

Welcome to
a new dimension!



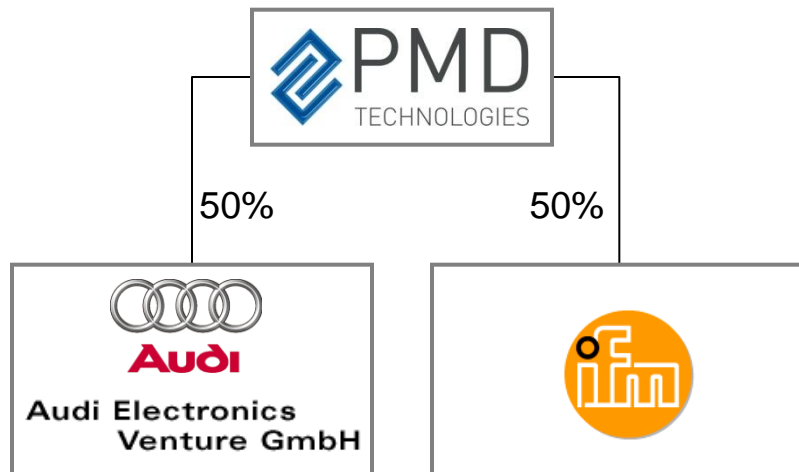
Discovering new dimensions – with PMDTec!

Are 40k pixels enough for everyone?

*Challenges and opportunities for PMD depth sensing technology in
the consumer market*

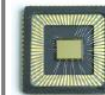
PMDTechnologies GmbH

Company & Shares



- ▶ **Founded:** 2002
- ▶ **Headquarters:** Siegen, Germany
- ▶ **Employees:** > 40
- ▶ **International patents:** > 40
- ▶ **Core competencies:**
 - CMOS Chip design
 - Chip test & qualification capabilities
 - Optics design
 - 3D Sensor modules & cameras

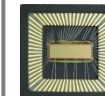
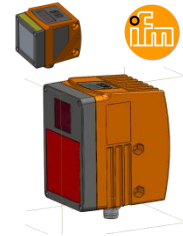
Current Products & Markets



Industrial

64x48; 160x120 Pixel

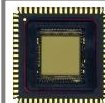
- ▶ Mass production since 2005
- ▶ Several 100.000 sensors in use



Automotive

64 x16; 160x120 Pixel

- ▶ Testing & qualification done
- ▶ 3rd generation built-in vehicle

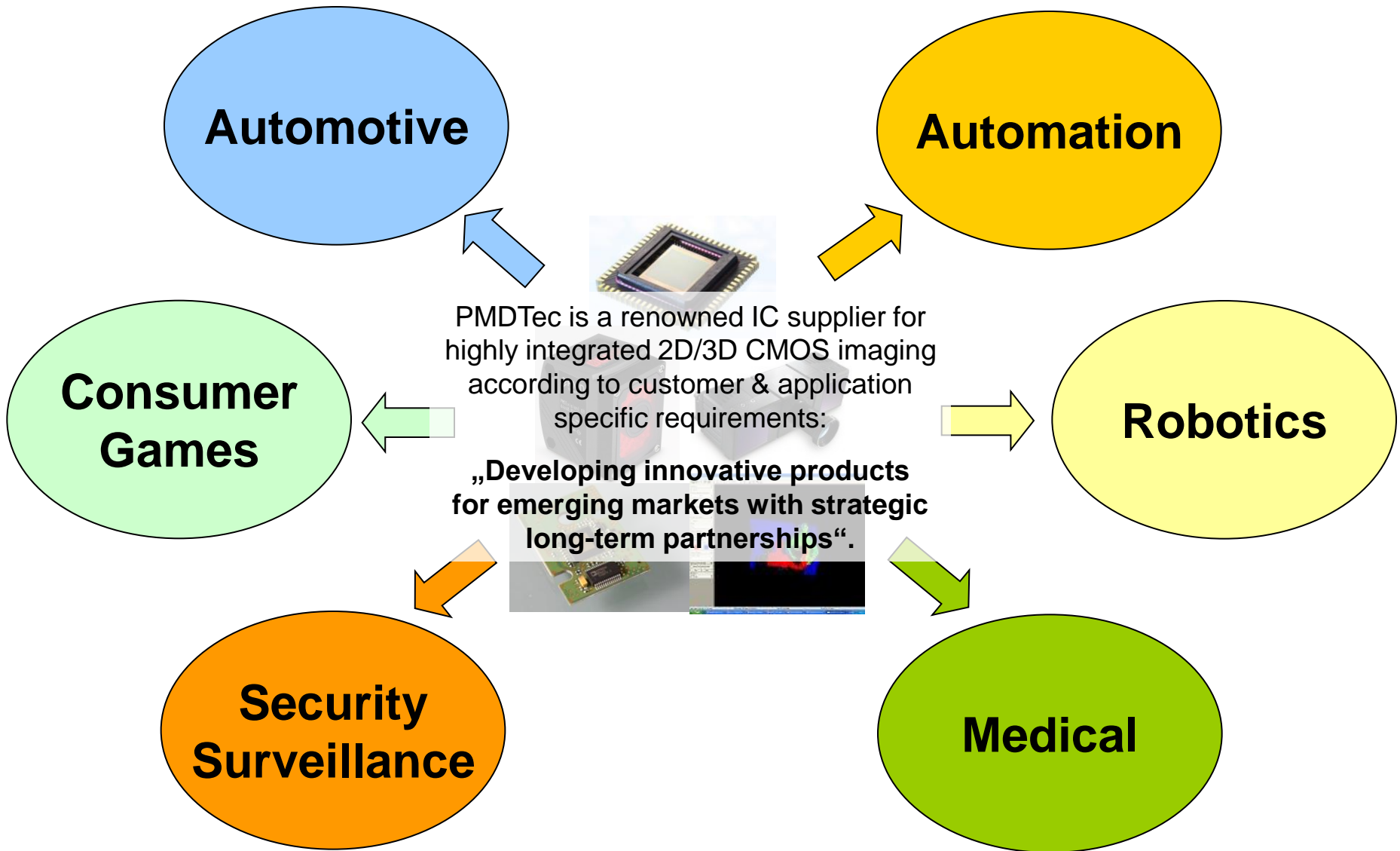


Consumer

200x200; >QVGA Pixel

- ▶ 100.000 gray scale & distance values in each pixel





A frequently heard statement:

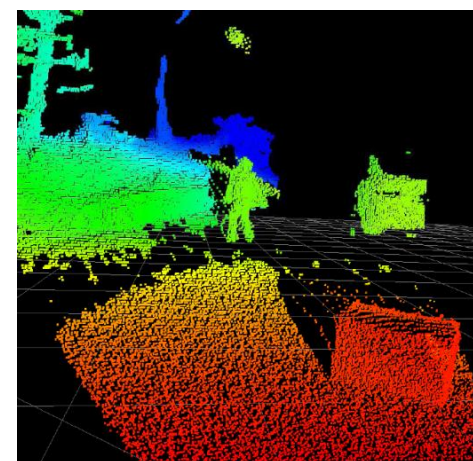
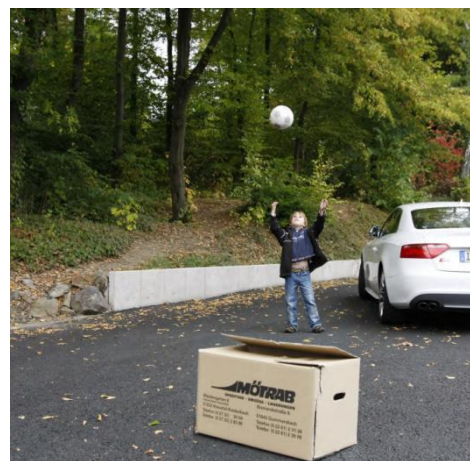
„ToF cameras provide a low lateral resolution...“

What is the issue with the resolution:

- 2D computer vision community is used to at least VGA resolution
- Computer vision algorithms are developed and well understood for higher resolutions (edge detection, calibration, etc)
- More ToF pixels → Smaller ToF pixels → Non-beneficial effect on the optical power budget

$$\Delta L = \frac{L}{360^\circ} \cdot \Delta\varphi = \frac{L}{\sqrt{8}} \cdot \frac{\sqrt{B}}{2 \cdot A}$$

ΔL ... Distance resolution
 L ... Non-ambiguity range
 B ... Background light + DC of active light
 A ... Amplitude of active light



A chip supplier's point of view:

Increasing the lateral resolution of a ToF chip ...

- ... leads to various technological challenges (time=money)
- ... is a door-opener for certain applications and market segments



The question is: Is there a sufficient market volume for „HD“ ToF sensors?

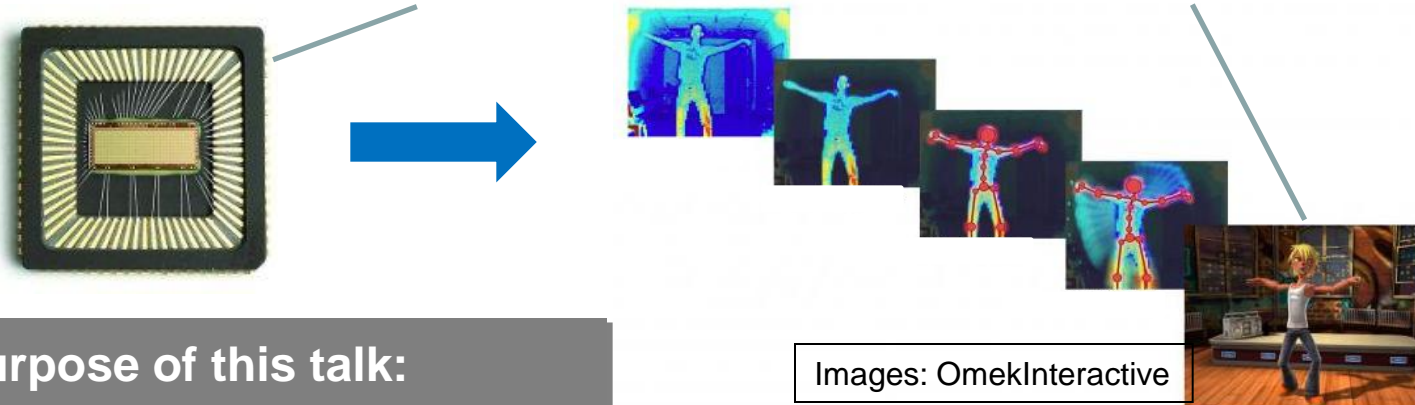
Famous volume estimations for other markets:

*"There is no reason for any individual to have a computer in his home."
Ken Olson, President of DEC, 1977*

"So I repeat that while theoretically and technically television may be feasible, yet commercially and financially I consider it an impossibility; a development of which we need not waste little time in dreaming."
Lee DeForest, Father of the electronic age, 1926

Lessons learned:

1. Future chip roadmaps need a clear vision of what the market needs.
2. Careful consideration of customer requests.
3. Customers do not buy a **chip** or a depth map, but a **functionality/application**.

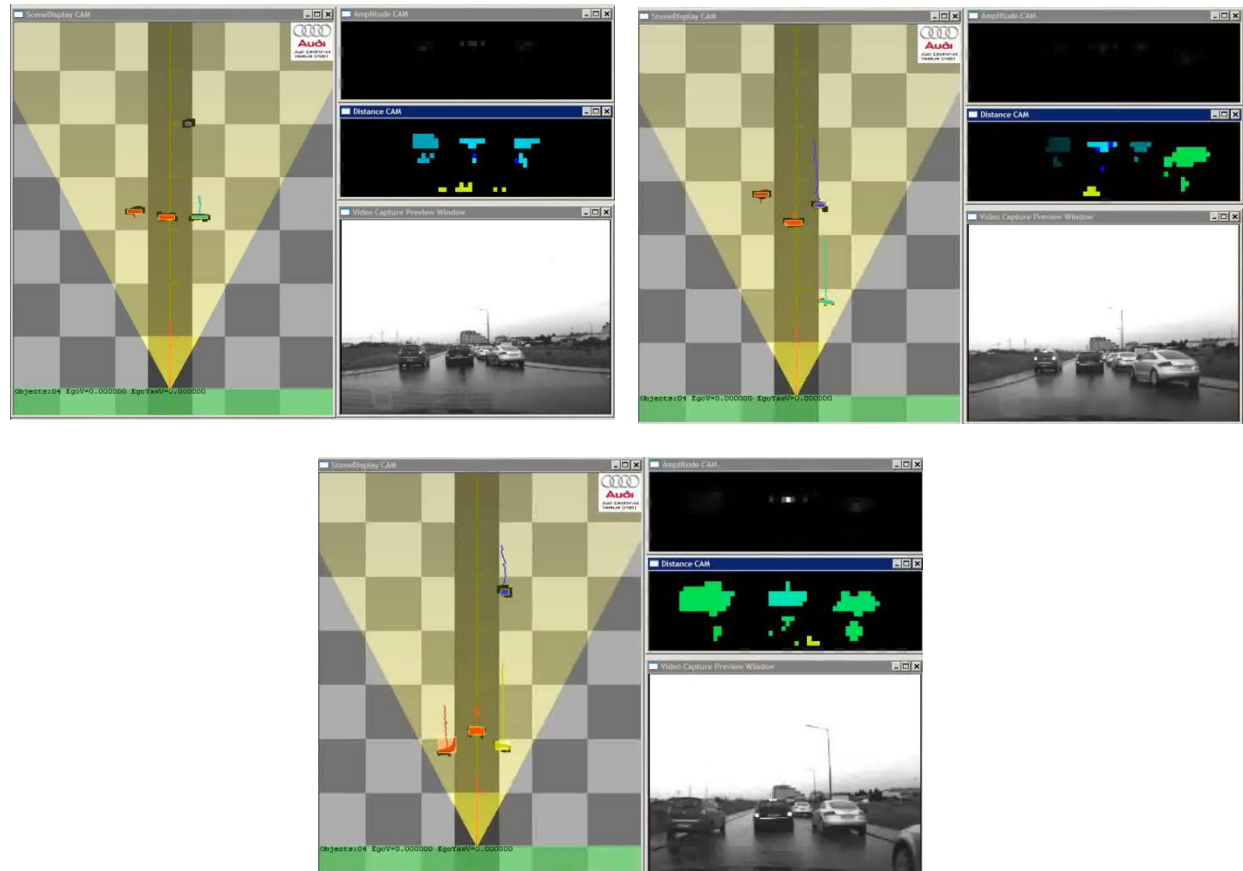


Purpose of this talk:

1. Illustrate various applications of PMD's technology in various markets and various lateral resolutions.
2. Draw conclusions on future chip resolutions and their potential in the consumer market.

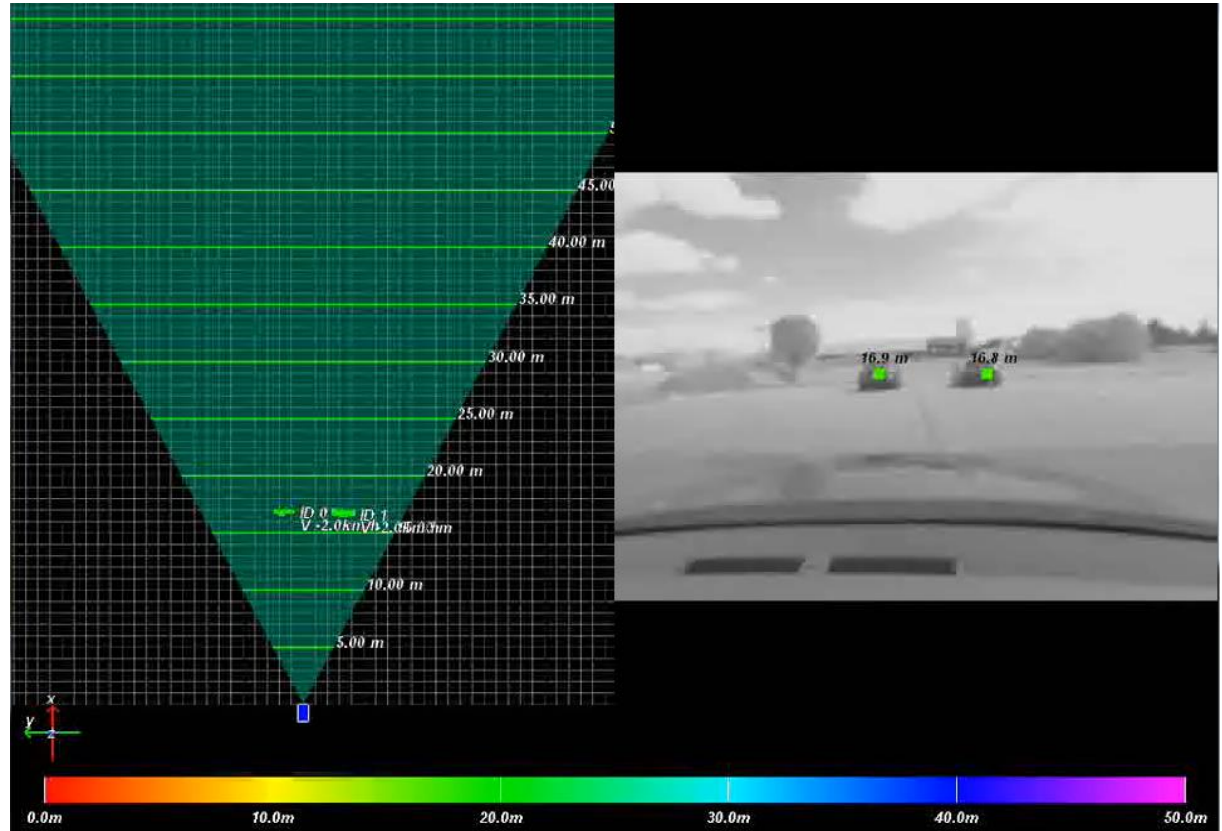
What is possible with 64x16 pixels?

- Object recognition and tracking under tough outdoor conditions (wet street)



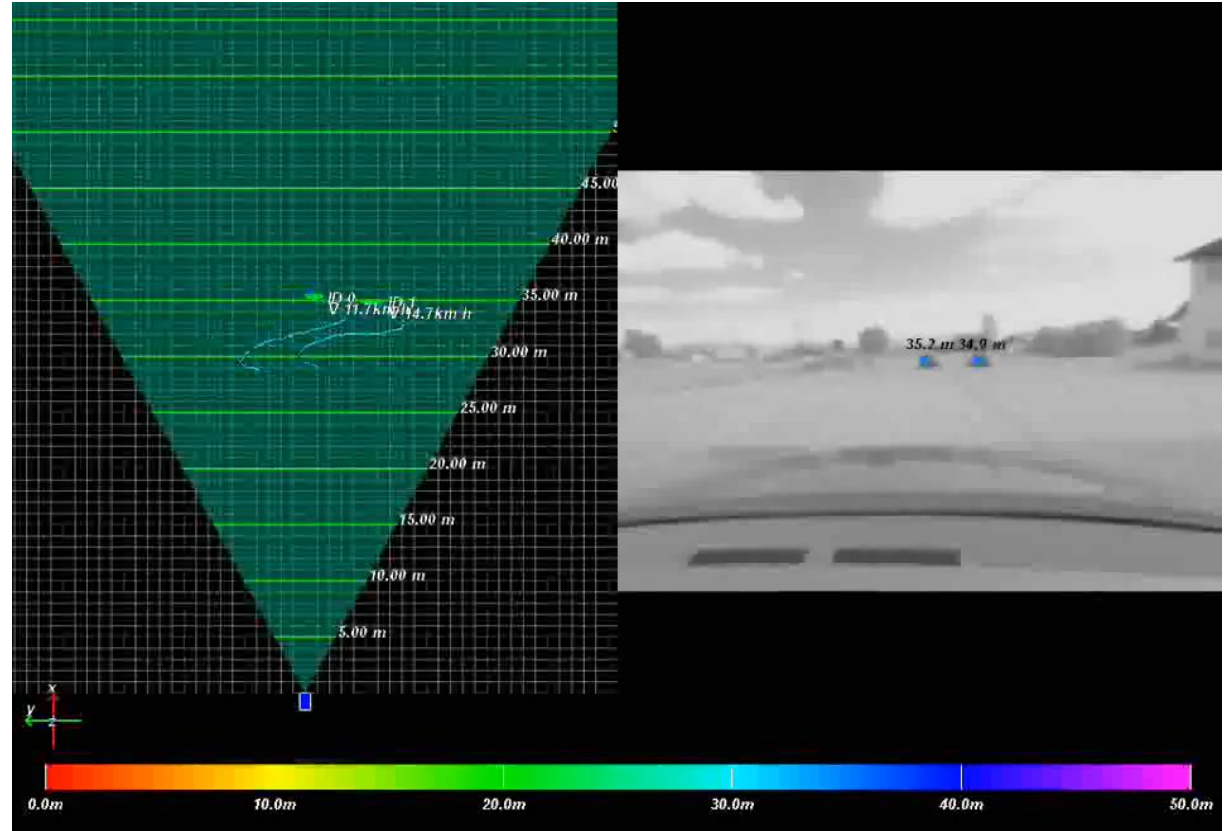
What is possible with 64x16 pixels?

- Object detection and tracking for large measurement ranges of >40m in sunlight
- Separation and classification of objects for pre-crash sensing



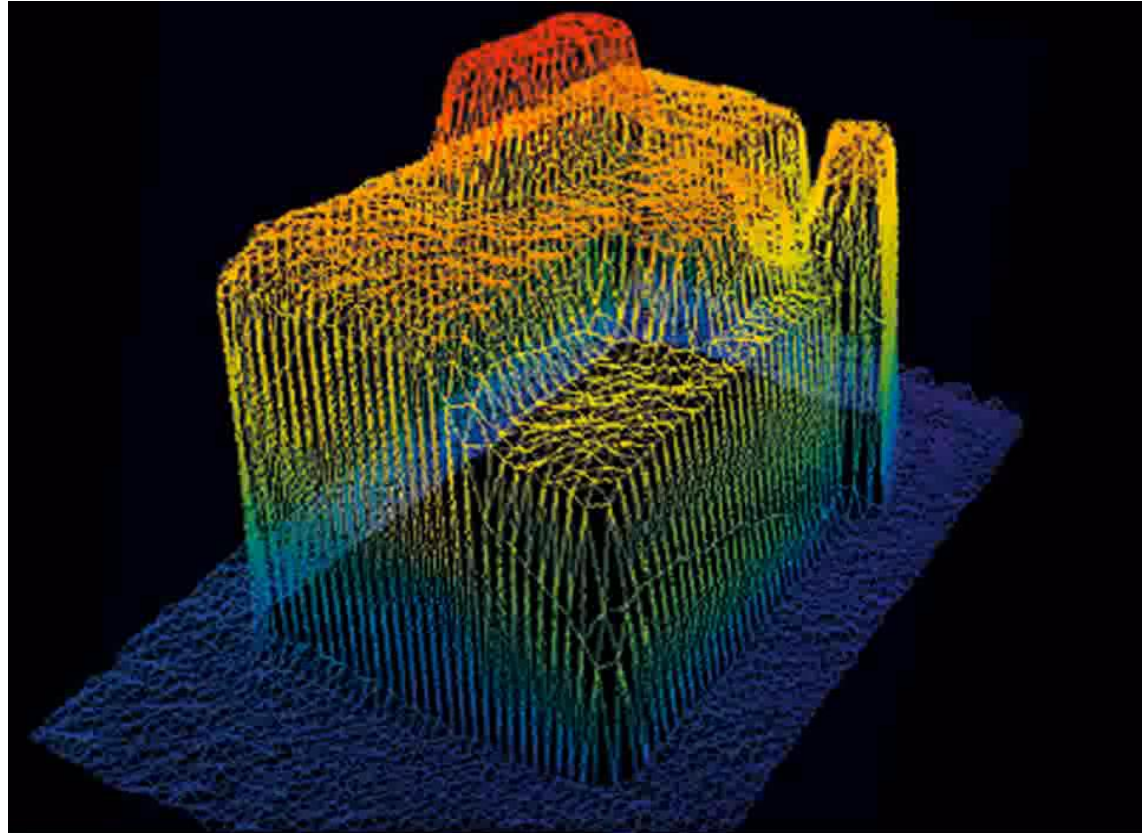
What is possible with 64x16 pixels?

- Object detection and tracking for large measurement ranges of >40m in sunlight
- Separation and classification of objects for pre-crash sensing



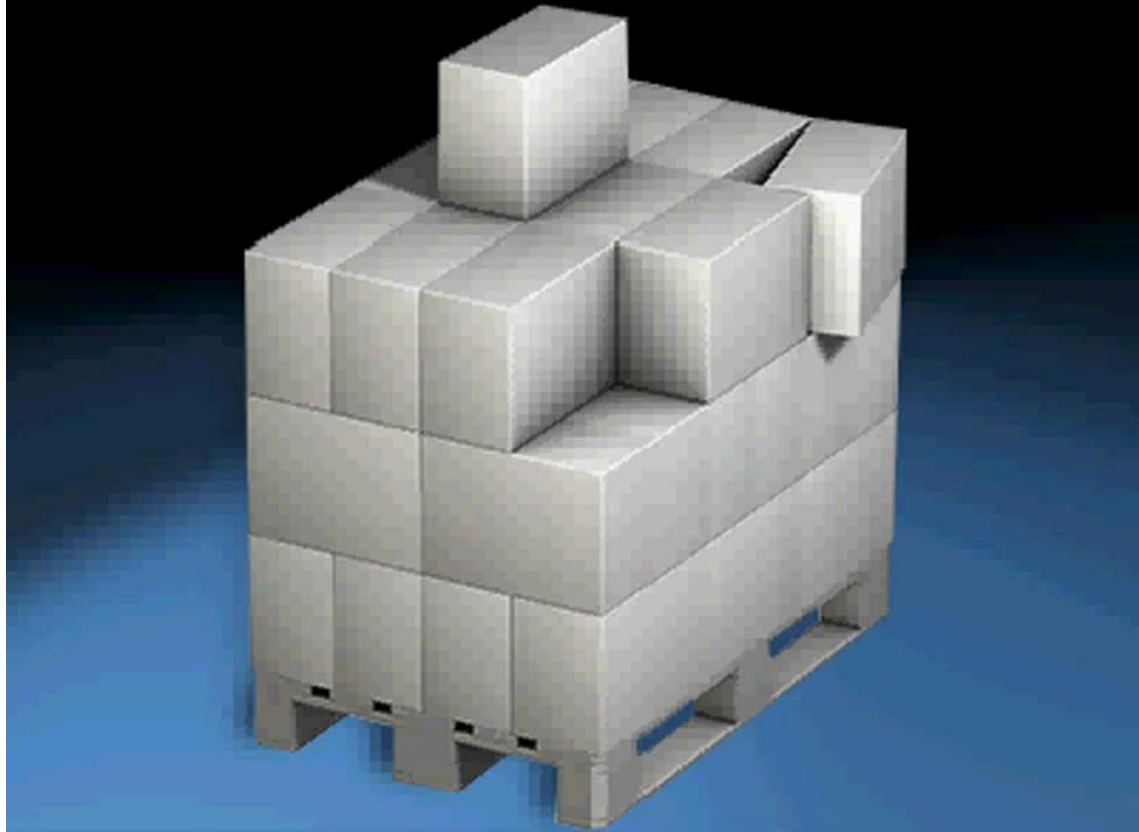
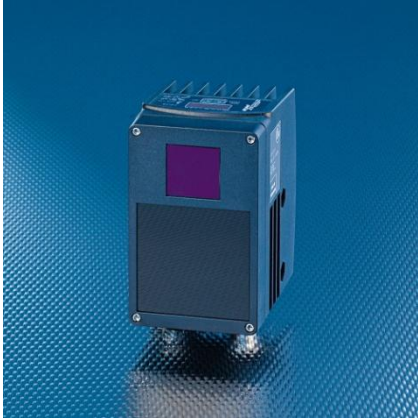
What is possible with 64x48 pixels?

- Intelligent bin-picking, out-of-place detection, ...



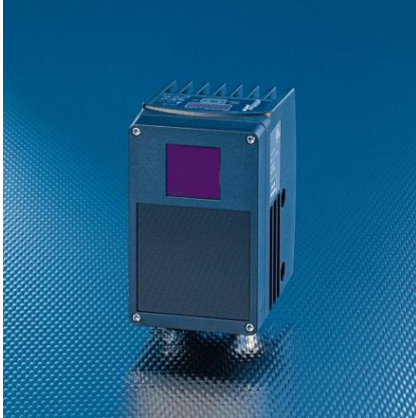
What is possible with 64x48 pixels?

- Intelligent bin-picking, out-of-place detection, ...



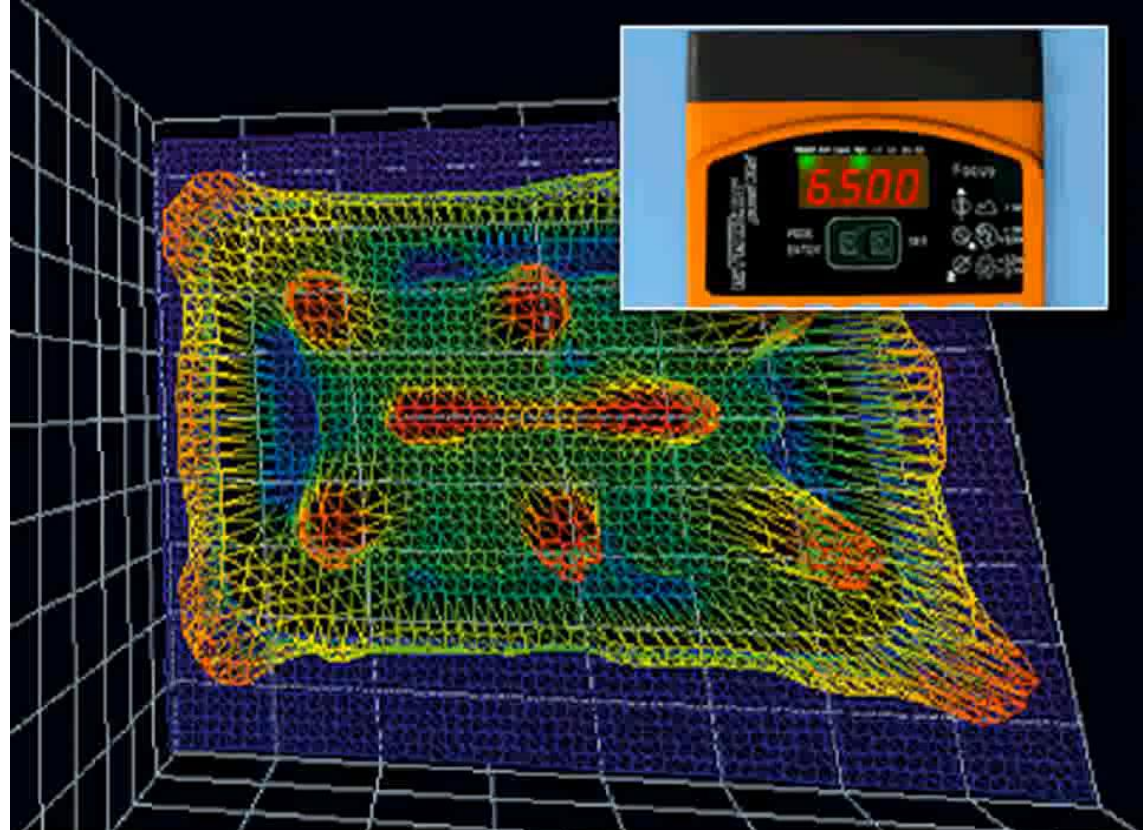
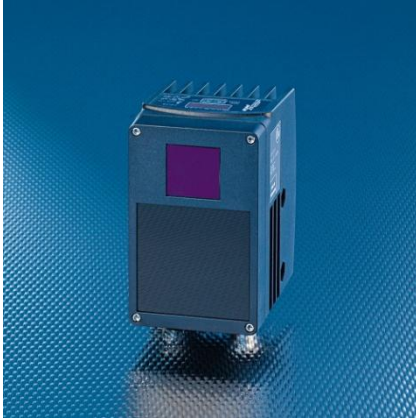
What is possible with 64x48 pixels?

- Intelligent bin-picking, out-of-place detection, ...



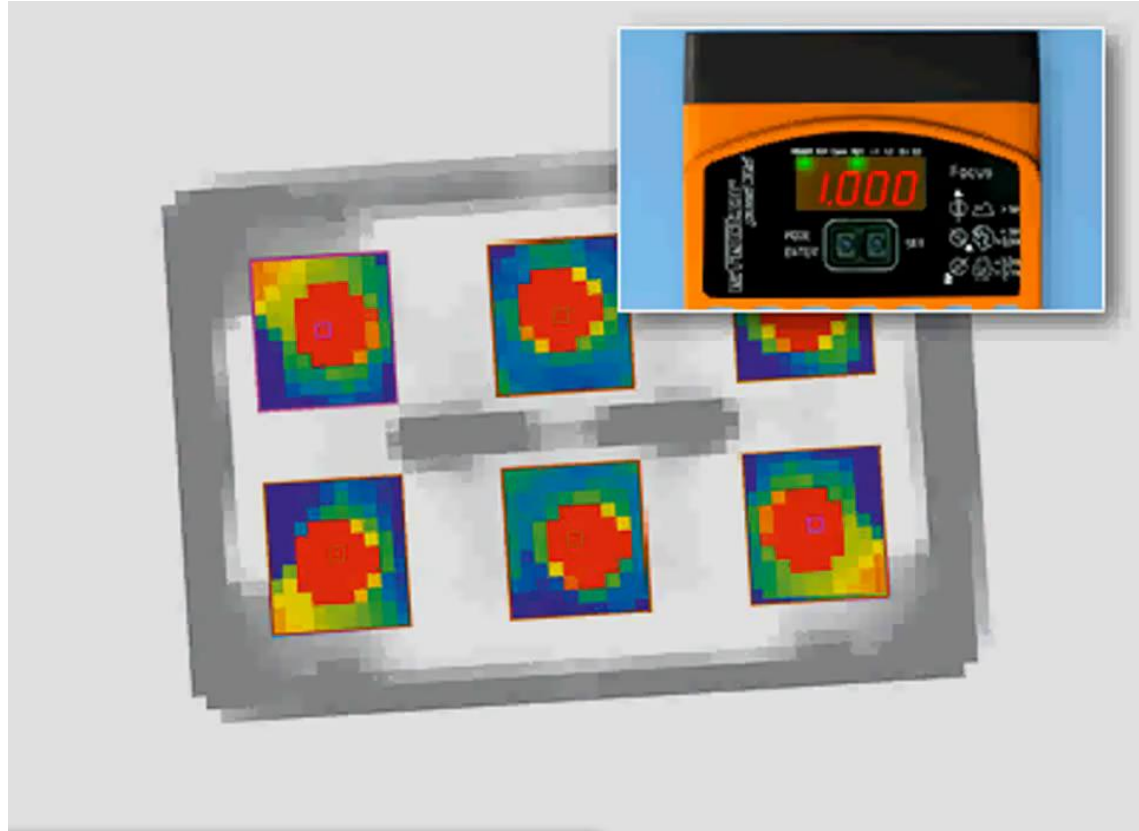
What is possible with 64x48 pixels?

- Intelligent bin-picking, out-of-place detection, ...



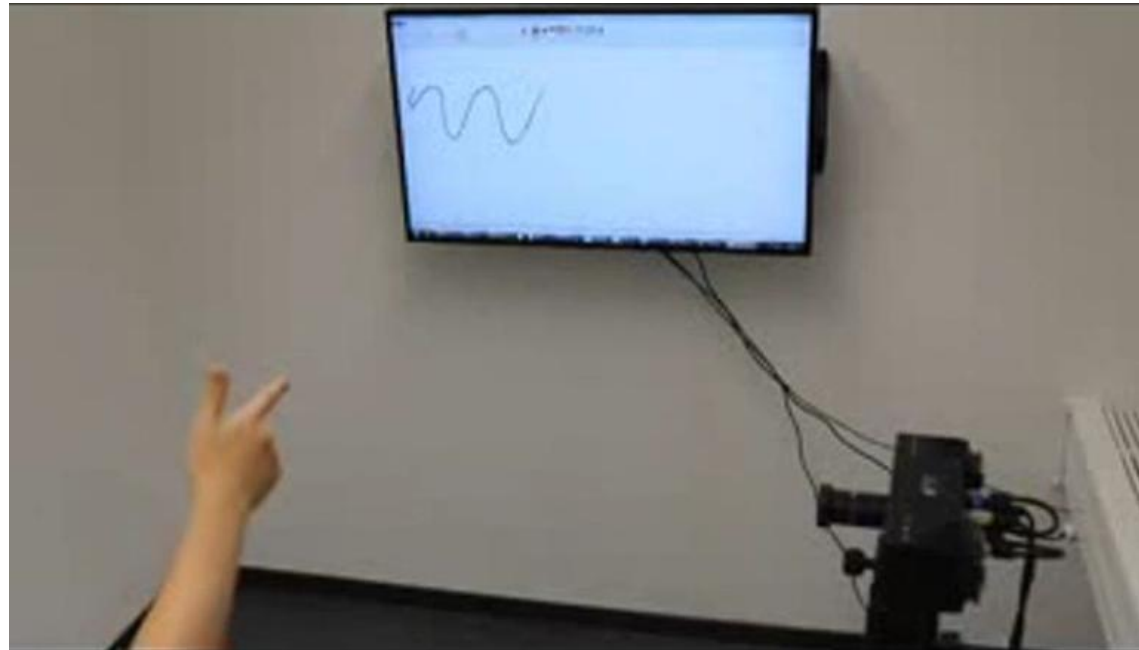
What is possible with 64x48 pixels?

- Intelligent bin-picking, out-of-place detection, ...



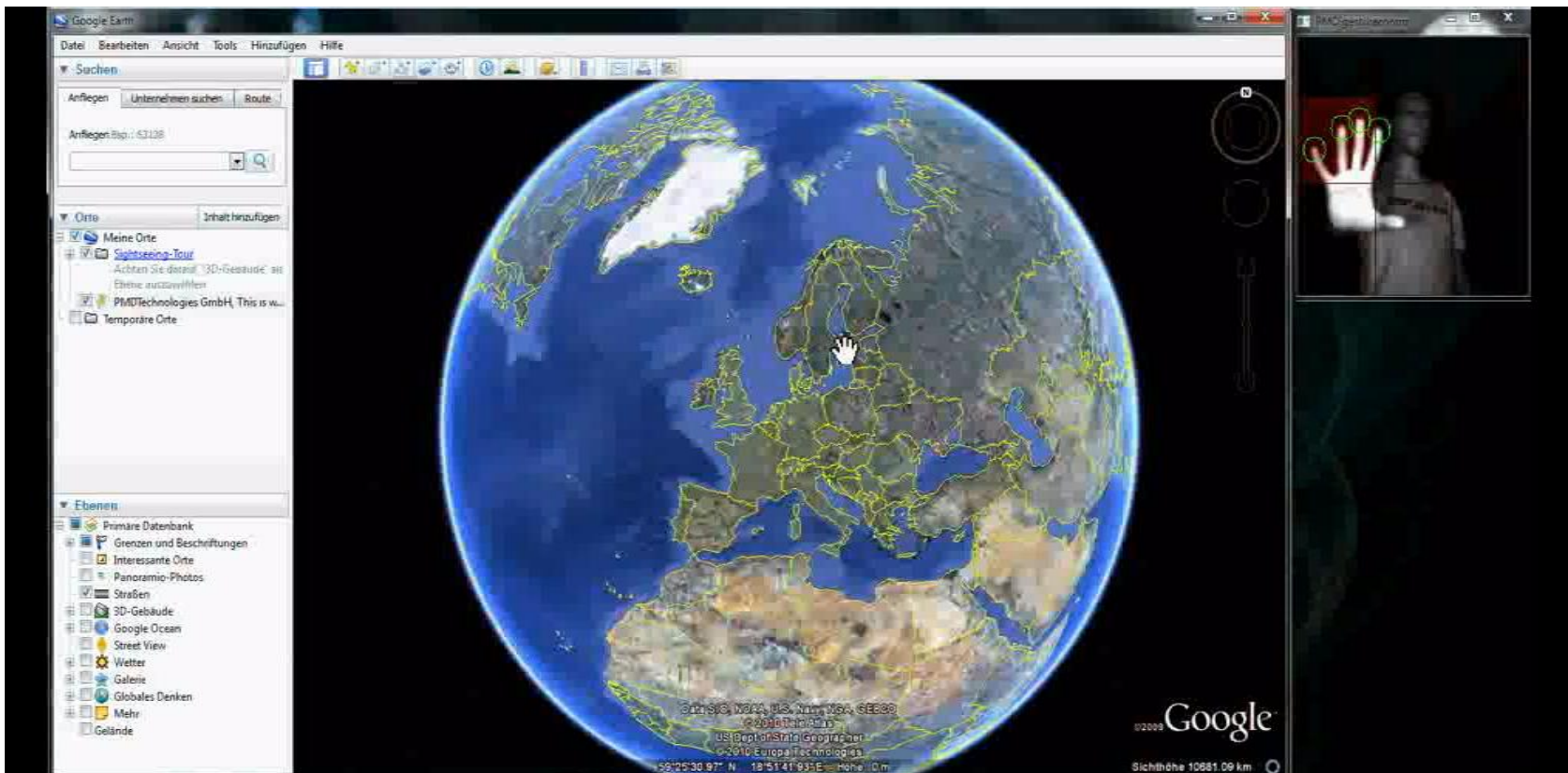
What is possible with 200x200 pixels?

- Medium working-range gesture-control
- Software solution provided by metrilus GmbH (www.metrilus.de)
- Metrilus provides also other software solutions for calibration and data enhancement



What is possible with 200x200 pixels?

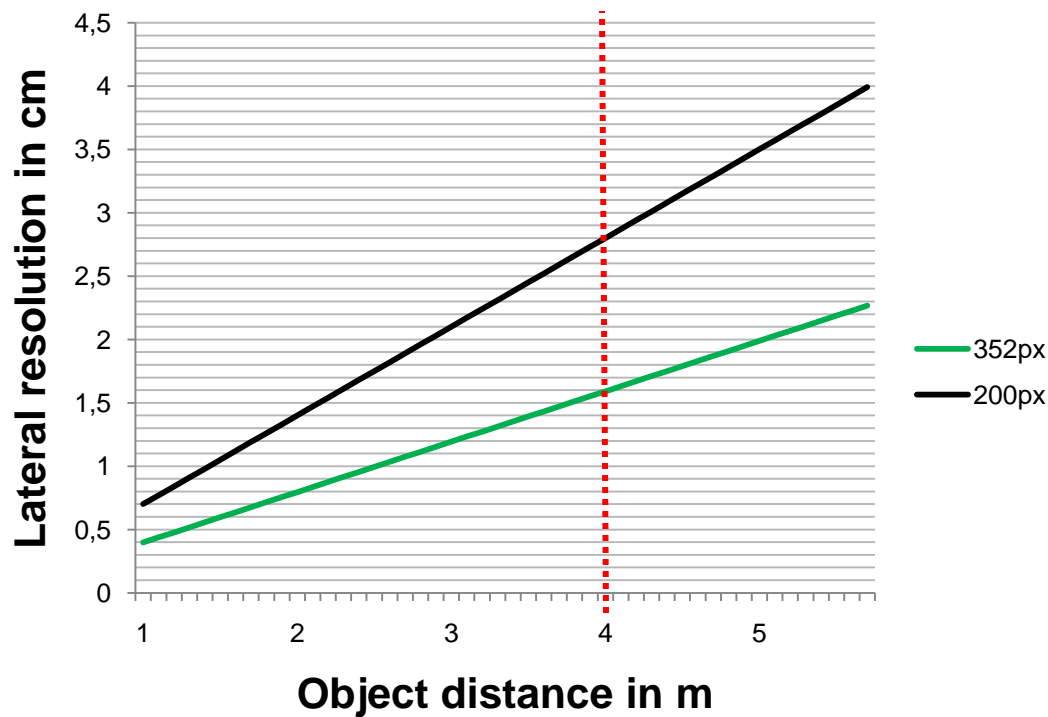
- Close-range human-machine-interface
- Completely miniaturized USB-powered system
- Detection of single fingers of a human hand



What can be expected at >QVGA resolution?

- Considering the consumer market full-body-pose estimation is very important
- Example scenario: How well can an arm be detected with for example CIF resolution?

Lateral resolution of CIF sensor depending on working distance



- 200px → 2.8cm@4m
- 352px → 1.5cm@4m



- Diameter of arm: approx. 8cm
→ 200px: ≤ 3px
→ 352px: ≤ 5px



- Object border → Removal of flying pixels, motion artefacts
→ 200px: Stable resolution of an arm difficult with remaining pixels
- 352px: Still enough pixels left for stable detection of an arm

1. PMDTec's roadmap aims at providing highest resolution for ToF chips
2. Unique feature of SBI will be available and provide outdoor/sunlight robustness for future PMD chips
3. Regarding the various applications described in this talk: Obviously, there is no principle need for a >QVGA resolution since different 3D measurement tasks can be accomplished successfully. The request for the necessity of a higher lateral resolution has to be judged application dependent and there are reasonable tendencies in the consumer market which require for example CIF resolution.
4. PMDTec provides application specific and mass-market capable solutions based on its broad palette of chip resolution.

Thanks for your attention.
Questions?

Contact:
j.penne@pmdtec.com