TECHNISCHE UNIVERSITÄT DRESDEN

Stiftungsprofessur für Baumaschinen

- Prof. Dr.-Ing. Frank Will
- Volker Waurich
- TU Dresden – Endowed Chair of Construction Machinery

Perspectives of a Connected and Automated Construction Site

18th October 2021

6th international VDI Conference - Connected Off-Highway Machines

Outline

1	**TU Dresden Endowed Chair of Construction Machinery**
2	**Research goals in construction machinery**
3	**Wireless communication systems for construction sites**
4	**Automation and model based operation**
5	**Research project „Bauen 4.0“**

TU Dresden –
Endowed Chair of Construction Machinery

TU Dresden - Endowed Chair of Construction Machinery

- 32,000 students
- 17 faculties
  → Faculty of Mechanical Engineering
    →Institute of Mechatronic Engineering
      → Endowed Chair of Construction Machinery

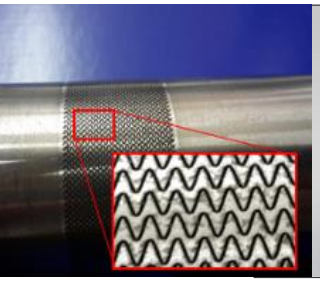
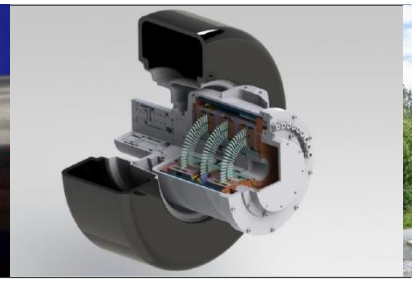
Stiftungsprofessur für Baumaschinen

https://tu-dresden.de/ing/maschinenwesen/imd/bm

https://www.linkedin.com/company/tudresden-baumaschinen/

- ~ 20 employees
- Mechanical workshop, machinery (excavators,wheel loaders, roller, concrete pump, etc.), test area

TU Dresden - Endowed Chair of Construction Machinery


drive systems & components

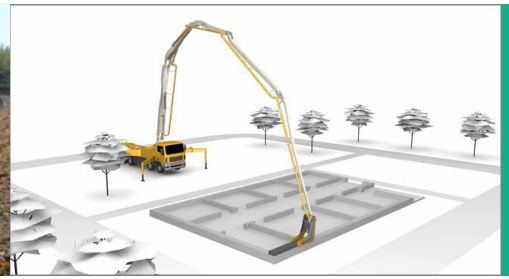



automation & digitalization

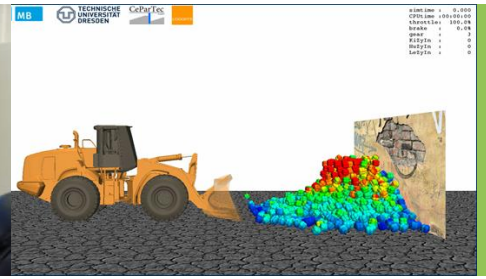




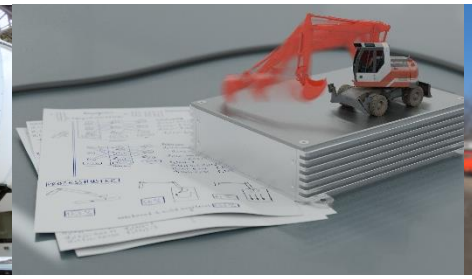




construction processes & disruptive technologies

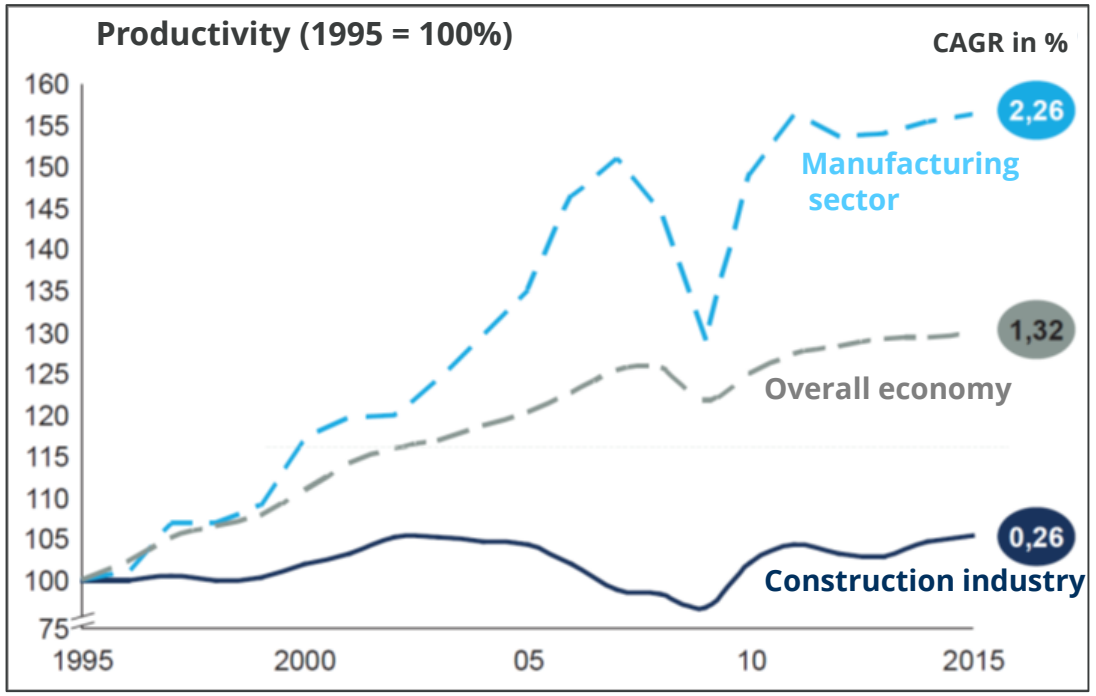



virtual product development & simulation


Research Goals in Construction Machinery

Challenges in Construction Industry



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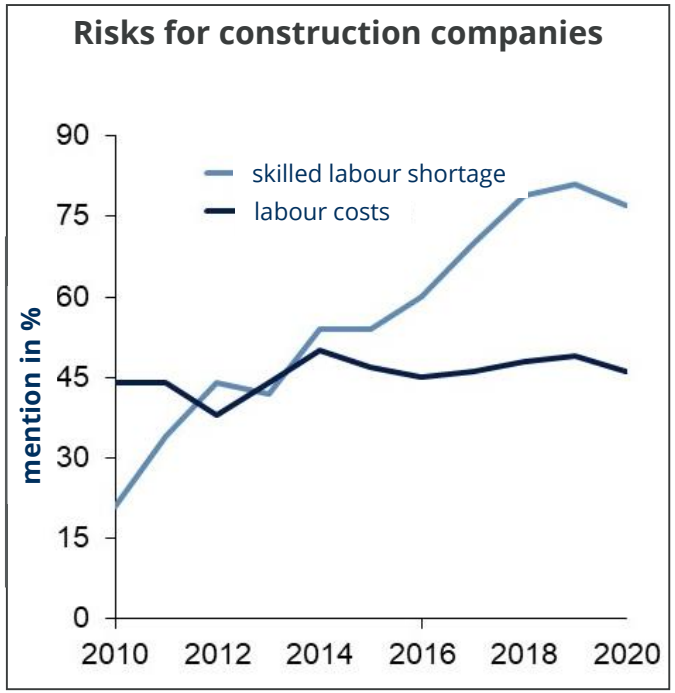

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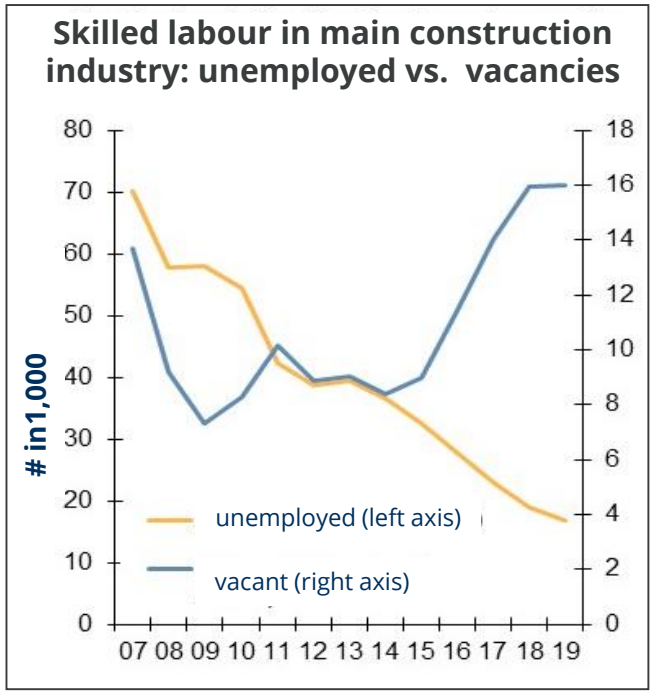

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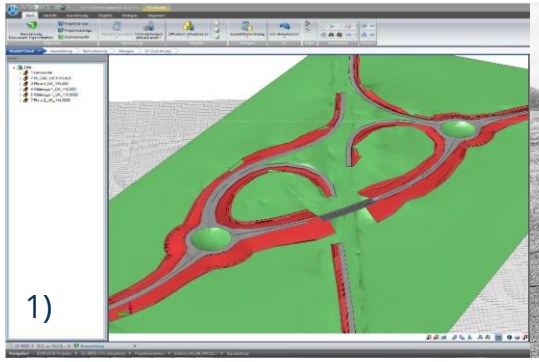
- Stagnating productivity growth
- Lack of (skilled) labour
- Increasing administrative effort (documentation, regulations)
- Fragmented industry (prime contractor – subcontractor)
- Low level of digitalization

1) Sebastian Stern, Gernot Strube, Carsten Lotz, André Kutz: Infrastruktur & Wohnen: Deutsche Ausbauziele in Gefahr (Studie). McKinsey & Company, 2018
2) https://www.bauindustrie.de/zahlen-fakten/bauwirtschaft-im-zahlenbild/fachkraeftemangel_bwz / 25.03.2021
3) https://www.bauindustrie.de/zahlen-fakten/bauwirtschaft-im-zahlenbild/beschftigung-und-arbeitslosigkeit-im-bauhauptgewerbe_bwz / 25.03.2021

Trends in Construction Machinery Industry

Model based construction

- BIM, GIS, DTM
- 3d-machine control systems
- As-built documentation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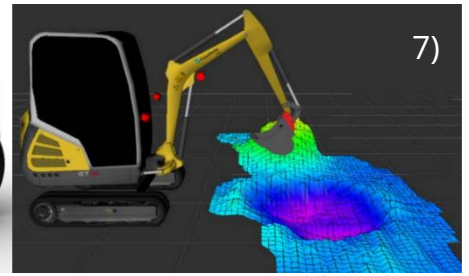
Connectivity

- Tracking/tracing
- Fleet-management systems
- Machine2machine communication

Automation

- Assistance/automation/autonomy
- Sensor technology
- AI, digital services

6)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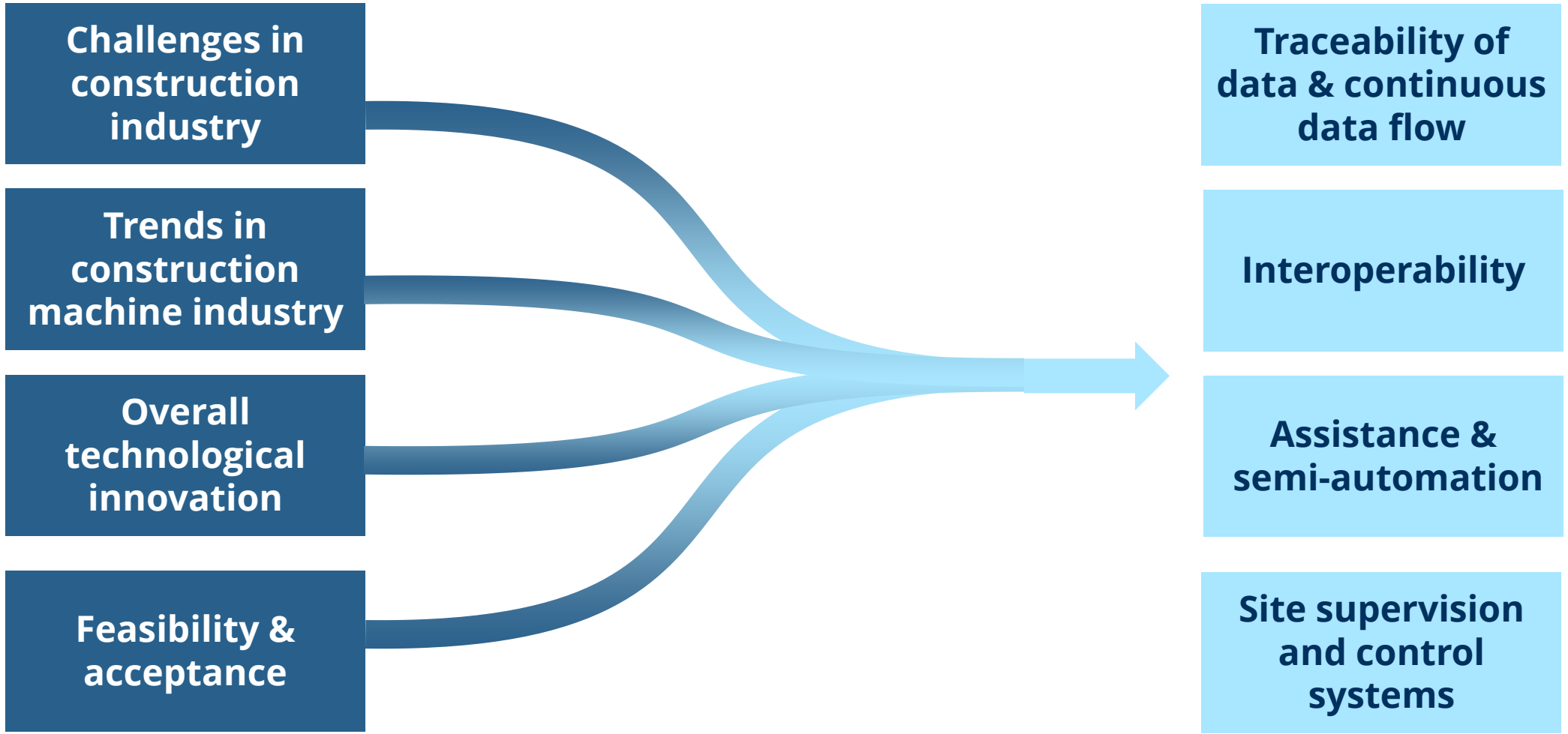
1) www.gestrata.at/images/2016/BiM5DimVerkehrswegebauErsteAnstzeundErfahrungenDipl.Ing.JensHoffmann.pdf (14.05.2020)
2) https://www.mts-online.de/uploads/tx_owlslider/digitale-baustelle-mts-navi-600x4007.jpg
3) https://insideunmannedsystems.com/wp-content/uploads/2021/08/3-_Drone_Mapping_-_Windover_Construction_at_FMUV_Project.jpg
4) www.baumaschinendienst.de/artikel/immer-unter-voller-kontrolle-8891/galerie-8907/4 / 28.06.2020
5) https://www.vemcon.de/wp-content/uploads/2018/08/VMC_Toolmanagement_03.jpg
6) www.wirtgen-group.com/de-de/news-und-media/hamm/autonome-walzen / 21.03.2021
7) Philipp Woock, Nina F. Heide, Daniel Kühn: Robotersysteme für die Dekontamination in menschenfeindlichen Umgebungen. 16. Leipziger Deponiefachtagung, 2020

Medium-Term Development Goals

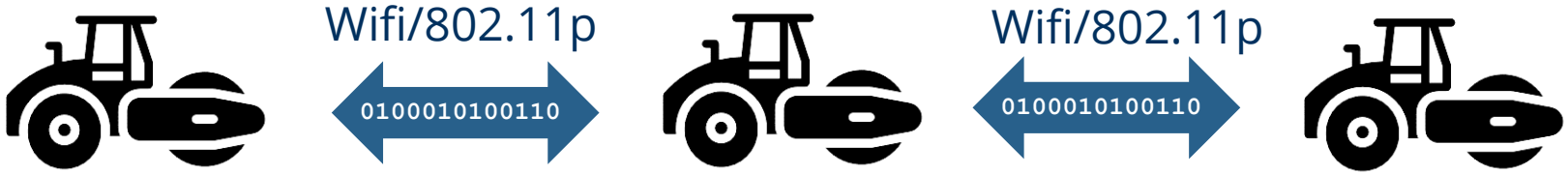


Wireless Communication Systems

State of the Art of Machine Communication on Site

- Fleet management

- V2V / shared map



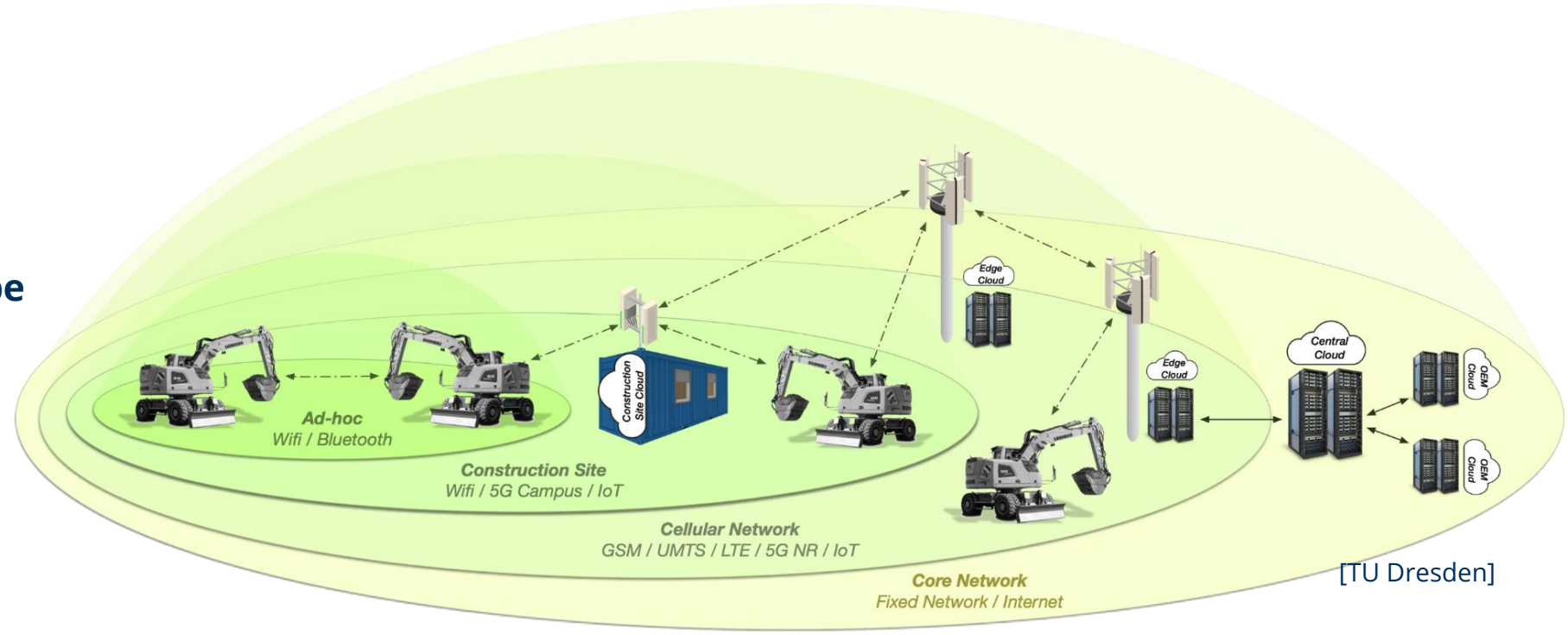
- V2V/ anti collision system

V2V...vehicle to vehicle

Requirements for on-site connectivity

- **Use-case specific connectivity:**
  - Data rate
  - # of participants
  - Latency
  - Coverage
  - Private infrastructure
  - Energy consumption

- **Construction site scope**
  - LPWAN
  - 5G Campus



[TU Dresden]

Spatial scope

Low-Power Wide-Area-Network (LPWAN)

Characteristics:

- Low-power
- Mid range (>1km) & penetration
- Cheap
- Low datarates (100bps-200kbps)

Use-case:

- Battery-driven trackers for materials & tools
- Low-cost sensor networks (e.g. concrete sensor, environmental sensors)

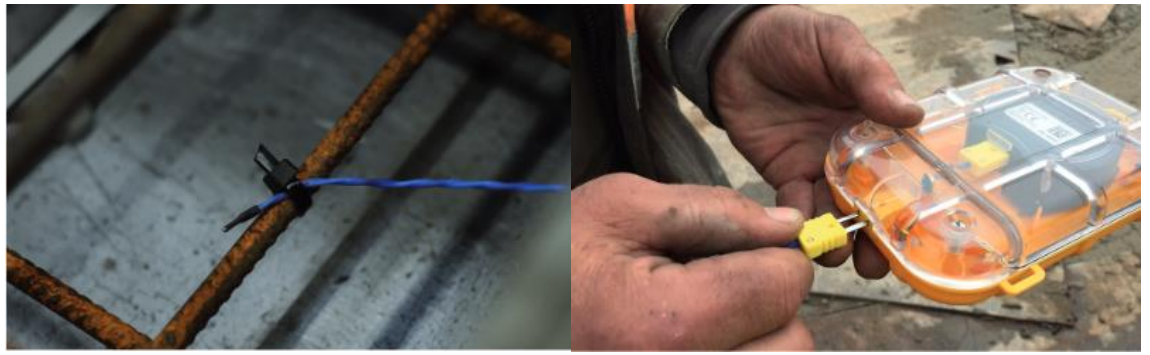
Technologies:

sigfox 3)

LoRa™ 4)

NB-IoT LTE-M 5)

1)



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1) https://www.ingenieur.de/wp-content/uploads/2021/08/2021_08_30_Industrie4.0_Bild_01-980x490.jpg
2) https://www.paschal.de/dokumente/deutsch/Flyer/Produktinfo_Maturix_de.pdf?m=1633596466
3) https://www.sigfox.com/sites/default/files/2017-01/Sigfox_Logo_RGB.png
4) https://www.lora-wan.de/wp-content/uploads/2019/03/lora-sharing-image.jpg
5) https://pycom.io/wp-content/uploads/2019/12/LTE-M.png

5G Cellular Network

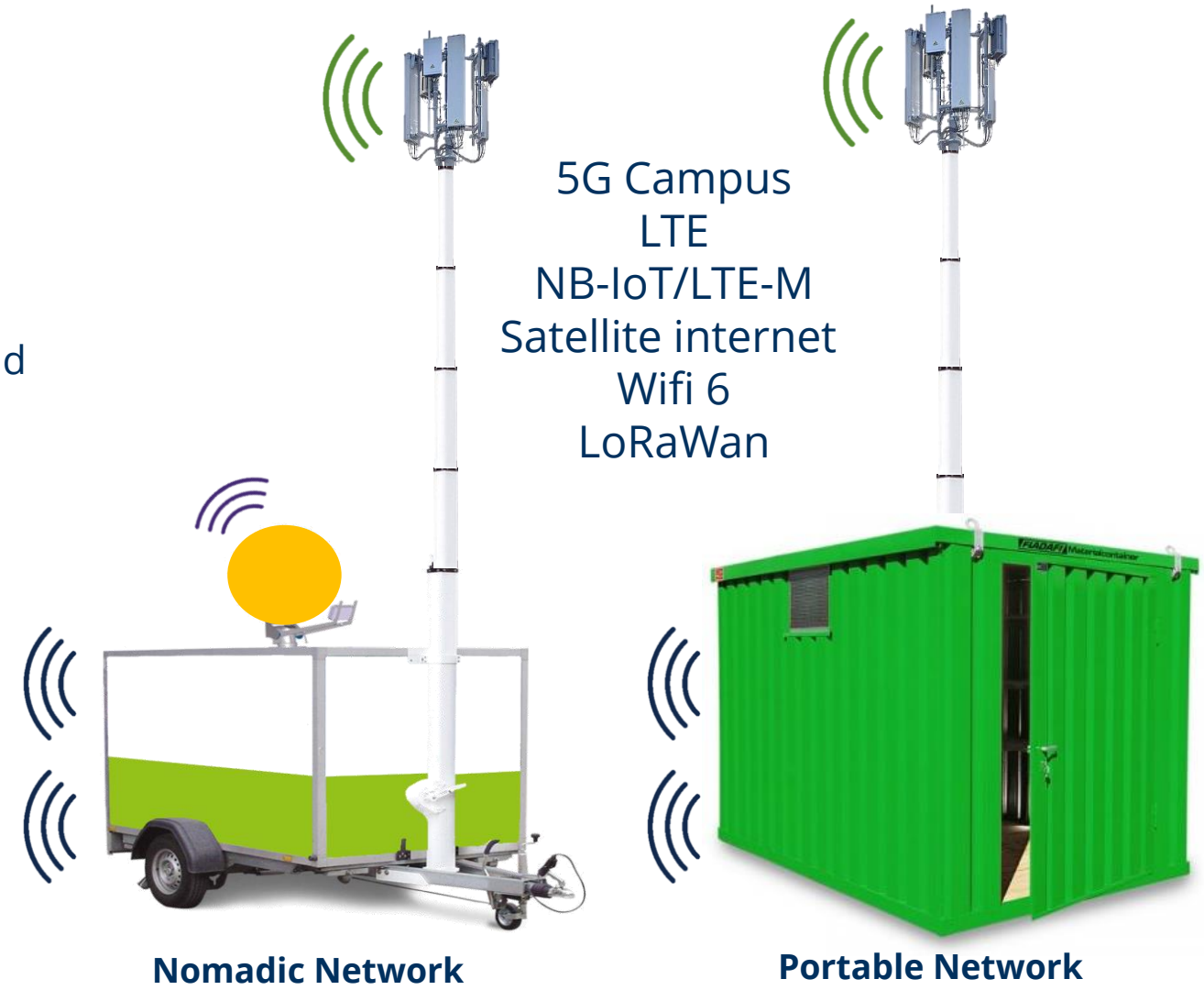
5G technology features a vast portfolio of communication technology.

Construction site relevant features:

- 5G Campus Networks
  - High performance, privacy, security, ressource and user management
- Local Edge Computing
  - On site data processing
- Network Slicing
  - Network virtualization, use case specific profiles (uRLLC, mMtC, eMBB)

Use cases:

- Site-information system / MES
- Tele-remote operation



Automation and Model Based Operation

State of the Art of Automated Construction Machines

- Major Development Tasks for Automated Machines:

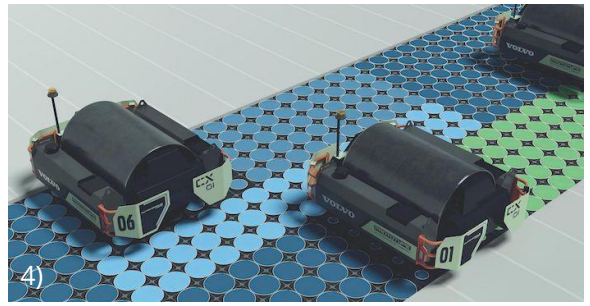
hydraulic and drive control	**work process & machine sensing**	**safety & collision detection**	**trajectory planning & work strategy**	**data interface and communication**

- Assistance Systems → Partial Automation → High Automation → Full Automation


1)

2)


3)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- Costs vs. Complexity
- How to operate partial and fully automated machinery?

1) https://img.forconstructionpros.com/files/base/acbm/fcp/image/2015/11/Cat_GRADE_with_ASSIST_on_HEX___C10686759.56547ba25e84f.png?auto=format%2Ccompress&q=70
2) https://www.smh.com.au/business/companies/no-one-behind-the-wheel-the-new-workforce-driving-australia-s-mines-20190411-p51dd2.html
3) https://www.youtube.com/watch?v=2tDf1p8OHik
4) https://www.ivtinternational.com/wp-content/uploads/2021/09/volvo-ce-unveils-cx01-2324x1200.jpeg

How to operate automated construction machines?

- **Who operates/orchestrates automated machines?**
- **User interface?**
- **Digital models? Standards? Interoperability?**


1)


2)


3)

→ Site management system

- realtime supervision
- scheduling
- distribution
- control functionalities
- productivity and quality reports
- interfaces to design & project management
- interfaces to machinery and tools


4)


5)

1) https://img.forconstructionpros.com/files/base/acbm/fcp/image/2020/05/FORT_Robotics_Remote_Control_Consctruction.5ec3e8e21d3a8.png?auto=format&fit=max&w=1440
2) https://img.freepik.com/free-photo/driving-worker-heavy-wheeled-tractor-workers-drive-orders-through-tablet-wheel-loader-excavator-with-backhoe-unloading-sand-works-construction-site_61243-578.jpg?size=626&ext=jpg
3) https://cdn1.vogel.de/unsafe/540x0/smart/images.vogel.de/vogelonline/bdb/291900/291989/original.jpg
4) https://www.produktion.de/assets/images/8/fertigung-5881c228.j
5) https://c0.wallpaperflare.com/preview/683/530/574/site-demolition-work-demolition-excavators.jpgpg

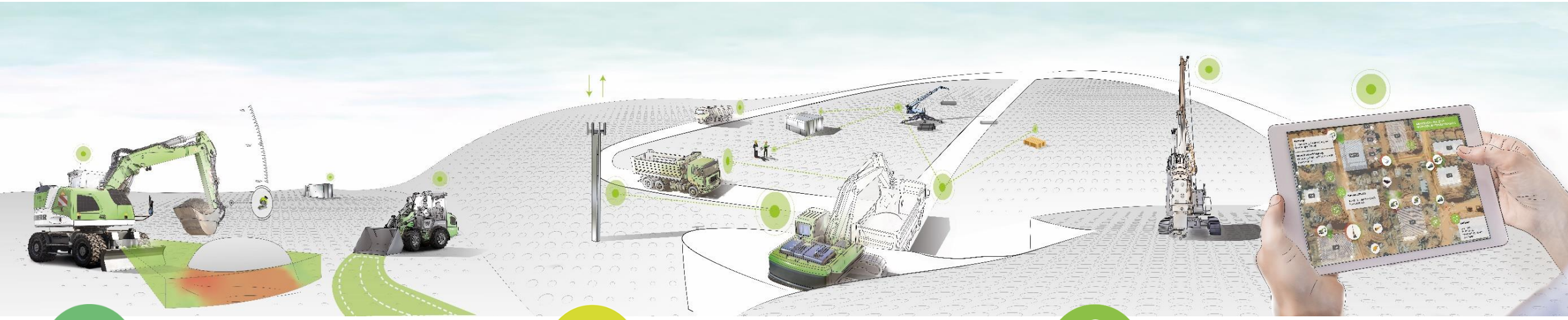
Joint Research Project „Bauen 4.0“

Project partners and organizational framework

Facts and Figures:

- Funding BMBF – INKOWE program
- Duration July 2019 – December 2022
- 22 industrial partners, 2 universities
- Accompanied by various associations
- Total costs 10 Mio. € / 5,0 Mio. € funding

The main topics



Automated, connected mobile machines

- Automation
- Assistance functions
- Remote control
- Environment recognition
- Vertical Integration

5G machine and construction site connectivity

- Connectivity Solutions
- Cloud Technologies
- Reliable and secure data exchange

Processes and solutions for the digital construction site

- Tracking & Tracing
- Simulation of construction processes
- BIM to BIMsite
- Driver guidance system 4.0

Demonstrators in the project

Automated, connected mobile machines

Vertical Integration via OPC UA

- Automated digging
- Remote operation
- Detection “as built” state

- Automated driving
- Environment recognition

- Automated processes

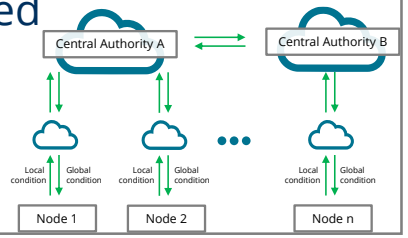
- Semi-automated load cycle

5G machine and construction site connectivity

- Multi-Connectivity module: WiFi, 5G, 4G, BLE…

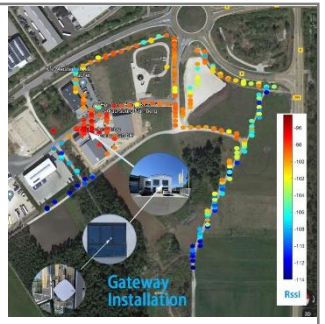
- Construction Site Networks: WiFi, 5G Campus

- Distributed Cloud Services



Processes and solutions for the digital construction site

- Tracking & Tracing of Material via LPWAN



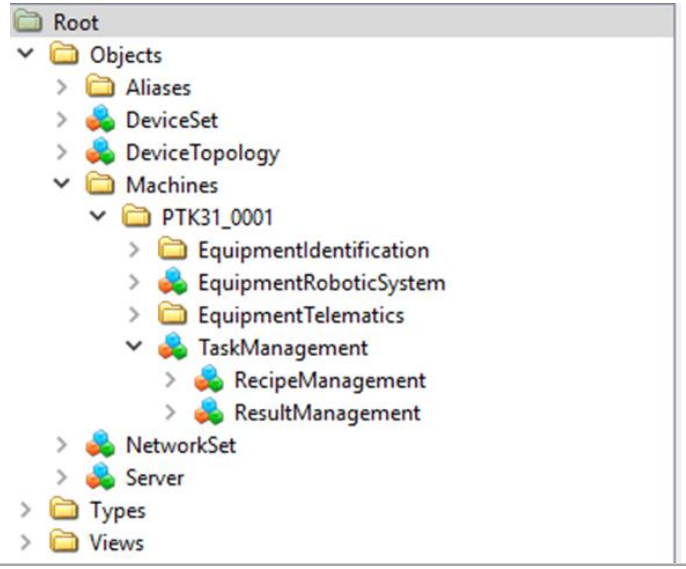
- Process optimization and progress prediction using simulation and machine data (e.g. with ISO 15143-3 data via OPC UA)

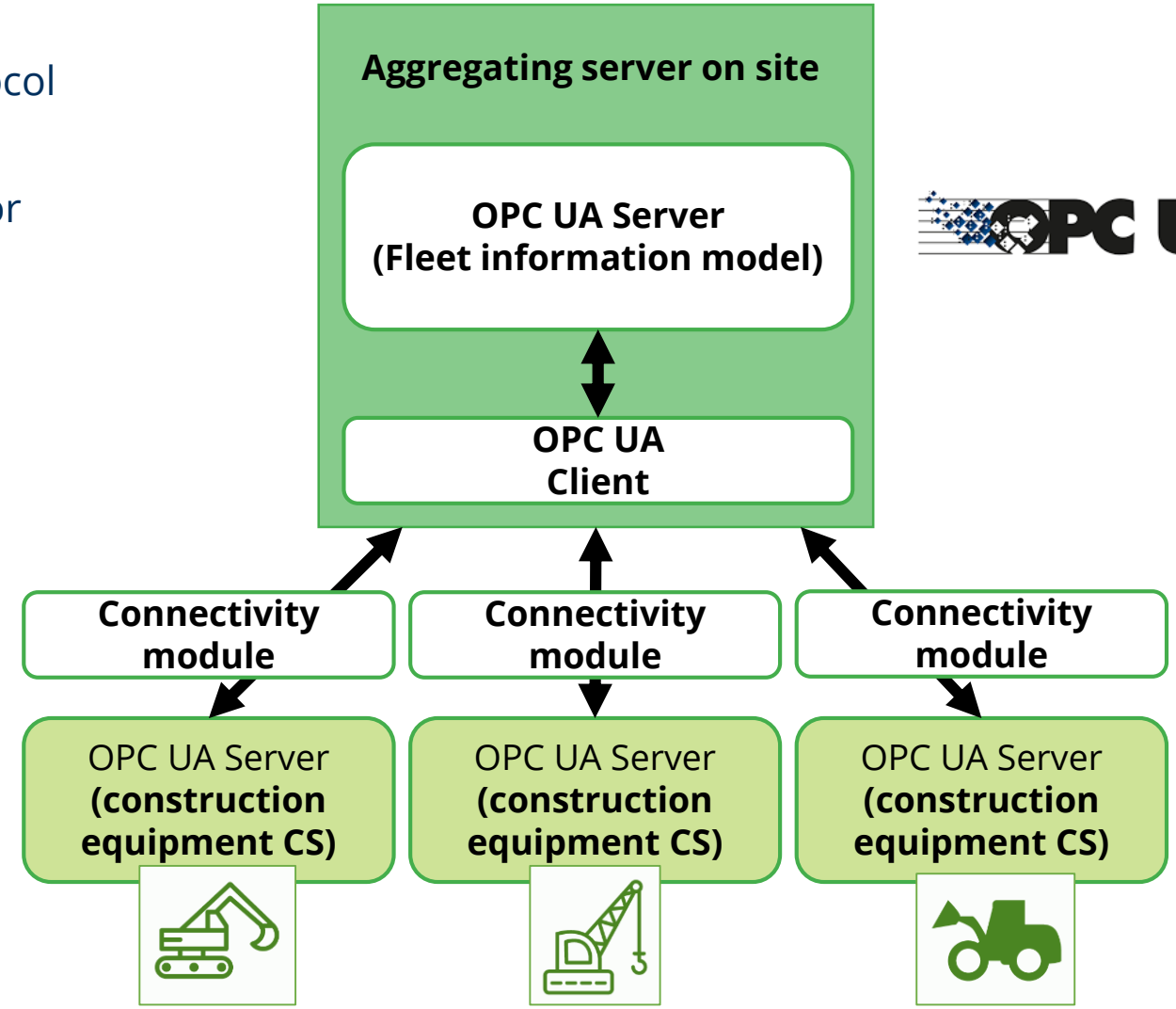
- AR-based driver assistance: Visualization via HoloLens

Machine interface development

- **OPC-UA** data model and communication protocol

- Specification of **interoperable data models** for construction equipment
  - machine identification
  - telematic data
  - kinematic data & robotic interface
  - task-management





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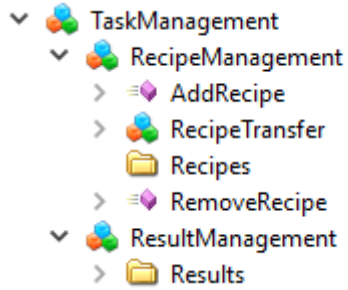
1) https://assets.new.siemens.com/siemens/assets/api/uuid:9cf74b3b-9e83-4789-a816-279fc3b0319d/width:1125/quality:high/opc-ua-foundation-logo.png

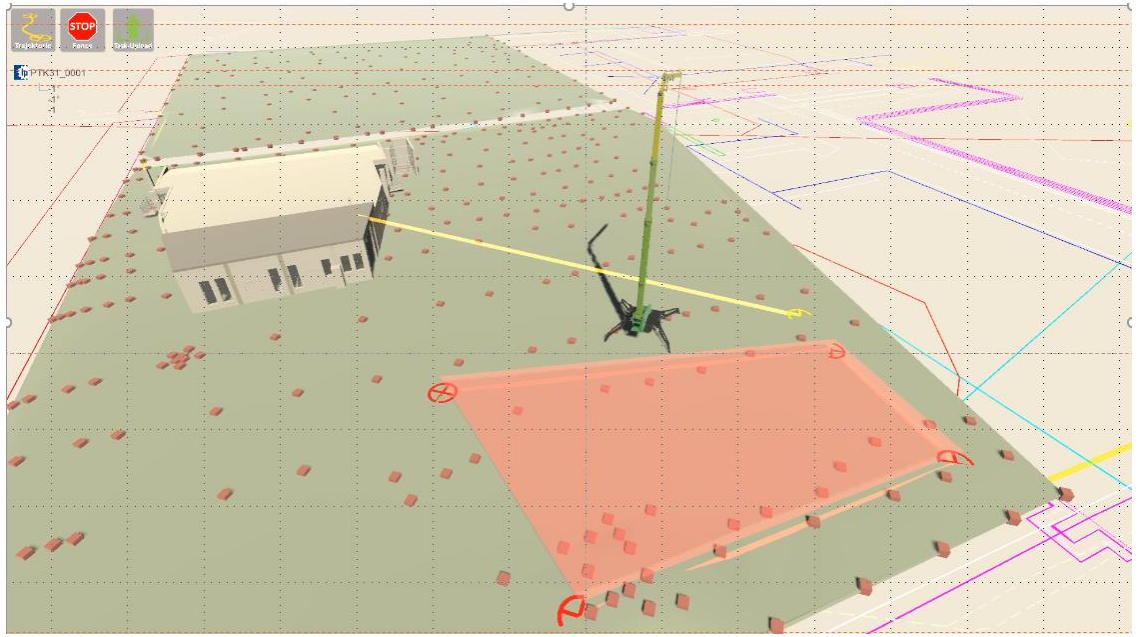
Task-Management

- Mission data is submitted via OPC-UA file transfer



- Topographic mission data in annotated LandXML

In accordance with ISO 15143-4

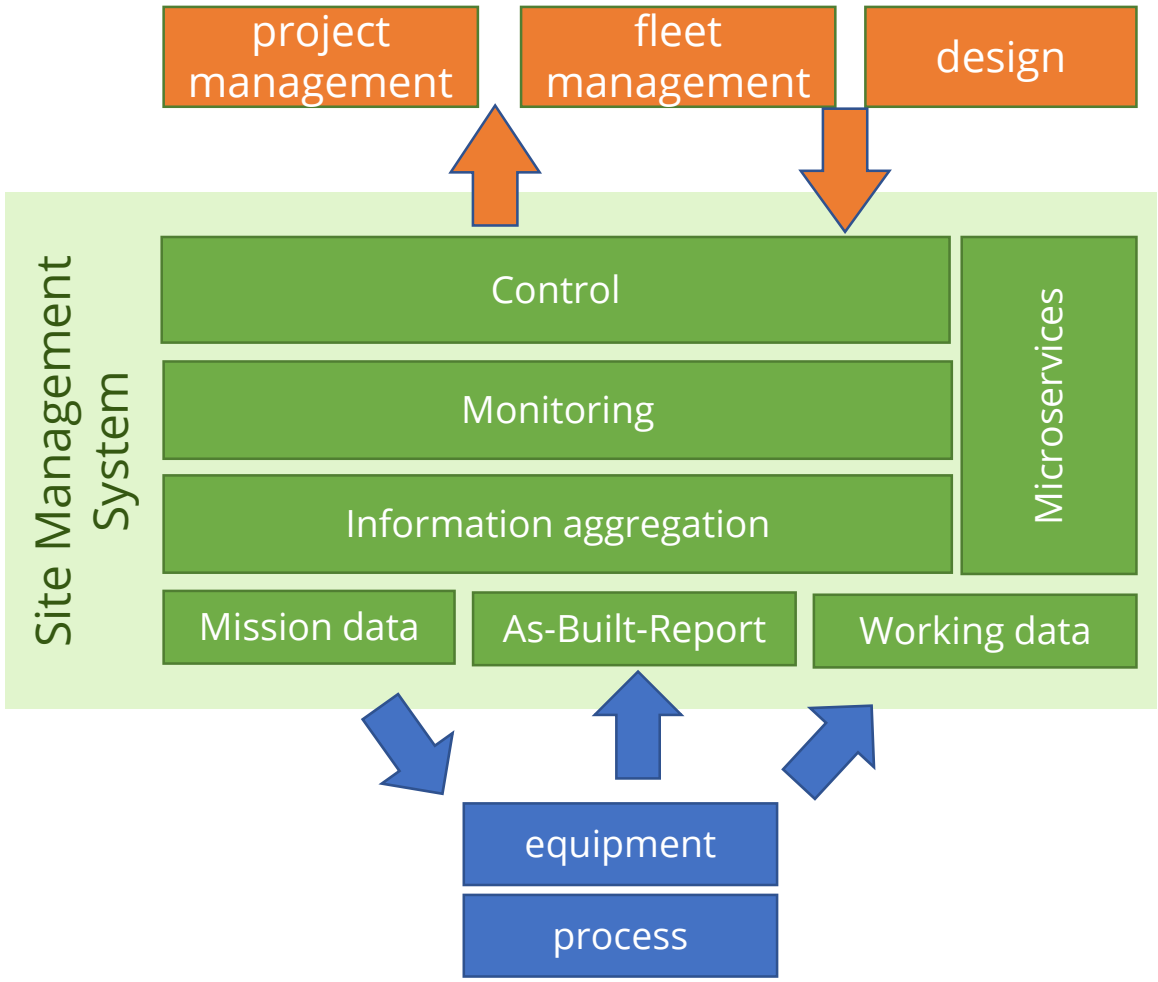


- Automation specific annotations
  - Geofences
  - Trajectories
  - Tracks
  - Dump areas
  - Target geometry

Site Management System

- Central information and management instance on site
- Server infrastructure on premise
- OPC-UA interfaces to all machines
- Edge-cloud and microservice architecture to implement 3rd party apps
  - realtime information system
  - shared map
  - scheduling
  - project management and report generation
  - process simulation

- 5G-campus / Wifi Mesh network



Summary and Outlook

- Initial operation of automated machines has started
- Tender for 5G Campus hardware is in progress
- Site information system is WIP
- 5G – unit prototypes are deployed

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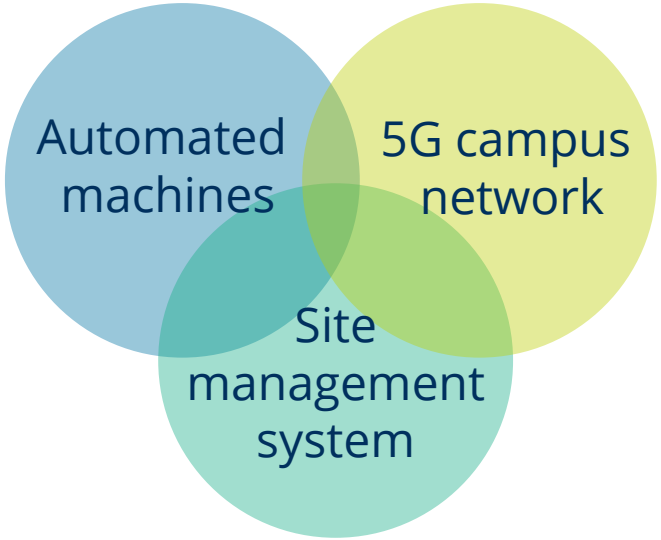
Autumn 2022: Bauen 4.0 final event



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Project Management Agency Karlsruhe
Karlsruhe Institute of Technology

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Baumaschinen

Thank you
for your attention.

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