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KI Fortschrittszentrum
LERNENDE SYSTEME UND KOGNITIVE ROBOTIK

Industrial Metaverse in Cognitive Robotics

market analysis and research gaps

February 2025

AI-generated by DALL-E (2025)

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1. Introduction
Motivation

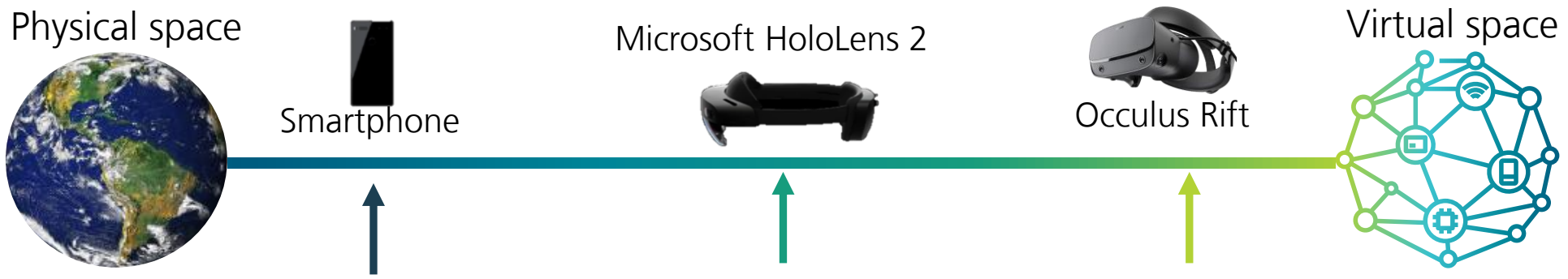
Problem statement
- Extended Reality (XR) is well-established in gaming, but not in industry
- Current offerings are often restricted to proprietary solutions and too diverse
- Rapidly evolving technologies pose challenges for companies, especially SMEs:
  - Lack of implementation expertise.
  - Integration issues with existing systems.
  - High costs and uncertain long-term support.

Technology potentials
- Immersive, connected, and autonomous industrial environment
- Control and monitor processes
- Increase HMI

Focus

1. Introduction

Terminology - what is Extended Reality



Augmented **R**eality (AR):

- Overlay holograms in the physical world
- No interaction

Mixed Reality (MR):

- Overlay holograms in the physical world
- Interaction

Virtual **R**eality (VR):

- Fully artificial digital environment
- Interaction possible

Image source: https://docs.microsoft.com/en-us/windows/mixed-reality/discover/mixed-reality

1. Introduction

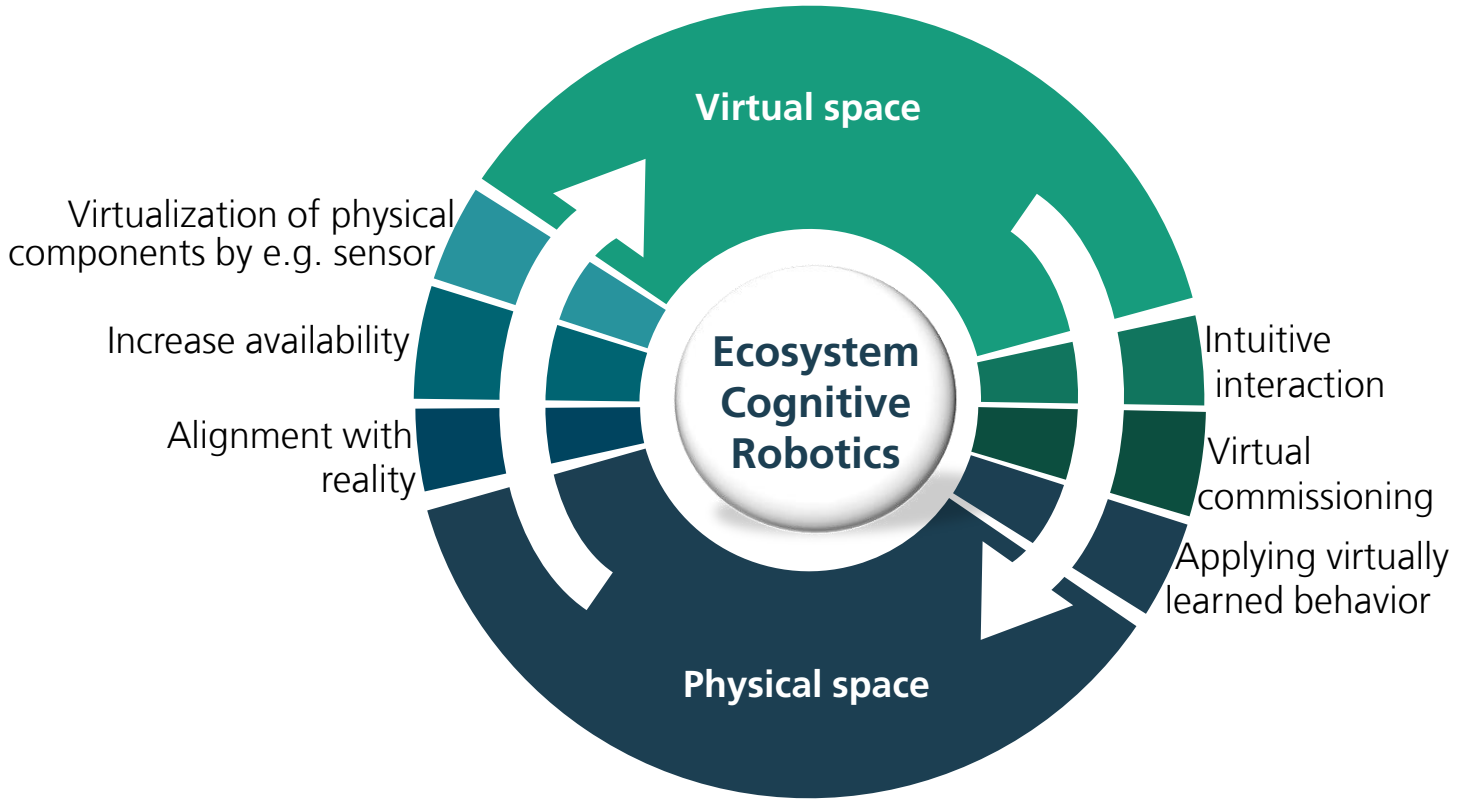
Terminology - Cognitive Robotics and Industrial Metaverse

Cognitive Robotics:

- Ability to operate in **dynamic** and **unpredictable** environments
- **Autonomous control** of interaction with the environment based on external information
- **Objective**: To improve the performance and autonomy of robot and assembly systems.

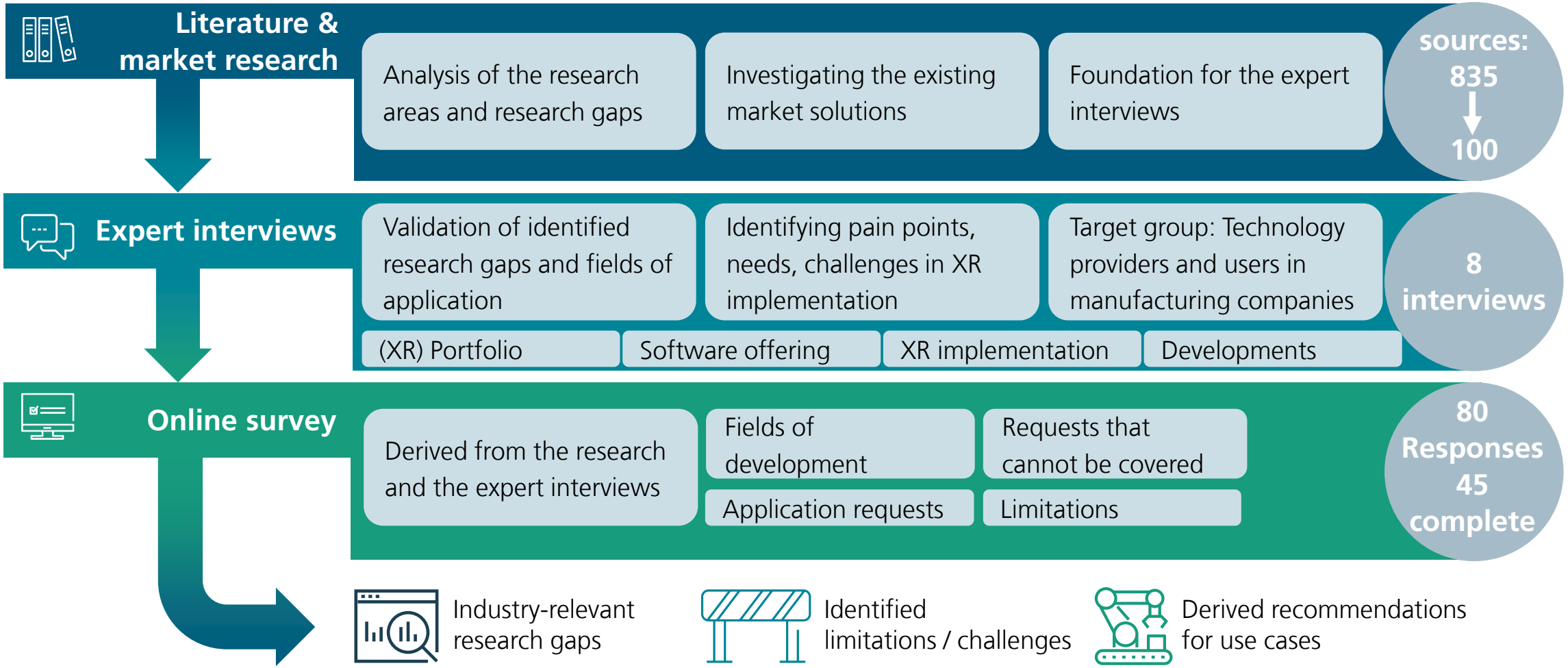
Industrial Metaverse:

- Integration of physical and virtual worlds to
  - optimize **industrial processes** and
  - develop **new value creation potential**
- **Core elements**: Digital twins, data exchange, infrastructure and much more



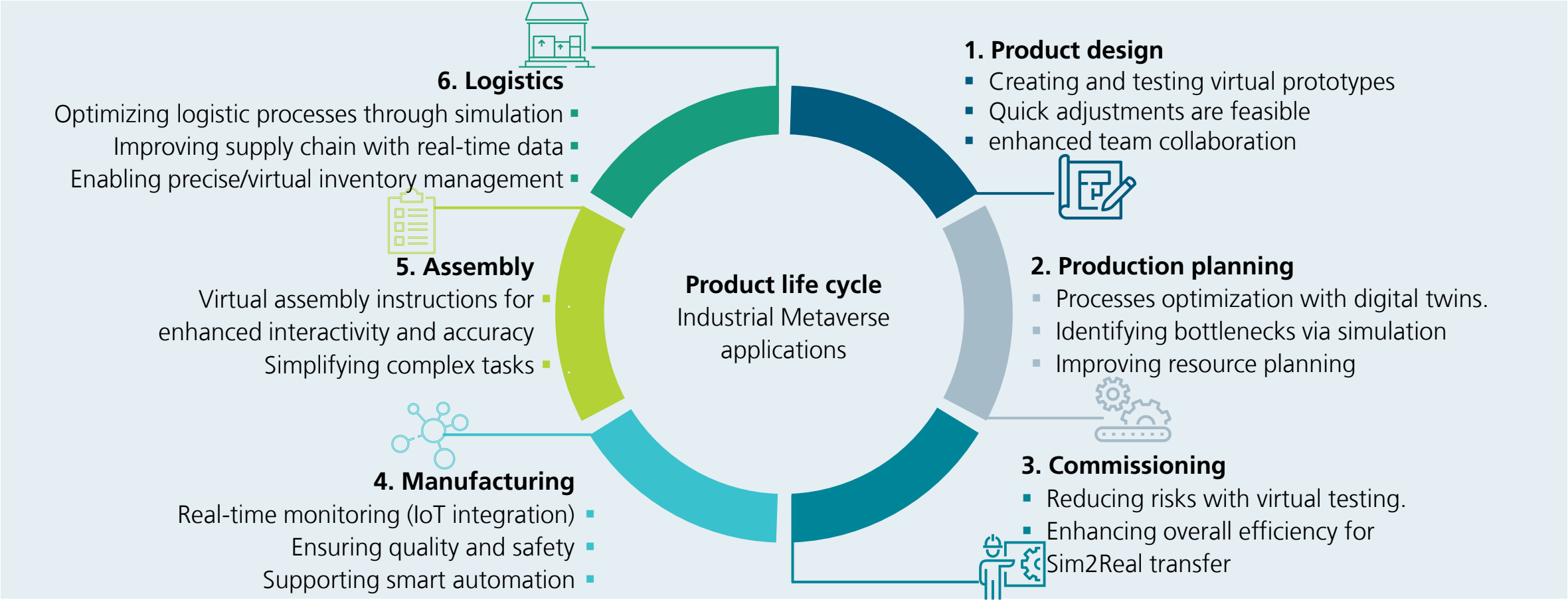
1. Introduction

Methodology



2. Key Insights

Research – applications across the product life cycle



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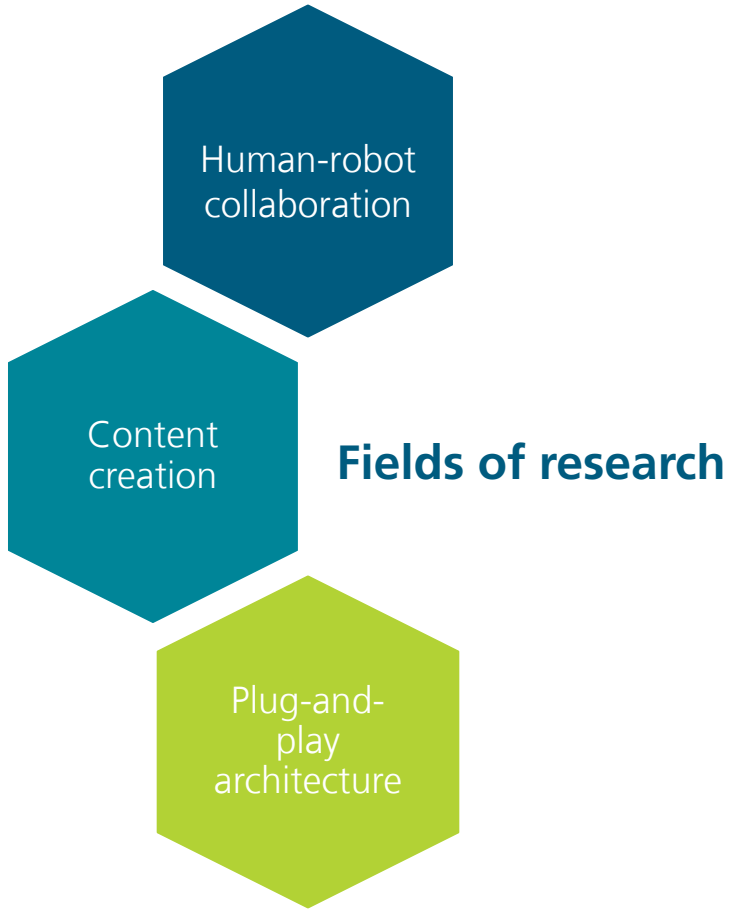
2. Key Insights

Research – relevant use cases and fields of research

- Virtual **qualification** and **training**: immersive training environments
- **Product design** and **prototyping:** generation and testing of virtual prototypes
- (Remote) **maintenance** and **monitoring**: technicians can monitor & maintain remotely
- **Collaboration** in a virtual environment
- **Digital Twins** and **Simulation** of complex production processes



Fields of research

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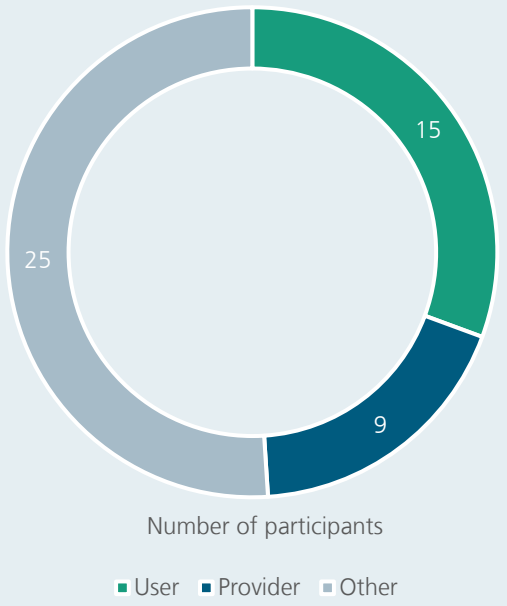
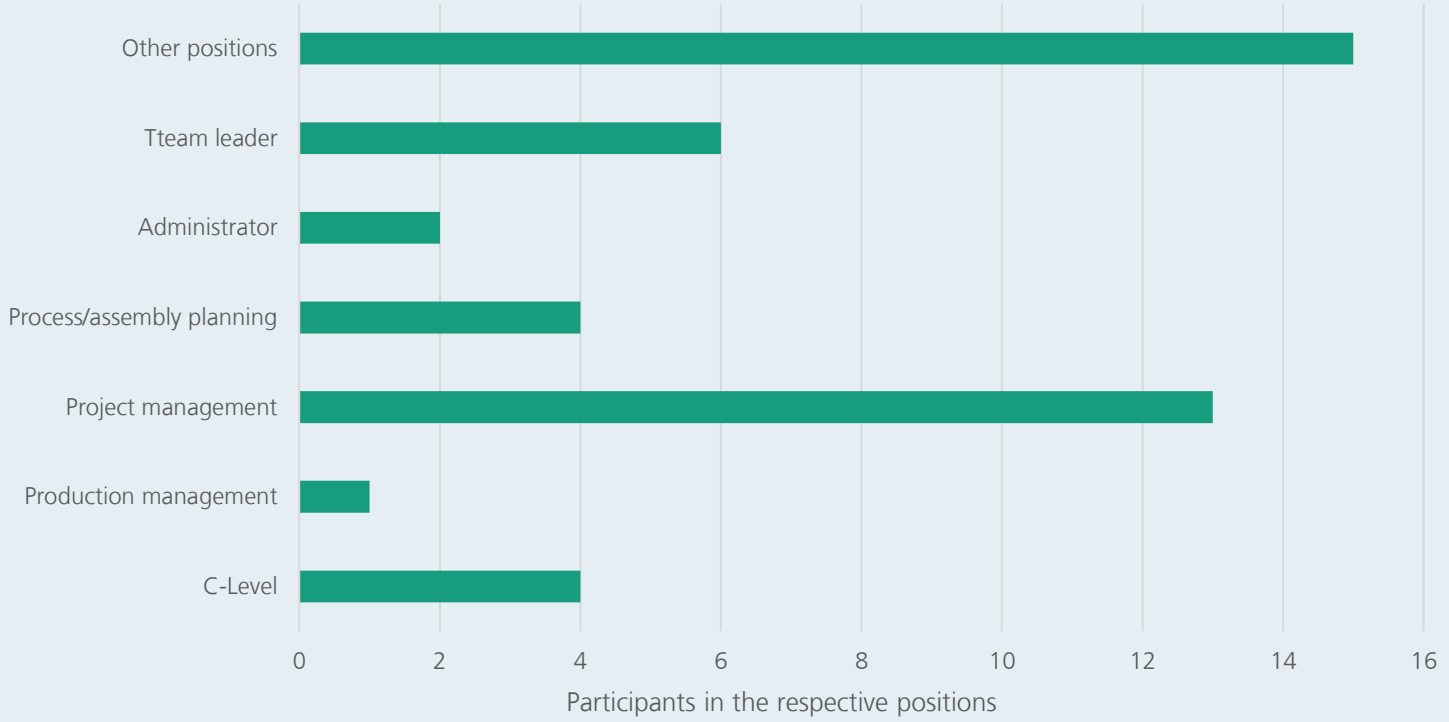
2. Key Insights

Survey participants

Experience with XR technologies



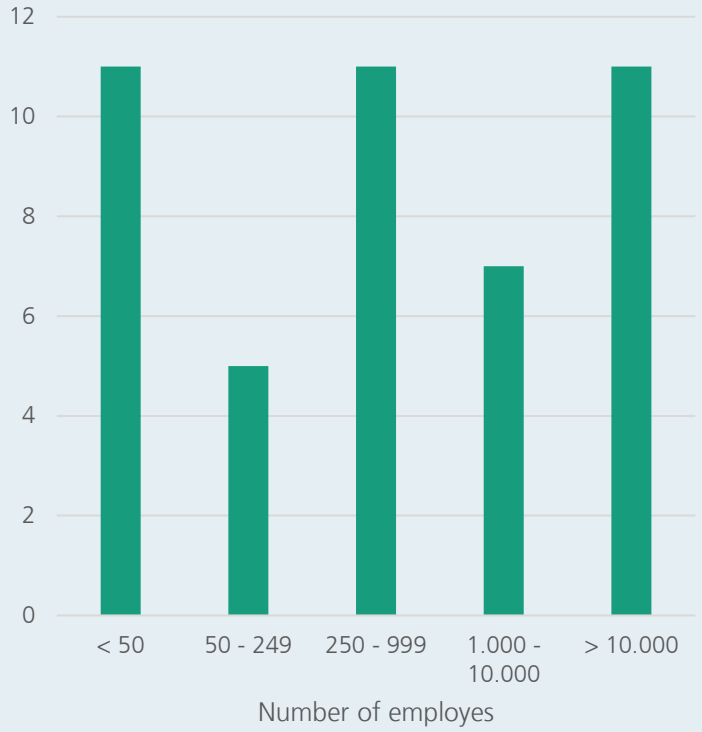
Job title



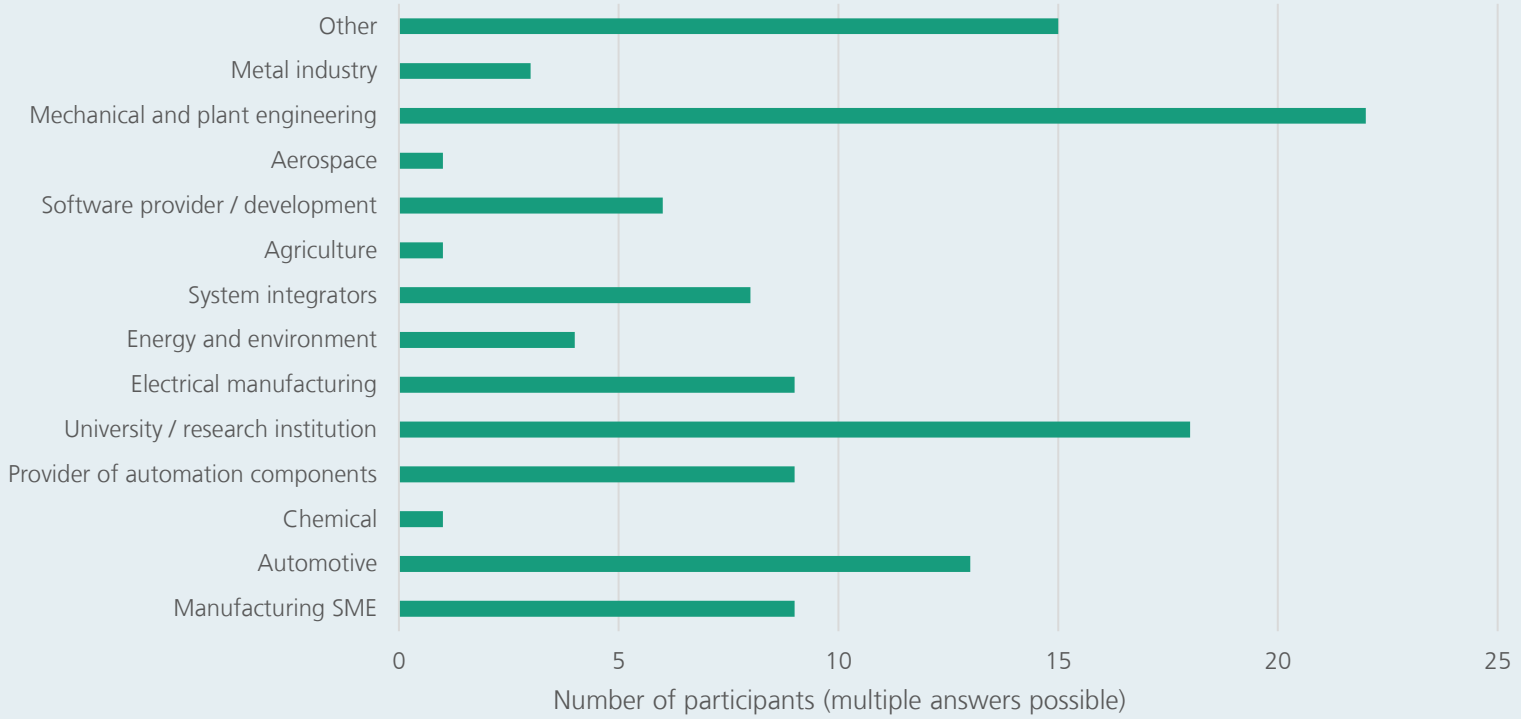
2. Key Insights

Survey participants

Company size



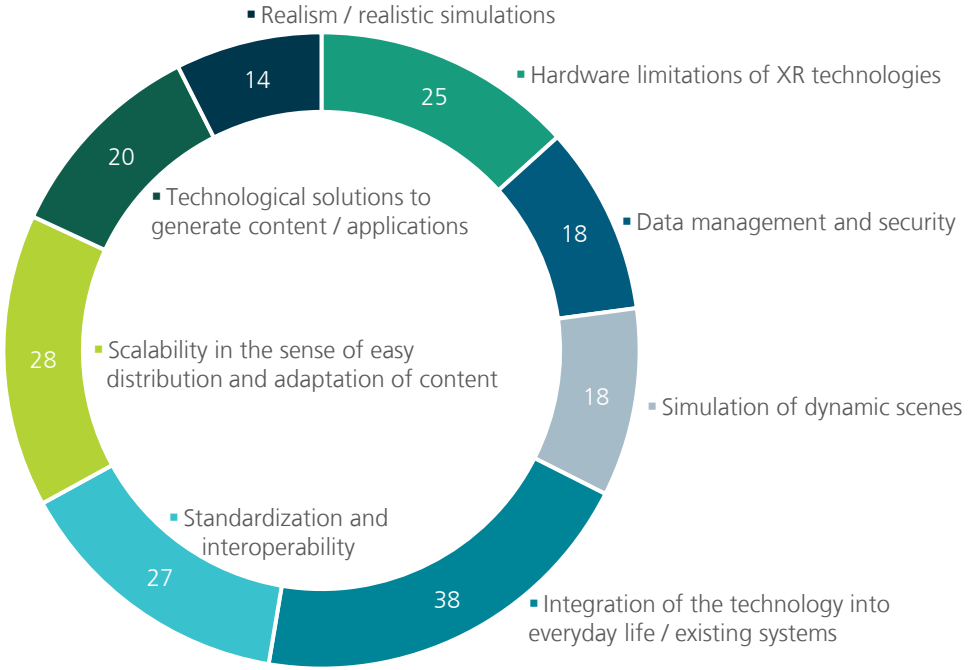
Which industries survey participants belong to?



2. Key Insights

Derived from the research and the conducted surveys

Number of responses in total: 53



1 **Obstacles and limitations**
General obstacles regarding the implementation of XR projects. From planning to integration and application

2 **Research and development needs**
Standardized and cross-sector solutions are desired / needed

3 **Advanced research and applications**
to identify research gaps that are not yet covered

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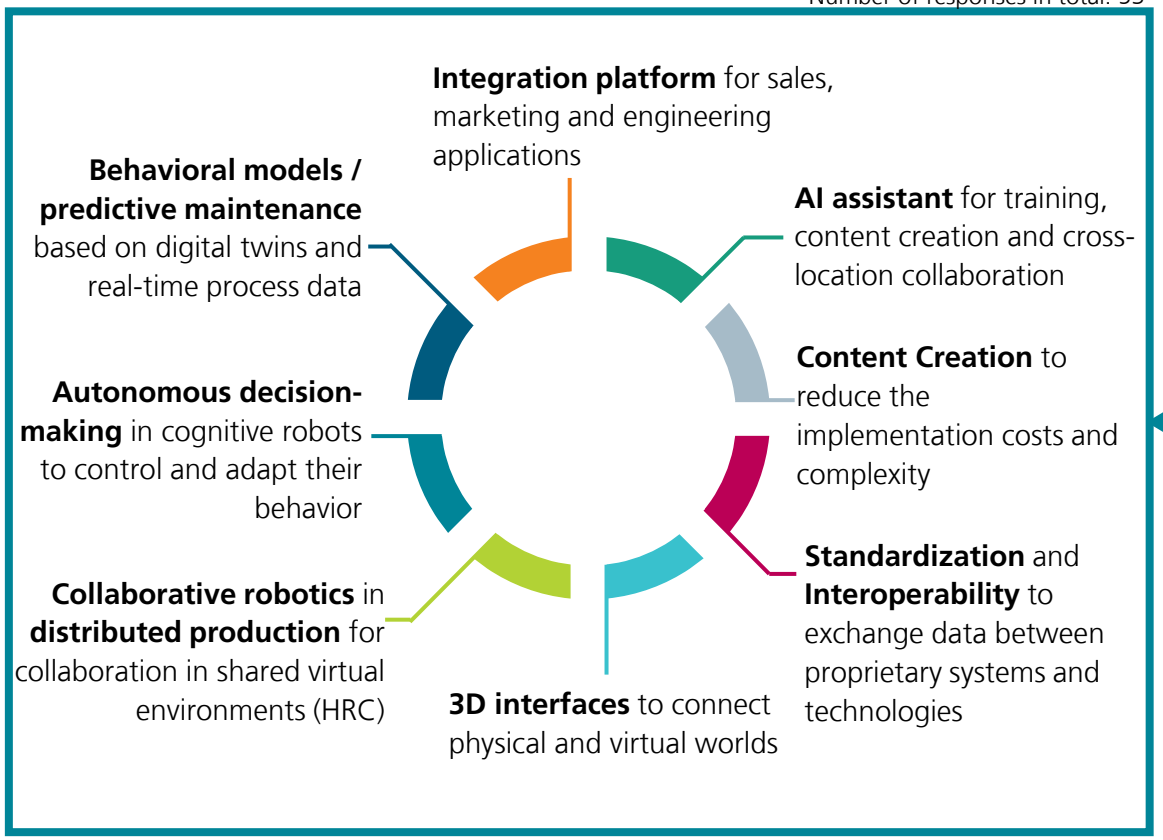

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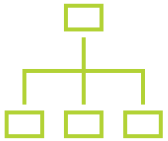
Digital Twins certain aspects of robots

Training and remote assistance

Metaverse software toolchains (e.g. Omniverse, Geminiware)

Digital checklists for assembly instructions



XR visualizations at shopfloor level

Planning tool for the production and commissioning of robots/cells

Platform or browser applications for collaborative design

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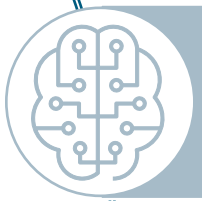
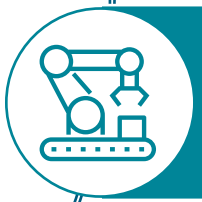
3. Conclusion

Derived research and development gaps

Standardization and interoperability: The need for open interfaces and standards between existing, proprietary platforms.



AI content creation in the industrial context: There is a lack of efficient methods for creating content for industrial applications, including CAD models, kinematic files, and environmental variables.

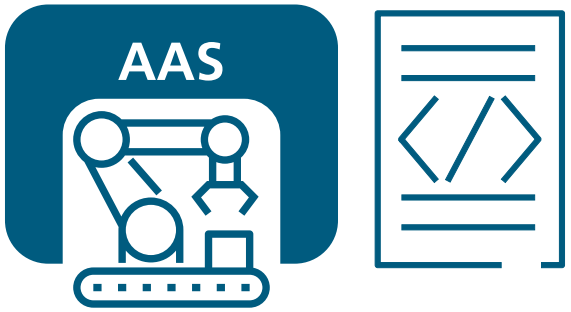


Integration of robotics technologies into the Metaverse: Solutions are needed to enable real-time control of content (e.g. process data) in virtual worlds using sensor data. This is essential not only for improving human-robot interaction but also for effectively connecting both technologies.

Plug-and-Play architectures: Companies require straightforward options for integrating existing production solutions into a new platform.

3. Conclusion

Use Case 1 - Plug & Play Third-Party Add-Ons Methodology for XR platforms



- Download ready-made **Asset Administration Shells** (AAS) of robots and machines
- Integration of **proprietary customer solutions**

Modular 3rd Party Add-On

- Converting different models into a standardized asset for the target platform
- ROS-Code integration should be possible

NVIDIA OMNIVERSE

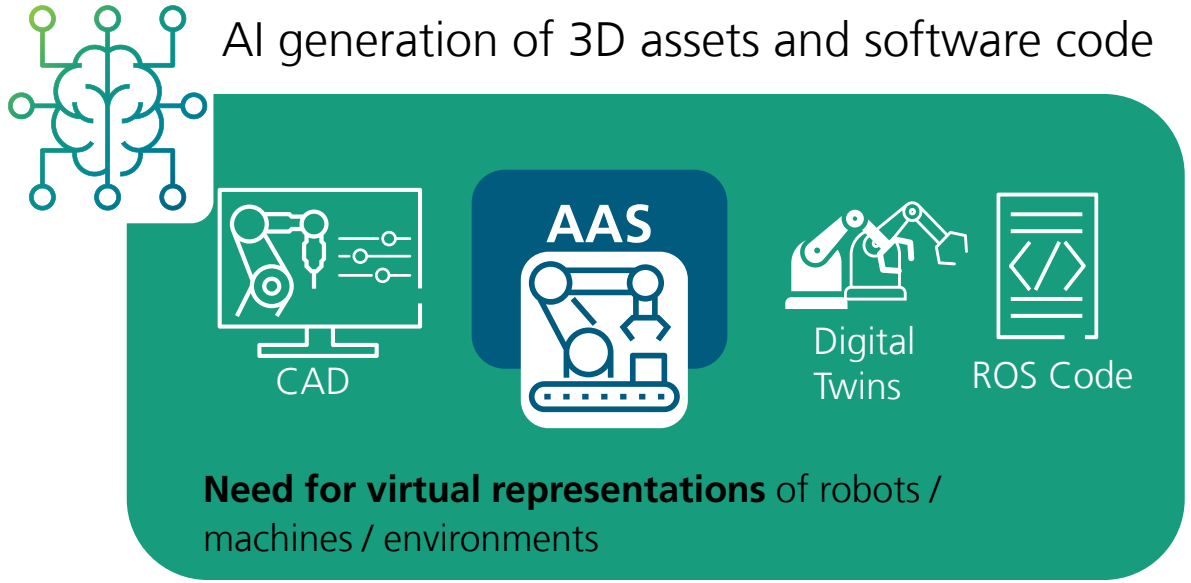
geminiware

standard software solution
for planning and design processes, maintenance and training applications, complex simulations

- companies have the opportunity to integrate digital twins of robots / machines into development platforms **without major development** effort
- **Not be dependent** on which APIs the target platform or internal system offers

3. Conclusion

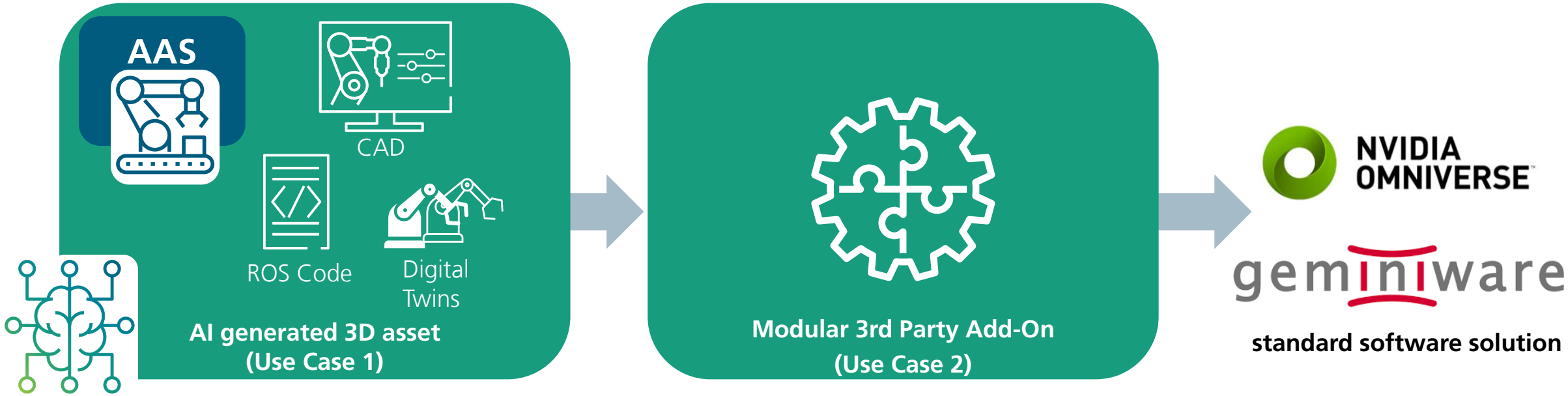
Use Case 2 - Development of robot-based 3D asset generation



- Automatically **merge** available sources such as CAD models and Digital Twins
- Generate **ROS-Code** via voice or text input to perform **dynamic maintenance tasks**
- Facilitating the creation of content in general

3. Conclusion

Use Case 3 – Combination of Use Case 1 and Use Case 2



- Use **Use Case 2** to **validate** the modular Plug-And-Play Add-On methodology (**Use Case 1**)
- Control robots based on **AI generated ROS Code**
- Integrate Digital Twins into virtual words to test and simulate their behavior in **different environmental settings**

Contact

Gesche Held
Automation planning
Tel. +49 711 970-3516
gesche.held@ipa.fraunhofer.de

Franz Falkenau
Interoperability for production
Tel. +49 711 970-3516
franz.falkenau@ipa.fraunhofer.de

Fraunhofer IPA
Nobelstraße 12
70569 Stuttgart
www.ipa.fraunhofer.de

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Fraunhofer Institute for Manufacturing Engineering and Automation IPA

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Prof. Dr.-Ing. Thomas Bauernhansl. Prof. Dr.-Ing. Marco Huber, Dr.-Ing Werner Kraus

Autoren
Gesche Held, Franz Falkenau

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Kontaktadresse
Fraunhofer-Institut für Produktionstechnik und Automatisierung IPA
Nobelstraße12, 70569 Stuttgart
Telefon+49 711 970-3874
presse@ipa.fraunhofer.de
https://www.ipa.fraunhofer.de

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