US ARMY RDECOM

U.S. Army Research, Development and Engineering Command

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Deployment of MBSE processes using SysML

October 2010

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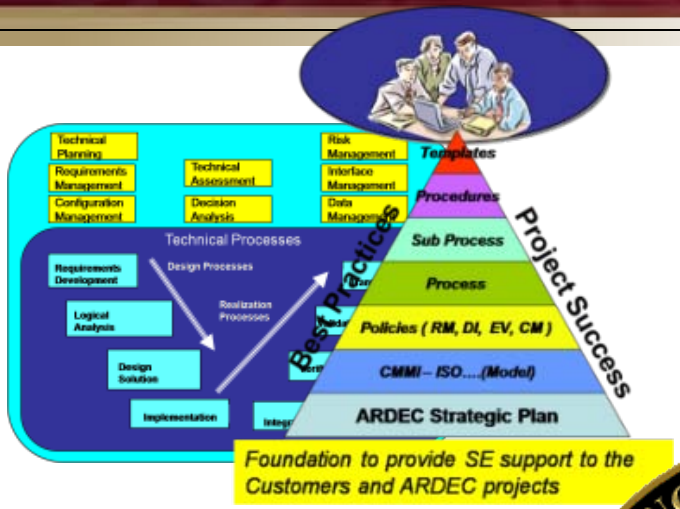
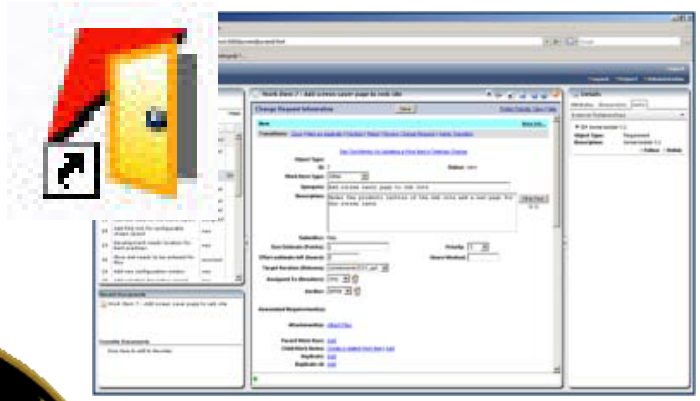
Topics

- Current SE at ARDEC Infrastructure
- Why move to MBSE?
- MBSE Gap Analysis
- Anticipated Benefits
- Three Pilot Projects
- Outreach
- Lessons Learned
- Summary

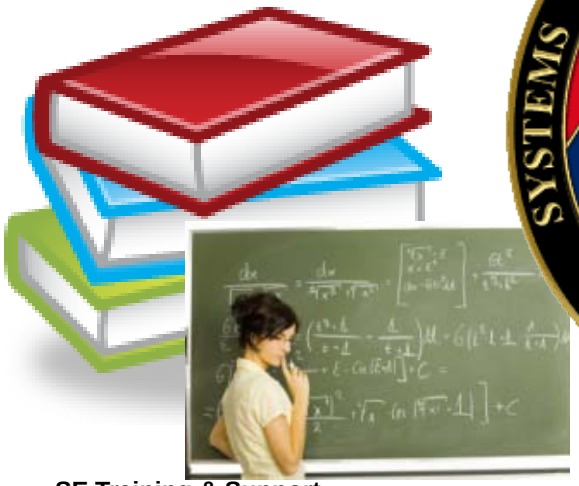
ARDEC Systems Engineering Infrastructure



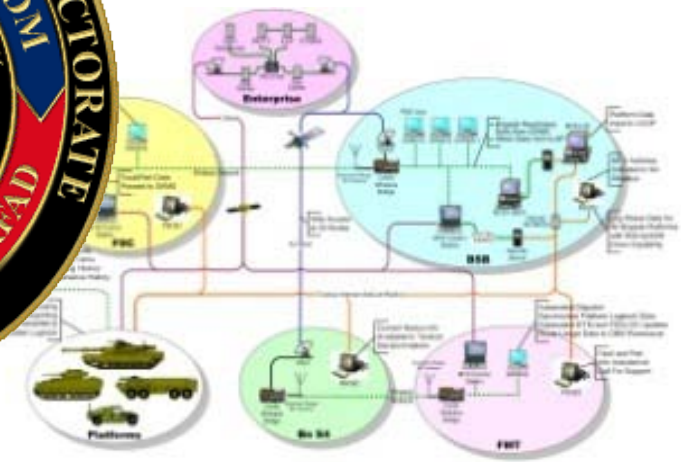
SE OSP Documents



SE Tool Suite



SE Training & Support



Collaboration Tools/Environment

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ARDEC Systems Engineering Infrastructure

ARDEC Systems Engineering (SE) Directorate has developed a core competency in SE processes and the tools and training to facilitate the application of the systems engineering best practices on projects.

SE Process

- SE Organization Standard Process (OSP) – ARDEC's systems engineering best practices captured and documented in Policies, Processes, Procedures and Templates. OSP available online to workforce. Metrics and measures defined, collected, and analyzed to facilitate continuous improvement of OSP

SE Tool Environment

- Maintain a central database for all supported ARDEC and PM programs
- Virtual terminal servers to facilitate collaboration for IPTs distributed across the country
- Includes access to RM, CM, modeling, architecture and publishing tools.

SE Training

- Develop key training in tools and processes that allow IPT members to perform effective Systems Engineering on projects.
    - Tools training
    - Process training
    - Customized SE practice area workshops

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Weapon System Acquisition Reform Act of 2009

Weapons Systems Acquisition Reform Act (WSARA) 2009:

Mandates SE applied to DoD programs

"The key to successful acquisition programs is getting things right from the start with sound systems engineering, cost-estimating, and developmental testing early in the program cycle."

–Senator Carl Levin (D-MI), Chairman, Senate Armed Services Committee

"This legislation is needed to focus acquisition and procurement on emphasizing systems engineering; more effective upfront planning and management of technology risk; and growing the acquisition workforce to meet program objectives."

–Senator John McCain (R-AZ), Ranking Member, Senate Armed Services Committee

Unanimously Approved by House and Senate!

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Why ARDEC's MBSE Initiative

To Develop in-house Model-Based Systems Engineering (MBSE) Capability to include Methodology, Tools, Training, and SMEs

- Formalizes the practice of systems engineering through the use of models
- Broad in scope
  - Integrates with multiple modeling domains across lifecycle from SoS to component
- Results in quality/productivity improvements & lower risk
  - Rigor and precision
  - Communications among system/project stakeholders
  - Management of complexity
- Encourage and facilitate integrated architectures in projects
  - Logical/Functional Architectures
    - Better understanding of interfaces
    - Better understanding of system behaviors and operations
  - More effective and efficient system development

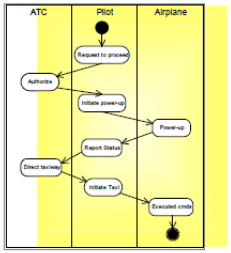
MBSE Gap Analysis

- **Goal:** To identify ARDEC needs related to MBSE using community knowledge as baseline against our SE process
- **Purpose:**
  - Understand the concept of system models
  - Establish a common lexicon for ARDEC MBSE
  - Identify tasks needed to begin the transition from the traditional document centric SE approach to a more model centric approach
  - Explain community-understood benefits of implementing MBSE
  - Identify challenges to ARDEC in adopting MBSE by understanding existing capabilities and where MBSE gaps exist
  - To suggest a path forward that will be implemented into the overall MBSE initiative

Past

Document centric

Future

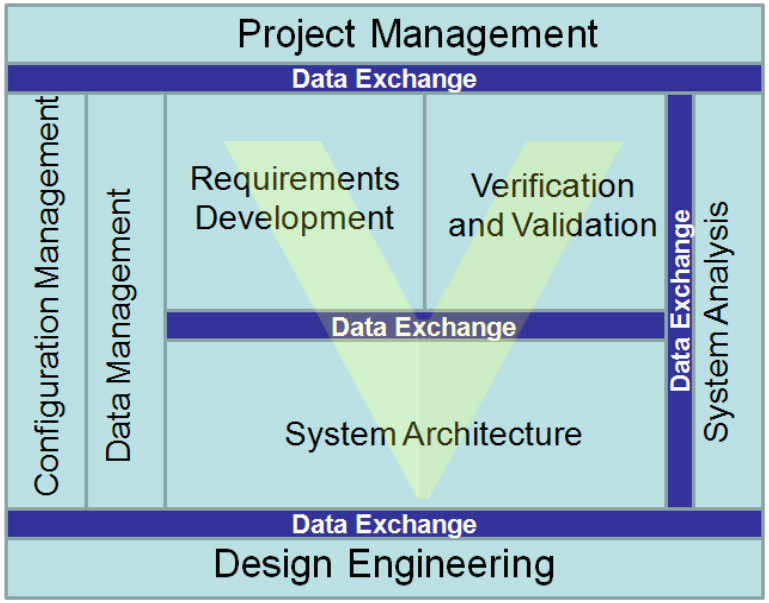


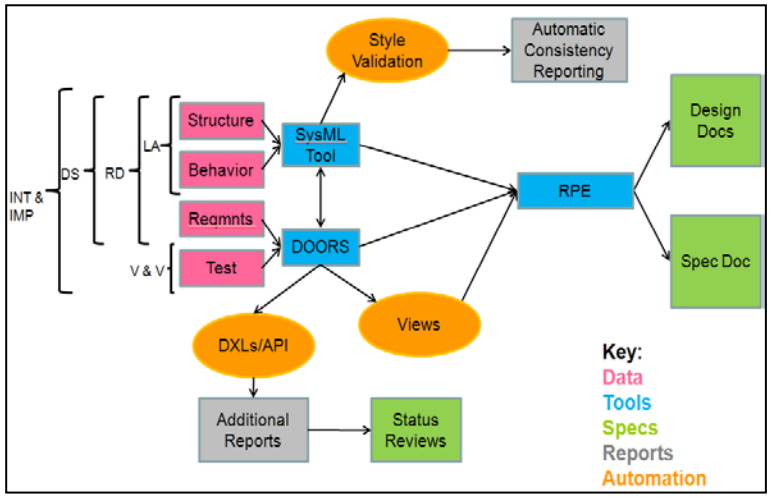
Model centric

Outputs of the MBSE Gap Analysis

- MBSE defined for ARDEC: formalized application of modeling to support the SE process throughout the entire lifecycle
- Defined an initial MBSE environment
  - Overall MBSE objective: enable M&S throughout the development lifecycle
  - Near term goal is to focus on the core SE activities (Requirements Development, Logical Analysis, and Design Solutions)
- Proposed an initial operating concept based on ARDECs existing capabilities
- Created a Gap Matrix which identifies:
  - "Present State" and "To Be State"
  - Gap Type (Process, Methods, Tools, Environment, People, or Technology)
  - Plan of Action, Dates, Resources, and Deliverables

Results from the Gap Analysis created the foundation for the activities of the MBSE Initiative





Automating the SE Process

The benefits of combining Requirements Management and MBSE activities are many. Combining these activities help the SE to:

- Formalize the design process
- Build more accurate and complete system descriptions
- Construct a consistent vocabulary for the system
- Improve requirements traceability and design rationale
- Reuse designs
- Manage Non-functional and Performance Requirements
- Perform impact analysis from anywhere in your design

SysML – How did we get here?

- **History of SysML**
  - 2001: INCOSE call to modify UML for application to MBSE
  - 2001: OMG Systems Engineering Domain Special Interest Group formed
  - 2003: UML for Systems Engineering RFP developed by INCOSE, issued by OMG
  - 2003: SysML Partners formed, author “Open SysML”
  - 2006: Multiple proposal “Merge” effort by OMG
  - 2007: OMG SysML 1.0 issued as a UML “Profile”
  - 2010: Ver 1.2 released

Three Pilot Projects

- Engagement Targeting System for Soldiers
  - Integrates with weapon to provide NLOS targeting
  - Stand-alone and Cooperative Engagement modes of operation
  - Requires interaction with both soldier and supporting infrastructure to complete mission requirements
  - *SysML model helpful for identifying and codifying functional dependencies on other systems, visualization of system functional boundaries*
- Programmable Artillery Round
  - Strict sequential interaction of components
  - Multiple mission scenarios each with multiple activity paths
  - *SysML provided visibility to required system and component logic*
- Automated Vehicle Health Management
  - Integrated ground vehicle health reporting and monitoring
  - Condition-Based Monitoring for preventive maintenance
  - Integrated Electronic Technical Manuals
  - *SysML models identified functional, communication, and interface components of the complex system/subsystem*.

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Outreach

- Community Involvement
  - Participation in INCOSE MBSE and Model Usability Working Groups
    - Attended both IW and IS
    - Gained exposure to current state of practice
    - Trends
    - Current Issues
  - Attendance at local INCOSE SysML Seminar
- Inclusion of External SME's
  - Sandy Friedenthal, SysML Partners – asked questions like:
    - "What problem are you trying to solve?"
    - "Did you really need sequence diagrams (vice activity diagrams) to visualize interactions"
  - Dr. Robert Cloutier, Associate Prof., Stevens Institute of Technology
    - "Why the rush to identify blocks?"

The hunt for best practices

Lessons Learned - Methodology

- SysML is a large and complicated language
  - To improve efficiency, remove parts that are irrelevant to your processes, model purposes and system make-up
- Address Islands of SE Responsibilities
  - Model artifacts often cross-cut organizational boundaries
  - Full benefits only realized when everybody is motivated to play in the same sandbox
- No One Source of Know How
  - Every situation is unique
  - Use Multiple references, toolkits and training for guidance
- Which behavior diagrams and when?
  - Benefits
  - Must Maintain Consistency Across Different Views
    - The more views you use, the greater the effort will be to accomplish this

Lessons Learned - ROI

- You don't make money the first time
- Model for a purpose (or Purposes)
- Purposes need to be managed like requirements
  - Never miss an opportunity to remind stakeholders what they are
  - Make sure everybody is on board of they change
- Success Requires Formalized SE Processes
  - that may not exist.
- Incorporate the use of SysML and MBSE in SEP
  - Include artifact production from model against project milestones

Lessons Learned - Language

opaque
subclass
stereotype
metaclass
binding
metamodel
primitive
alias
namespace
dependency
instance
association
polymorphism
delegation
inheritance
meta object facility
class
package
superclass

Early on, even the most experienced Systems Engineer will struggle to be productive

Lessons Learned – Tool/ Tool Selection

- Selection Made with Trade-off Analysis
  - Features uncovered after selection made
- For Pilots, Specific Tool Selected Not Seen As Important
  - Emphasis on learning language
  - Chose to use same tool on each project
- Process/Methodology Script Experience
  - Automated features may put you in a box that is inappropriate for your project
- Tools Use Different File Structures, Effects:
  - Model CM
  - Integration with Engineering Repositories
- SysML compliancy
  - Temptation to leave in features not part of SysML profile, adding complexity
- Different levels of consistency maintenance
- What is the definition of “executable”?
  - Behavior timeline
  - Design budgets (static and dynamic)

Summary

- Fundamentals of Systems Engineering reinforced through the creation of models
- Improvement seen in communications among system/project stakeholders
- Efficiencies not yet realized, require SysML proficiency at outset
- “Reverse Engineered” pilot projects -
  - Good for learning SysML
  - Helpful in support of developing processes
  - Missed opportunity to influence final outcome
- Model for a Purpose - *Begin with the end in mind!*