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National Physical Laboratory

EMS
Engineering Metrology Solutions
Where uncertainty matters

Verifying the dimensional performance of 3D X-ray computed tomography systems with metrology capability.

Michael McCarthy

3DMC 3D METROLOGY CONFERENCE

Engineering Metrology Solutions

National Physical Laboratory

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Experienced in delivering of Innovative industrial solutions associated with:

- Non-Contact/Tactile, Lab & Portable 3D coordinate measuring systems
- From the Micro to Large scale~ Point to Point Cloud data.
- Traceability Assessment to (ISO 17025)
- Performance Verification (ISO 10360)
- Bespoke metrology solutions

- Honorary Professor~~~ 3DIMPact 3D Imaging, Metrology & Photogrammetry Applied Coordinate Technologies UCL
- BSI ~XCT Panel Chair bsi.
- ISO ~ Principle member of TC 213 (CMM/CMS) ISO
- Engaging with industry & many NMI's world wide
- Lead Consultant at EMS

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EMS ~ Where uncertainty matters

XCT for 3D coordinate measurement

Which kit to acquire? How to compare? How to verify? What about Interim checks between services?

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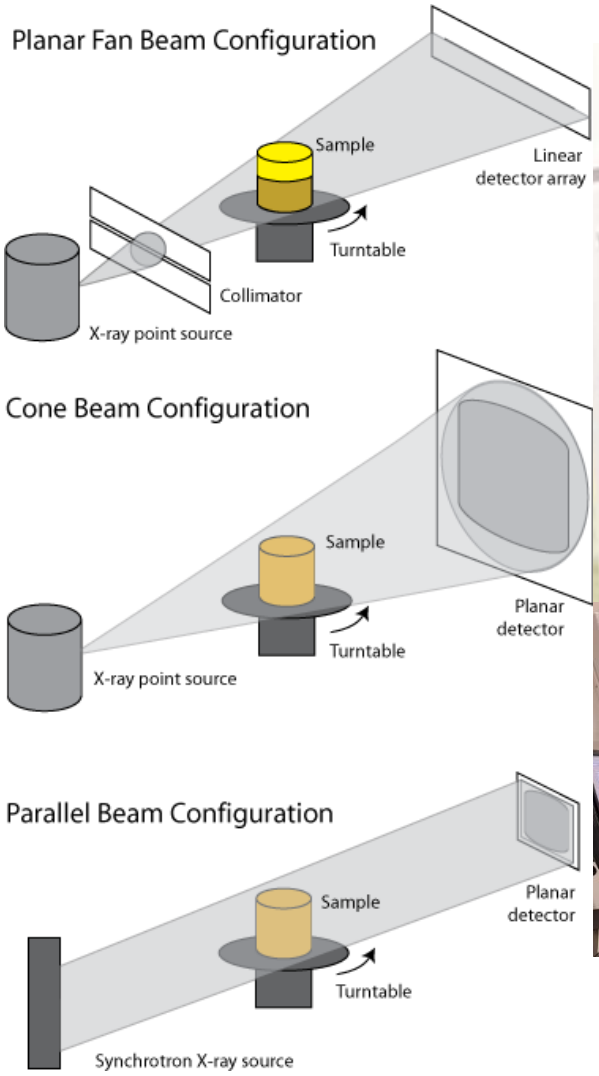

Verification~ XCT development

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- Demonstrating traceability to national standards.

  ~THE METRE

- Estimates the accuracy of measurement

  ~ Providing confidence and assurance

- ISO 10360 CMM/CMS standard, Checks MPE* within rated conditions.

(*Maximum Permissible Error)

Applications of standard

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- Acceptance testing
  - Contractual situation~ Manufacturer / End user
    - Purchasing, maintenance, repair, or upgrade.
- Reverification testing
  - Organisation's internal quality system
    - For probing and length.
- Interim checking
  - Periodic, a reduced reverification test
    - Demonstrate the probability that it meets MPE.

Maximum permissible error

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For example,

- When considering **Length** opposed to Probing errors, a term $E_{(MPE, L)}$ could be used to specify the length measuring accuracy (MPE) of a CMS /Metrology XCT system
- Such a MPE, can be stated in at least three different ways

Some ways of expressing MPE

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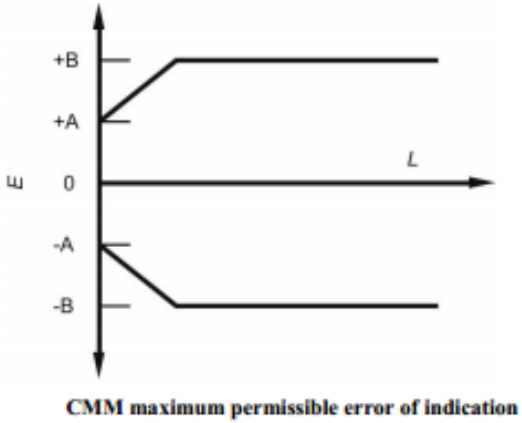
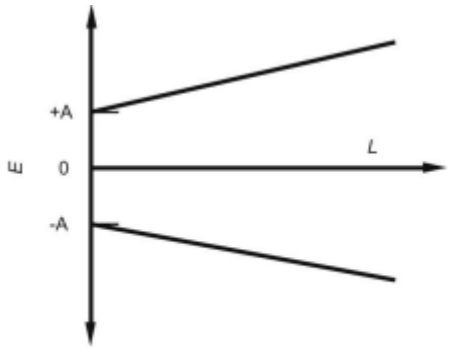
Case a



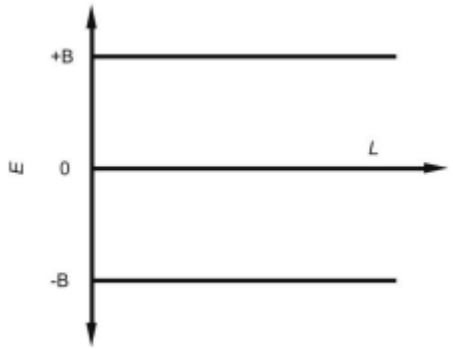
CMM maximum permissible error of indication

Case b

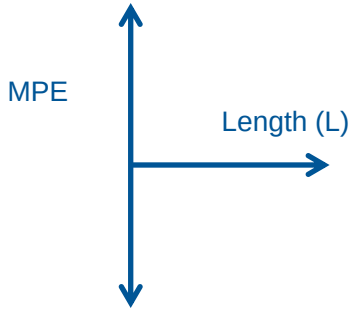


CMM maximum permissible error of indication

Case c



CMM maximum permissible error of indication



Ref: D.Flack NPL

XCT performance specifications 5 examples ref: Internet 11/9/17

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- **Example A)** SYSTEM CAPABILITIES~ Geometric Magnification: >2000x; Overall **Maximum System Resolution**: <500 nm
- **Example B)** **Maximum Permissable Error** MPE (perhaps they mean permissible?). MPE, no air conditioning required CT Sensor: P: 9,5 µm, E: (9.5+L/75) µm, MPE for advanced laboratory conditions CT Sensor: P: 6,5 µm, E: (6.5+L/75) µm;
- **Example C)** **Absolute accuracy** 9 + L/50 µm;
- **Example D)** **Resolution:** 3.5 - 6 µm; **Accuracy:** Down to 2.9 µm + L/100 Sphere center point error;
- **Example E)** **Precise metrology** MPE_{SD} = 8 µm + L/75, measured as a deviation of sphere distance.

To help confusion, examples do not use BIPM's VIM / ISO recommended language & nobody states the units of L? I guess its metres, or micrometres?

Tip: If L is in metres, buy the company! Not just their machine!

Geometrical Product Specifications (GPS) – Acceptance and re-verification tests for CMM / CMS

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ISO 10360-1: 2000 Part 1, (of nominally 12}
Vocabulary

Defining a CMM as a measuring system with the means to move a probing system and with capability to determine spatial coordinates on a workpiece surface

New wording CMS ‘Coordinate Measuring System’

What is a probe/surface? XCT is 3D Volume

XCT system not a CMM, its one of many CMSs?

ISO 10360 Part 11 currently under development for XCT by ISO/TC 213 committee

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Development Summary ~ISO 10360

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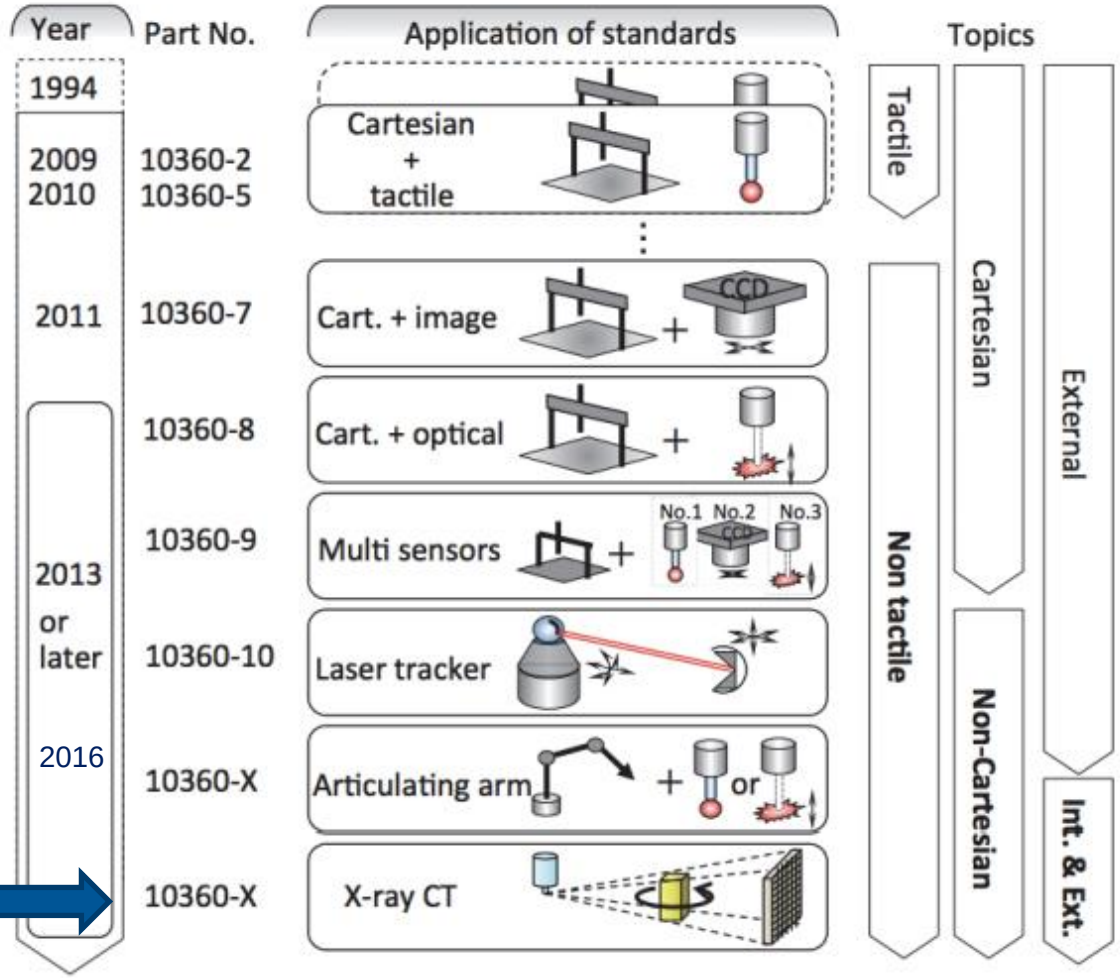

Unofficial ~CD Draft
XCT Part 11 at 3/2017

Toshiyuki Takatsuji ,
Makoto Abe ,
Hiroyuki Fujimoto
NMIJ
iCT Conference 2014)

ISO 10360 Part-11 XCT a document

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Current developmental status is:
Unofficial ‘CD’ committee draft @ 31.3.2017

Consists of:

- *Procedures*
- Recommended physical *test artefacts*, that can be used to *verify the performance* of both length and probing performance

The purpose of ISO 10360 XCT

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- **Intention:** Comparability with CMM.
- **Dedication:** Attenuation contrast ~ penetrating physical matter.
- **Defines:** Metrological characteristics and methods for testing XCT with single sensor.
- **Excludes:** Medical imaging & Eng' defect analyses.

ISO-10360 Part 11 XCT Considerations being debated

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- Length Error~ bi-directional /unidirectional
- Probing Errors
- Operating conditions: Environment, warm up cycles, thermal stability, software used
- Workpiece loading effects
- Measurement Volume & where in Volume?
- Measurement time
- Mono (or Multi-material)
- Materials: Considering~ Plastics; Aluminium; Steel
- Compatibility with the rest of ISO10360 parts

ISO XCT Task force members @ Sept 2017 members (Some main players)

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National Institute of Advanced Industrial Science and Technology
National Metrology Institute of Japan

ZEISS

PTB

Nikon

HEXAGON METROLOGY

NIST

NORTH STAR IMAGING, INC.
An ITW Company

EMS

werth Messtechnik

Example test samples
Material Influence (nominally size 50mm)

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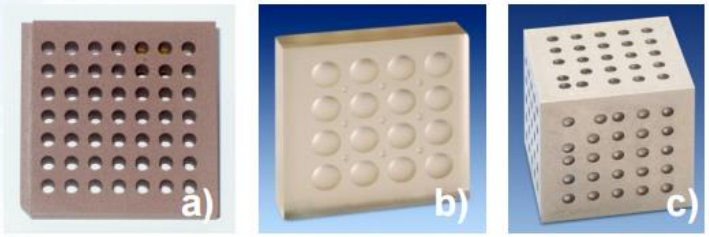
Length measurement error *E* testing

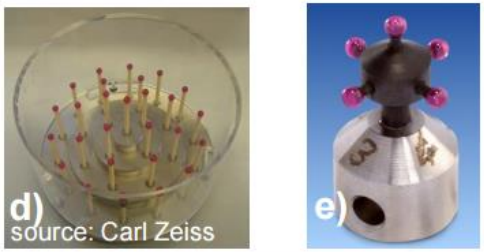
- **MPE_{Em} including material influence**; examples, implicit with internal features
  - a: hole plate
  - b: "calotte" plate
  - c: "calotte" cube



Under discussion:

Test with hole plate sufficient to show material influence?

- **MPE_{Ez} negligible material influence**
  - d: multiple sphere standards (stylus or probe forest)
  - e: stylus star



Additional measure-ments for material influence testing required (e.g. step cylinder)

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A hole plate design
Material influence

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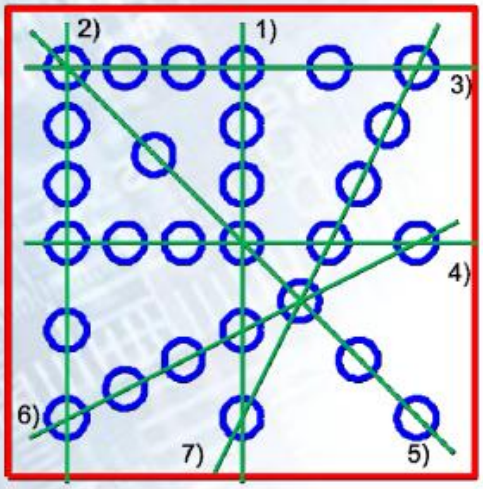
New design of hole plate with 28 holes



Advantage of new design:
7 lengths measured in one setting

Size considerations for aluminum
(low magnification case)

X-ray tube voltage in kV	Dimensions of square-shaped hole plate in mm			
	Side	Thickness	Diameter of holes	Material
90	18.0	3.0	1.5	Al
130	30.0	5.0	2.5	
225	48.0	8.0	4.0	
450	66.0	11.0	5.5	
600	77.0	13.0	6.0	

Size considerations for steel
(high magnification case)

X-ray tube voltage in kV	Dimensions of square-shaped hole plate in mm			
	Side	Thickness	Diameter of holes	Material
90	6.0	1.0	0.5	Fe
130				
225				
450				ZrO_2
600				WC

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Step cylinder gauge used for assessing internal measurement capability of dimensional X-ray CT. (max dia' 60mm)

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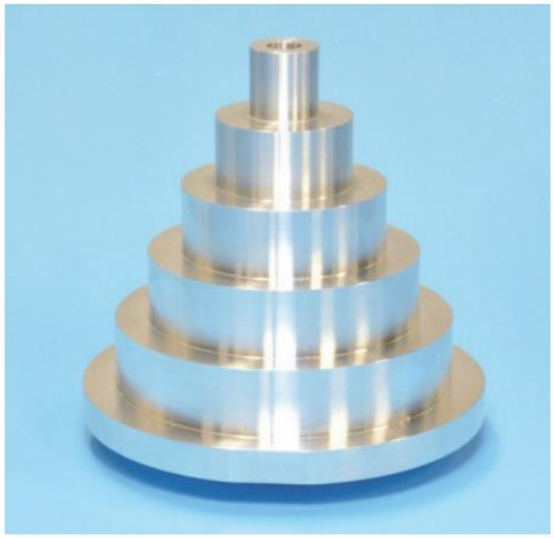

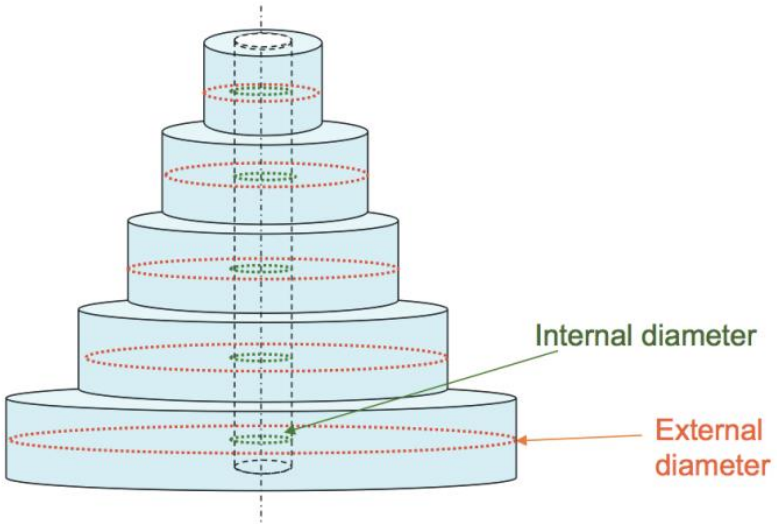

(Toshiyuki Takatsuji , Makoto Abe , Hiroyuki Fujimoto NMIJ iCT Conference 2014)

NMIJ

Summary:

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- Introduced XCT to 3DMC conference
- Defined XCT as a CMS and not a CMM
- Identified the importance of performance verification
- Reviewed MPE
- Established current industrial specifications are not ideal
- Reviewed evolution of ISO10360
- Advised that ISO part 11 for XCT under development
- Viewed some possible test artefacts that could be adopted
- Considered matters that may influence XCT performance

QUESTIONS Welcome?

Contact me for more information if required

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