Working towards a revised MPD standard (ISO 13473-1)

a sneak-peek on the current mind set

Bo Söderling; LMI Technologies Ltd

A look back....

1985-1990 – laser sensors are established as THE TOOL for road measurements.

1988 – Selcom introduces the first generation of laser sensors dedicated to texture measurements.

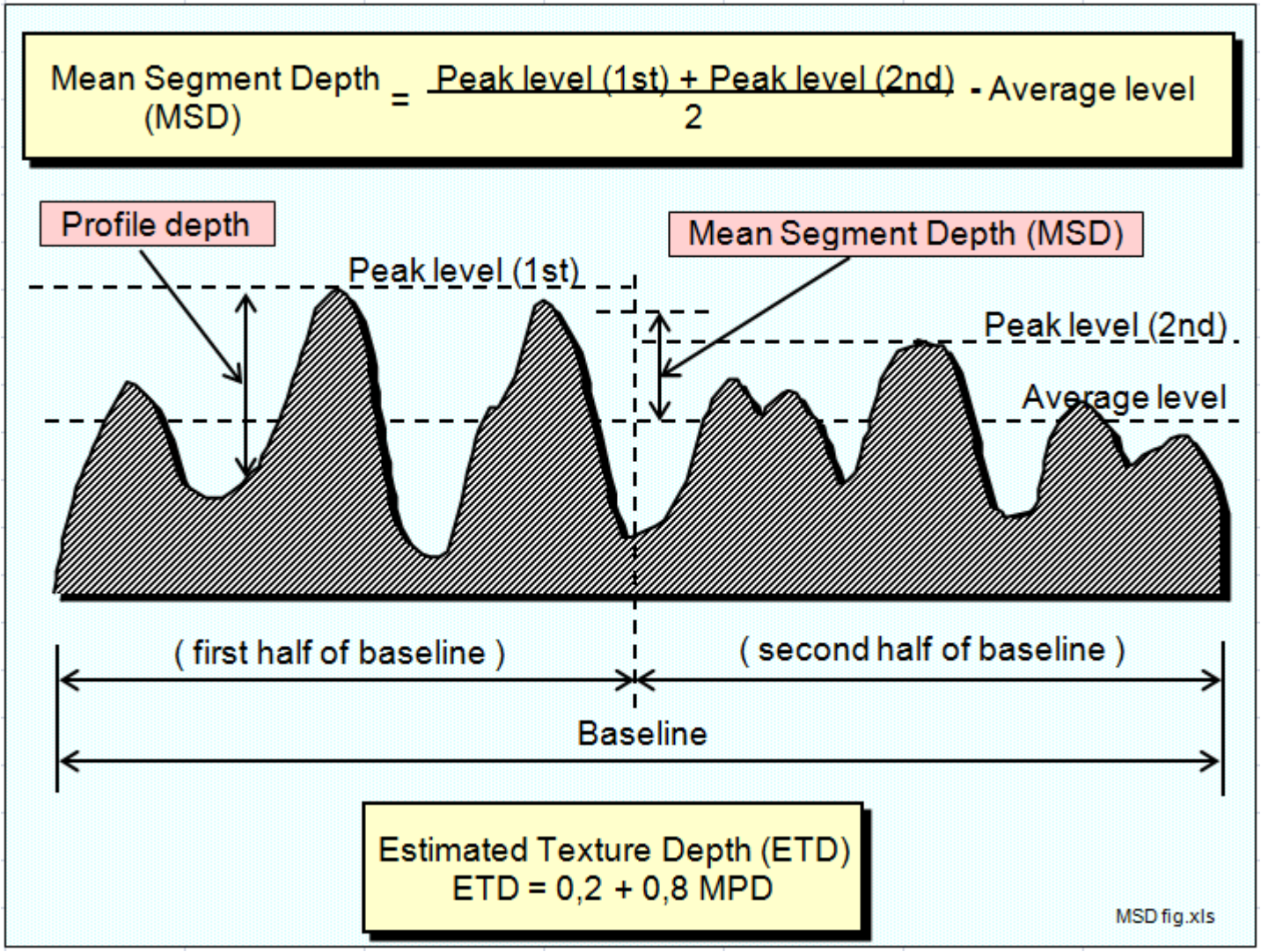
1997 – ISO 13473-1 is issued as a result of research and industry requirements to provide continuation and improvement from previous generation technologies and comparability.

1997-2011 – Industry demands drives technology towards higher sampling rates, larger MR's and smaller laser spots.

2009 – Selcom (now LMI Technologies) are invited to contribute as observers at WG39 to the revision of ISO 13473-1.

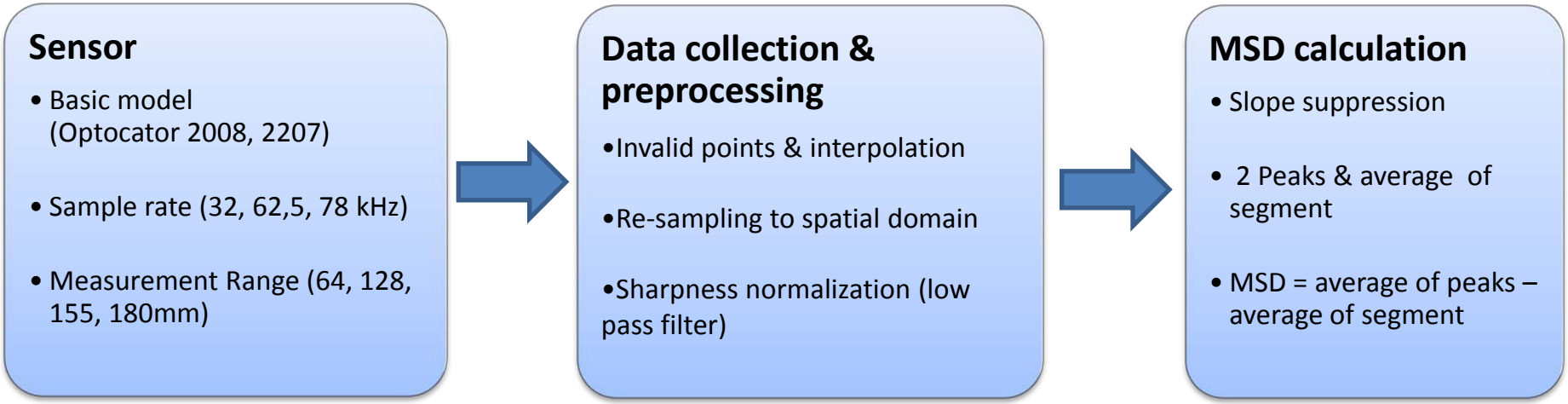
2009 - 2011– LMI participates in quarterly WG39 meetings to review the standard, identify weak points and establish improvements.

So what's it all about?



And how do we get there?

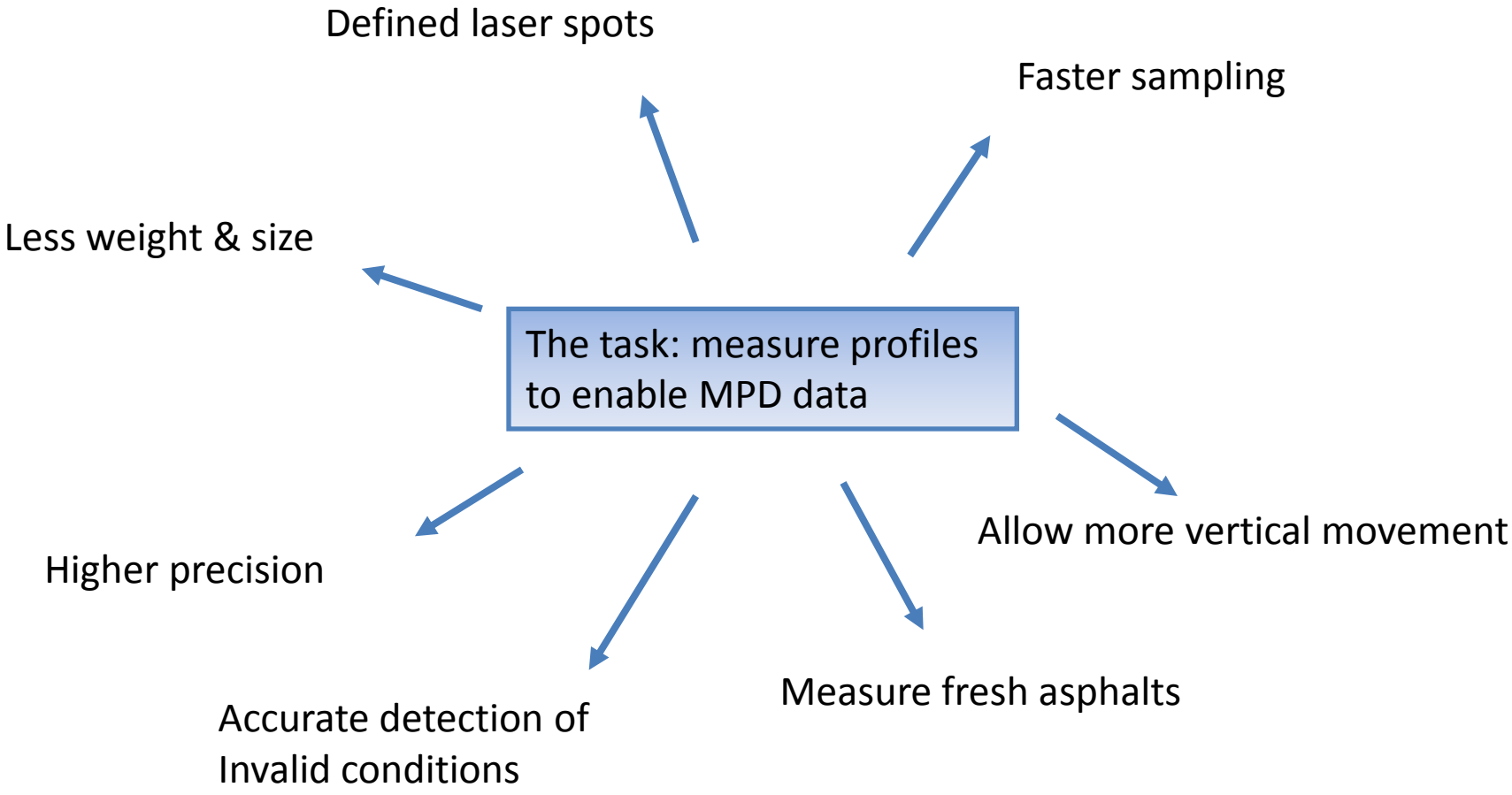
MSD/MPD; the process to get to the numbers



Sensor

- Basic type (Optocator 2008, 2207)
- Sample rate (32, 62,5, 78 kHz)
- Measurement Range (64, 128, 155, 180mm)

From the sensor stand-point...



Sensor optimization and verification

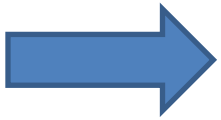
”The LMI approach”

- Establish methods to reproduce road sample discs with controlled properties.
- Develop a test system and software capable of evaluating MSD,MPD, ETD, RMS.
- Enable real road data collection from representative LMI ”test tracks”.
- Investigate the influence from various types of profile filtering.
- Benchmark, optimize and qualify products on an individual level by using results from all above.
- Improve designs based on experience from all above.

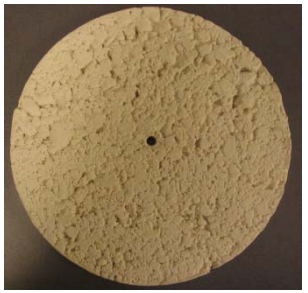
Sample disk reproduction procedure

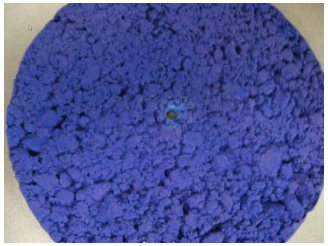
Clones with varying properties

Original

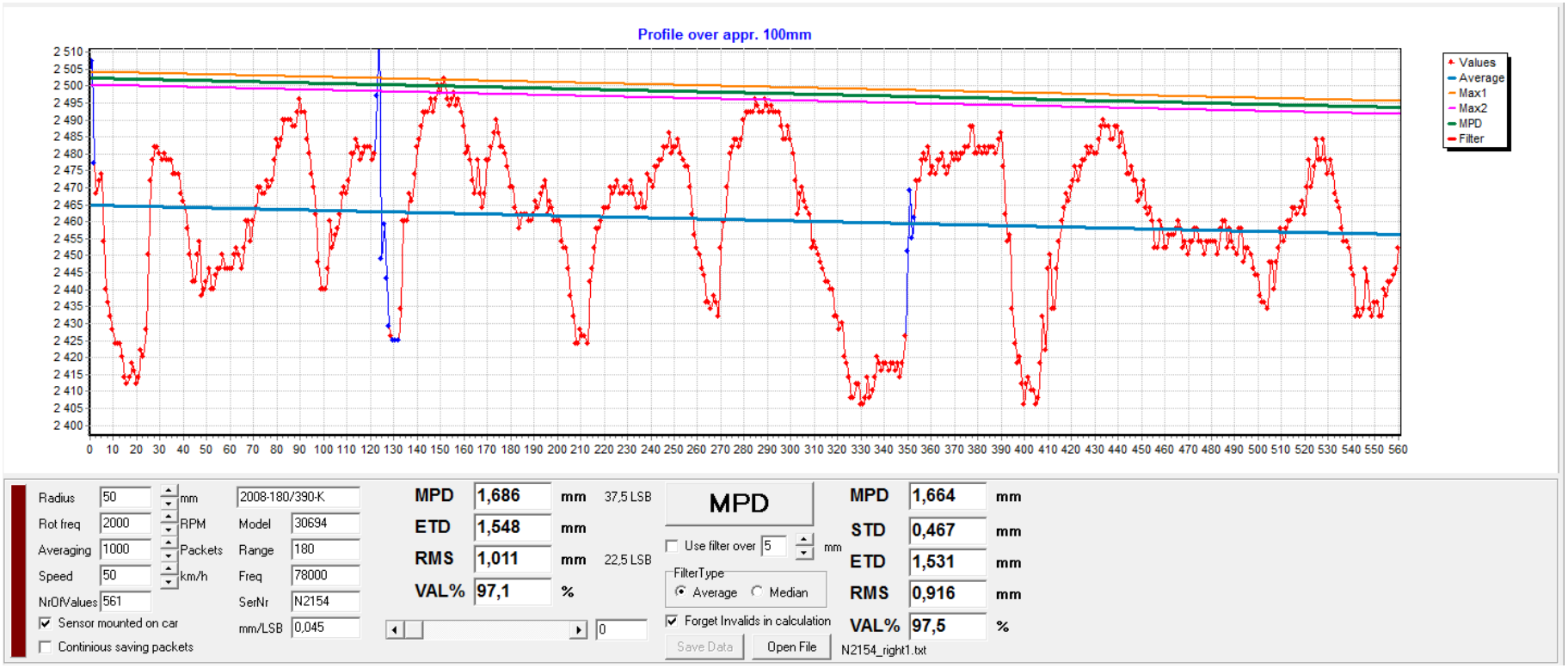


Silicone mold





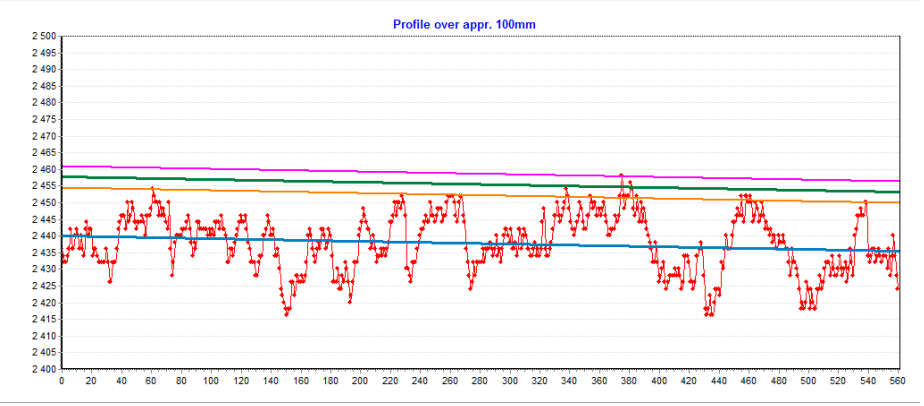
software tool for data collection & analysis

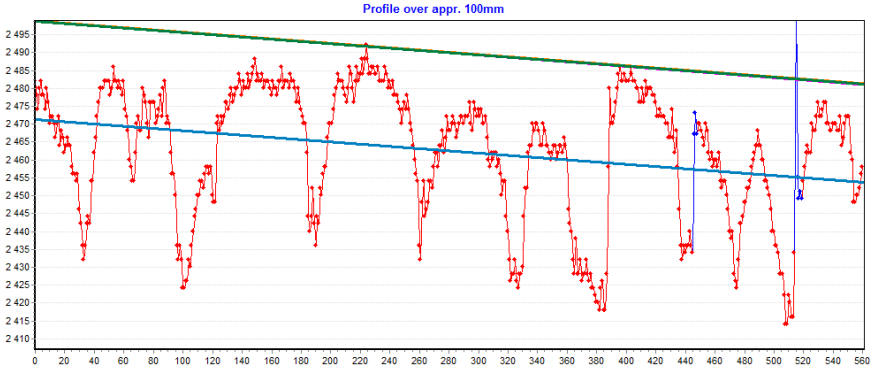


Test tracks of varying character

Site 1- MPD: 0,8 mm

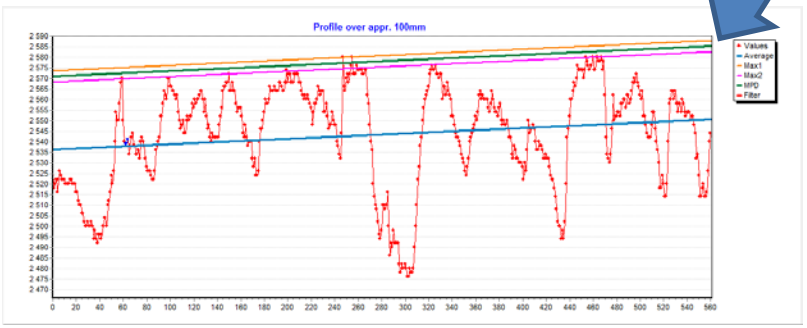
Site 2 – MPD: 1,45 mm



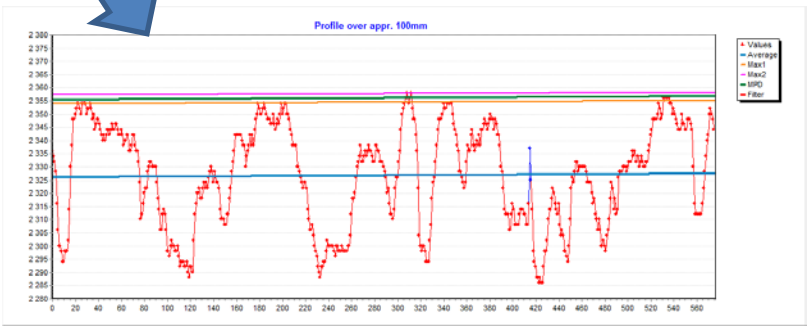


New ”High Power/Low Noise” option

- Higher power laser diodes enable higher data precision and reduced noise.
- Similar performance at 3 x speed.

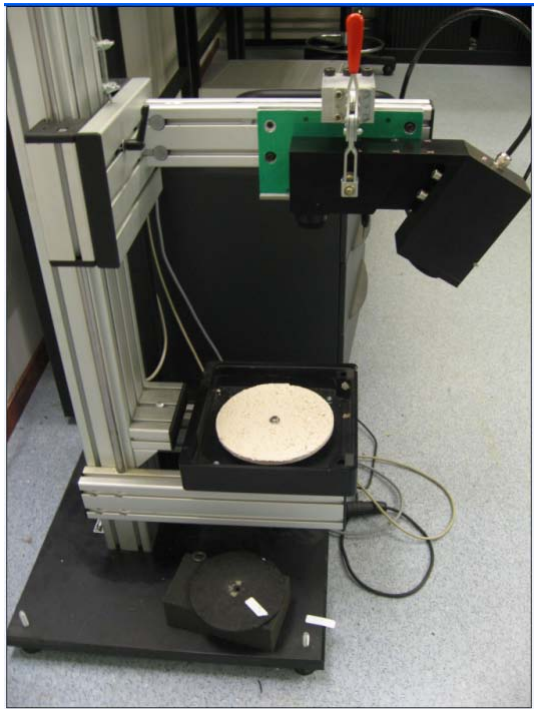


32 kHz sensor @ 20 kph



78 kHz High Power/Low Noise sensor @ 60 kph

Lab and ”live” ; LMI sensors are verified!



WG 39 proposes:

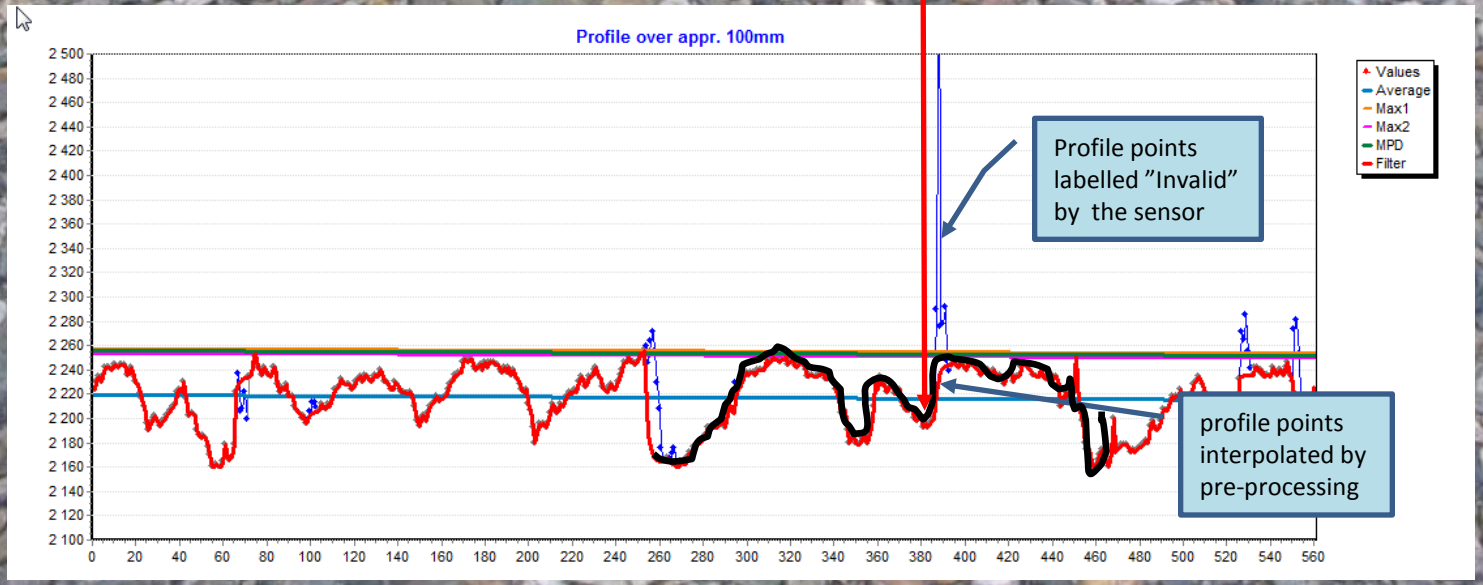
To be continued.....

Data collection & preprocessing

- Invalid points & interpolation
- Re-sampling to spatial domain
- Sharpness normalization (low pass filter)

Optical phenomena may blind the sensor

- occlussions
- ”impossible” slopes
- fresh asphalt



Drop-out identification and interpolation

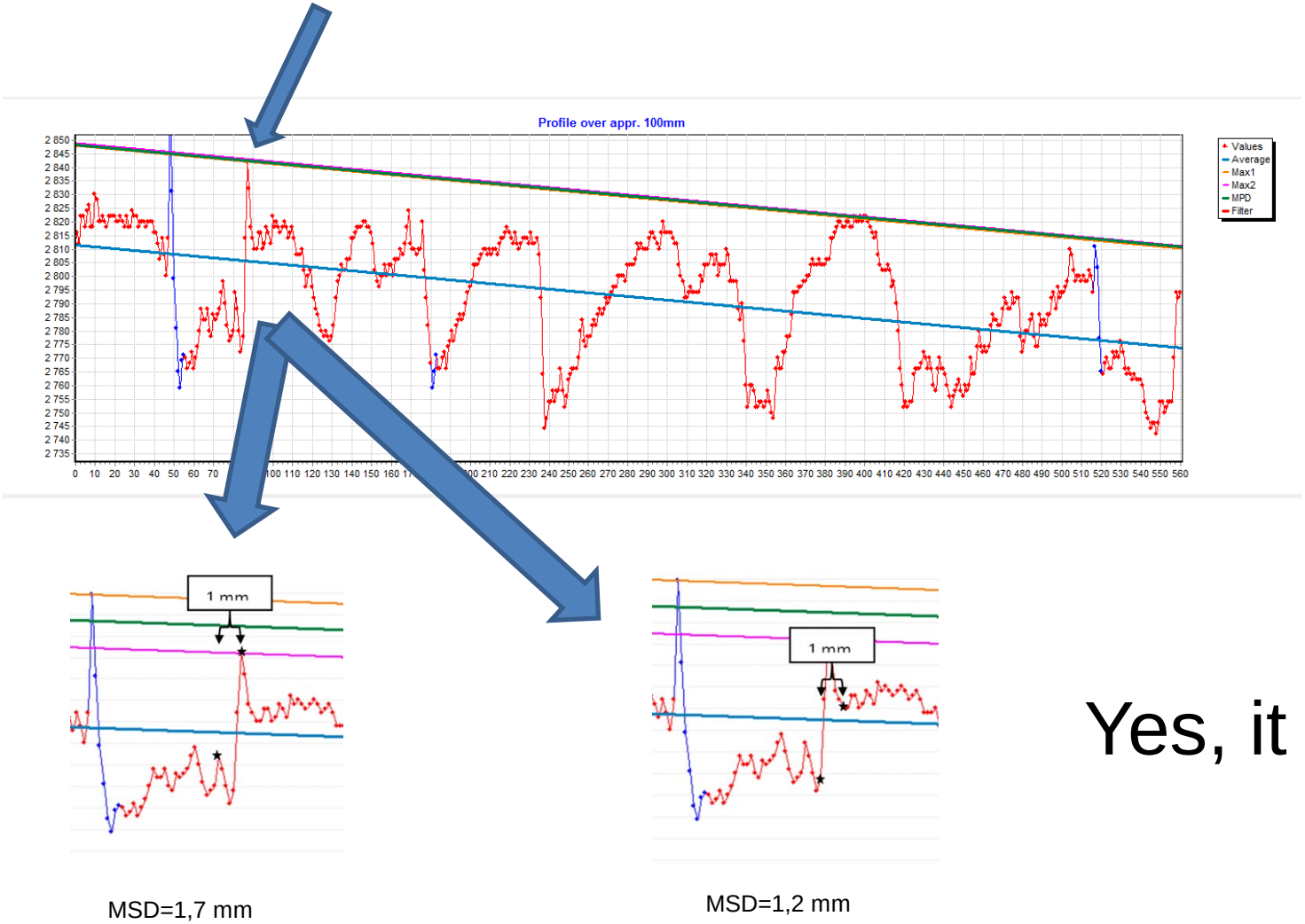
WG 39 proposes:

- Mandatory sensor detection of ”not enough light received” situations.
- Mandatory inclusion of bordering samples in Invalid data sections.
- Mandatory linear interpolation to fill in data in in Invalid data sections.

Data collection & preprocessing

- Invalid points & interpolation
- Re-sampling to spatial domain
- Sharpness normalization (low pass filter)

Re-sampling data; does it matter how you do it?



MSD=1,7 mm

MSD=1,2 mm

Yes, it does!

WG39 proposes:

- Mandatory re-sampling to 1 mm point spacing with a (new) option for 0,5 mm point spacing when sensor data is sampled at higher than 0,5 mm density

- Mandatory usage of available valid sensor data in re-sampled profile points at 1 mm or 0,5 mm spacing.

Data collection & preprocessing

- Invalid points & interpolation
- Re-sampling to spatial domain
- Sharpness normalization (low pass filter)

The standard demands:

”The response shall be basically flat within 5 mm to 50 mm texture wavelength , and spectral components with wavelengths greater than 100 mm and lower than 2,5 mm shall be significantly reduced”

”the process shall remove spatial frequency components which are above 400 m^{-1} (cycles/m), corresponding to a wavelength of 2,5 mm, but not affect spatial frequencies below 200 m^{-1} , corresponding to a wavelength of 5 mm (at least -3 dB at 2,5 mm and at most -1 dB at 5 mm with a slope of at least -6 dB/octave)”

So what are the properties that may vary?

- Type of filter
  - Butterworth, Bessel, Moving average, Median, complex FIR...?
- Cut-off wavelength
  - 1mm, 2 mm, 3 mm ...?
- Steepness
  - 6 dB/oktave, 12 dB/oktave...?

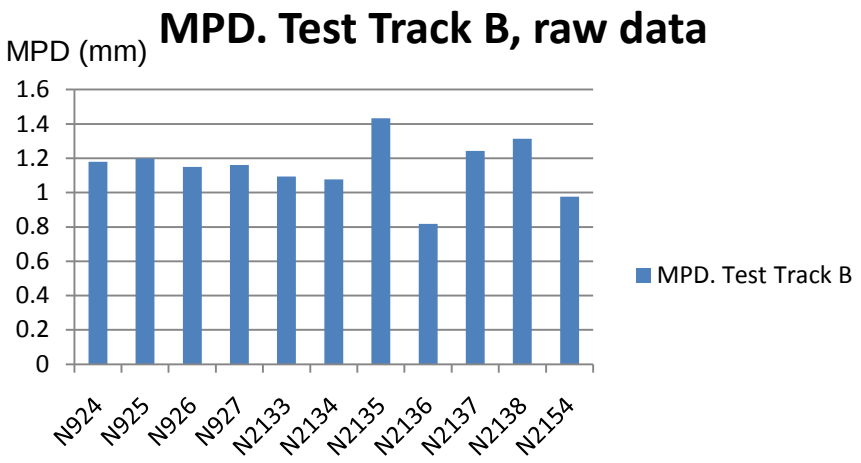
And how do they influence MPD?

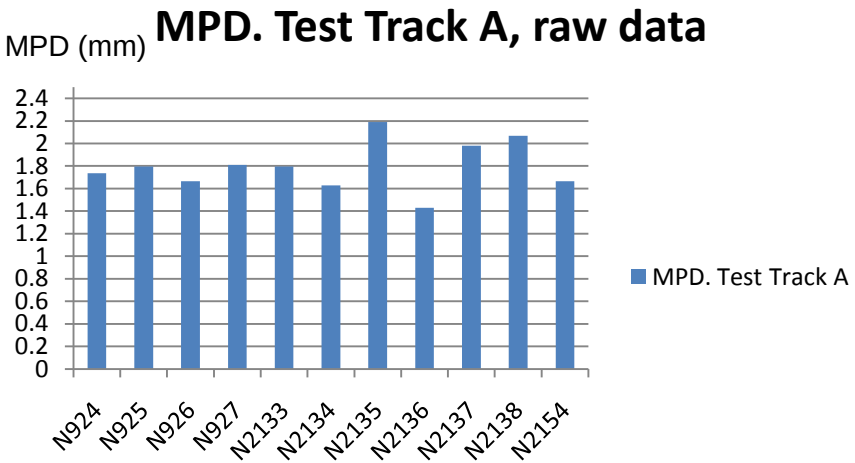
Sensor data recorded by LMI and analyzed
by Alejandro Amirola Sanz (Acciona)
& Bo Söderling (LMI Technologies)

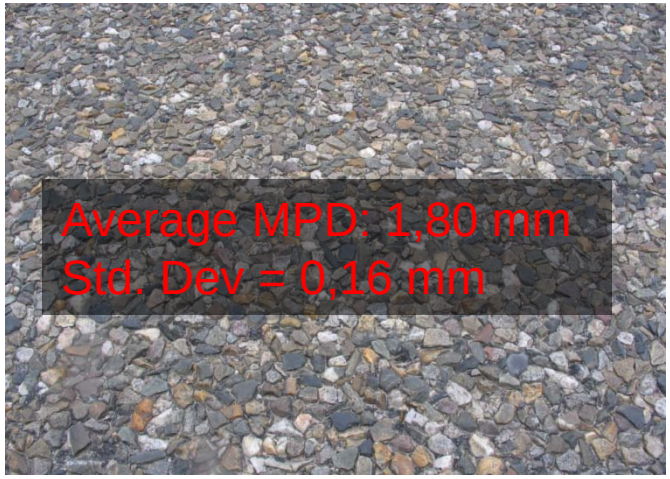
- Data from 10+ sensor models.
  - 2207 & 2008 models
  - 32, 62,5 & 78 kHz
  - 128, 155 & 180 mm MR
- Data recorded on known test tracks.

- Data recorded over a relevant speed span. 40, 50 & 90 km/H

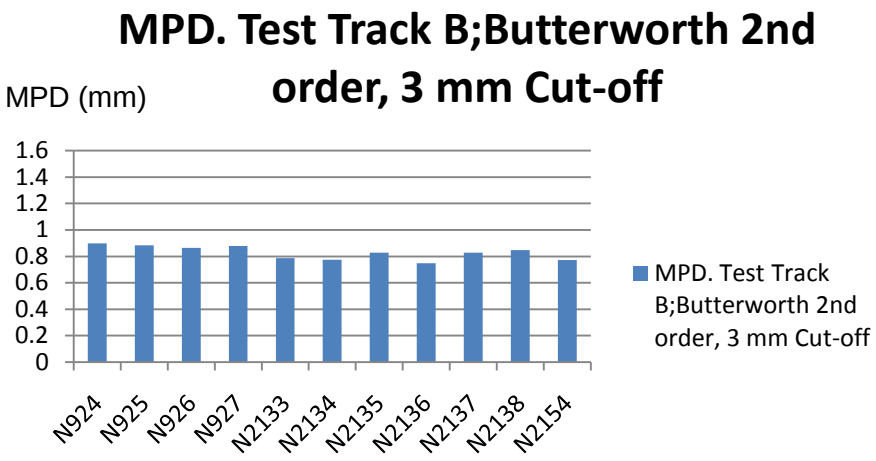
No filtering vs. a ”simple” filter

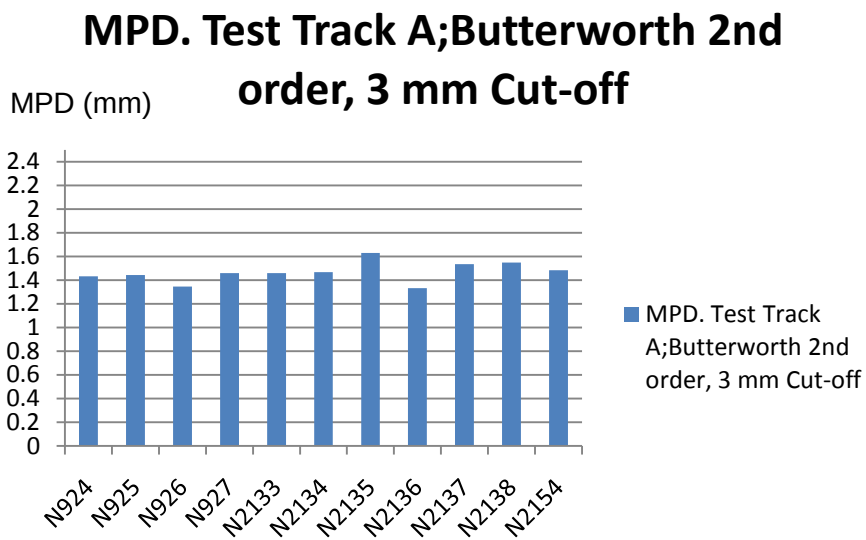






A Butterworth 2nd order, 3 mm Cut-off

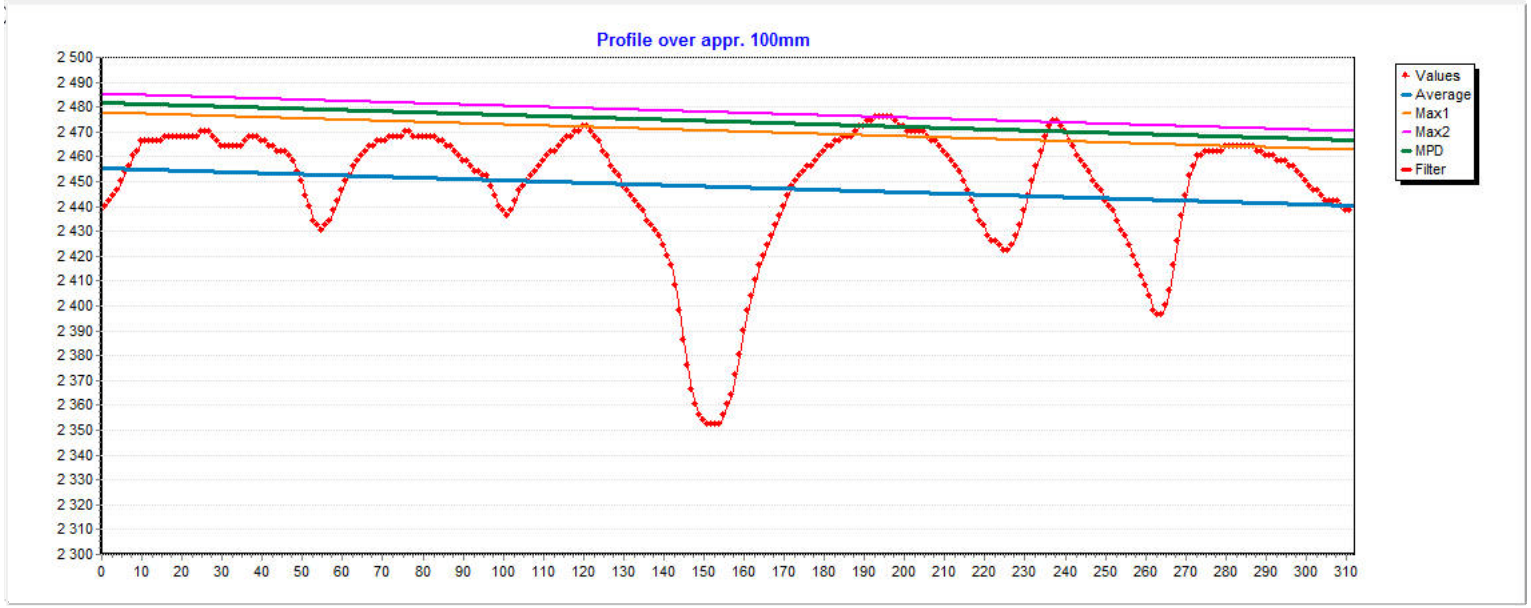




Filter cut-off: 0 – 5 mm

- 2008-180/390 High Power/Low Noise
- 78 kHz Sampling
- 90 km/hour
- Newly laid asphalt

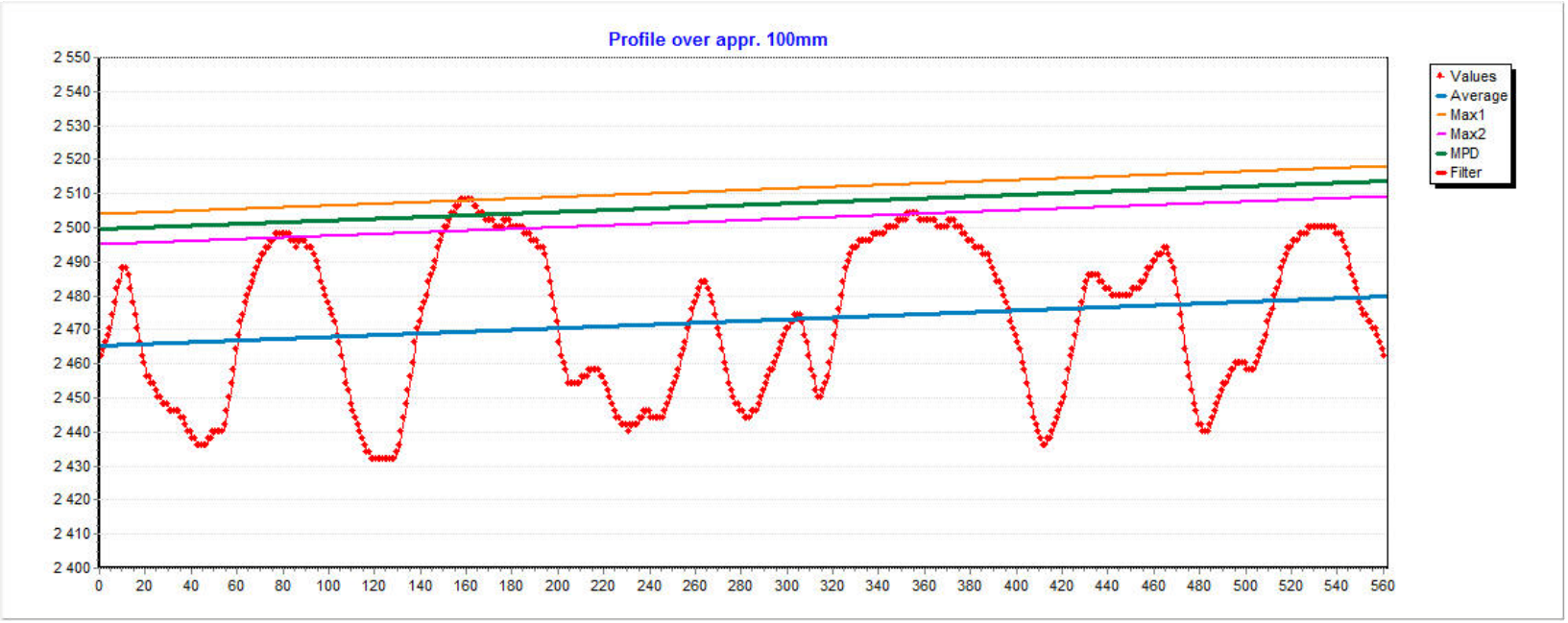
Raw data	1 mm	2 mm	3 mm	4 mm	5 mm
MPD:1,64 mm	1,66 mm	1,54 mm	1,47 mm	1,42 mm	1,38 mm



Filter cut-off: 0 – 5 mm

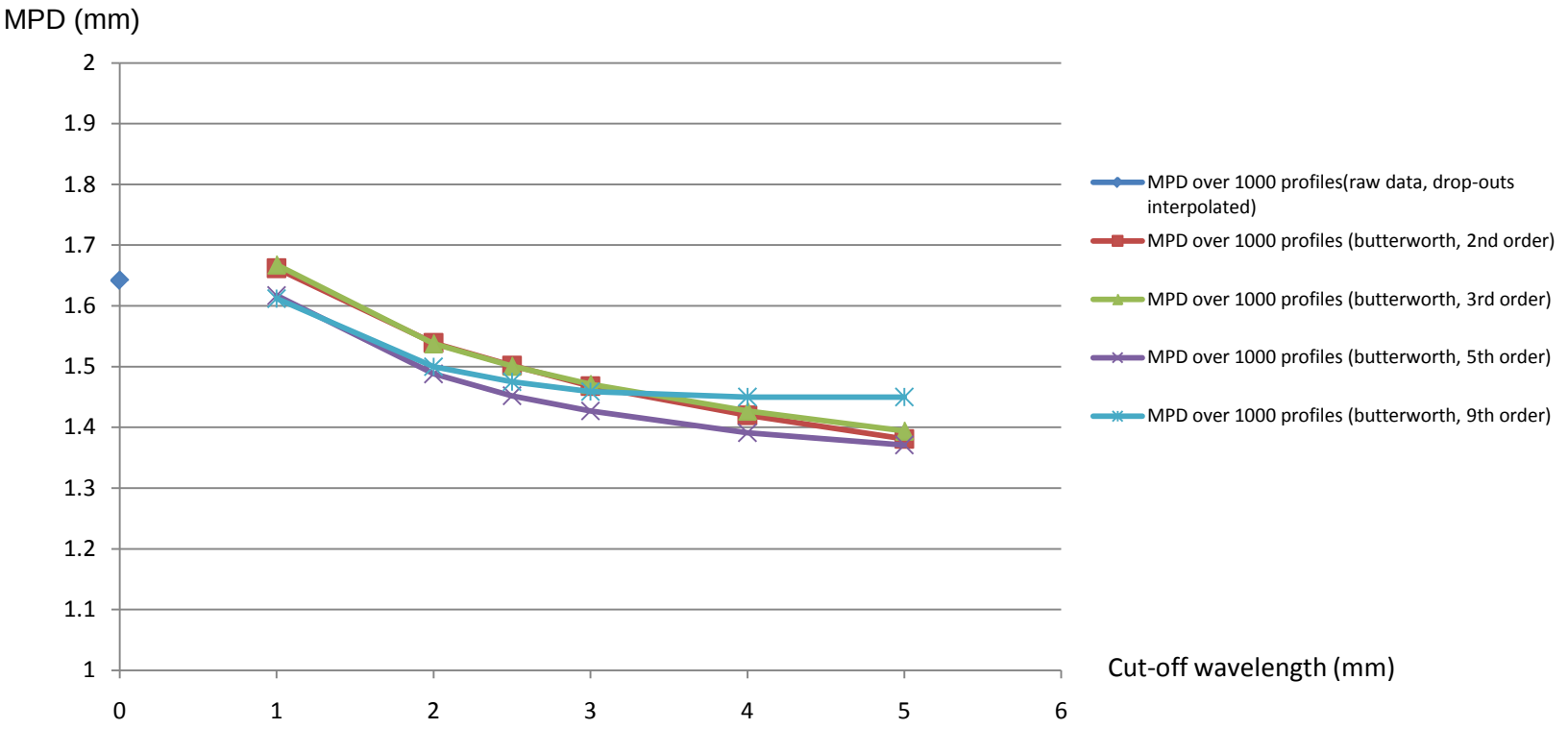
- 2008-180/390 (N2138)
- 62,5 kHz Sampling
- 40 km/hour
- Test site 2

Raw data	1 mm	2 mm	3 mm	4 mm	5 mm
MPD: 2,02 mm	1,81 mm	1,6 mm	1,48 mm	1,41 mm	1,35 mm



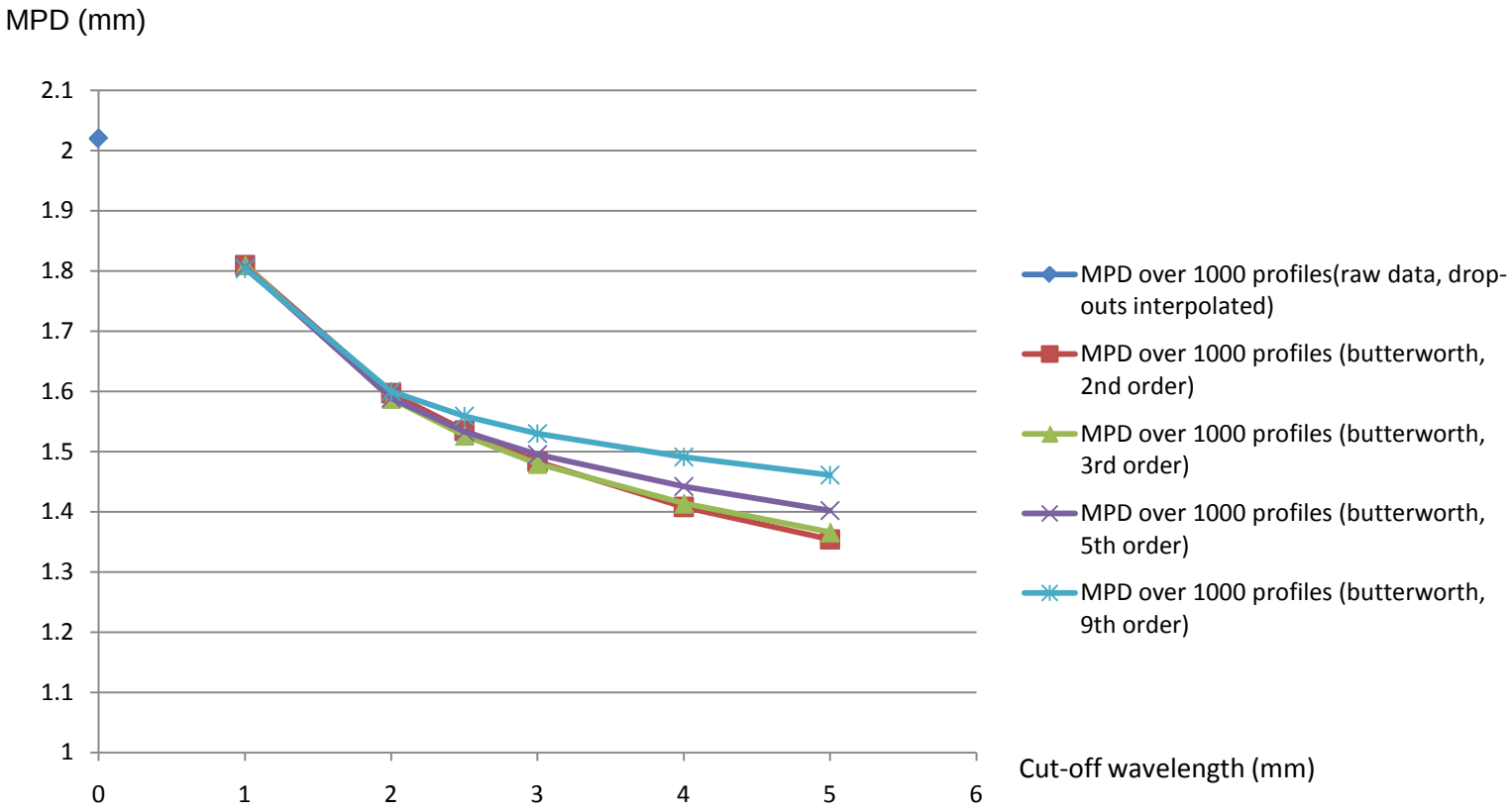
And the filter order...

- 2008-180/390 High Power/Low Noise (N2154)
- 78 kHz Sampling
- 90 km/hour
- Newly laid asphalt



And the filter order...

- 2008-180/390 (N2138)
- 62,5 kHz Sampling
- 40 km/hour
- Test site 2



Conclusions:

- Profile filtering normalizes results between sensor models.
- Filter cut-off definition has significant impact on MPD data
- Filter order has less impact

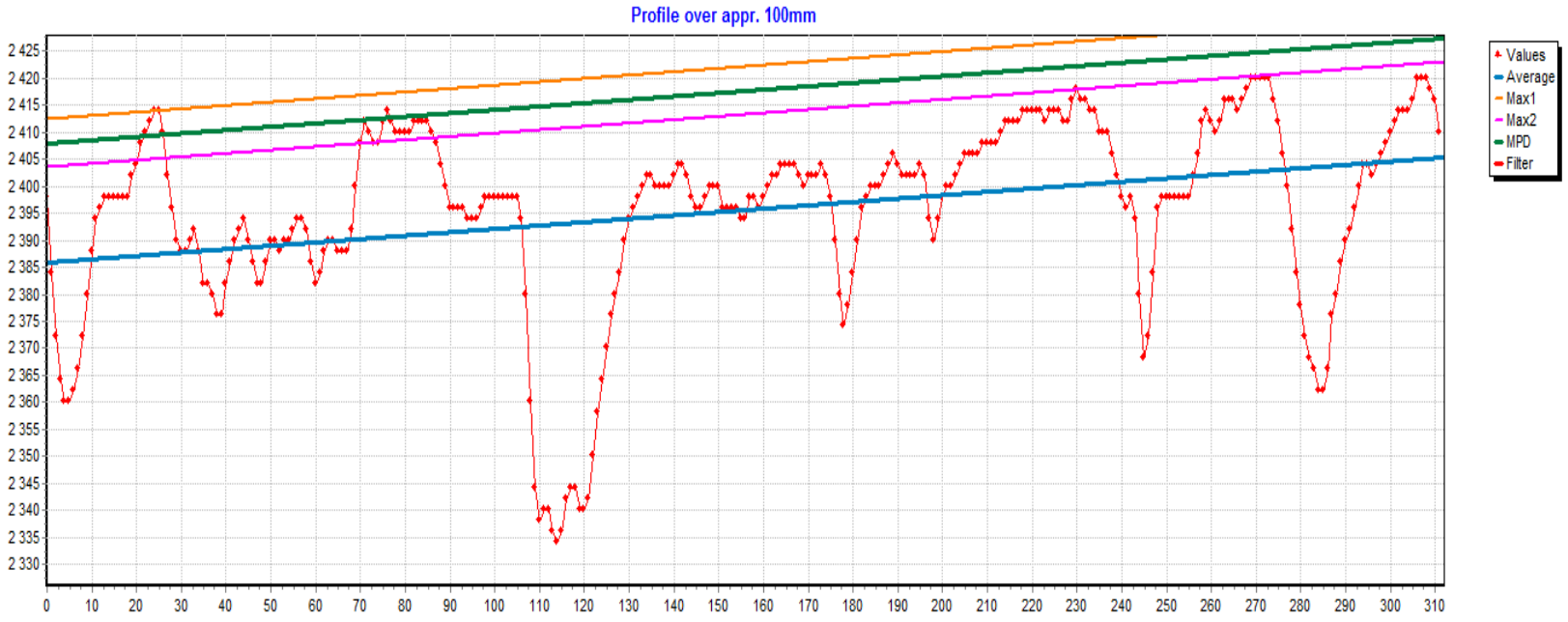
WG39 proposes:

- A mandatory and well defined filter implementation to be included in the standard
- Details TBD but simple (low order) rather than complex preferred.

MSD calculation

- Slope suppression
- 2 Peaks & average of segment
- MSD = average of peaks – average of segment

Slope suppression; a recent improvement



WG39 proposes:

- Slope suppression to become a mandatory procedure.

Thank you!