How to design a smart factory?

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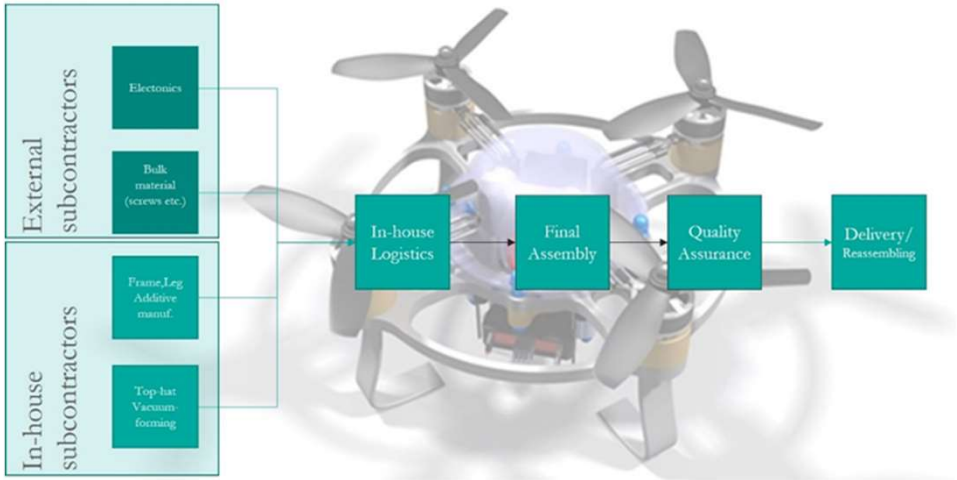
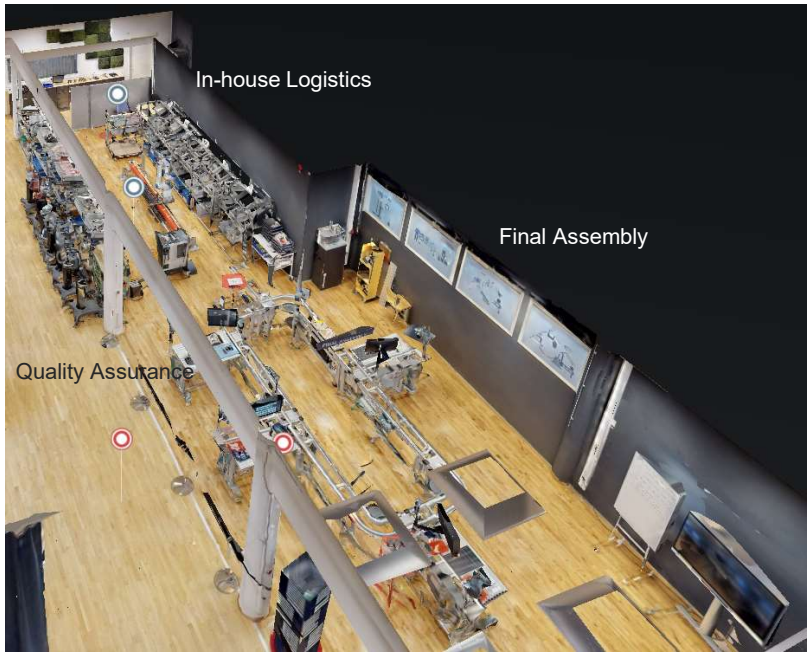
Chalmers University of technology

The Drone factory

- SWE-factory/Learning factory within industry 4.0





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System *of* Systems (SoS)

The distinction between a system and SoS lies in the meaning and significance of ‘gathering together’, teasingly hidden in the meaning of *of*.

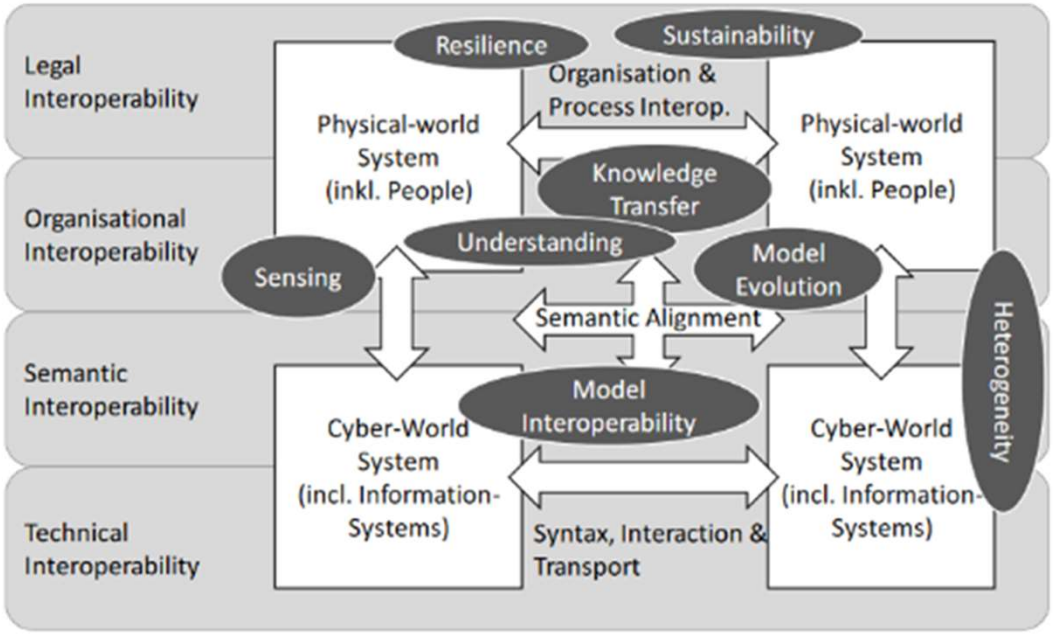
Boardman, J., and Brian J. Sauser. 2006. 'System of Systems - the meaning of of', 2006 IEEE/SMC International Conference on System of Systems Engineering: 6 pp

A typical SoS is characterized by having no defined permanent end state; i.e., the SoS continues to evolve as time passes, even after the original target architecture is achieved. It usually is subject to annual budget variations and has varying baselines, some of which are well defined and some of which are not (usually due to the annual budget variations). The typical SoS evolves slowly over time rather than through wholesale capability, swap-ins and the total SoS often is heterogeneous, with individual systems tailored based upon the particular site(s) to which they are deployed.

Developing a SoS, especially one involving a number of legacy systems, usually is a far more complex job than developing a stand-alone system.

Carlock, Paul G., and Robert E. Fenton. 2001. 'System of Systems (SoS) enterprise systems engineering for information-intensive organizations', Systems Engineering, 4: 242-61.

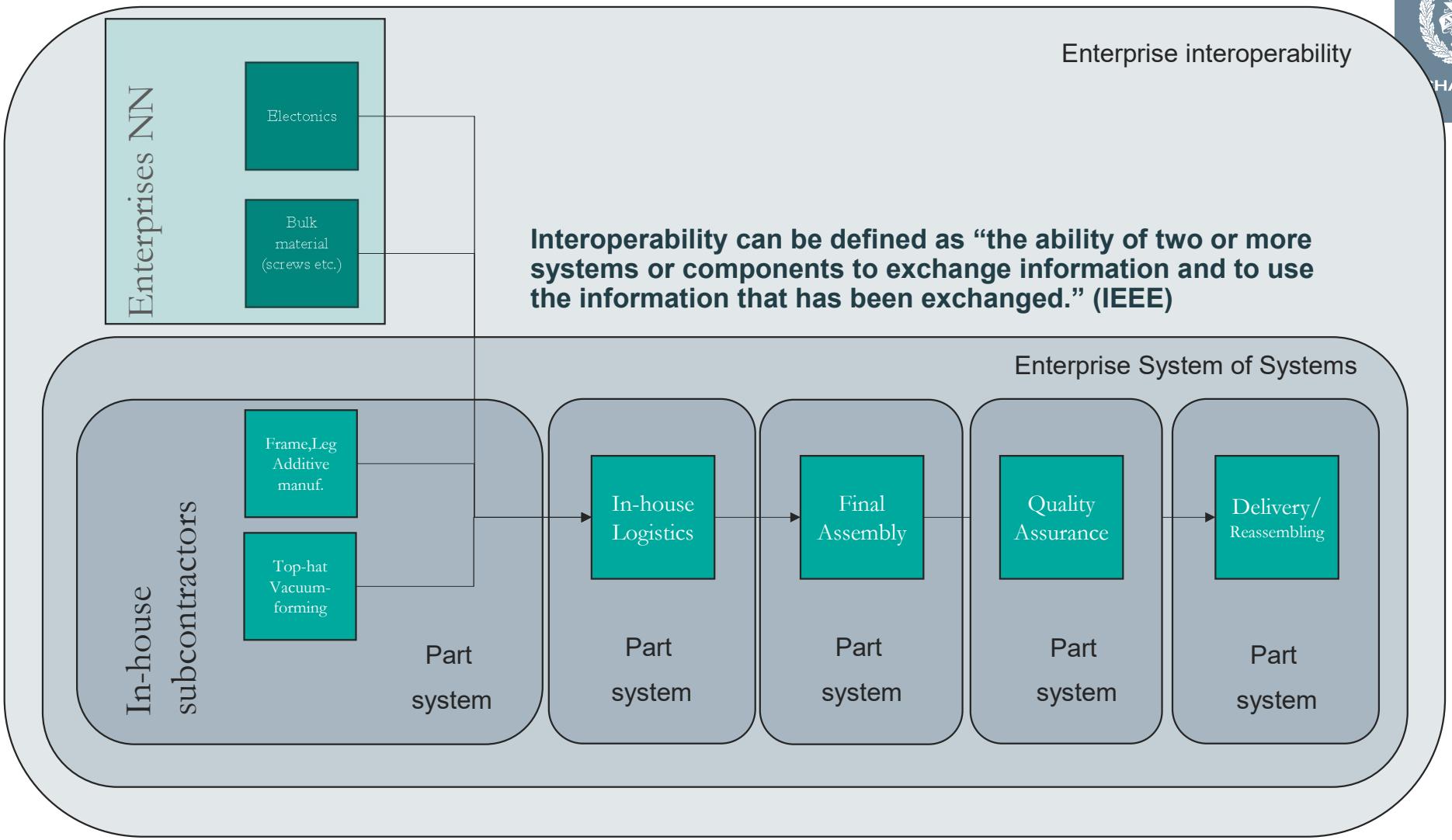
Levels of Interoperability



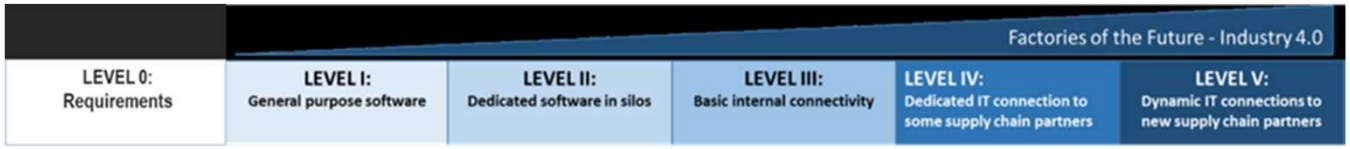
Panetto, H. et al.: Challenges for the Cyber-Physical Manufacturing Enterprises of the Future. Annual Reviews in Control, Vol. 47, pp. 200-213 (2019)

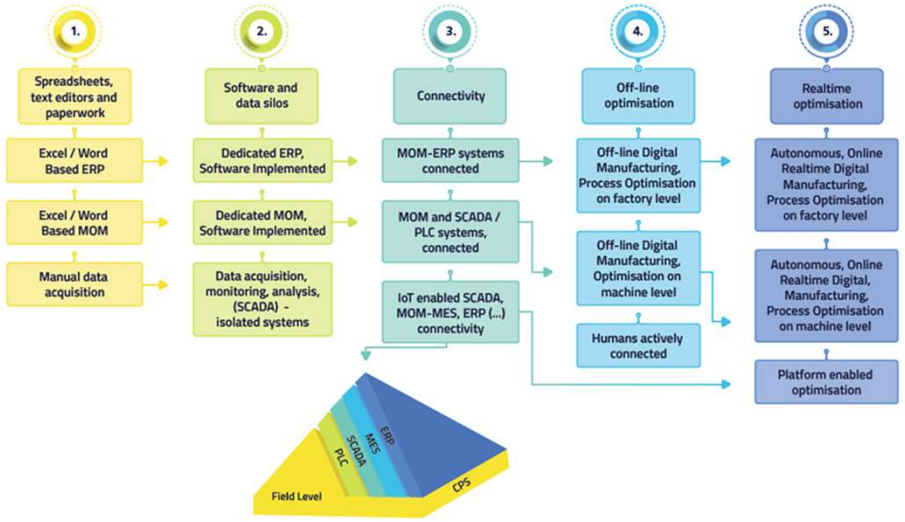
Table 1
Grand-Challenges for the Manufacturing Industry of the Future.

Challenges	Business	Knowledge	Applications	Communications (ICT)
Grand-Challenge 1. CPPS-based Manufacturing Plant Control	• Servitisation • Short lead-time to market • Data-driven performance management systems	• Biological transformation in manufacturing • Digitalisation of production	• Mass customisation • Big-data analytics • CPPS-based human interactions • Simulation models for CPPS-based manufacturing control	• IoT-enabled manufacturing • Cloud services • Smart manufacturing objects
Grand Challenge 2. Resilient digital manufacturing networks, collaborative control for Industry 4.0 and cyber-physical supply chains	• Business and strategy models • Strategic risk management • Customised supply network control • Customised flexible process-based services	• Business processes and operations in supply chains • Core competencies in the supply chains • Sharing principles and operation rules	• Collaborative software solutions • Simulation software for resilient and data-driven manufacturing systems • Tools for monitoring and control of disruptions in the supply chain	• Reliable communication networks • Broadband • Wireless applications • e-Work, e-Manufacturing, and e-Logiscs
Grand Challenge 3. Cyber-physical System-of-Systems interoperability	• Integration of business information • Ontology mapping and matching • Consistent enterprise-wide decision-making structure	• Interoperability of models and processes • Shared ontology • Explicit knowledge • Knowledge management system	• Modular and reconfigurable systems • Component-based software solutions (Plug-in/Plug-out) • Symbolic artificial intelligence and software agents • Agent-based simulation software • Cobots and new Human / Machine Interaction with Robots	• Standards • Interfaces and mediators • Interoperability • Service buses • Technologies for collaborative learning
Grand Challenge 4. Interdependent networked systems and data analytics for decision support	• New networked model of business • AI and data-driven business • Risk and operations management through analytics from Big Data	• Modelling of interdependencies • Dynamical analysis • Behavioural pattern identification	• Tools for monitoring and control • Building resilient systems • Prescriptive and predictive modelling • Risk analysis and control	• Open platforms • Interactive applications

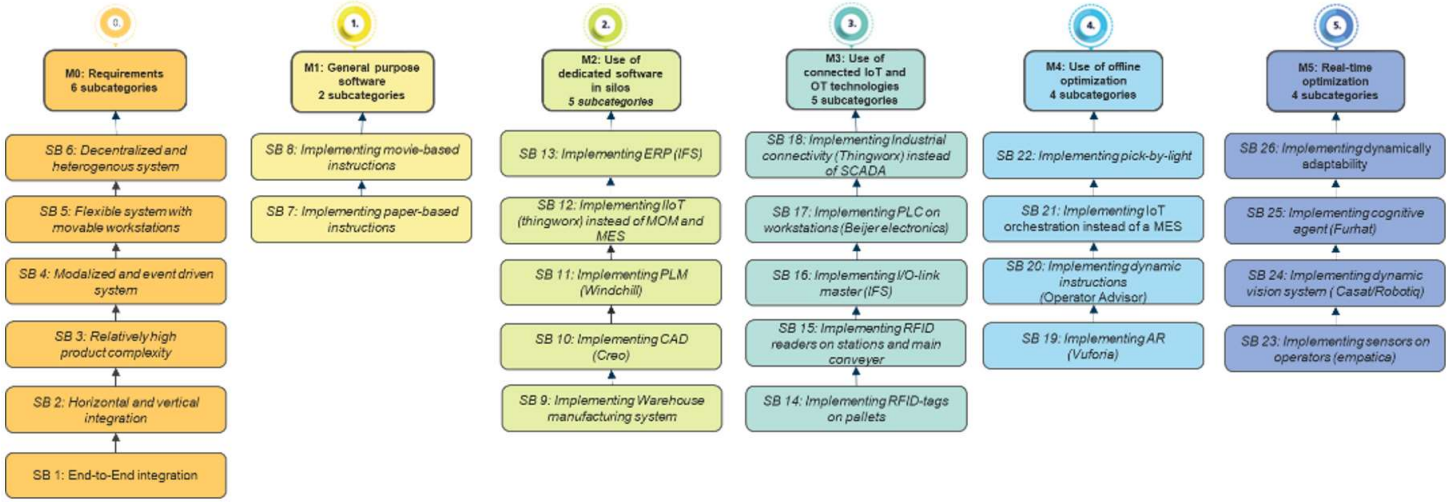

Enterprise interoperability
Enterprises NN
Electonics
Bulk material (screws etc.)
Interoperability can be defined as “the ability of two or more systems or components to exchange information and to use the information that has been exchanged.” (IEEE)
Enterprise System of Systems
In-house subcontractors
Frame,Leg Additive manuf.
Top-hat Vacuum-forming
Part system
In-house Logistics
Part system
Final Assembly
Part system
Quality Assurance
Part system
Delivery/ Reassembling
Part system

Pathway to factories of the future





The Drone Factory



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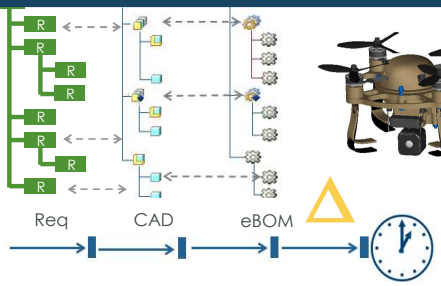
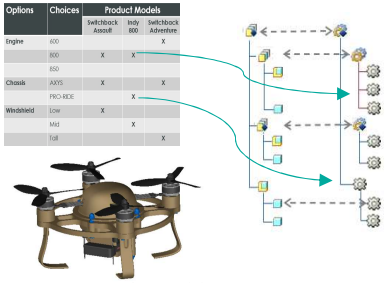
Digital Thread@Chalmers University Sii-Lab

PLM: BOM Management, Family Management, Req Mgmt

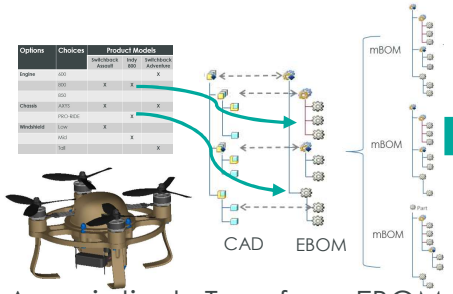


Manage and link CAD/BOM/Visualization for a modular EBOM structure

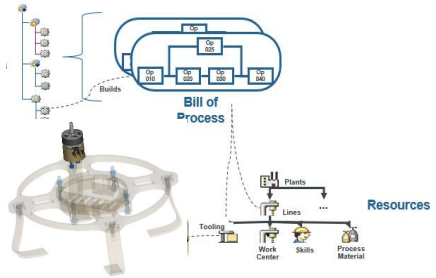


Plan product families, manage options and generate variants for multi-year product structures.

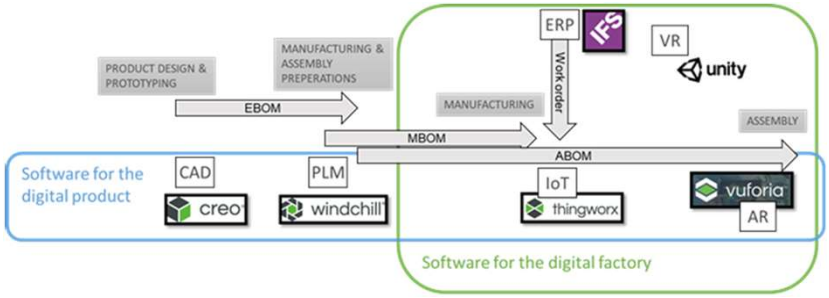
PLM: BOM Transformation, Digital Process Planning, Change Mgmt

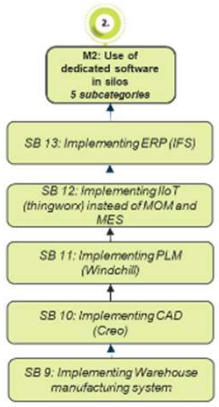


Associatively Transform EBOM to MBOM and EBOM to SBOM with Options and Logic



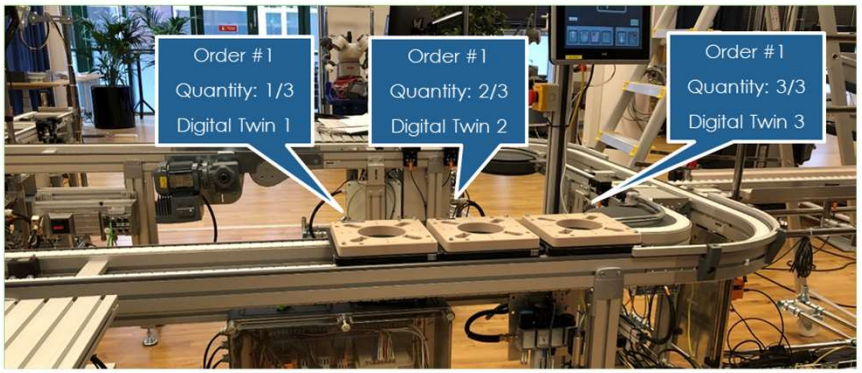
Concurrently Develop Mixed-Model Assembly Process Plans, AR for visualizing process plans





Final Assembly

Part system



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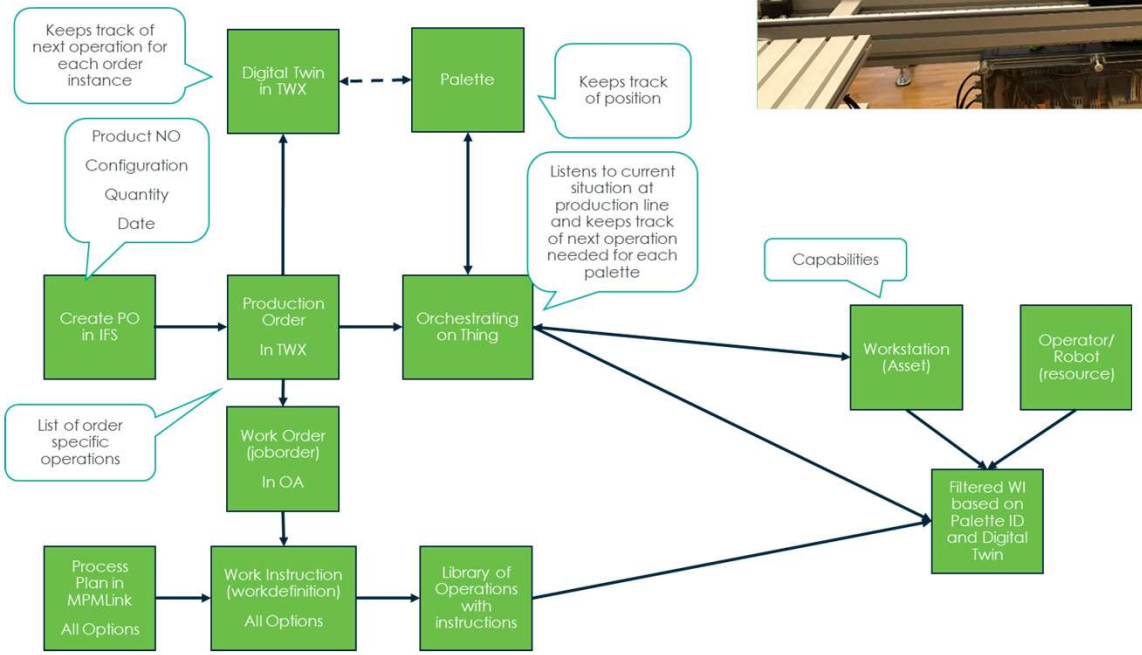
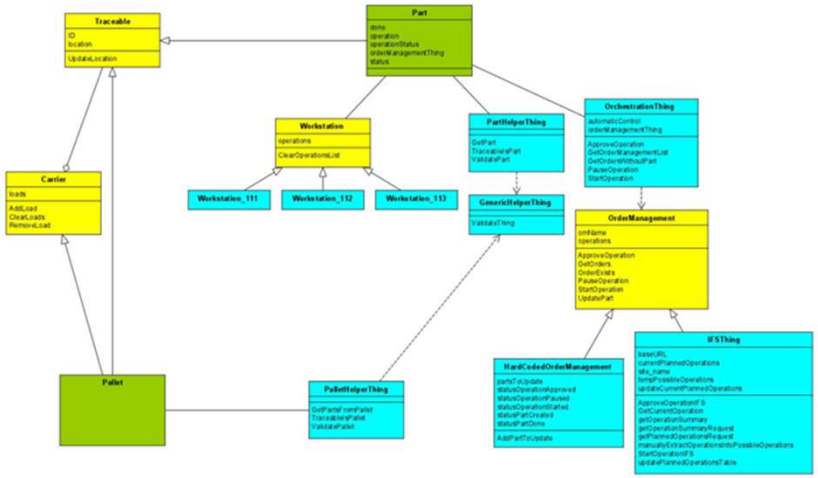
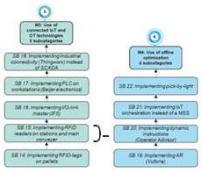
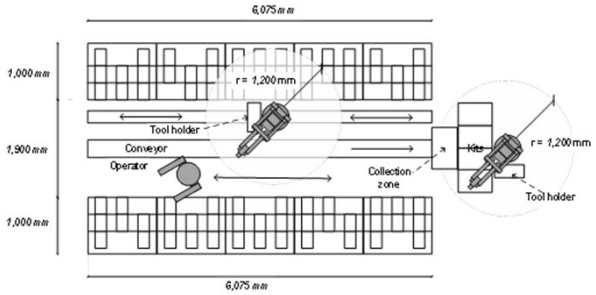






In-house Logistics

Part system



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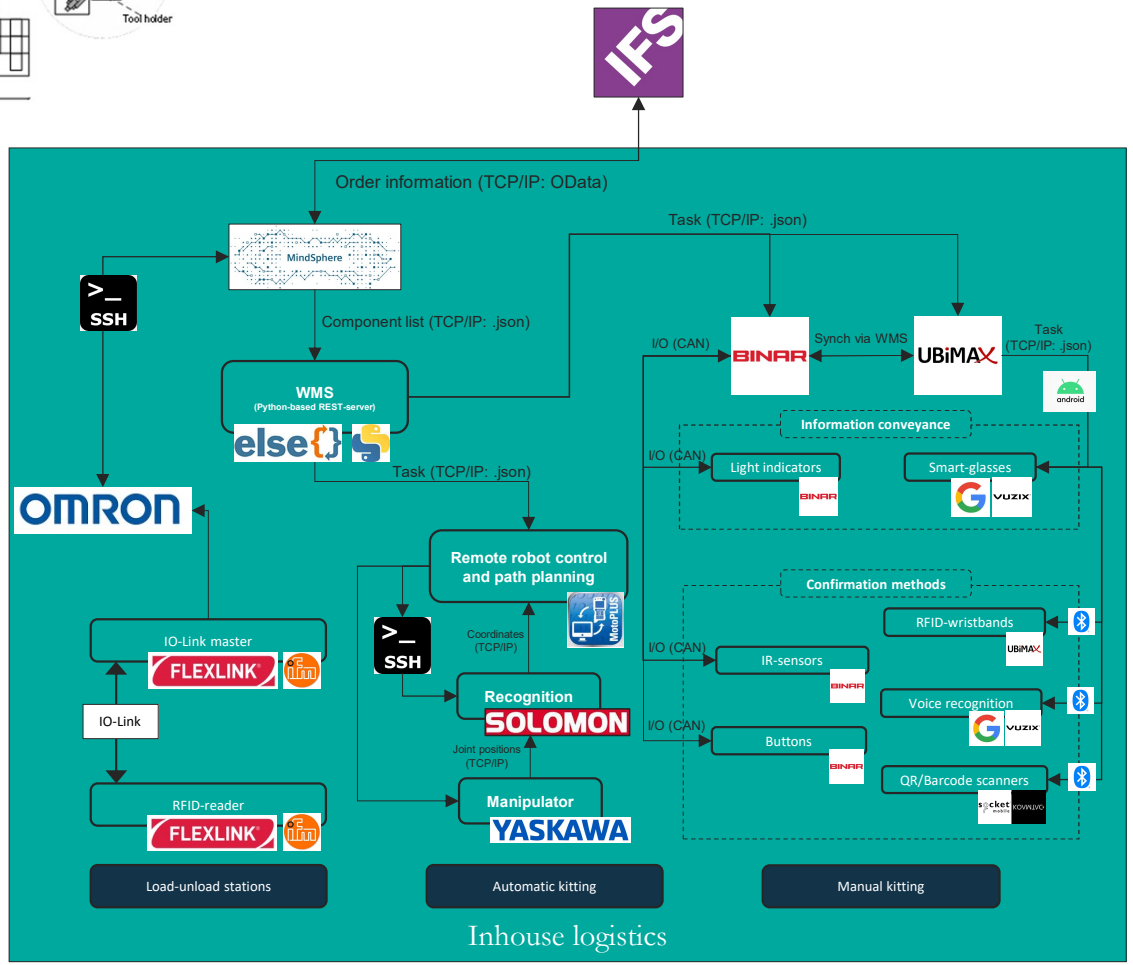
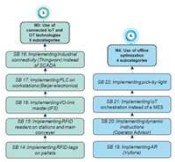
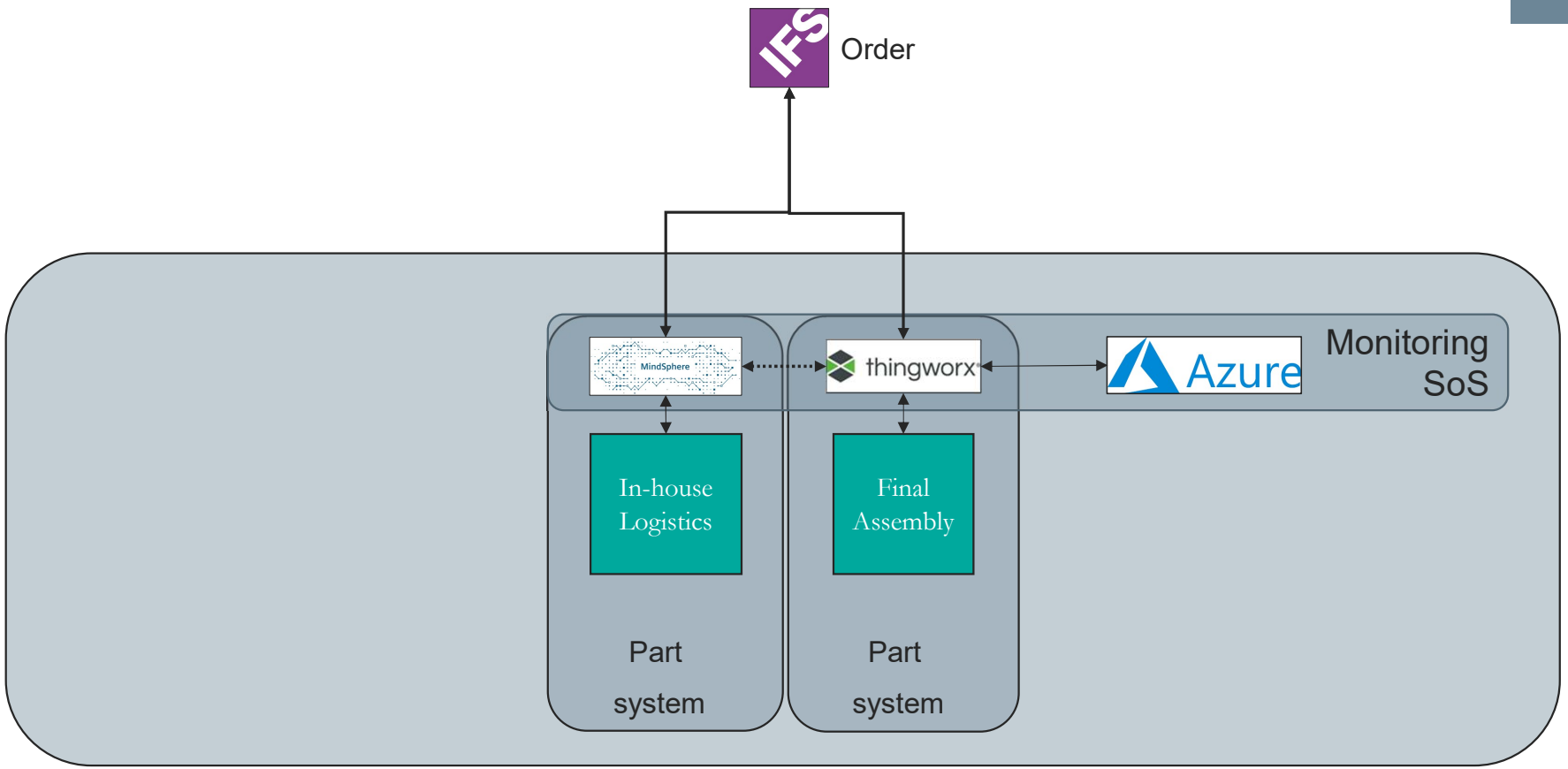


Inhouse logistics



System of systems



Level 4 and 5

- Interaction and interoperability between Human-Robot teams
- LCA and re-manufacturing
- Technologies for collaborative learning
- Machine learning and cognition
- System of systems and enterprise interoperability
- CPPS and real time optimistaion

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