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VALUE ENGINEERING IN SPACE MISSIONS

HOW CAN WE ACHIEVE EFFECTIVE VALUE-DRIVEN DESIGN IN EARLY PHASES?

DESIGN-TO-VALUE

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DESIGNING THE NEXT EUROPEAN MISSION

WHAT SHOULD MATTER MOST?



Imagine that your team is designing the **next European Earth Observation (EO) mission**.

You have the chance to secure some additional budget, but only enough to implement one of the following enhancements:



Improve Ground Sample Distance
from 1 m to 0.8 m



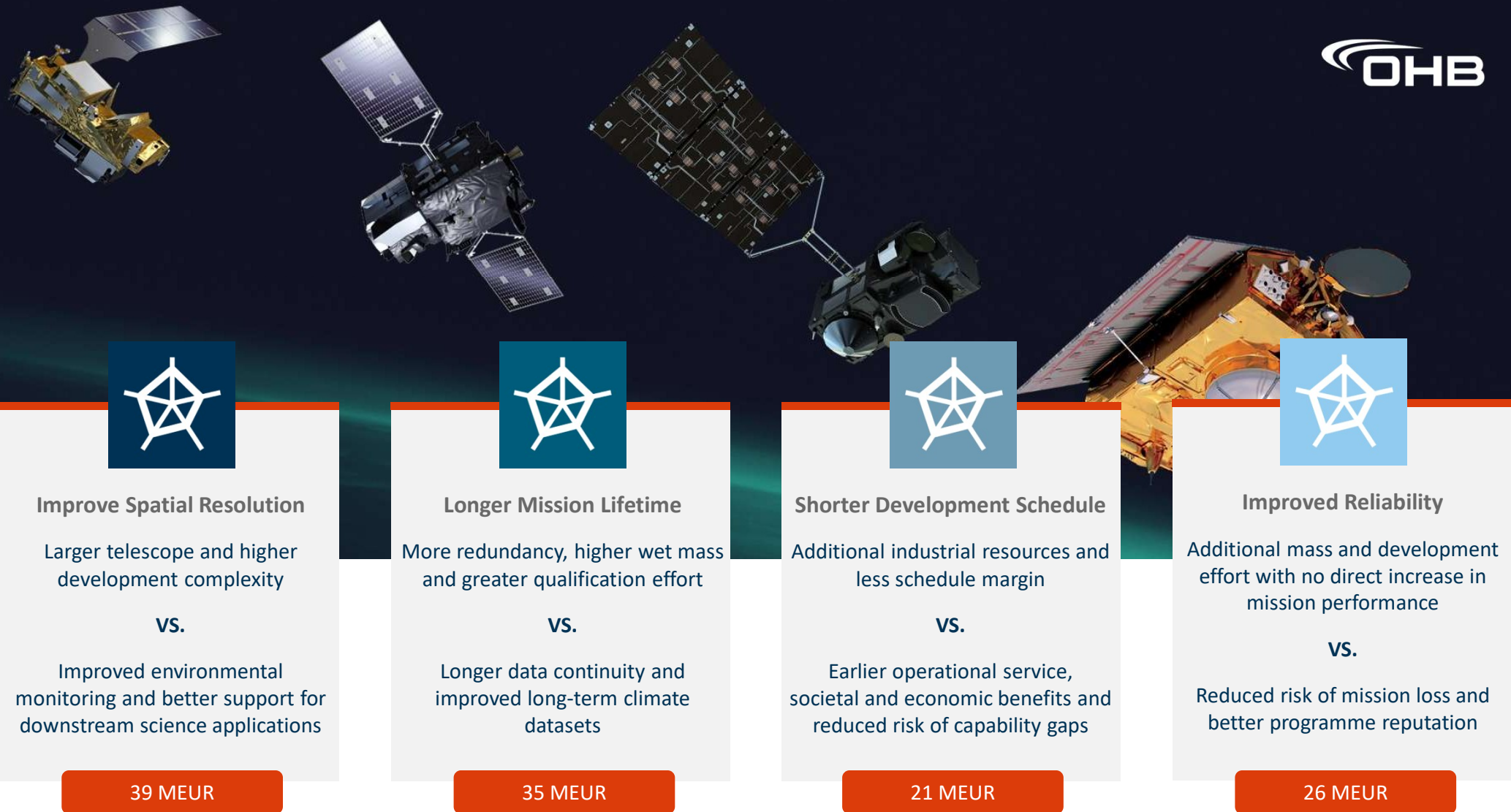
Reduce Development Schedule
by 12 Months



Increase Mission Lifetime
from 7 to 10 years



Improve Reliability



THE PROBLEM

HOW DO WE CHOOSE?



In Early Phase Studies (Phase 0/A):

High Uncertainty
in
Mission Definition
and
Cost Forecasts

**Evolving
Requirements**
as Mission Objectives,
Constraints,
and Stakeholder
Expectations
Mature

Different
Stakeholders
Optimize for
**Different
Objectives**

Impact of Design
Decisions
is **Not Always**
Transparent
Across the System

Strong Coupling
Between
**Technical and
Programmatic**
Decisions

When:

- Requirements are uncertain...
- Stakeholders disagree...

What exactly are we **OPTIMIZING?**



D2V METHODOLOGY

METHODOLOGY

The design-to-value methodology developed at OHB is structured around a concise set of **iterative steps**.



Step 1

Identification of the requirements that deliver the **highest value** to mission

Assess the Value of Each Requirement
Prioritize Through Expert Review
Select a **Subset** of Requirements to Focus On

1

2

3

Step 3

Allocation of quantified value across **system elements** through the Cost Breakdown Structure (CBS)

Allocate Requirement Value to **CBS Elements**
Combine Expert Judgment w/ Requirement Value
Calculate the **Total Value of Each CBS Element**

Step 2

Quantitative assessment of the **relative importance** of requirements

Quantify **Relative Requirement Value** using pairwise comparisons (matrix)

9 Much more important than

3 More important than

1 As important as

$\frac{1}{3}$ Less important than

$\frac{1}{9}$ Much less important than

Calculate **Requirement Weights** and **Value Scores**

Validate Consistency of Judgments

$$CI = \frac{\lambda_{\max} - n}{n - 1}$$

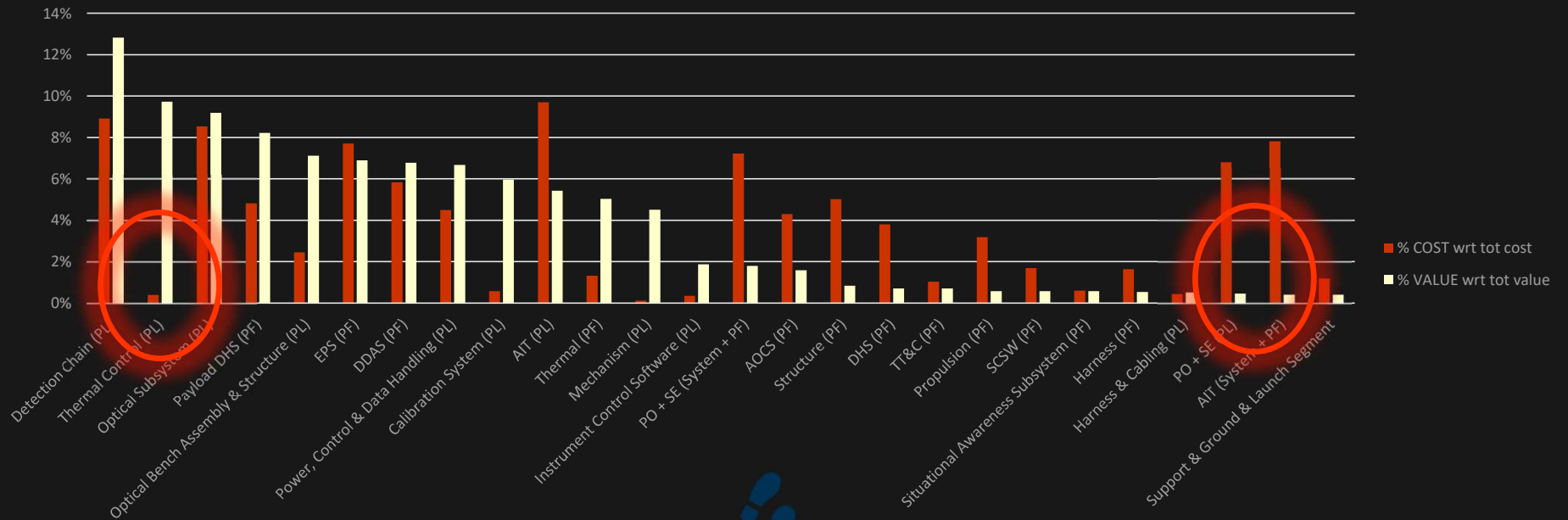
$$CR = \frac{CI}{RI}$$

D2V METHODOLOGY

METHODOLOGY



Cost and Value of CBS Elements



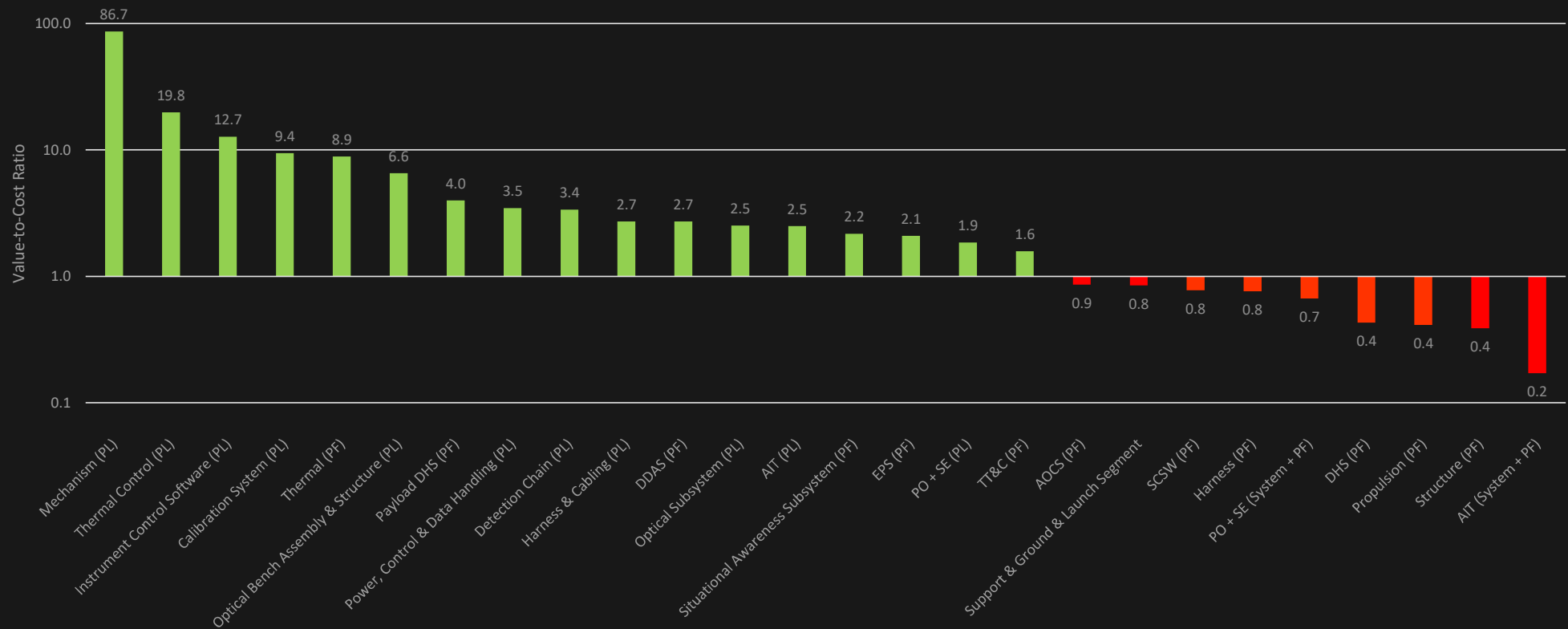
Step 4
Evaluation of **value-to-cost ratio** to support the design process

D2V METHODOLOGY

METHODOLOGY



Value-to-Cost Ratio of CBS Elements



D2V APPLICATION

WHAT WENT WELL



Case Study

- Early Phase Study
- EO Mission
- Copernicus Program



Structured
Requirement
Prioritization



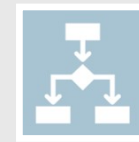
Visibility of
Cost
Drivers



Identification of
Affordable
Requirement
Relaxations



Quantification of
Impact of
Requirements
on Cost



Increased
Transparency
in Design
Trade-offs



Increased Cost
Awareness
Across the
Project Team

D2V APPLICATION

WHAT WE LEARNED



Design Changes Are a Domino



The value of a design change depends on **technical**, **programmatic** and **schedule impacts** **simultaneously** at any level

Cost Drivers Come in Group

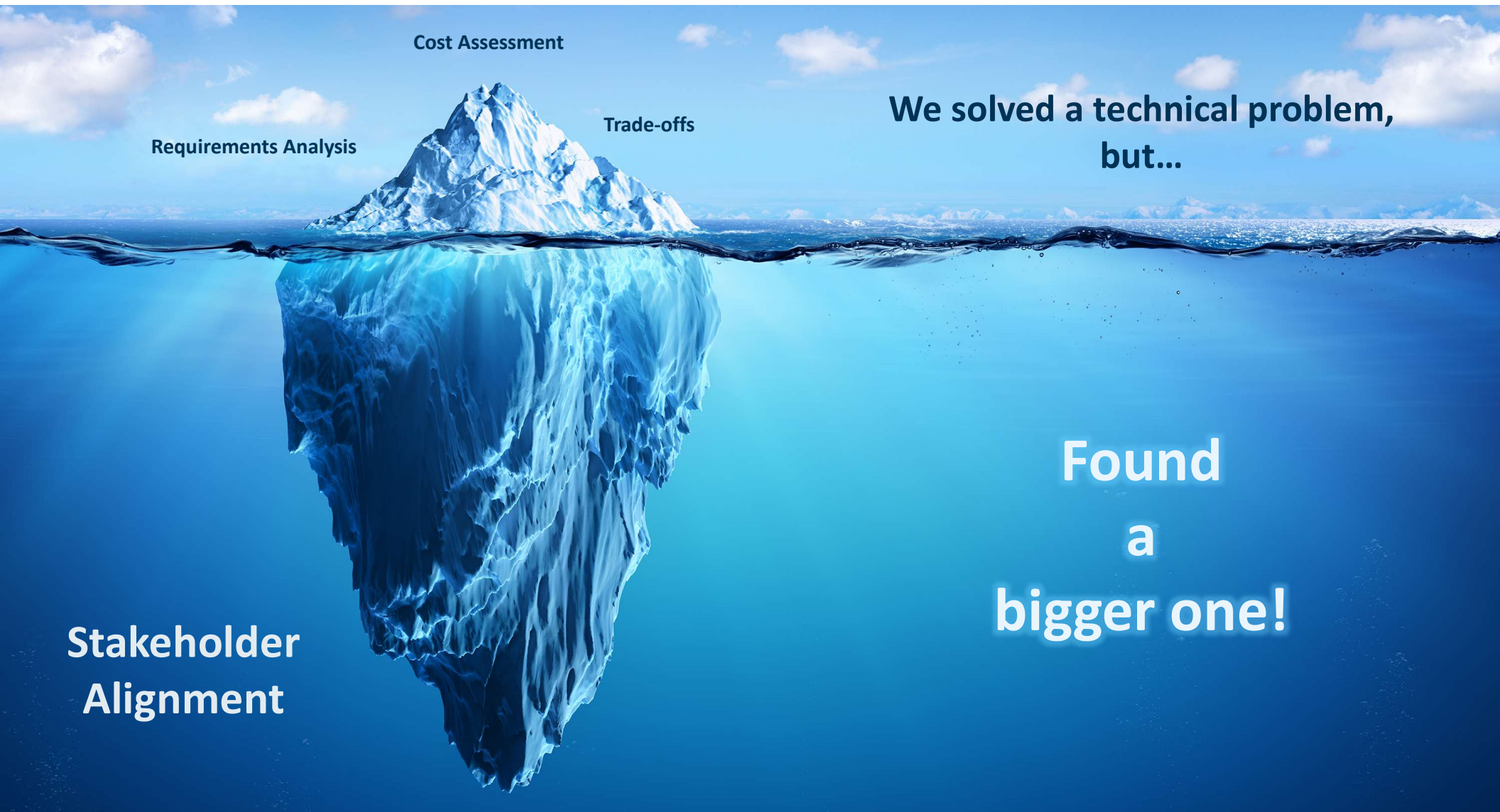


Meaningful savings are achieved by **relaxing multiple requirements** that drive the mission complexity

Cost-to-Value Does Not Behave Continuously



Mission architectures evolve through **discrete design choices** and threshold effects



Cost Assessment

Requirements Analysis

Trade-offs

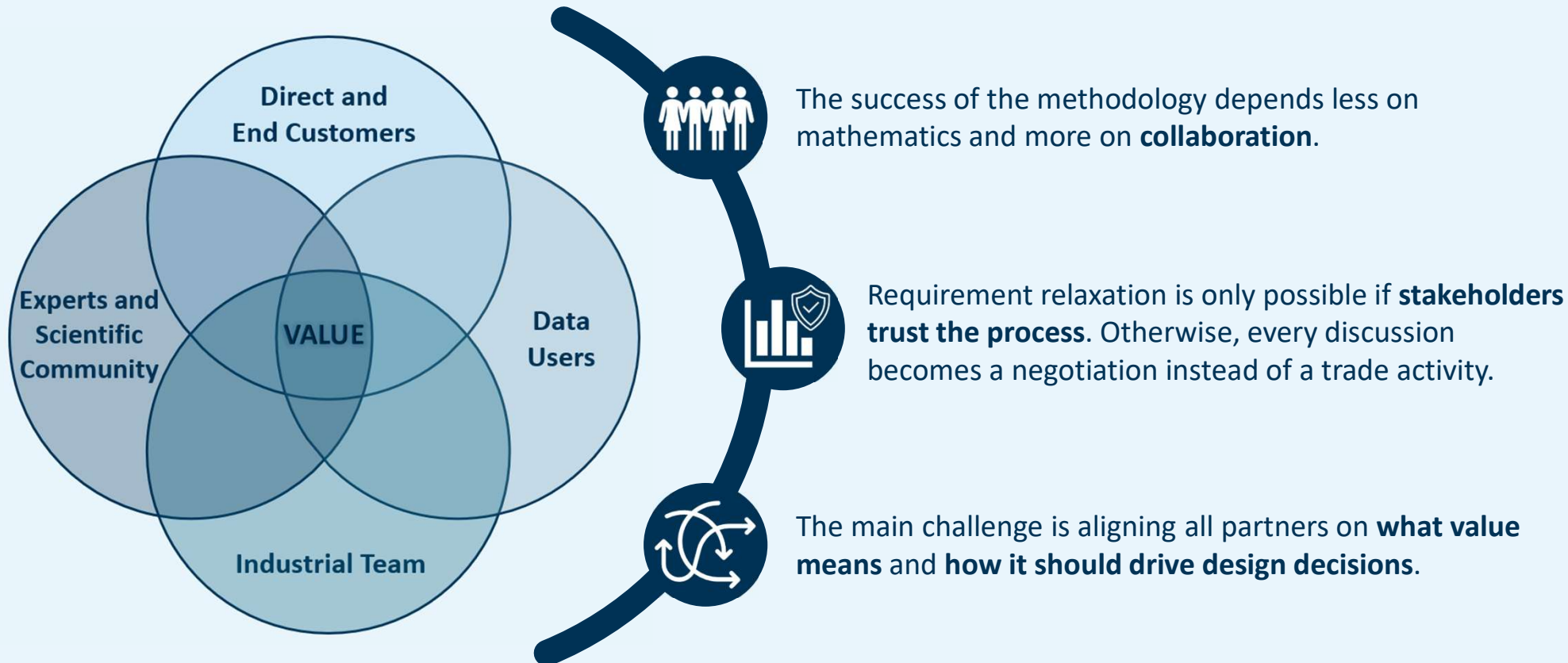
We solved a technical problem,
but...

Found
a
bigger one!

Stakeholder
Alignment

D2V APPLICATION

ADDITIONAL LESSON LEARNED



CONCLUSIONS

LET'S GO BACK TO WHERE WE STARTED



Would you now be able to select one design improvement for the next ESA mission?

DESIGNING THE NEXT EUROPEAN MISSION
WHAT SHOULD MATTER MOST?

Imagine that your team is designing the **next European Earth Observation (EO) mission**.
You have the chance to secure some additional budget, but only enough to **implement one** of the following enhancements:

-  **Improve Ground Sample Distance**
from 1 m to 0.8 m
-  **Reduce Development Schedule**
by 12 Months
-  **Increase Mission Lifetime**
from 7 to 10 years
-  **Improve Reliability**

D2V does not tell us what to choose, but why we are choosing it!



Stakeholder priorities become explicit



Different needs are quantitatively included into design trades

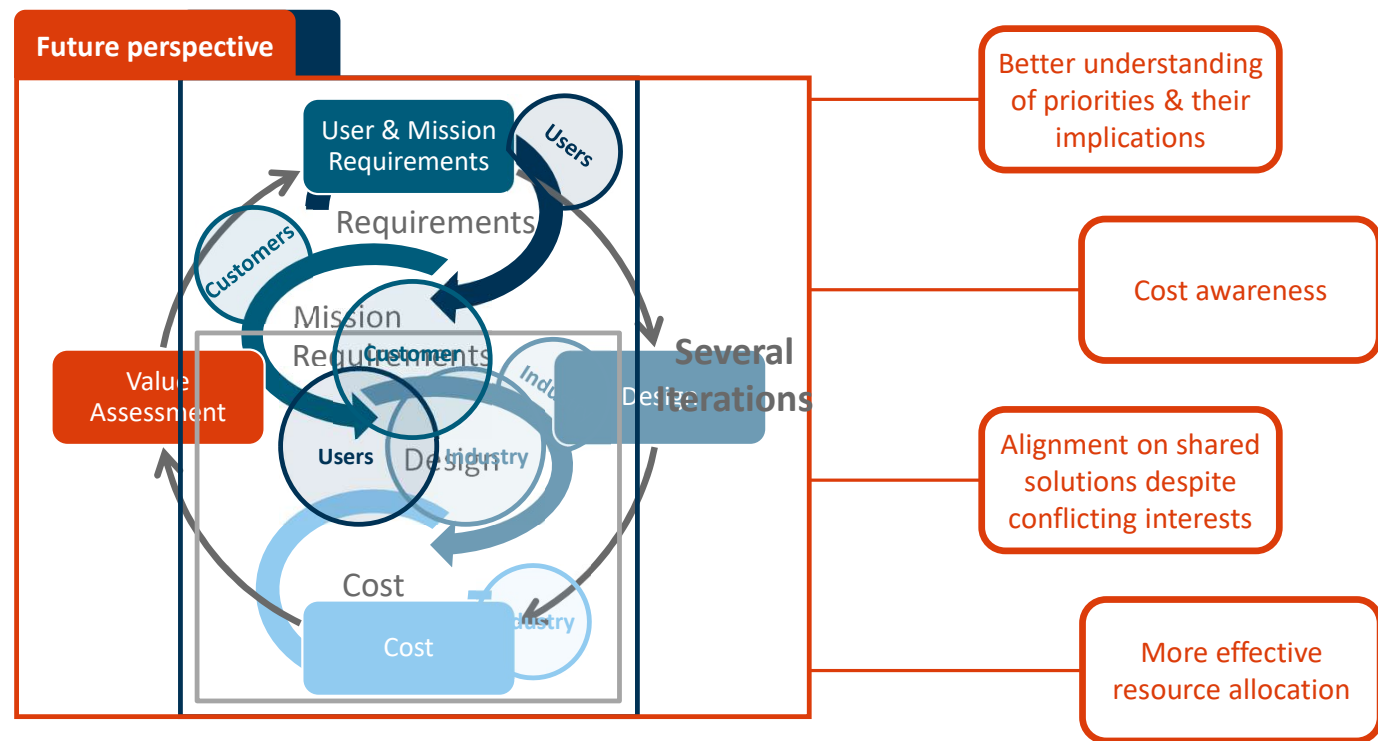


Value-to-cost analysis is carried out for requirements and solutions

The objective is to reach a **common understanding** of the consequences of technical and programmatical choices during mission design

CONCLUSION

FUTURE PERSPECTIVES



Two white speech bubble icons, one slightly overlapping the other, positioned above the text box.

The Space Industry must
move towards this **fully
integrated, collaborative
D2V framework** for
mission design.

Are you ready?



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TIME FOR QUESTIONS (5 MIN.)



THANK YOU!

We are expanding the team.

If you're interested, **contact us!**

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BACKUP SLIDES

DETAILED SLIDES FOR READING

D2V METHODOLOGY

METHODOLOGY



Requirements Value Analysis (Design-to-Value)

Step 1

Identification of the requirements that deliver the **highest value** to mission

1

Assess the Value of Each Requirement

Domain experts evaluate every requirement using the Value Contribution Index (VCI)

- 1 = Low value
- 2 = Medium value
- 3 = High value

Assessment is performed from the perspective of the scientific community to reflect mission objectives.

Prioritize Through Expert Review

- Experts collectively review and challenge the initial VCI rankings
- Requirements are prioritized based on:
 - Scientific/mission value
 - Potential for cost reduction

Select the D2V Focus Requirements

- Create a refined shortlist of the most impactful requirements (typically ≤ 10)
- Similar requirements may be grouped
- These selected requirements become the focus of the Design-to-Value analysis

D2V METHODOLOGY

METHODOLOGY



Quantify Relative Requirement Value Using Pairwise Comparisons

- Experts compare each requirement against every other requirement using a comparison matrix
- Qualitative judgments are converted into numerical scores to capture relative importance

9	Much more important than
3	More important than
1	As important as
$\frac{1}{3}$	Less important than
$\frac{1}{9}$	Much less important than

2

Step 2
Quantitative assessment of the **relative importance** of requirements

	R1	R2	R3	R4	R5	R6	...
R1	1.00	1.00	3.00	3.00	1.00	9.00	...
R2	1.00	1.00	3.00	3.00	1.00	9.00	...
R3	0.33	0.33	1.00	0.33	0.33	9.00	...
R4	0.33	0.33	3.00	1.00	0.33	9.00	...
R5	1.00	1.00	3.00	3.00	1.00	9.00	...
R6	0.11	0.11	0.11	0.11	0.11	1.00	...
...	...	...	...	...	...	...	1.00

D2V METHODOLOGY

METHODOLOGY



Calculate Requirement Weights and Value Scores

- Comparison matrix values are normalized by column
- Requirement weights are derived from the average normalized row values
- Final requirement values are calculated using the weighted matrix, producing a quantitative ranking of requirements

Normalized Matrix

	R1	R2	R3	R4	R5	R6	R7
R1	0.099	0.099	0.097	0.107	0.099	0.130	...
R2	0.099	0.099	0.097	0.107	0.099	0.130	...
R3	0.033	0.033	0.032	0.012	0.033	0.130	...
R4	0.033	0.033	0.097	0.036	0.033	0.130	...
R5	0.099	0.099	0.097	0.107	0.099	0.130	...
R6	0.011	0.011	0.004	0.004	0.011	0.014	...
R7	...	...	...	...	...	...	...

2

Step 2

Quantitative assessment of the **relative importance** of requirements

Requirement	Weighted Sum	Weight	λ
R1	1.403	9.92%	14.13891
R2	1.403	9.92%	14.13891
R3	0.659	4.69%	14.05
R4	0.789	5.37%	14.67839
R5	1.403	9.92%	14.13891
R6	0.236	1.81%	13.03387
R7	...	...	...

D2V METHODOLOGY

METHODOLOGY



Validate Consistency of Expert Judgments

- A consistency check based on Analytic Hierarchy Process (AHP) principles is performed
- The Consistency Ratio (CR) is calculated to verify the logical coherence of comparisons
- $CR < 0.10$ indicates acceptable consistency and reliable value rankings for subsequent cost-value trade-offs

Definitions

Consistency Index (CI)

Measures the degree of consistency in the pairwise comparison matrix

Random Index (RI)

A benchmark value based on randomly generated matrices. It depends on the size of the matrix.

Consistency Ratio (CR)

This is the key metric used to assess whether the comparisons are acceptably consistent.

2

Step 2

Quantitative assessment of the **relative importance** of requirements

$$CI = \frac{\lambda_{\max} - n}{n - 1}$$

$$CR = \frac{CI}{RI}$$

If $CR < 0.10$, the consistency is considered acceptable.

If $CR \geq 0.10$, the judgments may be too inconsistent and should be revised.

D2V METHODOLOGY

METHODOLOGY



Allocate Requirement Value to CBS Elements

- ⋮ Distribute the value of each requirement across the Cost Breakdown Structure (CBS) elements.
- ? Allocation answers the question: “How much does each CBS element contribute to fulfilling this requirement?”
- % Values are assigned as percentage contributions

Step 3

Allocation of quantified value across **system elements** through the Cost Breakdown Structure (CBS)

3

Combine Expert Judgment with Requirement Value

- Final CBS value allocation is based on:
 - 90% expert defined contribution
 - 10% requirement derived value
- This balances subsystem expertise with the quantified importance of each requirement

Calculate the Total Value of Each CBS Element

- Requirement values are multiplied by the corresponding CBS contribution percentages
- The contributions from all requirements are summed to obtain the overall value associated with each CBS element
- The result provides the basis for evaluating value-to-cost ratios at system and subsystem level

THE PROBLEM

HOW DO WE CHOOSE?



In Early Phase Studies (Phase 0/A):

- Mission objectives, system architecture, and implementation approaches are still maturing, resulting in **high uncertainty** in both technical solutions and associated cost estimates.
- Requirements are refined as knowledge increases, with new requirements introduced, existing requirements modified, and some requirements removed throughout the development lifecycle.
- Different stakeholders optimize for different objectives, such as mission performance, risk reduction, schedule, operability, or affordability. As the project evolves, these priorities are continuously reassessed, often leading to conflicting expectations and changing decision drivers.
- The impact of design decisions is not always transparent across the system. A local optimization within one subsystem may introduce cost, complexity, performance penalties, or risks elsewhere, making the overall value of a trade-off difficult to assess.
- Technical and programmatic constraints are **interconnected**. Changes in the technical solution can affect cost, schedule, risk, verification strategy, industrial organization, and development approach. Similarly, programmatic decisions can drive technical consequences, such as additional qualification activities, changes in development models, or modifications to the system architecture.

D2V APPLICATION

WHAT WE LEARNED



Design Changes Are a Domino



- Technical design, schedule, make-or-buy philosophy, component selection, DDVP plan, etc. are all deeply interconnected and equally affect cost and value
- The value of a design change depends on **technical**, **programmatic** and **schedule impacts simultaneously**

Cost Drivers Come in Group



- Significant cost reductions rarely originate from relaxing a single requirement
- **Meaningful savings are achieved by relaxing multiple requirements** that drive the mission complexity

Cost-to-Value Does Not Behave Continuously



- Mission architectures evolve through **discrete design choices** and threshold effects
- Examples:
 - Changing telescope diameter might not change launcher class
 - Relaxing mass by 5% might change nothing, relaxing it by 15% might eliminate a deployment mechanism