Report on ASME Verification & Validation of Computational Modeling

ASME V V 50 Committee--V&V of Computational Modeling for Advanced Manufacturing;

Meeting Nov 7-8, 2016, Schenectady, NY

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Content

- Purpose and Scope
- Intended Audience & Interests
- Background on ASME Model V&V Activities
- Model Verification and Validation – Awareness
- The Opportunity for ASME and INCOSE
- November 7-8, 2016, V V 50 Meeting—Topics

- References
- VV50 Committee Leadership

Purpose and Scope

- This is a report on the ASME V V 50 Standards Committee on V&V of Computational Modeling in Advanced Manufacturing.
- This report is focused on the Nov 7-8, 2016 meeting of the committee, but also includes general background on the ASME Standards Committees on Verification and Validation of Computational Modeling.
- This report is the for the Intended Audiences listed on the next page, and is focused on only certain limited aspects of the above.
- See the References for more information, or contact the author.

Intended Audience & Interests

- Indiana Virtual Verification Institute (VVI) Core Team
- INCOSE MBSE Leadership, INCOSE Patterns Working Group, and INCOSE Crossroads of America (CoA) Chapter
- Enterprises applying MBSE models

Intended Audience & Interests

- Reason for interests:
  - Although the use of models is not new, it is continuing to increase in importance and frequency.
  - There is not a shared agreement, across individuals and organizations, as to the description of uncertainty, risk, or confidence in those models.
  - As potential reliance on models grows, the need for such a framework also grows—trust is essential to commerce and society.
  - This is not just true for the "computational models" of interest to the ASME standards effort, but also to the more general class of "system models" (of which the former are a part) over system life cycles, of interest to the INCOSE systems community.
  - INCOSE sees the opportunity to collaborate with ASME, in describing frameworks that are as consistent as appropriate.

Background on ASME Model V&V Activities

- ASME generates formal standards across a wide range of subjects.
- Because the use of computational modeling and simulation of physical systems (e.g., FEA models, dynamical simulations, etc.) has become widespread, ASME formed a standards committee effort related to the verification and validation of such models.

Model Verification and Validation – Awareness

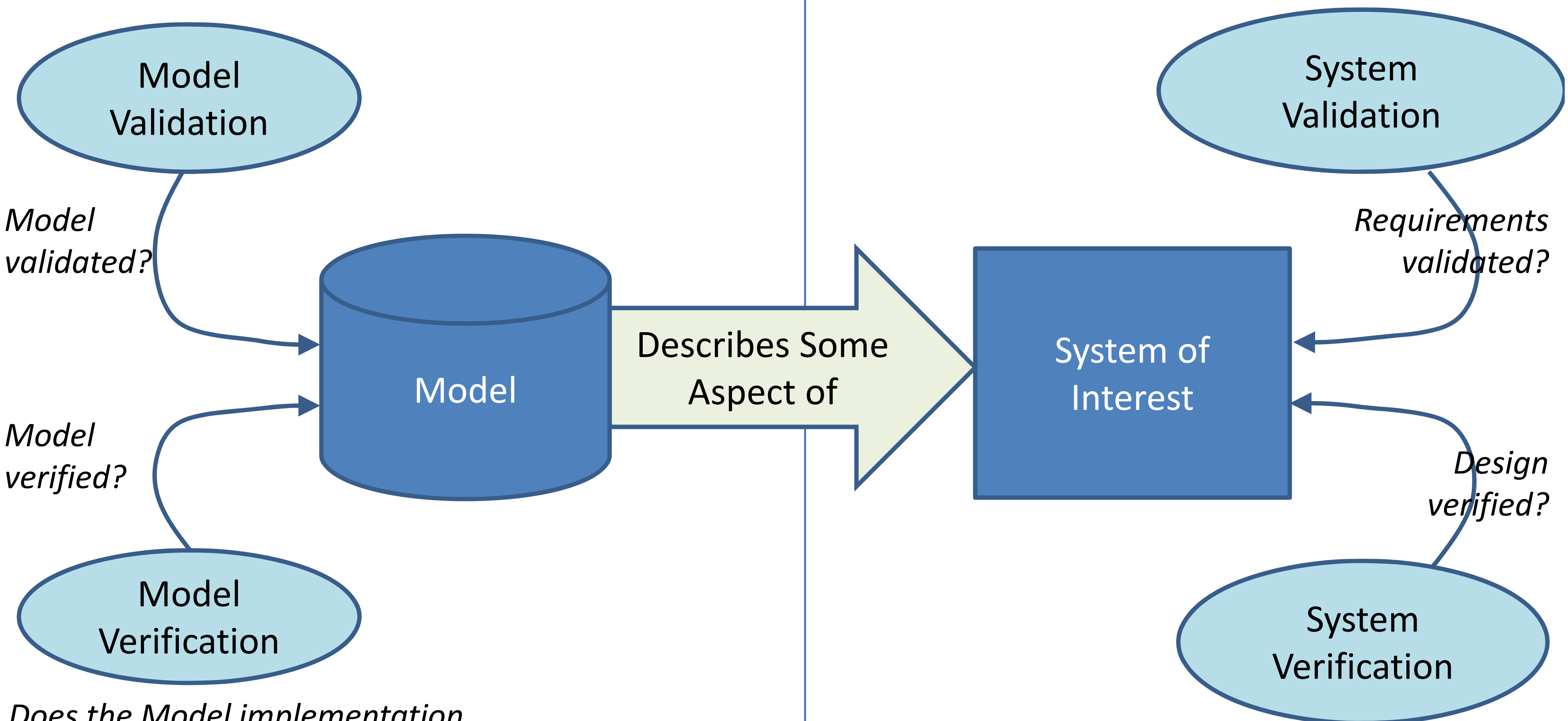
- Systems engineers and others are used to referring the "verification and validation" as related to designed systems, in this way:
  - Validation that the stated candidate requirements for a real system are appropriate in the eyes of the stakeholders in that system. (*Are we working on the right requirements?*)
  - Verification that the that a stated candidates design for a real system will result in a system meeting the stated requirements for that system. (*Are we working on the right design?*)
- However, the ASME Model VV effort is directly concerned not with the above V&V of systems, but instead with the verification and validation of computational models:
  - Although those might even be models of the same system as referenced above, the V&V of those models turns out to be a different idea than the V&V of the systems.

V&V of *Models*, Per Emerging ASME Model V&V Standards

Does the Model adequately describe what it is intended to describe?

V&V of *Systems*, Per ISO 15288 & INCOSE Handbook

Do the System Requirements describe what stakeholders need?



Does the Model implementation adequately represent what the Model says?

Does the System Design define a solution meeting the System Requirements?

Don't forget: A model (on the left) <u>may</u> be used for system verification or validation (on the right!)

Computational Models: Additional Distinguishing Aspects

- An additional distinction in currently visible models and modeling efforts is also delineated by the model V&V effort:
  - Internal "Physics-Based Models": These describe ***and explain*** external system behavior, using model content that shows how externally-visible behavior is generated by internal interactions, based on physics or other "scientific" or first principles models, of at least one level of decomposition. The emphasis is on discovery and use of the explanatory science of the decomposition.
  - External (black box) "Data Driven Models": These describe external system behavior, but solely in terms of the "black box" patterns of that behavior that can be seen externally, without regard for any "internal why" explaining the internal origin of that behavior. The emphasis is on discovery and use of the patterns of external behavior.
  - "Hybrid" Models: These combine both of the above aspects.

Data Driven Models "Black Box"

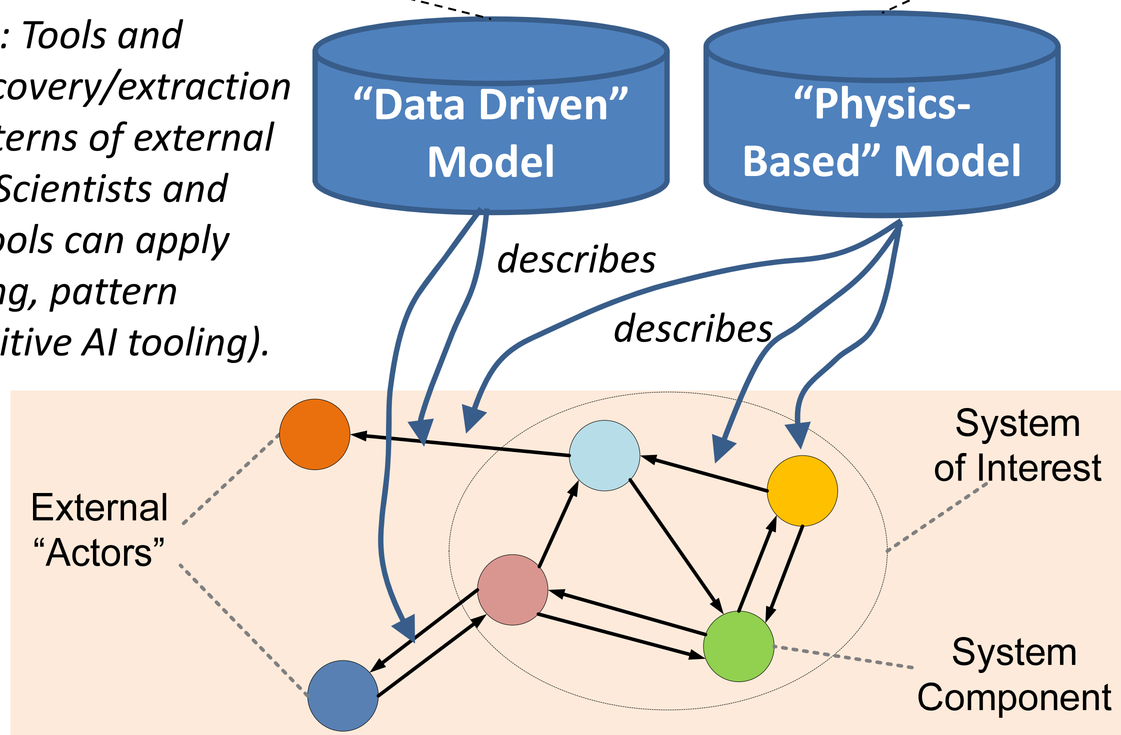
What is the behavior of the System of Interest, visible externally to the external actors with which it interacts?

<u>*Special interests*</u>*: Tools and methods for discovery/extraction of recurring patterns of external behavior. Data Scientists and their newer IT tools can apply here (data mining, pattern extraction, cognitive AI tooling).*

Physics Based "Internal Explanatory" Models

What are the internal interactions of the System of Interest, and how do they combine to cause/explain the behavior that is externally visible as interactions with external actors?

<u>*Special interests*</u>*: The hard sciences physical laws, and how they can be used to explain the externally visible behavior of the System of Interest. Physical Scientists and models from their disciplines can apply here.*



When expressed in S*Metamodel framework, the distinction and relationships of these two types of models becomes explicitly clear. It can be seen that this distinction retraces the history of the physical sciences, but with the latest tools. Remember the centuries-earlier studies of the night skies for patterns in the motion of stars and planets, followed later by the explanatory models of Newton and others.

The Opportunity for ASME and INCOSE

- INCOSE has a parent society-level initiative supporting the acceleration of the transformation of Systems Engineering to a model-based discipline:
  - The system models of interest to the INCOSE community are broader than the computational models of interest in the ASME Model V&V standardization effort—but the latter are a key subset of the former.
  - Moreover, many of the key ideas of Model V&V apply to that broader class of models, beginning with the concepts of model V&V itself, the issues of model life cycle management, concepts of data-driven and physics-based models, and others.
- Bill Schindel, co-chair of the INCOSE MBSE Patterns Working Group, joined ASME earlier in 2016, and has offered to join the Model Life Cycle Management sub-team (chaired by Joe Hightower, Boeing) of the ASME VV50 standards committee.
  - Bill has invited Joe to address the INCOSE MBSE Workshop at the International Workshop to be held in late January, 2017, in LA, concerning ASME VV 50.
  - Bill has also suggested that Joe consider joining or collaborating with the Model Management Working Group of INCOSE, which has related interests to Joe's.
- Opportunity for INCOSE and ASME to collaborate on their common interests:
  - The V and V of models (including general system models as well as computational)
  - The management of models over their life cycles
  - How the V&V of models fits into the larger system life cycle framework of ISO15288.
  - INCOSE IN Chapter supporting set up of an Indiana-based Virtual Verification Institute, including Additive Manufacturing applications.
- If the above prove to be of interest down the road, INCOSE also has a history of formalizing collaboration relationships with other organizations, use of Memoranda of Understanding, etc. – but usually after we have interested people active.

Nov. 7-8, 2016, ASME V V 50 Meeting Topical Highlights

- Hosted at GE Global Research, Schenectady, NY
- Approximately 23 attendees, plus 4 remote
- Chair: Sudarsan Rachuri, Pgm. Mgr., DOE Smart Manufacturing, Institute
- Vice-Chair: Mark Bennett, Pgm. Mgr., AFRL Manufacturing Technology Division
- ASME: Marian Heller, Steve Weinman, Dean Bartles
- Participants included: DOE, NIST, SWRI, AFRL, UL, MIT, Vanderbilt, Honeywell, GE, Boeing, Deere, ICTT
- GE's Brilliant Factory approach, use cases, challenges, review and tour of GE additive manufacturing and smart manufacturing facilities
- DOE Advanced Manufacturing Office focal issues include energy, clean energy processes, IT
- Plans for May meeting, at annual V&V Symposium

Nov. 7-8, 2016, ASME V V 50 Meeting Topical Highlights

- ASME Model V&V approach,
- data driven versus physics based models,
- standards teams and activities,
- membership types and expectations,
- sub-teams, including terminology, concepts taxonomy, model life cycle (Bill Schindel joined)
- connection to other ASME model VV committees (solid mechanics, fluid dynamics and heat transfer, nuclear, medical devices)
- manufacturing types coverage by committees,
- connection of product design models to manufacturing models,
- use cases,
- potential INCOSE-ASME collaboration,
- ASME model-based enterprise committee,
- types of ASME publications,
- levels of abstraction,
- ASME position on examples not in standards,
- ASTM library of unit operations,
- strategy for engaging software suppliers,
- PMML, CRISP-DM,
- NAS/NAE reports,
- special modeling challenges of additive manufacturing

References

- ASME Model V&V committees, draft documents
  https://cstools.asme.org/csconnect/CommitteePages.cfm?Committee=100003367

VV50 Committee Leadership

- Chair: Sudarsan Rachuri, Pgm. Mgr., DOE Smart Manufacturing, Institute

- Vice-Chair: Mark Bennett, Pgm. Mgr., AFRL Manufacturing Technology Division