

Paving Innovations – Existing, Emerging, Future



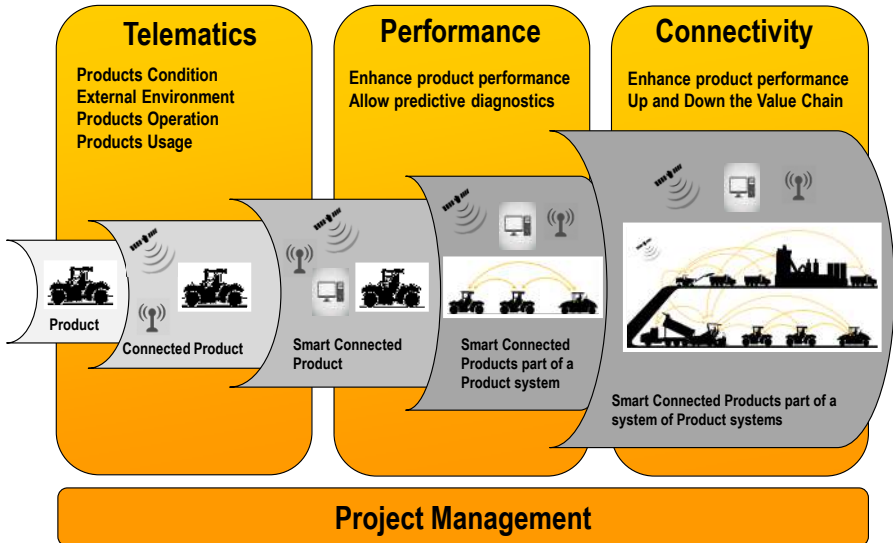
Presented by: Todd Mansell, Caterpillar



Caterpillar: Confidential Green

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TECHNOLOGY IS... REDEFINING INDUSTRY STANDARDS




Telematics
Products Condition
External Environment
Products Operation
Products Usage

Performance
Enhance product performance
Allow predictive diagnostics

Connectivity
Enhance product performance
Up and Down the Value Chain

Product
Connected Product
Smart Connected Product
Smart Connected Products part of a Product system
Smart Connected Products part of a system of Product systems

Project Management



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Existing Paver Technology



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3

Paver Hopper Temperature & Level



- Process control



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Lock-Out Selected Scred Controls



- Scred functions and feed system locked out in travel mode or maneuver mode for safety

- Lock out during paving for quality

- Crown
- Slope
- Height
- Auger height
- Tow-points

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Steering Guidance



- Friction steer maintains a constant turning radius - eliminating 'human error'



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Radar for MTV Spacing



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- Keeps distance between paver and MTV
- Reduces potential for paver and/or MTV stop
- Safety - collisions



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Paving Speed – Pre-set



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Caterpillar Paving Production Calculator





Apple iOS




Google Play

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Feed Sensors: 0, 2, or 4



- Can set to “0” feed sensors and manually set feeds if a feed sensor gets broken or damaged



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Hill Hold – Prevents Paver Rollback



- Brake stays engaged until propel system current exceeds valve cracking limit, or brake is engaged more than 2 seconds after propel lever leaves neutral



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Pave Start Assistant



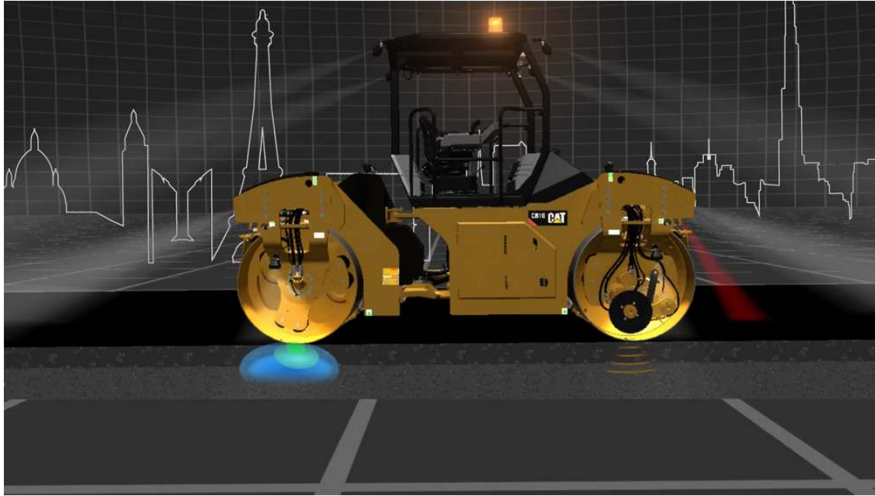
- Create/Save profiles
- Stores many machine settings for quick recall / paving setup
- Facilitate quick/easy pickup and restarts, such as parking lot applications
- Also great for production/highway paving
- Area paved – great for determining material yield

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Oscillation compaction



- Intermediate or finish rolling
- Less risk of damage
- Less aggressive



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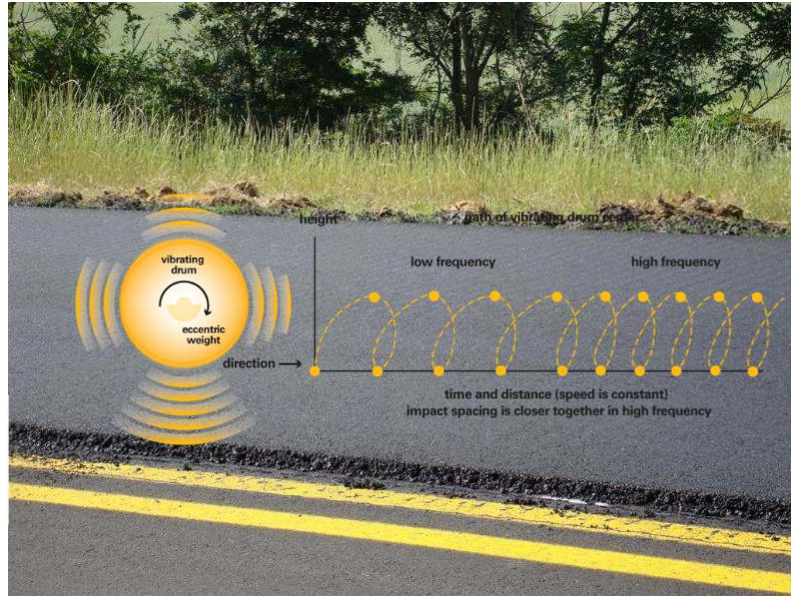
13

Roller speed 10-14 ipf



$$\text{Roller speed (fpm)} = \frac{\text{Frequency (vpm)}}{\text{Impacts per foot}}$$

$$\text{Speed} = \frac{3,000 \text{ vpm}}{10 \text{ ipf}} = 300 \text{ feet per minute}$$



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Setting Impacts per Foot

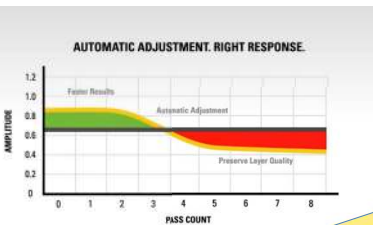


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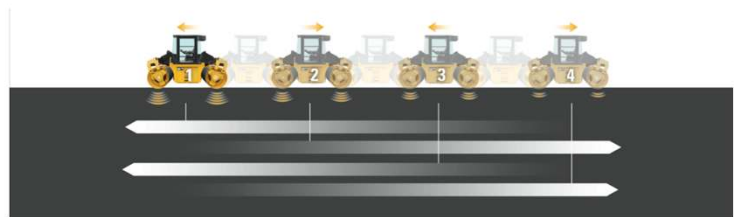
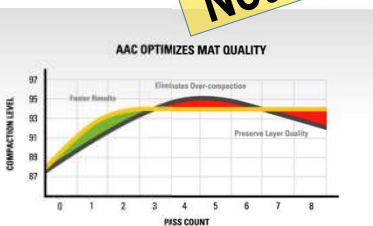
15

Auto-Adjustable Compaction



- Ensures the amplitude is optimized
- Good for inexperienced operators
- Good for consistency (PWL)
- Reduced risk of over-compaction

Not currently in production



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Grade Control – Mills and Pavers



- 2D References existing surface or stringline
- 3D references a design file
- Integrated with machine controls – operator's station or ground level
- One is not better – depends on application and what you're trying to achieve



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CAT

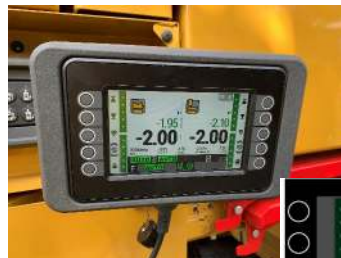
17

Cold planers – 3D Milling



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- Plug and play installation
- Utilizes machine harnesses & software

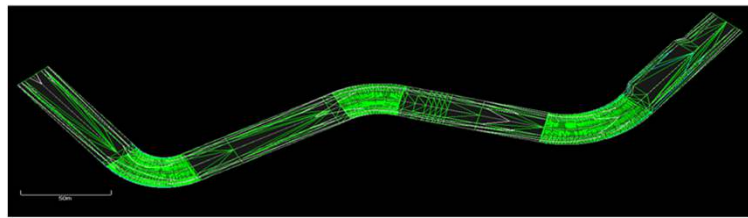
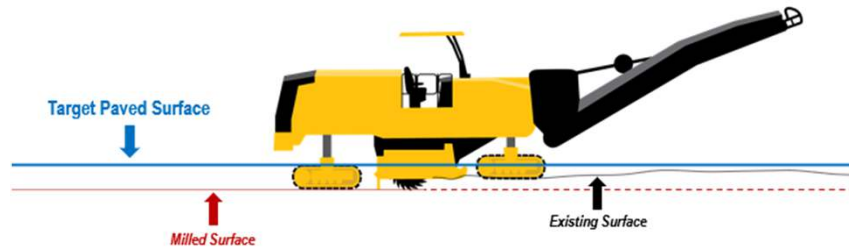


CAT

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Cold planers – 3D

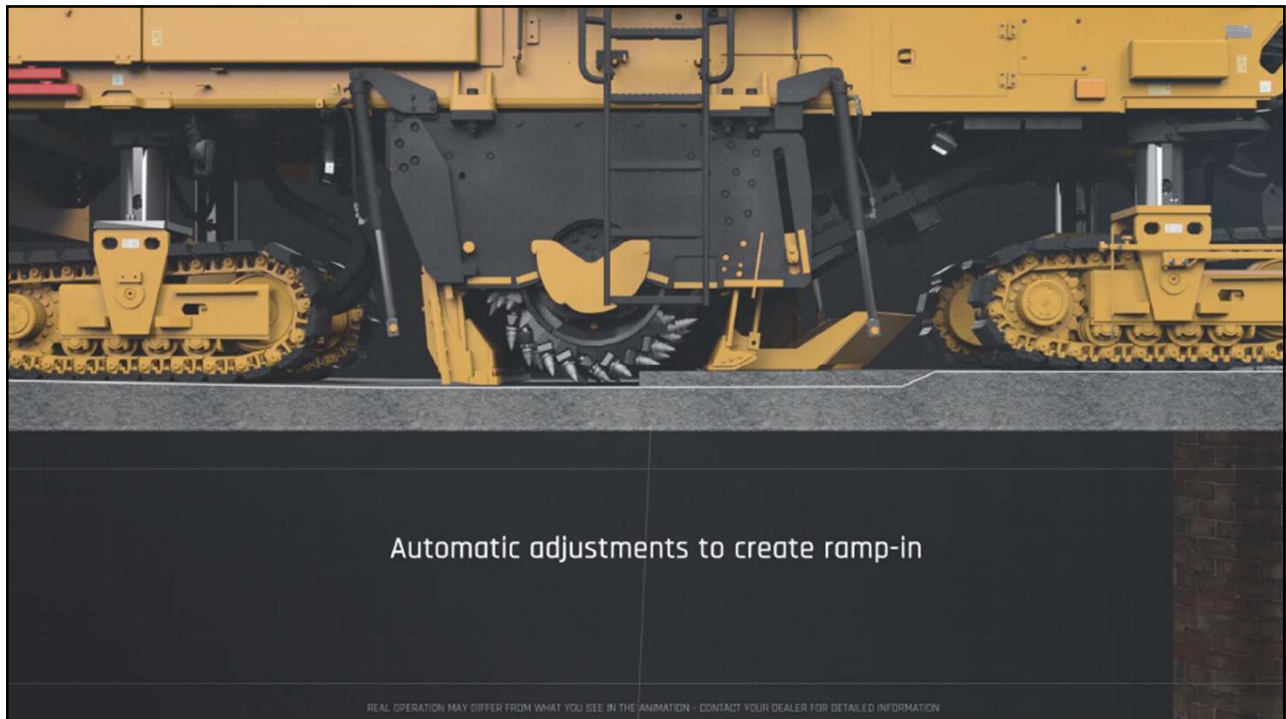
- Smoothness
- Change fix cross-slopes
- Less HMA to fill
- Complex transitions, supers, drainage
- No stringlines



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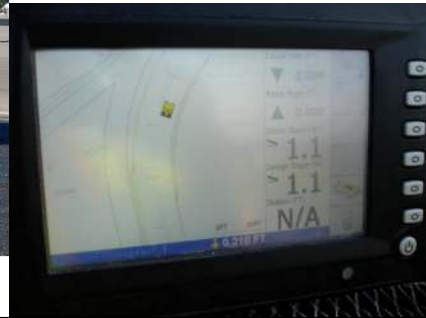
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3D-Grade Paving



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- Upgrade existing 2D system to 3D
- Universal Total Station



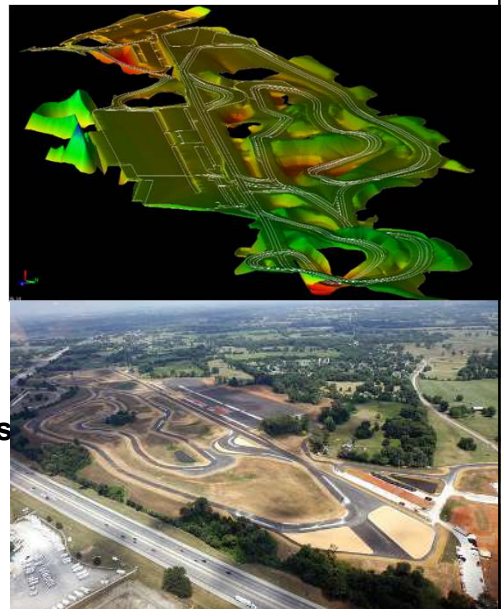
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3D Paving




- Accurate within 1/24"–1/8" (1-3 mm)
- Smoothness
 - Precise control of elevations and profile
- Complex designs
 - Transitions, super-elevations, cross-slopes
- Elimination of stringlines, staking
- Precise material quantities

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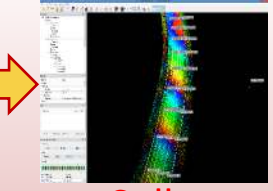


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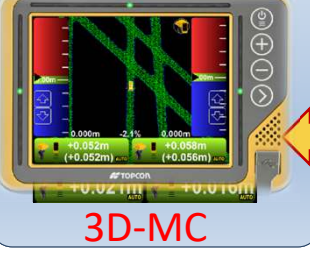
Topcon "Smoothride" 2D+



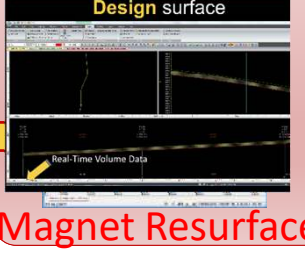
RD-M1 Collect




Collage



3D-MC



Magnet Resurface



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Compaction

Utilizes Global Navigation Satellite System (GNSS)


- GPS, GLONASS

Correlates measurements to a time & location:



- CMV, MDP, Temperature, Pass Count and Coverage
- Documents what was done – make every pass count
- Visual documentation of compaction quality or processes
- **Real-time data** on machine or back-office processing
- Data can be shared between multiple rollers on jobsite

Choice of accuracy:

- SBAS – provides accuracy to 1 meter
- RTK – provides millimeter accuracy



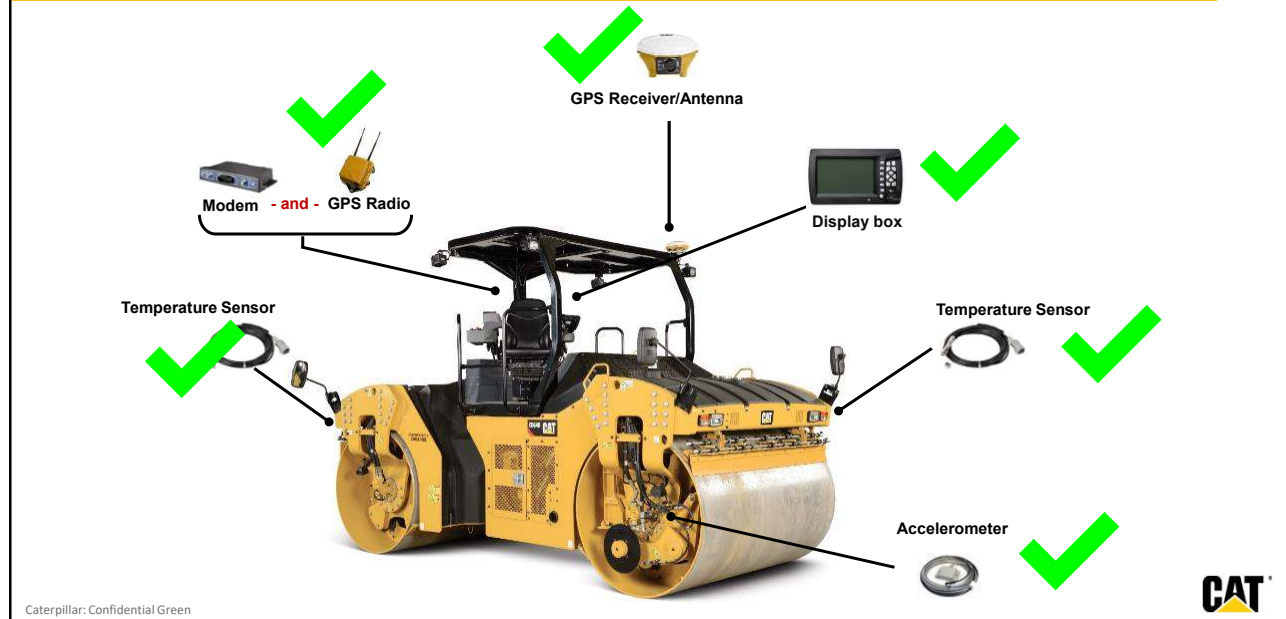
Conventional measurement only covers 1% of the job

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Intelligent Compaction (IC) Roller



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Summary: What IC can and cannot do...

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

ICMV \neq Density

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Color-coded Video Display - all data!



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How Can IC Help with Quality Control?

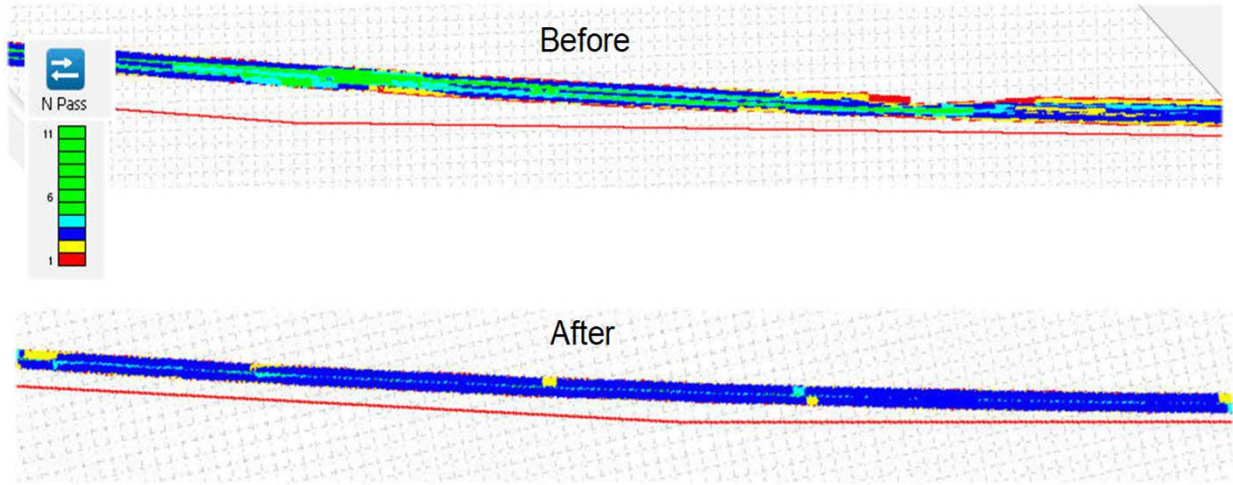
- Consistent pass count → uniform density (PWL)
- Rolling in temperature zones → uniform density (PWL)
- Intelligent Compaction Measurement Value (ICMV) → unproven
- *“Operator-assist”* tool for tracking rolling patterns
 - Transition zones - vibration on/off
 - Longitudinal joints – drum overlap
 - Night work – coverage/pass count
 - Stopping at an angle to the mat, coverage/pattern
 - Identifying soft spots
- Safety - reduced field testing
- Documentation of 100% of the job!

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Before & After – Pass Count Consistency!!

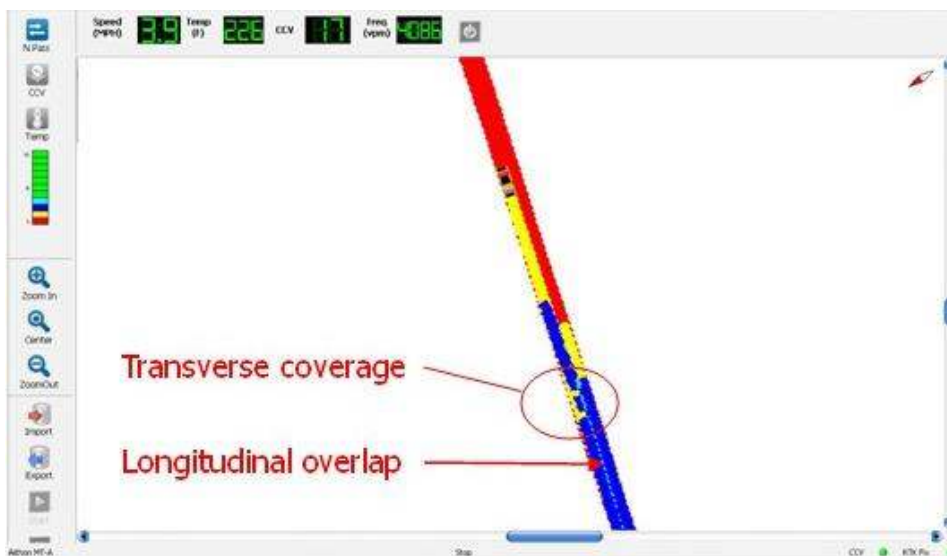


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Transition zones, longitudinal joints

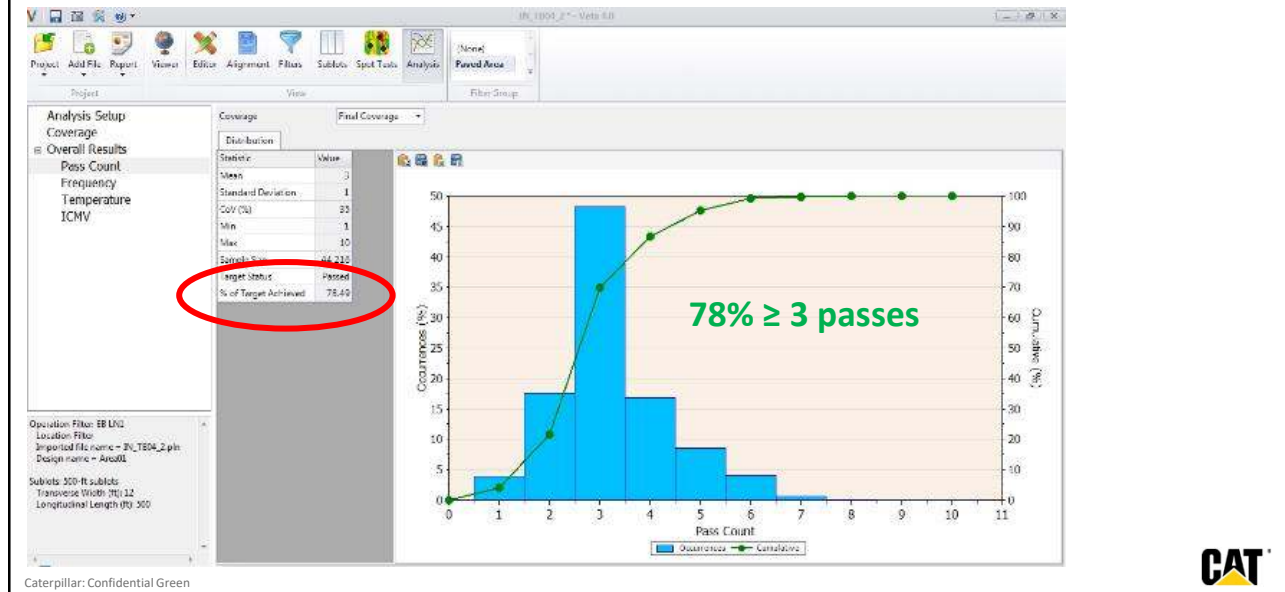


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Pass count in VETA Target = 3 passes



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Training Tool: Stop at an angle to the mat



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Night vision - “the back pass”



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First Pass on Unsupported Edge

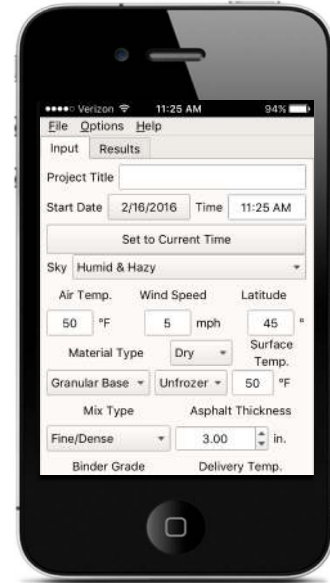
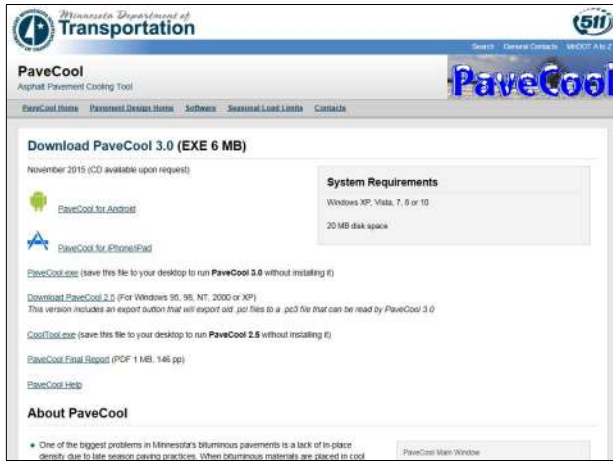


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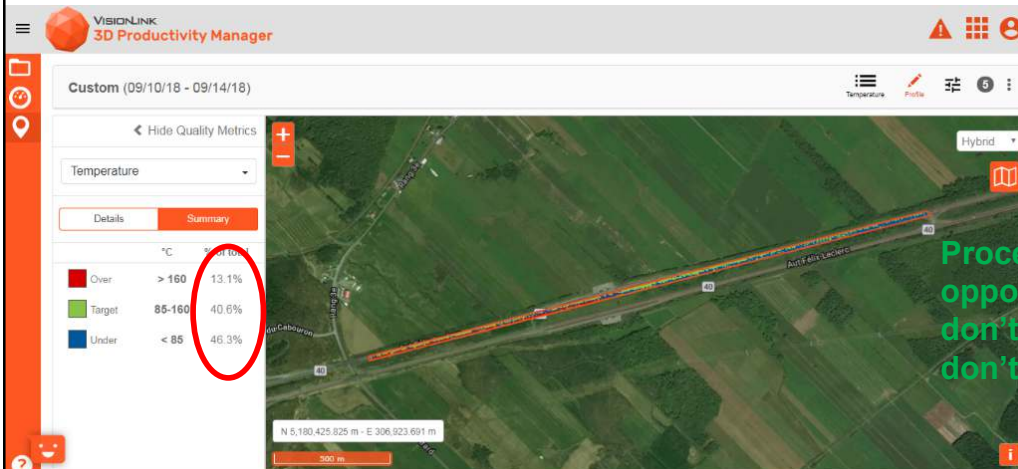
PaveCool or Multi-Cool website and App



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Temperature: 1st pass breakdown

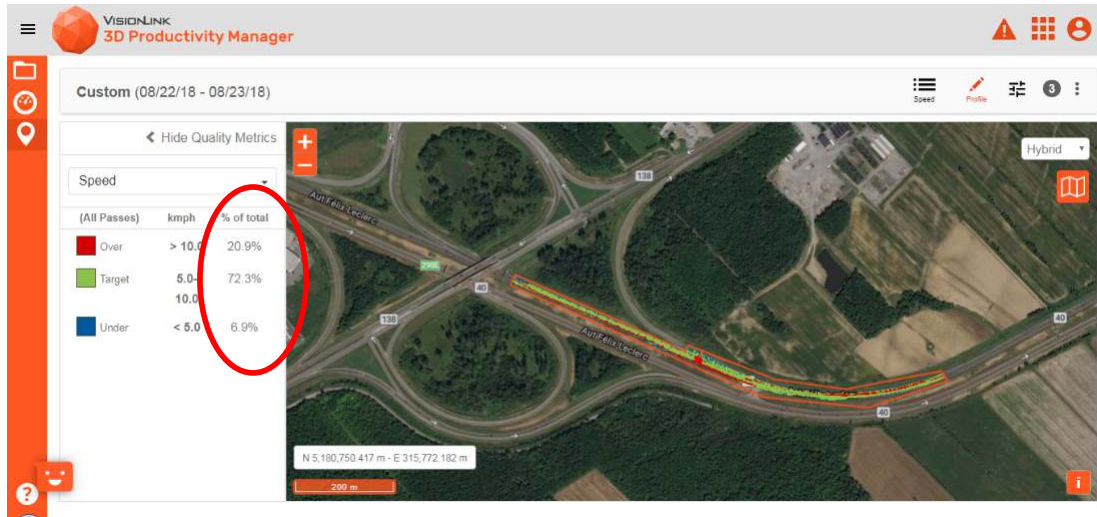


- Data indicates long breakdown passes
- Difficult to know without being on site and without plan file

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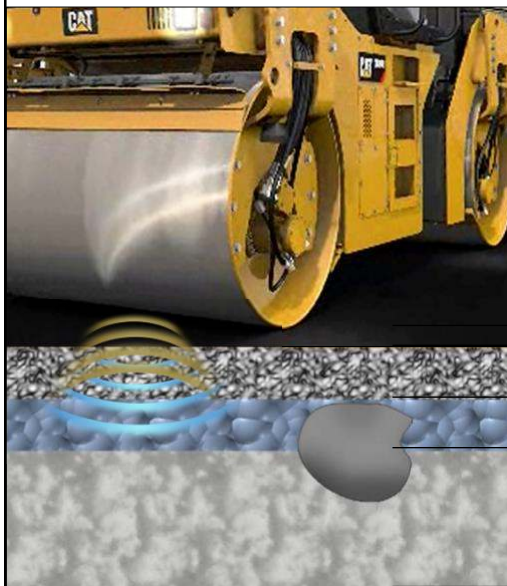
Speed: Smoothness & Density



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Accelerometer measures deep...



- Accelerometer technology measures deeper than the freshly paved lift of asphalt
- CMV value is a *composite* measurement
- Affected by amplitude, speed, direction, etc.

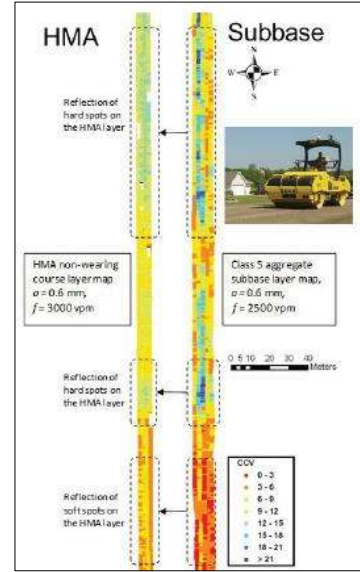
Mat being compacted
Existing HMA lift
Sub-base
Subgrade material

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Pre-mapping to find soft areas



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ICMV (accelerometer) – find weak areas



Soft base (Autoroute 40)

PCC Joints




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Telematics multiple solutions

EQUIPMENT MANAGEMENT



Basic – Equipment management

- MY.CAT.COM or the Cat app
- Hours, location, faults and fuel
- Maintenance schedules

Advanced – Equipment and site management


- VisionLink®
- Asset operation
- Projects and Geofences
- Notifications and special reports

Expert – Equipment and site management with advanced digital capability

- Customized support
- Condition monitoring
- API access


STANDARD WITH NEW MACHINE PURCHASE

CAT PRODUCTIVITY




- ✓ Digital productivity monitoring
- ✓ Efficiently manage jobsites using machine data
- ✓ Track
 - Material
 - Map view
 - Utilization
 - Cost

REMOTE SERVICES



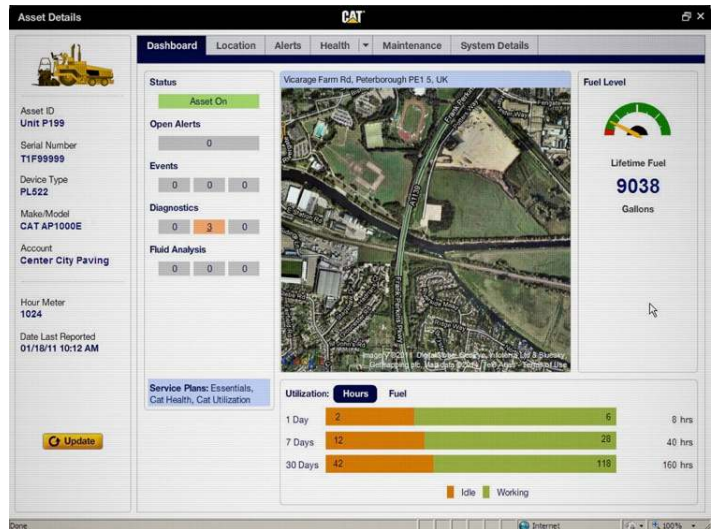
- ✓ Enables real time remote diagnostics on connected machines
- ✓ Reduces service calls
- ✓ Minimizes machine downtime
- ✓ Maximizes uptime with remote software updates



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Product Link™



Asset Details: Unit P199, Serial Number T1F99999, Device Type PL522, Make/Model CAT AP1000E, Account Center City Paving, Hour Meter 1024, Date Last Reported 01/18/11 10:12 AM

Status: Asset On


Location: Vicarage Farm Rd, Peterborough PE1 5, UK

Fuel Level: 9038 Gallons

Utilization:	Hours	Fuel
1 Day	2	6
7 Days	12	28
30 Days	42	118

Legend: Idle (orange), Working (green)

- Remote Monitoring
- Schedule maintenance
- Monitor Fuel consumption
- Asset Tracking
- Machine tracking
- Service and Maintenance Management
- Satellite and Cellular Connectivity



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Paver-Mounted Thermal Profiling (PMTTP)



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- Continuous
- Real-time on paver
- Stationary infrared camera
- Variable width
- Compatible direct upload to Veta software

» SPECIFICATIONS AND DIMENSIONS



TECHNICAL SPECIFICATIONS	
Temperature Mapping Range	80° - 200° C (167° - 392° F)
Temperature Accuracy	±1° C (±1.8° F)
DIMENSIONS	
Camera Eye Height	A 3.66 m (12')
Maximum Camera Height	4.27 m (14')
Minimum Camera Height	2.68 m (8' 10")
Collimation Zone	B 2.44 m (8')
Distance from Ground Plate - Maximum	C 3.66 m (12')
Maximum Width	D 9.14 m (30')



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Temperature Differentials = Density Differentials



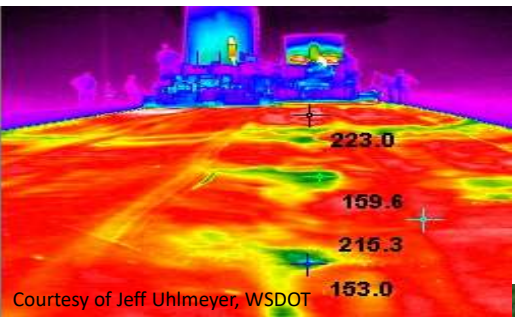
Courtesy of Jeff Uhlmeier, WSDOT

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This....becomes....this....



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Thermal Mapping in Real-Time on the Paver

Temperature
300°F
240°F
180°F

16202357.08
1515091.0E
286°F

Avg. Temperature (°F) **249** Delta Temperature (°F) **24**

0.00 in

Time	Temp
0:00:00	249
0:00:01	249
0:00:02	249
0:00:03	249
0:00:04	249
0:00:05	249
0:00:06	249
0:00:07	249
0:00:08	249
0:00:09	249
0:00:10	249
0:00:11	249
0:00:12	249
0:00:13	249
0:00:14	249
0:00:15	249
0:00:16	249
0:00:17	249
0:00:18	249
0:00:19	249
0:00:20	249

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WSDOT Research 1995-2000

Table 2. Percent Pass and Fail Density Criteria According to Temperature Differentials

	$\Delta T \geq 25^\circ\text{F}$	$\Delta T < 25^\circ\text{F}$
Number of Profiles	28	41
Failed both density criteria	20	4
Passed both density criteria	3	33
Failed only high - low	3	2
Failed only mean - low	2	2
Percent passing	10.7	80.5
Percent failing	89.3	19.5

Source: Washington State DOT "Tech Note" September 2001

- Washington State DOT research prompted 'shadow spec' for 2001 construction season

- Density profiles related to mat temperature from thermal camera

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How Can Thermal Imaging Help with QC?

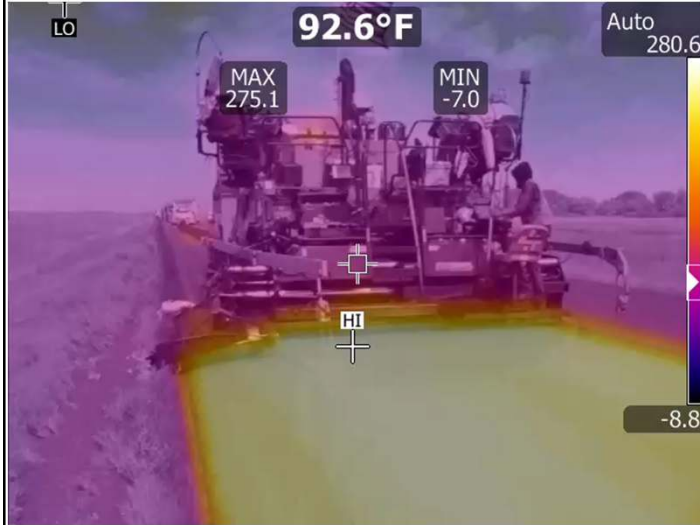
- Consistent mat temperatures = consistent compaction = better smoothness = extended pavement life
- Identify areas of improvement in process and equipment
 - Plant operations
 - Plant repairs
 - Mix segregation
 - Paving equipment setup & operation
 - Paving equipment repair

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Thermal Patterns: What do they Mean?



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- What temperature pattern am I seeing?
- What is this pattern telling me?
- What can I do to reduce temperature differentials?



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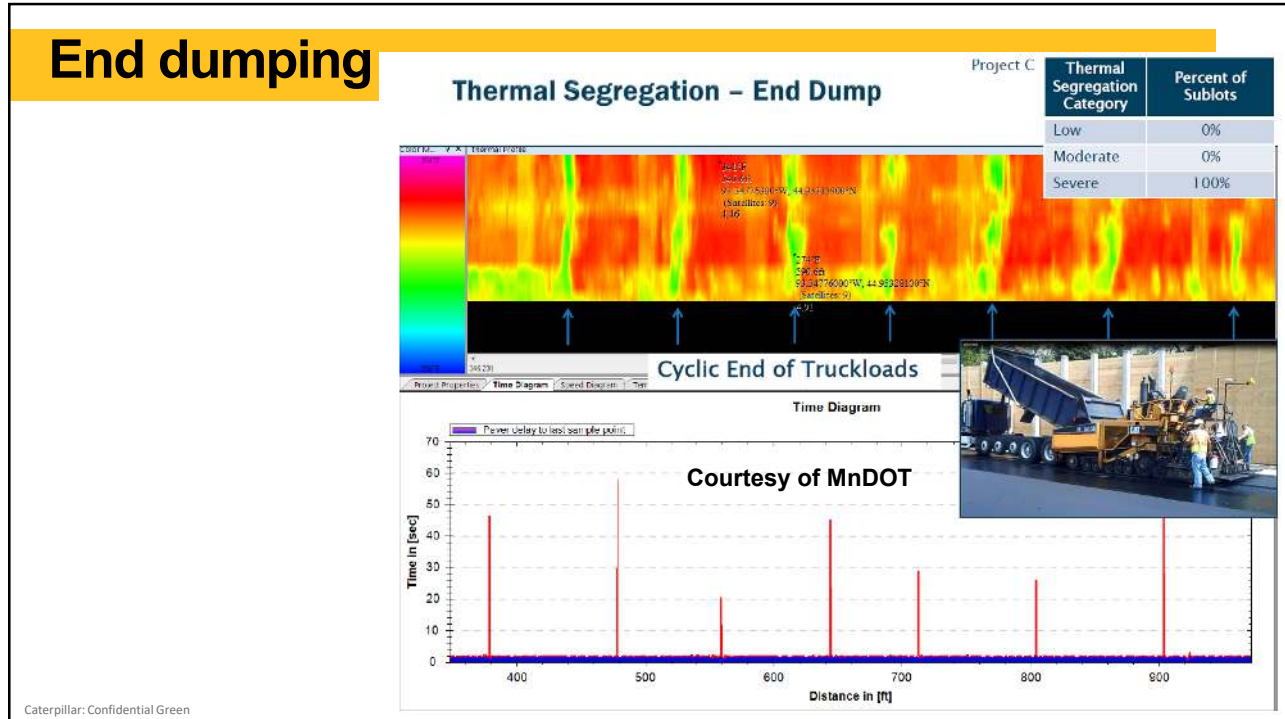
Truck Exchange – hopper level



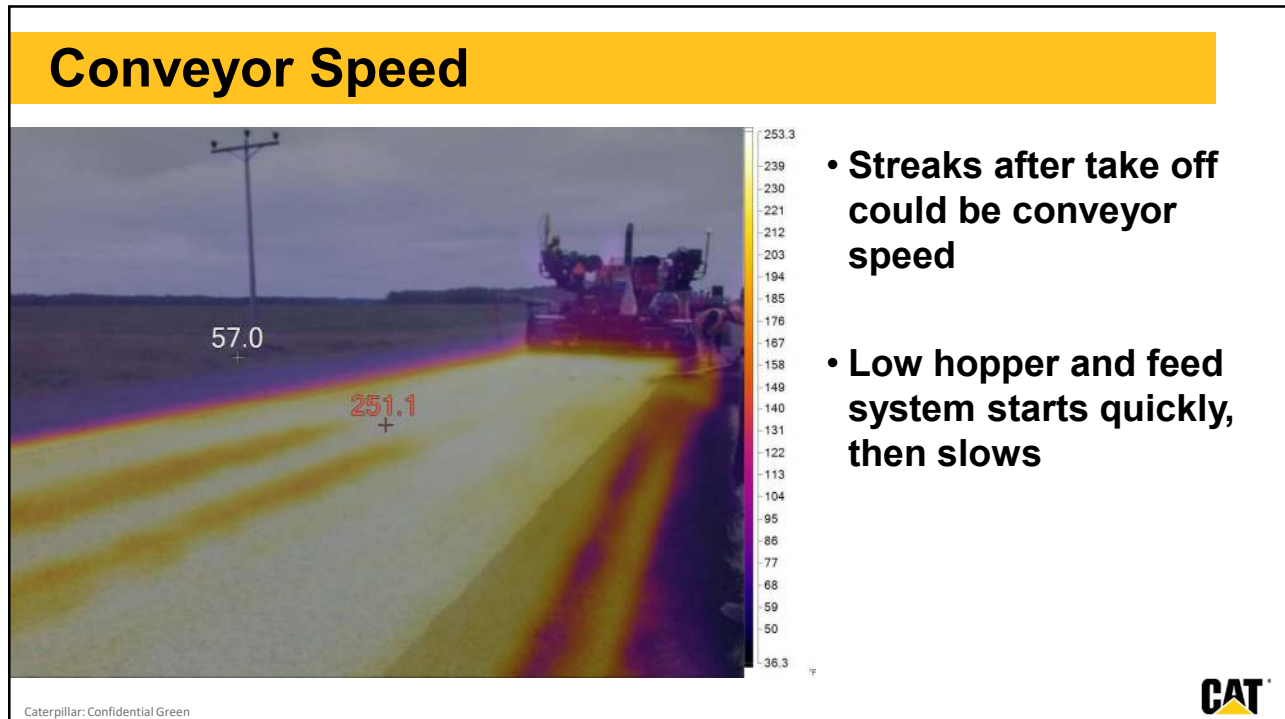
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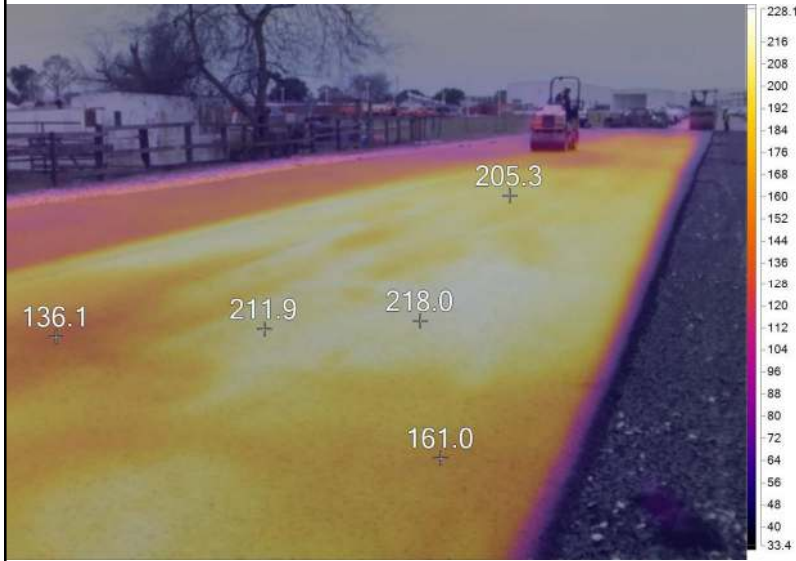


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Feeds Sensor position - on/off augers



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- Feed sensor position (aim) causing augers to go on/off



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Material Transfer Device



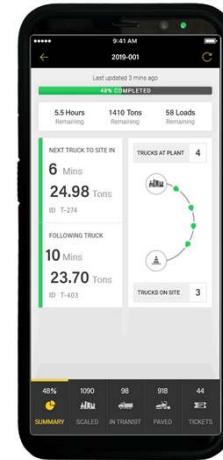
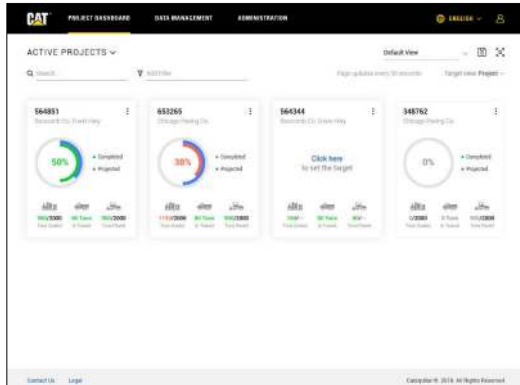
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eRoutes (MDMS)

[Web-based user interface](#) primarily for management employees to monitor realtime information as well as post-process jobsite data.



[Mobile application](#) primarily for paving foremen and paving crew members giving them the information they need to do their jobs better.



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Why eRoutes ??

QUICKLY SEE THE WHOLE PROCESS

- Merge paver/truck/ticket data into real-time information
- Cycle times/waiting times per job/truck/plant
- Tons loaded, in-transit, and paved

HELP ELIMINATE PAVER STOPS

- Your bonus depends on it!
- Balance laydown and delivery

DRIVER PERFORMANCE COMPARISON

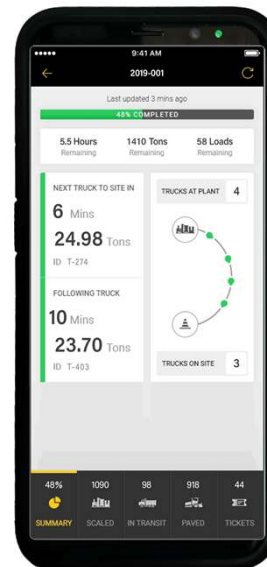
- Hire trucks/Company trucks? (Performance you expect?)
- "Where are my trucks!" (mystery solved!!)

BALANCE PLANT PRODUCTION FOR MULTIPLE CREWS

- The right mix produced at the right time
- Reduce plant wait times

TRACK YOUR MILLINGS

- Great way to monitor backhaul



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Paver & truck location with loadout data

Visibility to the Paving Process and Opportunity to Influence it

TIMING BY TRUCK AND JOB
 Cycle times
 Waiting times by Job and Truck

TRUCKING
 Driver performance

REPORTS
 By truck/job/mix

PRODUCTION (TONNAGE)
 Loaded
 In-transit
 Paved

MOBILE ALERTS
 First load
 Last load
 Running Totals

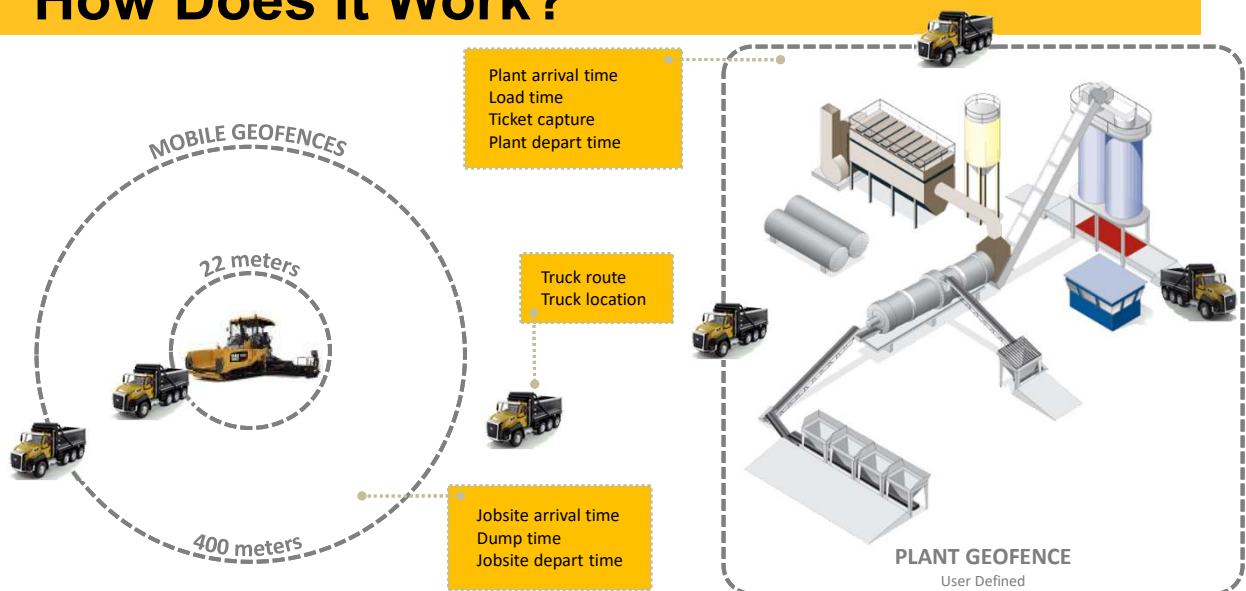
ARCHIVED DATA

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How Does it Work?



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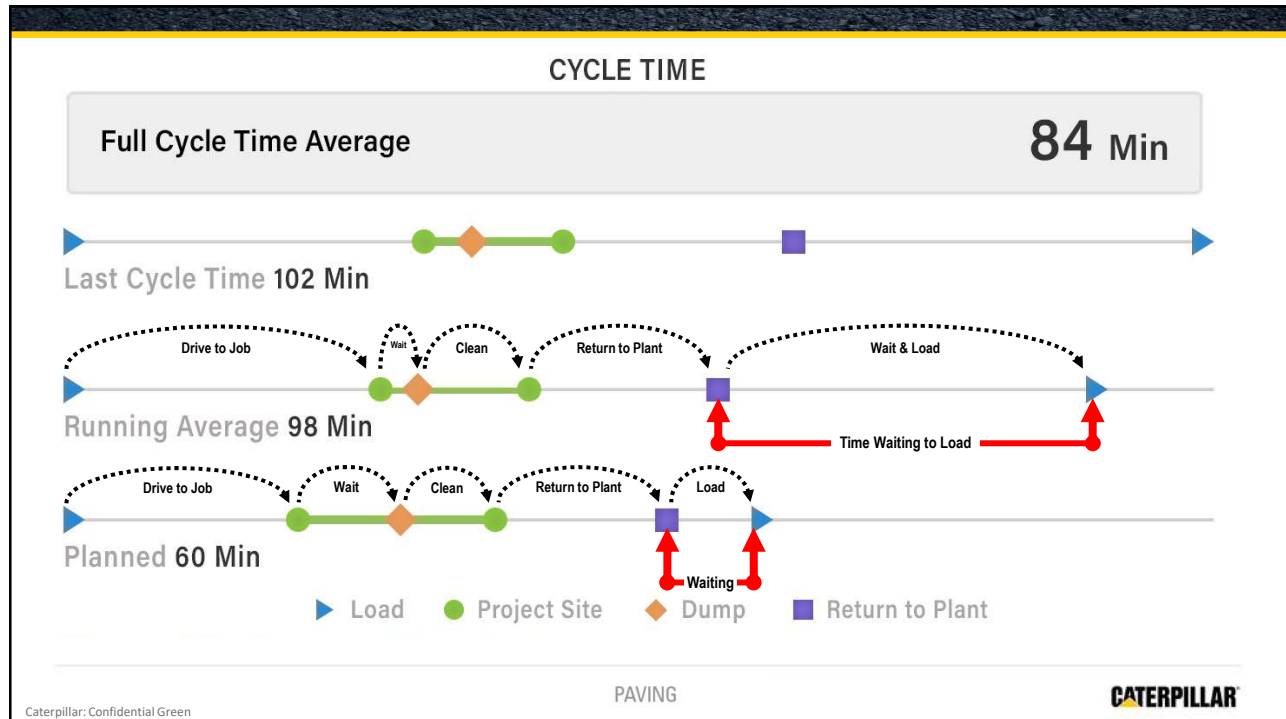
eRoutes Mobile App



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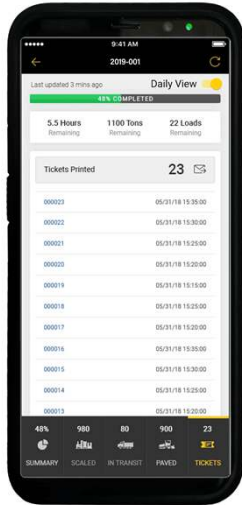


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eTickets



CAT PROJECT DASHBOARD DATA MANAGEMENT ADMINISTRATION ENGLISH

TICKETS

Search... Add Filter

Default View [Icons] Create Report

03/09/18 - 03/15/18

Plant ID	Truck ID	Ticket Number	Ticket Date/Time	Material ID	Customer ID	Action
BP Plant	CP007291	000007	03/15/18 17:00:00	320-350	8765432	ABC123 Void
BP Plant	CP007292	000006	03/15/18 17:00:00	320-350	8765432	ABC123 Voided
BP Plant	CP007293	000005	03/15/18 17:00:00	320-350	8765432	ABC123 Void
BP Plant	CP007294	000004	03/15/18 17:00:00	320-350	8765432	ABC123 Voided
BP Plant	CP007295	000003	03/15/18 17:00:00	18.95	G14520-350	8765432 ABC123 Void
BP Plant	CP007296	000002	03/15/18 17:00:00	19.55	G14520-350	8765432 ABC123 Void
BP Plant	CP007297	000001	03/15/18 17:00:00	19.2	G14520-350	8765432 ABC123 --

- CREATE PROJECT
- NOTIFICATIONS
- GROUP MANAGEMENT
- USER MANAGEMENT
- DEVICE MANAGEMENT
- ASSET MANAGEMENT
- REPORTS
- TRACE TOOL
- DEVICE CONFIGURATION

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eRoutes Desktop – Project Dashboard

eRoutes PROJECT DASHBOARD DATA MANAGEMENT ADMINISTRATION

ACTIVE PROJECTS

Search... Add Filter Target view: Project

1001-19
US-95

83% Completed Planned

17022 / 20000 224 US Tons
16629 / 20000
100 Tons Scaled 100 Tons Paved

1011-19
Smithville Airport

24% Completed Planned

18078 / 80000 14 US Tons
18964 / 80000
100 Tons Scaled 100 Tons Paved

1027-19
State Route 77

42% Completed Planned

4238 / 10000 39 US Tons
4210 / 10000
100 Tons Scaled 100 Tons Paved

1030-19
Main Street

63% Completed Planned

3545 / 5000 0 US Tons
3140 / 5000
100 Tons Scaled 100 Tons Paved

1033-19
Jones Township

43% Completed Planned

218 / 500 0 US Tons
218 / 500
100 Tons Scaled 100 Tons Paved

1042-19
1042-19

Click here to set the target

0 / -- 0 US Tons
0 / --
100 Tons Scaled 100 Tons Paved

Home | Log In

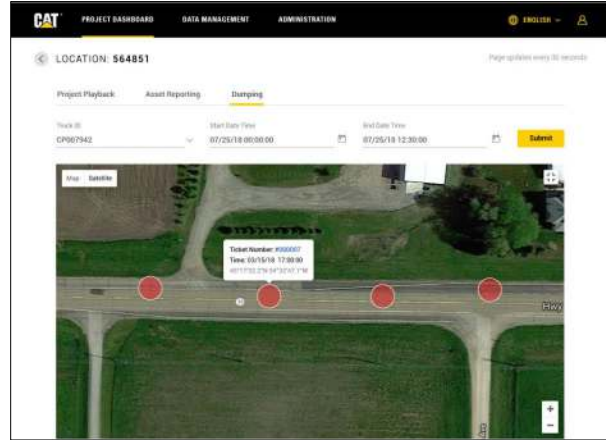
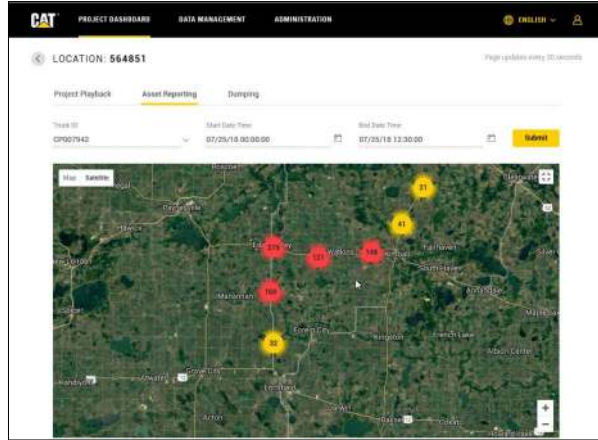
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eRoutes Desktop



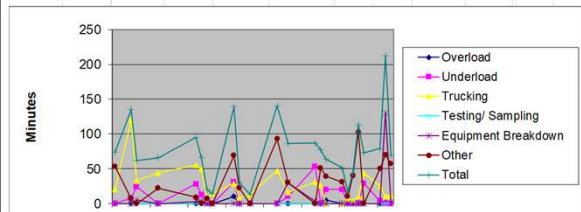
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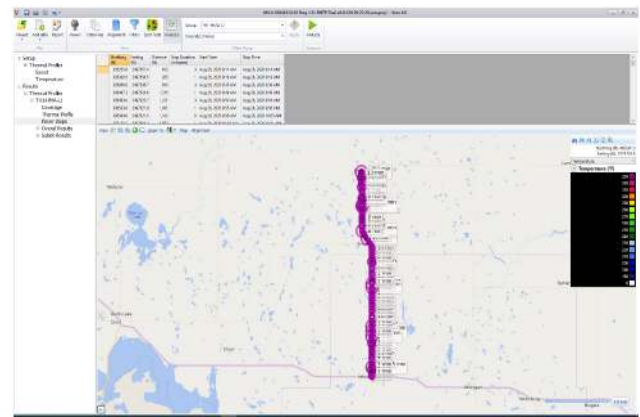
63

Paver Stop report – lost time

Date	Overload	Underload	Trucking	Testing/ Sampling	Equipment Breakdown	Other	Total	Number of Stops	Paving Time	Tons	Actual TFH	
#####	0	0	21	0	0	53	74	9	5.5	1080	253	
#####	0	8	120	0	0	7	135	29	8	2014	350	
#####	0	24	33	0	5	0	62	14	8	1998	287	
#####	0	0	44	0	0	22	66	11	8	1750	254	
#####	0	28	55	0	3	9	95	14	8	2050	319	
#####	0	13	49	0	4	0	66	13	8	2150	312	
#####	8	0	7	0	0	7	20	6	8	2079	271	
#####	0	0	14	0	0	0	14	4	7	1842	272	
#####	10	31	29	0	0	69	139	14	8	1300	229	
#####	0	0	8	0	0	22	30	3	3	266	106	
#####	0	0	13	0	0	0	13	5	8	1928	248	
#####	0	0	47	0	0	93	140	16	8	1673	295	
#####	0	10	16	0	30	30	86	9	8	1863	284	
#####	0	53	31	0	3	0	87	13	8	2061	315	
#####	0	0	26	0	0	51	77	10	6	1368	290	
#####	5	20	0	0	0	39	64	8	6	1484	301	
#####	0	20	0	0	0	31	51	5	6	1146	223	
#####	0	0	7	0	0	10	17	4	8	1706	221	
#####	0	0	4	0	0	40	44	5	8	1018	140	
#####	0	0	10	0	0	103	113	5	8	1533	251	
#####	0	29	44	0	0	0	73	11	8	2030	299	
#####	0	4	25	0	0	0	50	7	6	1153	173	
#####	2	0	10	0	0	130	70	212	6	8	1137	255
#####	0	0	12	0	0	57	69	9	8	1941	283	



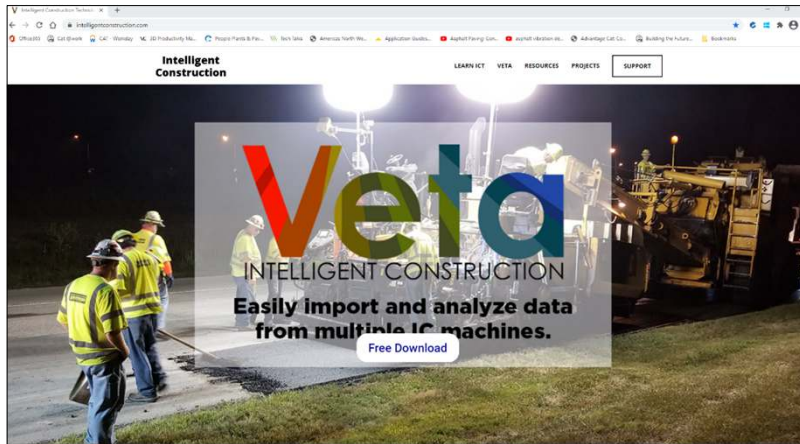
- Find efficiencies / downtime
- > 25% is very typical
- **Example:** Painting out lines!



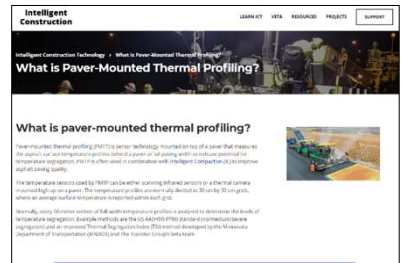
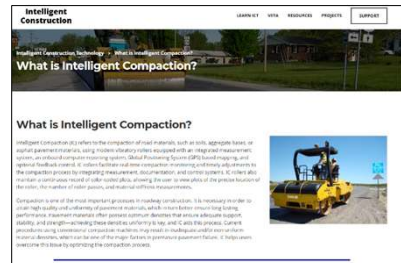
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Where to go for IC, Thermal & Veta software

www.intelligentconstruction.com



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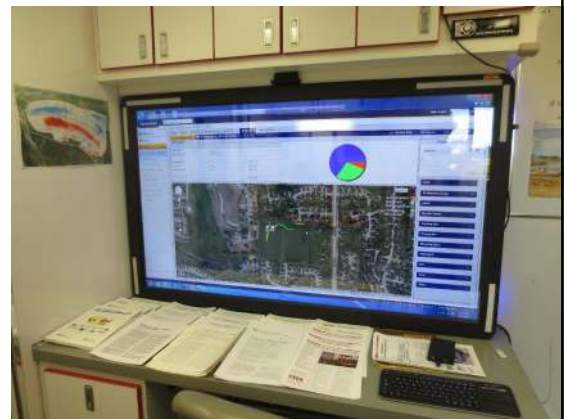


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Wireless data near 'real-time'



What data is going to help me?



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Visibility & Safety



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Fore/Aft Cameras

- Improve visibility of the operating path of the machine
- Integrated into the machine display

360° Cameras

- Improve visibility of the entire work area around the machine
- Separate, dedicated display
- First fit & Retrofit Kits



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Safety Kits

Description

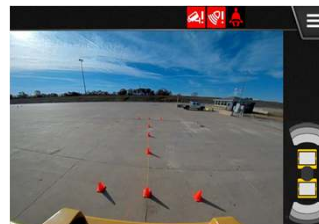
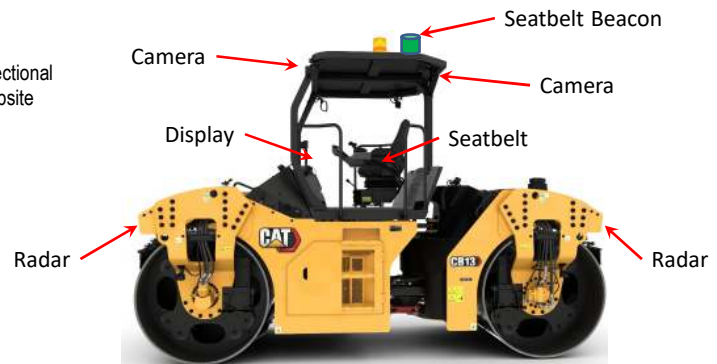
The ACOM Safety Kit is an aftermarket system that provides bi-directional camera views, bi-directional radar object detection and operator, jobsite and back-office seatbelt indication.

Scope

- Bidirectional Camera Views
 - Based on seat direction
- Bidirectional Radar Object Detection
 - Based on propel direction
- Seat Belt Usage Indication
 - Audible
 - Visual
 - Jobsite
 - VisionLink

Value

- Improved operator visibility of the worksite
- Alerts operator to objects in path of travel to prevent collisions
- Reminds operators to wear seatbelt
- Jobsite visibility to operator seatbelt usage
- Back Office seat belt use tracking & communication



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Semi-autonomous Soil Compaction



1. Where
2. How
3. Press "Auto"



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Command for Compaction – Soils



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Virtual Reality Training



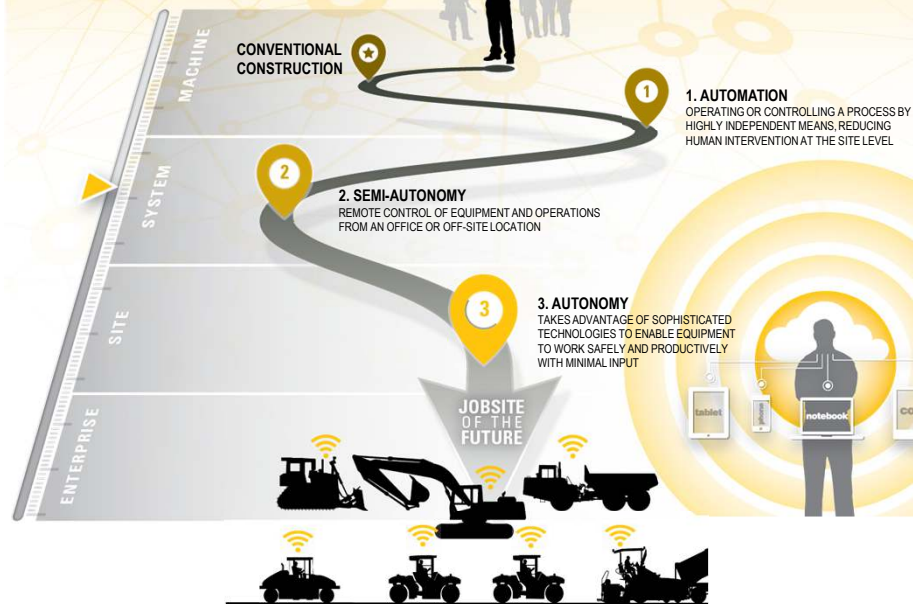
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- Portable, on-demand
- Safe
- Tracks individuals' progress



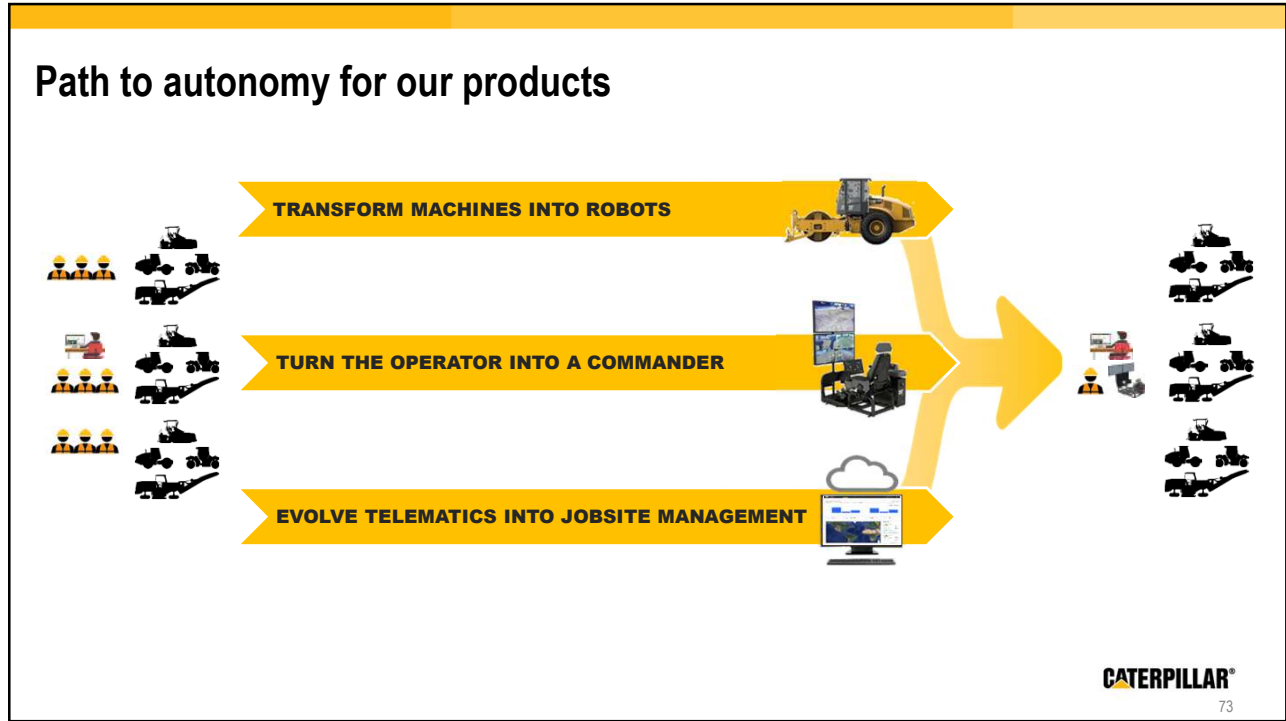
71

Roadmap to Autonomy

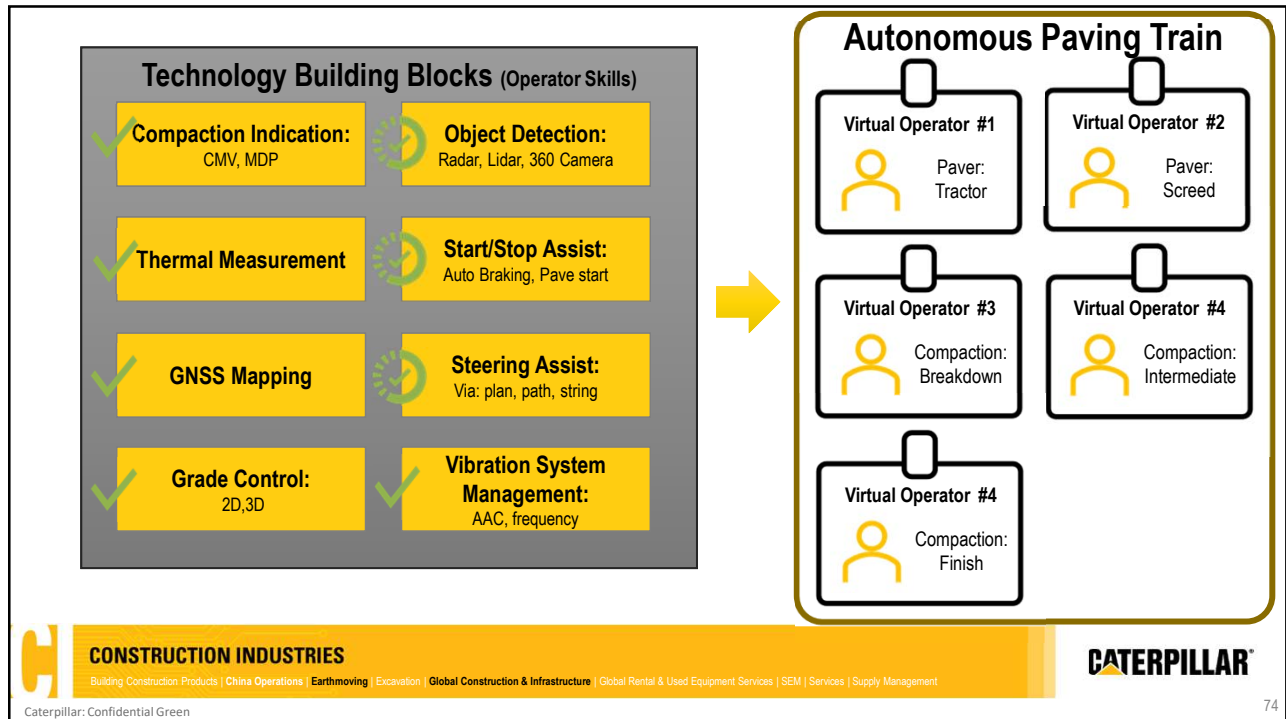


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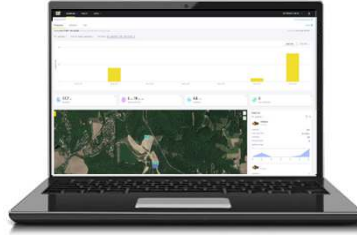
73



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Back Office Solutions

- ✓ One Platform
- ✓ Actionable insights
- ✓ Automatic progress to plan
- ✓ Feedback loop
- ✓ Full or multi-site project view
- ✓ Scenario planning
- ✓ Automatic Progress to Plan



CONSTRUCTION INDUSTRIES

Building Construction Products | China Operations | Earthmoving | Excavation | Global Construction & Infrastructure | Global Rental & Used Equipment Services | SEM | Services | Supply Management



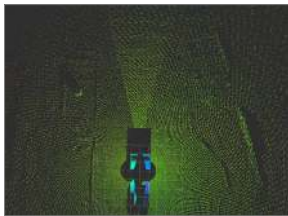
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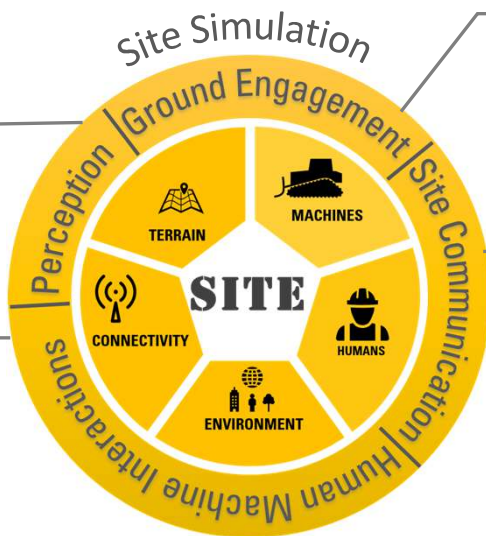
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Autonomy and Site Simulation - eVPG India

Lidar Simulation



Base Machine Closed Loop Dynasty



Terrain Deformation



Connection to Back Office



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Connecting the Jobsite Workflow

“How do I manage my jobsites more efficiently?”

! Asphalt – final, time sensitive product that is expensive to rework !

Coaching our Customers at the Site Level



Deeply integrating our machines with the back office will differentiate us from the competition.

CAT[®] PRODUCTIVITY



CATERPILLAR[®]

Commercializing efforts on the road to Autonomy



SCOM Command for Compaction Gen 1 Aftermarket Kit



SCOM Aftermarket Safety Kit



ACOM Aftermarket Safety Kit

COMING UP

Collision Avoidance

Remote Control



eRoutes



CAT Grade with Thermal Mapping for Pavers



CAT Productivity for Cold Planers

CAT Productivity for Pavers



CATERPILLAR[®]

Remote Operation

- In 2021, true remote operation of equipment became commercially available.
- This operation is running a JD 944 loader using Teleo's remote operator station.
- Potential Applications
 - Working in hazardous conditions
 - More controlled environment for the operator.
 - Operator could switch between multiple machines.
 - Production tracking and monitoring

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Technology is redefining the industry

<p>Telematics</p> <p>Products Condition External Environment Products Operation Products Usage</p>	<p>Performance</p> <p>Enhance product performance Allow predictive diagnostics</p>	<p>Connectivity</p> <p>Enhance product performance Through the Value Chain</p>	<p>Autonomy</p> <p>Full Jobsite Automation of Machines</p>
Product	Smart Product	Smart Connected Product	Smart Connected Products Part of a Product System
Compaction Mapping AAC (Automatic Adjustable Compaction)	Compaction Efficiency & Utilization	Compaction Optimization	Roller to Roller M2M Compaction Map Sharing – full documentation

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Autonomous rollers



Courtesy: HAMM T11



Courtesy: BOOMAG



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What's next ????



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The industry is starting to see non-OEM startups like Built Robotics and Teleo developing technology to add onto manufacturers' equipment. Some of this technology is coming over from the developments in self driving cars.

Could we see full autonomy on jobsites in just a few years ??

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Future Paving Technologies

- Artificial Intelligence – machines act & react based on live inputs

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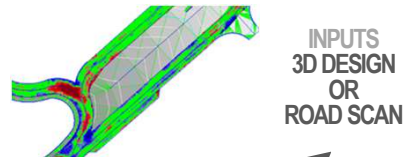
Fully Autonomous Paving site

ROBOTICS-WORLD
09.01.21 Published by Kennel Media Group VOLUME 1 - ISSUE 17

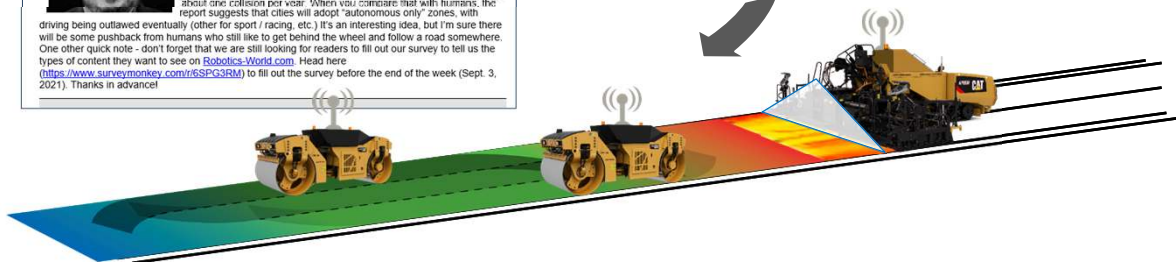
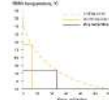
Accurate navigation in tunnels
MicroStrain® Sensing Systems Parker LORD

EDITOR MESSAGE
Could Driving be illegal in 2050?

As autonomous car companies continue their stride towards mass adoption, an interesting new report suggests that self-driving technologies will get so much better than humans, that by 2050 driving could be banned in the interest of safety. That's the thinking of IDTechex, which produced a report suggesting that autonomous technologies will match humans' ability in driving by 2024, and then surpass it by 2050 to about one collision per year. When you compare that with humans, the report suggests that cities will adopt "autonomous only" zones, with driving being outlawed eventually (other for sport / racing, etc.) It's an interesting idea, but I'm sure there will be some pushback from humans who still like to get behind the wheel and follow a road somewhere. One other quick note - don't forget that we are still looking for readers to fill out our survey to tell us the types of content they want to see on [Robotics-World.com](https://www.surveymonkey.com/r/6SPG3RM). Head here <https://www.surveymonkey.com/r/6SPG3RM> to fill out the survey before the end of the week (Sept. 3, 2021). Thanks in advance!



- Δ Width
- Depth
- Δ Time
- Δ Temp
- Δ Distance



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Thank you for your attention!!



Todd Mansell
mansell_todd@cat.com



Cat Paving YouTube Channel



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