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Developing a Model-Based Systems Engineering (MBSE) Land Domain Construct for Marine Corps Systems Command

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DEVELOPING AN MBSE LAND DOMAIN CONRUCT FOR MARINE CORPS SYSTEMS COMMAND

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Project Summary

The purpose of this research was to develop and evaluate a generic ontology and conceptual data model (CDM) that was created to support the naval domain, for applicability to Marine Corps Systems Command (MCSC) and the land domain using Force Design 2030 (Congressional Research Service Insight, 2022) for overarching guidance. The generic ontology and CDM were developed as part of an exploratory study, which considered system data entities, attributes, and relationships. This research effort identified a generic ontology and defined a CDM that represents the system of interest from multiple perspectives and allows for the exploration of the system holistically. This is fundamental to the implementation of a model-based systems engineering (MBSE) environment. A parsimonious ontology allows system entities to be reduced to their atomic level, and then by establishing a CDM (i.e., data schemas) allows for a virtual representation of the system to be defined. The ontology and CDM identify areas where interfaces must be developed to exchange data and identify data boundaries between organizations, modeling languages, presentation frameworks, and tools. The study approach considers the importance of designing a generic ontology that comprehensively represents the system across the lifecycle, analyzes the relationships between entities defined within the ontology, considers the ontology as a foundation for an authoritative source of truth and finally, designs a modeling plan that depicts the recommended path to transition from document-based systems engineering to a true MBSE-based land domain. In summary, an ontology and CDM were developed to define the entities and relationships for an entire system throughout its lifecycle. These products were verified utilizing a mission thread from Force Design 2030 representing the USMC land domain. Utilizing this ontology and CDM, and the derived modeling plan, the MCSC can begin transitioning from document-based systems engineering to a true MBSE-based land domain.

Keywords: *digital engineering, model-based systems engineering, Marine Corps Force Design 2030, land domain, ontology, conceptual data model*

Background

MCSC strives to evolve from a traditional document-based systems engineering environment to an MBSE environment. The importance of MCSC transitioning to MBSE has recently been elevated when the Department of the Navy (DoN) assigned MCSC to define an MBSE environment for the land domain.

This represents a significant change for the Marine Corps since it marks the transition to mission-focused system design and development. This focus requires several Marine Corps Commands to coordinate their modeling efforts to insure a system-of-systems perspective with an end-to-end mission focus. The land domain is part of a larger DoN effort to model the full-spectrum of activities and systems within naval warfare. This effort is being prescribed to gain better insights, and make better programmatic decisions, to support system development and influence integration across the naval warfare domains. The purpose of this study is to develop an ontology, CDM, and a transition approach that can be utilized by the MCSC to transition to an MBSE-based environment for the land domain.

This research adopts a portion of the lifecycle modeling language (LML) ontology as the basis because it represents an ontology that uses an economy of entities that have defined relationships and attributes to create a parsimonious list of entities. This research is not promoting the use of the LML nor endorsing any MBSE tool based on LML. The LML entities are only used because they are well-

defined, establish relationships, and are parsimonious. This type of ontology is known as an entity, relationship, attribute, or ERA. This research expanded the ERA ontology approach to include labels (ERA(L)). The labels allow for data to be further identified within an entity class to entity subclasses. Finally, to further facilitate mapping a data type was added.

Once a comprehensive ontology was created, the relationships between the entities defined within it were examined. This formal structure resulted in a CDM that serves as the basis of a common terminology and structure. This generic ontology and CDM were validated using real world systems. Three interim test cases were utilized, the Amphibious Combat Vehicle, Joint Air Domain Command and Control (JADC2) concept as well as the Marine Corps Enterprise Network (MCEN) architecture. Lastly, a mission thread derived from the United States Marine Corps (USMC) reorganization taking place under the Force Design 2030 initiative was utilized. Since the goal is to examine the entire lifecycle of a system, the conceptual data model is all inclusive but for presentation has been segmented into sections. A fundamental premise of this research is that an ontology should use an economy of entities approach to create a parsimonious list that allows entities from a data dictionary to be reduced to their atomic level, thereby identifying like entities. A parsimonious ontology is important to focus the engineers on a limited (but comprehensive from a systems perspective) set of entities. Having too many entities may lead engineers to use different entities for the same system element. Conversely, having too few entities will not fully identify the system elements.

Findings and Conclusions

The ontology was developed to reduce seemingly disparate entities from various program data dictionaries to the "atomic level" using a parsimonious set of entities. The relationships between them were then established in the CDM. In an ideal system model, each data type will be represented only one time as it is in the real-world, but can be viewed from several perspectives.

For MBSE to be successful, the full scope of the system should be modeled, most likely via different MBSE tools that represent a portion of the system. The purpose of the CDM is to model the various aspects of the system, using the ontology entities and relationships to create a virtual representation of the system. Using a combination of the ontology and CDM facilitates a "Rosetta Stone" to exchange data between different modeling languages, MBSE tools, and presentation frameworks, thus allowing system data to be developed with the best approach for the problem.

The land domain, as articulated in Force Design 2030, was applied to both the ontology and the CDM. Utilizing the developed ontology and the CDM, the system entities related up to the highest-level missions defined by strategic guidance as well as were decomposable and defined by the lowest levels of components. In the USMC, the series of model creation and ownership resides at various levels starting with Combat Development and Integration, USMC Systems Command, program offices, contractors as well as the multitude of subcontractors and other government components. Utilizing a defined ontology and CDM ensures that as different organizations create the various levels of the model, utilizing various languages and MBSE tools, the final product will have a consistent schema and fully represent the system.

In summary, an ontology and CDM were developed to define the entities for an entire system throughout its lifecycle. These products were verified utilizing a mission thread from Force Design 2030 representing the USMC land domain. The USMC Systems Command can now utilize the

developed ontology and CDM, along with the derived modeling plan, to begin its path towards transitioning from document-based systems engineering to a true MBSE-based land domain. Continued research will also be accomplished to verify this ontology and CDM against a wider set of systems and domains both within the naval domain as well as other services.

Recommendations for Further Research

This research has made great advances in defining a universal ontology and conceptual data model (CDM). The following opportunities for further research were identified.

First, while this research applied the generic ontology and CDM to the United States Marine Corps land domain, additional effort is needed to demonstrate its applicability to other domains. Validating the ontology and CDM with the Naval Operational Architecture, as well as other service component models such as the Army, is recommended. The success of this proposed research will enable the standardization of an ontology and CDM.

Second, for the ontology and CDM to be most effective, it needs to be implemented as a formal data exchange standard. An exploration of approaches that represent the complex knowledge about entities, the relationships between entities, and additional information needed to exchange data will provide a more holistic and comprehensive view to share data across various modeling languages, model-based systems engineering tools, and presentation frameworks.

Third, additional "model curation" research is needed. Currently, few efforts are exploring how system models will be governed in the future. Implementation of a universal ontology and CDM will require a more defined process for "model curation."

References

Congressional Research Service Insight. (2022). *New U.S. Marine Corps Force Design Initiative: Force Design 2030*. https://crsreports.congress.gov/product/pdf/IN/IN11281

Acronyms

CDM	conceptual data model
DoN	Department of the Navy
ERA	entity, relationship, attribute
LML	Lifecycle Modeling Language
MBSE	model-based systems engineering
MCEN	Marine Corps Enterprise Network
MCSC	Marine Corps Systems Command
USMC	United States Marine Corps