33rd Annual INCOSE international symposium

hybrid event

Honolulu HI USA

Value-driven System Engineering Approach addressing Manufacturing, Supply-chain and Aircraft Design in the Decision-Making Process

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Context

Including Manufacturing and Supply Chain Decisions in Design Stage – Why, SOTA & Concurrent Approach

Value-driven Decision Making

VALORISE to Identify the Best Solution trading Stakeholders 'Expectations

Conclusions & Further Activities

Key Fundings and Way Forward

AGILE4.0 MBSE-MDO Framework

Best Solution as the Solution Trading Stakeholders 'Expectations (design and production driven)

Application Case

Best Solution for Horizontal Tail Plane Design, Manufacturing & Supply Chain

Contents

Systems Definition

Decision Making Process including Manufacturing and Supply Chain

Supply Chain

Enterprises

Enabling Systems
(ES)

Systems that facilitate the life cycle activities of the SOI; they enable progress of the SOI in one or more of the life cycle stages*

System of Interest
(SoI)

Aircraft

Aircraft Components

Manufacturing

Machines

*INCOSE System Engineering Handbook, 4th Edition

Systems Engineering Stages

Decision Making Process including Manufacturing and Supply Chain

Identify Stakeholders 'Needs; Explore Concepts; Propose Viable Solutions

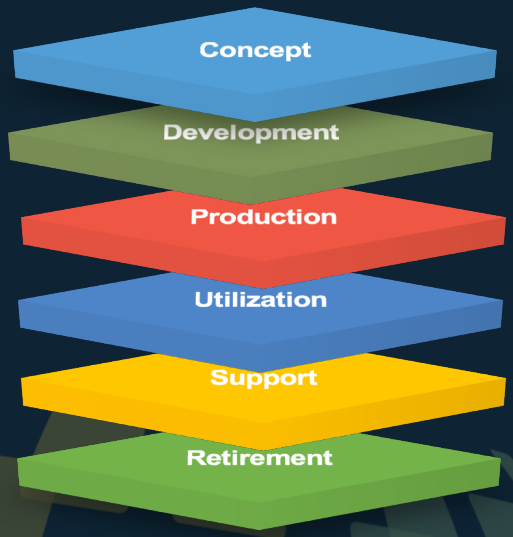
Refine System Requirements; Create Solution Description; Build System; Verify and Validate

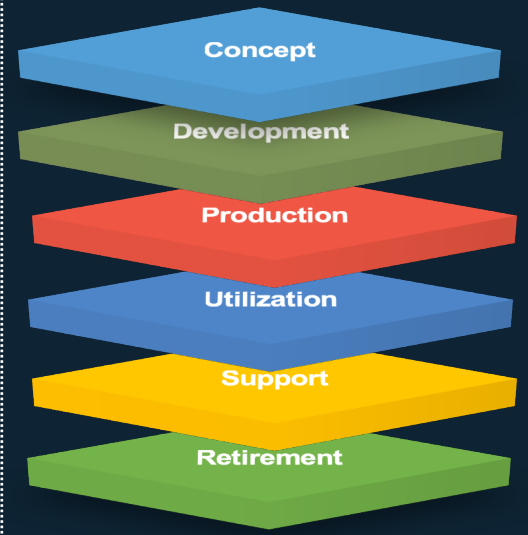
Produce System, Inspect and Test

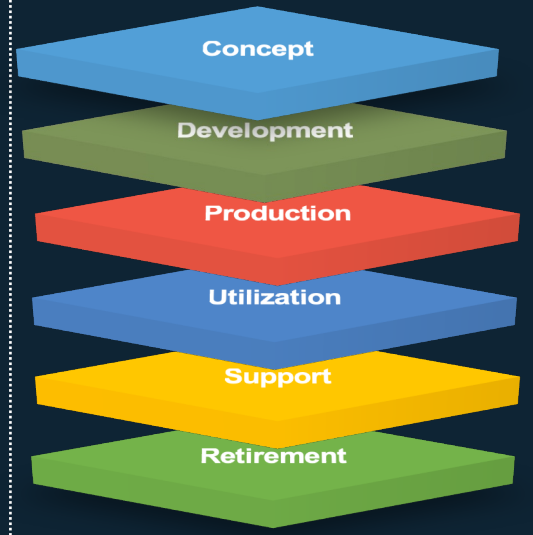
Operate System to Satisfy Users 'Needs

Provide Sustained System Capability

Store, Archive or Dispose of System







Each System has a Life-cycle Model*°

Aircraft
(SOI)

Supply Chain
(Enabling System)

Manufacturing
(Enabling System)

*ISO/IEC TR 27748,2010

Traditional Sequential Approach

Aircraft Design Fixed → Production Starts (Manufacturing, Supply Chain)

Identify Stakeholders 'Needs; Explore Concepts; Propose Viable Solutions

Refine System Requirements; Create Solution Description; Build System; Verify and Validate

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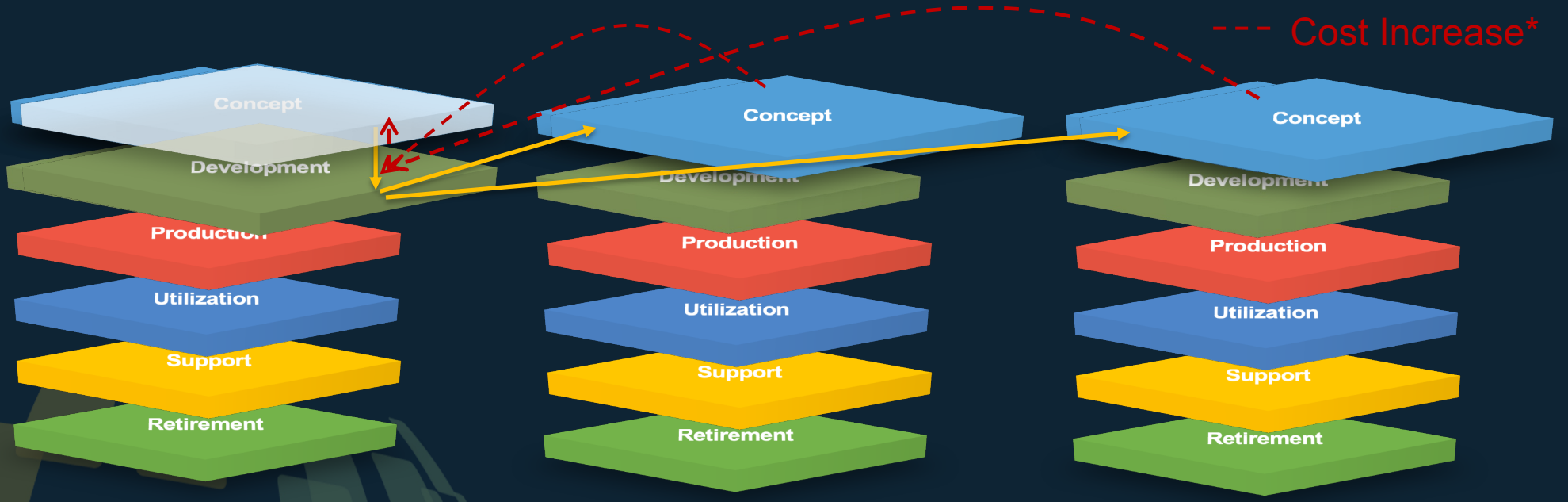


Aircraft
(SOI)

Supply Chain
(Enabling System)

Manufacturing
(Enabling System)

Supply Chain & Manufacturing Decisions **not** Addressed in Concept Stage

Concurrent Approach

Among Advantagies*:
- Avoid recall and rework in later stages (save cost, time)
- Perform Design and Production Driven Trade-off studies (in design phase)

Design of Aircraft, Manufacturing & Supply Chain at the same time

Identify Stakeholders 'Needs; Explore Concepts; Propose Viable Solutions

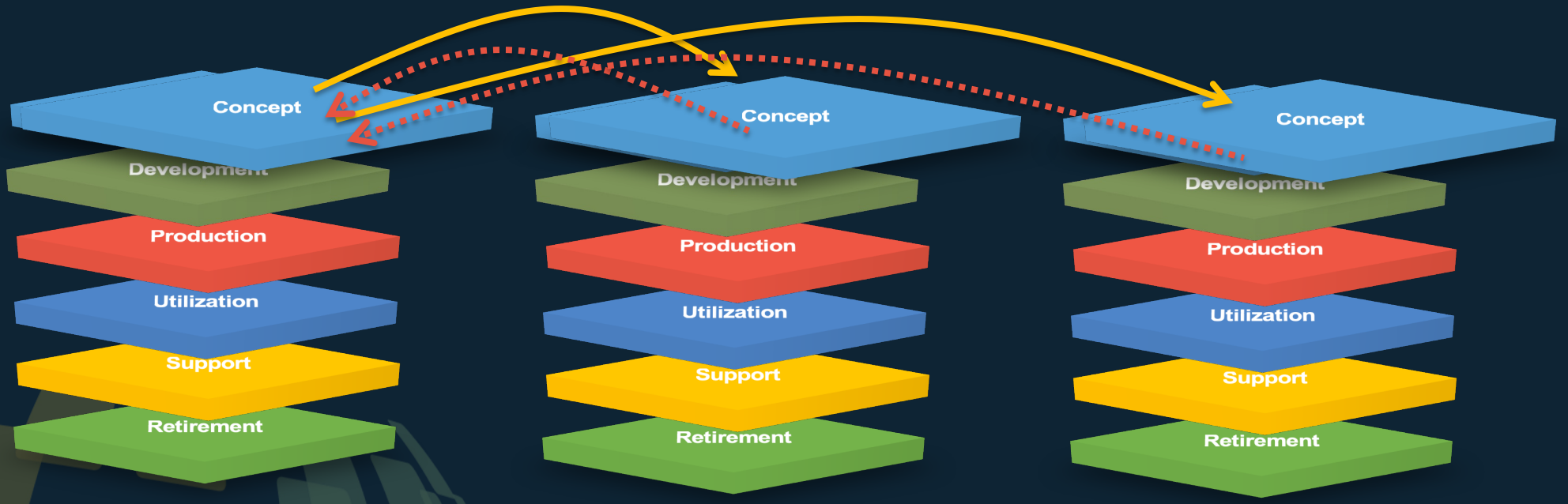
Refine System Requirements; Create Solution Description; Build System; Verify and Validate

Produce System, Inspect and Test

Operate System to Satisfy Users 'Needs

Provide Sustained System Capability

Store, Archive or Dispose of System



Aircraft (SOI)

Supply Chain (Enabling System)

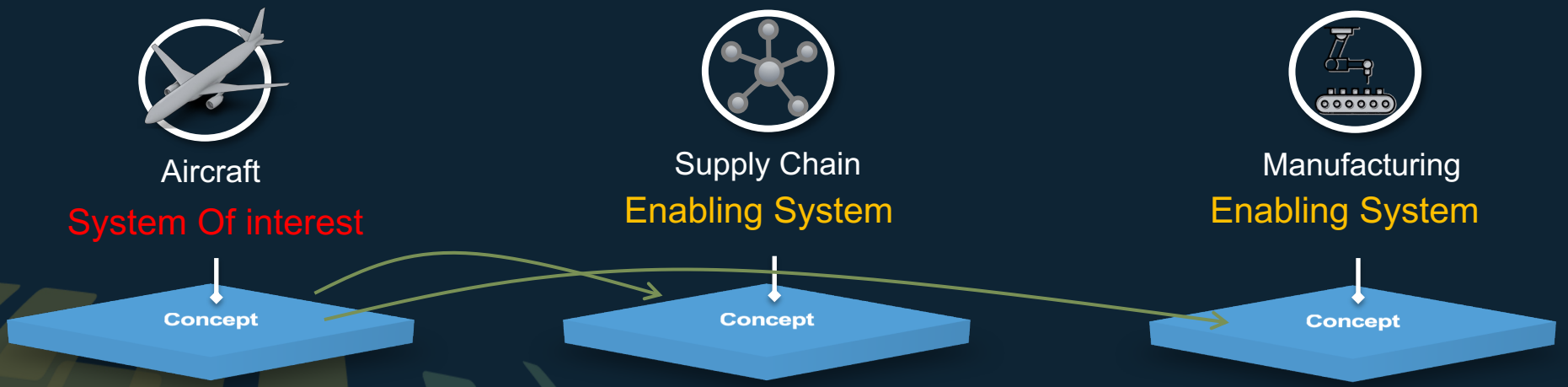
Manufacturing (Enabling System)

Aircraft, Supply Chain & Manufacturing Decisions Addressed in Concept Stage

*INCOSE System Engineering Handbook, 4th Edition

Concurrent Approach

Decision Making Process considering Manufacturing, Supply Chain and Aircraft



Create Relationships already in the Concept Stage between SOI and Enabling Systems

to

Propose a "Best Solution" Accounting for Manufacturing, Supply chain and Aircraft Design Variables

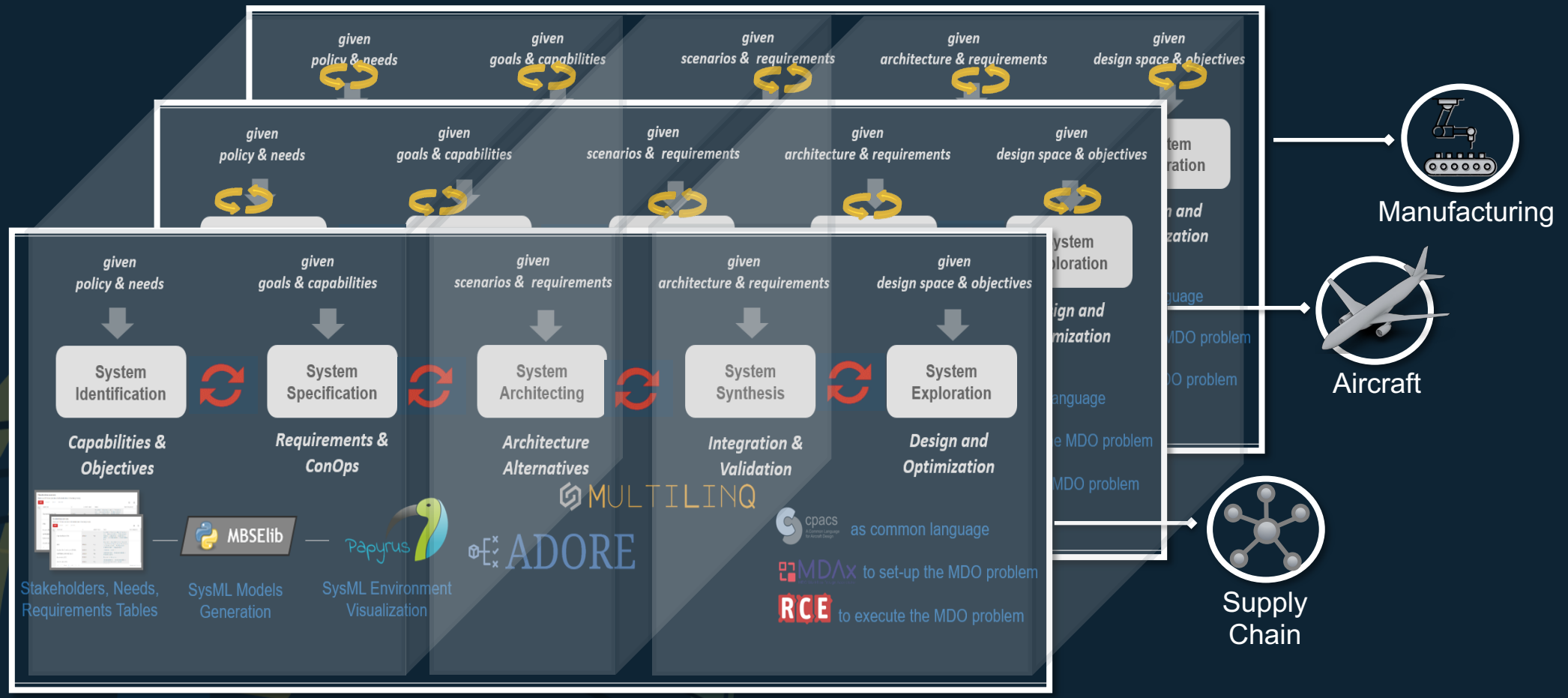
AGILE4.0 MBSE-MDO Framework

Best Solution as the Solution Matching Stakeholders´Expectation
Decision Making Process to link System Identification & System Exploration

AGILE 4.0 MBSE-MDO Framework

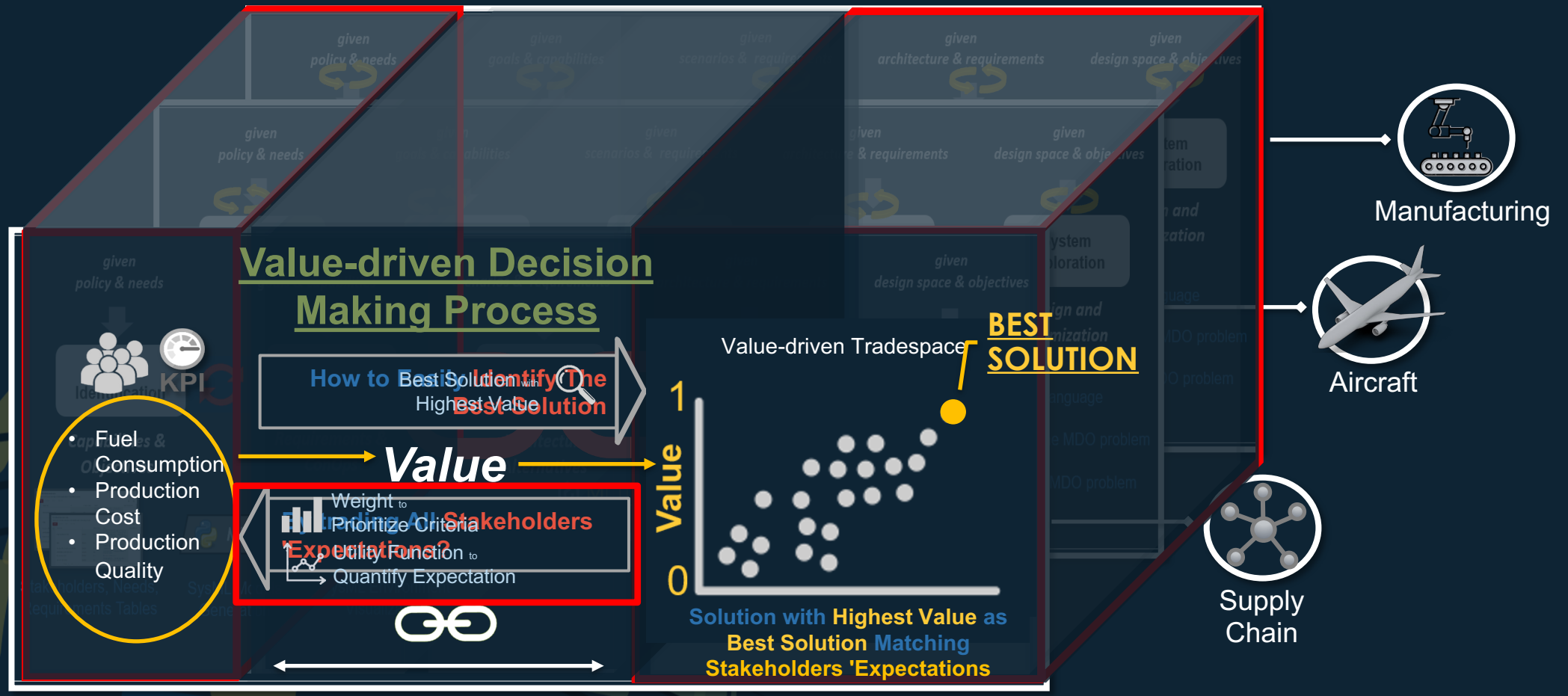
AGILE4.0 MBSE-MDO Framework

Extended to Enabling Systems (Supply Chain & Manufacturing)



www.agil4.eu/Application/SupplyChain

Value-driven Decision Making



Value-driven Decision-Making

Attributes

An attribute is a decision-maker perceived metric that measures how well a decision maker-defined objective is met*

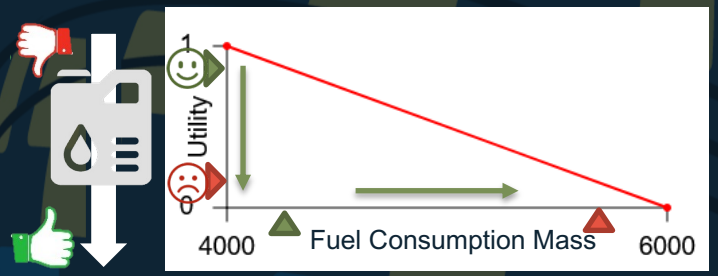
KPI

Weights

The decision-maker defines the relative importance of each attribute*

Utility Functions

Quantify the decision maker´s preferences*



- Trend to Model Stakeholders 'Expectations
- Boundaries to reduce Solution Design Space (Constraint)

V a l u e

Web-based Interactive Dashboard

- Quantify & Assess Stakeholder´s Expectations
- Real-time Data Visualization
- Explore Strategic Decision Scenarios

VALORISE

Value-driven tr**A**despace visua**L**izati**O**n, explo**R**at**I**on & as**SE**ssment

Application Case – Set-up & Objective

Design, Manufacturing & Supply Chain of an Horizontal Tail Plane

Stakeholders 'Expectations

Supply Chain

Production Time

Production Quality

Production Risk

* Key Players in Supply Chain Management

Optimized Design Space

Manufacturing Processes

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 Metal
Process →Stretch Form

10 14 13 13

4 9

Assembly Processes

1 Assembly 1 (Skins & Stringers) — Conventional Tooling; Drilling

2 Main Assembly HTP — Conventional Tooling, Solid Shim, Drilling

3 Final Assembly (HTP in Aircraft)

Identify the Best Supply Chain producing a specific Horizontal Tail Plane

Trading Stakeholders 'Expectations

Identify the Best Solution on Design Space

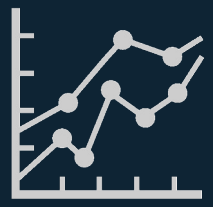
Trading Stakeholders 'Expectations

9x 10^6 Alternatives

9x Supply Chains

Value-driven Decision-Making Process

Stakeholders Expectations Quantitative Trend (Utility Functions)



Stakeholders Expectations Qualitative Trend

- Reference Value-driven Design Space
  - Not influenced by Stakeholders 'Expectations
  - (Linear Utility Functions, Same Weights)
- Stakeholders Value-driven Design Space
  - Driven by Stakeholders´Expectations
  - (Stakeholders Utility Functions, Same Weights)

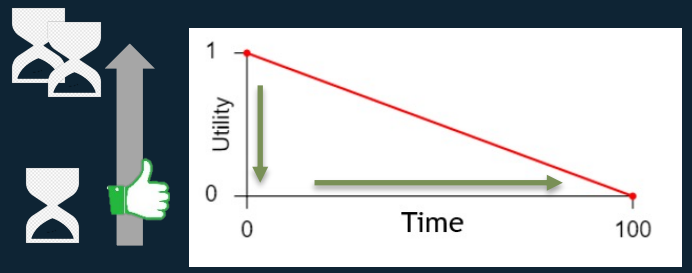
Identify the Best Supply Chain producing a specific Horizontal Tail Plane

Trading Stakeholders 'Expectations

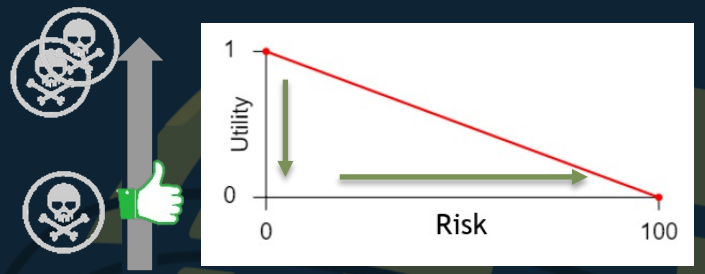
Reference Value-driven Design Space

Linear Utility Functions, Same Weights

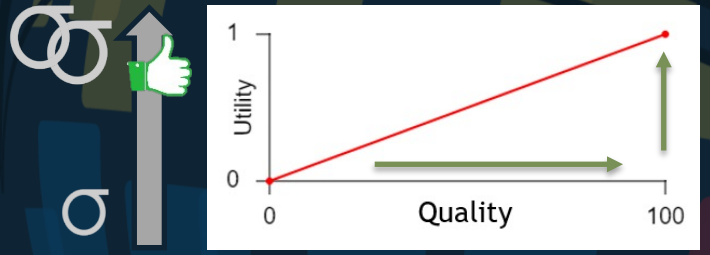
Production Time (0.33)



Production Risk (0.33)



Production Quality (0.33)



No Stakeholder 'Influence →

- Linearized Data Inputs*
- Linear Functions
- Same Weights

Reference Design Space

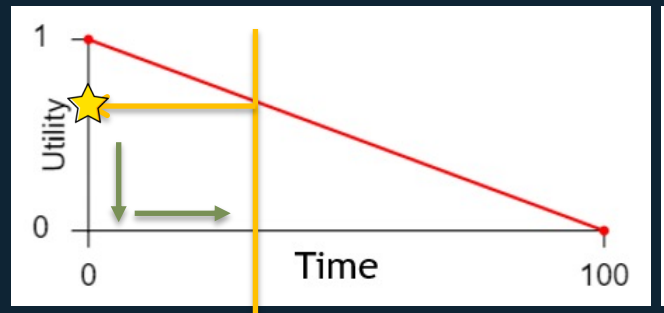
Is the **SOLUTION WITH HIGHEST VALUE** also **THE BEST SOLUTION** (matching Stakeholder's Expectations?)

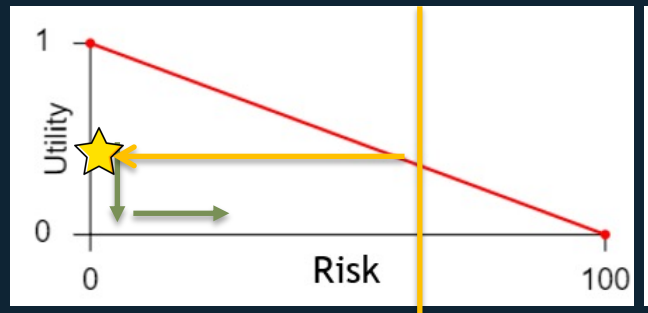
*Linearized Dimensionless Data because of Industrial IP

Stakeholder Value-driven Design Space

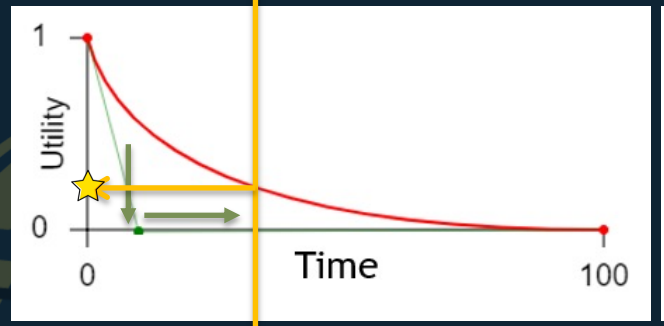
Utility Functions to Quantify Stakeholder´s Expectations – Implemented in VALORISE

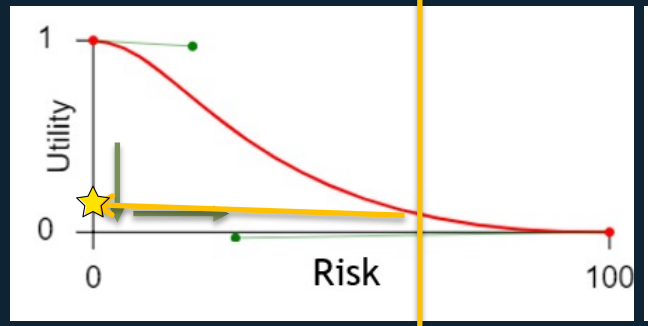
Linear Case

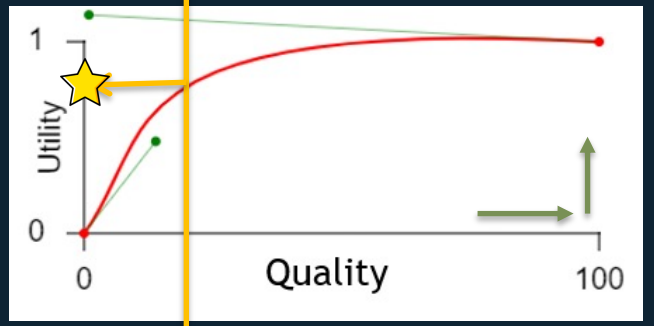




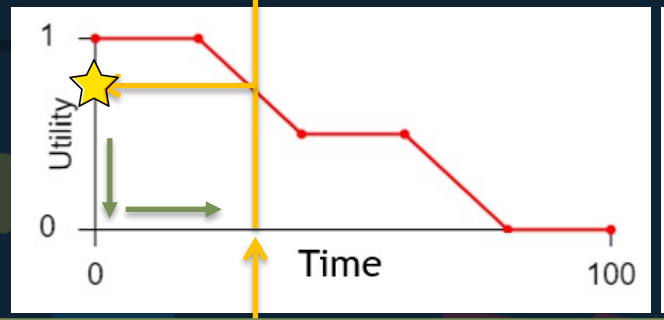
Stakeholder A

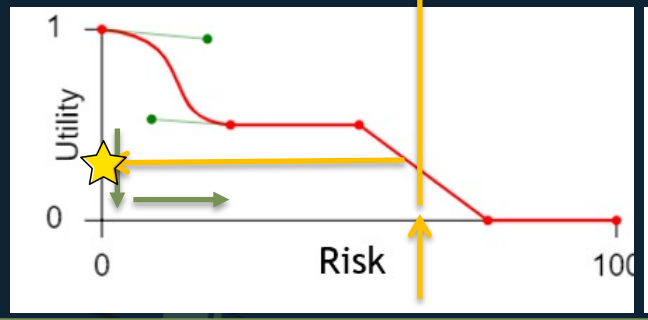


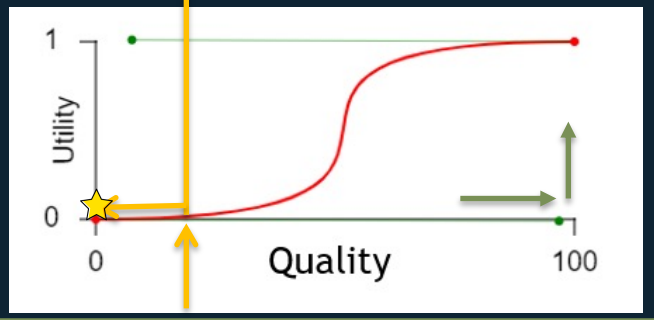




Stakeholder B







Stakeholder Value-driven Design Space

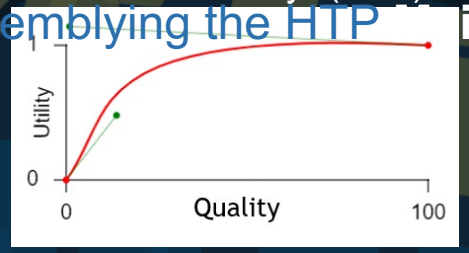
Stakeholder A

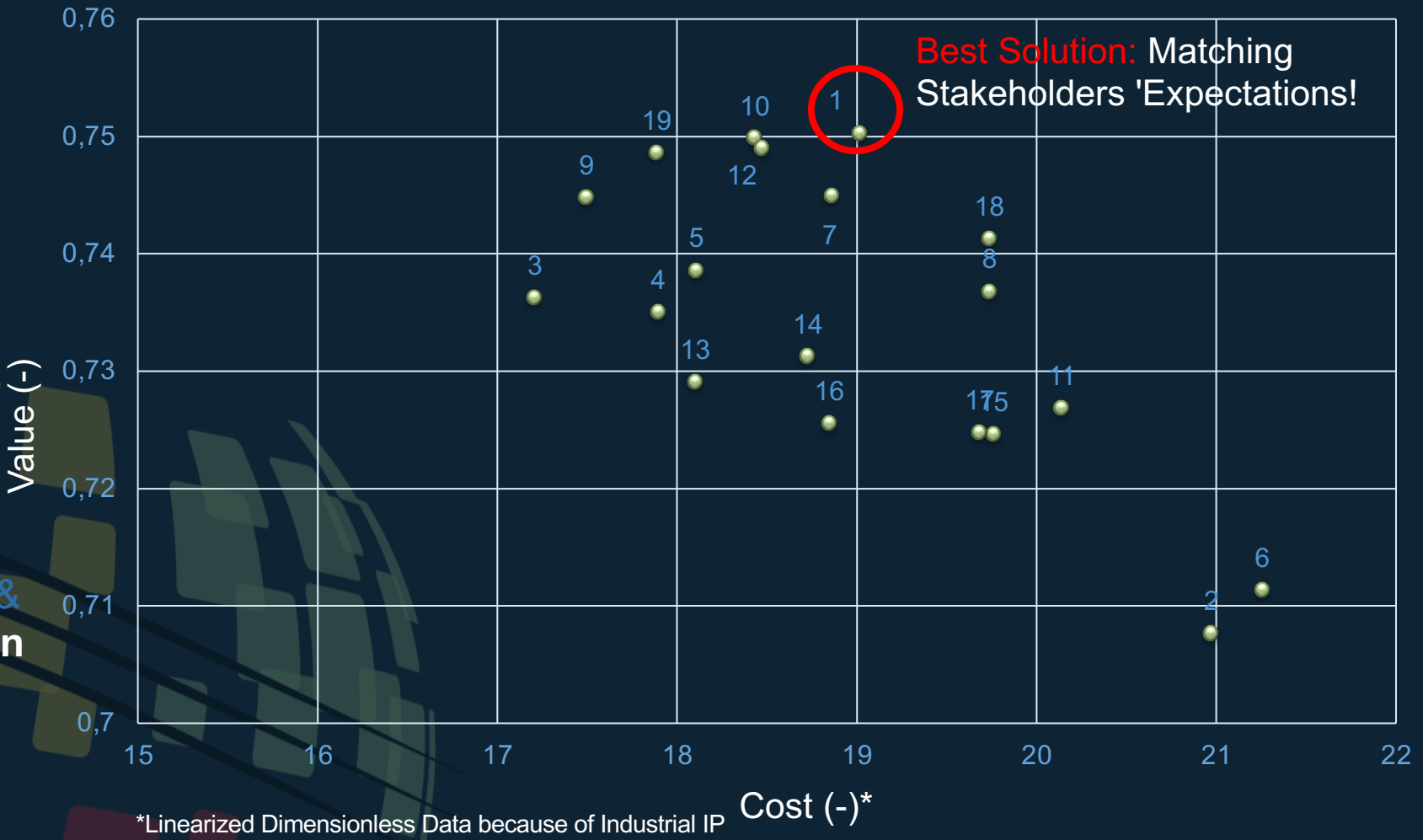
Production Time (0.33)

Best Solution

Supply Chain Manufacturing & Assemblying the HTP **inly in**

Production Quality (0.33)





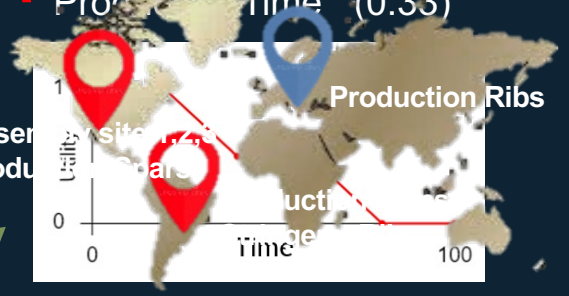
*Linearized Dimensionless Data because of Industrial IP

Stakeholder Value-driven Design Space

Stakeholder B

1

Prod… Time (0.33)



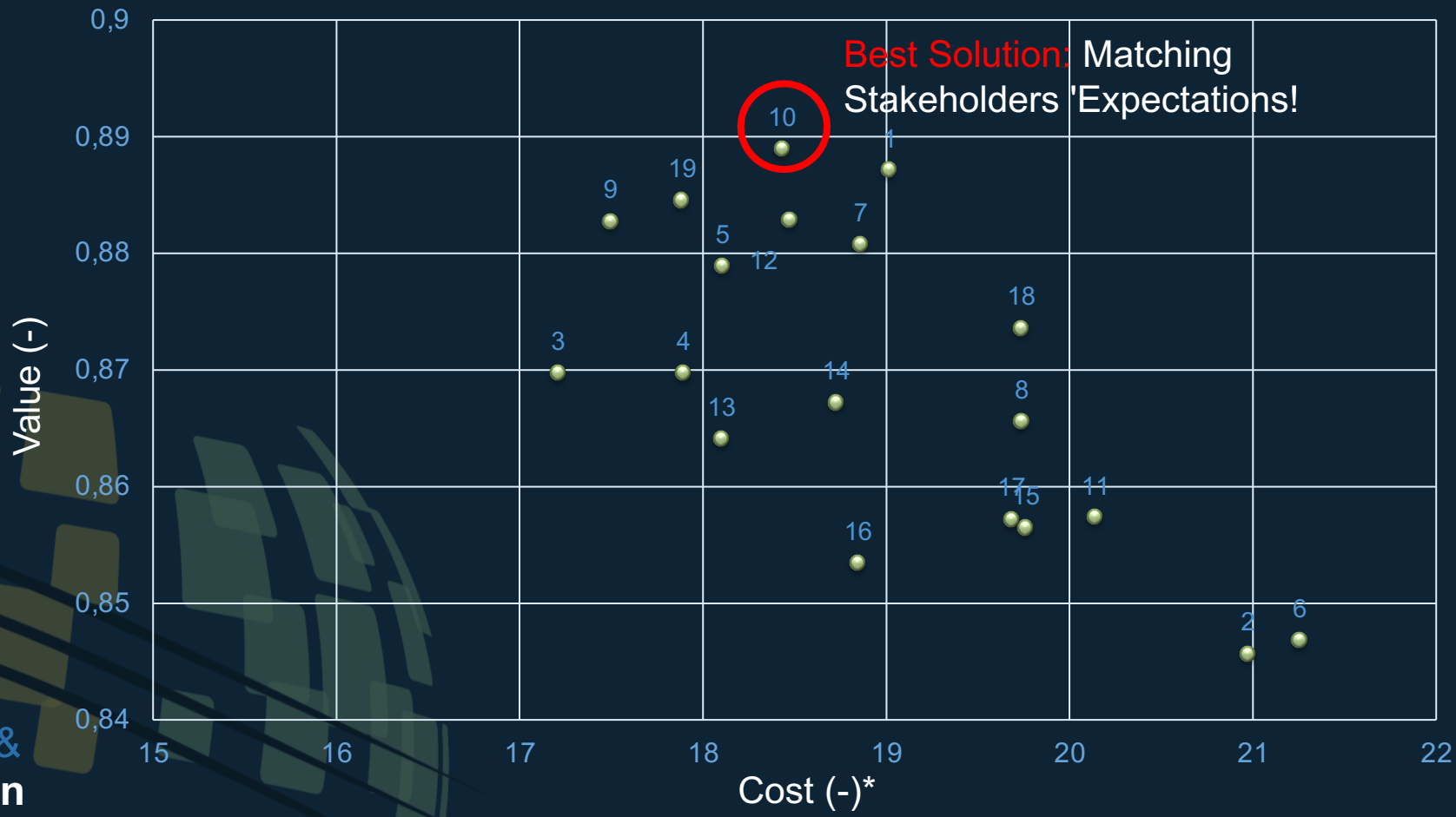
Competences of Enterprises Impact Risk, Time and Quality Risk Values well Cost

Production Risk (0.33)

10

Production Quality (0.33)

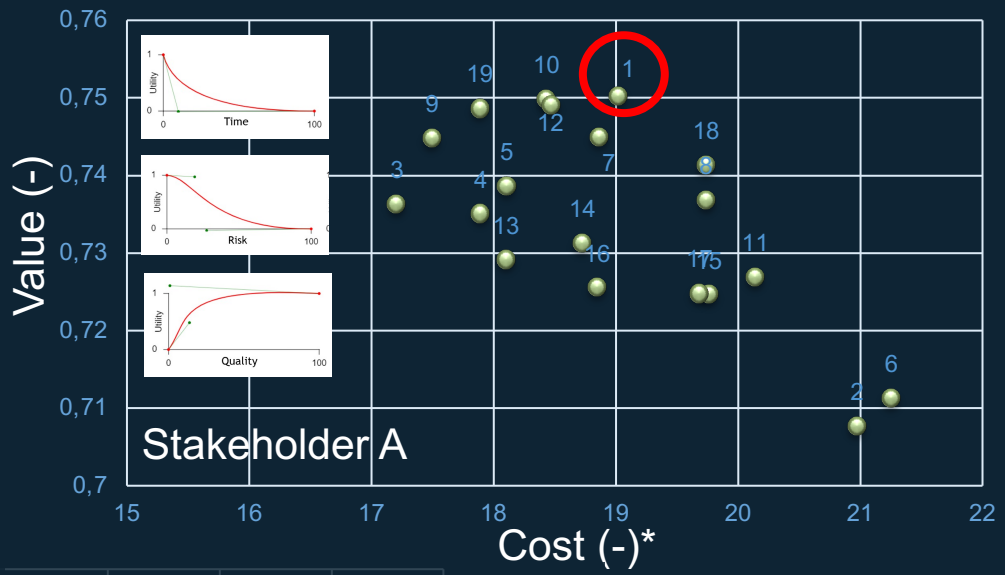
Sup… Manufacturing & Assemblying the HTP …inly in



*Linearized Dimensionless Data because of Industrial IP

Trade-off Studies

Stakeholder A Value-driven Tradespace



"The Best Solution Differ Based on Stakeholders 'Expectation Modelling"

*Linearized Dimensionless Data because of Industrial IP

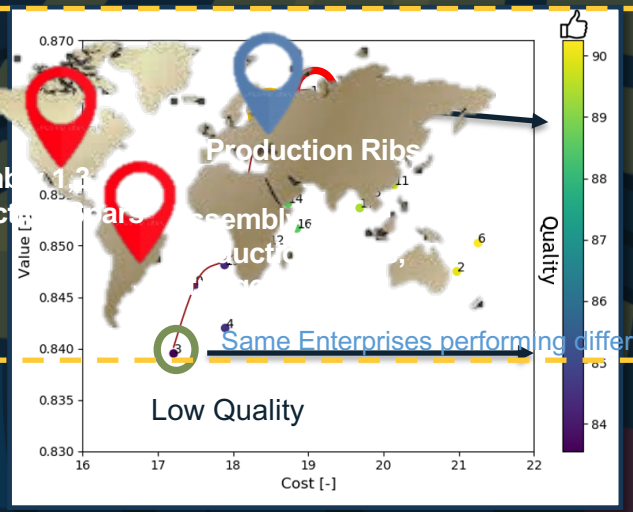
Trade-off Studies

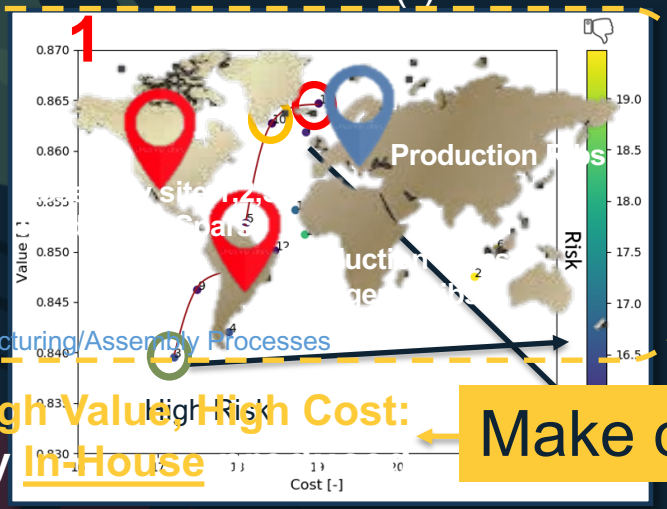
Value vs. Cost/Make or Buy

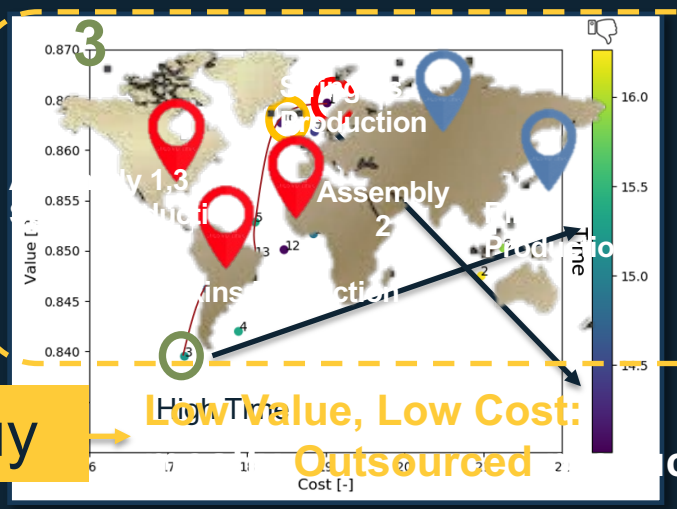
Solution 3 lowest value because of Low Quality, High Risk and Time

↓ +

Low Cost because of Enterprises Competences & Transportation (mostly water)







Same Enterprises performing different Manufacturing/Assembly Processes

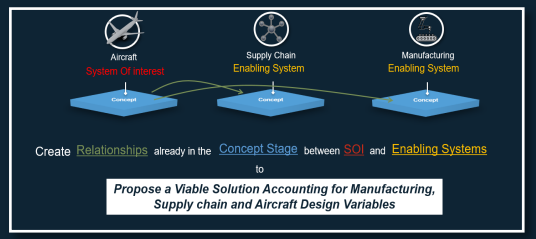
High Value, High Cost: mostly In-House ← **Make or Buy** → **Low Value, Low Cost:** Outsourced

Conclusion & Future Activities

- **Concurrent Approach in a SE Perspective**

Create Relationships in the Concept Life Cycle stage of SOI and Enabling Systems

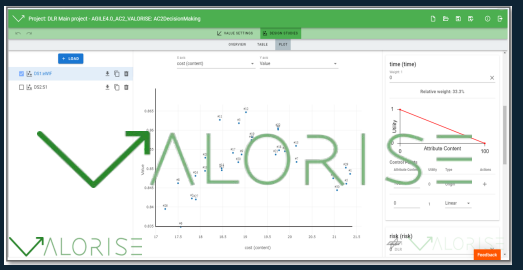
Assess & **Extend** the Approach to other Enabling Systems



- **Multi Attributes Decision-making Process**

VALORISE as Interactive Dashboard to identify the best solution trading stakeholders 'expectations

Improve the Dashboard; **Explore other Value-driven Theory**; Introduce **Uncertainty** in Decision-Making; Address **Decision-making before Optimization** (after System Architecting)



- **Aeronautical Application Case: Horizontal Tail Plane Design, Manufacturing & Supply Chain**

>The Best Solution can be different based on Stakeholders 'Expectations Model
>Shifting Decisions in the Design Phase Plane allows to perform trade-off studies increasing the value of the system under design (and over life cycle)

Increase the **complexity** of the application case including manufacturing choices (limitation also related to optimization algorithms)

To Know More

Poster: An Approach for Linking Heterogeneous Domain-Specific Models to Investigate Cabin System Variants
Today - Tuesday 18.07

Presentation: The MBSE competence at the German Aerospace Center
Wednesday - 15:30 – 16.10

Presentation: Value-driven Optimization Campaign Addressing Manufacturing, Supply Chain and Overall Aircraft Design Domains in the Early Development Stage
Thursday - 11:30 – 12.10

Thank you!

33rd Annual INCOSE international symposium

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