HEXAGON METROLOGY

Case Study Cranfield University

High-precision inspection for the European Extremely Large Telescope (E-ELT).

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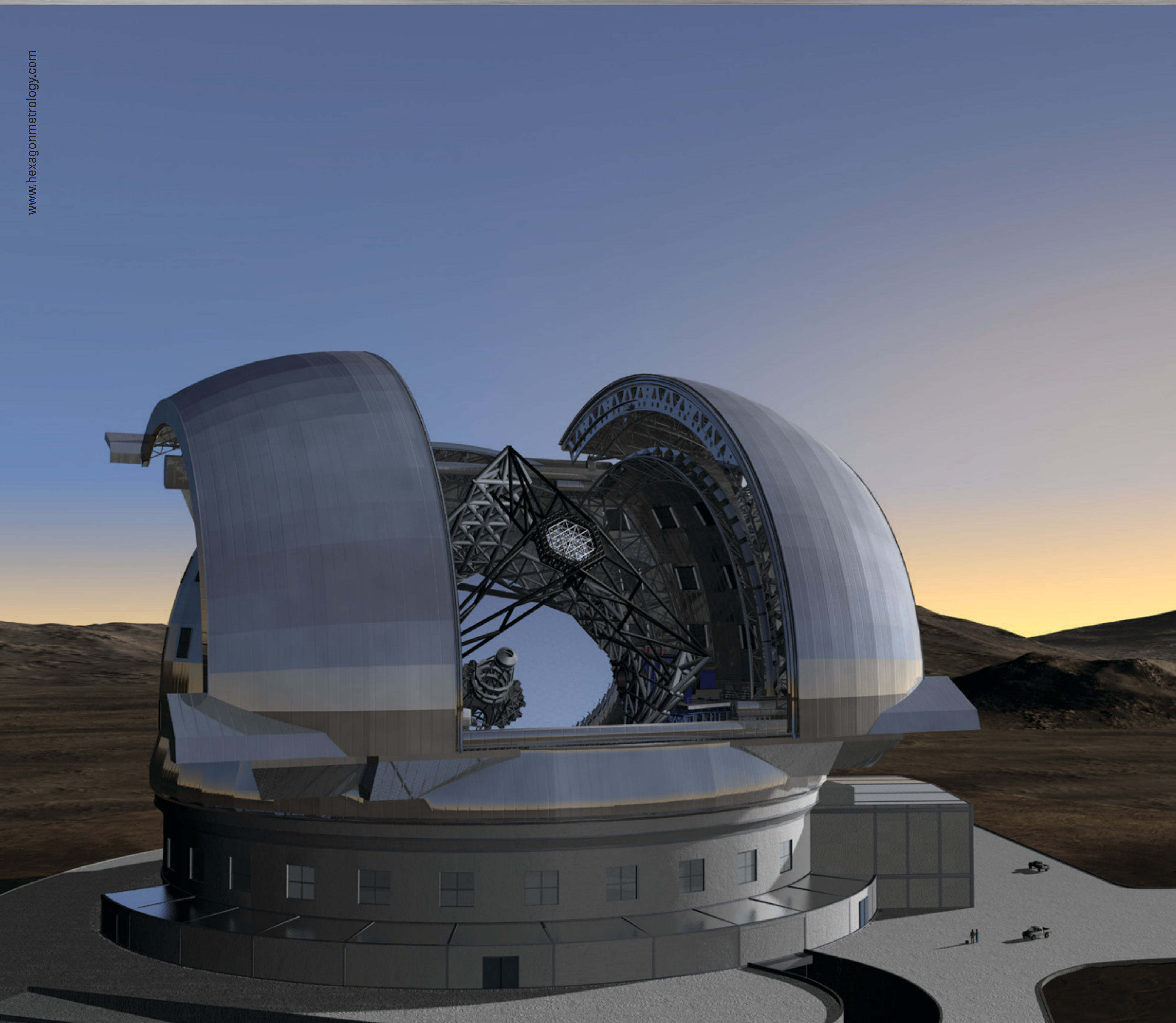

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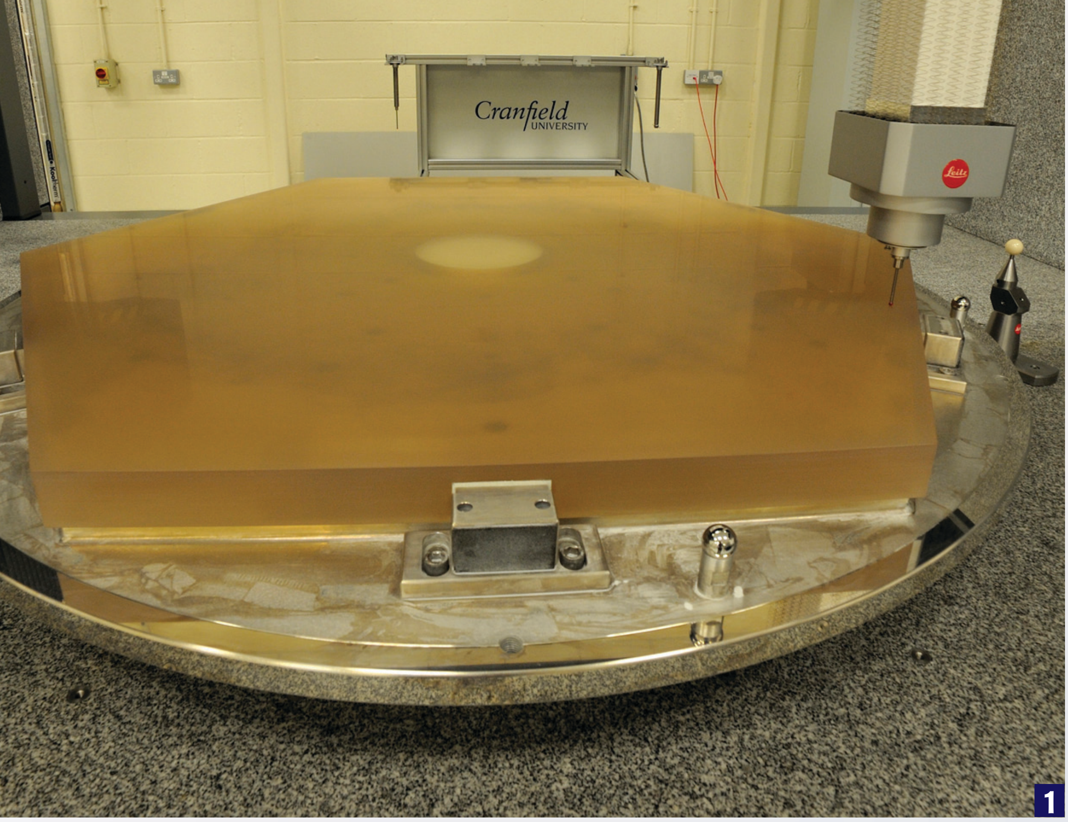
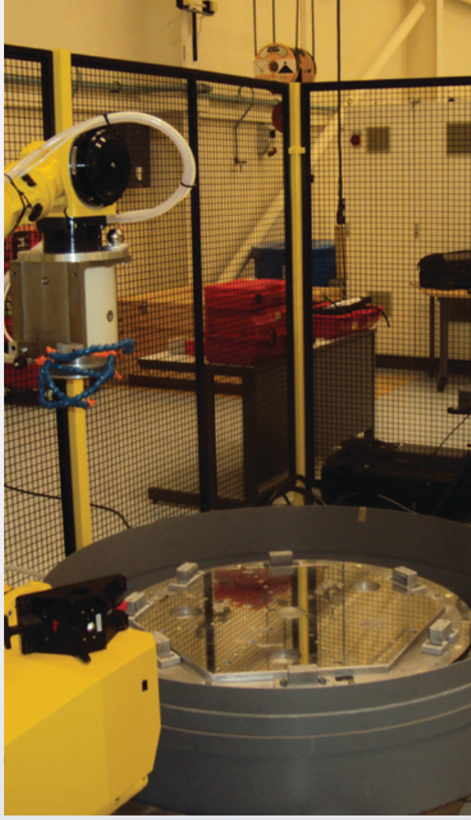
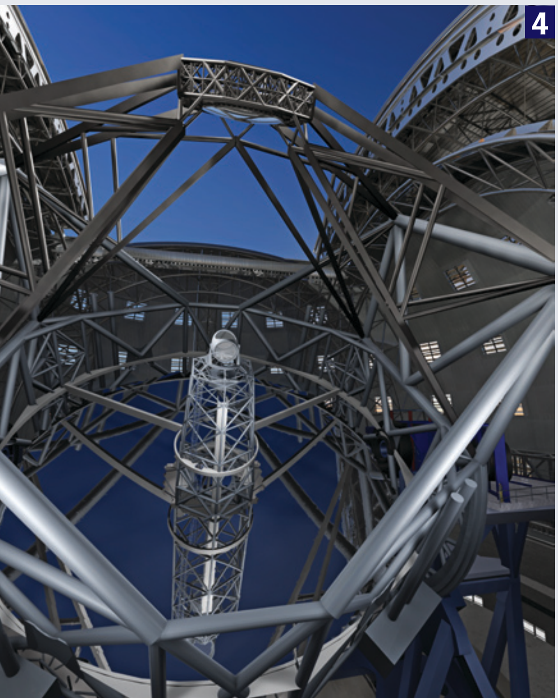
Leitz





The race is on for who will manufacture 1,000 mirrors for the European Extremely Large Telescope (E-ELT). Cranfield University in the UK has begun work on producing seven of the mirror segments for 'the world's biggest eye on the sky' with the aid of high accuracy measurement systems from Hexagon Metrology.

Built by the European Southern Observatory (ESO) the E-ELT, a ground-based telescope, will be 42m in diameter and made up of 1,000 hexagonal segments, each 1.5m wide and just 5cm thick. The E-ELT is four to five times larger and will gather 15 times more light than the largest optical telescopes operating today.



The production and measurement challenges for this project are significant. Cranfield University is the only organisation in the UK with the capability to undertake various stages of machining the mirror segments to the accuracy required. Cranfield's BoX (Big OptiX), a specialised grinding and measurement system, was developed at Cranfield specifically for realising these mirrors.

Located in Cranfield's Loxham Precision laboratory, which is sponsored by Hexagon Metrology, is a Leitz PMM-F 30.20.10 CMM. This Ultra High Accuracy (UHA) measuring system is used to verify the performance of the Cranfield BoX grinding machine and measures the mirror segments.

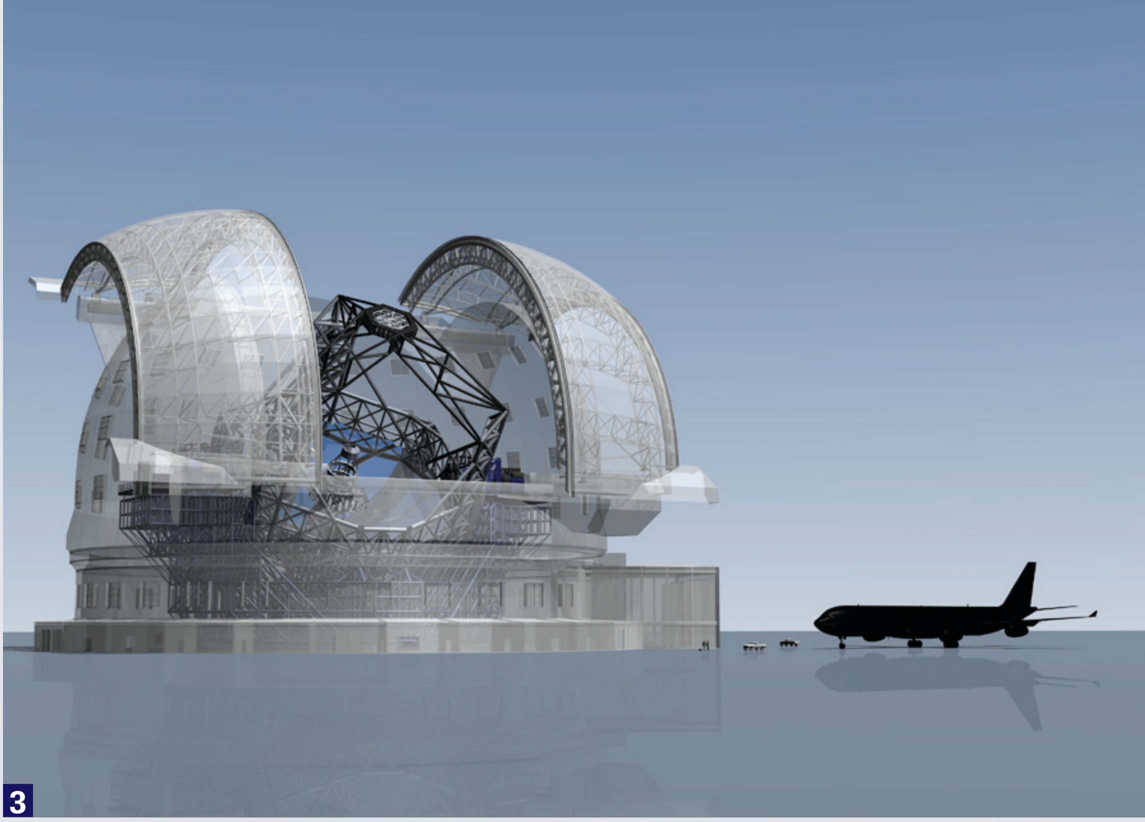
Professor Paul Shore, Head of the Cranfield University Precision Engineering, says, "What we've got in our BoX machine is an ultra precision grinding and metrology system made at Cranfield that grinds the part and performs some in-process measurement. The Leitz PMM-F is then used to validate the grinding and measurements done by the Cranfield BoX machine."

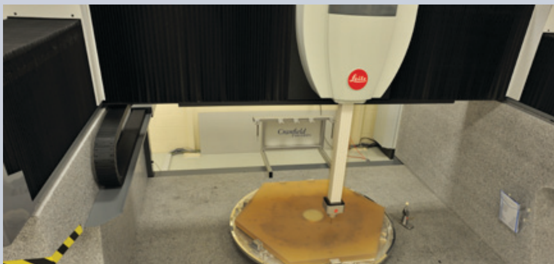
Super accurate
After processing at Cranfield, the mirrors are sent to Technium OpTIC (Opto-electronics Technology and Incubation Centre) in North Wales, where they will be polished and measured by OpTIC based researchers from three UK universities, Cranfield, UCL and Glyndwr. The segments are polished utilising error surface maps generated from the Leitz PMM-F. These identify high and low points for initial corrective polishing. The polished quality requirement is a surface roughness of 1-2 nanometres RMS and form accuracy of 10 nanometres RMS.

To verify these extreme surface accuracies, an 8 metre optical test tower has been designed and built at OpTIC. The test tower is sited over the top of the polishing machine, it utilises laser interferometry techniques to generate an optical wave front that conforms to the required mirror segment surface. The measured difference between the actual mirror surface and the required optical surface shape of the spherical wave front provides a surface error map. This error map is used to generate a tool path for the polishing machine which then adaptively polishes the mirror surface to achieve the desired 10 nanometre RMS form accuracy.

To ensure accurate alignment of the optical tower measurement system, a Leica Absolute Tracker AT901 is integrated into the tower structure. The laser tracker system measures the positioning of the tower's main optics during measurements, tracking any movement due to thermal effects which can be some microns over such a large structure.

Future development
To speed up the process even more and to add value to Cranfield's activities, Paul Shore's team are investigating a robotic lapping system. "The simple robot based process gives us a possible intermediate





1 *The Leitz PMM-F inspects one of the E-ELT mirrors*

2 *Leica Absolute Tracker AT901 utilises a Leica T-Mac to accurately analyse the robot's movements*

3 *The E-ELT here seen in a scale comparison with an Airbus A340 airplane*

4 *Close-up view of the novel 5-mirror approach of the 42-metre E-ELT*

process between grinding and polishing. It could alleviate any bottleneck operations in the latter stage of mirror production," explains Paul Shore. "The Cranfield team, assisted by Hexagon Metrology engineers are looking at a configuration using a standard Fanuc 5-axis robot fitted with a smoothing spindle."

A portable Leica Absolute Tracker AT901-Long Range has been used to check the robot system's motional accuracy capability as it moves the spindle across the mirror surface. One area of research is thermal stability and dimensional movement of robots over long periods of time. Cranfield researcher Andy Eve explains the process: "The Leica Absolute Tracker AT901 can be used to measure a point's x, y and z coordinate using a reflector or in 6 degrees of freedom by tracking pitch, yaw and roll angle of the tracker-machine control sensor Leica T-Mac. The investigation will also discover how much temperature shift is occurring on the robot during the lapping cycles. We are looking for repeatability of results to consider error compensation practices. It is an important investigation because it potentially adds a lot of value to our E-ELT mirror program."

Competitive edge

The European Southern Observatory, ESO, have placed two contracts for 7-off prototype mirror segments - one of which is with a UK consortium, headed up by OpTIC Glyndwr in North Wales who are working in close collaboration with Cranfield. When the prototypes are signed off the as yet un-named UK production company will bid for manufacturing quantities around 1,000 mirror segments in total.

What are the chances of the order (or part of the order) going to the UK consortium? A team from ESO arrived at Cranfield in July 2010 to look at the BoX and Leitz machine.

"In particular, they were interested in how we were using the CMM and how we dealt with the measurement data. The Cranfield code allows us to generate the "synthetic interferograms" using the Leitz PMM-F. We think ESO were happy with our technical process and the data demonstrated to them," says Paul Shore. "The issue here is now a production engineering one. We know that with some attention to production engineering issues, the Cranfield BoX grinding machine will grind each mirror segment within 20 hours. To our knowledge that is ten times faster than our competitors. We expect to take a number of orders in the near future for making more segments."

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Did you know?

The E-ELT will tackle the biggest scientific challenges of our time, and aim for a number of notable firsts, including tracking down Earth-like planets around other stars in the "habitable zones" where life could exist — one of the Holy Grails of modern observational astronomy. It will also perform "stellar archaeology" in nearby galaxies. The E-ELT will make fundamental contributions to cosmology by measuring the properties of the first stars and galaxies and probing the nature of dark matter and dark energy.

Hexagon Metrology is part of the Hexagon AB Group and includes leading metrology brands such as Brown & Sharpe, CogniTens, DEA, Leica Geosystems (Metrology Division), Leitz, m&h Inprocess Messtechnik, Optiv, PC-DMIS, QUINDOS, ROMER and TESA. Hexagon Metrology brands represent an unrivaled global installed base of millions of Coordinate Measuring Machines (CMMs), portable measuring systems and handheld instruments, and tens of thousands of metrology software licenses. Hexagon Metrology empowers its customers to fully control manufacturing processes that rely on dimensional precision, ensuring that products manufactured precisely conform to the original product design. The company offering of machines, systems and software is complemented by a wide range of product support, aftermarket and value-added services.

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Images courtesy of ESO www.eso.org

The E-ELT research and development at Cranfield is carried out by core staff of the EPSRC Ultra Precision and Structured Surfaces Integrated Knowledge Centre. (Including: Paul Morantz, Paul Comley, Xavier Tonnellier, Kevin Howard, Andy Eve and Paul Shore) www.epsrc.ac.uk.