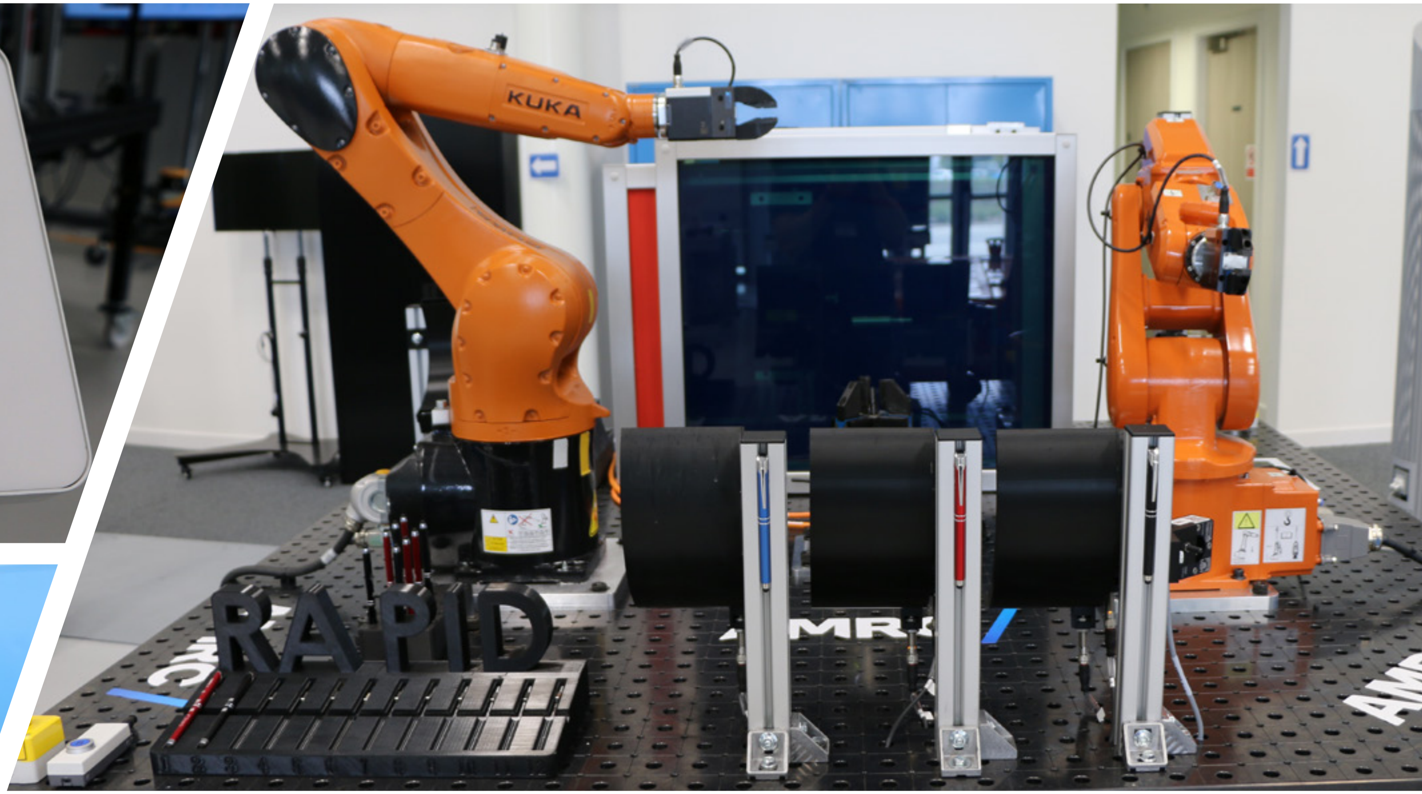
The University Of Sheffield.

AMRC Advanced Manufacturing Research Centre

Project RAPID

The reality of an Industry 4.0 demonstrator



WHERE DIGITAL MEETS MANUFACTURING

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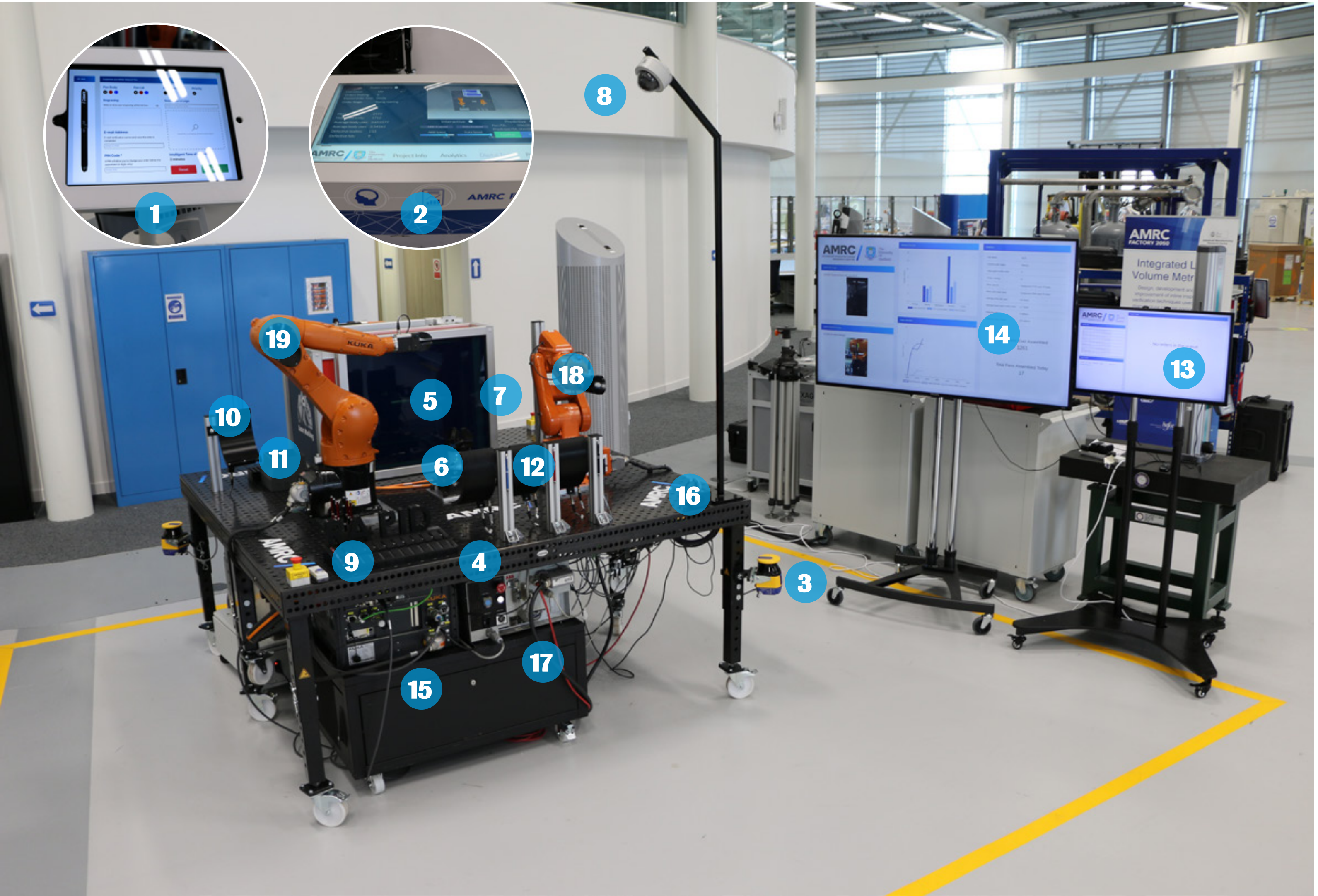
The idea of Industry 4.0 (i4.0) can be so intimidating that many companies simply choose to ignore it or put it on the long finger. However, the reality is that if industry doesn't adopt i4.0 concepts companies will struggle to be globally competitive in manufacturing. Our Rate Assembly Process Information Demonstrator (Project RAPID) aims to de-risk i4.0 implementations by incorporating as many i4.0 technologies and concepts as possible, while still having a realistic budget.

This document introduces the technologies that make up RAPID and how they work within it. If you want to discuss Project RAPID, i4.0 implementation, or any of the specific technologies used, please see the contact details on the last page.



Click the numbers on the image or the list below to find out more.

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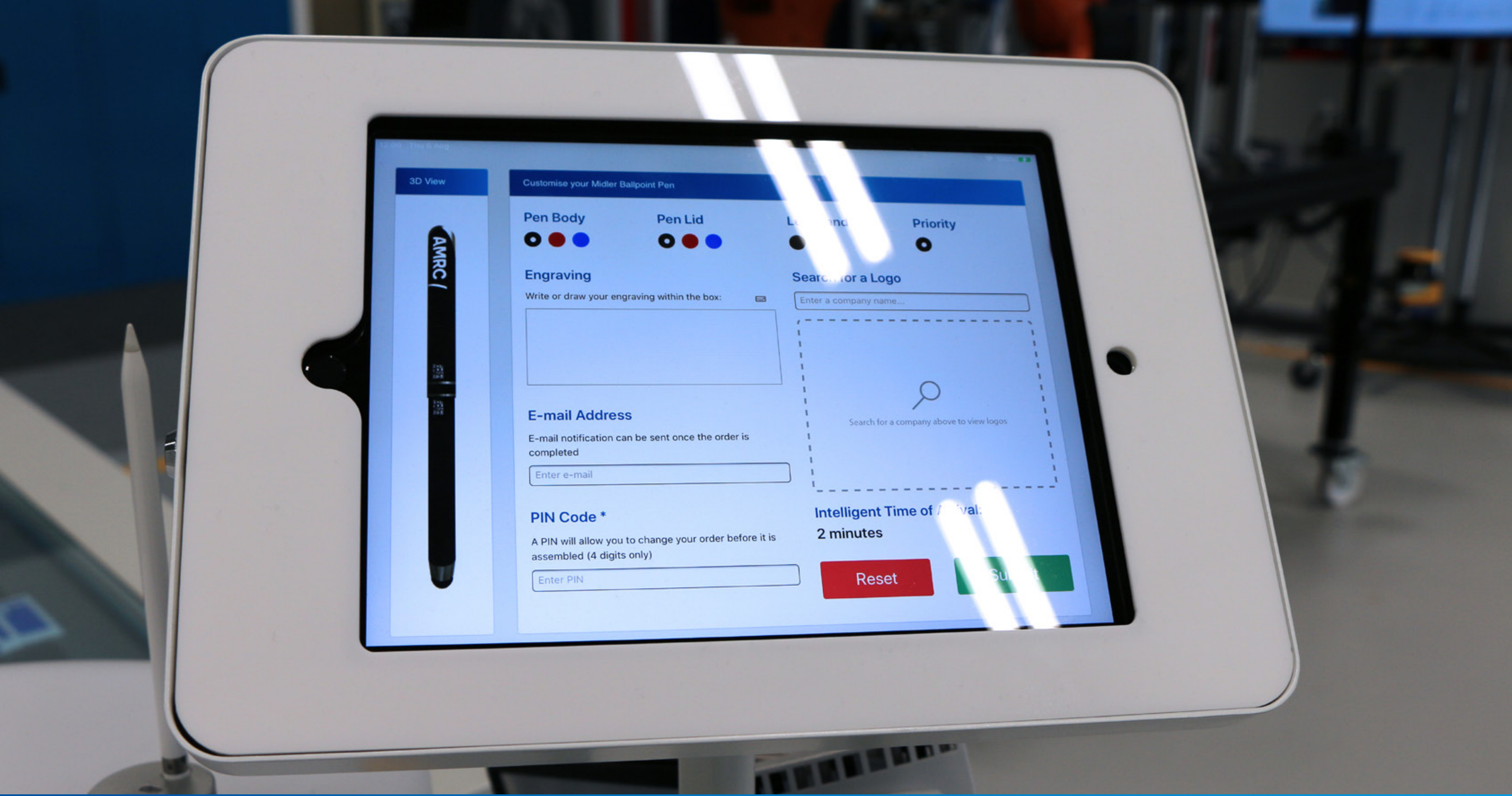
Partner contact details

AMRC contact details



1. Order Interface

Tablet based order interface written in HTML, Javascript & CSS using a ReactJS framework. This is where the user can customise their pen and place an order.. A live, manipulatable simulation allows the user to see the configuration of their pen, in real time, before they commit to ordering. Adjustments can be made to aspects such as component colour, signature engraving, logo engraving and left or right handed configuration.

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2. Smart Table

Touch-enabled 55 inch 'smart table' supporting multiple user interfaces that can be easily navigated by the user to self-educate and give information on the RAPID cell. The user interface has been created using the Unity games engine.

See next page for **Information Interface** details.

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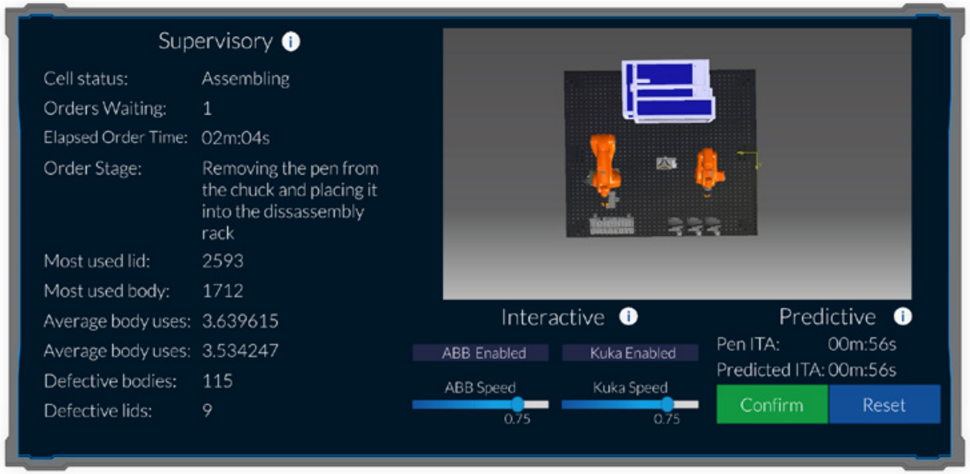

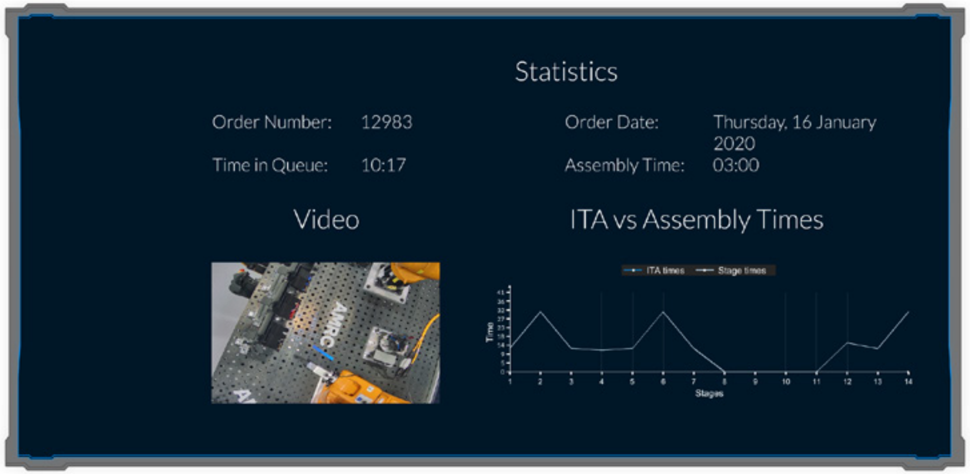

2. Smart Table (continued)

Information Interface

Intuitive interface allowing visitors to understand the key components of the cell and how they work and drill down into sub systems and components to learn more.

Digital Twin Interface

Three types of digital twin shown:

Supervisory – Displays live data from the RAPID cell.

Interactive – Allows the user to control the speed of each individual robotic arm in real time, remotely.

Predictive – Produces predictions of the completion time of a pen order, updated in real time using machine learning.

Order Lineage Interface

A visitor can enter their order number and see information about their pen such as when it was built, how many times each component was used before being used in their custom assembly, and how long the pen took to be assembled.

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3. Zonal Safety Laser Scanners

Safety laser scanners are utilised to minimise the risk of anyone being harmed by the cell. The safety scanners dynamically register when a human, or object, approach the cell. They recognise how close the person is to the cell and slow down, or stop, the robots accordingly. Numerous separate safety zones can be specified with different behaviour's happening in each. The scanners integrate with the cell's overall safety system.

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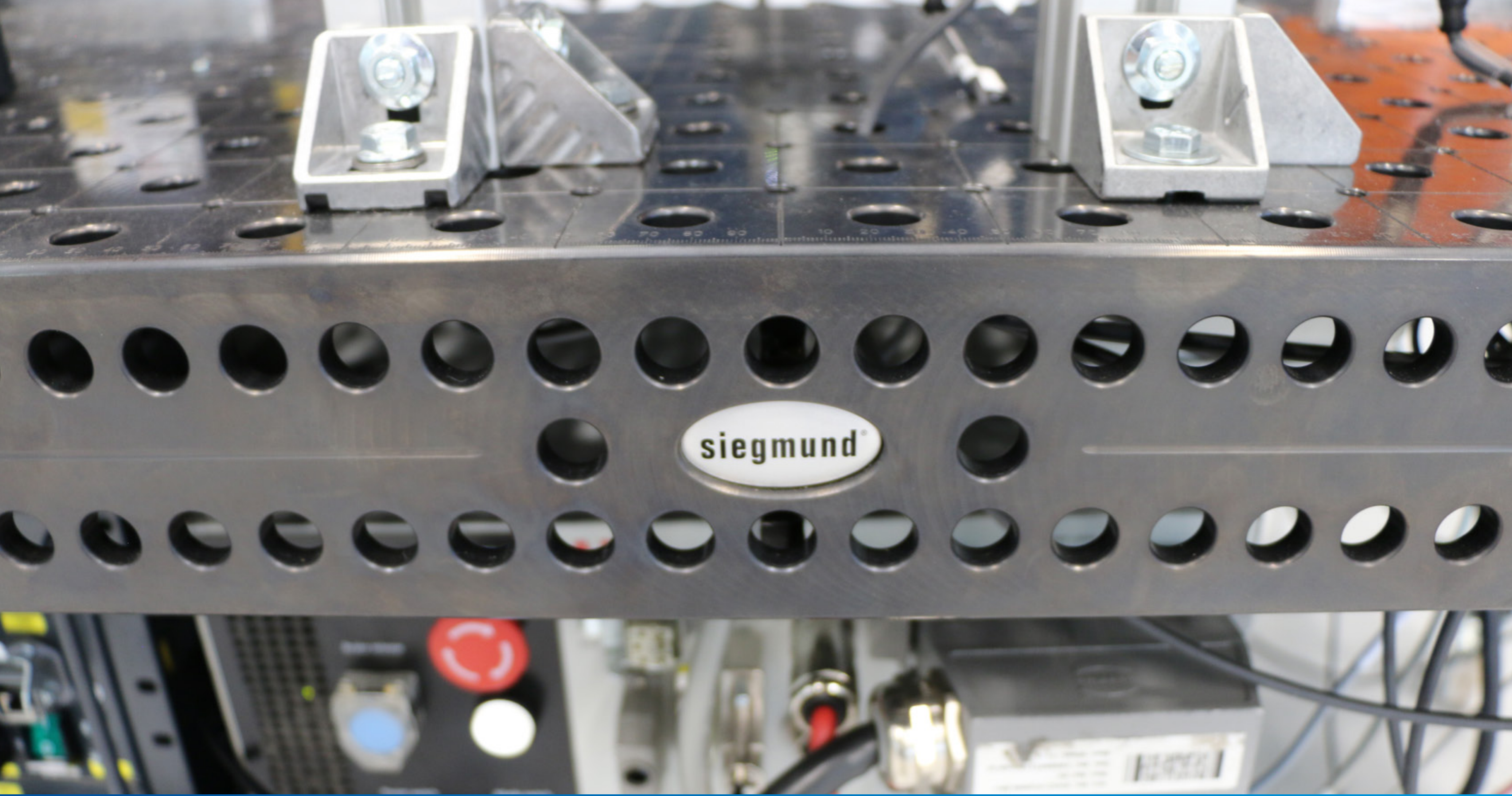

4. Reconfigurable Mounting Tables

High-precision mounting tables with M8 tapped holes 50mm apart allowing for components of the system to be moved around easily. This allows for multiple layouts to be tested quickly, additional components to be added easily, and for new functionality to be added if required at a later date. The tables are on wheels to allow for the RAPID demo to be moved easily to another bay on the shop floor or a trade show.

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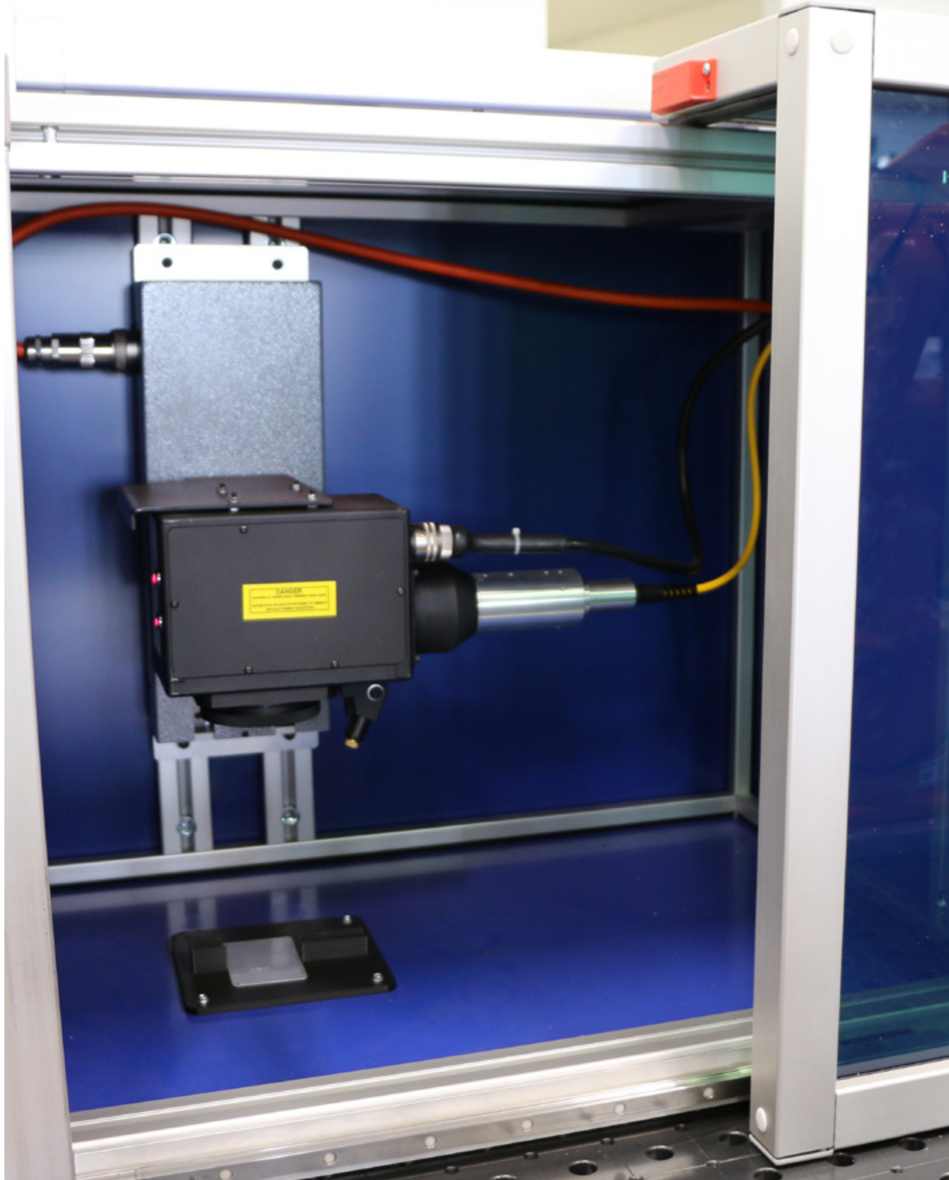

5. Laser Engraving Enclosure

The laser engraving enclosure houses a laser engraver that moves with three degrees of freedom to allow for the customised data matrix codes, signatures and logos to be added to the pens. The transparent front to the enclosure lets the user see the engraving as it happens. A linear drive and safety interlock are used to open and close the enclosure in a safe and automated way.

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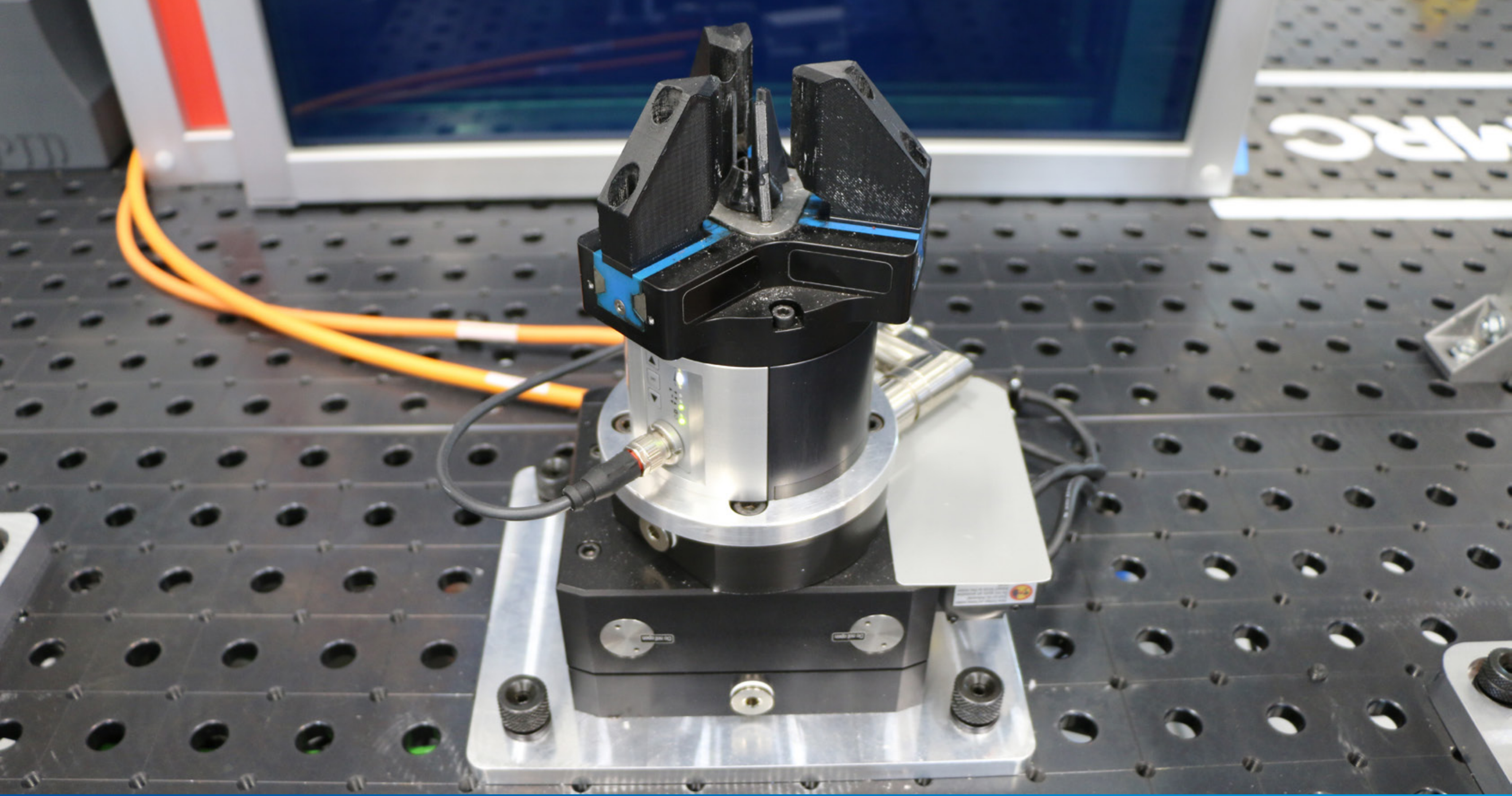

6. Turntable

The turntable in the centre of the system is where the build of the pen occurs. It has three grippers that hold the body of the pen in place while the robotic arms add components to it. The turntable works with the robot to align the data matrix codes and the lid clips on the pen correctly before being put in the engraver or completed pen racks. The pen is rotated in the chuck of the turntable to allow the pens to be inspected for defects and to identify the data matrix codes.

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7. Inspection Cameras

The inspection cameras look at the pen while in the turntable and identifies if the pen has a data matrix code, if there are any defects, and is used to verify that a process has been completed successfully. For example, placing a lid on the body of the pen. It is connected to the AI NVidia Edge device for the object detection and defect identification.

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8. Time-lapse Camera

A Pan Zoom Tilt (PTZ) camera is used to record each pen build on the cell. The recording is converted to a time-lapse GIF and emailed to the customer so they can see how their pen was assembled, even if they can't be there to see it with their own eyes.

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9. Completed Custom Pen Rack

Completed custom pens are positioned in this 3D printed collection rack by the robotic arms. Micro-switches recognise when a slot in the rack is empty and newly completed pens are added to the next free slot, ready for collection. Fused Deposition Modeling (FDM) polymer additive manufacture was used to create the majority of the fixturing on the cell; this meant new design iterations could be tested quickly and easily, and spares can be made on demand.

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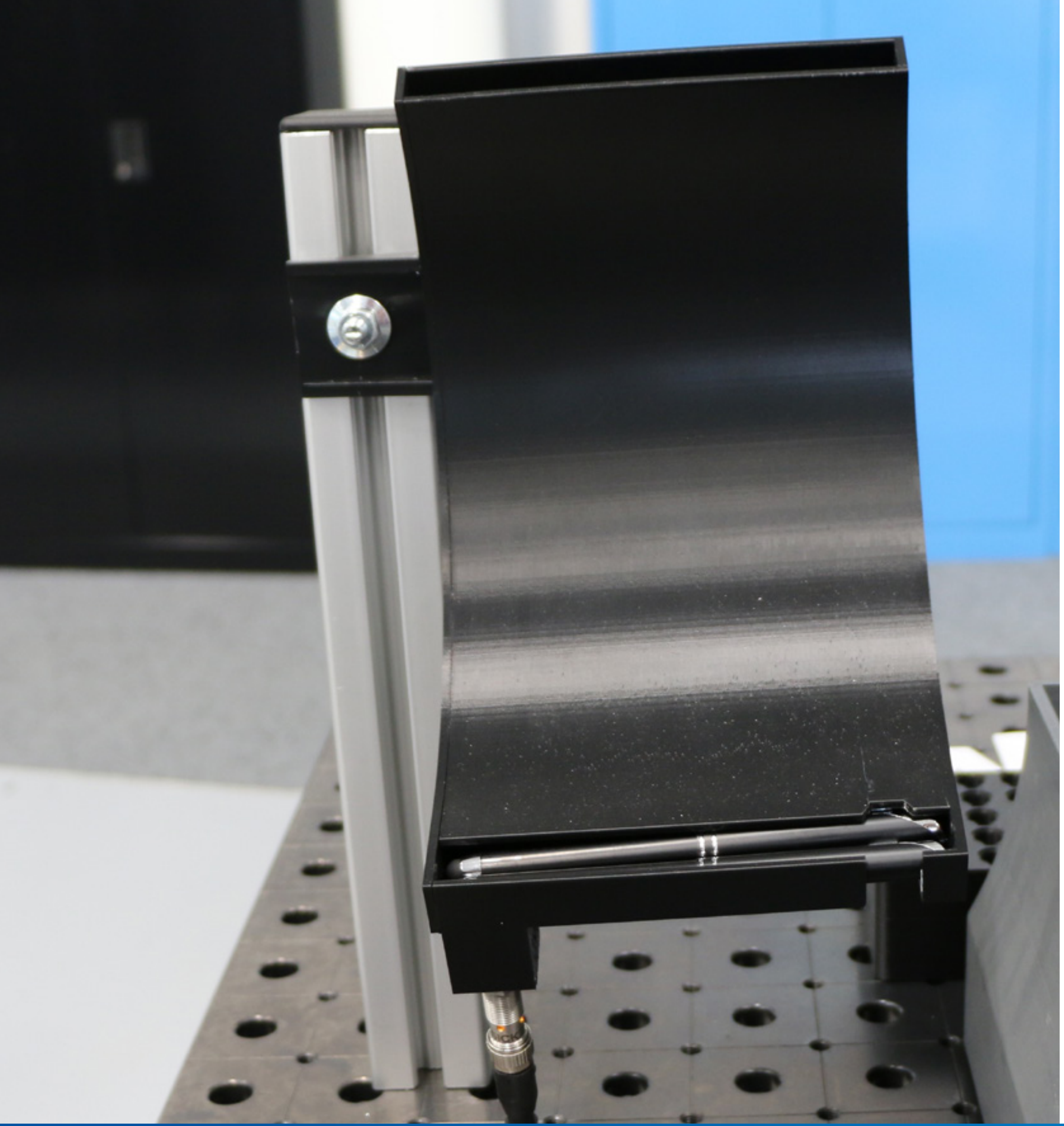

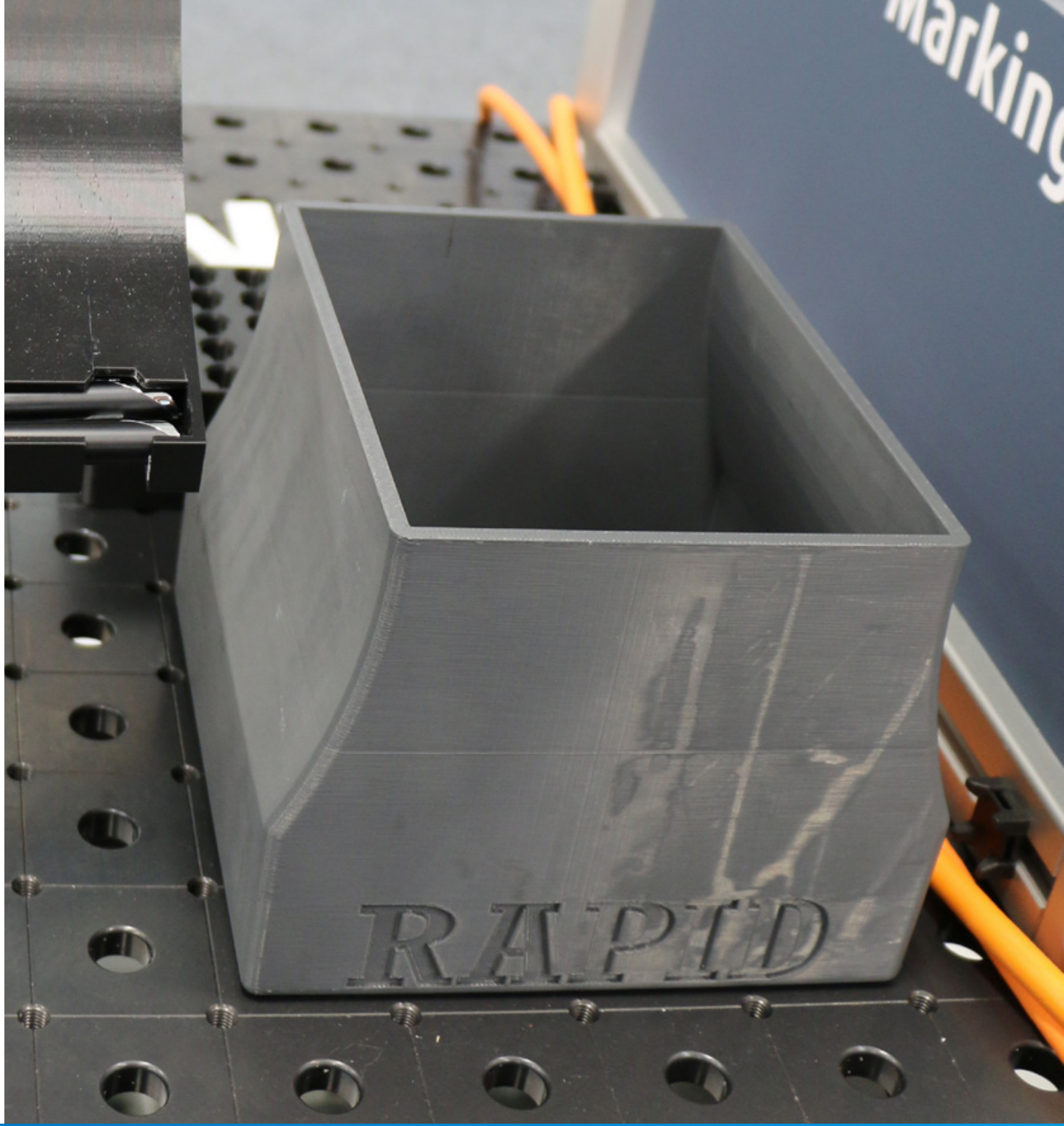

10. New Stock Pen Hopper

New pens arrive pre-assembled, this hopper holds these pens. RAPID takes pens from here, engraves QR codes on them, disassembles them and adds the components to the Pen Part Hoppers when stock levels are low.

11. Scrap Bin

When a defect is detected on a pen, or component, it is placed in the scrap bin. An operator then decides what to do with those components.

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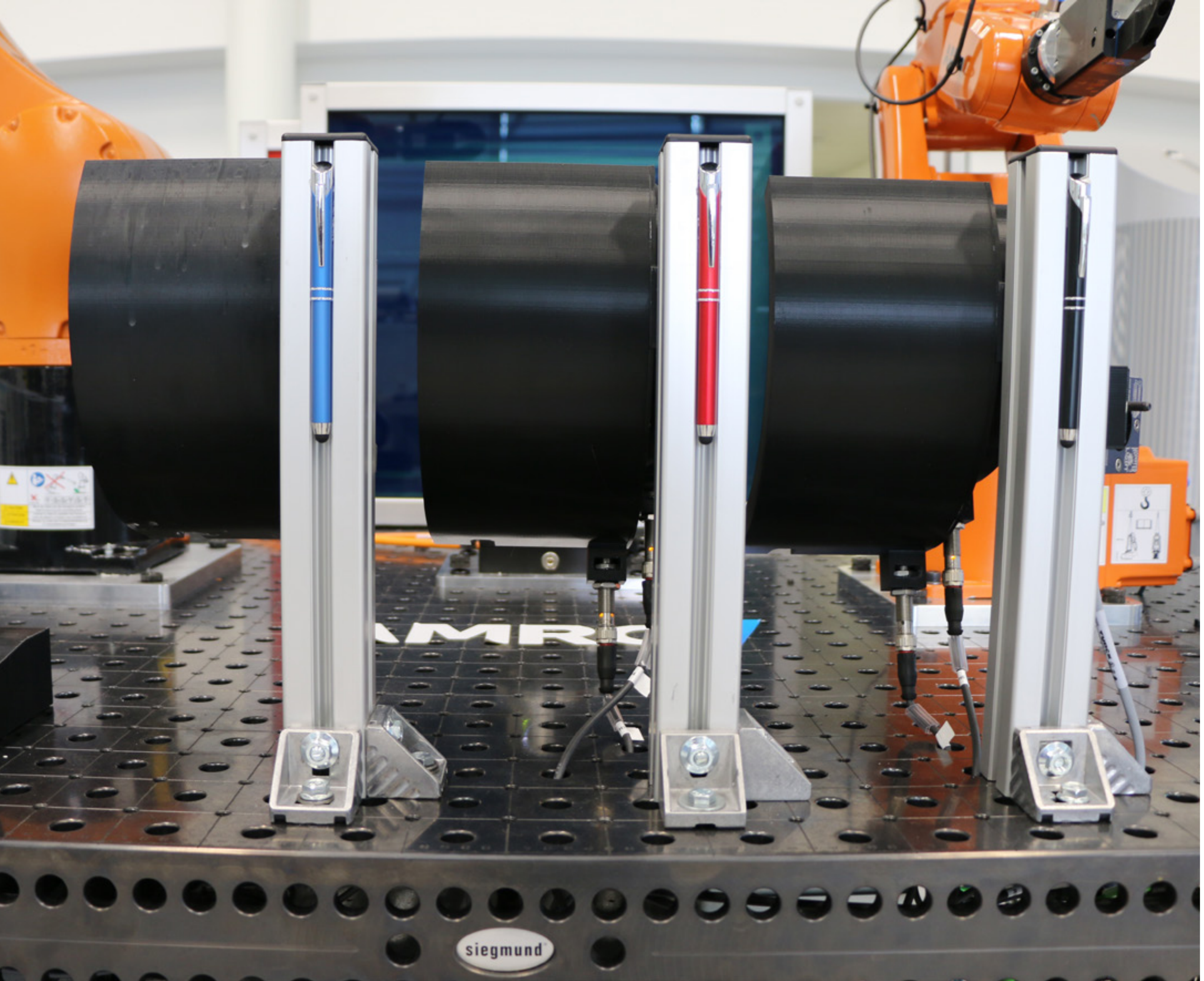

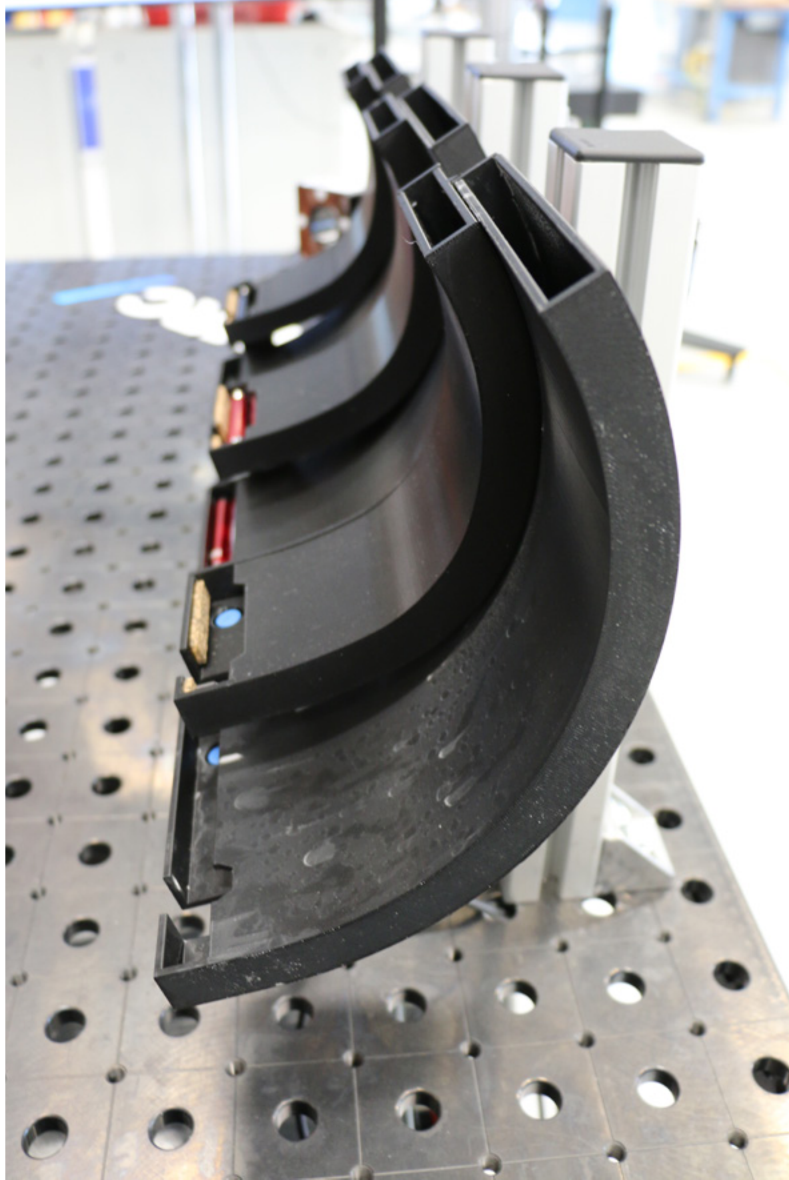

12. Pen Part Hoppers

Pen bodies and lids are fed into the system through these hoppers. They are designed to align the part in the same orientation every time. Sensors detect when a hopper is empty and new components are added by informing an operator, or automatically disassembling other pens in the demonstrator.

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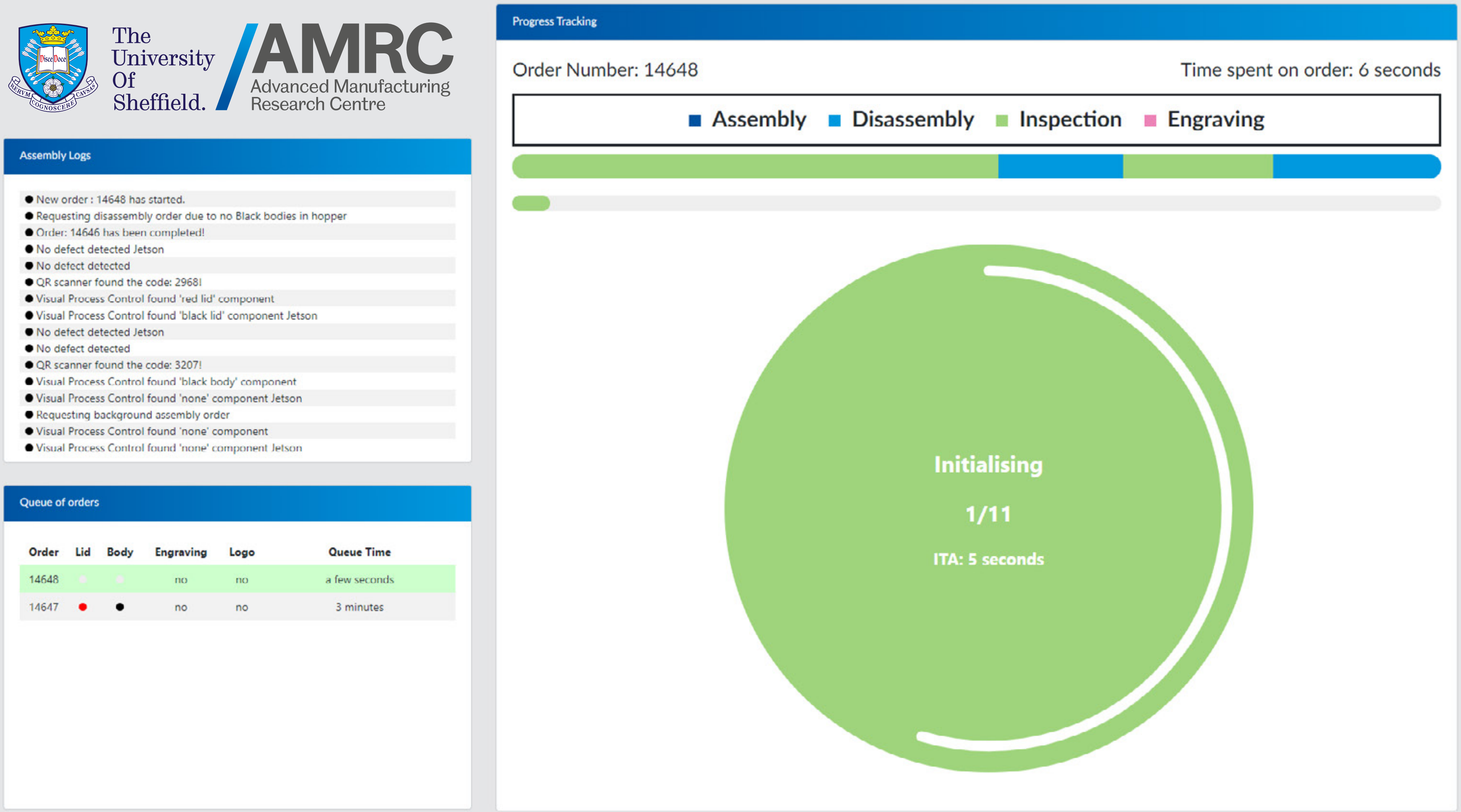

13. Order Status / Tracker Dashboard

The lists all orders that are queued with their basic specification. The visually intuitive interface shows what stage of the assembly the system is on and how close to completion it is. This visualisation allows the customer to track where their pen is and how the build is progressing.

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14. Data Screen

The additional data screen provides customisable informative data on what the system cameras see, what production rates are like over time, average time to complete an order, and much more. This gives the viewer an idea of what types of data could be gleaned from an i4.0 system.

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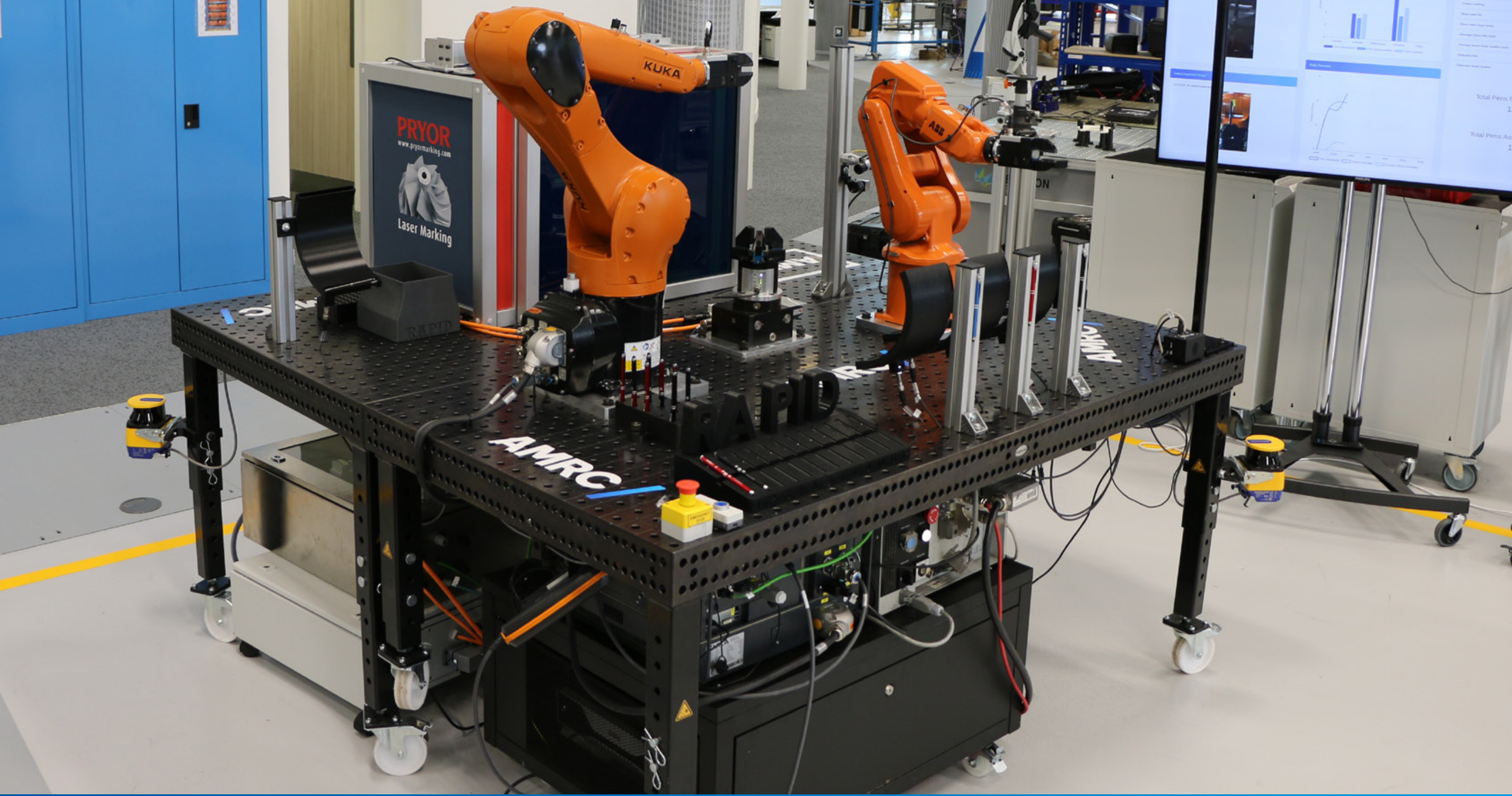

15. Industrial Network

The key operational technology (OT) components of the system (programmable logic controller (PLC), robots, laser engraver, safety systems) have been connected using a deterministic and robust EtherCAT protocol, where possible. For easy cabling, connections and adaptation the cell uses as much IOLink as possible too. Some components don't allow the use of IOLink and/or EtherCAT and those use other appropriate protocols.

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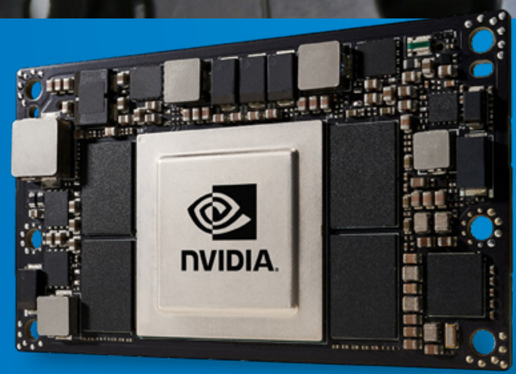
16. AI Edge Computer

This small, low cost, low power, edge computing device is an NVidia Jetson TX2. The Jetson runs all the artificial intelligence (AI) models for the vision based object and defect detection, and estimating when a pen will complete. The most commonly applicable neural networks for manufacturing are demonstrated with it.



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17. Local IT Infrastructure

A previously decommissioned Legacy Dell Precision R5400 Server is being utilised as the master control for the cell and acts as its beating heart. Free Open Source Software (FOSS) has been used as much as possible. The majority of the software is coded in JavaScript with the Node.js runtime environment and React.js framework on the frontend.

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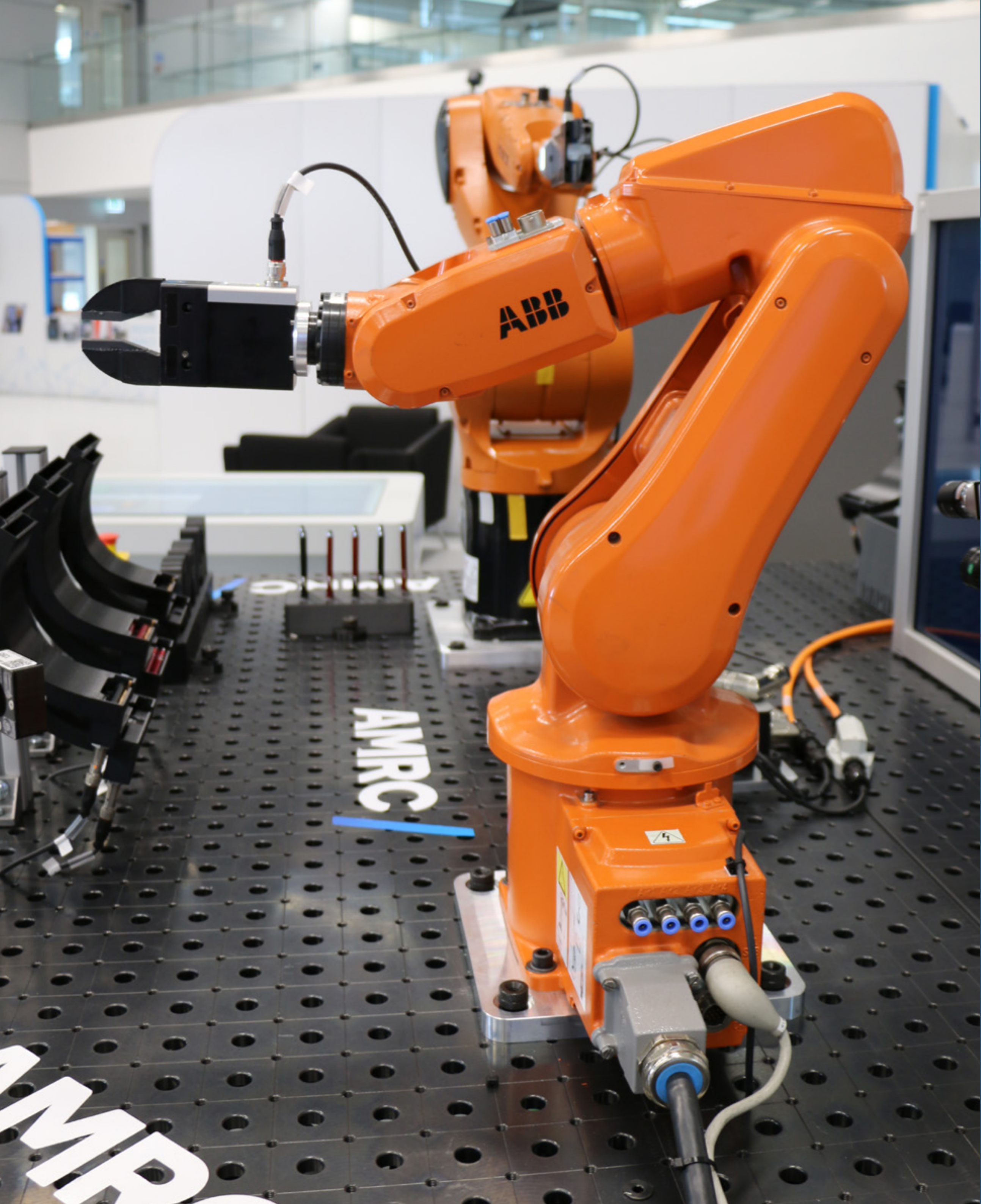

Robotic Arms

Two six axis serial link robotic arms are used in the RAPID cell. They are from two different manufacturers, different ages, use different communication methods, are programmed differently, and have different capabilities. Even though very different in many ways they have been configured to work together to pick up components, assemble/disassemble pens, and pass them to the engraver, turntable and completion hoppers. They can be turned off individually, or their speeds adjusted, without affecting the cells ability to complete tasks.

18. ABB120

The ABB arm is the older of the two robots and has a shorter reach. As such it can't perform all actions required by the cell without help from the KUKA arm. It communicates using 24V IO signals which makes it easier to understand when setting up but increases the wiring needed.

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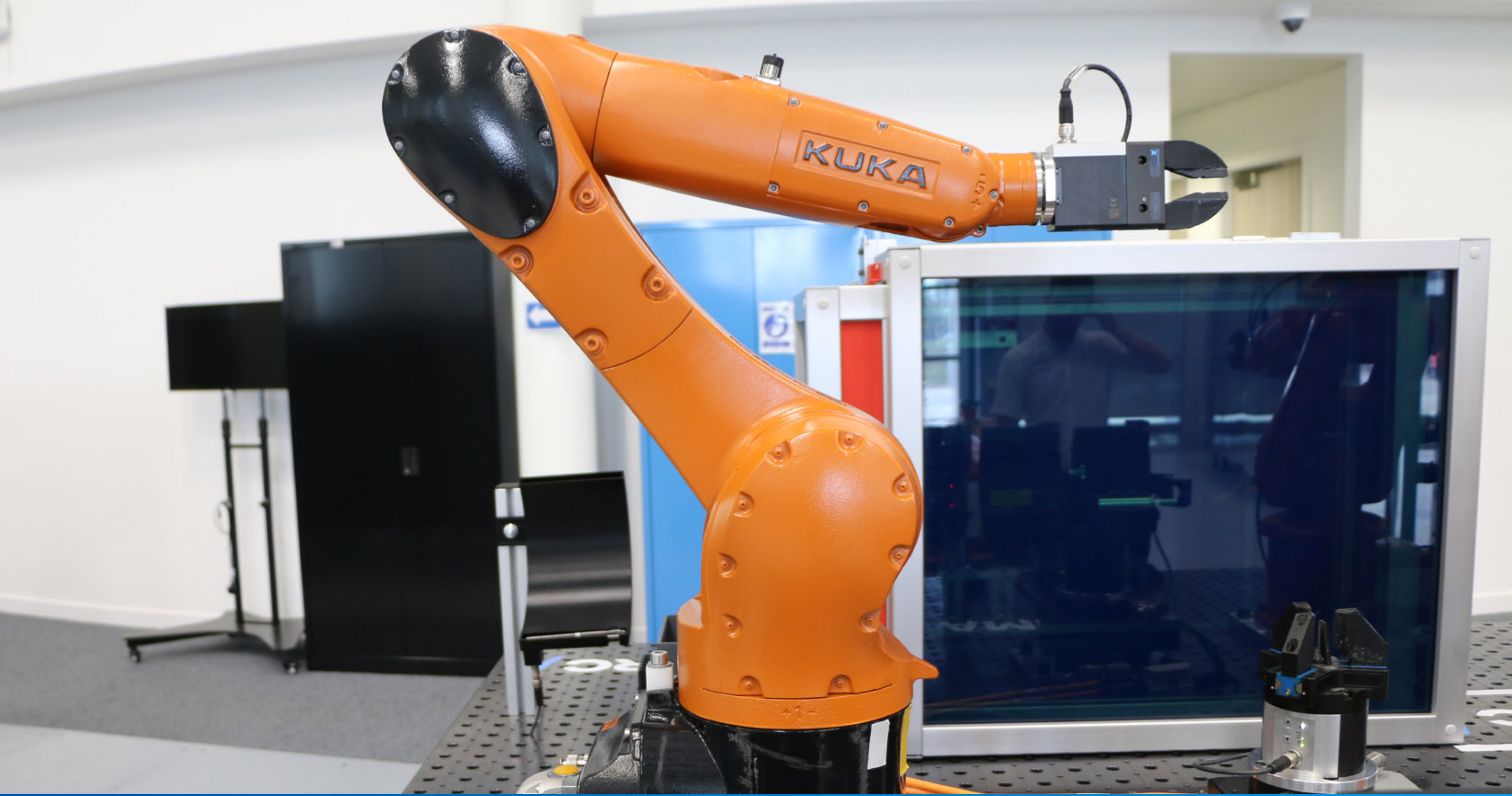

19. KUKA KR10 Agilus

The KUKA is the newer model of the two robots and has the reach to do all tasks required from the RAPID cell on its own, if needed. It communicates over EtherCAT, which minimises cabling.

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Zimmer Group	zimmer-group.com	henri.millard@zimmer-group.co.uk	Grippers for robotic arms

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