Digital Manufacturing 4.0

Human-centered Workplaces of the Future with Integrated Exoskeletons: Digital Twin Exo4*Logi*Prod

Future **Work** Lab

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Cognitive Engineering and Production, "Digital Manufacturing 4.0"

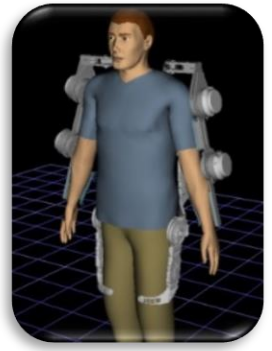
Deutsche Messe
Technology Academy

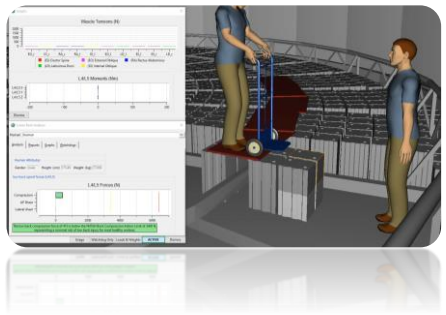
19 Mai 2020
Online-Event: **Cobots und Exoskelette**

Fraunhofer
IAO

Overview

- About Us: Fraunhofer Society, Fraunhofer Institute for Industrial Engineering
- My Experience in dealing with »Digital Manufacturing«
- Challenges for ergonomic workplaces in manufacturing and Musculoskeletal Disorder – MSD
- Exoskeleton technology – Modular concept. Benefits, Challenges
- Digitalisation of human-centred workplaces with integrated Exoskeletons. Application examples
- Exo4*Logi*Prod – 4 Steps methodology
- Demonstration in Future*Work*Lab: active and passive Exoskeletons





German Science and Education after 1945

1829 “Vereinigte Real- und Gewerbeschule" in Stuttgart - Wilhelm I. von Württemberg

1946 College of Technology, 1967 ⇒ Universität Stuttgart

1948 Kaiser-Wilhelm-Gesellschaft ⇒ Max-Planck Society (MPG)

1949 Fraunhofer Society for Applied Science (FhG)

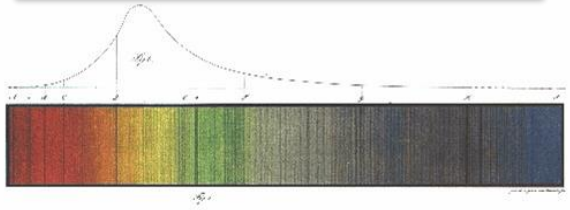
1951 German Research Foundation (DFG)

Joseph von Fraunhofer (1787 - 1826)

Researcher:
Discovery of »Fraunhofer Lines« in the sun spectrum 1814

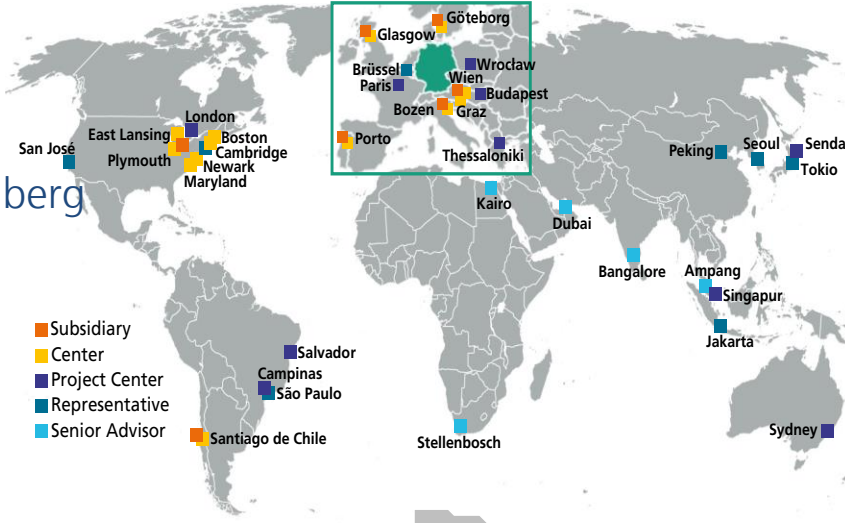
Inventor:
New methods of lens processing

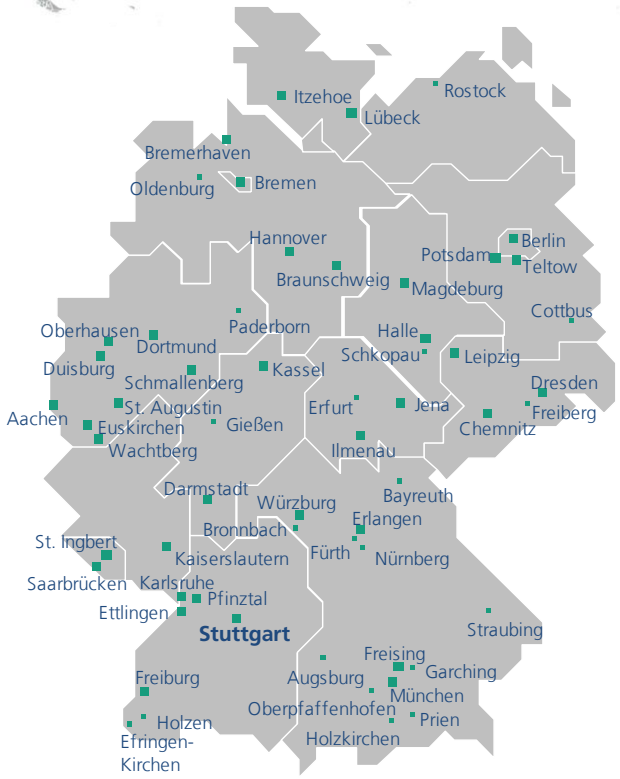
Entrepreneur:
Head of Royal Glass Factory



- 72 institutes and independent research units
- 26.600 employees
- Annual research budget: 2.1 billion euros*
- >1.8 billion euros from contracted research*

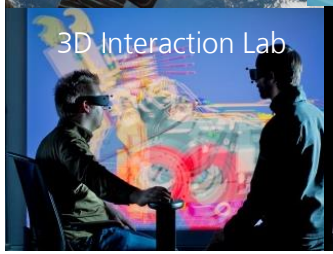
* Figures for 2018





Fraunhofer Institute for Industrial Engineering IAO

Institute of Human Factors and Technology Management, University of Stuttgart



- **Founded:** IAO – 1981, IAT – 1991
- **Budget:** 51.8 million euros, of which 33,7% are generated from industry
- **Staff:** ~650 employees

Figures from 2018, including IAT University of Stuttgart

- **Areas of Expertise:**
  - Corporate Development and Work Design
  - Service and Human Resources Management
  - **Cognitive Engineering and Production**
  - Information and Communication Technology
  - Technology and Innovation Management

Which are the most challenging workplaces?

Components assembly / disassembly

Car headlights assembly
(©CRF)

Battery disassembly
(©INDRA)

Working over the head

Protective shield assembly screwing
(©BMW)

Welding in the container
(©Einsenbau)

Hardly fully automation

Small lot sizes
Complex tasks
Required Human precision
and flexibility
High variability

Logistics

Manipulation of heavy parts
(©Einsenbau)

Relocation processes

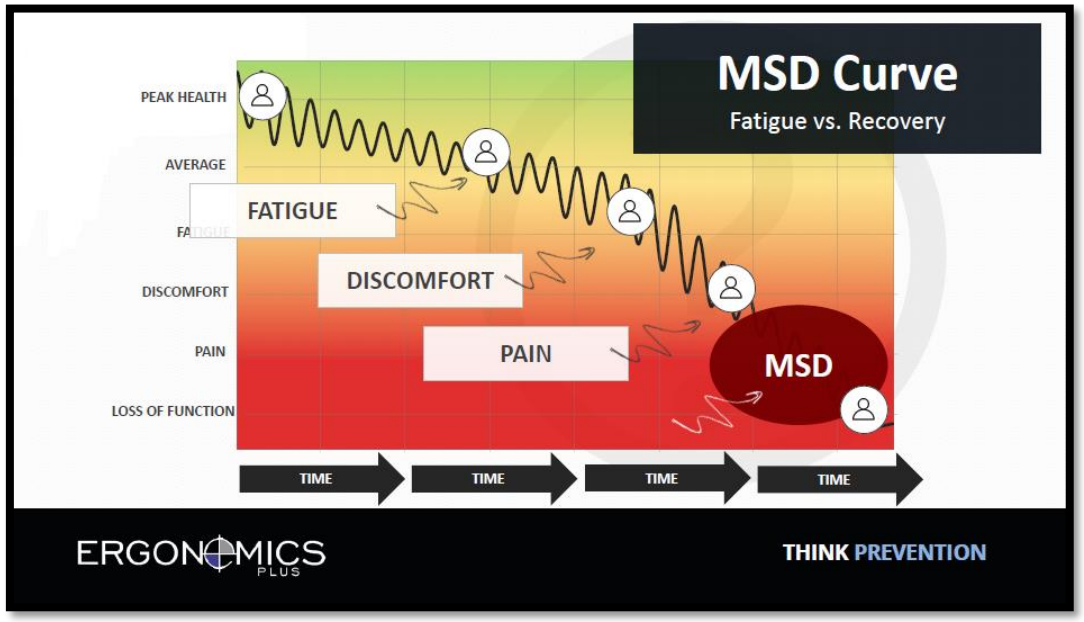
Maintenance

Pallets assembly / disassembly
(©Siemens)

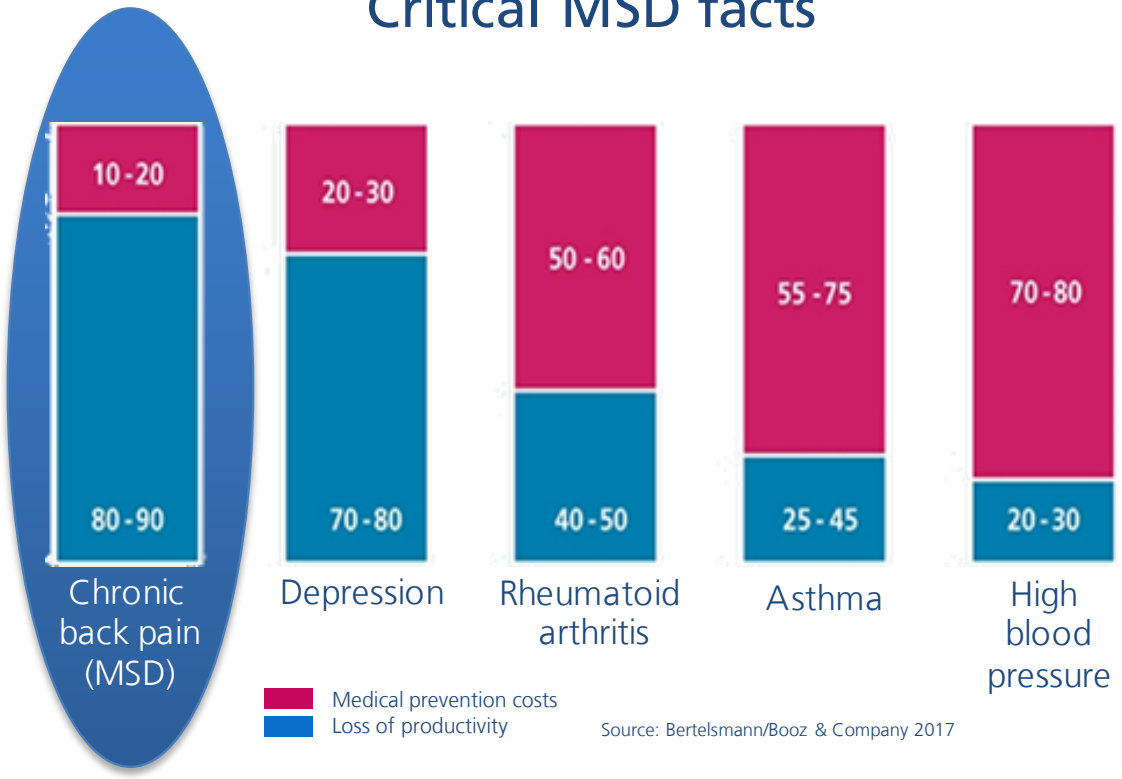
Rotor disassembly

Manipulation of heavy parts (Lifting, Lowering, Carrying, Twisting)
and Working over the head

What is Musculoskeletal Disorder - MSD?

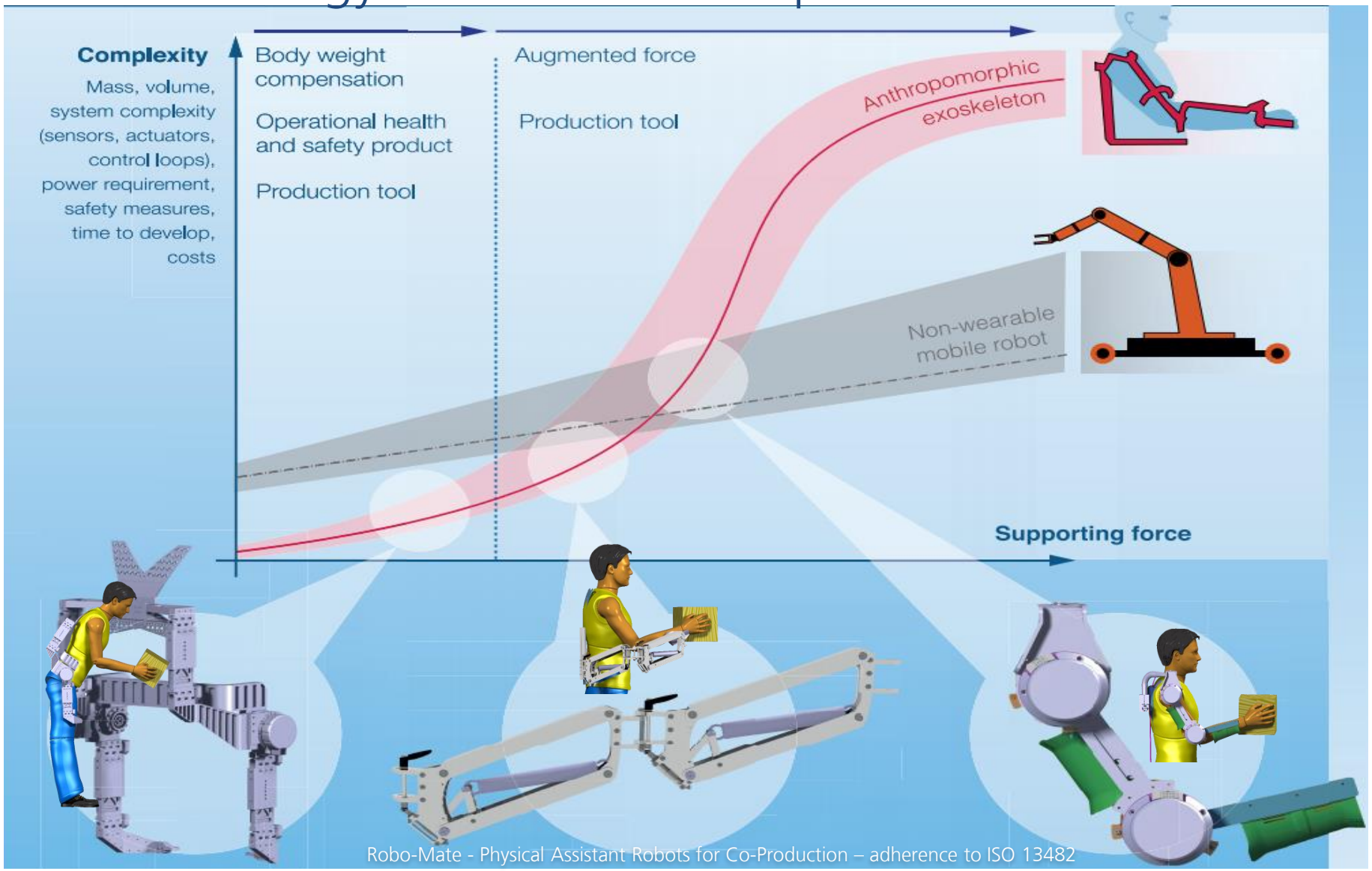


Critical MSD facts



Source: Bertelsmann/Booz & Company 2017

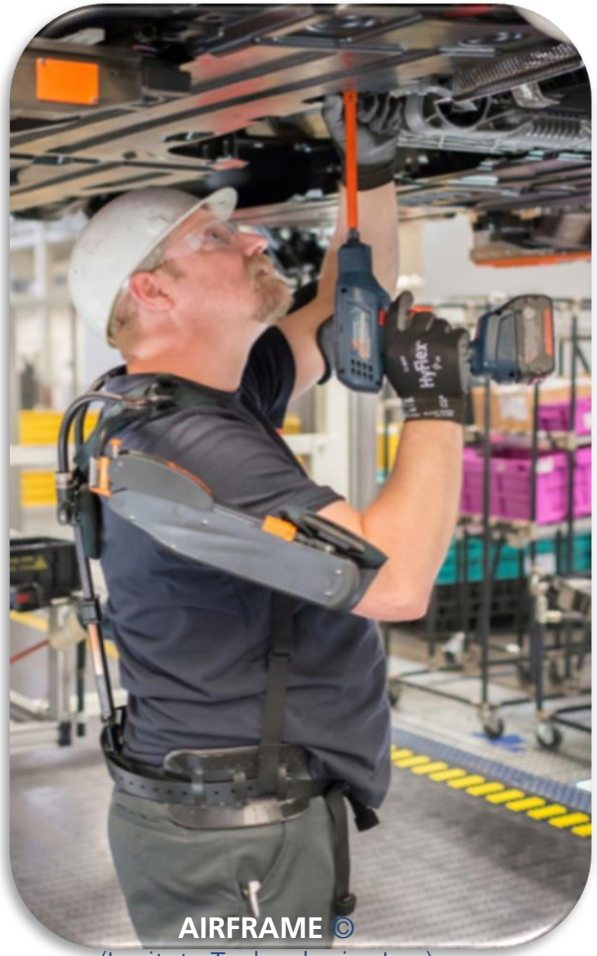
Exoskeleton technology? Modular Concept



Robo-Mate - Physical Assistant Robots for Co-Production – adherence to ISO 13482

Passive Exoskeletons and applications in manufacturing

Working over the head



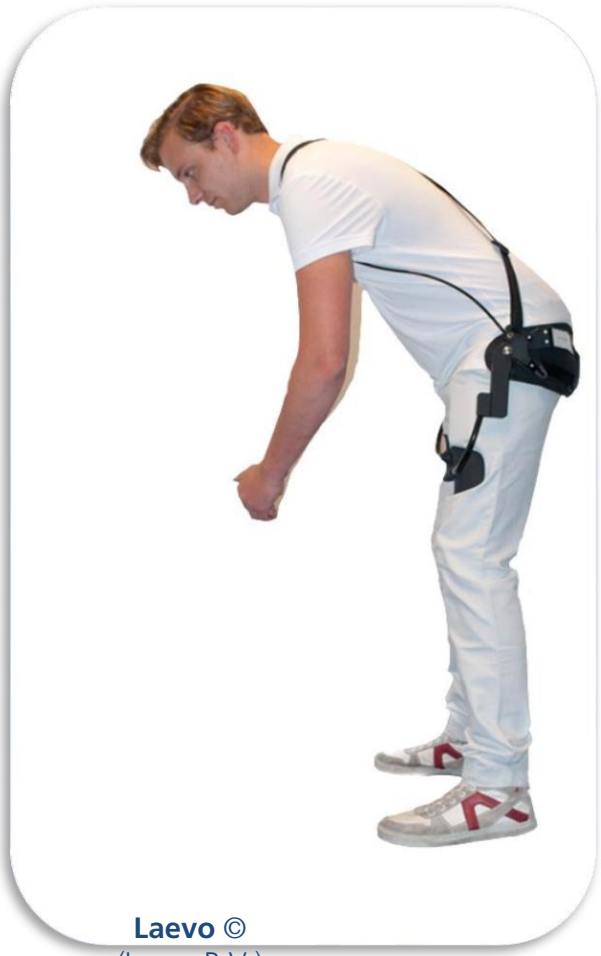
AIRFRAME ©
(Levitate Technologies Inc.)

Tool holder

Fortis ©
(Lockheed Martin)

Static processes

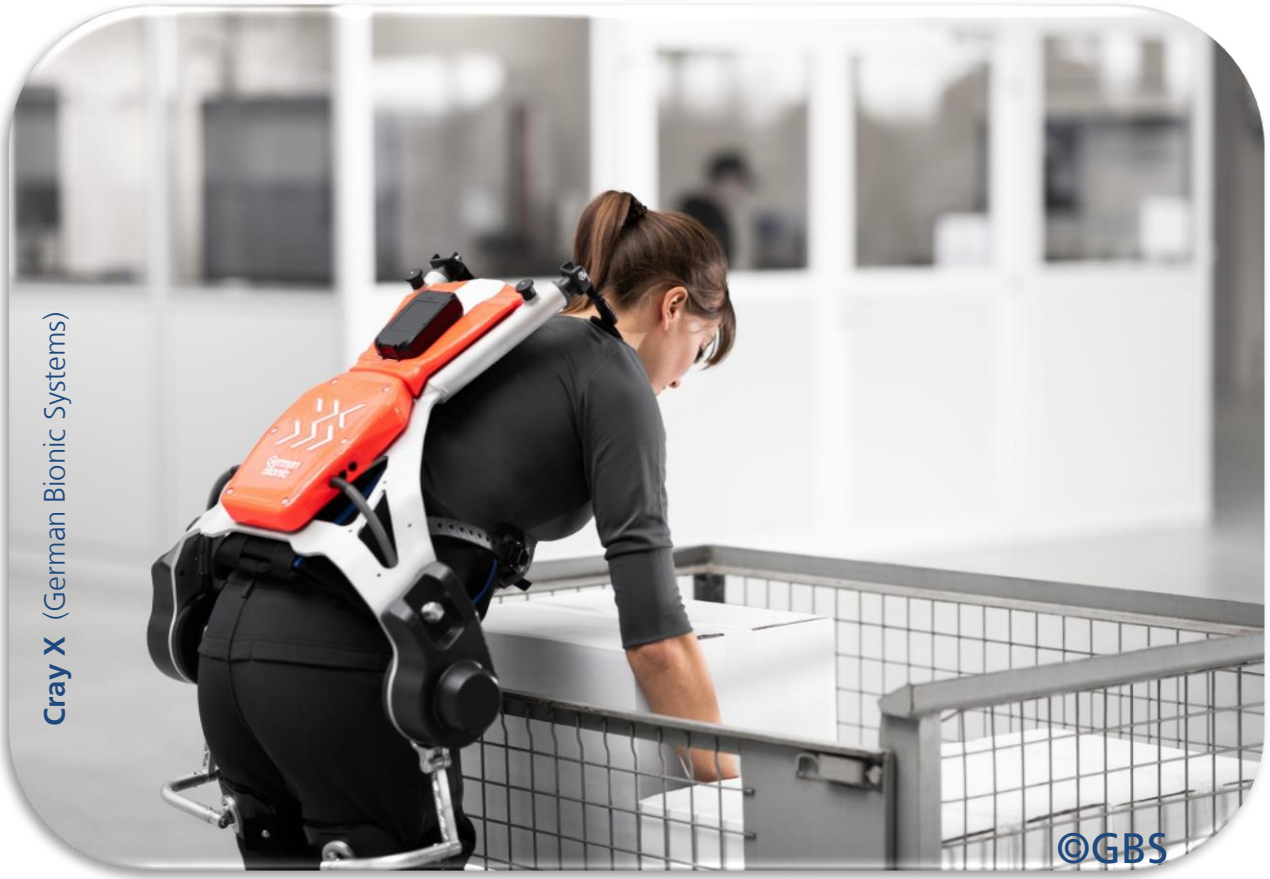
Chairless Chair ©
(Noonee)



Laevo ©
(Laevo B.V.)

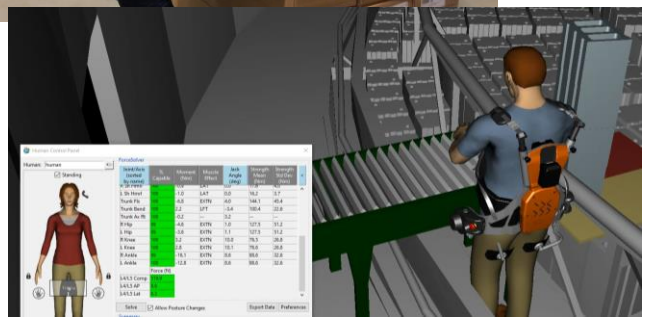
Active Exoskeletons: Research prototype and commercial product

ExoJacket: Fraunhofer IPA – Research active Exoskeleton demonstrator for upper body support and protection



CrayX: German Bionic Systems GmbH – Active commercial Exoskeleton for lower back support and protection

Motivation for Exoskeleton-based Workplaces



Exoskeletons:

- technology for *ergonomics*, *safety* and *environmentally friendly* workplaces (lowering, lifting, carrying and twisting of heavy goods and working over the head);
- increases and stimulates innovation, concentration capability, self-estime

Benefits:

- Ergonomic and safety workplaces
- Increased worker safety, security, satisfaction, motivation
- Enhanced worker capabilities: concentration, innovation
- Increased industrial sustainability:
  - social (ergonomics, safety);
  - environment (CO2);
  - productivity (high quality, precision, innovation).

Technical challenges:

- Comfort: up to 8 hour shifts, new work models?
- Unhindered movements
- Initial settings, wear/un-wear time; external support
- Power supply
- Mental harassment
- Captured data security, confidentiality, anonymization
- ELSI aspects: ethic, legal, social

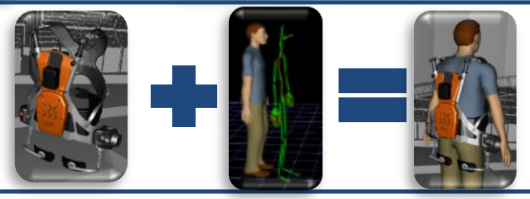
Design and optimization of human-centered workplaces with integrated Exoskeletons – Exo4*Logi*Prod

1. **Digital Twin** of **„As it is“** State

2. Ergonomics simulation of **„ As it is“** State

OWAS (Ovako Working Posture Analysis)
„Report Ergonomics Metrics“, LBA (Lower Back Analysis)
Force Solver

3. **Human+Exo Digital Twin -** Coupling Exoskeleton and Human Digital Twins



Fraunhofer IAO Innovation

4. Ergonomics simulation of the “**As it should be”** State with **Human+Exo Digital Twin**

5. Analysis **„As it is“ vs. „ As it should be“** States

vs.

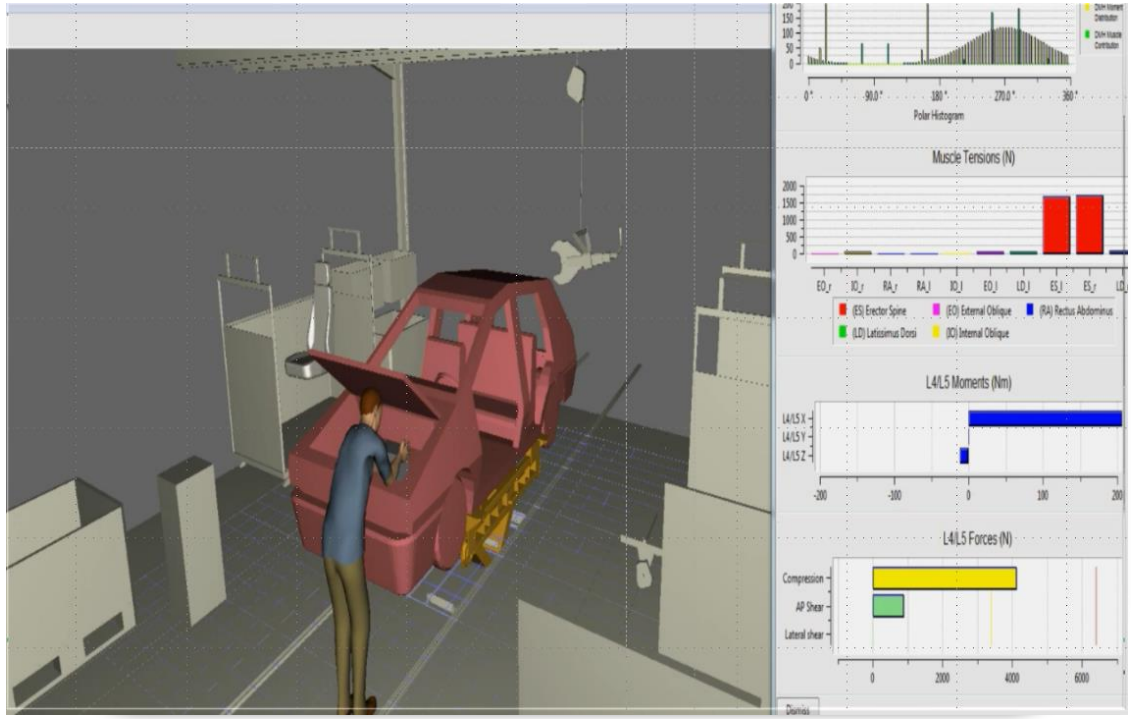
6. Planning/optimisation of hybrid workplace with integrated Exoskeletons. Hybrid working models. Implementation Roadmap and incremental improvments

Digital Transformation with Exoskeleton? (I)

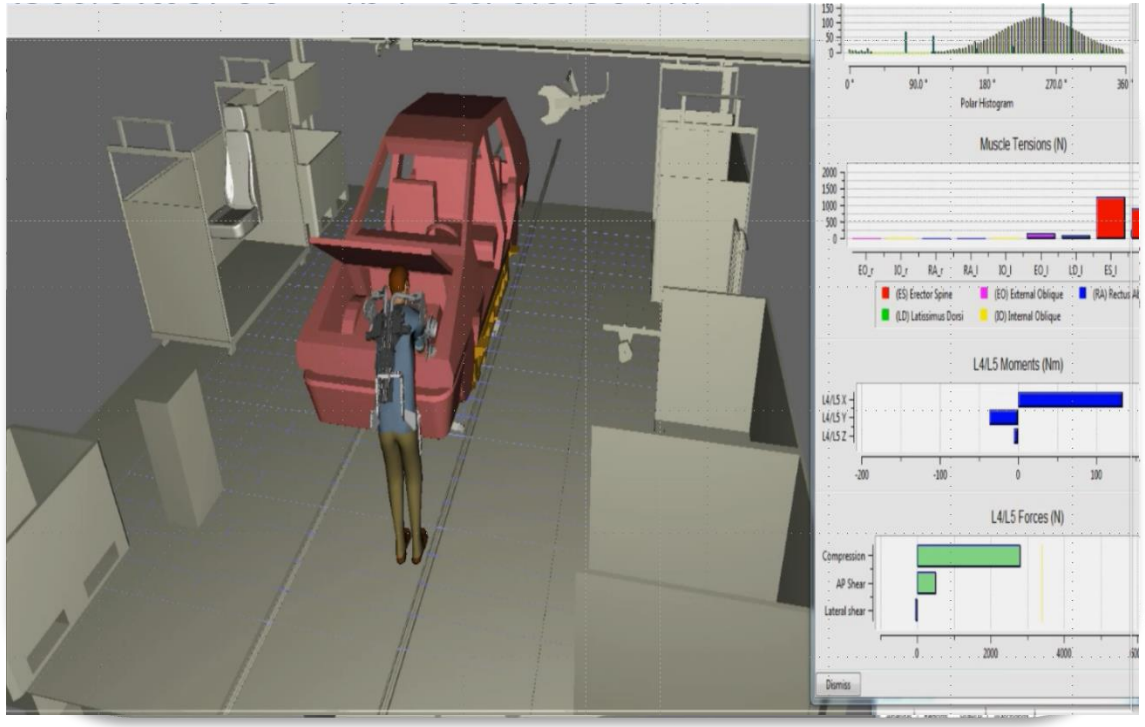
Car recycling Test Case: Removal of the driver's seat and of the battery

- Manipulated part: 25kg and 15kg;
- Distance walked per day: 1200m;
- Weight moved per day: 700kg.

Without Exoskeleton



With Active Exoskeleton



Lower Back Analysis Tool:

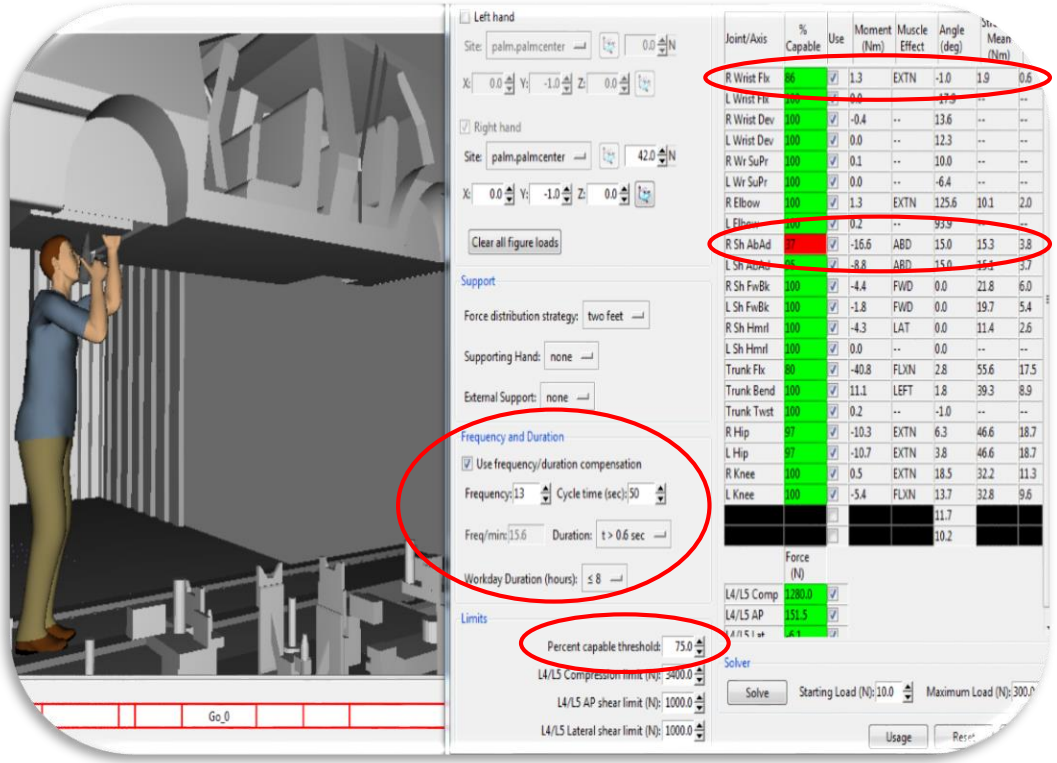
1) Forces (N); 2) Moments (Nm); 3) Muscle Tension (N); 4) DMH – Moment distribution

Digital Transformation with Exoskeleton? (II)

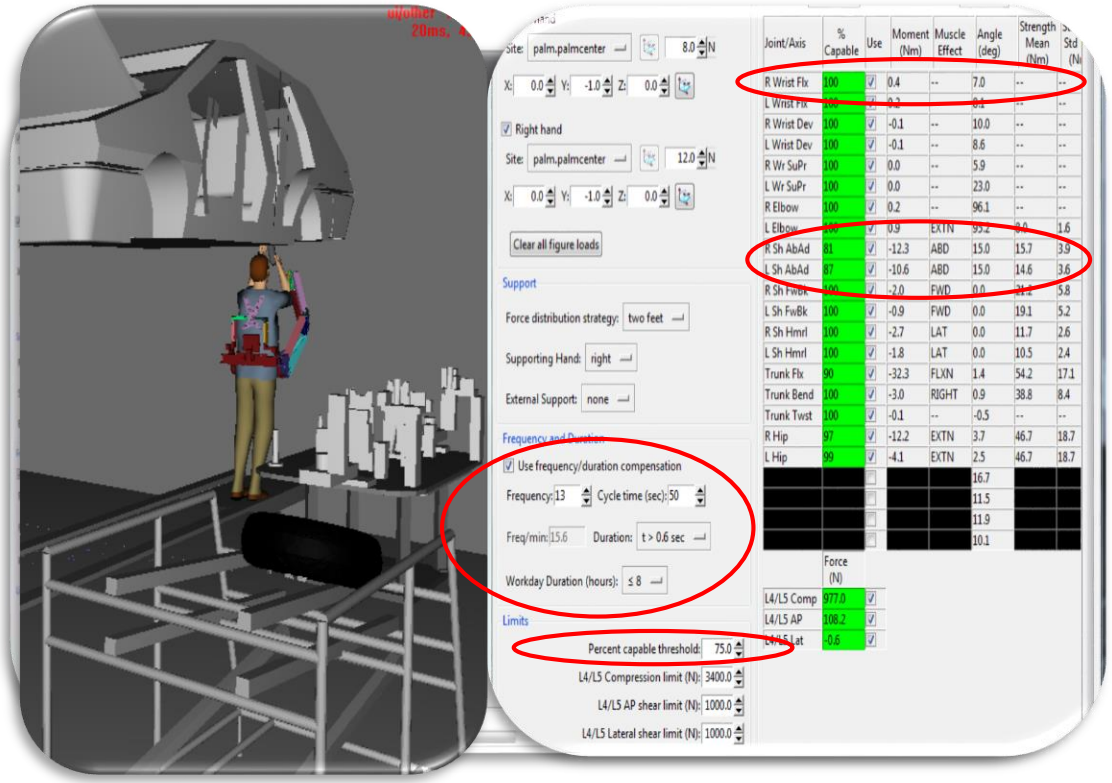
Car assembly Test Case: Working over the head - Shields Mounting

- Manipulated part: Screwing Machine 1,6kg;
- Distance walked per day: 700m;
- Process time/screw: 0,73 seconds;
- No. of screws: 13
- Torque Moment applied on the workers hand: 2,6Nm.

Without Exoskeleton

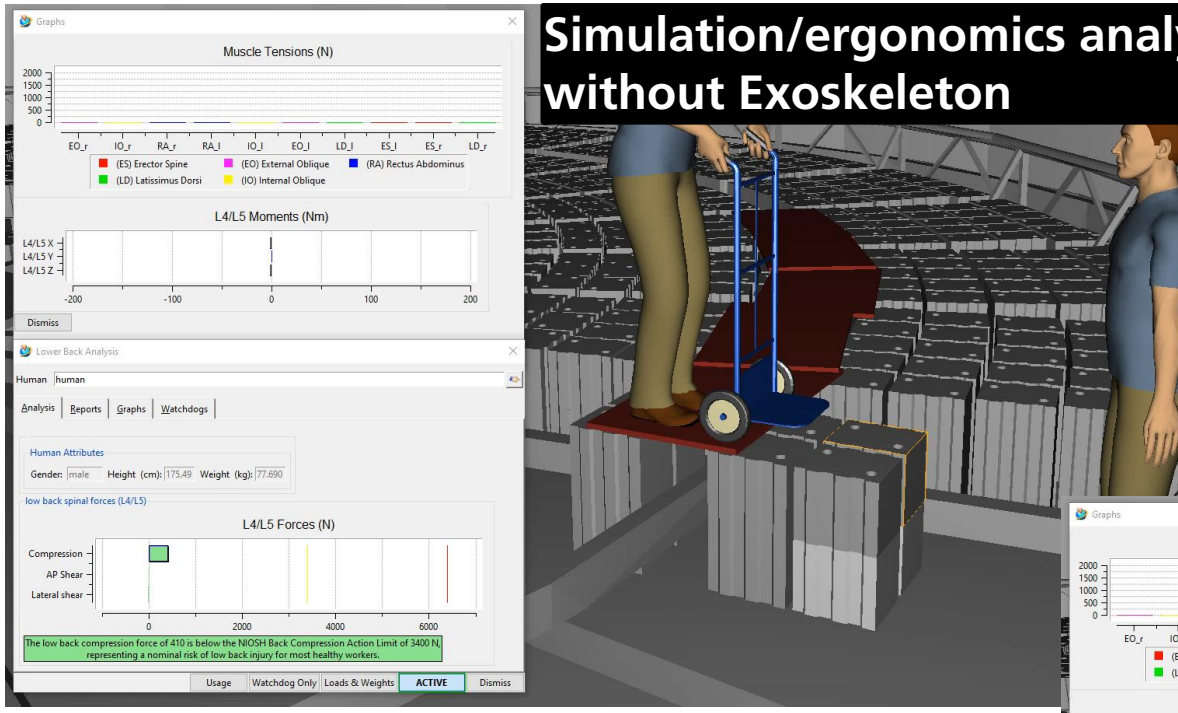


With Passive Exoskeleton



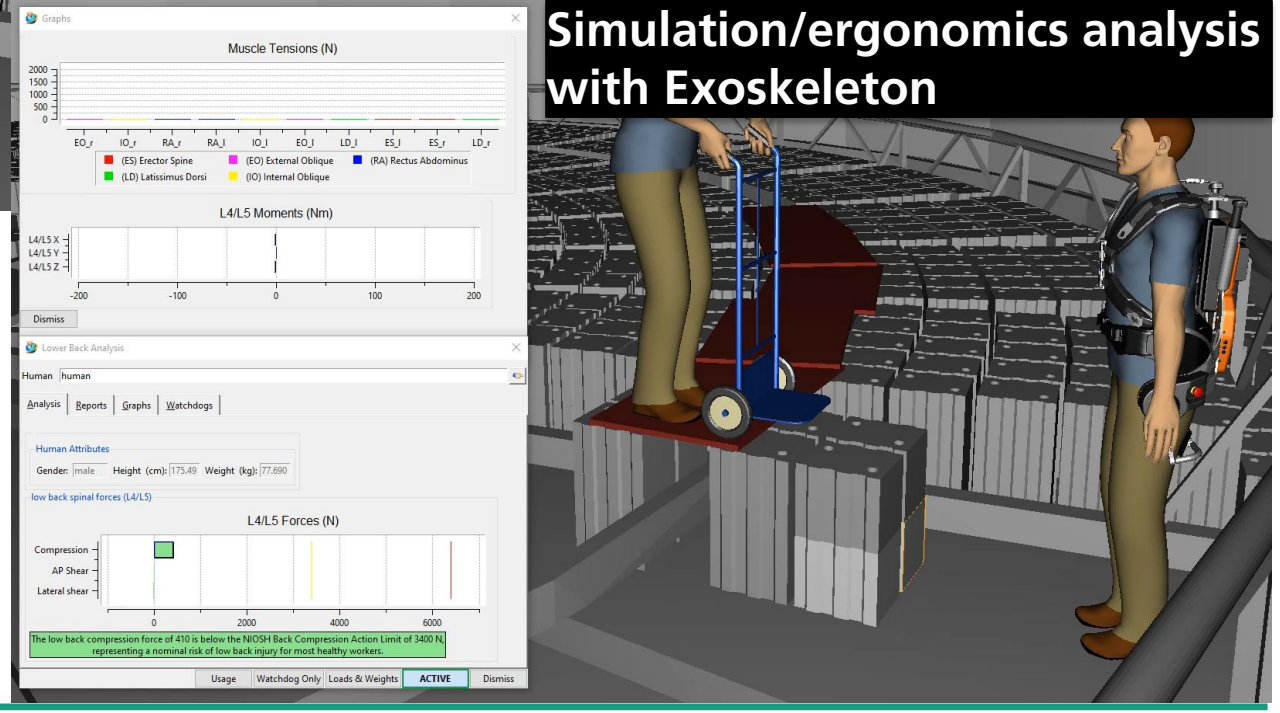
Force Solver Analysis Tool: Health of body joint based on frequency, cycle time, shift duration

Digital Transformation with Exoskeleton? (III)



Simulation/ergonomics analysis without Exoskeleton

Real life - Workplace model



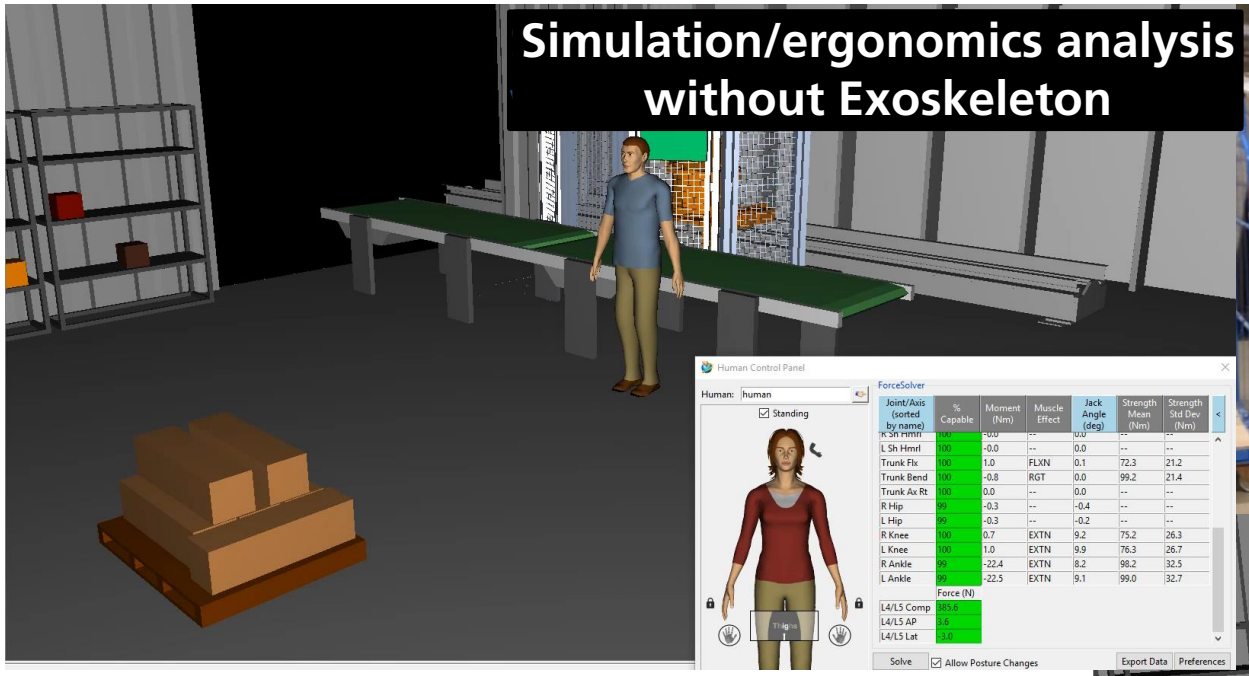
Simulation/ergonomics analysis with Exoskeleton

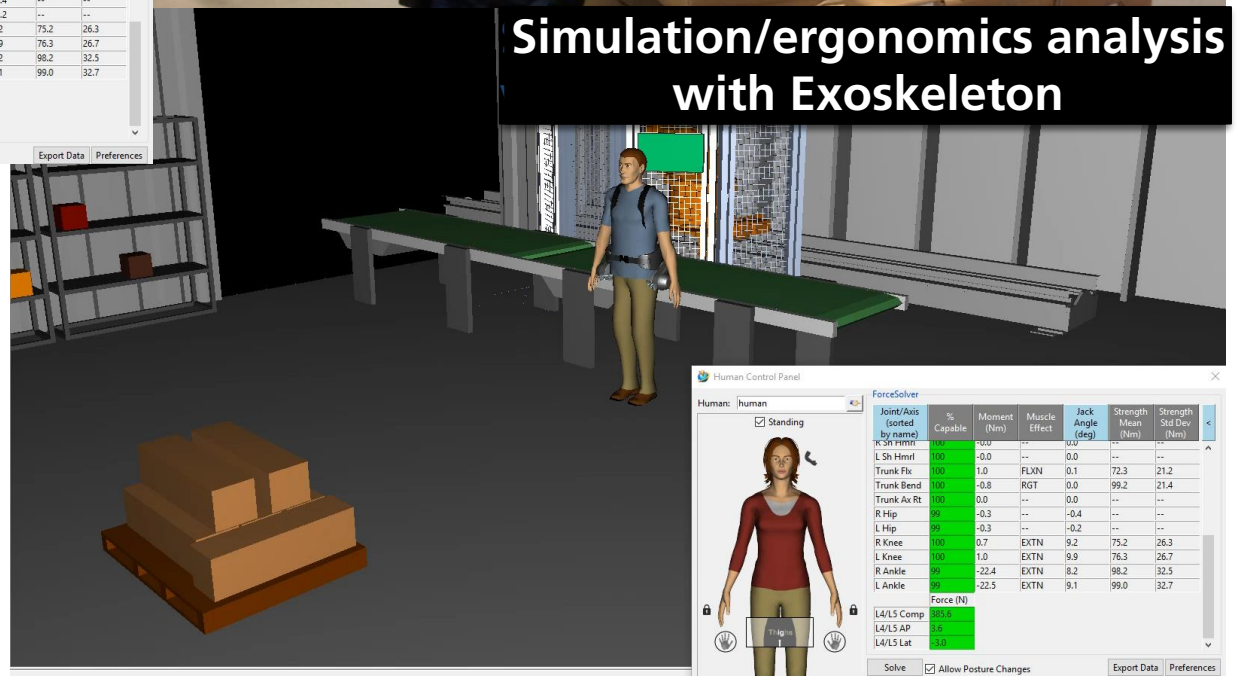
Construction industry: Manipulation of heavy parts

Test Case: Removing cement blocks for the Silos Maintenance

- Weight of the manipulated part: 20kg;
- Number of the manipulated parts/day: 250;
- Hours/Shift: 10;
- Weight moved by workers per day: 5000 kg.

Digital Transformation with Exoskeleton? (IV)





Logistics industry: Manipulation of heavy goods/parts

Test Case: Placement of a box on the conveyor belt.

- Weight of manipulated part: > 25 kg;
- Number of manipulated parts/shift: 125;
- Distance walked by workers per day: ~5.500 m;
- Weight moved by workers per day: ~ 3.500 kg.

Reference projects

Research:

BMBF: Exo4LogiProd - Arbeitsplätze der Zukunft mit integrierten intelligenten Exoskeletten für Logistik- und Produktionsprozesse in KMU (2019-2022)

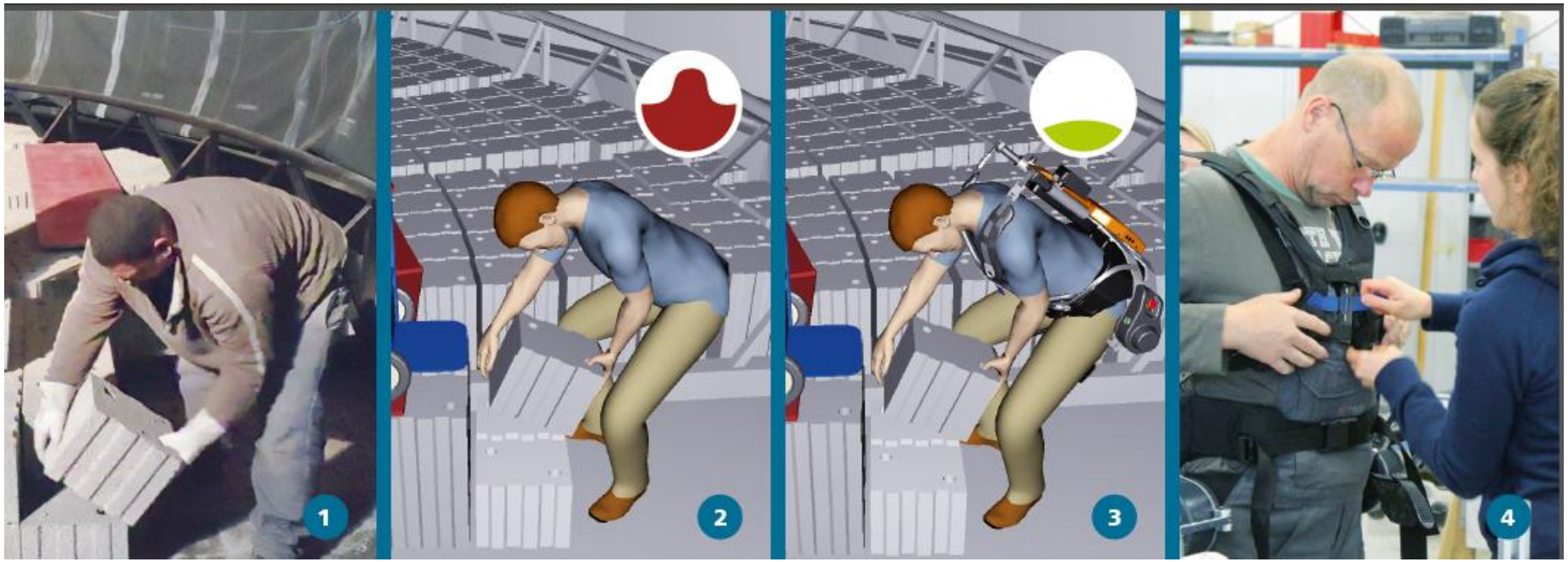
BMBF: Handwerk4.0 – Exoskeleton and Human-Robot Collaboration (in preparation)

EU FP7: RoboMate - Intelligent exoskeleton based on human-robot interaction for manipulation of heavy goods in Europe's factories of the future (2013-2017)

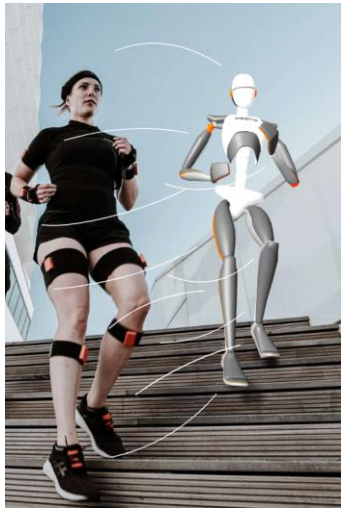
Industry:

- Automotive
- Construction
- Energy
- Logistics
- Food Processing

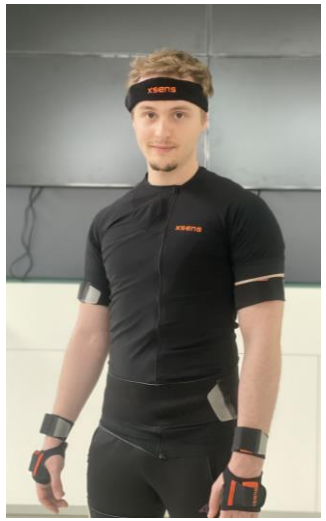
Exo4LogiProd



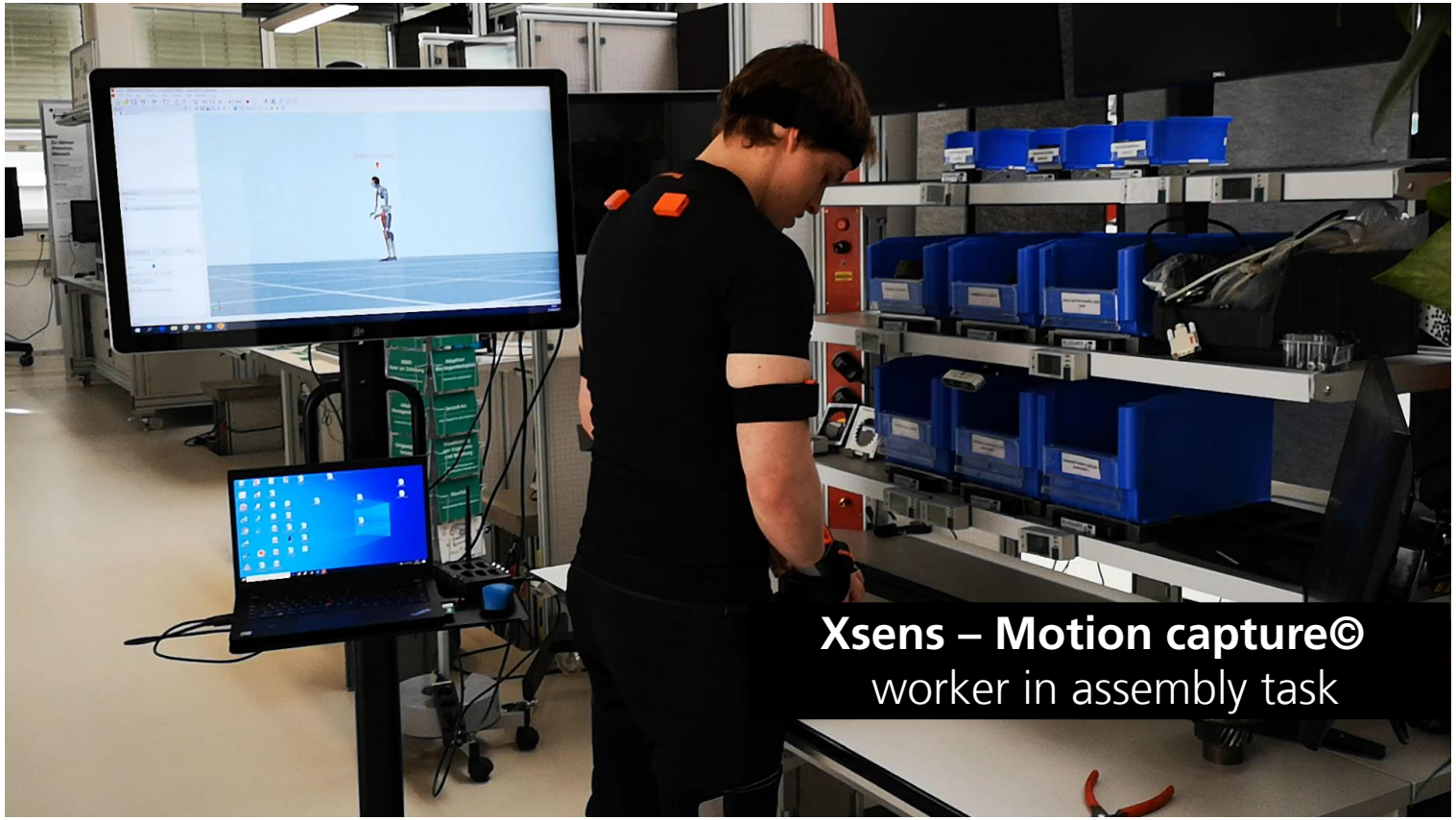
Real-time motion capture technology



Xsens - full body motion capturing © (https://www.xsens.com)

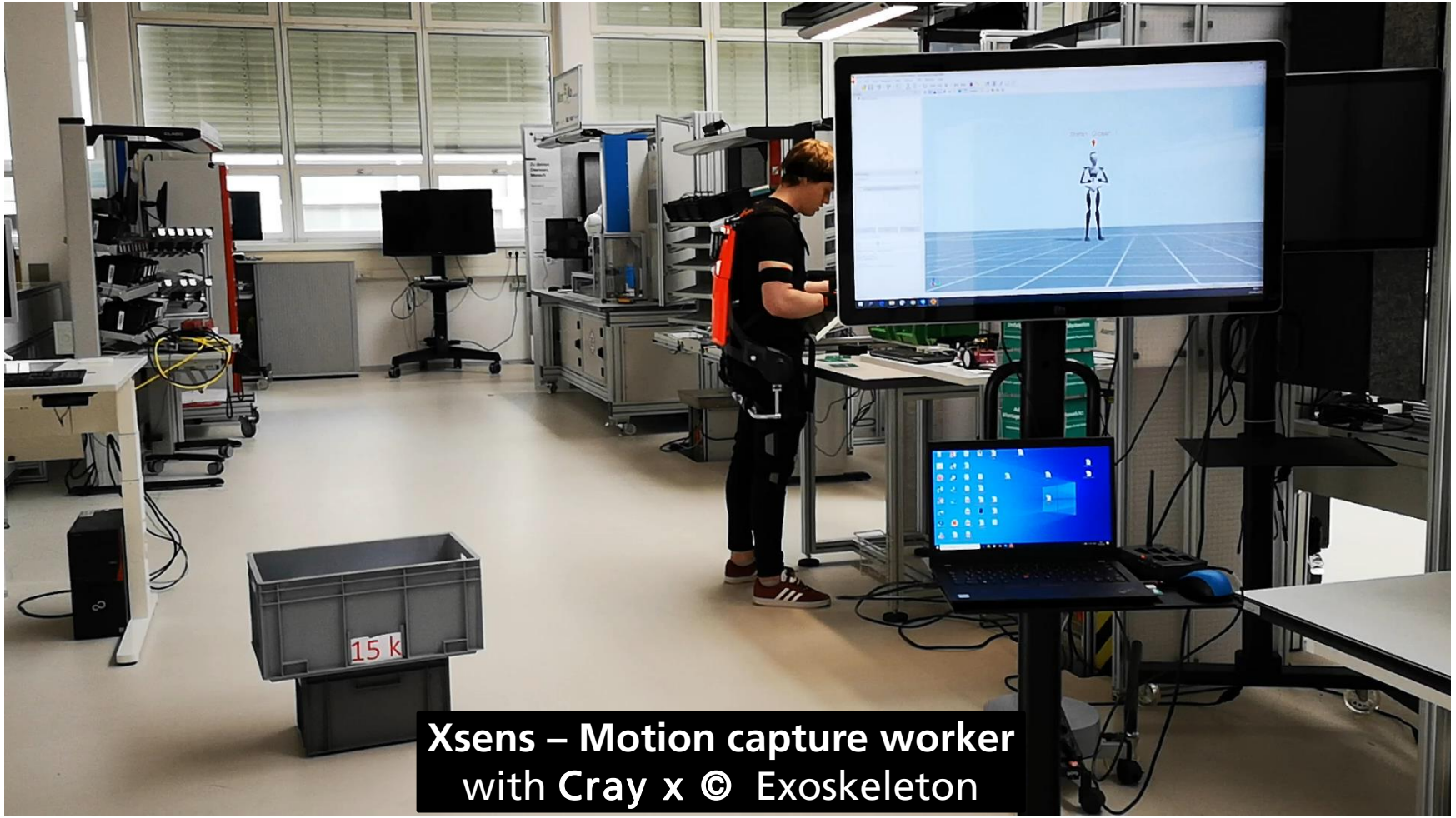


- Wearable sensor platform: 17 motion capturing sensors displaced all over the body for every movement part/joint
- MVN (Motion Virtualisation Technology)
- Analyze output supports joint angles, segment kinematics, segment global positions, and extensive sensor data.



Xsens – Motion capture©
worker in assembly task

Manipulation of heavy loads – Active Exoskeleton



Xsens – Motion capture worker
with **Cray x ©** Exoskeleton

Manipulation of heavy loads – In controlled environment

- Weight of the manipulated part: 15kg;
- Motion capture device reproduces in the virtual environment the movement and behavior of the human worker;
- The human worker is enhanced with a lower back support – Exoskeleton – manufactured by **GBS©** (https://www.germanbionic.com/)

Working over the head – Passive Exoskeleton

Xsens – Motion capture worker
with **SkelEX ©** Exoskeleton

Working over the head in controlled environment

- Working over the head – assembly tasks
- Motion capture device reproduces in the virtual environment the movement and behavior of the human worker;
- The human worker is enhanced with a upper-limbs support – Exoskeleton – manufactured by **SkelEX©** (https://www.skelex.com/)

Many warmly thanks!

Digital Twin Exo@Manufacturing2.0