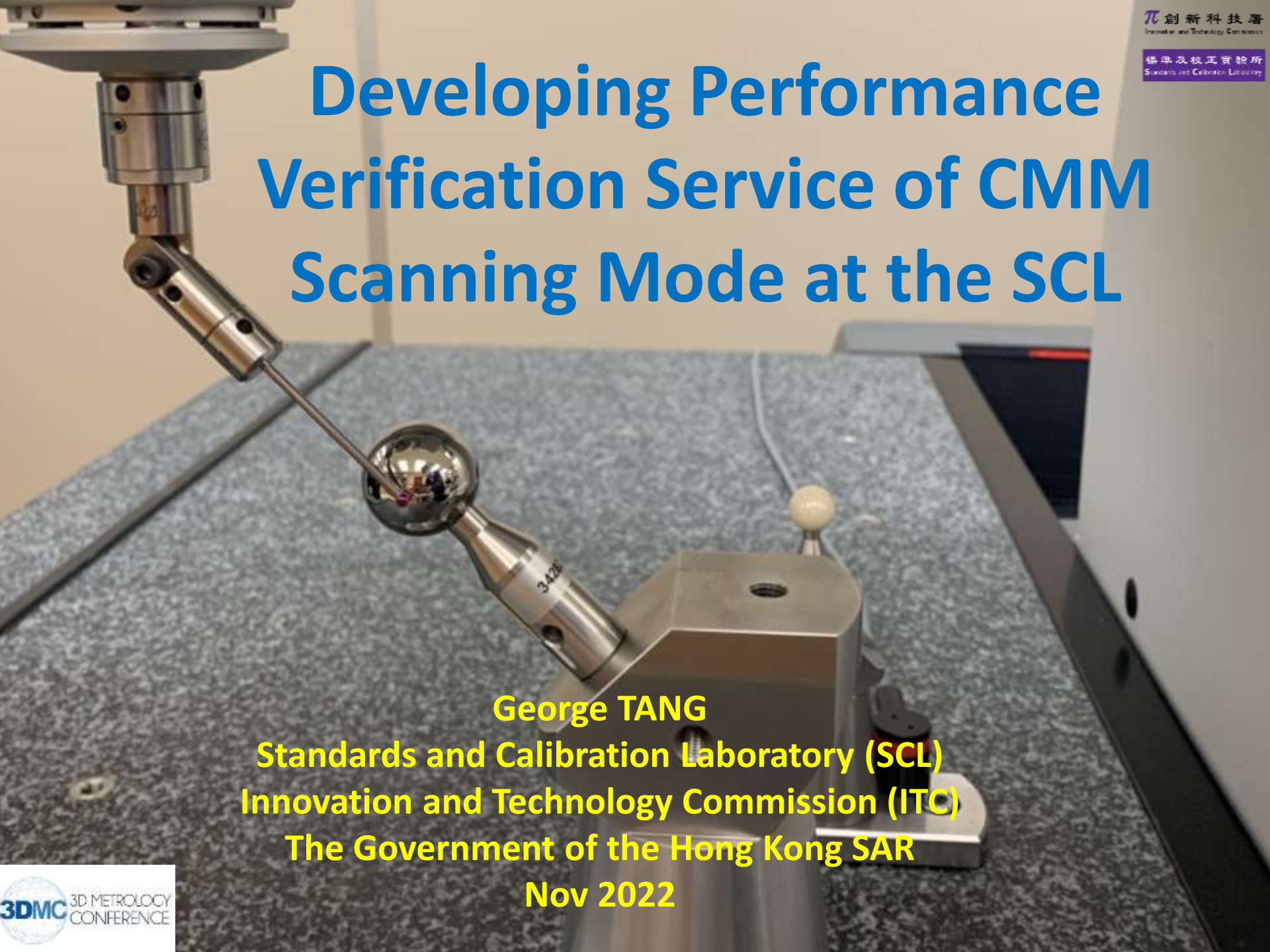

Developing Performance Verification Service of CMM Scanning Mode at the SCL

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The Government of the Hong Kong SAR

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3DMC 3D METROLOGY CONFERENCE

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2. Brief Summary of the Service
3. Highlights of ISO 10360-5:2020 Updates
4. Verification
   - Preparation Steps
   - Scanning Path
5. Results analysis and CMC
   - Verification of CMM generated results
   - Measurement Capability
   - Future Development

1. Introduction to Standards and Calibration Laboratory (SCL), Hong Kong, China

1. Standards and Calibration Laboratory (SCL) Mutual Recognition Arrangement

- SCL is a Signatory to the Mutual Recognition Arrangement of the International Committee of Weights and Measures (CIPM MRA)
- Through the CIPM MRA, SCL demonstrates the international equivalence of its measurement standards and mutual acceptance of the calibration and measurement certificates they issue. [97 NMIs]
- Over 190 Calibration and Measurement Capabilities (CMC) of SCL are listed at the CIPM MRA database.

Metrology Field	CMC
Acoustics	15
Electricity	66
Length	15
Mass and Related quantities	34
Thermometry	34
Time and Frequency	29
Total	**193**

CIPM MRA

創新科技署 Innovation and Technology Commission

標準及校正實驗所 Standards and Calibration Laboratory

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2. Brief Summary of the Service

2. CMM Scanning Mode Verification i.a.w. ISO 10360-5:2020

2. The problems

- (i) data and (ii) evaluation were genuinely generated with (iii) the required setting following the ISO standard strictly?
- Service covering all brands of CMM

3. Highlights of ISO 10360-5:2020 Updates

3. ISO-10360-5:2020 Update

- Parameter formatting
  - P_{THP} -> $P_{form.Sph.Scan:PP:Tact}$ (F: form , Sph: sphere, PP: pre-defined path, T:tactile)
  - MPE_{THP}-> $P_{form.Sph.Scan:PP:Tact,MPE}$ (MPE: maximum permissible error)
  - τ -> $\tau_{Sph.Scan:PP:Tact}$ (τ : time taken)
- Rated operating condition
  - MPT_{τ} -> $\tau_{Sph.Scan:PP:Tact,MPT}$ (MPT: maximum permissible time)
  - Unless manufacturer stated explicitly otherwise, test sphere shall meet all the following requirements for all of the associated MPEs

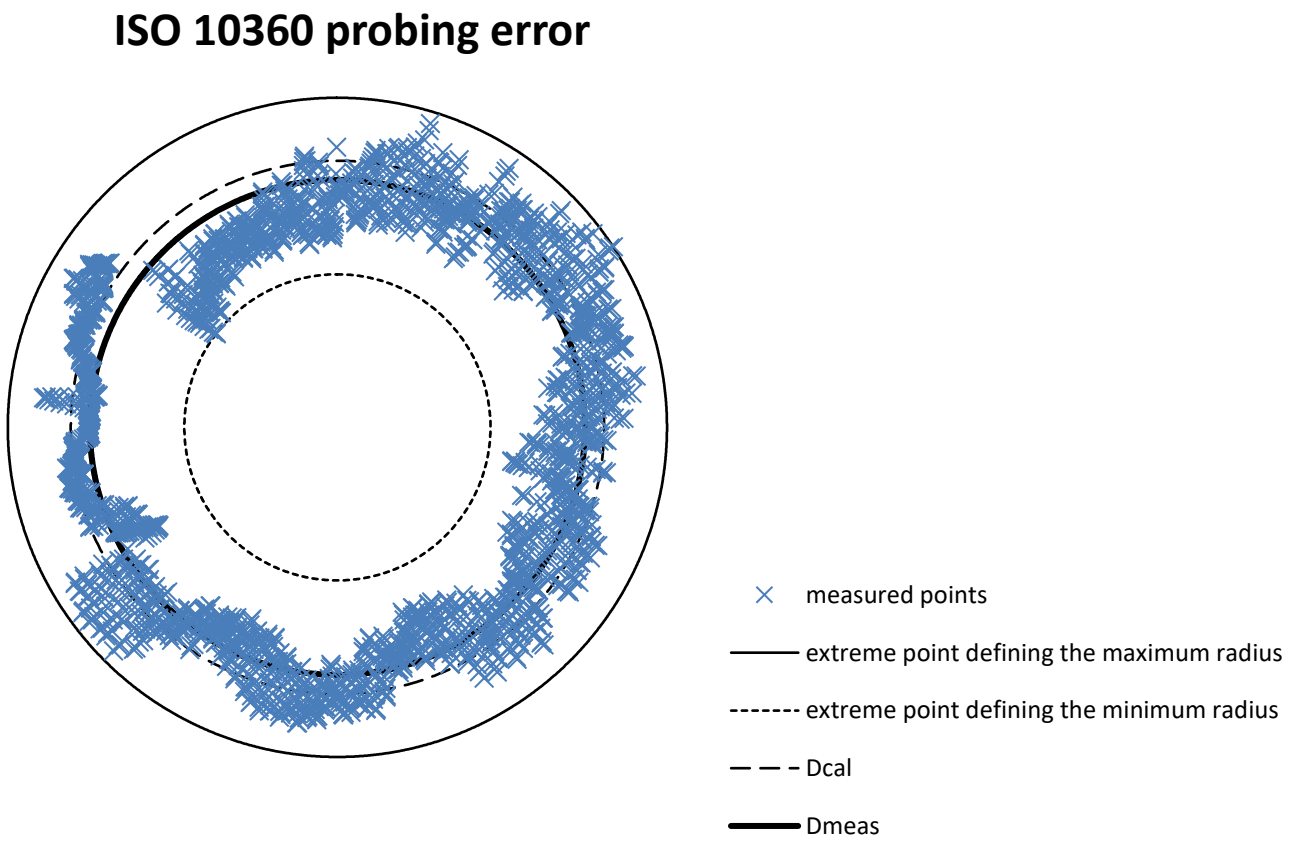
    F_{Cal} <= 20 % of $P_{form.Sph.1x25:SS:Tact,MPE}$ (SS: single stylus)

    $F_{Cal} + 1.65\ u_{(Cal)}$ <= 25 % of $P_{form.Sph.1x25:SS:Tact,MPE}$

    $F_{Cal} + 1.65\ u_{(Cal)}$ <= 2.5 μm

    Then the test sphere's sphericity is treated as zero in the evaluation of probing errors in this ISO.
- Sphere diameter of 24.9 mm – 25.5 mm shall be used
- Presentation using "2D simplified illustration"

3. 2D simplified illustration



4. Verification

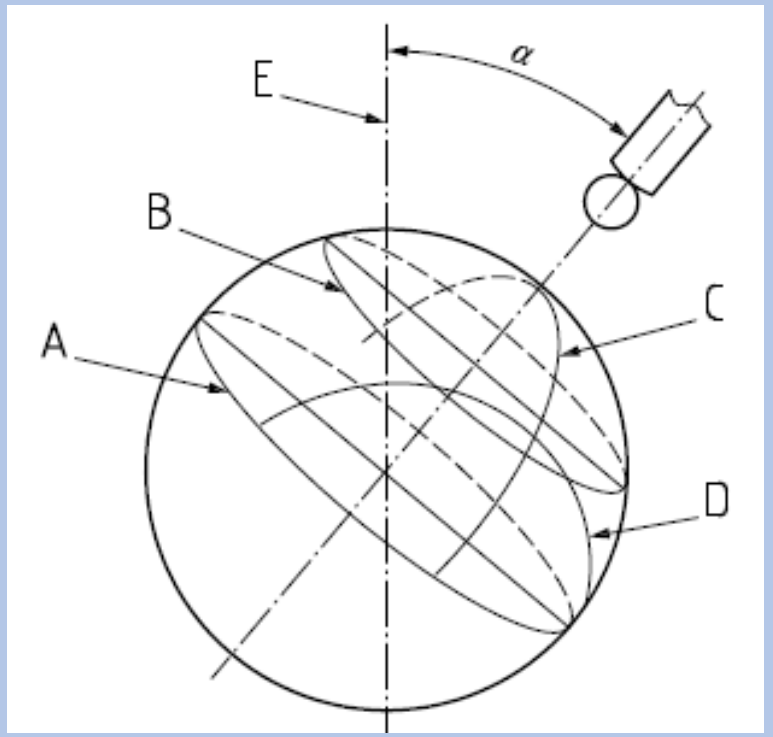
4. Preparation meeting with clients

- Explain the verification procedure of the standard (ISO 10360-5:2020).
- Pass the 3D printed 25 mm diameter dummy sphere for programme trial.

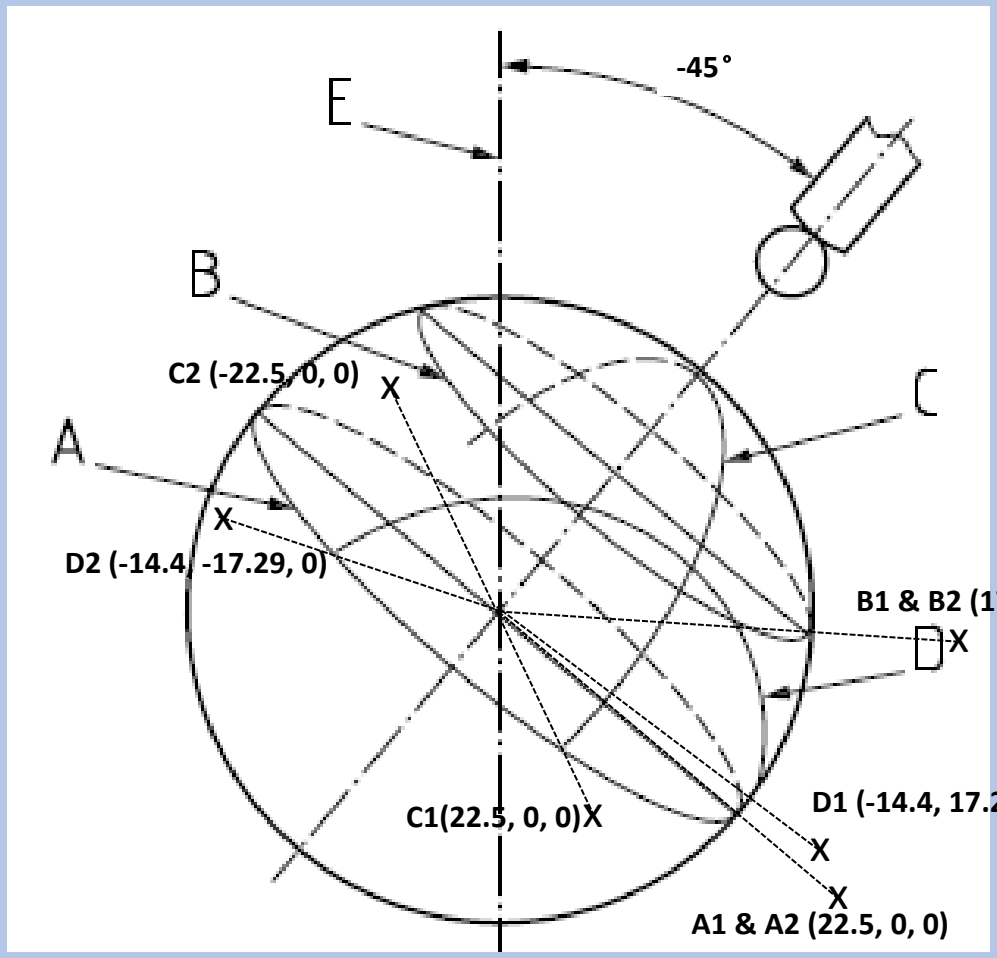
- (After the meeting) Client sends the programme to SCL in pdf or txt format for SCL to review
- If necessary, SCL asks the customer to demonstrate the scanning on-site or by video recording.

4. Scanning Program Description

- Plane A is equator
- Plane B is parallel to Plane A & 8 mm apart
- Planes B, C & D are mutually perpendicular
- Plane C goes through the pole
- Plane D is 8 mm offset from pole axis



4. Scanning Program Description



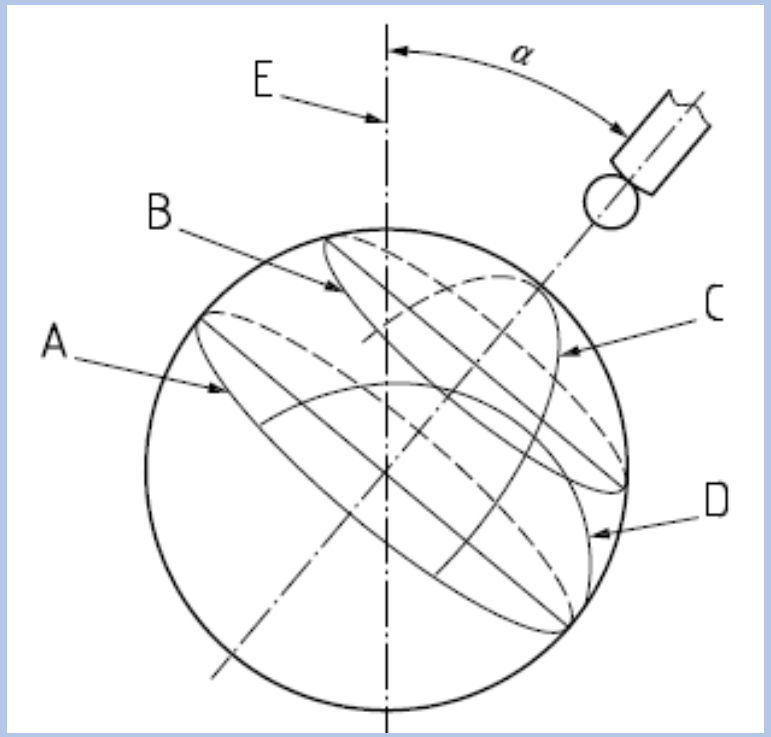
4. Scanning Program Description

1. Rotate the probe -45˚ along y-axis.
2. Create a new coordinate by rotating the coordinate 45˚ along y-axis. Use this new coordinate.
3. Move the probe to (22.5, 0, 0).
4. Move the probe onto path A and scan through path A. (Note: timer starts at this step. The probe should approach the sphere along a surface normal i.e. direction vector shall always point at the center of the sphere. This can take advantage on some existing programme of the CMM such as scanning sphere or cylinder.)
5. Move the probe back to (22.5, 0, 0).
6. Move the probe to (17.2884, 0, 14.4).
7. Move the probe onto path B and scan through path B.
8. Move the probe to (17.2884, 0, 14.4).
9. Move the probe to (22.5, 0, 0)
10. Move the probe onto path C and scan through path C.
11. Move the probe to (-22.5, 0, 0)
12. Move the probe to (-14.4, -17.2884, 0). (Check if this travel touches the sphere. Add intermediate step if required.)
13. Move the probe onto path D and scan through path D.
14. Move the probe to (-14.4, 17.2884, 0). Timer stops after this step completes.

5. Results Analysis & CMC

5. Excel calculator

- Number of data points
  - Point density ≤ 0.1 mm
  - Max normal distance from plane = 0.2 mm
  - Theoretical number of points = 2081



5. Excel calculator

Input data

28/4/2022
230V 50Hz 19.8 °C 55.5 %RH 994.7 hPa

Test sphere diameter			=Dcal	25.00007	mm	Testing criteria PSize.Sph.Scan:PP:Tact					0.8	µm
a) Scanning probing error, T_ij			=R_{max} - R_{min}	1.34728	µm	PForm.Sph.Scan:PP:Tact					1.6	µm
b) Max absolute difference between any individual calculated radius				0.866709565	µm	= Sph.Scan:PP:Tact					45	s
c) time taken for scanning test			= τ	45	s	for probing						

Co-ordinate =>	Xi (mm)	Yi (mm)	Zi (mm)	D (for D)	$X^2+Y^2+Z^2$	R_i (mm)	Rcal	Rmea	Rmax	Rmin	R_i-R (mm)
1	12.5000	-0.0002	0.0006	1.0000	156.25075	12.49985	12.50004	12.49989	12.50052	12.49917	-0.00004
2	12.4996	0.0980	0.0025	1.0000	156.25030	12.49983	12.50004	12.49989	12.50052	12.49917	-0.00006
3	12.4984	0.1961	0.0034	1.0000	156.24969	12.49980	12.50004	12.49989	12.50052	12.49917	-0.00008
4	12.4965	0.2943	0.0034	1.0000	156.24891	12.49977	12.50004	12.49989	12.50052	12.49917	-0.00011
5	12.4938	0.3924	0.0028	1.0000	156.24871	12.49977	12.50004	12.49989	12.50052	12.49917	-0.00012
6	12.4903	0.4905	0.0020	1.0000	156.24860	12.49976	12.50004	12.49989	12.50052	12.49917	-0.00013
7	12.4861	0.5886	0.0015	1.0000	156.24855	12.49976	12.50004	12.49989	12.50052	12.49917	-0.00013
8	12.4811	0.6867	0.0013	1.0000	156.24832	12.49975	12.50004	12.49989	12.50052	12.49917	-0.00014
9	12.4753	0.7847	0.0018	1.0000	156.24839	12.49976	12.50004	12.49989	12.50052	12.49917	-0.00013
10	12.4687	0.8826	0.0029	1.0000	156.24852	12.49976	12.50004	12.49989	12.50052	12.49917	-0.00013
11	12.4614	0.9805	0.0045	1.0000	156.24894	12.49978	12.50004	12.49989	12.50052	12.49917	-0.00011
12	12.4534	1.0784	0.0059	1.0000	156.24941	12.49980	12.50004	12.49989	12.50052	12.49917	-0.00009
13	12.4445	1.1762	0.0065	1.0000	156.24986	12.49982	12.50004	12.49989	12.50052	12.49917	-0.00007
14	12.4349	1.2739	0.0060	1.0000	156.25003	12.49983	12.50004	12.49989	12.50052	12.49917	-0.00006
15	12.4245	1.3715	0.0047	1.0000	156.24994	12.49982	12.50004	12.49989	12.50052	12.49917	-0.00006
16	12.4134	1.4690	0.0031	1.0000	156.24979	12.49982	12.50004	12.49989	12.50052	12.49917	-0.00007
17	12.4015	1.5665	0.0014	1.0000	156.24984	12.49982	12.50004	12.49989	12.50052	12.49917	-0.00007
18	12.3888	1.6638	0.0002	1.0000	156.24985	12.49982	12.50004	12.49989	12.50052	12.49917	-0.00007
19	12.3753	1.7611	-0.0003	1.0000	156.24973	12.49982	12.50004	12.49989	12.50052	12.49917	-0.00007
20	12.3611	1.8582	0.0002	1.0000	156.24996	12.49983	12.50004	12.49989	12.50052	12.49917	-0.00006
21	12.3462	1.9552	0.0018	1.0000	156.25085	12.49987	12.50004	12.49989	12.50052	12.49917	-0.00002
22	12.3305	2.0522	0.0038	1.0000	156.25181	12.49991	12.50004	12.49989	12.50052	12.49917	0.00002
23	12.3140	2.1489	0.0053	1.0000	156.25282	12.49995	12.50004	12.49989	12.50052	12.49917	0.00006
24	12.2968	2.2456	0.0060	1.0000	156.25359	12.49998	12.50004	12.49989	12.50052	12.49917	0.00009
25	12.2788	2.3421	0.0058	1.0000	156.25354	12.49998	12.50004	12.49989	12.50052	12.49917	0.00009
26	12.2599	2.4385	0.0049	1.0000	156.25246	12.49994	12.50004	12.49989	12.50052	12.49917	0.00005
27	12.2404	2.5347	0.0037	1.0000	156.25080	12.49987	12.50004	12.49989	12.50052	12.49917	-0.00002
28	12.2200	2.6307	0.0024	1.0000	156.24873	12.49979	12.50004	12.49989	12.50052	12.49917	-0.00010
29	12.1989	2.7266	0.0017	1.0000	156.24652	12.49970	12.50004	12.49989	12.50052	12.49917	-0.00019
30	12.1770	2.8223	0.0017	1.0000	156.24468	12.49963	12.50004	12.49989	12.50052	12.49917	-0.00026
31	12.1544	2.9178	0.0025	1.0000	156.24358	12.49959	12.50004	12.49989	12.50052	12.49917	-0.00030
32	12.1311	3.0132	0.0036	1.0000	156.24302	12.49957	12.50004	12.49989	12.50052	12.49917	-0.00032
33	12.1071	3.1084	0.0043	1.0000	156.24319	12.49957	12.50004	12.49989	12.50052	12.49917	-0.00032
34	12.0823	3.2034	0.0041	1.0000	156.24355	12.49959	12.50004	12.49989	12.50052	12.49917	-0.00030
35	12.0568	3.2982	0.0032	1.0000	156.24396	12.49961	12.50004	12.49989	12.50052	12.49917	-0.00028
36	12.0305	3.3928	0.0019	1.0000	156.24442	12.49963	12.50004	12.49989	12.50052	12.49917	-0.00026
37	12.0035	3.4872	0.0006	1.0000	156.24477	12.49964	12.50004	12.49989	12.50052	12.49917	-0.00025
38	11.9758	3.5813	-0.0002	1.0000	156.24553	12.49967	12.50004	12.49989	12.50052	12.49917	-0.00022
39	11.9473	3.6753	-0.0007	1.0000	156.24683	12.49973	12.50004	12.49989	12.50052	12.49917	-0.00016

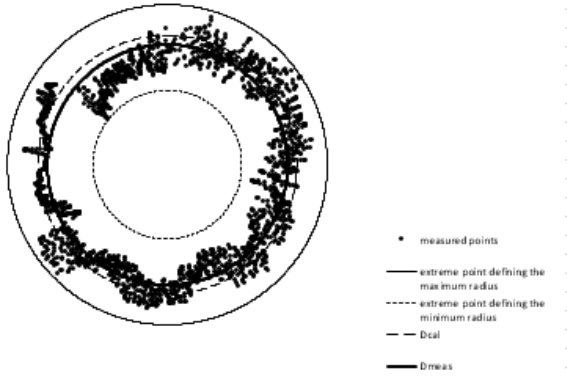
Compliance?

a)	YES	-0.29190	
b)	YES	1.3473	
c)	YES		

Coefficient	Fitted Coef	Fitted sd	Sensit Coef	$(a*b)^2$
A	0.0004	0.00002	0.0000	1.2344E-20
B	-0.0002	0.00002	0.0000	4.7385E-21
C	0.0004	0.00003	0.0000	4.6731E-20
D	156.2472	0.00018	0.0400	5.4019E-11
R^2 =>	1.000000			
sd =>	0.0056			
df =>	2175			

Center at =>	0.0002	-0.0001	0.0002	
Radius (mm) =>	12.499889			24.999778
Form error (mm) =>	0.00135			
Ucy (mm) =>	0.0000			

ISO 10360 probing error

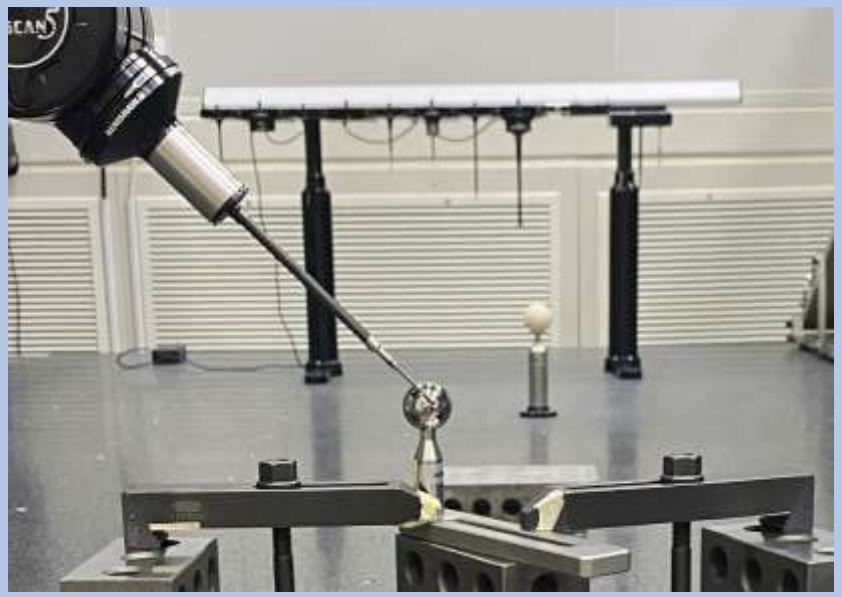


5. Results & Reporting Format

Measured Parameter	Measured Value			MPE (µm)
	Value y (µm)	Measurement Uncertainty		
		Expanded Uncertainty U (µm)	Coverage Factor k	
$P_{Size.Sph.Scan:PP:Tact}$*	-0.29 µm	0.15	2	0.80 µm
$P_{Form.Sph.Scan:PP:Tact}$	1.3 µm	N/A#	N/A#	1.6 µm
$\tau_{Sph.Scan:PP:Tact}$	45 s	N/A	N/A	45 s

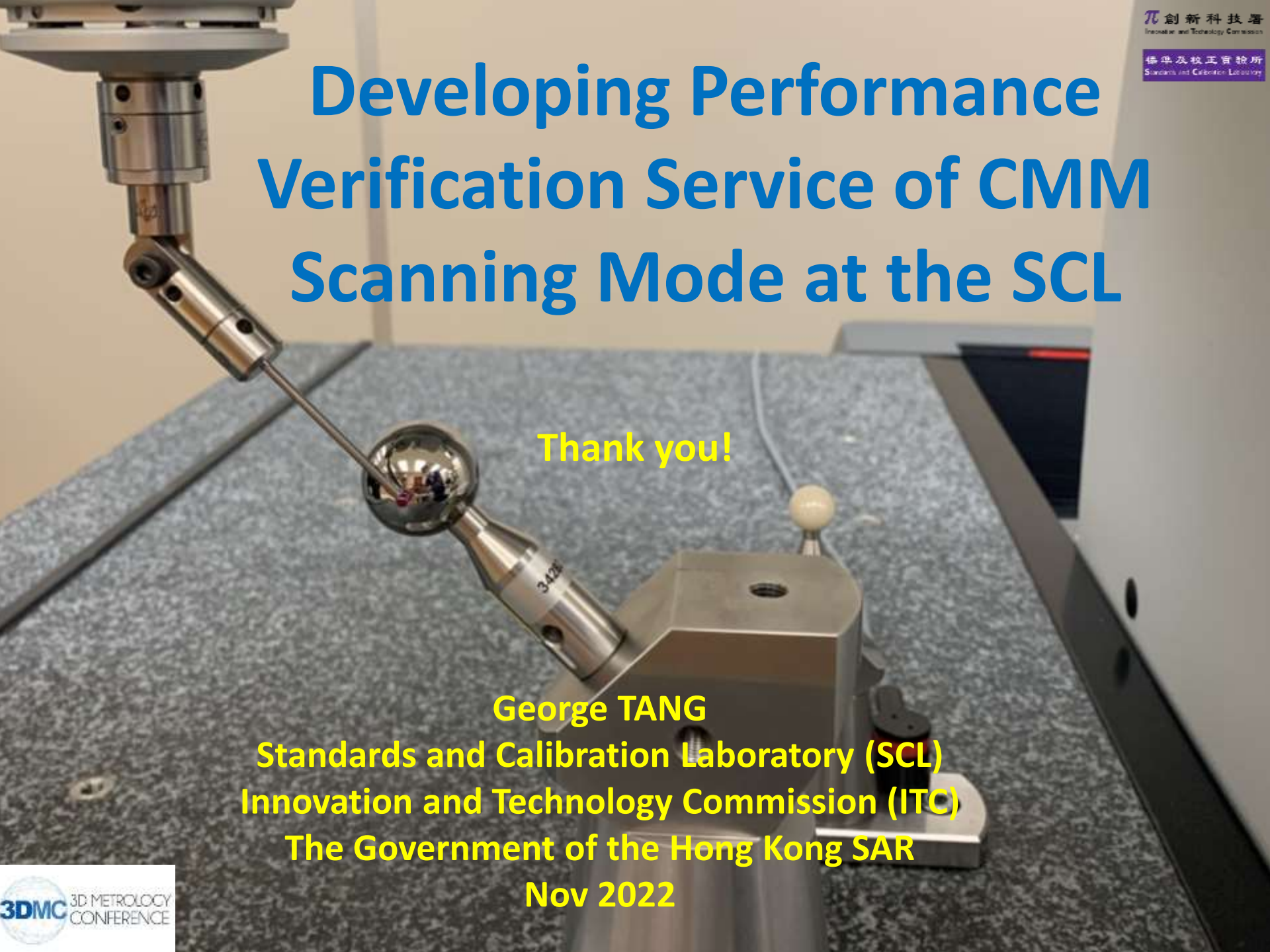
5. Measurement Capability

- $P_{Size.Sph.Scan:PP:Tact}$ = 0.8 µm
- $P_{Form.Sph.Scan:PP:Tact}$ = 1.6 µm



5. Future Development

- Articulated Arm CMM (AACMM) verification
- AACMM Laser Scanner verification
- CMM verification using laser tracer



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