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From Model-based to Model-and-Simulation-based Systems Architectures

Achieving quality engineering through descriptive and analytical models

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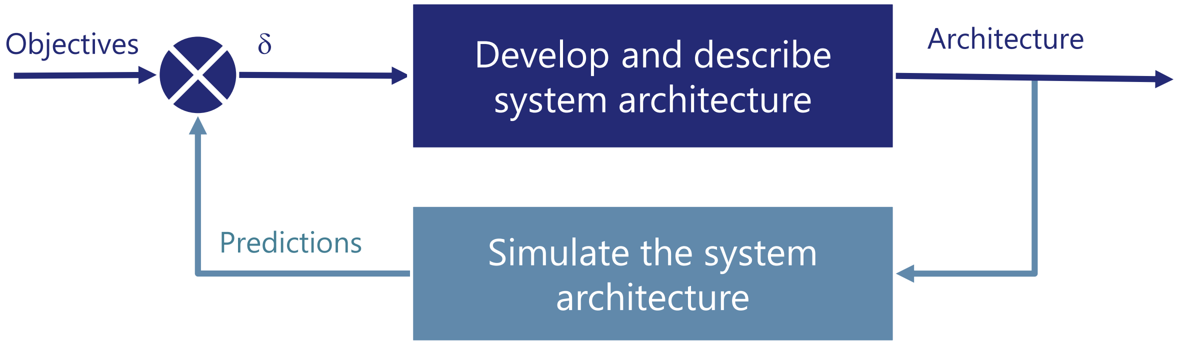
Do our MBSE practices and tools suffice to reduce the risks of our engineering programs?

What we call simulation here



(By the way, this pattern can be applied to many engineering activities other than Architecture)

Simulation – a cognition process that predicts effects, including any form of deliberation based on a model. Including:

- Workshops in which experts deliberate about the expected behavior of the system
- Automatic validation rules
- **Computer-assisted simulation of executable models**

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How, and under which conditions, simulation techniques can be articulated with MBSE to ensure proper quality architecture designs?

Agenda

Our MBSE approach

Limitations

How simulation fills the gaps

Case study

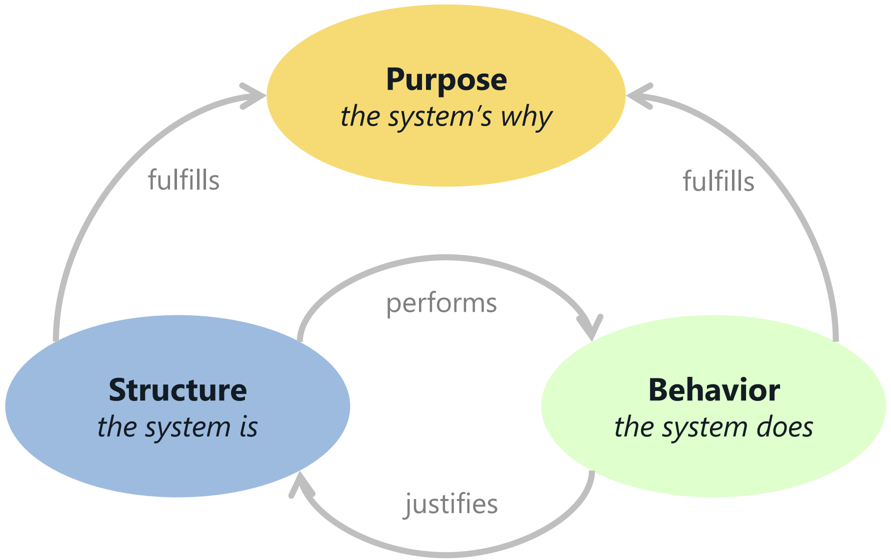
Our MBSE approach: ARCADIA method

ARCADIA drives you to adopt certain perspectives to ensure the consistency and completeness of your architecture design

Perspective	Objective
Operational Analysis	What the stakeholders need to accomplish
System Needs Analysis	What the system has to accomplish for the stakeholders
Conceptual Architecture	How the system will work to fulfill expectations
Finalized Architecture	How the system will be developed and built

ARCADIA Aspects

The *reason to exist* of the system: the services it provides in different contexts of usage, so to fulfill stakeholders expectations



The *form* – the entities that are considered during the different contexts of usage of the system, as well as the constituents of the system

The *function* – the expected behavior of the entities in the context of usage, of the system, and of its constituents

ARCADIA matrix – our “safety belt” when designing complex solutions

		ASPECTS				
		Purpose	Function	Modes & States	Structure	Interfaces
NEED PERSPECTIVES	**Operational Analysis** What the stakeholders need to accomplish					
	System Needs Analysis What the system has to accomplish for the stakeholders					
SOLUTION PERSPECTIVES	**Conceptual Architecture** How the system will work to fulfill expectations					
	Finalized Architecture How the system will be developed and built					

Each of these boxes refer to questions that are relevant when defining the architecture of a system.

And for each of these boxes, simulation has proven useful on ensuring the proper quality of the design

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(Some) MBSE limitations with regards to engineering goals

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In Systems-of-Systems and AI-powered systems contexts, static descriptions do not suffice to **understand emerging behaviors**

Multi-concerns analysis often require data out of the architecture model and powerful visualization techniques

Agility drives to frequently **show customers how the system provides the expected value**, which is not always feasible with static models

SECURE

Full consistency of design requires cross-checks between aspects, but they may be too specific or cannot be automated easily

Completeness of IVV strategies based on architecture elements often requires specific automated checks and executable models

AUTOMATE

Generation of IVV tests out of architecture models often requires double-checks to be useable by IVV teams

Tradeoffs and optimizations of design often require frequent trial and error cycles, which require executable models

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Filling the gaps with Simulation

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Unambiguous and **quantitative** simulation results with extensive visualization means

Enable to access and understand **emerging behaviors and performances**

Interactive simulation as a powerful communication mean

Improve **concurrent and collaborative engineering**

SECURE

Early and **continuously** Integrate, Verify and Validate the solution under design

Executable models enable to **secure the test cases** before real system is available.

AUTOMATE

Automate early test execution

Automate model coverage analysis

Automate document generation for behavioral aspect

Automate code generation for functions behavior

OPTIMIZATION

Enables **wider solution space exploration** and alternatives comparison

Automate the exploration, with parametrized model in an optimization loop to converge towards the best solution.

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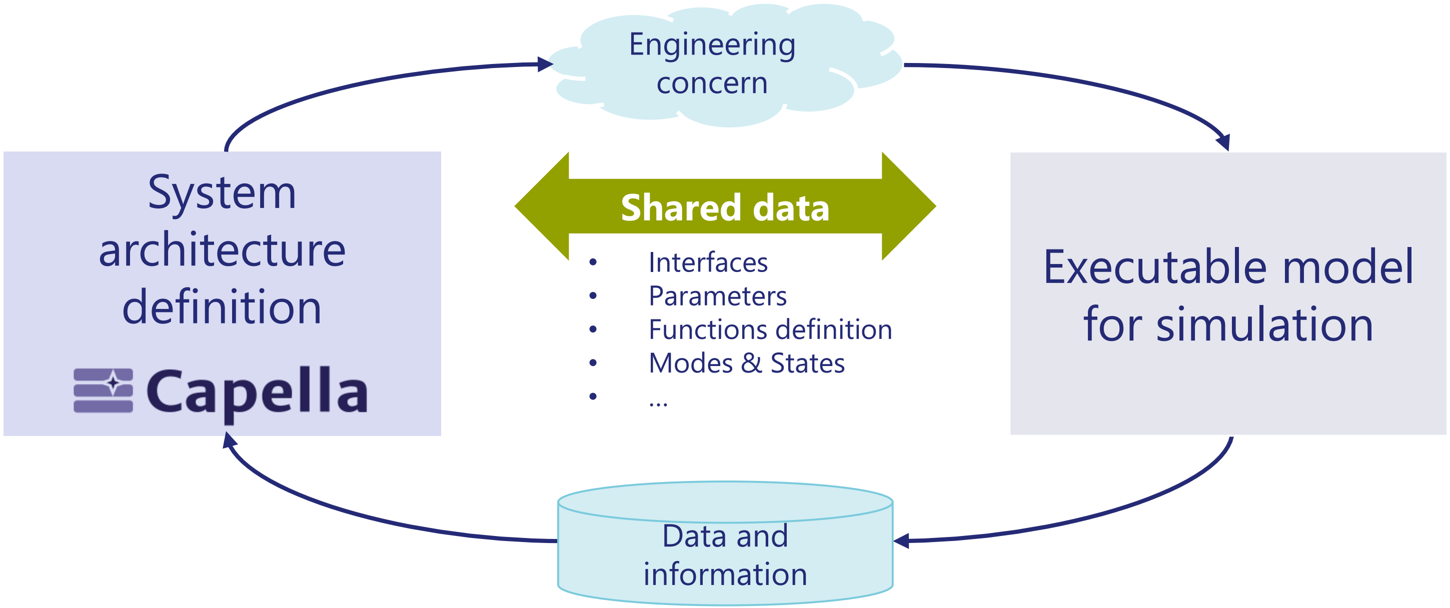
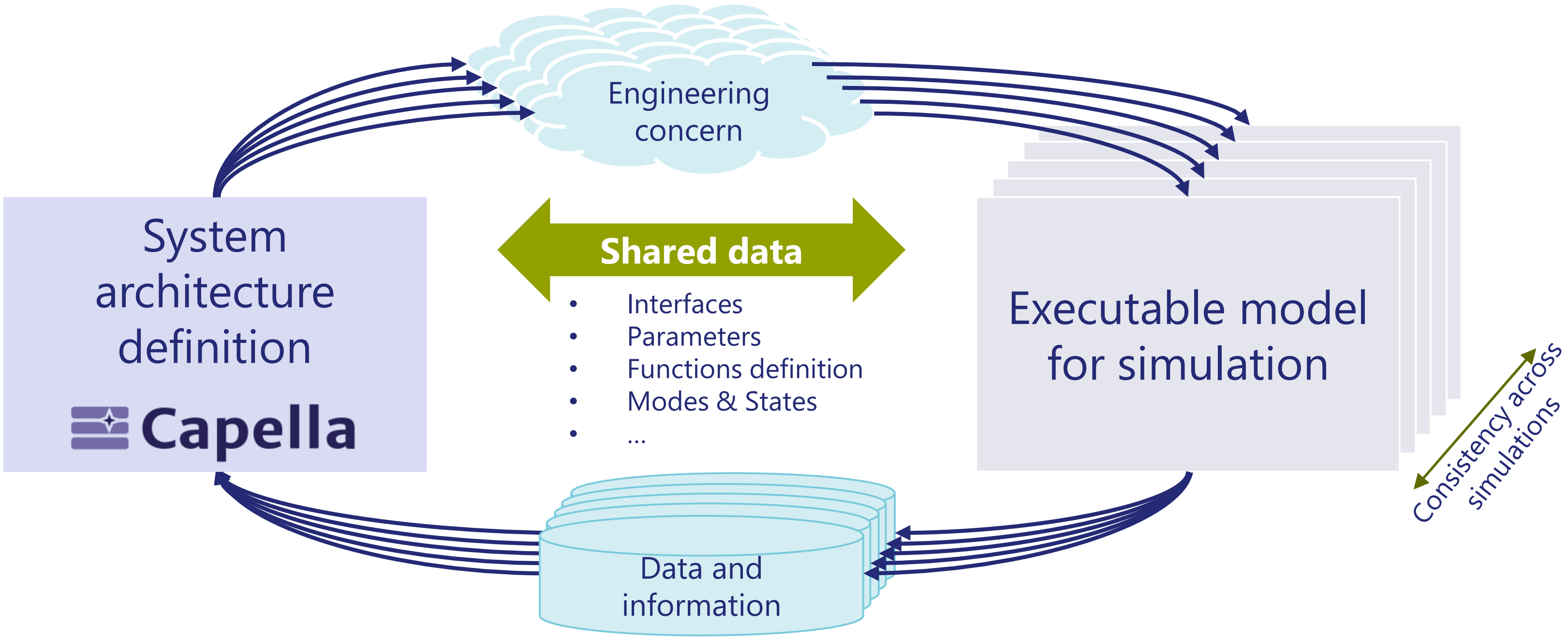
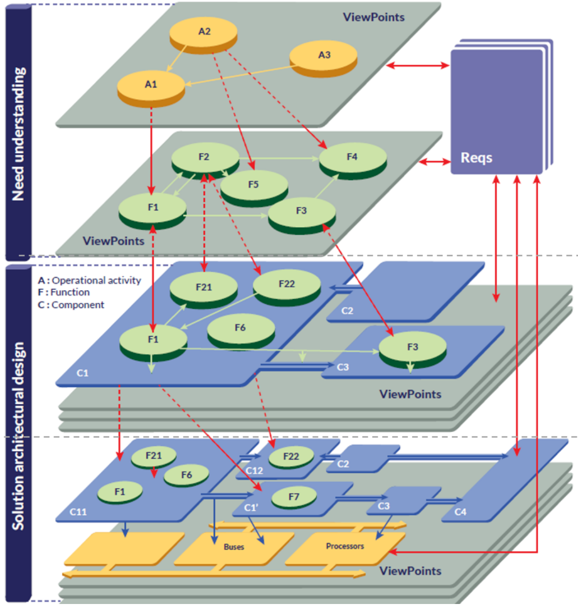
Ensuring a Digital thread is essential



Ensuring a Digital thread is essential



Case Study



Operational Analysis

What the users of the system need to accomplish

System Needs Analysis

What the system has to accomplish for the users

Logical Architecture *(conceptual solution)*

How the system will work in order to fulfil expectations

Physical Architecture (finalized solution)

How the system be developed and built

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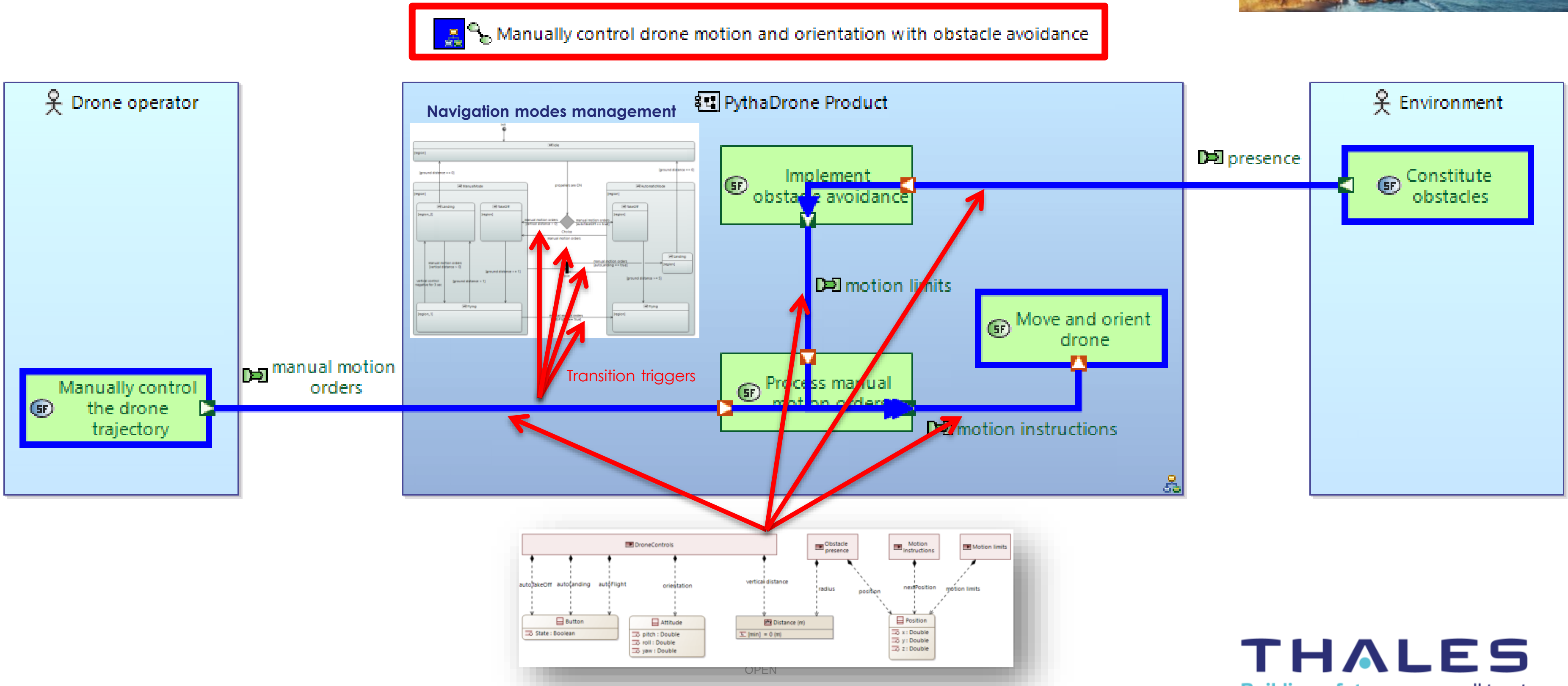
Case Study example

System Analysis: Functional Chain and Modes machines



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Case Study example

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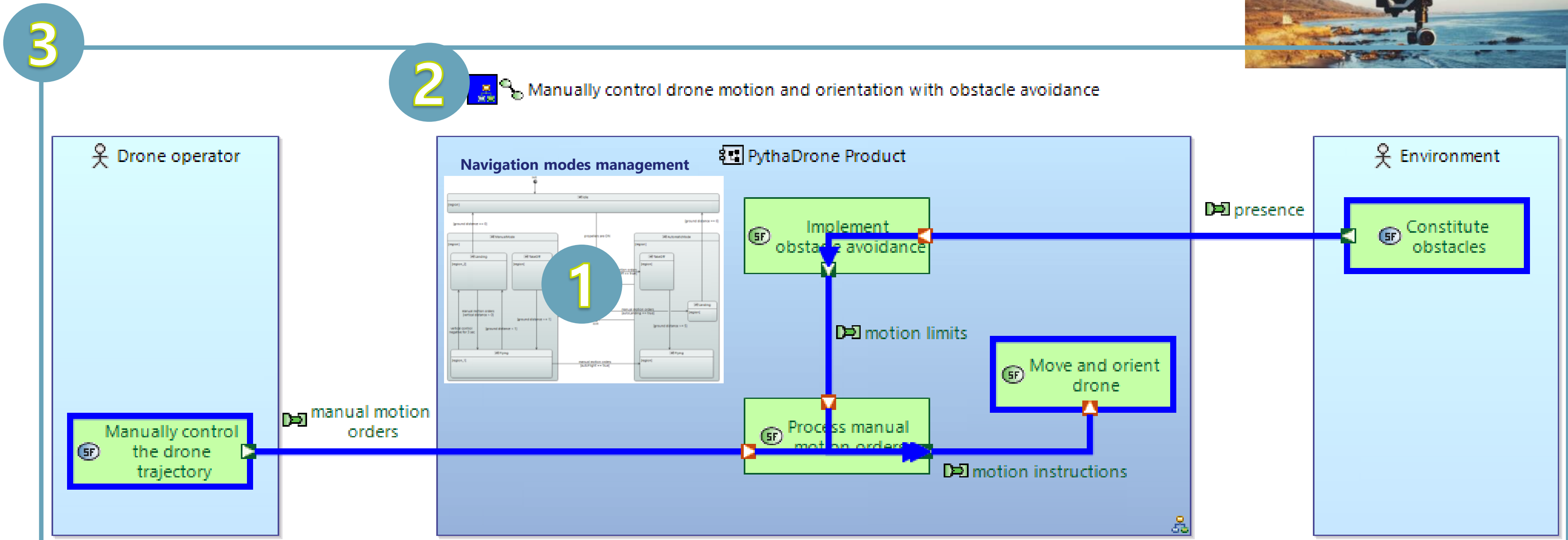

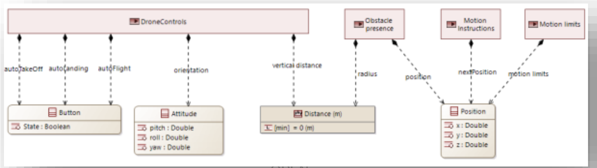

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Best Practices & Key Takeaways

Separation of concerns

- Descriptive and analytical model serve different objectives and may have different life-cycles; keep them separated but consistent

One analytical model per concern type

- Agility imposes fast question-analysis-answer loops, which are difficult to reach with one big simulation model (unless a perfect digital twin already exists!)

Frame simulation activities in your MBSE methodology

- Simulation models shall contribute to the objectives defined by the global modelling & simulation strategy, and shall be consistent with architecture artefacts

Ensuring a Digital Thread is essential

- Digital continuity and built-in consistency is a prerequisite for success

Drive the cultural shift

- Adapt organizations, processes and practices; do not be cheap on awareness and training efforts

Benefits on project effectiveness and engineering quality are field-proven

- The feedback from the frontline shows a negative correlation between the amount of system requirements covered by analytical models and the effort required on tests

Thank you

Q&A-time