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EMPLOYING ELASTIC MODEL GOVERNANCE TO STREAMLINE GROUND VEHICLE DEVELOPMENT

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ABSTRACT

To conceive, design, operate, and sustain capabilities to outpace adversaries, Digital Engineering (DE) is used to connect systems data and models as a continuum across disciplines. In this linked ecosystem, governance increases efficiency, confidence, insight, and understanding. This paper describes a model governance approach which can streamline and secure the DE ecosystem, aiding delivery of modernization and readiness. Model governance challenges are described, and related literature is summarized. An example elastic model governance guide is then provided. Key features include: (1) model-based guidance with in-model work instructions; (2) integration of the overall model governance system, DE infrastructure, individual models, and composite models; (3) scoping of model purpose and resolution of technical debt; (4) automated validation for insight on compliance; (5) customization for flexibility and tailoring. Integrating model governance practices with additional mechanisms for elasticity, flexibility, and automated validation provides robust control over the DE ecosystem to streamline ground vehicle development.

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1. INTRODUCTION

As the rate of technological innovation accelerates and Industry 4.0 proliferates, technological superiority requires rapid innovation and faster implementation. In this context, the United States Department of Defense introduced Digital Engineering (DE) where "Digital engineering is an integrated digital approach using authoritative sources of system data and models as a continuum throughout the development and life of a system. Digital engineering updates traditional systems engineering practices to take advantage of computational technology, modeling, analytics, and data sciences." [1]. A key part of this vision is establishing an end-to-end DE enterprise that connects the digital and physical worlds across a system's lifecycle [2]. The digital representation evolves alongside the end item, gaining continuous insight and knowledge from the operational environment.

As the U.S. Army Ground Vehicle Systems Center seeks to "Develop, integrate, demonstrate, and sustain ground vehicle systems capabilities to support Army modernization priorities and improve readiness" [3], DE enables this mission. Heightened congressional oversight of U.S. Army programs [4] and criticism of the Optionally Manned Fighting Vehicle (OMFV) acquisition approach [5], make robust DE implementation even more important.

The level of connectivity in DE presents a challenge for governance. Traditional configuration management and data management utilize static documents, where DE involves dynamic models which are linked. As the digital ecosystem swells, there is a heightened challenge to robustly manage heterogeneous linked models across disciplines, cultures, and contractual boundaries. This management includes proprietary information containerization, supply chain strategy, risk-based control, cybersecurity, and elasticity.

In addition to the technical challenges, there are cultural hurdles as humans learn to work in digitally connected ecosystems. One organization may have crisp process with tight storage controls and deep visibility into version evolution, where another organization with models now digitally connected to the first, may have a more relaxed approach, with critical models stored on a local hard drive. The issue of trust in models may also persist.

To be clear on terminology, here a model is an abstraction of a system, entity, or process, and could include a wide variety of disciplines, tools, languages, and fidelity levels. For example, a model could be a Systems Modeling Language (SysML) system descriptive model, a performance model, a cost model, a computer aided design (CAD) model, or a multi-disciplinary model which links SysML to performance to cost to CAD. The linked models in a modeling enterprise can extend across contractual and organizational boundaries. For example, a government customer's mission model could be linked to a prime contractor's architecture model which is linked to a supplier's performance model. In this paper, the term "individual model" refers to a single model, such as a SysML model or a performance model. The term "composite model" refers to two or more individual models which are connected, such as the SysML model digitally linked to the performance model. These are segments of what may later evolve to a further extended digital thread.

In the following sections, a survey of related literature is provided. An elastic, model-based approach to model governance is then described. Excerpts from an example elastic model governance guide are provided, and next steps are given.

2. LITERATURE REVIEW

When discussing governance of the DE ecosystem, literature from a variety of fields is useful. A survey of related literature is provided next, which includes data management, data governance, model management, knowledge management, configuration management, dark data, model curation, standards, elasticity, and model validation. An extended literature review can be found in [6].

With Industry 4.0, the key to success for any enterprise is data. Data management is "a comprehensive collection of practices, concepts, and processes dedicated to leveraging data assets for business success and compliance with data regulations. It spans the entire lifecycle of a given data asset from its original creation point to its final retirement, from end to end of an enterprise"

[7]. As organizations move towards the digital enterprise, the rate of information growth poses hurdles for data interoperability, storage, and analysis. Metadata is the descriptive information about the data itself, explaining various attributes of the data. The metadata can serve as a conduit to separate application and data, allowing the necessary steps to move towards semantic convergence. The use of ontologies enables improved data sharing using key semantics agreed across the enterprise for interoperability [8]. With common ontologies, metadata can be more easily addressable and discoverable, allowing for data independence from applications. This allows any consumer to have a better sense of how data were generated, transmitted, and stored.

Data governance is defined as, "a system of decision rights and accountabilities for information-related processes, executed according to agreed-upon models which describe who can take what actions with what information, and when, under what circumstances, using what methods" [9]. It is of concern for those who have an interest in how data are created, collected, processed, manipulated, stored, made available, used, and retired. Data governance programs can differ depending on focus, such as compliance, data integration, master data management. However, programs have the same three-part mission: (1) to make/collect/align rules, (2) to resolve issues, and (3) to monitor/enforce compliance while providing ongoing support to Data Stakeholders. Principles of data governance inform model governance.

Model management is a recognized need [10]. The Model Portfolio Management Guide [11] serves organizations who would like to manage their collection of models, and it is a solicitation reference document. In the International Council on Systems Engineering (INCOSE) Model-Based Capabilities Matrix [12], capability evolution of model management is measured from Stage 0 "ad hoc" to Stage 4 "applied to all models for an enterprise." Open Model Based Engineering Environment (OpenMBEE) is an integrated environment for engineering that is driven around connected models. "It enables engineers to work in the language of their choice and easily share and document their work across other tools" [13]. For large project teams, connected information results in connected engineers. The concept is to "update once, use everywhere" [14]. [15] is a comprehensive discussion on model lifecycle management with motivation, definitions, requirements, use cases, current practices, and future considerations.

Knowledge management is an area where many organizations struggle, as organizational knowledge is often kept within the heads of subject matter experts. As Systems Engineering continues its digital transformation with use of model-based techniques, understanding the decisions that led to options taken across the system lifecycle will allow for further reuse from one system development to another. For models to serve as a mechanism for knowledge management, one should understand what each model represents, where it is stored, and how it interrelates with other models. Context is key to identifying what can and cannot be reused.

The INCOSE Configuration Management (CM) Working Group has developed a white paper which discusses how traditional CM should be expanded to cover digital system models, digital twins, and digital threads [16]. They note that "a digital enterprise cannot solely rely on configuration management principles established during the era of document-centric enterprises" and "standard bodies focus mostly on data standards for the purpose of interoperability but are lacking when it comes to standardizing accountability and change reconciliation processes." They note the importance of incremental CM enforcement, instead of CM being turned on all at once when products go from exploratory phases into more controlled production phases. "In an environment where multiple domains and abstraction levels of models, twins, designs, and physical systems need to be consistently maintained, such conventional approaches produce technical debt that most often is never recovered."

Another interesting concept in data science is the idea of dark data. In [17], David Hand says, "dark data are data you don't have." He calls dark data the Achilles heel of data science, and he describes "how lack of awareness of what you are missing can lead to distorted understanding, incorrect conclusions, and mistaken actions" [18]. Shijin Pathrose uses a "databerg" illustration to highlight the magnitude of the dark data that lies beneath. He asserts that 65% of data are dark data hidden within networks, people, and machines [19].

Model curation is "the lifecycle management, control, preservation and active enhancement of models and associated information to ensure value for current and future use, as well as repurposing beyond initial purpose and context" [20]. Model credibility and its associated constructs (model confidence, model trust, model validation, model value) have been investigated in literature for more than four decades [21]. Re-examining this work in the context of model curation, combined with recent studies, yielded heuristics, two of which are particularly relevant. One is "Model credibility is influenced by a model consumer's capacity for transparency into the validation activities throughout its development and enhancement." A second is, "Credibility of the model collection is influenced by a model consumer's perception of expertise of the governance authority that accepted the model into the collection."

Multiple standards inform this discussion. The National Aeronautics and Space Administration (NASA) has a NASA Technical Standard NASA-STD-7009A, "Standard for Models and Simulations" which provides uniform engineering and technical requirements for processes, procedures, practices, and methods endorsed as standard for models and simulations (M&S) developed and used in NASA programs and projects [22]. There is an accompanying handbook, NASA-HDBK-7009A, "NASA Handbook for Models and Simulations: An Implementation Guide for NASA-STD-7009A" [23]. Some programs use this standard to evaluate every model on the program, from ground support equipment to flight critical models. As each model goes through a criticality assessment, the result determines the amount of individual model control required, which provides a method for introducing flexibility in application.

The U.S. Department of Defense has a Modeling and Simulation (M&S) Community of Interest (COI) Discovery Metadata Specification (MSC-DMS) which defines Discovery Metadata elements for M&S resources posted to community and organizational shared spaces [24]. With applicability beyond the aerospace and defense sector, ISO 10303-243 [25] specifies the use of the integrated resources necessary for the scope and information requirements for modelling and simulation information in a collaborative systems engineering context (MoSSEC).

As described by Taylor [26], elasticity is a concept in cloud computing where resources are acquired as they are needed, then released when they are no longer needed. In the cloud, this is done automatically and dynamically. Using this analogy for DE, the DE approach should be optimally sized for the needs of the project at each point in time. Ideally, this is done dynamically, since predicting all at project inception is difficult. The project evolves; the technology evolves; DE capabilities mature and evolve. DE should not be "set and forget."

For model validation, SAIC has a free system model validation tool which improves the quality of Systems Modeling Language (SysML) models [27]. The tool is a set of rules and customizations to guide teams to make uniform choices. "The rules enforce style guides and language semantics, resulting in system content that's machine-readable for analysis tools. Review time for large system models is reduced to minutes."

The literature in this survey forms the foundation for the methodology which is described next.

3. METHODOLOGY

Robust DE implementation streamlines ground vehicle development, delivering modernization priorities and improving readiness. A key part of robust DE implementation is governance of the models in the ecosystem. As seen in the last section, a broad set of diverse literature informs the design of a model governance system. Building from the literature reviewed, aspects of different approaches were harvested. This section describes the process undertaken to develop an example model governance guide.

The first step was to review existing literature and practice, as discussed in the previous section. The second step was to harvest aspects of existing literature for incorporation. The Aerospace Corporation references provided specific model governance items to consider [10-11]. The INCOSE Model-Based Capabilities Matrix provided definition of the desired mature capability, which is applying model management to all models for an enterprise [12]. With regards to OpenMBEE, two key concepts were the model management system, and the idea that connected information results in connected engineers [13-14]. Requirements from the Model Lifecycle Management for MBSE paper were used [15]. The INCOSE CM Working Group white paper showed that incremental CM enforcement is important, starting from the earliest exploratory phases [16].

Data management and data governance guidance was incorporated in structure and in requirements [7, 9]. For dark data, understanding the "data you don't have" contributed to model governance system (MGS) structure [17-18]. Considerations for model curation informed the MGS structure also, particularly the need for strong governance and transparent visibility to build trust [20-21]. NASA-STD-7009A contributed the process of addressing every model in a program individually, along with assessing the criticality of each model [22-23]. Also, the model lifecycle and the detailed lists of model considerations and questions were useful. The metadata specification informed the attributes to track [24]. ISO 10303-243 informed the work instructions [25]. The process was structured to be elastic and flexible, a key idea in [26]. From the SAIC Validation Tool, similar functionality was desired, so the governance guide can have automated validation to check for compliance [27].

The third step was to build the example elastic model governance guide for the digital thread. The final step was to obtain feedback from stakeholders, users, reviewers and update accordingly. This includes presenting to customer and peer communities for critical feedback. The next section describes the example model governance guide.

4. RESULT

The result is an example elastic model governance guide (MGG) which can be applied to ground vehicle DE ecosystems. The guide itself is built as a SysML model, so the benefits of a model-based approach are realized. The guide is accompanied by a custom SysML profile and a template for a model governance plan. These products were built with flexibility in mind, so users can customize, expand, or contract as best fits their context. Next are descriptions of the features.

For format, the Dassault Cameo Enterprise Architecture tool was chosen as the platform for the MGG. Rather than having a document to describe how to do modeling, a choice was made to provide model-based guidance with in-model work instructions. This embeds work instructions at the point of need to enhance usability. The choice also demonstrates the benefit of the model-based methods promoted by DE. The MGG provides structure to capture metadata from models across the DE ecosystem.

Four key sections are included in the MGG, as shown in Figure 1. First, the Model Governance System (MGS) is the overall, high-level system controlling governance across the program ecosystem. It is purposefully designed to ensure requirements are met, while enhancing visibility and traceability. Second, the DE Ecosystem (DEE) Infrastructure has the details of the network topology, tools, servers, clouds, etc. on which the program model artifacts are hosted. Third is the section for Individual Models. Fourth is the section for Composite Models, where two or more individual models are digitally connected.

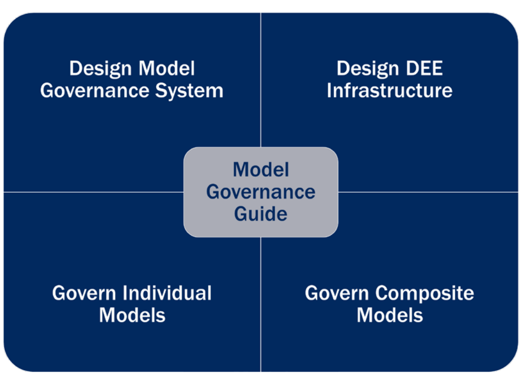


Figure 1: MGG key sections.

Figure 2 shows these key sections, along with the common, shared sections.

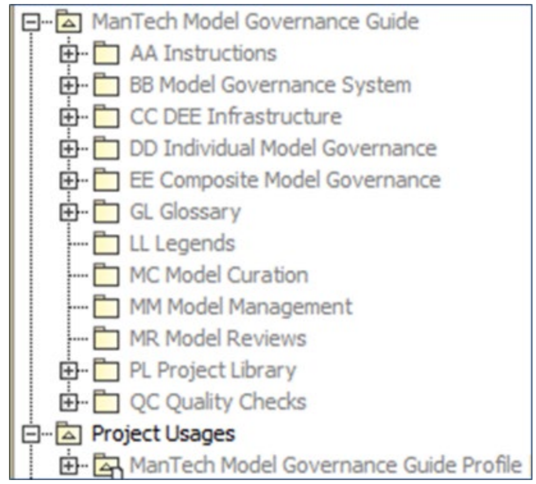


Figure 2: MGG structure.

At the next lower level, a repeatable structure is used to easily find information, as shown in Figure 3.

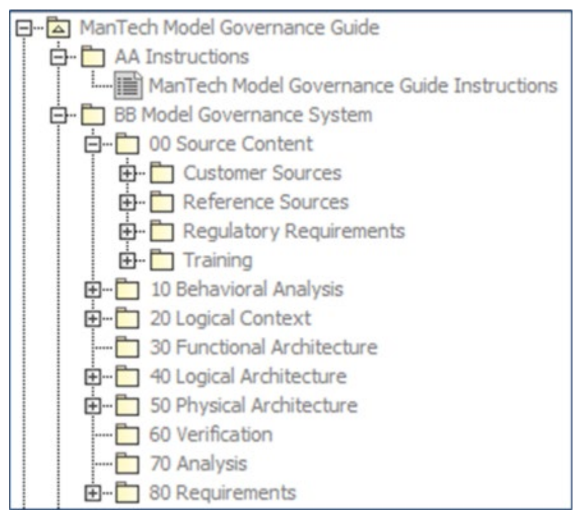


Figure 3: Example Navigation Aids.

Navigation aids such as landing pages and hyperlinks are provided throughout to provide clarity and enhance usability. Comments, descriptions, and instructions are abundant, embedding model governance knowledge at the point of relevance.

Work instructions are embedded in the model and provided at the point of need. They are written with clear wording and simple action pointers which reduces confusion to enhance compliance. Figures 4 and 5 show example work instructions.

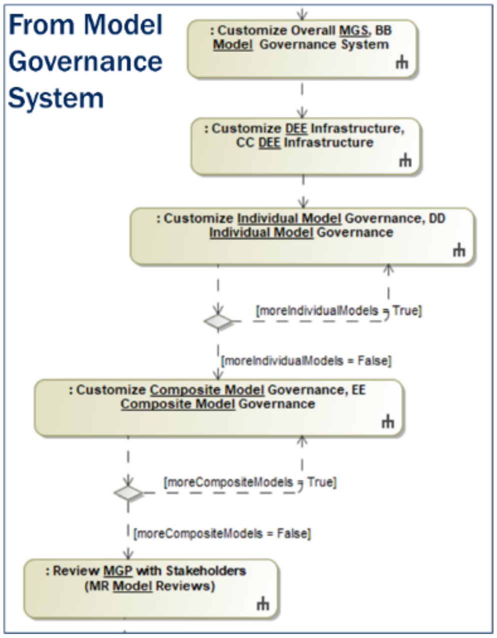


Figure 4: Example MGS work instructions

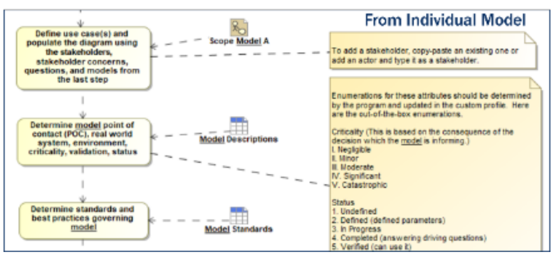


Figure 5: Example individual model instructions

The MGS itself is designed explicitly so known governance best practices are purposefully built into the controlling system. For ground vehicles, this allows a customized MGS specific to the ground vehicle program. Figure 6 shows example stakeholders and corresponding MGS use cases. Figure 7 shows example MGS requirements as shown in [15]. These can be customized to governance requirements for a ground vehicle program. Having the MGS described in an MBSE tool provides the MBSE benefits of enhanced consistency, improved traceability, viewable relationships, managed change, and analytics.

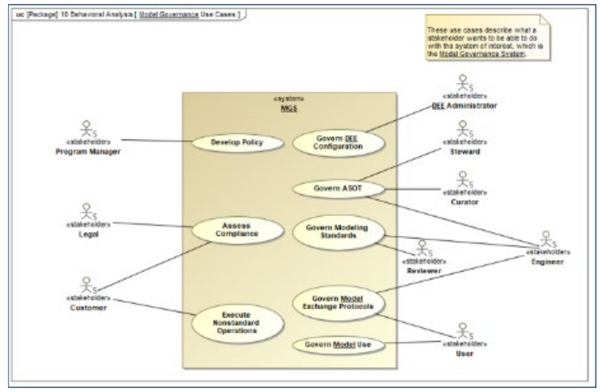
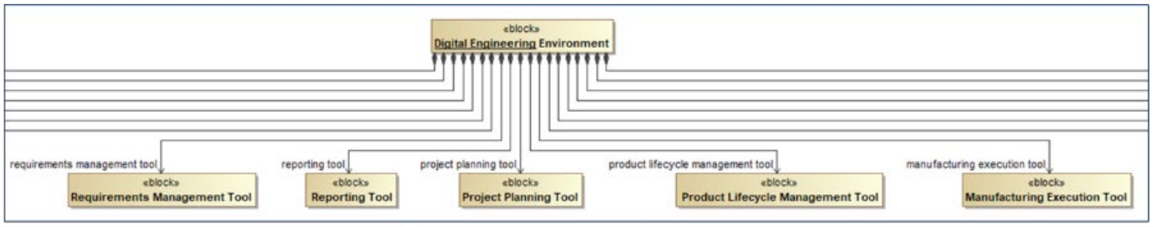


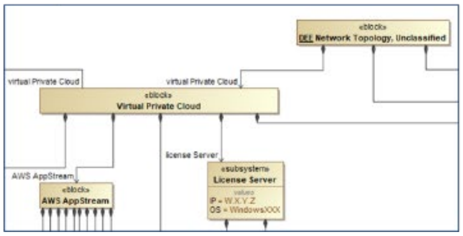
Figure 6: Example MGS use cases

△ Name	Text	Traced To
26 MGS Services		
26.1 Different Kinds	The MGS services shall include models of different kinds including geometric, analysis, and logical models (refer to model taxonomy in SEBoK Part 2 'Representing Systems with Models').	Fisher, Amit, M. Nol
26.2 Results	The MGS services shall include artifacts that result from the execution of models such as simulation and analysis results.	Fisher, Amit, M. Nol
26.3 Inputs	The MGS services shall include needed inputs to stimulate the models.	Fisher, Amit, M. Nol
26.4 Views	The MGS services shall include artifacts that are generated as views of the models including documents and reports.	Fisher, Amit, M. Nol
26.5 Environments	The MGS services shall include the tools and environments used to create, review, update and delete the models and related artifacts.	Fisher, Amit, M. Nol
26.6 Metadata	The MGS services shall include metadata about the models, the related artifacts, the tools and environments, and the users of the models and related artifacts.	Fisher, Amit, M. Nol
27 Model Content Modification	The MGS shall not modify the model content (excluding its metadata).	Fisher, Amit, M. Nol

Figure 7: Example MGS requirements

In the DEE infrastructure section, details of the ecosystem's computing infrastructure are also shown. This includes tool types, tool descriptions, realized tools, servers, clouds, license managers, etc. SysML may not be the right mechanism for topology details; however, including this information in the integrated model allows for links and relationships between the infrastructure elements and the digital artifacts hosted. Models can be related to their host location, and metachain navigation can be used for views and analytics. As data governance principles translate to model governance principles, it is important to understand who can take what actions, with what information, and when, under what circumstances, using





Name	Documentation	Realizes	Associations
Cameo Enterprise Architecture	Dassault Cameo is a model-based systems engineering tool.	Architecture Tool Verification Management T	Teamwork Cloud FlexNet Publisher Cameo Collaborator AWS AppStream
Matlab	Matlab is an analytical tool.	Analytical Tool	Computer A AWS AppStream
ModelCenter	ModelCenter is a tool which enables trades and multi-disciplinary optimization.	Analytical Tool Trades and Optimization T	FlexNet Embedded AWS AppStream

Figure 8: Example DEE infrastructure information

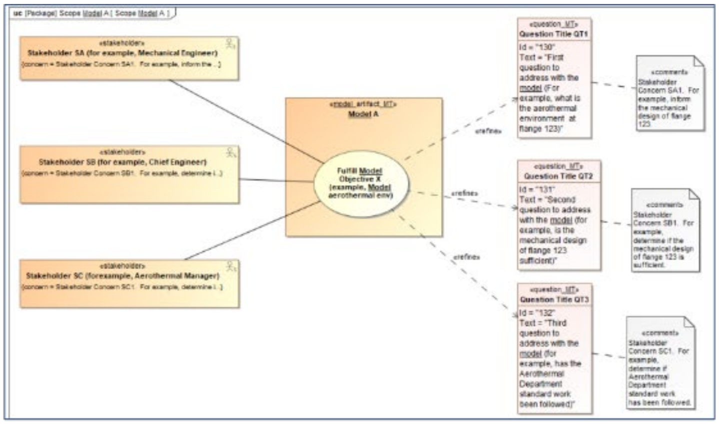
what methods. Understanding the infrastructure details can help with this, particularly when cross-tool automated analytics are being employed. Figure 8 shows example DEE infrastructure information.

For individual models to be most effective, it is important to understand the purpose of the model and scope effort accordingly. Though engineers may get excited to build models and delve deep into technical subjects of interest, modeling efforts need to address business needs. The fidelity required of the model is related to the questions the model is trying to answer and the technical debt being retired by completion of the modeling exercise. In the MGG, each individual model is tied to stakeholders, stakeholder concerns, and questions the model is to answer. An example is shown in Figure 9 for an aerothermal environment model. A Mechanical Engineer stakeholder may be interested in the aerothermal environment at Flange 123. The Chief Engineer may be concerned about the mechanical design of Flange 123 being sufficient. The Aerothermal Manager may be concerned about the Aerothermal Department standard work being followed. Each of these stakeholder concerns are tied to a question the model is to answer. These stakeholder concerns and questions help scope the modeling effort.

The relationships of artifacts in the MGG enable views for transparency and analysis. Figure 9 also shows an example of individual model description fields. Utilizing metachain navigation amplifies the analysis that can be done

Scoping of individual model effort can also be affected by attributes such as criticality, which is the consequence of the decision which the model is informing. Default values from the custom profile are Negligible, Minor, Moderate, Significant, Catastrophic. Users can adjust these enumerations and form governance rules on what actions are required for models of different criticality levels.

As shown earlier in Figure 5, work instructions are provided for managing individual models. The specific steps in these activity diagrams are starting suggestions, as are the custom profile attributes tracked for each model. The challenge is finding a balance. For individuals accustomed to storing math models on their local hard drive and controlling their own versioning, the idea of sharing model location and tracking a small set of model metadata may seem onerous. For individuals accustomed to a large, standardized 150-step process for model development and validation, a reduced



#	Name	Documentation	Associated Assumptions	Associated Risks	Traced to Standards	Use Cases	Questions2	Satisfies	Allocated To	Location
1	Model A	This is the description of Model A...	Assumption B Assumption A	Risk R1	Standard 1 (for example, I Best Practice 3 (for examp Standard 2 (for example, (	Fulfill Model Objective X (e	Question Title QT1 Question Title QT2 Question Title QT3	23 Modeling Questions MGSG-116 Risk MGSG-2 Model Name	ansys : ANSYS	AWS AppStream

Figure 9: Example scoping of individual model

set of governance steps may seem trivial. The MGG is built for customization and flexibility, so the expectations and rules can be adapted and properly sized for the program context. Interestingly, governance of the full DE ecosystem in an acquisition chain will likely connect models from a range of cultural norms. Digitally connecting model artifacts created in heterogeneous cultural norms benefits from clear, transparent, consistent, and measurable model governance.

Composite models are two or more individual models. The activity flows are comparable to individual model governance, though additional concern is taken for governance of change since models are more interdependent and coordinated effort is needed. Figure 10 provides an example.

Automated model validation is used to improve compliance to model governance guidance. A custom profile accompanies the MGG, and a custom set of validation rules have been established to enforce governance

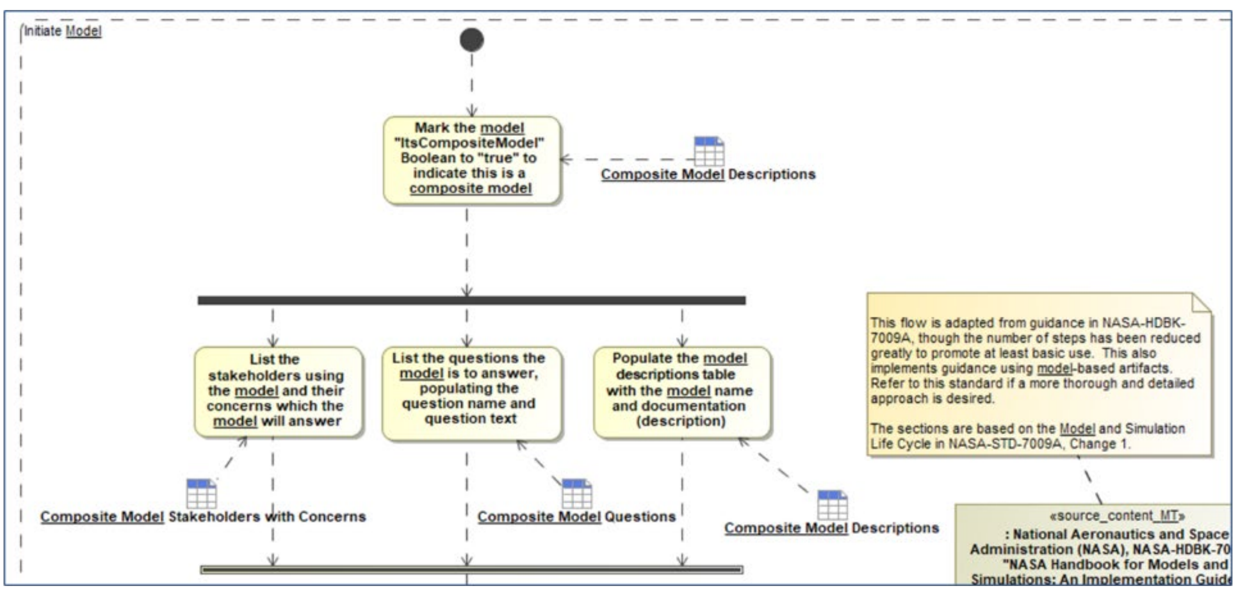


Figure 10: Example DEE infrastructure information

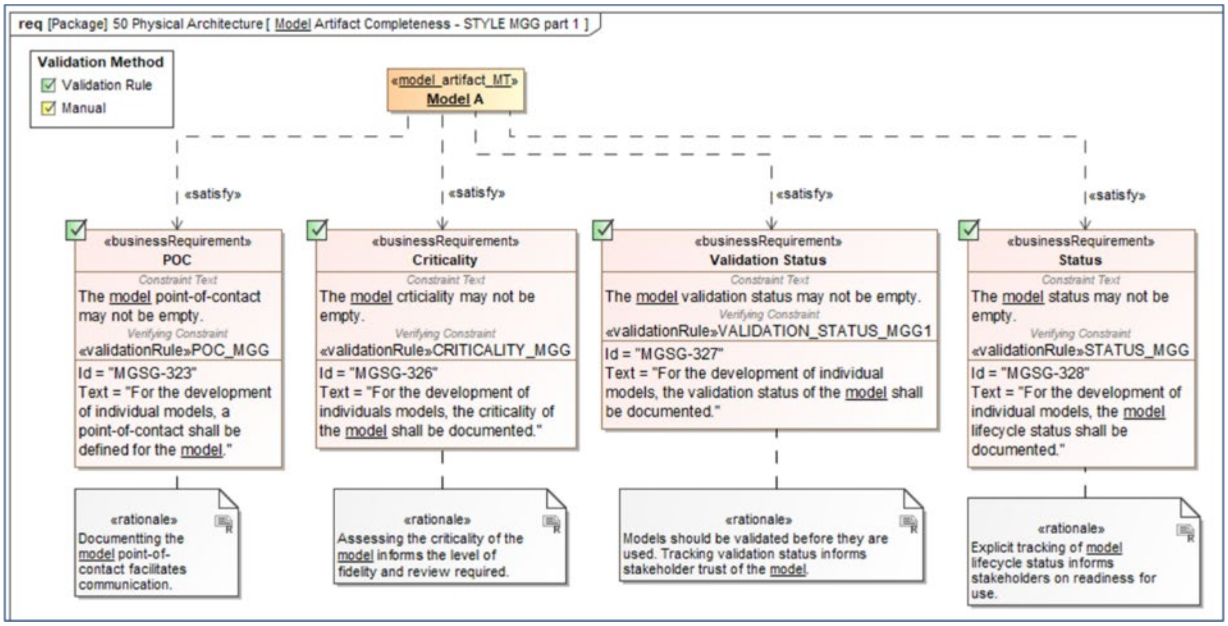


Figure 11: Example use of validation rules for compliance

expectations. With system content that is machine-readable, review for compliance can be reduced to minutes. Figure 11 shows an example of using validation rules for compliance.

The ManTech Marine Systems Engineering Directorate is piloting the example MGG. As stated by Mark Stimeling and Rebecca Quintero, "The Model Governance Guide provided our team with a framework for developing data governance rules and techniques to execute a rigorous enterprise modeling program. Establishing a set of model controls is no different and just as important as establishing Security Controls in the Cybersecurity discipline. With this effort, our customer will improve their business process management, degree of data integrity, and communication and transparency among Stakeholders. Without Model Governance the desired degree of model and data integrity cannot be achieved." For one customer, this team adapted the governance model to be in the customer preferred Innoslate tool instead, showing the flexibility of the guide and the ability to build the governance model in other tools besides Cameo. Additional pilot projects are underway, and the MGG will be updated as needed. The model governance mechanisms described can be applied to ground vehicle programs as well.

5. NEXT STEPS

Next steps for the model governance work include enhancing automation to scrape models for metadata to populate governance fields automatically, adding validation checking across the digital thread, updating the standard DEE views to explicitly track cybersecurity, and responding to feedback as received. More ISO 10303-243 integration will be added. In addition, integration of analytics will be enhanced. Additional pilot projects are also being pursued, including ground vehicle applications.

6. SUMMARY

As ground vehicle DE ecosystems swell, there is a heightened challenge to robustly govern heterogeneous linked models across disciplines and across contractual boundaries. Building on existing literature related to model governance, an example elastic MGG is described. Key features include: (1) model-based guidance with in-model work instructions; (2) integration of the overall MGS, DEE, individual models, and composite models; (3) scoping of model purpose and resolution of technical debt; (4) automated validation for insight on compliance; (5) customization for flexibility and tailoring. Including these interacting elements improves integration, since elements can be referenced, linked, and checked. In-model work instructions enhance usability. Intentionally designing the MGS ensures veracity of the authoritative source of truth. Tracing model purpose through needs addressed, questions answered, and technical debt resolved provides scope, establishes transparency into system development status, and captures context for potential reuse. Automated validation provides insight on compliance and enables synchronized data structuring for analytics applications to enhance program outcomes. The elastic structure for customization provides flexibility and tailoring for context. Employing elastic model governance can streamline ground vehicle development to actualize modernization priorities and improve readiness.

7. REFERENCES

[1] U.S. Department of Defense, "Digital Engineering" website, viewed April 2022, https://ac.cto.mil/digital_engineering.

[2] U.S. Department of Defense, "Digital Engineering Strategy," 2018, viewed April 2022, available at, https://ac.cto.mil/wp-content/uploads/2019/06/2018-Digital-Engineering-Strategy_Approved_PrintVersion.pdf.

[3] U.S. Army, Ground Vehicle Systems Center, "Mission," viewed April 2022, available at, https://www.usarmygvsc.com/mission/.

[4] A. Feickert, Congressional Research Service, "The Army's Optionally Manned Fighting Vehicle (OMFV) Program: Background and Issues for Congress," R45519, December 28, 2021.

[5] R. Mortlock, "Been There, Done That: Behavioral Acquisition," Army AL&T News, March 23, 2022.

[6] H. Davidz and D. Orellana, "Controlling the Digital Engineering Ecosystem: An Elastic Model Governance Guide for the Digital Thread," 32nd Annual INCOSE International Symposium, June 2022.

[7] M. Knight, Dataversity, "What is Data Management?" December 2021, accessed April 2022, available at, https://www.dataversity.net/what-is-data-management/#.

[8] D. Orellana and W. Mandrick, "The Ontology of Systems Engineering: Towards a Computational Digital Engineering Semantic Framework," 2019, Procedia Computer Science, 153, pp. 268-276.

[9] Data Governance Institute, "Data Governance: The Basic Information." viewed April 2022, available at, https://datagovernance.com/the-data-governance-basics/adg-data-governance-basics.

[10] Hoheb, A, M Zetilyan, A Chang, J Howie 2021, 'Model Portfolio Management (MPM) Guide: A Guide to Defining the Scope, Purpose, Tasks and Products of Model Portfolio Management', The Aerospace Corporation Systems Engineering Forum, May 2021.

[11] Hoheb, A, A Chang, M Zetilyan, J Howie 2020, 'Model Portfolio Management Guide', Aerospace Corporation Technical Operating Report TOR-2020-01577, September 2020

[12] Hale, J, A Hoheb 2020, 'INCOSE Model-Based Capabilities Matrix and User's Guide', Version 1.0.

[13] OpenMBEE, "Open Model Based Engineering Environment (OpenMBEE),"

accessed April 2022, available at, https://www.openmbee.org.

[14] R. Karban and C. Delp, “OpenMBEE Intro @MODELS'20,” YouTube video, accessed April 2022, available at, https://www.youtube.com/watch?v=ofKgcDrBFZQ.

[15] A. Fisher, M. Nolan, S. Friedenthal, M. Loeffler, M. Sampson, M. Bajaj, L. VanZandt, K. Hovery, J. Palmer, L. Hart, “Model Lifecycle Management for MBSE,” International Council on Systems Engineering International Symposium, 2014.

[16] INCOSE Configuration Management Working Group, “Configuration Management in the Context of a Model-Based Enterprise,” White Paper Revision B, 2021.

[17] D. Hand, “10-Minute Talks: Dark Data,” 2020, accessed April 2022, available at, https://www.thebritishacademy.ac.uk/podcasts/10-minute-talks-dark-data.

[18] D. Hand, “Dark Data: Why What You Don’t Know Matters,” 2022, accessed April 2022, available at, https://darkdata.website.

[19] S. Pathrose, ‘Why Organizations Need to Leverage Data Governance on Dark Data’, SG Analytics, 2019, accessed April 2022, available at, https://us.sganalytics.com/blog/why-leverage-data-governance-on-dark-data.

[20] D. Rhodes, “How Model Curation Influences Model Duration,” 2019 INCOSE International Workshop, MBSE Lightning Round, accessed April 2022, available at, https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:rhodes_lightninground2019_modelcuration.pdf.

[21] D. Rhodes, “Investigating Model Credibility within a Model Curation Context,” 18th Annual Conference on Systems Engineering Research (CSER), October 2020.

[22] National Aeronautics and Space Administration (NASA) 2016, ‘Standard for Models and Simulations’, NASA-STD-7009A w/Change 1, approved 2016-12-07, viewed 20 November 2021, <https://standards.nasa.gov/standard/nasa/nasa-std-7009>.

[23] NASA 2019, ‘NASA Handbook for Models and Simulations: An Implementation Guide for NASA-STD-7009A’, NASA-HDBK-7009A, approved 2019-05-08, viewed 20 November 2021, <https://standards.nasa.gov/standard/nasa/nasa-hdbk-7009>.

[24] “Modeling and Simulation (M&S) Community of Interest (COI) Discovery Metadata Specificaiton (MSC-DMS) version 1.5” July 2021, accessed April 2022, available at, https://www.msco.mil/MSReferences/MSResourceDiscovery.aspx.

[25] ISO 10303-243, “Industrial Automation Systems and Integration - Product Data Representation and Exchange - Part 243: Application Protocol: For Modelling and Simulation Information in a Collaborative Systems Engineering Context (MoSSEC),” 2021.

[26] M. Taylor, “An Elastic Approach to Digital Engineering,” National Defense Industrial Association (NDIA) Systems and Mission Engineering Conference, December 2021.

[27] SAIC, “Digital Engineering Validation Tool,” November 2021, accessed April 2022, available at https://www.saic.com/digital-engineering-validation.