

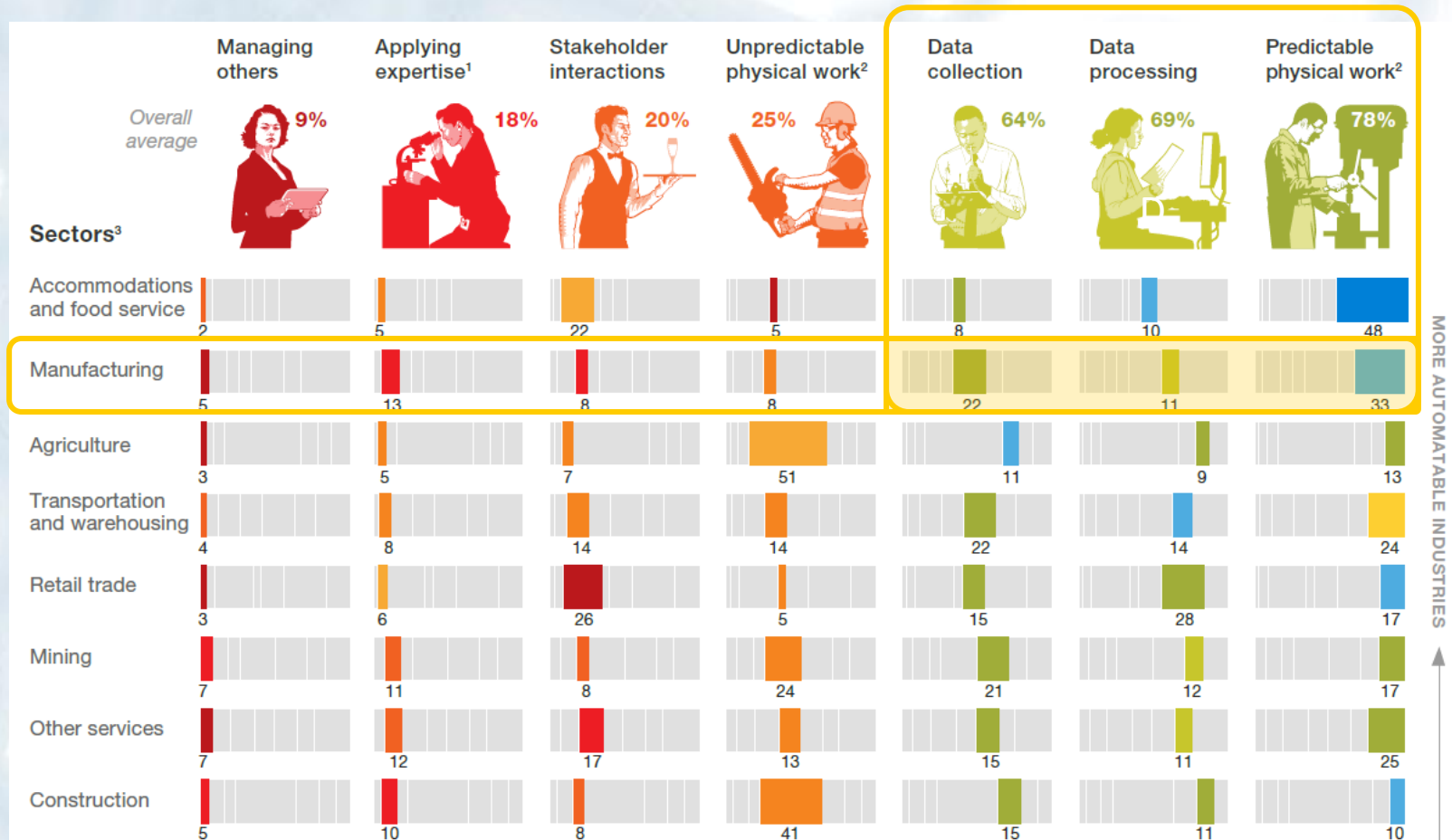
The Future of Collaborative Robotic Manufacturing

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Potential for automation

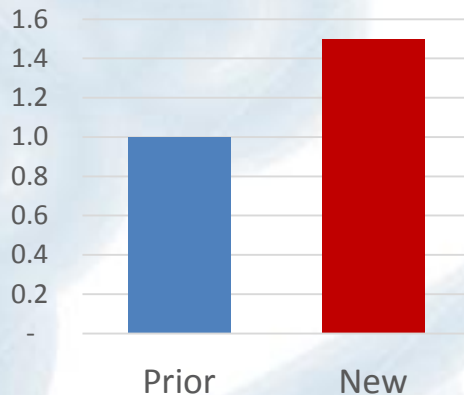


Source: McKinsey & Company, “The Technical Potential for Automation in the U.S.”, 2016

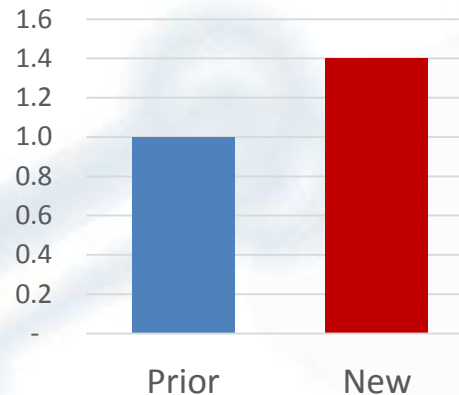
Growth is top priority for industry

- 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

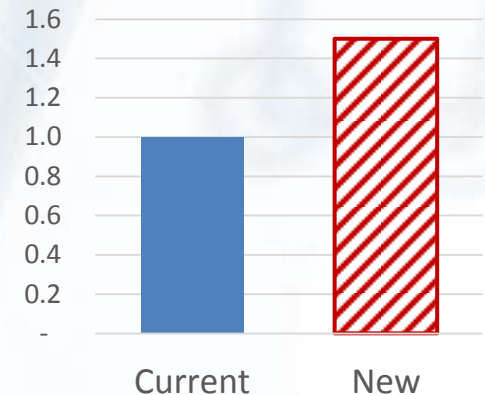
Potential for 30% to 50% gains



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)



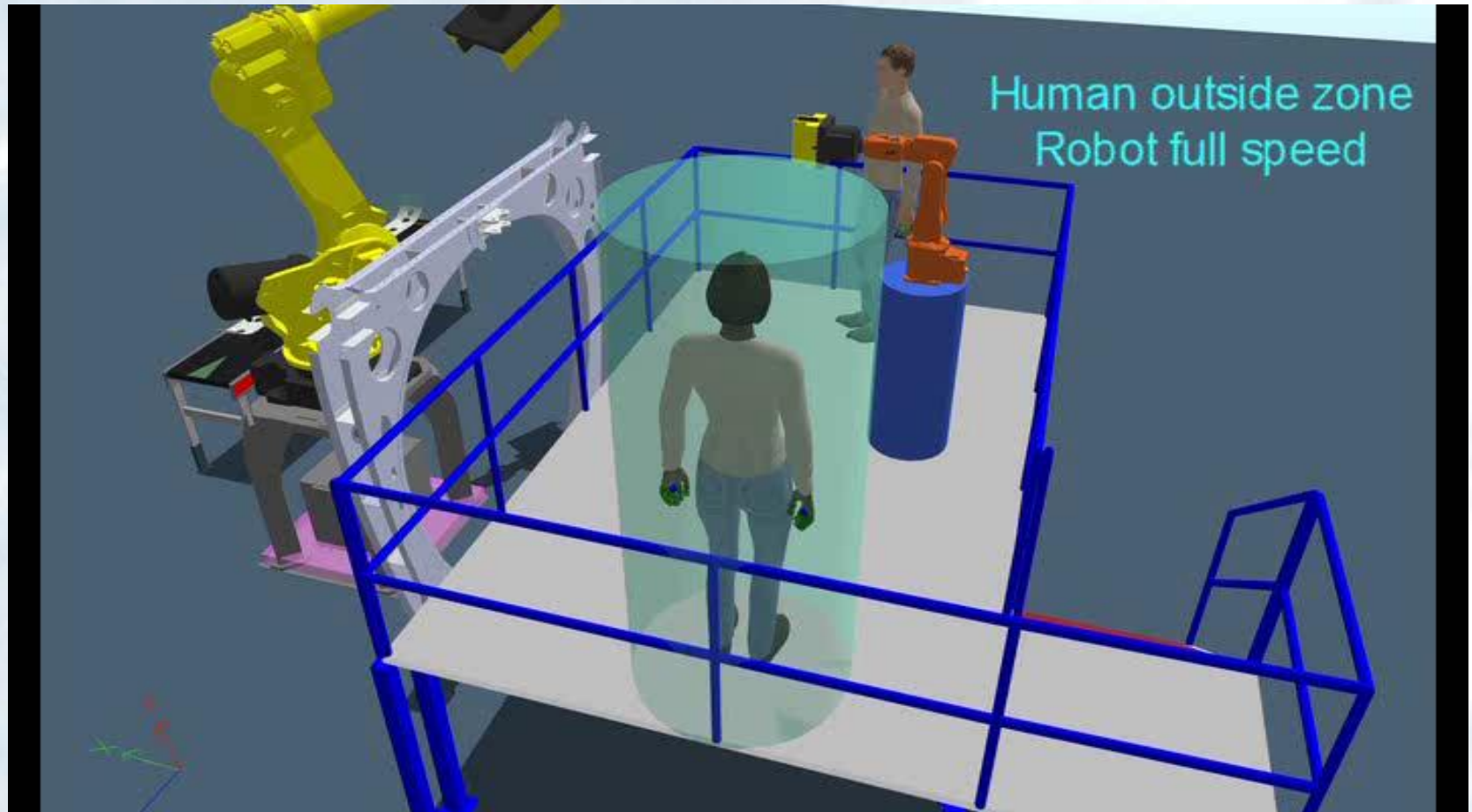
Pressure sensitive skin (Kuka)



Load cell in base (Fanuc)

Power and force limiting approaches

Separation monitoring example



Collaborative operations

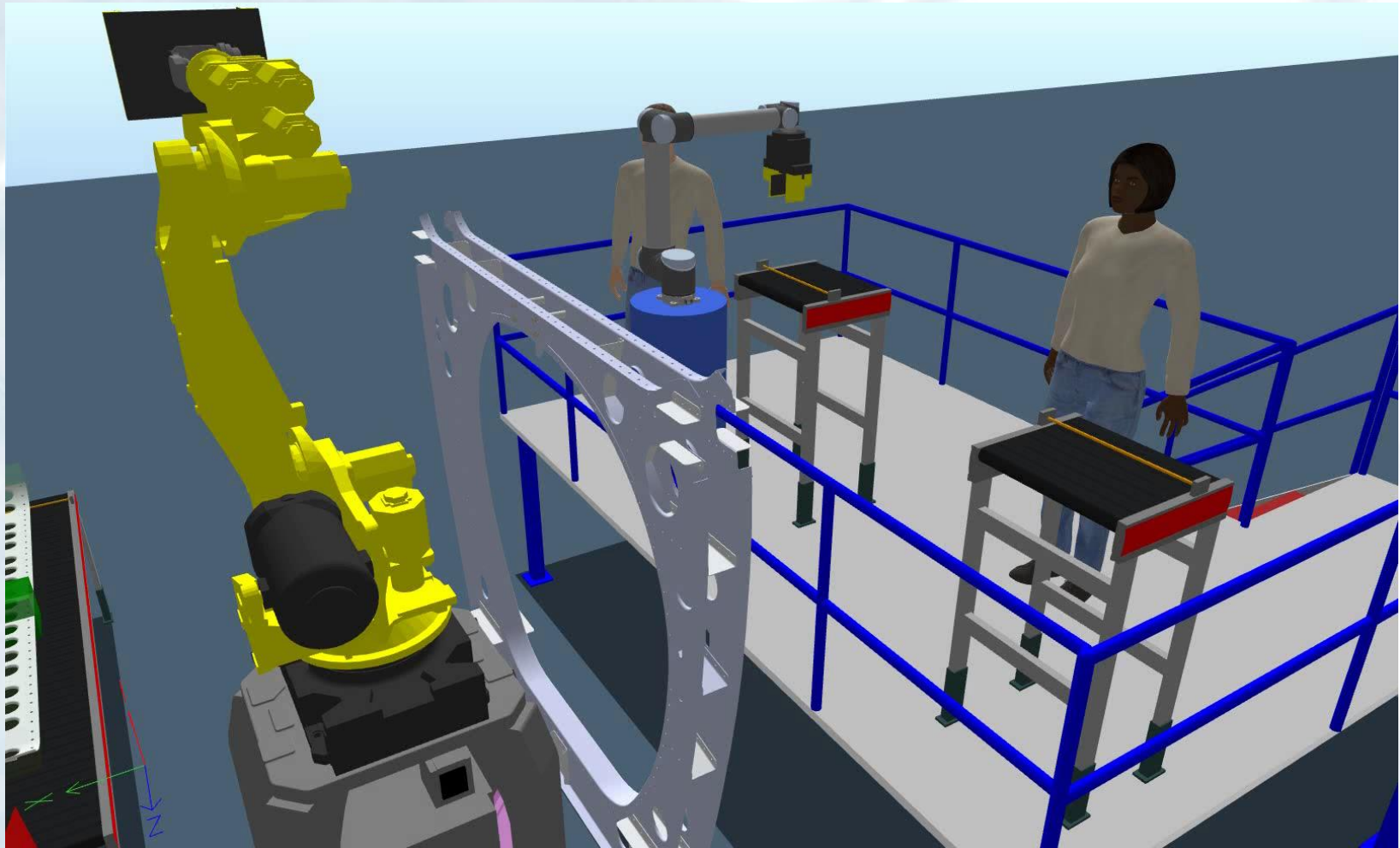
- Collaborative operations
 - Robot and human perform tasks simultaneously during task execution
- Sequential process flow
 - Most common implementation today
 - Human and CoBot have separate tasks
 - Buffers in between to prevent starving / blocking
- Task sharing
 - Human and CoBot work at team
 -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



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



Human interaction



Process for successful tech transfer

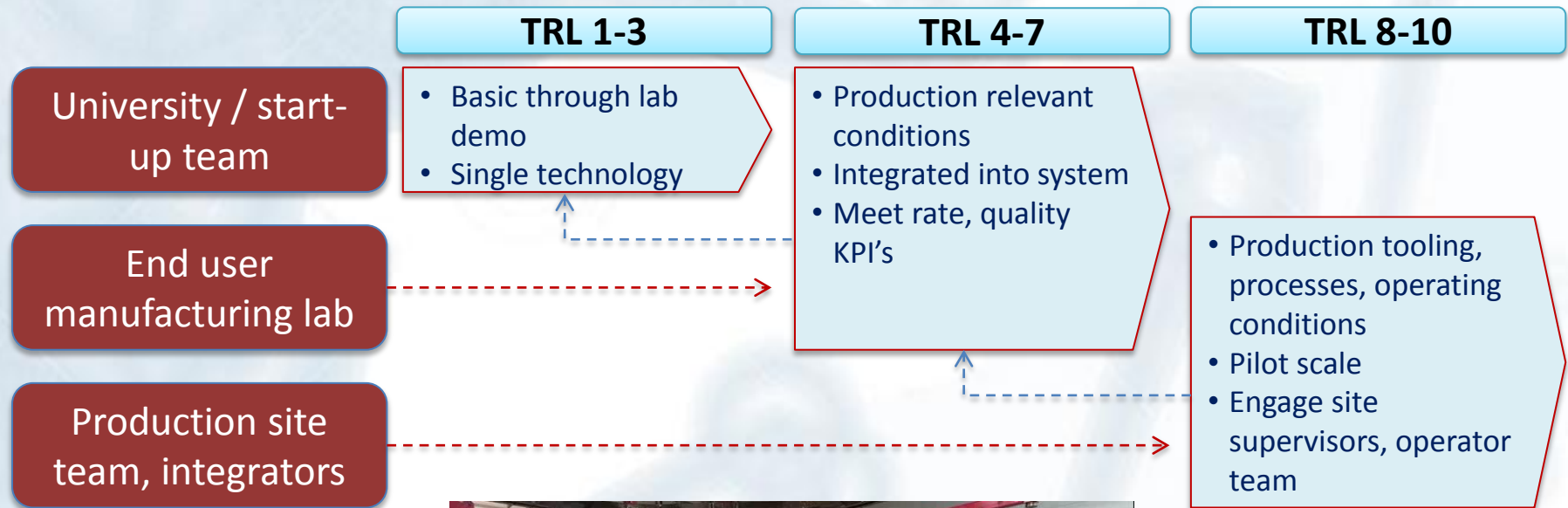


ABB	PepsiCo
Boeing	Peugeot
CocaCola	Target
Fanuc	UTX
GE	Walmart



Future reading

Manufacturing Leadership Journal: October 2016

