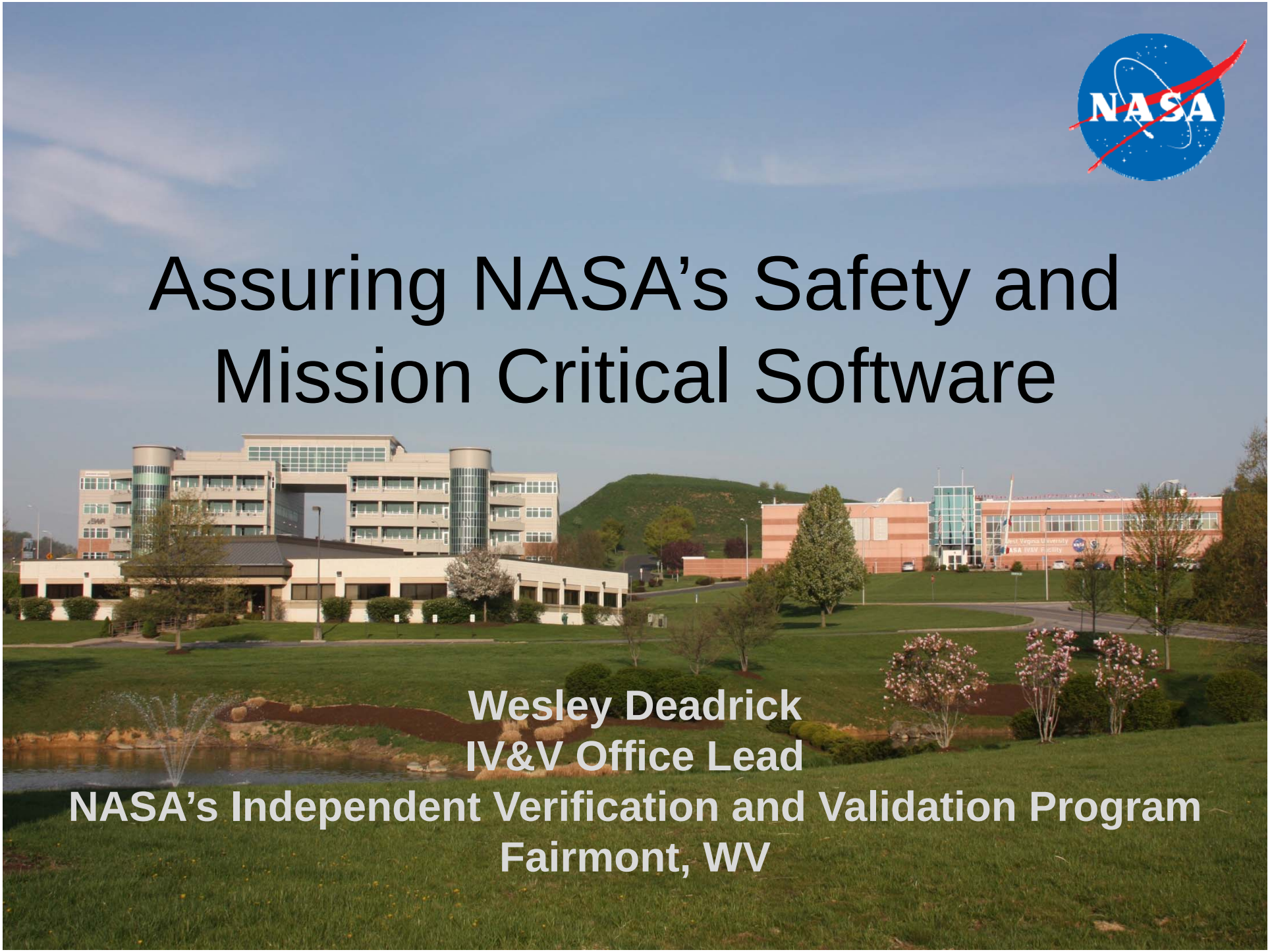


Assuring NASA's Safety and Mission Critical Software

Wesley Deadrick
IV&V Office Lead
NASA's Independent Verification and Validation Program
Fairmont, WV

Origins of IV&V within NASA

- NASA's IV&V Program: established in 1993
- Founded under the NASA Office of Safety and Mission Assurance (OSMA) as a direct result of recommendations made by the National Research Council (NRC) and the Report of the Presidential Commission on the Space Shuttle Challenger Accident.

The Need for IV&V

NASA Decides That A Software Error Doomed The Mars Global Surveyor Spacecraft

By Keith Cowing Posted Wednesday, January 10, 2007

During a meeting of the Mars Explorat
Group Meeting in Washington Dc, yest
McNamee, Mars Exploration Program
the recent failure of the Mars Global Surveyor (MG
spacecraft.

Software Glitch Blamed for Turning Satellite Into Space Zombie

Peter B. de S

Software Glitch Means Loss of NASA's De Comet Probe

timothy posted about 4 months ago | from Taco Cowboy

Taco Cowboy writes "'NASA is ca
comet probe after a suspected so

Office of the Chief Engineer

Reports

Text Size

Technical Excellence Initiative

NASA Study on Flight Software Complexity

In 2007 the NASA Office of Chief Engineer commissioned a multi-Center study of the growth in flight software size and complexity in NASA space missions. The

Inquiry Board Traces Ariane 5 Failure to Overflow Error

Readers of *SIAM News* may remember that on June 4, less than a minute into its first flight, the French rocket Ariane 5 self-
des études spatiales) and ESA (the European Space Agency) to investigate the failure was chaired by applied mathematician

Developing complex, safety and mission-critical software systems is inherently challenging, and that creates risk.

What is IV&V?

Independent Verification and Validation (IV&V) is an objective examination of safety and mission critical software processes and products

Independence: 3 key parameters:
- Technical Independence
- Managerial Independence
- Financial Independence

Systems Engineering: Determines if the **right system** has been built and that it has been **built correctly**

NASA IV&V perspectives:
- Will the system's software…
  - Do what it is supposed to do?
  - Not do what it is not supposed to do?
  - Respond as expected under adverse conditions?

IV&V Technical Approaches:
- Aligned with IEEE 1012
- Captured in a Catalog of Methods
- Spans the full project lifecycle

IV&V Assurance Strategy

The IV&V Project's strategy for providing mission assurance
Assurance Strategy is driven by the specific needs of an individual project
Implemented via an Assurance Design
Communicated via Assurance Statements

What is IV&V? (continued)

- The IV&V Assurance Strategy is the selection and implementation of IV&V validation and verification processes
  - Implementation of the IV&V processes are driven by the IV&V Project's risk assessment and unique characteristics
  - The Assurance Strategy is tailored to the needs of the individual projects
- The validation process provides empirical evidence that engineering products:
  - Satisfy system requirements allocated to software
  - Solve the right problems
  - Satisfy the intended use and user needs in expected operational environments
- The verification process provides empirical evidence that engineering products:
  - Conform to requirements (for example: for correctness, completeness, consistency, accuracy) during all life cycle phases (requirements, design, code, test)
  - Satisfy standards and best practices
  - Establish a basis for assessing the completion of each life cycle phase, and initiating other life cycle phases

What is IV&V? (continued)

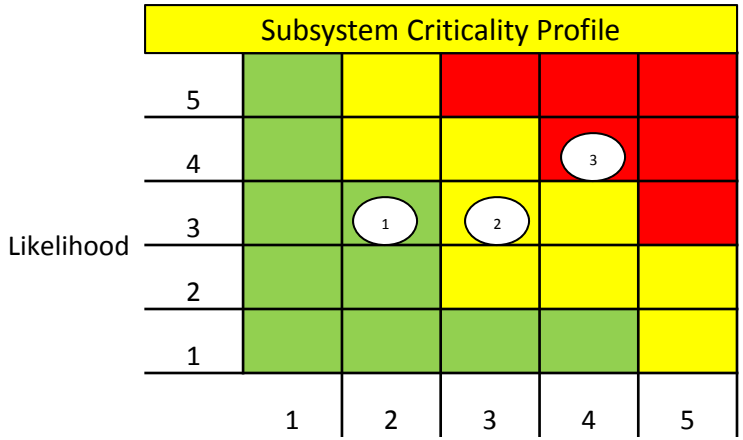
- IV&V processes include assessments, analyses, evaluations, reviews, inspections, and testing of software artifacts during the entire development lifecycle that create evidence
  - Evidence is used to formulate recommendations that improve the quality (or reliability) of the system software
  - Evidence is used to make conclusions about the quality (or reliability) of the system software
  - Evidence is used to gain insight into the technical progress
  - Evidence is used to judge how thorough you've critiqued the system
- How much evidence → it is a trade-off between criticality of the system being acquired/deployed
  - Life-sustaining subsystems would warrant an evidence package that clearly & objectively shows the software will operate safely (or clearly shows that it won't)
  - Data management subsystems may warrant less of an evidence package
- The amount of evidence needed determines the rigor of the analysis
  - Analytical Rigor is the type and amount of IV&V processes to use for analysis

Establishing the IV&V Assurance Strategy

- The IV&V Program assesses the system to determine:
  - The inherent risk associated with the system capabilities
  - The role of software in those capabilities
  - Which software elements of the system warrant IV&V analysis
    - Software elements are generally the focal point of IV&V analyses; however, other lifecycle artifacts (for example: concept documentation, system design, etc…) are utilized to inform lower-level analyses
- Our process is called "Portfolio Based Risk Assessment" (PBRA)
  - Results in scores for impact (a measure of the effect of a problem) and likelihood (the potential for the existence of errors) for each system capability and software element
  - Enables informed decision making regarding:
    - What parts of the system should IV&V work on
    - What analytical rigor should IV&V apply (for example: dynamic analysis should be conducted to thoroughly test the implementation of the protocol used for communications)

Establishing the IV&V Assurance Strategy (continued)

Desired Capabilities	Cruise - GNC	1 Cruise - Thermal	2 Cruise - Telecom	Cruise Power	3 EDL GNC	Rover: Startup & Initialization	Rover: C&DH
	Responsible Subsystems						
Conduct habitability investigations							
Launch to Mars							
Cruise to Mars	x	x	x	x		x	x
Trajectory control	x		x				
Attitude Control	x		x				
Approach Mars					x		
Trajectory control	x				x		
Attitude Control	x						
Maintain flight systems							
Establish and maintain power				x			x
Establish and maintain thermal control		x					x
Perform fault detection							x
Establish and maintain communications			x				x
Gather engineering and housekeeping data	x	x	x	x	x	x	x
EDL							
Pre-EDL					x		
Entry					x		
Descent					x		
Landing					x		
Perform surface operations							
Traverse the Martian surface						x	x
Acquire and handle samples						x	x
Evaluate current position via TRS data							
Perform reconnaissance activity						x	x
Collect science data						x	x



Subsystem 1 – do not recommend IV&V
Subsystem 2 – recommend IV&V utilizing Static Analysis
Subsystem 3 – recommend IV&V utilizing Dynamic Analysis
Subsystem n …

less ← Amount of Rigor & Evidence Needed → more

Manual Analysis	Static Analysis	Dynamic Analysis	Formal Analysis
SMEs conduct formal or informal inspections & evidence is recorded simply as issues	SMEs evaluate structure & content using various perspectives supported by CASE tools. Evidence is recorded as issues & supplemented with coverage	SMEs execute system & evaluate results. Evidence is recorded more thoroughly as to make the case for what works and what are limitations	SMEs apply formalisms & mathematical rigor to prove existence or absence of critical properties

Implementing the IV&V Assurance Strategy

- IV&V Assurance Strategy is implemented through the Assurance Design
  - The Assurance Design specifics the Technical Reference, inputs, analysis techniques, and objective evidence necessary to achieve the IV&V Project's Objectives
  - Like the Assurance Strategy, the Assurance Design is specific to the needs of an individual project
    - Constructed to allow the IV&V Project to generate evidence to assure the critical capabilities and mitigate system risk
    - Areas of risk identified in the PBRA are key inputs into the development of the Assurance Design
- Assurance Statements are utilized to communicate the results of the implementation of the IV&V Assurance Strategy
  - A statement of the assurance that is being provided (or intended to be provided) by IV&V to a stakeholder or stakeholders on a system or subsystem
    - Assurance statements are typically formulated at the beginning of a IV&V Project and refined as necessary throughout execution

Tools for Implementing the IV&V Assurance Strategy

- NASA's IV&V Program strives to continually develop new capabilities to support the execution of the IV&V Assurance Strategy
  - IV&V Techniques are documented in a Catalog of Methods (CoM)
  - Techniques are continually refined and tailored to the needs of the projects
- To maintain relevance, the IV&V Program selectively invests in new technologies necessary to assure NASA's safety and mission critical software
  - NASA's IV&V Program is advancing the state of the practice in Cybersecurity / Information Assurance and Independent Testing
    - Advanced techniques and capabilities are being developed to enable the program to keep pace with current development trends and emerging risk factors
    - Information Assurance and Independent Testing are becoming an increasingly prominent component of IV&V Project's Assurance Strategies

Cybersecurity / Information Assurance

Ensuring Mission and Safety Critical Software and Systems Operate Reliably, Safely, and Securely

Threat and Risk Assessment

- FISMA Compliance
- Life-cycle
  - Provide mission security assurance throughout design, development, implementation, operation, maintenance, and disposition
  - Assessment and Authorization (A&A)
- Authority to Operate (ATO)

Vulnerability Assessment / Penetration Testing

- Implementation of Security Controls
- Monitoring of Security Controls
- Static Code Analysis (SCA)

IV&V In-Phase IA Support

- Build security in “from the ground up.”
- Security Architecture Verification
- IV&V Methods

CyberLab

- Component of ITC JSTAR Lab
- Virtualized servers
- Penetration Test tools
- Cybersecurity Knowledge Base
- Cybersecurity Training Program
- Mission System Virtualization and Testing

Independent Testing

Develop, maintain, and operate adaptable test environments for NASA's IV&V Program that enable the dynamic analysis of software behaviors for multiple NASA missions

Simulation

- Functional Software-only Simulators
- NASA Operational Middleware (NOS)
  - Common emulation software
  - Middleware
- Spacecraft Simulators
  - Ground systems, instruments, spacecraft dynamics
- Small Sat
- Integrate many technologies to create solutions

Automation

- Simulation Verification
- Increase Testing
  - Unit Testing
  - System Testing
- Automated Installations and Simulator Deployments

Testing

- Provide evidence-based assurance to customer
- Risk-focused independent testing
- Focused on testing adverse conditions
  - Fault injection, back-to-back scenarios, etc.

Virtualization

- Heavy reliance on virtualization technologies
  - Development
  - Simulator Releases
  - Rapid Deployment
  - Evaluation Environments

Summary
Benefits of IV&V

- Yields higher confidence that delivered products are error free and meet the user needs.
- Increases likelihood of uncovering high-risk errors early in the development lifecycle.
  - Allows time for the design team to evolve a comprehensive solution rather than forcing them into a makeshift fix to accommodate deadlines
- Delivers ongoing status indicators and performance reporting to decision makers (e.g. program managers).
  - The customer is provided an incremental preview of system performance with the chance to make early adjustments.
- Reduces the need for rework from the developing contractor thereby reducing total costs to programs and projects.
- Facilitates the transfer of system and software engineering best practices.

IV&V leads to higher quality products, reduced risk, greater insight, reduced cost, and knowledge transfer.

QUESTIONS?


INDEPENDENT VERIFICATION AND VALIDATION PROGRAM
20 YEARS OF EXCELLENCE
NASA

IV&V Services

CCP

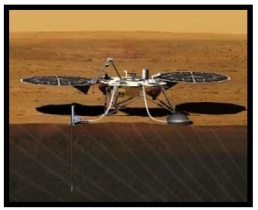

DSCOVR


ECTP


GPM


GOES-R


GSDO


InSight

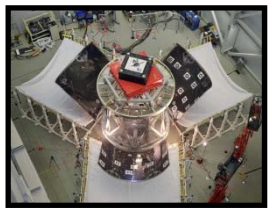

ISS


JWST


JPSS


MAVEN


MMS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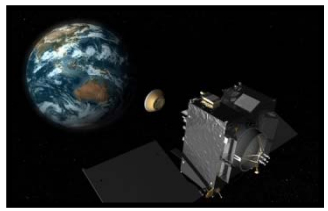
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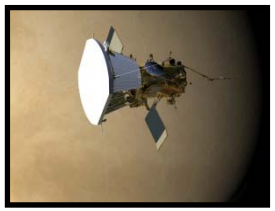
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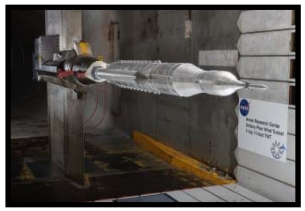
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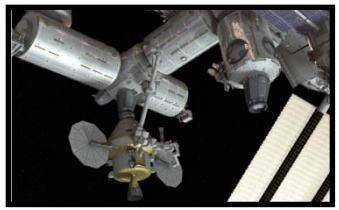
SGSS

IV&V plays a key role in a number of high-profile NASA and non-NASA missions.

Generic Look at IV&V