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DATAWorks 2023: Model Verification in a Digital Engineering Environment: An Operational Test Perspective

Jo Anna Capp, Project Leader

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DATAWorks 2023: Model Verification in a Digital Engineering Environment: An Operational Test Perspective

Jo Anna Capp, Project Leader

Executive Summary

Digital engineering uses digital artifacts, models, and data to build a complete information model of a complex system. The information model is a digital representation of the physical system. It includes data about its future function, design, manufacturing process, configuration, and performance.

Modeling and simulation of the system performance is a key part of the digital engineering system. It may allow for reduced live testing throughout the lifecycle of the weapon system, but only if the performance model is verified, validated, and accredited for operational use.

This product provides a framework for model verification from an operational test perspective. The framework will:

- Highlight the importance of conducting model verification with the operational use in mind.
- Describe how the model's operational space should be defined during verification.
- Demonstrate how using space-filling designs during model verification allows the tester to understand the contours of the model operational space.
- Describe how understanding the model's operational space during verification can allow for more efficient resource allocation during model validation.

DATAWorks 2023: Model Verification in a Digital Engineering Environment: An Operational Test Perspective

Dr. Jo Anna Capp, Project Leader

April 25, 2023

Institute for Defense Analyses
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Digital engineering is the construction of digital models representing every characteristic of a complex system under development

- Design using digital architectural and system models
- Integrate data across models
- Support models through system production and sustainment

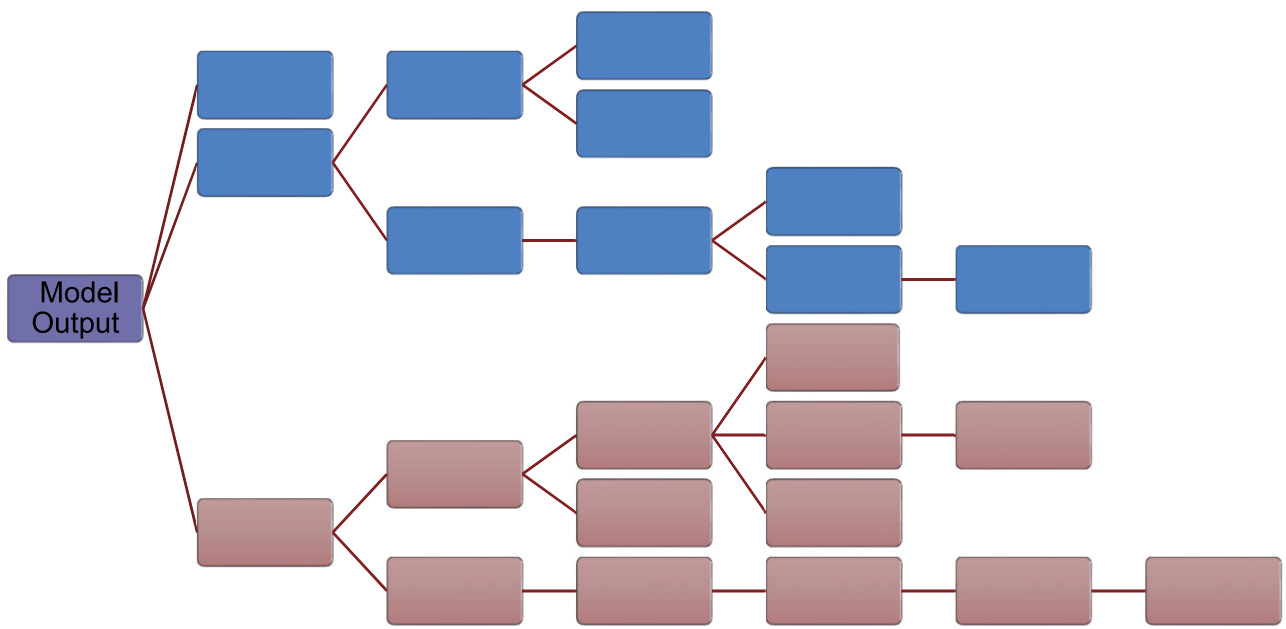
Digital engineering and advanced computational resources make it possible to model the end-to-end operation of weapon systems

Model verification and validation activities for digital engineering models should:

- be scoped to the end-to-end mission and availability of real-world data
- inform the model validation plan
- accurately characterize model knowns, unknowns, and errors

Federated model VV&A must combine data from multiple sources

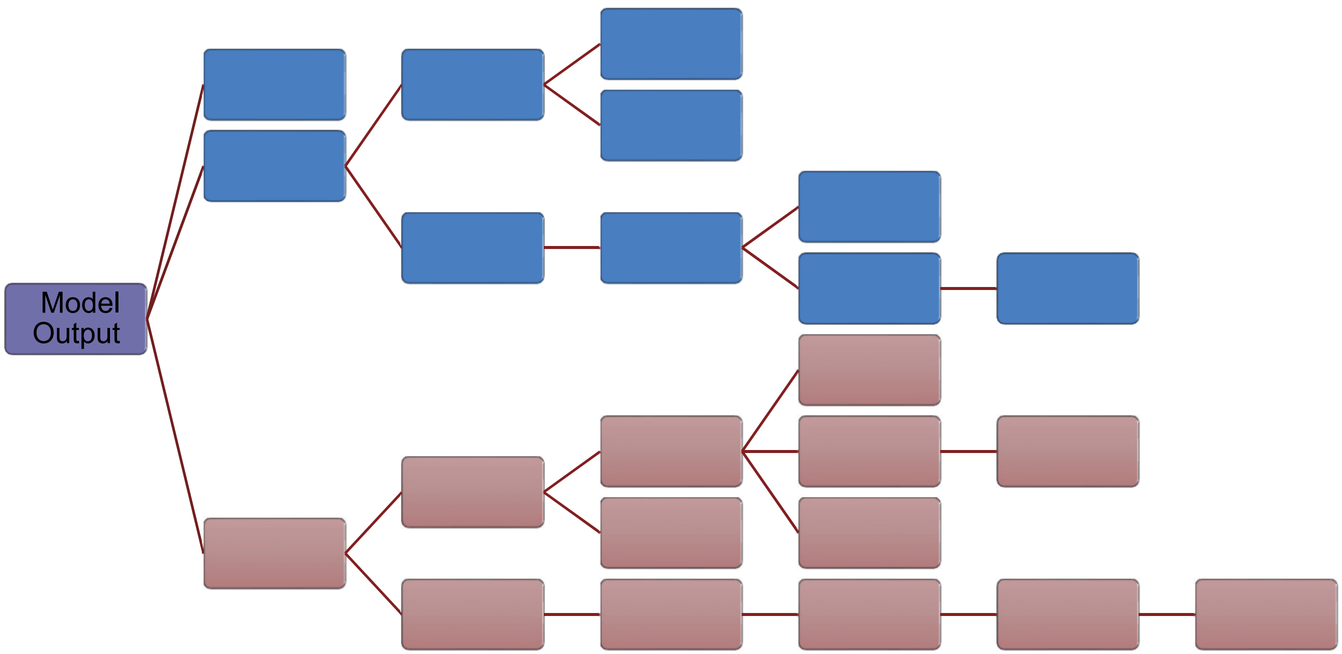
- Live test data
- Intel analysis
- Surrogate testing
- Engineering emulators
- HWIL/SWIL simulators
- SME judgement



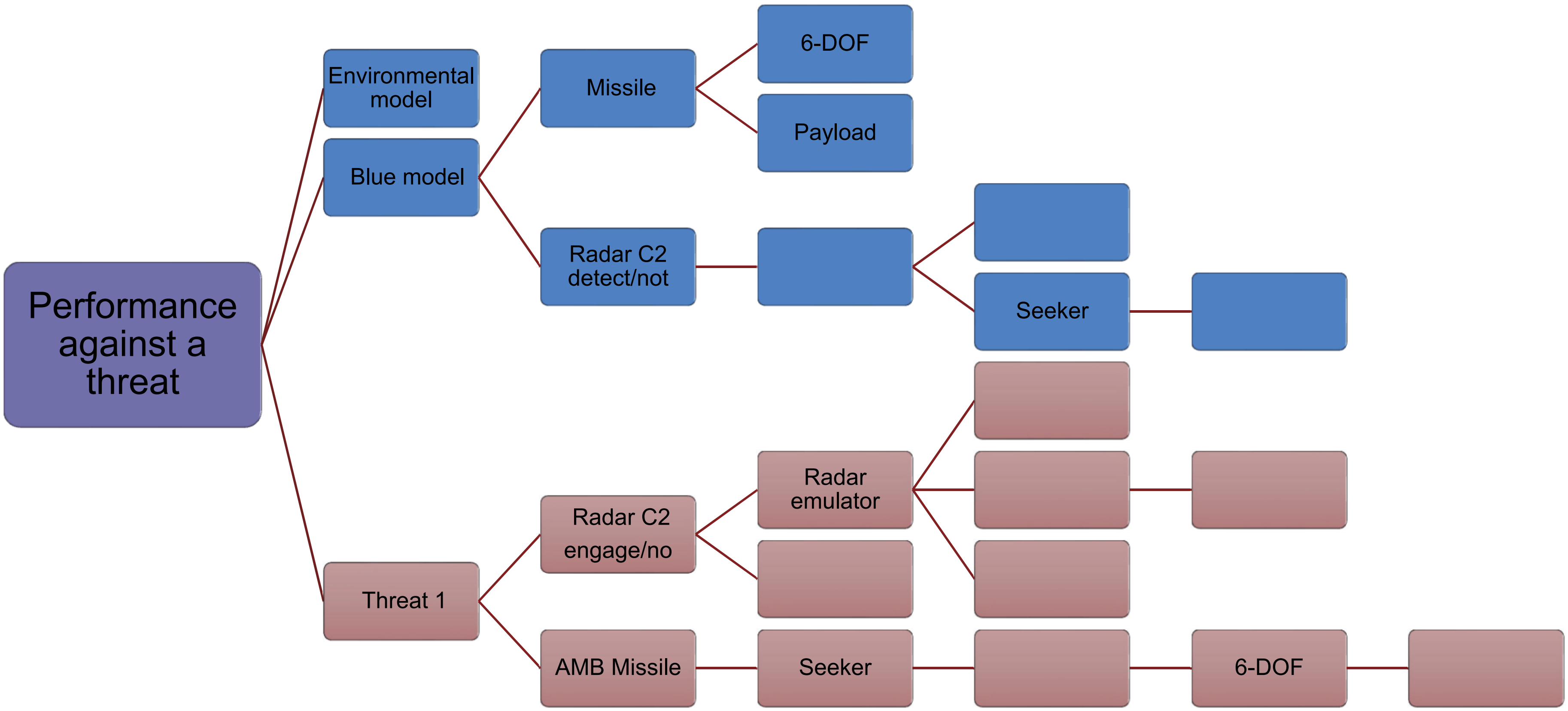
Acronyms: HWIL/SWIL – hardware in the loop / software in the loop; SME – subject matter expert; VV&A – verification, validation, and accreditation

How should we focus test and modelling resources for complex models?

- Which parts of the model matter for the operational assessment?
- Does every sub-model require the same level of validation?
- How do we define accreditation criteria when collecting end-to-end validation data is not feasible?

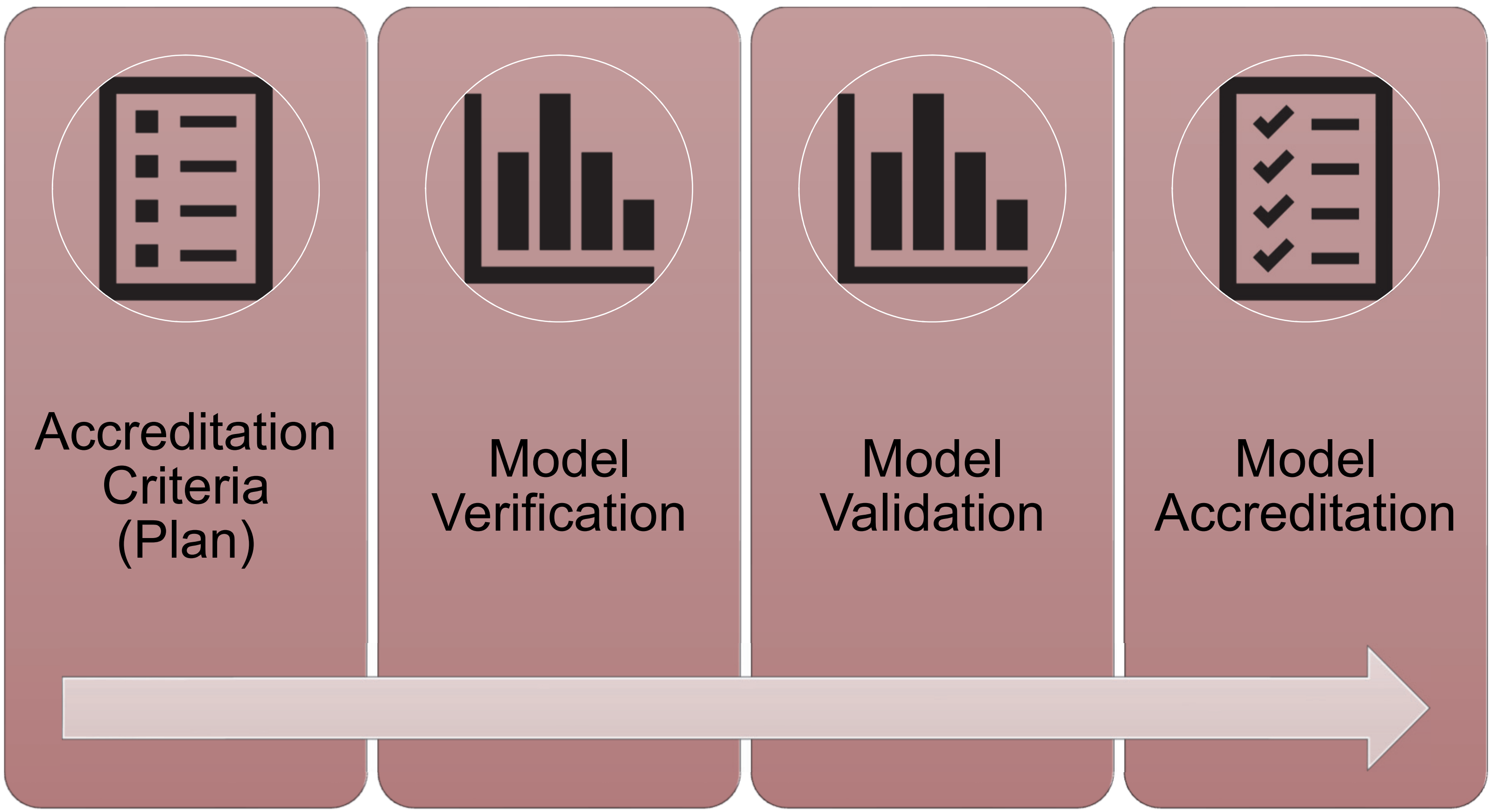


How do we accredit models in data-constrained environments?



Acronyms: AMB – anti-ballistic missile; C2 – command and control; 6-DOF – 6 Degree of Freedom flight simulation; EO/IR – electro-optical/infrared

The traditional VV&A processes should be applied to complex models



Acronyms: VV&A – verification, validation, and accreditation

V&V definitions may change depending on the user

- Verification: the process of determining a model implementation accurately represents the conceptual description of the model
  - Operational Verification: the process of determining model variance in reference to the intended operational use-space
- Validation: confirming that the model achieves its intended purpose
  - Statistical Validation: the process by which model outputs are systematically and rigorously compared to real-world data

Acronyms: V&V – verification and validation

Characterizing model space is a key verification process to allocate validation resources

Accreditation Plan

- What is the model?
- **How will the model be used?**
- **What is the operational space?**
- When is the model good enough?

Model Verification

- Correct implementation
  - Concept
  - De-bugged
  - Reasonable
- **Characterize model space**
- Sensitivity Analysis

Model Validation

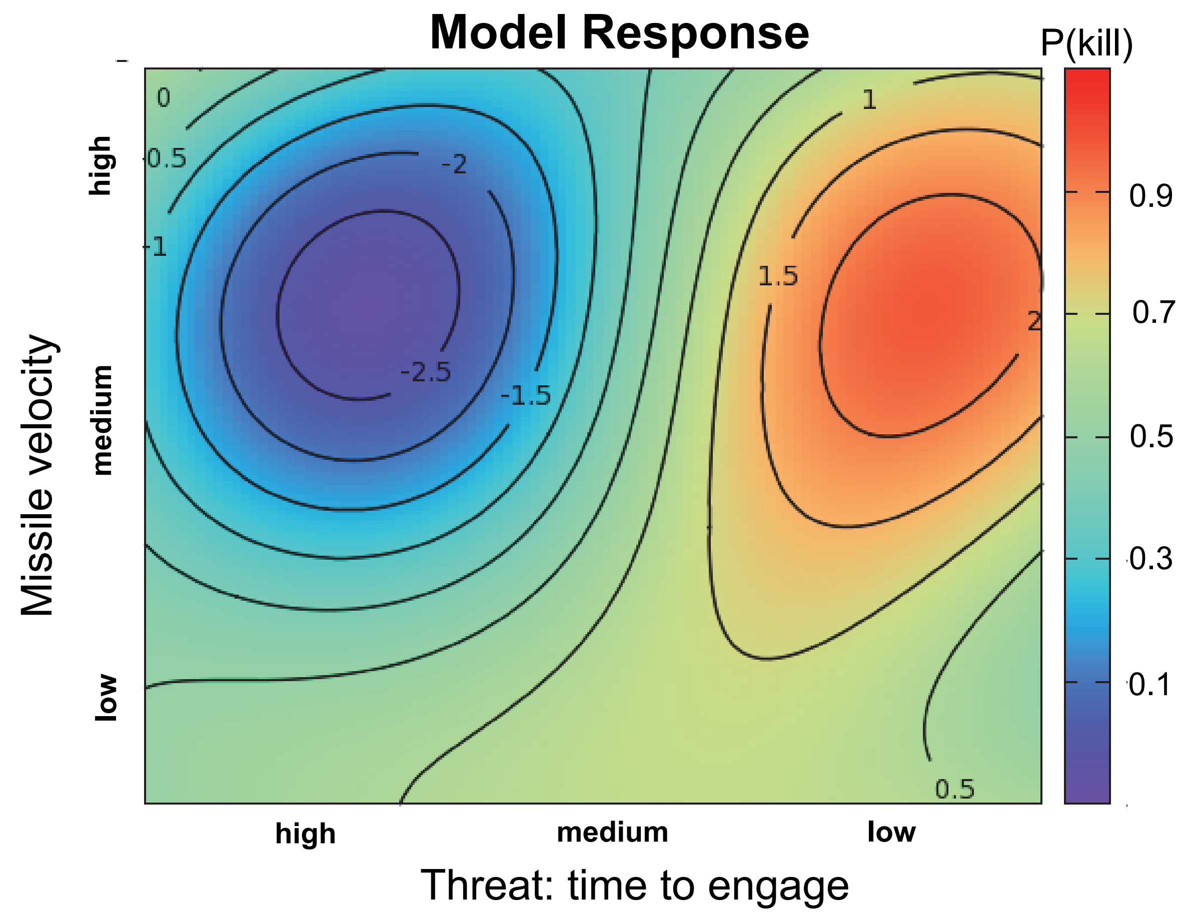
- Structural validation
- **Validation with live data (input -> output)**
- **SME (face) validation**

Model Accreditation

- Is the model good enough for the intended use?
- Is there a support plan in place for model updates over system lifecycle?

Acronyms: SME – subject matter expert

Verification should characterize the model response across operational space



Note: P(kill) is the probability that the missile will disable the target

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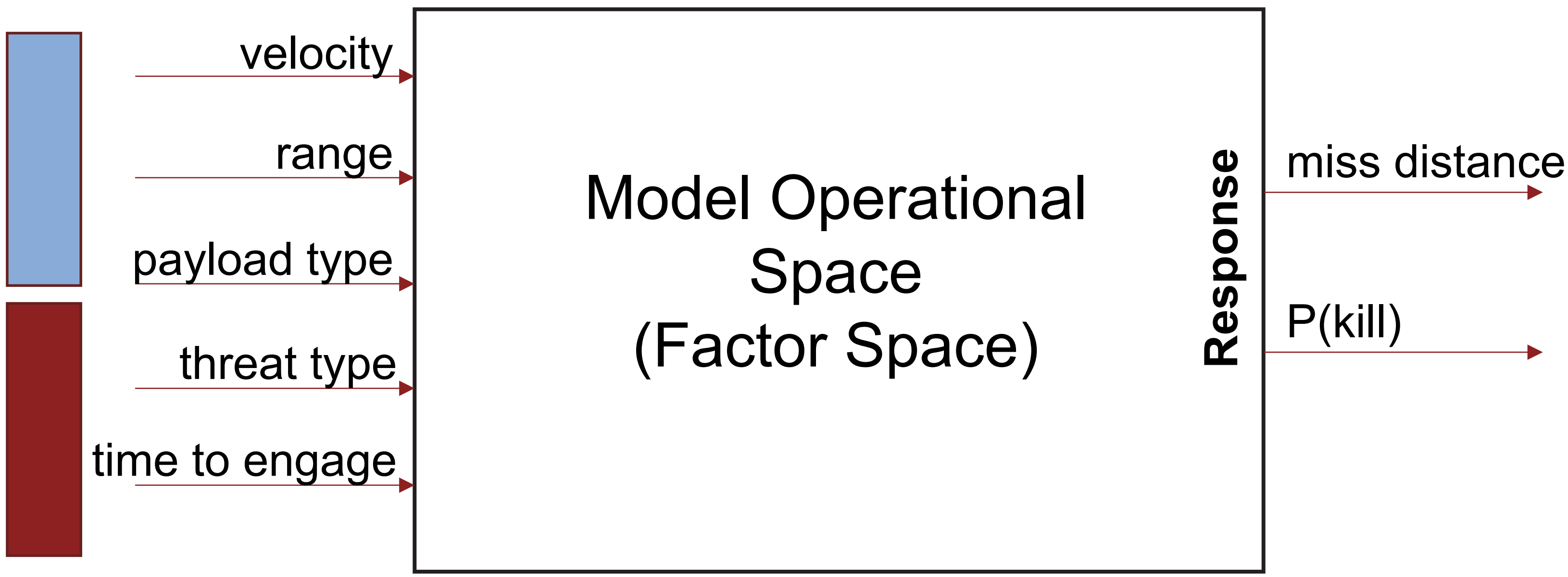
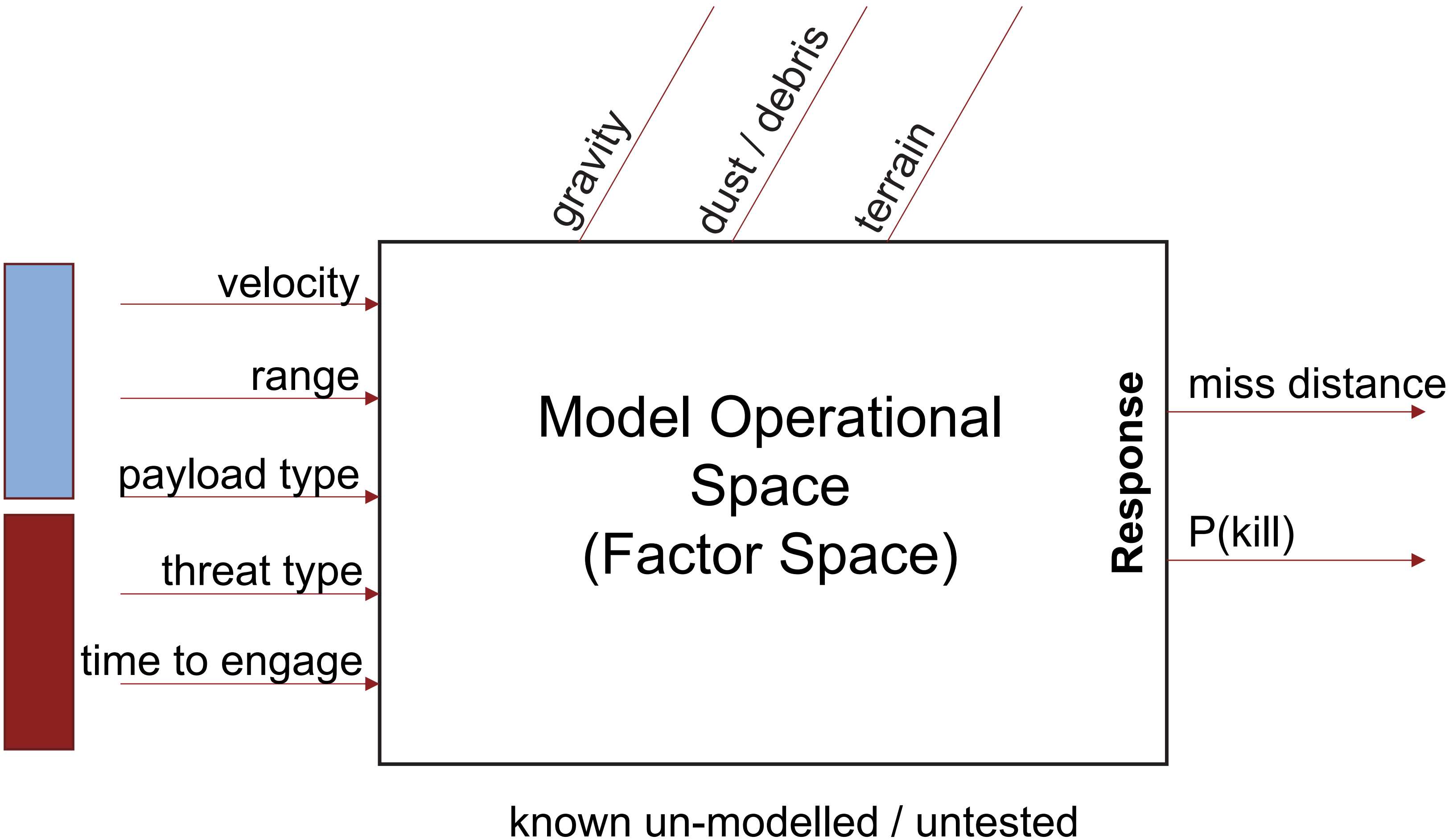
Acronyms: SME – subject matter expert

A model's intended use and operational space should be defined during concept development



Note: P(kill) is the probability that the missile will disable the target

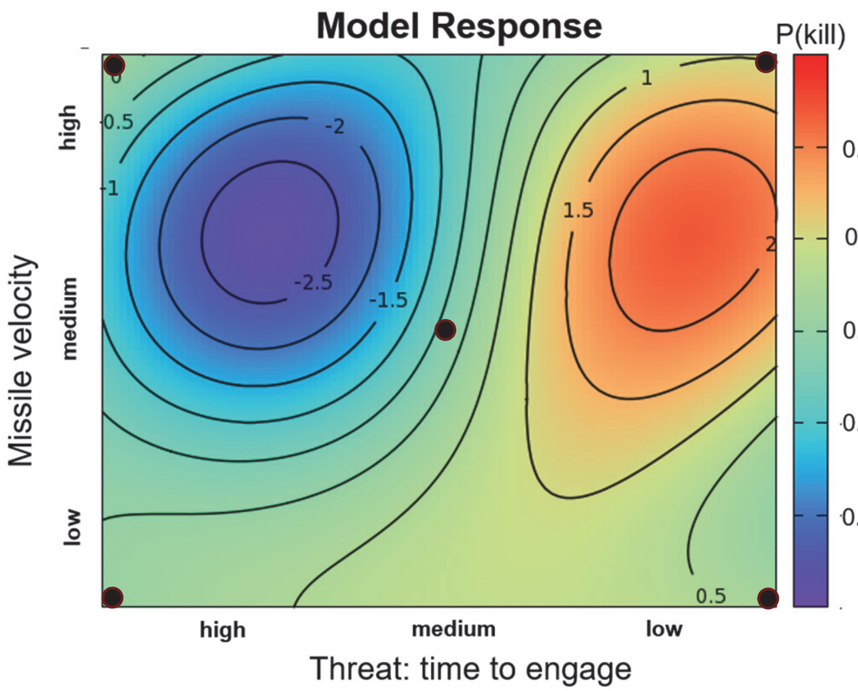
Operational model space should be defined according to feasibility of validating the model



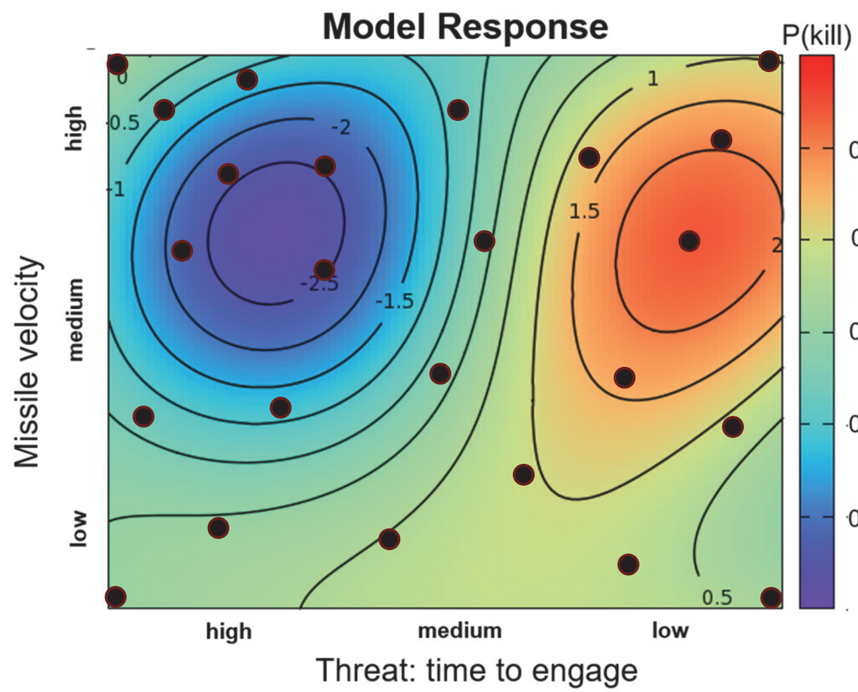
Note: P(kill) is the probability that the missile will disable the target

Space-filling designs characterize model response space better than classical designs

Classical screening designs may miss contours unless the underlying mathematical model is known

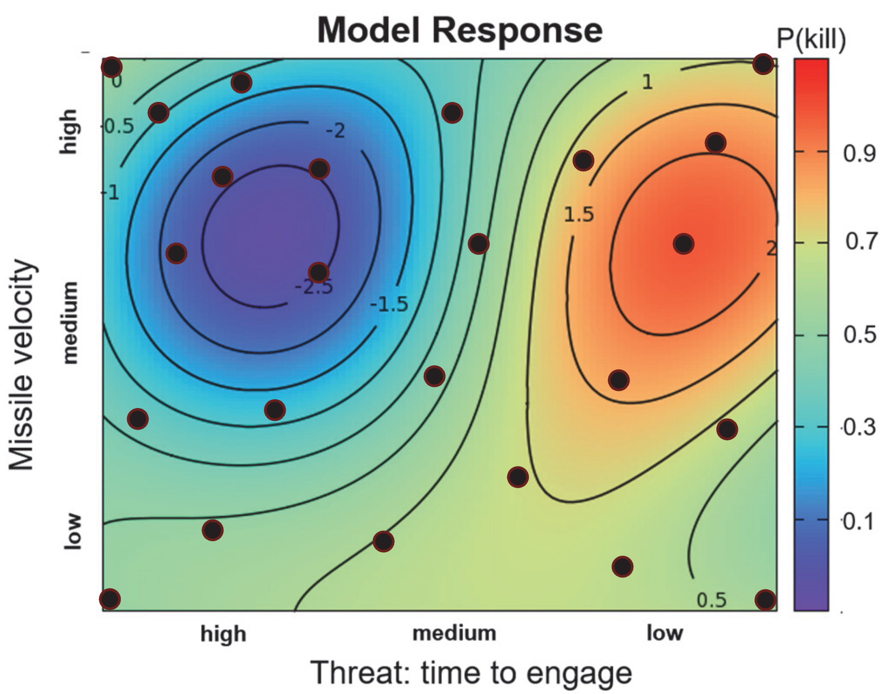


Space-filling designs provide more information about the contours of the operational space



Note: P(kill) is the probability that the missile will disable the target

Model response space analysis error should be captured in order to inform validation process



- **Ideal:** Perform a Monte Carlo analysis for each point on the response space to characterize response uncertainty
- **Alternative 1:** Perform analyses at least three times with random seeds to get a rough uncertainty estimate
- **Alternative 2:** Use a sufficient number of data points in the SFD to have high confidence and power in assumed model. Fit data to the model.

Note: P(kill) is the probability that the missile will disable the target

SFD – space-filling design

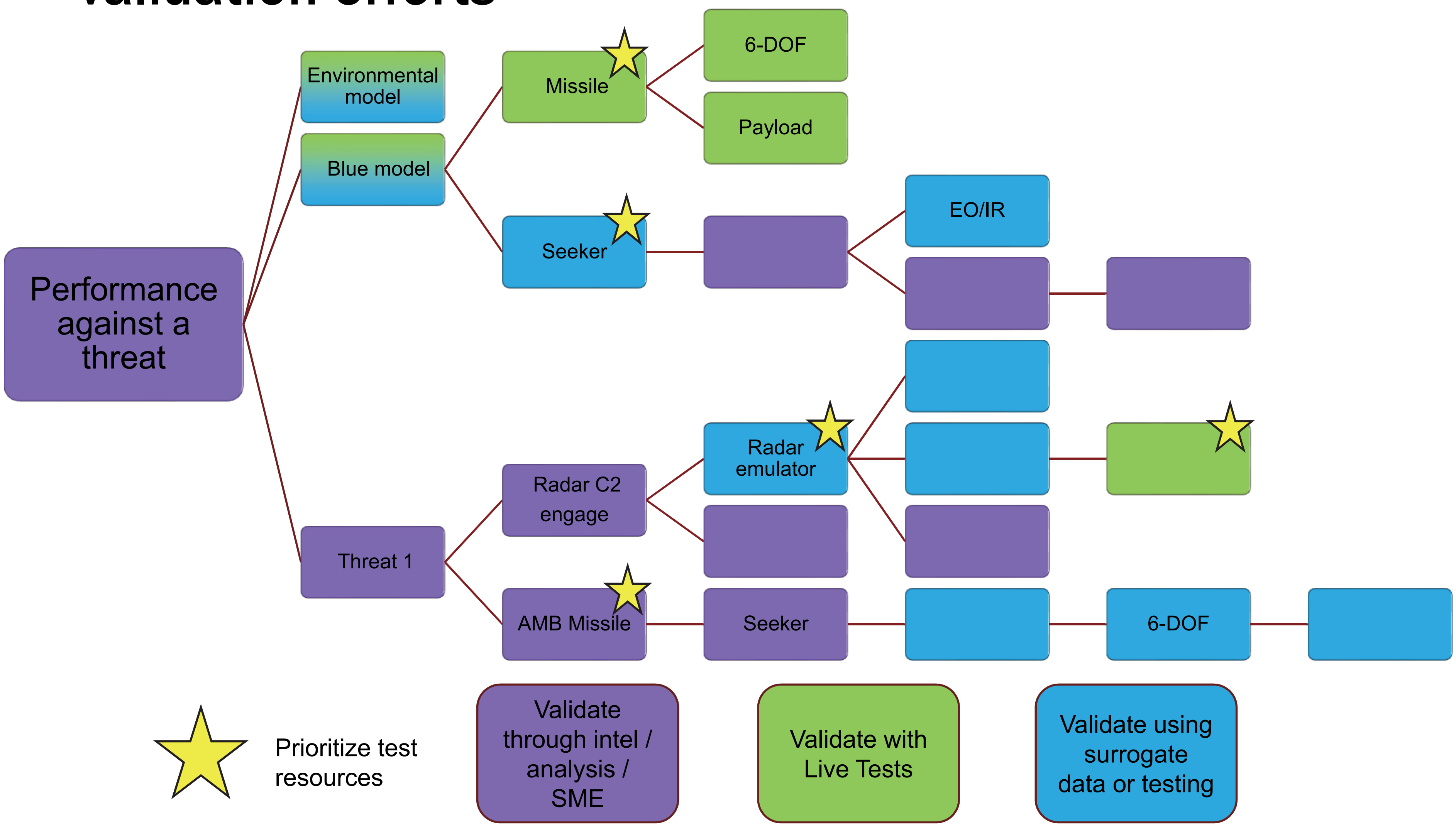
Information from response space characterization and sensitivity analyses inform the validation strategy

- Response space characterization will:
  - Identify key operational factors that change the response the most
  - Identify regions (contours) of operational space where the model response is changing rapidly
  - Allow for *systematic* SME (face) validation of model response

- Sensitivity analyses will:
  - Identify sub-model inputs that most affect sub-model outputs
  - Focus validation efforts on sub-models with highest input/output parameter uncertainty

Acronyms: SME – subject matter expert

Information from verification efforts should shape validation efforts



Acronyms: AMB – anti-ballistic missile; C2 – command and control; 6-DOF – 6 Degree of Freedom flight simulation; EO/IR – electro-optical/infrared

Federated model V&V should be a step-wise process, where the verification results inform the validation strategy – including allocation of test resources.

Acronyms: V&V – verification and validation

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As the Department of Defense adopts digital engineering strategies for acquisition systems in development, programs are embracing the use of highly federated models to assess the end-to-end performance of weapon systems, to include the threat environment. Often, due to resource limitations or political constraints, there is limited live data with which to validate the end-to-end performance of these models. In these cases, careful verification of the model, including from an operational factor-space perspective, early in model development can assist testers in prioritizing resources for model validation in later system development. This presentation will discuss how using Design of Experiments to assess the operational factor space can shape model verification efforts and provide data for model validation focused on the end-to-end performance of the system.

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