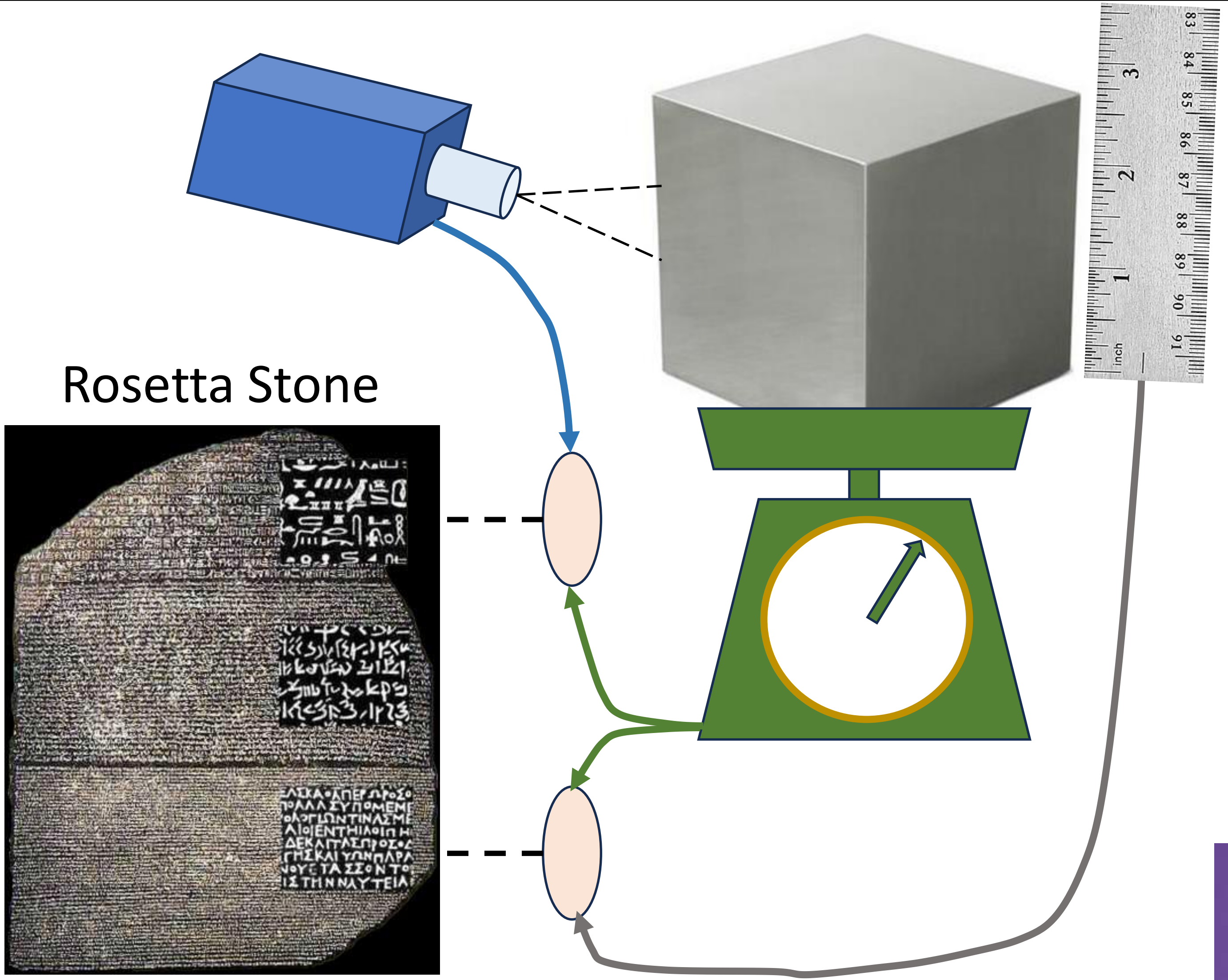
A Cross-Society Collaboration Project: Mapping Consistency Confirmation Frameworks of Different Communities

VVS2024-138662

V1.7.3



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1 – AIAA Digital Engineering Integration Committee
2 – INCOSE/OMG MBSE Patterns Working Group
3 – ASME VV50 Model Life Cycle Working Group

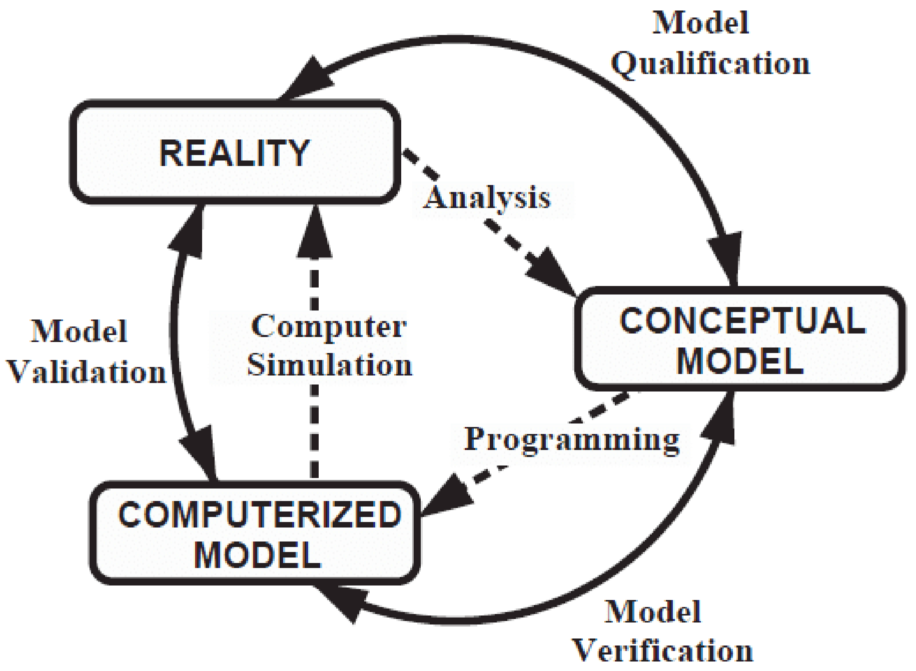
ASME VVUQ 2024 Symposium
Verification, Validation, and Uncertainty Quantification Symposium

Disciplines are not isolated-- so their metrics should not be

- We increasingly rely on computational models, but practices for related development still vary across disciplines.
- Example: Computational models are sometimes part of larger systems:
  - e.g., A smart milling machine with built-in model, estimating tool wear.
- Designers of those systems include practitioners across multiple disciplines, who must effectively communicate and work together.
- That includes their methods and metrics used to assess confidence in the resulting integrated system as well as its components.

Disciplines are not isolated--so their metrics should not be

- This story began in contemplating a 1979 (now somewhat dated) overview diagram of computational model V&V relationships [1], whose history is discussed in [2]:
  - How does the "computational modeling" community think about it?
  - How would the "product engineering" community think about it?
- More on this example later herein.



From [1]

Disciplines are not isolated-- so their metrics should not be

- Computational modelers apply standard frameworks developed specifically for establishing confidence in models – e.g., ASME VVUQ Standards VVUQ-1, 10, etc. [3], [4]
- Others use standards frameworks for establishing confidence in the overall system design—e.g., ISO 15288, IEEE 1012, etc. [5]
- There are good reasons for the contents of each of these frameworks.

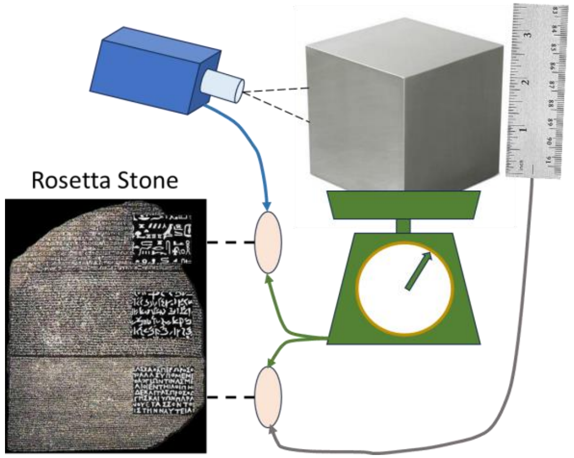
Disciplines are not isolated-- so their metrics should not be

- In spite of using some of the same “V and V” terms, these frameworks appear to assign different meanings to them, and have different perspectives:
  - Different <u>**terms**</u> for the same concept.
  - Different <u>**concepts**</u> labeled with the same term.
  - Different <u>**relationships**</u> between concepts.
- <u>*For integrated work on a single system*</u>, how do these different frameworks function together?

Observation

- While preparing an ASME VV50 guideline about managing confidence in advanced manufacturing computational models across their entire life cycles [6] . . .
- . . . the authoring team has treated the computational model as an engineered subsystem of the larger evolving system into which it is integrated, . . .
- . . . invoking the related engineering V&V standards, along with computational modeling V&V standards.
- We observed this has been confusing for computational modeling specialists used to a different V&V framework.
- This combination has given us some important insights.
- We believe that <u>clearer mapping between these frameworks</u> would be beneficial.

Making comparisons: A project

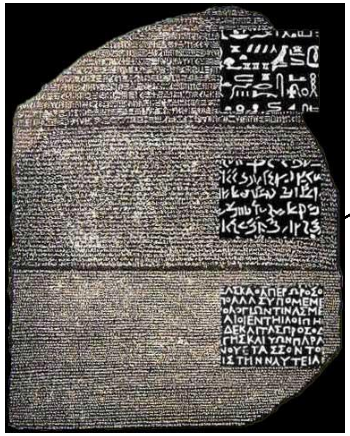


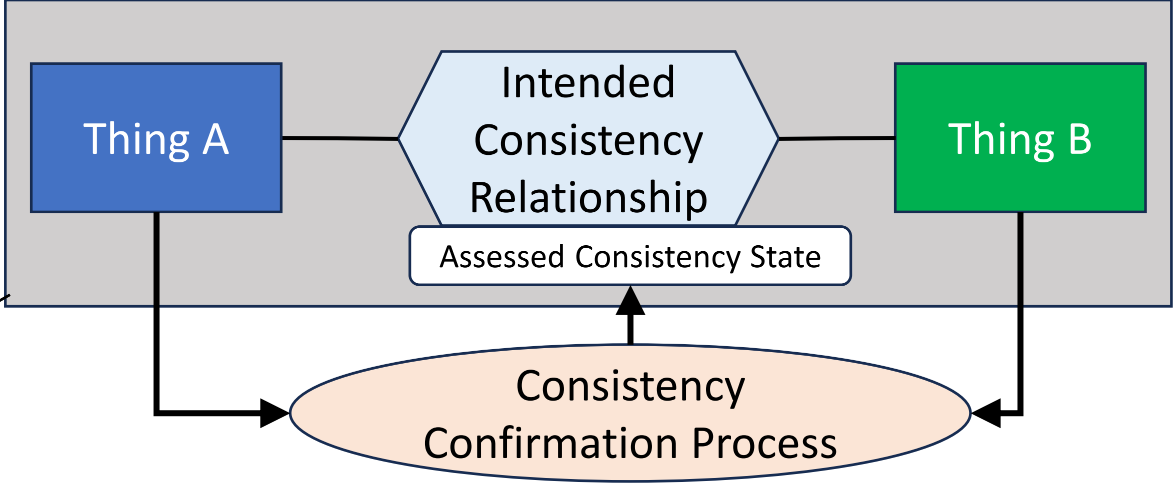
- We are not suggesting that any of these frameworks replace the others.
- Rather, we have started a preliminary project, collaborating across working groups from several technical societies, to establish a mapping between the frameworks, facilitating improved communication between communities.
- This project involves working group representation from:
  - ASME VV50 (Model Life Cycle Working Group)
  - AIAA Digital Engineering Integration Committee (Confidence in Models Subcmtee)
  - INCOSE/OMG MBSE Initiative (MBSE Patterns Working Group)
  - NAFEMS (Systems Modeling & Simulation Working Group)

- Mapping different frameworks using a shared abstraction “Rosetta Stone” . . .

Our "Rosetta Stone" abstraction is "Consistency Management"

Rosetta Stone

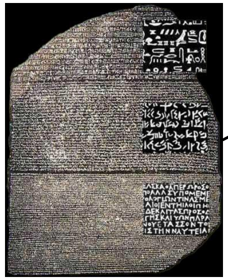


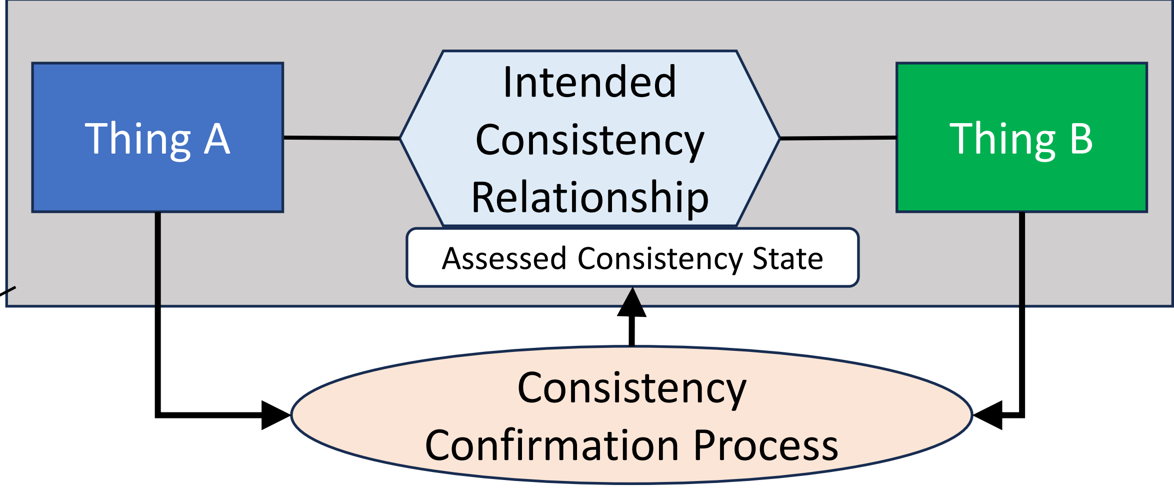


- An abstraction that may be applied equally to each of the different frameworks:
  - All those frameworks check whether <u>pairs of things</u> are "consistent" with each other, where "consistent" has various formally defined types. [2][7][8][9]
- Examples for <u>computational models</u>, (per VVUQ 1-2022) [3]
  - "Verification is the process of establishing the mathematical correctness of the **computational model** with respect to a **referent**." (e.g., a **mathematical model**)
  - "Validation is the process of determining the degree to which a **model** represents the **empirical data** from the perspective of the context of use."

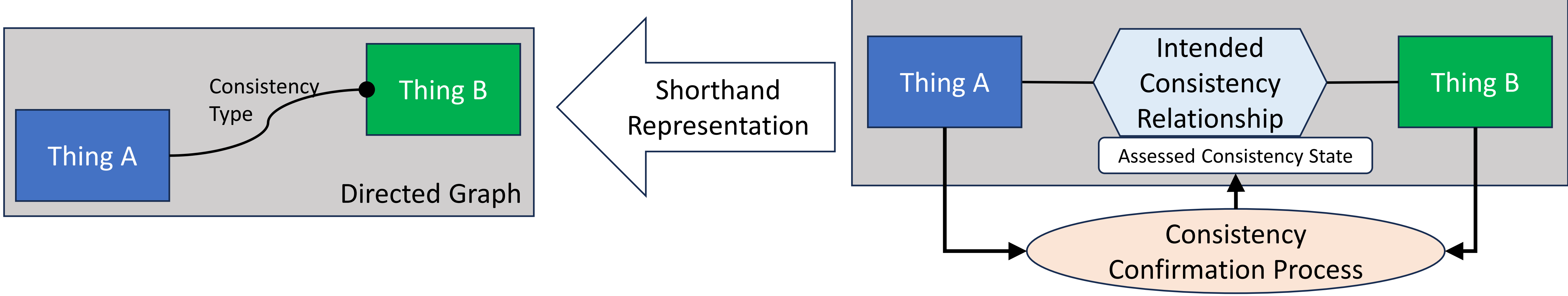
Our "Rosetta Stone" abstraction is "Consistency Management"

Rosetta Stone



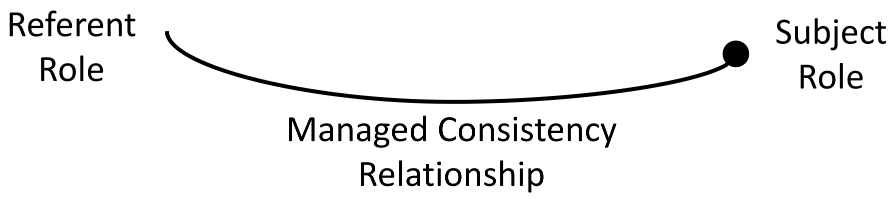


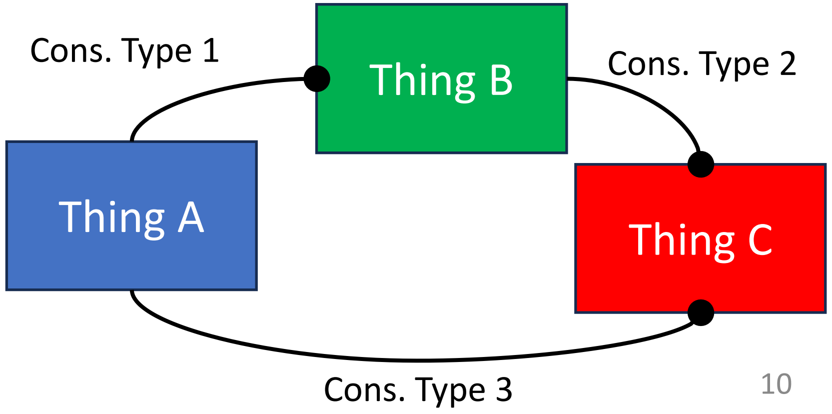
- Likewise, examples for <u>engineered systems</u>, (per ISO 15288) [5]
  - "The purpose of the verification process is to provide objective evidence that a **system, system element, or artefact** fulfils its **specified requirements and characteristics**."
  - "The purpose of the validation process is to provide objective evidence that the **system, when in use**, fulfils its **business or mission objectives and stakeholder needs and requirements**, achieving its intended use in its intended operational environment."
  - "Validation is also applicable to the **artefacts (e.g. requirements, architecture, design, design characteristics, or system elements**) produced in the definition and realization of the system."
  - "The validation process determines that the 'right solution is built'. The verification process determines that the 'solution is built right' ".



- For any single discipline, the set of all its <u>consistency relationship types</u> (described by the discipline's standard practices) is a "directed graph" of pairwise <u>*intended*</u> consistencies:
  - The graph nodes are the compared things.
  - The graph edges (the linking lines) are <u>the types of consistency sought</u> (the consistency relationship, to be assessed).
  - This is <u>not</u> a process diagram—it is a model of <u>information relationships</u>.

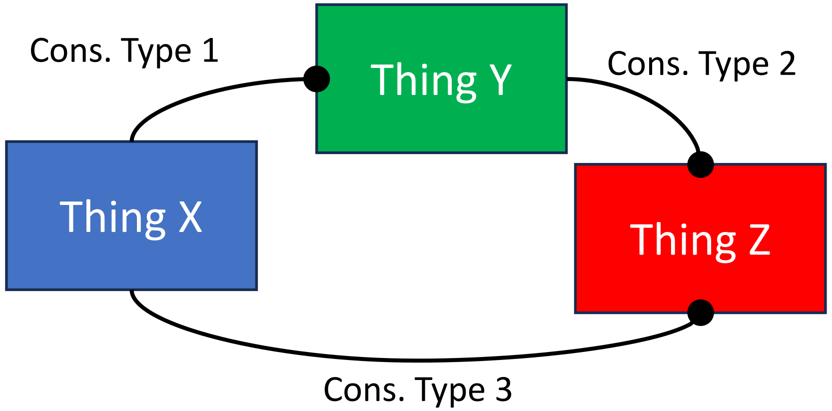
- The graph links are "directed" to differentiate things we are checking (subjects) from what we are checking them against (referents):

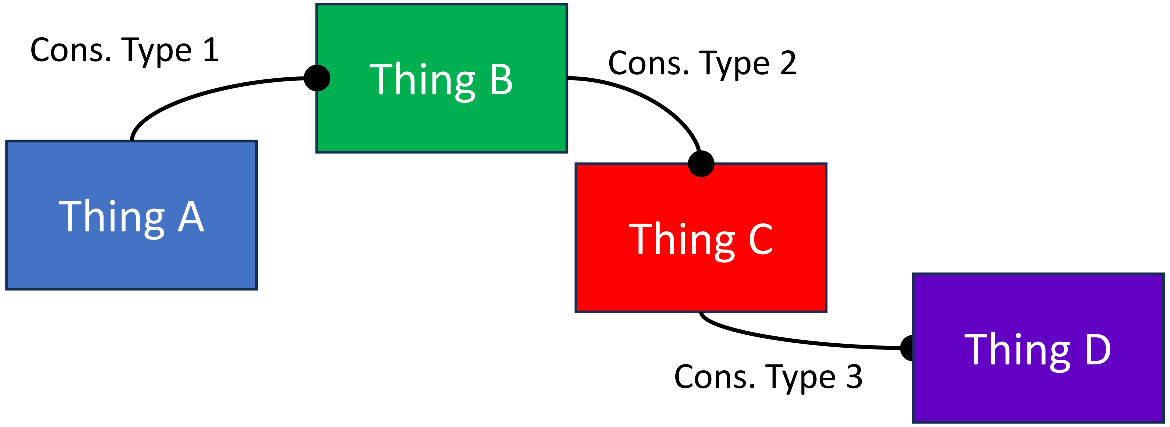




Consistency management: Representation for comparison

- Each such directed graph can be represented by an “N^2 adjacency matrix”:
  - Placing the compared things as headings for matrix rows and columns, the links become “consistency type” entries in the matrix cells.





In Computational Modeling community:
- “Referent”
- “Subject“

	From			
To		X	Y	Z
	X			
	Y	Cons. 1		
	Z	Cons. 3	Cons. 2	

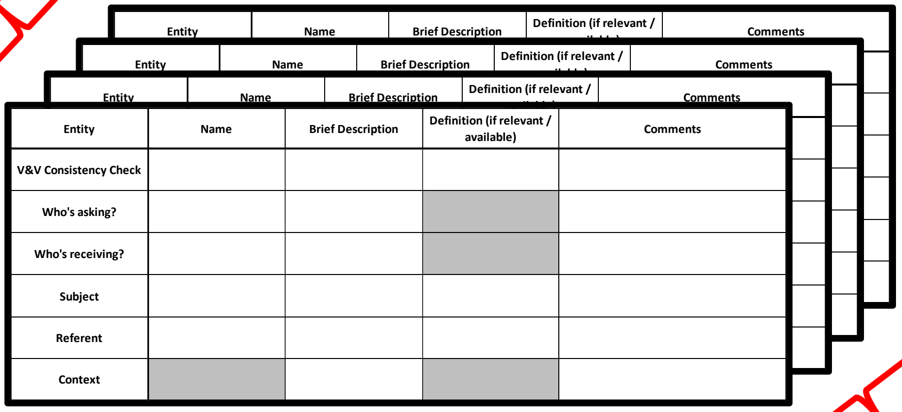
	From				
To		A	B	C	D
	A				
	B	Cons. 1			
	C		Cons. 2		
	D			Cons. 3	

Survey of consistency management frameworks: Data collection and assembly of Rosetta mapping

Survey data collection "card" for a **single managed consistency type**

Entity	Name	Brief Description	Definition (if relevant / available)	Comments
V&V Consistency Check				
Who's asking?				
Who's receiving?				
Subject				
Referent				
Context				

Managed consistency Type cards for a **single discipline**



Merge

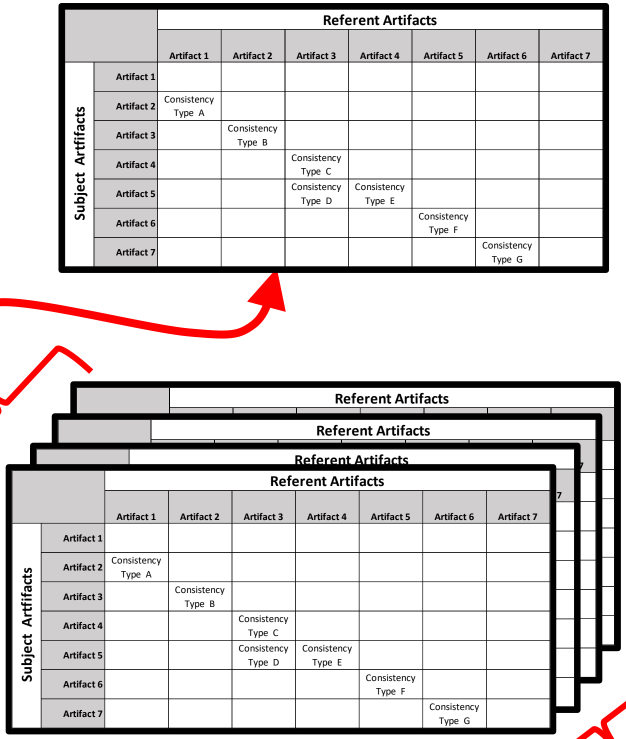
N^2 matrix of consistencies for a **single discipline**

Subject Artifacts \ Referent Artifacts	Artifact 1	Artifact 2	Artifact 3	Artifact 4	Artifact 5	Artifact 6	Artifact 7
Artifact 1							
Artifact 2	Consistency Type A						
Artifact 3		Consistency Type B					
Artifact 4			Consistency Type C				
Artifact 5			Consistency Type D	Consistency Type E			
Artifact 6					Consistency Type F		
Artifact 7						Consistency Type G	

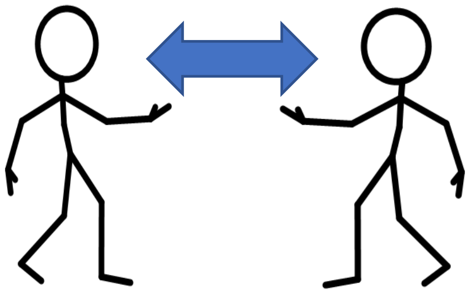
Multiple disciplines

Merge

Rosetta Stone: Multiple disciplines mapping



Our collaborative project



- Not so hard: This approach does not require any changes to discipline methods or nomenclatures!
- It simply captures them in a common, shared (matrix) representation(s) that makes their coverages and relationships evident.
- So, it need not be extremely difficult.
- But it does encourage objective conversation between the disciplines. [13]
- Accordingly, our "social strategy" is to carry this out as a collaboration between the technical societies associated with the disciplines.
- Our deliverable is the reference mapping, targeted across 2024 to cover Computational Model and ISO15288 Engineering communities.
- We plan to report on progress over 2024, at meetings of ASME, AIAA, NAFEMS, and INCOSE.
- **<u>Get involved</u>**: Contact the authors if you are interested in participation or results.

Insight gained from a simple warm-up example

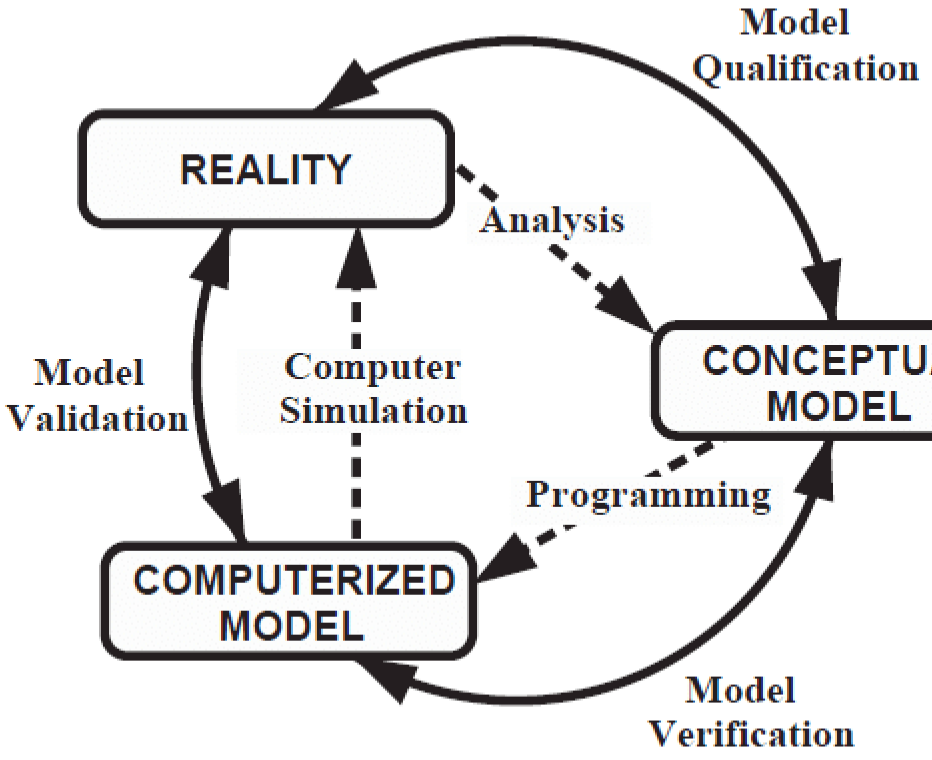
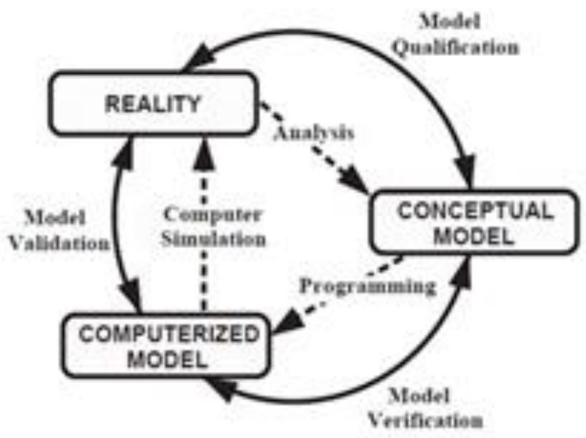


Diagram: The role of V&V in the development of simulation models (Schlesinger, 1979) [1].

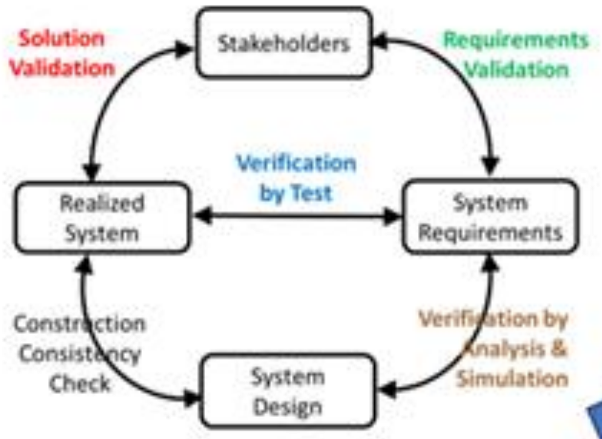
- This 1979 graph diagram is somewhat dated, but is a simple example with key ideas that continue to apply.
- An informative discussion of this diagram and subsequent history is in Oberkampf and Roy (2010) [2], pp 22 and its following sections.

Historical Computational Model V&V

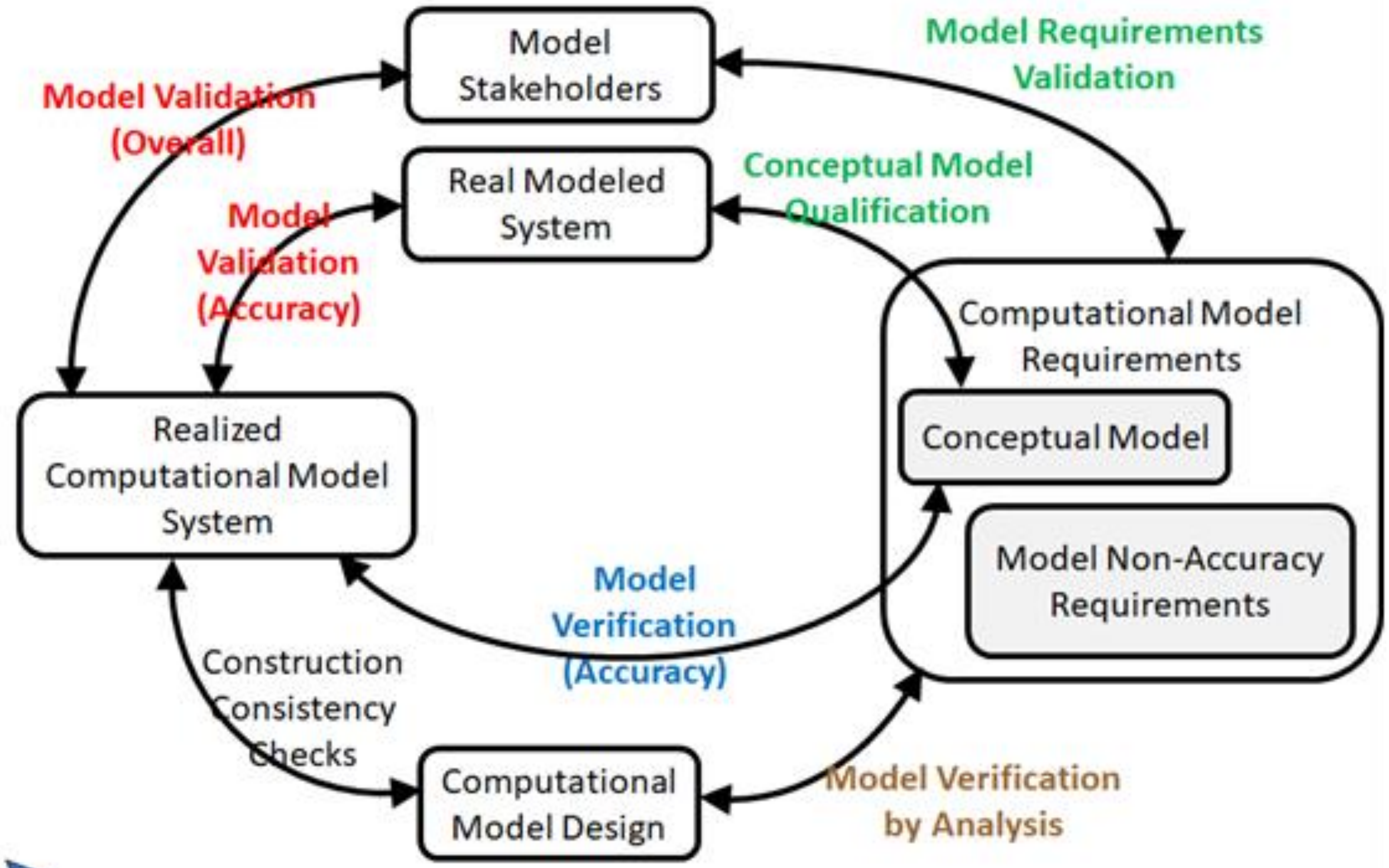


The role of V&V in the development of simulation models (Schlesinger, 1979) [1].

Historical ISO15288 V&V



Combined V&V View



Questions, discussion

References

[1] Schlesinger, S., “Terminology for Model Credibility”, *Simulation*, 32(3), 103-104, 1979.

[2] Oberkampf, W. and Roy, C., *Verification and Validation in Scientific Computing*, Cambridge U. Press, 2010.

[3] ASME VVUQ 1-2022: Verification, Validation, and Uncertainty Quantification Terminology in Computational Modeling and Simulation”, 2022.

[4] ASME V&V 10-2019: “Standard for Verification and Validation in Computational Solid Mechanics”, 2019.

[5] ISO, "ISO/IEC/IEEE 15288-2023: ISO/IEC/IEEE International Standard - Systems and software engineering -- System life cycle processes", 2023.

[6] Hightower, et al, “Verification and Validation Interactions with the Model Life Cycle: Status of a VV50 Working Group”, in *Proc of ASME V&V Symposium*, May 2021. Download from -- https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:model_life_cycle_working_group_status_v1.2.5.pdf

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[8] “Consistency Management as an Integrating Paradigm for Digital Life Cycle Management with Learning”. Download from -- https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:patterns:aselcm_pattern_--_consistency_management_as_a_digital_life_cycle_management_paradigm_v1.3.1.pdf

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[11] Walden, D., et al, eds., *INCOSE Systems Engineering Handbook*, Fifth Edition, International Council on Systems Engineering, San Diego, Ca, 2023.

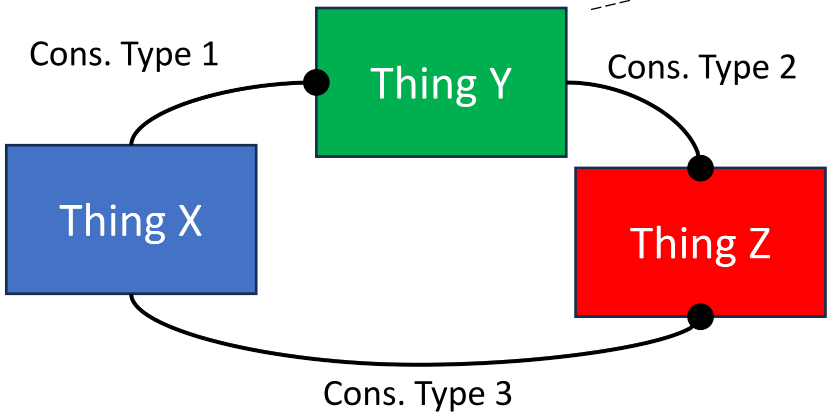
[12] Schindel, W., “Innovation Ecosystem Dynamics, Value and Learning I: What Can Hamilton Tell Us?”, accepted for appearance in *Proc of INCOSE 2024 International Symposium*, Dublin, Ireland.

[13] Taylor, N., and Schindel, W., “CFD Validation: Illustrations of Mutual Accountability and Validation Dialog throughout the Engineering Lifecycle”, in *Proc of AIAA 2024 SciTech Conference*, Orlando, FL.

Acronyms

- AIAA - American Institute of Aeronautics and Astronautics
- ASELCM – Agile Systems Engineering Life Cycle Model
- ASME – American Society of Mechanical Engineers
- CAF – Credibility Assessment Framework
- DEIC – Digital Engineering Integration Committee
- EE – Electrical Engineering or Electrical Engineer
- INCOSE – International Council on Systems Engineering
- ISO – International Standards Organization
- ME – Mechanical Engineering or Mechanical Engineer
- MBSE – Model-Based Systems Engineering
- N^2 – N x N, indicating a square matrix with common headings on rows and columns
- NAFEMS – National Agency for Finite Element Methods and Standards
- V&V – Verification and Validation
- VVUQ – Verification, Validation and Uncertainty Quantification
- WG – Working Group

More on consistency management: How linked are these entities?

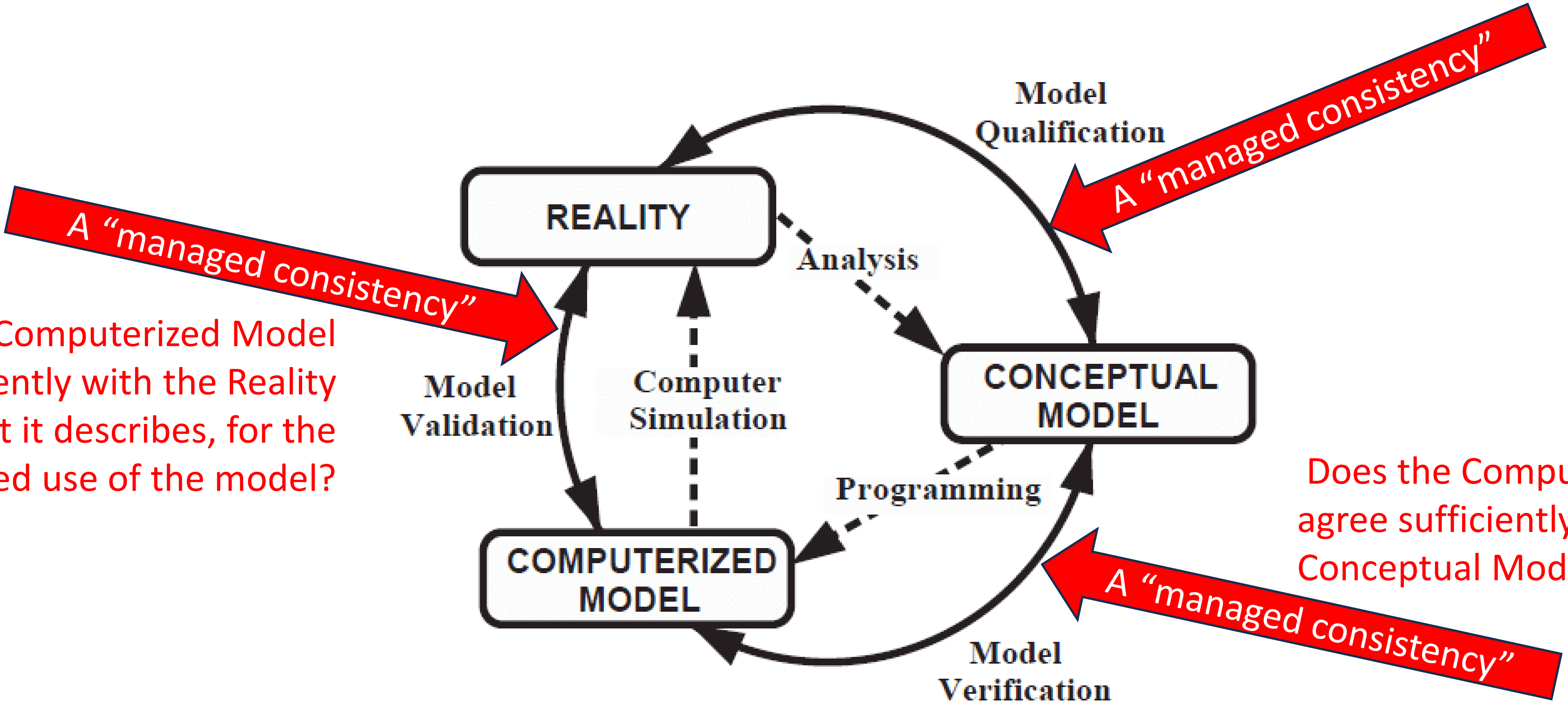


	From			
		X	Y	Z
To	X			
	Y	Cons. 1		
	Z	Cons. 3	Cons. 2	

- A single “Thing” can be both a referent and subject – see Thing Y here.
- A single “Thing” can be informed by / compared to more than one referent—see Thing Z here.
- A single “Thing” can be a referent for more than one subject—see Thing X here.
- A referent can be some product of development, observation, a standard, some earlier learned reference pattern, or other suitable kind of reference.

More about the example

Is the Conceptual Model suitable as a model of Reality, for the intended purpose?

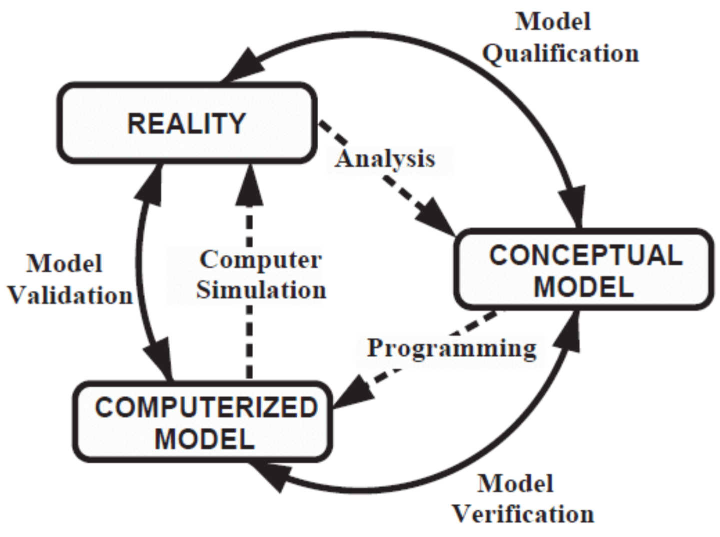


Does the Computerized Model agree sufficiently with the Reality system that it describes, for the intended use of the model?

Does the Computerized Model agree sufficiently with the Conceptual Model it is based upon?

Diagram: The role of V&V in the development of simulation models (Schlesinger, 1979) [1].

Example Matrix of Consistency Checks—Computational Model Cases in Diagram



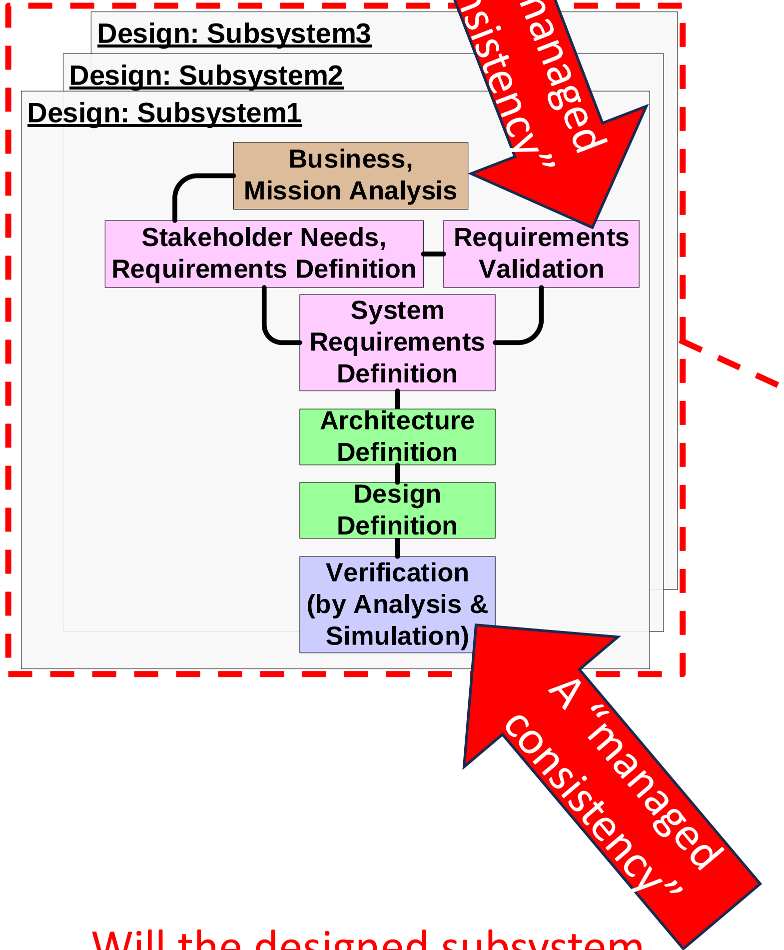
		Upstream						
		Model Stakeholders	Real Modeled System	Computational Model Requirements	Conceptual/ Math Model	Model Non-Accuracy Requirements	Computational Model Design	Realized Computational Model System
Downstream	Model Stakeholders							
	Real Modeled System							
	Computational Model Requirements							
	Conceptual/ Math Model		**Conceptual Model Qualification**					
	Model Non-Accuracy Requirements							
	Computational Model Design							
	Realized Computational Model System		**Model Validation (Accuracy)**		**Model Verification (Accuracy)**			

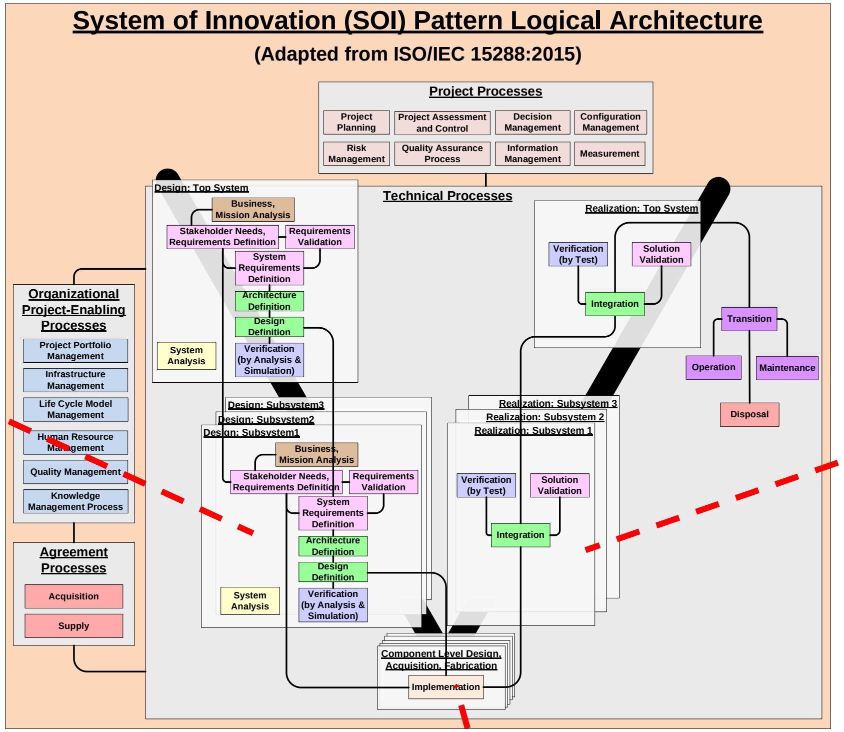
Do the subsystem requirements represent the stakeholder needs and "flowed down" decomposed allocated requirements adequately for purpose?

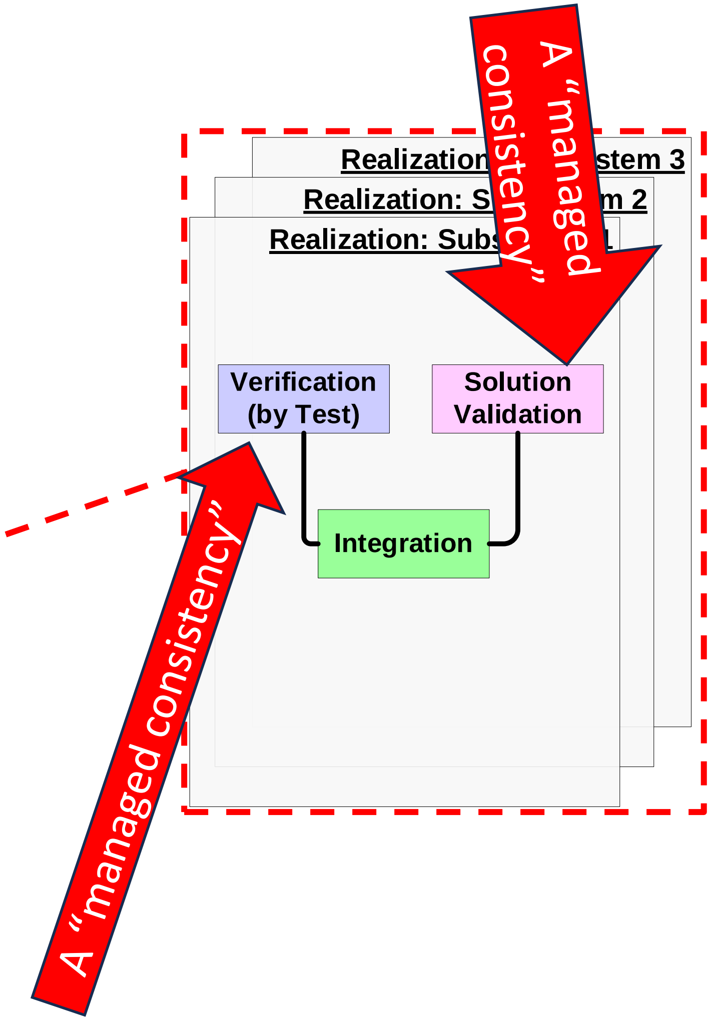
Computation Model As Engineered Subsystem:

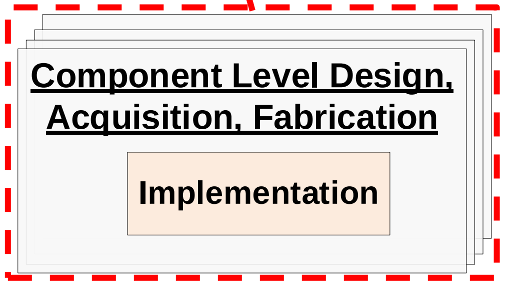
Systems Engineering "Vee" Perspective on Engineering of Systems (as in ISO15288 [5], INCOSE Handbook [11], etc.)

Does the implemented subsystem satisfy its stakeholders?





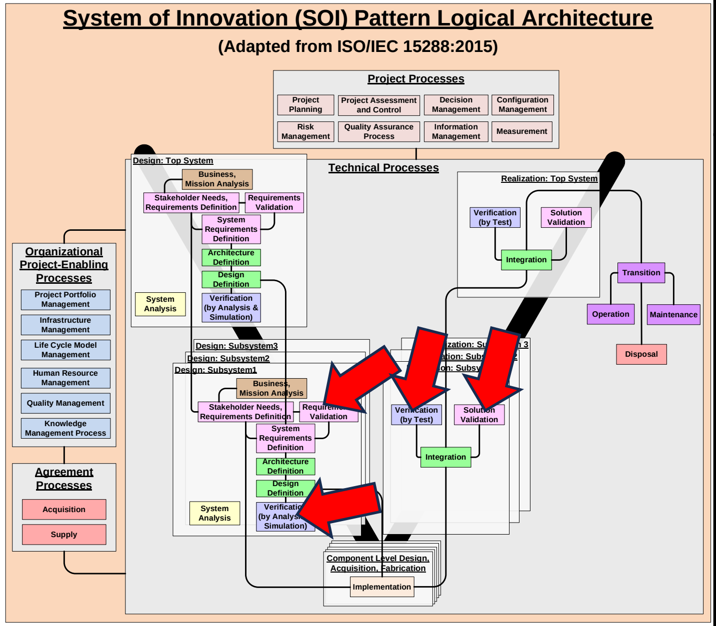




Will the designed subsystem predictably behave in sufficient agreement with its requirements?

Does the implemented subsystem behave in sufficient agreement with its requirements?

Example Matrix of Consistency Checks—Engineered System Cases in Diagram



		Upstream						
		Model Stakeholders	Real Modeled System	Computational Model Requirements	Conceptual / Math Model	Model Non-Accuracy Requirements	Computational Model Design	Realized Computational Model System
Downstream	Model Stakeholders							
	Real Modeled System							
	Computational Model Requirements	**Model Requirements Validation**						
	Conceptual/ Math Model							
	Model Non-Accuracy Requirements							
	Computational Model Design			**Model Verification by Analysis**				
	Realized Computational Model System	**Model Validation (Overall)**					**Construction Consistency Checks**	