Software and Hardware improvements using 1mm x 1mm resolution 3D road surface data

By
John Laurent
Pavemetrics Systems inc.
www.pavemetrics.com

Pavemetrics: Sensors for Infrastructure Inspection

- **Founded 2009; a “Spin-off” of Canada’s National Optics Institute (INO)**
- **3D sensor development**
- **Automated data processing algorithm development**
- **Technology used for Roads, Runways, Rails, Tunnels (400+ systems)**
- **40+ countries**

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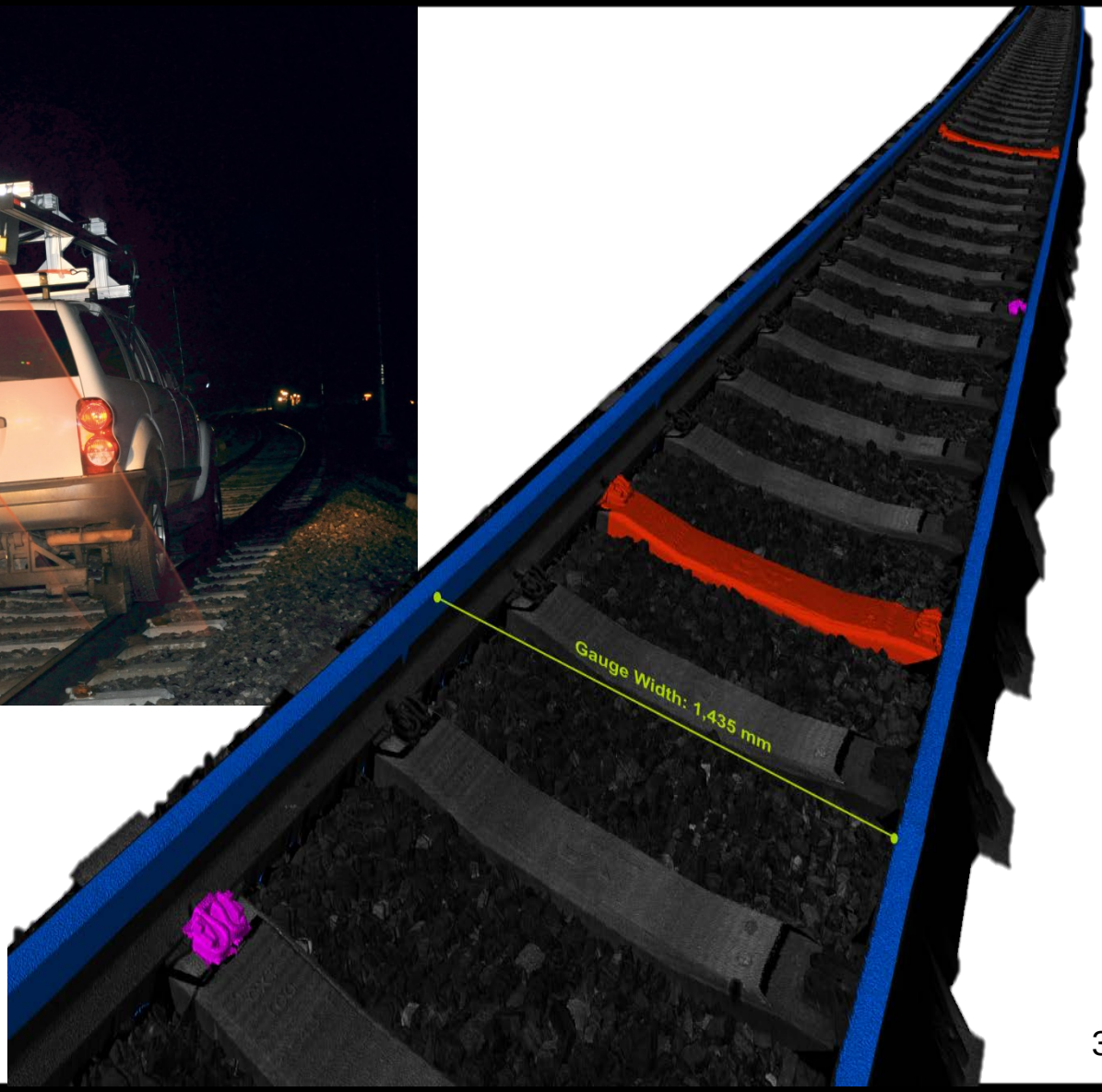
APPLICATION: Rails



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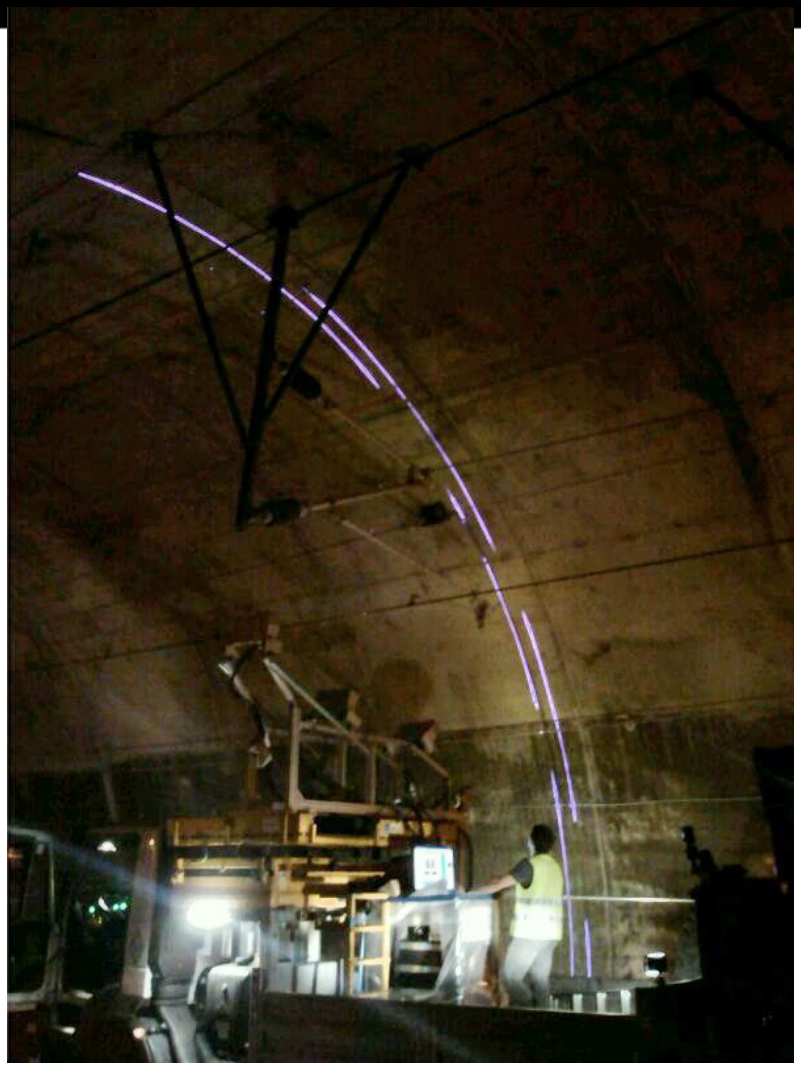
LTSS – Tunnel scanning



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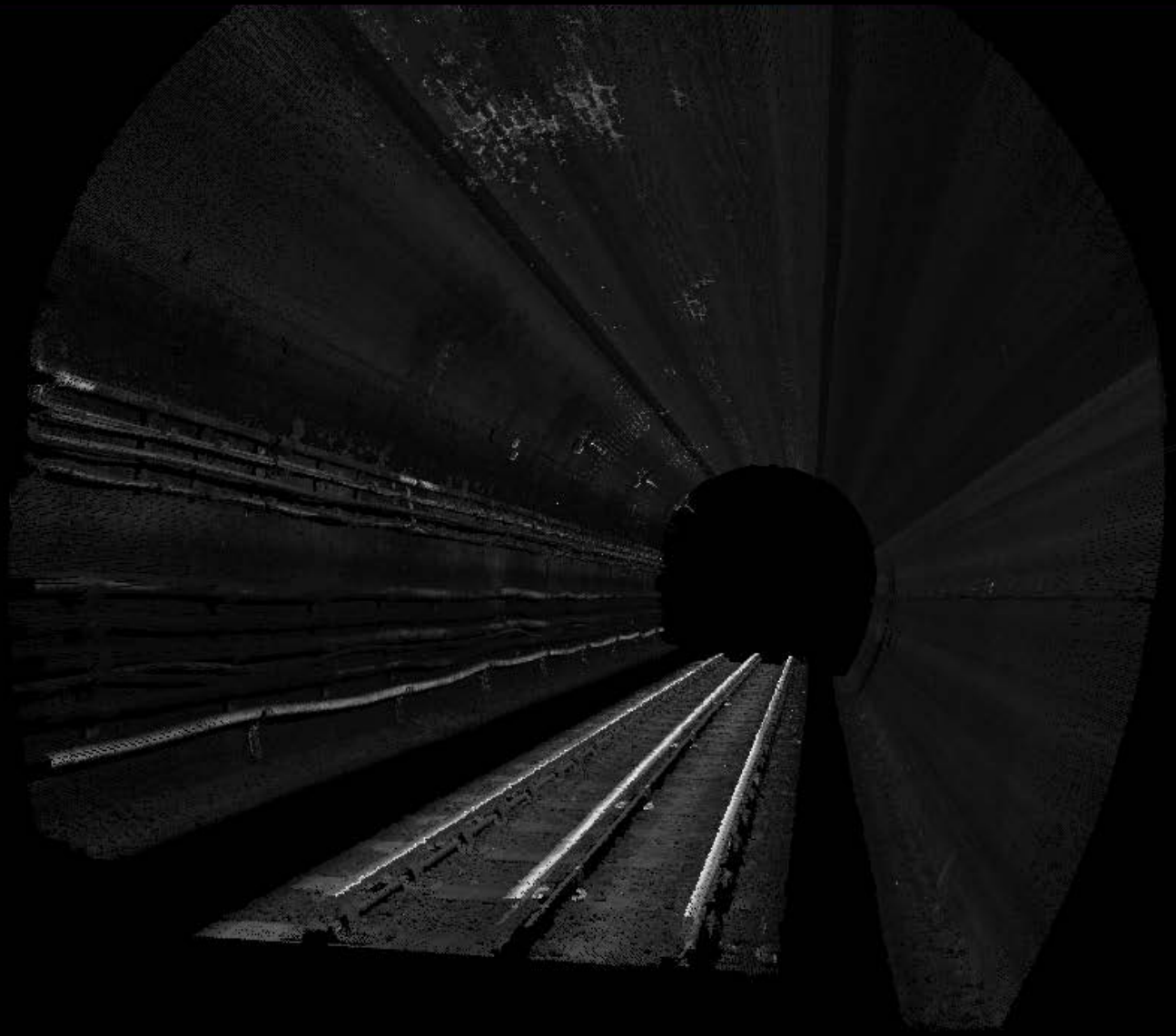
LCMS/LTSS Capabilities



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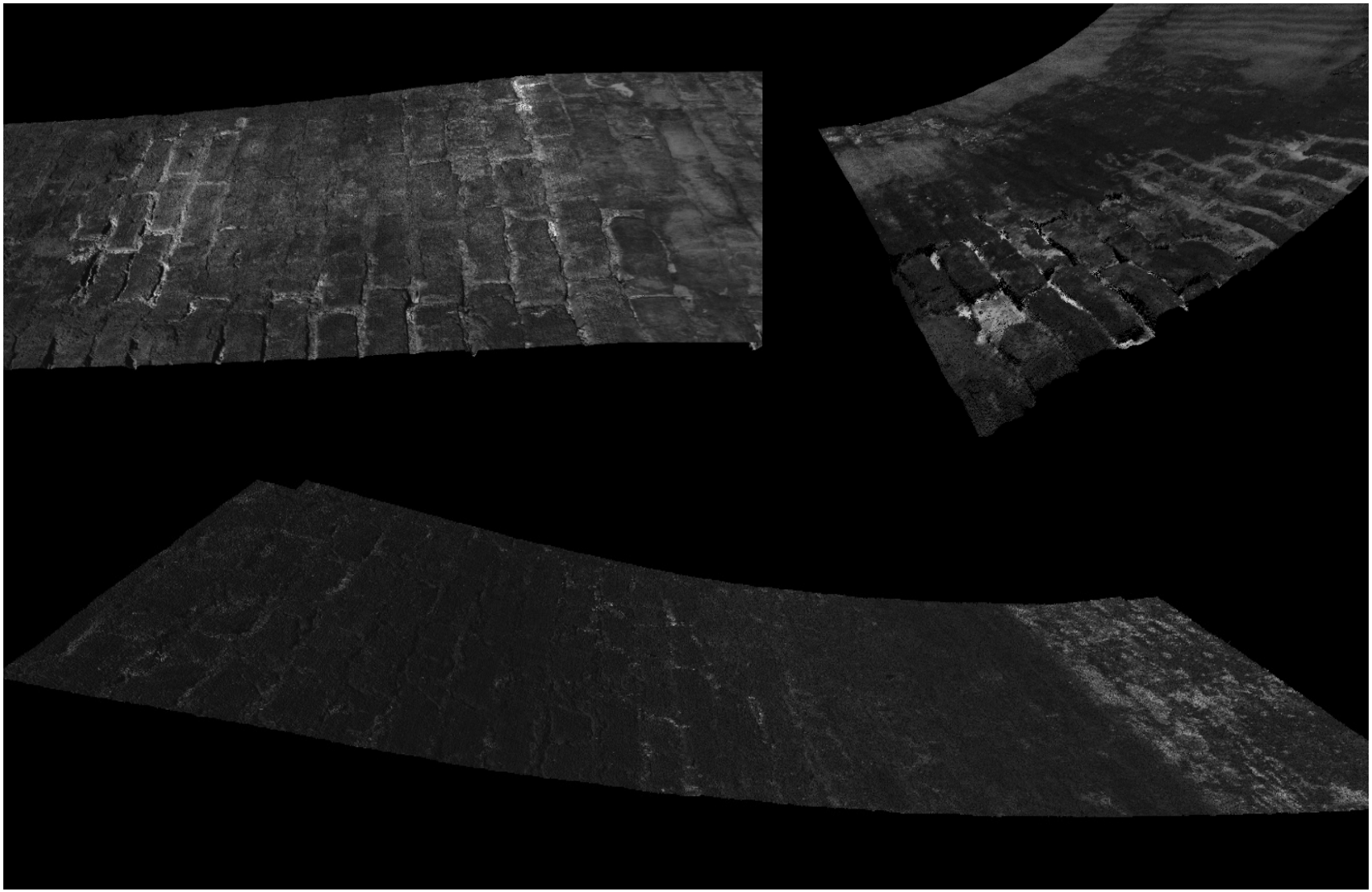
LCMS/LTSS Capabilities



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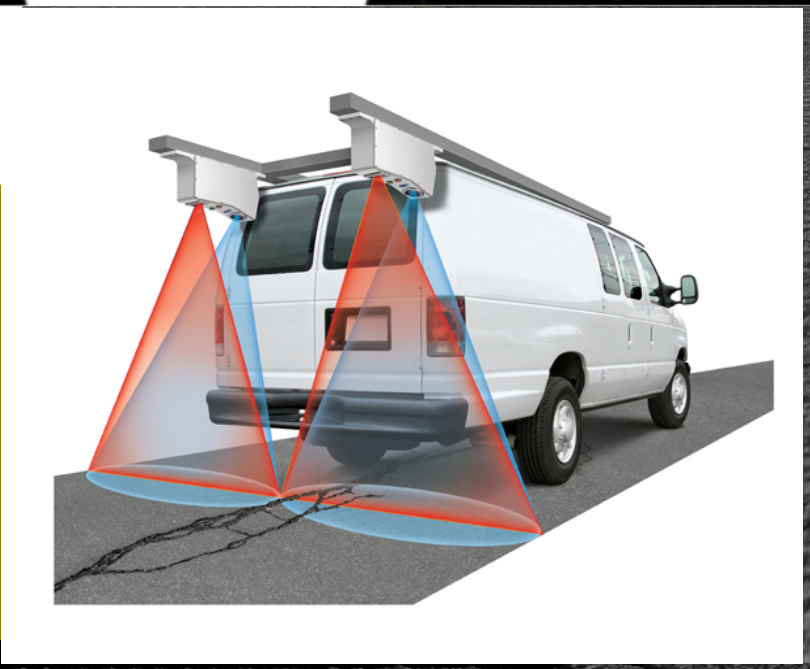
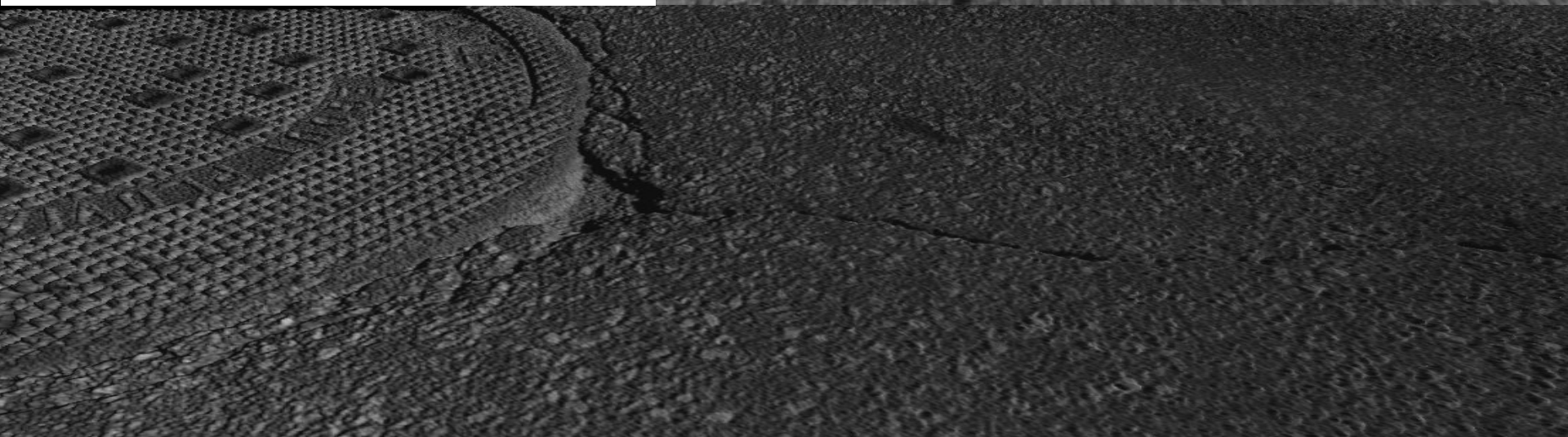
APPLICATION: Roads





Technologies Offered

- **LCMS**

- **LRIS - Line Scan Imaging**

- **LRMS – Rut measurement system**

Technologies Offered

- LCMS
- LRIS - Line Scan Imaging
- LRMS – Rut measurement system

Technologies Offered

LCMS - 2

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Specifications

LCMS-1 vs LCMS - 2

Specifications	LCMS -1	LCMS-2
Acquisition Rate	5,600 profiles/s	28,000 profiles/s
Range Accuracy/Resolution	*0.5mm / 0.25mm*	*0.25mm / 0.05mm**
Lateral Resolution	1mm	1mm
Field of View (lateral)	4m	4m
Data rate per km	0.6 Gb/km	3 Gb/km

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Improved vertical resolution

- **ASTM and AASHTO standards utilized by the road profiling industry (ASTM E950, AASHTO M328, 56, 57) require the use of sensors with a vertical resolution of 0.05 mm or greater.**

- **vertical resolution specifications previously published by Pavemetrics for the LCMS were *not* based on comparable test methods adopted by other line lasers (RoLine, Gocator) currently accepted in the industry.**

- **However, LCMS sensors do indeed meet the 0.05 mm requirement when vertical measurements are made with comparable tests.**

Gocator model 2342A-3B-12 Resolution and Test Method

Gocator 2300 Series

The Gocator 2300 series consists of the sensor models defined below.

MODEL	2320	2330	2340	2350	2370	2375	2380
Data Points / Profile	1280	1280	1280	1280	1280	1280	1280
Linearity Z (+/- % of MR)	0.01	0.01	0.01	0.01	0.04	0.05	0.04
Resolution Z (mm)	0.0018 - 0.0030	0.006 - 0.014	0.013 - 0.037	0.019 - 0.060	0.055 - 0.200	0.154-0.353	0.092- 0.488
Resolution X (mm) (Profile Data Interval)	0.014 - 0.021	0.044 - 0.075	0.095 - 0.170	0.150 - 0.300	0.275 - 0.550	0.27 - 0.80	0.375 - 1.100
Repeatability Z (µm)	0.4	0.8	1.2	2	8	N/A	12
Clearance Distance (CD) (mm)	40	90	190	300	400	650	350
Measurement Range (MR) (mm)	25	80	210	400	500	1350	800
Field of View (FOV) (mm)	18 - 26	47 - 85	96 - 194	158 - 365	308 - 687	345 - 1028	390 - 1260
Recommended Laser Class	2M	2M	3R	3R	3B	3B-N	3B
Other Laser Classes	3R	3R, 3B	3B	3B			
Dimensions (mm)	35x120x149.5	49x75x142	49x75x197	49x75x272	49x75x272	49x75x272	49x75x272
Weight (kg)	0.8	0.74	0.94	1.3	1.3	1.3	1.3

Optical models, laser classes, and packages can be customized. Contact LMI for more details.

Specifications stated are based on standard laser classes. Linearity Z, Resolution Z, and Repeatability Z may vary for other laser classes.

All specification measurements are performed on LMI's standard calibration target (a diffuse, painted white surface).

Linearity Z is the worst case difference in average height measured, compared to the actual position over the measurement range.

Resolution Z is the maximum variability of height measurements across multiple frames, with 95% confidence.

Resolution X is the distance between data points along the laser line.

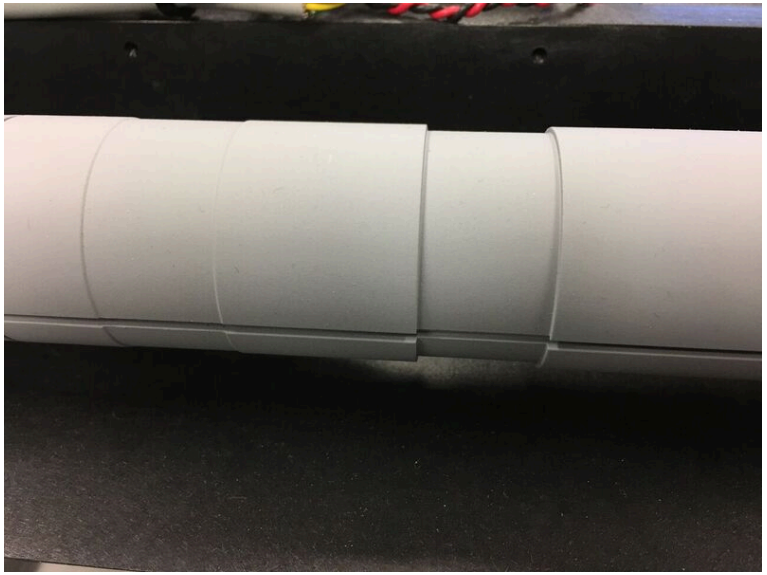
Repeatability Z is measured with a flat target at the middle of the measurement range. It is the 95% confidence variation of the average height over 4096 frames. Height values are averaged over the full FOV.

LMI Gocator 2300 & 2880 Series User Manual, Document revision: D

- **The vertical resolution (Z) of the Gocator is reported as 0.013 – 0.037 mm**
- **Selcom's test to determine resolution involves multiple scans of an object with a diffuse, painted white surface (a calibration target)**
- **Resolution is defined as the "maximum variability of height measurements across multiple frames, with a 95% confidence"**

LCMS Resolution Evaluation Procedure 1/3

- **The objective of the Pavemetrics' test was to likewise establish resolution by determining the "maximum variability of height measurements across multiple frames, with a 95% confidence"**
- **The first step in the evaluation was to create a similar calibration target**
- **The Pavemetrics-developed target is a precision-machined cylinder with a diffuse, painted surface**



Close-up View of Pavemetrics' Calibration Target

LCMS Resolution Evaluation Procedure 2/3

- **A computer-controlled, high-accuracy, translation table was then used to control the position of the calibration target/object in relation to the LCMS**
- **The LCMS is setup to scan within its working range and is initialized for scanning the target**
- **While the LCMS was scanning, the translation table was used to move the target away from the sensor at a step distance of 0.05 mm**
- **This movement produced a change in vertical distance (of 0.05 mm) which the LCMS was used to measure**

Computer-controlled Translation Table

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LCMS Resolution Evaluation Procedure 3/3

- **The cylinder was put into rotation in order to simulate the motion of a vehicle.**
- **LCMS height/distance measurements were made across multiple frames with outputs at 1 inch intervals with the LCMS.**
- **Likewise, the variability of height measurements made across multiple frames was then analyzed**
- **The analysis established the maximum variability of height measurements made by the LCMS across multiple frames to be 0.012-0.042 mm at a confidence level of 95%**

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LCMS-2 – Crack detection

- **Same road sections were scanned with both the LCMS 1 and LCMS 2**
- **LCMS 1 scans were at the standard 5mm interval**
- **LCMS 2 scans were at 5mm, 2mm and 1mm for comparison purposes**

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Example 1 – 5mm *LCMS 1*

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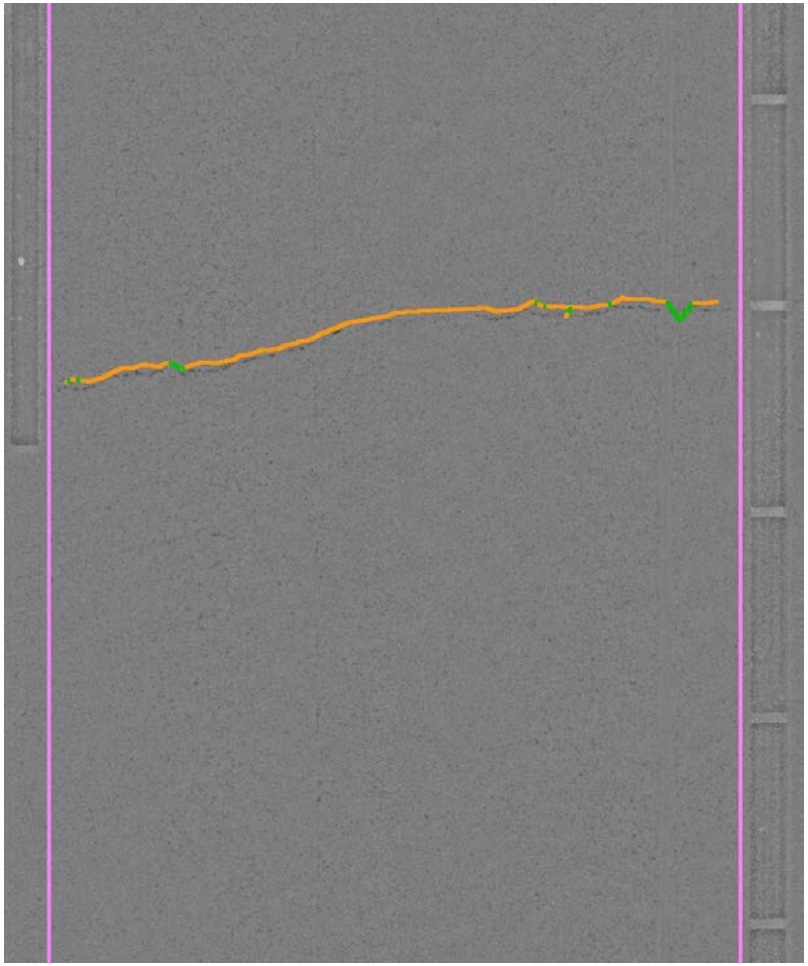
Example 1 – 5mm *LCMS 2*



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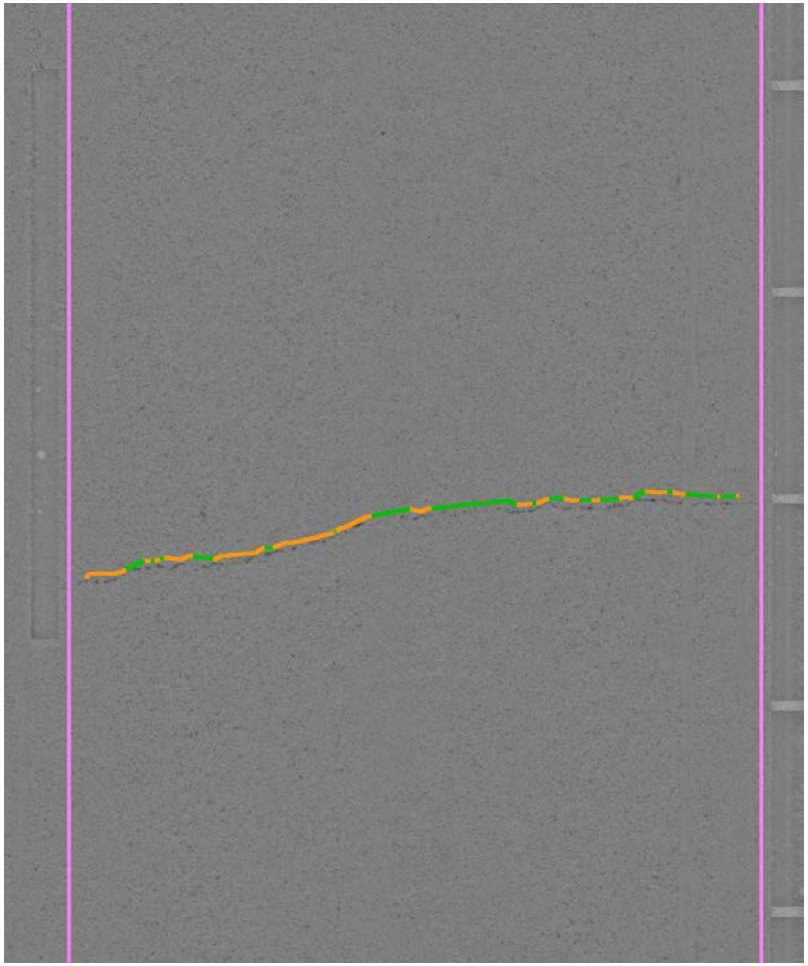
Example 1 – 2mm *LCMS 2*



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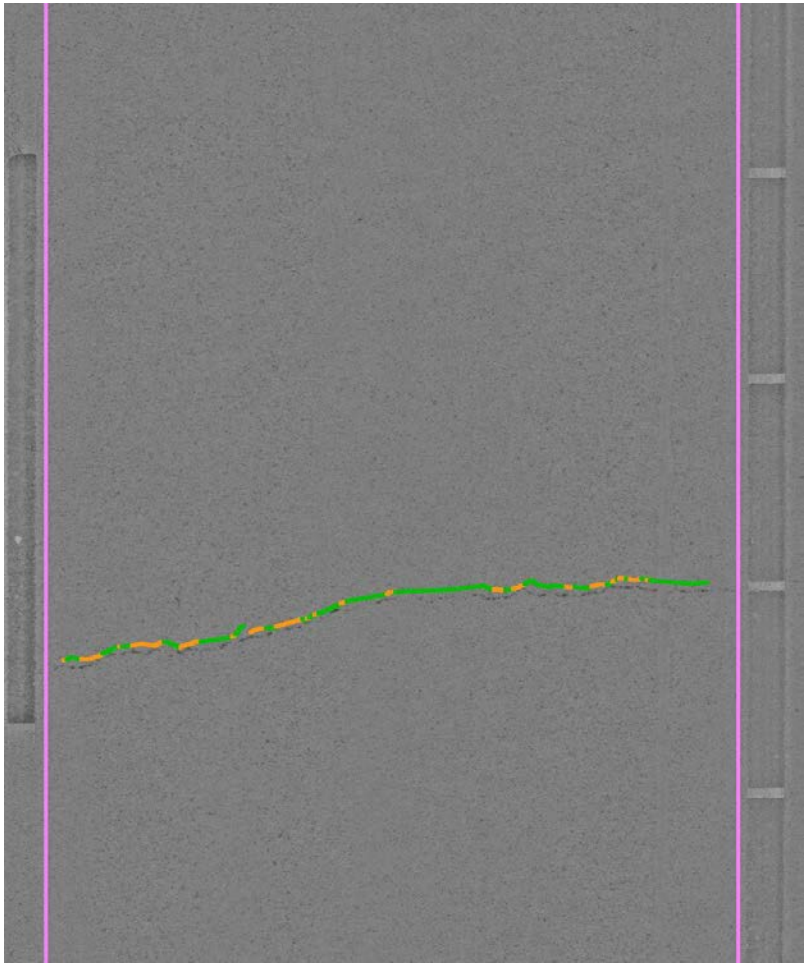
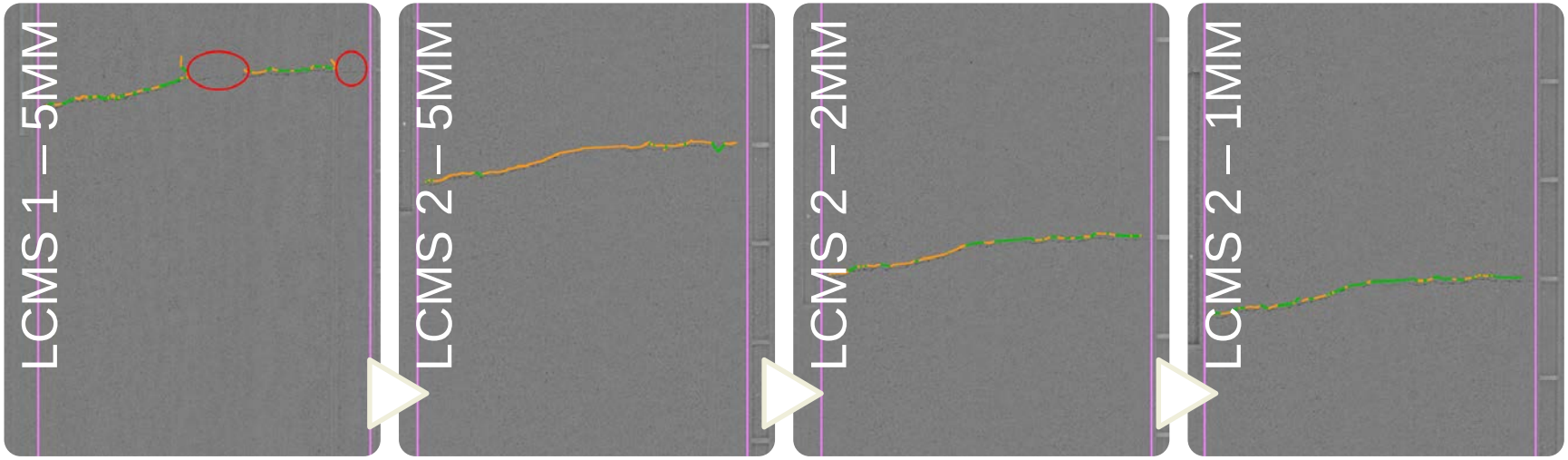
Example 1 – 1mm *LCMS 2*



Example 1 – All Configurations



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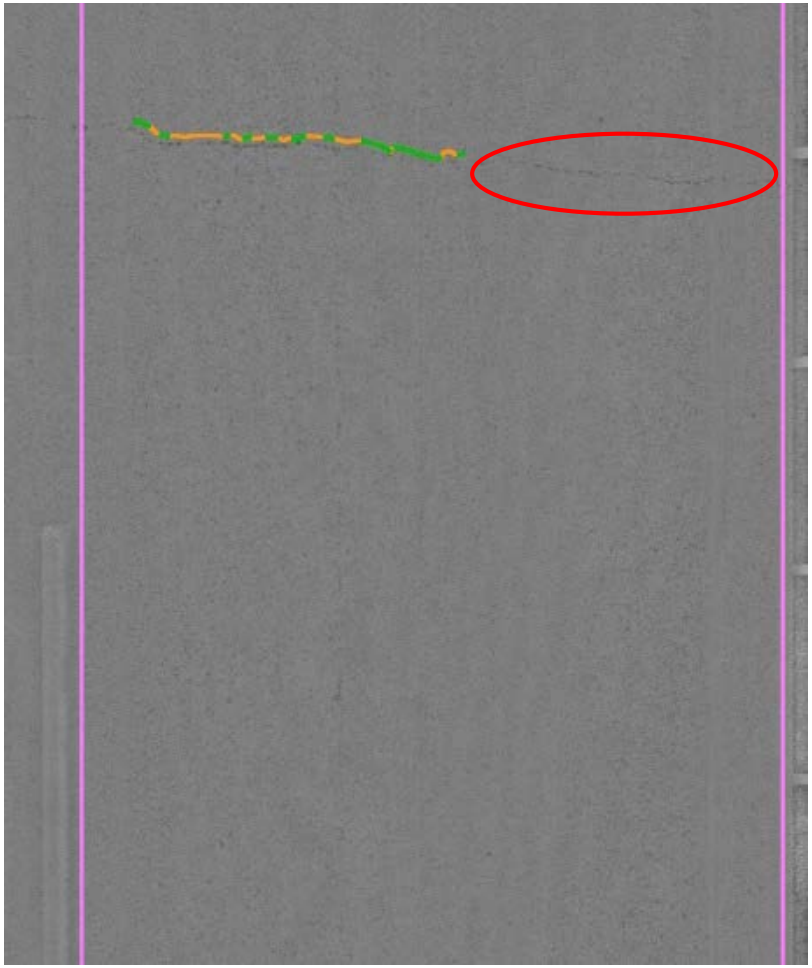
Example 2 – 5mm *LCMS 1*



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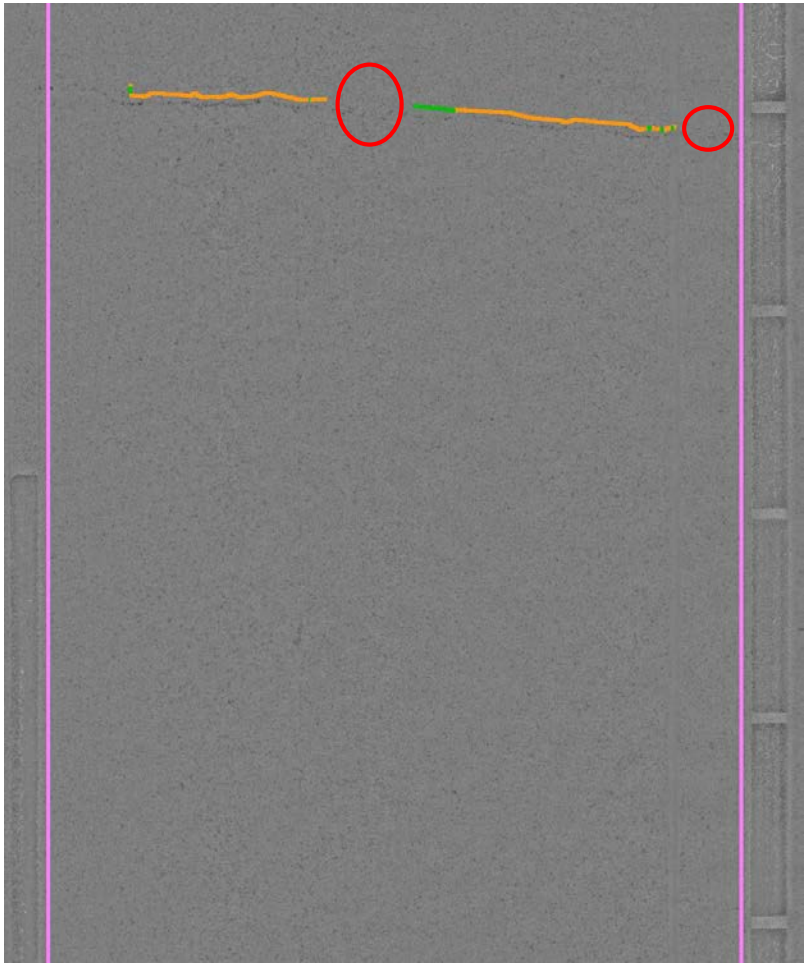
Example 2 – 5mm *LCMS 2*



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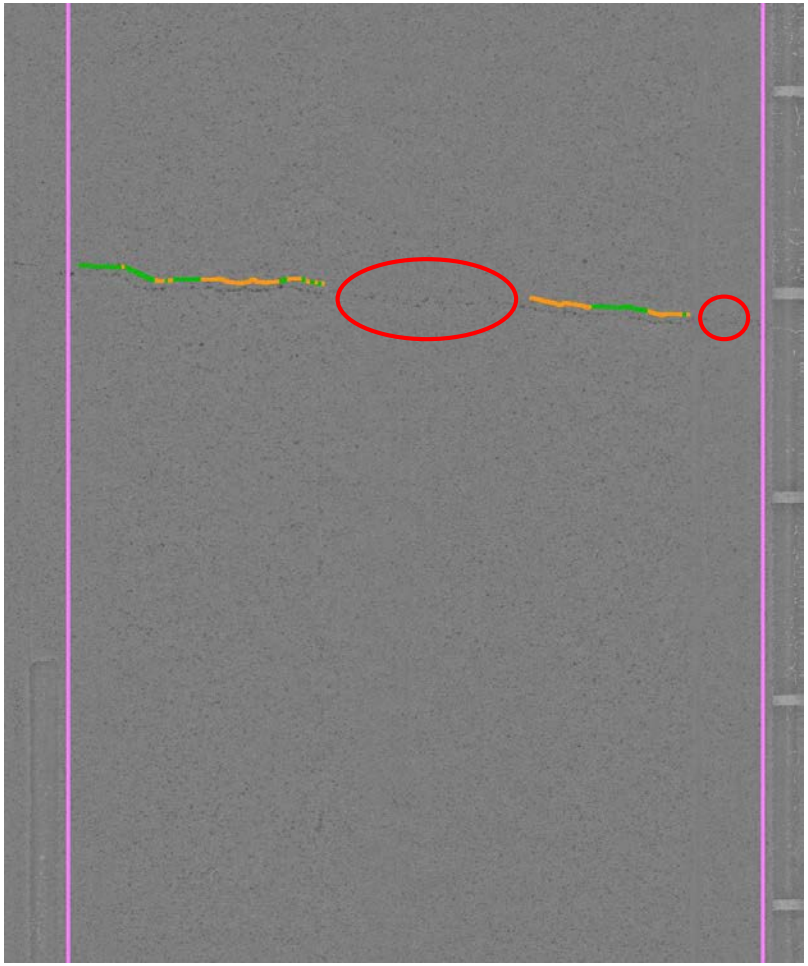
Example 2 – 2mm *LCMS 2*



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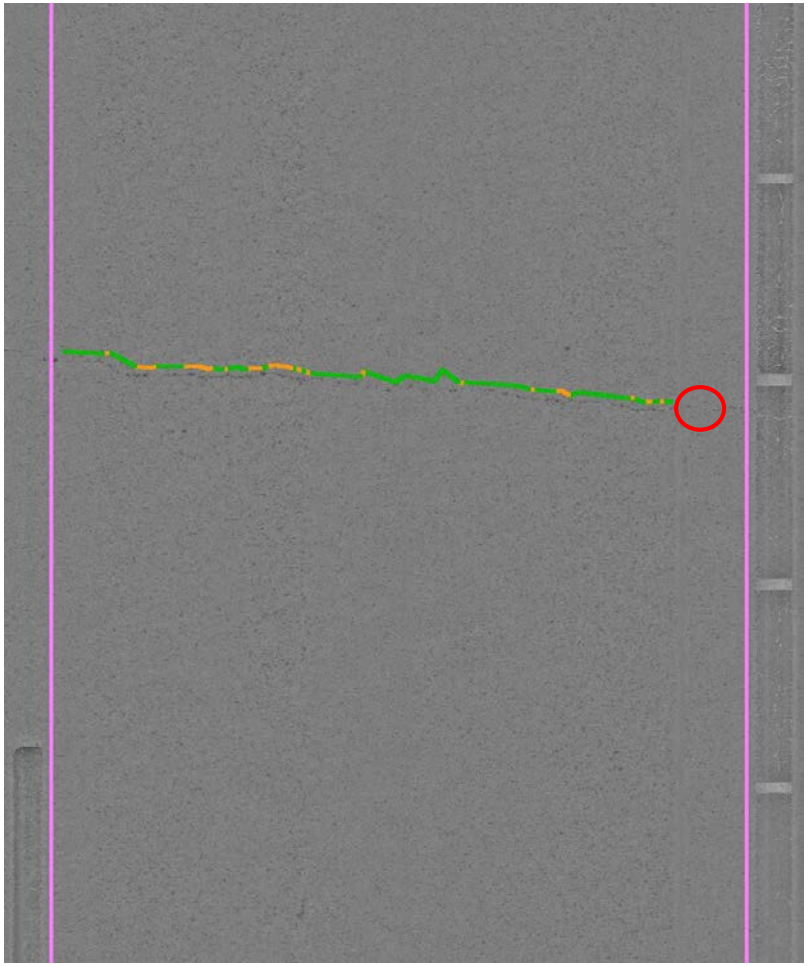
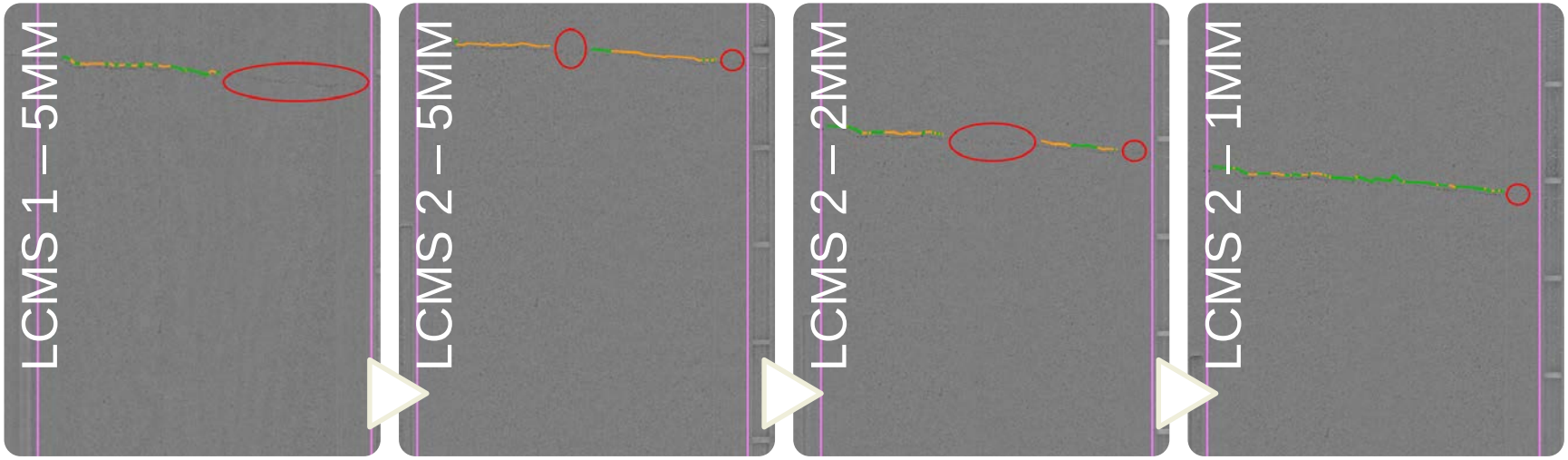
Example 2 – 1mm *LCMS 2*



Example 2 – All Configurations



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Example 3 – 5mm *LCMS 1*

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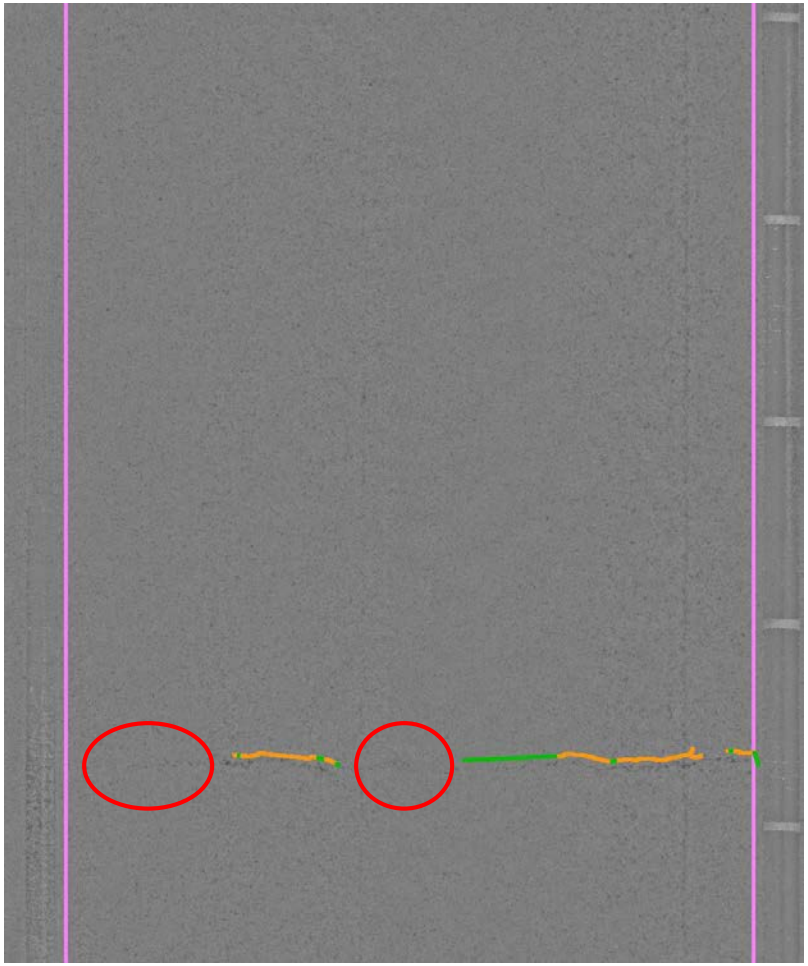
Example 3 – 5mm *LCMS 2*



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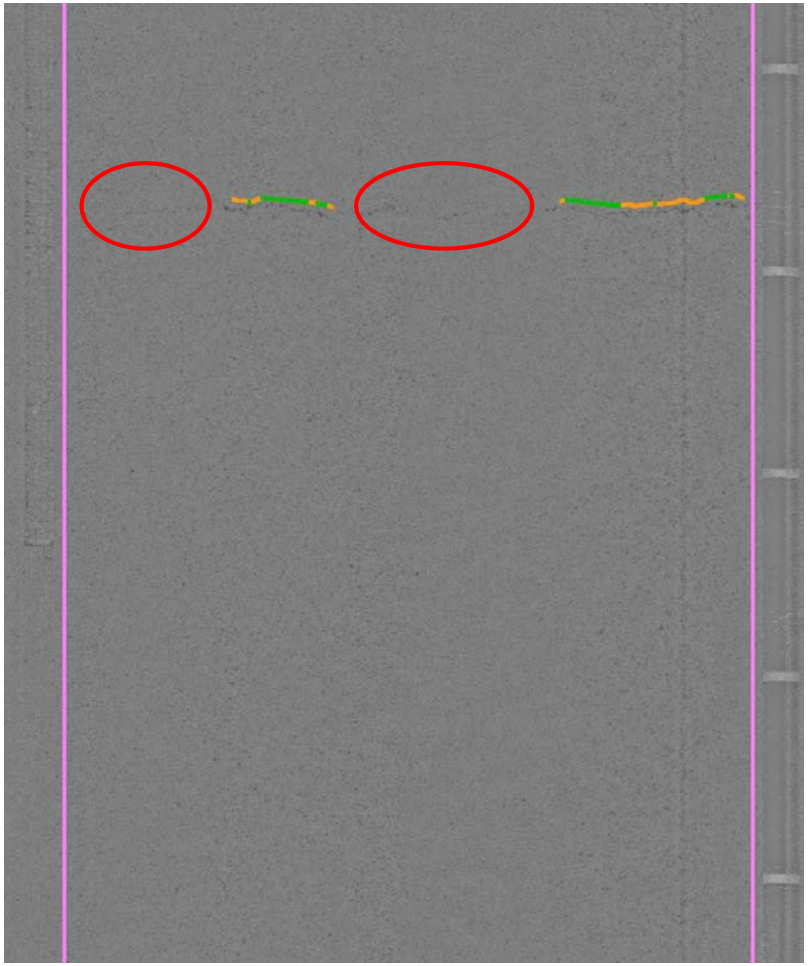
Example 3 – 2mm *LCMS 2*



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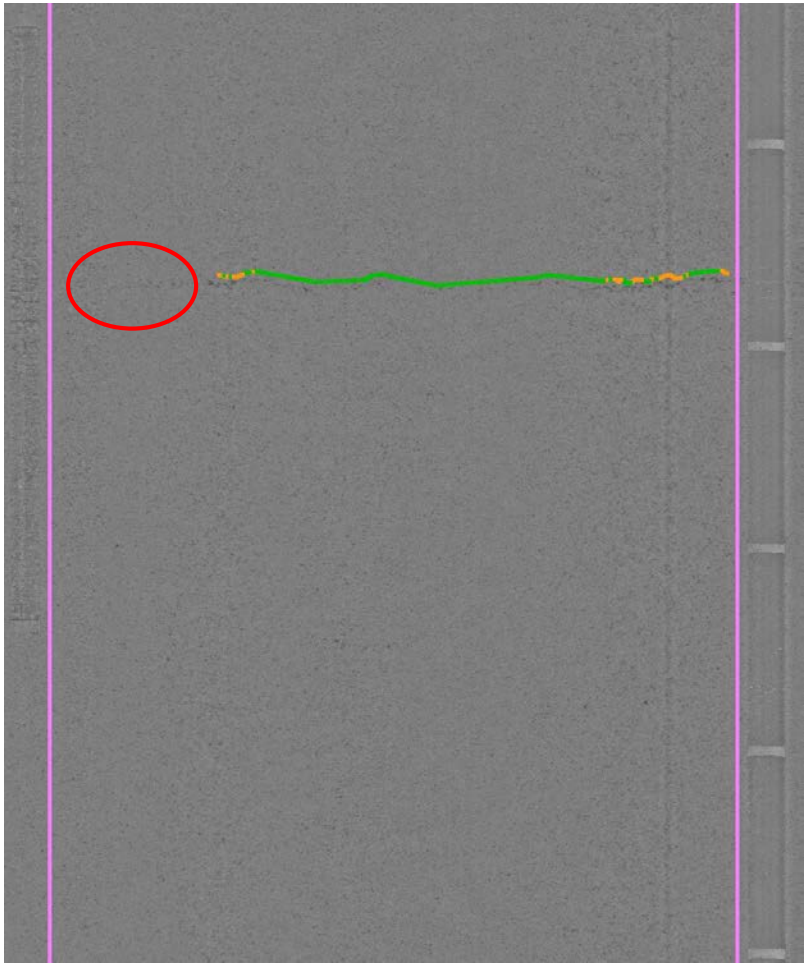
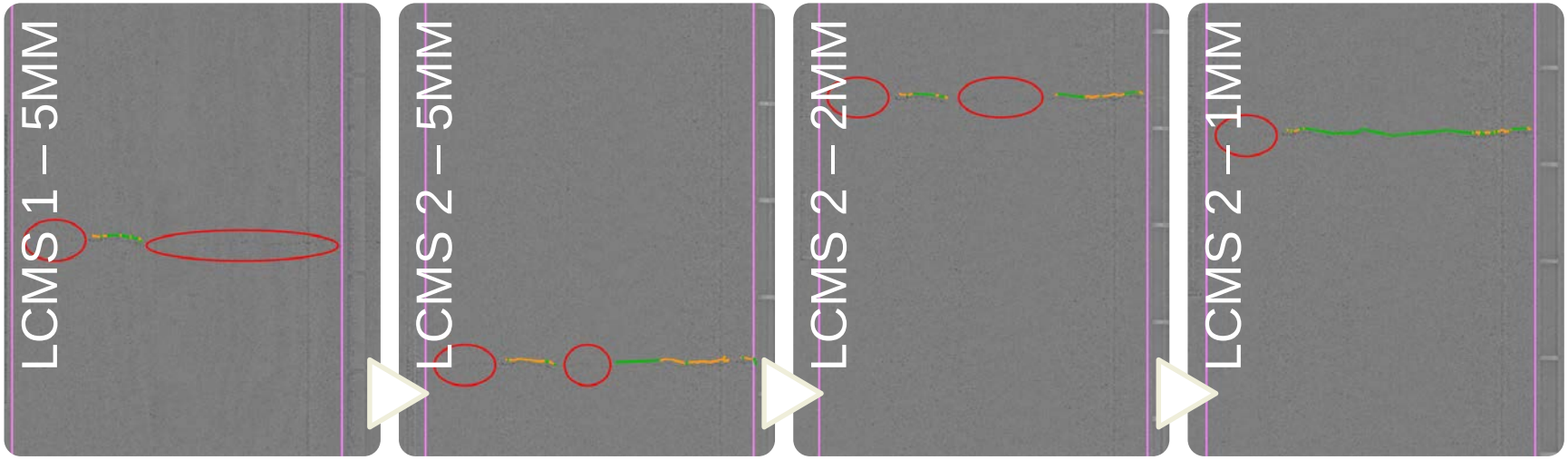
Example 3 – 1mm *LCMS 2*



Example 3 – All Configurations



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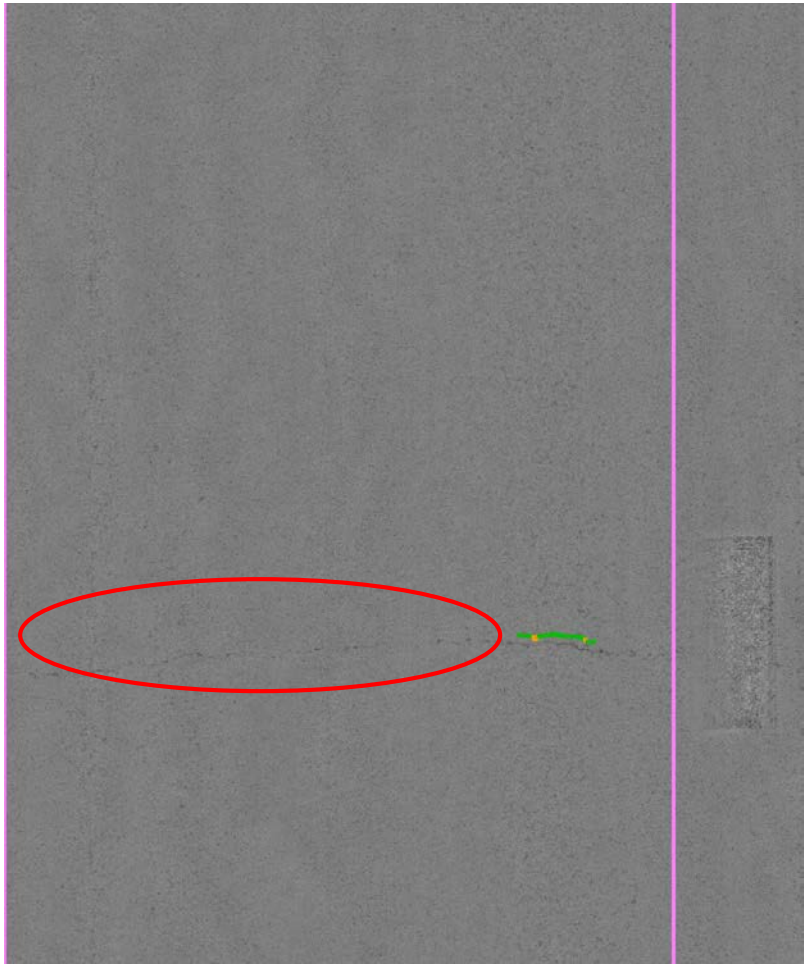
Example 4 – 5mm *LCMS 1*



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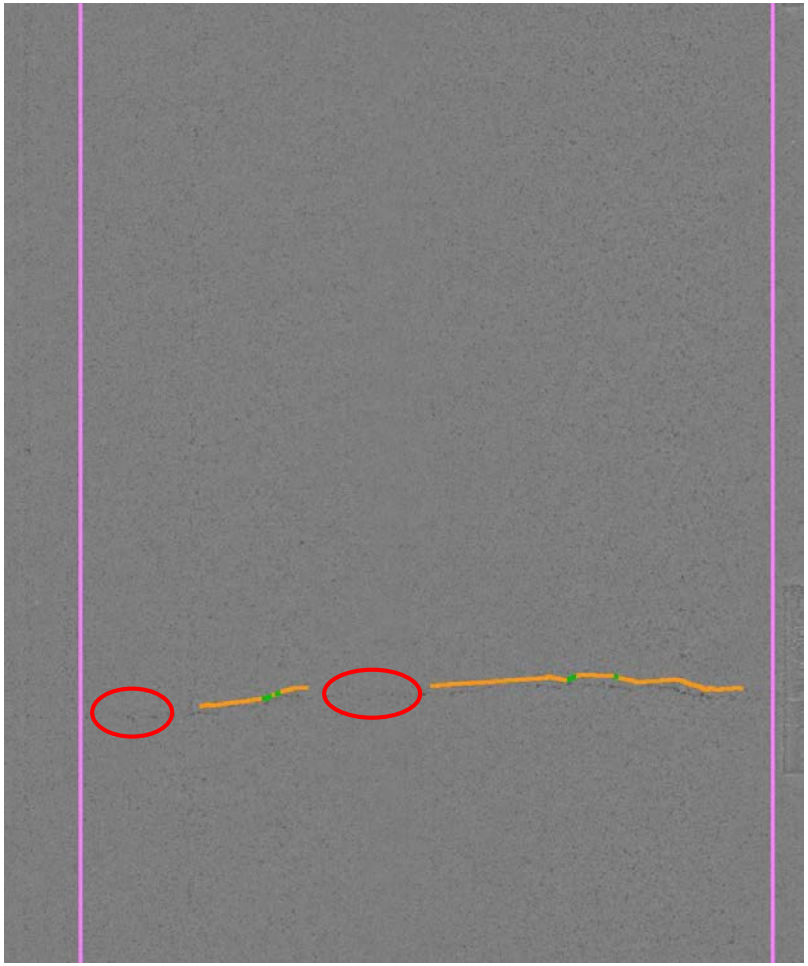
Example 4 – 5mm *LCMS 2*



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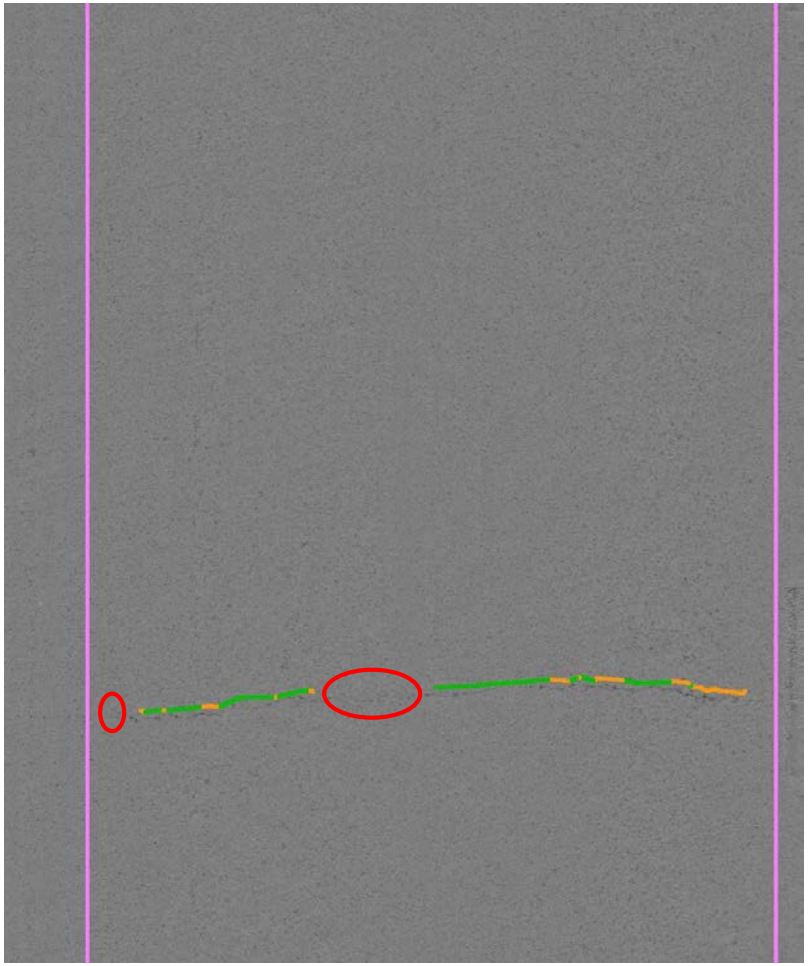
Example 4 – 2mm *LCMS 2*



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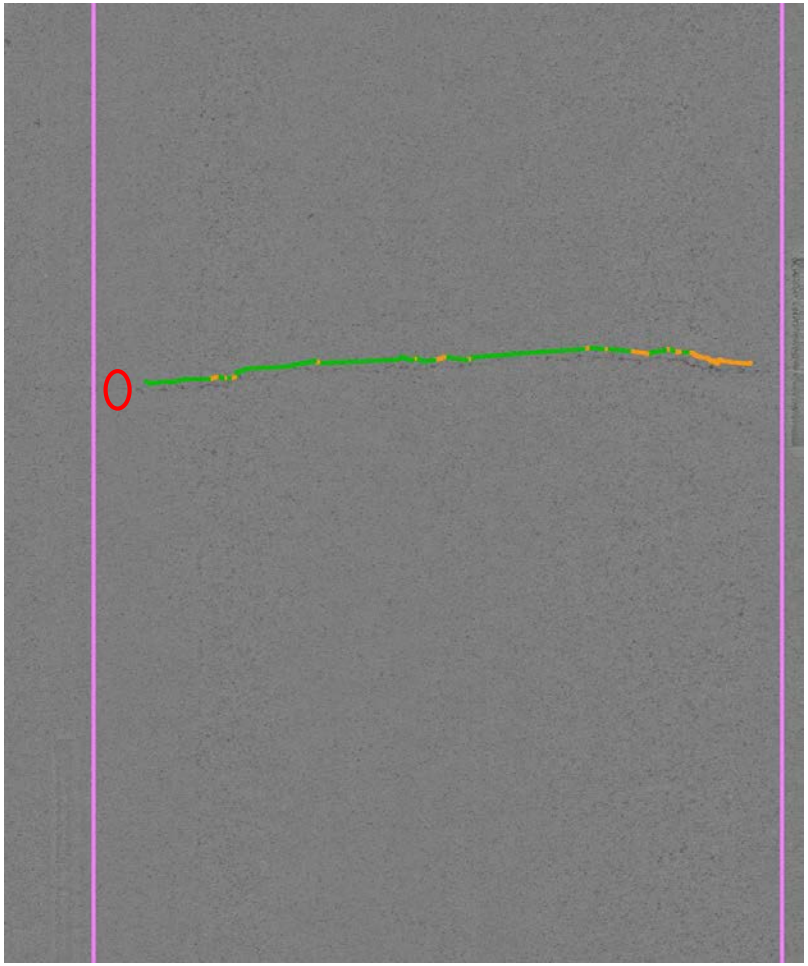
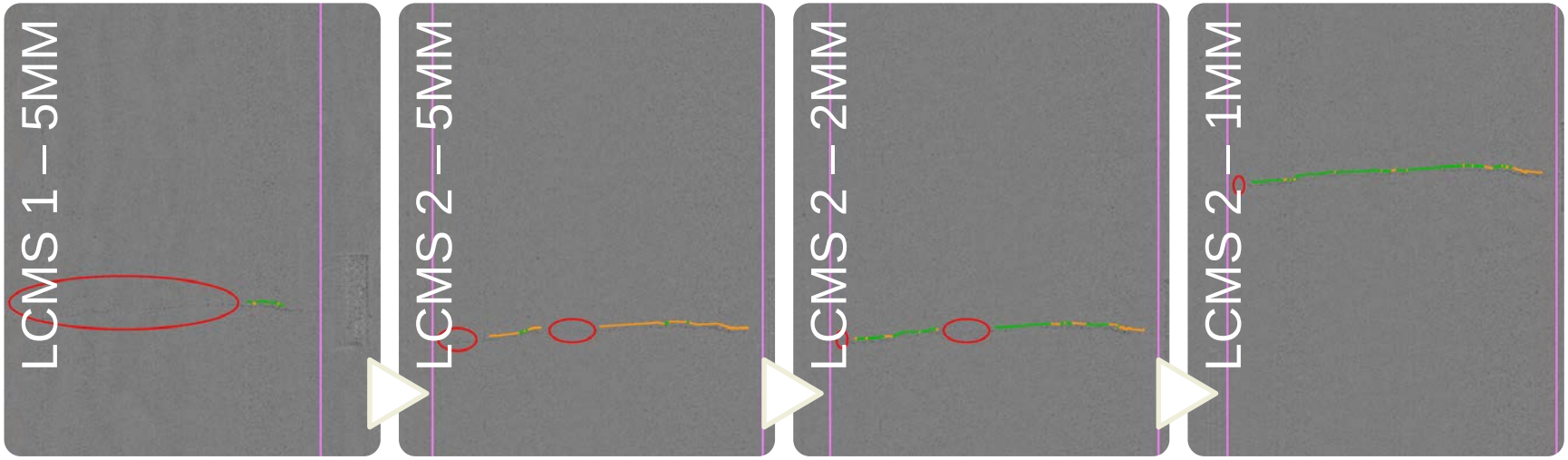
Example 4 – 1mm *LCMS 2*



Example 4 – All Configurations



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LCMS-2 – Crack detection

- **The LCMS 2 provides more complete crack detection and is more sensitive to finer cracks**
- **Improvements are apparent even if you operate an LCMS 2 using a 5mm collection interval**
- **However 2mm and 1mm intervals will further improve results**

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Storage needs

Specifications	LCMS-2
Data rate per km	3Gb/km
10,000 mile network	*48Tb*
16 units x 50$	*$800*

HGST Ultrastar 7K3000 HUA723030ALA640 (0F12456) 3TB 7200RPM 64MB Cache SATA III 6.0Gb/s 3.5" Enterprise Hard Drive

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- Hard Disk Size: **3.0 TB**
- Hardware Interface: **sata 6 0 gb**
- Memory Storage Capacity: **64.0 MB**
- Form Factor: **3.5 Inches**
- Hardware Platform: **Mac**

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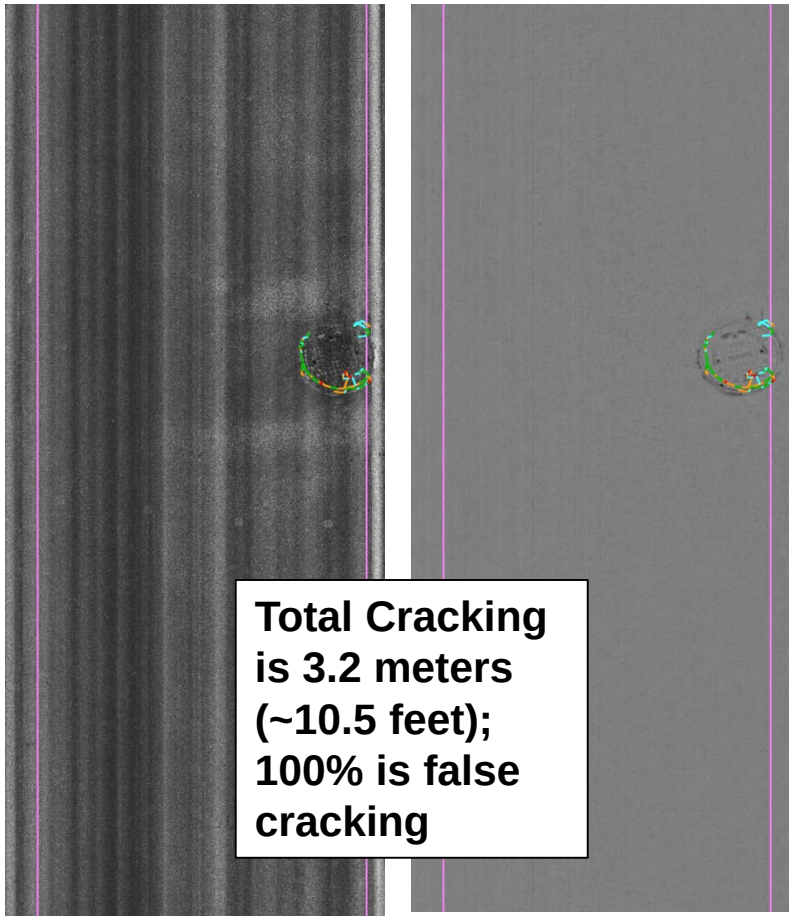
New Feature – Man made object detection

Open Manhole Cover

Closed Manhole Cover

Storm-drain

Problem (Example 1)



- **This pavement is in excellent shape; not a crack to be seen…**
- **However, there is a small break in the surface around the edge of the manhole cover**
- **This generates 3.2 m of false cracking**
- **100% of this cracking is false**

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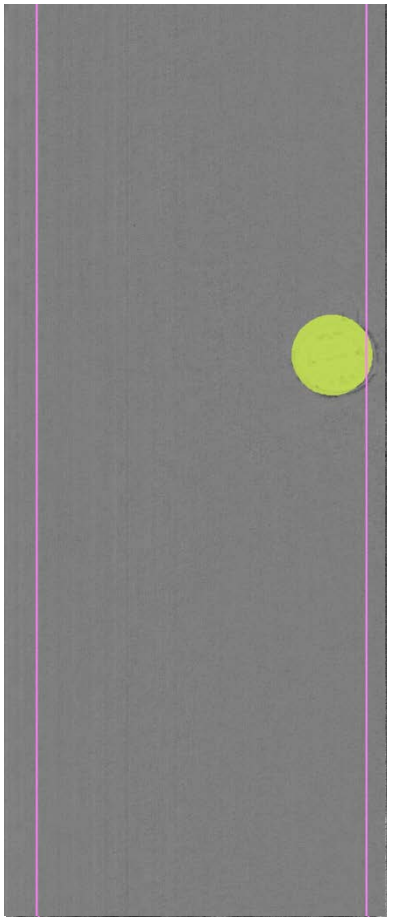
Solution

- **We deliberately detect the MMO first in order to exclude it from crack detection**
- **This also allows us to add value by inventorying it**
- **Now the cracking quantity here is 0 meters; which is correct**



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Data That Are Reported

- **Bounding box: the X, Y location of box which is drawn around the detected object (can relate back to GPS and milepoint)**
- **Area: the calculated area of the object**
- **Radius: only reported for manholes, radius of the manhole**
- **Width and Height: width and height of the drain or its bounding box**
- **Perimeter: list of points that form the perimeter of the object, useful for highlighting the object in images used for reporting**
- **Type: two types reported at present; closed manhole or storm-drain/open man-hole**

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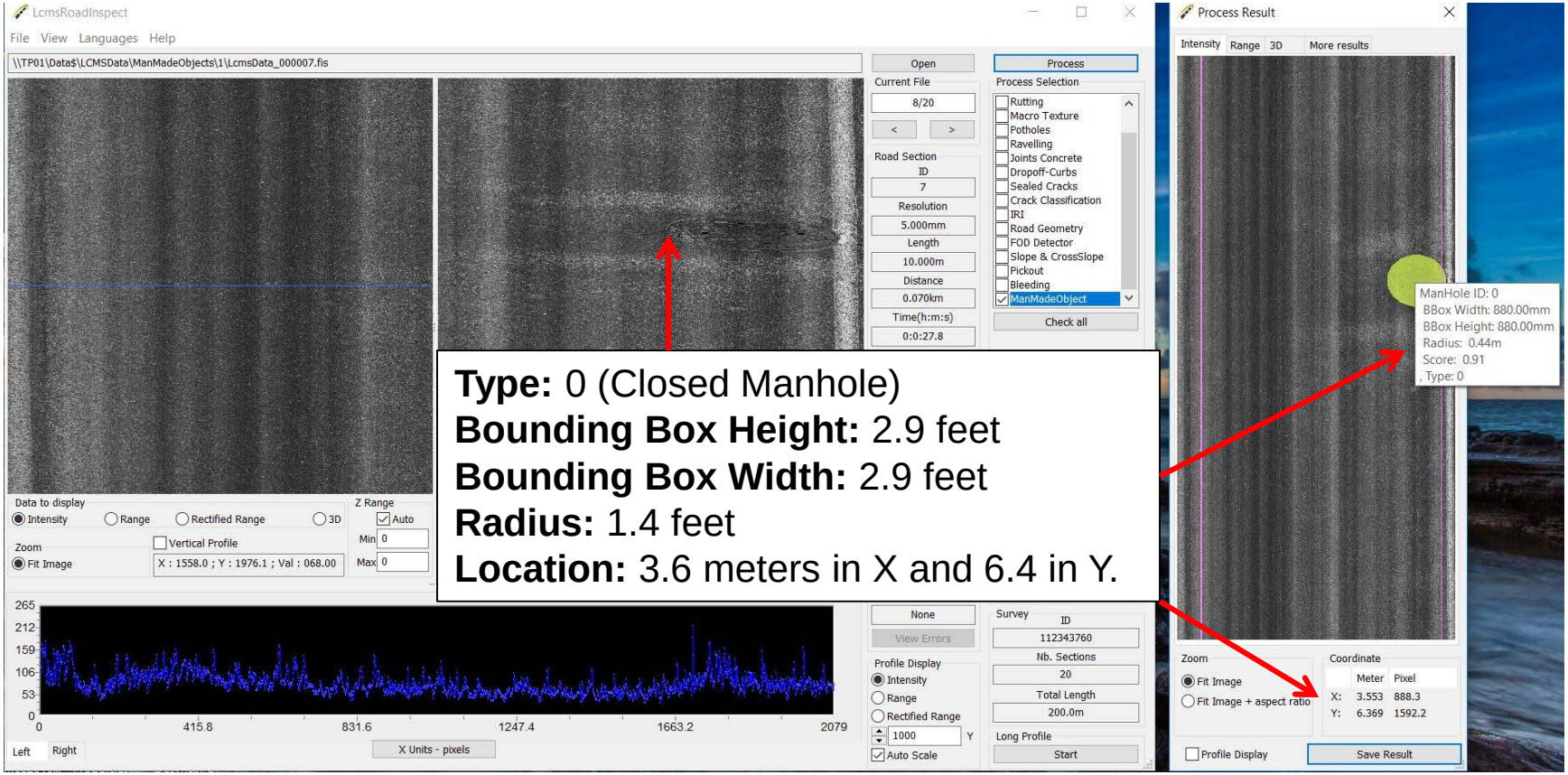
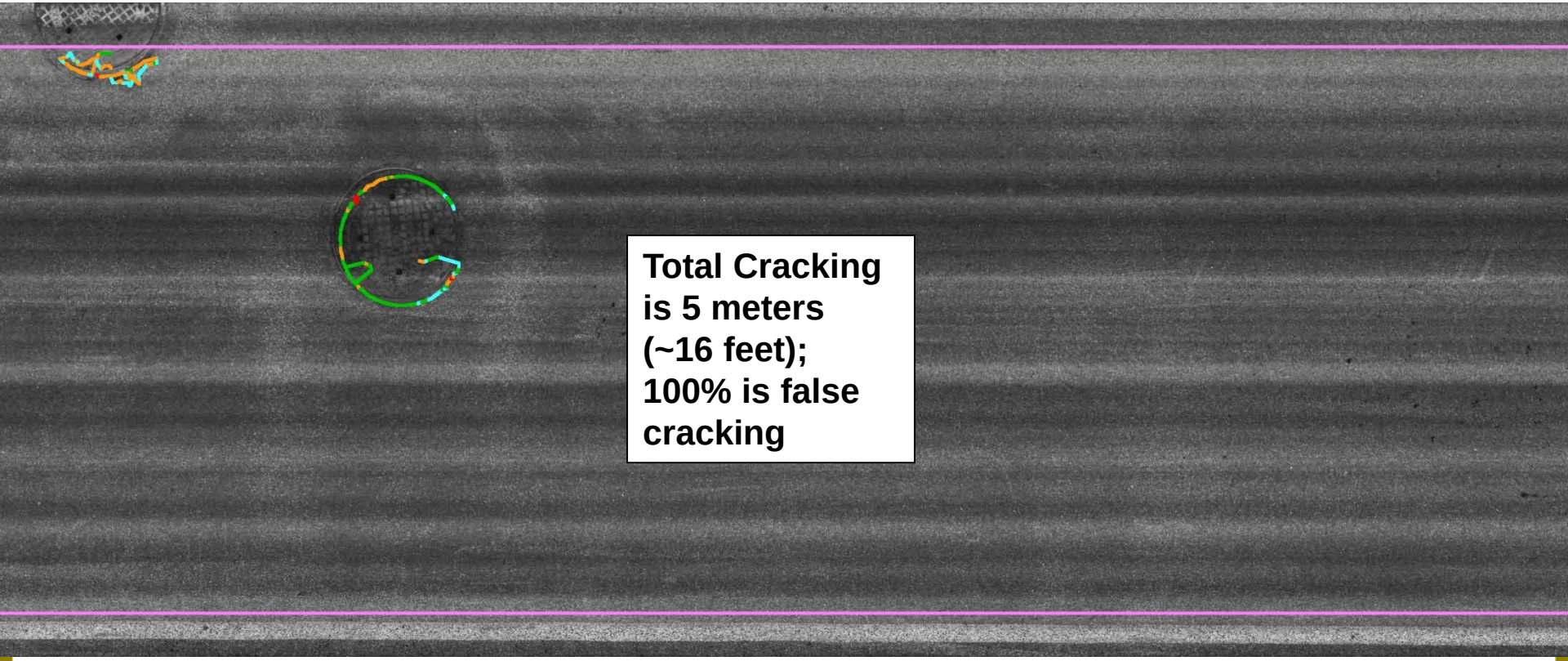
LCMSRoadInspect Interface



Type: 0 (Closed Manhole)
Bounding Box Height: 2.9 feet
Bounding Box Width: 2.9 feet
Radius: 1.4 feet
Location: 3.6 meters in X and 6.4 in Y.

Example 2: Without MMO Detection



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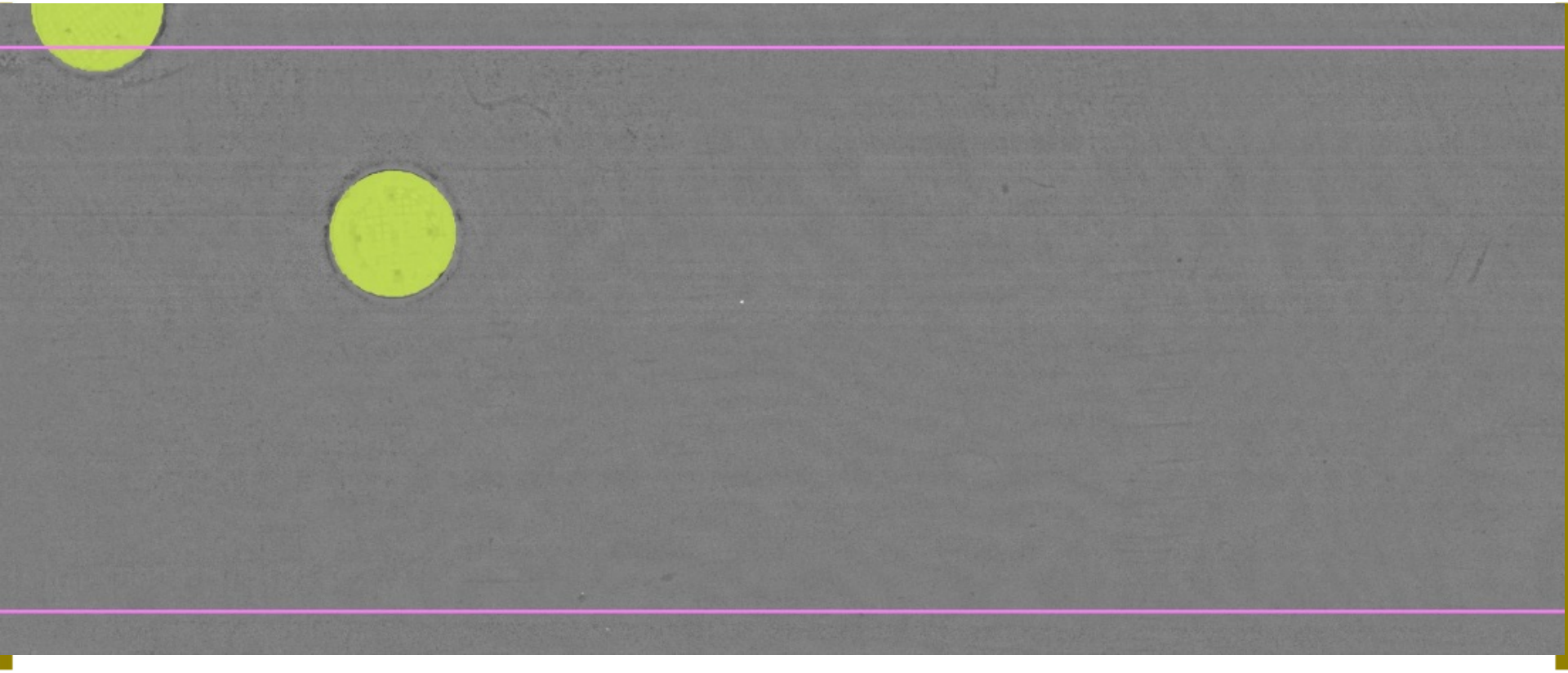
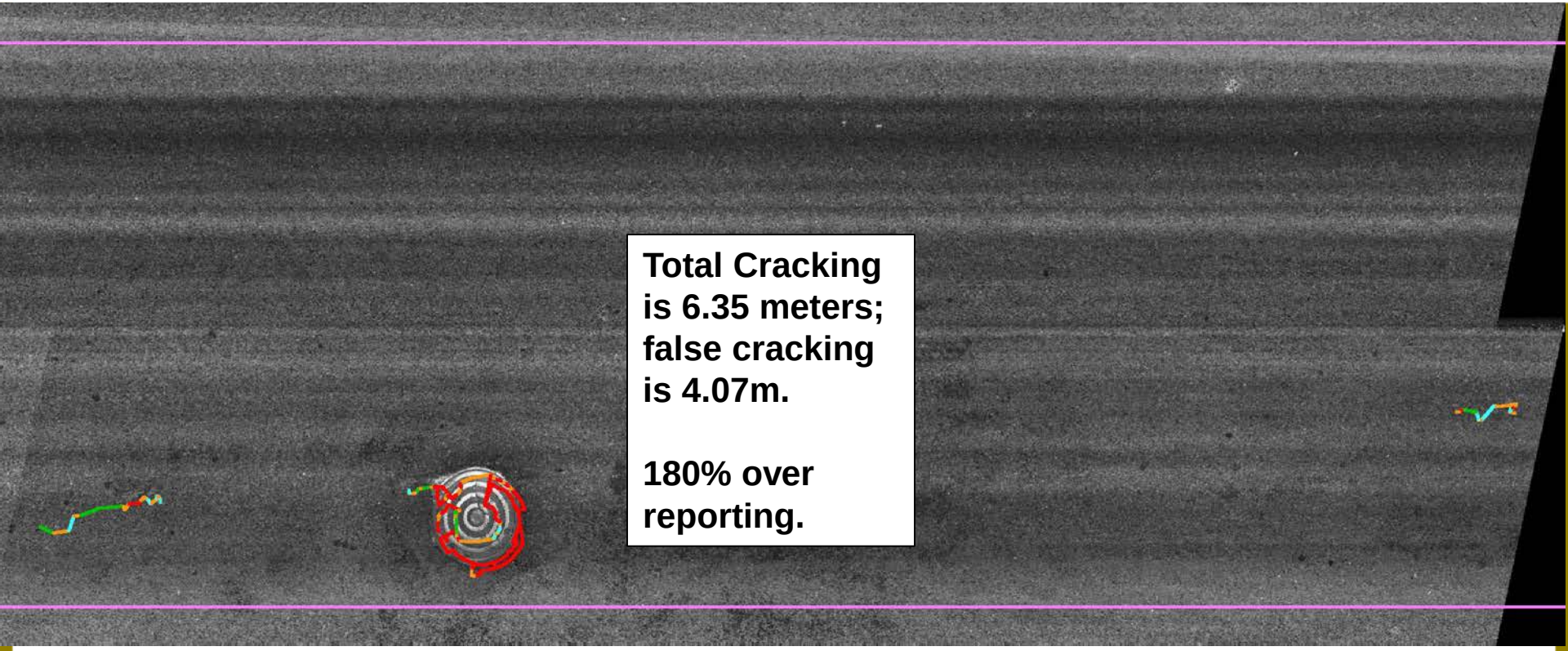


Example 3: Without MMO Detection



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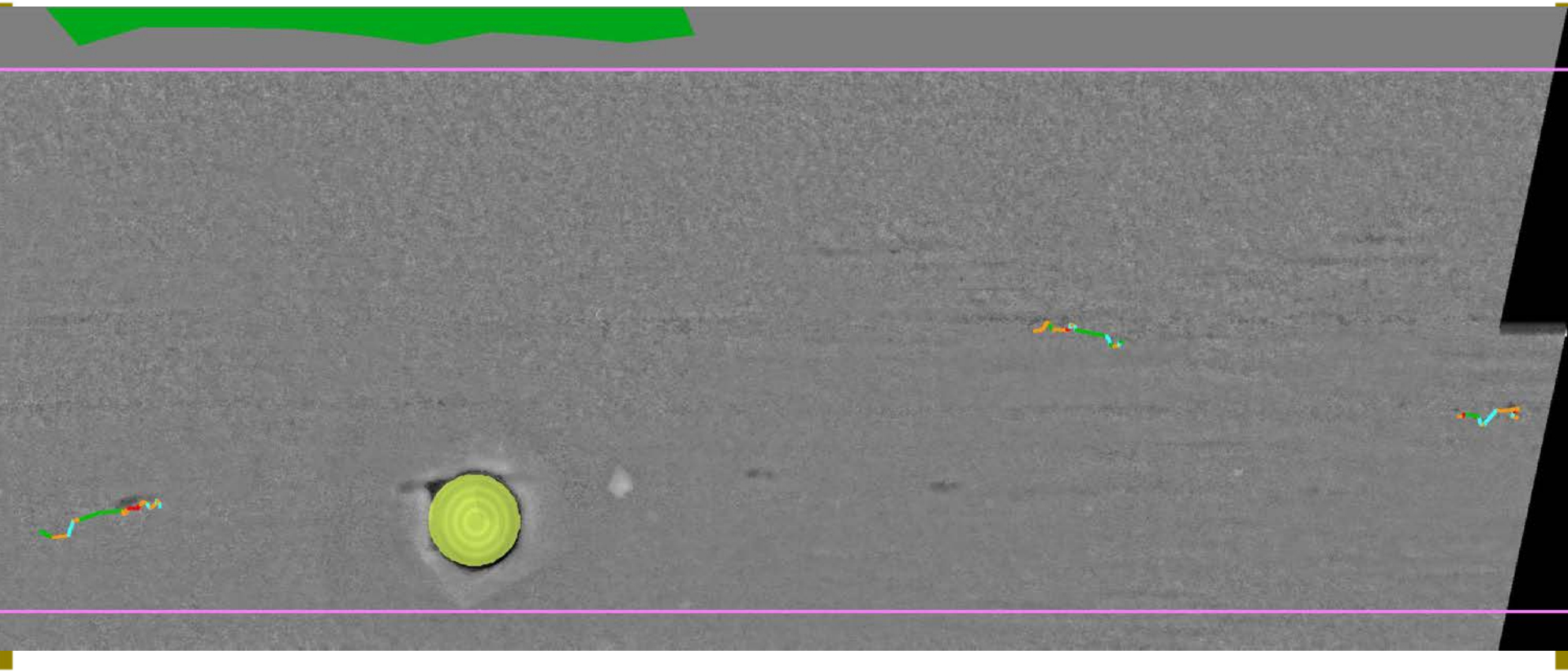
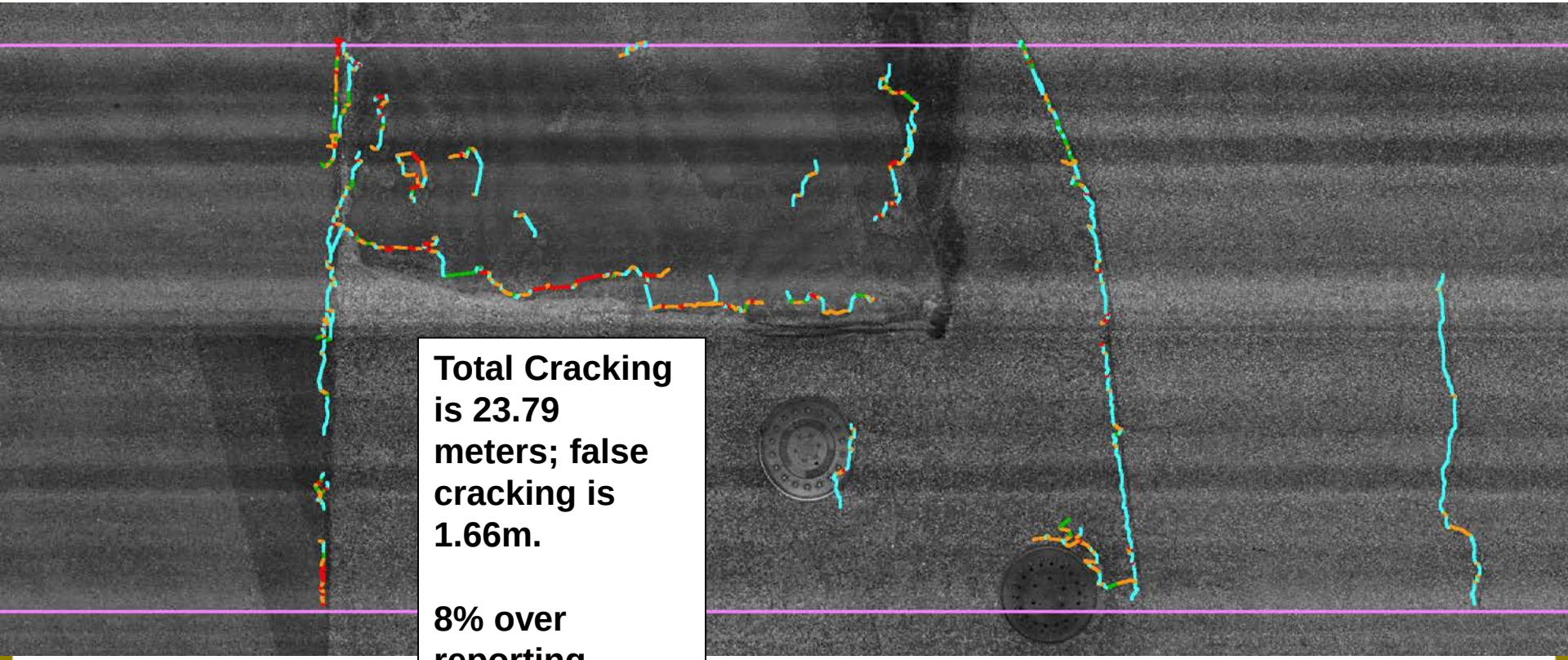
Example 3: With MMO Detection



Example 4: Without MMO Detection



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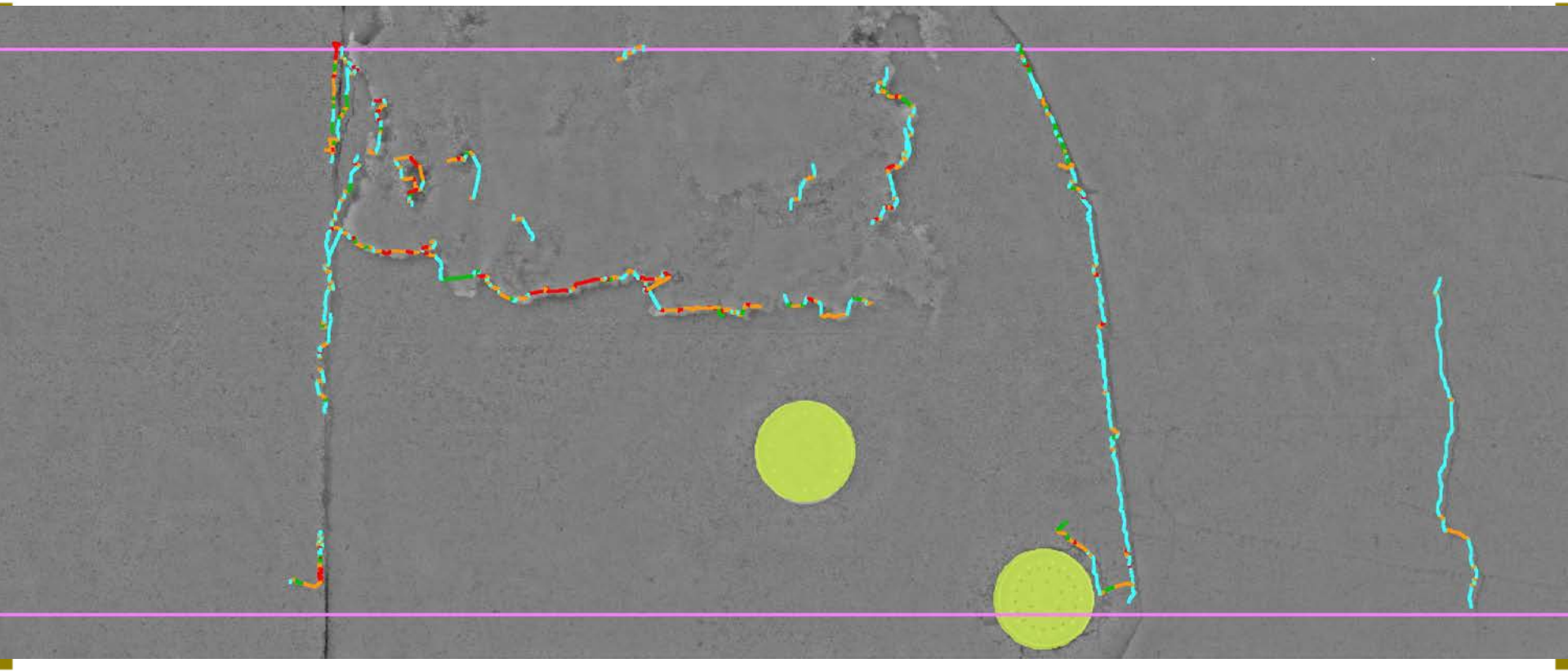
Example 4: With MMO Detection



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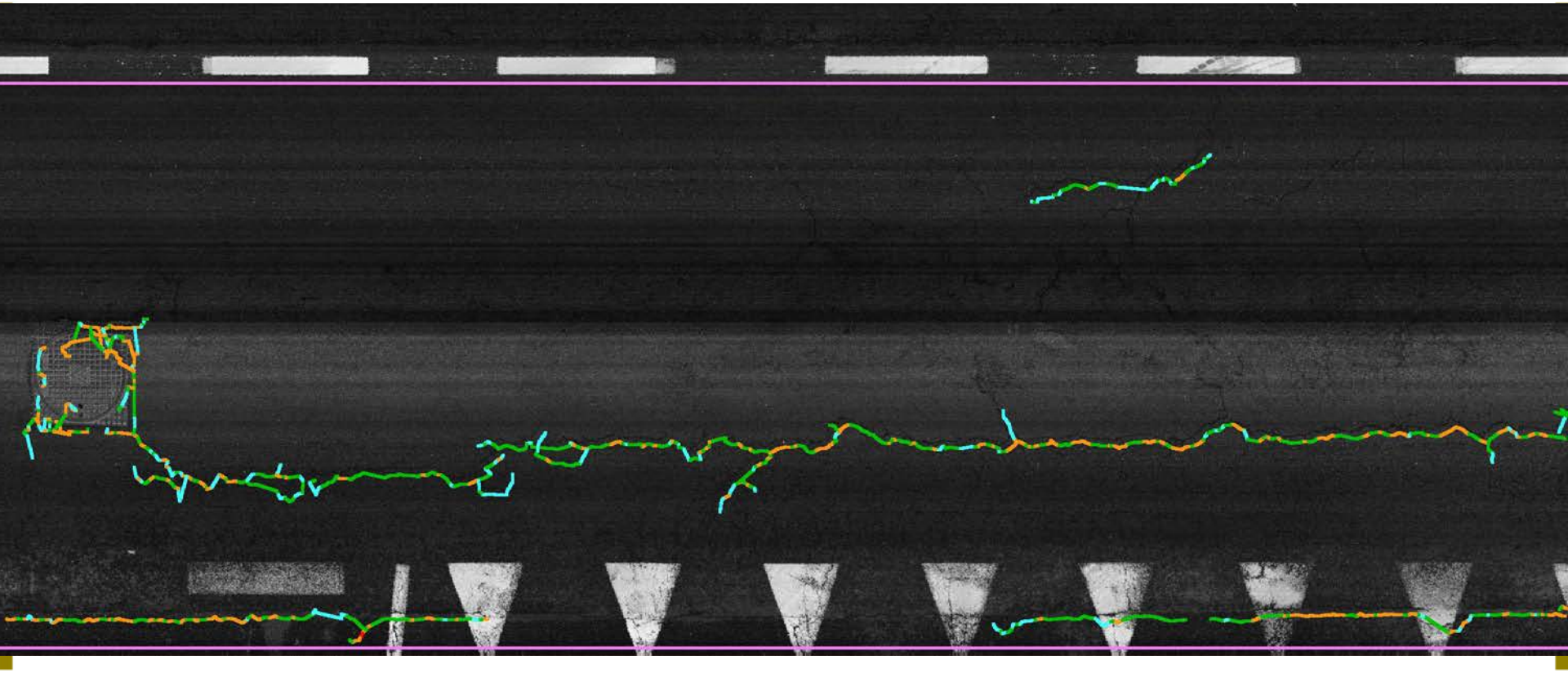
Example 5: Without MMO



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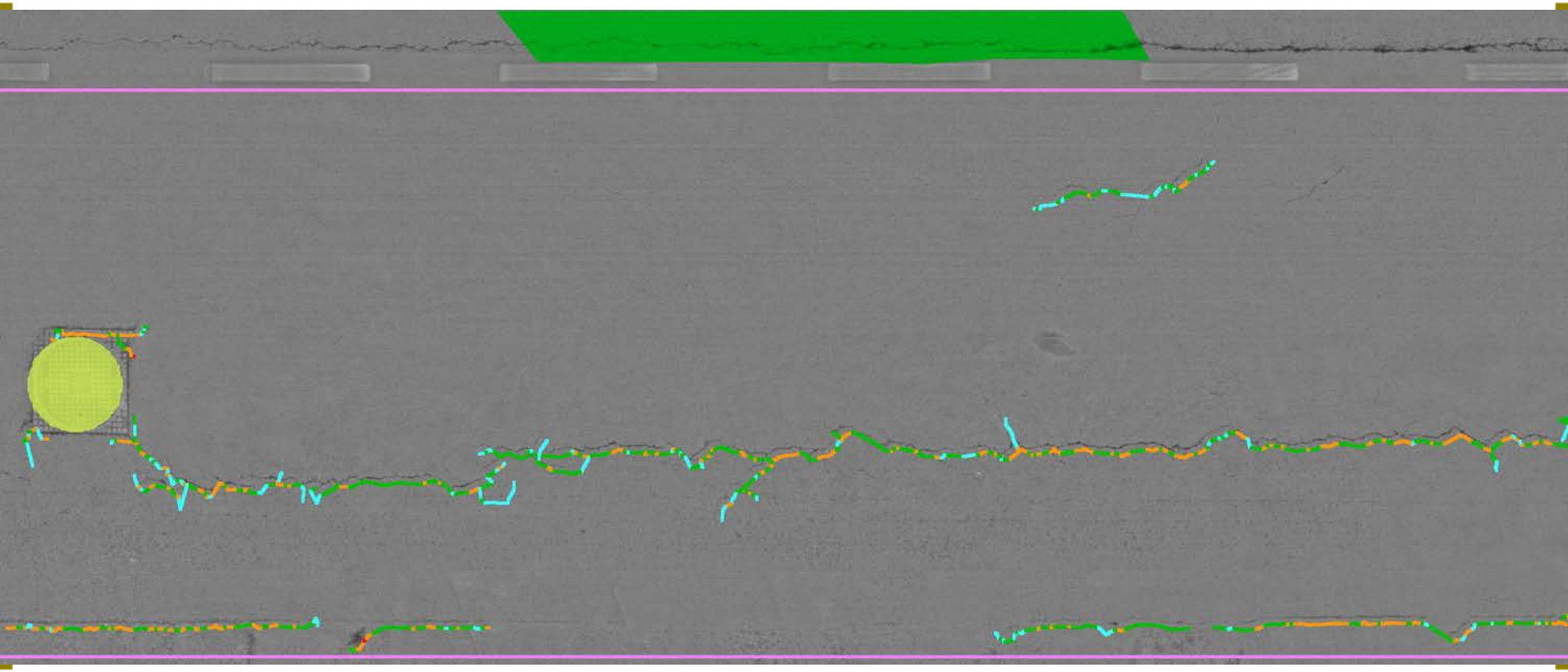
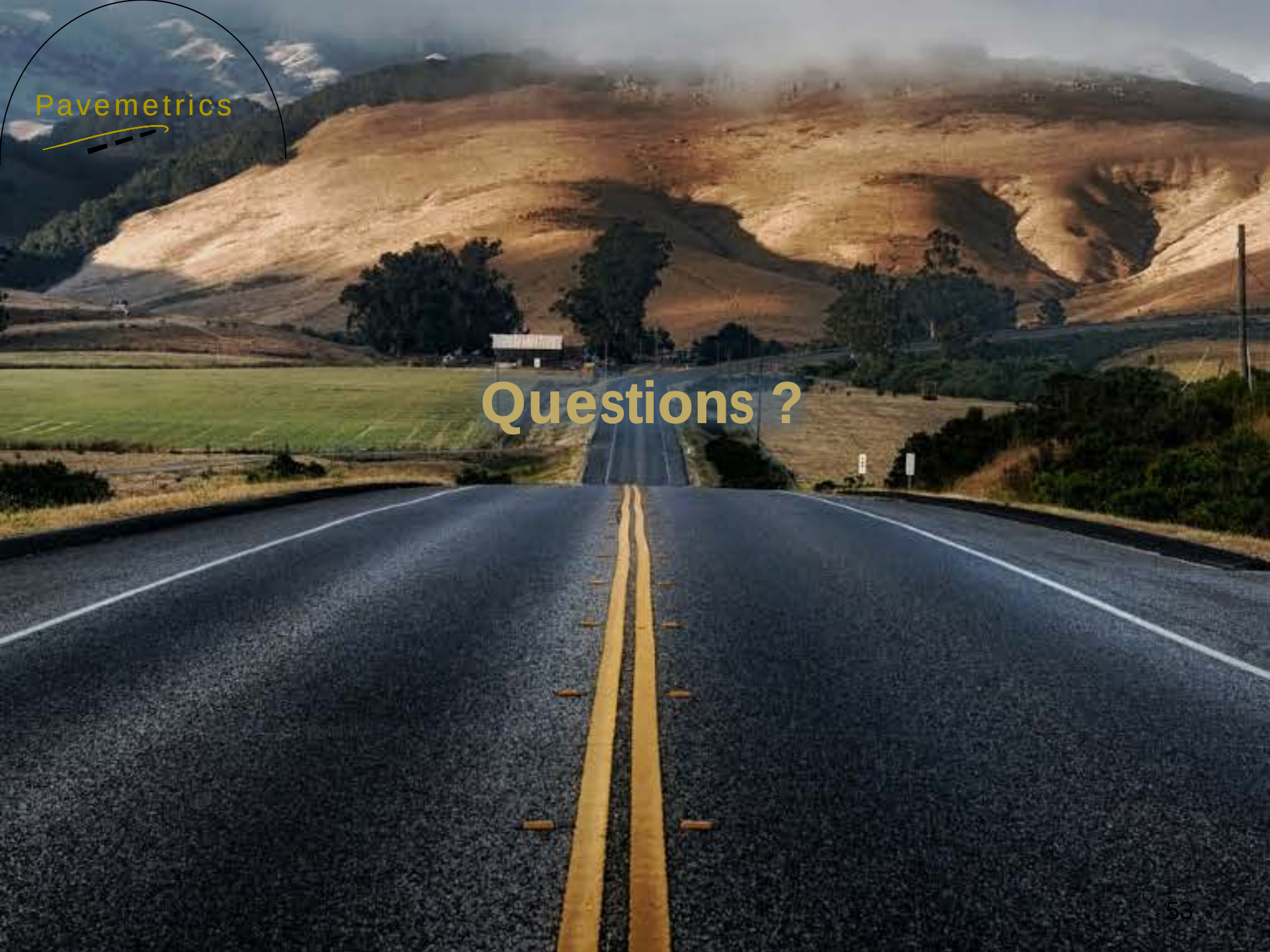
Example 5: With MMO Detection

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Questions ?