SET Level

Simulation-based Development and Testing of Automated Driving

Supported by:

Federal Ministry for Economic Affairs and Energy

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PROJECT of the PEGASUS FAMILY

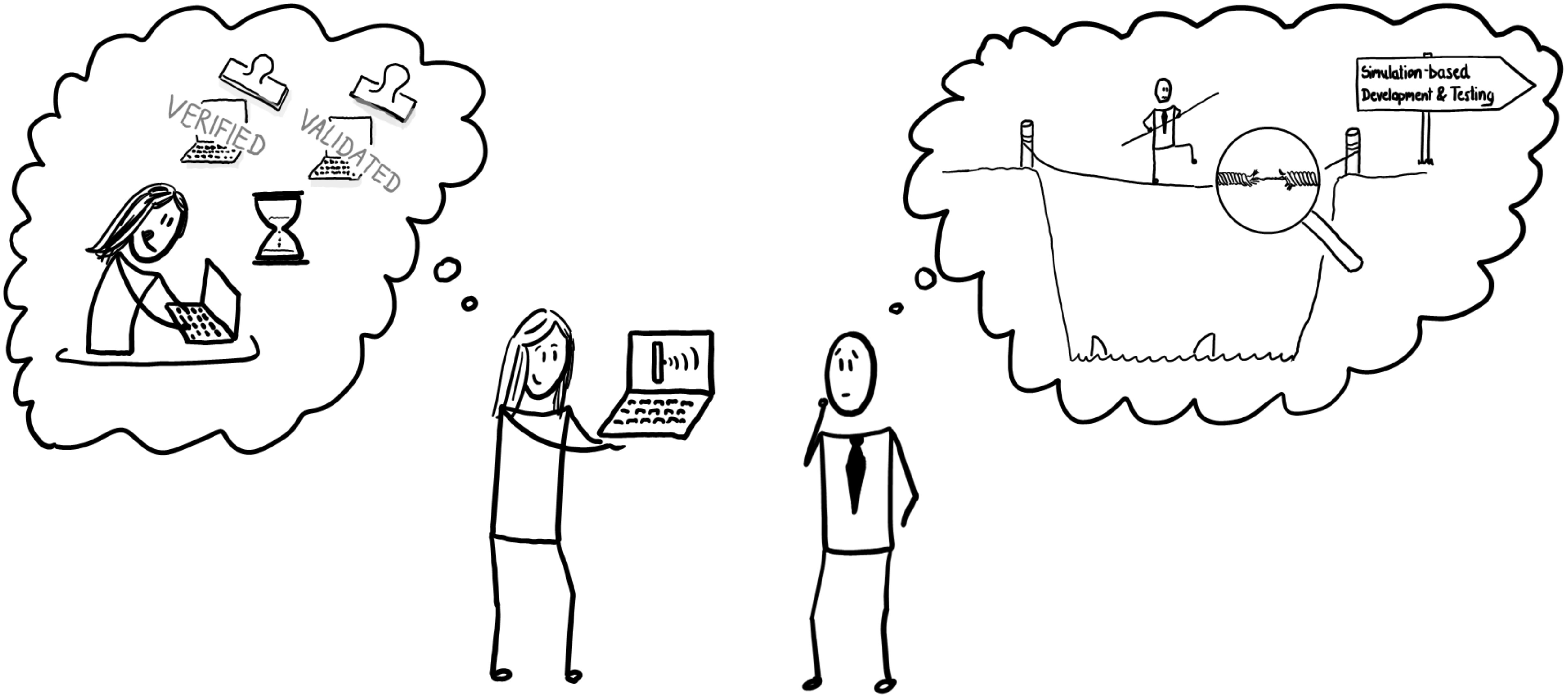
It‘s all about Trust – Simulation Credibility

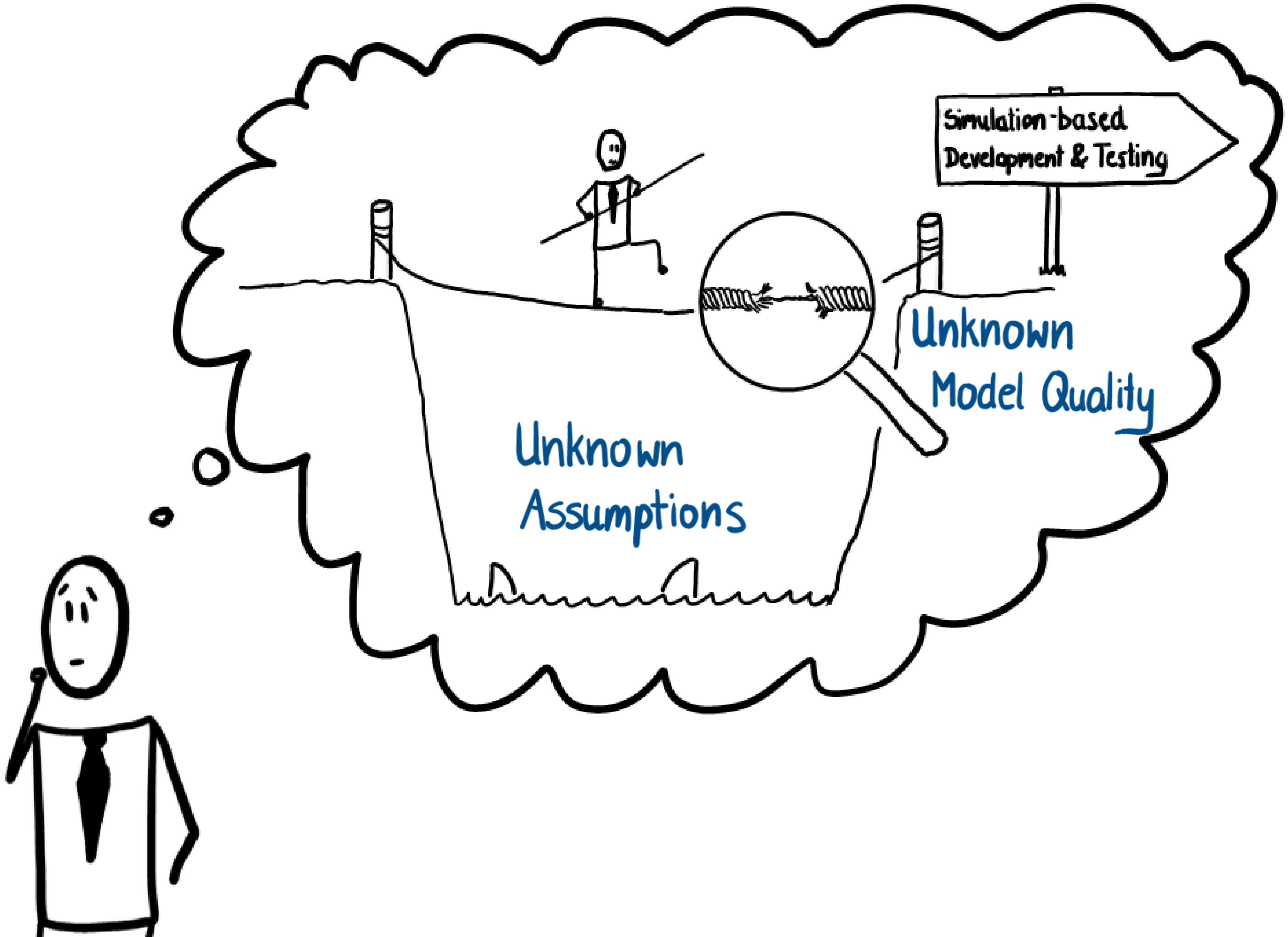
Anne Grätz (Bosch), Dirk Frerichs (Opel) , Birte Kramer (OFFIS)

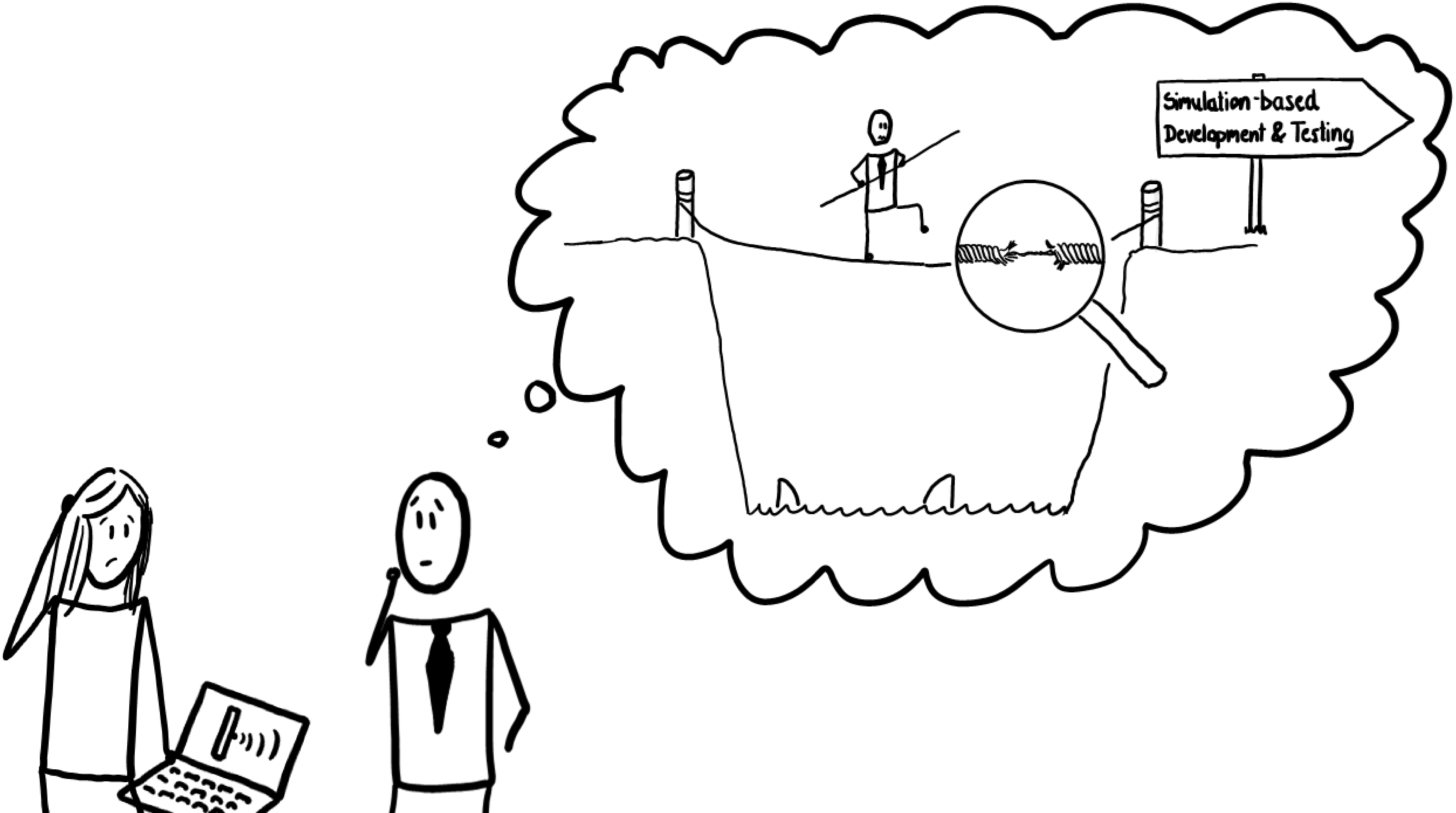
29.04.2021


VERIFIED
VALIDATED


VERIFIED
VALIDATED


VERIFIED
VALIDATED
Simulation-based
Development & Testing


Simulation-based
Development & Testing
Unknown
Model Quality
Unknown
Assumptions


Simulation-based
Development & Testing

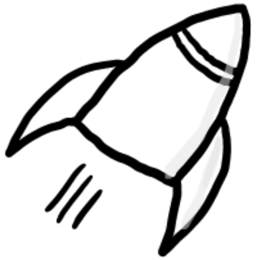
Do you trust
in your models?

Why?

CREDIBILITY

"Model credibility refers to the decision maker's confidence in the model. One goal of the V&V process is to gain this credibility." [1]

"The quality to elicit belief or trust in M&S results" [2]



NASA

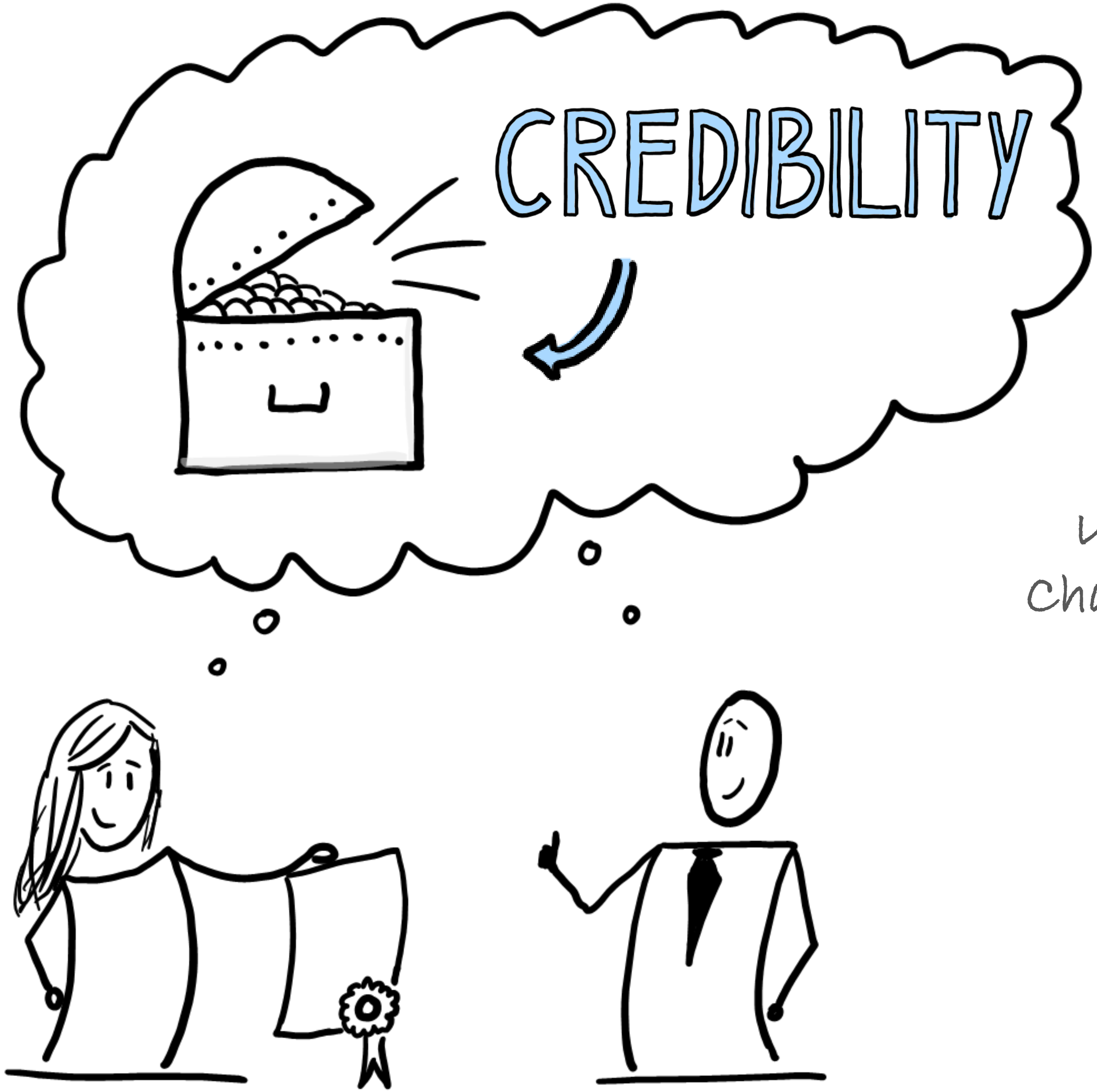
[1] John S. Carson, 2002 : "Model Verification and Validation"

[2] NASA Standard for models and simulations NASA-STD-7009A, 2016

Verification

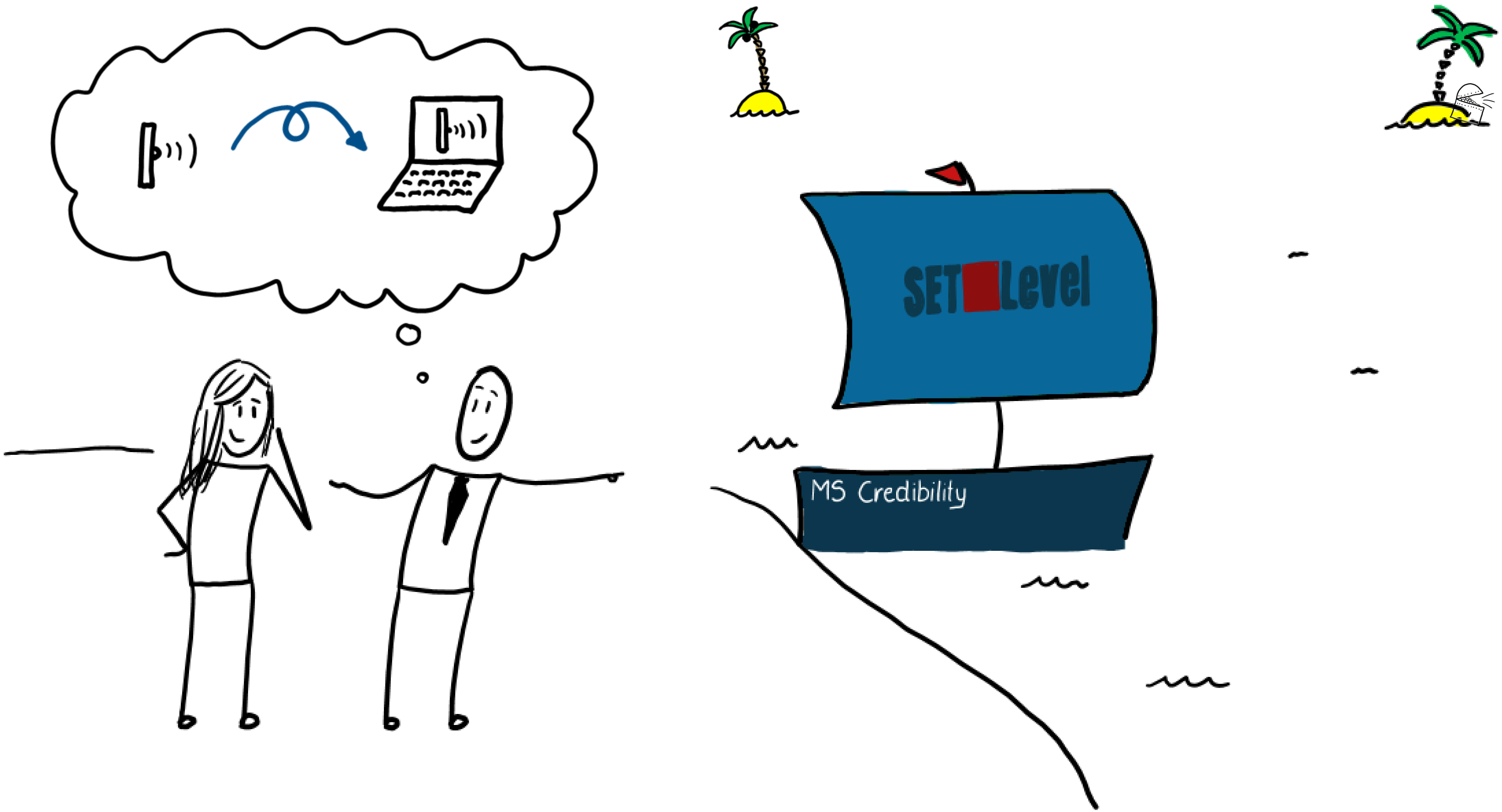
Validation

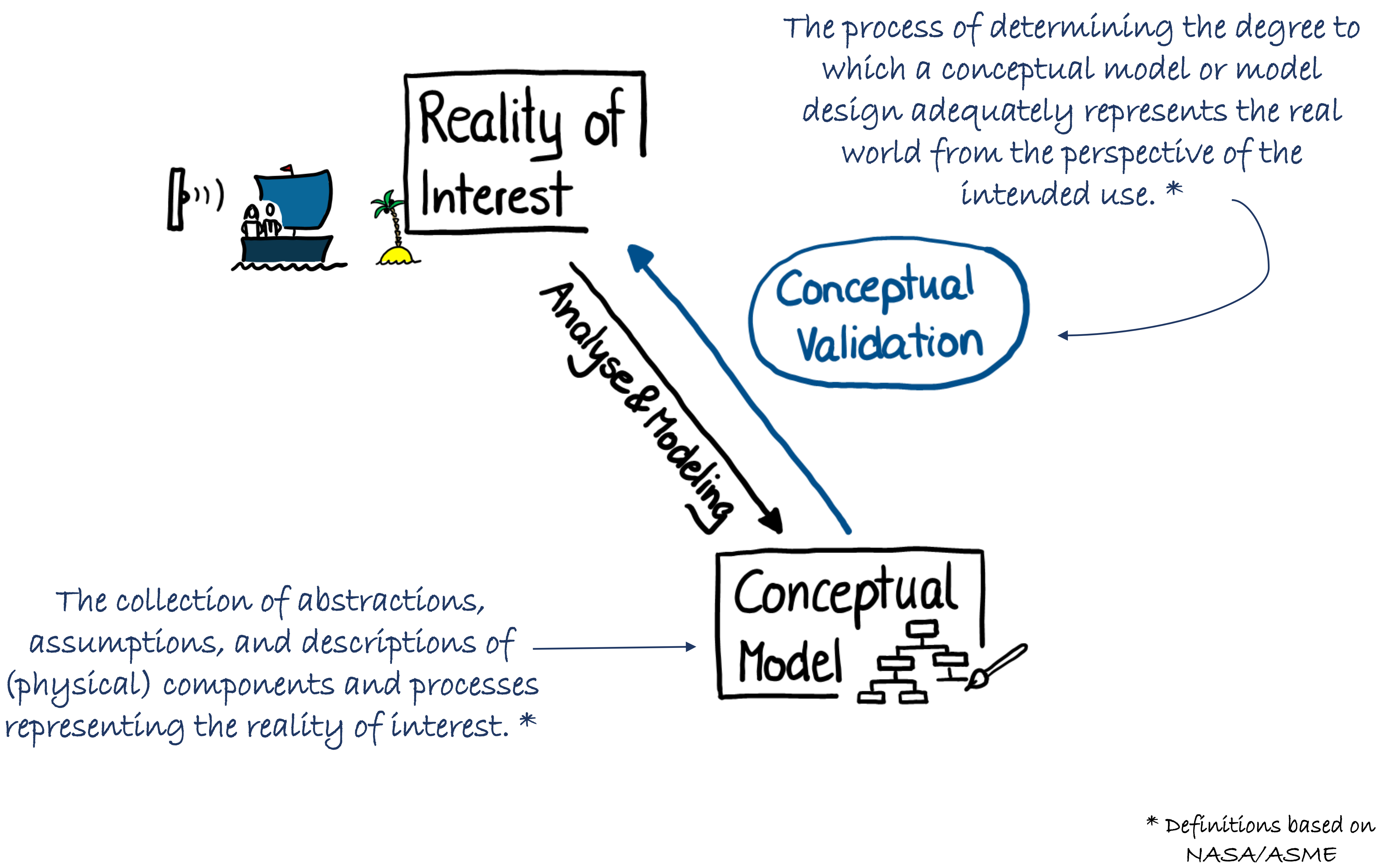
Result
Robustness



Data
Credibility

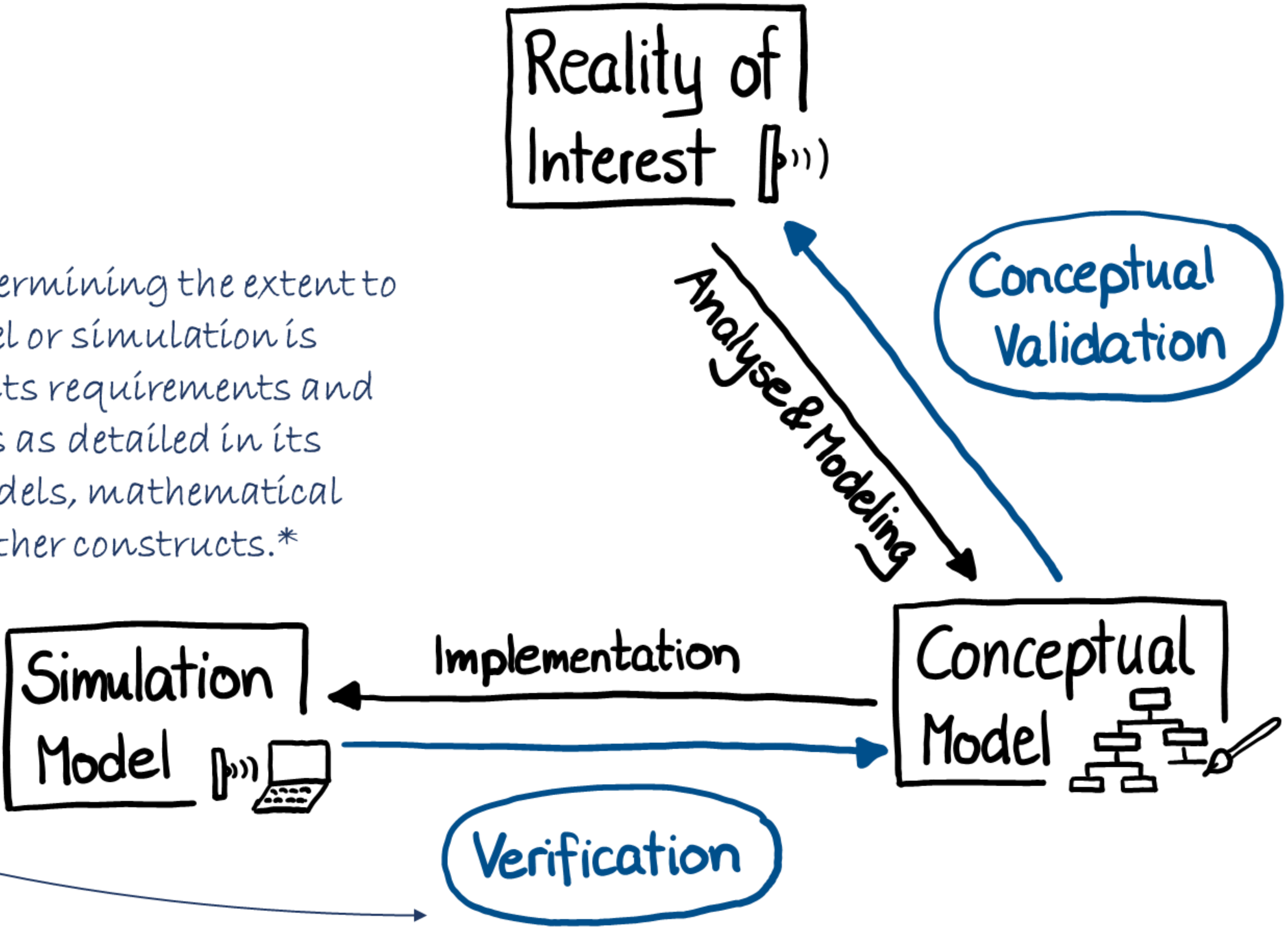
Uncertainty
Characterization


SET Level
MS Credibility



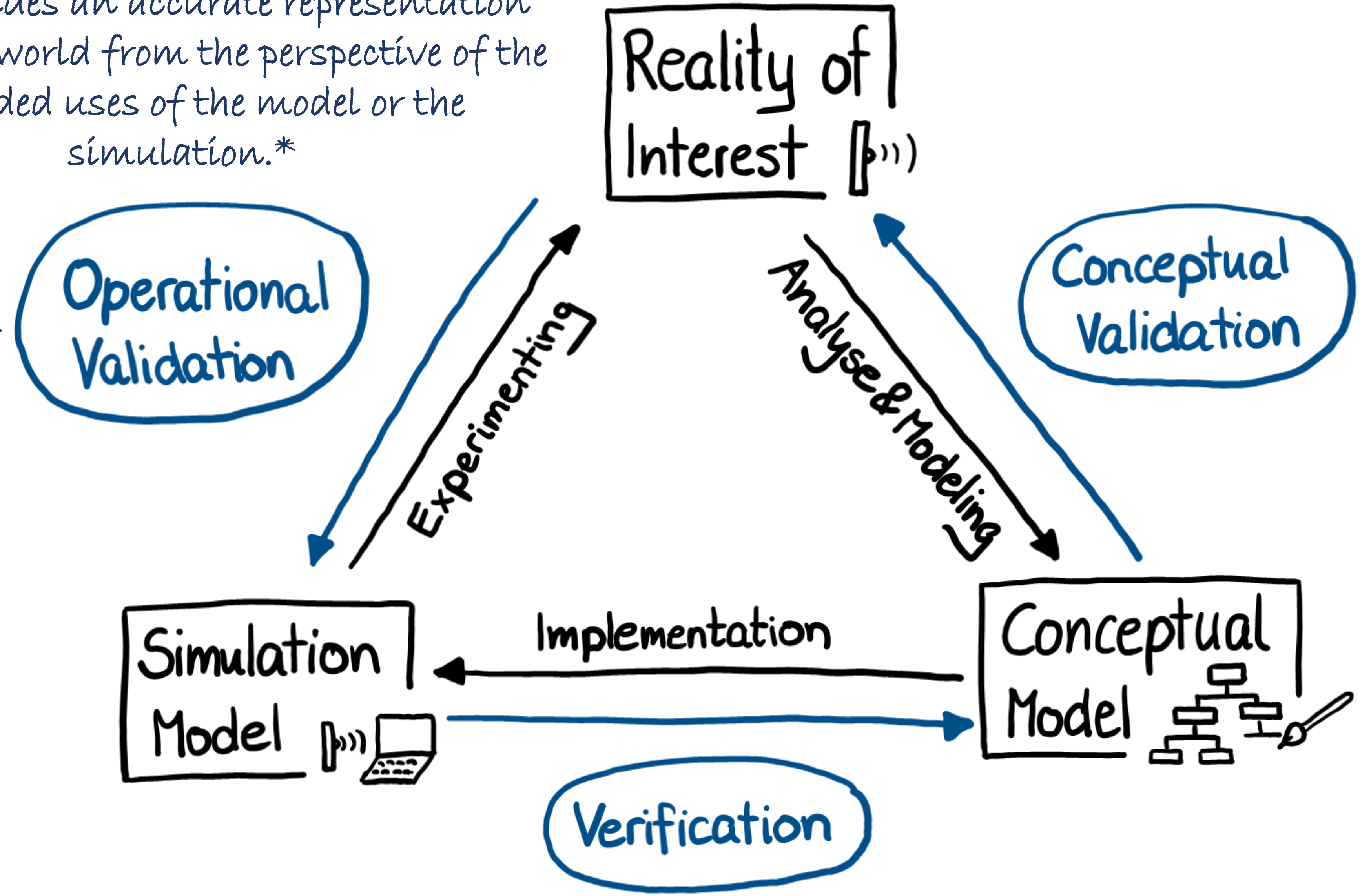
The process of determining the degree to which a conceptual model or model design adequately represents the real world from the perspective of the intended use. *
Reality of Interest
Analyse & Modeling
Conceptual Validation
The collection of abstractions, assumptions, and descriptions of (physical) components and processes representing the reality of interest. *
Conceptual Model
* Definitions based on NASA/ASME

The process of determining the extent to which a model or simulation is compliant with its requirements and specifications as detailed in its conceptual models, mathematical models, or other constructs.*



* Definitions based on NASA/ASME

The process of determining the degree to which an operating model or simulation is or provides an accurate representation of the real world from the perspective of the intended uses of the model or the simulation.*



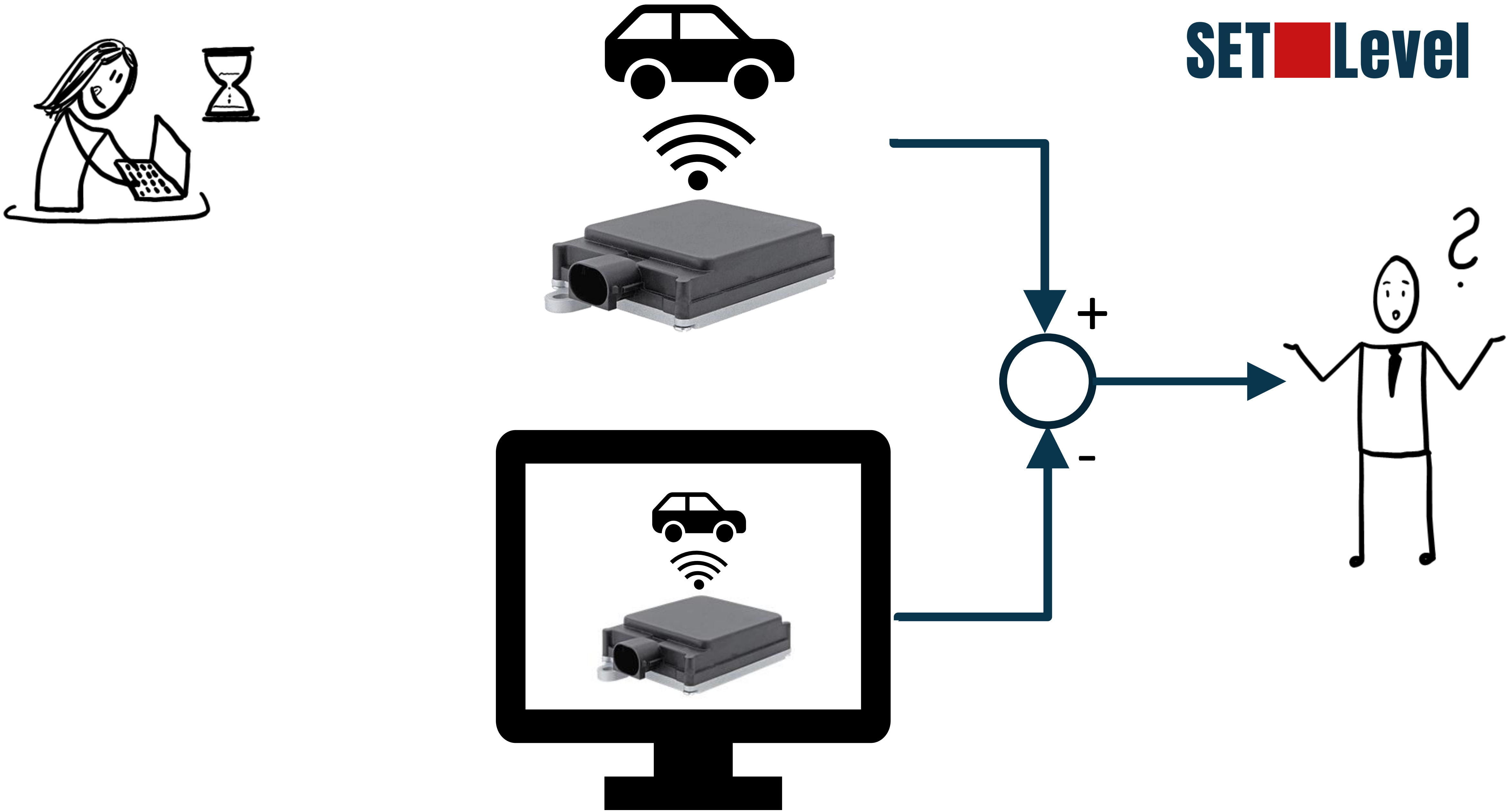
* Definitions based on NASA/ASME

Requirements for Verification/Validation

SET Level

- Depending on the intended use, a simulation model needs to fulfill different requirements
- We propose a level-based approach similar to NASA 7009-A

Level	Validation
4	Modeling and Simulation (M&S) results compare favorably to measurements on the Real World System (RWS) in its operating environment or to results from a higher-fidelity M&S that satisfies the conditions for Level 4. Validation points completely span the domain of operation for the RWS. Favorable comparisons are obtained for all response quantities.
3	…
2	…
1	The model is conceptually validated. The problem statement (intended use) is clearly stated and well understood. The conceptual model, requirements and specifications are correct and sufficiently address the problem.
0	Insufficient evidence



SET Level

CS number	10db/sqm Corner	10db/sqm Corner
	Distance to target object	Velocity of target object
1	6 m	
2	15 m	
3	20 m	
4	40 m	
5	60 m	
6	80 m	
7	100 m	
8	125 m	
9	148 m	
10	149 m	
11	150 m	

CS number	Target Pedestrian	
	Longitudinal distance	Lateral distance
1	150 m	
2	150 m	
3	149 m	
4	149 m	
9	100 m	
10	100 m	
11	80 m	
12	80 m	
		-4 m

check for distance accuracy
→ stationary target

CS number	Target Vehicle
	Relative velocity of target object
1	-10 km/h
2	- 30 km/h
3	- 50 km/h
4	- 50 km/h
5	- 70 km/h
6	- 70 km/h
7	- 90 km/h
8	- 90 km/h
9	+ 10 km/h
10	+ 10 km/h
11	+ 30 km/h
12	+ 30 km/h
13	
16	+ 70 km/h
17	+ 90 km/h
18	+ 90 km/h

check for relative velocity → constant speed

Validity Assessment Map for MVC StaticCorner x_pos

	1	2	3	4	5	6	7	8	9	10	11
1	1	1	1	2	3	1	1	1	1	1	1
2		1	1	1	3	1	1	1	1	1	1
3			2	3	3	1	1	1	1	1	2
4				3	2	2	2	3	2	2	1
5					3	3	3	3	3	3	3
6						1	1	1	1	1	1
7							1	1	1	1	1
8								1	1	1	2
9									1	1	1
10										1	1
11											2

V_{abs} = (64|18|18)%, res.: 5%

V_{rel} = (65|15|20|0)%, res.: 1%

vel

Validity Assessment Report

My_radar_model (LRR_0815)

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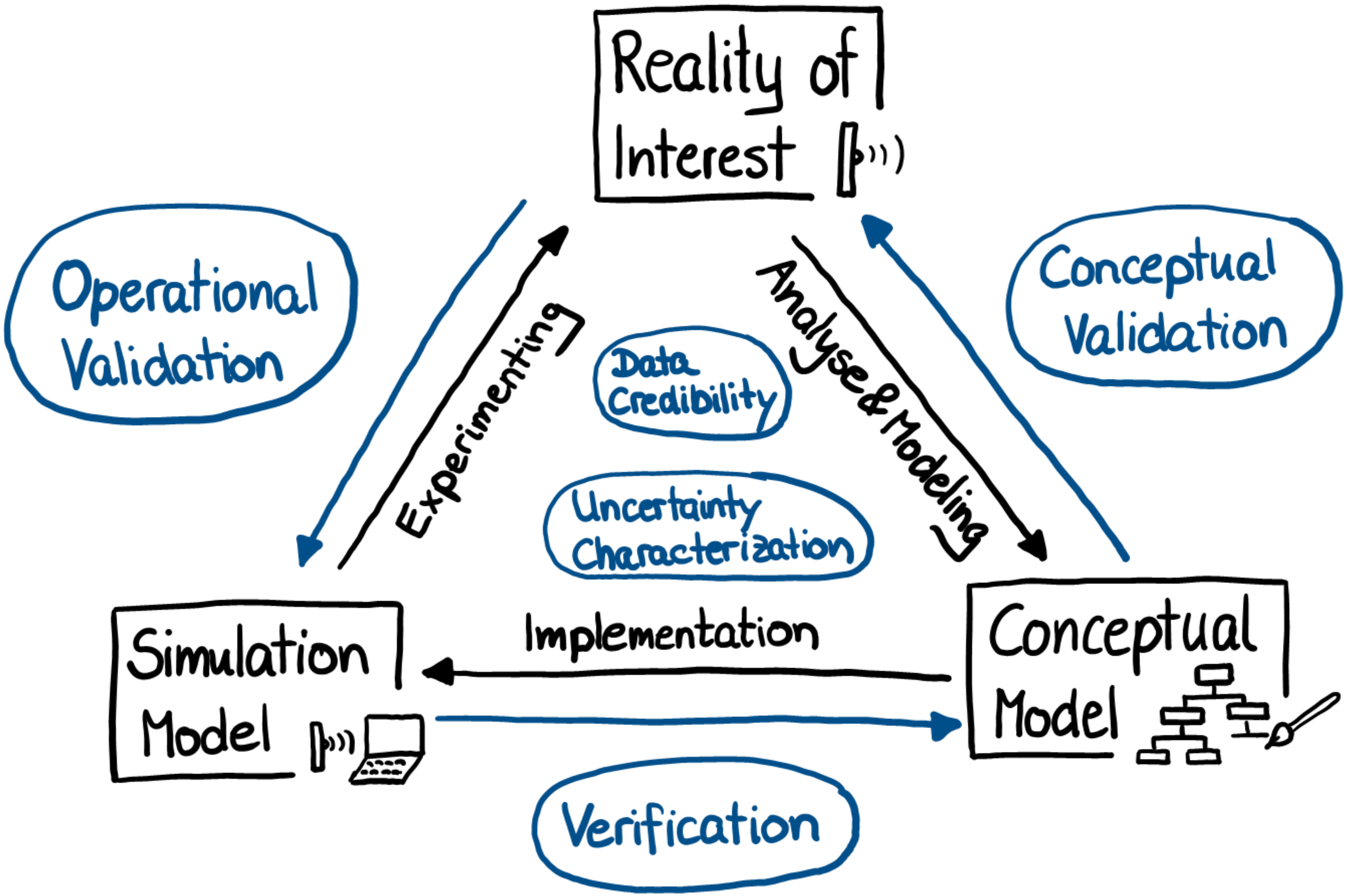

Reality of Interest
Operational Validation
Conceptual Validation
Experimenting
Analyse & Modeling
Data Credibility
Uncertainty Characterization
Simulation Model
Implementation
Conceptual Model
Verification

Selection of Suitable V&V-Activities

Application Domain	Credibility Criteria
Sensor	Operational Validation
Sensor	Conceptual Validation
⋮	⋮
Vehicle Dynamics	Operational Validation

Input from Process

Selection of Suitable V&V-Activities

Focus: Why and How? → Methods

Focus: What? → Validation Criteria

Application Domain	Credibility Criteria	Methods	Validation Criteria	Techniques	Roles
Sensor	Operational Validation				
Sensor	Conceptual Validation				
⋮	⋮				
Vehicle Dynamics	Operational Validation				

Input from Process | **Library of V&V-Methods and -Techniques**

Selection of Suitable V&V-Activities

SETLevel

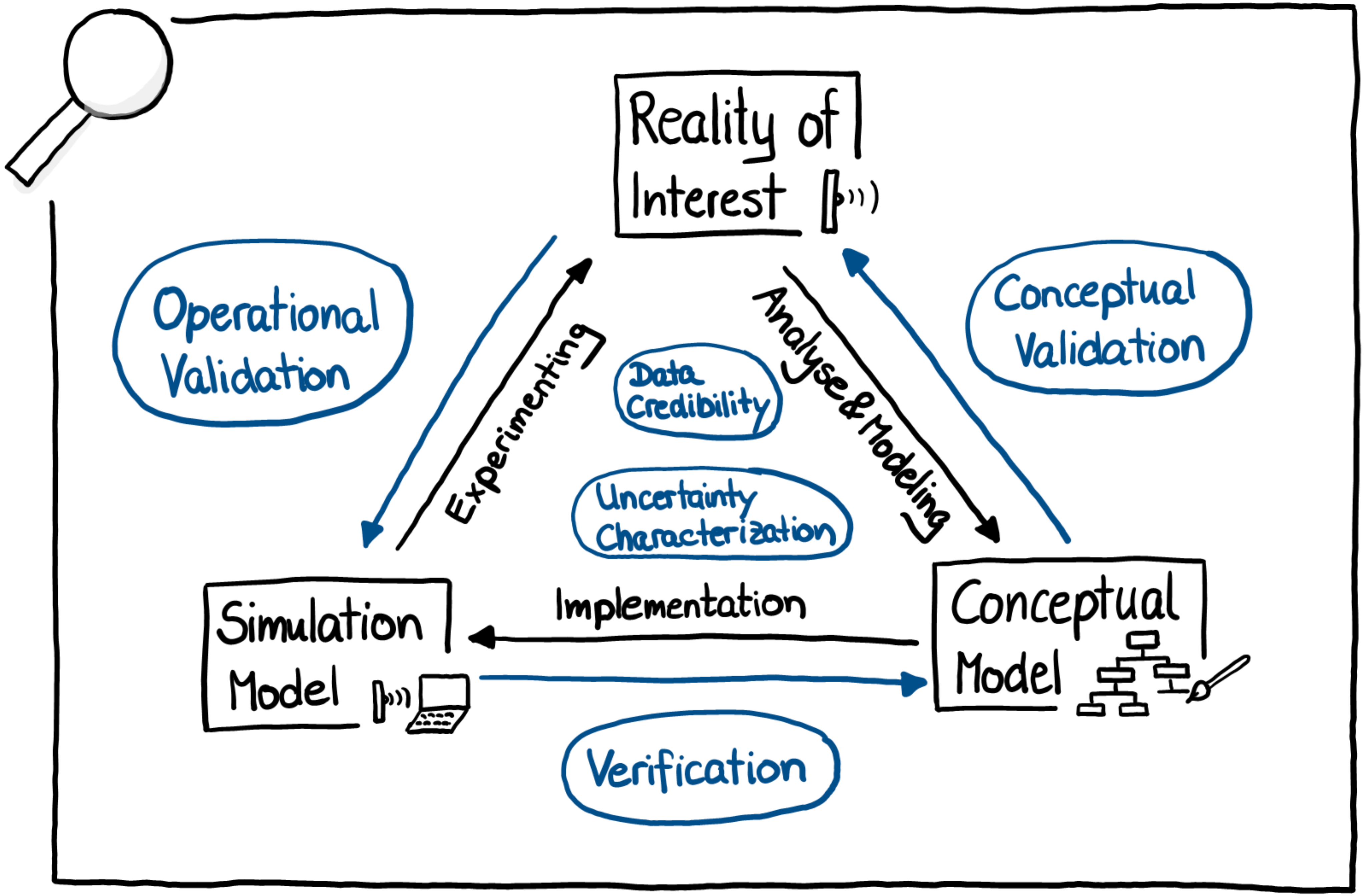
Focus: Why and How? → Methods

Focus: What? → Validation Criteria

Application Domain	Credibility Criteria	Methods	Validation Criteria	Techniques	Roles
Sensor	Operational Validation	Req.-based, Statistical (Viehof)	Metric Validity Criteria	Sensitivity Analysis	• Developer • Testdriver
		⋮	⋮	⋮	⋮
Sensor	Conceptual Validation				
⋮	⋮				
Vehicle Dynamics	Operational Validation				

Input from Process (Application Domain, Credibility Criteria)

Library of V&V-Methods and -Techniques (Methods, Validation Criteria, Techniques, Roles)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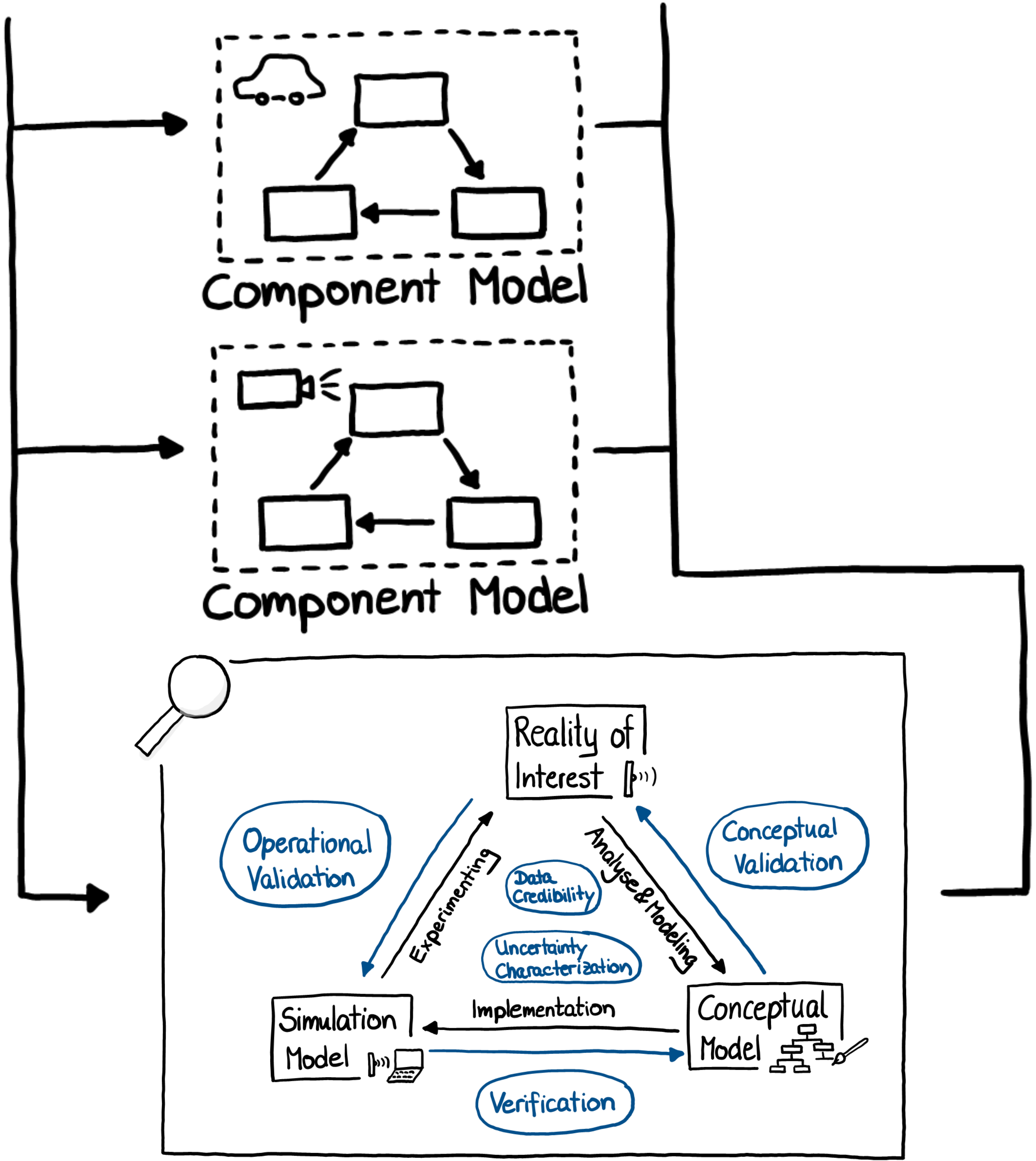
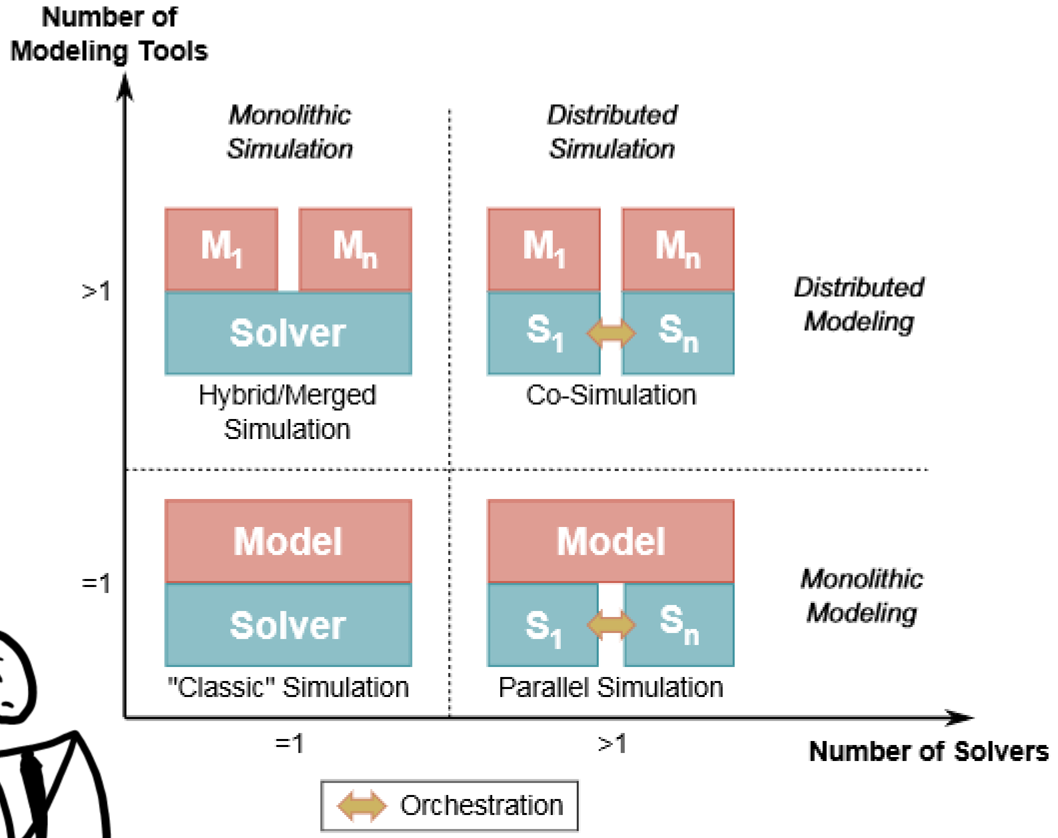
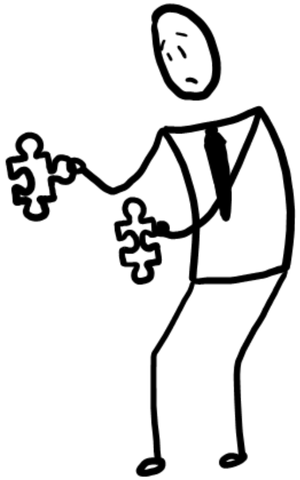


Component Model
Component Model
Reality of Interest
Operational Validation
Conceptual Validation
Experimenting
Analyse & Modeling
Data Credibility
Uncertainty Characterization
Simulation Model
Implementation
Conceptual Model
Verification

Quality Criteria for Coupling of Simulation Models

- What do we even mean by coupling (models vs. simulators)?
- Why is coupling necessary?
  - Generally desirable to abstain from coupling (potential source of error, often introduces delays)
  - However, often necessary, e.g., due to complexity, modularity requirements, or IP protection

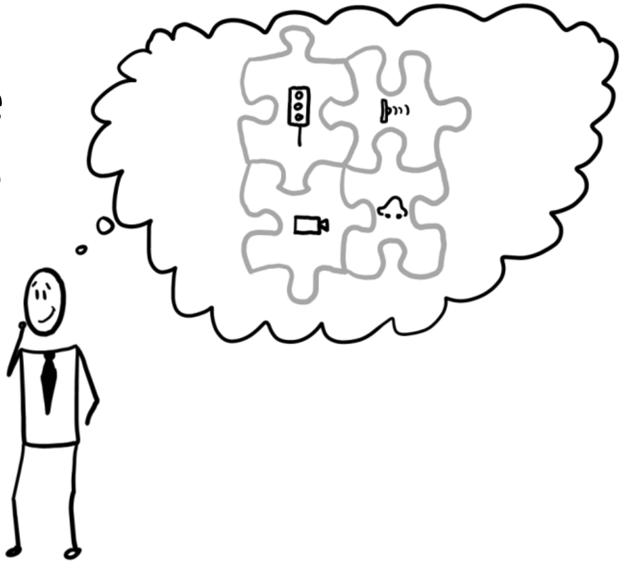


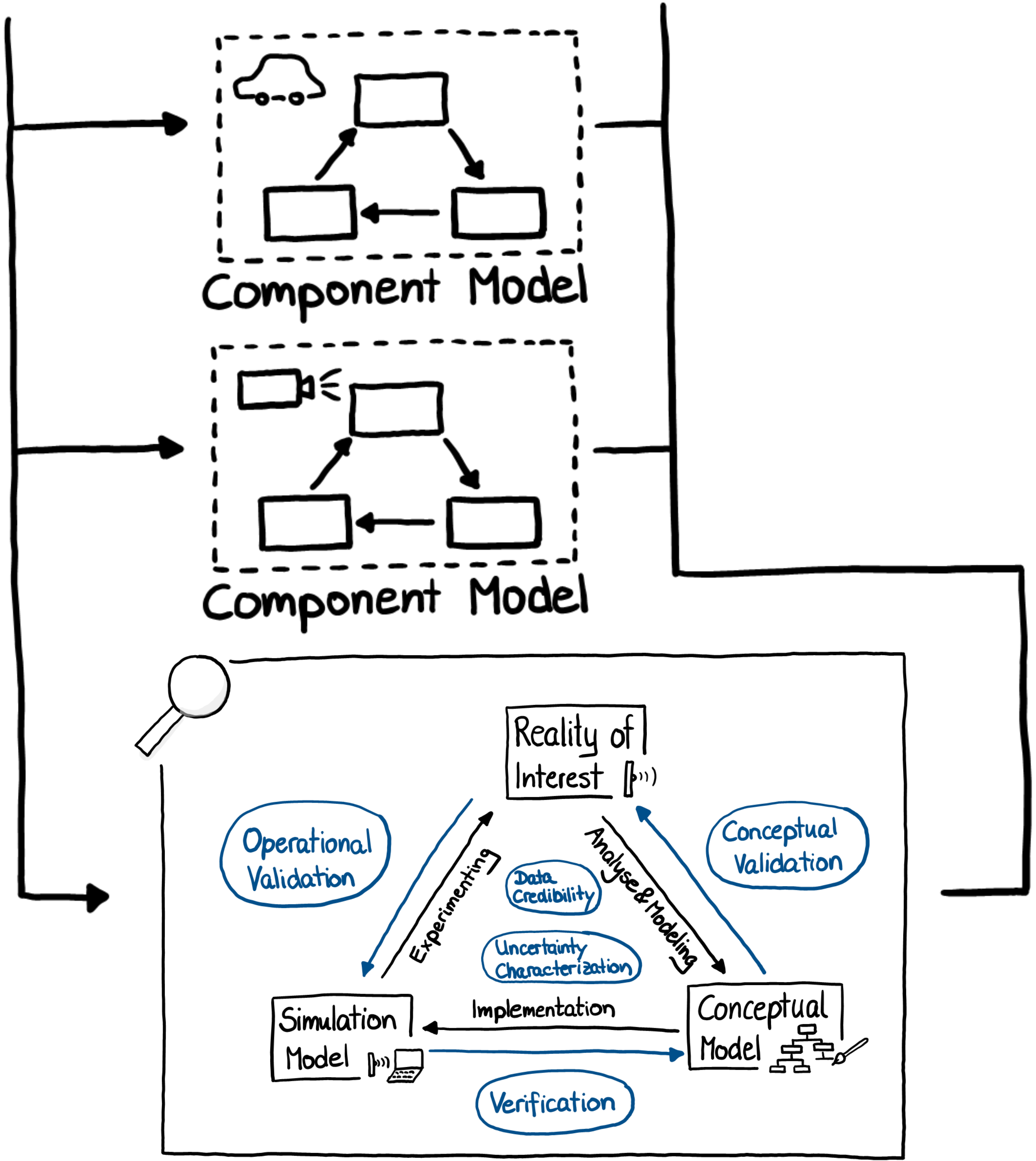


Quality Criteria for Coupling of Simulation Models

SET Level

- High Level Goal: Identify, quantify, and assess the influence of coupling
- Ideal Strategy: For one instantiation of a simulation platform, compare with a monolitic system
    - Due to lack of monolithic system
        - Assess coupling mechanisms in general (e.g., comparing models of computation of the coupled system, analyse necessary information)
        - Also test coupling mechanisms for “easier“ models where we actually have access to a monolitic system and then generate more general statements

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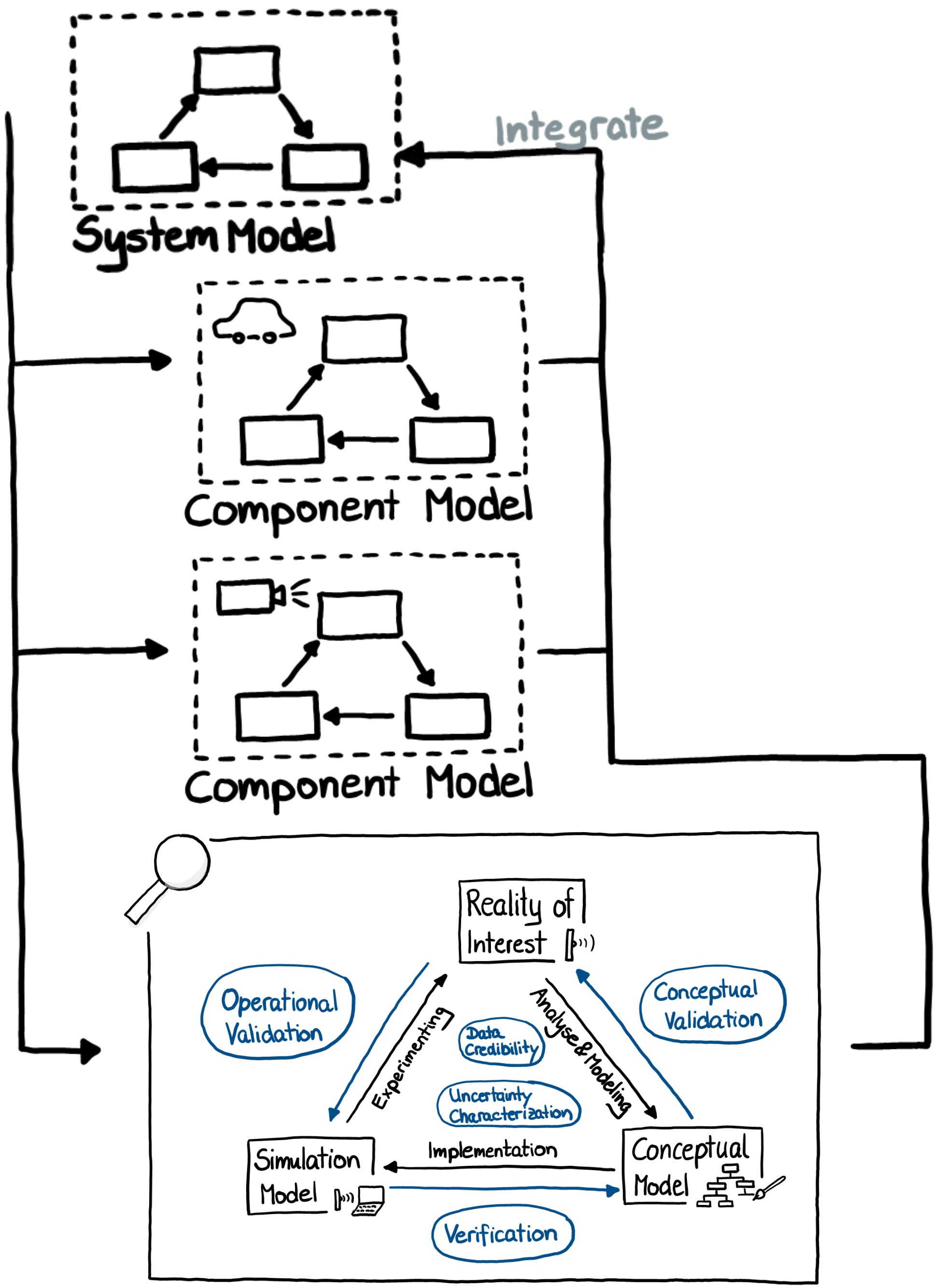

Integrate
System Model
Component Model
Component Model
Reality of Interest
Operational Validation
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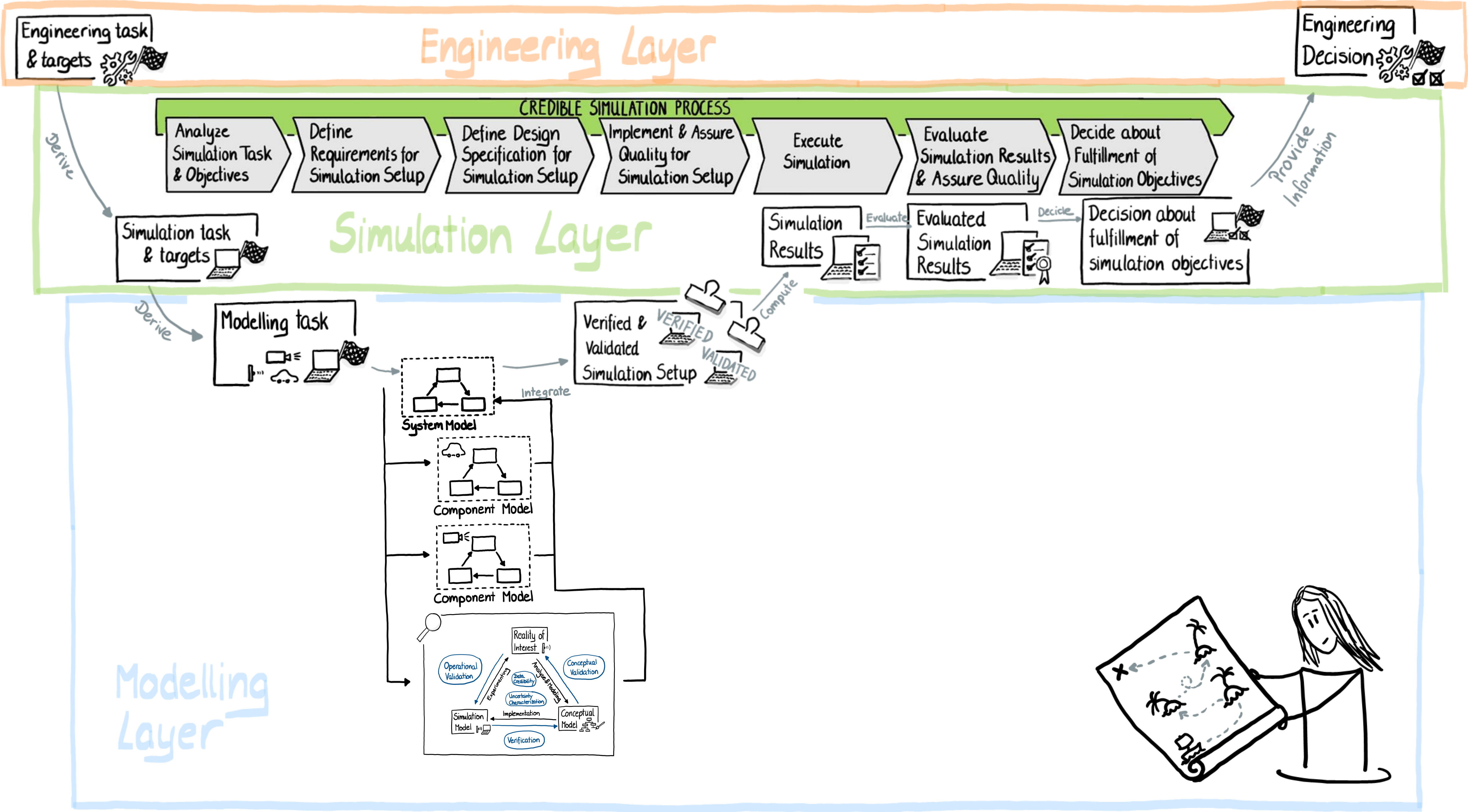

Engineering task & targets
Engineering Layer
Engineering Decision
CREDIBLE SIMULATION PROCESS
Analyze Simulation Task & Objectives
Define Requirements for Simulation Setup
Define Design Specification for Simulation Setup
Implement & Assure Quality for Simulation Setup
Execute Simulation
Evaluate Simulation Results & Assure Quality
Decide about Fulfillment of Simulation Objectives
Derive
Provide Information
Simulation task & targets
Simulation Layer
Simulation Results
Evaluate
Evaluated Simulation Results
Decide
Decision about fulfillment of simulation objectives
Derive
Modelling task
Compute
Verified & Validated Simulation Setup
VERIFIED
VALIDATED
Integrate
System Model
Component Model
Component Model
Reality of Interest
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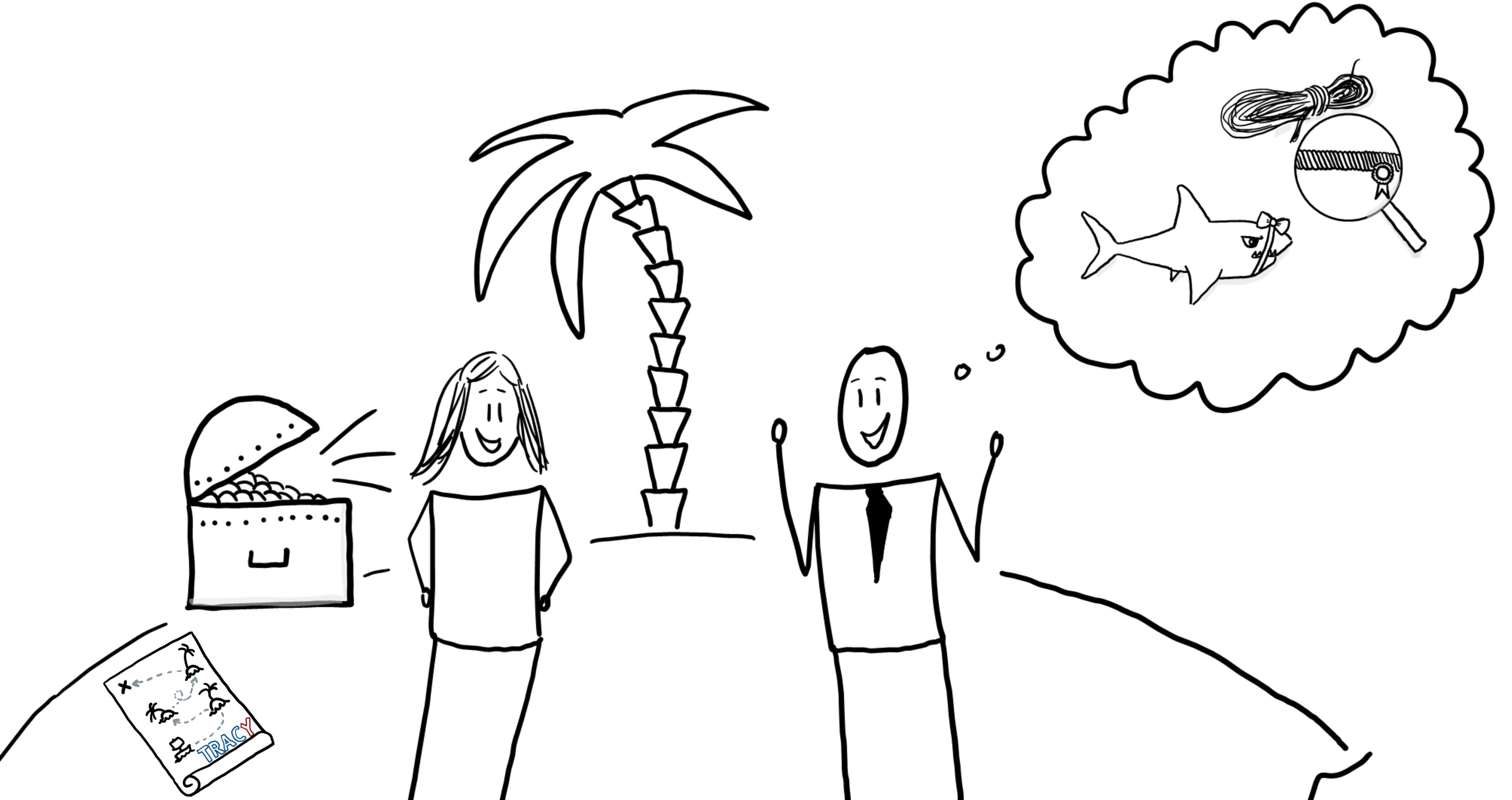
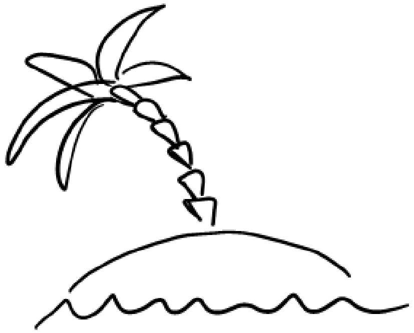
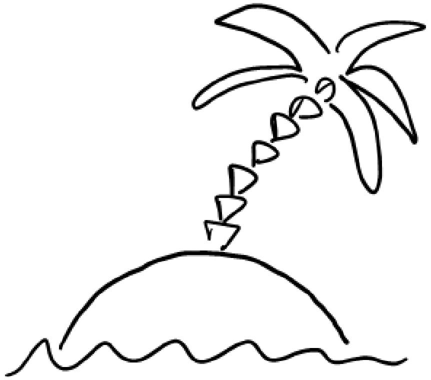
Verification
Modelling Layer


TRACY



Bay of Model
Credibility




Simulation
Credibility
Sea

...to be continued

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