Defense Standardization Program

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Modeling and Simulation

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Director's Forum

Modeling and Simulation in Today's DoD

When I remodeled my kitchen, I made a scale drawing of the room and paper cutouts of the various cabinets and appliances—then moved them around to see what would fit where and what the "flow" would be while working at the counter, stove, and sink and retrieving things from cabinets and the refrigerator. In my woodworking shop, I often make a scale model or a prototype of something before committing to the full-scale version or the one made from walnut or ebony. These are examples of modeling in a very simplified form. At much more complex scales, computer-based models and simulations are used every day by DoD and industry to help simplify and try out complicated ideas.

Models are generally used to simplify complex concepts, products, and processes to make them easier to understand; therefore, they are often used to aid complex decision making. There are many types of models, each suited for a subset of applications, ranging from conceptual to detailed, from physical to behavioral, from deterministic to stochastic, and from simple to complex. A model implemented over time is a simulation. Simulations are often classified as live (real people operating real systems), virtual (real people operating simulated systems), or constructive (simulated people operating simulated systems).

Modeling and simulation, like standardization, plays a significant but unseen role in our daily lives, and that is especially true in the military. Today, modeling and simulation applications comprise a critical tool set for the design, engineering, test, and evaluation of defense systems, for operational concept development and wargaming, for training and mission rehearsal, and for real-time situational awareness and analysis tools.

Defense engineers, warfighters, and decision makers use models and simulations in the engineering and operation of defense systems, as well as the training and execution of strategic, operational, and tactical decision making and operations. For example, engineers use 3-D digital models to design and assemble aircraft carriers, production managers use 3-D models and discrete event simulations to plan and manage assembly lines for aircraft and vehicle parts and systems, and maintenance workers use models and augmented reality to plan and conduct maintenance. Furthermore, the system-centric practices of design and engineering increasingly use high-fidelity, physics-based models to improve system performance and quality.

Gregory E. Saunders
Director
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In the operational domain, warfighters use live, virtual, and constructive (LVC) simulations to train and operate at the strategic, operational, tactical, and individual skill levels. Large, international LVC exercises are conducted multiple times a year to practice operations with coalition partners and to experiment with new concepts and capabilities. Simulations provide the ability to train and conduct mission rehearsal in a variety of operational environments against a variety of threats, based on the warfighter's mission set. Models and simulations are also present in the warfighters' tactical decision aids and in other tools used to maintain situational awareness during operations.

To support these complex tasks, models, LVC simulations, and supporting hardware, software, and databases are often integrated to produce complex synthetic environments for analysis, experimentation, and training at the strategic, mission, or engagement levels; or they are integrated to conduct high-fidelity, physics-based simulations for design, test, and analysis of components, sub-system, and system performance. In either case, standardization is key to intelligent and accurate exchange of data between models and systems. Standards enable interoperability at the physical interfaces, at the syntactic level for data exchange, and at a deeper "conceptual" or "semantic" level to promote meaningful exchange of information. Though we are quite proficient at the former two, there is still much work remaining to fully achieve interoperability at a deeply reliable and consistent level.

This issue of the *Defense Standardization Program Journal* highlights some of the current capabilities, concepts and needs, and possibilities empowered by standardization of and for models and simulations. This is a domain in which DoD has invested heavily, and one where we have benefited greatly from the efforts and products of non-government standards bodies. In these articles, you will find proven, stable standards that have enabled interoperability and aided engineers and architects for decades. You will also see possibilities and needs for new standards, to make the most of the mobility and ubiquity of computing devices, the rapid growth of virtual and augmented technologies, and the evolution of model-based engineering tools and practices in DoD. Perhaps you are able to apply some of the highlighted standards in your programs, or you would like to get more involved in shaping the future of digital engineering for defense systems, or the integration and interoperability of models and simulations for large-scale LVC exercises.

For more information on modeling and simulation in DoD, visit *https://www.msco.mil/*; for digital engineering, visit *https://www.acq.osd.mil/se/initiatives/init_de.html.*

DoD Standards-Based Digital Engineering for Acquisition

By Steven A. MacLaird

This article introduces executives, engineers, contracting, financial, and program managers to the Object Management Group (OMG®) standards—also known as specifications—and modeling expertise by introducing a short list of standards. These standards are later put into use case scenarios to help the reader understand how OMG's block approach helps create a planned, organized system for long-term solutions. OMG standards are used throughout the Department of Defense and the commercial world to ensure that seamless systems integration and shared information meet specified criteria.

Many times, the first question asked is, "Why standards?" Simply put, the answer covers rapid development and testing, complexity management, cost reduction, rapid integration, reliability, and cyber security.

OMG was founded in 1989 and since its inception has assisted DoD, the Ministries of Defense (MoD), the North Atlantic Treaty Organization (NATO), and both U.S. and international commercial industries in a number of standard initiatives. OMG divides its work into technology horizontals (platforms) and industry verticals (domains). OMG products are in use in more than 100 countries, in several major systems areas, and over two dozen vertical markets. Horizontals include cross-cutting capabilities such as architectures, middleware, modeling, processes, and systems assurance. Verticals are identified as industry interest areas such as automobiles, business, case management, finance, health, insurance, manufacturing, retail, robotics, software security, space, technical debt, telecommunications, telescopes, and command, control, communications, computers, and intelligence (C4I).

OBJECT MANAGEMENT GROUP AND OMG PROGRAMS QUICK SUMMARY

Object Management Group

OMG (www.omg.org) is an international, open membership, not-for-profit technology standards consortium. Founded in 1989, its mission is to develop technology standards for a wide range of industries (including automotive, business, finance, healthcare, insurance, security, space, and the Industrial Internet of Things). OMG is dedicated to bringing together its international membership of end users, vendors, government agencies, universities, and research institutions to develop and revise standards as technologies change throughout the years. OMG is well known for its suite of modeling standards, such as Meta-Object Facility, Unified Modeling Language, and Systems Modeling Language, as well as its high-level software communication standards, such as the Common Object Requirements Broker Architecture, Data Distribution System, and Software Communications Architecture.

OMG Programs

OMG provides the support infrastructure for the Industrial Internet Consortium (IIC®), Consortium IT Software Quality (CISQ®), and Cloud Standards Customer Council (CSCC®). Membership cost is based upon entity and size.

IIC (www.iiconsortium.org)

The IIC is an open-membership organization, formed to accelerate the development, adoption, and widespread use of interconnected machines and devices, intelligent analytics, and people at work. The IIC focuses on test beds to prove out theories, plans, and objectives before going to market. IIC working groups coordinate and establish the priorities and enabling technologies of the industrial internet in order to accelerate market adoption and drive down the barriers to entry. The IIC today has more than two dozen major (multimillion-dollar) test beds in manufacturing and production, healthcare, electricity grids, agriculture, smart city services, and more, proving out the use of the Internet of Things in industrial settings.

CISQ (www.it-cisq.org)

CISQ is an IT industry leadership group composed of IT executives from the Global 2000, system integrators, outsourced service providers, and software technology vendors committed to developing standards to automate the measurement of software size, quality characteristics, and related software quality measures from source code. CISQ is working on standards to manage cyber security, resiliency, and technical debt. It's worth highlighting that CISQ's initial targets are the common weakness enumerations (CWEs) as defined by MITRE and the Department of Homeland Security. CISQ security measures were developed to predict the vulnerability of application source code to external attack. The measures identify the top 22 CWEs in software, which represent the most widespread and frequently exploited security weaknesses. CISQ provides policy makers with insight and recommendations regarding the implications of technology-related legislation, regulations, policies, and proposals on software quality, risk, and resilience.

CSCC (www.cloud-council.org)

The CSCC is an OMG end-user advocacy group dedicated to accelerating the cloud's successful adoption and drilling down into standards, security, and interoperability issues surrounding the transition to the cloud. Members join the CSCC to discover best practices and to learn about cloud standards and open-source initiatives within one organization.

OMG members have designed standards for many communities. The following is a small list to provide a view of OMG's breadth and depth (the entire list can be found at *www.omg.org/technology/documents/vault.htm.)*

Common Object Requirements Broker Architecture (CORBA™)

CORBA is one of OMG's most successful sets of standards; it is nearly 30 years old and running live in more than 5 billion settings right now (every mobile phone, every JTRS radio, every robot, every banking system, etc.). Computer systems, networks, and cell phones all use CORBA as the preeminent architecture of choice. CORBA is a vendor-independent architecture and infrastructure that computer applications use to work together over networks using the standard Internet Inter-ORB Protocol (IIOP). IIOP allows any CORBA-based program from any vendor—on almost any computer, operating system, program language, and network—to interoperate with a CORBA-based program from the same or other vendor. Use case: cell phones, mainframe computers, networks, software-defined radios, and so forth. *Reference: www.omg.org/corba/corba-e.htm.*

Business Process Modeling Notation (BPMN™)

BPMN is a precise, complete, and graphical notation for documenting well-defined business processes. BPMN resolves many ambiguities found in textual process specifications by assigning activities to specific actors. Analysis of the resulting models can be used to drive process improvement initiatives, regardless of whether the processes are automated or manual. Because the graphical model is readily understandable by non-technical people, it serves as a bridge that allows collaboration between business stakeholders and IT personnel. OMG's BPMN 2.0.1 specification has been published as International Organization for Standardization (ISO)/International Electrotechnical Commission (IEC) International Standard 19510:2013. Use case: The Veterans Administration is using BPMN to modernize its medical records management and business processes. *Reference: www.omg.org/intro/TripleCrown.pdf, healthcare.omg.org.*

Unified Architecture Framework (UAF®)

The Unified Profile for DoD Architecture Framework MoD (UPDM), Ministry of Defense AF, and NATO AF were recently renamed the Unified Architecture Framework after being updated with new capabilities. The UAF is a generic, commercially oriented architecture framework based on the UPDM. The UAF defines ways to represent an enterprise architecture so that stakeholders can focus on specific areas of interest in the enterprise without losing sight of the

Unified Architecture Framework

big picture. The UAF meets the specific business, operational, and system-of-systems integration needs of commercial and industrial enterprises as well as DoD, the U.K. MoD, and other defense organizations. Use case: DoD uses consistent enterprise architectures (as models) based on generic enterprise and system concepts with rich semantics. *Reference: www.omg.org/intro/UAF.pdf.*

Data Distribution System (DDS™)

DDS allows various systems to transfer data simultaneously to different users who can quickly determine and ensure mission success. DDS was the first open international middleware standard directly addressing publish-subscribe communications for real-time and embedded systems. DDS introduces a virtual Global Data Space where applications can share information by simply reading and writing data objects addressed by means of an application-defined name (topic) and a key. DDS features fine and extensive control of quality of service parameters, including reliability, bandwidth delivery deadlines, and resource limits. DDS also supports the construction of local object models linked to the Global Data Space. Use case: dam reservoir monitoring, Orion Delta IV launch vehicle mission operations. *Reference: www.omg.org/intro/DDS.pdf, portals.omg.org/dds/what-is-dds-3.*

Information Exchange Framework (IEF™)

IEF establishes a family of specifications for responsible information sharing and safeguarding capabilities for email exchange, file sharing, instant messaging (chat), structured messaging, and web services. IEF provides Simple View IEF Scope. The first in the envisioned family of IEF specifications has been published—the Information Exchange Packaging Policy Vocabulary. This specification provides a policy vocabulary and Unified Modeling Language (UML) profile model for secure packaging and processing of structured information elements, such as the National Information Exchange Model, Structured Threat Information eXpression, Cyber Observable eXpression, and Trusted Automated eXchange of Indicator Information. Use case: Office of Defense National Intelligence and Canadian Department of National Defense.
Reference: www.omg.org/intro/IEF.pdf.

OMG's Systems Modeling Language (SysML™)

SysML is an enabler of a model-based systems engineering (MBSE) approach to improve productivity and quality and reduce risk for complex systems development. SysML is being used as part of an MBSE approach by a broad range of industries including aerospace and defense, automotive, and biomedical. SysML is a general-purpose graphical modeling language for specifying, analyzing, designing, and verifying complex systems that may include hardware, software, information, personnel, procedures, and facilities. A system model expressed in SysML provides a cross-disciplinary representation to enable integration with other engineering models and tools. Use case: the auto industry, CubeSat reference model, manufacturing, space, and telescopes. *Reference: www.omgsysml.org, www.omg.org/intro/SysML.pdf, www.omg.org/intro/CubeSat.pdf.*

Software Communications Architecture (SCA) for Software-Defined Radios (SDR)

OBJECT MANAGEMENT GROUP®

SCA

SCA was named by DoD for the Joint Tactical Radio System and divided into buildable blocks by OMG; it was made up of multiple standards including CORBA, UML Software-Based Communications (SBC), UML for System on a Chip, and UML Profile for Advanced and Integrated Telecommunications Services. OMG currently has a Secure Network Communications (SNC) RFI available for comment to update the SBC standard to address current networking and cyber security, move the standard from UML to SysML, and create auto-generating code capabilities for international commercial use. Use case: terrestrial and space communications. *Reference: www.omg.org/intro/SCAV.pdf, www.omg.org/intro/SNC.pdf, www.omg.org/news/releases/pr2017/11-20-17.htm.*

CURRENT OMG WORK INITIATIVES

OMG is working on several initiatives that DoD and industry may want to engage in by becoming contributing and influencing members of a working group. The members drive all OMG initiatives through OMG task forces, working groups, and special interest groups. The OMG staff work with the chairs of each group to offer support in managing quarterly meeting logistics, marketing outreach, and education for events and upcoming efforts. Following are some of the initiatives:

- Finalizing the UPDM to the UAF.
- Modernizing the SBC/SCA to the SNC through the SDR/SBC (chartered June 2017) with the Middleware and Related Services Task Force. *Reference: www.omg.org/mars.*
- Coordinating with the National Aeronautics and Space Administration (NASA), the National Oceanic Atmospheric Agency, and the U.S. Air Force Space and Missile Center to create coordinated space ground systems and orbit systems sets of standards to be usable by all. *Reference: www.omg.org/space, www.omg.org/intro/Space.pdf.*
- Modernizing SysML for the coming decades—SysML Version 2.0. *Reference: www.omgsysml.org.*
- The Veterans Administration is working on BPMN to modernize health records management systems. *Reference: healthcare.omg.org, www.omg.org/intro/Healthcare.pdf.*
- OMG's range of solutions extends to a wide variety of industry verticals, such as finance (Financial Industry Business Ontology and Financial Instrument Global Identifier) and the retail standards recently moved from the National Retail Federation to OMG. *Reference: www.omg.org/hot-topics/finance.htm, www.omg.org/spec/FIGI/About-FIGI.*
- The International Council of Systems Engineers used OMG's SysML to create a CubeSat reference model providing businesses and academic institutions a plan on how to build a small satellite, assess launch considerations, and coordinate with stakeholders. *Reference: www.omg.org/intro/CubeSat.pdf.*
- OMG's Information Exchange Framework is getting increased attention as it establishes a family of specifications for responsible information sharing and safeguarding capabilities. Those capabilities include email exchange, file sharing, instant messaging (chat), structured messaging, and web services. *Reference: www.omg.org/intro/IEF.pdf.*

- OMG's C4I Task Force recently produced the Open Architecture Radar Interface Standard for radar systems, working in the Cyber Security for Front Line Systems, and its work on IEF is in the final stages for approval, which revolutionizes how Machine to Machine coordinates and verifies accurate information for real-time decisions. *Reference: www.omg.org/spec/OARIS/About-OARIS, www.omg.org/intro/Cybersecurity.pdf.*

OMG's portfolio of programs (i.e., engineering, modeling, and standards) ensures that standards are spread among the matrix of horizontal and vertical program needs. This creates a "block effect" to allow integration capabilities as you move from program to program affecting the Industrial Internet of Things (i.e., test beds), to the cloud (i.e., deployment), and addresses cyber-security concerns (CISQ— i.e., measurement). The benefits of and continuing need for international, commercial standards are as follows:

- Drivers for open standards include increased requirements for interoperability and increased requirements to reduce cost.
- Using standards enables governance, reduces vendor lock-in, and reduces life-cycle costs.
- Standards increase competition during acquisition and maintenance cycles by
  - minimizing tailoring and customization;
  - reducing vendor-driven compliance validation, verification, and certifications;
  - providing wider access to subject matter experts; and
  - providing greater access to training opportunities.

Moving to a standards-based requirements approach allows departments and vendors to address the "what" versus the "how" and to focus more on the critical end product.

EMBRACING THE OMG STANDARDS

A good example of the collaboration between OMG and OMG programs is how CISQ identified the critical areas surrounding cyber security and how to manage the associated technical debt risk reduction measures associated with computer coding. Following are the five key areas of cyber security: (1) automated function points, (2) reliability, (3) performance efficiency, (4) security, and (5) maintainability. Each of these areas required standardization. The CISQ membership worked on the proposed standard and sponsored each of the five areas through the OMG process over a 4.5-year period. Today, these five areas are standards embraced by worldwide governments, industries, and academic institutions.

CISQ sponsors and executes three to four symposiums per year to discuss current issues and technical debt reduction measures as well as the benefits of artificial intelligence in automated coding characteristics and the benefits to various communities. Another example of OMG and OMG program collaboration is the Industrial Internet Security Framework created by the IIC *(http://www.iiconsortium.org/IISF.htm).*

This article's introduction introduced proposed scenarios intended to help the reader understand how OMG builds standards to be applied in "block" or "kernal" effect in order to impact the overall enterprise. Two scenarios are provided. One is an actual event carried out in 2016 documented on *60 Minutes* and entitled "The Coming Swarm" *(35-second preview—www.youtube.com/watch?v=NSxFDjPAV7M; 20-minute documentary—www.cbsnews.com/news/60-minutes-capturing-the-perdix-drone-swarm).*

The final scenario is presented as a mind tickler and is based on a plan to develop a system-of-systems approach for ground control stations to control terrestrial, air, and space assets. Information collected is distributed to multiple distribution points to be analyzed and acted upon by Machine to Machine (M2M) and Machine to Human (M2H) decision makers.

In the "Coming Swarm" documentary, the U.S. Navy's Naval Innovation Advisory Council addresses the pacing challenge of "How do we deploy critical warfighting and secure software to Navy networks and autonomous systems in a few weeks?" To do that, they believe that the next-generation cyber-security systems need to be smarter, orders of magnitude faster, and able to evolve against real-time threats and do that through modified international commercial standards. To do so, artificial intelligence and model-based methods significantly improve software quality and security, and they decrease software transition timelines and cost.

In the documentary, you will see that three Navy F-18s launch more than 100 autonomous drones the size of a human drone. They interact with each other as they fly their mission, providing data to a central data bank for analysis. This program used 18 OMG standards, which enable the program to be successful and to be completed in less than 18 months.

To enable a cyber-security transformation, artificial intelligence and model-based methods are used combined with international commercial standards that are available today for free from OMG. The top "Human in the Loop" state-of-the-art software development process can take a very long time—months and years! And, the cyber-security process is typically a bolt-on process at the end of the development pipeline.

Prototyped processes where humans can operate on the loop and not in it are used and redesigned, when necessary. We are working toward a process in which security is considered up front and built in at the very beginning. This process attempts to improve both software quality and security while decreasing software transition timelines from years and months to weeks. *Figure 1* depicts the process that was considered in the design.

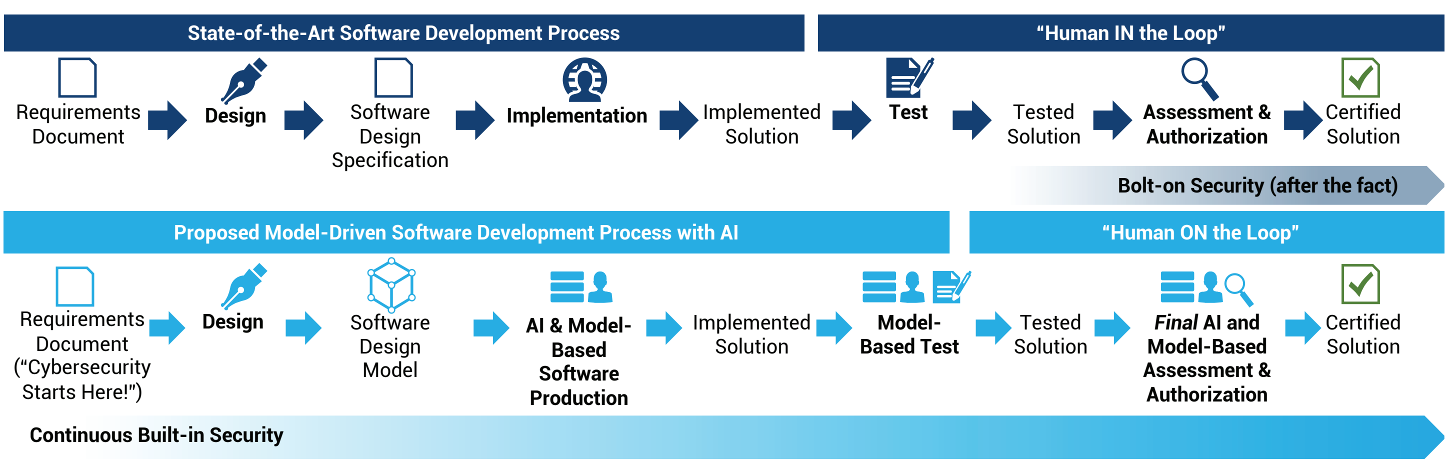

Figure 1. The cyber-security transformation process.

Today there are multiple ground stations deployed to control ground, air, and space platforms. These ground stations, whether mobile or stationary, all have similar functions to control a platform or asset, whether terrestrial, in the air, or in space. One should consider it "a rock" that needs to be told what to do, where to go, what data to collect, whom to send the data to, how to assess, where to maneuver to collect the data, and what information to ask for to complete its mission. To support this plan, OMG would recommend using UML and SysML to map out the system from the beginning. This would allow a digital twin to be developed up front and identify validation and verification goals and desires. SysML is the preferred modeling tool recommendation because it adds the ability to address behavioral characteristics. Thus, when there is "misbehavior," also known as a failure, SysML directs managers to both the misbehavior and the affected areas, which reduces the failure analysis time versus performing a tooth-to-tail root-cause analysis. UML would still have usefulness in some areas. This mapping would then identify the architecture, business processes, coordination requirements, data distribution services, directive alerts and alarms, M2M and M2H characteristics, stakeholders, relationships, communication requirements, logistics, training, and record keeping.

CORBA would provide the middleware for the DoD UAF, IEF security framework. DDS would distribute data over the software radio SCA that would provide voice, video, and data to and from command centers for situational awareness. OMG's Space Domain ground station effort—including XML Telemetric and Command Exchange, Ground Equipment Monitoring Service, Satellites Operations Language Metamodel, and OMG's C4I Domain Alert Management System—and NASA's sponsored Command Control Management Service would be a start for ground control stations for terrestrial, air, and space assets. If business processes were to be added, records would be required to document actions using OMG's BPMN and Records Management System.

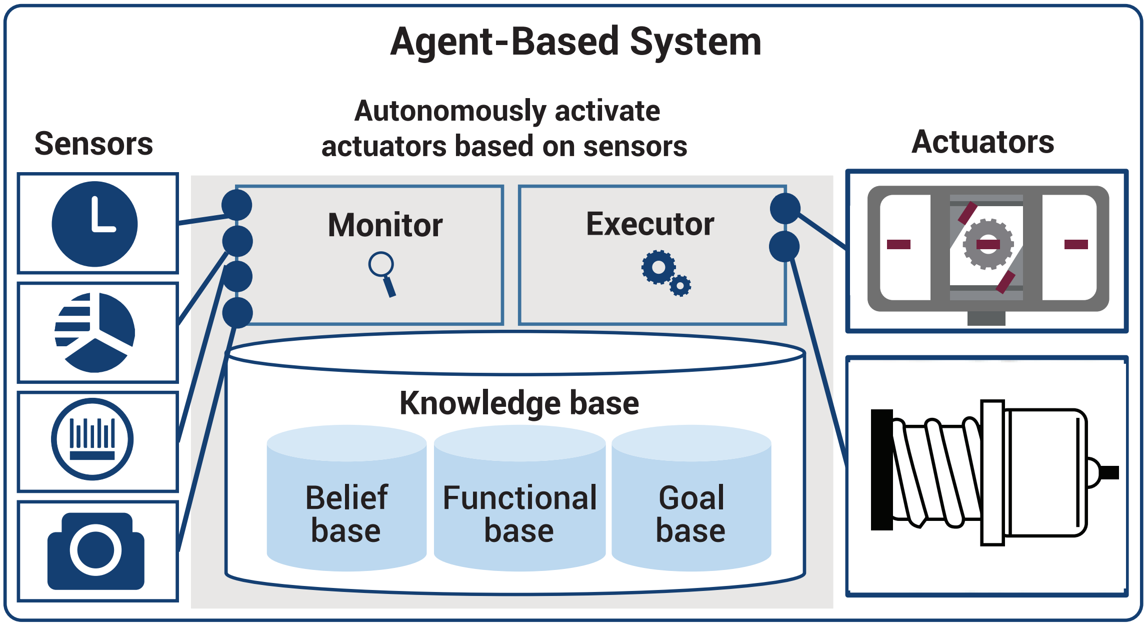

Figure 2. Elements of an agent-based system.

The above scenario would establish the foundation for autonomous systems supporting data distribution services, ontology standards (human and machine benefits), archetype modeling language, Meta-Object Facility, Resource Description Framework, Interaction Flow Modeling Language, knowledge discovery modeling, and operational threat and risk modeling.

All of the above creates game-changing capabilities that can tie military, justice, and industrial information databases to aid in decision making by using an executable suite of standards and agent and event meta-models. To do this requires the collaboration of government, industry, and academia organizations. Designing the collaboration with the best minds available allows for the design of tools that are intuitive agent-based systems *(see Figure 2)*, which are easy to use, have less buttons and more autonomy, provide less time from concept to deployment, and are designed in secure solutions from the start.

This creates a better future with broader positive impacts to national defense and the public's quality of life, all derived from a standards-based requirement approach. This is OMG's goal and purpose.

ADDITIONAL FACTS

OMG standards are covered in more than 10,000 books on Amazon.com; the standards (e.g., UML, SysML) are taught in junior colleges, 4-year degree programs, and post-graduate programs. All OMG standards are freely available from the OMG website. Due to OMG's stringent approval process, many OMG standard specifications are fast-tracked through ISO/IEC Joint Technical Committee 1 unchanged. OMG specifications typically take 18 to 24 months to develop, and then they take an additional 6 months more to be adopted by ISO (a reduction to the normal 5-to-7-year ISO process). ISO then adds a cover sheet and publishes it, allowing the specification to be purchased from ISO.

About the Author

Col. (Ret.) Steven "Steve" A. MacLaird is OMG's senior vice president for government and industry strategy. He served as a military advisor to the United Arab Emirates from 2013 to 2015, where he advised their military on acquisition practices, and he has owned and operated Highland Consulting Group since his retirement. Col. MacLaird retired from the U.S. Air Force after 27.5 years of service in 2005. His last assignment was as the system program director of the Joint Tactical Radio System, Joint Program Office. During his service, he was involved in the acquisition, contract and financial management, and integration responsibilities of over 85 percent of the Air Force's aircraft types. He also was involved with the missile integration on F-15E and F-16C/D aircraft, was the Program Executive Office's AWACS E-3 director to the Air Staff, and was Joint STARS E-8 production program manager. Col. MacLaird's expertise in aircraft production management led to his early recognition as an aircraft acquisition firefighter and his selection to correct many production line challenges from 1987 to 2001. Of his 27.5 years of service, 19 were directly involved with 26 international countries. His experience and knowledge in the air/land/sea and space-based command, control, and communications battle management kill chain landed him on the 1997 Air Force Scientific Advisory Board, which developed the Air Force's Global Engagement and Awareness Strategy. Early in his career, Col. MacLaird was directly responsible for the contracts for the Hubble Telescope Chassis and Space-Based Deformable Mirror Development, satellites, and many aircraft.

Drilling into the Processes and Models for Standards-Based Digital Engineering

By Victor Harrison

There is a true story about a world-renowned manufacturing company that had one factory using a completely different digital engineering environment than what was in use by the rest of the corporation. The problem was this one factory's technical base was not open nor was it standards based. This affected the corporation's ability to enable group technology services within and between its factories. Even though the rest of the corporation practiced standards-based digital engineering, the design engineering, reuse of component designs into new products, repair-part inventories, and even dealer-service inventories were negatively affected.

The point of this story is that establishing a holistic, open, and standards-based digital engineering environment that uses Object Management Group (OMG®)[1] community-developed models, processes, and outcome specifications saves time and money, improves quality, enables mass customization, shortens time to market, and increases interoperability. This article explores the kinds of processes and model-based outcomes that are necessary and how OMG standards have helped enable discrete and continuous engineering as well as software systems delivery.

Oh, yes: the one maverick factory in the above story has since switched to the open and standards-based digital engineering environment in use by the rest of the enterprise.

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[1] Object Management Group and OMG are registered trademarks of the Object Management Group.

STANDARDS-BASED DIGITAL ENGINEERING—THE OMG APPROACH

As the preceding story points out, practicing digital engineering does not mean that the benefits of standardization are achieved by coincidence, nor does it mean that a mere statement of compliance to standards will add value to a digital-engineering effort and environment. Rather, for standards to be of value, what is required is a connection between a standard's attributes and one or more digital engineering outcomes that produce value. Passive, declarative standards compliance is not enough.

Why Passive Standard Compliance Is Not Enough—an Example

Institute of Electrical and Electronics Engineers (IEEE) 1471 is a standard for conceptual architectures and their contents. The problem is that almost any systems engineering effort can be declared IEEE 1471 compliant. Passive, declarative compliance to a standard does nothing to add value to a delivered system. But, as it turns out, there is an active way to comply with IEEE 1471: it can be used as the basis for qualifying the "fit" of design patterns to a particular system's solution. This is a form of active compliance in which a standard, in this case IEEE 1471, drives the digital engineering description, attributes, and outcomes. As will be seen in the next section, the OMG approach is active compliance based, which controls the characteristics of delivered assets.

The OMG Approach to Standards-Based Digital Engineering

As noted above, the OMG approach to digital engineering is in the form of active compliance (*see Figure 1*). This is the home page of a reusable model for digital engineering. It has been used as the basis for various digital engineering efforts that have included pure software systems, hybrid hardware or software systems, and complete data center environments. The models are standard Unified Modeling Language (UML), Systems Modeling Language (SysML), and Business Process Model and Notation (BPMN) models and are not proprietary in either their depiction or their content. Context-specific views of the models are supported. Compliance with various standards is built in. Elements of the standards are allocated as attributes or methods to other

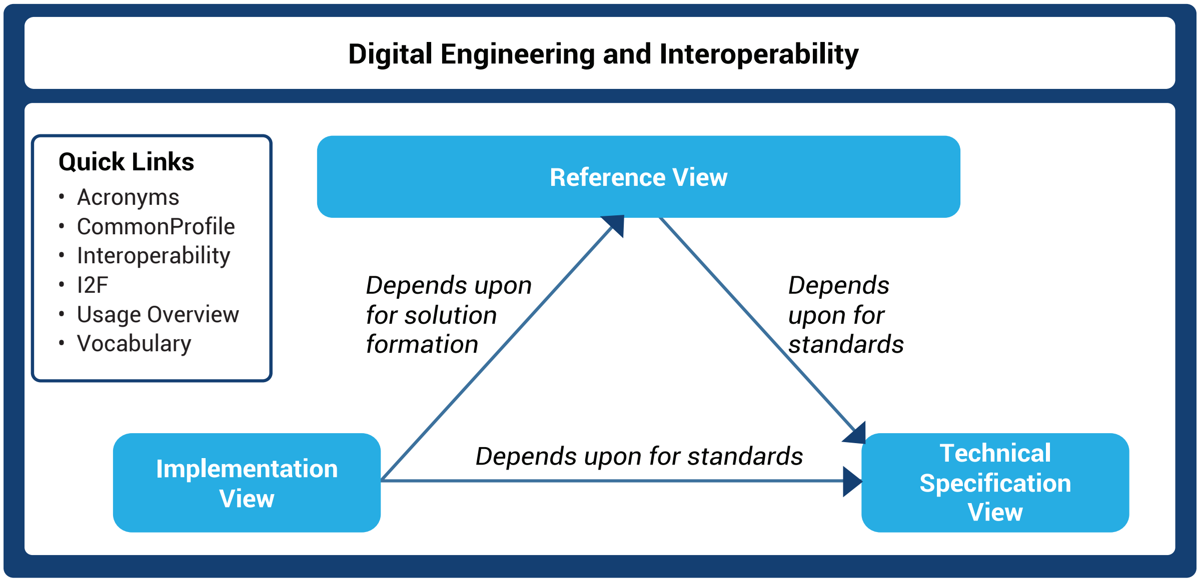

Figure 1. Digital engineering website (http://empoweringgovernment.org/Digital_Engineering_and_Interoperability).

components of this model. Using the model elements as the basis for design-to-delivery engineering thereby ensures compliance. In many circumstances, the structure and nature of an element is the basis for satisfying parts of multiple standards. This is quite useful when standards-based model elements need to be used in problem- or system-specific contexts. And as is the case with any model based on UML or SysML, test cases can be generated from the model along with code, supporting documentation, and the results of built-in modeling and simulation (M&S) of the model.

A CONTINUOUS MODEL-BASED PROCESS OF DIGITAL ENGINEERING

The way engineering has been practiced over the years has not been much different from how products are manufactured on an assembly line. Engineers and technicians perform specialized jobs in an assembly line often with little digital repository integration. Model-based systems engineering not only permits but encourages concurrent work, integrated work teams, and usage of a common and integrated digital repository of model elements and artifacts.

To help facilitate this concurrency and share model-repository-based engineering, organizations put into place some form of the nine workflows depicted in *Figure 2.* Key characteristics include the continuous and iterative process of digital engineering; the utilization of models; and a common repository used to store, merge, and validate artifacts.

Consider Figure 2: The process starts by **(1)** qualifying the characteristics of candidate projects—the pipeline—followed by **(2)** the analysis of desired outcomes, characteristics, and measures. **(3)** A group technology-based "priming framework" of partially constructed content is chosen (see the previous section and Figure 1). **(4)** Specific design components are selected and **(5)** used to initialize a digital model that is used to **(6)** describe the product. **(7)** Simulation is built in and reuses the modeling artifacts. **(8)** Outputs are generated for code finishing and experimental shop testing. **(9)** Test results, code, microcode, and so forth are imported back into the model, as required, for further detailing and then regeneration. Each process in the workflow contains many parts.

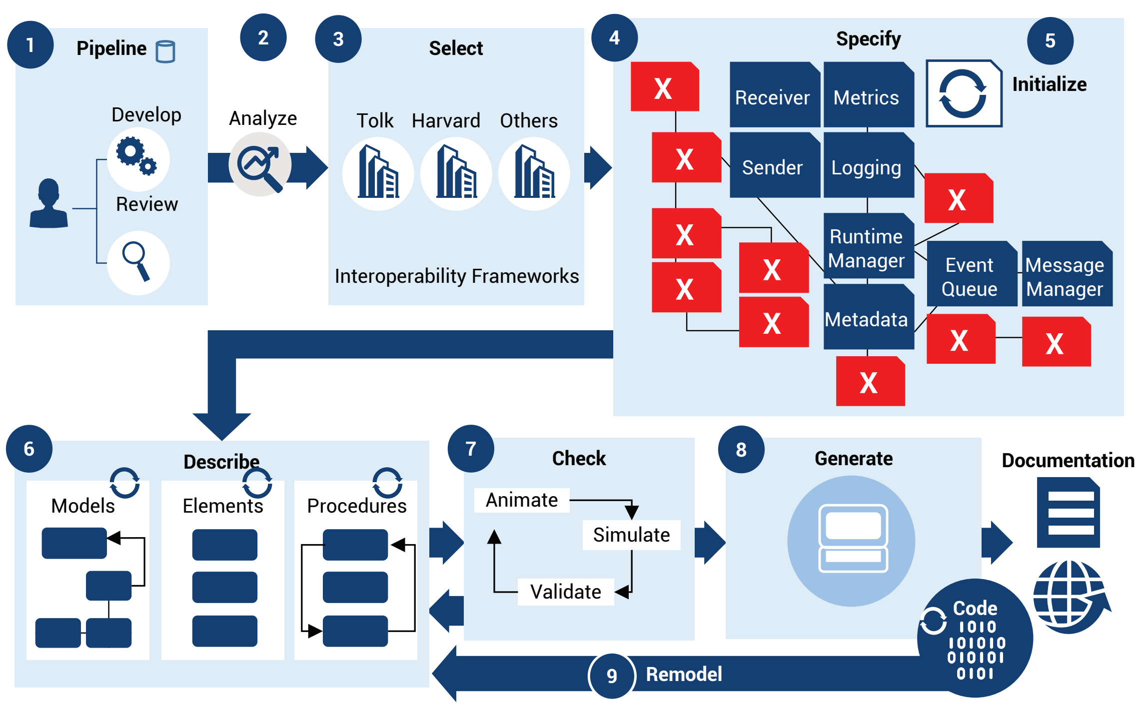

Figure 2. *Using model-based outcomes in a continuous workflow.*

Drill-Down 1: Work Threads and Reviews

The nine processes depicted in *Figure 2* provide the structure and phasing for model-based systems engineering (MBSE) work threads—that is, sets of tasks that can be executed concurrently in which the outcomes of each task contribute content that supports the creation of work products. These work threads overlap, meaning they can be done concurrently: yes, it is possible, even desirable, to perform some engineering tasks concurrently with requirements elicitation. In *Figure 3*, note that the "phasing" (top stripe) aligns with the overall flow. Reading down for a phase then yields the MBSE work threads associated with the phase. Also note that the MBSE-based details depicted in *Figure 2* align with Information Technology Infrastructure Library (ITIL®) phases and activities. For example, Phase 1 from *Figure 2*—Pipeline—aligns with the ITIL "Vision" phase and uses MBSE work threads for "Capabilities," the start of "Requirements," "Performance & TPMs" (technical performance measures), `and "Semantics & Metadata."

Model-based systems engineering not only permits but encourages concurrent work, integrated work teams, and usage of a common and integrated digital repository of model elements and artifacts.

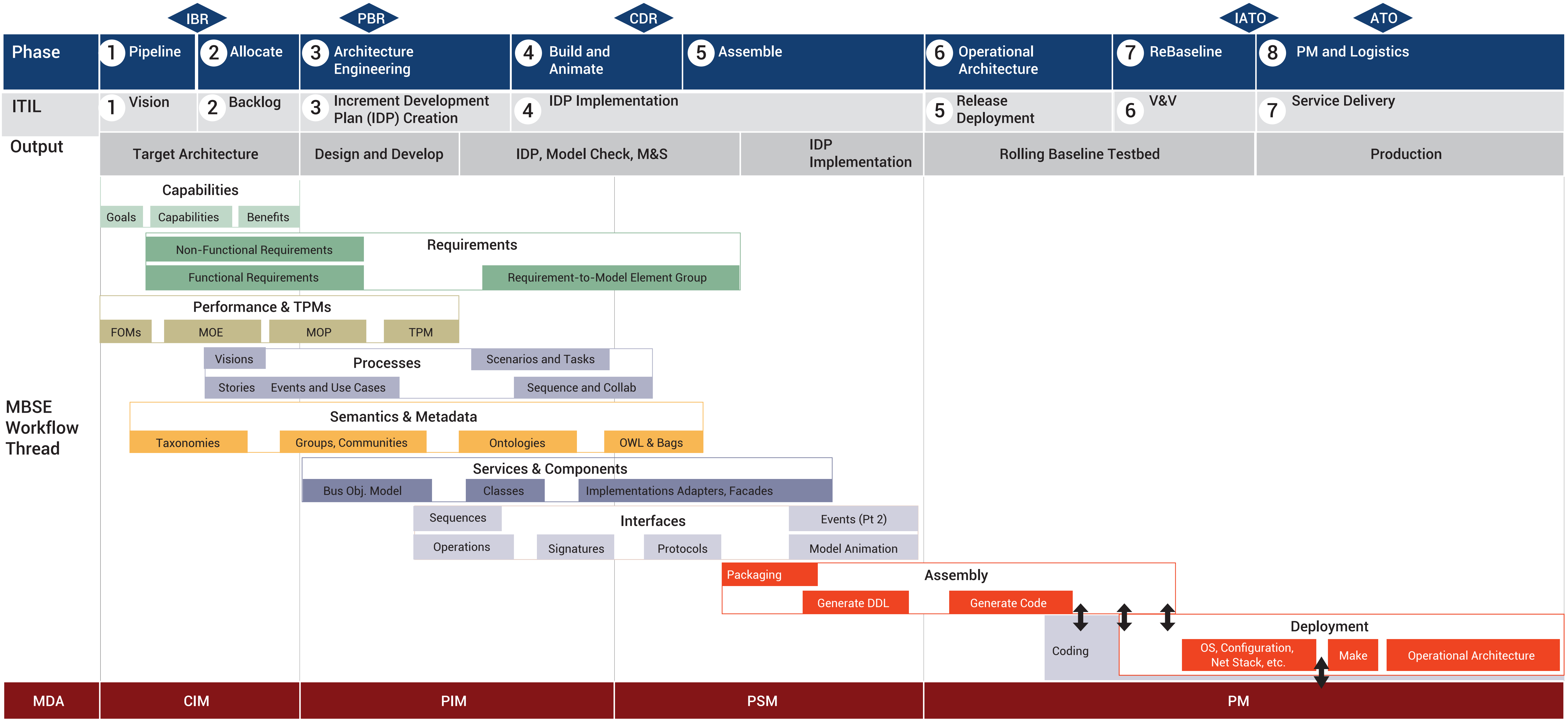

Figure 3. Drill-down 1: Work organized into concurrent and content-specific work threads.

Drill-Down 2: Activities, Outputs, and Reviews

Figure 4, and its key depicted in *Figure 5*, continues drilling into the details and specifics of continuous digital engineering. Figure 4 specifies each MBSE *work thread* depicted in Figure 3 as a set of tasks that produce various outputs. Unlike traditional engineering where work products from one step or phase of engineering are often "printed out" and then reentered into the next phase, Figure 4 overviews a 100 percent digital engineering process and the work products that are produced and committed to a Model Repository—the "MREP" in Figure 4. The diagram also includes an indication of when content is committed to the repository.

Figure 4 also depicts where specific kinds of reviews are performed *(the green boxes)*, the group technology model-based inputs into the process *(yellow disk icon)*, the kinds of work products that are produced by task, and the continuous nature of the process.

Drill-Down 3: Specific Tasks for Each Activity

Next, tasks from Figure 4 are decomposed into processes. By way of example, the major work of (2) Analyze, depicted in Figures 2 through 5, is classifying and initializing the digital engineering model. Figure 4 depicts this as

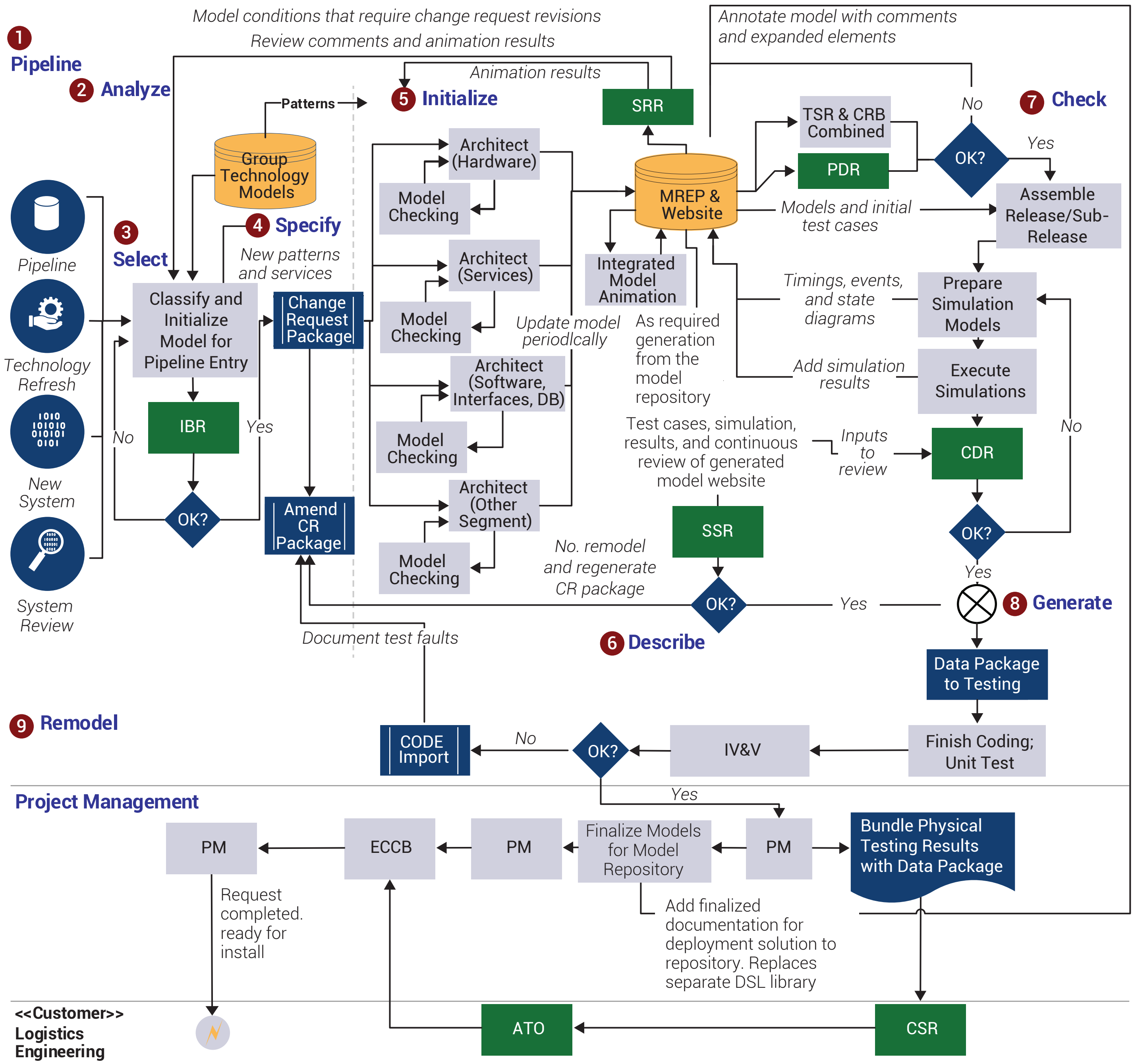

Figure 4. Drill-down 2: Activities, outputs, and reviews.

the very first process, resulting in initialization of a model and leading to an initial baseline review (IBR). *Figure 6*, next page, drills into the classifying and initializing the digital engineering model activity by depicting the process step tasks, reviews, and process flow for this activity. And in many cases, each activity can further be decomposed into sub-activities with their own tasks. See, for example, "3.3 Review RFC and Change Proposal."

KEY

ATO	**Authority to Operate.**
CDR	**Critical Design Review.** Assesses overall program health and readiness for production. Special emphasis on M&S.
CSR	**Customer Service Representative.** In accordance with CSR CONOPS, reviews bundles with focus on C2, asset management, and end-user support needs.
ECCB	**Enterprise Change Control Board.** Responsible for approval or rejection of projects prior to implementation. Composed of government and <<CUSTOMER>> contractor representatives.
IBR	**Initial Baseline Review**. Review scope and model-based requirements, scope, and content alignment.
MREP	**Model Repository.** Contains all engineering artifacts and replaces need for DCL, DMC, and Doc Control.
PCL	**Proving Control Lab.** This is a testbed and service testing lab hosted and maintained by the <<CUSTOMER>> contractor.
PDR	**Preliminary Design Review**. Scheduled and continuous review of <<CUSTOMER>> model website with comments. Continuous. Final PDR in person with signoff for simulation design and execution.
PM	**Project Management**. Every engineering project cycle is managed by a project manager.
SRR	**System Requirements Review.** Review of the MREP model, requirements allocation, requirements transformation, model checking reports, model animation runs, and M&S outputs. SRR-I and SRR-II done on demand against website and as scheduled.
SSR	**System Specification Review.** A DON review of 400 series documents generated from the repository and corresponding model assets used to communicate the specification of some portion of the to-be solution.

***Figure 5**. Key for Figure 4.*

A Bit on the Activity Check

In the **(7)** Check process from Figure 2, model checking, model animation, and model-based simulation can, and should, reuse all of the model artifacts created in **(6)** Describe (Figure 2). As depicted in Figure 7, there are actually three processes involved:

- **Model checking.** This is like a compiler check for a digital engineering model.
- **Model animation.** This is animating the model for the purpose of checking that sequences of expected activities are reached as expected.
- **Model simulation.** This builds upon model checking and animation by adding timings, updating the process model, and describing event models.

By integrating M&S, like that depicted above, into the engineering process, you avoid the usual problem of having to re-describe the model in an M&S-only tool. The avoidance of having to do this improves the quality and reduces the cost and overall time to delivery.

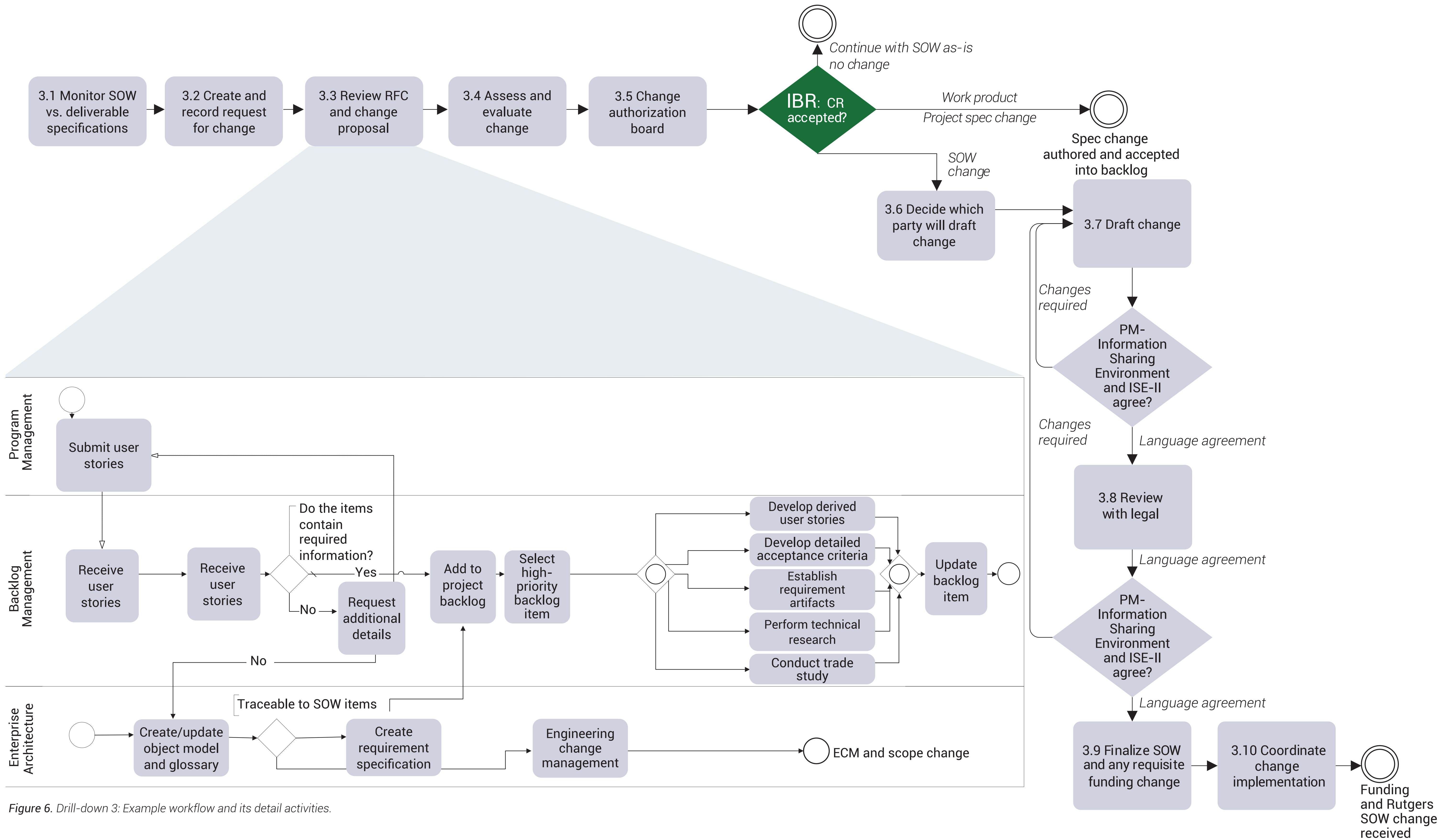

Figure 6. *Drill-down 3: Example workflow and its detail activities.*

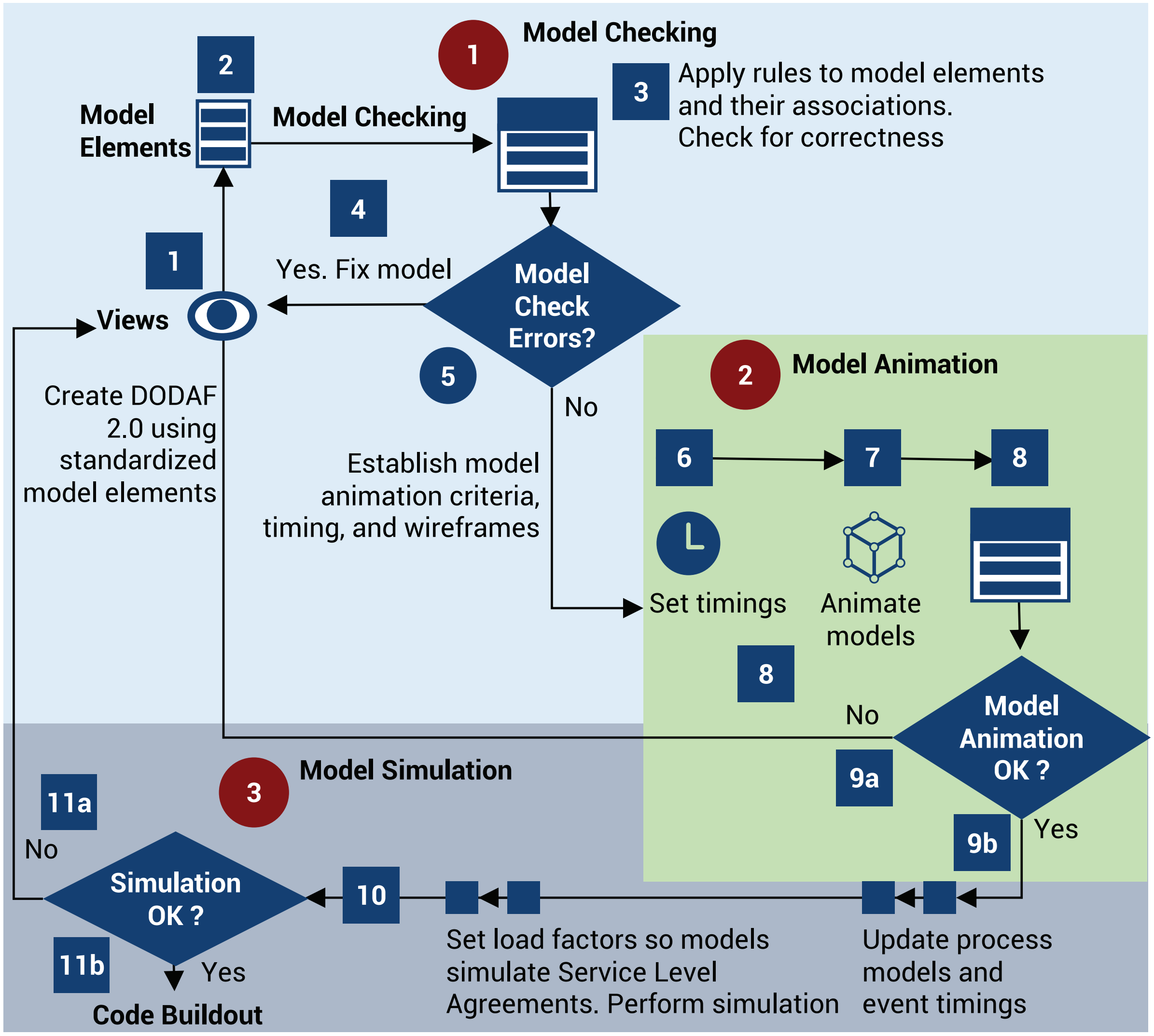

Figure 7. *Model-based modeling and simulation.*

Conclusion

By establishing a digital engineering environment based upon standards-based processes (e.g., MBSE) and artifacts (e.g., SysML, BPMN, model-based M&S), it is not only possible to practice 100 percent digital engineering, it is practical. A holistic, open, and standards-based digital engineering environment using Object Management Group community-developed models, processes, and outcomes saves time and money, improves quality, enables mass customization, shortens time to market, and increases interoperability. Additionally, it is also possible to formulate standardized RFP text requesting that contractors use and comply with the open and standards-based digital engineering environment. Finally, reviews such as the IBR or system requirements review become natural events in the life cycle of a systems engineering effort because the artifacts are accessible from repositories.

About the Author

Victor Harrison, senior vice president of the Object Management Group, focuses on government initiatives and advanced technology identification, specification, creation, testability, and adoption. Before joining OMG, he spent over 40 years as a technology leader providing services to more than a hundred different organizations ranging from commercial enterprises to federal and state agencies to software vendors. Mr. Harrison is a patent holder and is an acknowledged industry expert in interoperability and system of systems integration and enterprise, metadata-driven environments, cloud-enabled services, model-driven architecture, intrinsically secure architectures, MBSE, and pattern-based engineering. He also has served on the OMG Board of Directors and the SOA Consortium; co-founded the CyberSecurity Consortium and Community of Practice; has been published in magazines as diverse as CIO magazine *and the* Journal of Object Oriented Programming*; and has spoken at numerous conferences such as Gartner's Architecture and BPM Conferences, INCOSE, and the IT Security Automation Conference. Mr. Harrison also has participated in the ODNI/NSA Computational Cybersecurity workshops, an annual by-invitation-only event, and is currently assisting the government with the adoption of interoperable system architectures.*

SISO's Enduring Partnership with Defense Standardization

By Katherine L. Morse

SISO OVERVIEW

The vision of the Simulation Interoperability Standards Organization (SISO) is to be the organization dedicated to the promotion of modeling and simulation (M&S) interoperability and reuse for the benefit of diverse M&S communities, including developers, procurers, and users, worldwide.

SISO's mission is to provide an open forum that promotes the interoperability and reuse of models and simulations through the exchange of ideas, the examination of technologies, and the development of standards.

SISO seeks to maintain itself as a world-class organization that satisfies the needs of its members. To accomplish this goal, SISO employs the following operating principles:

- **Communication**: SISO shall strive to provide an open atmosphere inviting vigorous dialogue, discussion, and debate among its members, with experts and practitioners in related domains, and with the many and diverse organizations worldwide having interest in simulation interoperability standards. Communications interoperability—in the human sense—is a fundamental tenet of SISO's operating principles.
- **Responsiveness and responsibility**: SISO shall be responsive to the communities it serves. It shall be responsible for providing products and services that promote interoperability with the least possible impact on existing applications.
- **Quality**: SISO activities and products shall reflect technical excellence and the highest quality work.
- **Discipline**: SISO shall exercise due process in all activities, operating according to clearly stated policies and procedures.
- **Fairness**: SISO activities shall provide the right to appeal at all levels.
- **Openness**: SISO shall carry out all activities in an open forum where every participant can be involved in the process and solutions are reached by consensus. All policies and procedures employed in this process are publicly available and readily accessible in written and electronic form.
- **Consensus**: SISO shall strive always for the solution that best addresses the broadest possible spectrum of its members' needs and concerns.

COLLABORATING WITH DOD

SISO (and its predecessor organizations) has a long history of collaboration with the Department of Defense in the development of defense-specific and dual-use standards.[1] This collaboration started with the Distributed Interactive Simulation (DIS) standards, an example of defense-specific standards. DIS defines protocols for linking simulations of various types at multiple locations to create realistic, complex, virtual worlds for the simulation of highly interactive activities. This brings together systems built for separate purposes, technologies from different eras, products from various vendors, and platforms from various services, and it enables their interoperation. DIS exercises are intended to support a mixture of virtual entities with computer-controlled behavior (computer-generated forces), virtual entities with live operators (human-in-the-loop simulators), live entities (operational platforms and test and evaluation systems), and constructive entities (wargames and other automated simulations).

DIS was followed by the High Level Architecture (HLA), the leading standard for distributed simulation. Started in the early 1990s, HLA is now in its third revision as a standard under the Institute for Electrical and Electronics Engineers (IEEE). The HLA has three components:

- Framework and Rules[2]
- Federate Interface Specification[3]
- Object Model Template Specification.[4]

The HLA was developed to provide a common functional architecture for distributed modeling and simulation. The HLA defines an integrated approach that provides a common framework for the interconnection of interacting simulations. It is the subject of a North Atlantic Treaty Organization (NATO) Standards Agreement (STANAG).[5] The HLA is an example of a dual-use technology with broad functions and an open ecosystem of suppliers. There are a large number of implementations (run-time infrastructures, federates, federations, and support tools). It is in use in more than 40 nations for defense simulation and civilian applications, for example, manufacturing, energy, transportation, and medical.

A systems engineering process for federations was developed in parallel with the HLA—the Federation Development and Execution Process (FEDEP).[6] The FEDEP-recommended practice captures the processes and procedures to be followed by users of the HLA to develop and execute federations. It was intended as a higher-level framework into which low-level management and systems engineering practices native to HLA user organizations could be integrated and tailored for specific uses. The FEDEP was initially standardized as IEEE 1516.3, a member of the HLA family of standards.

While the FEDEP was HLA specific, much of its guidance applied universally to distributed simulation engineering across all architectures

1 "Distributed Interactive Simulation—Application Protocols," IEEE Standard 1278.1, December 19, 2012.

2 "High Level Architecture—Framework and Rules," IEEE Standard 1516, August 18, 2010.

3 "High Level Architecture—Federate Interface Specification," IEEE Standard 1516.1, August 18, 2010.

4 "High Level Architecture—Object Model Template Specification," IEEE Standard 1516.2, August 18, 2010.

5 NATO–STANAG 4603, "Modeling and Simulation Architecture Standards for Technical Interoperability: High Level Architecture (HLA)."

6 "Federation Development and Execution Process (FEDEP)," IEEE Standard 1516.3, March 20, 2003.

and protocols. As a result, the FEDEP was generalized as a systems engineering process for building and executing distributed simulation applications—the Distributed Simulation Engineering and Execution Process (DSEEP).[7] The DSEEP incorporates fundamental concepts from existing process models within the HLA, DIS, and Test and Training Enabling Architecture (TENA) communities, and it reflects a broad consensus as to the key activities and tasks needed to build distributed simulation environments. The DSEEP was approved as an IEEE Recommended Practice (IEEE 1730) in January 2011.

The Live-Virtual-Constructive Architecture Roadmap[8] Implementation (LVCAR-I) project led to the development of several standards. One of them is a recommended practice for applying the DSEEP to the development and execution of distributed simulation environments that include more than one simulation architecture or protocol. The distributed simulation architectures to which the recommended practice applies include DIS, HLA, and TENA. The DSEEP Multi-Architecture Overlay (DMAO)[9] identifies and describes multi-architecture issues and provides recommended actions for simulation environment developers faced with those issues. The DMAO also augments the DSEEP lists of inputs, recommended tasks, and outcomes with additional inputs, recommended tasks, and outcomes that apply to multi-architecture simulation environments. This document is an overlay to the DSEEP.

The Federation Engineering Agreements Template (FEAT),[10] another LVCAR-I standard, provides a standardized format for recording federation agreements to increase their usability and reuse. The template is an eXtensible Markup Language (XML) schema from which compliant, XML-based federation agreement documents can be created. Creating the template as an XML schema allows XML-enabled tools to both validate conformant documents and edit and exchange agreements documents without introducing incompatibilities.

Two other standards from LVCAR-I are currently in development under the umbrella of Gateway Description and Configuration Languages.[11] The two standards proposed are XML-based formal languages to be used during gateway selection and configuration:

- **Gateway Description Language**—a common human-readable and machine-readable format/syntax for describing both user gateway requirements and the capabilities that individual gateways can offer to users. This language also includes gateway performance information.
- **Gateway Filtering Language**—a common human-readable and machine-readable format/syntax for capturing the traffic-filtering details of a gateway.

The Military Scenario Definition Language (MSDL)[12] is an XML-based language designed to support military scenario development, providing the M&S community with the following:

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7 "Distributed Simulation Engineering and Execution Process (DSEEP)," IEEE Standard 1730, January 24, 2011.

8 Henninger, Amy E., et al., "Live Virtual Constructive (LVC) Architecture Roadmap (AR)," USD(AT&L)/DDR&E/P&P/M&S CO, 2008.

9 "DSEEP Multi-Architecture Overlay (DMAO)," IEEE Standard 1730.1, August 23, 2013.

10 "Federation Engineering Agreements Template (FEAT)," SISO-STD-012-2013, http://www.sisostds.org/FEATProgrammersReference.

11 "Gateway Description and Configuration Languages," https://www.sisostds.org/StandardsActivities/DevelopmentGroups/GatewayDescriptionandConfigurationLanguages.aspx.

12 "Military Scenario Definition Language (MSDL)," May 11, 2015, https://www.sisostds.org/DigitalLibrary.aspx?Command=Core_Download&EntryId=45690.

- A common mechanism for verifying and loading military scenarios
- The ability to create a military scenario that can be shared between simulations and command, control, communications, computers, and intelligence devices
- A way to improve scenario consistency between federated simulations
- The ability to reuse military scenarios as scenario descriptions are standardized throughout the Army, Joint, and international communities and across simulation domains (e.g., training exercise, analysis).

MSDL includes element relationships, data types and boundary constraints, and the associated business rules of each element and its attribution.

STANDARDS DEVELOPMENT PROCESSES

Because governments recognize the strong market advantage that one developer's technical approach may convey, legal constraints such as anti-trust laws drive most commercial standards development organizations (SDOs) to similar processes for achieving openness and fairness. The following are processes that generally apply in open standards development:

- An authoritative body establishes policies, procedures, and processes and ensures they are followed.
- Membership in the standards development process is not unduly restrictive.
- Voting rights are uniformly and fairly applied.
- At each stage of development, members are allowed to comment and given sufficient time to do so.
- Consensus, but not unanimity, must be achieved.
- The standard is made readily available (with or without a license fee).

Legal constraints such as anti-trust laws drive most commercial standards development organizations (SDOs) to similar processes for achieving openness and fairness.

SISO'S STANDARDS ACTIVITY COMMITTEE

Figure 1 illustrates, at the top level, how SISO implements a process as described in the preceding section. The SISO Standards Activity Committee (SAC) has responsibility for overseeing this process. The SAC ensures that product development groups (PDGs) follow the SISO policies and procedures,[13] [14] in the development of standards. The SISO SAC is also the IEEE standards sponsor committee for simulation interoperability standards, referred to by IEEE as Computer/Simulation Interoperability.

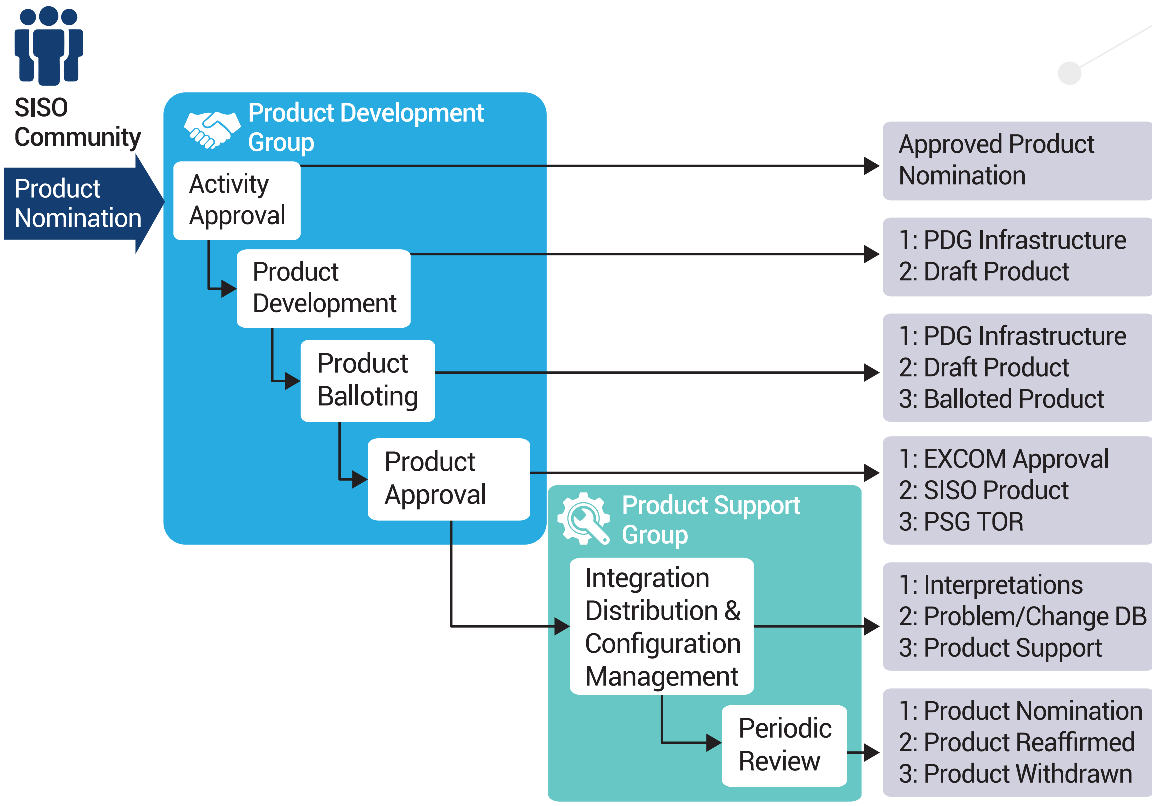

Figure 1. SISO development process.

SIMULATION INNOVATION WORKSHOP

SISO has a relatively unique structure with respect to the Simulation Innovation Workshop. The workshop is held once a year. In addition to providing a forum for the exchange of technical ideas and results related to simulation interoperability, SISO's PDGs, study groups (SGs), and other groups meet to work face-to-face. Sometimes the ideas expressed in papers are the genesis for new SGs and standards, creating a pipeline of standards and other products. And sometimes papers are written and presented that detail analysis and decisions made in the development of SISO standards, creating a permanent record of decisions that affect standards but don't appear in the standards.

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[13] "SISO Policies & Procedures," June 19, 2017, https://www.sisostds.org/DigitalLibrary.aspx?Command=Core_Download&EntryId=45774.

[14] "SISO Balloted Products Development and Support Process," November 14, 2011, https://www.sisostds.org/DigitalLibrary.aspx?Command=Core_Download&EntryId=32713.

STANDARDS DEVELOPMENT RESOURCE REQUIREMENTS

There is a common misconception that SDOs provide resources to develop standards. This is only partially correct. SDOs, including SISO, provide the infrastructure and processes for developing standards, but standards development requires other resources that must be provided to ensure technically robust standards. These resources come from organizations that benefit from the standards:

- Experts who will develop the standards. Standards cannot be developed without a solid time commitment from subject matter experts (SMEs).
- Facilitators who will direct the standards development process. Effective standards development activities need organized, engaged officers who are knowledgeable on the technology and its applications, but not at the level of SMEs.
- Prototypes/reference implementations. These are both proofs that the standard is technically viable and test beds for experimenting with changes to the standard; standards without technical proof are a bad idea.
- Trusted, neutral compliance testing. Bogus compliance claims for products and implementations can ruin user confidence in a standard; both product developers and users must trust the accuracy and neutrality of the compliance process.
- Education and outreach. Members of the community must know about the standard and its applicability if they're going to use it; some form of customer support or help desk is key to heading off misinformation early and often.

THE FUTURE

The SISO SAC is currently developing a standards roadmap, a framework that will articulate the SISO standards that currently exist, the relationships among these standards, user guidance on which standards best apply to different situations, where users can obtain the standards, and areas where standards are needed but do not exist.

SISO is always evaluating technical innovations for their potential to be incorporated into M&S-specific standards. This exploration happens through the establishment of SGs. The Exploration of Next Generation Technology Applications to Modeling and Simulation SG is exploring the latest industry technology trends and available solutions, specifically focused on their applicability to the M&S domain. Examples include wearable technology, streaming, advanced hardware, cloud services, and data-sharing applications.

The Cloud-Based Modeling & Simulation SG is identifying and documenting existing M&S in cloud activities, documenting best practices, highlighting lessons learned, and identifying where potential standards might facilitate adoption by other practitioners. This SG is organized into three teams looking at cloud capabilities, models, and architecture.

The Acquisition M&S Standards Profile PDG is developing a standard to provide guidance on the selection and use of M&S standards and recommended practices to support the acquisition life cycle.

About the Author

Katherine L. Morse is a member of the principal professional staff at the Johns Hopkins University Applied Physics Laboratory, where she researches and develops technologies for improving simulation engineering, implementation, and application. She received a BS in mathematics, a BA in Russian, and an MS in computer science from the University of Arizona and an MS and PhD in information and computer science from the University of California, Irvine. Dr. Morse has worked in computing for over 35 years, 20 of them contributing to open international standards. She is currently the chair of the SISO Standards Activity Committee.

The opinions expressed in this article are strictly those of the author and do not necessarily reflect the opinions of her employer, her government sponsors, or SISO.

RIEDP: An M&S Standard for Environmental Data Sharing

By Jean-Louis Gougeat

SIMULATION, TRAINING, AND ENVIRONMENTAL DATA

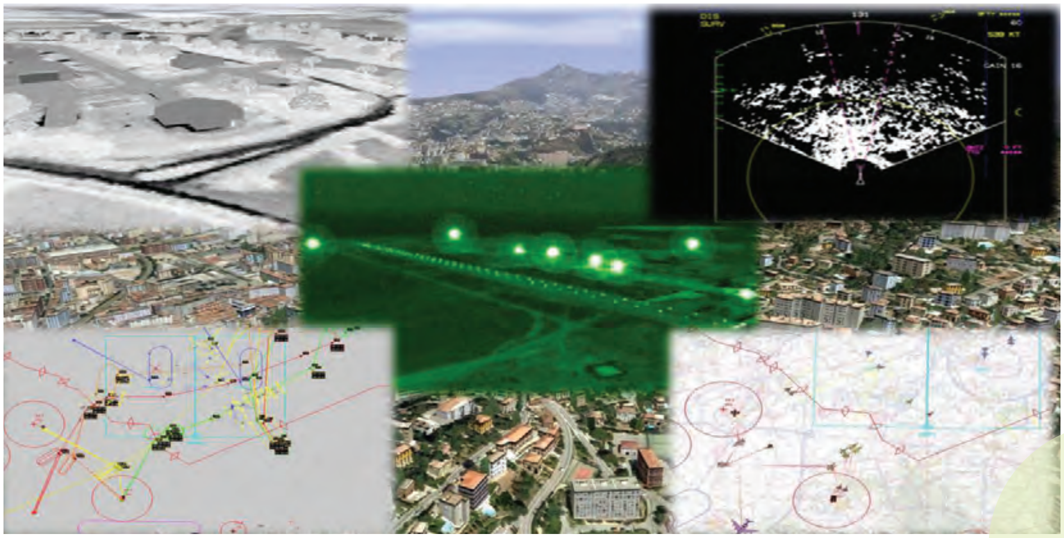
The use of live-virtual-constructive (LVC) simulation for training in a joint and coalition context is growing. The complex nature of LVC demands strong interoperability standards for data sharing and exchange. One critical area of data exchange is the environmental data used by the various LVC systems, applications, and participants.

An environmental database may include an integration of terrain, ocean, weather/atmosphere, space, sub-surface, and all related data required for modeling and simulation (M&S) of entities and phenomena.

The production of an environmental database is a significant part of the overall M&S development cost. In addition, the consistency of environmental databases between LVC simulation applications *(Figure 1)* is critical for fair fight.

Then, seeking *the* approach that would foster interoperability and reduce the overall cost is a "holy grail" to the broader M&S community. Ongoing projects in many international government programs, as well as initiatives from industry, contribute to solutions in this area *(Figure 2)*. The database generation processes of most initiatives rely heavily on commercial off-the-shelf products and

Diverse and Large Environmental Content for Different LVC Systems



With a wide range of target applications: visual, sensors, IOS, CGF, C2, etc.

Figure 1. Consistent environmental data—critical to simulation interoperability.

			Projects						
Nature	Standards		Process Oriented			DB Oriented			Other
Name	SIF	SEDRIS	NPSI	AFCD	SE Core	CDB	Missionland	Other	EDS
Origin	U.S. DoD	U.S. DoD	U.S. Navy	USAF	U.S Army	USSOCOM	NATO	e.g., French Air Force	U.S. DoD
Introduction date	1991	1994	2004	2006	2008	2004	2010	2006	201x
Standard	Yes	Yes ISO	User standard	User standard	User standard	User and commercial standard	User standard	User standard	Reuse of standards
Open standard	Yes	Yes	Limited	Limited	Limited	OGC	Limited	Limited	—
Approach	Format according to standard	Standardized semantics and data model + format according to standard	• **Based on de-facto standard formats (GIS source) but no consistent semantics or data model** • **Similar but not standard data generation process**						Data discovery and access
Availability of commercial support tools	**Obsolete**	**Tools developed in SERRIS COI**	**Commercial tools for commercial and standard formats**						Portal

Key: AFCD: Air Force Common Dataset
EDS: Enterprise Data Services
NPSJ: NAVAIR Portable Source Initiative
CDB: Common Database
SEDRIS: Synthetic Environment Data Representation and Interchange Specification
SE Core: Synthetic Environment Core
SIF: SSDB (Standard Simulator Database) Interchange Format

Figure 2. International government programs and initiatives from industry.

de-facto or standard formats. Despite the similarities in how the initiatives approach the data generation process, and any subsequent data sharing, there are significant differences, which lead to divergence in how data are handled.

It is agreed that the "solution" should rely on a standards-based approach that addresses both the data generation process and the data exchange. However, until the inception of the Reuse and Interoperation of Environmental Data and Processes (RIEDP), a standard that tackles *both* the process and the data has not been available.

SISO AND THE RIEDP EFFORT

The Simulation Interoperability Standards Organization (SISO) is an international organization dedicated to the promotion of M&S interoperability and reuse, for the benefit of a broad range of M&S communities. SISO develops formally balloted and approved standards that are the results of consensus agreements on specifications, practices, and/or methodologies for use in simulation industry applications.

A Special Session on the "Reuse of Environmental Data for Simulation: Processes, Standards, and Lessons Learned" was held during the Fall 2009 SISO Workshop to discuss with international simulation stakeholders the current state of the art and the varying degrees of requirements in this area. The results of the Special Session led to the formation of a SISO Study Group (SG), followed by a Product Development Group (PDG), to establish standards for RIEDP.

RIEDP PDG's primary goal is to promote the reusability of environmental database generation efforts and to foster interoperability between simulation systems through a standardized understanding of both their data products and their data generation processes. The focus is on the harmonization of environmental database generation processes and the means to exchange such generated data, at various points in the process—after the source data collection stage but before the runtime/proprietary database creation stage.

To accomplish these goals, RIEDP PDG is establishing two SISO products. The first of these products is the RIEDP Data Model Foundations specification, which is the main subject of this article.

RIEDP Data Model Foundations Product

The RIEDP Data Model Foundations product formalizes the elements that are used in the creation of environmental databases for M&S applications. It includes the following:

- A high-level process, and the associated data-flow stages and tasks, collectively identified as the RIEDP Reference Process Model (RPM)
- A reference data model for expressing any data produced through the RPM, defined as the Reference Abstract Data Model (RADM)
- Geospatial conventions
- An attribution model
- An effective approach for the use of metadata
- RIEDP-required formats for the exchange of RIEDP-compliant data
- An organization of data on the media
- Profiles for conformance.

The combination of these elements allows different database generation processes and systems to relate to each other, and to compare, contrast, and map their database generation processes and data model capabilities using the RIEDP products. Some of the key components of the RIEDP Data Model Foundations product are highlighted below.

RIEDP Reference Process Model

The process of generating environmental databases is composed of multiple stages, which progressively transform the source data until the required simulation databases for the target applications are created. The RIEDP effort studied the existing processes and factored the common stages and tasks into a standardized form. The RPM, presented in *Figure 3*, embodies this standardized approach, identifies the stages from which RIEDP-compliant data can be made available for external sharing and reuse, and highlights the data flow between the stages. These stages are as follows:

1. Define requirements
2. Collect source data
3. Clean source data
4. Create/modify library data
5. Align source layers
6. Establish baseline data
7. Intensify baseline data
8. Specialize data for target applications
9. Generate runtime target databases.

In addition, the Export stage allows the database producer to offer the appropriate data in accordance with the RIEDP specification. This requires conversion of the database to the appropriate set of RIEDP-required formats (see below) in accordance with the RADM.

RIEDP Reference Abstract Data Model

The RADM formalizes the data organization and relationships for sharing the RIEDP-compliant data at the output of the RPM stages that feed the Export stage. The main components of the RADM are as follows:

- Tiles or region
- Layers (elevation, imagery features, etc.)
- Reusable objects in the library (3D models, textures, special areas, feature templates, reference tables)
- Attribution for all components
- Metadata, catalog, and repository.

Figure 4 shows the key elements of the RADM in relation to a pictorial depiction of environmental

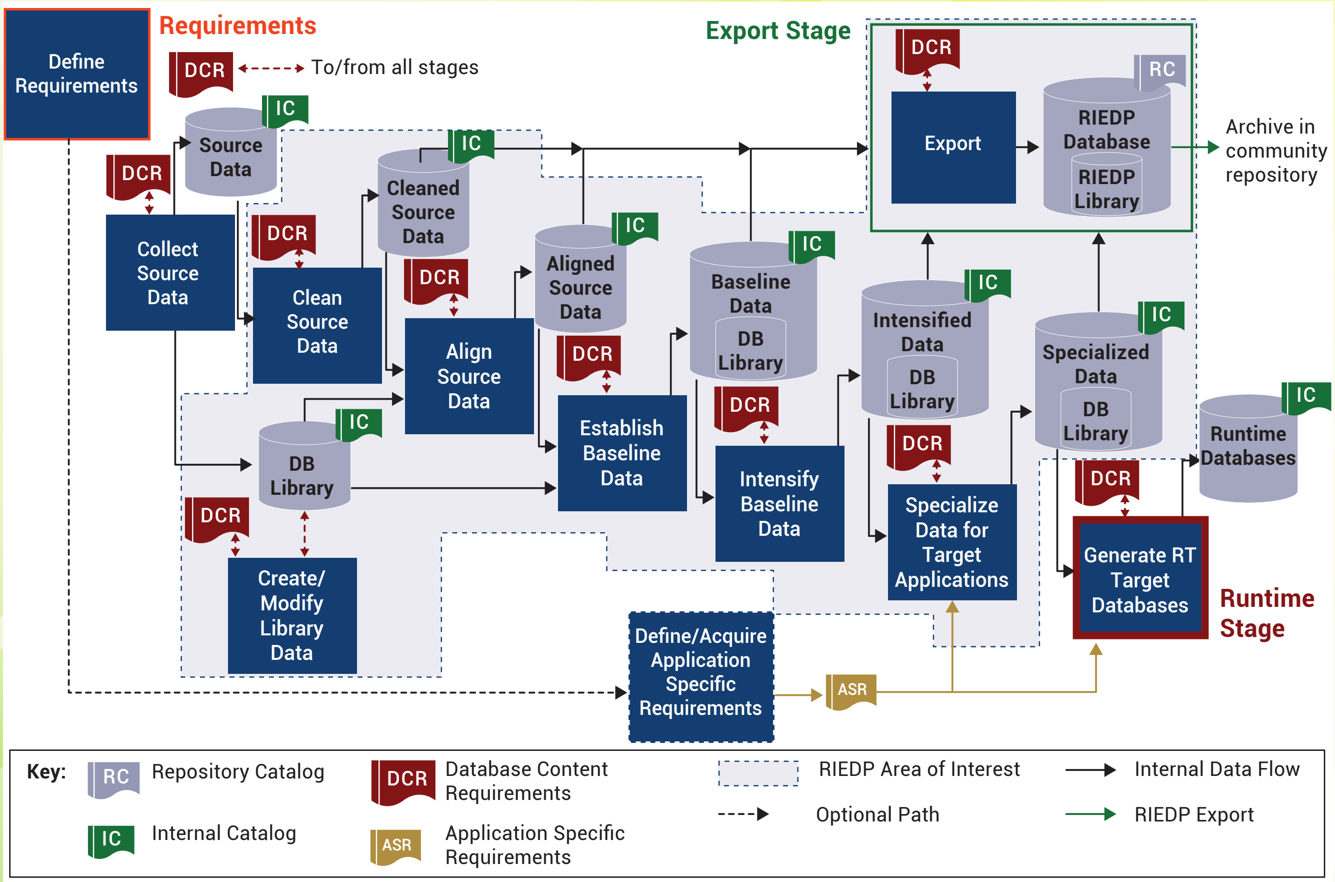


Figure 3. The RIEDP reference process model.

data. The actual RADM is a complete set of classes expressed in Unified Modeling Language form and is fully specified in the RIEDP Data Model Foundations product.

RIEDP-Required Formats

The RIEDP effort leverages the use of existing common formats and formalizes the details in the use of these formats within the context of the RADM. The current data formats required for RIEDP-compliant data exchange are as follows:

- GeoTIFF (revision 1.0, October 1995)—for terrain elevation data
- ESRI Shapefile (technical description white paper, July 1998)—for instances of terrain features and vector data
- GeoTIFF (revision 1.0, October 1995) or JPEG 2000 (ISO/IEC 15444, Part 1)—for terrain imagery data, as well as other raster-based data
- OpenFlight (version 16.0 or higher)—for 3D models, both natural and manmade, placed on the terrain or dynamically included in the environment
- PNG (ISO/IEC 15948:2004), SGI RGB, or SGI RGBA image formats—for texture maps, used in portraying object surfaces and some terrain surfaces.

In addition, XML (and an associated XML schema) is used to provide those RIEDP-required data not supported through the above formats.

Profiles for Conformance

RIEDP provides specific profiles to which RIEDP-compliant data products may conform. These profiles also accommodate the variety of data products used in different simulation applications in the community.

The RIEDP profiles specify the authorized subsets of the capabilities provided in the RIEDP specification. The table in *Figure 5* provides an overview of the relationships between standardized profiles, the RPM stages, and the RADM classes they support. Required and optional content for each profile is identified as

- Required (R),
- Required with conditions (Ri), or
- Optional (O),

with additional conditions indicated in the legend.

Details and Other Components

The details on the components above, as well as the description of other components not mentioned here, are specified in the RIEDP Data Model Foundations document, which is available from the SISO website.

RIEDP vs. Other Initiatives

The key components of the RIEDP Data Model Foundations were formed after the long analysis and development process within the SISO RIEDP SG and PDG based on the contribution of the main initiatives from the training community. The table in *Figure 6* provides an overview and contrasts how each of the key RIEDP capabilities and data model components relate to other initiatives.

Note: The common database (CDB) version listed in the table is that currently used in the M&S community, which is different from the version identified as an Open Geospatial Consortium specification. Also, the use of metadata in CDB is different from how metadata is commonly used in the community.

Conclusion

RIEDP gets the benefit of the lessons learned from all initiatives. RIEDP reuses and relies on existing international standards, including the SEDRIS ISO/IEC standards for representation of environmental data and the PNG ISO/ IEC standard for transfer of imagery data, and formats commonly used by the M&S community in its data generation activities (as noted earlier).

This allows the best sharing of data, independently from the often-proprietary target application implementations, with a current scope for addressing static terrain and visual system data. The RIEDP capabilities are also designed to be extensible as the requirements evolve. In addition, RIEDP capabilities may be useful in Mission Command applications and related systems,t especially as there are overlaps in some of the data and formats used by both communities.

Pictorial Depiction of the Components of a Database

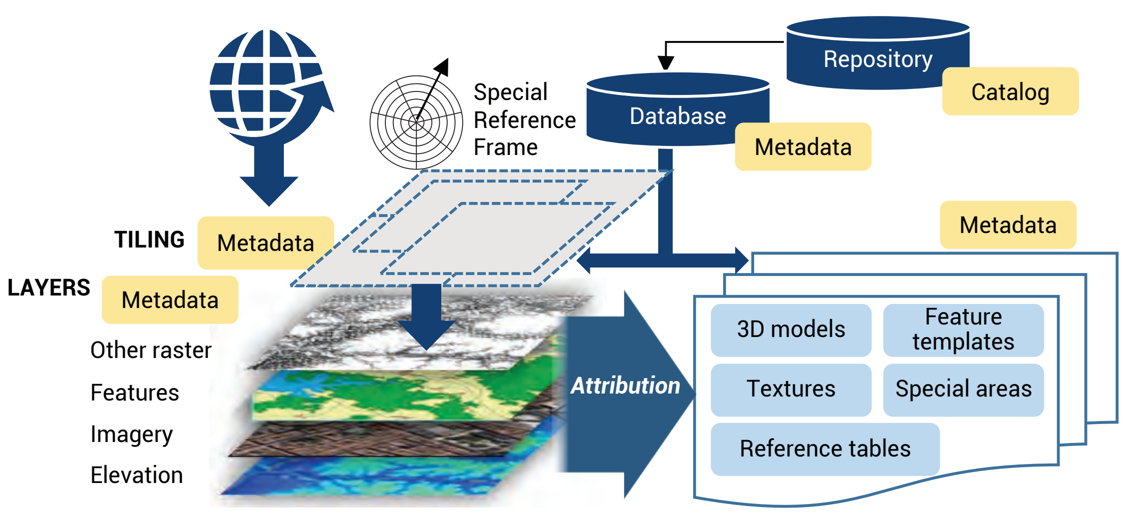


Figure 4. The RIEDP reference abstract data model.

Profile		Profile names	Basic-Cleaned	Basic-Aligned	Library-Only	Basic-Baseline	Single-content Baseline	Feature-based 2D/3D Map	Raster-based 2D/3D map	Ground Mapping Radar Rendering	Mission Command	Automated Reasoning	Visual Rendering	Visual Rendering w/ Aerial Imagery
		Profile ID	**1 BCP**	**2 BAP**	**3 LOP**	**4 BBP**	**5 SBP**	**6 FMP**	**7 RMP**	**8 GMRP**	**9 MCP**	**10 ARP**	**11 VRP**	**12 VRIP**
RPM	Exporting Stages	Clean source data	✓											
		Align source layers		✓										
		Establish baseline data			✓	✓	✓							
		Intensify baseline data					✓	✓	✓	✓	✓	✓	✓	✓
		Specialize data for target application					✓	✓	✓	✓	✓	✓	✓	✓
RADM	DB	Product summary metadata	R	R	R	R	R	R	R	R	R	R	R	R
		Spatial reference	R	R	-	R	Ri1	R	R	R	R	R	R	R
	Tile/Region	Layers summary metadata	R	R	-	R	Ri2	R	R	R	R	R	R	R
		Elevation	R≥1	R≥2	-	R	R=1*	R	R	R	R	R	R	R
		Imagery	R≥1	R≥2	-	R	R=1*	-	R	-	R	O	-	R
		Other raster	R≥1	R≥2	-	O	R=1*	-	-	O	O	O	O	O
		Feature instance	R≥1	R≥2	-	R	R=1*	R	-	R	R	R	R	R
	Library	Library summary metadata	-	-	R	R	Ri2	Ri2	-	Ri2	Ri2	Ri2	R	R
		3D model	-	-	R≥1	R	R≥1*	-	-	O	-	O	R	R
		Texture	-	-	R≥1	R	R≥1*	-	-	-	-	-	R	R
		Special area	-	-	R≥1	O	R≥1*	-	-	O	O	O	O	O
		Feature template	-	-	R≥1	Ri3	R≥1*	Ri3	_	Ri3	Ri3	Ri3	R	R
		Reference table	-	-	R≥1	Ri3	R≥1*	Ri4	-	Ri4	Ri4	Ri4	R	R

Figure 5. The profiles for conformance to RIEDP.

The RIEDP Data Model Foundations document is currently in the balloting phase, in accordance with the SISO procedures. Approval by the Standards Activity Committee is expected in 2018. However, the content of this product is currently available *(www.sisostds.org)* and may be used in practice. The second RIEPD product, the RIEDP Detailed Feature Description Document, is currently under development. It should be available by the end of 2018.

Acknowledgments

This article reflects the ongoing standardization work in SISO RIEDP PDG and is derived from the efforts of the PDG members and especially the contributions of the Drafting Group members.

Key Topics for Database Sharing

Topic	SEDRIS	AFCD	NPSI	CDB	SECORE	RIEDP
Process Models	X	X	X	X	✓	✓
Data Model	✓ DRM	X	X	0	X	✓
Attribution	✓ EDCS	X	X	✓	✓	✓
Spatial Reference	✓ SRM	0	0	✓	✓	✓
Formats	✓ STF	✓ COTS	✓ COTS	✓ COTS	✓ COTS	✓ COTS
Physical Org	✓ STF	0	0	✓	✓	✓
Metadata	✓	X	0	0	0	✓
Profile	0	X	X	X	X	✓
Scope (vs. RIEDP/RPM)	All stages but "Runtime…"	Until stage "Align…"	Until stage "Align…"	Stage Runtime	All stages	All stages but "Runtime…"

Key: ✓ Expressed X Inexistent or unexpressed 0 Partial or specific

Figure 6. RIEDP vs. other initiatives.

About the Author

Jean-Louis Gougeat has been a senior project manager at Sogitec Industries–France since 2001. He has 25 years of experience with research and development projects for the French Ministries of Defense and, more specifically, 20 years in simulation projects for the training of military personnel, including company-level training with live simulation, flight training with virtual simulation, and command and staff training with constructive simulation. Mr. Gougeat is the chairman of the SISO Product Development Group on the Reuse and Interoperation of Environmental Data and Processes.

Program News

Topical Information on Standardization Programs and People

NATO STANDARDIZATION OFFICE GETS NEW DIRECTOR

On February 28, 2018, Major General Edvardas Mazeikis handed over the command of the NATO Standardization Office (NSO) to Brigadier General Zoltan Gulyas. General Gulyas, a Hungarian Air Force helicopter pilot, brings in his broad operational expertise and all of his experience, lastly gained as deputy commander of the Hungarian Defence Forces Military Augmentation and Training Command in Budapest.

For more information about the new director of the NSO, please visit the Director's Corner on the NSO website.

Major General (Ret.) Mazeikis will continue his efforts to enhance interoperability and promote standardization in the coming years. For his new appointment at the European Defence Agency and for his personal future, the NSO staff and NATO's standardization community wish him all the very best.

ANSI: CELEBRATING 100 YEARS

From 1918 to 2018! The American National Standards Institute (ANSI) is proud to celebrate 100 years. The history of ANSI and the U.S. voluntary standards system is dynamic and evocative of the market-driven spirit that continues today.

To celebrate its centennial, ANSI is planning a number of special events and activities. For more information, see its website at *https://www.ansi.org/about_ansi/introduction/history?menuid=1*.

For the ANSI Centennial Timeline, go to *https://share.ansi.org/Shared%20Documents/News%20and%20Publications/Brochures/ANSI-centennial-timeline.pdf.*

For the ANSI Historical Overview Video, go to *https://www.youtube.com/watch?v=kVMd87XZakI.*

Events

Upcoming Events and Information

PSMC SPRING 2018 MEETING
APRIL 24–26, 2018, TYSONS, VA

The Parts Standardization and Management Committee (PSMC) will hold its spring 2018 meeting at LMI headquarters, 7940 Jones Branch Drive, Tysons, VA. Primary topic areas to be addressed include parts management strategic objectives, parts management awareness and training, additive manufacturing, and microelectronics. Participation is only open to PSMC participants. If you are interested in becoming a PSMC participant, please contact Robin Brown at robin.brown@dla.mil or 571-767-1415.

2018 DSP WORKSHOP
JULY 9–12, 2018, TYSONS, VA

The Defense Standardization Program Office will be hosting a Defense Standardization Program Workshop at LMI in Tysons, VA. The workshop will be open to federal employees and immediate support contractors, but space will be limited. Attendees will benefit from this opportunity to interact with standardization executives, participate in standardization training and tutorials, and collaborate in working groups to develop new approaches to outstanding issues. For more information, visit *http://www.dsp.dla.mil.*

2018 SES ANNUAL CONFERENCE
AUGUST 7–8, 2018, NASHVILLE, TN

The 67th Annual Society for Standards Professionals Conference will take place in August in Nashville with the theme of "Dynamic Diversity: Expanding the Future of Standardization." Katherine E. Morgan, president of ASTM International, will be the keynote speaker for the event.

WORLD STANDARDS WEEK 2018

OCTOBER 15–19, 2018, WASHINGTON, DC

Registration will be available soon for the 2018 World Standards Week. For more information, visit *www.ansi.org*.

U.S. CELEBRATION OF WORLD STANDARDS DAY

OCTOBER 18, 2018, WASHINGTON, DC

The U.S. Celebration of World Standards Day at the Fairmont Washington is "an event that recognizes the critical role of various stakeholders across the standards community, including business leaders, industry, academia, and government." ANSI will serve as the administrating organization for this event in recognition of its 100th anniversary. For more information, visit *www.ansi.org.*

2018 DMSMS CONFERENCE

DECEMBER 3–6, 2018, NASHVILLE, TN

The 2018 Diminishing Manufacturing Sources and Material Shortages Conference will be held at the Music City Center in Nashville. There will be training, breakout, and plenary sessions aimed at providing insights that you can use to minimize the budget and schedule risks caused by obsolescence while enhancing future readiness. Qualified attendees (active U.S. military, government, or current DD2354 on file) also will be able to attend the concurrent Defense Manufacturing Conference at no additional expense, giving you access to more technical information for the same travel cost. For more information on the event, go to *www.dmsmsmeeting.com.*

Upcoming Issues

Call for Contributors

We are always seeking articles that relate to our themes or other standardization topics. We invite anyone involved in standardization—government employees, military personnel, industry leaders, members of academia, and others—to submit proposed articles for use in the *DSP Journal*. Please let us know if you would like to contribute.

Following are our themes for upcoming issues:

Issue	Theme
April–June 2018	International Standards
July–September 2018	Energy Standards
October—December 2018	Standardization Tools and Programs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Sunday
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Technology
Innovation
SYSTEM
DEFENSE STANDARDIZATION PROGRAM
MAKING SYSTEMS WORK TOGETHER