Risk-Based VV&A (RBA) Methodology Update

Presented to the NDIA M&S Committee

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V-C-2 Roadmap: Improving VV&A Implementation

Task Performers:
1. The Johns Hopkins University Applied Physics Laboratory (a DoD University Affiliated Research Center)
2. Aeronautical Systems Center’s Simulation and Analysis Facility (SIMAF)
3. Naval Air Systems Command’s Battlespace Modeling Verification & Validation Branch (BMVVB)
4. Systems Engineering Research Center (SERC) (a DoD University Affiliated Research Center)
Risk Based Accreditation (RBA)

Balancing the cost of knowing against the risk of assuming.
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
Steps in Building the RBA Approach

May 2009

RBA Literature Survey
- Collected > 350 references
- Organized references into 6 categories:
  - Decision making
  - Risk management
  - Risk assessment
  - Uncertainty analysis
  - VV&A
  - General techniques

October 2009

RBA Method Assessment
- Identified & evaluated over 60 methods from the literature survey
- Combined with a previous V&V technique assessment to build a technique ontology with > 200 methods
- Discovered no significant technological gaps in realizing RBA
- Identified several opportunities to apply techniques from other domains to VV&A

RBA Initial Methodology
The RBA Methodology Builds upon the Concepts from Many Sources and Thinkers

- 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

- V&V Composite Model
- Validation Process Maturity

- Risk-driven software development
- Spiral development model

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

- Validation Process Maturity
- Risk-driven software development
- Spiral development model
Motivation for Tailoring VV&A Processes:
- Every VV&A problem is different because of differences in
  - Uses of M&S
    - M&S requirements
    - Tolerable use risks
  - Resource constraints
    - Available information
    - People & skills
    - Funding
    - Time
  - When VV&A starts in the M&S life cycle
- No single set of VV&A activities & tasks can efficiently accommodate all of these differences.
- Today, VV&A practitioners lack concrete tailoring guidance so they re-invent their VV&A processes with each problem.
- This solution works but produces results that cannot be reliably independently repeated or efficiently taught.
Use Risk Concepts

- Use Risk Estimate is a function of:
  - simulation prediction uncertainty
  - V&V evidence uncertainty
  - simulation importance measure
- M&S Importance Measure is a function of:
  - probability that M&S limitations will adversely affect the intended use
  - consequences of those effects

The simplest functions for describing use risk are the products of the uncertainties and importance measure.
The Initial RBA Overview

1.0 Determine Needed Capabilities
- Obtain Requirements 1.1
- Identify Capabilities 1.2
- Group Requirements 1.3

M&S Intended Uses

2.0 Characterize Risk Areas
- Specify M&S Impact on User Decision 2.1
- Determine Capability Importance 2.2
- Determine Capability Maturity Level 2.3

3.0 Plan V&V
- Choose Activities and Tasks 3.1
- Choose Techniques 3.2
- Estimate Schedule, Cost & Resource Requirements 3.3
- Estimate Schedule, Cost & Resource Requirements 3.4

3.1 V&V Composite Model
- V&V Technique Ontology
- Cost Model
- Schedule
- Resources

4.0 Collect and Report V&V Evidence
- Characterize M&S Capabilities 4.1
- Characterize M&S Limitations 4.2
- Communicate Evidence to Users 4.3
Steps in the RBA Methodology

- Obtain requirements from users & their representatives
- Identify needed representational capabilities
- Organize needed capabilities into related groupings

- Determine if the user can specify the M&S role
- Determine M&S importance to each capability
- Determine needed validation maturity level from assigned importance

- Choose V&V activities & tasks to be performed
- Choose V&V techniques to meet needed validation maturity
- Estimate schedule, costs & resource requirements

- Characterize M&S capabilities
- Characterize M&S limitations
- Communicate V&V evidence to the M&S users
Decomposing M&S Capabilities and Assigning Importance Levels to Identify Risk

Object Hierarchy

Air-Ground Warfare
  - Air Defense
  - Aircraft
    - F-16
    - A-10
      - Sensors
      - Weapons
        - AGM-65
        - GBU-12
          - Laser Guidance
          - Mk-82 Warhead

<table>
<thead>
<tr>
<th>Object</th>
<th>M&amp;S Importance Level</th>
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The RBA Tailoring Concept

Accreditation Information Needs → Acceptability Criteria

Generate V&V Plan Scope & Assumptions

Select the V&V Activities & Tasks

VV&A Composite Model

Choose the V&V Techniques

VV&A Technique Catalog

Allocate Resources to the V&V Tasks

Build the V&V Effort Schedule

Validation Referent

Use Risk Characterization

Available Resources

V&V Plan Scope & Assumptions

V&V Activities & Tasks

V&V Techniques

V&V Resource Allocation

V&V Effort Schedule
The VV&A Composite Model

- **Plan the V&V Effort**
  - Develop the V&V Approach
  - Identify the V&V Resources
  - Build the V&V Schedule
  - Estimate the V&V Costs
  - Prepare the V&V Plan
  - Execute & Evolve the V&V Plan

- **Apply Relevant Historical Information**
  - Collect & Analyze Developer Accounts of Simulation Capabilities & Limitations
  - Collect & Analyze the V&V and Testing Histories
  - Collect & Analyze Prior Use History
  - Integrate & Employ the Historical Evidence

- **Verify & Validate the Simulation Conceptual Model**
  - Verify the Simulation Conceptual Model
  - Validate the Simulation Conceptual Model
  - Verify & Validate Available Scenarios
  - Integrate & Employ the Conceptual Model V&V Evidence

- **Perform Supplemental Verification**
  - Determine the Scope of Supplemental Verification Needed
  - Verify the Simulation Design Products
  - Verify the Simulation Object Code
  - Verify the Simulation Executable
  - Verify the Development Products against the Simulation Conceptual Model
  - Verify the Development Products for Standards Compliance

- **Apply the Verification Products to Validation**
  - Infer the Simulation Capabilities from the Verification Products
  - Infer the Simulation Limitations from the Verification Products
  - Infer the Information Gaps from the Verification Products
  - Employ the Verification Evidence

- **Verify & Validate the Data & Knowledge Sets**
  - Identify the Data & Knowledge Sources & Their Pedigrees
  - Verify the Data & Knowledge Sets
  - Validate Data & Knowledge Sets Where Needed
  - Integrate & Employ the Data & Knowledge V&V Evidence

- **Validate Simulation Results**
  - Leverage Developer Test Results for Results Validation
  - Derive Results Validation Test Scenarios
  - Plan for Results Validation
  - Collect Simulation Output for Results Validation
  - Integrate & Employ the Validation Testing Results

- **Integrate the V&V Evidence**
  - Integrate the V&V Evidence
  - Prepare the V&V Report
  - Support Any Archival of the V&V Products
The VV&A Technique Catalog

- Constructed upon the foundation first established by Balci, 1996

- Significantly augmented by the results from a massive search of the risk and VV&A literature to identify techniques that could support risk-based accreditation

- Currently, catalogs and organizes techniques into a tentative taxonomy

- Will evolve that taxonomy into an ontology by
  - Maturing the elements of the taxonomy
  - Capturing the relationships between techniques
  - Capturing the relationships between techniques & VV&A tasks
The RBA Map of Known Use Risks across the Capabilities Landscape

<table>
<thead>
<tr>
<th>REQ ID</th>
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Summary of the RBA Approach

Optimize the V&V Process

- Group M&S capability needs to focus the V&V process
- Prioritize capability need groups by M&S importance to tighten the focus of the V&V effort upon the important capabilities
- Choose V&V tasks to provide the needed coverage
- Choose techniques according to the maturity required by M&S importance
- Reduce & quantify uncertainties according to M&S importance
- Execute the RBA methodology as turns around a spiral that successively refine & enhance the V&V evidence

Minimize Use Risk

- Use M&S importance as a V&V process optimization criterion
- Quantify M&S uncertainties
- Reduce V&V process uncertainties where possible
- Quantify the V&V process uncertainties that cannot be reduced
- Estimate the use risks from the M&S importance & uncertainties
- Provide the user with a map of M&S capabilities & use risks so they can minimize their use risks