Evolution and Revolution – I4.0 part I

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Agenda

- Introduction of inventions - evolution
- Background of I4.0
- Industrial revolutions – control of systems
- Challenges to Industry 4.0
- Integration of real and virtual world
- Super Smart Society
- Industry transformation

https://www.youtube.com/watch?v=VRm7oRCTkjE

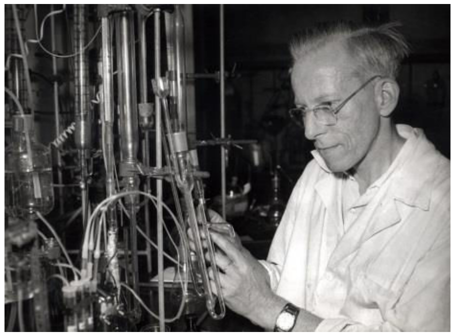
Czech famous inventors

Jaroslav Heyrovský

- The Nobel laureate**,** was part of the team that discovered the staircase process depending electric current-voltage, discoverer of polarography, founded a polarographic institute
  (*picture source: archive of the ÚFCH J.Heyrovského AV ČR, v.v.i.*)

Antonín Holý

- Author of more than sixty Czech and international patents, developed an effective remedy for ringworm and his improved versions of the drugs are used to AIDS treatment, also developed a cure for hepatitis B
  (*picture source: Institute of Organic Chemistry and Biochemistry AS CR, v.v.i.*)



Otto Wichterle

- The inventor of contact lenses, founder of the Institute of Macromolecular Chemistry, patented manufacturing process sparsely cross-linked hydrogels, the author of more than two hundred scientific publications, 150 inventions and patents
  (*picture sources: Czech Centres*)

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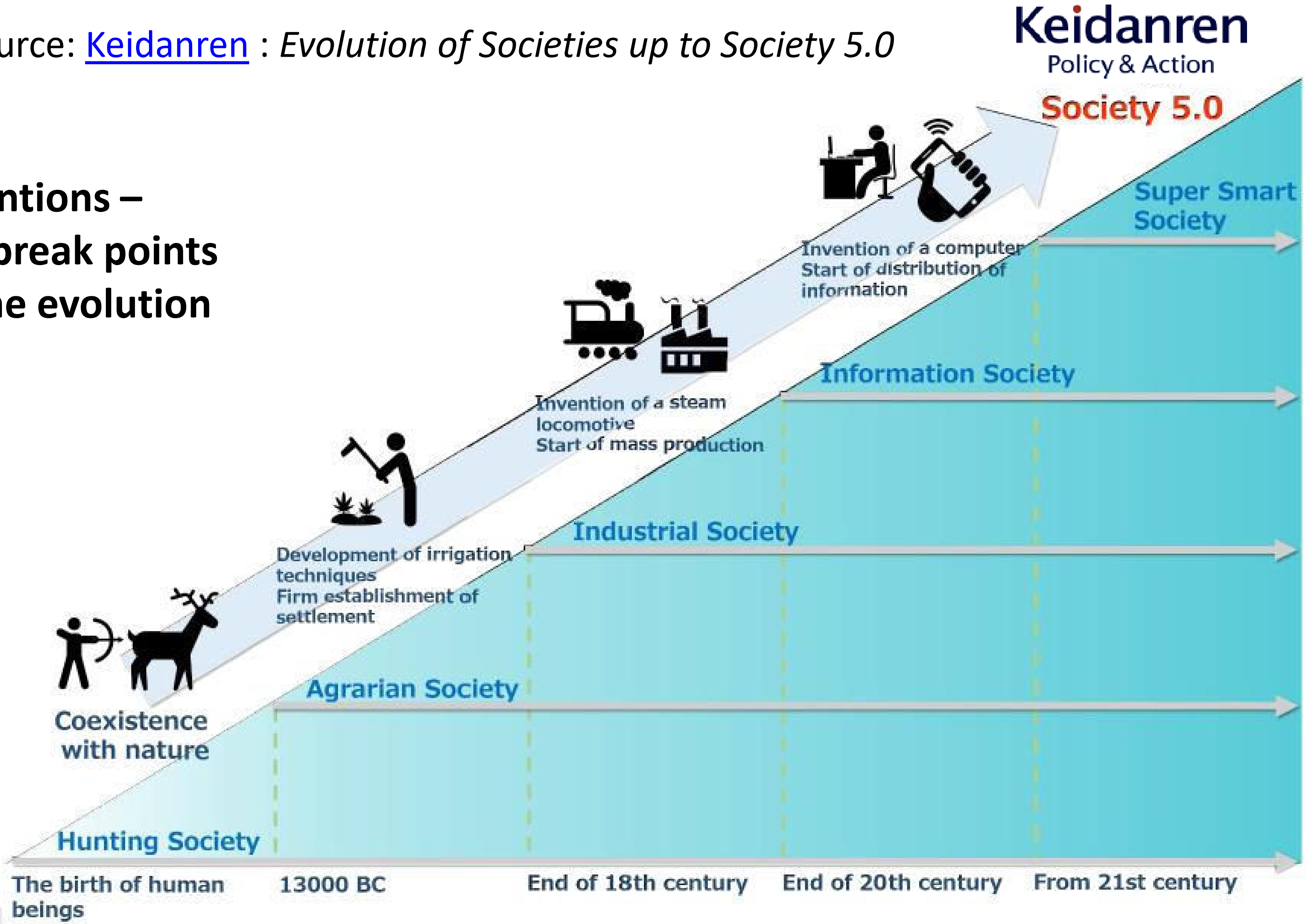
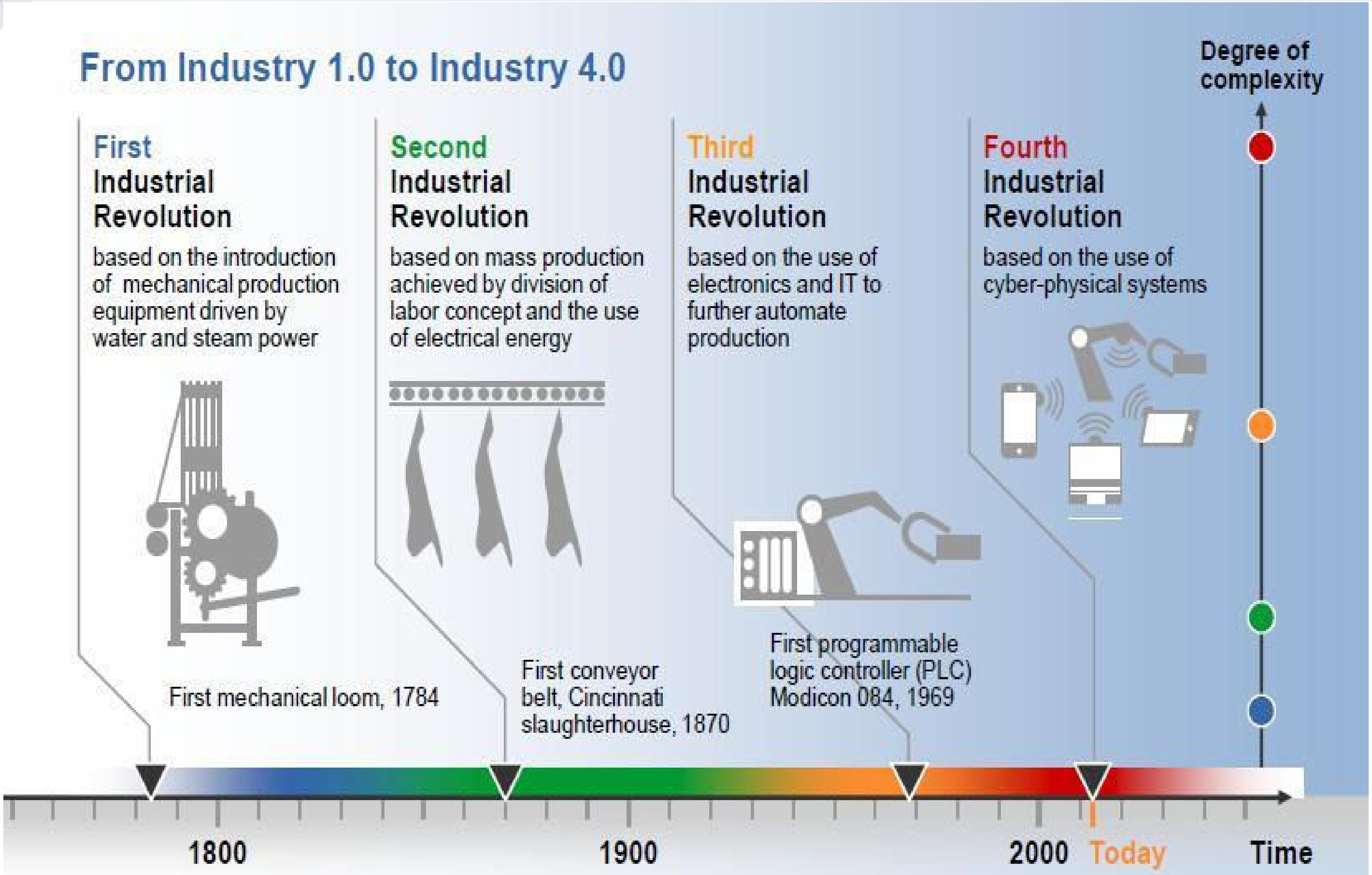
Evolution in the frame of 2020 vision

Source: Keidanren : *Evolution of Societies up to Society 5.0*

Inventions –
the break points
of the evolution

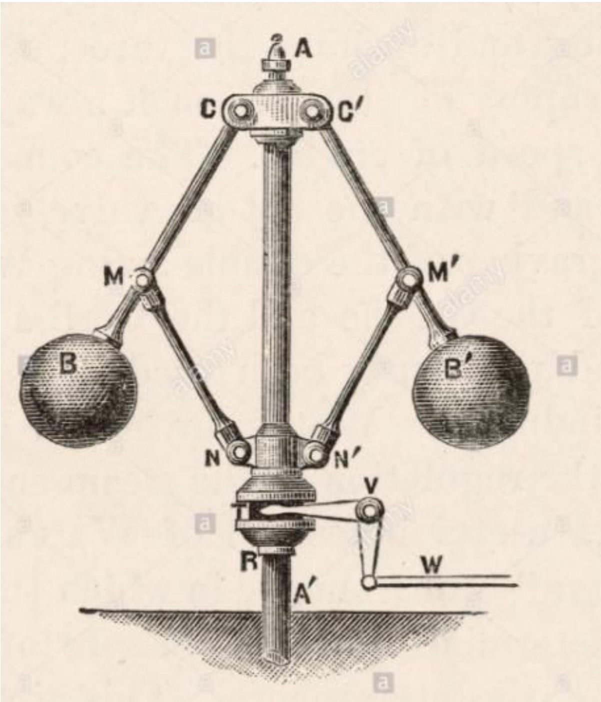


Industrial revolutions – control of systems



Source: https://www.google.cz/Industry 4.0

Industrial revolutions – control of systems



- Operational feedback in industry – James Watt, steam,
  - First proportional industrial controller
- Control in full range of quantity – models of objects
  - Production lines, serial production, electricity
- Program feedback – PLC, distributed control,
  - State space models of objects
- Symbolic feedback – distributed models of the world,
  - Sharing of the knowledge, ontology

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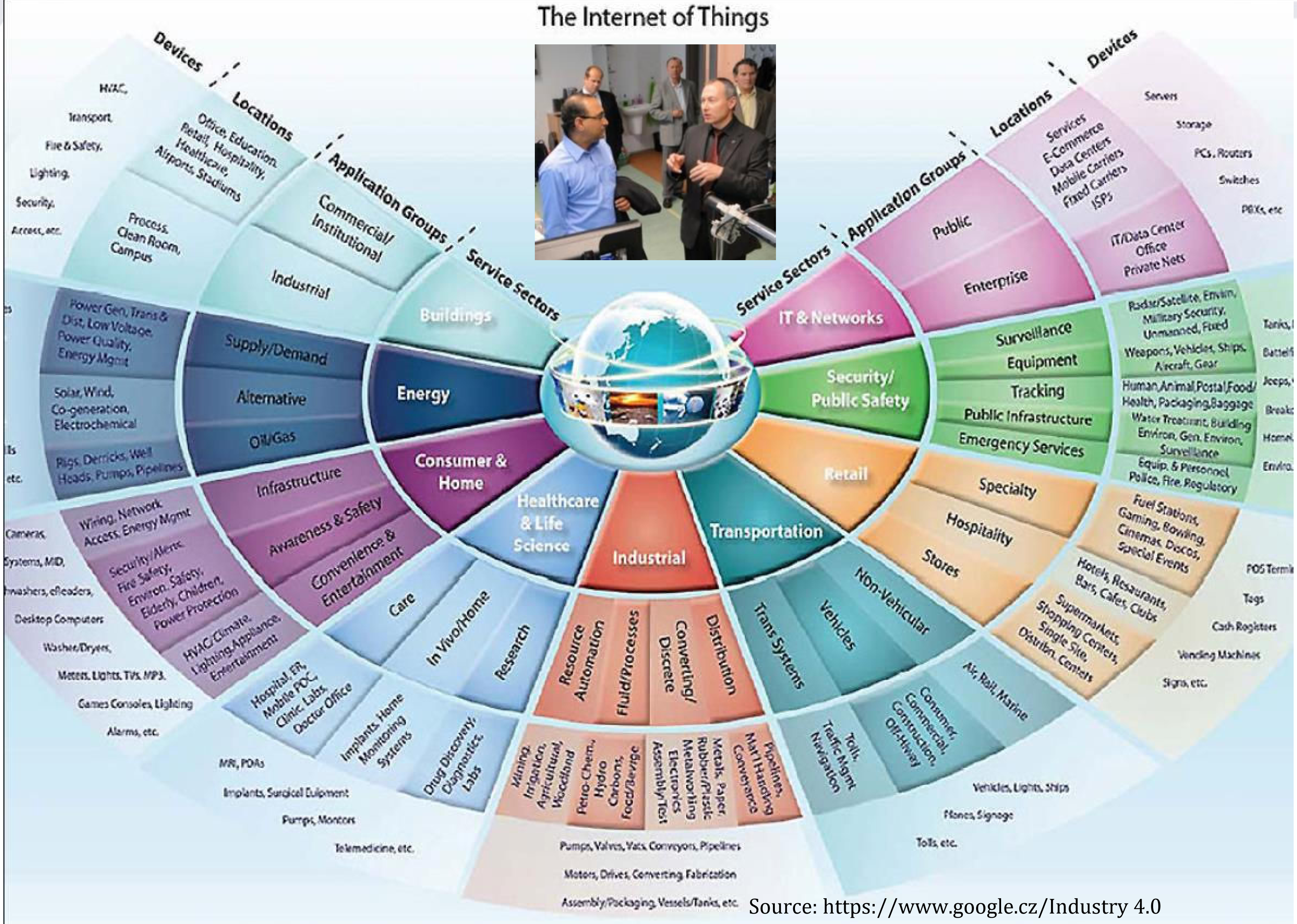
New philosophy of systems

- System in system utilization
- Integration of distributed parts (systems)
- Interconnection in hierarchical levels
- New opportunity for industry (companies)
- Challenge for the future competitiveness
- Super-system prosperity (Society???)
- Interconnecting of Things, Services, People,
  - IoT, IoS, IoP, IoE, … IoIndustry = **IoPro**

Challenges to Industry 4.0

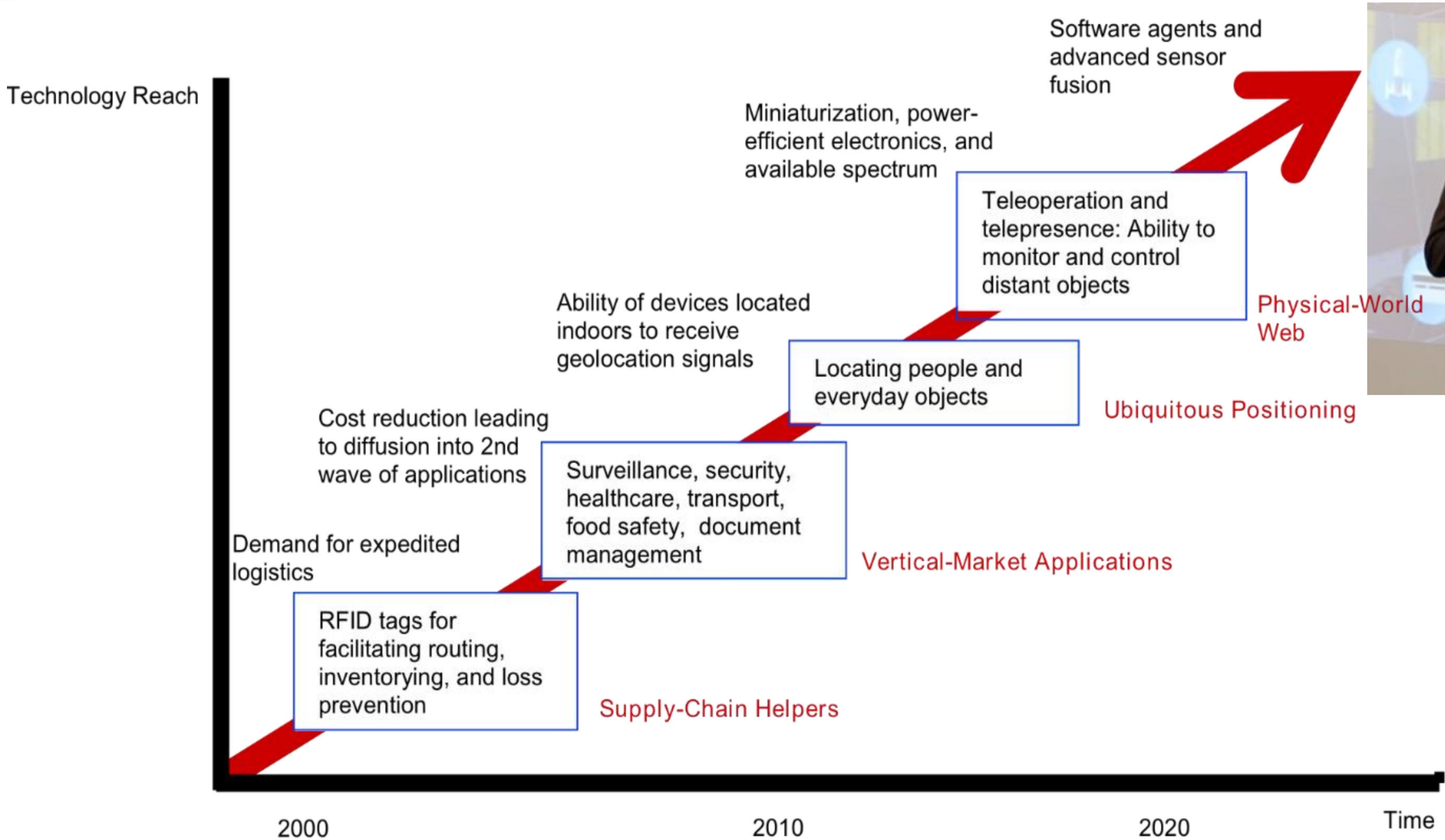


Source: https://www.google.cz/Industry 4.0

I4.0 – Technology development IoT

Massachusetts Institute of Technology

TECHNOLOGY ROADMAP: THE INTERNET OF THINGS



Source: SRI Consulting Business Intelligence

Potential of IoT - Challenges

Global economic potential of the Internet of Things

Nine settings where added value is expected	Size in 2025, $ trillion[1] (Low estimate - High estimate)
Factories – eg., operations management, predictive maintenance	1.2 - 3.7
Cities – eg., public safety and health, traffic control	0.9 - 1.7
Human – eg., monitoring and managing illness, improving wellness	0.2 - 1.6
Retail – eg., self-checkout, smart customer-relationship	0.4 - 1.2
Logistics – eg., logistics routing, autonomous vehicles, navigation	0.6 - 0.9
Work sites – eg., operations management, equipment maintenance	0.2 - 0.9
Vehicles – eg., condition-based maintenance, reduced insurance	0.2 - 0.7
Homes – eg., energy management, safety and security	0.2 - 0.3
Offices – eg., augmented reality for training	0.1 - 0.2

Total $ 4 trillion - $ 11 trillion

[1]Adjusted to 2015 dollars, for sized applications only; includes consumer surplus. Numbers do not sum to total, because of rounding

trillion | 1 000 000 000 000 (= 10^{12}) | bilion

Source: McKinsey Global Institute analysis, June 2015

Potentials and Challenges

Directions for the future of manufacturing

	Player	Situation	Goals	Means
Industrie 4.0	Germany	Growing competition	Leadership in Cyber-Physical-Systems	Integrating ICT into manufacturing
Industrial Internet	USA, UK	Service-centred economy	Re-industrialization	Adding manufacturing to ICT
Full Automation	East Asia	Labour shortage, rising labour costs	Cheaper, faster, less labour	Using robots for manufacturing

Source: Ralf Wehrspohn, Fraunhofer Institute, TACR Day, 20. 10. 2016, Prague

Potentials and Challenges

Challenges in Industrie 4.0 technologies

Health and Environment
e.g. Human-Machine-**Interaction**/Cooperation

Production and Supply of Services
e.g. **Cyber Physical Systems**, predictive maintenance, customized and adaptive production ...

Communication and Knowledge
e.g. data **security** and safety, data rate and **latency**, deep **learning** ...

Energy and Resources
e.g. closed-loop production, **energy self-sufficiency**, intelligent grids

Mobility and Transport
e.g. autonomous vehicles, **decentralized multi-agent logistics** ...

Security and Protection
e.g. cyber security, trusted data exchange, **resilient systems** ...

Source: Ralf Wehrspohn, Fraunhofer Institute, TACR Day, 20. 10. 2016, Prague

Principles of the new production revolution – Creative Industry 4.0

Culture & Creative Industries

Raw materials	Manufac-turing	Trade services	Info. services	Human services

SOFTWARE: animation, 3D printing, virtual reality, simulators, PC games, **artificial intelligence**

DIGITIZATION: Internet of Things & Services, **new business models**, shared economy, e-culture,

ADVERTISEMENT: online marketing, **cross marketing**, gamification, branding

MEDIA: knowledge transfer, marketing, video, big data, **social media**, communication

ARTS: visualization, **interactive teaching aids**, creative ecosystem, allocation factor

DESIGN: design thinking, product design, service design, **all 5 senses design solutions**

Creative Economy 4.0

Background of I4.0

- Incentives in the society
- Human resources – educational systems,
  - (3rd revolution – MIT model) Massachusetts Institute of Technology
- Labor market changes, creative activities
- Investment into new infrastructure
- Research and development dynamics
- Information and Communication technology
- Interconnecting of machinery, robots, artificial agents, …

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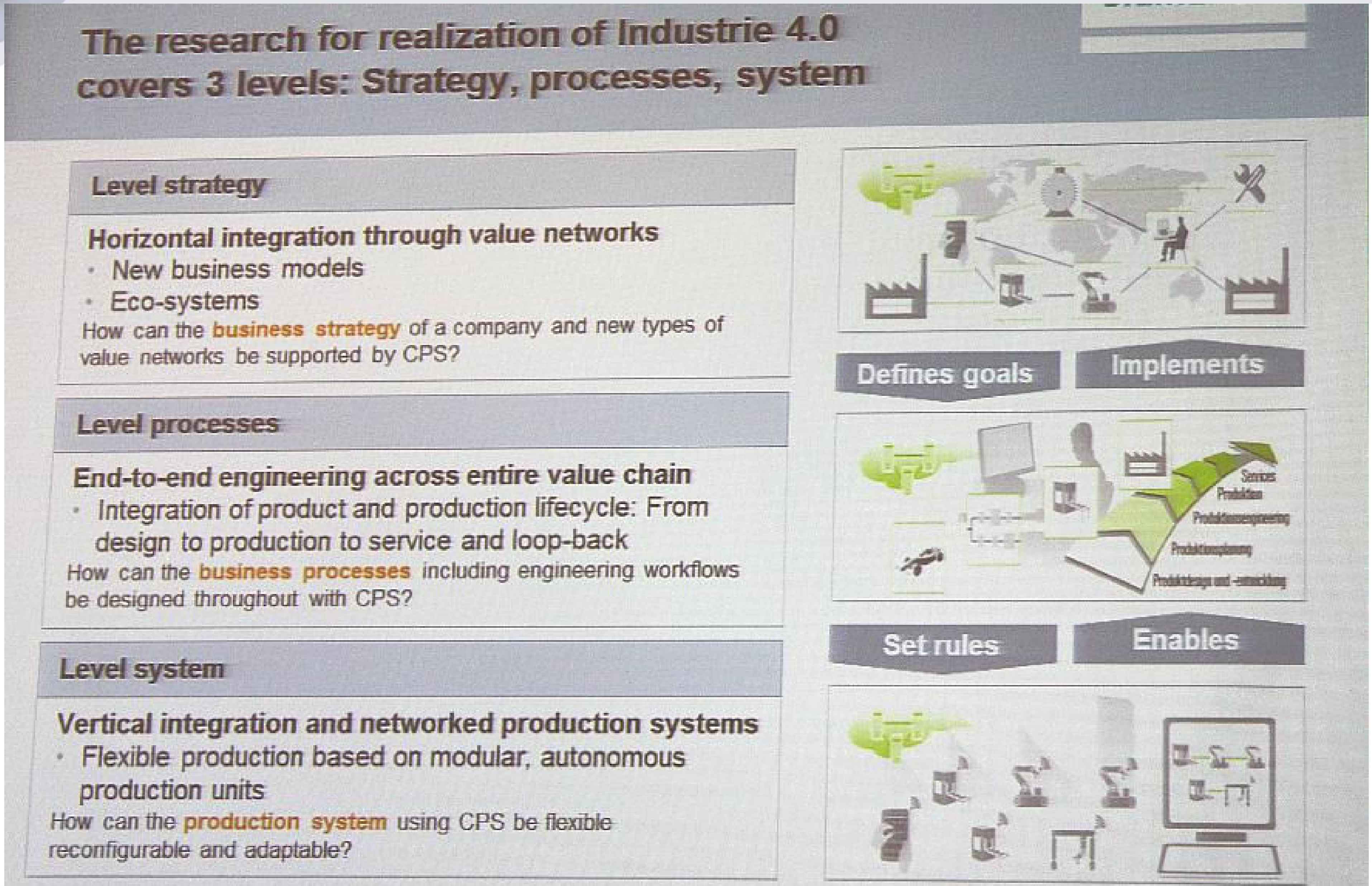
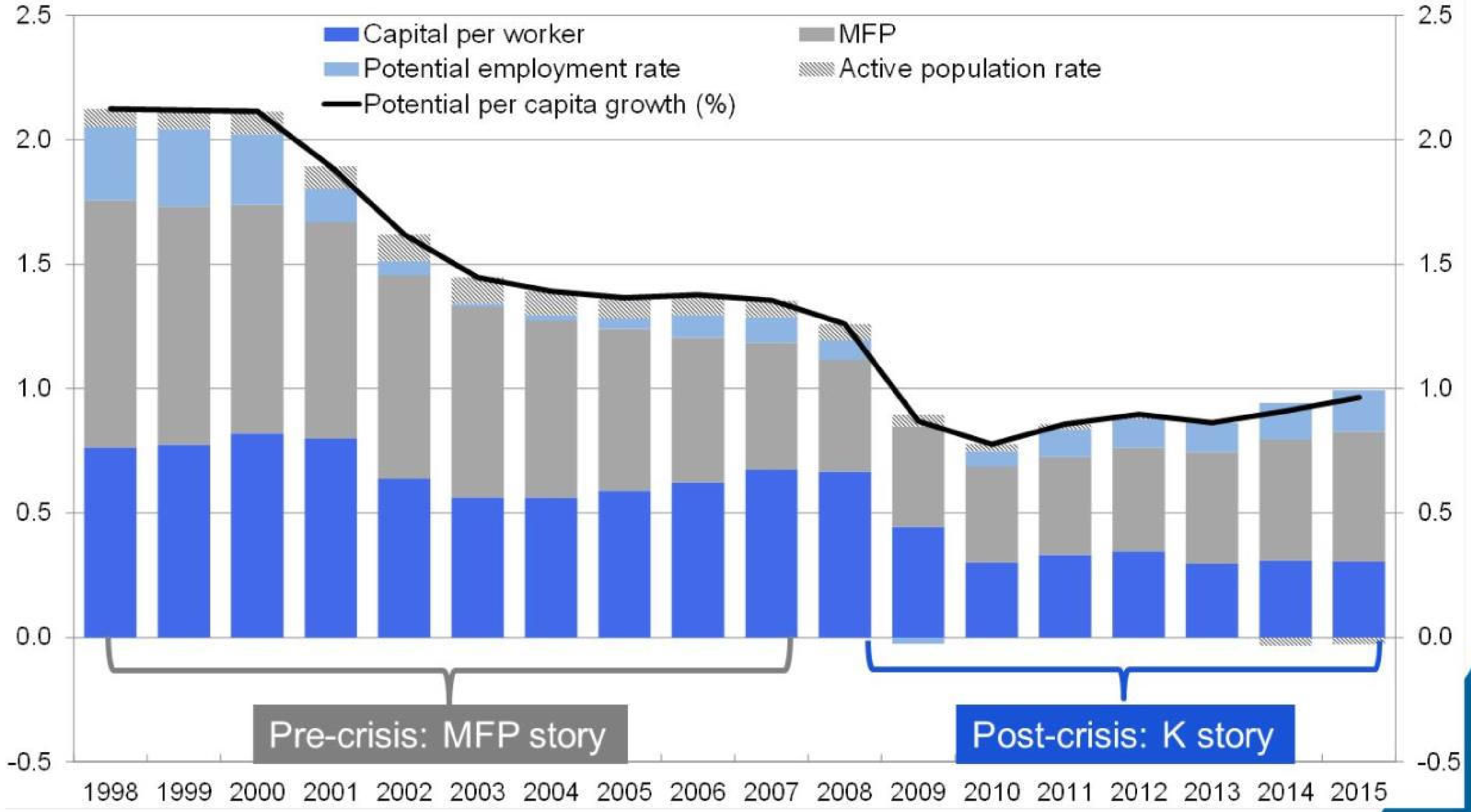
Industrial revolutions – CPS



Source: IoT 2014 International Conference, MIT Boston, USA

The possible productivity benefits of digital technologies are urgently needed.

Contribution to potential per capita output growth (% pts unless otherwise noted)

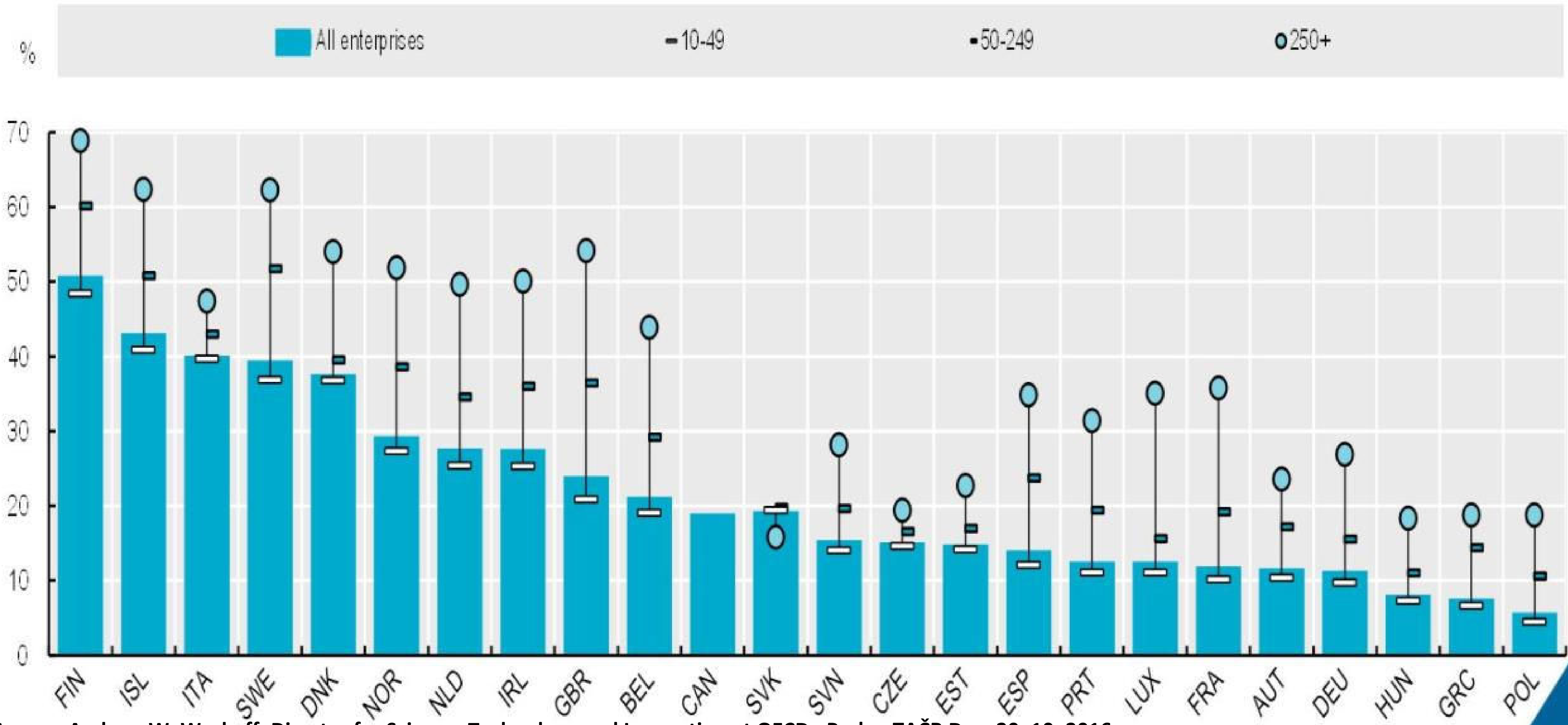


Source: OECD Economic Outlook 2016, Volume 1.

Well designed institutions needed for technology diffusion and adoption

Enterprises using cloud computing services by employment size class, 2014

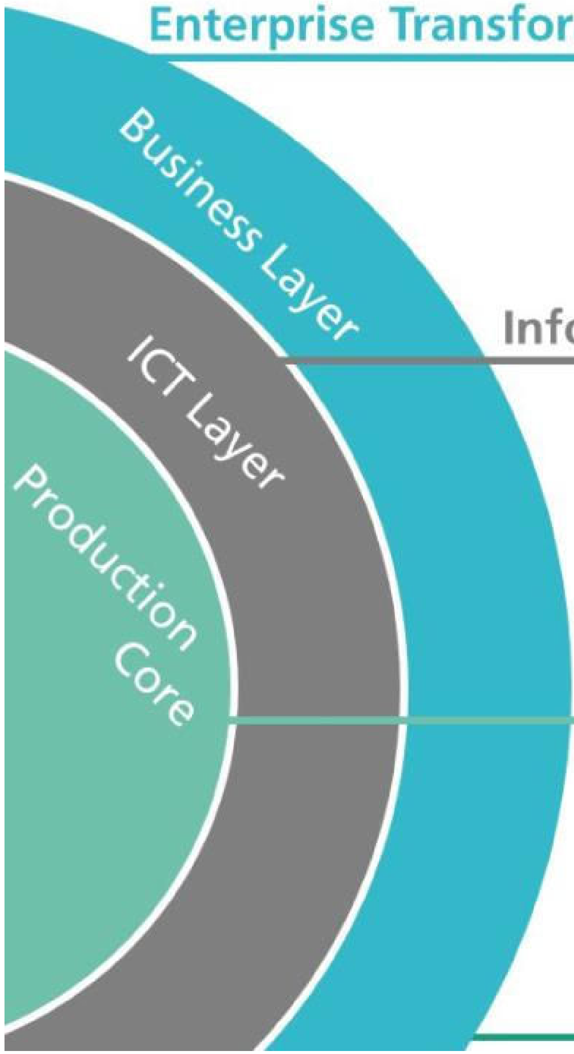
As a percentage of enterprises in each employment size class



Source: Andrew W. Wyckoff, Director for Science, Technology and Innovation at OECD, Praha, TAČR Day, 20. 10. 2016

Fraunhofer I4.0 „Layer Model“

Dimensions of Industrie 4.0: Fraunhofer »Layer Model«



Enterprise Transformation

- Business models
- Management
- Human resources

Information and Communication enabling Technologies

- Standardization
- Data rates and low latency communication
- Data and cyber security
- etc.

Data-driven Production Technologies for Industrie 4.0

- Cyber-Physical-Systems
- Machine Learning in Production Processes
- Autonomous Systems
- etc.

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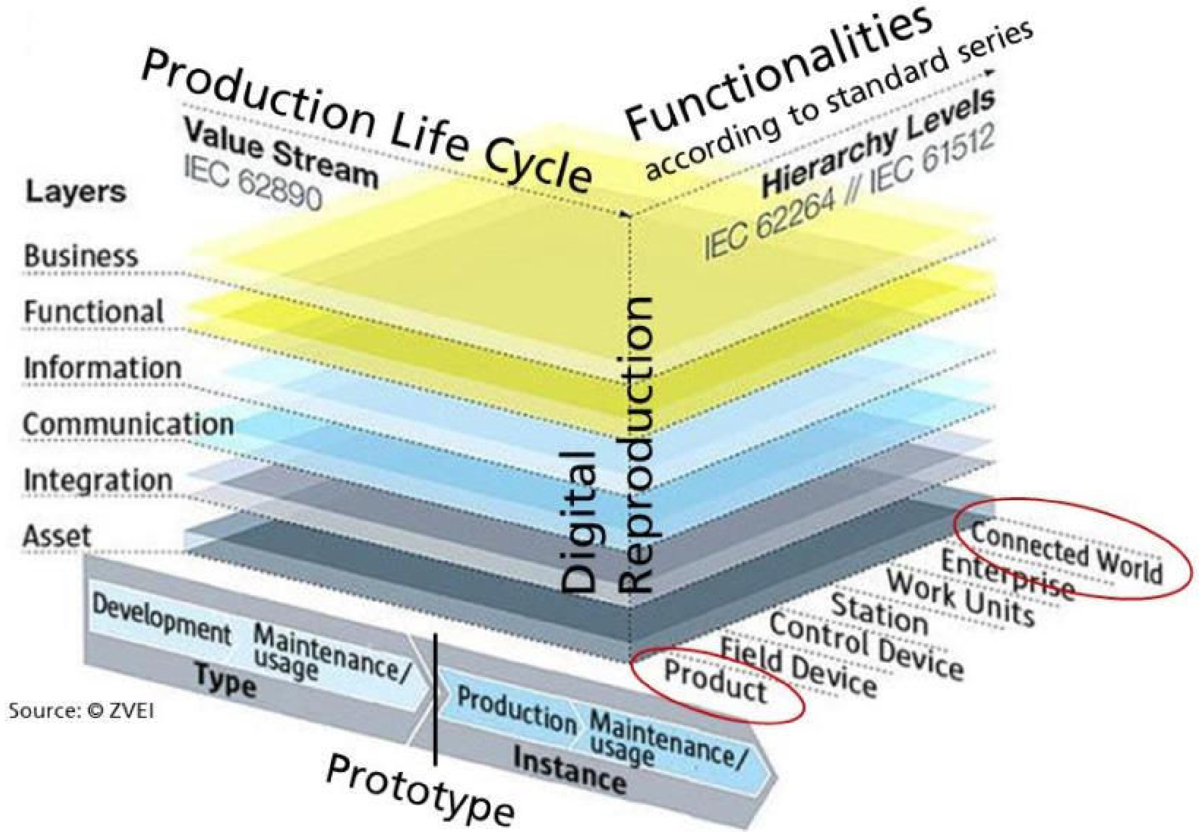
Source: Ralf Wehrspohn, Fraunhofer Institute, TACR Day, 20. 10. 2016, Prague

Requirments for Data Driven Production

Requirement: Standardization

Reference-Architecture-Model Industrie 4.0
(RAMI 4.0)

- Three-tier system
- Joint development by: Bitkom, VDMA, ZVEI, Plattform Industrie 4.0



Standardization goals I4.0:

- **Identification** (location of participants)
- **Semantics** (communication)
- **Quality of service** (low latency, reliability)

→ compatibility and interoperability

3.00×10^8 m/s, 300,000 km/s

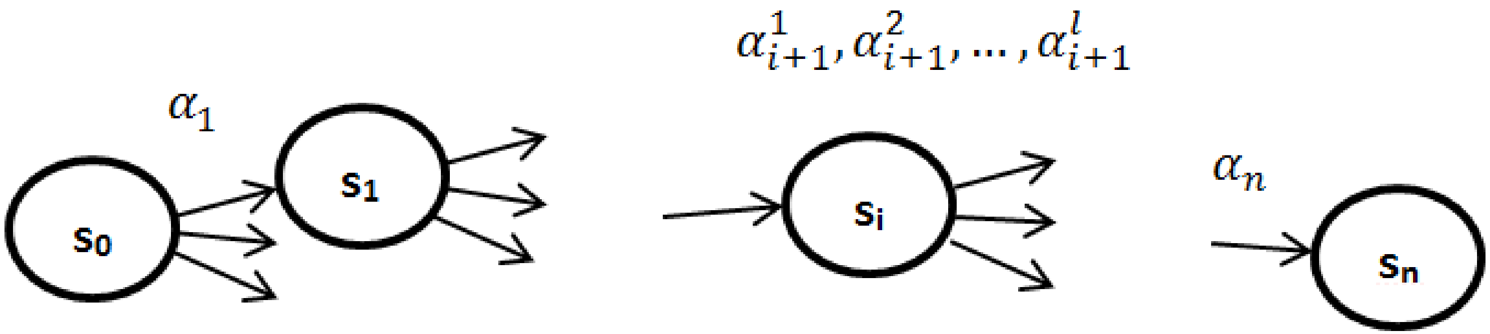
Source: Ralf Wehrspohn, Fraunhofer Institute, TACR Day, 20. 10. 2016, Prague

Models - Formal Systems

Formal language – communication

Information - knowledge - skills

State space representation



Models – control system

- surrounding world

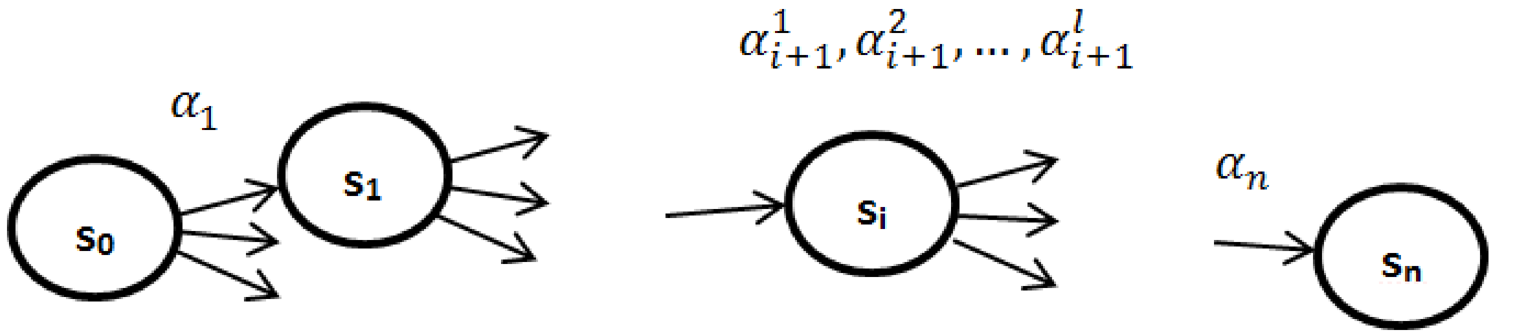
Formal Systems in Control

Information - knowledge - skills

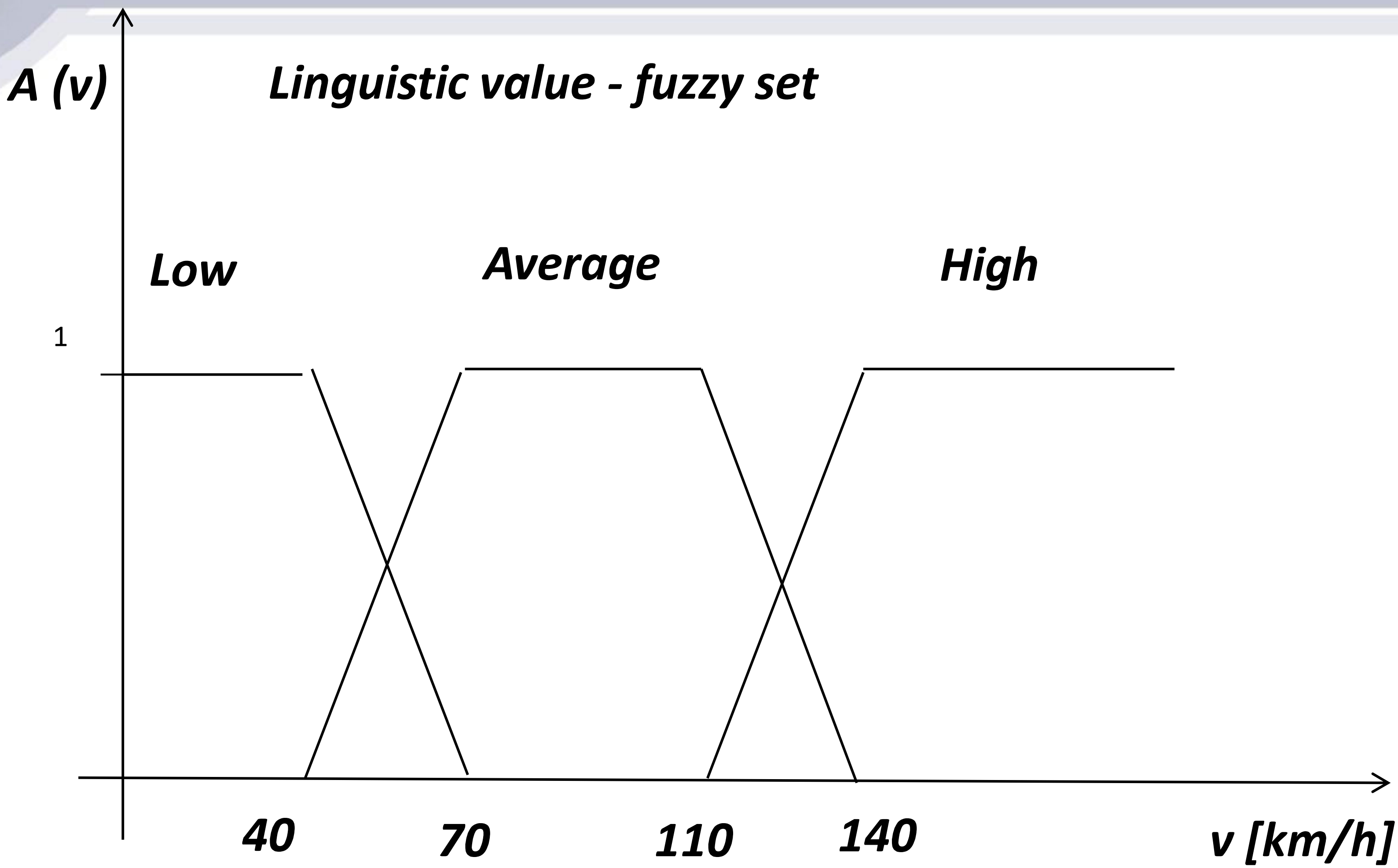
- Information - Share in books
- Knowledge - Transfer by teachers
- Skills - learn by practice

Intelligent control needs

MODELS & SKILS!!!

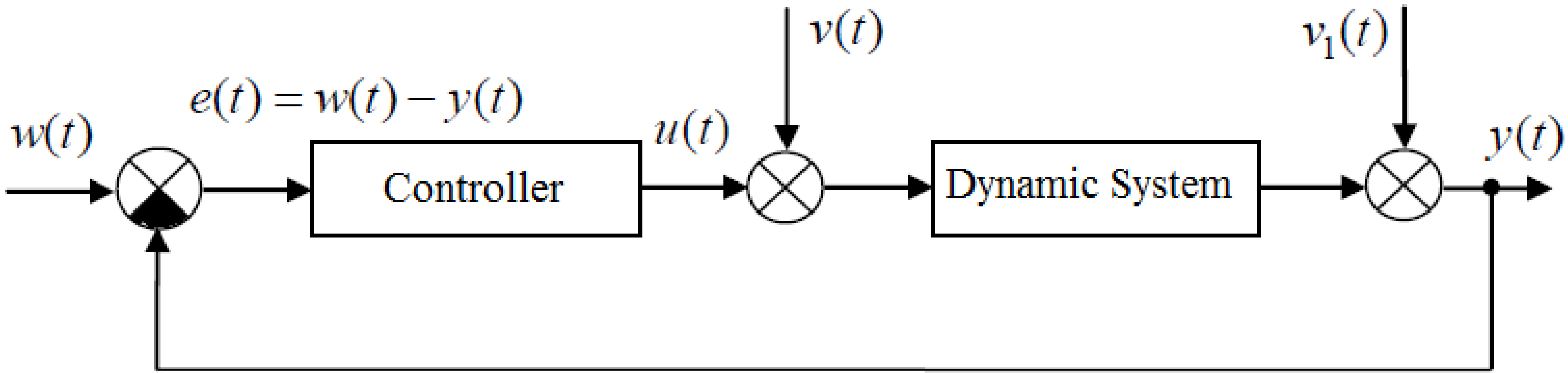


Knowledge example



- Information - Measurement - Objective
- Knowledge - Transfer - Subjective

Feedback Control - Basic



Control algorithm

Dynamic behavior Model of Object

https://www.youtube.com/watch?v=wCj1kJ1Fyk4&t=16s

https://www.youtube.com/watch?v=rVlhMGQgDkY

Will you be the intelligent agent or Biorobot?

THANK YOU FOR THE ATTENTION

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https://www.youtube.com/watch?v=voNBzuI7IJ4

Ph.D. students with Sanjay E. Sarma (2012)

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