SYSTEMS ENGINEERING RESEARCH CENTER

Digital Engineering Migration Of Evolved Strategic Satcom System Engineering and Technical Management Processes

WRT-1054

Dr Mark Blackburn

US Space Force (USSF) Space System Command (SSC)

STEVENS INSTITUTE of TECHNOLOGY
THE INNOVATION UNIVERSITY®

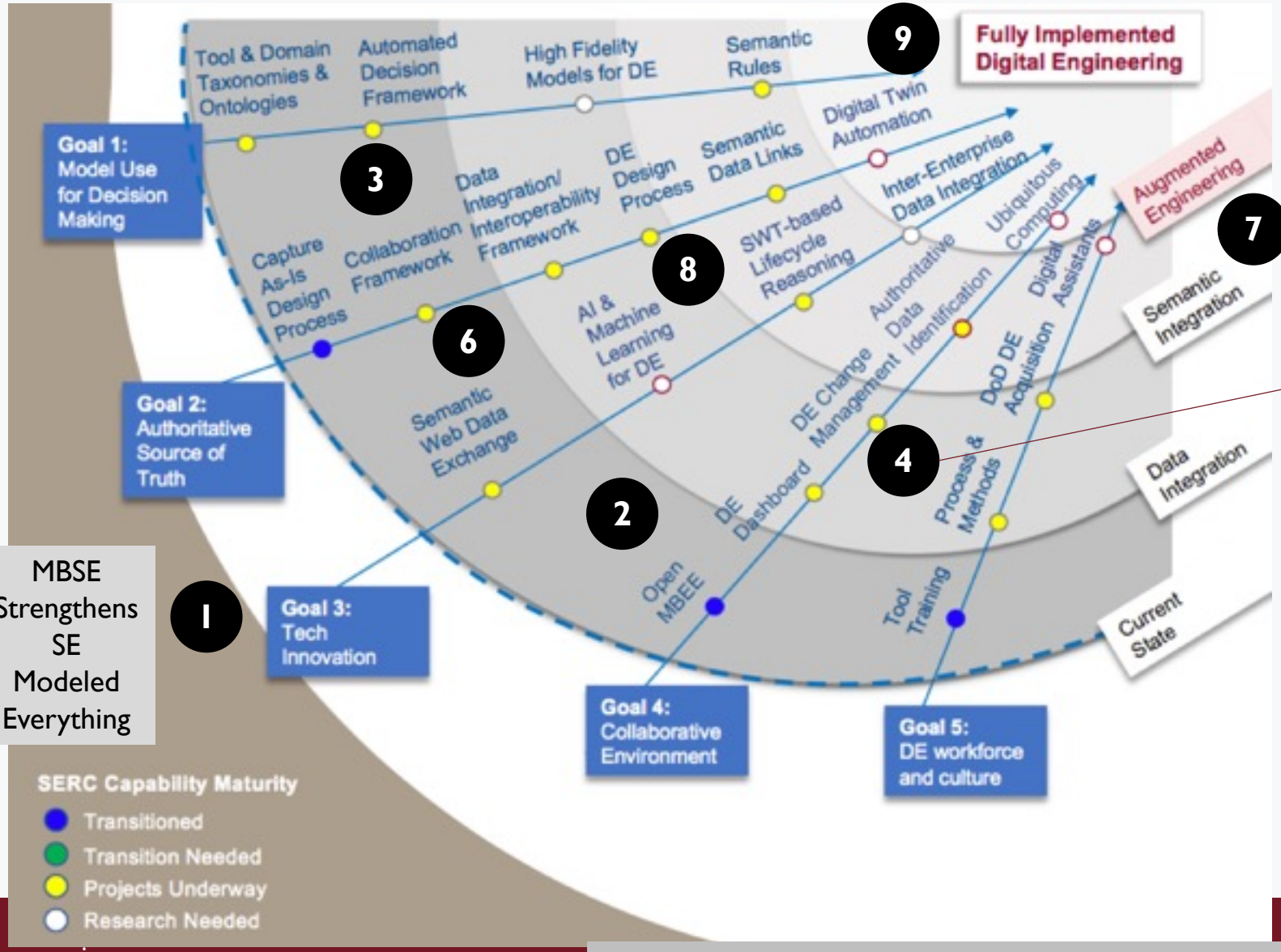
Georgia Tech
Aerospace Systems Design Laboratory

ANNUAL RESEARCH REVIEW 2022

Organization

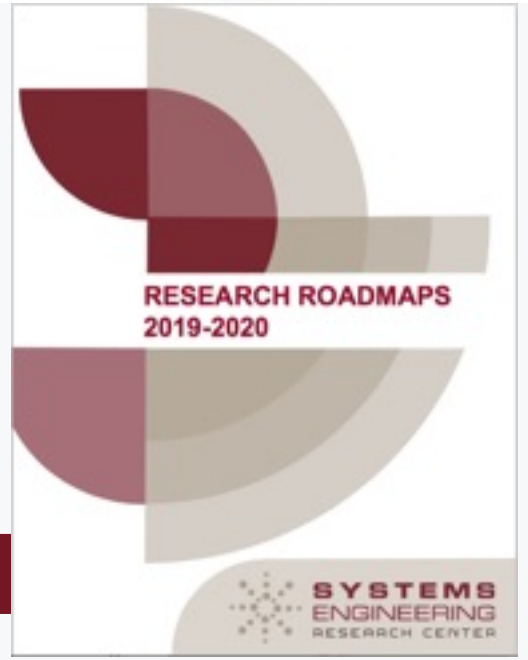
- **WHY:** Understand Big Picture of Digital Engineering for Program Adoption
- **WHAT:** Digital Engineering Enabling Technologies extending prior research from NAVAIR Skyzer Surrogate Pilot and Systems Engineering Transformation
- **HOW:** "Full Stack" of Models for New Surrogate Case Study called "Spacer" using publicly available sources from FireSat/CubeSat
  - Investigating use of Research from Armament Interoperability and Integration Framework (IoIF) and Methodologies
- **HOW WELL:** Transitioning research using Spacer case study and supporting workforce development with Digital Engineering Bootcamp training and associated workshop

Digital Engineering for Systems Engineering Roadmap: Goals are Mutually Supportive not Orthogonal



MBSE Strengthens SE Modeled Everything

Methodology Artifacts are Enabler for Digital Signoff



* https://sercuarc.org/wp-content/uploads/2020/01/ROADMAPS_2.3.pdf

Spacer is Surrogate Pilot & Experimental Use Cases

- Spacer uses modeling patterns/methods to create Authoritative Source of Truth (AST) demonstrated for NAVAIR Skyzer Surrogate Pilot
- Spacer derived from publicly available sources CubeSat/FireSAT to provide unclassified modeling examples for demonstrations and workforce development
- Spacer modeled using NAVAIR Systems Engineering Method (NAVSEM), which specifies artifacts for Digital Signoffs to transform away from CDRLs & DiDs
- "Full Stack" includes Graphical CONOPs, Mission, System, discipline-specific, Stakeholder Analysis Models (e.g., Cost) & may use ontologies & reference models
- Digital Engineering SOW under development to request industry bidders produce RFP response models that link to Spacer "Full Stack" as part of AST
- Demonstrates Art-of-the-Possible by modeling "everything" like Skyzer
- Capturing modeling effort using a Flipbook to support training and adoption

"Full Stack" of Space Force Use Case for Models Enabling Digital Engineering & Acquisition Analyses

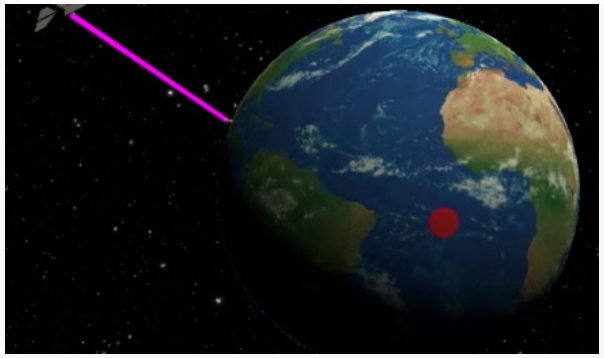
Using and Tailoring Reference Models (some derived from MIL-STDs)

Reference models characterize reusable information and process

NAVSEM Model | Airworthiness Model | CBT&E / MBTD Model | Cyber Model | Reliability and Maintainability | Cost Model | More...

NAVSEM Compliant

Graphical CONOPs derived from publicly available sources FireSat



Project Usage

Mission Model

Space Model

Ground System Model

"Full Stack" **Spacer**

Contractor RFP Response Model (1..*)

- Guidance & Navigation
- Communication
- Power
- Payload
- Etc.

- Spacecraft Command
- Ground Equipment Control
- Communication
- Mission Data Processing
- Etc.

...

Stakeholder Analysis Models

Instance of CBT&E / MBTD Model

Instance of Cyber Model

Instance of Cost Model

Evaluation Model

Criteria focused on Capability-based Test & Evaluation (CBT&E) and Mission-based Test Design (MBTD)

Cyber criteria needed for mission and system

New Cost Modeling approach based on using MBSE artifacts

RFP Evaluation Model for Source Selection

How to model to develop Authoritative Source of Truth

Digital Engineering Bootcamp Overview

- Learn the concepts of the “big picture” about Digital Engineering
- Learn the concepts of models, types of models and associated modeling methods that apply to different levels of modeling
- Learn how to link models to create an Authoritative Source of Truth (aka Information) to support Collaborative Information Sharing
- Learn how model management extends configuration management
- Learn how ontologies and semantic technologies enable interoperability of modeling information across domains and for different levels of modeling
- Learn how models promote better decision making for acquisition enabled by linked models and collaborative environment
- Use class exercises and DE tools to navigate through and find model information generated with OpenMBEE DocGen using a case study

DE Bootcamp Course Parts and Themes

	Module Title	Introduction	Advanced	MBE	MBSE	Modeling Methods	DE Env./Tools	OpenMBEE	DocGen	ASOT	Digital Signoffs	Ontologies	IoIF	Decision Framework	Model Management	Roadmaps	Skyzer / Spacer	SysML	MDAO	Reference Models	Hazard/Safety/Cyber	Exercise
Overview	Transforming Systems Engineering through Model-Centric Engineering / MBSE	60	60		1	1	1	1	1	1	1	1	1		1	1	1	1		1		
	Ontologies for Engineering: A Pragmatic Perspective	60	60		1	1	1					1	1									
	Establishing a Digital Engineering Environment and Model Management Methods using Spacer		60		1	1	1	1	1	1					1							
	Introduction to OpenMBEE for MBSE	60	60																			
MBE/MBSE Modeling Methods & Tools	Fundamental Concepts and Terminology in Models and Modeling	60		1	1	1																
	Model Based Engineering	60	60	1	1	1	1															
	Model Based Systems Engineering and SysML through Model-Centric Engineering / MBSE)	60	60	1	1	1	1	1	1	1	1						1					1
	Introduction to Digital Engineering Tools		60	1	1		1	1		1		1	1					1	1	1		
	Introduction to MBSE Modeling Methods		60		1	1	1	1	1	1	1							1				1
	Linking Stakeholder Analsis Model to the "Full Stack" of Technical Models		90	1	1	1	1			1					1		1	1				
IoIF Ontologies & Semantic Technologies	Fundamental Concepts for Using and Extending Interoperability and Integration Framework		90	1	1	1	1					1	1	1				1				1
	Cyber Ontology Case Study Overview		45		1	1	1					1	1					1				1
	Computer System Model (SysML) for the Cyber Use Case		60		1	1	1					1	1					1				1
	Building and Extending a Cyber Ontology For Vulnerabilities		60		1	1	1					1	1					1				1
	Jupyter Notebook for Executing Use Case		60			1	1						1									1
	Using Assessment Flow Diagram (AFD) to Model Cross-Domain Model Integration		60		1	1	1					1	1	1				1				1
	The Assessment Flow Diagram and IoIF: Semantics of IoIF Interfaces		60		1	1	1					1	1	1				1				1
	Tool Proxies: IoIF Services for Exchanging Data between IoIF and Tools		60			1							1					1				1
	Decision Framework, Decision Ontology and Dashboard	60	60		1	1	1					1	1	1				1				1
	Strategy System Program (SSP) Ontologies Enabled by Interoperability and Integration Framework (IoIF)		60		1	1	1					1	1	1	1			1				
Special Topics	Tradespace Analysis Using Multidisciplenary Design, Analysis and Optimization (MDAO)		60	1	1	1	1			1				1				1	1			
	Integrating Hazard Analysis with SysML System Models		60		1	1												1		1	1	
	Digital Engineering Bootcamp Workshop	180		1	1	1	1	1	1	1				1	1						1	

Overview of Workshop Planning (Under Development)

- *Plans Are Worthless, But Planning Is Everything (maybe Dwight D Eisenhower).*
- Occurs at end of training to reinforce knowledge gained from training
- Action Plan for Program Deployment as last module of DE Bootcamp
  - Deploy Digital Engineering to a program
  - Establish Collaborative DE Environment
  - Narrow focus on deep dive of Technical Models and why area was selected
  - Identify needed MBSE and SME team/roles
  - Know how to use Model Management of DE Environment
  - Create Source Selection Evaluation (consider Digital Signoff – see Skyzer example)
  - Evaluate Contractor System of Interest (SOI) System Model Plan
  - Plan for How Mission and System Models, and Contractor Models Support Verification
  - Determine Technical Progress Monitoring
  - Address Data Rights to DE Data and Information throughout Life Cycle
  - Determine DE Technical Performance Measures
  - Use Reference Models to be used or to be produced

Flipbook Outline

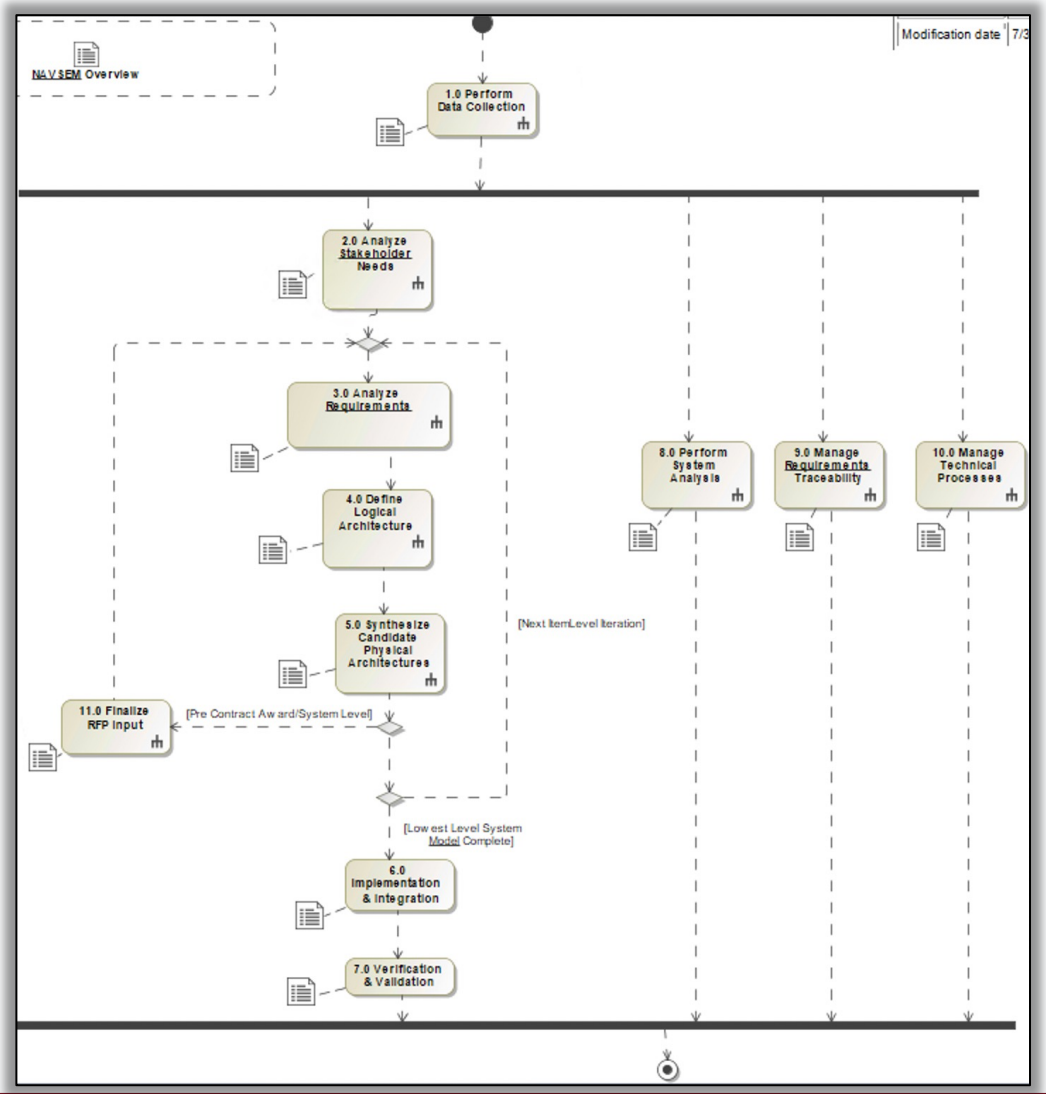
- Provides step-by-step guidance from the Spacer modeling effort
- Full Stack Overview
- Setup
  - Creating Models
  - Collaboration Platform
  - Project Usage
  - OpenMBEE
- NAVAIR Systems Engineering Method (NAVSEM)
  - Steps to be Compliant with NAVSEM with FireSat Example Model
- Use Flipbook as a way to help Space Force assess current models and plans

NAVAIR Systems Engineering Method (NAVSEM)

- Developed out of Systems Engineering Research Center (SERC) research task RT-195
- NAVSEM aligns to MIL-STD-499, IEEE 15288.1-2014, and OOSEM, but is tailored for the DoD environment and NAVAIR process
  - Generic enough to be useful for other processes
- Applied towards Skyzer (unmanned aerial vehicle – UAV) Mission and System models to demonstrate effectiveness
- Objectives
  - Defines the overarching systems engineering process
  - Identifies major tasks to be accomplished when modeling digital system artifacts
  - Supports the generation of the government systems engineering plan
  - Ensures model completeness and consistency
- Selected method for Spacer models

NAVSEM is Documented in a Distro A. SysML Model

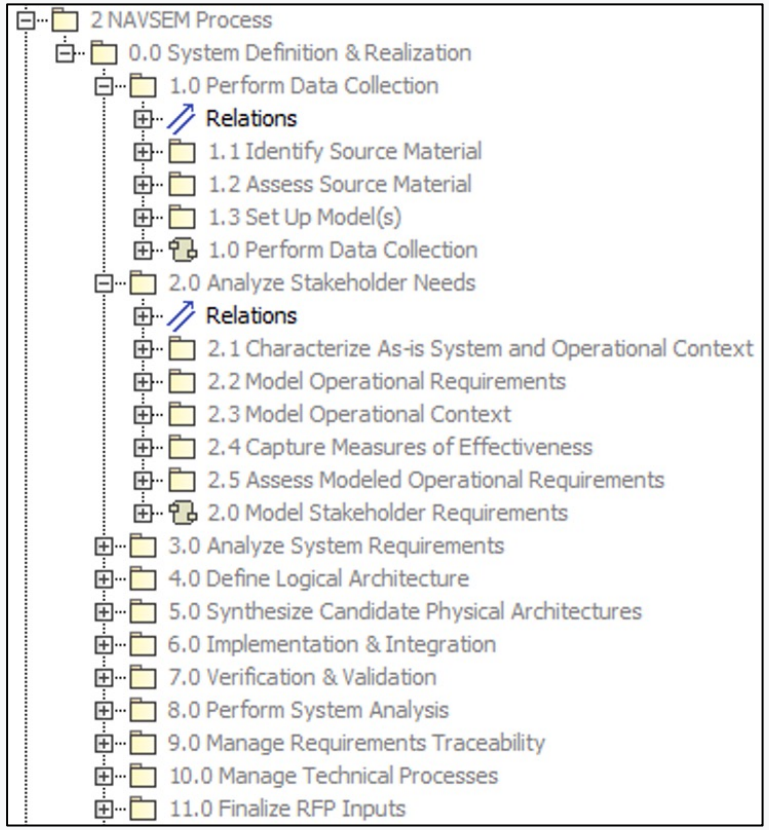
1. Perform Data Collection
2. Analyze Stakeholder Needs
3. Analyze Requirements
4. Define Logical Architecture
5. Synthesize Candidate Physical Architectures
6. Implementation & Integration
7. Verification & Validation
8. Perform System Analysis
9. Manage Requirements Traceability
10. Manage Technical Processes
11. Finalize RFP Input



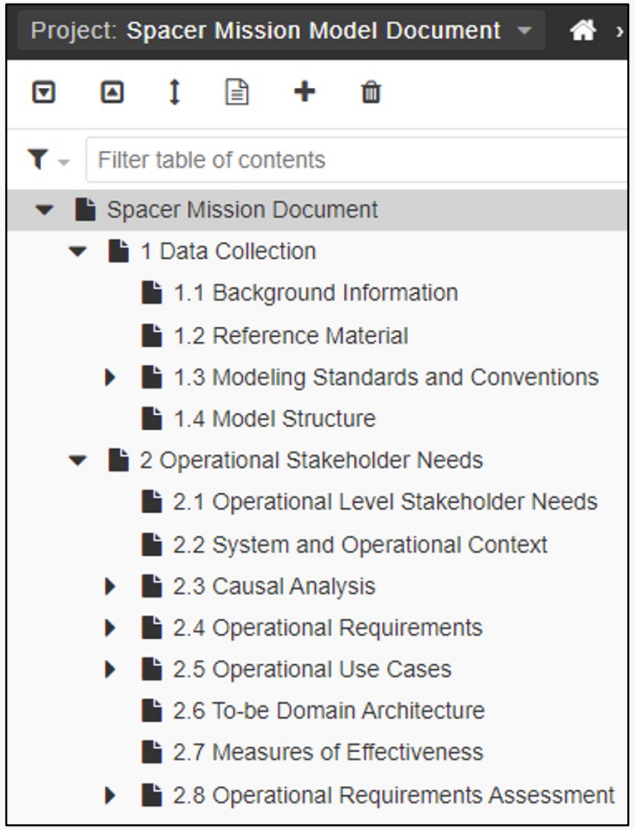
Model's Setup and Compliance with NAVSEM

- Using NAVSEM, models can be setup and organized more efficiently
- Document Models can be used to keep track of compliance with NAVSEM
  - The outline of the Document model is consistent with the NAVSEM process steps
  - If information is missing from an element within the outline, then this tells us model information is missing and thus not yet fully compliant with NAVSEM

Process Steps shown in MagicDraw Containment Tree



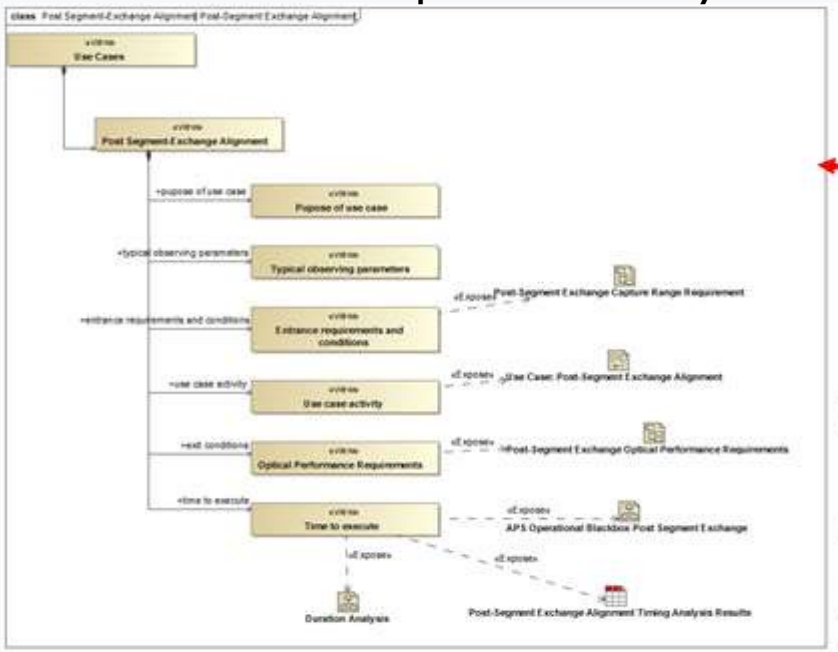
DocGen Output in OpenMBEE View Editor web-app



- Spacer Mission Model shown for example
- Spacer Mission Model covers Steps 1 and 2 in NAVSEM

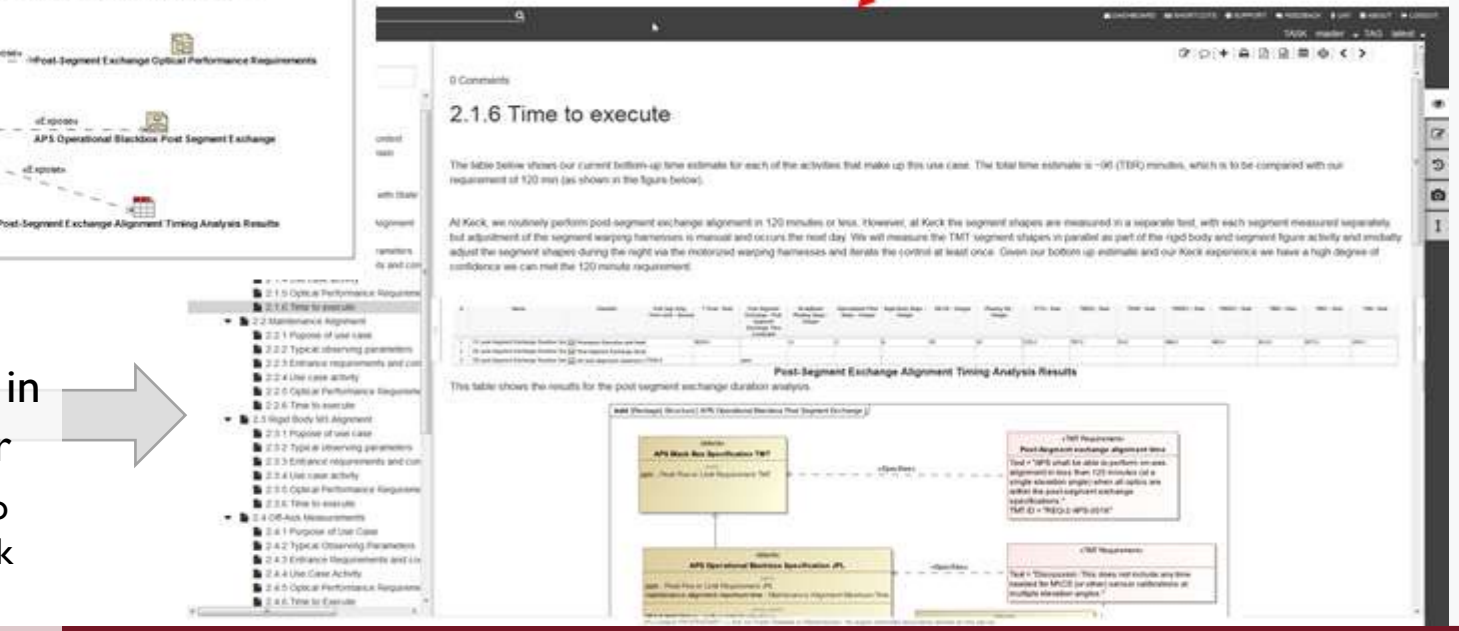
OpenMBEE as Part of Digital Engineering Environment

Model Development Kit/DocGen
View and Viewpoint Hierarchy



Model Management System

View Editor



Visualization in View Editor
(allows edits to be pushed back into model)

Why OpenMBEE

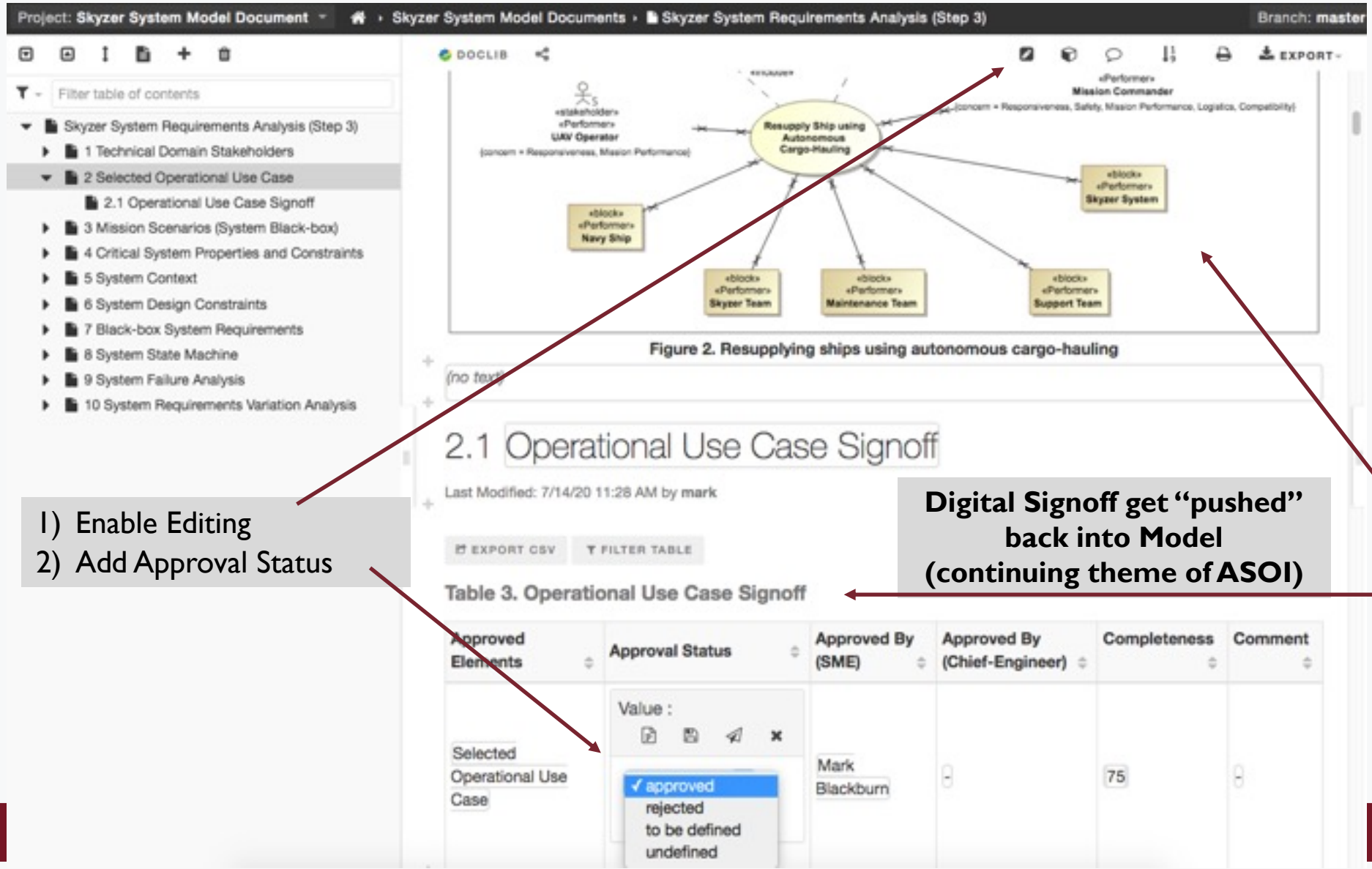
- MBSE has been around about 20 years and processes, methods and tools have matured
- Digital Engineering Transformations for many organizations and Government who acquires large scale systems of system is resulting in moving away from documents and instead using integrated models, tools and technologies
- Engineering user are only part of the community
- Need for broader understanding by Subject Matter Experts (SME) that now must provide information to Stakeholder Analysis Models (e.g., Cost, Reliability, Risk, etc.) that link with the technical models

https://www.openmbee.org/

Objectives for Using OpenMBEE for Course Exercises

- Understand how OpenMBEE DocGen and View Editor provide a type of Tool Proxy
  - Learn to use View Editor to read DocGen produced model views
  - Understand how Excel is also a Tool Proxy
  - Learn how to use Tool Proxies to find relevant information linked to technical models
- SMEs still must understand how Model Management in OpenMBEE and Teamwork Cloud work together
- Understand how SME can use Digital Signoffs to accept or reject model updates on information generated from the model in View Editor

Digital Signoff for Operational Use Case



1) Enable Editing
2) Add Approval Status

Digital Signoff get "pushed" back into Model (continuing theme of ASOI)

Evidence (model artifact) needed to make a decision is co-located with the Digital Signoff (table)

Conclusions – How Well

- Transitioning research using Spacer case study derived from publicly available sources
- Spacer support workforce development with Digital Engineering Bootcamp training and associated workshop
- Spacer modeled using NAVSEM
- Spacer modeled using modularity pattern used for Skyzer
- OpenMBEE provides a way for Subject Matter Experts to navigate DocGen generated model information using View Editor
- OpenMBEE is an enabler that support Digital Signoffs in View Editor

Research Tasks and Collaborator Network

RT-48 (2013)
- Mark Blackburn (PI), Stevens
- Rob Cloutier (Co-PI) - Stevens
- Eirik Hole - Stevens
- Gary Witus – Wayne State

RT-118 (2014)
- Mark Blackburn (PI), Stevens
- Rob Cloutier - Stevens
- Eirik Hole - Stevens
- Gary Witus – Wayne State

RT-141 (2015)
- Mark Blackburn (PI), Stevens
- Mary Bone - Stevens
- Gary Witus – Wayne State

RT-157 (2016)
- Mark Blackburn (PI), Stevens
- Mary Bone - Stevens
- Roger Blake - Stevens
- Mark Austin – Univ. Maryland
- Leonard Petnga – Univ. of Maryland

RT-170 (2016)
- Mark Blackburn (PI), Stevens
- Mary Bone - Stevens
- Deva Henry - Stevens
- Paul Grogan - Stevens
- Steven Hoffenson - Stevens
- Mark Austin – Univ. of Maryland
- Leonard Petnga – Univ. of Maryland
- Maria Coelho (Grad) – UMD
- Russell Peak – Georgia Tech.
- Stephen Edwards – Georgia Tech.
- Adam Baker (Grad) – Georgia Tech.
- Marlin Ballard (Grad) – Georgia Tech.

RT-168 – Phase I & II (2016)
- Mark Blackburn (PI), Stevens
- Dinesh Verma (Co-PI) – Stevens
- Ralph Giffin
- Roger Blake - Stevens
- Mary Bone – Stevens
- Andrew Dawson – Stevens (Phase I)
- Rick Dove
- John Dzielski, Stevens
- Paul Grogan - Stevens
- Deva Henry – Stevens (Phase I)
- Bob Hathaway - Stevens
- Steven Hoffenson - Stevens
- Eirik Hole - Stevens
- Roger Jones – Stevens
- Benjamine Kruse - Stevens
- Jeff McDonald – Stevens (Phase I)
- Kishore Pochiraju – Stevens
- Chris Snyder - Stevens
- Gregg Vesonder – Stevens (Phase I)
- Lu Xiao – Stevens (Phase I)
- Brian Chell (Grad) – Stevens
- Luigi Ballarinni (Grad) – Stevens
- Harsh Kevadia (Grad) – Stevens
- Kunal Batra (Grad) – Stevens
- Khushali Dave (Grad) – Stevens
- Rob Cloutier – Visiting Professor
- Robin Dillon-Merrill – Georgetown
- Ian Grosse – UMass
- Tom Hagedorn – UMass
- Todd Richmond – USC
- Edgar Evangelista – USC

RT-195 (2018)
- Mark Blackburn (PI), Stevens
- Mary Bone - Stevens
- Ralph Giffin - Stevens
- Benjamin Kruse - Stevens
- Russell Peak – Georgia Tech.
- Stephen Edwards – Georgia Tech.
- Adam Baker (Grad) – Georgia Tech.
- Marlin Ballard (Grad) – Georgia Tech.
- Donna Rhodes - MIT
- Mark Austin – Univ. Maryland
- Maria Coelho (Grad) – Univ. Maryland

WRT-1008 (2019)
- Mark Blackburn (PI), Stevens
- Mary Bone - Stevens
- John Dzielski- Stevens
- Benjamin Kruse - Stevens
- Bill Rouse – Stevens/Georgetown
- Russell Peak – Georgia Tech.
- Selcuk Cimtalay – Georgia Tech.
- Adam Baker (Grad) – Georgia Tech.
- Marlin Ballard (Grad) – Georgia Tech.
- Alanna Carnevale (Grad) – Georgia Tech.
- William Stock (Grad) – Georgia Tech.
- Michael Szostak (Grad) – Georgia Tech.
- Donna Rhodes - MIT
- Mark Austin – Univ. Maryland
- Maria Coelho (Grad) – Univ. Maryland

WRT-1025 (2020)
- Mark Blackburn (PI), Stevens
- Mark Austin (Co-PI) – Univ. Maryland
- Maria Coelho (Grad) – Univ. Maryland

ART-002 (2018) – ART-022 (2021/22)
- Mark Blackburn (PI), Stevens
- Dinesh Verma (Co-PI) – Stevens
- Kunal Batra – Stevens
- Mary Bone - Stevens
- John Dzielski, Stevens
- Steven Hoffenson - Stevens
- Steve Hespelt – Stevens
- Tom Hagedorn – Stevens
- Roger Jones – Stevens
- Philip Odonkor – Stevens
- Benjamin Kruse – Stevens/VT
- Chris Snyder - Stevens
- Brian Chell – Stevens
- Daniel Dunbar (PhD) – Stevens
- Maximillian Vierlboeck (PhD) - Stevens
- Andrew Underwood (Ungrad) – Stevens
- Benjamin Steinwurtzel (Ungrad)
- Cory Phillipe (Grad) - Stevens
- Ian Grosse – Univ. of Massachucetts
- Doug Eddy – Univ. of Massachucetts
- Joe Gabbard – Virginia Tech
- Kyle Tanous– Virginia Tech
- Jared Van Dam (PhD) – Virginia Tech
- Kelsey Quinn (PhD) – Virginia Tech

WRT-1036 (2020)
- Mark Blackburn (PI), Stevens
- John Dzielski- Stevens
- Russell Peak – Georgia Tech.
- Selcuk Cimtalay – Georgia Tech.
- Taylor Fields – Georgia Tech.
- William Stock (Grad) – Georgia Tech.
- Sahil Panchal – Georgia Tech
- Jake Sisavath – Georgia Tech
- Gabriel Rizzo – Georgia Tech

WRT-1054 (2022)
- **Mark Blackburn (PI), Stevens**
- **John Dzielski- Stevens**
- **Tom Hagedorn – Stevens**
- **Steve Hespelt – Stevens**
- **Russell Peak – Georgia Tech.**
- **Selcuk Cimtalay – Georgia Tech.**
- **Taylor Fields – Georgia Tech**.

SYSTEMS ENGINEERING RESEARCH CENTER

THANK YOU

Stay connected with us online.

Spacer is Surrogate Pilot & Experiments Use Cases for USSF

- Spacer Surrogate Pilot will:
  - Develop a model-based SOW to request industry bidders for response models that elaborate DAF's mission/system models;
  - Characterize the concept of "authoritative source of truth", as part of the "stack and array of models and data within a Digital Engineering Environment;
  - Develop digital equivalents of document based CDRLs and DiDs, to allow digital review and signoffs;
  - The Spacer is derived from publicly available sources for an unclassified modeling environment to allow workforce development and demonstrations.
  - The Spacer "Full Modeling Stack" includes interoperable models from the mission level (CONOPs) to the system level; and to discipline and domain specific technical (physics-based) models and related ontologies – multi-level and multi-discipline tradespace analyses