Source of Acquisition
NASA Marshall Space Flight Center

Title: *An Overview of Space Exploration Simulation (Basis of Confidence) Documentation*, Alleen Bray, The AEgis Technologies Group, Inc. and Joe Hale, Marshall Space Flight Center

Abstract:

Models and simulations (M&S) are critical resources in the exploration of space. They support program management, systems engineering, integration, analysis, test, and operations by providing critical information that supports key analyses and decisions (technical, cost and schedule). Consequently, there is a clear need to establish a solid understanding of M&S strengths and weaknesses, and the bounds within which they can credibly support decision-making. In this presentation we will describe how development of simulation capability documentation will be used to form a Basis of Confidence (Basis of Confidence) for National Aeronautics and Space Administration (NASA) M&S. The process by which BoC documentation is developed will be addressed, as well as the structure and critical concepts that are essential for establishing credibility of NASA's Exploration Systems Mission Directorate (ESMD) legacy M&S. We will illustrate the significance of BOC documentation in supporting decision makers and Accreditation Authorities in M&S risk management.

M&S V&V Are The Twin Pillars of Simulation Credibility

Pre-decisional DRAFT

"Accuracy"

S/W Accuracy | **Data Accuracy** | **Output Accuracy**

"V&V"

Verification | Validation

S/W ACCURACY + **DATA ACCURACY** + **OUTPUT ACCURACY**

Simulation meets design requirements, operates as designed and is free of errors in software

Simulation input data, validation data and data manipulations are appropriate and accurate

Simulation outputs match the real world "well enough" to be of use in a particular problem

But, There are Other Components Of Simulation Credibility

Pre-decisional DRAFT

Simulation Credibility

STRUCTURED ACCREDITATION ASSESSMENT

Capability

M&S Requirements

Problem

Accuracy

Usability

User Capabilities

Credible Solution

CAPABILITY

Simulation possesses all required functionality and fidelity for the problem being solved

+

USABILITY

Simulation has adequate user support to facilitate correct operation and interpretation of its outputs

IM&S Accreditation Must Consider and Address All of These Factors!

The Basis of Simulation Confidence

Pre-decisional DRAFT

Simulation Credibility

STRUCTURED ACCREDITATION ASSESSMENT

Capability

M&S Requirements

Problem

Accuracy

Usability

User Capabilities

Credible Solution

CAPABILITY

Simulation possesses all required functionality and fidelity for the problem being solved

+

USABILITY

Simulation has adequate user support to facilitate correct operation and interpretation of its outputs

SW ACCURACY + DATA ACCURACY + OUTPUT ACCURACY

Simulation meets design requirements, operates as designed and is free of errors in software

Simulation input data, validation data and data manipulations are appropriate and accurate

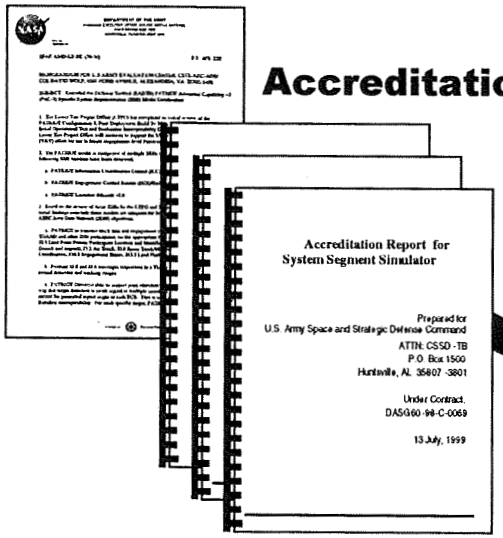
Simulation outputs match the real world "well enough" to be of use in a particular problem

IM&S BOC Documentation Must Address All of These Factors!

Basis of Confidence (BOC) Document Overview

Pre-decisional DRAFT

Accreditations

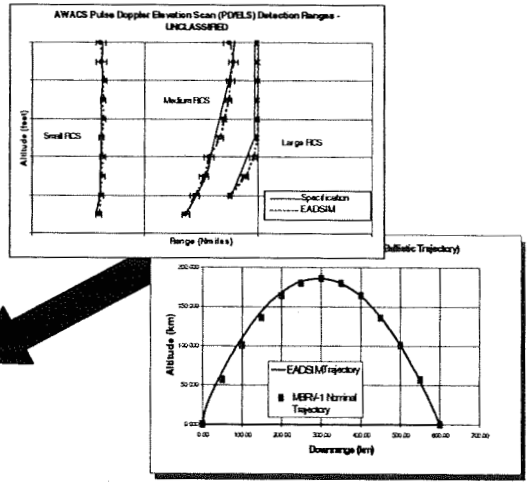


Processes,
Testing, etc.

Basis of Confidence
System Segment Simulator

Prepared for ESMD

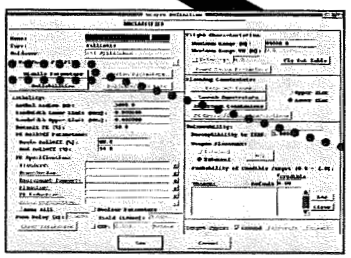
Functional Element Validation

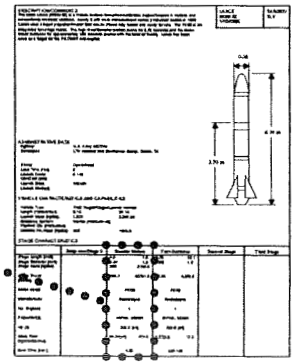


Functional Element Verification

Single Pulse Radar Calculations			
Input Parameters	Symbol	Value	Units
Transmitter Peak Power	P	46000	Watts
Pulse Width	τ	0.001	meters
Transmitter Gain	Gt	1.00000	
Receiver Gain	Gr	1.00000	
Radar Wavelength	λ	0.023	meters
Radar Cross Section	σ	1.00	square Meters
Boltzman's Constant	k	1.38E-23	Watts/Hz *K
Effective System Input Temperature	Ts	290	*K
Pattern Propagation Factor	F	1.00000	
System Losses	L	1.00000	
Probabilty of False Alarm	Pfa	3.00E-05	
Calculated SNR Threshold			
SNR Threshold	Thr	4.564	

Data Verification and Validation





BOCs Document M&S Capability and Credibility

ESMD IM&S BOC Process

Pre-decisional DRAFT

- ESMD IM&S BOC documentation utilizes the Joint Accreditation Support Activity (JASA) Accreditation Support Package (ASP) methodology.

  The objective is to establish a credible foundation for future efforts and to support the ESM IM&S capabilities assessment process in the areas of verification, validation, acceptability criteria and accreditation

- The ESMD IM&S BOC document suite will provide for three separate levels of reports defined below.

  - BOC I: provides a potential IM&S user with a characterization of the current state of the model with respect to criteria related to its general acceptability for use.
  - BOC II: provides IM&S users with a high-level of confidence that outputs resulting from valid ranges of inputs are accurate representations of real world conditions and outcomes. When coupled with the information contained in BOC I, the BOC II will provide users with the best available confidence level in model results short of detailed, total model V&V
  - BOC III: provides the most detailed assessment of model credibility possible given the verification and validation (V&V) efforts conducted

ESMD IM&S BOC Development Process

Pre-decisional DRAFT

PHASE 1
Identify...Decide

- Directives and Essential Tasks
- Stakeholders & Players
- ID Products & Develop Strategy

PHASE 2
Assess...Detect

- Assessments, Experiments, Tests
- Analyze and Assess Progress
- Identify Potential Solutions

PHASE 3
Report...Deliver

- Influence ESMD VV&A Policy & Strategy
- Feedback
- Influence Development Process

Increasing Credibility and Confidence

- Implement BOC I Assessment Strategy
- Develop Assessment Checklists, Data Collection Plan and conduct Leader Training
- Conduct "Off-the-Shelf" External Net Assessment
- Analyze data from assessments and identify issues and focus areas for exercise assessments
- Prepare BOC I document

- Analyze data collected from assessments
- Identify potential near-term fixes for the model
- Develop & recommend solutions
- Conduct "Hands On" Assessment of select Exercises, Experiments and Tests
- Incorporate lessons learned into BOC I document
- Prepare BOC II document

- Capture VV&A lessons learned
- Integrate into model requirements, and programs
- Feedback to ESMD Level I on practice
- Publish assessment on progress in achieving ESMD mission
- Prepare BOC III document

ESMD IM&S BOC I Outline: General Description

Pre-decisional DRAFT

Provides a potential user with a characterization of the current state of the subject model with respect to criteria related to its general acceptability for use. The information collected in this level will characterize the model well enough to provide an initial determination of its suitability for a particular application.

Provides a general indication of whether the model is suitable for further consideration for use in a particular application

Identifies model support and also provides confidence that the model is managed and supported well enough to yield consistent results across the spectrum of users and applications.

PART I: GENERAL DESCRIPTION

1. Overview
   - 1.1 Objectives and general requirements of the model
   - 1.2 Categories of model (data driven, distinct entity, closed-form analytical solution, iterative, etc.)
   - 1.3 Summary of phenomenology modeled (sensors, system interoperability, logistics, lethality, etc.)
   - 1.4 Summary of sub-components of the model
   - 1.5 Major discriminating features relative to similar models
   - 1.6 Model segment(s) and module(s)
2. Model Usage
   - 2.1 Cite distribution limitations, licenses, or costs
   - 2.2 User interface characterization (graphics, rendered scenes, numerical output, etc.)
   - 2.3 Analyst's tools description
3. Model Support
   - 3.1 Hardware and software support requirements
   - 3.2 Model interoperability features – HLA, DIS, and other
   - 3.3 Organization name, office/rank, telephone and e-mail for model POC

ESMD IM&S BOC I Outline: Configuration Management

Pre-decisional DRAFT

PART II: CONFIGURATION MANAGEMENT

Provides a description of the model configuration baseline, including version history, current version status, model development policy, documentation availability, and a summary of configuration management policies, procedures, guidelines and support functions for the model. Model documentation release history will be described.

1. CM Baseline
   - 1.1 Current version and release date
   - 1.2 Baseline build configuration with current capabilities
   - 1.3 Beta testing organization, location
   - 1.4 Version history with capability history (version differences, see Table 1)
   - 1.5 Development approach
   - 1.6 Current Capability Maturity Model (CMM) level of the model developer and outline any plans to change CMM levels

Identifies processes used for model version revision and control, and processes to identify required error fixes. All appropriate documents will be referenced.

2. Version Control
   - 2.1 Process for addressing model requirements
   - 2.2 Process for addressing reported model errors and software changes (control boards, user errors, etc.)
   - 2.3 Requirement process development
   - 2.4 Schedule template and stages
   - 2.5 Requirements flow process

ESMD IM&S BOC I Outline: Model Assumptions and Limitations

Pre-decisional DRAFT

Summarizes the implicit and explicit model assumptions and limitations inherent due to design and/or coding assumptions or structure.

Known errors or anomalies, not yet fixed, found as a result of prior V&V efforts will be listed.

Known limitations, not yet fixed, found as a result of prior V&V, conceptual model validation, or prior usage efforts will be listed.

PART III: MODEL ASSUMPTION AND LIMITATIONS

1. Assumptions
   - 1.1 Algorithmic
   - 1.2 Structural
2. Known errors
3. Limitations
   - 3.1 Modeling the elements of the system
   - 3.2 Representation of phenomenology (natural and man-made)
   - 3.3 Indicate preparation, pre-test, run time, and post-run analysis
   - 3.4 Potential solutions to errors, limitations and shortcomings
   - 3.5 Upgradeability
   - 3.6 Hardware limitations
   - 3.7 Software limitations
   - 3.8 Modeling Human in Control/Command and Control

ESMD IM&S BOC I Outline: Model History

Pre-decisional DRAFT

Summarizes model's development history.

Summarizes model's usage history, as well as current user base and major studies and exercises supported.

Summarizes model's prior, verification and validation (V&V) activities and associated results as well as prior accreditations.

PART IV: MODEL HISTORY

1. Development History
   - 1.1 The model's original intended purpose
   - 1.2 When, where and by whom was the model developed? (Include contact information)
   - 1.3 Planned developments and purpose of future developments
   - 1.4 Responsible parties for development efforts
   - 1.5 Model development date, location(s), and developer name and organization
2. Usage History
   - 2.1 Anticipated use (if different)
   - 2.2 Current user base
   - 2.3 Major studies supported by the model
3. VV&A History
   - 3.1 Cite any live test events for which VV&A were performed
   - 3.2 V&V performed where, when and by whom
   - 3.3 Identify independent accreditation agents
   - 3.4 Specify formal and informal accreditations

ESMD IM&S BOC I Outline: Documentation

Pre-decisional DRAFT

Provides a review of the status of model documentation and its conformity to accepted documentation standards, as well as a review of documentation with respect to verification requirements.

This section contains a complete reference list to relevant documents.

The reference list will identify the documents closely associated with the BOC I level.

PART V: DOCUMENTATION

1. Description of the simulation conceptual model
2. Development/requirements documentation
3. System specification documentation
4. Configuration Management (CM) documentation
5. Process documentation
   - 5.1 VV&A management plan/process
   - 5.2 Development planning documentation
   - 5.3 Data management plan
6. Release documentation
   - 6.1 User documentation
   - 6.2 Programmers guide
7. Historical Metrics

ESMD IM&S BOC I Outline: SW Quality

Pre-decisional DRAFT

Provides a summary of overall software quality as characterized by conformance to accepted design and coding practices will be addressed.

The documentation associated with the development and VV&A processes will be summarized.

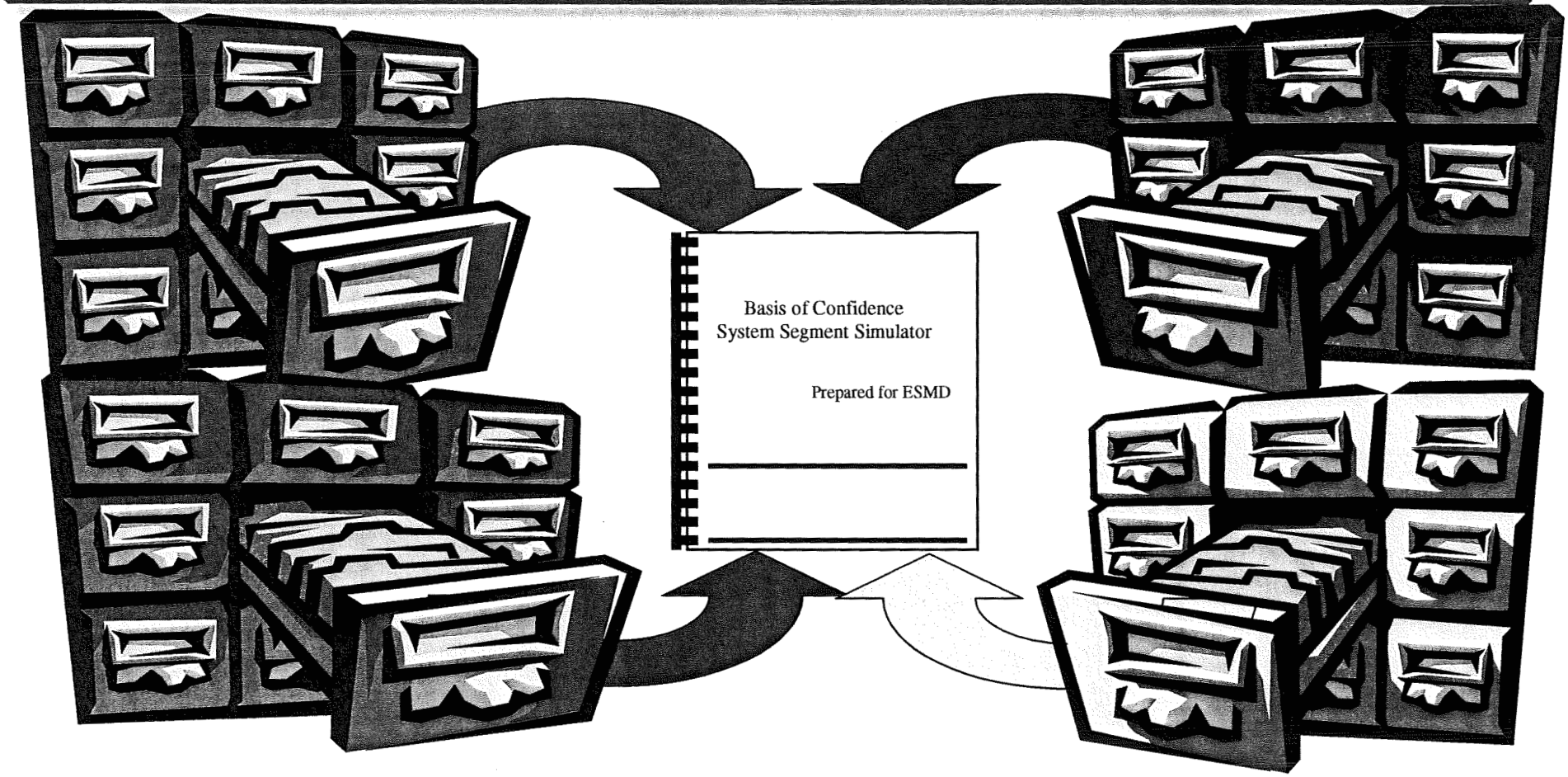
This will also summarize the established metrics of the simulation software. This general assessment is a summary of the individual assessments offered in the above categories.

PART VI: SOFTWARE QUALITY

1. Description of the developer's software quality
2. Development/requirements documentation
3. System specification documentation
4. Configuration Management (CM) documentation
5. Process documentation
   - 5.1 VV&A management plan/process
   - 5.2 Development planning documentation
   - 5.3 Data management plan
6. Release documentation
   - 6.1 User documentation
   - 6.2 Programmers guide
7. Historical Metrics

Summary

Pre-decisional DRAFT



BOC Documents establish a credible foundation for future analysis efforts and support the ESM IM&S capabilities assessment process in the areas of verification, validation, acceptability criteria and accreditation!

Backup

Assessing Simulation Accuracy*

Pre-decisional DRAFT

- **Documented and Appropriate Processes**
  - Development team has a common view of what to do, how to do it and how to report the results
- **Sufficient and Appropriate Resources**
  - Adequate numbers of qualified resources are available to implement and document the results
- **Appropriate Artifacts**
  - Appropriate documentation is produced during S/W development and testing that supports end-user confidence
- **Acceptable Results**
  - Documented results of S/W development, testing and configuration management activities meet end-user requirements

SOFTWARE

DATA

OUTPUTS

* Measures of merit depend on type of accuracy being evaluated

Assessing Simulation Capability & Usability

Pre-decisional DRAFT

- SIMULATION CAPABILITY
  - Clearly defined and documented descriptions of simulation functionality and fidelity
    - Data flow diagrams, top-level design documentation, engineering descriptions, I/O relationships, etc.
  - Clearly articulated assumptions & limitations

Ensures the end-user fully understands capabilities and limitations of simulation

- SIMULATION USABILITY
  - Good Configuration Management
    - Documentation, Data, Test Sets, Software
  - Current User manuals, training materials, User groups, on-call technical support

Ensures the end-user knows what he's getting, that he can run simulation properly and can interpret its outputs credibly

WHY SHOULD NASA AND ESMD CARE?

- Modeling & simulation tools are ***CRITICAL RESOURCES*** for analysis, test, and evaluation
  - Supporting key decisions (technical, cost and schedule)
  - Risks inherent in key decisions mandate risk management
- The ***NEED*** exists to regularize the verification and validation of modeling and simulation tools (data, models, test beds) and activities (studies, exercises)
- A ***DELIBERATE PROGRAM*** of activity to establish confidence in the operation of models & simulations and in the significance of modeling & simulation results is imperative

Availability of Information about the M&S

- The Quality of M&S documentation affects the cost of V&V (especially verification)
  - e.g., no S/W design documentation means you have to reverse engineer the code to do verification
- Three cost drivers
  - Cost of buying information about the model
  - Cost of reconstructing unavailable information
  - Cost difference incurred when forced to replace a relatively "cheap" V&V technique with a more expensive V&V technique