



Advanced
Manufacturing
Solutions

Advanced Manufacturing With Robots

European Robot Forum 2014





Mr. Franck Messmer

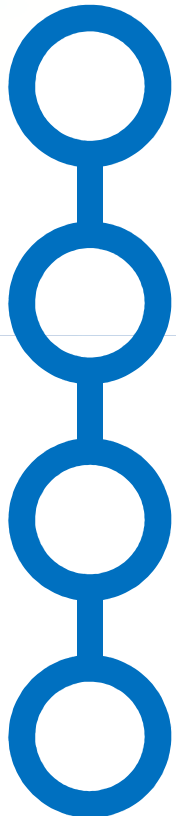
Delcam Robotics Development Manager
Delcam PLC, Birmingham, UK

Product: “*PowerMILL Robot*”

Background:

- Mechanical and CAM software development University in France
- 7 years at Delcam France (Bespoke projects and CNC postprocessors)
- 4 years at Delcam PLC, UK (Development of Robotics)
- Participate to the COMET Project...

Content



Milling with robot: Challenges and COMET solution

Delcam robotics solution: PowerMILL Robot

Robot milling applications overview

Future of Advanced Manufacturing with robots

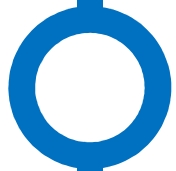
Content



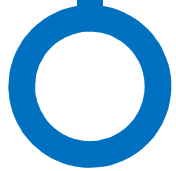
Milling with robot: Challenges and COMET solution



Delcam robotics solution: PowerMILL Robot



Robot milling applications overview



Future of Advanced Manufacturing with robots

Milling with robots

Why? (1 of 2)

- European manufacturing industry:
 - Flexibility, quality, reliability and low life-cycle costs
 - Diverse machining operations with short changeover, programming and set-up times
- Industrial robot technology:
 - Flexible (due to their lay-out)
 - Cost efficient (2-5 times)



Milling with robots

Why? (1 of 2)

Equipment – Feature	Robot Setup Workspace: 3m ³	Machine Tool Setup 1 Workspace: 1 m ³	Machine Tool Setup 2 Workspace: 2.4m ³
Machine Tool 1 (Haas VF-6/50TR)		220.000,00 €	
Machine Tool 2 (Haas VR-11B)			335.000,00 €
Industrial Robot (180kg payload)	60.000,00 €		
HSC Spindle	5.000,00 €		
Additional Equipment	5.000,00 €		
Total	70.000,00 €	220.000,00 €	335.000,00 €

- Industrial robot technology:
 - Flexible (due to their lay-out)
 - Cost efficient (2-5 times)



Milling with robots

Why? (2 of 2)

- But:
 - Industrial robots lack absolute positioning accuracy
 - Lack reliable programming and simulation tools to ensure first time right machining

Milling with robots

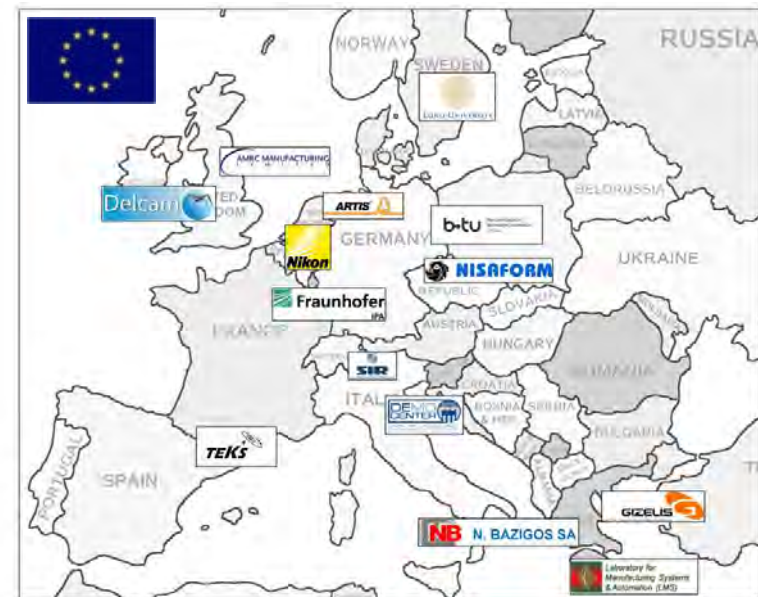
Why? (2 of 2)

- But:
 - Industrial robots lack absolute positioning accuracy
 - Lack reliable programming and simulation tools to ensure first time right machining

- COMET project:
 - Solve
 - Demonstrate
 - Disseminate

Plug-and-produce **CO**mponents and **MET**hods
for adaptive control of industrial robots
enabling cost effective, high precision
manufacturing in factories of the future

Franck Messmer fm@delcam.com



COMET

How? (1 of 2)



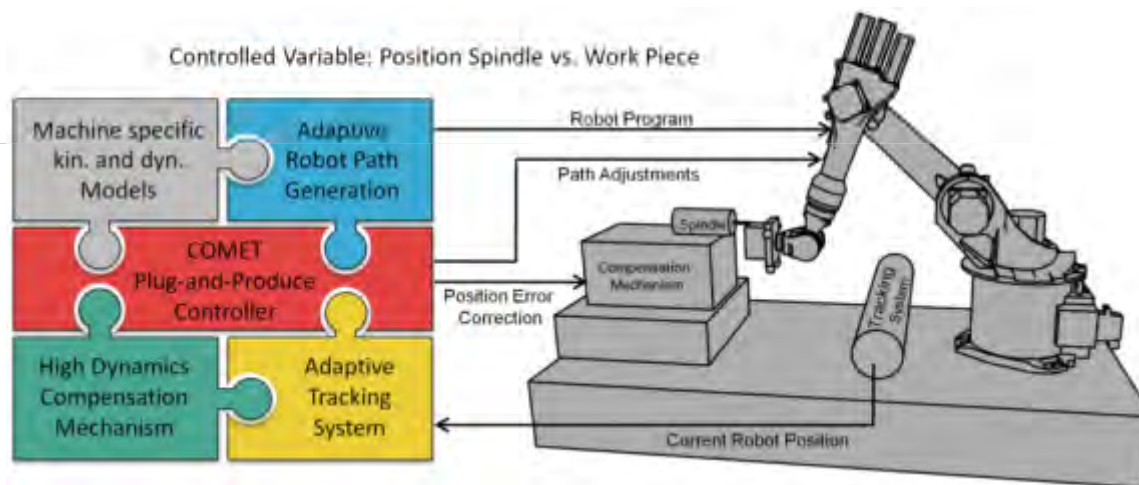
- Can't fly 'on its own' (flying brick)
- Modelled its 'aerodynamic behaviour'
- Integrated this model in the control software to support the pilot
- Sensors to correct

Lockheed Martin F-117A

COMET

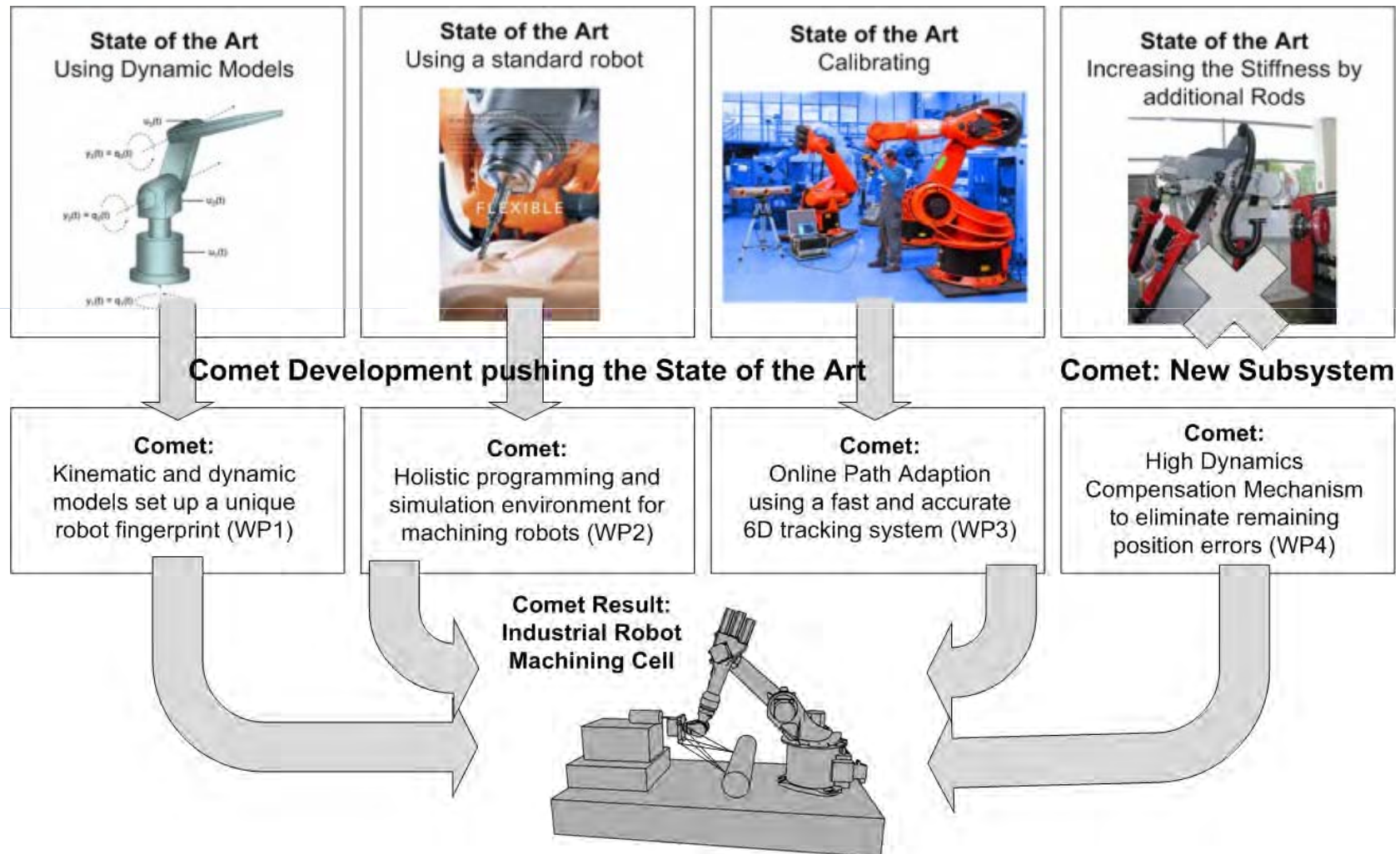
How? (2 of 2)

- Not accurate by itself (machining)
- Modelled its 'kinematic & dynamic behaviour'
- Integrated this model in the control software to support the programmer
- Sensors to correct



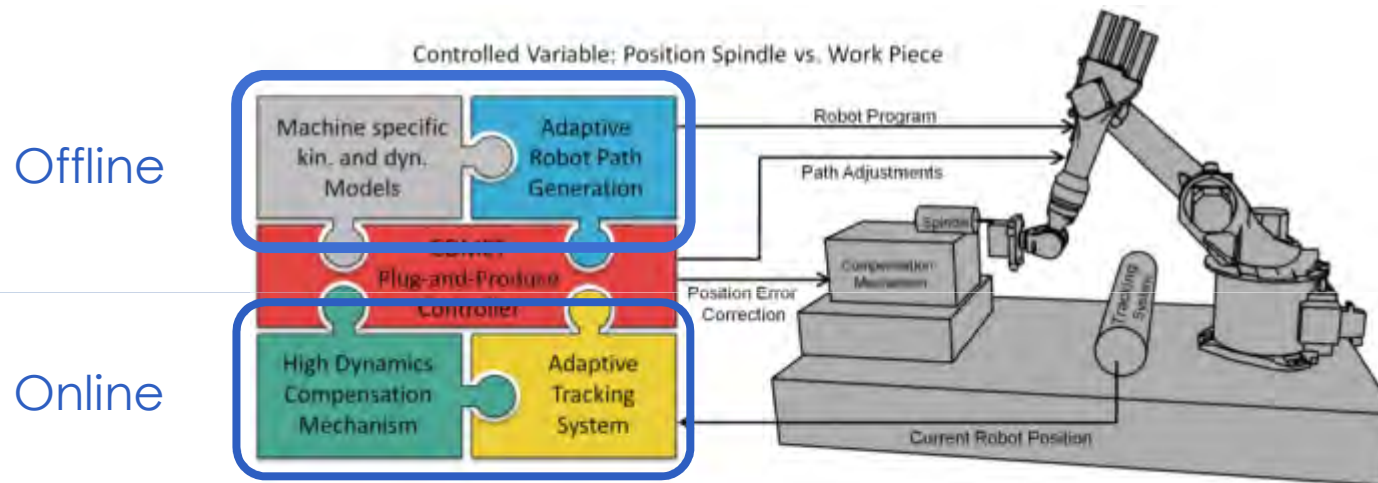
COMET

What? (1 of 2)



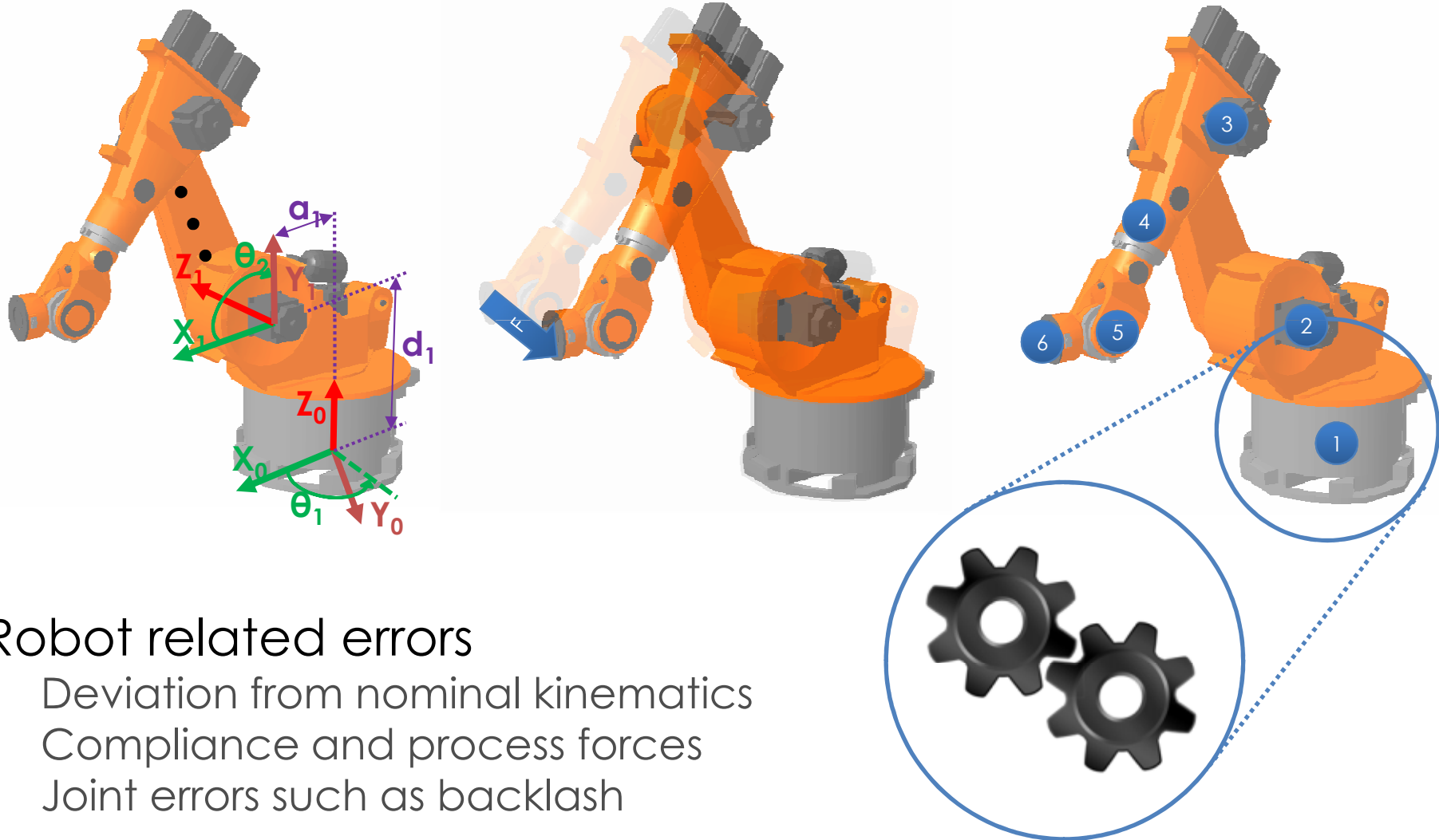
COMET

What? (2 of 2)



“Enabling accurate machining with robots in **an industrial setting**”

Intermezzo: robot related errors



Robot related errors

- Deviation from nominal kinematics
- Compliance and process forces
- Joint errors such as backlash

COMET Results

Tangible results per WP

The real Comet project goal is not only about achieving machining accuracy:

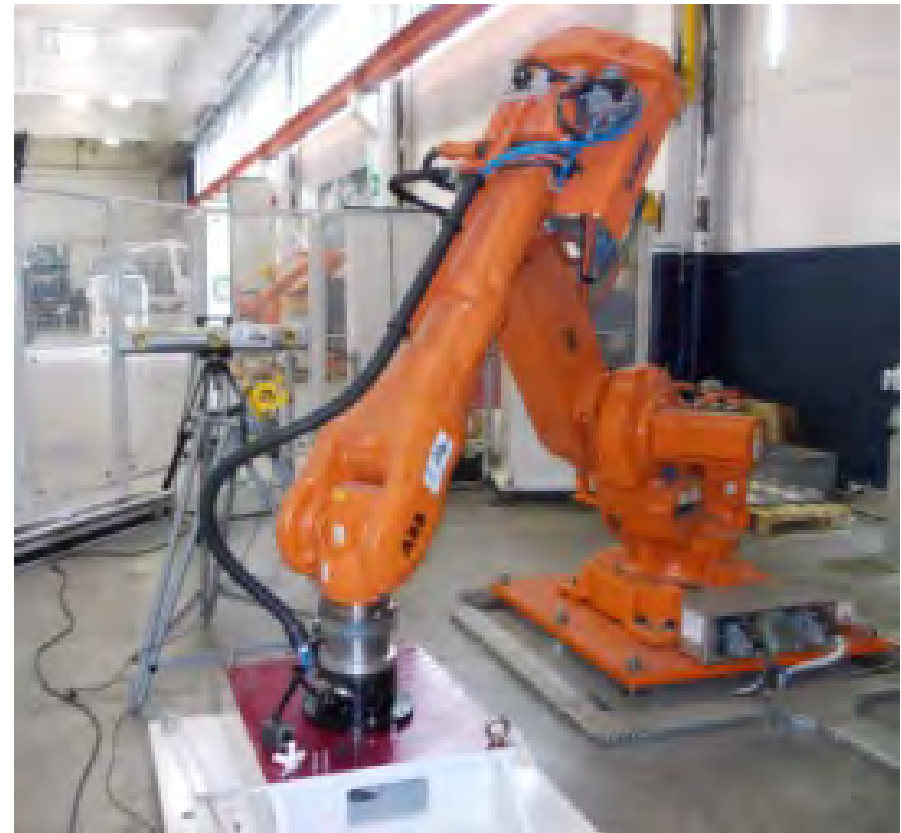
- **4 technological innovations** based on high scientific content
- Stimulating **industrial robotics evolution**
- **Complete robot machining platform** with different levels of accuracy, performance and business models (costs/profits) able to open **new markets and applications**

“Increasing motion accuracy of mechatronic systems “

4 technological innovations

WP1- modeling and robot system identification

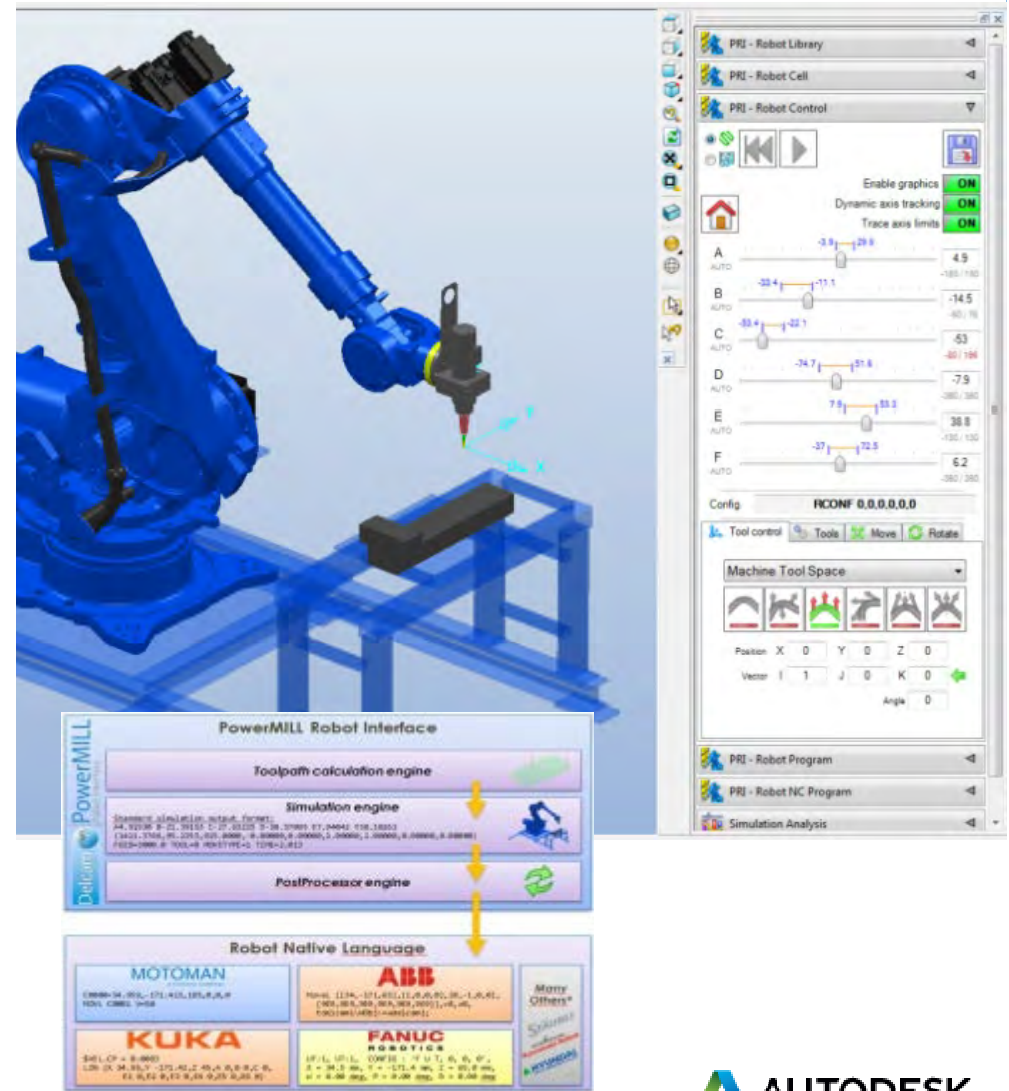
- **Robot accurate behavior**
modeling to predict and
compensate errors using
**Kinematic, (S) Blash, Joint Based
models**
- Scientific findings that could also
be the **foundation of future robot
controllers**
- **Patent** for really and profitably
apply the scientific results
- Methods exploitable for
**increasing accuracy of
mechatronic systems** in the wider
sense



4 technological innovations

WP2- robot machining simulation

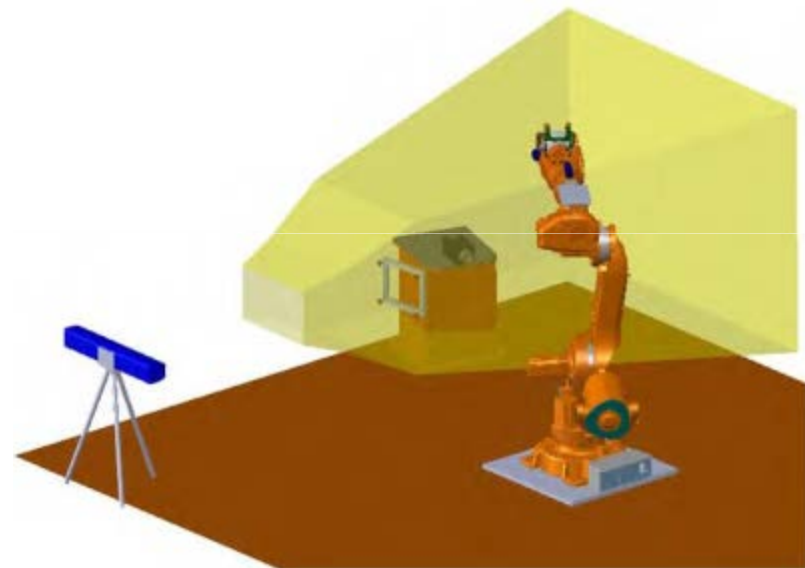
- **Developed from state of the art limitations and user needs**
- **Robot machining CAM:** really addressing robot machining unique features
- **Offline compensation** for a robust, low cost of investment robot machining
- **Simulation tools** and methods developed may be adopted also for machine tools



4 technological innovations

WP3- sensing and tracking

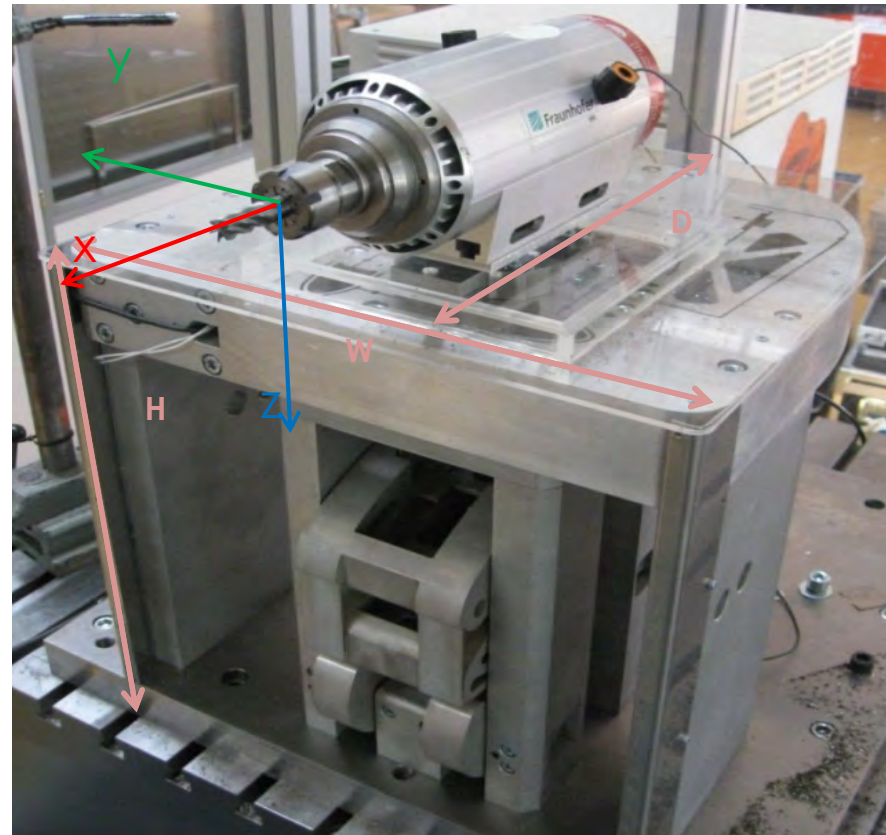
- **From static into dynamic accuracy**
- **New tracker concept:** lower cost, multiple targets
- **Extending robot controllers with external fast I/Os** (ABB as demo case) : enhanced performance enabling **industrial robotics evolution**
- **Process accuracy beyond robot accuracy!!!**
- **Many other fields of applications:** high precision assembly , dexterous manipulations etc



4 technological innovations

WP4: adaptive, high precision compensation

- **HDCM**: Online high accuracy and high frequency compensation
- **“High” stroke piezo actuation**
- Higher cost of investment balanced from **superior accuracy** able to gain **new market sectors**
- The **full COMET robot machining!**



COMET

COMET solution for robotic machining



Turbine Disc

800 mm, 119.2 kg, Inconel

Machining to be done with robot:
Deburring

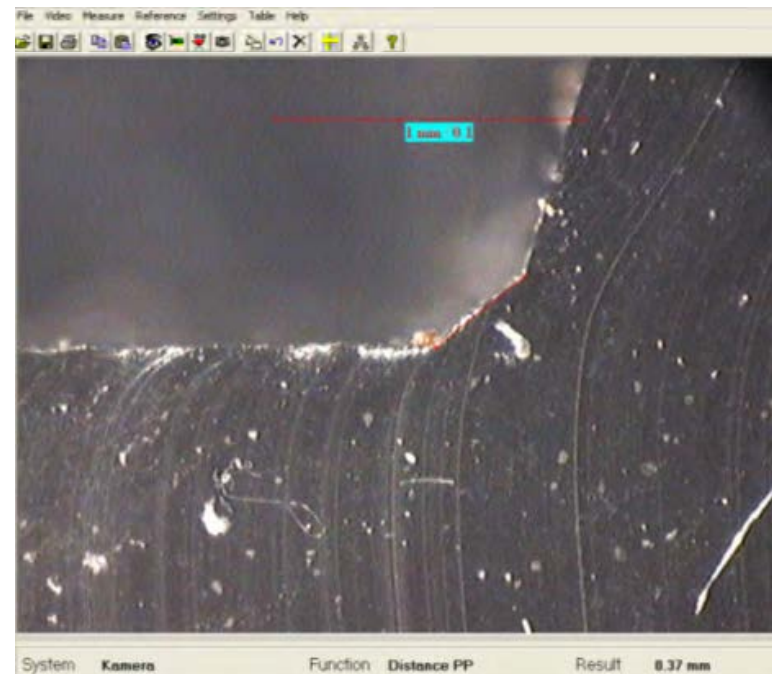
Accuracy: 0.3 mm chamfer land

**Automating of deburring teeth profiles of big turbines,
now done manually**

Aerospace market

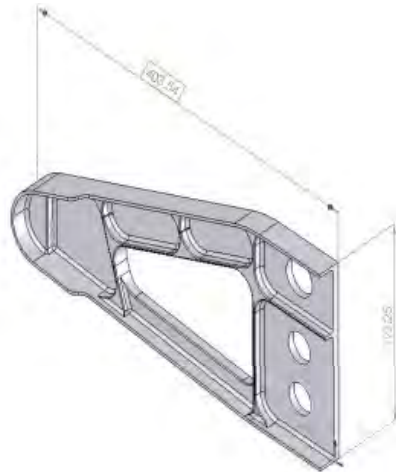
Demo results:

0.3 mm chamfer land achieved



COMET

COMET solution for robotic machining



Wing's leading edge 403,54 X
193,25 mm, 0,5 Kg,
Aluminium (AL 6061)

Machining to be done with robot:
Full machining from Aluminium
Block

Accuracy requirement: 0.1 mm

Full machining of Aluminium Aircraft components

Robot: cheaper and more flexible than CNC

no size limitation

Aircraft manufacturing industry

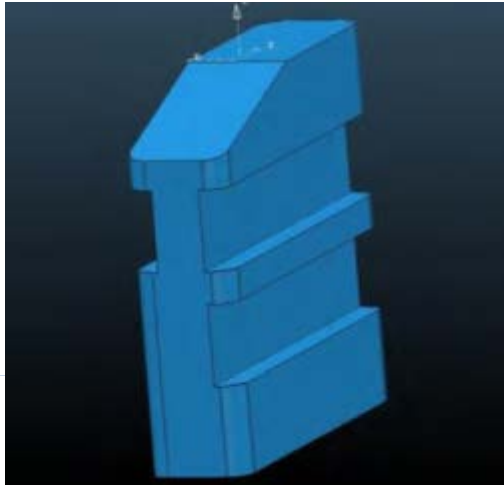
Demo results:

**part fully machined, accuracy to improve
but OK for roughing.**



COMET

COMET solution for robotic machining



Steel component of a Bending Machine

107x27x99 mm, 2,6 Kg, Mould steel
DIN 1.1730

Machining to be done with robot:
the full shaping (Side Milling,
Contouring, Slotting)

Accuracy requirement: 0.05 mm

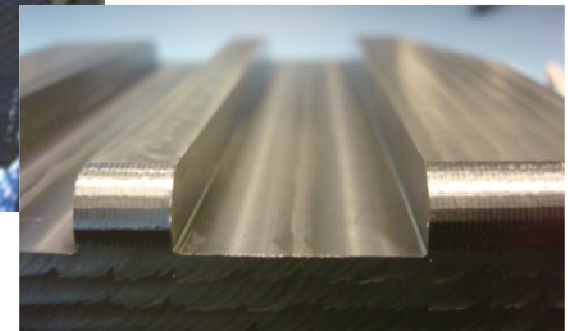
Full machining of accurate and complex shape steel components

Robot: cheaper and more flexible than CNC allowing complete machining with no repositioning

High precision components market

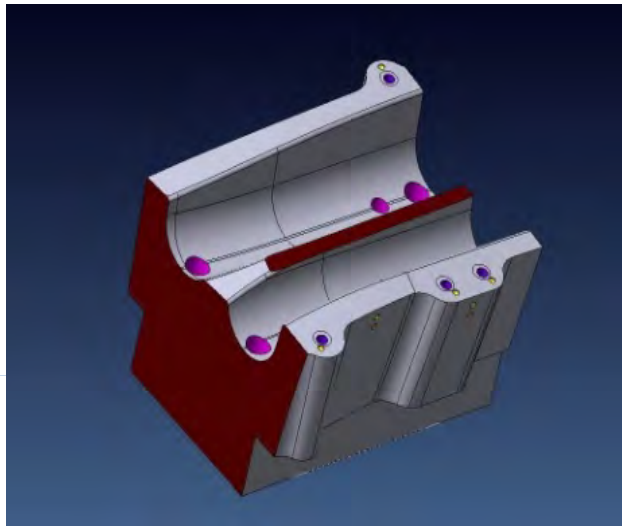
Demo results:

accuracy satisfactory, average dimensional deviation < 0.06 mm



COMET

COMET solution for robotic machining



Injection mould part

150 mm x 150 mm x 110 mm,
7,6 Kg, Steel (DIN 1.2312 40
CrMnS86)

Machining to be done with robot:
Side Milling, Contouring, Profiling

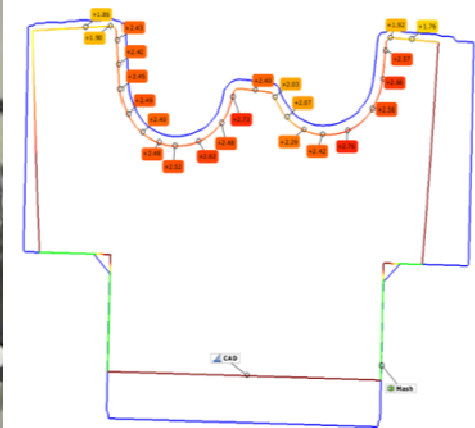
Accuracy requirement: 0.05 mm

- **Full machining of steel moulds**

Robot: cheaper and more flexible than CNC
allowing complete machining with no repositioning
Mould sector (injection moulding, thermoforming)

Demo results:

**accuracy satisfactory, deviations on section
profile ~ 0.13 mm; surface smoothness to improve**



COMET

COMET solution for robotic machining

Datum C – Plane RIF-C

Datum B – Plane RIF-B

Datum A – Plane RIF-A



Automotive brake caliper –
290x155x80mm,
2,7Kg - Aluminium (AlSi7Mg0.5)

Machining operations: Face milling,
Contour milling, Drilling and
Chamfering

Accuracy requirements: Geometrical
dimensions and tolerances defined
according to ISO 2768-fH (*Standards*
ISO 22768-1:1989 & ISO 2768-2:1989).

Measurement by vision system &/O
offline CMM inspection.

COMET

COMET solution for robotic machining

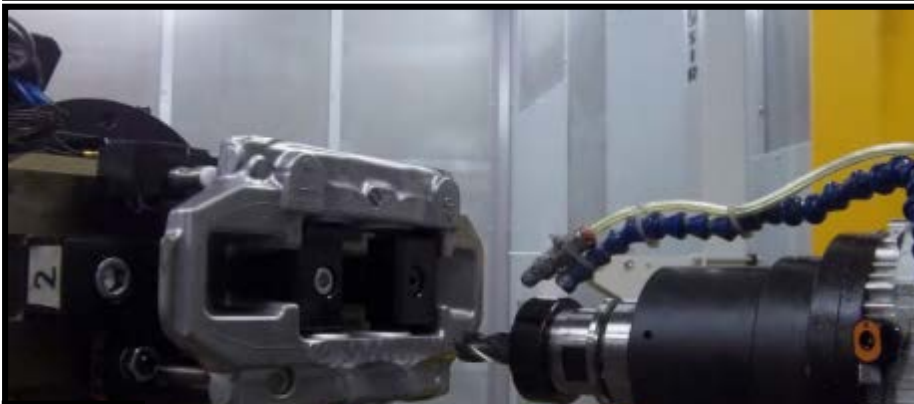
OP10 Face Milling



OP20 Drilling



OP10 Face Milling

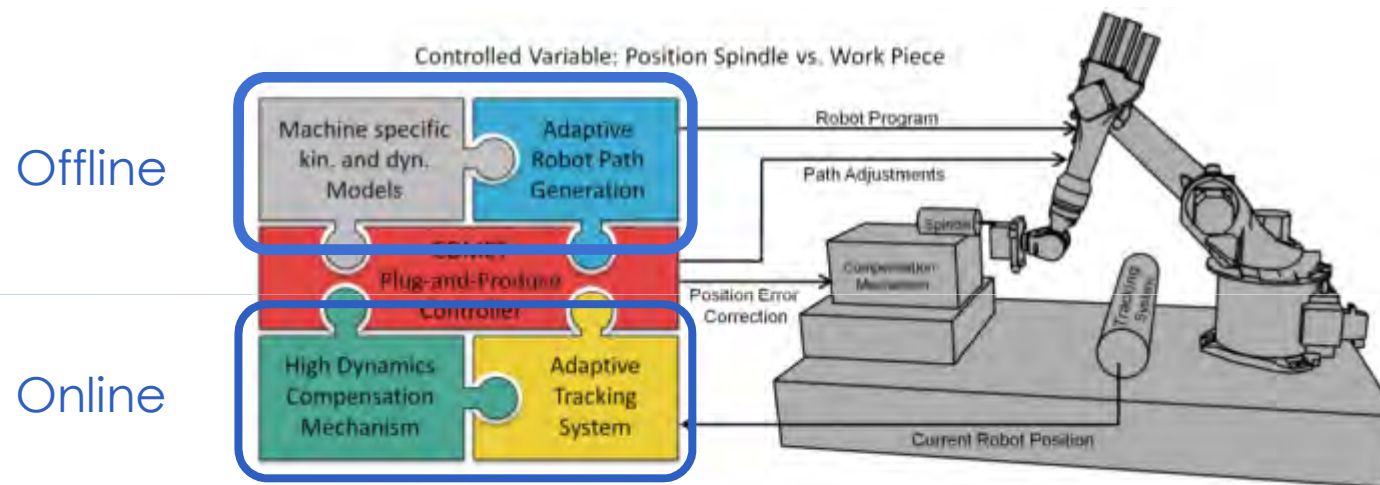


OP20 Chamfering



COMET

COMET solution for robotic machining

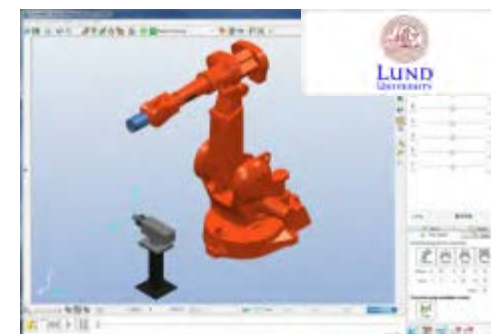
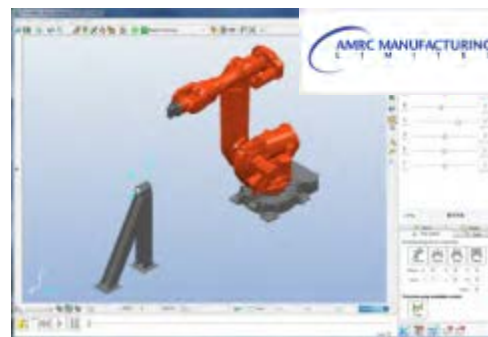


“Enabling accurate machining with robots in **an industrial setting**”

COMET

Robot cells

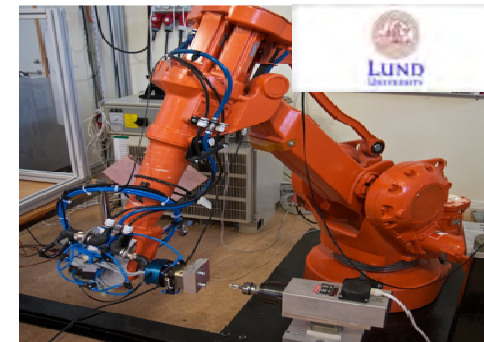
Within COMET, 8 demonstrator cells were setup and used for the R&D and demonstration activities.



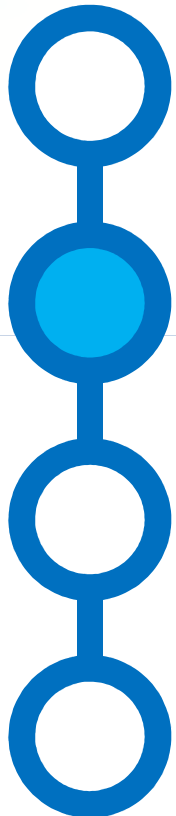
COMET

Robot cells

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Content



Milling with robot: Challenges and COMET solution

Delcam robotics solution: PowerMILL Robot

Robot milling applications overview

Future of Advanced Manufacturing with robots

What is “PowerMILL Robot”?

➔ CAM & Robot Simulation Software

Toolpath generation



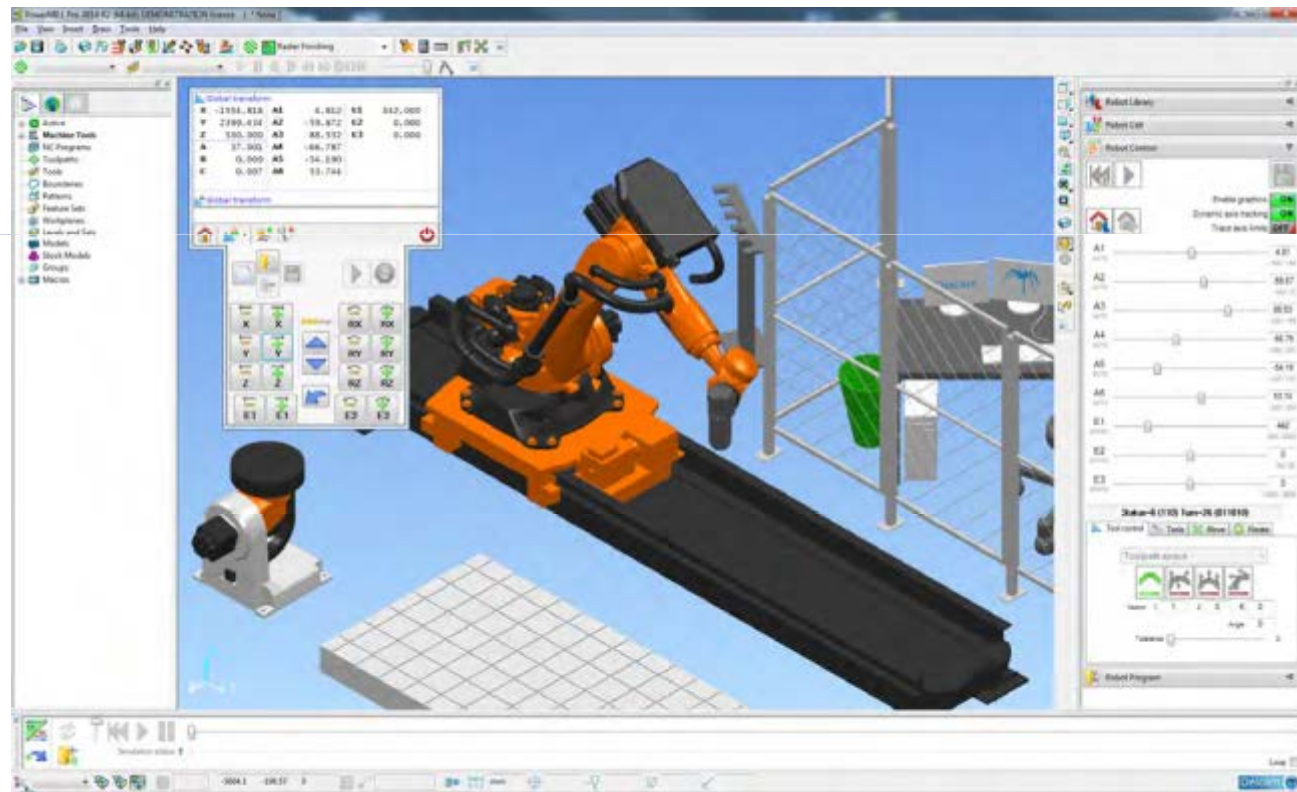
Robot simulation



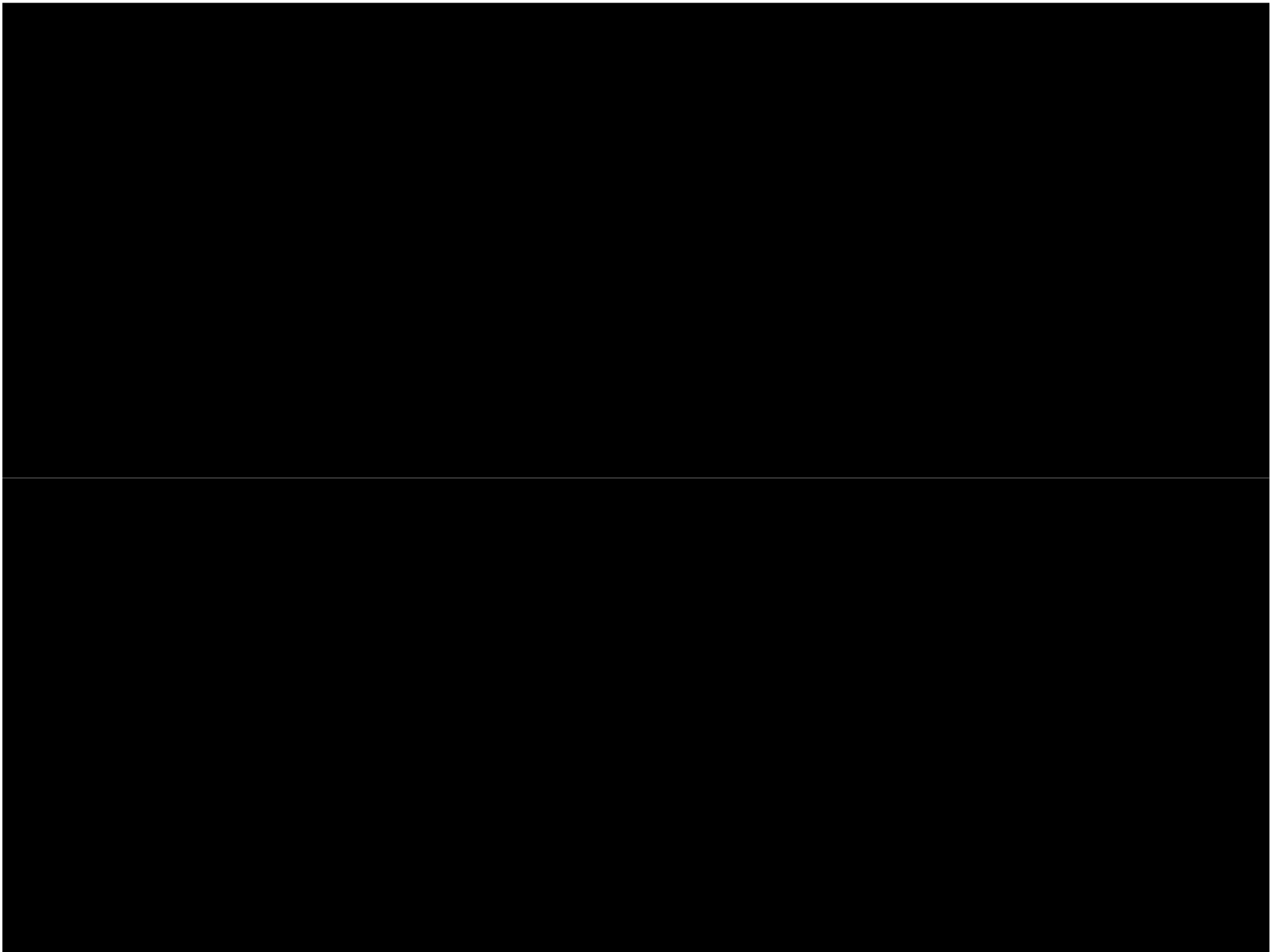
Robot programs



Robot



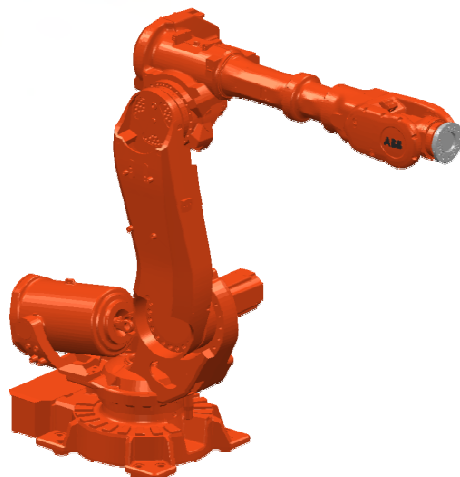
Delcam PowerMILL Robot



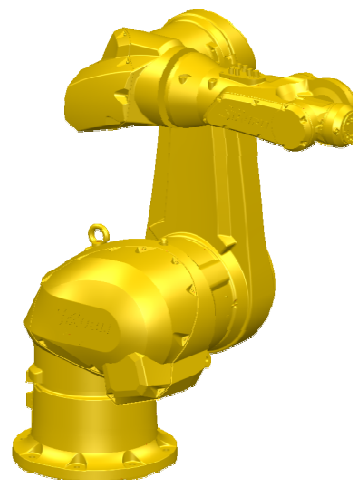
Supported robot



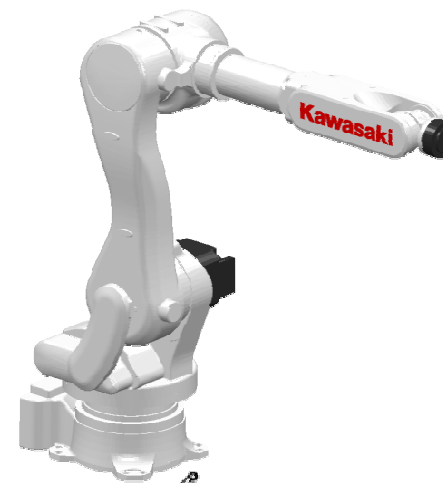
KUKA



ABB



STÄUBLI



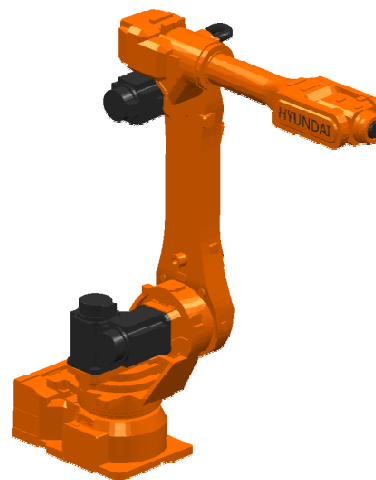
Simple & friendly
Kawasaki Robot



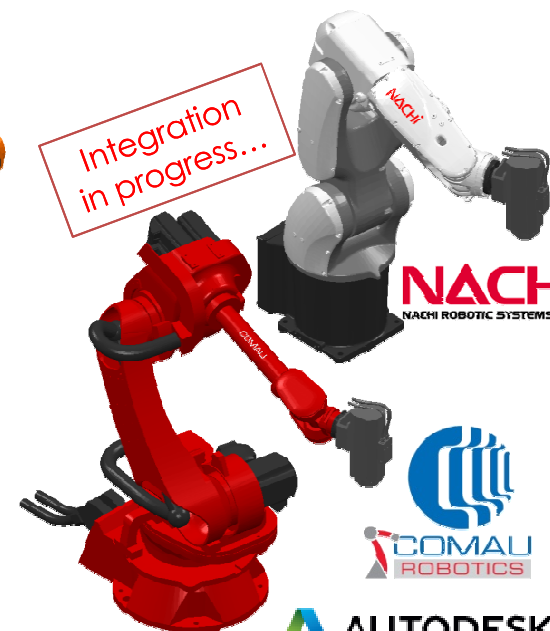
FANUC
ROBOTICS



MOTOMAN
A YASKAWA COMPANY

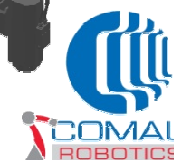


HYUNDAI
HEAVY INDUSTRIES CO., LTD.



NACHI
NACHI ROBOTIC SYSTEMS INC.

Integration
in progress...

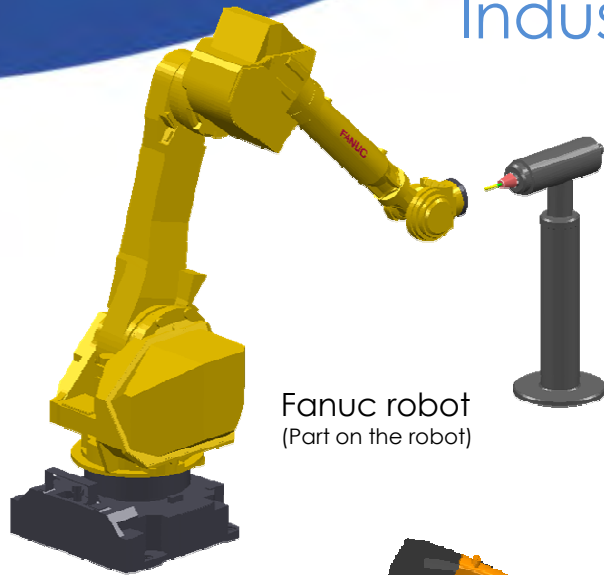


COMAU
ROBOTICS

AUTODESK.

Supported robot

Industrial robots with up to 6 external axes...



Fanuc robot
(Part on the robot)

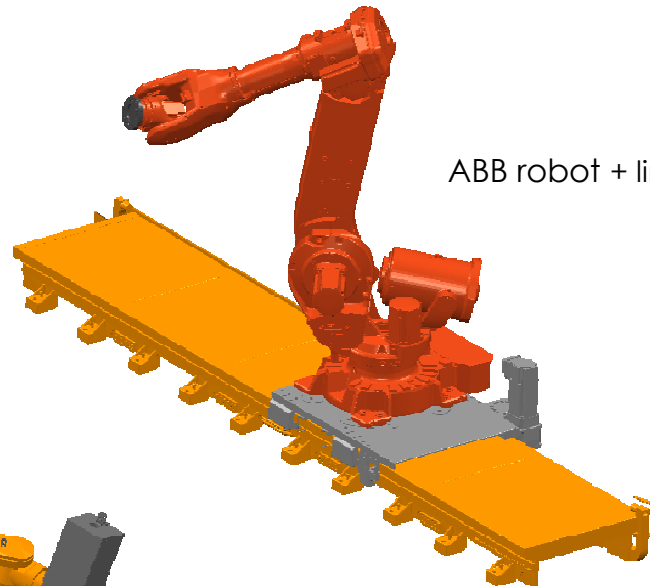
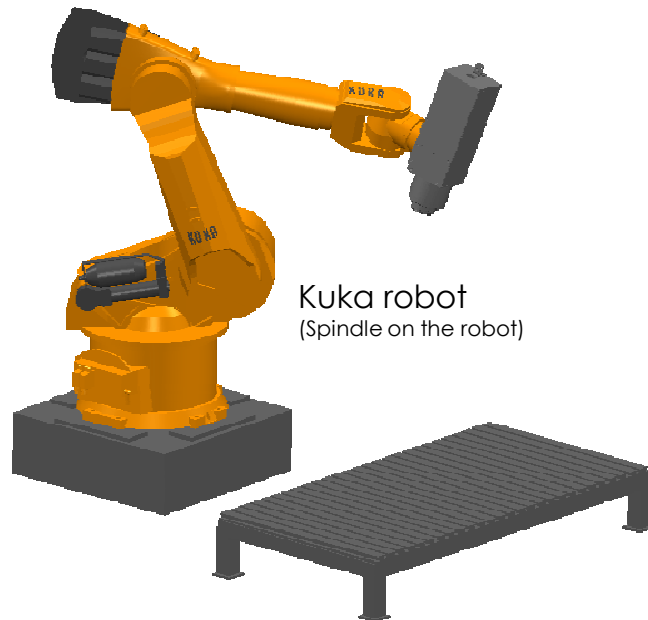
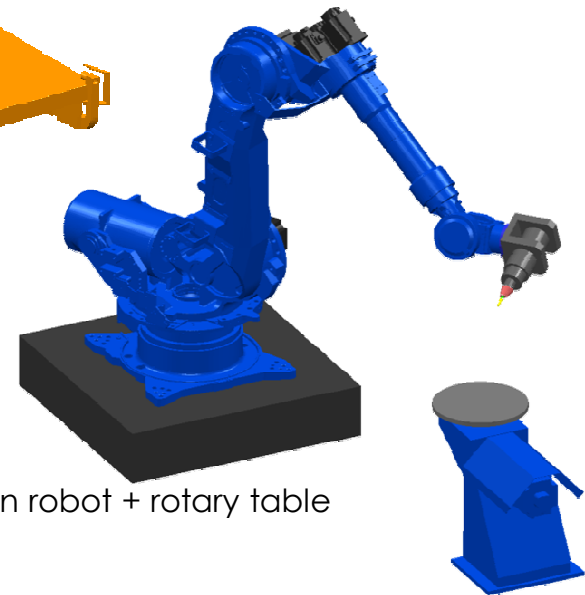


ABB robot + linear track



Kuka robot
(Spindle on the robot)



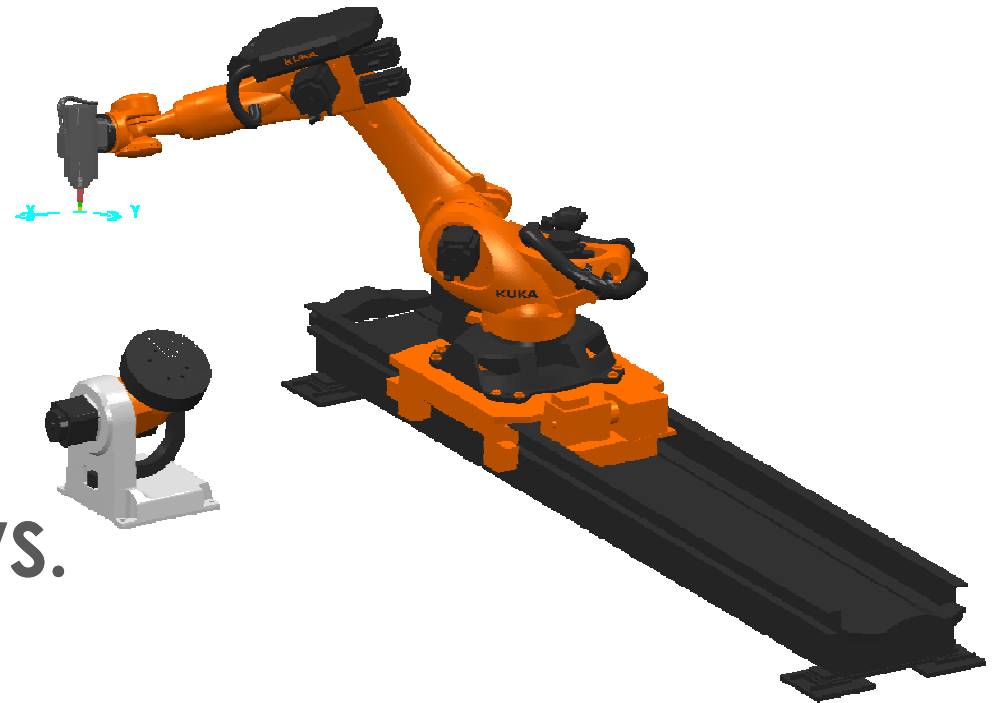
Motoman robot + rotary table

Machine tool vs Robot

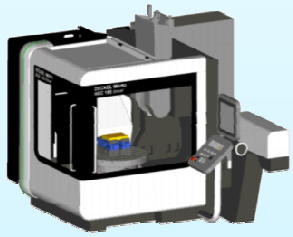
Machine tools and robots are not competitors!



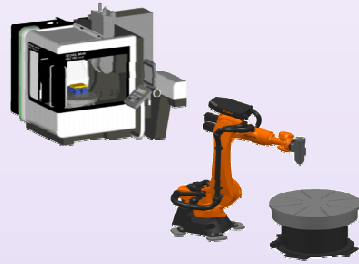
VS.



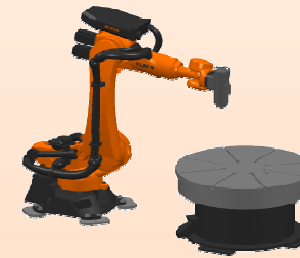
Different machines = Different applications



**Accuracy is critical.
Metallic parts**



**Accuracy is not critical.
Non metallic parts.**



**Size, flexibility, environment is critical.
Non metallic parts & Not only milling applications!**



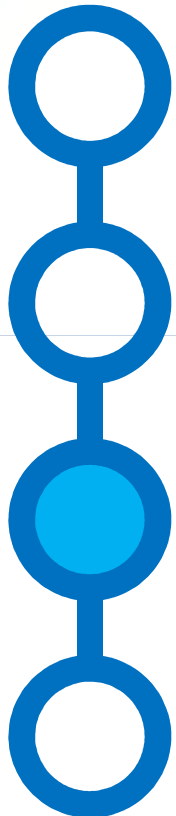
Franck Messmer



frm@delcam.com



Content



Milling with robot: Challenges and COMET solution

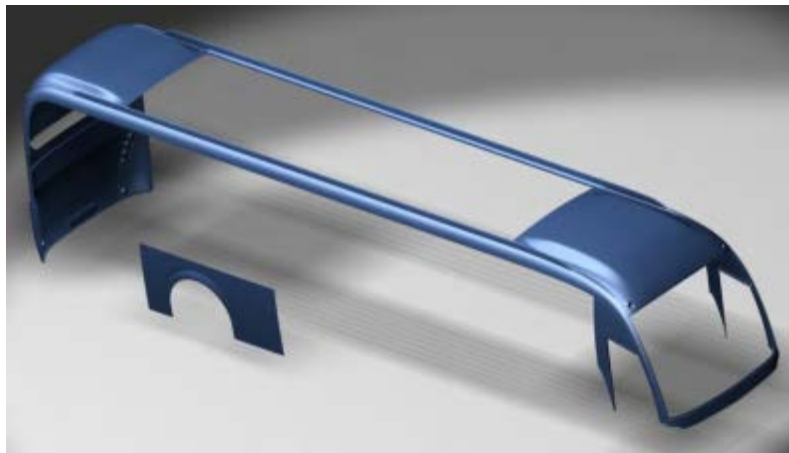
Delcam robotics solution: PowerMILL Robot

Robot milling applications overview

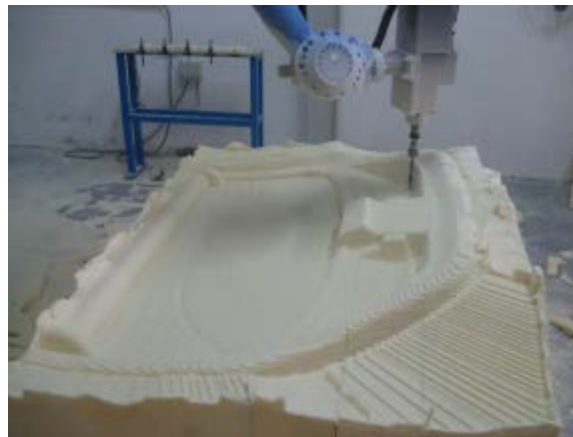
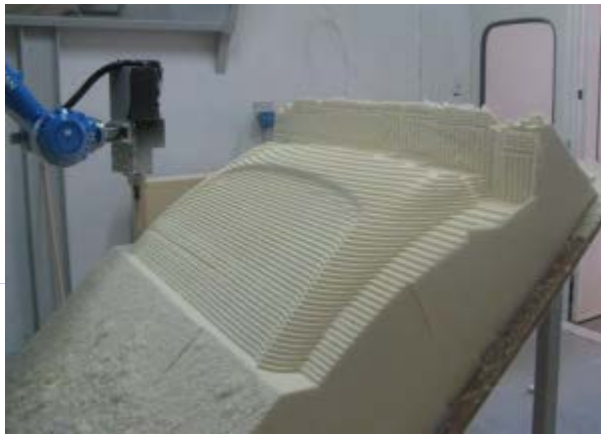
Future of Advanced Manufacturing with robots

- No previous CAD/CAM knowledge
- Current PowerMILL Robot & PowerSHAPE users





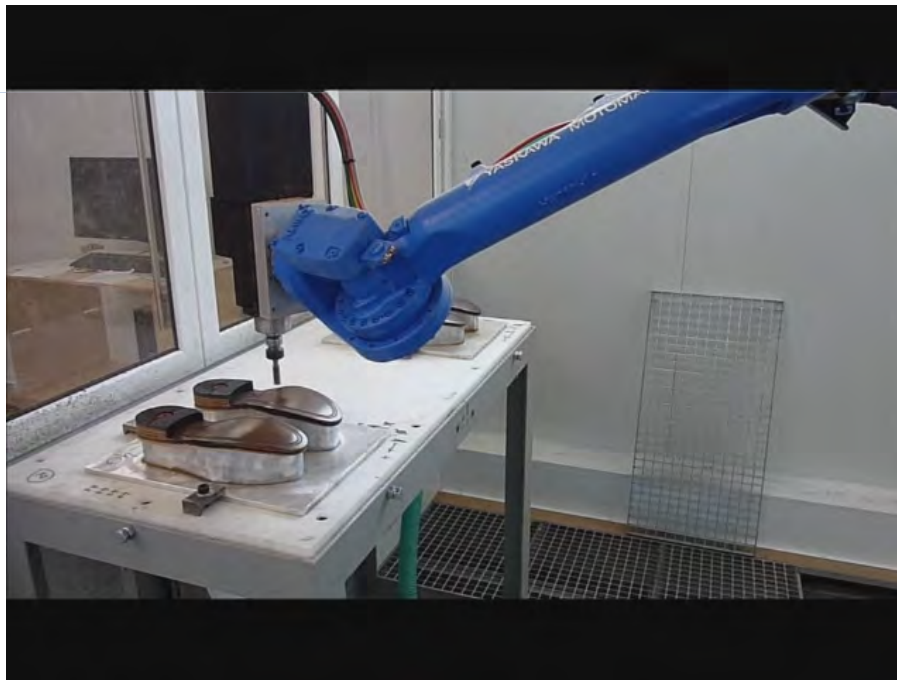
Case Study 2



Case Study 3



- Vancal was established in 1986 in Stª Maria da Feira, Portugal
- Produces shoe sole components
- Exports worldwide



Case Study 4



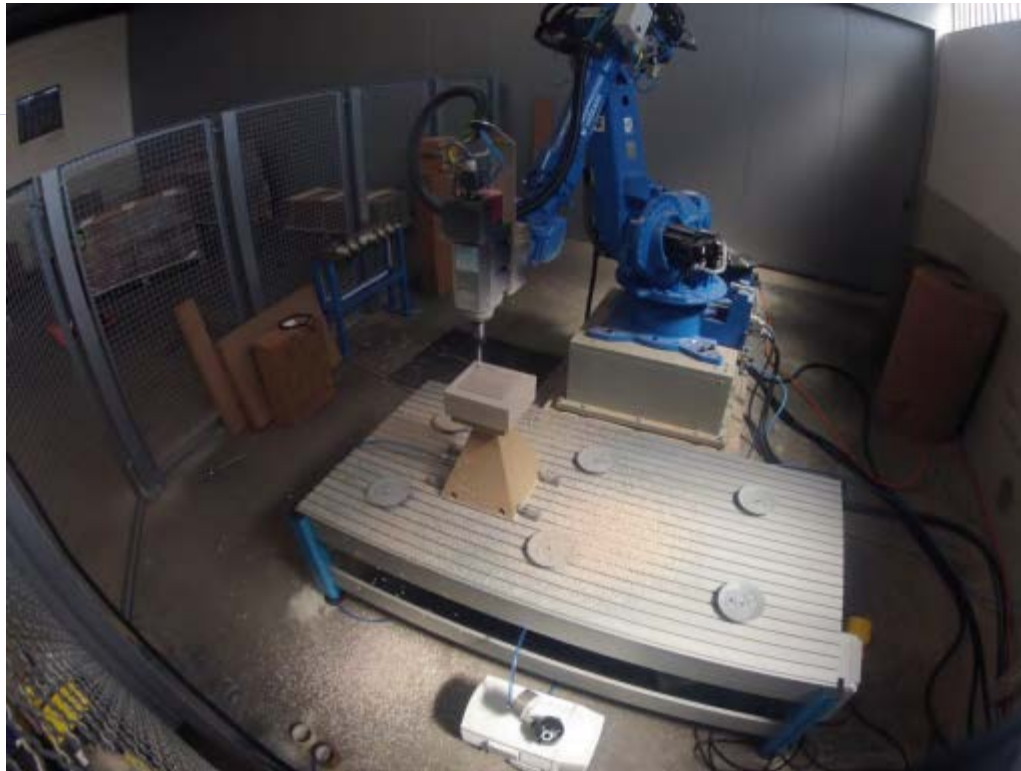
- Works in the Cork Industry
- Acoustic panels
- No previous CAD/CAM knowledge
- Wishes to Design and develop Cork products.



Case Study 4



- Rotary table
- 2x1m table with vacuum
- Tool Change



Case Study 5

CEIIA



Case Study 5

CEIIA



Danish Technological Institute

- TailorCrete – EU funded research project, integrating robotics and automation into concrete construction industry.



Case Study 6



DANISH
TECHNOLOGICAL
INSTITUTE



Case Study 7

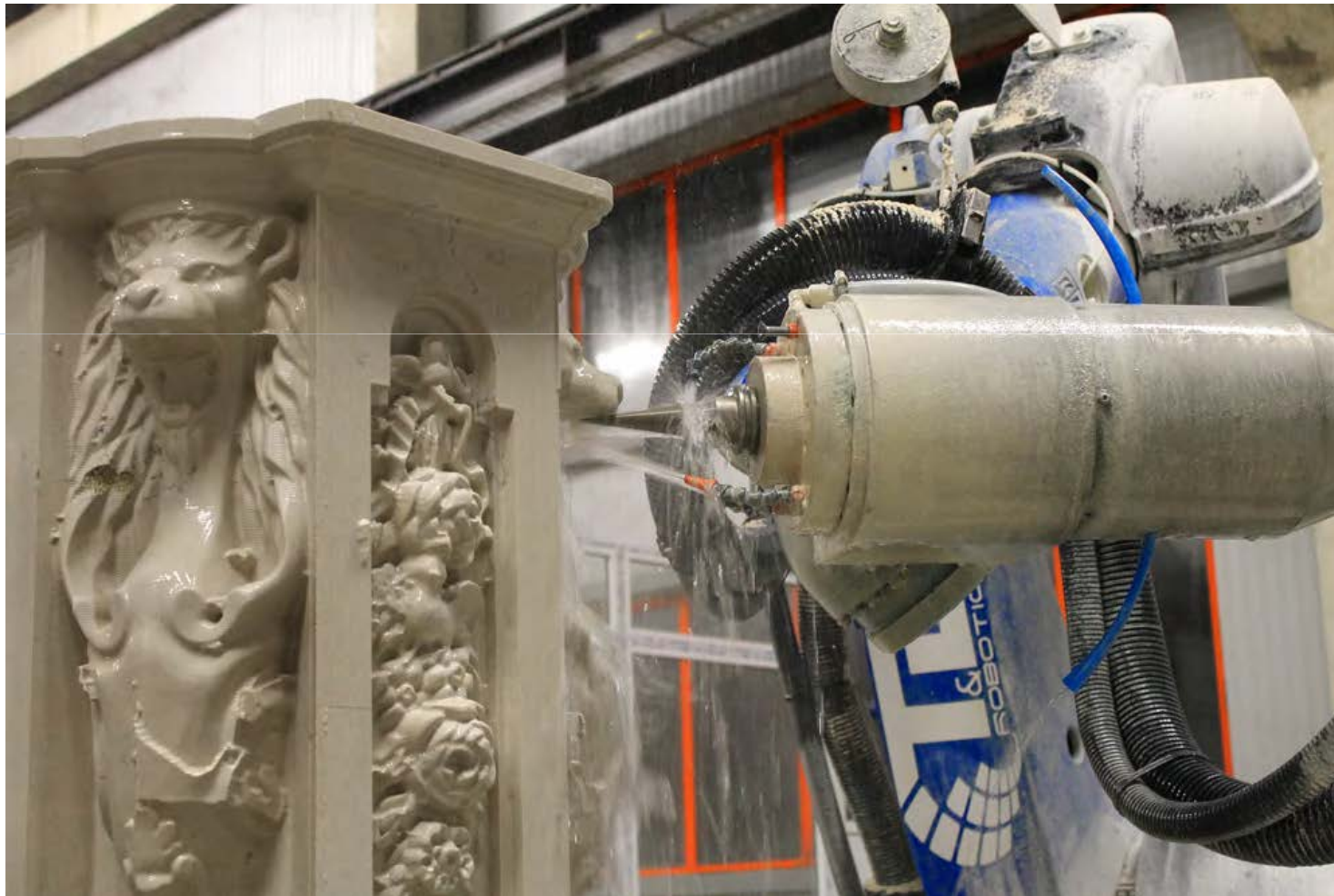


Case Study 7



Case Study 8

 **YOTOVSTONE**
STONE PROCESSING FACTORY



Case Study 8

 **YOTOVSTONE**
STONE PROCESSING FACTORY



Case Study 8

 **YOTOVSTONE**
STONE PROCESSING FACTORY



Case Study 9



Case Study 9



Case Study 9



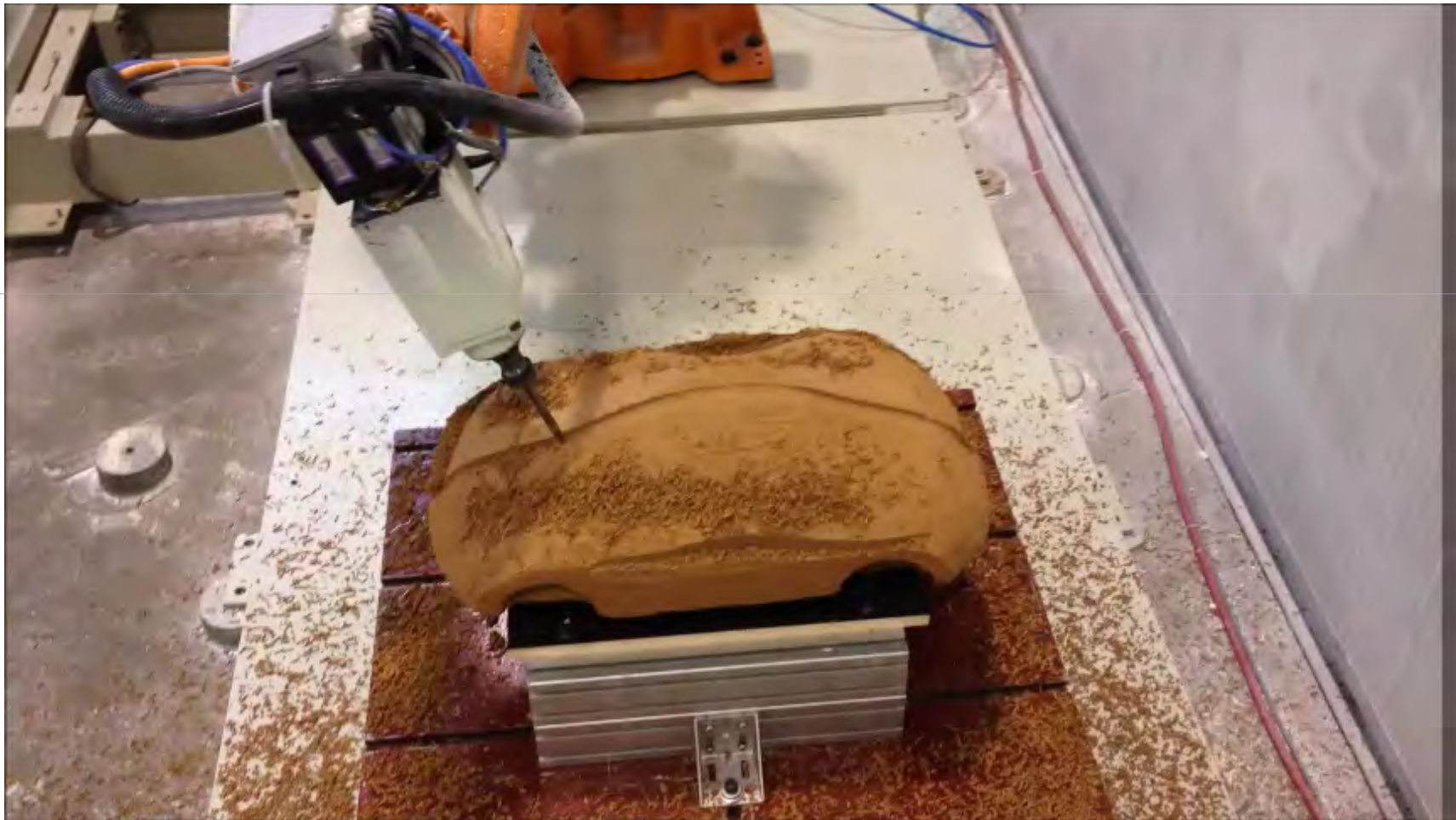
Case Study 10

Design and prototypes...

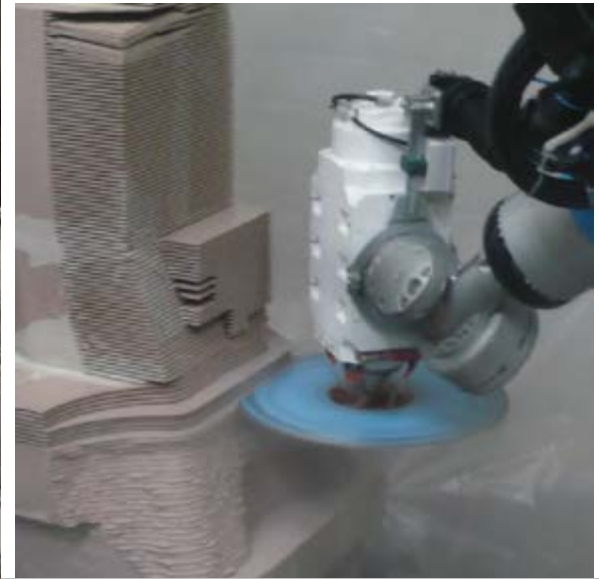


Case Study 10

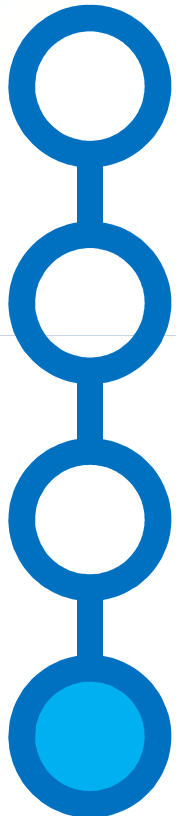
Design and prototypes...



And much more...



Content



Milling with robot: Challenges and COMET solution



Delcam robotics solution: PowerMILL Robot

Robot milling applications overview


Future of Advanced Manufacturing with robots

Applications?

Machining:

-  Sculpture in stone and wood
-  Modeling (foam, resin,...)

Trimming:

-  Trimming of all types of materials with Milling tool (Knife, Water Jet...)

Drilling:

-  Drilling of all types of materials

Welding/Cladding:

-  Plasma
-  Laser
-  Cladding

Grinding:

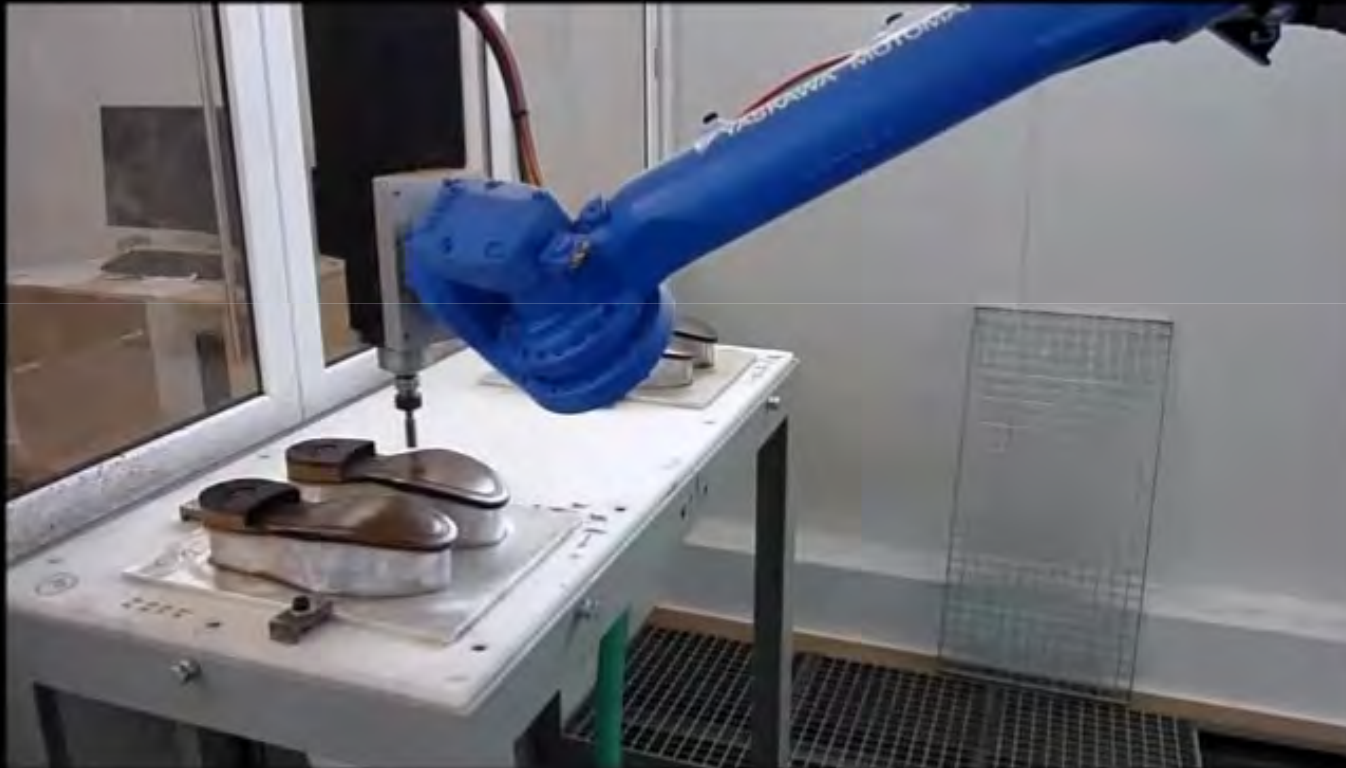
-  Linishing
-  Polishing

Measurement:

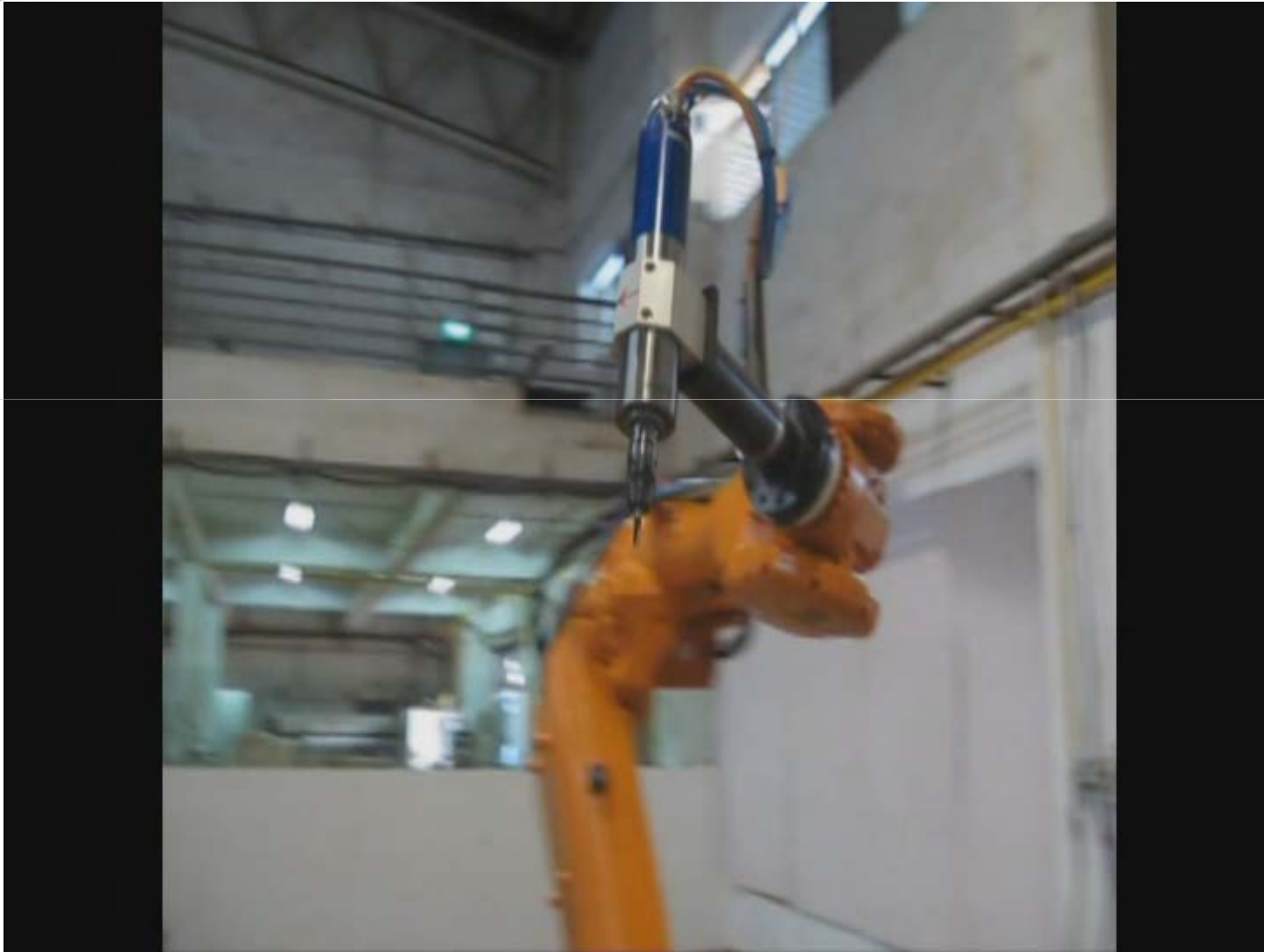
-  Non-destructive testing

...

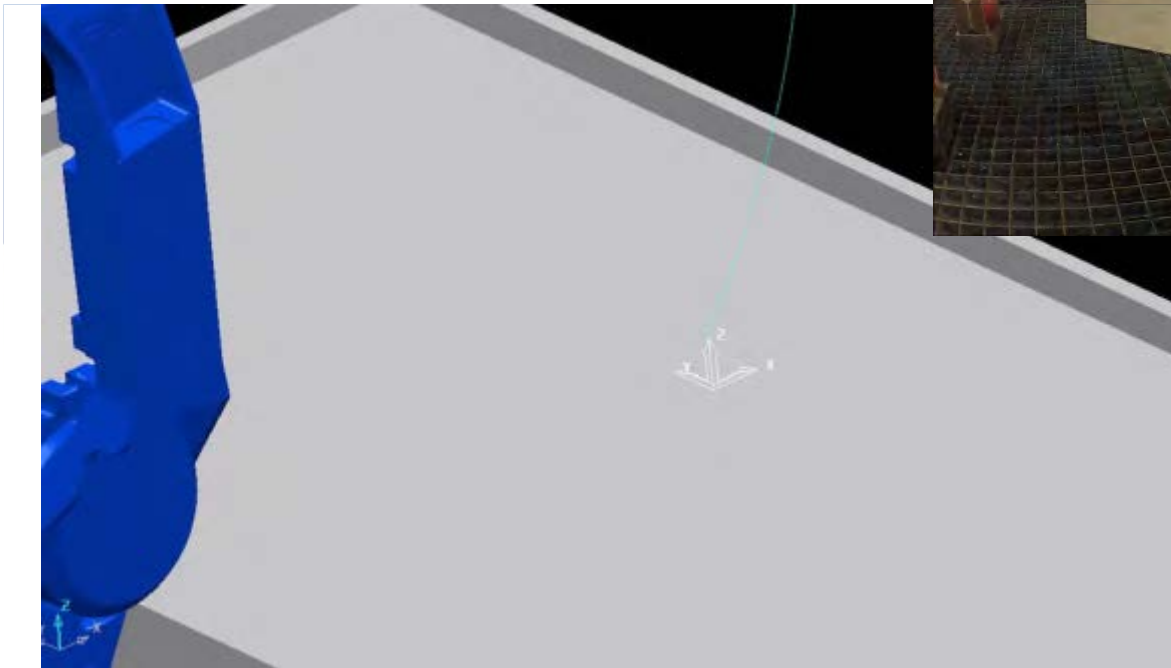
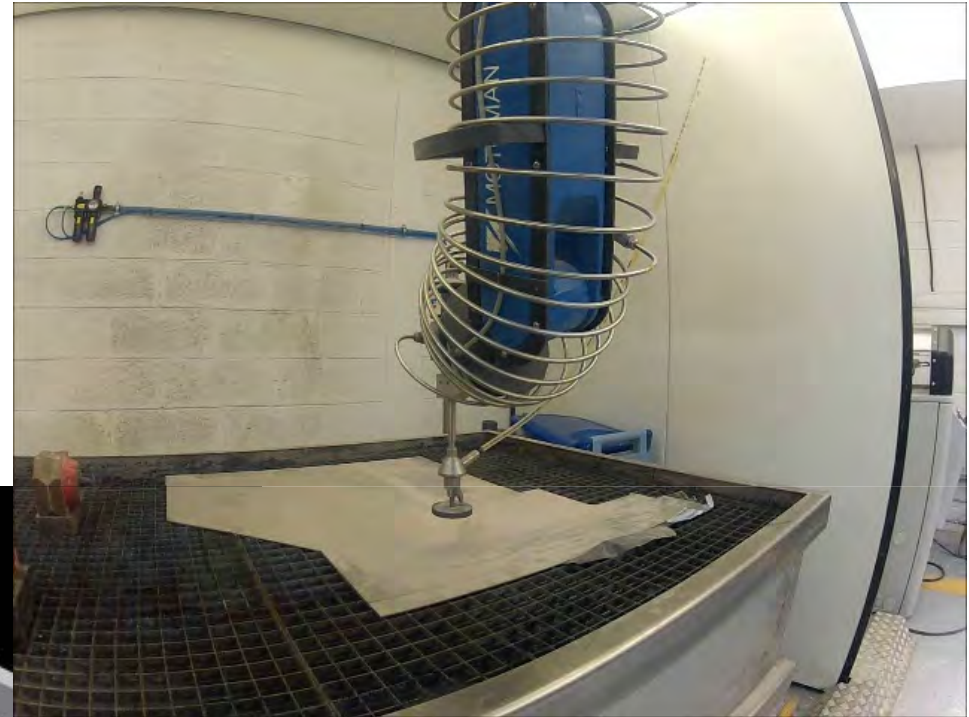
Milling/Trimming



Drilling



Waterjet/Laser/Plasma cutting

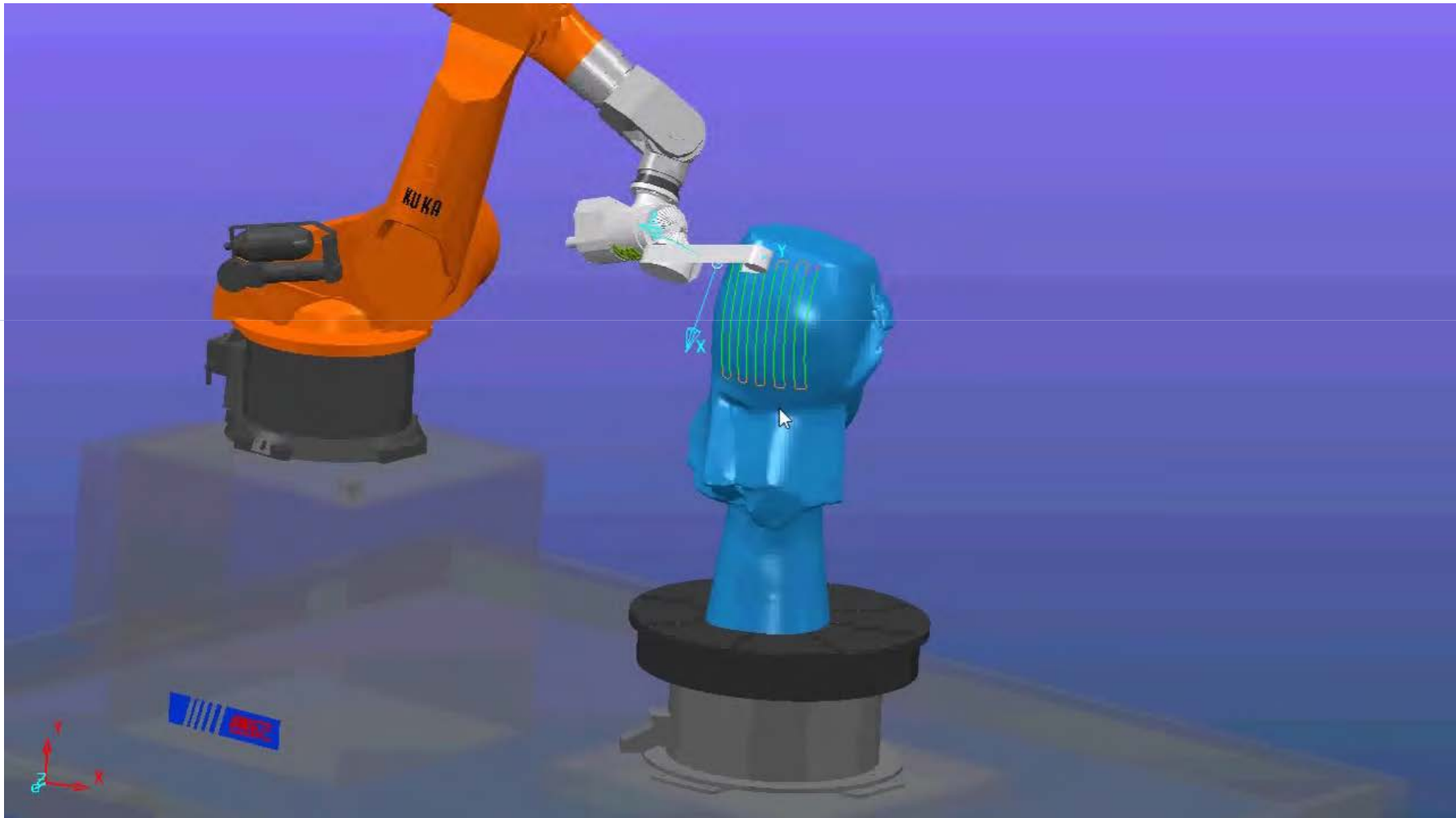


Additive manufacturing

Cladding / Welding



Grinding



Linishing/Polishing

Robot research cell @Delcam PLC, UK



Linishing/Polishing

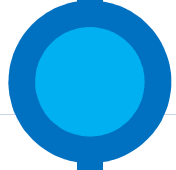
Robot research cell @Delcam PLC, UK



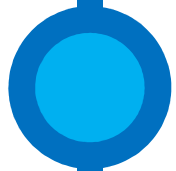
What have you seen?



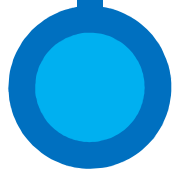
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Future of Advanced Manufacturing with robots

Thanks for your attention



Mr. Franck Messmer
Delcam PLC, Birmingham, UK
frm@delcam.com

<http://www.delcam-robotics.com/>

<http://www.cometproject.eu/>