Industry Innovations and Thought Leaders:

Silver Bullet Technologies

Michael Roney, IntPE

www.iron-moustache.com

Heavy Haul Technology Benchmarking Participants

- Australia
- Brazil
- Canada
- China Railway
- Europe
- Russia
- South Africa
- Sweden-Norway Nordic Heavy Haul Assoc.
- USA


Silver Bullet Innovations

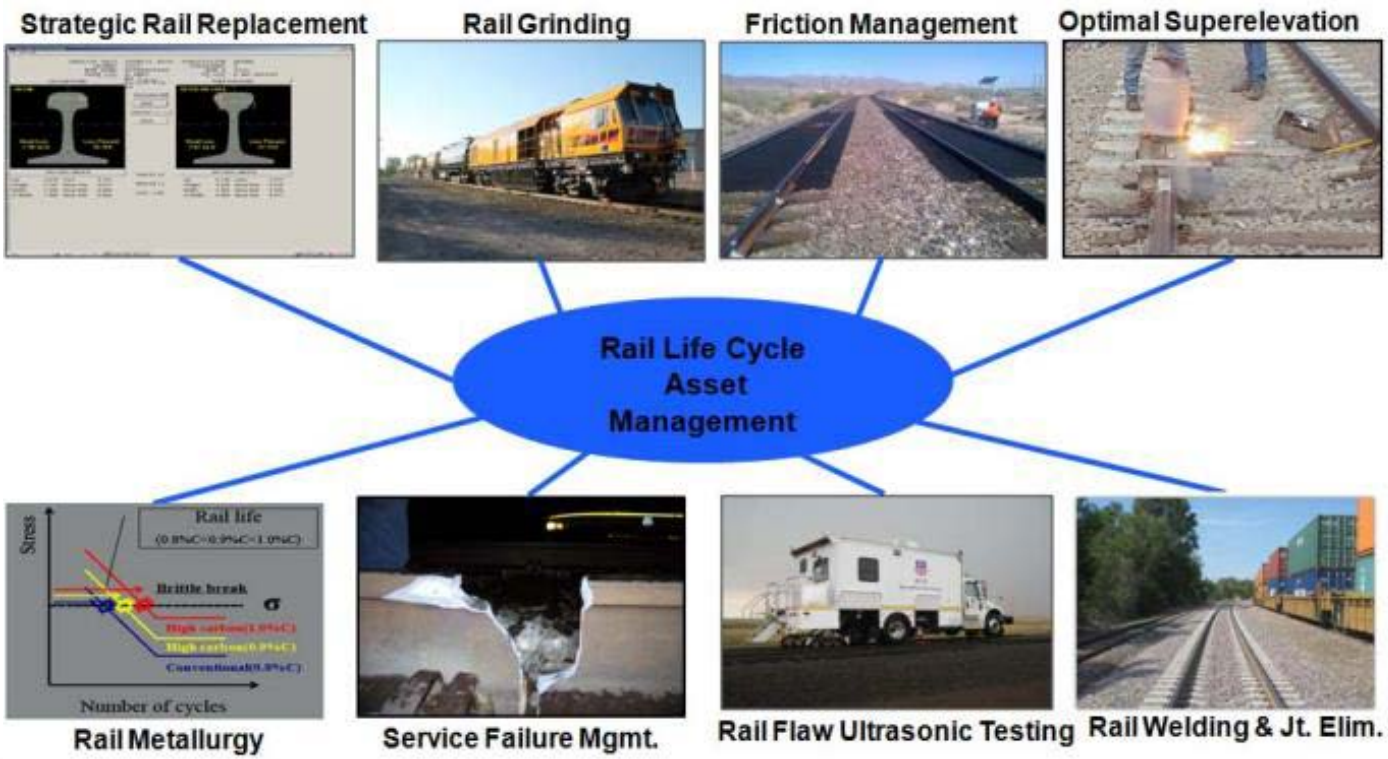
1. Precision control of wheel/rail interaction
2. Computer-assisted rolling stock inspection
3. Computer-assisted track inspections
4. Communications-based train control
5. Autonomous train operations

Wheel/Rail Interaction Management

We know the "sweet spot":

1. **Rail grinding at the "Magic Wear Rate" to low stress rail profiles**
2. **Wheel/rail friction maintained at 0.3-0.35 on top and <0.25 on rail gauge face**
3. **Wheel profiles designed for moderate single point contact and wheel tread hollows maintained < 2.5 mm**
4. **Superelevation set to account for train buff and draft forces**
5. **Micro-alloyed wheels and rails with 350 BHN plus hardness**

Rail Life Cycle Management at UPRR



Wheel/Rail Interaction Management

What is possible with good execution:

1. **30%-50% reduction in lateral forces**
2. **10-fold reductions in rail gauge face/wheel flange wear**
3. **Complete control of rolling contact fatigue**
4. **Rail lives of 5 BGT in tangents, 1.5 MGT in 5 degree curves, wheel lives of 1.5 million miles**

Computer-assisted Rolling Stock Inspection

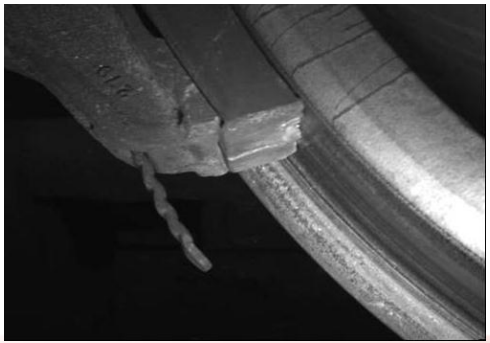
Finding the "sweet spot":

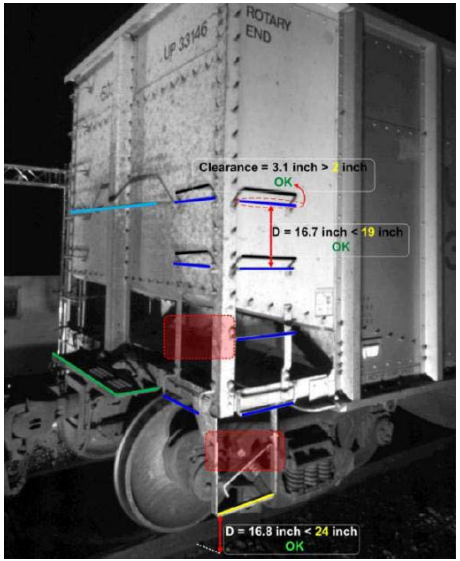
1. **All potential wheel, truck, bearing, or brake issues are detected by wayside or onboard performance detectors equipped with trending algorithms**

2. **All cracks, bent, worn or missing components are detected by digital imaging and either recognized by machine intelligence or by systematic review of images by inspectors while trains are en route.**

Building Blocks

AIR Tablet





Digital Imaging Inspection of Freight Car Safety Appliances

FACTIS Digital Imaging Inspection of Brake Shoes and Wheel Wear

Computer-assisted Rolling Stock Inspection

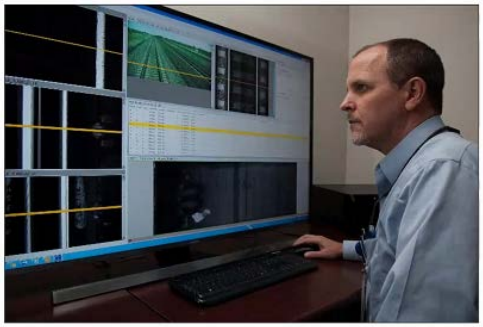
What is possible:

1. **Elimination of visual/manual inspections of standing trains**
2. **Carmen directed to specific locations in train for verification and repair in-train of BOE defects**
3. **Predictive analytics on emerging maintenance issues**

Car inspectors in China

Computer-assisted Track Inspection

Virtual Track Walk Software



1. All potential rail, tie, ballast, geometry, turnout and subgrade issues are detected by onboard or wayside performance detectors equipped with trending algorithms.

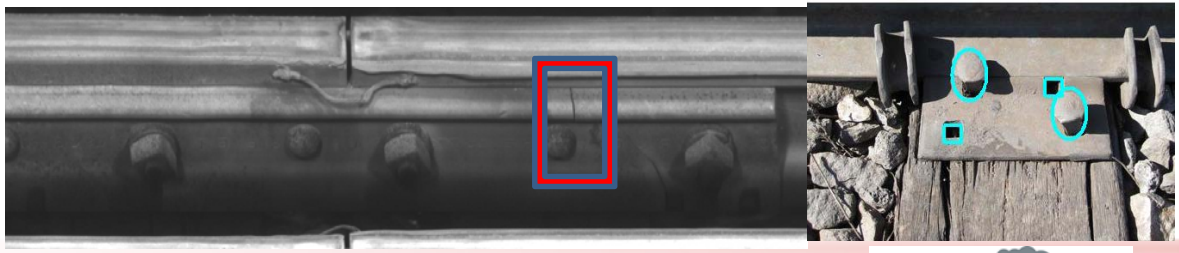
2. All cracks, worn or missing components are detected by ultrasound or digital imaging and either recognized by machine intelligence or by systematic review of images by inspectors without the need to be on track.

Computer-assisted Track Inspection

What is possible:

1. **Elimination of routine visual/manual inspections of track and turnouts.**

2. **Track repair crews directed to specific locations in track by GPS for verification and repair.**



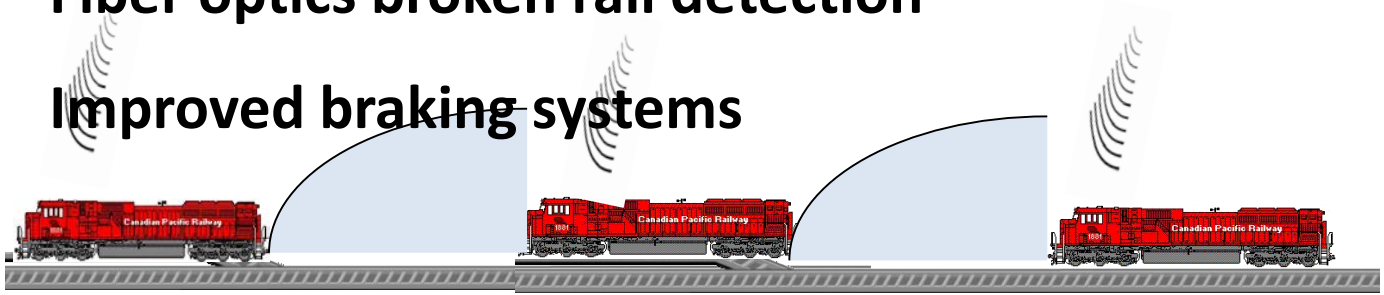
Communications Based Train Control

- A continuous automated train control system
- High resolution train location
- Control point remote monitoring
- Independent from track circuits
- Continuous bi-directional train to wayside data communications.
- Trainborne and wayside processors enable ATP
- Automated train operation is enabled

Communications Based Train Control

The Enablers:

1. Standalone PTC without fixed signals
2. 4G communications capabilities
3. Fiber optics broken rail detection
4. Improved braking systems



Communications Based Train Control

What is Possible:

1. **Virtual moving blocks allowing trains to operate at tight headways**
2. **Train plan adapted to available capacity at any point in time**
3. **Trains launched and dispatched with computer algorithms**
4. **Computer based train protection**

Autonomous Train Operations

What is Possible:

1. Drivers not required in locomotive cab
2. Driving strategy optimized for route and consist
3. Reduced in-train forces and fuel
4. Overseen by roving Trainmasters

Rio Tinto Auto Haul Train

Key Enabling Technologies

- 4G communications networks
- Energy harvesting from freight cars
- Fiber optics distributed acoustic sensing (to 10m)
- Digital imaging with computer pattern recognition
- Real time data mining analytics

Rail 4.0

A new range of disruptive technologies, collectively labelled 'The Fourth Industrial Revolution' (4iR) will imminently transform the way we live and work by fusing the physical, digital and natural worlds together. Incorporating machine learning, artificial intelligence; synthetic training; autonomous systems; and data analytics, 4iR technologies are all distinct areas of innovation but the characteristic they all share is an ability to transform industries, economies and processes.

A.k.a. "We need to change to be relevant".

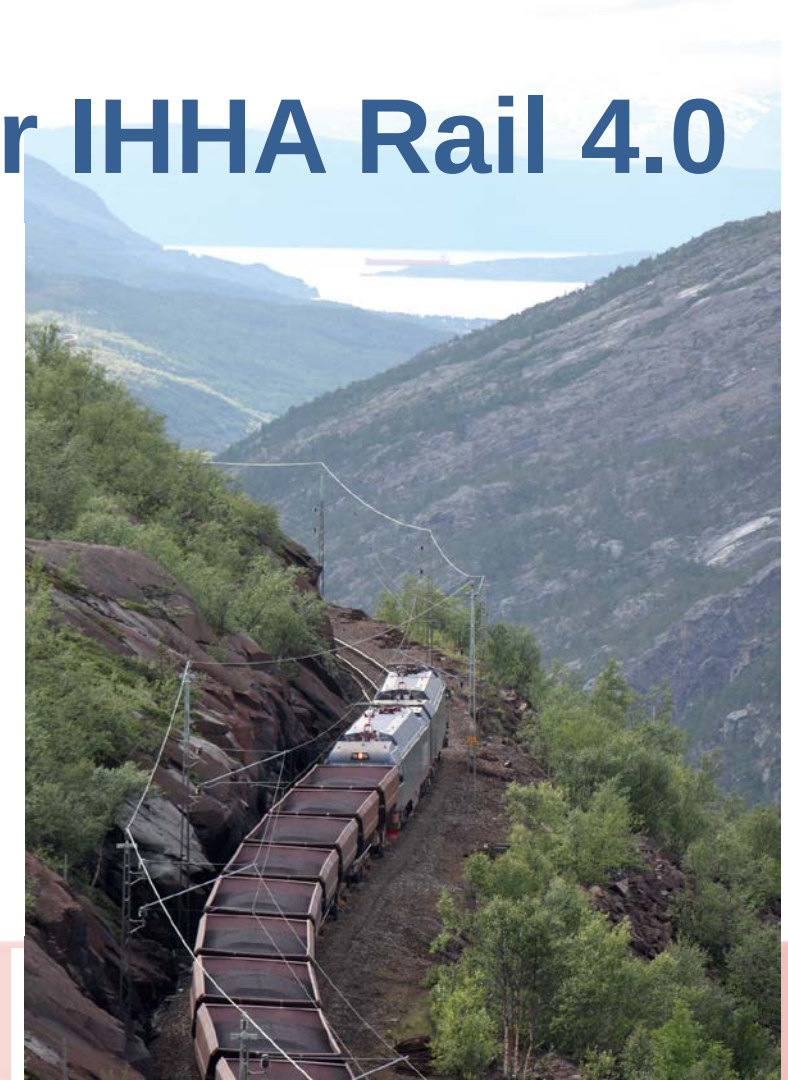
Join us in Norway for IHHA Rail 4.0

08. - 12. June

IHHA

NARVIK 2019

INTERNATIONAL HEAVY HAUL ASSOCIATION STS CONFERENCE



HEAVY HAUL SEMINAR • MAY 2-3, 2018