
Abstract:

NASA's Exploration Systems Mission Directorate (ESMD) is implementing a management approach for modeling and simulation (M&S) that will provide decision-makers information on the model's fidelity, credibility, and quality. This information will allow the decision-maker to understand the risks involved in using a model's results in the decision-making process. This presentation will discuss NASA's approach for verification and validation (V&V) of its models or simulations supporting space exploration. This presentation will describe NASA's V&V process and the associated M&S verification and validation (V&V) activities required to support the decision-making process. The M&S V&V Plan and V&V Report templates for ESMD will also be illustrated.
An Overview of NASA's IM&S Verification and Validation Process Plan and Specification for Space Exploration

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Centralized oversight and decentralized execution of IM&S VV&A activities across ESMD to increase credibility and reduce risks associated with decisions based on M&S.

IM&S VV&A is the complement to the overall IM&S Strategy!
**The Core Process of IM&S VV&A**

**VERIFICATION**
The process of determining that a model [or simulation] implementation and its associated data accurately represents the developer’s conceptual description and specifications... *Did we build that thing right?*

**VALIDATION**
The process of determining the degree to which a model [or simulation] and its associated data provides an accurate representation the real world from the perspective of the intended uses of the model or simulation... *Did we build the right thing?*

**ACCREDITATION**
The official certification that a model or simulation or federation of models and simulations and its associated data is acceptable for use for a specific purpose... *Should it be used?*

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**An underlying implicit principle is Creditability: Can It be trusted?**
Purpose of IM&S

- Modeling and Simulations (M&S) are Integral to every aspect of the ESMD Program (Program -> Projects -> Components)
  - Cost Analysis
  - Risk Assessments
  - Planning
  - Requirements Definition
  - Test and Verification
  - Technology Evaluation
  - Training

- Effective Management of M&S has several key Objectives
  - Provide Timely Trusted Data for Decision Makers
  - Reduce Lifecycle Cost and Risk
    - Better requirements, designs, tests, training
  - Minimize Slips in Schedule
    - Timely data for decision makers to support Prioritizing Efforts

Institutionalizing M&S Management and VV&A Practices Early is Critical to Long-Term Success
Additional Influences

- Numerous Reports Have Identified Significant Issues with the Use (misuse) of M&S within NASA
  - Ineffective use, access, and "outright misuse"
  - Need for Validated M&S Tools
  - Need for Management of M&S tools across Agency

- FY'05 Congressional Direction for NASA to establish a M&S Strategy and Implementation
  - "...develop and implement an integrated system simulation strategy".

NASA Must Address The Management (Development, VV&A and Use) of M&S!
Current Situation

- Multiple Levels of new Management (L1-L3)
- Aggressive Development Schedule with Independent Milestones
- Involvement of Multiple Centers
  - Each vying for $ 
  - Each with Own M&S Tools, Processes, and Capabilities
- Wide Spectrum of M&S Tools
  - Project Needs are being Identified and Developed Independently
  - Tool Funding Path is not aligned to ESMD Management Structure
  - Redundancy in Capability is Common
  - Leveraging Existing Capabilities is based on self Discovery
  - Gaps in Capability Exist
  - VV&A is Rare – Trust in Analysis Results is based on Individuals.
  - Impact of VV&A is Imposing if Required Uniformly Across ESMD

Need to Establish a “Common Sense” VV&A Approach
Recommended Approach

• Establish a Unified Paradigm for the VV&A of M&S throughout ESMD
  – Centralized Guidance with Decentralized Execution to:
    – Define M&S and VV&A Policy
    – Define standards (e.g. interface, interoperability, data)
    – Develop M&S Management Roles/Responsibilities to be levied on existing
      Program/Project Management Structures
    – Require Program and Projects to Develop M&S Support Plans
      – Document the Use of M&S in support of Program and Project Level Activities.
      – Identify M&S Gaps and Overlaps to support future development needs/priorities.
      – Mandate Risk Based VV&A Implementation – 5 Levels (High risk = significant
        VV&A).
  – Facilitate Communication of M&S Capabilities across ESMD through an M&S
    Resource Repository (Metadata of accredited M&S).

Goal: Establish Effective M&S VV&A Policy and Practices Supporting Space Exploration!
<table>
<thead>
<tr>
<th>Roles</th>
<th>Function</th>
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</thead>
<tbody>
<tr>
<td>IM&amp;S VV&amp;A TWG Lead</td>
<td>• POC for VV&amp;A Planning Guidance</td>
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<tr>
<td></td>
<td>• Oversee assimilation of VV&amp;A into program planning</td>
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<td></td>
<td>• Oversee outreach and indoctrination activities across ESMD</td>
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<td></td>
<td>• Oversee and manage MSRR</td>
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<tr>
<td>IM&amp;S VV&amp;A Brokers</td>
<td>• Conduct VV&amp;A Outreach</td>
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<td></td>
<td>• Oversee/audit VV&amp;A Planning and Activities</td>
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<td></td>
<td>• Review and approve VV&amp;A products</td>
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<td></td>
<td>• Assess M&amp;S PM manage agents</td>
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<tr>
<td></td>
<td>• Collect metadata for MSRR</td>
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<td></td>
<td>• Representative in SE&amp;I and T&amp;E planning activities</td>
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</table>

IM&S VV&A Technical Working Group is the Market Bringing Together M&S Sponsors, Users, Developers and VV&A Agents!
Overview of IM&S VV&A Roles and Responsibilities

**IM&S VV&A TWG Lead & VV&A Brokers**
- Define and maintain policy guidance and directives for ESMD IM&S VV&A
- Conduct VV&A Outreach
- Assign VV&A TWG Support
- Support M&S Risk Assessment
- Develop Simulation Capability Documentation
- Assist in developing Accreditation and V&V Plans and Reports
- Develop Simulation Capability Documentation
- Concur on all
  - Accreditation Plans
  - V&V Plans
  - V&V Reports
  - Accreditation Reports
  - Data V&V Reports

**Users, Accreditation Agents, V&V Agents, & SMEs**
- Support M&S Risk Assessment
- Develop Accreditation Criteria
- Develop Accreditation Plans
- Develop V&V Plans
- Develop V&V Reports
- Conduct V&V program
- Conduct Data V&V
- Develop Accreditation Reports
- Develop Accreditation Memoranda

Clear Demarcation of IM&S VV&A Roles and Responsibilities.
# Key Players of IM&S VV&A Process

<table>
<thead>
<tr>
<th>Roles</th>
<th>Function</th>
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<tbody>
<tr>
<td>M&amp;S User</td>
<td>• Identify and defines need for M&amp;S to solve problem or make decision.</td>
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<tr>
<td></td>
<td>• Define M&amp;S requirements,</td>
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<td>• Define Accreditation criteria,</td>
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<td>• Intended use,</td>
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<td>• Makes accreditation decision,</td>
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<td>• Accepts the results.</td>
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<tr>
<td>M&amp;S PM</td>
<td>• Planning and Managing resources for M&amp;S development</td>
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<td></td>
<td>• Direct overall M&amp;S effort</td>
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<td></td>
<td>• Oversee CM and maintenance of simulation</td>
</tr>
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<td></td>
<td>• Mange modification effort of legacy M&amp;S</td>
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<tr>
<td>M&amp;S Developer</td>
<td>• Constructing or modifying the M&amp;S</td>
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<tr>
<td></td>
<td>• Prepare the data used in M&amp;S</td>
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<td></td>
<td>• Provide technical expertise on M&amp;S capabilities</td>
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<tr>
<td>Roles</td>
<td>Function</td>
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<td>-----------------------------</td>
<td>--------------------------------------------------------------------------</td>
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<tr>
<td>M&amp;S V &amp;V Agent</td>
<td>• Provide evidence of M&amp;S fitness for intended use by ensuring that all VV&amp;A tasks are properly carried out.</td>
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<tr>
<td>M&amp;S Accreditation Agent</td>
<td>• Conduct accreditation assessment</td>
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<td></td>
<td>• Provides guidance to the V&amp;V Agent to ensure all necessary evidence is obtained of M&amp;S fitness</td>
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<td></td>
<td>• Collects and assess the evidence</td>
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<td></td>
<td>• Provides the results to User</td>
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<td></td>
<td>• Make accreditation decision (i.e. accreditation authority)</td>
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<tr>
<td>M&amp;S Proponent</td>
<td>• Manage M&amp;S throughout the lifecycle</td>
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<td>• Configuration Control of official version</td>
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<td></td>
<td>• Maintain and enhance capability</td>
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<td>• Manage usage, protect form damage and misuse</td>
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<tr>
<td>SME</td>
<td>• An auxiliary role that contributes to VV&amp;A effort</td>
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<tr>
<td></td>
<td>• Recognized authority in specific area or discipline</td>
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<td></td>
<td>• Help user establish requirement and acceptability criteria</td>
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<td>• Participate in V&amp;V and Accreditation assessment activities as needed</td>
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</table>
## IM&S VV&A Roles and Responsibilities Matrix

**Pre-decisional DRAFT**

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>VV&amp;A TWG Lead</th>
<th>VV&amp;A TWG (Brokers)</th>
<th>User</th>
<th>M&amp;S PM/Proponent</th>
<th>Developer</th>
<th>V&amp;V Agent</th>
<th>Accreditation Agent</th>
<th>SME</th>
</tr>
</thead>
<tbody>
<tr>
<td>VV&amp;A Outreach</td>
<td>Lead</td>
<td>Assist</td>
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<tr>
<td>Risk Assessment</td>
<td>Assist</td>
<td>Lead</td>
<td>Monitor</td>
<td>Assist</td>
<td>Assist</td>
<td>Assist</td>
<td>Assist</td>
<td></td>
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<tr>
<td>Develop Simulation Capability Document (Basis of Confidence)</td>
<td>Approve</td>
<td>Lead</td>
<td>Assist</td>
<td>Assist</td>
<td>Assist</td>
<td>Assist</td>
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<td></td>
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<tr>
<td>Define Acceptability Criteria</td>
<td>Approve</td>
<td>Assist</td>
<td>Monitor</td>
<td>Assist</td>
<td>Assist</td>
<td>Assist</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Develop Accreditation Plan</td>
<td>Concur</td>
<td>Assist</td>
<td>Review</td>
<td>Review</td>
<td>Assist</td>
<td>Lead</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Develop V&amp;V Plans</td>
<td>Concur</td>
<td>Assist</td>
<td>Review</td>
<td>Review</td>
<td>Review</td>
<td>Lead</td>
<td></td>
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<tr>
<td>Verify &amp; Validate Data</td>
<td>Concur</td>
<td>Review</td>
<td>Approve</td>
<td>Monitor</td>
<td>Assist</td>
<td>Lead</td>
<td></td>
<td>Perform</td>
</tr>
<tr>
<td>Prepare V&amp;V Report</td>
<td>Concur</td>
<td>Assist</td>
<td>Review</td>
<td>Review</td>
<td>Lead</td>
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<tr>
<td>Gather Additional Accreditation Info</td>
<td>Monitor</td>
<td>Monitor</td>
<td>Assist</td>
<td>Assist</td>
<td>Lead</td>
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<tr>
<td>Prepare Accreditation Report</td>
<td>Concur</td>
<td>Assist</td>
<td>Monitor</td>
<td>Review</td>
<td>Lead</td>
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<tr>
<td>Accreditation Decision</td>
<td>Assist</td>
<td>Lead</td>
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<tr>
<td>Prepare Accreditation Memo</td>
<td>Concur</td>
<td>Assist</td>
<td>Review</td>
<td></td>
<td>Lead</td>
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</table>

### Role Definitions

- **Lead**: Leads the task. Normally involves active participation from others.
- **Perform**: Actually does the task. Normally involves little active participation from others.
- **Assist**: Actively participates in task (e.g., conducting tests, providing information).
- **Review**: Participation normally limited to reviewing results of task and providing recommendations.
- **Monitor**: Oversees task to ensure it is done appropriately but does not normally participate.
- **Approve**: Determines when an activity is satisfactorily completed and another can begin. Determines what activity should be pursued next (e.g., whether to continue on to the next scheduled activity or to return to a previous activity).
- **Concur**: Confers when an activity is satisfactorily completed.
Roles & Responsibilities Within the
**IM&S VV&A TWG**

**Pre-decisional DRAFT**

**IM&S Organizational Roles & Responsibilities**
- **Chairs**
- **Audits**
- **Members of**
- **Charters**
- **Appoints**
  - Designates for the lead role
- **Sponsors**
  - Proponent for, funds for, owns the need for
- **Designates**
  - Proposes and funds participation in
- **Provides**
  - Supplies person and funds, role

**New role that reports to IM&S manager**
**New role for IM&S in existing Org**
**Existing IM&S roles**

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**Level X IM&S Mgmt Panel**
- Recommends WG membership roles, schedule, budget...
- Provides documented need for IM&S tool (thru MSSP).

**VV&A TWG**
- Member of...
- Upon approval, Charters...

**VV&A WGs**
- Have WG members...

**Ad hoc VV&A WGs for each Tool**

**Coordinates with OCE for assignment**

**Existing ORG (some new roles)**
IM&S VV&A Activity Planning Process

Pre-decisional DRAFT

- The first step in the V&V Planning process addresses IM&S credibility requirements (that is, identifying the credibility requirements of the Accreditation Authority).

- The Accreditation Process Plan and Specification provides details for accomplishing a M&S risk assessment.

- The risk assessment will establish the extent of V&V that is to be done and the depth and volume of documentation and artifacts that must be present to support the accreditation process and formal accreditation decision.

Putting the A in Front of V&V!
Risk analyses determine the best use of all the VV&A resources available by addressing the risks inherent in the acceptance and use of M&S data.
• M&S risk analyses addresses the impact to the program if the M&S is wrong (consequences).

• This assessment is then weighted by the likelihood of the M&S being wrong (probability of occurrence) to determine the best use of all the resources available.

• The 5 x 5 probability impact diagram (PID) illustrates the range of scores for an M&S defined during the preliminary accreditation planning activities.

• The IM&S Accreditation Process Plan and Specification
  – Provides details relating to the accreditation planning
  – Addresses the multi-dimensional nature of the V&V program inherent with implementation of tailored Accreditation Support Packages (V&V products suites) that are based on:
    • Accreditation Level (~Risk Level): I (Low)
    • Accreditation Level (~Risk Level): II (Medium) or
    • Accreditation Level (~Risk Level): III (High)
VV&A is a M&S Risk Mitigation Program

In a Perfectly Engineered World,
M&S V&V Will:

1] Facilitate better program decisions and control throughout the life cycle by independent assessment and verification of requirements.

2] Enable assessment and review of M&S component designs throughout their life cycle.

3] Prevent Development Risk of over-investing in simulations that are good enough for their intended use.

4] Ensure adequate simulation-quality to enable virtual test and evaluation of digital representations of systems, thus saving on expensive physical system testing, and allowing test across otherwise impractical conditions.

5] Guard against use of a simulation outside its designed operational space, by verification of assumptions, caveats, and data-generation limitations.

M&S VV&A activities contribute to reducing program risks.
The next step in the V&V Planning process addresses the identification of the V&V requirements.

The V&V Process Plan and Specification provides the details of the ESMD M&S V&V enterprise, which are based on industry best practices as captured in:

- Department of Defense, Modeling and Simulation Office (DMSO) Recommended Practices Guide (RPG), and

Establishes Expectations and Provides Guidance for V&V Planning and Execution.
The key elements to establish M&S credibility include:

- Capability: Identifying the functional representations within the M&S; that is, what the M&S does (and what it does it not do).
- Correctness:
  - Software Correctness: Identifies errors in the software (determined by verification tasks)
  - Results (Output) Correctness: Identifies how well the M&S compares with “real world” data
- Fitness of Purpose: Identifying those aspects of the M&S that support the intended use(s).
- Usability: Identifying those features of the M&S that ensure the user does not misuse the M&S (documentation, user groups, etc.).
- Data correctness: Identifying the completeness and confidence in both input and embedded M&S data.