Intelligent Compaction

FOLEY CAT

Presented by Todd Mansell

NJAPA

What is Intelligent Compaction?

"Intelligent Compaction (IC) refers to the compaction of road materials, such as soils, aggregate bases, or asphalt pavement materials, using modern vibratory rollers equipped with an integrated measurement system, an onboard computer reporting system, Global Positioning System (GPS) based mapping, and optional feedback control. IC rollers facilitate real-time compaction monitoring and timely adjustments to the compaction process by integrating measurement, documentation, and control systems. IC rollers also maintain a continuous record of color-coded plots, allowing the user to view plots of the precise location of the roller, the number of roller passes, temperature, and material stiffness measurements."

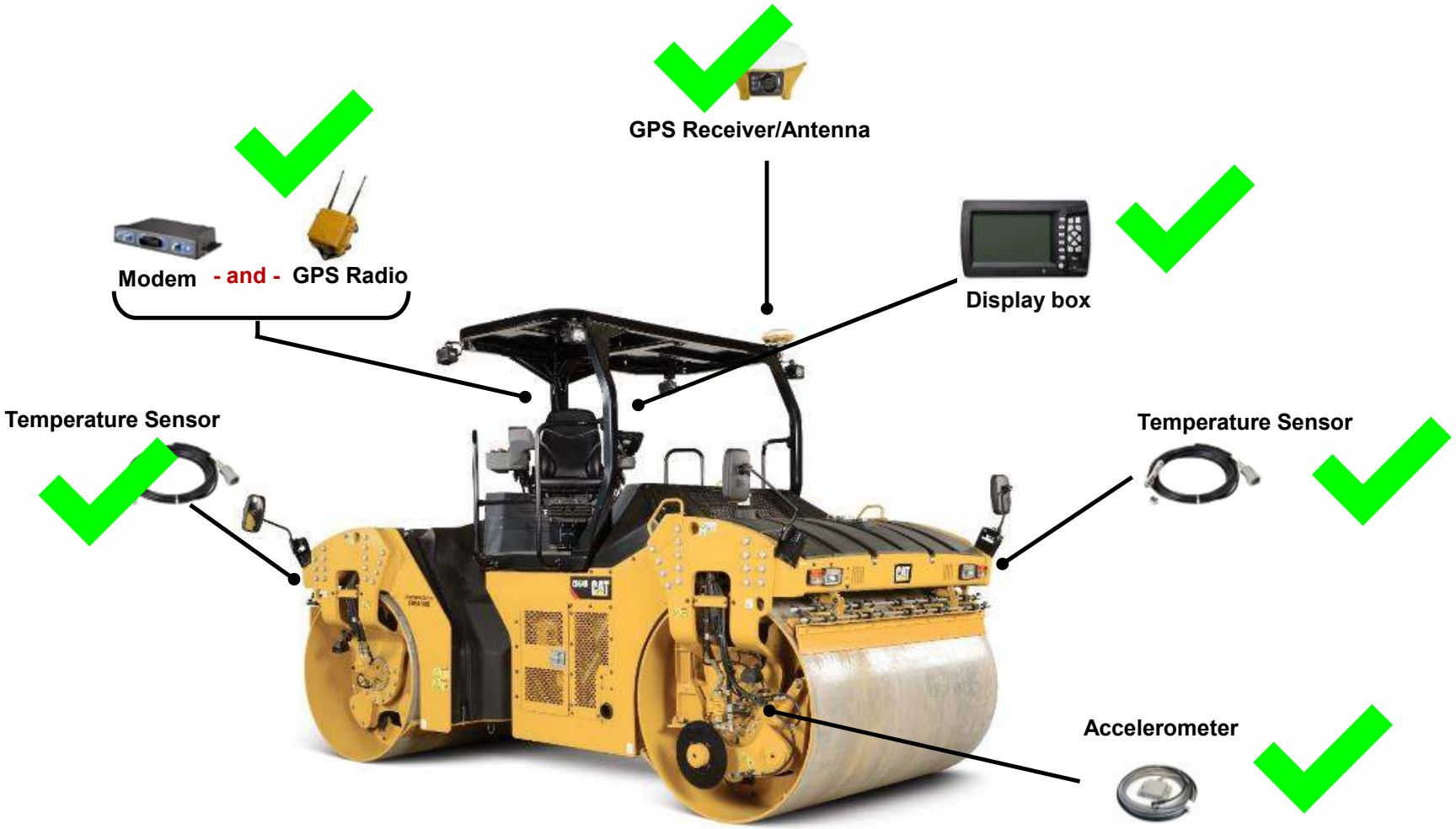
Source: FHWA 2012


With the conventional compaction measurement, what percentage of the surface is actually tested?
Less than 1%

Basic Components of IC:

1. **Positioning (GNSS) – Pass Counting & Location**
   - GNSS – Global Navigation Satellite System (GPS), SBAS, UTS, VRS
2. **Intelligent Compaction Measurement Value (ICMV)**
   - CMV, HCQ, Evib, CCV, others…
3. **Temperature measurement**
4. **Color-coded video display of “real-time” information**
5. **Data management – office and mobile software**
   - Storing & analyzing data

Components on an Asphalt IC roller



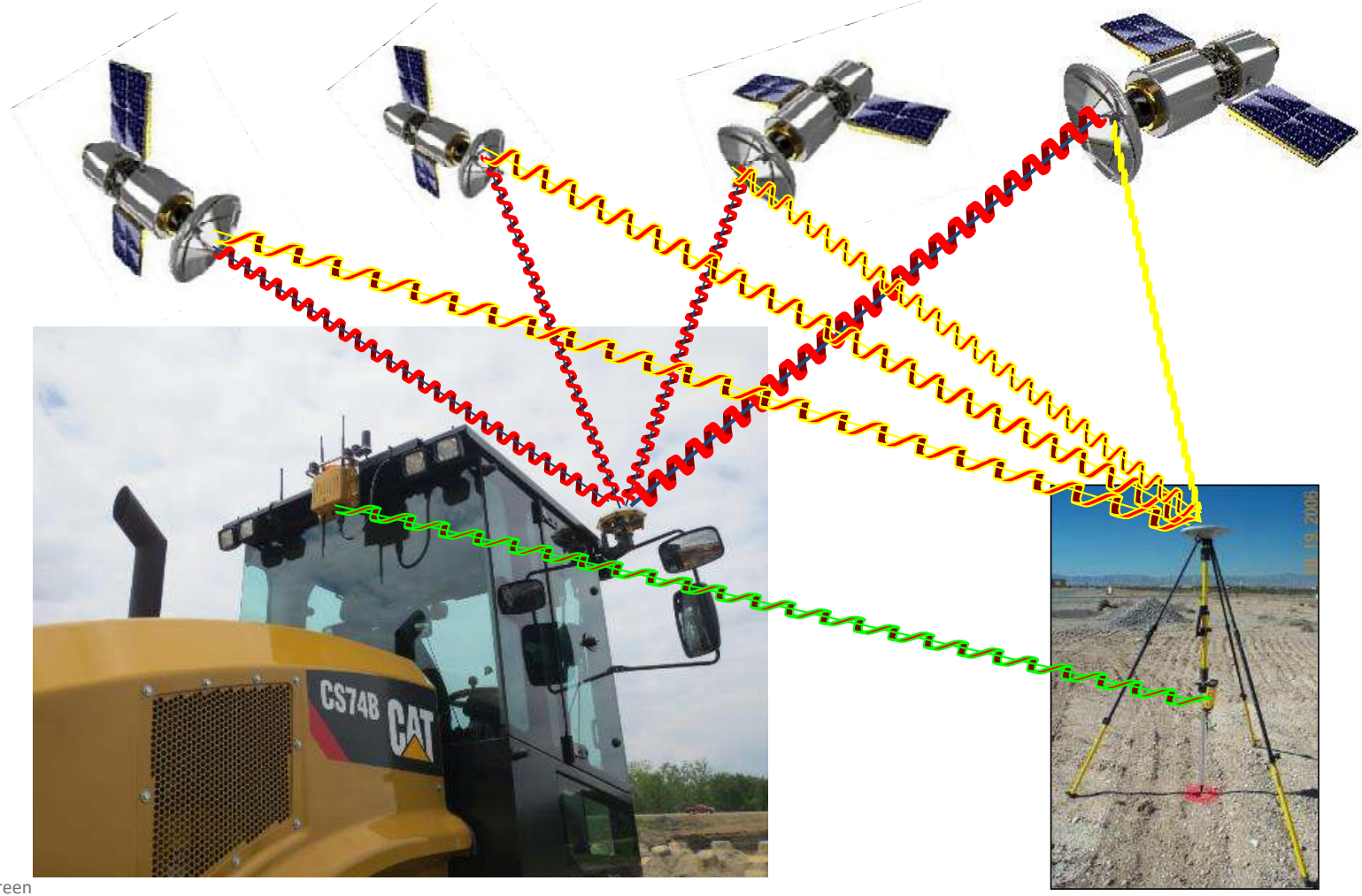
What does IC measure?

- Location
- Pass count (coverage)
- Surface temperature
- “Stiffness” as measured by an accelerometer
- Does not measure density!

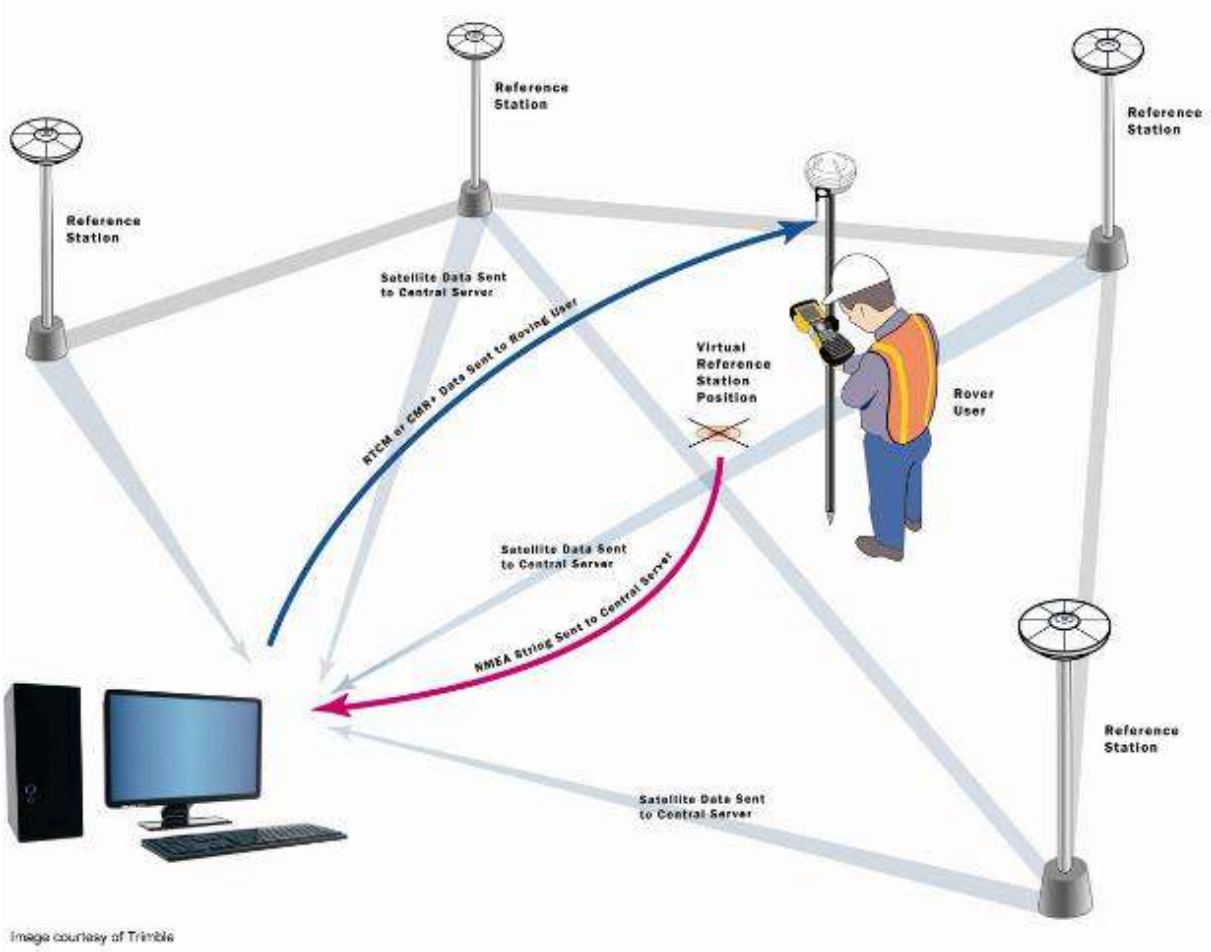
Color-coded Video Display - all data!

Positioning Accuracy

Real-Time Kinematic (RTK)



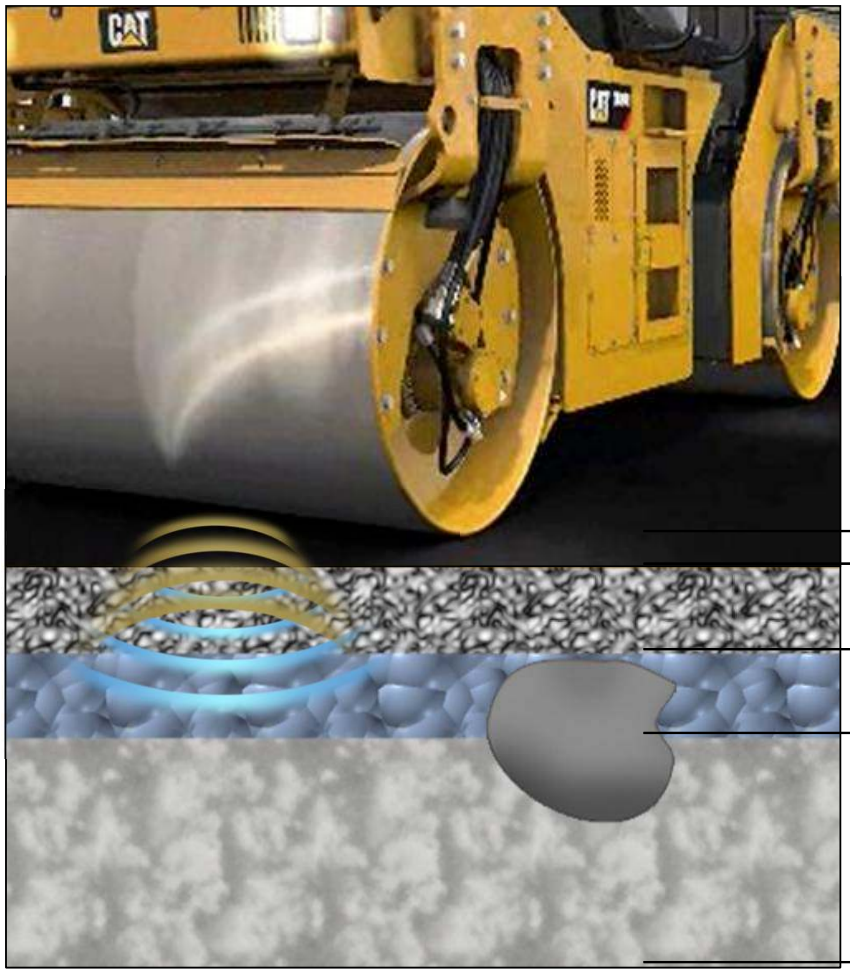
Virtual Reference Station (VRS)



Accelerometer – front drum only

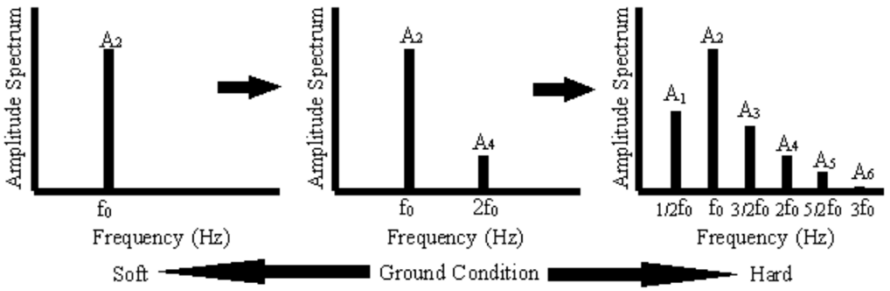
- All OEMs use accelerometers
- Vibration is required to obtain a reading

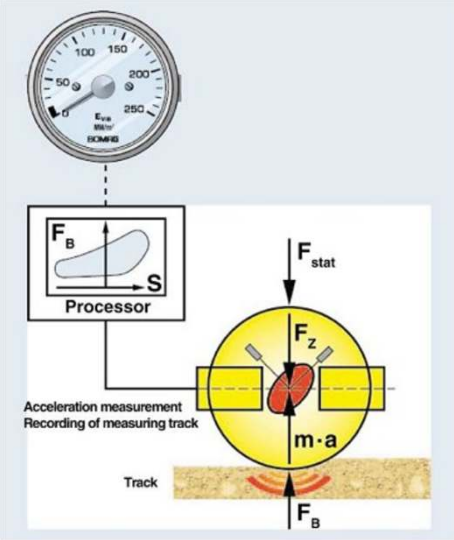
Accelerometer measures more than lift being paved...



- **Accelerometer measures deeper than the lift of asphalt being paved**
- **ICMV value is a *composite* measure of the stiffness of the current lift and the layers below it**

Are all accelerometers the same?



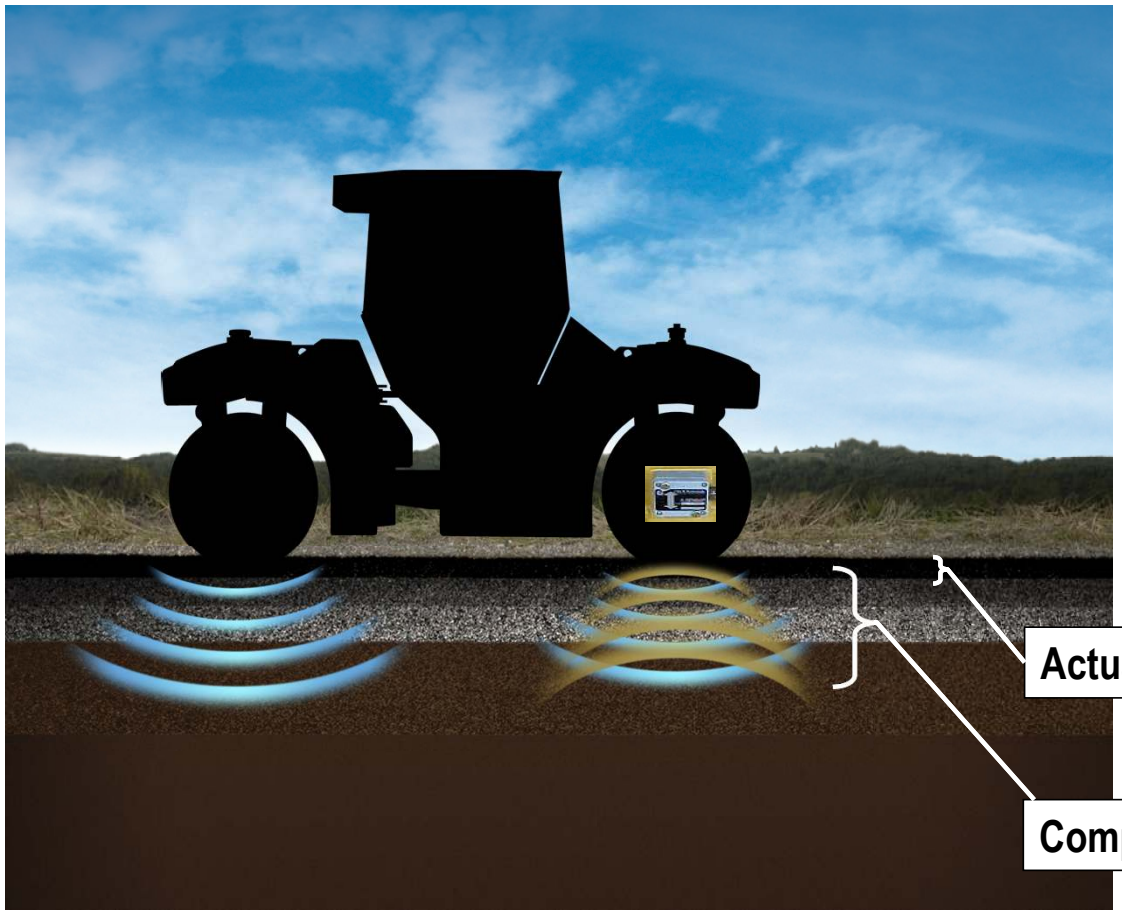


- Yes & No
- Hardware could be the same
- Output data is the same signal
- Mathematical modeling (processing) of data is what differentiates manufacturers' products

Density Direct – Volvo Neural Network

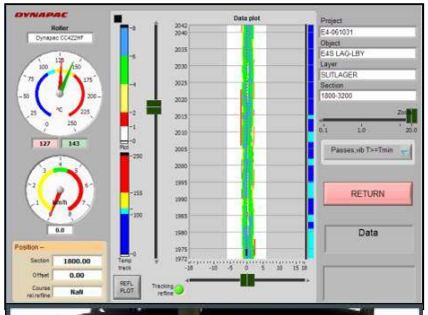
- Uses accelerometer
- "Intelligent Process" that learns
- Neural networks
- Produces EDV – direct reading of "Estimated Density Value"

Accelerometer measures more than lift being paved



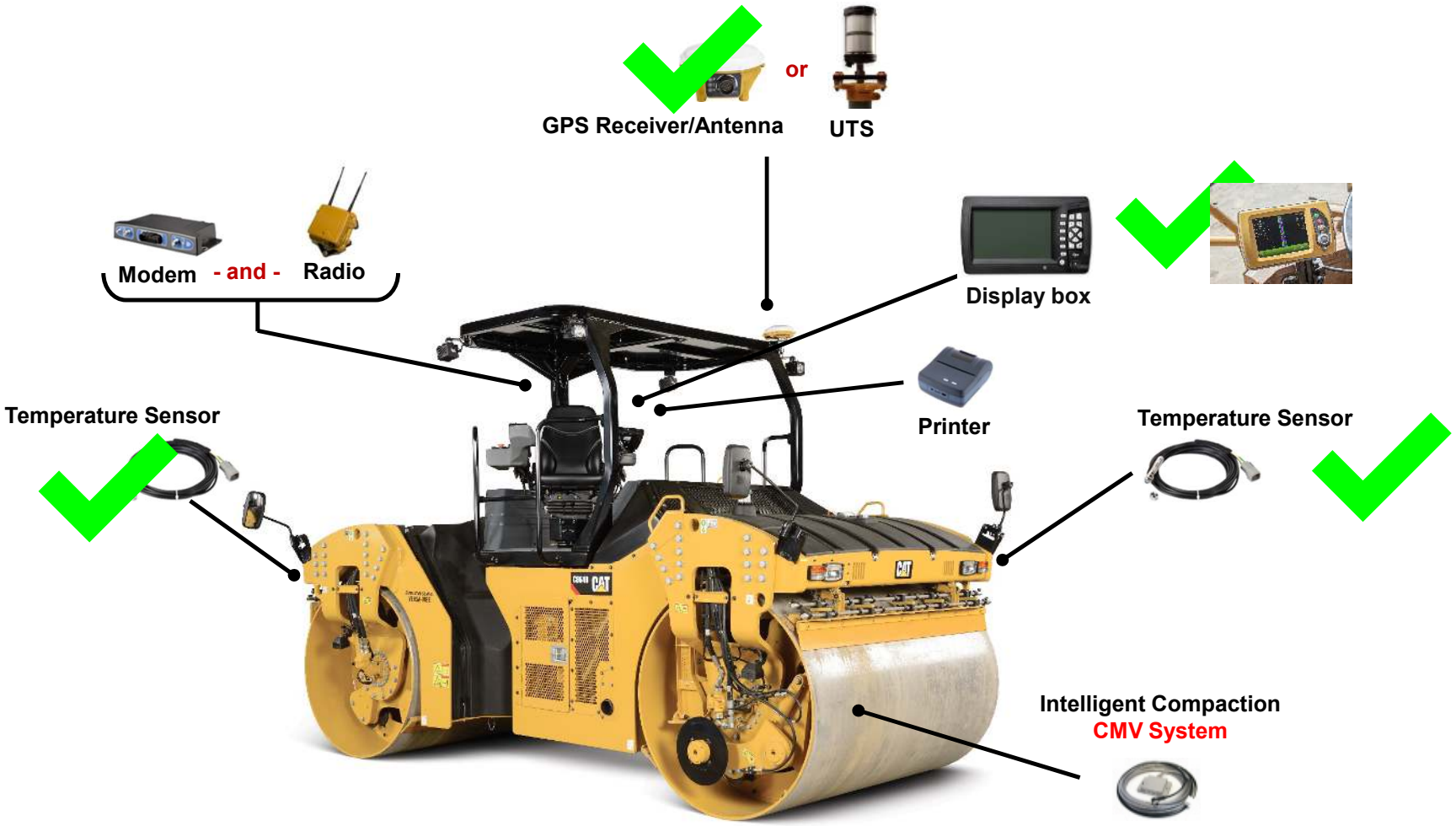
- Measurement depth varies based on amplitude setting
- Useful indicator of base and sub-base layer stiffness

OEM Solutions



- Purchase various accuracies of GPS/positioning systems
- Temp & Pass Count only
- Accelerometer is optional
- Product support through dealer
- Availability can still be an issue
- Rental option?

Retrofit options…



Retrofit Options for any Roller

Moba, Trimble, TopCon, others???

Advantages	Disadvantages
Fits any roller	Not integrated (speed, f, A, other data not available)
May be less expensive	May be more expensive
“Portable” from machine to machine	Limited Product Support through equipment dealer??

Examples of “ICMV” values from different OEMs

	ICMV	Units	Trade name
Bomag	E_{vib}	MN/m^2	**E_{vib}**
Case/Amman	ACE	??	ACE
Caterpillar	CMV	Unitless	**C**ompaction **M**eter **V**alue
Dynapac	CMV	??	**C**ompaction **M**eter **V**alue
Hamm	HMV	Unitless	**H**amm **M**easuring **V**alue
Sakai	CCV	Unitless	**C**ompaction **C**ontrol **V**alue
TopCon	CCV	Unitless	**C**ompaction **C**ontrol **V**alue
Trimble	CMV	Unitless	**C**ompaction **M**eter **V**alue
Volvo	EDV	Density %	**E**stimated **D**ensity **V**alue

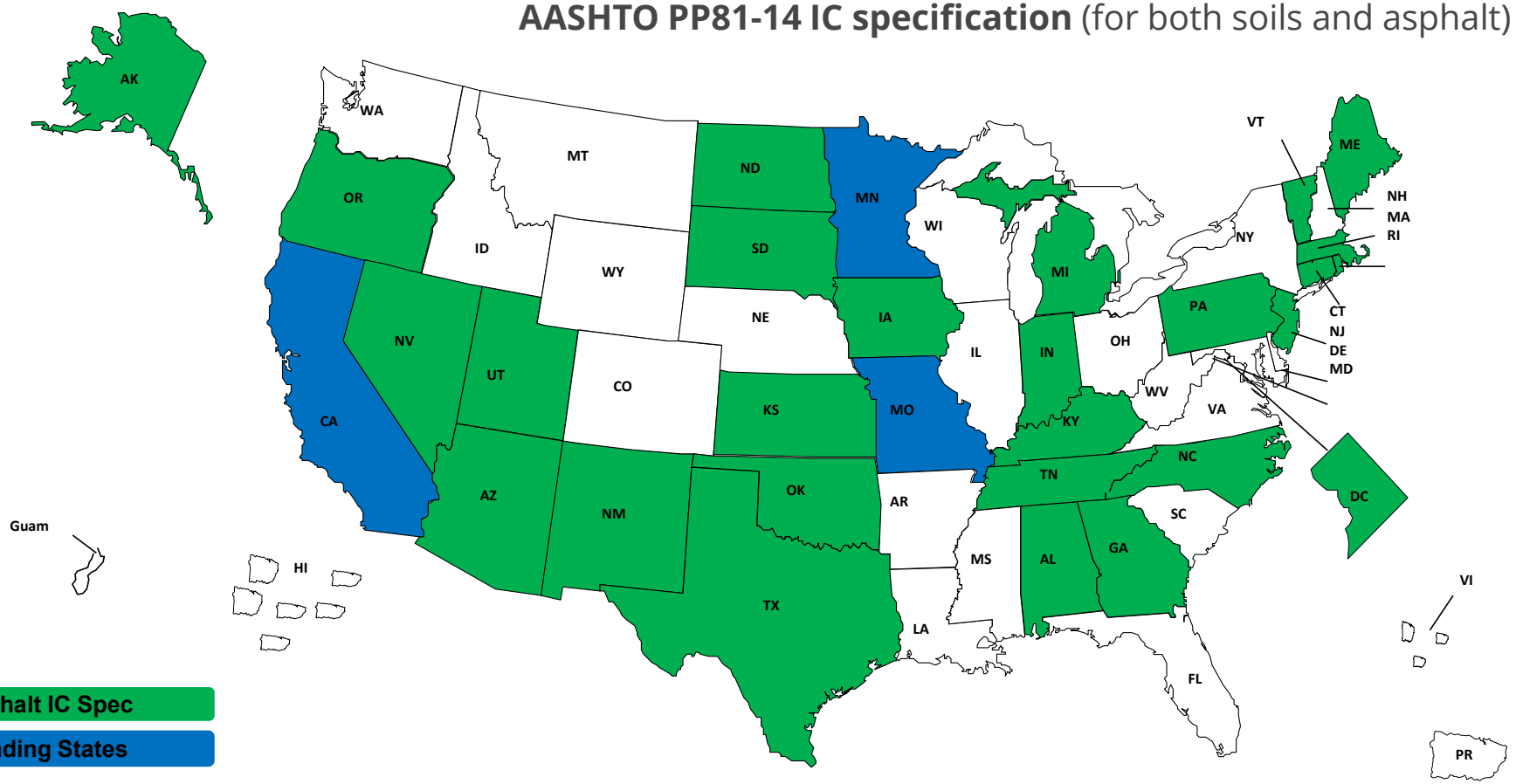
Things to understand about ICMVs…

- ICMV is an **indicator** of material stiffness, **not** a measure of density.
- ICMV values are influenced by sub-surface conditions up to 6 feet below the surface
- **ICMV values are influenced by many factors**: speed, direction of machine, amplitude setting, frequency setting, material properties, and more
- Good correlations between ICMVs and conventional measurement methods are difficult to achieve, but possible in some cases
- Repeatable correlations between ICMVs and Density have not been shown to exist
- ICMV values are not comparable between machines. It is unique to each roller.

ICMV ≠ Density

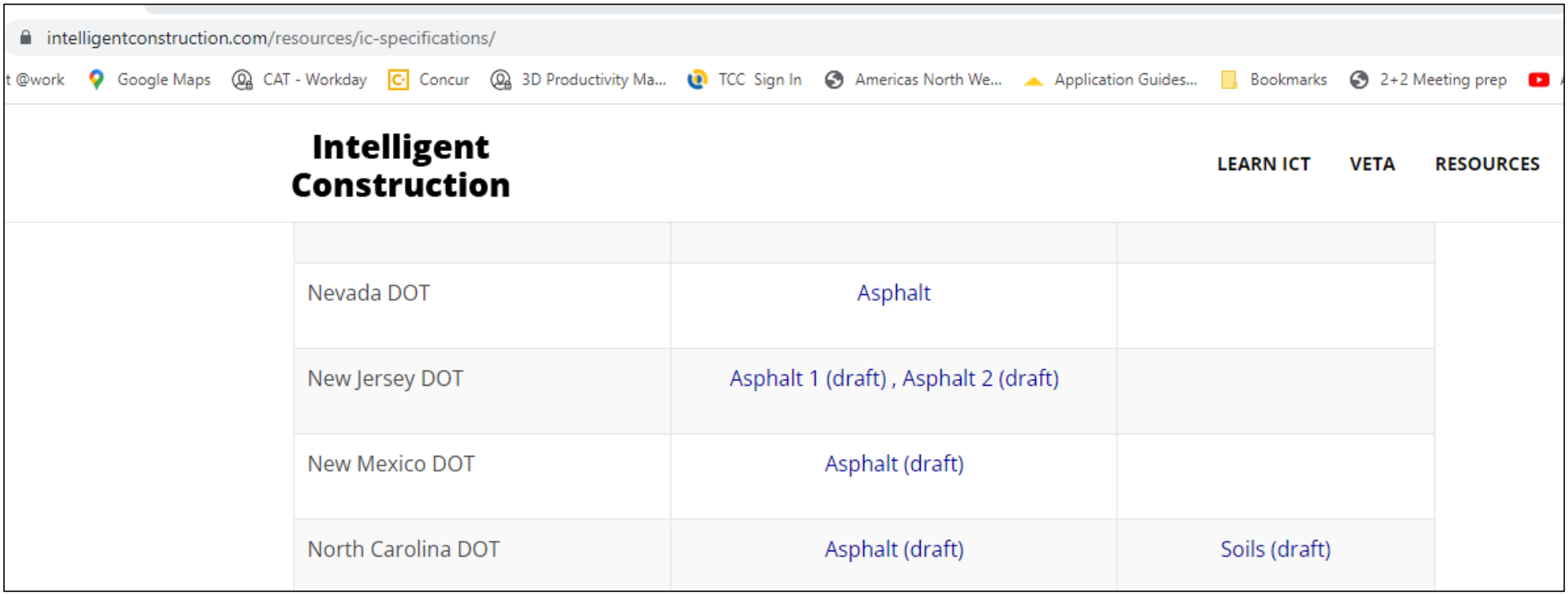
Asphalt IC Specifications

AASHTO PP81-14 IC specification (for both soils and asphalt)



New Jersey Asphalt IC Specification

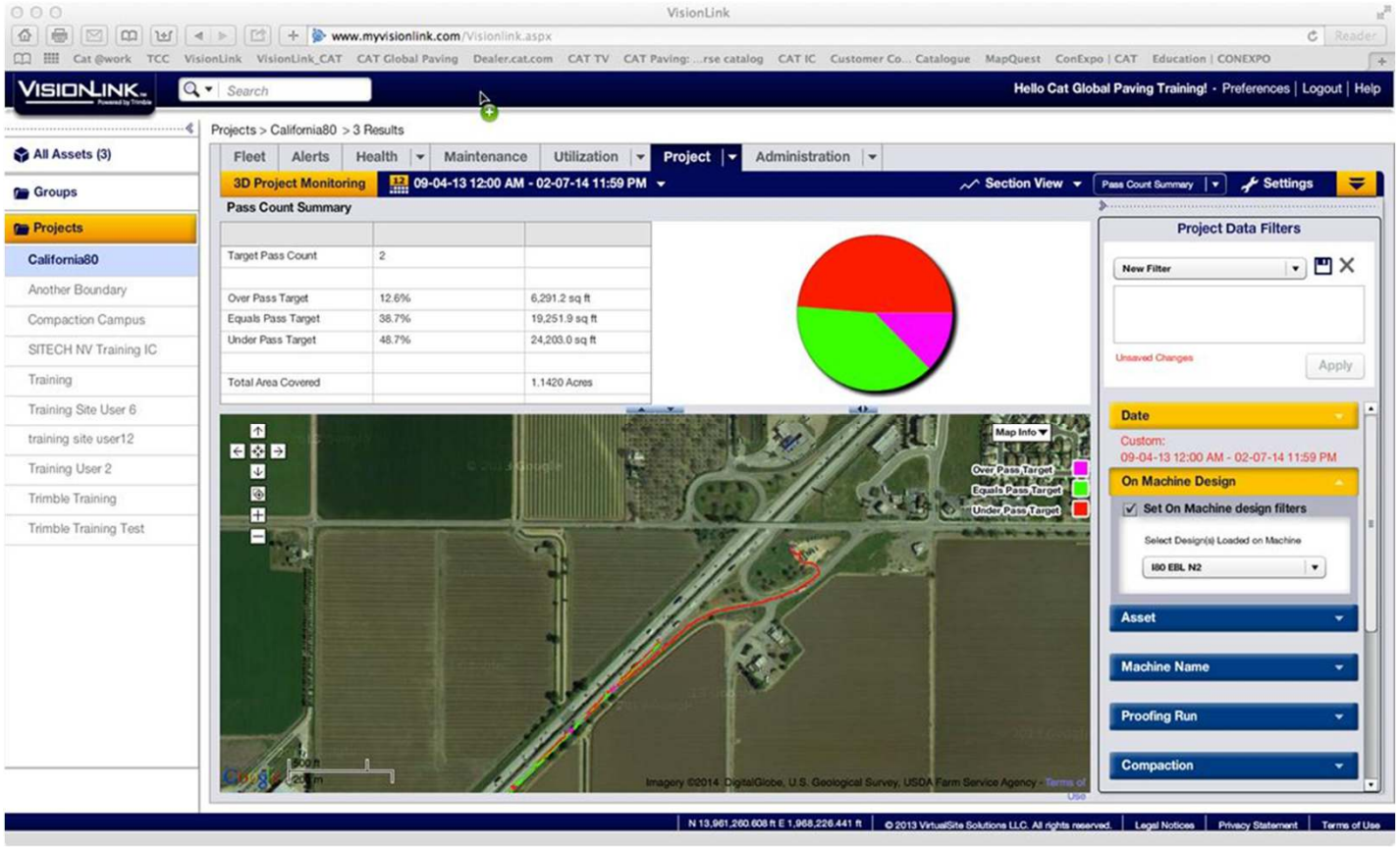
www.intelligentconstruction.com



Nevada DOT	Asphalt	
New Jersey DOT	Asphalt 1 (draft) , Asphalt 2 (draft)	
New Mexico DOT	Asphalt (draft)	
North Carolina DOT	Asphalt (draft)	Soils (draft)

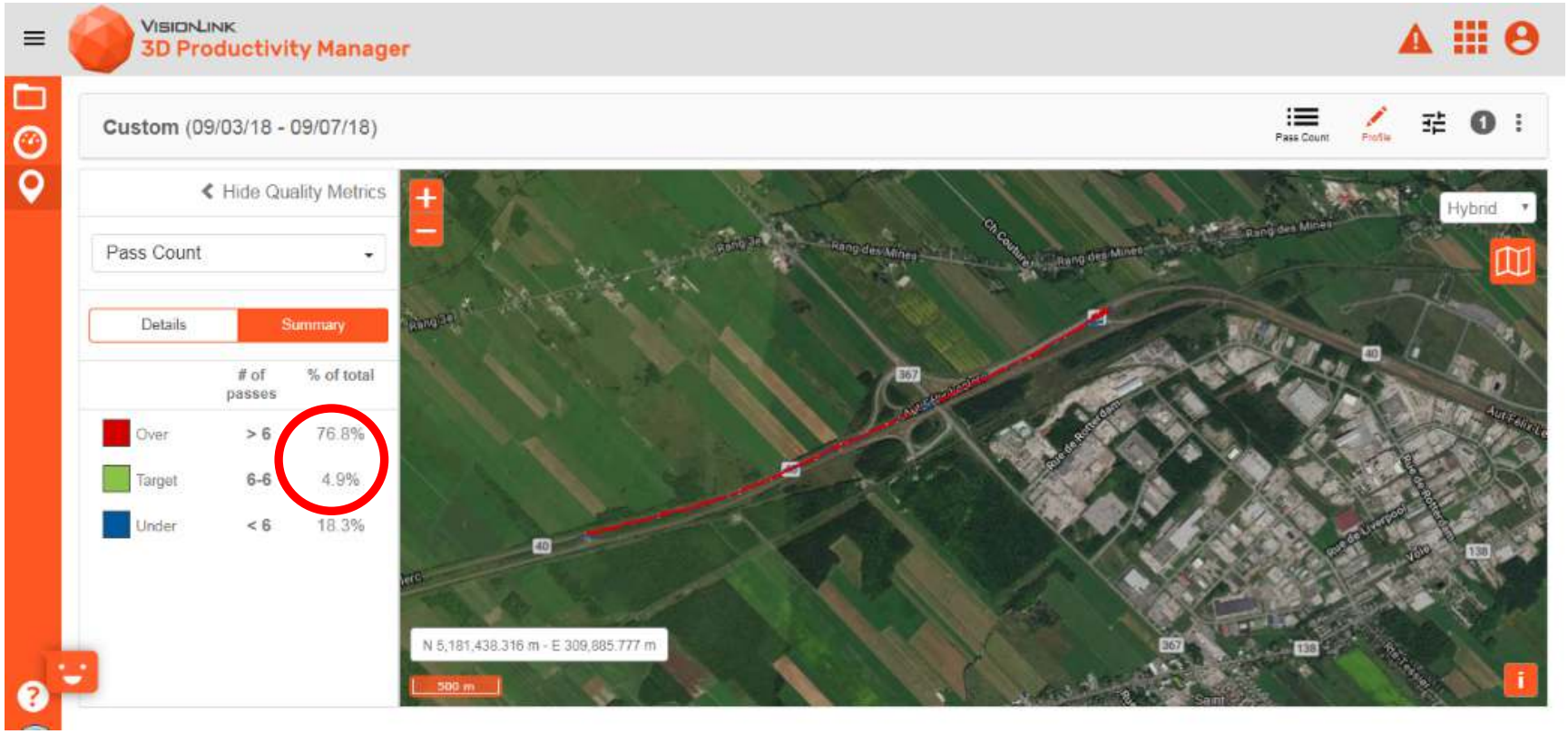
Pass counts

Pass Counts vs Target Pass Count



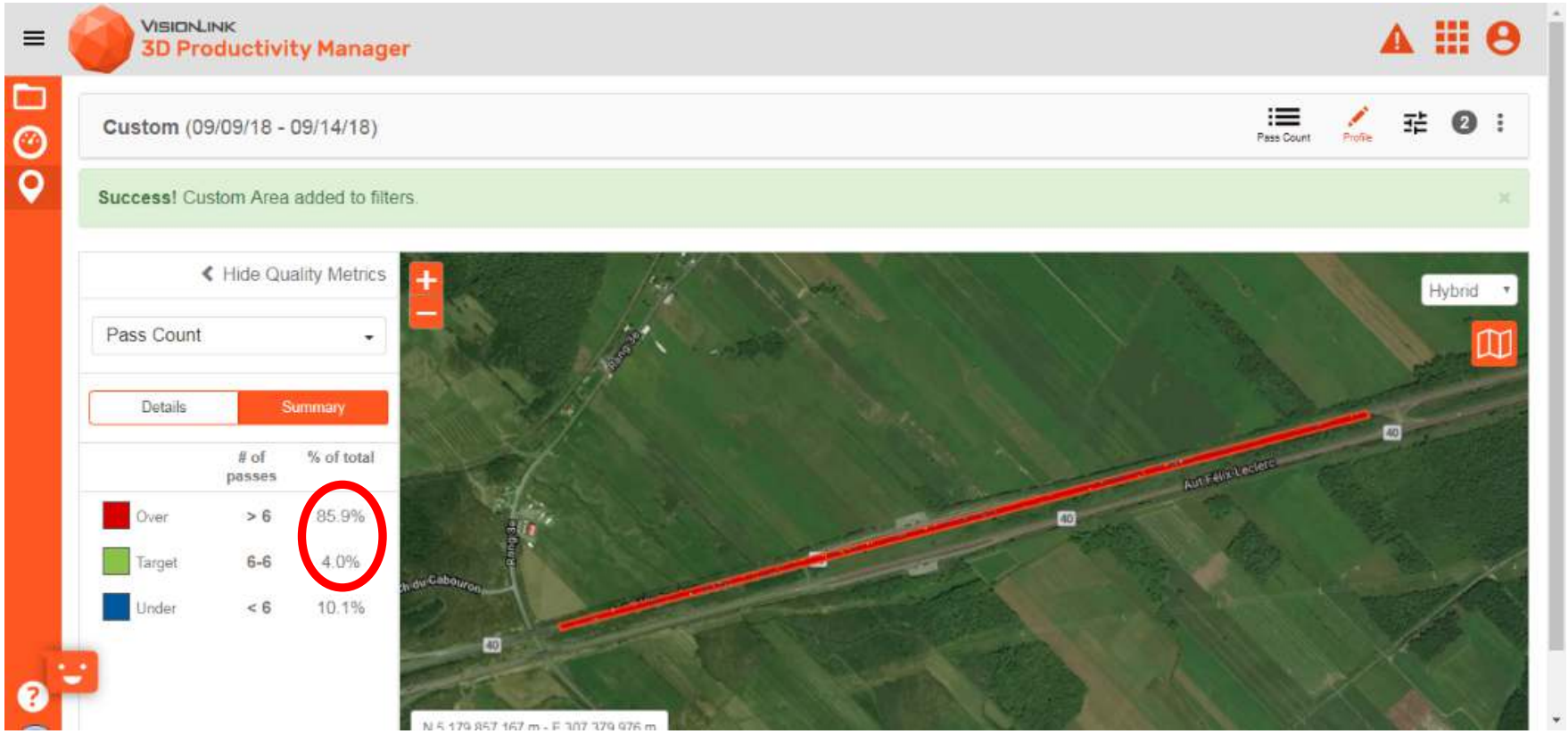
- Method specs
- Test Section rolling pattern
- PWL Specs
- Night paving

Pass Count: Not Using Mapping



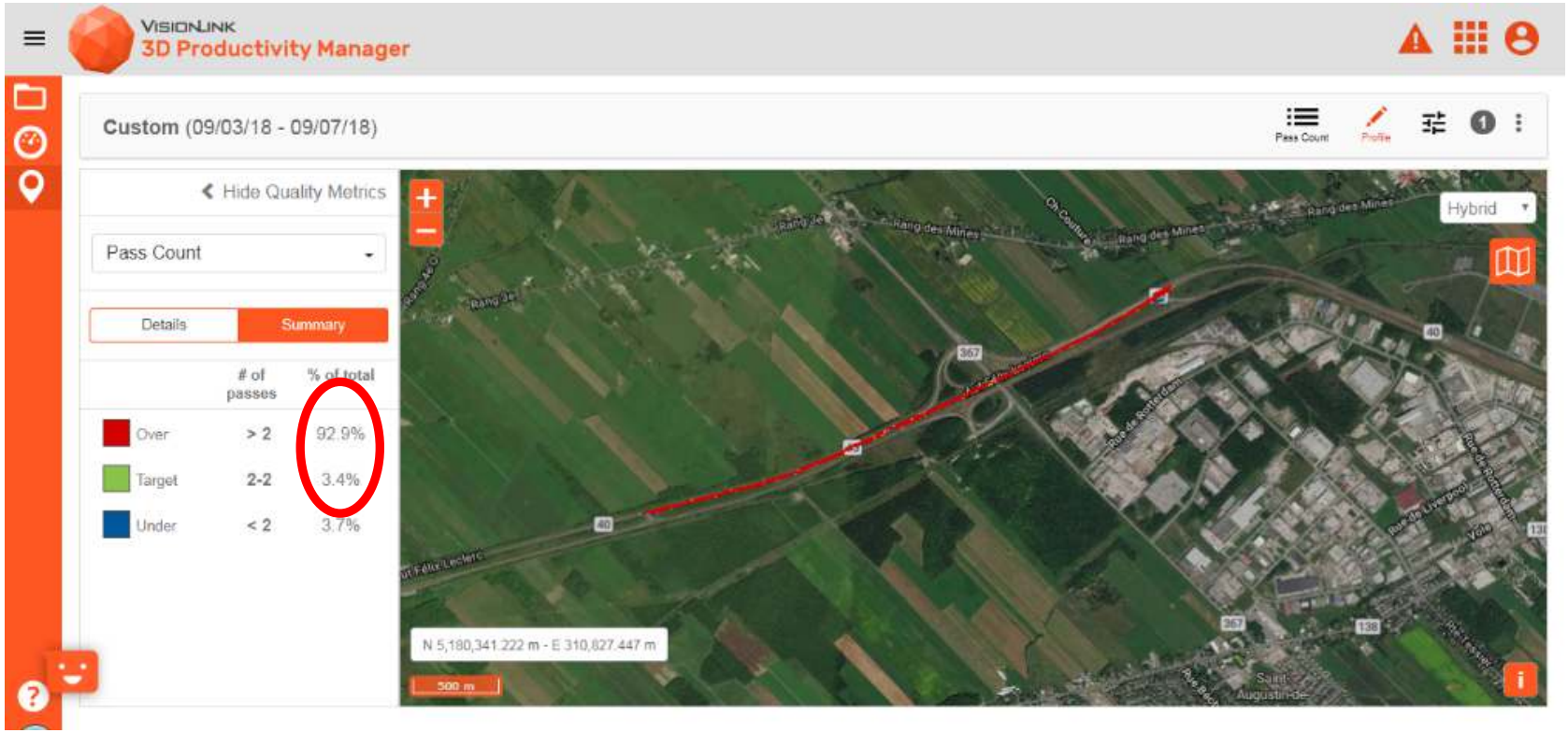
- **All rollers** 83% > target pass (6)

Pass Count: Using Mapping



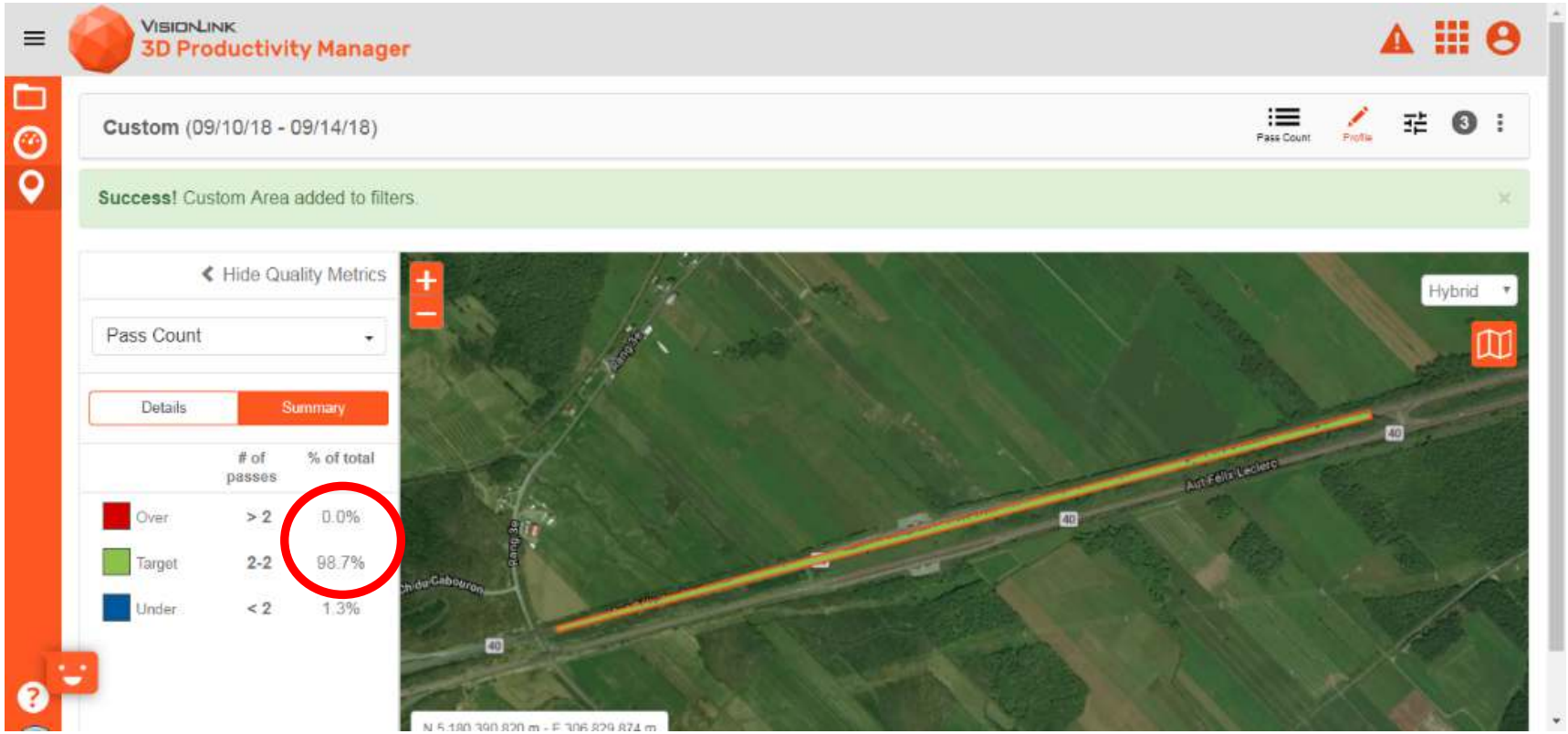
- **All rollers** 90% > target pass (6)

Pass Count: Not Using Mapping



- **Breakdown rollers only**: 96% > target pass for breakdown

Pass Count: Using Mapping



- **Breakdown rollers only**: 99% > target pass for breakdown

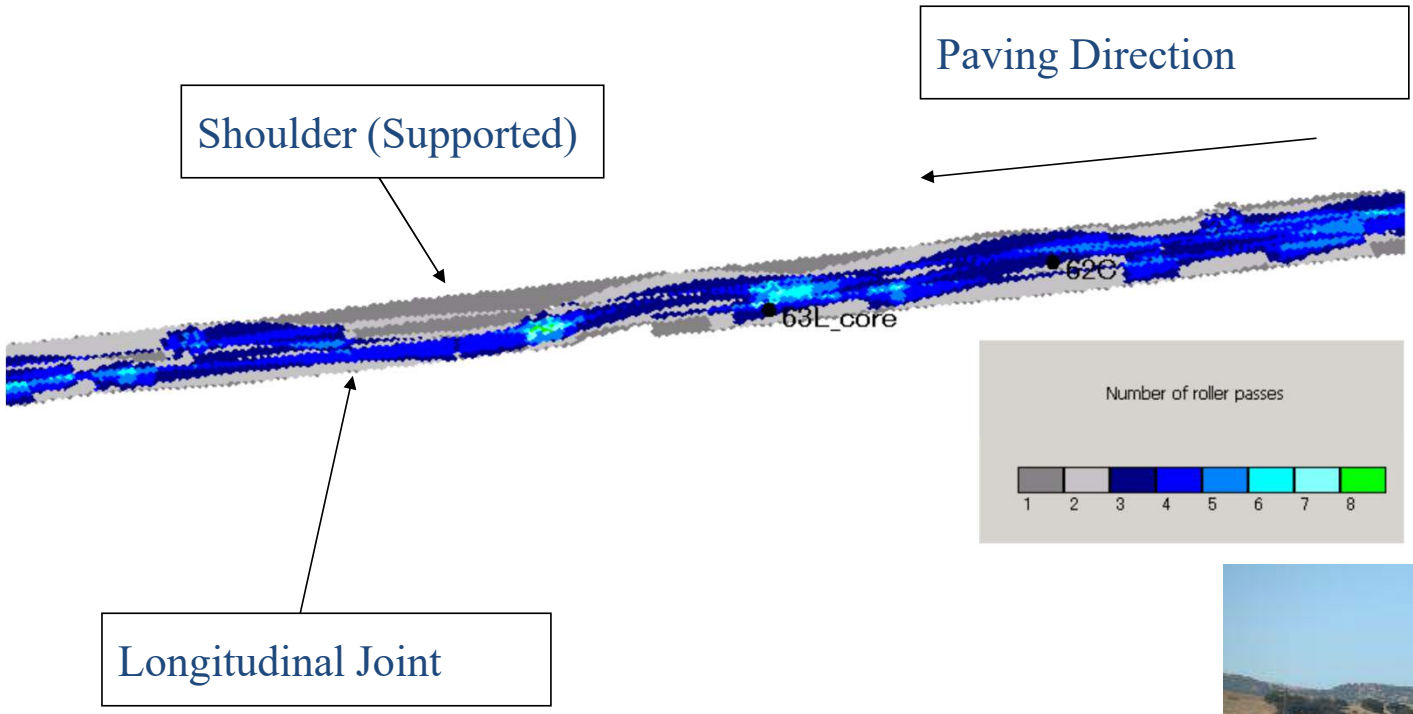
Pass Count summary

- Pass count coverage improved using mapping

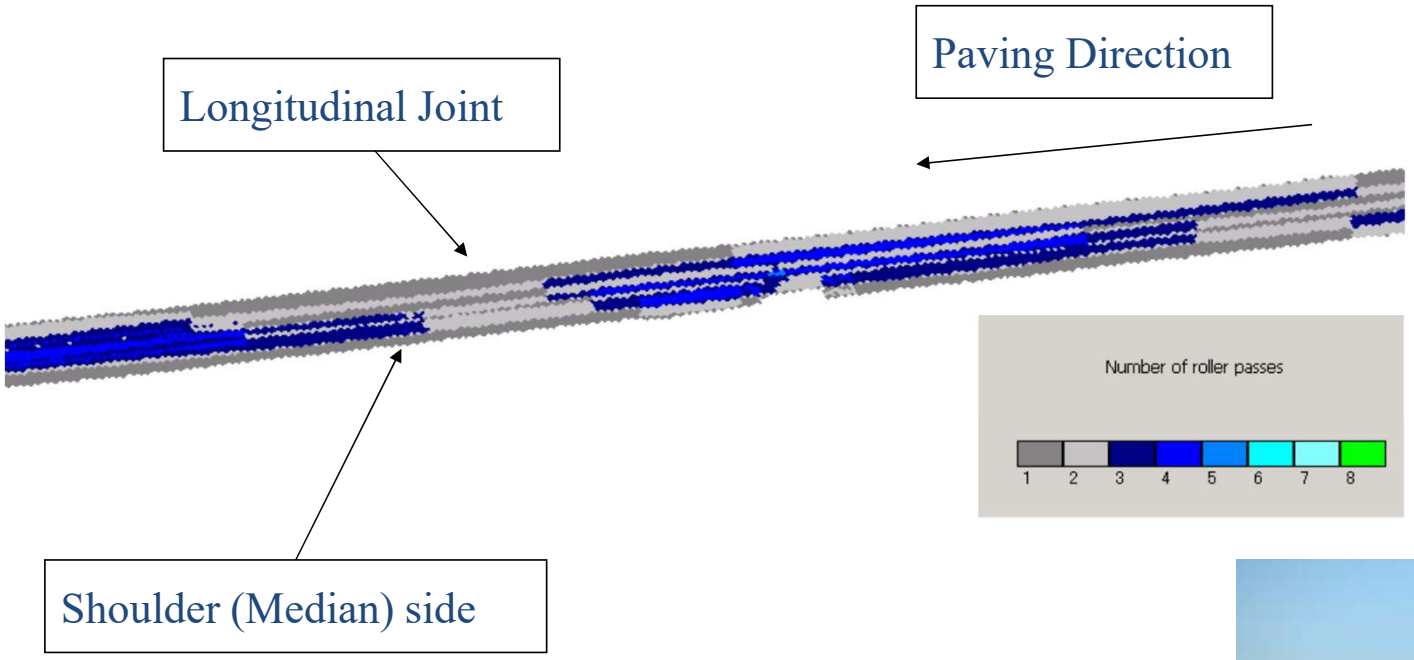
- Breakdown rolling (target = 2 passes)
  - Before training: 93% had 2 passes
  - After training: 99% had 2 passes

- All rollers (target = 6 passes)
  - Before training: 83% had 6 passes
  - After training: 90% had 6 passes

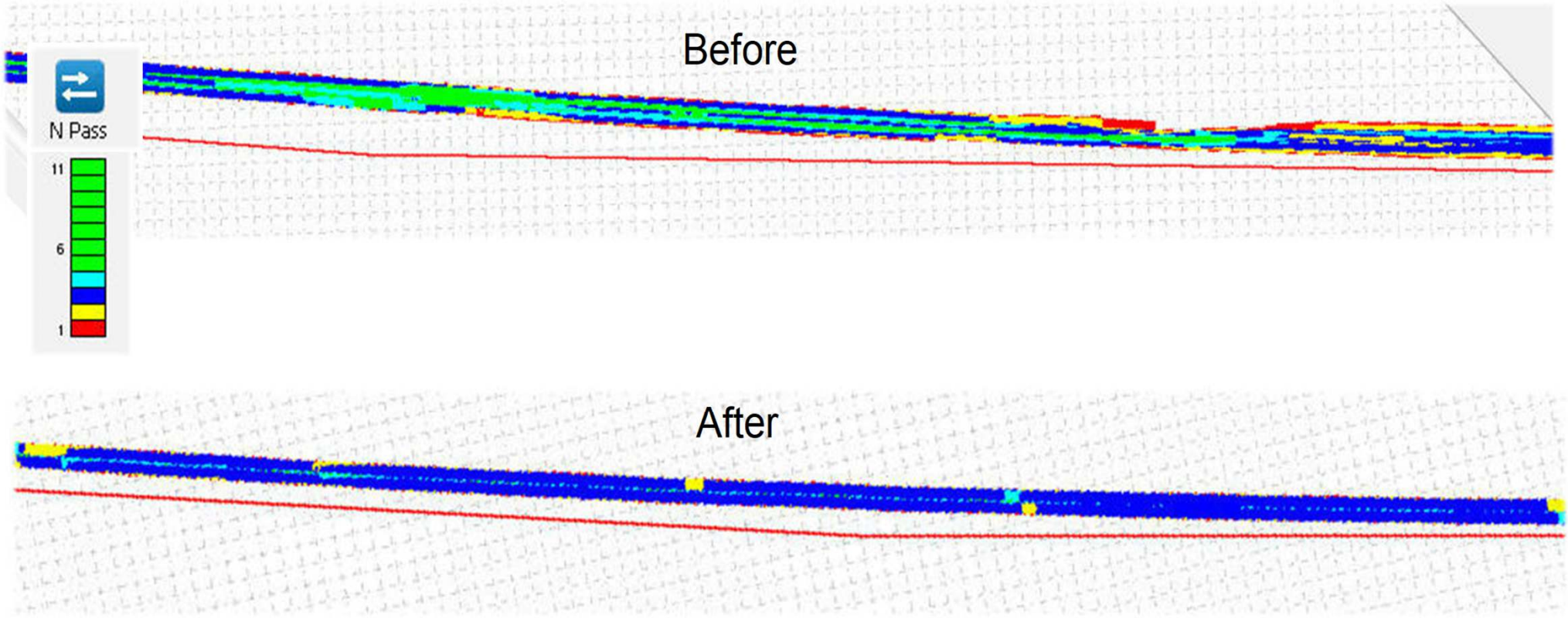
Hwy 68 Breakdown rolling



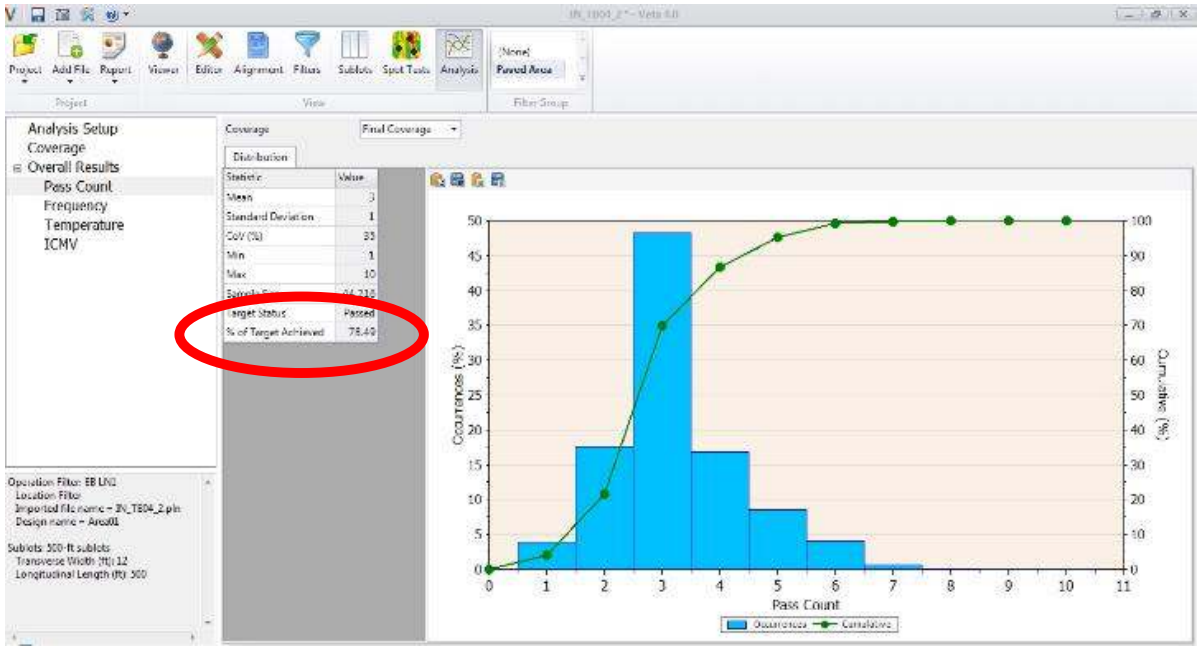
Hwy 68 - finish rolling



Before & After IC - Consistency!!



Determining % Coverage in VETA

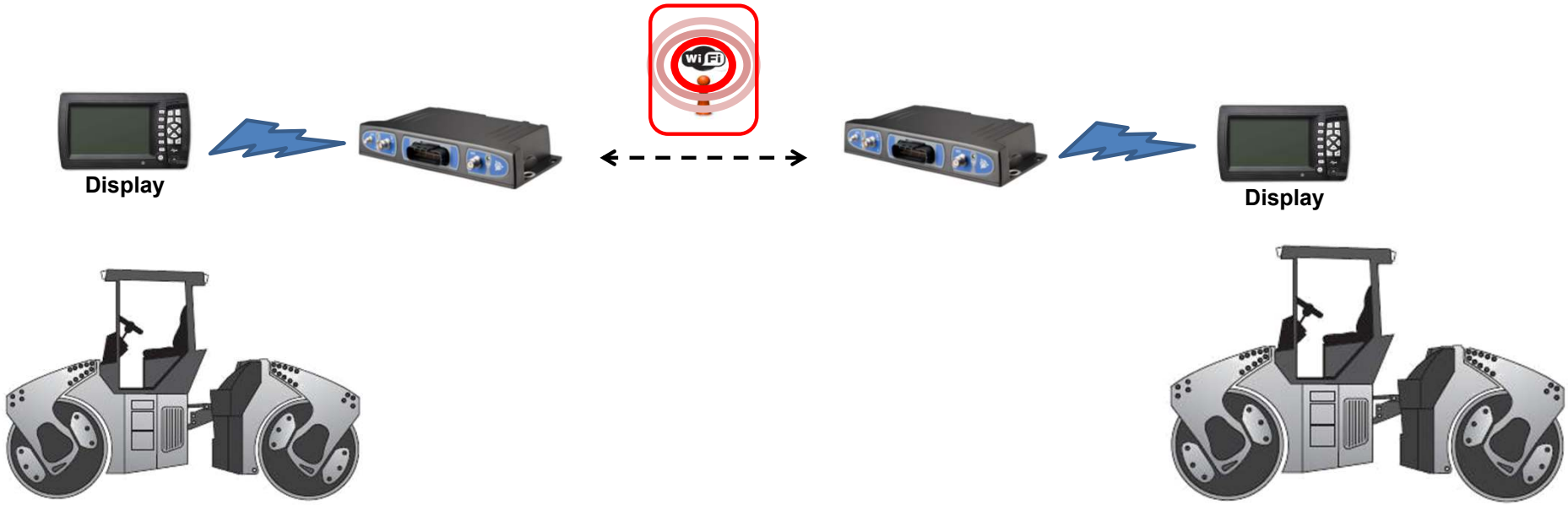


- % Coverage can be determined by:
  1. Creating Filters in VETA
  2. Manually trimming data in VL before exporting
  3. Having roller operator manually turn mapping “on” or “off” when he/she leaves the ‘IC Area’

Uniform Pass Count

- Meet required number of passes per test strip or method spec
- Uniformity of Compaction - PWL specifications
- Roller Speed
  - Is the roller able to keep up with paver and get 10 - 14 ipf ?
  - Do I need another roller? Change frequency? Amplitude?
  - Does paver need to slow down?
- Training tool for operators to see their pattern

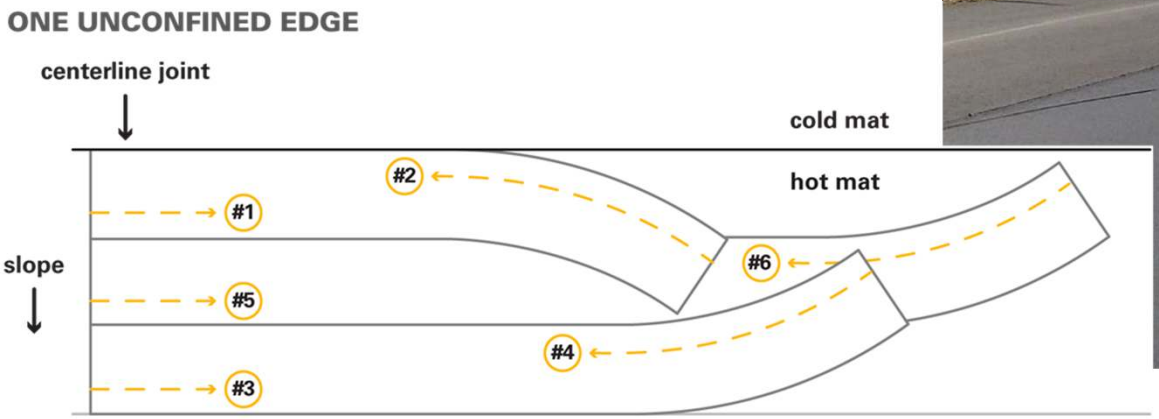
Machine to machine mapping



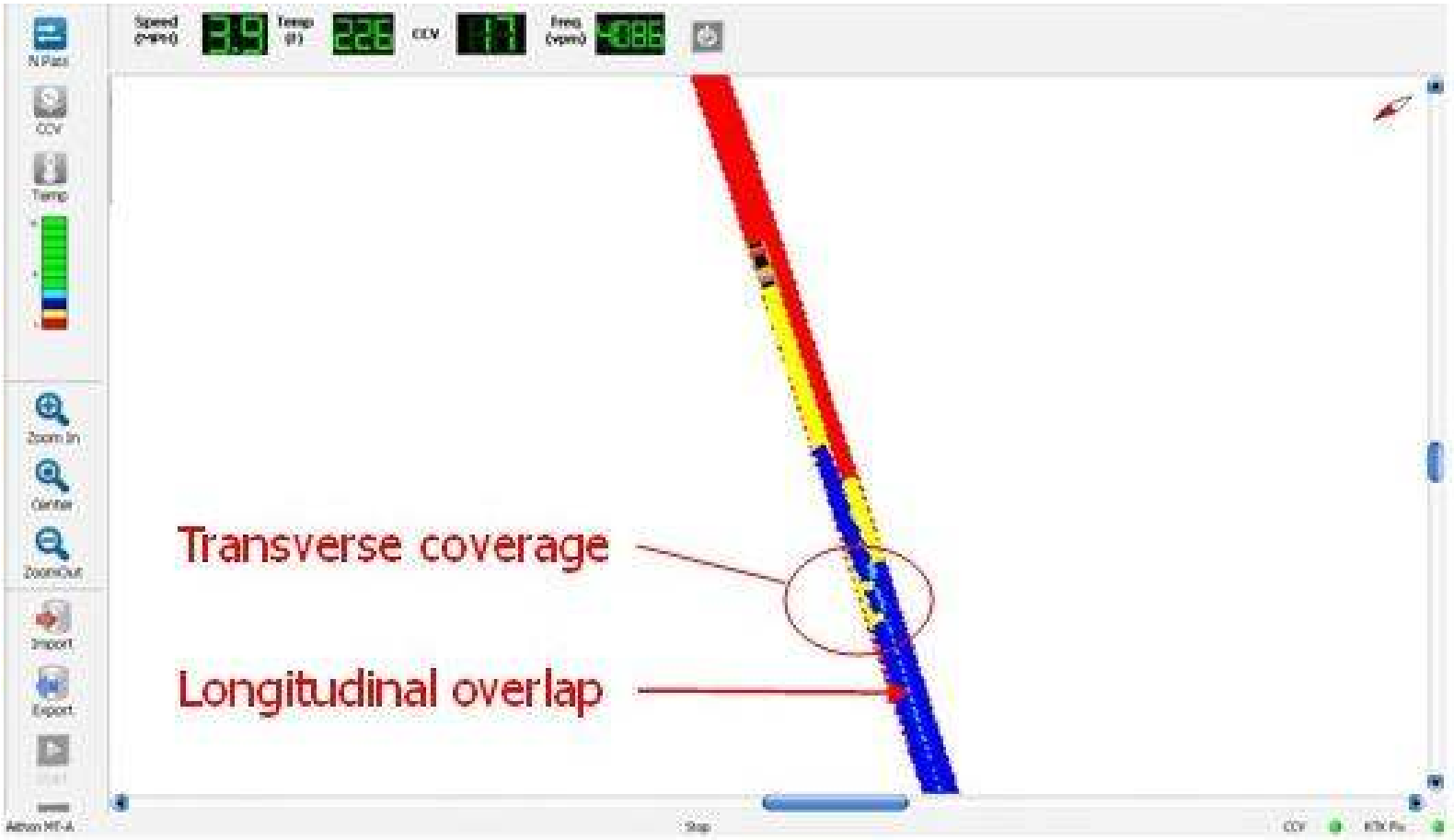
Machine-to-Machine (M2M)

Rolling Pattern Training Tool

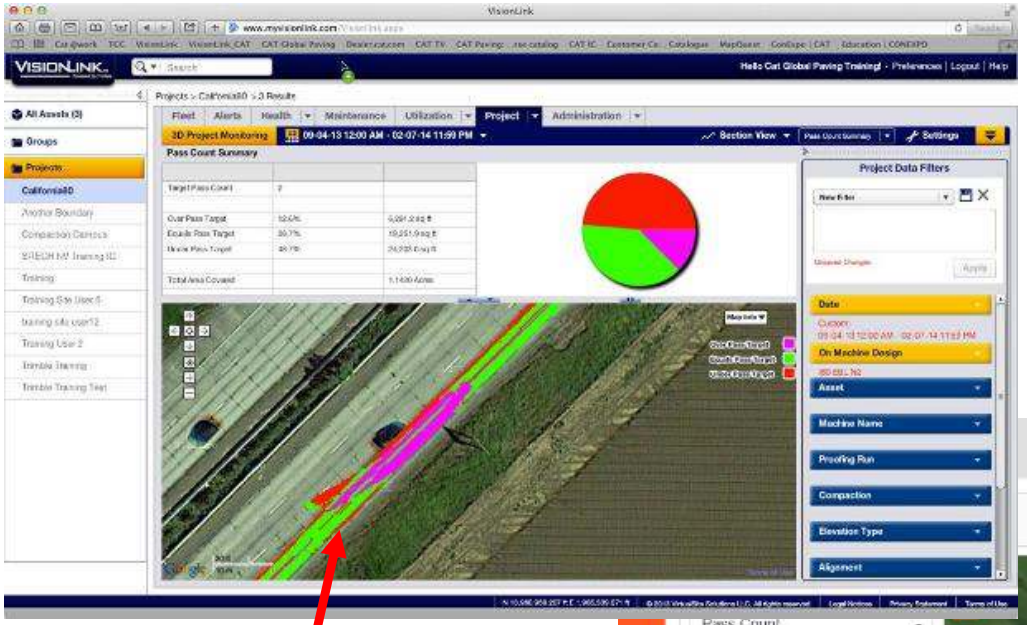
- Turning out at end of pass
- Direct correlation to smoothness (IRI)



Transition zones, longitudinal joints

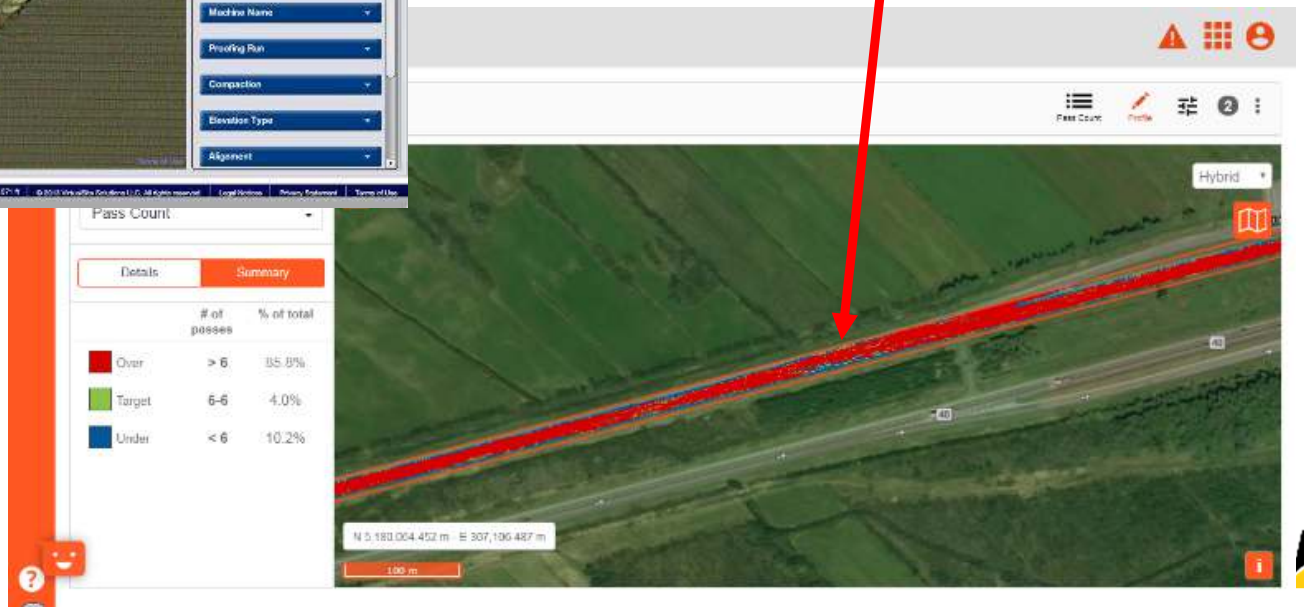


Transition Zones



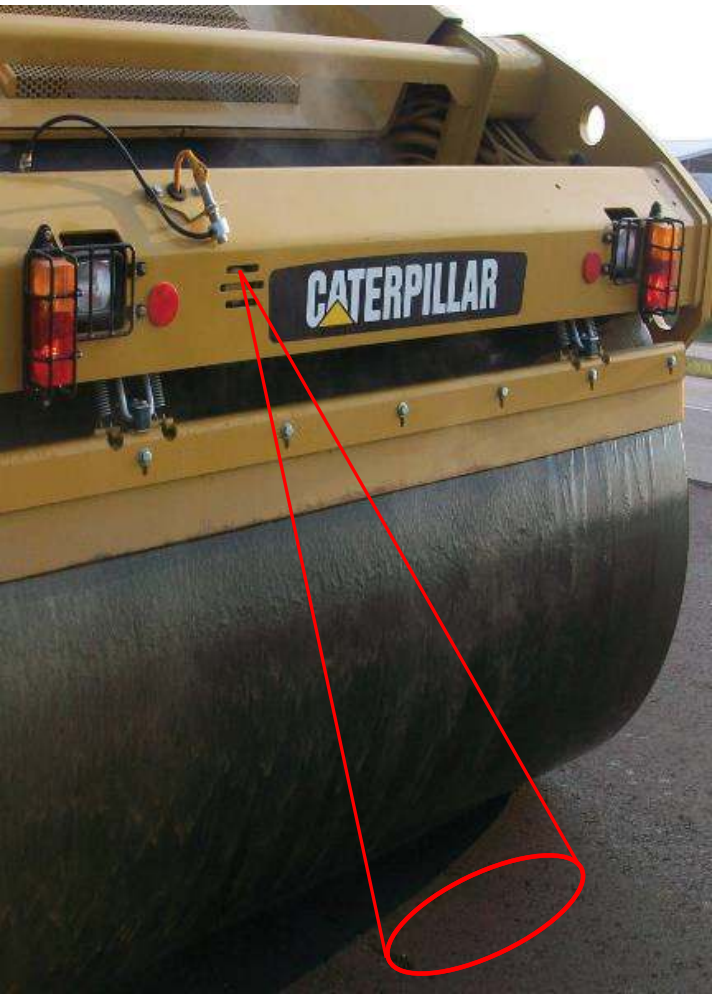
I-80 (Calif)

Route 40 Quebec



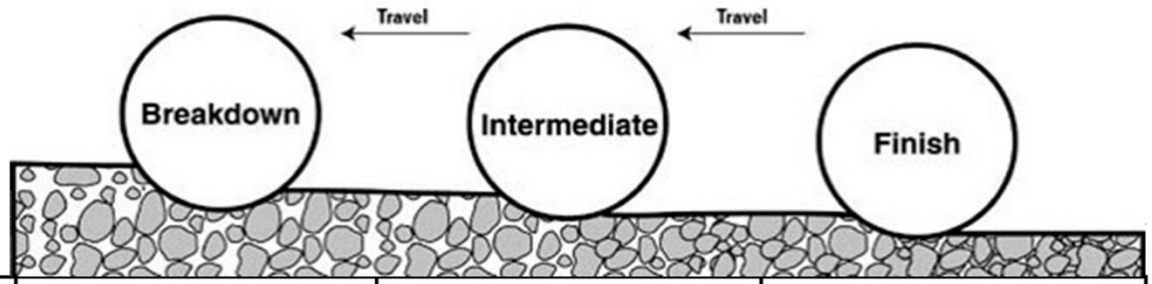
Night vision - “the back pass”

Temperature measurement



- Dual temp sensors allow measuring mat temperature ahead of water spray from the drum
- Keep operator informed of when to begin rolling and when to stop
- Help avoid tender-zones
- Eliminates hand-held devices

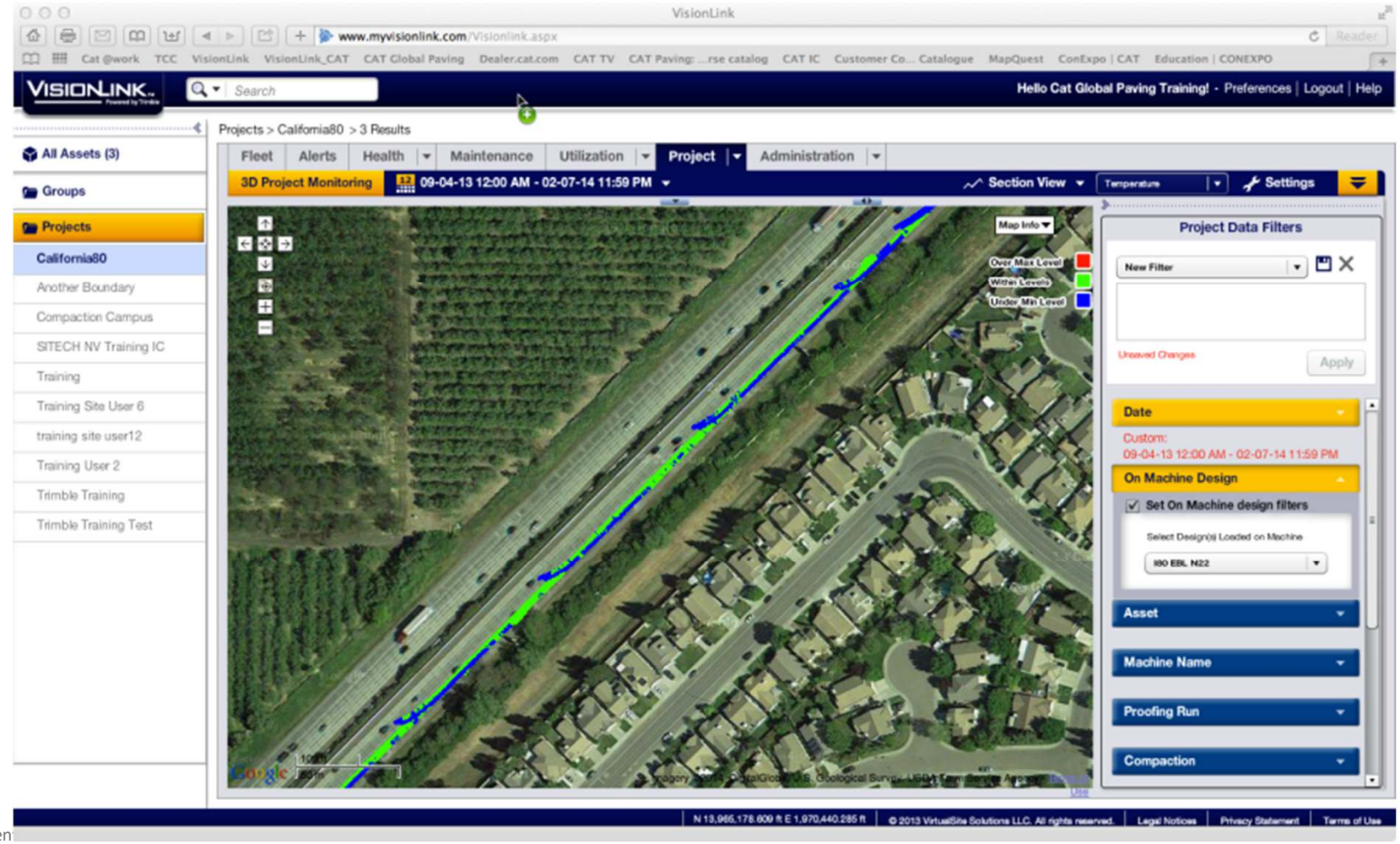
Temperature Zones



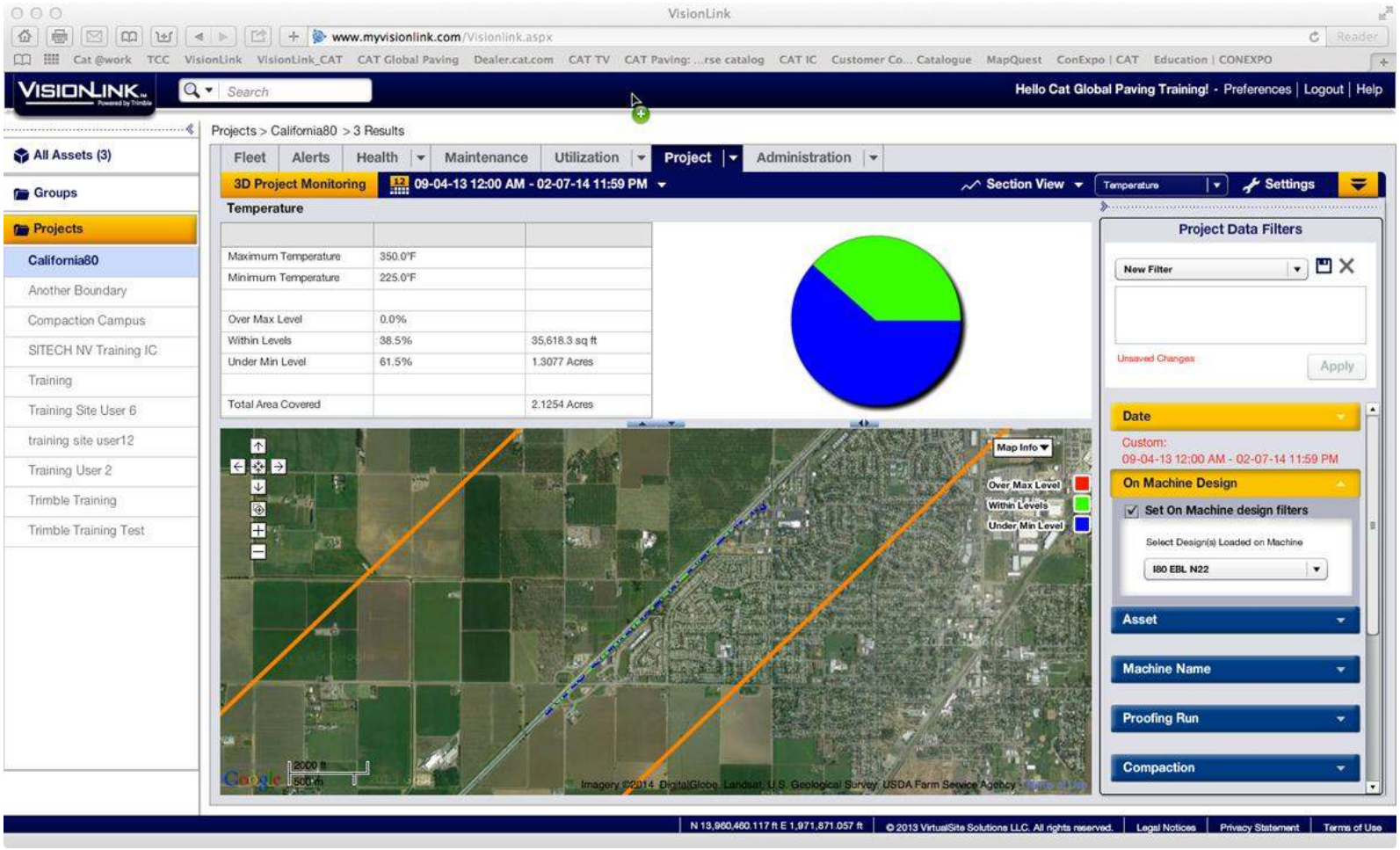
%TMD	90-92%	92-94%	94+ %
			
Temp	300-260˚F	260-200˚F	200-160˚F
Coverage	3	2	2 (1 vibe, 1 static)
Settings	High A, Low F	90 psi	Low A, static
	126 feet	200 feet	200 feet

- Stay in established temp zones
- Avoid Tender Zone
- Identify & troubleshoot “cold” mix

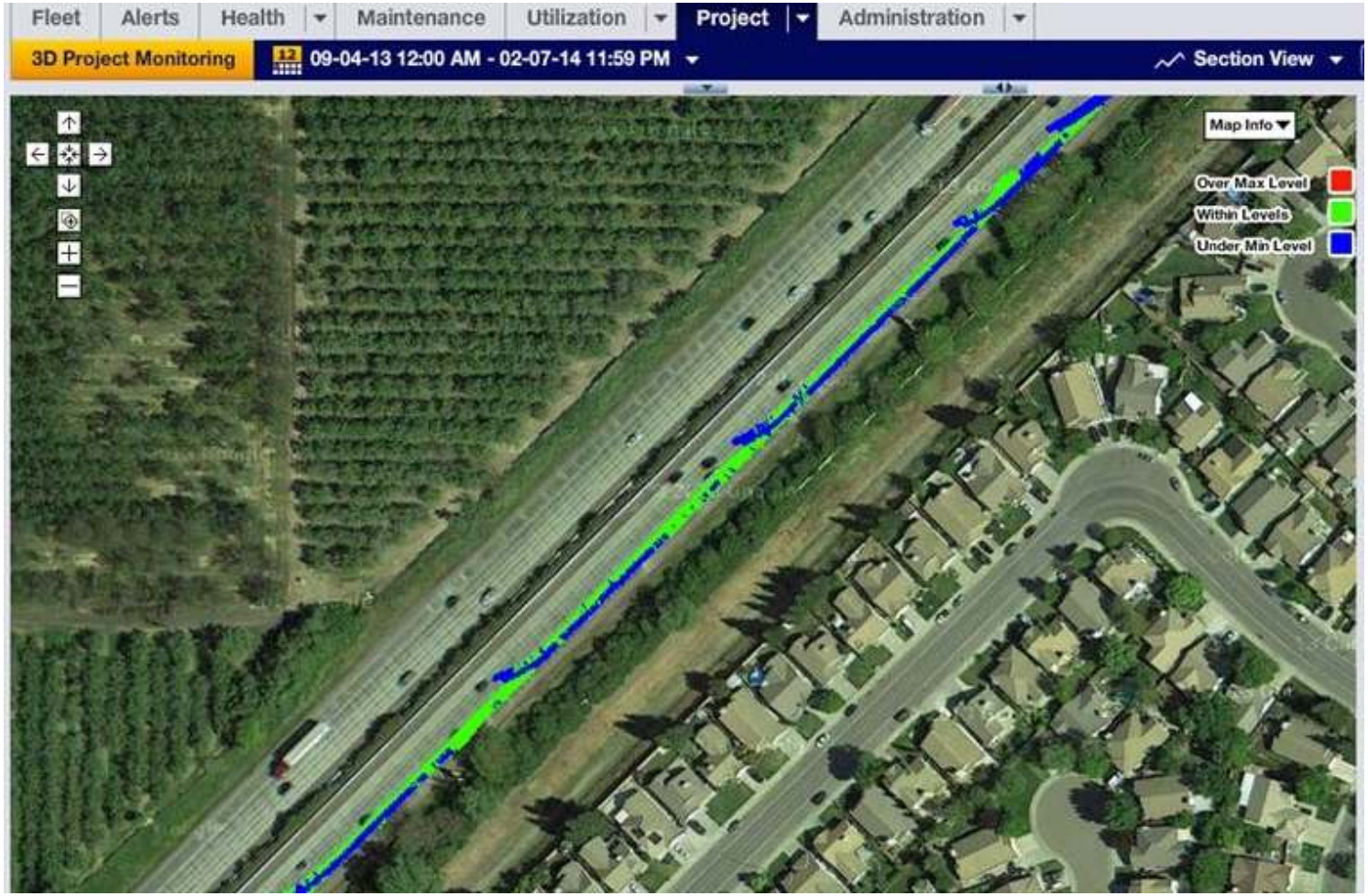
I-80 Temperature



I-80 Temperature range



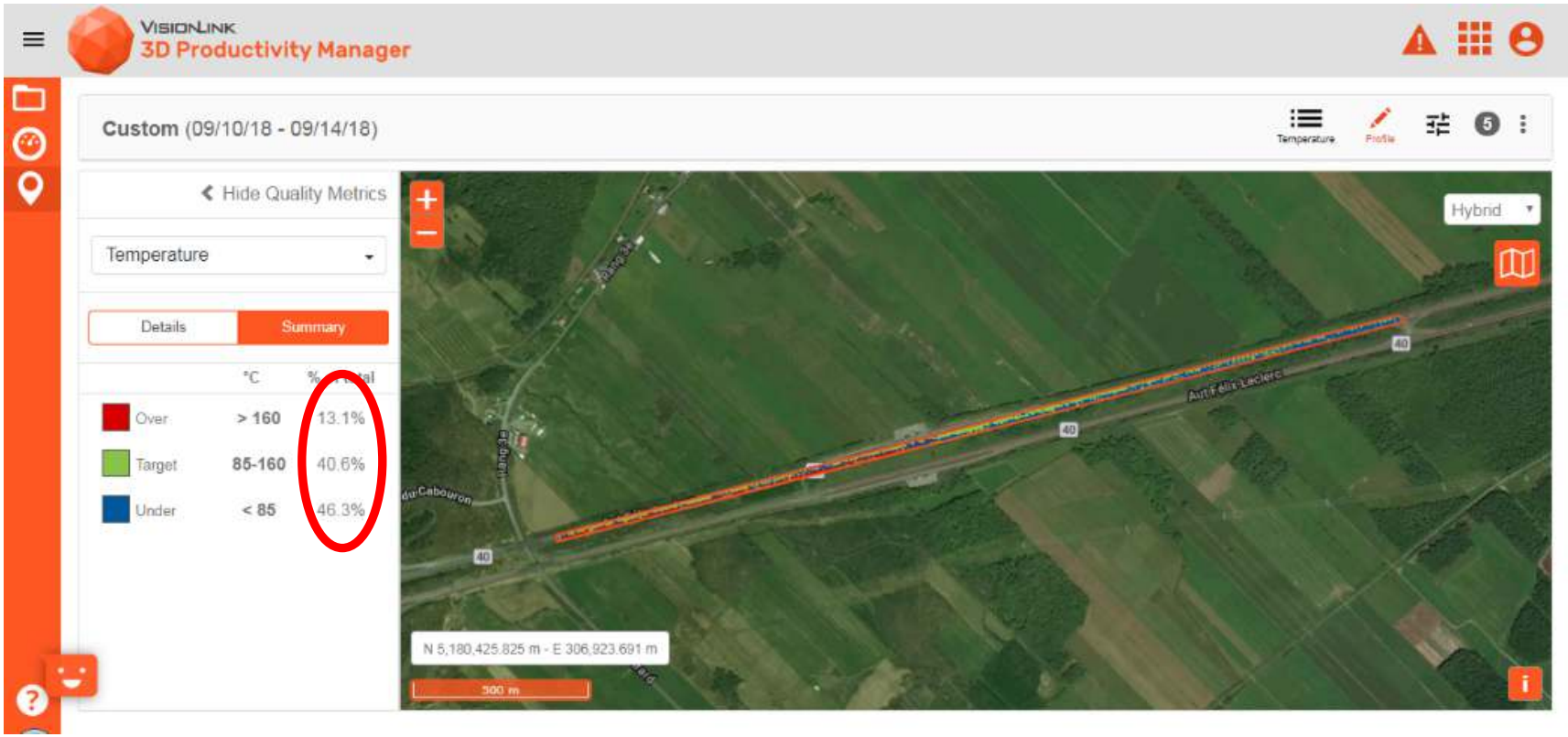
I-80 Temperature Challenges



Process control opportunity –

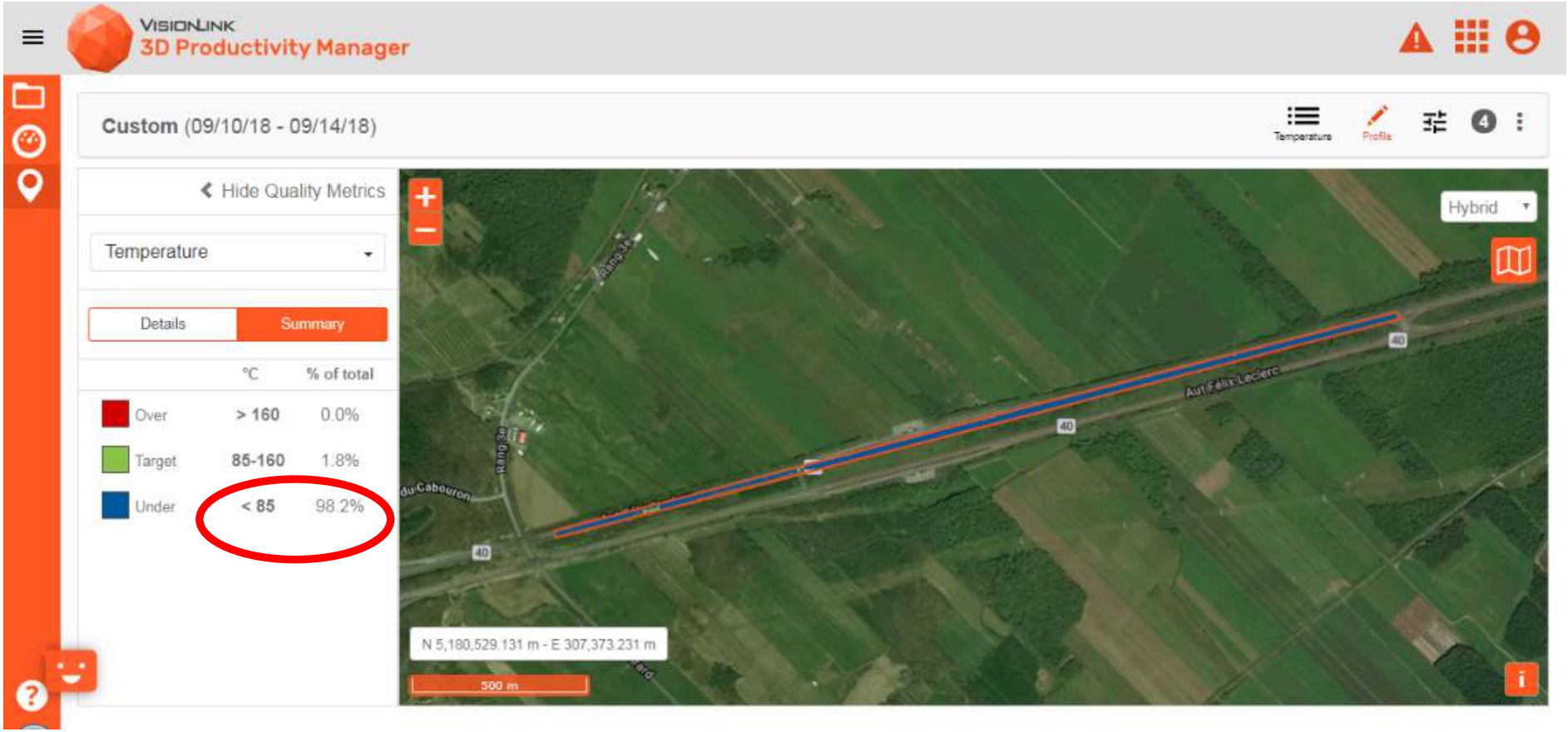
"You don't know what you don't know!!"

Temp: 1st pass breakdown

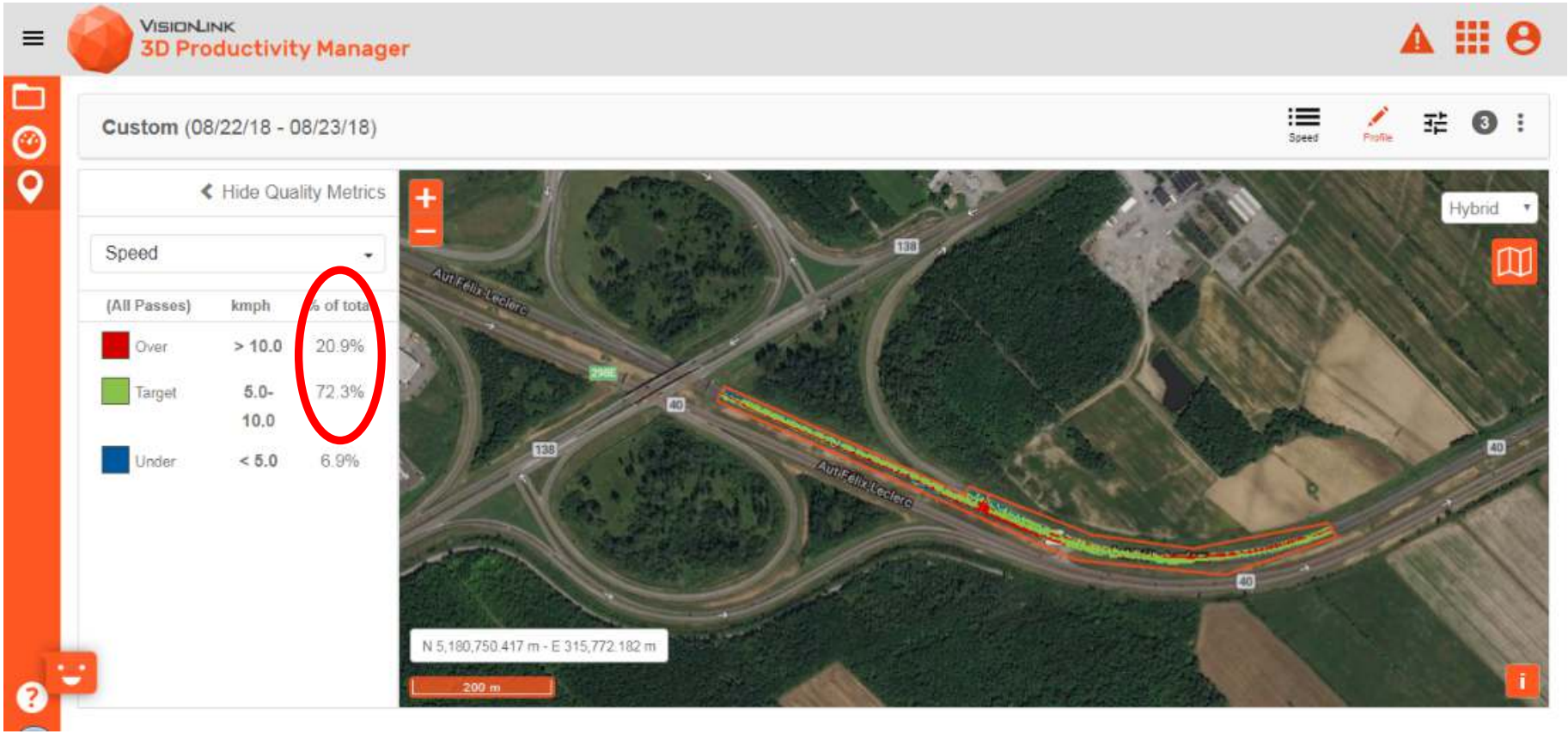


- Data indicates long breakdown passes
- Difficult to know without being on site and without plan file

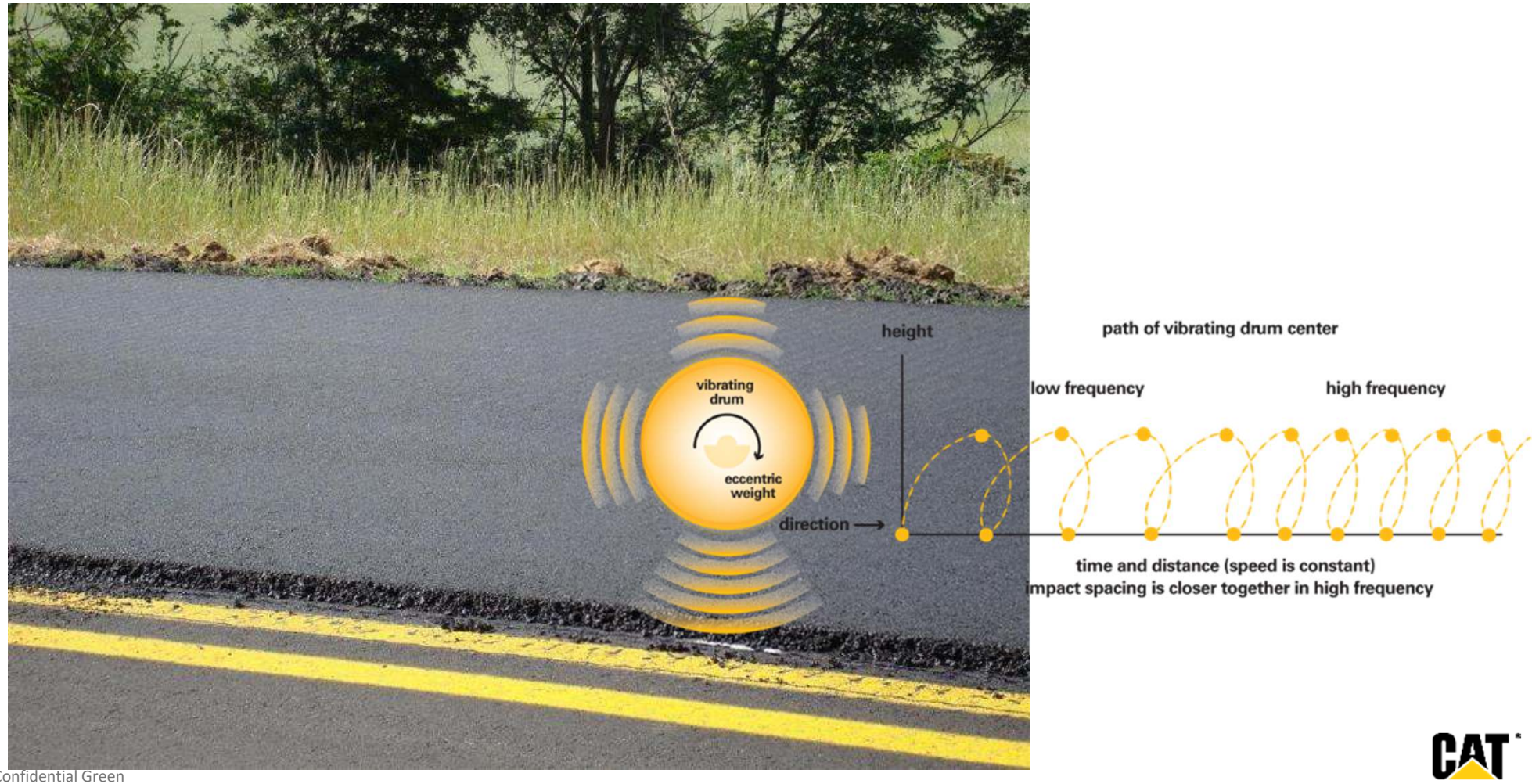
Temperature: last pass finish



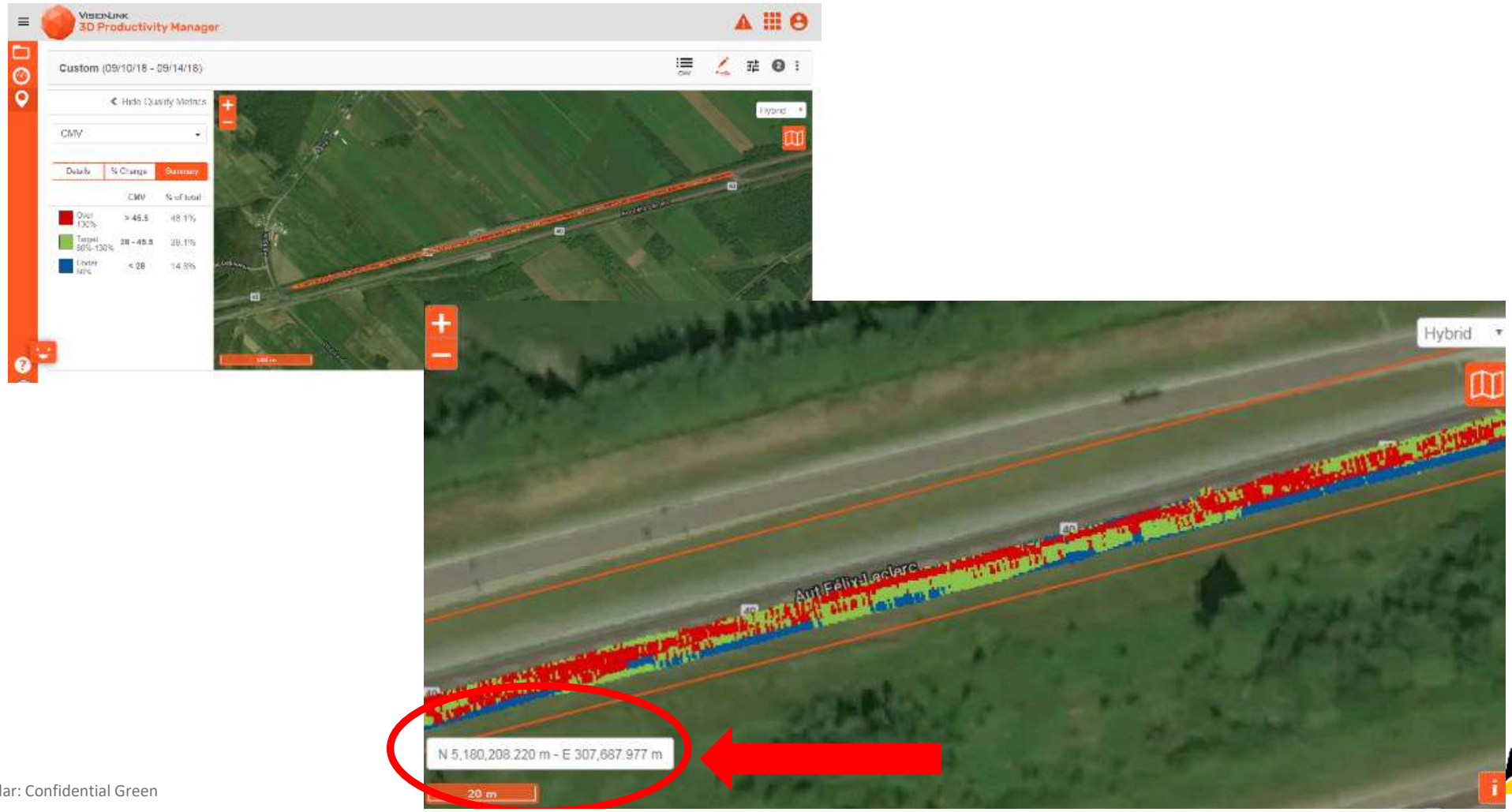
Speed: Smoothness & Density



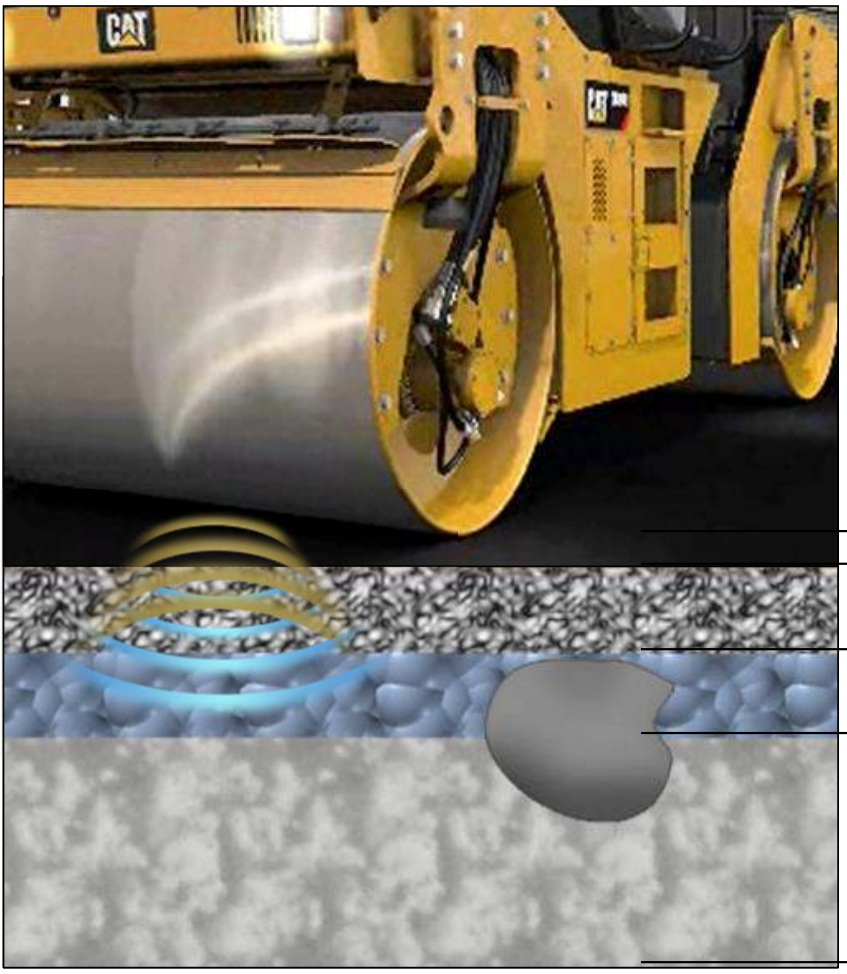
Roller Speed should be 10 - 14 ipf



ICMV (accelerometer value)



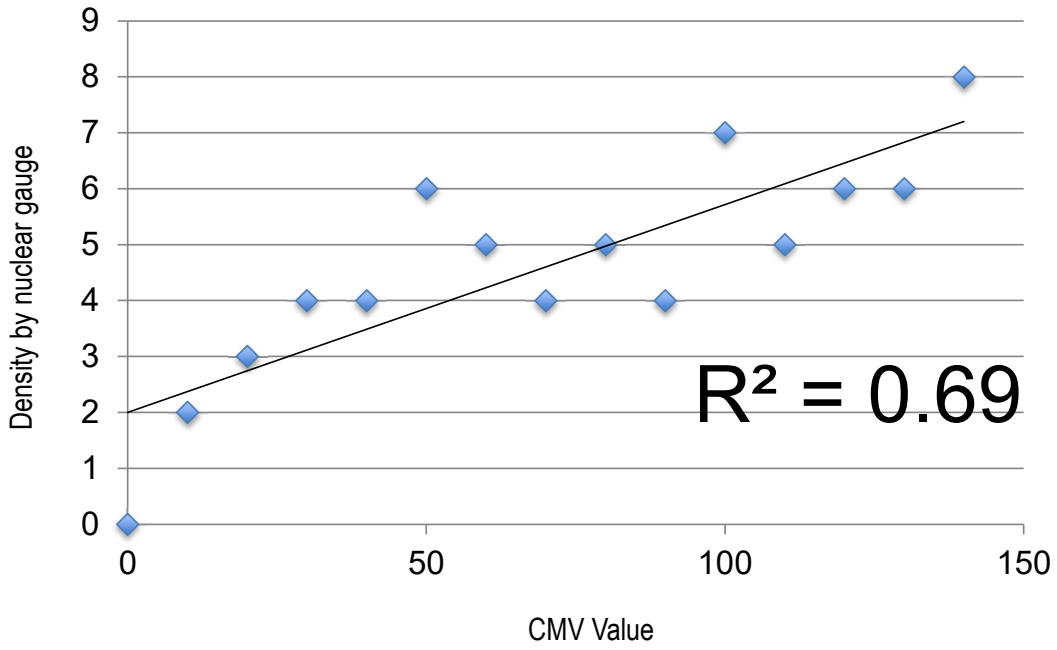
Remember...ICMV measures deep...



- **CMV value is a *composite* measurement**
- **Affected by amplitude, speed, direction, etc.**

Correlation of ICMV with existing test methods

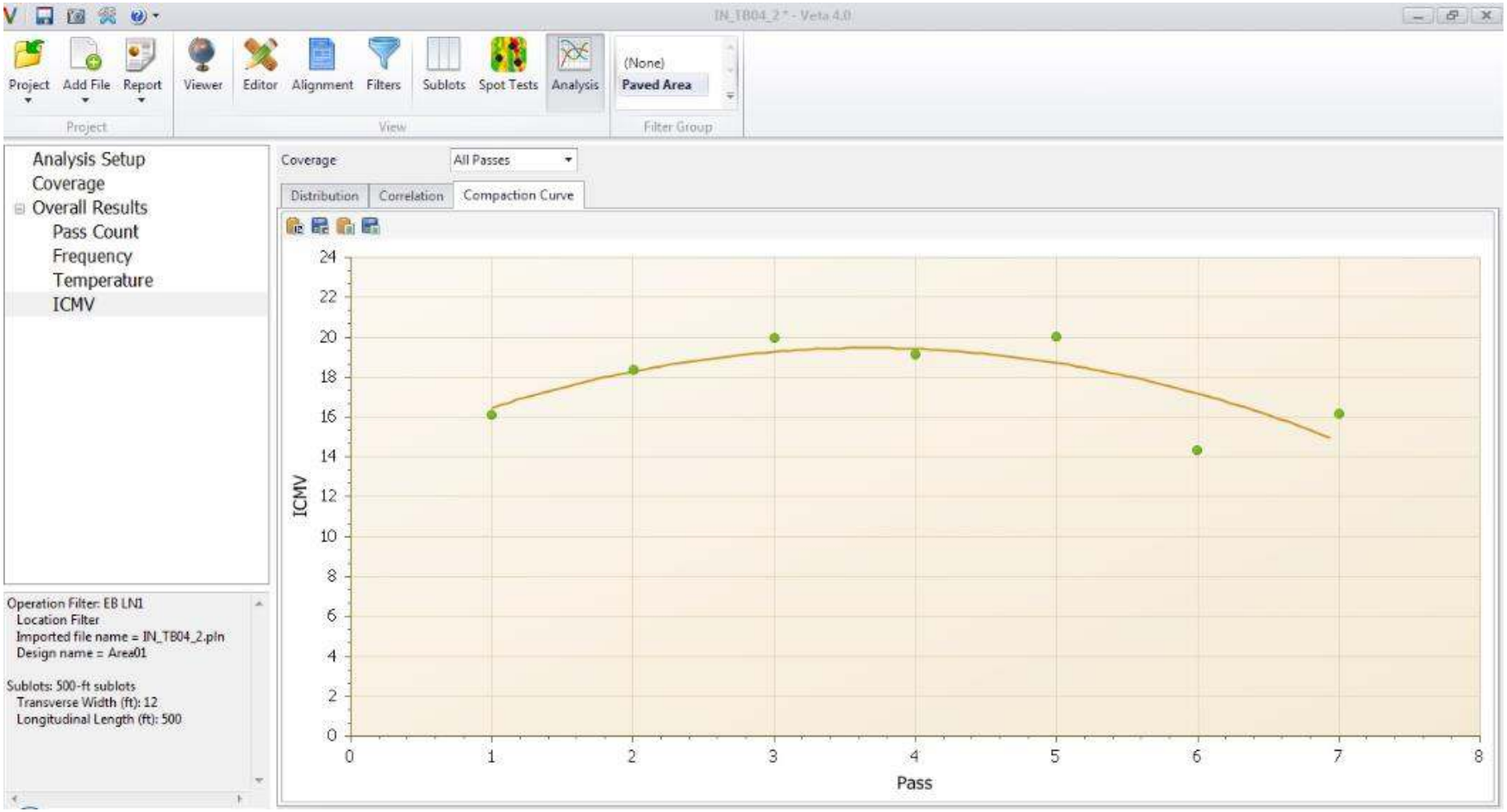
Correlating ICMV with existing test methods



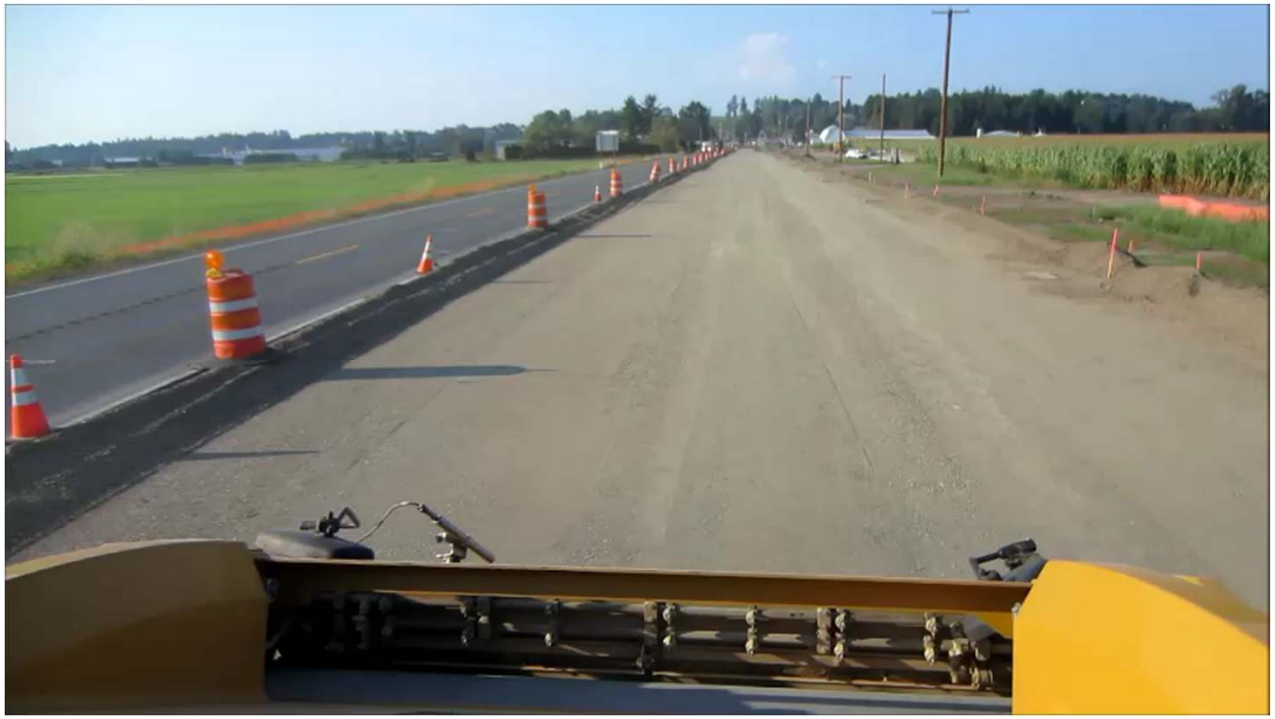
R^2 = 1.00 = perfect correlation

- **Plot a linear regression analysis of the conventional test data and the CMV data to establish an R^2 value**
- **R^2 is an indication of how well CMV represents the density or stiffness data measured using conventional methods**
- **Repeatable correlations between ICMV and density have not been proven**

Compaction Curve in VETA



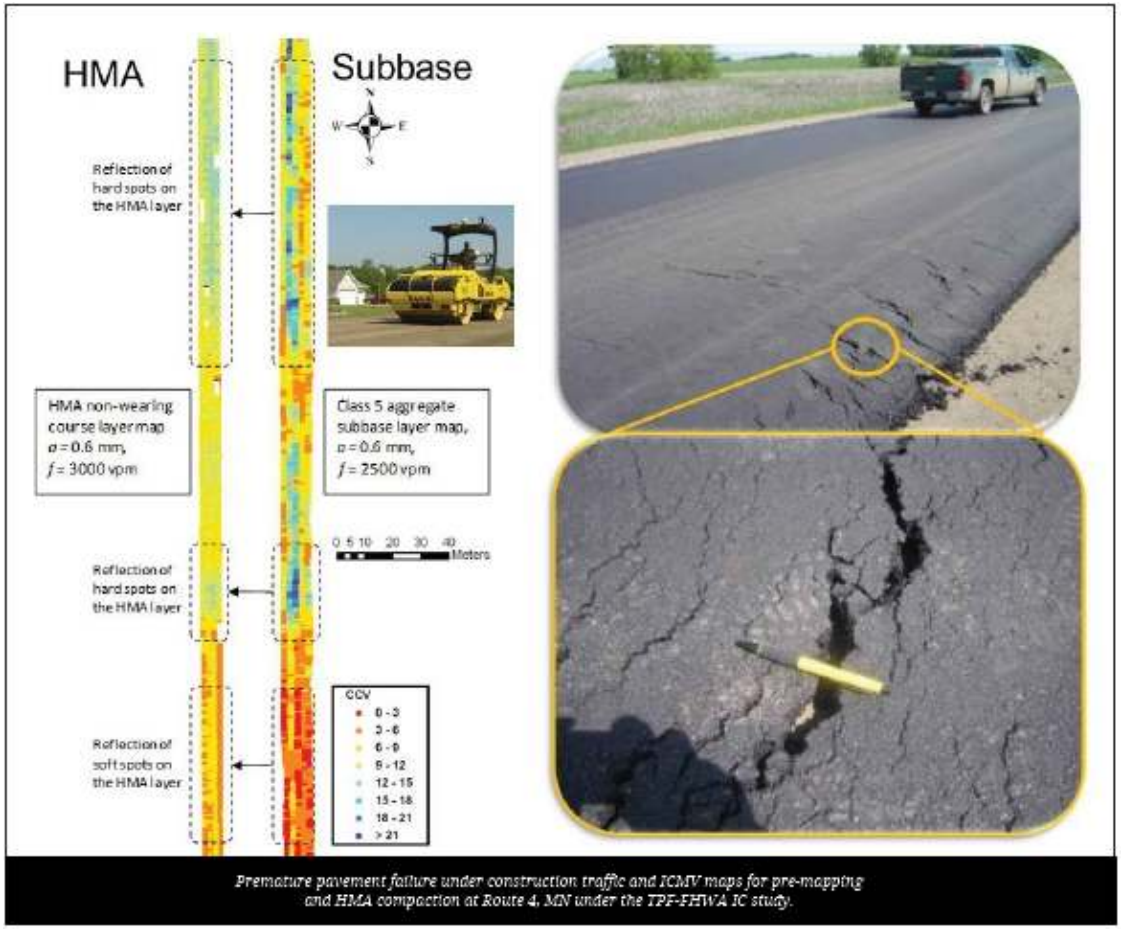
Pre-mapping to find soft areas



- Can be done in one pass
- ICMVs obtained to identify relative weak areas prior to paving
- Depth and extent of “soft spot” is difficult to identify

Kandiyohi County, MN Pre-mapping

Pre-Mapping in MN



Premature pavement failure under construction traffic and ICMV maps for pre-mapping and HMA compaction at Route 4, MN under the TPF-FHWA IC study.

TECHNICAL BRIEF

U.S. Department of Transportation
Federal Highway Administration

DEFINITION OF PRE-MAPPING

Pre-mapping is defined as measuring base line stiffness of existing support materials using an IC roller. The IC measurement value (ICMV) system is used to estimate stiffness based on acceleration signals caused by roller drum rebound.

The pre-mapping ICMV and its measurement depths–typically 2 to 3 feet–depend on the roller type, weight, drum dimension, vibration frequency and amplitude, speed, direction of travel, and the stiffness of the mapped materials.

Candidate support materials for pre-mapping include granular full-depth reclamation materials or their equivalent. Typically, the IC machines used to pre-map existing pavement subsurface structural support are the same as those used to construct subsequent layers. In order to prevent "double jump" during pre-mapping, the IC machine settings (including speed, vibration frequency, and amplitude) must be carefully selected.

With IC, teams can identify soft spots during construction and make corrective actions. If the soft spot was caused by excess moisture in the soil, the materials can be dicked and aired out before recompaction. If the soft spot occurred due to insufficient moisture, water can be added to the materials before recompaction.

INTELLIGENT COMPACTION FOR PRE-MAPPING

TECHNICAL BRIEF

A Sakai double drum IC roller pre-mapping the granular base at Route 4, MN under the TPF-FHWA IC study.

BACKGROUND

Intelligent compaction (IC) is an equipment-based technology to improve quality control of compaction. IC vibratory rollers are equipped with a high precision global positioning system (GPS), infrared temperature sensors, an accelerometer-based measurement system, and an onboard color-coded display. IC has been used to improve compaction control for various pavement materials including granular and clayey soils, subbase materials, and asphalt materials.

Pre-mapping originated as a research activity on the 2008 FHWA TPF IC project in Minnesota. The project team used a Sakai double-drum IC roller to measure the baseline support condition by mapping subbase materials at low vibration frequency and amplitude prior to the asphalt layer construction at Route 4. Later during paving, construction traffic caused the asphalt layer to fail prematurely. A soft spot had occurred–and the team later realized they could identify the soft spot in the pre-mapping data. Due to this discovery, the industry now recognizes the value of pre-mapping; the data collected by pre-mapping can help construction team identify potential soft spots before pavement failure.

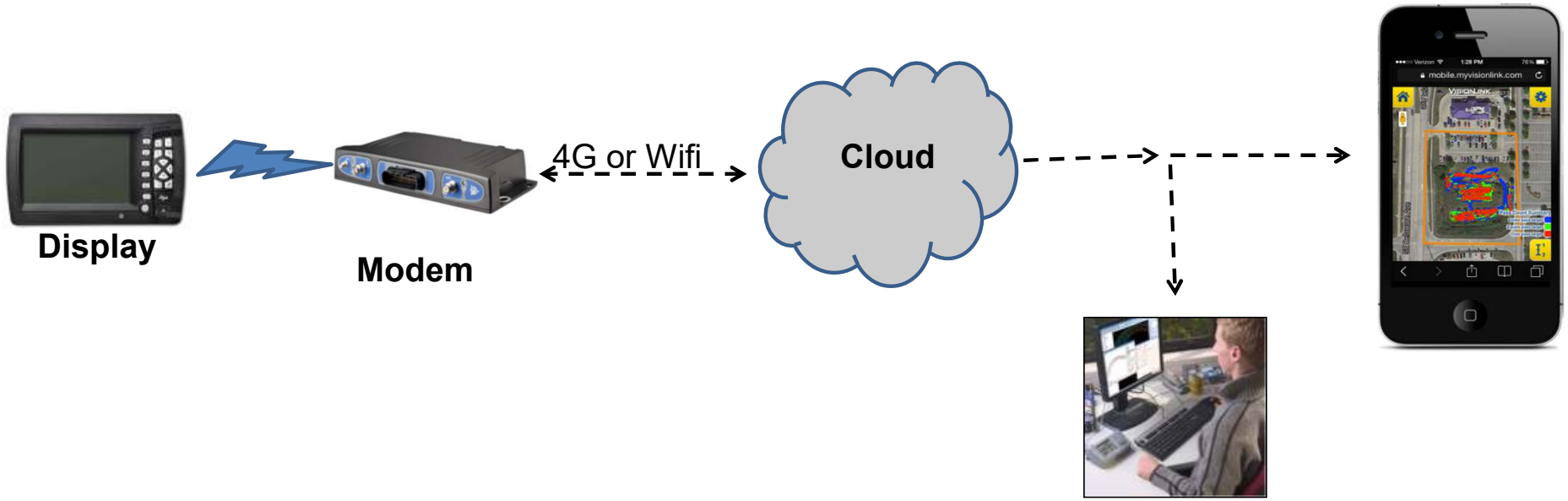
As of today, several state department of transportation (DOT) IC specifications include pre-mapping as an option or requirement. This tech brief intends to provide the best available technical information regarding pre-mapping in order to clarify its advantages and limitations.

I-80 GPS Coordinates - Forensic Analysis?

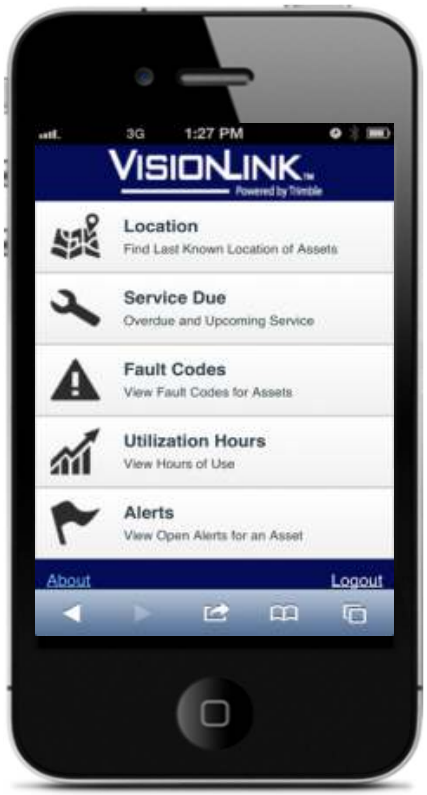
Operator’s view – soil project

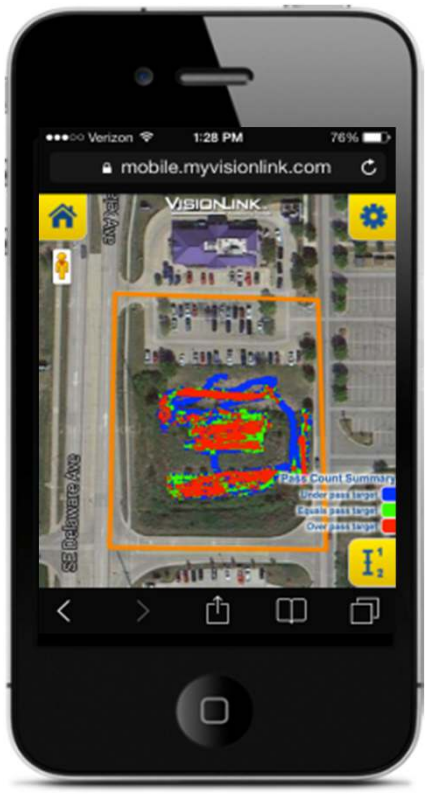
IC High Speed Data Sync

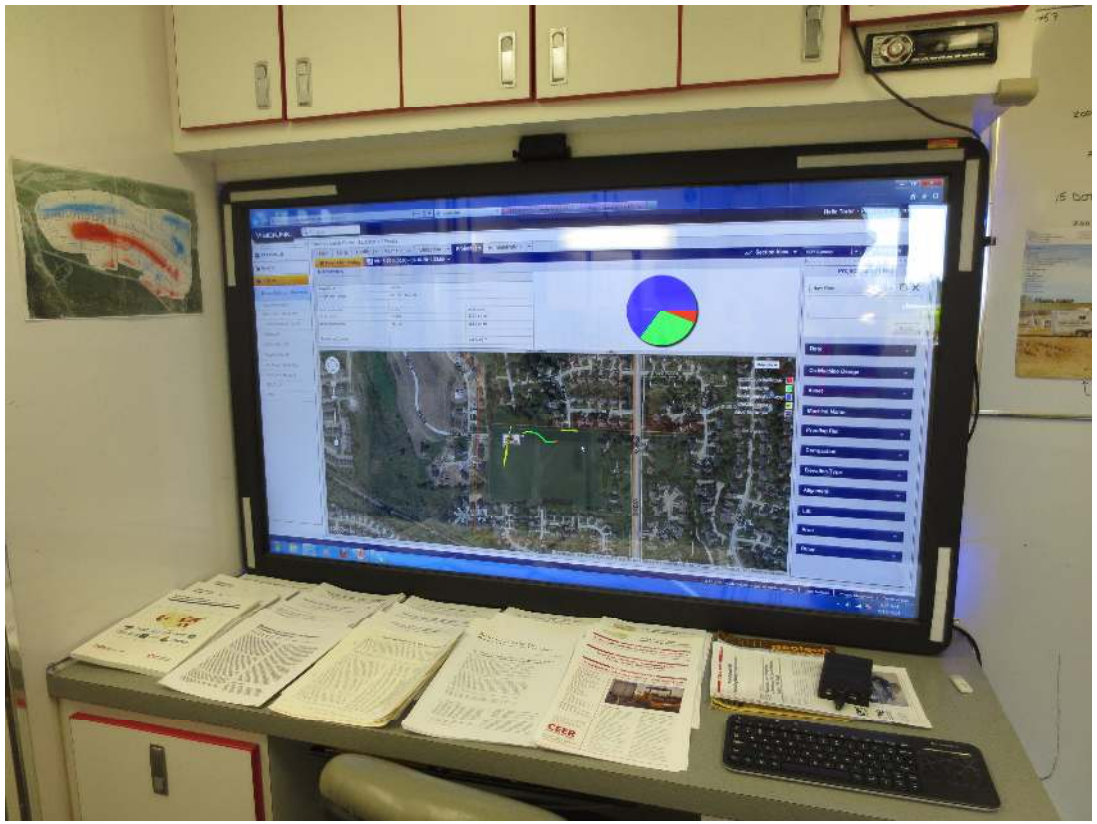
Much faster wireless sync to/from office and machines using high speed data link



Wireless data near ‘real-time’







Courtesy: Dr. White, Iowa State University

Summary: What IC can and cannot do…

- Can record coverage (passes)
- Can record surface temperature
- Can identify relative “soft spots” at depth unknown
- Can record accurate locations
- Cannot measure density

ICMV ≠ Density

Daily set-up for IC Mapping

1. Start the machine
2. Press the Power button on the IC display
3. Verify connectivity (base station or VRS – cellular base)
4. Select the Design file (if available) or create a New Map file
5. Enter the target number of passes & temperature limits
6. Start rolling

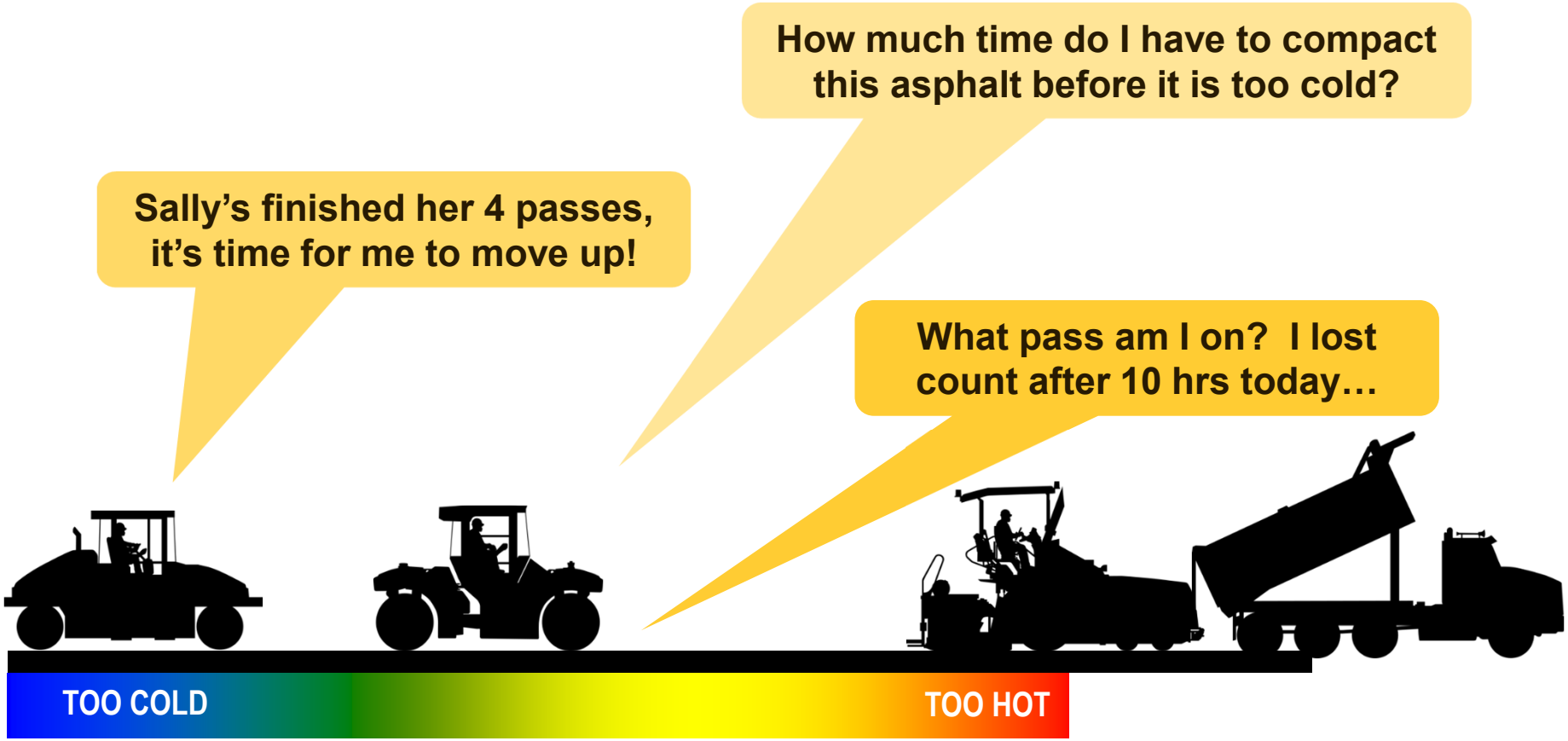
Total time, approximately 5 minutes to start rolling!

Remove antenna and display box daily – depends...about 5 min

Summarizing the benefits of IC

- Information that is “actionable” in real-time on the job
- Operator – self-training and self-monitoring tool
- Uniform coverage = better density & smoothness = bonus pay
- Transition zones
- Statistical pay factor specs PWL - consistency!
- Night work
- Temperature monitoring
- Longitudinal joint overlap/joint density
- Identifying relative soft spots in base
- Reduced field testing – safety/cost
- Documentation of 100% of compaction

Real-time information I can work with!!



IC Checklist – Ask Questions!!

Intelligent Compaction FIELD checklist	Complete
Intelligent Compaction equipment to be used. Model(s):	
Who owns the machine(s)?	
Owner information (name, phone number, e-mail)	
CAT Dealer address	
CAT Dealer contact person (name, phone number, e-mail)	
Will the CAT Dealer rep be there? Name. Contact info.	
Will the CAT Territory Manager be there? Name. Contact info.	
Job Site Location & Contacts	
Directions to the job site **or** physical address:	
Type of job (highway, airport, commercial site, etc.):	
Name and number of the Job Supervisor or Foreman:	
Name and number of the Quality Control Representative:	
Job specs & compaction information	
Current compaction measuring methods (nuke gauge, etc.):	
Copy of the asphalt mix designs (asphalt only):	
Copy of the Proctor(s) (soils only):	
Copy of all applicable compaction specifications:	
Equipment & GPS information	
Does the roller have an SNM940 wireless modem installed?	
Full serial number of the SNM940(s) wireless data modem:	
Full serial number of the IC roller(s):	
Full serial number of the IC Display(s) CB450 or CB460:	
Expiry date of Product Key for CD450/460 display?	
SITECH GPS contact person (name, phone number, e-mail):	
Does the Owner/Dealer have a TCC account?	
Does the Owner/Dealer have a VisionLink™ (VL) account?	
Does the VL account have the ***3D Project Monitoring*** option?	
Need job site GPS coordinate calibration file (***.dc** or ***.cal** file)	
Need UTM Zone of job site.	
Have you used GPS for surveying?	
Have you used GPS positioning on a machine?	
What machine/brand of GPS have you used?	
What accuracy of GPS do you require? (RTK, SBAS, other...)	
To view lines such as edges of pavement, etc., need a ***.dxf** file	
To monitor elevation changes, need ***.ttm** file (RTK-GPS only)	
Radio channel that GPS Base Station is transmitting on (RTK)	

1. **Do I need to meet a specification? What is the equipment spec?**
2. **How many, and which roller do I need the IC equipment on?**
3. **Do I need wireless data transfer? Is it worth the additional cost?**
4. **Can I rent or do I need to purchase?**
5. **What GPS accuracy do I need? Can I upgrade later to higher accuracy?**

Training: Contact Equipment Dealer

ASPHALT COMPACTION OPERATIONS TRAINING WITH INTELLIGENT COMPACTION

Course Description:

This class is focused on highway paving operations. The daily curriculum for this introductory level class includes approximately 3 hours of classroom training and 5 hours of hands-on field training at the demonstration site. Operation of Cat B-Series asphalt compactors equipped with Cat® Compaction Control (Cat temperature and pass count mapping system) using global positioning systems (GPS) will be used to compact sand, RAP or other materials used to simulate asphalt mix. Field exercises will reinforce what is taught in the classroom.

Classroom Sessions:

- Asphalt compaction theory
- Machine controls, operation and start-up checklist for Cat B-Series asphalt compactors
- Introduction to Cat's *Paving Production Calculator* and *Amplitude Selection* mobile apps
- Amplitude, frequency and roller speed settings
- Rolling patterns - including longitudinal and transverse joint compaction
- Typical asphalt compaction specifications and acceptance test methods
- Introduction to Cat® Compaction Control (intelligent compaction)
- Brief introduction to VisionLink® office software for viewing IC data

Hands-on Training:

- B-Series asphalt compactor controls, operation and start-up checklist
- Rolling pattern field exercises using dry material such as sand to simulate asphalt
- Cat® Compaction Control basic system setup and operation
- Using Cat® Compaction Control to improve quality and efficiency on the job in real-time

The course concludes with a written and a hands-on final examination.

Objectives:

Upon completion of this course, students will know and understand:

- Cat B-Series asphalt compactor controls and operation
- How to select amplitude, frequency and roller speed based on job requirements
- How to establish an efficient rolling pattern and know when and how to make changes
- Typical asphalt compaction specifications and acceptance test methods
- Understand the methodology for using Cat® Compaction Control to improve quality and efficiency on the job

Who Should Attend: Roller operators, paving foremen/superintendents, quality control personnel, asphalt density field technicians.

Prerequisites: None

Additional Information:

- Course Fees: Due no later than 30 days after the class concludes.
- Course Length: 2.5 days, concluding at 12 noon on Day 3
- Language: Course taught in English

Compaction Operations Training Agenda

DAY 1: Classroom

- Introductions
- Compaction and Intelligent Compaction overview
- Machine controls & operation
  - SCOM KEBU7578
  - ACOM SEBU8819
- Soil Compaction Theory Basics
- Introduction to Machine Drive Power (MDP) and Compaction Meter Value (CMV)
  - Caterpillar - hardware options
  - MDP by the Numbers

DAY 1: Field Exercises

- Safety walkarounds and familiarize with controls
- Basic display menu navigation (Sauer controller) and setup
- Drive and observe MDP values – forward/reverse/different speeds

DAY 2: Classroom

- Asphalt Compaction Theory Basics
- Introduction to: Temperature and Pass Count mapping
  - Caterpillar - hardware options
  - GPS options
- Setting a target MDP (or CMV) value

DAY 2: Field Exercises

- Setting a target MDP (or CMV) value
- Generate an In-Field report
- Do a Proofing Run
- Export data

DAY 3: Classroom

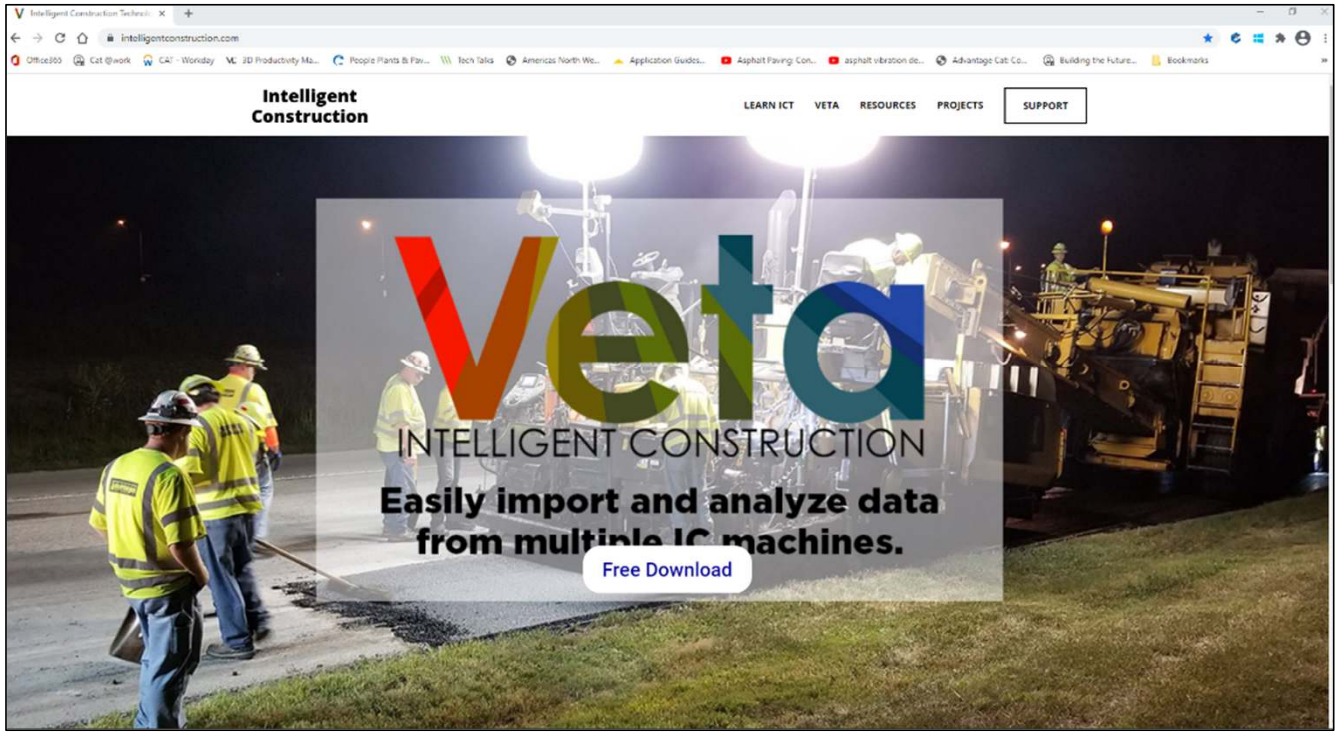
- Introduction to VisionLink software
  - VisionLink 3-D Project Monitoring (compaction) module
- Introduction to Business Center HCE
- Create a new project in VisionLink
- Export data to USB and upload to VL
- Analyze data in VL
  - Create a job report from VL for export, printing
- Introduction to VEDA software

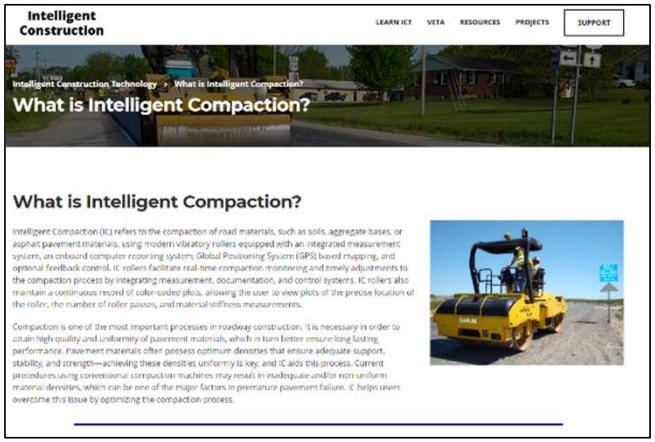
DAY 3: Field Exercise

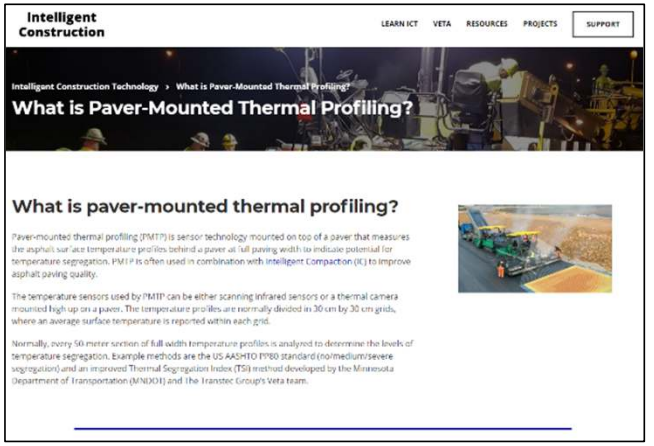
- Final written test
- Final practical test on the machine
  - The Compaction Challenge: friendly competition
  - Export data from machine

Where to go for IC, Thermal & Veta software

www.intelligentconstruction.com







Thank-you for your attention