Performance verification of industrial CT systems~ how do you know if a system meets specification?

Michael McCarthy PhD

Engineering Metrology Solutions

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BSI XCT Panel Chair. Principle member of ISO/TC 213

Nottingham: 3rd July 2018

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Thank you for inviting me to this NPL event, kindly hosted by Professor Richard Leach and his Manufacturing Metrology Team

2018

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Michael McCarthy ~ Roles

Current

- Independent dimensional metrology consultant [2016-]
  - Bespoke Engineering Metrology Solutions and Standards training;
  - Instrument design for high precision and measurement traceability.

- UK's principle member ~ ISO TC213 XCT [2007-];
- Chairman ~ BSI's XCT standards panel [2013-];
- Laboratory Assessor ISO/IEC 17025 [2016-];
- Honorary Professor ~ UCL. 3D metrology IMpact [2016 -].

Previous

- B.Sc…Mech Eng; Ph.D ~ Non-contact 3D Metrology. Cranfield (CIT) [1995];
- Principal Research Scientist NPL [1983 - 2016];
- Director, Engineering & Scientific [1979 -1983].

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Engagements examples include:

Airbus, Saab, Rolls Royce, UCL 3D IMpact, Nikon, X-Tek Systems, Mitutoyo, BMW, JLR, Leitz, Nissan, Honda, Aicon 3D, Hexagon, Ross Ceramics, Renishaw, GOM.GmbH, Steinbichler, Zeiss, Breuckmann, Delphi, Xaar, Depuy, Johnson & Johnson, Medtronic, Mazak, Hitachi, Red Bull, Third Dimension, Faro, Central Scanning, Guys, BARTS, AWE, Rutherford, JET, various government departments, and NPL.

30 ~ NMI's including ~ USA, Japan, China, Canada, Thailand, Russia & all European laboratories from PTB (Germany) to perhaps the smallest on Malta.

EURAMET, EMPIR, TC-L, BIPM, IOP, ISO213/10360, BSI Optical/XCT,

Marie Curie InteraqCT~ Leuven / Padova Universities.

EPSRC's SEAHA at the Bartlett. 20~UK Universities, Catapults Centres , Serco, QMT, IEEE, CMSC, EUSPEN, Lamdamap, SPIE and ASPE.

How do you know if a dimensional XCT system meets specification?

- Well generally you just don't…So tough…..
- Why?

- Because specifications are often sparse or complex and expressed in different ways. Users can be confused and furthermore there is currently 'no' ISO Standard;
- Material and thermal related effects seem to be almost unlimited;

- There is a VDI guide, great! but of limited scope;
- Currently ISO TC213/WG10 are developing an XCT dimensional verification standard~ part-11of ISO10360 range;

- ISO standard status? Good news…..A committee draft is now in circulation.

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XCT performance specifications, random examples ref: Internet 10/7/17 (DXCT 2017)

1) SYSTEM CAPABILITIES ~ Geometric Magnification: >2000x; Overall **Maximum System Resolution**: <500 nm;

2) **Maximum Permissible Error** 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;

3) **Absolute accuracy** 9 + L/50 µm;

4) **Resolution:** 3.5 - 6 µm; **Accuracy:** Down to 2.9 µm + L/100. Sphere center point error;

5) **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 Microns?

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Specifications, random examples: Internet 28/7/18 Caveats Creeping in 👍

1) Air bearing Multi-sensor CMM ‘inc X-ray’, complete 3D measurements with the highest precision. MPE: down to 2.5 µm. Maximum part Dia = 172 mm; Lmax. = 357 mm (depending on the aspect ration of the components). Application: Measurement and digitizing of plastic, light metal, and graphite parts.

2) Nominal Workpiece Envelope: Diameter: 30 cm Height: 30 cm; Overall Maximum System Detectability: ~2 µm; Exact specifications vary depending on tube, detector, and other optional configurations.

3) Accuracy (µm) MPE_{SD}; 9+L/50 (L in mm); Sample size (maximum); Diameter 250 mm, Height 450 mm; Applies only to single material samples with a maximum diameter of 250 mm and maximum height of 250 mm.

4) Accuracy (MPE complies with VDI/VDE 2630 sheet 1.3) Sphere center point error SD 4.5+L/50 µm; Probing error PS 3 µm; PF 4 µm; Length measurement error E 8+L/100 µm; Max. Diameter in mm 170; Max. Height in mm 150.

5) Detail visibility of up to 150 nm with water-cooled 190 kV transmission tube; Sample Diameter 300 mm; Sample Height 500 mm; Precise metrology MPE_{SD} = 8 µm + L/75, measured as a deviation of sphere distance referring to VDI 2630-1.3.

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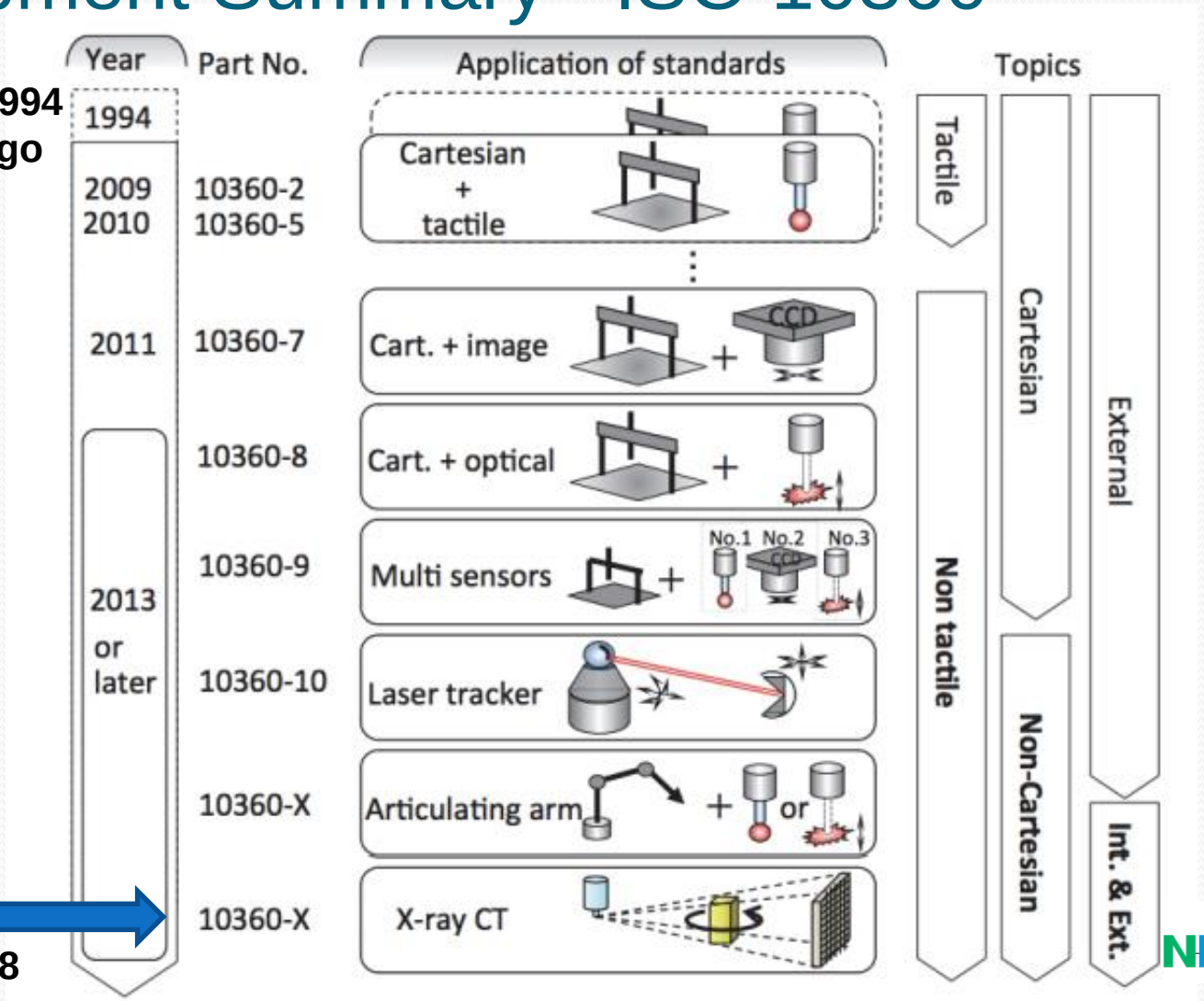
Development Summary ~ISO 10360

Started before 1994
Some 25 years ago

AA Part 12
Published 2016

Unofficial Draft
XCT Part 11 at 9/2017

Official CD 6/2018



(Takatsuji , Abe, Fujimoto NMIJ iCT 2014)

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ISO verification~ XCT 3D. What does it do?

- Demonstrates traceability to national standards.
- Estimates the accuracy of measurements
  - Provides confidence
  - Assuring reliability in the measurements.
- The ISO 10360 series of standards, can check MPE supporting
  - Acceptance;
  - Re-verification tests;
  - Interim checks.

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Internationally agreed* purpose of ISO 10360 XCT

- Intention: To achieve comparability with the characteristics of coordinate measuring systems with tactile and with optical sensors.
- Dedicated to measurements which are predominantly based on the attenuation contrast when penetrating physical matter.
- Define metrological characteristics and methods for testing XCT with a single sensor which are dedicated to dimensional measurements of workpieces.
- Excludes: medical imaging, medical dimensional measurements and as well non-destructive (material) defect analyses.

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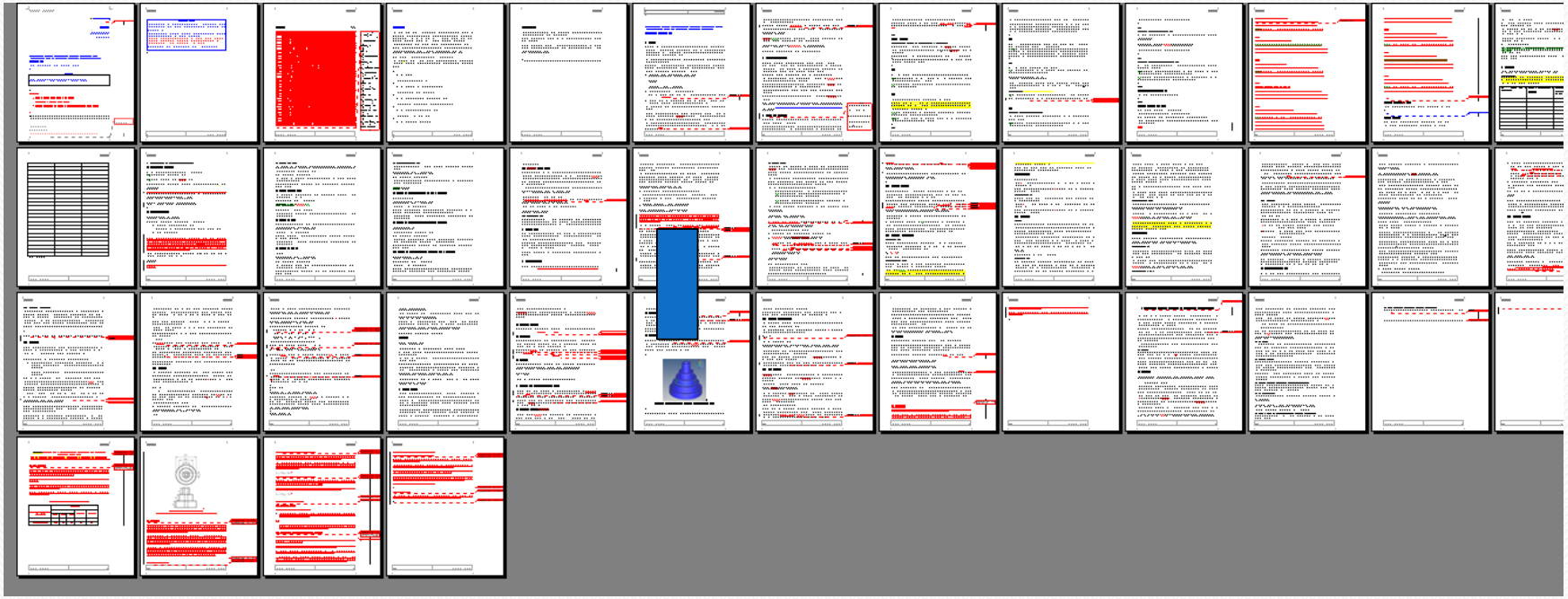
ISO 10360 Part-11, XCT task force's draft (pre committee-draft [CD]), nominally mid- 2017.



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Reaction to XTC task force's private draft

- Balloted internally with in ISO213-WG10 during late 2017. It received a massive 111 technical comments;
- An extremely high percentage of these from Germany & Japan~ many good comments which are now included in the current CD.

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ISO.TC213.N2116 ISO10360-11 official (CD) 6/2018, XCT ballot ‘NOW’

70 page Document

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XCT (CD). The key chapters (Ch)

1. Scope
2. Normative references
3. Terms and definitions
4. Symbols
5. Requirement for metrological characteristics
6. Acceptance tests and reverification tests
7. Compliance with the specifications
8. Application
9. Literature

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Ch 1-4. Scope, Normative, Terms & Symbols

1. Scope
2. Normative references
3. Terms and definitions
4. Symbols

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Ch 5. Requirement for metrological characteristics

- 5.1 Environmental conditions
- 5.2 Operating conditions
- 5.3 Probing form error
- 5.4 Probing dispersion error
- 5.5 Probing size error
- 5.6 Probing size error All
- 5.7 Circle probing form error
- 5.8 Bidirectional Length measurement error
- 5.9 Length measurement error average
- 5.10 Workpiece loading effects
- 5.11 Measurement time
- 5.12 Criteria for material of reference standards
- 5.13 Characteristics assessed with explicit use of pre-knowledge

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Ch 6. Acceptance & reverification tests

- **6.1 General**
- **6.2 Probing characteristics**
- 6.2.1 Principle
- 6.2.2 Measuring equipment
- 6.2.3 Procedure
- 6.2.4 Derivation of test results
- **6.3 Length measurement error average**
- 6.3.1 Principle
- 6.3.2 Measuring equipment
- 6.3.3 Procedure
- 6.3.4 Derivation of test results

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Ch 7. Compliance with the specifications

- **7.1 Acceptance tests**
- 7.1.1 Acceptance criteria
- **7.2 Reverification tests**
- 7.2.1 Reverification criteria
- **7.3 Interim checks application**
- 7.3.1 Reference standards
- 7.3.2 Procedure
- 7.3.3 Analysis and compliance with specifications

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Ch 8-9. Application, Literature

- **8 Application**
- **8.1 Acceptance test**
- **8.2 Reverification test**
- **8.3 Interim check**
- **9 Literature**

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XCT (CD) Informative annexes

- Annex A: Metrological structural resolution for dimensional measurements
- Annex B : Description of CT scanning modes and guidance for testing
- Annex C : Reference standards for length error measurements
- Annex D : Hardware configurations of CT-based CMSs

- Annex E : Annex E (informative) Relation to the GPS matrix model

Fundamental GPS standards		Global GPS standards						
		General GPS standards						
		Chain link number	1	2	3	4	5	6
		Size					X	
		Distance					X	
		Radius					X	
		Angle					X	
		Form of line independent of datum					X	
		Form of line dependent of datum					X	
		Form of surface independent of datum					X	
		Form of surface dependent of datum					X	
		Orientation					X	
		Location					X	
		Circular run-out						
		Total run-out						
		Datums					X	
		Roughness profile						
		Waviness profile						
		Primary profile						
		Surface imperfections						
		Edges						

Figure E.1 Position in the GPS matrix model

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A call for UK industry to ‘now’ review this June 2018 ISO XCT CD.

- In Three to Four years time an XCT ISO verification standard could be published highly based around this CD.
- You will most probably be forced to use the standard.
- **This should worry you? Will it support or hinder your work?**
- You can potentially influence the final standard, by reviewing the CD and providing written comments.
- Don’t sit back and for example, just let, our the Germans, American or Japanese friends etc…and their industries have a standard that meets their needs **and NOT YOURS / or that of UK !**

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So you want to help review this XCT CD? How do you get a copy ?

Ask me today? Or email ASAP either:

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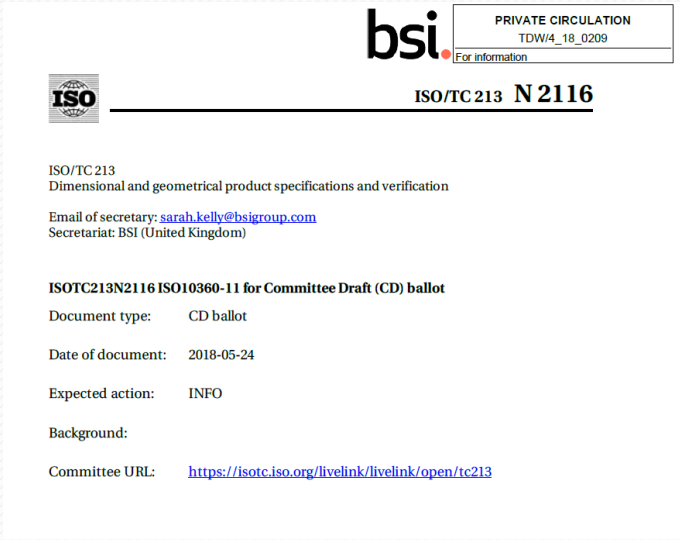
sarah.kelly@bsigroup.com



bsi. PRIVATE CIRCULATION TDW/4_18_0209 For information

ISO ISO/TC 213 N 2116

ISO/TC 213
Dimensional and geometrical product specifications and verification

Email of secretary: sarah.kelly@bsigroup.com
Secretariat: BSI (United Kingdom)

ISOTC213N2116 ISO10360-11 for Committee Draft (CD) ballot

Document type: CD ballot

Date of document: 2018-05-24

Expected action: INFO

Background:

Committee URL: https://isotc.iso.org/livelink/livelink/open/tc213

When does this CD ballot close?

- Comments to be sent to BSI before 10th August 2108.*
- Comments must be written and supported with technical justification.

I URGE YOU TO GET YOUR VIEWS ACROSS NOW

This is a real opportunity for you to get your opinions ~ that is what you and UK needs incorporated into the standard.

Hard or soft Brexit won't help us here

* BSI needs to time to prepare your comments, before they send them to ISO prior to 16th Aug 2018

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BSI hosting XCT meeting to discuss this draft ISO standard

- The standard will have an impact on your work.

  Act NOW.

- The meeting is to review and discuss the latest voting document on the XCT standard that is being developed within the ISO/TC 213 international committee area.

- The UK can submit comments with its vote to support the UK view on the content of the draft.

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NOTICE OF MEETING
Monday 16th JULY 2018, BSI London

TDW/4/4/1, Technical product realization – XCT

Monday 16th July 2018, starting at 11.00h
BSI, 389 Chiswick High Road, London W4 4AL

If you would like to be invited, contact either:
michael.mccarthy.x@gmail.com
sarah.kelly@bsigroup.com

Moving forwards

- Development of draft ISO XCT document continues under joint German & Japanese chairmanship, with international input. **CD in UK, distribution ~started June 2018**
- When published it is highly likely to have an impact your work; so get involved?
- UK industry strongly encouraged to, review drafts and input ideas into ISO via, BSI. **Dead line for comments on XCT CD is 10th August 2018**
- BSI TDW4/TPR1 meets two to four times a year. Your are welcome.
- BSI's XCT ISO10360 standards user group, we meet a few times per year or as required~ Join the next meeting on **16th July 2018 at BSI, London.**
- How do you know if a system meets specification? Well you will be far better placed to determine this, once the ISO10360 Part 11 become formalised; but sadly that is a few years away yet (2022?).

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