2012 EL Project Title and Number: Systems Engineering Standards

Program Title: Systems Integration for Manufacturing and Construction Applications

Principal Investigator: Conrad Bock, 734

Project Staff:

Conrad Bock
Allison Barnard Feeney
Peter Denno
Frank Riddick
Joshua Lubell
Simon Frechette
Albert Jones
Ion Matei
Sylvere Krima
Raphael Barbau
Anantha Narayanan
John Baras

Date Prepared: September 2, 2011

Summary: Systems engineering is a holistic, integrative discipline, wherein the contributions of many engineering disciplines are evaluated and balanced, one against another, to produce a coherent whole[1]. Each discipline uses different software tools and its body of knowledge to generate models with distinct viewpoints on the whole system. The systems engineering community lacks the measurement science needed to integrate knowledge, tools, and models in support of complex, manufactured systems design. This project will develop the measurement science foundation needed to enable this integration. The foundation will use formal methods to develop standard information models and languages. The outcome will be standards that facilitate (1) the integration of component models into a unified models of the entire system, and (2) the automation of many, currently manual, systems engineering tasks. The impact will be an increase in the productivity of systems engineers and their ability to build, maintain, and validate models.

[1] See *NASA Systems Engineering Handbook*, NASA/SP-2007-6105 Rev1, available at http://education.ksc.nasa.gov/esmdspacegrant/Documents/NASA%20SP-2007-6105%20Rev%201%20Final%2031Dec2007.pdf

Description:
Objective: By 2015, this project will develop the measurement science foundation for enabling engineers to build, integrate, and validate systems models more efficiently and more accurately.

What is the new technical idea? Designing, developing and sustaining complex systems requires many models with different viewpoints on the same system, depending on the engineering disciplines involved. There are hardware and software models, conceptual and detailed design models, user interaction and internal function models. At the center are computer-interpretable representations of the system's structure and behavior. Some models might be for communication with customers, and others for engineering analysis and simulation. The current standards landscape for representing these models is incomplete, disconnected and ambiguous.[2,3] There is no standard framework for reconciling the many viewpoints on the system models. There is no way to know that a piece of information in one model is referring to the same system component from another model.

Incremental improvements in the standards landscape are insufficient to simultaneously (1) manage the rapid increases in system complexity and globalization of engineering organizations and (2) achieve breakthrough productivity improvements needed to boost competitiveness of U.S. industry. Engineering of complex manufactured systems demands a new, formal, model-based approach that addresses dynamic relationships between multiple models of the same system. Formal approaches enable standards to cover multiple uses unambiguously. They facilitate identification of missing and imprecise portions of standards, translation between standards, and evaluation of proposals for augmenting, clarifying, and connecting standards. This project will apply formal model-based techniques to fill gaps in existing systems engineering standards, connect standards that are used together, and reduce their ambiguity. It will focus on prominent information model and systems modeling standards used in development, compliance testing, integration, and architecture of complex manufactured systems.

What is the research plan? The *Systems Engineering Standards Project* will address development, compliance, integration, and architecture of model-based systems engineering information model and systems modeling standards identified by industry and government road maps and consortia. In the first years of the project (FY12-14) we will develop the measurement science foundation that will enable the integration of integrate the knowledge, tools, and models in support of complex, manufactured systems design. In the final year (FY15), new systems engineering standards and architectures will be tested in pilot projects with partners from industry and academia. The project has four interrelated areas of activity.

- Systems engineering standards architecture. Perform research in architectures supporting multiple systems engineering viewpoints. Develop metrics and evaluate exchange protocol approaches for systems engineering standards. Define guidelines for the rigorous definition of these protocols. Research feasibility of agent-based architectures as a platform for system engineering model evaluation. Prototype open architecture for agent-based system engineering model evaluation.

---

[2] See *INCOSE Systems Engineering Vision 2020.* Available at http://www.incose.org/ProductsPubs/products/sevision2020.aspx
[3] *Systems-2020 Study, Final Report,* Booz Allen Hamilton, 16 August 2010. Available at http://www.acq.osd.mil/ se/docs/BAH-Systems-2020-Report-Final.pdf.

- System engineering standards integration. Lead development and standardization of formal integration between systems engineering standards. These standards will enable system models developed closer to the customer to be combined with models closer to engineering. The results will permit customer needs to be captured more accurately and interchange between systems engineering models to occur more easily.
- System engineering standards development. Lead development and standardization of upgrades to systems engineering standards that incorporate research in formalization of standards and model-based techniques. Identify gaps and ambiguities in systems engineering standards, and develop formalized upgrades to those standards to address them.
- System engineering standards compliance. Lead in enabling the uniform implementation and shared understanding of systems engineering standards. Major tasks include (1) contribution of research and tools supporting self-service validation and interoperability testing for models, (2) simplification of specification documents, and (3) formalization of language semantics and diagram definition.

These activities will be conducted in concert with industry development and deployment efforts, to ensure the standards will be implemented and used to increase productivity. Industry partners and customers will be involved in choosing which standards to pursue, how they will be designed, and the way they will be implemented and deployed. Some standards bodies require industry commitment during the development process, an approach that we will follow in our engagement with any standards body.

The activities will develop the measurement science foundation needed to integrate the knowledge, tools, and models in support of complex, manufactured systems design by applying frameworks to improve standards architecture, integrating standards that are to be used together, filling gaps in existing systems engineering standards, and ensuring compliance to these standards through testing and formalization.

The project will also undertake economic analysis of the manufacturing sector. The project will produce a set of comparative statistics for manufacturing and a NIST Special Publication documenting the manufacturing statistics procedure. The NIST Special Publication will focus on technology-intensive manufacturing sectors. It will review primary sources of data available on the manufacturing industry and then develop a set of comparative statistics. After identifying pertinent research, relevant data will be identified and obtained. The data will then be processed and organized into meaningful comparative statistics. In FY 2013, the project will prepare a future economic impact study and produce a white paper documenting the process through which areas of study were prioritized. Producing the white paper will involve in-depth discussions with the project team, literature reviews on project-related topics, identification of key project-related stakeholders, the sectors affected, and the type and nature of any project-related benefits and costs. The results of this analysis will identify those SIMCA projects that will yield the largest benefits to the affected sector(s) from an economic impact study.

Major Accomplishments:
Recent Results:

Outputs:

- Two journal papers on formalization of product and process modeling languages
- Book chapter on upgrades to a widely-used enterprise-level process modeling language
- Peer-reviewed conference paper presenting an improved method for developing on-demand, interoperable exchange specifications for product lifecycle information
- Workshop to gather architectural and testing requirements for systems engineering exchange standards
- New architecture for the STEP product data exchange standard that leverages semantic web technologies and enables use of widely-used modeling languages.
- Tooling that produces data exchange constructs and data populations.

Outcomes:

- New systems engineering additions to STEP standard, integrating systems engineering with many other forms of product data shared between production tooling.
- Upgraded process modeling in widely-used systems engineering standard, providing increased productivity in specifying behavior of manufactured systems.
- Tooling for self-service testing of implementations of widely-used systems engineering standard, used by software vendors and engineers to improve interoperability of these implementations.
- Upgraded interaction modeling in the UML modeling language, providing increased productivity in specifying multi-company manufacturing processes.
- Open-source tooling developed by NIST that performs transformations between standard information modeling languages is being used and extended in multiple data integration projects.
- Architecture developed by NIST for integrating two widely-used systems engineering standards being piloted in an industry lifecycle management integration project.

Standards and Codes:

Standard	NIST Staff	Expected Outputs/Outcomes
OMG Systems Modeling Language (SysML)/Unified Modeling Language (UML)	Denno Bock Barnard Feeney	Self-service interoperability testing tools for SysML/UML delivered and in use. SysML/UML formalized and simplified. SysML/UML extensions for system modularization, diagram definition, engineering change management, system variance, agent modeling, simulation integration, and execution standardized.
Business Process Model and Notation (BPMN), and OAGIS (Open Applications Group Integration Specification)	Bock	SysML/UML integrated with BPMN Processes standard. BPMN and OAGIS Scenario integration report.
OMG Unified Profile for DODAF/MODAF (UPDM)	Denno Barnard Feeney	Delivery of UPDM validation and interoperability testing tools, conformance and validation testing capabilities.
ISO 10303-233 STEP Systems Engineering	Barnard Feeney	AP233 mapped to SysML to provide an aligned data exchange capability for systems modeling.
ISO 10303-239 STEP Product Lifecycle Support	Barnard Feeney	AP239 compatible with Systems Engineering requirements and other STEP standards.
OASIS Product Life Cycle Support	Lubell Barnard Feeney	Metrics for evaluating AP233/PLCS standardization approaches. AP233/PLCS guidelines, data exchange tools, testing strategies.