National Aeronautics and Space Administration

Model-Based Systems Engineering Pathfinder: Informing the Next Steps

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MBSE

MBSE Pathfinder Context

- Numerous MBSE efforts at NASA over the past decade
  - Several Center workshops
  - 30+ SysML training classes at multiple Centers
  - NASA Integrated Model-Centric Architecture initiative

- Push to transition to a Cloud environment
  - Pilot a floating license environment for engineering software
  - Evaluate a common domain for model archive and sharing

… effectively utilize 21st Century technology, tools, and methods across NASA's diverse portfolio of programs, projects, and technological innovations

Systems Engineering Technical Discipline Team

- Organization within the NASA Engineering and Safety Center (division of the Office of the Chief Engineer)
- Provides systems engineering expertise to the Agency
  - Perform value-added independent testing, analysis, and assessments of NASA's high-risk projects to ensure safety and mission success
  - Provides senior NASA management with a perspective on the health of Agency systems engineering
  - Develops and implements plans for Agency systems engineering investments
- Led by the NASA Systems Engineering Technical Fellow
- Sponsor of the MBSE Pathfinder
  - Framework and management of the activity
  - MBSE training for the participants
  - Access to a consistent set of MBSE tools

Participants and Work Approach

- Teams
  - Diverse, small, and agile
  - Worked in parallel for eight months

	Team 1	Team 2	Team 3	Team 4
Number of participants	8	6	8	5
Number of Centers	7	5	5	4
Engineering disciplines	aerospace electrical mechanical software systems	aerospace mechanical systems	electrical mechanical software systems	aerospace mechanical systems
Aerospace experience				
25+ years	4	2	4	1
11 to 25 years	2	0	1	2
0 to 10 years	2	4	3	2
Previous MBSE experience				
High	0	1	0	1
Medium	3	0	3	1
Low	4	1	3	3
None	1	4	2	0

- Leverage existing data and products for start and comparison
- Situational learning, creativity, and innovation
- Maximize exposure to collaborative, virtual system modeling

Growing the NASA MBSE Community

Goal or Objective	Result
• Multi-center collaboration • Get all Centers to the same minimum level • Recognize champions and users of MBSE within NASA • Develop aligned capability and community across the Centers	• Eight NASA Centers and JPL participated – 30+ participants on the teams – Each team had participants from four or more Centers – Initial training class for all participants provided a common starting point • Expert identification – Among the participants – People and other resources at their Centers • Communities of practice at several Centers increased

Mission Focus Areas

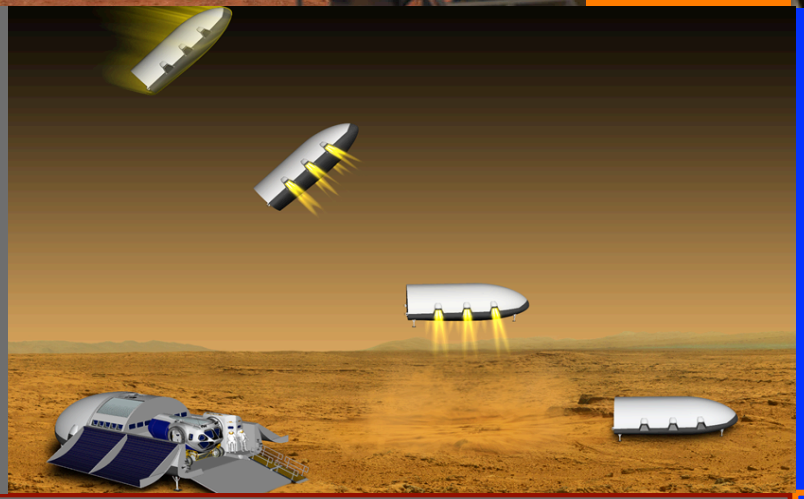
Design Reference Mission Architecture - Mars In-Situ Resource Utilization

Top level and mission-to-mission architecture re-use

Liquid Oxygen / Methane Engine

Advanced manufacturing environment

Integrated analysis among mission and sub-systems



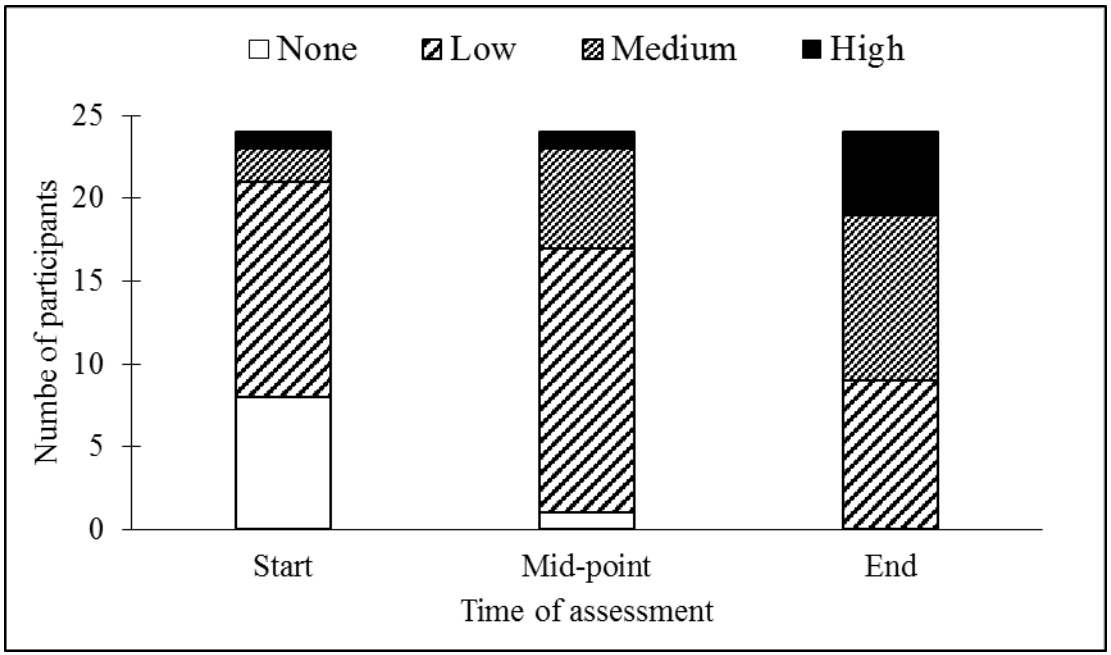
Exploration Class Element - Lander

Real-world repetitive missions

Sounding Rocket Mission Flow Shadow

Learning to Model

- Learning opportunities
  - On-the-job experience
  - Hands-on training, consultation, and feedback on modeling products
  - Webinars, demonstrations, and reuse of other models
- Learning areas
  - Virtual teams in a collaborative, model-based environment
  - Modeling language and tool suite
  - Generate systems engineering products from a system model



MBSE Skills Self-Assessment Results

Modeling Real Problems

Goal or Objective	Result
• Apply MBSE to real NASA issues • Develop expert capability (be a smart buyer) that can assist in developing a systems engineering vision and next steps • Examine reuse of models and data	• Focus areas related to NASA missions – Multiple MBSE topics were explored collectively in sufficient depth to understand the area • Eight months of experience increased understanding – Developed reference architectures, libraries, templates, and other reusable items – Examined use of models for data analysis and storing data associated with model elements such as value properties

Working Together Across the Agency

- Many organizations and cultures

Changing Agency and Center Cultures

Goal or Objective	Result
• Provide an opportunity to participate in an Agency-level activity and change the culture • Understand opportunity and difficulty for implementing an agency-wide integrated approach • Capture issues and opportunities	• NESC sponsored the activity • Grew the NASA Cloud – Cloud resources were available to all participants • Agency-wide collaboration area noted as highly desirable • Knowledge Capture – Monthly team virtual meetings – Face-to-face meetings – Final Reports with opportunities and difficulties

MBSE Pathfinder 2016 Outcome

- Technical
  - All teams accomplished a significant amount of system modeling work
  - Participants used many different approaches, tools, and processes
  - Participants identified lessons-learned along the way and at the end

- Knowledge capture areas
  - Lessons-learned about this pathfinder
  - Learning to model
  - How to do systems engineering with MBSE
  - MBSE with other areas
  - NASA infrastructure
  - Acceptance of MBSE

Learning about the Pathfinder and Modeling

Topic Area	Comments and Recommendations
Lessons-learned about this Pathfinder	• Focus on doing systems engineering • Model more of the life-cycle of a product • Link models from different teams
Learning to model	• Develop a model from within a familiar domain • Focus on a particular project: have a problem to solve
How to do systems engineering with MBSE	• Too early to standardize on a specific toolset • Start the adoption in a thoughtful and incremental way – Mapping from document-based artifacts to MBSE products – Configuration Management is critical
MBSE with other areas	• Consider data as the "single source of truth" – Involves data transformation, presentation, analysis, and multiple levels of detail – Consider data in system models vs. discipline areas

Infrastructure for and Acceptance of MBSE

Topic Area	Comments and Recommendations
NASA infrastructure	• Recommend a NASA-wide MBSE wiki to facilitate communication and socialization => glossary, best practices, etc. • Grow the NASA Cloud => more access, more users • Engineer the MBSE ecosystem
Acceptance of MBSE	• Scattered use at centers with small successes – Not a cohesive story • Identify a champion at each Center to tie stories together • Use stakeholder analysis to drive priorities

MBSE Pathfinder 2016 Summary

- It is possible to succeed with a Pathfinder
  - Recognized difficulties
    - Relatively short amount of time
    - Many inexperienced people
  - Factors for success
    - Management support from all levels
    - Quick, real-world experiences
    - Active involvement of experienced and expert personnel

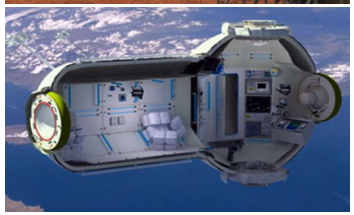
- Benefits to NASA
  - Trained and experienced cohort – smart buyers
  - Go-to resource for Centers, Agency, national, and international groups
  - Increase or revival of Center MBSE working and learning groups

MBSE Pathfinder 2017 Overview

- Implement lessons learned from 2016
  - New or modified mission focus areas
  - New cross-cutting themes team
  - Grow the NASA Cloud infrastructure and shared licensing approach
- Expected outcomes
  - Development of SE products across the life-cycle
  - Integration with various engineering design and analysis tools
- Develop planning options for Agency-wide engagement
  - Use the MBSE Pathfinder as a pilot for options under consideration

MBSE Pathfinder 2017 Mission Focus Areas

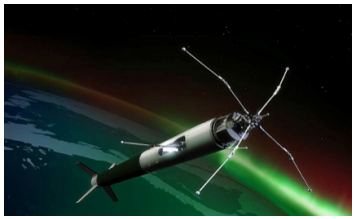
- ISRU, Trades for Mars Mission



- In-Space Habitat Element, Requirements and Design

- Engine, Requirements Compliance and Test Configurations

- Launch Vehicle Payload Adapter, Structure Design and Build



- Sounding Rocket, Mission Flow Shadowing

Growing the MBSE Community

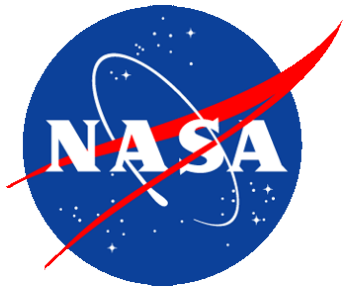
- MBSE Pathfinder Cross-cutting Themes Team
  - Promote cross-team interactions and product integration
  - Address common topic areas
  - Library of common practices

- Virtual NASA MBSE Community of Practice Pilot
  - Online collaborative portal
  - Knowledge repository

Conclusion

- MBSE Pathfinder achieved the 2016 objectives
  - Teams modeled systems-of-interest selected from NASA missions
  - Virtual environment represented the modern workplace
  - Provided significant number of lessons-learned for next steps
  - Established a collaborative community
- MBSE Pathfinder in 2017 continues to mature the implementation
  - Stronger NASA program and stakeholder partnering
  - Continued refinement of modeling integration approach
    - Within the systems engineering domain
    - Across other engineering disciplines
  - Develop and assess a federated Agency MBSE deployment

Moving NASA Systems Engineering Forward…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