
WRI 2019

Location Determination

1) Global Navigation Satellite System (GNSS)

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

More satellites means more accuracy



Ref: 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

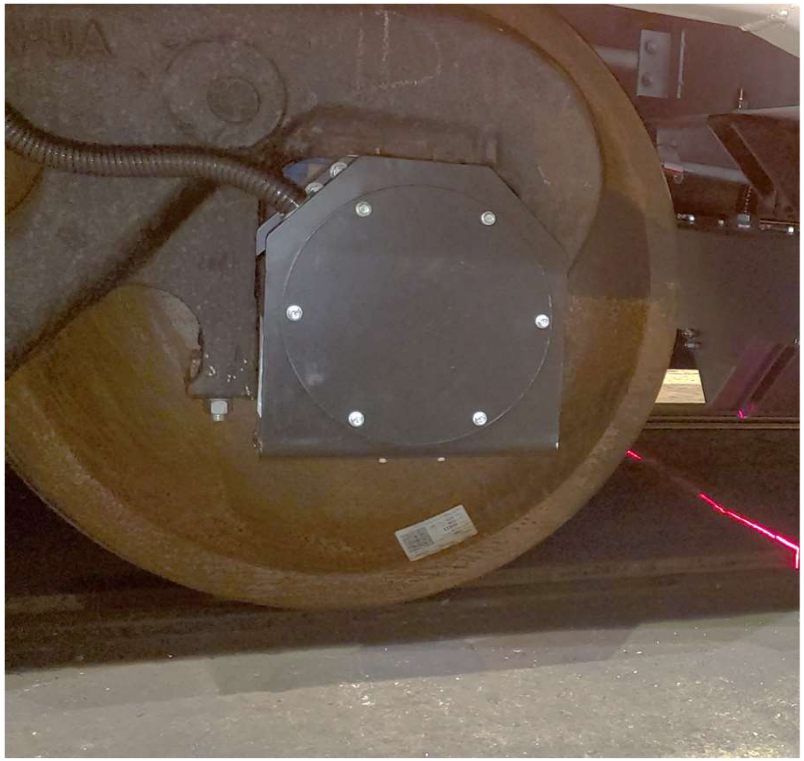
6) Wheel Tachometer (aka Encoder)

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



Imaging

Cameras

"Line Scan" Cameras
aka "Slit Scan"

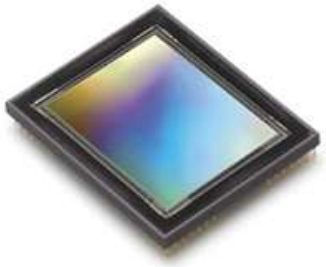
Works like your document scanner

"Area Scan" Cameras
aka "Full Frame"

Works like your standard camera

Cameras

Line Scan Sensor

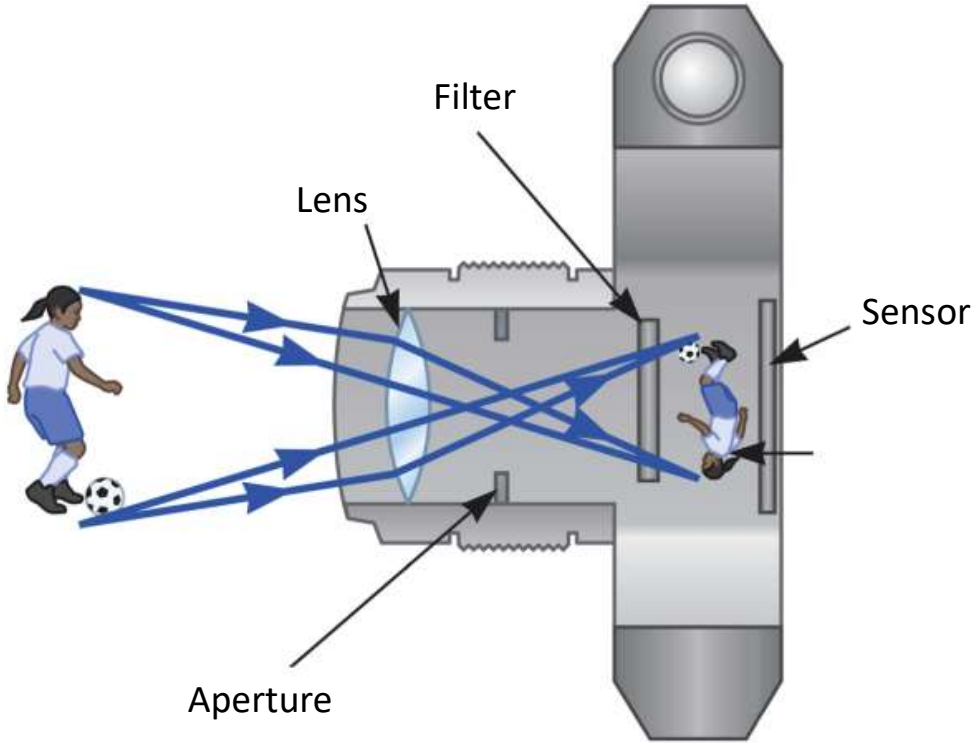


Area Scan Sensor

Light is converted to electricity similar to a solar cell.

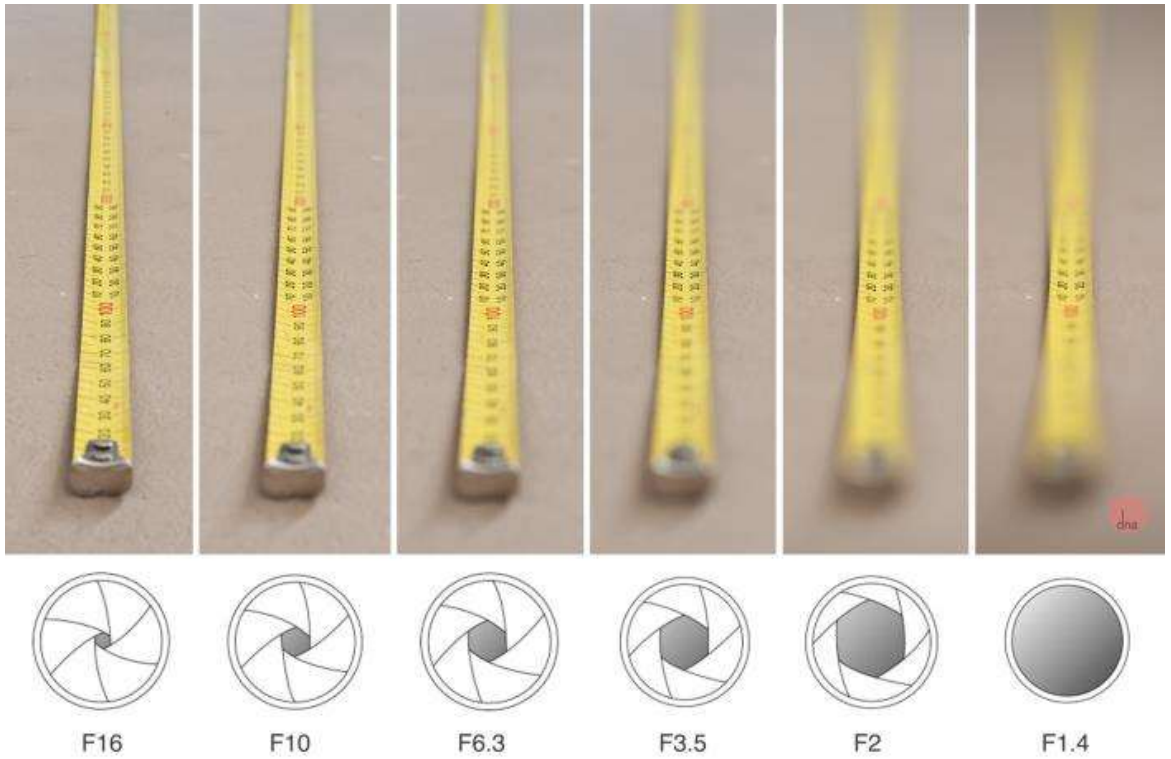
Imagery sensors are like a grid of very tiny solar cells.

Cameras



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

Cameras



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.

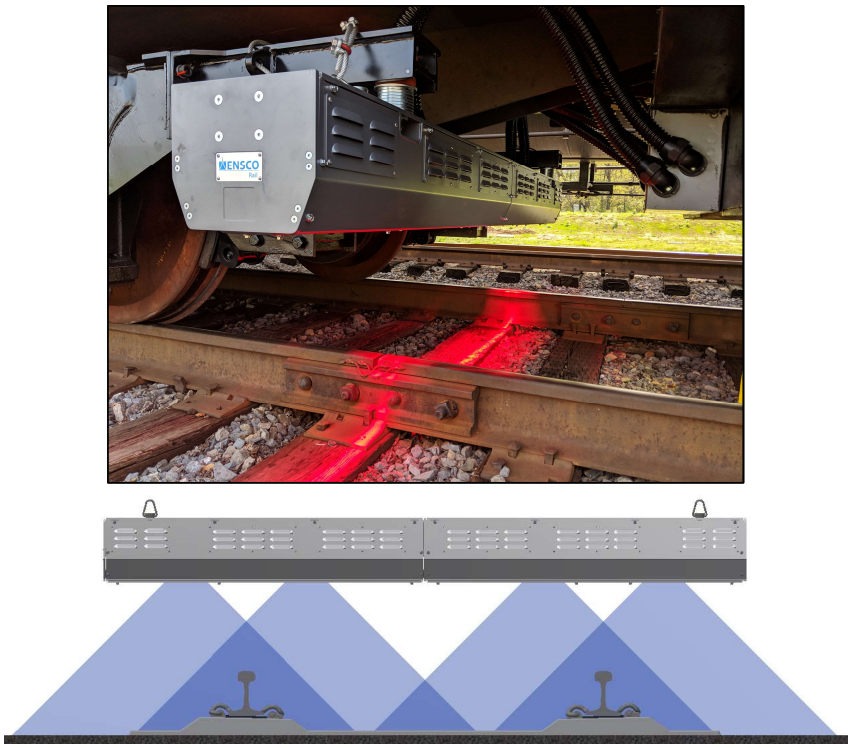
Want **fast shutter speed** to capture quickly moving objects.

Generally **need lots of light**.

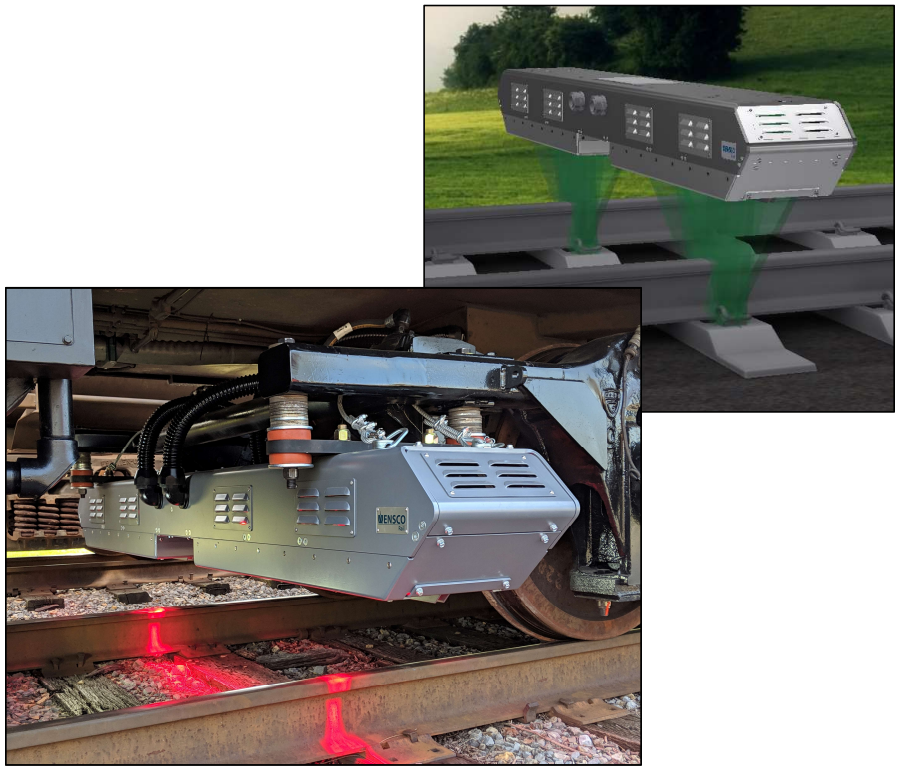
Example Camera Systems

Wheel Sensor

Example Camera Systems

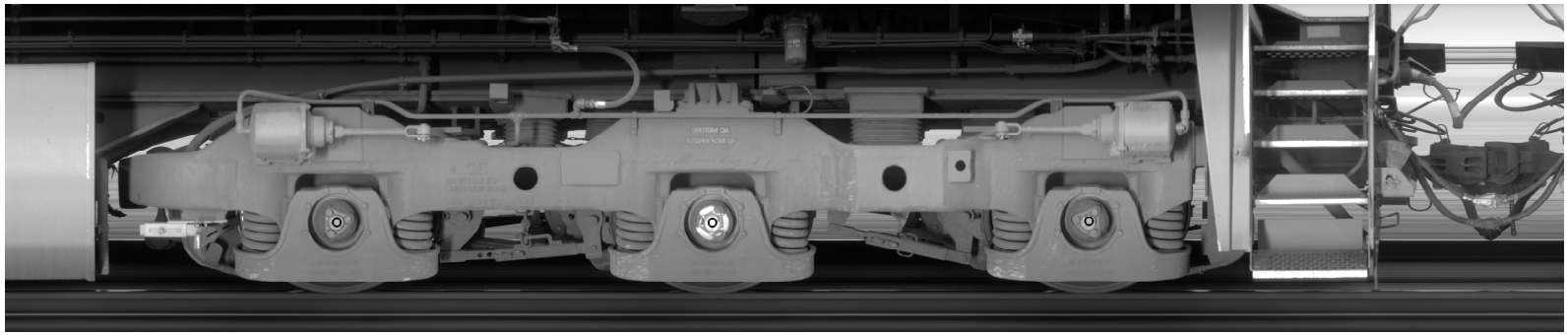


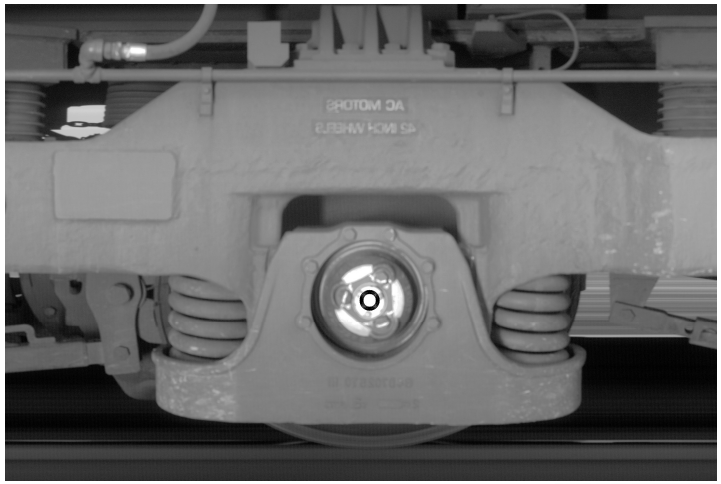
Track Component Imaging



Joint Bar Imaging

Example Line Scan Images





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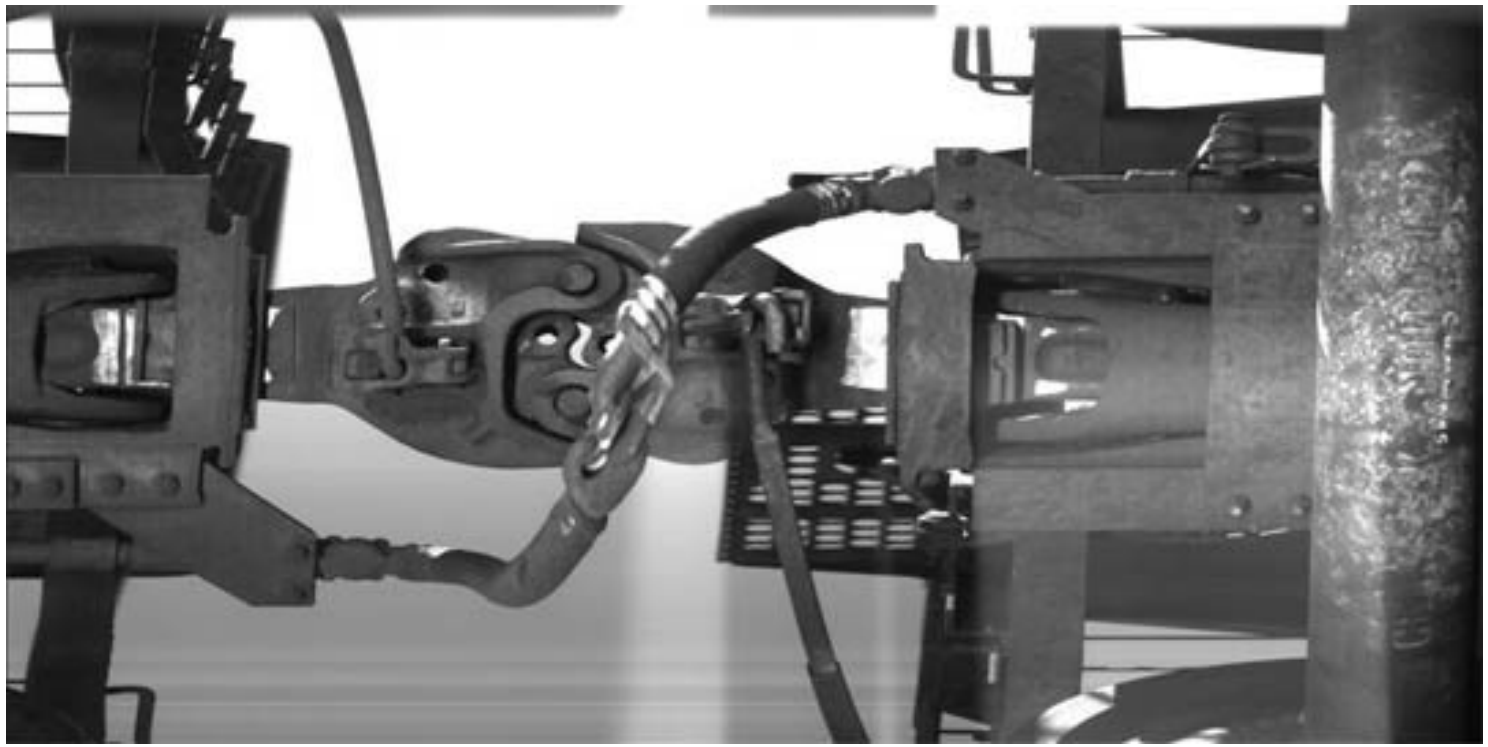

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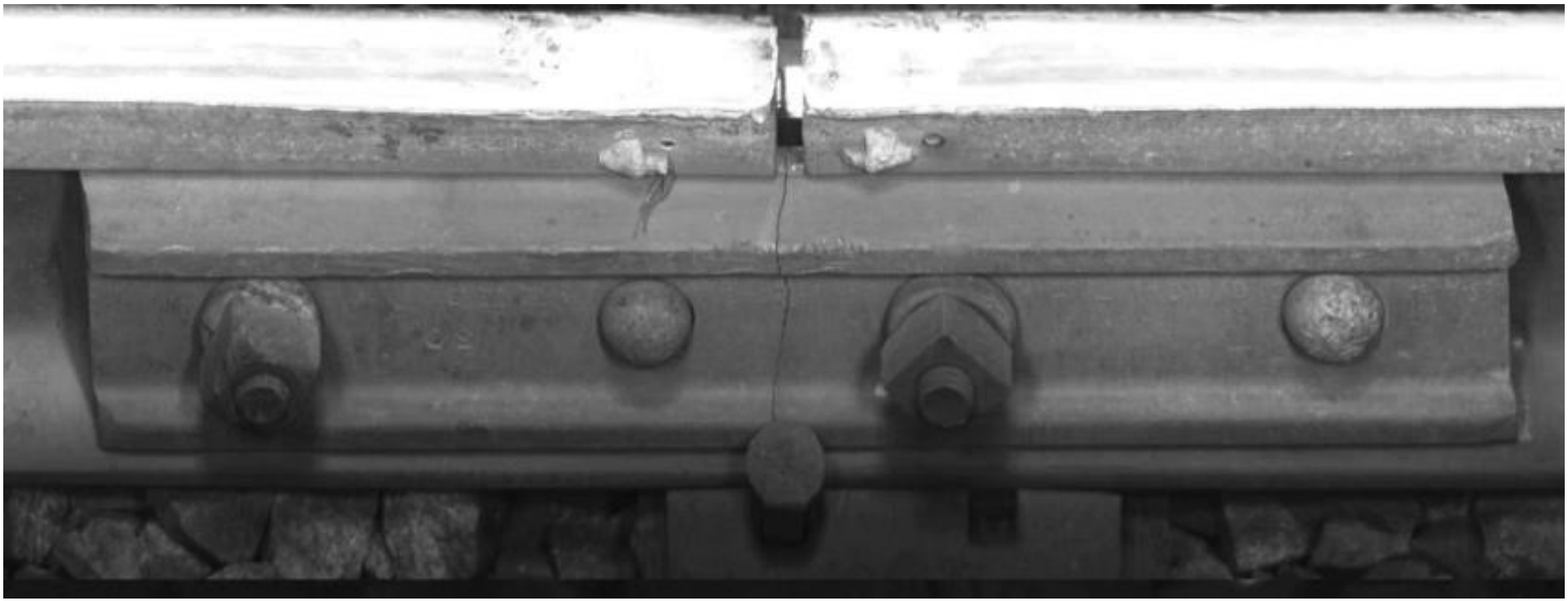

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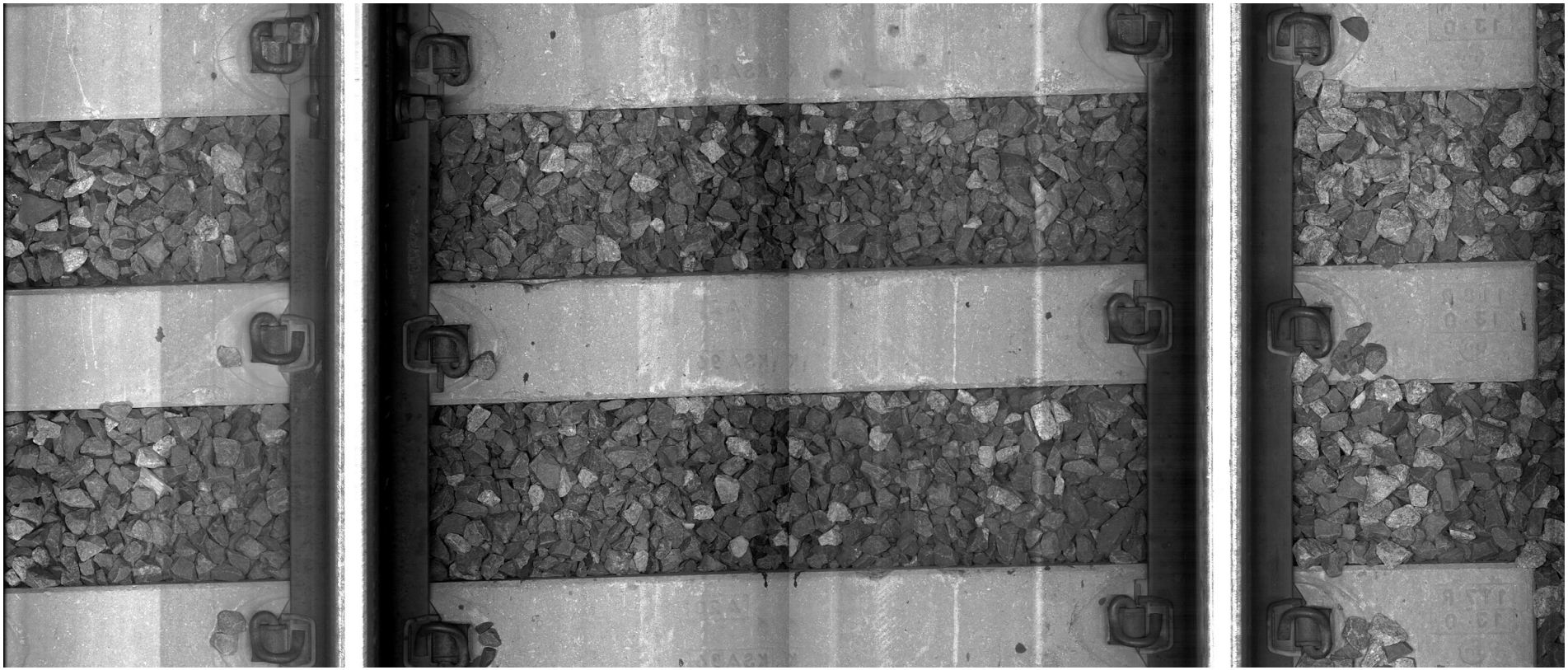
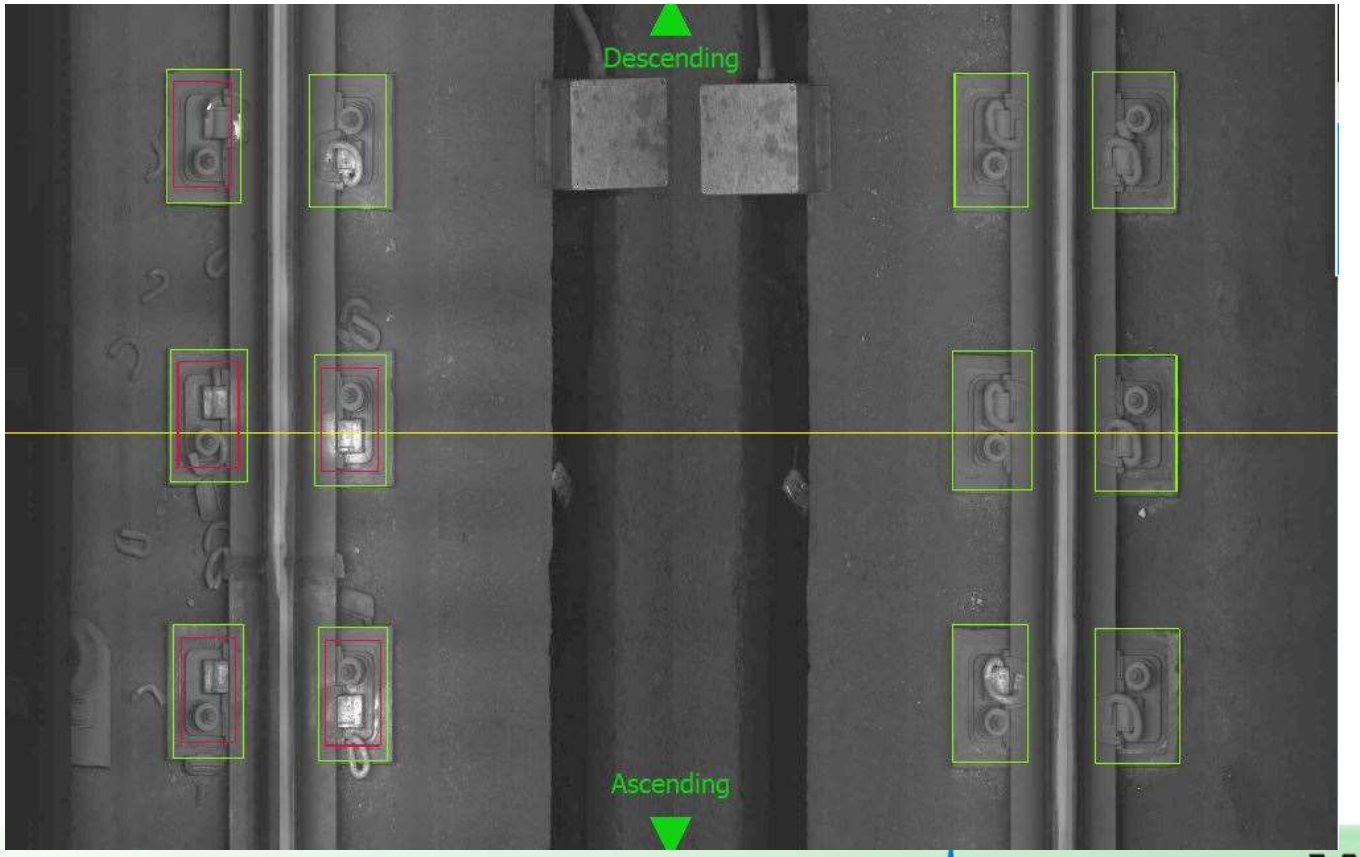
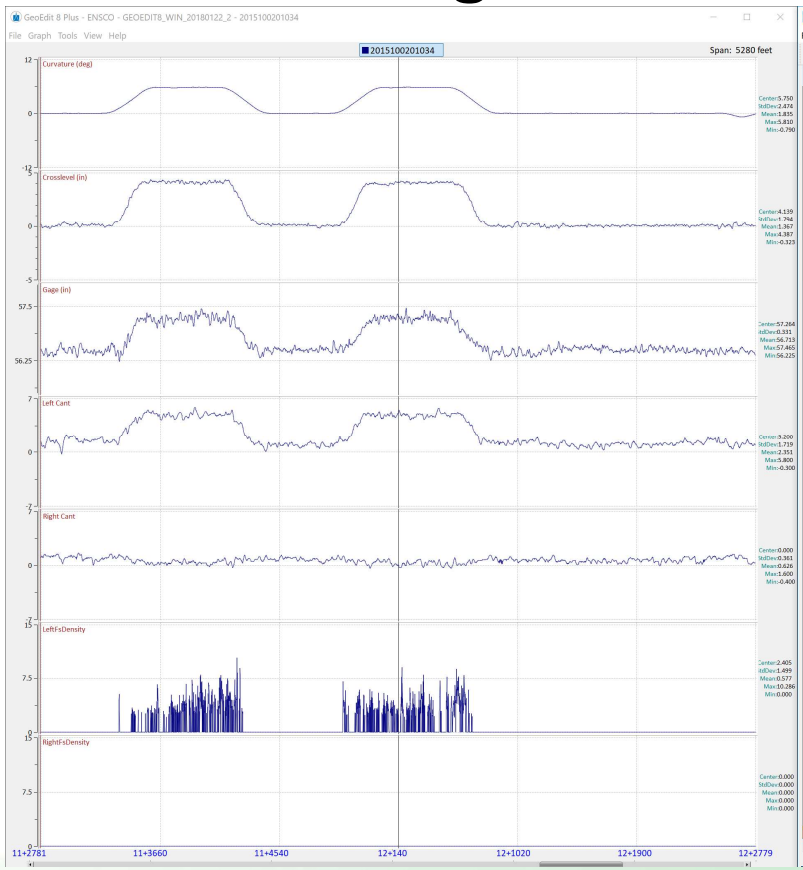


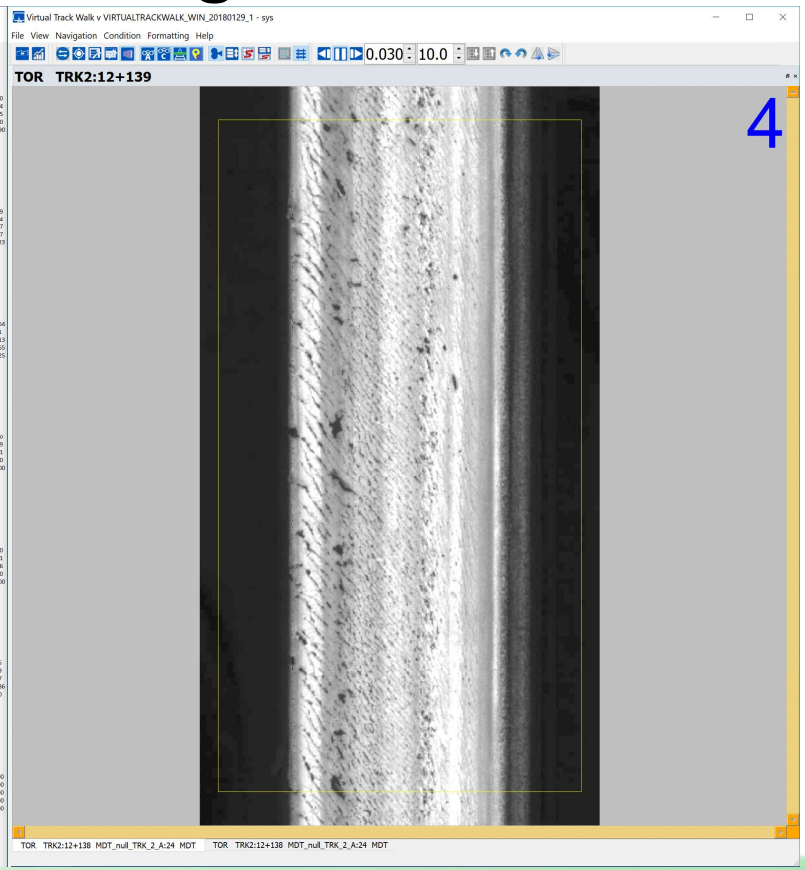
Example Automated Exception Detection using Line Scan Images



Example Automated Strip Chart Generation using Line Scan Images

- Curvature (deg)
- Crosslevel (in)
- Gage (in)
- L Cant (deg)
- R Cant (deg)
- L FS Crack Density
- R FS Crack Density



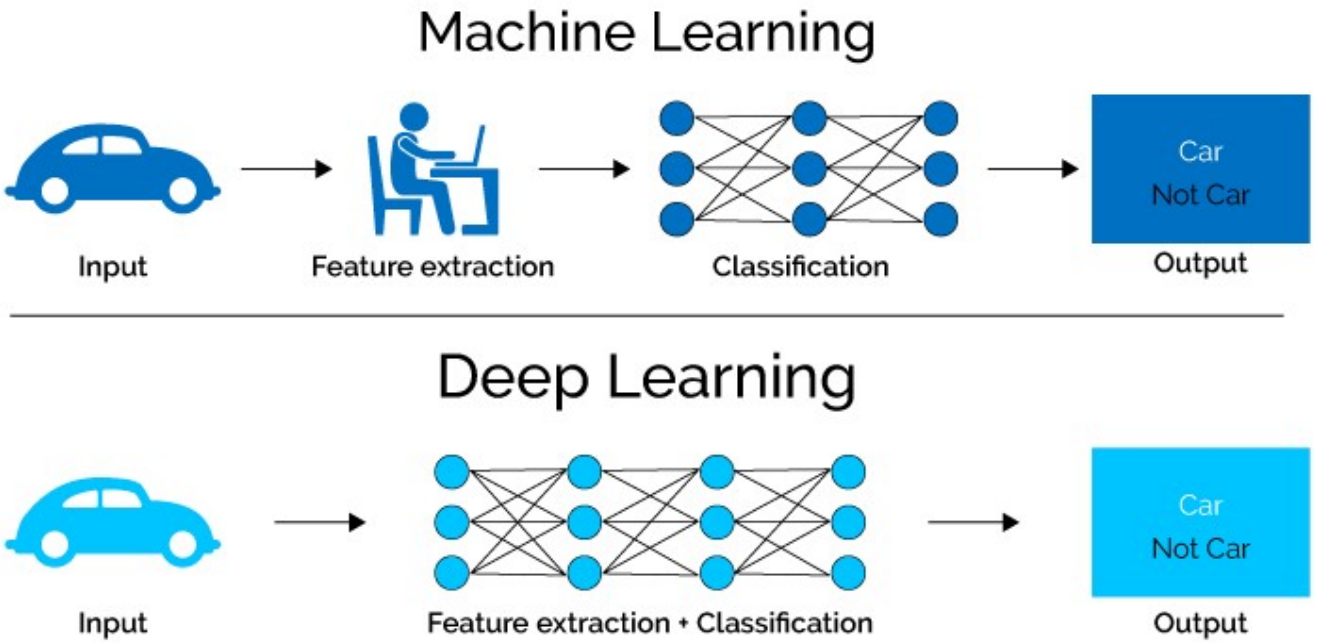


Machine Vision Algorithm Development

A current popular method is Deep Learning Neural Networks

Less dependent on feature extraction

More dependent on lots of labeled training images

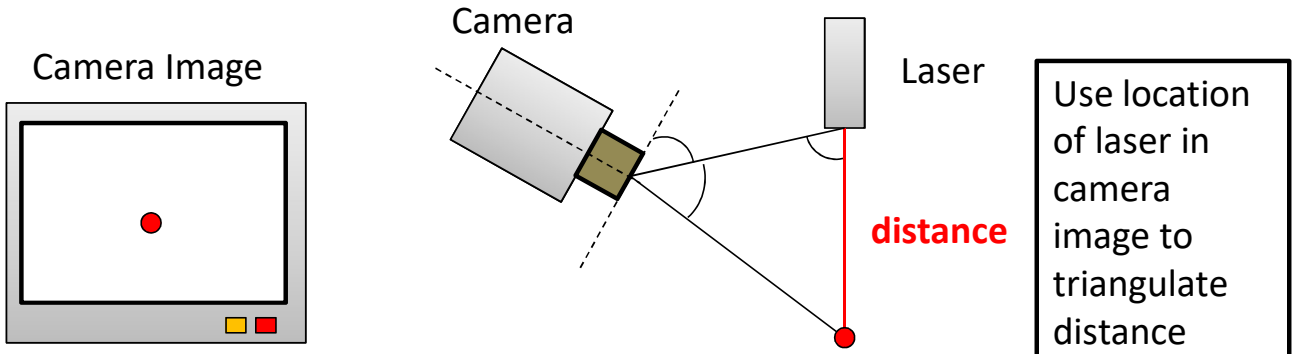


Ref: https://semiengineering.com/deep-learning-spreads/

Laser Profiling and LiDAR

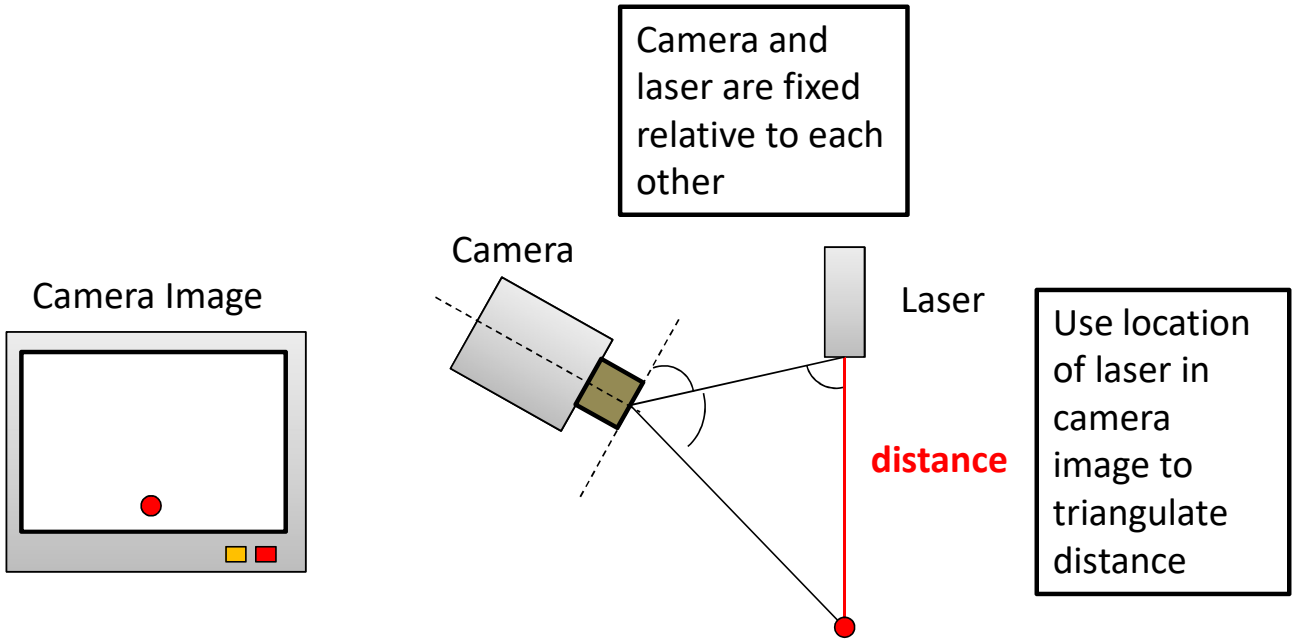
Laser Triangulation Measurement

Camera and laser are fixed relative to each other

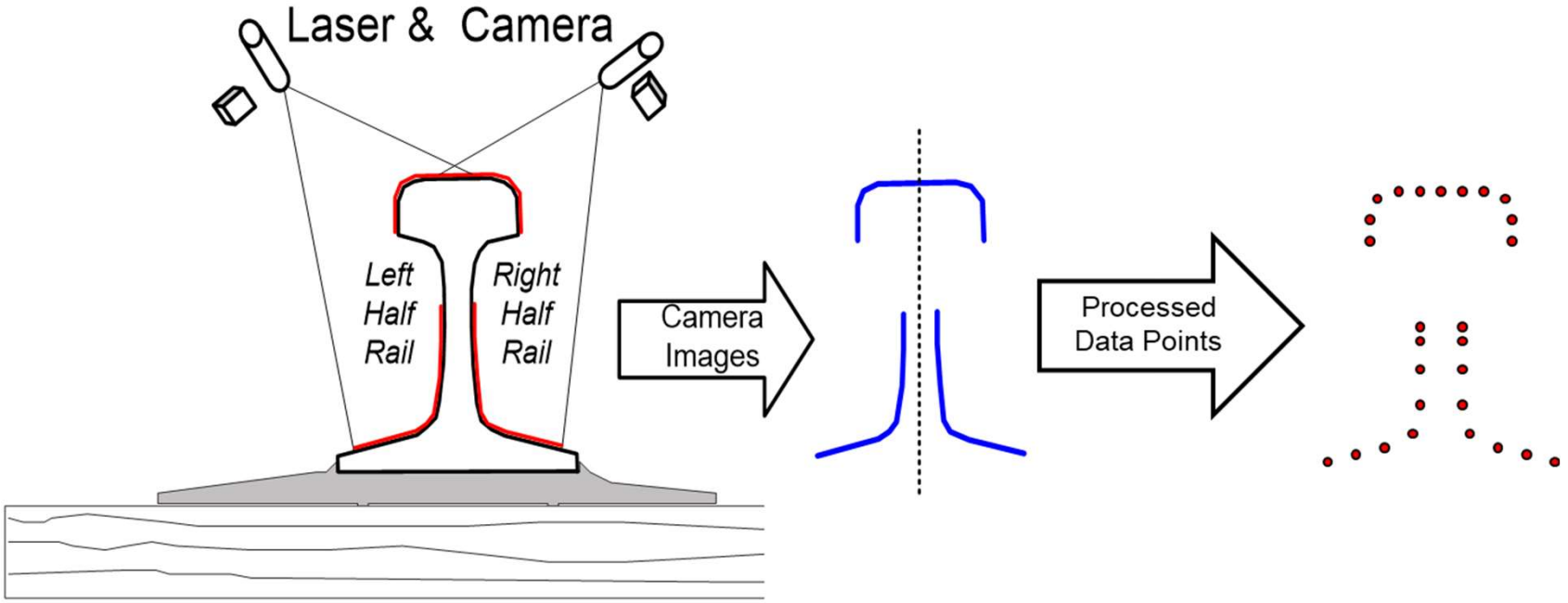


Use location of laser in camera image to triangulate distance

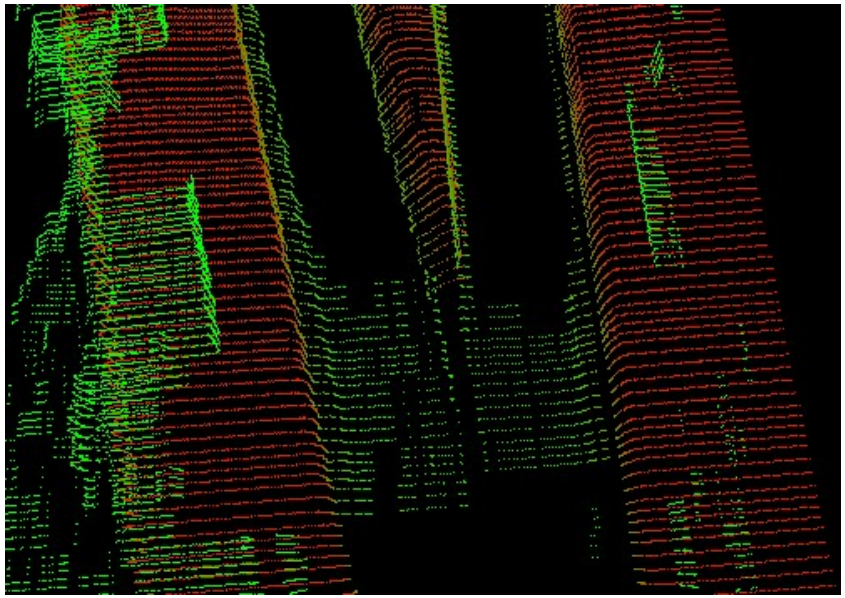
Laser Triangulation Measurement



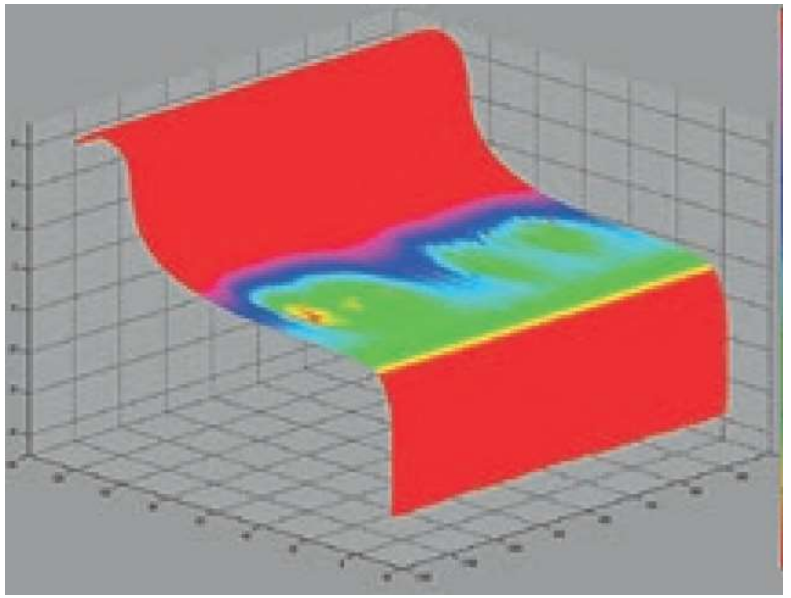
Laser Triangulation Measurement: Rail Profile Measurement



Laser Triangulation Measurement: 3D Profiling

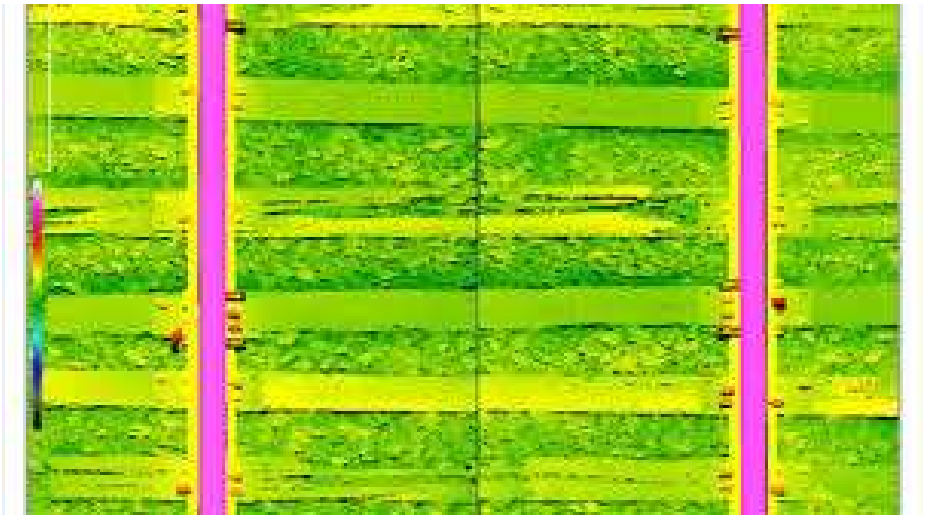


High Sample Rate Scan at Frog

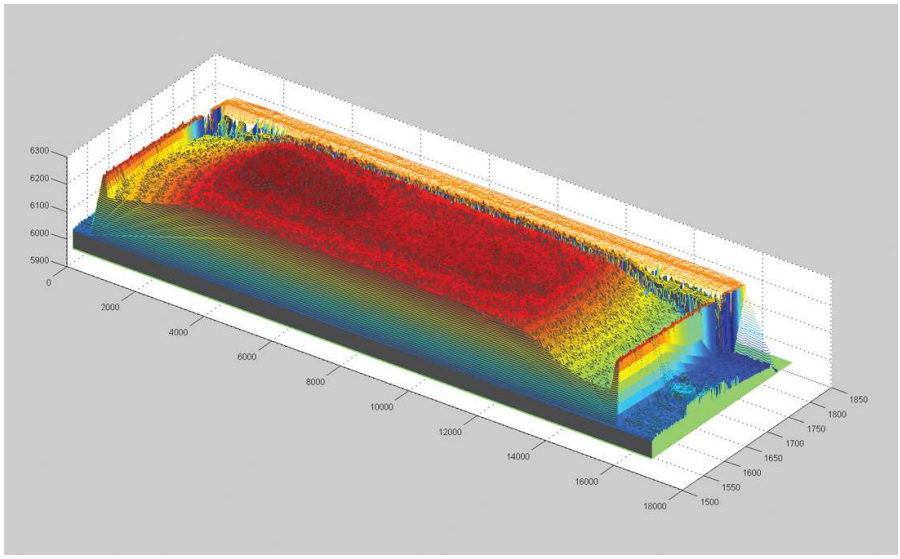


High Sample Rate Scan on Wheel Tread

Laser Triangulation Measurement: 3D Profiling



Track Bed 3D Laser Profile



Coal in Coal Hopper 3D Laser Profile

LiDAR Basics

LiDAR Basics

Laser is emitted

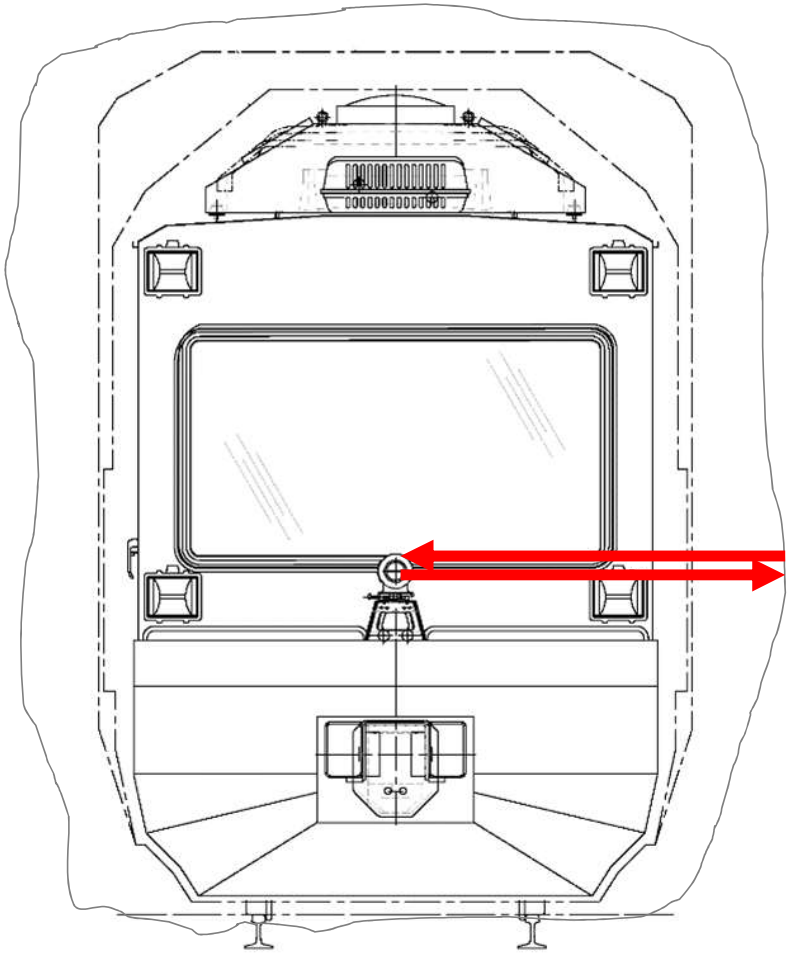
LiDAR Basics

Laser is emitted

Laser bounces off surface

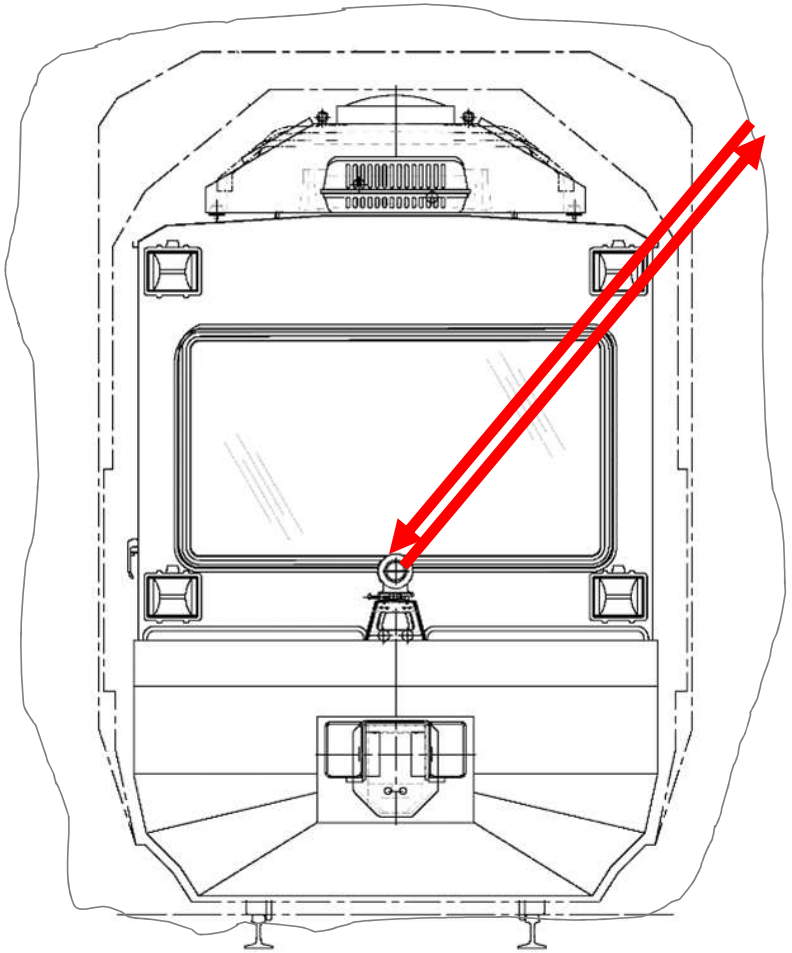
Travel time is measured and converted to distance

Clearance Measurement



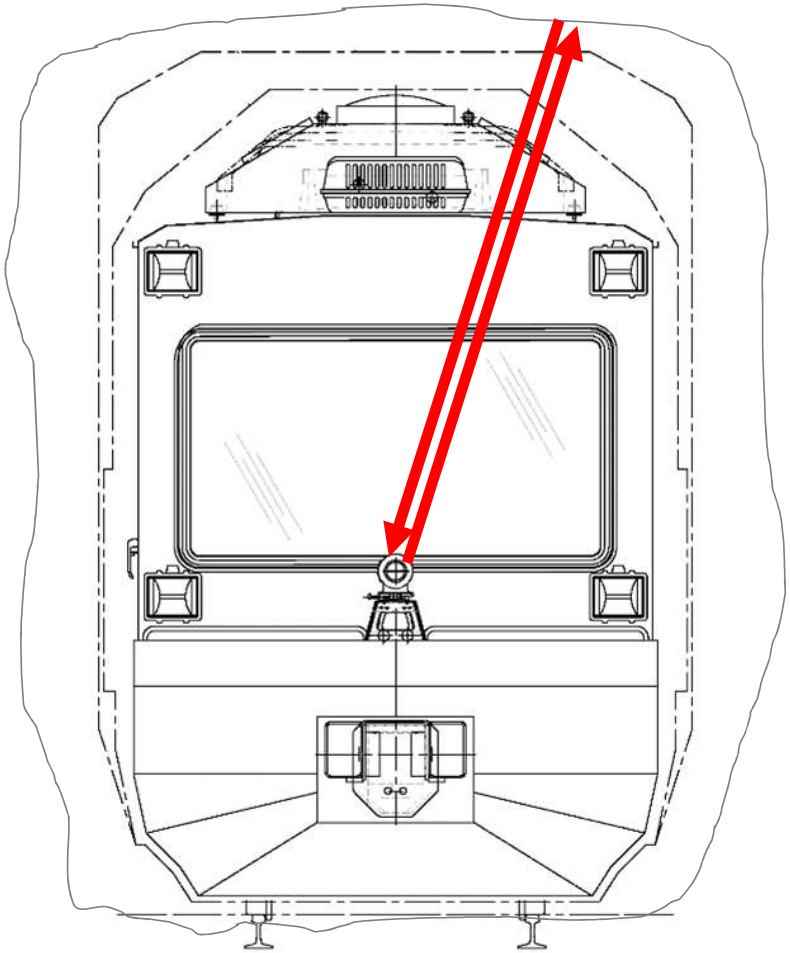
LiDAR works by shooting a laser point and measuring the time it takes to return.

Clearance Measurement



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

Clearance Measurement



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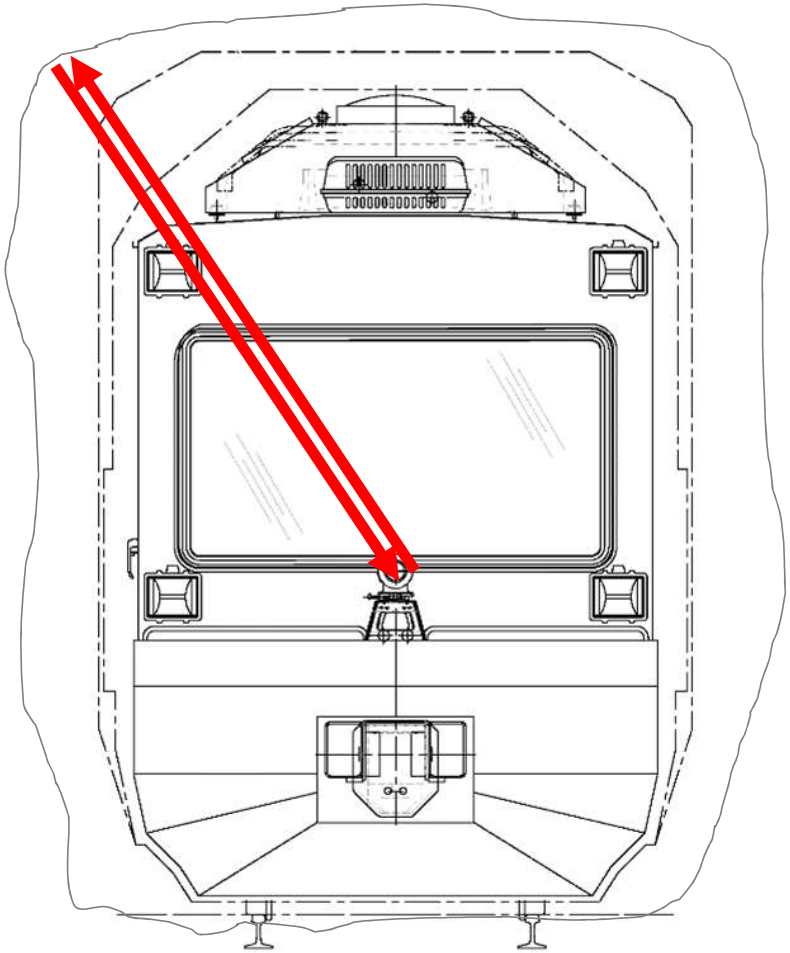

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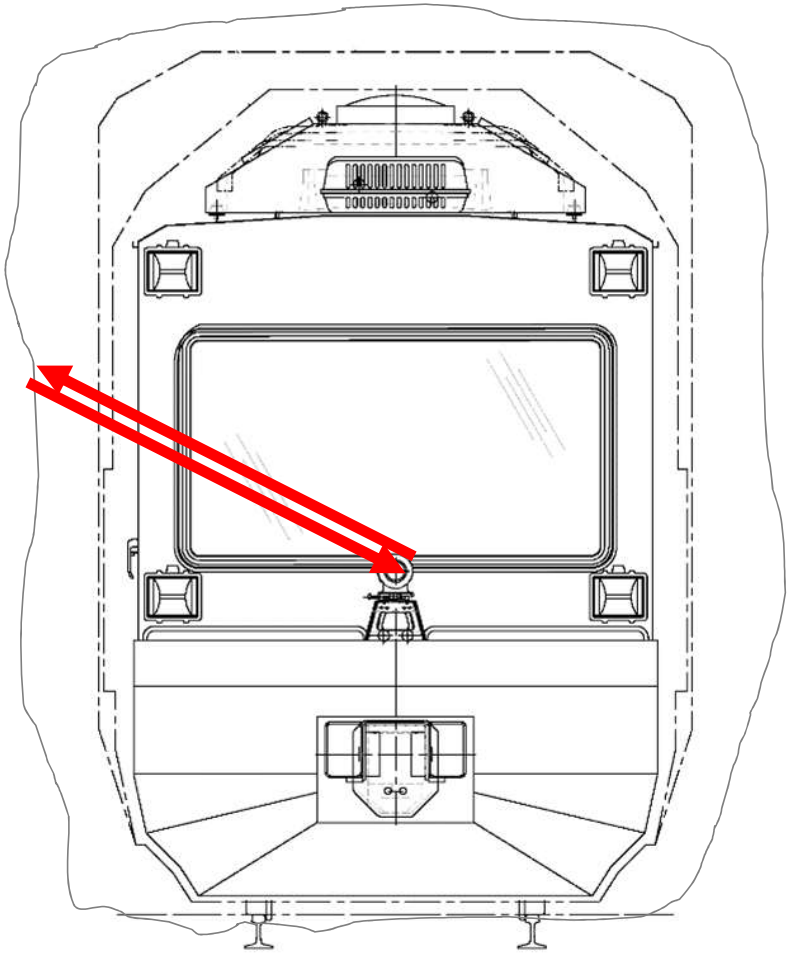

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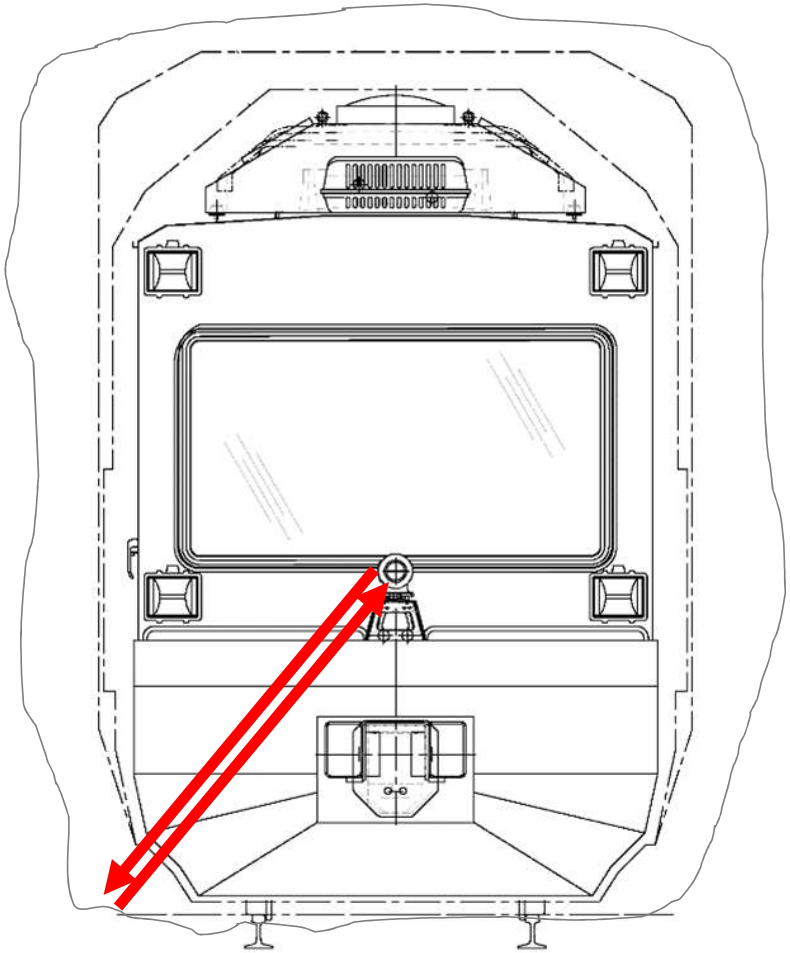

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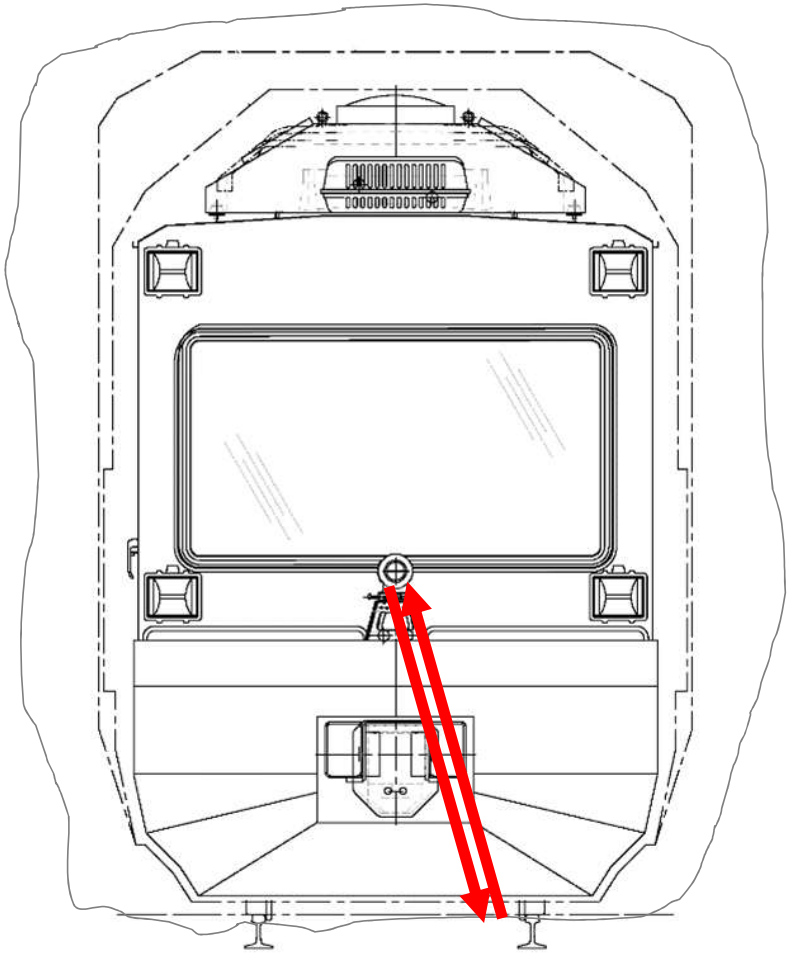

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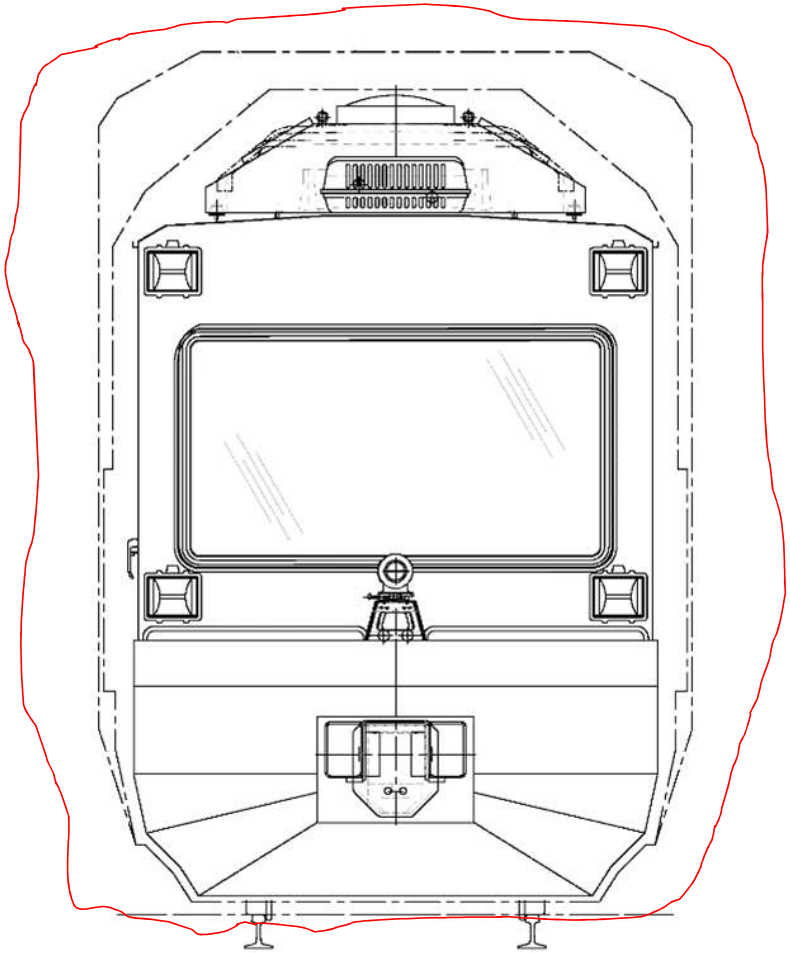

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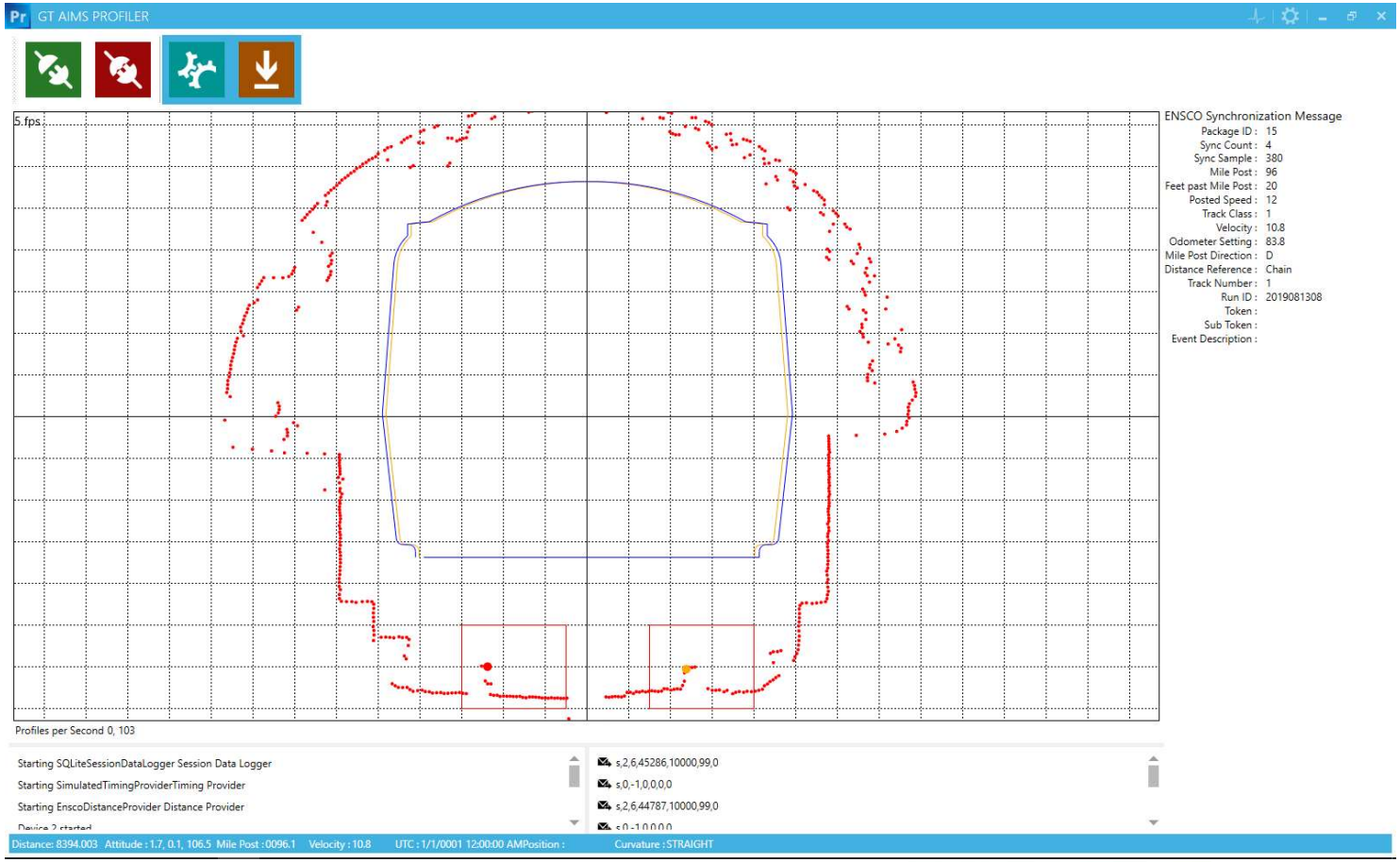
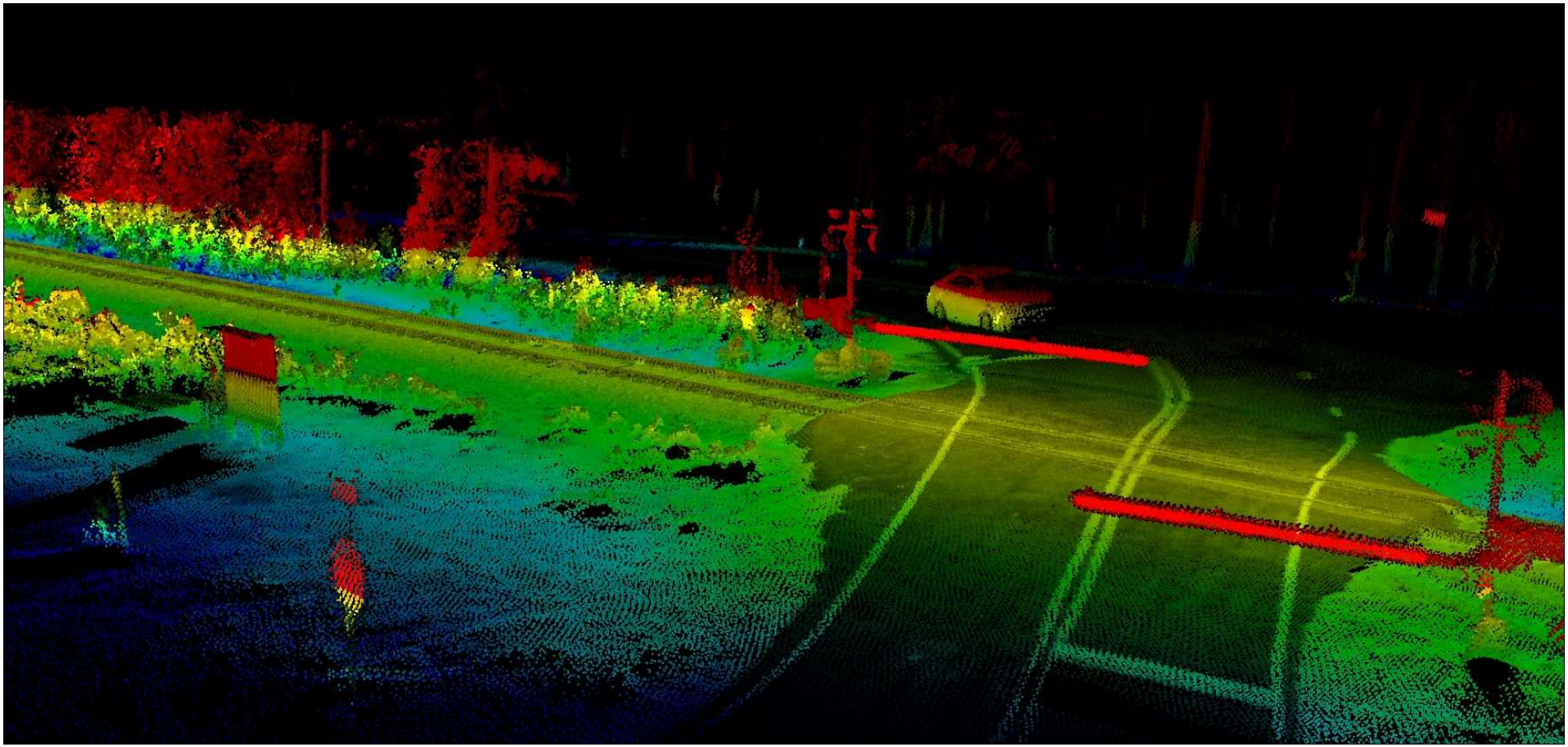
LiDAR for Clearance Measurement



LiDAR for Clearance Measurement

LiDAR for Right-of-Way Inspection

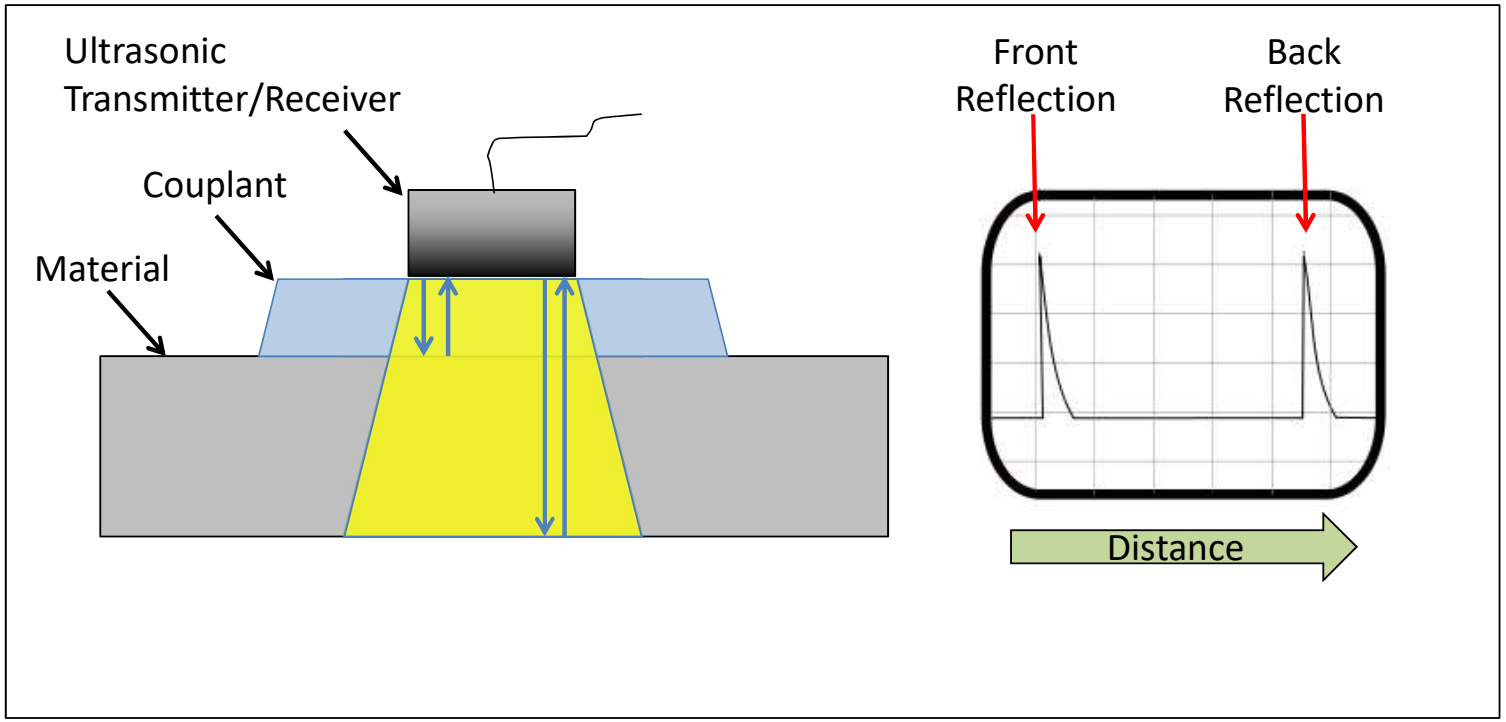
LiDAR for Clearance Measurement



Ultrasonic Measurement

Ultrasonic Sensors

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



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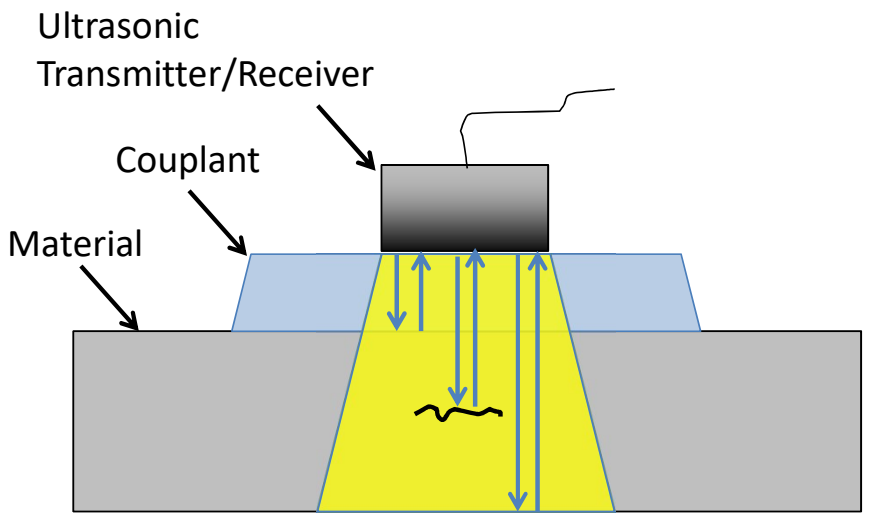
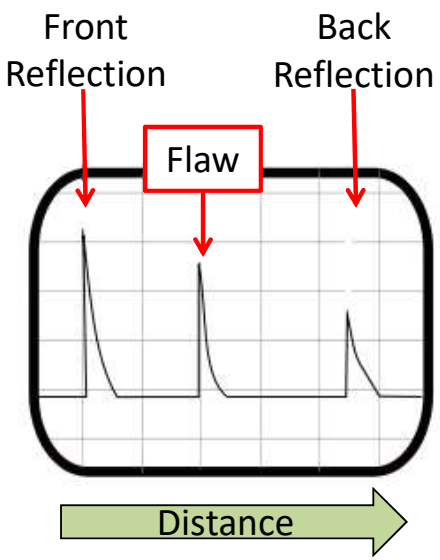




- Uses ultrasonic waves to reflect from surfaces and measure the “time of flight” to determine distance.

Ultrasonic Rail Flaw Detectors

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

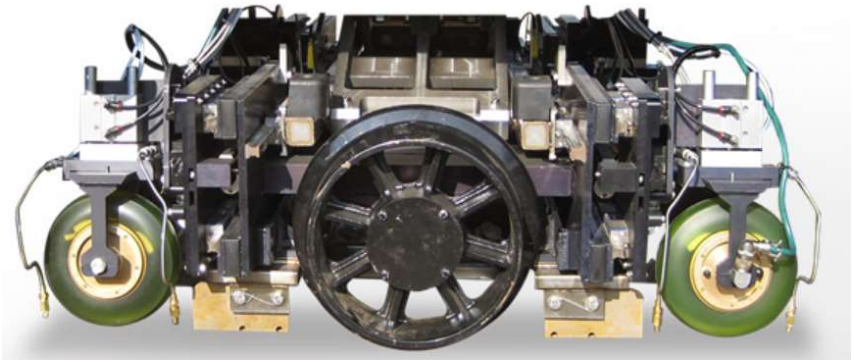
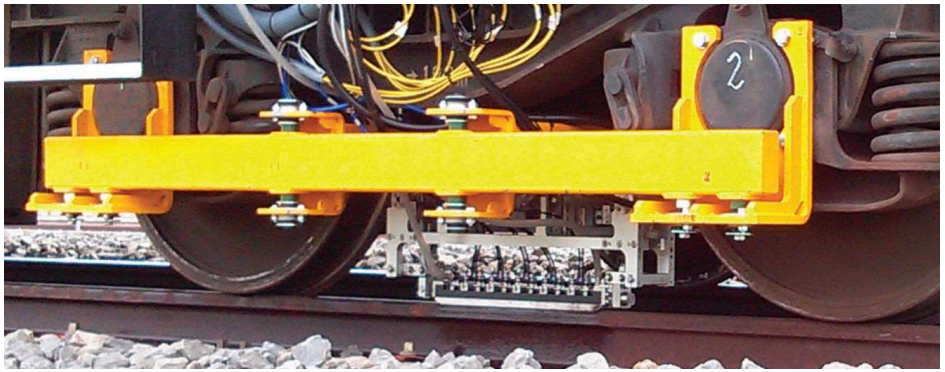


Image from Nordco
http://www.nordco.com/products-catalog/inspection-technologies/rail-bound-inspection-systems/rail-bound-rail-flaw-inspection-system-.htm

Exampled 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

B-Scan

Composite of multiple sensors to better visualize the flaw

A-Scan

Individual Sensor

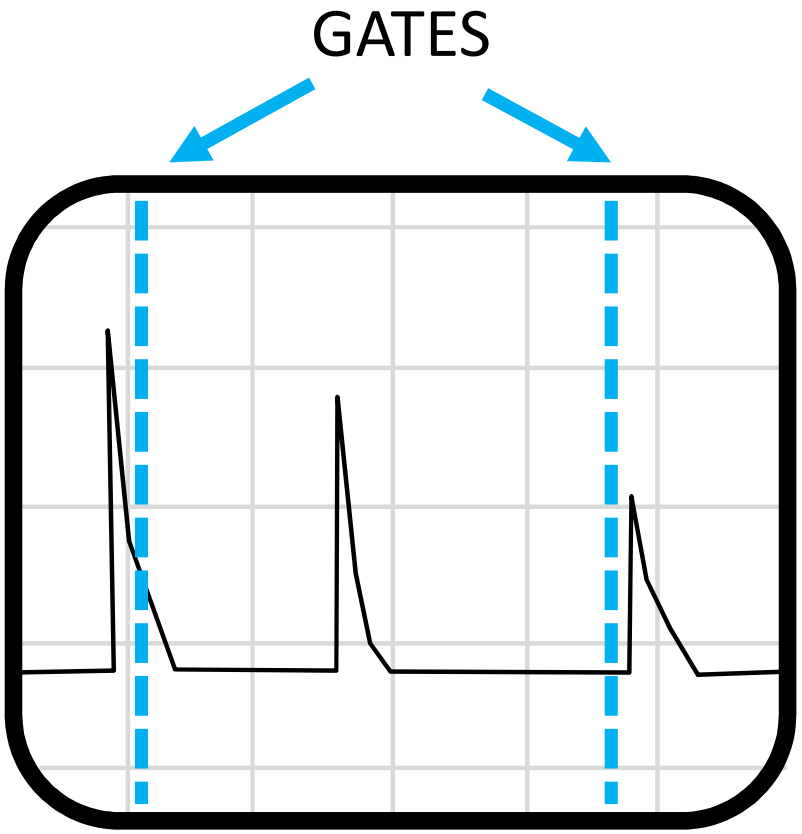
Image from Nordco
http://www.nordco.com/products-catalog/inspection-technologies/vehicle-inspection-systems/NRS-260-Prime.htm

A Scan

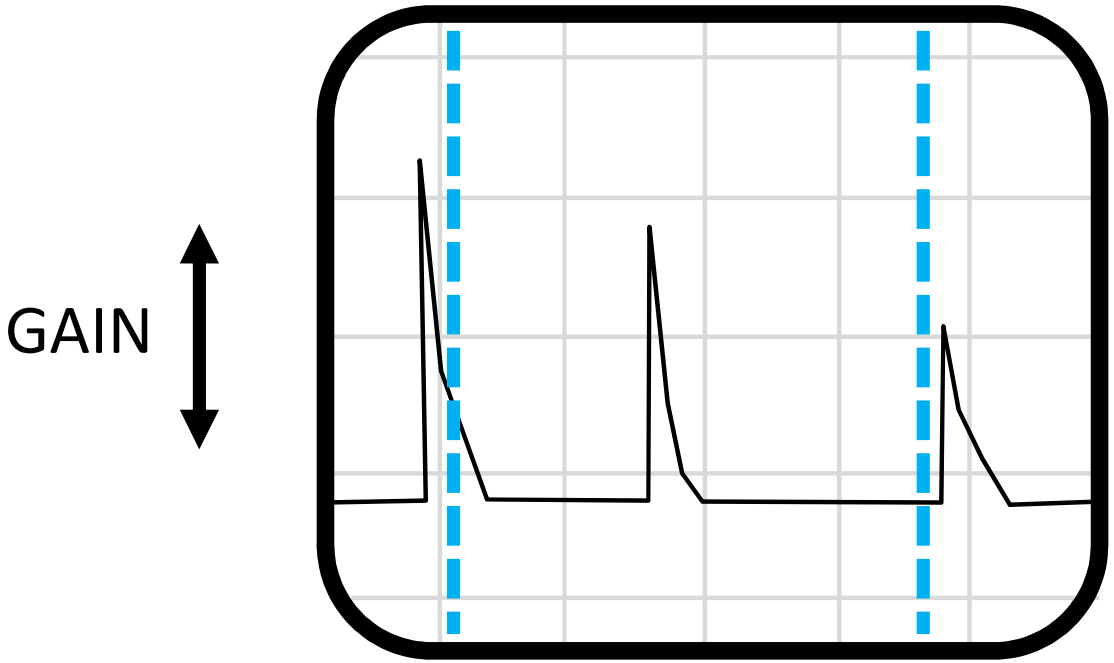
NEAR THE PROBE

FAR AWAY FROM THE PROBE

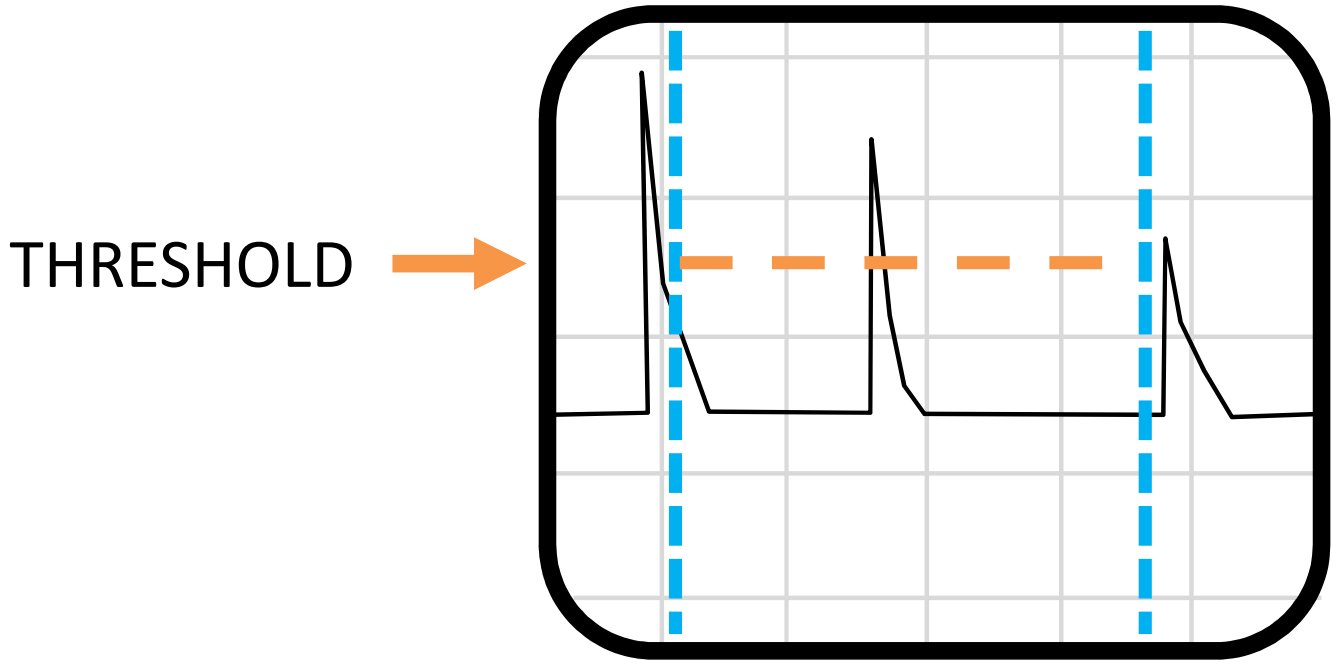
A Scan



A Scan



A Scan



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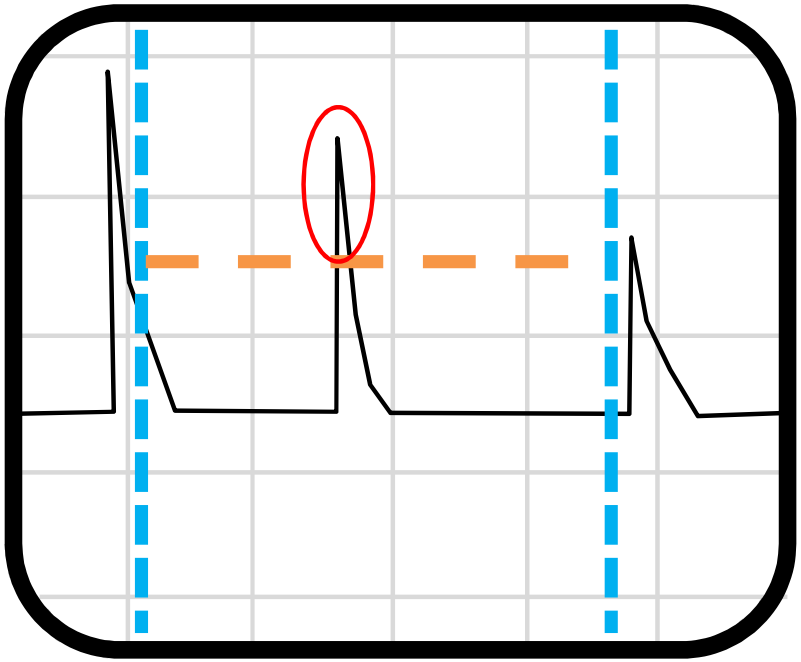
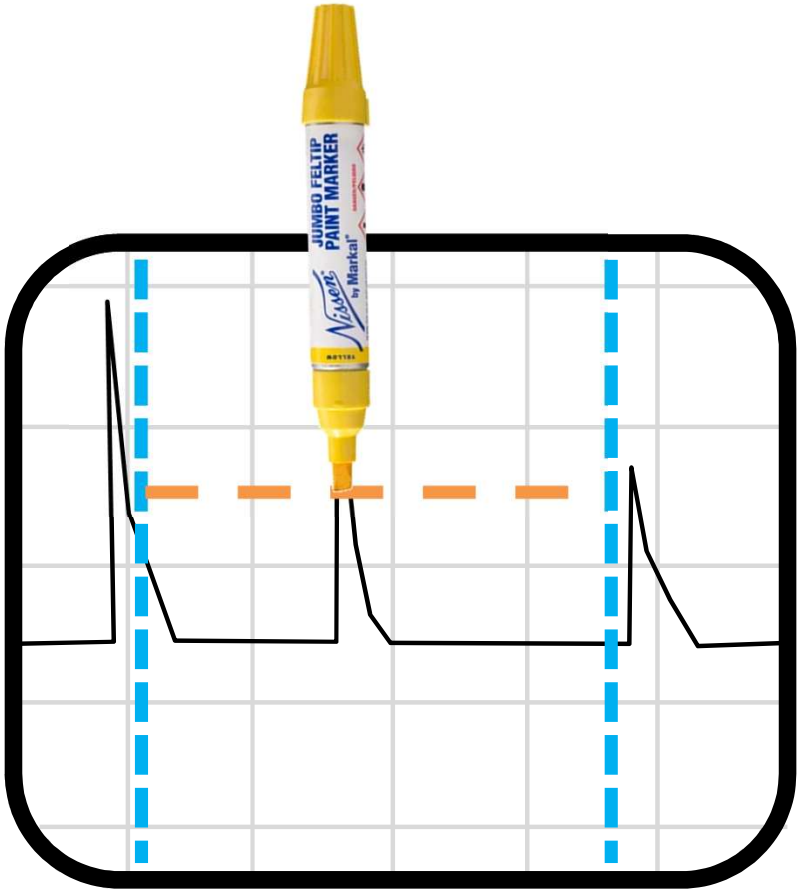
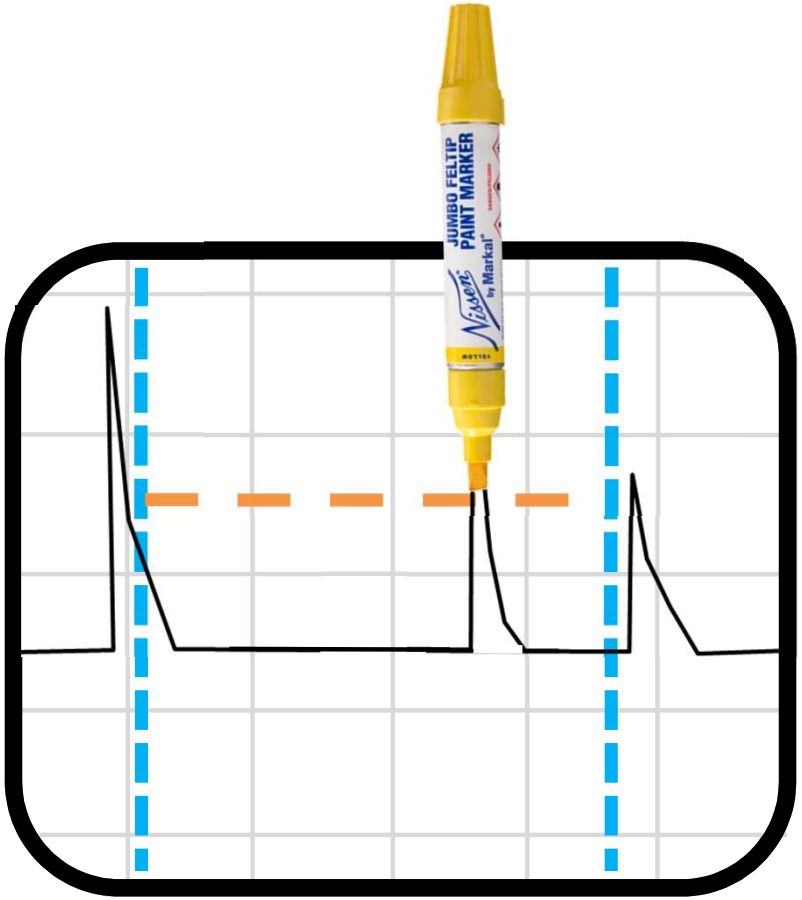


A Scan



A Scan

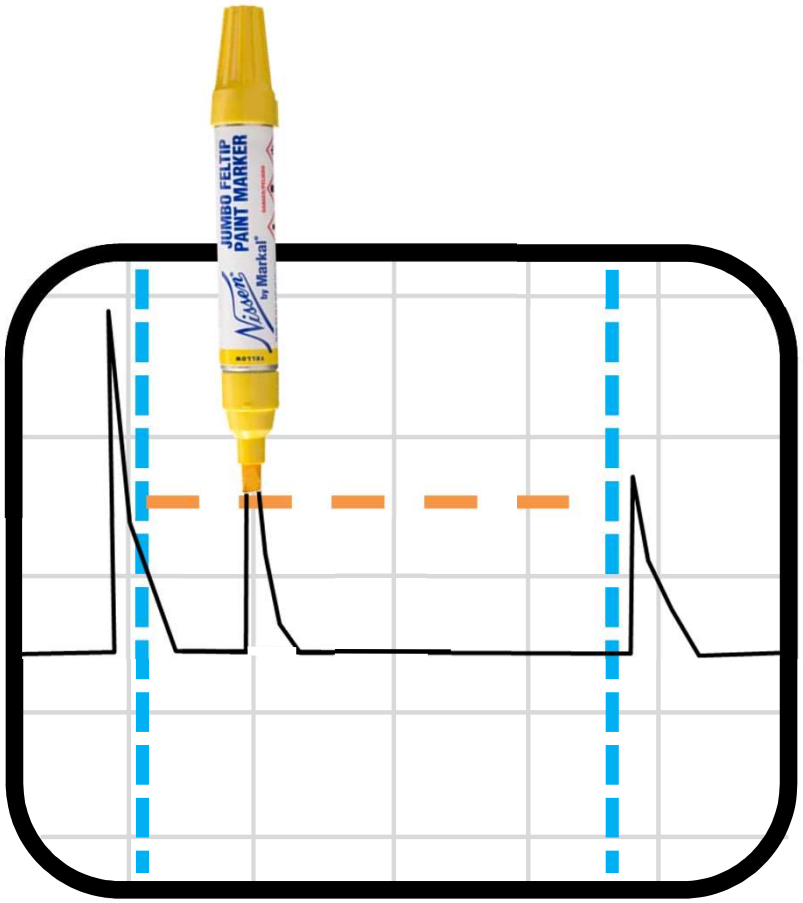
NEAR THE PROBE



FAR AWAY FROM THE PROBE

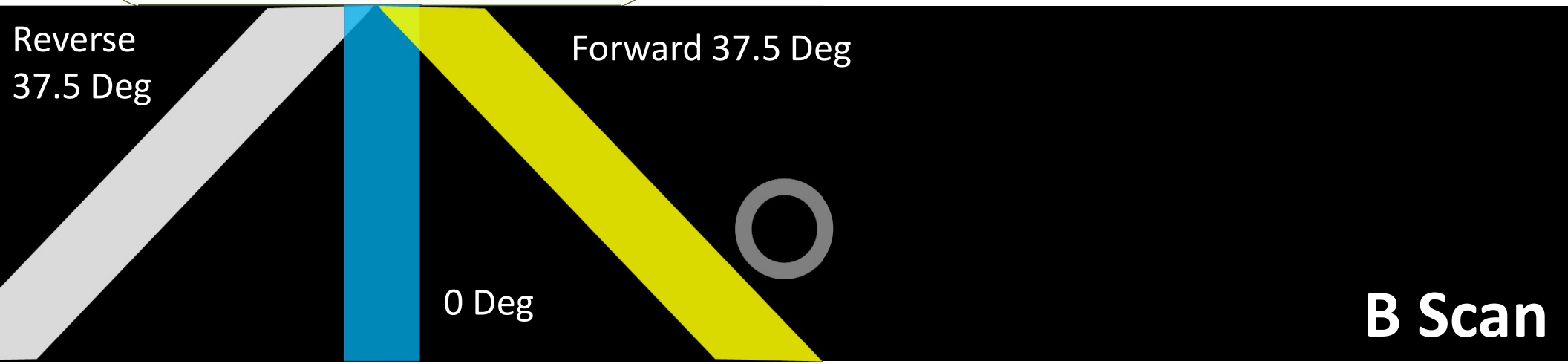
A Scan

NEAR THE PROBE

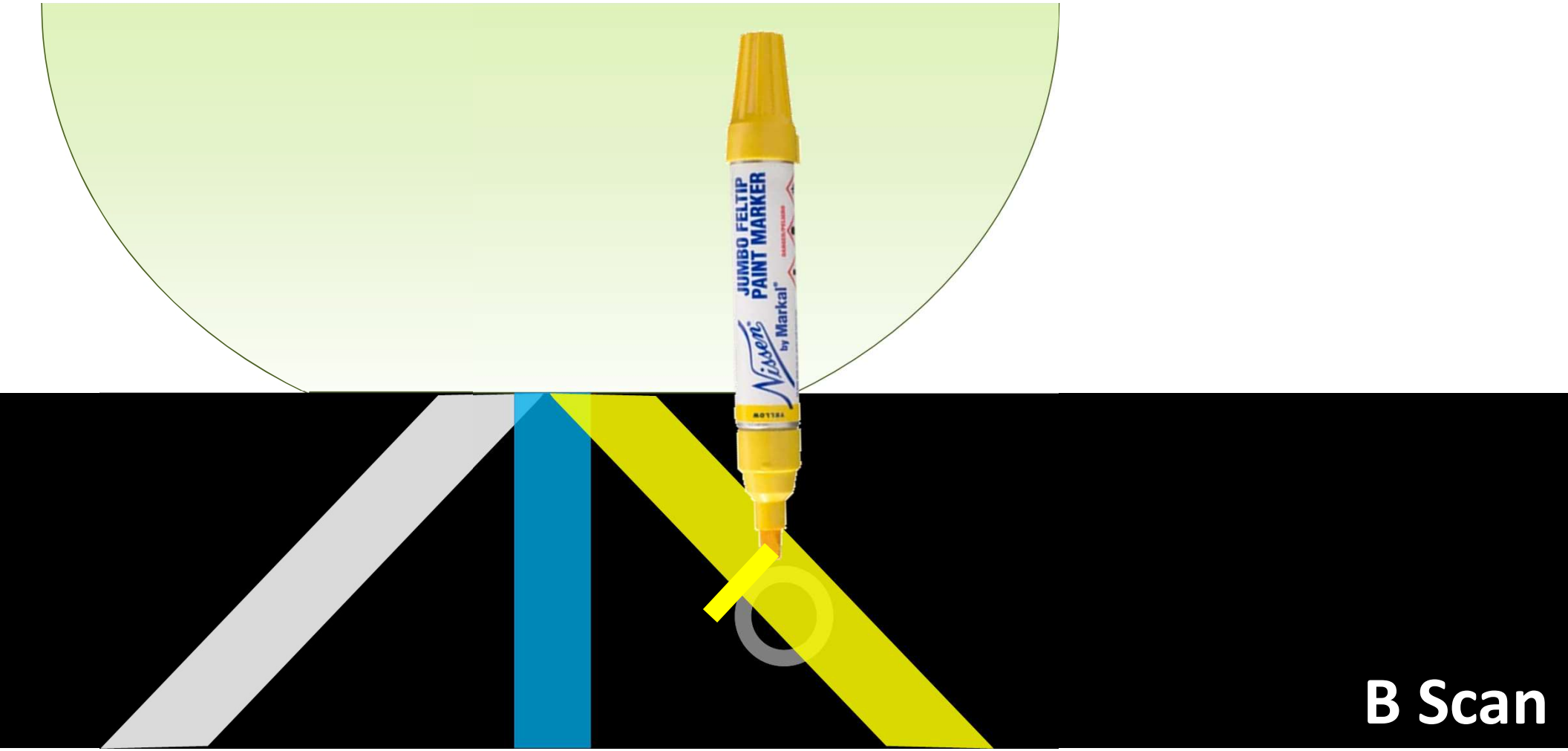


FAR AWAY FROM THE PROBE

Wheel Probe



B Scan



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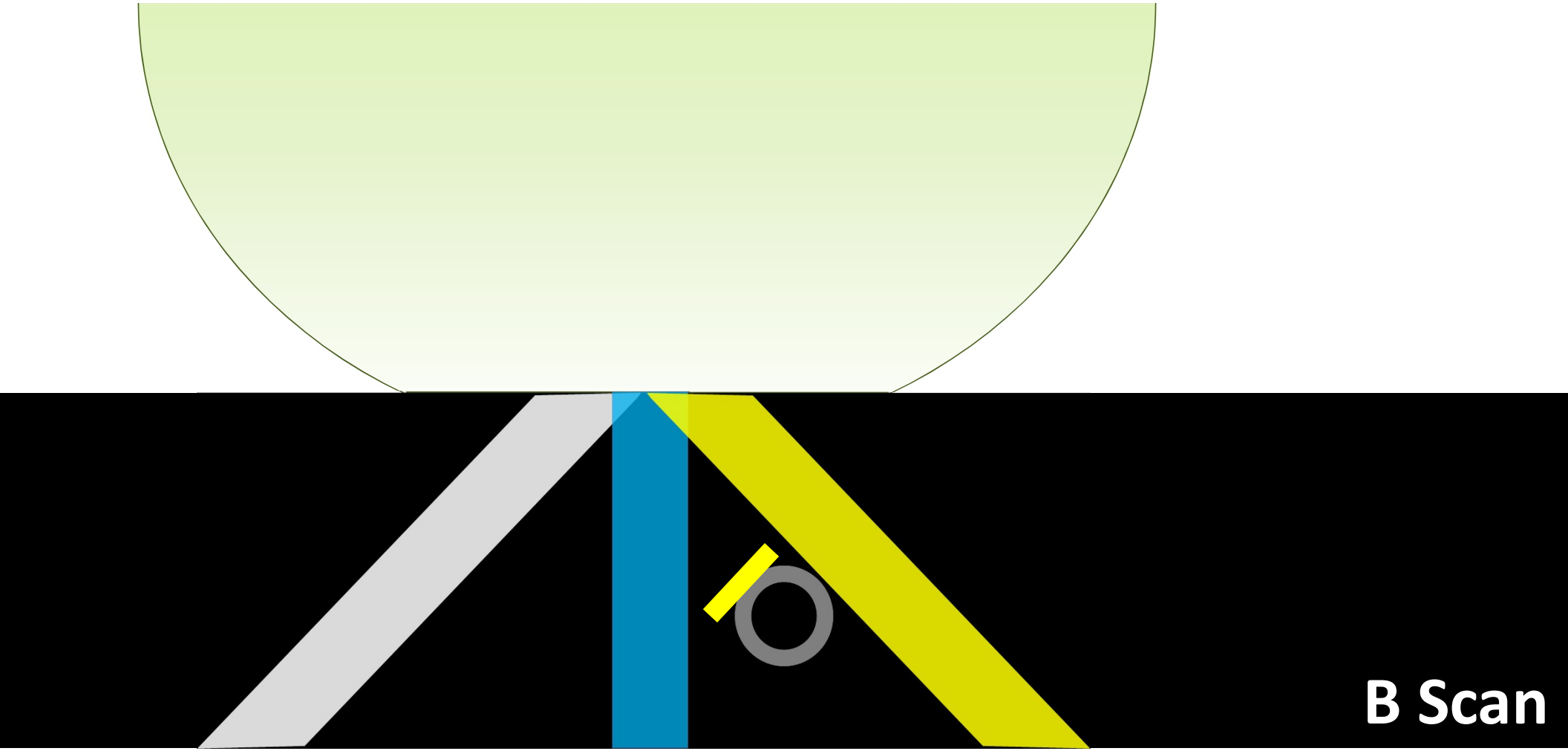

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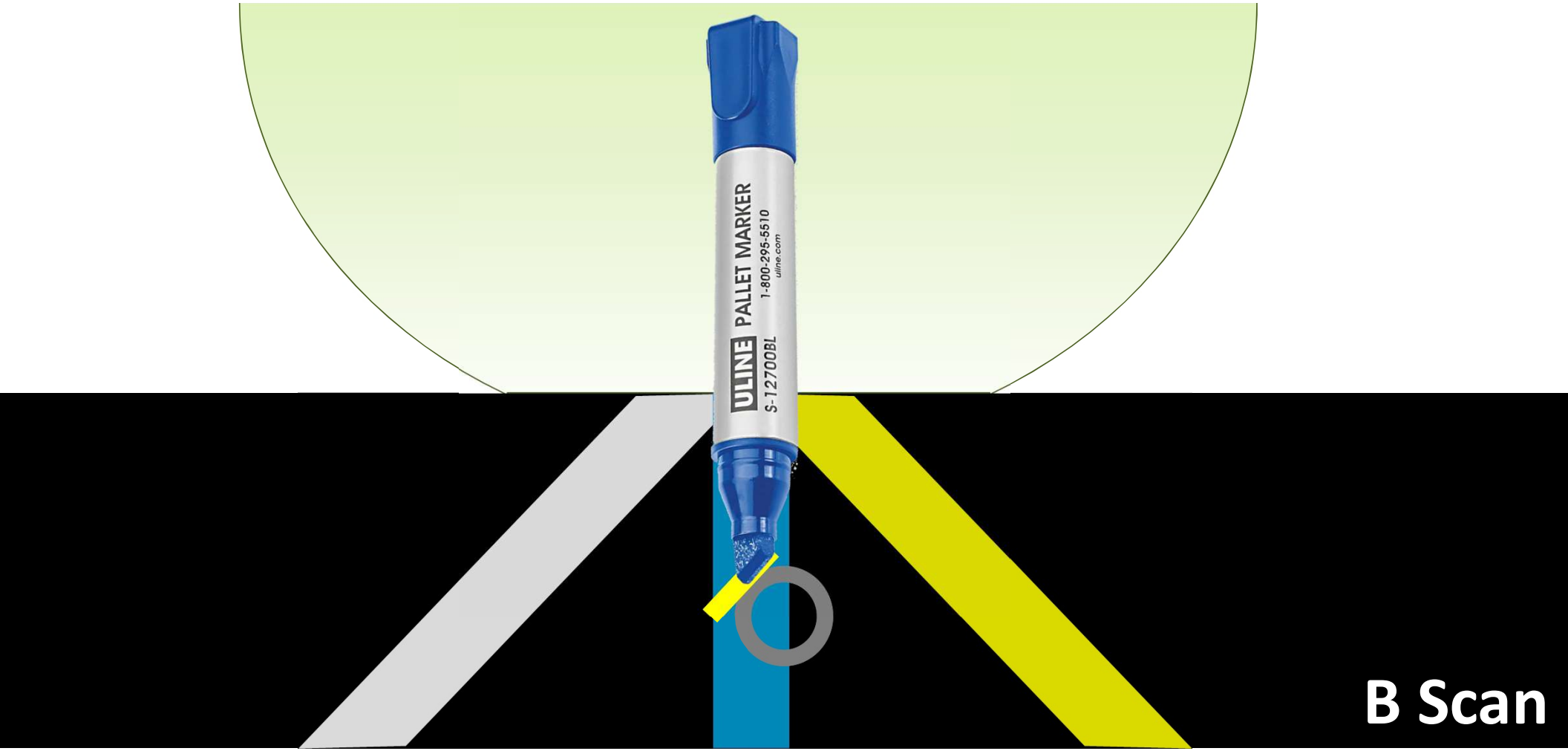

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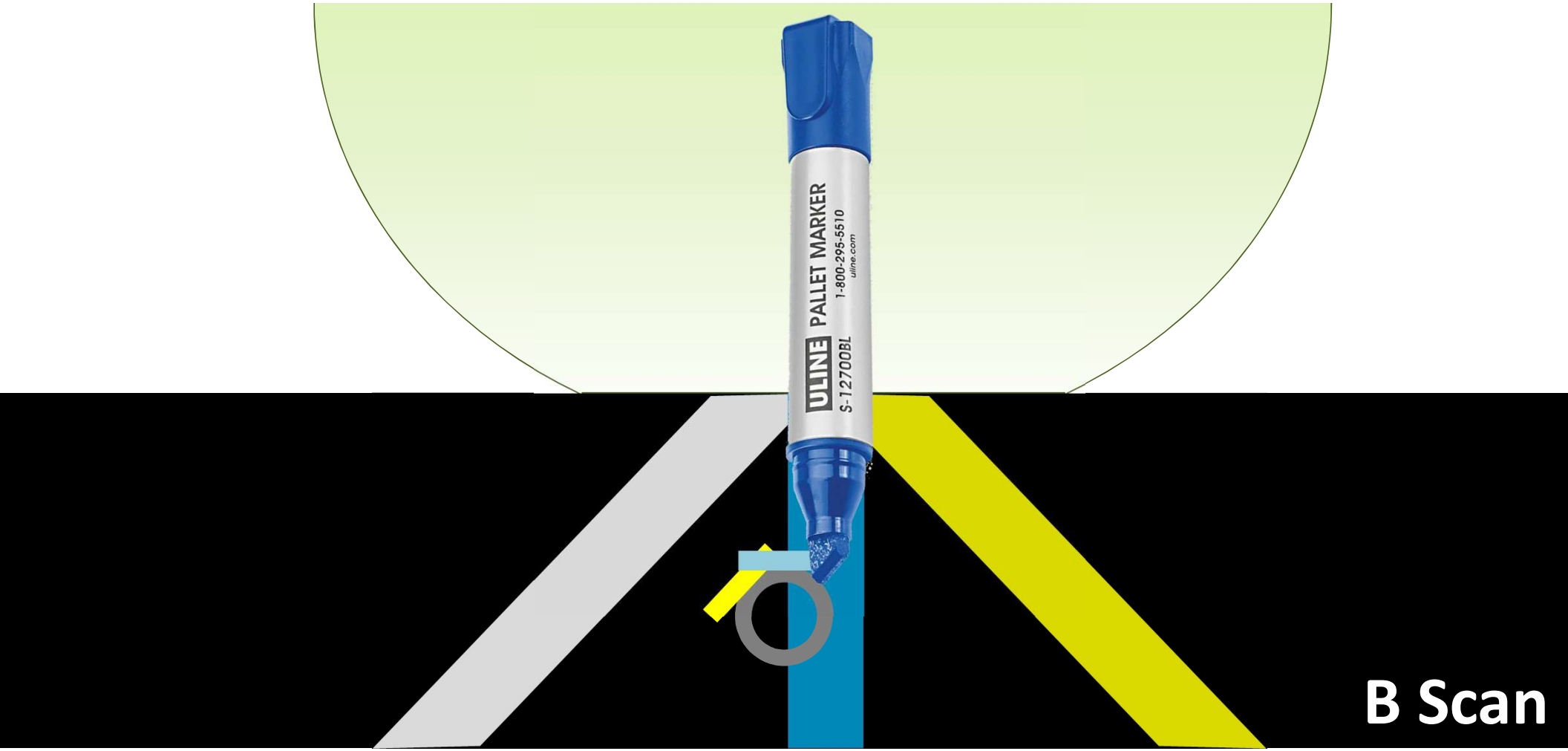

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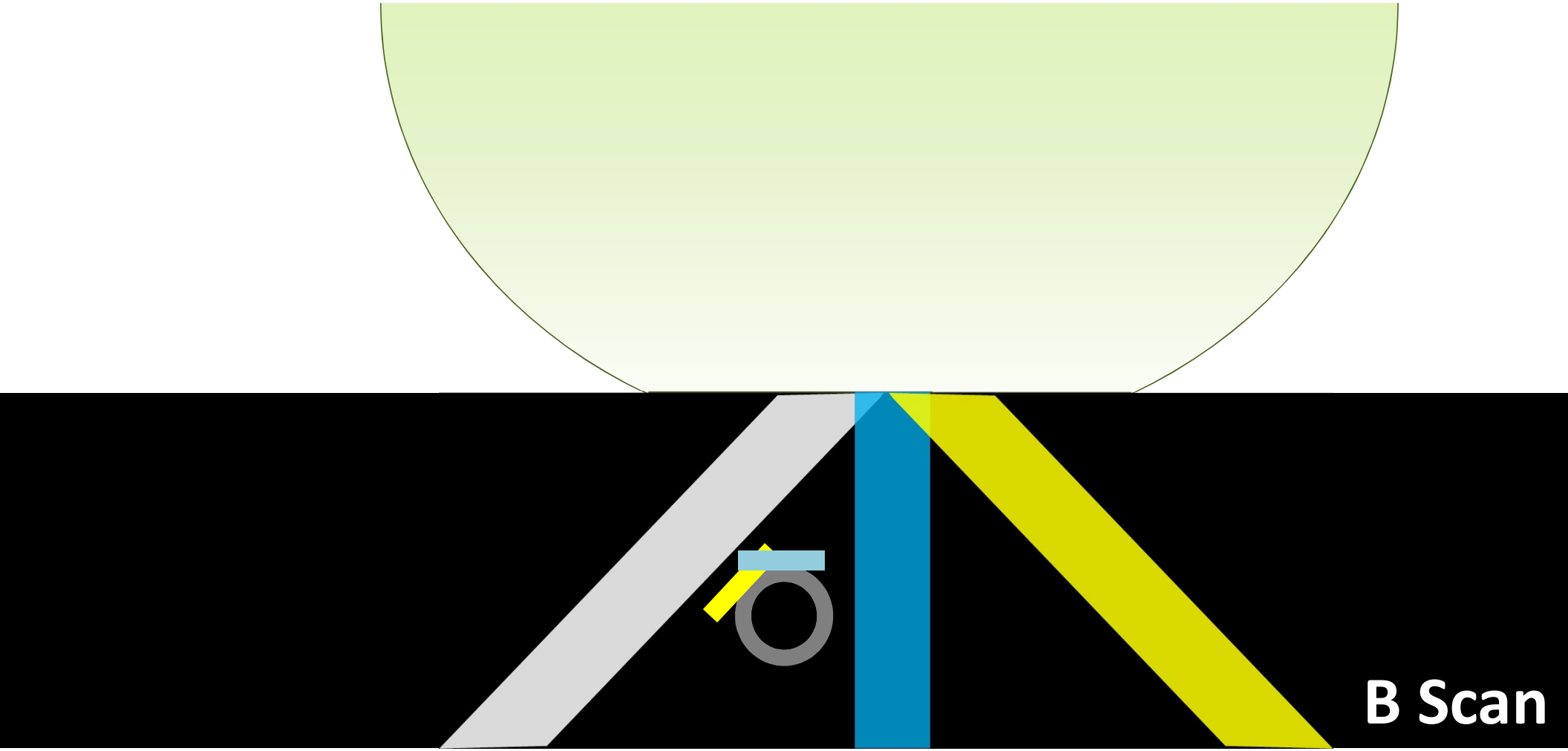
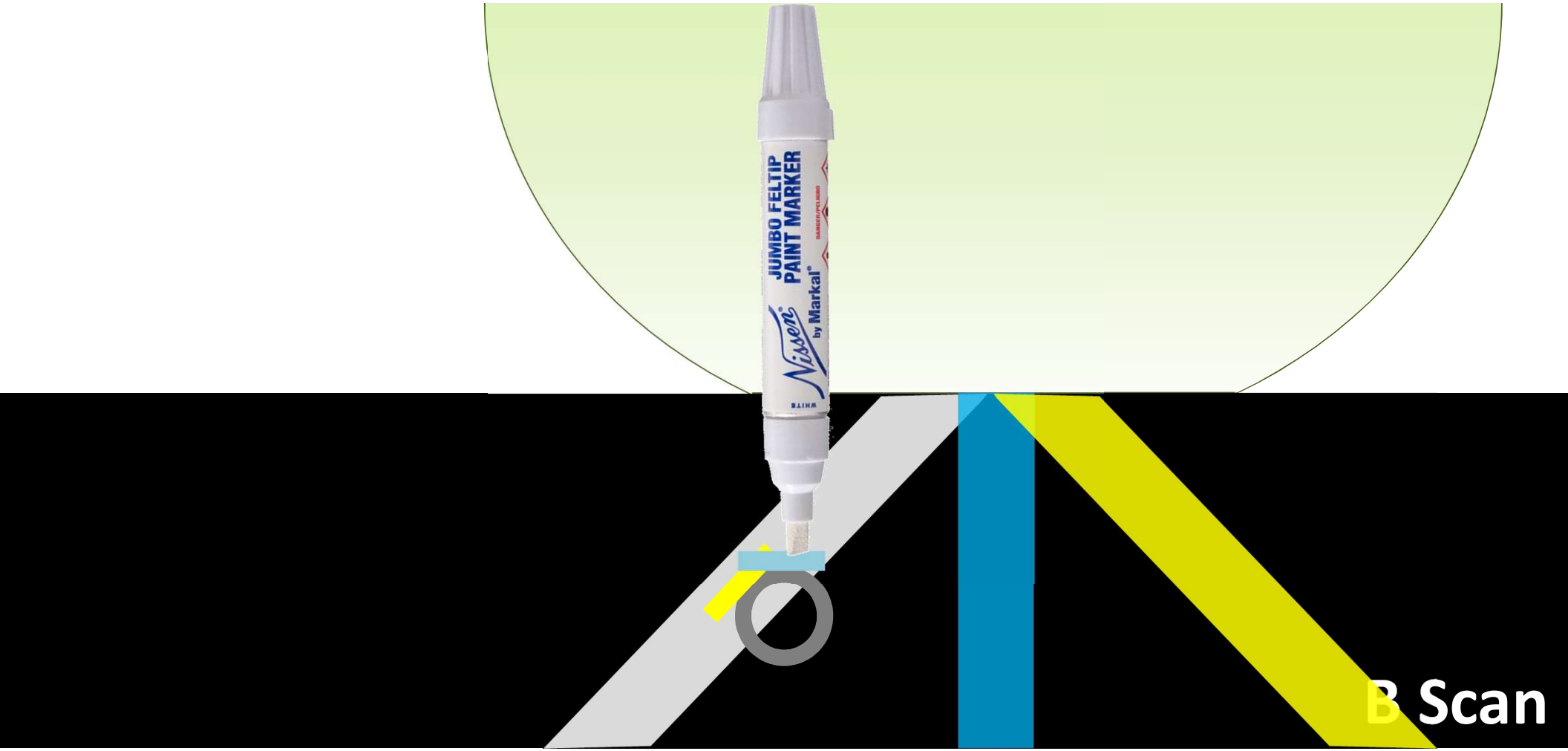
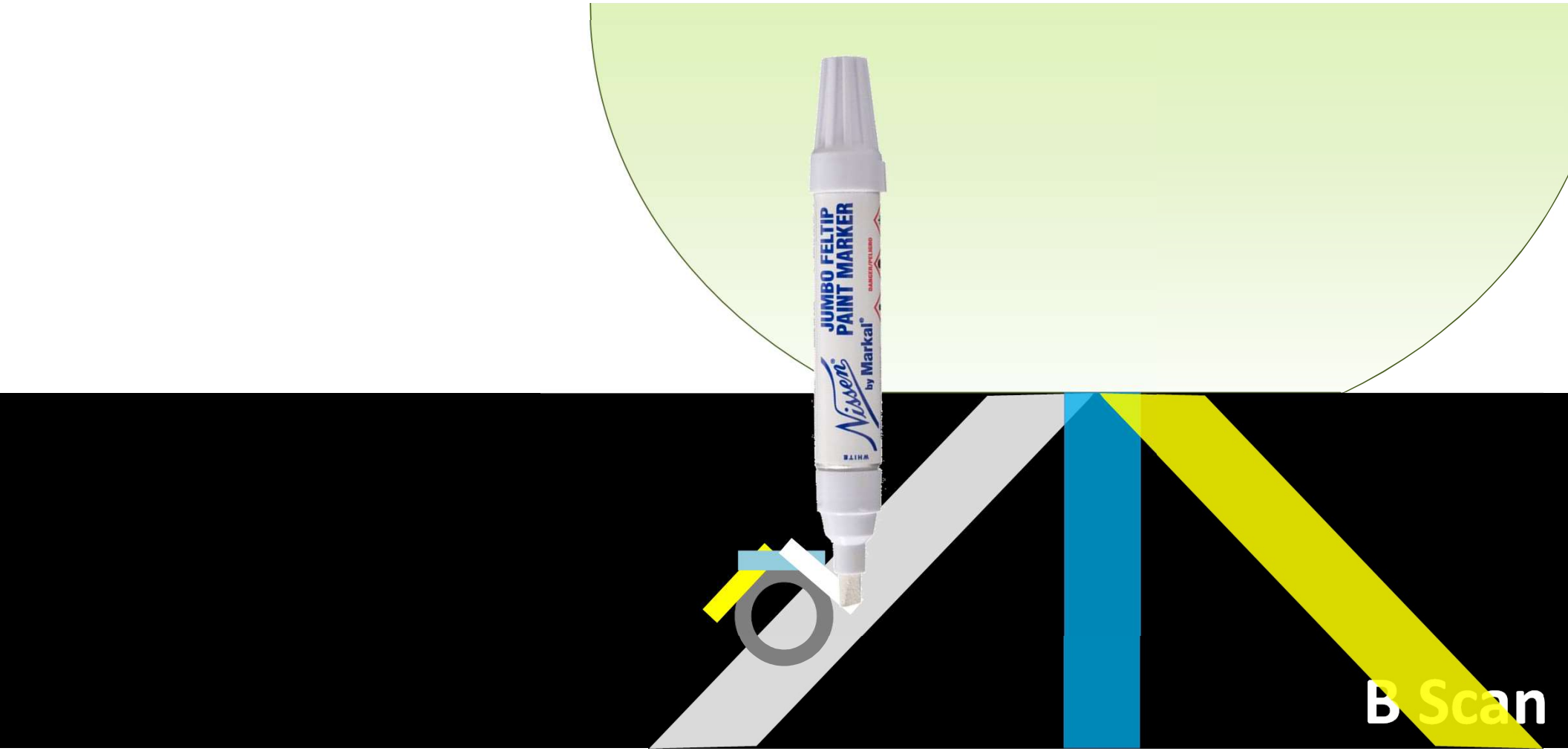

B Scan



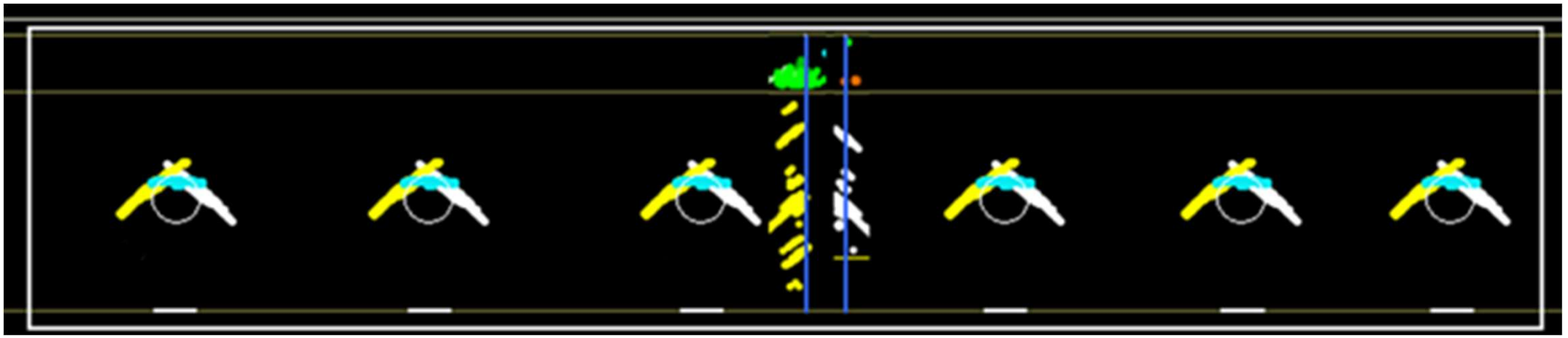
B Scan



B Scan

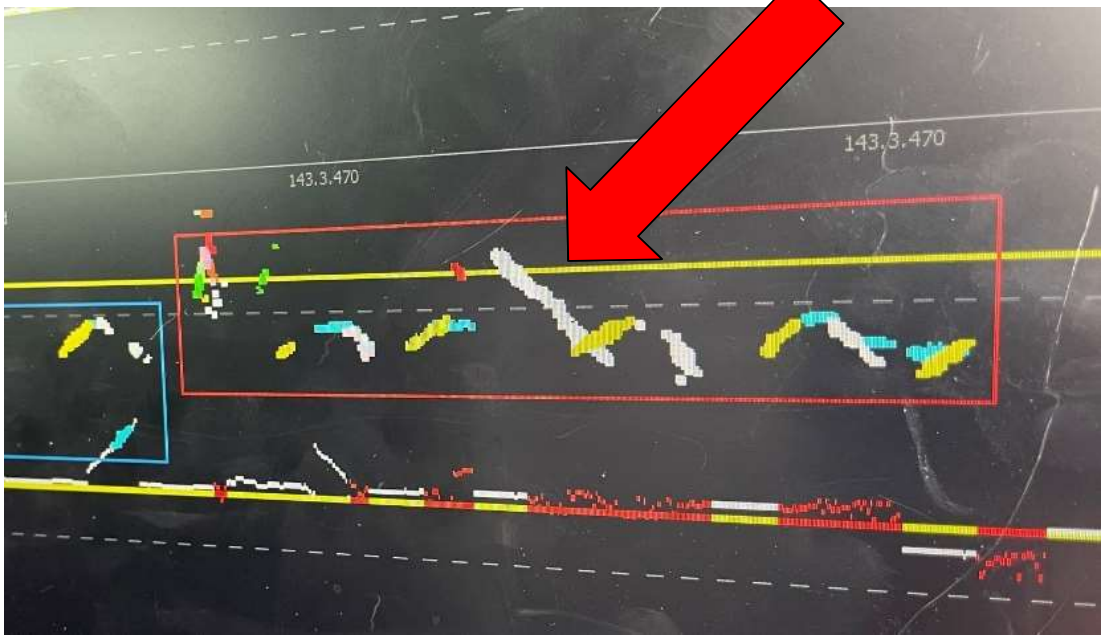
B Scan

B Scan



Example B-Scan of bolt holes in joint bar

Example Bolt Hole Crack in B-Scan



Example Cracked Wheel Detector

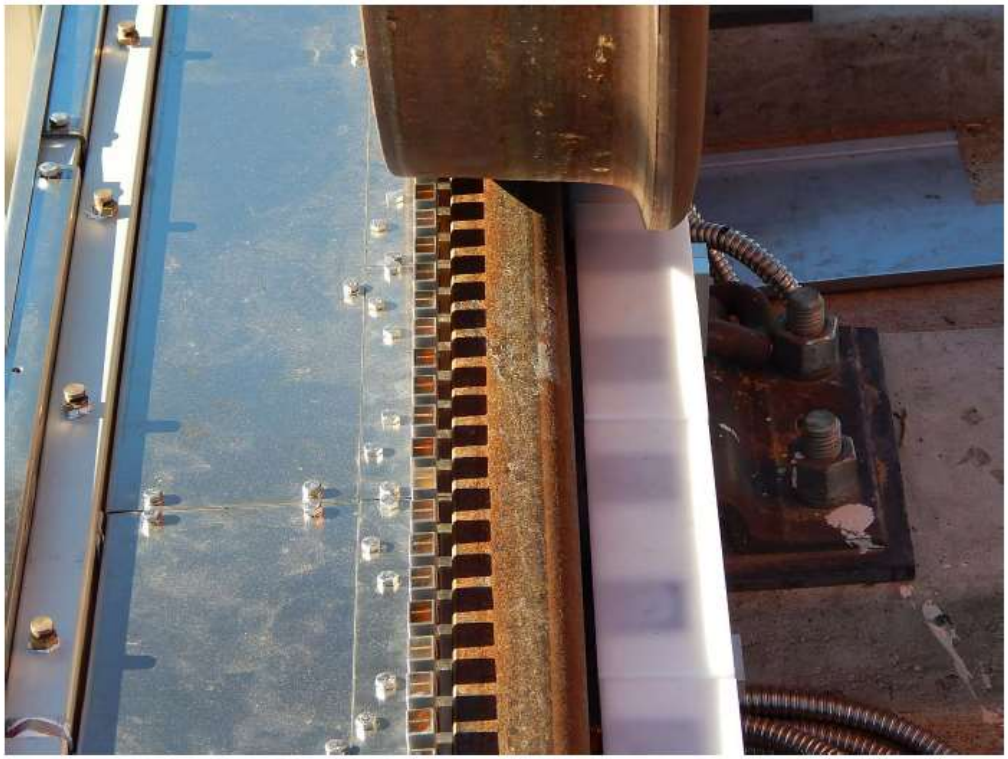
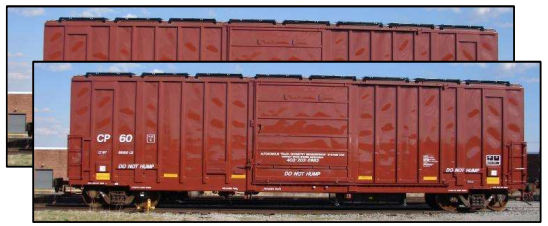
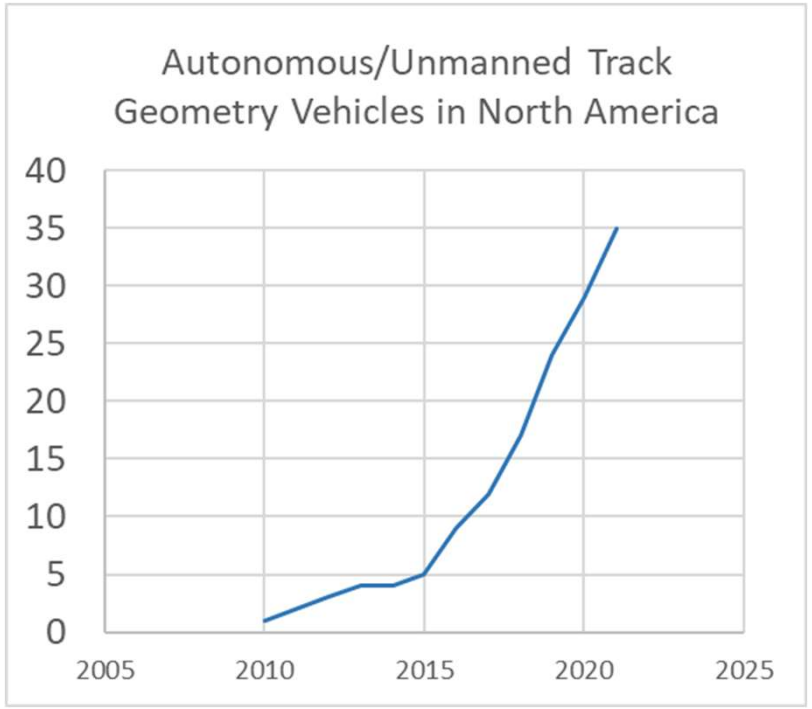


Image from Proceedings of 2018 AAR Review Matthew Witte, " Effectiveness of Cracked Rim Detectors to Identify Broken Wheels"

The Future is Here

1) Autonomous Track Inspection

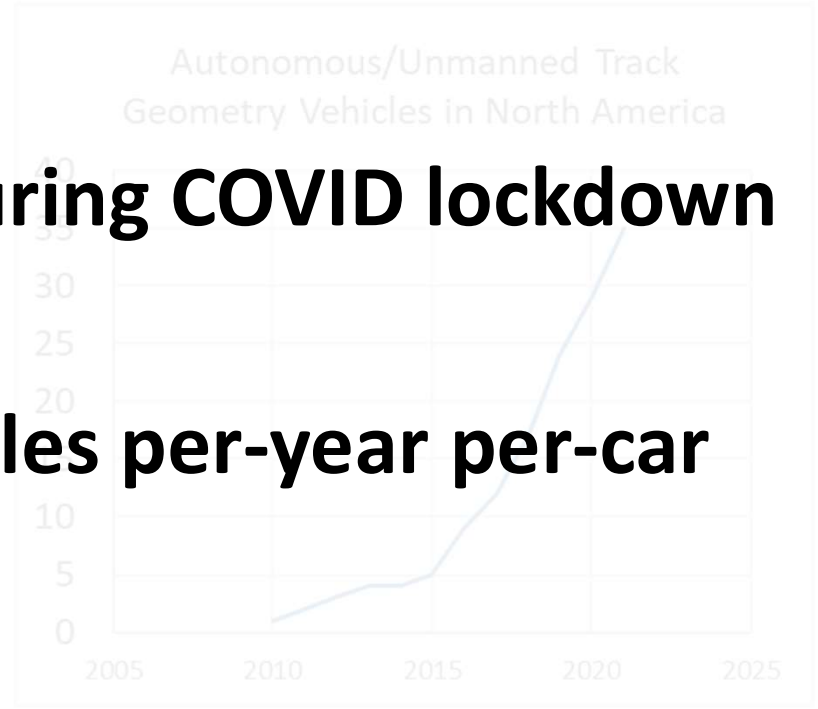




1) Autonomous Track Inspection

Surveying didn't slow down during COVID lockdown

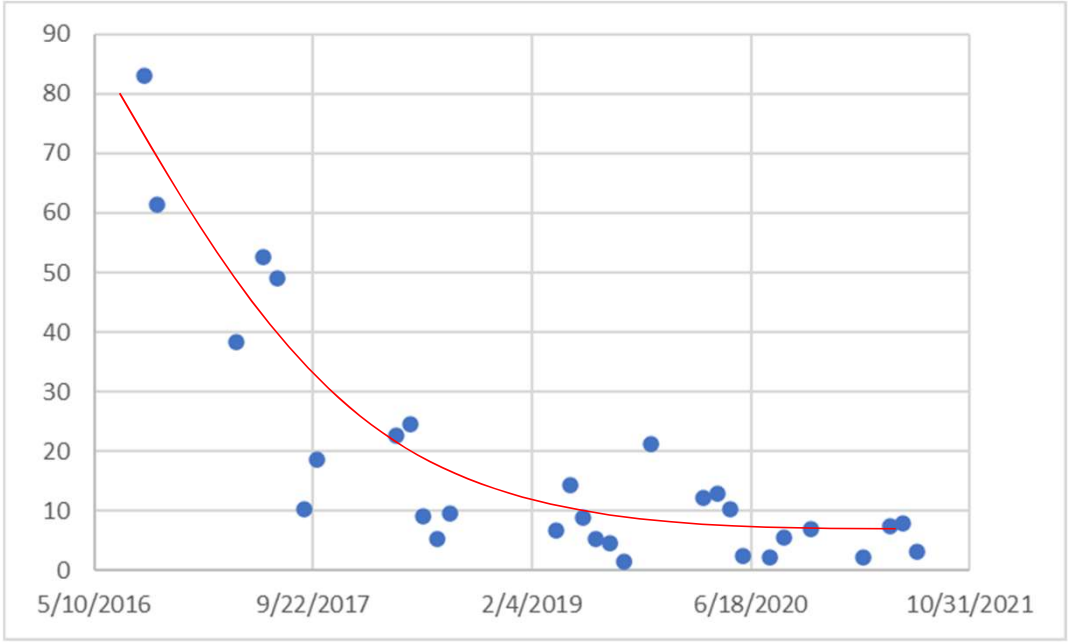
Starting to achieve 100,000 miles per-year per-car



1) Autonomous Track Inspection

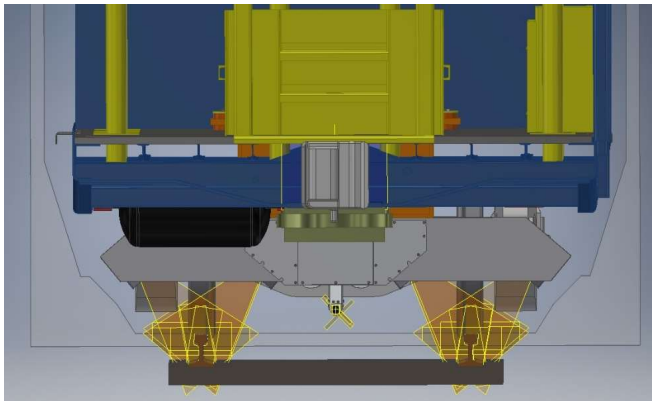
Monthly Survey Maximums of Urgent Exceptions per 100 Miles on Example Subdivision

Regulatory Exceptions per 100 Miles

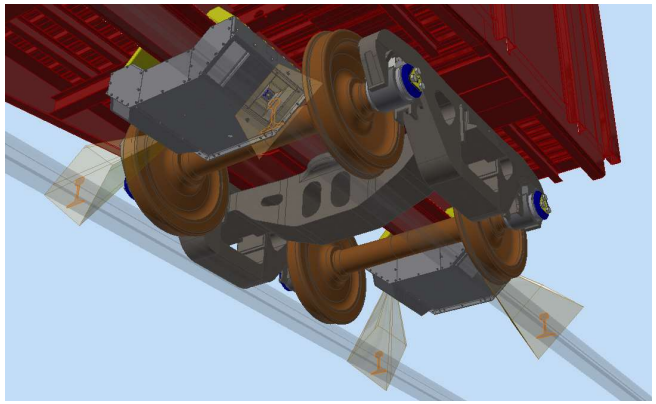


10X Reduction

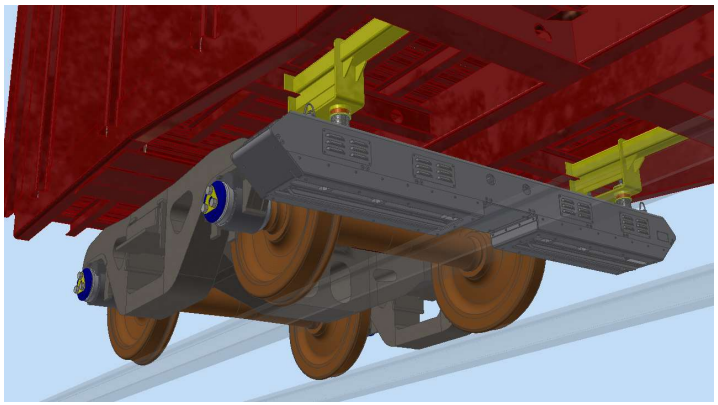
1) Autonomous Track Inspection



Carbody Mounted Autonomous Rail Profile

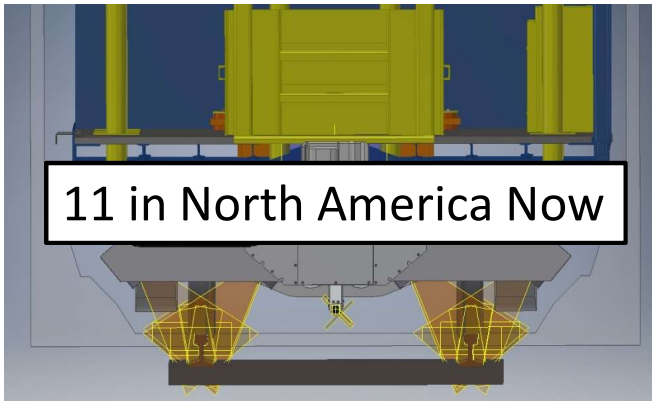


Carbody Mounted Autonomous Zero Speed Track Geometry

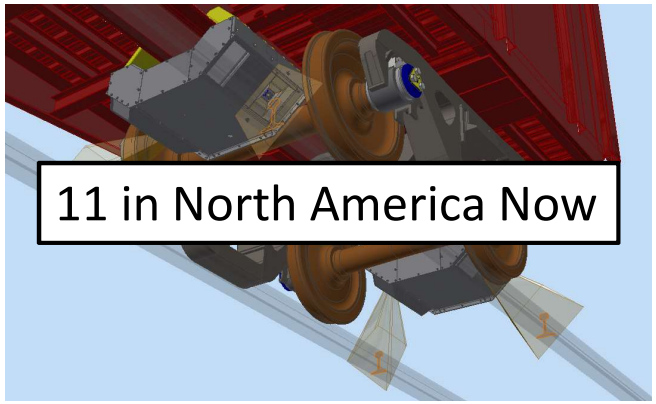


Carbody Mounted Autonomous Joint Bar Imaging

1) Autonomous Track Inspection



Carbody
Mounted
Autonomous
Rail Profile



Carbody
Mounted
Autonomous
Zero Speed
Track Geometry

Carbody
Mounted
Autonomous
Joint Bar
Imaging

2) Reducing Field Visual Inspections

Regulators are issuing waivers for reduced field visual inspections.

Increased automated inspection is required to reduce field visual inspections.

2) Reducing Field Visual Inspections

Track Inspection

Train Inspection

Ref: https://beenavision.com/TrainWatch.php

3) Digital Twin

Definition:

A **digital twin** is a virtual representation that serves as the real-time digital counterpart of a physical object or process.

Gain insights for improvements

What-if analysis

Real-time operation modifications

Ref: https://www.railexpress.com.au/going-data-insights-the-value-digital-twin-rail/

3) Digital Twin

THEN….

3) Digital Twin

NOW…

Autonomous Track Geometry

VAMPIRE
VAMPIRE
VAMPIRE VAMPIRE
VAMPIRE VAMPIRE

Derailment Risk

Track Deterioration Loads
(Virtual Instrumented Wheelset)

Rail Wear Index

Questions?