33rd Annual **INCOSE**
international symposium

hybrid event

Honolulu HI USA

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The MBSE competence at the German Aerospace Center

15-20 July - 2023   www.incose.org/symp2023 #INCOSEIS

What is the paper about?
Main "product" produced and delivered with this work

- **Survey** on the MBSE competence available at the German Aerospace Center (DLR)

- **Assessment** about the MBSE competence at the DLR

(how mature is the MBSE competence?)

- **MBSE Competence** defined in terms of:
  - Method
  - Process
  - Modeling language
  - Tool

Contents

- **Motivation**
  - Why have we done this work? What are the **benefits** for DLR and for externals?

- **Background**
  - What is the **German Aerospace Center**? In which context have we done the work?

- **Methodology**
  - How have we **organized** the work?

- **Main Results**
  - What are the main **outcomes** from the work? What are their **implications**?

- **Conclusions**
  - What are the main **limitations** of the work? Which **follow-up activities** are envisioned?

Motivation
Why have we done this work? What are the benefits for DLR and for externals?

Study aims at answering to four questions:

1. **What MBSE competence** does the DLR have? What is its **level of maturity**?

2. Which **MBSE methods, modeling languages and tools** are used in DLR?

3. **How "active"** is DLR in terms of MBSE initiatives? How many **publications** and **projects**?

4. *Who within the DLR has the different MSBE competences?*

Benefits (for DLR and externals)**:**

- New **synergies** and **collaborations** within/outside the organization

- **DLR strategy** for new developments and research projects

- **Increase the MBSE competence** @DLR

→ **ultimate goal: create conditions that would improve the state-of-the-art related to MBSE**

German Aerospace Center
Deutsches Zentrum für Luft- und Raumfahrt (DLR)

- National Research Center
  - Aeronautics
  - Space
  - Transport
  - Energy
  - Digitalization
  - Security

- Space Agency
- Project Management Office
- ~ 10000 Employees
- More than 50 institutes
- 30 sites in Germany
- budget more than 3 bn EUR

Bild: Nonwarit/Fotolia

BREMERHAVEN
STADE
HAMBURG
NEUSTRELITZ
OLDENBURG
BREMEN
TRAUEN
BERLIN
BRAUNSCHWEIG
GÖTTINGEN
DRESDEN
KÖLN
JENA
JÜLICH
BONN
LAMPOLDSHAUSEN
STUTTGART
AUGSBURG
OBERPFAFFENHOFEN
WEILHEIM

DLR MBSE-Ops internal project
Operationalizing MBSE @ DLR

MBSE-Ops

- ▪ **Ambition:**

  Consolidation of MBSE competences scattered across DLR domains, accelerating the development of innovative complex systems within the DLR

- ▪ **Technical objectives:**

  1. *Map MBSE processes, methods and tools*
     → *Activities and outcomes addressed in this paper* ←

  2. *Develop the concept for a common "DLR MBSE operational environment"*

  3. *Demonstrate cross-sector interoperability*
     Define and develop representative case studies through MBSE

  4. *Promote and demystify MBSE @DLR*
     Organize workshops and Open Day events

Institute of System Architectures in Aeronautics

Institute of Networked Energy Systems

Institute of Space Systems

Institute of Flight Systems

Institute of Software Technology

Institute of Vehicle Concepts

Institute of System Dynamics and Control

✈ Aeronautics

🛰 Space

🚆 Transport

🔋 Energy

BREMERHAVEN · STADE · HAMBURG · NEUSTRELITZ · OLDENBURG · BREMEN · TRAUEN · BERLIN · BRAUNSCHWEIG · GÖTTINGEN · DRESDEN · JÜLICH · KÖLN · BONN · JENA · LAMPOLDSHAUSEN · STUTTGART · AUGSBURG · OBERPFAFFENHOFEN · WEILHEIM

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Methodology
How have we organized the work?

1. Literature review & Metamodel

2. Group interviews

Not queryable

3. Modeling and assessment of Competence map
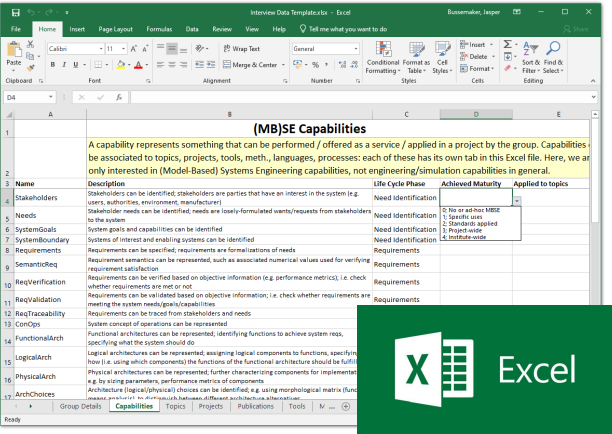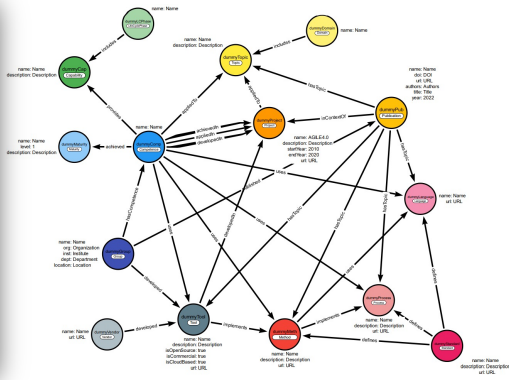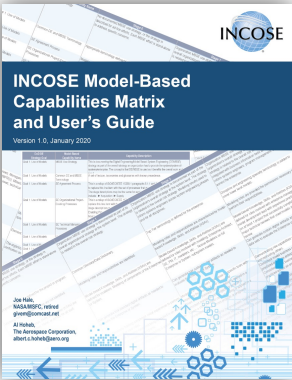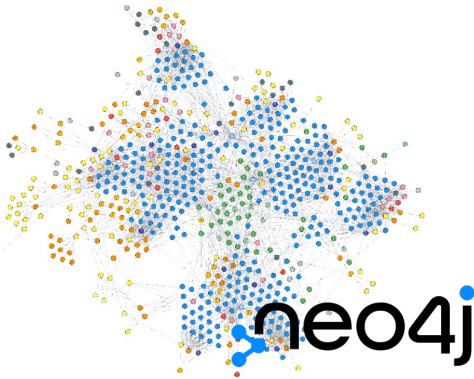
Queryable

Methodology
Literature review

- Material (e.g. papers, reports) **supporting the work**
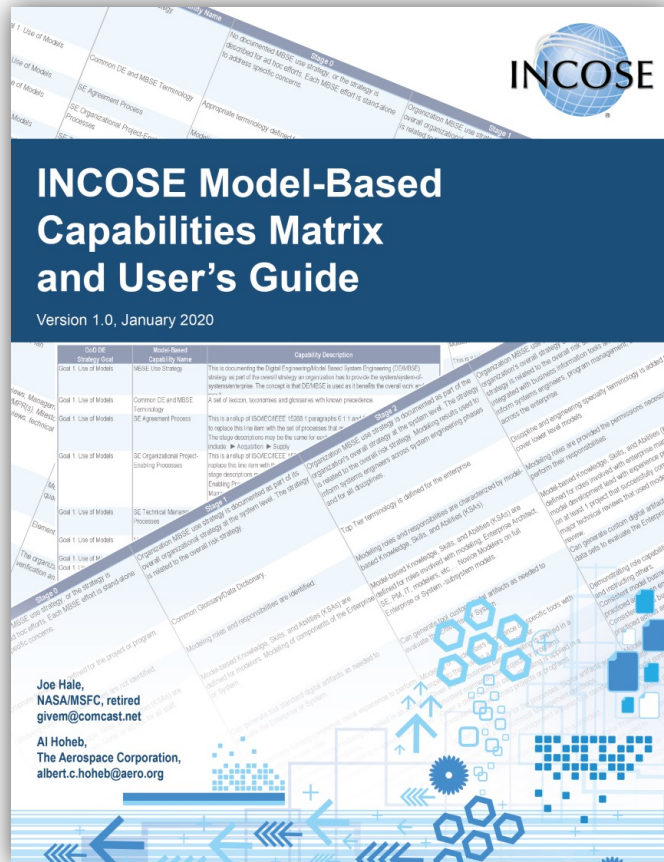
Tool for organizational self-assessment:

- Identify the organization's current Model-Based capability
- Identify the targeted capability stage

Results used to **create plans for organization's development** of Model-Based capabilities

- **Similar initiatives in other organizations**

https://ntrs.nasa.gov/citations/20205003969

Study Results/Overview

Independent Assessment Of Perception From External/non-NASA Systems Engineering (SE) Sources

Submitted To:
NASA Tech Fellow For SE
Submitted By:
Harlan Brown & Company, Inc.
Gerald J. Pawlikowski, Senior Project Manager
610-678-6200, gjpawlikowski@verizon.net

What Is The Current State of SE Within Organizations You Work With/Or Within Your Organization?
(SE capabilities rated on a 1-5 scale, with 4 or higher = adequate, 3-3.9 = marginal, and less than 3 = inadequate)

What MBSE Modeling Tools Are You Most Familiar With?
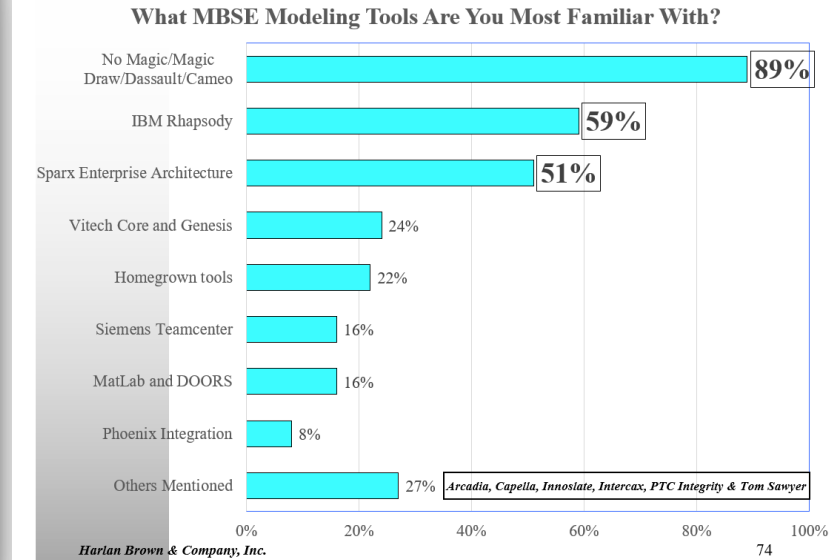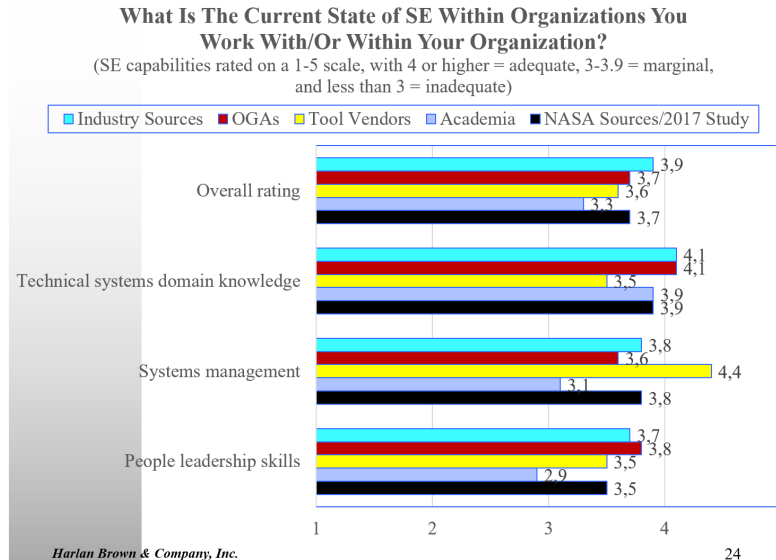
(Example) Survey to identify the adoption of **(Model-Based) Systems Engineering capabilities** within **NASA and its collaborating partners**

→ What is the current MBSE state in your organization?

Definitions and Metamodel
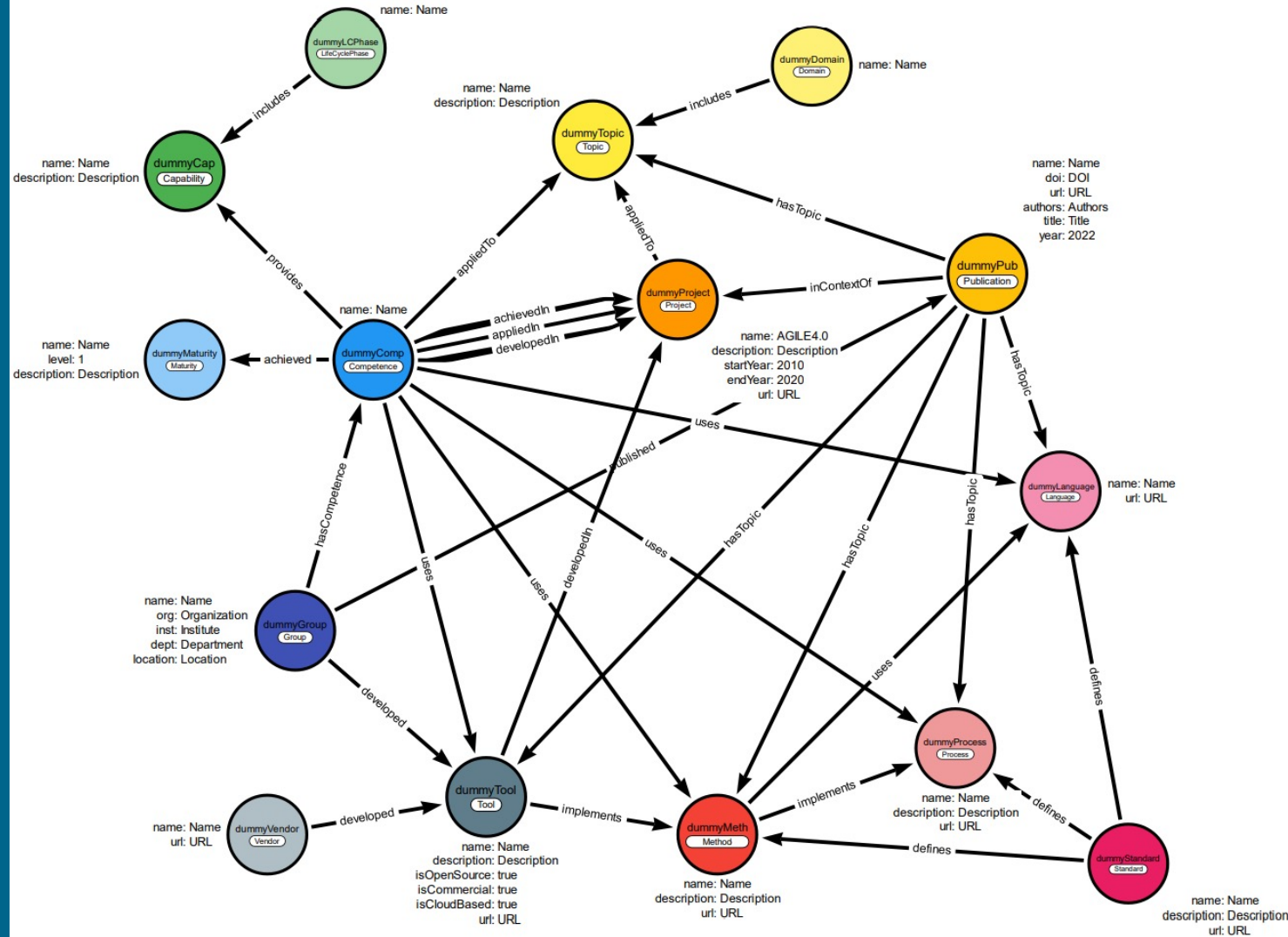
Capability (& life cycle phase)
Logical System Architecting
(ISO 15288: Architectural Design)

Competence (& maturity level & group)
Logical System Architecting with level 4 by a DDP group
(level 2: Institute-wide)

Topic, domain
Aircraft design, aeronautics

Project, publication
EU H2020 AGILE 4.0, Bussemaker et al. INCOSE IS 2023

Process
System Architecting Process

Method
Arcadia

Tool (& tool vendor)
Cameo Systems Modeler (Dassault Systèmes)

Language
SysML

Standard
ISO 15288 (standard for System Life-cycle Processes)

MBSE competence map

Luca Boggero (DLR) *et al.*, "**The MBSE competence at the German Aerospace Center**" @INCOSE IS 2023 – Honolulu (US-HI), July 19th 2023

Main results
What **MBSE competences** does the DLR have?

39 capabilities defined in different life-cycle stages

Requirements (ISO 15288: Requirements Analysis)

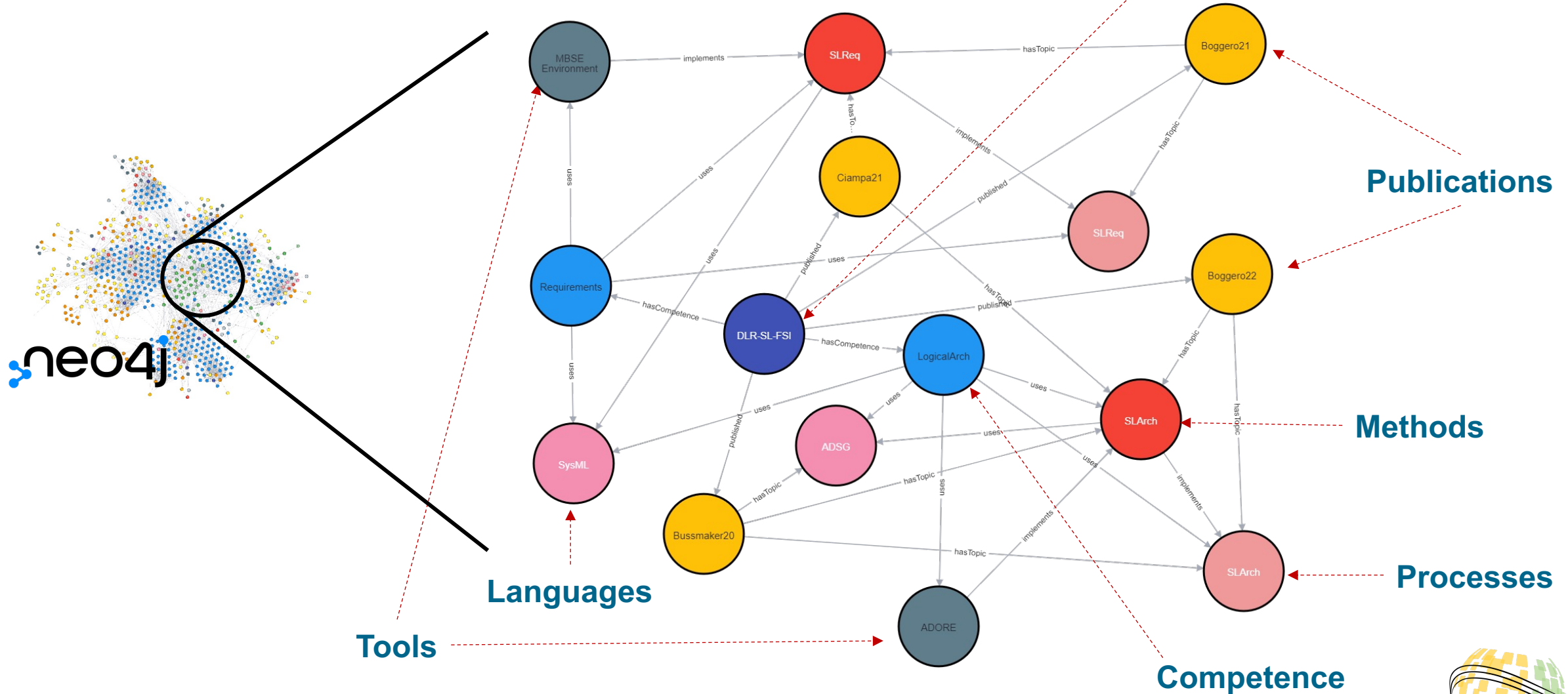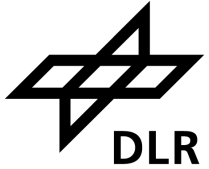| Capability	Description	# groups	Maturity
Requirements	Requirements can be specified; requirements are formalizations of needs	16	Range: 0-4 Mode: 3 Mean: 2.2
SemanticReq	Requirement semantics can be represented, such as associated numerical values used for verifying requirement satisfaction	10	Range: 0-4 Mode: 1 Mean: 1.7
ReqVerification	Requirements can be verified based on objective information (e.g. performance metrics); i.e. check whether requirements are met or not	15	Range: 0-3 Mode: 1 Mean: 0.9
ReqValidation	Requirements can be validated based on objective information; i.e. check whether requirements are meeting the system needs/goals/capabilities	10	Range: 0-3 Mode: 1 Mean: 0.9
ReqTraceability	Requirements can be traced from stakeholders and needs	12	Range: 0-4 Mode: 3 Mean: 2.1
ConOps	System concept of operations can be represented	11	Range: 0-3 Mode: 0, 1 Mean: 1

Number of DLR groups that have each capability

Maturity level
- **Range** of maturity level
- **Mode** (maturity level for the <u>majority</u> of DLR groups)
- Weighted **mean** (<u>average</u> maturity level in DLR)

Maturity level	Description
0	No or ad-hoc MBSE
1	Specific uses
2	Standards applied
3	Project-wide
4	Institute-wide
5	DLR-wide

Main considerations:

- DLR can address **capabilities covering the whole system life-cycle**
  → but mainly in the <u>development phase</u>
- **MBSE expertise is increasing** in DLR
  → but <u>not a company-wise</u> adoption of common MBSE processes, methodologies standards and tools
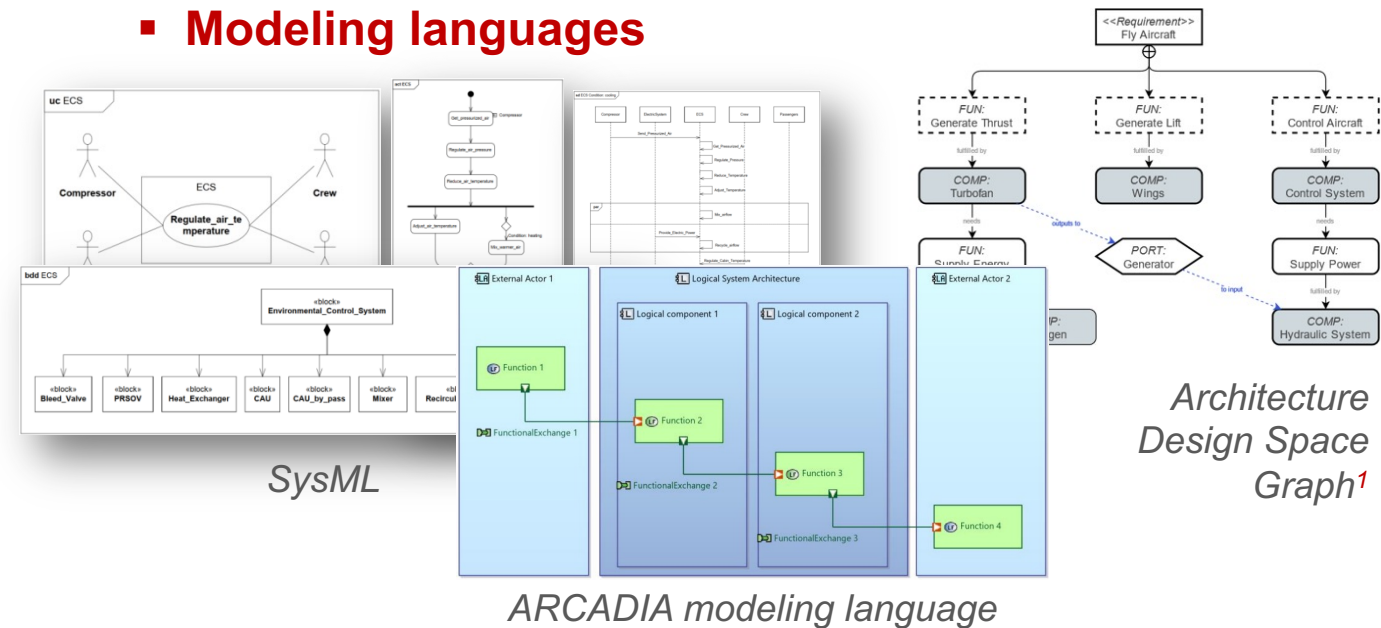
▪ **Methods**

- ▪ OOSEM (Object-Oriented SE Method
- ▪ Arcadia
- ▪ SYSMOD
- ▪ FAS (Functional Architecture for Systems)
- ▪ DLR-developed methods[1]

▪ **Modeling languages**

SysML

ARCADIA modeling language

Architecture Design Space Graph[1]

▪ **Tools**

Commercial tools

Open-source tools

ADORE
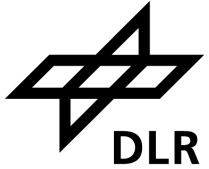System Architectures generation, modelling and visualization

DLR-developed tools[1]
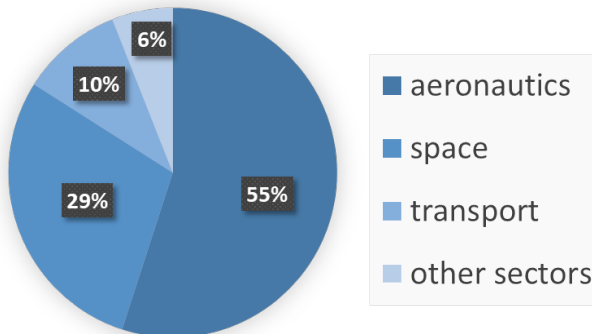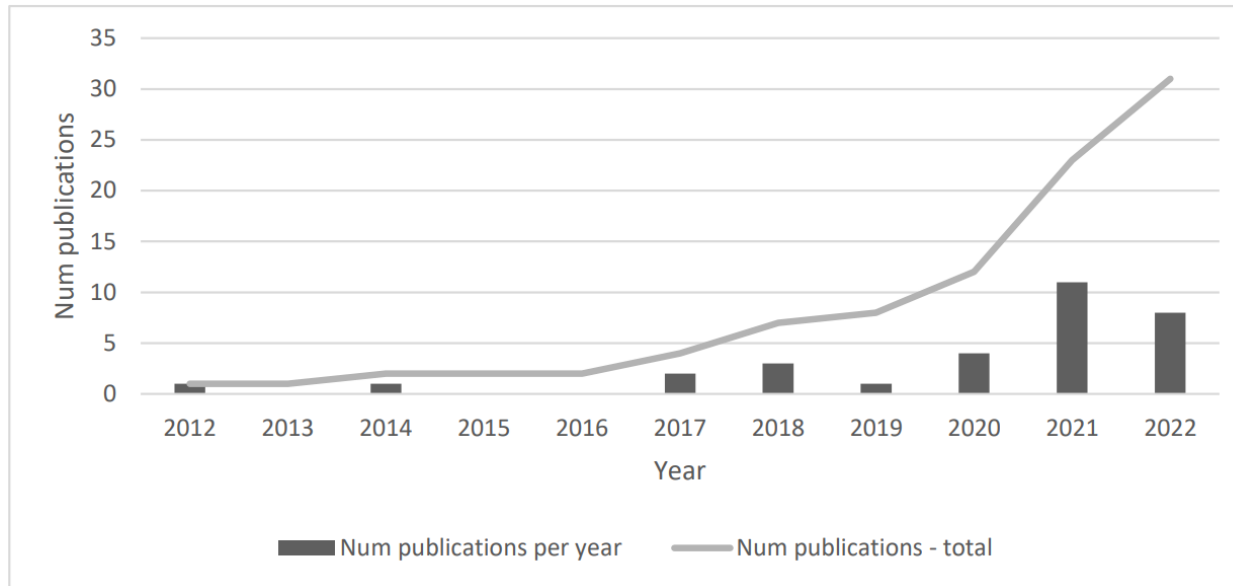
[1] *more information in the paper*

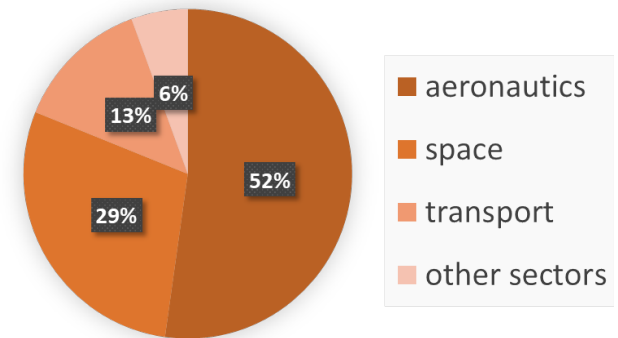# How "**active**" is DLR in terms of MBSE initiatives?

MBSE-related **publications**

- **31 papers** published by DLR in the last **10 years**
- **Increasing trend** of number of publications every year
- **Almost exponential increase** of number of publications every year
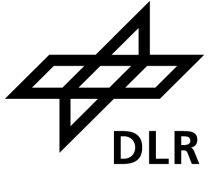
MBSE-related **projects**

- **58 projects** where DLR is involved (DLR-internal, German and international)
- **MBSE-Ops** involves more than one sector

→ **DLR is becoming more active in MBSE - related research. Many more publications and projects are expected in the next years**

Conclusions
Limitations of the work and future activities

- **Target of the paper**
  - Development of **competence map** collecting **MBSE methods, modeling languages and tools** available in the different **research domains of DLR**

- **Main outcomes and considerations**
  - **DLR is active and mature in MBSE** activities since al least ten years
  - **Different MBSE methodologies** (e.g. methods, tools) are adopted in the different institutes
  - Identification of **new research opportunities**, within the DLR and with other organizations

- **Limitations**
  - **Only 15 DLR groups** have been identified and interviewed
  - MBSE competence map reflects the **status at October 2022**
  - **Map published within the DLR only**

- **Future activities**
  - Identify and interview **more DLR groups** doing MBSE research activities
  - Keep the MBSE competence map **updated**

What is the current MBSE state in your organization?

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