

The logo consists of a large white circle with a yellow border, resembling a magnifying glass. Inside the circle, the word "Pavemetrics" is written in yellow. Below the text is a stylized road crack, represented by a solid yellow line that curves and then becomes a dashed black line.

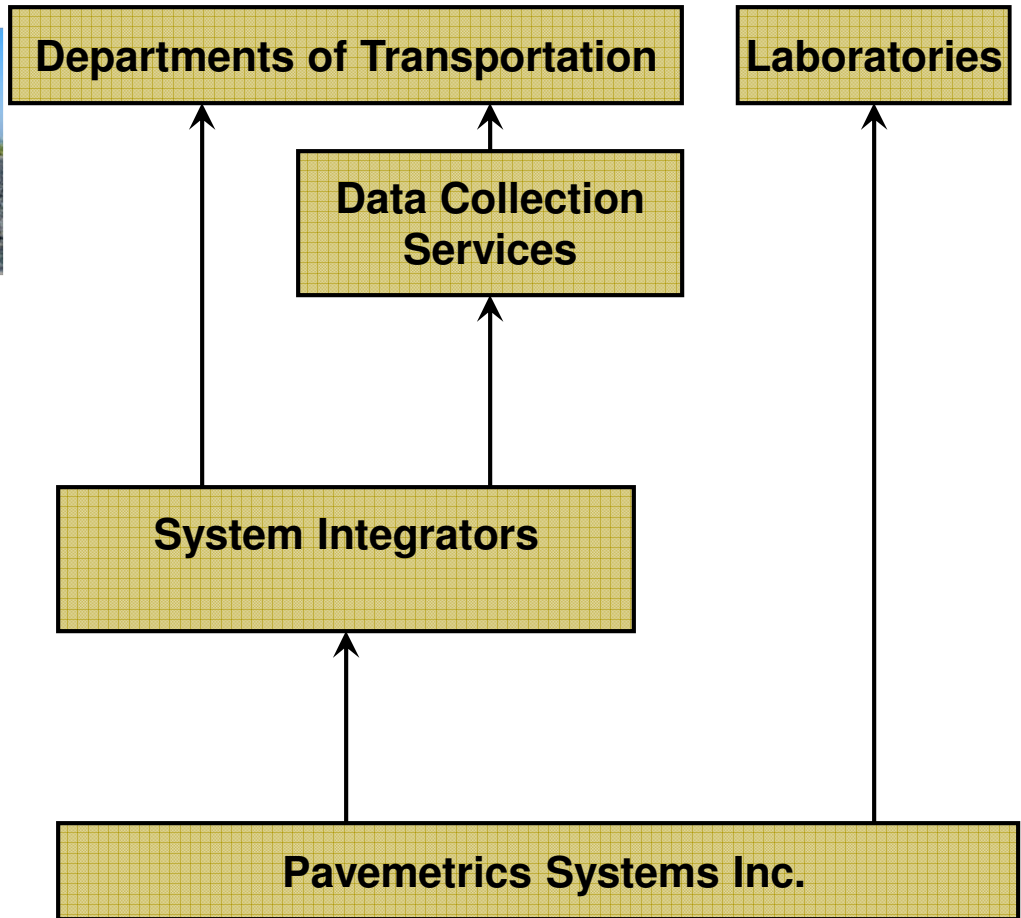
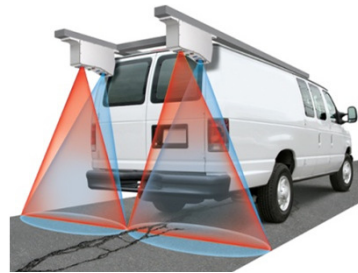
**Pavemetrics**

# **LCMS – Laser Crack Measurement System**

Vision Technology for Inspection of Transportation Infrastructures

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# Pavemetrics Systems Have Been Deployed World Wide



# TimeLine and sensors history

R&D project with the MTQ to develop a laser rutting system

Roadware is the first integrator to embrace the LRMS technology

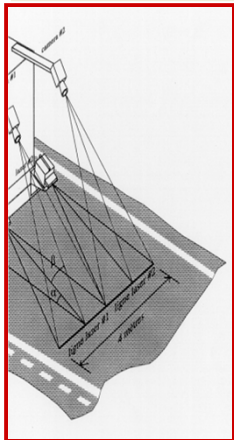
**A technological revolution:** a prototype of a 3D crack detection system is developed and tested on the road (**LCMS 140Hz**)

Acquisition rate of the **LCMS** is decupled to 1400Hz. Development of the algorithms.

The MTQ tests the **LCMS** 1400Hz on a survey level: 15 000 km of roads are collected.



1995...



MTQ operates the first LRSM. It collects 4m transverse profiles at 25Hz



2000



MTQ operates the first LRSM. It collects 4m transverse profiles at 25Hz

2002



2004



LRMS is now faster : High Speed version now captures 3D profiles at 150Hz

2006



2006



LRIS is introduced. 1mm road images with crack enhancement is now possible!

2008

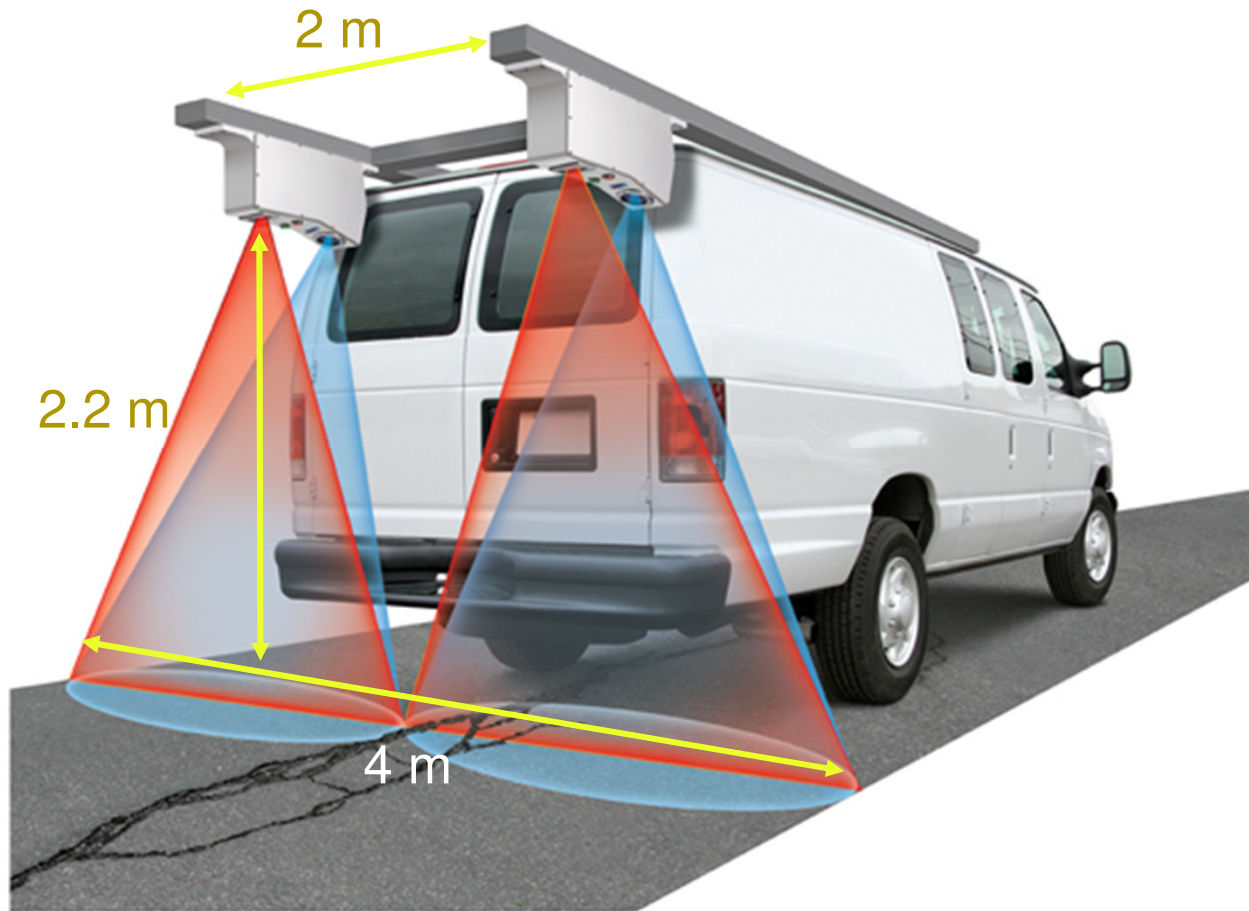
2010



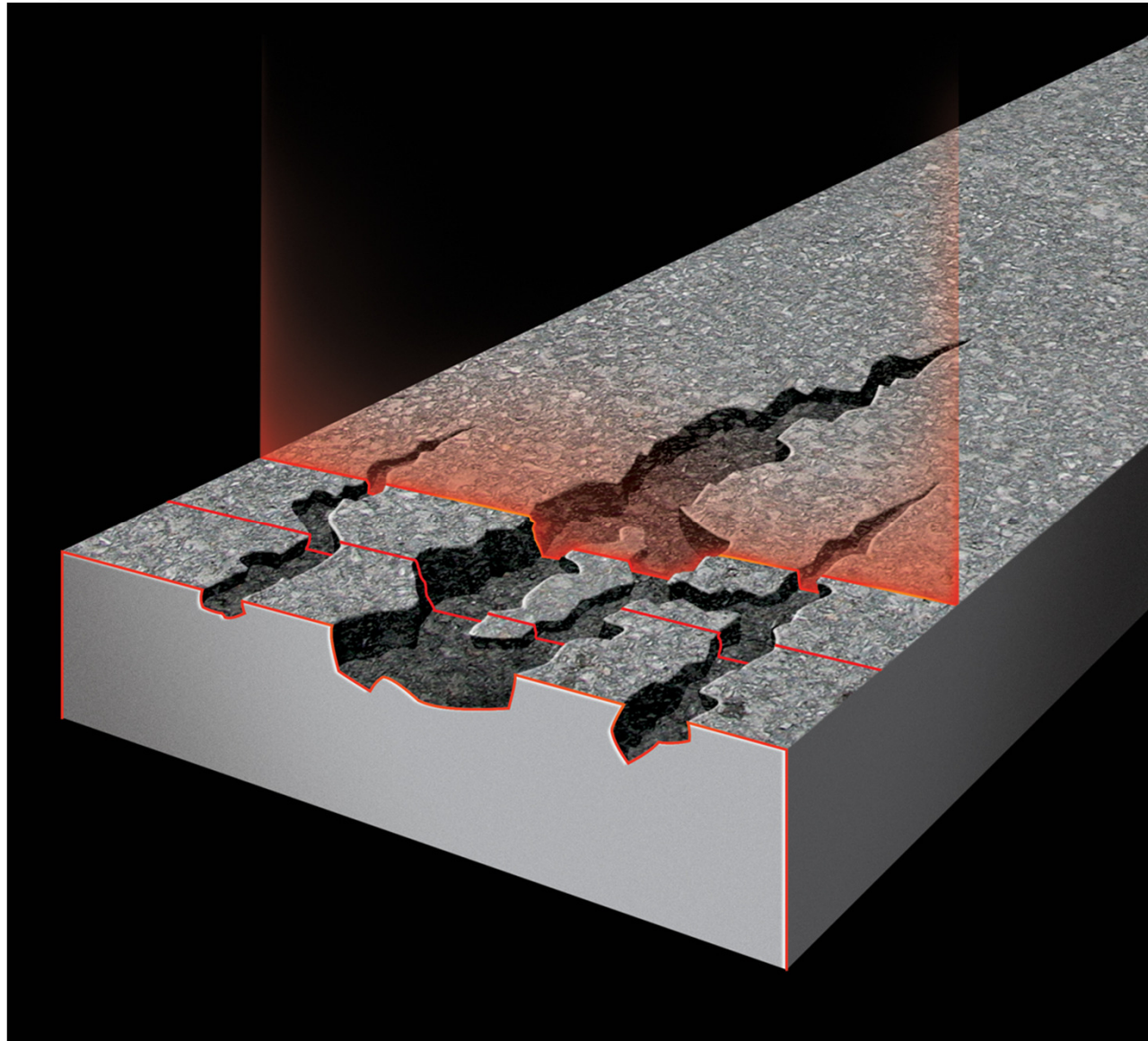
2010



**LCMS 5600Hz** is commercialized. Let the latest generation our 3D road sensor surprise you!

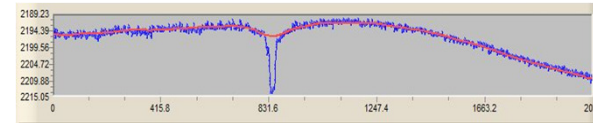
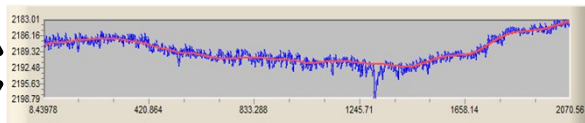


# Laser profiling (principle)



What makes a 3D sensor very good for crack measurement?

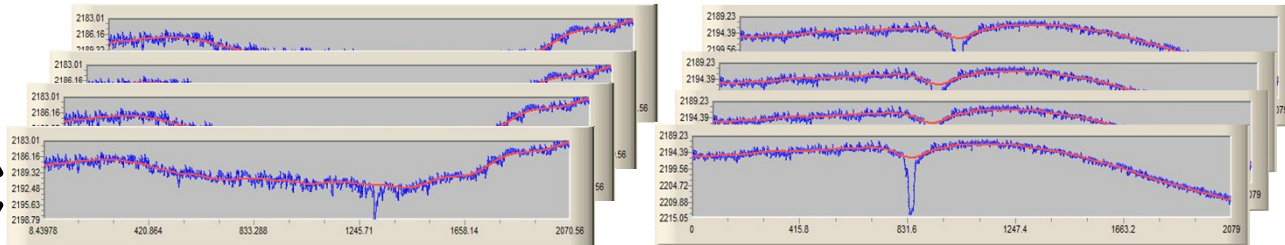
Excellent 3D Accuracy



Good Lateral Resolution

What makes a 3D sensor very good for crack measurement?

Excellent 3D Accuracy



High Acquisition Rate



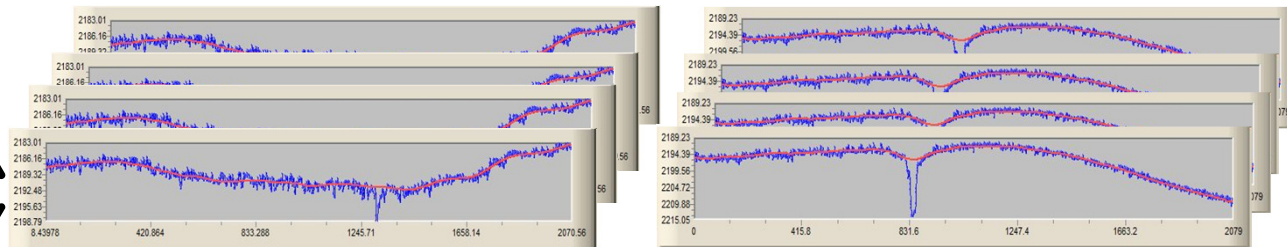
Good Lateral Resolution





## What makes a 3D sensor very good for crack measurement?

Excellent 3D Accuracy



High Acquisition Rate



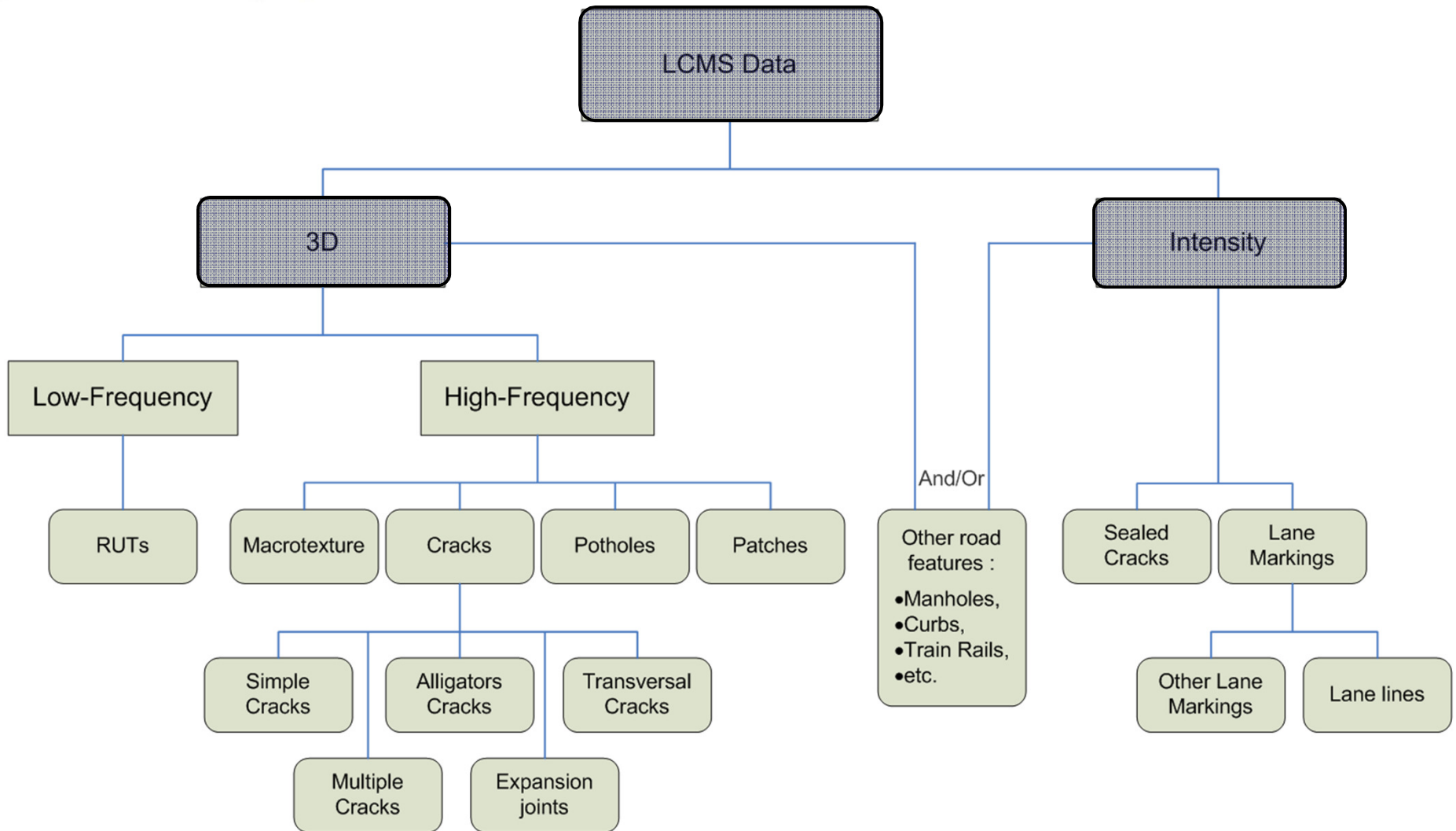
Good Lateral Resolution



### LCMS Specifications

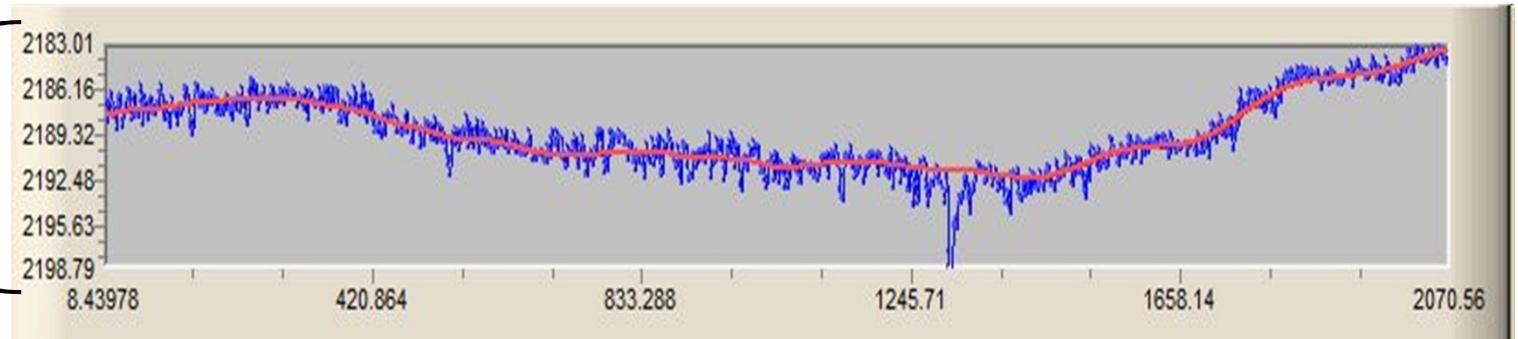
Acquisition Rate	11,200 profiles/s
Range Accuracy	0.5mm
Lateral Resolution	1mm (FOV = 4m)

# LCMS Data Processing Tree



# Single Road Profile (2 meter)

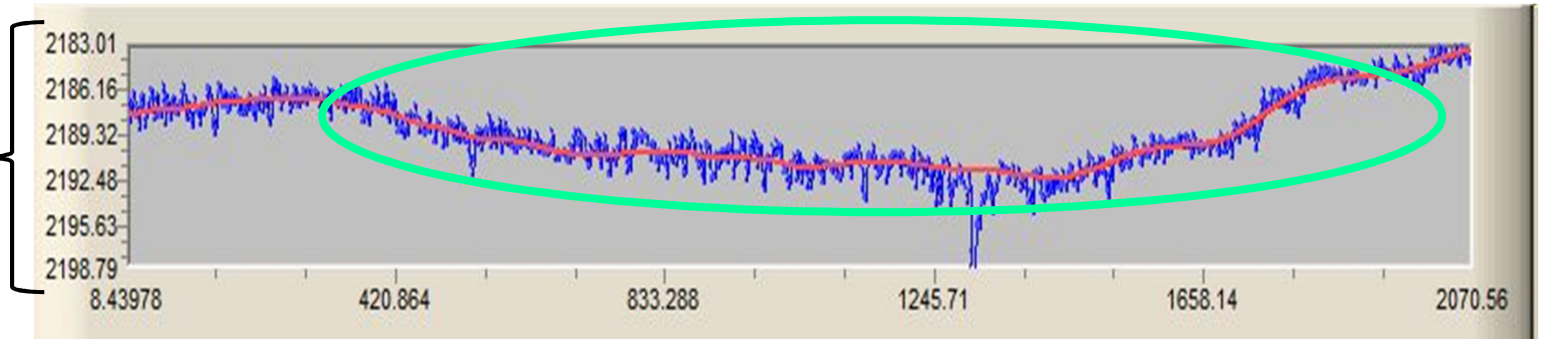
Distance  
between Sensor  
and ground  
(in mm)



# Single Road Profile (2 meter)

Rut

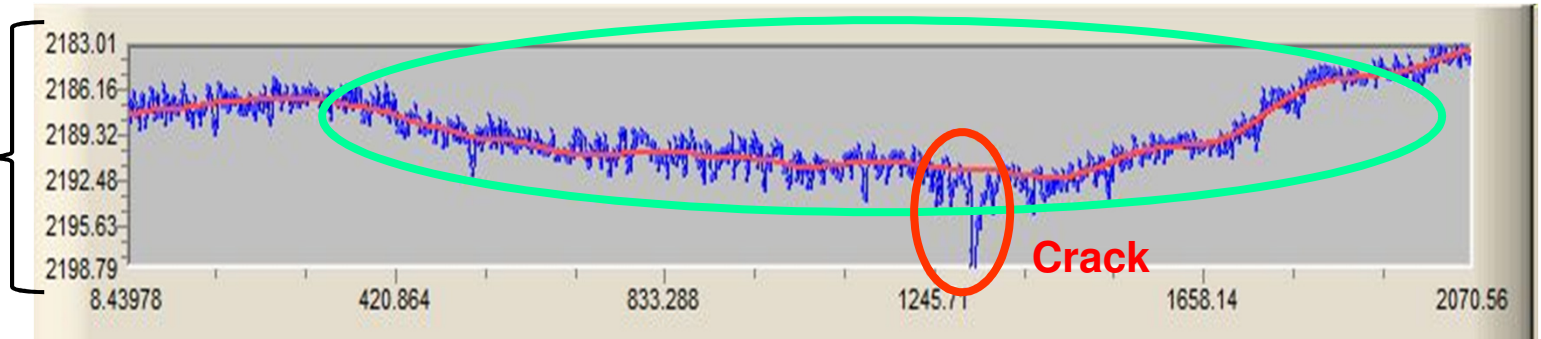
Distance  
between Sensor  
and ground  
(in mm)



# Single Road Profile (2 meter)

Rut

Distance  
between Sensor  
and ground  
(in mm)

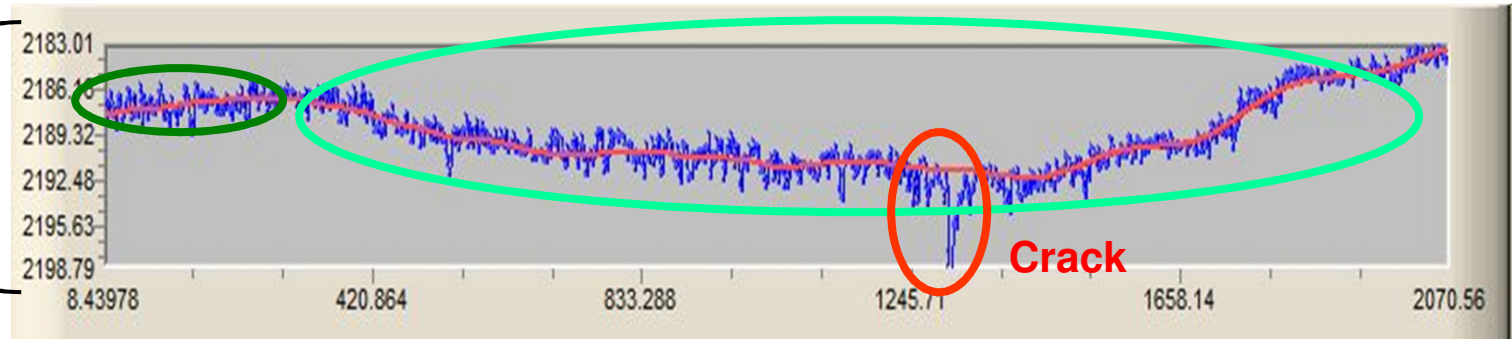


# Single Road Profile (2 meter)

Macro-texture

Rut

Distance  
between Sensor  
and ground  
(in mm)

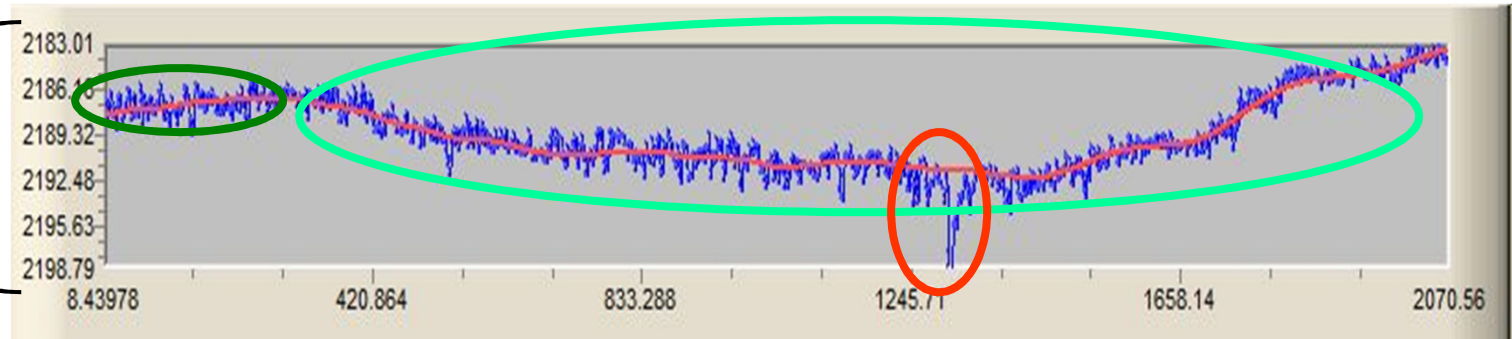


# Single Road Profile (2 meter)

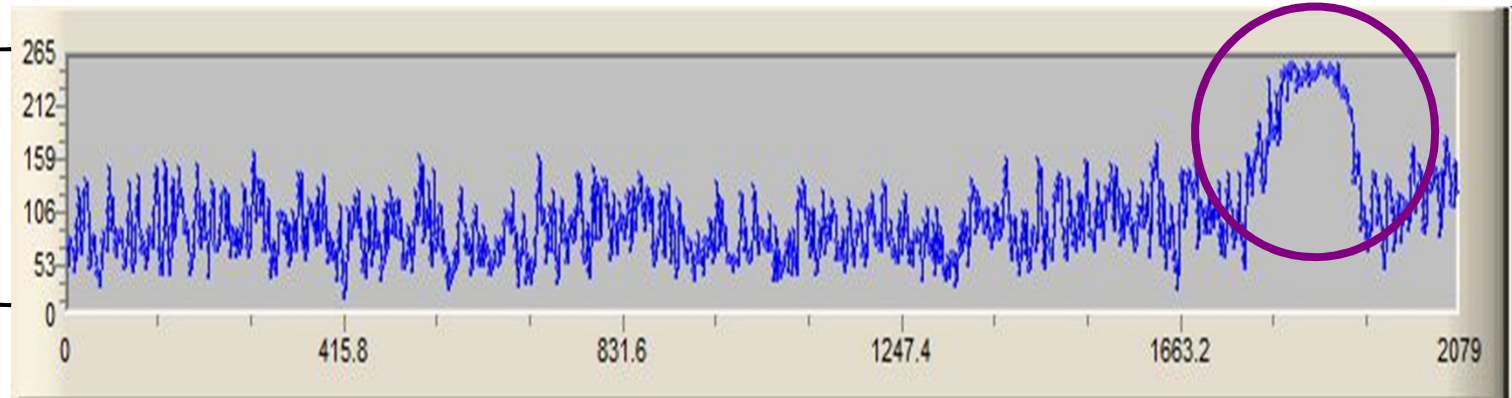
Macro-texture

Rut

Distance  
between Sensor  
and ground  
(in mm)



Laser intensity  
(black = 0,  
white = 255)



Right Lane  
Marking

# Range + Intensity = 3D !

The screenshot displays the Pavemetrics software interface with two overlapping windows. The left window shows a 2D view of a pavement surface with a crack. The right window shows a 3D perspective view of the same pavement surface, highlighting the depth of the crack. Both windows have a control panel on the left with various settings.

**Left Window Settings:**

- Current File: 516/820
- Road Section Id: 515
- Resolution: 5.0mm
- Length: 2.0m
- Distance: 1.030km
- Time (h:m:s): 0:1:6.4
- Proc Selection:  Lane Mark,  Crack,  Rutting,  Macro Tex.,  Potholes
- Sensitivity: 1
- Result Display:  Lane Mark,  Crack,  Potholes
- Proc. Multiple: Start, Stop, Status Done, Cur Sec. Id 515, Progress 1/1, Analysis Time 1632.3ms, Errors None
- System Info: Survey Id 2050454015, Nb Sections 820, Total Length 1.640km
- Data to display:  Intensity,  Range,  Rectified Range
- Zoom:  Fit Image,  Zoom 100%,  Zoom Free 2
- Z Range:  Auto, Min 2166.27, Max 2206.27
- Profile Disp.:  Intensity,  Range,  Rectif. Rng,  CCD, 193 Y,  Auto Scale

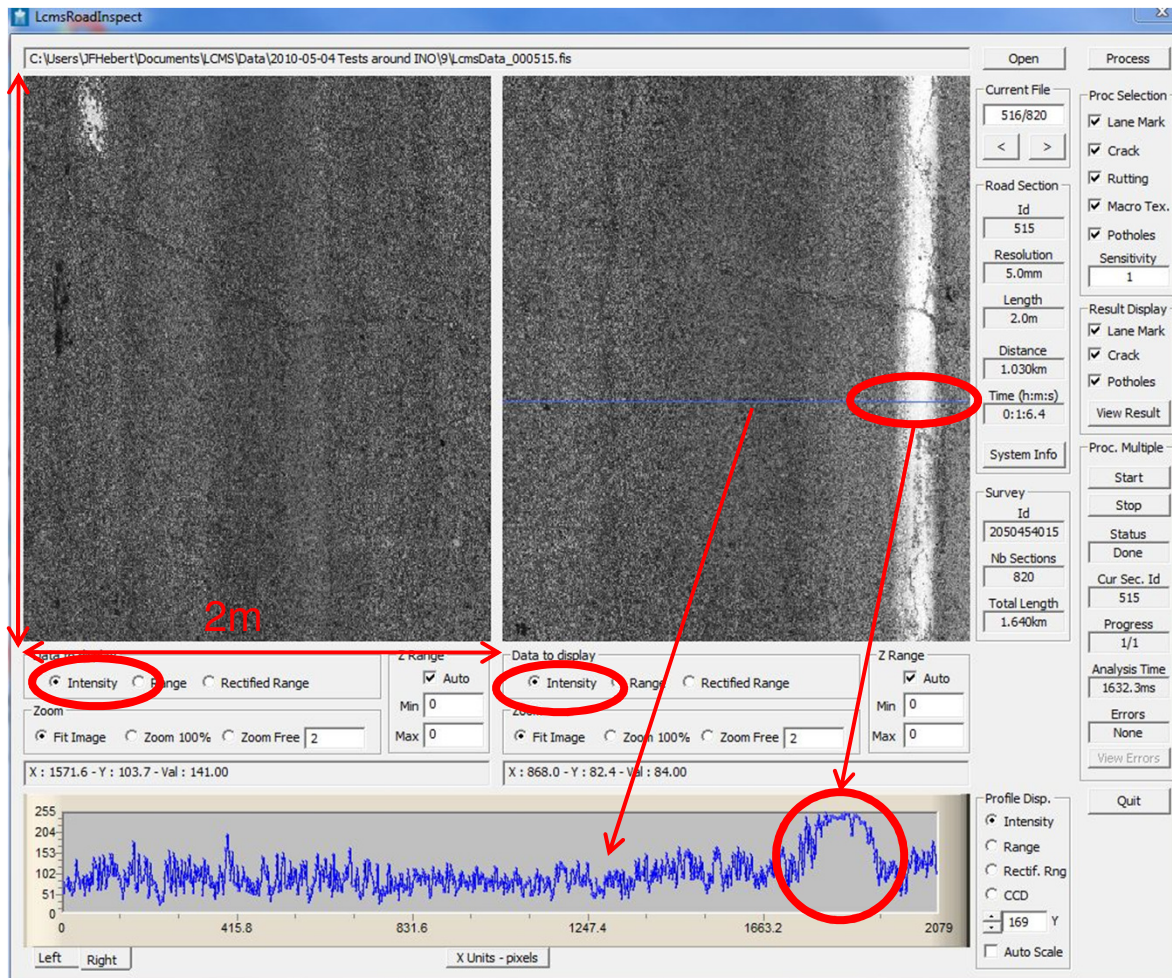
**Right Window Settings:**

- Current File: 516/820
- Road Section Id: 515
- Resolution: 5.0mm
- Length: 2.0m
- Distance: 1.030km
- Time (h:m:s): 0:1:6.4
- System Info: Survey Id 2050454015, Nb Sections 820, Total Length 1.640km
- Data to display:  Intensity,  Range,  Rectif. Rng,  CCD
- Zoom Free: 2
- Z Range:  Auto, Min 0, Max 0
- Profile Disp.:  Intensity,  Range,  Rectif. Rng,  CCD, 169 Y,  Auto Scale



# Road Section: Intensity Data

400 road profiles captured every 5 mm = 2m road section



**Definition:**  
A Road Section is a set of profiles merged together.

**Can be viewed in:**

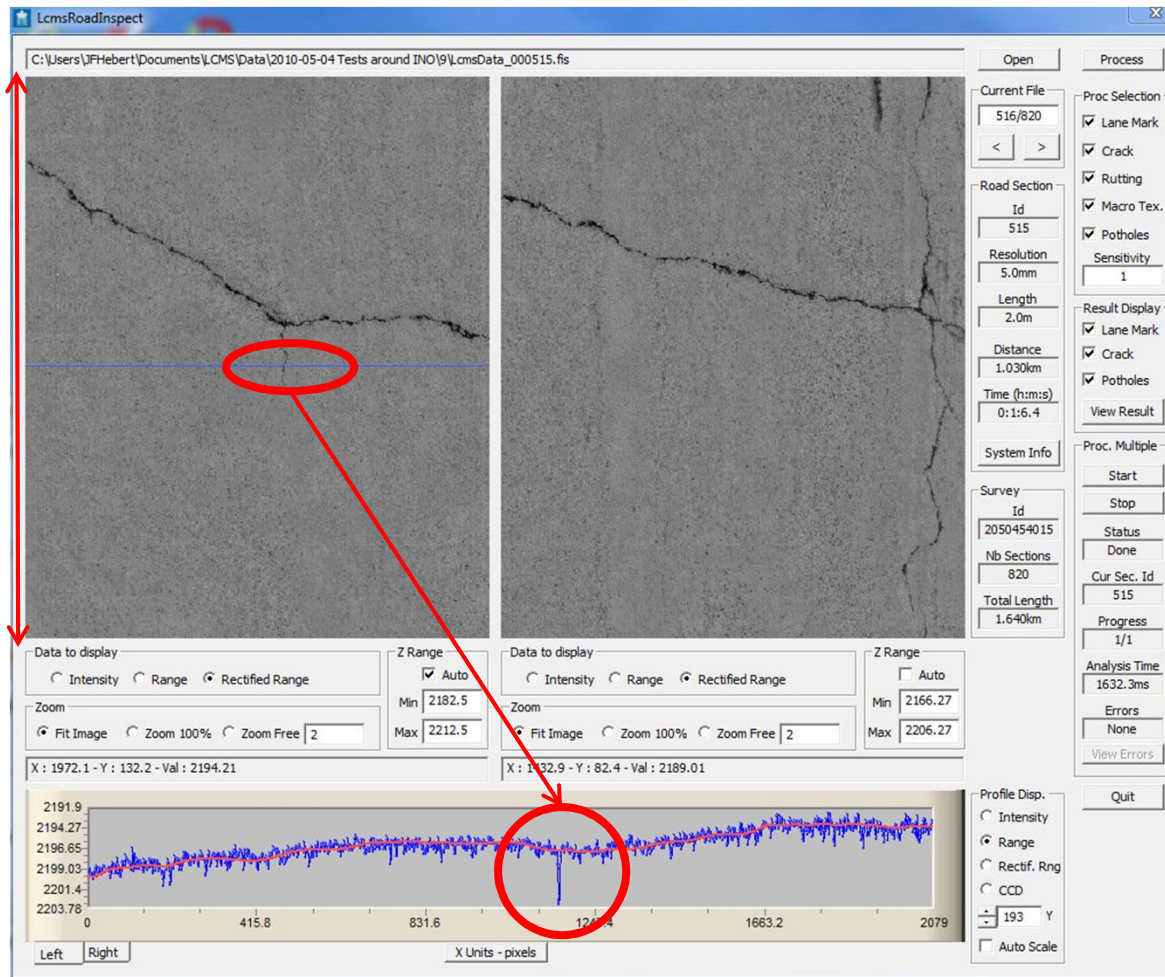
- Intensity
- Range

**Intensity:**

- Depends on the reflective properties of the surface.

# Road Section: Range Data

400 road profiles captured every 5 mm = 2m road section



## Range:

- Gives the distance to the ground.

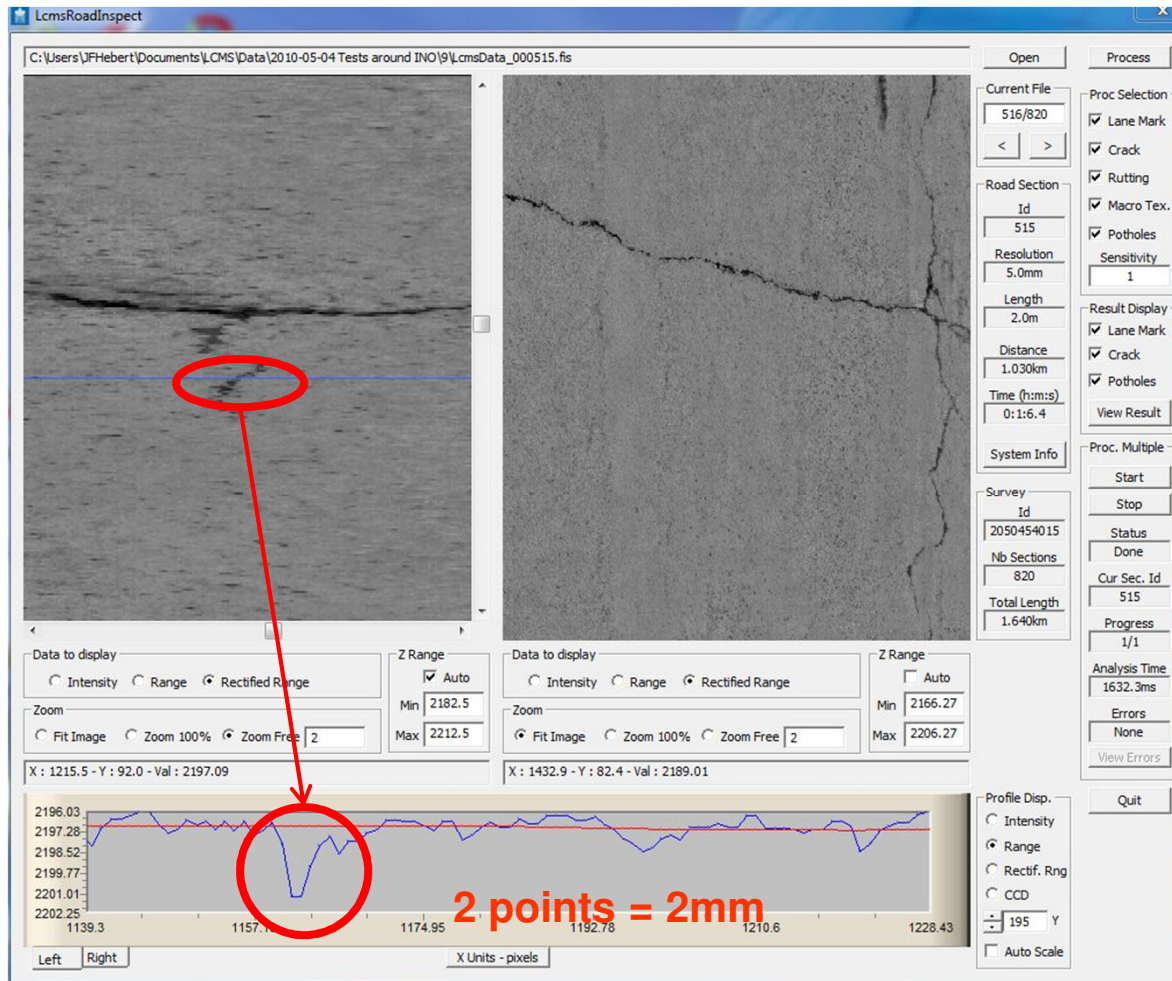
## Mapping to 2D Viewer:

- Darker points = further away
- Gray points = on-surface
- White points = closer

## Cracks:

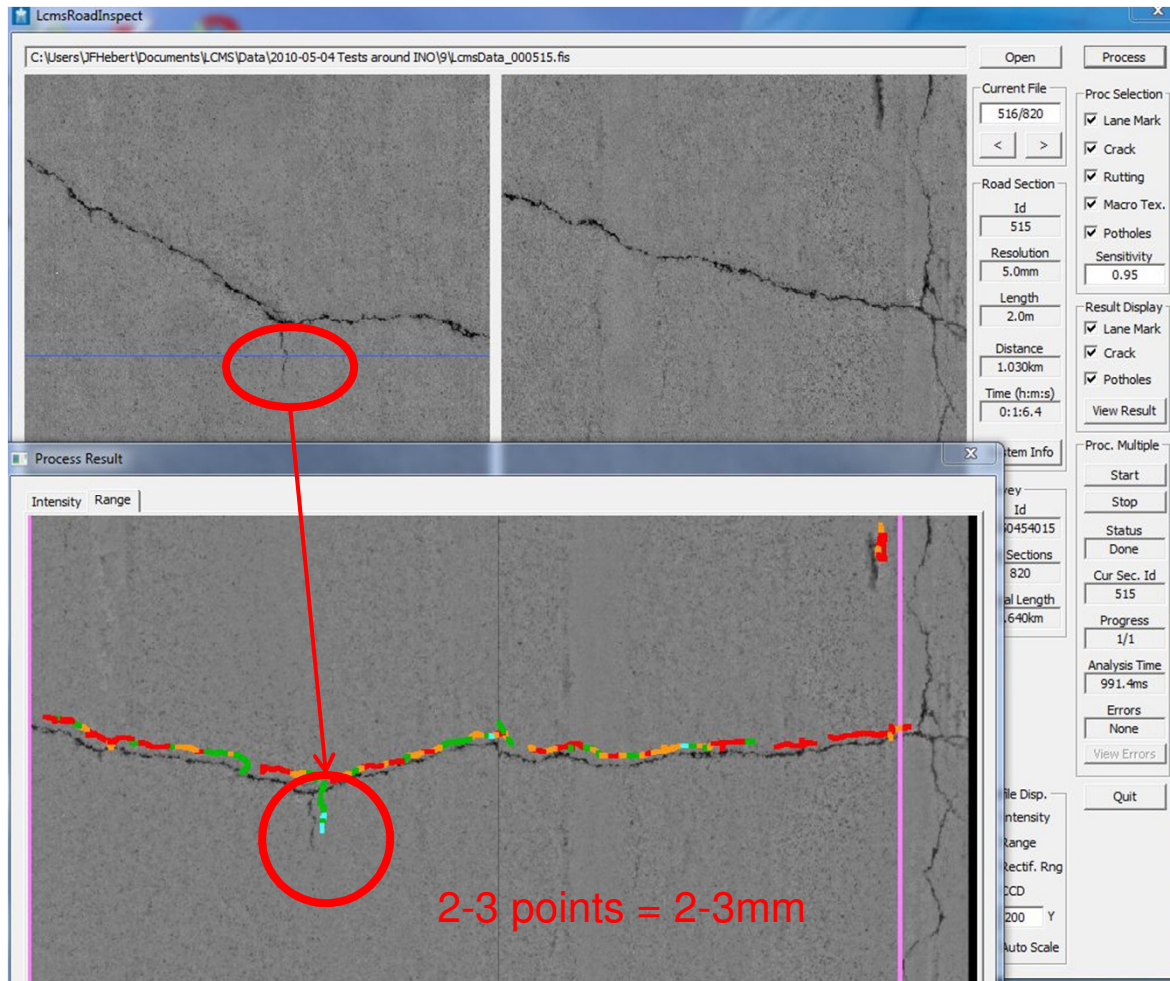
- Notch in the profile
- Appear darker in range image

# Road Section: Range Data (zoomed)



Zoom on a 2 to 3 mm crack

# Crack detection example

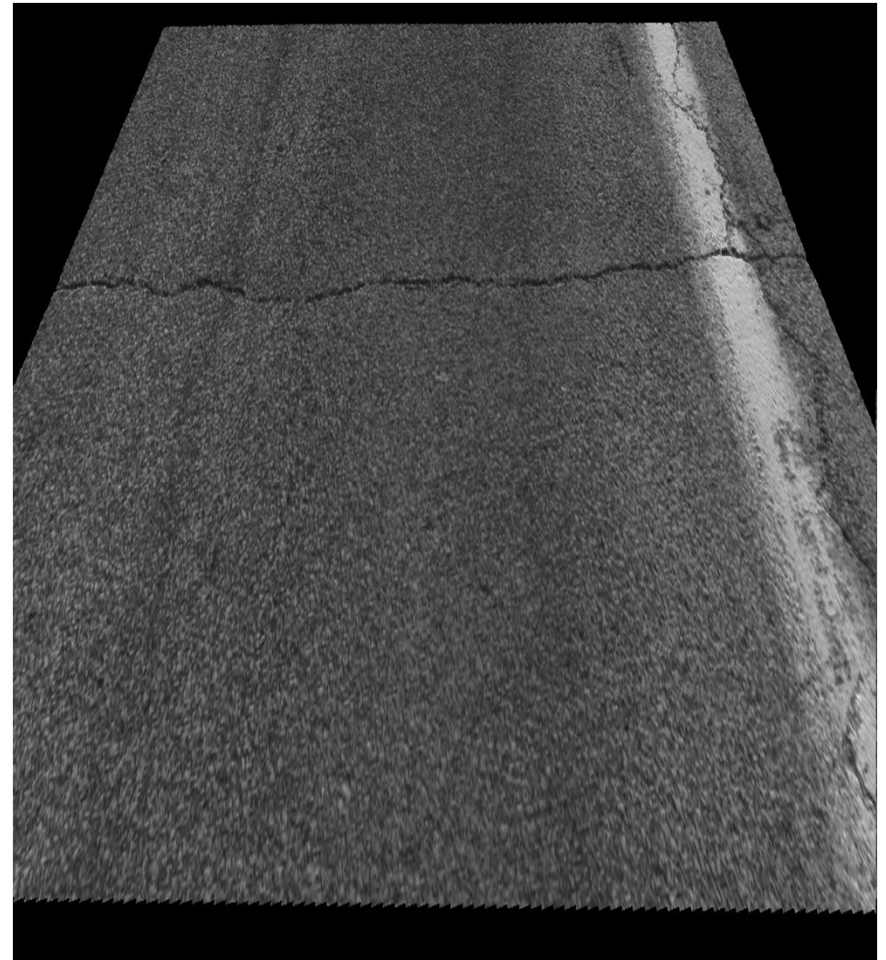
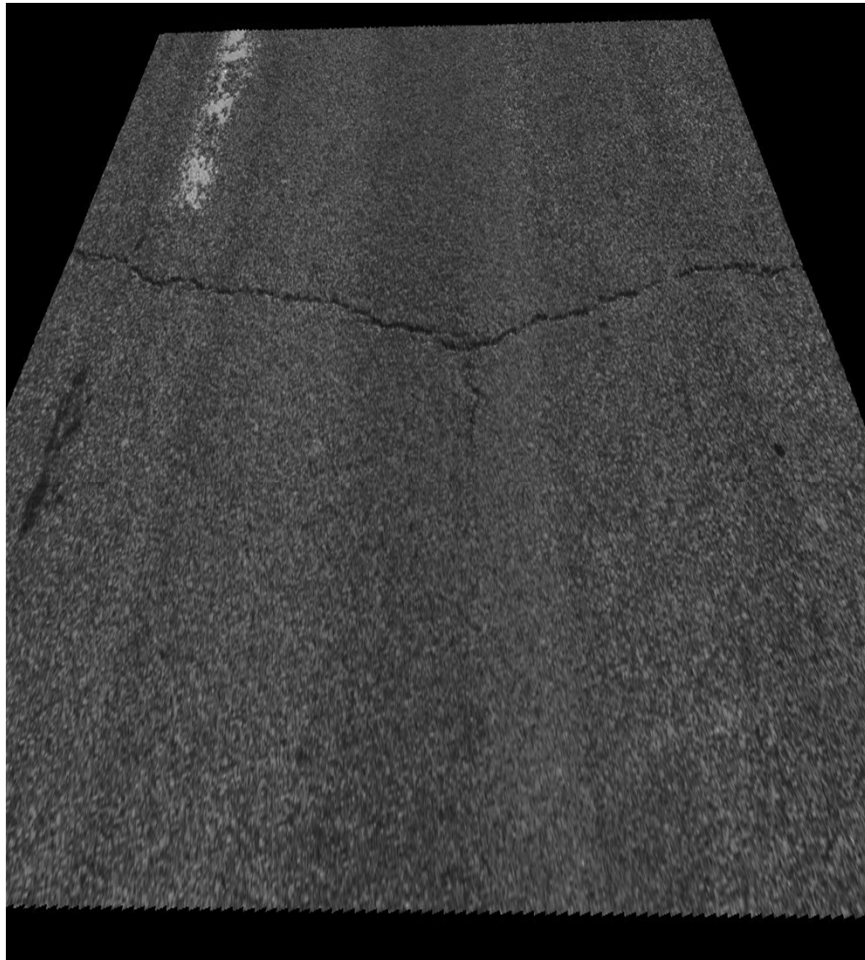


## LCMSLib:

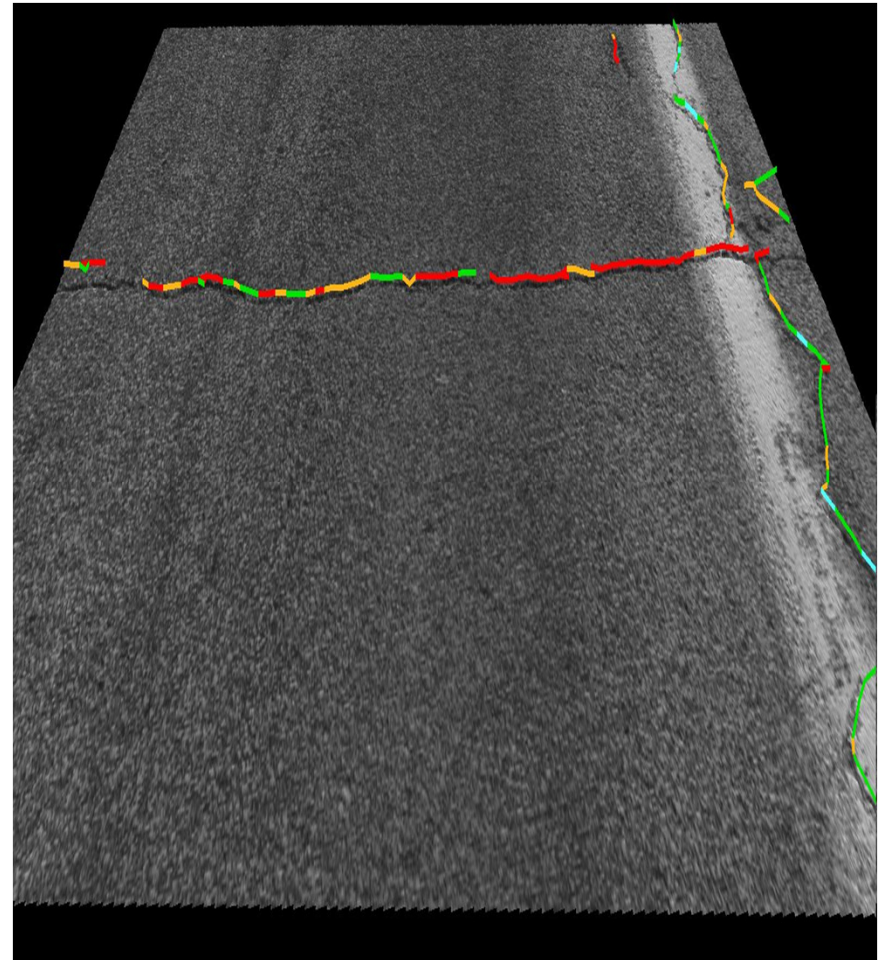
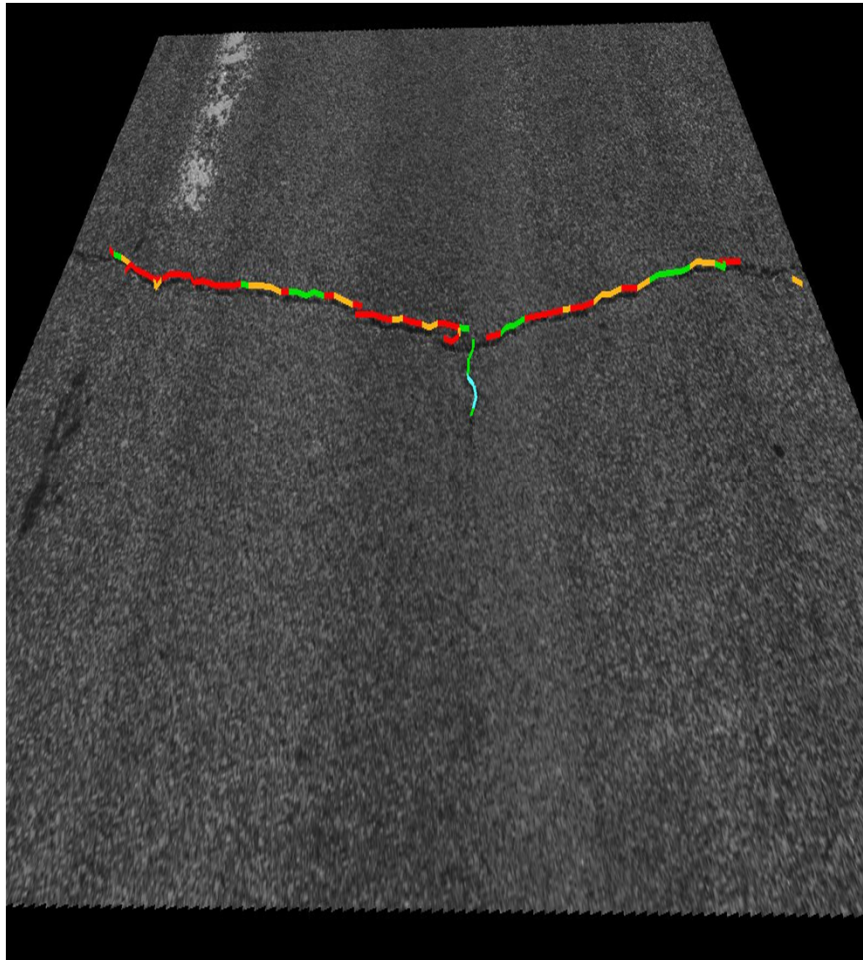
- C/C++ Win32 DLL library
- Easy to interface (Open, Process, GetResults)
- Outputs crackmap as a XML string.

```

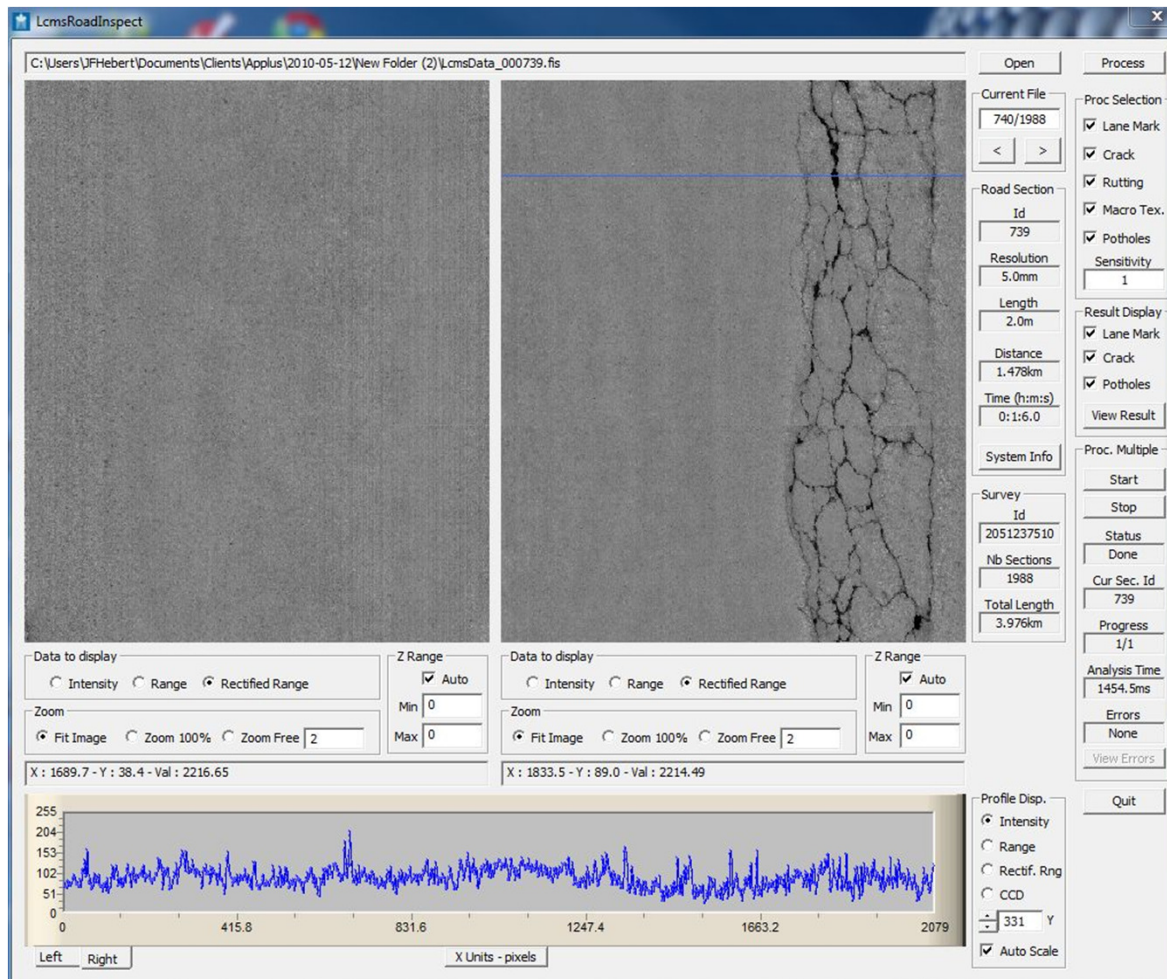
- <CrackInformation>
  <DataFormat>1.0</DataFormat>
- <Unit>
  <X>millimeter</X>
  <Y>millimeter</Y>
  <Width>millimeter</Width>
</Unit>
- <CrackList>
- <Crack>
  - <Node>
    <X>2093.0</X>
    <Y>9445.0</Y>
    <Width>11.8</Width>
  </Node>
  - <Node>
    <X>2098.0</X>
    <Y>9465.0</Y>
    <Width>11.2</Width>
  </Node>
  - <Node>
    <X>2104.0</X>
    <Y>9485.0</Y>
  </Node>
  </Crack>
</CrackList>
  
```



# Automatic Crack Detection Length, Type, Severity



# Alligator Cracks



Definition  
Alligator cracking

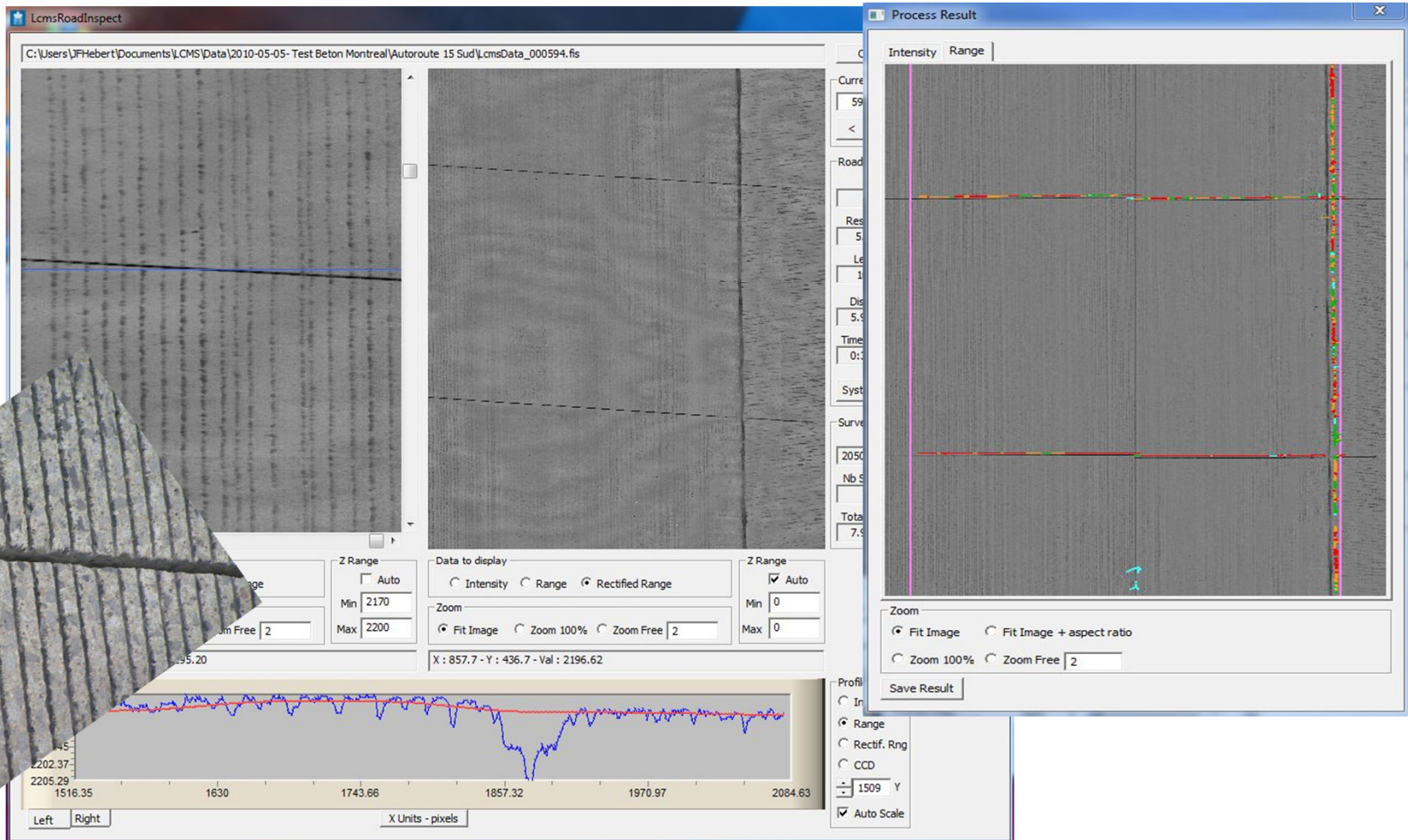
# Alligator Cracks

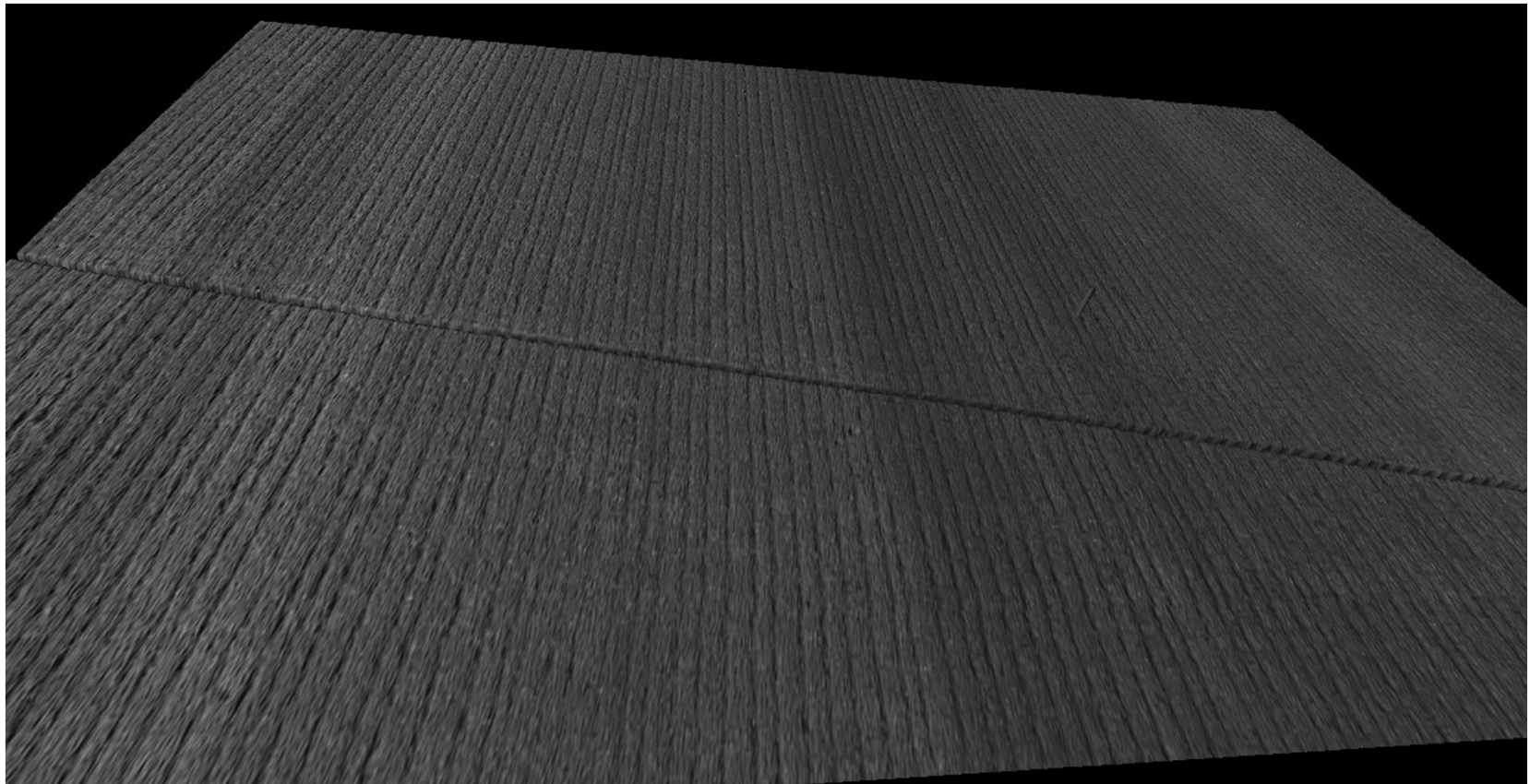
The screenshot displays the LcmsRoadInspect software interface. On the left, a 3D perspective view shows a road surface with a network of alligator cracks. In the center, a 2D top-down view shows the same road surface with a blue line indicating the current section. The right side of the interface features a control panel with the following sections:

- Open / Process**: Buttons for file operations.
- Current File**: 740/1988
- Road Section**:
  - Id: 739
  - Resolution: 5.0mm
  - Length: 2.0m
  - Distance: 1.478km
  - Time (h:m:s): 0:1:6.0
- System Info**:
  - Survey Id: 2051237510
  - Nb Sections: 1988
  - Total Length: 3.976km
- Z Range**:
  - Auto:
  - Min: 0
  - Max: 0
- Zoom Free**: 2
- Profile Disp.**:
  - Intensity:
  - Range:
  - Rectif. Rng:
  - CCD:
  - 331 Y
  - Auto Scale:
- Proc. Selection**:
  - Lane Mark:
  - Crack:
  - Rutting:
  - Macro Tex.:
  - Potholes:
  - Sensitivity: 1
- Result Display**:
  - Lane Mark:
  - Crack:
  - Potholes:
- Proc. Multiple**: Start, Stop, Status, Done, Cur Sec. Id (739), Progress (1/1), Analysis Time (1454.5ms), Errors (None), View Errors, Quit

At the bottom of the control panel, a profile graph shows a blue line representing the road surface profile, with x-axis values 1663.2 and 2079.







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# Chip seal surfaces

The screenshot displays the LcmsRoadInspect software interface. The main window shows a 3D perspective view of a road surface scan, with a white lane marking visible. The interface includes a file explorer at the top, a control panel on the right, and a profile graph at the bottom.

**File Explorer:** G:\Customer Data\MTQ\DT67 - ChipSeal\100721\_1330\_0013811111\_1\100721\_1330\_0013811111\_1\_001403.fis

**Control Panel (Right):**

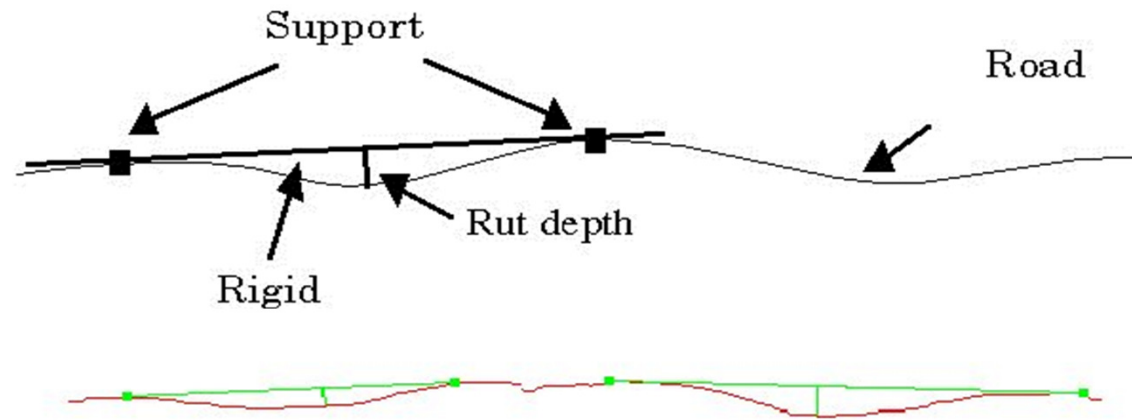
- Open:** 104/962
- Road Section:** Id: 1402, Resolution: 5.0mm, Length: 10.0m, Distance: 14.020km, Time (h:m:s): 0:10:54.7
- Proc Selection:**  Lane Mark,  Crack,  Rutting,  Macro Tex.,  Potholes
- Result Display:**  Lane Mark,  Crack,  Potholes
- Proc. Multiple:** Start, Stop, Status: -, Cur Sec. Id: -, Progress: -, Analysis Time: -, Errors: -, View Errors
- Survey:** Id: 2072148719, Nb Sections: 962, Total Length: 9.620km
- Z Range:**  Auto, Min: 0, Max: 0
- Profile Disp.:**  Intensity,  Range,  Rectif. Rng,  CCD, Y: 232,  Auto Scale
- Proc Selection:**  Mtq Classif
- Result Display:**  Mtq Classif
- Quit**

**Profile Graph (Bottom):**

The graph shows a profile of the road surface. The Y-axis represents elevation in pixels, ranging from 2271.43 to 2212.18. The X-axis represents distance in pixels, ranging from 0 to 2079. The profile shows a relatively flat surface with a slight dip around 1663.2 pixels.

X Units - pixels	Y (Elevation - pixels)
0	2271.43
415.8	2271.43
831.6	2271.43
1247.4	2271.43
1663.2	2271.43
2079	2212.18

# Manual rut depth measurements



**LRMS Demo** [X]

File Help

Display:  **Fit. Profiles**,  **Markings**,  **RUTs**,  Intensity,  3-Point Simulation,  5-Point Simulation

**StraightEdge**

Gage Width:  mm. [19 mm, 75 mm]

Length:  mm. [1730 mm, INF]

**Sensors Spacing**

Wheel Path:  mm. [500 mm, 1250 mm]

Outside:  mm. [1251 mm, 2000 mm]

00060905\_210\_Right.bmp [Previous] [Next] 00060905\_210\_Left.bmp

Status: The Sensor class returned : eNO\_ERROR      Status: The Sensor class returned : eNO\_ERROR

**Right Sensor      Looking Backward      Left Sensor**

**LRMS Algorithms**

Depth:  mm. C-Sec:  mm<sup>2</sup>. Width:  mm.

**Multi-Point Systems**

Depth:  mm.

**LRMS Algorithms**

Depth:  mm. C-Sec:  mm<sup>2</sup>. Width:  mm.

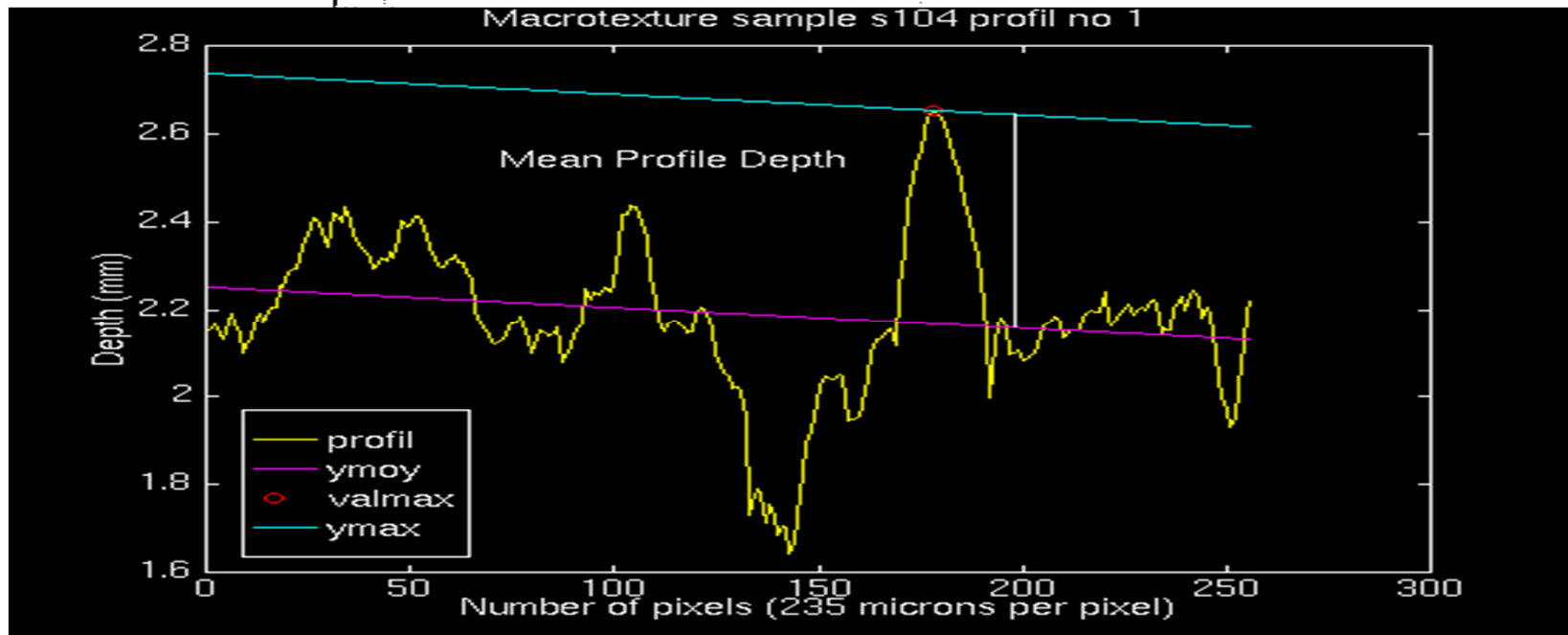
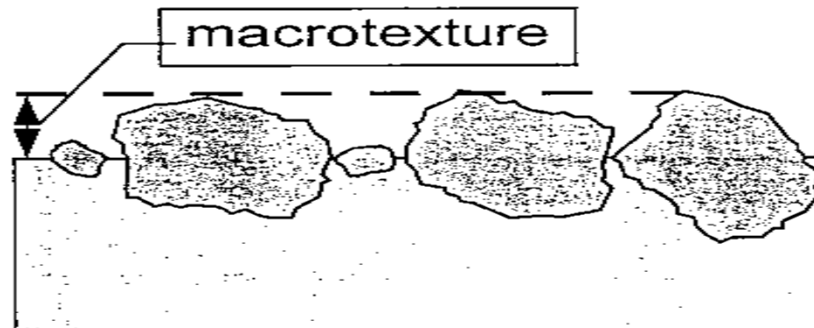
**Multi-Point Systems**

Depth:  mm.

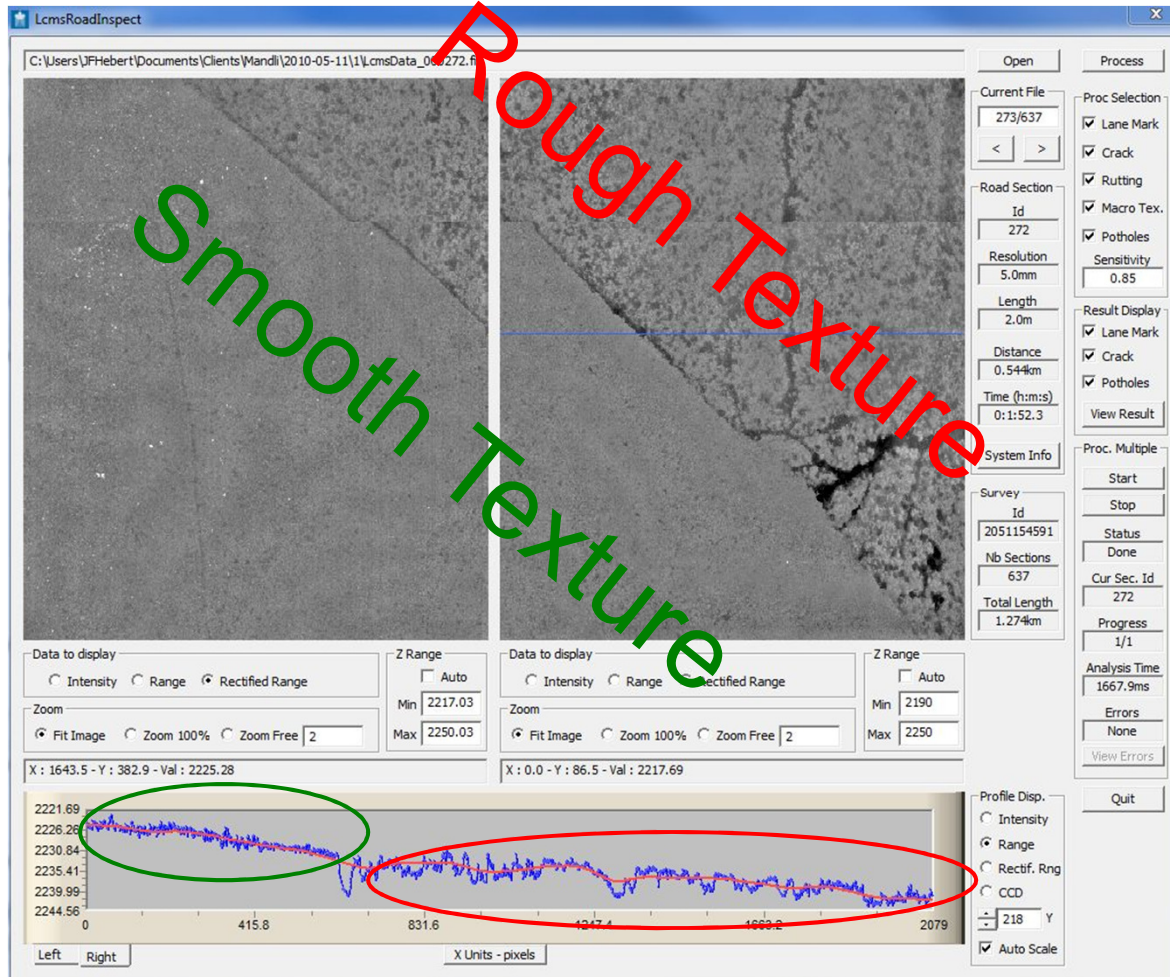
# Validation – 10 m intervals

RUT DEPTH (mm)	Right rut			Left rut		
	INO		MTQ	INO		MTQ
	Avg.	Std. Dev.	Rut Bar	Avg.	Std. Dev.	Rut Bar
<b>10</b>	5.2	0.4	6.0	6.4	0.9	4.0
<b>50</b>	9.2	0.3	10.0	6.2	0.6	6.0
<b>100</b>	14.7	1.1	13.0	9.2	0.8	10.0
<b>150</b>	14.8	0.7	14.0	4.3	0.3	3.0
<b>200</b>	22.6	0.4	22.0	1.4	0.4	2.0
<b>250</b>	19.6	0.7	19.0	6.2	0.6	5.0
<b>300</b>	19.7	0.7	23.0	7.3	3.2	8.0
<b>350</b>	37.6	2.2	42.0	10.4	1.2	7.0
<b>Average (of 40 segments)</b>	<b>20.3</b>	<b>1.0</b>	<b>21.7</b>	<b>8.8</b>	<b>1.1</b>	<b>7.1</b>

# Macrotexture (MPD - ASTM E1845-01)



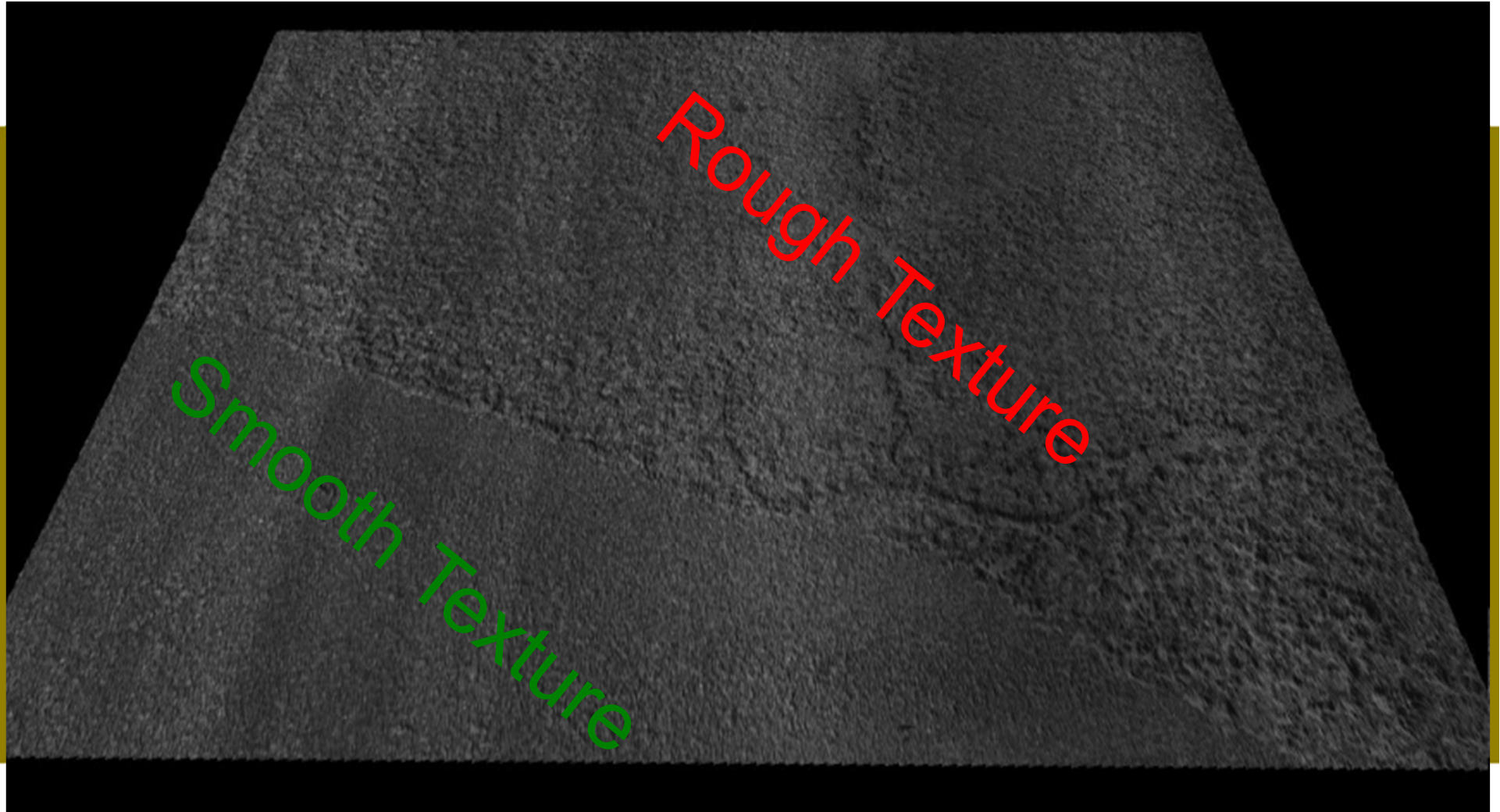
# Macrotexture (MPD - ASTM E1845-01)



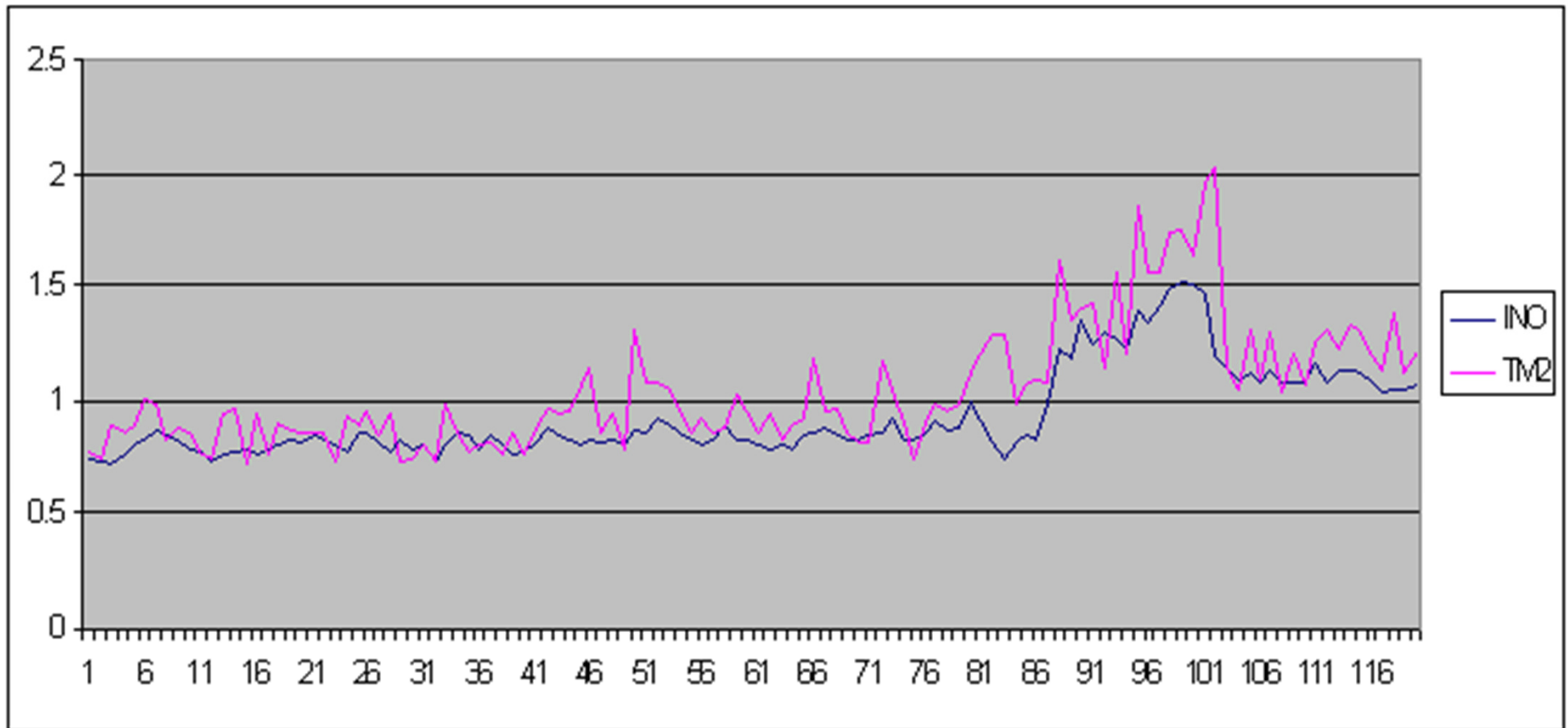
- Preliminary results are promising
- Studies are underway to compare with other devices



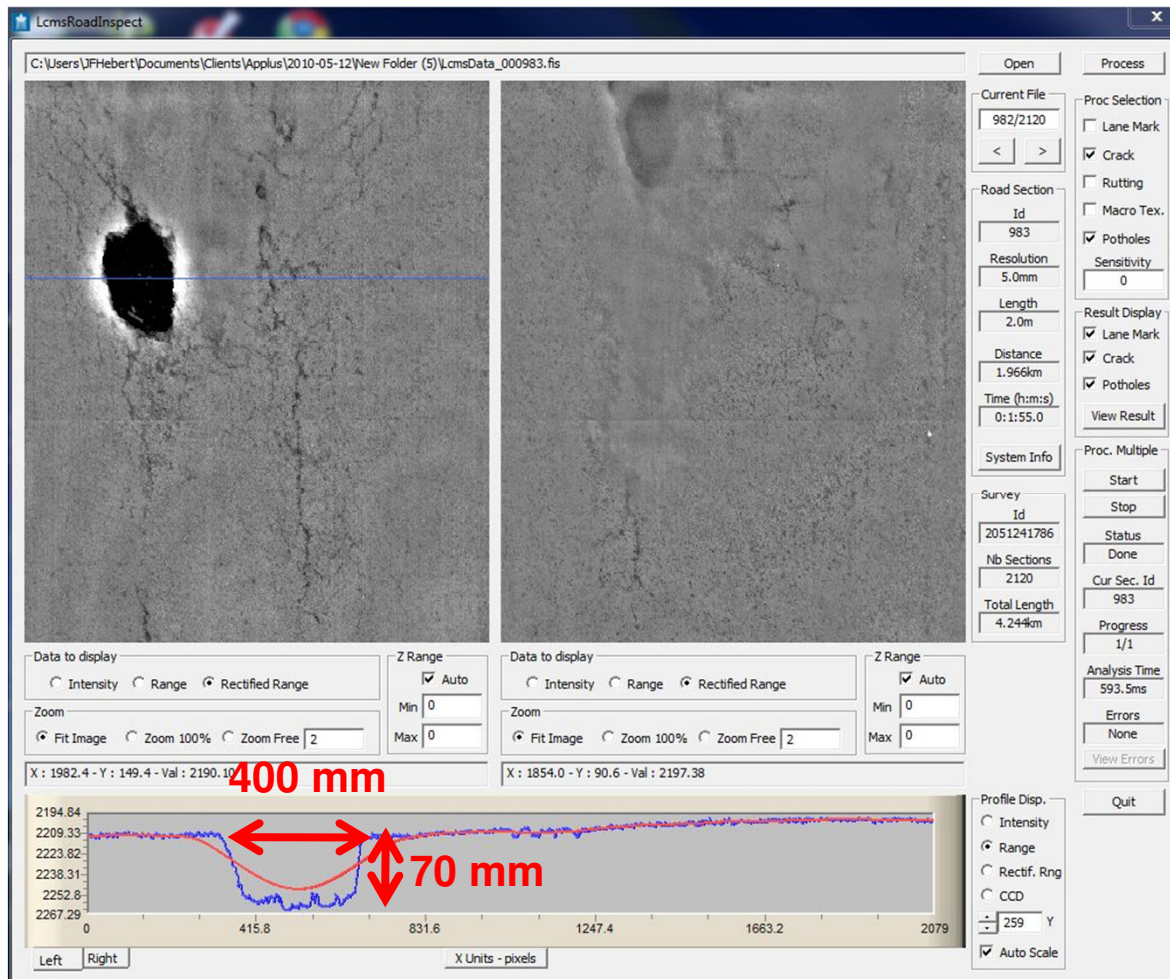
# Macrotexture (MPD - ASTM E1845-01)

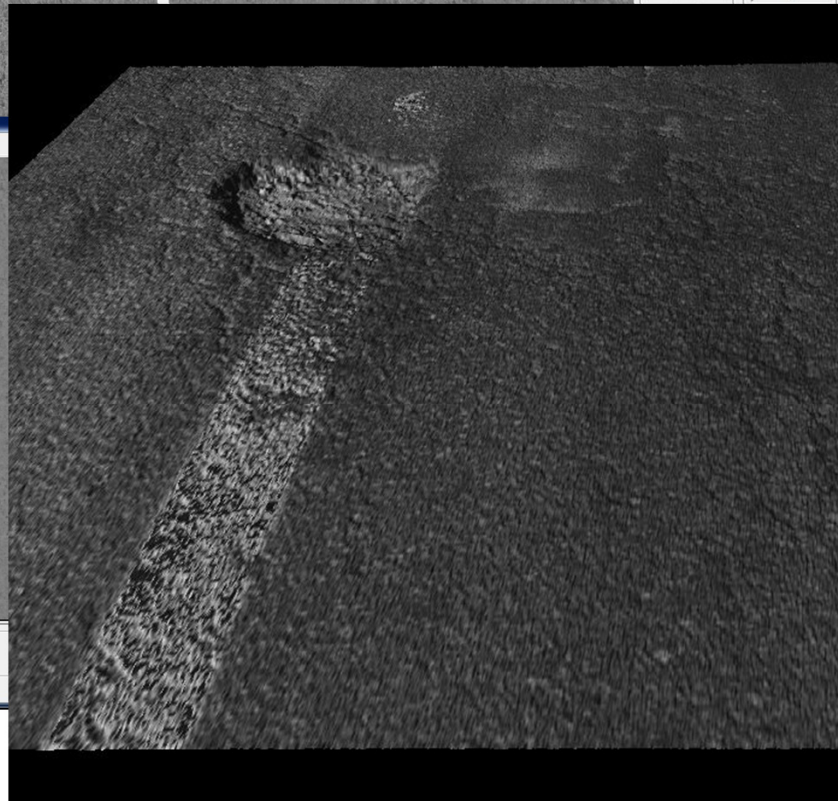
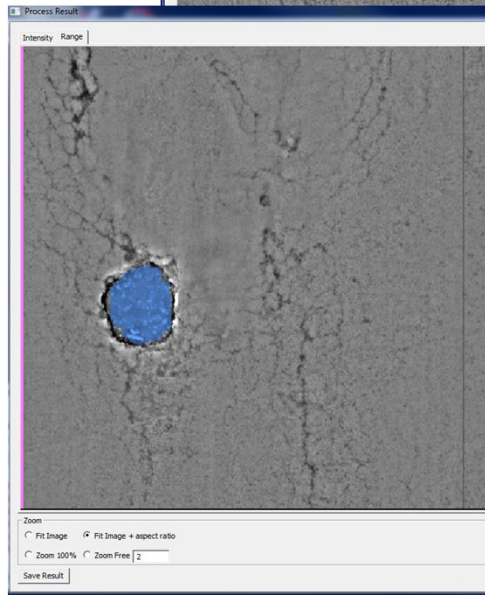
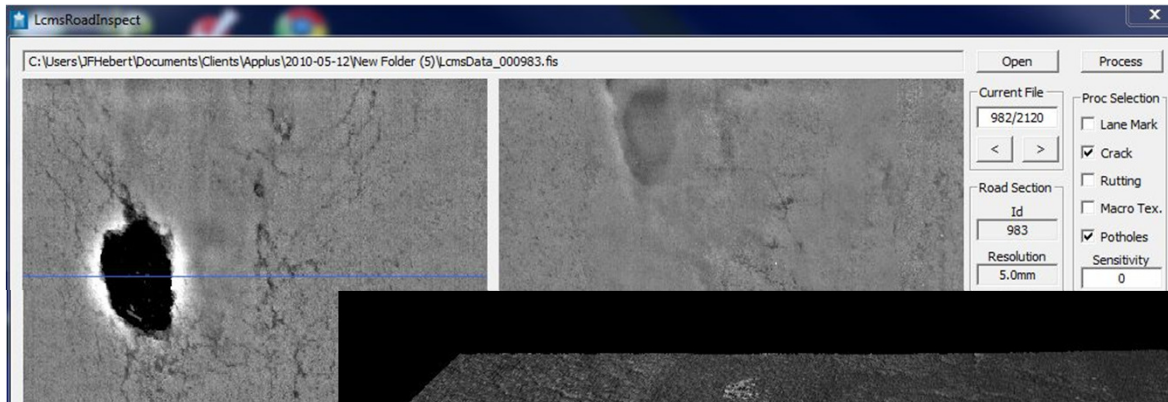


# Macro-texture results (LCMS vs WDM – TM2)



# Pothole Detection



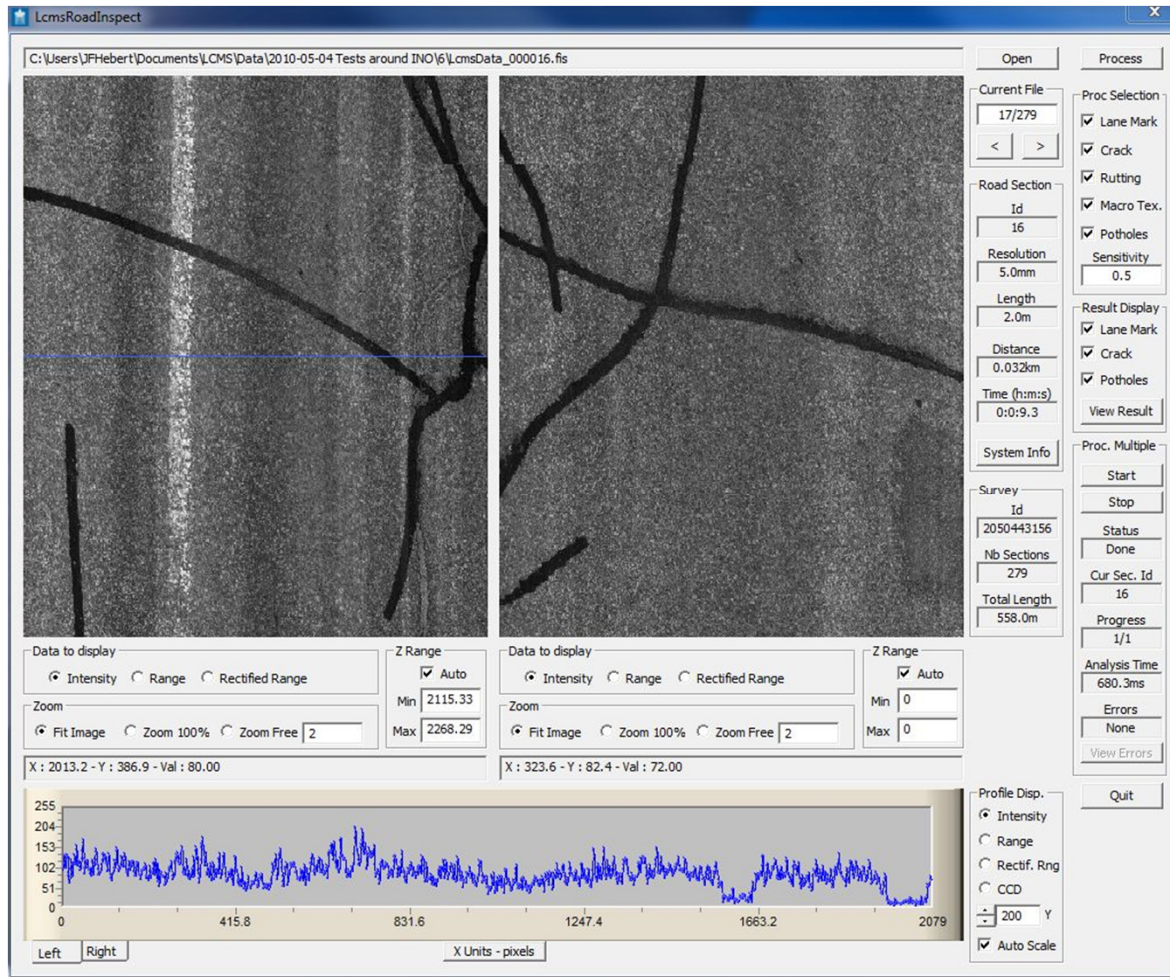


•Our library detects and characterize the potholes

Characterization:

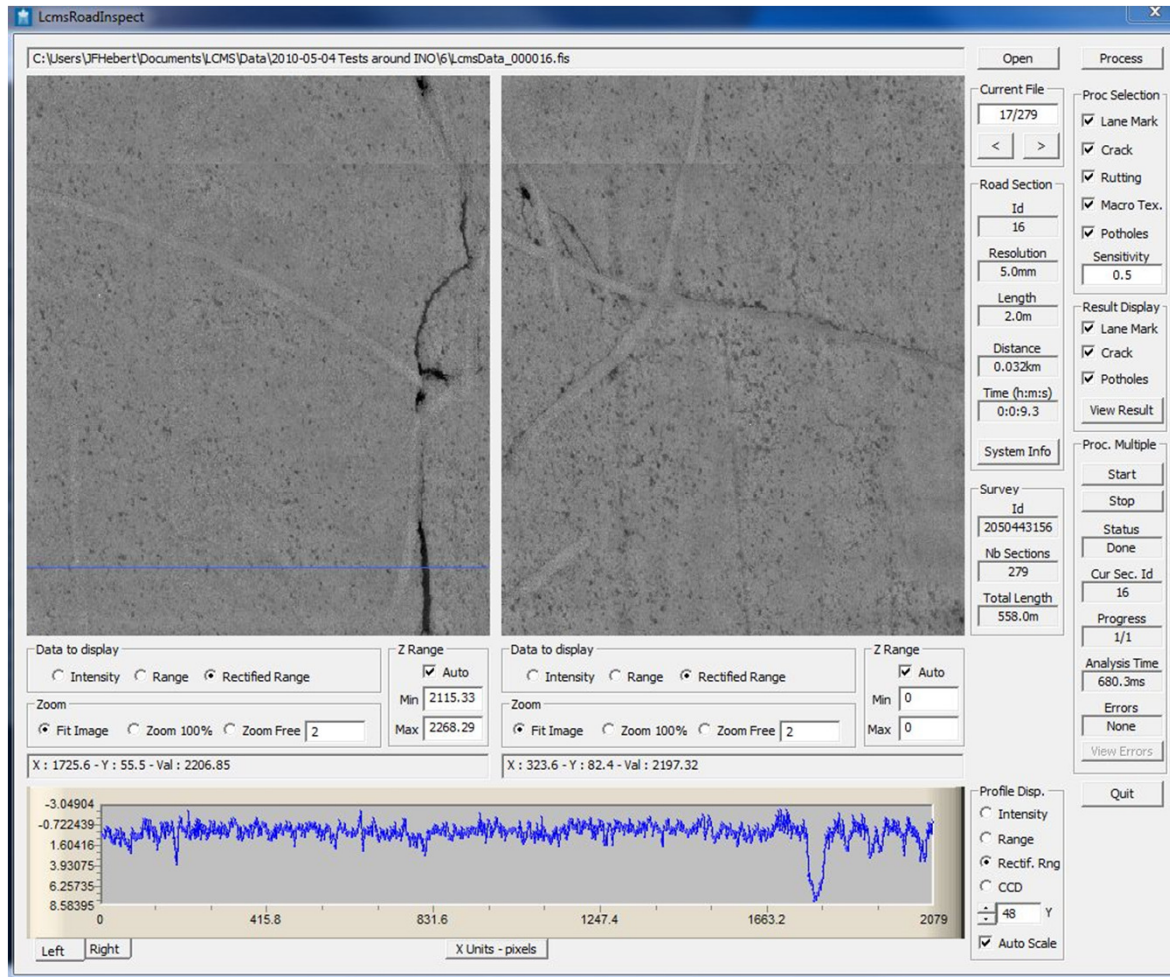
- Bounding box
- Area
- Perimeter (list of points)
- Volume

# Sealed cracks: Work in progress...



•Sealed cracks are visible in the intensity images ...

# Sealed cracks: Work in progress...



•But they aren't visible in 3D...



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# Network level testing





# Network level validation tests

- 990 000 images of 10m sections were visually evaluated
  - In all 9 900 km of road network was evaluated
  - Visual results were seperated into 4 classes:

Good

OK

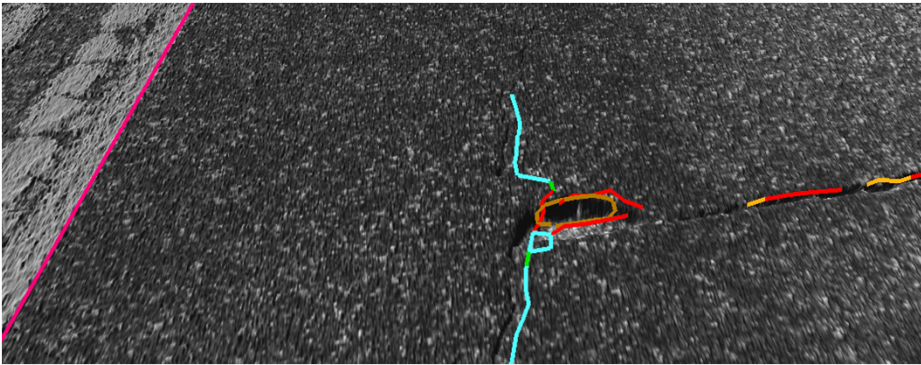
Bad

NA = other

# Results – network level visual evaluation

District #	Total ( sections)	Results (manual classification)							
		Number of images (10m sections)				Proportion (%)			
		Good	Average	Bad	NA	Good	Average	Bad	NA
84	35288	34144	310	144	690	96,8	0,9	0,4	2,0
85	4243	4101	53	51	38	96,7	1,2	1,2	0,9
86	147903	144040	516	1520	1827	97,4	0,3	1,0	1,2
87	149926	138453	1170	5728	4575	92,3	0,8	3,8	3,1
88	189097	183010	1064	2002	3021	96,8	0,6	1,1	1,6
89	125003	121835	442	2015	711	97,5	0,4	1,6	0,6
90	123653	116930	2980	2434	1309	94,6	2,4	2,0	1,1
91 & 92	215513	213142	197	956	1218	98,9	0,1	0,4	0,6
<b>Total</b>	<b>990626</b>	<b>955655</b>	<b>6732</b>	<b>14850</b>	<b>13389</b>	<b>96,5</b>	<b>0,7</b>	<b>1,5</b>	<b>1,4</b>

- Lane Marking cracks and Pothole Detection

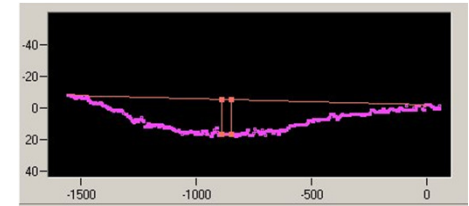


- Tining Concrete



- Rut Measurement

- Type
- Depth
- Width



- Sealed Cracks Detection



- Macro-Texture Measurement using MPD - ASTM E1845-01

