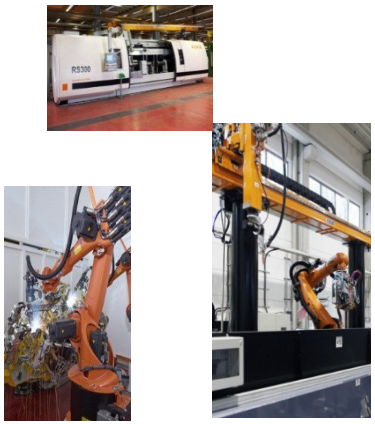
KUKA | Component, Cell, Solution & Service from one Single Source

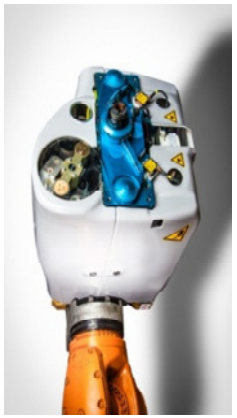
KUKA

KUKA Robotics	KUKA Industries	KUKA Systems	Swisslog
Product	Cell	Solutions	
			
Rev 2014: 834 M€ Rev 2019: ~ 1300 M€	Rev 2014: 300 M€ Rev 2019: ~ 500 M€	Rev 2014: 930 M€ Rev 2019: ~ 1100 M€	Rev 2014: 559 M€ Rev 2019: ~ 925 M€

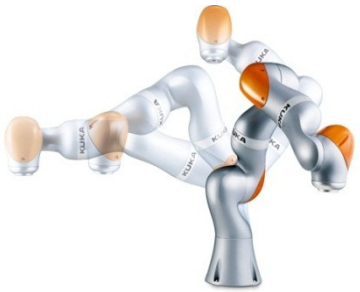
Integrated software solutions and modular product platform

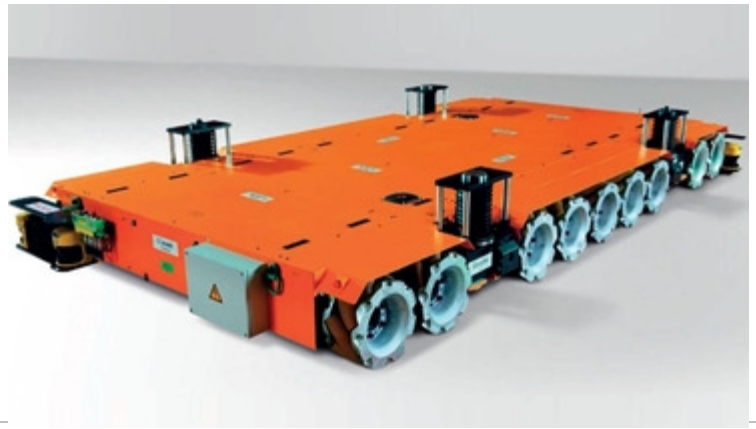
Robotics expertise | **Integration know-how** | **Systems and process expertise**

Global market access



- **Aerospace**
  - Devices and equipment for structural components
  - Automated solutions for various process steps
  - Technology bricks as Drilling & Fastening, Sealing, Painting, etc.
- **Automotive**
  - Body Structures
  - Bonding Technology
  - Assembly & Test
  - Production Operations
- **Advanced Technology Solutions**
  - System solutions based on LBR iiwa
  - Location-flexible process stations with human-robot collaboration

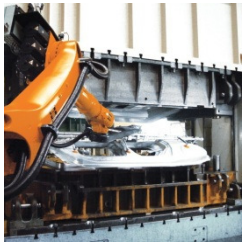




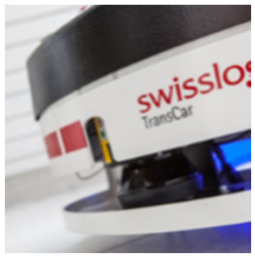
- **Robots**
  - Small robots
  - Small payloads
  - Medium payloads
  - High payloads
  - Heavy duty
  - Special models
  - Sensitive robotics with the LBR iiwa
- **Software**
  - Controls
  - Application modules
  - Customer Service
- **Omnimove**








- **Arc & Laser Solutions**
  - Welding cells and lines, arc and laser welding technologies and laser cutting
- **Casting Solutions**
  - Production solutions for the casting industry with presses, cells and lines
- **Advanced Welding Solutions**
  - Machines and robot-based solutions for friction and magnetarc welding joints
- **Technology Solutions**
  - Solutions for the manufacturing in the battery and solar industries
- **Customer Service und Technology Services**
  - Service, spare parts and technology consulting



- **Warehouse & Distribution Solutions**
  - Storage and retrieval machines for pallet and small-part high-bay warehouses
  - Warehouse systems: from small parts to single items to pallets

- **Healthcare Solutions**
  - Automated material transport (hospital pneumatic tube system)
  - Driverless container transportation systems
  - Automated solutions for hospital pharmacies
  - Automation in patient care sector (medication management)

KUKA

Sales revenue € 2.1 bn

12,102 Employees (incl. Swisslog)

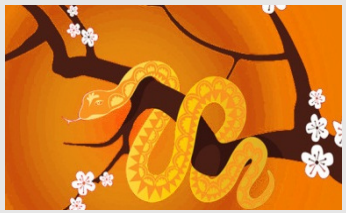
2014

Growth ~100%

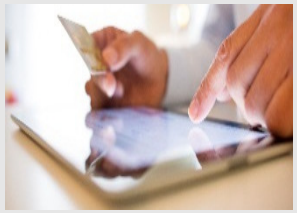
KUKA Aerospace

New Markets

New Products / Industry 4.0



China



Swisslog / E-Commerce

Sales revenue € 4 - 4.5 bn

2020

Megatrends | Changes to the Global Society

Economic

- Globalization
- **Flexibility and Versatility**
- Transport and logistics
- Value chain
- **Market, customer and consumption**

Technological

- **Digitalization of the Manufacturing Industry**
  - Big Data, Internet of Things/M2M, Cloud Technology
  - Digitalization and knowledge management
  - Usability, next-level GUIs
  - Advanced Robotics (e.g. Human-Robot Collaboration), additive manufacturing (e.g. 3D print)
- Industry meets IT
- New materials and lightweight construction
- Medicine and healthcare

Social

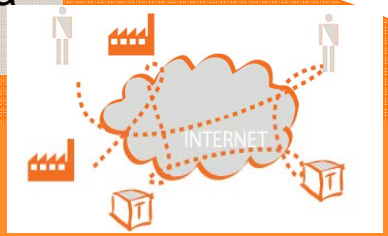
- **Demographic Change**
- Urbanization
- Mobility
- Education, knowledge and work
- **Health and safety for employees**

Ecological

- Resource availability
- **Climate protection, sustainability**

KUKA

“Industry meets IT”
Connect components, systems and data of different systems with each other



Intelligent robot systems support humans in the factory of the future

Standardized Interfaces based on **mainstream IT**

Human in the Focus

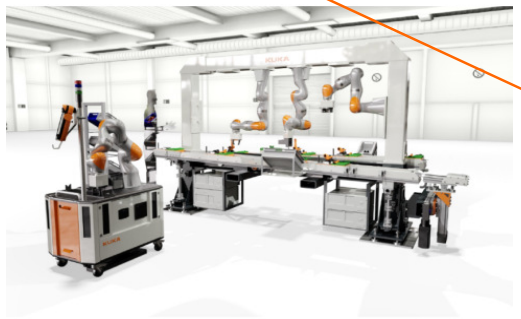
Robots enable humans to network in the digital world

Sensitive and safe robot-based automation solutions **(LBR iiwa)**

KUKA

1. **Human-Robot Collaboration**

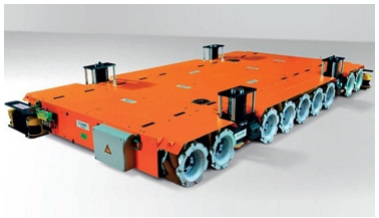
- Demographic Change
- Versatile Production



Smart Factory

3. **Mobility**

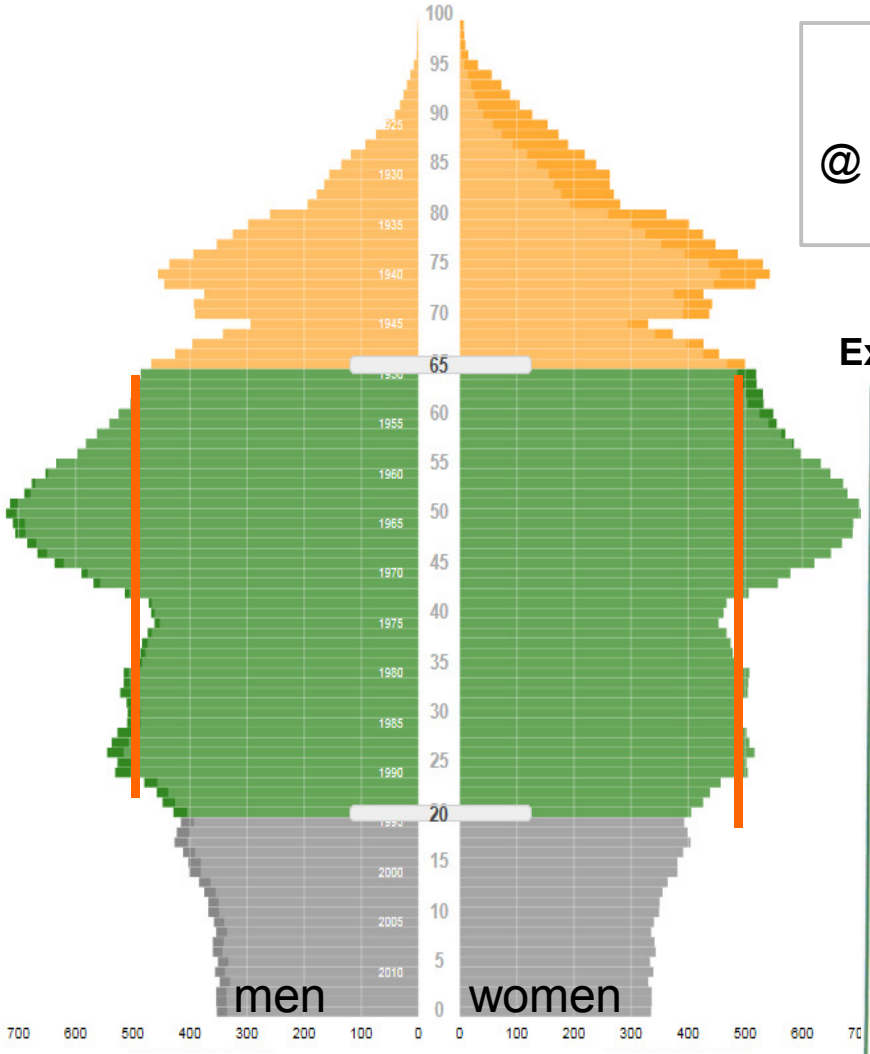
- Holistic Concept for Logistics & Production



2. **Intelligent control concepts enable the Connection to the IT– “Smart Platforms”**

- Digitalization of the Manufacturing Industry

Social Change | Demographic Change leads to Changes in the Structure of Employment

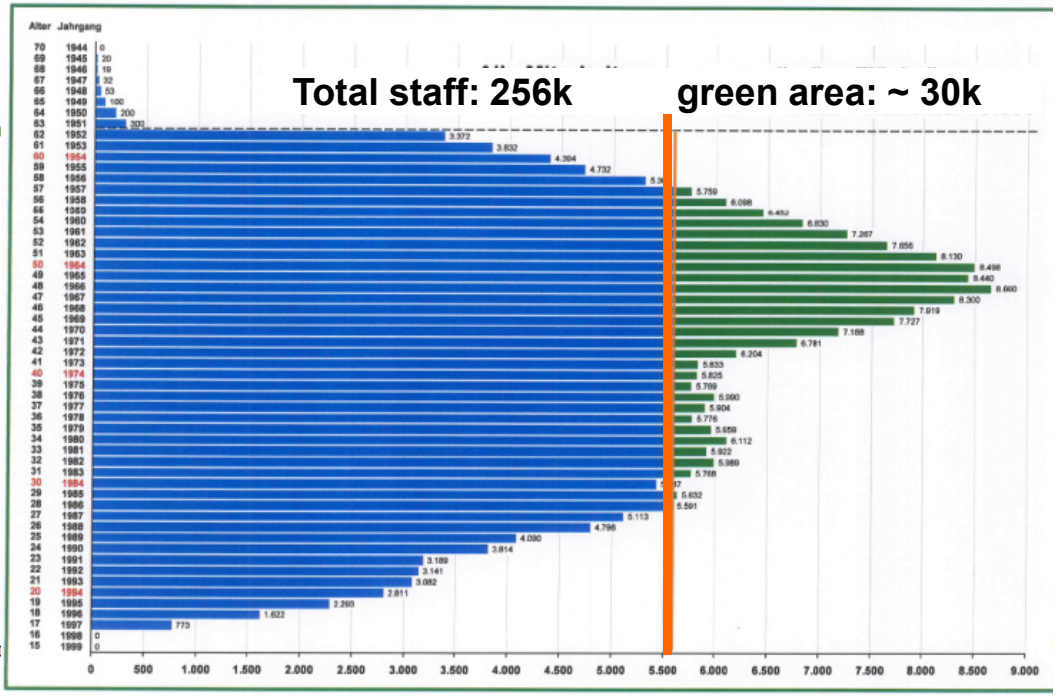


Age structure Germany 2014

Average age of workforce in 2014: ~ 50 years

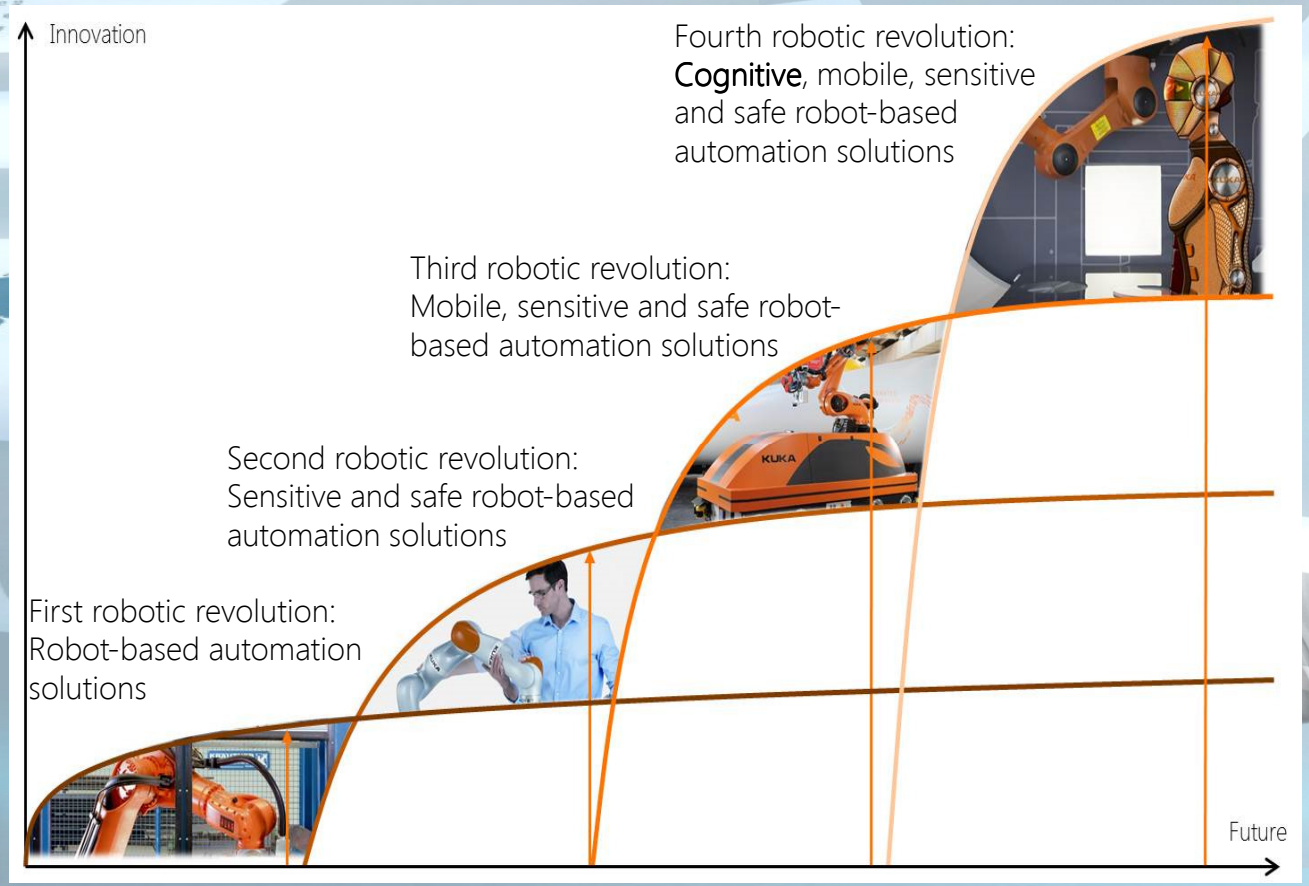
@ VW **more than 30k people** will retire in the next 10 years and **cannot easily be replaced**

Example: Age structure VW Germany, total staff 2014

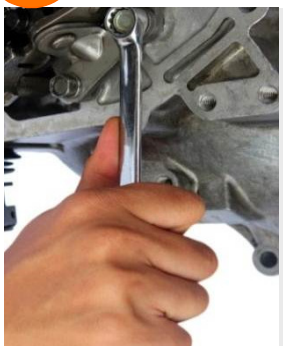


KUKA

Generation R – Dealing with Robots is just as natural as dealing with Smartphones for us today



1.



Manual Production

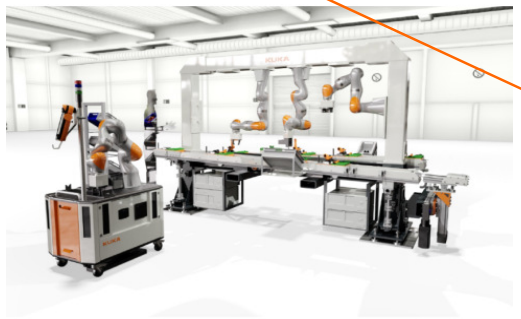
Human-Robot Collaboration

Full Automation

KUKA

1. **Human-Robot Collaboration**

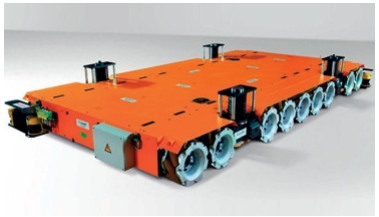
- Demographic Change
- Versatile Production



Smart Factory

3. **Mobility**

- Holistic Concept for Logistics & Production

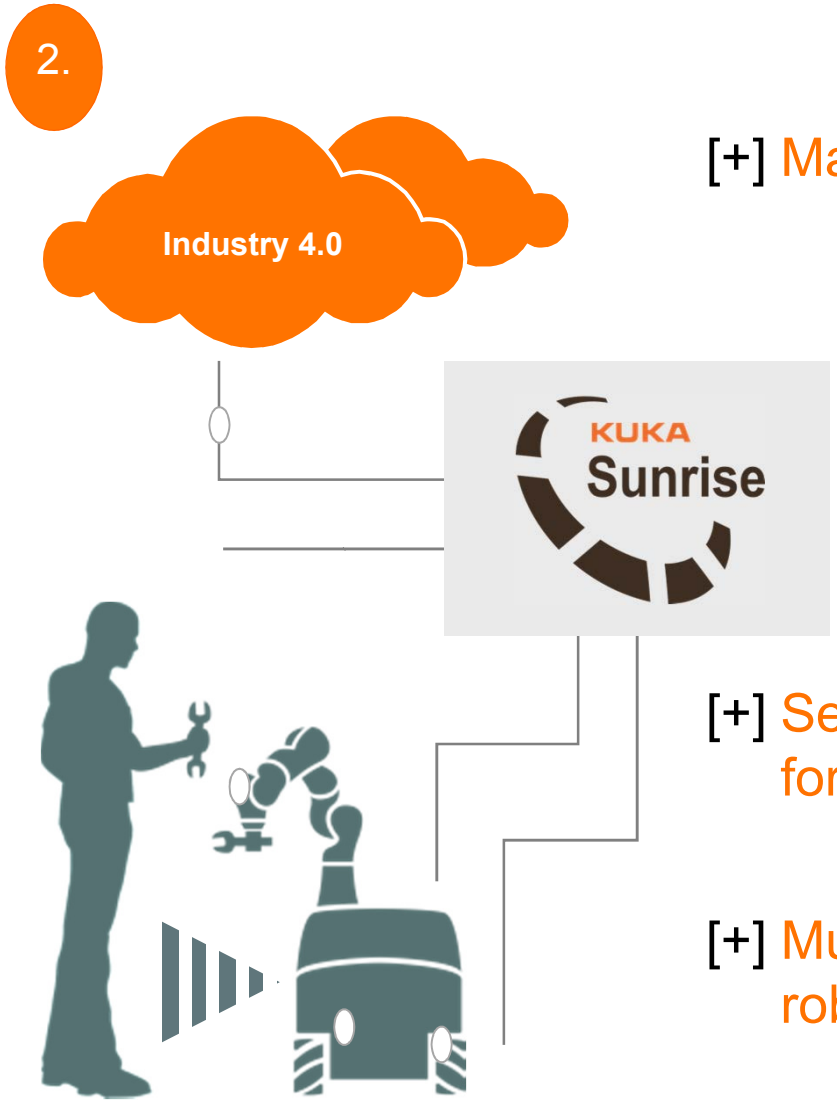


2. **Intelligent control concepts enable the Connection to the IT– “Smart Platforms”**

- Digitalization of the Manufacturing Industry

KUKA

2.



[+] Mainstream IT & standardized Interfaces

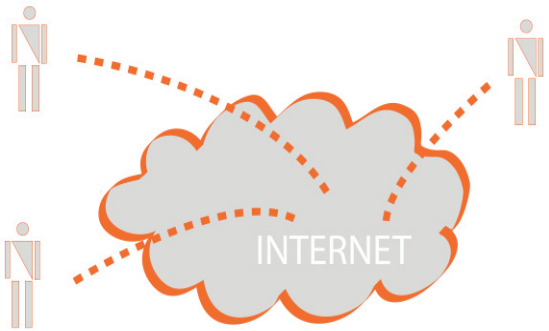
[+] Human-Robot Collaboration

[+] Flexible automation with mobile and autonomous robots

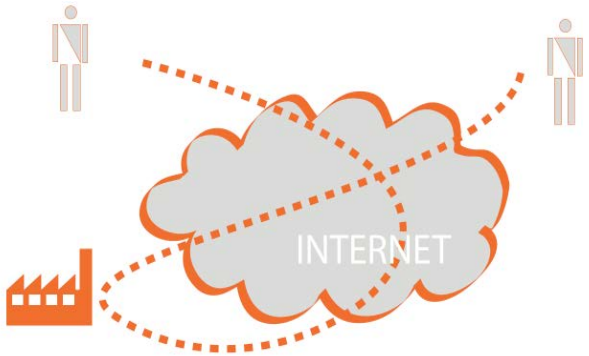
[+] Sensor-based applications for Smart Solutions

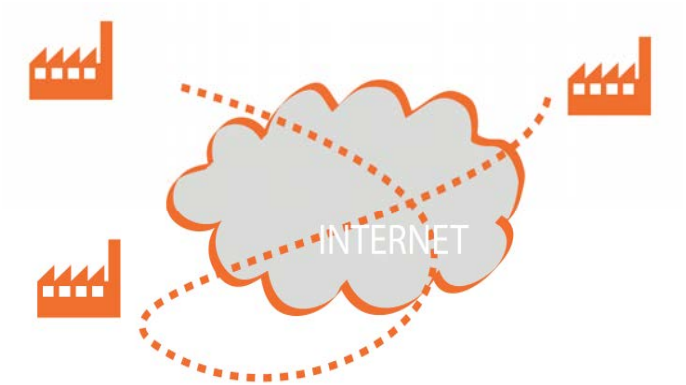
[+] Multi-kinematics for robot systems

Human 2 Human

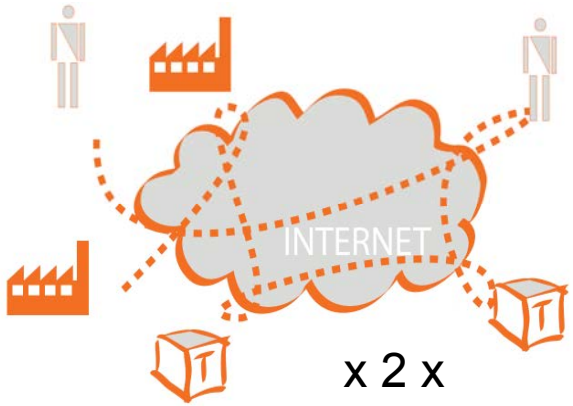


Human 2 Machine





Machine 2 Machine

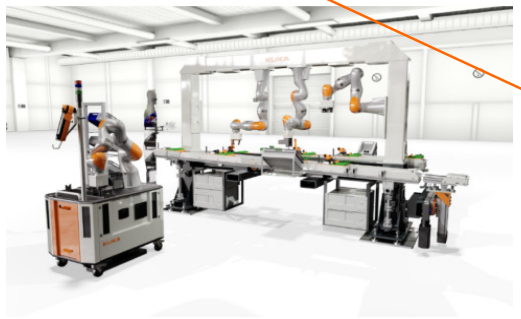


→ Leads to new Eco Systems

KUKA

1. **Human-Robot Collaboration**

- Demographic Change
- Versatile Production



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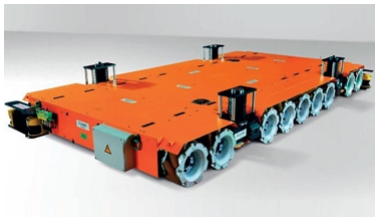
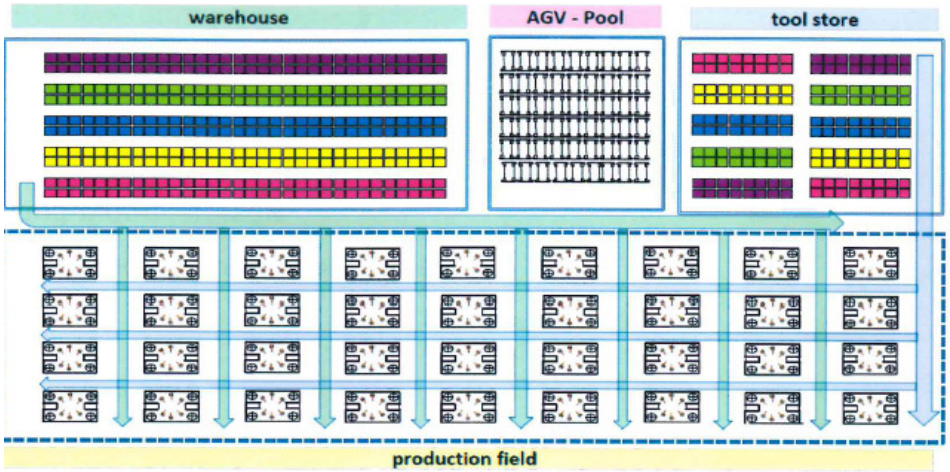


2. **Intelligent control concepts enable the Connection to the IT– “Smart Platforms”**

- Digitalization of the Manufacturing Industry

3.

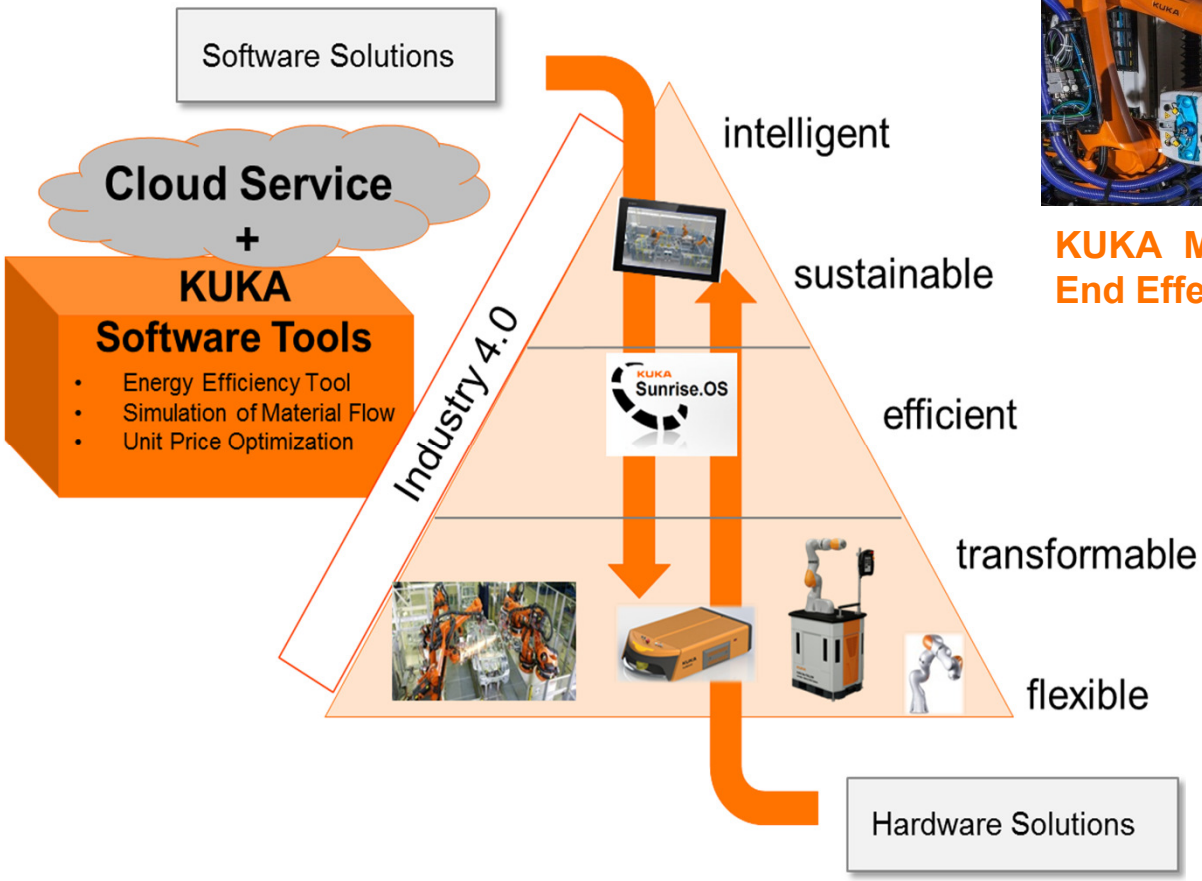
- Transformation of logistics know-how from warehousing and distribution to production logistics
- Gripping and handling concepts with the LBR iiwa
- Warehouse systems are completely independent of the order size
- Bottlenecks are reported automatically, projection based on empirical data
- Intelligent combination of automation and logistics know-how for an integrated production solution
- Flexible and versatile equipment for material handling

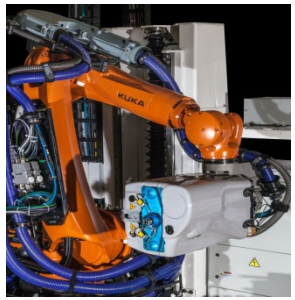



KUKA

- Smart combination of Automatization and Logistics for handling and production
- Versatile and flexible equipment leads to a flexible and scalable production
- Re-usable assets → MFEE (Multi Functional End Effector, MRP Mobile Robotic Platform, Omnimove

Industry 4.0 | Software and Hardware Solutions required





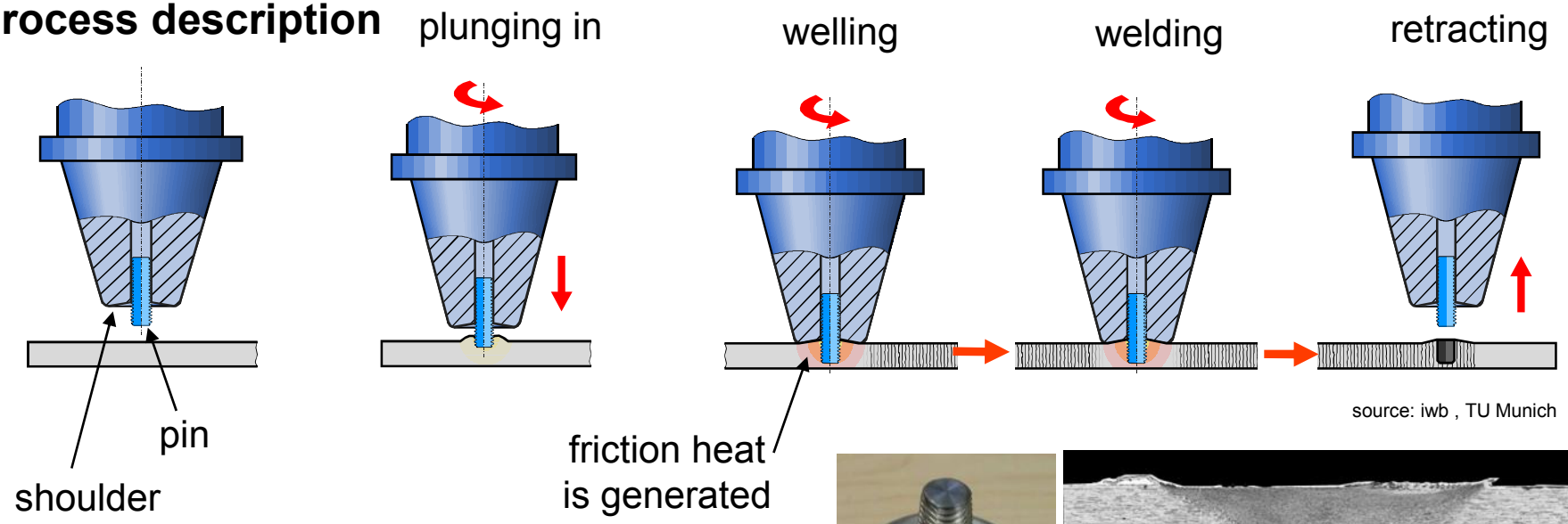
KUKA Multi-Functional End Effector MFEE

KUKA Mobil Robot Platform MRP

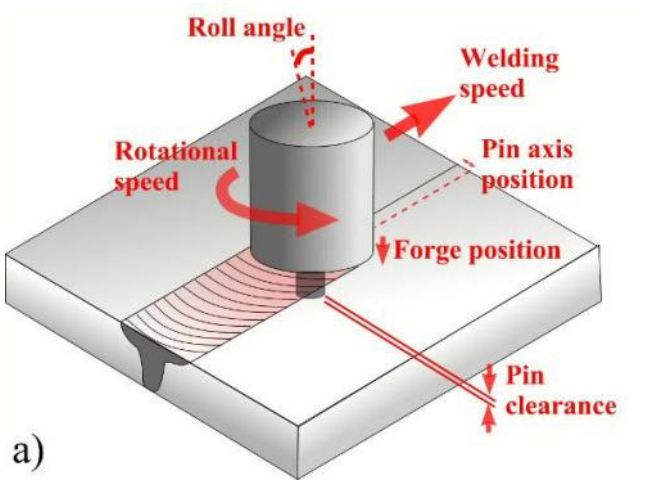
Outlook | KUKA sets Trends in Automation

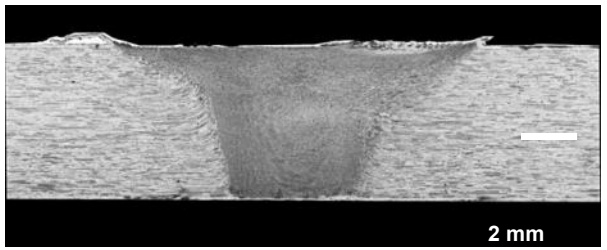
KUKA

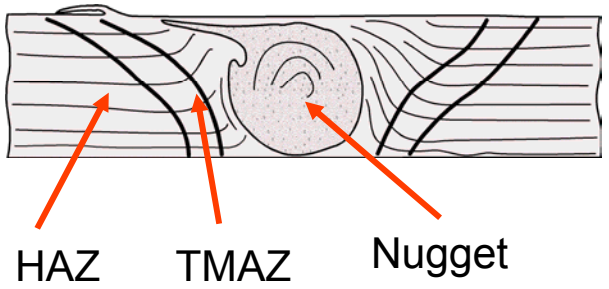
Process description



source: iwb , TU Munich







FSW Technology Landscape

Material Universe

- All kinds of Aluminum (Al) alloys
- Al + Fe
- Al + Ti
- Al + Mg
- Mg + Mg
- Polymer based Thermoplastics

Welding Depth

- **Milling/Gantry Machines:** 0.3mm to 100mm
- **Robot :** 0.3mm to 8mm (extended from 8mm to 15 mm)

Machines

- Robots
- CNC Milling Machines
- Gantry Machines

Current User Markets

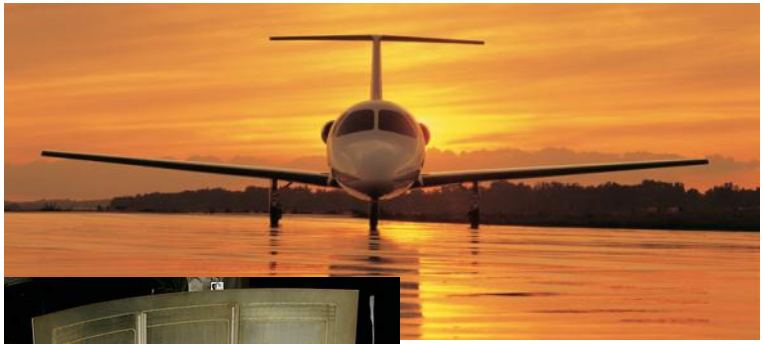
- Auto (OEM + Suppliers)
- Aerospace
- Rail (Metro Transport)
- Shipbuilding
- Extrusions
- Wind Energy
- Consumer electronics
- Medical Equipment….. & many more

source: Airbus-IW

Introduction – FSW Application

welding of fuselage of the Eclipse 500 Business Jet

structural component of the McLaren 12 C
(source: McLaren)



structural component of the Panoz Esperante
(source: Friction Stir Link)

Introduction – Application fields

Pictures/Courtesy: sapa:

Electronic components manufacturing

shipbuilding

(HSC Gotland Ferry)
(source: Internet)

railway manufacturing

Shinkansen
(source: Internet-Hitachi)

Relevant machines for FSW

German Engineering. Since 1898.

KUKA. The key figures.

KUKA YOUR IDEAS.

Sustainability. An integral feature of our corporate culture.

KUKA. Diversity & flexibility.

Different machine concepts suitable for FSW

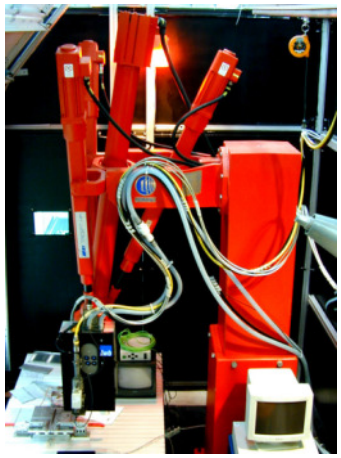
Special FSW machines

source: ESAB

source: Heller

CNC milling machines

Parallelkinematic Systems (Tripods, Hexapods)



source: Airbus-IW/KUKA

Articulated arm robots

Comparison

	FSW machine	milling machine	parallel-kinematics	articulated arm robot
control	advantageous	advantageous	advantageous	advantageous
stiffness	advantageous	balanced	balanced	less advantageous
space requirement	less advantageous	less advantageous	balanced	advantageous
working area	advantageous	balanced	balanced	advantageous
3D-capability	less advantageous	less advantageous	balanced	advantageous
welding depth	advantageous	balanced	balanced	less advantageous
invest	less advantageous	balanced	balanced	advantageous

Solved; force cotrol

Limitation[1*)]

advantageous balanced less advantageous

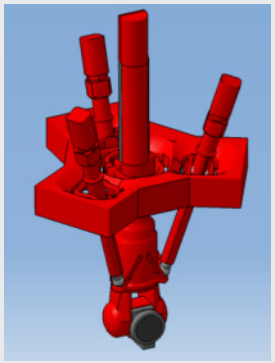
source: iwb , TU Munich

[1*)] → Articulated arm robots represent a flexible tool, which are suited for FSW on thin profiles (testet from0,3 mm to 8 mm Al alloy, 2xxx, 5xxx, 6xxx, 7xxx).

Available FSW Platforms

CAPITAL COST

Parallel Kinematic Machines



Advantages
- high payload & stiffness
- accuracy
- 3D-capability

Limitations
- cost
- workspace

Gantry-Type FSW Machines

Advantages
- high payload & stiffness
- accuracy
- workspace

Limitations
- cost
- non reconfigurable

Source: Eclipse Aviation

WORK ENVELOPE

Modified Machining Centres

Source: MAKINO

Advantages
- low cost
- high payload & stiffness
- accuracy

Limitations
- workspace

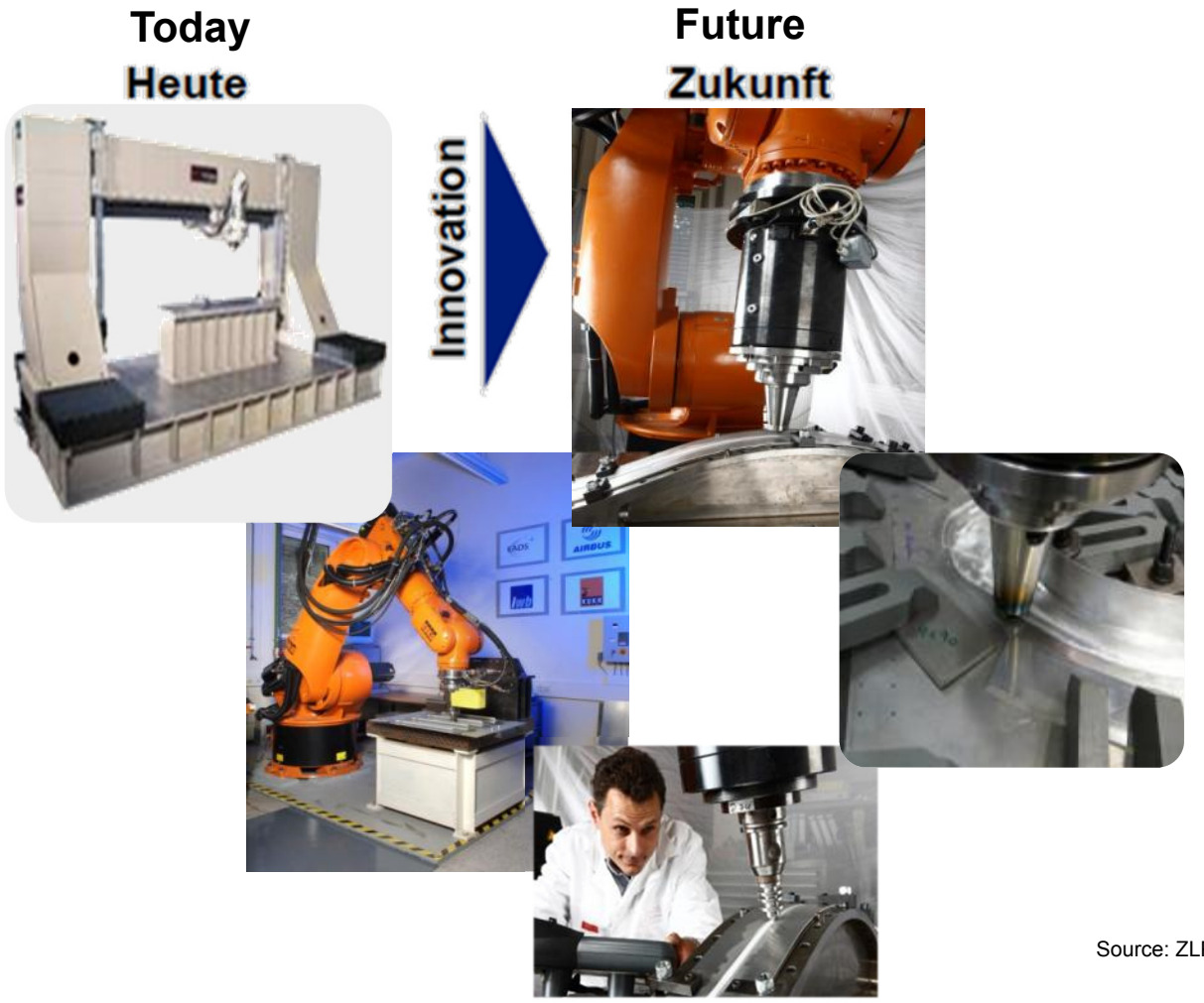
Serial Industrial Robots

Advantages
- low cost
- payload
- 3D-capability/workspace
- reconfigurable

Limitations
- stiffness
- low dynamics

Rail mounted

source: CNRC



Source: ZLP Nord-Süd, DLR

History of RoboFSW

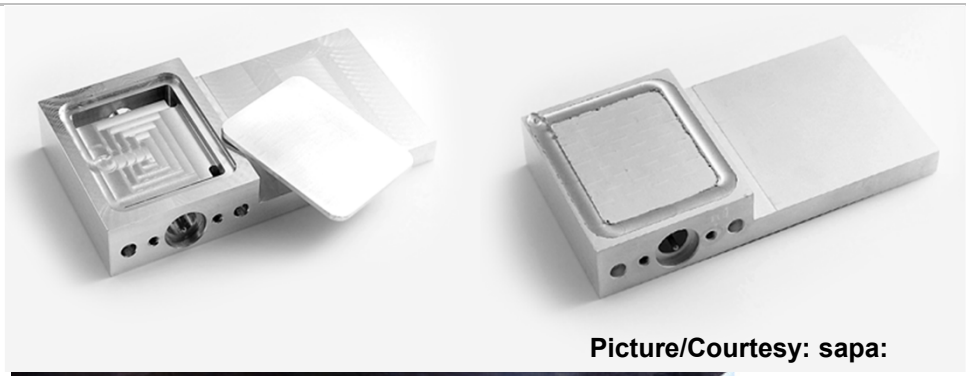
Start 2003 -> request from SAPA

2004 / July -> request from EADS

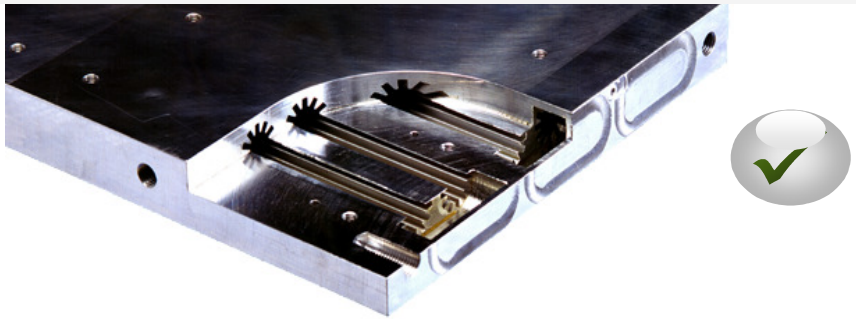
2005 / Feb -> Consortium
- **Airbus, EADS**
- **iwb, KUKA Roboter**

2007-> order for electrical spindel and new robot to CNRC Montreal also to BMW

2008 -> finish Airbus project
2009 -> FSW robot to AUDI
2010 -> Eurocopter + LTH (casting)
2011 -> electronic ind.
2012 -> electronic ind.
2013 -> automotive (Daimler)
2014 -> railway (Hitachi), aero (ShinMaywa)
2015 -> aero



Picture/Courtesy: sapa:



Picture/Courtesy: AIRBUS- IW

Capability of a high payload articulated arm robot

The „RoboFSW“ consortium for evaluation (2004)

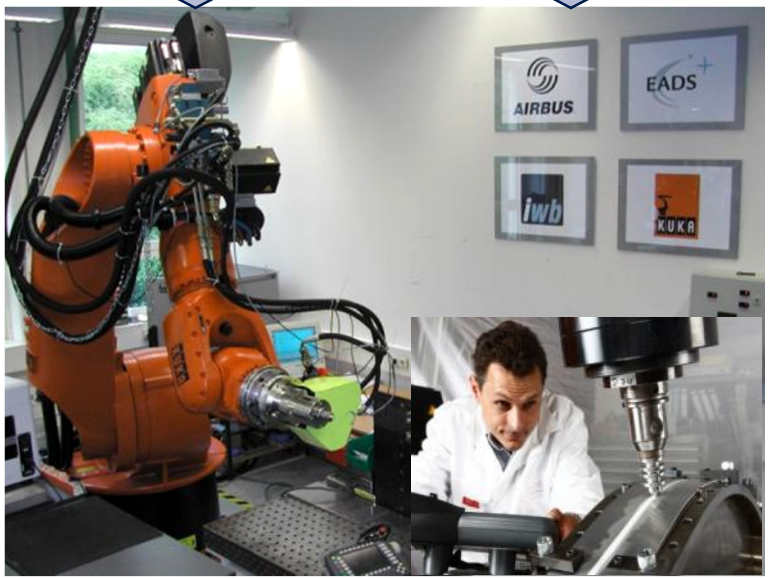
AIRBUS GROUP
AIRBUS
EADS KUKA
iwb

application

evaluation &
system integration

supply of KR500 &
optimization

experimentals,
simulation & evaluation



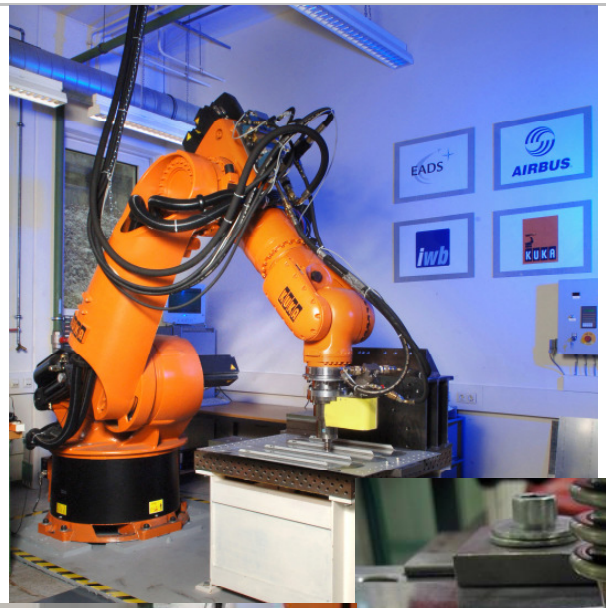
Capability of a high payload articulated arm robot

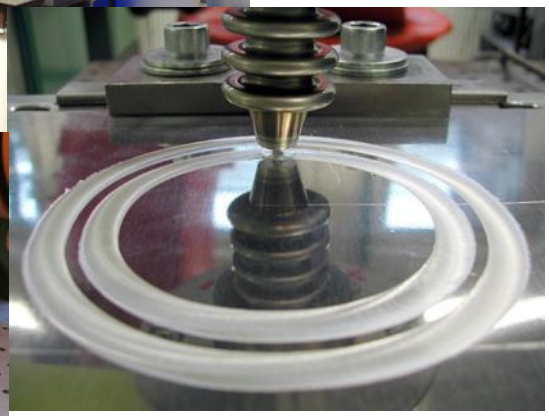
Initial - classic FSW system (2004)

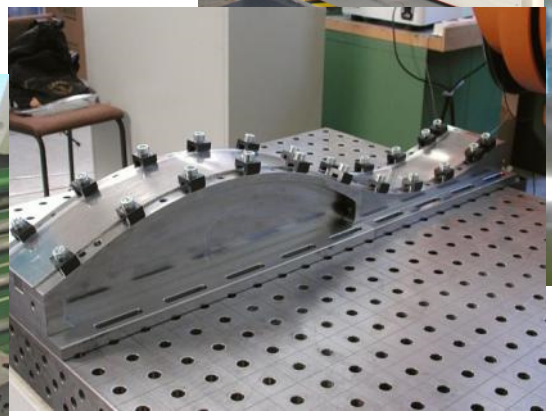
Robot
- KUKA KR500
- modified to realize higher process forces – KR 500MT

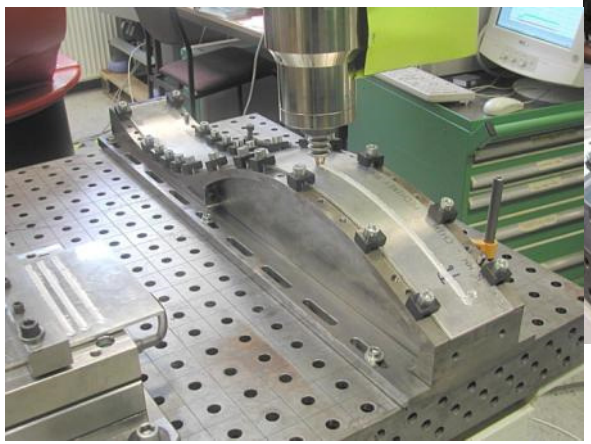
Welding head
- hydraulically driven
- rotation speed up to 2800 rpm

Process forces
- force sensor between flange and welding head
- process force controlled without any additional axes





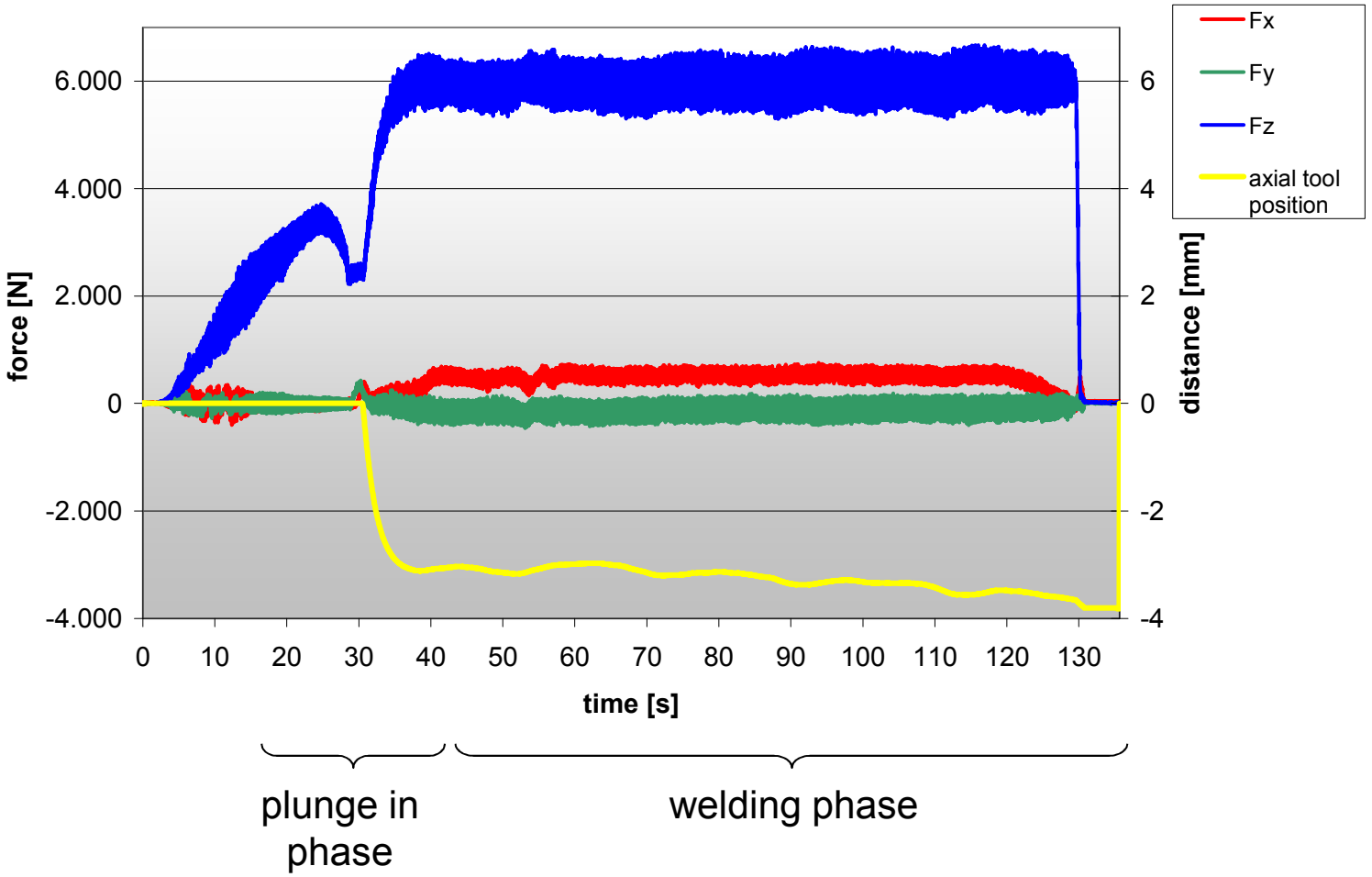




Souce: AIRBUS –IW Laboratory

Capability of a high payload articulated arm robot

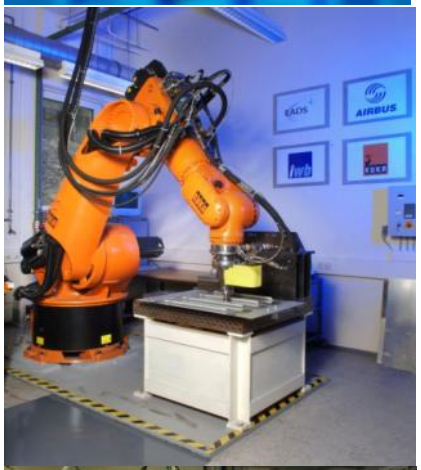
Force controlled welding mode without additional axes



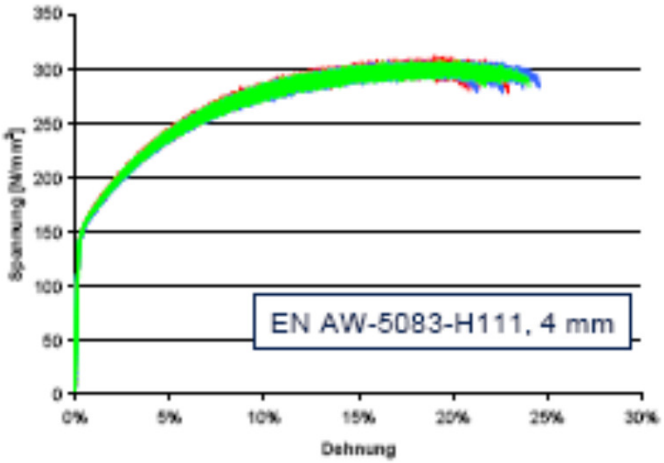
source: iwb/Airbus - IW

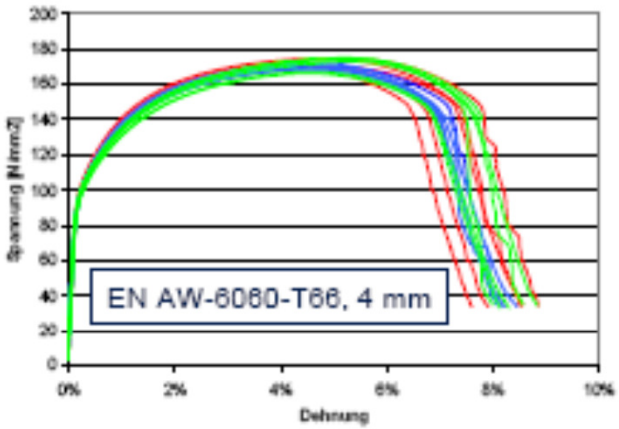
Capability of a high payload articulated arm robot compared with other FSW Machines (Heller and ESAB)

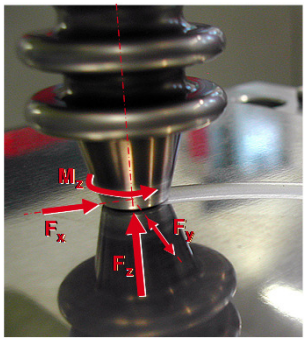
Quelle: Heller




Picture: EADS







Without Quality difference between the machines - Benchmark:

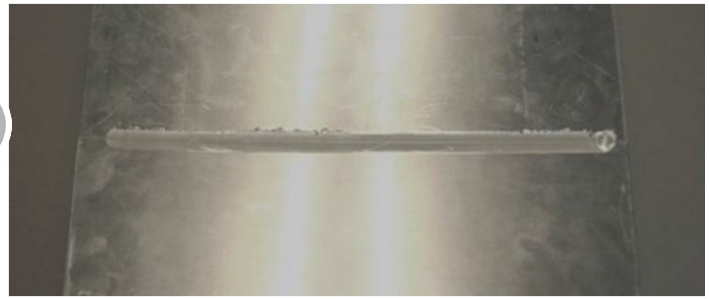
- modified milling machine
- KUKA articulated arm
- esab FSW laboratory machine

source: iwb / Airbus-IW

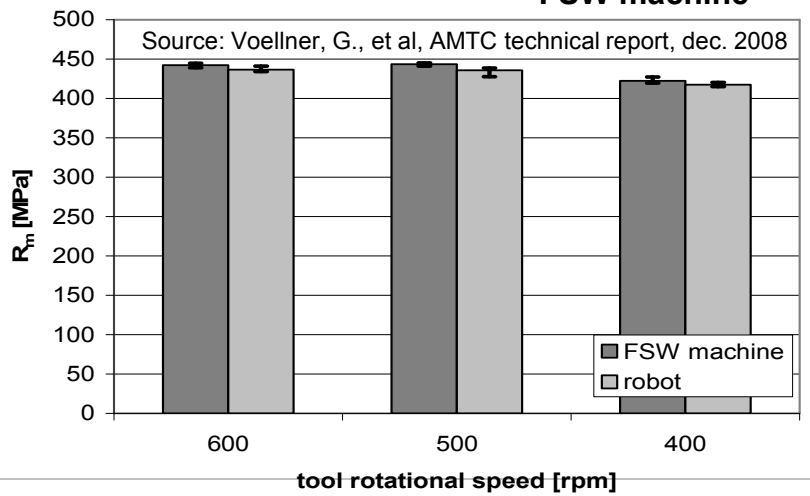
Results - capability of the robot welds

Properties of resulting Butt joints

2,3-mm 2024-T3 Butt weld

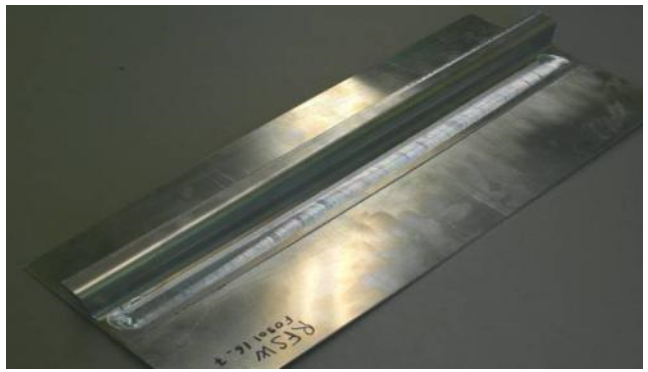


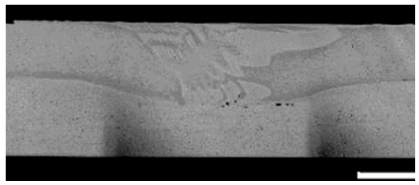
Robot **FSW machine**



Properties of resulting Lap joints

1,6-mm 7075-T6 stringer on 2,3-mm 2024-T3 skin





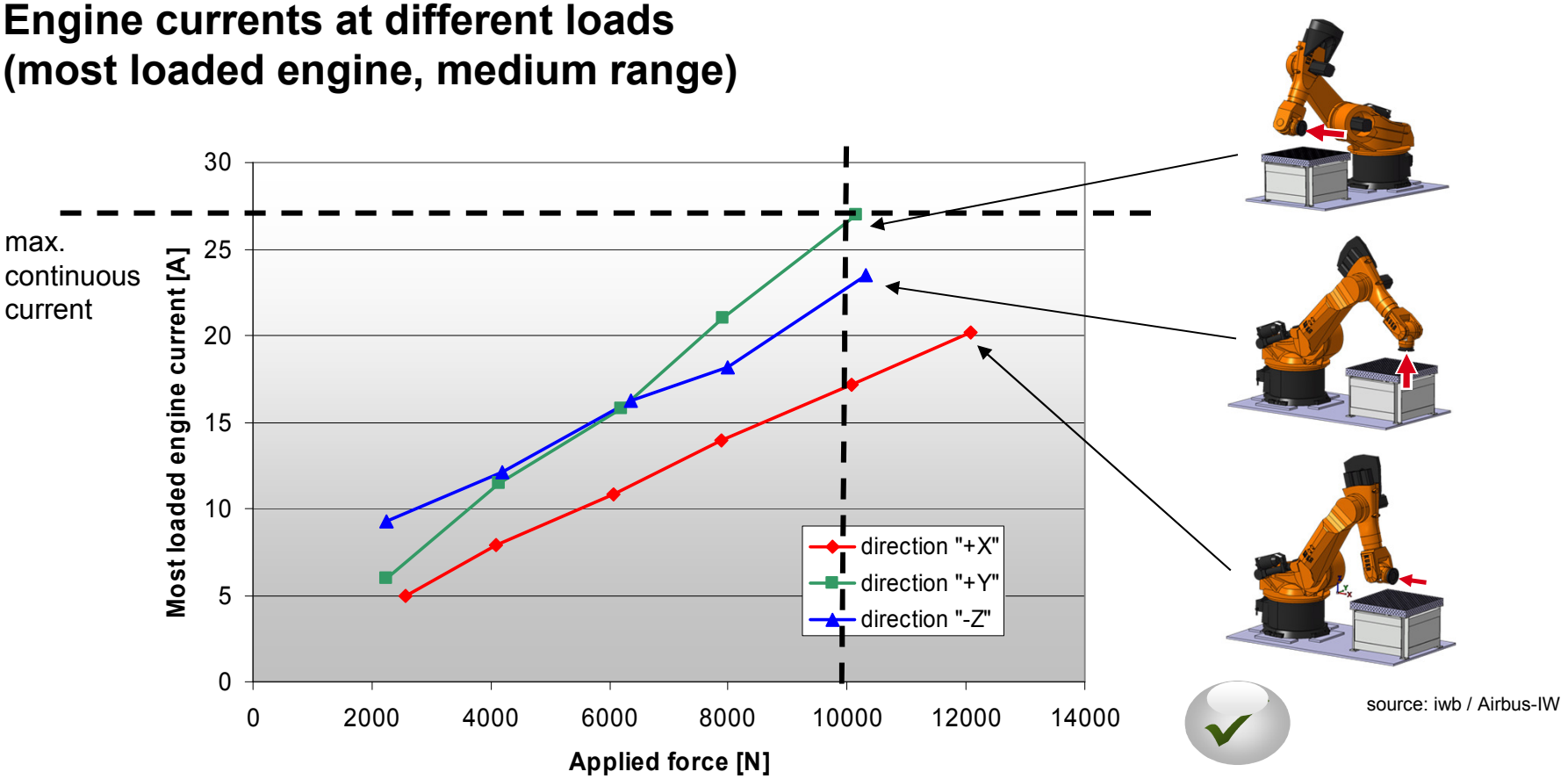
Robot **FSW machine**

- Equivalent cross sections were observed for Butt and Lap welds
- Good correlation between tensile properties of robotically-welded butt welds compared to FSW machine

source: iwb/CNRC

Push button for more weld examples

Engine currents at different loads (most loaded engine, medium range)

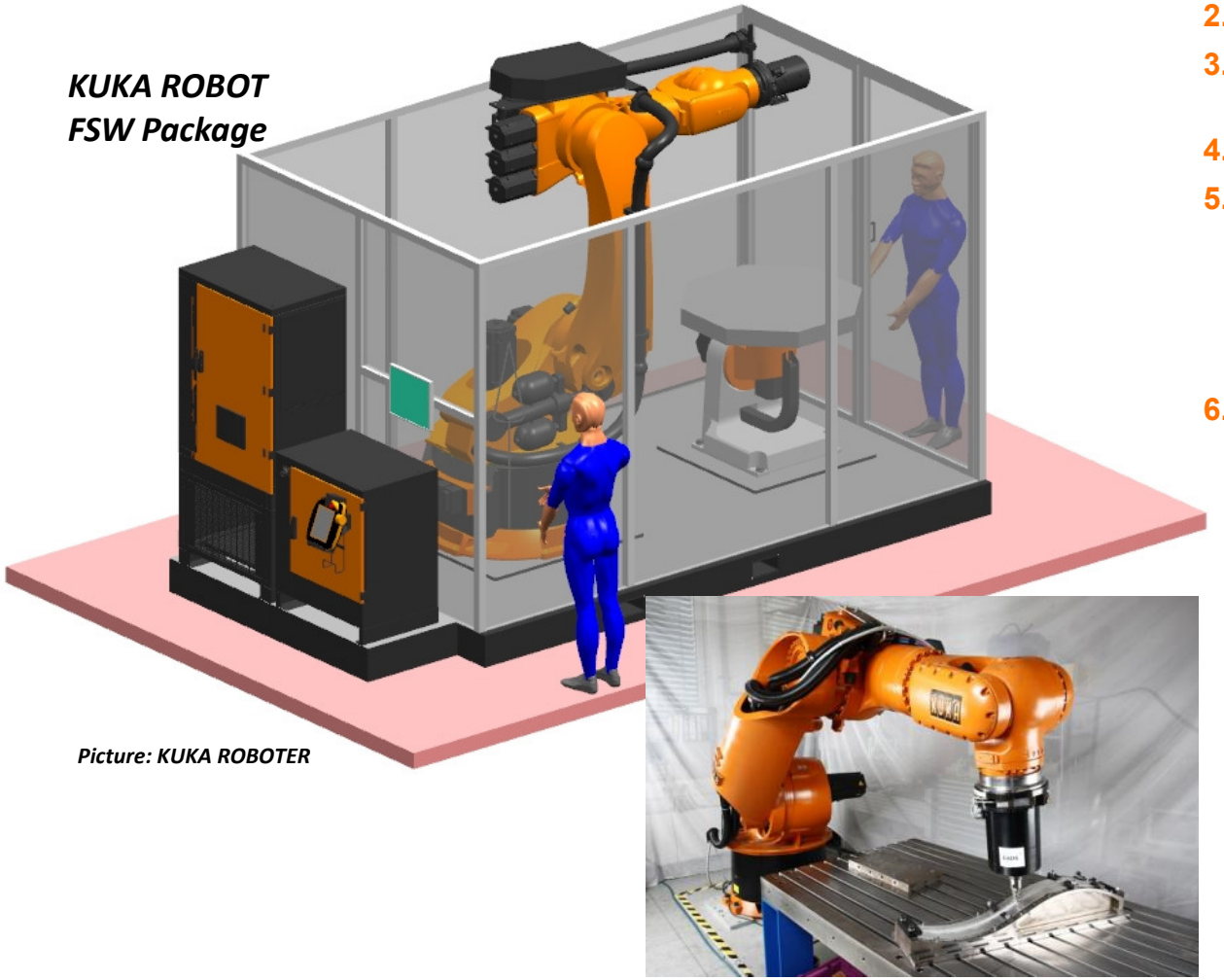


source: iwb / Airbus-IW

→ **process forces of up to 10 kN can be achieved in every basic end-effector orientation** **(in defined Positions of robot work room more Process forces; on request scalabable up to 18 KN)**

KUKA Capability

Actual classic FSW system package



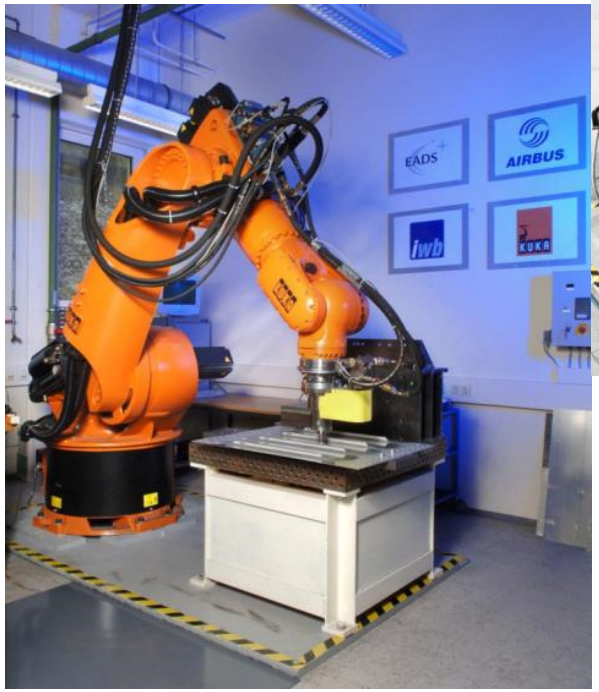
Picture: KUKA ROBOTER

1. **KUKA KR 500-3 MT**
2. **KUKA KRC4 8.2**
3. **Integrated spindle drive as 7th axis of the robot control cabinet KRC4**
4. **Spindle (~45Nm, 3500-5000 rpm)**
5. **Technology cabinet**
   - Hydraulic unit
   - Spindle coolant unit
   - Safety PLC (Siemens ET200s F-CPU)
   - Interface for customer cell
6. **Energy supply including K-Box**

Development (→success)

KUKA

First robot solution 2004



Solution 2015

Innovation Award