M&S Use Risk Identification and Management

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Presentation Outline

This presentation will focus on the M&S Use Risk Methodology (MURM) and will cover:

- **Why the MURM was developed**
- **What the MURM is, an overview**
- **Basic steps in the MURM**
- **Key MURM Elements**
- **Expected MURM outputs and benefits**

MURM Background

MURM Objectives

Leverage existing concepts to evolve a methodology to:

- **Weigh VV&A investments against the risk of making a bad decision due to unreliable M&S results**
- **Tailor the V&V and Accreditation Efforts based on risk**
- **Perform Methods/Technique/Resource Trade-offs**

Why MURM?

Previous risk-based M&S assessments have deficiencies:

- Lack cogent mathematical foundation
- Sometimes included unintended bias
- Can't explicitly relate V&V endeavors to risk

Fundamental Driver for MURM: the need to combine M&S risk assessment and VV&A planning in a coherent fashion.

M&S Use Risk Methodology (MURM) provides:

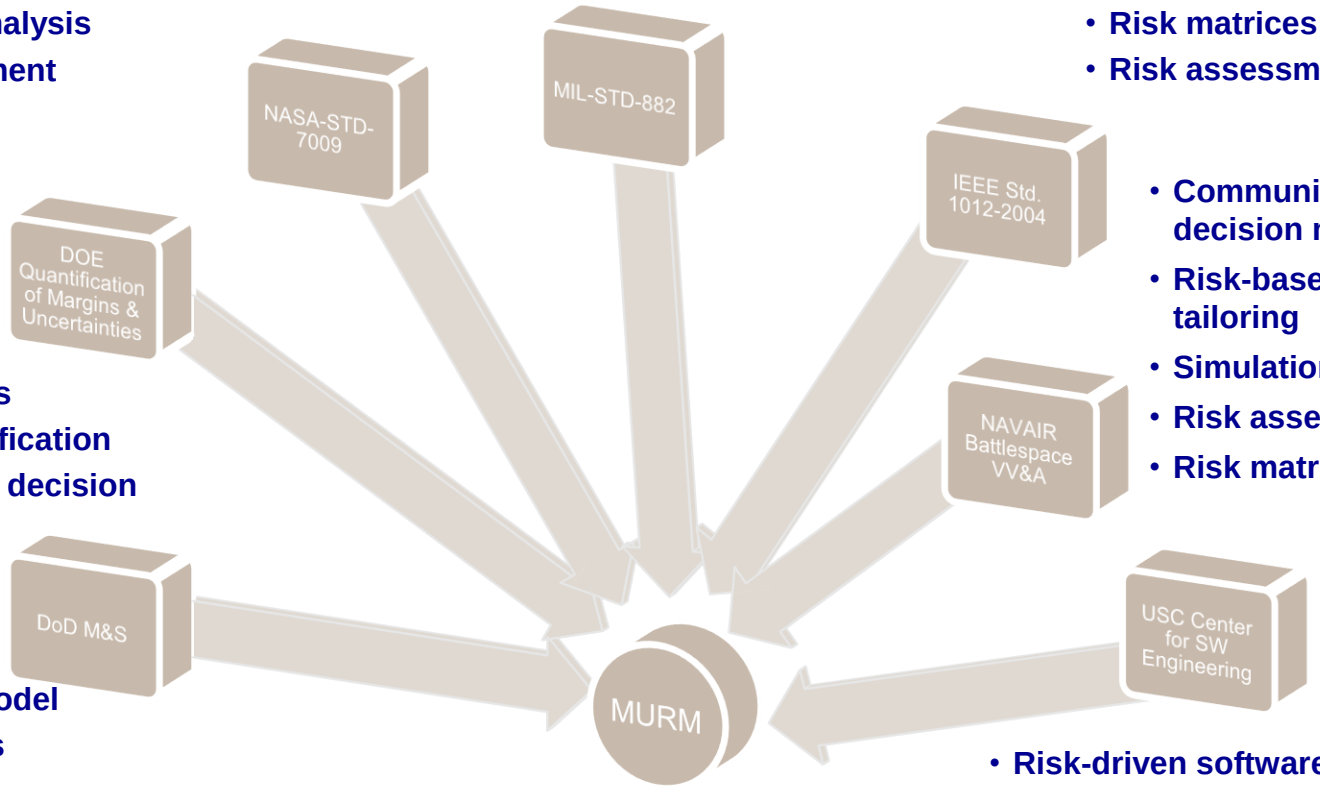
- Coherent math foundation for M&S Use Risk
- Minimizes or avoids unintended bias
- Explicit relation of V&V to M&S Use Risk
- Facilitates automation of M&S Use Risk assessment

The MURM Builds upon Existing Concepts

- Communication to decision makers
- Uncertainty quantification
- Credibility assessment
- Sensitivity analysis
- Risk assessment

- Severity categories
- Probability levels
- Risk assessment values
- Risk acceptance levels

- Risk-based V&V tailoring
- Software integrity level
- Risk matrices
- Risk assessment



- Confidence ratios
- Sensitivity analysis
- Uncertainty quantification
- Communication to decision makers

- Communication to decision makers
- Risk-based VV&A tailoring
- Simulation importance
- Risk assessment
- Risk matrices

- V&V Composite Model
- Validation Process Maturity

- Risk-driven software development
- Spiral development model

Risk & Risk-related Analysis Is Complex

- Review of standards found half-dozen definitions each with negative, neutral, and broad connotations for risk, which indicates the complexity of the subject.
- Descriptors often indicate the aspect of risk being addressed: e.g., programmatic risk, technical risk, operational risk, etc.
- Many simplify risk and treat the approach as if it fully addresses risk. Common definition is:

  Risk = (likelihood of Error) * (Consequence of Error)

- MURM focuses on a definition that accommodates both assessment of the consequences of using M&S results and the impact of V&V planning and execution.

MURM Definition

M&S Use Risk – Key Definition

- MURM is not just a collection of tables and figures. MURM applies an underlying mathematical formula based on the definition for M&S Use Risk:

  The probability that inappropriate application of M&S Results for the intended use will produce unacceptable consequences to the decision-maker.

- MURM calculations are driven by:

  (1) P(Causes)
  - The maturity of the definition of M&S use space
  - The relationship of the requirements
  - The rigor of the V&V Evidence

  (2) P(Effects)
  - The impact if the M&S results are applied incorrectly
  - The Reliance on the M&S

- Math Logic Foundation enables:
  - Explicit relationship of M&S Use Risk to V&V endeavors
  - Facilitates automation of UR assessment

MURM Implementation

MURM Mathematical Basis

- MURM calculations are based on Dr. Pete Pandolfini's Decision Support Analysis Tool (DSAT)
- A DSAT is a model synthesizing the elements of a decision to inform decision-makers about the decision space
- DSAT is grounded in objectivity, using only available (justified) information, defensible mathematics, and the maximum information entropy principle

KEY ELEMENTS OF THE MURM CALCULATIONS

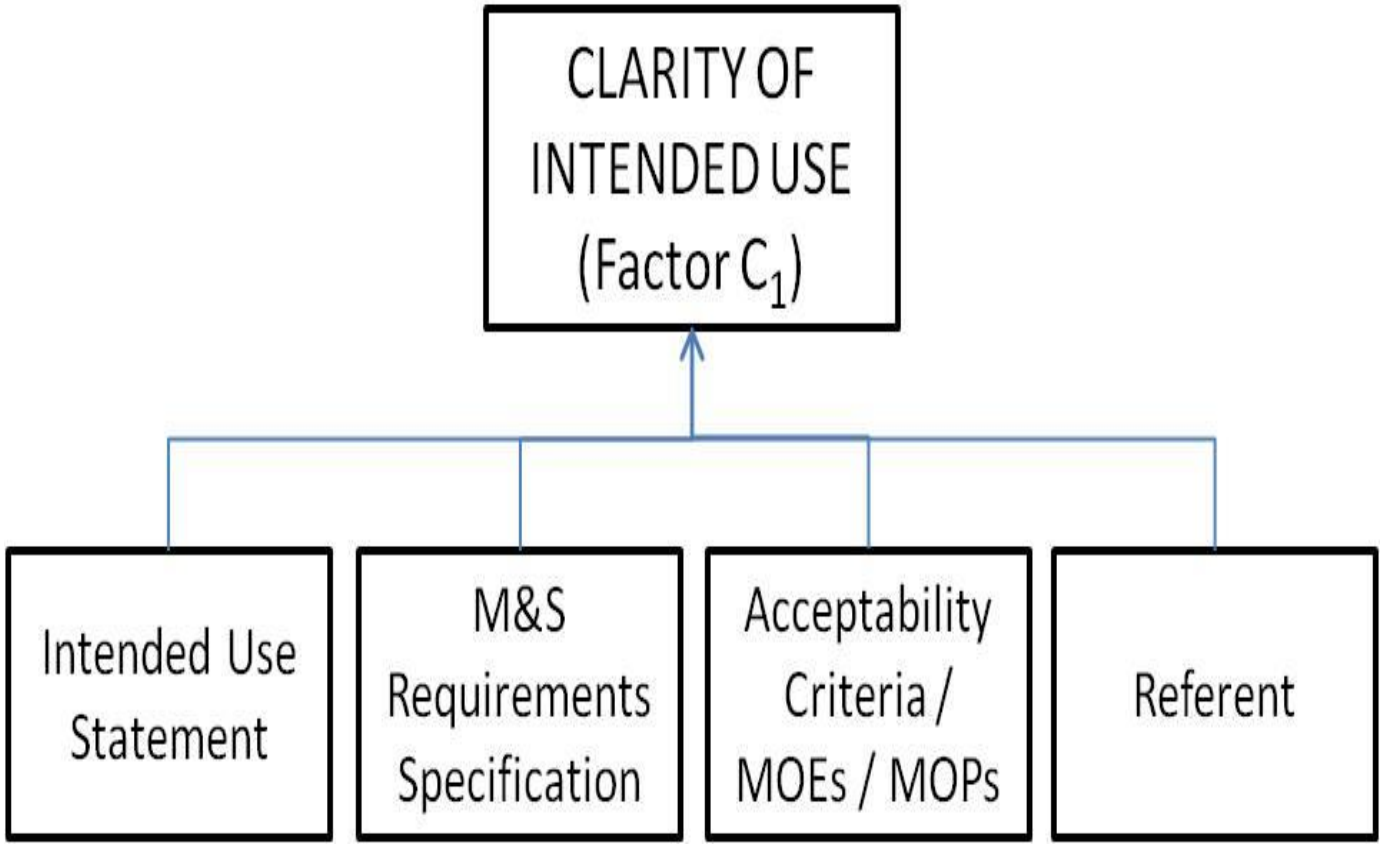
- **Evaluation Factor – Key Components of the MURM Calculation**
- **State Tables – List of the possible levels for an Evaluation Factor**
- **Factor Weighting – Allows the assessment to emphasize characteristics and/or Evaluation Factors that are more critical**

Decomposition of P(Causes)

p(Causes) is derived from:

- C_1 ≡ Level of understanding associated with how the M&S will be used, the required representation, and Referent Knowledge (i.e., Clarity)
- C_2 ≡ Prioritization of Requirements (i.e., Importance)
- C_3 ≡ Rigor of the V&V Evidence Collected (i.e., Confidence)

CLARITY OF INTENDED USE (MURM FACTOR C_1)



Example: State Table Probabilities For Causes

Table F-2: State Table for Factor C_1 (Clarity), Assignment of $p(C_1)$

Factor Level	Clarity of Intended Use	Level Weighting	$p(C_1)$
A	Lucid	1	0.167
B	Partial clarity	3	0.5
C	Unclear	5	0.833

Table F-3: State Table for Factor C_2 (Importance), Assignment of $p(C_2)$

Factor Level	Consequence / Mitigation	Level Weighting	$p(C_2)$
A	Negligible consequence / Mitigation not required	1	0.038
B	Negligible consequence / Mitigation complete	3	0.115
C	Negligible consequence / Mitigation partial or Minor consequence / Mitigation complete	6	0.231
D	Negligible consequence / Mitigation impossible or Minor consequence / Mitigation partial or Serious consequence / Mitigation complete	11	0.423
E	Minor consequence / Mitigation impossible or Serious consequence / Mitigation partial or Grave consequence / Mitigation complete	17	0.654
F	Serious consequence / Mitigation impossible or Grave consequence / Mitigation partial	22	0.846
G	Grave consequence / Mitigation impossible	25	0.962

Examples of factor state tables

Built using mathematical logic & maximum information entropy principle

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Decomposition of P(Effects)

p(Effects) is the probability of the effects resulting from unacceptable consequences to the decision-maker and is derived from to key components: M&S Impact and M&S Reliance

- **M&S Impact is an indication of how much information the M&S is providing relative to the decision space.**
- **M&S Reliance is an indication of the dependence on using M&S Results in making the decision.**

M&S Impact

M&S Intended Use	M&S Impact
5	**Intended Use** addresses **multiple areas of high impact to the decision,** key experiment, study, or analysis; key program review or test event; key system performance analysis or requirements definition; primary test objective or test article design; critical operational issue; key technical or managerial decision; critical skills training; regulatory compliance, licensing, permitting, or law.
4	**Intended Use** addresses **a single area of high impact to the decision**, key experiment, study, or analysis; key program review or test event; key system performance analysis or requirements definition; primary test objective or test article design; critical operational issue; key technical or managerial decision; critical training; regulatory compliance, licensing, permitting, or law.
3	**Intended Use** addresses **multiple areas of medium and low impact to the decision**, other experiment, study, or analysis, other program review or test event; other system performance analysis or requirements definition; secondary test objective; other skills training; other technical or managerial decision.
2	**Intended Use** addresses **a single area of medium impact to the decision**, other experiment, study, or analysis, other program review or test event; other system performance analysis or requirements definition; secondary test objective; other skills training; other technical or managerial decision.
1	**Intended Use** addresses **a single area of low impact to the decision,** objective or analysis that is not a significant factor in the technical or managerial decision-making process.

User Reliance on M&S in Decision Making

M&S Reliance	
4	**M&S** will be the ***only*** method employed to support the decision-making process.
3	**M&S** will be the ***primary*** method, employed with other non-M&S methods, to support the decision-making process.
2	**M&S** will be a ***secondary*** method, employed with other non-M&S methods, to support the decision-making process, and will provide significant data unavailable through other means.
1	**M&S** will be a ***supplemental*** method, employed with other non-M&S methods, to support the decision-making process, and will provide supplemental data already available through other means.

Example: State Table Probabilities For Effects

Example of more complex Effects state table

Table F4-3: State Table for Effects Factor, Assignment of p(Effects)

Factor Level	Probability of Unacceptable Consequences to Decision-Maker Based on Dependency/Use Area	Level Weighting	p(Effects)
A	Supplemental Use/Single Low Risk Area	1	0.025
B	(Supplemental Use/Single Medium Risk Area) or (Secondary Use/Single Low Risk Area)	4	0.100
C	(Supplemental Use/Multiple Med-Low Risk Area) or (Secondary Use/Single Medium Risk Area) or (Primary Use/Single Low Risk Area)	9	0.225
D	(Supplemental Use/Single High Risk Area) or (Secondary Use/Multiple Med-Low Risk Area) or (Primary Use/Single Medium Risk Area) or (Only Use/Single Low Risk Area)	16	0.400
E	(Supplemental Use/Multiple High Risk Area) or (Secondary Use/Single High Risk Area) or (Primary Use/Multiple Med-Low Risk Area) or (Only Use/Single Medium Risk Area)	24	0.600
F	(Secondary Use/Multiple High Risk Area) or (Primary Use/Single High Risk Area) or (Only Use/Multiple Med-Low Risk Area)	31	0.775
G	(Primary Use/Multiple High Risk Area) or (Only Use/Single High Risk Area)	36	0.900
H	(Only Use/Multiple High Risk Area)	39	0.975

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EXAMPLES
CALCULATIONS OF M&S USE RISK

Suppose for Requirement #2, it is determined Effects Level is "A"

p(Causes) = 0.930
p(Effects) = 0.025

M&S Use Risk = 0.930×0.025 × [1- 0.930 + 0.930×0.025] = 0.002 (*Very Low*)

Suppose for Requirement #4, it is determined Effects Level is "C"

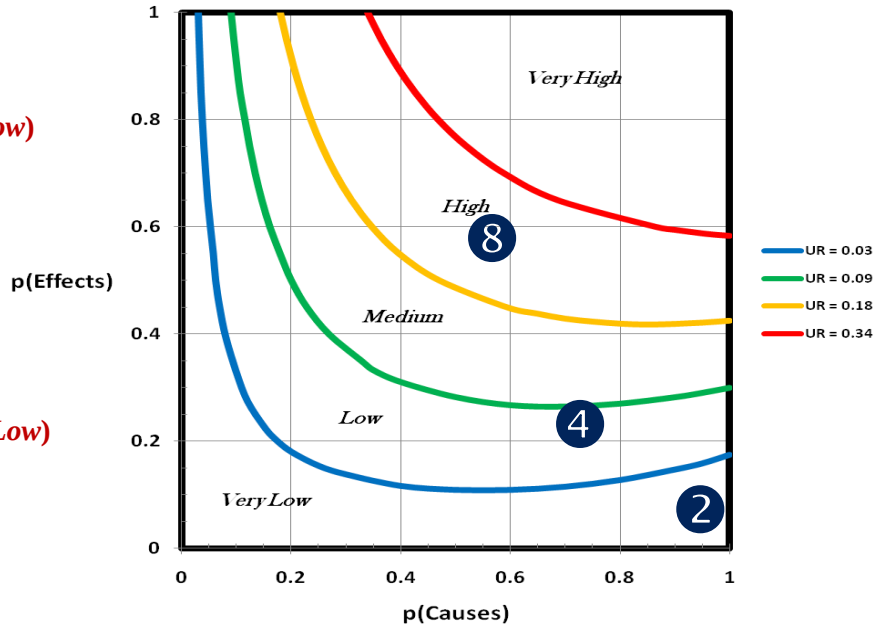
p(Causes) = 0.735
p(Effects) = 0.225

M&S Use Risk = 0.735×0.225 × [1- 0.735 + 0.735×0.225] = 0.071 (*Very Low*)

Suppose for Requirement #8, it is determined Effects Level is "E"

p(Causes) = 0.543
p(Effects) = 0.600

M&S Use Risk = 0.543×0.600 × [1- 0.543 + 0.543×0.600] = 0.255 (*High*)



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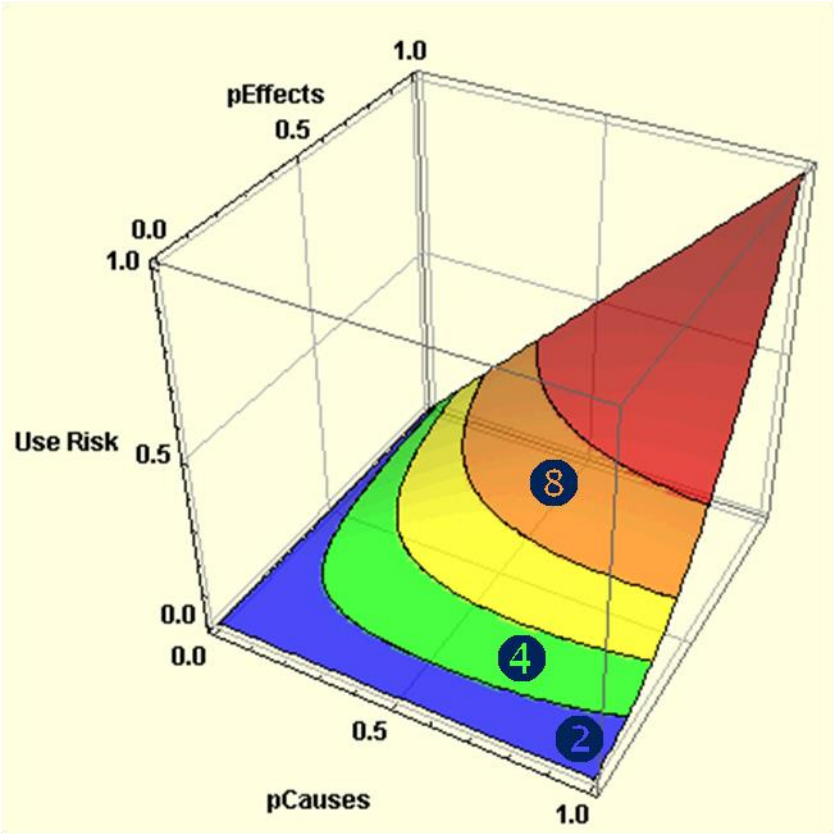
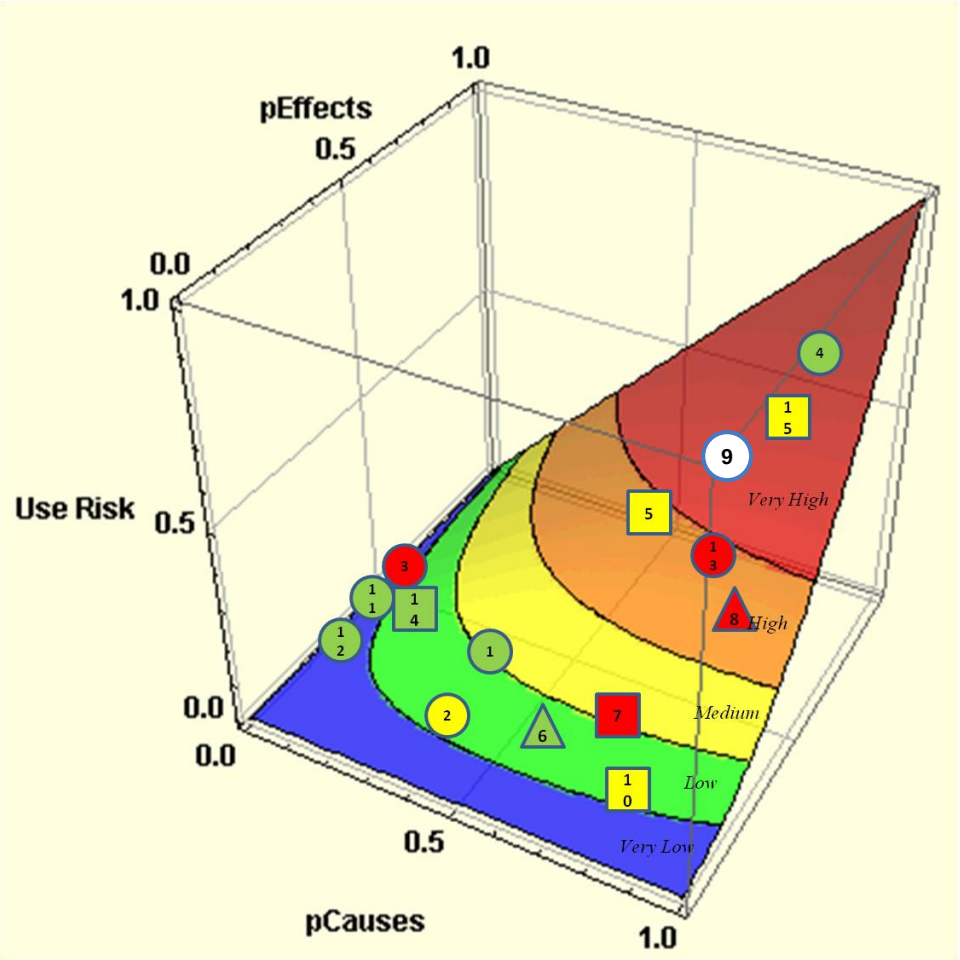


VISUALIZATION OF MURM RESULTS



Illustrated are results for 15 capabilities & their associated M&S User Risk

A capability is identified by a number within its symbol

A capability's priority is noted by the shape of its symbol

A capability's disposition is noted by the color of its fill

The position of the capability's symbol on the risk surface indicates its M&S User Risk; the surface is divided into five equal area regions and are labeled from Very Low risk to Very High risk.

The distribution of the symbols give a sense of the User Risk status of the M&S; for example, #4, a high priority capability, met its acceptability criteria but the risk level, perhaps driven in part by the $p(C_3)$ recommendation confidence, propels it into the high user risk region.

Comments about MURM

- MURM allows full use of *ALL* available information in Use Risk assessment: objective (quantitative), limited (such as only knowing ranking of alternatives), and subjective
- Use of information entropy theory reduces or precludes inadvertent & intended bias in assessment
- MURM operates at M&S individual capability levels (vice only treating M&S results as a whole)
- State tables support Use Risk computation – can be developed to the level supported by available information
- Any sophisticated math methodology requires particular math skills. With automation, V&V personnel will be able to use MURM just as *Mathematica* is used effectively by those without the math skills to apply all of its techniques without use of that program.

More Information Is Available

For detailed discussion of MURM and its application or to obtain the MURM report:

Contact Simone Youngblood (JHU/APL) at

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