



EXAELIA

Flying Testbeds for Novel Long-Range Aircraft

Writing well-formed requirements for the successful design of sustainable long-range aircraft: a structured approach

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EASN 15th International Conference

October 14-17, 2025

Madrid, Spain



Funded by
the European Union

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What is the Problem?



Which car do you **need**?



Were the **requirements** good?

Typical causes of software project failure

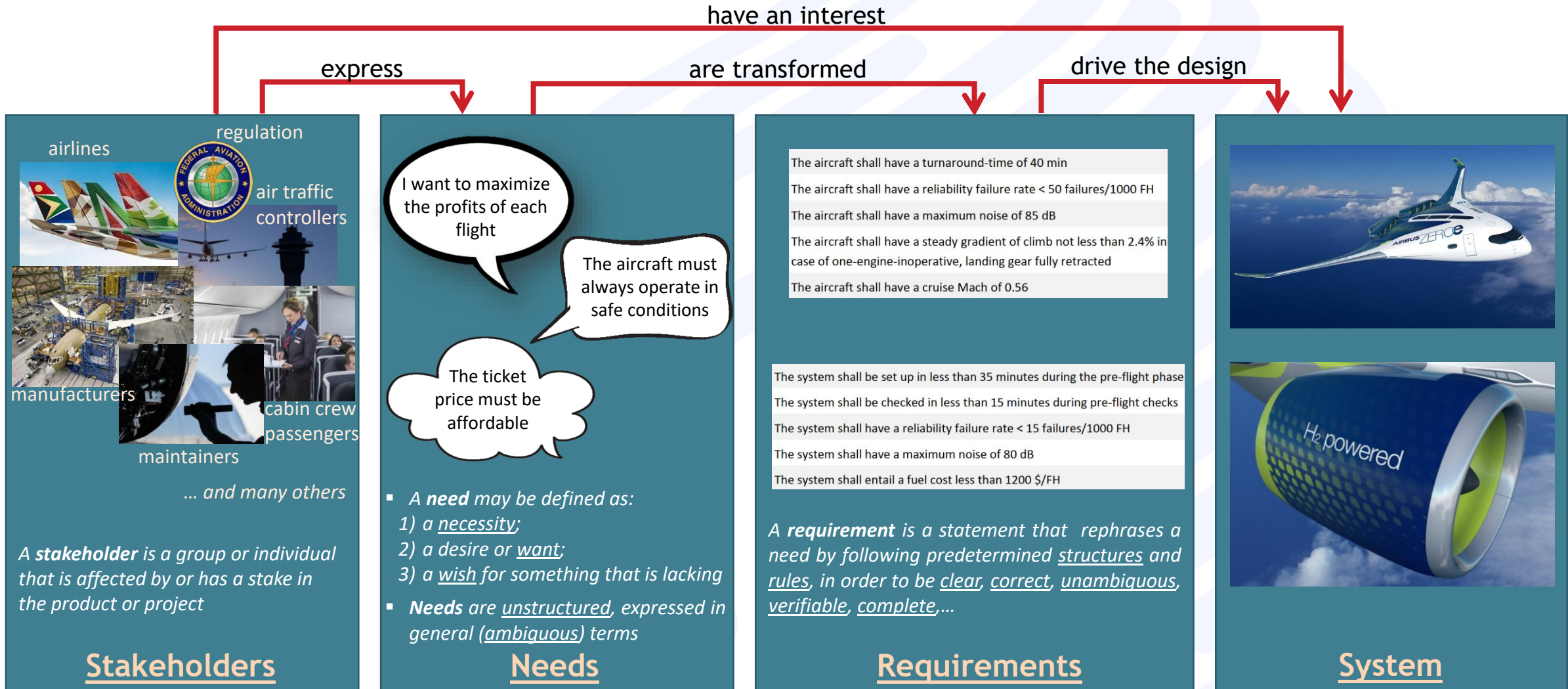
Incomplete requirements	13.1%
Lack of stakeholders involvement	12.4%
Unrealistic expectations	9.9%
Changing of requirements	8.7%

Source: The Standish Group,
"The CHAOS Report" 1994

It is important:

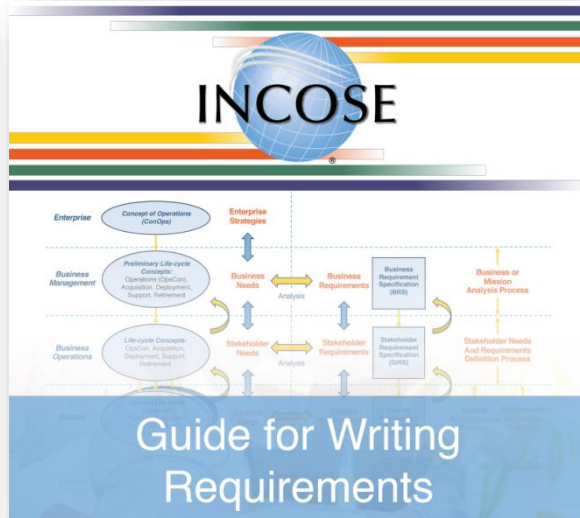
- To correctly capture stakeholder **needs**
- To correctly transform these needs into "well-formed **requirements**"

Stakeholders, Needs and Requirements



Focus of the presentation: writing well-formed requirements (clear, correct, complete, unambiguous, verifiable, ...)

Well-formed Requirements: rules



Characteristics of requirements

- Necessary
- Appropriate
- Unambiguous
- Complete
- Singular
- Feasible
- Verifiable
- Correct
- Conforming

Rules

R40 - Avoid the use of abbreviations in requirement statements.

Elaboration:

The use of abbreviations adds ambiguity and needs to be avoided.

Examples:

Unacceptable: It would not be acceptable for one requirement to refer to the abbreviation "op" meaning operation and another to refer to the "op" meaning the operator.

Acceptable: Avoid the abbreviation and use the full term every time.

Characteristics that are established by this rule:

C9 - Conforming

C11 - Consistent

C13 - Comprehensible

C14 - Able to be Validated

Other INCOSE rules:

- Use definite article "the" rather than the indefinite article "a"
- Use the active voice in the main sentence structure with the responsible entity clearly identified
- Use appropriate units when stating quantities
- Define terms (in glossary)

All the rules are in: INCOSE, "Guide for Writing Requirements, INCOSE-TP-2010-006-01," 2012

Well-formed Requirements: patterns

Pattern: “each type of requirement has a standard grammar, a set of mandatory and [optional elements] that ensure verifiability related to the type” ¹

- **Functional**
The **SYSTEM** shall [exhibit] **FUNCTION** [while in **CONDITION**]
- **Performance**
The **SYSTEM** shall **FUNCTION** with **PERFORMANCE** [and **TIMING** upon **EVENT TRIGGER**] while in **CONDITION**
- **Design (constraint)**
The **SYSTEM** shall [exhibit] **DESIGN CONSTRAINTS** [in accordance with **PERFORMANCE** while in **CONDITION**]
- **Environmental**
The **SYSTEM** shall [exhibit] **CHARACTERISTIC** during/after exposure to **ENVIRONMENT** [for **EXPOSURE DURATION**]
- **Suitability**
The **SYSTEM** shall exhibit **CHARACTERISTIC** with **PERFORMANCE** while **CONDITION** [for **CONDITION DURATION**]

N.B. Patterns adapted from ¹

Examples:

The **aircraft** shall **provide propulsive power** [**during the entire mission**]

The **aircraft** shall **fly** with a speed of minimum Mach 0.8 **while in cruise**

The **aircraft** shall have **technologies with maturity TRL 9** [**in 2020**]

The **aircraft** shall **be maneuverable** in case of icing conditions [**for the entire flight**]

The **aircraft** shall exhibit **a steady gradient of climb** of minimum 2.4% while **the condition of one-engine-inoperative**

¹ R. Carson, Implementing structured requirements to improve requirements quality, INCOSE IS, Seattle, WA, 2015

Well-formed Requirements: attributes

Attribute: “additional information included with a requirement statement, which is used to aid in the management of that requirement”¹

Subset of INCOSE attributes:

- System Of Interest (SOI) primary verification method / Means of Compliance
- Trace to parent requirements (or source)
- Unique identifier
- Originator/Author (/Owner)
- Stakeholders
- Version number
- Requirement verification status
- Requirement validation status
- Priority
- Type/Category

Example:

ID	Req. statement	Parent	M.o.C.	Owner	Stakeh.	Version	Type	...
R_26	The a/c shall fly...	R_02	OpenAD	DLR	Airlines	0.2	Performance	...

¹ M. J. Ryan and L. S. Wheatcraft, “On a Cohesive Set of Requirements Engineering Terms”, INCOSE Systems Engineering Vol 20 Issue 2, pages 118-130, 2017



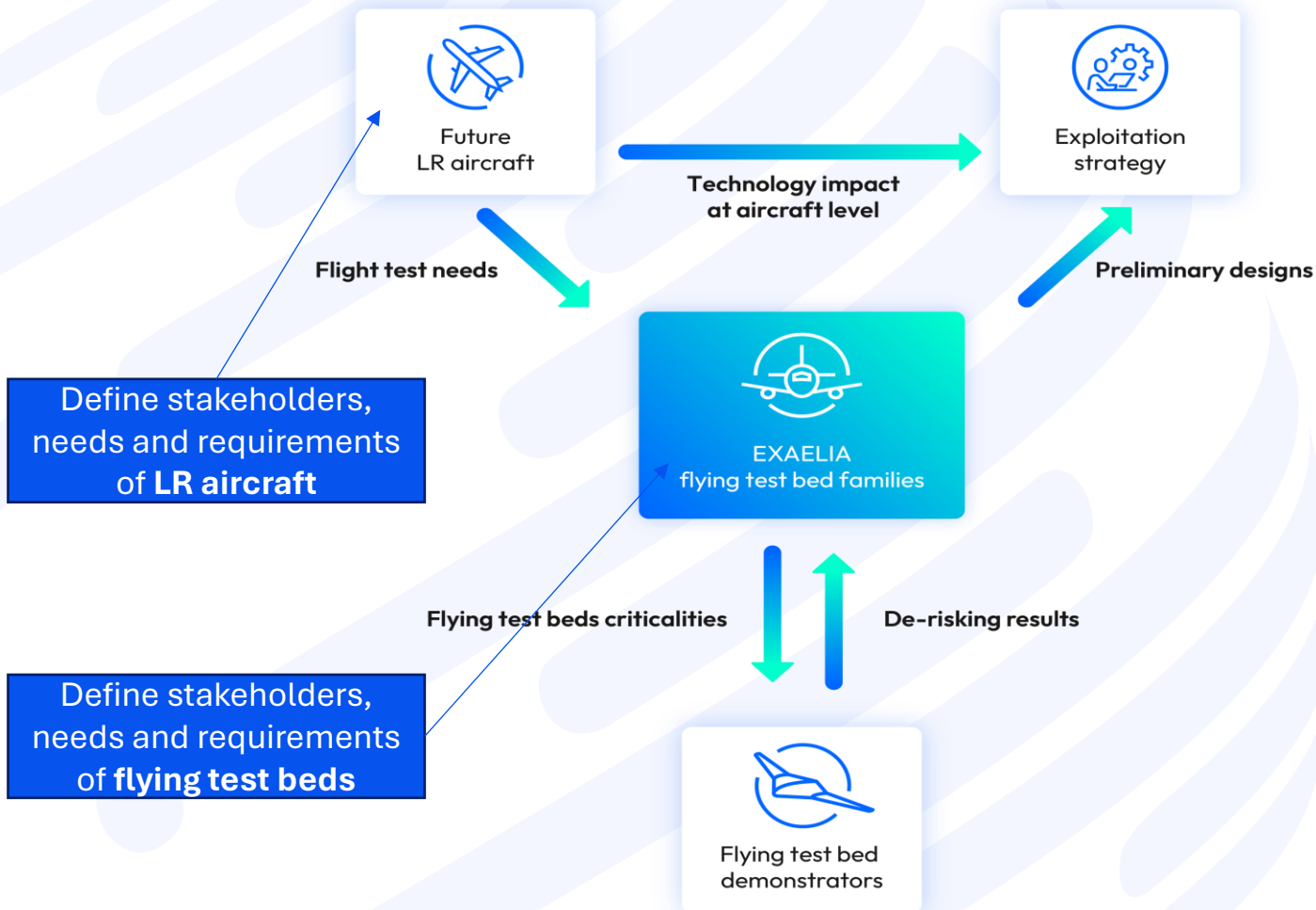
EXAELIA

Flying Testbeds for Novel Long-Range Aircraft

Aim: To design and identify promising commercial aircraft configurations for long-range missions, de-risk critical technologies through innovative flying testbeds and flight testing, and develop a European strategy for the dissemination and exploitation of these advancements in aerospace.



- Horizon Europe project
- Start date: 1 January 2025
- Duration: 42 months
- Budget: 16.2 Meuro
- 23 partners (22 EU + 1 UK)



Example from the EXAELIA project



Society
(stakeholder)



Aviation must not harm the environment! (need)

From needs
to requirements



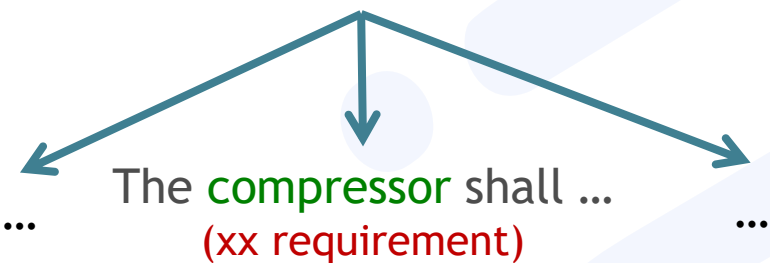
The aircraft shall minimize environmental impact (functional requirement)



The aircraft shall emit CO2 emissions of max TBD kg while in flight (performance requirement)



The propulsion system shall emit CO2 emissions of max TBD kg while in flight (performance requirement)



The compressor shall ... (xx requirement)



More info in the following presentation:
“Identification of Sustainability-related Stakeholder Needs and Requirements for the Conceptual Design of Future Long-Range Aircraft” by Markatos *et al.*



Conclusions

Take aways

- A project/product can't be successful if 1) its **stakeholder needs** are not correctly captured; 2) needs are not transformed into “**well-formed**” requirements
- Well-formed requirements are **clear, correct, complete, unambiguous, verifiable, ...**
- **Structures and rules** have been presented to ensure requirements are well-formed
- Structures and rules are applied in the **EXAELIA project** for the design of **future Long Range Aircraft**
- **Future work** will address the definition of stakeholders, needs and requirements of **flying test beds**
- **Future work** will include **requirement verification** and **link to impact assessments**



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