

Title: *An Overview of NASA's IM&S Verification and Validation Process Plan and Specification for Space Exploration*, Robert M. Gravitz, The Aegis Technologies Group, Inc., and Joseph Hale, NASA MSFC

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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ESMD IM&S VV&A Prime Directive



Pre-decisional DRAFT

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



Pre-decisional DRAFT

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?*

"It works as I thought it would."



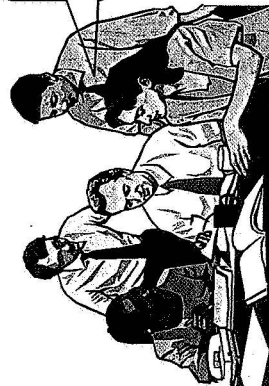
Developer
Verification Agent

"It looks just like the real thing."



Functional Expert
Validation Agent

"It suits my needs."



Requester/User
Accreditation Agent

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?*

An underlying implicit principle is Creditability: Can It be trusted?



Purpose of IM&S



Pre-decisional DRAET

- **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**

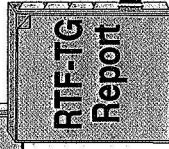
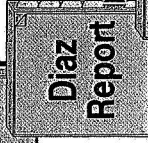


Additional Influences



Pre-decisional DRAFT

- **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



Pre-decisional DRAFT

- **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



Pre-decisional DRAFT

- **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).

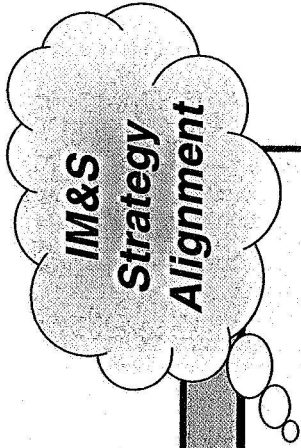
Goal: Establish Effective M&S VV&A Policy and Practices Supporting Space Exploration!



IM&S VV&A Technical Working Group (TWG)



Pre-decisional DRAFT



Roles	Function
IM&S VV&A TWG Lead	<ul style="list-style-type: none"> • POC for VV&A Planning Guidance • Oversee assimilation of VV&A into program planning • Oversee outreach and indoctrination activities across ESMD • Oversee and manage MSRR
IM&S VV&A Brokers	<ul style="list-style-type: none"> • Conduct VV&A Outreach • Oversee/audit VV&A Planning and Activities • Review and approve VV&A products • Assess M&S PM manage agents • Collect metadata for MSRR • Representative in SE&I and T&E planning activities

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



Pre-decisional DRAFT

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



Pre-decisional DRAFT

Roles	Function
M&S User	<ul style="list-style-type: none">• Identify and defines need for M&S to solve problem or make decision.• Define M&S requirements,• Define Accreditation criteria,• Intended use,• Makes accreditation decision,• Accepts the results.
M&S PM	<ul style="list-style-type: none">• Planning and Managing resources for M&S development• Direct overall M&S effort• Oversee CM and maintenance of simulation• Manage modification effort of legacy M&S
M&S Developer	<ul style="list-style-type: none">• Constructing or modifying the M&S• Prepare the data used in M&S• Provide technical expertise on M&S capabilities



Key Players of IM&S VV&A Process Continue



Pre-decisional DRAFT

Roles	Function
M&S V &V Agent	<ul style="list-style-type: none"> • Provide evidence of M&S fitness for intended use by ensuring that all VV&A tasks are properly carried out.
M&S Accreditation Agent	<ul style="list-style-type: none"> • Conduct accreditation assessment • Provides guidance to the V&V Agent to ensure all necessary evidence is obtain of M&S fitness • Collects and assess the evidence • Provides the results to User • Make accreditation decision (i.e. accreditation authority)
M&S Proponent	<ul style="list-style-type: none"> • Manage M&S throughout the lifecycle • Configuration Control of official version • Maintain and enhance capability • Manage usage, protect form damage and misuse
SME	<ul style="list-style-type: none"> • An auxiliary role that contributes to VV&A effort • Recognized authority in specific area or discipline • Help user establish requirement and acceptability criteria • Participate in V&V and Accreditation assessment activities as needed



IM&S VV&A Roles and Responsibilities Matrix



Pre-decisional DRAFT

ACTIVITY	ROLES/FUNCTIONS									
	VV&A TWG Lead	VV&A TWG (Brokers)	User	M&S PMI Proponent	Developer	V&V Agent	Accreditation Agent	SME		
VV&A Policy Development	Lead	Perform	Review	Review	Review	Review	Review	Review		
VV&A Outreach	Lead	Assist								
Risk Assessment ¹		Assist	Lead	Monitor	Assist	Assist	Assist	Assist		
Develop Simulation Capability Document (Basis of Confidence)	Approve	Lead	Assist	Assist	Assist	Assist	Assist	Assist		
Define Acceptability Criteria		Assist	Assist	Monitor	Assist	Assist	Lead	Assist		
Develop Accreditation Plan	Concur	Assist	Review	Assist		Assist	Lead			
Develop V&V Plans ²	Concur	Assist	Review	Assist	Review	Lead				
Verify & Validate Data	Concur	Review	Review	Approve	Assist	Lead	Assist	Perform		
Prepare V&V Report	Concur	Assist	Approve	Monitor	Assist	Lead				
Gather Additional Accreditation Info		Monitor		Approve		Lead				
Prepare Accreditation Report	Concur	Assist	Monitor	Assist		Assist	Lead	Assist		
Accreditation Decision	Assist	Review	Lead				Lead	Assist		
Prepare Accreditation Memo	Concur	Assist	Perform				Lead	Perform		
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.									



IM&S V&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

ESMD IM&S Accreditation Process Plan and Specification
Baseline Version 2.0

STAFFING DRAFT - FOR REVIEW AND COMMENT

Modeling and Simulation (M&S) ACCREDITATION PROCESS PLAN AND SPECIFICATION

Exploration Systems Mission Directorate
(ESMD) NP-21

March 9, 2006

Baseline Version 2.0



National Aeronautics and Space Administration
Marshall Space Flight Center
Huntsville, Alabama

V&A

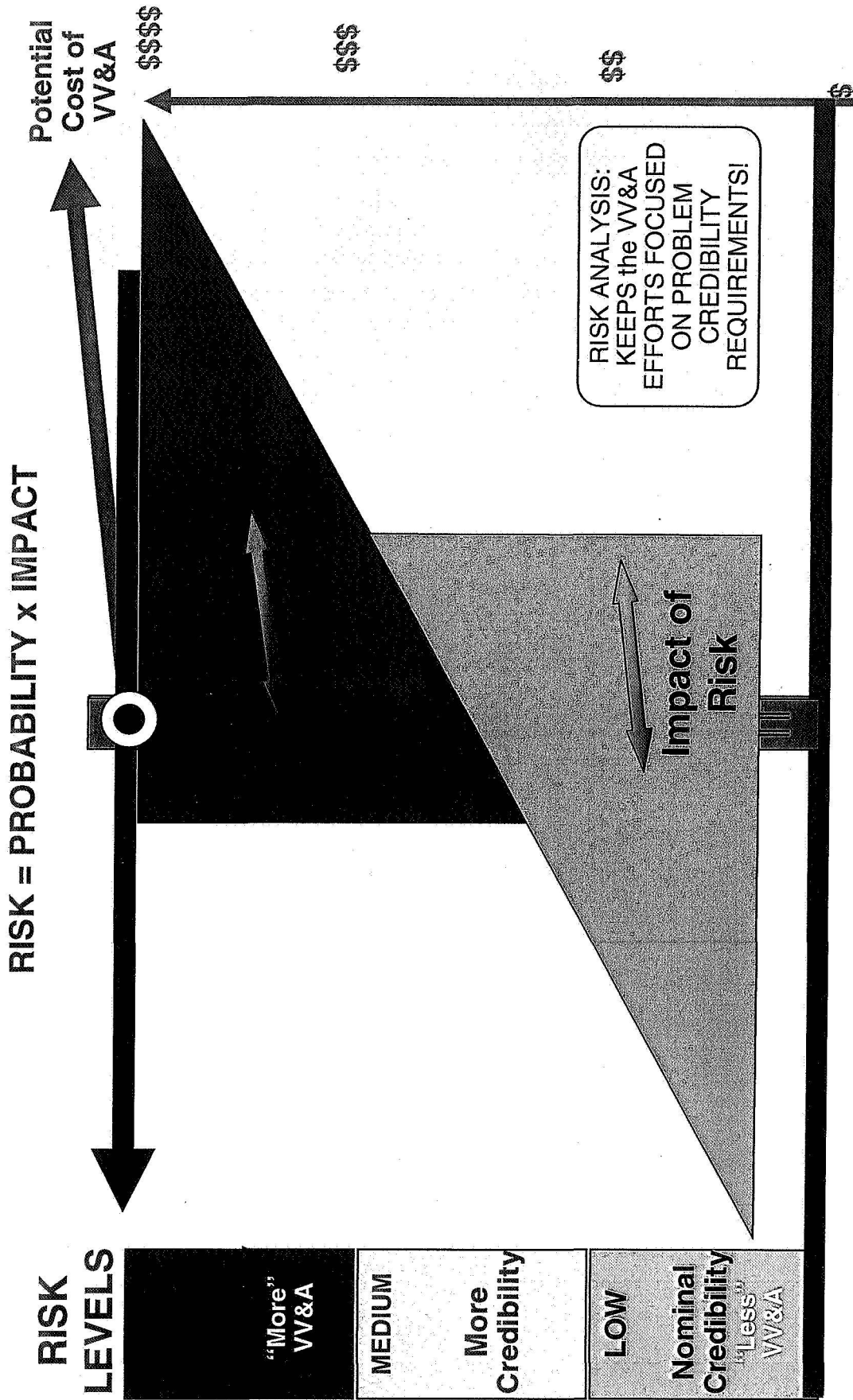
Putting the A in Front of V&V!



The Role of Risk Analyses



Pre-decisional DRAFT



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.



VV&A is a M&S Risk Mitigation Program

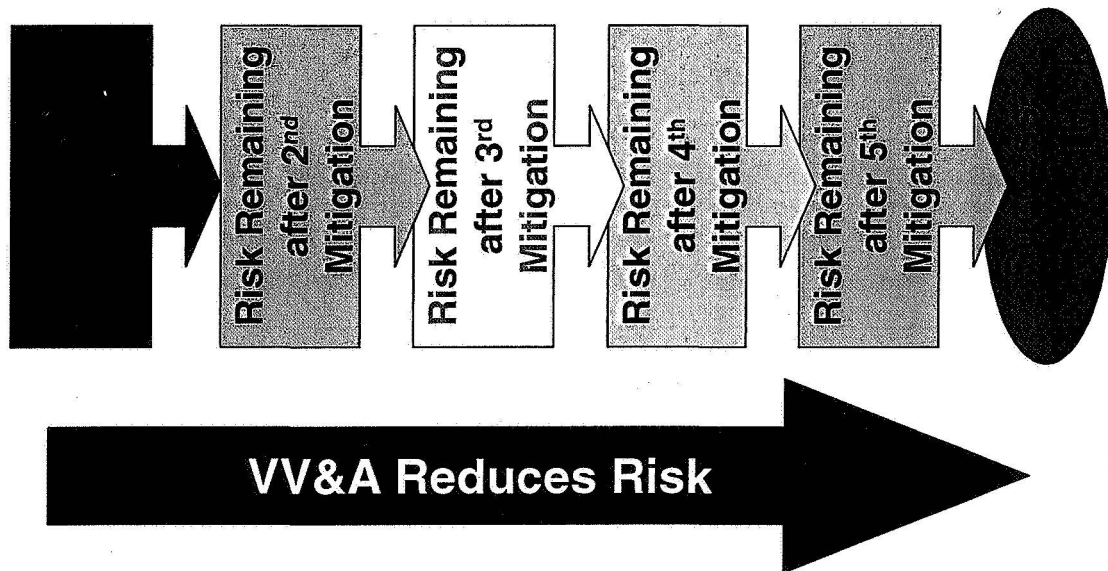


Pre-decisional DRAFT

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.



NASA IM&S V&V Process Plan and Specification



Pre-decisional DRAFT

• 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
- U.S. Navy's Joint Accreditation Support Activity (JASA) Accreditation Support Package (ASP) specification.

ESMD IM&S V&V Process Plan and Specification
Baseline Version 2.0

STAFFING DRAFT - FOR REVIEW AND COMMENT

Modeling and Simulation (M&S) VERIFICATION AND VALIDATION (V&V) PROCESS PLAN AND SPECIFICATION

Exploration Systems Mission Directorate
(ESMD) NP-21

March 9, 2006

Baseline Version 2.0



National Aeronautics and Space Administration
Marshall Space Flight Center
Huntsville, Alabama

Establishes Expectations and Provides Guidance for V&V Planning and Execution.



Key Elements Addressed In IM&S V&V Planning Process

Pre-decisional DRAFT



- 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.

These Elements of M&S Credibility Are Addressed in IM&S V&V Planning.