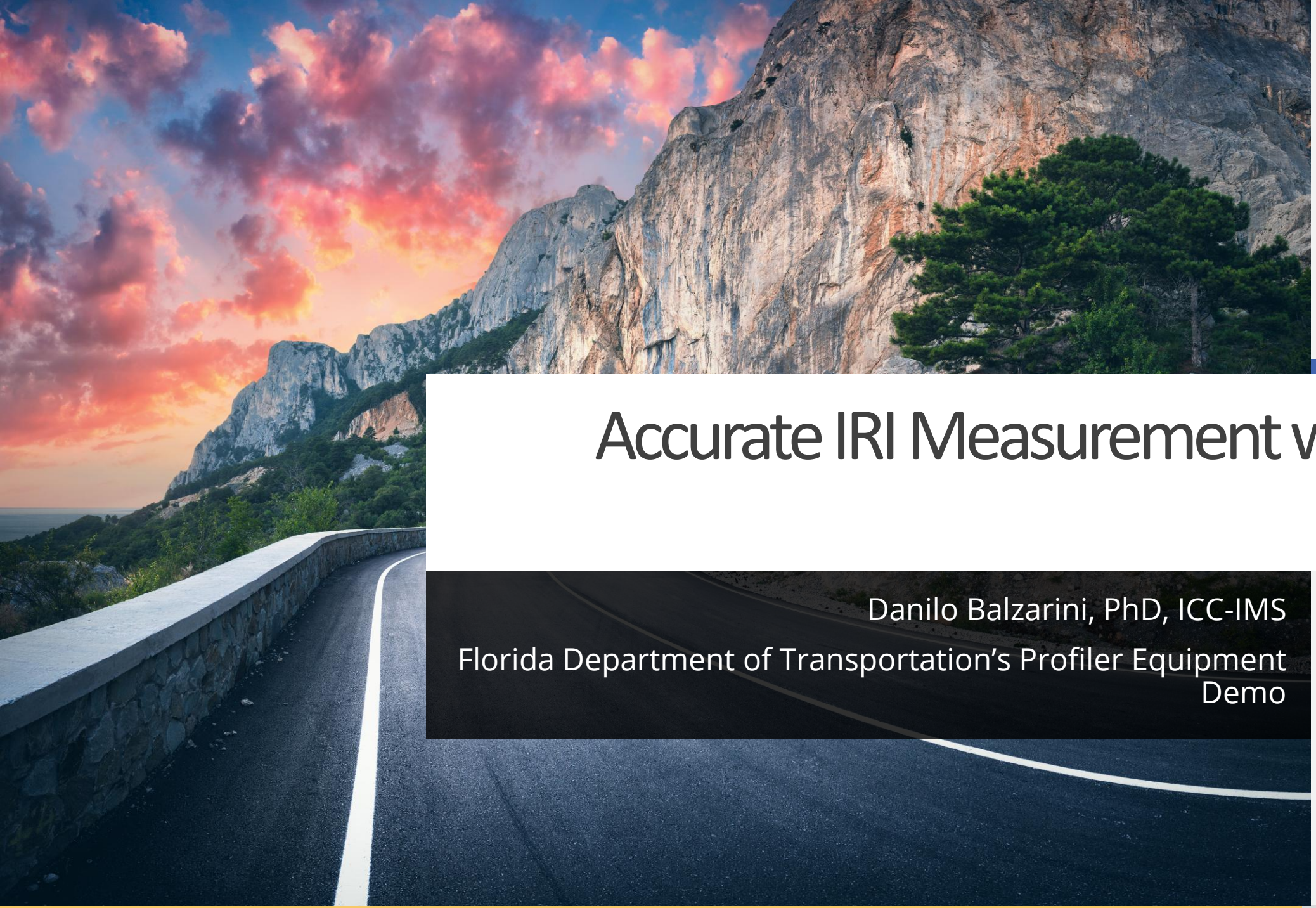


Accurate IRI Measurement with Inertial Profilers

Danilo Balzarini, PhD, ICC-IMS

Florida Department of Transportation's Profiler Equipment Demo

ICC
INTERNATIONAL CYBERNETICS

Why does ride quality matter?

Smoothness is the pavement property road users notice first



Reveals defects

Roughness can point to problems in the mix, the compaction or the base.



Amplifies truck loads

Bumps turn heavy trucks into dynamic impact loads that damage the road.



Shortens pavement life

Rougher pavements deteriorate faster than smooth ones.



Drives complaints

Rough roads are still the #1 reason road users complain.

Measure what road users feel — and measure it the same way every time.

Why do we need a standard measurement?

Every vehicle feels the same road differently

WHAT CHANGES THE RIDE

Vehicle mass **Suspension** **Tires** **Driving speed**

So a “bump feel” or bump indicator is not enough.

A VALID MEASUREMENT MUST BE

Accurate

Matches the reference (known “true”) value

Repeatable

Repeated runs give results close to each other

Reproducible

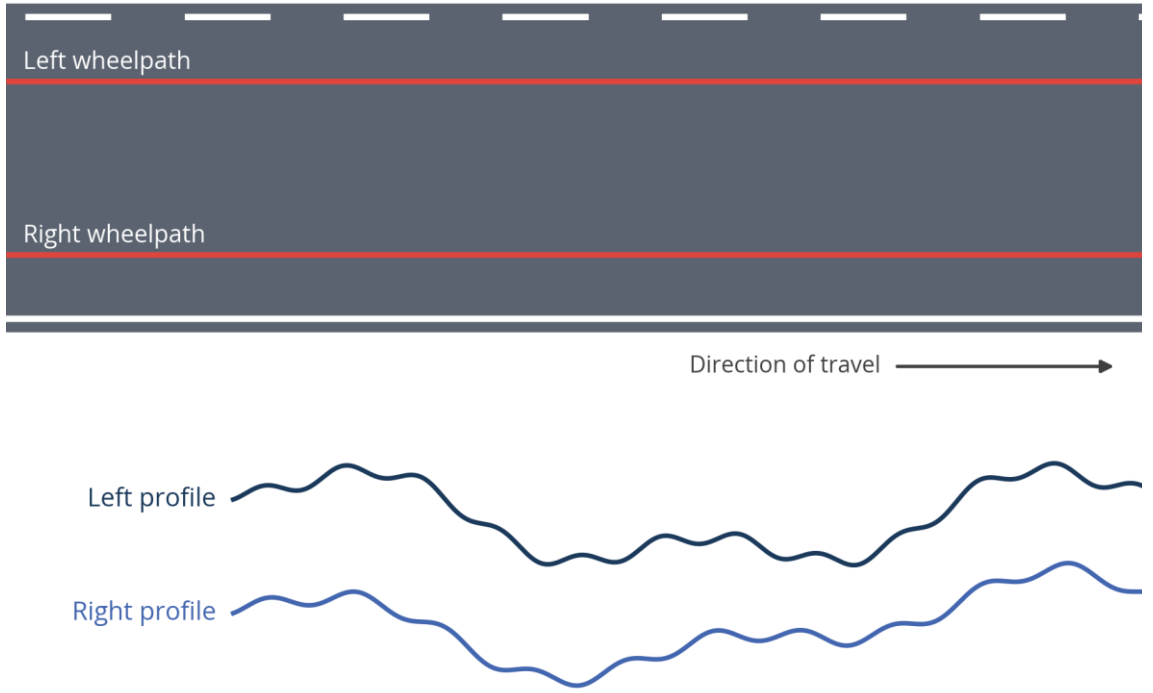
Different crews and devices get the same answer



What is the International Roughness Index (IRI)?

A standard number computed from the measured road profile

1. **Measure** the longitudinal profile in each wheelpath
2. **Simulate** a standard quarter-car driving over that profile
3. **Report** the result as IRI, in inches per mile



Anyone who measures the profile accurately gets the same IRI.

And the profile itself can be checked against a reference.

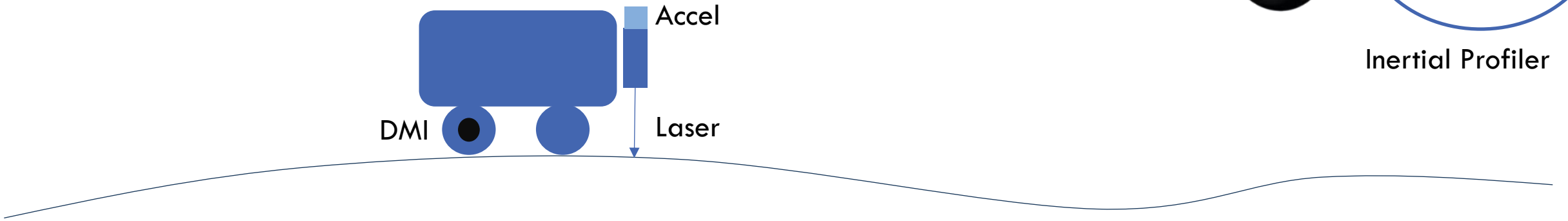
How does the profiler measure the profile?

A high-speed inertial profiler combines three instruments

- **Laser**
  Distance from the sensor to the road, d
- **Accelerometer**
  Vertical motion of the sensor, integrated to height h
- **DMI**
  Distance along the road, x, for every reading

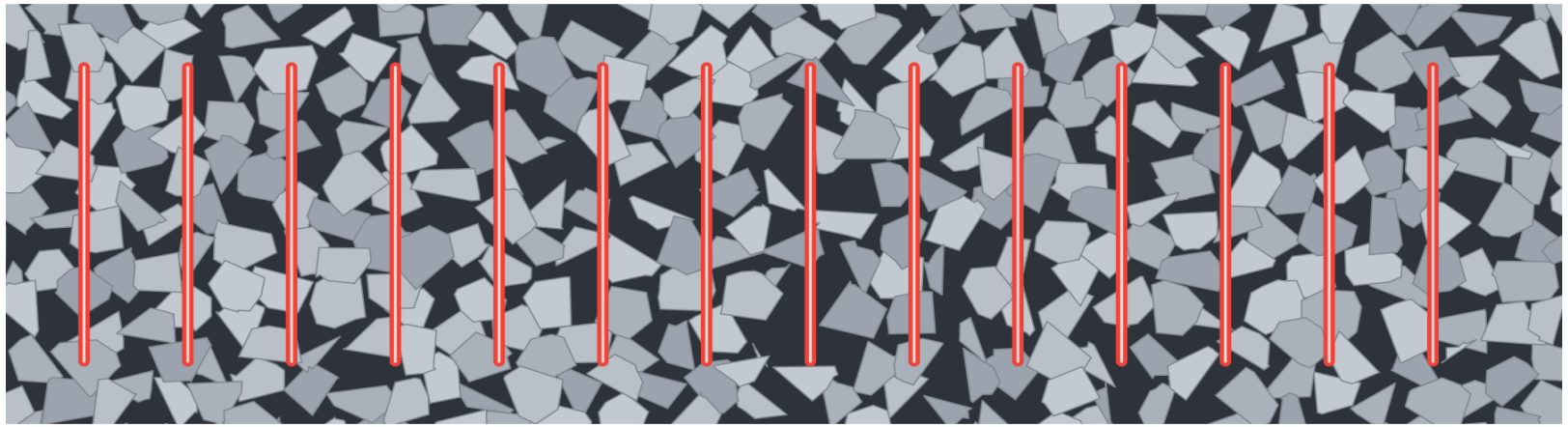


Inertial Profiler



Line laser

TOP VIEW · OPEN-GRADED SURFACE



Direction of travel

Line laser

Reads points across a 10cm transverse line. Less sensitive to texture and driving path. Several DOTs requires line lasers for IRI acceptance.

How is IRI calculated?

A standard quarter-car is simulated over the profile at 50 mph

Laser, accelerometer & DMI data › **ICC profile processing** › **Longitudinal profile** › **Quarter-car simulation** › **IRI (in/mi)**

IRI = accumulated suspension travel of the quarter-car ÷ distance traveled

Fixed, standard car parameters (ASTM E1926), so the result depends only on the road

Simulated speed of 80 km/h (≈ 50 mph), regardless of how fast the profiler drove

Computed separately for each wheelpath

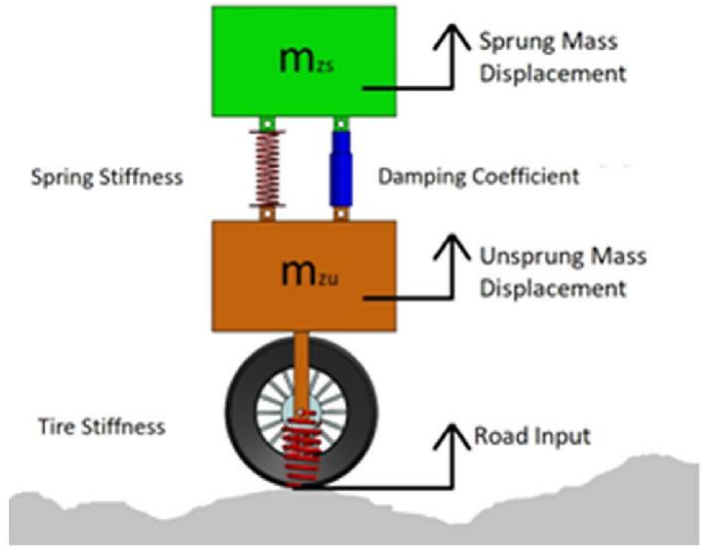


Image: Marathe, Khot & Nagler (2022), J. Vibration Eng. & Technologies

How are the profilers certified?

Each sensor is checked, then the full system is compared run to run and to a reference

Block test

Lasers read blocks of known height

Bounce test

Body motion is cancelled, not counted

DMI test

Distance matches a surveyed length

PROVAL CROSS-CORRELATION, %

Repeatability
Run vs run, same truck

97 mean

≥ 92 required

Accuracy
Truck vs reference profiler

95 mean

≥ 90 required

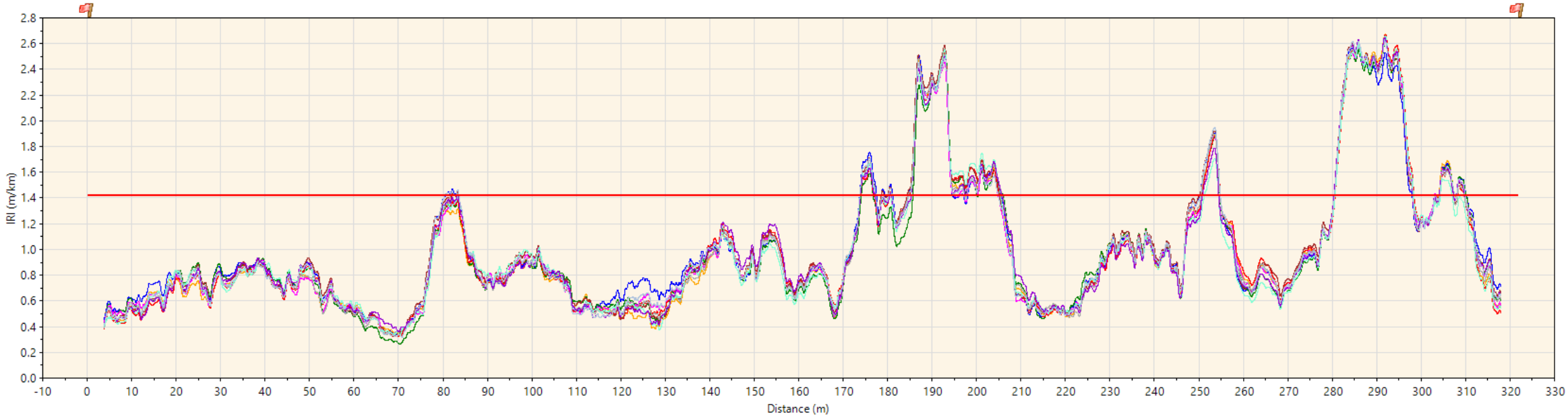
Cross-correlation compares the **shape** of the profile, not just the IRI.

Statistic	Repeat. L	Repeat. R	Accuracy L	Accuracy R
Comparisons	45	45	10	10
% passing	100	100	100	100
Mean	**96.86**	**97.55**	**95.50**	**94.29**
Minimum	**92.34**	**94.76**	**94.14**	**91.74**
Maximum	99.15	99.28	96.44	96.20
Std. deviation	1.6	1.2	0.7	1.6
Grade	Passed	Passed	Passed	Passed

ProVAL certification statistics, ICC inertial profiler (%)

Evaluating the profiles, not just IRI

Repeatable profiles mean repeatable IRI



Rolling IRI (m/km) along the section, left wheelpath

Every run finds the same rough spots, at the same locations, with the same severity. The profiler is measuring the road, not the run.

Every Speed Profiler (ESP)

Valid profile and IRI at any speed, including stops and starts



US Patent No. 9,404,738 · Canadian Patent No. 2,849,225

The low-speed problem: traditional inertial profilers cannot produce valid profile or IRI below about 12 mph.

A NEW WORKING PRINCIPLE

Dual line lasers

in each wheelpath

IMU

measures sensor orientation in each wheelpath

New algorithm

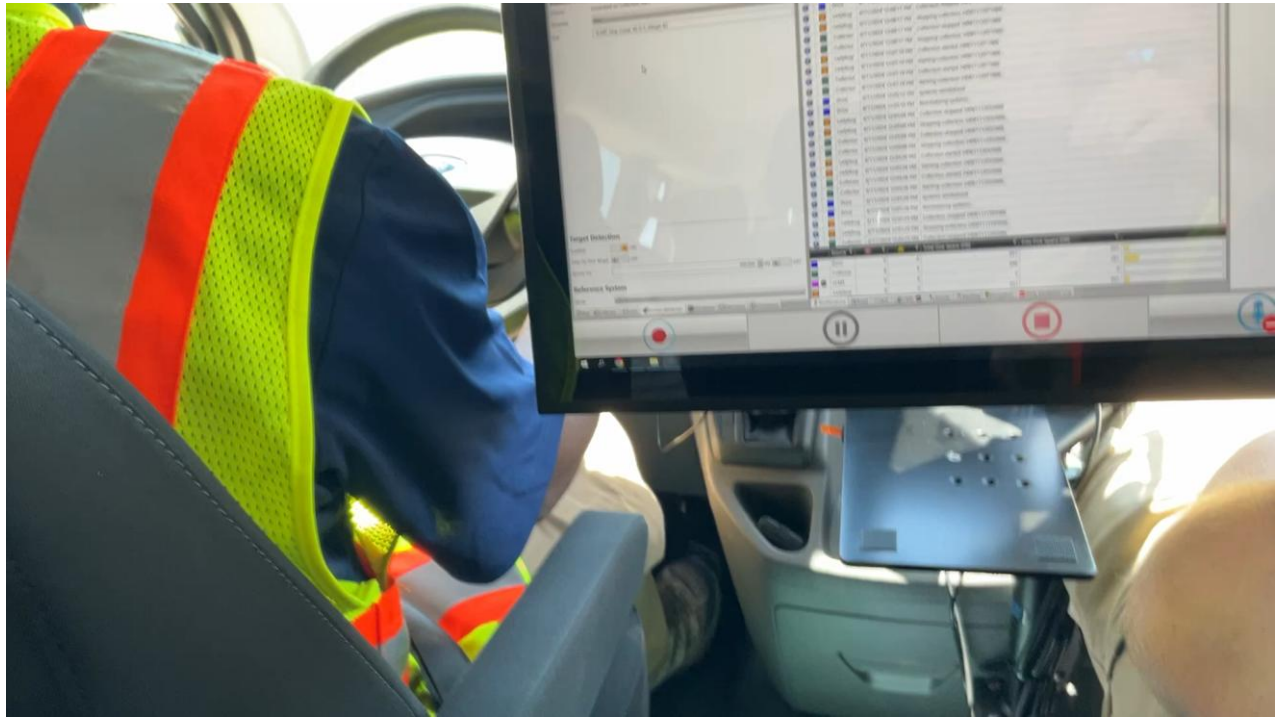
patented profile calculation

ESP validation at ICART

Illinois Certification and Research Track, June 11, 2024

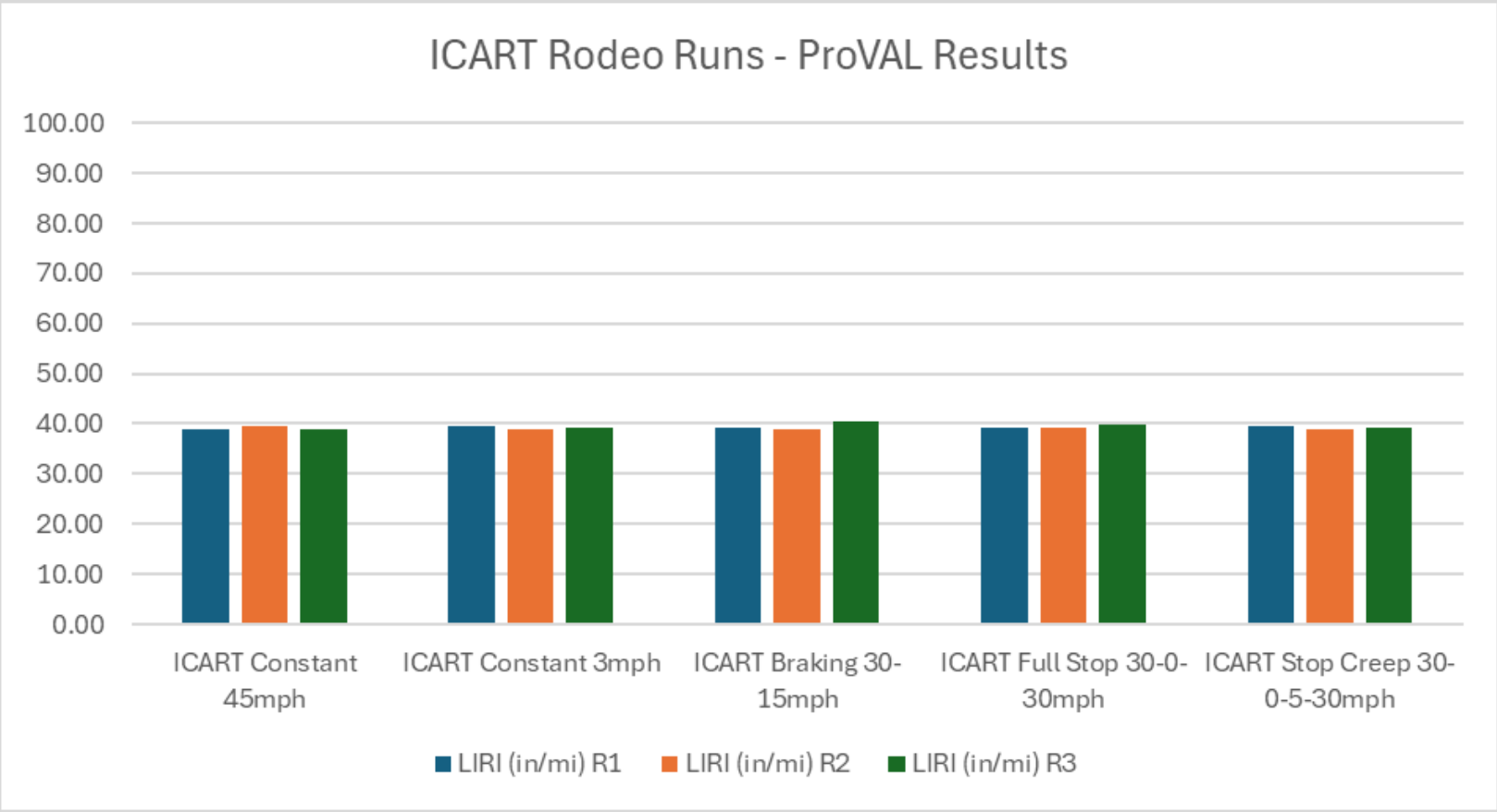
FIVE TEST TYPES

1. **Constant** 45 mph
2. **Constant** 3 mph
3. **Braking** 30 → 15 mph
4. **Full stop** 30 → 0 → 30 mph
5. **Stop & creep** 30 → 0 → 5 → 30 mph



ESP validation results

Same IRI on every run: at 45 mph, at 3 mph, braking, or through a full stop



≈ 40

in/mi left-wheelpath IRI, on every run

15

runs: 5 speed scenarios × 3 repeats

ESP profiles through a full stop

Profiles from repeated stop-and-go runs lie on top of each other



Top: 30-0-30 mph, 60 s stop. Bottom: 30-0-5-30 mph, 5 s stop with 3 mph creep. Thin lines: profiles (m); thick lines: speed (m/s, right axis).



Thank You

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