Verification and Validation Interactions with the Model Life Cycle: Status of a VV50 Working Group

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VVUQ 50: VERIFICATION, VALIDATION, AND UNCERTAINTY QUANTIFICATION OF COMPUTATIONAL MODELING FOR ADVANCED MANUFACTURING

ASME VV50 Working Group: "Verification and Validation Interactions with the Model Life Cycle"

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ACROSS THE MODEL LIFE CYCLE: CREATING AN MVP / GUIDELINE / STANDARD DOCUMENT

- Other ASME publications address how to perform model VVUQ in detail, referenced but not repeated in our project.
- The focus of our work is how computational model VVUQ in particular, and computational model credibility in general, are maintained across the (sometimes long, often dynamic) model life cycle.

The series of stages through which a model passes during its effective life

Define the Model Life Cycle

Establish Model Requirements

- Stakeholder requirements
- Technical Requirements

Develop Models

- Develop Model
- Verify Model
- Validate Model

Deploy Models

- Deliver Model to End User
- Document Maintenance Procedures
- Implement
- Train users

Use & Maintain Models

- Perform Revalidation
- Monitor performance
- Perform Corrective Action

Retire Models

- Track User Dependency
- Advise of Retirement Plans
- Retire Version
- Retire Family

Leverage of Configurable Model-based Patterns, within the publication

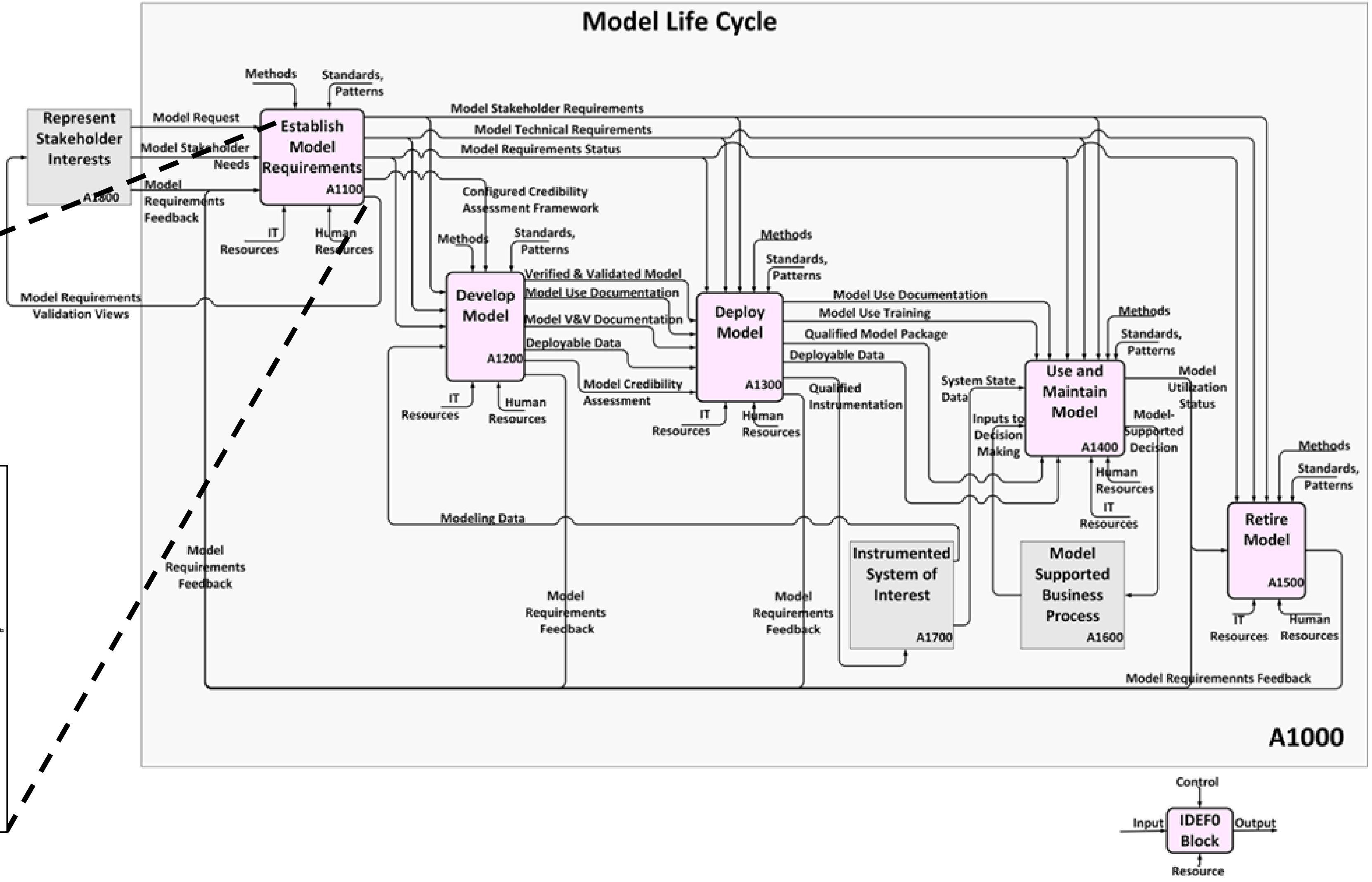
Five Kinds of "Models" in the Draft Publication

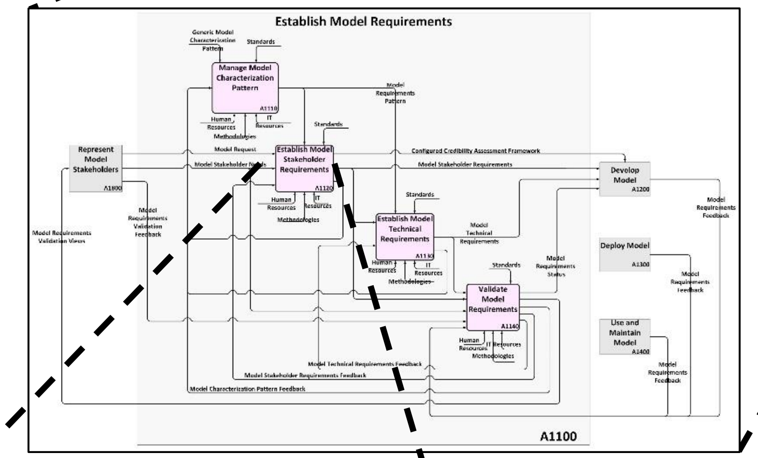
- Computational Models
- Model Life Cycle Model (IDEF)
- Model Characterization Pattern--MCP (SysML et al) (P)
- Credibility Assessment Framework (P)
- Manufacturing System Domain Pattern (P)

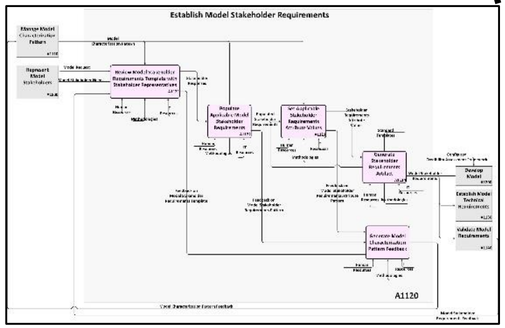
Leverage of Configurable Pattens

- The latter three models above are formal configurable patterns: structured models with fixed and variable parts.
- They can be formally configured for specific computational models and specific situations.
- The Model Characterization Pattern, when configured per stakeholder needs, generates formal requirements for a computational model, as a basis for its future V&V.
- Our guideline includes having explicit stakeholder and technical requirements for a computational model—but the MCP makes that goal easier to achieve.

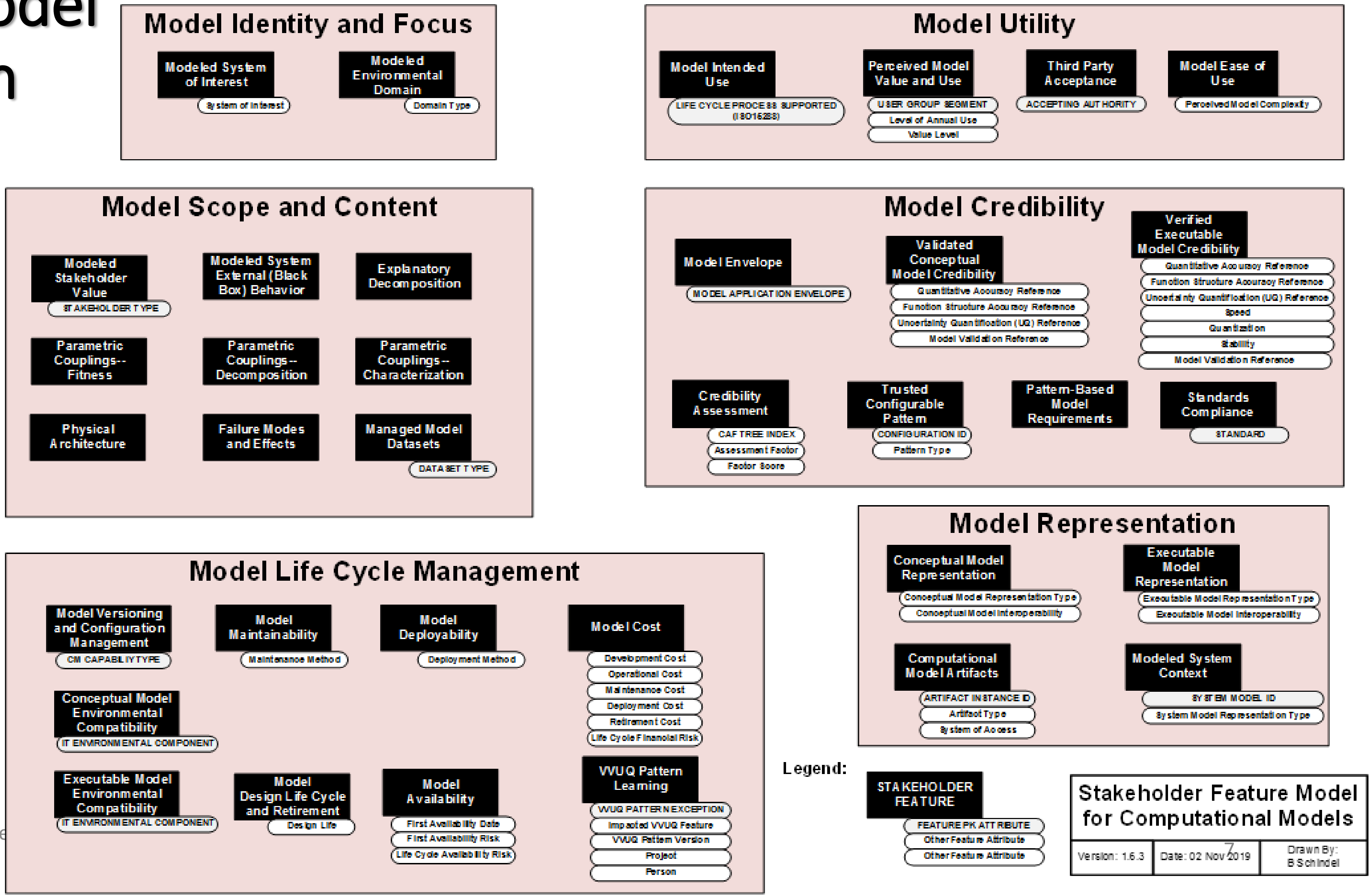
An IDEF model: The computational model life cycle





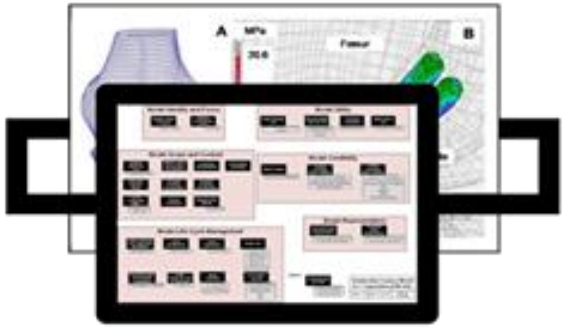


A Configurable Pattern: The Model Characterization Pattern

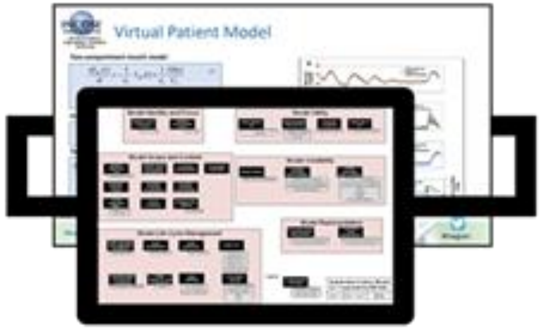


Model Characterization Pattern: Universal Metadata "Wrapper" for all Virtual Models

FEA Model

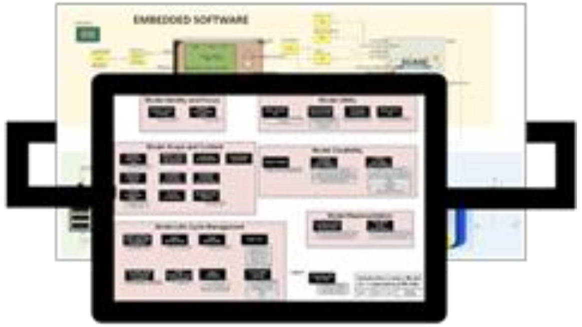


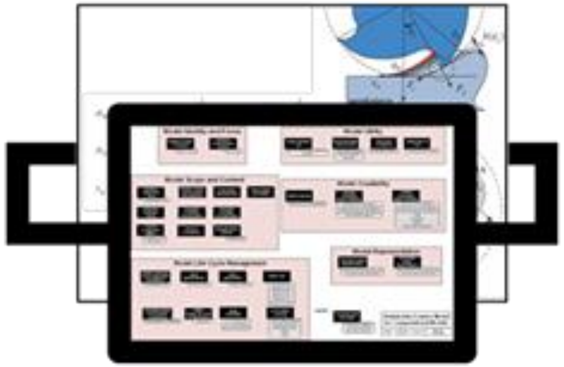
ODE Model



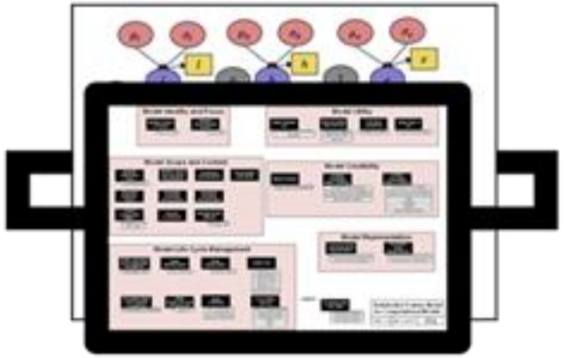
CFD Model

Multi-Domain System Model

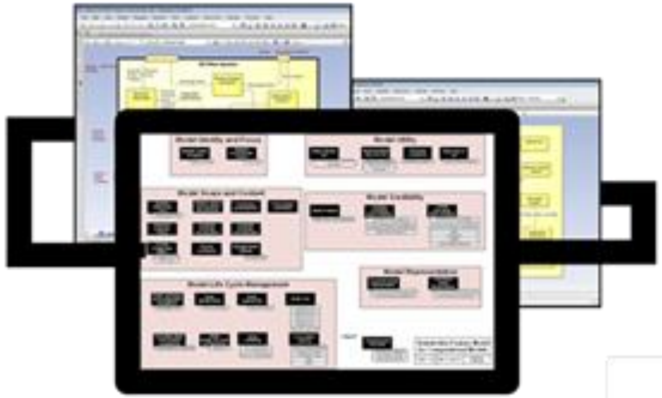




Physics-Based PDE Model



Data-Driven Bayesian Network Model



MBSE Model

BACKGROUND

Advanced Manufacturing

"…a family of activities that

(a) depend on the use and coordination of information, automation, computation, software, sensing, and networking, and/or

(b) make use of cutting-edge materials and emerging capabilities enabled by the physical and biological sciences, for example nanotechnology, chemistry, and biology.

This involves both new ways to manufacture existing products, and especially the manufacture of new products emerging from new advanced technologies."

(President's Council of Advisors on Science and Technology, 2012)

Computational Models

“The use of mathematics, statistics, physics and computer science to study the mechanism and behavior of complex systems by computer simulation.

A computational model contains numerous variables that characterize the system being studied.

Simulation is done by adjusting these variables and observing how the changes affect the outcomes predicted by the model.”

(https://www.nibib.nih.gov/science-education/glossary#g-42826)

Integrating Computational Models into Advanced Manufacturing

Control process outcomes:

e.g., for Additive Manufacturing processes (Paul, et al., 2019) or Automated Machine Positioning Controls (Rudberg, 2013)

Design manufacturing processes,:

e.g., for Additive Manufacturing processes (Gatsos, Elsayed, Zhai, & Lados, 2019)

Manage product quality:

e.g., for Predictive Model-Based Quality Inspection (Schmitt, Bonig, et al, 2020)

Predict maintenance requirements:

e.g., for Prognostics (Vogl, Weiss, & Helu, 2016)

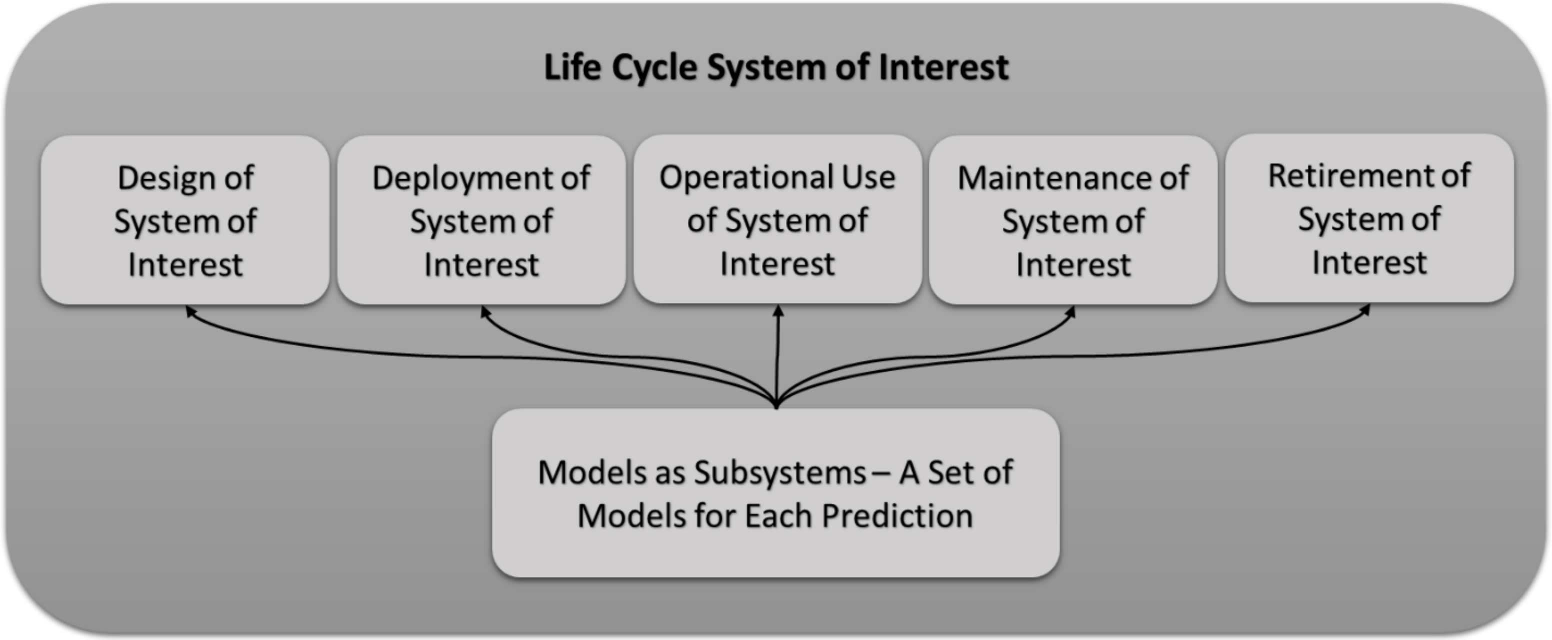
Determine resource demands,:

e.g., for Predicting Energy Consumption (Ak, Helu, & Rachuri, 2015)

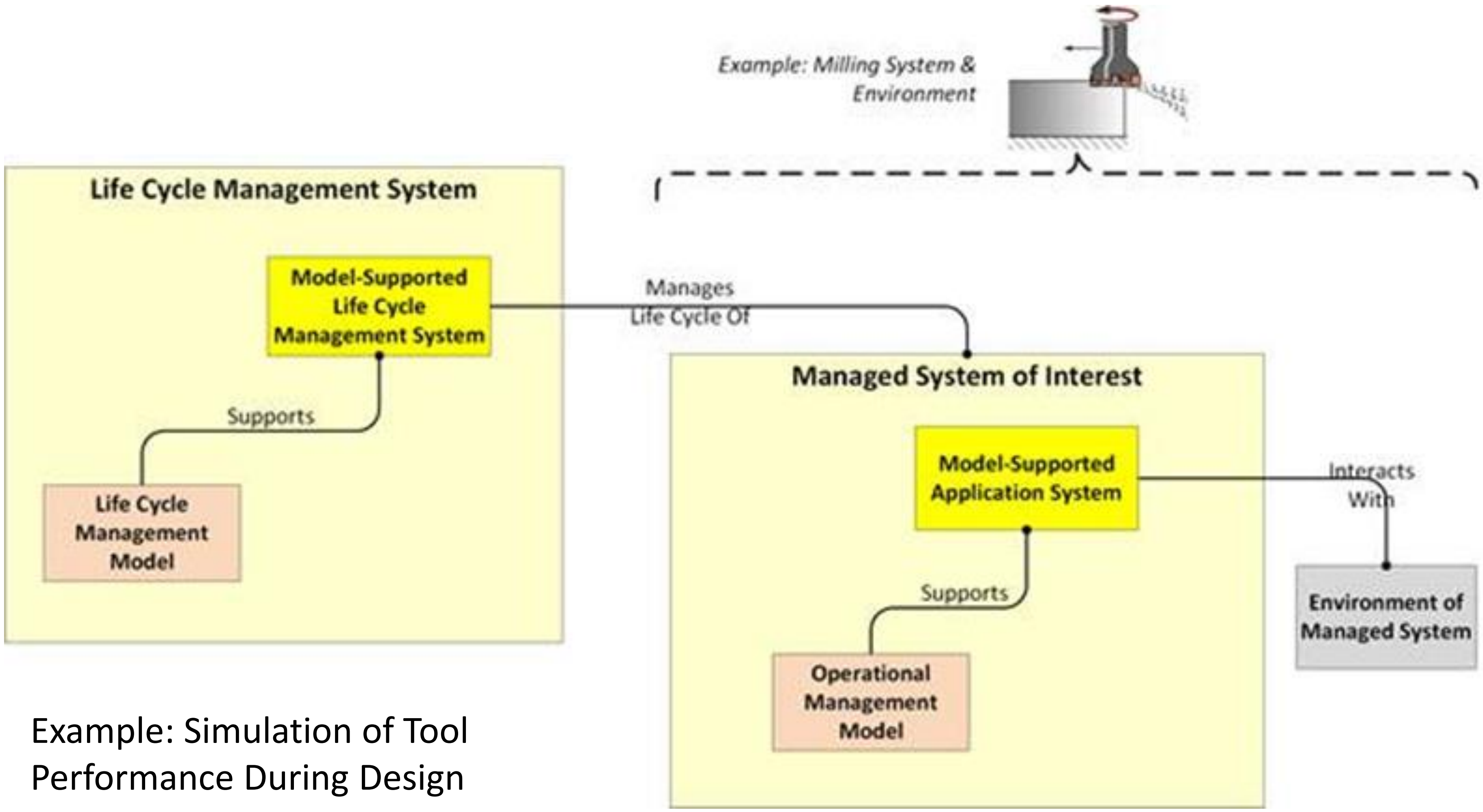
Manage capacity

(Gallego-Garcia, Reschke, & Garcia-Garcia, 2019)

Generic Relationship of Computational Models within a System of Interest



Logical System Reference Boundaries for Advanced Manufacturing System of Interest



Example: Simulation of Tool Performance During Design

Example: On-line prognostics

Decisions in Advanced Manufacturing

Predicting the requirements for process capability

Predicting product conformance to requirements

Predicting inventory requirements

Predicting maintenance requirements

All of which affect

- Cost to manufacture
- Product performance for the customer

FEATURES OF THE GUIDE

Target Audience

Strategically Integrate the Life Cycle into an Advanced Manufacturing Production System	Managers who are responsible for the strategic decision may optionally want to read Introductory material Individuals who are responsible for developing policies, processes, and other relevant documentation for a Model Life Cycle in an AMPS should read the complete document
Incorporating a Computational Model Into a System of Interest	Project Managers who are responsible for specific computational model project Individuals who are tasked with participating in the Model Life Cycle project should read material relevant to the individual role and responsibility. • Model Developer – modelers • Model Implementers - programmers • Model Users – Operators, Mechanics, Installers, Quality Inspectors • Model Maintainers – System Maintainers, Developers

Organization of each technical chapter of the publication (by life cycle stage)

Introduction	Overview of Computational Model Life Cycle Process
Narrative	A Textual description of the Life Cycle Process An IDEF0 Model for the Life Cycle Process
Life Cycle Stage Formal Model	A succinct, general, formal IDEF model of that stage of the CMLC Accompanied by a formal definition of the elements of that life cycle stage
Elaboration	Additional relevant topics that are examined in greater detail Used as needed

Key Accomplishments to Date:

- Developed the use of an S*Pattern Model Characterization Pattern (MCP) for model requirements management
- Generalized Model Development Process with an emphasis on the connections to the rest of the model life cycle
- Interactions between the Life Cycle and Model Credibility
- Drafts reviewed for Establish Model Requirements and Develop Model chapters
- First Draft of Model Deployment , in review
- First Draft of Model Use and Maintenance, ready for review

WHAT’S NEXT?

Next Steps

- Work to clarify inter-stage alignments and common terminology – In Progress
- Develop Draft for Model Retirement Activity
- Deliver Draft Document to V&V50 for review and initial balloting - June 2021

References

Applying Model-Based Patterns to Enhance Innovation Productivity Across the Computational Model Life Cycle — Bill Schindel, -- ASME V&V Symposium 2019

Challenges to Verification and Validation of Data-Driven Models used in Prognostic Health Management of Nuclear Power Plants — Dr. Laura Pullum – ASME V&V Symposium 2019

ASME V&V40 Assessing Credibility of Computational Modeling Through Verification and Validation: Application To Medical Devices

Verification and Validation in Scientific Computing — William Oberkampf & Christopher Roy

Q&A

Questions?

For future questions

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