NPS-MV-08-003

NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

Toward a Verification, Validation, and Accreditation (VV&A) Ontology

by

Curtis Blais

31 December 2008

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Prepared for:
Space and Naval Warfare (SPAWAR) Systems Center Atlantic
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Charleston, SC 29405-1821

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This report was prepared by the Naval Postgraduate School's (NPS) Modeling, Virtual Environments and Simulation (MOVES) Institute and funded by Space and Naval Warfare (SPAWAR) Systems Center Atlantic (SSCLANT).

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REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.			
1. AGENCY USE ONLY ***(Leave blank)***	**2. REPORT DATE** 31 December 2008	**3. REPORT TYPE AND DATES COVERED** Technical Report	
4. TITLE AND SUBTITLE: Title (Mix case letters) Toward a Verification, Validation, and Accreditation (VV&A) Ontology			**5. FUNDING NUMBERS** **N6523607WR00390**
6. AUTHOR(S) Curtis Blais			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			**8. PERFORMING ORGANIZATION REPORT NUMBER** NPS-MV-08-003
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) Space and Naval Warfare Systems Center 2921 Avenue B Charleston, South Carolina 29405-1821			**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES The views expressed in this report are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT **Approved for public release; distribution is unlimited**			**12b. DISTRIBUTION CODE** A
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14. SUBJECT TERMS Verification, Validation, Accreditation, Modeling, Simulation, XML, Schema, Metadata, Semantic Web, OWL			**15. NUMBER OF PAGES** 63
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UU

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

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ABSTRACT

The Department of Defense (DoD) Modeling and Simulation Steering Committee (M&S SC) is sponsoring several Acquisition Modeling and Simulation (M&S) Projects. One of those projects is titled, "Standardized Documentation for Verification, Validation, and Accreditation (VV&A)." Previous efforts defined standardized content and format requirements (i.e., templates) for four core VV&A documents, now codified in a new Military Standard (MIL-STD-3022) and associated Data Item Descriptions. A tool is under development to automate those templates to assist developers in creating standardized VV&A information across the DoD and Military Departments. In support of this effort, the Naval Postgraduate School was tasked to specify data structures and content using the Extensible Markup Language (XML) for metadata and content of VV&A documentation. Based on the initial work, NPS was further tasked to design and develop an ontological foundation for formal description of VV&A information. This document describes preliminary work toward development of an ontology for VV&A that will facilitate future search, discovery, and processing of VV&A information to better meet user needs.

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TABLE OF CONTENTS

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LIST OF FIGURES

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ACRONYMS AND ABBREVIATIONS

DL	Description Logic
DoD	Department of Defense
DoDD	Department of Defense Directive
DoDI	Department of Defense Instruction
DVDT	DoD VV&A Documentation Tool
ER	Entity-Relationship
GIG	Global Information Grid
HTML	Hyper-Text Markup Language
HTTP	Hyper-Text Transfer Protocol
IRI	International Resource Identifier
M&S	Modeling and Simulation
M&S CO	Modeling and Simulation Coordination Office
M&S SC	Modeling and Simulation Steering Committee
MDR	Metadata Registry
MIL-STD	Military Standard
MOVES	Modeling, Virtual Environments, and Simulation
NPS	Naval Postgraduate School
OWL	Web Ontology Language
RDF	Resource Description Framework
RDFS	Resource Description Framework Schema
SME	Subject Matter Expert
SOA	Service Oriented Architecture
SOW	Statement of Work
SPARQL	SPARQL Protocol and RDF Query Language
SPAWAR	Space and Naval Warfare Command
SSCLANT	SPAWAR Systems Center, Atlantic
UML	Unified Modeling Language
URI	Uniform Resource Identifier
URL	Uniform Resource Locator
URN	Uniform Resource Name
V&V	Verification and Validation

VV&A	Verification, Validation and Accreditation
XML	Extensible Markup Language

ACKNOWLEDGMENTS

The author thanks other members of the Department of Defense (DoD) Verification, Validation, and Accreditation (VV&A) Documentation Tool (DVDT) project team for their assistance and support of this effort: Mr. Kevin Charlow, Space and Naval Warfare Systems Center, Atlantic (SSCLANT); Mr. David Broyles, SSCLANT; Dr. Richard Daehler-Wilking, SSCLANT; and Ms. Marcy Stutzman, Northrop Grumman.

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EXECUTIVE SUMMARY

The goal of this research is to specify the semantics of Verification, Validation, and Accreditation (VV&A) information to enable more effective search and automated reasoning with that information than is possible from the structural descriptions provided in Extensible Markup Language (XML) schema representations. A preliminary ontology has been developed that describes concepts and relationships derived from the DoD Standard Practice for Documentation of Verification, Validation, and Accreditation (VV&A) for Models and Simulations (MIL-STD-3022). The ontology is expressed in the Web Ontology Language (OWL), one of the principal elements of the emerging Semantic Web intended to make information in web-based architectures more readily understood and actionable by computer software.

Additional work is required to define more completely the relationships and logical constraints across concepts that will enable more powerful automated processes operating on the VV&A information. As initially defined, the VV&A ontology provides a basis for further research and development of semantic descriptions of VV&A information leading to future development of applications operating on that information.

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I. INTRODUCTION

A. BACKGROUND

The Department of Defense (DoD) Modeling and Simulation Steering Committee (M&S SC) Acquisition M&S Community Lead, Mr. Chris DiPetto, Deputy Director for Developmental Test and Evaluation, has sponsored several Acquisition Modeling and Simulation (M&S) Projects. One of those projects is titled "Standardized Documentation for Verification, Validation, and Accreditation (VV&A)." Early work in this project defined standardized content and format requirements (i.e., templates) for four core VV&A documents resulting in approval of MIL-STD-3022 in January, 2008 (Department of Defense, 2008). Using templates with standard format and content requirements to document VV&A information across DoD will help users better understand if an M&S can meet their needs because they will know what kind of information is available and where to look in the document for that information. The standard includes Data Item Descriptions that can be included in contract procurement packages to ensure conformance to these practices. A DoD VV&A Documentation Tool (DVDT) has been developed to automate those templates to assist developers in creating standardized VV&A information across the DoD and Military Departments. This effort included identification of specific VV&A metadata to enable the sharing of information across all communities enabled by M&S via the Global Information Grid (GIG) anywhere in the world and at anytime. The work further addressed policy and technology gaps previously identified by the M&S SC in their Common and Cross-Cutting Business Plan (Modeling and Simulation Steering Committee, 2006) in addition to objectives from the DoD Acquisition M&S Master Plan (DoD, 2006).

Previous work (Blais, 2008) specified the structure and content of the four standardized VV&A documents Accreditation Plan, Accreditation Report, V&V Plan, and V&V Report) in the form of Extensible Markup Language (XML) schemas, including metadata describing those documents, as shown in Figure 1 and Figure 2 (refer to the cited reference for detailed discussion of these diagrams).

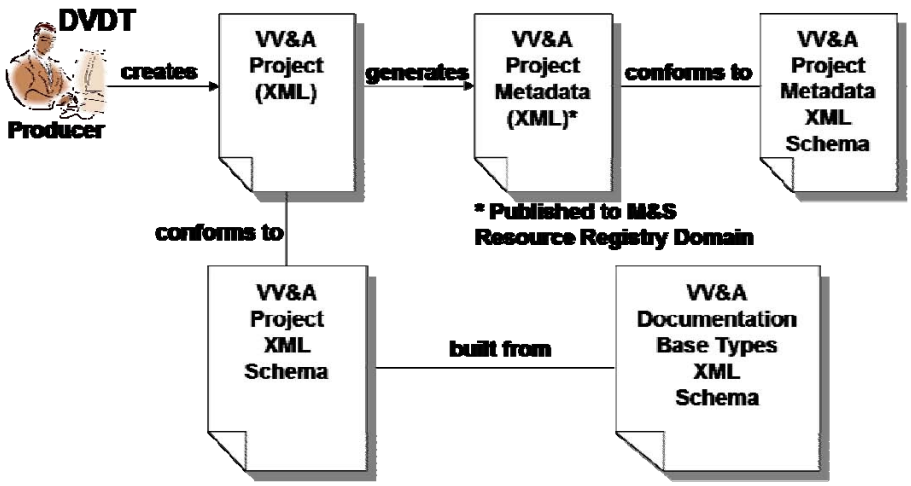

Figure 1. XML Schema documents describe the structure and content of the VV&A documentation project-level information, including metadata for posting to the Global Information Grid (Blais, 2008).

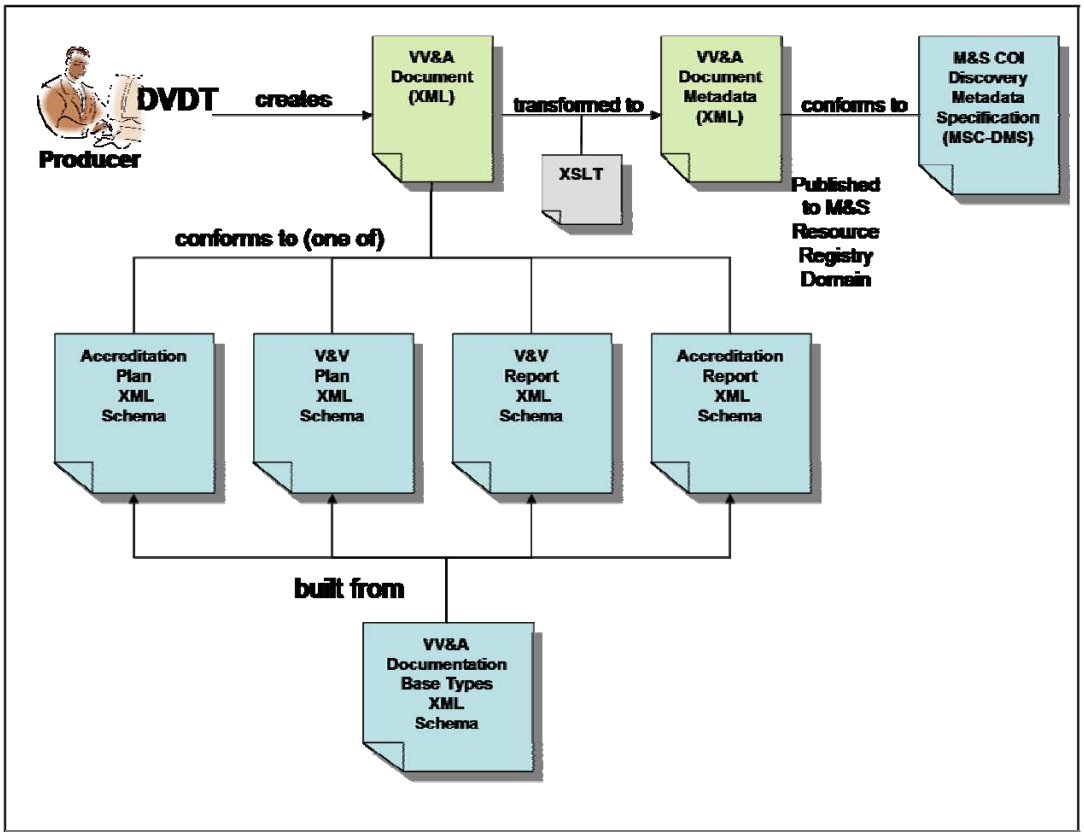

Figure 2. XML Schema documents describe the structure and content of the standard VV&A documentation templates as well as metadata for posting to the Global Information Grid (Blais, 2008).

To further describe VV&A information to create a foundation for future application software, the Navy Space and Warfare (SPAWAR) Systems Command Atlantic (SSCLANT) tasked the Naval Postgraduate School (NPS) Modeling, Virtual Environments, and Simulation (MOVES) Institute to to design and develop an ontological foundation for formal description of VV&A information.

B. PURPOSE

This document describes preliminary specification of the semantics of VV&A information to further supplement previous development of XML schemas describing the structure and content of (1) standardized VV&A documentation defined in MIL-STD-3022 and (2) project-level and document-level metadata used to publish information about the VV&A documents.

C. DOCUMENT CONTENT

Section I provides an introduction to the VV&A Standardized Documentation project, giving background information identifying the sponsor and participating organizations, describing the purpose of the work, and providing a description of the content of the document. Section II describes the Semantic Web and related information technology as foundation for the technical approach. Section III describes the technical approach. Section IV describes the preliminary taxonomy of VV&A information concepts derived from MIL-STD-3022. Section V provides preliminary ontology constructs layered on the taxonomy from Section IV. Section V provides a summary and recommendations for follow-on work. Appendix A provides a listing of the Web Ontology Language (OWL) file resulting from this work. The document concludes with a list of references and an initial distribution list for individuals and organizations receiving this document.

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II. DESCRIBING SEMANTICS IN DATA MODELS

A. INTRODUCTION

This chapter provides a brief overview of the primary technology elements of the Semantic Web and their use in description of semantics of VV&A information.

B. THE SEMANTIC WEB[1]

The World Wide Web has experienced unprecedented growth over the past 20 years, fueled largely by the use of Hypertext Markup Language (HTML), Hypertext Transfer Protocol (HTTP), and Universal Resource Identifiers (URIs) as simplistic mechanisms for putting information into document files, posting and accessing those files, and linking those files, respectively. However, HTML primarily describes how the information should be displayed in browser software, rather than providing clear descriptions of the content contained in the document. To address this shortcoming, the World Wide Web Consortium (W3C; http://www.w3.org) created the Extensible Markup Language (XML; http://www.w3.org/XML) as a standard way to create and apply markup to the content of Web documents to make the content more readily accessible by software. As shown in the previous work (Blais, 2008), XML is an effective way to describe the structure and content of the standardized VV&A documents and related metadata. While initial application of XML made description of Web content much more precise, it largely described content in a structured, syntactic manner. As the demand for greater automation in accessing and processing Web content continued to rise, principal designers and researchers on the Web created a new vision, called the Semantic Web, to enable description of the semantics of the information.

> The Semantic Web will bring structure to the meangful content of Web pages, creating an environment where software agents roaming from page to page can readily carry out sophisticated tasks for users. … The Semantic Web is not a separate Web but an extension of the current one, in which information is given well-defined meaning, better enabling computers and people to work in cooperation. … To date, the Web has developed most rapidly as a medium of documents for people rather than for data and information that can be processed automatically. The Semantic Web aims to make up for this. (Berners-Lee *et al.*, 2001)

[1] The discussion in this section is adapted from material from (Johnson & Blais, 2008).

Semantics refers to the meaning of the information. Meaning derives from context—how concepts are related to each other for a particular purpose. Formalisms have been developed using XML that help specify semantics in a way that conforms to common practices on the World Wide Web. In the Semantic Web, "the explicit representation of the semantics underlying data, programs, pages, and other Web resources will enable a knowledge-based Web that provides a qualitatively new level of service" (Daconta et al., 2003, p. xxi). The Semantic Web is an extension of the World Wide Web in which information is given semantically-rich descriptions that enable automated processing by software. The W3C has created additional layers of markup, building on the base of XML, to provide description of the semantics of the information. The Semantic Web is an evolution of the current Web, built from the foundation of open standards on which the Web is built. Building blocks of the Semantic Web are shown in Figure 3. Below, we provide a brief description of the layers of the Semantic Web stack and highlight their relevance to the VV&A ontology development.

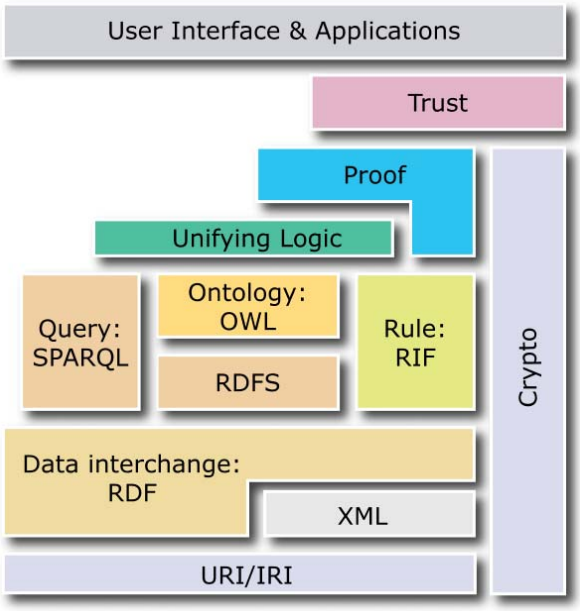

Figure 3. Principal Building Blocks of the Semantic Web Stack[2]

[2] World Wide Web Consortium; see http://www.w3.org/2007/03/layerCake.png.

As shown, the foundation of the Semantic Web stack is the Uniform Resource Identifier / International Resource Identifier (URI/IRI). The URI/IRI is an identification scheme for resources on the Web. The most common form is the Universal Resource Locator (URL) (a form of URI) generally used for links to documents in the HTML. Current development of metadata records describing M&S resources (which include VV&A documentation) has a provision for identification of URIs assigned to facilitate linking to information related to a particular resource (M&SCO, 2008). Later discussion will show the use of URIs to identify abstract resources in the expression of assertions and relationships in the description of semantics of VV&A inforamtion.

As introduced earlier, XML is a standard for defining markup languages. Markup languages enable information content to be self-describing for human and machine processing. The XML Schema language (http://www.w3.org/XML/Schema) provides a capability to define the structure and content of XML documents that can be validated against the schema definition. Earlier work (Blais, 2008) established the structure and content of VV&A documentation and project-level metadata using the XML Schema language.

The Resource Description Framework (RDF) is a language for stating basic assertions in the form of subject-predicate-object triplets (http://www.w3.org/RDF). Each of the elements in an RDF statement is an abstract Web resource identified by a URI. RDF and its schema language (RDFS; http://www.w3.org/TR/rdf-schema) provide foundational semantics for description of taxonomies (class hierarchies) supporting inference and search (Alesso & Smith, 2006). RDFS provides an XML vocabulary to define classes and subclass relationships (taxonomies) as well as to define properties associated with classes (ontologies) (Alesso & Smith, 2006). RDF and RDFS are used in the description of the semantics of VV&A information, as we will see in Section IV.

The lower layers of the Semantic Web stack (URI/IRI, XML, and RDF) provide the ability to describe information (metadata and schemas) and to express knowledge (assertions). Query languages provide a means to access information. The XML Query language is used to search XML documents by exploiting the hierarchical tree structure of the documents (XPath expressions). The SPARQL Protocol and RDF Query Language

(http://www.w3.org/2009/sparql/wiki/Main_Page) provides a means to search RDF expressions by exploiting the subject-predicate-object graph structure of the expressions (pattern matching). Future semantic search capabilities in the M&S Catalog effort to discover VV&A information may employ such query capabilities.

The Web Ontology Language (OWL; http://www.w3.org/2004/OWL) extends RDF/RDFS constructs to provide more precise description of classes, subclasses, and relationships among classes (properties). OWL adds the capability to define local scope of properties, disjointness of classes, Boolean combinations of classes, cardinality restrictions, special characteristics of properties (e.g., functional, transitive, symmetric), and other aspects not expressible with RDF/RDFS (Alesso & Smith, 2006). In addition to using the language to describe classes and relationships, OWL also describes instances (members) of classes, which allows creation of knowledge bases containing information about the domain of interest (e.g., VV&A information). OWL includes three sublanguages (OWL Full, OWL DL, and OWL Lite), providing three levels of logical expressivity and resultant computational trade-offs. OWL Lite is the simplest of the three, excluding the ability to define enumerated classes, disjointness statements, and arbitrary cardinality (Alesso & Smith, 2006). OWL DL (Description Logic) permits expression of a subset of first order logic that guarantees decidability (determining an answer in finite time). The preliminary ontology development described in the present document uses OWL DL. Use of OWL will maximize utility by software applications, including use of openly available reasoning engines that can be used to check for ontology consistency and to make inferences about instances in the asset knowledge base.

Brief descriptions of the higher layers of the Semantic Web stack are discussed below, but are not employed in this preliminary ontology development work. Nonetheless, they provide a rich area for follow-on research and development. In particular, rules and rule-based systems provide additional expressiveness in describing the logic of a system. Rules permit software to infer a conclusion from a premise (Alesso & Smith, 2006). Rules may be used in the formalized specification of VV&A inforamtion to enrich the descriptions, particularly to encode business rules, policies, and processes appropriate to VV&A activities. The use of the well-established Web-based

conventions in the information technology community provides a basis for application of a variety of common logical computations. Developments such as the M&S Catalog will be able to employ existing products that can operate on the semantic descriptions using provably correct methods. Cryptologic aspects of the Semantic Web stack cut across all the layers, supporting such functionality as authentication, encryption, and digital signature (Eastlake & Niles, 2003). All of the previously introduced layers support the establishment of trust in the encoded information. Trust is obtained by being able to anticipate the actions of a system and have a reasonable expectation that the system will act correctly (i.e., as intended). Trust is often established and maintained through transparency. One of the advantages of the use of the Semantic Web practices is visibility of the information through its description in metadata, semantic descriptions, rules, and computationally sound (provably correct) logic. Clearly, users of the VV&A information must be able to rely on the trustworthiness of the content when obtaining information on M&S systems. While we will not address this aspect of the information semantics directly, the goal in formalizing the semantic description of VV&A information is to make it as explicit and accessible as possible to humans and machines to ultimately promote the highest levels of the Semantic Web stack.

Well-defined syntax and semantics for description of metadata, taxonomies, and ontology for VV&A information will facilitate development of software applications and user interfaces. By describing VV&A information using common Semantic Web constructs, the work products will readily support development of various applications, including Web Services in a service-oriented architecture (SOA), while also providing a basis for future applications employing emerging Semantic Web Services technologies.

C. ONTOLOGY

The Semantic Web will improve ability to use web-based resources by enabling automation of such actions as locating content, collating and cross-relating content, and drawing conclusions from information found in two or more separate sources (Dumbill, 2001). Key to realization of the Semantic Web is representation of knowledge in a way that can be readily stored, accessed, and processed by software. For a particular domain of interest, this involves identification and description of the primary concepts in that

domain and a description of how the concepts relate to each other. A formal specification of a conceptualization is called an *ontology* (Gruber, 1993).

There are a number of data modeling techniques providing different levels of detail and specificity.[3] One way to view the "semantics landscape" is shown in the "Ontology Spectrum" in Figure 4. The diagram shows representations of "weak" semantics (superficial descriptions of meaning) at the lower left and progressive stages towards definition of "strong" semantics (rich descriptions of meaning enabling automated reasoning) at the upper right. The figure also shows the techniques and standards used to represent semantics at various levels of the spectrum. It is important to note that different modeling and description techniques have different levels of expressiveness, and are therefore suited to different purposes. In working toward a conceptual model of VV&A information, we are attempting to move the data description up the spectrum toward semantic interoperability by starting with a controlled vocabulary and concept taxonomy, and then adding refinements through stronger formalizations.

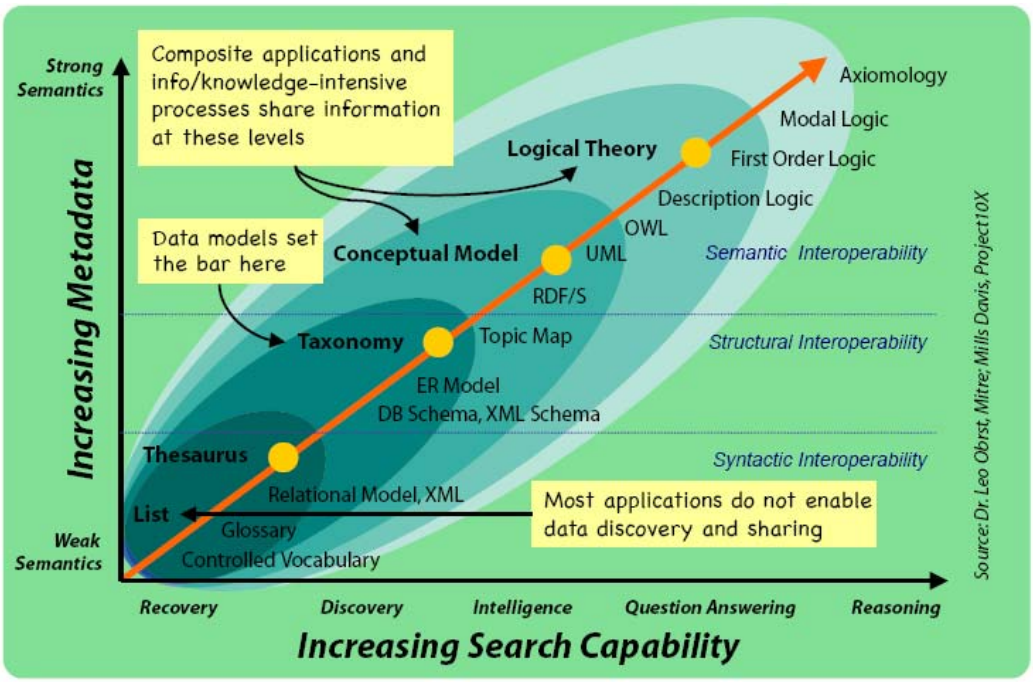

Figure 4. A view of an Ontology Spectrum (Obrst and Davis, 2005)

[3] This discussion is adapted from a similar treatment in (Blais et al., 2005).

A common definition for ontology is a "formal, explicit specification of a shared conceptualization" (Gruber, 1993). That is, an ontology provides a formalized vocabulary of terms and relationships among those terms used and understood within a domain, a "shared and common understanding of a domain that can be communicated between people and heterogeneous and widely spread application systems" (Fensel, 2001). In (Noy and McGinness, 2001), the authors give the following reasons for developing an ontology (direct quotes from the source are shown in *italics*):

- *To share common understanding of the structure of information among people or software agents*
- *To enable reuse of domain knowledge* (within and across domains)
- *To make domain assumptions explicit* (encoding human interpretation of the information into the description of the information itself to promote common understanding by human and software agents)
- *To separate domain knowledge from the operational knowledge* (separating "what" the information entails from "how" the information is used)
- *To analyze domain knowledge* (starting from a clear description of current understanding of the information)

Clearly, "data models" do not fall into a single category along the spectrum. In fact, the distinction between "data model" and "ontology" in the literature is not clear. In (Davis, 2006), the author surveys a number of references and concludes that "all models classifiable on the ontology spectrum can be considered ontologies to a degree, however models with stronger semantics are more accurately classified as ontologies in the generally accepted sense than those with weaker semantics." The immediate goal of the VV&A ontology development work is description of foundational data model to the level of a meaningful classification scheme ("Taxonomy" in Figure 4). Refinements to the model in follow-on tasking can apply stronger formalizations to provide more detailed semantics that will ultimately move the VV&A information model into the realm of "Logical Theory" on the spectrum. This will be accomplished through the identification

and formalization of interrelationships across the classes of data making up the VV&A information as well as formal constraints on class properties and application rules.

The description of the content of standardized VV&A documents in MIL-STD-3022 identifies a list of domain concepts at the lowest level in the ontology spectrum (controlled vocabulary) as well as meaningful collections of information. This follows a recommendation from (McGinness, 2002) to survey tables of contents from domain relevant publications as a possible source for domain taxonomies. Definition of the relationships among concepts and categories of concepts provides additional semantic content to the information model, moving up the ontology spectrum to notions of Relational Model, Entity-Relation (ER) Model, Unified Modeling Language (UML), and even to the beginnings of logical theory specifications, in accordance with the degree of formality and specificity used in the formalization of the information model. As stated above, for the current effort, the target is preliminary definition of semantics to the level of Taxonomy so that a thorough identification and classification of VV&A information is obtained as a basis for refinement through stronger semantics in follow-on efforts. Follow-on data model refinement can include application of Semantic Web constructs to push the information modeling to higher levels of semantic representation so that software can perform automated reasoning on VV&A information to further assist users in determining suitability of an M&S resource for a particular need.

D. SUMMARY

This chapter provided an overview of Semantic Web and ontology concepts that provide the technical basis for development of a preliminary semantic description of VV&A information. The next section describes the technical approach based on these concepts.

III. TECHNICAL APPROACH

A. INTRODUCTION

This chapter describes a general technical approach and software tool used in development of a preliminary description of the semantics of VV&A information based on MIL-STD-3022.

B. ONTOLOGY DEVELOPMENT[4]

While the Ontology Spectrum in Figure 4 can be seen as a guide for adding stronger semantics to a data model, a complementary approach to development of an information model is outlined in (Noy & McGuinness, 2001). The approach involves seven steps and some additional guidelines and tests for grooming a nascent ontology. The following discussion identifies and applies these steps in the context of the VV&A information model (in the summary to follow, *italicized* font is used to denote text used verbatim from the reference).

Step 1. Determine the domain and scope of the ontology.

The following questions help limit the scope:

- *What is the domain the ontology will cover?* For VV&A information, the domain is the content of standardized VV&A information specified in MIL-STD-3022.
- *For what are we going to use the ontology?* The ontology will be used in software applications to provide a standard identification of VV&A documentation terminology and information relationships, supporting reuse of the domain knowledge, making domain assumptions explicit, and for improving specificity of information search for users seeking to identify M&S systems applicable for their particular use.
- *For what types of questions the information in the ontology should provide answers?* The ontology (i.e., the knowledge base built from the ontology structure) will support direct queries such as the status of validation tests

[4] This discussion is adapted from a similar treatment in (Blais et al., 2005).

against the requirements of an M&S system, as well as indirect queries or logical inferences, such as locating resources related to an M&S system of interest or inferring if an M&S system suitable for one use may also be suitable for another purpose based on the characterization of the M&S system and relationships across the various uses. Developing a list of competency questions helps to limit the ontology scope. When the ontology is formalized, the questions should be answerable using a knowledge base of instances created in accordance with the ontology.

- *Who will use and maintain the ontology?* The primary users of the ontology will be software application developers. If adopted as an approved representation of VV&A information from MIL-STD-3022, a government organization, such as the DoD M&S Coordination Office (M&S CO), or designated support organization, may assume responsibility for maintenance of the ontology. If approved for use, the ontology files should be posted to the DoD Metadata Registry (MDR) for access by the DoD Enterprise.

Step 2. Consider reusing existing ontologies.

In early stages of this work, a number of references were examined for identification of VV&A concepts and relationships. These included early taxonomies such as those from (Hartley, 1997) and (THALES, 2004), shown in Figure 5 and Figure 6, respectively, and the DoD VV&A Recommended Practices Guide (available at http://vva.msco.mil/Default.htm). During the time of that early research, the MIL-STD-3022 was being drafted. Upon its release in January 2008, this DoD Standard Practice became the definitive source for standardized content of VV&A documentation and the basis for development of the XML Schema (Blais, 2008) and document templates automated by the DVDT. The most complementary strategy, then, is to develop richer semantic descriptions of the information provided in VV&A documents conforming to MIL-STD-3022. In so doing, the semantic descriptions become available to enhance various operations of query, discovery, and reasoning to find and utilize VV&A information contributing to decisions about the suitability of M&S resource systems.

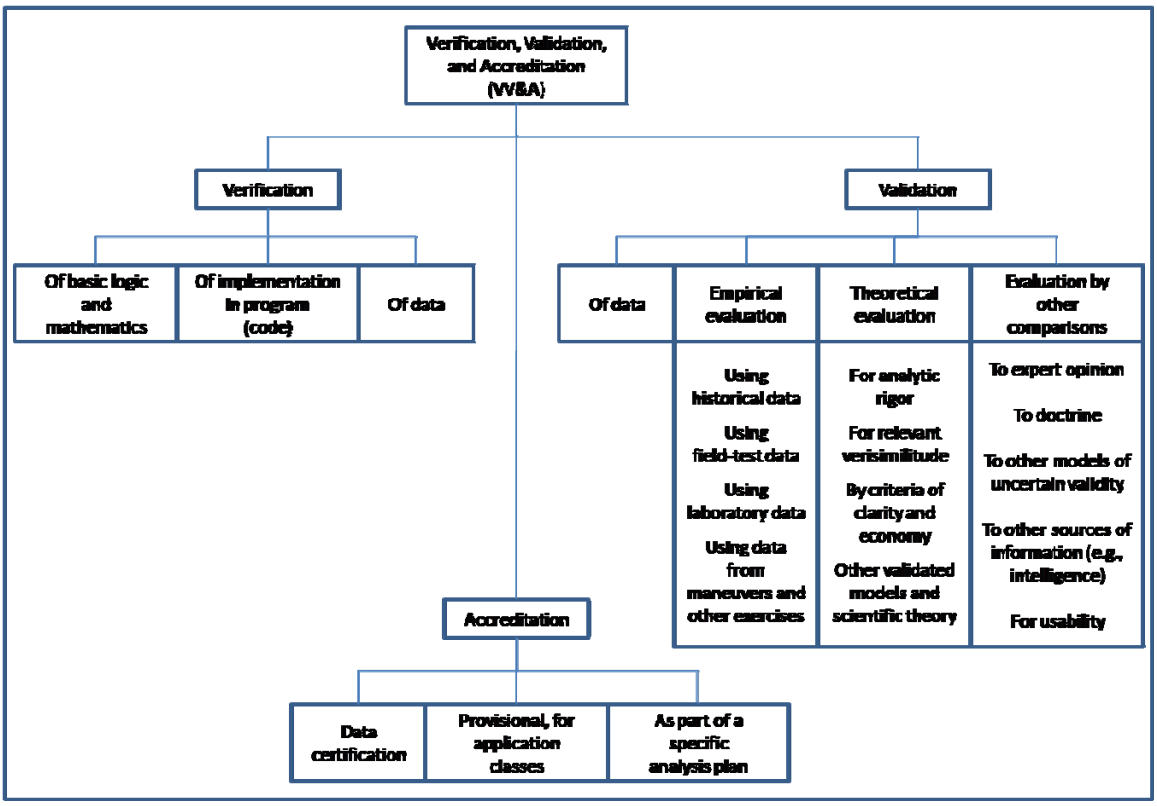

Figure 5. V&V Taxonomy (Hartley, 1997)

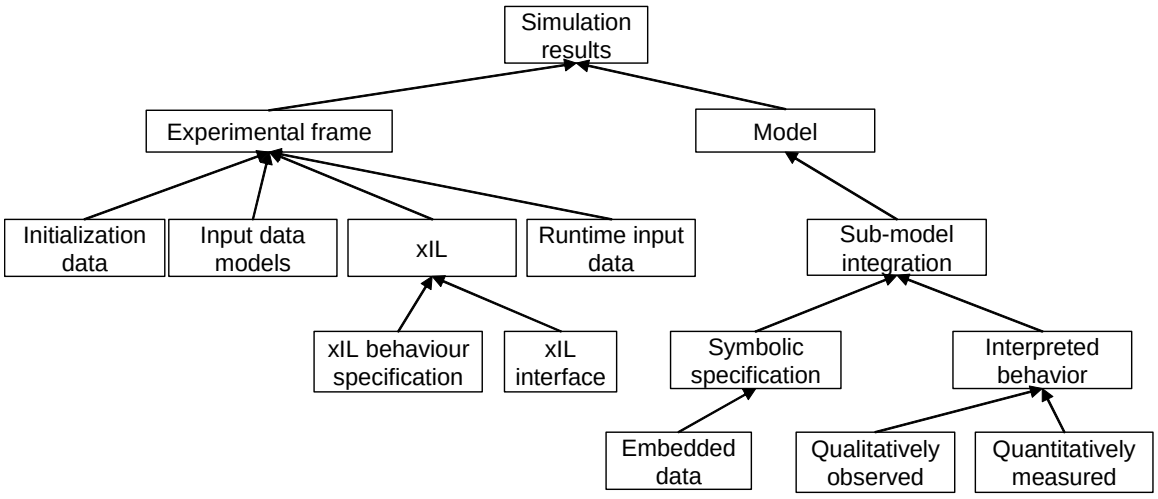

Figure 6. V&V Taxonomy (THALES, 2004)

Since the MIL-STD-3022 is so recently approved as a standard (January, 2008), no ontologies have yet been developed to describe VV&A information in accordance with that standard.

Step 3. Enumerate important terms in the ontology.

It is important to list and describe all terms relevant to the domain; i.e., to collect all terms *we would like either to make statements about or explain to the user.* This activity is not particularly concerned with whether the term represents a class or slot (attribute), or how classes fit into a taxonomy. It is also not concerned if there is overlap between meanings of the terms. The purpose here is to capture the lexicon of the domain or take an inventory of the domain's language. For the present work, VV&A concepts and terminology are extracted directly from the documentation content specified in MIL-STD-3022.

Step 4. Define the classes and the class hierarchy.

In establishing a class hierarchy, we are looking for "*is-a*" relationships between classes where a lower level class inherits properties from a higher level class, and possibly adds new properties. Suppose `Process` represents the general class of processes that can be performed. One subclass of the `Process` class is `VVAProcess`, those processes that are defined to perform VV&A activities. One aspect of the characterization of a `Process` can be the various roles agents (human or otherwise) take on in the performance of the process. As a subclass of the `Process` class, the `VVAProcess` also has performers in various roles, but the `VVAProcess` subclass may be distinguished from, say, a `SoftwareManagement` subclass, by the different collection of roles assigned to performers of the respective process.

For our purposes here, and following the distinction made in (Tolk and Blais, 2005), we consider a taxonomy to be "a tree structure of classifications for a given set of objects" and an ontology to be "an attempt to formulate an exhaustive and rigorous conceptual schema within a given domain" (a definition that is consistent with our earlier discussion). One key distinction is that an ontology does not need to strictly be a tree

structure, but can represent a multiple inheritance hierarchy (i.e., where a subclass inherits some properties from each of its superclasses).

Terms identifying classes are taken from the domain lexicon inventoried in Step 3. The terms that *describe objects having independent existence rather than terms that describe those objects* are chosen for classes. Usually if one can ask the unary argument question, "Is the object a `className`?", then the term is a class. As above, since a `VVAProcess` *is-a* `Process`, then `Process` represents a class.

In accordance with MIL-STD-3022, each VV&A document contains a particular set of information. We can describe VV&A concepts from a process perspective as activities to perform in doing VV&A. We can also describe the concepts from a document perspective as content pertinent to each type of VV&A document (i.e., accreditation plan, V&V plan, V&V report, and accreditation report). For this preliminary work, we take the latter approach, relying directly on the organization of information in the documents.

Step 5. Define the properties of classes – slots.

After identifying terms/concepts in the lexicon that refer to classes, the remaining terms are likely to be properties. The properties must be ascribed as slots (or *attributes*) to the classes they elaborate. The properties can be:

- *intrinsic*, such as the M&S requirements traceability matrix content in a VV&A document;
- *extrinsic*, such as the title of a VV&A document;
- parts of the object if complex, and either physical or abstract, such as a `VVPlan` having `VVMethodology` and `VVIssues` document sections;
- relationships to other individuals, such as the association of an `AccreditationPlan` to a `VVPlan`.

Usually if one can ask the binary argument question, "What is the `propertyName` (e.g., `title`) of this `className` (e.g., `VVADocument`)?", then the term is a property. As introduced earlier, all subclasses inherit the slots (attributes,

properties) of their superclass(es). For example, if `VVAProcess` *is-a* `Process` and all `Process` objects have the `Participants` property, then `VVAProcess` inherits the `Participants` property (this is not to say every instance of a `VVAProcess` has the same value for the `Participants` property).

Step 6. Define the facets of the slots.

The slots defined in Step 5 can have different facets. Common facets include:

- cardinality - A slot can have single values, such as saying a VVADocument `hasTitle` some title string. A slot can also have multiple values. For example, several personnel may be assigned to fill the `hasSubjectMatterExpert` slot of a `VVAProcess`. A cardinality facet describes the number of possible values of a slot.
- value-type - string, number, Boolean, enumerated, instance-type (if specifying other class individuals)
- domain or range - It might be easier to specify a class by restricting the domain and range of certain properties instead of listing all class individuals as possible values.

Step 7. Create Instances.

Creating instances is the process of situating an individual within the class structure and describing the individual with the class slots. This step creates a knowledge base conforming to the specified ontological structure. *There is a fine line where the ontology ends and the knowledge base begins.* Although Noy and McGuinness present this last activity as a step in ontology creation, population of a VV&A knowledge base is not within the scope of this project. If the preliminary ontology is extended and refined through follow-on work, and subsequently employed in VV&A documentation applications, then instances of various classes will be defined as a matter of course.

C. ONTOLOGY DEVELOPMENT TOOL

The Protégé ontology development tool from Stanford University (http://protege.stanford.edu) was used to define the initial VV&A documentation ontology. A screenshot of the VV&A ontology structure in Protégé is shown in Figure 7. The panel at the left side of the window shows a portion of the class hierarchy. The upper area of the right hand side of the screen shows annotation properties on the selected class (in the figure, the subclass named AccreditationInformationNeeds is highlighted on the left, and the annotation property named rdfs:comment provides a textual description of the class as defined in MIL-STD-3022). The middle portion of the right hand side is where defining characteristics of the class are stated (here, the `AccreditationInformationNeeds` subclass is defined as a subclass of `DocumentSections`). The Protégé tool provides a capability to generate the ontology in OWL format for use by other software applications. Full description of the Protégé tool is beyond the scope of this document. The interested reader can freely obtain the software and documentation from the Protégé site.

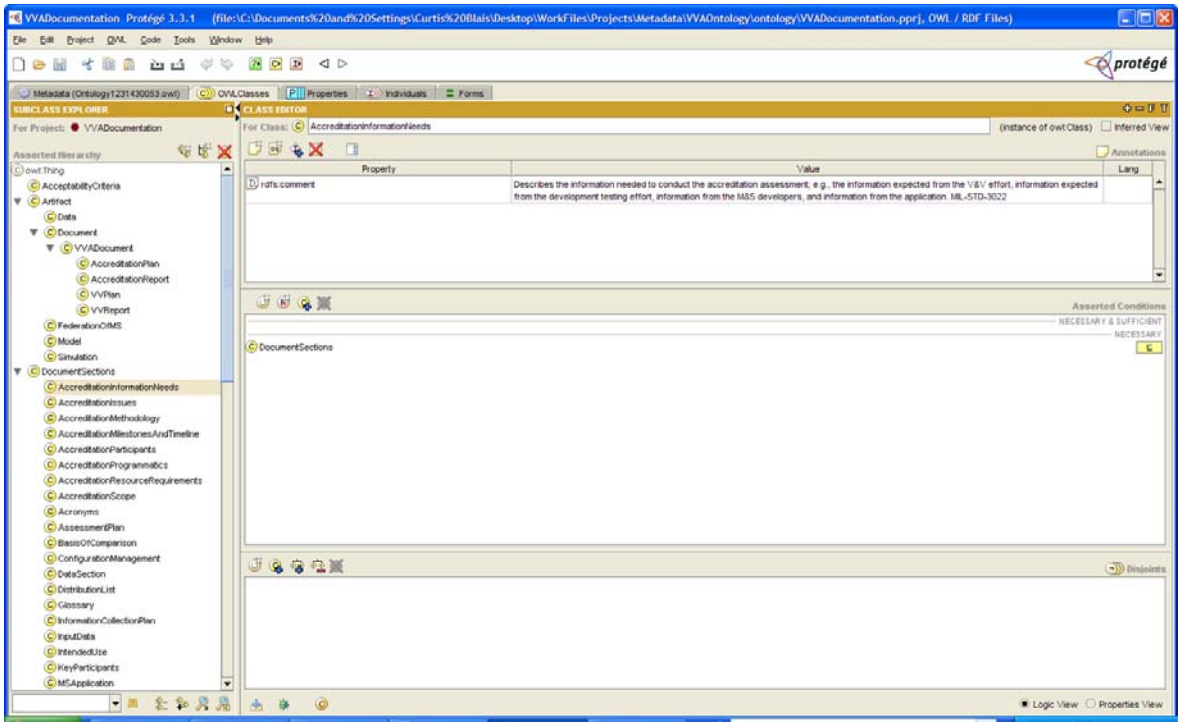

Figure 7. VV&A Information Class Hierarchy in Protégé

D. SUMMARY

This chapter described a general ontology development methodology and software tool as applied to the development of a preliminary description of the semantics of VV&A information based on MIL-STD-3022. The next section describes the ontology developed to date as a foundation for follow-on efforts.

IV. VV&A CONCEPTS

A. INTRODUCTION

This chapter describes the preliminary ontology of VV&A concepts derived from the MIL-STD-3022. It is important to note up front that the ontology is not complete at the time of this writing, nor is it necessarily consistent as some parts of the work are considered exploratory at this time. There are numerous ways to organize information in a domain of interest; some partial approaches are shown in the ontology for future consideration but will need to be removed or revised later as the work matures. The current product should be considered illustrative, not definitive, at this stage of development.

B. VV&A ONTOLOGY

Figure 8 provides an overview of the structure and content of the four standardized VV&A documents from the MIL-STD-3022. As discussed earlier, this standard provides an excellent starting point for describing information important to the planning and conduct of VV&A processes, including capture of the information artifacts from performance of those processes. To delineate the VV&A document contents in a taxonomic structure, a general class was defined named DocumentSections. The subclasses correspond to document sections and subsections from MIL-STD-3022. Each of the VV&A documents can then be characterized based on their collection of content; i.e., the set of `DocumentSections` that make up the document. For example, an `AccreditationPlan` can be considered as a `VVADocument` (subclass of the `Document` class, which is a subclass of the `Artifact` class) satisfying a set of axioms; namely, that the `AccreditationPlan` *hasSection* some `ExecutiveSummary`[5] and *hasSection* some `ProblemStatement` and *hasSection* some `MSRequirementsAndAcceptabilityCriteria`, etc. through the appropriate list of information content for the particular subclass of VV&A document. Work is needed to fill out these defining characteristics to more fully specify such semantics. Note that use

[5] Note, *hasSection* is a property relating an instance of the `Document` class to an instance of the `DocumentSection` class.

of the more general `Artifact` concept enables concepts in this ontology to be related to one dealing with software development lifecycle products, as defined in (Johnson & Blais, 2008).

Accreditation Plan	V&V Plan	V&V Report	Accreditation Report
Executive Summary	Executive Summary	Executive Summary	Executive Summary
1 Problem Statement	*1 Problem Statement*	*1 Problem Statement*	*1 Problem Statement*
2 M&S Requirements and Acceptability Criteria	*2 M&S Requirements and Acceptability Criteria*	*2 M&S Requirements and Acceptability Criteria*	*2 M&S Requirements and Acceptability Criteria*
3 M&S Assumptions, Capabilities, Limitations & Risks/Impacts	*3 M&S Assumptions, Capabilities, Limitations & Risks/Impacts*	*3 M&S Assumptions, Capabilities, Limitations & Risks/Impacts*	*3 M&S Assumptions, Capabilities, Limitations & Risks/Impacts*
4 Accreditation Methodology	4 V&V Methodology	4 V&V Task Analysis	4 Accreditation Assessment
5 Accreditation Issues	5 V&V Issues	5 V&V Recommendations	5 Accreditation Recommendations
6 Key Participants	*6 Key Participants*	*6 Key Participants*	*6 Key Participants*
7 Planned Accreditation Resources	7 Planned V&V Resources	7 Actual V&V Resources Expended	7 Actual Accreditation Resources Expended
		8 V&V Lessons Learned	8 Accreditation Lessons Learned
Suggested Appendices *A M&S Description* *B M&S Requirements Traceability Matrix* *C Basis of Comparison* *D References* *E Acronyms* *F Glossary* G Accreditation Programmatics H Distribution List	Suggested Appendices *A M&S Description* *B M&S Requirements Traceability Matrix* *C Basis of Comparison* *D References* *E Acronyms* *F Glossary* G V&V Programmatics H Distribution List I Accreditation Plan	Suggested Appendices *A M&S Description* *B M&S Requirements Traceability Matrix* *C Basis of Comparison* *D References* *E Acronyms* *F Glossary* G V&V Programmatics H Distribution List I V&V Plan J Test Information	Suggested Appendices *A M&S Description* *B M&S Requirements Traceability Matrix* *C Basis of Comparison* *D References* *E Acronyms* *F Glossary* G Accreditation Programmatics H Distribution List I Accreditation Plan J V&V Report

Figure 8. Summary of Structure and Content of the Standardized VV&A Documents (from MIL-STD-3022)

Some general concepts in the preliminary ontology are defined to enable further specification of VV&A semantics. For example, VV&A planning and performance involves activities, performers, resources (e.g., funding), and schedule. These are basic concepts that can be used to define processes. In particular, a validataion process can be characterized by a particular set of activities and performers (e.g., a validation process would involve participants in the role of "V&V agent", but may not involve an "accreditation agent"). Significant work is needed to flesh out the concept of processes

and to characterize VV&A processes with respect to the planning information provided in the Accreditation Plan and V&V Plan documents.

Some initial properties have been defined in the preliminary ontology. Datatype properties relate a value to an instance of a class. The following have been defined as starting points: *hasMSName* (string-valued property of a `VVADocument`); *hasVersion* (string-valued property of a `Document`); *hasSponsorPM* (string-valued property of a `Document`); *hasMSVersion* (string-valued property of a `VVADocument`); *hasDate* (date-valued property of a `Document`); *hasTitle* (string-valued property of a `Document`); *hasDocumentType* (string-valued property of a `Document`); and *hasProgramProject* (string-valued property of a `Document`). Note that these examples make a distinction in the domain of the property; i.e., some relate values to instances of the `Document` class and some relate values to instances of the `VVADocument` class, a subclass of the `Document` class. Therefore, instances of the `VVADocument` class also possess properties defined at the superclass level, such as *hasTitle* and *hasVersion*, but become specialized by properties defined only at the subclass level, such as *hasMSName* and *hasMSVersion* (see Figure 9). These distinctions can be reflected in the axioms that define the classes and subclasses (not yet specified in this preliminary ontology). Also note that several of the properties, such as *hasMSName* and *hasVersion*, are declared as functional, meaning the properties are single-valued. Further analysis is needed in follow-on work to determine if these settings are appropriate for these and other yet-to-be-defined properties.

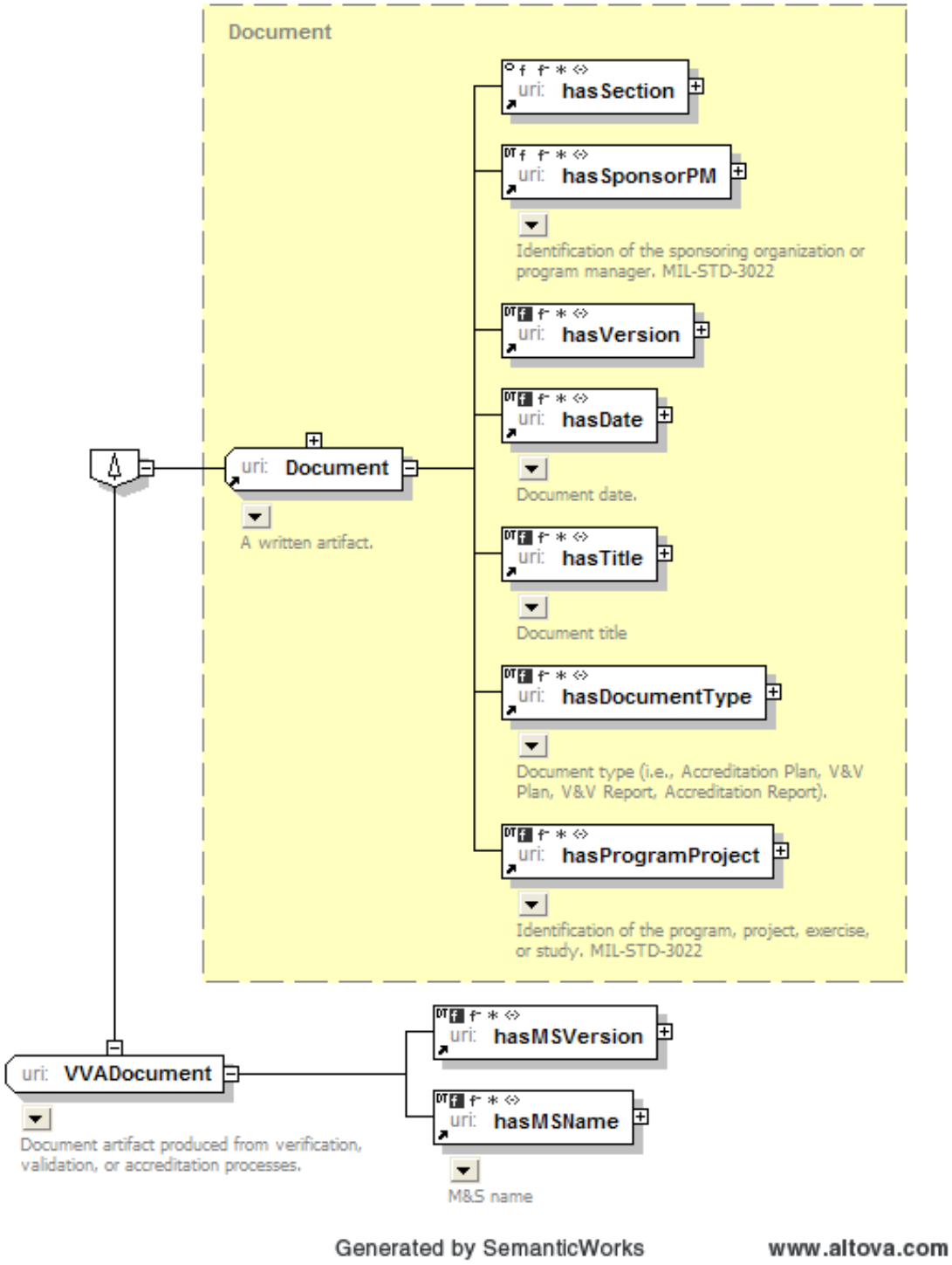

Figure 9. Portion of the VV&A Ontology showing the Document class and its VVADocument subclass, identifying their class-specific datatype properties

Also, several object properties, relating an instance of a class to one or more (depending on cardinality) instances of another class have been defined; for example: *isSubSectionOf* (relating an instance of `DocumentSection` to an instance of `DocumentSection`, to create a hierarchy of sections as appropriate to a particular document); *hasSection* (relating an instance of `Document` to one or more instances of `DocumentSection`, to identify the sections contained in a document); *hasRole* (relates an instance of `Participant` to one or more instances of `Role`); *participatesIn* (relates an instance of `Participant` to an one or more instances of `Process`); *containedIn* (relates an instance of `DocumentSection` to one or more instances of `Document`); *isProducedBy* (relates an instance of `Artifact` to one or more instances of `Process`); *produces* (relates an instance of `Process` to one or more instances of `Artifact`); *hasParticipant* (relates an instance of `Process` to one or more instances of `Participant`); and *hasSubSection* (relates an instance of `DocumentSection` to an instance of `DocumentSection`). In the definition of these properties, some consideration is given to inverse relationships that can be inferred. For example, if a particular person (instance of `Participant`) *participatesIn* a particular process (instance of `Process`), then it can be inferred from the definition of the inverse relationship that the particular process *hasParticipant* the particular individual. For software processing, these are powerful relationships. Another example of an OWL axiom defined on an object property is the transitive property of the *isSubSectionOf* relationship. If an instance of a `DocumentSection` (e.g., consider an instance of the subclass `MSUseHistory`) *isSubSectionOf* an instance of another `DocumentSection` (e.g., consider an instance of the subclass `MSDevelopmentAndStructure`), and that instance is an instance of another `DocumentSection` (e.g., consider an instance of the `MSDescription` subclass), then the transitive axiom allows software to infer that the first instance (member of the `MSUseHistory` subclass) *isSubSectionOf* the third instance (member of the `MSDescription` subclass). Such relationships can help, for example, in performing a deep search of a document tree structure to find all subsections of a particular section down through the subtree. As with the data properties, more work

is needed to identify and define object properties and axioms of those properties that can best benefit future use of VV&A information (again, properties defined in the present work should be considered illustrative, not definitive).

Annotations in the ontology (rdfs:comment assertions) provide definition of the domain lexicon (the classes and properties). These are largely extracted from the MIL-STD-3022 when such descriptions were provided there.

A complete listing of the ontology represented in OWL is provided in the ontology listing in Appendix A for readers familiar with those expressions.

C. SUMMARY

This section provided an overview of the preliminary ontology development for VV&A information based on MIL-STD-3022. The next section provides conclusions and recommendations for future work to extend and refine this initial representation.

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The work to date has been a very preliminary attempt to describe major VV&A concepts from the MIL-STD-3022. Much work remains to refine and complete the concepts and relationships to create a usable ontology for software development. The current approach provides a foundation for such further work on the basis of what it shows and what issues and questions it raises regarding different conceptual approaches that can be taken. The ontology work begins to explore further movement from the traditional notion of documentation consisting of narrative paragraphs to more explicit specification of key items of information from which narrative paragraphs can be constructed that was started in the XML Schema work.

B. RECOMMENDATIONS FOR FUTURE WORK

Additional work is required to provide more precise and complete description of the semantics of VV&A information. Several areas of follow-on work were identified in the discussion in the previous section (i.e., identification of classes, construction of class hierarchies, and specification of datatype properties, object properties, property axioms, class definition axioms, etc.). Taxonomic lists (e.g., types of M&S resources) from the M&S Community of Interest Discovery Metadata Specification (M&SCO, 2008) can be brought into the ontology. Moreover, a sample implementation should be developed to demonstrate how the ontology constructs can be used to assist information retrieval and processing. Such work can include integration with the M&S Catalog to provide richer semantics for search and discovery of M&S resources based on VV&A information. This may be obtained through employment of portions of the ontology (e.g., taxonomic hierarchies of terms) or through automation of knowledge discovery based on the existence of certain information in the knowledge base (e.g., if certain information is known about an M&S resource, then certain other information can be inferred). Semantic enrichment of data across the M&S Enterprise is a significant area for further study and development to one day achieve the visionary goals of the Semantic Web.

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APPENDIX A. PRELIMINARY VV&A ONTOLOGY

Following is an OWL representation of the preliminary VV&A ontology discussed in this document.

```
<?xml version="1.0"?>
<rdf:RDF xml:base="http://www.owl-ontologies.com/Ontology1231430053.owl" xmlns="http://www.owl-ontologies.com/Ontology1231430053.owl#" xmlns:owl="http://www.w3.org/2002/07/owl#" xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#" xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#" xmlns:xsd="http://www.w3.org/2001/XMLSchema#">
	<owl:Ontology rdf:about=""/>
	<owl:Class rdf:ID="FederationOfMS">
		<rdfs:subClassOf>
			<owl:Class rdf:ID="Artifact"/>
		</rdfs:subClassOf>
		<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">A federation of models and simulations is a system ofinteracting models and/or simulations, and a supporting infrastructure that are based on a common understanding of the objects portrayed in the system.  MIL-STD-3022</rdfs:comment>
	</owl:Class>
	<owl:Class rdf:ID="PlannedAccreditationResources">
		<rdfs:subClassOf>
			<owl:Class rdf:ID="DocumentSection"/>
		</rdfs:subClassOf>
		<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Discusses the resources required to implement the Accreditation Plan, such as performers, man-hours, materials, and funding. This information establishes a mechanism for tracking required resources, the availability of resources, and the impact of resource availability on performing accreditation activities and meeting milestones.MIL-STD-3022</rdfs:comment>
	</owl:Class>
	<owl:Class rdf:ID="Simulation">
		<rdfs:subClassOf>
			<owl:Class rdf:about="#Artifact"/>
		</rdfs:subClassOf>
		<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">One or more models embedded in an environment enabling execution, observation, and measurement.</rdfs:comment>
	</owl:Class>
	<owl:Class rdf:ID="Verification">
		<rdfs:subClassOf>
			<owl:Class rdf:ID="VVAProcess"/>
		</rdfs:subClassOf>
		<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">The process of determining that a model, simulation, or federation of models and simulations implementations and their associated data accurately represent the developer's conceptual description and specifications. MIL-STD-3022</rdfs:comment>
	</owl:Class>
	<owl:Class rdf:ID="MSAssumptions">
		<rdfs:subClassOf>
			<owl:Class rdf:about="#DocumentSection"/>
```

```
                </rdfs:subClassOf>
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Describes the known assumptions about the M&amp;amp;S and the data used in support of the M&amp;amp;S in the context of the problem. MIL-STD-3022</rdfs:comment>
        </owl:Class>
        <owl:Class rdf:about="#DocumentSection">
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Identifiable portions of a document artifact.</rdfs:comment>
        </owl:Class>
        <owl:Class rdf:ID="AccreditationProgrammatics">
                <rdfs:subClassOf rdf:resource="#DocumentSection"/>
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Contains detailed information regarding resource allocation and funding that can be used to track VV&amp;amp;A expenditures. MIL-STD-3022</rdfs:comment>
        </owl:Class>
        <owl:Class rdf:ID="KeyParticipants">
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Identifies the participants involved in the VV&amp;amp;A effort as well as the roles that they are assigned and their key responsibilities within that role. Roles and key responsibilities are defined during initial planning; names and contact information of the actual participants are added when they are determined. For each person serving as a Subject Matter Expert (SME), include a listing of the person's qualifications. MIL-STD-3022</rdfs:comment>
                <rdfs:subClassOf rdf:resource="#DocumentSection"/>
        </owl:Class>
        <owl:Class rdf:ID="MSCapabilitiesAndLimitations">
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Summarizes the capabilities and limitations of the M&amp;amp;S. MIL-STD-3022</rdfs:comment>
                <rdfs:subClassOf rdf:resource="#DocumentSection"/>
        </owl:Class>
        <owl:Class rdf:ID="ConfigurationControlBoard">
                <rdfs:subClassOf>
                        <owl:Class rdf:ID="Role"/>
                </rdfs:subClassOf>
        </owl:Class>
        <owl:Class rdf:ID="MSDevelopmentTeam">
                <rdfs:subClassOf>
                        <owl:Class rdf:about="#Role"/>
                </rdfs:subClassOf>
        </owl:Class>
        <owl:Class rdf:ID="DataSource">
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Organization responsible for providing an identified set of information supporting an activity.</rdfs:comment>
                <rdfs:subClassOf>
                        <owl:Class rdf:about="#Role"/>
                </rdfs:subClassOf>
        </owl:Class>
        <owl:Class rdf:ID="PointOfContact">
                <rdfs:subClassOf>
                        <owl:Class rdf:about="#Role"/>
                </rdfs:subClassOf>
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Person or organization holding particular informaiton about a product or process.</rdfs:comment>
```

```
	</owl:Class>
	<owl:Class rdf:ID="OtherParticipants">
		<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Identifies the members of the application program and model development effort with V&amp;amp;V or accreditation responsibilities as well as others who have a role in the VV&amp;amp;A processes. The information should include their position or role, contact information, and VV&amp;amp;A responsibilities. Typical roles include M&amp;amp;S Program Manager, M&amp;amp;S Application Sponsor, M&amp;amp;S User, M&amp;amp;S Developer, Data Source, Milestone Decision Authority, Program Office, M&amp;amp;S Development Team, User Group, Configuration Control Board, and SMEs.</rdfs:comment>
		<rdfs:subClassOf rdf:resource="#DocumentSection"/>
	</owl:Class>
	<owl:Class rdf:ID="MSDescriptionOverview">
		<rdfs:subClassOf rdf:resource="#DocumentSection"/>
		<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Provides a description of the M&amp;amp;S including the type of model (e.g., stochastic, deterministic, high resolution, low resolution, human in the loop, hardware in the loop, stand-alone, engineering, or aggregated), and what types of problems it is intended to support (e.g., training, force structure analysis, command and control, experimentation, system analysis, or analysis of alternatives).  MIL-STD-3022</rdfs:comment>
	</owl:Class>
	<owl:Class rdf:ID="MSUseHistory">
		<rdfs:subClassOf rdf:resource="#DocumentSection"/>
		<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Describes how and when the model has been used in the past as well as references relevant historical use documents. MIL-STD-3022</rdfs:comment>
	</owl:Class>
	<owl:Class rdf:ID="ValidationAuthority">
		<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">The organization or individual responsible to approve the validity of a model, simulation, or federation of models and simulations for a particular use.</rdfs:comment>
		<rdfs:subClassOf>
			<owl:Class rdf:about="#Role"/>
		</rdfs:subClassOf>
	</owl:Class>
	<owl:Class rdf:ID="MSInformation">
		<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Describes known factos that constrain the development and/or use of the M&amp;amp;S or that impede the VV&amp;amp;A effort, including the assumptions, capabilities, limitations, and risk factors affecting M&amp;amp;S development and risks associated with using the M&amp;amp;S for the intended use. MIL-STD-3022</rdfs:comment>
		<rdfs:subClassOf rdf:resource="#DocumentSection"/>
	</owl:Class>
	<owl:Class rdf:ID="OutputData">
		<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Identifies the M&amp;amp;S output data, including a definition, the unit of measure, and the range of values for each data item. MIL-STD-3022</rdfs:comment>
		<rdfs:subClassOf rdf:resource="#DocumentSection"/>
	</owl:Class>
	<owl:Class rdf:ID="SubjectMatterExpert">
		<rdfs:subClassOf>
			<owl:Class rdf:about="#Role"/>
		</rdfs:subClassOf>
		<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Person or organization having particular expertise in a knowledge domain or acquired skill.</rdfs:comment>
	</owl:Class>
	<owl:Class rdf:ID="Accreditation">
```

```
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">The official certification that a model, simulation, or federation of models and simulations and its associated data are acceptable for use for a specific purpose. MIL-STD-3022</rdfs:comment>
                <rdfs:subClassOf>
                    <owl:Class rdf:about="#VVAProcess"/>
                </rdfs:subClassOf>
            </owl:Class>
            <owl:Class rdf:ID="References">
                <rdfs:subClassOf rdf:resource="#DocumentSection"/>
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Identifies all the references used in the development of the document. MIL-STD-3022</rdfs:comment>
            </owl:Class>
            <owl:Class rdf:ID="MSApplication">
                <rdfs:subClassOf rdf:resource="#DocumentSection"/>
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Describes how the M&amp;amp;S will b eused in the overall program and lists the program objectives the M&amp;amp;S should meet in order to fulfill the intended use. MIL-STD-3022</rdfs:comment>
            </owl:Class>
            <owl:Class rdf:ID="UserGroup">
                <rdfs:subClassOf>
                    <owl:Class rdf:about="#Role"/>
                </rdfs:subClassOf>
            </owl:Class>
            <owl:Class rdf:ID="AccreditationParticipants">
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Lists the participants involved in the accreditation effort, including their contact information, assigned role, and the key responsibilities associated with that role. Typical accreditation roles include Accreditation Authority, Accreditation Agent, Accreditation Team, and SMEs. MIL-STD-3022</rdfs:comment>
                <rdfs:subClassOf rdf:resource="#DocumentSection"/>
            </owl:Class>
            <owl:Class rdf:ID="AccreditationMilestonesAndTimeline">
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Provides a chart of the overall program timeline with program, development, V&amp;amp;V, and accreditation milestones. The activities, tasks, and events, and their associated milestones, products, and deadlines should be consistent with information provided elsewhere in the plan. MIL-STD-3022</rdfs:comment>
                <rdfs:subClassOf rdf:resource="#DocumentSection"/>
            </owl:Class>
            <owl:Class rdf:ID="AccreditationReport">
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Focuses on documnting the results of the accreditation assessment; documenting the recommendations in support of the accreditation decision; and documnting lessons learned during accreditation. MIL-STD-3022</rdfs:comment>
                <rdfs:subClassOf>
                    <owl:Class rdf:ID="VVADocument"/>
                </rdfs:subClassOf>
            </owl:Class>
            <owl:Class rdf:ID="AccreditationPlan">
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Focuses on: defining the criteria to be used during the accreditation assessment; defining the methodology to conduct the accreditation assessment; defining the resources needed to perform the accreditation assessment; and identifying issues associated with performing the accreditation assessment. MIL-STD-3022</rdfs:comment>
                <rdfs:subClassOf>
                    <owl:Class rdf:about="#VVADocument"/>
                </rdfs:subClassOf>
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                                </owl:someValuesFrom>
                        </owl:Restriction>
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                <rdfs:subClassOf>
                        <owl:Restriction>
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                                        <owl:ObjectProperty rdf:about="#hasSection"/>
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rdf:ID="MSRequirementsAndAcceptabilityCriteria"/>
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                </rdfs:subClassOf>
                <rdfs:subClassOf>
                        <owl:Restriction>
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                                        <owl:ObjectProperty rdf:about="#hasSection"/>
                                </owl:onProperty>
                        </owl:Restriction>
                </rdfs:subClassOf>
        </owl:Class>
        <owl:Class rdf:about="#Role">
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Assigned
or assumed responsibility or authority of a participant in a process.</rdfs:comment>
        </owl:Class>
        <owl:Class rdf:ID="Document">
                <rdfs:subClassOf>
                        <owl:Class rdf:about="#Artifact"/>
                </rdfs:subClassOf>
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">A written
artifact.</rdfs:comment>
        </owl:Class>
        <owl:Class rdf:ID="Process">
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">An
organized collection of activities to achieve a desired outcome.</rdfs:comment>
        </owl:Class>
        <owl:Class rdf:ID="Validation">
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">The
process of determining the degree to which a model, simulation, or federation of models and simulations,
and their associated data are accurate representations of the real world from the perspective of the intended
use(s). MIL-STD-3022</rdfs:comment>
                <rdfs:subClassOf>
                        <owl:Class rdf:about="#VVAProcess"/>
                </rdfs:subClassOf>
```

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	</owl:Class>
	<owl:Class rdf:ID="VVPlan">
		<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">The
Verification and Validation Plan focuses on defining the methodology for scoping the V&amp;amp;V effort to
the application and the acceptability criteria; defining the V&amp;amp;V tasks that will produce information to
support the accreditation assessment; defining the resources needed to perform the V&amp;amp;V; and
identifyng issues associated with performing the V&amp;amp;V. MIL-STD-3022</rdfs:comment>
		<rdfs:subClassOf>
			<owl:Class rdf:about="#VVADocument"/>
		</rdfs:subClassOf>
	</owl:Class>
	<owl:Class rdf:ID="MSDescription">
		<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Contains
pertinent detailed information about the M&amp;amp;S being assessed. MIL-STD-3022</rdfs:comment>
		<rdfs:subClassOf rdf:resource="#DocumentSection"/>
	</owl:Class>
	<owl:Class rdf:ID="VVAgent">
		<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">The person
or organization designated to perform the verification, validation, or both , of a model, simulation, or
federation of models and simulations, and their associated data. MIL-STD-3022</rdfs:comment>
		<rdfs:subClassOf rdf:resource="#Role"/>
	</owl:Class>
	<owl:Class rdf:ID="AccreditationResourceRequirements">
		<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Identifies
the resources needed to accomplish the accreditation as planned. The information provided here should
include the activity, task, or event; assigned performer; and the list of required resources (e.g., SMEs,
equipment, and TDY funding). MIL-STD-3022</rdfs:comment>
		<rdfs:subClassOf rdf:resource="#DocumentSection"/>
	</owl:Class>
	<owl:Class rdf:ID="Data">
		<rdfs:subClassOf>
			<owl:Class rdf:about="#Artifact"/>
		</rdfs:subClassOf>
		<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">A
representation of facts, concepts, or instructions in a formalized manner suitable for communication,
interpretation, or processing by humans or by automatic means. MIL-STD-3022</rdfs:comment>
	</owl:Class>
	<owl:Class rdf:ID="ConfigurationManagement">
		<rdfs:subClassOf rdf:resource="#DocumentSection"/>
		<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Describes
the M&amp;amp;S configuration management program, lists the M&amp;amp;S artifacts and products that are under
configuration management, identifies documentation and reporting requirements that impact the
VV&amp;amp;A effort, and provides contact information.  MIL-STD-3022</rdfs:comment>
	</owl:Class>
	<owl:Class rdf:ID="IntendedUse">
		<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Describes
the problem to be addressed by the M&amp;amp;S, including the system or process being represented and the
role it plays in the overall program. MIL-STD-3022</rdfs:comment>
		<rdfs:subClassOf rdf:resource="#DocumentSection"/>
	</owl:Class>
	<owl:Class rdf:ID="MSRequirementsTraceabilityMatrix">
		<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Establishes
the links between the M&amp;amp;S requirements, the acceptability criteria, and the evidence collected during
the V&amp;amp;V processes. Provides representation of the chain of information that evolves as the
VV&amp;amp;A processes are implemented. As implementation progresses from the planning to reporting
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phases, th traceability matrix assists in the identification of information gaps that may result from VV&amp;amp;A activities not performed, not addressed, or not funded.  MIL-STD-3022</rdfs:comment>
                <rdfs:subClassOf rdf:resource="#DocumentSection"/>
        </owl:Class>
        <owl:Class rdf:ID="AccreditationAgent">
                <rdfs:subClassOf rdf:resource="#Role"/>
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">The organization designated to conduct an accreditation assessment for an M&amp;amp;S application. MIL-STD-3022</rdfs:comment>
        </owl:Class>
        <owl:Class rdf:ID="DataVV">
                <rdfs:subClassOf>
                        <owl:Class rdf:about="#VVAProcess"/>
                </rdfs:subClassOf>
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Data verification and validation (V&amp;amp;V) is the process of verigying the internal consistency and correctness of data and validating that it represents real-world entities approriate for its intended purpose or an expected range of purposes. The process has two perspectives: the producer and the user. MIL-STD-3022</rdfs:comment>
        </owl:Class>
        <owl:Class rdf:ID="InformationCollectionPlan">
                <rdfs:subClassOf rdf:resource="#DocumentSection"/>
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Describes how, when, and from whom the information is to be obtained, the form in which the information is to be provided, and the priority of each item. MIL-STD-3022</rdfs:comment>
        </owl:Class>
        <owl:Class rdf:ID="MilestoneDecisionAuthority">
                <rdfs:subClassOf rdf:resource="#Role"/>
        </owl:Class>
        <owl:Class rdf:ID="Participant">
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Person or organization making a particular contribution of resources, effort, or authority to a process.</rdfs:comment>
                <owl:equivalentClass>
                        <owl:Class>
                                <owl:intersectionOf rdf:parseType="Collection">
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                                                <owl:onProperty>
                                                        <owl:ObjectProperty rdf:ID="hasRole"/>
                                                </owl:onProperty>
                                                <owl:someValuesFrom rdf:resource="#Role"/>
                                        </owl:Restriction>
                                        <owl:Restriction>
                                                <owl:someValuesFrom rdf:resource="#Process"/>
                                                <owl:onProperty>
                                                        <owl:ObjectProperty rdf:ID="participatesIn"/>
                                                </owl:onProperty>
                                        </owl:Restriction>
                                </owl:intersectionOf>
                        </owl:Class>
                </owl:equivalentClass>
        </owl:Class>
        <owl:Class rdf:ID="TitlePage">
                <rdfs:subClassOf rdf:resource="#DocumentSection"/>
```

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                <rdfs:comment
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Information on the title page should comply
with organizational guidelines. MIL-STD-3022</rdfs:comment>
        </owl:Class>
        <owl:Class rdf:ID="MSRisksAndImpacts">
                <rdfs:subClassOf rdf:resource="#DocumentSection"/>
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Describes
the known risks associated with the development and/or use of the M&amp;amp;S within the context of the
application. Risk factors include identified constraints and limitations; tasks selection and implementation;
and schedule. The impacts associated with these risk factors are also described. MIL-STD-
3022</rdfs:comment>
        </owl:Class>
        <owl:Class rdf:ID="InputData">
                <rdfs:subClassOf rdf:resource="#DocumentSection"/>
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Identifies
the data required to populate an execute the M&amp;amp;S, including input data sets, hard-wired data
(constants), environmental data, and operational data. Provide descriptive metadata, metrics, and
authoritative or approved sources for each. MIL-STD-3022</rdfs:comment>
        </owl:Class>
        <owl:Class rdf:ID="DataSection">
                <rdfs:subClassOf rdf:resource="#DocumentSection"/>
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string"/>
        </owl:Class>
        <owl:Class rdf:ID="AccreditationAuthority">
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">The
organization or individual responsible to approve the use of a model, simulation, or federation of models
and simulations for a particular application (see also M&amp;amp;S Application Sponsor). MIL-STD-
3022</rdfs:comment>
                <rdfs:subClassOf rdf:resource="#Role"/>
        </owl:Class>
        <owl:Class rdf:ID="Glossary">
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Contains
definitions that aid in the understanding of the document. MIL-STD-3022</rdfs:comment>
                <rdfs:subClassOf rdf:resource="#DocumentSection"/>
        </owl:Class>
        <owl:Class rdf:ID="MSProponent">
                <rdfs:subClassOf rdf:resource="#Role"/>
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">The DoD
Component organization that has primary responsibility to initiate development and life-cycle management
of the reference version of one or more models and/or simulations. MIL-STD-3022</rdfs:comment>
        </owl:Class>
        <owl:Class rdf:ID="MSDevelopmentAndStructure">
                <rdfs:subClassOf rdf:resource="#DocumentSection"/>
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Provides
informatino  about how the M&amp;amp;S is organized and/or constructed (e.g., the M&amp;amp;S design),
hardware and software specifics, and technical statistics (e.g., runtime speed, capacity, and bandwidth). For
M&amp;amp;S under development, this section includes the M&amp;amp;S development plan, including the
development paradigm being followed (e.g., spiral development or model-test-model), and basic
assumptions about its execution. MIL-STD-3022</rdfs:comment>
        </owl:Class>
        <owl:Class rdf:ID="VVReport">
                <rdfs:subClassOf>
                        <owl:Class rdf:about="#VVADocument"/>
                </rdfs:subClassOf>
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<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">The Verification and Validation Report focuses on documenting the results of the V&V tasks; documenting M&S assumptions, capabilities, limitations, risks, and impacts; identifying unresolved issues associated with V&V implementation, and documenting lessons learned during V&V. MIL-STD-3022</rdfs:comment>
</owl:Class>
<owl:Class rdf:ID="AccreditationMethodology">
<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Describes the methods to be used in an accreditation assessment. MIL-STD-3022</rdfs:comment>
<rdfs:subClassOf rdf:resource="#DocumentSection"/>
</owl:Class>
<owl:Class rdf:about="#VVAProcess">
<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">A process to conduct verification, validation, or accreditation of an M&S system for an intended purpose(s) or use(s).</rdfs:comment>
<rdfs:subClassOf rdf:resource="#Process"/>
</owl:Class>
<owl:Class rdf:ID="MSApplicationSponsor">
<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">The modeling and simulation application sponsor is the organization that accredits and uses the results or products from a specific application of a model or simulation (also see Accreditation Authority and M&S User). MIL-STD-3022</rdfs:comment>
<rdfs:subClassOf rdf:resource="#Role"/>
</owl:Class>
<owl:Class rdf:ID="VVTeam">
<rdfs:subClassOf rdf:resource="#Role"/>
<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Member of team performing some V&V activity.</rdfs:comment>
</owl:Class>
<owl:Class rdf:ID="MSOverview">
<rdfs:subClassOf rdf:resource="#DocumentSection"/>
<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Provides an overview of the M&S for which the plan or report is written and discusses the level of configuration control tha tcurrently exists for the M&S. MIL-STD-3022</rdfs:comment>
</owl:Class>
<owl:Class rdf:ID="AccreditationIssues">
<rdfs:subClassOf rdf:resource="#DocumentSection"/>
<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Describes issues associated with the accreditation effort that may arise due to resourcing, scheduling, development, or data problems. Identifies the issue, the likelihood of its occurrence, contingency plans for addressing it, and the probability of success. MIL-STD-3022</rdfs:comment>
</owl:Class>
<owl:Class rdf:ID="MSDeveloper">
<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">The agency that develops an M&S or the agency that is overseeing the M&S development by a contractor. MIL-STD-3022</rdfs:comment>
<rdfs:subClassOf rdf:resource="#Role"/>
</owl:Class>
<owl:Class rdf:ID="Acronyms">
<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Identifies all acronyms used in the document. MIL-STD-3022</rdfs:comment>
<rdfs:subClassOf rdf:resource="#DocumentSection"/>
</owl:Class>
<owl:Class rdf:ID="VVParticipants">

<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Lists the participants involved in the V&V effort, including their contact information, assigned role, and the key responsibilities associated with that role. Typical V&V roles include M&S Proponent, V&V Agent, V&V Team, Validation Authority, Data Source, and SMEs. MIL-STD-3022</rdfs:comment>
<rdfs:subClassOf rdf:resource="#DocumentSection"/>
</owl:Class>
<owl:Class rdf:ID="AcceptabilityCriteria">
<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">A set of standards that a particular model, simulation, or federation will meet to be accredited for a specific purpose. MIL-STD-3022</rdfs:comment>
</owl:Class>
<owl:Class rdf:ID="AccreditationScope">
<rdfs:subClassOf rdf:resource="#DocumentSection"/>
<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Describes the scope of the accreditation effort based on the assessment of the risk of using the M&S and the availability of resources. MIL-STD-3022</rdfs:comment>
</owl:Class>
<owl:Class rdf:about="#ExecutiveSummary">
<rdfs:subClassOf rdf:resource="#DocumentSection"/>
<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">A synopsis of the major elements from all sections of the document, with emphasis on accreditation scope, M&S requirements, acceptability criteria, accreditation methodology, and accreditation issues.</rdfs:comment>
</owl:Class>
<owl:Class rdf:ID="Domain">
<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">An area of interest to a particular set of participants in a process. For example, participants in VV&A processes for M&S are interested in models,simulations, and federations of M&S.</rdfs:comment>
</owl:Class>
<owl:Class rdf:ID="MSCapabilities">
<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Describes the known capabilities of the M&S. MIL-STD-3022</rdfs:comment>
<rdfs:subClassOf rdf:resource="#DocumentSection"/>
</owl:Class>
<owl:Class rdf:ID="MSLimitations">
<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Describes the known constraints and limitations associated with the development, testing, and/or use of the M&S. These constraints and limitations may be introduced as a result of an ongoing development process or may result from information garnered in previous VV&A efforts. Limiting factors include constraints on M&S capability as well as constraints associated with M&S testing that may result in inadequate information (e.g., inadequate resources, inadequate technical knowledge and subject matter expertise, unavailable data, inadequately defined M&S requirements and methodologies, and inadequate test environments) to support the M&S assessment process. MIL-STD-3022</rdfs:comment>
<rdfs:subClassOf rdf:resource="#DocumentSection"/>
</owl:Class>
<owl:Class rdf:ID="DistributionList">
<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Provides the distribution list for hardcopies or digital copies of the approved document. MIL-STD-3022</rdfs:comment>
<rdfs:subClassOf rdf:resource="#DocumentSection"/>
</owl:Class>
<owl:Class rdf:ID="AssessmentPlan">
<rdfs:subClassOf rdf:resource="#DocumentSection"/>
<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Describes the assessment events, including the assessment techniques to be used, the specific roles and

responsibilities of the participants, the milestones to be achieved, and the products to be produced. MIL-STD-3022</rdfs:comment>
</owl:Class>
<owl:Class rdf:about="#ProblemStatement">
<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Describes the problem the M&S is expected to address. The problem statement serves as the foundation for the definition of requirements, acceptability criteria, and ultimately the accreditation assessment. It documents (1) the question(s) to be answered and the particular aspects of the problem that the M&S will be used to help address; (2) the decisions that will be made based on the M&S results; and (3) the consequences resulting from erroneous M&S outputs. MIL-STD-3022</rdfs:comment>
<rdfs:subClassOf rdf:resource="#DocumentSection"/>
</owl:Class>
<owl:Class rdf:ID="MSUser">
<rdfs:subClassOf rdf:resource="#Role"/>
<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Term used to represeent the organization, group, or person responsible for the overall application. The M&S User needs to solve a problem or make a decision and wants to use modeling or simulation to do so. The M&S User defines the requirements, establishes the criteria by which model or simulation fitness will be assessed, determines what method or methods to use, makes the accreditation decision, and ultimately accepts the results (also see M&S Application Sponsor). MIL-STD-3022</rdfs:comment>
</owl:Class>
<owl:Class rdf:ID="MilitaryDepartment">
<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">The Department of the Army, Department of the Navy, and Department of the Air Force, including their National Guard and Reserve components. MIL-STD-3022</rdfs:comment>
</owl:Class>
<owl:Class rdf:ID="BasisOfComparison">
<rdfs:subClassOf rdf:resource="#DocumentSection"/>
<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Describes the basis of comparison used for validation. The basis for comparison serves as the reference against which the accuracy of the M&S representations is measured. The basis of comparison can come in many forms, such as the results of experiments, theory developed from experiments, validated results from other M&S, and expert knowledge obtained through research or from SMEs. MIL-STD-3022</rdfs:comment>
</owl:Class>
<owl:Class rdf:ID="MSProgramManager">
<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">The individual responsiible for planning and managing resources for simulation development, directing the overall simualtion effort, and overseeing configuration management and maintenance of the simulation. In legacy simulation reuse when a major modification effort is involved, the M&S User may designate an M&S Program Manager to plan and manage that modification effort. MIL-STD-3022</rdfs:comment>
<rdfs:subClassOf rdf:resource="#Role"/>
</owl:Class>
<owl:Class rdf:about="#MSRequirementsAndAcceptabilityCriteria">
<rdfs:subClassOf rdf:resource="#DocumentSection"/>
<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Describes the M&S requirements defined for the intended use, the derived acceptability criterial that should be met to satisfy the requirements, the quantitative and qualitative metrics used to measure their success, and the order of their priority. MIL-STD-3022</rdfs:comment>
</owl:Class>
<owl:Class rdf:ID="ProgramOffice">
<rdfs:subClassOf rdf:resource="#Role"/>
</owl:Class>
<owl:Class rdf:about="#Artifact">

<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Product or outcome of a process.</rdfs:comment>
</owl:Class>
<owl:Class rdf:ID="AccreditationInformationNeeds">
<rdfs:subClassOf rdf:resource="#DocumentSection"/>
<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Describes the information needed to conduct the accreditation assessment; e.g., the information expected from the V&V effort, information expected from the development testing effort, information from the M&S developers, and information from the application. MIL-STD-3022</rdfs:comment>
</owl:Class>
<owl:Class rdf:about="#VVADocument">
<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Document artifact produced from verification, validation, or accreditation processes.</rdfs:comment>
<rdfs:subClassOf rdf:resource="#Document"/>
</owl:Class>
<owl:Class rdf:ID="Model">
<rdfs:subClassOf rdf:resource="#Artifact"/>
<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">A physical, mathematical, or otherwise logical represetnation of a system, entity, phenomenon, or process. MIL-STD-3022</rdfs:comment>
</owl:Class>
<owl:Class rdf:ID="ModelingAndSimulation">
<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">n. The discipline that comprises the development and/or use of models and simuations (DoDD 5000.59); v. The use of models and simulations, either statically or over time, to develop data as a basis for making managerial or technical decisions. This includes, but is not limited to, emulators, prototypes, simulators, and stimulators (DoDI 5000.61). From MIL-STD-3022</rdfs:comment>
<rdfs:subClassOf rdf:resource="#Domain"/>
</owl:Class>
<owl:ObjectProperty rdf:about="#hasRole">
<rdfs:domain rdf:resource="#Participant"/>
<rdfs:range rdf:resource="#Role"/>
</owl:ObjectProperty>
<owl:ObjectProperty rdf:ID="containedIn">
<rdfs:range rdf:resource="#Document"/>
<rdfs:domain rdf:resource="#DocumentSection"/>
</owl:ObjectProperty>
<owl:ObjectProperty rdf:ID="hasSubSection">
<rdfs:range rdf:resource="#DocumentSection"/>
<rdfs:domain rdf:resource="#DocumentSection"/>
</owl:ObjectProperty>
<owl:ObjectProperty rdf:ID="isProducedBy">
<owl:inverseOf>
<owl:ObjectProperty rdf:ID="produces"/>
</owl:inverseOf>
<rdfs:domain rdf:resource="#Artifact"/>
<rdfs:range rdf:resource="#Process"/>
</owl:ObjectProperty>
<owl:ObjectProperty rdf:ID="hasParticipant">
<owl:inverseOf>
<owl:ObjectProperty rdf:about="#participatesIn"/>
</owl:inverseOf>
<rdfs:domain rdf:resource="#Process"/>
<rdfs:range rdf:resource="#Participant"/>
</owl:ObjectProperty>

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        <owl:ObjectProperty rdf:about="#produces">
                <rdfs:range rdf:resource="#Artifact"/>
                <rdfs:domain rdf:resource="#Process"/>
                <owl:inverseOf rdf:resource="#isProducedBy"/>
        </owl:ObjectProperty>
        <owl:ObjectProperty rdf:about="#participatesIn">
                <owl:inverseOf rdf:resource="#hasParticipant"/>
                <rdfs:domain rdf:resource="#Participant"/>
                <rdfs:range rdf:resource="#Process"/>
        </owl:ObjectProperty>
        <owl:ObjectProperty rdf:about="#hasSection">
                <rdfs:range rdf:resource="#DocumentSection"/>
                <rdfs:domain rdf:resource="#Document"/>
        </owl:ObjectProperty>
        <owl:DatatypeProperty rdf:ID="hasSponsorPM">
                <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
                <rdfs:domain rdf:resource="#Document"/>
                <rdfs:comment
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Identification of the sponsoring organization
or program manager. MIL-STD-3022</rdfs:comment>
        </owl:DatatypeProperty>
        <owl:TransitiveProperty rdf:ID="isSubSectionOf">
                <rdfs:range rdf:resource="#DocumentSection"/>
                <rdfs:domain rdf:resource="#DocumentSection"/>
                <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#ObjectProperty"/>
        </owl:TransitiveProperty>
        <owl:FunctionalProperty rdf:ID="hasMSVersion">
                <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
                <rdfs:domain rdf:resource="#VVADocument"/>
                <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#DatatypeProperty"/>
        </owl:FunctionalProperty>
        <owl:FunctionalProperty rdf:ID="hasMSName">
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">M&amp;amp;S
name</rdfs:comment>
                <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#DatatypeProperty"/>
                <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
                <rdfs:domain rdf:resource="#VVADocument"/>
        </owl:FunctionalProperty>
        <owl:FunctionalProperty rdf:ID="hasVersion">
                <rdfs:domain rdf:resource="#Document"/>
                <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#DatatypeProperty"/>
                <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
        </owl:FunctionalProperty>
        <owl:FunctionalProperty rdf:ID="hasDate">
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Document
date.</rdfs:comment>
                <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#date"/>
                <rdfs:domain rdf:resource="#Document"/>
                <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#DatatypeProperty"/>
        </owl:FunctionalProperty>
        <owl:FunctionalProperty rdf:ID="hasTitle">
                <rdfs:domain rdf:resource="#Document"/>
                <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
                <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#DatatypeProperty"/>
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                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Document
title</rdfs:comment>
        </owl:FunctionalProperty>
        <owl:FunctionalProperty rdf:ID="hasDocumentType">
                <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#DatatypeProperty"/>
                <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Document
type (i.e., Accreditation Plan, V&amp;amp;V Plan, V&amp;amp;V Report, Accreditation Report).</rdfs:comment>
                <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
                <rdfs:domain rdf:resource="#Document"/>
        </owl:FunctionalProperty>
        <owl:FunctionalProperty rdf:ID="hasProgramProject">
                <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#DatatypeProperty"/>
                <rdfs:comment
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Identification of the program, project,
exercise, or study. MIL-STD-3022</rdfs:comment>
                <rdfs:domain rdf:resource="#Document"/>
                <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
        </owl:FunctionalProperty>
        <AccreditationAuthority rdf:ID="AccreditationAuthority_46"/>
</rdf:RDF>
```

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