



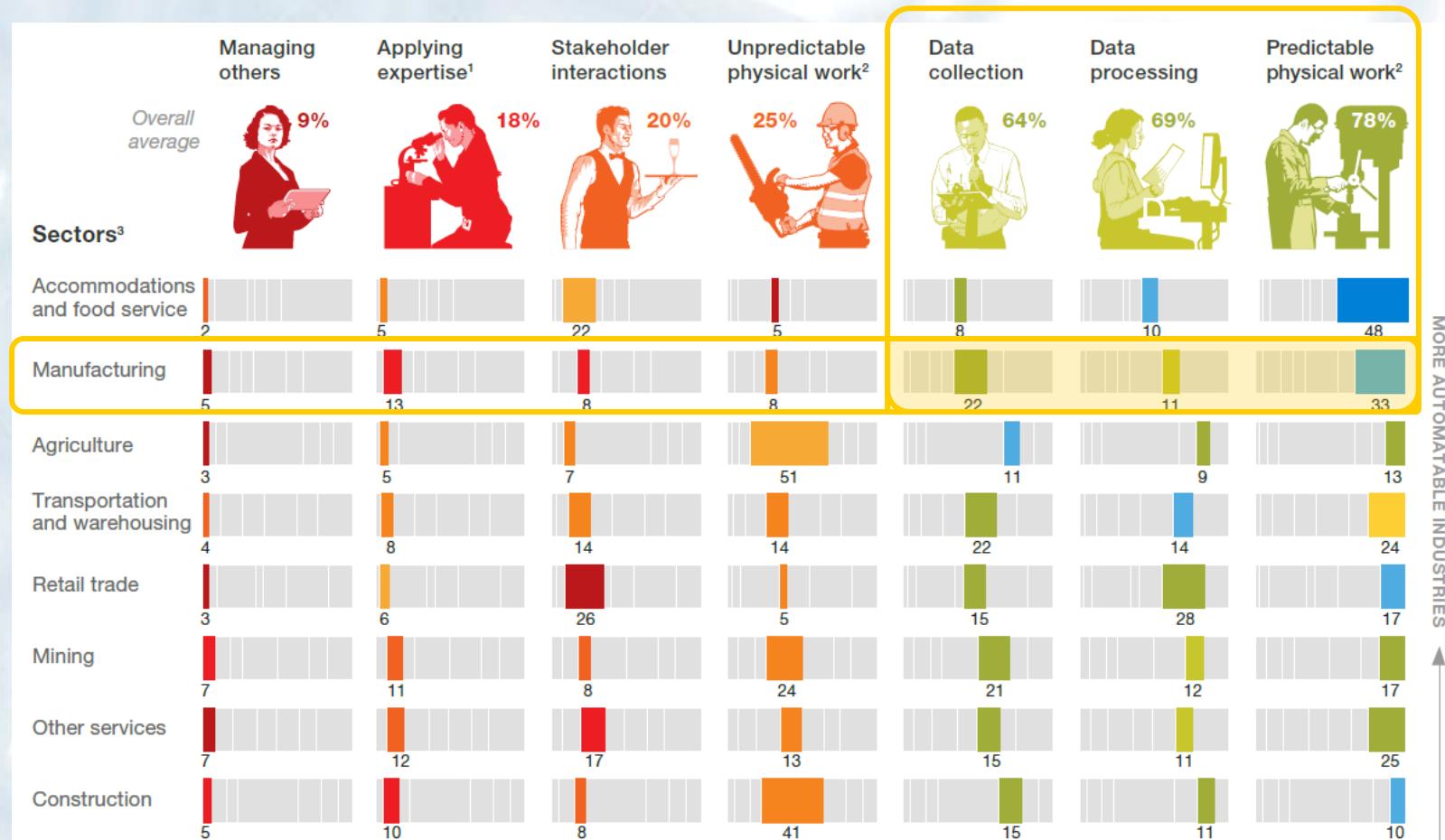
# The Future of Collaborative Robotic Manufacturing

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Washington DC, October 26, 2016

# Potential for automation

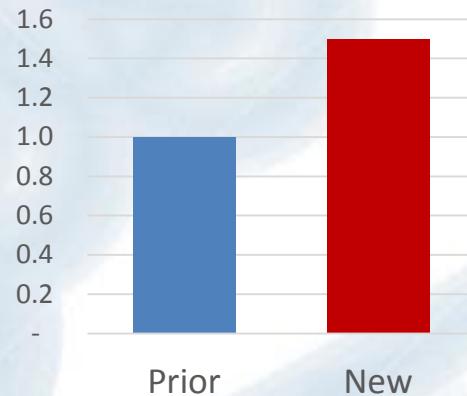
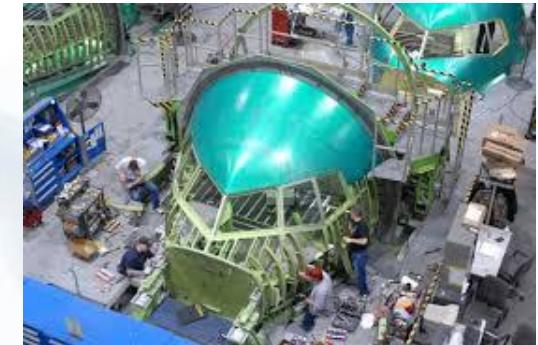


Source: McKinsey & Company, "The Technical Potential for Automation in the U.S.", 2016

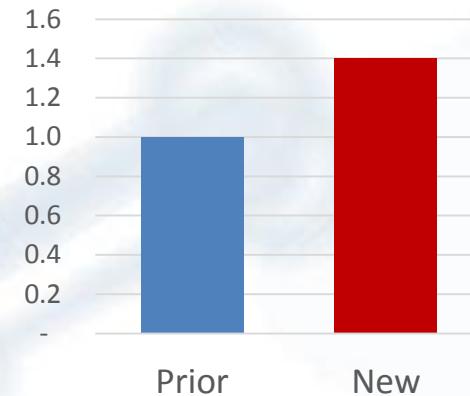
# Growth is top priority for industry

- OEM, Tier 1, SME survey results
  - Reduction in time and cost to change configuration of product manufactured
  - Reduction in time and cost to introduce new products
  - Increase in sales due to increased production capacity and flexibility
- All point to need for increased flexibility
- Goal is 30% to 50% gains

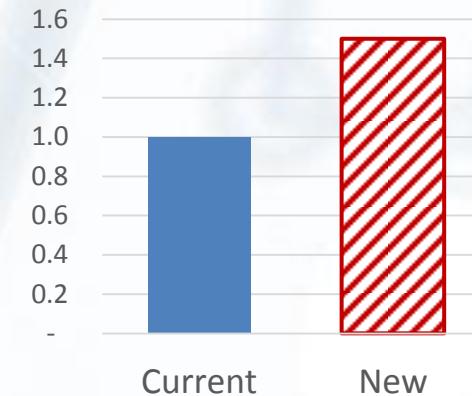
# Potential for 30% to 50% gains



Consumer goods  
(in production)



Automated DC  
(in production)



Aerospace  
(opportunity)

# Advanced robot manufacturing needs



- Mass manufacturing -> mass customization
- Multiple manufacturing processes
- Reduce cost of integration
- Humans and co-robots working in limited floor space

# Future collaborative manufacturing

Aerospace industry example



# Standards for safe human interaction

- ISO/TS 15066 Technical Specification
  - Safety-rated monitored stop
  - Hand guiding
  - Speed and separation monitoring
  - Power and force limiting
- Still requires full risk assessment
  - Includes all equipment and processes in cell
  - following industry best practices (FMECA)



Current / encoder based torque estimates (Universal)



Series elastic actuators (ReThink)



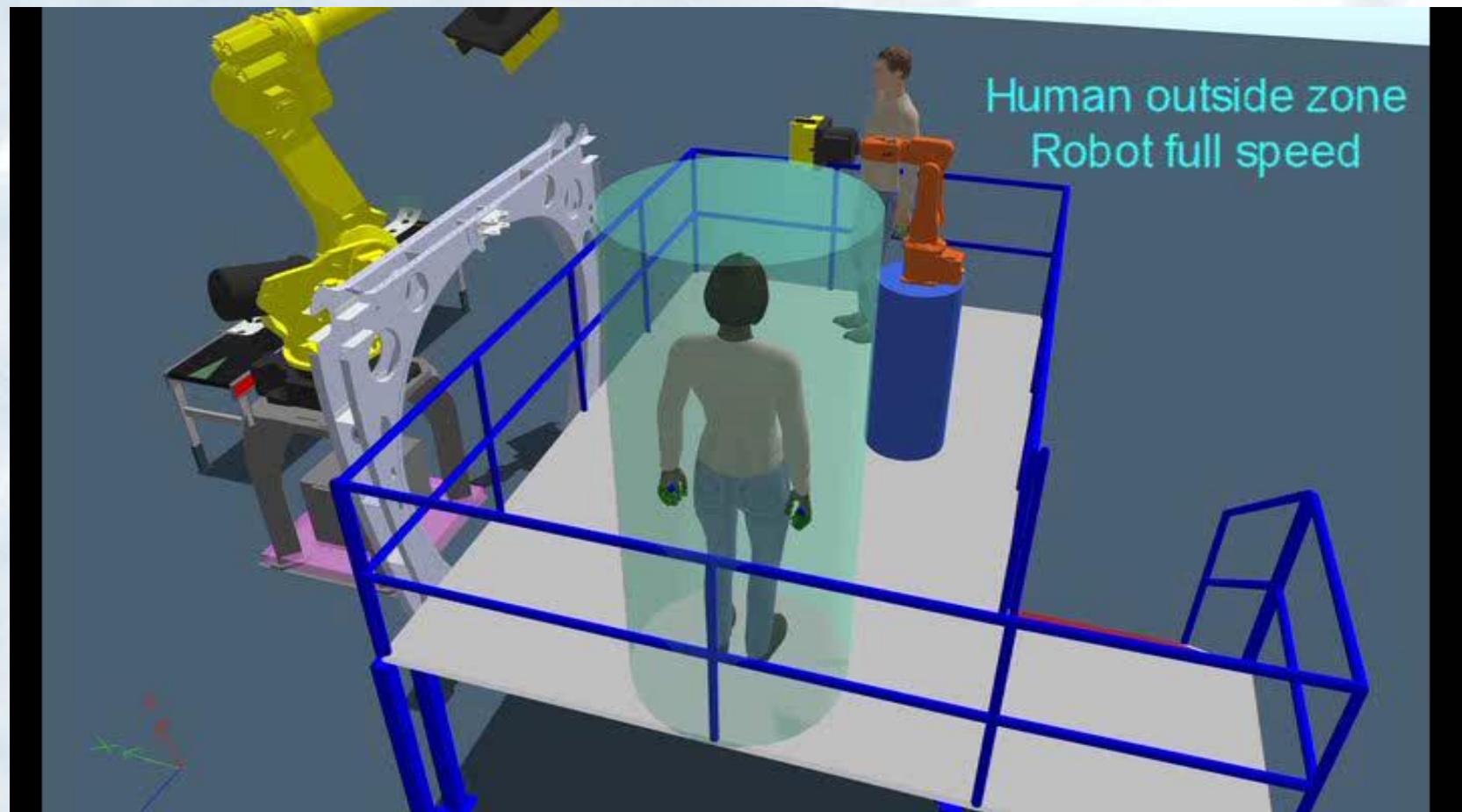
Pressure sensitive skin (Kuka)



Load cell in base (Fanuc)

**Power and force limiting approaches**

# Separation monitoring example



# Collaborative operations

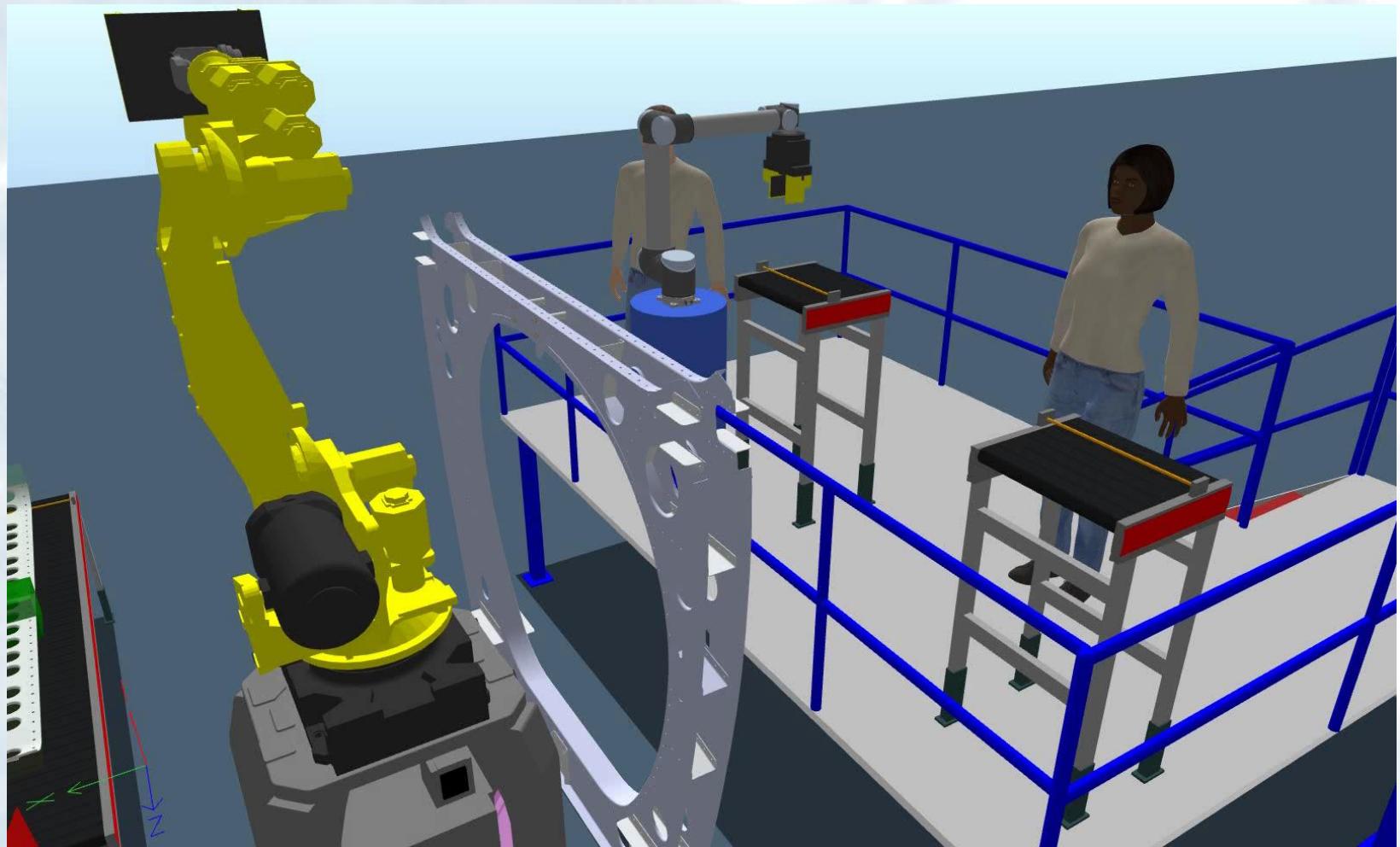
- Collaborative operations
  - Robot and human perform tasks simultaneously during task execution
- Sequential process flow
  - Most common implementation today
  - Human and CoBot have separate tasks
  - Buffers in between to prevent starving / blocking
- Task sharing
  - Human and CoBot work at team
  - Requires higher level of coordination, communication, flexibility



# Sequential process example



# Task sharing process example



# Multi-level human collaboration

Planning and control levels

## Task level

- Planning, scheduling, layout, flow
- Re-planning

Human interaction



## Control level

- Auto robot path / process planning
- Mobile robot route planning
- Situation awareness, adaptive control

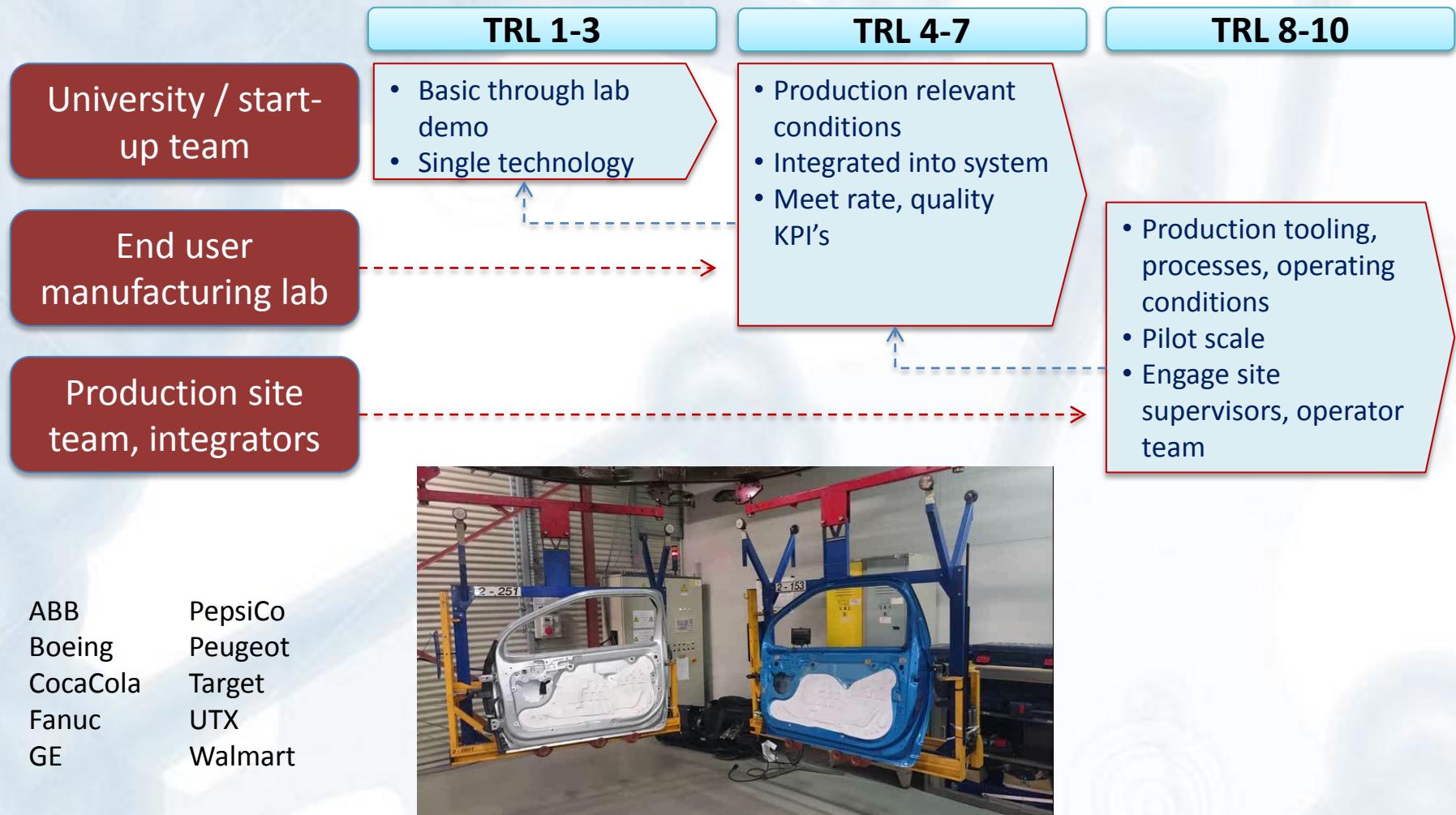


## Machine level

- Machines, processes, tooling, fixtures
- Machine, process, human sensing



# Process for successful tech transfer



# Future reading

Manufacturing Leadership Journal: October 2016

