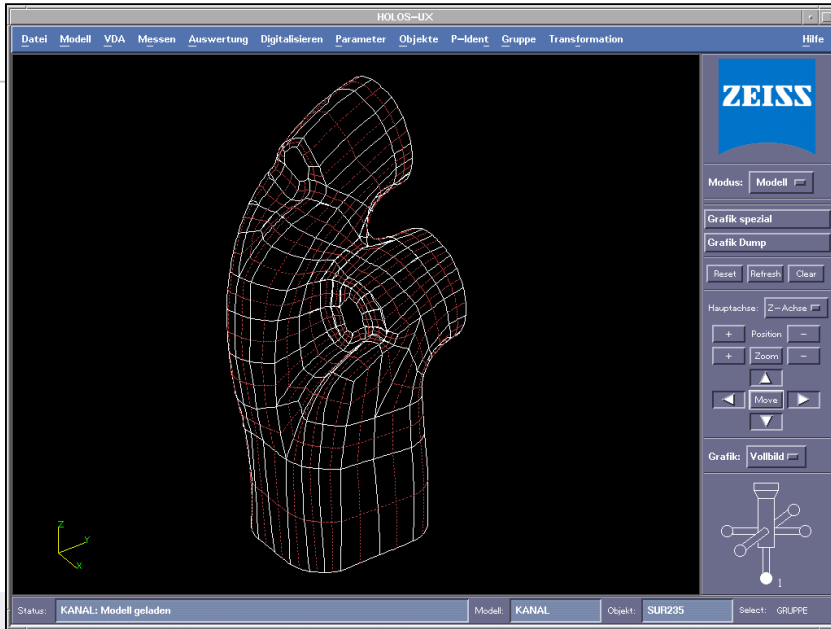


# CMMs and Optical CMSs - A Comparison



**Dietrich Imkamp**  
Director Visual Systems  
Aachen, 2016-11-24

# Where do we come from? Measurements of Freeform Surfaces on CMMs



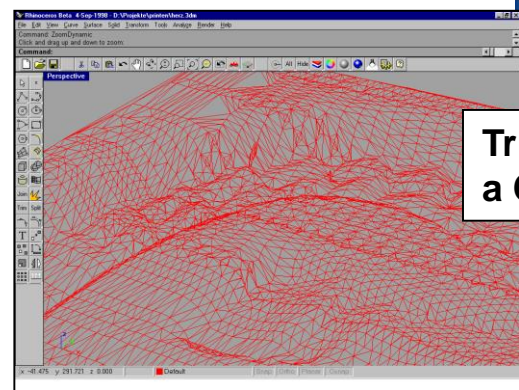
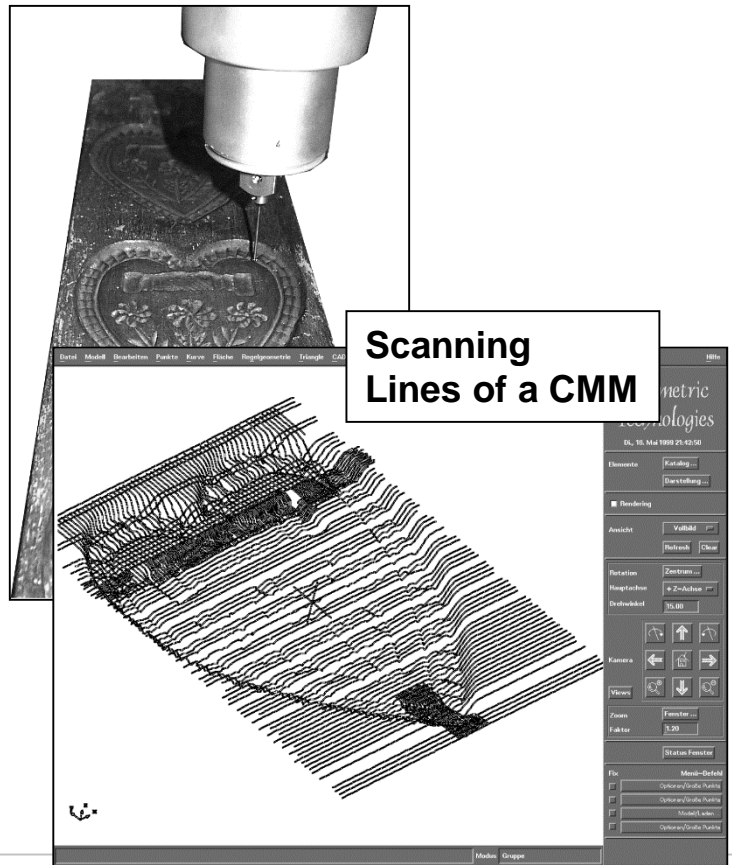
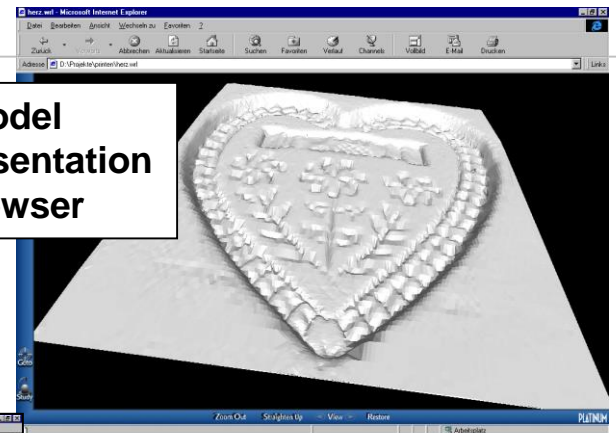
# Reverse Engineering for Forming Tools



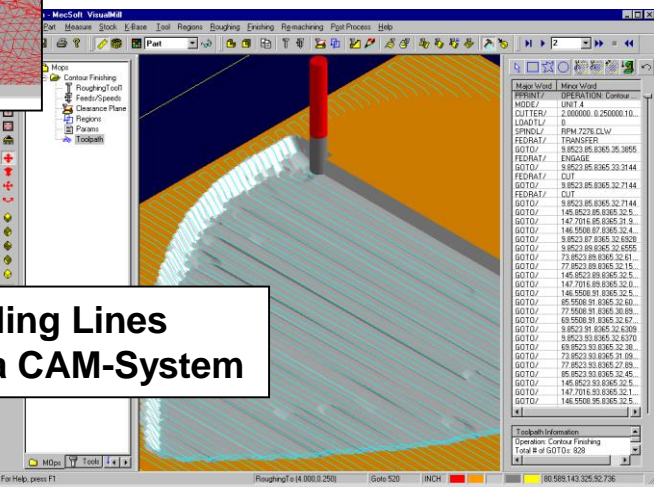
<http://www.kockartz.be/van-den-daele/>



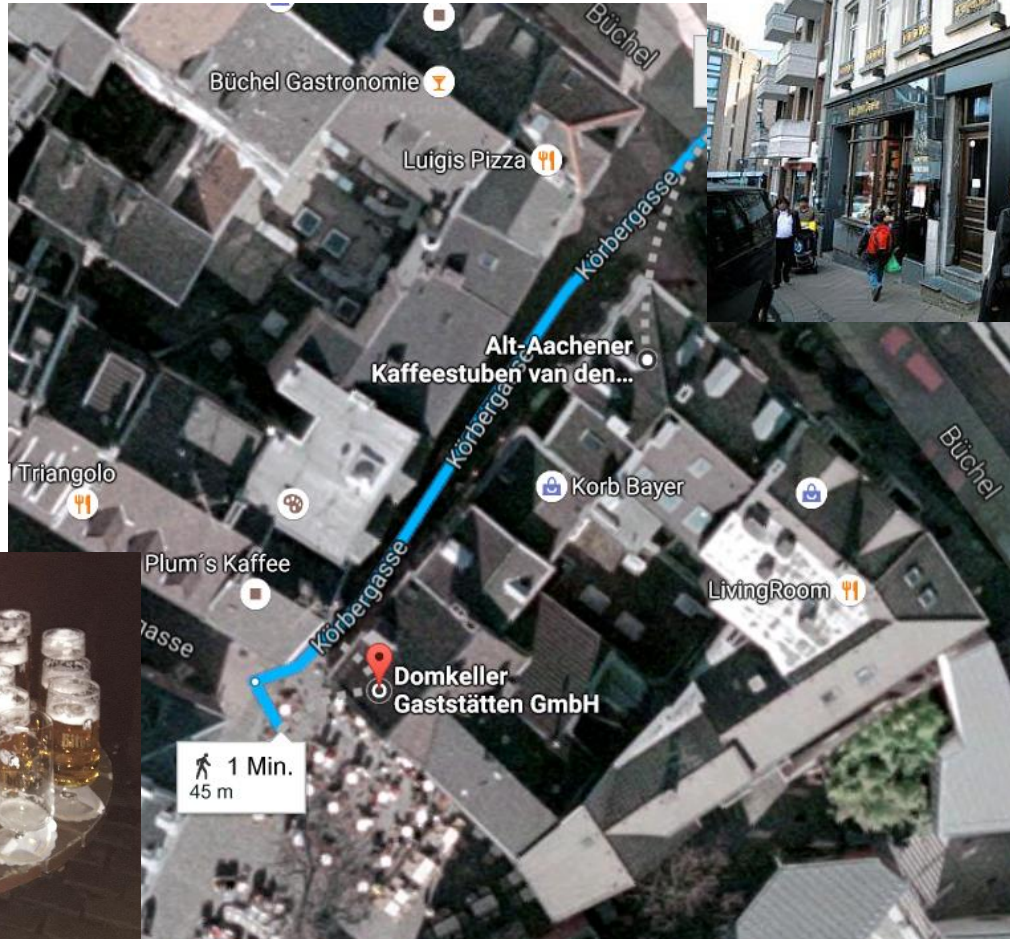
**3D-Triangulation Model (VRML-File) for Presentation with an Internet Browser**



**Triangulation in a CAD-System**



# How do you find the “Alt-Aachener Café-Stuben Van den Daele ”



# New Opportunities: Mobile, Shop-Floor Environment and Personnel



Source: Schwarz, J.: Zahlreiche Produktvarianten digitalisiert, in: VDI-Z 158 (2016), Nr. 7/8, S. 60-61  
<http://www.ingenieur.de/VDI-Z/2016/Ausgabe-07-08/Sonderteil-Qualitaetssicherung/Zahlreiche-Produktvarianten-digitalisiert>

**1** From CMM to CMS

**2** Measuring Procedures

**3** Comparison

**4** Conclusion

**1** From CMM to CMS

**2** Measuring Procedures

**3** Comparison

**4** Conclusion

# Measuring System for Freeform Surfaces



Legend:	full match:	
	little match:	

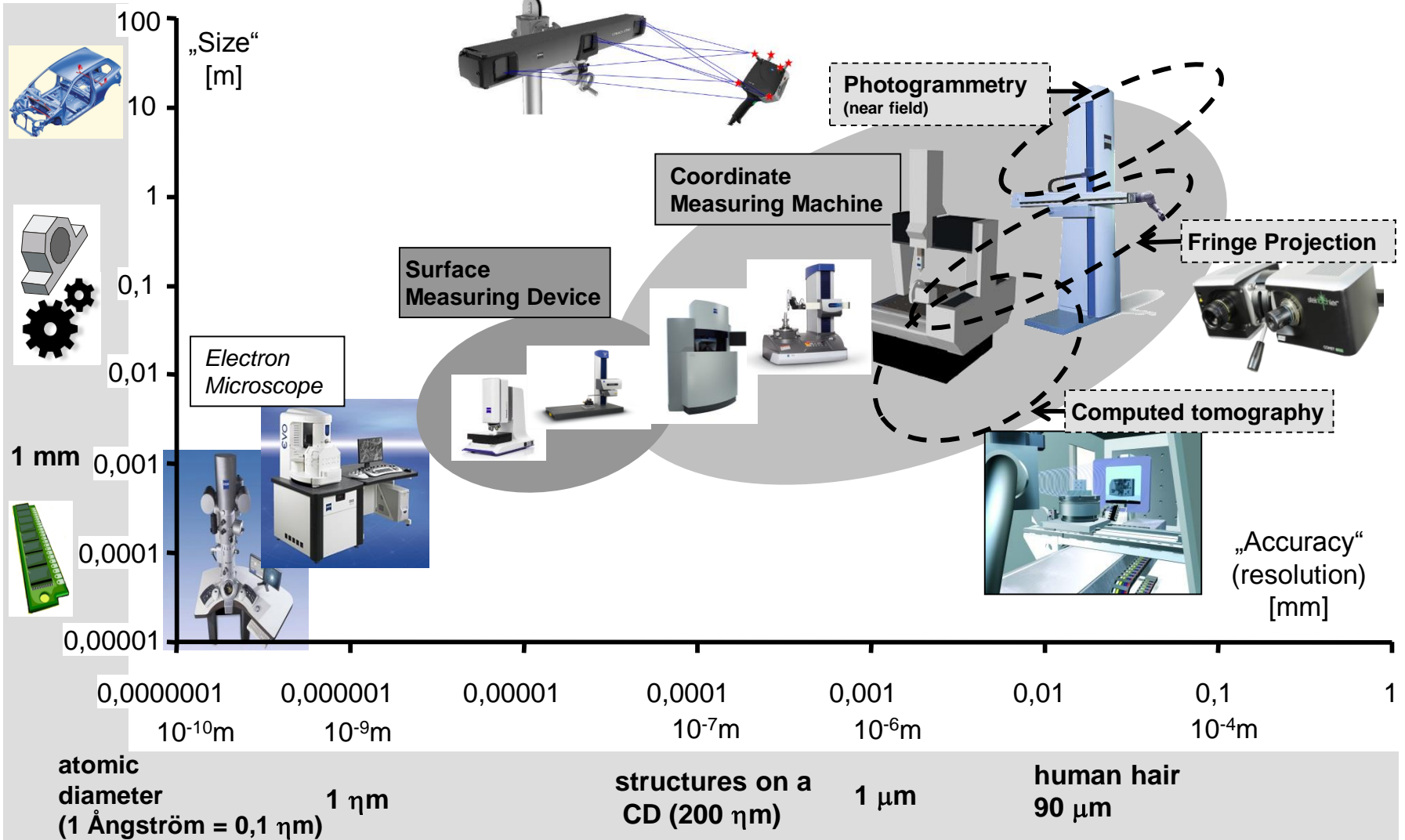
Laser tracker	Direct Comparison	Tactile CMM	Optical CMM	X-ray tomography	Fringe projection	Fringe reflection / Deflectometry	Photogrammetry
---------------	-------------------	-------------	-------------	------------------	-------------------	-----------------------------------	----------------

<b>Part dimensions</b>								
large								
medium								
small								
micro								
<b>Shape complexity</b>								
low								
medium								
high								
<b>Material and surface</b>								
hard, not sensitive								
deformable								
specular								
transparent								
opaque								
<b>Traceability</b>								

Quelle: Savio, E., De Chiffre, L., Schmitt, R.: Metrology of freeform shaped parts, in: Annals of the CIRP Vol. 56/2/2007; S. 810-835.



# Coordinate Measuring Machines and Systems from ZEISS in Industrial Production: Examples from Computer Chip to Car Body





INTERNATIONAL  
STANDARD

**ISO  
10360-1**

NORME  
INTERNATIONALE

First edition  
Première édition  
2000-11-15

INTERNATIONAL  
STANDARD

**ISO  
10360-8**

First edition  
2013-12-01

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**Geometrical Product Specifications  
(GPS) — Acceptance and reverification  
tests for coordinate measuring machines  
(CMM) —**

Part 1:  
**Vocabulary**

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**Geometrical product specifications  
(GPS) — Acceptance and reverification  
tests for coordinate measuring  
systems (CMS) —**

Part 8:  
**CMMs with optical distance sensors**

**1** From CMM to CMS

**2** Measuring Procedures

**3** Comparison

**4** Conclusion

# Freeform Surface Inspection



**Nominal**

**Actual**

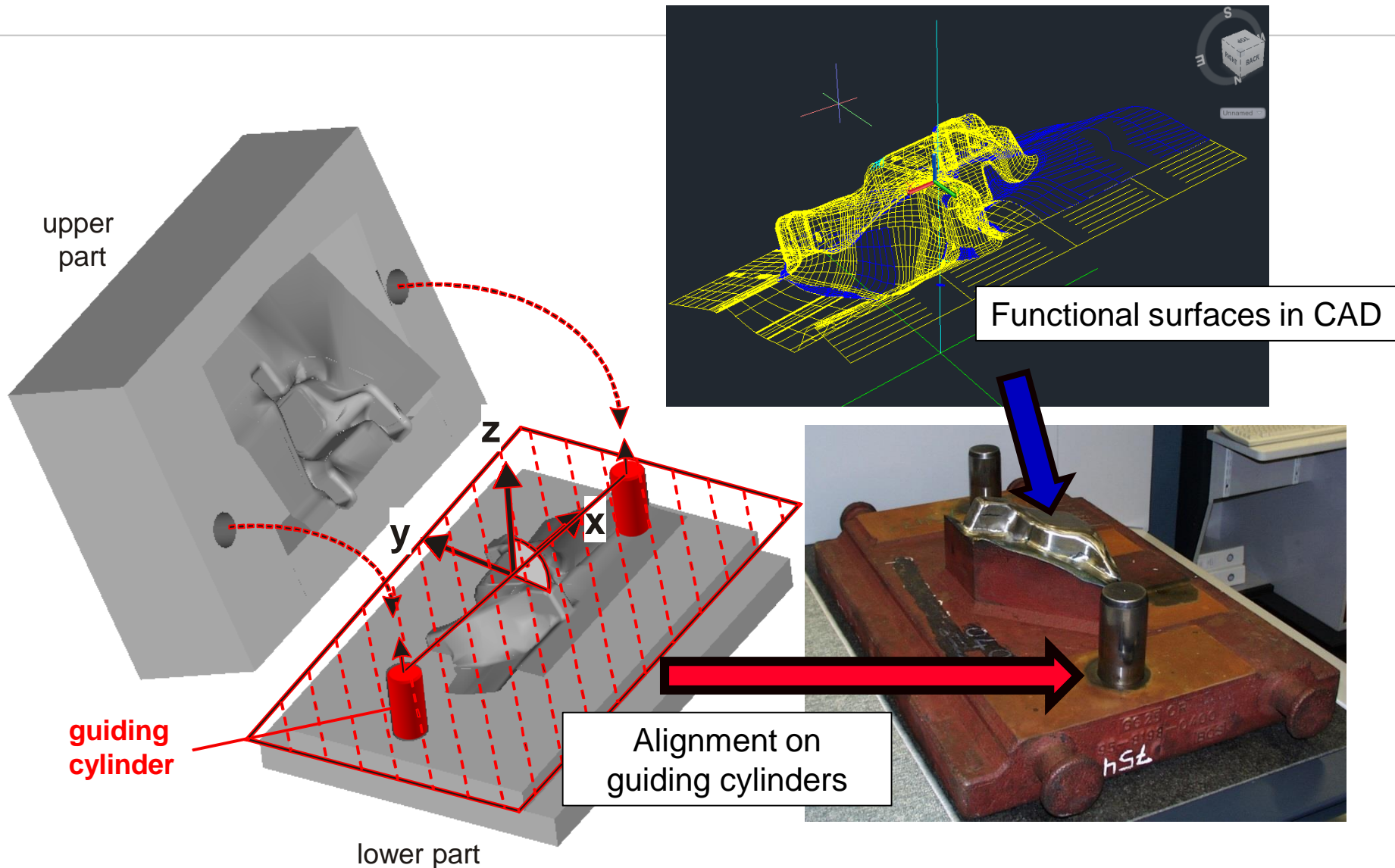
**Comparison**

0.0950 mm  
0.0950 mm - 0.0950 mm  
0.0750 mm - 0.0950 mm  
0.0650 mm - 0.0750 mm  
0.0550 mm - 0.0650 mm  
0.0450 mm - 0.0550 mm  
0.0350 mm - 0.0450 mm  
0.0250 mm - 0.0350 mm  
0.0150 mm - 0.0250 mm  
0.0050 mm - 0.0150 mm  
-0.0050 mm - 0.0050 mm  
-0.0150 mm - -0.0050 mm  
-0.0250 mm - -0.0150 mm  
-0.0350 mm - -0.0250 mm  
-0.0450 mm - -0.0350 mm  
-0.0550 mm - -0.0450 mm  
-0.0650 mm - -0.0550 mm  
-0.0750 mm - -0.0650 mm  
-0.0850 mm - -0.0750 mm  
-0.0950 mm - -0.0850 mm  
< -0.0950 mm

10.11.1990 09:46:53  
Darstellung  
Grafik: Dump  
Rendering  
Reset Refresh Clear  
Hauptachse: +Z-Achse  
15  
Rotation 9.00  
Zoom Move  
Grafik: Vollbild  
EDIT  
Überhöhungsfaktor = 1,00  
obere Toleranz = 0,0050 mm  
untere Toleranz = -0,0050 mm

Status: |prt\_3.rc: Modell geladen| Modell: |prt\_3.e| Objekt: FC000299| Select: EXCEL

# Freeform Surface Inspection based on Function Oriented Registration (Alignment)

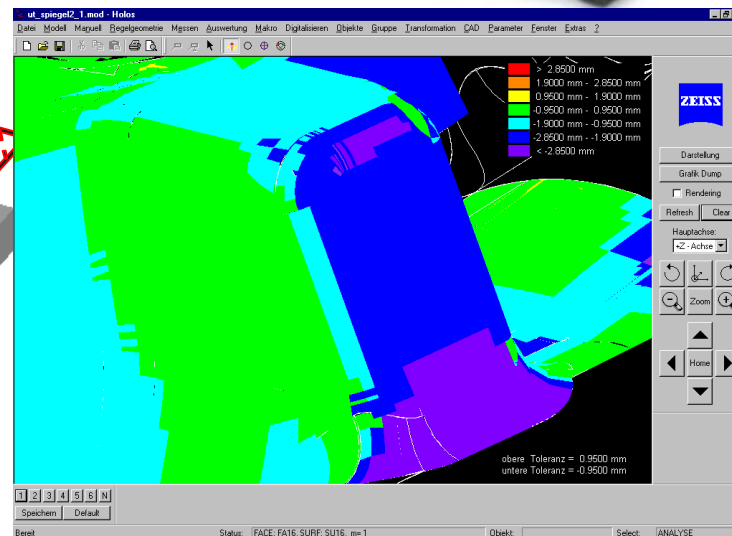
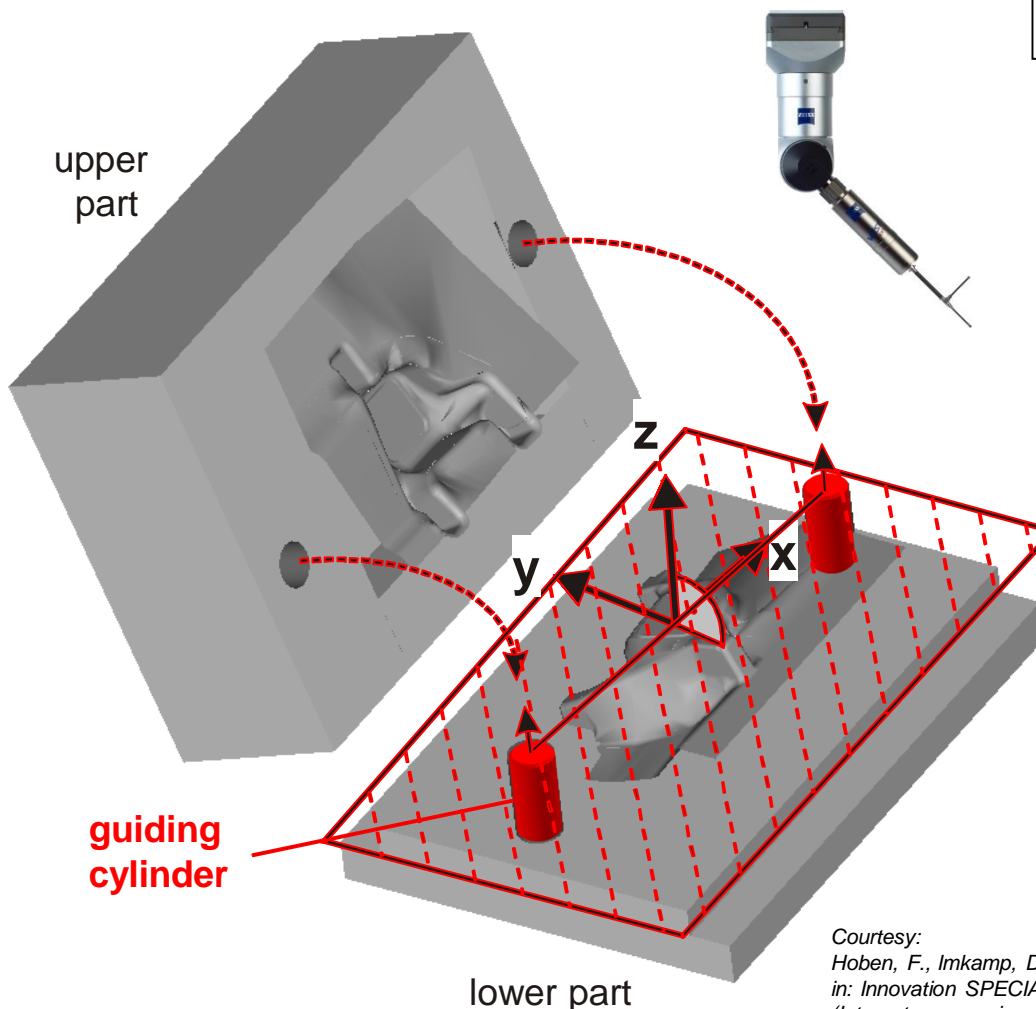


# Freeform Surface Inspection based on Function Oriented Registration (Alignment) Measurement on a Multi-Sensor CMM



alignment and check of tool guiding (die set)

check of surface form



Courtesy:  
 Hoben, F., Imkamp, D.: Multi Application Sensor System (MASS) – Greater than the Sum of Its Sensors,  
 in: Innovation SPECIAL Metrology 9, 2007, Carl Zeiss Industrielle Messtechnik GmbH, Oberkochen 2007.  
 (Internet: [www.zeiss.de/imt](http://www.zeiss.de/imt))

**1** From CMM to CMS

**2** Measuring Procedures

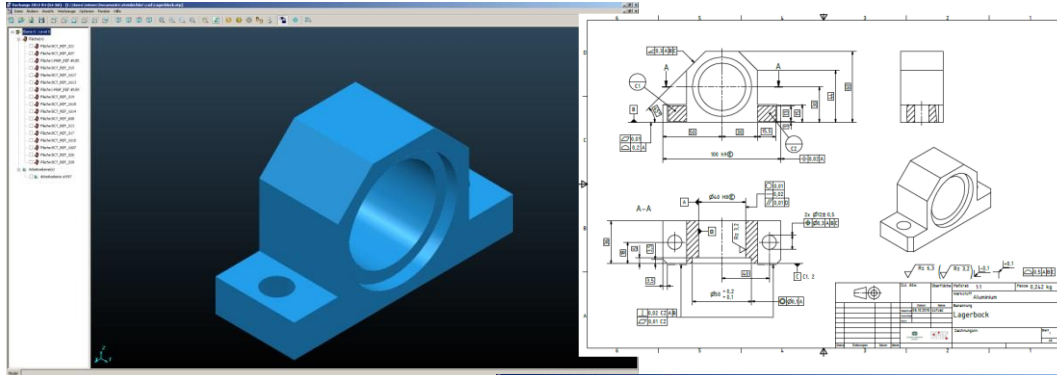
**3** Comparison

**4** Conclusion

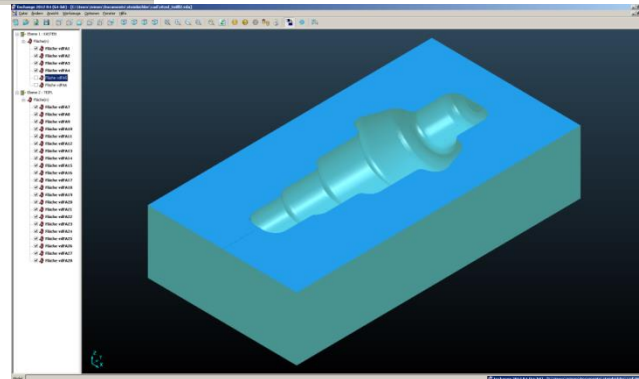
# Workpieces for Comparison



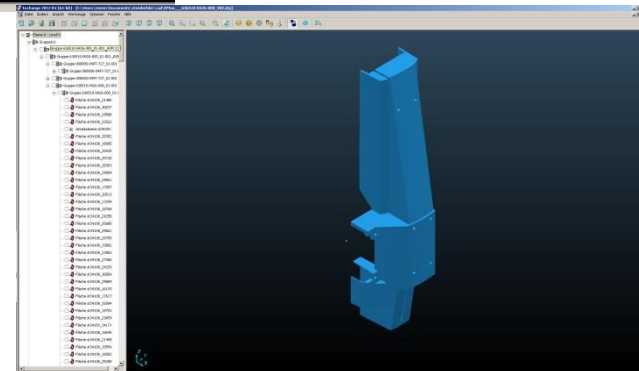
**Bearing Block**



**Forming Tool (for Gear Shaft)**



**Housing (for CMM DuraMax)**

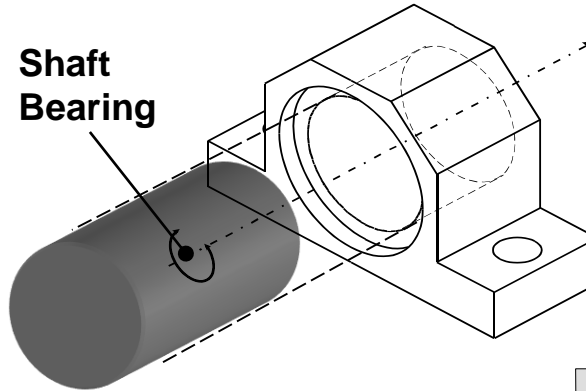




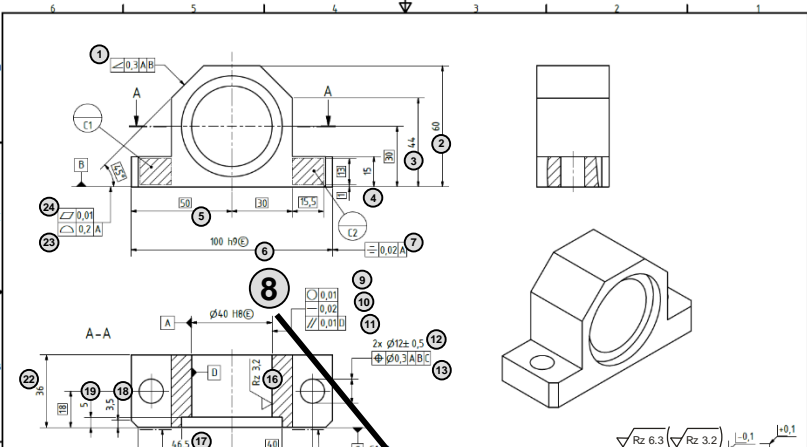
# “Characteristic Oriented Measurement” on a CMM with its different Tactile and Optical Sensors



Drawing's characteristics define mechanical functionality



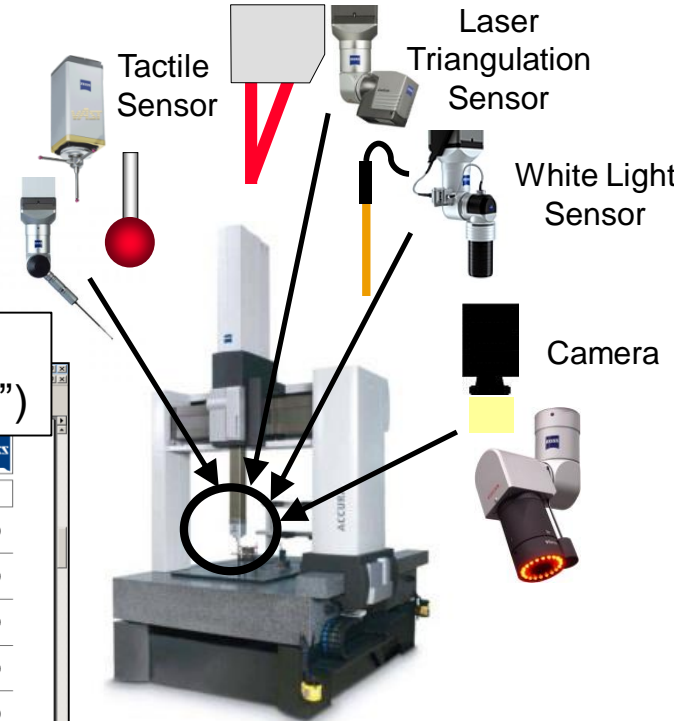
Shaft Bearing



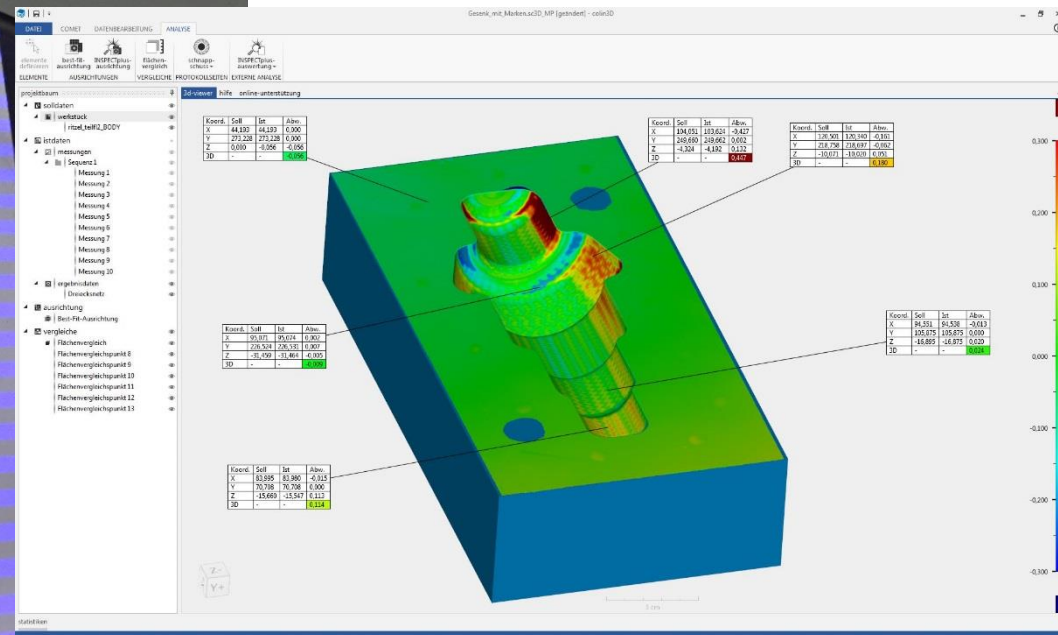
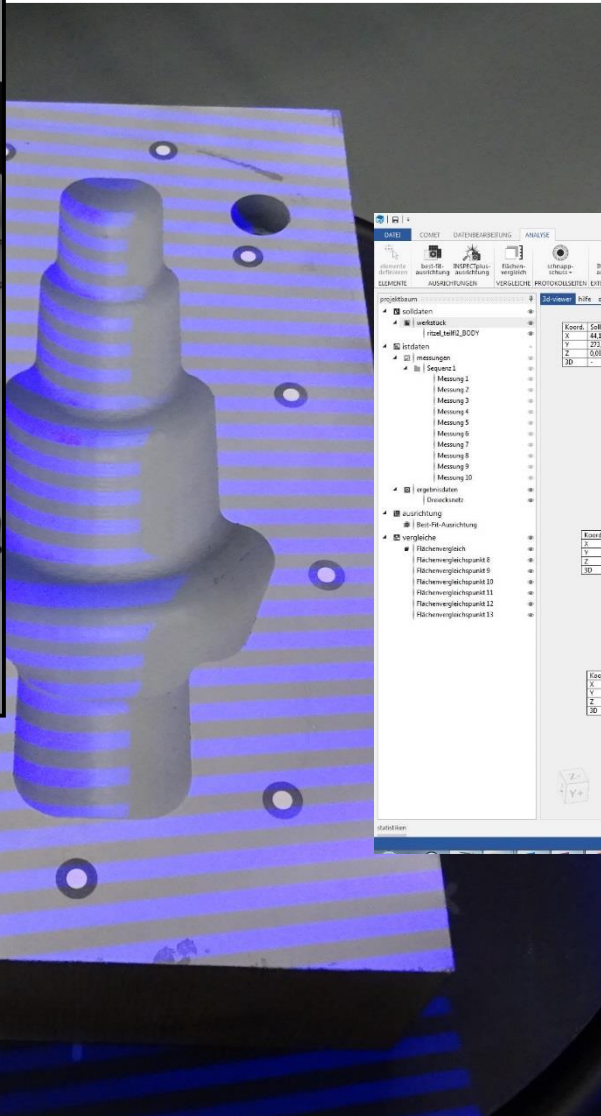
Example: Diameter

Measuring Protocol (“Characteristics List”)

	WName	Polnr	Ursatz	Datum	
	H_123_2345_2	Wagner	1:34:18	10 Juni 2003	ZEISS
	Istwert	Sollwert	obere Td.	untere Td.	Abweichung
32	80.0000	80.0000	0.0000	-0.0190	-0.0000
45	70.0000	70.0000	0.1000	-0.1000	0.0000
46	70.0000	70.0000	0.3000	-0.3000	0.0000
40	35.0000	35.0000	0.3000	-0.3000	0.0000
50	50.0000	50.0000	0.3000	-0.3000	0.0000
52	45.0000	45.0000	0.3000	-0.3000	0.0000



# “Surface Oriented Measurement” with CMS (Fringe Projection)



# Comparison of Measurements using CMM and CMS (Photogrammetry System) with Tactile Sensor and Laser Triangulation Sensor



tactile sensor / (XXT)



CMM with



laser triangulation (LineScan 2-100)



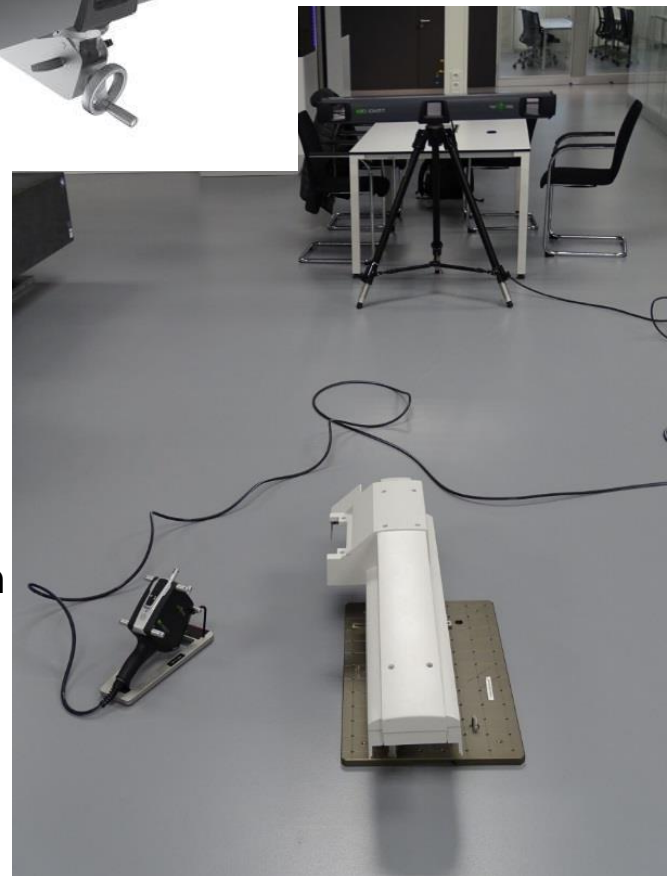
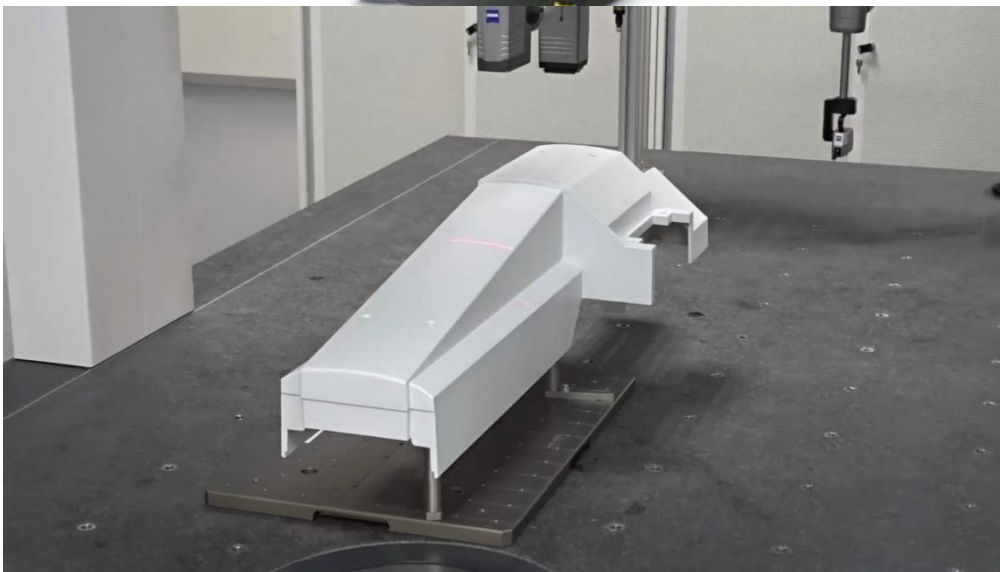
Photogrammetry System / CMS (T-Track)



with tactile sensor / (T-Point)



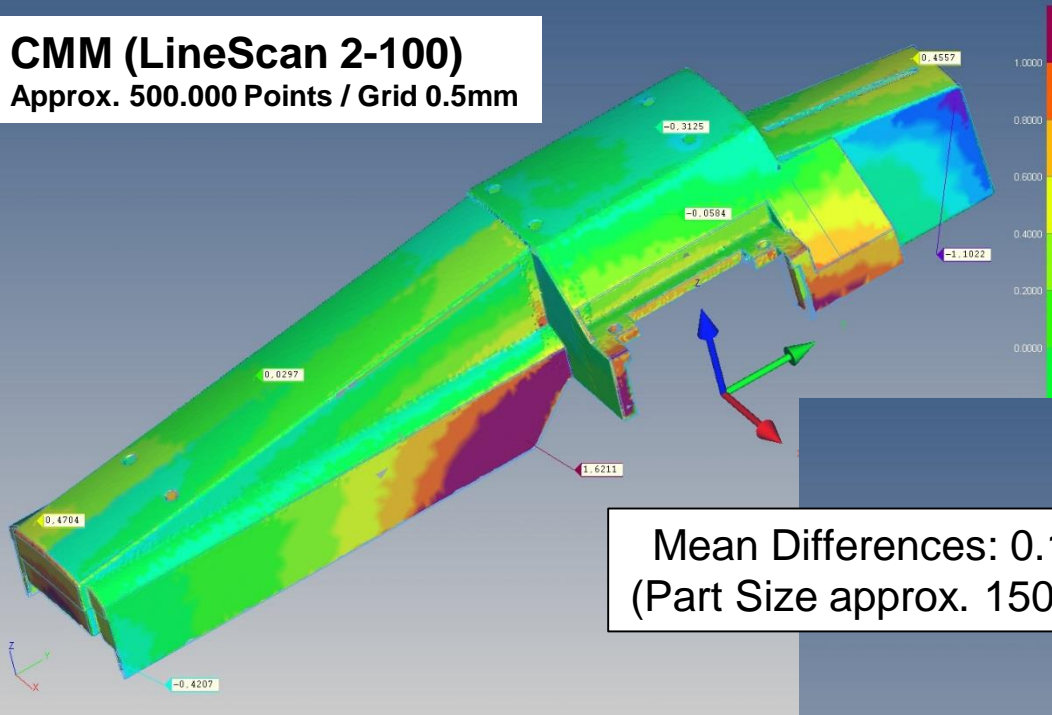
laser triangulation (T-Scan)



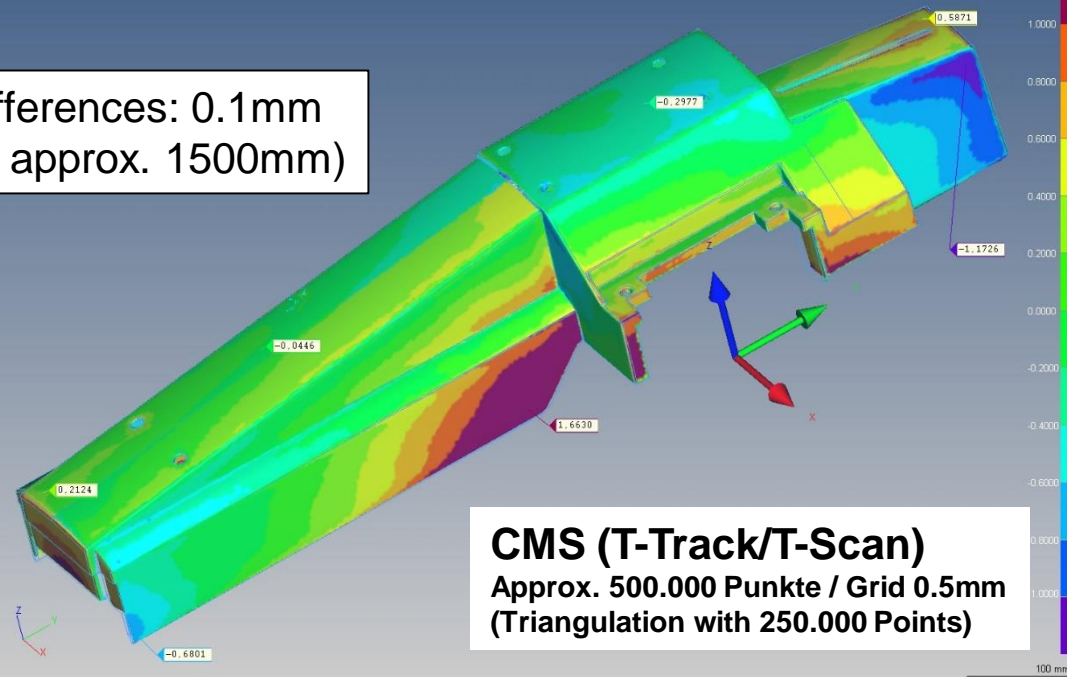
# Comparison of Measurements using CMM and CMS with Tactile Sensor and Laser Triangulation Sensor: Results with Best-Fit



**CMM (LineScan 2-100)**  
Approx. 500.000 Points / Grid 0.5mm



Mean Differences: 0.1mm  
(Part Size approx. 1500mm)



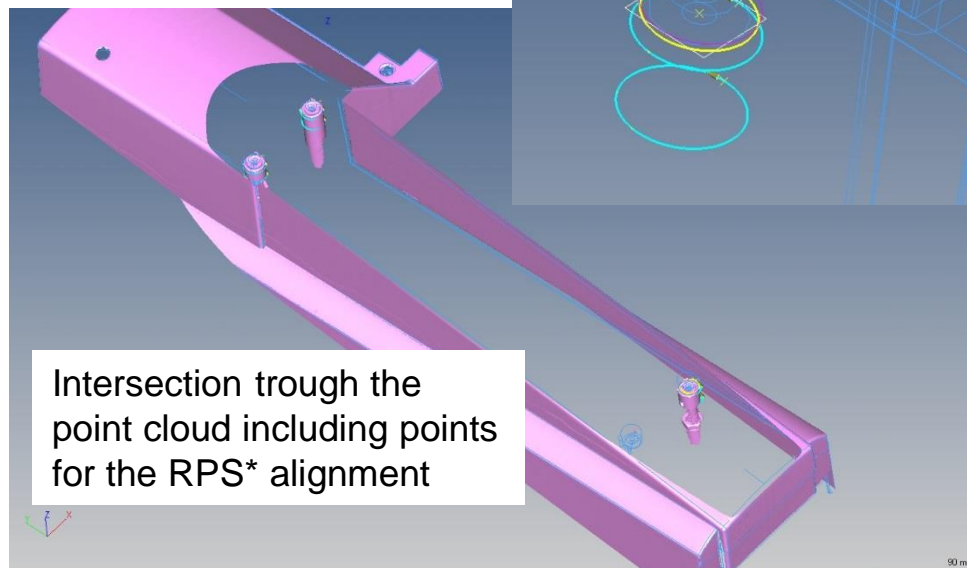
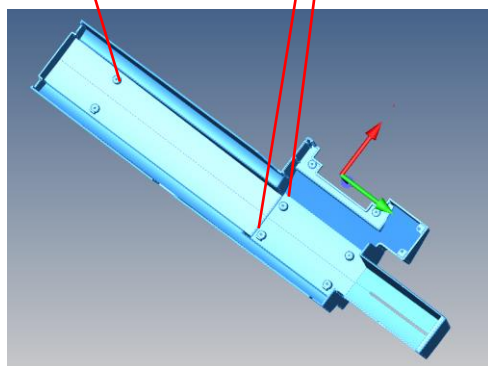
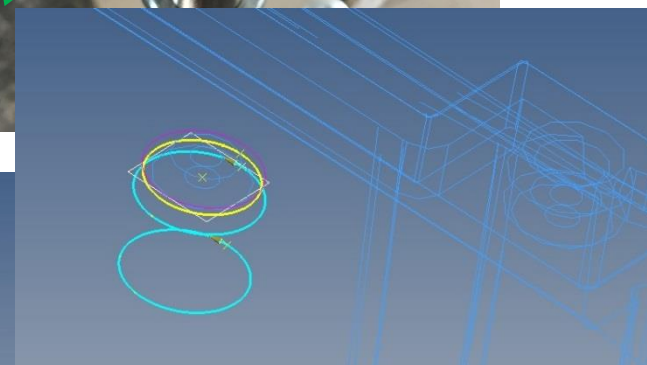
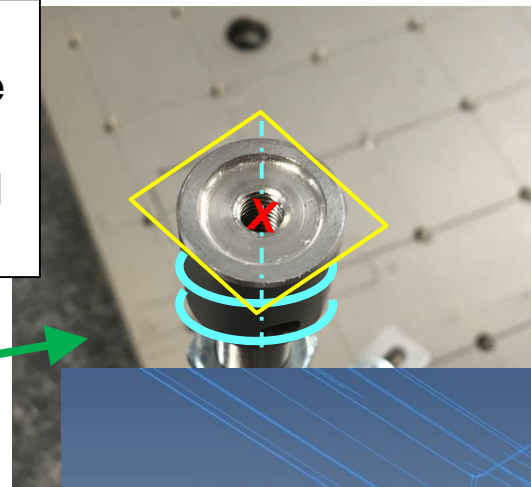
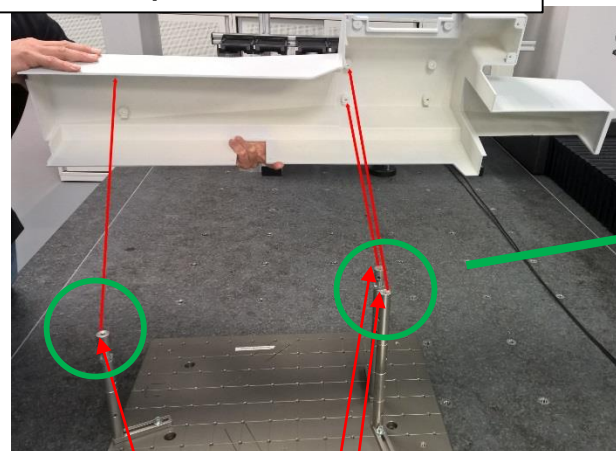
**CMS (T-Track/T-Scan)**  
Approx. 500.000 Punkte / Grid 0.5mm  
(Triangulation with 250.000 Points)

# Comparison of Measurements using CMM and CMS with Tactile Sensor and Laser Triangulation: Function Oriented Alignment



RPS\* alignment: forming a coordinate system from the "screw points" (**intersection point** between **top face** and **cylinder axis of tape hole**)

carrier for the simulation of assembly with 3 fixed "screw points"

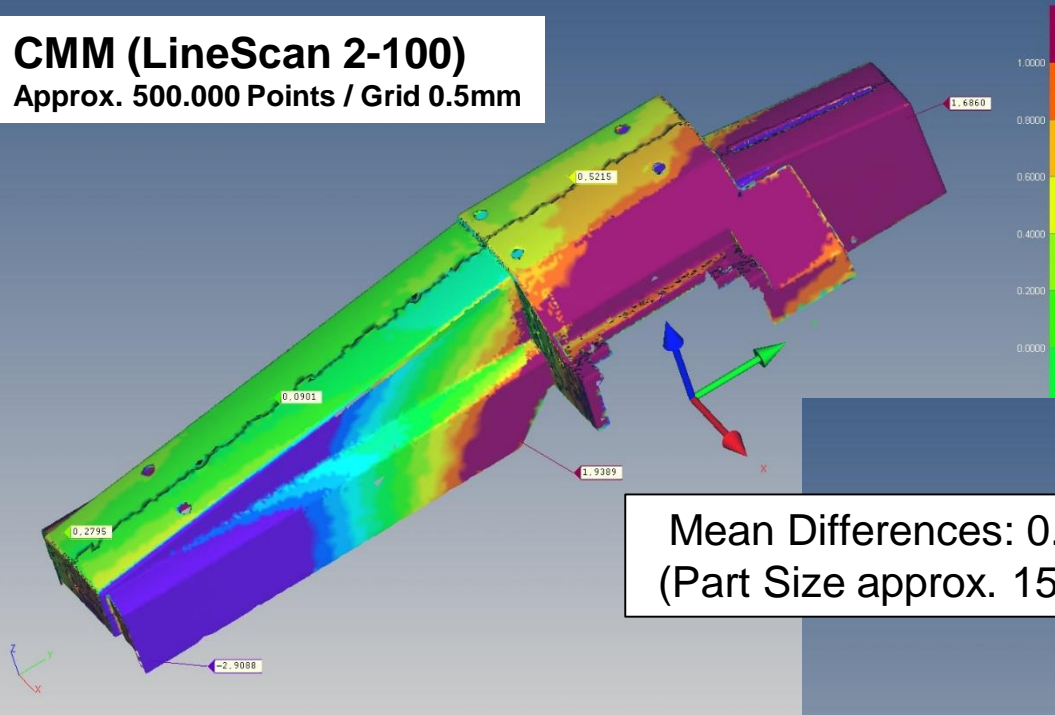


Intersection trough the point cloud including points for the RPS\* alignment

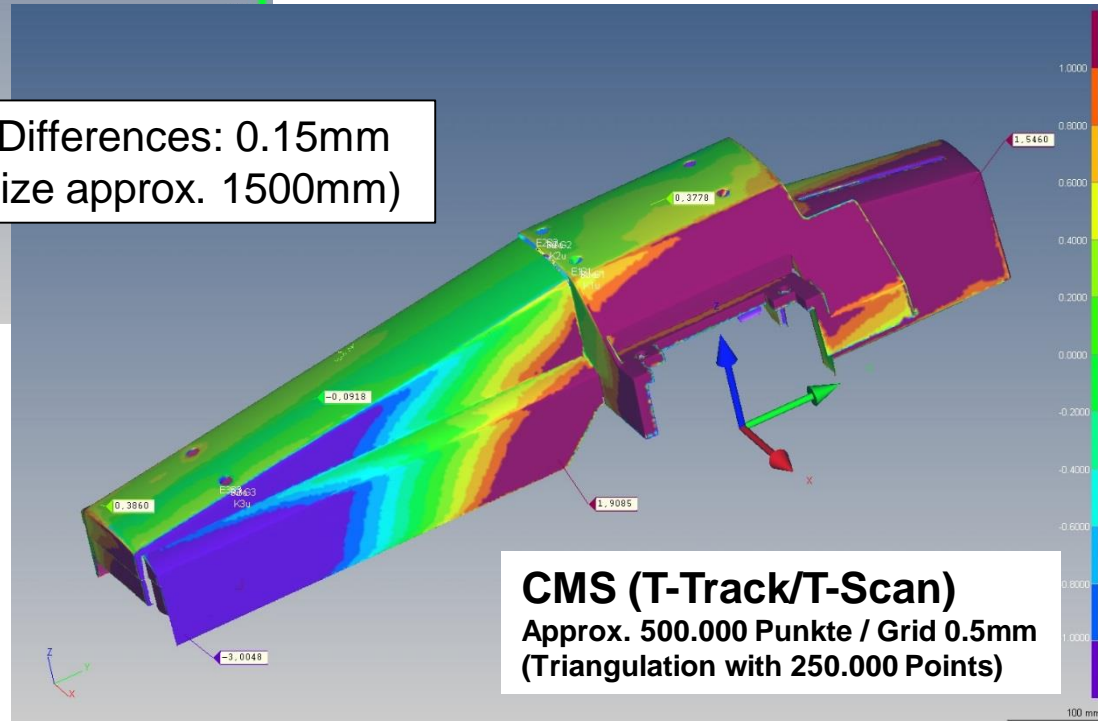
# Comparison of Measurements using CMM and CMS with Tactile Sensor and Laser Triangulation Sensor: Results with Function Oriented Alignment



**CMM (LineScan 2-100)**  
Approx. 500.000 Points / Grid 0.5mm



Mean Differences: 0.15mm  
(Part Size approx. 1500mm)



**CMS (T-Track/T-Scan)**  
Approx. 500.000 Punkte / Grid 0.5mm  
(Triangulation with 250.000 Points)

# Comparison of Measurements using CMM and CMS with Tactile Sensor and Laser Triangulation Sensor: Time



## CMM (LineScan / Tactile Sensor)

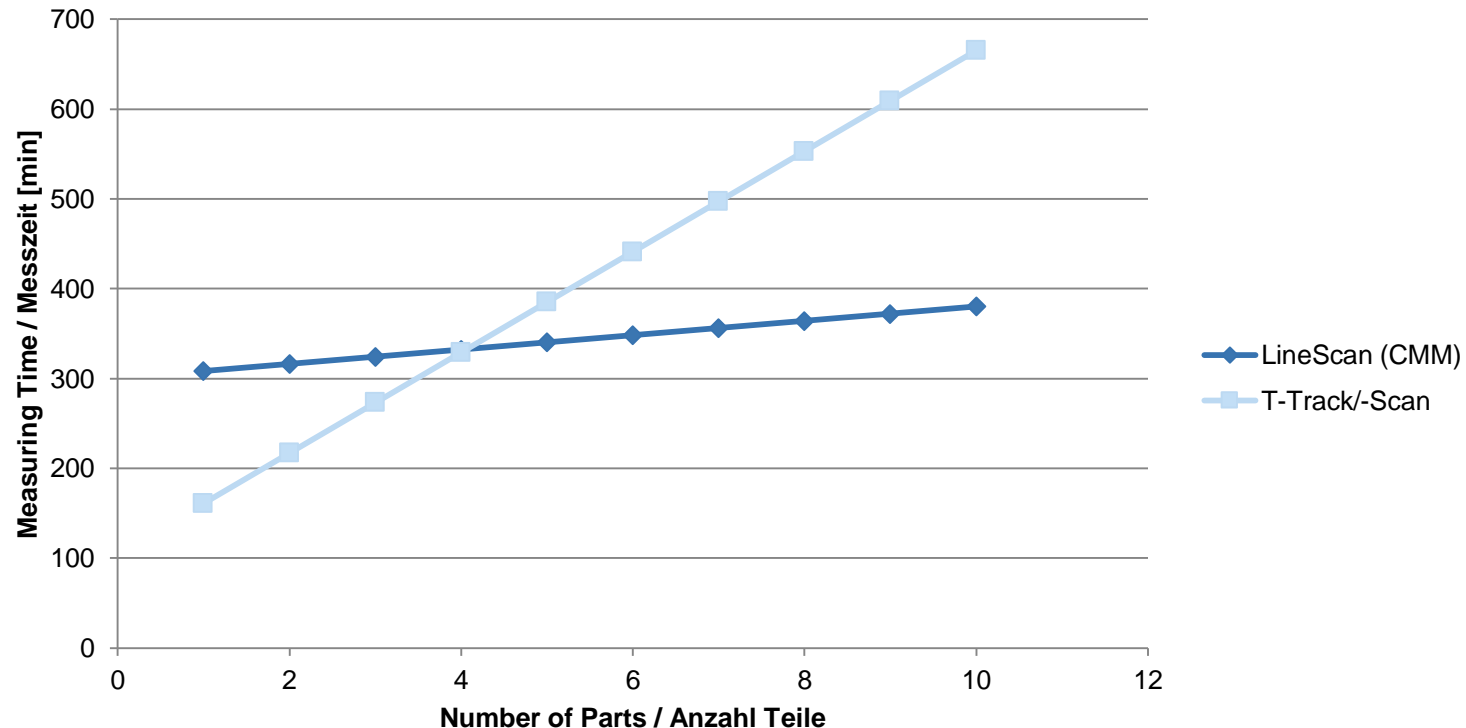
**Setup Time: 300min**

**Time per Part: 8min**

## CMS (T-Track / -Scan)

**Setup Time: 105min**

**Time per Part: 56min**



# Comparison of Measurements using CMM and CMS with Tactile Sensor and Laser Triangulation Sensor: Summary



## CMM (LineScan / Tactile Sensor)



## CMS (T-Track / -Scan)



### Benefits (Example):

- faster for 5 and more parts
- automatic run possible
- high reproducibility
- flexible for large number of characteristics

### Benefits (Example):

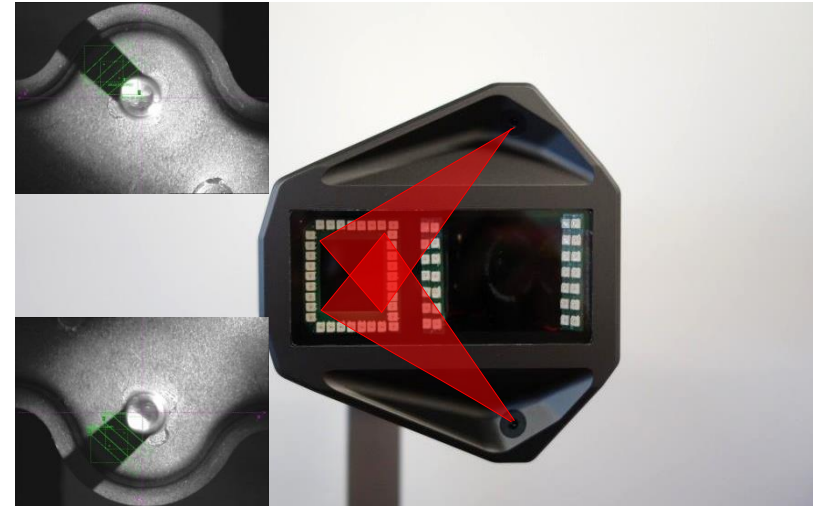
- faster for up to 5 parts
- ease of use
- mobile
- lower hardware price than CMM



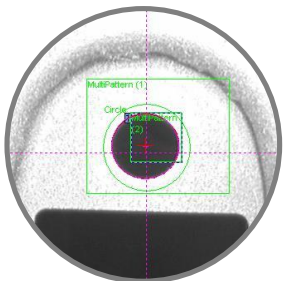
# Automated CMS with Robot: Multi-Line-Laser-Triangulation, Image Processing and Shadow Analysis for Measurement of Characteristics on Car Bodies



- Shadow-Evaluation for Bolt Position Measurement

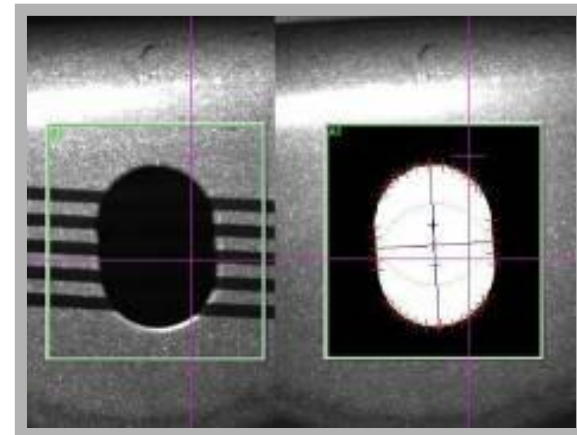


- Camera for Image Processing

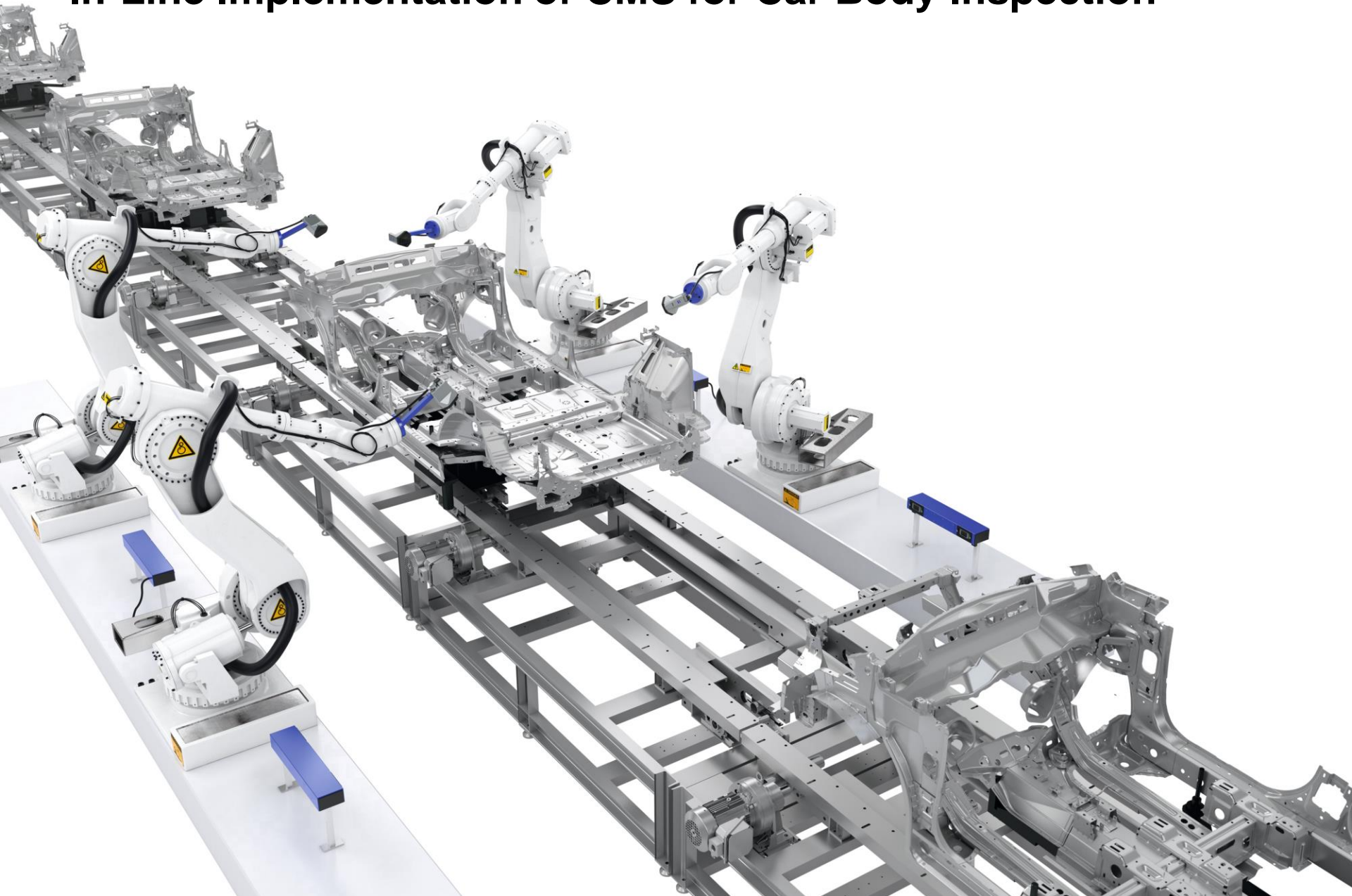


Source: Carl Zeiss Automated Inspection GmbH & Co. KG  
(<http://www.zeiss.com/metrology/products/systems/process-control-and-inspection/car-body-solutions/3d-measuring-cells/aimax.html> )

- Multi-Line-Triangulation



# In-Line Implementation of CMS for Car Body Inspection



**1** From CMM to CMS

**2** Measuring Procedures

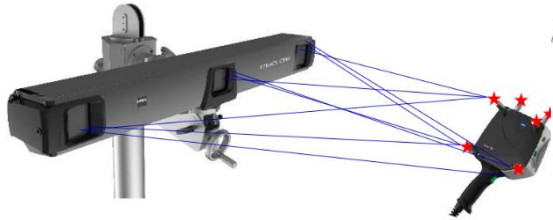
**3** Comparison

**4** Conclusion

# Optical CMSs and CMMs - A Comparison



## T-TRACK with T-SCAN



COMET

### Optical CMS (manual)

- mobile: the instrument comes to the measuring object
- easy manual data recording and colored graphical result presentation

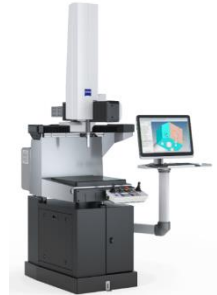
### Optical CMS with Robot (automated)

- automated
- fast and robust through robot carrier

AIMax



DuraMax

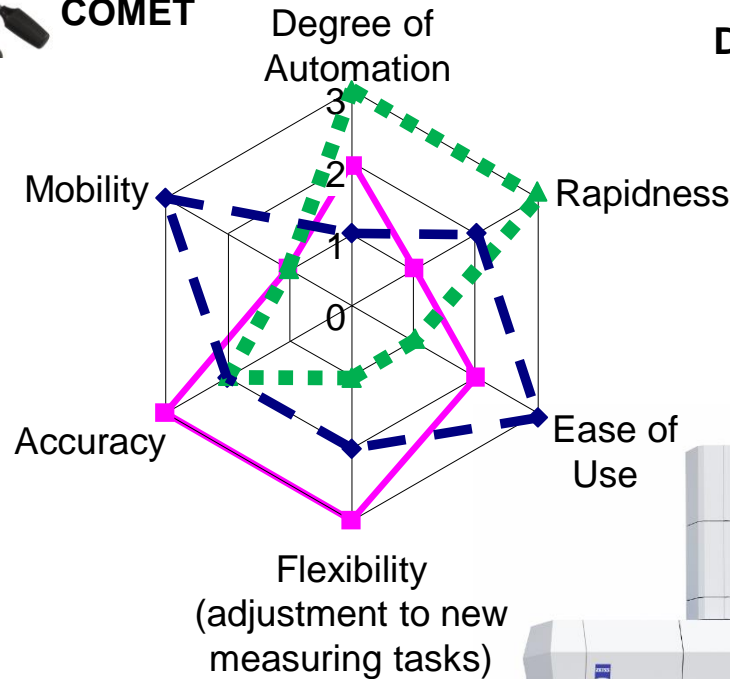


### CMM

- „build-in“ Automation
- Large Range of available Sensors



ACCURA



MMZ

