# A Pavement Longitudinal Inertial Profiler based on 1mm 3D Surface Data

**Kelvin C. P. Wang and**

**Yang Liu, Cheng Chen, Allen Zhang, Josh Li, Justin Thweatt**

**Oklahoma State University/WayLink**

**September 17, 2014**

Pavement Evaluation 2014

September 15-18, 2014 ▼ Blacksburg, Virginia

RPUG Road Profile Users' Group

# Outline

- Green Lasers
- Profiler Hardware
- Profiler Software Interface
- Software Algorithms
- Profiler Field Validations
- Conclusions

# PaveVision3D Ultra (3D Ultra)


# Green Lasers for 3D Ultra

# Advantages of Green Laser

- More Stable: better height data for 3D
- More Uniform: better 2D intensity data
- Consuming Less Power: no generator needed
- Fully Visible: street safer

# Profiler Hardware

- PaveVision3D Ultra: full-lane coverage at 0.3 mm resolution in the vertical direction
- Accelerometer: a transducer that provides an output proportional to acceleration
- DMI : a distance measuring device that provides triggering for 3D laser imaging sensor
- Other devices
  - To sample the acceleration data per DMI pulses
  - To provide communication support for synchronization among hardware sensors

# 3D Ultra

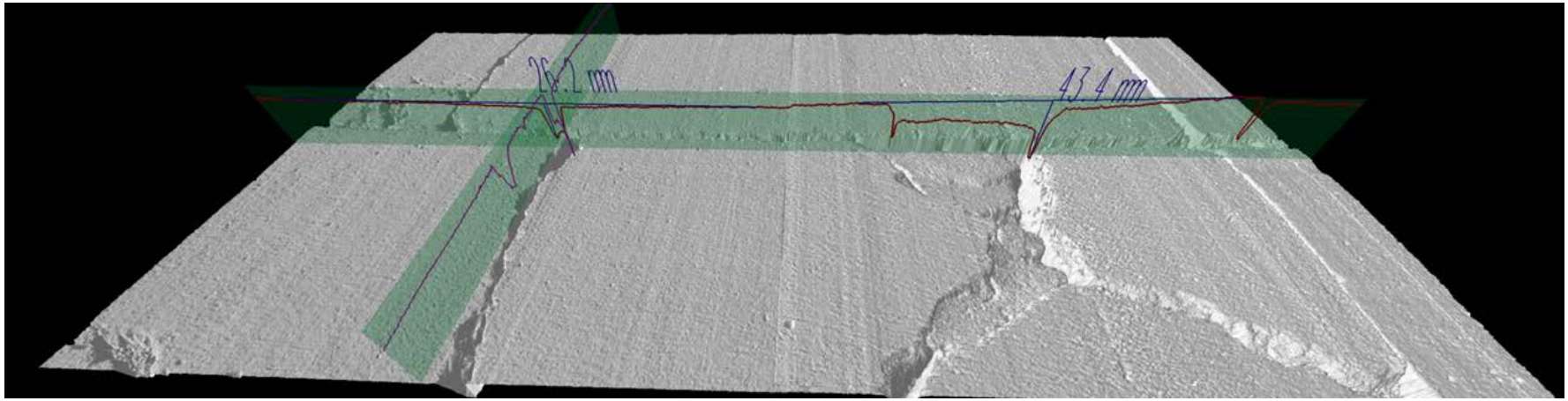
- Integrated vehicular surveying platform: cracking, rutting, texture/hydroplaning, longitudinal profiling
- 30KHz 3D profile scanning rate: true 1mm resolution in three dimensions at 60 MPH (100 KM/H)
- Synchronized array of sensors: 3D cameras, uniform green lasers for ultra-high-speed shutters, 3D accelerometers, high-precision IMU
- Full-lane coverage (4-meter width): 4000 3D transverse points
- Total system power consumption: 500 Watts
- Data collection: continuous collection for several hours at 1 to 2GB/lane-mile data

# Accelerometer and DMI

- Integration: Critical for Digital Accelerometers
- 3D Points in the Center of Wheel-Paths for Height Data

# Pavement 3D Capture

- Acquire true 1mm 3D pavement surface data
- Provide longitudinal height information for profiler

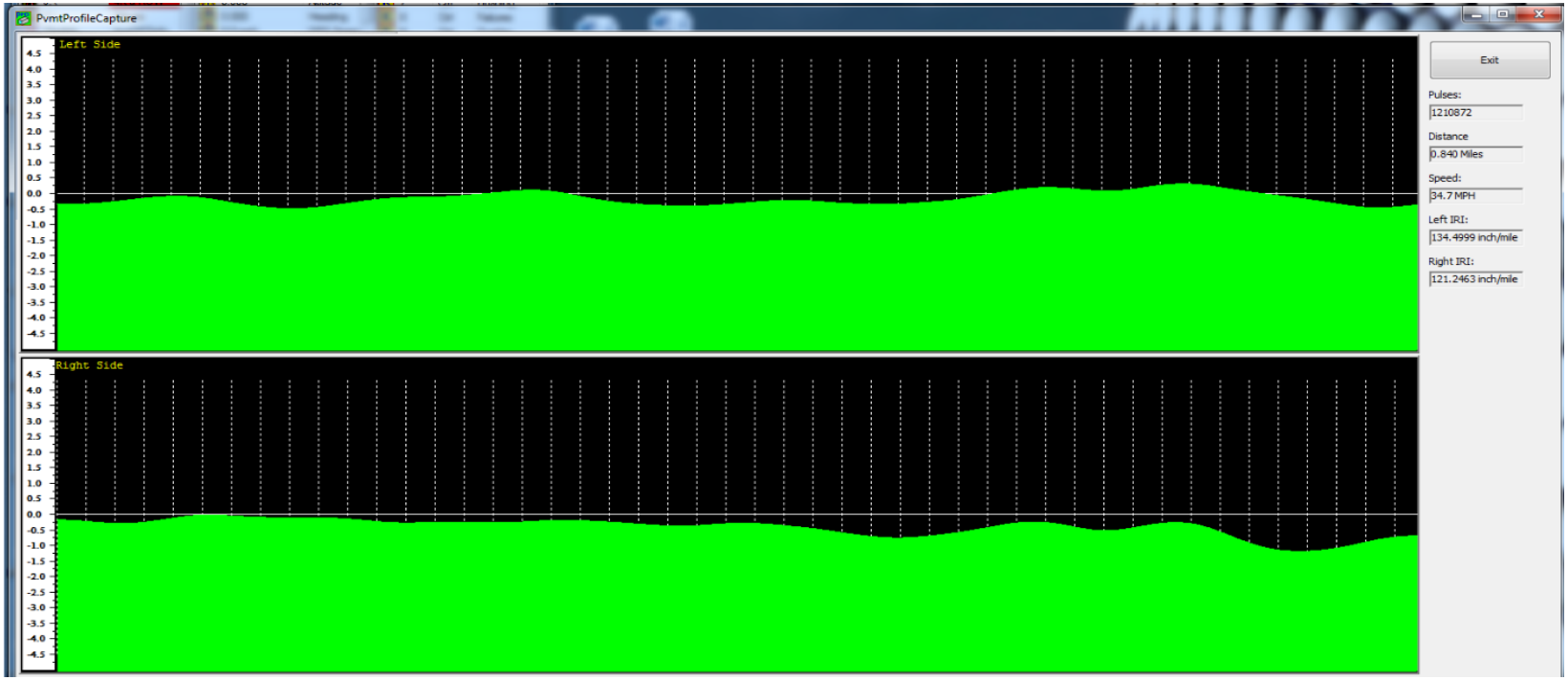


# Profiler Software

- Software Capabilities
  - Data Collection
  - Bounce Test
  - Profile View
  - Calibration

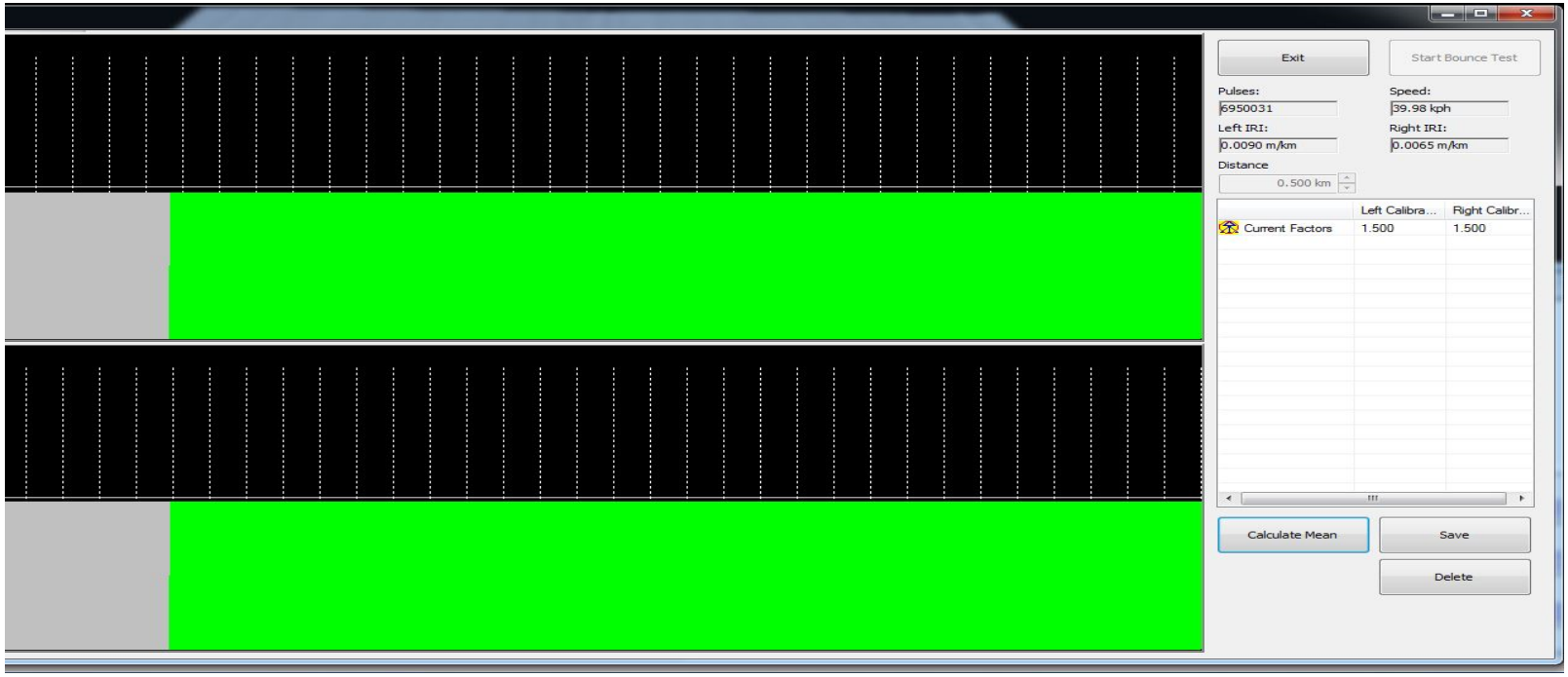
# Profiler Software

- Data Collection
  - Display distance traveled and speed
  - Display pavement profile in real time
  - Display IRI values for LWP and RWP



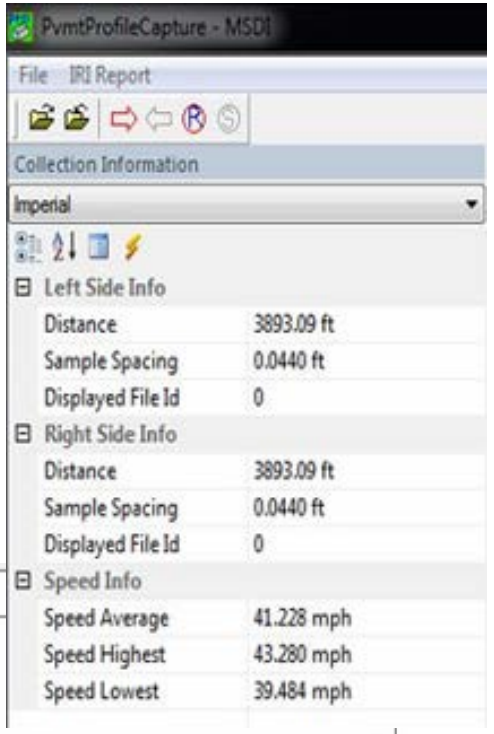
# Profiler Software

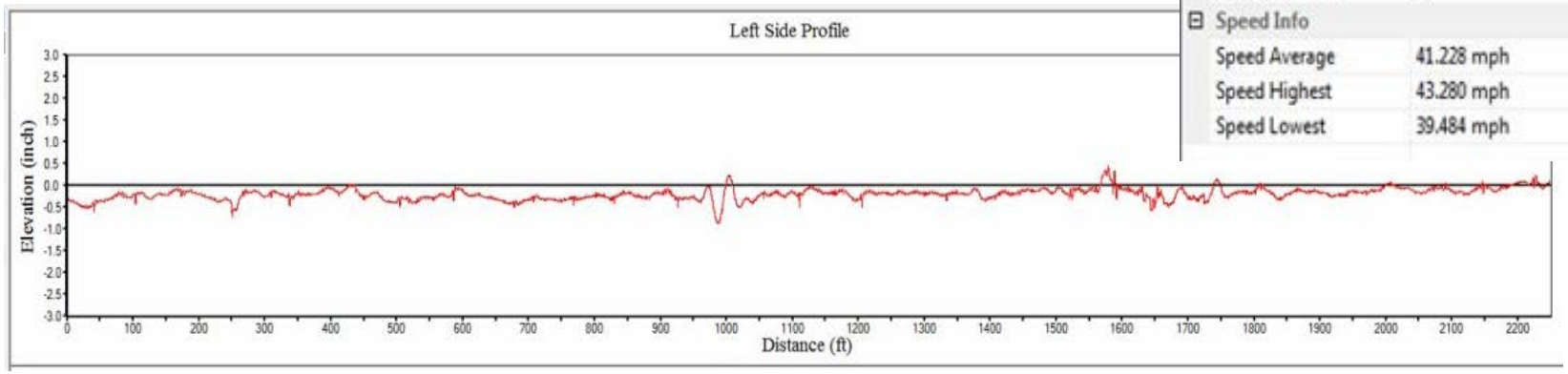
- Bounce Test
  - Display IRI values on LWP and RWP during bouncing test
  - Calculate calibration factors

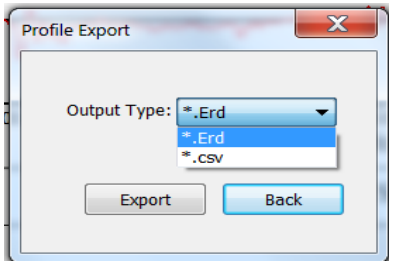


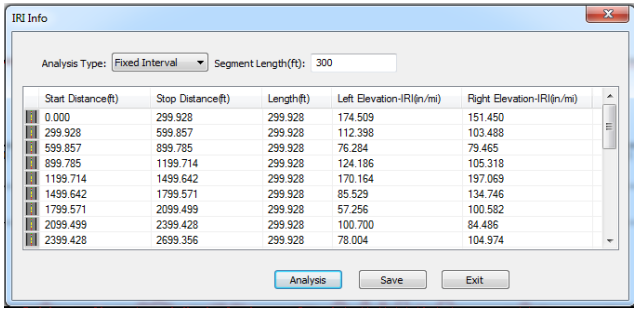
# Profiler Software

- Profile View
  - Display profile data
  - Display basic data collection information
  - Calculate IRI values
  - Export .ERD or .CSV file



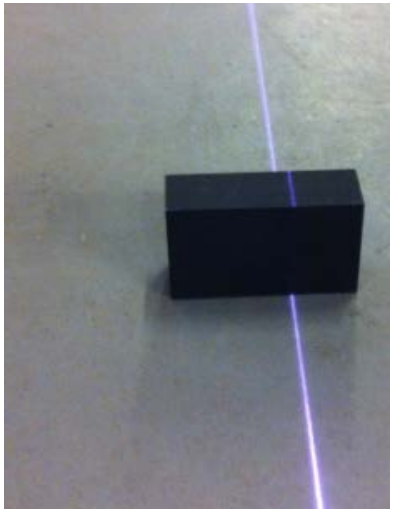



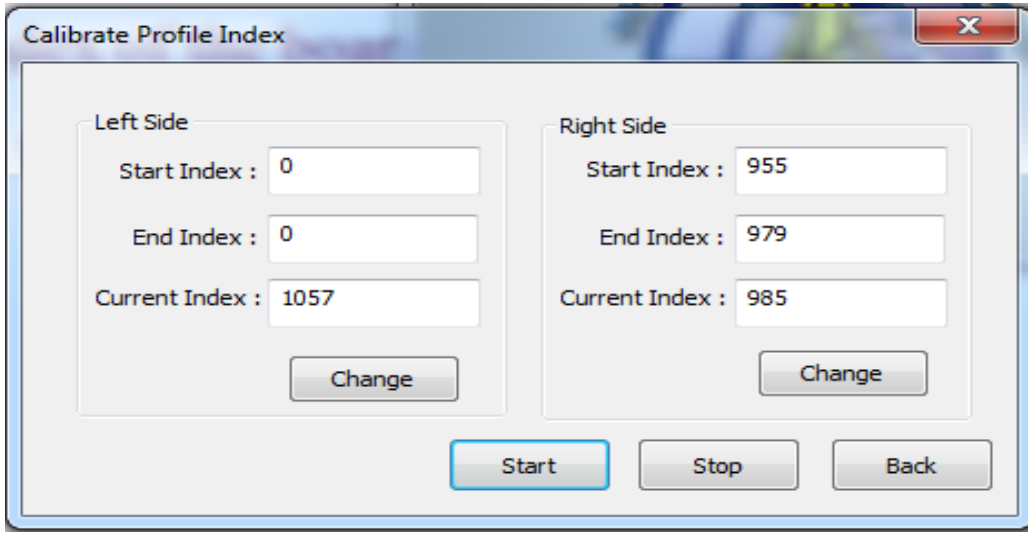



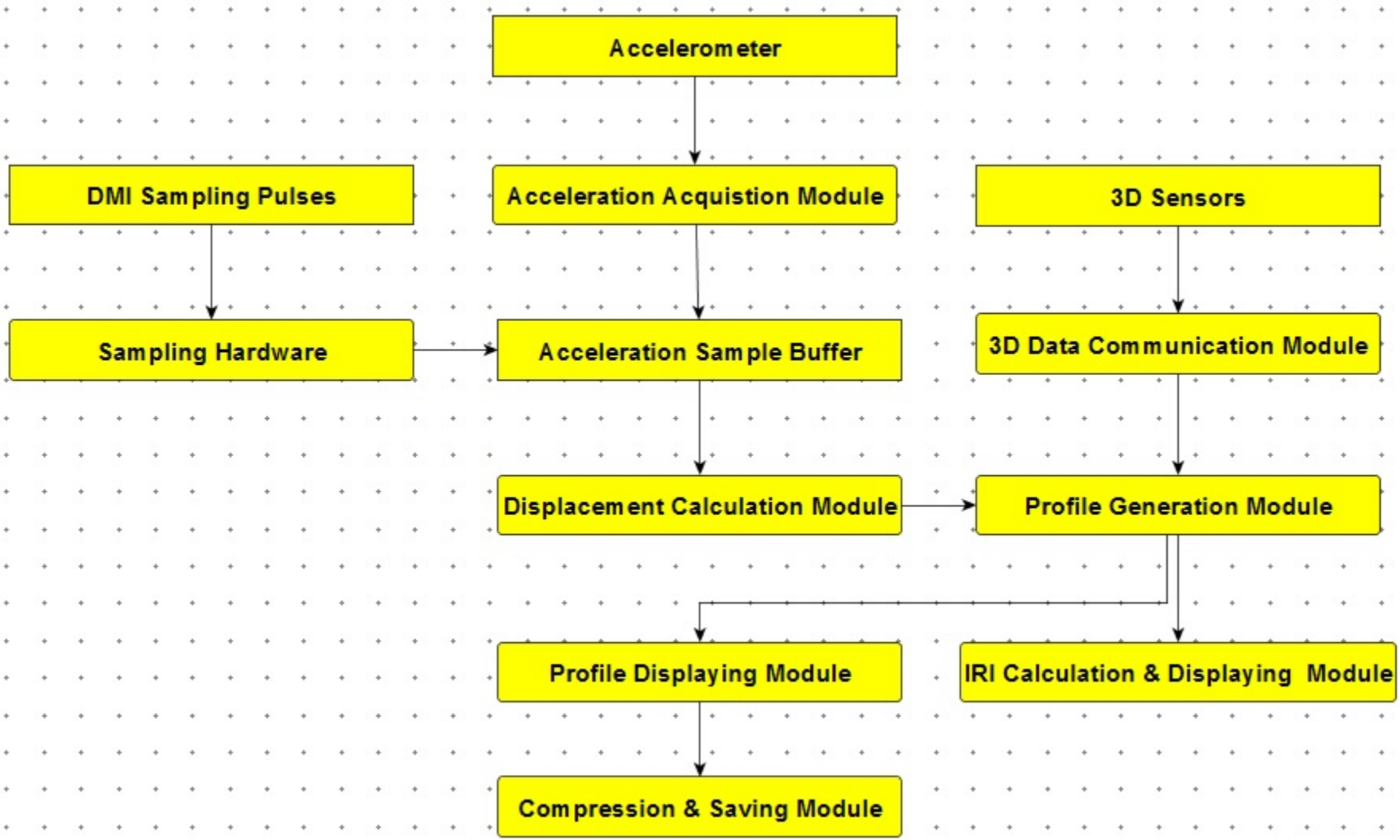
# Profiler Software

- Calibration
  - To identify longitudinal profile(s) in the wheel path for profiler

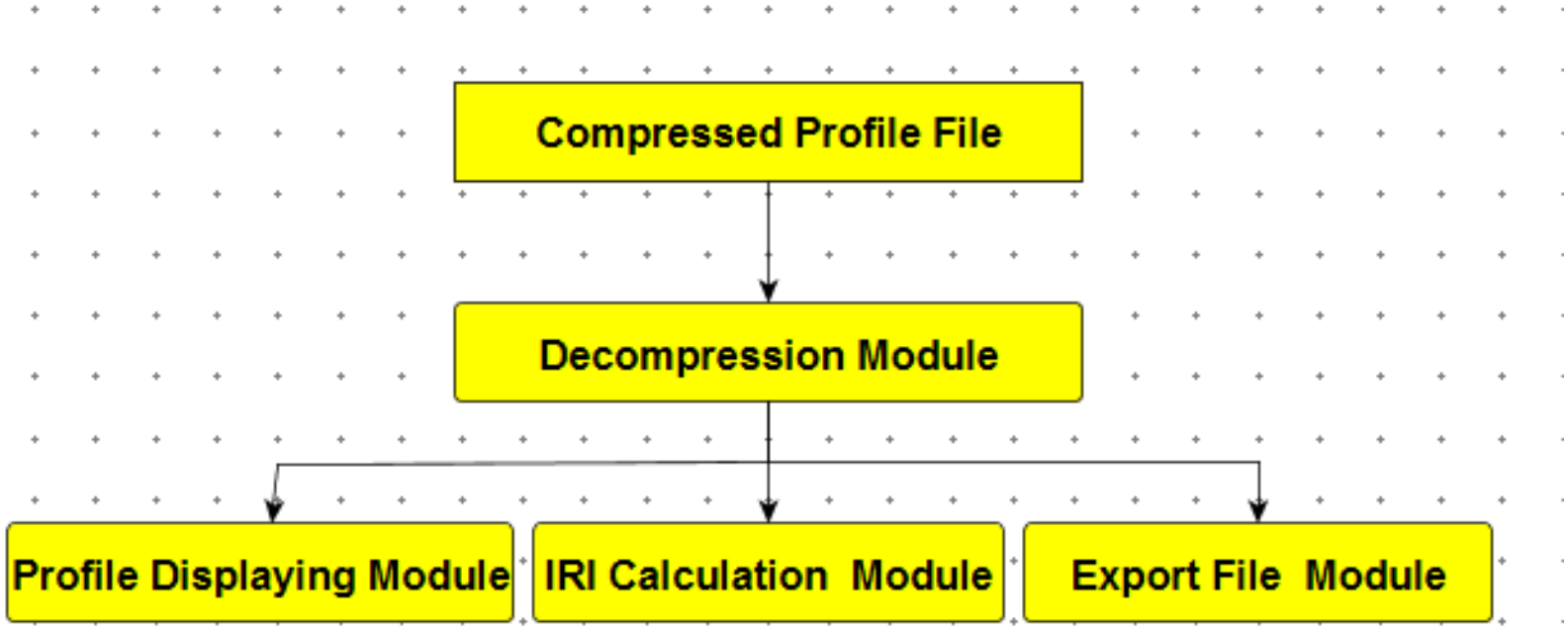




# Profiling Data Acquisition



# Profiling Data View



# Software Algorithms

- Real-time zero-mean: remove the trend (DC-offset) in the acceleration data.
- Low pass filter (Anti-Aliasing Filter): remove high frequency noise
- Double Integration: calculate the distance
- Butterworth band pass filter: preserve useful waveform, filter the unwanted waveform
- Out-of-range handler: process the data when the 3D laser imaging data is out of the camera view
- IRI calculation based on quarter-car model

# Profiler Validation Test

- Bounce tests
  - Verify the accuracy of Calculated Displacement Data
  - Evaluate synchronization of accelerometer and 3D height data
- Field test
  - Three test road
  - 10 repeating passes
  - Each speed: 3 passes

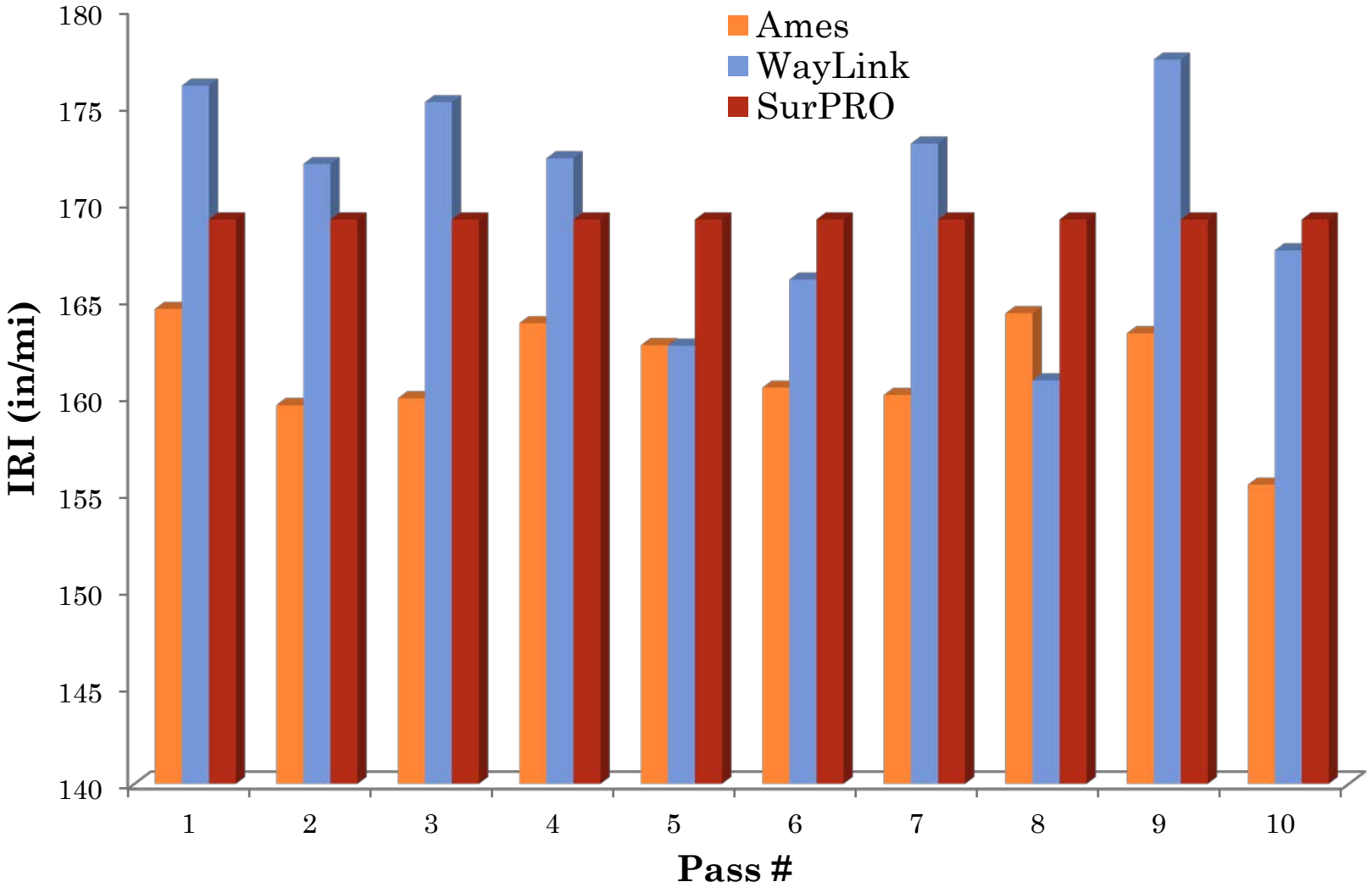
# Data Collection Instruments

- SurPRO 3500: reference device at 1 inch sampling interval
- Ames: 1 inch sampling interval
- WayLink: 0.5 inch sampling interval

# Field Test – Site 1

- Asphalt surface
- 1,100ft tangent section with lead-in & lead-out
- Automatic triggering for consistent start & end of data collection
- 10 repeating passes
- Multiple speeds

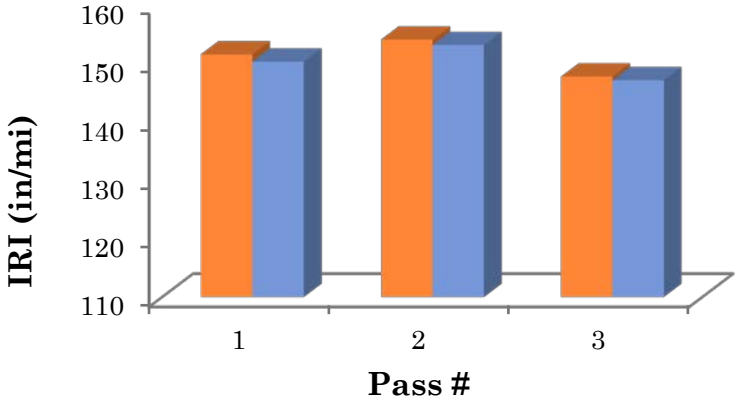
# Field Test – Site 1



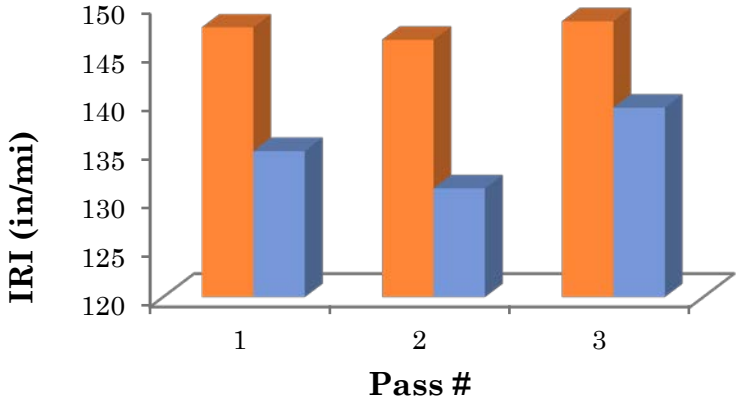
# Field Test – Site 1

| Pass # | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 81.5% | 80.9% | 82.4% | 83.0% | 84.9% | 75.9% | 77.3% | 82.0% | 83.0% |
| 2 | 81.5% | | 89.2% | 88.9% | 88.2% | 87.8% | 78.9% | 81.9% | 90.6% | 80.6% |
| 3 | 80.9% | 89.2% | | 89.3% | 88.6% | 89.0% | 81.6% | 77.7% | 88.2% | 87.5% |
| 4 | 82.4% | 88.9% | 89.3% | | 91.0% | 85.0% | 79.3% | 75.9% | 87.3% | 80.6% |
| 5 | 83.0% | 88.2% | 88.6% | 91.0% | | 91.7% | 79.5% | 79.4% | 87.5% | 85.7% |
| 6 | 84.9% | 87.8% | 89.0% | 85.0% | 91.7% | | 81.2% | 81.8% | 88.5% | 91.4% |
| 7 | 75.9% | 78.9% | 81.6% | 79.3% | 79.5% | 81.2% | | 75.6% | 78.9% | 79.4% |
| 8 | 77.3% | 81.9% | 77.7% | 75.9% | 79.4% | 81.8% | 75.6% | | 77.5% | 73.0% |
| 9 | 82.0% | 90.6% | 88.2% | 87.3% | 87.5% | 88.5% | 78.9% | 77.5% | | 86.6% |
| 10 | 83.0% | 80.6% | 87.5% | 80.6% | 85.7% | 91.4% | 79.4% | 73.0% | 86.6% | |

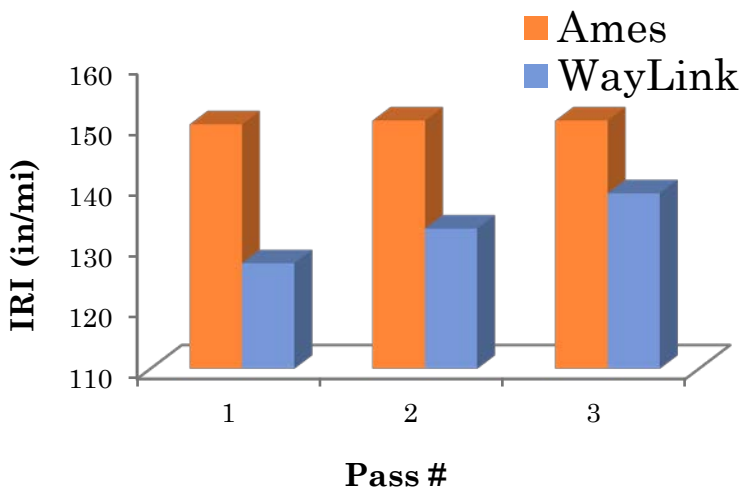
# Field Test – Site 1




10 mph




20 mph

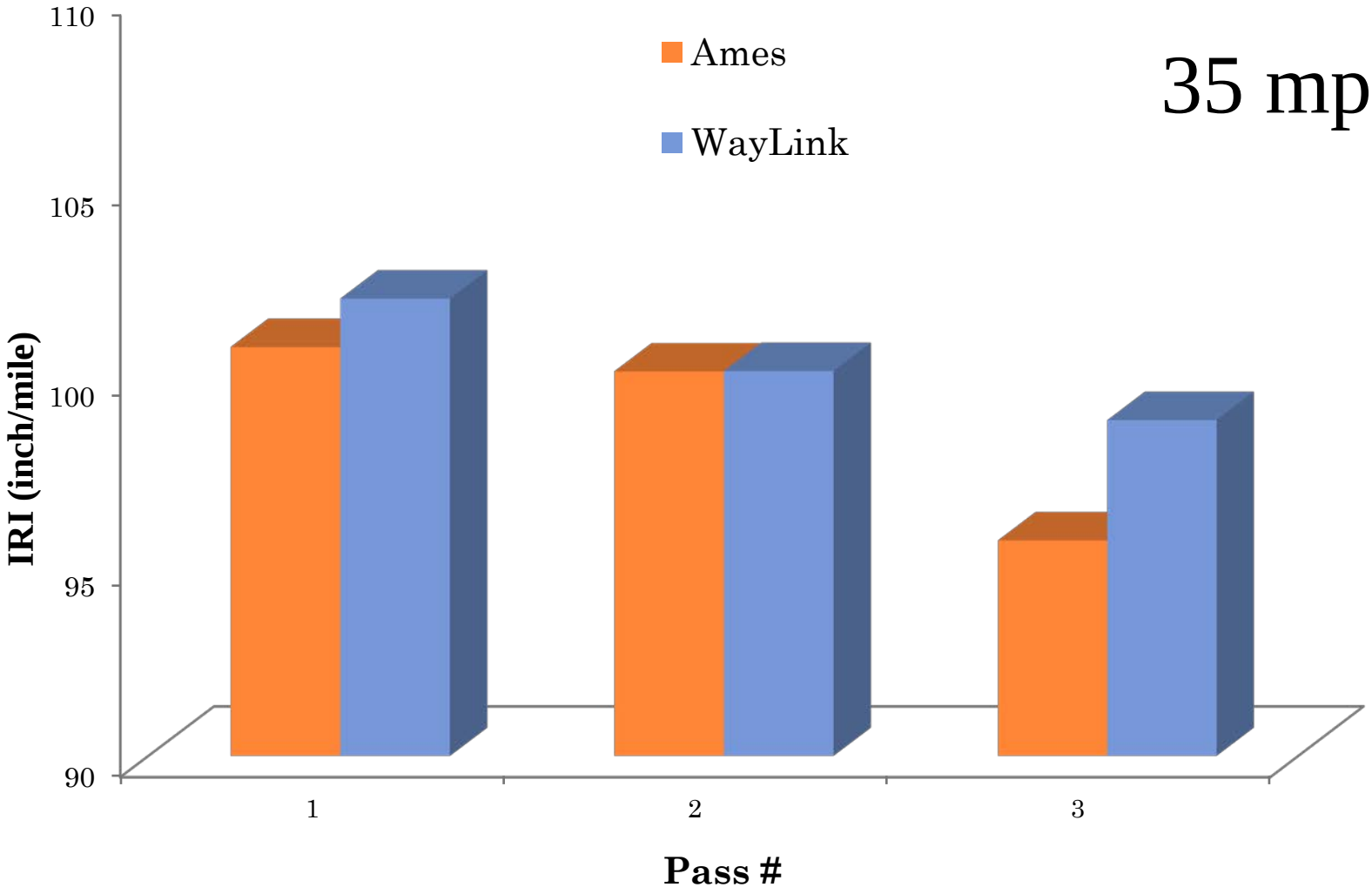



30 mph

# Field Test – Site 2

- PCC surface
- With longitudinal grade and horizontal curve

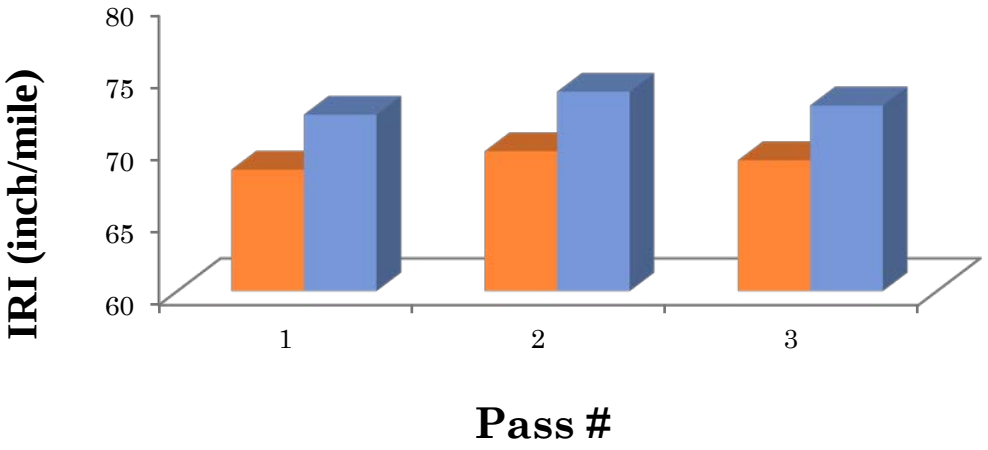
# Field Test – Site 2



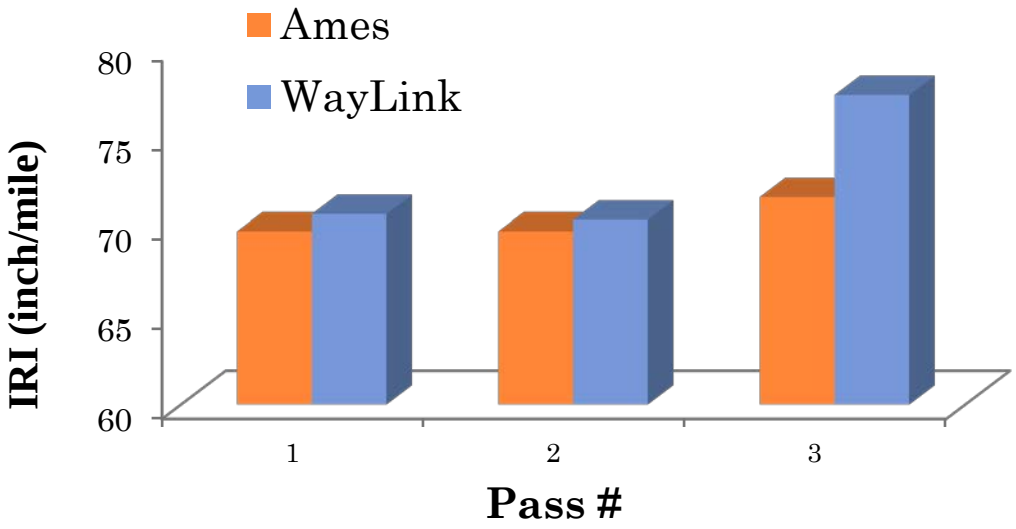
# Field Test – Site 3

- Asphalt surface
- High speed: 50mph, 60mph

# Field Test – Site 3




50 mph




60 mph

# Conclusions

- Integrated into 3D Ultra Sensors
- Repeatable Results
  - Multiple passes
  - Various speeds
  - Various road conditions and geometry
- What is next?
  - Further improve precision/bias and repeatability to meet profiler certification requirements