THE FUTURE OF RAILROAD SAFETY

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PRESENTATION OVERVIEW

- **Safety Objective and Concepts**
- **Safety Value and Perception**
- **Railroad State of Good Repair**
- **Track Inspection Quality Indices**
- **Future Safety Strategy—Value of Safety**

PURPOSE AND FIRST PRIORITY IS SAFETY

- Duty and responsibility to enforce the railroad safety laws of the United States
- Promote and enhance safety in all areas of railroad operations, and
- Monitor and assess safety risks to reduce railroad-related accidents

CURRENT OBJECTIVE

To examine and consider the track inspection process in order to get the most value out of an integrated inspection strategy

FRA SAFETY CONCEPT

- Envisioned the regulations as a evolving set of requirements subject to continuous revisions that were intended to keep pace with both FRA and industry innovations and research,
- Reviews relevant safety statistics, findings in prior safety inspections and investigations, and
- Also guided by statutory requirements, congressional directives, recommendations by the National Transportation Safety Board and other oversight bodies, including the DOT Office of the Inspector General

FRA SAFETY CONCEPT

- Since enactment of the *Federal Railroad Safety Act* of 1970 (45 U.S. C.~421 et seq.) the concept of safety generally is in harmony with the concept of rail safety, that is, it varies with the time, the issue, the role of various stakeholders, the prominence of technology, and the level of supervision and customary practice
- The level of acceptable risks of accident and injury is on a scale where public values and attitudes toward risks, as well as, benefits *change.*
- *When are risks unacceptable?*

SAFETY PERCEPTION

1. We commonly struggle with the question of how likely a derailment will occur considering borderline equipment and track conditions and combinations that 'excite' wheel lift/climb, center-bowl separation scenarios,
2. We share a zero-tolerance responsibility with the rail industry,
3. Public demand for railroad safety generally continues evolving to higher acceptable levels and is viewed from two perspectives—safety of people (casualties) and property damage (dollars)
4. Manual inspections tend to focus on the track structure condition and associated mechanical and environmental deterioration,
5. Automated inspections tends to focus on track and rail geometry condition and associated lateral and vertical accelerations (g—forces). There are 'intangibles', but automated inspections are increasingly vital supplement to manual inspections,
6. Both inspection types seemingly has stood apart in assessing inspection priorities, both manual and automated inspections need shared focus in future—Hybrid Inspection System,

7. Principally, our safety focus should be redirected to identifying high-risk track geometry combinations causing undesirable stress and deterioration to the track structure subgrade,
8. It is often difficult to recognize (manually) the inherent combinations of poor track geometry and its overloading (stress-state) effect on the track structure that leads to conditions of instability, such as failed ballast, fastener fatigue, and rail seat deterioration, as wheel loads and capacity increase,
9. The question is: should we continue to mainly focus and rely on individual conditions in isolation OR should we also consider compliant combinations that contribute and influence poor car behavior and deteriorates the track structure? Often leading to component failure,
10. Performance-based technology systems such as: Gage Restraint; Automated Track Inspection, Ride Quality, and Vehicle/Track Interaction systems have proven successful to help inspectors identify developing and noncompliant locations,

VALUE OF SAFETY (LIFE)

1. The 21st century have introduced an era of new technology and the benefits of innovation are being felt and expanded.
2. Current FRA geometry regulations are a mixture of performance-based and prescriptive-design approach,
3. Is this track safety (pass or fail) approach valid and meaningful, are we having a effective influence on SAFETY,
4. Do we fully understand the cause of derailments (failure mechanism) and do we need regulatory change?
5. Future track inspection technology can better understand and identify safety tendencies that degrade structural components and threaten SAFETY,
6. To a greater extent, now is the time to change the way we think of SAFETY, change and influence behavior, and reduce derailments.

RAILROAD STATE OF GOOD REPAIR

Future Considerations:

1. Increased track usage decreases available track time for inspection and repair
2. Heavier trains on standard components in long-term service accelerates fatigue risks
3. Higher speeds will tighten allowed geometry variations, accelerating the maintenance cycle
4. Longer train lengths may require stronger track structure to support additional in-line train forces
5. How can the current standard and measurement ‘under load’ practice be improved and is the adoption of minimum safety standards acceptable?

Track Inspection Quality is Critical

Experienced Inspectors and Automated Inspection Devices

Experienced Inspectors/Visual

- More Detailed Inspection
- Better decision-making on discovered defects
- Capable of searching for larger variety/type
- Easier adjustment of search parameters

Automated Inspection Devices

Higher detection rate
Better at locating
- Small variations from normal
- Not plainly visible

Minimizes human influences/errors
Consistent and Precise inspection
- Day and night

Hybrid Inspection System (HIS) Approach

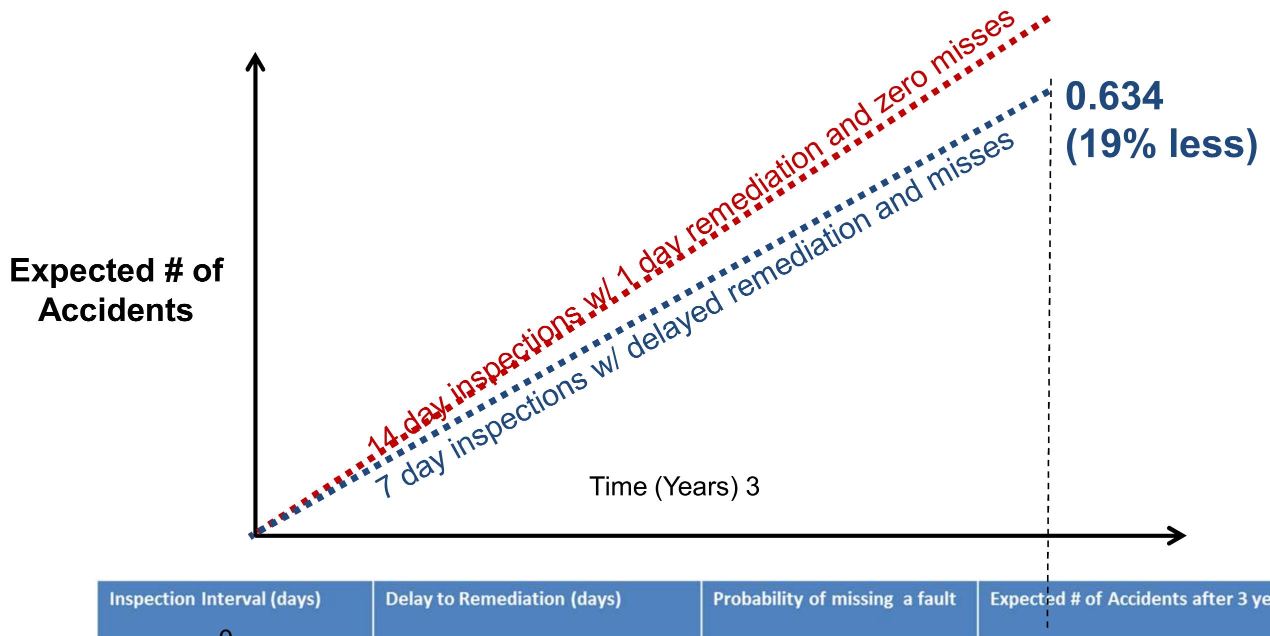
HIS research has shown:

- Neither the human nor the automated systems achieved good performance results,
- The automated system was better at locating the defects (search) but could not classify them as acceptable or rejectable (decision-making) as well as the human inspectors,
- Earlier studies (Juran 1974) indicated that human inspections typically find only ~80% of the defects

"Allocating the search function to machines and the decision-making function to humans results in better performance than either pure human or pure machine".

*Source: Drury and Sinclair, 1983 "Human Factors" , *Hout et al., 1993, International Journal of Human Factors in Manufacturing*

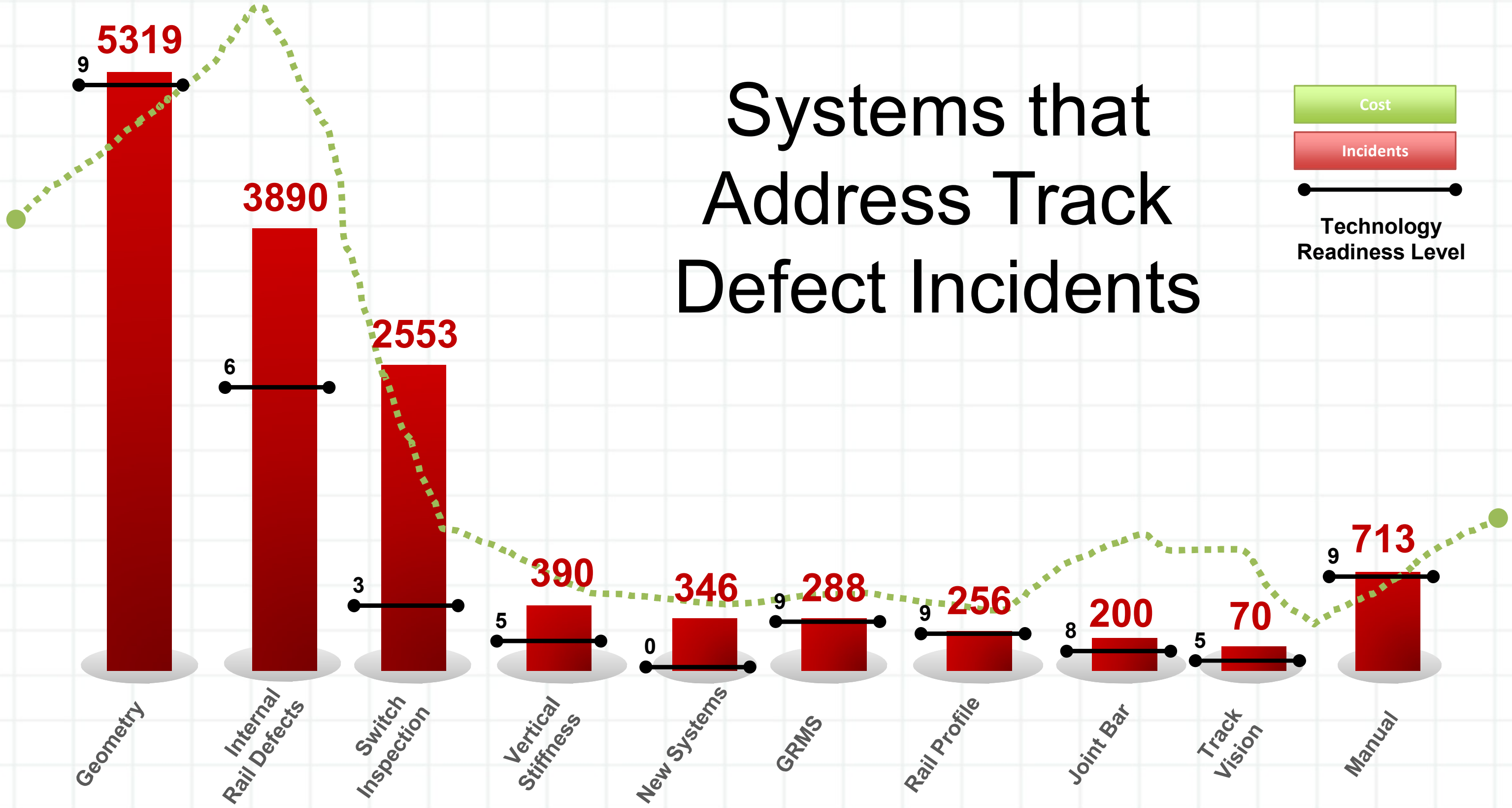
Key to Track Safety—Inspection Frequency



Inspection Interval (days)	Delay to Remediation (days)	Probability of missing a fault	Expected # of Accidents after 3 years
14	1	0	0.783
7	3	0	0.634 (19% less)
7	1	0.23	0.634 (19% less)
7	2	0.13	0.635 (19% less)

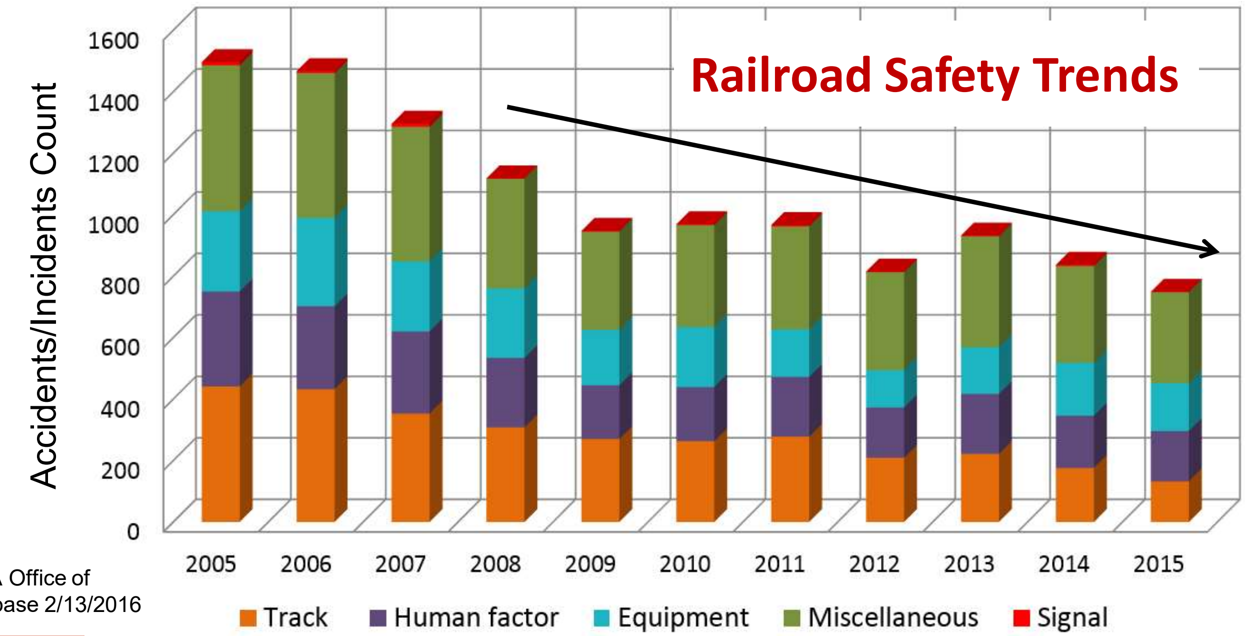
Source: Dr. Rome's Markov program

Systems that Address Track Defect Incidents



Source: Source: FRA Office of Safety Database

Driving High Consequence Derailments to Zero!



Source: FRA Office of Safety Database 2/13/2016

The Federal Railroad Administration's mission is to enable the safe, reliable, and efficient movement of people and goods for a strong America, now and in the future.

PROCESS CHANGE

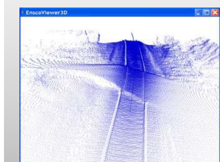
- Can we modify our processes to allow the development of ***training*** and ***cross-validation*** datasets to develop ***machine learning algorithms*** that can significantly improve the output of the process?

FRA INSPECTION SYSTEMS

Track Geometry System
Capture all standard geometry issues

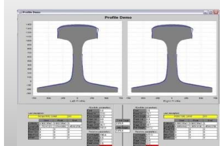
GRMS
Tie and fastener performance

VTI
Find high wheel impact locations



Grade Crossing Mapping System
To measure and determine humped grade crossings

**Items available but not currently installed*



Rail Profile
Detect rail wear

Vision Based Inspection*
Detect rail breaks, joint bars, missing ties and fasteners, defective ties

Rail Defect Detection*
Detect internal rail flaws

GPR*
Capture drainage, ballast fouling levels and ballast thickness

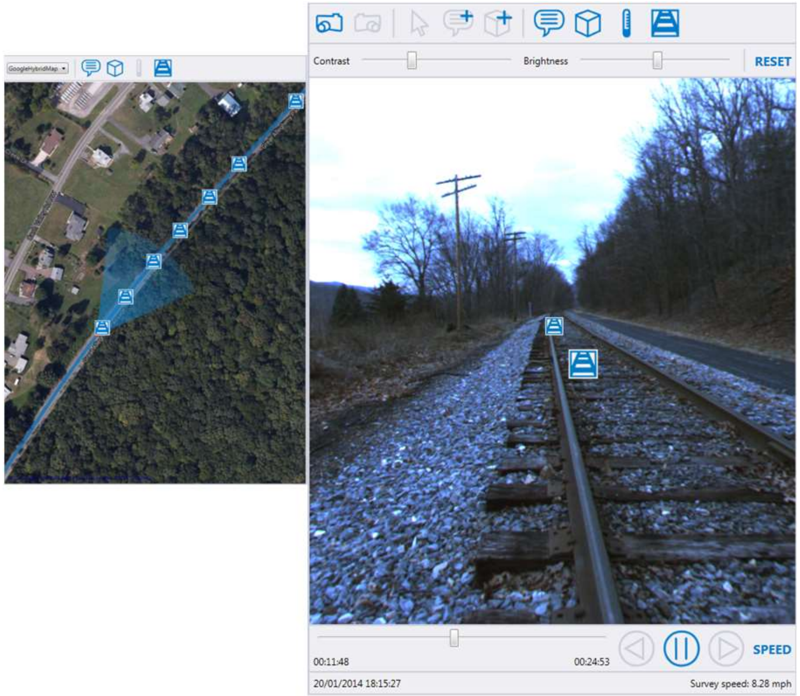
Vertical Stiffness*
Locate subgrade issues and track support issues

Train Control Monitoring System*
Assure PTC communications are working properly

**Systems are work in progress*

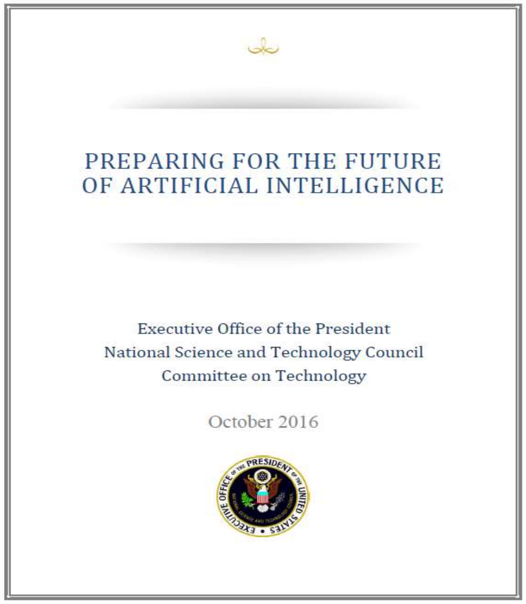
Track and Track-Side Video System*

- Virtual Environment
  - Immersive video environment for visual surveys.
  - Natural interface to a large quantity of hi-quality imagery that replicates the experience of actually being track-side.
  - Benefits such as:
    - Geographic navigation of video.
    - Auto geo-location.
    - Object tracking.
    - Visualisation, manipulation and creation of GIS objects.
  - Displays GIS objects as video overlays in their real-world locations.



**Product of CREATEC – Create Technologies Ltd*

Future—Preparing for Artificial Intelligence (AI)


PREPARING FOR THE FUTURE OF ARTIFICIAL INTELLIGENCE

Executive Office of the President
National Science and Technology Council
Committee on Technology

October 2016

Recommendation 3: The Federal Government should explore ways to improve the capacity of key agencies to apply AI to their missions.

Recommendation 7: The Department of Transportation should work with industry and researchers on ways to increase sharing of data for safety, research, and other purposes.

Recommendation 9: The Department of Transportation should continue to develop an evolving framework for regulation to enable the safe integration of fully automated vehicles and UAS, including novel vehicle designs, into the transportation system.

Recommendation 13: The Federal government should prioritize basic and long-term AI research. The Nation as a whole would benefit from a steady increase in Federal and private-sector AI R&D, with a particular emphasis on basic research and long-term, high-risk research initiatives.

"Researchers reported that enthusiasm for and investment in AI research has fluctuated over recent decades—one low period was known as the "AI winter"—and they emphasized the importance of sustained investment given the history of major computer science advances taking 15-years or more to transition from conception in the lab to industrial maturity."

Industry Benefits with New Technology

A World Transformed: What Are the Top 30 Innovations of the Last 30 Years? *

- Internet, broadband, WWW (browser and html)
- PC/laptop computers
- Mobile phones
- E-mail
- DNA testing and sequencing/Human genome mapping
- Magnetic Resonance Imaging (MRI)
- Microprocessors
- Fiber optics
- Office software (spreadsheets, word processors)
- Non-invasive laser/robotic surgery (laparoscopy)
- Open source software and services (e.g., Linux, Wikipedia)
- Light emitting diodes
- Liquid crystal display (LCD)
- Global Positioning Systems (GPS)
- Online shopping/ecommerce/auctions (e.g., eBay)
- Media file compression (jpeg, mpeg, mp3)
- Microfinance
- Photovoltaic Solar Energy
- Large scale wind turbines
- Social networking via the Internet
- Graphic user interface (GUI)
- Digital photography/videography
- RFID and applications (e.g., EZ Pass)
- Genetically modified plants
- Bio fuels
- Bar codes and scanners
- ATMs
- Stents
- SRAM flash memory
- Anti retroviral treatment for AIDS

**Nightly Business Report (PBS) 02/2009*

A Brief History of Track Innovation

- Force Estimation using Track Geometry Data (2002)
- Neural Networks for Dynamic Simulation (2007)
- Joint Bar Inspection System (2009)
- Virtual Car (2010)
- Automated Track Geometry Exception Editing (2010)
- Machine Vision Learning (2013)
- Machine Vision of Concrete Ties (2014)
- Risk-Based Scheduling Prioritization (2014)
- Rail Temperature Prediction through Weather Modeling (2016)
- Passive Non-Contact High Speed Rail Inspection (2016)

A Brief History of Track Innovation

- Flange-Bearing, Spring, Movable and Heavy-point Frogs,
- Tangential Turnouts,
- Premium Rail Components,
- Internal Rail Detection,
- CWR procedures,
- Roadway Worker Protection,
- Automated Inspection of Concrete Crossties

Future—Railroad Capacity

- Railroads will increase axle loads, train frequencies, train lengths, and operating speeds,
- Expected higher rates of track component fatigue, wear, and overall track structural degradation, demanding greater inspection frequency,
- Railroads are adapting by using better component designs, materials, procedures and processes,
- Inspection Training is paramount (new Part 243)

Next 25 years → **100 Million more people** → **2.8 Billion more tons of freight**

Future—Track Inspection

Looking into the future, industry and the academic world are encouraged to continue to develop new ideas, railroad knowledge, and complementary technology that supplements visual and automated inspections

“Innovation is more important than knowledge”—Albert Einstein

Future—Track Inspection

Among the most promising digital railway technologies:

1. Performance-based Big Data Trending (create roadmaps to remove obstacles),
2. **Change Detection—Rail and Aerial (UAS) Autonomous Vehicles, and Satellite Imagery,**
3. Predictive Analytics and Virtual Reality (Training),
4. **Artificial Intelligence and Learning Algorithms (Swarm Robotics—inspect, repair and maintain infrastructure),**
5. **Wearable Safety Devices, Portable Accelerometers, and hand-held displacement devices,**
6. Cloud-based Digital Track Notebooks—Tablets,
7. **Augmented Reality (Hologram and Photographic measurement tools)**
8. **Smart—Rail, Rocks, and Crosstie Systems Interfacing with Wayside Detection Systems to alert trains of unsafe conditions and generate kinetic energy.**

Future—Track Inspection

9. Automated algorithms to convert collected data to useful information,
10. *New techniques, approaches, and studies* to convert data to information, to knowledge,
11. *Implementation of knowledge* into remediation procedures, inspector training, railroad culture,
12. ***FRA, Universities, and Industry Partners* sharing data (blockchain technology) to aid in AI development for risk reduction and safety,**
13. ***New autonomous methods*, non-contact, low maintenance, higher speed inspection technologies,**
14. Development of *new technologies* to fill gaps in data,
15. Enhanced *automated defect detection algorithms* developed through supervised learning processes,
16. ***Regulation modifications* to allow automated approaches that improve safety and minimize safety risk and liability,**
17. **Create *roadmap* for removing innovation obstacles (involving government, railroad, supplier, and research)**

The Future Of Safety Depends On How We Learn From One Another!

THANK YOU—QUESTIONS

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