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V&V Credibility: Predictive Capability and Maturity Model (PCMM)

PRESENTED BY

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Introduction to PCMM

Pre-requisite: Create a PIRT

What is a PIRT (Phenomena Identification and Ranking Table)?

- Define key physical phenomena that will be needed for an application of interest
- Rank importance of each phenomena relative to a specific output quantity of interest
- Assess adequacy and gaps in capabilities relative to the intended use

PIRT adequacy elements

- Math model
- Code
- Validation
- Model parameters

How does the PCMM differ from the PIRT?

- The PIRT assesses how well the model captures the desired physics – feeds directly into physics and material model fidelity element of PCMM and also informs other elements
- PIRT covers capability adequacy at high level, and then the PCMM focuses on detailed V&V/UQ activities and evidence

What is the PCMM?

The Predictive Capability Maturity Model (PCMM) is a multi-dimensional qualitative metric to facilitate discussion and communication of credibility evidence

- Primary purposes:
  - Determine readiness of modeling capabilities and simulation products for use in various applications and decisions (e.g., design, ES derivation, qualification)
  - Identify gaps in the current credibility evidence for an application and prioritize additional activities
  - Measure progress of an integrated simulation effort over the lifetime of an analysis
- PCMM components:
  - Elements – the dimensions of the credibility evidence
  - Maturity levels – a relative measure of the state of the evidence and level of effort around each element
  - Element criteria – major features of the evidence to consider for each element

PCMM: What it is and what it is not

PCMM is:

A planning tool to highlight and prioritize detailed V&V activities at an early stage of an analysis

A communication tool that *must* include a discussion of the supporting evidence to tell a credibility story

A tool for informing risk in the use of modeling and simulation

PCMM is NOT:

An absolute number or a score

A mechanism for criticizing and poking holes in analysis credibility

What does PCMM do?

Use PCMM to:

(1) Help collect a comprehensive set of evidence

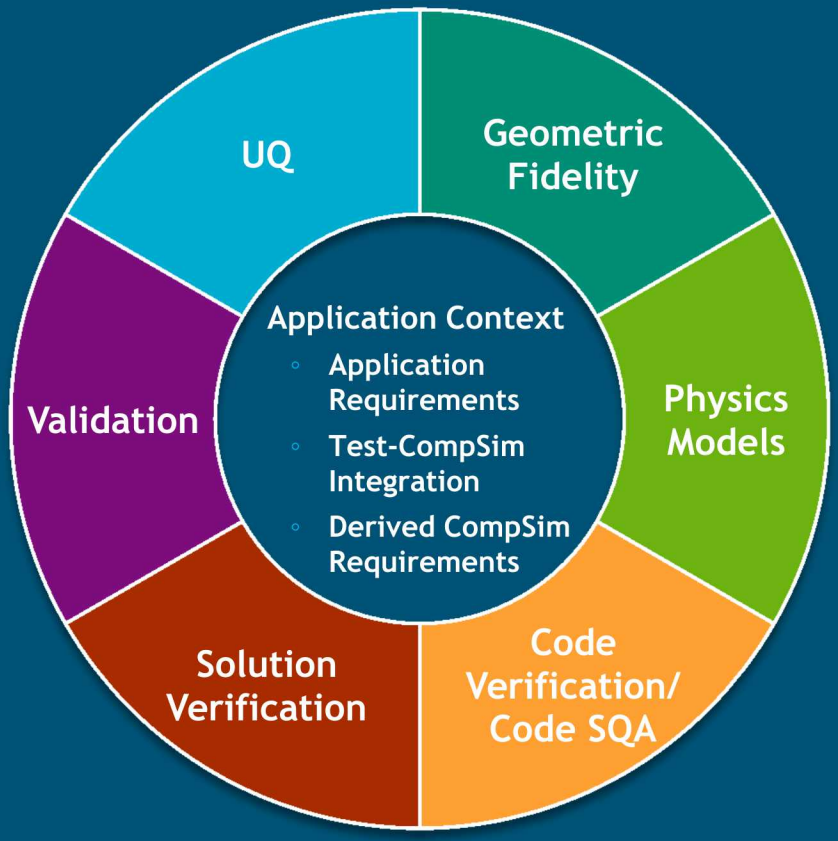
(2) Organize the evidence to tell the story

The *evidence* must exist before it can be evaluated

- What evidence will be generated?
- Will it tell a coherent story?
- Will it be adequate?

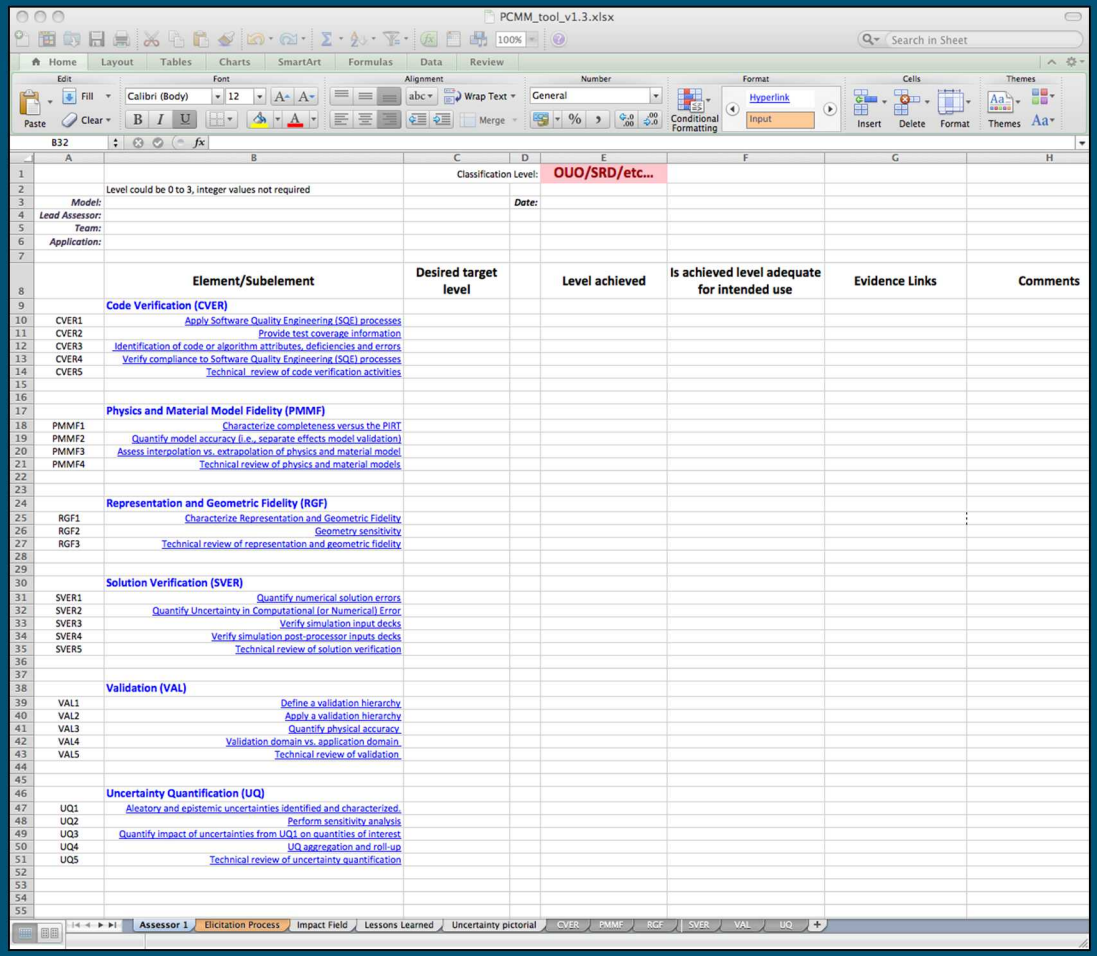
PCMM elements – dimensions of the evidence

- Geometric Fidelity
- Physics and Material Model Fidelity
- Code Verification
- Solution Verification
- Validation
- Uncertainty Quantification



This evidence feeds into a credibility story - 1544 has developed a template for communicating this story

Current PCMM Tool



PCMM_tool_v1.3.xlsx

	A	B	C	D	E	F	G	H
1			Classification Level:		OUO/SRD/etc...			
2		Level could be 0 to 3, integer values not required						
3	Model:			Date:				
4	Lead Assessor:							
5	Team:							
6	Application:							
7								
8		Element/Subelement	Desired target level		Level achieved	Is achieved level adequate for intended use	Evidence Links	Comments
9		**Code Verification (CVER)**						
10	CVER1	Apply Software Quality Engineering (SQE) processes						
11	CVER2	Provide test coverage information						
12	CVER3	Identification of code or algorithm attributes, deficiencies and errors						
13	CVER4	Verify compliance to Software Quality Engineering (SQE) processes						
14	CVER5	Technical review of code verification activities						
15								
16								
17		**Physics and Material Model Fidelity (PMMF)**						
18	PMMF1	Characterize completeness versus the PIRT						
19	PMMF2	Quantify model accuracy (i.e., separate effects model validation)						
20	PMMF3	Assess interpolation vs. extrapolation of physics and material model						
21	PMMF4	Technical review of physics and material models						
22								
23								
24		**Representation and Geometric Fidelity (RGF)**						
25	RGF1	Characterize Representation and Geometric Fidelity						
26	RGF2	Geometry sensitivity						
27	RGF3	Technical review of representation and geometric fidelity						
28								
29								
30		**Solution Verification (SVER)**						
31	SVER1	Quantify numerical solution errors						
32	SVER2	Quantify Uncertainty in Computational (or Numerical) Error						
33	SVER3	Verify simulation input decks						
34	SVER4	Verify simulation post-processor inputs decks						
35	SVER5	Technical review of solution verification						
36								
37								
38		**Validation (VAL)**						
39	VAL1	Define a validation hierarchy						
40	VAL2	Apply a validation hierarchy						
41	VAL3	Quantify physical accuracy						
42	VAL4	Validation domain vs. application domain						
43	VAL5	Technical review of validation						
44								
45								
46		**Uncertainty Quantification (UQ)**						
47	UQ1	Aleatory and epistemic uncertainties identified and characterized.						
48	UQ2	Perform sensitivity analysis						
49	UQ3	Quantify impact of uncertainties from UQ1 on quantities of interest						
50	UQ4	UQ aggregation and roll-up						
51	UQ5	Technical review of uncertainty quantification						
52								
53								
54								
55								

Assessor 1 | Elicitation Process | Impact Field | Lessons Learned | Uncertainty pictorial | CVER | PMMF | RGF | SVER | VAL | UQ

Use the tool to facilitate discussions about the evidence and specific V&V/UQ activities – maturity levels are relative and qualitative, not a final report card!

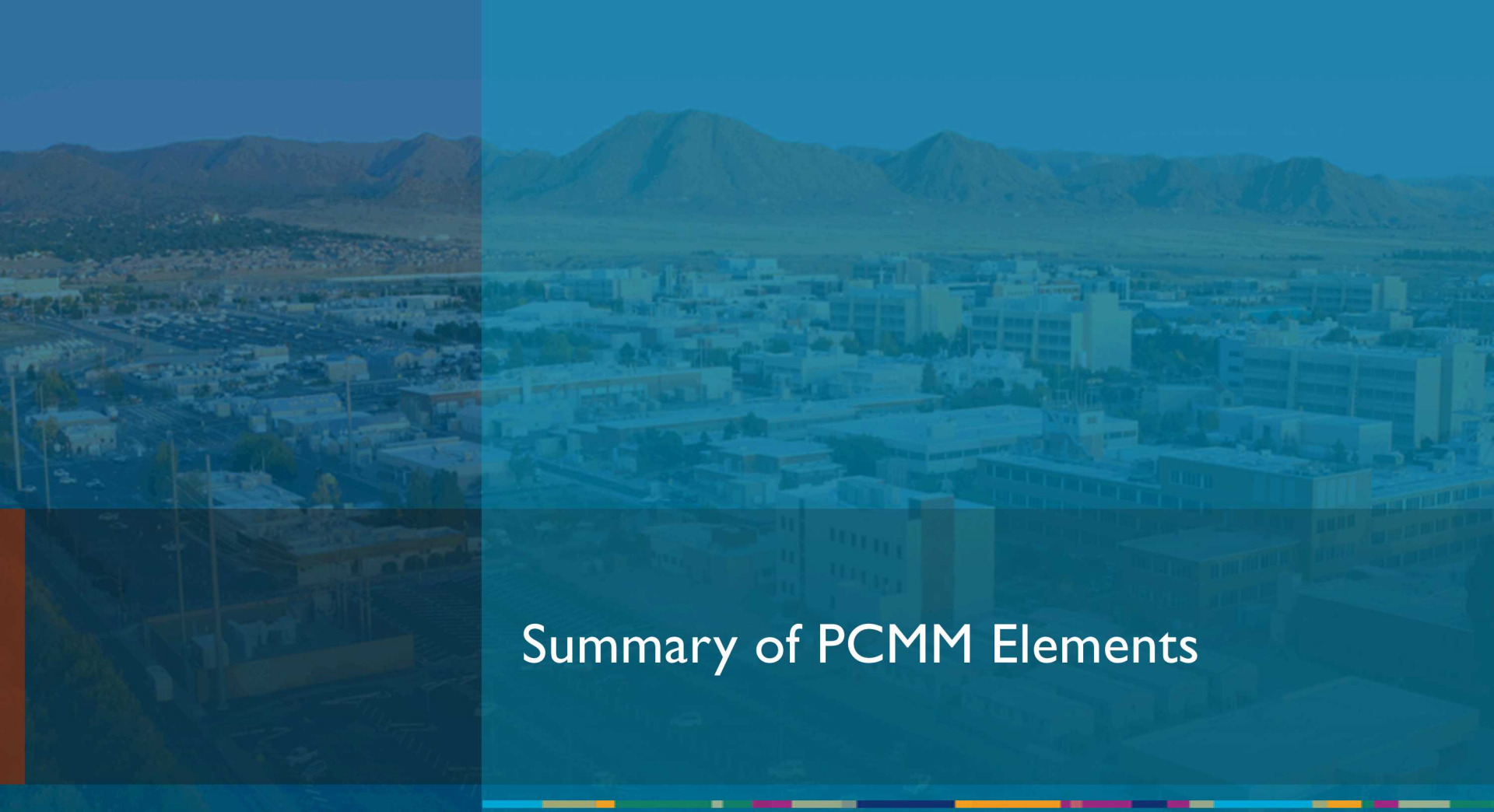
Guidelines for Meeting Facilitation

Guidelines for meeting facilitation

- Who should be included?
  - Facilitator, V&V partners, analysts, code developers, experimentalists, stakeholders
- When should they be held?
  - Q2 of FY19
- How much time should be allocated?
  - Depends on what the team is willing to do (1 hr per element, 2 hrs total, etc)
  - Minimally, we recommended a 2 hr meeting to brief the team on what a PCMM is and the purpose, then start working on the spreadsheet. Remaining tasks can be delegated as "homework"
- Logistics for your team to work out:
  - Nominate a stakeholder for each element
  - Decide who takes the notes
  - What to do offline before/after meetings
  - Decide on action items

Guidance on Facilitation

- General guidelines:
  - Make sure everyone's opinion is heard, not just the person who speaks the most and/or loudest (try a roundtable for each topic)
  - Be respectful of everyone's ideas
  - Have two facilitators:
    - One takes notes
    - One guides the conversation and mindful of timekeeping (don't let conversations get too off topic – try to cover the amount of material planned for)
  - Make it clear what information participants should come prepared with to discuss. Perhaps gathering evidence ahead of time could save time and streamline conversation.



Summary of PCMM Elements

Representation and Geometric Fidelity (RGF)

Goal:

- Identify the elements of the application geometry model that have been de-featured and understand the potential sensitivity to these approximations

Needed evidence:

- To what extent is the geometry important?
- Are approximations/simplifications being made and why?

As-Modeled As-Designed

How are geometric feature simplifications influencing simulation results?

Physics and Material Model Fidelity (PMMF)

Goal:

- Identify the important physics and material models and their readiness for the intended use and identify gaps

Needed evidence:

- Model selection
  - What choices were made and why?
  - Is it sufficient for the given application?
- Physics-based vs. empirical models
  - Are we within the range of applicability for our assumptions?

PIRT

Phenomena	*Importance*	*Adequacy for Intended Use*			
		Math Model	Code	Validation	Model Parameter
Phenomena 1	H	H	M	L	L
Phenomena 2	M	H	M	L	L
Phenomena 3	L	H	M	L	L

Are important physics models adequate? Key gaps mitigated?

Code Verification (CVER)

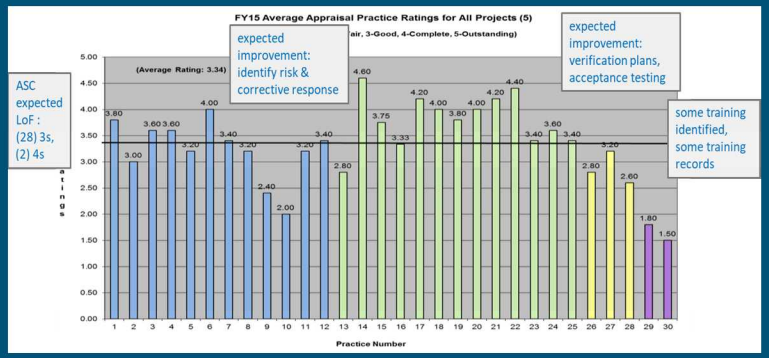
Goal:

- Identify the important code capabilities for the intended use and understand their current readiness and verification pedigree

Needed evidence:

- Software development process
  - What is the process for developing the code base?
  - What are the SQA standards?
- How is the code base maintained?
- Verification testing
  - Are there tests for important features?
  - Verification tests or regression tests?
  - Do the available tests cover what the code is being used for?

Summary of Verification Test Coverage



What is the evidence for code credibility?

Solution Verification (SVER)

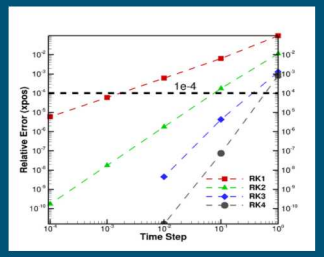
Goal:

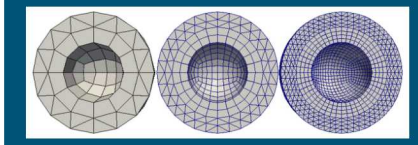
- Identify spatial, temporal, and/or stochastic resolution limitations in the application simulation

Needed evidence:

- What type of solvers are being used in the code?
  - Do they converge?
  - What are the limitations?
- Are approximations/simplifications needed?
  - How much error is incurred?
  - Has the numerical error been quantified?

Mesh Refinement Study





How do numerical solution or human errors affect simulation results?

Validation (VAL)

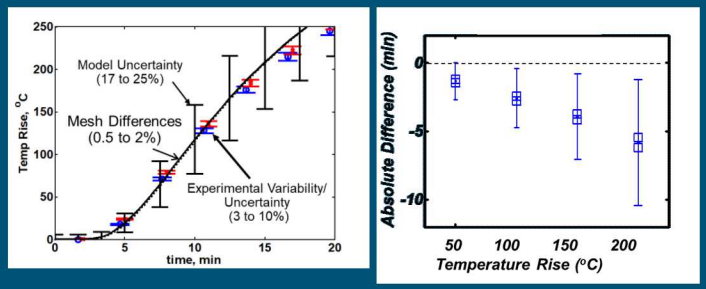
Goal:

- Identify existing validation comparisons and understand hierarchy coverage and the degree of extrapolation from the validation conditions to the application conditions

Needed evidence:

- Do we have test data available for this application?
- How similar are the tested conditions to the ones we want to predict?
- Have we assessed our model with the data?
  - How did it perform?
  - Were the results quantitative or qualitative?
  - Did we consider uncertainty in the comparison?

Model Validation Assessment



What is the discrepancy between simulation and experiments?

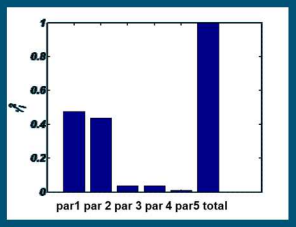
Uncertainty Quantification (UQ)

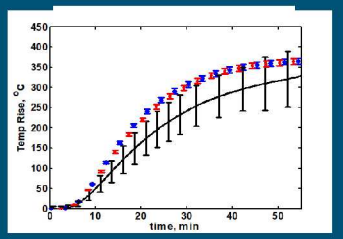
Goal:

- Understand the identification and characterization of input uncertainties, the quantification of output uncertainties, and the extrapolation of the validation uncertainties to the application

Needed evidence:

- Have we considered known uncertainty sources?
  - How well are they understood?
  - Can they be characterized well?
- Have we studied the effect of these uncertainty sources on the output?





How are uncertainties assessed and reflected in simulation predictions?

PCMM Process

Suggested Implementation of the PCMM

1. Discuss the body of evidence that is currently available

2. Identify key gaps and evidence and prioritize additional detailed activities to perform (subject to project constraints)

3. Generate additional evidence

4. Manage the evidence
   - Document it
   - Archive it
   - Report evidence status periodically – update PCMM as appropriate

Guidelines for this meeting

Discuss each element in detail (refer to tool)

- Take notes on status, existing evidence, needed evidence, current maturity, and major priorities

Roles for the meeting

- Facilitator to lead discussion and take notes
- Assign primary stakeholder for each PCMM element
- Primary stakeholder for each element to summarize findings and communicate/track key outstanding action items

What about the "scoring"?

PCMM is currently being used as a planning activity

Proposal: Map a list of activities to desired/required level of rigor for the model. Score can be percentage complete. Include working definition of credibility and use "scores" for prioritization of activities.

Ex: "This will be an "As Is" model. A minimal set of verification practices will need to be ensured. One on one peer review and a mesh convergence study."

This does not mean 100% completeness = 100% credible.

*Use evidence and examples to back up any assessments

Working definition of credibility

Credibility is a term that is not often well defined. For the purposes of this project plan, credibility of a result/data/analysis has two main elements:

- Pedigree of the result/data/analysis and
- Acceptance by the customer for the intended use,

where pedigree is composed of

- Maturity of the capabilities used,
- Extent of V&V and uncertainty quantification, and
- Level of rigor applied (both formality of process and accuracy of methods).

The evidence package associated with pedigree includes, but is not limited to, documented descriptions and assessments of M&S activities identified in the Predictive Capability Maturity Model (PCMM) (representation/geometric fidelity, physics/material model fidelity, code verification, solution verification, model validation, uncertainty quantification/sensitivity analysis). A tiered approach to rigor is applied to these activities as warranted by the intended use of M&S.

Conclusions and Summary

Process Outcomes and Conclusions

Summarize key findings

Discuss communication plan for other project stakeholders

- General high-level group consensus on status and readiness for decision making

Discuss documentation expectations

- Has the existing evidence been documented?
- Where does it need to go?

Remaining action items (additional activities to perform and documentation):

- Owner
- Path forward