

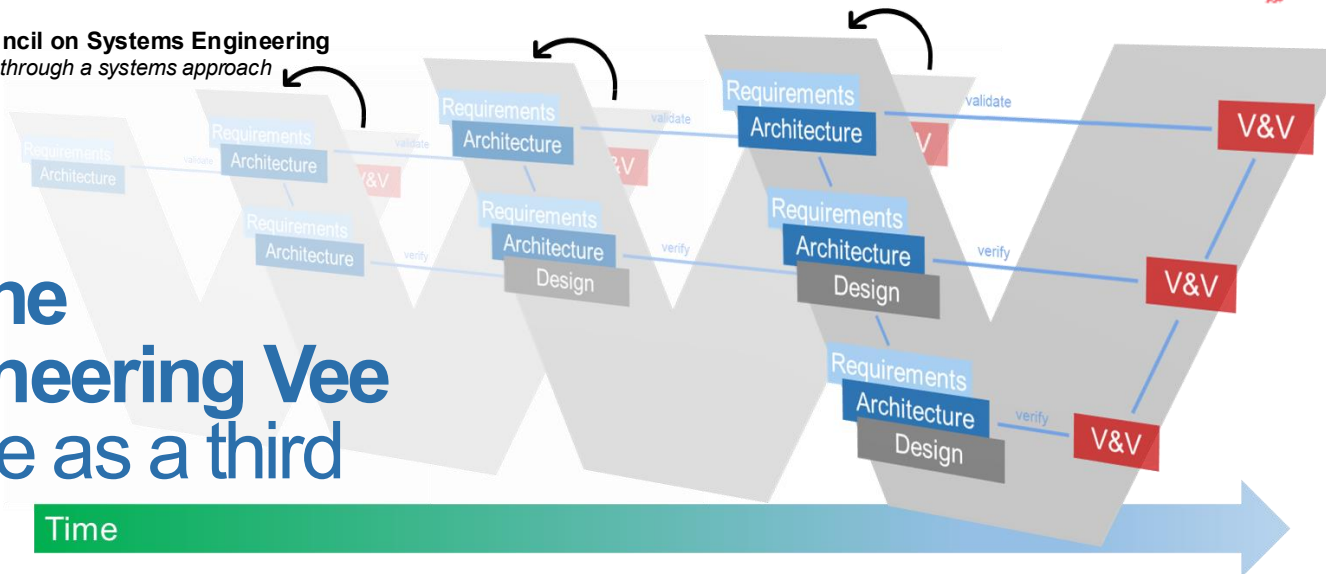


International Council on Systems Engineering
A better world through a systems approach



Generalizing the Systems Engineering Vee

Introducing Time as a third Dimension and Refining the Role of Analysis Tools



Alexander Busch, Ph.D., CSEP

Ansys/Synopsys, SMSWG

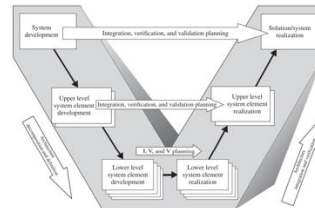
Greg Garstecki, CSEP

Garstecki Modeling Solutions, SMSWG

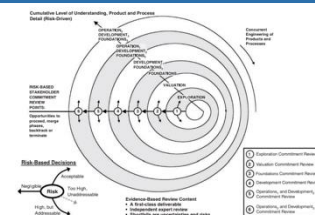
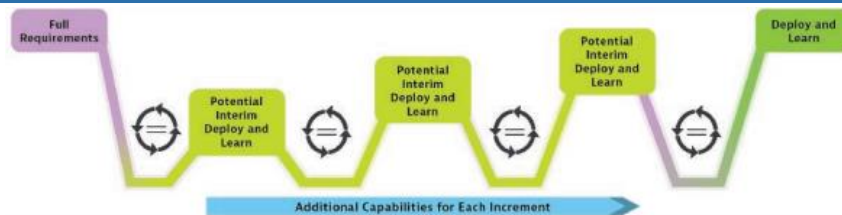


What SE Life Cycle Model do you use?

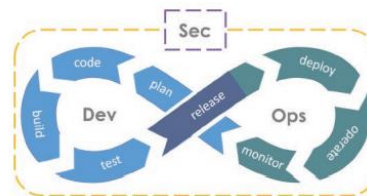
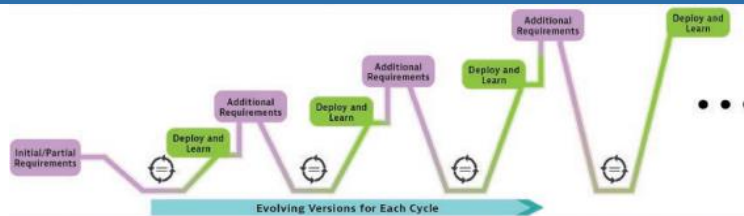
Sequential



Incremental



Evolutionary





Generalizing the Systems Engineering Vee **Introducing Time as a third Dimension**

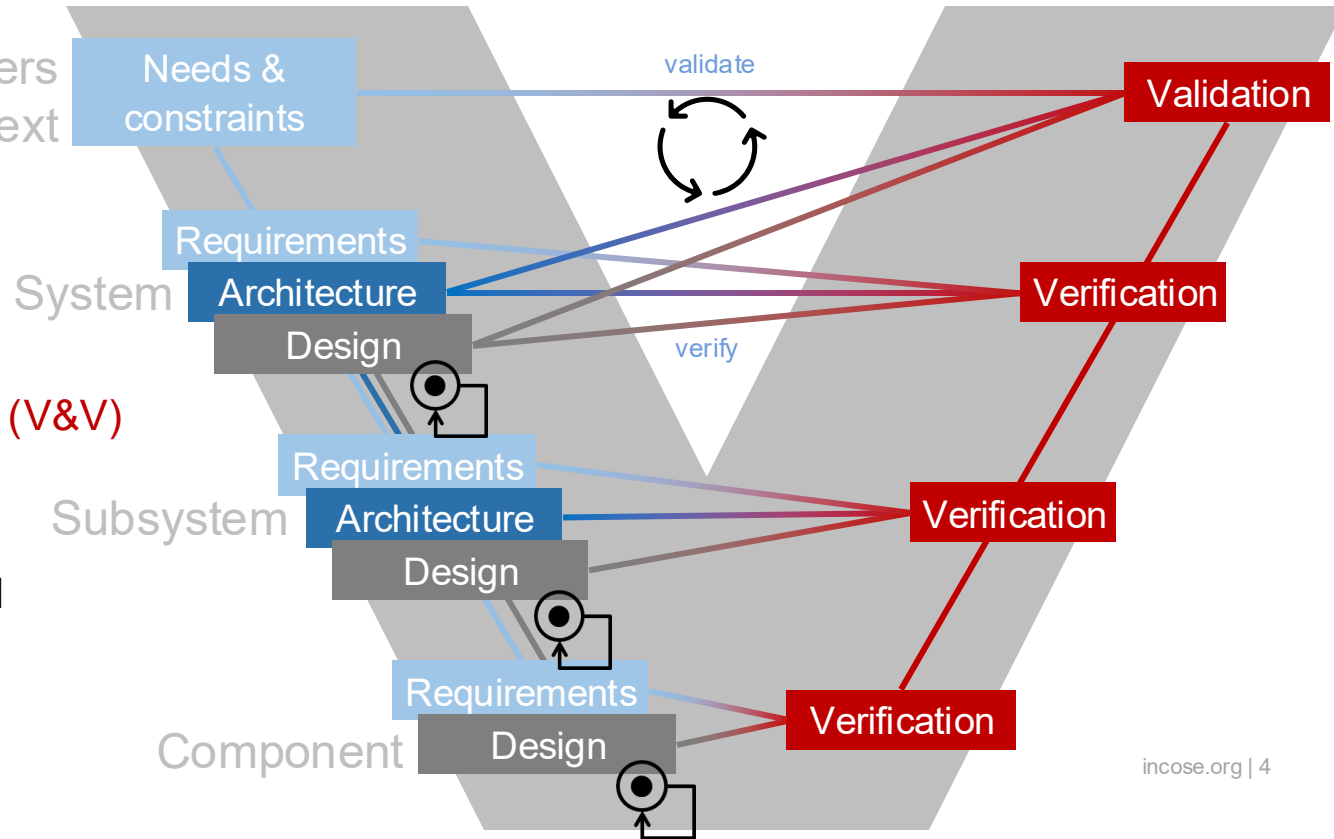
The Vee: Does not show time!

It is a **logical concept** relating:

- Needs & Reqmts
- Technical solutions
- Integration of elements into systems
- Verification and Validation (V&V)

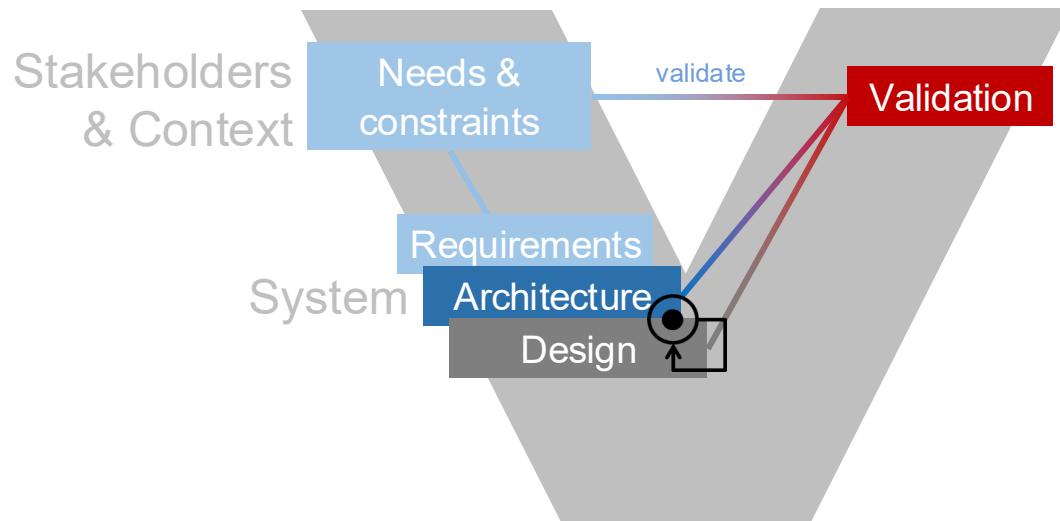
and is applied

- **recursively** (🔍) across all relevant levels
- **iteratively** (🔄) over time



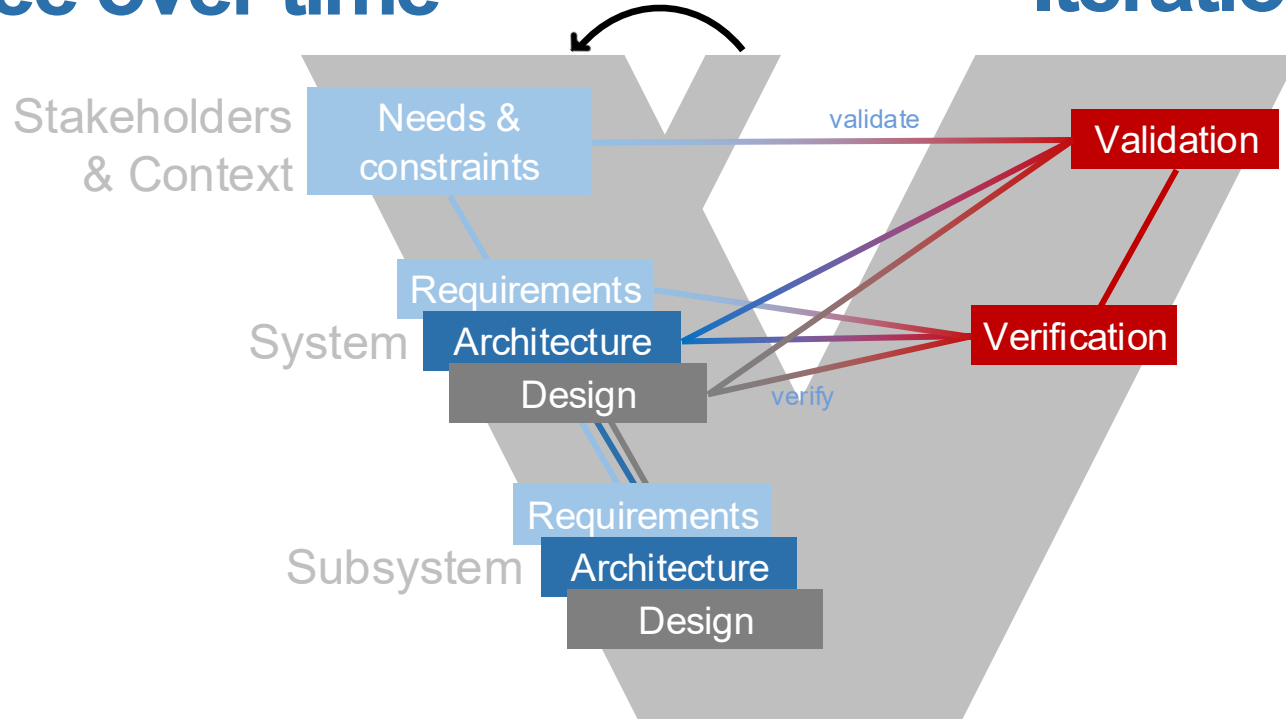
The Vee over time

Iteration 1



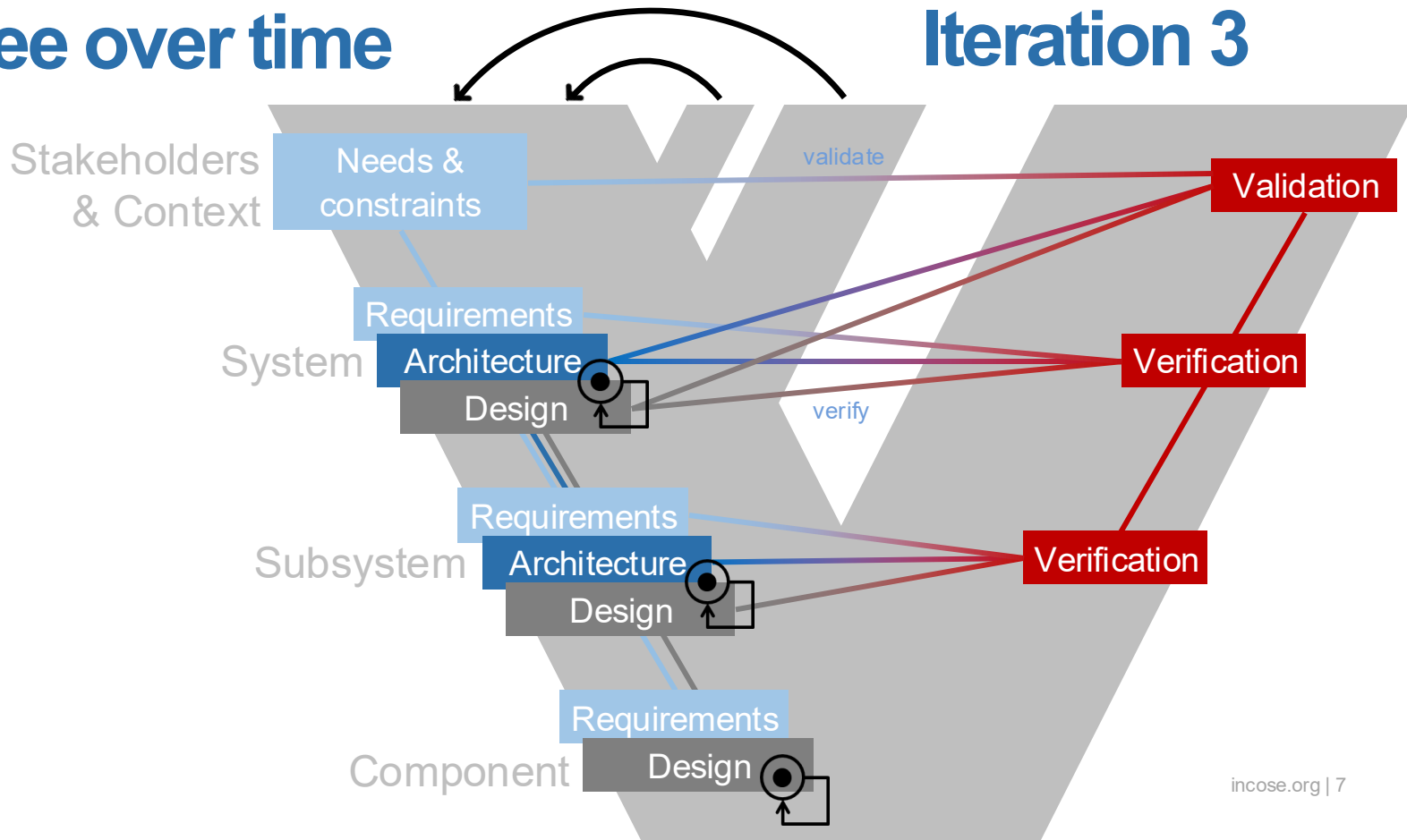
The Vee over time

Iteration 2



The Vee over time

Iteration 3



The Vee over time

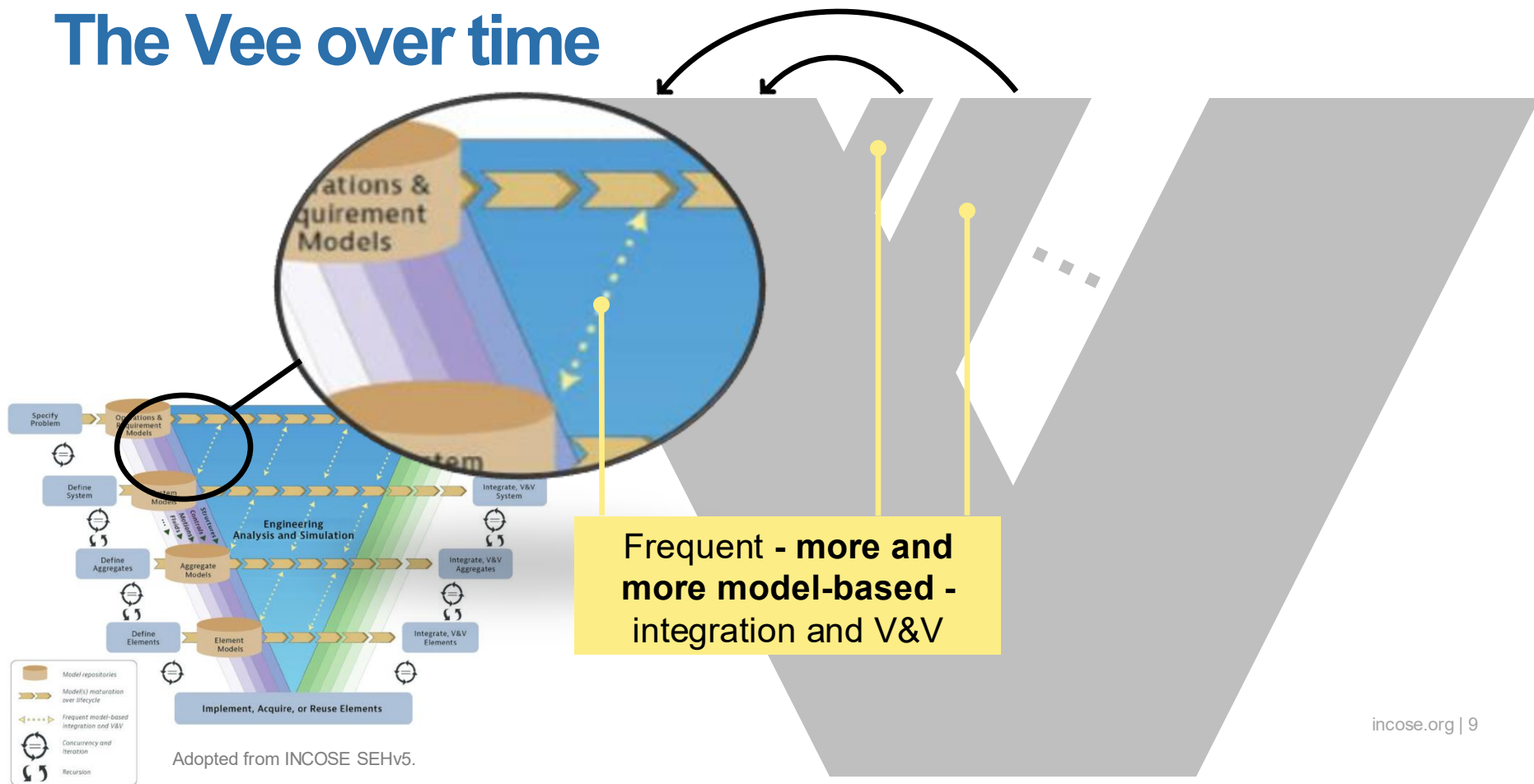
Iteration n



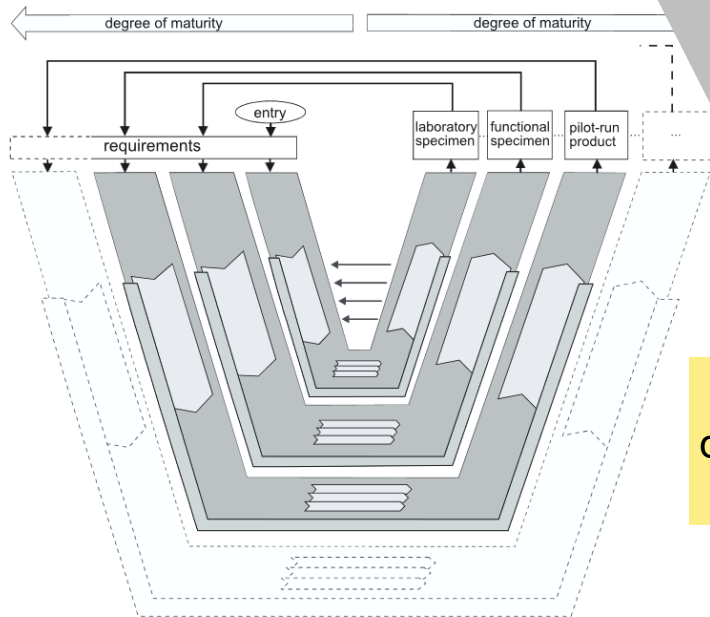
Each Vee may be interpreted as:

- an implicit and microscopic iteration throughout development as you are learning about the system
- the explicit development sprints you have in an Agile process
- the explicit and macroscopic baselines you have in a phase-gate process
- (insert your process)

The Vee over time



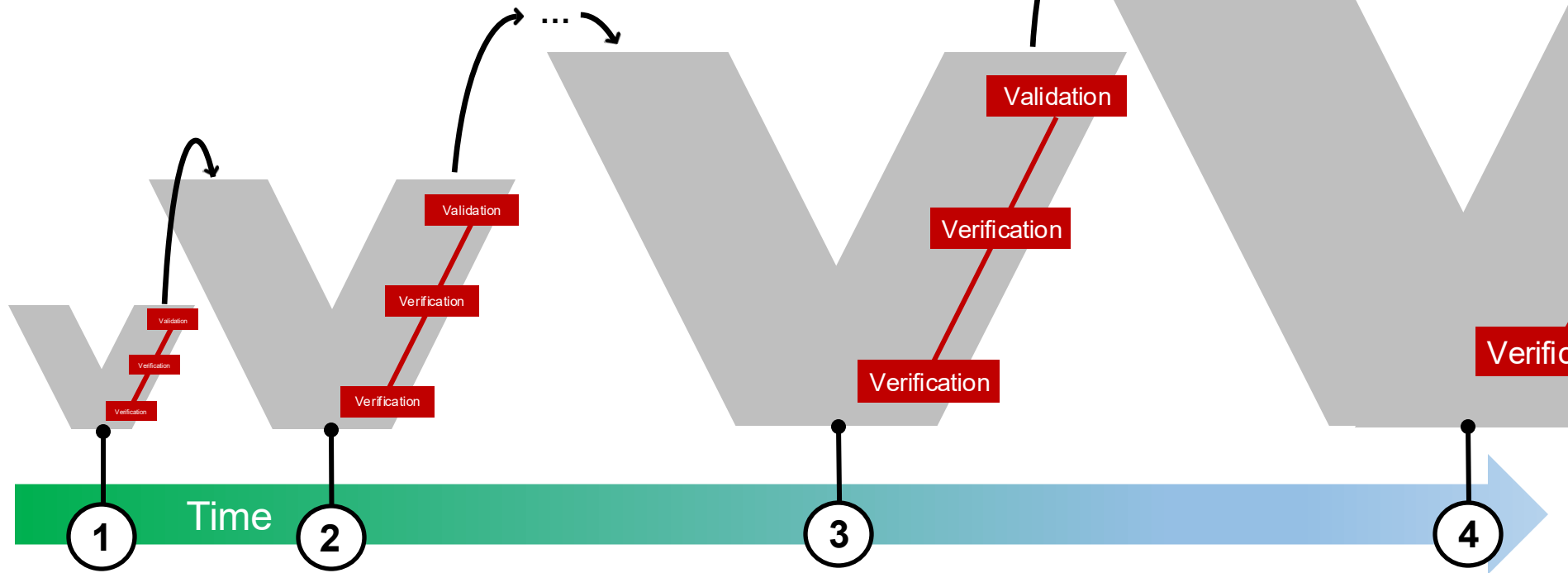
The Vee over time



Adopted from VDI 2206:2004.

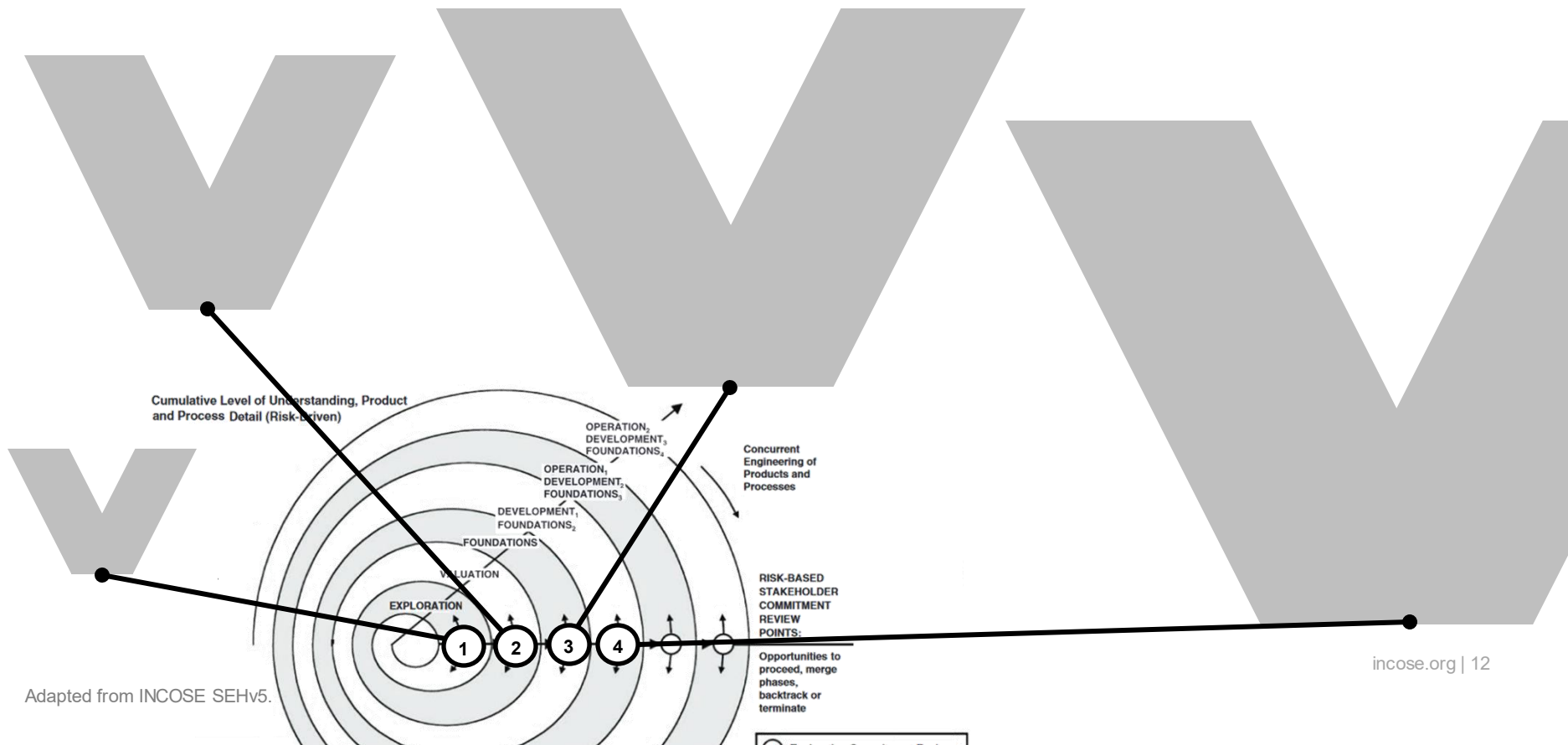
Macro-cycles to increase degree of product maturity (VDI 2206)

The Vee over time and V&V

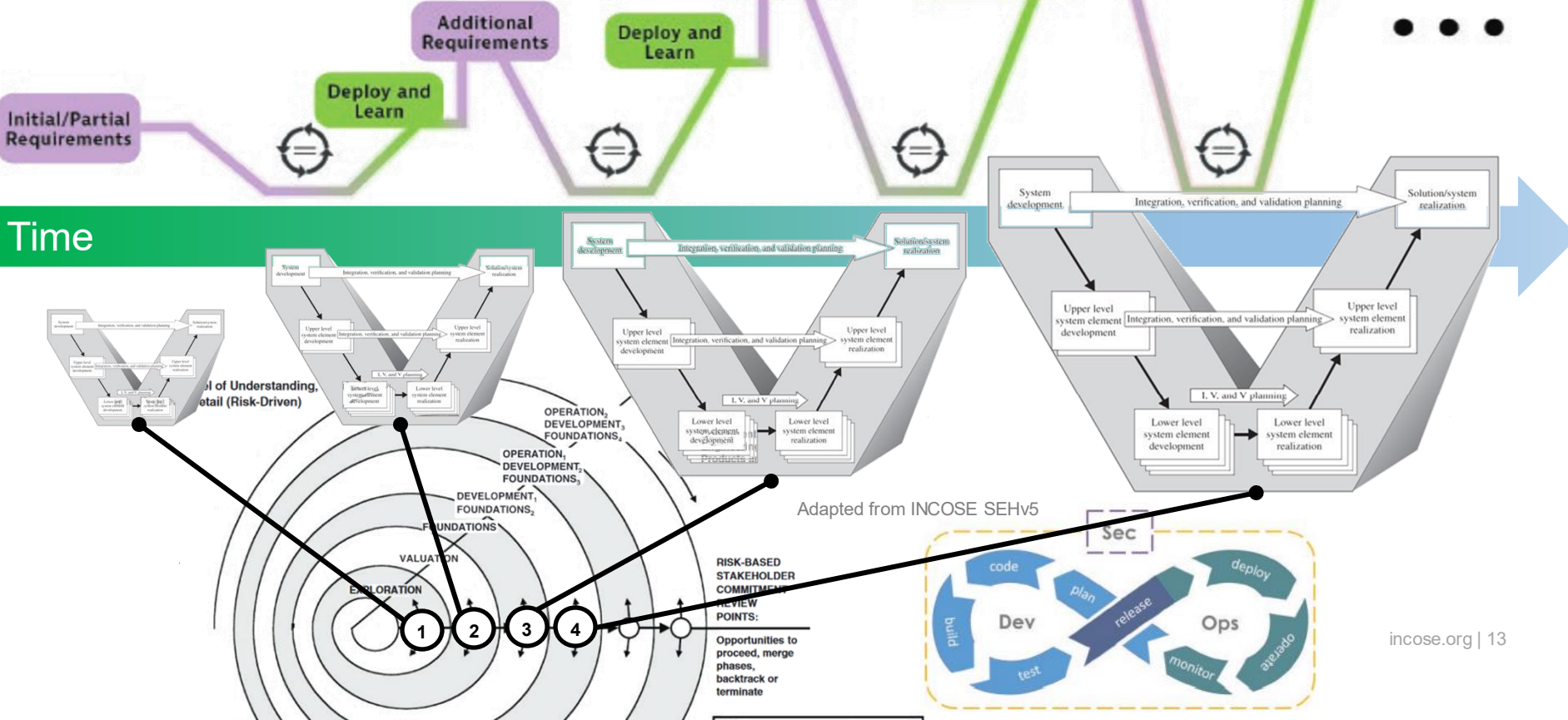


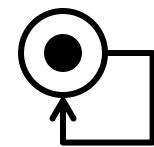
Snapshots of the Sol's dev state: Versions, Milestones, Baselines, Project Gates, ...

The Vee over time

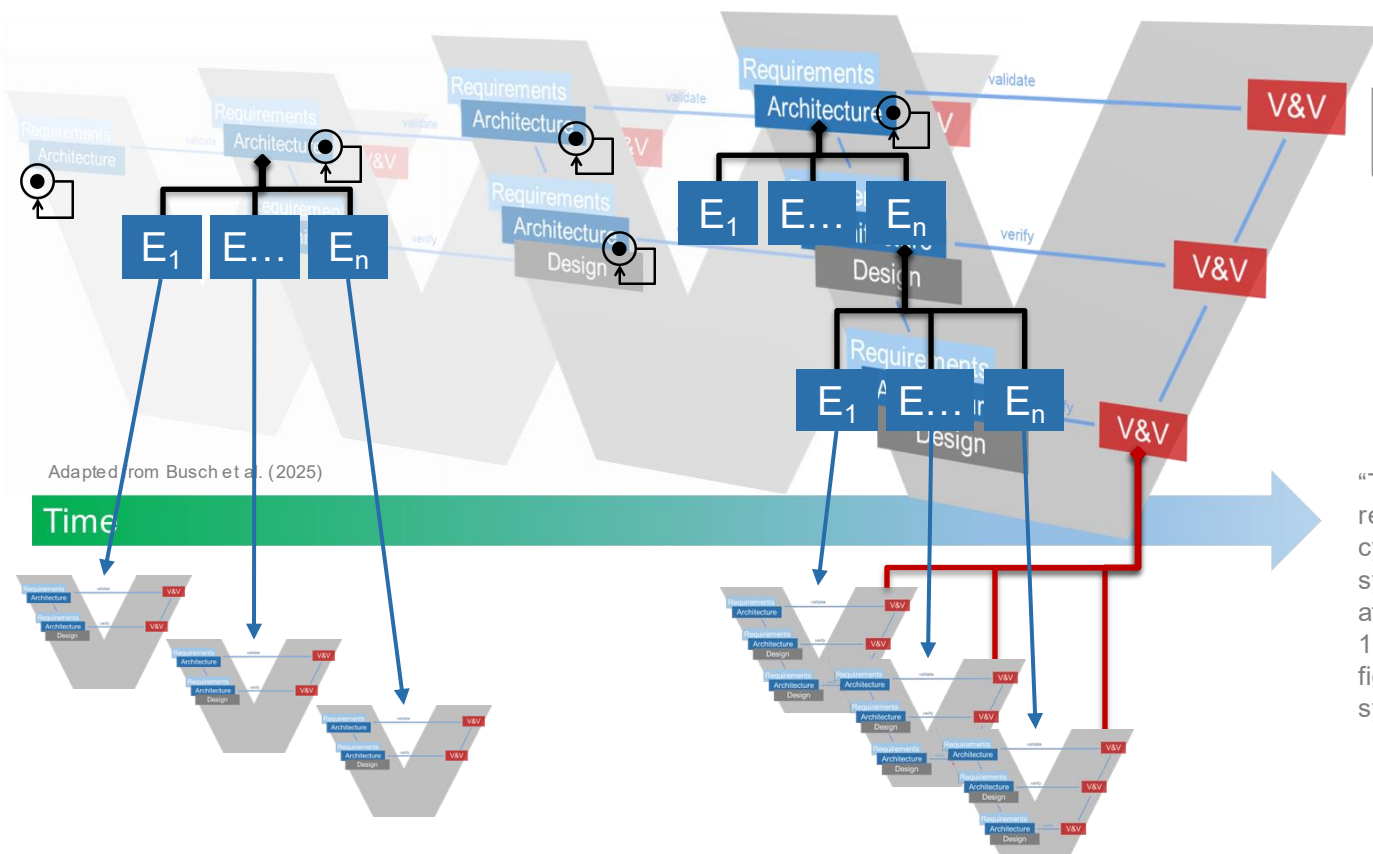


The Vee over time

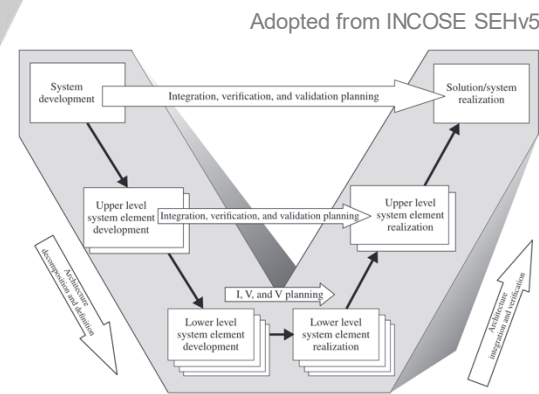




The Vee over levels: Recursiveness



Adapted from Busch et al. (2025)

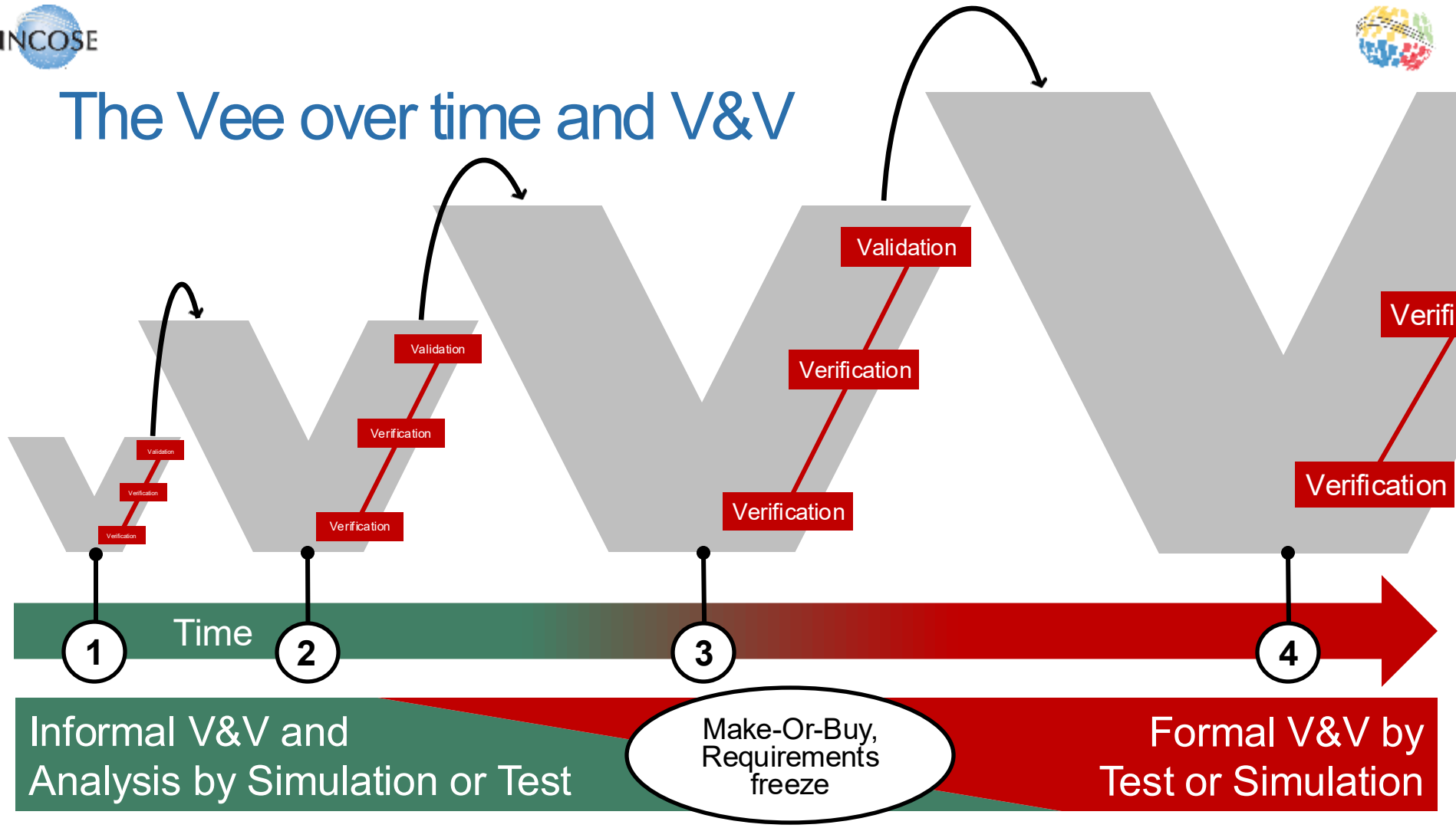


“The bottom of the Vee depicts either the recursive application of the systems life cycle processes at the next level of the system hierarchy or the implementation of atomic system elements (see Section 1.3.5). The broadening at the base of the figure shows the growth in the number of system elements.” (SEHv5)

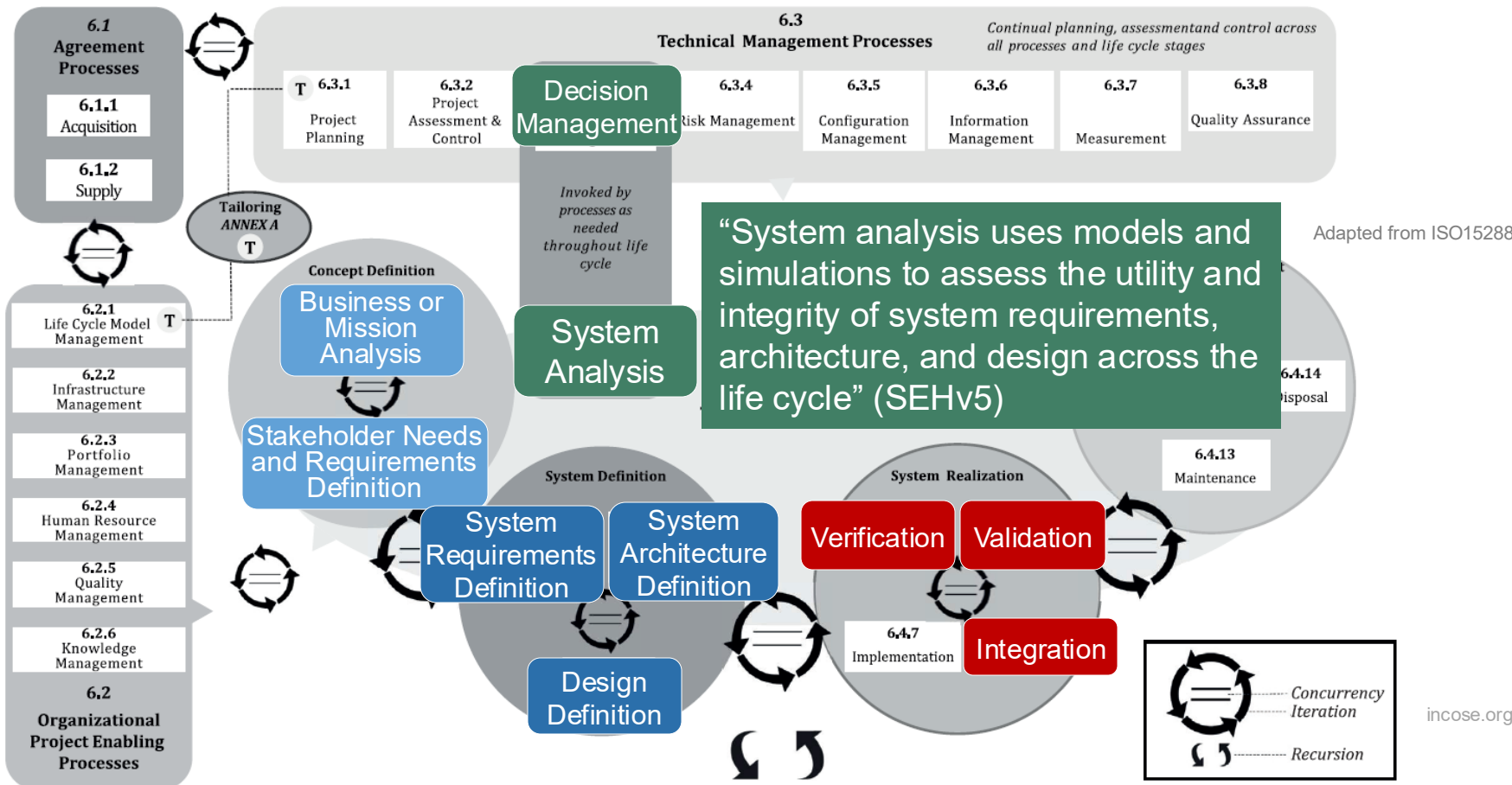


Generalizing the Systems Engineering Vee **Refining the Role of Analysis Tools**

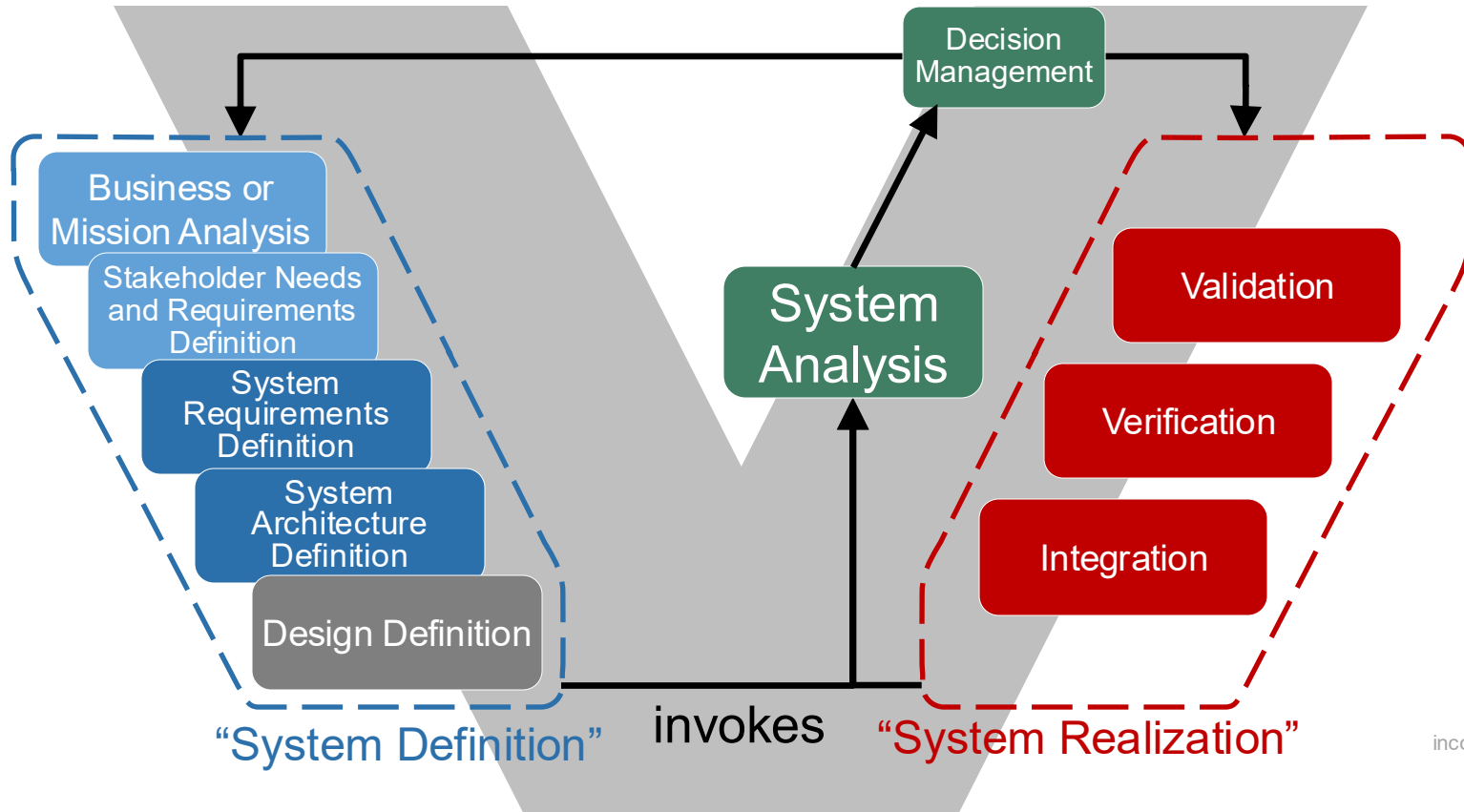
The Vee over time and V&V



ISO 15288 processes

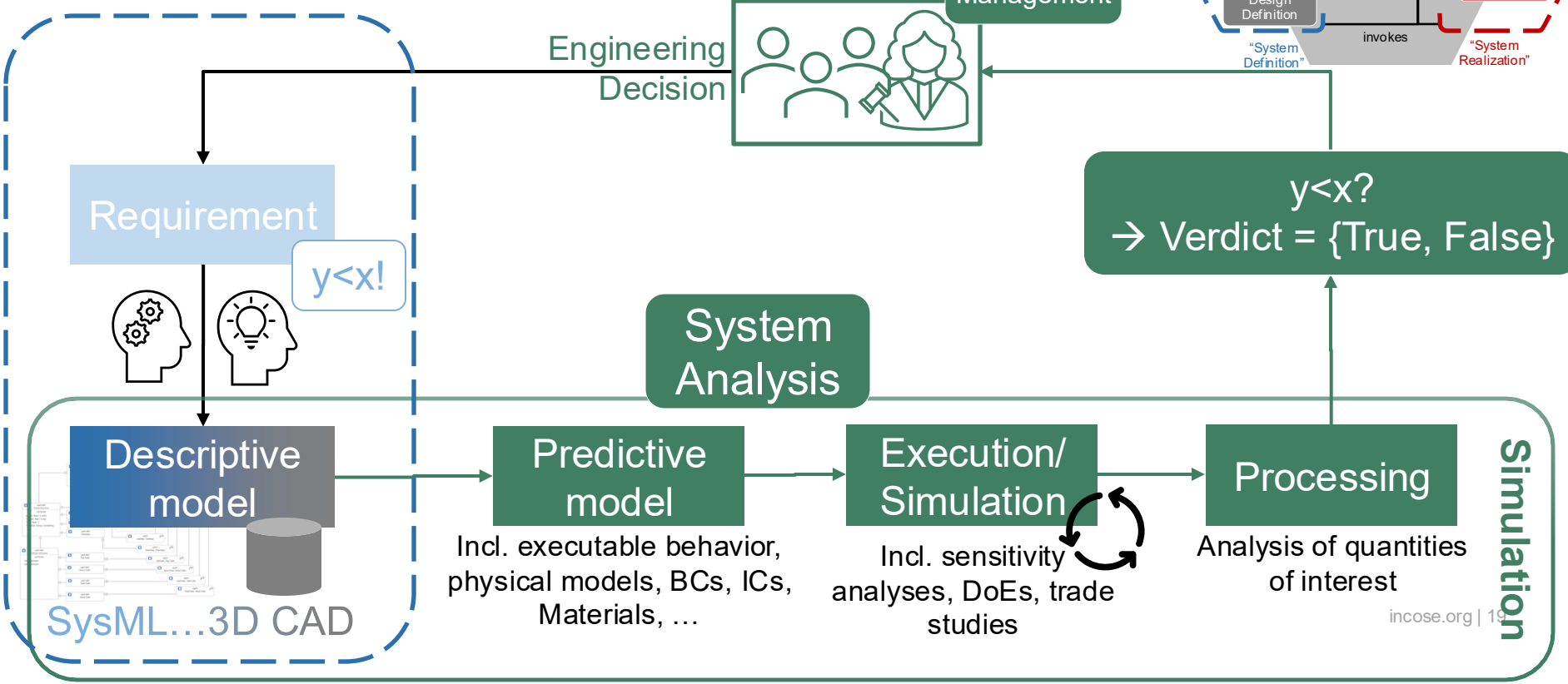


ISO 15288 processes on an atomic Vee element



A SE feedback/control loop

Partly adopted from ISO/IEC/IEEE 42020:2019, ISO/IEC/IEEE 24641:2023

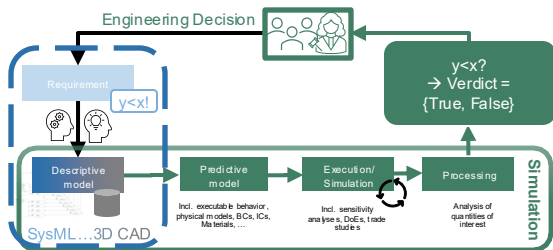
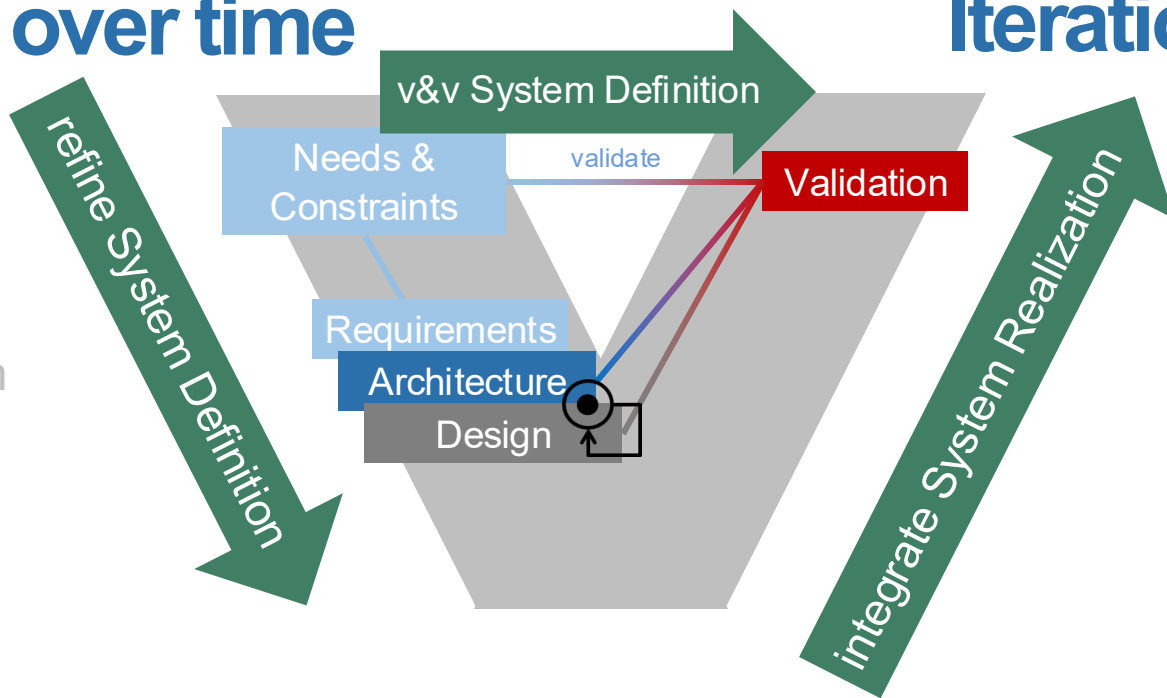


The Vee over time

Iteration 1

Stakeholders
& Context

System



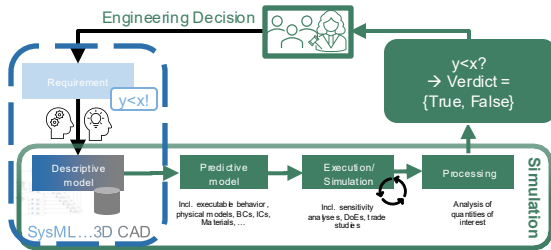
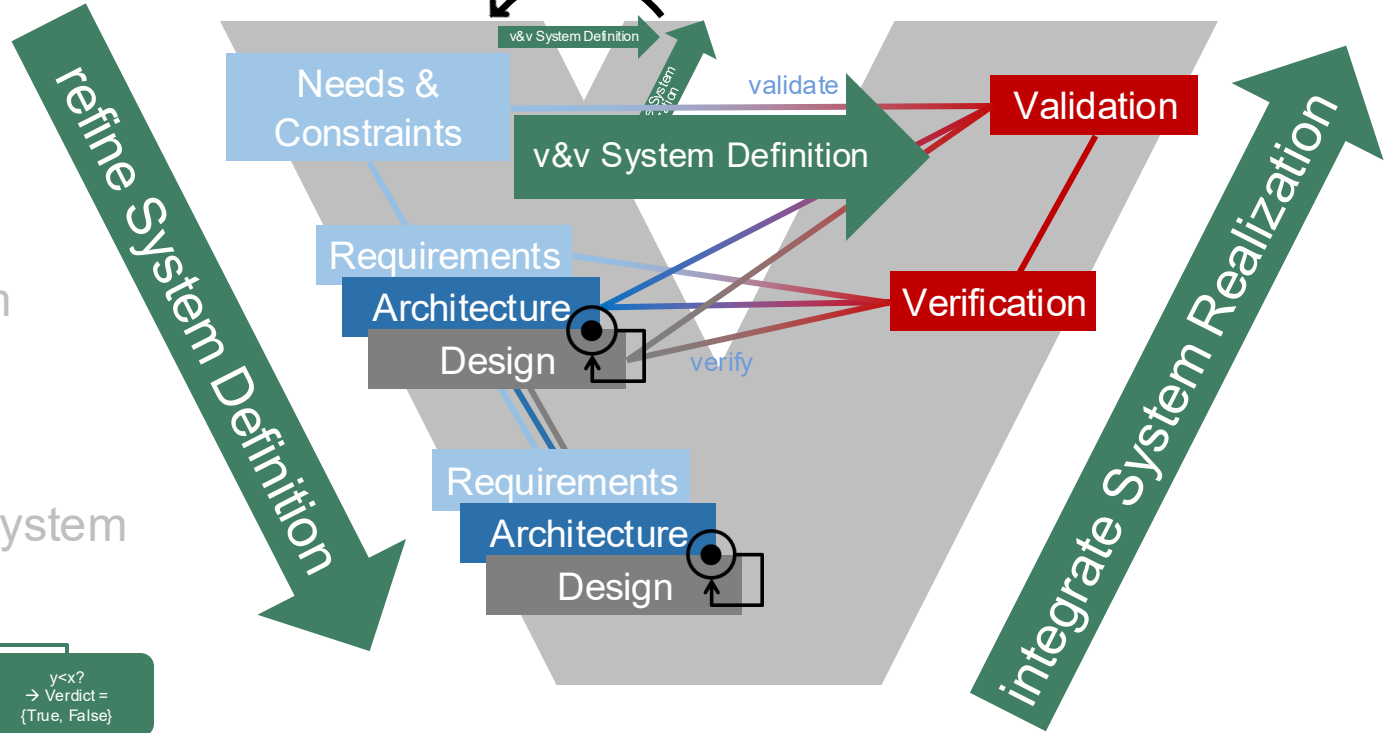
The Vee over time

Iteration 2

Stakeholders
& Context

System

Subsystem



The Vee over time

Iteration 3

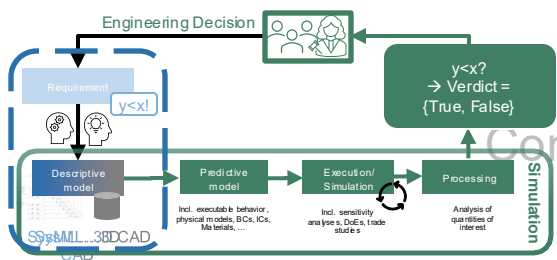
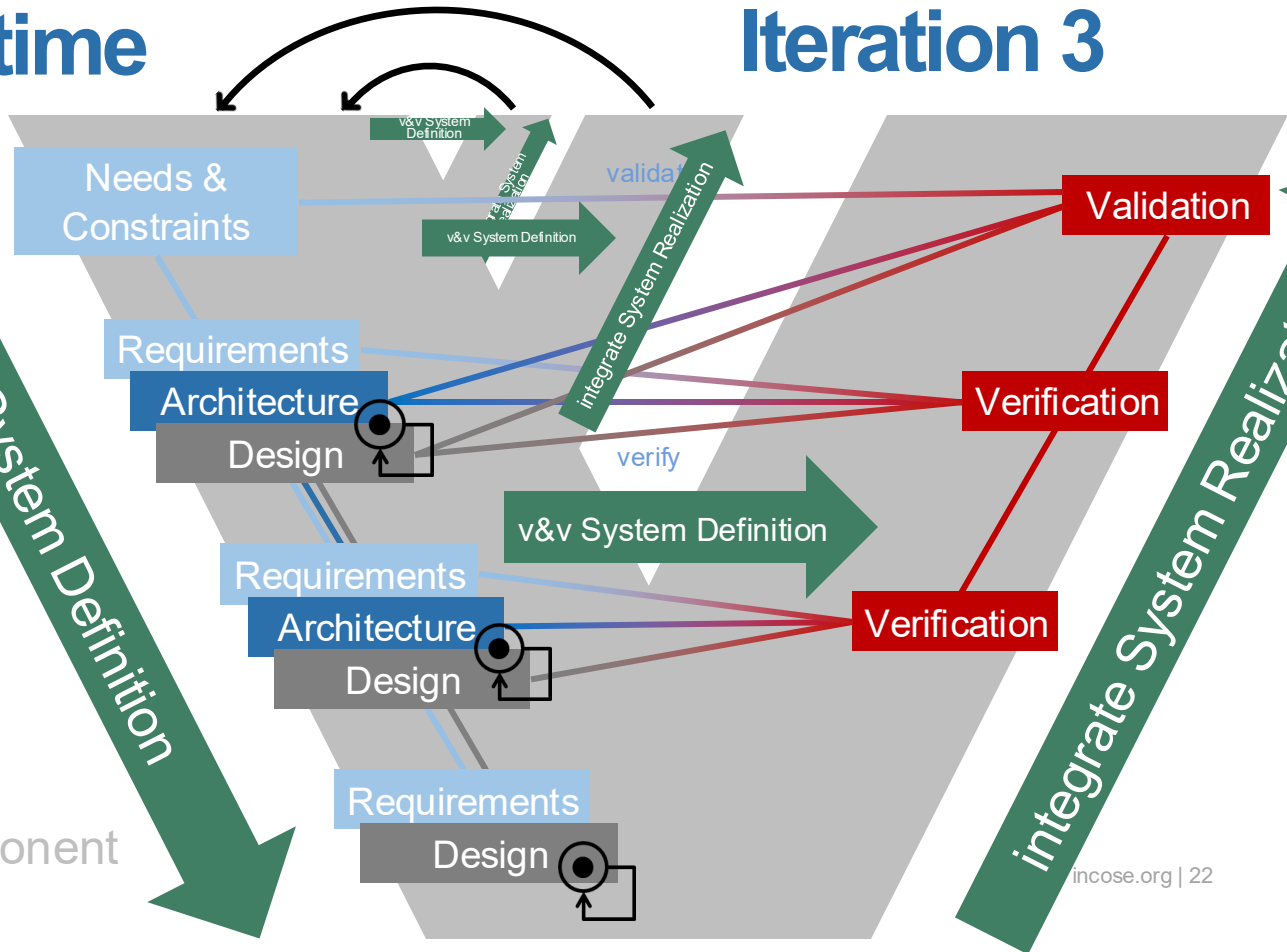
Stakeholders
& Context

System

Subsystem

refine System Definition

integrate System Realization

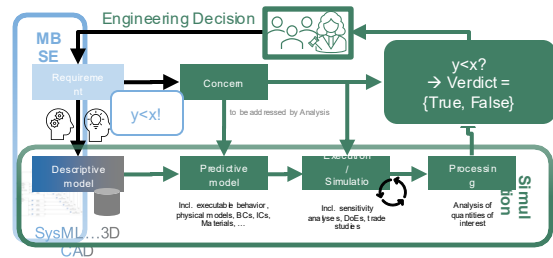
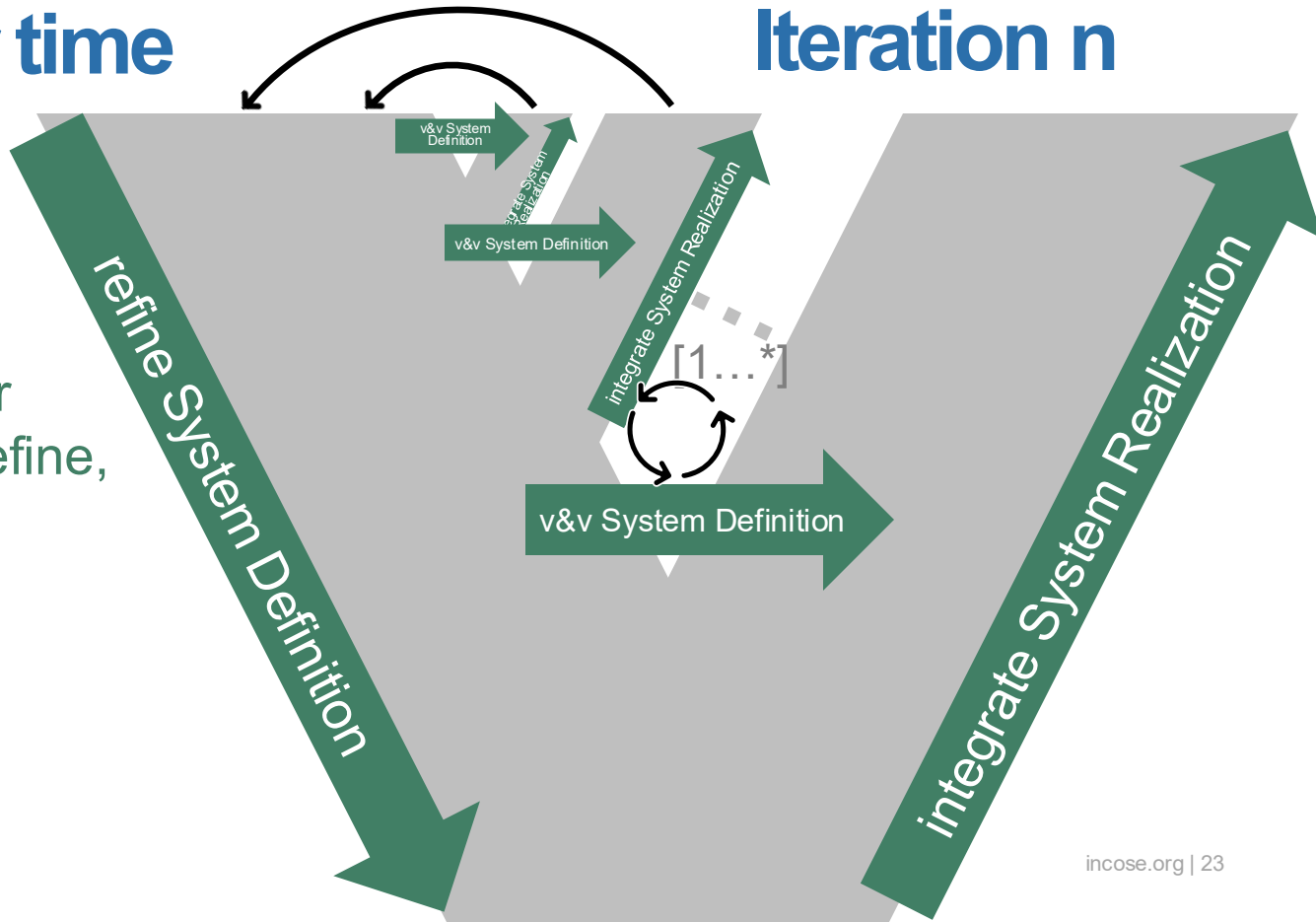


The Vee over time

Iteration n

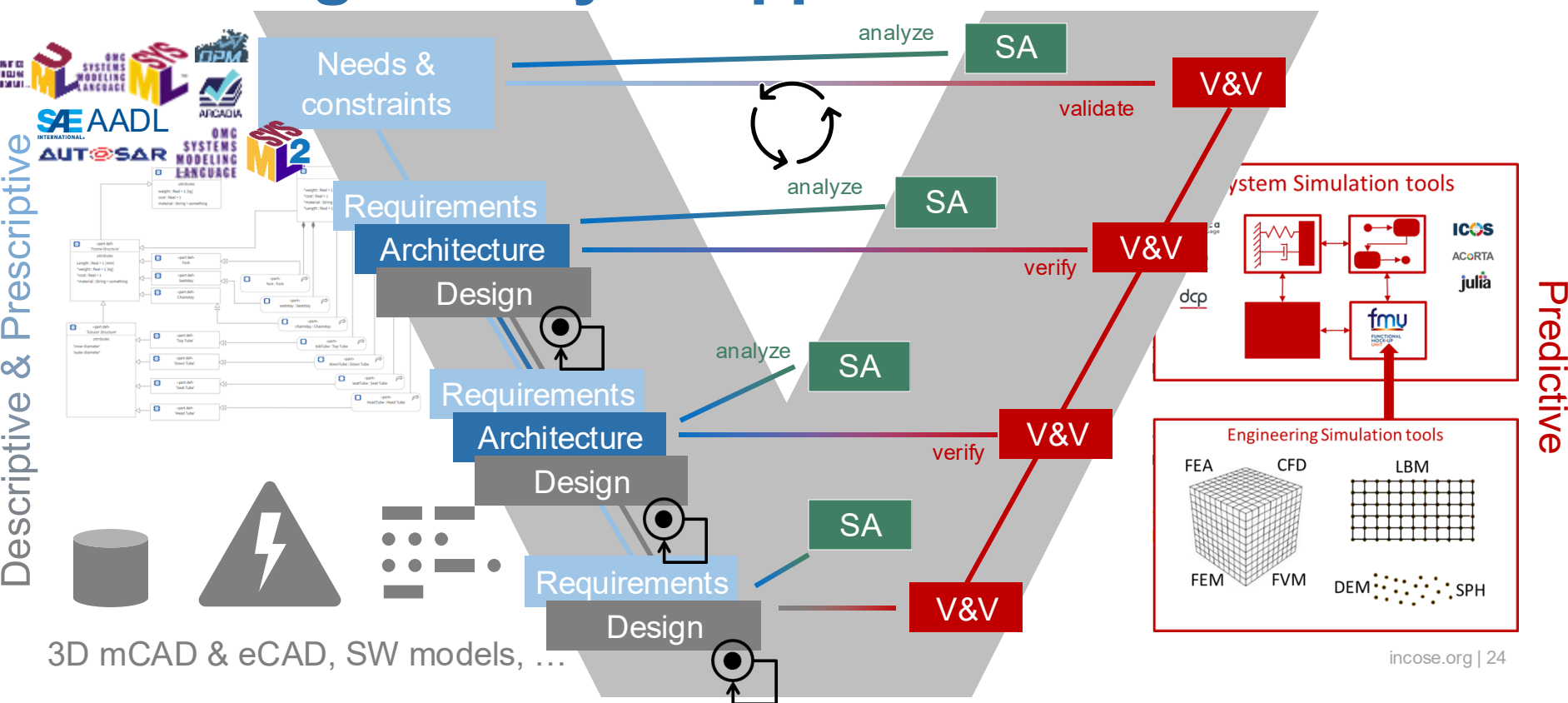
System Analysis

System analysis and simulation in particular is iteratively used to refine, integrate, and v&v all artefacts.



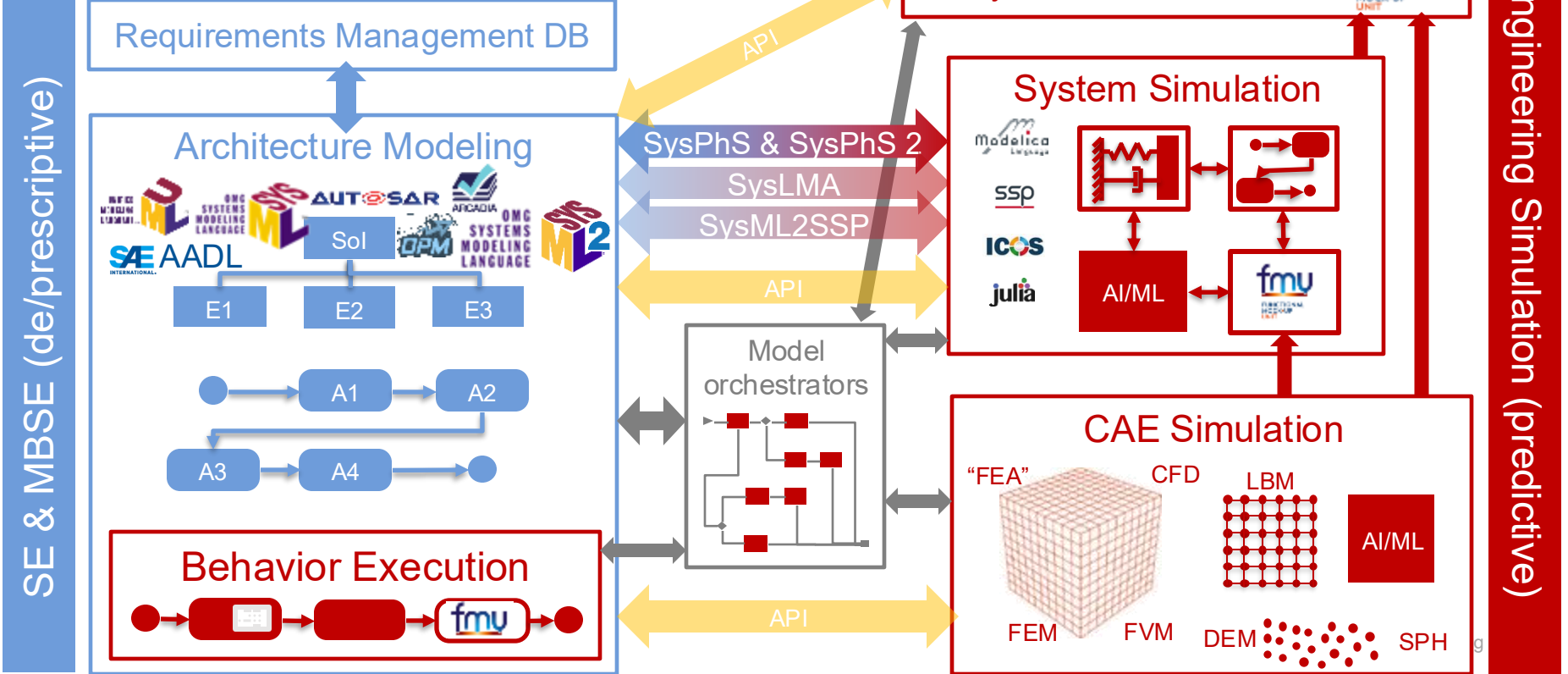
Modeling & Analysis approaches & tools

Descriptive & Prescriptive



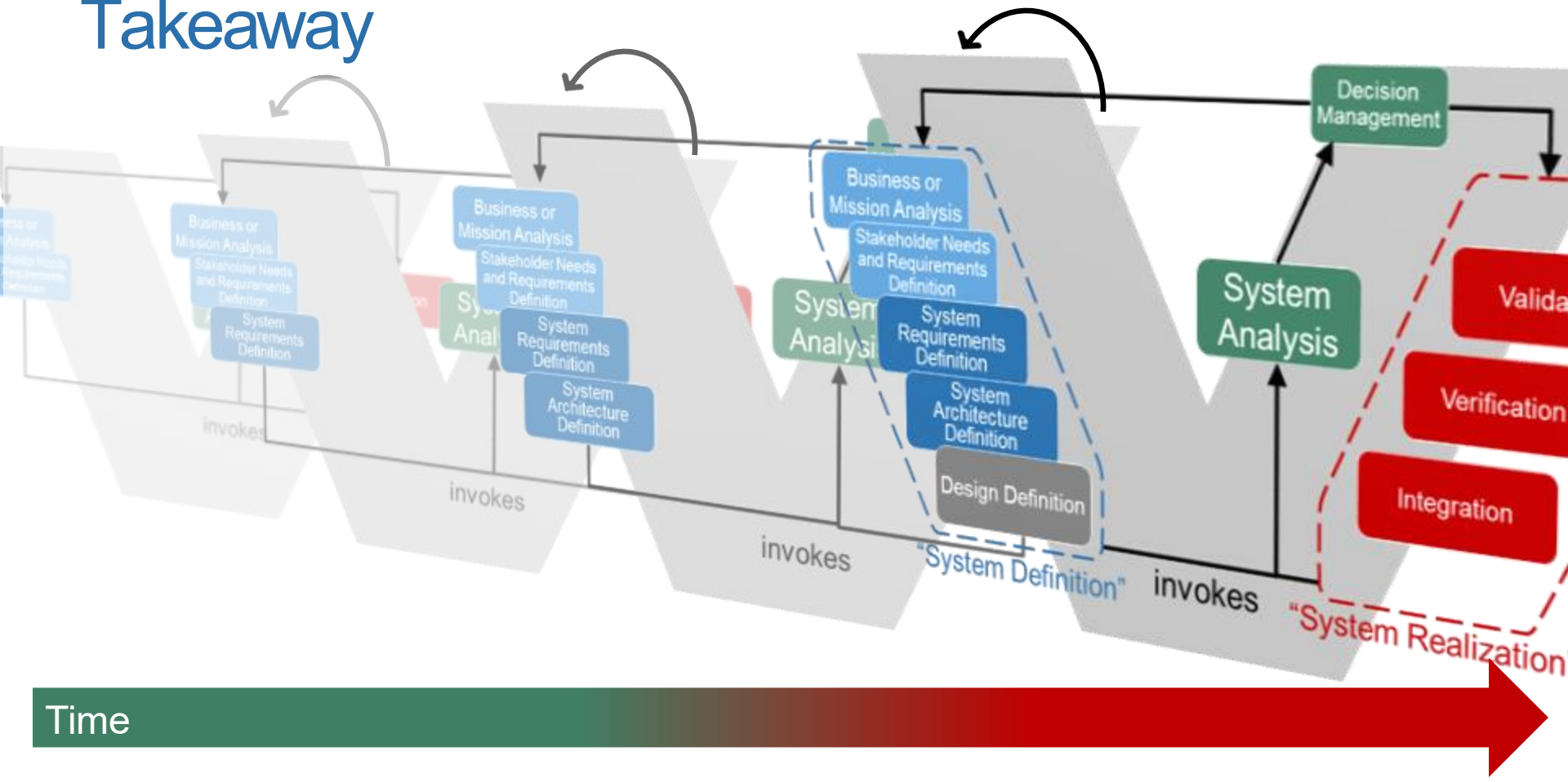
3D mCAD & eCAD, SW models, ...

MBSE & Simulation



Adapted from: Busch, Alexander, Rodney L. Dreisbach, and Frank Popielas. "What Do Simulation Engineers Need To Know About Systems Engineering And MBSE." Salzburg, Austria, 2025.

Takeaway



Thank you.

SMSWG



Alex Busch, Ph.D., CSEP
Ansys/Synopsys, SMSWG

Lead Application Engineer @ Ansys/Synopsys

alexander.busch@ansys.com

Focus Team Lead @ SMSWG

alexander.busch@incose.net

LinkedIn



Greg Garstecki, CSEP, OCSMP
Garstecki Modeling Solutions

Principal Consultant

gregmg@garsteckimodelingsolutions.com

Contributor to SMSWG & ESQMS Focus Teams

References

Busch, Alexander, Rodney L. Dreisbach, and Frank Popielas. “What Do Simulation Engineers Need To Know About Systems Engineering And MBSE.” In *Proceedings of the 20th NAFEMS World Congress (NWC) 2025*. Salzburg, Austria, 2025.
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VDI 2206. “VDI 2206:2004 - Design methodology for mechatronic system.” Verein Deutscher Ingenieure (VDI), VDI-Fachbereich Produktentwicklung und Mechatronik, 2004. <https://www.vdi.de/richtlinien/details/vdi-2206-entwicklungsmethodik-fuer-mechatronische-systeme>.



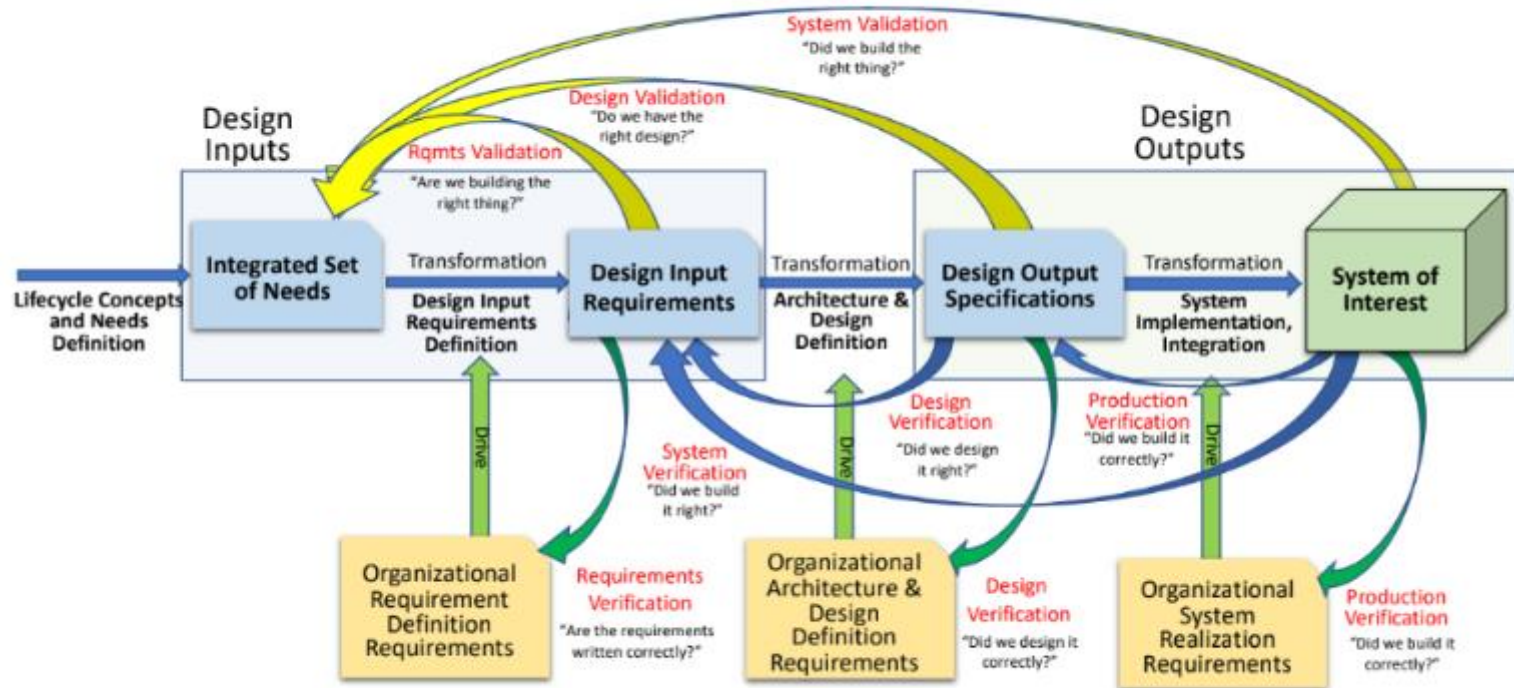
35th Annual **INCOSE**
international symposium

hybrid event

Ottawa, Canada
26 - 31 July 2025

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1.9 Needs and Requirements in the Context of Verification and Validation,

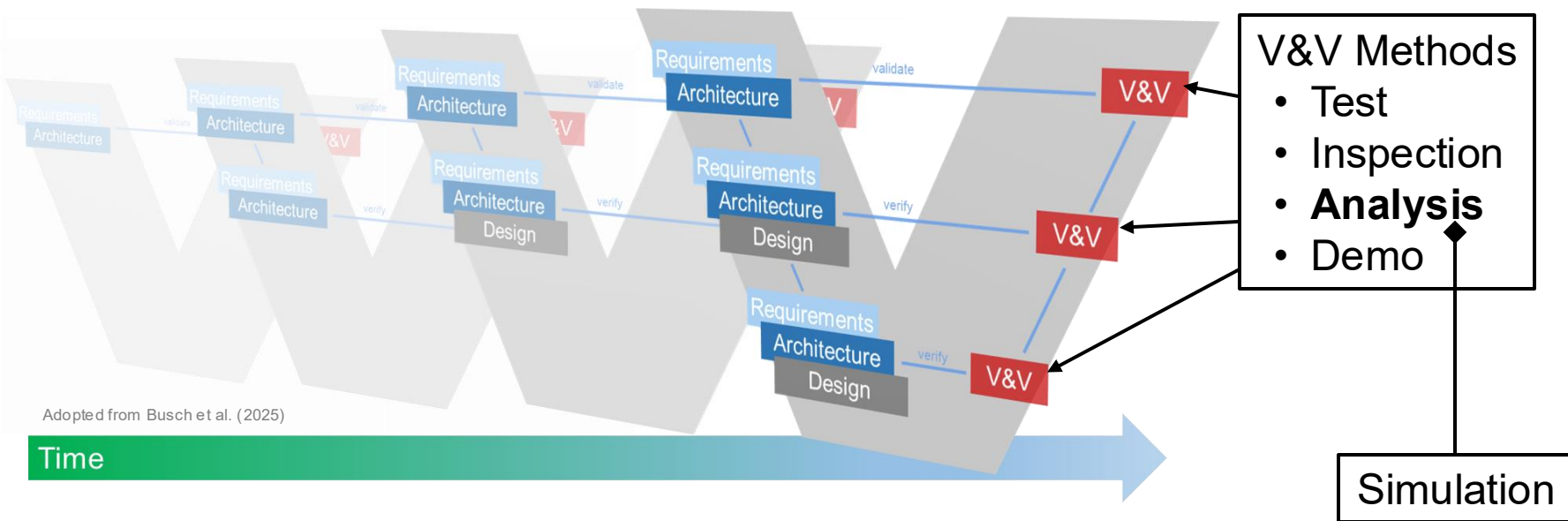


Derived from Ryan, M. J.; Wheatcraft, L.S., "On the Use of the Terms Verification and Validation", February 2017

Figure 5: Needs and Requirements in the Context of Verification and Validation

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Simulation over time



Adopted from Busch et al. (2025)

Informal V&V by
Simulation or Test
→ **System Analysis**

Formal V&V by
Simulation or Test
→ **V&V**

A SE feedback/control loop

Partly adopted from ISO/IEC/IEEE 42020:2019, ISO/IEC/IEEE 24641:2023

