OFFICE OF RESEARCH & DEVELOPMENT

2012 R&D REVIEW

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FRA Non-contact LIDAR-based Tachometer

U.S. Department of Transportation
Federal Railroad Administration

Acknowledgements & Stakeholders

Acknowledgements

- Mr. Michael Craft, Virginia Tech
- Mr. Carvel Holton, Virginia Tech
- Mark Beaubien, Yankee Environmental Systems
- **RTL Students:** Tarek Shalaby and Josh Muñoz
- **Norfolk Southern R&T Team:** Scott Hailey, Sean Woody, Steve Smith, Tim Childress, Barry Radford, James "Tree" Harris, Mike Hedrick, and Brad Kerchof

Stakeholders & Project Partners

- U.S. Railroads
- Norfolk Southern
- Railway Technologies Laboratory – Virginia Tech

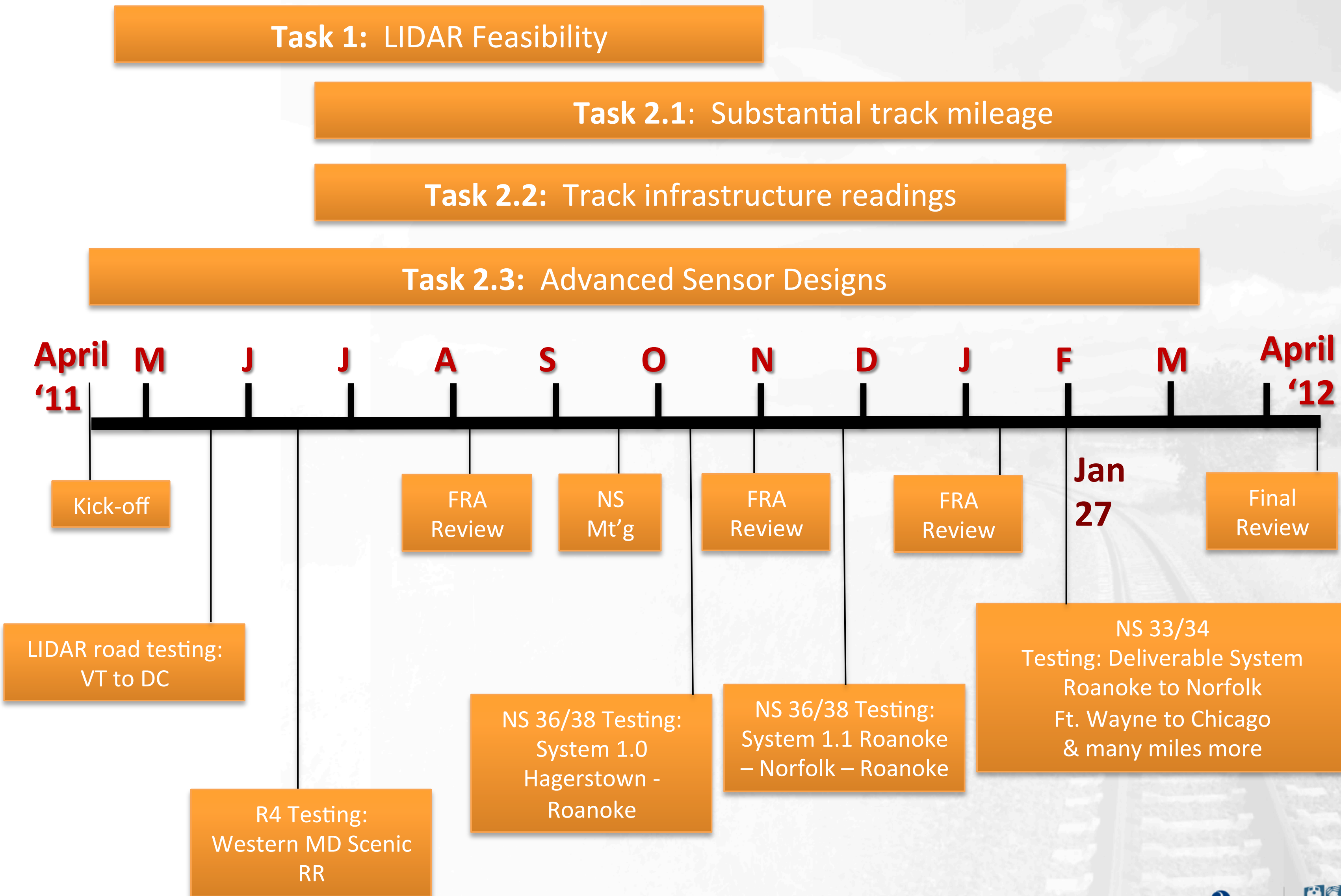
Description of Project

- Demonstrate the ability of the technology to measure true ground speed in a non-contact manner
  - To a degree of accuracy superior to existing technologies on both tangent and curved tracks and extract
- Provide the means for measuring instantaneous track curvature in a non-contacting fashion
- Demonstrate the speed performance capabilities of the technology over substantial track mileage on FRA rolling stock
- Advance autonomous sensor designs capable of outputting analog signals that may be recorded by a separate data acquisition system

Objectives

- Providing the ability to measure true track speed and curvature will advance the state of the art beyond
  - Wheel mounted tachometers that are used for measuring track speed
  - Inertial systems used for track curvature
- Wheel mounted tachometers are subjected to track-induced vibrations
  - Require a large amount of maintenance
  - Periodic calibration
  - Can be subject to error caused by wheel slip (creepage)
- Inertial Systems that are used for measuring track curvature do not work well at low speeds (below 8 – 10 MPH)
  - Only provide track curvature over a long cord

Program Timeline



Program Achievements

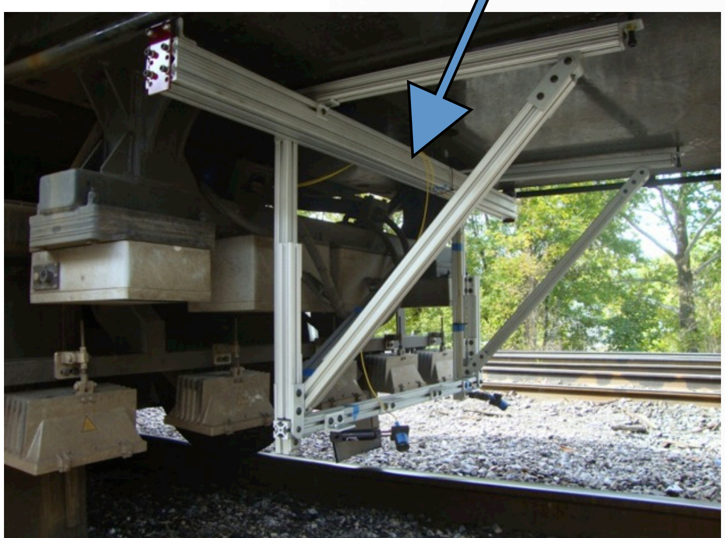
- Demonstrate the ability of LIDAR to measure true ground speed in a non-contact manner and to a degree of accuracy superior to existing technologies on both tangent and curved tracks and extract instantaneous track curvature
- Demonstrate the speed performance capabilities of the technology over substantial track mileage on FRA rolling stock
- Assess technology potential for extracting rail/equipment condition and location from acquired speed data
- Advance autonomous sensor designs capable of outputting analog signals that may be recorded by a separate data acquisition system

System Capabilities: LIDAR is capable of accurately measuring velocity and distance

- Data analysis has shown the LIDAR system to be capable of:
  - Accurately measuring
    - velocity and distance traveled in a non-contact manner
    - track curvature
  - Extensions to one foot pulse signal output to other sensors and systems

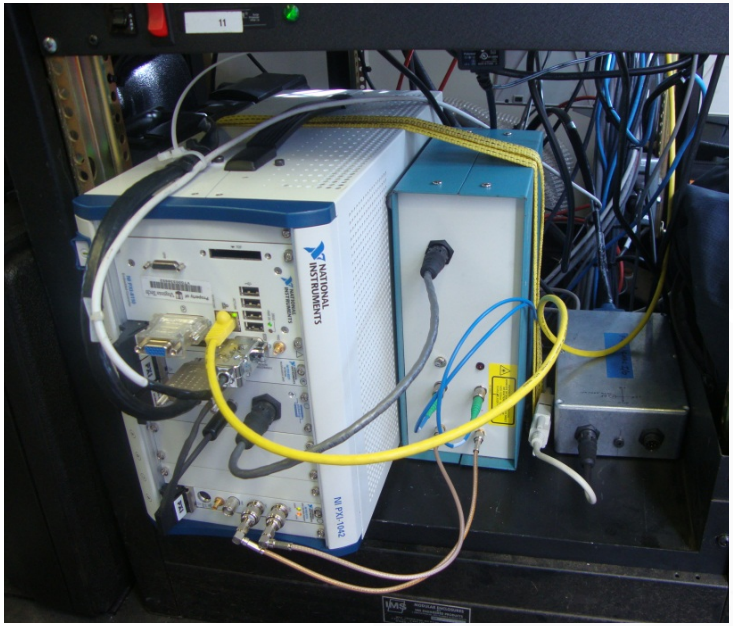
- Various optical housings and beam configurations have been tested
  - Top of rail and gage corner focal points
  - Truck mounted and body mounted beams

The VT LIDAR system was upgraded and installed on the NS 36/38



Data collection capabilities expanded to include encoder and vibration data

The ruggedized PXI hardware was installed and tested on NS 33/34 beginning in January, 2012



The KVM network used to interface with the PXI hardware

Beam setup was changed to TOR to improve curvature measurements when truck mounted

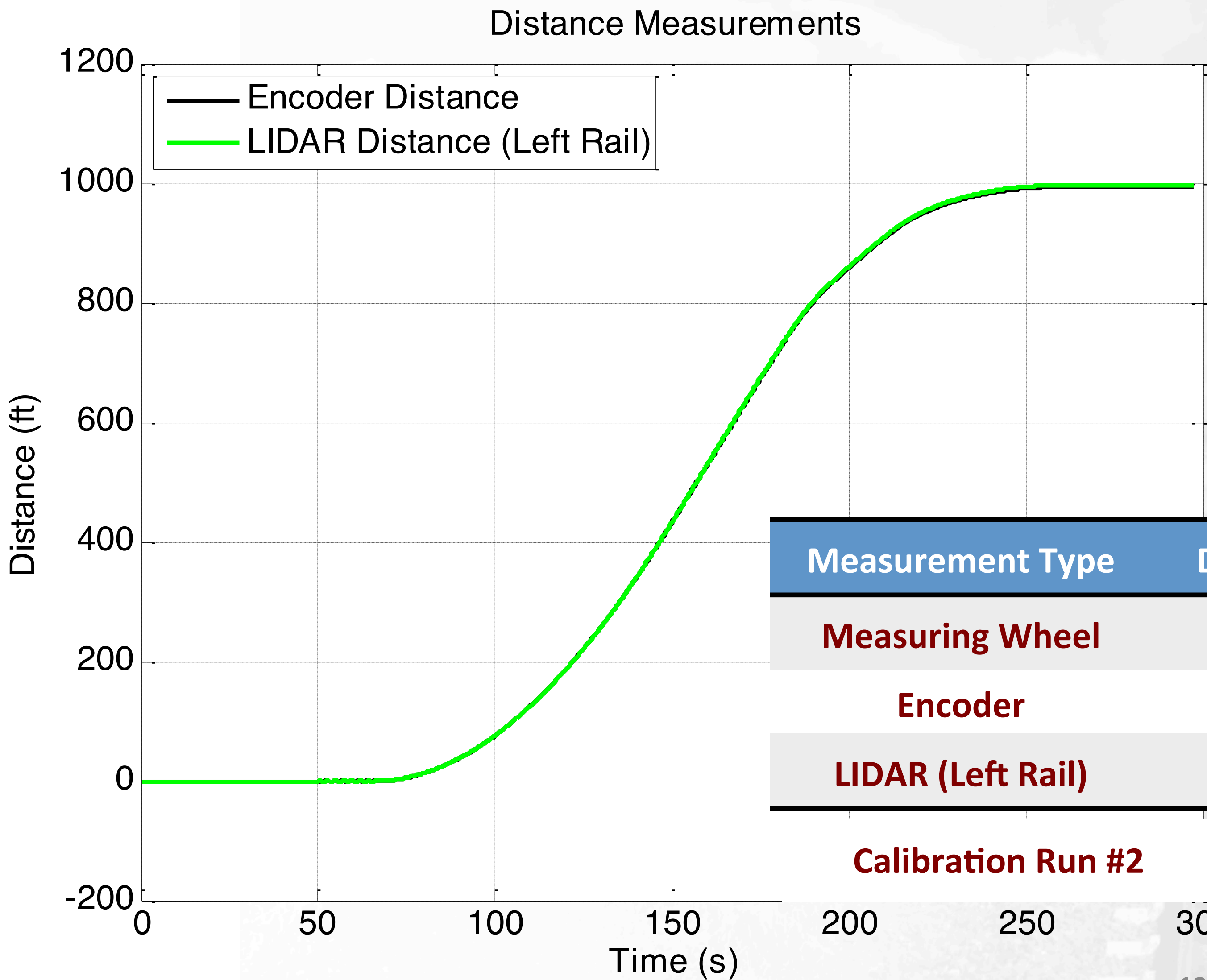
The system ran continuously each test day, with no intervention by the user

- System performed with no supervision after initial data session was started
- At the end of each test day, the data was saved for secure post processing analysis

Norfolk Southern has been very accommodating to Virginia Tech (VT) during all phases of this project

Two 1000ft, ground-truth measurements were made near Crewe, VA, to calibrate the LIDAR system and encoder

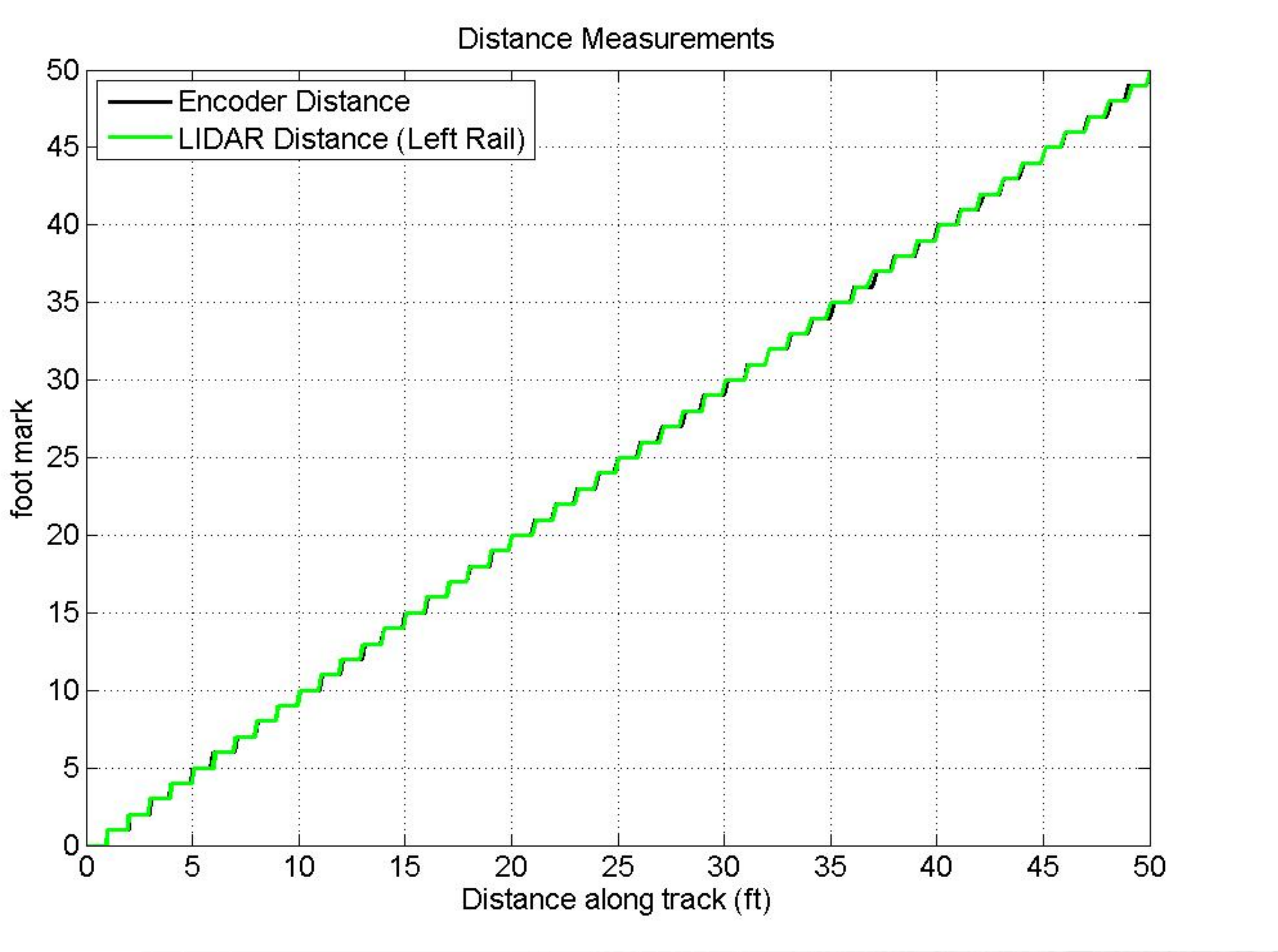
LIDAR shows improved performance over the encoder, within the accuracy of the measured track (using a measuring wheel)



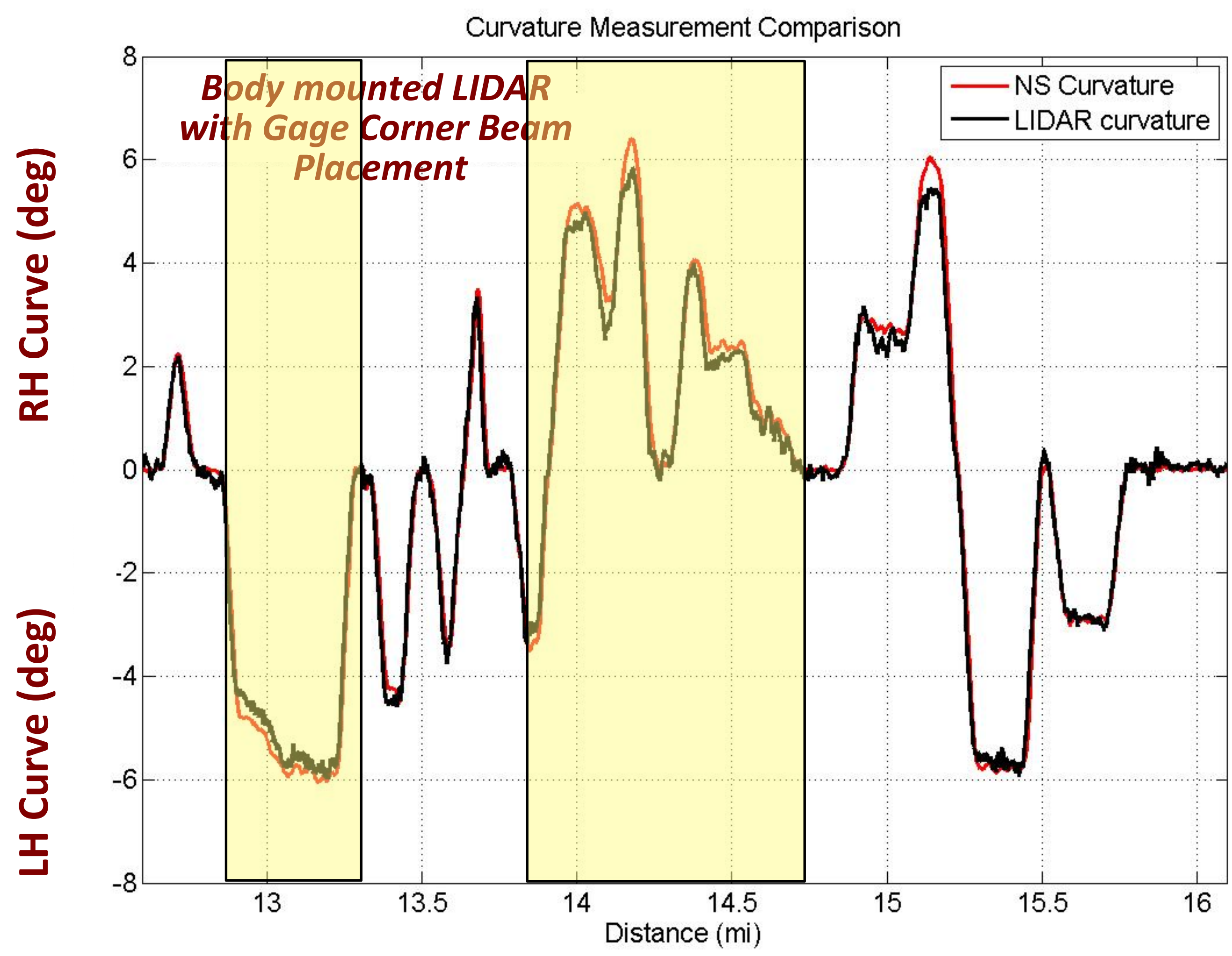
Measurement Type	Distance
Measuring Wheel	999.3ft
Encoder	994.0ft
LIDAR (Left Rail)	997.4ft

Calibration Run #2

A foot marker comparison shows consistent foot counts are possible with the LIDAR technology



LIDAR curvature measurements show close correlation with the NS geometry car measurements



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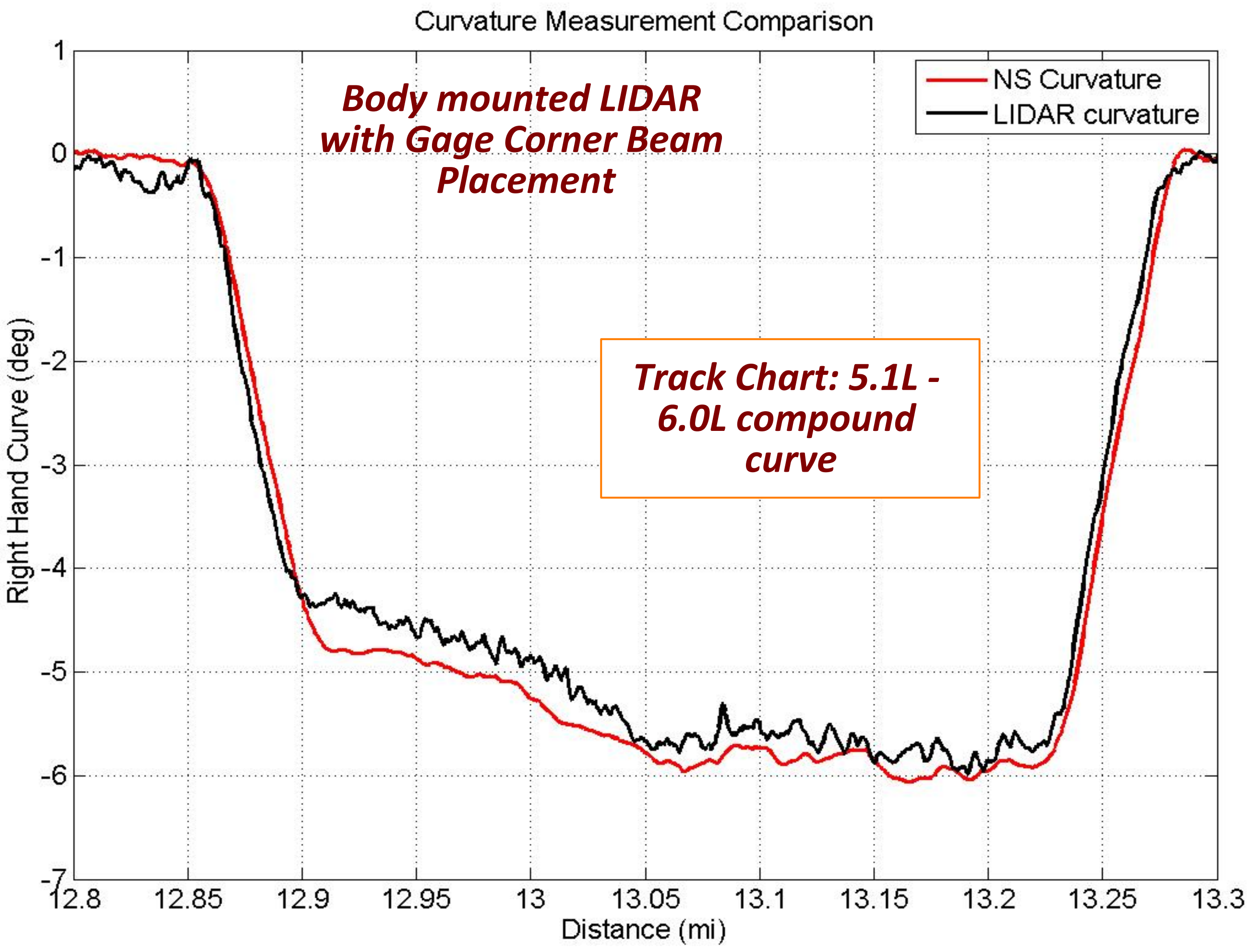
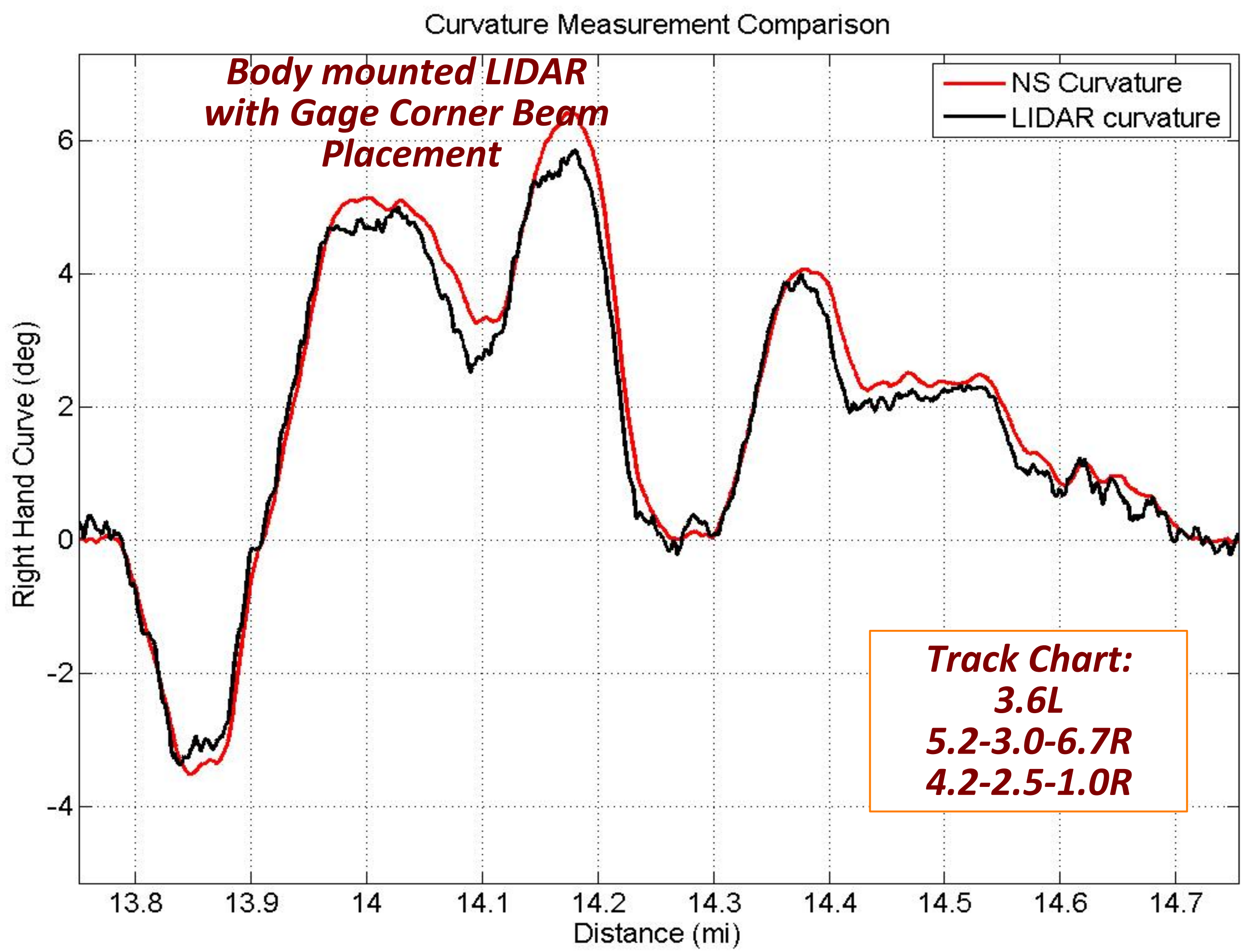
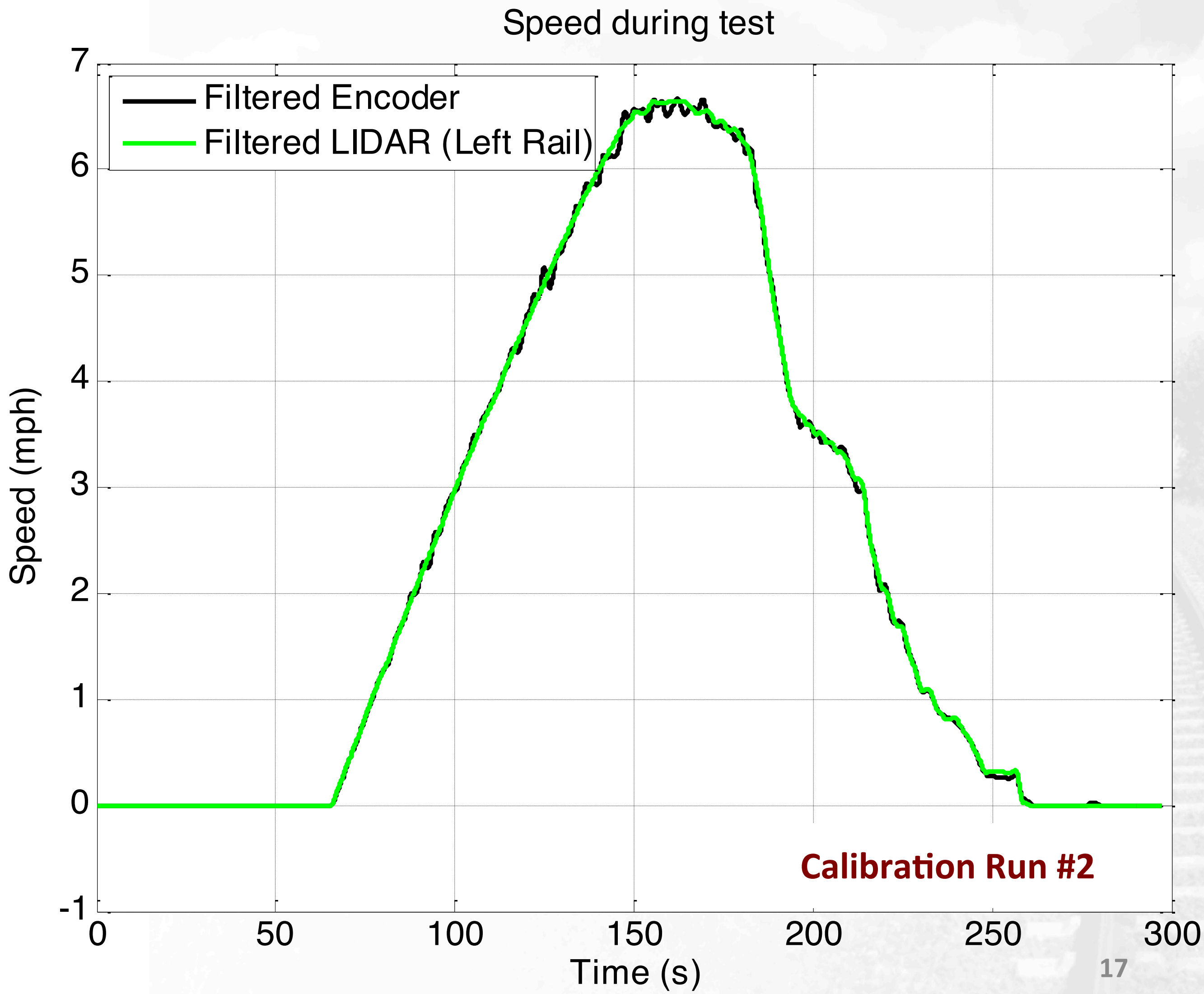
LIDAR system able to measure compound curves



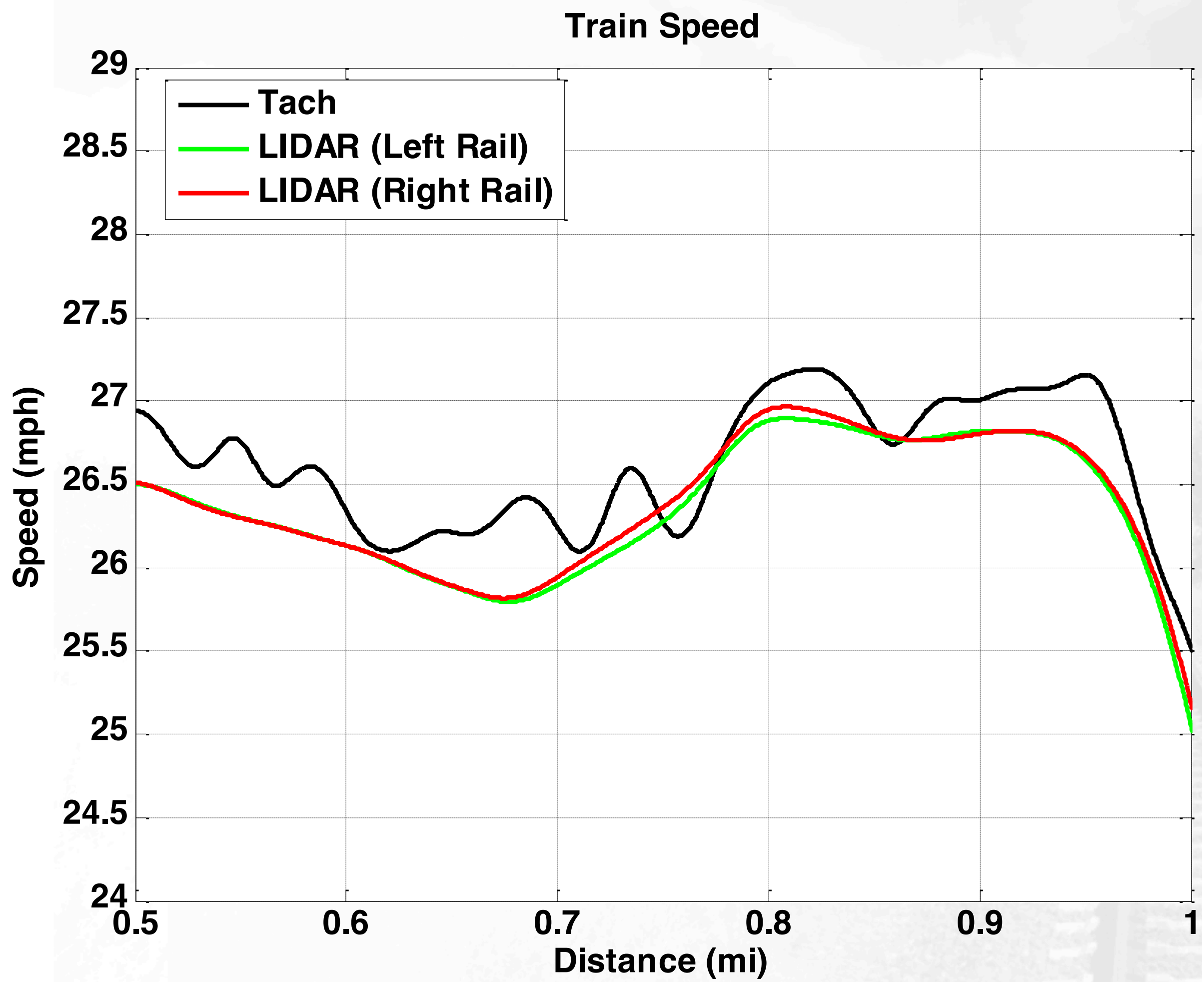
NS curvature measurement is smoother than the LIDAR measurement (filtering effect?)



The LIDAR and encoder speeds match closely – Encoder shows more variation

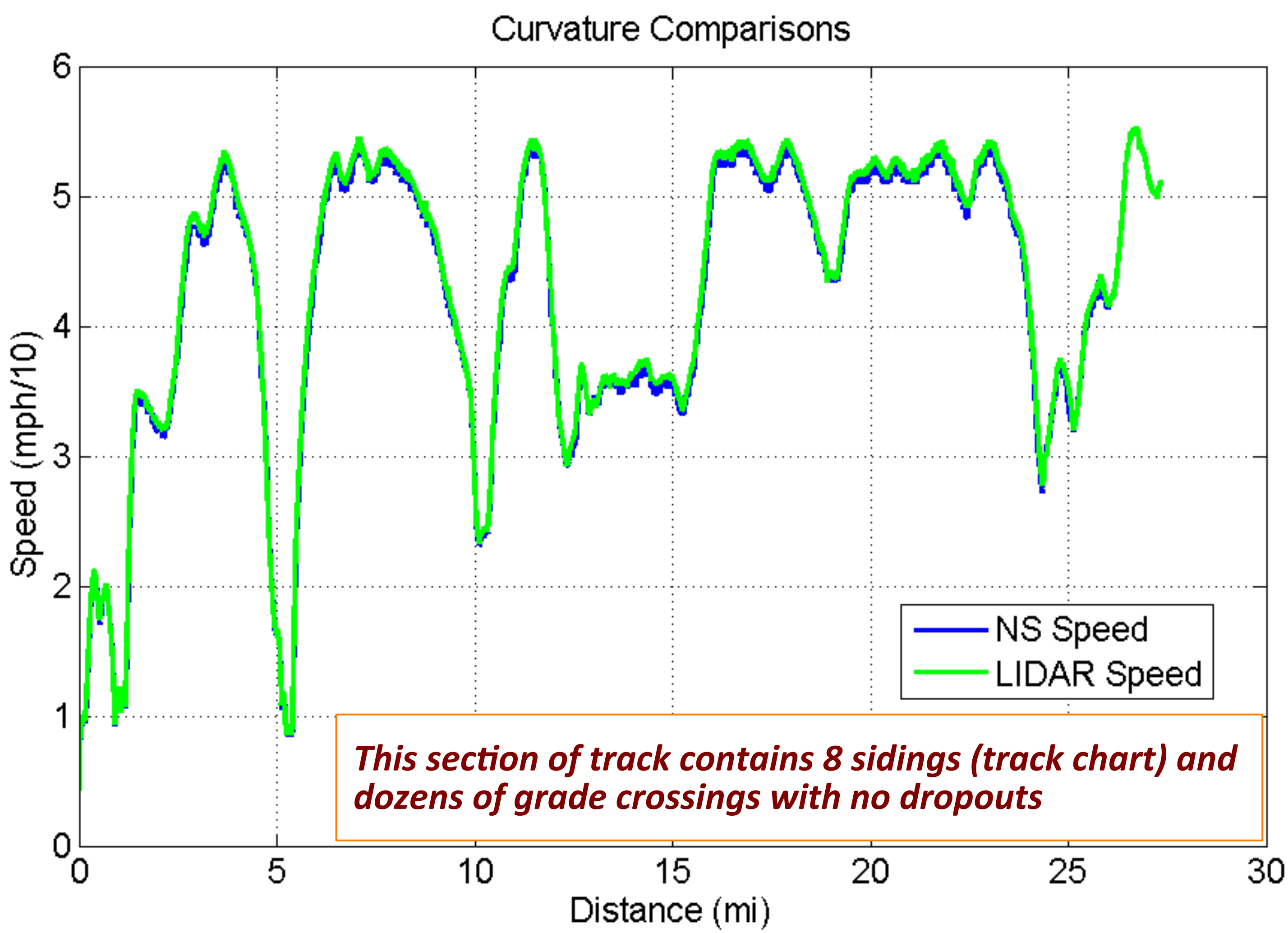


The general trends between LIDAR and Tach speed are the same, although the Tach shows more fluctuations



Sample from Ft. Wayne to Chicago tangent-curve-tangent

Special track work does not affect the system function
No "dropouts" over a 30-mile section of track



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LIDAR system collected data during times of significant wind and rainfall

Some of our tests were conducted in heavy rain and wind gusts over 20 mph

Benefits & Disadvantages

Benefits

- Eye-safe lasers
- Far more accurate
- Far more repeatable and controlled
- Can perform very accurate curvature measurements, over a short cordal length
- Leads to significant technological advances
- Significantly improve our ability to measure track geometry

Disadvantages

- New technology
- Higher costs
- Requires getting used to
- Requires periodic attention to ensure the lens is clean

Positive Project Support

- FRA provided the Virginia Tech team the opportunity to interact with partners such that can help with the project
- We were also provided with a great deal of anecdotal data by FRA from their past work with Track/Train Interaction, in the Track and Infrastructure Division

Project Complications

- Improving a laboratory grade system to the levels of a filed-hardened system is non-trivial
- The greatest complication stems from balancing the project
  - Requirements
  - Costs
  - Timeline
- The logistics of running field tests are complicated
  - Train scheduling
  - Costs
  - Accessing the data
  - Ensuring proper functioning of the system
- Calibration with field data
- Results accuracy and validity
- There is some skepticism with believing/accepting the results from a new measurement device

Lessons Learned

- Virginia Tech (VT) LIDAR technology is an effective alternative to a wheel-mounted encoder
- Also provides other critical data about the track and vehicle performance
  - Non-contact distance measurement
  - Accurate velocity measurement from 0.1 – 120* mph
  - Curvature measurement
  - 1ft signal, tach pulse capable
  - Continuous operation regardless of special track work or crossings
  - Consistent, repeatable measurements
  - Operable in inclement weather
  - Reduced measurement variation compared to tachometer

Key Success Factors

- The key to the success of the project has been due to:
  - Involvement of key partners in the project
    - Yankee Environmental Systems
    - Norfolk Southern
- Frequent interaction between the project team and FRA
  - Periodic program reviews with FRA
  - Included the entire research team
  - Opted for face-to-face meetings
  - Went beyond presentations
    - The meetings were working sessions
    - Often lasted ½ day
- The meetings included the project stakeholders beyond our sponsor
- The free and frequent communication between the project team and the stakeholders have proven to be positive and rewarding

Recommendations

- Conduct a one-year study on
  - Assessing the LIDAR system's capability to provide information beyond track distance, speed, and curvature
    - Can we measure track geometry?
- Continue testing the system on the NS rail geometry car for further assessing its field capabilities and weaknesses
    - Software/Hardware improvements?
- Advance the system hardware and software toward a production-ready, field-deployable device
    - Additional hardware and software elements?
- Key element:
  - Continued partnership among FRA, NS, YES, and VT
- Main Deliverable
  - Plug-and-play system for FRA ATGMS

Break/Posters | Nearby Food Options (all within 5-7 minutes walking distance)

- Au Bon Pain: 601 Indiana Ave NW # 1Washington, DC 20004
- Burger King: 501 G Street NW, Washington, DC 20001
- Chipotle: 601 F Street NW, Washington, DC 20005
- Cosi: 601 Pennsylvania Ave NW # 2 Washington, DC 20004
- Dunkin Donuts: 601 F Street NW, Washington, DC 20004
- Firehook Bakery & Coffee House: 441 4th Street NW, Washington, DC 20001
- Jack’s Famous Deli: 501 3rd St NW # 2, Washington, DC 20001
- Quiznos Sandwiches: 772 5th St NW, Washington, DC 20001
- Starbucks: 443 7th St. NW, Washington, DC 20004
- Subway: 501 D Street NW, Washington, DC 20001