Carnegie Mellon University Software Engineering Institute

NPS Acquisition Research Symposium

Synergizing the Software Acquisition Pathway (SWP) With the Unified Architecture Framework (UAF) For Operationalization

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Introduction

- DoD policy and directives motivate the transformation from document-based information to structured model-based information to enable opportunities for enhanced analysis, decision-making, and collaboration between stakeholders
- Effective model-based systems engineering (MBSE) to support acquisition objectives requires structure and ontology for capturing and transforming information into useful digital assets. The Unified Architecture Framework (UAF) provides a structured ontology for enterprise architecture definition that aligns well to Department of Defense (DoD) Adaptive Acquisition Framework (AAF) Software Acquisition Pathway (SWP).
- The SEI presents a foundation for a consistent MBSE strategy for the SWP using a scenario-based approach for constructing and analyzing value in operational process flows and aligning UAF views to structure information

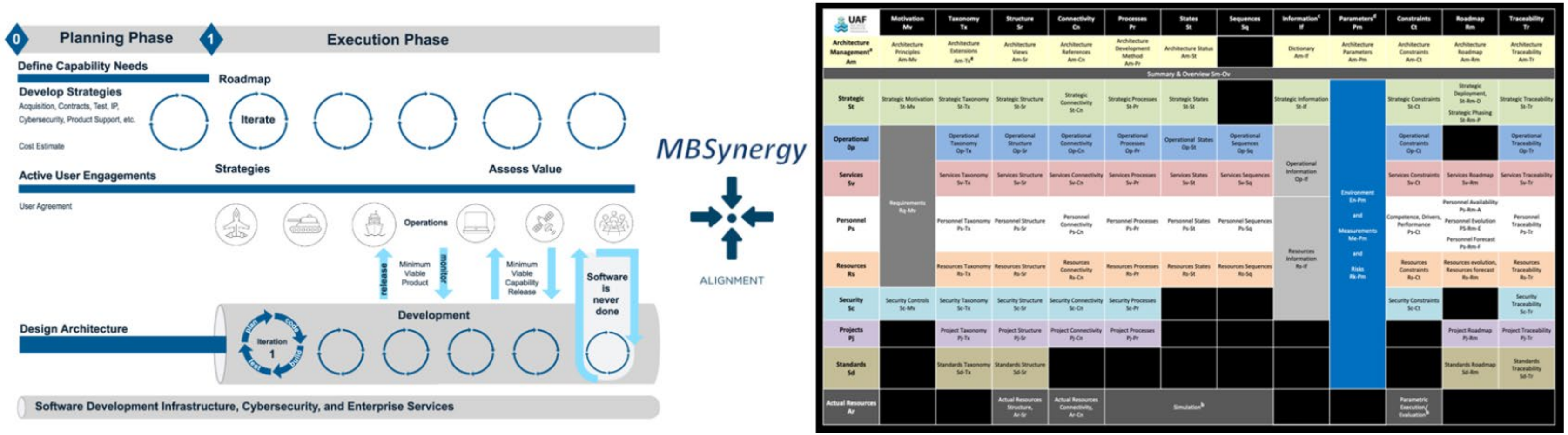

Figure 1: SEI MBSynergy – Aligning the SWP to UAF

Lifecycle View of the Software Acquisition Pathway

- Purpose is to provide software intensive development programs with a streamlined path for rapid and iterative software capability delivery to users
- Established in the FY20 NDAA Section 800 and is further defined in DODI 5000.87
- 86 DoD programs using the SWP
- 2 phases (Planning & Execution) with the objective of delivery capability within 1 year
- 34 identified documents or collections of information required with varying applicability based on attributes of the program

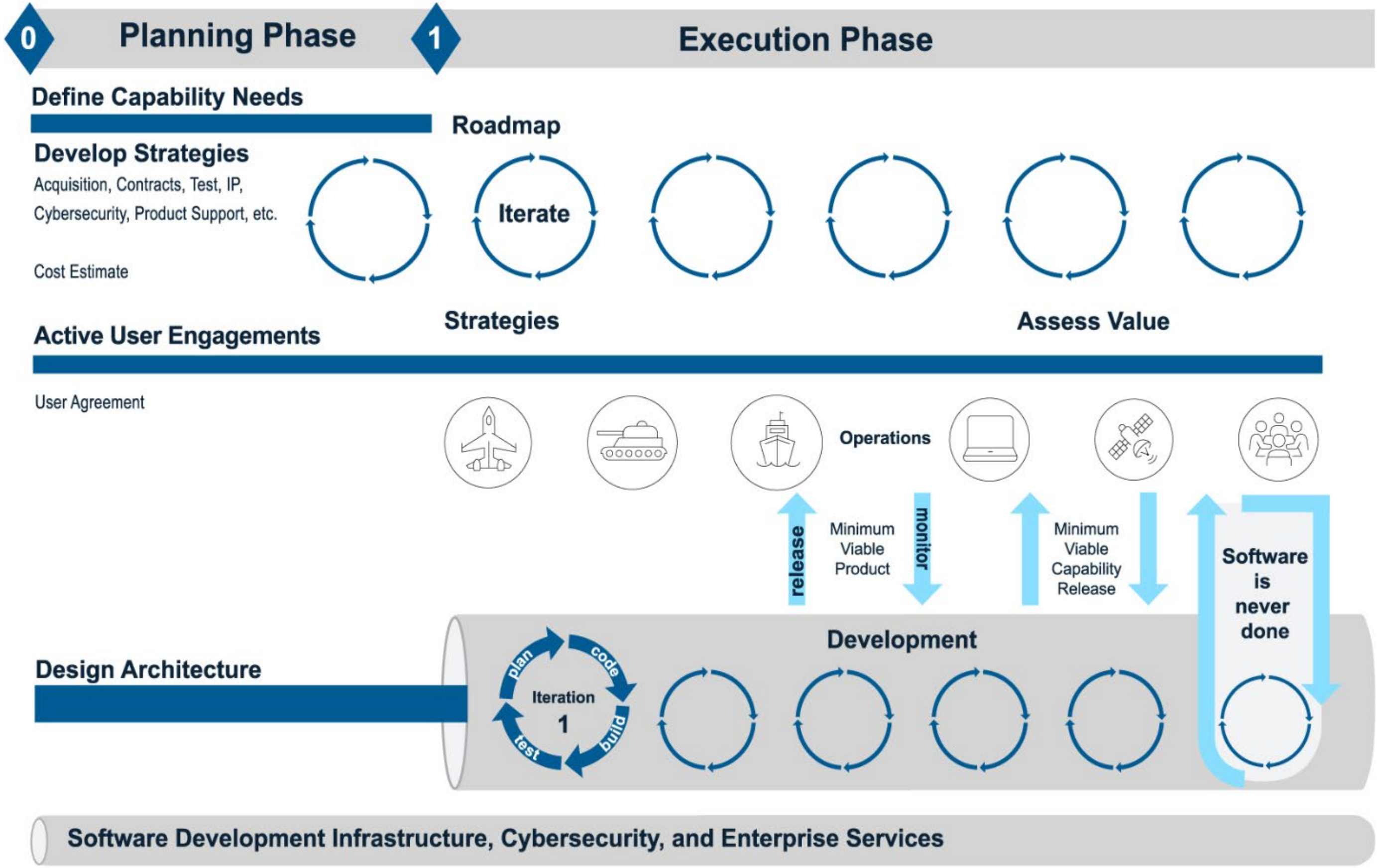

Figure 2: Lifecycle view of Software Acquisition [Source: Defense Acquisition University “Software Acquisition | Adaptive Acquisition Framework”]

Unified Architecture Framework

- Architecture framework that provides visualization for specific stakeholders concerns through engineering domains organized by various views
- Evolved from DODAF/MODAF/UPDM and built on SysML
- 89 views
- UAF defines a metamodel for each viewpoint- the main concepts and relationships you need to build this specific viewpoint
- Enterprise Architecture Guide for UAF provides a workflow for model developers

Aspect

Viewpoints	Motivation Mv	Taxonomy Tx	Structure Sr	Connectivity Cn	Processes Pr	States St	Sequences Sq	Information[c] If	Parameters[d] Pm	Constraints Ct	Roadmap Rm	Traceability Tr
Architecture Management[a] Am	Architecture Principles Am-Mv	Architecture Extensions Am-Tx[e]	Architecture Views Am-Sr	Architecture References Am-Cn	Architecture Development Method Am-Pr	Architecture Status Am-St		Dictionary Am-If	Architecture Parameters Am-Pm	Architecture Constraints Am-Ct	Architecture Roadmap Am-Rm	Architecture Traceability Am-Tr
Summary & Overview Sm-Ov												
Strategic St	Strategic Motivation St-Mv	Strategic Taxonomy St-Tx	Strategic Structure St-Sr	Strategic Connectivity St-Cn	Strategic Processes St-Pr	Strategic States St-St		Strategic Information St-If	Environment En-Pm and Measurements Me-Pm and Risks Rk-Pm	Strategic Constraints St-Ct	Strategic Deployment, St-Rm-D Strategic Phasing St-Rm-P	Strategic Traceability St-Tr
Operational Op	Requirements Rq-Mv	Operational Taxonomy Op-Tx	Operational Structure Op-Sr	Operational Connectivity Op-Cn	Operational Processes Op-Pr	Operational States Op-St	Operational Sequences Op-Sq	Operational Information Op-If		Operational Constraints Op-Ct		Operational Traceability Op-Tr
Services Sv		Services Taxonomy Sv-Tx	Services Structure Sv-Sr	Services Connectivity Sv-Cn	Services Processes Sv-Pr	Services States Sv-St	Services Sequences Sv-Sq			Services Constraints Sv-Ct	Services Roadmap Sv-Rm	Services Traceability Sv-Tr
Personnel Ps		Personnel Taxonomy Ps-Tx	Personnel Structure Ps-Sr	Personnel Connectivity Ps-Cn	Personnel Processes Ps-Pr	Personnel States Ps-St	Personnel Sequences Ps-Sq	Resources Information Rs-If		Competence, Drivers, Performance Ps-Ct	Personnel Availability Ps-Rm-A Personnel Evolution PS-Rm-E Personnel Forecast Ps-Rm-F	Personnel Traceability Ps-Tr
Resources Rs		Resources Taxonomy Rs-Tx	Resources Structure Rs-Sr	Resources Connectivity Rs-Cn	Resources Processes Rs-Pr	Resources States Rs-St	Resources Sequences Rs-Sq			Resources Constraints Rs-Ct	Resources evolution, Resources forecast Rs-Rm	Resources Traceability Rs-Tr
Security Sc	Security Controls Sc-Mv	Security Taxonomy Sc-Tx	Security Structure Sc-Sr	Security Connectivity Sc-Cn	Security Processes Sc-Pr					Security Constraints Sc-Ct		Security Traceability Sc-Tr
Projects Pj		Project Taxonomy Pj-Tx	Project Structure Pj-Sr	Project Connectivity Pj-Cn	Project Processes Pj-Pr						Project Roadmap Pj-Rm	Project Traceability Pj-Tr
Standards Sd		Standards Taxonomy Sd-Tx	Standards Structure Sd-Sr								Standards Roadmap Sd-Rm	Standards Traceability Sd-Tr
Actual Resources Ar			Actual Resources Structure, Ar-Sr	Actual Resources Connectivity, Ar-Cn	Simulation[b]					Parametric Execution/ Evaluation[b]		

Figure 3: UAF View Matrix [Source: Unified Architecture Framework (UAF) Domain Metamodel Version 1.2, Copyright © 2025 Object Management Group ®, OMG ®, Reprint Permission Granted.]

Basis for Mapping SWP Activities to Scenarios

SEI has designed a process founded on principles of CMU SEI's Architecture Tradeoff Analysis Method (ATAM) for using scenario-based analysis for eliciting MBSE value in enterprise activities. The model-based approach guides users through the processes of:

- eliciting scenarios for the use of MBSE as part of the enterprise architecture
- capturing enterprise goals and objectives aligned to quality attributes
- understanding the model-based processes and flow of information
- defining the measures that will verify that the goals will be achieved

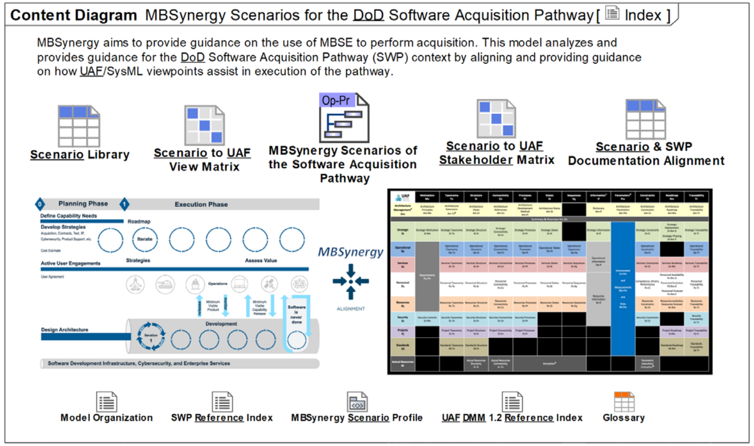

Figure 4: SEI MBSynergy SWP Model

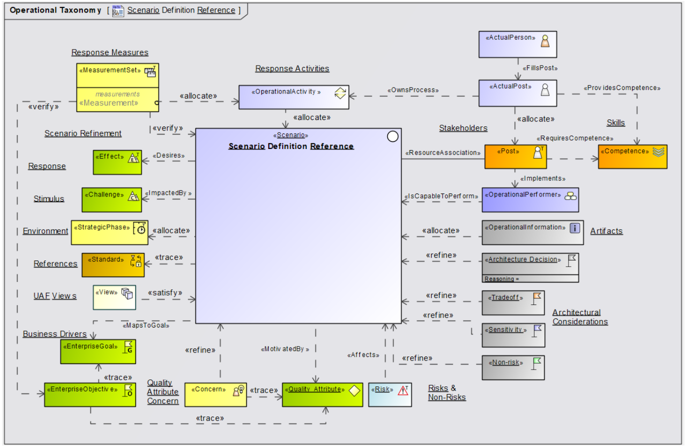

Figure 5: SEI MBSynergy Scenario Profile

MBSynergy SWP Scenario Model connects SWP information to UAF DMM v1.2 information and analyzes SWP scenarios using the MBSynergy Scenario Profile.

The MBSynergy Scenario Profile is a SEI model resource that provides capability for developing MBSynergy scenarios in Cameo Enterprise Architect based on the Architecture Tradeoff Analysis Method (ATAM)

Software Acquisition Pathway Scenarios

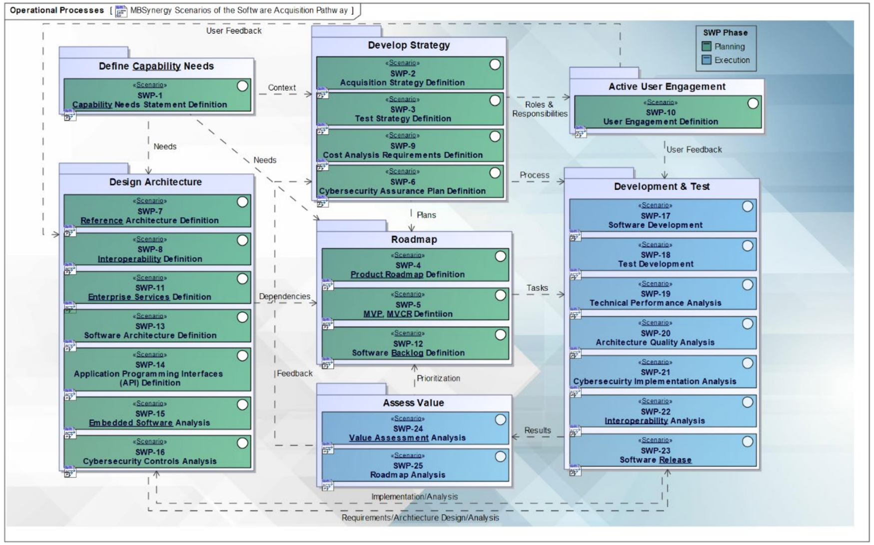

Figure 6: SEI MBSynergy SWP Scenarios

The model is a reference architecture for stakeholders of the SWP to use for understanding the mechanisms to efficiently use UAF for structuring information and performing analysis. Each scenario is analyzed for its set of activities, stakeholders' roles, UAF views consumed/produced, quality attributes, enterprise architecture considerations, measures, and risks/non-risks.

- Derived a set of scenarios where a model-based approach offers value based on enduring tasks and information artifacts defined for the SWP
- 25 Scenarios Identified. Organized by SWP Phase and Enduring Tasks: *Define Capability Needs, Develop Strategy, Design Architecture, Plan Roadmap, Engage Active Users, Develop & Test, and Assess Value*
- Mapped scenarios to statutory and regulatory information needs

#	Id	Name	Aligned Documentation	Source	Applicability
1	SWP-1	Capability Needs Statement Definition	OI164 Capability Needs Statement OI171 Clinger Cohen Act (CCA) Compliance OI183 Software Initial Capabilities Document (SW-ICD)	DODI 5000.87 Clinger-Cohen Act (CCA)	Regulatory Statutory
2	SWP-2	Acquisition Strategy Definition	OI158 Acquisition Strategy OI168 Intellectual Property Strategy OI163 Product Support Strategy OI160 Business Case Analysis OI171 Clinger Cohen Act (CCA) Compliance OI169 Periodic updates to strategies	10 USC 2431a DODI 5000.87 Clinger-Cohen Act (CCA)	Statutory for major programs (> ACAT II) Regulatory Statutory
3	SWP-3	Test Strategy Definition	OI150 Test Strategy OI169 Periodic updates to strategies	DODI 5000.87 DODI 5000.96	Regulatory;Programs on DOT&E Oversight list may require a TEMP. Regulatory
4	SWP-4	Product Roadmap Definition	OI161 Initial Product Roadmap OI153 Product Roadmap OI154 Program Backlog	DODI 5000.82, Subtitle III of Title 40 DODI 5000.87	Statutory Regulatory
5	SWP-5	MVP, MVCR Defintiion	OI161 Initial Product Roadmap OI154 Program Backlog	DODI 5000.82, Subtitle III of Title 40 DODI 5000.87	Statutory Regulatory
6	SWP-6	Cybersecurity Assurance Plan Definition	OI156 Cybersecurity Plan OI171 Clinger Cohen Act (CCA) Compliance OI169 Periodic updates to strategies	40 USC 11313 DODI 5000.87 Clinger-Cohen Act (CCA)	Statutory for Mission Critical and Mission Essential IT programs Statutory Regulatory
7	SWP-7	Reference Architecture Definition	OI162 Information Support Plan OI167 Bandwidth Requirements Review OI171 Clinger Cohen Act (CCA) Compliance OI157 System Architecture	DODI 8330.01 §1047, P.L. 110-417 DODI 5000.87 Clinger-Cohen Act (CCA)	Regulatory Statutory for programs > ACAT II; Regulatory for Others Statutory
8	SWP-8	Interoperability Definition	OI157 System Architecture OI167 Bandwidth Requirements Review	DODI 5000.87 §1047, P.L. 110-417	Regulatory Statutory for programs > ACAT II; Regulatory for Others

Figure 7: MBSynergy SWP Scenarios Aligned to Required Documentation

Mapping Scenarios to UAF Views

Capability Needs Statement (CNS)

Transforming document-based information to structured model elements expressed in standardized enterprise architecture views.

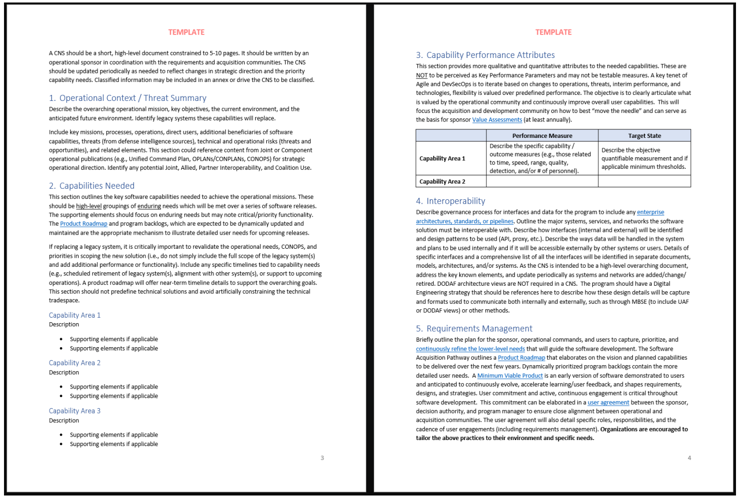

Figure 8: DAU CNS Document Template

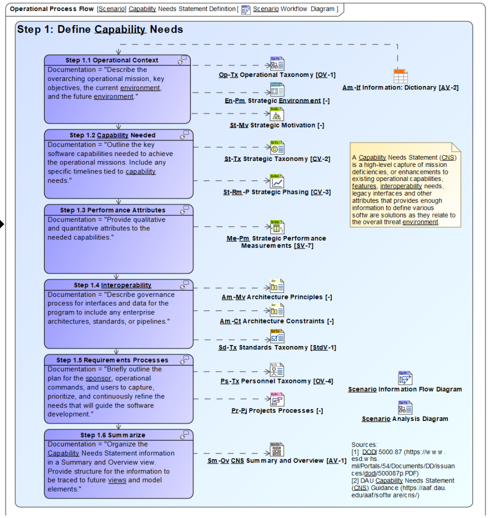

Figure 9: Model View of CNS Scenarios

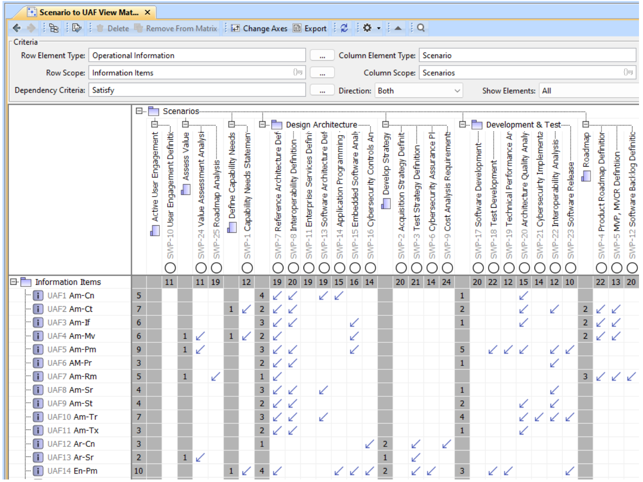

Figure 10: SWP Scenario to UAF View Matrix

By mapping the structured information to the scenarios, the flow of information across the lifecycle can be analyzed and the rationale for traceability from scenario to scenario can be established.

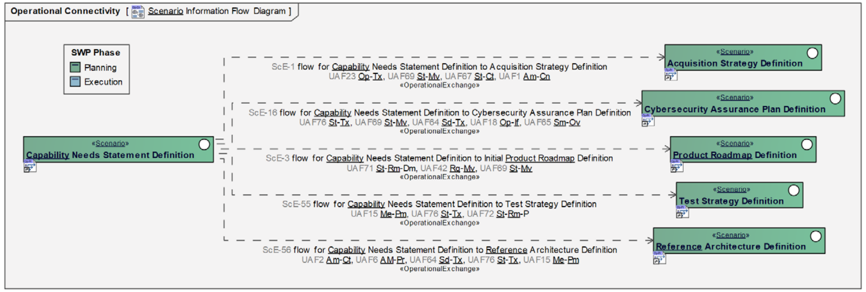

Figure 11: Scenario Connectivity Diagram - UAF Information Flow Analysis

Mapping of the UAF views to the SWP scenarios was performed by comparing definitions in the UAF DMM 1.2 specification and the regulatory and statutory information requirements of the SWP.

Conclusion & Next Steps

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Summary:

- Presented a foundational concept for a consistent application of model-based systems engineering in DoD SWP programs using UAF
- Identified 25 scenarios for the operationalization of UAF as part of the SWP Planning and Execution phases
- Illustrated UAF view alignment with the Capability Needs Statement (CNS)
- For SWP programs, this study and related artifacts aim to be resource for achieving a part of their digital engineering strategy, providing the ability to:
  - Structure and aggregate lifecycle information in a well-organized model, moving away from document-based information, to streamline communication and better understand interfaces between information needs
  - Generate robust traceability in lifecycle artifacts to support the concept of digital threads
  - Provide a foundation for analysis to occur early in the SWP, enabling more informed decision-making and higher levels of assurance for the desired quality attributes of the enterprise and the software capability being developed
  - Align with policy (DODI 5000.97) and digital engineering directives from each of the DoD military departments

Next Steps

- SEI plans to develop a technical report capturing the full breadth of content related to the scenarios developed for the SWP
- SEI is interested in pilot projects to demonstrate the use of the UAF views and to explore the required resources needed to fully operationalize the approach
- Conduct future research into the use of models as part of the SWP, including how models can be continuously developed/monitored along-side software, and developed using AI-Assisted tools

Biography & Contact Information

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Colin Dempsey is a Senior Model-Based Engineering Project Manager for the Assuring Cyber-Physical Systems division and Model-Based Engineering team at Carnegie Mellon University's Software Engineering Institute (CMU SEI). He holds an MSE in Systems Engineering from Johns Hopkins University. His area of expertise and research focus on the practical application of model-based systems engineering (MBSE) methodologies to facilitate the design, development, and analysis of software-intensive systems for the DoD. Prior to joining CMU SEI, he was a systems engineering professional in DoD industry leading efforts in MBSE, Product Line Engineering (PLE), and Digital Engineering transformation.

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Jérôme Hugues is a Principal Architecture Researcher at the Carnegie Mellon University Software Engineering Institute for the Assuring Cyber-Physical Systems team. Jérôme is the principal lead for the SEI MBSynergy Line Project initiative. He holds a Habilitation à Diriger les Recherches (HDR, 2017), a PhD (2005) and an engineering degree (2002) from Telecom ParisTech. His research concentrates on software architecture to support the design of complex software-based real-time and embedded systems, and the programming languages and artifacts that support them. Prior to joining the CMU/SEI, he was a professor at the Department of Engineering of Complex Systems of the Institute for Space and Aeronautics Engineering (ISAE).