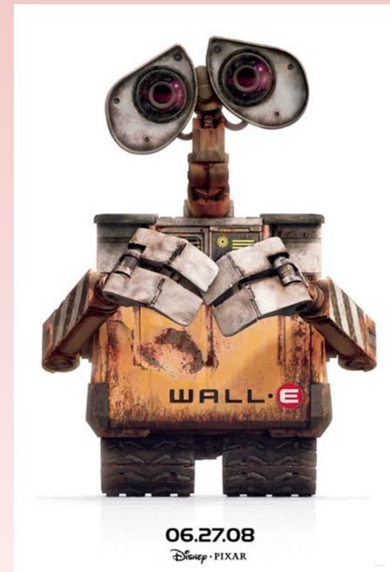
Machine Vision: A Closer Look



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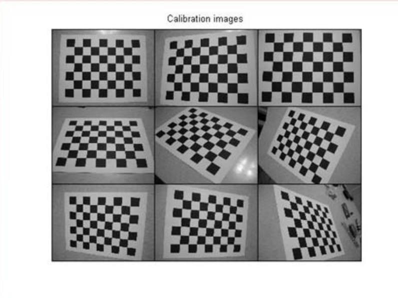
CSX

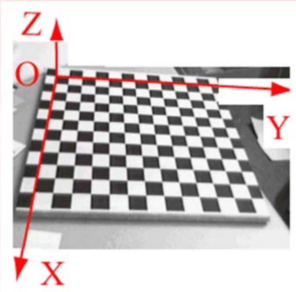
Components of Machine Vision

- **Optics:** Maps the 3-D world size objects onto the small sensor
  - Lens
  - Protective glass window
- **Sensor:** Converts the projection from the lens into pixels
  - Pixel Size
  - Resolution
  - Sensitivity
  - Noise level
- **Filter:**
  - Passes desired and blocks undesired light wavelengths
  - Passes or blocks light form certain directions only
  - Pass or block light with certain polarizations
- **Capture:** Captures the camera transferred out of camera into a computer
  - Speed
  - Camera interface
    - GigE (1 Gbps)
    - Camera Link (2, 4, 5.4, 6.8 and 16Gbps)
    - CoaXpress (25 Gbps)

Components of Machine Vision

- **Trigger:** lets the camera know when to take a picture. Need to locate train objects and track them.
  - Wheel sensors, Force sensors, Optical sensors
- **Calibration:** Enables the image to know the real world properties of objects such as size and depth





- **Analytics:** Process of analyzing image data to generate information about the objects of interest e.g. size, shape, etc.

New Advances in MV

- Higher availability and lower cost
- **New sensors:** just look at your cell phone camera
- **New cameras:** Sensor speed, quality & and camera speed; Slow motion in your phone runs at 240 fps.
  - 5,000 fps is possible with under $10,000 per camera
- **Lighting systems:** LED, laser, structured light, strobe lights
- **Narrow band lights:** New lighting systems with extreme intensity at narrow bands
- **Huge computational** power in your everyday computers
- New algorithms are capable of much more than imagined 10 years ago

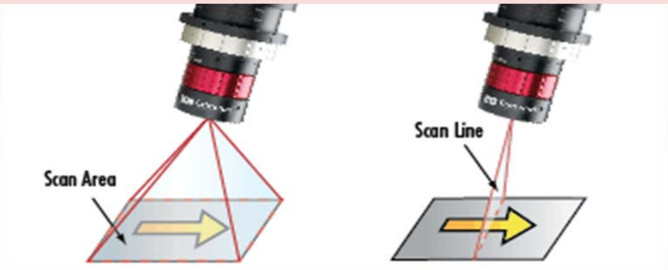
2-D vs 3-D

- For image analysis, 3D images can be a huge plus
- Not all 3D images are good
- Generating 3D images in the real world is not simple and can create more problems
  - Multi-camera (stereo vision)
  - Structured light (Xbox kinect)
  - Composite methods
- Laser based 3D point cloud are very useful
- Creating 3D image data generated by composite methods (combining 2D images and depth information) is effective way of generating 3D information
- 3D images are in many cases over rated and may not be as productive as some expect
- 3D data in many applications can only provide good supporting information

Line Scan vs. Area Scan

Area scans

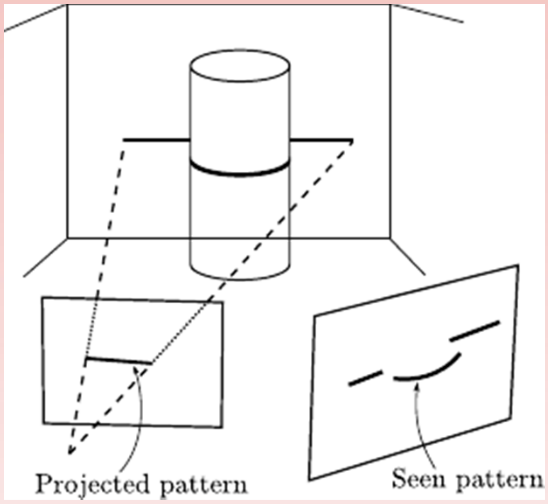
- Easy to use
- Perspective effect in both dimensions
- May require image stitching
- Needed for 3D data



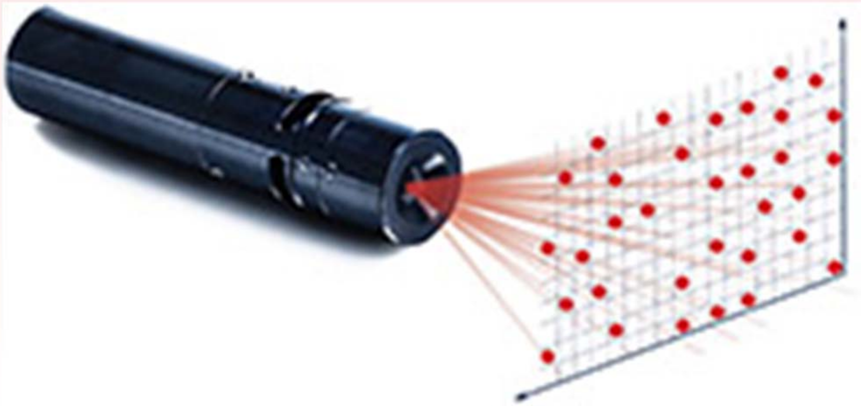
Line scan

- Well suited for long moving linear objects: Trains
- Efficient lighting
- May require cropping
- Better suited for applications with ambient light problems

Lighting



- LED technology
- High power laser diode technology
- Sophisticated structured lights
  - 100,000 point laser light
- High speed strobe lighting
- Narrow band lights
- Multispectral lighting
- NIR and UV lighting



Storage of Images

For *one* line scan camera, with *uncompressed* output:
One mm per scan
One 50' car = 15000 scans = 30 Mbytes per camera per car

How much for an entire train?
100 cars x 10 cameras x 30 Mbytes per camera per car = 30 Gbytes

After JPG compression:
30 GBytes = 3 GBytes

What is the download time?
- With 10 mbps connection: 40 minutes
- With 1 Gbps connection: 24 seconds

Some newer systems generate more than 1 TB of data per train.

Challenges for MV in Rail

Several imaging factors are difficult to control in the railroad environment:

- Ambient light
- Train speed
- Surface conditions
- Environmental conditions
- *Heavy* shock and vibration

➢ Need for high quality images: High data rates

➢ Need for intelligent image analytics : High computational complexity

Hardware Components

First Step: Start with a well drained, tangent site.

Next: Create "railroad proof" wayside installations – with blowers, heating pads, shutters; protection from dragging equipment

Then add: Wheel sensors for timing of image acquisition; power

What does this mean for future track maintenance?

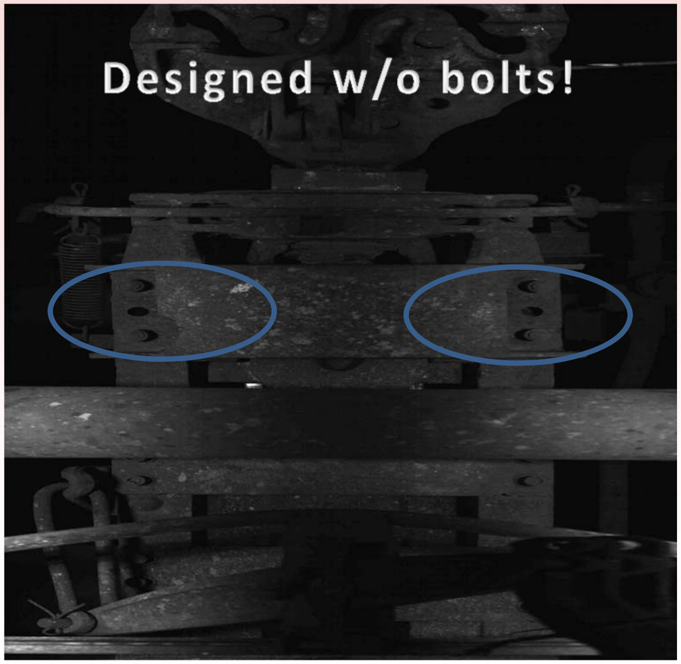
The tamper always wins!

Processing of Images & Alarms

- Should humans review ALL images? Only some?
- CSX sees 9-10,000 axles per day per system (~25 trains)

Processing of Images & Alarms

- Algorithms aren't perfect!
- Images aren't perfect!
- Car construction isn't standard!



Integrating Images into RR Operations

- Use only Meta data?

Defect Code Description :

Code 0 : No defect
Code 1 : Single Missing Fastener
Code 2 : Double Missing Fasteners, Two sides
Code 3 : Double Missing Fasteners, single side
Code 4 : More than two missing fasteners
Code 5 : Missing Plate
Code 6 : Rotated plate
Code 7 : Displaced plate

- When should trains be stopped?

- Who can make the repair?

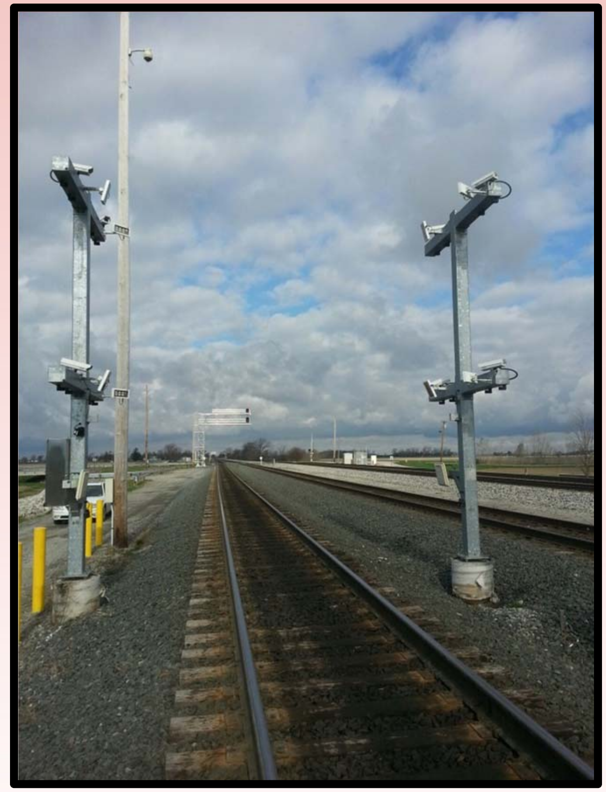
Current Applications in Rail

What is currently available in the market place?

- Wheel Profile Measurement
- Truck Inspection
- Brake shoe measurement and component inspection
- Undercarriage condition monitoring
- Coupler securement inspection →
- Track Inspection
- Low hanging air hose inspection
- Asset monitoring (tunnels, etc.)

Intermodal Inventory

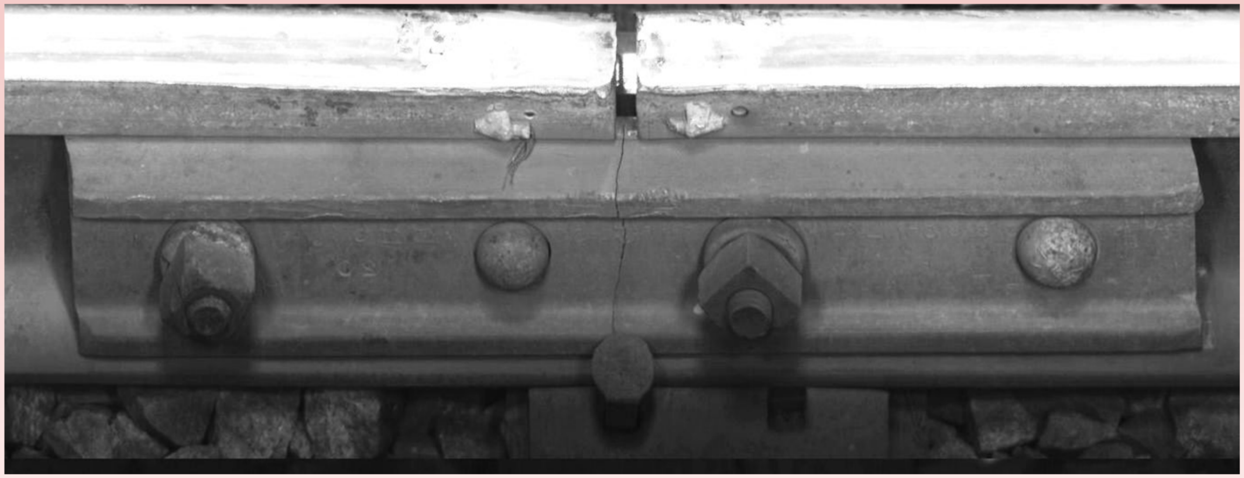
Gate Software with integrated OCR to update inventory & position.

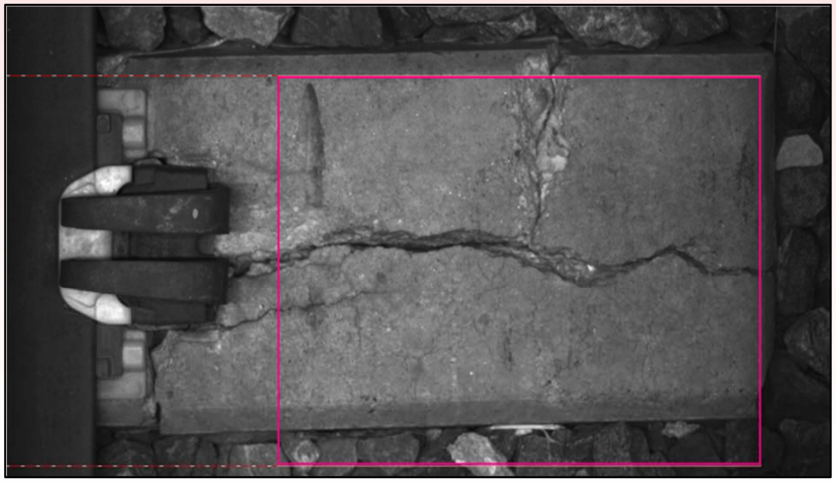


APS Technology at CSX's NWOH Intermodal Yard

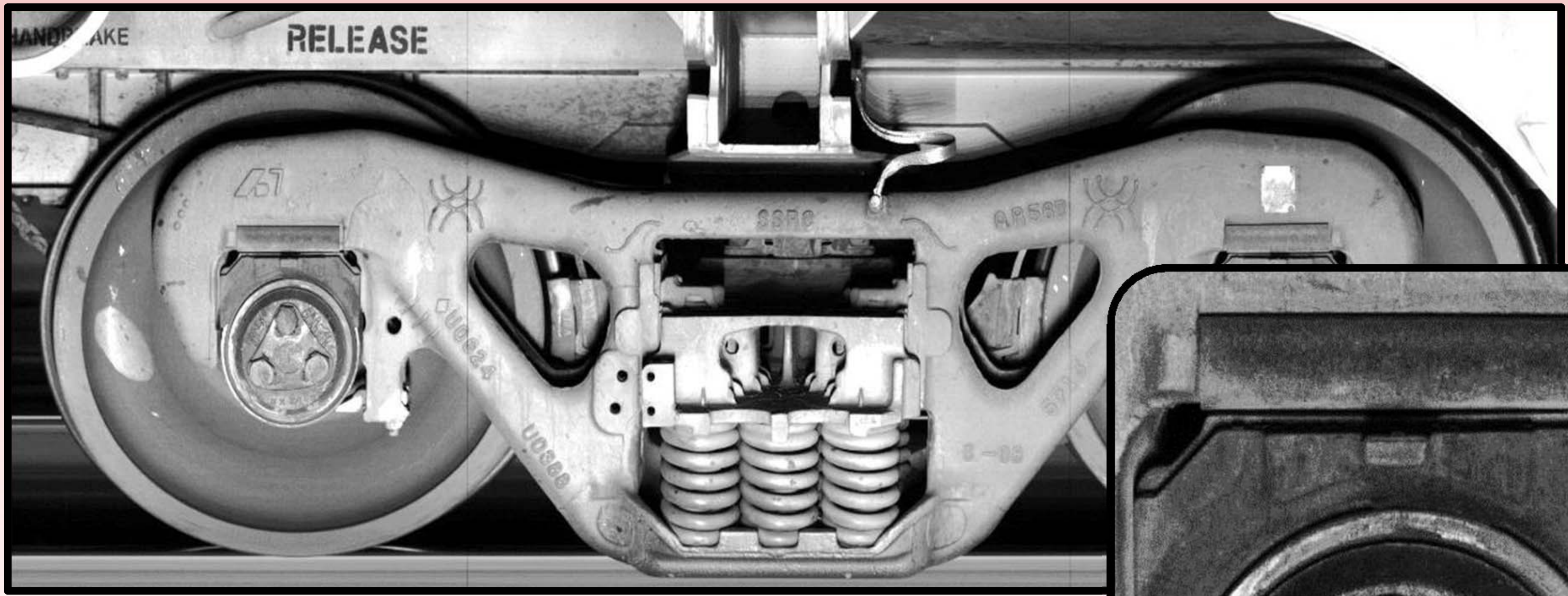
Track Inspection Tools

Track Inspection Results

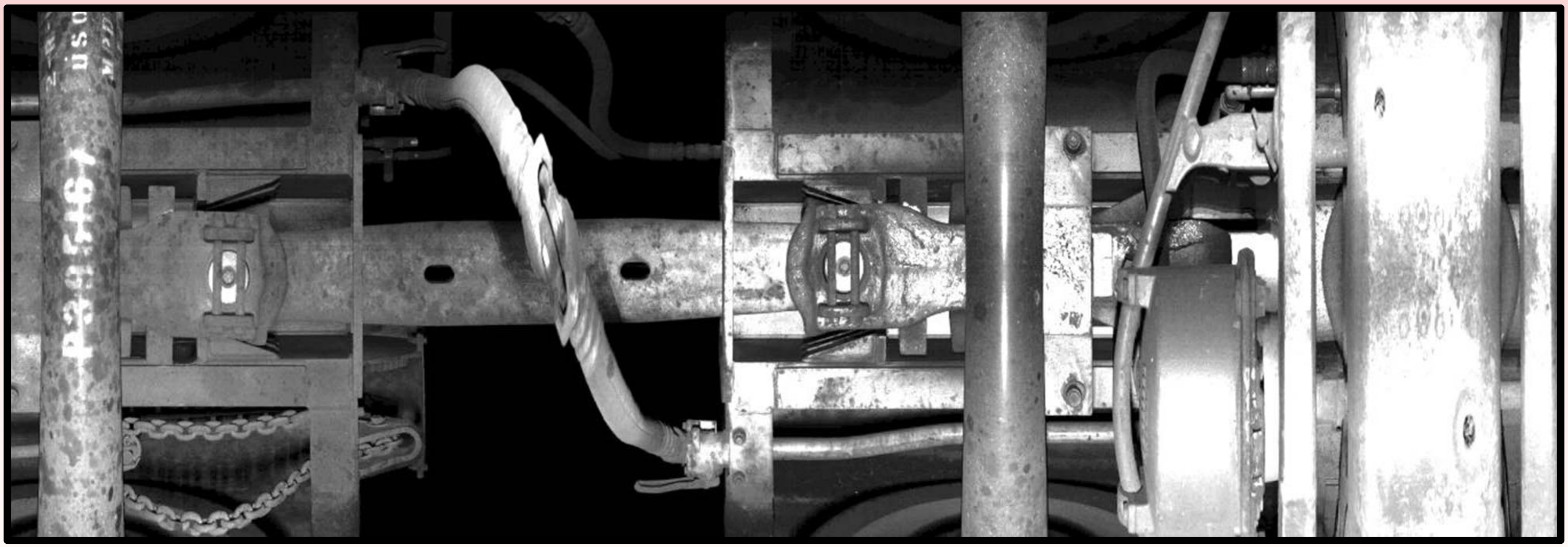




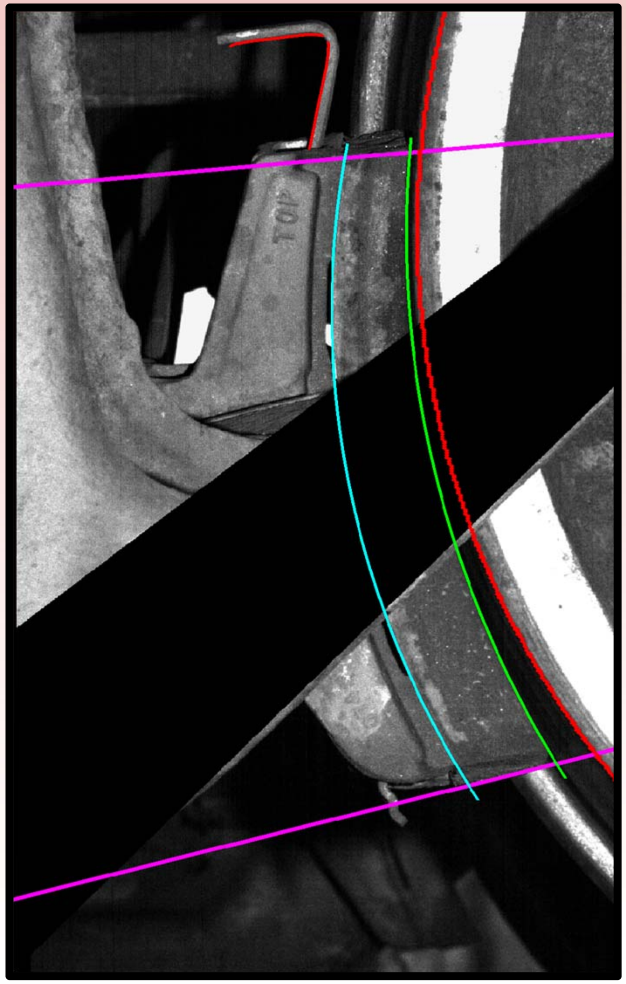
Truck Inspection



Undercarriage MV

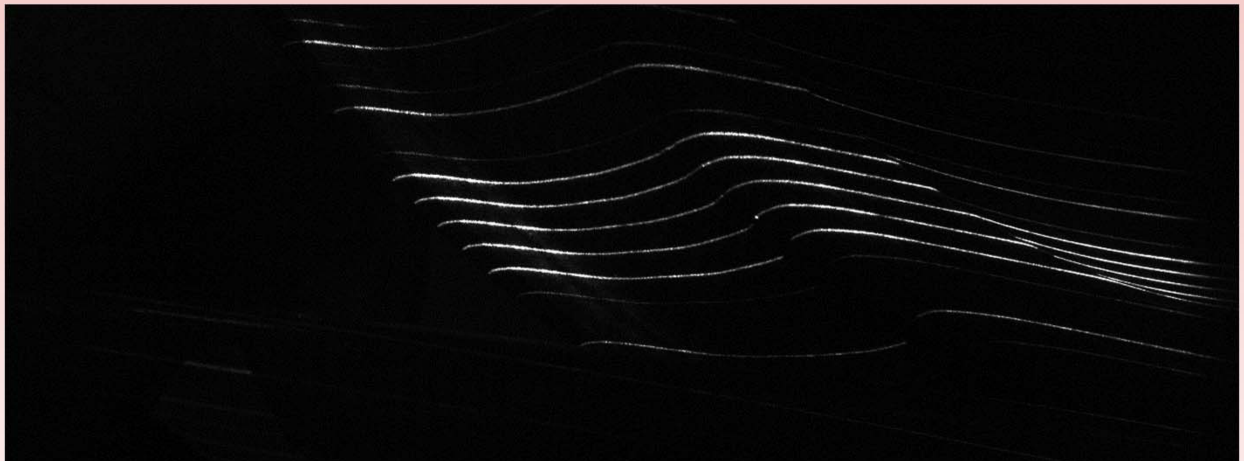


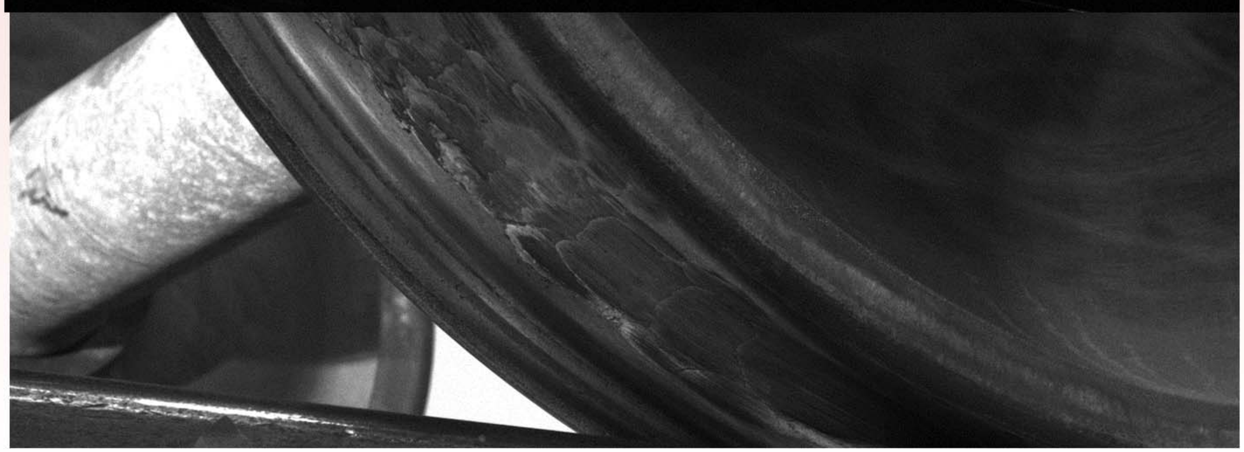
Brake Shoe Thickness MV



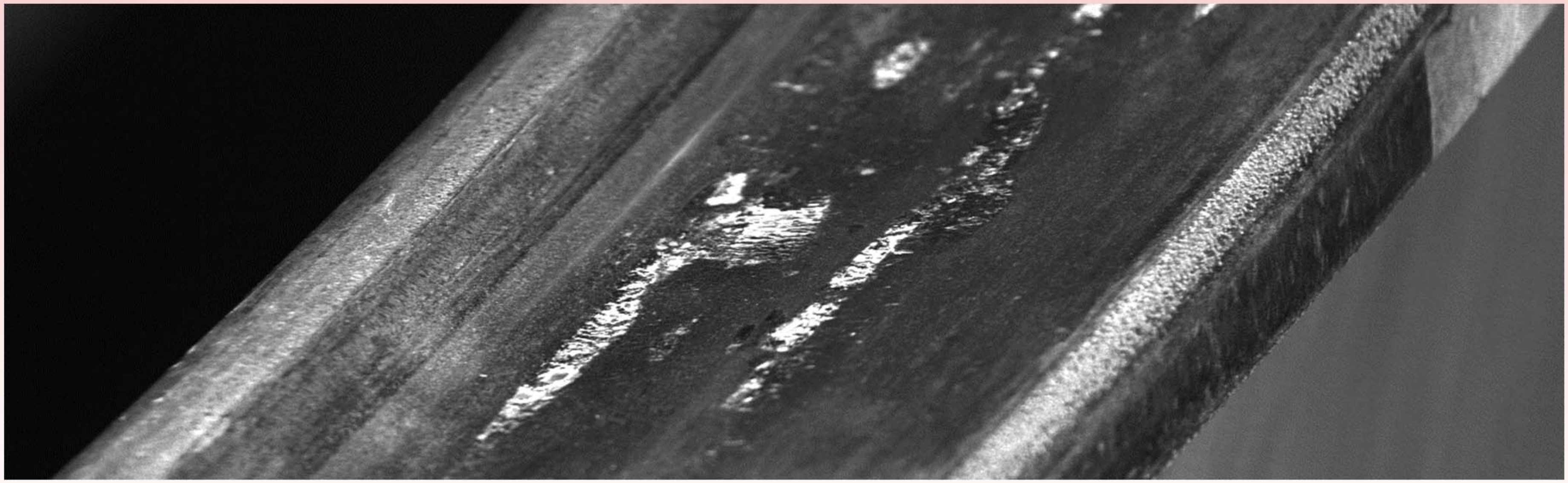
Laser Scan – Same Wheel in Motion

Tread Surface Defects



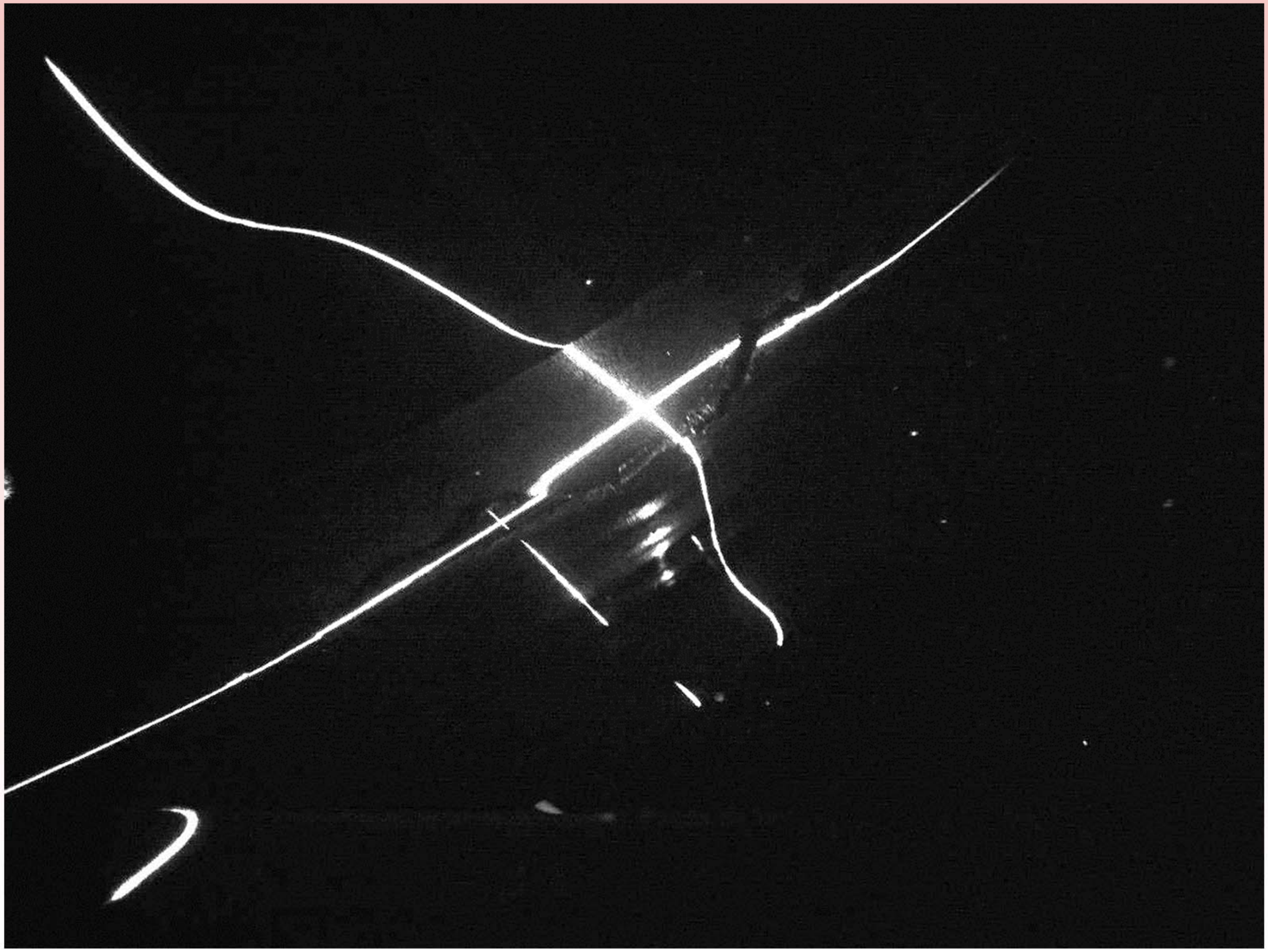


Surface Image Quality



Surface Image Discontinuity

Surface Image Discontinuity



Future Uses of MV Tools

- MV + OCR to support AEI (beyond Intermodal)
- MV to validate AEI – A vs. B end; axle count
- Border protection
- Aerodynamic/intermodal “slot” efficiency
- Forward-looking IR locomotive cameras
- Inward cameras with Gesture Based Interfaces

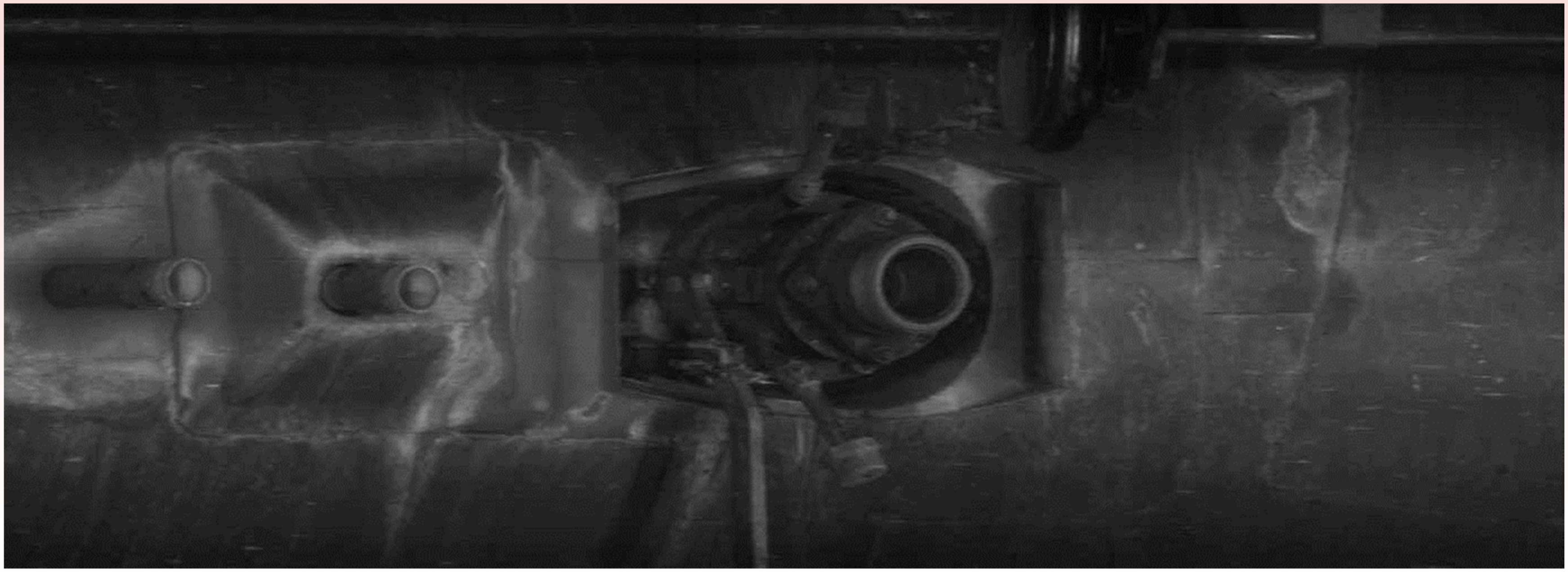
California’s
MetroLink Camera

Future Uses of MV Tools

- Whole car imaging to support damage claims
- Open Top Load Securement

Future Uses of MV Tools

- Inspection of center of car components (tank car valves, slack adjusters)



Questions?

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