Model-based approach for the automatic inclusion of production considerations in the conceptual design of aircraft structures

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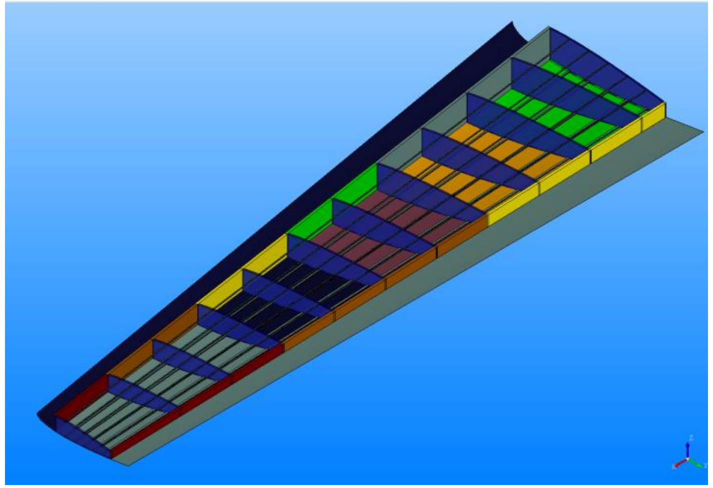
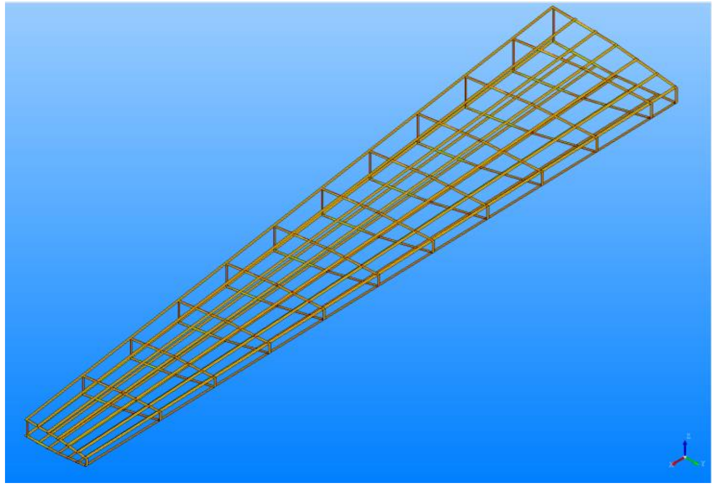
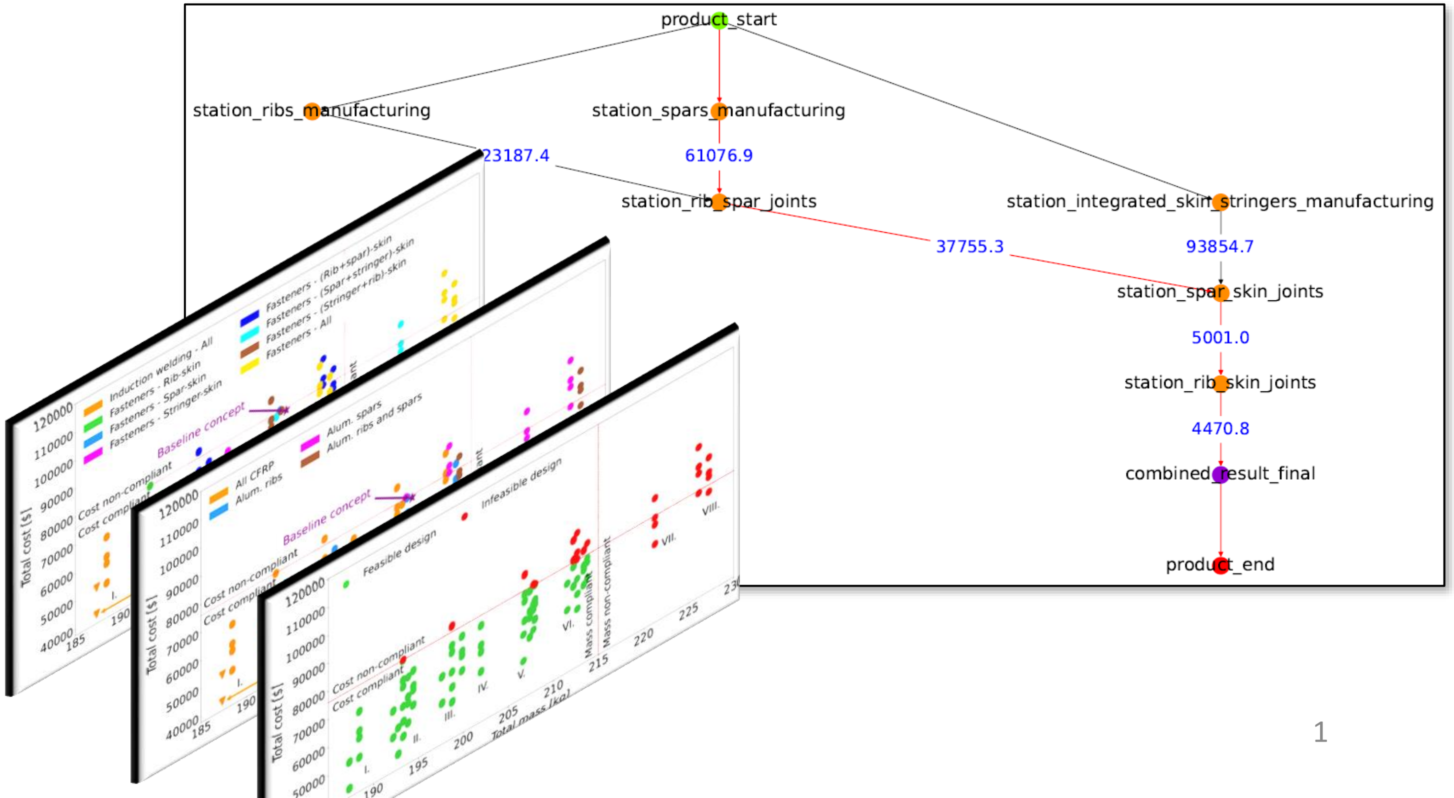
Presenter:

D Bansal







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Overview

Introduction: Importance of production considerations in conceptual design

Current methodologies to include production in design and the limitations thereof

Proposed methodology: the Manufacturing Information Model

Industrial case study: Conceptual design of a wingbox

Conclusions

Recommendations for future work

All icons from www.flaticon.com

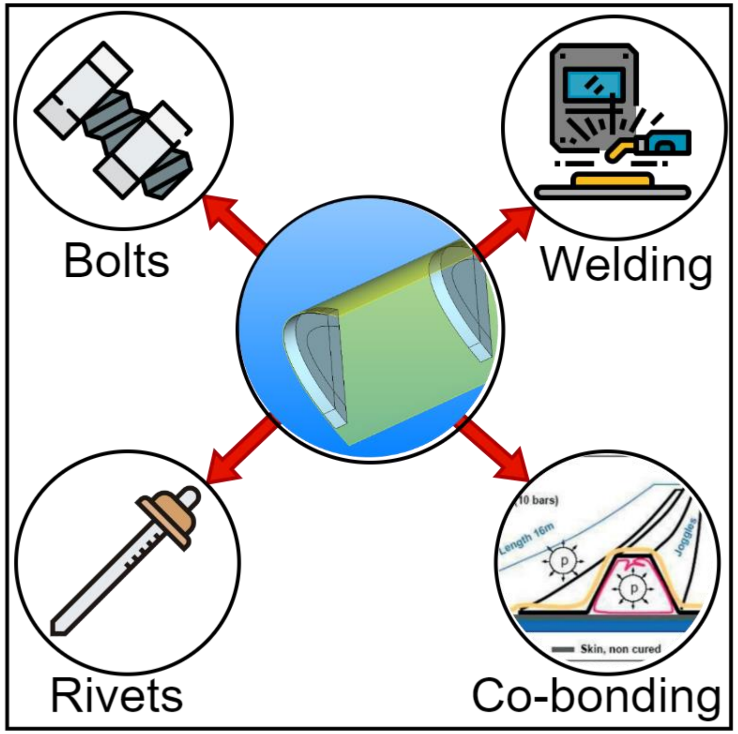
Introduction:
Importance of production considerations in conceptual design

Production considerations

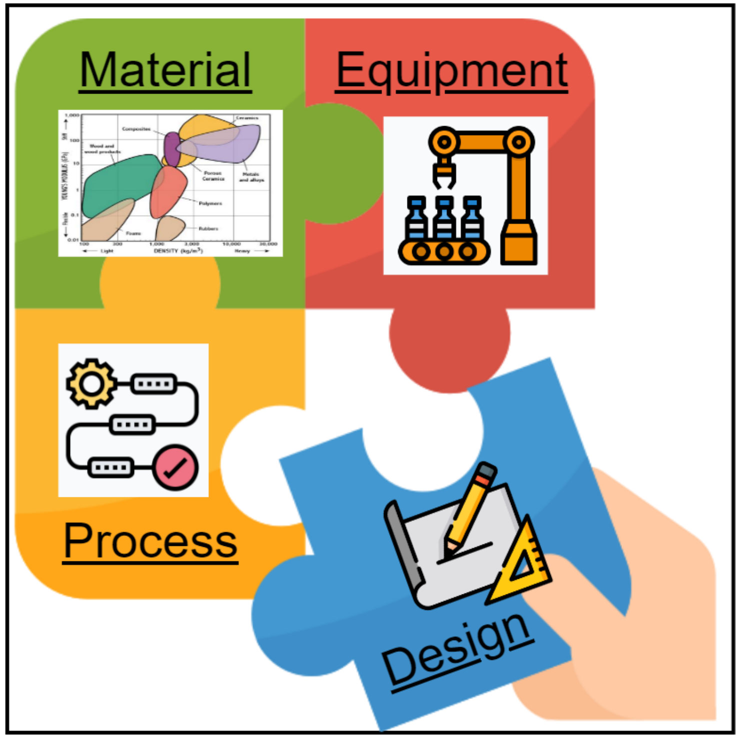
“factors from the perspective of production, that have an influence on the system design”

Examples:

1. Joint information

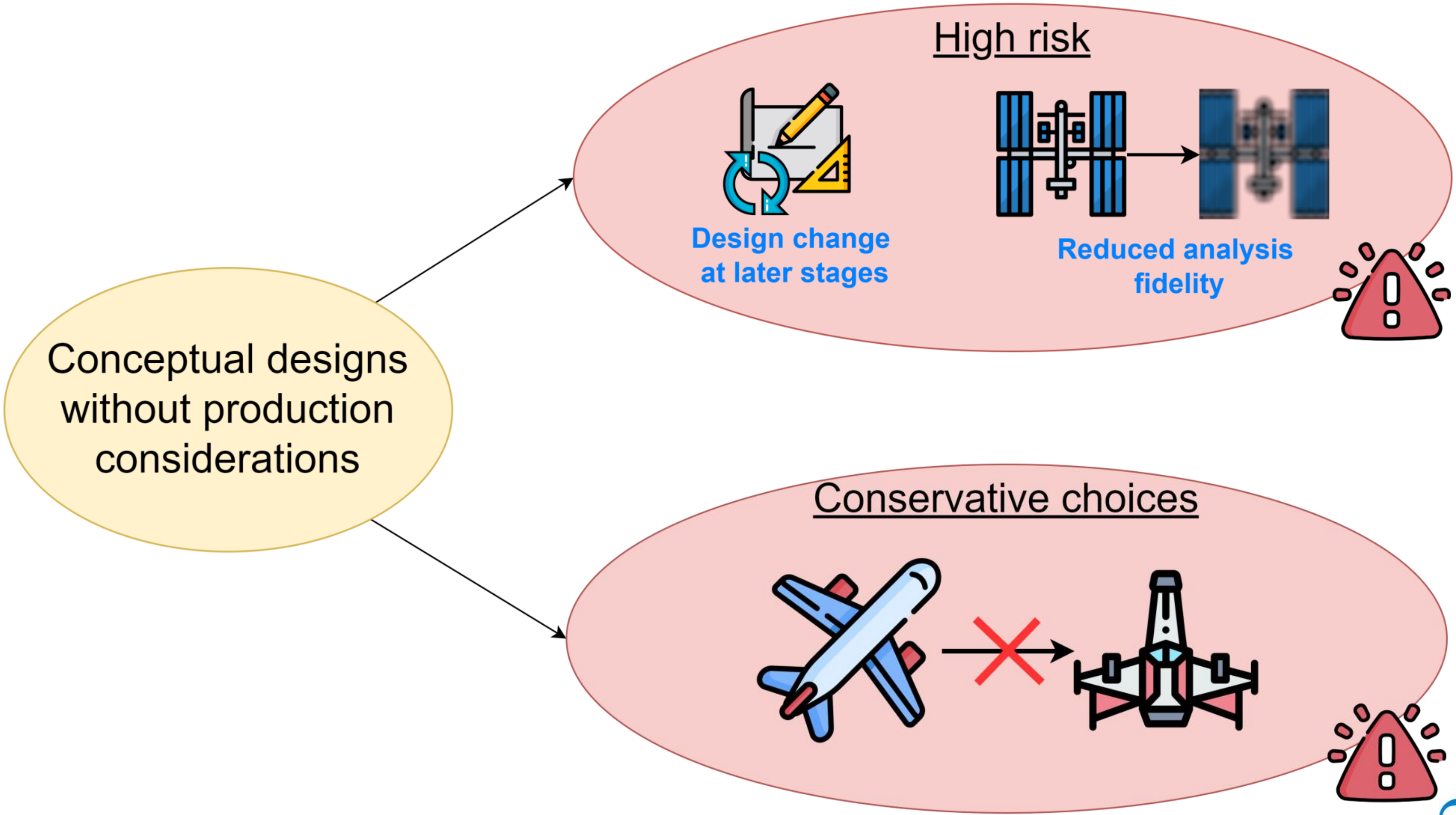


2. Product Compatibility



Picture sources:
http://www-g.eng.cam.ac.uk/125/now/mfs/tutorial/non_IE/charts.html
Hiken, A., "The Evolution of the Composite Fuselage - A Manufacturing Perspective," *SAE Int. J. Aerosp.*, 2017

Introduction:
Importance of production considerations in conceptual design



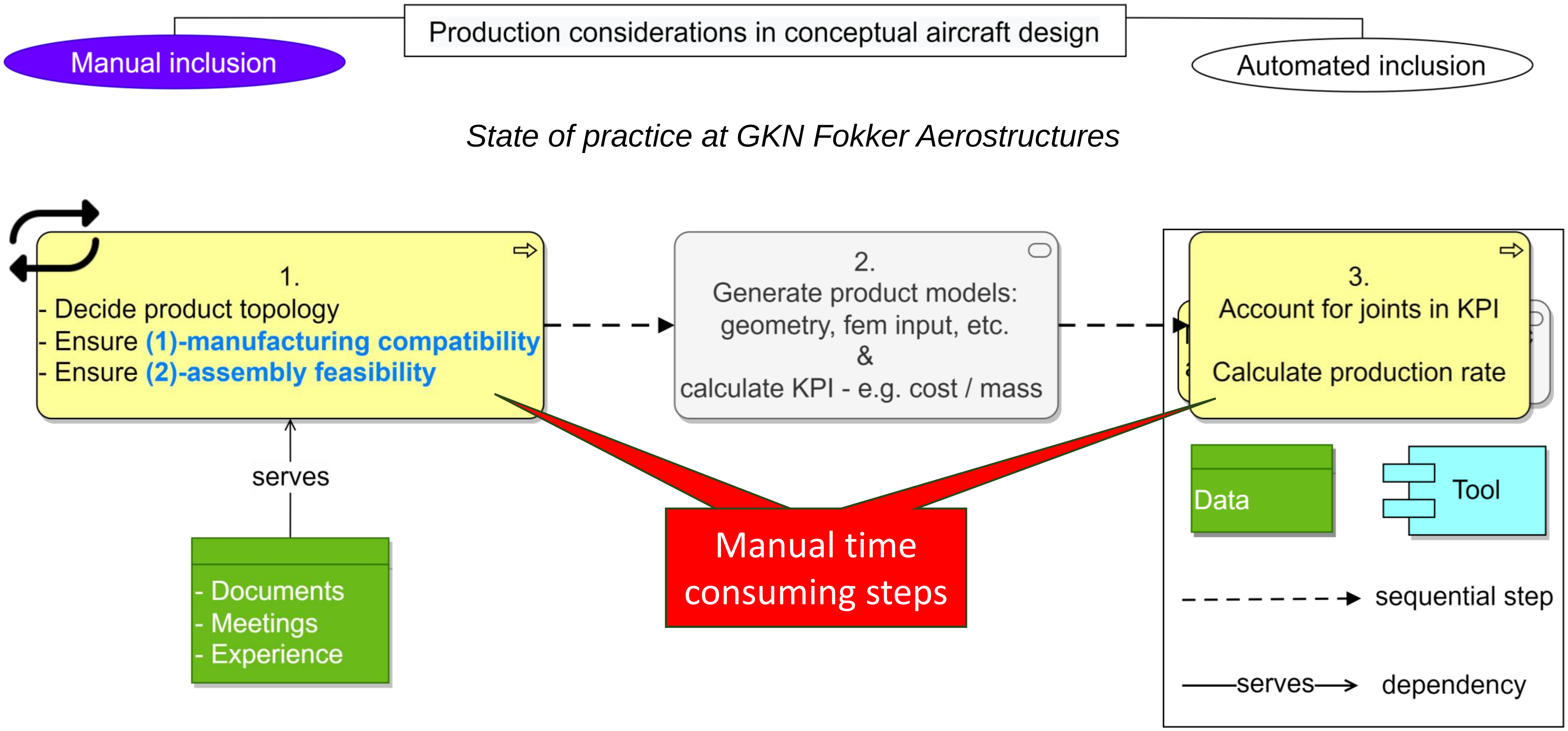
Current methodologies to include production in design and the limitations thereof

Production considerations in conceptual aircraft design

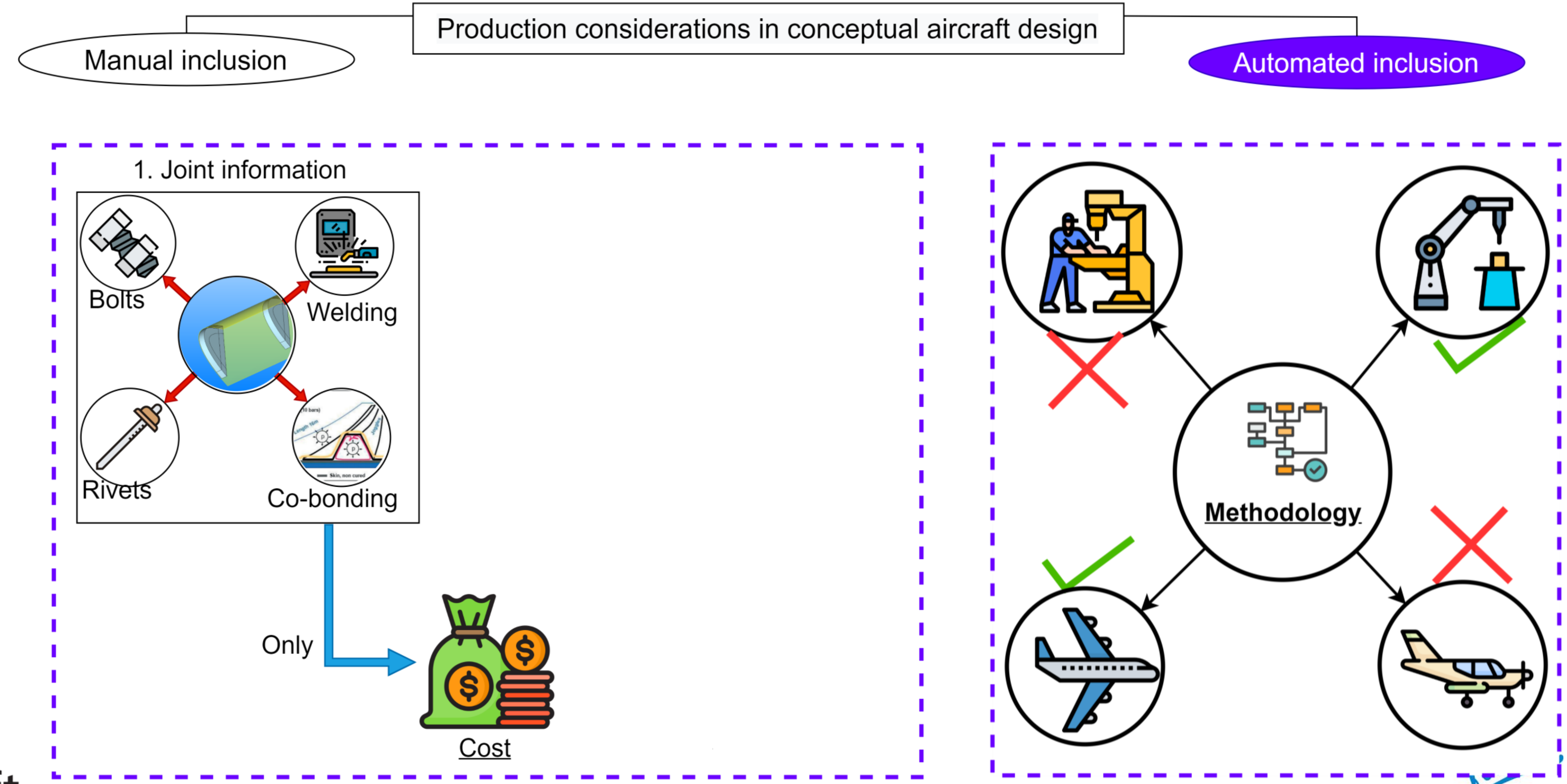
Manual inclusion

Automated inclusion

Current methodologies to include production in design and the limitations thereof



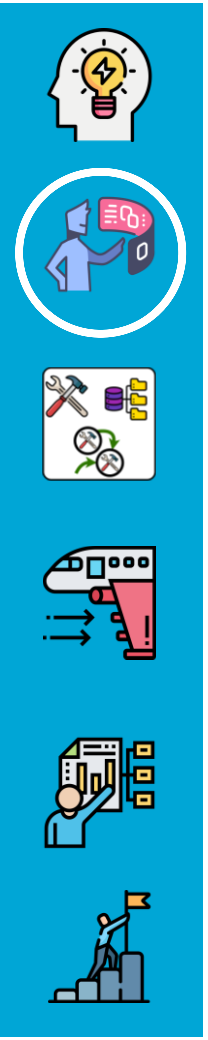
Current methodologies to include production in design and the limitations thereof



1. Production considerations accounted for only as manufacturing cost

2. Non-generic methodologies

Current methodologies to include production in design and the limitations thereof

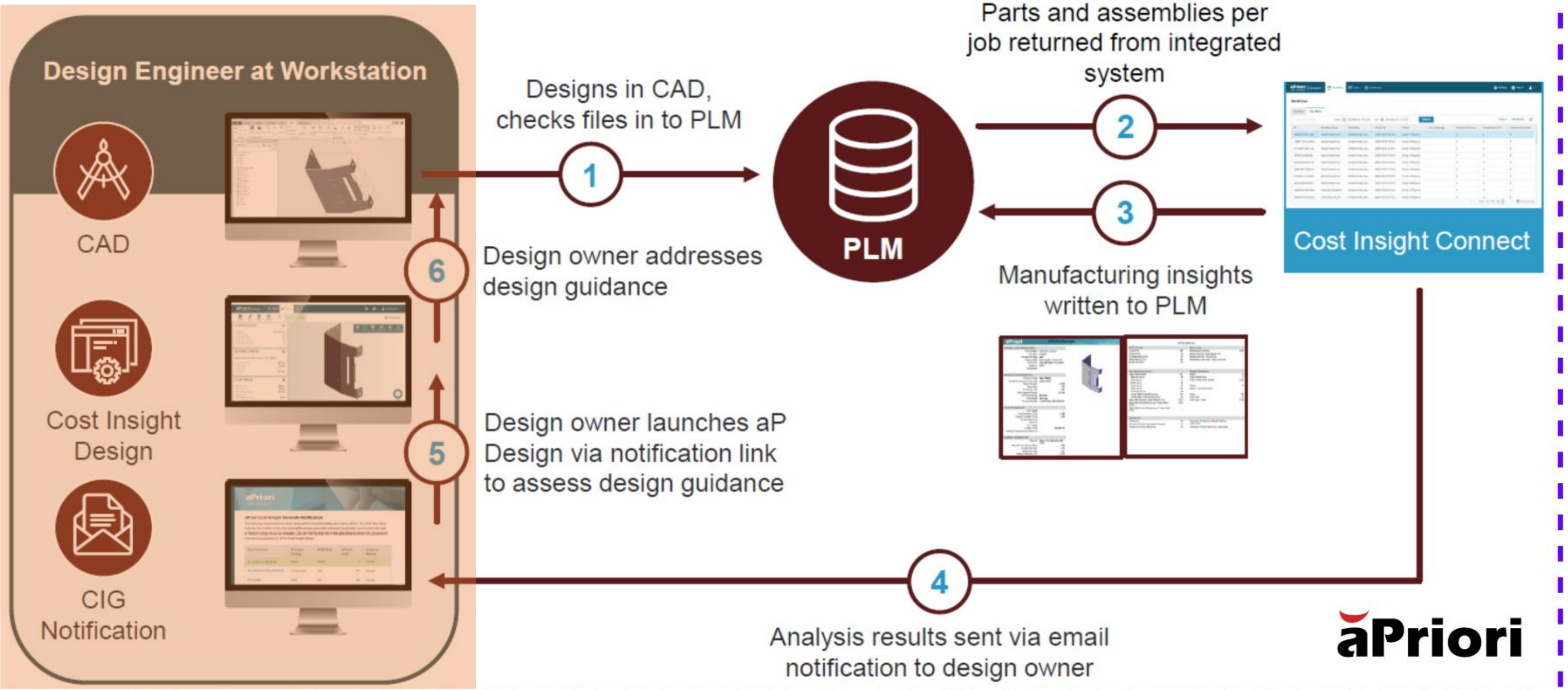


Production considerations in conceptual aircraft design

Manual inclusion

Automated inclusion

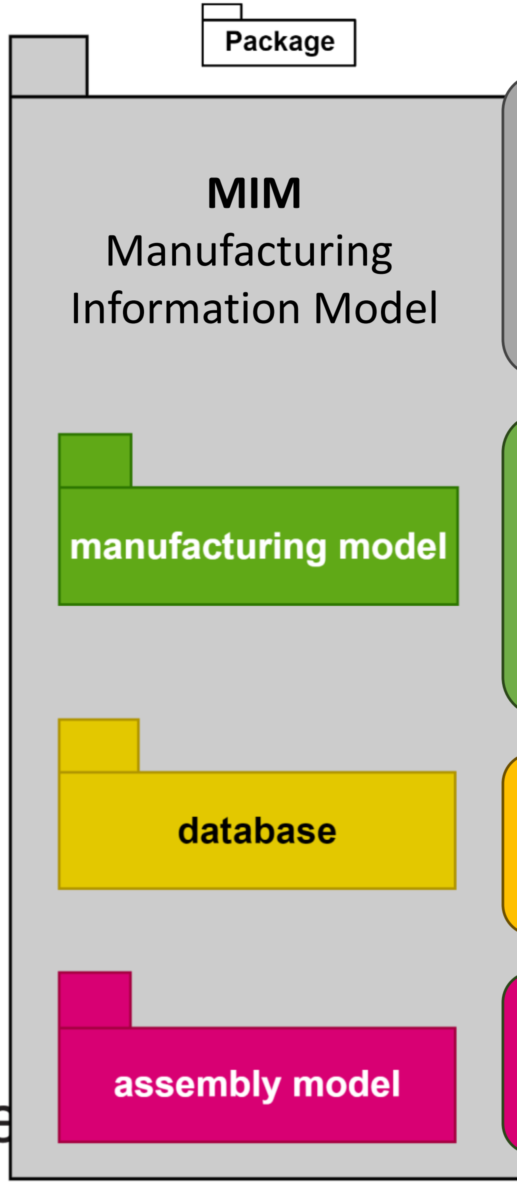
Source: https://www.apriori.com/blog/apriori-22-1-expands-manufacturing-insights-cost-savings-analysis/



3. Use of commercial software unsuitable for automation / conceptual design

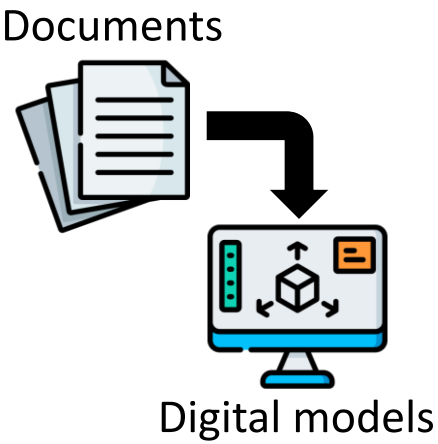
4. Manufacturing & assembly not considered together

Proposed methodology: the Manufacturing Information Model



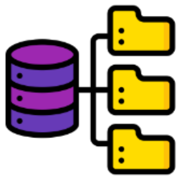
Solutions developed in this research

- ⇒ Model based approach over <documents, experience, meetings>
  - ⇒ Suitable for automation / conceptual design
  - ⇒ Faster; enables knowledge reuse
- ⇒ MIM integrates with KBE applications to capture production information & allow related analyses

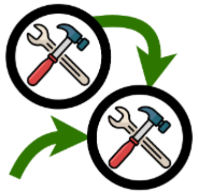


- ⇒ Captures manufacturing information for each product component
- ⇒ **Generic**: independent of design type, manufacturing method, material etc.
- ⇒ **Enables analyses**: Compatibility, mass

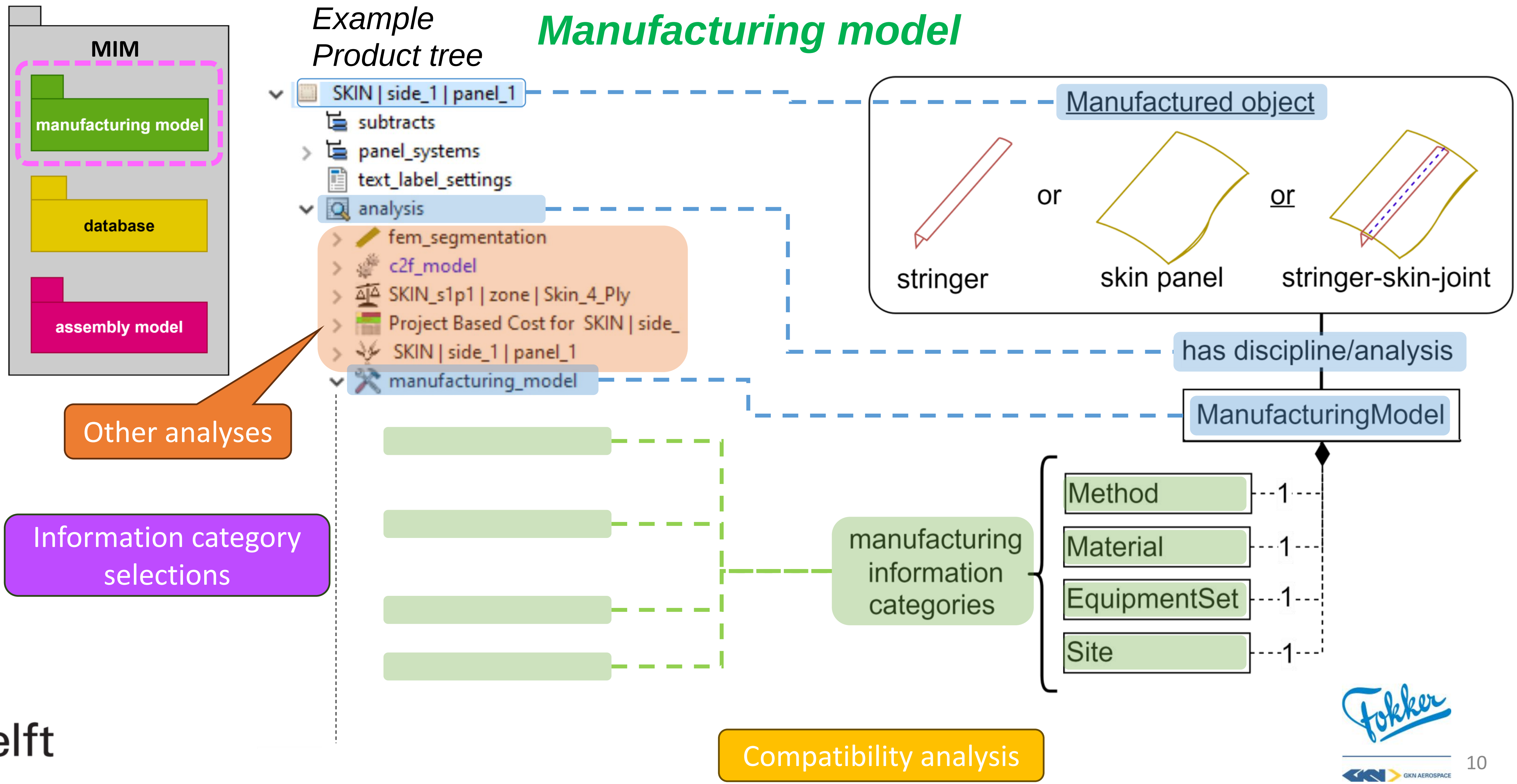
- ⇒ Provides information to define manufacturing model
- ⇒ **Generic**: extension possible to include new design types, manufacturing methods, materials etc.



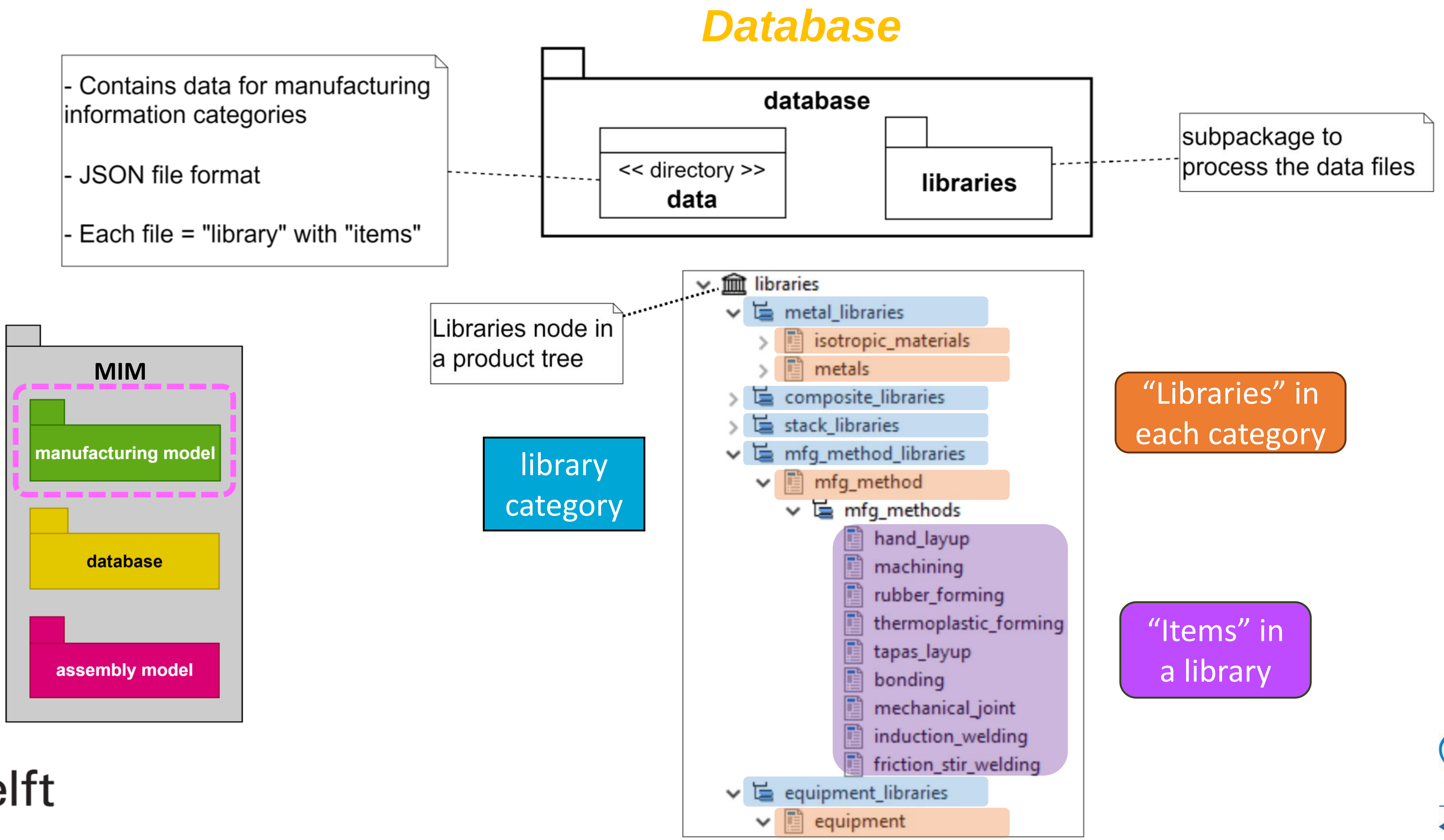
- ⇒ Captures assembly sequence information for a product
- ⇒ Assembly + manufacturing together
- ⇒ **Enables analyses**: Production rate



Proposed methodology: the Manufacturing Information Model



Proposed methodology: the Manufacturing Information Model



Proposed methodology: the Manufacturing Information Model

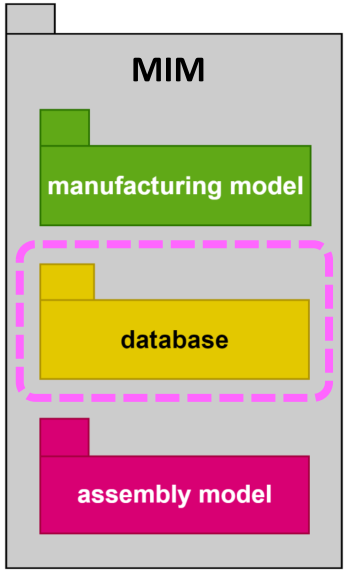
Assembly model

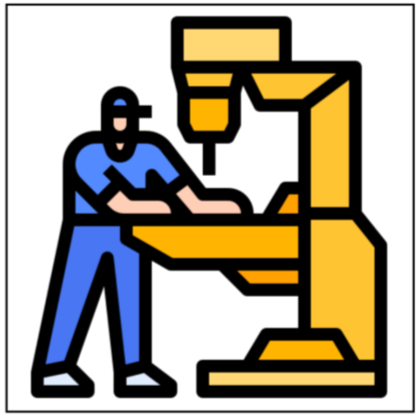
Operation

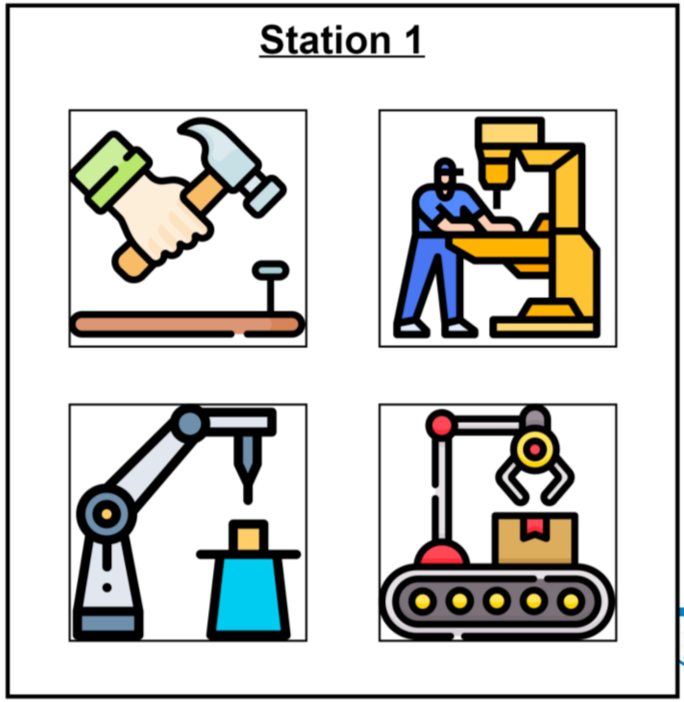
Execution of manufacturing process(es) that result in materialisation of a manufactured primitive

Station

A physical location where a set of manufacturing operations take place







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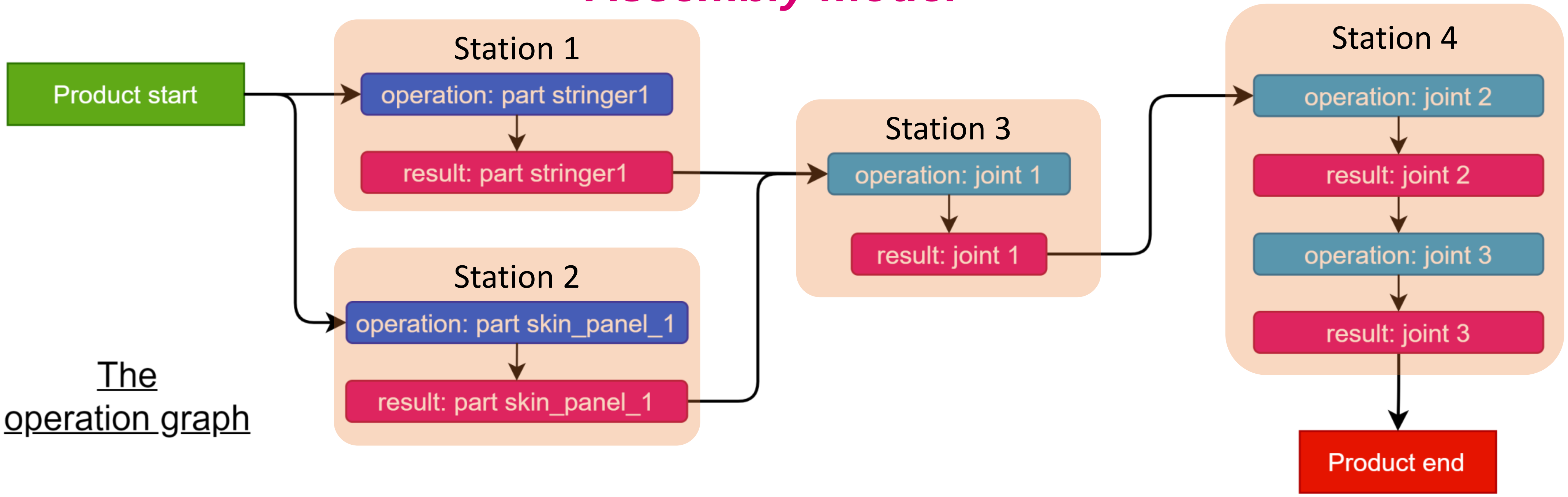
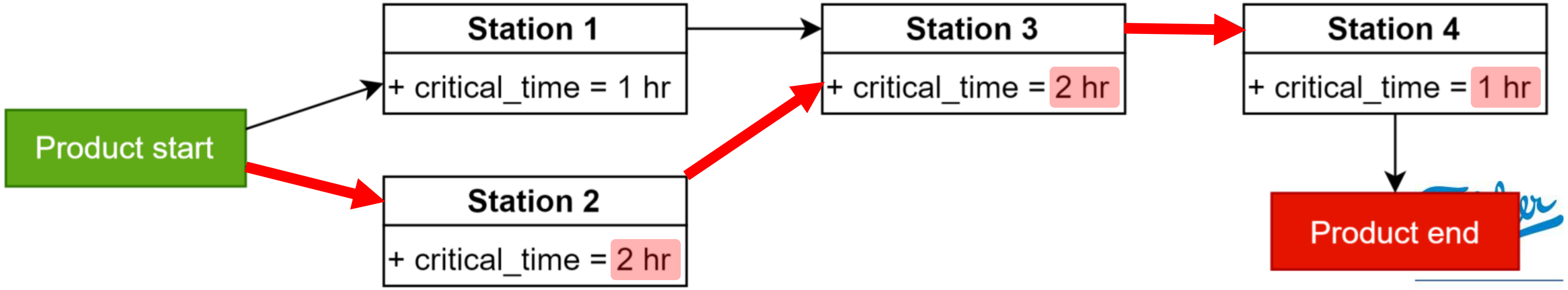
Proposed methodology: the Manufacturing Information Model

Assembly model

The operation graph



The station graph



Proposed methodology: the Manufacturing Information Model

MIM has been implemented using:

ParaPy – Knowledge Based Engineering Software

KBE features

- Runtime catching
- Dependency tracking
- Demand-driven evaluation

NetworkX – Network Analysis in Python

For graphs in the assembly model

Sources:
https://www.parapy.nl/ (accessed 25 August 2022)
https://networkx.org/ (accessed 25 August 2022)

Industrial case study:
Conceptual design of a wingbox

Design workflow with automated inclusion of production considerations

1.
Decide product topology including joints
(manually)

2.
Setup and execute DOE with manufacturing model
(design variables control mfg. model category selections)

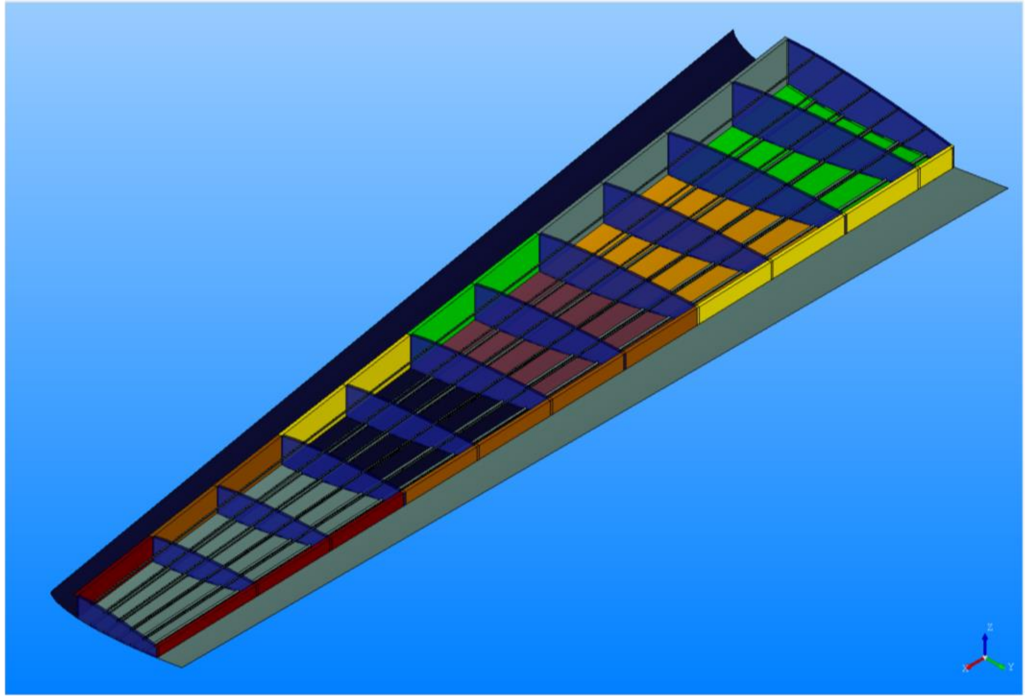
KPI = total cost & mass

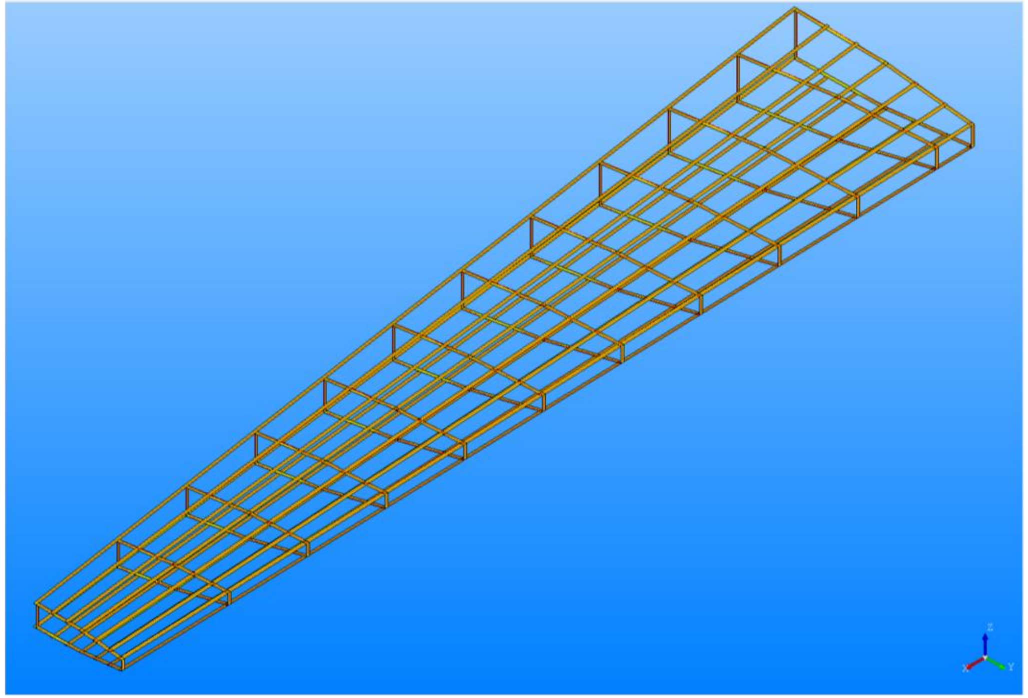
3.
Setup and execute DOE with assembly model
(design variables control assembly sequence)

KPI = production rate

Industrial case study:
Conceptual design of a wingbox

1. Product Topology





Part primitives:

- skin panels x 2
- stringers x 10
- ribs x 12
- spars x 2

Joint primitives:

- skin-stringer joints
- skin-rib joints
- skin-spar joints
- rib-spar joints

Industrial case study:
Conceptual design of a wingbox

2. Manufacturing model DOE

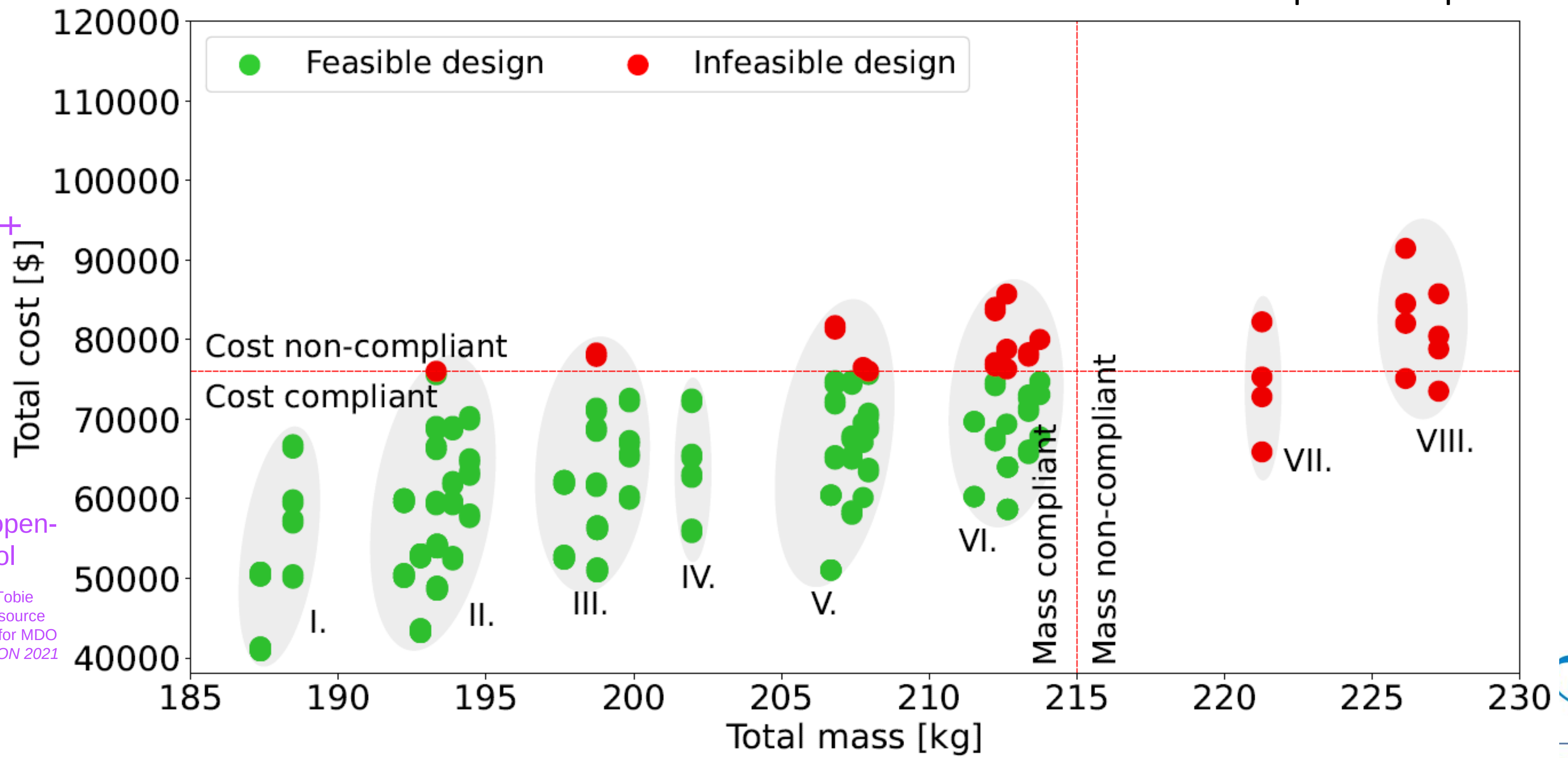
Design variables

Industrial case study:
Conceptual design of a wingbox

2. Manufacturing model DOE

Results: *Scatter plot of all valid* design points*

*pass compatibility checks



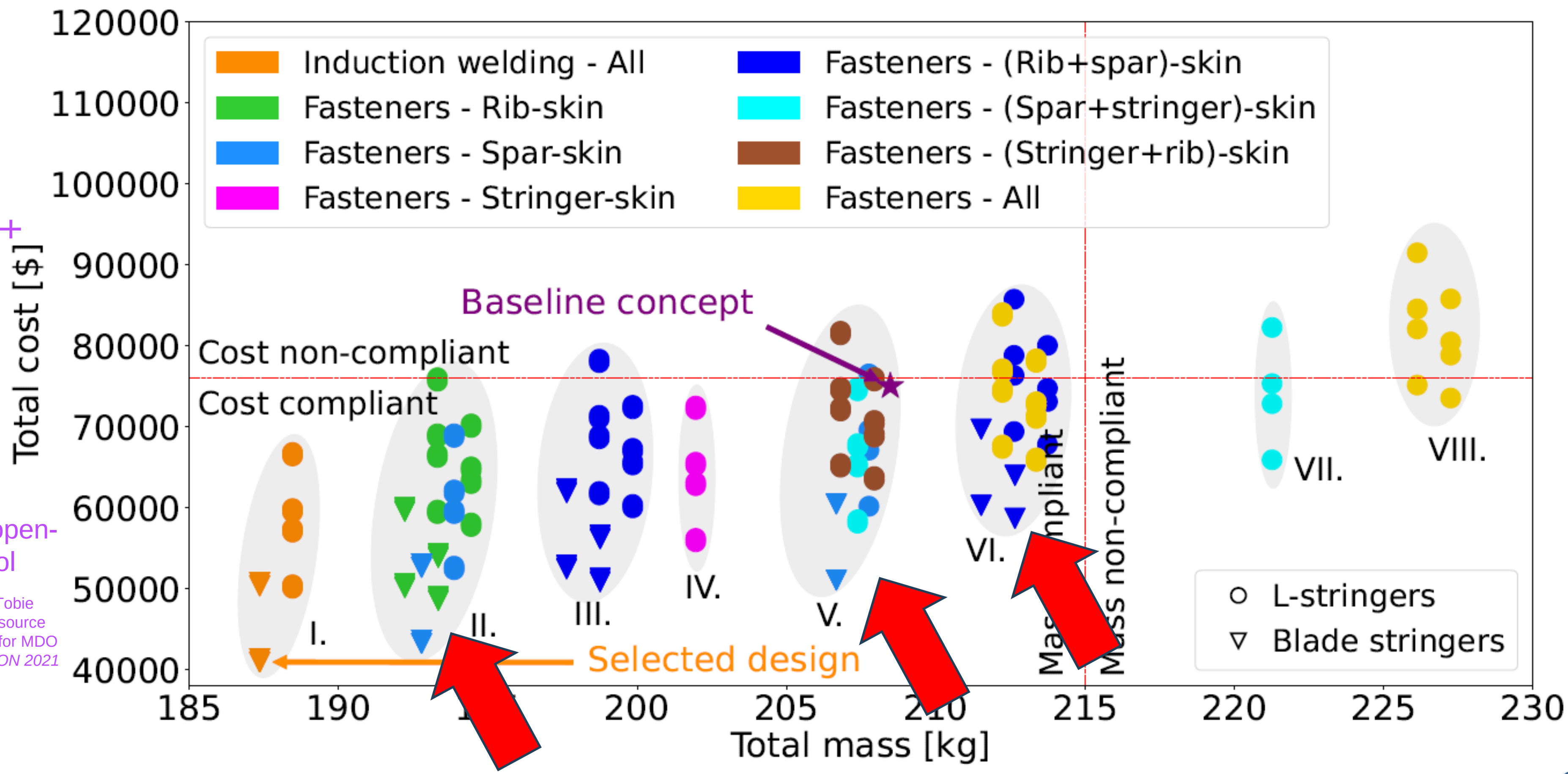
† Cost from an open-source cost tool

van der Laan, Ton, and Tobie van den Berg. "An open source part cost estimation tool for MDO purposes." *AIAA AVIATION 2021 FORUM*. 2021.

Industrial case study:
Conceptual design of a wingbox

2. Manufacturing model DOE

Results: *Valid design points based on the joining method*



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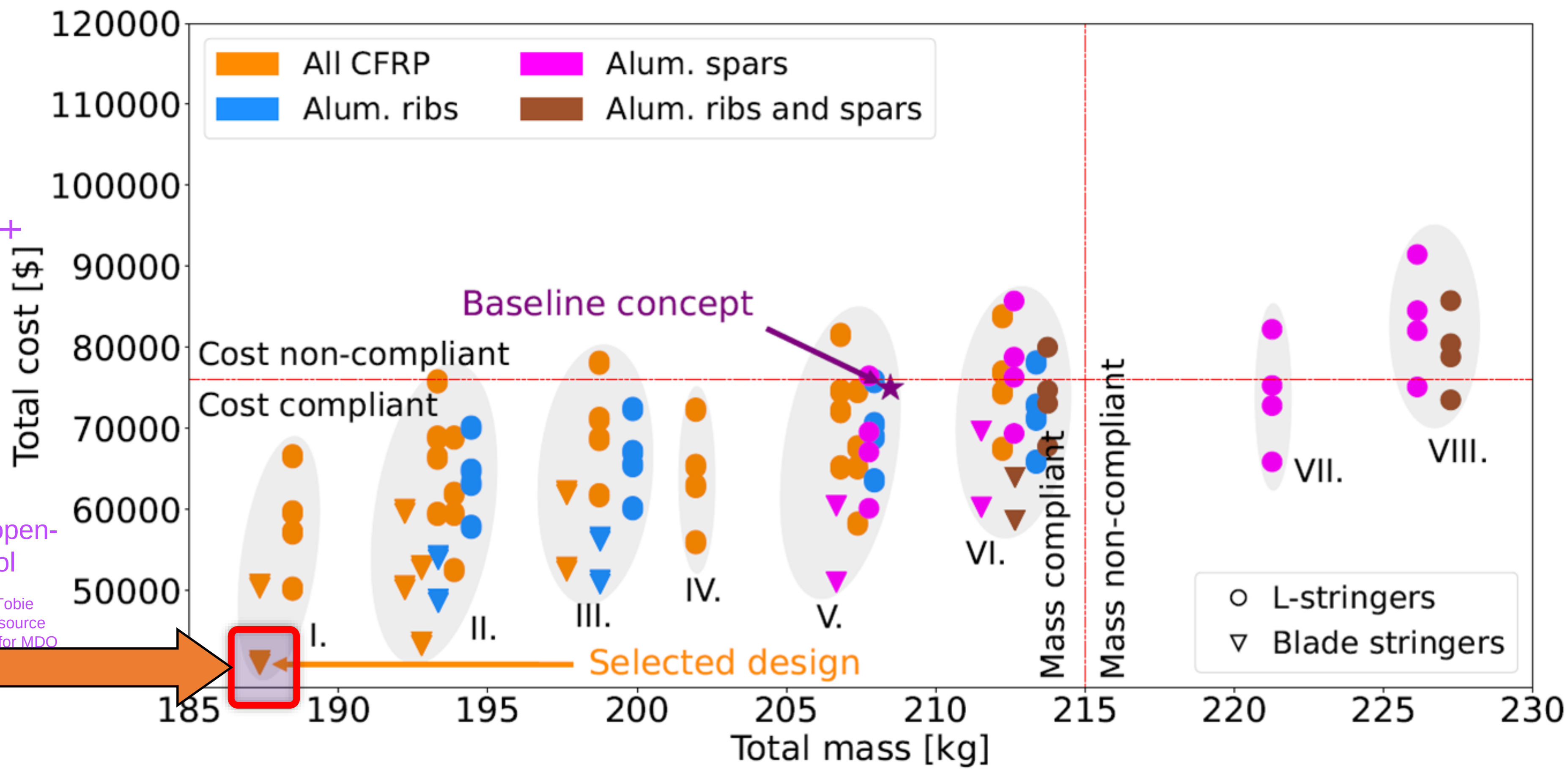
Industrial case study:
Conceptual design of a wingbox

2. Manufacturing model DOE

Results*: Valid design points based on the *part material



Cost from an open-source cost tool

van der Laan, Ton, and Tobie van den Berg. "An open source part cost estimation tool for MDO purposes." *AIAA* … *FORUM*. 2021.

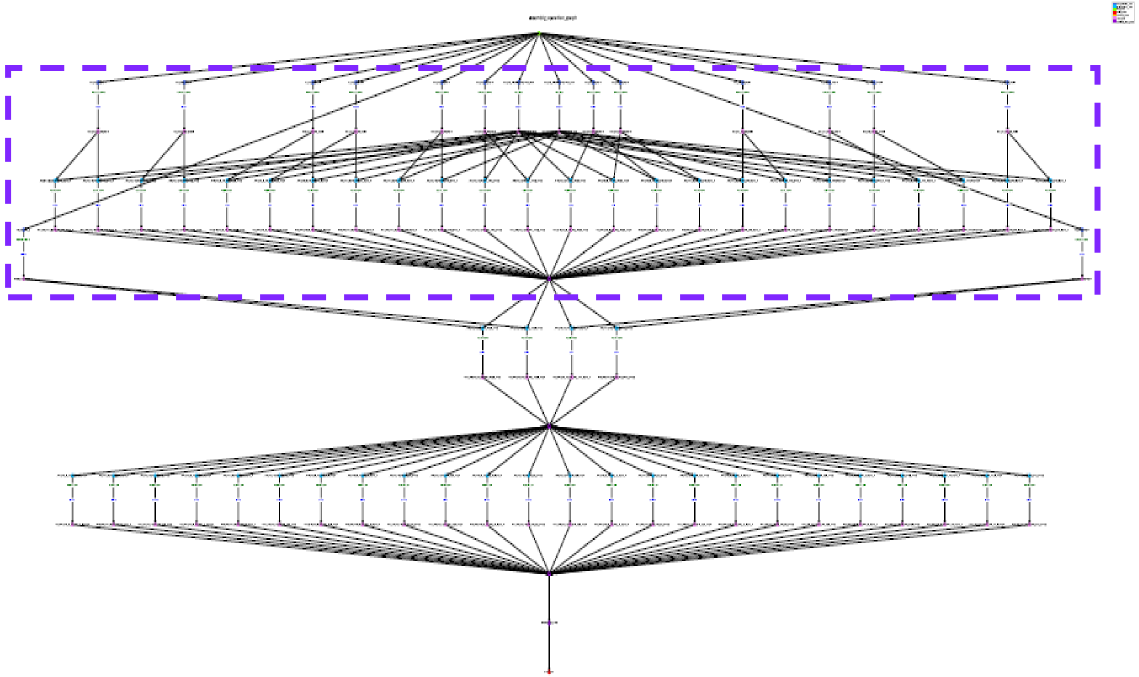
Industrial case study:
Conceptual design of a wingbox

5. Assembly model DOE

Results

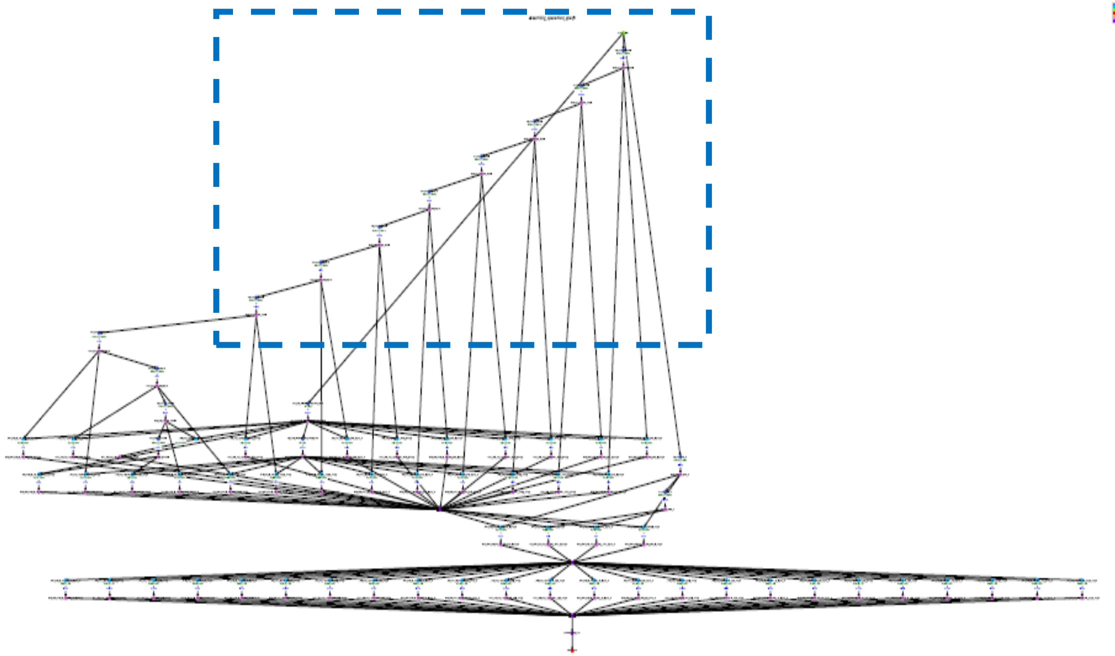
Operation graph of design point **706**

Shipsets per month = **18.4**



Operation graph of design point **274**

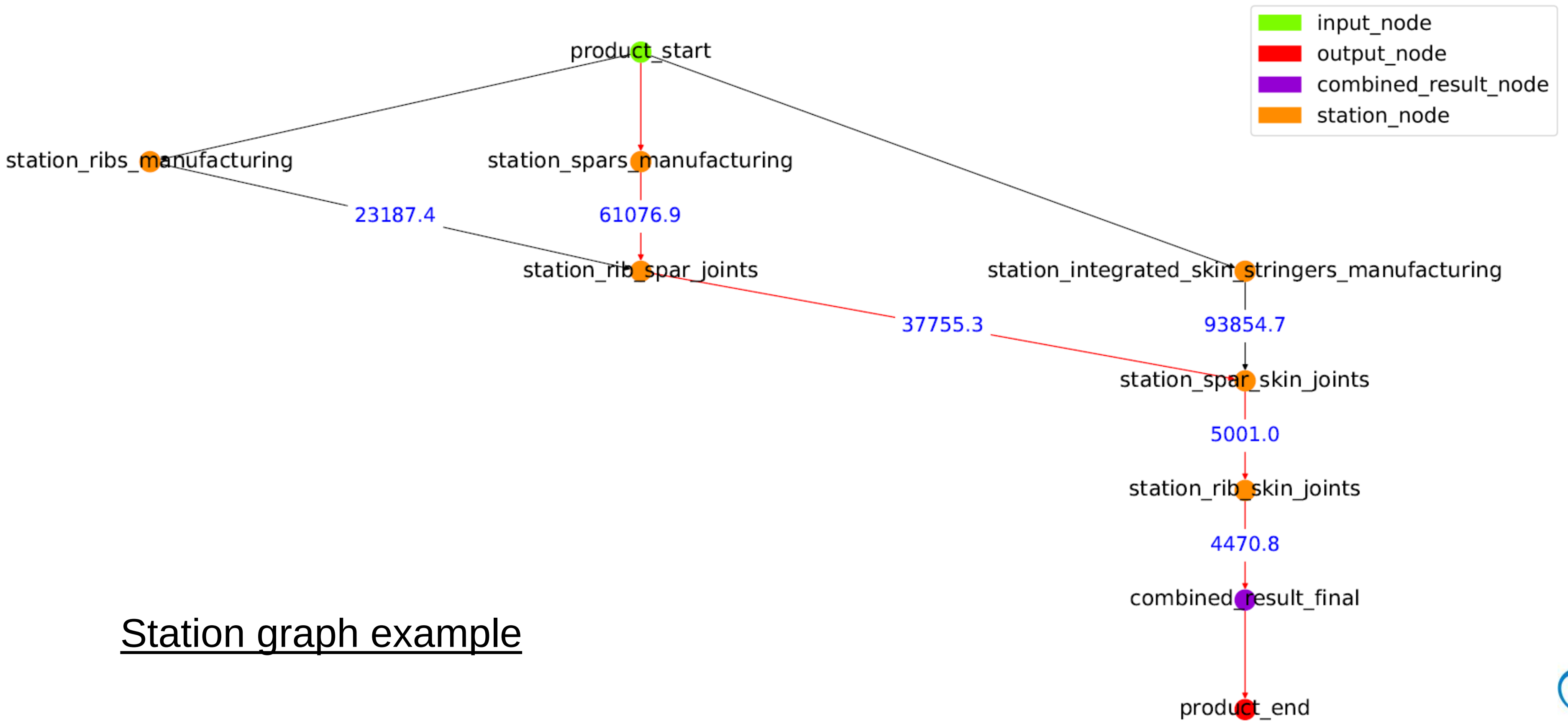
Shipsets per month = **9.4**



Industrial case study:
Conceptual design of a wingbox

5. Assembly model DOE

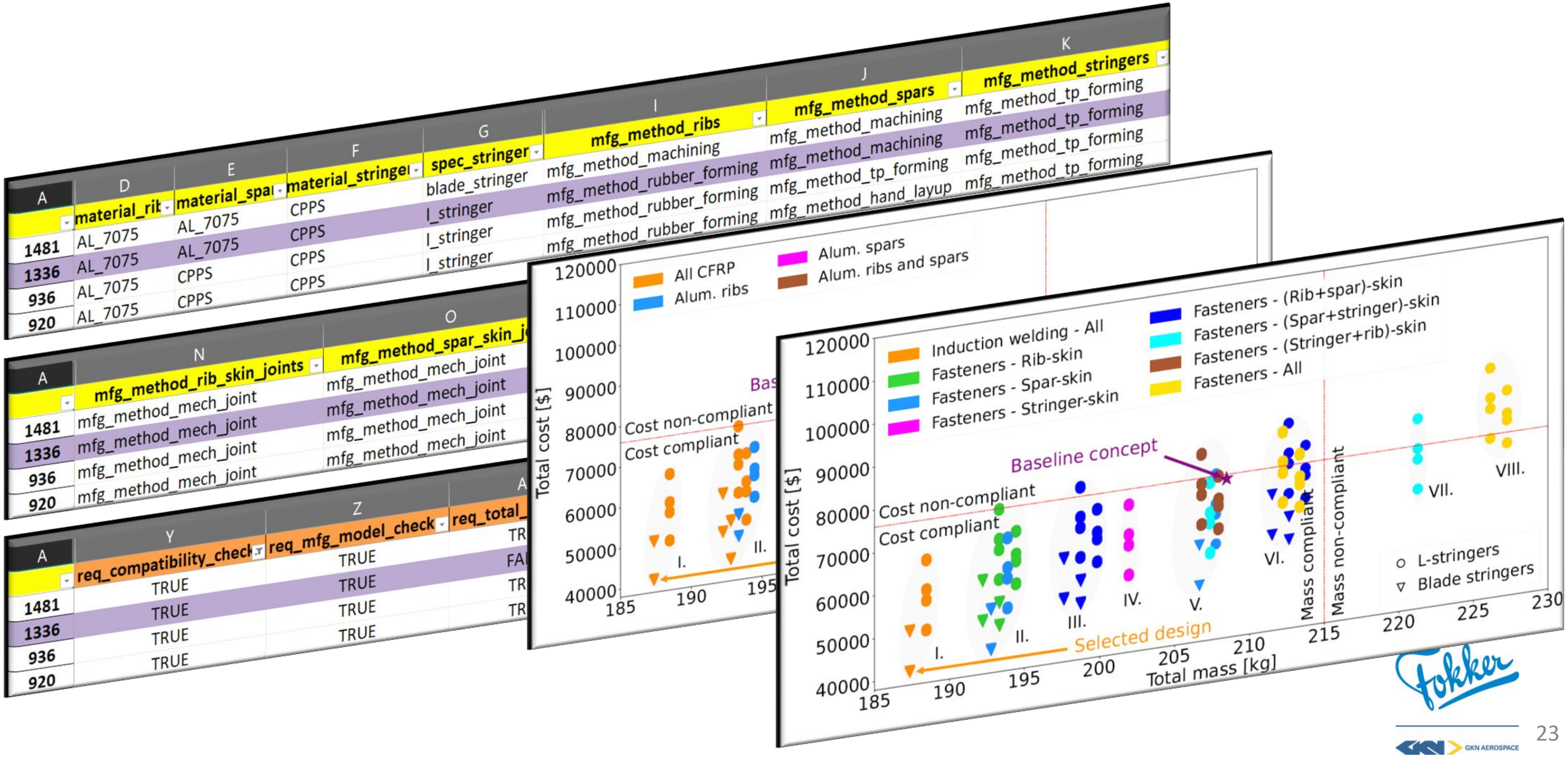
Results



Station graph example

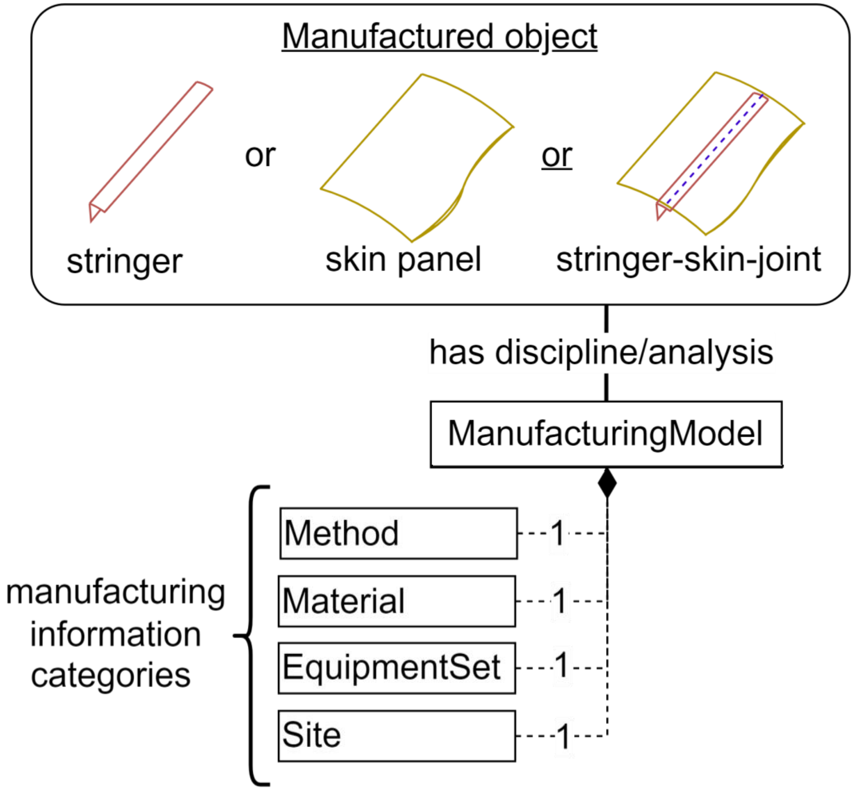
Conclusions

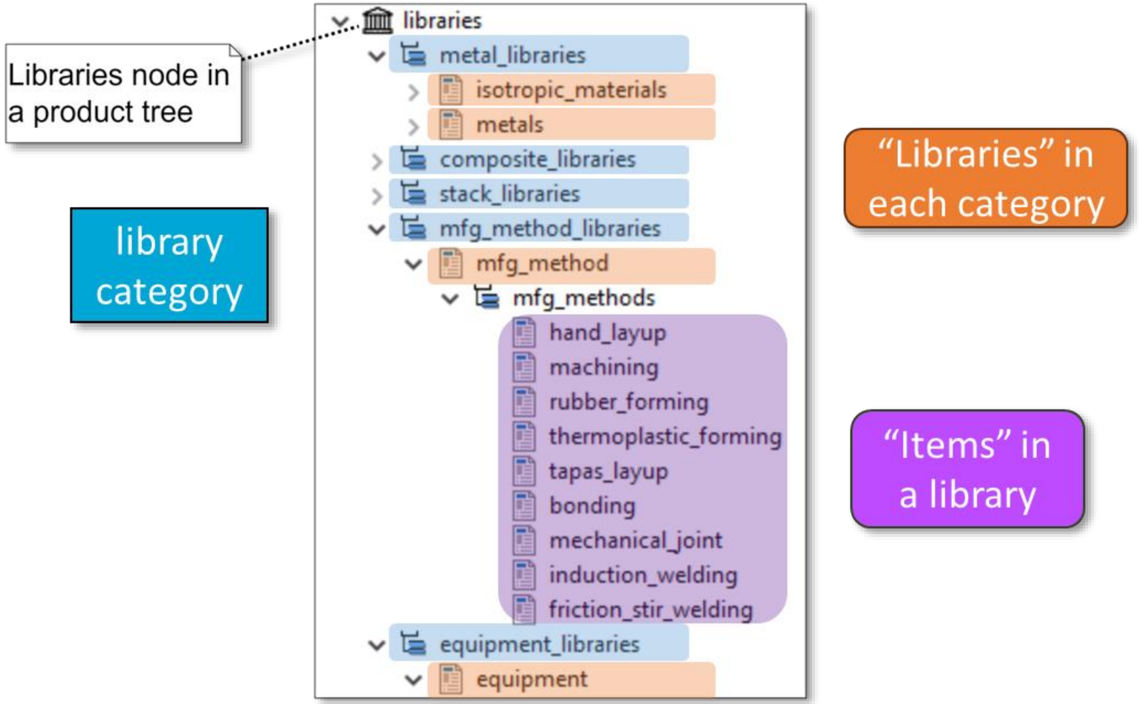
1. The MIM allows for identification of trends, and to rank different manufacturing concepts based on the imposed requirements, which helps in making trade-off decisions



Conclusions

2. The MIM provides a generic structure to capture and organise production related information in a product system



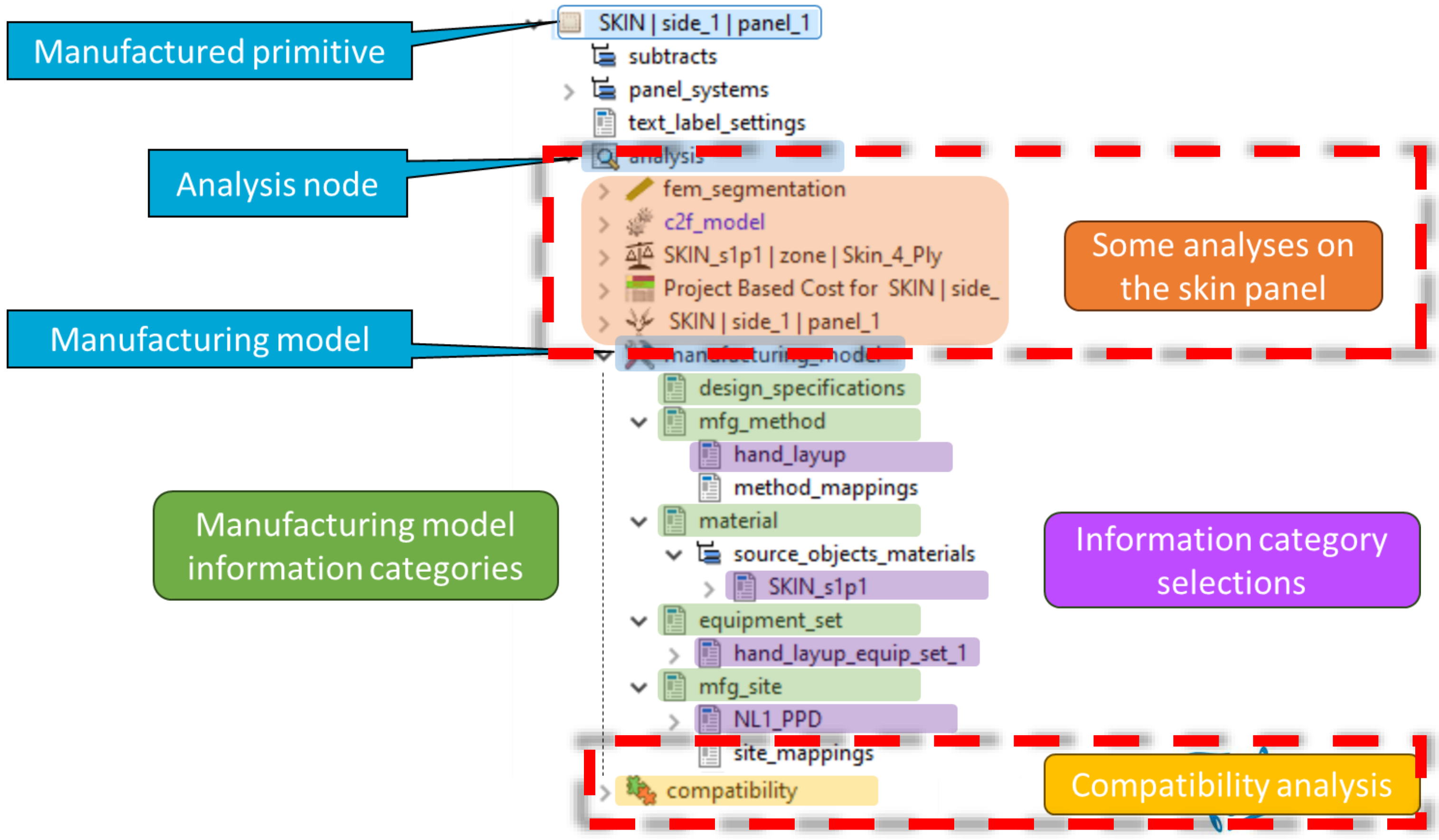


Conclusions

3. The MIM provides a single source for all production information for each manufactured primitive in a product model

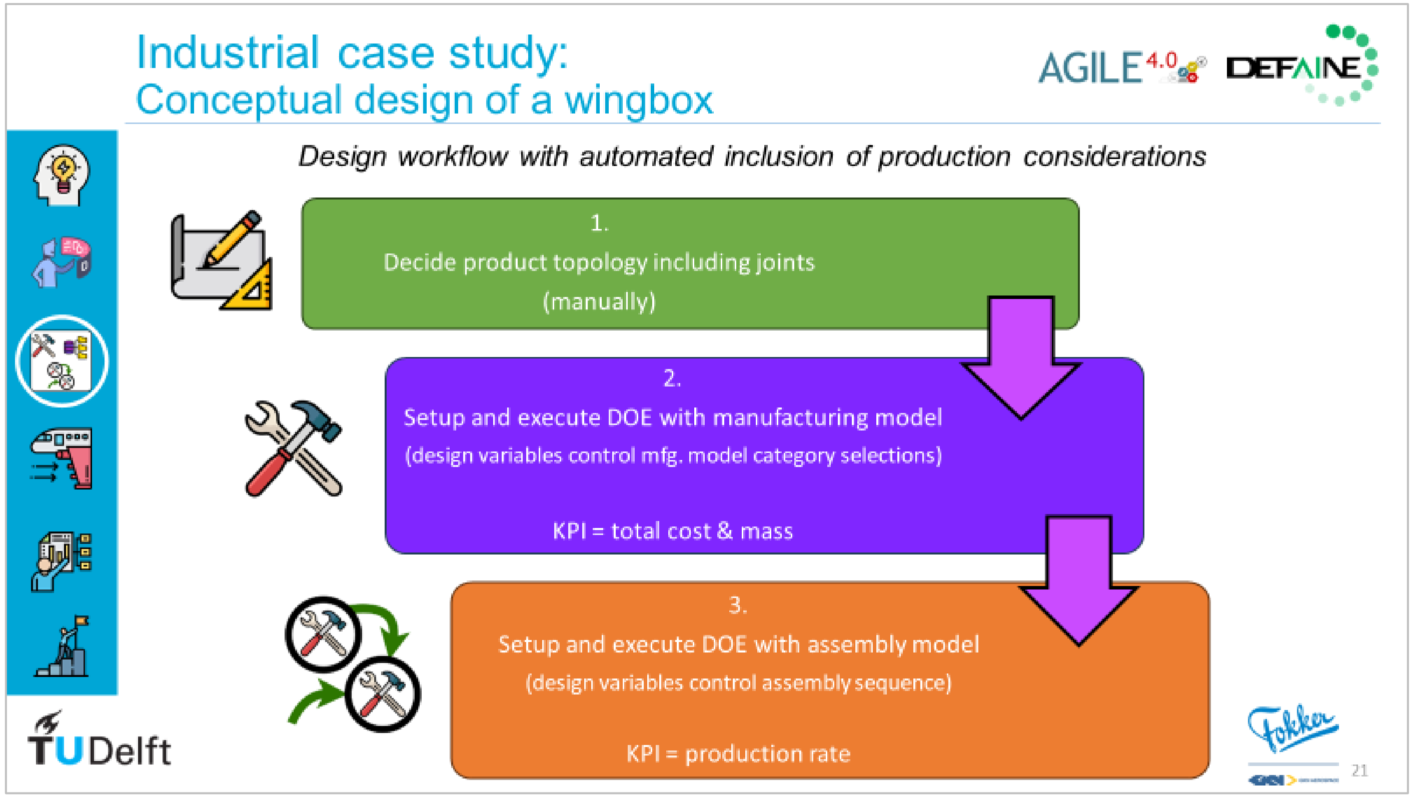
This enables easy integration of related analysis tools:

- ❑ Cost
- ❑ Mass
- ❑ Compatibility
- ❑ Production rate



Recommendations for future work

1. Use MIM in multidisciplinary design optimisation (MDO) workflows to optimise all disciplines at together (design/manufacturing/assembly)



<u>Sequential design workflow:</u>

Possibility of missing out on good designs based on choices at previous steps(s)

Thank you for your attention

The research presented in this paper has partially been performed in the framework of the **AGILE 4.0 (Towards Cyber-physical Collaborative Aircraft Development)** and **DEFAINE (Design Exploration Framework based on AI for froNt-loaded Engineering)** projects and has received funding from the European Union programs Horizon 2020 (grant agreement n815112) and ITEA 3 Call 6 project 19009.

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