Manufacturing Technology Centre

Inspiring Great British Manufacturing

SAFETY IN INTELLIGENT MANUFACTURING

Jeremy Hadall

November 2017

BACKGROUND

- Opened in 2011
- Independent RTO
- To bridge the valley of death
- Prove innovative manufacturing ideas
- Manufacturing system solutions
- Training

UNIVERSITY OF BIRMINGHAM

Loughborough University

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

TWI

WE'RE BRINGING SOLUTIONS TO LIFE

- Large scale projects converting ideas into viable processes, that are transferred into industry
- Working with project partners to access research and development funding via European, national and local government
- Improving UK productivity

ROBOTICS AND AUTONOMOUS SYSTEMS

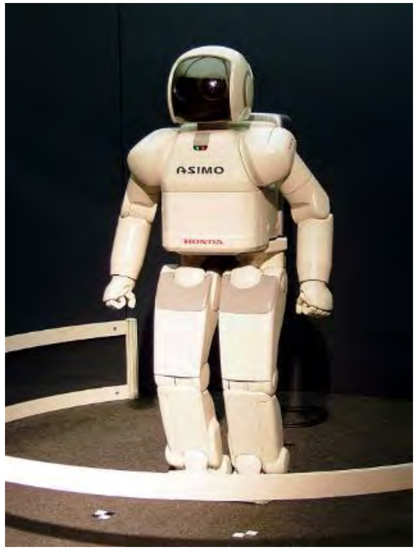
- Specialise in the automation of manufacturing processes in a novel and collaborative way
- Development of advanced technologies including robotic manipulators, sensing technologies, adaptability, and the ability to think and act autonomously
- World-class equipment ranging from state-of-the-art robotic and automation systems, through to industrial scale manufacturing cells

INDUSTRIAL ROBOTS

WHAT IS A ROBOT?

A MECHANICAL **OR** VIRTUAL AGENT

- Can be autonomous or semi-autonomous
- The word was first termed by a Czech playwright in 1921
- But there have been accounts of ‘automata’ dating back to ancient civilisation
- Can take many forms from Honda’s ASMIO to industrial robots to ‘Big Dog’



Images: Honda/Boston Dynamics/Fanuc

A LITTLE BIT OF HISTORY…

172 THE MECCANO MAGAZINE

An Automatic Block-Setting Crane

Meccano Model Controlled by a Robot Unit

THE model illustrated on this page is a blocksetting crane of splendid design, but unlike other examples of this popular type it actually builds walls, simple dams or breakwaters automatically. Without any aid from its designer, it lifts up miniature blocks from piles arranged near it and places each in position with such uncanny certainty that anyone watching it at work might almost think it capable of thinking.

The builder of this astonishing model is Mr. Griffith P. Taylor, Toronto, who appears to have had a Wellsian vision of "Things To Come" in a world in which human labour will not be necessary for building up the creations of engineers and architects. He has named his model "Robot Gargantua." Its "brain centre," as it may be called, is the unit shown on the left in the illustration. This controls every movement and carries out each in its turn.

Although the chief interest lies in the robot mechanism, the crane itself incorporates many ingenious and novel constructional features. For example, the boom swivels on a vertical pillar, inside the main tower, that is provided with two roller bearings, one fixed to the underside of the boom and the other to a point on the pillar itself and near its lower end. This arrangement is sometimes used in the construction of actual cranes of this kind, but is seldom adopted by model-builders. Another feature of the crane is that all the levers by which its various operations are controlled are grouped together at the base. The chief purpose of this is to enable them to be connected easily to the robot mechanism. The block-lifting gear and hoisting trolley are operated through a gear-box placed at the top of the boom pillar, and slewing of the boom is carried out through separate gearing situated at the base of the tower. All the movements are driven by a single motor mounted in the base.

The robot unit is designed so that it can be used to control automatically, not only the crane illustrated here, but also any other type of machine, such as an excavator or a dragline, that incorporates not more than five different operations. It works by moving the control levers of the crane in their proper order.

The robot is driven by the same motor that operates the crane. Its central feature is a roll of paper punched with holes set out on a pre-arranged system. The roll resembles on a miniature scale those used for operating player pianos. It is drawn slowly over a brass drum and there passes under a row of spring brushes, which are connected in separate electric circuits and press lightly on the paper. When a hole passes beneath one of the brushes, this makes contact with the drum, and so completes the electric circuit through it. This current operates a solenoid that is used to move one of the control levers of the crane by means of a special differential drive operated by the crane motor.

A revolution counter gives the number of revolutions of the shaft of the robot and also of that driving the crane. The counter is used in preparing the paper roll, which is done in the robot itself.

The method by which the exact positions of the holes is determined is very complicated, but an outline of the process will make it clear. A simple structure is first designed and a plan drawing made, after which the layout of blocks from which the structure is to be built is considered. The number of revolutions of the robot and crane driving shafts required to transfer each block to its allotted position is then determined. In a similar manner the movements of the trolleys and of the grabbing and hoisting tackles required for the positioning of each block are calculated. These calculations are then tabulated, and the machine set accordingly.

Suppose the hoisting of a block is found to require 150 revolutions of the driving shaft. The lever that controls this operation then must first be moved to start the crane working, and after 150 revolutions have been made the position of the lever must be reversed to stop the operation. The roll of paper is placed on the rollers and set in motion. As the counter registers each required number of revolutions, as set out on the tabulated list, the mechanism is stopped and a hole is punched in the paper in such a position that the appropriate brush makes contact with the drum. In a similar manner holes are punched to control other movements, and thus the complete sequence of movements required to build the structure is recorded on the paper roll. The time taken to erect the brick structure shown in the illustration was 50 minutes.

A remarkable model block-setting crane that automatically builds simple structures. Its movements are controlled by an ingenious robot mechanism, which is seen at the base of the tower on the left of the illustration. The model is the work of Mr. Griffith P. Taylor, Toronto.

Meccano Magazine – March 1938

- The first recognised industrial robot
  - Invented in 1938
  - Powered by a single motor
  - Controlled by punch tape

40 YEARS OF DEVELOPMENT

www.gizmodo.fr

Image: ABB

- 1956 – UNIMATION, USA
    - World's first hydraulic, programmable robot

- 1974 – ASEA, SWEDEN
    - First commercially available all-electric microprocessor controlled robot

ROBOTS IN MANUFACTURING TODAY

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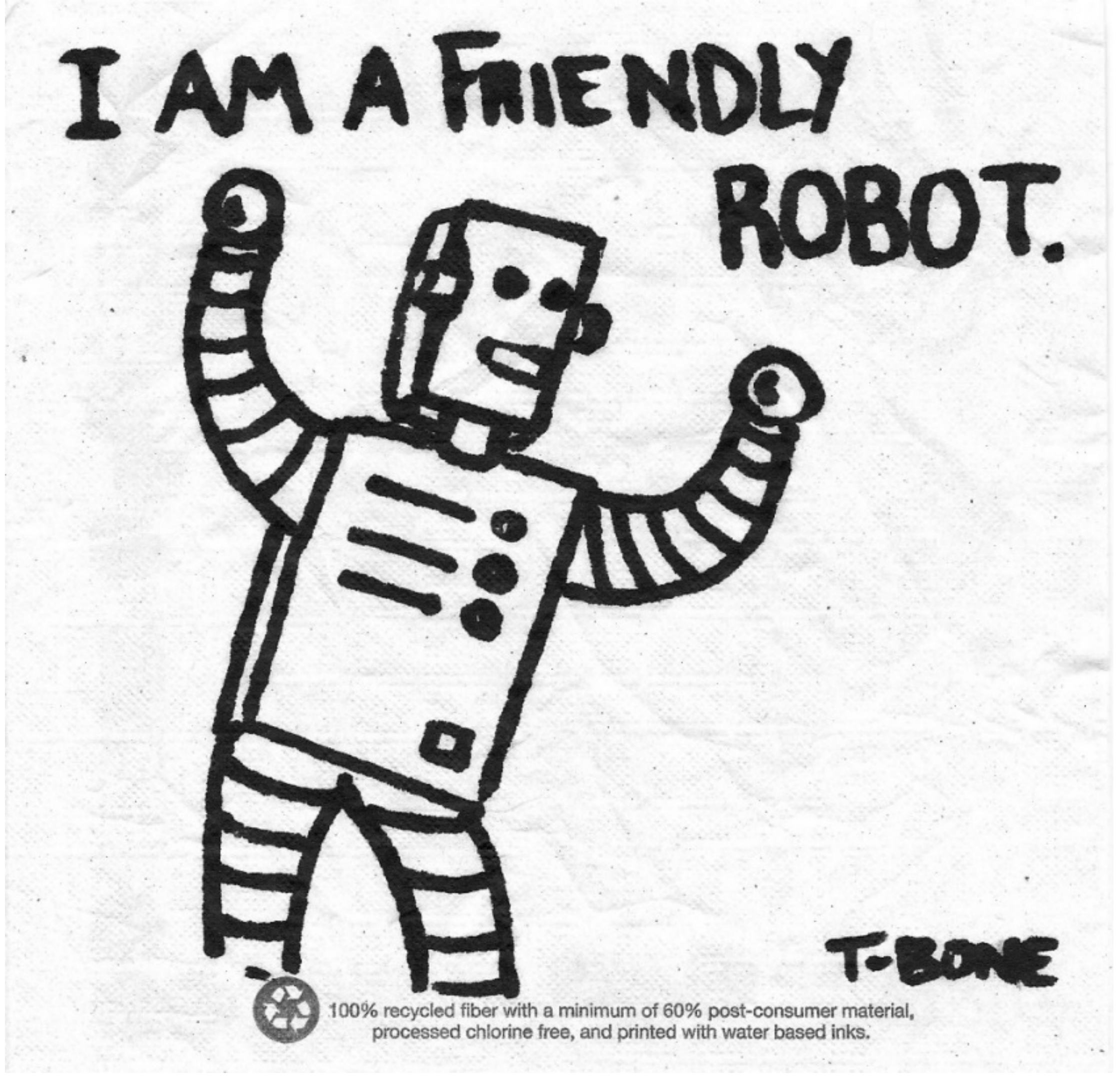
Image: Paul Sakuma/Associated Press

HUMAN FRIENDLY ROBOTS

HUMAN FRIENDLY ROBOTS



A NEW GENERATION OF ROBOTS

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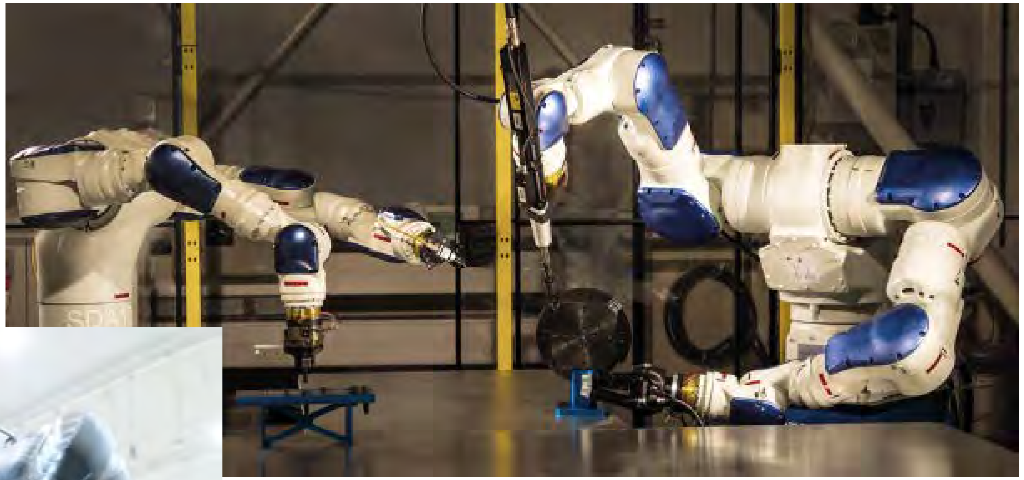


Images (from top left): Universal Robots/ABB/Kuka Robotics/Rethink Robotics/EPSRC CIM for Intelligent Automation

PERCIEVED ADVANTAGES & CHALLENGES

- Human Robot Collaboration
- Productivity
- Flexibility
- Low Running Costs

- Collaboration vs Risk
  - Complicated Safety Cases
- Scaling
  - Everything we’ve seen so far is small…
- Economic Costs
  - Purchase & Ownership
- Achieving Productivity
  - Making the most of humans & robots working together
- Application Design
  - Ergonomics, ease of use, etc.

SAFETY APPROACHES

SAFETY FUNCTIONS OF INDUSTRIAL ROBOTS

- E-Stop's
- Protective Stop's
- Operating Modes
  - Automatic/Manual High Speed/Manual
- Pendant Controls
  - 'Dead Man' Handle
  - Start/Restart
  - Hold to Run
- Limit Switches
- Muting Functions
- ***ALL GOVERNED BY ISO 10218***

Image: Comau

COLLABORATIVE ROBOTS

QUICK QUIZ

Which of these is a 'collaborative' robot?

a) The industrial robot?
b) The force/torque limited robot?
c) Both?
d) Neither?

THE CORRECT ANSWER IS…

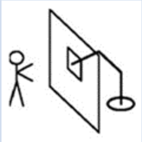
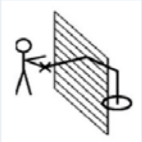
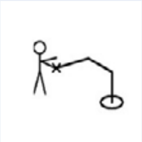
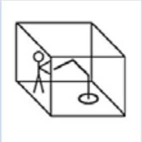
c) Both !!

Image: Kuka

Image: ABB

TYPES OF COLLABORATIVE OPERATION

According to ISO 10218-1

ISO10218-1 Clause	Type of Collaborative Operation	Main Means of Risk Reduction	Pictogram (ISO 10218-1)
5.10.2	Safety-rated monitored stop (Example: manual loading station)	No robot motion when operator is in collaborative work space	
5.10.3	Hand Guiding (Example: operation as assist device)	Robot motion only through direct input of operator	 
5.10.4	Speed and separation monitoring (Example: replenishing parts containers)	Robot motion only when separation distance above minimum separation distance	 
5.10.5	Power and force limiting by inherent design or control (Example: ABB YuMi, Kuka iiwa, Universal Robot URx)	In contact events, robot can only impart limited static and dynamics forces	

COLLABORATIVE ROBOTS

- SO THIS POSES THE QUESTION…
  - Does this mean that robots no longer need guarding?

- Yes and No…
  - It all depends on the process the automation is carrying out and the risk assessment…

SAFETY STANDARDS FOR ROBOTS

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A-Level

IEC 61508 – Functional Safety	ISO 12100 – Risk Assessment

European Machinery Directive 2006/42/EC

B-Level

EN ISO 13849-1:2008	IEC 62061:2005

C-Level

ISO11161 – Integrated Manufacturing Systems	ISO10218-1 - Robot	ISO 10218-2 – Robot System/Cell

Other C-level machinery standards that may be needed

BIOMECHANICAL LIMIT CRITERIA

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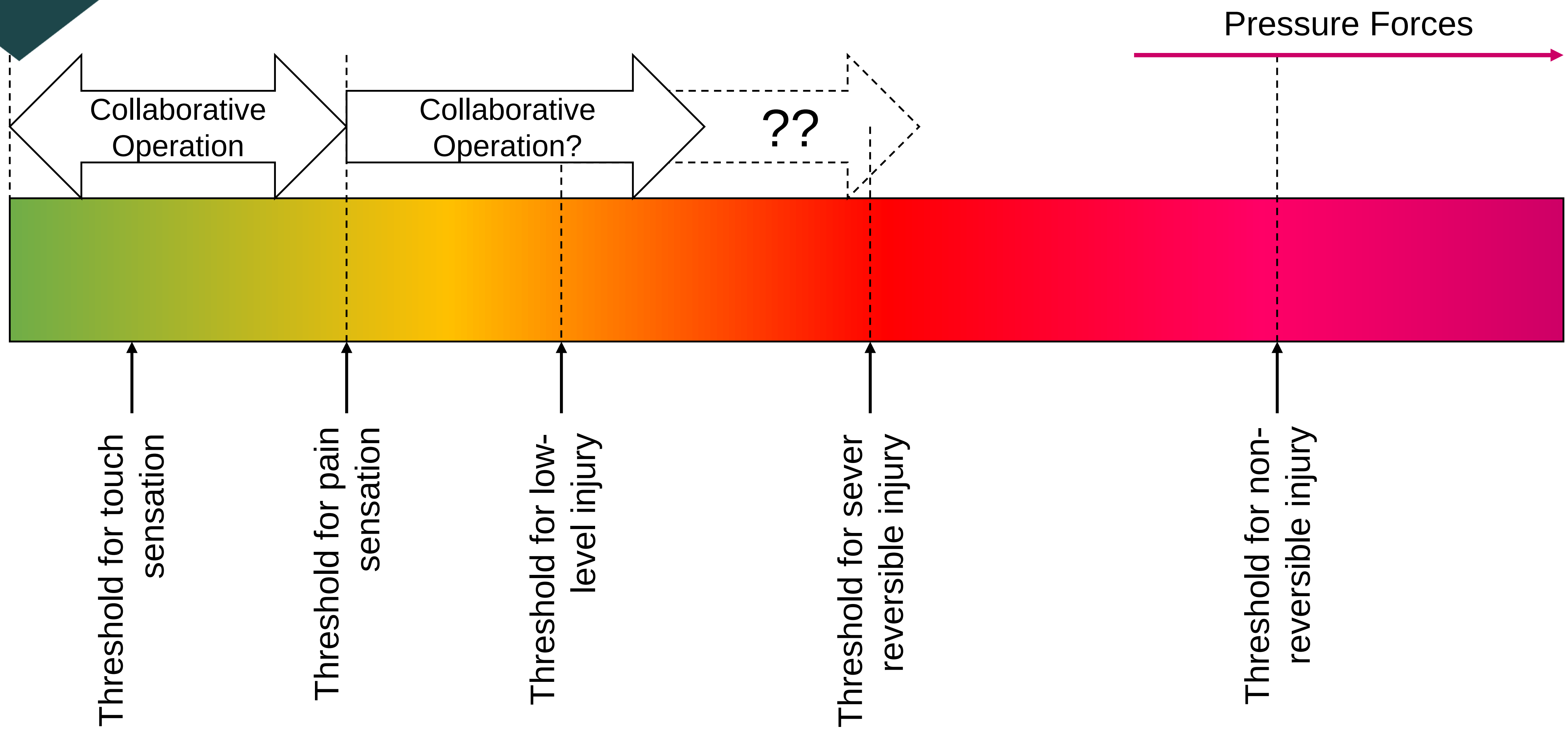
ISO/TS 15066 – Clause 5.44 "Power & Force Limiting"

Free Impact/transient contact		Constrained Impact/Quasi-Static Contact	
Contact event is short (<50ms) Human body part can recoil		Contact duration is "extended" Human body part cannot recoil & is trapped	
Accessible Parameters in Design or Control Effective mass (robot pose, payload) Speed (relative)		**Accessible Parameters in Design or Control** Force (joint torques, pose)	
Pain Threshold	**Minor Injury Threshold**	**Pain Threshold**	**Minor Injury Threshold**
Highest loading level accepted in design	Highest loading level accepted in risk assessment in case of single failure	Highest loading level accepted in design	Highest loading level accepted in risk assessment in case of single failure

QUASI-STATIC CONTACT – SEVERITY



Adapted from: Industrial Safety Requirements for Collaborative Robots and Applications - Matthias, B – ABB Corporate R&D

APPLICATION PROTECTION LEVELS

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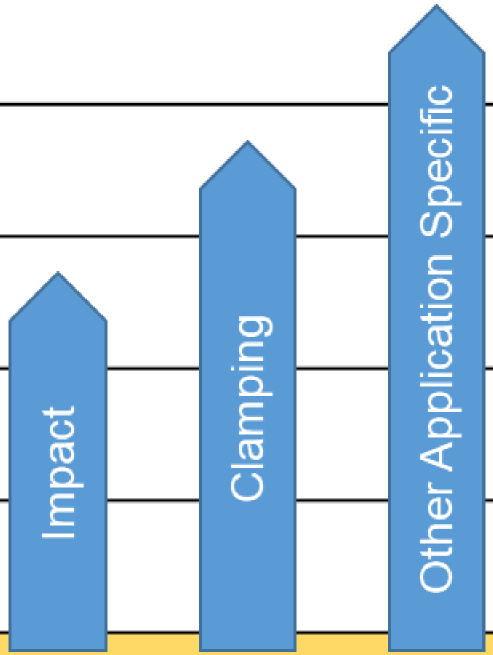
Risk Reduction Measures		
	Level 6	Perception-based real-time adjustment to environment
	Level 5	Personal protective equipment
	Level 4	Software-based collision detection, manual back-drivability
	Level 3	Power and speed limitation
	Level 2	Injury-avoiding mechanical design and soft padding
	Level 1	Low payload and low robot inertia
Robot System – Mechanical Hazards		



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USE CASES

Image: ABB

Image: Faude.de

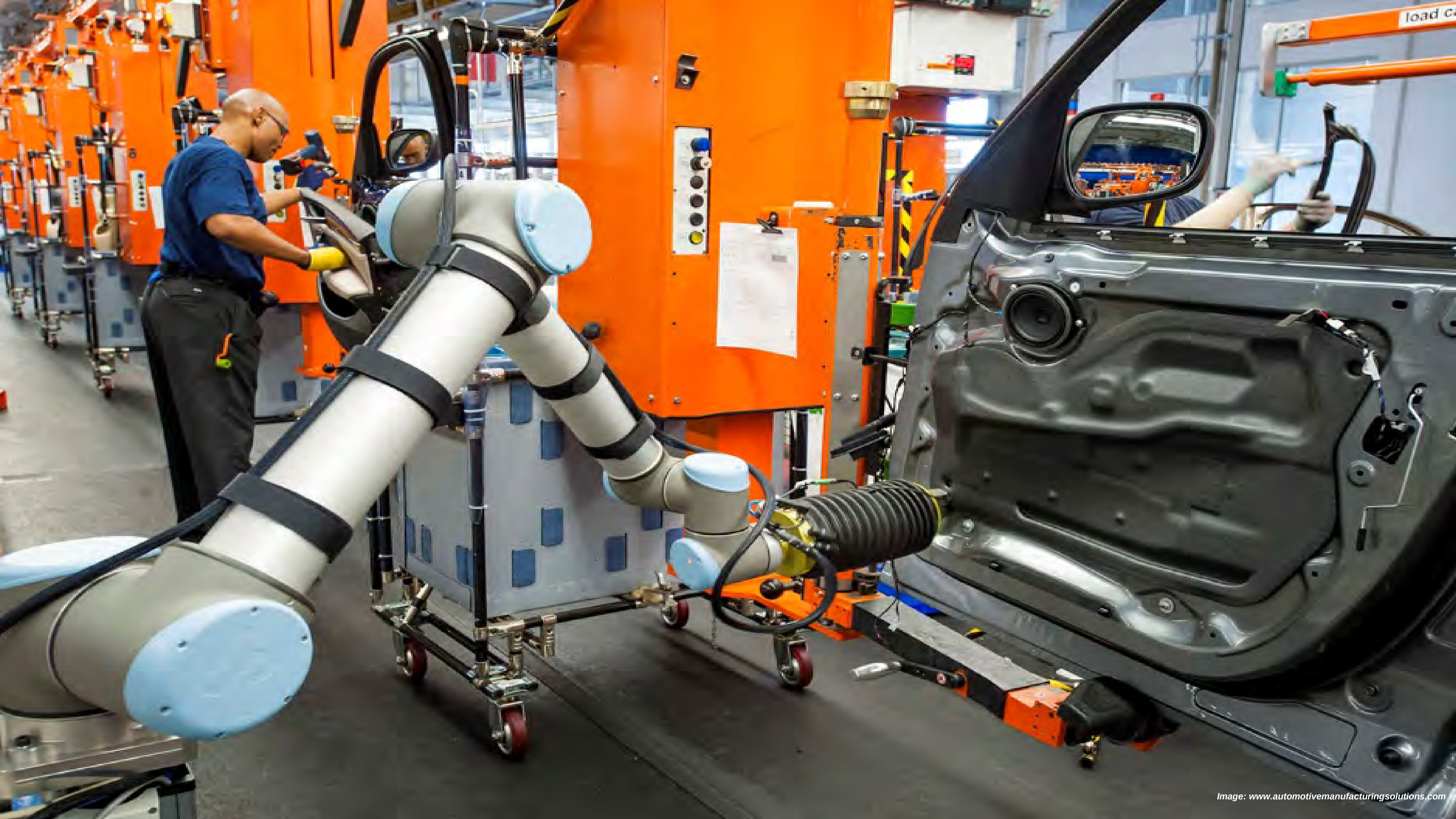

Image: www.automotivemanufacturingsolutions.com

SCALING

- All the robots that are currently marketed as ‘collaborative’ are small
  - This generally makes them safer
- But industry needs bigger payloads and working ranges
- So how do we go from this…

Image: Kuka Systems

SCALING

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- All the robots that are currently marketed as ‘collaborative’ are small
  - This generally makes them safer

- But industry needs bigger payloads and working ranges

- So how do we go from this…
  - …to this?

Image: MTC

Image: Kuka Systems

COLLABORATIVE WORKSPACES

CURRENT MTC RESEARCH

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- To break the barriers between robots, humans and the environment so that we can have a truly collaborative workspace between humans and machines

- To overcome technical safety and security challenges to achieve the above

- To provide a platform for universities to research on and industry to exploit

- To provide advise and scientific data and results to regulatory bodies leading to recognised industrial standards

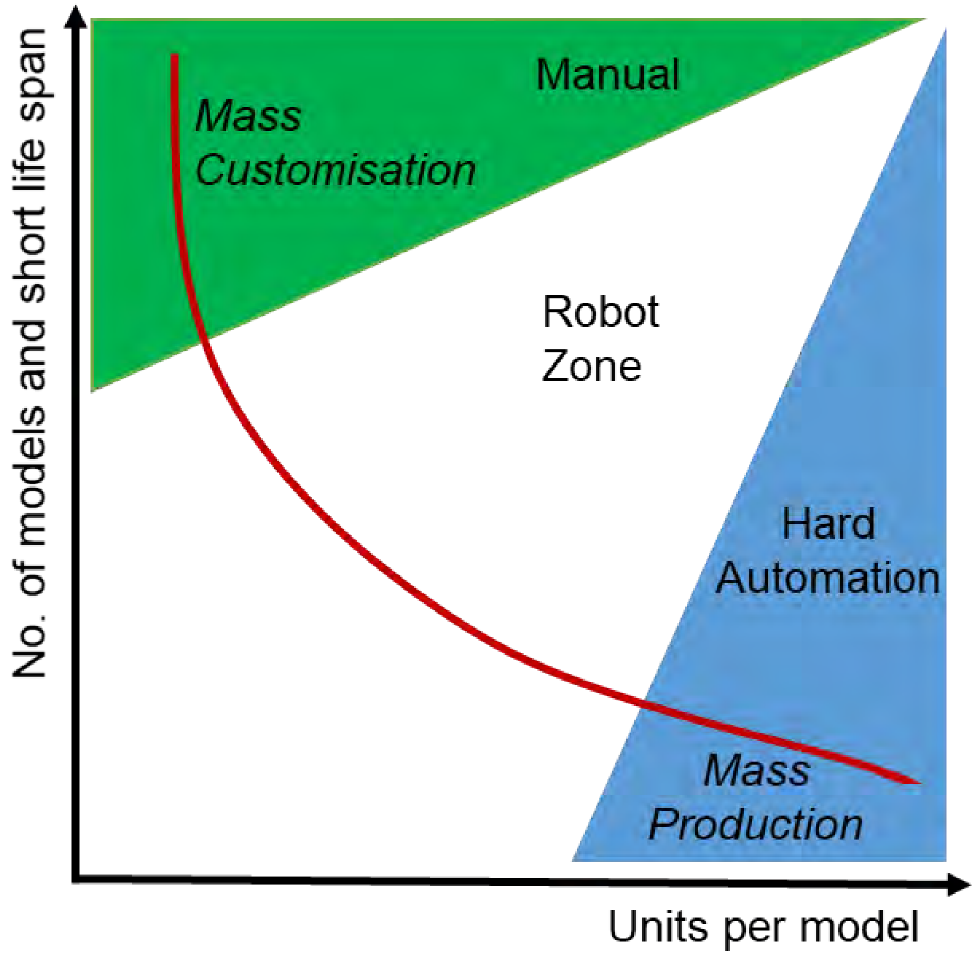
COLLABORATIVE WORKER

Image: MTC

ECONOMIC MOTIVATION

DO YOU REALLY NEED COLLABORATION?

- Mass customisation
  - Increasing product variants
  - Shorter product lifetimes
- Competition from low cost economies
- Product flexibility



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Any Questions?