

Selected topics from KUKA Brainport Industries annual conference 12.10.2016

- Introduction to KUKA
- Basic usecases for robots
- Robots in Healthcare
 - Robots inside the OR
 - Medical Robots
 - Medical Robots with KUKA inside
 - Challenge to make a medical robot
- KUKAs medical platform
- Industry 4.0
- What's next?

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KUKA, division healthcare

Date: Oct. 12th 2016



Technology transfer from Industrial automation to Healthcare



The KUKA Group in Figures



+ 14,000 employees worldwide

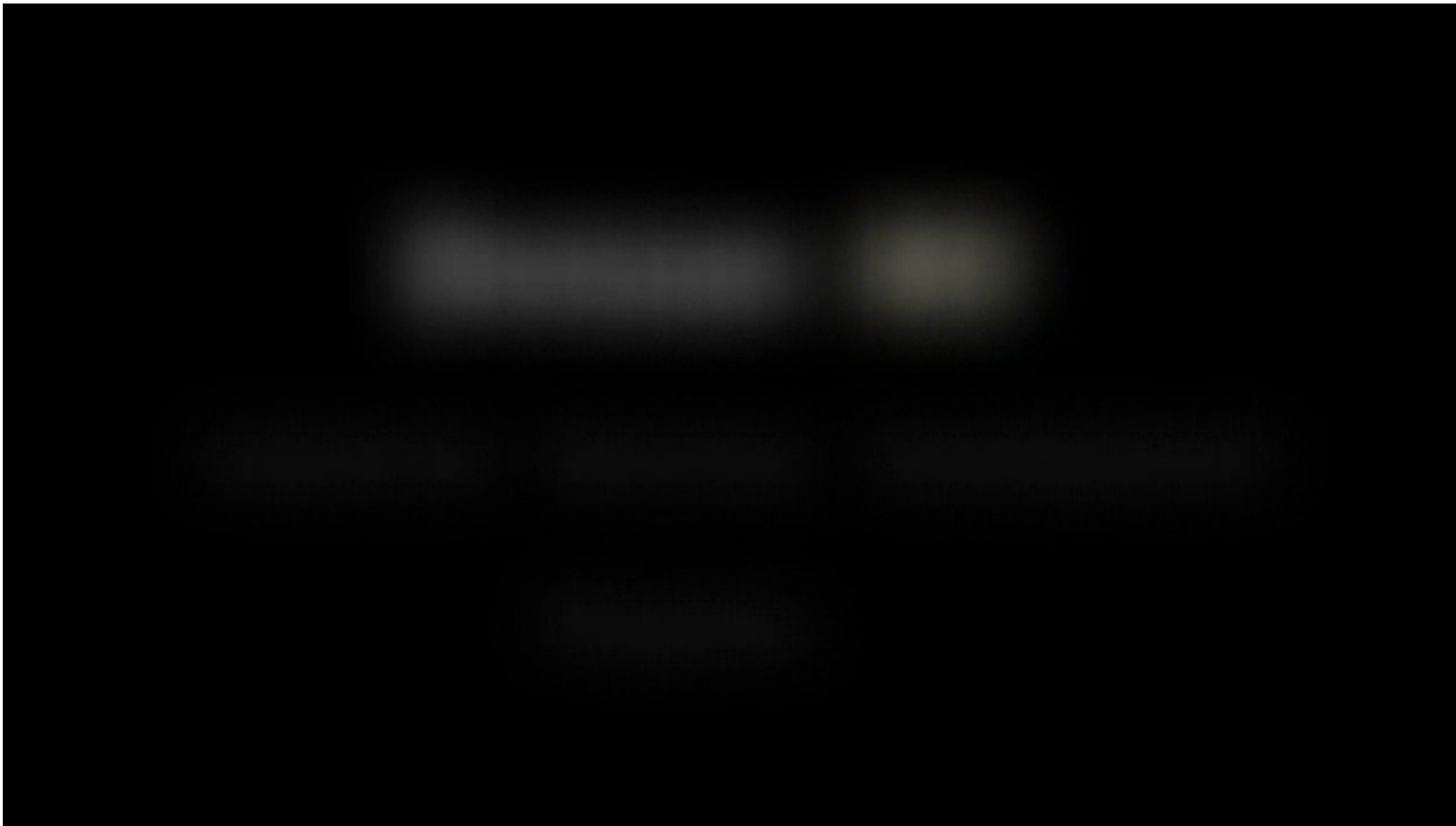
40+ countries worldwide

≈ \$3.0B in Sales* (2015)



\$100+ Millions in R&D (4-5%)

Thousands of Customers





Small product overview



LBR iiwa

The first industrial robot worldwide designed for human-robot collaboration. Sensitive, safe and able to learn.

KR AGILUS Series

The small robot series with unparalleled performance at the highest of speeds.

KR Cybertech

Minimized disruptive contour and streamlined design. Saves valuable space and reaches any point, even in confined spaces.

KR 30 / KR 60 Series

Masters payloads up to 60 kg and a pose repeatability of ± 0.08 mm. Precision handling of even heavy work pieces is thus no problem.

KR QUANTEC Series

Stands out for its maximum dynamism, extreme stiffness and high performance combined with low weight.

KR 500 Series

Heavyweight Champion of handling, machining and palletizing large and heavy components.

Light Weight
(3-14 kg)

Small Robots
(3-10 kg)

Low Payloads
(6-20 kg)

Medium Payloads
(30-60 kg)

High Payloads
(80-300 kg)

Heavy Duty
(300-1300 kg)

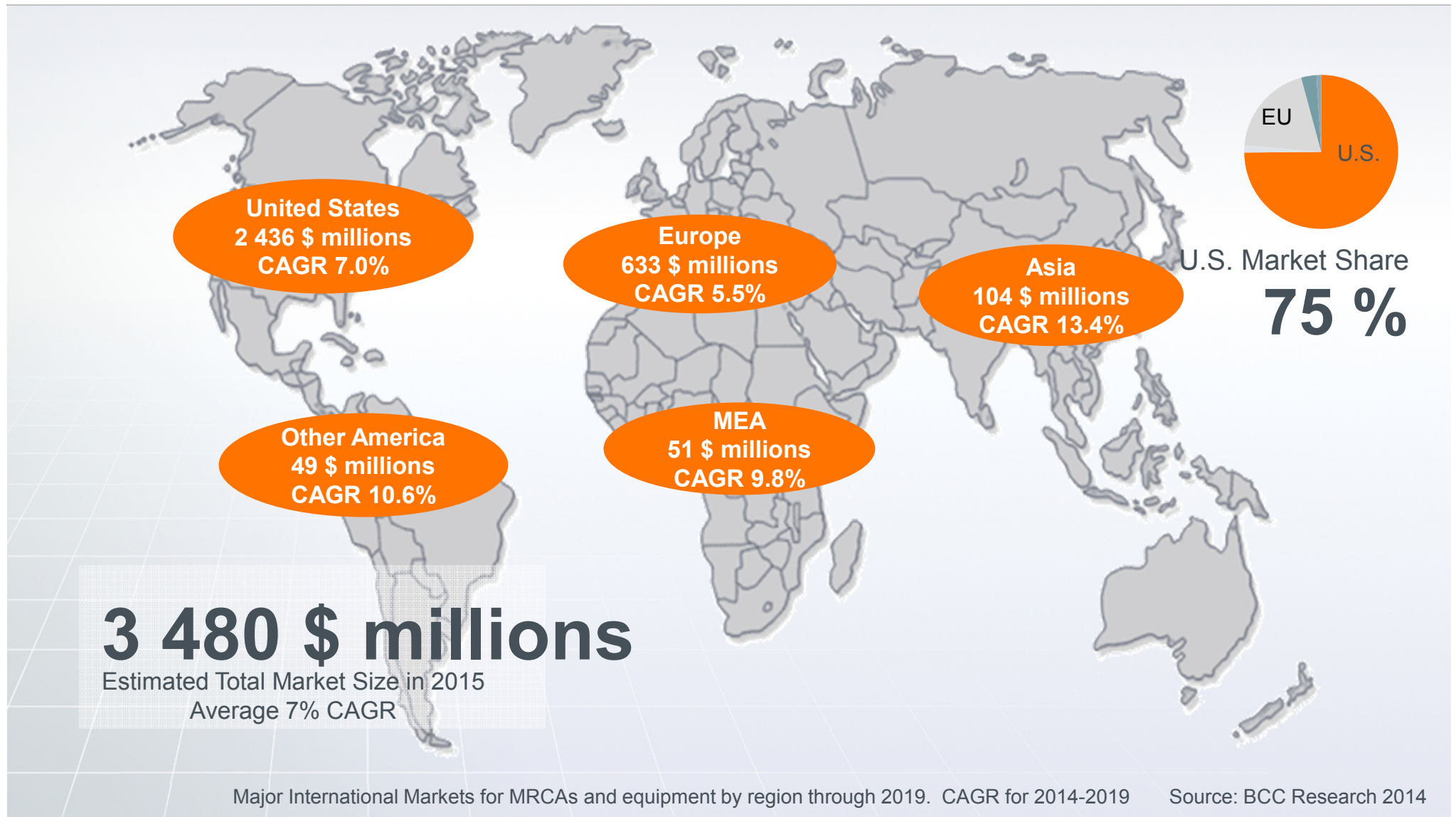


- Robots can move fast, exact and repeatable to a position and on paths
- Robots have a deterministic behaviour
- Robots can be strong and move heavy tools
- Robots will not become tired and can work 24/7
- Robots have no claim for ergonomic workplace
- Qualified offline simulation / plant- / production planning, fast ramp up.

Chances in Medical/Healthcare:

- Elimination of the humans arms shortcomings (Tremor, inaccuracies, weakness, ..)
- High offline treatment planning is now possible
- High accurate treatment execution after treatment-planning
- Let the operators sit in ergonomic position
- Add a better vision by magnifying Stereo-Endoscope, 4K vision.
- Enable MIS Interventions which can't be done by open surgery
- Intelligent Rehab

Medical Robotics and Computer Assisted Surgery Market worldwide





History and Trends in Medical Robotics



Overview Medical Robotics





Total Hip / Knee Replacement assisted by robots

1992: Integrated Surgical Systems: RoboDoc



~1998 CASPAR by ortoMAQUET



Intuitive Surgical

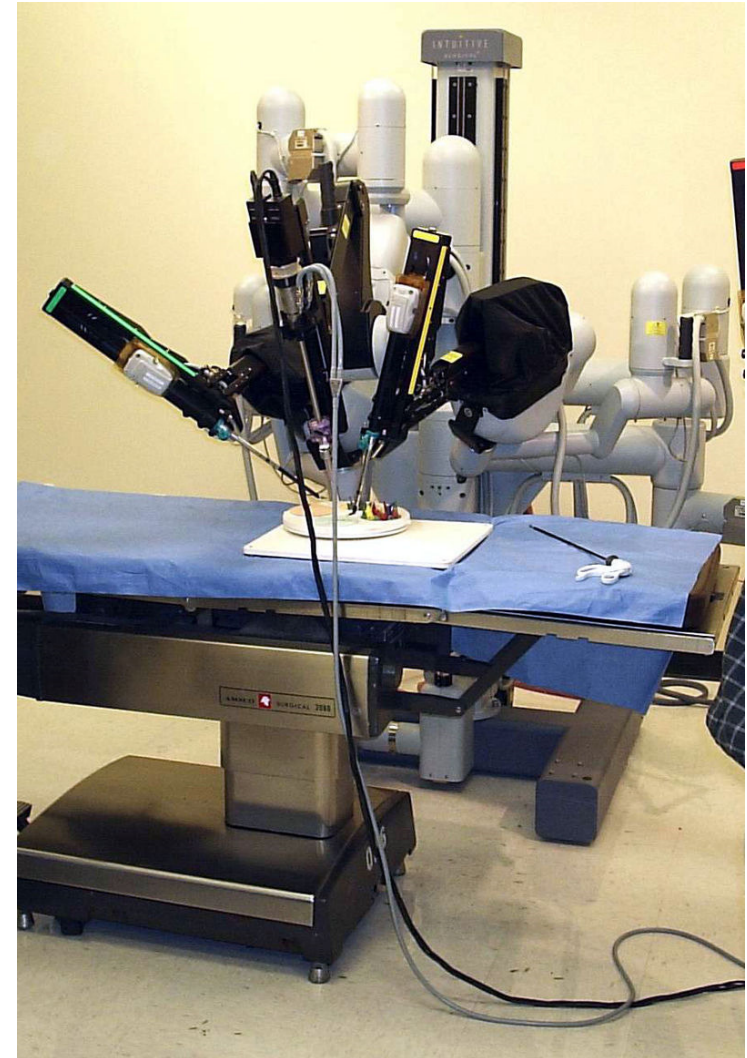
1997 Ready for testing

1999 Markteinführung Europa

2000 FDA Zulassung für Laparaskopie

2000 46 MIO USD Venture Capital

2003 Verschmelzung mit ComputerMotion





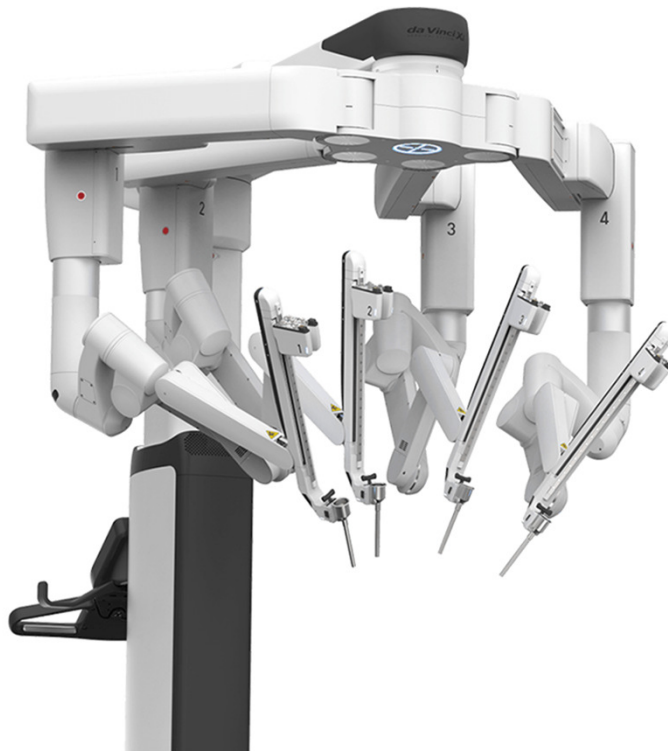
Surgical Robot Market in Detail

2 785 \$ millions

Estimated Size of Surgical Robot Market in 2015

80%

Intuitive Surgical Market Share
in Surgical Robots



- **Financial Performance 2014**

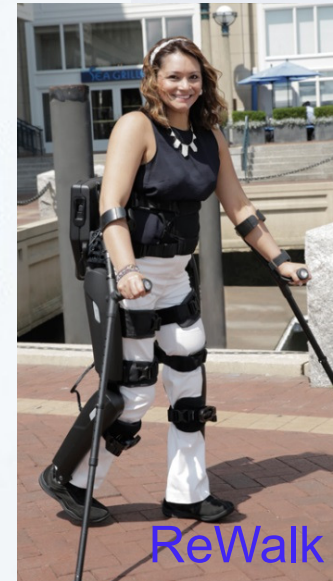
- Worldwide procedures grew by approximately 9% year over year
- 432 da Vinci Surgical System shipped
- Total revenue was \$2.1 billion

Source: BCC Research 2014



Cyberdyne

ActiveLink/
Panasonic



ReWalk

- Megatrend Exoskeletons
Multi-purpose including Rehab



EksoBionics



Hyundai



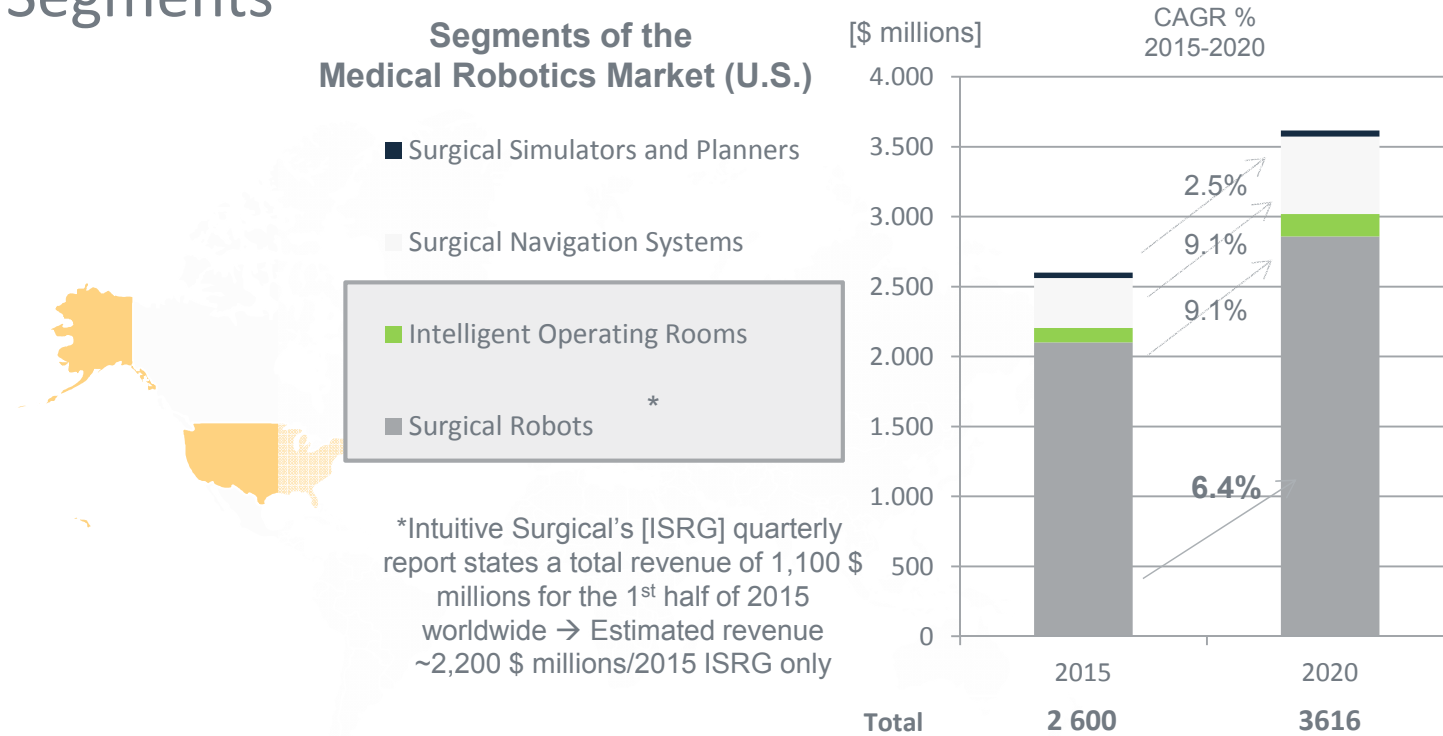
Mindwalker/March



Indego



U.S. Medical Robotics and Computer Assisted Surgery Market by Segments



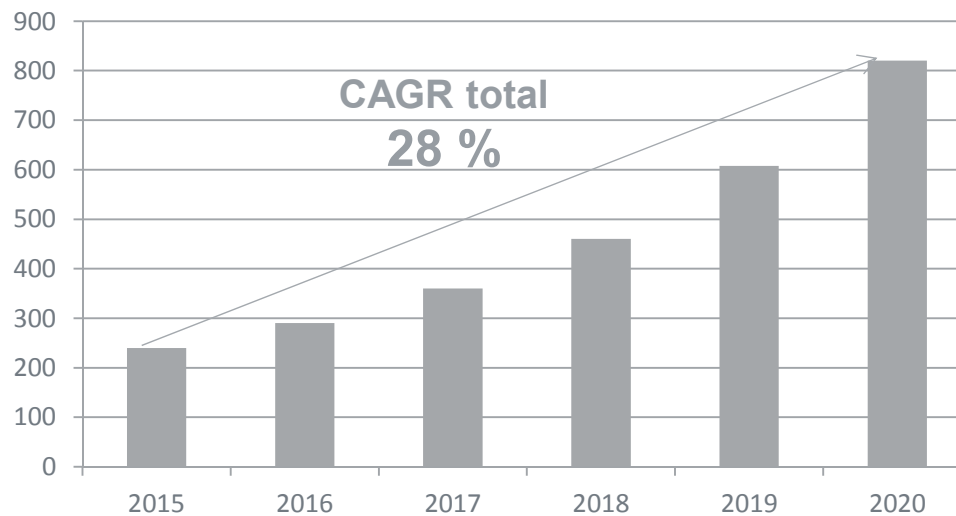
Equipment Type [\$ millions]	2015	2020	CAGR% 2015-2020
Surgical Robots	2 101	2 859.2	6.4
Intelligent Operating Rooms	104.1	160.9	9.1
Surgical Navigation Systems	357.1	552.6	9.1
Surgical Simulators and Planners	38.2	43.4	2.5

Source: BCC Research 2014



Rehabilitation Market Expectations

Rehabilitation Robot Market Forecast, \$Mio,
Worldwide, 2015-2020¹



Year	2015	2016	2017	2018	2019	2020
\$ Mio	239.8	290.1	359.8	460.5	607.9	820,6
CAGR	18%	21%	24%	28%	32%	35%

Key findings

- 8-10 relevant manufacturers on the market
- Top 50 manufacturers share 25% of the market²

→ Fragmented Market

→ Huge estimated CAGR

} High Potential

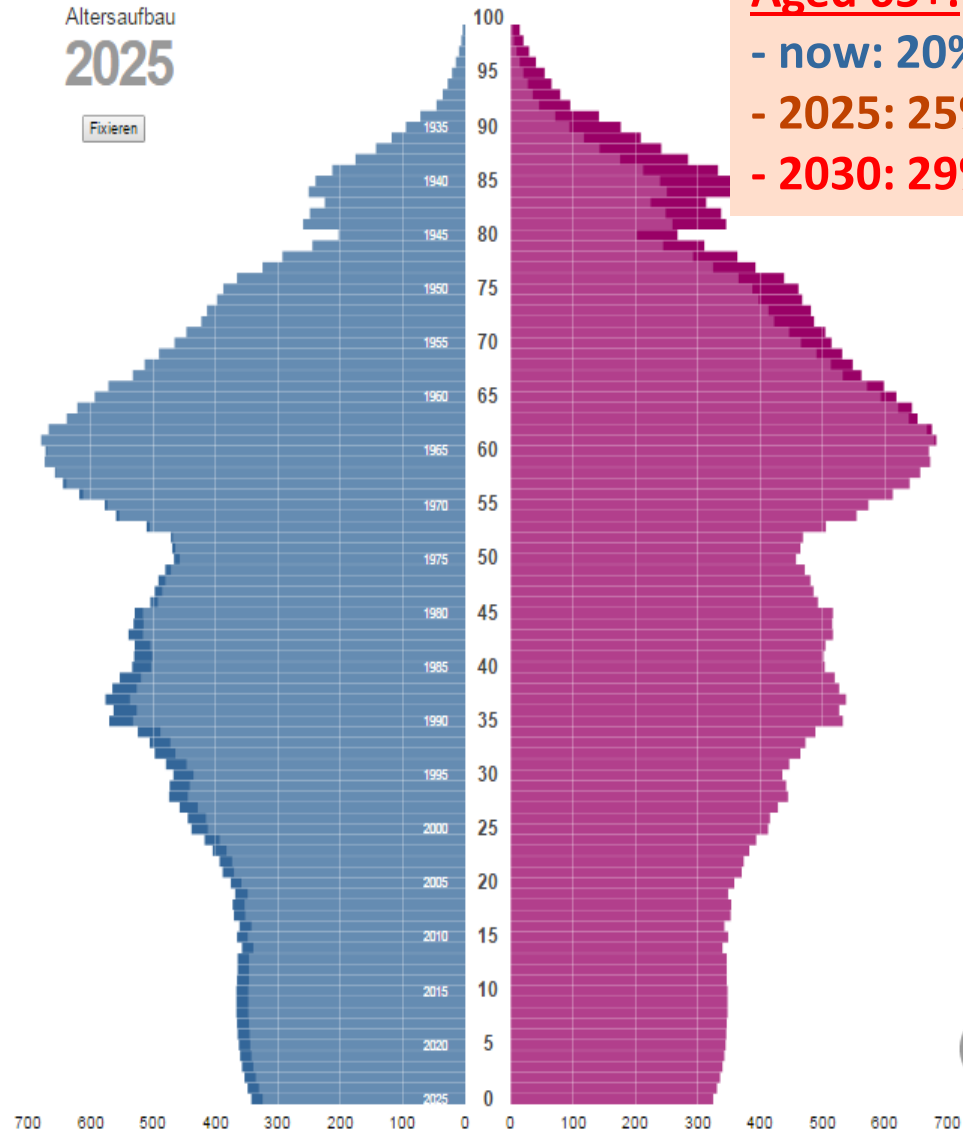
¹ WinterGreen Research 2015

² Novumed 2013

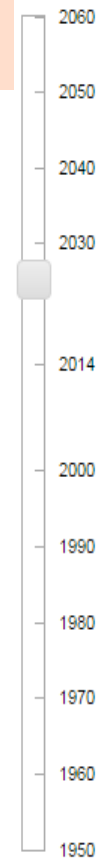


koordinierte Bevölkerungsvorausberechnung für Deutschland

STATIS
Statistisches Bundesamt



Aged 65+:
- now: 20%
- 2025: 25%
- 2030: 29%



Varianten

- Kontinuität bei schwächerer Zuwanderung
- Kontinuität bei stärkerer Zuwanderung
- Relativ alte Bevölkerung
- Relativ junge Bevölkerung

Annahmen G1-L2-W1

- Geburtenhäufigkeit
1,4 Kinder je Frau
- Lebenserwartung bei Geburt 2060
86,7 Jahre für Jungen
90,4 Jahre für Mädchen
- Wanderungssaldo (ab 2021)
+ 100 000 Personen

Alter	Millionen	Anteil
65+	20,0	25%
20-64	46,6	58%
<20	14,1	18%
Insgesamt	80,7	100%

Medianalter 46,9 | Altenquotient 43

Altersgruppen



Megatrends in Medical Device Technology

Success through intelligent Assistance Systems

Price Pressure

- Improvement on cost structure through Hospital Automization
- Quality management measures gain importance in the clinic
- Medical Robotics enables for less invasive procedures



Lack of skilled employees

- Robotic assistant systems can assist during interventions
- Robotic systems for elderly care can improve the patient's experience
- Hospital automization can improve the logistic processes



Rising Demand for Quality

- Rising pressure from competing hospitals
- Robotic solutions as unique selling point
- Improved quality control through automatic data acquisition



Demografic Change

- Rising number of interventions with fewer skilled employees
- Home care applications can enhance the active phase for elderly



Medical devices with **_KUKA_**inside





- Tumors are treated using a robot-guided LINAC (emission of high-energy X-ray radiation). Compared with conventional systems, this allows extremely flexible positioning of the LINAC around the patient and thus optimal radiation angles.
- KUKA supplies RoboCouch control and mechanical components for patient positioning.



Copyright by Accuray



System partner for angiography



- KUKA delivered the robot technology for this, the world's first robotic angiography system. In order to take X-ray images, a C-arm is installed on the KUKA robot.
- Fast motions and versatile positioning options allow for high flexibility for patients and doctors as well as for a rapid switch from interventional to surgical use.

Copyright by Siemens Healthcare



KUKA medrobotics achievements - #2 in the field of medical robotics (>1500 installations)*



- 650 Artis Zeego installations



- 350 CyberKnife installations



- More than 550 installations for RPP



- 80 LBR installations med environment
- LBR med in the race to the customer 2016



Robotic patient positioners



Accuray Robocouch



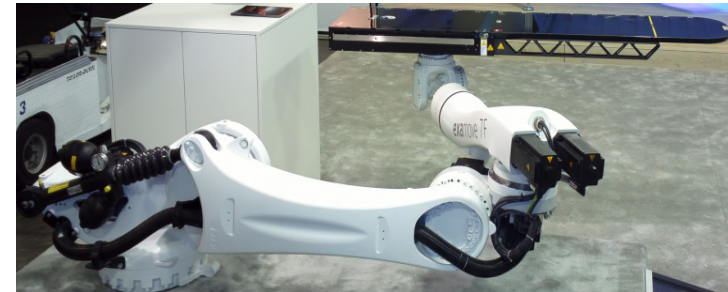
BEC examove 6C



Optivus-Couch



Forte-Couch



BEC examove 7F

Hippotherapie – Intelligent Motions Hirob



- Neurorehabilitation by Hippotherapie directly in the hospital
- No Hygienic implications
- Original horse saddle motion simulation.
- Stimulation of the hip region for neuronal stimulation of moto-sensoric system in the brain.
- Stimulation of neuro-plasticity



Movie: Hippo-therapy



HaiLeg: High articulated intelligent Leg - Analysis and Rehab



Functional trajectory analysis, diagnosis, training, rehab, performance feedback, high force



KUKA Maid

[Pre-Development project: Stroller]

- Standing up aid
- Transport-helper
- AGV features
- surveillance
- walking rehab
- walking companion
- mobility assistant

...





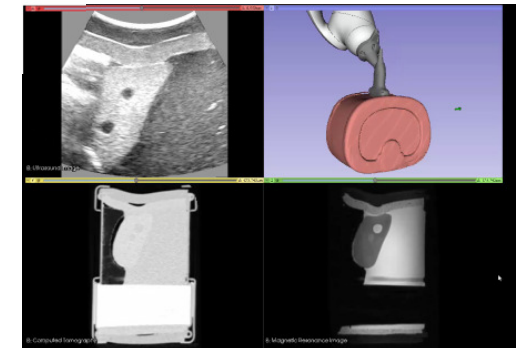
Robotic OR of the Future?



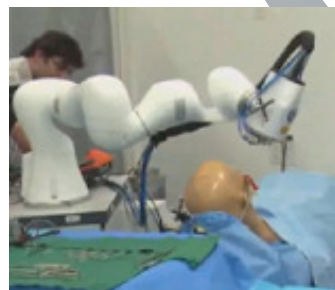
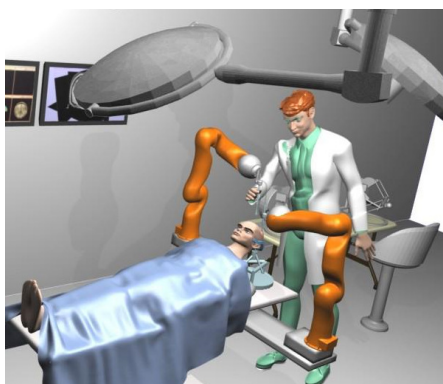
*Assisted and Guided
Therapy/Interventions*



*Multimodal
Interventional Imaging*



combining
components and data
into
**solutions and medical
workplaces**

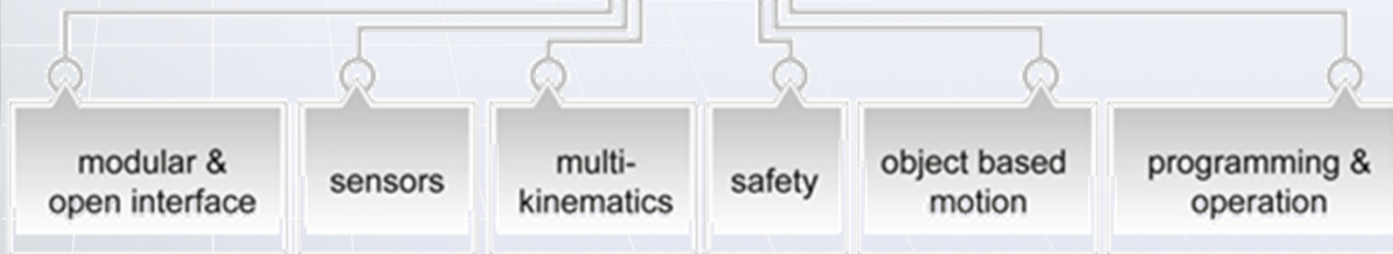
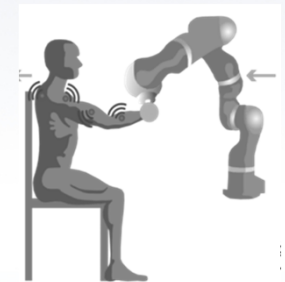
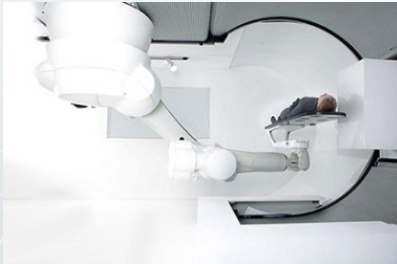


*Robotic Patient
Positioning*



KUKA Medical Robotic Platform for Industry Partners and Research

A robotic platform for research, clinical trials and medical products





The challenge of the medical market (for us)



“factory economy”



New & complex markets



Customers want to do completely NEW things

Challenge for R&D

- New robotic behaviours
- New safety measures

Internet Technology

- New interfaces to customers IT

Intelligent Robot Software

- Programming free operation
- 100% expected behaviours



It's not enough to just ship the robots

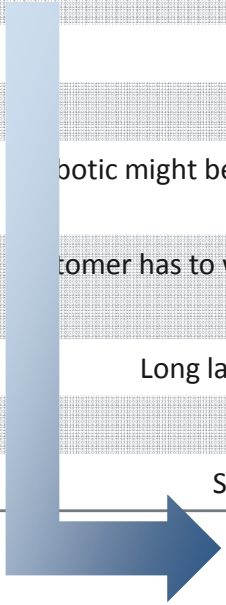


Industry

Medical

Differences in Product development and Product Lifecycle

Industry	Medical
High volumes	Small volumes
Production is evolutionary highly optimised and is ,humming' for thousands of the same robots	Individual solutions. Often in parallel to serial production / re-work after serial production needed.
Technical product „enhancements“ without involving the customer	Strict change management. Changes might be relevant for medical clearance
Acting, as we think it is best. Frequent changes on the system during ist lifetime	10 years unchanged product
Fence, Emergency stop.	HRC, EMG mostly not suitable
Machine directive (no danger for life)	Medical directives, ISO -60601, -13485, -62304 Riskanalysis, Systemanalysis, CB-Reports
Maximum load from the spec.	4-times static overload
Poor industrial design	Smart Medical-Design
One rampup/programming, > 10 Mio. cycles	Specific system behaviour
Customer „grew up“ with robotic, well experienced	robotic might be completely new → Intensive „robotic customer care“ needed.
Customer consumes robots. Time to SOP / Market < 2 weeks after shipping	Customer has to wait for medical clearance. High investment, high risk, TTM 2J++, (if ever)
No PLM, Unload robots from Truck and leave	Long lasting PLM, Quality assurance contracts
Minimal error reporting	Error tracking and reporting
Customer is responsible for his production	Supplier also carries responsibility

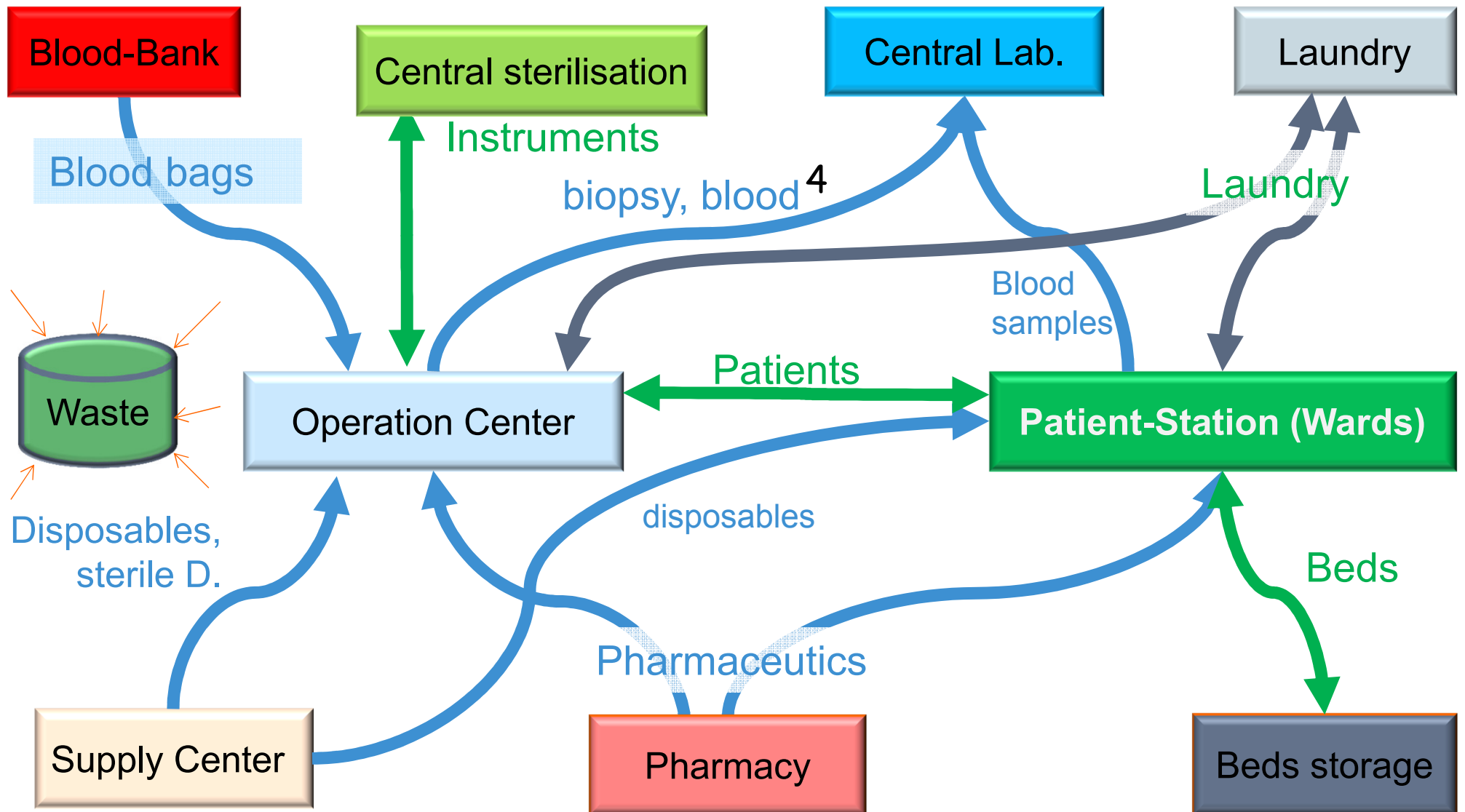


Much more complex for supplier

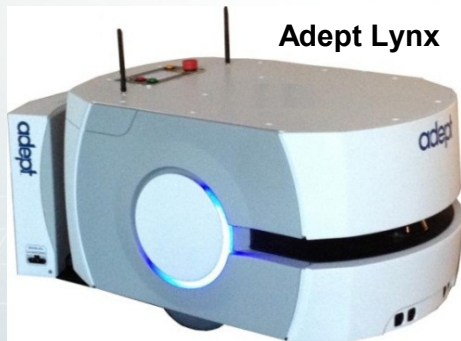
Hospital logistics

Generic Map of stations and routes / Overview

KUKA



little overview



Panasonic

Hospi-Rimo



Communication Assistance Robot "HOSPI-Rimo"

Panasonic

HOSPI-R



RCab300



GoCart
YuJinRobot.com



Industry 4.0

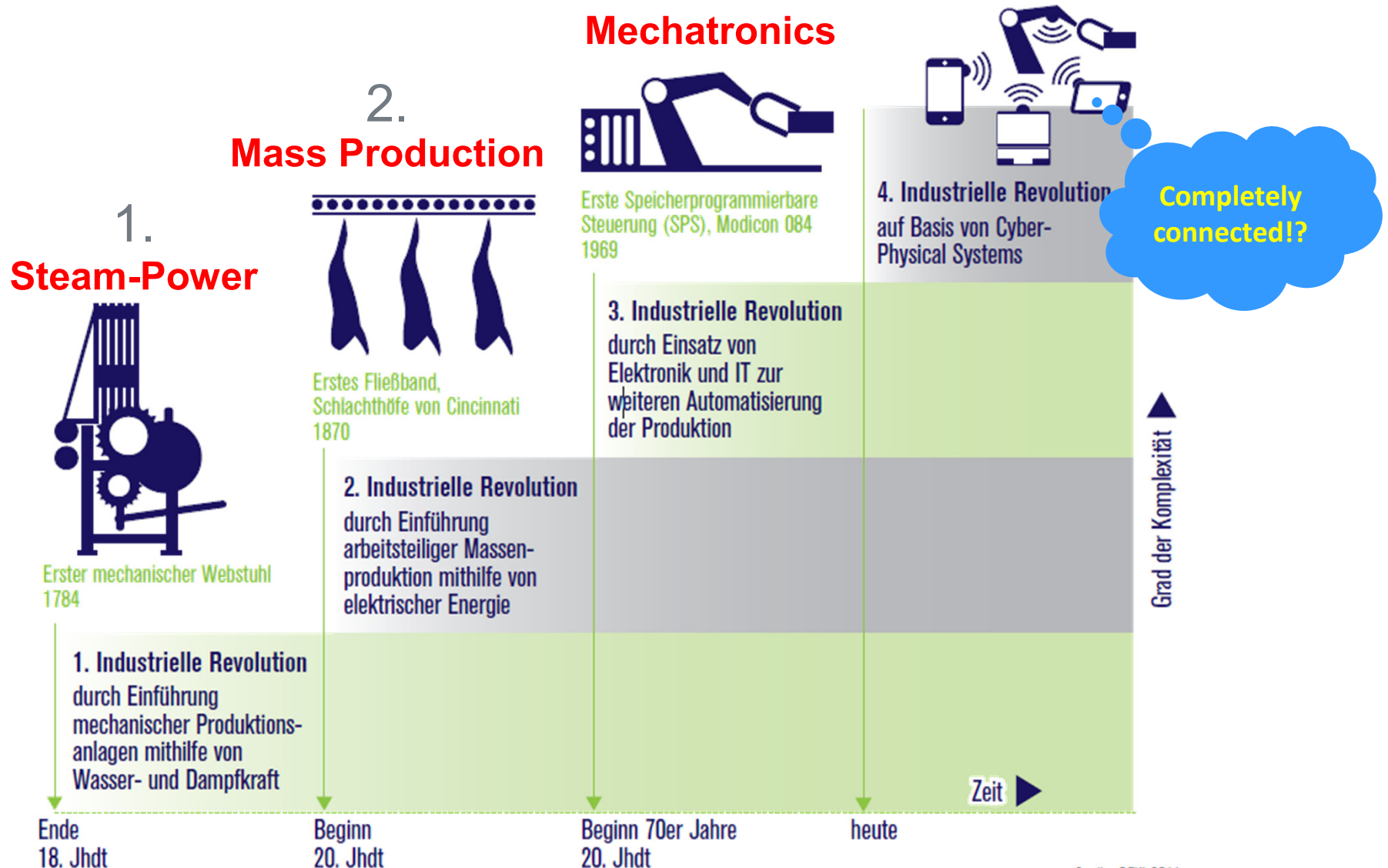




3.

Cyber Physical Systems CPS

4.

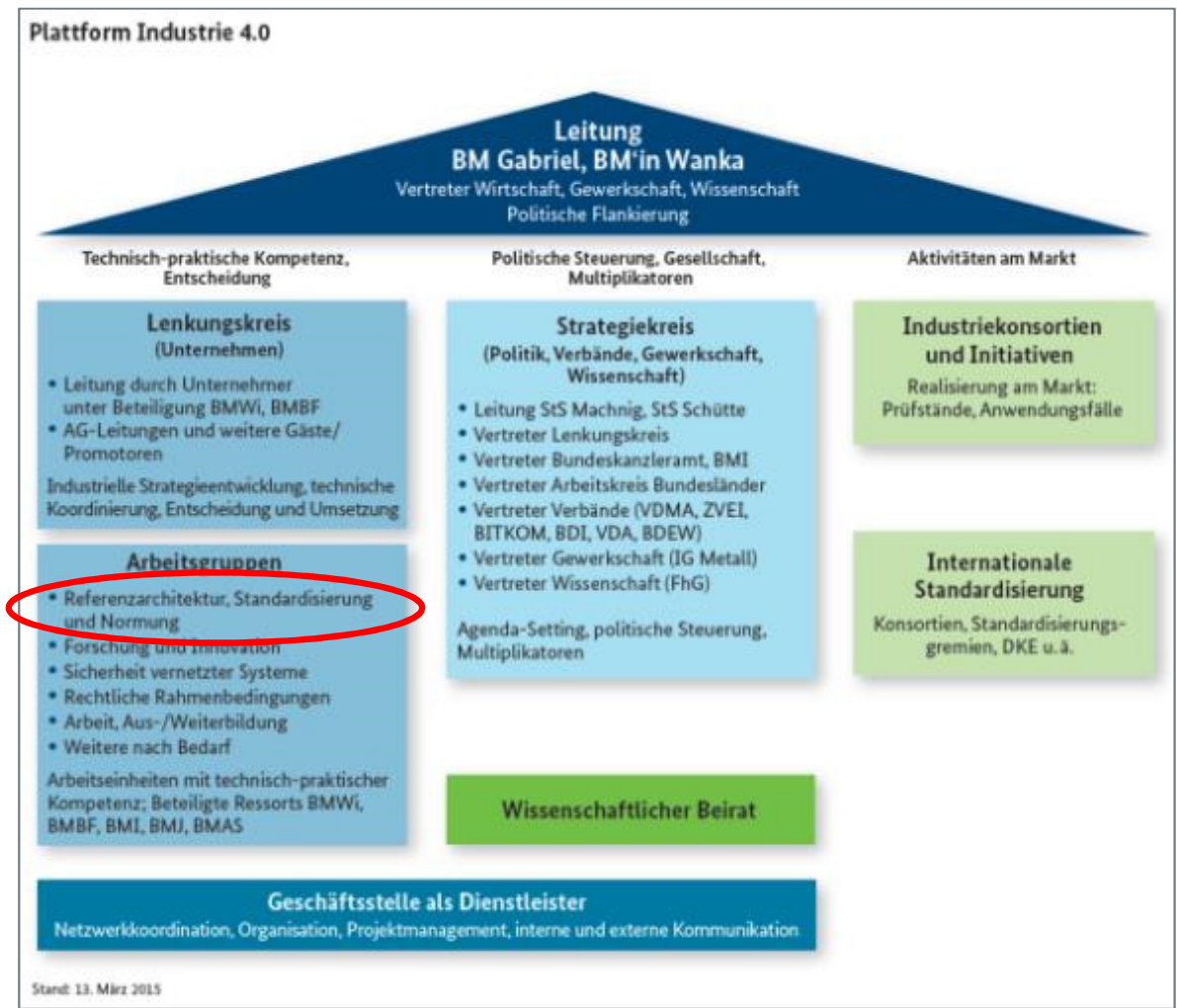


Quelle: DFKI 2011



Industry 4.0

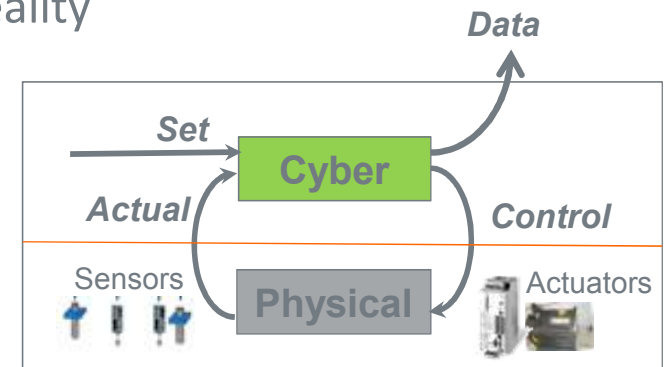
- Industry 4.0 is one of ten „Future Projects” of the German Government
 - 1000 Mio. € grants
 - Controlled by the German Government
 - Supervised by Chancellor Angela Merkel (visited KUKA in 03/15)
 - Minister for Economic Affairs & Energy Sigmar Gabriel
 - Minister for Education & Research Johanna Wanka
 - KUKA set one of the vice chairmen in the “Reference Architecture and Standardization” working group (Andreas Keibel)





What are Cyber Physical Systems?

- ... measure the physical and chemical environment with sensors (“Actual Value”)
- ... calculate a digital representation of the physical/chemical reality
 - „Virtualization“ of the reality (“Virtual Reality”)
 - “Digital Twin”, “Digital Mirror”, “Digital Shadow”, etc.
- ... continuously compare this situation with “Set Values”
- ... compute new “Control values” and give them out to actuators
- ➔ closed loop controls
- ... can be distributed (holon)
- ... and hierarchical (holarchic)
- ... and self-similar like fractals
 - “Fractal Automation”[®] by KUKA since 1999
 - <http://www.m.trademarks411.com/marks/75865864-fractal-automation>



Printing Press, Bosch-Rexroth



Source: <http://offsetpressman.blogspot.com/2011/03/how-flying-paster-works.html>



Large Hadron Collider, Cern



Power generation and distribution



Mars Rover



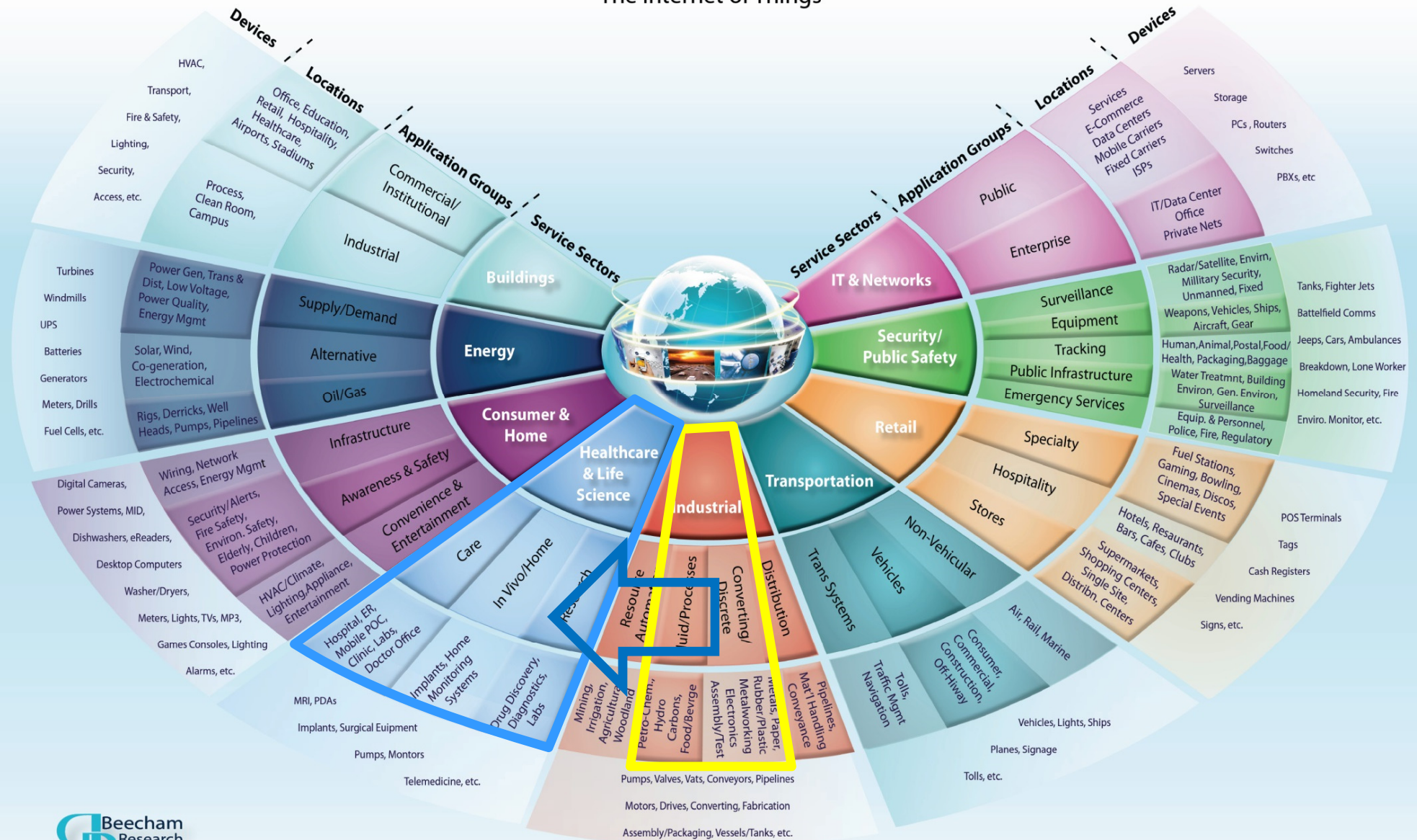
Automotive Industry



THE INTERNET of THINGS (IoT)

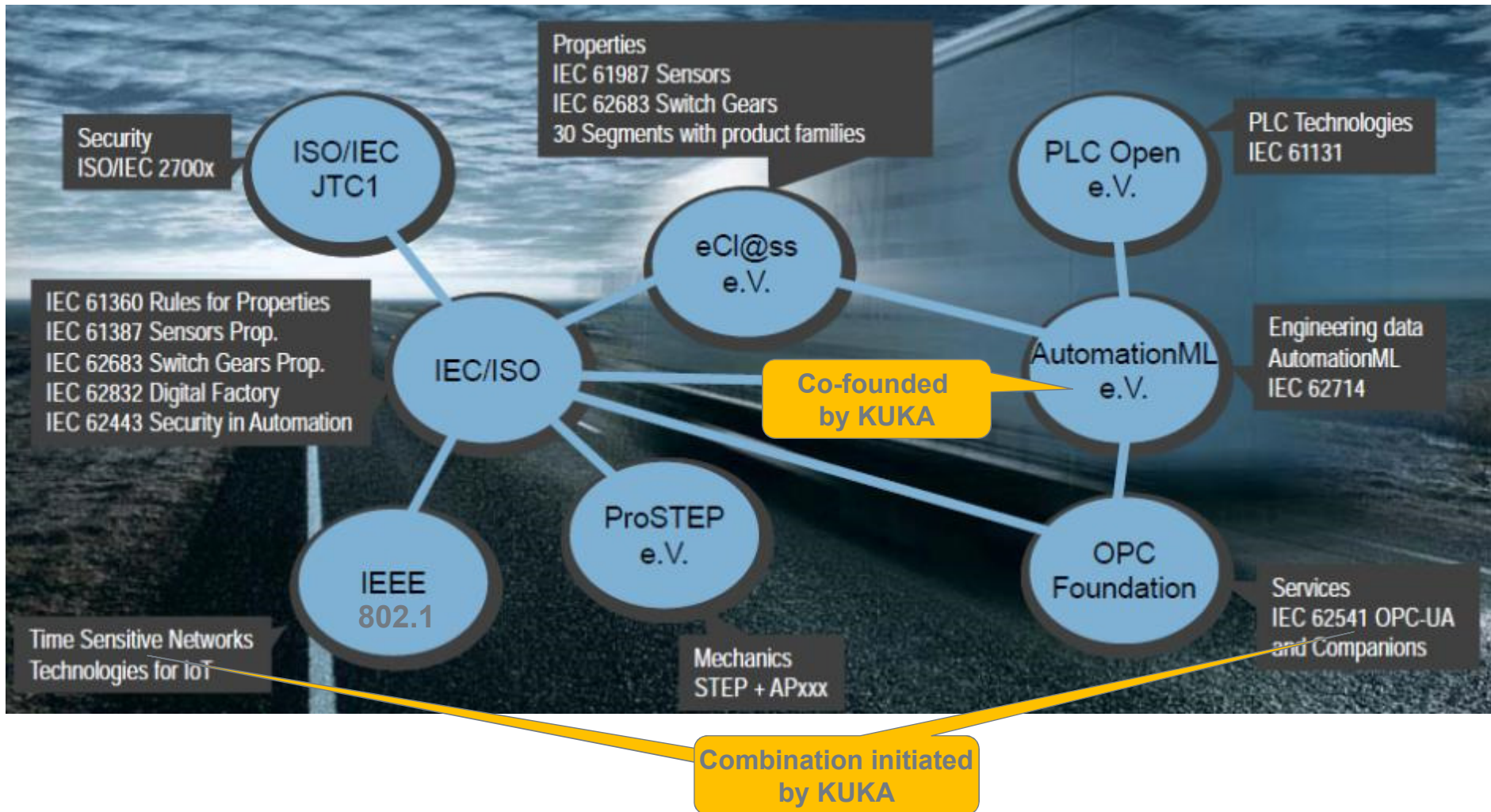
M2M World of Connected Services

The Internet of Things



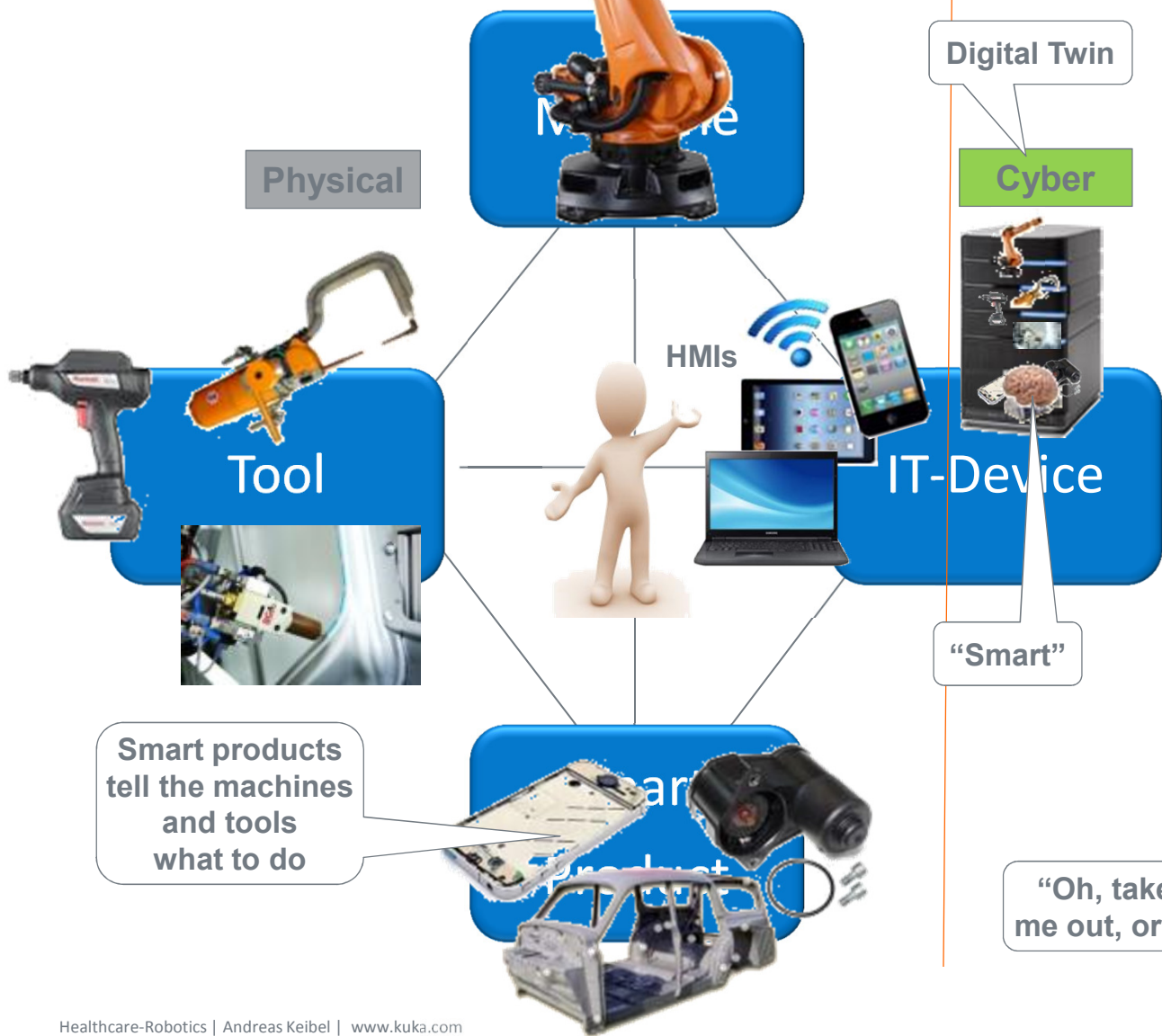


International Standards are key to Industry 4.0





Industry 4.0 Components and their Virtualizations



“Smart products” are not new:
Brothers Grimm
“Mother Hulda” (Frau Holle)

“Oh, shake me, shake me,
 we apples are all of us ripe!”

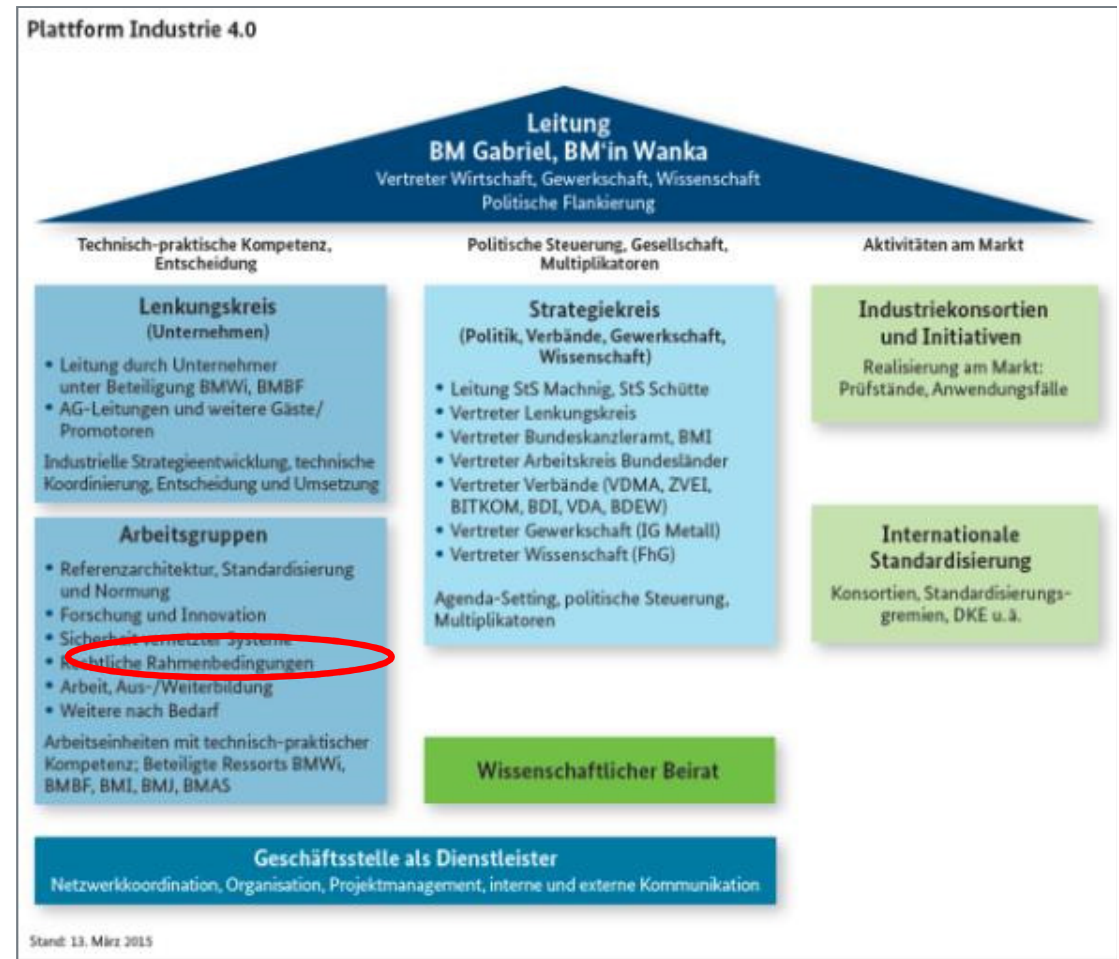


“Oh, take me out, take
 me out, or we shall burn!”

KUKA What about Security?



- Obviously, Security is mission critical for Industry 4.0
- However, there are only little real new requirements
- Big business already runs in the cloud and on IT-Systems since many years...
- ... with all known problems (Stuxnet, Sony Hack, Bundestag, etc.)
- There are many ways to overcome these requirements
 - I.e. keep your data in the private cloud
- There is a separate working group in the Industry 4.0 Platform just to address security
- (Functional) Safety is another topic but has only little touch points with security





Downside:

DDoS by hacked IoT Devices (Cameras, Sensors, Routers, ...)

- **OCT 16: Source Code for IoT Botnet 'Mirai' Released. Access to 350K+ devices. This botnet already caused 1.1 Tera Bit/s DDOS**
- **Gartner Inc. forecasts** that 6.4 billion connected things will be in use worldwide in 2016, up 30 percent from 2015, and will reach 20.8 billion by 2020.

Risks of unsafe IoT

- DDoS
- Self inflaming machines by software driven overheating
- Dangerous health-supporting devices. E.g. pacemakers, dosing-devices...
- Power-station attacks, production site attacks....



Any upcoming robotic megatrends?

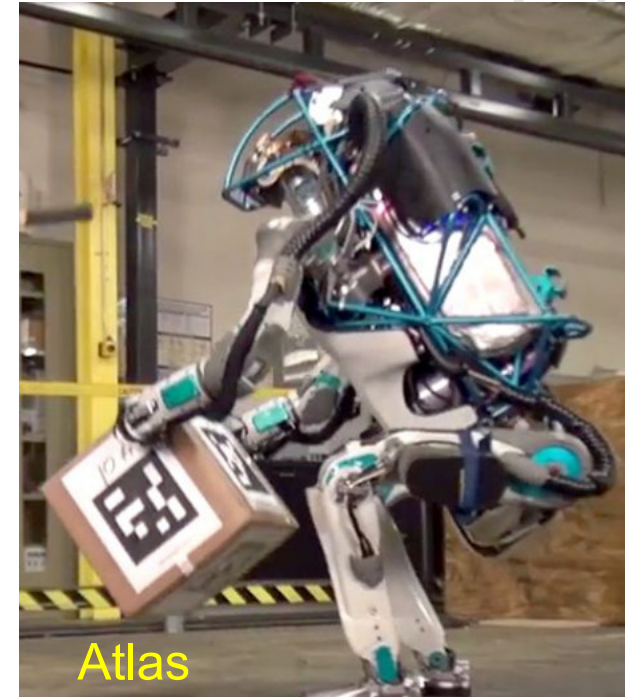


Autonomous operating vehicles reaching into our daily life



KUKA

Robots reaching into our daily life.



- No mass-production, too expensive, yet.
- No service concept
- No safety concept
- Too dangerous
- Error-prone

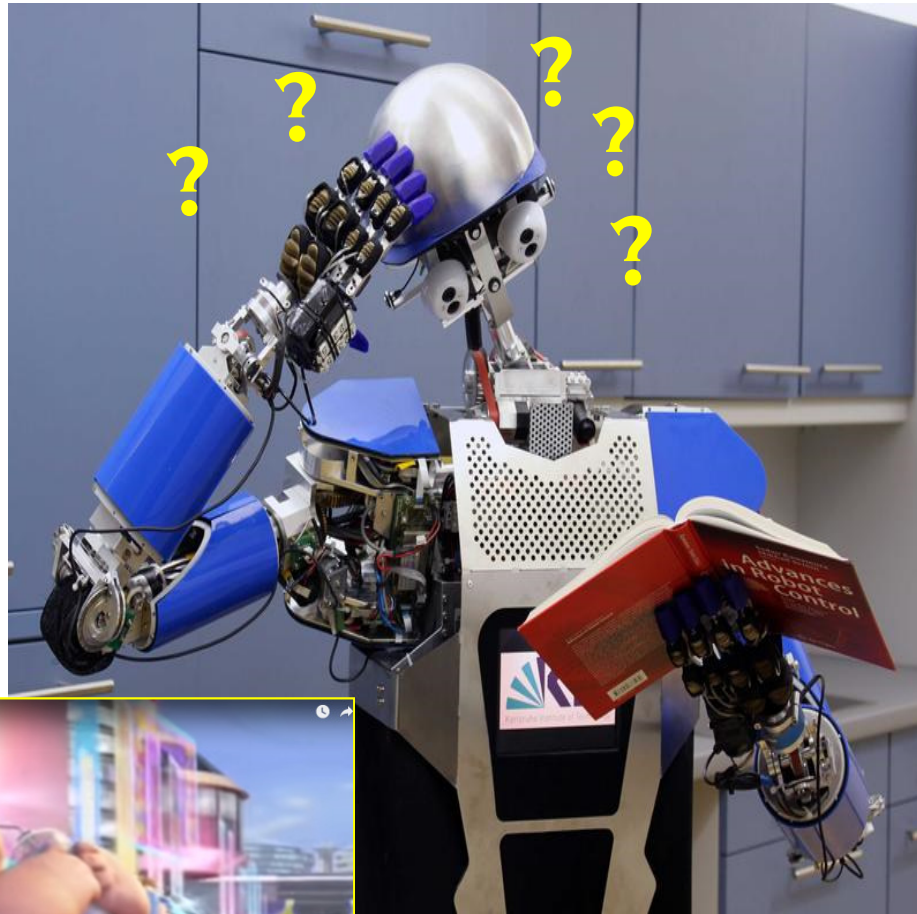
- Not accepted yet



KUKA

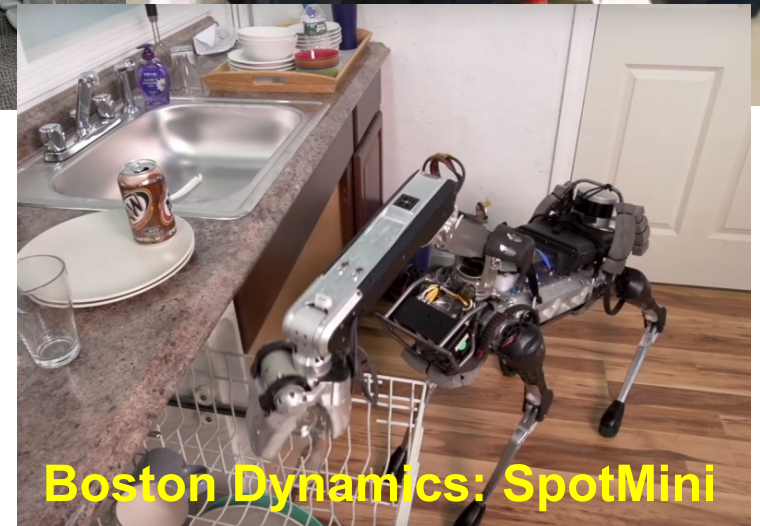


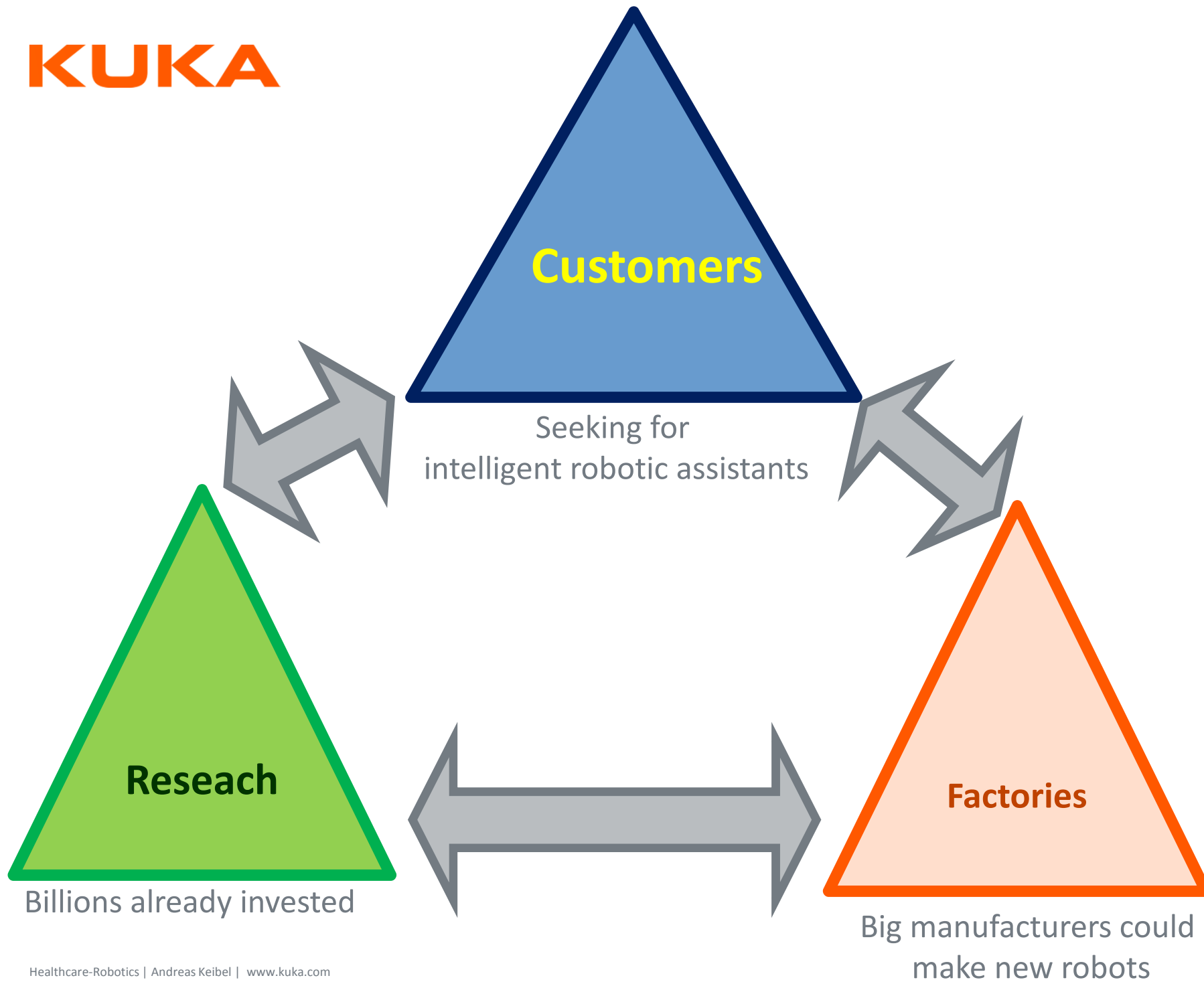
Robots for the elderly?



Care Robots

KUKA





THE END

Thank you for your attention!

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Special Backup



Molekular Intervention as Treatment of Patients with oligo metastasis

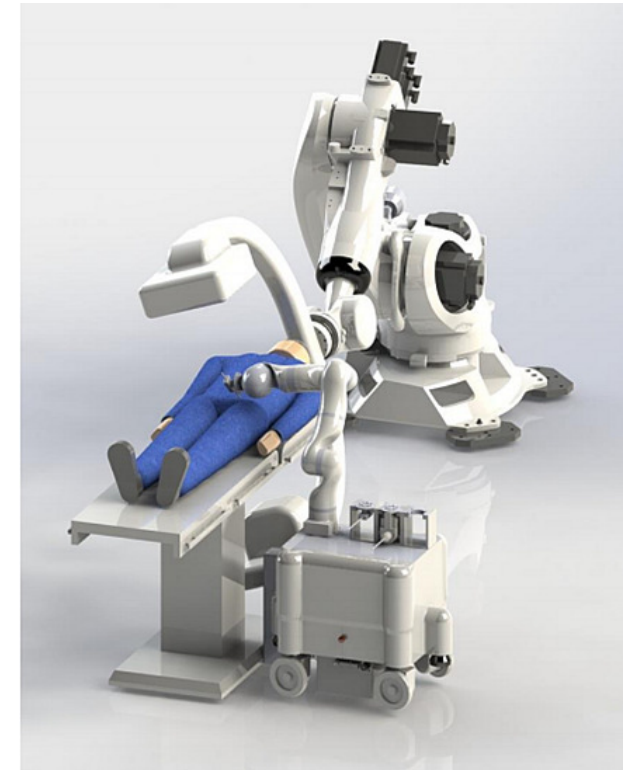


Leitprojekt M²INT

Entwicklung einer Systemplattform für die Minimalinvasive Molekular Assistierte Intervention

ERSTE NAVIGIERTE ROBOTERGESTÜTZTE BIOPSIE

Mannheim 2014



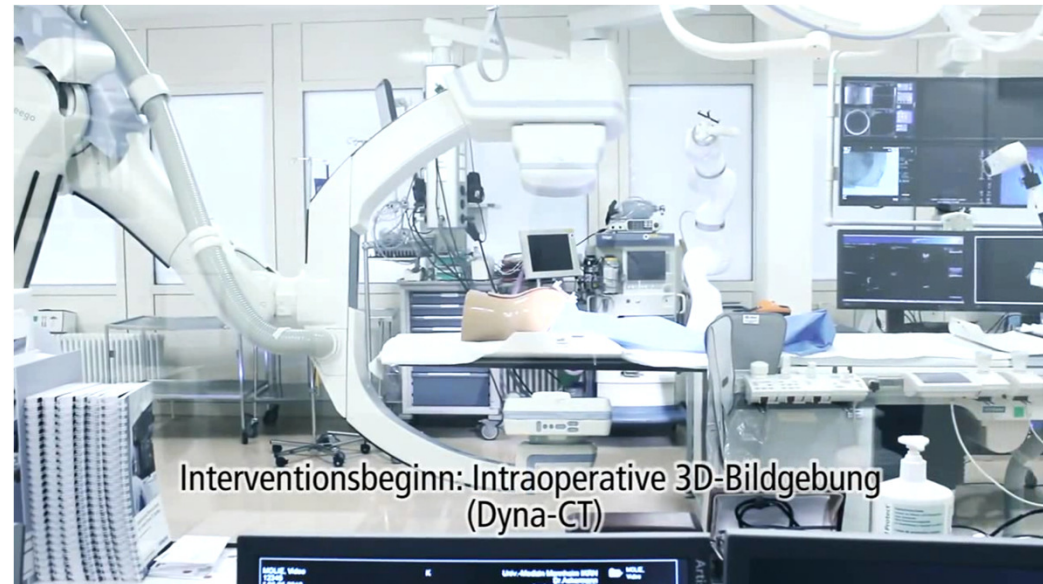
- Target: flexible System platform for minimal invasive, assisted molecular intervention
- Robot based stationary or on a mobile AGV-plattform, cooperatively telemanipulatable, autonomous support to approach target situs.
- Integration with Siemens Imaging System Artis Zeego
- Authors: J. Stallkamp et al.



Molecular Intervention for Treatment of Patients with Oligometastases

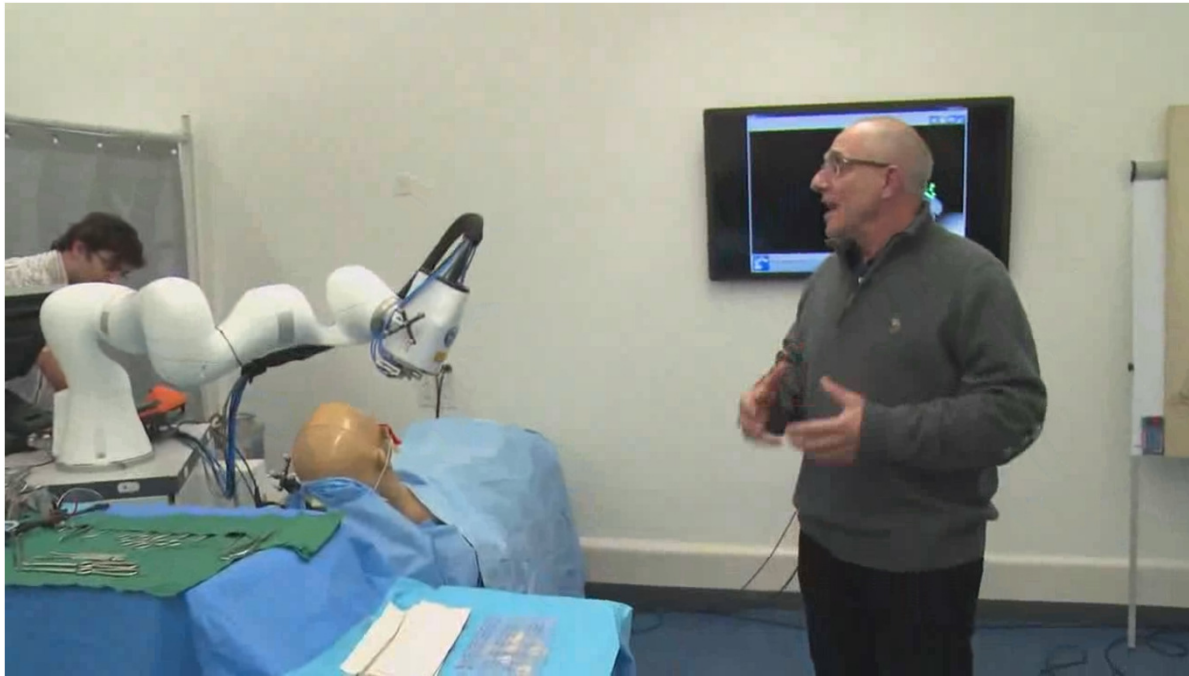


- Flexible platform for minimal invasive, assisted molecular intervention
- The robot on its mobile platform can operate cooperatively, autonomous or based on telemanipulation.
- Integration of platform with Siemens' Artis zeego.





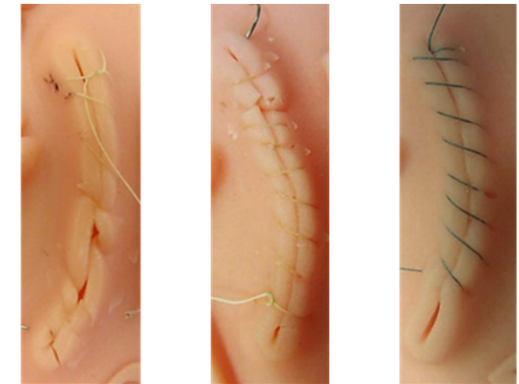
AOT AG – Laser-Osteotomy for Cranio-Maxillofacial Surgery



- Spin-Off from University Basel, founded 2011
- “Cold” Laserablation for bone cutting
- The laser head is held by a KUKA LBR robot
- Functional cuts are planned based on preoperative CT images
- The cut lines are executed using the laser head and the robot
- Authors: A. Bruno, P. Cattin, P. Jürgens, H.-F. Zeilhofer



STAR System (Smart Tissue Anastomosis Robot)



Laparoscopic 9 minutes daVinci 5 minutes STAR 1 minute

- An automatic suturing tool was motorized and attached to the KUKA LBR robot
- Using the camera image, suture points are defined and the tissue is tracked
- The automatic movement is being calculated and executed, closing the anastomosis



MURAB: MRI and Ultrasound Robotic Assisted Biopsy

Universiteit Twente (UT)

Università degli studi di Verona (UV)

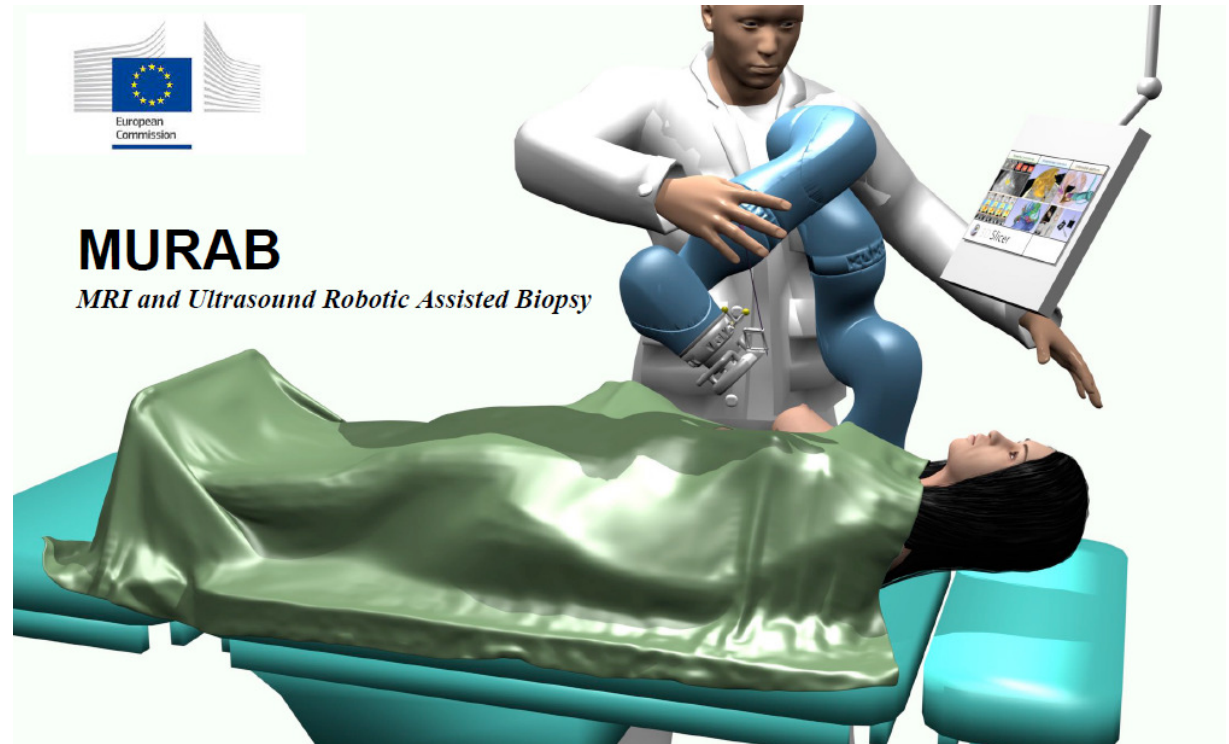
Radboud University & Radboudumc (UMCN)

KUKA Roboter GmbH (KUKA)

SIEMENS NL (SIEMENS)

Stichting Ziekenhuisgroep Twente (ZGT)

Medizinische Universitaet Wien (MUW)



Clinical

- **Enabling US-guided biopsies of lesions that are visible** on US images, but with higher accuracy (without previous MR imaging)
- **Enabling US-guided biopsies of lesions that are not visible** on US images
- **Patient discomfort reduction** because US-guided biopsies can be smaller
- **Efficiency increase for the patient** by preventing return visits (which also reduces discomfort)
- **Efficiency increase for the doctor** by speeding up current (MR-guided) biopsies