33rd Annual INCOSE international symposium

hybrid event

Honolulu, HI, USA
July 15 - 20, 2023

Value-driven Optimization Campaign Addressing Manufacturing, Supply Chain and Overall Aircraft Design Domains in the Early Development Stage

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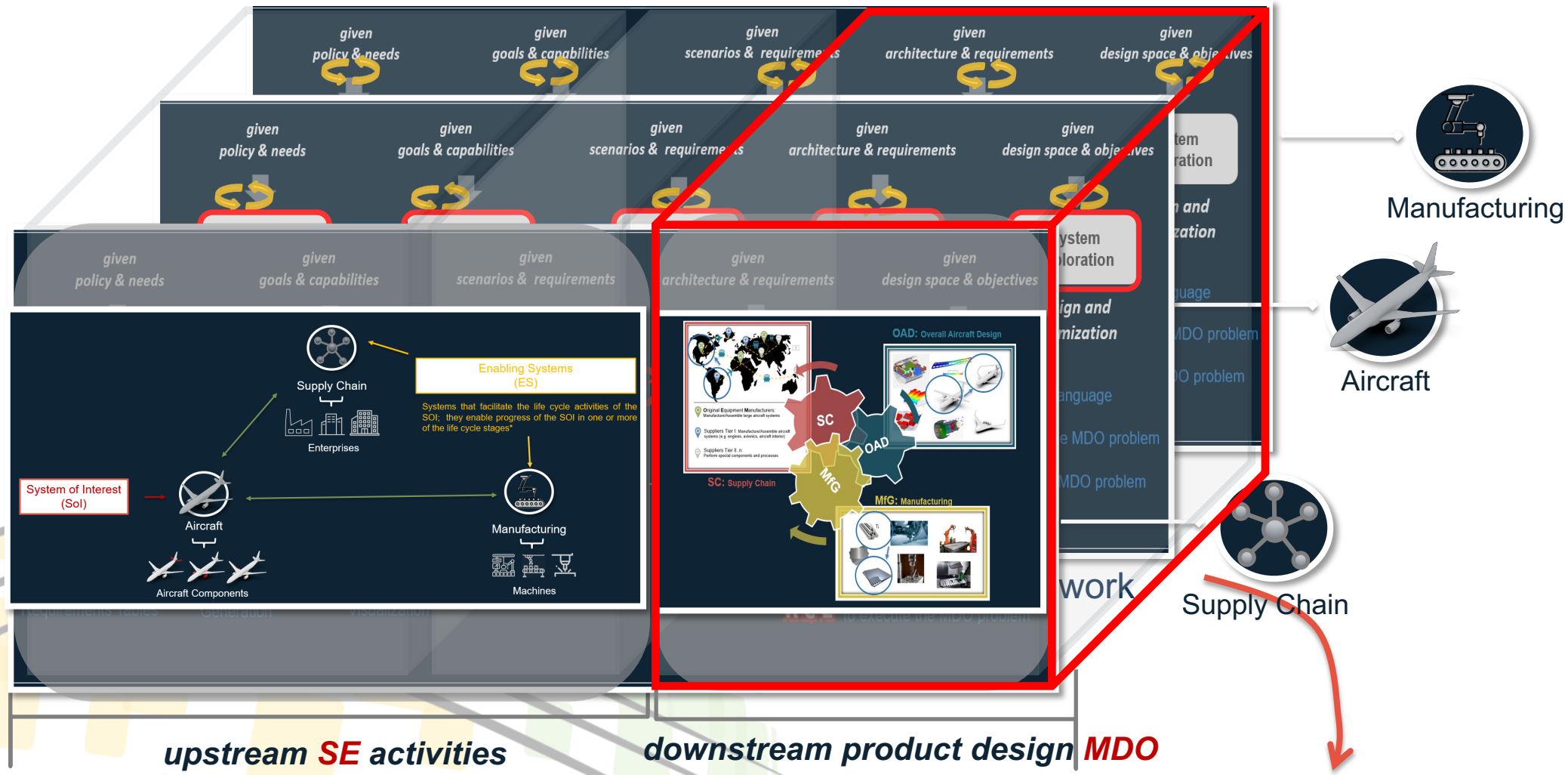
Research Objective

www.agil4.eu/Application/SupplyChain



Identify the *"Optimum Solution"* Accounting Simultaneously for Manufacturing, Supply Chain & Aircraft Design Variables

Value-driven
Multi-**D**omains **O**ptimization (**MDO**)
Campaign

Formulation

Methodology to perform MDO Campaign

Implementation

Models & Tools to perform MDO Campaign

Results

Optimum Solution for the Design, Manufacturing and Supply Chain of Horizontal Tail Plane

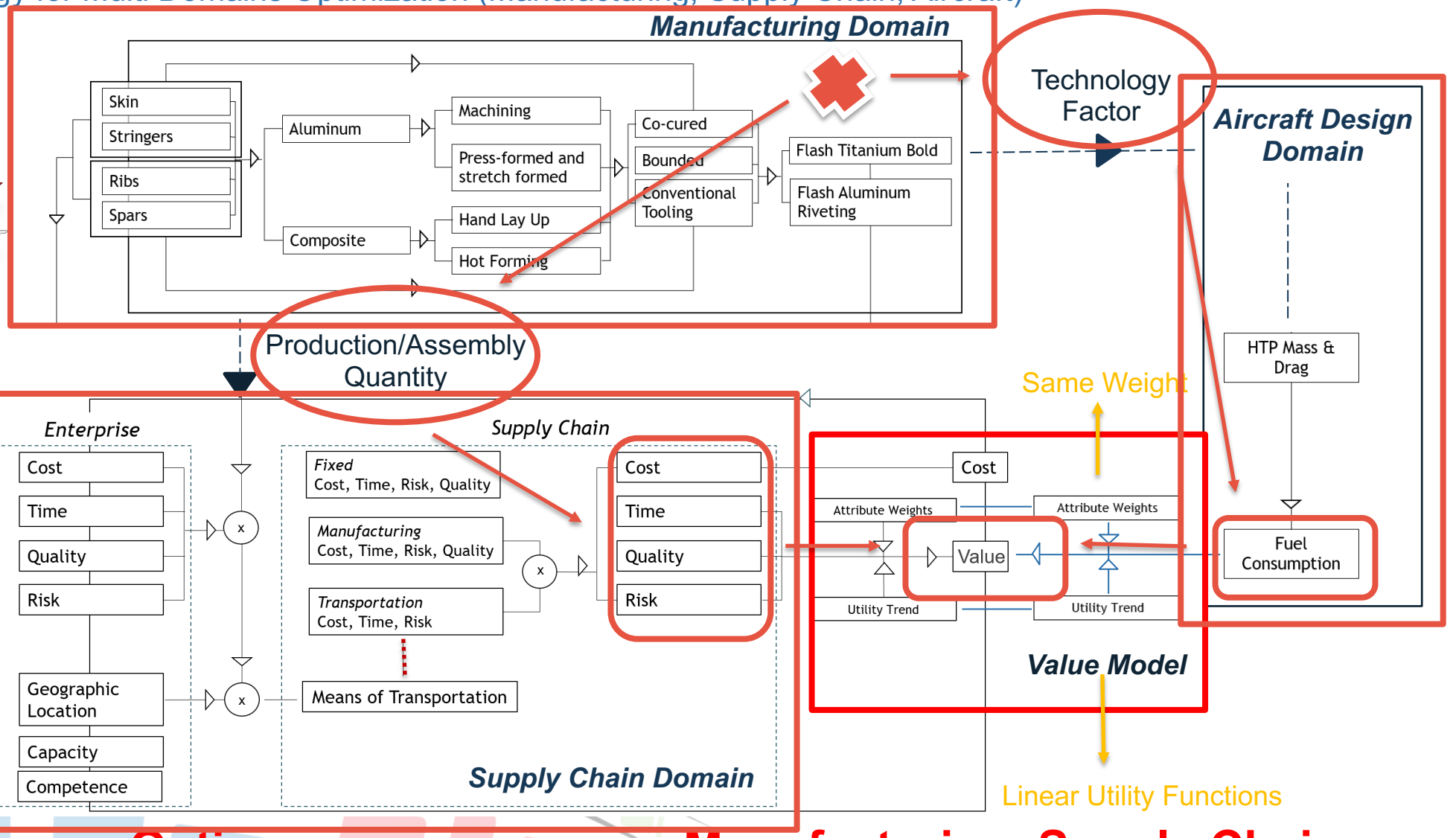
Conclusion & Further Activities

Key Fundings & Way Forward

Contents

MDO Formulation

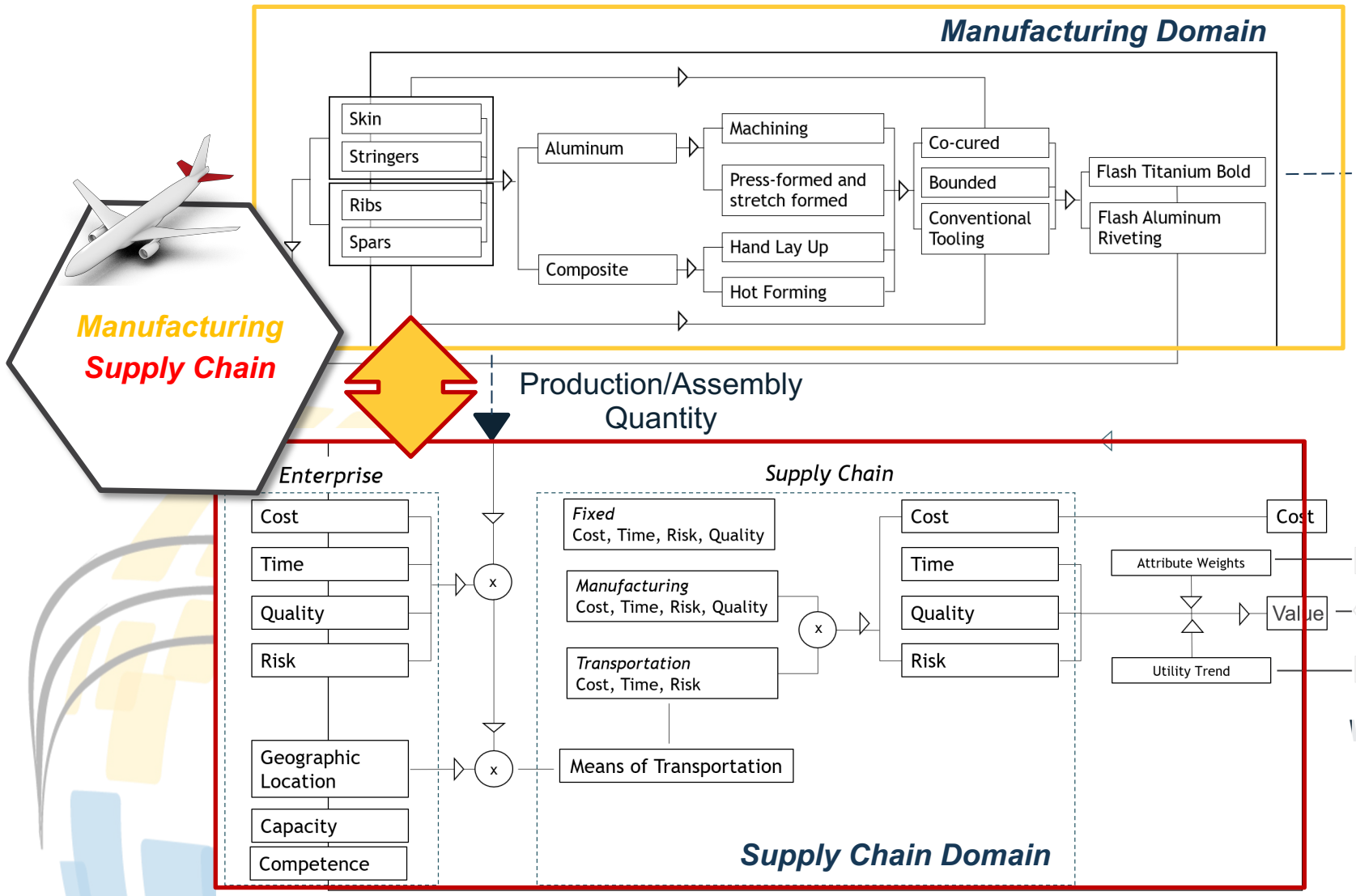
Methodology for Multi Domains Optimization (Manufacturing, Supply Chain, Aircraft)



Indentify the **Optimum** Solution considering **Manufacturing, Supply Chain, Aircraft Domains** Simultaneously

MDO Campaign

MDO* Problem coupling Manufacturing & Supply Chain Domains

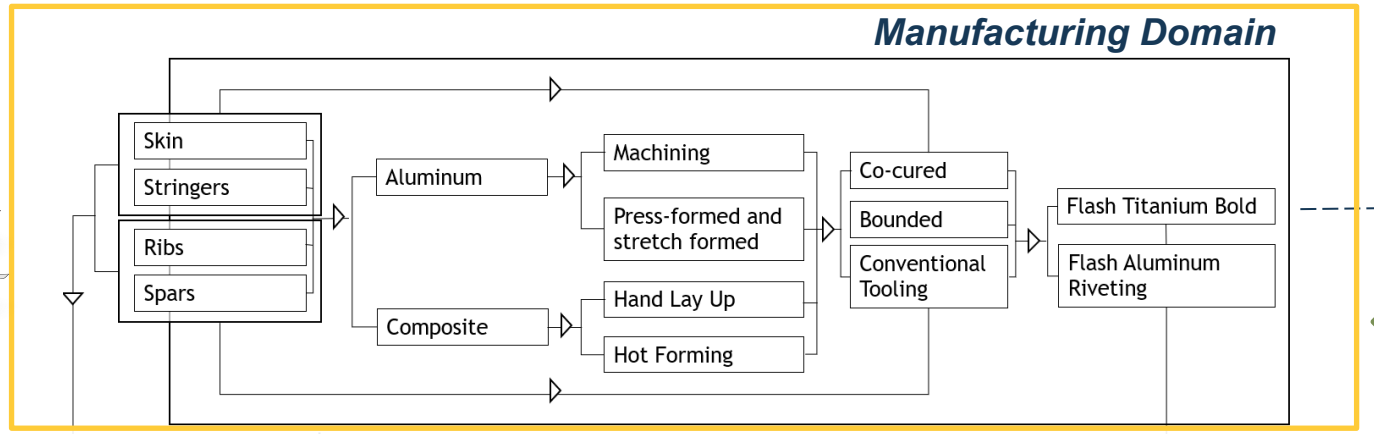


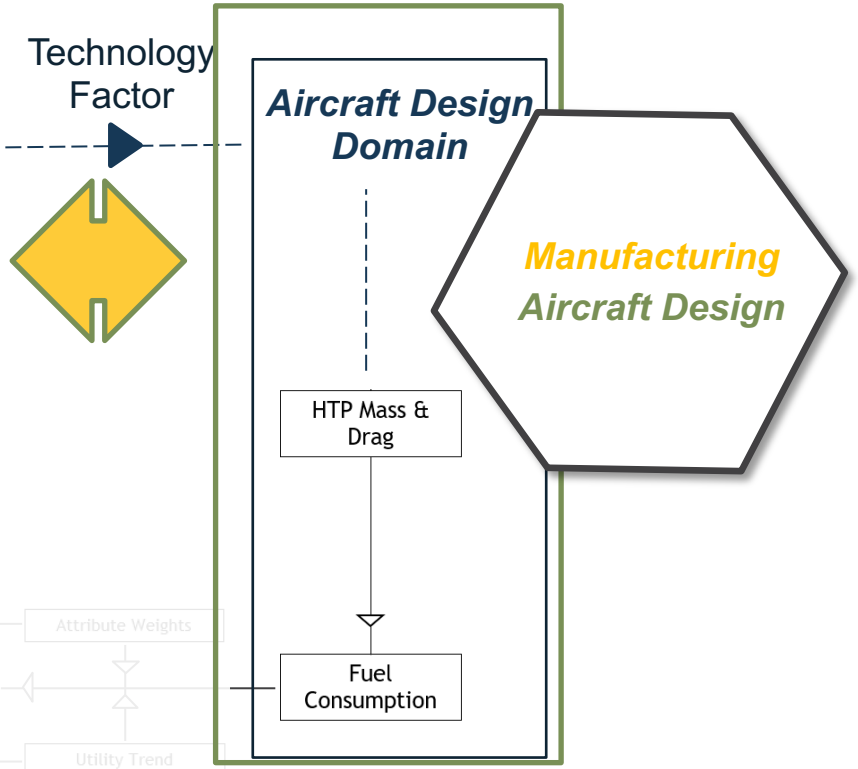
Identify the **Optimum** Supply Chain for a Specific Aircraft based on Manufacturing Choices

MDO* as Multi Domains Optimization

MDO Campaign

MDO* Problem coupling Manufacturing & Aircraft Design Domains



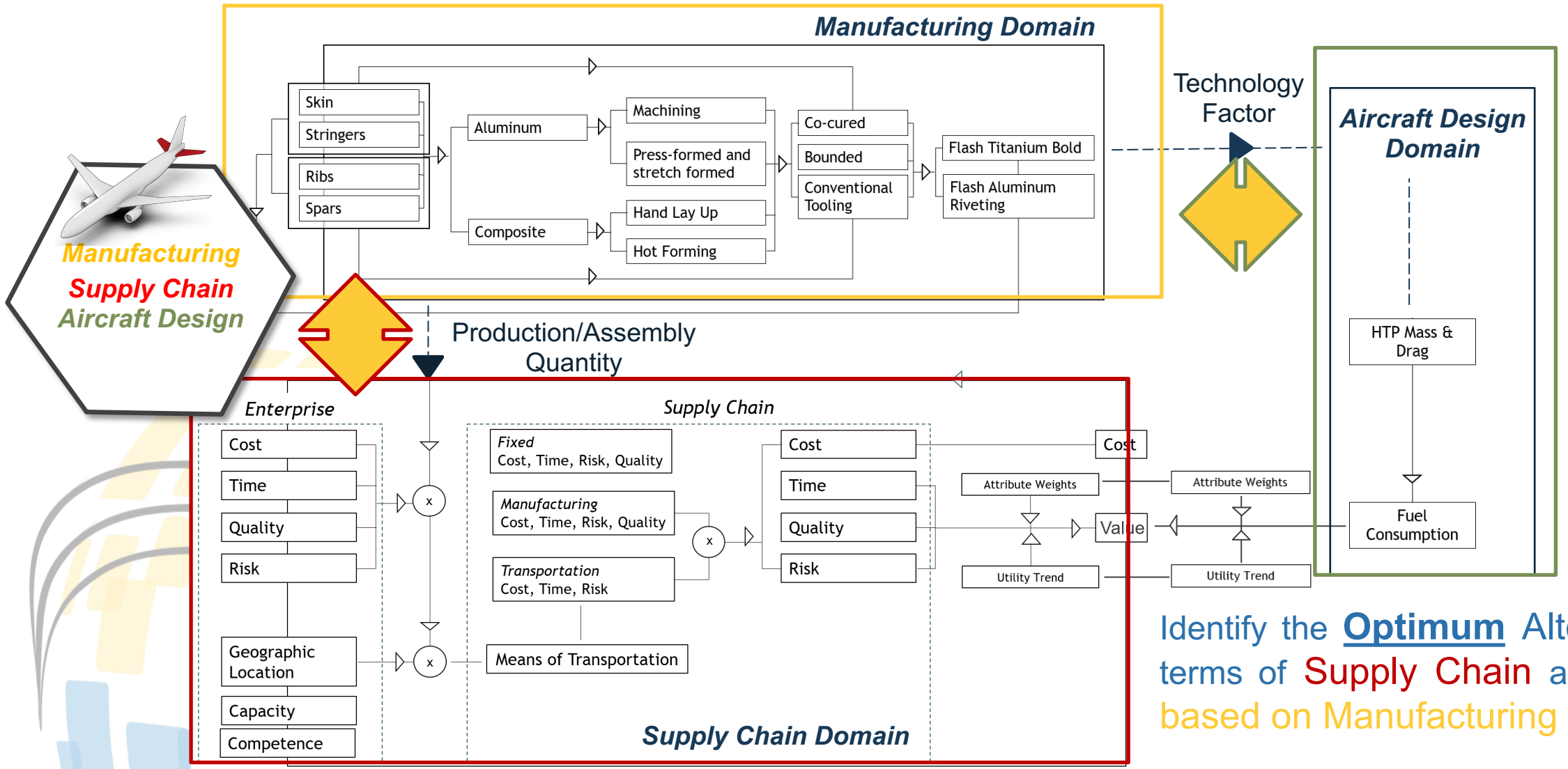


Identify the **Optimum** Aircraft based on Manufacturing Choices

MDO* as Multi Domains Optimization

MDO Campaign

MDO* Problem coupling Manufacturing, Supply Chain & Aircraft Design



Identify the **Optimum** Alternative in terms of Supply Chain and Aircraft based on Manufacturing Choices

MDO* as Multi Domains Optimization

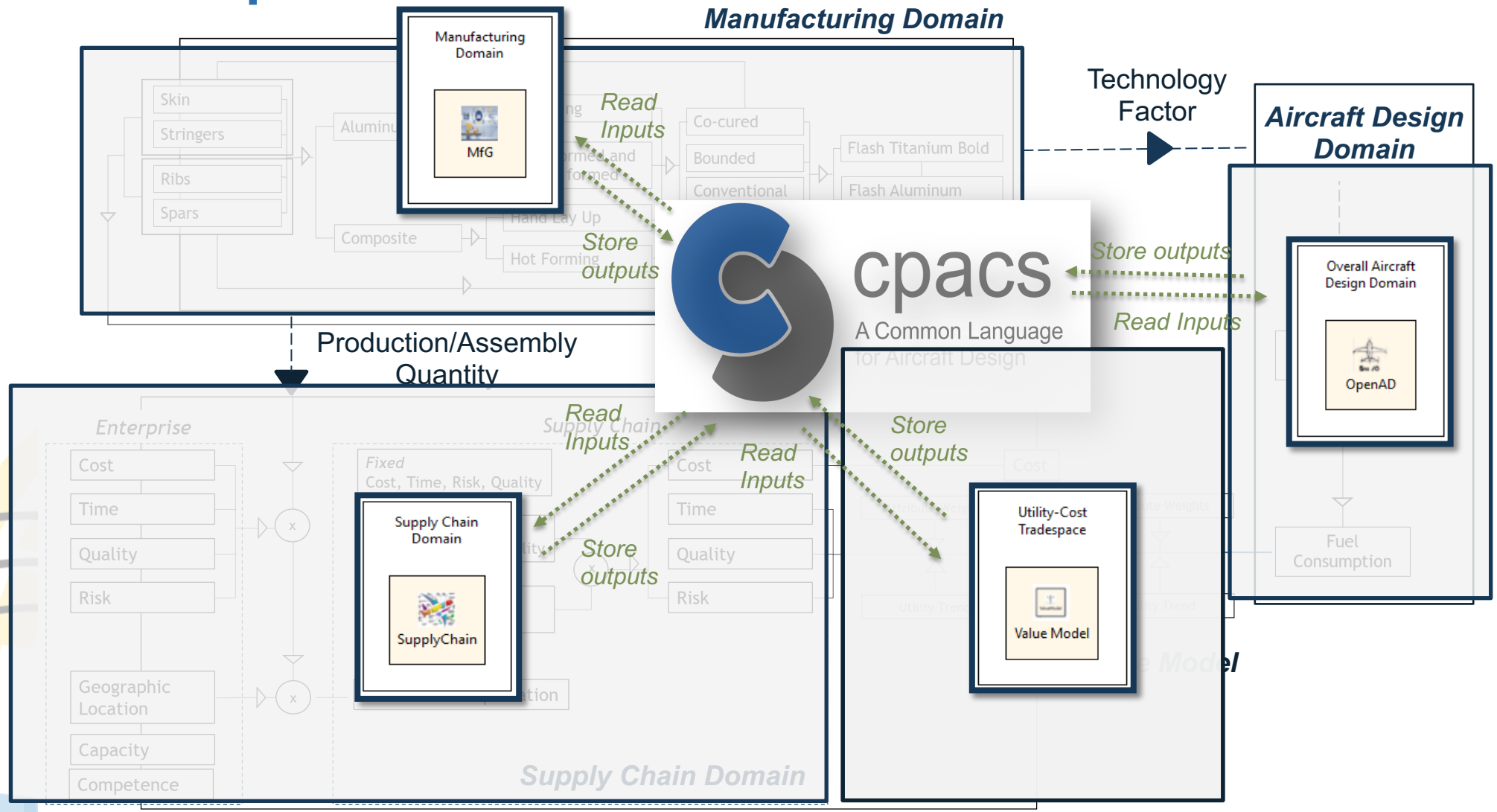
Value-driven MDO Campaign

Identify the Optimum **Supply Chain** for a Specific **Aircraft** based on Manufacturing Choices

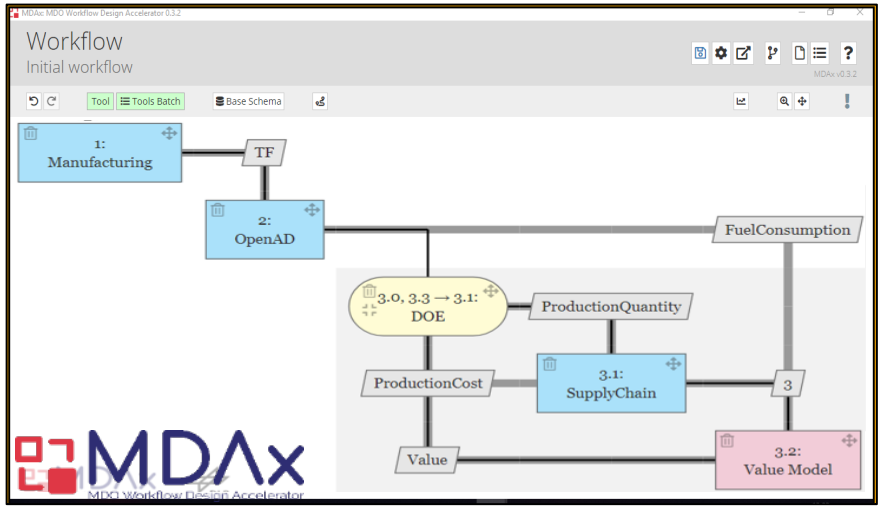
Identify the Optimum **Aircraft** based on Manufacturing Choices

Identify the Optimum Alternative in terms of **Supply Chain** and **Aircraft** based on Manufacturing Choices

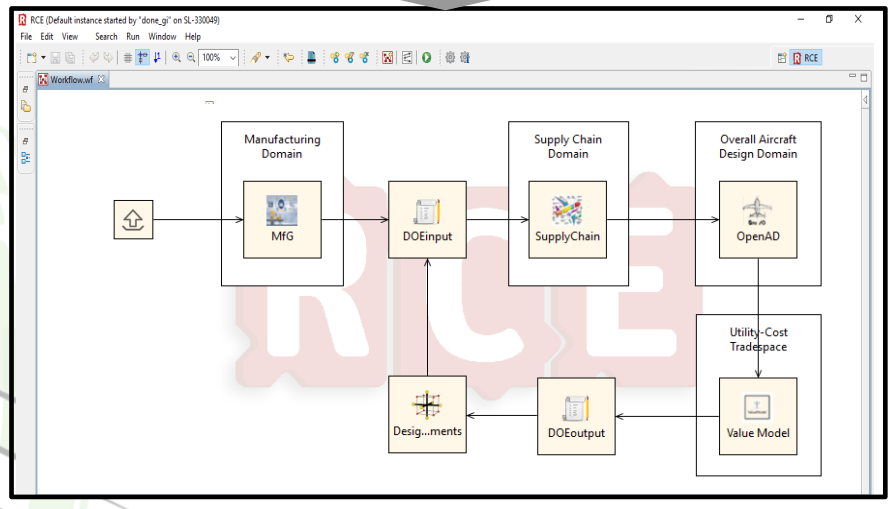
MDO Implementation



MDO Implementation



MDAx to set-up the MDO Problem



RCE to execute the MDO Problem

MDAX: Page Risueño et al., "MDAx: Agile Generation of Collaborative MDAO Workflows for Complex Systems," in AIAA AVIATION 2020
RCE: https://rcenvironment.de/.

Value-driven MDO Campaign

Manufacturing
Supply Chain

Identify the Optimum **Supply Chain** for a Specific **Aircraft** based on Manufacturing Choices

Identify the Optimum **Aircraft** based on Manufacturing Choices

Manufacturing
Aircraft Design

Manufacturing
Supply Chain
Aircraft Design

Identify the Optimum Alternative in terms of **Supply Chain** and **Aircraft** based on Manufacturing Choices

For More Information about the optimization algorithms used: N. Bartoli, M.-A. Bouhlel, I. Kurek, R. Lafage, T. Lefebvre, J. Morlier, R. Priem, V. Stilz and R. Regis, "Improvement of efficient global optimization with application to aircraft wing design," 2016.

Manufacturing & Supply Chain MDO

Identify the Optimum Supply Chain for a Specific Aircraft based on Manufacturing Choices

Material & Process	Competence
Aluminum, Machining	6
Sheet Metal, Stretch Form	10
Metal, Z-extrusion	0
Drilling	4
Fastening	7
…	..

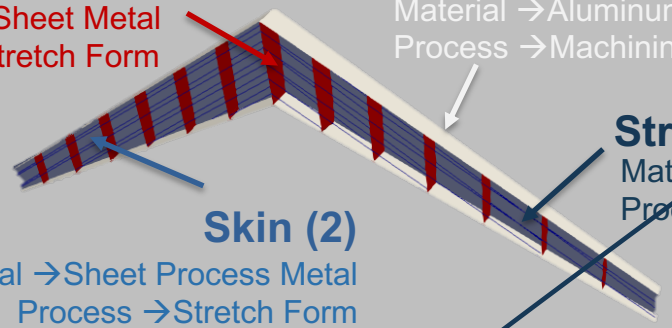
Production

Ribs (20)
Material →Aluminum & Sheet Metal
Process →Machining, Stretch Form

Spars (2)
Material →Aluminum
Process →Machining

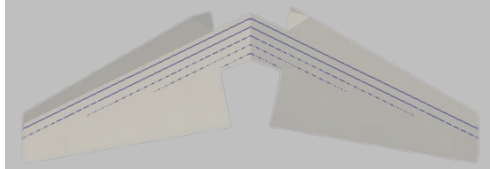
Stringers (30)
Material →Metal
Process →Z-Extrusion

Skin (2)
Material →Sheet Process Metal
Process →Stretch Form



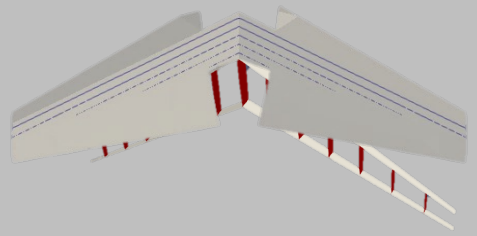
Assembly

1 **Assembly 1 (Skins & Stringers)**



Conventional Tooling
Drilling

2 **Main Assembly (HTP)**



Conventional Tooling, Solid Slim

3 **Final Assembly (HTP in Aircraft)**

Supply Chain: combination of enterprises

Manufacturing
Supply Chain

Manufacturing & Supply Chain MDO

3 MDO Problems Executed

❖ MDO Problem 1

Production of All HTP components, Few enterprises Involved

→ Test Tools Compatibility, Explore Optimization Strategy to follow

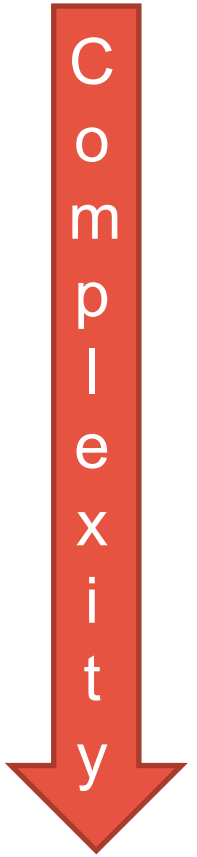
❖ MDO Problem 2

Production of Skins & Stringers, High Number of Enterprises Involved

→ Test Tool Compatibility for Remote Execution, Explore Optimization Algorithms

❖ MDO Problem 3

Production of All HTP Components & High Number of Enterprises Involved

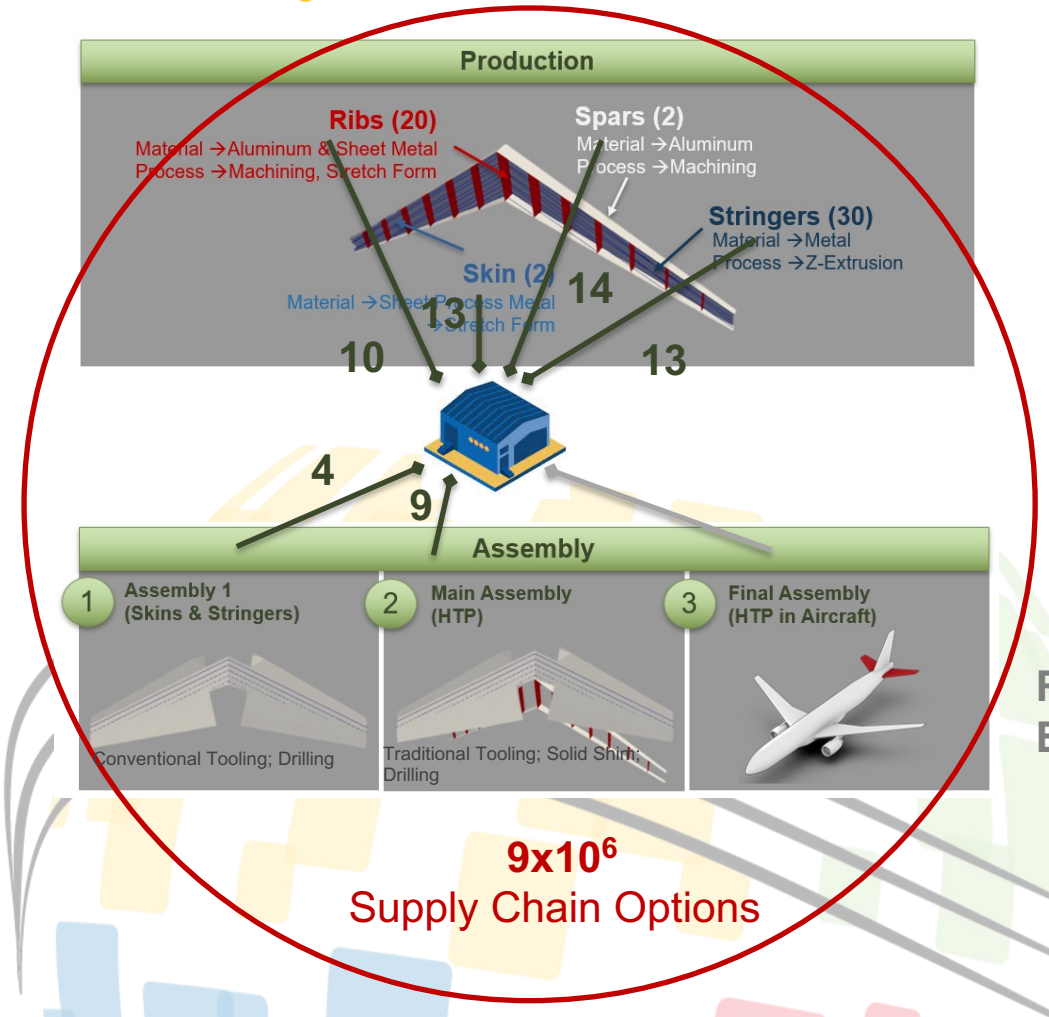


- Number of Components to be Produced
- Number of Enterprises

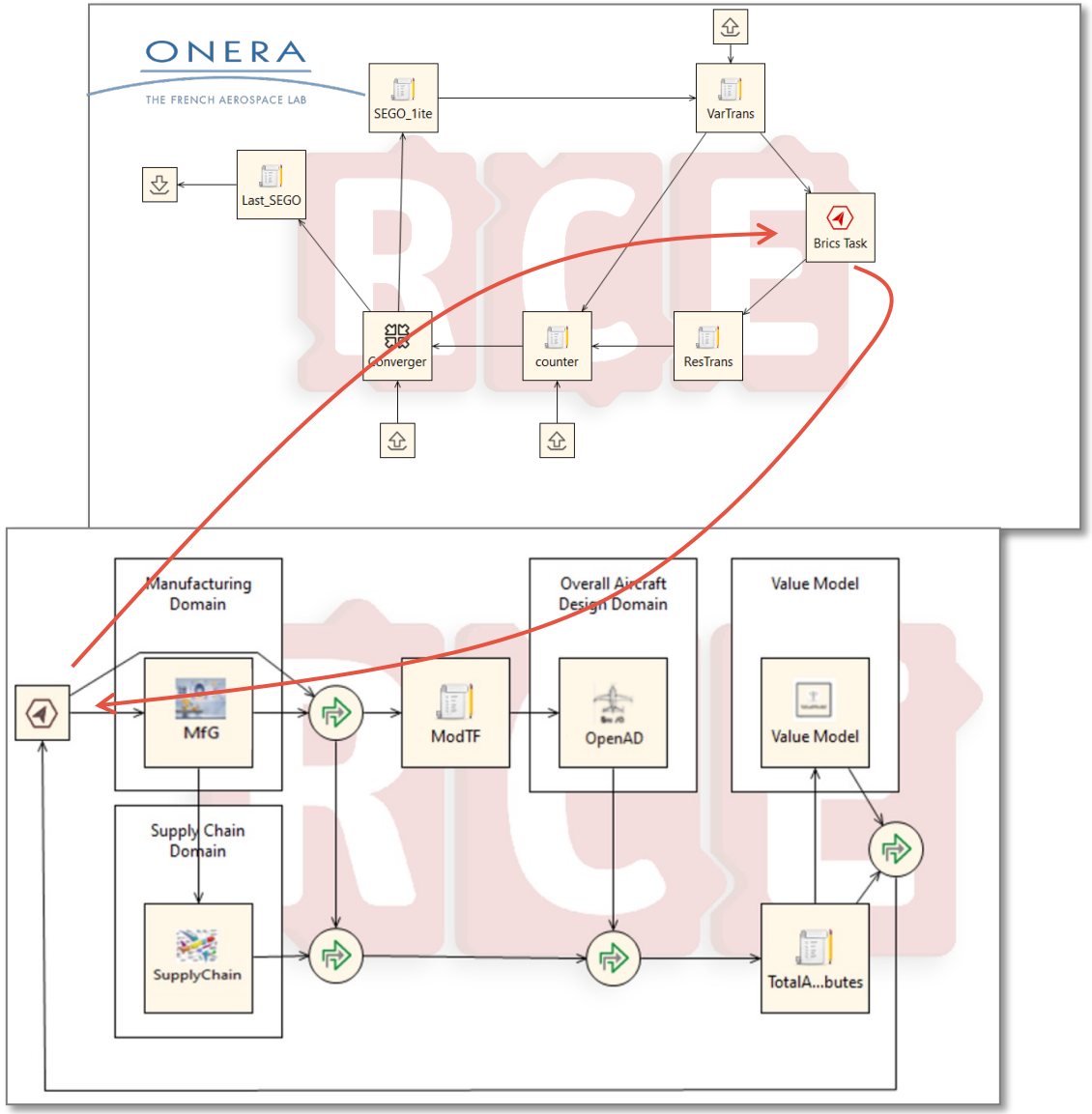
For More Information about the complete optimization design campaign: Merola´s Master Thesis (Value-driven Optimization Campaign, 2022)

MDO Problem 3: Set-up & Execution

Identify the Optimum Supply Chain for a Specific Aircraft based on Manufacturing Choices



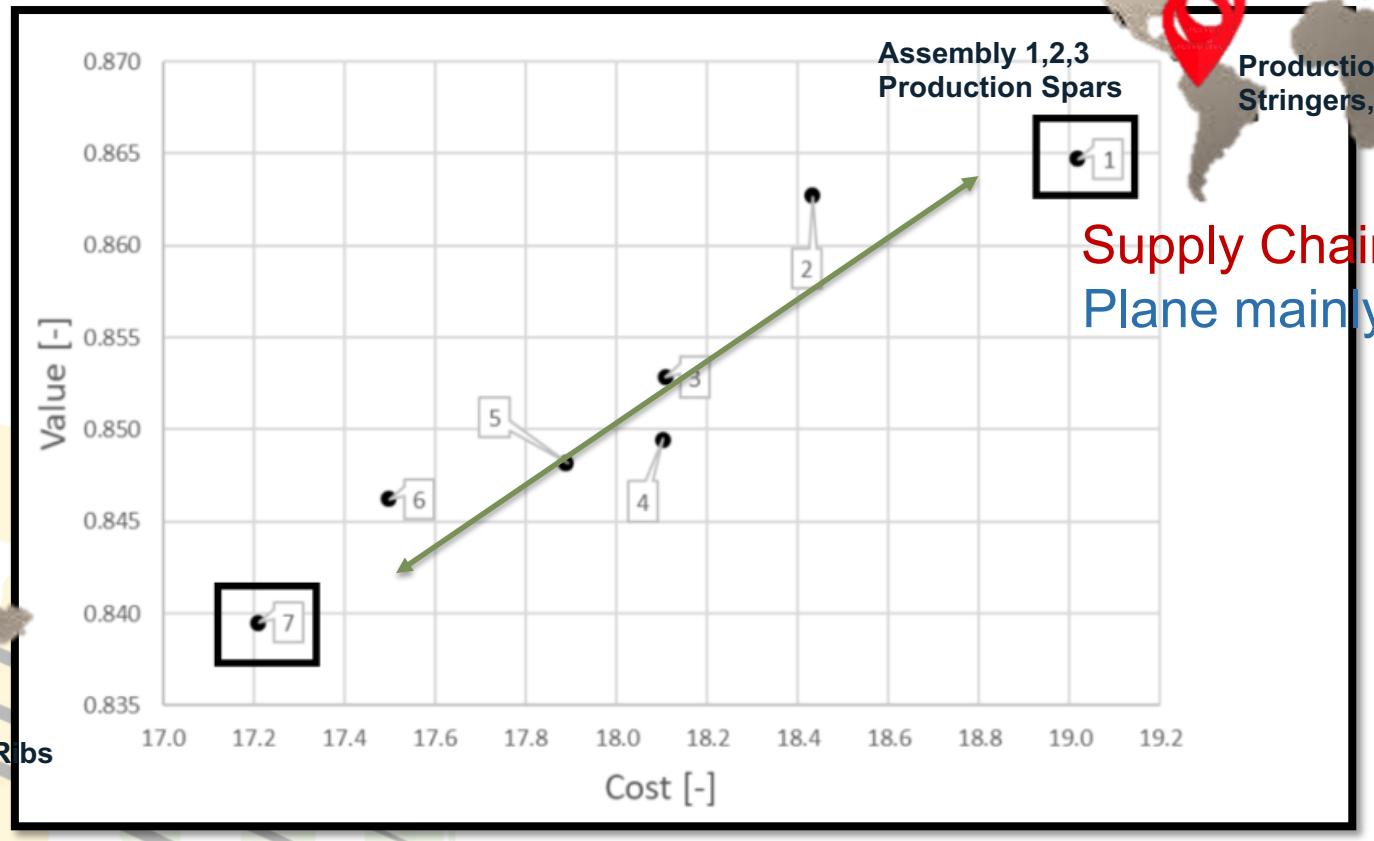
Remotely Executed



MDO Problem 3: Value-driven Pareto-Front

Identify the Optimum Supply Chain for a Specific Aircraft based on Manufacturing Choices

Supply Chain: Horizontal Tail
Plane mainly made in House



Supply Chain: Horizontal Tail
Plane mainly Outsourced

Value-driven MDO Campaign

Identify the Optimum **Supply Chain** for a Specific **Aircraft** based on Manufacturing Choices

-Collaborative Workflow Working
-Computational Time Increasing over MDO Problems (Increasing size)
-Limitation from Optimization Algorithms in Managing High Size MDO problems

Identify the Optimum **Aircraft** based on Manufacturing Choices

Manufacturing & Design MDO

Identify the Optimum Aircraft based on Manufacturing Choices

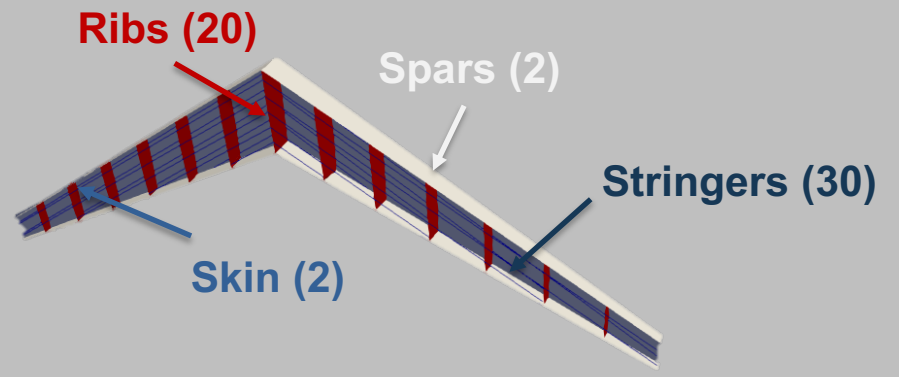
Production

Aluminum Machining Skin

Aluminum Machining Stringers

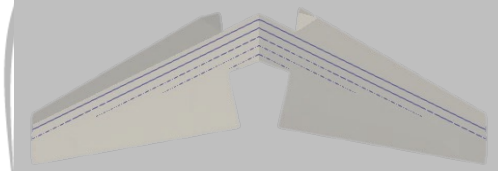
Aluminum Machining Spars

Ribs?



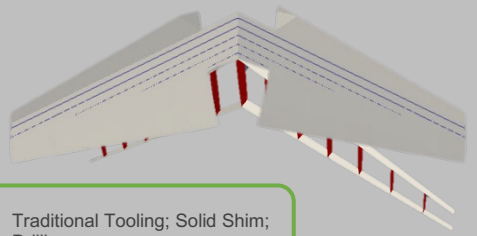
Assembly

1 **Assembly 1 (Skins & Stringers)**



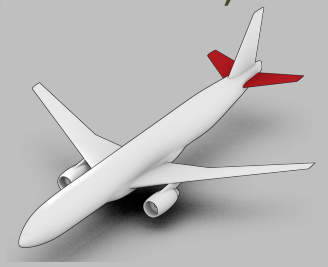
Conventional Tooling; Drilling

2 **Main Assembly (HTP)**



Traditional Tooling; Solid Shim; Drilling

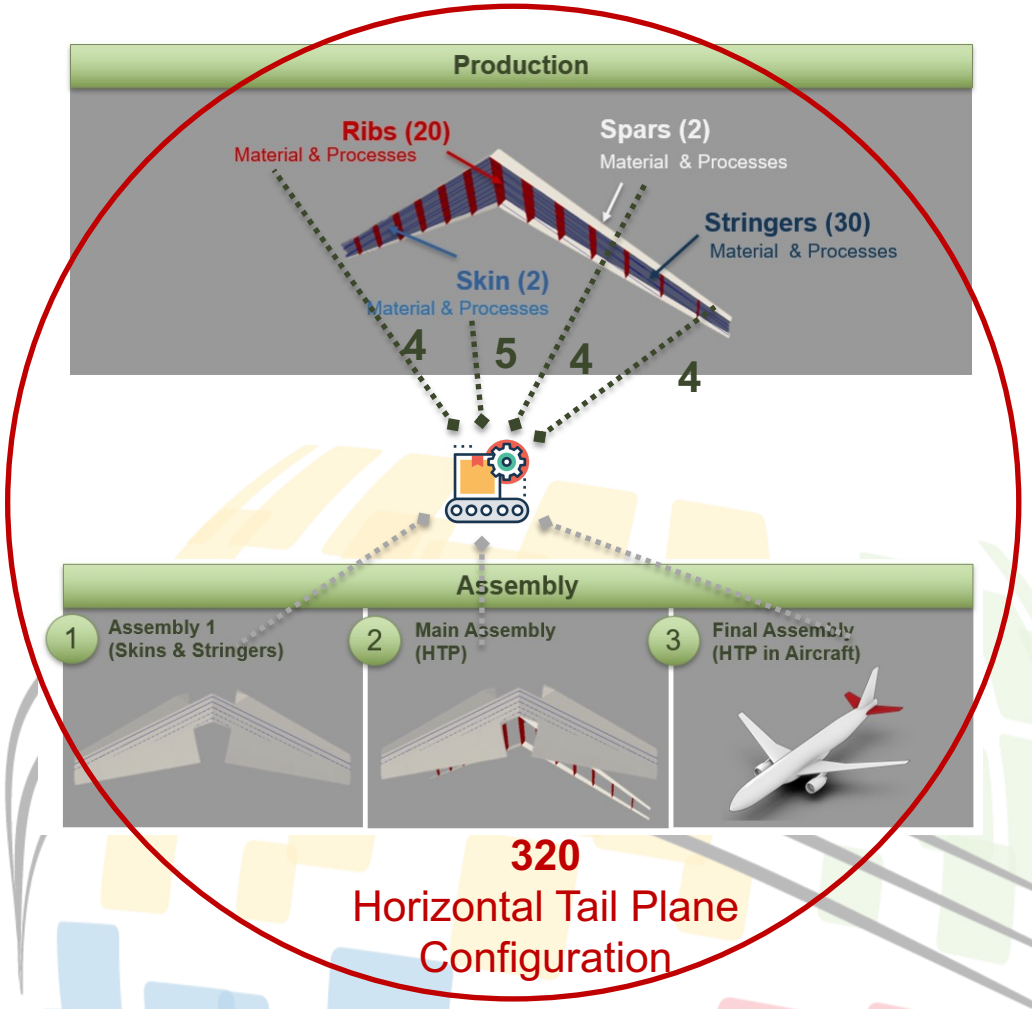
3 **Final Assembly (HTP in Aircraft)**



Manufacturing Aircraft Design

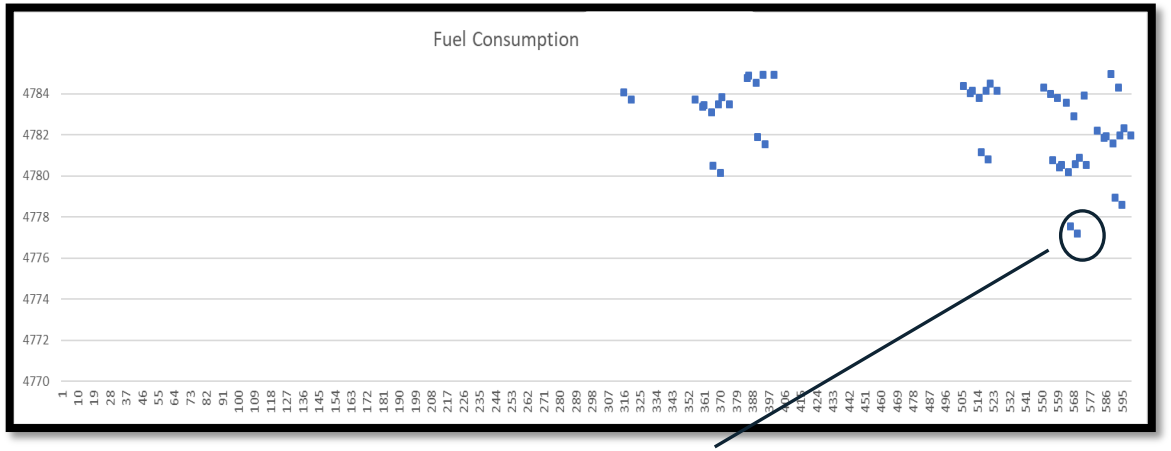
Manufacturing & Design – Set-up/Execution/Results

Identify the Optimum Aircraft based on Manufacturing Choices



320
Horizontal Tail Plane
Configuration

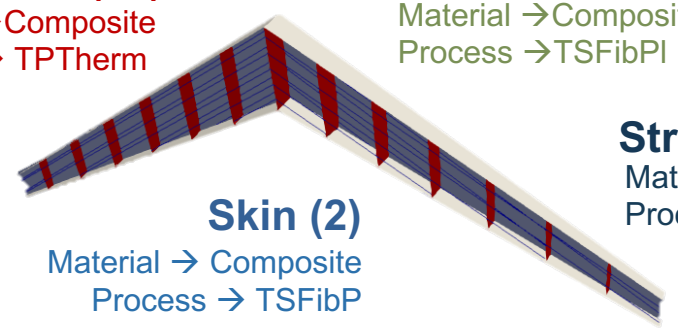
Remotely
Executed



Optimum: Aircraft with Horizontal Tail Plane mainly made by Composite

Ribs (20)
Material →Composite
Process → TPTherm

Spars (2)
Material →Composite
Process →TSFibPl



Stringers (30)
Material →Composite
Process →TSHand

Skin (2)
Material → Composite
Process → TSFibP

Manufacturing
Aircraft Design

Value-driven MDO Campaign

Identify the Optimum **Supply Chain** for a Specific **Aircraft** based on Manufacturing Choices

-Collaborative Workflow running
-Computational Time increasing over MDO Problems (increasing size)
-Limitation from Optimization Algorithms in Managing high size MDO problems

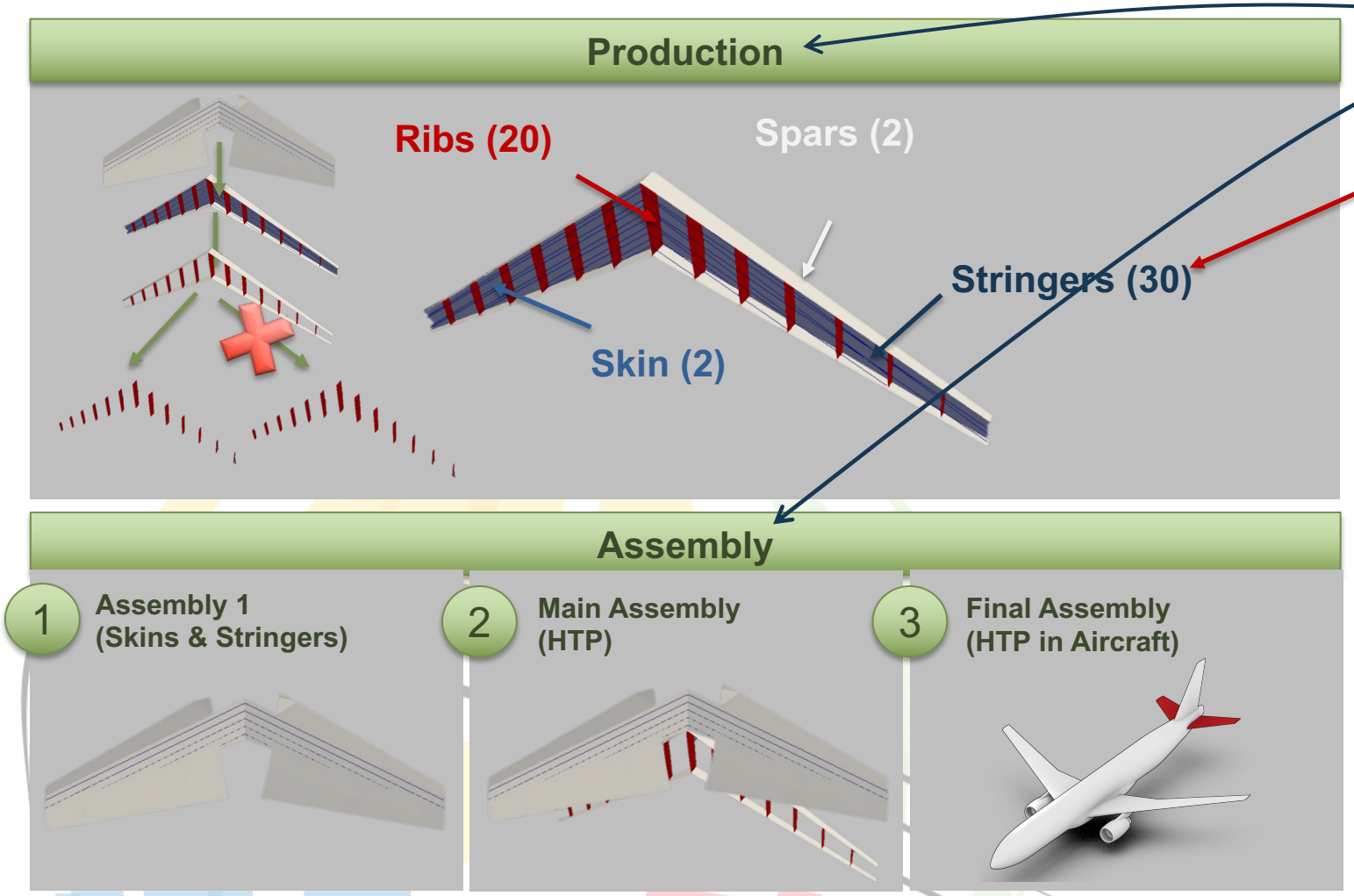
Identify the Optimum **Aircraft** based on Manufacturing Choices

- Limitation in used Optimization Algorithms in managing the high number of Unfeasible Solutions (related to the choice of Materials & Processes)

Identify the Optimum Alternative in terms of **Supply Chain** and **Aircraft** based on Manufacturing Choices

Manufacturing, Design & Supply Chain MDO

Identify the Optimum Alternative in terms of Supply Chain and the Aircraft based on Manufacturing Choices



Material & Process	Competence
Aluminum, Machining	6
Sheet Metal, Stretch Form	10
Metal, Z-extrusion	0
Drilling	4
Fastening	7
…	..

Manufacturing, Design & Supply Chain MDO

Identify the Optimum Alternative in terms of Supply Chain and the Aircraft based on Manufacturing Choices

2 MDO Problems Executed

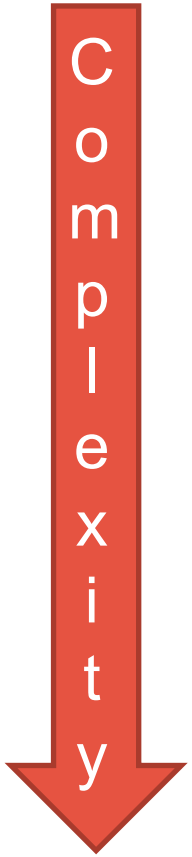
❖ MDO Problem 1

Few Manufacturing Choices, Few enterprises Involved

→ Proof of Concept

❖ MDO Problem 2

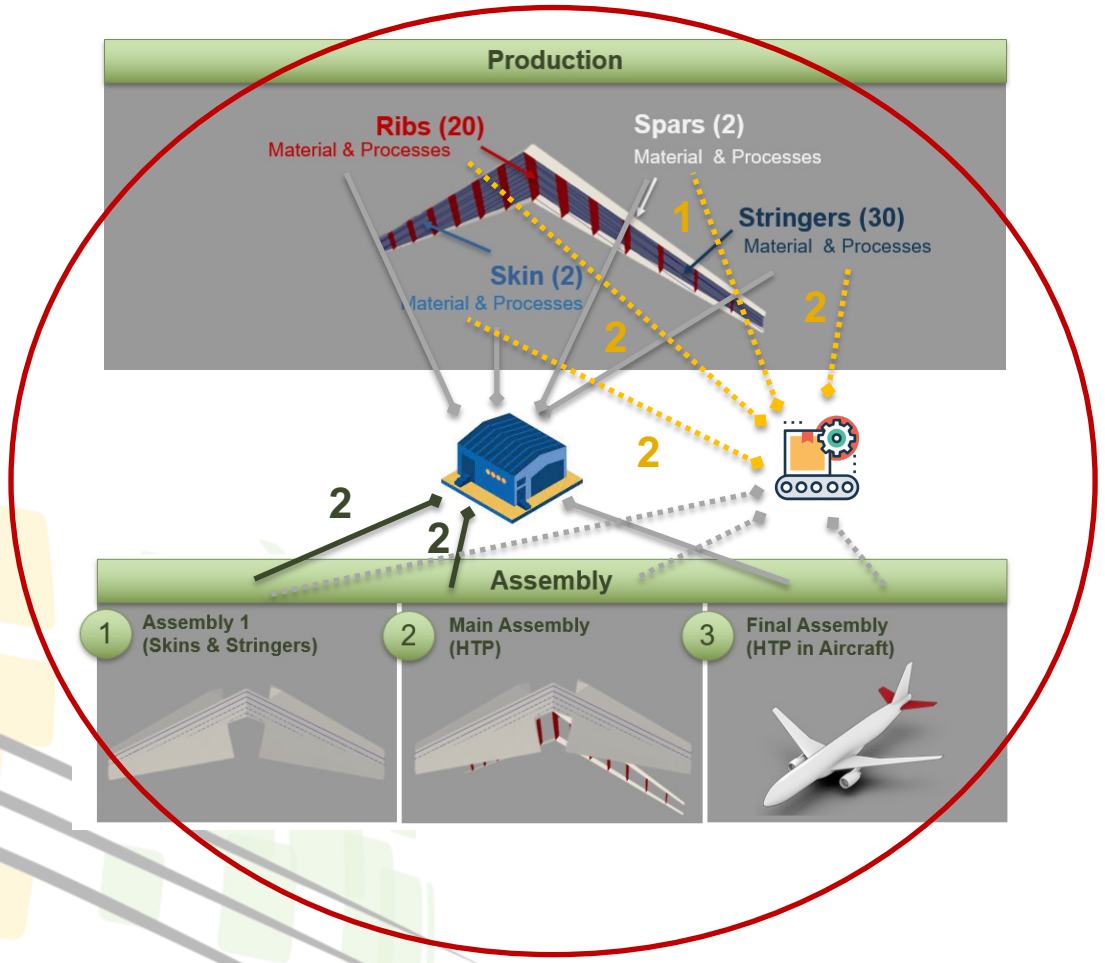
High Number of Manufacturing Choices, High Number of Enterprises Involved



- Number of Components to be Produced
- Number of Enterprises
- Number of Materials & Processes

MDO Problem 1

Identify the Optimum Alternative in terms of Supply Chain and the Aircraft based on Manufacturing Choices



16 Alternatives: 8 HTP configurations made by 2 Supply Chain Options

MDO Problem 1

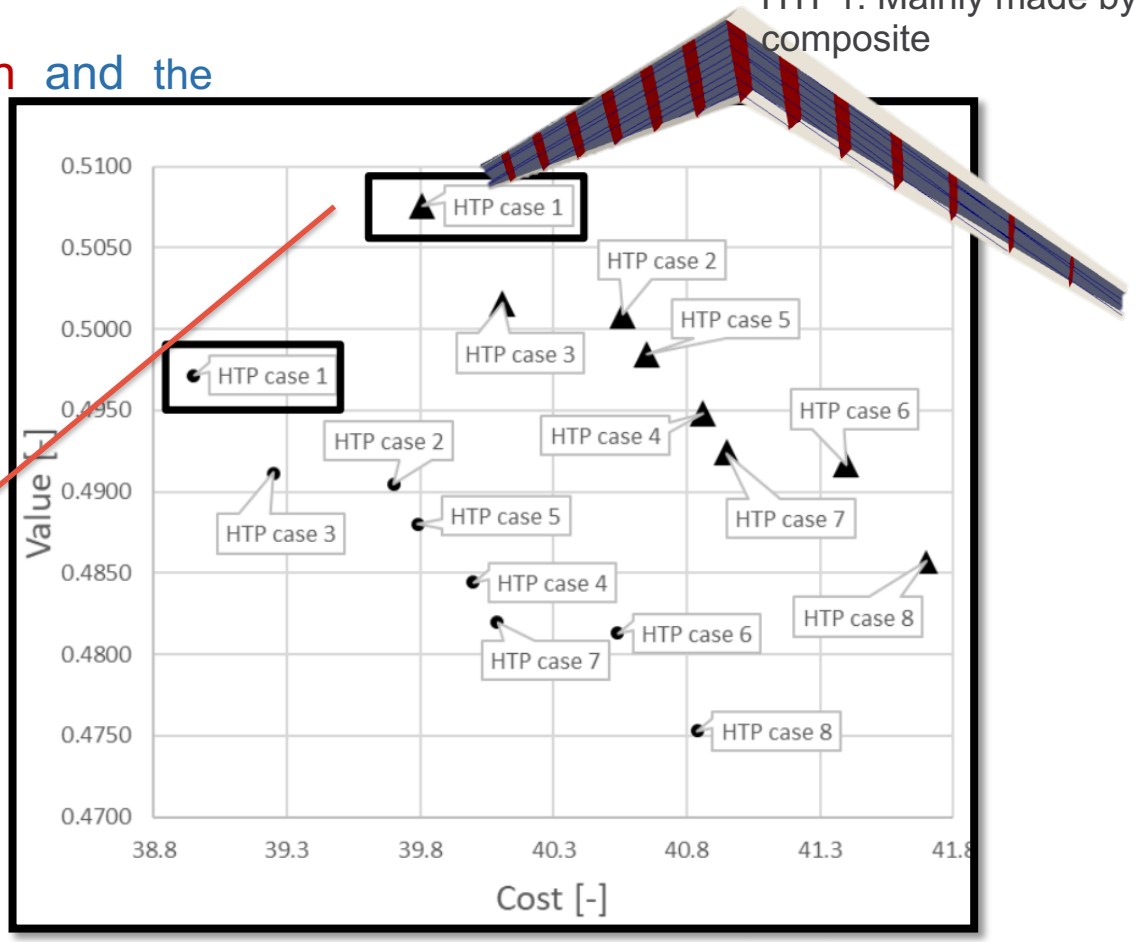
Identify the Optimum Alternative in terms of Supply Chain and the Aircraft based on Manufacturing Choices

Each Solution refers to an Aircraft Configuration (or Horizontal Tail Plane) and Supply Chain

HTP1 has highest value, however the one produced by Supply Chain 1 has a Higher Value than the one produced by Supply Chain 2

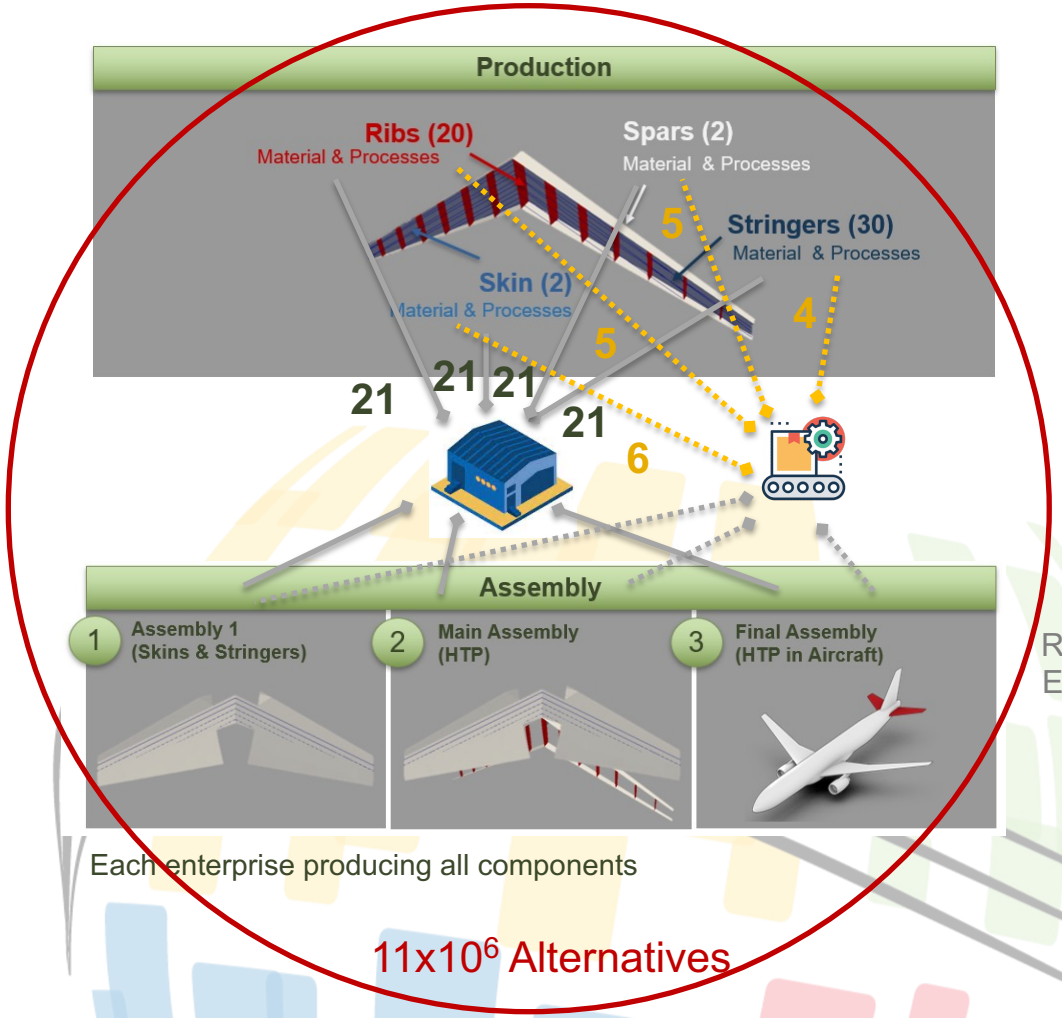
Optimum Performant & Competitive Aircraft!

HTP1: Mainly made by composite



MDO Problem 2: Preliminary Results

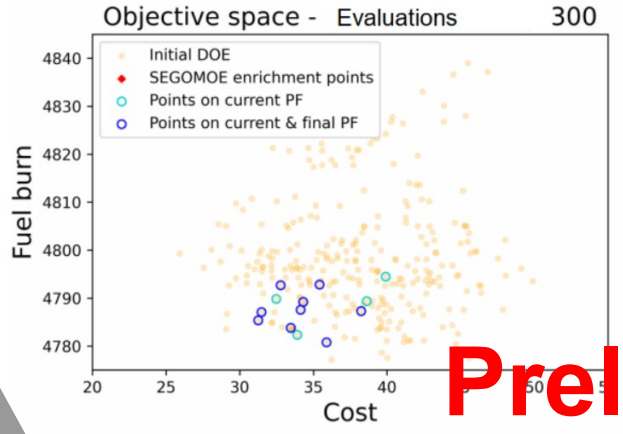
Identify the Optimum Alternative in terms of Supply Chain and the Aircraft based on Manufacturing Choices

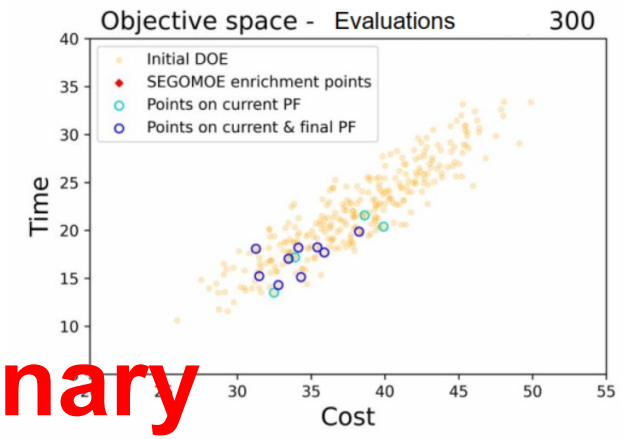


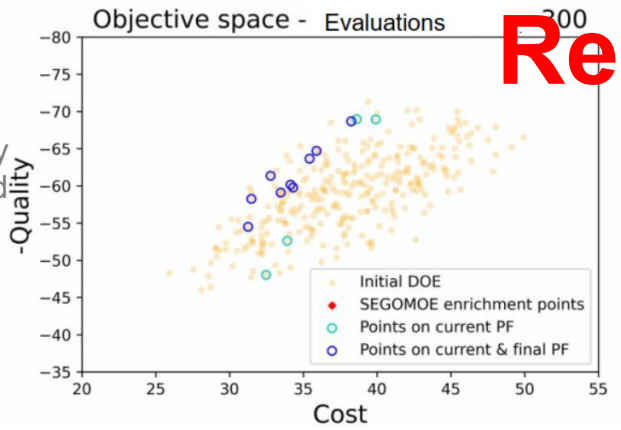
Each enterprise producing all components

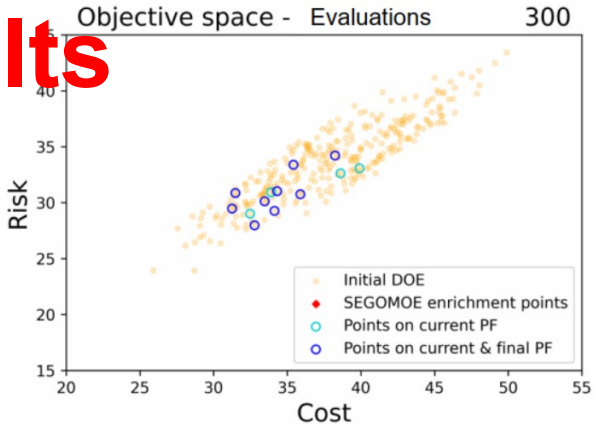
$11x10^6$ Alternatives

Remotely Executed









Preliminary Results

Value-driven MDO Campaign

Identify the Optimum **Supply Chain** for a Specific **Aircraft** based on Manufacturing Choices

-Collaborative Workflow running
-Computational Time increasing over MDO Problems (increasing size)
-Limitation from Optimization Algorithms in Managing high size MDO problems

Identify the Optimum **Aircraft** based on Manufacturing Choices

- Limitation in used Optimization Algorithms in managing the high number of Unfeasible Solutions (related to the choice of Materials & Processes)

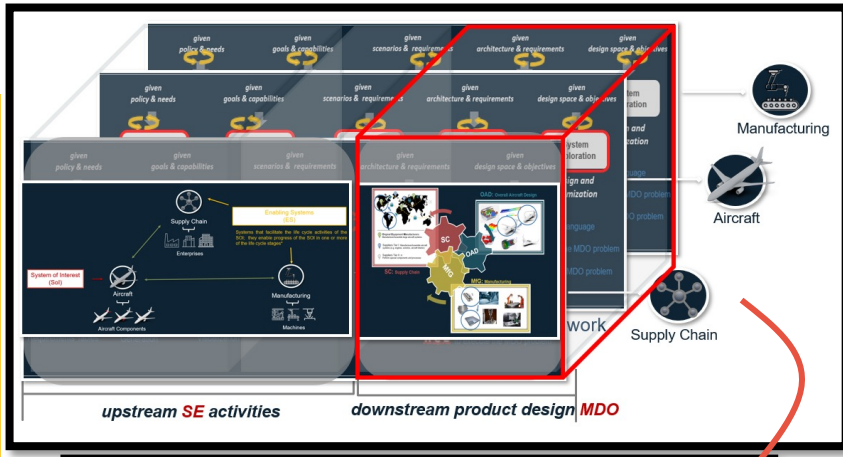
Identify the Optimum Alternative in terms of **Supply Chain** and **Aircraft** based on Manufacturing Choices

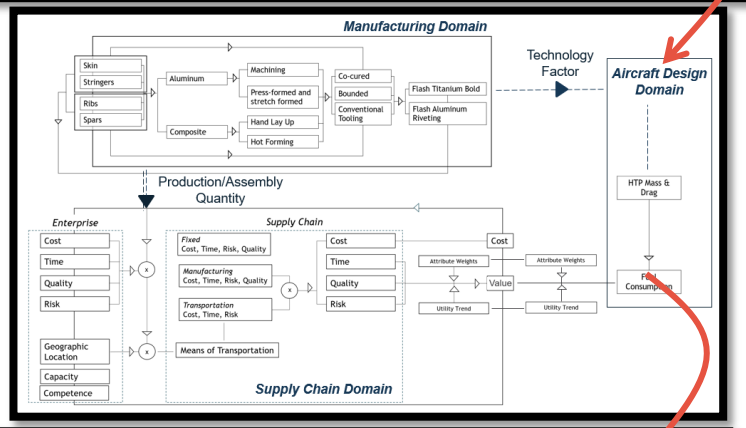
-Genetic Opimization Algorithm well suit this MDO problems
-Computation Time Drastically Increase

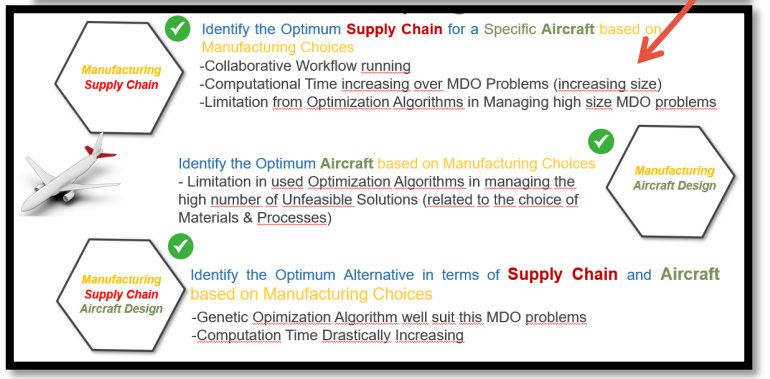
Conclusions & Further Activities

- Multi Domains Optimization Campaign including Manufacturing, Supply and Aircraft Design allows to identify the Performant and Competitive Solution
- Value-driven Pareto Front simplify the visualization of Multiple Objective Pareto-front
- Limitations in Optimization Capabilities limit the Exploration of the Design Space

- Filter Architectures before Addressing Multi Domains Optimization
- Explore other Optimization Algorithms suitable for Multi-Domains Problem







Thank you!

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hybrid event

Honolulu, HI, USA
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www.incose.org/symp2023
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LinkedIn: **Giuseppa (Pina) Donelli**