Advances in active edge control, as applied to 1.4m hexagonal mirror segments

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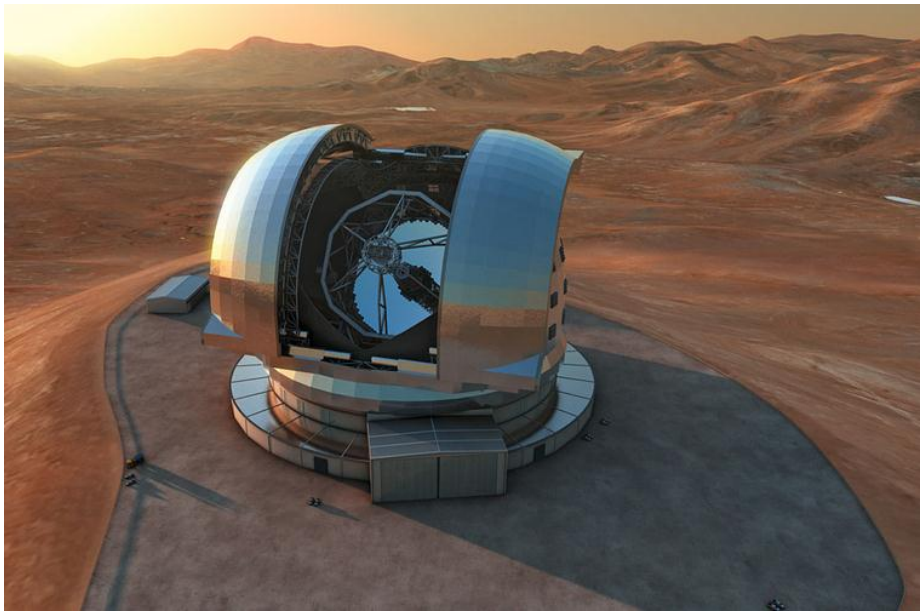
Outline

- Context of the European Extremely Large Telescope
- New process chain
- Challenge of edges
- Results achieved

Context – the 39.3m aperture "E-ELT"
European Extremely Large Telescope



Artist's impression

- Optical/IR telescope
- Originally 42m primary R=84m
- De-scoped to 39m, R=69m
- 798 segments + 133 spares
- 1.4m a/corners hexagons

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Off-axis aspheric prototypes:- ESO surface specification (very abridged!)

	Average	Max.
Form RMS (excluding 10mm edge-zone)	**25nm**	**50nm**
Form RMS (Mid spatial frequency component:- low-order terms removed)	**7.5nm**	**15nm**
Edge-zone mis-figure PVq (95%)	**100nm**	**200nm**

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Prototype segments

- REOSC-SAGEM (France) have manufactured prototypes for ESO using a process-chain:-
  - Polish roundals
  - cut hexagonal
  - Ion figure
- ESO commissioned OpTIC to develop a new process-chain and manufacture prototypes
  - Final hexagonal shape throughout

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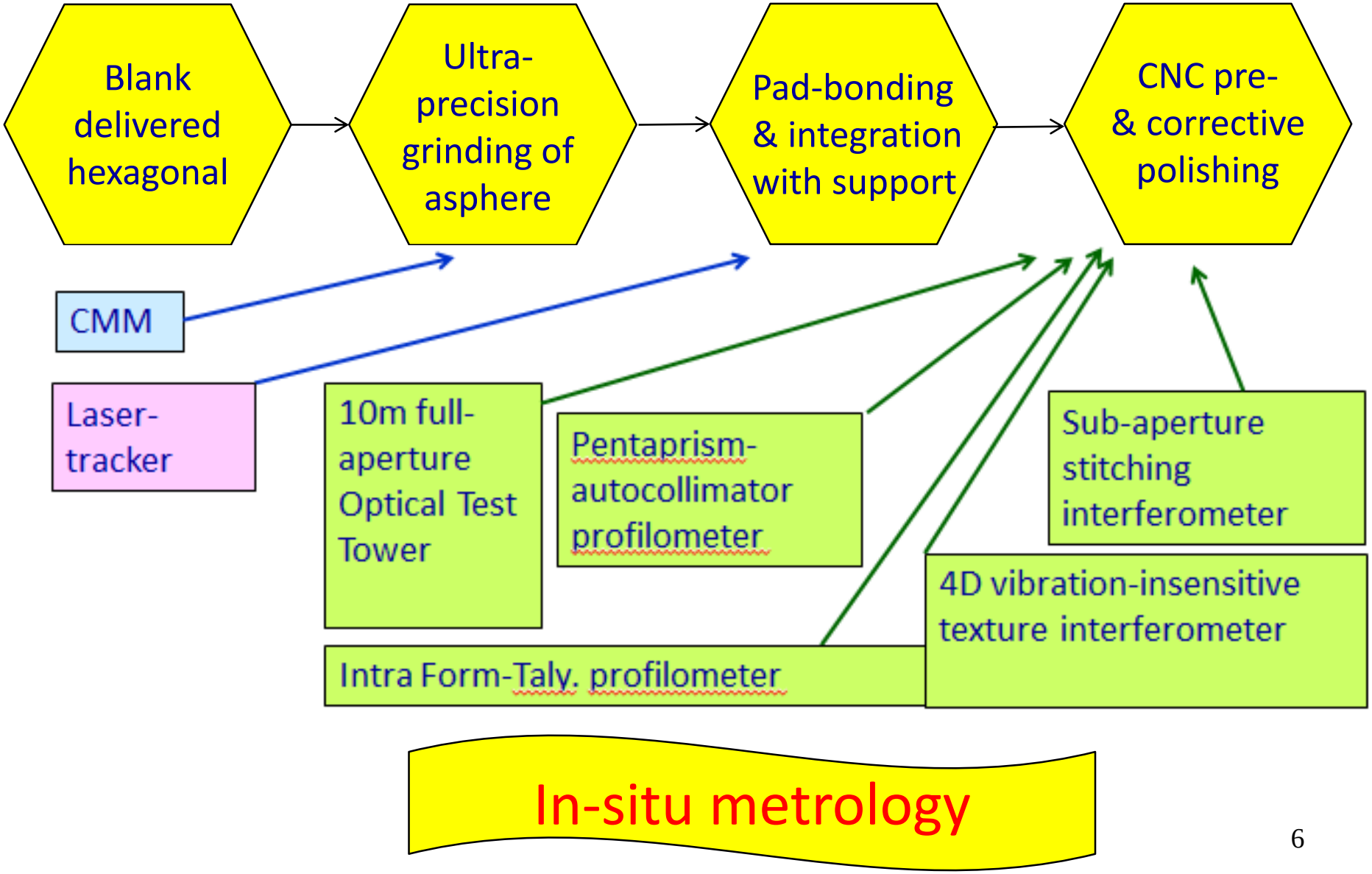
New process chain



Acknowledgement:- Cranfield University

High-speed grinding the off-axis asphere

BoX™ machine

Machine & process designed by Cranfield University

Manufactured by Cranfield Precision Ltd

- Three E-ELT prototype segments successfully ground

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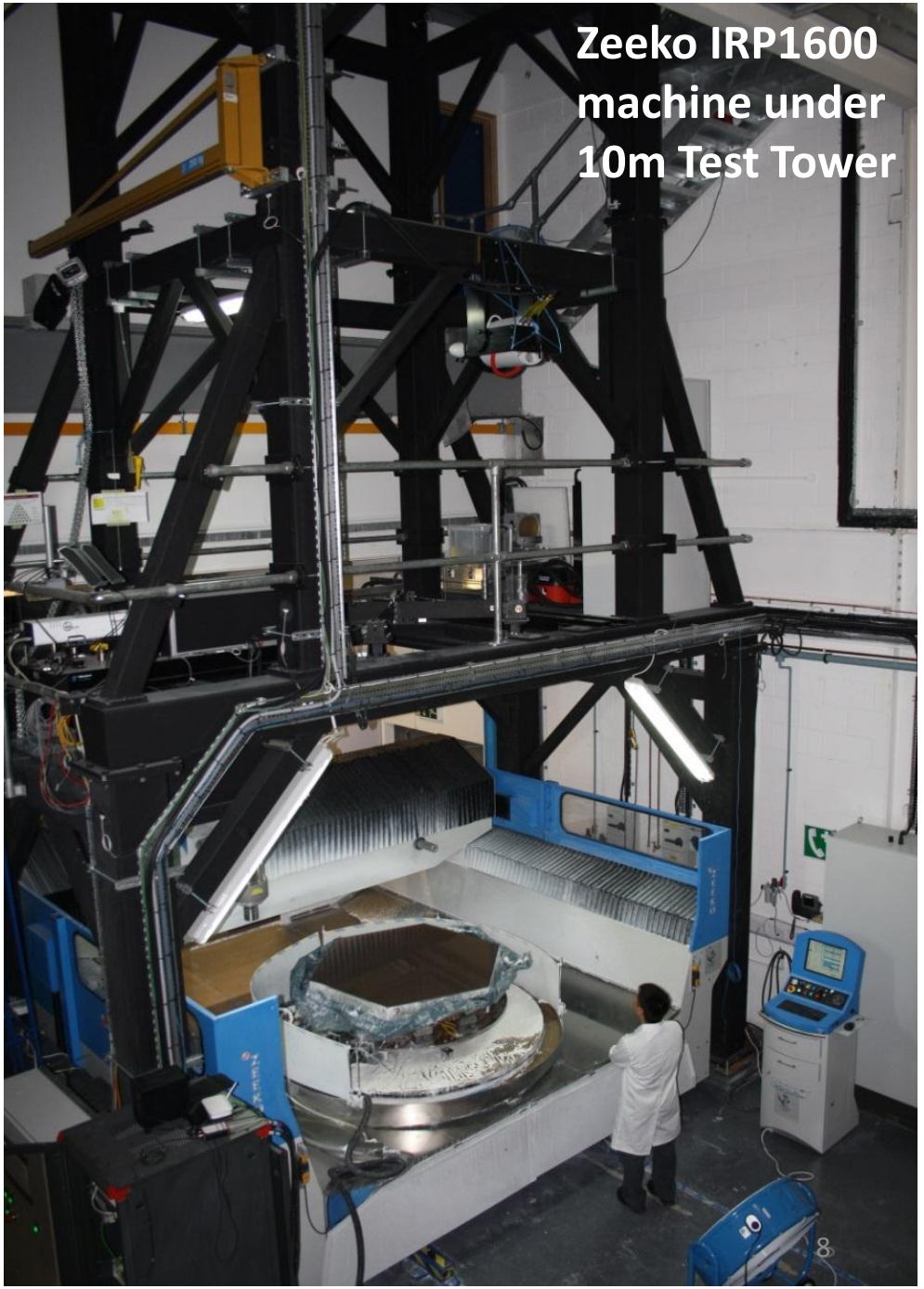
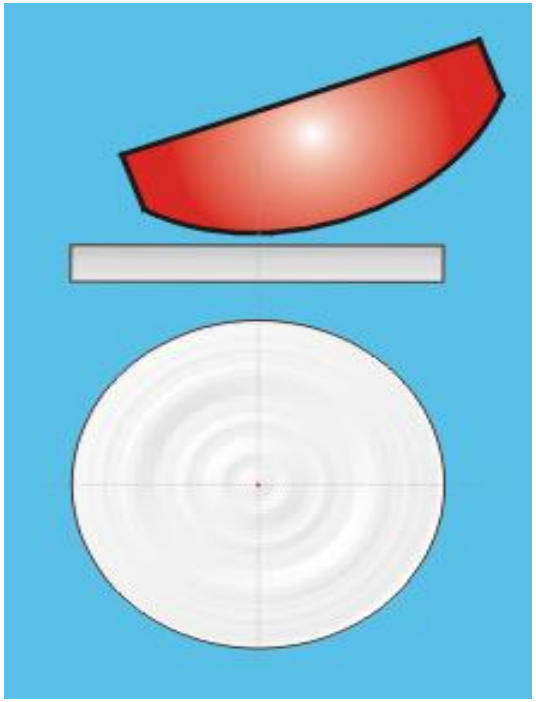
ZEEKO Ltd

Polishing Facility
at OpTIC, N. Wales





Precession™ bonnet polishing

Vary influence function size, as the polishing spot approaches the edge of the part

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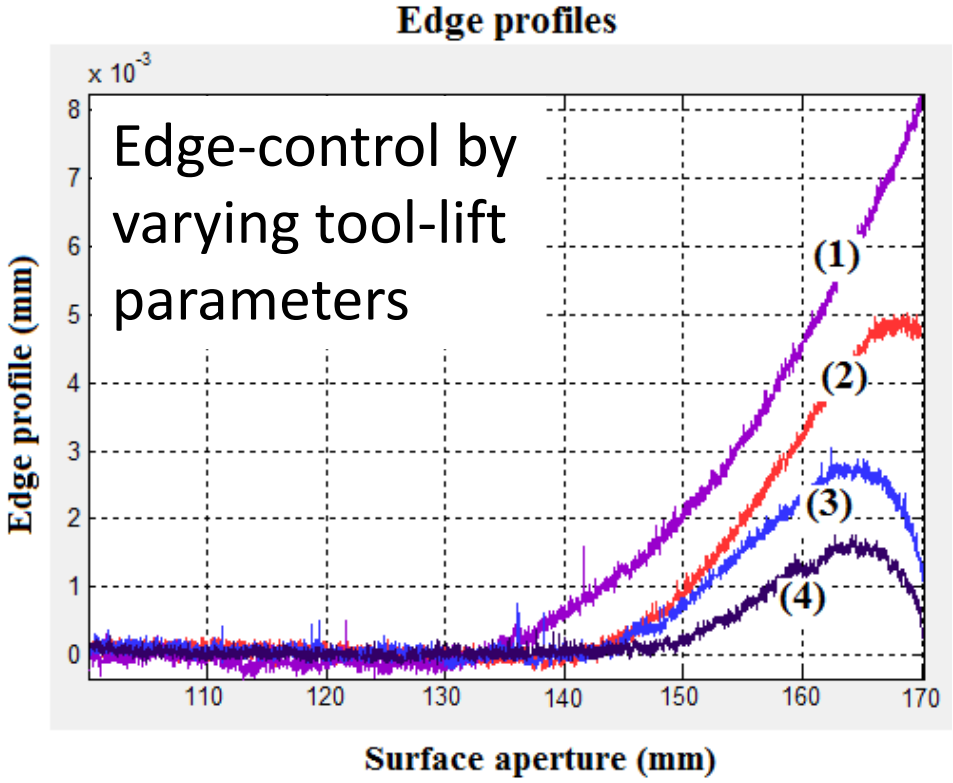
Segment edge strategy

- Raster tool-paths with small polishing spots

1. Apply only *half* the specified 1mm x 45° bevel
2. *Precession*™ polishing
   - Spot-size control to create *raised* edges
   - Dwell-time moderation to control form



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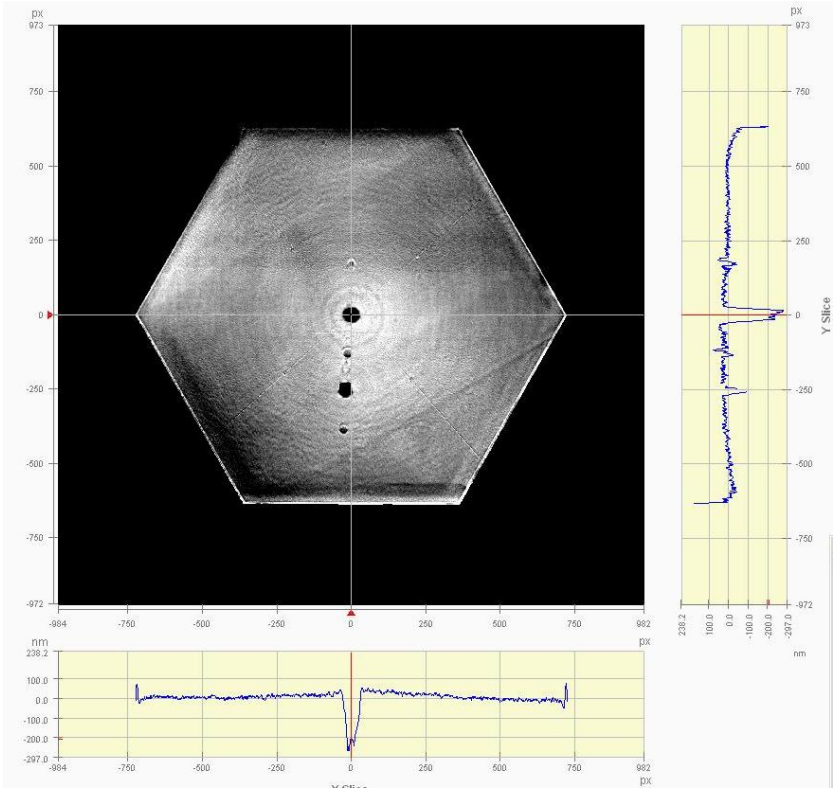
Segment edge strategy (contd)

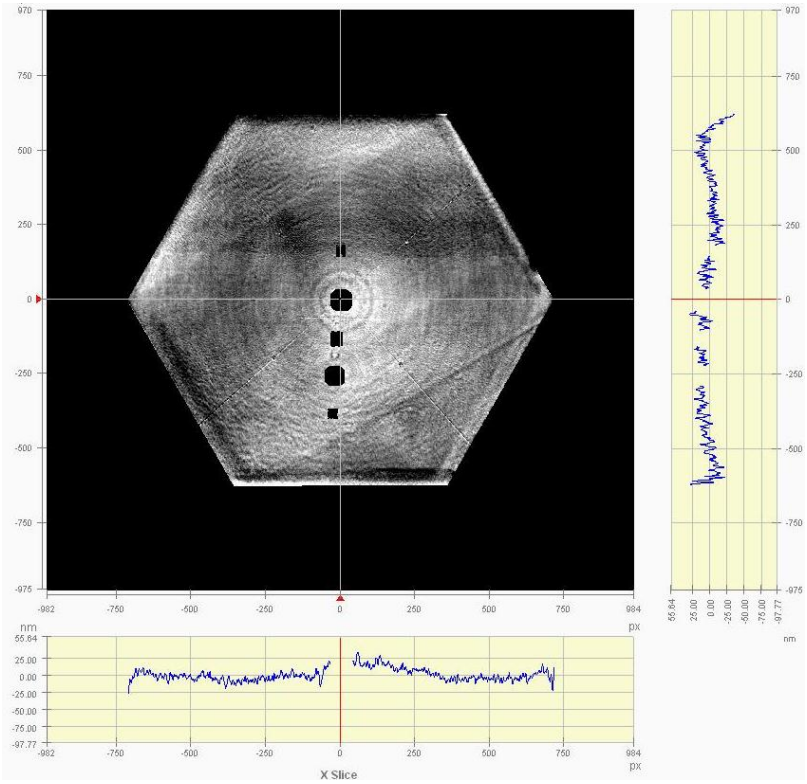
3. Polishing on Zeeko machine with rotating hard-pitch tool
   - Lower the raised edges
   - Hydrodynamic slurry effects roll the extreme edge

4. Apply the final half of the bevel

SPN04 – delivered and accepted



Full Aperture to edge
Only tip/tilt removed
23nm RMS Surface



10mm edge zone cropped,
ESO low-order allowances removed,
CGH artifacts masked
10nm RMS Surface

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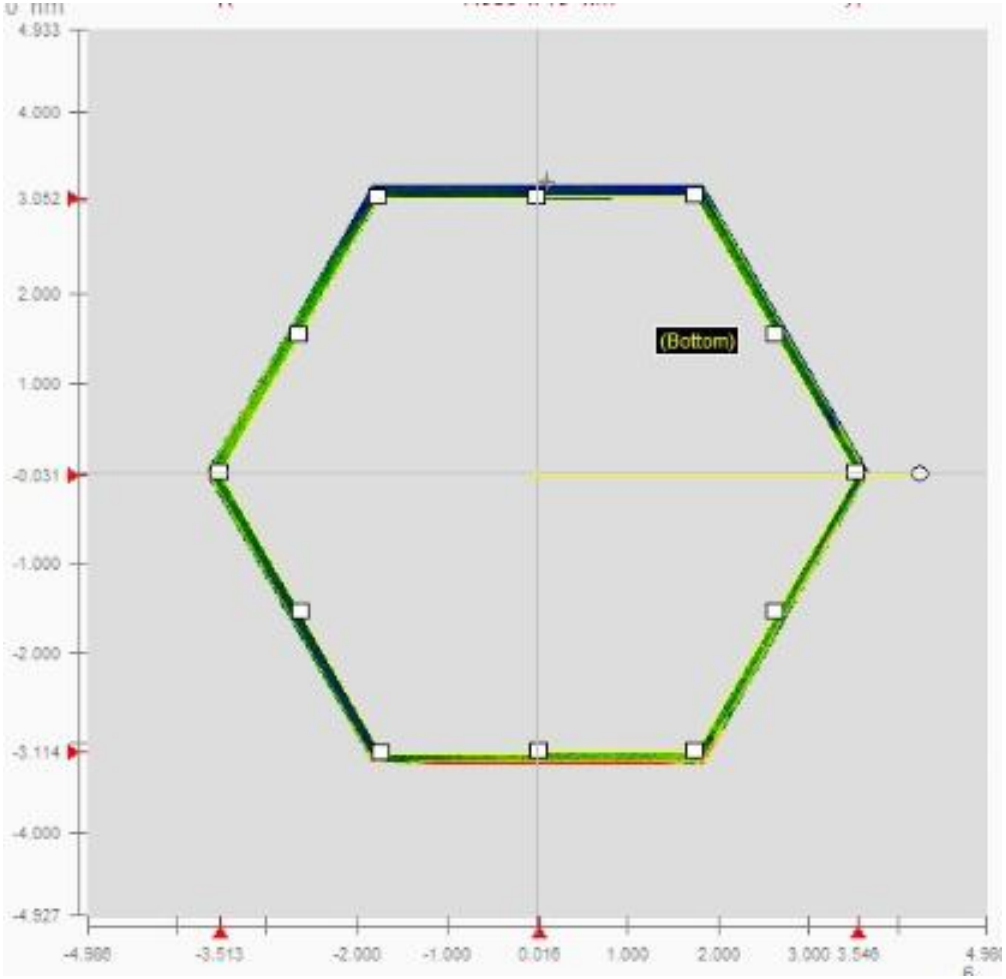
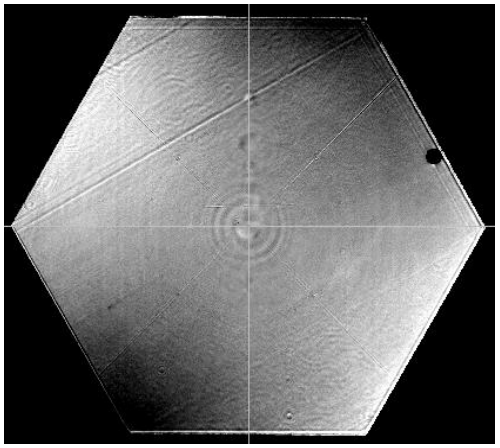
Edge result on SPN04



Edge-zone isolated from bulk data and analysed separately

172nm PVq (95%) surface

SPN01 delivered & accepted



- Uncertainties represent *repeatabilities*
- *Absolute RMS accuracies* estimated as:-
  - 21nm (form)
  - 13nm (form, low orders removed)

RMS form (excluding the 10mm wide edge-zone); No low-order allowances removed	25.4nm ± 4.8nm
RMS form (excluding the 10mm wide edge-zone); Low-order terms removed	7.5nm ± 2nm
Six edges (PVq 95%)	**Worst 263nm** **Average 199nm** **Best 117nm**

SPN03 – almost complete

- Awaiting final polishing run before arranging acceptance by ESO. Current status as follows:-

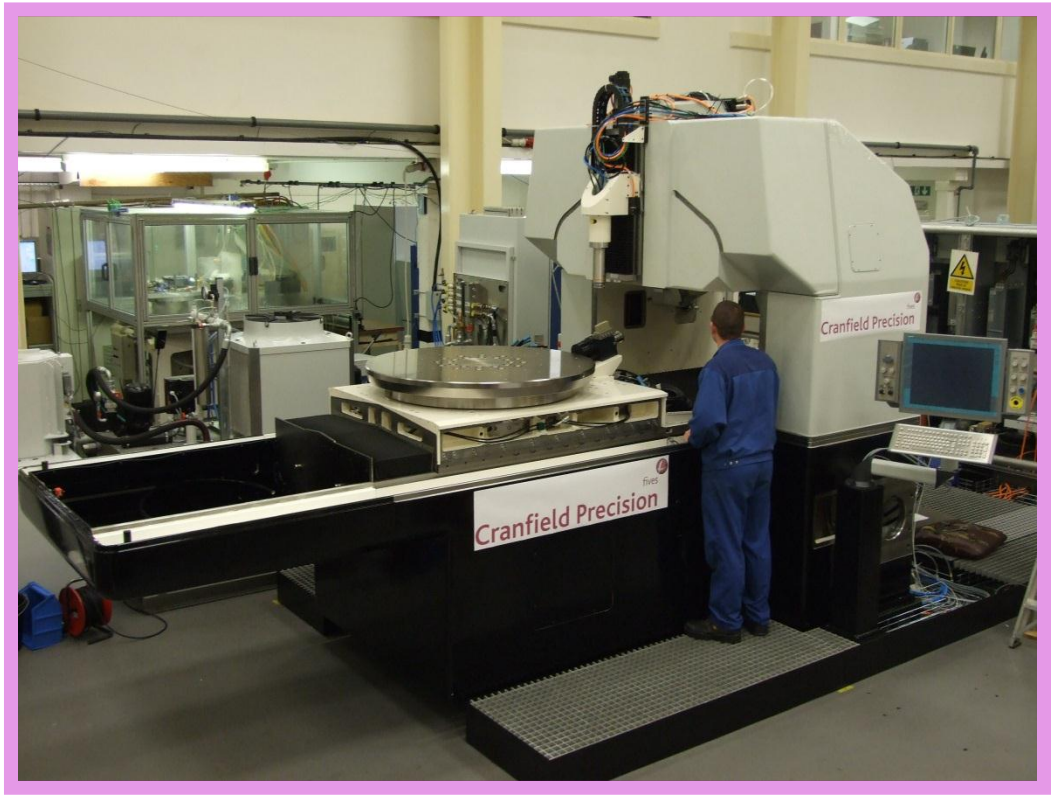
RMS form (excluding the 10mm wide edge-zone); No low-order allowances removed	24.9nm
RMS form (excluding the 10mm wide edge-zone); Low-order terms removed	9.8nm
Six edges (PVq 95%)	**All < 200nm PVq (95%)**

Cranfield Precision Ltd

New generation of CNC ultra-precision grinding machines

New 1.2m machine
Grinding trials
expected end-2014

Machines to match Zeeko family (including 1.6m version)



Summary

- Segments delivered are the ***only*** E-ELT prototype segments that meet form & mid spatial specs
- First demonstration manufacturing in hexagonal format throughout, including edge-polishing
- Complementary roles:-
  - OpTIC offers process development and polishing
  - Zeeko & Cranfield Precision manufacture machines & metrology instrumentation
- Working to establish industry consortium to bid for share of segment manufacturing contracts

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Thank you!

ACKNOWLEDGEMENTS

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ESO: segment prototype contract

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- Welsh Government

Zeeko Ltd: Build of IRP1600 machine and tech. support

Cranfield University and Cranfield Precision Ltd: development of BoX grinder and grinding of segments