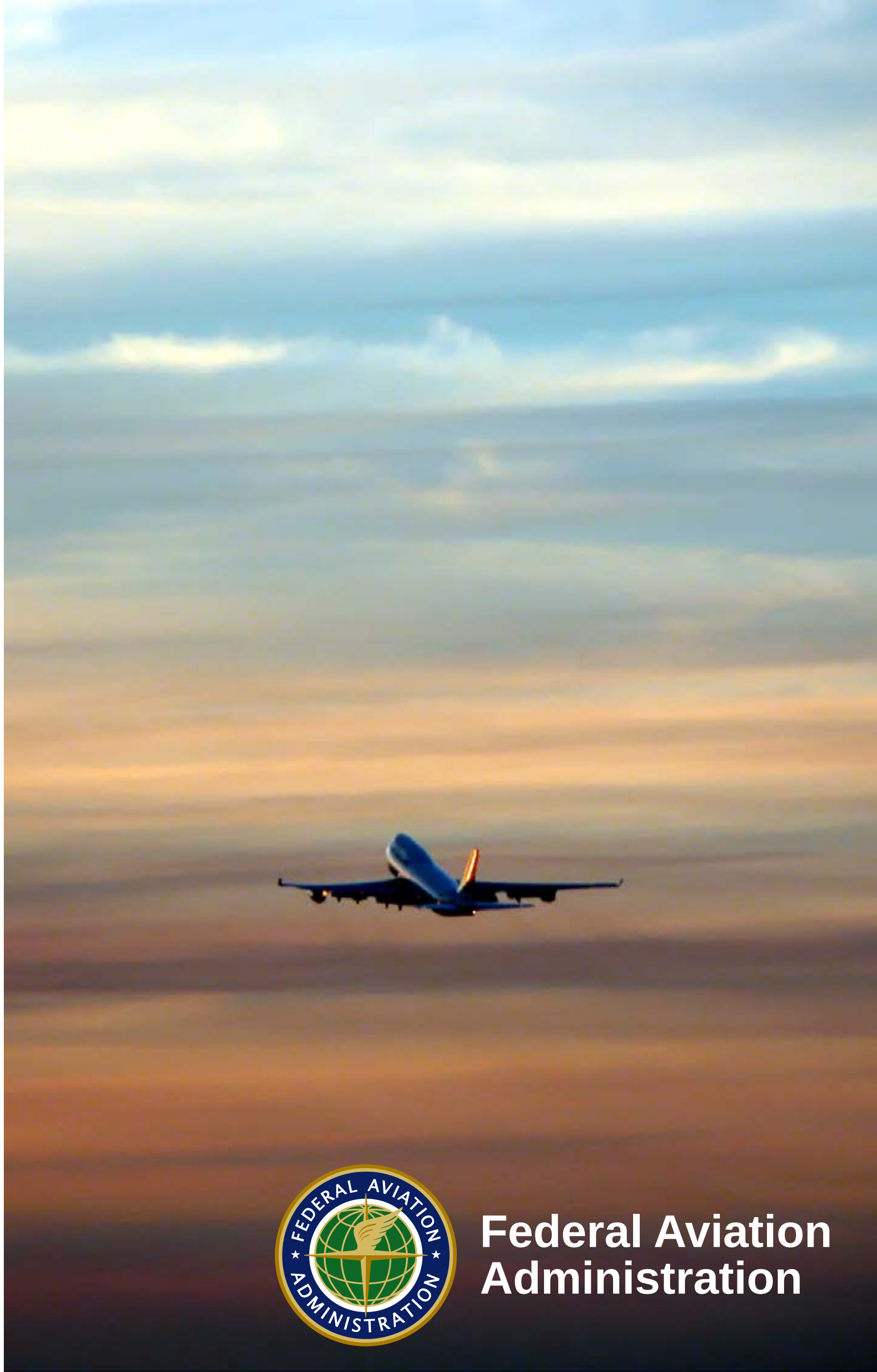
Update on ASME V&V Activities



Presented to: M&S Workshop

By: David Moorcroft

Federal Aviation Administration

Date: August 2019

Standard for Test Uncertainty

ASME PTC 19.1-2018: Test Uncertainty

This Standard specifies procedures for evaluation of uncertainties in test measurements, parameters and methods, and for propagation of those uncertainties into the uncertainty of a test result. Depending on the application, uncertainty sources may be classified either by the presumed effect (systematic or random) on the measurement or test result, or by the process in which they may be quantified (Type A or Type B). The end result of an uncertainty analysis is a numerical estimate of the test uncertainty with an appropriate confidence level.

V&V Standards Committee in Computational Modeling and Simulation

- V&V 10 - Verification and Validation in Computational Solid Mechanics
- V&V 20 - Verification and Validation in Computational Fluid Dynamics and Heat Transfer
- V&V 30 - Verification and Validation in Computational Simulation of Nuclear System Thermal Fluids Behavior
- V&V 40 - Verification and Validation in Computational Modeling of Medical Devices
- V&V 50 - Verification and Validation in Computational Modeling for Advanced Manufacturing
- V&V 60 – Verification and Validation of Computational Modeling in Energy Systems

- Standards committee formed in 2010

- Subcommittees formed:
- V&V 10 – 2001
- V&V 20 – 2004
- V&V 30 – 2010
- V&V 40 – 2011
- V&V 50 – 2016
- V&V 60 – 2017

V&V Standards Committee

Charter: Coordinate, promote, and foster the development of standards that provide procedures for assessing and quantifying the accuracy and credibility of computational models and simulations.

Chair: **Tina Morrison, FDA**
Vice-Chair: **Ben Thacker, SwRI**
Secretary: **Kathryn Hyam, ASME [HyamK@asme.org]**
Michelle Pagano, ASME [PaganoM@asme.org]

Members:

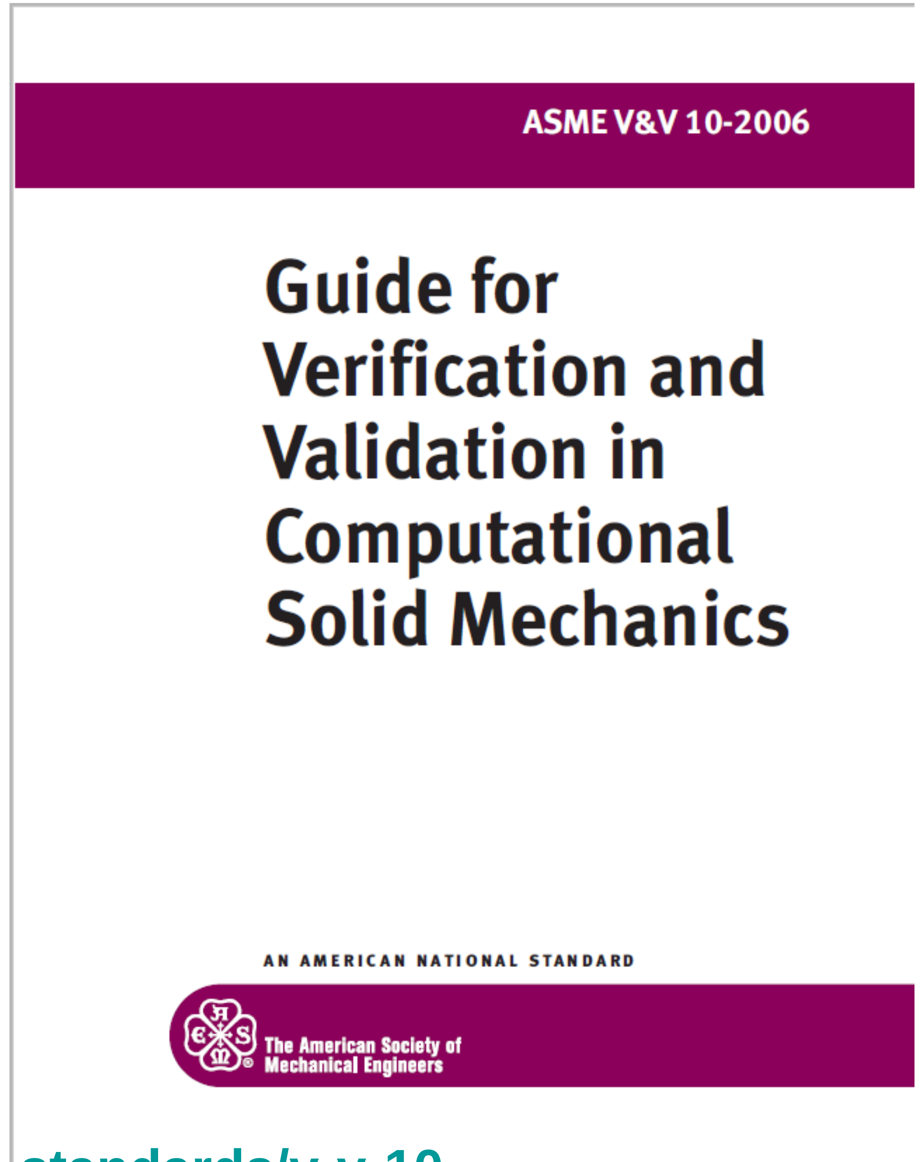
- Mark Benedict, AFRL
- Jeff Bischoff, Zimmer Biomet
- Scott Doebling, Los Alamos
- Kevin Dowding, Sandia National Lab
- Luis Eca, IST
- Chris Freitas, SwRI
- Yassin Hassan, Texas A&M
- Marc Horner, Ansys
- Josh Kaizer, US NRC
- David Moorcroft, FAA
- Sudarsan Rachuri, DoE
- Richard Schultz, Consultant
- Vinod Sharma, Exponent

V&V 10: Verification and Validation in Computational Solid Mechanics

- **V&V 10-2006 - <u>Guide for Verification and Validation</u> in Computational Solid Mechanics – Revision approved**
- **V&V 10.1-2012 - An <u>Illustration of the Concepts of Verification and Validation</u> in Computational Solid Mechanics – Revision underway**
- **Draft V&V 10.2 - <u>Role of Uncertainty Quantification</u> in Verification and Validation of Computational Solid Mechanics Models – Out for Ballot**
- **Draft V&V 10.3 - <u>Role of Validation Metrics</u> in Verification and Validation of Computational Solid Mechanics Models – Underway**

V&V 10-2006

- **Provides a common language, a conceptual framework, and general guidance for implementing the processes of computational model V&V**
- **Title will change to “Standard”**


ASME V&V 10-2006

Guide for Verification and Validation in Computational Solid Mechanics

AN AMERICAN NATIONAL STANDARD

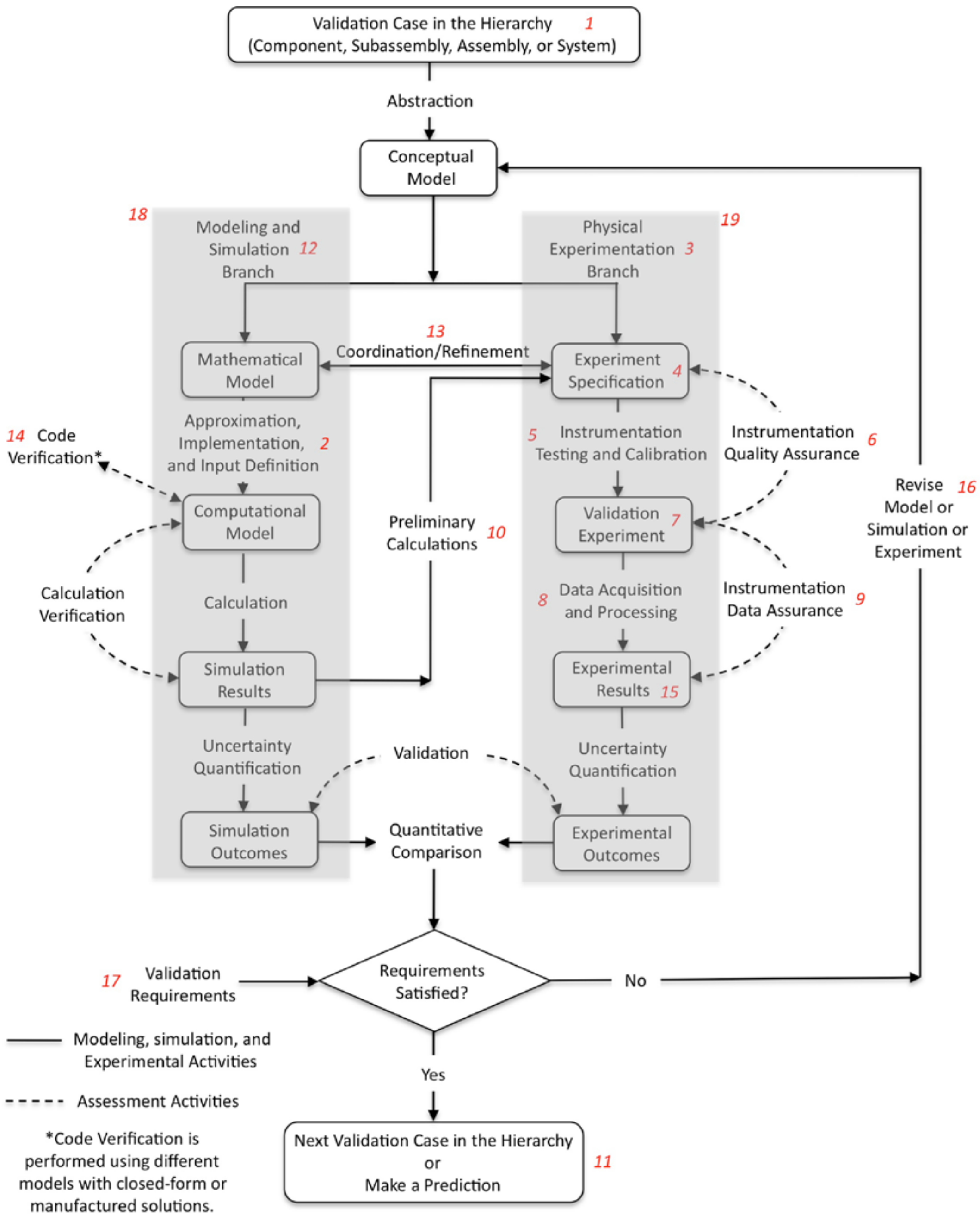
The American Society of Mechanical Engineers

- https://www.asme.org/products/codes-standards/v-v-10-2006-guide-verification-validation

V&V 10-2006: Highlights

- **Predictive Capability**
- **V&V Plan**
- **Model Development**
- **Verification**
  - Code Verification
  - Calculation Verification
- **Validation**
  - Validation Experiments
  - Quantitative Accuracy Assessment
- **Uncertainty Quantification**
- **Documentation**
- **Glossary**

Changes from original ASME diagram marked in red.



V&V 40: V&V for Computational Modeling of Medical Devices

- **Charter:** Provide procedures to standardize verification and validation for computational modeling of medical devices

- **V&V 40-2018** - Assessing Credibility of Computational Modeling through Verification and Validation: Application to Medical Devices
  - Examples are focused on medical devices, but the concepts are broadly applicable

ASME V&V Symposium

Annual (May) symposium includes plenary sessions and paper presentations on verification, validation, and uncertainty quantification across multiple fields of computational mechanics

https://www.asme.org/events/vandv/about

- **2019 was the 7th symposium, ~125 accepted presentations and ~200 registered attendees**
- **Preconference activities include technical training seminars and V&V standards development committee meetings**
- **Evening networking reception added in 2016**
- **2020 Symposium will be in Baltimore, MD May 20-22**

ASME Journal of Verification, Validation and Uncertainty Quantification

This quarterly journal is intended to be a vehicle for disseminating original and applied research, illustrative examples, and high-quality validation experiments and data in the field of verification, validation and uncertainty quantification of computational models in all areas of engineering and applied science. Papers that address any aspect of the V&V process, as well as the interpolation or extrapolation of the results to the model use context are of interest.

- **First issue released March 2016 http://verification.asmedigitalcollection.asme.org/issues.aspx**

Application of V&V 40-2018 to a Hypothetical Aircraft Seat Certification Project

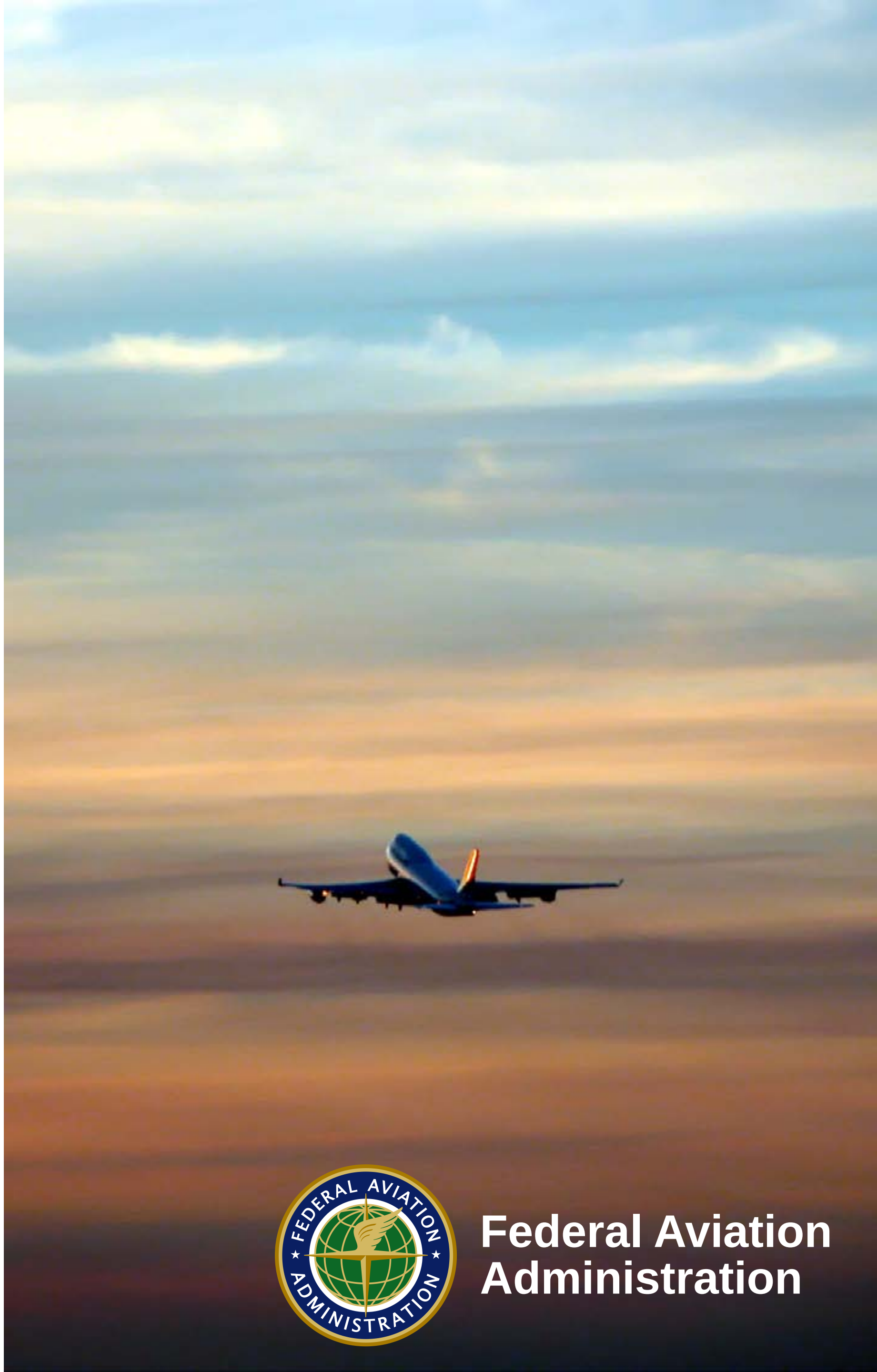
Presented to: ASME V&V Symposium

By: David Moorcroft

Joseph Pellettiere

Federal Aviation Administration

Date: May 2019



Background (cont'd)

- **FAA allows for the use of modeling and simulation (M&S) to demonstrate compliance with federal regulations in certain scenarios**
- **Guidance material provides a methodology (AC 20-146A)**
  - Under what conditions M&S can be used
  - Documentation requirements
  - High level verification and validation (V&V) guidance
  - Emphasizes communication between applicant and FAA
- **No standardized means to determine credibility of M&S**

ASME V&V 40-2018

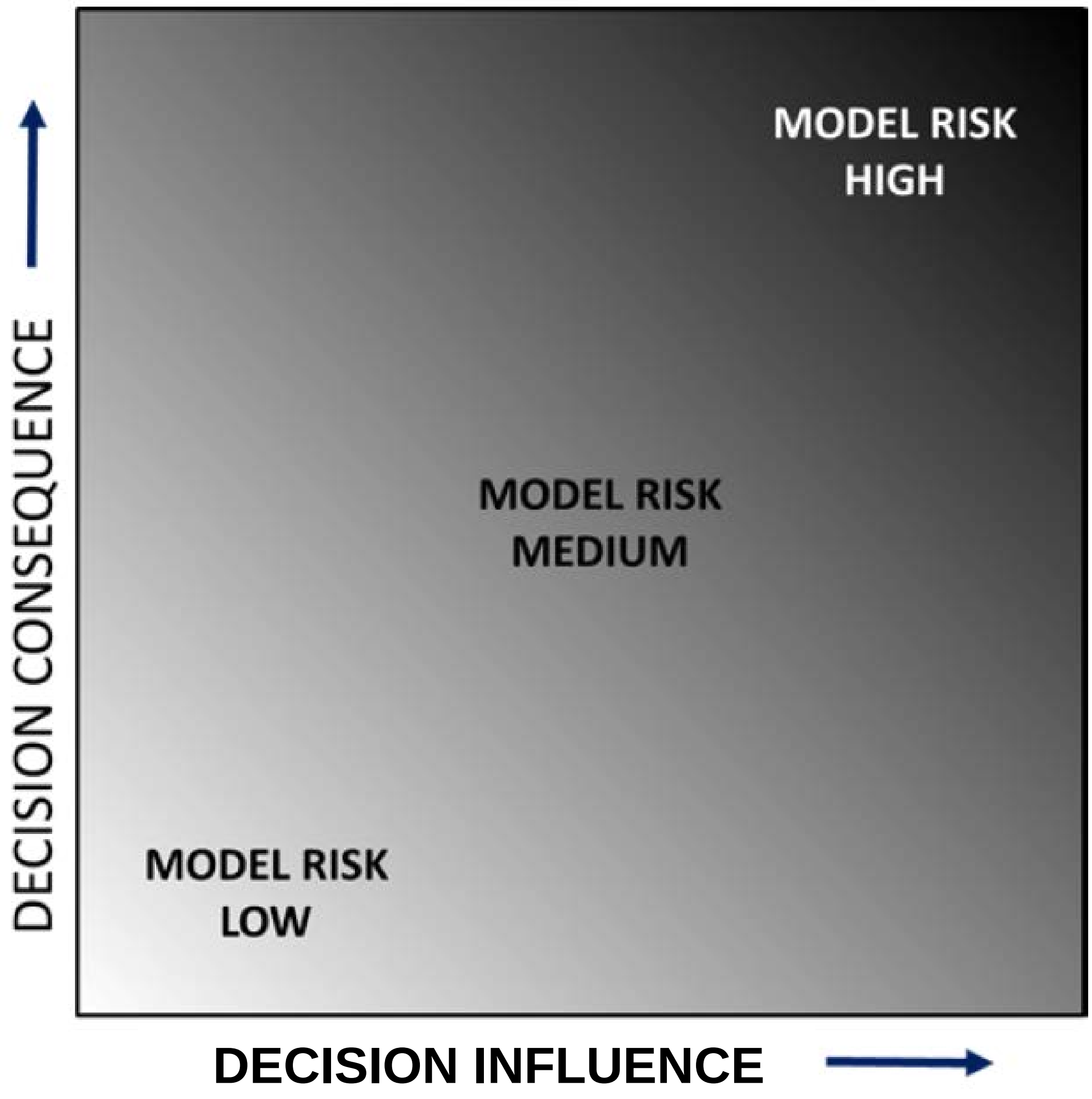
- "Assessing Credibility of Computational Modeling Through Verification and Validation: Application to Medical Devices"
- Provides guidance on assessing the relevance and adequacy of V&V activities for computational models used to support device development and evaluation
- Risk-informed credibility assessment framework centered on establishing that model credibility is commensurate with the risk associated with the decisions' influenced by the computational model

ASME V&V 40-2018

- **Model Risk:** combination of decision influence and consequence

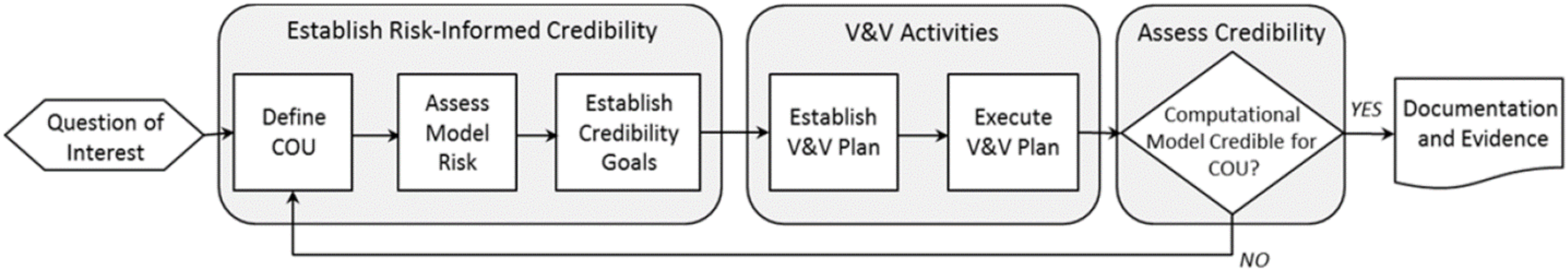
- **Decision Influence:** contribution of M&S outcome to the decision being made

- **Decision Consequence:** impact if the M&S outcomes prove incorrect



ASME V&V 40-2018

- **Credibility: the trust, through the collection of evidence, in the predictive capability of a computational model for a context of use (COU)**



- **Risk is used to determine how much V&V is necessary to support the model in that context of use [i.e. what is the minimum amount of V&V necessary to have a credible model]**

ASME V&V 40-2018

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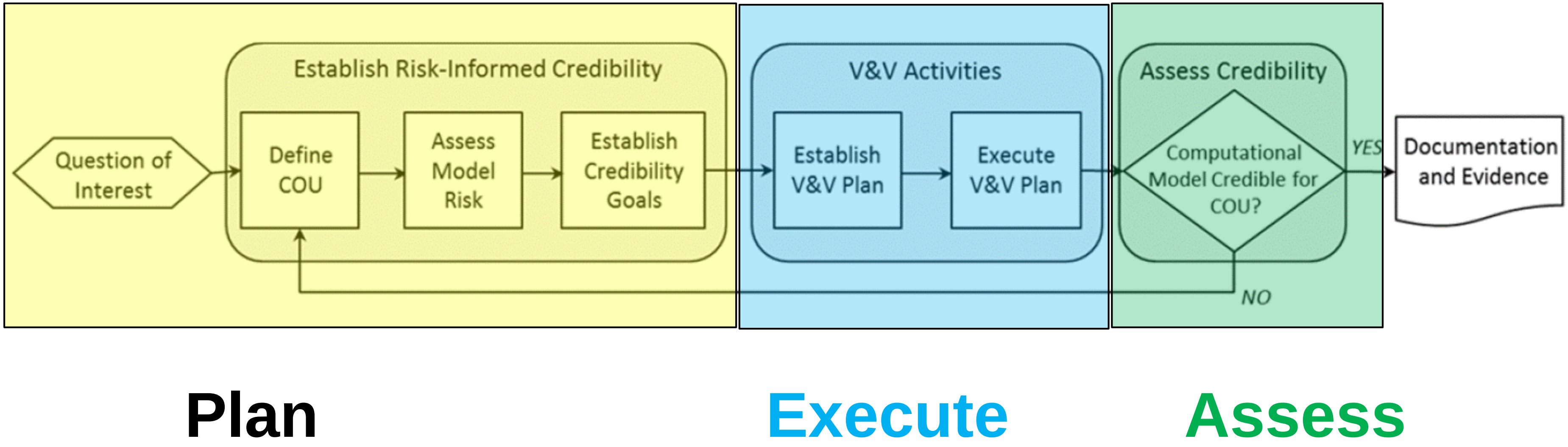

Credibility Factors [13]

Activities		Credibility Factors
Verification	Code	Software Quality Assurance
		Numerical Code Verification
	Calculation	Discretization Error
		Numerical Solver Error
		Use Error
Validation	Computational Model	Model Form
		Model Input
	Comparator	Test Samples
		Test Conditions
	Assessment	Equivalency of Input Parameters
		Output Comparison
Applicability		Relevance of the Quantities of Interest **(QOI)**
		Relevance of the Validation Activities to the COU

Aviation Example

- **Question of Interest:** **demonstrate that a seat design is in compliance with federal regulations for structural integrity**
- **Context of Use:** **explicit, dynamic finite element analysis (FEA) used to evaluate the structural integrity of the seats under emergency landing conditions. The FEA model is used to predict the worst-case scenarios, which will then be subsequently tested to demonstrate compliance to the applicable federal regulations**

Aviation Example

- **Decision Influence:** high influence on the selection of the final test condition, but a low influence on the final certification decision
- **Consequence:** an incorrect decision is moderate for the applicant, as failing the physical test can cause expensive program delays; conversely, poor optimization of the seat structure may unnecessarily increase costs. For the regulator, the consequence is low, since the final physical test must show structural integrity
- **Risk:** moderate for applicant, low for the regulator

Proposed Requirements [Low-Moderate Risk]

- **Levels based on graduations listed in V&V 40**
  - Some factors are further subdivided
  - Graduations contain between 2 and 4 levels
  - Higher levels are more rigorous

Verification Credibility Factors

Credibility Factor	Requirement
SQA	Trusted COTS software [Level 1 of 3]
Code Verification	Evaluate material models for primary load path [Level 1.5 of 4]
Discretization Error	Evaluate for primary load path (error <0.5%) [Level 2 of 3]
Solver Error	Solver parameters based on company SOP [Level 1 of 3]
Use Error	Key inputs and outputs were verified by internal peer review [Level 3 of 4]

Proposed Requirements [Low-Moderate Risk]

Validation and Applicability Credibility Factors

Credibility Factor	Requirement
Model Form	Model form assumptions based on company SOP [Level 1 of 3]
Model Input	Sensitivity analysis performed on key parameters [Level 2 of 3]
Test Samples	Production quality samples, limited statistical evidence [Level 1.5 of 4]
Test Conditions	Match regulatory requirements (typical lab pulse) [Level 2 of 4]
Input Parameters	The types and ranges of all inputs are equivalent [Level 3 of 3]
Output Comparison	Primary channels within 15%, secondary channels within 40% [all outputs are equivalent] [Level 2 of 4]
Relevance of QOI	Match regulatory requirements [Level 3 of 3]
Relevance of Validation	Match regulatory requirements [Level 3 of 4]

Discussion

- **Currently, certification is based on a specified, idealized laboratory test**
- **The model is able to exactly replicate that test, therefore some credibility factors will always be at or near the highest level regardless of risk**
  – Input parameters, output comparison, relevance of QOI, and relevance of validation

Discussion (cont'd)

- **Tentative interest in applying this framework to aviation certification projects**
- **Both FAA certification engineers and seat OEMs need to be more familiar with the framework before feeling comfortable with its use**
- **Determination of risk was not consistent**
  - Asked 4 groups, got 4 different answers
- **Credibility factors can guide the FAA on questions to ask and provides industry a way to justify their answers**

Overview

- Determining whether a computational model is credible for decision-making and determining how much verification and validation (V&V) is enough is important
- FAA guidance recommends applicants work with the FAA to define the level of rigor
- ASME V&V 40 provides one method of systematically answering those questions

Questions?