MDDI Case Study: MBSE yields Business Value for PEO C4I PMW/A 170 “GPNTS”

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Introduction

PMW/A 170 retained CACI to perform a pilot introduction of CACI's Model-Driven Design and Implementation (MDDI) methodology for Model-based Systems Engineering (MBSE)

Responsible for the timely realization of the GPS-assisted Position, Navigation, and Timing Joint Capability throughout the Fleet, PEO C4I PMW/A 170 sought ways and means to digitize its acquisition and planning information represented in numerous Excel spreadsheets, Word documents, PDF documents, Visio diagrams, and in partial model artifacts from Systems Architect, Sparx Enterprise Architect, and Cameo EA. The customer also sought ways and means to rapidly generate CDRLs such as Capability Production Documents and Requirements Traceability Matrices. The customer further sought advice on how to manage architecture content that reflects the deployment of their primary system, the Global Positioning System (GPS)-Based Positioning, Navigation, and Timing Service (GPNTS), across the vessels of the Navy Fleet where much of the system information is common throughout, yet connectivity detail varies from vessel to vessel. PMW/A 170 contracted CACI in Spring 2019 to perform a 6-month pilot introduction of CACI's Model-Driven Design and Implementation (MDDI) methodology for Model-based Systems Engineering (MBSE).

- CACI's Model-Driven Design and Implementation for Systems Engineering methodology moves organizations from stove-piped, document-centric processes to a dynamic, digital engineering environment that enables on-demand analysis, testing and prototyping of new and consolidated capability solutions while mitigating redundancies, inaccuracies, and inefficiencies.

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Challenge

Avoid Redundancy; Keep Information Accurate; Answer Usage and Schedule Question Promptly

The Communications and GPS Navigation Program Office, PMW/A 170, provides and supports interoperable, cost-effective positioning, navigation, and timing (PNT) services, assured and resilient communications, and GPS navigation to enable information warfare capabilities for maritime forces. (See "2018 The SPAWAR List".)

GPS-Based Positioning, Navigation, and Timing Services (GPNTS) is an Acquisition Category (ACAT) III program that is the Navy's next generation surface PNT system that back-fits the Navigation Sensor System Interface (NAVSSI) and WRN-6 to support mission-critical, real-time PNT data services for weapons, combat, navigation, and other command, control, communications, computers, and intelligence (C4I) systems. GPNTS provides a robust, secure, integrated, and interoperable network-centric PNT capability. Raytheon of San Diego, CA is the supplier of the GPNTS equipment.

PMW/A 170's GPNTS Integration Team members are responsible for the connectivity of GPNTS equipment into the Fleet's hundreds of vessels. Although some configurations recur from vessel platform to vessel platform—for example, many Destroyers within the *Arleigh Burke*-class (DDG 51) will use the same GPNTS wiring configuration on the DDG 51 hull. There are extensive differences in the wiring configuration of the GPNTS systems with peer Naval systems from vessel to vessel—for example, the configurations vary between Destroyers, Carriers, Littoral Combat Ships, and within the individual hulls of a particular class. PMW/A 170 staff are required to be able to assure that GPNTS can backfill the legacy NAVSSI system previously installed on a vessel and to deliver and receive the proper signals through the available cables and wires.

Figure 1: Typical Traditional PMW/A Integration Challenge with Redundant and Inconsistent Information spread throughout Excel and Visio Files

Before the introduction of MDDI and MBSE, PMW/A 170 used a document-based approach to fulfil this integration mission using many Excel spreadsheets and Visio diagrams. As the number of vessels scheduled to receive GPNTS during their availability periods increased, PMW/A 170's limited staff found themselves challenged to answer decision maker asks due to the lack of a data-centric approach to provide reports and analytics on demand.

Overview

Governance, Curation, Sound Practices, and Model Analytics deliver the value of MBSE

The key terms used in this whitepaper and related links to support materials include:

Term	Definition	Relevance	For More Information
MDDI	Model-Driven Design and Implementation	CACI's methodology for MBSE	http://www.caci.com
"Ways"	The techniques, tactics, or methods to attain the "ends"	Strategy is a combination of ways and means to attain ends—and this paper discusses strategy to efficiently manage the complexity of connections.	Chapter 2, "A Primer in Strategy Development", https://apps.dtic.mil/dtic/tr/fulltext/u2/a387893.pdf
"Means"	The resources needed during the "ways" to attain the "ends"		
"Ends"	The goals sought		
MBSE	Model-Based Systems Engineering	The intentional and collaborative use of models of digital engineering elements throughout the Systems Development Lifecycle to improve the effectiveness of Systems Engineering.	http://www.omgsysml.org/
UPDM	Unified Profile for DoDAF (Department of Defense Architecture Framework) and MODAF (U.K. Ministry of Defense Architecture Framework)	The ISO and OMG notational and semantic standard for the modeling of enterprise architectures and systems engineering solutions.	https://www.omg.org/spec/UPDM/

CACI's MDDI analysts worked with PMW/A 170 over the summer of 2019 to:

- Rapidly ingest appropriate Government Furnished Information (GFI) content;
- Normalize inconsistencies in GFI; and
- Align architectural information with reference standards and models such as NAVWAR 5.0's PNT Reference Architecture and NAVWAR's Naval X – SYSCOM reference profile and libraries.

CACI implemented "MDDI Accelerators"—analytics inside the modeling environment—for the chosen Cameo EA UPDM modeling environment to automatically and repeatedly generate artifacts such as a JCIDS Capability Production Document (CPD) with all the content of the manually produced GFI and with nearly identical presentation style.

Additional "accelerators" included in-tool analytics to monitor content for conformance to organizational modeling conventions and those to execute on demand business queries such as "across all modeled configurations, which of these configurations imply that they deliver a sought capability" and "looking across all modeled configurations, which GPNTS hardware ports remain unused because no configuration yet includes a connected use of the port."

The resulting GPNTS model is rich in both "strategic" capability content and in "tactical" hardware implementation content – demonstrating the ability of MBSE to handle both soft and hard concerns, limited to neither software nor IT systems alone.

Throughout the pilot, CACI mentored the PMW/A 170 staff in best practices for: tool usage, model construction, complexity management, governance, curation, proper use of notations including UML, SysML, and UPDM, report generation, and the authoring of new queries as needed.

MDDI Value Delivered

When the Object Management Group standardized UML, SysML, and UPDM, it intentionally avoided prescribing methodology. When adopting MBSE, organizations must provide and follow their own methodology. Without experience, formulating or choosing an effective methodology for MBSE is difficult, especially amidst the cultural change in engineering that MBSE entails. For the benefit of many external and internal programs, CACI has been formulating and refining its MDDI Methodology for MBSE for years. CACI exploits MDDI not because MBSE is trendy, but because our customers succeed when they practice MDDI.

CACI's MDDI analysts conversed with and exchanged information with PMW/A 170 staff during the summer of 2019, and quickly enabled PMW/A 170 to obtain the following business values from MDDI and its MBSE initiative.

- Governance Best Practices
- Reuse, Alignment, and Semantic Ontological Commitment
- Instructor-guided, hands-on, individualized, domain-specific training to exploit MDDI and MBSE for GPNTS content
- Joint Capability Area (JCA) Capability-based Acquisition (CBA) architecture
- Capability Fit/Gap Analytics
- Alignment with NAVWAR 5.0 mandates, policies, and semantic content for MBSE
- Modeling of Security concerns using Security Viewpoint elements and Data and Information traced to Committee on National Security Systems Instruction (CN SSI) guidance, National Institute of Standards and Technology (NIST) Security Controls, Risk Management Framework (RMF) workflows, and artifacts for Enterprise Mission Assurance Support Service (eMASS)

- Requirements Management and Traceability and SV-6 System to System Exchange Reports with traceability to Requirements and to Interface Control Documents
- Model-based tactics for System Wiring variability across the Fleet
- Dynamic, Gantt-style, Fielding Plans and Gantt-style Capability Phasing
- Dynamic, as-needed, Exchange Reports
- Dynamic Quality and Consistency Audits

Briefly, the following outlines the CACI and PMW/A 170 activity for these business values. Contact CACI for additional details on topics of interest.

Governance: CACI MDDI analysts recommended a team-level organization structure of roles and responsibilities and rights to assure that the content of models maintains quality and relevance, and that alteration of model content is controlled and documented. CACI analysts also communicated the importance of conventions and curation.

Reuse and Alignment: CACI MDDI analysts, having exposure to modeling practices, mandates, and libraries in use throughout industry and the Government, showed PMW/A 170 how to construct models of models where more-domain-specific models may draw upon more-general models for both library content and for conformance to taxonomies, thesauri, and ontologies when available and applicable. For example, PMW/A 170 models should be semantically aligned with NAVWAR's and PEO C4I's Positioning, Navigation, and Timing Reference Architecture, with the SPAWAR EA ID data model (a form of a knowledge thesaurus), and with NAVWAR's Naval-X SYSCOM reference architecture. CACI MDDI analysts guided PMW/A 170 through the integration of these external reference models directly into their GPNTS model—without replication of content, without write-access to the standardized content. The resultant GPNTS model is amenable to programmed analytics that can query for GPNTS-specific elements, as well as for specialized elements that generalize the elements of these reference models.

Domain-specific Training: CACI MDDI trainers led PMW/A 170 staff through two weeks of lecture and experiential knowledge transfer, guiding the staff to not merely be aware of general characteristics of model-based Systems Engineering but rather to gain fluency using concepts and tools to craft GPNTS-specific, business-useful content and artifacts. For example, the Integration staff learned and demonstrated how to construct a richly populated and connected DoDAF System View (internal) SV-2 that expresses how an aft and a forward GPNTS rack on a particular vessel (e.g. the DDG 51 USS *Arleigh Burke*) connects its CompactPCI enclosure's rear-panel and fiber-patch panel ports with electric and fiber cables to the numerous

Naval systems (e.g. WSN-7 or BFTN or CANES) found throughout the platform ship.

JCA CBA acquisition architecture: Acquisition programs, depending on their importance and size, often are mandated to perform capability-based acquisition practices according to the Joint Capabilities Integration and Development System. (This implies that Systems being promoted as solutions must have evidence of being able to exhibit the capabilities of the Commanders' intentions—where a capability is defined as the ability to attain a desired effect.) CACI MDDI analysts guided PMW/A 170 in the use of DoDAF's Capability Viewpoint to represent GPNTS-specific capabilities, the Enterprise overview of GPNTS capabilities, and traceability to JCA capabilities from the Business Enterprise Architecture (BEA) and DITPR reference sources. CACI reinforced the force-multiplying productivity power of modular, composable models by linking in their existing JCA library versus redundantly, inefficiently, remodeling capabilities from JCIDS into the GPNTS model.

Capability Fit / Gap Analysis: MBSE repositories hold a detailed "network graph" of explicitly related and indirectly semantically implied related elements. For example, a well-formed UPDM MBSE model has chains of relationships from modeled capabilities, through Operational Performers, to implementing systems. CACI MDDI analysts exploited this semantic knowledge to provide PMW/A 170 with MDDI Accelerators that dynamically answer crucial business queries such as: "Which modeled Systems can, either directly or indirectly via their inheritance and aggregation structures, exhibit the capability of interest, within this particular date range?" Furthermore, CACI MDDI analysts demonstrated how to exploit the model to answer questions about what hasn't been explicitly modeled, such as "If I told you that a System you know of exhibits this new capability I have in mind, which of the Systems in the model can and cannot exhibit that capability according to their current structural composition?" CACI MDDI analysts communicated how to expose these queries and their result sets in the modeling tool in various forms such as Table Reports, interactive graphical diagrams, and dynamic Packages whose members come and go depending on whether they meet or do not meet the conditions of the query.

Security Concerns: PMW/A 170 provided a CPD to CACI that identified applicable RMF, CN SSI 1253, and NIST 800-53 security concerns as text statements only. CACI MDDI analysts were able to exploit CACI's existing portfolio of Security models—including those for RMF, CN SSI 1253, and NIST 800-53—to replace the text statements about derived Security Control Families and Security Categorizations with integrated, connected model references from GPNTS content to these reference libraries' elements.

Systems Wiring tactics, SV-6, and RTM: After reviewing PMW/A 170's GFI, CACI MDDI analysts observed the occurrence of patterns in the diagrams and deduced that the crucial difference from vessel platform to vessel platform is neither the structure of the GPNTS, nor the set of peer Naval systems, but rather the set of connections between the GPNTS and peer Naval systems. CACI MDDI analysts introduced System Viewpoint abstractions to represent the common elements of each GPNTS installation and capability configurations for each platform to encapsulate the set of connections for each platform. In this case, a connector indicates each of the physical transmit or receive ports on the AFT or FWD GPNTS, the physical receive or transmit port on the peer Naval system, and the type of cabling used for the port-to-port connections. Each such connector may further express what informational protocol data units are exchanged, relevant Interface Control Descriptions, and applicable Requirements satisfied. The resulting detailed set of Connections is exploited by intentionally added MDDI accelerators to answer business queries and to aid the PMW/A 170 staff in assuring high-quality model content. CACI MDDI analysts also enhanced DoDAF's typical SV-6 Systems to Systems Exchange Matrix with details on Requirements satisfied, ICDs related, elements exchanged, and related SV-2 diagrams where the exchanges are shown.

Temporal Matters, Capability Phasing and Systems Technical Roadmaps: The OMG's UPDM superset of DoDAF includes concepts for the modeling of certain time-related concerns such as capability available over calendar time, Project Management scheduling over calendar time, and Systems implementation milestones over calendar time. CACI MDDI worked with PMW/A 170 to achieve a dynamic integration of capability phasing, Project Management schedules for Vessel Availability intervals, and System Capability Configurations representing GPNTS deployments in time such that an integrated dashboard of capabilities, projects, and GPNTS Deployments is offered to the analysts where time information is entered only once in one place and those dates or durations are used throughout the various roadmaps. This innovative modeling of temporal models offers PMW/A 170 the opportunity not only to move from Visio drawings for Systems details, but to move out of isolated Excel spreadsheets for Fleet Fielding Plan details.

CACI's MDDI wasn't PMW/A 170's first exposure to MBSE—but PMW/A 170 staff claim that it has been their most successful engagement to date. Prior exposure included introductory training on the building blocks of SysML and engagement with a contractor who left behind a collection of bitmaps illustrating architectural sketches with no tools to exploit the figures. None of that prior MBSE exposure left PMW/A 170 with the necessary information to exploit GPNTS and Naval Maritime Systems' information for business purposes on an ongoing and independent basis as it is now doing after its adoption of CACI MDDI.

Conclusion

CACI MDDI has been transformative for PMW/A 170; it can be transformative for your program.

CACI believes that Navy programs can benefit from the strategies and tactics of MBSE. CACI recommends the use of architecture and systems engineering for accelerating the pace and quality of acquisition and implementation programs. Further, CACI recommends regarding one's model as a repository of business intelligence which is grown and curated in order to aid the organization in making good business decisions in a timely manner. Finally, CACI recommends leveraging skilled model curators who are empowered with the responsibility of assuring that model content conforms to conventions and maintains high fidelity so that the analytics used in the model return reliable business intelligence.

CACI MDDI has been transformative for PMW/A 170, helping the program office formalize its digital engineering vision and practices, accelerate its adoption of innovative MBSE thinking and practices, and collaborate strategically amongst a variety of acquisition disciplines from traditional integration engineering up to Program Management and Fielding Plan Management.