AMRC

ADVANCED MANUFACTURING RESEARCH CENTRE

The University Of Sheffield.

Integrated Manufacturing Group
Capability directory

amrc.co.uk

CATAPULT
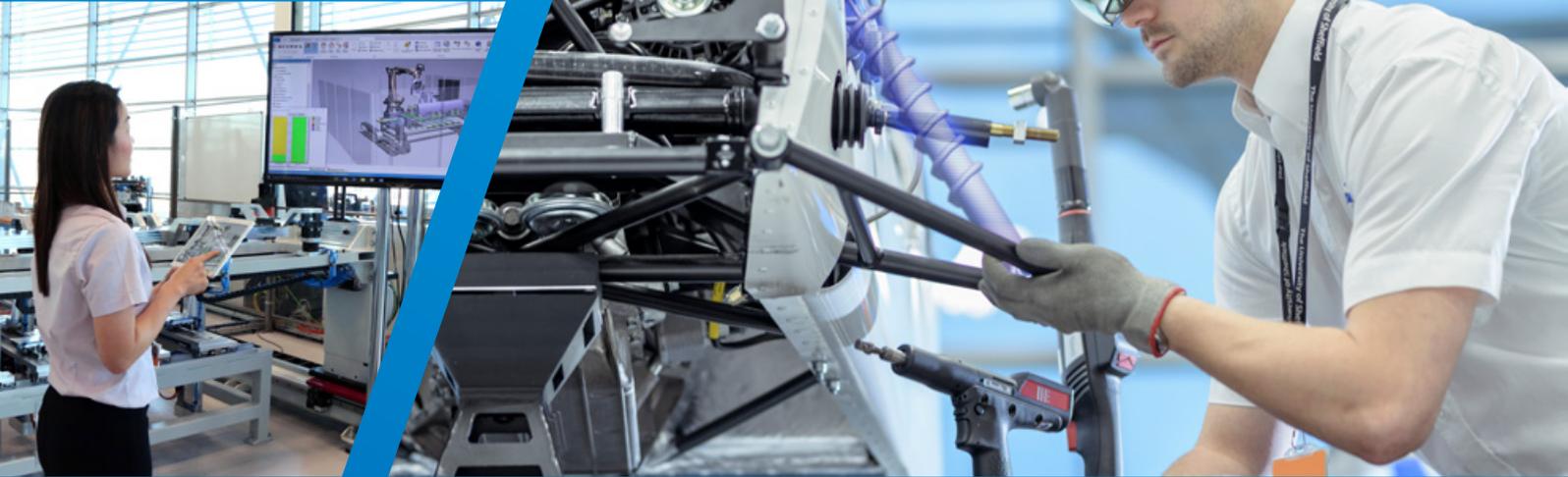High Value Manufacturing

AMRC/

The AMRC Integrated Manufacturing Group (IMG) are developing ways of meeting demand for high variation and mass customisation, intelligent machines and processes that monitor and optimise their operations, techniques to shorten lead times and ramp production up and down rapidly, ways of handling and making sense of big data, human machine collaboration and techniques for digitally assisted assembly.

Our resources are open to manufacturing businesses of all sizes and we apply our knowledge and deliver impact across a wide range of sectors including aerospace, automotive and transport, construction and energy.

We are leaders in the development of augmented reality solutions with smart connected tools and devices, used for complex assemblies where automation is not applicable. We are equally adept in integrated large volume metrology – including the design, development and process improvement of inline inspection and verification techniques used during the manufacture of large components and complex assemblies.

Our research into the smart applications of robotics and automation have led to partnerships with the leading names in aerospace and defence. A collaboration with BAE Systems has de-risked a major robotics investment for the company and is now on the way to achieving significant, six figure cost savings for the company.

We are also at the forefront of manufacturing informatics, integrating sensor and measurement systems, data collection, analytics, visualisation and decision making to drive step changes in the manufacturing processes.

Our main research themes are:

- **Robotics and automation**
- **Digitally assisted assembly**
- **Integrated large volume metrology**
- **Manufacturing informatics**

This document is a brief introduction to current IMG capabilities. For any enquires relating to potential projects or IMG capability, please feel free to email me at the address below.

Ben Morgan, Head of IMG
b.morgan@amrc.co.uk

The AMRC Integrated Manufacturing Group can bring a wide range of capabilities and expertise to our industrial partners.

Technical capabilities

▶ Click page to jump

CASE STUDY   Where you see this icon, click it to read the Case Study.

See next page for: **Software** and **Equipment capabilities**.

Software

▶Click page to jump

See next page for: **Equipment capabilities**.

Equipment

Continues on next page.

Equipment – continued

Robotics and Automation

Robotics and automation are widely used to carry out simple repeatable tasks in industries with high production volumes, such as automotive and food processing. IMG specialise in developing robotic systems for low-volume, high-value markets such as aerospace, where robots have to carry out significantly more complex and variable tasks with greater accuracy.

IMG use a diverse collection of robots and automation equipment from the world's most advanced suppliers, including Kuka, ABB, Mitsubishi, Güdel and Siemens.

CASE STUDY

Integrated Large-Volume Metrology

The continuing drive for more fuel efficient aircraft has led to manufacturing tolerances becoming tighter and the introduction of weight saving materials whose properties are more unpredictable.

This has put increased emphasis on the importance of metrology and IMG work closely with AMRC partners to ensure that they are at the cutting edge in the field.

Metrology has been of paramount importance in flagship projects to build aircraft with high composite content, such as the Boeing 787 and Airbus A350.

Using in-process measurement and integrated metrology machinery simplifies the assembly of these flexible structures from components that have been supplied from multiple locations around the world.
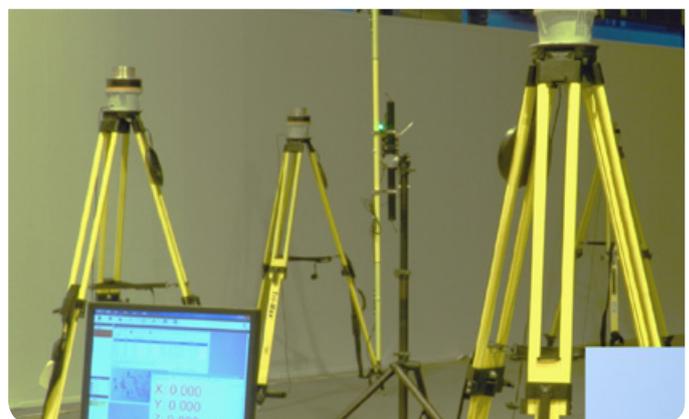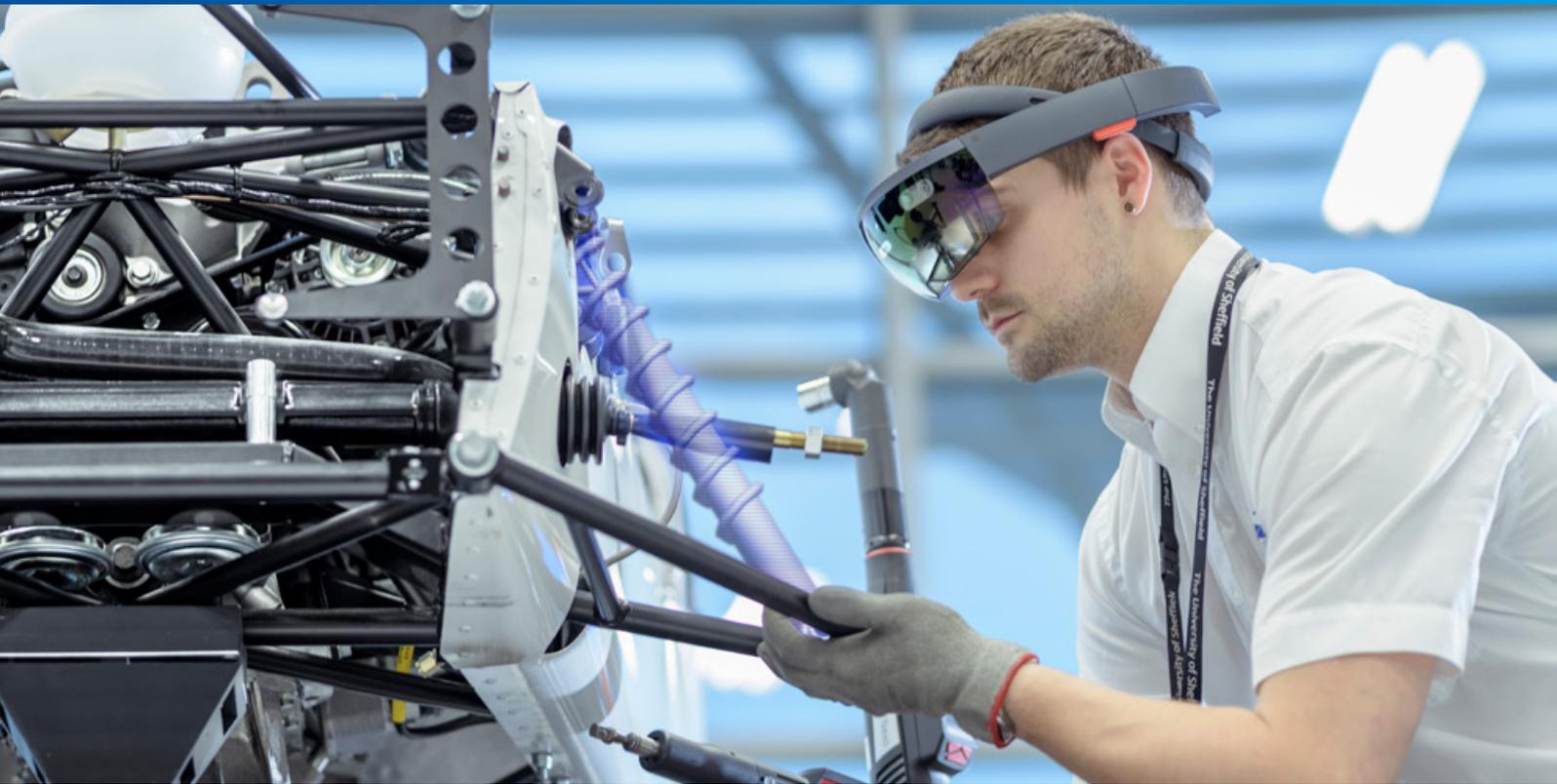
Digitally Assisted Assembly

Digitally Assisted Assembly provides opportunities for increasing production rates, improving quality and reducing cost when a task is too complex, involves too much variation or simply would not be cost effective to automate. IMG are developing digital, semi-automated assembly capabilities, incorporating Augmented Reality (AR) and Intelligent Workbenches.

These self-teaching systems supply detailed assembly instructions that allow inexperienced operators to successfully complete complex tasks. Systems can simultaneously capture data from intelligent tools and sensors which is then used to validate processes and ensure traceability. In-line quality checks provide early detection of manufacturing problems and decrease the number of defects at the end of the process.

IMG have an extensive suite of associated software from leading suppliers, ranging from CAD and offline programming to augmented reality and metrology data-analysis systems.
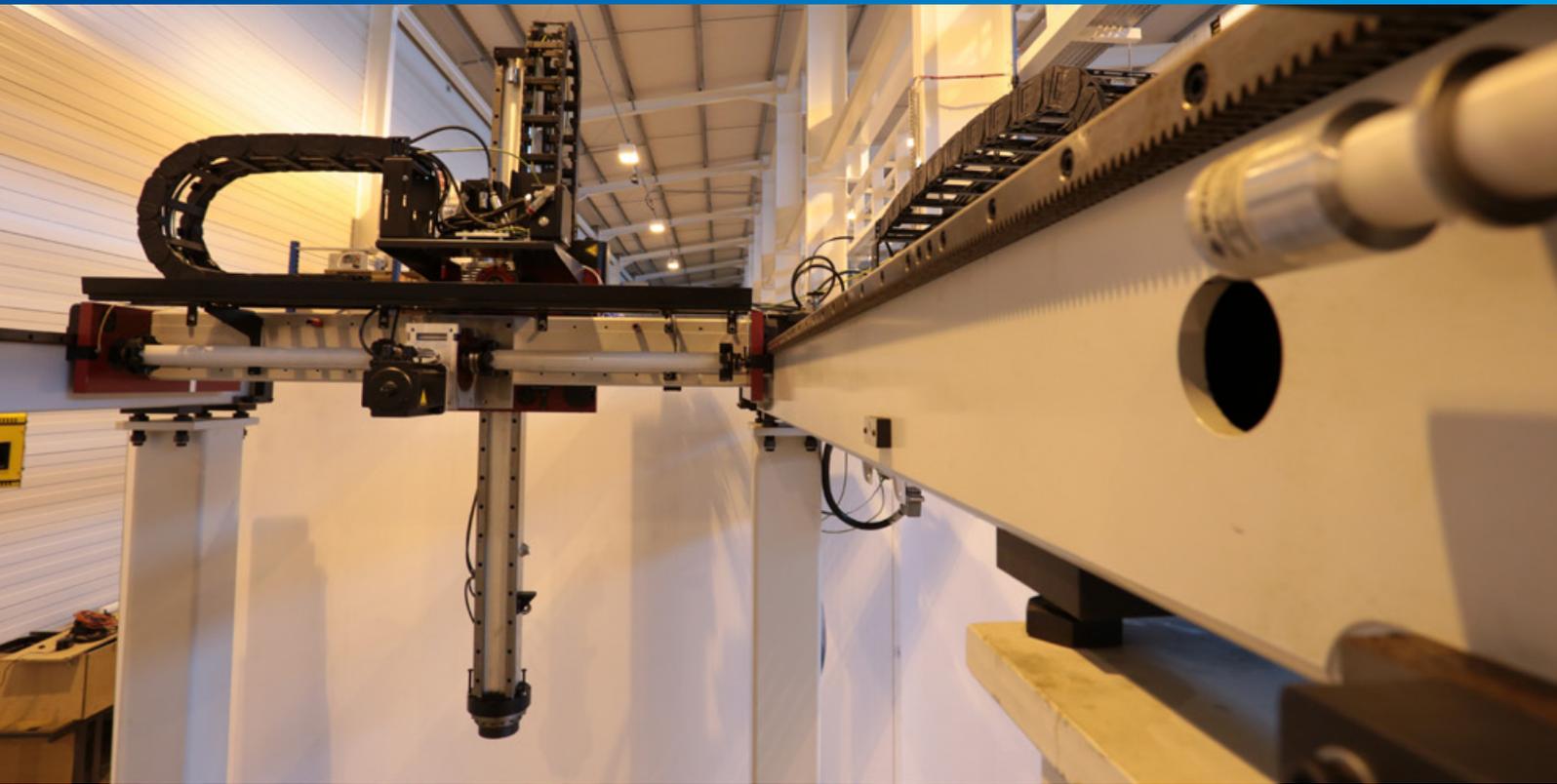
6-Axis Robots and Gantries

Industrial 6-axis robots form the bulk of the work within IMG, and all members of IMG staff are proficient in operating and programming robots from at least one of the leading manufacturers. Robots, gantries and external axes from ABB, Fanuc, Güdel, Kuka and Mitsubishi are either in-use already or are being investigated and developed by IMG to enable interchangeable and configurable manufacturing within aerospace assembly, manufacture and beyond.

IMG use a variety of online and offline programming software and methods including DELMIA, Delcam PowerMILL and RobotMaster to complete projects involving the integration of robotics with past, current and new technologies and processes.

ANY OTHER IMAGES ?

ANY OTHER IMAGES ?

Technical Capabilities   **IMG Skillset**

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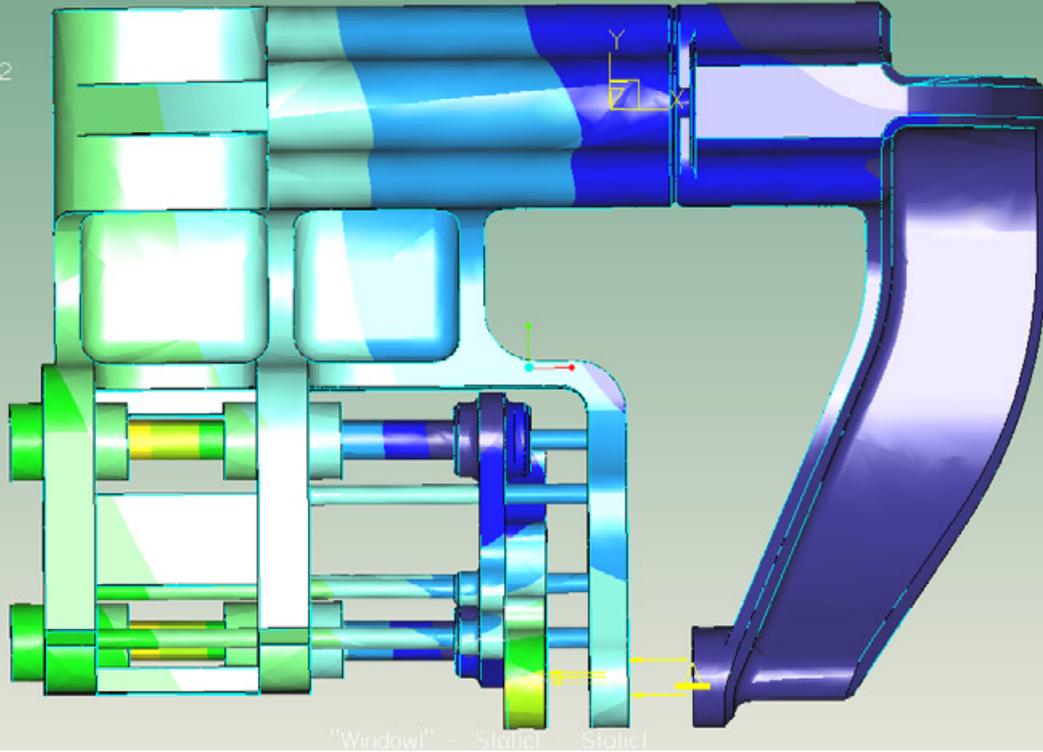
"Window1"   -   Static1   -   Static1

Design

Throughout project work, IMG aim to deliver complete solutions for our customers. An essential part of this process is designing appropriate components and setups to allow this to happen. This is done by delivering high-quality CAD to our in-house IMG and AMRC facilities and to local suppliers to fabricate items ranging from jigs and brackets, to end effectors and machining tables.

IMG involvement covers the entire process from initial scoping, to integration and commissioning of final demonstrators, through to fully operational production cells.

ANY OTHER DESIGN/CAD IMAGES ?

ANY OTHER DESIGN/CAD IMAGES ?
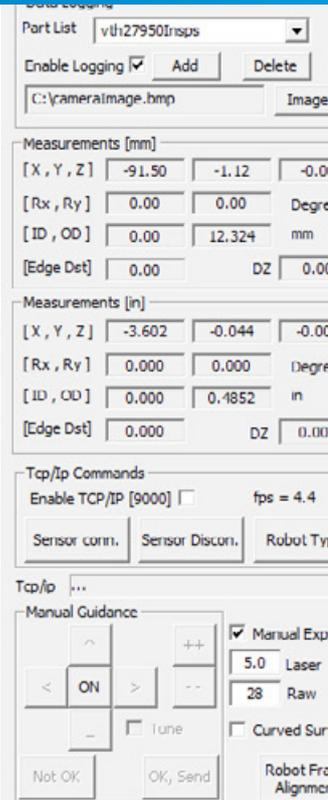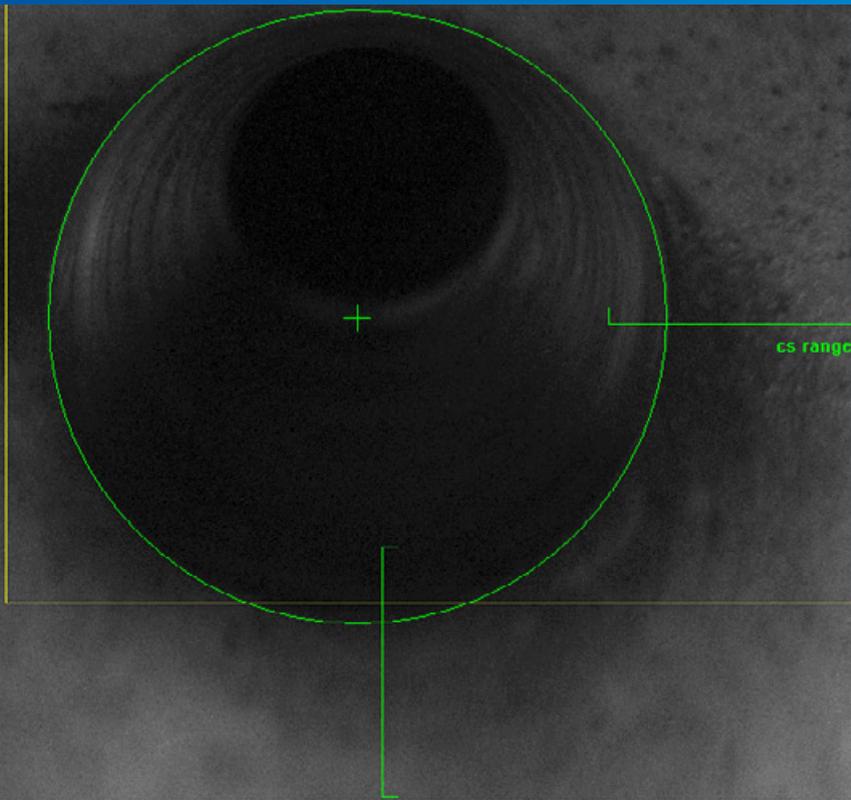
Measurement, Metrology and Vision Systems

Aerospace components and assemblies must be manufactured and assembled to high specification and strict quality requirements, to ensure that the finished product is entirely safe and fit for purpose. IMG have developed an in-house metrology expertise for measurement of large volumes. IMG also have a range of metrology hardware available for use, including laser trackers, CMM cameras, probes, scanners and indoor GPS for accurate measurement and reverse engineering capabilities.

In addition to metrology and measurement, IMG have conducted investigations into the integration and use of vision systems for verification and other purposes within manufacturing and automation cells. This includes safety scanning and supervision systems that provide an appropriately safe working environment where human-machine interaction is required in semi-automated manufacture and assembly.
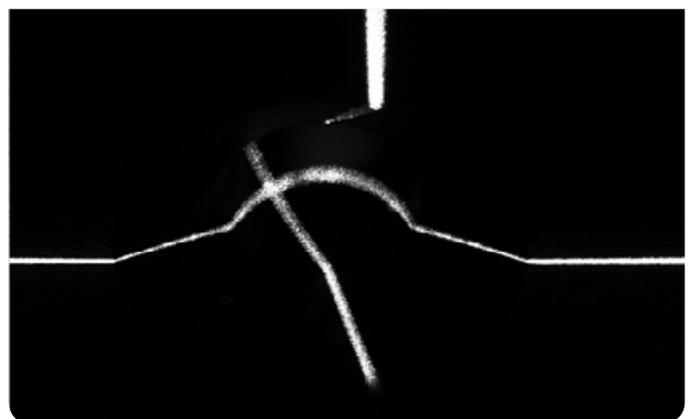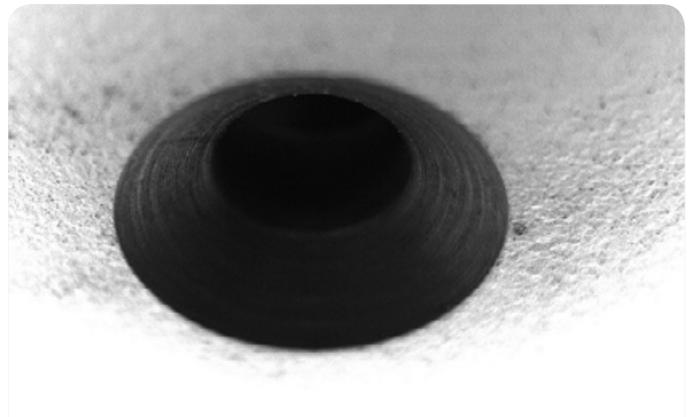
Advanced Visualisation

The Integrated Manufacturing Group's advanced visualisation team is researching new and innovated ways the future workforce consume information. By leveraging 3D assets and real-time data streams, tools such as augmented and virtual reality can be used to add significant value to existing workflows, or even create new ones entirely. Working with informatics to understand the implications of the technology on an enterprise scale. The visualisation team are hardware and software agnostic and are able to deploy to a multitude of hardware using a range of software packages.

CASE STUDY

CASE STUDY
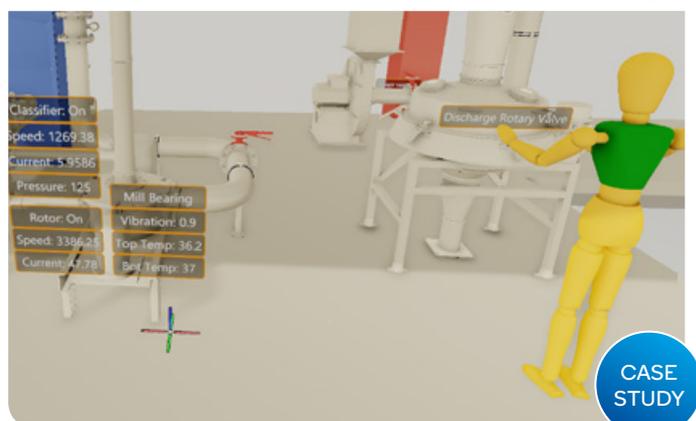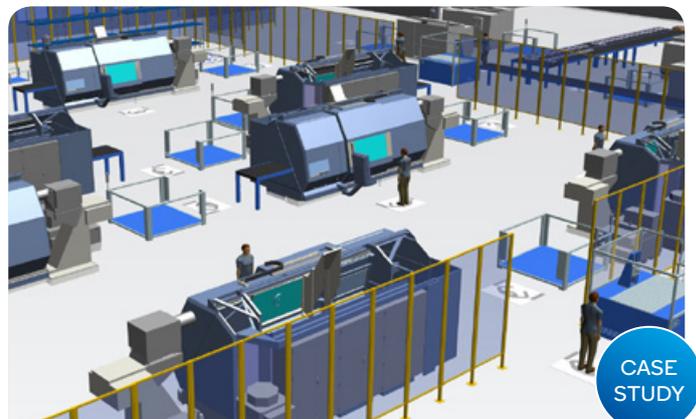
Augmented Reality

Our AR work involves creating workflows for assembly, maintenance and remote support, as well as providing insight into how these tools can be effectively integrated into existing processes. Our development path pays close attention to emerging tools and techniques for authoring content such that the return on investment can be maximised. We also perform studies into the effectiveness of current AR solution and provide through both quantitative and qualitative user studies.

Virtual Reality

Virtual reality is becoming established as a core technology in manufacturing. The AMRC are involved in research which supports VR for training, factory layout, and design review. The visualisation team are working closely with industrial technology providers to create immersive digital twins and, when combined with discrete event simulation.

CASE STUDY

CASE STUDY
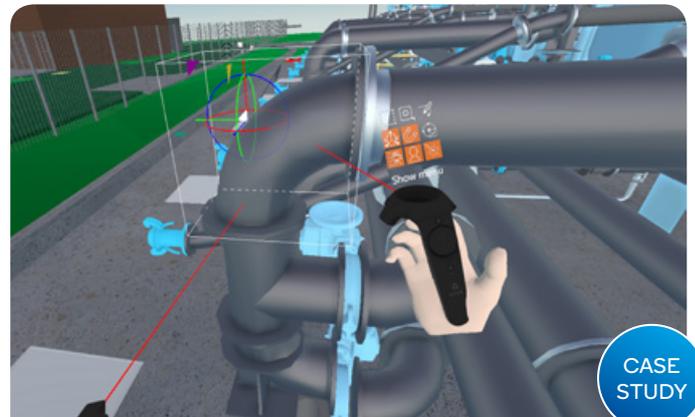
WATCHES, TRACKING, SCANNERS?

Wearable Technology

Creating holistic workflows which can leverage the functionality of a suite of wearables, such as smart watches, tracking technologies, and scanners. 'We also pay close attention' to the communication standards and best practice which can bridge them together.

WATCHES, TRACKING, SCANNERS?

WATCHES, TRACKING, SCANNERS?
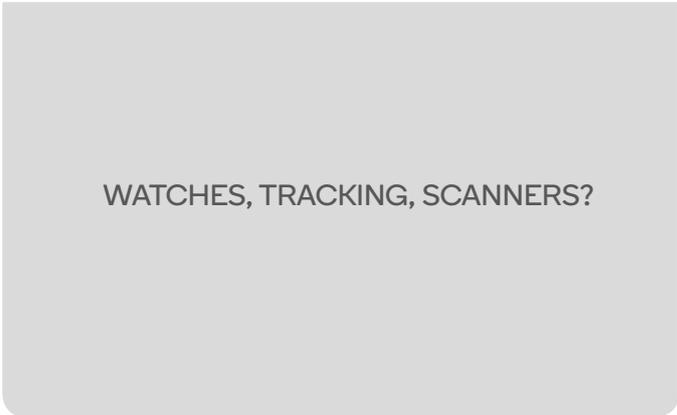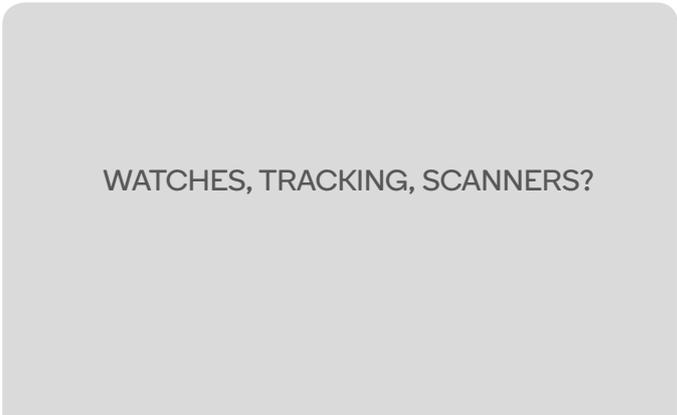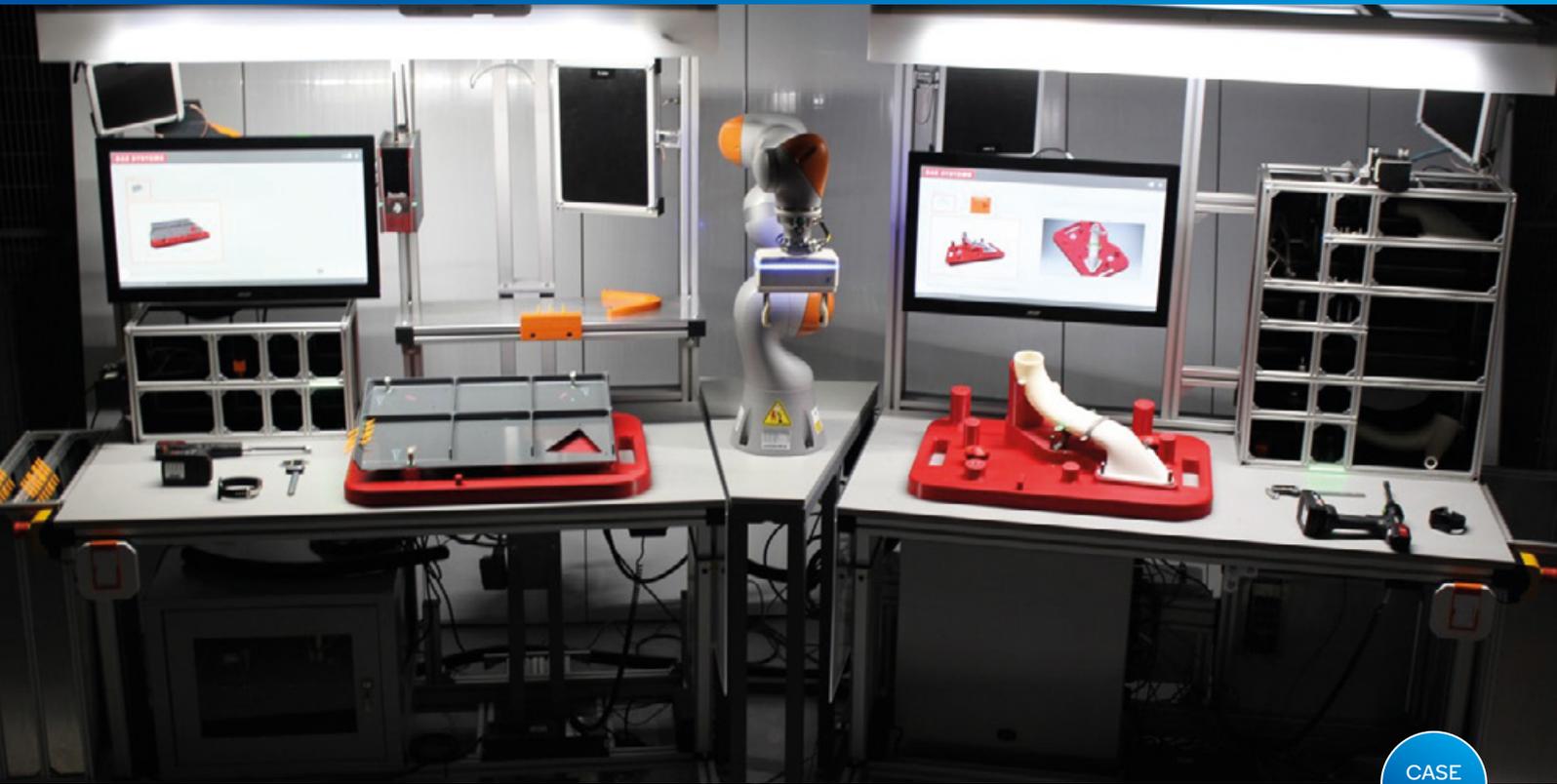
CASE STUDY

Digital Workflows

Digitisation of the process often provides a significant proportion of the value of AR. Digitisation of legacy workflows is often the first step towards more advances tools such as AR and wearable technology. The AMRC have extensive knowledge in both enterprise-ready and small-scale techniques for creating digital workflows. Prior studies have yielded significant impact in rate and quality during manual processes.

Our work in digital workflows includes both point-of-use mobile devices, such as tablets and mobile devices, and purpose built technologies. Our intelligent workbench research is based on creating a dedicated assembly station that has a primary focues of 'right first time' assembly, by leveraging tools for in-process validation and verification.

CASE STUDY

Control Systems and Programming

Control is an integral part of automation to ensure high quality and consistency in production, and therefore has a key presence in many, if not all IMG project work. IMG's specialist control engineers have experience with Siemens and Mitsubishi PLCs and their associated programming environments and languages, including Ladder Diagram, Structured Control Language and Function Block Diagram, as well as other programming languages such as C and C#, and the Microsoft .Net framework.

ANY OTHERS IMAGES?

ANY OTHERS IMAGES?

Developed Technologies

Through lessons learned in previous and current project work, IMG have developed extensive knowledge and exclusive experience in the following assembly processes and technologies through engaging with a variety of local, national and international partners, customers and suppliers:

- One-way build philosophy
- Composite lay-up
- Robotic drilling, countersinking and fastening
- Adhesive application and verification
- Robotic machining of metallics and composites
- Fully and semi-automated measurement
- Semi-automated assembly
- Use of external linear and rotary robotic axes
- Wireless technologies for industrial purposes
- Robotic accuracy improvement

- Robotic non-destructive testing
- Discrete event simulation
- Self-adaptive machining
- Robotic force control
- Pick and place
- Robotic deburring and finishing
- Digital work instructions
- Parallel kinematic machining
- iGPS
- Flexible and reconfigurable fixturing

IMG work on a wide range of industry-led research projects addressing current manufacturing challenges in the field of large-volume and complex assembly. IMG carry out a range of generic research projects on behalf of the AMRC's industrial members.

Recent projects include:

Robotic Calibration

Industrial robots produce results that are highly repeatable, but lack the accuracy required in most aerospace processes. IMG researchers are testing and developing calibration systems for robotic arms that will allow for relatively cheap 'plug-and-play' robots to undertake high-precision aerospace tasks.
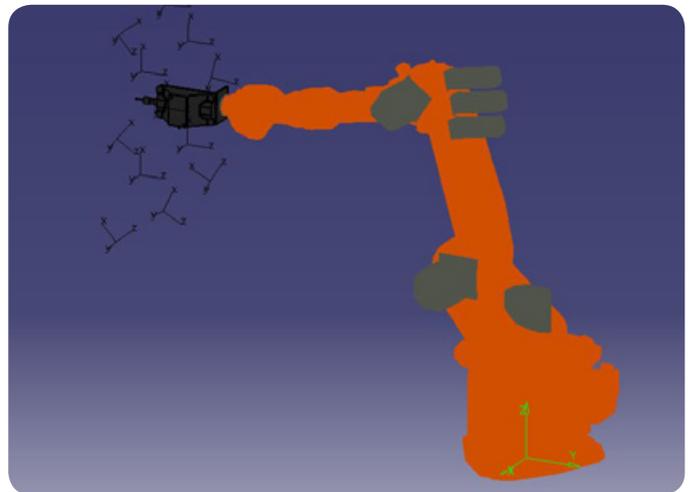
Robotic Machining

Significant improvements in recent years mean that robots can now be used for some machining tasks. IMG is currently working with leading high-end automotive manufacturers on several projects in this field.
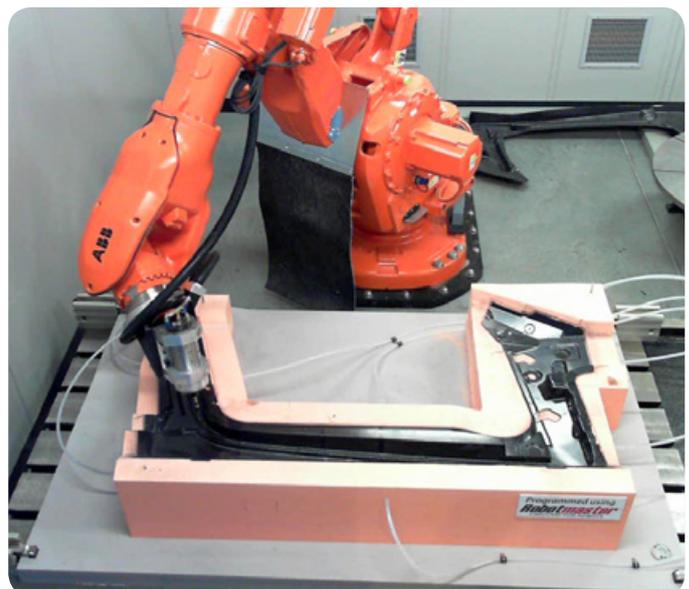
Robot Dynamics

IMG researchers have been investigating the dynamic stability of serial robot arms to help develop new techniques to counteract structural vibrations that cause 'chatter' when robots are used for machining.

These extensive studies have resulted in major insights into how the dynamic response of robotic structures can be improved.
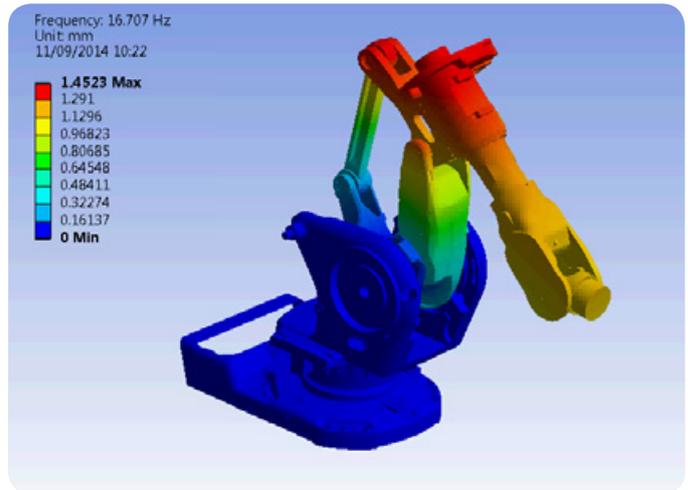
Human-Machine Interaction

IMG researchers have been assessing the suitability of revolutionary new ways for operators and automation to interact, which have emerged thanks to the impact of increased computing power on functionality and safety systems.
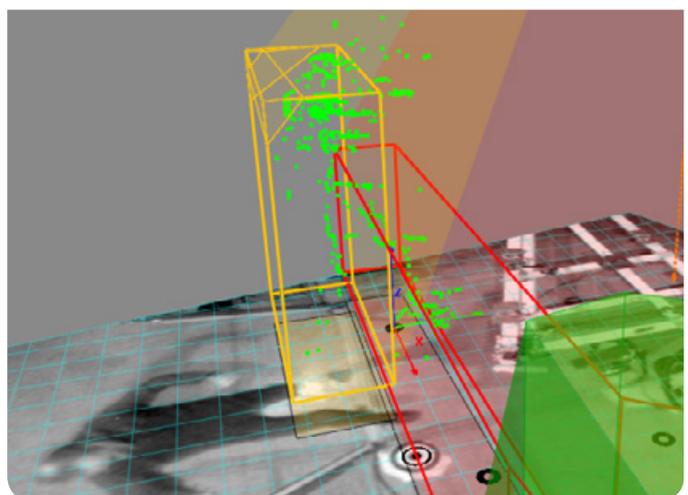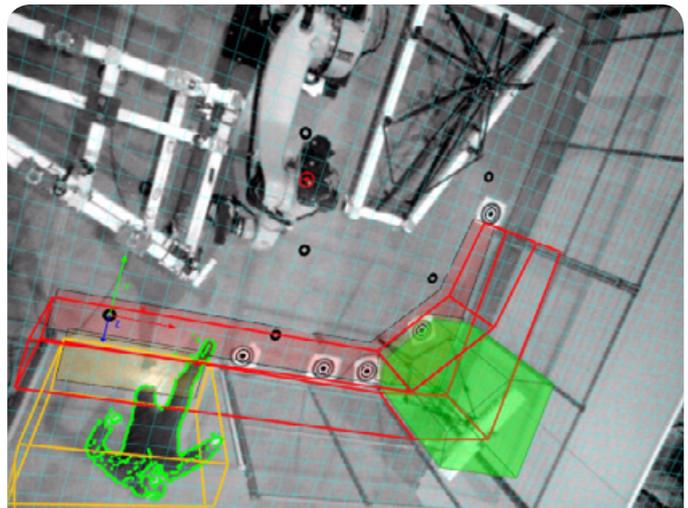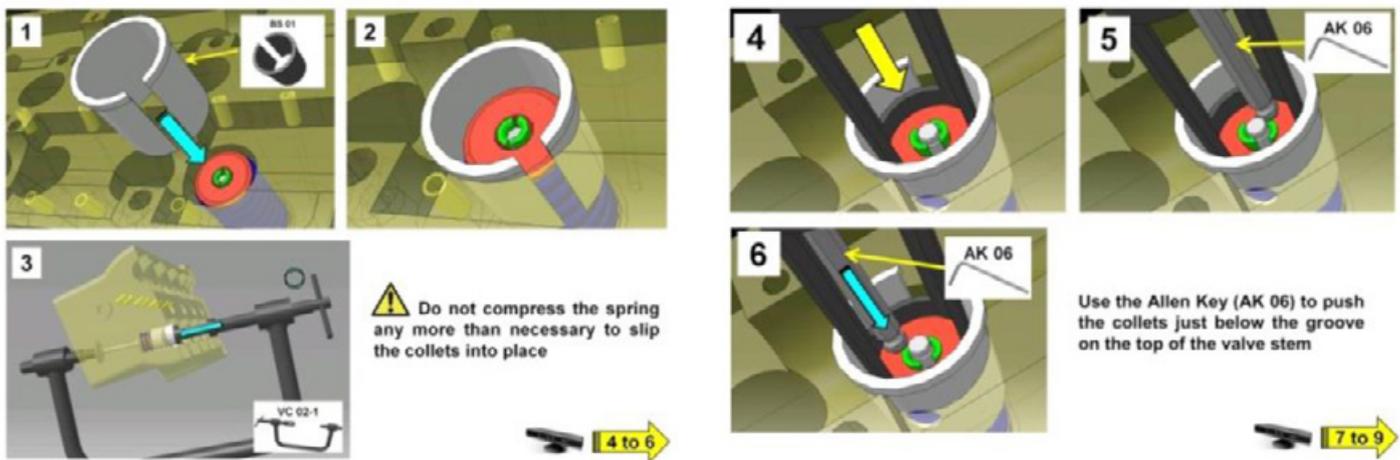
Augmented Reality Manual Assembly

IMG has developed an 'Augmented Reality' driven workbench to improve manual assembly performance where automation is not economically viable. This equipment enables operators to carry out complex assembly tasks with little or no training, and has the potential to be an incredibly useful knowledge capture tool.

Externally Funded Projects

IMG also work on a variety of externally funded collaborative projects alongside key industrial and academic partners. Recent and ongoing projects include Validation & Integration of Manufacturing Enablers for future Wing Structures (VIEWS), Future of the Aircraft Factory (FoAF) and Vehicle ARchitectures for CITY cars (VARCITY), a national programme led by Jaguar Cars with funding from the Innovate UK, which aims to develop technologies for a premium city car for the year 2020.

IMG have acquired an in-depth proficiency with a variety of software for design, offline programming, simulation and analysis for developed cells, systems and associated equipment, a few examples of which are described below.

This also demonstrates how quickly and well IMG engineers are capable of learning and using new supplier and equipment specific software for project related activities.

Catia

Dassault Systèmes' CATIA is IMG's most commonly used 3D CAD platform due to its specialist modules with features designed specifically for use in the aerospace and automotive industries. Individual fasteners to full aircraft assemblies can be modelled, analysed, and exported in a variety of file formats to other software packages for further manipulation, or simply for 2D or 3D drawings.
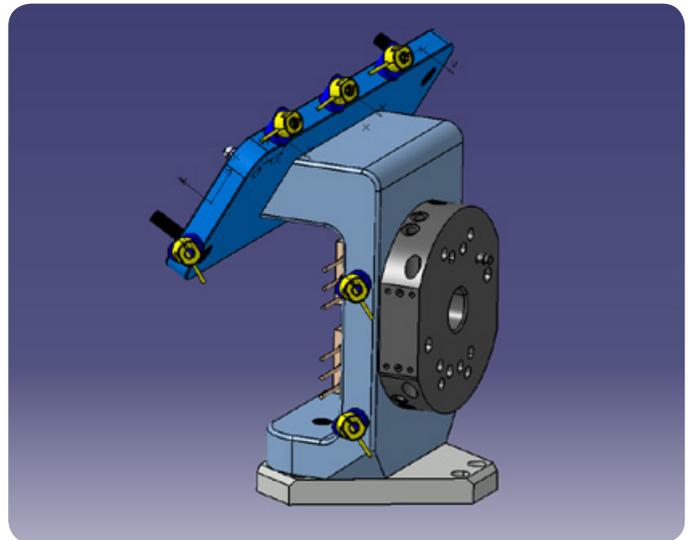
Delmia

Dassault Systèmes' DELMIA is a sister package to CATIA used for the simulation and visualisation of moving mechanical parts, robots and personnel within the manufacturing process. This allows for offline planning, fault-finding and optimisation before designs are completed for prototyping and manufacture.
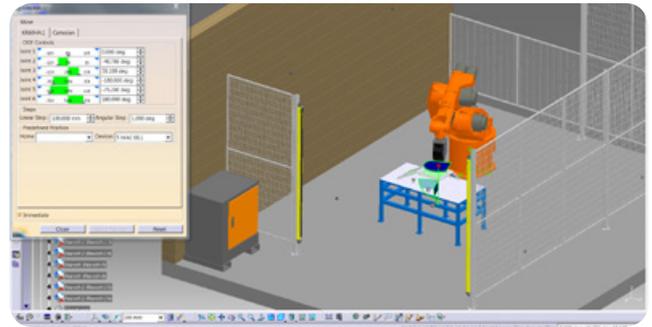
ABB RobotStudio

RobotStudio is an offline robot programming solution for ABB robots. Robotic movements and signals can be simulated, virtually tested and optimised, before being written in RAPID programming language and transferred directly to the robot controller or teach pendant via USB. This can provide numerous benefits including risk reduction, faster start-up, shorter change-over times and increased productivity when compared to manual ABB RAPID programming.
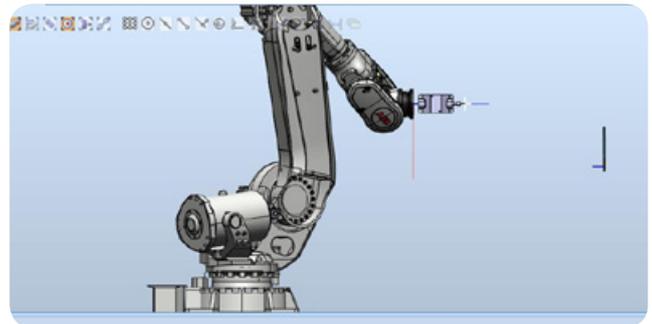
Delcam PowerSHAPE and PowerMILL Robot Interface

Delcam's PowerMILL software is commonly used in industry to produce CNC machining code, also known as G-code. This G-code can be converted via PowerMILL's Robot Interface into robot code for virtually any kind of industrial 6-axis robot. In this way, the specialist machining capabilities in Delcam can be transferred directly to robotic machining operations.
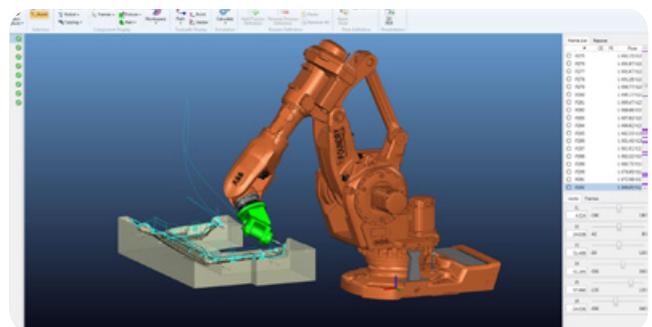
KUKA.Sim Pro

KUKA.Sim Pro is an offline robot programming solution for Kuka robots. Robot movements and outputs can be simulated and optimised before testing in virtual environment to obtain information such as cycle time including effects of physical constraints such as motors and brakes. With its library of components and support of a range of CAD formats KUKA.Sim Pro allows a process to be fully realised in simulation before deployment, reducing risk and start-up time compared to online programming.

Mastercam Robotmaster

Mastercam's Robotmaster is able to generate simulations and robot program code for Stäubli, Fanuc, ABB, Motoman and Kuka robots for a range of machining operations. The software's unique robot path optimisation tool allows the user to identify exactly how and why the robot path is unfit for purpose and how they wish to resolve this.

Siemens NX

NX for manufacturing provides a complete solution for part manufacturing from CAM to CNC controller. NX can improve manufacturing productivity by means of reductions in NC programming, machining time, higher quality parts and maximisation of resources.
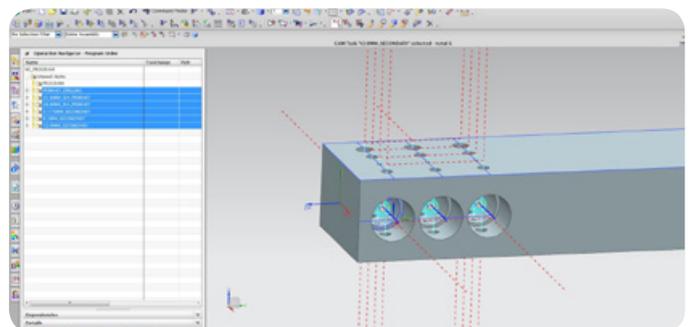
Spatial Analyser

Spatial Analyser by New River Kinematics is an open source, instrument independent and traceable 3D graphical data analysis software. SA has the ability to automatically record data and analyse against imported CAD models or shapes built in SA, reporting the findings in a user friendly format.
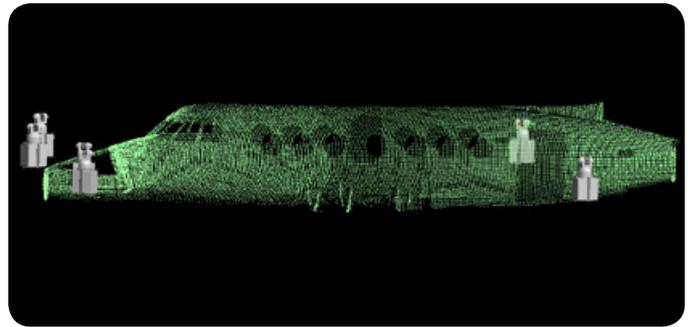
PolyWorks

PolyWorks is a comprehensive software solution that allows the extraction of CAD entities such as curves, surfaces, parametric sketches, and prismatic features from polygonal models of digitized parts to serve as the starting point in a professional CAD modelling solution. Polyworks is excellent at handing large data sets and point clouds, making it ideal for reverse engineering.
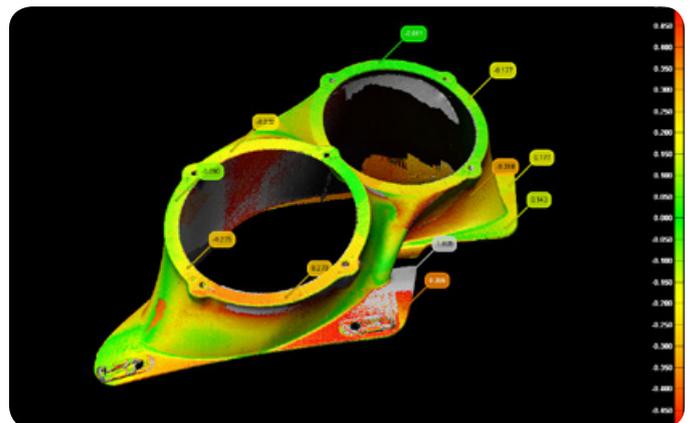
ANSYS Workbench

The ANSYS Workbench platform is a framework unifying the advanced engineering simulation suite of technologies from ANSYS. This allows complex multi-physics simulations such as robot-dynamics and machine-dynamics to be performed from CAD models, aiding the design and manufacturing process.
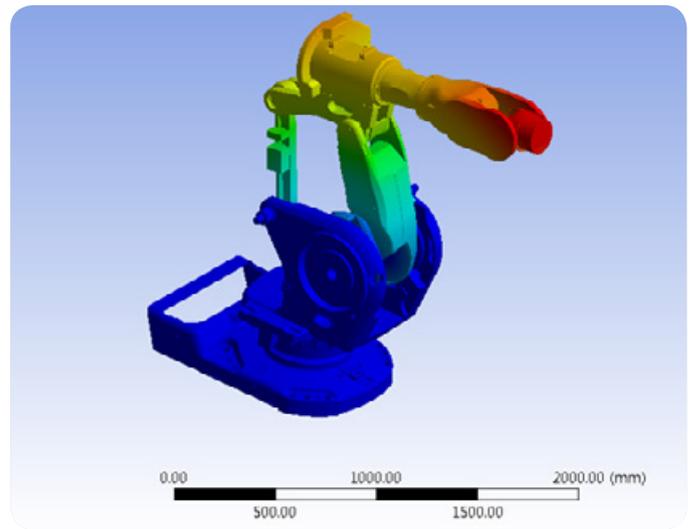
LabVIEW

LabVIEW is a graphical programming platform from National Instruments that aids the integration of hardware and software used in data acquisition, automation and instrument control.
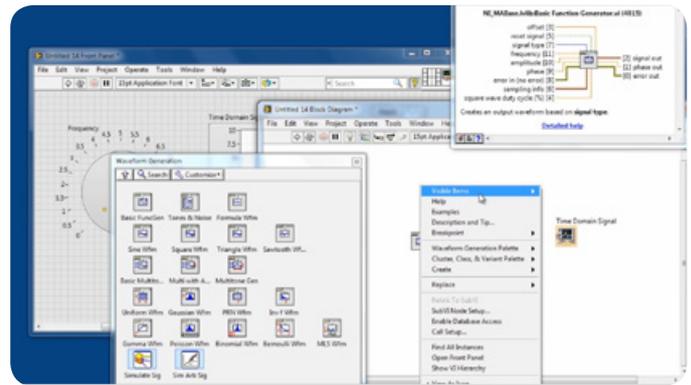
Siemens WinCC and TIA portal

The Seimens' WinCC in the Totally Integrated Automation (TIA) Portal will be part of a supervisory control and data acquisition (SCADA) system to be installed in Factory 2050, showcasing how data gathering technology might be used in a modern factory to monitor variables such as power consumption and temperature.
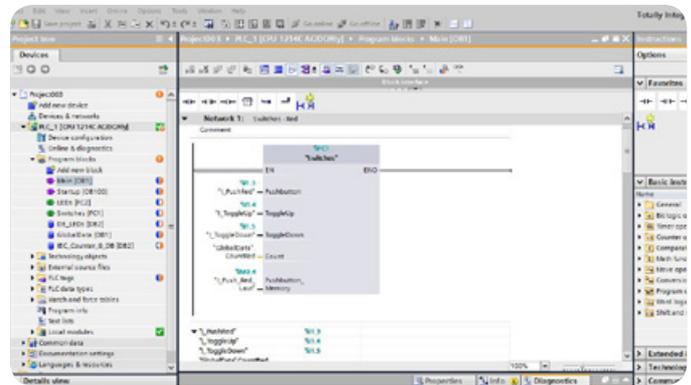
Witness

Lanner's Witness software is a discrete event simulation package that allows the impact of automation and layout on factory flow to be analysed.
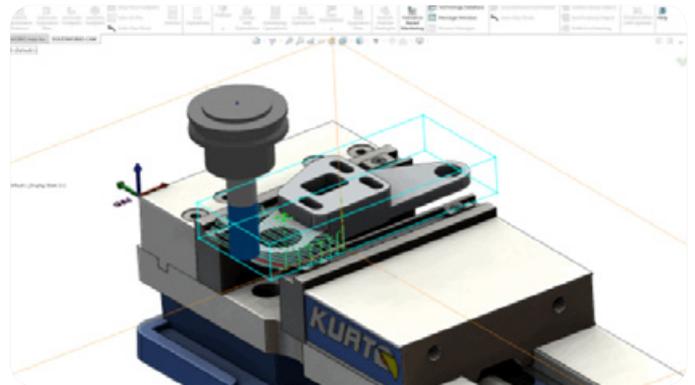
Autodesk Suite

Autodesk suite is a wide selection of 2D and 3D CAD and visualisation software packages, widely used across a range of industries including; construction, manufacturing, media and entertainment.

SolidWorks

SolidWorks is a 3D solid modelling (CAD) and (CAE) program published by Dassault Systèmes. It is widely used in the manufacturing and construction industries

Anylogic

Anylogic is a single platform dynamic simulation software package that incorporates discrete event, agent based and systems dynamics modelling. It includes its own industry specific libraries for a range of simulations including process modelling, fluid logistics, materials handling etc...
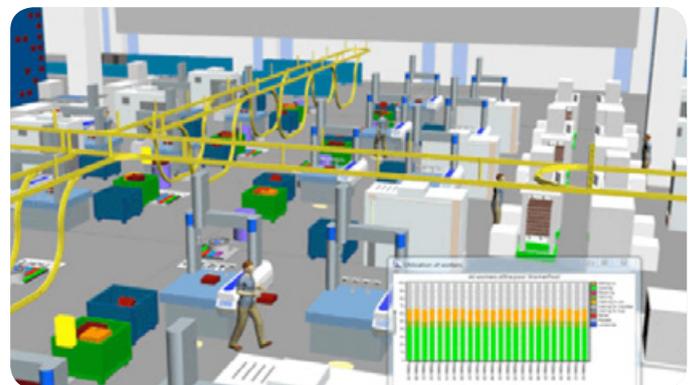
Plant Simulation

Siemens Tecnomatrix Plant Simulation software enables the creation of digital models of logistic systems (such as production), allowing you to run experiments and what-if scenarios without disturbing existing production systems

ABB 120

The ABB 120 is a small multipurpose robot weighing just 25 kg but is capable of handling a payload of up to 3 kg. The ABB 120 is adept for rapid pick and place under an industry leading repeatability of 0.01 mm, whilst being extremely flexible it is also highly agile. IMG have two of these robots and because of their relatively light weight, they are used at shows and exhibitions to demonstrate the latest IMG projects.

Payload	3 kg
Max. reach	580 mm
Number of axes	6
Repeatability	0.01 mm
Weight	25 kg
Mounting positions	Floor, ceiling
Controller	IRC5

ABB IRB 4600

The IRB 4600 is a 6-axis serial arm capable of manipulating payloads up to 60 kg. Due to its low weight and compact design the IRB 4600 has fast acceleration and a high top speed, making it well suited to tasks such as material handling, welding or cutting.

Payload	3 kg
Supplementary payload	20 kg
Max. reach	2060 mm
Repeatability	±0.06 mm
Weight	435 kg
Mounting positions	Floor, ceiling
Controller	IRC5

ABB IRB 6700 with integrated MID 500 turntable

The IRB 6700 is a heavy duty 6-axis robot capable of handling payloads of up to 235 kg. In Factory 2050 this will be integrated with a MID 500 turntable capable of payloads up to 1300 kg, allowing the robot to perform machining operations on large components several metres cubed in volume.

Payload (arm)	235 kg
Supplementary payload (arm)	50 kg
Payload (turntable)	1300 kg
Max. reach	2650 mm
Repeatability	±0.05 mm
Mounting positions	Floor
Controller	IRC5
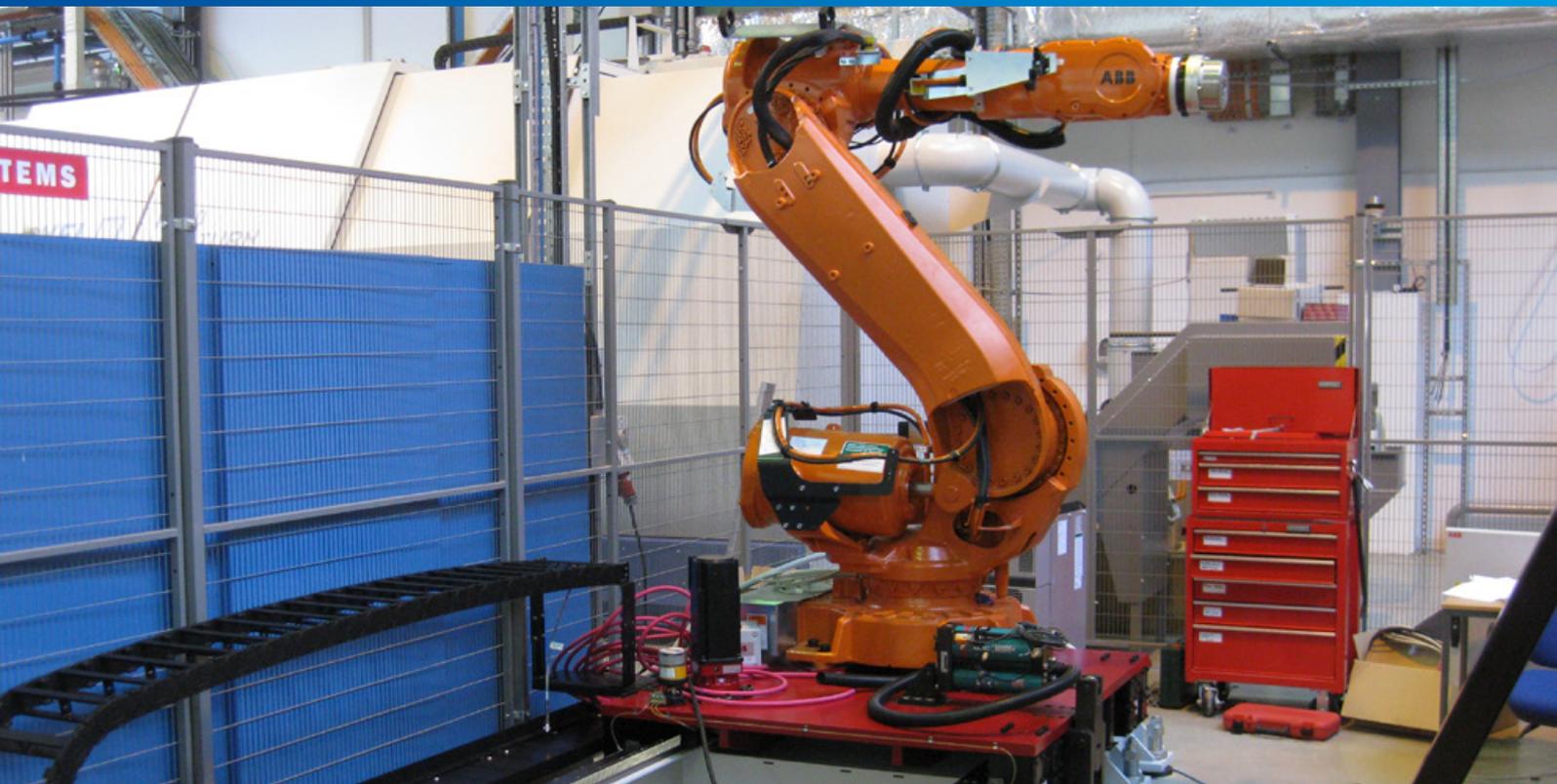
ABB IRB 6640

The IRB 6640 is a high production capacity robot, with a payload of up to 235 kg, making it suitable for heavy load applications. IMG has two of these robots. The first is used as a general workhorse for machining metal and for work piece inspection. The second 6640 is mounted on a Gudel linear rail giving it an impressive working volume, whilst not decreasing its dynamic stiffness. It is currently used for gluing trials and can be fitted with either a Viscotec or Dopag adhesive dispensing system. Additionally the robot can be re-fitted with a Leica T Scan 5 for work piece inspection.

Payload	235 kg
Max. reach	2550 mm
Number of axes	6
Repeatability	0.07 mm
Weight	1310-1405 kg
Mounting positions	Floor
Controller	IRC5
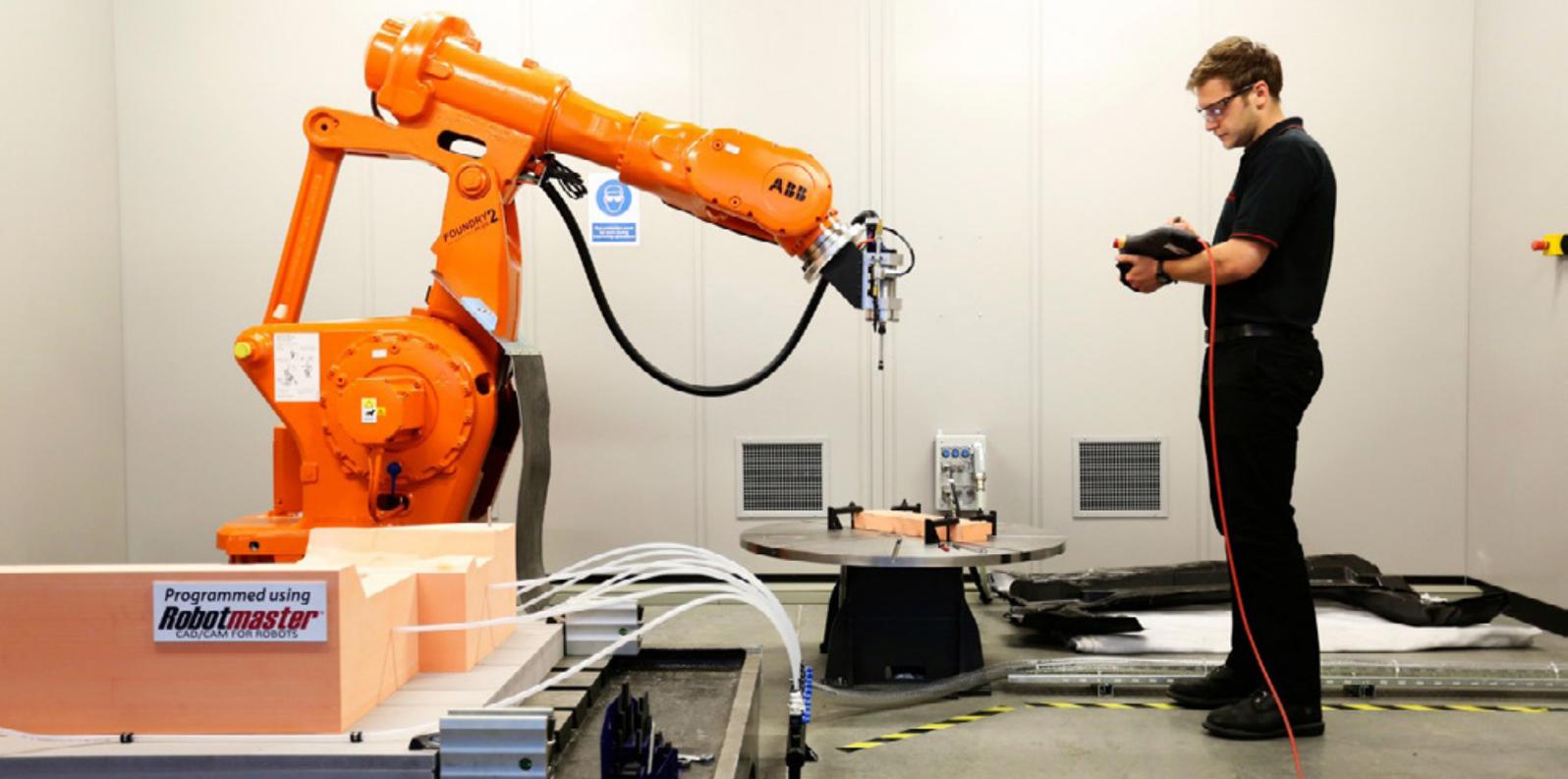
ABB IRB 6660

The IRB 6660 is the first dedicated robot for pre-machining applications in the foundry industry. The design for the 6660 was optimised for high-performance industries such as finishing, and pre-machining such as milling, grinding, cutting and sawing. The cell was primarily set up as a low-cost alternative to a conventional 5 axis gantry CNC machine tool. The symmetrical robot provides more rigidity compared to standard robots with similar specifications. The cell has the additional capabilities of a rotary table and particulate extraction.

Payload	205 kg
Max. reach	3100 mm
Number of axes	6
Repeatability	0.07 – 0.11 mm
Weight	1730 kg
Mounting positions	Floor
Controller	IRC5

KUKA KR 16-2

The KR 16-2 is a versatile and flexible 6-axis robot suitable for a range of manufacturing environments. The KR 16-2 can be used for handling, loading, welding, forming machine tools and palletizing. IMG found this robot invaluable for positioning the GOM scanner, the laser shearography system and for other metrology based projects.

Payload	16 kg
Supplementary payload	10 kg
Max. reach	1610 mm
Number of axes	6
Repeatability	<±0.05 mm
Weight	235 kg
Mounting positions	Floor, ceiling
Controller	KR C4
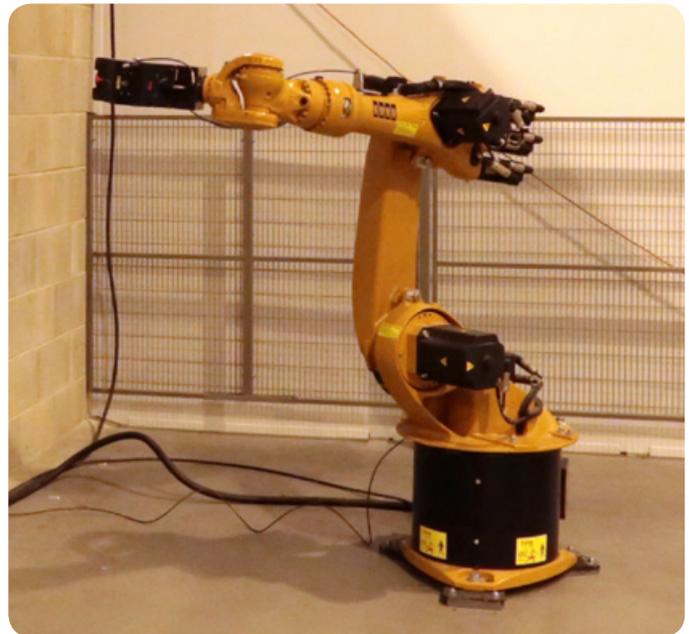
KUKA KR 60 HA

The KR 60 HA is a 6-axis robot specifically designed for high-accuracy applications such as laser cutting, welding and machining. Due to its increased rigidity the KR 60 HA can repeatedly position a 60 kg payload to within 0.05 mm and will be used to investigate the accuracy of off-the-shelf robots with open-loop position control.

Payload	60 kg
Supplementary payload	35 kg
Max. reach	2033 mm
Number of axes	6
Repeatability	<±0.05 mm
Weight	665 kg
Mounting positions	Floor, ceiling
Controller	KR C4

KUKA KR 240 R2900 ultra (x2)

The KR 240 R2900 is the highest power-density currently available on the market in this range, handling payloads of up to 240 kg with a reach of 2.9 m. Two of these class-leading robots will be installed in Factory 2050.

Payload	240 kg
Supplementary payload	50 kg
Max. reach	2896 mm
Repeatability	±0.06 mm
Weight	1145 kg
Mounting positions	Floor, ceiling
Controller	KR C4
Protection class	IP 65

KUKA KR 1000 Titan LR750

The KR 1000 Titan LR750 is a heavy-duty 6-axis robot capable of bridging distances of up 7.5 m and handling payloads of up to 750 kg. The Titan has the greatest lifting capacity of all robots in Factory 2050 and is used as part of the Accurate Robotic Machining System A.R.M.S. built as collaboration with the AMRC, ElectroImpact, Siemens, Renishaw and funded by Innovate UK. ElectoImpact's 'Accurate Robot' upgrade. replaces the system KRC4 controller with a Siemens 840D controller, increasing its processing power. On each joint, the external linear encoders have been fitted in order to measure the exact rotation joint eliminating errors due to backlash and deflections.

The unloaded positional accuracy of the system is currently 0.1mm in 3DoF across its entire working volume. The system has the capabilities to machine most metallic materials including titanium. In addition to the machining capabilities, A.R.M.S. also has a robotic drill clamp foot to enable high accuracy drilling.

Payload	750 kg
Supplementary payload	50 kg
Max. reach	3601 mm
Number of axes	6
Repeatability	<±0.1 mm
Weight	4750 kg
Mounting positions	Floor
Controller	KR C4

KUKA KR 270

The KR 270 was the highest power-density 6-axis robot available on the market within the high payload range. Whilst having similar form and spatial requirements to other KUKA robots of the same class, the KR 270 gives maximum power. This robot is integrated into a cell that has three Stäubli tool changers and a KUKA seventh axis.

Payload	270 kg
Supplementary payload	50 kg
Max. reach	2700 mm
Number of axes	6
Repeatability	<±0.06 mm
Weight	1412 kg
Mounting positions	Floor, ceiling
Controller	KR C4
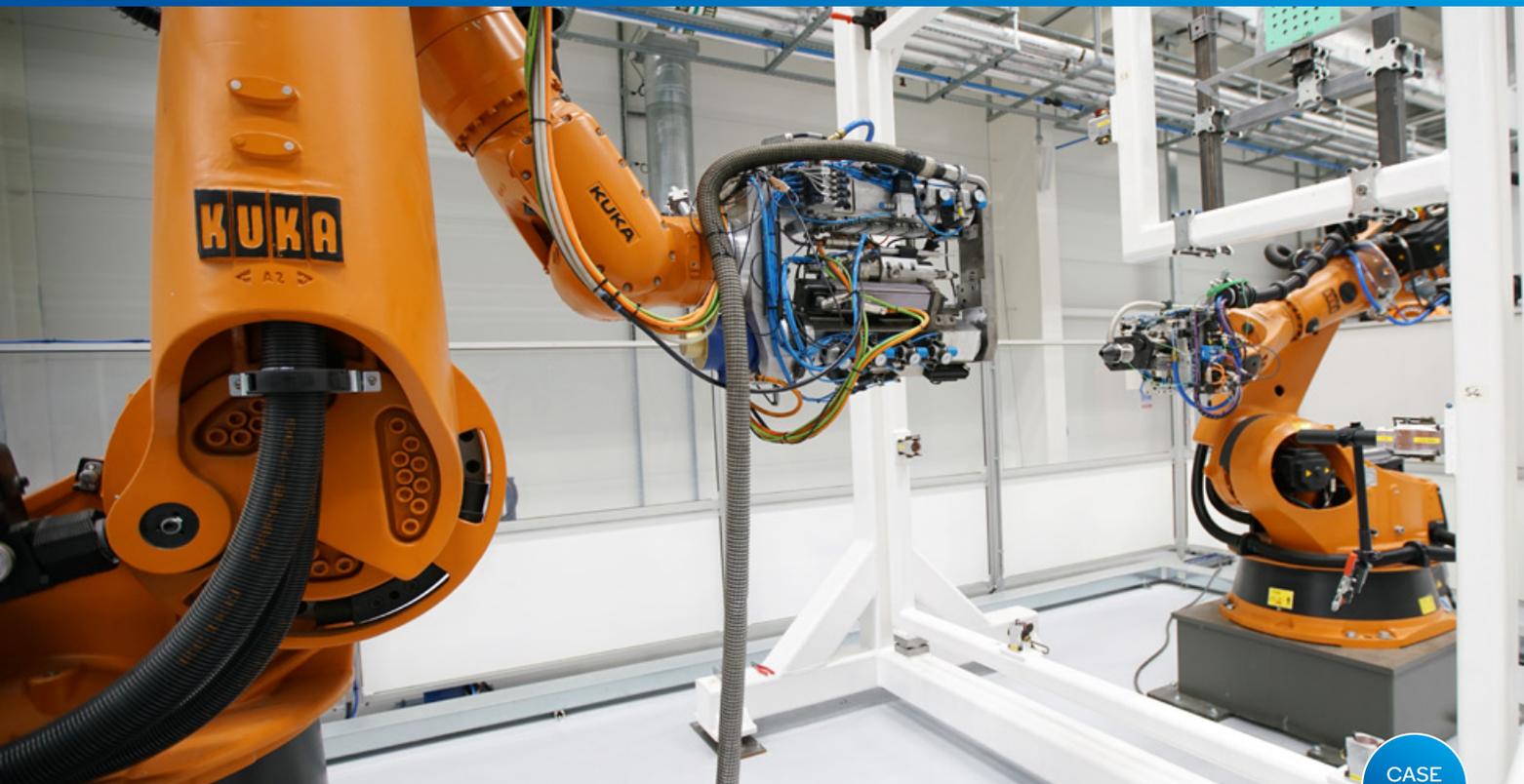
CASE STUDY

KUKA KR 360 and KR180-2

The KR 360 is a heavy-duty 6-axis robot offering a large working envelope and reach. Capable of handling loads of up to 360 kg with a repeatability of ±0.08 mm, the KR 360 is typically used for a wide range of applications, from welding to painting, assembly to machine operations. This robot is used at the AMRC to position a large drilling and countersinking end effector. The robot has been integrated with various vision and metrology systems to ascertain how accurately the end effector can be placed.

The KR 180-2 is a robust 6-axis robot designed for use in palletising operations. Utilising high performance gears, the KR 180-2 is capable of up 27 cycles per minute. It is designed for use in a small environment and has a narrow base frame and small footprint. This robot has been used at the AMRC as a slave robot on the drilling and countersinking rig.

KUKA KR 360

Payload	360 kg
Supplementary payload	50 kg
Max. reach	2826 mm
Number of axes	6
Repeatability	±0.08 mm
Weight	2385 kg
Mounting positions	Floor, ceiling
Controller	KR C4
Protection class	IP 65

KUKA KR 180-2

Payload	180 kg
Supplementary payload	50 kg
Max. reach	2700 mm
Number of axes	6
Repeatability	±0.06 mm
Weight	1267 kg
Mounting positions	Floor
Controller	KR C2 Edition 2005

Mitsubishi Melfa Robot RV-3SB

The RV-3SB is a high-speed, high-precision robot. It has a slim profile with a compact body, designed for integration into existing cells. This robot has been used on a variety of projects, including being mounted on the Güdel FP-1 gantry to create a redundant manipulator, providing a simulation of a snake arm robot.

Payload	3 kg
Max. reach	642 mm
Number of axes	6
Repeatability	0.01 mm
Weight	37 kg
Mounting positions	Floor, ceiling
Controller	CR1B-571

Mini Exechon – Robot Machining Platform

The mini-exechon is a fully mobile robot arm. The unit has been designed such that it can be modulated into manageable loads. Many of the major structural components such as the actuators, gimbals and housings can be disassembled to allow the machine to be easily transported to allow for operations such as in-field repair machining. The components are constructed from the latest carbon-fiber technology, which drastically reduces the weight whilst providing the stiffness required. The system is a lightweight Parallel Kinematic Machine P.K.M.. MiniX utilises the increased rigidity which comes with P.K.M. whilst retaining some of the flexibilities conventional robots have.

Total Weight	250 kg
Cube Volume	1200 mm x 1200 mm x 1200 mm

CASE STUDY

Flexpicker:
ABB – IRB360-6/1600

A four axis parallel robot capable of the fastest picking applications and specifically optimized for picking and placing applications. The robot is equipped with the IRC5 controller and robot control software, RobotWare. The IRB 360 is extremely powerful with an acceleration of up to10g's, and a handling capactity of up to 8kg. This results in a system which is capable of achieving 200 picks per minute (defined by cycle and load).

Payload	6 kg
Diameter	1600 mm
Position Repeatability	0.1 mm
Weight	145 kg
Robot Mounting	Inverted

Güdel FP-4

The FP-4 is a portal type gantry system allowing for use in a diverse range of heavy industries such as logistics, automotive and aerospace. Utilising a rack and pinion drive, the gantry is suited for applications which require large work areas while maintaining a high degree of accuracy. The gantry has a repeatability of 0.05mm for loads 100kg and up to 160kg in high load mode.

Axis	x	y	z
Payload [N]	1000	1000	1000
Speed [m min-1]	112,5	112,5	67,5
Acceleration [ms-2]	1,5	4	2,5
Gearbox ratio	6	6	10
Size of GÜDEL gearbox type AE	090	060	060
Stroke of axis per motor revolution [mm]	25	25	25
Acceleration time [s]	1,25	0,469	0,45
Stroke of axis while accelerating [m]	1,172	0,439	0,253
Motor speed [min-1]	4500	4500	4500
Stall torque of motor [Nm]	1,8	1	4,5
Max. torque of motor [Nm]	9	5,3	5,6

KUKA youBot (x2)

The KUKA youBot is a 5-axis serial robot arm and gripper which can be mounted on an omnidirectional (omniMove) platform. The KUKA youBots will be used in Factory 2050 for research, training and demonstration of cooperative mobile robotics.

Manipulator

Height	655 mm
Working envelope	0.513 m^3
Weight	5.8 kg
Payload	0.5 kg
Repeatability	0.1 mm

OmniMove platform

Length	580 mm
Width	376 mm
Height	140 mm
Payload	20 kg
Repeatability	0.8 mm

Baxter Research Robot

The Baxter research robot is a twin-armed robot designed to work safely with humans. The robot has two 7-axis arms with compliant joints making it ideal for handling small payloads and working in cooperation with humans, performing tasks such as passing tools or components.

Baxter will be used in Factory 2050 to investigate and demonstrate how collaborative human-robot interaction could be used in manufacturing.

Height (on pedestal)	1.77 – 1.90 m

KUKA omniRob

The omniRob uses omnidirectional drive allowing it to manoeuvre payloads up to 360 kg in tight spaces. Using laser scanners mounted on the vehicle and sensors on the wheels, the KUKA omniRob will be able to navigate autonomously around Factory 2050, creating a map of its surroundings using the simultaneous localisation and mapping (SLAM) method.

Dimensions	1.2 x 0.75 x 0.7 m
Weight	360 kg
Payload	400 kg
Positioning accuracy	±2 mm

KUKA omniMove UTV-2 E575 15000

The omniMove UTV-2 (universal transport vehicle) E575 15000 is a second, larger autonomous vehicle for Factory 2050. It uses an omnidirectional drive to allow it move sideways, diagonally, or to rotate on the spot, to deliver payloads of up to 15,000 kg to within a few millimetres under remote control by an operator.

Dimensions	4.2 x 1.7 x 0.65 m
Weight	7,500 kg
Payload	15,000 kg
Positioning accuracy	± 5 mm or ± 2 mm with optical guidance

MiR 200 AGVs

The MiR200 can autonomously manoeuvre payloads of up to 200Kg around its working environment, with the aid of a map it generates using the simultaneous localisation and mapping (SLAM) method. Using SICK S300 laser scanners, a 3D depth scanner and upward facing cameras the vehicle is able to navigate around the Factory 2050 workshop. With the addition of the fleet software our two MR200s can operate safely and efficiently together conduct autonomous logistical and inspection activities.

Dimensions	0.89 x 0.58 x 0.35 m
Weight	67 kg
Payload	200 kg
Positioning accuracy	± 50mm or ± 10mm with optical guidance
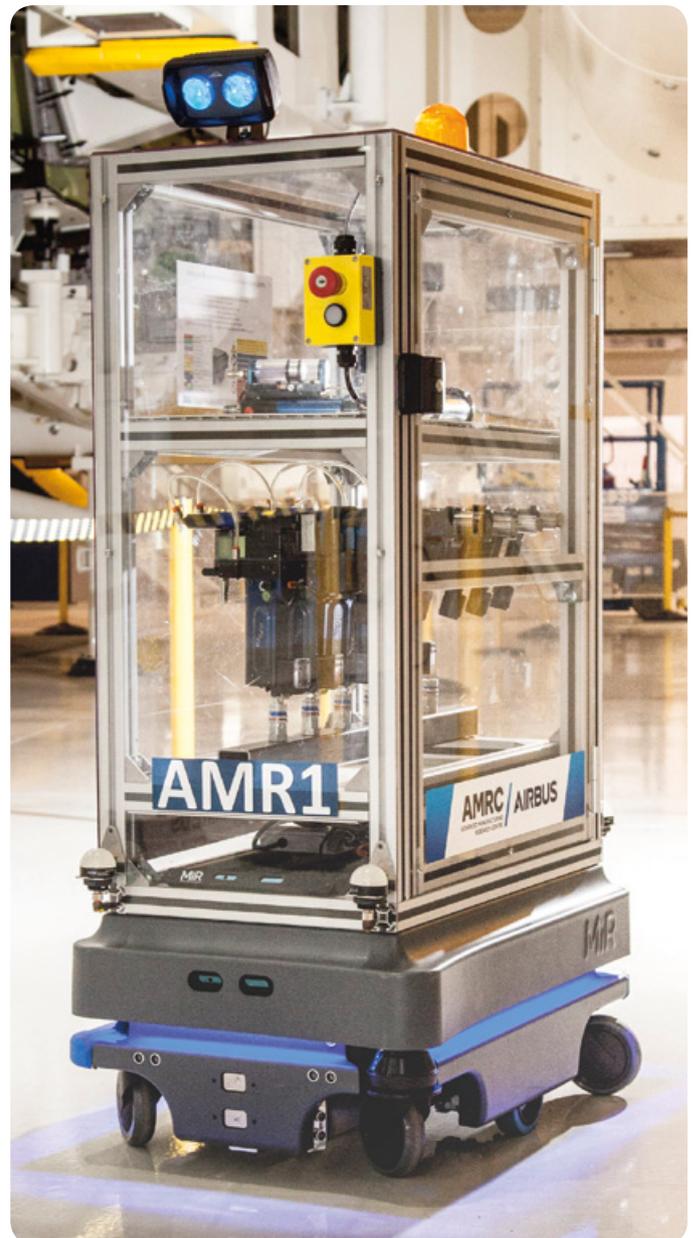
Smart Tools

Smart tools are integral to the Factory 4.0 concepts of digital guidance and build verification. Smart tools can easily be added into existing processes allowing for automatic tool setting for each assembly stage. Automated setting aims to reduce operator error and acts as a guide for unfamiliar assembly processes. Smart tools can also be integrated into smart benches and used alongside smart working instructions reducing non-conformity and aiding traceability. In addition the feedback and validation of the forces/torques applied during each stage provides vital accountability data for safety critical assembly.

Any images of specific tools or are we keeping it as a generic overview?

Kuka iiwa

The world's first series-produced sensitive, and therefore HRC-compatible, robot. Fitted with joint torque sensors the iiwa can detect immediately and reduce its levels of force and speed instantly. Its position and compliance control enables it to handle delicate components without creating crushing and shearing hazards.

Payload	14 kg
Maximum Reach	820 mm
Position repeatability	± 0.15 mm
Weight	30 kg
Protection Class	IP 54

Universal UR10

The UR10 collaborative robot is currently the largest industrial robotic arm developed by Universal, with a payload of up to 10kg. The collaborative industrial robot is easy to program, offering fast set-up times with on average taking half a day to get up and running. With the set-up for an untrained operator to unpack the Cobot, mount it, and program the first simple task being typically less than an hour.

Payload	10 kg
Maximum Reach	1300 mm
Position Repeatability	± 0.1 mm
Weight	30 kg
Protection Class	IP 54
Footprint	Ø 190 mm
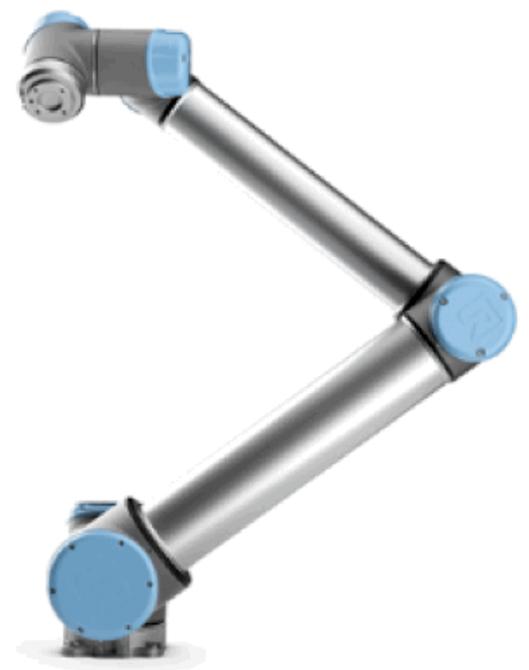
Fanuc CR35IA

Boasting a payload of 35kg it makes it currently the world's strongest collaborative robot, the combined reach and payload certification make it ideally suited to a whole range of manual process that typically teams of workers would have to complete together without risk of injury.

Payload	35 kg
Maximum Reach	1813 mm
Position repeatability	± 0.03 mm
Weight	990 kg
Protection Class	IP 54

BoxJoint

BoxJoint is a fixturing solution allowing for the joining of standard box sections beams without the need for welding. Using nuts, bolts and laser cut plates, the beams are joined together through a rigid friction joint and can be used for a wide range of materials, such as steel, aluminium, fibre glass and carbon fibre. The joints come in a variety of sizes, allowing various applications from tool holding to fixturing for aerostructures.

Schunk Fixturing

IMG employ a wide range of Schunk fixturing in machining cells, including:

- Rota-S Plus 160 stationary clamping chuck, with replaceable hard and soft jaws
- Rota-S Plus 400 stationary clamping chuck, with replaceable hard and soft jaws
- KSM 90-650 multiple clamping systems, with replaceable stationary and adjustable jaws
- Kontec KSK 5A 100 5-axis self-centring vice, with replaceable clamping jaws
- Kontec KSE wedge clamping elements
- SPK 180 jaw boxes, including replaceable hard jaws

Leica AT402

The Leica Absolute Tracker AT402 is a portable CMM for large volume inspection and measurement. The tracker records the absolute distance to reflectors placed on the test object by time of flight which can then be compared to nominal CAD models. The AT402 tracker can be remotely controlled wirelessly over LAN or by IR remote control which, coupled with the large measurement volume, allows very large objects to be quickly scanned without the need to reposition the tracker.

Typical Volume	120 m
Horizontal	360°
Vertical	± 145°
Angular Resolution	0.07 arc sec
Angular Repeatability	± 7.5 μm +3 μm/m
Angle Accuracy	± 15 μm +6 μm/m
Distance Resolution	± 5 μm
Distance Accuracy	± 10 μm
Sensor size	258/225/477 mm
Sensor weight	7.3 kg
Controller Size	250/112/63 mm
Controller Weight	0.84 kg
Temperature Range	-25 to +70°C
Relative Humidity	Max 95% non-condensing
Elevation	-700 to 5500 m

Leica Absolute Tracker AT960

The AT960 laser tracker is a portable CMM which allows accurate large volume tracking and inspection across large distances. The AT960 can be paired with various T-products to give hand-held wireless probing (Leica T-Probe), hand-held contactless scanning (Leica T-Scan), and full machine control abilities (Leica T-Mac). This allows the tracking of moving objects and the collection of large quantities of high-quality data from any material, without struggling with shiny or dark surfaces.

Typical Volume	120 m
Typical Volume with other T-products	30 m
Horizontal	360°
Vertical	± 145°
Angular Resolution	0.07 arc sec
Angular Repeatability	± 7.5 µm +3 µm/m
Angle accuracy	± 15 µm +6 µm/m
Sensor size	258/225/477 mm
Sensor weight	13.8 kg
Controller Size	249/148/59 mm
Controller Weight	1.65 kg (approx)
Temperature Range	-25 to +40°C
Relative Humidity	Max 95% non-condensing
Elevation	<3500 m

White light scanner

The Hexagon Metrology WLS400 is a manually operated white light scanner used for non-contact 3D metrology, quality inspection and digitisation. The high-intensity blue LEDs project a random pattern onto the part which is simultaneously recorded on three cameras. This pattern is analysed to reconstruct the object surface, yielding high density point clouds which can be compared against CAD or used in reverse engineering.

Probing error	25 μm
Spacing error	25 μm
Flatness error	20 μm
Plane measurement accuracy (single tile)w	25 μm
Point cloud accuracy (3x2x1 m object)	0.1 mm
Planar hole centres accuracy (3x2x1 m object)	0.15 mm
Exposure time (typical)	10 ms

ROMER Absolute Arm RA7525SE

The RA7525SE is a portable 7-axis CMM which can be equipped with a HP-L-20.8 Laser Scanner for rapid point cloud capture for inspection and reverse engineering.

Arm

Measuring range	2.5 m
Probing point repeatability	27 μm
Probing volumetric accuracy	±38 μm
Arm weight	8.5 kg
Working temperature	0 to 50 °C
Relative humidity	10 to 90 % non-condensing

Laser Scanner

Data rate	Max. 150,000 points per second
Minimum point spacing	13 μm
Probing form error	9 μm
Probing dispersion value	36 μm

Renishaw RMP600 and RMP40
Machine Probes and Measurement Tips

The RMP600 is a compact, high accuracy touch probe with radio signal transmission, offering all the benefits of automated job set-up, plus the ability to measure complex 3D part geometries on all sizes of machining centres including 5-axis machines.

The RMP600 combines patented RENGAGE™ strain gauge technology with a unique frequency hopping radio transmission system that operates over a range of up to 15 m. The RMP600 is the most

flexible, high precision machine tool radio probe in the world, and unlike other conventional probes, increased stylus lengths can be supported with no significant decrease in overall probe performance.

Whilst the RMP600 is suitable for medium to large machining centres and mill-turn centres, the RMP40 is an ultra-compact version, suitable for machines with small HSK and taper spindles.

Principal application	Workpiece inspection and job set-up on multi-tasking machines, machining centres and gantry machining centres.
Transmission type	Frequency hopping spread spectrum (FHSS) radio Radio frequency 2,400 MHz to 2,483.5 MHz.
Operating range	Up to 15 m
Recommended styli	High modulus carbon fibre, lengths 50 to 200 mm
Weight without shank	(including batteries) 1,010 g
Sense directions	±X, ±Y, +Z
2D lobing in X, Y	±0.25 µm with 50 mm stylus length ±0.25 µm with 100 mm stylus length
3D lobing in X, Y, Z	±1.00 µm with 50 mm stylus length ±1.75 µm with 100 mm stylus length
Stylus trigger force XY plane (typical minimum) +Z direction (typical minimum)	0.20 N 1.90 N
Stylus overtravel force XY plane (typical minimum) +Z direction (typical minimum)	2.80 N 9.80 N
Minimum probing speed	3 mm/min with auto-reset
Sealing	IPX8 (EN/IEC 60529)
Operating temperature	+5 to +50 °C

Omega Compression Load Cells

LCM401-50 and LCM401-100 Compression Load Cells are used for the measurement of applied forces in compression in one direction, for both metrology and control feedback purposes. Operating force ranges are 0-50 kg force and 0-100 kg force respectively.

V-STARS D5 System

The V-STARS D5 gives high-speed, real-time 3D measurement from multi-camera configuration comprising of two DynaMo D5 cameras. The system is well suited to be fixed within a measurement cell configuration for extended periods of time. Thus the system is well suited to high-speed dynamic monitoring of object movement and deformation, as well as to repeat inspection within an assembly line environment.

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Measurement Rate	3Hz – 10Hz
Accuracy	±14 µm
Camera Resolution	5Mp
Shutter Time	30 µs
Shutter Life	Unlimited

ADDITIONAL PROJECTOR

ADDITIONAL PROJECTOR
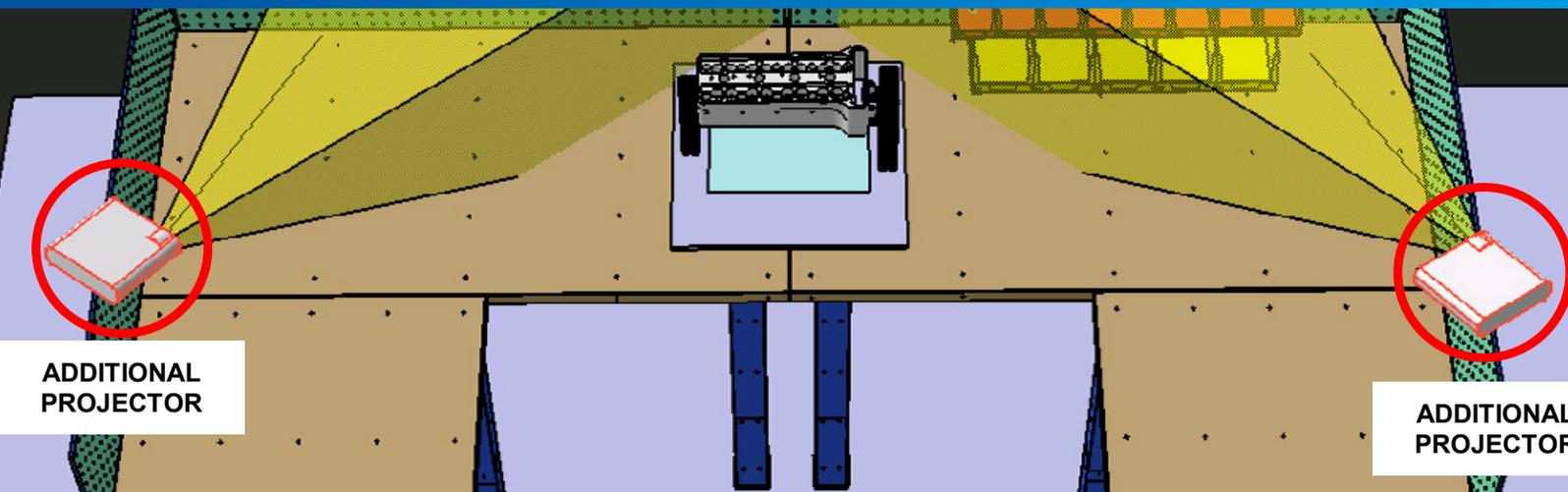
Intelligent Workbench system

The Intelligent Workbench is an IMG technology demonstrator designed to emphasise the benefits of the digitally assisted assembly methodology. Typically the system comprises of multiple projectors for locational instructions, touch screen digital instruction displays, light indicators, smart fixturing and smart tools. The integration of digital measurement equipment also allows for inline validation and traceability.

The systems are aimed at high value low volume assembly of complex components. They provide centrally managed, reconfigurable, step-by-step, digital aided, assembly and validation that can be conducted by operators with varying skill levels.

Customisable operator profiles allow for tailored work instructions that vary in detail depending on the operator's prior experience, therefore ensuring the most efficient assembly cycles. The addition of smart fixturing and cobots also enable complex tasks that can often require two or more operators, to be completed by a single operator.

Smart Fixture with integral sensors and weigh scales

Laser projector and vision system


Kitting tray

Smart Tools

LPT 10 Laser Projector

The LPT 10 is a cost-effective and long-range light templating system. This targetless laser projector makes it possible to assist the assembly of parts by using CAD models and LPT's RayTracer software suite, to project 3D optical templates directly onto any work surface.

The system delivers a working range of 0.61 m to 12.19 m enabling a large working range with flexibility of positioning of the projectors.

Power Input	110/240 Vac 50/60 Hz
Laser Power	< 5 mW
Laser Class	3R
Laser Wavelength	532 nm (green)
Projection Distance	0.61 m to 12.19 m
Dynamic Projection Accuracy	0.25 mm
Line Width	0.5 mm
Projector Weight	25.78 kg
Projector Size (L x W x H)	717.5 mm x 404.4 mm x 174.75 mm
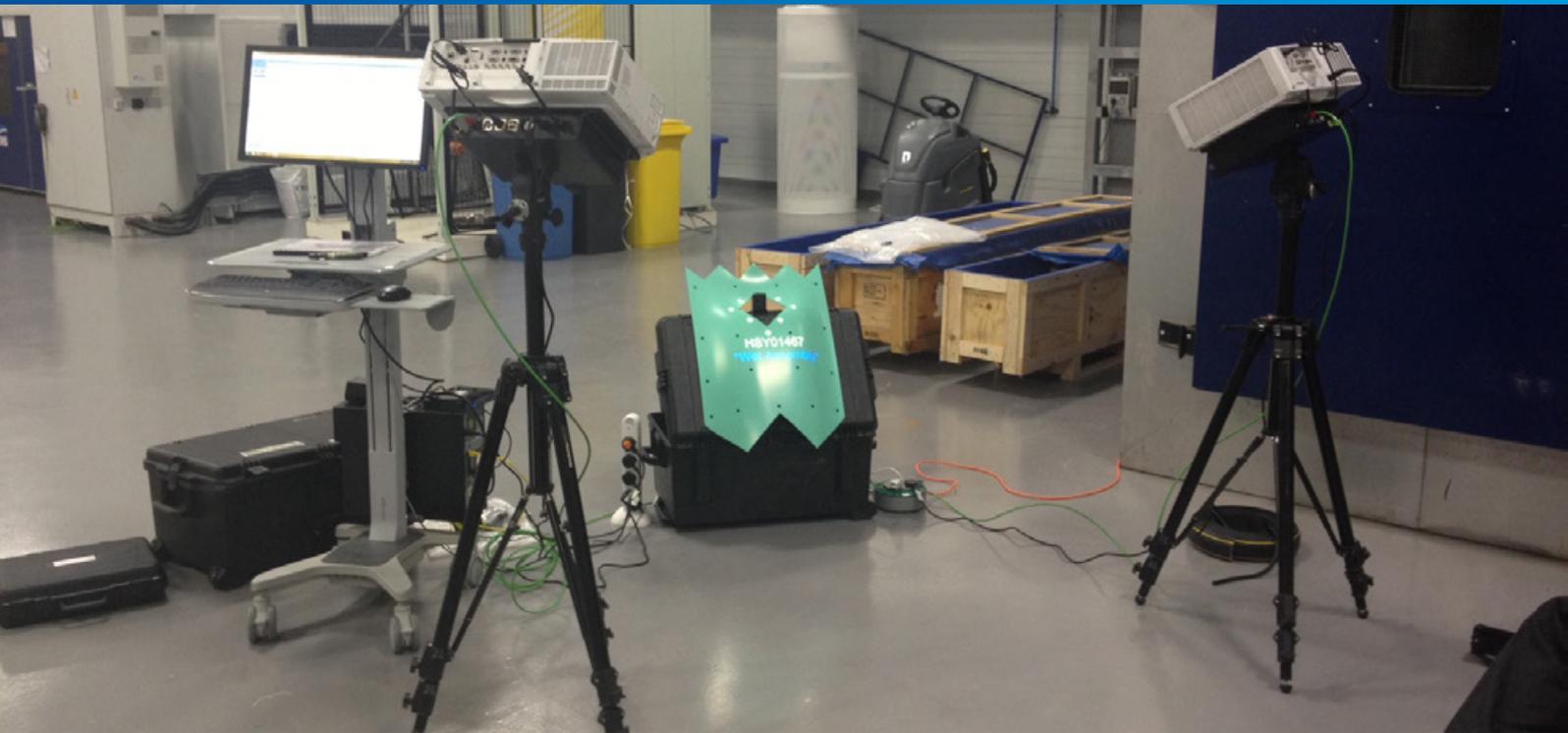
Projection Works Optical Projection System

This system provides guidance and additional information to technicians and operators, by projecting assembly instructions directly onto the workpiece. The system is based around high-powered, rugged projectors that utilise interchangeable lenses, deliver high lumen output and are capable of a high number of duty cycles. Mounted beneath each projector, a ProjectorVision 3D translator uses the 3D data from the CAD model of the workpiece, together with the sensed geometry of the workpiece in relation to the projector, to calculate the correct distortions to apply to the projected image.
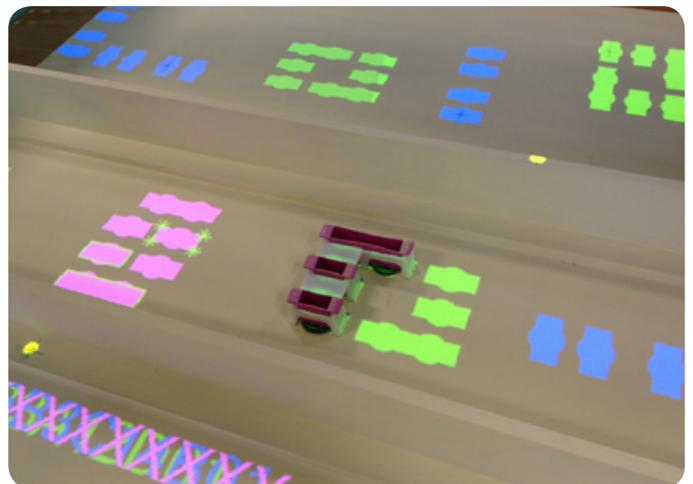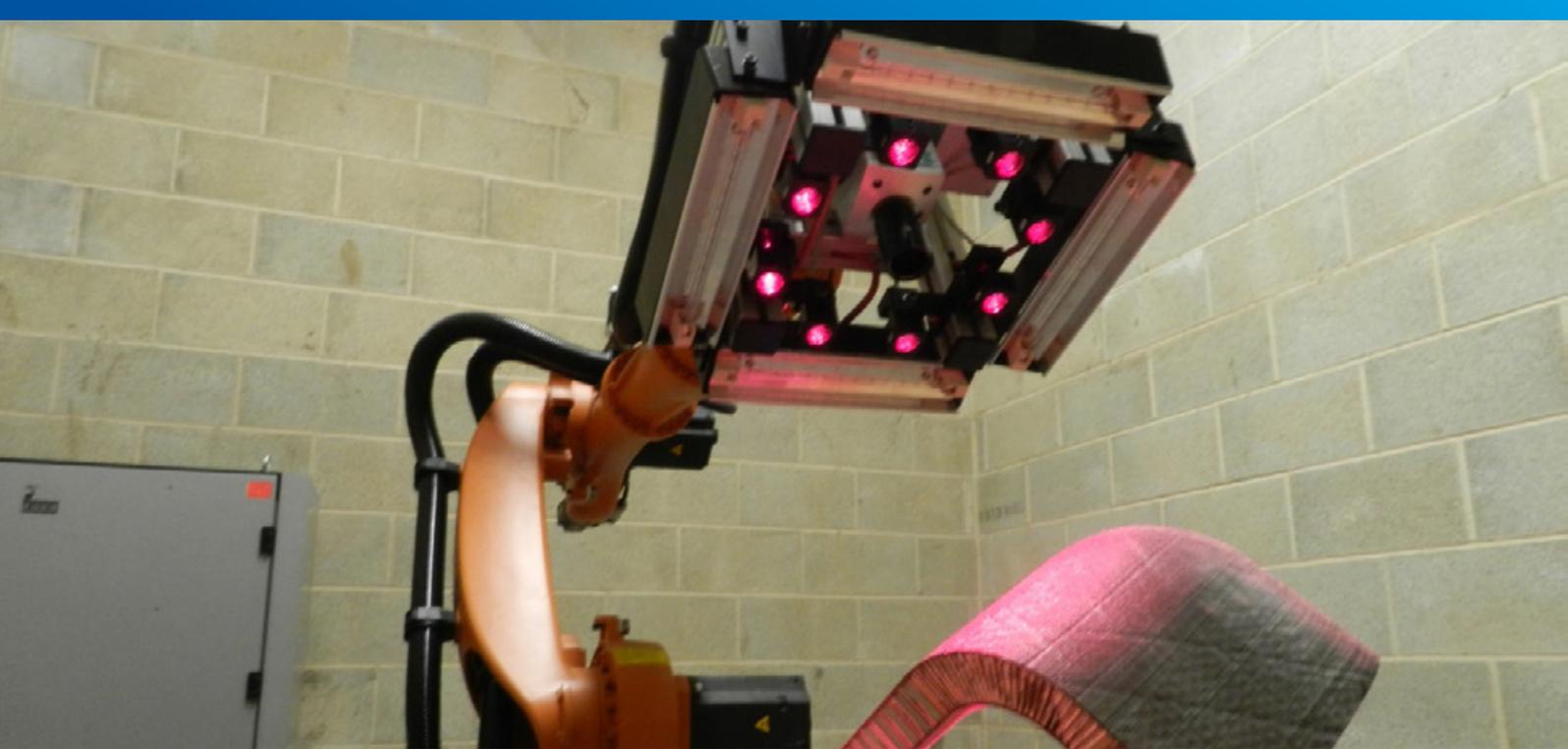
Dantec Dynamics Q800 NDT System

The Dantec Dynamics Q800 system uses digital shearography, an optical non-destructive testing method, to provide fast and accurate analysis of material discontinuities. 4 75 watt heaters apply an excitation or loading to the part to be tested. As the loading is released and the part returns to its regular state, defects are identified by detecting the strain discontinuities on the part's surface using a high spec camera. This system offers an alternative solution to traditional manual ultrasonic NDT, and is ideal for thin composite and aluminium honeycomb sandwich structures.

Sick S3000
2D Safety Laser Scanners

The Factory 2050 workshop floor will be made up of reconfigurable automated and robotic manufacturing and assembly cells. The safety of personnel on the workshop floor - be it staff, engineers, operators, customers, suppliers or visitors - must be monitored appropriately whilst these cells are in operation.

Floor mounted 2D safety laser scanners are installed to provide monitoring, control and protection of defined hazardous areas of 2D space.

These compact, intelligent systems scan their surroundings and measure distances by using the time-of-flight principle of measurement. The integrated rotating mirror creates a two-dimensional scan for freely defined protection areas.

The protective field is a 190° sector, extending up to 7 m from the scanner. The warning field extends out to a maximum of 49 m from the scanner. Response time is 60 ms and the resolution can be selected as 30, 40, 50, 70 or 150 mm as required.

Pilz SafetyEYE™
Safe Camera System

The SafetyEYE™ safe camera system provides 3D zone monitoring and control, by detecting and responding to objects (e.g. personnel, vehicles etc.) that encroach into defined 3D detection (amber) and 3D warning (red) zones. The system provides alerting and control responses appropriate to the type of zone violation that has been sensed.

A typical detection response would be to bring the relevant machine to a reduced speed, whereas a typical warning response would be to bring the machine to a safe standstill. Automatic restart can be programmed and the system copes well with human-robot cooperation within the detection and warning zones.

The system provides 3D body protection up to 7.5 m high operating range, with a maximum visible range (footprint) of approx. 72 m^2 in the form of a 4-sided pyramid shape.
The system is capable of detecting objects down to 40 mm, with a minimum reaction time of 265 ms.
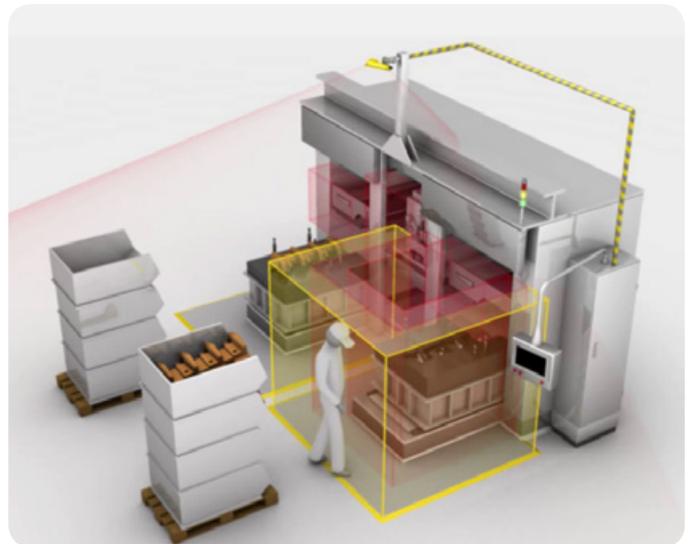
Pilz PSENopt
Safety Light Curtains

Safety Light curtains with infra-red beams add rugged, reliable, and intelligent protection to machine cells, increasing the safety levels for operators and any other personnel who come into close proximity of the cell.

These intelligent light beam devices provide full body protection in accordance with EN/IEC 61496-1/-2, to prevent entry into cells whilst they are operating.

Pilz PNOZ
Multi Safety Controllers

Dedicated Safety Controllers provide the intelligent core of flexible, re-configurable and re-usable safety systems, for use across many IMG research cells. The Pilz MP1 Safety Controllers bridge the gap between classic safety relays and programmable control systems, and consist of a base unit and various expansion modules.

The controllers accept and process inputs from a wide variety of safety sensors and devices, including:

- E-STOP pushbuttons
- Operating mode selector switches
- Enabling switches
- Two-hand buttons
- Safety gates
- Light curtains
- Light beam devices
- Speeds
- Analogue input signals
- Pressure sensitive mats
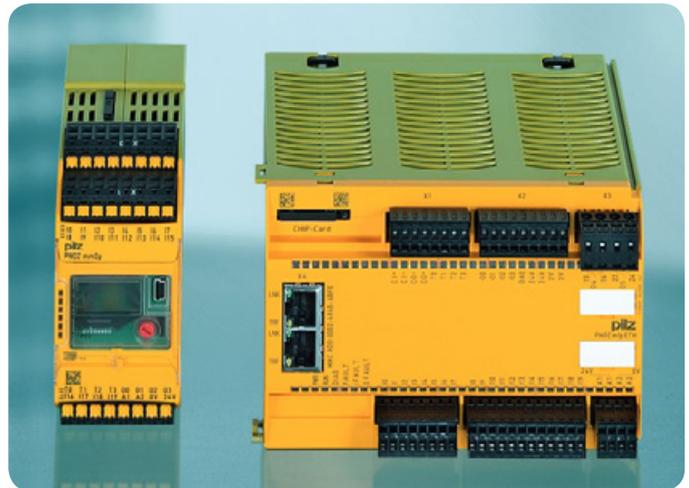
Mazak VTC800/30SR

The MAZAK VTC800 is a 5-axis vertical travelling column (VTC) CNC machining centre which will be used inFactory 2050 to fabricate specialist one-off components for a range of projects from materials including composites (i.e. carbon fibre, modelling block) and a variety of ferrous and non-ferrous metals (i.e. stainless steels, mild steels, aluminium and brass).

Zoller Automated Tool Setter

ZOLLER Redomatic universal presetting, measuring and heat-shrink machine has been especially designed for the heat-shrinking of tools to nominal length, while at the same time presetting and measuring tools of all kinds.

Using its automatic length adjustment device, tools can be shrunk to at least ±10 µm accuracy quickly, easily and automatically.

uPrint SE Plus 3D Printer

The 3D printer is used for rapidly creating parts and prototypes needed for conceptual modelling, functional prototyping, manufacturing tools, and end effector parts from engineering thermoplastics such as ABS.

The raw material used by the printer is available in a range of colours, so that the parts produced can easily have different coloured areas or volumes. The 3D printer uses soluble support technology, so that supporting structures generated during the creation of the part can be dissolved once the printing of the part is finished.

The minimum layer thickness is 0.254 mm and is adjustable by the user during the definition of the print job. The printer is able to process 3D CAD data in STL format generated by 3D CAD packages such as Catia.

Siemens WinCC v7.3 Shop-floor Data Capture system (SCADA)

The Siemens SCADA system is a flexible, modular, expandable data gathering system providing production analysis, remote operation/monitoring, and environmental/power monitoring for multiple robotic cells, for aiding manufacture and demonstrating big data gathering technology.

The concept behind SCADA is to provide an initial showpiece of the data gathering technology that would be used in a modern factory, and to create a test-bed for research on the use of gathered data in innovative projects with the AMRC's partners.

SCADA operates on its own VPN and is based on Siemens technology, as used in many of the IMG cells in PLC and other control/monitoring systems.

Ubisense component tracking systems

The Ubisense component tracking system consists of networked sensors and industrial tags that will be used in Factory 2050 to track large pieces of equipment, machines and parts to within 15 cm. This information will be relayed to a networked device and used to effectively manage resources.

AMRC/

CATAPULT
High Value Manufacturing

European Union
European Regional
Development Fund

Working with
Innovate UK