
IFAC INCOM 2024 INTERNATIONAL FEDERATION OF AUTOMATIC CONTROL

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# Knowledge-Data Driven for Cyber-Physical Production Systems in the Aerospace Industry: Current Issues and Emergent Technologies

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# AGENDA

## Context
- Introduction
- Problem Statement
- Research Aim

## Automated characterization of an ASM part manufacturing process
- General approach
- Specific application in the Aerospace Industry
- Methodologies for Manufacturing of Aerospace Parts

Context | Literature Survey and Analysis | Discussion | Conclusion

## Literature Review
- Materials and Methods
- Systematic Literature Review
- Paper Classification

## Conclusion
- Conclusion
- Future Work

# MOTIVATION

## Evidences:

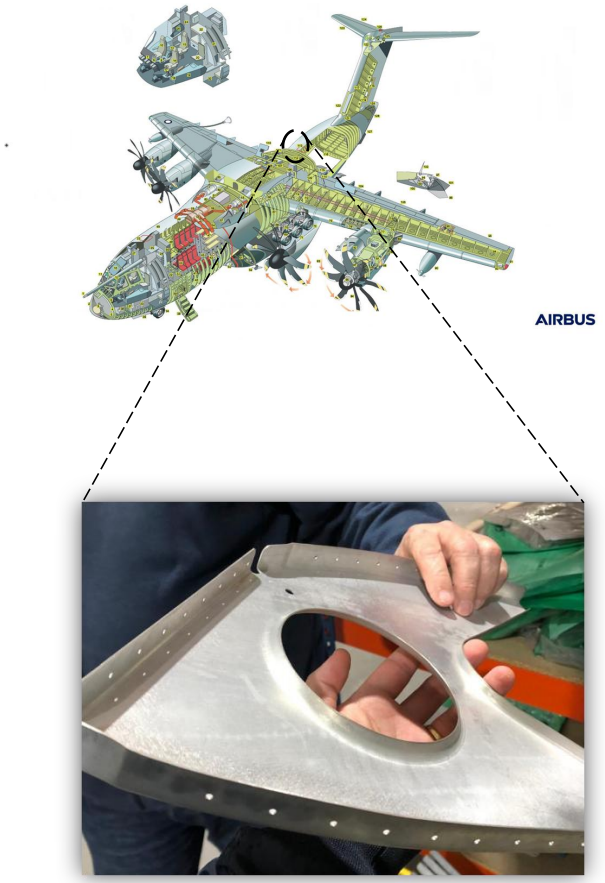
- The increased demand for **customised products** has strongly impacted the aerospace industry's ability to adapt to a **fast and agile manufacturing model**.

- The **Manufacturing System (MS)** of an aircraft can hold 70% costs of a new program, and it is not designed for a flexible capacity management.

- Aerospace Industry involves a delicate balance of scientific principles, **engineering expertise** and **hands-on experience**.

## Needs:

- Reduce the **manufacturing time** and simultaneously **reduce the potential of conceptual errors** during the manufacturing phase of manufacturing parts, **collect** explicit, implicit, and tacit **knowledge** from experts in each department of the aerospace industry.



# PROBLEM STATEMENT

**Aerospace Sheet Metal parts**

Engineering's Knowledge Team

## Design

- List of Features
  - ❑ Web Features
  - ❑ Trim Features
  - ❑ Deformation Features
- Drawing Information
  - ❑ Tolerances
  - ❑ FDT information
- Material
  - ❑ Properties
  - ❑ Raw material cost
  - ❑ Market Available
- Requirements

❑ *How does the design data go to production system?*

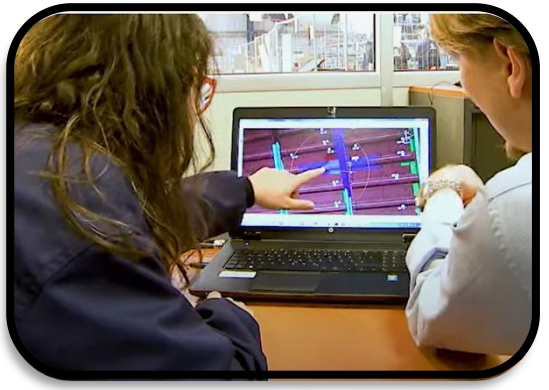
❑ *How can we ensure the reliability of information?*

❑ *How can we infer the feasibility of manufacturing considering available resources?* ?

*Interoperable Product Design & Manufacturing*

❑ Engineering Team

❑ All of factory's knowledge



## Manufacturing

- Process Planning
  - ❑ Steps of all process
- Costing
  - ❑ Estimate the ASM part Cost
- Quality Assurance
  - ❑ Infer the possibility to assure the requirements
- Tooling Design
  - ❑ Design the necessary tools (Jigs, models etc.)
- Manufacturing
  - ❑ Types of Machines Available
  - ❑ Strategies of Machining
  - ❑ Tools and infrastructure
  - ❑ NC Program to Machine

## RESEARCH AIM

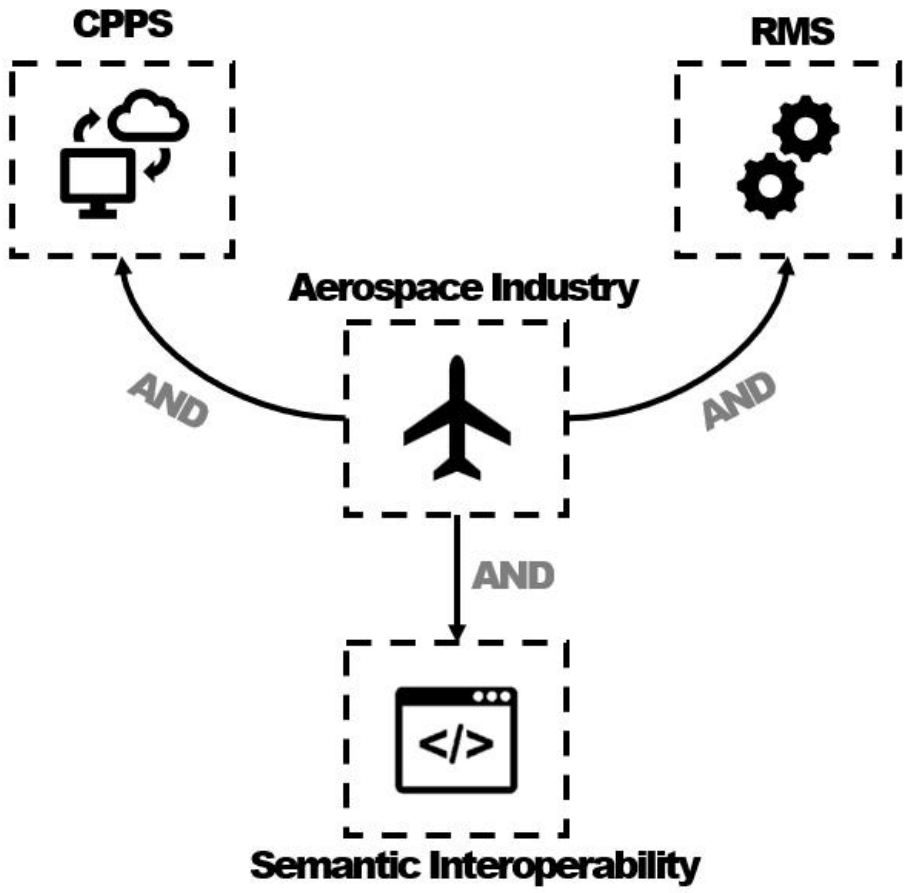
Discuss the current issues and emergent technologies across the systematic literature review and content analysis to address the following issues:

- Research Question 1 (RQ1): *What are the **current issues and emergent technologies** in CPPS and KDD for the Aerospace Industry?*
- Research Question 2 (RI2): *What is the **gap in CPPS and KDD** for the aerospace industry?*

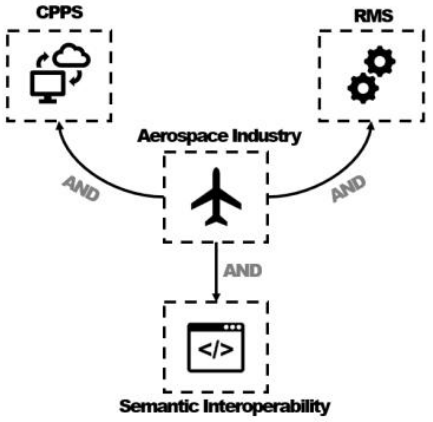
# SYSTEMATIC LITERATURE REVIEW

| Inclusion Criteria | |
|---|---|
| Papers are written in English | Main international jo and correspondingly journals that help an is low while the worl |
| Peer-reviewed articles | Journals that are no the information cor consistent review pr |
| Articles from 2005 to 2023 | Aerospace enginee where technologica reviewing articles understand how ma over time to meet th |

| Keywords | Aerospace Industry | CPPS |
|---|---|---|
| Synonymous | Aerospace Factories | Cyber-Physic Systems |
| | Aerospace Manufacturing | Smart Factori OR Industry 4. |




| Exclusion Criteria |
|---|
| n of manufacturing, intelligent systems, or nanufacturing systems concepts. |
| not address manufacturing systems. |
| ed before 2005. |
| not written in English. |
| not peer-reviewed. |
| 05 to 2020 with less than five citations. |



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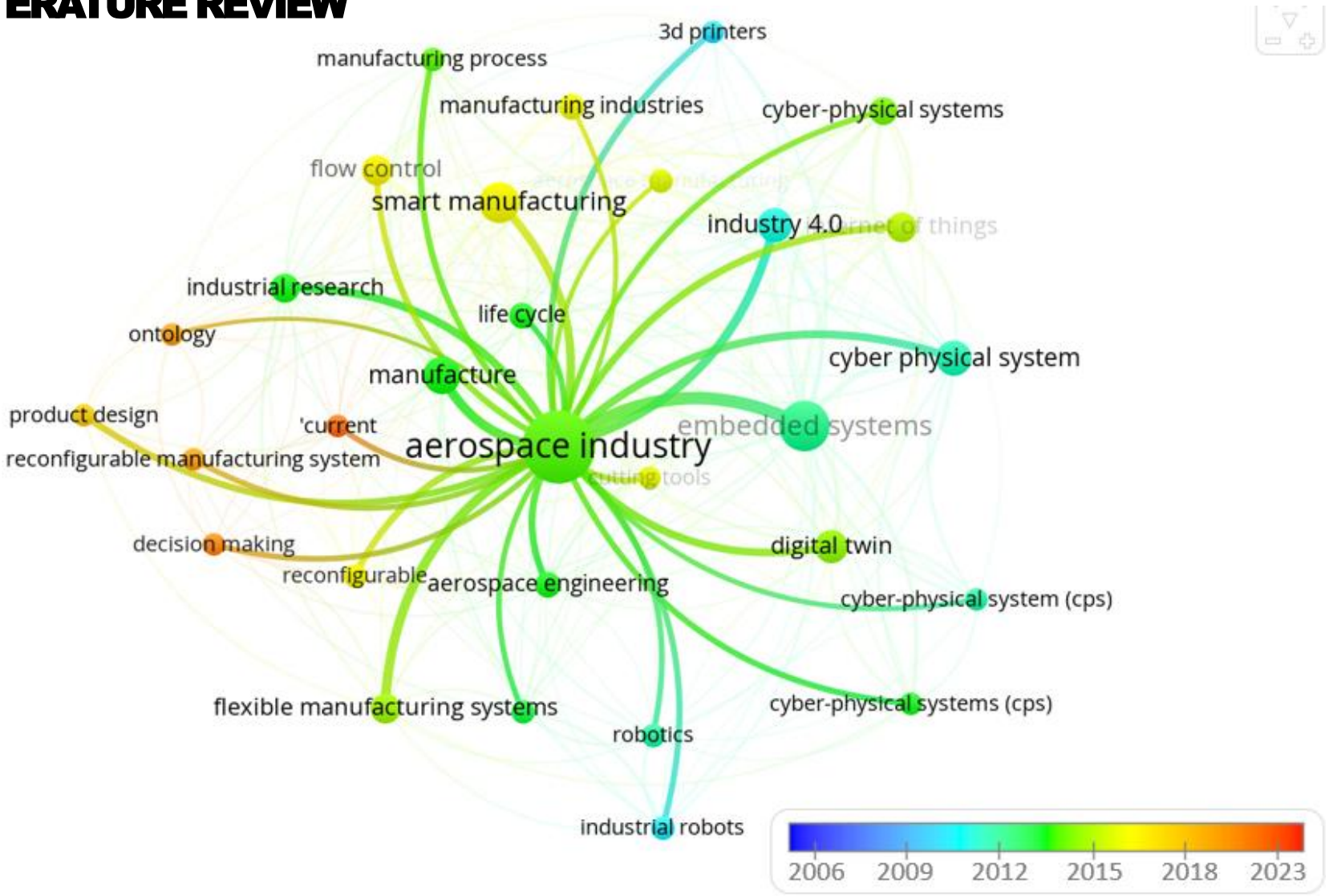

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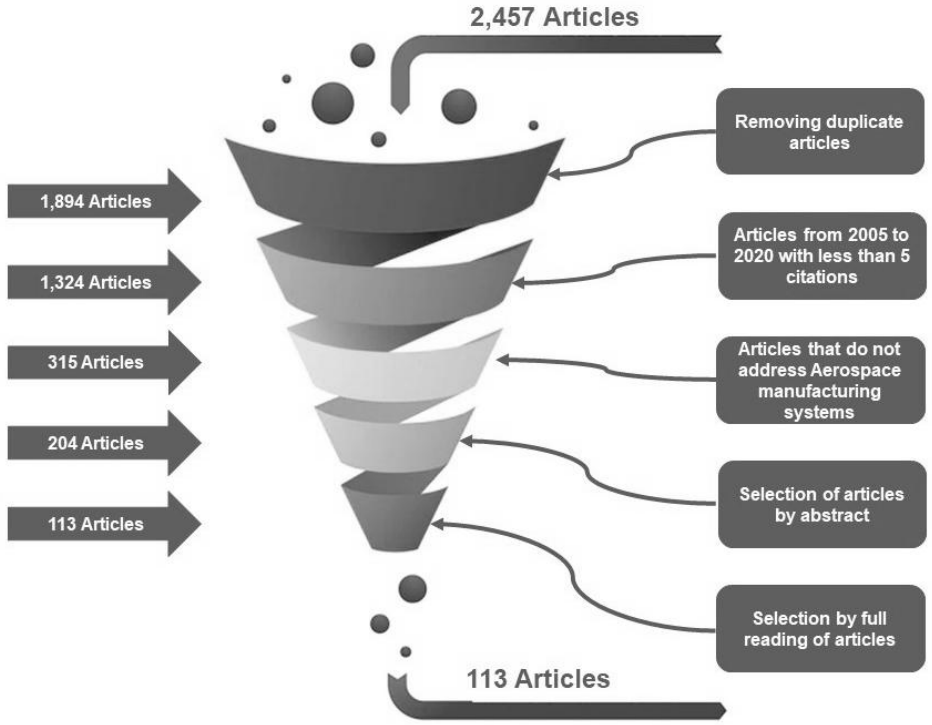


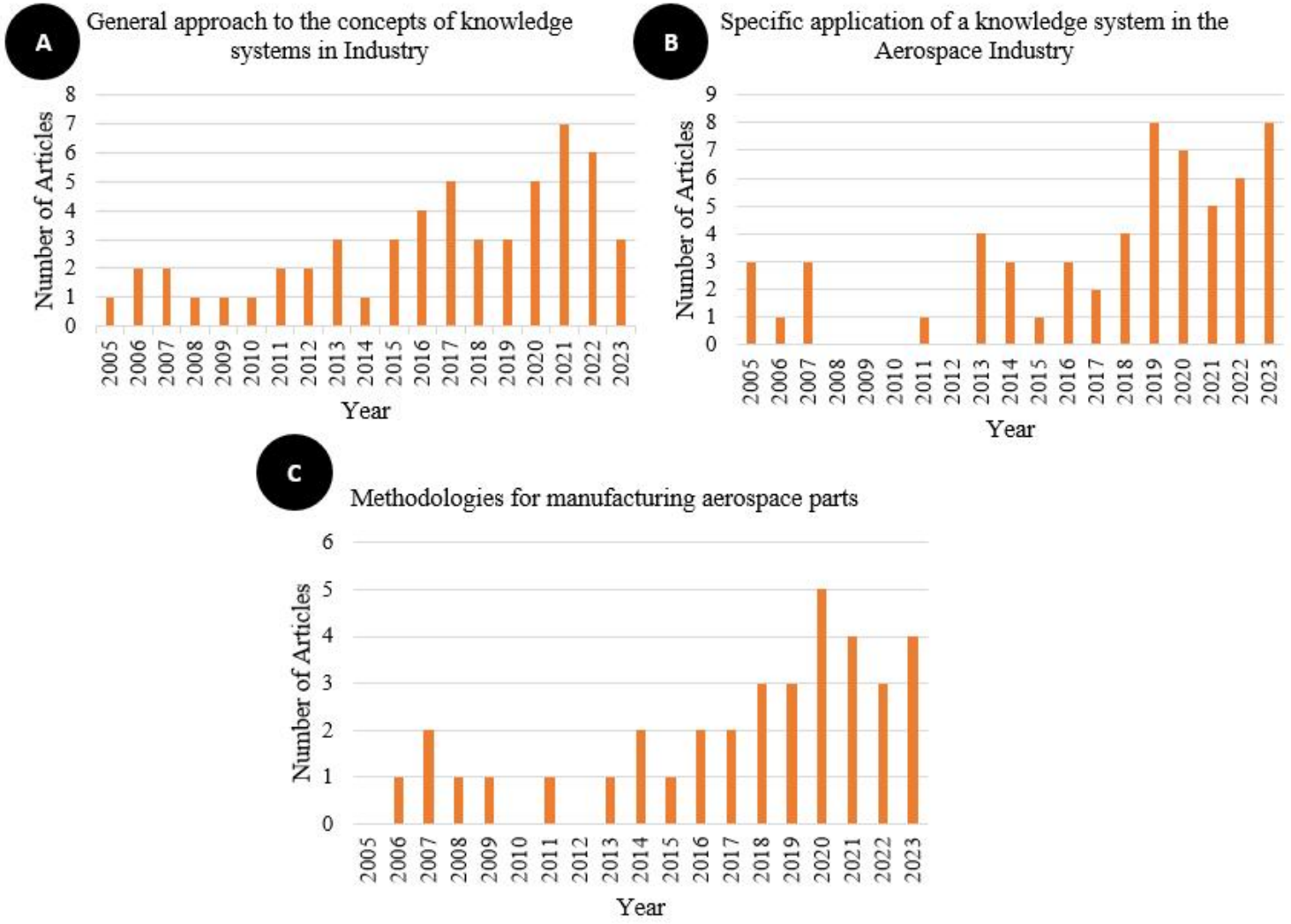

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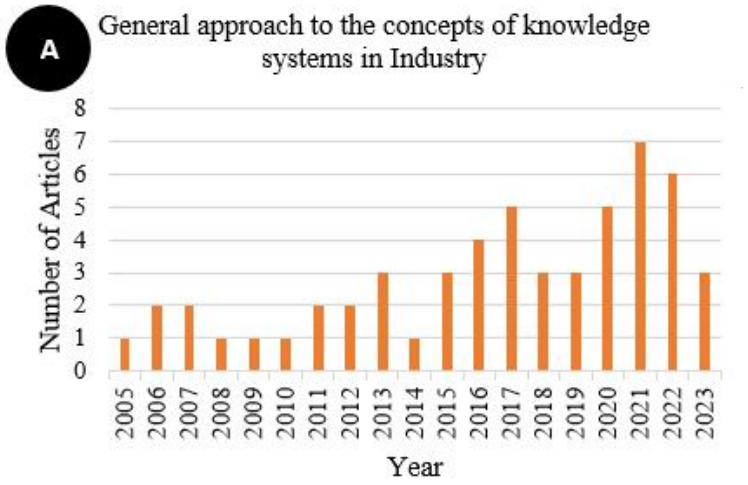


| Authors | Concept/technique |
|---|---|
| (Szejka et. al, 2021) | Knowledge-Based System |
| (Leal et al., 2019) | Ontology |
| (Staab and Studer, 2010) | Ontology |
| (Kesseler, 2006) | Knowledge-Based Engineering |
| (La Rocca and Van Tooren, 2007) | Knowledge-Based Engineering |
| (Van Tooren et. al, 2005) | Knowledge-Based Engineering |
| (Trappey et al., 2013) | Ontology-Based Engineering |
| (Sanya and Shehab, 2014) | KBE and Ontology |
| (Mas et al., 2019) | Ontology |
| (Pereira et. al, 2022) | Ontology |
| (Arista et. al, 2023) | Ontology-Based Engineering |
| (Kurmar, 2019) | Knowledge-Based System |
| (Ríos et al., 2005) | Knowledge-Based Engineering |

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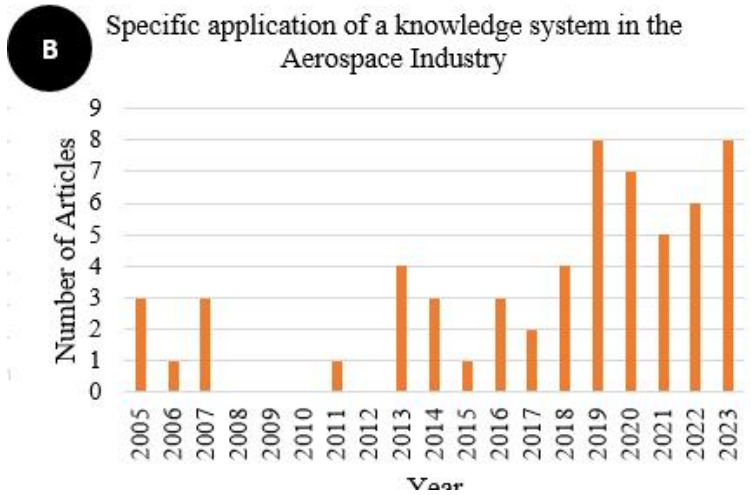
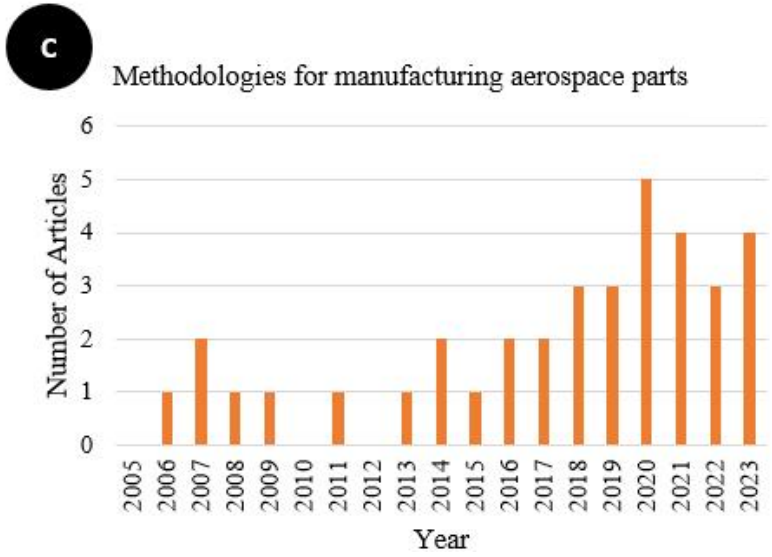



| Authors | Sectors |
|---|---|
| (Van Tooren et. al, 2005) | Engineering Design Phase |
| (Emberey et al., 2007) | Engineering Design Phase |
| (Mas et al., 2016) | Assembly Lines |
| (Page and Nagel, 2019) | Engineering Design Phase |
| (Miah and Zhang, 2023) | Assembly Lines |
| (Adamczyk et al. 2020) | Manufacturing System |
| (Arista et. al, 2023) | Manufacturing System |
| (Ghaffarishahri and Rivest, 2020) | Engineering Design Phase |
| (Szejka et. al, 2017) | Engineering Design Phase |

# SYSTEMATIC LITERATURE REVIEW




| Authors | Methodology |
|---|---|
| (Solano et. al, 2014) | Data-Driven |
| (Estefan et. al, 2007) | Model-Based System Engineering |
| (Arista et. al, 2023) | Models for Manufacturing |
| (Morales-Palma, 2022) | Models for Manufacturing |
| (Oliva et al., 2020) | Models for Manufacturing |
| (Song et al., 2013) | Data-Driven |
| (Montáns, et. al, 2019) | Data-Driven |
| (Arista et. al, 2020) | Models for Manufacturing |
| (Madni and Sievers, 2018) | Model-Based System Engineering |
| (De Saqui-Sannes et al., 2022) | Model-Based System Engineering |
| (Mas et al., 2018) | Models for Manufacturing |

# DISCUSSION

- To answer **RQ1**, different methodologies have been found to address the entire aerospace manufacturing process. The **MfM methodology proved to be effective** since it encompasses various sectors of the industry.

**Service Layer**

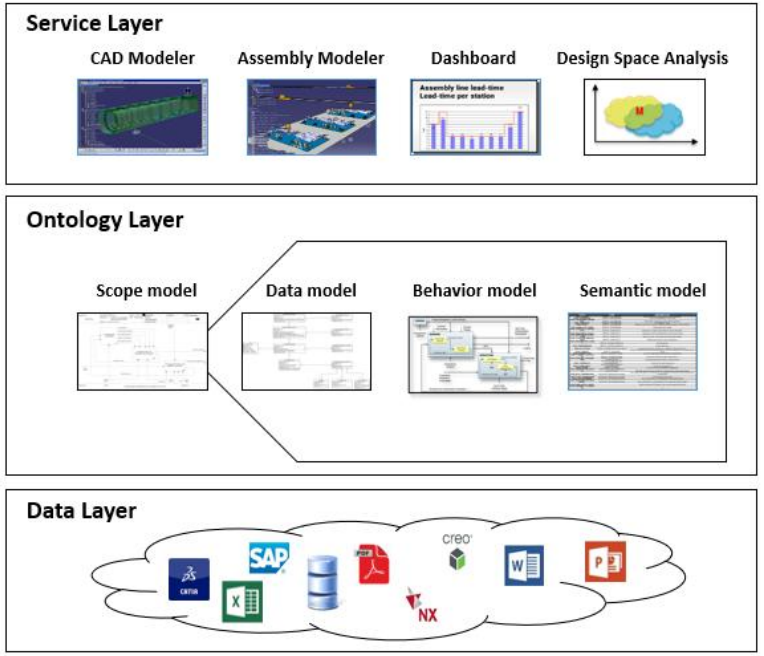
Authoring, Simulation, Visualising, Data Analytics, Design Space Exploration and Dashboards

**Ontology Layer**

Scope, Behaviour, Semantic and Data models

**Data Layer**

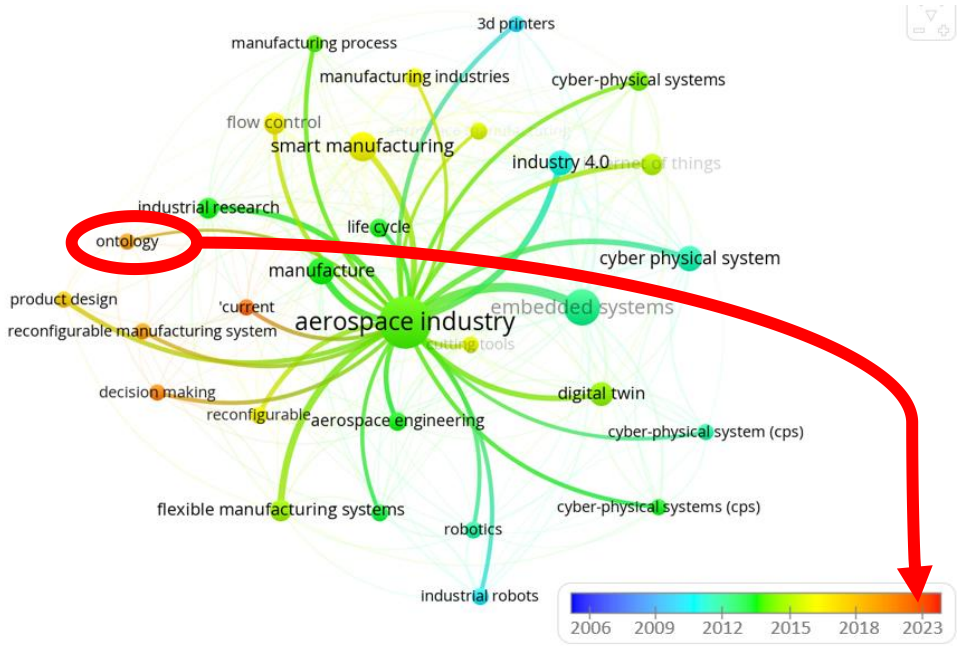
Data sources, Databases (Structured, Non-structured, Document-based) and Interfaces




Research Issue 1 (RI1): What are the **current issues and emergent technologies** in CPPS and KDD for the Aerospace Industry?

# DISCUSSION

- To answer **RQ2**, ontologies are an emerging technology in recent years and this technology can solve the problem of collecting and manipulate explicit and tacit knowledge. However, **another gap is the integration of commercial tools with human tacit knowledge into a system**. This system needs to be able to interoperate among various languages and software.




Research Issue 2 (RI2): What is the **gap in CPPS and KDD** for the aerospace industry?

# CONCLUSION AND FUTURE WORKS

- Currently, **there are a limited number of CPPS applications in the aerospace industry**. Demonstrating its applicability remains necessary, considering industry constraints.
- Existing methodologies do **not bring all product data in an automated manner**, which is the most suitable way due to the use of different tools that cannot communicate.
- **There is still a significant amount of intrinsic knowledge among experienced industry personnel**. This knowledge also needs to be addressed digitally. With this, the CPPS can effectively support industry sectors.
- Information from multiple domains related to ASM parts Design and Manufacturing **can be formalised in an ontological approach and mapped through interoperable mechanisms** to share, convert, and translate information in a CPPS based on MfM.
- The Product Knowledge-Based System of ASM parts **can extract information from different sources** like STEP files, databases, or tacit human information from experts to accurately infer values or procedures.

As a result, it will be possible to extract product information in an automated manner. Existing Model-Based methodologies can integrate stored knowledge through ontologies with commercial software tools.

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# Thank You

## Questions

The authors would like to thank to Sevilla University colleagues and PUCPR University and CT Engineering Group colleagues for their support and contribution during the development of this work.

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