



# NASA Models & Simulations (M&S)

Including the NASA Standard for M&S

August 2016

# Premise for an M&S Standard



- A major point of understanding:
  - All M&S results *implicitly, if not explicitly*, contain *uncertainty*.
- M&S Results were presented in a variety of ways
  - Many Types of M&S
  - Many Types of Applications
- Sometimes credibility topics were addressed
  - Again, in a variety of ways
  - And, incompletely
  - Heavily focused on VV&A (Verification, Validation, & Accreditation)
- What is essential:
  - A Common Vocabulary
  - Rigorous Testing of the M&S
  - A baseline methodology for Reporting Results

# The Perfect Example



- The System & Problem are **understood perfectly** (with extensive supporting data)
- The System & Problem are **modeled perfectly** – an exact match, including fidelity
- The **M&S requirements** are **perfectly formulated**
- The **M&S requirements** (including those from NASA-STD-7009) were **all met** without waivers
- All **abstractions** in the M&S are **inconsequential**
- M&S **assumptions** are **understood** and **none** were **violated**
- The M&S was used well **within its limits of operation**
- **No errors or warnings** occurred during the execution of the M&S
- The results are/appear **reasonable**
- Sources of error/**uncertainty** are **known**
- The error/**uncertainty** on the results is **quantitative & acceptable**
- **Credibility** assessment **meets** or exceeds P/P **expectations**

**NASA-STD-7009 exists to help deal with the fact that *in practice* we rarely approach this ideal.**

# Background



Document	Document Number	Revision	Published
M&S Standard	NASA-STD-7009	Baseline	July 2008
M&S Handbook	NASA-HDBK-7009	Baseline	October 2013
M&S Standard	NASA-STD-7009	Rev. A	July 2016
M&S Handbook	NASA-HDBK-7009	Rev. A	<b>In Development</b>

- M&S Standard Development – Prompted by findings from Shuttle Columbia Accident
- M&S Handbook Development – An Implementation Guide to NASA-STD-7009
- Revision prompted by real-world experience in implementing the Standard
- Rev. A STD contains: 39 Requirements & 49 Recommendations

# Overarching Concepts for M&S



- Applies to ALL TYPES of M&S
- Provide a Common Terminology Base
- Follow a Defined Process in the development & use of an M&S (M&S Life Cycle) {Charts 7-9}
- Define M&S Acceptance Criteria, including
  - M&S Intended Use
  - Criteria for
    - Verification
    - Validation
    - Uncertainty Characterization
    - Reporting {Chart 13}
    - Configuration Management
- Assess
  - Criticality addressed by the M&S {Chart 6}
  - Proposed Use of an M&S {Chart 11}
  - Credibility of M&S-based Results {Chart 12}
  - Risk of Accepting M&S-based Results {Chart 15}
- Document! (i.e., provide evidence of what is accomplished)
  - In Development
  - In Use

# Criticality Assessment



<b>M&amp;S Results Influence</b>	5: Controlling	(G)	(Y)	(R)	(R)	(R)
	4: Significant	(G)	(Y)	(Y)	(R)	(R)
	3: Moderate	(G)	(Y)	(Y)	(Y)	(R)
	2: Minor	(G)	(G)	(G)	(Y)	(Y)
	1: Negligible	(G)	(G)	(G)	(G)	(Y)
		I: Negligible	II: Minor	III: Moderate	IV: Significant	V: Catastrophic
		<b>Decision Consequence</b>				

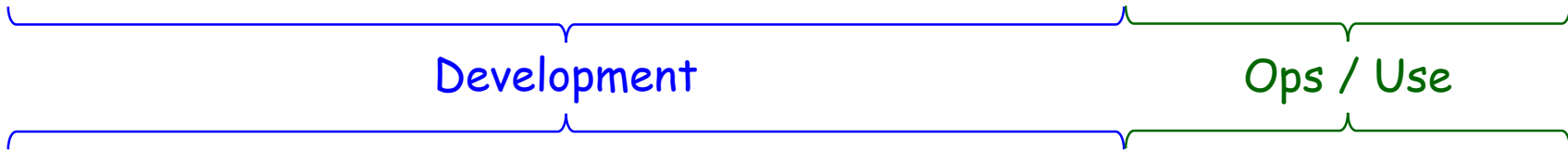
Sample Matrix is 5x5

# Lifecycles



## NASA Prog/Proj Mgt Lifecycle

Pre-Phase A	Phase A	Phase B	Phase C	Phase D	Phase E	Phase F
Conceptual Studies	Concept & Technology Development	Preliminary Design & Technology Completion	Final Design & Fabrication	System Assembly, Integration, & Test	Operations & Sustainment	Closeout



Model Initiation	Concept Development	Model Design	Model Construction	Model Testing	Model Use / Ops	Model/Anal. Archiving
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## M&S Lifecycle

# M&S Life Cycle



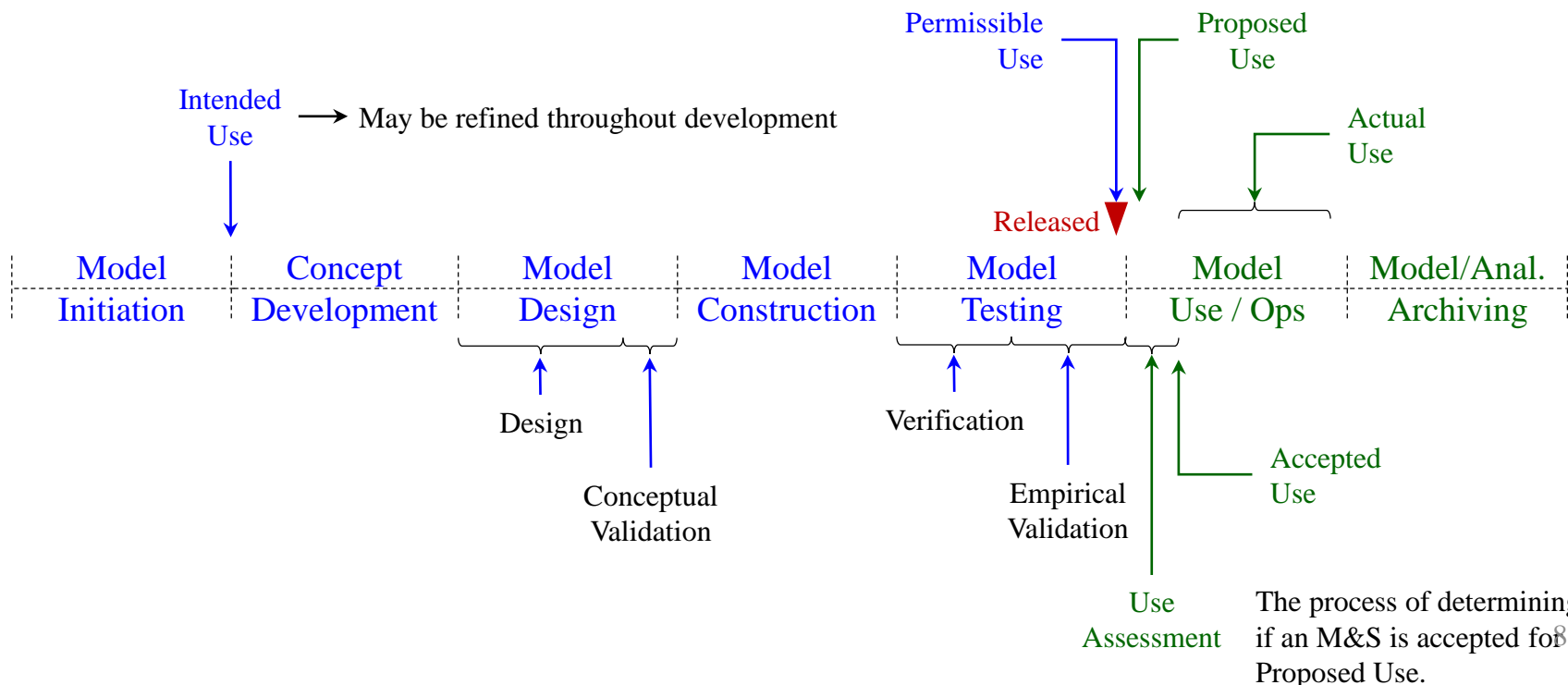
**Intended Use** – The expected purpose and application of an M&S.

**Permissible Use** – The purposes for which an M&S is formally allowed.

**Proposed Use** – A desired specific application of an M&S.

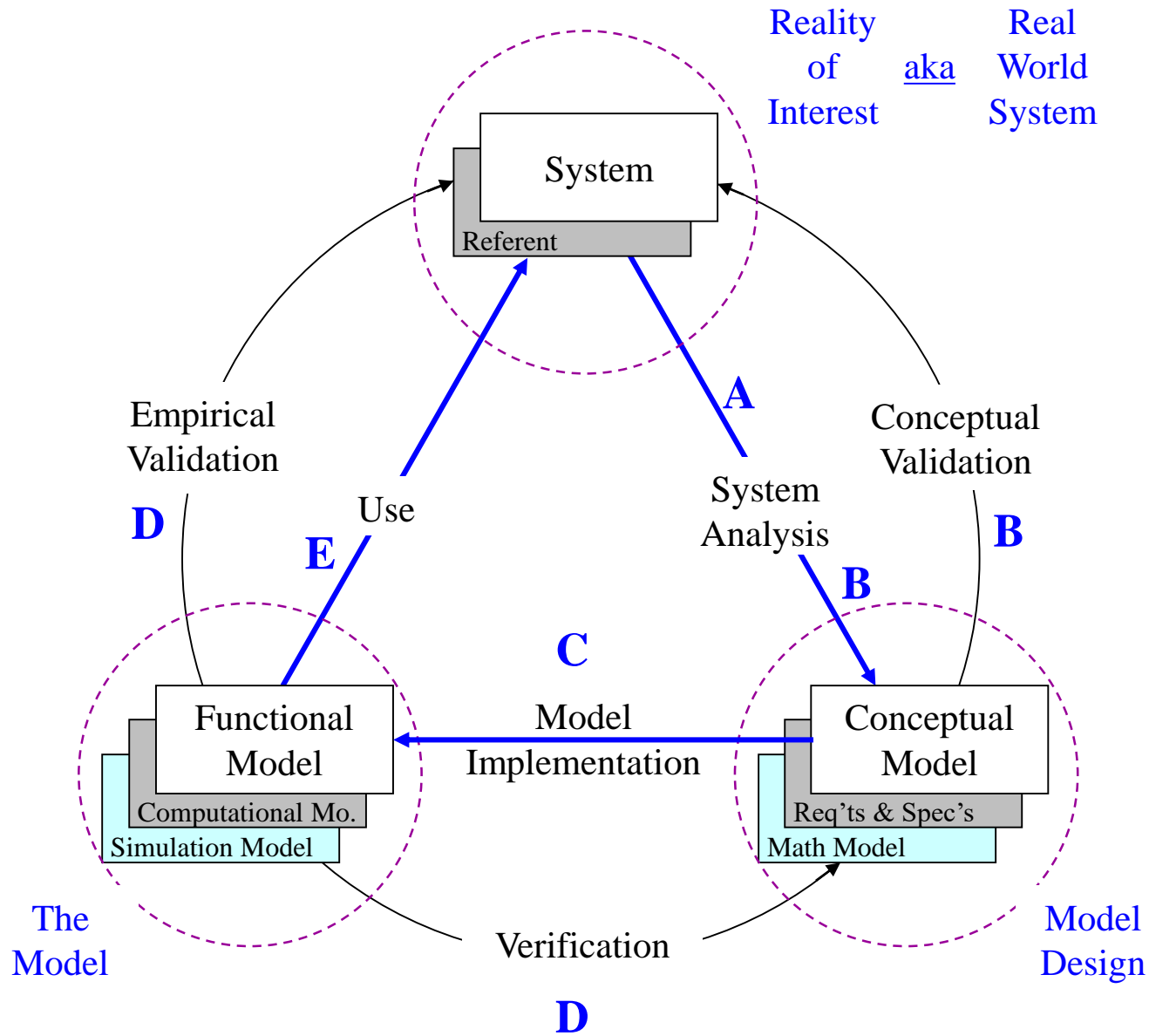
**Accepted Use** – The successful outcome of a Use Assessment designating that the M&S is accepted for a Proposed Use.

**Actual Use** – The specific purpose and domain of application for which an M&S is being, or was, used.





# The Fundamental M&S Process



# M&S Development Concepts



- Document Aspects of the **RWS** to Model
- Document M&S **Design**
  - Conceptually Validate the M&S Design prior to Implementation
- Implement the M&S
- Distinctly & Separately
  - **Verify** the M&S
  - **Validate** the M&S, including:
    - Accuracy (& Precision)
    - Abstractions & Assumptions
    - Characterizing Uncertainty
    - Characterizing Sensitivities
- Document **Permissible Uses** of the M&S

# M&S Use Concepts



- Assessment of the Use of the M&S – Compare its Proposed Use to its Permissible Uses
- Plan & Document M&S Setup & Scenarios for Use
- Characterize M&S Uncertainties in
  - The M&S
  - M&S Scenarios (Inputs)
  - M&S Output (Results)
- Understand Sensitivities in M&S Results
- Placard Results for Uses outside Permissible Uses {Charts 13-14}
- Assess Credibility {Chart 12}
- Report Results Completely {Charts 13-15}



# Reporting M&S Results

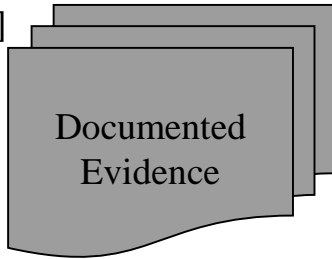


- Estimated Results
- Results Uncertainty
  - The Processes to Obtain the estimate of Uncertainty
- Results Sensitivity
- Caveats to Results / Analysis
  - Unachieved Acceptance Criteria
  - Violation of
    - any Assumptions
    - the Limits of Operation
  - Warning and Error Messages
  - Unfavorable
    - Proposed use assessments
    - Setup/Execution Assessments
  - Waivers to Requirements
- Technical Review Findings
- Qualifications of
  - Developers
  - Users/Analysts
- What's Documented
  - & What is Not Documented
- Assessment of and Rationale for the Risks associated with the M&S Use
  - Criticality
  - Caveats
  - Uncertainty
  - Credibility
  - Technical Review
  - People Qualifications
  - M&S Doc'n

# M&S Results Reporting



[M&S 38]

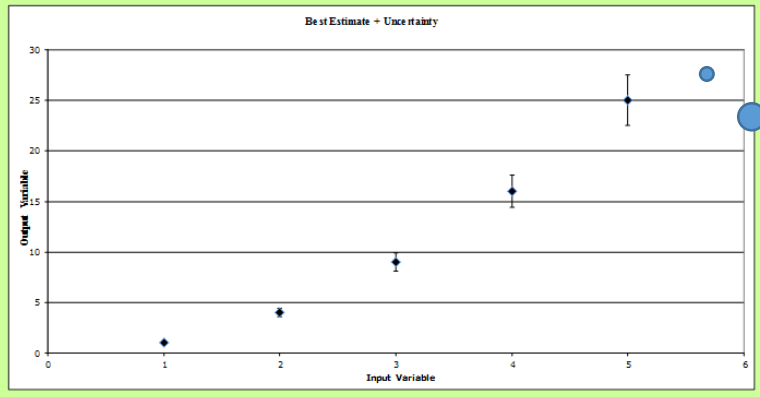


Documented Evidence

Estimate

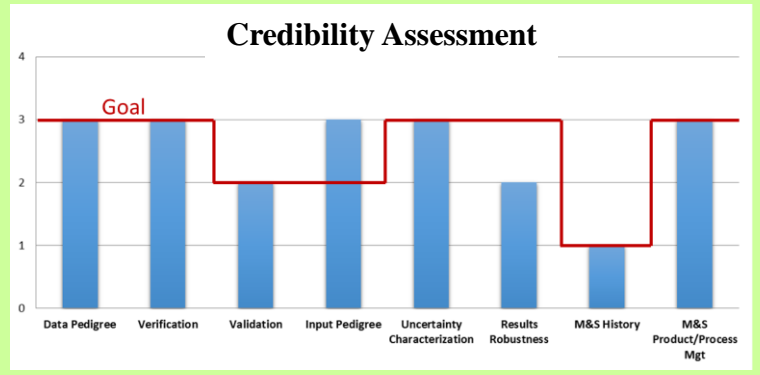
[M&S 33]

## Estimate w/ Uncertainty



[M&S 35]

## Credibility Assessment



[M&S 32]

## Analysis Caveats:

- Unachieved acceptance criteria
- Violation of Assumptions
- Violation of Limits of Operation
- Execution Warnings & Errors
- Unfavorable Intended Use
- Req't Waivers

**CAUTION**

**Analysis Performed Outside the Limits of Operation**

[M&S 26 (2)]

[M&S 39]

## M&S Risk Elements:

- Criticality
- Caveats
- Uncertainty
- Credibility
- Technical Review
- People Qualifications
- M&S Doc'n

<b>Likelihood</b> (of inability to correctly represent the RWS)	5: Very High	
	4: High	
	3: Moderate	
	2: Low	
	1: Very Low	
		<b>Elements of Risk</b>

# M&S Risk Assessment



- Taken with the knowledge of Criticality (Appendix D)

<b>Likelihood</b> (of inability to correctly represent the RWS)	5: Very High	Red
	4: High	Red
	3: Moderate	Yellow
	2: Low	Light Green
	1: Very Low	Light Green
	<b>Elements of Risk</b>	

- Do any of the Reporting Elements increase the likelihood of the M&S incorrectly representing the RWS?

- Caveats
- Uncertainty
- Credibility
- Technical Review
- People Qualifications
- M&S Documentation

- The Risk incurred from a Model or Simulation is in its ability to correctly represent the Real World System (Reality of Interest)
- The Risk to the RWS is assessed by the Decision Maker

# Last Words



- Application of all the Requirements in All situations may be daunting
- Applying a Standard to ALL Types of M&S is challenging
- Tailoring is permitted, if
  - Documented
  - Approved by the appropriate Technical Authority
- Consult Discipline Specific Recommended Practices