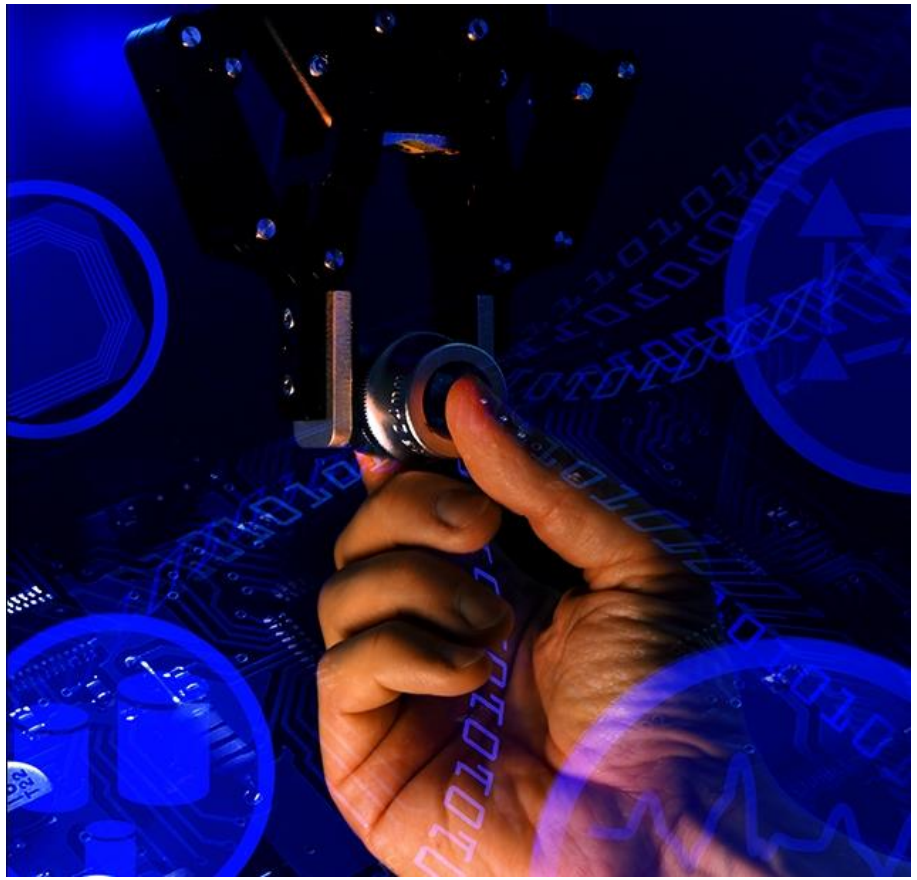
MTA SZTAKI
Hungarian Academy of Sciences
Computer and Automation Research Institute

Engineering and Management Intelligence Laboratory

RDI portfolio



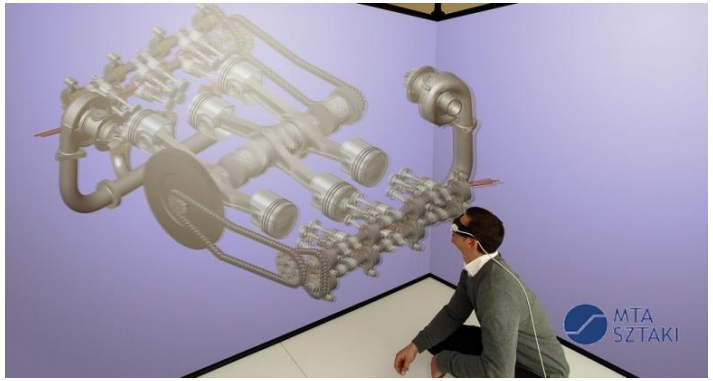
Presented by:
Zsolt Kemény
zsolt.kemeny@sztaki.mta.hu

September 13, 2018

MTA **SZTAKI – Introduction**

- Established in 1964
- EU Centre of Excellence in IT, Computer Science and Control
- Basic and applied research
- Contract-based R&Đ&I activity mainly on complex systems, turnkey realizations
- Transferring up-to-date results to industry and universities

- **Basic research**
  - Computer science
  - Systems- and control theory
  - Engineering and business intelligence
  - Machine perception and human-computer interaction
- **Applied research and innovation**
  - Vehicles and transportation systems
  - Production informatics and logistics
  - Energy and sustainable development
  - Security and surveillance
  - Networking systems and services, distributed computing

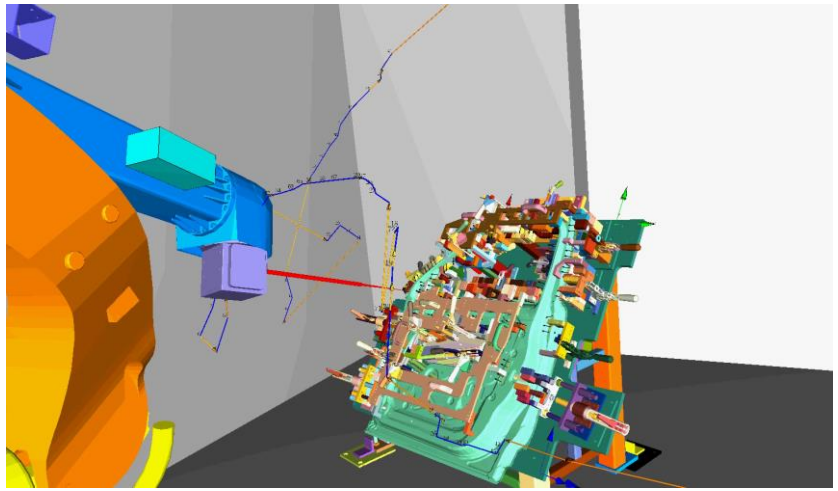


MTA **SZTAKI – Introduction**

Key figures

- Budget
  - 11 MEuros/year
  - ~30% basic funding
- Staff
  - 220
- International reputation
  - CIRP
  - IFAC
  - IEEE
  - IMEKO
  - acatech
  - KVAB
  - 45 EU VII projects
  - 12 H2020 projects

- **Basic research**
  - Computer science
  - Systems- and control theory
  - Engineering and business intelligence
  - Machine perception and human-computer interaction
- **Applied research and innovation**
  - Vehicles and transportation systems
  - Production informatics and logistics
  - Energy and sustainable development
  - Security and surveillance
  - Networking systems and services, distributed computing

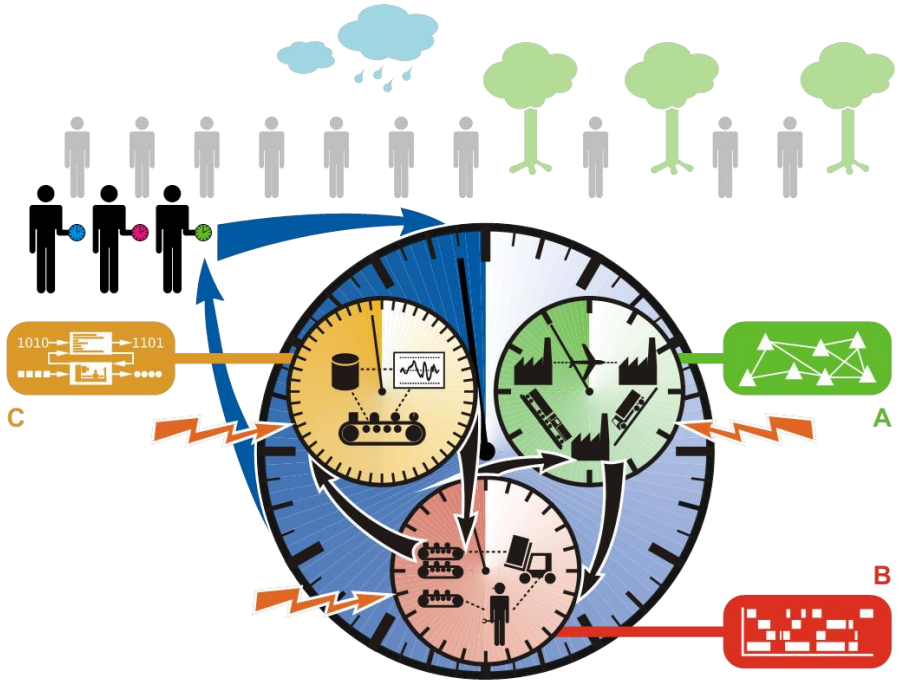


EMI–Research Laboratory on Engineering & Management Intelligence

- **Head of Laboratory: Dr. József Váncza**
- **EMI's mission**

  Research and elaboration of techniques applicable for handling complex production and business systems working in an uncertain, changing environment, with special emphasis on manufacturing automation, production informatics, operation research, artificial intelligence ad machine learning approaches, balancing the aspects of optimization, autonomy and cooperation.

- **Main research areas**
  - modelling, control and optimization of technical and business processes
  - handling changes and disturbances in complex systems
  - distributed modelling of extended enterprises and production networks
  - modelling and simulation of large production and business systems, digital factories



Towards Cyber-Physical Production Systems (CPPS)

- **CPPSs consist of**
  - *autonomous* and *cooperative* elements and subsystems
  - that are getting into *connection* with each other
  - in *situation dependent* ways,
  - on and across *all levels of production*,
  - from *processes*, through *machines* and production *systems*, up to production and logistics *networks*.
- **CPPSs are characterized by their ability to**
  - directly acquire physical data by using *sensors* and act on the physical world by using *actuators*,
  - *analyze* and *store* the acquired data and interact both with the physical and the virtual world,
  - are *networked* spontaneously amongst each other and with global information systems by wired or wireless communication means,
  - use *worldwide available data and services*,
  - have *smart*, *multi-modal human-machine interfaces.*


Contents lists available at ScienceDirect

CIRP Annals - Manufacturing Technology

journal homepage: http://ees.elsevier.com/cirp/default.asp

Cyber-physical systems in manufacturing

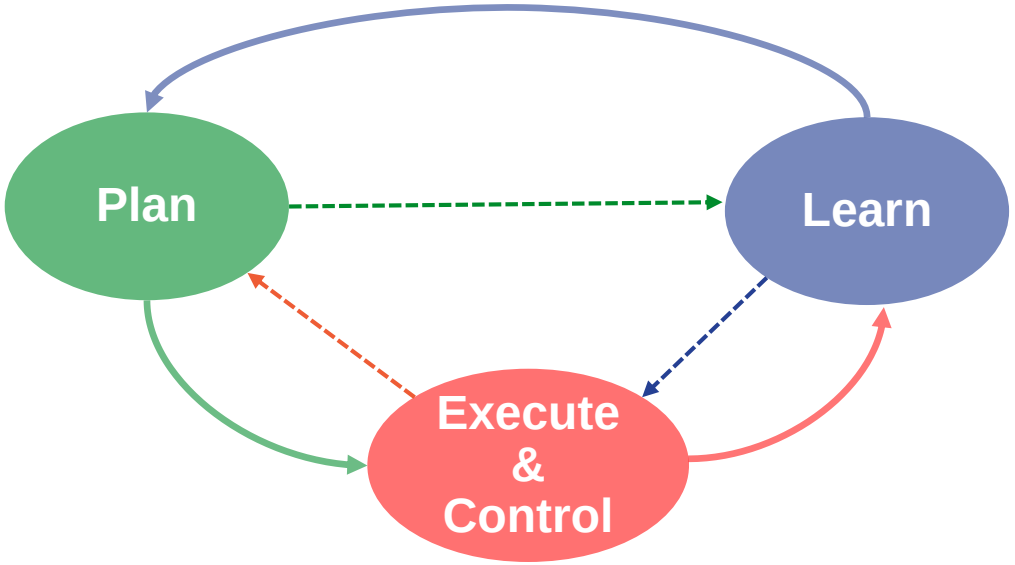
L. Monostori (1)[a,b,*], B. Kádár (2)[a], T. Bauernhansl[c,d], S. Kondoh (2)[e], S. Kumara (1)[f], G. Reinhart (1)[g], O. Sauer (3)[h], G. Schuh (1)[i,j], W. Sihn (1)[k], K. Ueda (1)[l,1]

[a] Fraunhofer Project Centre for Production Management and Informatics, Institute for Computer Science and Control, Hungarian Academy of Sciences, Budapest, Hungary
[b] Department of Manufacturing Science and Technology, Budapest University of Technology and Economics, Budapest, Hungary
[c] Fraunhofer Institute for Manufacturing Engineering and Automation, (IPA), Germany
[d] University of Stuttgart, Germany
[e] National Institute of Advanced Industrial Science and Technology (AIST), Japan
[f] Pennsylvania State University, USA
[g] Institute of Machine Tools and Industrial Engineering, Chair of Industrial Engineering and Assembly Technology, Technische Universität München, Germany
[h] Fraunhofer Institute for Optronics, System Technology and Image Processing (IOSB), Karlsruhe, Germany
[i] Fraunhofer Institute for Production Technology, (IPT), Germany
[j] RWTH Aachen University, Germany
[k] Institute for Management Science, Division Industrial and Systems Engineering, TU Vienna, Austria
[l] The University of Tokyo, Japan

Our approach and competences to/in CPPS

Research areas

- Manufacturing process planning
- Process management and control
- Robotics and mechanisms
  - Including human–robot symbiosis
- System design
  - Reconfigurable manufacturing
- Production planning and scheduling
- Production and logistics networks
- Energy system management



General requirements

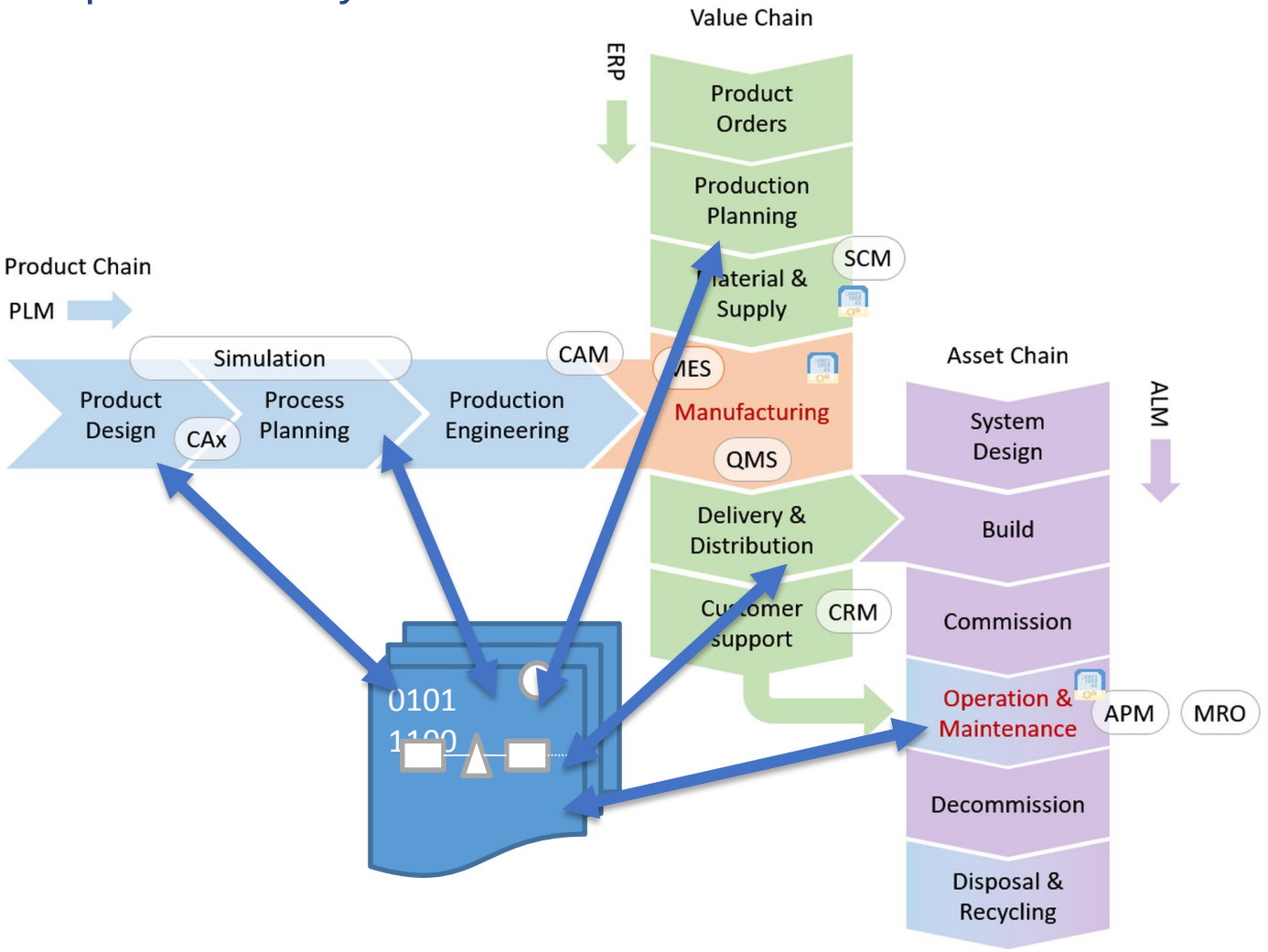
- Multi-objective optimization
- Adaptivity, robustness
- Handling complexity, efficiency
- Decentralization, collaboration, cooperation
- Safety and security
- Sustainability

Methods and tools

- Digital twin
  - Discrete-event simulation
  - Agent-based simulation
  - Geometric modelling
- Mathematical and constraint programming
- Statistical machine learning
- Scheduling theory
- Game theory, mechanism design
- Sensor networks
- IoT, cloud computing

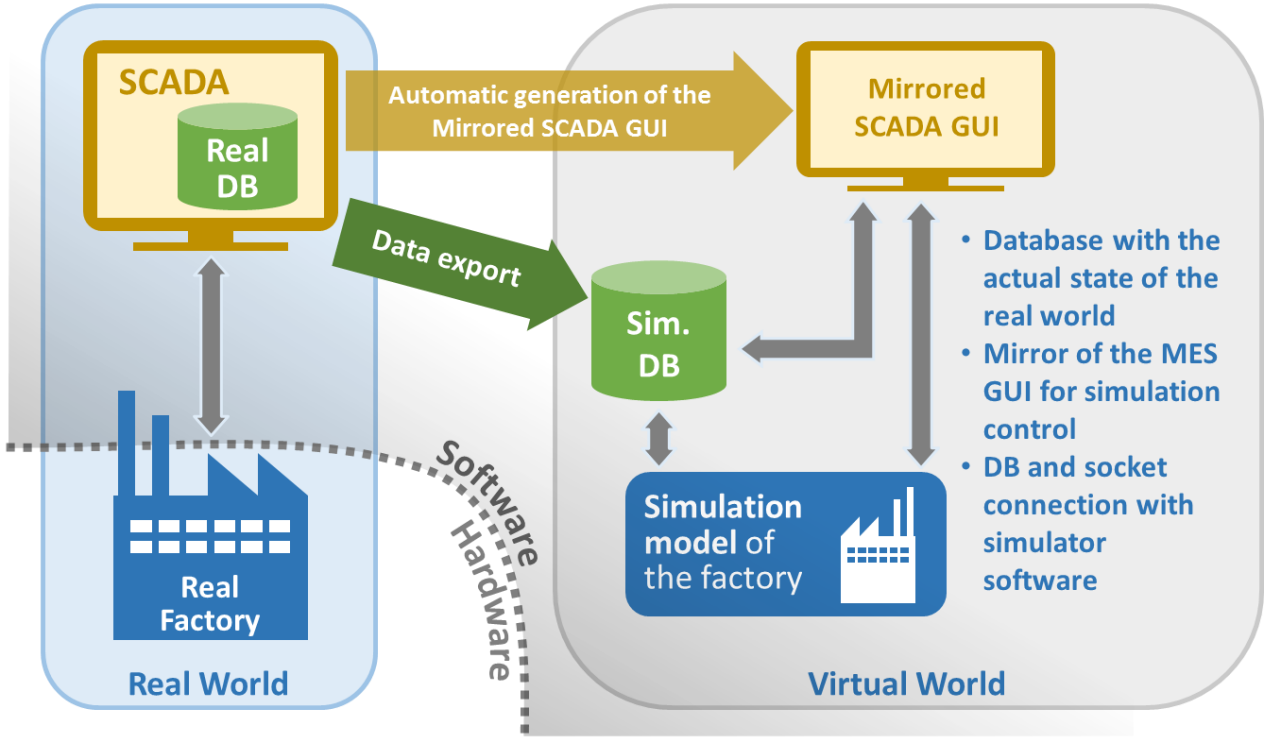
Working with Digital Twin

- Modelling, configuration and design, analysis of production systems
- Methodology
  - Discrete-event simulation models
  - Engineering models
    - CAD and mechanism models
  - Multi-agent approach, more and more
- Maintaining digital twin/thread
  - Linked with actual system – always up-to-date
  - Along the whole engineering process
  - Along the whole life-cycle
- Professional and own toolset
  - Siemens' PLM software
  - Mathematica and its Linkage Designer
  - Mathematical programming environments
  - Anylogic's agent technology



Digital Enterprise Technologies: simulation

- Discrete-event simulation
  - Re-usable modules
  - Automated model building
  - Experiment design
  - Matching of real and simulated system
- Day-to-day industrial consultancy

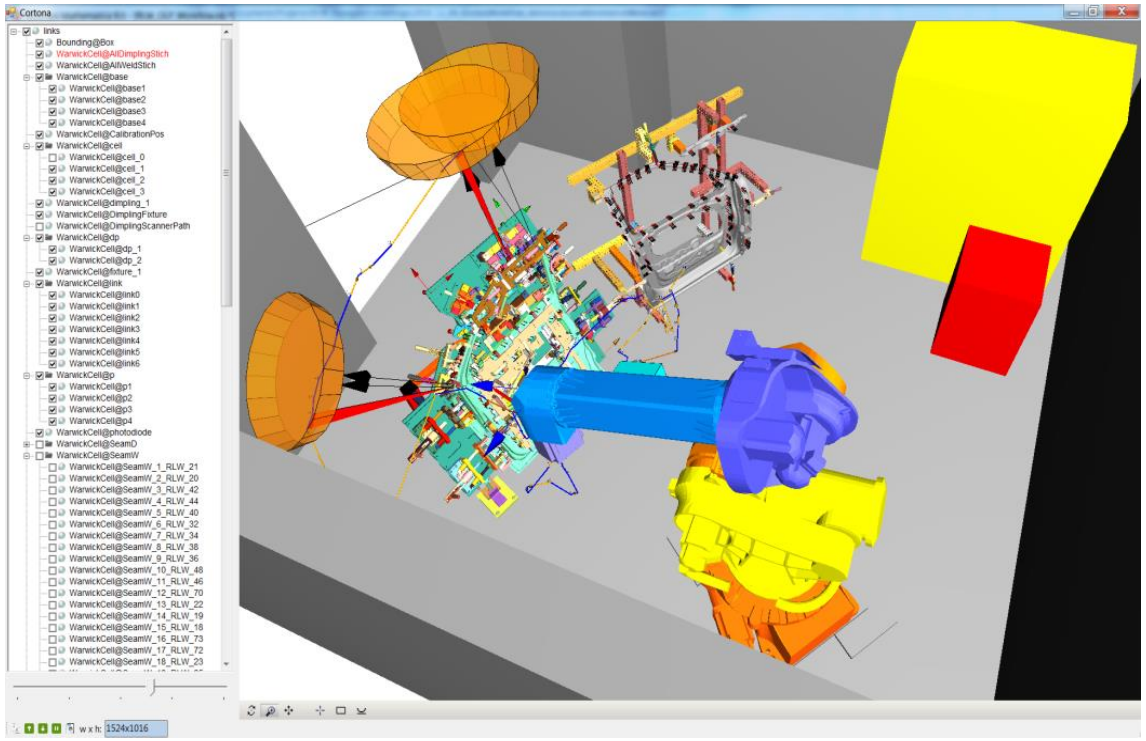


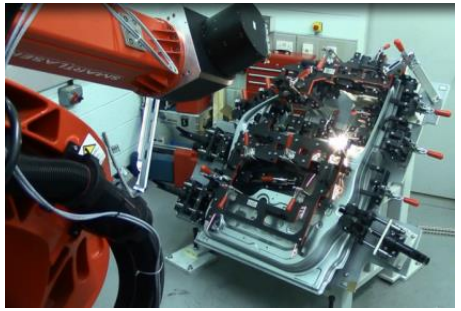
Production planning and scheduling

- Multi-criteria, efficient and robust systems
  - Key to network-level robustness
- Consistency between planning and scheduling
  - Automated model building
- Advanced human-machine interface
  - Responsiveness
  - Safeguards
  - Multi-mode visualization
- System integration and workflow
- Continuous support, maintenance and adaptation
- Custom-tailored vs. generic tool-based approaches
- From theory to industrial applications (and back)

Robotics & mechanisms

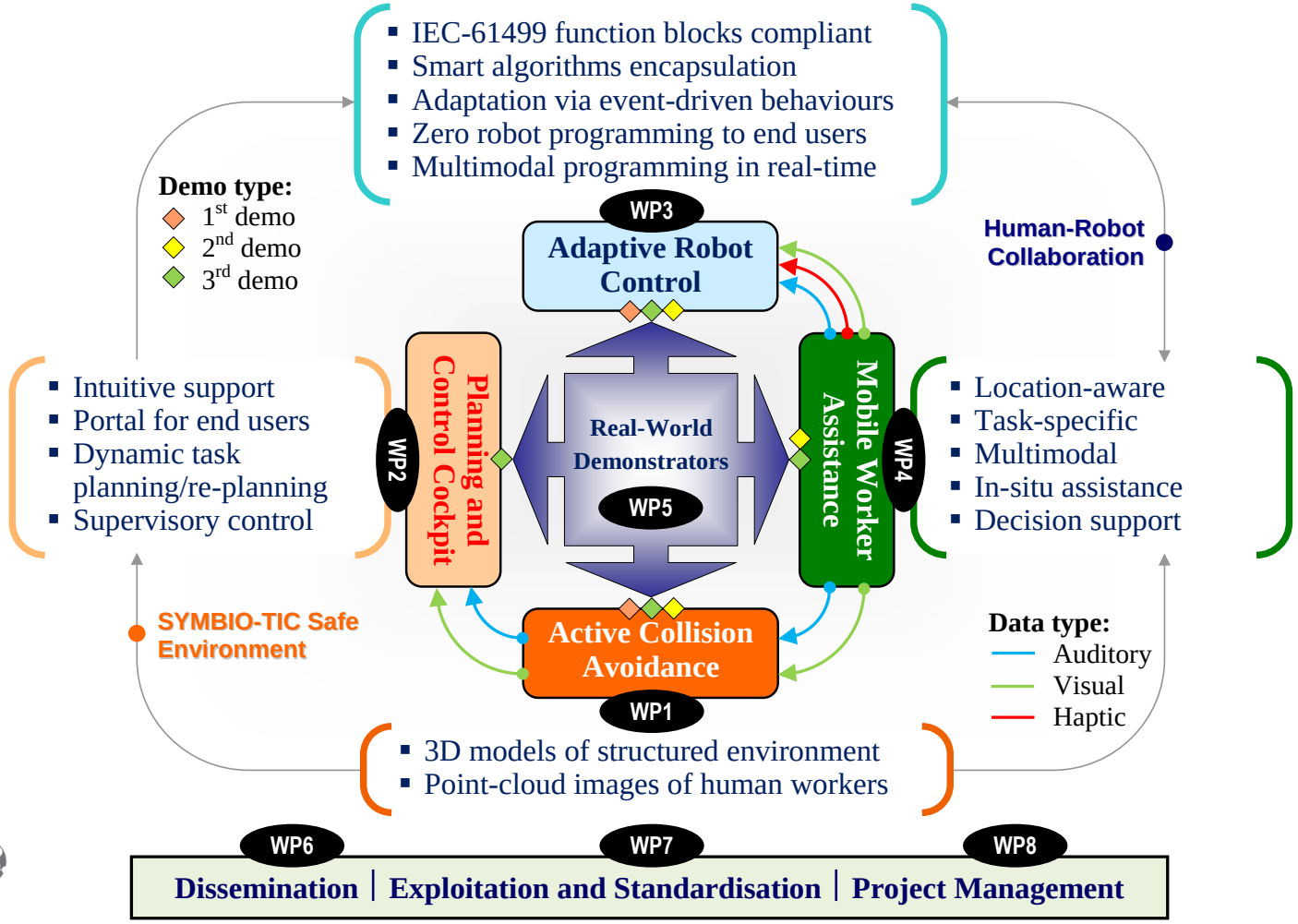
- Planning, simulating, validating robotic system behavior
- “Zero-programming”
  - Departing from product and resource models
  - Executable robot code (+ work instructions)
- Verification before physical commissioning
  - Geometric reasoning
  - Optimization
    - Task sequence, path, joint movement, cycle-time
  - Right-first-time design
  - Shorter development and test lead times
- Remote laser welding (RLW)
  - With Jaguar LandRover and Comau





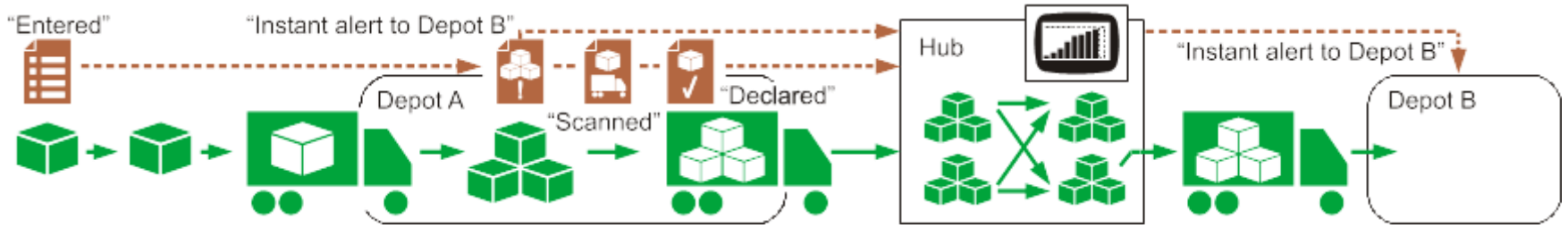
Human–robot collaboration

- Combining the best of two worlds
  - Repetability, speed, precision vs.
  - Flexibility and adaptation
- Automation also on small scale
- Working together in shared workspace
- Human safety first
- Novel intuitive interfaces
  - Smart phone
  - Gesture
  - Voice
  - Augmented reality
- Zero-programming
  - Instruction and
  - Robot code generation
- Case studies in assembly

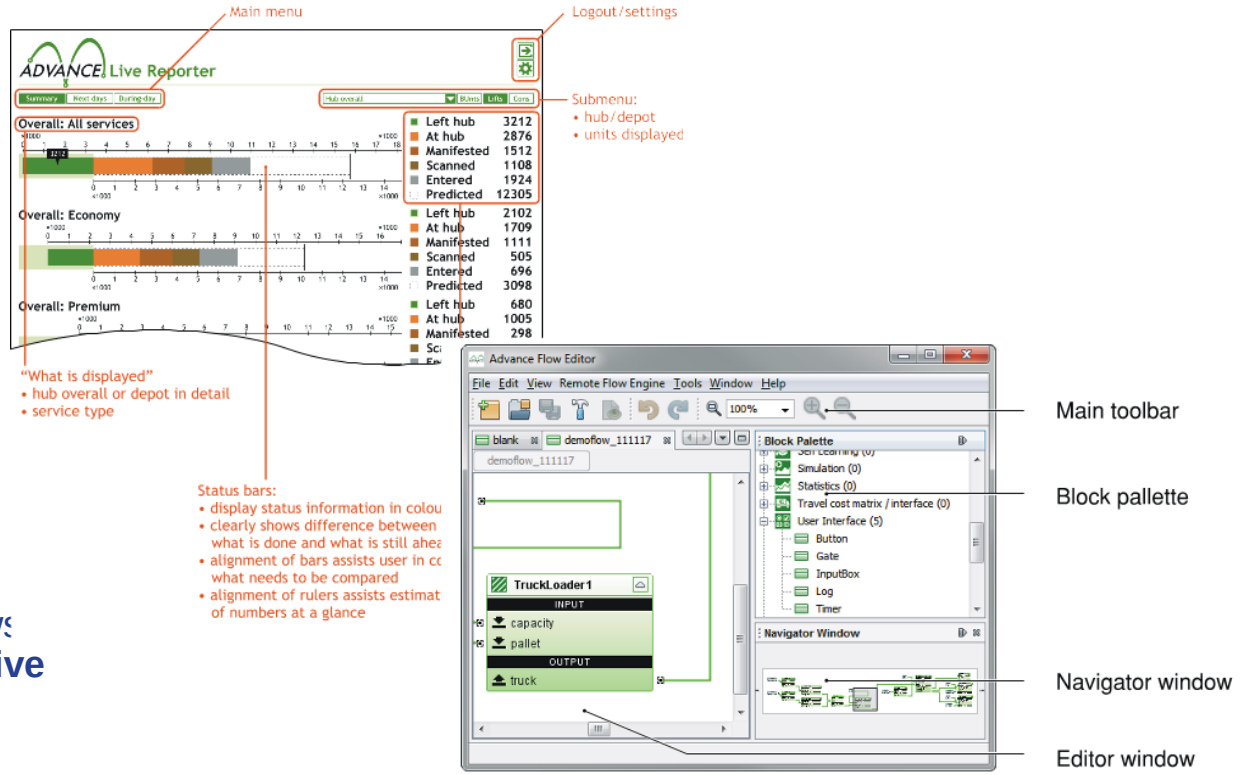


ADVANCE—Advanced Predictive-Analysis-Based Decision Support Engine for Logistics

- Application scenario: LTL hub-and-spoke network
- One major player operating central hub
- Local enterprises contracted with collection and delivery

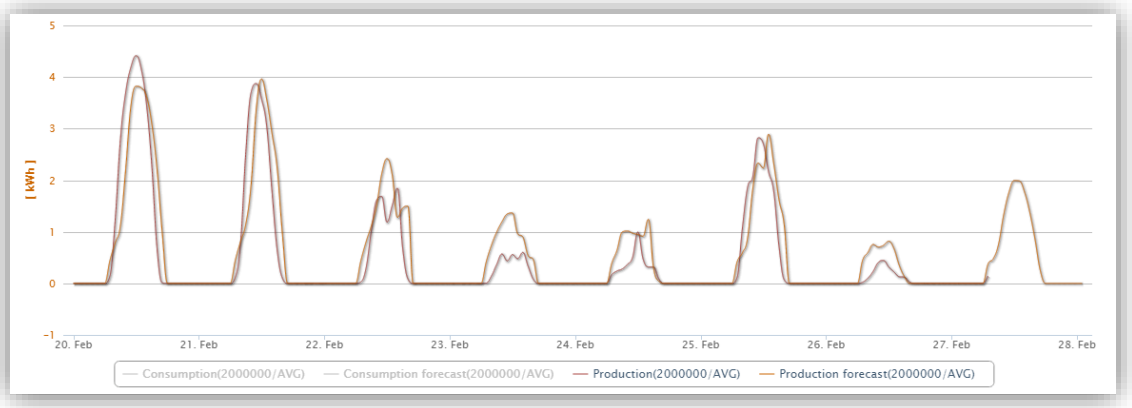


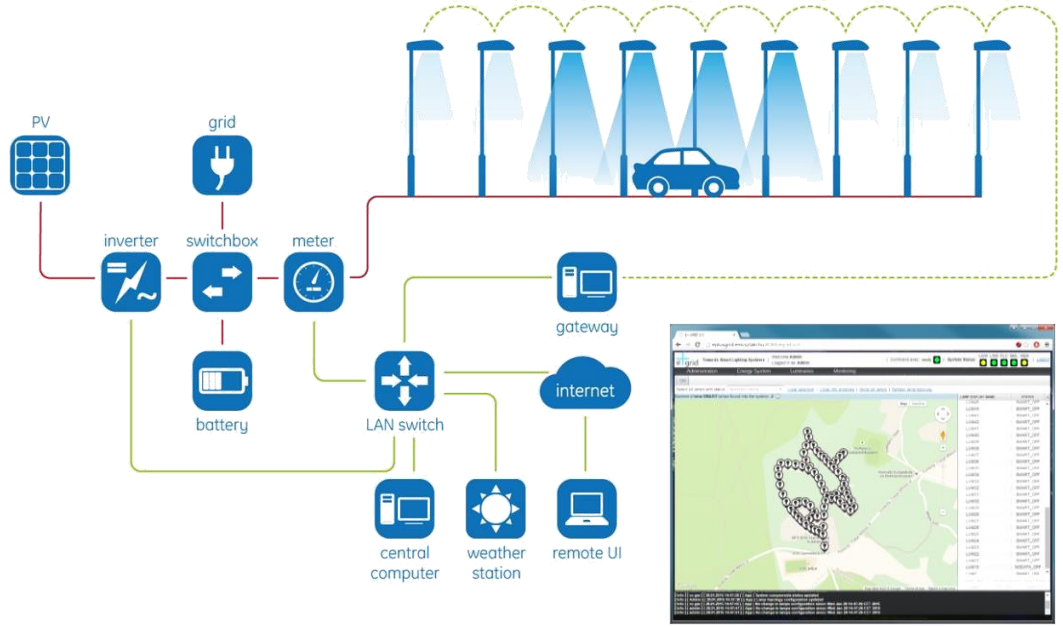
- Required: balanced utilisation of transportation assets
- Key problem of legacy processes: transparency impaired by established practice
- Solution components:
  - modeling and prediction
  - human-interpretable decision support
  - transparency tailored to needs of specific user groups
  - key to flexible infrastructure: developing and running dataflows complete dataflow-oriented environment—continued in **reactive programming famework** development



Energy systems, smart grid/city

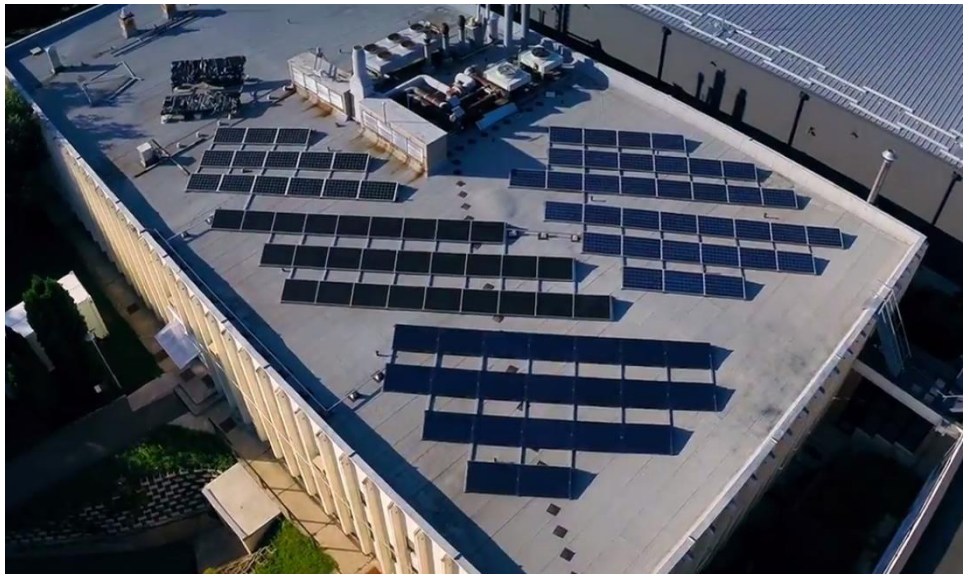
- Smart energy-positive public lighting system (GE)
  - Stochastic machine learning
  - Control of energy flow
  - Communication network
  - Smart user interface
- Demand–response management
  - Renewables
  - Demand aggregation
  - Tariff optimization
  - Local and global control
- Towards smart grid/city/transport and urban factories
- Maintenance planning & scheduling
  - Distance, special resources, teamwork
  - Sources of uncertainty (humans, weather)
  - Gamesa (wind farm), E-on (national service system)

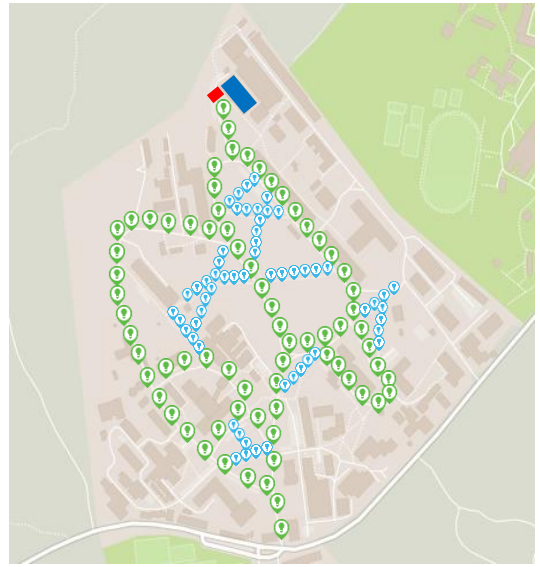




E+grid—intelligent energy-positive street lighting

- Adaptive: lighting according to traffic and environmental conditions
- Energy-positive: produces more energy than it consumes in a year
- Prototype system configuration:
  - 191 intelligent LED luminaires (6,4 kW)
  - Roof-mounted PV panels (21 kWp total, 3 different technologies)
  - Battery storage (18 kWh total, 2 different technologies)
  - At a research campus of the Academy



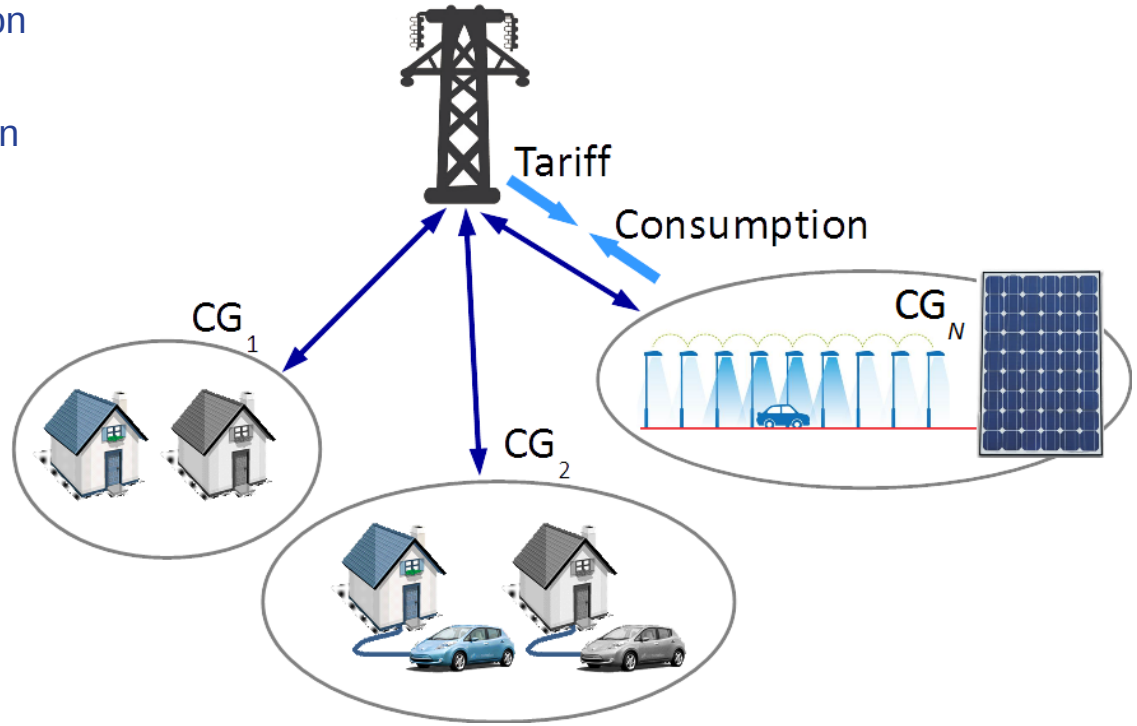


- Central controller implemented at SZTAKI
  - Monitoring and controlling the lighting system
  - Forecasting energy production & consumption
  - Optimizing energy flow to minimize energy cost
  - Web-based user interface

Demand–response management in smart grids

- Stackelberg game approach to demand response management
  - Energy retailer sets time-of-use tariff
  - Consumers schedule their consumption to minimize cost & maximize utility
  - Bilevel programming solution approach
    - Conversion to single-level QCQP using primal-dual reformulation
    - Solved using successive linear programming
    - Outperforms earlier approaches based on the KKT reformulation

- Selected challenges for future research
  - Identifying consumer models from historical data
  - Models for specific applications (industries, HVAC, etc.)
  - Extension to stochastic variant



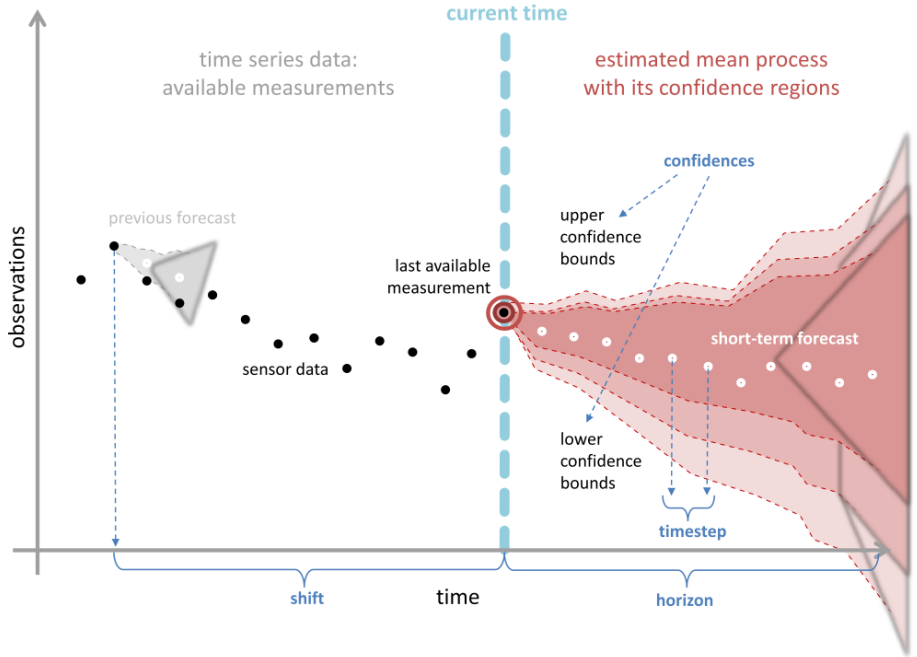
Machine learning, data analytics, big data

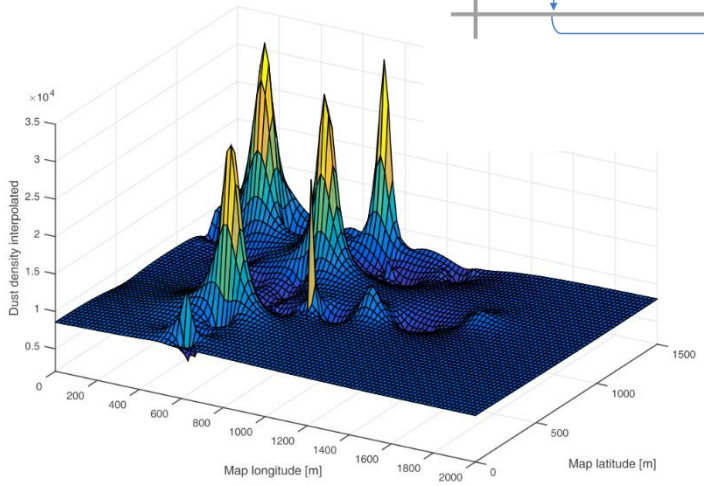
RDI for Manufacturing Industry

- Failure recognition, prediction
- Predictive maintenance
- Lead time prediction
- Stock level prediction, optimization
- Decision support in production control
- Explorative data analysis
- Data filtering, pre-processing

Solution methods

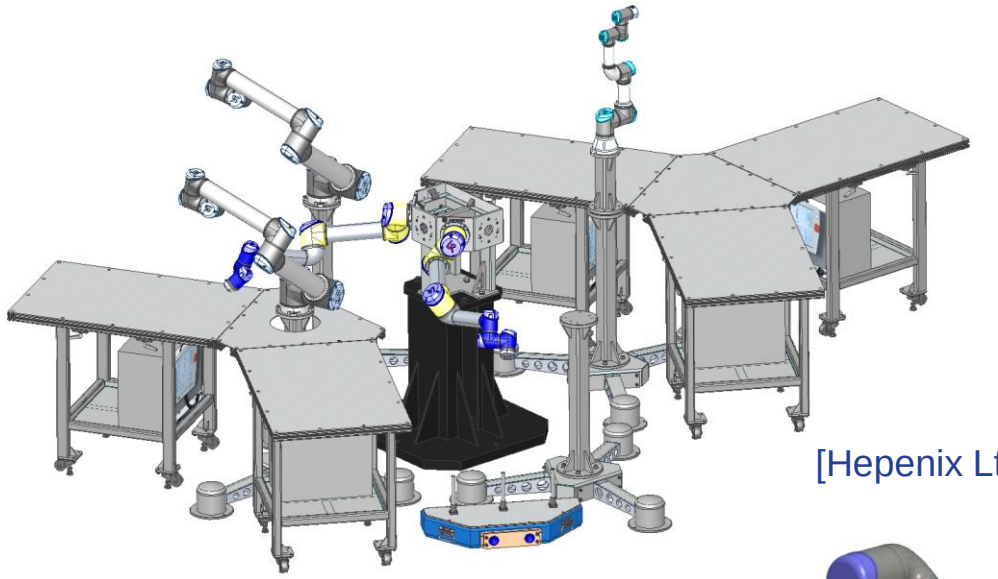
- Stochastic modeling & control
- Statistical machine learning
- Simulation-based approaches
- Signal processing
- System identification
- Mathematical programming, optimisation



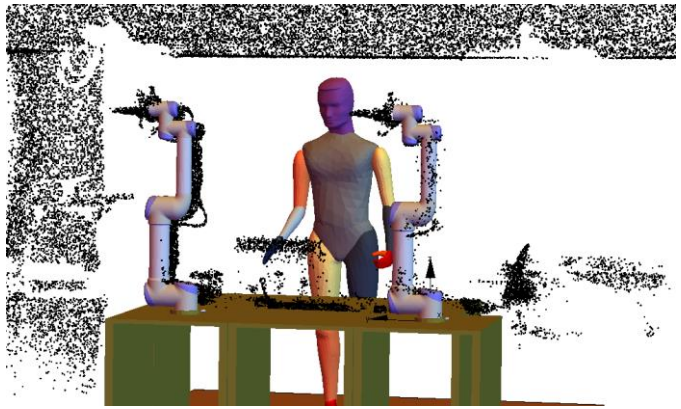


CPPS pilot system for production and logistics

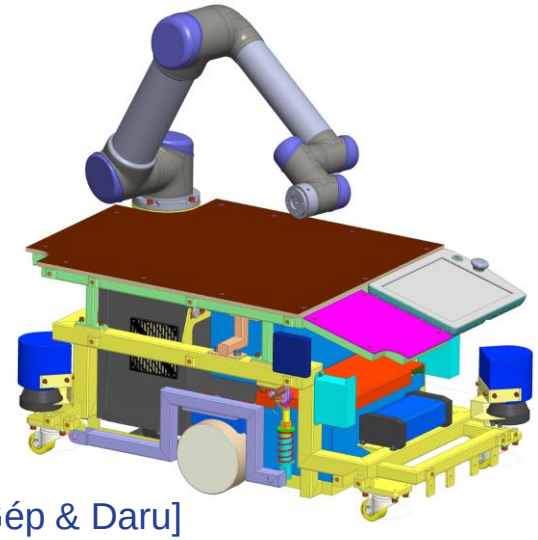
- **Human–robot collaborative assembly**
  - Reconfigurable workstations
  - Sensors: point cloud, visual, RFID, force, torque
  - Multi-modal human–robot communication
  - Warranted safety
  - Automated assembly planning
    - CAD → robot code, work instructions
  - Automatic off-line programming
- **Internal logistics with autonomous AGVs**
  - Localization
  - Dynamic pick-up and delivery
  - Path planning
  - Centralized and distributed control
- **Digital twin**
  - For designing structure and planning behavior
  - Automatic calibration



[Hepenix Ltd]

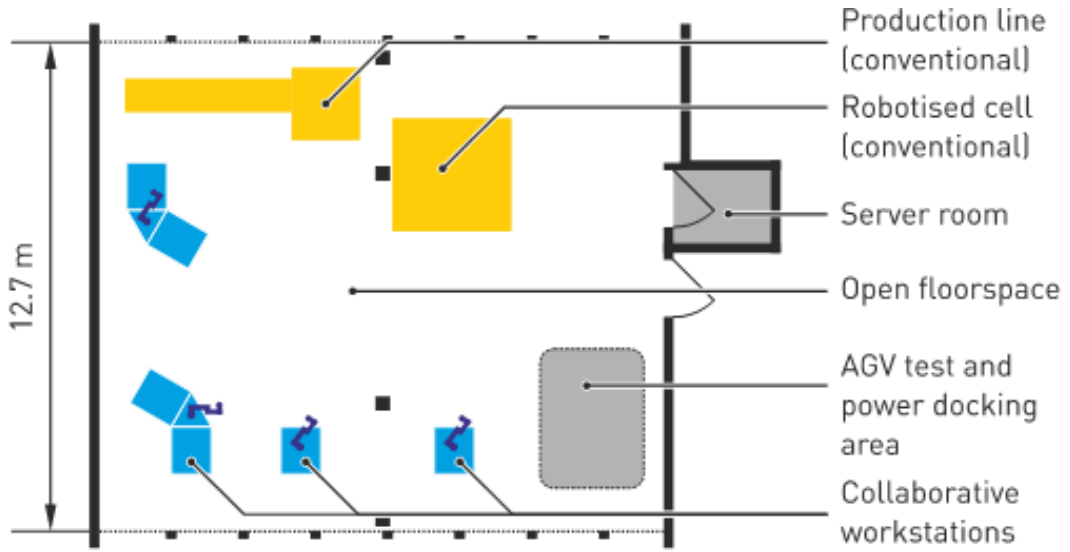


[MTA SZTAKI]



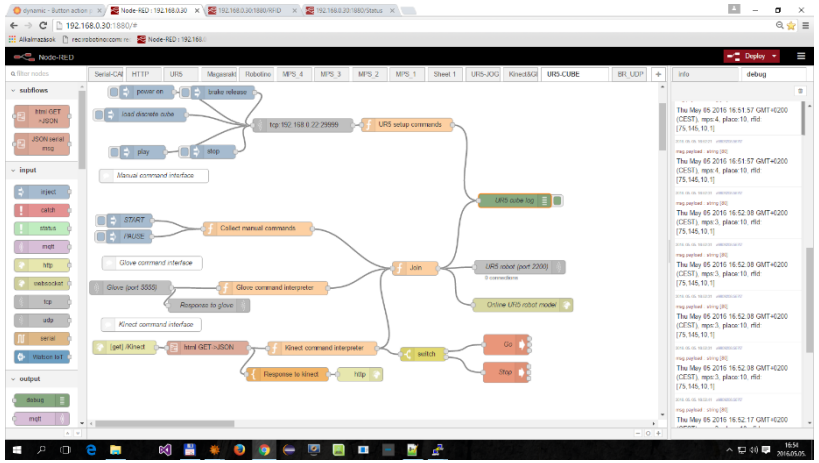
[Gép & Daru]

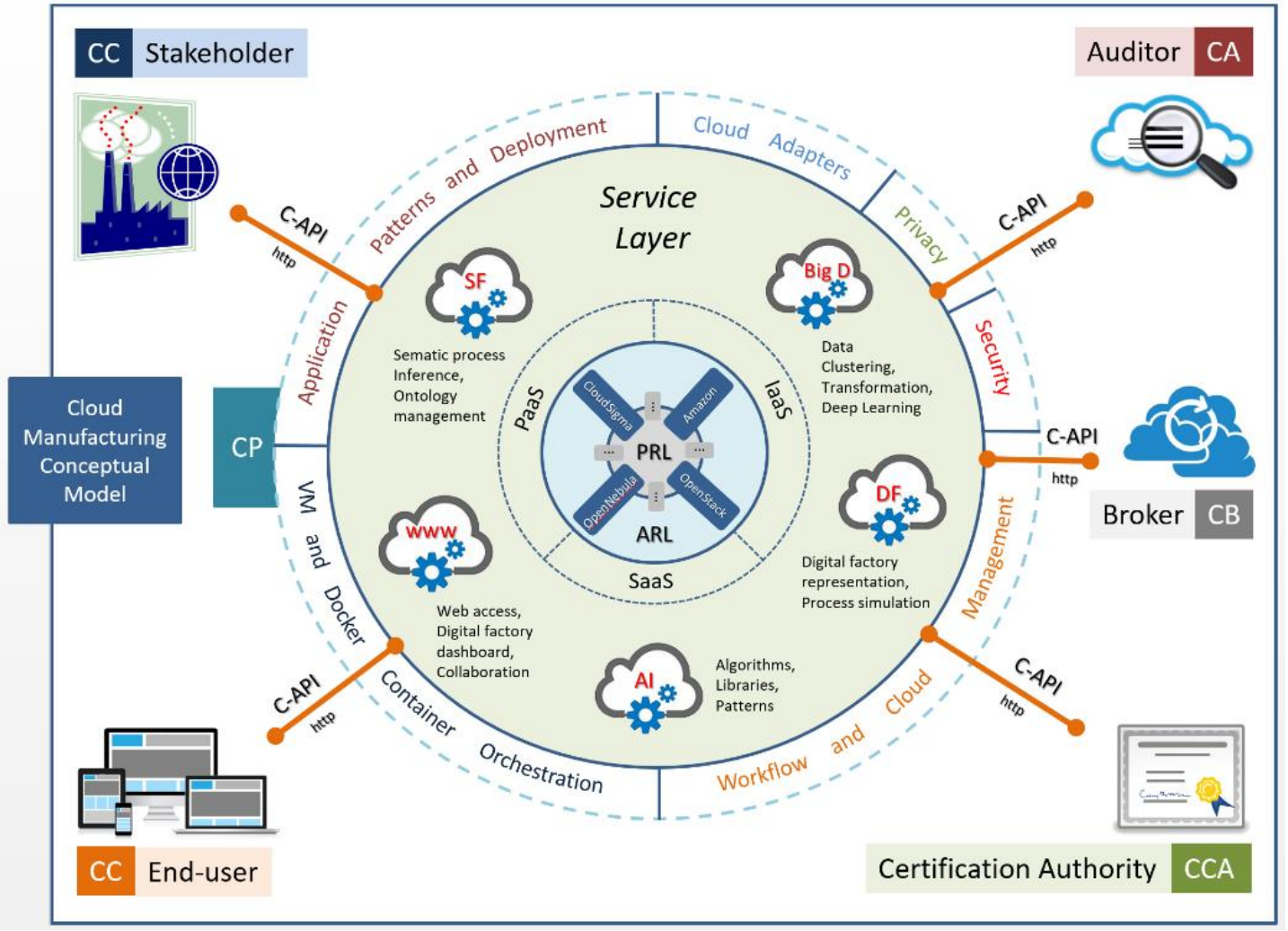
CPPS pilot system for production and logistics



CPPS service: IoT, cloud manufacturing

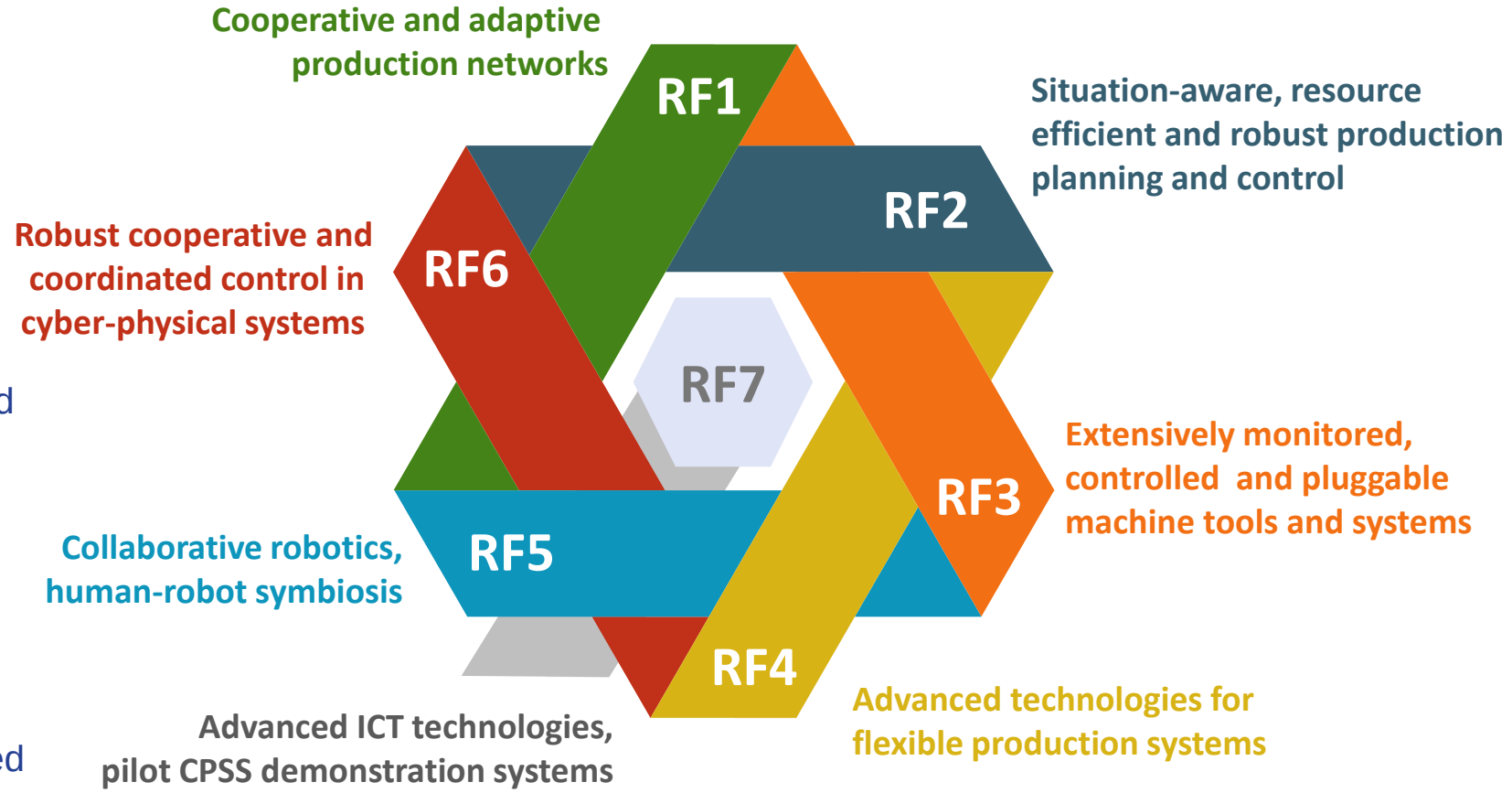
- General vs. specific services
  - Like GE's Predix, HITACHI's Lumada
- Trust
  - Openness, sharing of data vs.
  - Private data, security, safety
- Reliability and responsiveness
- Service definition and management
- Affordability





EPIC Center of Excellence

- EU 2020 “Spreading Excellence” Teaming project (2017-2024)
- Leading-edge knowledge centre of cyber-physical production systems
- Members
  - MTA SZTAKI (host)
  - Fraunhofer IPA, IPK, IPT, Austria
  - Budapest University of Technology and Economics
  - National Research, Development and Innovation Office (NKFIH)
- Mission
  - Accelerate **innovation**,
  - realize industrial **solutions**,
  - train new generations of highly qualified **professionals,**
  - support the development of a sustainable and competitive European manufacturing **ecosystem**



Thank you for your attention