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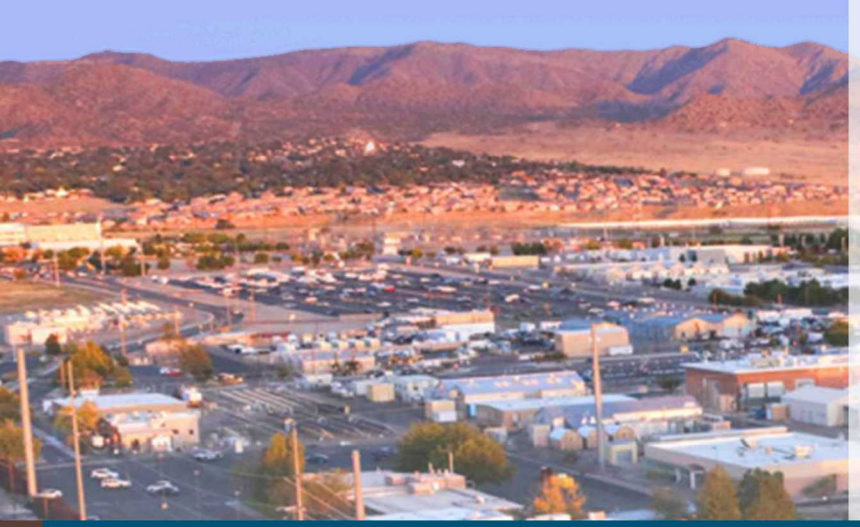

What Questions Would a Systems Engineer Ask to Assess MBSE Models as Credible?

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Introduction

CONTEXT:

- Increasing system complexity + digital engineering = steadily increasing complexity of system models (to include MBSE models)

THE PROBLEM:

- Define practical, objective, and affordable methods for evaluating the credibility of MBSE models

THE APPROACH:

- Tailor the evaluation methods from the VVUQ body of knowledge by applying the experience of a broad range of MBSE SMEs

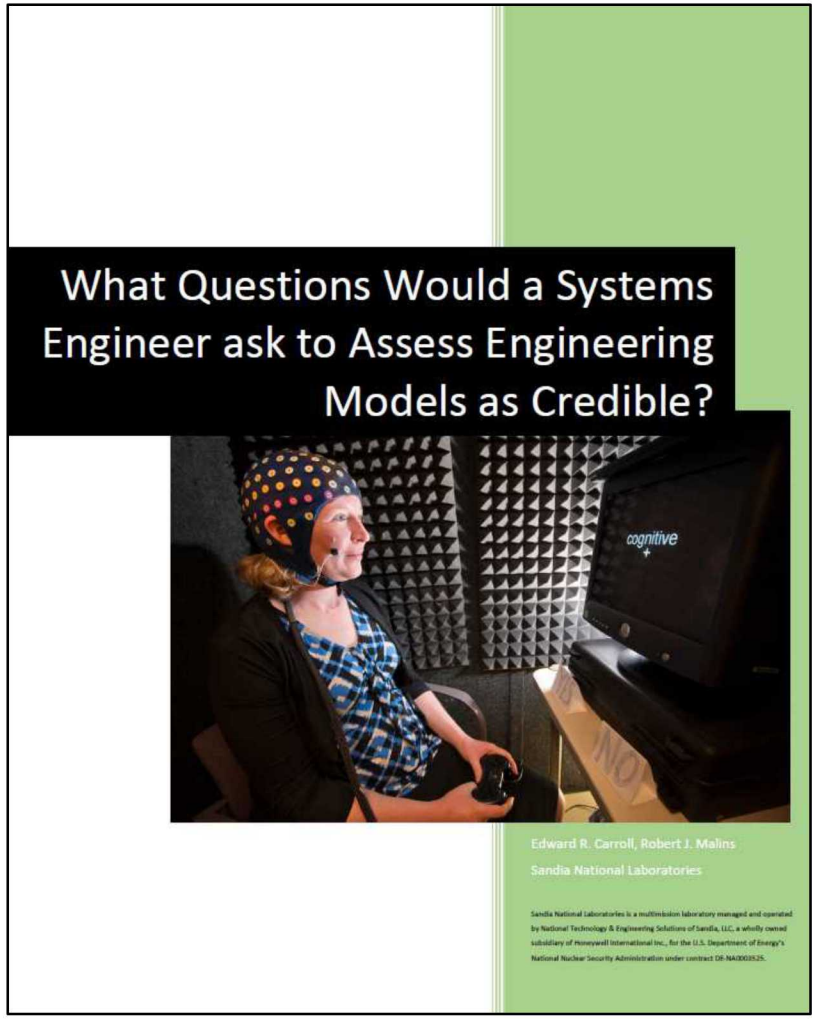
OUTCOME:

- Defined six overarching criteria for MBSE model credibility and expanded each criterion into a series of measures that can be objectively evaluated

TODAY'S GOAL:

- Make contact with practitioners who are interested in reviewing the details, providing feedback, and collaborating on the path forward

Please Take One of the Handouts



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Overview: MBSE Model Credibility Criteria

Credibility Criteria	Description
Compliance (with MBSE good practices and domain standard ontology)	The model properly and fully conforms to MBSE good practices and established guidelines; there are no errors and/or omissions relative to MBSE guidelines; the model properly employs the standard ontology for the domain of interest.
Accuracy (ability to accurately and effectively fulfill the intended use of the model)	The model can answer the questions that are put to it, given that these questions were defined up front; the model is structured to answer the questions and contains sufficient information to produce the answers.
Correctness (how well the model describes the real-world system)	The model properly and fully represents the real-world system of interest, including system composition, system behaviors, and system employment characteristics; the model can be used in lieu of the real system to answer questions of interest.
Completeness (maturity of the model in the context of the program developing the model)	The model's maturity is appropriate for the current system lifecycle stage; the model's contents will accomplish the intended use of the model and the intended use of the system being modeled.
Testability (ability of the model to participate in testing the design)	The model can serve as a key element of design for testability and test first/test exploration; the model provides behavior representations that are executable and provides useful guidance to test first/test exploration of design options
Reusability (reuse of previous models in the current model + ability to reuse current model's elements)	Model development employed model elements reused from previous models; the model provides elements to a library for reuse; the model displays the patterns appropriate to the domain of the system.

Evaluating MBSE Credibility Criteria

Each criterion has been decomposed into detailed measures related to objective characteristics of an MBSE model

Credibility Criteria	Description
Compliance (with MBSE good practices and domain standard ontology)	The model properly and fully conforms to MBSE goo guidelines; there are no errors and/or omissions rela properly employs the standard ontology for the dom
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Reusability (reuse of previous models in the current model + ability to reuse current model's elements)	Model development employed model elements reus provides elements to a library for reuse; the model c the domain of the system.

Outcomes: MBSE Credibility Measures (1 of 12)

- Criterion: Compliance (with MBSE good practices and domain standard ontology)
- Measures (Part 1 of 2)
  - "Is the model correctly based on the chosen domain standard ontology?
    - Are all elements of the model represented as entities that are part of the ontology?
    - Are the minimum number of ontology elements represented in the model?
    - Are all triples/relationships in the model part of the ontology?
    - Does the model contain specified requirement-function patterns?"
  - "Does the model structure follow a standard or MBSE guideline?

3	the measure is clearly manifest in the model (the model executed the required process well)
2	the measure is partially manifest in the model (some req'd processes are missing or executed poorly)
1	the measure is not clearly manifest in the model (many req'd processes are missing or executed poorly)
0	the measure appears to be absent from the model
N/A	the measure addresses topics that were not part of the project and are inappropriate for the model

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pecified style guide (e.g., for layout)?

ions they support?"

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While the measures require engineering judgement to evaluate, they should lead to more consistent and more reproducible evaluations.

Automating MBSE Model Evaluation

Some Criteria/Measures are readily automated

- Compliance: Do the MBSE elements follow the program specified style guide (e.g., for naming)?
- Compliance: Does the model provide traceability from architectural options to the requirements?
- Correctness: Are all system functions traceable to a validated requirement?

Some Criteria/Measures could be automated for a specified MBSE ontology

- Compliance: Are all triples/relationships in the model part of the domain ontology?
- Completeness: Are there omitted objects? (requires domain specific MBSE guidelines)
- Completeness: Are there omitted relationships? (requires domain specific MBSE guidelines)

Some Criteria/Measures could be tracked via attributes within the MBSE model

- Accuracy: Are Key Performance Indicators included and mapped to relevant system elements?
- Testability: Have all design experiment outcomes been used to evaluate the model's simulated behavior?

Many MBSE tools already have evaluations similar to these built into the tool; additional evaluations could be programmed via the tool's API

Outcomes: MBSE Credibility Measures (1 of 12)

Criterion: Compliance (with MBSE good practices and domain standard ontology)

Measures (Part 1 of 2)

- Is the model correctly based on the chosen domain standard ontology?
  - Are all elements of the model represented as entities that are part of the ontology?
  - Are the minimum number of ontology elements represented in the model?
  - Are all triples/relationships in the model part of the ontology?
  - Does the model contain specified requirement-function patterns?
- Does the model structure follow a standard or MBSE guideline?
  - Is the model intelligible?
  - Can the model be navigated and understood without external help?
  - Does the model enable understanding of the overall design?
  - Does the model minimize its internal complexity?
  - Does the model set the stage to minimize design complexity?
- Do the model artifacts follow MBSE good practice guidelines?
  - Do the MBSE elements follow the program specified style guide (e.g., for naming)?
  - Do the MBSE artifacts (e.g., diagrams, dependency matrices) follow the program specified style guide (e.g., for layout)?
  - Are the MBSE artifacts mapped to the proper program milestones?
  - Are all fit-for-purpose MBSE artifacts fully explained and mapped to the user decisions they support?

Outcomes: MBSE Credibility Measures (2 of 12)

Criterion: Compliance (with MBSE good practices and domain standard ontology)

Measures (Part 2 of 2)

- Does the model comply with OWL 2.0 standards?
- Does the model enable the full range of analyses for MBSE good practice guideline?
  - Does the model/model artifacts support identification of single point failures?
  - Does the model/model artifacts support the design analysis for surety strategy implementation?
- Have elements that do not trace to a req't been justified and accepted by the customer?
- Does the model provide traceability from the architectural options to the requirements and can the model show that the options satisfy user needs?
- Are there modeling tool error messages that have not yet been resolved?
- Have appropriate levels of configuration management and access control been applied?
- Does the model incorporate good design practices (e.g., include parameters addressing design for manufacturability)

Outcomes: MBSE Credibility Measures (3 of 12)

Criterion: Accuracy (ability to accurately & effectively fulfill the model's intended use)

Measures (Part 1 of 2)

- **Is this model the right model for the intended use?**
  - Have the model users been identified, and their needs incorporated into the model design?
  - Have the stakeholders in the model and the system been identified and their needs incorporated into appropriate model elements?
  - Has the scope of the architecture been determined to meet the needs of the stakeholders?
  - Can the model show that the scope satisfies stakeholder needs?
  - Does model meet the needs of the user of the model?
  - Does model meet the needs of the user of the system?
  - Have stakeholders signed off on how the MBSE model interprets their needs?
- **Have the critical data elements and metadata for this architecture been identified and incorporated into appropriate model elements?**
  - Are the Key Performance Indicators included in the model and mapped to the relevant system elements
  - Are the Critical Success Factors for the system application included in the model and mapped to the relevant system elements?
  - Have the critical constraints on the system design space been incorporated into the model?
  - [NOTE: there may be other critical data elements and domain specific critical data elements]

Outcomes: MBSE Credibility Measures (4 of 12)

Criterion: Accuracy (ability to accurately & effectively fulfill the model's intended use)

Measures (Part 2 of 2)

- **Have the critical data elements for the model been collected through a verified and validated process?**
- **Can the model / has the model answered the stakeholder questions? Have the stakeholders signed off on this?**
- **Can the model distinguish between the current design and any past designs of the same system? (e.g., identify details that did not exist in previous designs)**

Outcomes: MBSE Credibility Measures (5 of 12)

Criterion: Correctness (how well the model describes the real world system)

Measures (Part 1 of 2)

- **Has the model development process correctly followed systems engineering standards (e.g., ISO 15288)?**
- **Has the model been developed by staff with appropriate training in model development, systems engineering, and the real-world system?**
- **Have the model elements been derived from valid sources using a validated process? (e.g., use cases from CONOPS, architecture from use cases, functions that are achievable)**
- **Are all system functions traceable to a validated requirement or else properly justified and evaluated -- and disabled if needed -- for inclusion into the design?**
- **Have functional simulations been executed and documented?**
- **Have all errors during functional simulation been resolved?**
- **Have procedures been employed to ensure all functional paths have been tested through simulation?**

Outcomes: MBSE Credibility Measures (6 of 12)

Criterion: Correctness (how well the model describes the real-world system)

Measures (Part 2 of 2)

- **Do the functional simulations demonstrate the appropriate behavior for the model?**
- **Have all behavior deficiencies been reviewed with SMEs and resolved?**
- **Can the MBSE model be traced to detailed design models (e.g., CAD, ECAD)?**
- **Can all elements of the detailed design model trace to the MBSE model?**
- **Does the model provide evidence showing that the design employs good design practices (e.g., for manufacturability)**

Outcomes: MBSE Credibility Measures (7 of 12)

Criterion: Completeness (maturity of the model relative to the context of the maturity of the program)

Measures (Part 1 of 2)

- Are there omitted objects? (e.g., are there missing req'ts? are there missing use cases?)
- Are there omitted relationships? (e.g., are there req'ts without functions? have all functions been allocated to components?)
- Are there omitted system artifacts? (e.g., have all functions been addressed via behavior diagrams? have all states been included in state diagrams?)
- Does the model include action plans to gather the information and build any omitted objects, relationships, or artifacts?
- Have all the necessary attributes of objects and relationships been filled in?
- [for early program stages] Does the model have the appropriate elements and maturity for the current point in the system lifecycle?
- [for early program stages] Does the model include mitigation plans to address any missing or not yet validated requirements?

Outcomes: MBSE Credibility Measures (8 of 12)

Criterion: Completeness (maturity of the model relative to the context of the maturity of the program)

Measures (Part 2 of 2)

- **[for early program stages] Does the model include mitigation plans to address any missing specifications (TBDs or VOIDs)?**
- **Have all the appropriate (for the current program stage) model elements been brought under configuration management, reviewed, and used to create a design baseline?**
- **Do all system requirements have verification requirements included in the model? Are these validation requirements linked to test or other validation plans, events, and outcomes?**
- **Have surety analyses been completed and mitigation strategies established for all surety faults? Have associated req'ts been incorporated into the model?**
- **Does the model define HW & SW to sufficient detail to enable technical management of subcontractors providing the HW/SW?**
- **Are any requirements partially satisfied or not satisfied by the design? Have all model details been reviewed for maturity/TRL?**

Outcomes: MBSE Credibility Measures (9 of 12)

Criterion: Testability (ability of the model to participate in testing the design)

Measures (Part 1 of 2)

- Are there sources of truth that can be used to evaluate the appropriateness of the behaviors displayed by the model?
- Are the model simulation results reproducible? Do the simulation results display the system intent?
- Has the model been part of experiments and reviews that have evaluated the TRL & MRL of components, assemblies, subsystems?
- Has the model's behavior simulation been used as part of a design experiment?
- Have all design experiment outcomes been used to evaluate the model's simulated behavior?
- Have mitigation plans been developed for all test-behavior mismatches? Are these mitigation plans tracked within the model?
- Have tests been identified to measure how well requirements and constraints are satisfied?
- Have the model data elements been used to drive an external simulation of the system?

Outcomes: MBSE Credibility Measures (10 of 12)

Criterion: Testability (ability of the model to participate in testing the design)

Measures (Part 2 of 2)

- **Have all external simulation outcomes been used to evaluate the model's simulated behavior?**
- **Have mitigation plans been developed for all simulation-behavior mismatches? Are these mitigation plans tracked within the model?**
- **Do the model simulations clearly demonstrate the intended impact of the constraints defined in the model.**

Outcomes: MBSE Credibility Measures (11 of 12)

Criterion: Model Reusability (ability of the model to reuse elements from a model library and to provide elements into such a library)

Measures (Part 1 of 2)

- **Has the domain of the system been clearly defined from the perspective of identifying existing models that represent the domain?**
- **Have previous models representing this domain been identified and obtained for reuse?**
- **Have design and/or model patterns been identified to characterize the models representing this domain?**
- **Has a library or compendium of model (design) elements been established from which reusable model elements can be derived?**
- **Does the model reuse elements from other models in the system's domain?**
- **Does the model reproduce the patterns that are displayed by models in the system's domain?**

Outcomes: MBSE Credibility Measures (12 of 12)

Criterion: Model Reusability (ability of the model to reuse elements from a model library and to provide elements into such a library)

Measures (Part 2 of 2)

- **Does the model include elements that are not present in the domain compendium and that could be reused in future system developments in this domain?**
- **Does the model manifest patterns that have not been observed in this domain and that could be the basis for future system developments in this domain**

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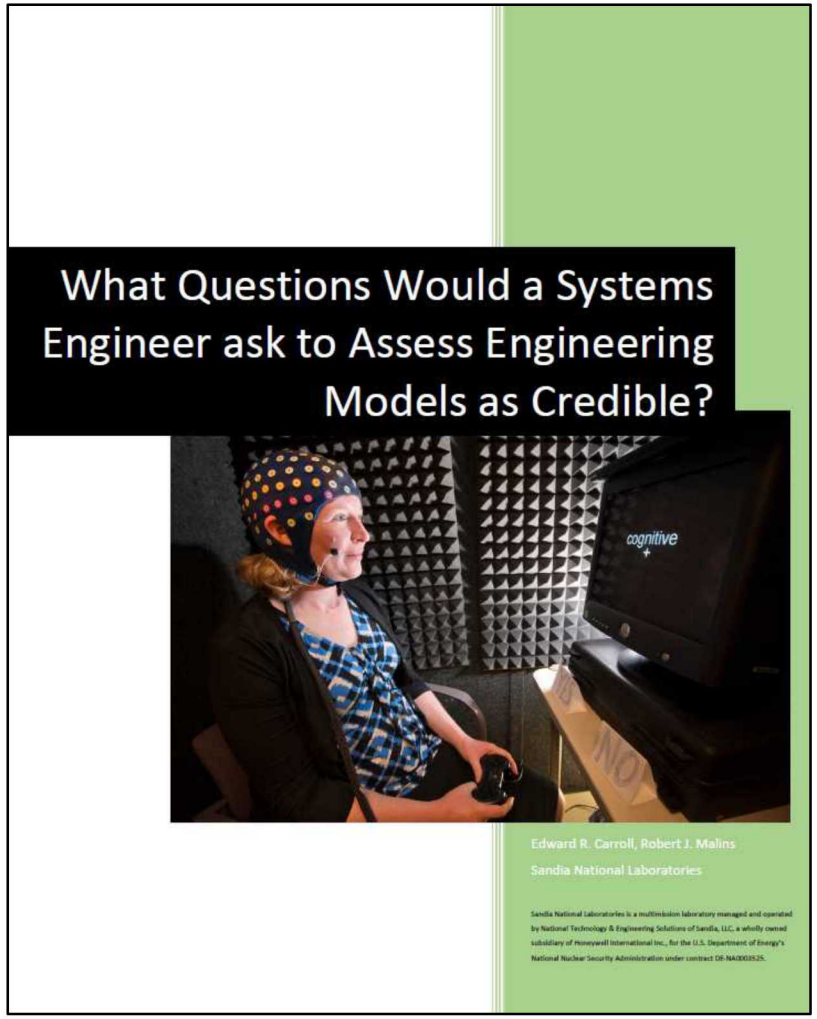

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