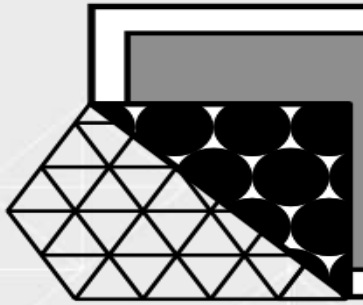
UCL ENGINEERING
Department of Civil, Environmental & Geomatic Engineering (CEGE)
↳3D Imaging, Metrology, Photogrammetry Applied Coordinate Technologies (3DIMPact)



WHERE'S MY DRILL? PHOTOGRAMMETRIC HAND TOOL TRACKING FOR AEROSPACE APPLICATIONS

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3DIMPact
3D Imaging, Metrology & Photogrammetry Applied Coordinate Technologies

Royal Academy of Engineering

AIRBUS

Context - aerospace drilling hand tools

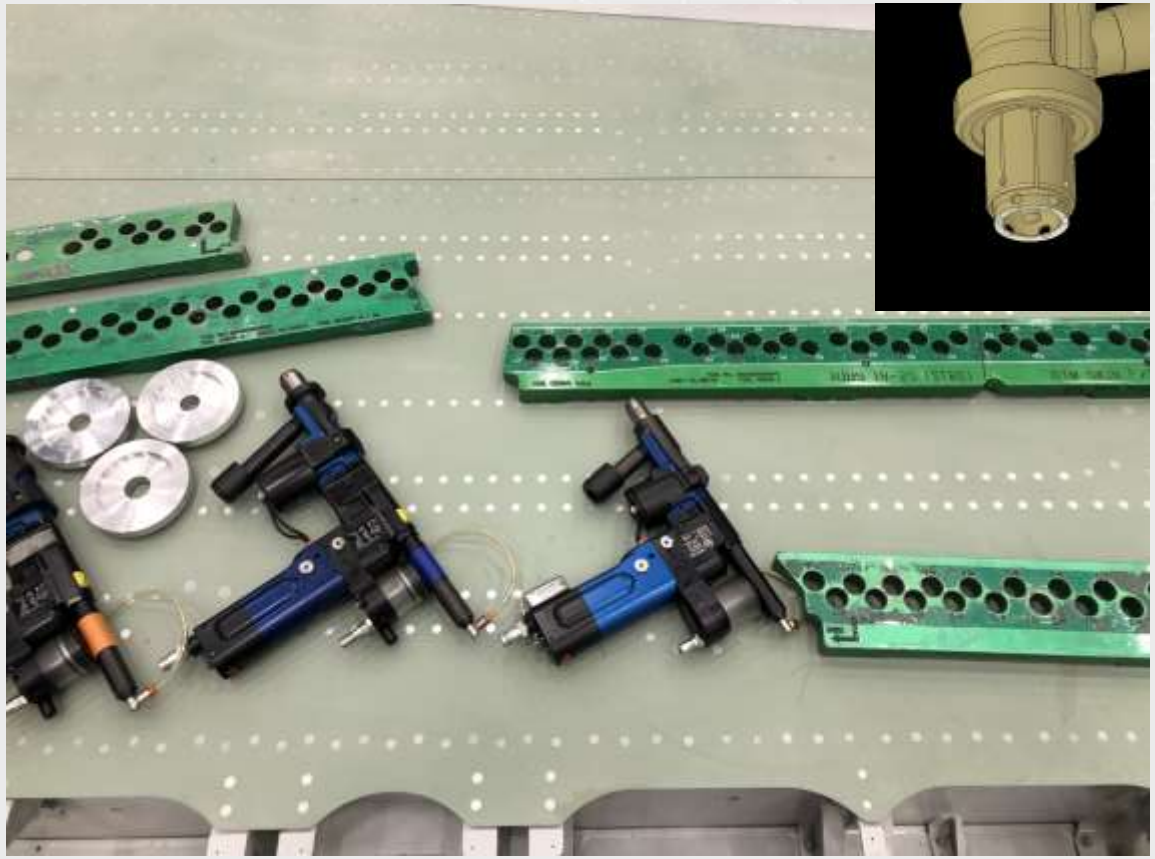
- In aerospace manufacture, specialist tools drill through multi-layer stacks of materials, enabling the fastening together of components into larger assemblies to form wings and fuselage sections.
- Digital hand drilling tools are being developed which are able to measure, record and transmit information concerning torque, depth of cut and start / stop times. This is needed to better understand and monitor hole quality and thereby ensure conformance to engineering requirements.
- Improving productivity also requires real-time knowledge of the location of each tool in relation to the manufactured object which ultimately confirms and logs the quality of each drilled hole.

Demonstrator Development

In this demonstrator at UCL the positions of air powered drilling units of varying sizes were tracked in drilling templates mounted at locations on a section of Airbus A321 wing on loan from Airbus.

Fasteners, visible as shiny circles on the A321 wing section, show some typical fastener patterns.

- Drill templates with specified hole patterns are mounted on the wing.
- A drilling unit is located in a template hole and air pressure is used to activate the drill's collet, locking the tool into position.
- The hole is bored through the stack of materials and optionally countersunk.
- The collet is unlocked and the drilling unit moved to the next hole where the cycle is repeated.
- The operator has flexibility on the hole drilling order.

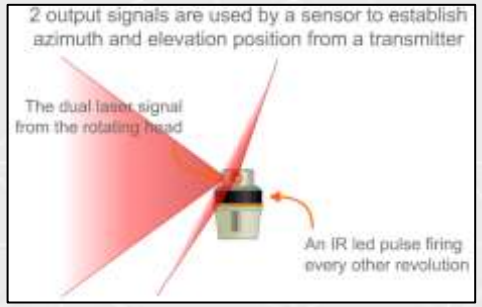


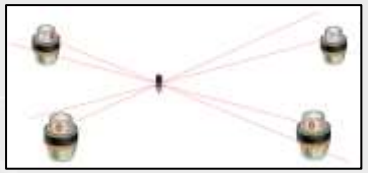
Indoor location (optical): iGPS, LT, Photogrammetry

7D KINEMATIC METROLOGY

iGPS was a Nikon system until 2019.

Fan beam transmitters determine directions to multiple active receivers. 3D location requires 2+ transmitters.





API NOTHING BEYOND MEASURE

Laser tracker manufacturers: API, FARO, Hexagon

A single tracker follows range and direction to a single moving target (3D reflector, 6D touch or scan probe) which is used for object measurement.

VICON

Motion capture (MoCap) over wide spaces based on photogrammetry. Multiple MoCap manufacturers.

Multiple cameras track multiple people and objects. Accuracy in mm, not µm.

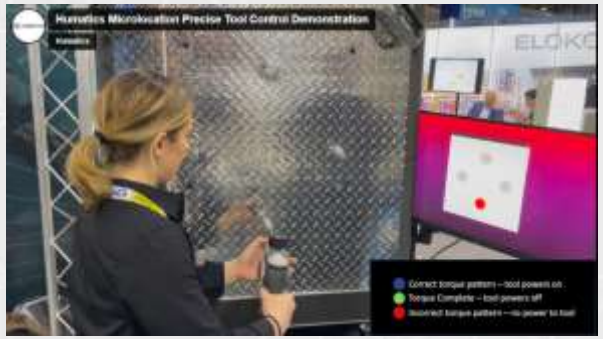
Indoor location (non optical): RF, UWB and acoustic

RF and UWB location: 2 examples from several systems

Robust tracking at mm level.

RF Drill positioning

HUMATICS



UWB Asset location

pozyx

RF and acoustic location

Cricket Indoor Location System

MIT research prior to 2010
No commercial application found.

Radio and ultrasonic wave transmitters were monitored by listening devices which were located by range measurements.

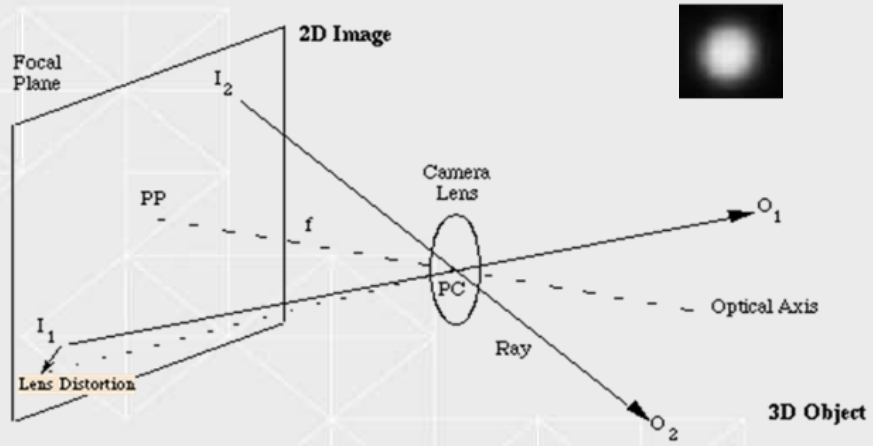
All sources visible on

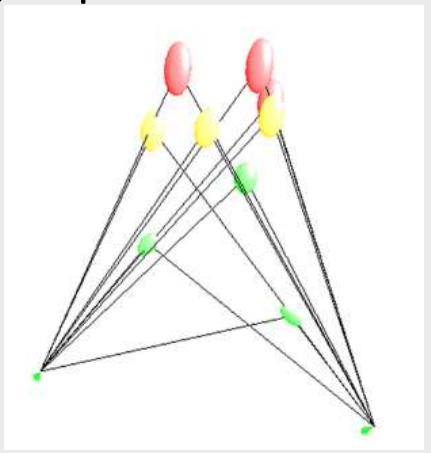
explore3dm

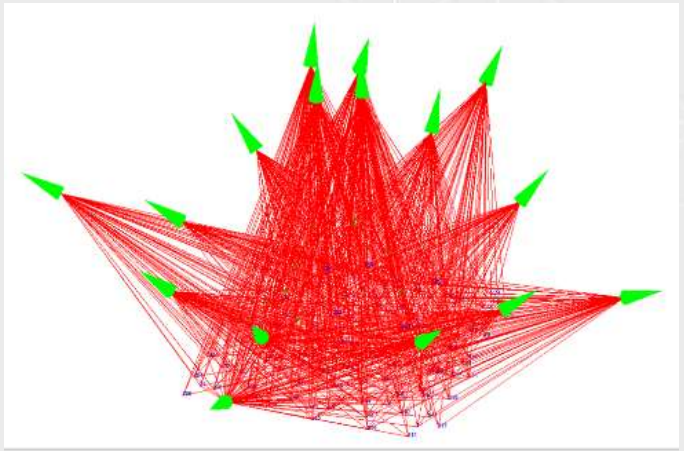
www.explore3dm.org

Large volume measurement with networks of cameras

- Synchronized cameras can be used to measure directions in space, from which you can accurately and reliably reconstruct the locations and dynamics of recognizable features
- Increasing the number and geometry of the lines of sight improves the quality and robustness of the measurements to achieve engineering requirements

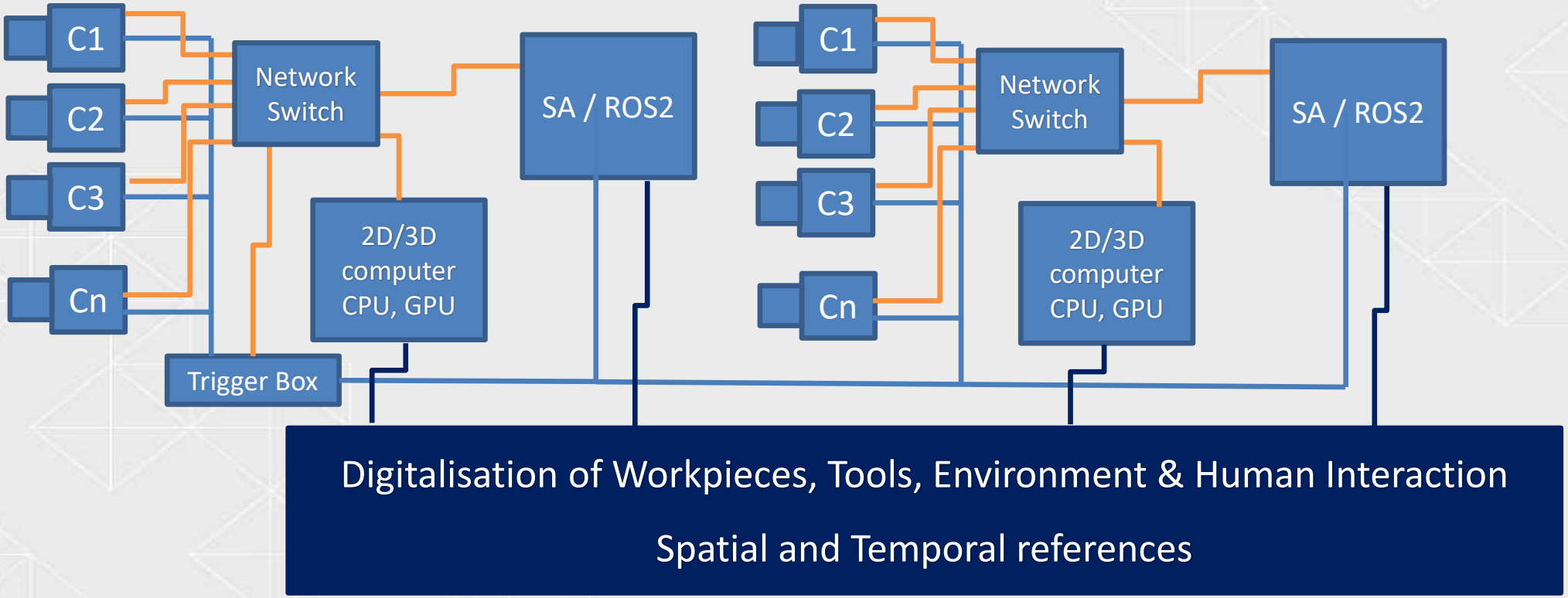






- As working volumes get larger, the quality, number and geometry of the angular measurements must be improved to achieve required accuracies
- Challenges specific to large volume include feature visibility, maintaining traceable scale, thermal changes in object, camera and environment, air turbulence
- Solving engineering measurement challenges demands robust solutions to deal with variables such as light levels, surface forms and finishes, scene complexity and human factors

Modular system architecture



Extendable imaging network has parallels with CCTV and overlaps with dedicated targeting cameras e.g. motion capture systems and 6D laser trackers.

Convergence driven by hardware and software technologies and Internet of Things interchangeability.

Feature detection, identification and measurement in factory environments

Physical

- Lighting and filtering
- Feature size and background
- Imaging and surface geometry
- Camera lens and sensor capabilities

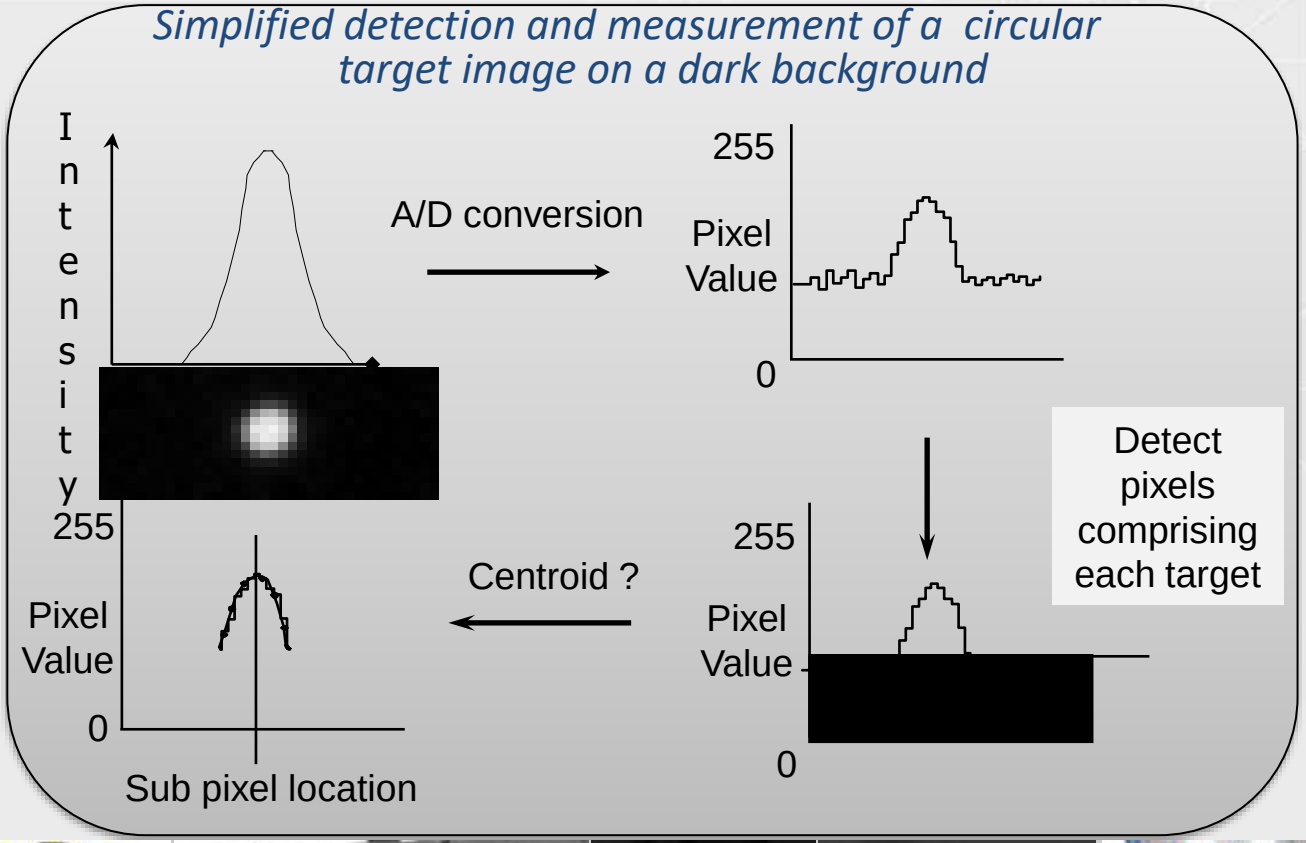
Algorithms

- Image intensity and gradients
- Size and shape [e.g. perimeter / area]
- Machine learning

Parallel Processing

- CPU and GPU image libraries
  - [e.g. Intel IPP and Nvidia NPP]

Reliable and robust solutions in factory environments are challenging



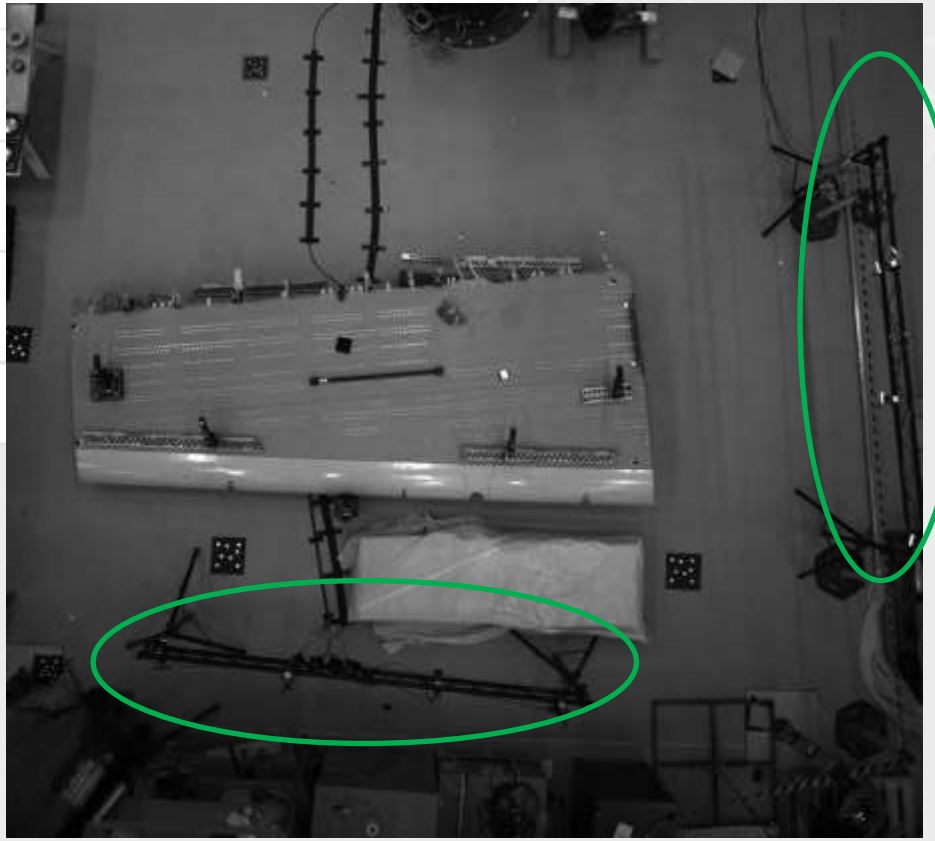
Human factors, clutter, light sources, reflections, H&S retro materials

5m wing section and two groups of synchronised cameras

Drill templates laid out using pilot hole fixings and alignments typical of those used in manufacture.

12MP and 5MP low-cost cameras mounted on two gantries.

All imaging in factory-like conditions.

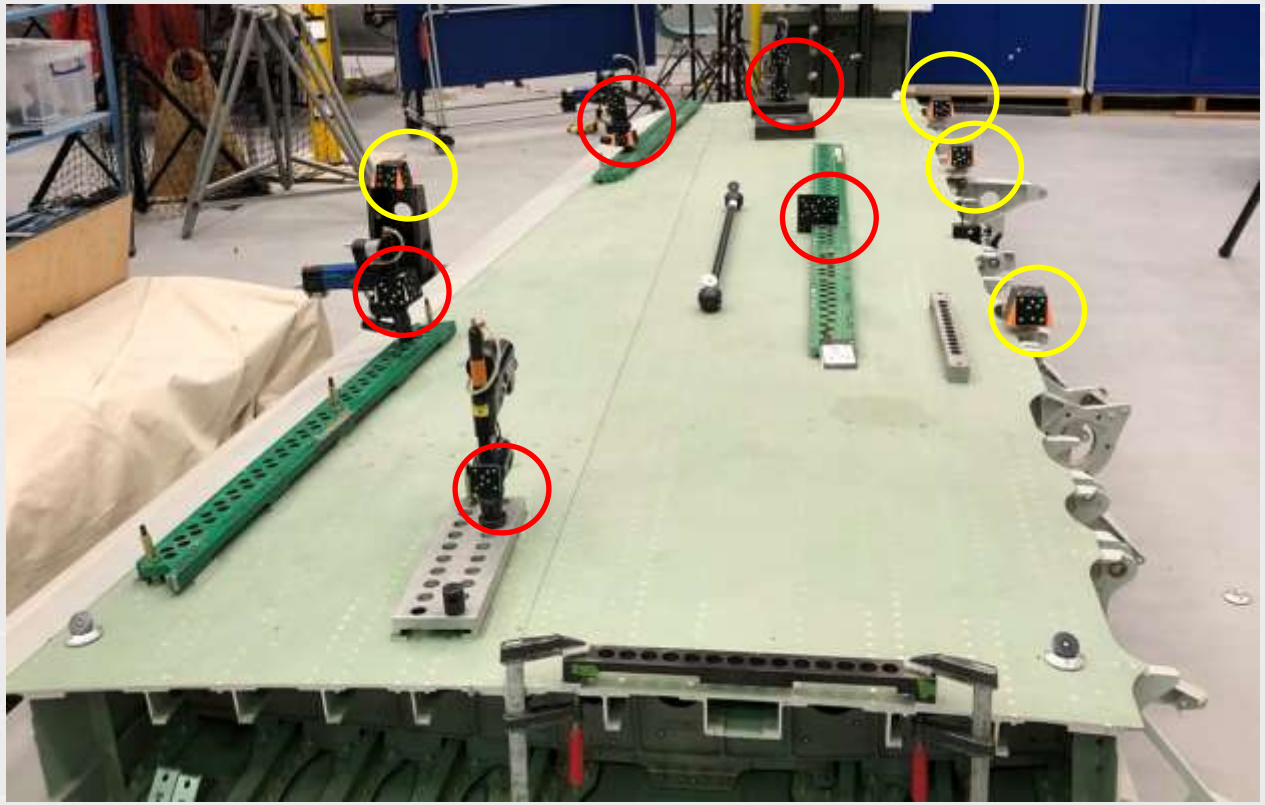


Metrology nests and coded photogrammetric targets define a suitable coordinate datum.

Nest coordinates and drill template hole reference locations estimated from a USMN laser tracker network using NRK SA software.

Implementation - photogrammetric reference target blocks, tracked drilling units with varying coded target configurations

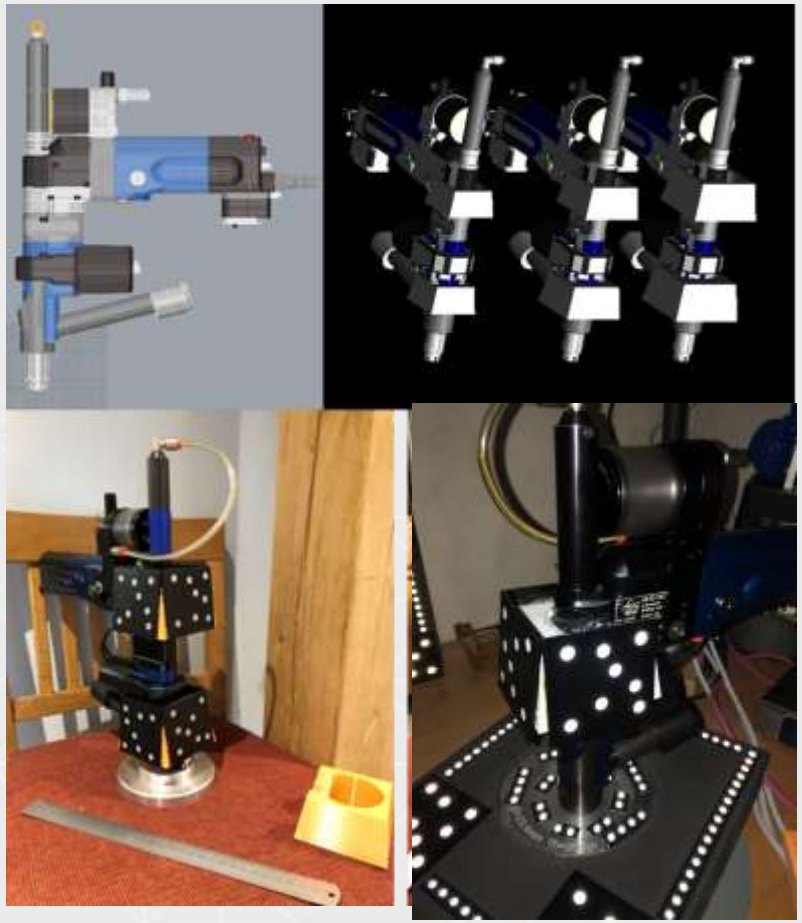
Drill 1 with a double constellation of three sided 70x70 mm coded target blocks



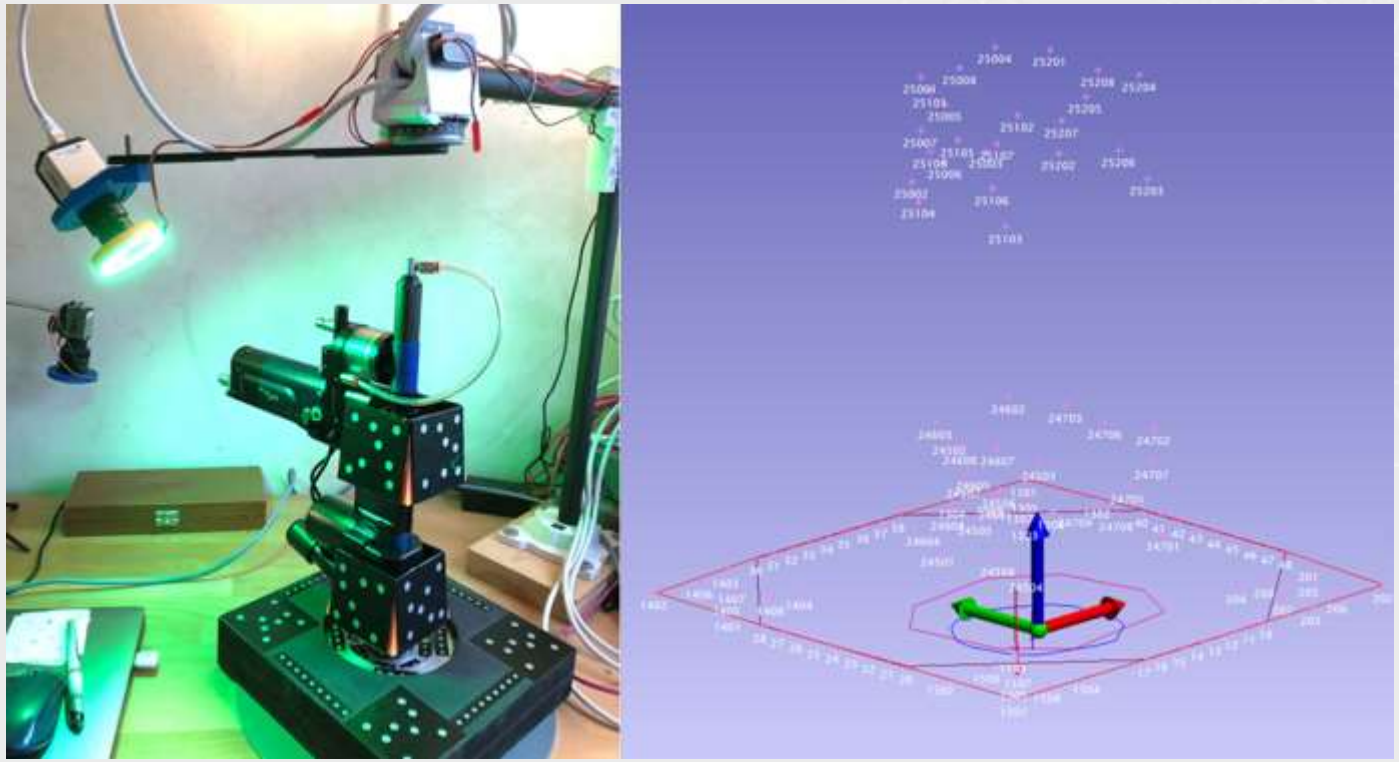
Yellow circles are reference target blocks, red circles are tracked objects

Drill 4 with a 50x50 mm coded target

Tool characterisation with calibrated reference block and orbiting camera



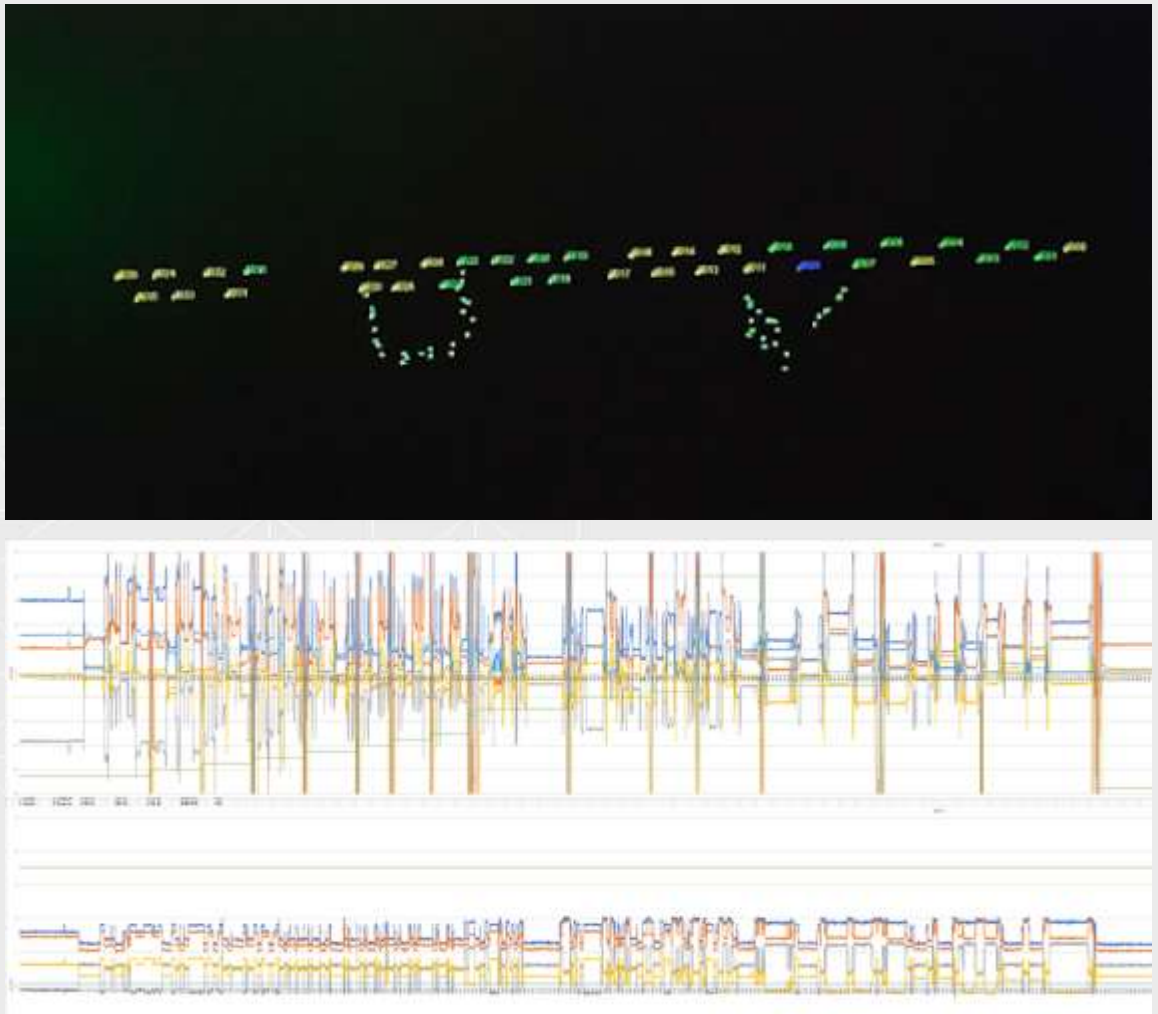
Design models and an approx. £100 3D printer produce a rigid body target around the drill body



Coordinate data from self-calibrating bundle adjustment enable drill axis and collet surface contact plane to be estimated.

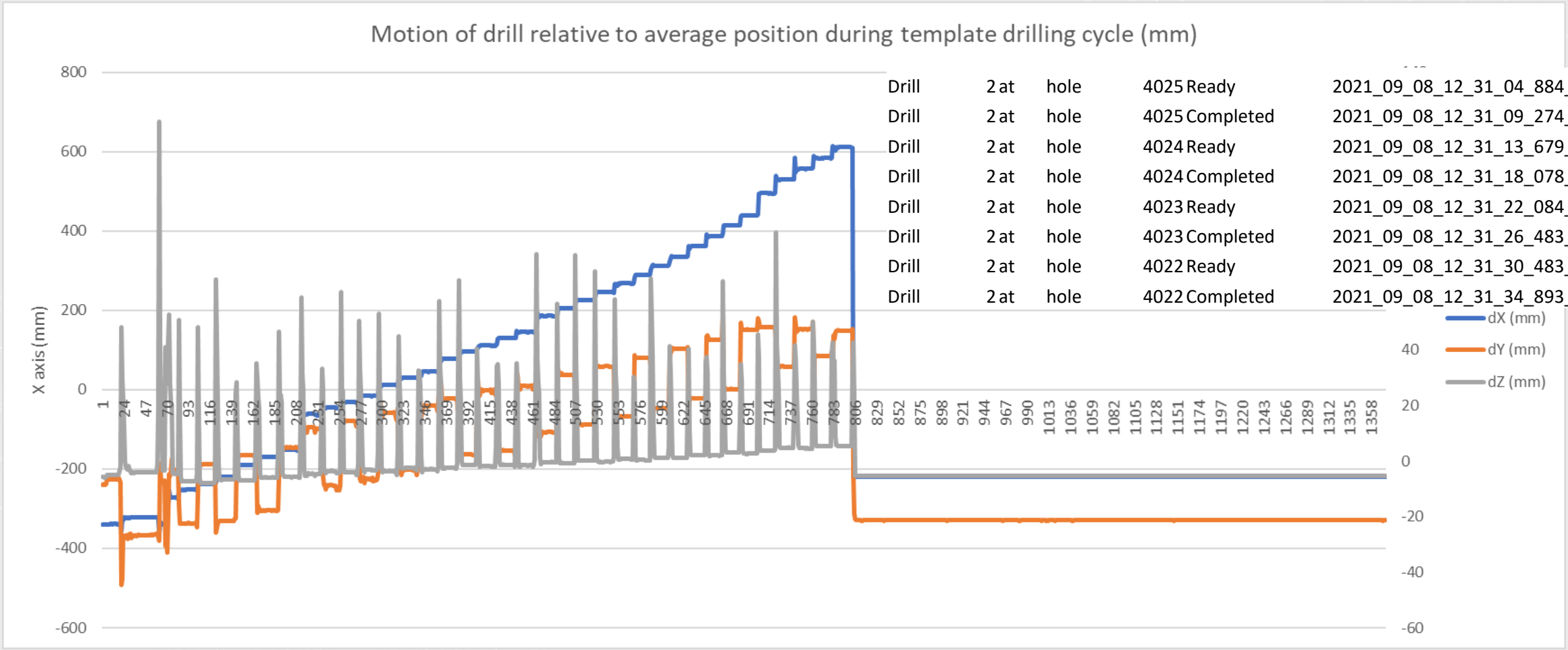
Result is a self calibrating automatic characterisation system capable of determining drill surface contact point to < 50 μm with respect to the constellation of coded targets

Multi-operator demonstration



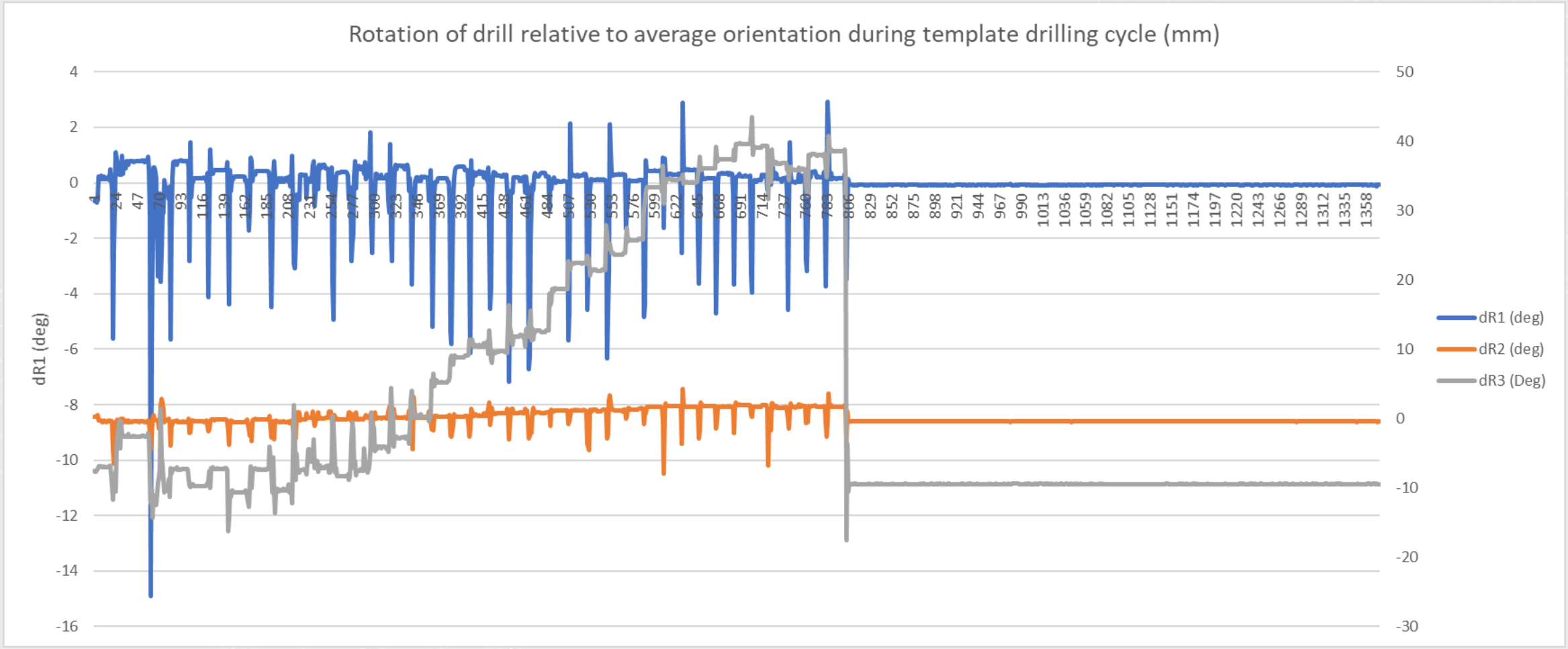
Lab demonstration of low-cost photogrammetry system tracking multiple drilling units at 10Hz

Drilling cycle across a template: Relative Position



Time-stamped spatial data linked to digital drilling workflow

Drilling cycle across a template: Relative Rotation



Tool rotations linked to tool cycle and operator activity

Summary

- Constellations of low-cost cameras based on off-the-shelf components can reliably track multiple drilling tools at the required scale in an environment that parallels factory conditions.
- Flexible deployment of sensors in static or mobile constellations as part of factory infrastructure is possible with easy-to-access hardware.
- Drilling tool targeting and characterization is being refined and automated.
- A full-scale demonstrator is under development at Airbus.
- Future system developments improving accuracy and utility will support a wider set of tasks as the UCL system is enhanced and translated into Airbus.