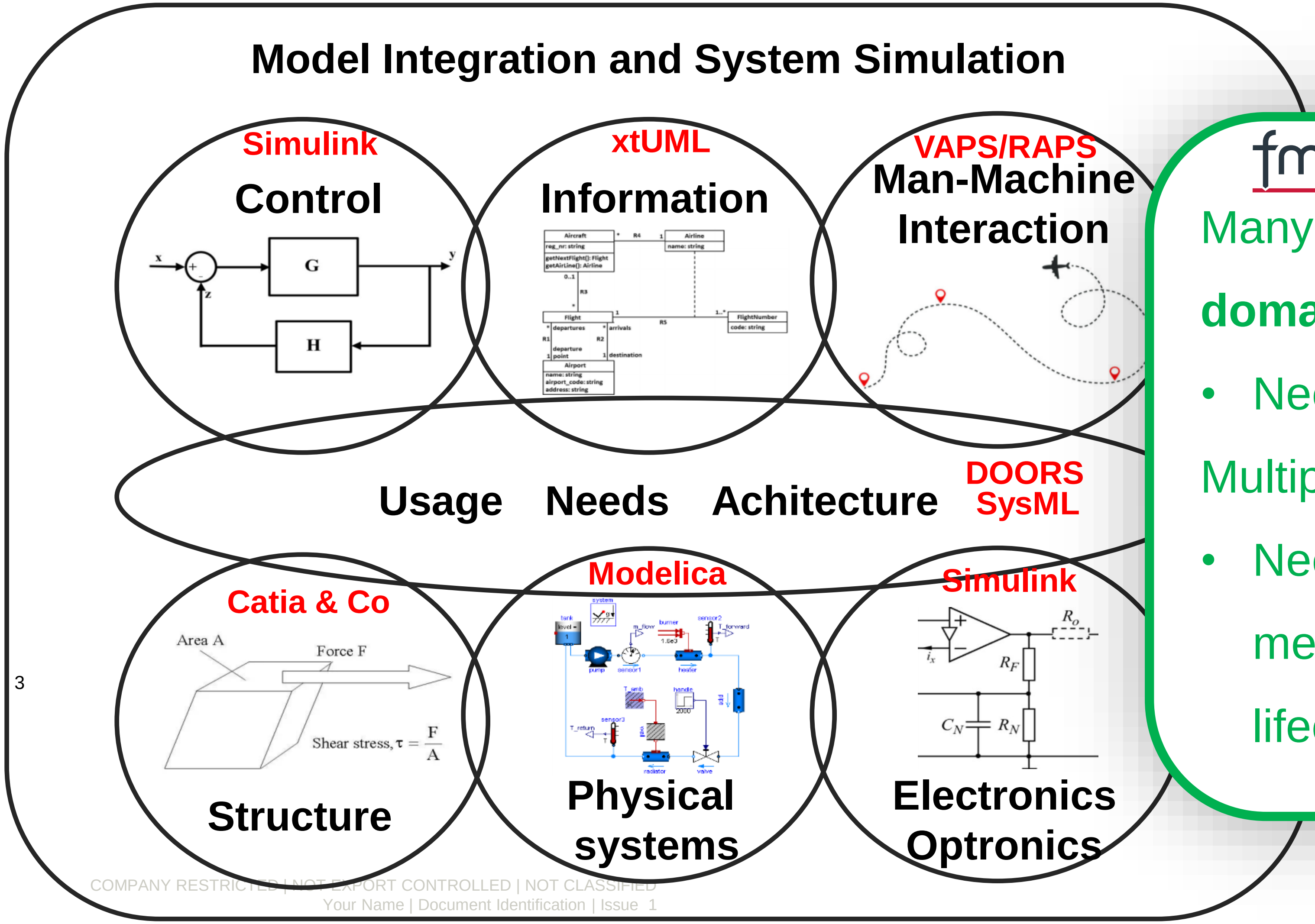
Excuse me Sir/Madam, which Model?

Erik Herzog, Johanna Walle’n Axehill, Robert Hällqvist. Saab Aeronautics

Excuse me Sir/Madam, which Model?
Background

- Models and MBSE at Saab
  - Many different models used for many different purposes
- Establish Taxonomy
  - Based on their purpose
  - Avoid misunderstanding
  - Simplify reuse
  - Increase quality in model based desitionmaking

MBSE DOMAINS – GRIPEN EXAMPLE
Background



fmi Functional Mock-Up Interface

ssp System Structure & Parameterization

Many **different languages and domains**

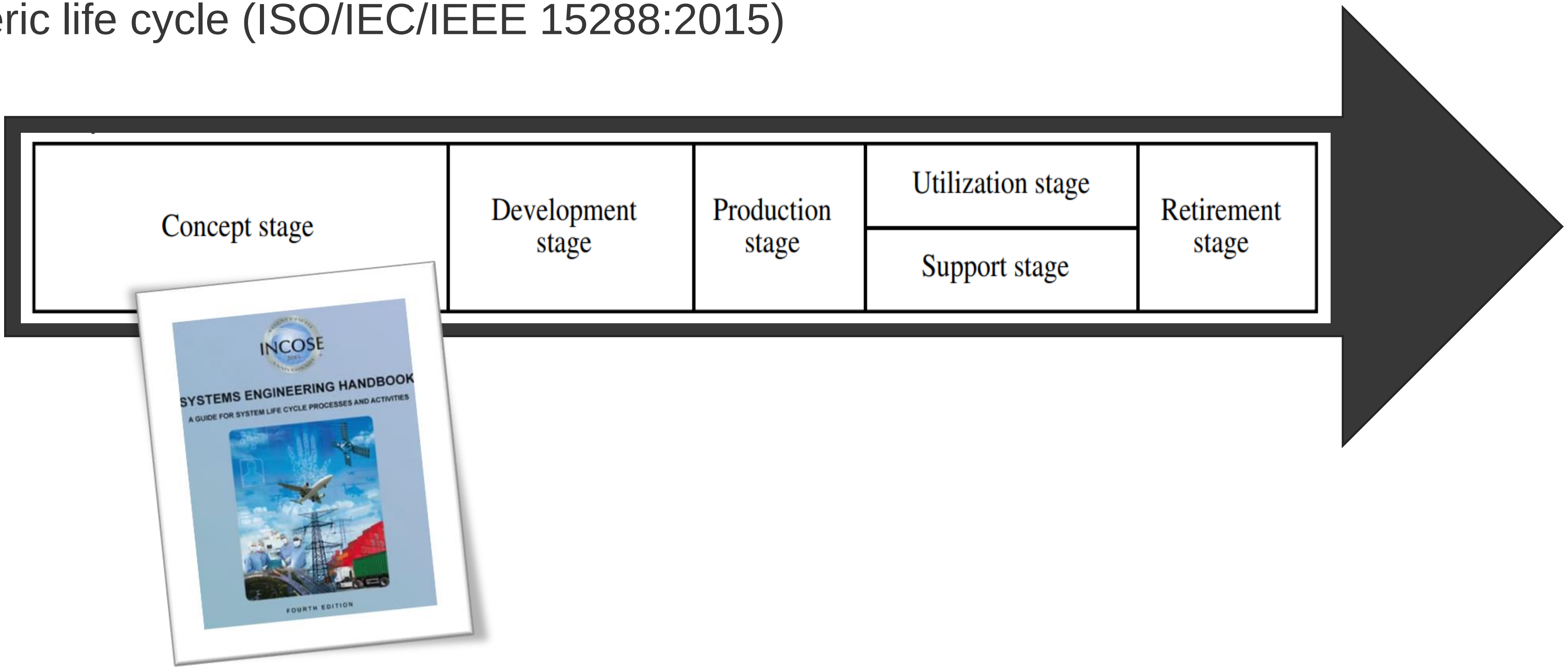
- Need for interface standards

Multiple **interrelated models**

- Need for configuration mechanisms throughout all lifecycle phases

Modeling and Simulation Today at Saab

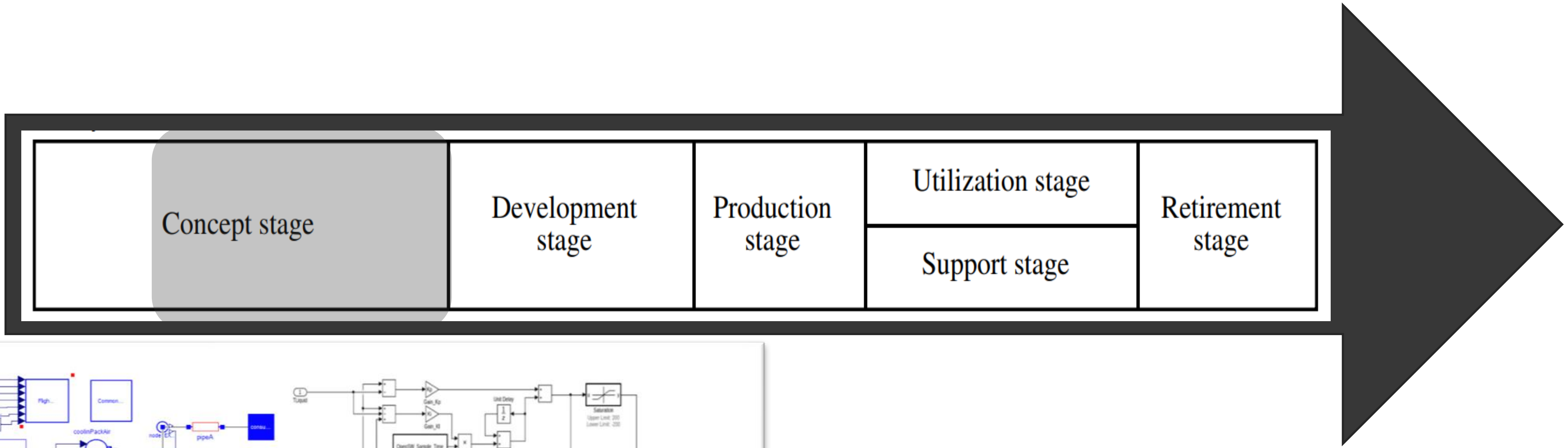
- Used to various degrees in a all life cycle stages
- Generic life cycle (ISO/IEC/IEEE 15288:2015)

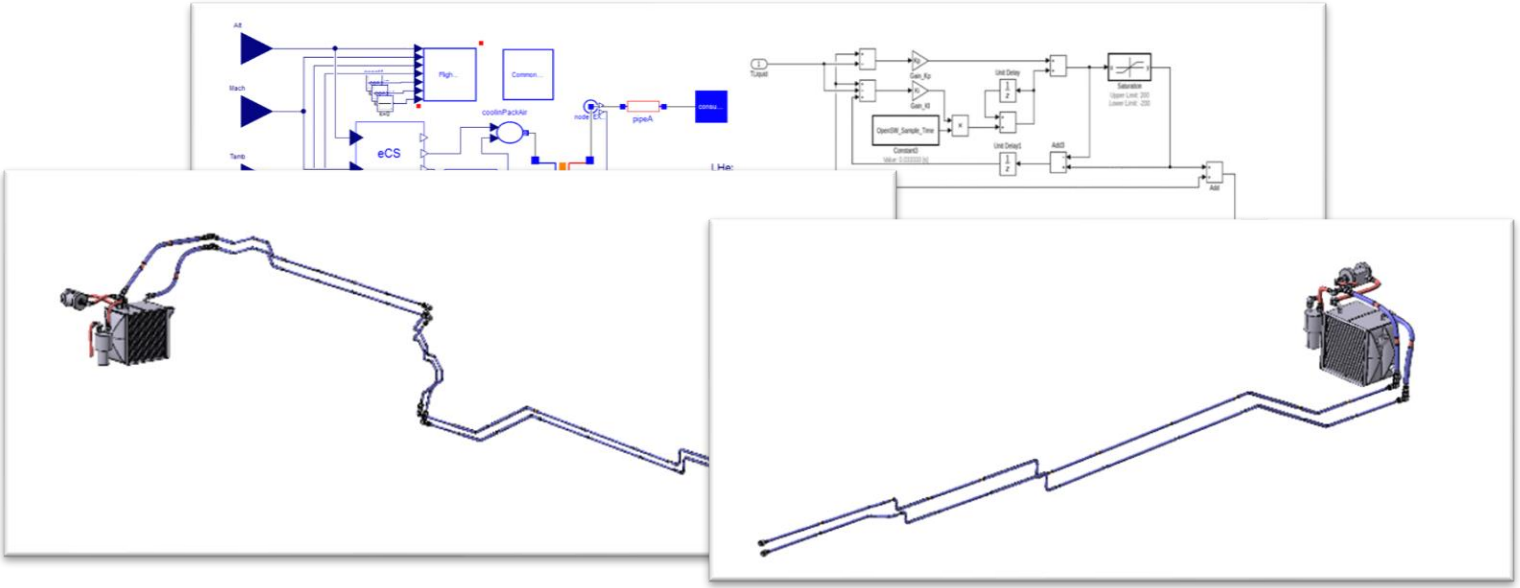


INCOSE. Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities. Fourth Edition, Wiley

Modeling and Simulation Today at Saab

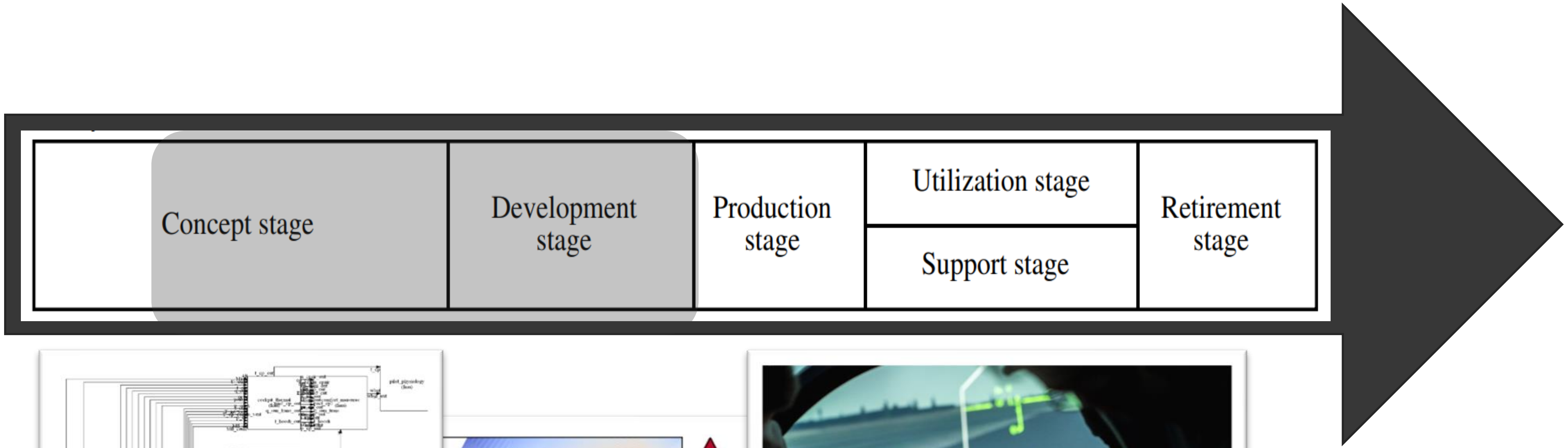
- Evaluation of sub-system architectures

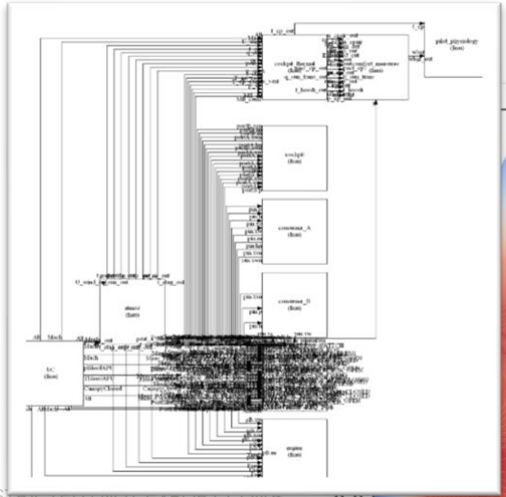


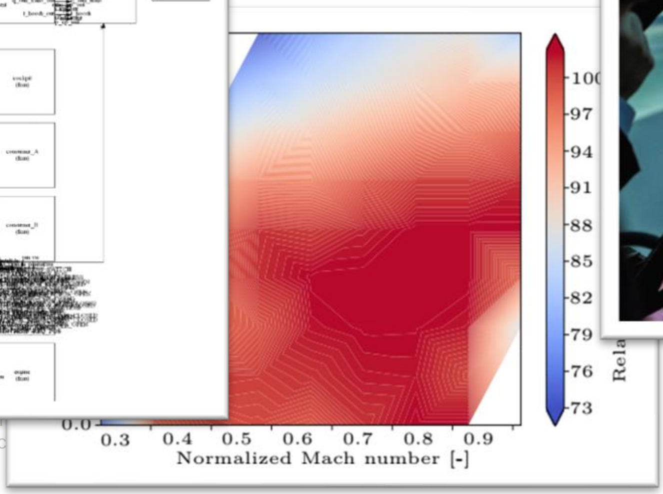


Modeling and Simulation Today at Saab

- Support hardware and software design



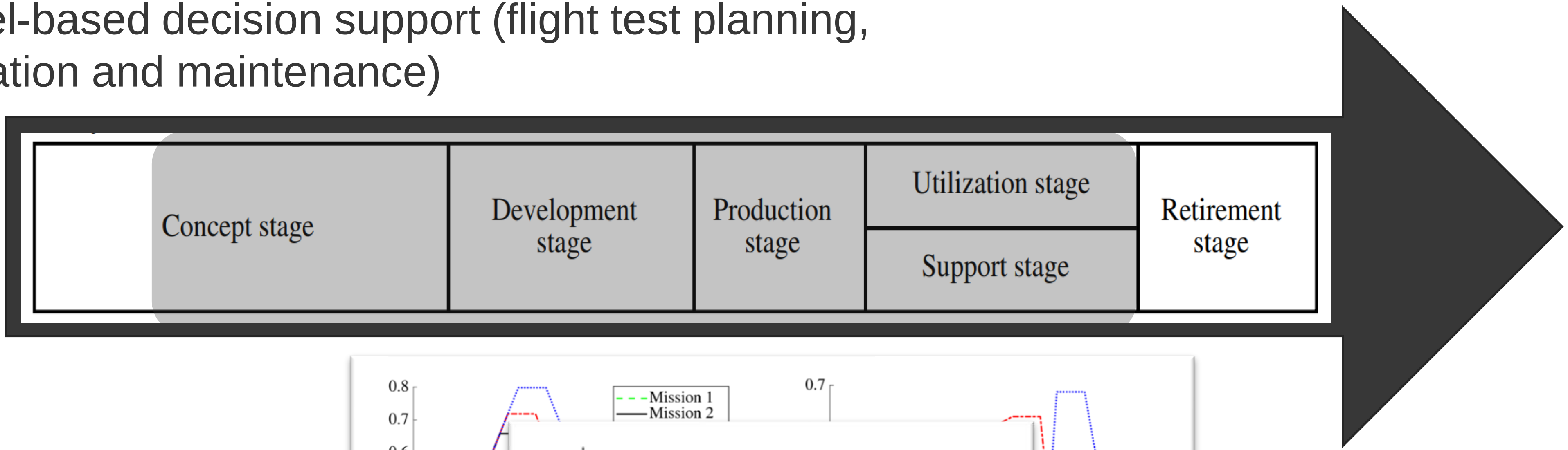


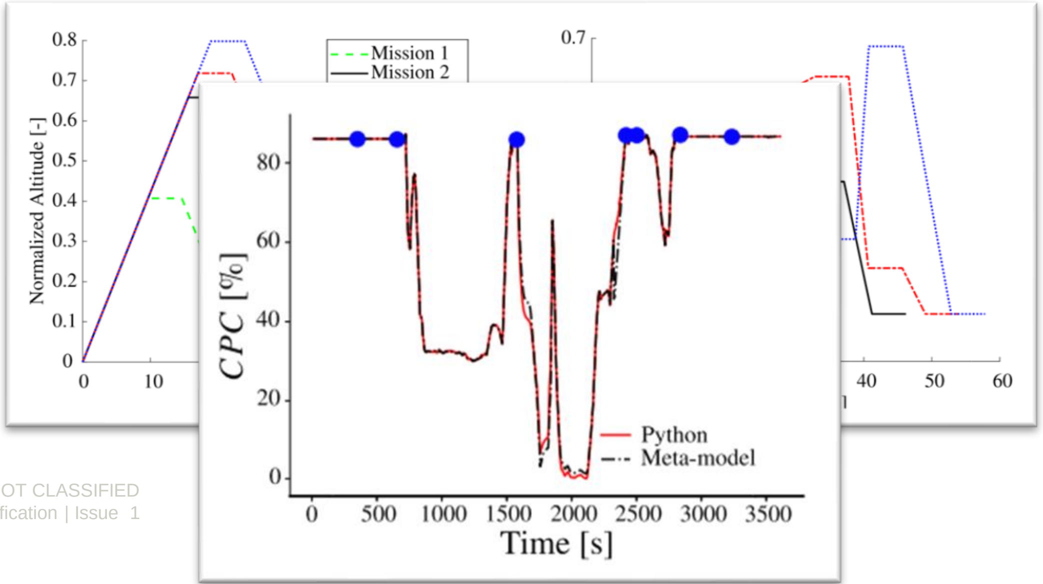


Modeling and Simulation Today at Saab

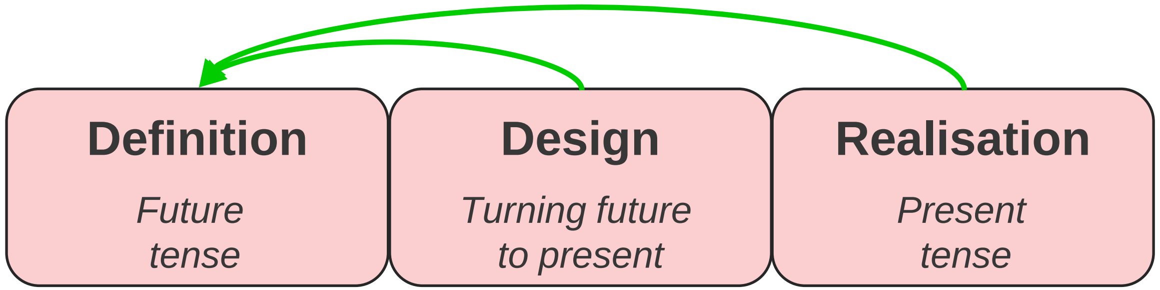
Focus of Research

- Model-based software verification
- Model-based decision support (flight test planning, operation and maintenance)





Model Tenses*



Definition model

- How the system will **be structured in the long-time** perspective, i.e. the system architecture that will eventually be realised.
- Provides a rather non-detailed view of a future system

*Herzog E, Axehill JW and Nordling Larsson Å 2022, 'Perspectives on Models', In proceedings of the INCOSE workshop EMEA WSEC, Sevilla, Spain.

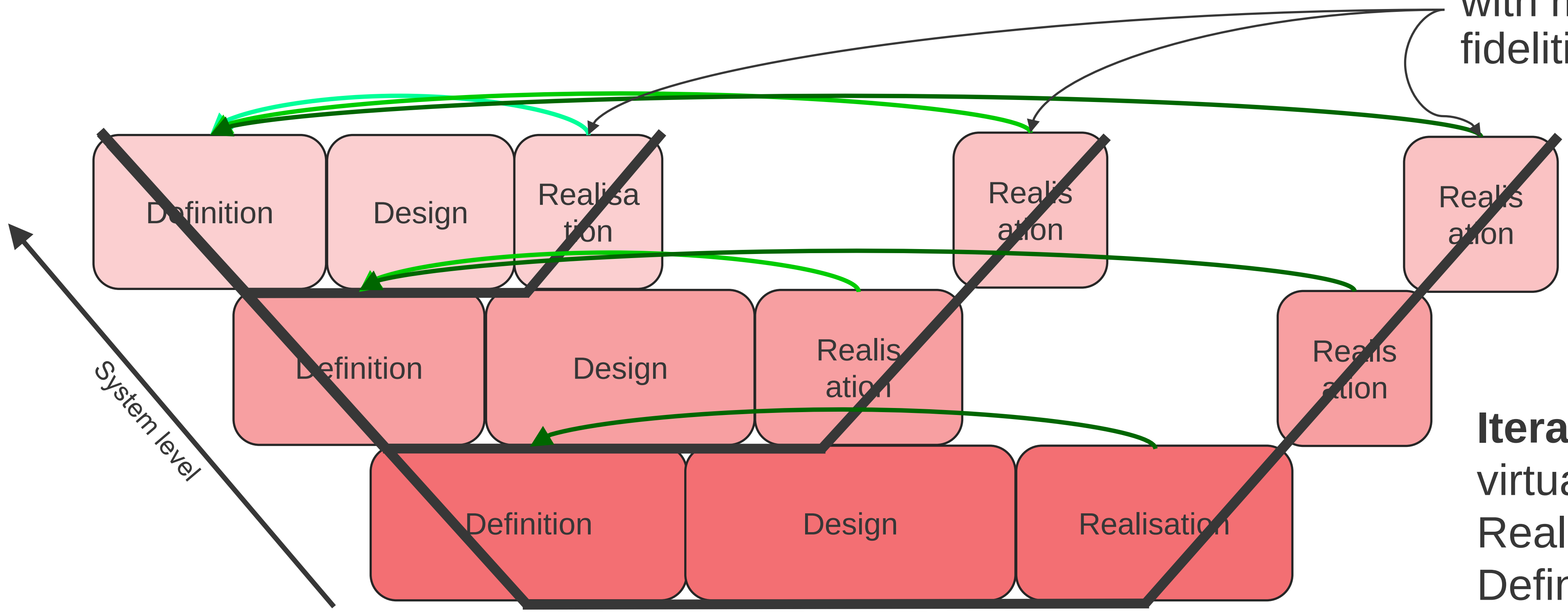
Design model

- Captures a system element from a **particular perspective,** i.e. interfaces and key properties
- Multiple **Design models** may be required to adequately represent the intent in a Definition model
  - Multiple languages, e.g. Simulink, Modelica, CFD

Realisation model (physical/virtual)

- **Multiple virtual** Realisations with different fidelities and perspectives may be created
- Realisation **interconnection models** are required for composite Realisations

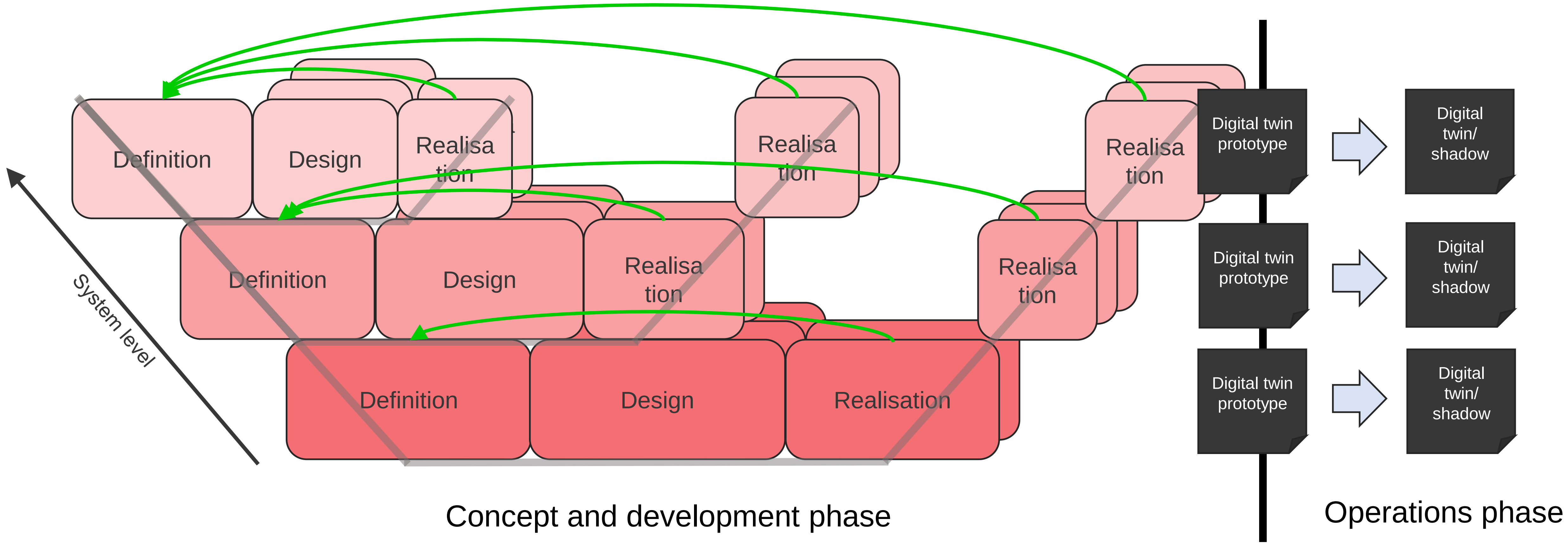
Model Tenses



Multiple virtual Realisations with multiple perspectives, fidelities and credibilities

Iterative feedback from virtual and physical Realisations to shape the Definition and Design models

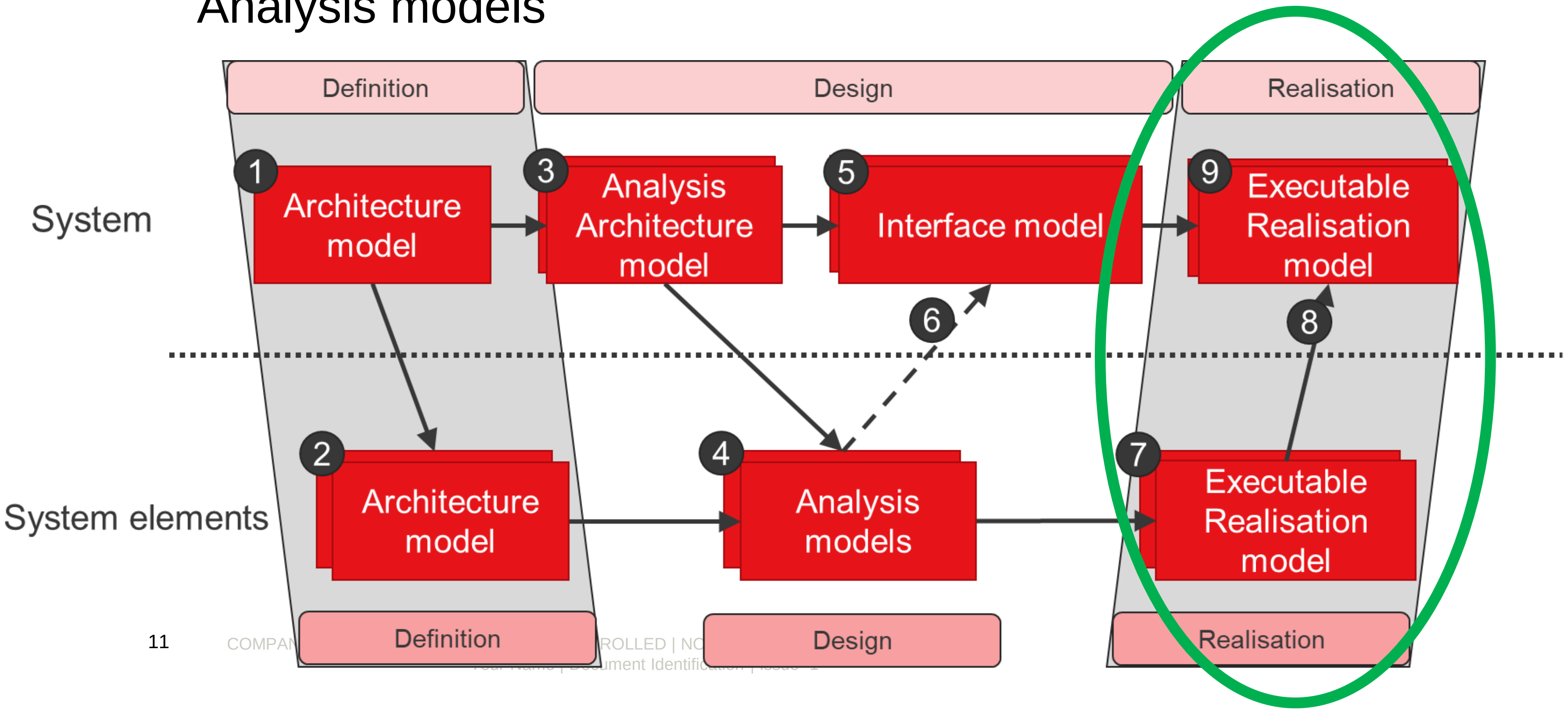
Model Tenses

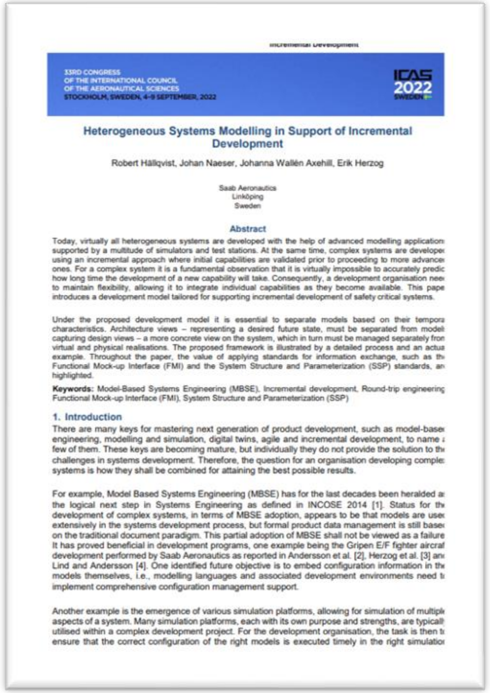


*Grieves M and Vickers J 2017. Digital Twin: Mitigating Unpredictable, Undesirable Emergent Behavior in Complex Systems. In: Kahlen, J., Flumerfelt, S., Alves, A. (eds) Transdisciplinary Perspectives on Complex Systems. Springer

Model Tenses
Model types

- Focus of this presentation: 7and 9) Executable Realization Models
- Other artifacts described in*: 1) Architecture, 2) Analysis Architecture, 3) Interface, 4) Analysis models





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STOCKHOLM, SWEDEN, 4-9 SEPTEMBER, 2022

ICAS 2022 SWEDEN

Heterogeneous Systems Modelling in Support of Incremental Development

Robert Hällqvist, Johan Naeser, Johanna Wallén Axehill, Erik Herzog

Saab Aeronautics
Linköping
Sweden

Abstract

Today, virtually all heterogeneous systems are developed with the help of advanced modelling application supported by a multitude of simulators and test stations. At the same time, complex systems are develope using an incremental approach where initial capabilities are validated prior to proceeding to more advance ones. For a complex system it is a fundamental observation that it is virtually impossible to accurately predic how long time the development of a new capability will take. Consequently, a development organisation nee to maintain flexibility, allowing it to integrate individual capabilities as they become available. This pape introduces a development model tailored for supporting incremental development of safety critical systems.

Under the proposed development model it is essential to separate models based on their tempora characteristics. Architecture views – representing a desired future state, must be separated from model capturing design views – a more concrete view on the system, which in turn must be managed separately fron virtual and physical realisations. The proposed framework is illustrated by a detailed process and an actua example. Throughout the paper, the value of applying standards for information exchange, such as th Functional Mock-up Interface (FMI) and the System Structure and Parameterization (SSP) standards, ar highlighted.

Keywords: Model-Based Systems Engineering (MBSE), Incremental development, Round-trip engineering Functional Mock-up Interface (FMI), System Structure and Parameterization (SSP)

1. Introduction

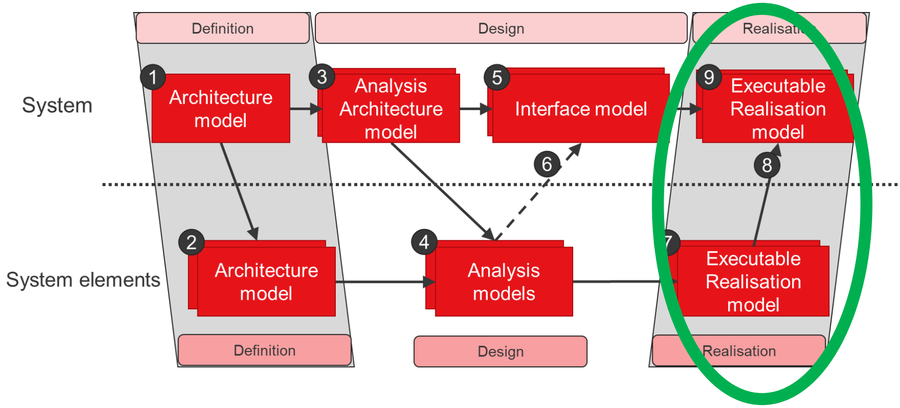
There are many keys for mastering next generation of product development, such as model-base engineering, modelling and simulation, digital twins, agile and incremental development, to name a few of them. These keys are becoming mature, but individually they do not provide the solution to th challenges in systems development. Therefore, the question for an organisation developing comple systems is how they shall be combined for attaining the best possible results.

For example, Model Based Systems Engineering (MBSE) has for the last decades been heralded a the logical next step in Systems Engineering as defined in INCOSE 2014 [1]. Status for th development of complex systems, in terms of MBSE adoption, appears to be that models are use extensively in the systems development process, but formal product data management is still base on the traditional document paradigm. This partial adoption of MBSE shall not be viewed as a failure It has proved beneficial in development programs, one example being the Gripen E/F fighter aircraf development performed by Saab Aeronautics as reported in Andersson et al. [2], Herzog et al. [3] an Lind and Andersson [4]. One identified future objective is to embed configuration information in th models themselves, i.e., modelling languages and associated development environments need t implement comprehensive configuration management support.

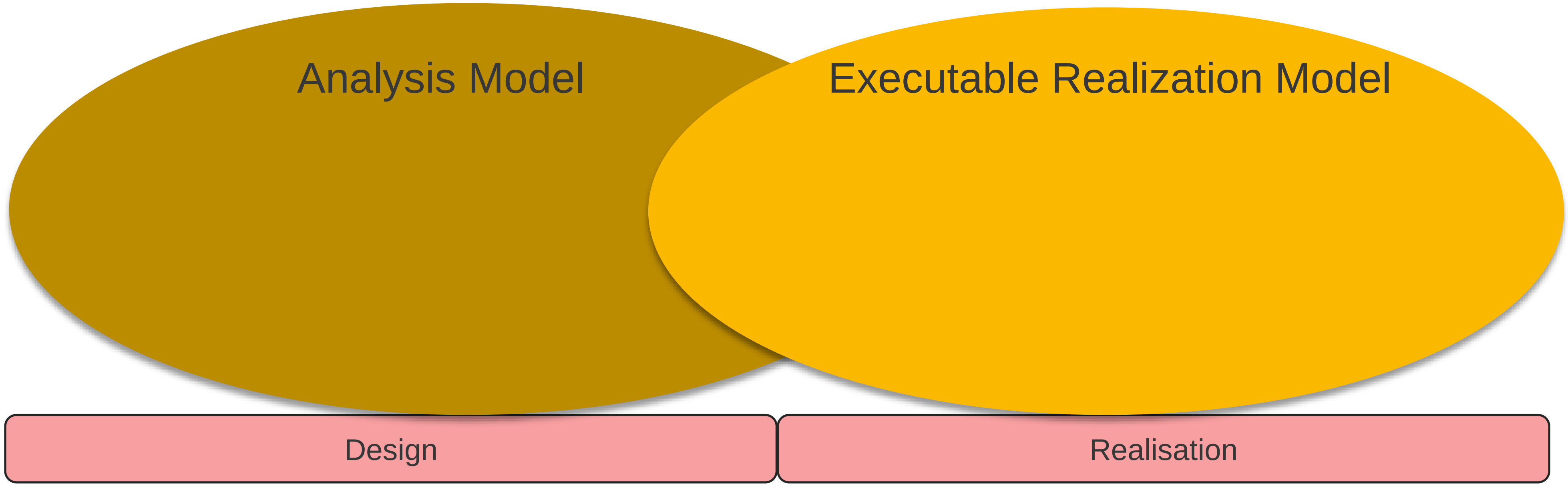
Another example is the emergence of various simulation platforms, allowing for simulation of multipl aspects of a system. Many simulation platforms, each with its own purpose and strengths, are typicall utilised within a complex development project. For the development organisation, the task is then t ensure that the correct configuration of the right models is executed timely in the right simulatio

***Hällqvist, Naeser, Axehill, and Herzog, HETEROGENEOUS SYSTEMS MODELLING IN SUPPORT OF INCREMENTAL DEVELOPMENT, ICAS 2022,**

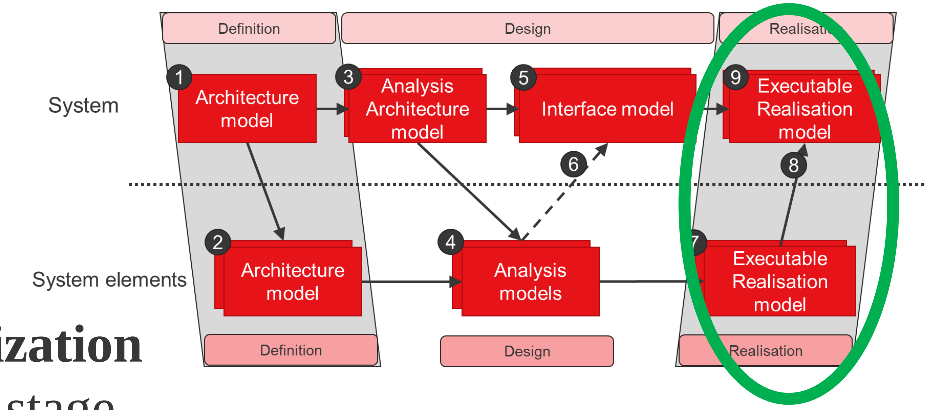
Executable Realisation Model



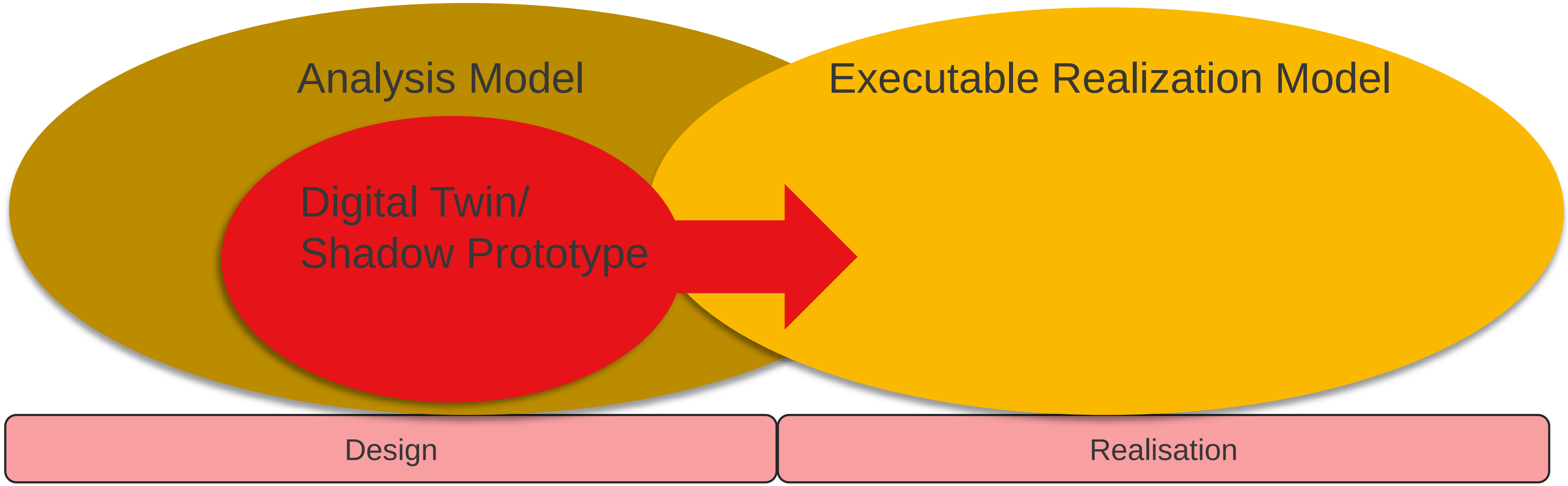
- A **digital artifact** that an *experiment* can be applied to in order to answer **questions about a corresponding physical logical artifact** (realised or not).
- Example: **A control system simulation model,** used in a system simulator during development **of a specific product configuration**.



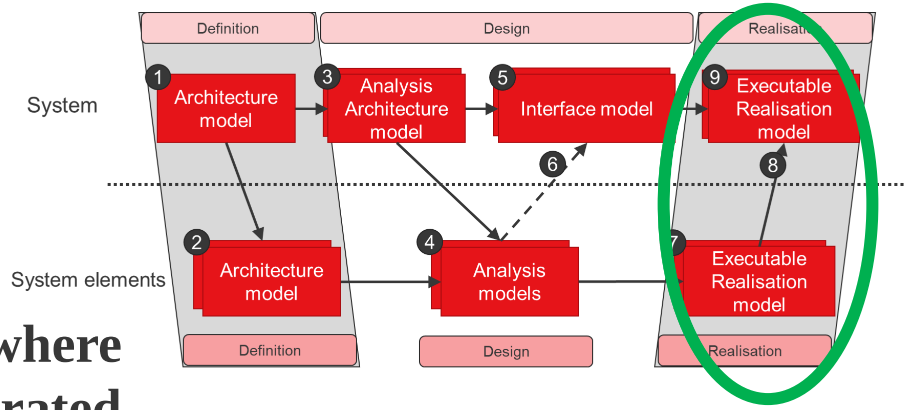
Digital Twin/Shadow Prototype



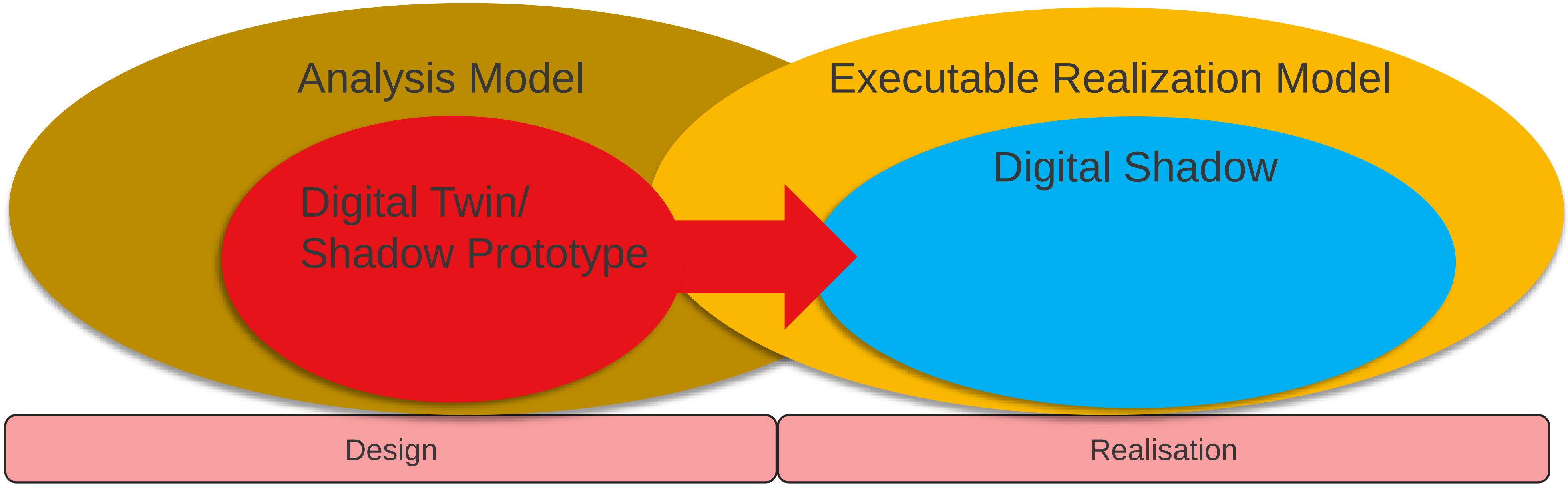
- A **Digital Shadow/Twin Prototype** is **Analysis or Realization Model** decided to be used as a **Digital Twin/Shadow** at a later stage.



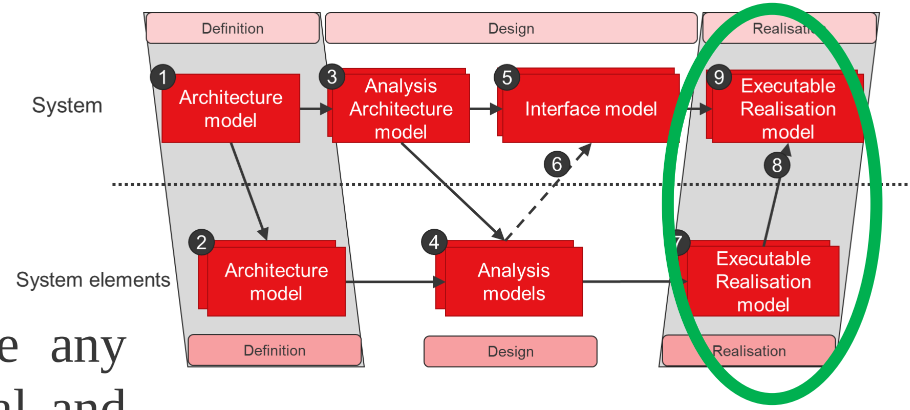
Digital Shadow



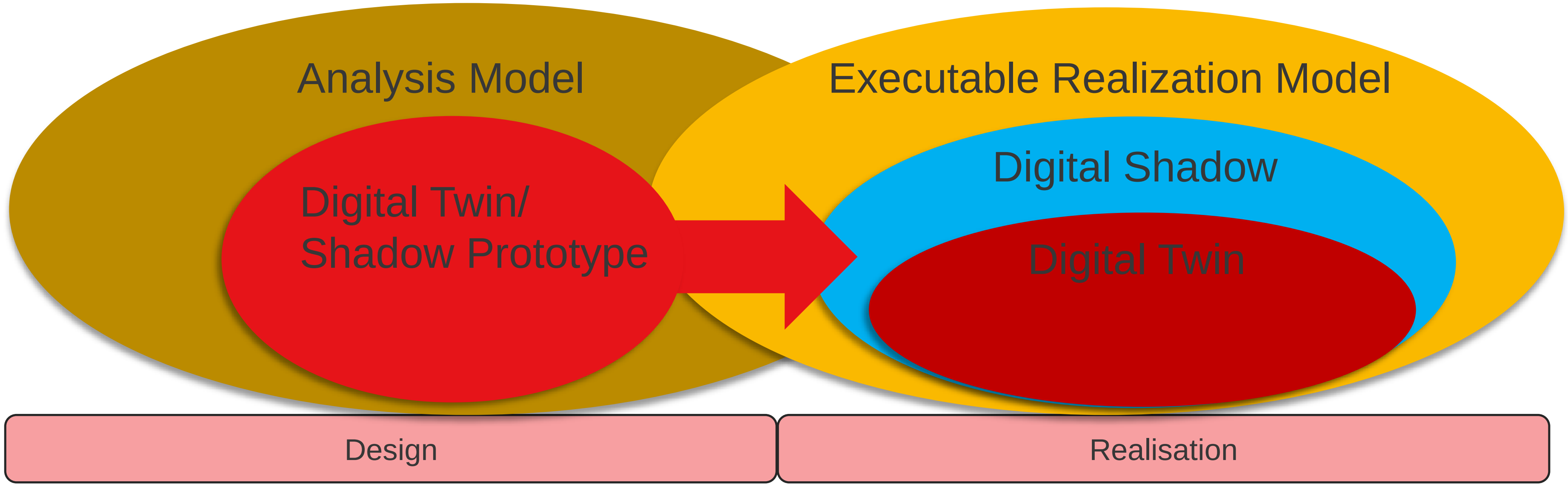
- A **Digital Shadow** is an **Executable Realisation Model where relevant information from the physical space is incorporated automatically**. A Digital Shadow is *passive* in the sense that it does not automatically influence the actual system it represents.
- Example: A model processing aircraft maintenance information, received automatically from the aircraft during or after flight.



Digital Twin



- A **Digital Twin** is an Executable Realisation Model where any relevant bi-directional flow of information between the virtual and physical spaces is exchanged automatically. In this sense, the Digital Twin is *active*.
- Example: A model used during test of equipment, where software parameters in the equipment are changed automatically based on the information analysed automatically during or after the test.



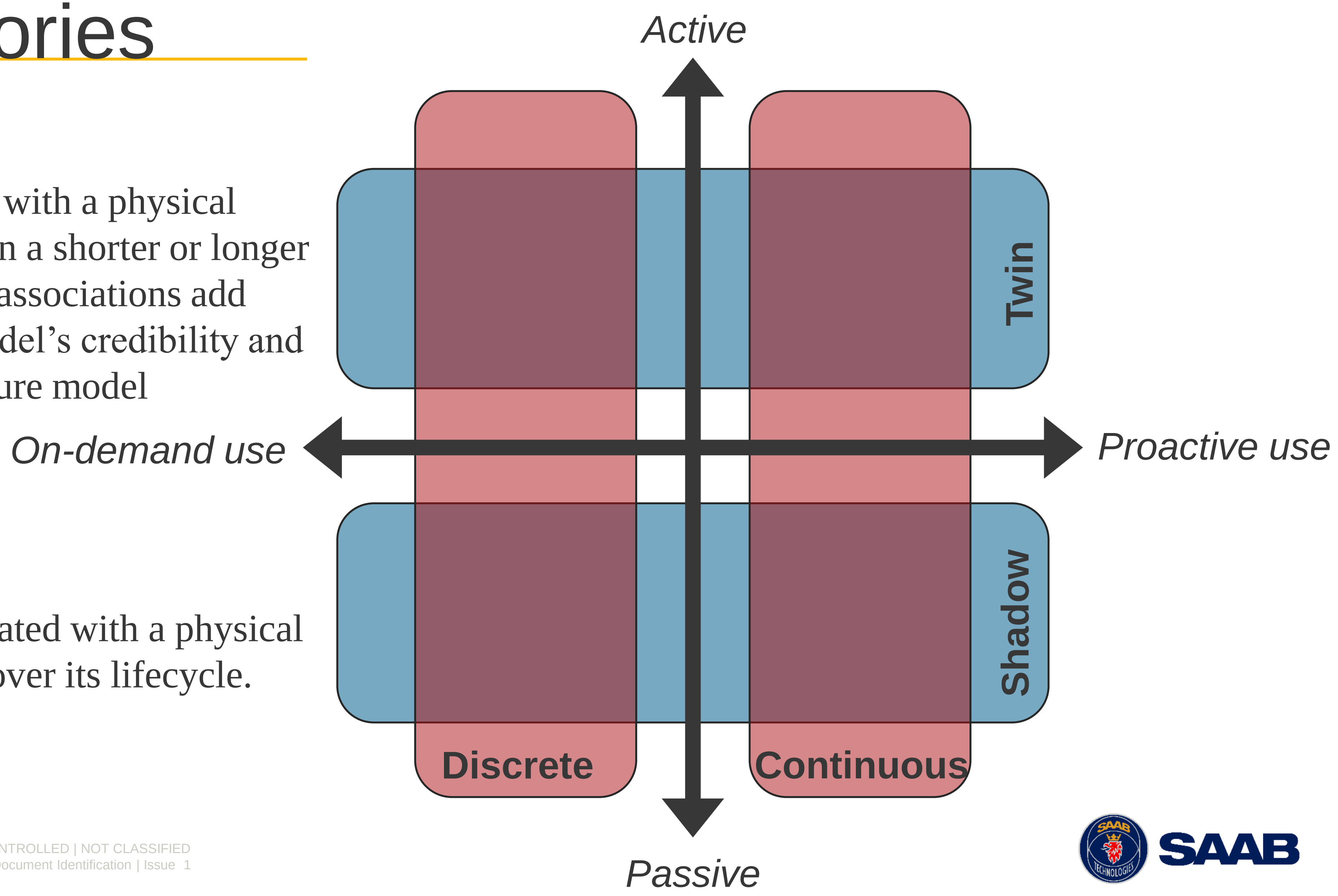
Digital Twins and Shadows
Use categories

On-demand

- A model associated with a physical product individual in a shorter or longer time interval. Such associations add insights into the model's credibility and may be used for future model development.

Proactive

- A model that associated with a physical product individual over its lifecycle.

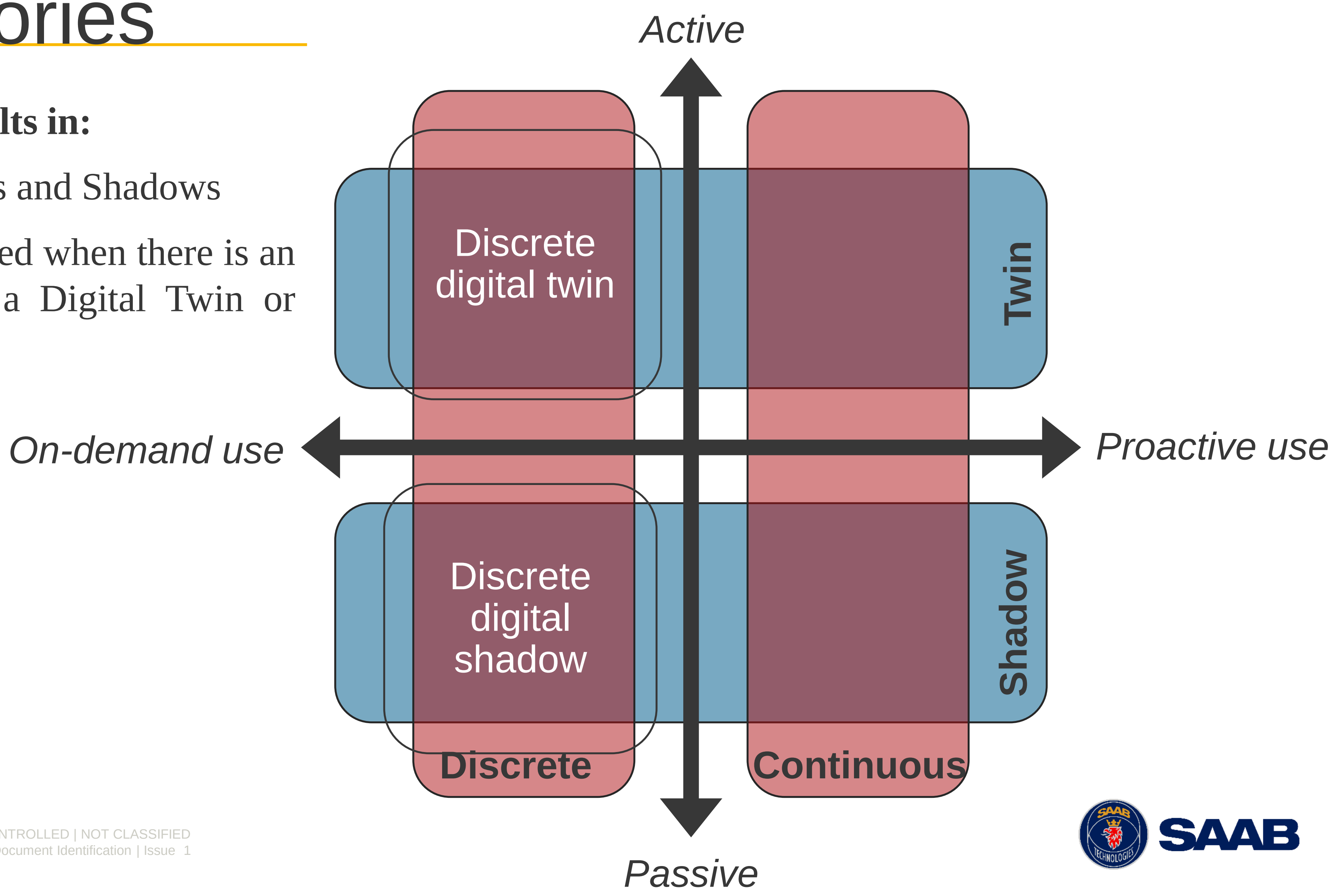


Digital Twins and Shadows
Use categories

On-demand use results in:

Discrete Digital Twins and Shadows

- Maintained and used when there is an explicit need for a Digital Twin or Shadow.



SAAB

Digital Twins and Shadows
Use categories

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Discrete Digital Twins and Shadows

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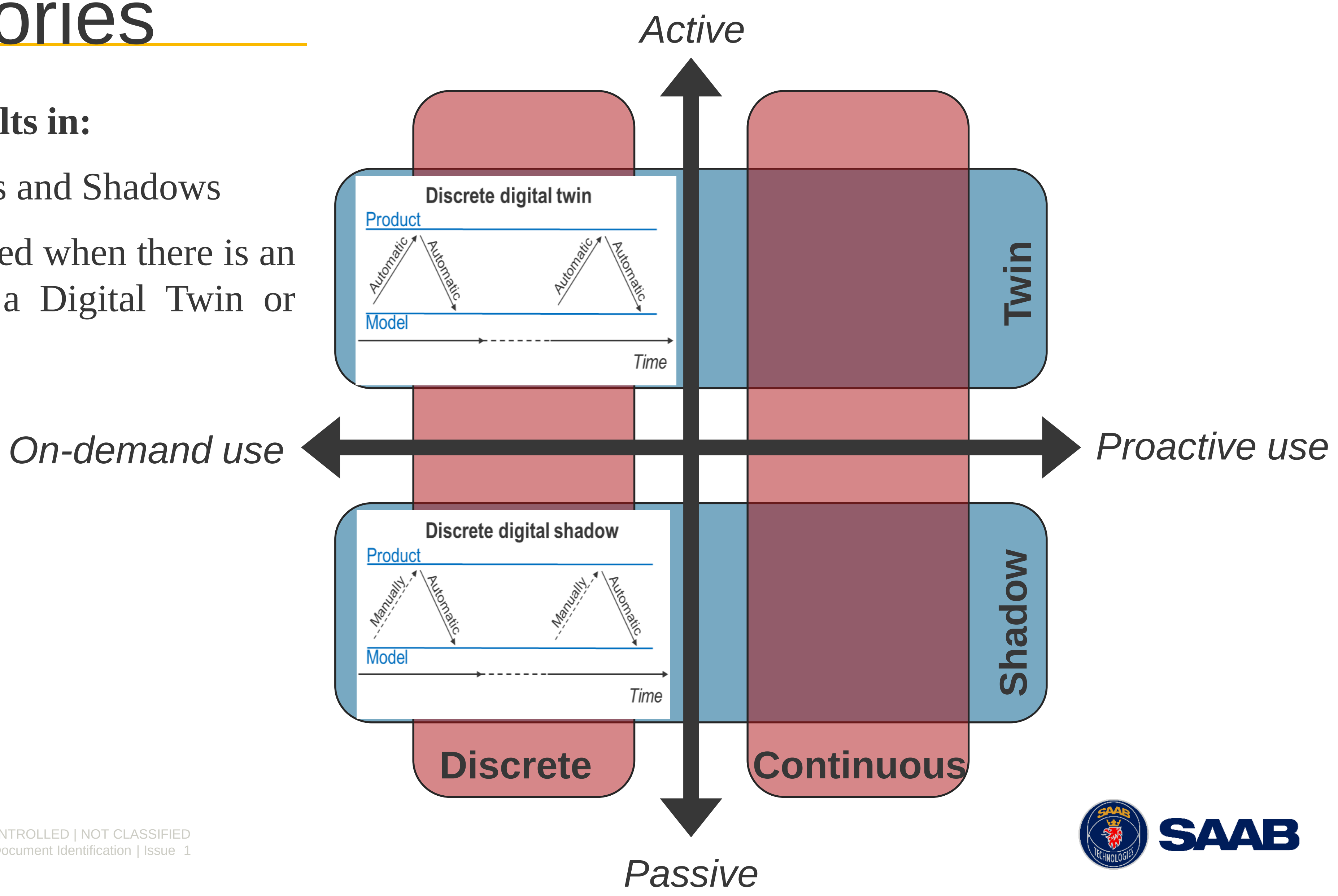


Digital Twins and Shadows
Use categories

On-demand use results in:

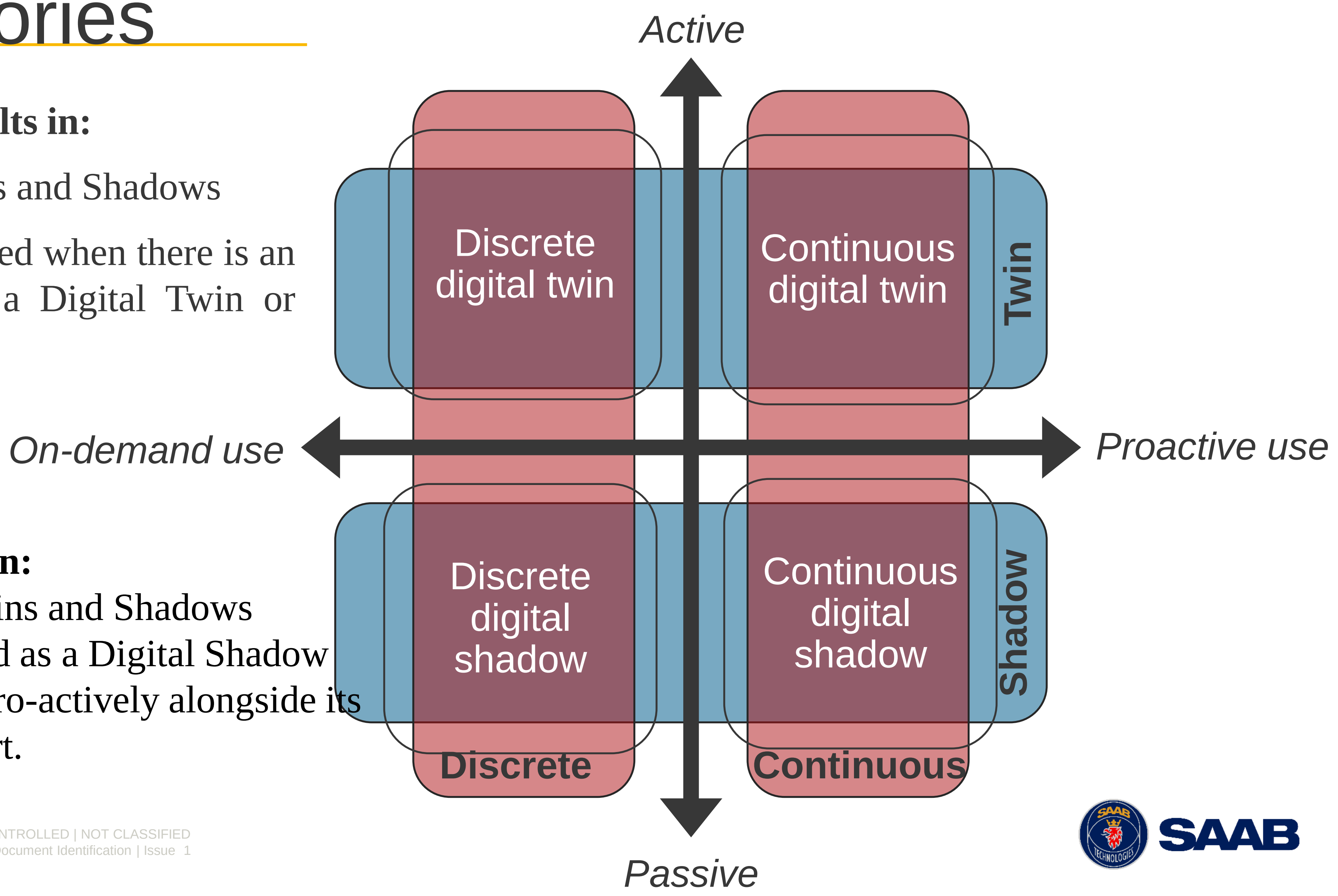
Discrete Digital Twins and Shadows

- Maintained and used when there is an explicit need for a Digital Twin or Shadow.

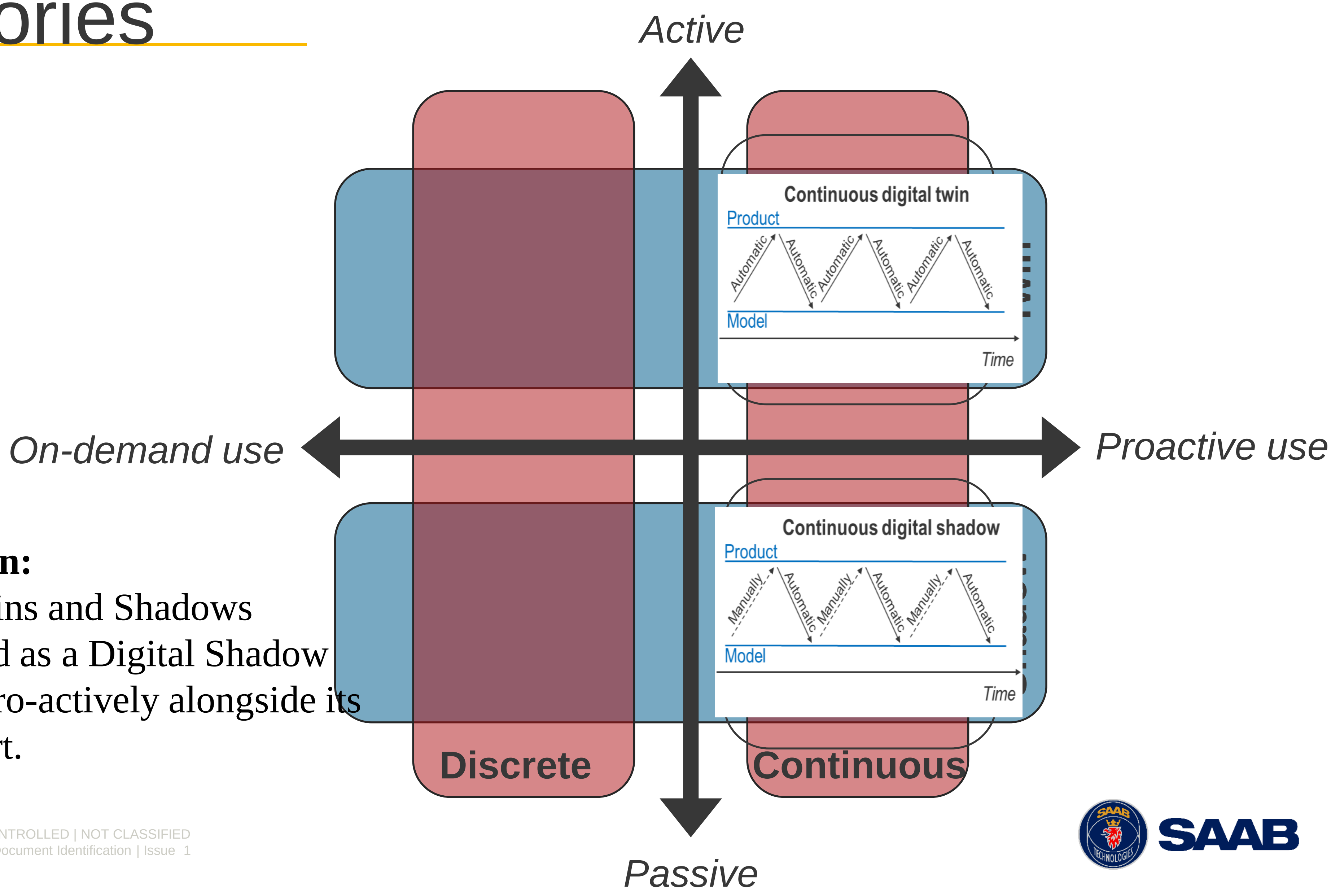
Proactive use results in:

Continuous Digital Twins and Shadows

- maintained and used as a Digital Shadow continuously and pro-actively alongside its physical counterpart.



Digital Twins and Shadows
Use categories



Proactive use results in:

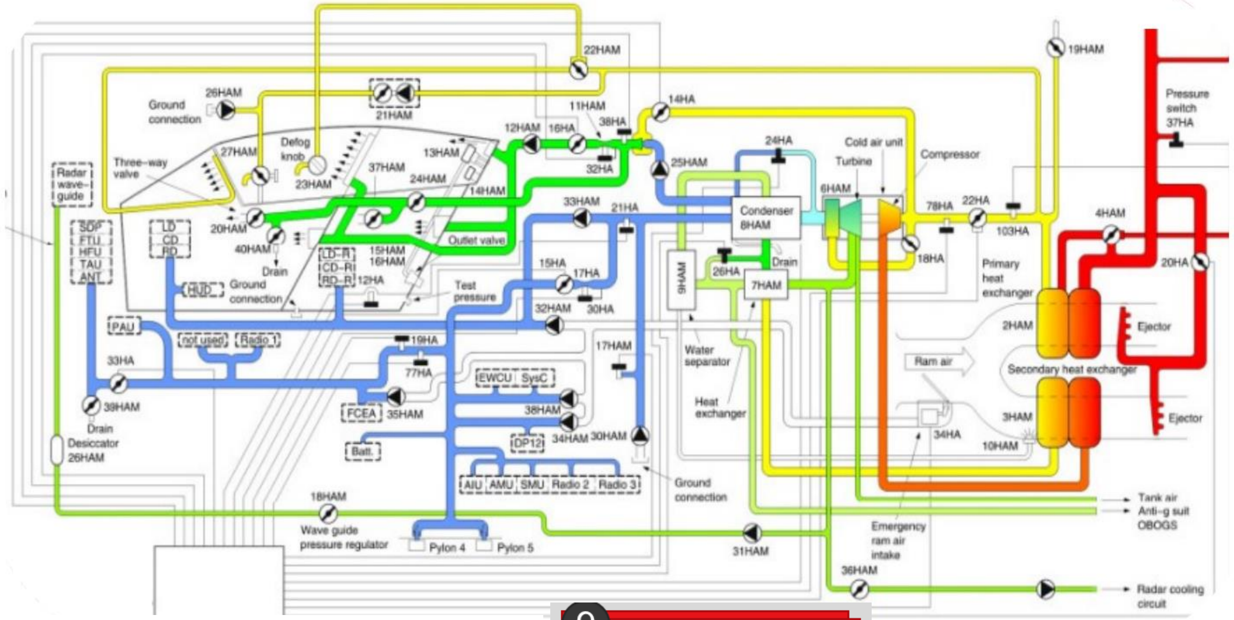
Continuous Digital Twins and Shadows

- maintained and used as a Digital Shadow continuously and pro-actively alongside its physical counterpart.

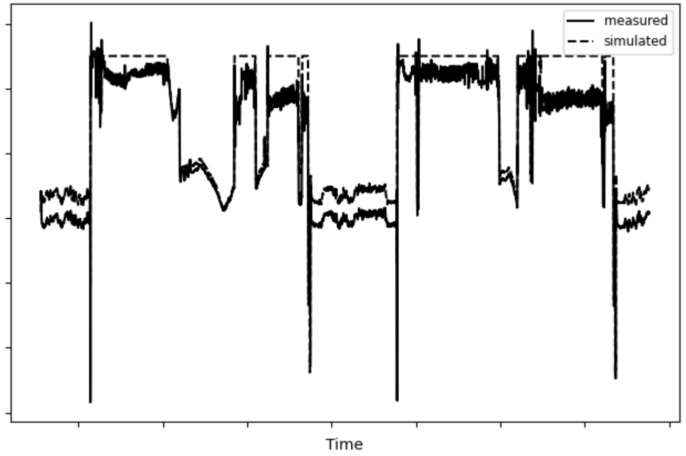
Example:
Continuous Digital Twin/Shadow

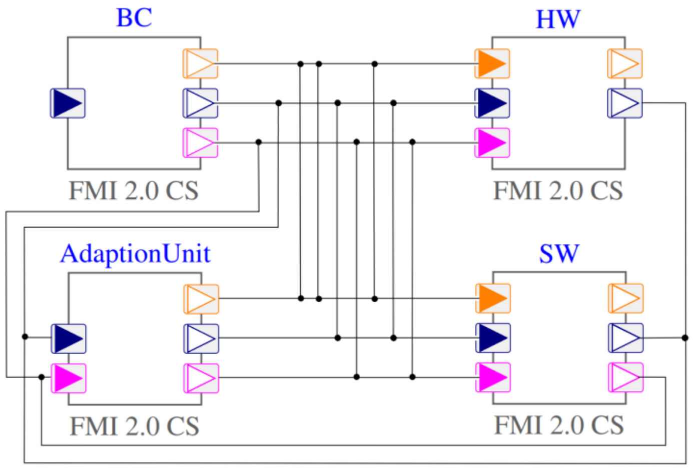
- Automatically executed (Jenkins pipeline) once new measurements are made available on file system.
    - OMSimulator
    - Represents multiple different configurations
- Used for hardware model validation

1 Architecture model



Digital twin/ shadow





9 Executable Realisation model

3 Analysis Architecture model

4 Analysis models

Conclusions

- Taxonomy
  - Covering Definition, Design and Realization
  - Extension of Digital Twin and Shadow terminology
  - An extension of the previously published model framework
- Agreement on nomenclature simplifies discussions related
  - to model properties, such as credibility and related sub-categories

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Thank You!

Questions?

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