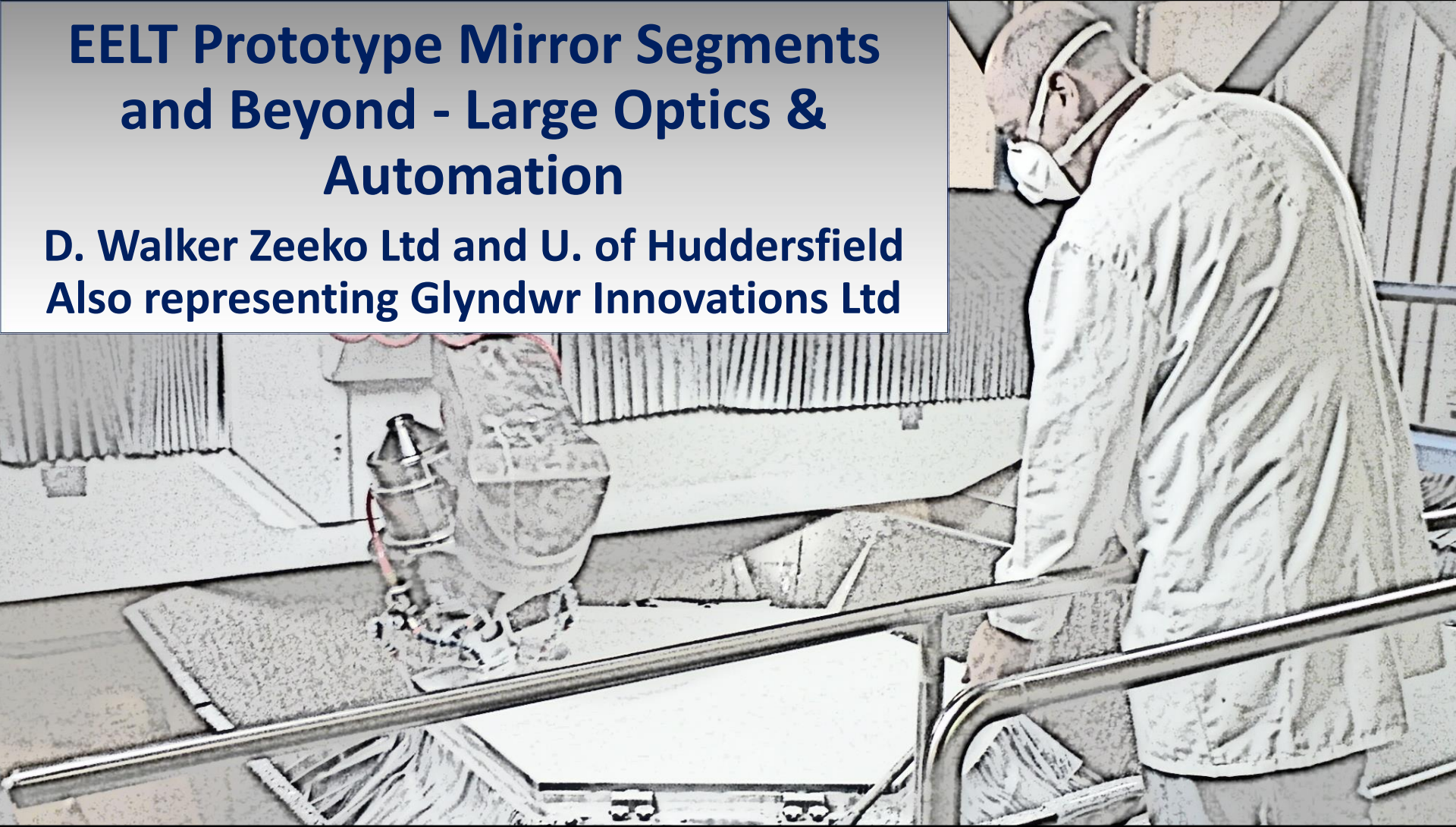


# **EELT Prototype Mirror Segments and Beyond - Large Optics & Automation**

**D. Walker Zeeko Ltd and U. of Huddersfield  
Also representing Glyndwr Innovations Ltd**



# OpTIC Centre North Wales



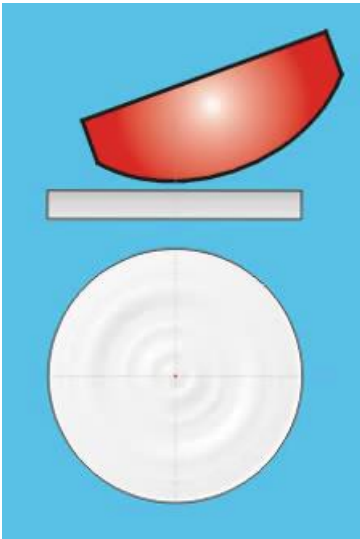
- Company incubation
- Technology Centre
- Business Development

- 2004 Established by Welsh Government
- 2004 DDW's UCL group moved into OpTIC
- 2009 Optic acquired & operated by Glyndwr U.
- 2015 DDW's group employed by Huddersfield University at OpTIC



# The early days – NASA SBIR grant

*“Edge Control in Large Segmented Optics Using Zeeko Polishing Technology”, Proposal S4.04-9574*



- SBIR project resulted in an active way to control edges in CNC polishing using the Zeeko *Precessions*<sup>™</sup> process
  - Progressively reduce spot-size encountering edge
  - Program tool-lift & speed profiles to leave a small, sharp up-standing edge
  - Remove upstand by polishing entire part with a small pitch tool (cleans up mid-spatials too)

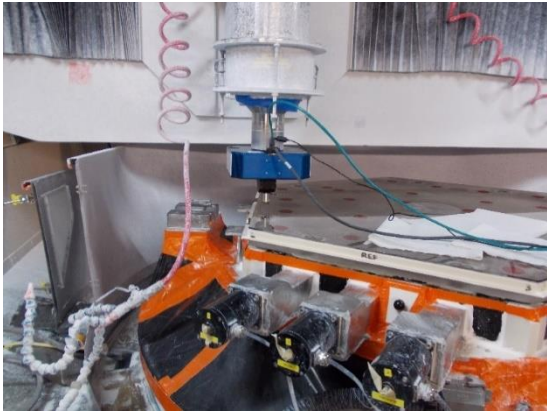
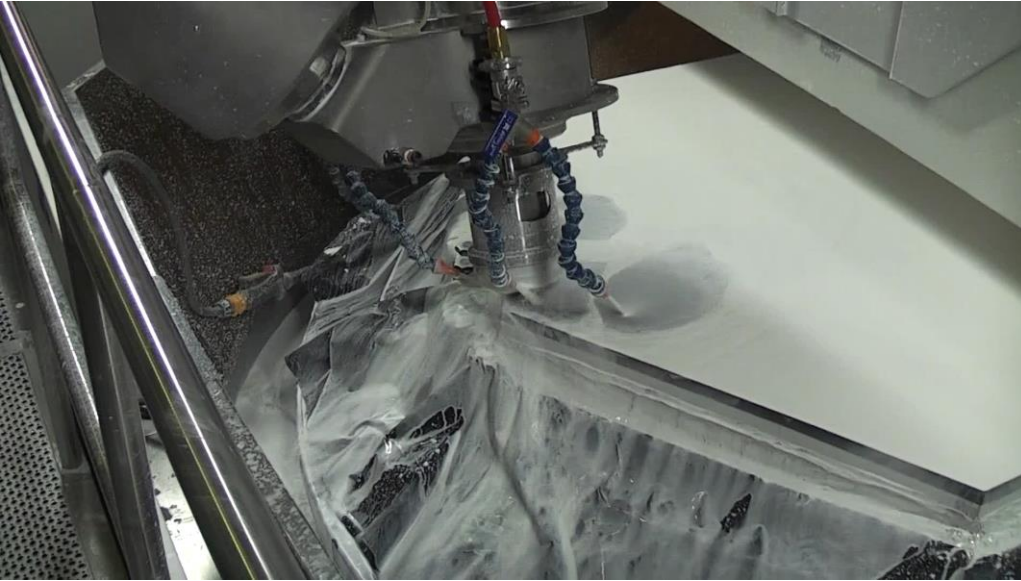
# E-ELT prototype segment contract

- ESO invited Zeeko to tender for producing prototype segments for 39m European Extremely Large Telescope
  - Segments 1.4m across corners, off-axis aspheric, 84m ROC
- Zeeko established a consortium, led by OpTIC Centre
- Partners continued development to support tender
- Award of €5m contract by ESO was strongly influenced by unique ability to polish hexagons directly, and achieve edge spec. (as demonstrated on witness parts)
- Zeeko seconded development staff to support OpTIC
- Edge-control further optimised by OpTIC during fabrication of full-size segments

# Metrology

- IRP1600 located under 10m high Test Tower at OpTIC
- Segment *in-situ* on IRP1600 machine throughout
- Metrology designed & built by Glyndwr's ESO team
- FII-aperture interferometry:-
  - *Differential* with respect to a thick Zerodur Master Spherical Segment (MSS) of same base radius
  - MSS absolute form characterised to 2nm rms by rotation / sheer
  - Test coordinate frame certified by laser tracker
- MSS and segment absolute ROC by scanning-pentaprism profilometer mounted on IRP1600 bridge
- Instruments carried by IRP1600 motion-system:-
  - Surface texture by 4D Tech. simultaneous phase White Light interferometer
  - Beam expanded and 4D 6000 interferometer

# Segment fabrication



4D white light interferometer

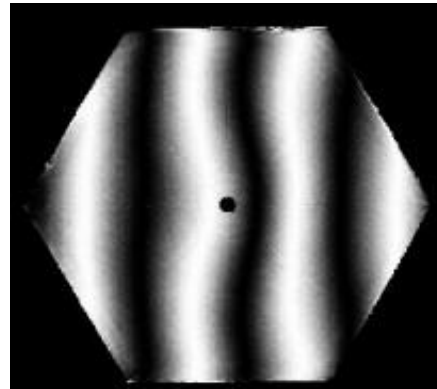
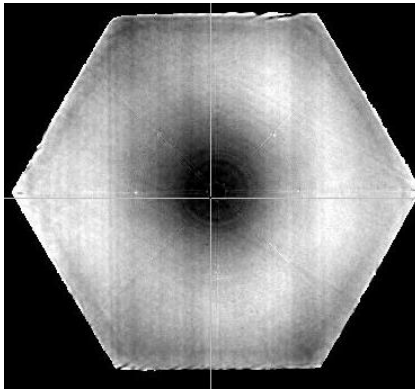


Pentaprism profilometer

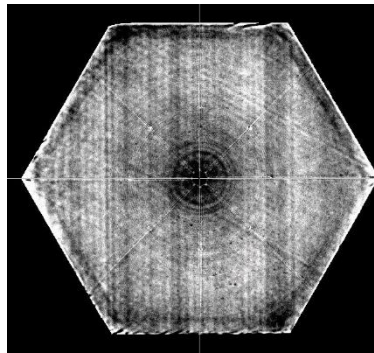


10m test tower

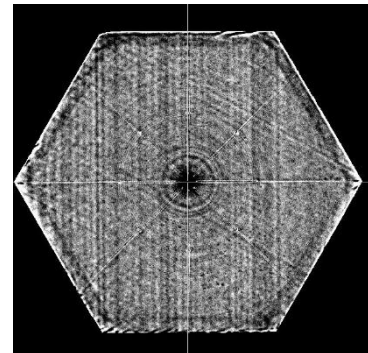
# 1.5m MSS:- to specification



- MSS result
  - $16.8\text{nm} \pm 2\text{nm}$  RMS surface
  - (clear aperture)

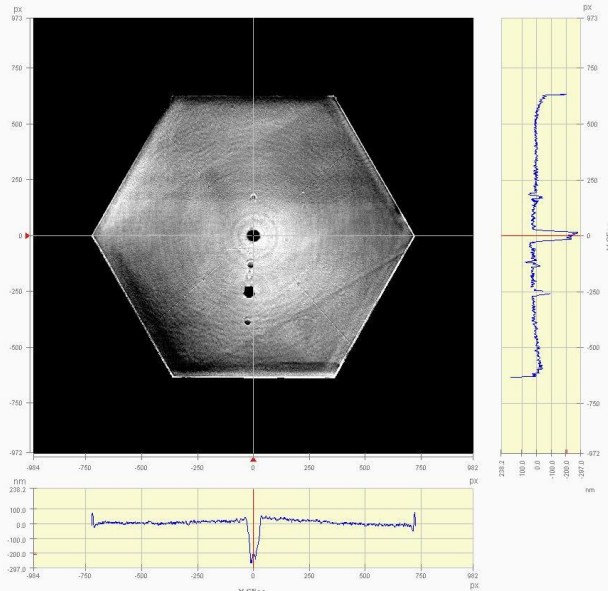


5.5nm RMS:  
spatial scales  
<250mm

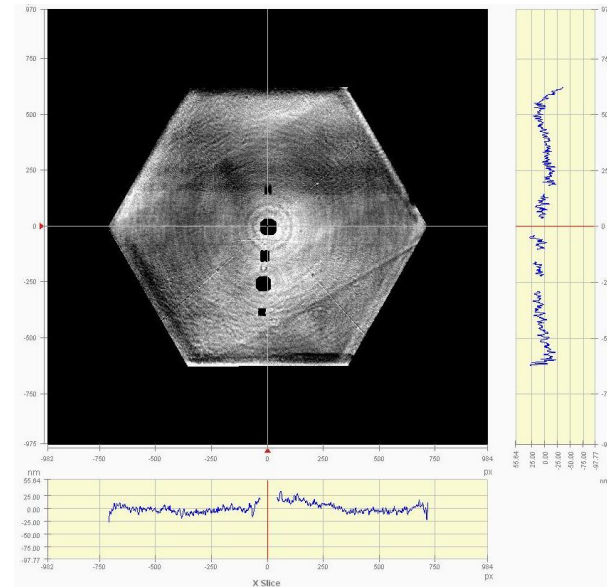


4.2nm RMS:  
spatial scales  
<100mm

# SPN04–Unreserved Acceptance by ESO



Full Aperture to edge  
Only tip/tilt removed  
**22.9nm RMS Surface**



10mm edge zone cropped,  
ESO low-order allowances removed,  
CGH artifacts masked  
**10.3nm RMS Surface**



# Beyond segments

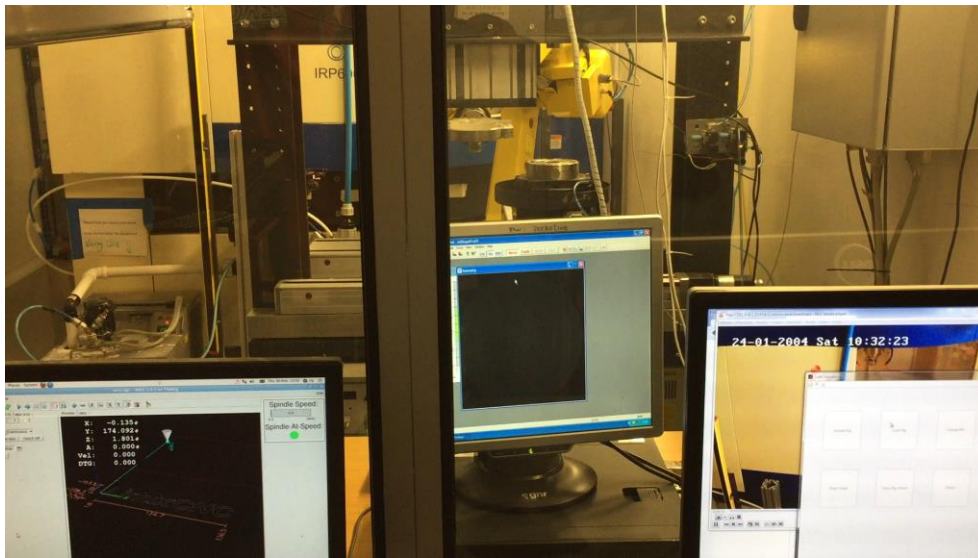
## Glyndwr Innovations Ltd (GIL)

- Commercial business established at the OpTIC Centre
- Manufactures optics 300mm to 2m
- Light-weighting FEA & manufacturing capability
- Opto-mechanical design of systems and optical supports
- Metrology and optical design services
- Contracts secured from Space, Defence and Science-base sectors



# Segment serial fabrication

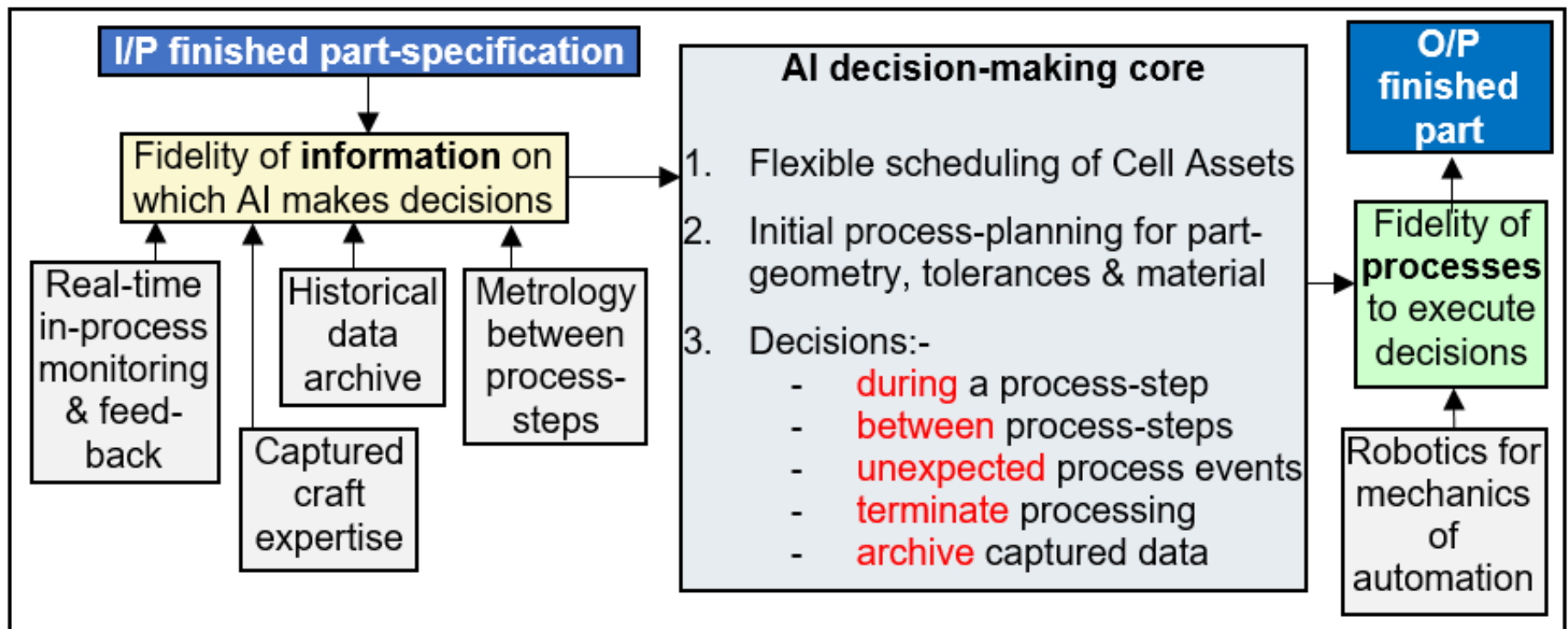
- Requirement for telescope 798 segments
- Including maintenance spares 931 segments
- Under terms of tender:-
  - Tenderers limited to large companies with substantial financial backing
  - GIL not eligible to bid directly (ESO financial constraints)
  - Participated in a bid that was submitted
  - Future involvement currently unclear



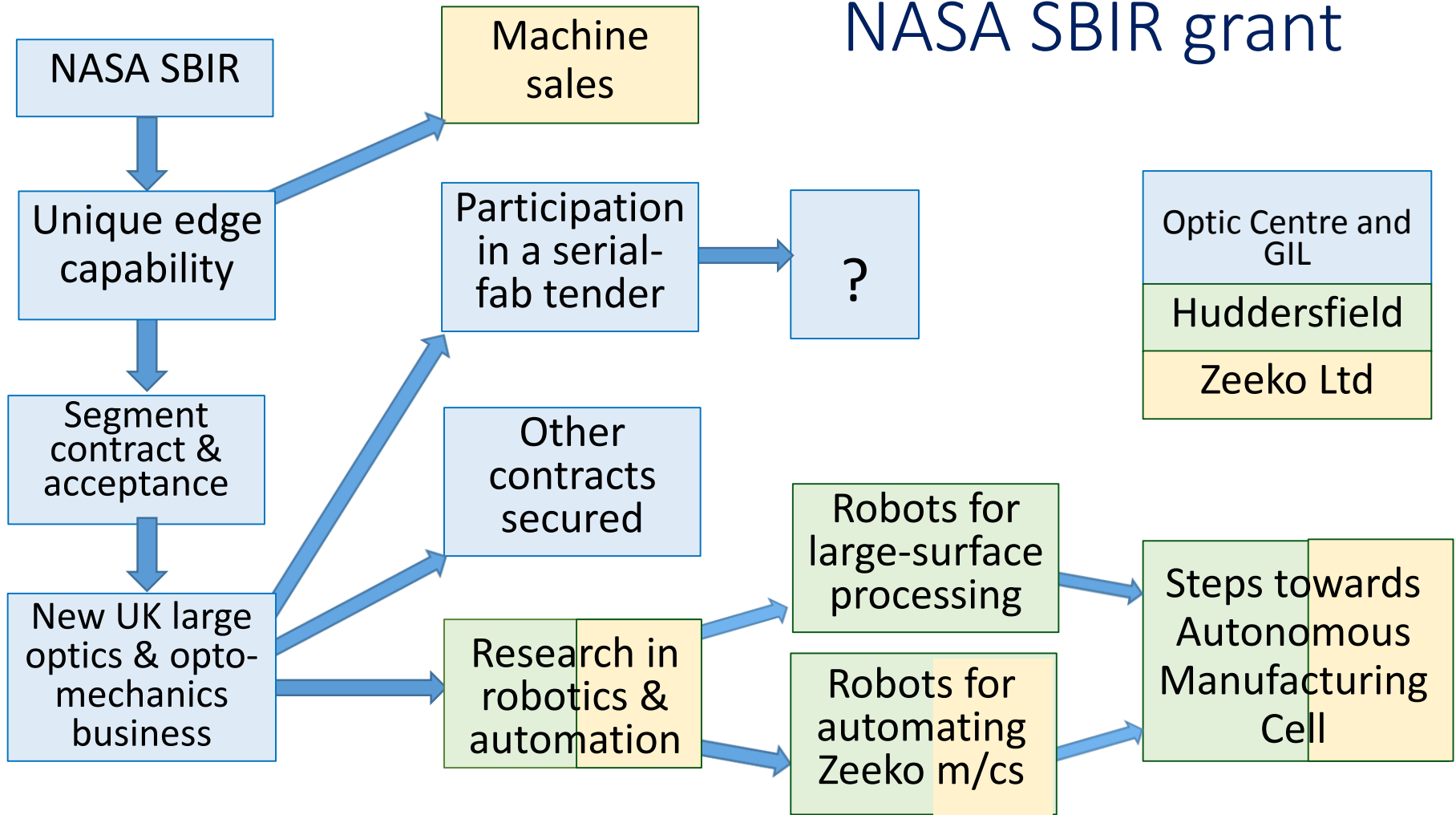
## The Vision:- Autonomous manufacturing cell

- Segment project stimulated R&D in process automation
- Now operational:-
  - Robot loading/unloading of Zeeko m/c
  - Auto wash-down
  - Robot transfer of part to interferometer
  - Auto alignment and fringe-capture
- Autonomous Cell
  - UK consortium with requisite skills – centred on decision-making through AI.

# Our approach



# Benefits from NASA SBIR grant



# Conclusion

A modest 'pump-priming' investment at a critical stage can have very significant impacts in different ways.

So ... thank you!