Overview of Fraunhofer Competencies in System Engineering Research

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Fraunhofer Center Maryland (FC-MD)
Center for Experimental Software Engineering

- A not-for-profit applied research & technology transfer organization

- Founded in 1997 by Dr. Victor Basili and Dr. Marv Zelkowitz

- Affiliated with University of Maryland at College Park

- One of six Fraunhofer USA Centers

- **Vision**:
  - Apply a scientific/engineering method to system and software engineering
  - Utilize past results to guide development choices
  - Use organizational learning as the key to improvement

Fraunhofer Center Maryland (FC-MD)
Our Staff

- ~25 technical personnel
  - Scientists
    - Many with significant track records of research and tech transfer
  - Applied Technology Engineers
    - Many with 20+ years of experience in government and commercial organizations
  - Part-time university faculty (associate and adjunct professors)
    - Maintaining tight connection with local university departments
  - Interns
    - University students who desire experience on cutting-edge problems as part of their studies

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Fraunhofer Center Maryland (FC-MD)
Partners & Customers

Mission: Advance real-world practices via empirically validated research into system- and software-engineering technologies and processes

We bridge research and application, working with:

- Government organizations (DoD, NASA, …)
- Large industrial companies (Boeing, Motorola, …)
- Small/medium-sized organizations (KeyMind,…)
- National labs (Los Alamos Labs, ….)
- Universities and research centers (CMU, USC, MIT, …)
- …and others (SEI, MITRE, JHU/APL, ...)

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Example of Competencies: SERC EM Task

- Goals:
  - Compare SEPAT effectiveness measures with DAPS assessment methodology to determine gaps and coverage
  - Provide constructive feedback to both model owners as appropriate.
  - Determine the significance of SEPAT effectiveness measures w/r/t SADB negative findings.
- Example research methods: Use very experienced SMEs to
  - Identify and select key topic areas
  - Analyze both reference docs and create comparison map
  - Request SADB findings on key queries and map to SEPAT

SE EM Framework Area			Interpretation	DAPS Section	DAPS Topic Covered
1 Concurrent definition of system requirements and solutions					
	1.1	Understanding of stakeholder needs: capabilities, operational concept, key performance parameters, enterprise fit (legacy)		1.1	CONOPS
		1.1.1 At Milestone A, have the KPPs been identified in clear, comprehensive, concise terms that are understandable to the users of the system?	Understandable, comprehensive requirements	1.3.2	KPPs and KSAs
		1.1.2 Has a CONOPS been developed showing that the system can be operated to handle both nominal and off-nominal workloads, and to meet response time requirements?	feasible workload demonstrated at CONOPS; are scenarios quantified	1.1 1.2 1.3.1	CONOPS Analysis of Alternatives Reasonableness, Stability, and Testability
		1.1.3 Has the ability of the system to meet mission effectiveness goals been verified through the use of modeling and simulation?	verification of mission goals	1.2.1 1.3.1 4.4.2	Validity and Currency (1.2 Analysis of Alternatives) Reasonableness, Stability, and Testability Modeling and Simulation Tools

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Example of Competencies: SERC EM Task

- Results:
  - The SEPAT has 'rolled up' many subtopics into fewer effectiveness areas; DAPS is more broad and more specific
  - Several key concepts found in SEPAT seem to be absent or used in a different manner in the DAPS context, such as
    - Negotiating roles & responsibilities
    - Nominal/off-nominal
    - Stakeholder concurrence/acceptance
    - Feasibility evidence
    - Timeboxing
  - DAPS is very DoD-process oriented; as a result, its guidance on what the program should do when is more specific, e.g., each section addresses Milestones A, B, and C as appropriate.
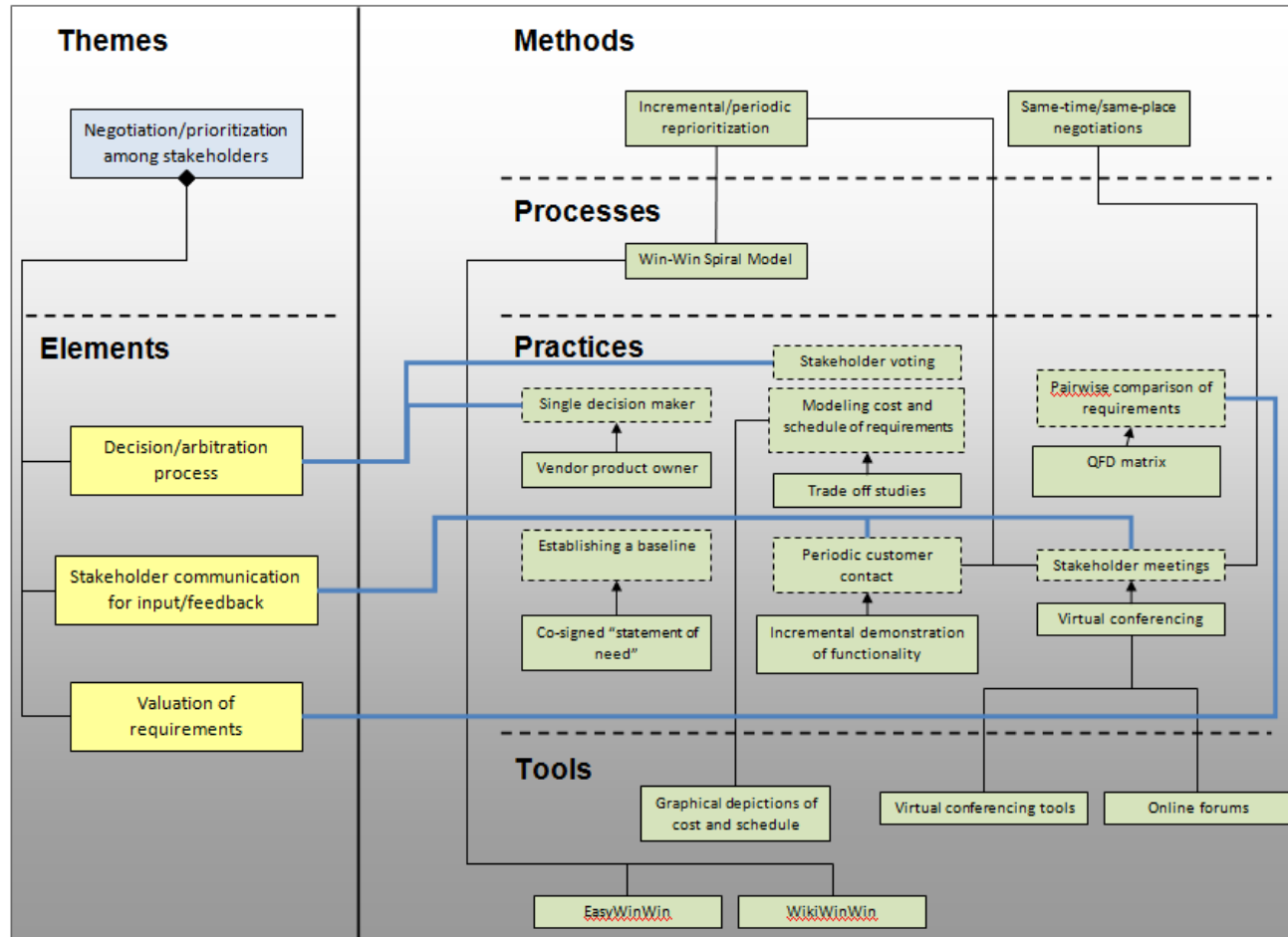
Example of Competencies: SERC MPT Task

- Goals:
  - Explore MPTs & gaps w/r/t **agility and responsiveness to change**, in context
  - **Conceptualize** agile challenges along with:
    - Themes – Important components of a solution for each challenge
    - Elements – Key activities that must be completed to achieve each theme
    - MPTs – Existing sets of methods, processes, and tools that together provide an actionable way of achieving an element.
- Example research methods:
  - Conducted survey of organizations with relevant experience
  - Qualitative analysis of responses to identify concrete suggestions, contexts where appropriate, and areas still missing concrete MPTs
- Results: The bridge maps we are creating provide a way of encapsulating practical experience as to MPTs that can be recommended & further research to be done.

Example of Competencies: SERC MPT Task

Results (cont.):

- Worked with sponsor to understand context
- 100+ surveys analyzed
- Initial 'bridge diagrams' allow recommending initial MPTs for context
- Gap analysis allows discovery of areas requiring research to develop new MPTs

Example of Competencies: DOD Best Practices Clearinghouse

- Goals:
  - Provide the **system engineering workforce** with recommendations about applicable MPTs, based on experiential information from practice
  - **Communicate the effectiveness** of SE MPTs based on cost, schedule, and quality impact on real projects
- Example research methods:
  - Exploring use of multiple methods (interviews, surveys, questionnaires) to elicit experiential information
  - Application of qualitative and quantitative reasoning to aggregate information about practice's costs and benefits
  - Developing information tagging by context, keywords, ontologies
- Results:
  - A published website and growing support team of contributors and SMEs (e.g. from DAU campuses, AFIT)
  - ~10K page views / month

Defense Acquisition University

Name: **Practice *X***		Practice Maturity
∑	•Practice X has been successfully applied … •Use it to … •For more information click on the following links: • …	(Bronze)(Gold)

Evidence 1

Source
Context
Results

Evidence 2

Source
Context
Results

Evidence 3

Source
Context
Results

Evidence 4

Source
Context
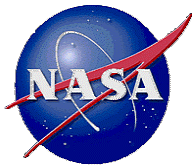Results

6 4 5

- **Goals**:
  - Provide some quantifiable evidence of potential risk w/r/t software safety and whether projects are addressing that risk
  - Approach is applicable to other key properties of the system early in the lifecycle

- **Example research methods**:
  - Developing models that isolate specific deficiencies, codify the risks, and offer possible responses
    - Identify data in the artifacts available to address the problem
    - Identify gaps in the data and propose responses to those gaps
  - Evaluate artifacts produced by the process over time
    - E.g. Evaluating software-related hazard reports from multiple Constellation elements (Orion, Ares US, J-2X)
    - Monitor areas of risk over time
   - Do not depend on designs or code alone to evaluate safety

# Example of Competencies: Software Safety Metrics

- **Results**:
  - Modeling hazards:
    - Models of deficiencies in software risk causes, e.g. lack of specificity
    - Currently extending model to characterize software controls and verifications
  - Modeling the evolution of software-related hazards to:
    - Provide snapshots of software risk areas
    - Identify highest risk elements, systems and subsystems
    - Find mission drivers with the highest risk related to software
  - Developing metric templates for SR&QA personnel and vendors
  - Analysis of hazard reports is applicable and relevant to NASA projects with a similar hazard analysis and reporting structure
  - Future work will expand this approach to artifacts other than hazard reports
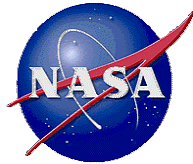
# Example of Competencies: Improving Sys & SW Tech Reviews

- Goals:
  - **Fundamental** research aimed at applying a proven system engineering practice to contemporary constraints and problems
  - Work with many NASA missions aimed at **integration** of inspection best practices **with program execution activities**
  - Further deployment to reach the **NASA System Engineering workforce**
- Example research methods:
  - Quantitative statistical testing based on 2500+ data points
  - Tailoring of method to project environments, handling software- and system-level technical documents
  - Encoding research results into tool support for use by NASA teams
- Results:
  - Concrete, practical information formulated and infused with teams
  - Tool support developed and tested
  - Inclusion in NASA's safety curriculum
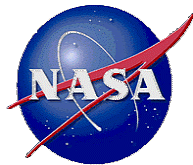
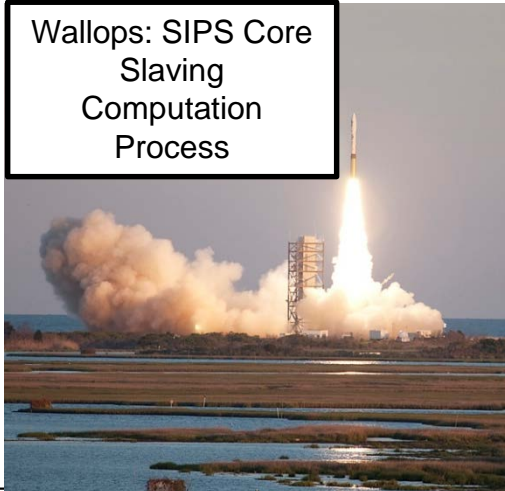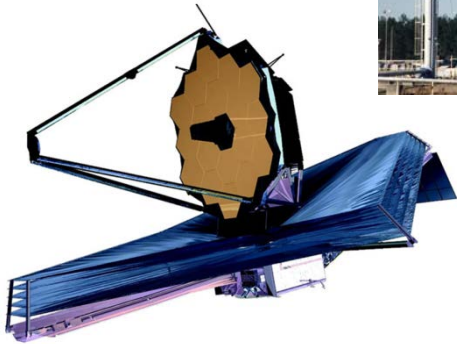# Example of Competencies: Improving Sys & SW Tech Reviews
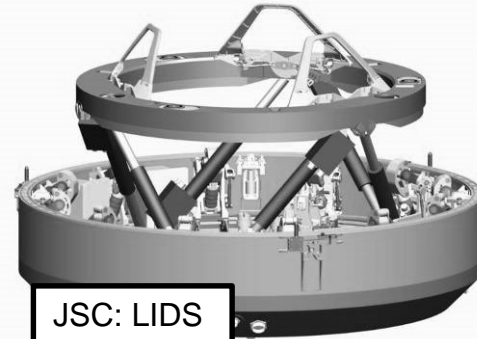

SSC: LH Barge Ladder Logic
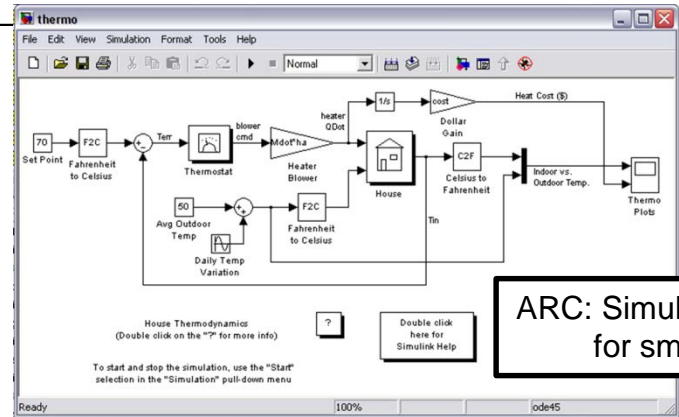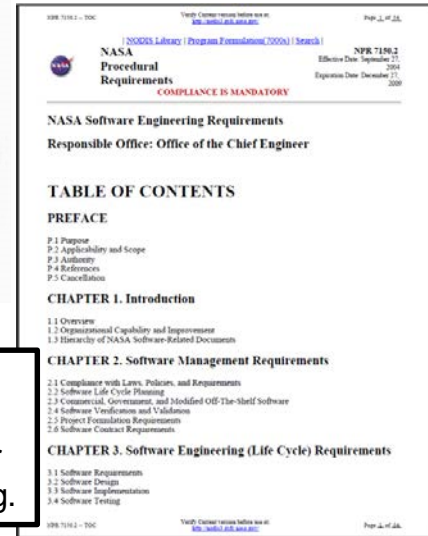
ARC: Simulink models for smallsat

IV&V: James Webb Space Telescope

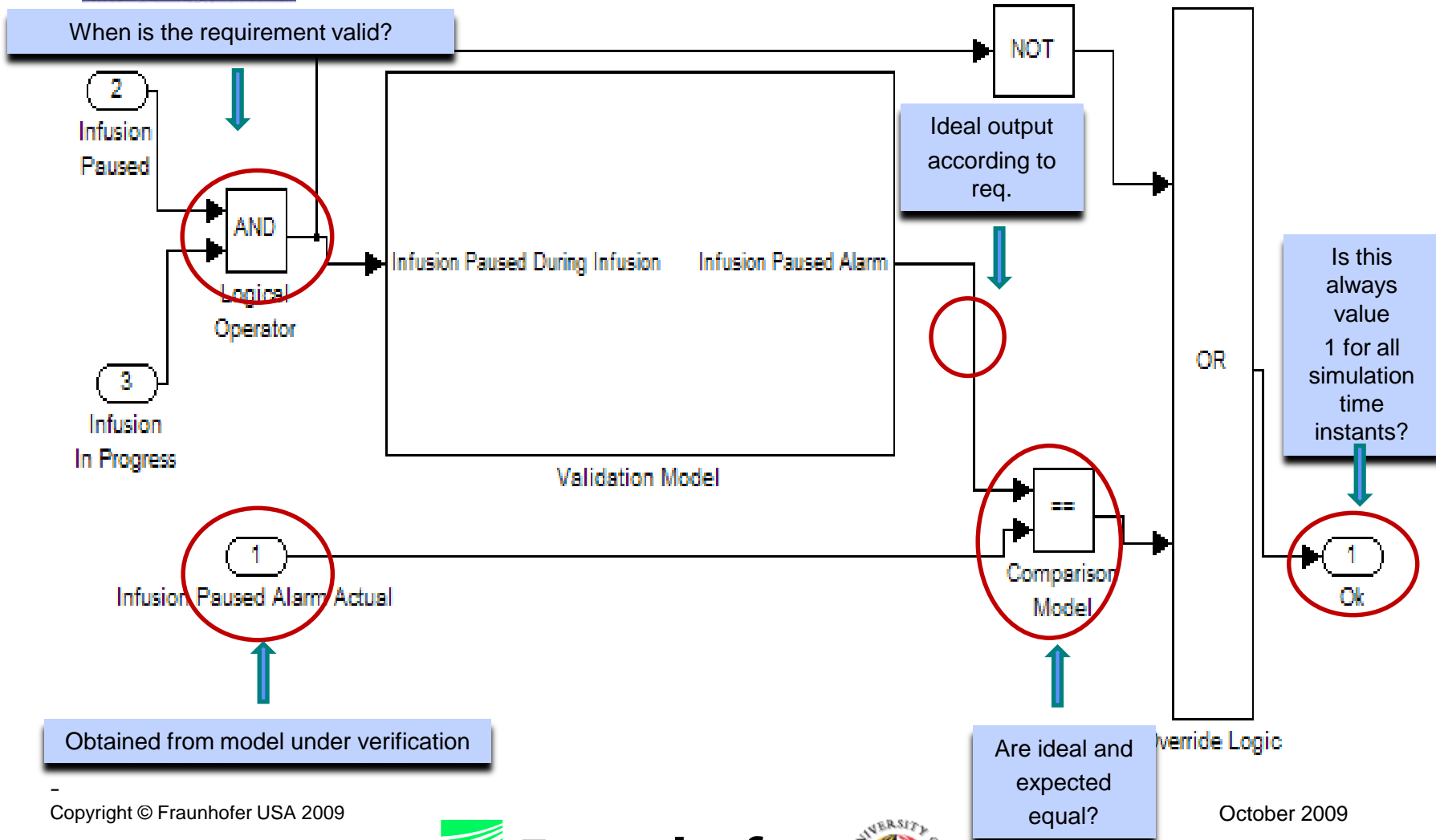Wallops: SIPS Core Slaving Computation Process

JSC: LIDS

GSFC & MSFC: NPR 7150.2 procedural reqts for software engineering.

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Example of Competencies: Model-based V&V of med devices

- Goals:
  - Demonstrate feasibility & cost effectiveness of an **advanced MPT** (model-based checking) for complex, safety-critical systems
- Example Research Methods:
  - Work with customer on real system to address scalability concerns
  - Ensure integration with industry standard modeling tools
- Results:
  - This practice currently being piloted as part of the Generic Infusion Pump (GIP) project
  - Models of a GIP have been constructed
  - Safety requirements created from hazards analysis
  - Safety requirements converted into monitor models (26 done so far)
  - Verified against GIP model

Example of Competencies: Model-based V&V of med devices

When is the requirement valid?

2
Infusion Paused

3
Infusion In Progress

AND
Logical Operator

Infusion Paused During Infusion   Infusion Paused Alarm

Validation Model

NOT

Ideal output according to req.

1
Infusion Paused Alarm Actual

Obtained from model under verification

==
Comparison Model

Are ideal and expected equal?

OR

Override Logic

Is this always value 1 for all simulation time instants?

1
Ok

October 2009

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Summary

- Proven results in a variety of contexts
  - Including safety- and mission-criticality
- …and for a number of sponsors.

- Effective at working both with researchers and engineers
  - And communicating results that improve work in progress

- Central theme of results: Learning from <u>analysis</u>, <u>measurement</u>, and <u>experience</u>

For More Info…

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October 2009

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For More Info… Key pubs (excerpts)

- **SERC UARC:**
  - Pennotti, M., Turner, R., and Shull, F., "Evaluating the Effectiveness of Systems and Software Engineering Methods, Processes and Tools for Use in Defense Programs," Proc. IEEE International Systems Conference, pp. 319-322. Vancouver, BC, Canada, March 23-26, 2009.
- **DOD Best Practices Clearinghouse:**
  - **https://bpch.dau.mil**
  - Feldmann, R., Shull, F., and Shaw, M., "Decision Support for Best Practices: Lessons Learned on Bridging the Gap between Research and Applied Practice," Acquisition Review Journal, vol. 14, no. 1, pp. 235-247, February 2007.
- **NASA Safety Metrics for Constellation:**
  - Contact Dr. Victor Basili, **basili@fc-md.umd.edu**
- **NASA Software & System Technical Reviews:**
  - Denger, C., and Shull, F., "A Practical Approach for Quality-Driven Inspections," IEEE Software, vol. 24, no. 2, pp. 79-86, March/April 2007.
- **FDA Model-Based V&V:**
  - Penn Engineering Technical Report, **http://repository.upenn.edu/cis_reports/893/**