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Integrated Logistics Environment (ILE) Project Final Report

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TABLE OF CONTENTS

1 Introduction

1.1 ILE Project Scope

Over the past several years the ISE Projects have been developing and prototyping tools to enable an Integrated Shipbuilding Environment (ISE). Recently the Navy Product Data Initiative (NPDI) has written a specification for the next generation Navy shipbuilding Integrated Product Data Environment (IPDE) system. These two projects are the culmination of several years of work investigating the challenge of sharing information across IPDE systems. The Integrated Logistics Environment (ILE) Project has continued these efforts by completing and validating the Ship Common Information Model (SCIM) defined by the NPDI Project.

During its first phase, the ILE Project used the tools and methods developed by the ISE Team and applied them to two current shipbuilding requirements: VIRGINIA Class IPDE data migration and the sharing of structural manufacturing work across shipyards. Moreover, this project used the NPDI Ship Common Information Model (SCIM) as the basis for these two pilots. As a result, this project not only benefitted two current Navy programs but also demonstrated the capabilities of the NPDI SCIM as the means for supporting interoperability of the next generation IPDE. The second phase of the ILE Project completed the remaining chapters of the SCIM document and updated the existing chapters to incorporate lessons learned during the validation efforts undertaken in phase one.

The ISE and NPDI Projects together comprise a body of work that has been preparing to support the next generation IPDE capabilities. Among other goals, the next generation IPDE is to support a new level of information interoperability. The ISE Projects have methodically prototyped the data sharing issues peculiar to each of the application domains pertinent to U.S. Navy shipbuilding. The NPDI and the associated SCIM task are documenting a performance and information specification for that IPDE system. One of the results of this work is the definition of the information requirements for a digital ship product model for U.S. Navy shipbuilding. These requirements are captured in the SCIM portion of the IPDE Specification. The ILE Project applied the ISE architecture and methodology to some imminent production requirements. This work has demonstrated the validity and sufficiency of the SCIM information specification. The tasks in phase one exercised the SCIM information requirements and uncovered some deficiencies that have inhibited production utility of the specification. These findings were used in phase two of the project to correct those deficiencies in the existing SCIM chapters and to complete the remaining SCIM chapters using the lessons learned from phase one.

Thus, the ILE Project addressed validation of the Ship Common Information Model (SCIM), as well as completion of this document. The end result provides a prototypical inter-enterprise interoperability infrastructure to help enable shipyard interoperability and systems integration functions across the entire ship’s life cycle.

1.2 ILE Project Participants

The Integrated Logistics Environment (ILE) Project was an NSRP ASE sponsored, industry led project. The ILE Team was led by Electric Boat Corporation (EB) with members from the following organizations:

- Huntington Ingalls Industries (HII) – Ingalls
- Huntington Ingalls Industries (HII) – Newport News
- Northrop Grumman Technical Services (NGTS)
- Product Data Services Corporation (PDSC)

1.3 Document Objective

This is the Final Report of the NSRP Project for an Integrated Logistics Environment (ILE).

The main thrust of this document is to summarize the accomplishments of this project and identify the major project deliverables and their location so the reader can obtain more detailed information if he/she desires.

The deliverables, SCIM development environment, meeting minutes, and presentations from the ILE Project are available on the ISE Tools Website at: www.isetools.org

In addition, the Ship Common Information Model (SCIM) which is the primary product of the ILE Project will be publicly available on the www.nsrp.org Website along with an executive summary in the form of a video produced by the "Panel Project Technology Transfer Templates", which was an NSRP Panel Project under the Workforce Development Panel.

2 NOMENCLATURE

2.1 Acronyms and Abbreviations

2D: Two Dimensional

3D: Three Dimensional

AP: Application Protocol

APL: Allowance Parts List

ArgoUML: ArgoUML is an UML diagramming application written in Java

ARM: Application Reference Model

ASE: Advanced Shipbuilding Enterprise program of the NSRP

CAD: Computer-Aided Design

CAE: Computer-Aided Engineering

CAM: Computer-Aided Manufacturing

CAS: Chemical Abstract Service

CATIA: Computer Aided Three-dimensional Interactive Application: It is a multi-platform CAD/CAM/CAE commercial software suite from Dassault Systemes

CDM: CATIA Data Manager

COTS: Commercial-Off-The-Shelf

CPC: Common Parts Catalog

CPP: Common Parts Procurement

CVN 21: The project name used by the U.S. Navy, its contractors, and Congress to denote the development of the next design in supercarriers

DDG 1000: USS Zumwalt (DDG-1000) is the lead ship of the Zumwalt class of guided missile destroyers

DED: Data Element Dictionary of the Common Parts Catalog

EB: Electric Boat Corporation

FEA: Finite Element Analysis

GD&T: Geometric Dimensioning and Tolerancing

HII: Huntington Ingalls Industries

HM&E: Hull, Mechanical, and Electrical

HTML: HyperText Markup Language

HVAC: Heating, Ventilation, and Air-Conditioning

ILE: Integrated Logistics Environment Project

IPDE: Integrated Product Data Environment

ISE: Integrated Shipbuilding Environment Project

ISO: International Organization for Standardization

ISPE: Integrated Steel Processing Environment Project

MACPAC: Manufacturing Resource Planning System in use at Electric Boat

NASSCO: National Steel and Shipbuilding Company

NAVSEA: Naval Sea Systems Command

NGSB-GC: Northrop Grumman Shipbuilding – Gulf Coast

As of 3/31/2011 NGSB-GC became Ingalls Shipbuilding, a Division of Huntington Ingalls Industries, Inc.

NGSB-NN: Northrop Grumman Shipbuilding – Newport News

As of 3/31/2011 NGSB-NN became Newport News Shipbuilding, a Division of Huntington Ingalls Industries, Inc.

NGTS: Northrop Grumman Technical Services

NPDI: Navy Product Data Initiative

NSRP: National Shipbuilding Research Program

NSN: National Stock Number

NX: A highly advanced CAD/CAM/CAE software package from Siemens PLM Software

PDM: Product Data Management

PDSC: Product Data Services Corporation

PEO: Program Executive Offices

PLCS: Product Life Cycle Support

PLM: Product Lifecycle Management

RFP: Request for Proposal

RPC: Remote Procedure Call

RT: SCLSIS Record Types

S1000D: International Specification for the Procurement and Production of Technical Publications

SCIM: Ship Common Information Model

SCLSIS: Ship Configuration and Logistics Support Information System

SNAME: Society of Naval Architects and Marine Engineers

SOAP: Simple Object Access Protocol

SPS: Ship Production Symposium

STEP: STandard for the Exchange of Product Model Data (ISO 10303)

TC: TeamCenter: An integrated suite of PLM applications from Siemens PLM Software

TIA: Technology Investment Agreement

UDDI: Universal Description Discovery and Integration

UML: Unified Modeling Language

UoF: Unit of Functionality

VIRGINIA: The Virginia is a class of nuclear-powered fast attack submarines in service with the United States Navy

WSDL: Web Service Definition Language

XML: Extensible Markup Language

XSLT: Extensible Stylesheet Language Transformation

XSL-FO: Extensible Stylesheet Language Formatting Objects

3 TASK 1 – TOOLS AND METHODS FOR SUPPORTING NEXT GENERATION SHIPBUILDING IPDE (SCIM EVALUATION)

Over the past several years the National Shipbuilding Research Program (NSRP) Integrated Shipbuilding Environment (ISE) Project has been developing and prototyping tools to enable interoperability among shipyard and Navy systems. Recently, a specification for the next generation Navy shipbuilding Integrated Product Data Environment (IPDE) system was written as part of the Navy Product Data Initiative (NPDI) Project. Included in the IPDE specification is the Ship Common Information Model (SCIM), an information model derived from the STEP Shipbuilding Application Protocols, which defines the minimum set of entities, attributes, and relationships required to support Navy shipbuilding data exchange requirements.

Task 1 of the Integrated Logistics Environment (ILE) Project demonstrated the capabilities of the NPDI SCIM as the means for supporting the next generation IPDE. This first phase of ILE applied the tools, methods, and information models developed by the ISE Team and the NPDI SCIM Project to two current shipbuilding requirements: VIRGINIA Class IPDE data migration (Subtask 1.1) and the sharing of structural design information with manufacturing systems across shipyards (Subtask 1.2).

3.1 Subtask 1.1- Migrating VIRGINIA Class IPDE Data

The focus of this subtask was to analyze the extraction of piping and structural data from the VIRGINIA IPDE in SCIM format.

The VIRGINIA Class submarine is in the midst of its production cycle with several more hulls pending. The current VIRGINIA Class IPDE platform is approaching its end of life and Electric Boat (EB) is in the process of implementing a new next generation IPDE. A major effort is currently underway to migrate most if not all the VIRGINIA design data from the current system to the next generation IPDE.

The VIRGINIA Class IPDE, owing to limitations in the COTS CAD/PDM tools, is a highly customized solution. Moreover, the VIRGINIA Class IPDE is a system that evolved and grew as the VIRGINIA Class design progressed and as new requirements and issues revealed themselves. As a result, the VIRGINIA product model does not possess the degree of data model integrity that is expected in a new system. Thus, the exact entities, attributes, properties, and relationships that must be migrated to the new IPDE are not obvious. Recent experience in extracting information from the system to support new manufacturing processes has revealed a number of technical questions that must be solved before a data migration can be successfully completed. Major decisions in this effort revolve around which pieces of the product model must be migrated, and how to maintain their relationships in the new system.

The SCIM is intended to provide the information requirements to guide the extraction and collection of product data and specifies the entities, attributes, and properties required for exchange in each discipline.

Unfortunately, the SCIM was not available in time to support the early efforts of VIRGINIA data migration. If the SCIM had been issued and validated before the VIRGINIA Class data migration began, the information models specified in the SCIM could have been used to help implement the change of VIRGINIA Class IPDE platforms. However, since the VIRGINIA data migration is already underway, and the SCIM was not yet completed, this task served as a means of validating several chapters of the SCIM (in particular, those dealing with piping and structural models) by evaluating how the information models specified in the SCIM support the VIRGINIA data migration effort. The task validated the thoroughness and correctness of the SCIM information requirements in these disciplines.

The task focused on the extraction of structural and piping models because these represent a major portion of the VIRGINIA product model, and because those chapters of the SCIM were already complete. Specifically, as data was pulled from the VIRGINIA Class IPDE, it was externalized in a straightforward XML mapping. This externalization was then transformed to the default SCIM representation. At this point it was possible to analyze the contents of the VIRGINIA Class IPDE extraction and the SCIM model. Any discrepancies or mismatches that were found have been resolved, and the open source SCIM model has been updated, where appropriate. It should be noted that much of this work done so far has been largely manual, consisting of a side by side comparison – since robust schema validation tools for the SCIM do not yet exist.

Potentially, this task has benefitted the VIRGINIA Class data migration efforts by revealing properties or attributes of the product model that are required to be moved to the new IPDE. However, the primary benefits of the task were in using VIRGINIA data for the validation of the information models in the SCIM. It thus used VIRGINIA as a means for verifying the ability of the SCIM to support interoperability of the next generation IPDE.

The deficiencies that were discovered in the SCIM, or difficulties in using the SCIM-specified format, were addressed during Task 2 for Completion of the Ship Common Information Model. Thus, the results of Subtask 1.1 led directly to enhancements of the SCIM as it was completed in Task 2.

3.1.1 SCIM Piping Information Model

Piping systems are used to convey and process fluids or gases within a variety of engineering products. Generally, a piping system comprises a network of pipes and piping components (fittings and valves), and is attached to processing equipment such as pressure vessels and pumps. Large piping systems are generally attached to some supporting structure through the use of pipe supports and hangers.

Four major application areas corresponding to major stages of piping product life cycle are:

- contract/functional design;
- detail design;
- production engineering;
- support engineering.

Users/developers of piping product information in these stages of product life cycle have different information requirements and views of the product. Users in the contract design stage view a piping system principally as a functional network of equipment.

Functional design stage designers see piping in much the same way but develop and use much more detailed information concerning operating states of a system, and the characteristics of sub-networks of piping within an overall system (pipelines) in terms of material specifications and flow characteristics. They also, for some systems, develop and use data concerning the loading on, and fixity of, portions of the system in order to evaluate stress levels. The functional view is typically used to identify a preliminary purchasing bill of material in which purchase specification and long lead-time equipment and components are identified. The functional design stage view is also the one which, along with contract specifications, is used in formulating and performing systems testing following installation. Because of the commonality of views in the contract and functional design stages, they can be combined into a single application area.

Detail design users have a three-dimensional arrangements view of piping. They are concerned with the arrangement in 3-D space of piping components meeting the applicable system specification and with ensuring that the arranged components are free from interference with the surrounding environment. This view of the data is also the view that typically supports the final purchasing bills of material.

Production engineering stage users are concerned with defining piping assemblies and the information needed to fabricate the pieces of these assemblies. This information can consist of bending instructions, joining instructions/specifications, and coating instructions. They also specify the installation processes to be used to install such assemblies in the final product and the post-installation tasks to be carried out. The production engineering function creates and makes use of the production bill of material view.

The piping product view taken by users in the support engineering stage is mainly that of the functional design, but from the standpoint of defining the support requirements of the product. Such requirements include spare parts complements, maintenance procedures and related documentation, and operational specifications and documentation.

3.1.1.1 Piping Physical Chapter

The Piping Physical Chapter of the SCIM focuses on the second and third of the application areas above – detail design and production engineering. It specifies the product model information needed to capture the design and facilitate the manufacturing of the piping system. Information concerning items such as operating states, material specifications, and flow characteristics are captured in the Piping Functional Chapter of the SCIM.

3.1.1.1.1 Piping Specific Geometry

Pipes are not represented using the various solid geometric entities that are permitted for components (e.g. Constructive Solid Geometry, Boundary Representation, or Wireframe). Instead, a pipe is described by a Curve representing its Centerline. The radius and wall thickness of the pipe will be provided as attributes of the pipe entity, rather than as properties of the geometric representation. This representation applies to Straight Pipes, as well as Bent Pipes, both of which have their geometry specified by the shape and parameters of their centerlines.

Pipes (and other Design_occurrences) can be placed in the ship using traditional ship reference points via the Location_in_ship application object. The Ship_item_location and Relative_item_location entities are used to position a Pipe or other Design_occurrence based on the translation and rotation of a point and set of axes, or based upon the relative position of this Design_occurrence with respect to another Design_occurrence.

A Piping_size_description is used to explain or summarize the physical size of a piping connector or a piping system component, based on a set of dimensional characteristics, and an optional dimensional standard. Each Piping_size_description is an Inside_and_thickness, an Outside_and_thickness, a Pressure_class, or a Schedule.

Piping components (as opposed to Pipe) are located within the ship by a combination of the Standard_point, Global_axis_placement, Location_in_ship, and Local_co_ordinate_system entities. The Standard_point specifies an x, y, z coordinate position on the generic part defined for the component that will position the instance of the component in the ship.

A Global_axis_placement defines a fixed system of right handed orthogonal axes to which geometric data are referred. A Global_axis_placement shall have a positive Z-axis in an upwards direction starting from the base of the ship and a positive X-axis running along the ship on the intersection of the centerline with the base. In one case it is directed from the after part of the ship to the forward part of the ship and in the other it is directed from the forward part of the ship to the after part of the ship. The origin of the Global_axis_placement can be any point on the X-axis. The distance of the after perpendicular from the origin and the orientation of the X-axis shall be specified. If any other system of axes is used, local or global, then the transformation relations between it and the Global_axis_placement shall be specified.

A Local_co_ordinate_system is used to locate an object in space. A Local_co_ordinate_system is always defined with respect to another coordinate system. This might be a Global_axis_placement or another Local_co_ordinate_system that is a member in the same hierarchy.

The location_and_orientation specifies the relative position and orientation of the Design_occurrence within the Ship.

3.1.1.2 Piping Functional Chapter

The Piping Functional Chapter of the SCIM is designed to capture the connectivity and logical structure of a 2D representation of a piping system. It focuses on the first and fourth of the application areas above – contract/functional design and support engineering. It specifies information concerning items such as operating states, material specifications, and flow characteristics.

The piping functional configuration entails connectivity, sequencing, component size, and schedule, and may include other information, such as equipment tag numbers and requirements to perform consistency checks between the functional and physical representations of the design. This data will include:

- basic engineering data as needed for spatial layout and configuration of systems
- references to functional requirements of piping systems, such as stream data and operational characteristics
- references to or designation of functional characteristics of components and connected equipment as required for system design

The SCIM chapter on Piping Functional describes the functional connectivity of a piping system and the functional connectivity among objects in that system. It provides the information that describes the functional links and properties of a flow stream in a piping system. It includes information about the segments in the line and the specifications for these segments, such as design criteria, service conditions, and line identifier.

3.1.1.2.1 Functional Instances

Several entities in this chapter of the SCIM have the suffix “functional” attached. In those cases, the entity represents an instance of this item in a 2D representation, rather than the detailed 3D description provided in the design occurrence. For example, as quoted in the SCIM XML: “The Piping_system_component-functional represents an instance of the Piping_system_component in a 2D model.”

In general, “functional” is a descriptive adjective that, when applied to an item, refers to the actions, activities, or capabilities, that the item provides or may provide to fulfill a purpose.

The functional configuration entails connectivity, sequencing, component size, and schedule, and may include other information, such as equipment tag numbers and requirements to perform consistency checks between the functional and physical representations of the design.

One should note that a functional connection can exist between two items without a physical joining of the items.

3.1.1.3 PDM Chapter

The purpose, the only purpose, of the shipbuilding Integrated Product Data Environment (IPDE) is to create and manage a digital ship product model. The ship product model is broader than some may expect, encompassing not just the ship design but also the catalogs of parts that support the design, the planning, manufacturing and testing information to realize the design, the engineering models to analyze the design, and the logistics models to support and maintain the ship itself. The ship product model is not a single monolith. It spans the aforementioned life cycle stages and resides in a number of different (though interconnected) systems, applications, and data repositories. These various systems, while managing distinct aspects of the product, depend upon information in other portions of the IPDE, and the product model itself must behave as if it is managed on one logical repository. This is necessary so that the items of the product model are available for re-use, for sharing, for collaboration, and for internal consistency. Across the life cycle stages, the representations of many items evolve, and the IPDE must be able to maintain the proper associations not just between the progress stages of each item, but also between items and the data objects that define their properties, and between items and the other items they depend upon.

Many of the properties and associations captured in particular application systems are unique to a single application domain; however, as a result of the need for integration within the model, there are some elements of the product model that are common and generic. The PDM Chapter of the SCIM defines those common elements. Technically, many of the entities defined in this section are the abstract supertypes of the items that are more specifically defined in each application domain.

The PDM Chapter (also known as the PLM Core) entities are abstract in that they appear in the ship product model only as instances of the more specialized application specific types. The purpose of an abstract supertype is to collect data that is common to all its more specific subtypes. In the case of the PLM Core that data is concerned primarily with configuration management, a requirement that befalls all the items in the ship product model - irrespective of life cycle stage or application domain. Configuration management is comprised of a number of facets: one is the ability to create and manage versions of items within the ship product model. This capability applies across the entire product model. A second fact relates to the effectivity of items, which in the shipbuilding world is treated as hull applicability. The PLM Core defines the entities by which each item in the ship product model is applicable to certain hulls or a certain class of hulls. This capability preponderates in the design stage, but it appears in other stages as well.

Finally, there has traditionally been a practice of associating certain metadata with items in the ship product model. In the early PDM systems, this metadata consisted of properties, such as author, creation date, etc., which were tied to the models or files managed by the PDM system. In today's PLM approach, this metadata is tied to particular items within the product model. The PLM Core metadata properties include approval data, the association of documents to items in the product model, certification, and contract references. The PLM Core also describes how product model items are to be linked to various geometric representations of shape. Finally, the PLM Core defines the high level means to define collections or aggregations of items. These aggregations may be hierarchical (as for a product structure or indented bill of material), or they may be unordered (as a for a model's worth of items).

3.1.2 Piping Information Model Developed for VIRGINIA Migration

3.1.2.1 Submarine Data Migration Task at Electric Boat

At Electric Boat, the Submarine Data Migration Task exists because EB’s CATIA-based Integrated Product Development Environment (IPDE) will become unsupported and must be retired in the 2013 timeframe, and submarine product model data managed in that system will need to be migrated to the new IPDE system before that time. Prior to that, this task will determine the best balance between automated and manual techniques to ensure a cost-effective and reliable migration. This task will also make decisions regarding the out-sourcing or in-sourcing of various tools to be used in the effort.

Submarine product model data consists of geometric data and attribute data. By and large, the geometric data is processed by a CAD system and the attribute data with a database management system (although there are exceptions to this parceling). The VIRGINIA Class IPDE uses the CATIA Data Manager (CDM) to manage its attribute data and CATIA V4 to process its geometric data. The next-generation IPDE uses Siemens' TeamCenter (TC) to manage its attribute data and NX to process its geometric data.

The VIRGINIA Class IPDE is the source of data for and/or integrates with a number of other systems, including parts management (CPC), scheduling (Artemis), manufacturing resource planning (MACPAC), and various manufacturing execution systems. Data migration from the VIRGINIA Class IPDE to the new IPDE must be timed so that downstream and integrated applications will be ready by 2013 to receive data from the new IPDE.

EB's CATIA-based Integrated Product Development Environment (IPDE) is the vehicle for the creation and management of a digital product model of the VIRGINIA Class submarine. The digital product model is an artifact that consists solely of data; the Submarine Data Migration project will extract, transform, and load that product model data into the next-generation IPDE system so that the functionality of the new IPDE can be used to process VIRGINIA Class design data after the current IPDE is retired. The VIRGINIA Class product model is comprised of two distinct categories of data: the geometric (or CAD) data and the attribute (or tabular) data. The task will migrate both categories of VIRGINIA Class piping product data.

3.1.2.2 Structure of the VIRGINIA Piping Migration Model

The VIRGINIA piping migration model was designed to capture the information needed for the data migration from the CATIA/CDM system to NX/TeamCenter. It was not based on general industry or surface ship requirements, and therefore was not intended to be as complete as the SCIM piping model. The attributes associated with any entity tended to be those stored in the CATIA Data Manager (CDM) database as it is used at Electric Boat, rather than being based on abstract properties of a theoretical piping CAD system.

3.1.2.3 Significant Differences from the SCIM Model

The VIRGINIA migration model is not broken down by Piping Physical, Piping Functional, and PDM. Instead, it consists of one model incorporating the essential features of all these chapters that were deemed needed for VIRGINIA migration efforts.

Attributes were placed in the SCIM generally because that information was required in order to model the piping system. On the other hand, as stated above, attributes were added to the VIRGINIA piping migration model when that data was loaded into the CATIA/CDM system. Thus, a given attribute which might be required (and therefore included in the SCIM), but could be derived or deduced from other data in CDM, would thus not be included in the VIRGINIA piping migration model.

All aspects of the migration have not yet been addressed, so the VIRGINIA migration model is not complete. In particular, Piping Supports have not yet been modeled, even though they are addressed in the Piping chapters of the SCIM.

In support of and as part of the requirements definition for the Submarine Data Migration Task, a set of assumptions has been established. The purpose of the assumptions is to present an accurate level of expectations and, in particular, to note technical and/or procedural constraints that may curtail some expectations. A deliverable of the project will be the documentation of the strategic assumptions. In general, these assumptions do not apply to the SCIM piping information model, since the SCIM is designed to provide a mechanism for transfer of all the product data including GD&T, to handle hull-specific as-designed product data, and to permit two way transfers. Thus, the unique requirements for the VIRGINIA migration piping model have caused some distinct differences between that and the SCIM model.

3.1.3 Comparison of Piping Information Models

3.1.3.1 Enhancements Needed to VIRGINIA Piping Migration Model

As was discussed above in Section 3.1.2, the VIRGINIA piping migration model was established with a very different set of goals than the SCIM, which inevitably caused differences in the structure of the two models. However, in the course of performing Subtask 1.1 for Migrating VIRGINIA Class IPDE Data, comparison with the SCIM revealed some deficiencies in the VIRGINIA piping migration model.

Thus, although the primary goal of this task was to evaluate and improve the SCIM, an ancillary benefit is enhancements determined for the VIRGINIA piping migration model. Since the Submarine Data Migration Task will be active for several years, it is anticipated that further enhancements will continue to be identified for the VIRGINIA piping migration model and possibly for the SCIM.

The following modifications have been made to the VIRGINIA piping migration model as a result of the analysis conducted during the ILE Project:

- The structure and association of parts has been adjusted in both the SCIM and the VIRGINIA piping migration model to better reflect the relationships between parts in a catalog versus particular instances of parts in a design. An entity to describe parts that was called Cpc_design_part has been replaced by a structure of entities called Catalog_part, Design_part, Generic_part, and Master_part_definition with both Design_part and Catalog_part being subtypes of Generic_part, and Design_part having an association with Catalog_part and Master_part_definition. All properties and entities required for the part were assigned to the appropriate entity based on whether they applied to the catalog representation of the part, or were properties of a particular instance of that part.
- Along with this new part structure, the association between Design_occurrence and Design_part was replaced by an association between Design_occurrence and Generic_part.
- Several attributes referring to class, version, or owner_id for a part were removed from the VIRGINIA piping migration model as this migration is designed to transfer only the latest model, and not track a historical record of previous revisions or applicablilites.
- Several "make from" relationships extracted from the CDM database, which were tied to the Design_occurrence entity, have been moved to Design_part as they are properties of the part and not the particular instance.
- An attribute was added to the entity for Design_occurrence_definition to permit a pointer to related documents. This capability was originally available in the SCIM under the entity for Pdm_design_definition, but was not provided in the VIRGINIA piping migration model.
- An attribute to capture the Paint Schedule for a part was also added to the Piping_design_occurrence_definition. This requirement from the data migration effort was previously missing from both the SCIM and the VIRGINIA piping migration models.

3.1.3.2 Modifications Needed in SCIM

The information model in the SCIM to represent piping systems involves entities, attributes, and properties from three different chapters within the SCIM:

- Product Data Management (PDM)
- Piping Physical
- Piping Functional

The ILE Subtask for Migrating VIRGINIA Class IPDE Data is analyzing all of the piping data that needs to be migrated, no matter which of the SCIM chapters is required to represent it. Examination began with the representation in the SCIM PDM Chapter and then proceeded to review the modeling in the Piping Physical Chapter. Only minimal attention is being paid to the Piping Functional Chapter, as the piping migration is focusing on the 3D product model, rather than the 2D representation of the piping system. The VIRGINIA Piping Migration and its comparison to the SCIM will be an ongoing effort throughout the course of the ILE Project, and all proposed revisions to the SCIM will be recorded during this project, and then delivered with the revised SCIM documents at the end of the two year ILE effort.

3.1.3.2.1 Product Data Management Chapter (PDM)

The most significant change to the structure and association of parts in the PDM Chapter is similar to the one described above for the VIRGINIA piping migration model. In order to better reflect the relationships between parts in a catalog versus particular instances of parts in a design, an entity to describe parts that was called Cpc_design_part has been replaced the entities called Catalog_part and Design_part which are both subtypes of Generic_part, and Design_part having an association with Catalog_part and also to Design_part_definition. All properties and entities required for the part were assigned to the appropriate entity based on whether they applied to the catalog representation of the part, or were properties of a particular instance of that part.

Other changes reflected an improved method for the SCIM to capture change and revision information as well as an expansion of the attributes attached to a given part to better reflect all of the properties that were required for the VIRGINIA piping migration.

3.1.3.2.2 Piping Physical Chapter

A significant change was made to the structure of the items in the Piping Physical Chapter. This chapter contained itemized entities to indicate the possible fitting types, flange types, connector types, etc. Since the permitted types of these entities are already specified in the Common Parts Procurement (CPP) Chapter of the SCIM, it was decided that the Piping Physical Chapter should not repeat these lists, but instead should reference the CPP Chapter for applicable types, and then specify the acceptable attributes for each particular type. Matrices were inserted in this chapter of the SCIM to indicate the possible attributes of fittings, flanges, etc. and which ones apply to each particular type.

3.1.3.2.2.1 Pipes and Piping Parts

The change described above made to the PDM Chapter and the VIRGINIA piping migration model to replace the Cpc_design_part entity was also implemented in the Piping Physical Chapter of the SCIM. In order to better reflect the relationships between parts in a catalog versus particular instances of parts in a design, the entity to describe parts that was called Cpc_design_part has been replaced by a structure of entities called Catalog_part, Design_part, and Generic_part with both Design_part and Catalog_part being subtypes of Generic_part, and Design_part having an association with Catalog_part and also to Design_part_definition. All properties and entities required for the part were assigned to the appropriate entity based on whether they applied to the catalog representation of the part, or were properties of a particular instance of that part.

In conjunction with the above change, Piping_system_component_part was made a subtype of Design_part, not Generic_part.

To permit the description of distance required on a pipe for Clamping or Fitup, an attribute called Additional_length_code has been added to the Design_occurrence entity.

The attributes for End_to_end_cut_length and End_to_end_cut_length_unit have been moved to the Pipe_part entity rather than the Straight_pipe_entity.

In the entity for Pipe_part, a property was added for Min_allowable_wall and its Unit of measure.

The entities for Schedule, Inside_and_outside_thickness, and Pressure_class will be moved out of the Piping Physical Chapter and placed in the Common Parts Procurement Chapter of the SCIM.

In the entity for Pipe_size_description, the property for Dimensional_standard will also be moved to the Common Parts Procurement Chapter.

An association was added from Pipe_instance to Pipe_instance_centerline.

3.1.3.2.2.2 Connections and Ports

The philosophy discussed above of referencing the CPP Chapter (rather than including lists for all possible types in the Piping Physical Chapter) will cause significant changes in the handling of connections and ports in the SCIM.

The current SCIM has an entity for Piping_connector with subtypes of the many possible connector types. This will be replaced by an entity called Port_physical with a property called Port_type. The Port_type property will then have an enumerated list of possible values that correspond to the subtypes of connectors. This method of handling connectors was instituted in the Piping Data Migration Project, and is an improvement over the structure in the SCIM.

The entity for Piping_physical_connector will be replaced by an entity for Port_physical_occurrence which will be pointed to by Piping_connection and will in turn point to Port_physical.

In a similar manner, the entity for Connector_definition now has subtypes of the many different types of connectors. These subtypes will be removed and replaced by a property for Connector_definition_type which will contain an enumerated list of the possible connector types.

A matrix will be created and added to the SCIM relating Port_type to Attribute which will indicate which attributes apply to which port types.

3.1.4 SCIM Structural Information Model

The SCIM provides an information model for the computer-interpretable representation of product information and for the exchange of product data. The objective is to provide a neutral mechanism capable of describing products throughout their life cycle. This mechanism is suitable not only for neutral file exchange, but also as a basis for implementing and sharing product databases, and as a basis for archiving.

3.1.4.1 Structural Detailed Design Chapter

The Structural Detailed Design Chapter of the SCIM specifies an information model and schema for the exchange of product data representing the definition of ship structures and its related data. It defines the context, scope and information requirements for the communication of ship structural data and specifies the integrated resources necessary to satisfy these requirements.

These data may need to be exchanged or shared between different organizations. Such organizations include ship owners, ship classification societies, design agencies and fabricators. This chapter of the SCIM has been developed to support the shipbuilding activities and computer applications associated with the pre-design, the main design, the manufacturing, the maintenance (repair), and the inspection and survey during operation life cycle phases for commercial or naval ships.

The Structural Detailed Design Chapter of the SCIM supports the exchange and sharing of ship structures data. It has been developed in conjunction with other chapters so that important shipbuilding concepts are common and interoperable within the SCIM chapters. The ship structures product model provides a set of subtypes of item for describing the ship structures which are listed in Figure 1 below. It includes ship, parts as well as their connections, systems, assemblies and hull_cross_sections as they are the essential subtypes employed in this chapter.

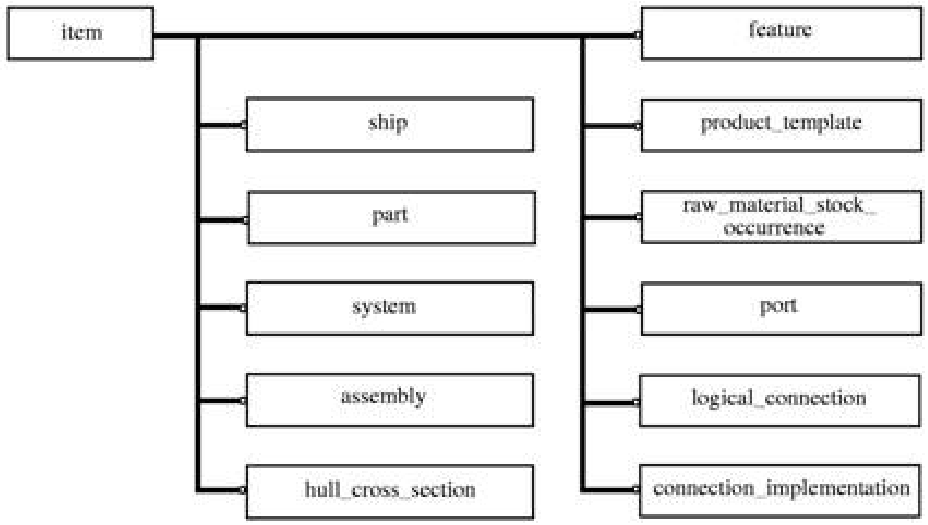

Figure 1 - Subtypes of Items for Ship Structures

This chapter of the SCIM is derived from ISO 10303-218: Application Protocol - Ship Structures. In ISO 10303-218, the schema for defining detailed design and manufacturing information is based on the definition and relationship of three main types of entities: items, design definitions, and manufacturing definitions. Items represent individual instances of elements within a structural envelope. Types of items in a structural model include structural parts (e.g., plates, profiles, assemblies) and structural features (e.g., weld/fabrication information, internal/edge cutouts). Design definition data captures all the information necessary for the complete definition of the structural components of a ship. In a feature-based design, structural features, such as interior and edge cutouts and preparations, are defined parametrically and associated to their corresponding design items. For example, a center location and radius parametrically define a circular hole, and profile cross-section dimensions parametrically define a stiffener penetration along the plate's edge. In the case of the design definition, each of these feature's geometric representation are independently referenceable within the SCIM data. Instances of like features are derived from a common source thus simplifying the geometry model and making it possible to utilize feature libraries, which allow a single geometry representation to be shared across various design elements. Also, defining individual features in a model allows them to be further characterized by their function.

3.1.4.2 PDM Chapter

The Structural Information Model also references the PDM Chapter of the SCIM (as does the Piping Information Model). Background information on the PDM Chapter is provided in Sections 3.1.1.3 and 4.2.4.

3.1.5 Structural Information Model Developed for VIRGINIA Migration

3.1.5.1 Submarine Data Migration Task at Electric Boat

The data migration task for structures is following the same basic tenets as the Piping Data Migration Task, so the descriptions in Section 3.1.2.1 apply to this application also.

3.1.5.2 Structure of the VIRGINIA Structural Migration Model

The VIRGINIA structural migration model was designed to capture the information needed for the data migration from the CATIA/CDM system to NX/TeamCenter. It was not based on general industry or surface ship requirements, and therefore was not intended to be as complete as the SCIM structural model. The attributes associated with any entity tended to be those stored in the CATIA Data Manager (CDM) database as it is used at Electric Boat, rather than being based on abstract properties of a theoretical structural CAD system.

3.1.5.3 Significant Differences from the SCIM Model

The VIRGINIA migration model is not broken down into Structural Detailed Design and PDM, as is the SCIM. Instead, it consists of one model incorporating the essential features of both of these chapters that were deemed needed for VIRGINIA migration efforts.

Attributes were placed in the SCIM generally because that information was required in order to model the structural system. On the other hand, as stated above, attributes were added to the VIRGINIA structural migration model when that data was loaded into the CATIA/CDM system. Thus, a given attribute which might be required (and therefore included in the SCIM), but could be derived or deduced from other data in CDM, would thus not be included in the VIRGINIA structural migration model.

All aspects of the migration have not yet been addressed, so the VIRGINIA migration model is not complete. In particular, all the requirements for areas such as welding or lofting have not yet been modeled. Therefore, this validation task will focus on the entities, properties, and attributes that are currently in the structural migration model, and are captured in the Structural Detailed Design and PDM Chapters of the SCIM.

In support of and as part of the requirements definition for the Submarine Data Migration Task, a set of assumptions has been established. The purpose of the assumptions is to present an accurate level of expectations and, in particular, to note technical and/or procedural constraints that may curtail some expectations. A deliverable of the project will be the documentation of the strategic assumptions. In general, these assumptions do not apply to the SCIM structural information model, since the SCIM is designed to provide a mechanism for transfer of all the product data including GD&T, to handle hull-specific as-designed product data, and to permit two way transfers. Also, the VIRGINIA structural migration model focuses on those parts required for submarines, and does not include many specific types of structural parts that are required only for surface ships which are defined in the SCIM. Thus, the unique requirements for the VIRGINIA structural migration model have caused some distinct differences between that and the SCIM model.

3.1.6 Comparison of Structural Information Models

3.1.6.1 Enhancements Needed to VIRGINIA Structural Migration Model

As was discussed above in Section 3.1.5, the VIRGINIA structural migration model was established with a very different set of goals than the SCIM, which inevitably caused differences in the content of the two models. However, in the course of performing Subtask 1.1 for Migrating VIRGINIA Class IPDE Data, comparison with the SCIM revealed some deficiencies in the VIRGINIA structural migration model.

Thus, although the primary goal of this task was to evaluate and improve the SCIM, an ancillary benefit is enhancements determined for the VIRGINIA structural migration model. Since the Submarine Data Migration Task will be active for several years, it is anticipated that further enhancements will continue to be identified for the VIRGINIA structural migration model and possibly for the SCIM.

The following modifications have been made to the VIRGINIA structural migration model as a result of the analysis conducted during the ILE Project:

- The structure and association of parts has been adjusted in both the SCIM and the VIRGINIA structural migration model to better reflect the relationships between parts in a catalog versus particular instances of parts in a design. An entity to describe parts that was called Cpc_design_part has been replaced by a structure of entities called Catalog_part, Design_part, Generic_part, and Master_part_definition with both Design_part and Catalog_part being subtypes of Generic_part, and Design_part having an association with Catalog_part and Master_part_definition. All properties and entities required for the part were assigned to the appropriate entity based on whether they applied to the catalog representation of the part, or were properties of a particular instance of that part.
- Along with this new part structure, the association between Design_occurrence and Design_part was replaced by an association between Design_occurrence and Generic_part.
- Several attributes referring to class, version, or owner_id for a part were removed from the VIRGINIA structural migration model as this migration is designed to transfer only the latest model, and not track a historical record of previous revisions or applicablilites.
- Several "make from" relationships extracted from the CDM database, which were tied to the Design_occurrence entity, have been moved to Design_part as they are properties of the part and not the particular instance.
- An attribute was added to the entity for Design_occurrence_definition to permit a pointer to related documents. This capability was originally available in the SCIM under the entity for Pdm_design_definition, but was not provided in the VIRGINIA structural migration model.
- Several attributes were identified that are needed in the SCIM to define items such as Paint Schedule, Cut Lengths for Lofting, etc. These attributes which are required for structural manufacturing have been added to the Structural Detailed Design Chapter of the SCIM.

3.1.6.2 Modifications Needed in SCIM

The information model in the SCIM to represent structural systems involves entities, attributes, and properties from two different chapters within the SCIM:

- Product Data Management (PDM)
- Structural Detailed Design

The ILE Subtask for Migrating VIRGINIA Class IPDE Data is analyzing all of the structural data that needs to be migrated, no matter which of the SCIM chapters is required to represent it. Examination began with the representation in the SCIM PDM Chapter and then proceeded to review the modeling in the Structural Detailed Design Chapter. The VIRGINIA structural migration and its comparison to the SCIM was an ongoing effort throughout the course of the ILE Project, and all proposed revisions to the SCIM were recorded during this project, and then delivered with the revised SCIM documents at the end of the two year ILE effort.

3.1.6.2.1 Product Data Management Chapter (PDM)

The most significant change to the structure and association of parts in the PDM Chapter is similar to the one described above for the VIRGINIA structural migration model. In order to better reflect the relationships between parts in a catalog versus particular instances of parts in a design, an entity to describe parts that was called Cpc_design_part has been replaced the entities called Catalog_part and Design_part which are both subtypes of Generic_part, and Design_part having an association with Catalog_part and also to Design_part_definition. All properties and entities required for the part were assigned to the appropriate entity based on whether they applied to the catalog representation of the part, or were properties of a particular instance of that part.

Other changes reflected an improved method for the SCIM to capture change and revision information as well as an expansion of the attributes attached to a given part to better reflect all of the properties that were required for the VIRGINIA structural migration.

3.1.6.2.2 Structural Detailed Design Chapter

The change described above made to the PDM Chapter and the VIRGINIA structural migration model to replace the Cpc_design_part entity was also implemented in the Structural Detailed Design Chapter of the SCIM. In order to better reflect the relationships between parts in a catalog versus particular instances of parts in a design, the entity to describe parts that was called Cpc_design_part has been replaced by a structure of entities called Catalog_part, Design_part, and Generic_part with both Design_part and Catalog_part being subtypes of Generic_part, and Design_part having an association with Catalog_part and also to Design_part_definition. All properties and entities required for the part were assigned to the appropriate entity based on whether they applied to the catalog representation of the part, or were properties of a particular instance of that part.

A significant difference in the construction of the VIRGINIA structural migration model vs. the SCIM Structural Detailed Design Chapter results from the fact that the VIRGINIA Data Migration Project focuses on those parts required for submarines, and does not include many specific types of structural parts which are defined in the SCIM but are required only for surface ships. Thus, the unique requirements for the VIRGINIA structural migration model have caused some distinct differences between that and the SCIM model.

In particular, the SCIM model defines an entity called “Feature_design_definition” with subtypes that explicitly cite various types of structural parts and their properties and attributes. Although some of these subtyped parts are used on submarines, their prevalence and variety is much less extensive than those used in the design and construction of surface ships for the U.S. Navy, and, consequently these multiple type of features were not treated as explicit entities in the VIRGINIA structural migration data model. This does not reduce the requirement for these subtypes in the SCIM, but decreases the ability to validate that portion of the SCIM based on the VIRGINIA data migration.

Among these subtypes of the “Feature_design_definition” entity in the SCIM are:

- Corner_cutout_design_definition
- Round_corner__design_definition
- Inward_round_corner_design_definition
- Outward_round_corner_design_definition
- Bevel_design_definition
- Shear_bevel_design_definition
- Rectangular_corner_cutback_design_definition
- Edge_cutout_design_definition
- Drain_hole_cutout_design_definition
- Interior_cutout_design_definition
- Free_form_interior_cutout_design_definition
- Circular_cutout_design_definition
- Elliptical_cutout_design_definition
- Elongated_oval_cutout_design_definition
- Rectangular_cutout_design_definition
- Round_corner_rectangular_cutout_design_definition
- Round_edge_rectangular_cutout_design_definition
- Triangular_cutout_design_definition

- Position_feature_design_definition
- Seam_design_definition
- Structural_added_material_feature_design_definition

3.1.6.2.3 Structural Manufacturing Chapter

The chapter of the SCIM on Structural Detailed Design is derived from ISO 10303-218: Application Protocol - Ship Structures. In ISO 10303-218, the schema for defining detailed design and manufacturing information is based on the definition and relationship of three main types of entities: items, design definitions, and manufacturing definitions. In the chapter of the SCIM for Structural Detailed Design, the manufacturing definitions are not included; they will be specified in a later chapter of the SCIM.

Thus, the plans for the SCIM included developing a separate chapter to define the entities, properties, and attributes needed for an exchange to support Structural Manufacturing. In some of the proposals for the SCIM, this was identified as the chapter for "Structural CAM".

In developing the VIRGINIA structural migration model, it was decided not to separate design and manufacturing requirements, and to include entities supporting either activity in one model. Analysis of this model reveals that the number of entities needed just to support manufacturing is not very large, and many of the entities needed to support manufacturing are also required in a detailed design model.

The STEP Application Protocol from which the SCIM is derived (ISO 10303-218: Application Protocol - Ship Structures) also does not separate design and manufacturing requirements into separate documents.

A separate SCIM Structural Manufacturing Chapter would of necessity duplicate many entities from the PDM and Structural Detailed Design Chapters, without developing many new entities.

Therefore, as a result of Subtask 1.1 of the ILE Project, it was recommended that the philosophy used for ISO 10303-218 and the VIRGINIA structural migration model be followed in completing the SCIM, and that the SCIM chapter for Structural Detailed Design be expanded to include manufacturing entities, rather than developing a separate SCIM chapter to support manufacturing alone.

This philosophy was adopted by the ILE Team, and the SCIM chapter for Structural Detailed Design has been expanded to include manufacturing entities.

3.2 Subtask 1.2 – Sharing Structural Design Data with Manufacturing Systems across Shipyards

Subtask 1.2 of ILE Phase 1 focused on the requirements for sharing structural design information with manufacturing systems across shipyards. The scenario of efficiently exchanging ship product data from design to manufacturing, whether it is within the same shipyard or between two shipyards, has repeated itself time and again in recent years. Historically, the shipyards have not had a viable method for importing structural design data from one shipyard into the manufacturing system of another shipyard. In addition, there are currently very few, if any, systems in place to translate design data to the manufacturing systems of other yards.

Subtask 1.2 addressed the exchange of structural design data from the prime designer to a manufacturing yard, either within the same shipyard or in a second shipyard, and analyzed whether the SCIM provides a sufficient data model to facilitate this exchange. The approach for this task was to define the data model for the exchange of structural design data with manufacturing using existing programs as examples, compare the data model to the SCIM data model, identify gaps in the SCIM data model, and make recommendations for improving the SCIM. These tasks were documented in three deliverables:

- Structural Model Import Requirements Report
- SCIM Gap Analysis Report
- Final Dataset Results Report

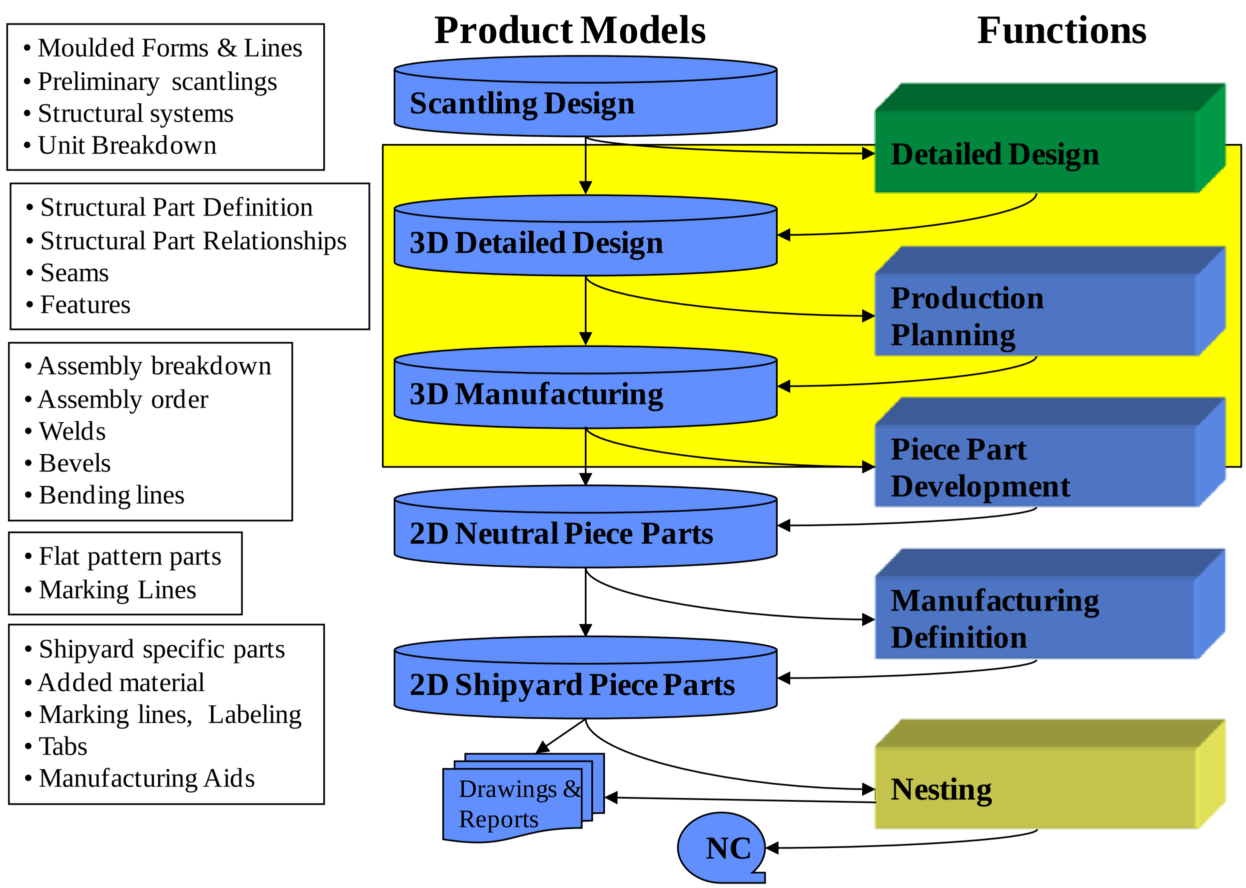

Figure 2 - Shipbuilding Product Models

The structural design data required by manufacturing was identified using the work of the NSRP Integrated Steel Processing Environment (ISPE) Project and example data for the CVN 21 and DDG 1000 programs. These requirements are documented in the first deliverable for the ILE Project, Structural Model Import Requirements

The gaps identified between the structural design data requirements and the SCIM are documented in the second deliverable for the project, Structural Model Gap Analysis

Figure 2 above depicts a notional set of product models in the center, their general content on the left, and the functions which produce or consume the data in the various product models on the right. The focus of this task was on the exchange of the Design Product Model with manufacturing in order to perform the production planning function and develop the 3D Manufacturing Product Model (indicated by the yellow box). This information was compared to the SCIM Structural Design Chapter to validate the SCIM content for meeting the design to manufacturing data exchange requirements.

3.2.1 Assumptions

The following assumptions are made regarding the scope of this effort:

- The Shipyard Common Process Model developed previously for the NSRP Integrated Steel Processing Environment (ISPE) Project is still an accurate high level depiction of the shipyard design and manufacturing processes
- While internal processes and systems may be different within different shipyards, a similar set of design data is required to perform the manufacturing functions

- This effort was focused on common 3D Detailed Design Product Model and 3D Manufacturing Product Model, not specific data required to feed shipyard-specific manufacturing tools

3.2.2 Gap Analysis Approach

This section describes the approach for performing the gap analysis between the structural model exchange requirements, identified in the Structural Model Import Requirements Report, and the SCIM Structural Design Chapter. The detailed results of the gap analysis are described in Section 3.2.3.

3.2.2.1 Data

Three primary sets of data were used to perform the analysis. The first set of data was from the NSRP Integrated Steel Processing Environment (ISPE) Project. The ISPE Project documented a set of common processes and data for the development and exchange of structural design and manufacturing information across several shipyards including NGSB-GC (Avondale and Ingalls), NGSB-NN, and General Dynamics Electric Boat. This information is documented in the ISPE Shipyard Requirements Final Report. Of course, since the publishing of the ISPE Report, the shipyard's names have changed to HII – Ingalls and HII – Newport News.

The second set of data was from the DDG 1000 program, specifically the design data being transferred from CATIA V5 to TeamCenter Enterprise and the data planned for transfer from TeamcCnter Enterprise to TeamCenter Manufacturing to support the Manufacturing Planning process.

The third set of data was from the CVN 21 program. This data included the product model data for Design, Manufacturing, and Planning as well as sample entities and attributes from the CATIA V4 design tool.

This data is described in the first project deliverable, Structural Model Import Requirements.

3.2.2.2 Analysis Approach

The overall approach to the SCIM gap analysis was to understand the current content of the SCIM AP 218 Chapter, analyze and organize the data obtained for DDG 1000 and CVN 21 to facilitate an orderly comparison with the SCIM, and then perform mappings between the project data and the SCIM data to identify any gaps in the SCIM data.

An initial analysis was performed to obtain an understanding of the derivation of the SCIM AP 218 data entities and attributes relative to the AP 218 Application Reference Model (ARM) and several context schemas developed on the ISE-4 Project for structural features, lofting, and manufacturing. This analysis highlighted entities not included in the SCIM AP 218 Chapter and reasons for their exclusion. It also provided a baseline understanding of the SCIM AP 218 data from which further analysis and mapping could be performed.

The structural design data obtained from the DDG 1000 and CVN 21 Projects were analyzed to understand the information and organize it in a way that would facilitate comparison with the SCIM data. An initial attempt to organize the data according to the ISPE common data organization revealed that this approach would not facilitate direct comparison to the SCIM. Because of this, a decision was made to organize the data according to the main structural entities defined in the SCIM: structural systems/assemblies, plates, and profiles. Once the data was organized in this manner, a mapping was performed between the project data and the SCIM.

An analysis was also performed on the ISPE common data requirements to understand this information and assess its applicability to the current SCIM validation effort. It was determined that the common processes and data described in the ISPE final report were still representative of the shipyard processes and data requirements, making this another good source of information for comparison to the SCIM. The common entities and attributes identified in the ISPE Project were mapped to the SCIM to identify potential gaps in the SCIM data.

3.2.3 Gap Analysis Results

3.2.3.1 ISPE Common Data Mapping to SCIM

The ISPE Project defined a set of common data requirements including the following information:

- Entity Categories
- Attribute Categories
- Attribute Names
- Entity Relationship Diagram

The Gap analysis results section of the ILE Project Phase 1 Final Report includes an extensive set of tables which together provide a mapping of ISPE common data requirements to the SCIM and identifies gaps. Included in that report are tables of "ISPE Build Tree Mapping to SCIM", "ISPE Component Entity Mapping to SCIM", "ISPE Part Entity Mapping to SCIM", and "ISPE Common Attribute Mapping to SCIM".

3.2.3.2 Mapping to SCIM

Section 4.2 of the ILE Project Phase 1 Final Report provides a mapping of sample structural design data to the SCIM and identifies gaps. A detailed mapping of NGSB-NN CATIA data to SCIM is provided in an Excel spreadsheet in that report. The spreadsheet also includes a mapping of ISPE Common Data to SCIM as well as a summary of the gaps and discussions and recommendations from the 11 January 2011 ILE team meeting in Norfolk, VA. A detailed README tab is also included which describes the contents of the spreadsheet.

3.2.3.3 SCIM Structural Model Gap Summary

Section 4.3 of the ILE Project Phase 1 Final Report provides a summary of the SCIM Structural Model Gaps identified in this analysis, along with recommended changes to the SCIM Structural Design Chapter. This section also included a recommended final disposition of the gaps which was used to guide the development of this chapter in Phase 2 of the ILE Project.

3.2.4 Issues and Resolutions

The gaps identified in Subtask 1.2 were used as the basis for the enhancements to the Structural Detailed Design Chapter of the SCIM which were made during Phase 2 of the ILE Project.

In general, Subtask 1.2 identified numerous issues for the SCIM and made recommendations for their resolution. These improvements were incorporated during the rewrite of the SCIM that occurred during Phase 2 of the ILE Project.

4 TASK 2 – COMPLETION OF THE SHIP COMMON INFORMATION MODEL (SCIM DEVELOPMENT)

4.1 Tools and Style Selected for Document

The original versions of the SCIM were written using Microsoft InfoPath. While this tool was capable of performing the task, it had difficulty processing the large files and varied formats required for the SCIM chapters. The context schemas were created in XML, while the diagrams were done in a tool called ArgoUML, and the text files were developed in Microsoft Word. Microsoft Excel was used to create tabular data in support of context schema and HTML development.

At the start of Phase 2 of the ILE Project, an investigation was conducted to determine if there were better tools available to produce the final SCIM document. After extensive evaluation, the ILE Team selected a combination of Altova StyleVision and Altova XMLSpy as the tools that would be used to complete the SCIM.

XML, ArgoUML, and Word were still used to compile the various components that were assembled into the final document.

StyleVision is a broad-spectrum XSLT. Altova calls StyleVision a "stylesheet designer," but that technically accurate designation doesn't really do the software justice. With StyleVision, you draw your desired output page visually, much like you would draw an app form in Microsoft Visual Studio or a web page in Adobe Dreamweaver. In this page you include both static content (text, images, and form elements) and dynamic content (XML nodes and database elements). When you're done, StyleVision generates the XSLT transforms needed to convert your data sources into one or more desired output formats that look like your original design. In a nutshell, StyleVision generates standards-compliant XSLT and XSL-FO stylesheets based on your design, enabling true single-source, multi-output, dynamic-content publishing. XSLT transforms are the "programs" that change structured, hard-to-read data in XML files and databases into formatted, visually pleasing online or print pages.

XMLSpy is an advanced XML editor for modeling, editing, transforming, and debugging XML-related technologies. The XML editor delivers the power you need to create the most advanced XML and Web applications, yet at the same time it’s flexible enough to allow you to work with any XML technology in a way that best suits the complexity of the document and your preferences, for instance, if you prefer to develop in a text view or graphical view, or switch back and forth between the two while editing. XMLSpy is the only XML editor that includes new Smart Fix XML validation. With Smart Fix, the XML editor not only identifies validation errors, but also enumerates the possible corrections for fixing them, and will make the required changes automatically based on your selection. This revolutionary new functionality reduces the time spent troubleshooting and testing considerably.

It should be emphasized that these tools were used to enhance the appearance and readability of the SCIM. The reader is not required to have them available in order to view the SCIM document in its entirety. XMLspy was used for SCIM context schema development and as a support tool for input document development for StyleVision, such as converting information authored in Word and Excel to XML. StyleVision was used to convert the SCIM context schemas and authored data in XML format to HTML. Thus, the SCIM documentation only requires a web browser to read.

4.2 Structure of the SCIM

4.2.1 SCIM Executive Summary

The Navy Product Data Initiative (NPDI) was established in response to a NAVSEA request to reduce ship acquisition and maintenance costs associated with computer systems used in the design, manufacture, and life cycle support of shipbuilding programs. The effort was sponsored by the National Shipbuilding Research Program (NSRP) and funded by the Program Executive Offices (PEO) Submarines, Carriers, and Ships. NAVSEA tasked the NSRP to specify the requirements for and drive the implementation of product data systems based on an open architecture having suitable functionality and enterprise-wide interoperability to support affordable Navy vessel design, construction, and service life support. The NPDI developed a proposed Integrated Product Data Environment (IPDE) Specification to be invoked on future shipbuilding/service life contracts, and a proposed assessment mechanism to measure compliance, effectiveness, and provide guidance for a shipbuilder's IPDE implementation.

An integral component of all shipbuilding programs is the shipbuilder's IPDE. This collection of business processes, computer systems, and associated services, which house the product model data, enable people to work in concert towards common business goals throughout the life cycle of a product. The establishment of new shipbuilding programs has frequently required shipbuilder IPDEs to be extensively upgraded, or at times replaced, to leverage technology advances enabling improved shipbuilding processes. A common drawback of these environments is their proprietary (closed) architecture inhibiting the flexibility to reconfigure and adapt to changing program requirements without significant, costly customization. Despite the investment by both the Navy and the shipyards in building and maintaining these systems, there are still many shortfalls in the ability of existing IPDEs to efficiently manage changes and share product information with Navy activities or other shipyards.

Representatives from Northrop Grumman Shipbuilding, Electric Boat, NASSCO, Bath Iron Works and NAVSEA drafted the IPDE Specification based on lessons learned from previous submarine, carrier, and ship programs. It represents hundreds of man-years of experience in the design, development, and deployment of IPDEs. The IPDE Specification is intended to help implementers: identify common IPDE capabilities based on best industry practices, improve configuration management processes, build similar IPDEs to minimize software design, acquisition, and maintenance, enable IPDE interoperability between ship HM&E collaborators (designers, builders, equipment suppliers, Navy laboratories) and mission/weapon systems suppliers, and facilitate digital delivery of ship engineering and logistics data to customer's IPDEs for eventual life cycle support. The IPDE Specification also provides the shipyards the criteria which are needed to efficiently manage product data throughout a ship life cycle and a common statement of need for commercial software vendors to enhance their products. The ultimate goal is to enable shipbuilders and operators to minimize total ownership costs. It is anticipated that the Navy and shipbuilders will determine how to implement this information in future ship acquisition projects (RFP language, specifications, contract language, instructions, guidance documents, etc) to achieve the ultimate goal of reduced total ownership costs for all stakeholders.

The Ship Common Information Model (SCIM) defines the minimum information that must be maintained within an IPDE to enable effective interoperability among shipbuilding IPDEs. The SCIM is referenced by several IPDE specification requirements related to IPDE interoperability. The SCIM was partially developed under the NPDI Project and completed under the Integrated Logistics Environment (ILE) Project with initial publication in October 2012.

4.2.2 SCIM Overview

4.2.2.1 Introduction

The Ship Common Information Model (SCIM) defines the minimum information that must be maintained within an IPDE to enable effective interoperability among shipbuilding IPDEs. The primary purpose of the SCIM is to specify the information that must be captured and exchanged by the shipbuilding IPDEs. The SCIM is intended to be used throughout a typical shipbuilding life cycle, and is designed to be invoked and mandated on future U.S. Navy shipbuilding contracts.

The SCIM is based on several existing Application Protocols (AP) within the ISO 10303 Standard and the schemas developed under the NSRP Integrated Shipbuilding Environment (ISE) Projects for the various shipbuilding domains. ISO 10303 is an international standard for the computer-interpretable representation and exchange of product manufacturing information, known informally as STEP (STandard for the Exchange of Product model data). The objective of STEP is to provide a mechanism capable of describing product data throughout the life cycle of a product, independent of any particular system. Schema elements from the STEP standards that are relevant to the shipbuilding domain have been identified and organized as one coherent product model schema in the SCIM, with the goal to define a single, common data vocabulary for data exchange and application integration.

The SCIM also includes shipbuilding specific information that may not be included in the STEP APs. In general, attributes and properties in SCIM models will be a subset of the attributes and properties in the associated STEP Standard and augmented with other information required for shipbuilding product model exchanges.

The SCIM includes the application areas of major importance for a shipbuilding product model. The following is a list of functional areas covered by the SCIM:

- Product Data Management and Change Management Fundamentals
- Ship Moulded Forms
- Ship Arrangement
- Ship Structures
- Piping Physical Design
- Piping Functional Design
- Product Life Cycle Support
- Common Parts Procurement
- HVAC Design
- Engineering Analysis
- Electrotechnical Design and Installation

4.2.2.2 Using the SCIM

Almost every major recent U.S. Navy ship design and/or construction contract has involved collaboration among multiple shipyards. For example, the Ford Class Carrier is being designed and built by Huntington Ingalls Industries - Newport News Shipbuilding (HII-NNS) and General Dynamics Electric Boat (EB), the Zumwalt Class Destroyer is being designed and built by HII - Ingalls Shipbuilding and Bath Iron Works, and the VIRGINIA Class Submarine is being built by EB and HII-NNS. With the current economic environment, this trend is likely to continue. The Navy views system interoperability as enabling multiple yards to be viewed as "One Shipyard". Interoperability among computer systems within a shipyard has also become a major issue as Computer-Aided Design, Engineering, and Manufacturing systems (CAD/CAE/CAM) usage has expanded in U.S. shipyards. Interoperability problems are further exacerbated because the length of time to design and build a ship often exceeds the life span of current computer systems and requirements for life cycle support of the ship will far exceed the life span of current computer systems.

Throughout the ship life cycle a set of applications capture and maintain product model data in native format. At any time during the lifecycle, product model data may need to be transferred to external systems or archived. The SCIM provides a means to facilitate the product model internal and external exchange and archiving requirements throughout the ship life cycle as illustrated in Figure 3 below.

The process for using the SCIM in data exchanges includes the following high level steps:

1. Define a Data Exchange Scenario (Use Case)
2. Define Data Exchange Requirements
3. Identify Applicable SCIM Chapters
4. Compare SCIM to Data Exchange Requirements
5. Augment SCIM Data Model to Satisfy Unique Data Exchange Requirements
6. Develop Implementation Agreement
7. Develop Translators
8. Exchange Data
9. Verify Data Exchange

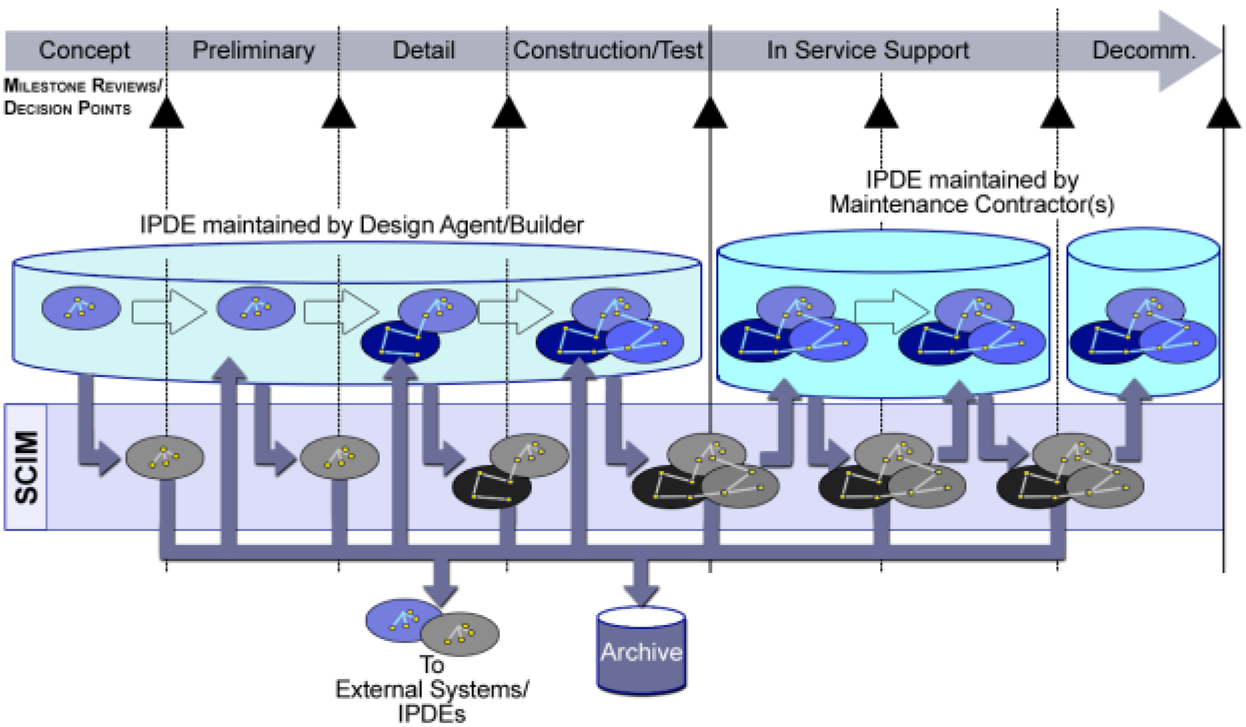

Figure 3 - Using the SCIM throughout the Lifecycle

4.2.2.3 Exchange Scenarios

The SCIM can be used for many scenarios within the Shipbuilding environment including:

- Sharing data among Shipyard IPDE Design, Manufacturing, and Logistics systems
- Sharing data with Shipyard co-design and manufacturing partners
- Exchanging data between the Navy and the Shipyards
- Feeding later life cycle uses such as logistics support, simplified product model visualization, and part information within Navy systems

4.2.3 SCIM Chapter Outline

The following SCIM Chapter Outline reveals the structure of each chapter and identifies the sources of each section as either the merged context schema or the author.

- Chapter Name
    - Table of Contents
        - Autogenerated by StyleVision template
    - Table of Figures
        - Autogenerated by StyleVision template
    - Table of Tables
        - Autogenerated by StyleVision template
    - Overview
        - Authored text and figures
    - Entities
        - Entity name
            - StyleVision gets from Context Schema
        - Definition
            - StyleVision gets from Context Schema
        - Additional Information
            - Authored Data
        - Data Model Context
            - Authored Diagram from ArgoUML
              (See Figure 4 below for an example)

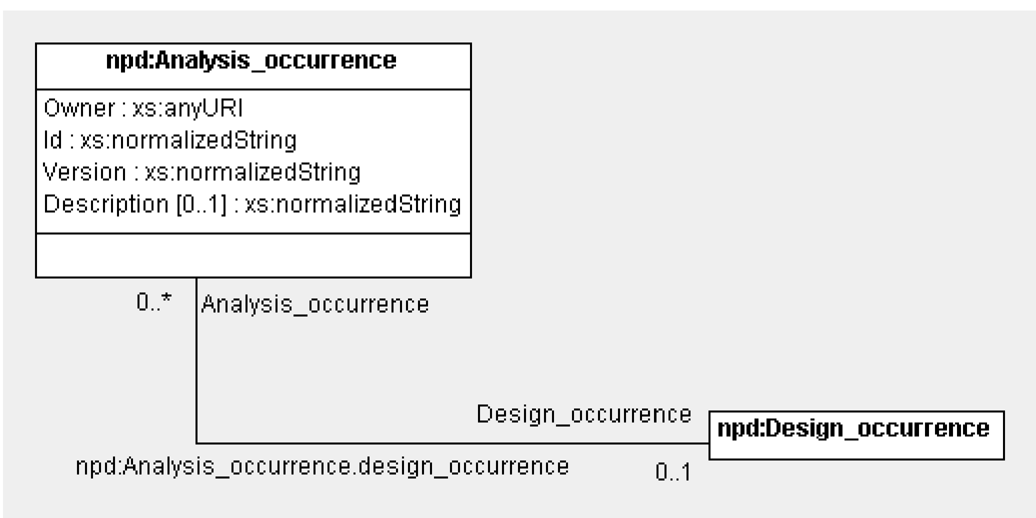

Figure 4 – Context Diagram Generated by StyleVision

-
    -
        - Properties
            - StyleVision gets from Context Schema
    - Simple Types
        - StyleVision gets content from Context Schema
    - Associations
        - StyleVision gets content from Context Schema
    - Traceability Matrix

- StyleVision gets SCIM Entity / Properties / Associations from Context Schema

4.2.4 Product Data Management (PDM) – SCIM Chapter 1

This section provides an overview of the Product Data Management (PDM) Core portion of the Ship Common Information Model (SCIM) and describes its relationship with the following application domain-specific information requirements.

The purpose of the shipbuilding Integrated Product Data Environment (IPDE) is to create and manage a digital ship product model. The ship product model is broader than some may expect, encompassing not just the ship design but also the catalogs of parts that support the design, the planning, manufacturing and testing information to realize the design, the engineering models to analyze the design, and the logistics models to support and maintain the ship itself. The ship product model is not a single monolith. It spans the aforementioned life cycle stages and resides in a number of different (though interconnected) systems, applications, and data repositories. These various systems, while managing distinct aspects of the product, depend upon information in other portions of the IPDE, and the product model must behave as if it is managed on one logical repository. This is necessary so that the items of the product model are available for re-use, for sharing, for collaboration, and for internal consistency. Across the life cycle stages, the representations of many items evolve, and the IPDE must be able to maintain the proper associations not just between the progress stages of each item, but also between items and the data objects that define their properties, and between items and the other items they depend upon.

Many of the properties and associations captured in particular application systems are unique to a single application domain; however, as a result of the need for integration within the model, there are some elements of the product model that are common and generic. This section of the SCIM defines those common elements. Technically, many of the entities defined in this section are the abstract supertypes of the items that are more specifically defined in each application domain.

4.2.5 Ship Moulded Forms – SCIM Chapter 2

This chapter of the SCIM specifies an information model and schema for the exchange of product data representing the definition of ship moulded forms and related hydrostatic properties.

The definition of moulded forms supports the geometrical representation of the ship hull, propellers, rudders, thrusters, appendages, as well as the internal arrangement and structural surfaces of the ship. This surface definition does not include information on the thickness or type of the material from which it is constructed. Thickness and material information is provided in the Ship Structures (AP218) Chapter, which may reference the underlying moulded form surface on which the structural parts are defined.

A moulded form of particular interest is the ship hull, which is referred to as the hull moulded form. Hull form types supported include both mono- and multi-hull forms. The hull moulded form will be exchanged between companies during the initial design and is the basis of intact stability and hydrostatic calculations. The hydrostatic properties included in this chapter of the SCIM are those of the intact hull that depend on the ship's draught, such as displacement, centre of buoyancy, and centre of flotation. Damaged stability is not included in this chapter as no information on ship compartmentation is described. Instead, the Ship Arrangements (AP215) Chapter of the SCIM may be used to represent damaged stability data.

Representation of the shape of each moulded form can be communicated either as a surface representation or as a table of offsets. The non-manifold surface shape representation is shared with other chapters of the SCIM, and is used by various parts of the ISO STEP series of standards for geometry exchange. The offset point representation included in this chapter is generally used in ship design only for the definition of moulded forms, as a set of sectional cuts parallel to the primary ship axes and represented by points.

In addition to the geometric shape representation of each moulded form, design parameters are provided which represent the main dimensions and design intent for certain types of moulded forms. These parameters may be useful for ship performance calculations as well as for use in ship design systems that support parametric definitions.

General characteristics are included that convey the ship overall dimensions as well as standard measurements used to identify the ship characteristics under classification society and naval rules.

Configuration management, versioning, approval and hull applicability information is inherited from the PDM Chapter of the SCIM. A collection of the individual moulded forms that represents a snapshot in time of a particular version of the entire ship moulded form design is termed the ship moulded form. This ship moulded form collection is a specialization of the PDM design occurrence object, its constituent children being the individual moulded form objects. Similarly, each individual moulded form is a specialization of the PDM concept of design occurrence, and the design definition for the moulded form is a specialization of the PDM design occurrence definition.

4.2.6 Ship Arrangement – SCIM Chapter 3

This chapter of the SCIM specifies an information model and schema for the exchange of product data representing the definition of ship compartmentation and related properties. It is based on the business objects standardized in the ISO 10303-215 standard.

The hull form of a ship is internally subdivided early in the design lifecycle by the introduction of many additional surfaces. These surfaces are associated with the moulded form elements such as bulkheads and decks. Structural entities such as plate parts and stiffeners will be defined on these surfaces as the design progresses. A region of the ship, whether it be interior to the hull, such as a tank, or enclosing one of its exposed decks, such as a helicopter landing platform, is designated a space. Two types of spaces are addressed by this chapter of the SCIM: compartments and zones. Compartments represent physical, bounded spaces. Zones represent regions surrounded by some abstract boundary or alternatively can be defined as a set of compartments without a separate geometric representation.

The most common type of spatial partitioning is the subdivision of a ship into compartments. A compartment is very similar to the idea of a room in a building. Every volume enclosed by horizontal and vertical boundaries, except for minor utility areas such as peacoat lockers, linen lockers, cleaning gear lockers, and other similar areas, is considered a compartment. The compartment is bounded by the surfaces representing structural decks and bulkheads and also by non-structural (or non-load bearing) surfaces that form joiner bulkheads. Compartments may be classified according to the function they perform with regard to the operation of the ship. The types of spaces supported by the SCIM are cargo/stowage (both liquid and dry cargo), void, habitable, and machinery/equipment spaces. Collections of attributes have been defined for the various compartments depending on its designated use. Compartments serve a vital function in configuration managing engineering part occurrences throughout the lifecycle of the ship.

In some cases, the same surfaces that subdivide a ship into compartments may also be used to subdivide the ship into zones. In other cases, additional moulded form geometry elements or geometric surfaces may be required to define zone boundaries. On naval ships, multiple zone subdivisions such as pressure (collective protection system), subsafe, damage control, and arrangement zones will be defined and each subdivides the ship into an independent set of spaces.

In addition to identifying the various spaces on the ship, it is important to represent the connectivity between these spaces. This model supports several types of relationships between spaces, specifically adjacency and access, functional, positional, connection, and enclosing. Functional relationships can be used to record the fact that one space's design parameters are dependent on some functional characteristic of another space, such as a pair of port and starboard ballast tanks used for anti-roll stabilization. Positional relationships capture design intent expressing the fact that certain spaces must maintain geometric characteristics similar to another space, such as two spaces that should maintain the same transverse width dimension. Finally, enclosing relationships allow the product model to record the fact that one space may be completely surrounded by another space, such as a free-standing Lube Oil Settling Tank in the Machinery Space.

From a functional standpoint, the model has been developed to associate properties with the various compartments appropriate to their function. These properties include volumetric capacities, length measures, and cross-sectional areas. The ability to specify constraints on these properties is provided for where appropriate so as to assist engineers in the early stages of design. For example, it is possible to specify a minimum length for a compartment, as well as a maximum length for the compartment. Likewise, it is possible to record an estimated compartment volume, as well as a calculated and a measured value after the ship is constructed.

Organizational control and oversight of the ship product model development process is often carried out by space rather than by ship systems. A Space product structuring mechanism is included to allow the maintenance of the relationships between a space and all of the individual parts that are located within the space (in the case of ship mechanical and engineering systems), or that constitute its boundaries (in the case of structural systems).

Configuration management, versioning, approval, hull applicability and the geometric representation is inherited from the PDM Chapter of the SCIM. Each individual compartment or zone is a specialization of the PDM concept of design occurrence, and the design definition for the space is a specialization of the PDM design occurrence definition.

4.2.7 Ship Structures – SCIM Chapter 4

The SCIM provides an information model for the computer-interpretable representation of product information and for the exchange of product data. The objective is to provide a neutral mechanism capable of describing products throughout their life cycle. This mechanism is suitable not only for neutral file exchange, but also as a basis for implementing and sharing product databases, and as a basis for archiving.

This chapter of the SCIM specifies an information model and schema for the exchange of product data representing the definition of ship structures and its related data. It defines the context, scope and information requirements for the communication of ship structural data and specifies the integrated resources necessary to satisfy these requirements. These data may need to be exchanged or shared between different organizations. Such organizations include ship owners, ship classification societies, design agencies and fabricators. This chapter of the SCIM has been developed to support the shipbuilding activities and computer applications associated with the pre-design, the main design, the manufacturing, the maintenance (repair), and the inspection and survey during operation life cycle phases for commercial or naval ships.

This chapter of the SCIM supports the exchange and sharing of ship structures data. It has been developed in conjunction with other chapters so that important shipbuilding concepts are common and interoperable within the SCIM chapters. The ship structures product model provides a set of subtypes of item for describing the ship structures. It includes ship, parts as well as their connections, systems, assemblies and hull_cross_sections as they are the essential subtypes employed in this chapter.

This chapter of the SCIM is derived from ISO 10303-218: Application Protocol - Ship Structures. In ISO 10303-218, the schema for defining detailed design and manufacturing information is based on the definition and relationship of three main types of entities: items, design definitions, and manufacturing definitions. Items represent individual instances of elements within a structural envelope. Types of items in a structural model include structural parts (e.g., plates, profiles, assemblies) and structural features (e.g., weld/fabrication information, internal/edge cutouts). Design definition data captures all the information necessary for the complete definition of the structural components of a ship. In a feature-based design, structural features, such as interior and edge cutouts and preparations, are defined parametrically and associated to their corresponding design items. For example, a center location and radius parametrically define a circular hole, and profile cross-section dimensions parametrically define a stiffener penetration along the plate's edge. In the case of the design definition, each of these feature's geometric representation are independently referenceable within the SCIM data. Instances of like features are derived from a common source thus simplifying the geometry model and making it possible to utilize feature libraries, which allow a single geometry representation to be shared across various design elements. Also, defining individual features in a model allows them to be further characterized by their function.

The SCIM AP 218 context schema supports both design and manufacturing of ship structures. Planning/manufacturing entities for assembly order, scheduling, routing, shop floor assignments, or shop floor manufacturing processes are not addressed by this chapter.

4.2.8 Piping Physical Design – SCIM Chapter 5

This chapter of the Ship Common Information Model (SCIM) defines a subset of STEP AP 227 required to capture and exchange the ship Piping Physical Design and Pipe Stress Analysis information.

4.2.8.1 Piping Physical Design

Piping systems are used to convey and process fluids or gases within a variety of engineering products. Generally, a piping system comprises a network of pipes and piping components (fittings and valves), and is attached to processing equipment such as pressure vessels and pumps. Large piping systems are generally attached to some supporting structure through the use of pipe supports and hangers.

Four major application areas corresponding to major stages of piping product life cycle are:

- contract/functional design;
- detail design;
- production engineering;
- support engineering.

Users/developers of piping product information in these stages of product life cycle have different information requirements and views of the product. Users in the contract design stage design view a piping system principally as a functional network of equipment.

Functional design stage designers see piping in much the same way but develop and use much more detailed information concerning operating states of a system, and the characteristics of sub-networks of piping within an overall system (pipelines) in terms of material specifications and flow characteristics. They also, for some systems, develop and use data concerning the loading, and fixity of, portions of the system in order to evaluate stress levels. The functional view is typically used to identify a preliminary purchasing bill of material in which purchase specification and long lead-time equipment and components are identified.

The functional design stage view is also the one which, along with contract specifications, is used in formulating and performing systems testing following installation. Because of the commonality of views in the contract and functional design stages, they can be combined into a single application area.

Detail design users have a three-dimensional arrangements view of piping. They are concerned with the arrangement in 3-D space of piping components meeting the applicable system specification and with ensuring that the arranged components are free from interference with the surrounding environment. This view of the data is also the view that typically supports the final purchasing bills of material.

Production engineering stage users are concerned with defining piping assemblies and the information needed to fabricate the pieces of these assemblies. This information can consist of bending instructions, joining instructions/specifications, and coating instructions. They also specify the installation processes to be used to install such assemblies in the final product and the post-installation tasks to be carried out. The production engineering function creates and makes use of the production bill of material view.

The piping product view taken by users in the support engineering stage is mainly that of the functional design, but from the standpoint of defining the support requirements of the product. Such requirements include spare parts complements, maintenance procedures and related documentation, and operational specifications and documentation.

This chapter of the SCIM (Piping Physical) will focus on the second and third of the application areas above – detail design and production engineering. It will specify the product model information needed to capture the design and facilitate the manufacturing of the piping system. Information concerning items such as operating states, material specifications, and flow characteristics will be captured by the Piping functional model described in the next chapter of the SCIM.

The AP227 Plant spatial configuration STEP standard identifies Plant objects, Plant_item objects, Plant_system objects, and other components associated with the Plant. The SCIM replaces “Plant” with “Ship”, i.e., Ship objects, Ship_item objects, Ship_system objects and other components associated with the Ship.

The STEP application objects are entities in SCIM. The Piping Physical Design entities have been organized into the following functional groups:

- Piping Specific Geometry
- Connectors and Connections
- Pipe Details and Assemblies
- Pipe Collections
- Piping Systems
- Instances and Parts - Instrumentation and Control
- Instances and Parts - Piping Supports
- Instances and Parts - Reinforcing Components
- Instances and Parts - General
- Instances and Parts - Miscellaneous Piping Systems
- Instances and Parts - Pipe
- Instances and Parts - Valves
- Instances and Parts - Fittings
- Instances and Parts - Flanges
- Instances and Parts - Spacers
- Instances and Parts - Insulation

4.2.8.2 Pipe Stress Analysis

Another important application supported by the SCIM chapters for Piping Physical and Piping Functional is the information required for “Pipe Stress Analysis” of the piping model. “Pipe Stress Analysis” is a term applied to calculations, which address the static and dynamic loading resulting from the effects of gravity, internal and external pressure, changes in fluid flow rate, and seismic activity.

Most of the attributes and properties required to support Pipe Stress Analysis were already included in AP227 and the Piping Physical or Piping Functional Chapters of the SCIM. However, to insure that the

SCIM supported the information necessary to perform a stress analysis of the piping model, a few additional entities, associations, and simple types were added to the Piping Physical and Piping Functional Chapters. In particular, entity "npd:Ship_item_weight" was added to the Piping Physical Chapter. See the Piping Functional Chapter for a list of the entities, associations, and simple types added to that chapter.

4.2.9 Piping Functional Design – SCIM Chapter 6

This chapter of the Ship Common Information Model (SCIM) defines a subset of STEP AP 227 required to capture and exchange the ship Piping Functional Design and Pipe Stress Analysis information.

4.2.9.1 Piping Functional Design

Piping systems are used to convey and process fluids or gases within a variety of engineering products. Generally, a piping system comprises a network of pipes and piping components (fittings and valves), and is attached to processing equipment such as pressure vessels and pumps. Large piping systems are generally attached to some supporting structure through the use of pipe supports and hangers.

Four major application areas corresponding to major stages of piping product life cycle are:

- contract/functional design;
- detail design;
- production engineering;
- support engineering.

Users/developers of piping product information in these stages of product life cycle have different information requirements and views of the product. Users in the contract design stage design view a piping system principally as a functional network of equipment.

Functional design stage designers see piping in much the same way but develop and use much more detailed information concerning operating states of a system, and the characteristics of sub networks of piping within an overall system (pipelines) in terms of material specifications and flow characteristics. They also, for some systems, develop and use data concerning the loading on, and fixity of, portions of the system in order to evaluate stress levels. The functional view is typically used to identify a preliminary purchasing bill of material in which purchase specification and long lead-time equipment and components are identified. The functional design stage view is also the one which, along with contract specifications, is used in formulating and performing systems testing following installation.

Because of the commonality of views in the contract and functional design stages, they can be combined into a single application area. Detail design users have a three-dimensional arrangements view of piping. They are concerned with the arrangement in 3D space of piping components meeting the applicable system specification and with ensuring that the arranged components are free from interference with the surrounding environment. This view of the data is also the view that typically supports the final purchasing bills of material.

Production engineering stage users are concerned with defining piping assemblies and the information needed to fabricate the pieces of these assemblies. This information can consist of bending instructions, joining instructions/specifications, and coating instructions. They also specify the installation processes to be used to install such assemblies in the final product and the post-installation tasks to be carried out. The production engineering function creates and makes use of the production bill of material view.

The piping product view taken by users in the support engineering stage is mainly that of the functional design, but from the standpoint of defining the support requirements of the product. Such requirements include spare parts complements, maintenance procedures and related documentation, and operational specifications and documentation.

This chapter of the SCIM (Piping Functional) will focus on the first and fourth of the application areas above – contract/functional design and support engineering. It will specify information concerning items such as operating states, material specifications, and flow characteristics. The previous chapter of the SCIM (Piping Physical) addressed the areas of detail design and production engineering.

The piping functional configuration entails connectivity, sequencing, component size, and schedule, and may include other information, such as equipment tag numbers and requirements to perform consistency checks between the functional and physical representations of the design.

This data will include:

- basic engineering data as needed for spatial layout and configuration of systems
- references to functional requirements of piping systems, such as stream data and operational characteristics
- references to or designation of functional characteristics of components and connected equipment as required for system design.

The SCIM chapter on Piping Functional describes the functional connectivity of a piping system and the functional connectivity among objects in that system. It provides the information that describes the functional links and properties of a flow stream in a piping system. It includes information about the segments in the line and the specifications for these segments, such as design criteria, service conditions, and line identifier.

4.2.9.2 Pipe Stress Analysis

Another important application supported by the SCIM chapters for Piping Physical and Piping Functional is the information required for "Pipe Stress Analysis" of the piping model. "Pipe Stress Analysis" is a term applied to calculations, which address the static and dynamic loading resulting from the effects of gravity, internal and external pressure, changes in fluid flow rate, and seismic activity.

Most of the attributes and properties required to support Pipe Stress Analysis were already included in AP227 and the Piping Physical or Piping Functional Chapters of the SCIM. However, to insure that the SCIM supported the information necessary to perform a stress analysis of the piping model, a few additional entities, associations, and simple types were added to the Piping Physical and Piping Functional Chapters. In particular, entity "npd:Ship_item_weight" was added to the Piping Physical Chapter and the following entities, associations, and simple types were included in the Piping Functional Chapter:

Entities:

- npd:Material_specification_selection
- npd:Material_specification_subset_reference
- npd:Required_material_description

Associations:

- npd:material_specification_selection.is_used_by
- npd:required_material_description.is_satisfied_by
- npd:ship_item.satisfies
- npd:ship_item_connector.defines

Simple Types:

- Required_or_optional

4.2.10 Product Life Cycle Support (PLCS) – SCIM Chapter 7

4.2.10.1 SCIM PLCS Scope

The Ship Common Information Model (SCIM) defines a subset of the STEP APs required to capture and exchange ship product model information and enable effective interoperability among US Navy sponsored shipbuilding environments and systems. The PLCS Chapter of SCIM is derived from STEP AP239 Product Life Cycle Support (PLCS) and focuses on the life cycle data applicable to the shipbuilding domain.

This version of the SCIM PLCS Chapter is derived from the work completed on the NSRP ISE-6 (Integrated Shipbuilding Environment) Project, with lessons learned from the DDG 1000 Integrated Product Data Environment (IPDE) effort, and focuses mainly on the Product Definition Information areas of the STEP PLCS standard which are highlighted in Figure 5. The STEP PLCS Data Planning Model is described in detail in the SCIM Supplemental Information. Further development of the SCIM PLCS Chapter is required to include the additional areas of the STEP PLCS standard depicted in Figure 5.

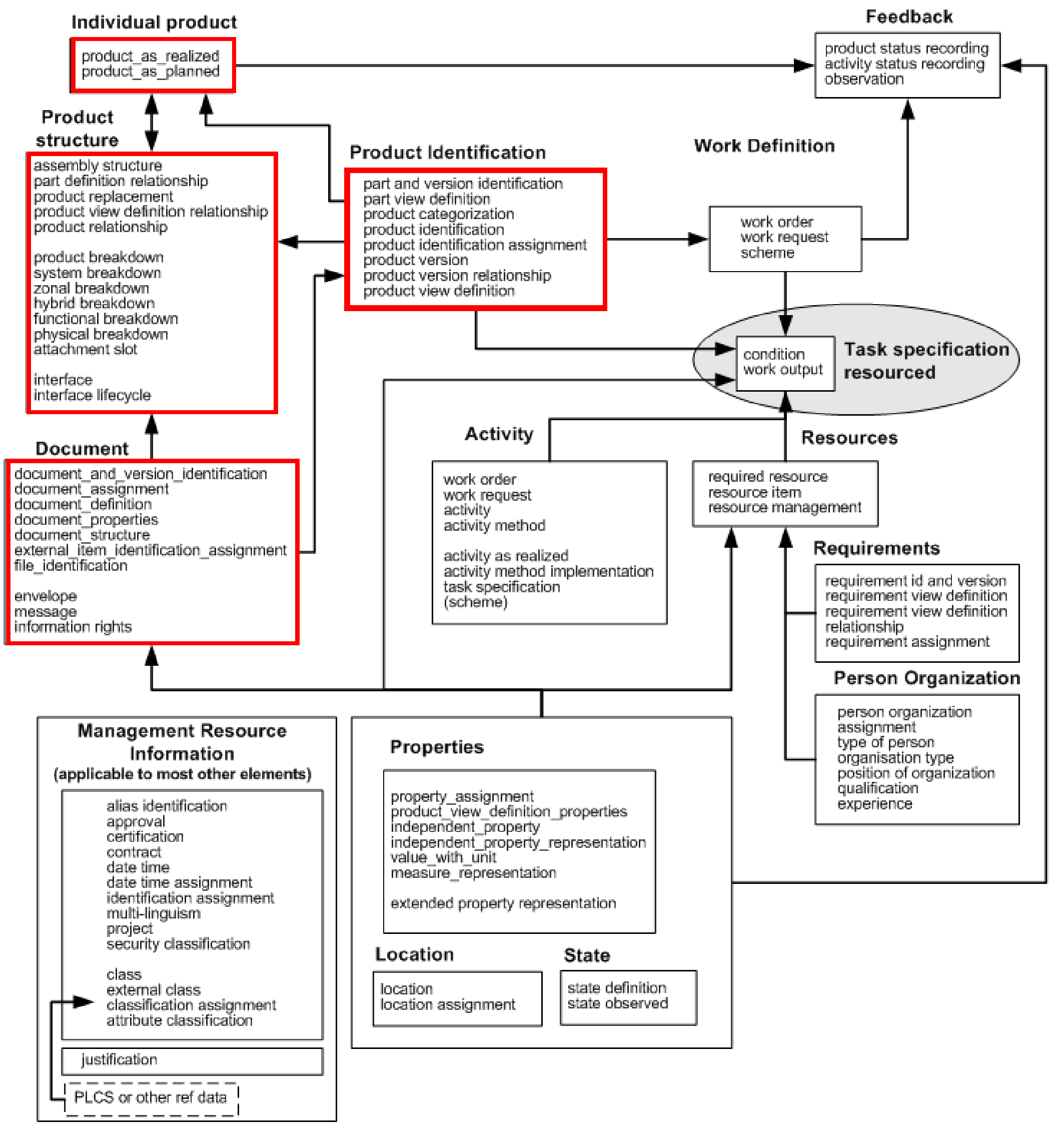

Figure 5 - SCIM PLCS Chapter Focus within STEP PLCS Data Planning Model

4.2.10.2 SCIM PLCS Overview

The current entities and relationships identified within the SCIM PLCS Chapter are focused on maintaining configuration information for a specific ship or class of ships, as well as defining relationships and maintaining information on related design and logistics product information. Some of the SCIM PLCS entities are derived from or related to entities defined in the SCIM Product Data Management (PDM) Chapter. In these cases the SCIM PLCS entities inherit the attributes and relationships from their parent SCIM PDM entities. The entities in this chapter are organized into Functional Areas to enhance the organization of the chapter and facilitate understanding of the data. The following SCIM PLCS entities, organized within each functional area, are defined in this chapter:

Breakdown Structures

- System_breakdown_element
- System_breakdown_structure
- HSC_breakdown_element
- HSC_breakdown_structure
- Org_unit

Documents

- Lsd_metadata
- Drawing
- Technical_manual
- Training
- Logistics_analysis
- S1000d_module
- Publication_module
- Data_module

Logistics Configuration Items

- Logistics_configuration_item
- Installed_item
- Rotatable_pool_item

Maintenance

- Maintenance_task
- Corrective_maintenance_task
- Planned_maintenance_task
- Maintenance_index_page
- Maintenance_requirement_card

Parts

- Oem_catalog_part
- Supply_part
- Repairable_part
- Onboard_spare_part

Vendor Information

- Procurement_specification
- Purchase_order
- Vendor_furnished_information

The following SCIM PDM entities are included in the SCIM PLCS logical data model; however, they are defined in the SCIM PDM Chapter:

- Catalog_part
- Configuration_item
- Design_occurrence
- Design_occurrence_assembly
- Document_metadata
- Logistics_occurrence
- Ship

From the standpoint of the Navy shipbuilding environment, the data currently defined in this chapter closely resembles the Ship Configuration and Logistics Support Information System (SCLSIS) data defined in NAVSEA Technical Specification 9090-700. There is not a one-to-one correspondence between SCIM PLCS entities and SCLSIS Record Types (RT); however, most of the SCLSIS attributes for RT1, RT2, and RT3 are captured in the current SCIM PLCS model and are appropriately identified as SCLSIS records in the documentation. For example, the SCIM PLCS entities HSC_breakdown_element, Logistics_configuration_item, Installed_item, and Repairable_part include most of the SCLSIS RT2 data attributes. In addition, the SCIM PLCS entity Lsd_metadata, along with the SCIM PDM entity Document_metadata, includes most of the SCLSIS RT3 attributes.

In addition to the standard configuration and logistics support document data found in SCLSIS, the current SCIM PDM/PLCS model includes entities to capture design information and the relationship between design and logistics information (see SCIM PDM entity Design_occurrence). It also expands the document entity (see entity Document_metadata) to capture technical data in the form of S1000D data modules and publication modules (see entity S1000d_module and related sub-classes) as well as vendor furnished information and additional design information.

4.2.10.3 Chapter Overview

SCIM Section 7.2 describes the SCIM PLCS model entities by functional area including a functional area class diagram providing key entities, attributes, and associations within the functional area. Entity descriptions include the entity definition, property definitions, additional information as appropriate, and a context diagram showing the entity and its relationships to other SCIM entities.

SCIM Section 7.3 provides a list of simple types with definitions for the SCIM PLCS entities.

SCIM Section 7.4 provides a list of associations with definitions for the SCIM PLCS entities.

SCIM Section 7.5 provides traceability from the SCIM PLCS entities, properties, and associations to the STEP PLCS entities, properties, and associations.

An overview of the STEP PLCS standard, including STEP PLCS Information Requirements and STEP PLCS Implementation Requirements is provided in the SCIM Supplemental Information.

4.2.11 Common Parts Procurement (CPP) – SCIM Chapter 8

4.2.11.1 Introduction

This section provides an overview of the Common Parts Procurement (CPP) Chapter of the Ship Common Information Model (SCIM). The purpose of the CPP Chapter is to describe the use of the Common Parts Catalog (CPC) in the design and life cycle maintenance of a ship in order to facilitate the standardization and procurement of common parts across Navy ship classes. This chapter is based on the Common Parts Catalog (CPC) Data Element Dictionary (DED), Rev. 1, December 31, 2010. The CPC DED was a Deliverable under a Task of the NSRP ASE Project Technology Investment Agreement (TIA) #2010-621, Common Parts Catalog (CPC) Enhancements. The information in this chapter provides a summary of the CPC data model and can be traced back to the CPC DED for additional detail.

This chapter differs from other SCIM chapters in that it provides SCIM data model integration with the data model of an existing database implementation currently being used in several commercial shipyards, whereas the other chapters provide a SCIM data model independent of any database or data exchange implementations. Since the shipyards have already developed a database for a common parts catalog, there is no need to recreate a data model for this information in the SCIM. Instead, the design and logistics entities within the SCIM are integrated with the CPC entities to leverage the detailed standard part information already maintained in the CPC. The integration between the SCIM and CPC entities allows the SCIM to utilize the CPC information model without duplication of data or the creation of a separate data model for common parts procurement. In a shipyard IPDE implementation or data exchange scenario, the SCIM could be used to maintain the design and logistics data and link to the CPC database for standard part information. The details of the relationship between the SCIM data model and the CPC data model are described in the SCIM and CPC Data Models section.

The CPC is a real-time, searchable inter-shipyard parts catalog in production at General Dynamics Electric Boat, General Dynamics Bath Iron Works, and Huntington Ingalls Industries - Ingalls Shipbuilding. It has facilitated a reduction in the number of parts on Navy ship designs through the capability to support formal part standardization programs for new designs within and across participating shipyards. The CPC employs standard data definition protocols and utilizes a robust search engine to create and share part information within and between multiple shipyards in order to streamline design, production, and life cycle maintenance. While the CPC was primarily developed for use in the ship design process, it facilitates the ability to provide data to downstream systems in the areas of material availability, ordering, and quality inspection tracking.

The CPC provides standardized equivalency/sourcing information on the various part numbering formats at the participating private shipyards, while delivering increased speed and accuracy in information retrieval, reductions in the number of parts through non-duplication and data reuse, and more visibility and timely access to the data. A robust search capability ensures identification of existing duplicate part numbers and eliminates the generation of new part numbers for components already shown in the catalog. The catalog also facilitates process improvements for the participating shipyards to address supply chain issues of non-standard part requirements from yard to yard and small quantity orders not fulfilling minimum production runs. Because CPC facilitates a formal part standardization program for a new design, fleet maintenance issues that can be addressed include decreased variety of parts to maintain the fleet and the potential for visibility of design part data and construction yard inventory. Electronic part sharing has the potential to virtually integrate Navy inventories with shipyards.

The CPC is analogous to the electronic version of the books at the auto supply store. It provides cross-reference and equivalency information on procured and manufactured parts for all participating shipyards. It also contains specification history, National Stock Number (NSN) (where applicable), supplier and shipyard part numbers, and standardized parts related data.

4.2.11.2 Background

Under the shipyard legacy systems, catalog data and part numbering formats differed greatly between the private shipyards, leading to an abundance of duplicate and nonstandard parts. This situation was exacerbated by an inability to link or share information between the private yards. The ability to limit part populations in new ship designs and supply support was constrained by poor technology and a lack of interoperability between industry and the Navy.

NAVSEA encouraged the commercial shipyards to pursue part commonality through the NSRP, leading to the CPC project. The CPC, connecting major shipbuilders, facilitates the Navy goals of reducing support costs while improving readiness by providing ready access to high quality source part information. With the CPC, a 10 to 20 percent reduction in parts cost is projected through the availability of existing standard data and the facilitation of formal part standardization programs.

The CPC went online at General Dynamics Electric Boat and Bath Iron Works in May 2004 and at Huntington Ingalls Industries - Ingalls Shipbuilding in June 2004. In September of 2004, the catalogs of all three yards were linked for continuous real-time interaction and parts equivalency determination. There are discussions underway at HII - Newport News Shipbuilding and NASSCO to implement the CPC in their respective shipyards.

4.2.11.3 SCIM and CPC Data Models

The SCIM data model is integrated with the CPC data model through the npd:Catalog_part entity described in the PDM Chapter, and its relationship to npd:Design_part (PDM Chapter), npd:Logistics_configuration_item (PLCS Chapter) and npd:Part_Object (CPP Chapter). Design parts are items of the ship design that are managed independent of end use in a particular ship and may be instanced more than once in a ship design. Some Computer-Aided Design (CAD) systems manage parts in internal catalogs which are defined based on form, fit, and function. These CAD catalog parts, represented by the npd:Design_part entity, may be parametrically defined, such as the case of commonly used fittings and piping specifications, or may be explicitly defined, such as the case of a pump or an electrical panel. The standard parts from the CAD catalog used in a particular design are modeled as instances of npd:Design_part so they can be placed in the ship design as npd:Design_occurrence instances. The npd:Design_part entity has a relationship to an npd:Catalog_part entity. The npd:Catalog_part is the base class for npd:Part_Object which provides part procurement information from the shipyard Common Parts Catalog (CPC). Typically, a part's procurement information from the CPC may be satisfied by many different actual parts, possibly from multiple vendors. The npd:Logistics_configuration_item entity also has a relationship to an npd:Catalog_part entity to link the logistics information to relevant part information for the development of logistics products.

The primary purpose of the CPC data model context is to provide a means to represent parts data, specifically, procured commodity parts. Each part type contains the properties to describe the characteristics needed to evaluate the usefulness of a part for a particular purpose and to distinguish the part from other alternative parts available perhaps from other vendors. There are two categories of "parts" that are deliberately excluded from this context: complex, high level assemblies and Computer-Aided Design (CAD) parts. Although the CPC database provides for rudimentary product structuring, high-level, custom designed assemblies are represented in PDM contexts. Similarly, while each catalog part is associated with one or more geometric (CAD) representations, these representations are not managed as part of the CPC context - rather these parts are represented in the product model contexts by discipline.

The CPC implementation includes part equivalency (no drawing change) and common characteristics across all parts, such as catalog number, noun, material type, etc. There are also unique data fields that are only applicable to specific part types to promote data standardization. Whenever the private yards become aware that a National Stock Number exists for a part number, that relationship is captured in CPC. CPC also has the capability to show allowance parts list (APL) data and higher/lower assembly data where applicable. Procurement information and business data (e.g., vendor pricing) will not be shared by this system to protect appropriately sensitive proprietary data.

One of the most challenging aspects of parts data management is identification. Each part in the CPC context is identified, persistently, by an identifier that is unique to the organization supplying the part. The

CPC context also supports part equivalency; an equivalency association links a part to the equivalent parts in other CPC databases. This association is needed because part identifiers are specific to each owning organization. Finally, CPC parts may also be associated to National Stock Numbers.

One important feature of the CPC context is that it includes part related documents, that is, various documents that are needed to qualify and describe the parts themselves. Part documents include various specification documents. Parts documents may be versioned and amended; particular versions of part documents are associated with the pertinent parts. Moreover, the association of part document to part also designates the hull applicability, those hulls to which this particular version of a part document applies. Specification histories and part audit histories can also be represented. Finally, parts may be associated with various supplemental documents, such as allowance parts lists (APL), Chemical Abstract Service (CAS), and environmental legislation.

As mentioned previously in this Overview, the CPC is an implemented database with a corresponding physical data model depicting class associations and attributes as they are implemented in the shipyard CPC instances. The data models in the SCIM are at the logical level, meaning they describe the real world entities, associations, and attributes, but there may be multiple ways to implement the data model in a physical database. In order to avoid some of the details of the implementation and increase the understanding of the CPC data model, the class and context diagrams in this chapter have been simplified. Specifically, many of the “mapping” classes used in the CPC implementation to implement complex many-to-many relationships between classes have been removed in order to simplify some of the diagrams. However, the mapping classes are still summarized in the SCIM in the section of the chapter that provides details of each entity and their attributes.

4.2.11.4 CPC Implementation

The CPC web service can be used to provide external applications on-demand access to CPC data. The data provided by the service mainly consists of vendor or shipyard part data associated with catalog part entries in the CPC. This web service is designed to facilitate the exchange of data between the CPC and external applications that require CPC data. The service, as currently designed, provides the minimum set of operations that will allow for searching the catalog to create a list of parts that meet a specific set of requirements, for locating and downloading the details of a part entry in the CPC, and for adding new part entries into the CPC. A part entry in the context of this web service is always considered to be the set of data associated with a vendor/shipyard part definition (part instance) that the CPC is responsible for managing. The term web services describes a standardized way of integrating web-based applications using the XML, SOAP, WSDL and UDDI open standards over an internet protocol backbone. XML is used to tag the data, SOAP is used to transfer the data, WSDL is used for describing the services available, and UDDI is used for listing what services are available. Used primarily as a means for businesses to communicate with each other and with clients, web services allow organizations to communicate data without intimate knowledge of each other's information technology systems behind the firewall. This definition and associated set of standards are supported in concept by the CPC web service. The CPC web service does use XML based SOAP messages that are described in WSDL. A deployed CPC web service could be registered in a UDDI repository.

Each of the three operations provided in the CPC web service utilizes a Remote Procedure Call (RPC) style of communication. RPC requests can be transmitted synchronously or asynchronously. Synchronous RPC requests are employed when an application expects a quick response or cannot continue without the data provided by the web service. It is this model that the CPC web service follows. In other words, the web service operations will function with the premise that the application making a request to the CPC web service will wait for a response. As result, each service is required to provide a response when the requested processing is complete. The CPC web service identifies three methods: fetch, query and update. A description of each of the methods, their parameters and their returned information follows.

The fetch operation is used to obtain a part definition from a part definition identifier. The part definition identifier is a String that uniquely identifies the part definition instance in the CPC application. This identifier is used by applications to obtain the details of the part instance in the CPC application. This definition data will be returned as XML content inside a container element based upon the CPC XML Schema. Only one part definition is returned with each fetch operation invocation. Therefore only one identifier can be passed to the service with each invocation. An empty container element is returned if a part definition identifier is passed that does not match a part definition instance inside the CPC application datastore.

The query operation is used to obtain a list of part definition identifiers from an Xquery query String. The Xquery query string identifies the criteria that the requesting application is requesting the CPC web service use to evaluate against the CPC parts datastore (the set of part definition instances it manages). Xquery is a standard for describing queries against XML documents. This query string can be used to locate part definitions that meet some set of application requirements. For instance, an application may need to locate all part definitions for butterfly valves with interior diameter of 2 inches. The Xquery string parameter is used to obtain a part definition identifier of the part definitions that meet the query's criteria. In addition, the query may result in more than one item being found that meets the criteria and as result a list of part definition identifiers may be returned. Finally it may result in no items being found and therefore an empty list may also be returned. For each of the three possible outcomes (single item matches, multiple items match, no items match) the results are returned to the invoking application as XML content using a container element from the CPC XML Schema, containing the matching part definition identifiers.

The update operation is used to add or replace a part definition inside the CPC application's datastore. The update operation requires two parameters, a part definition and a part definition identifier String. If the part definition identifier matches a part definition instance in the CPC application datastore then the part definition will replaced the one matching in the datastore. If the part definition identifier does not match then a part definition will be added into the CPC application's datastore using the part definition identifier as a reference identifier. The part definition must be XML content contained within a container element from the CPC XML Schema. Upon completion of the update the method will return the part definition identifier used in the update to the invoking application.

4.2.12 Heating, Ventilation, and Air-Conditioning (HVAC) Design – SCIM Chapter 9

This chapter of the SCIM specifies requirements for the exchange of information required for the design, analysis, and installation of heating, ventilation, and air-conditioning (HVAC) components and HVAC systems. It also specifies requirements for the exchange of functional characteristics of HVAC components and systems.

HVAC systems are used to convey and disperse air for the purpose of temperature control within a variety of engineering products. Generally, an HVAC system comprises a network of ducts and HVAC components (fittings and valves), and is attached to processing equipment such as air-conditioning or heating units. Large HVAC systems are generally attached to some supporting structure through the use of supports and hangers.

Four major application areas corresponding to major stages of HVAC product life cycle are:

- contract/functional design;
- detail design;
- production engineering;
- support engineering.

Users/developers of HVAC product information in these stages of product life cycle have different information requirements and views of the product. Users in the contract design stage design view an HVAC system principally as a functional network of equipment.

Functional design stage designers see HVAC in much the same way but develop and use much more detailed information concerning operating states of a system, and the characteristics of sub-networks of HVAC components within an overall system in terms of material specifications and flow characteristics. They also, for some systems, develop and use data concerning the loading, and fixity, of portions of the system in order to evaluate stress levels. The functional view is typically used to identify a preliminary purchasing bill of material in which purchase specification and long lead-time equipment and components are identified.

The functional design stage view is also the one which, along with contract specifications, is used in formulating and performing systems testing following installation. Because of the commonality of views in the contract and functional design stages, they can be combined into a single application area.

Detail design users have a three-dimensional arrangements view of HVAC systems. They are concerned with the arrangement in 3-D space of HVAC components meeting the applicable system specification and with ensuring that the arranged components are free from interference with the surrounding environment. This view of the data is also the view that typically supports the final purchasing bills of material.

Production engineering stage users are concerned with defining HVAC assemblies and the information needed to fabricate the pieces of these assemblies. This information can consist of bending instructions, joining instructions/specifications, and coating instructions. They also specify the installation processes to be used to install such assemblies in the final product and the post-installation tasks to be carried out. The production engineering function creates and makes use of the production bill of material view.

The HVAC product view taken by users in the support engineering stage is mainly that of the functional design, but from the standpoint of defining the support requirements of the product. Such requirements include spare parts complements, maintenance procedures and related documentation, and operational specifications and documentation.

This chapter of the SCIM (AP227 HVAC Design) applies to all four of the application areas above. It specifies the product model information needed to capture the design and facilitate the manufacturing of the HVAC system. In addition, it describes the functional connectivity of an HVAC system and the functional connectivity among objects in that system.

The AP227 Plant spatial configuration STEP standard identifies Plant objects, Plant_item objects, Plant_system objects, and other components associated with the Plant. The SCIM replaces “Plant” with “Ship”, i.e., Ship objects, Ship_item objects, Ship_system objects and other components associated with the Ship.

The STEP application objects are entities in SCIM. The entities have been organized into the following functional groups:

- Components
- Connectors and Connections
- Fittings
- HVAC Characteristics
- HVAC Specific Geometry
- Sections
- Supports
- Systems

- Terminations

4.2.13 Engineering Analysis – SCIM Chapter 10

This chapter of the SCIM specifies an information model and schema for the exchange of product data representing the definition of engineering analysis process and products. It is based on the business objects standardized in the 2nd Edition of the ISO 10303-209 standard.

The Engineering Analysis Chapter includes general analysis concepts that can be used in many types of analysis. These are referred to as the Engineering Analysis Core Model in ISO 10303-209. These core concepts relate an Engineering Analysis to the design data which is being analyzed. In addition to identifying the source part or system that is being analyzed, and referencing the nominal design shape developed by the ship designers, the capability is included to provide a simplified "idealized" shape from which a numerical analysis model can be derived. In the case of finite element analysis for structural parts and systems, this idealized shape is normally a mid-plane surface representation of the structural parts. Configuration management capabilities from the PDM Chapter of the SCIM provide organizational tracking and approval of each version of the analysis data, identification of the ship design contract applicable to the analysis, and record the security classification of the data.

While the majority of the Engineering Analysis Chapter of the SCIM is applicable to any type of analysis, specific constructs are included for the documentation of Finite Element Analyses and their relationship to the design data documented in other chapters of the SCIM. These include identification of FEA models, analysis results and the documents containing the analysis reports resulting from the particular analysis. It is expected that the detailed FEA model meshes, loads, conditions and similar data will be communicated in digital files conforming to ISO 10303-209. Due to the large size of the analysis data, most industrial organizations are investigating handling this ISO 10303-209 data in a binary format conforming to ISO 10303-26, rather than in XML. The capability is included to reference and configuration manage these binary digital files as well as their relationship to both the source design data and any interim simplified geometric representation that was used to derive the analysis data.

4.2.14 Electrotechnical Design and Installation – SCIM Chapter 11

4.2.14.1 Introduction

This SCIM chapter describes a data model for design and installation information of electrotechnical equipment used in ships, plants, industrial systems or vehicles. This part describes the information shared between the parties involved in the design, the installation and the commissioning of the apparatus. Design is understood as a process of combining components such as generators, motors, transformers, relays, programmable logic controllers, or software, etc., that comprise a system. Such a system may also be used to control the navigation, environment or combat systems on a ship or a chemical process in a factory. The description includes various characteristics of the design, such as physical aspects or the aspects related to the installation of the equipment. The functional design aspects of AP212 were descoped as described below.

Arrangement data, the routing of cables and the arrangement of the equipment is described by the installation, course, and site Units of Functionality (UoFs). In many cases the system components are categorized in accordance to an existing classification system. The classification UoF specifies the necessary concepts.

The information flow within the system may be described by specifying the signals that are generated, processed or transmitted within the system. The messages UoF comprises the concepts that specify the information flow.

Requirements and constraints levied against the system are represented by conditions that affect the products used and their installation.

The detailed product information of procured or premanufactured parts is not included in AP212, hence that information is not in this SCIM data model. However, access to the shipyard Common Parts Catalog logical model as described in SCIM Chapter 8, Common Parts Procurement, is provided through PDM Chapter entity, npd:Catalog_part.

4.2.14.2 Adaptation of AP212 to the SCIM

The goal of the SCIM is to define the "minimum information that must be maintained within an IPDE to enable effective interoperability among shipbuilding IPDEs." To accomplish that for the SCIM Electrotechnical Design and Installation Chapter, the following three concepts were applied:

- Support use cases described in the AP212 Usage Guide for the Exchange of Ship Electrical System Data,
- Considered details of drawing implementation as out of scope of the SCIM,
- Use the lighter weight SCIM PDM Chapter data model where applicable.

The AP212 Usage Guide for the Exchange of Ship Electrical System Data (NSRP 0425: NSRP Electrical/Cableway Application Protocol, V2.0, November 15, 2000) was reviewed to ensure a subset of AP212 was included in the SCIM to support the use cases identified in the Usage Guide. NSRP 0425 in PDF format is accessible from the AP212 Usage Guide for the Exchange of Ship Electrical System Data page, which is accessed from the SCIM Appendices page. In addition a mapping of SCIM implemented AP212 UoFs and entities to Usage Guide use cases is presented on the AP212 Usage Guide for the Exchange of Ship Electrical System Data page.

There are efforts ongoing at several shipyards to implement electronic drawings and data exchange. The SCIM was not considered the data model to support this.

The SCIM PDM Chapter includes lighter weight data models for Approvals that can be applied to the AP212 Effectivity_data, Organizational_data, and Work_management UoFs.

The application of these concepts to determine which AP212 Units of Functionality were implemented is summarized in the following table.

Table 4-1 - AP212 Units of Functionality implemented based on SCIM Electrotechnical Design and Installation Chapter development concepts

AP212 Unit of Functionality (UoF)	Status in the SCIM	Rationale
Allocation (AL1)	Not Implemented	Not used in Usage Guide Use Cases
Classification (CA1)	Implemented	Used in 5 of 11 Usage Guide Use Cases
Conditions (CD1)	Implemented	Important in A.3.11, Drawing, Use Case
Configuration_management (CF1)	Down Scoped	Not used in Usage Guide Use Cases; Functional related entities removed (specification, solutions); SCIM focuses on component hierarchies and the physical placement of components and instances
Course (CO1)	Implemented	Supports path specification of cable ducts or wireways
Designation (DE1)	Implemented	Used in 10 of 11 Usage Guide Use Cases

AP212 Unit of Functionality (UoF)	Status in the SCIM	Rationale
Dimensioned_documentation (DI1)	Not Implemented	Details of drawing implementation is out of scope of the SCIM
Documentation (DO1)	Down scoped	Focus on the drawing as an object and not the drawing content
Effectivity_data (EF1)	Not Implemented	Replaced with PDM data model
External_reference (ER1)	Down Scoped	Downscoped to replace the document properties application objects with the PDM entity npd:Document_metadata; augmented to access to the PDM external reference model to other SCIM chapter instance files
Function_structure (F1)	Not Implemented	Not used in Usage Guide Use Cases
Functional_connectivity (C1)	Not Implemented	Not used in Usage Guide Use Cases
Installation (IN1)	Implemented	Critical to A.3.9, Cableway design, and A.3.10, Cable and equipment installation, Use Cases
Messages (M1)	Implemented	Critical to A.3.6, Messages, Use Case
Network_allocation (NA1)	Not Implemented	Not used in Usage Guide Use Cases
Organizational_data (OD1)	Down scoped	Replaced with PDM data model
Physical_connectivity (PC1)	Implemented	Used in 6 of 11 Usage Guide Use Cases
Product_structure (PD1)	Implemented	Used in 11 of 11 Usage Guide Use Cases
Properties (PR1)	Implemented	Used in 9 of 11 Usage Guide Use Cases
Remark (R1)	Not Implemented	Details of information such as comments, assembly instructions, manufacturing instructions is out of scope of the SCIM.
Schematic_documentation (SC1)	Not Implemented	Details of drawing implementation is out of scope of the SCIM
Site (SI1)	Implemented	Critical to A.3.9, Cableway design, and A.3.10, Cable and equipment installation, Use Cases
Work_management (W1)	Down scoped	Replaced with PDM data model

4.2.14.3 SCIM AP212 Integration with PDM

To fully take advantage of the power of the SCIM data model, AP212 was integrated with the SCIM Product Data Management (PDM) Chapter to create the SCIM Electrotechnical Design and Installation

Chapter. The PDM Chapter is comprised of the following functional groups, which are described in SCIM Chapter 1:

- Ship Identification
- Hull Configuration
- Parts
- Part Lifecycle Views
- Design Requirements
- Part Design Properties
- Part Shape
- Documents
- Approvals
- Engineering Change

SCIM AP212 Integration with PDM focuses on the Parts, Part Lifecycle Views, Design Requirements, Part Shape, and Approvals functional groups of PDM. Guidance for this integration was obtained from the AP212 Usage Guide. Generally, key AP212 entities were either subtyped from PDM entities or related to PDM entities via associations. Subtyping and relationships preserve the AP212 data model features via AP212 associations of the subtype, while permitting access to the PDM data model features through the supertype and its associations with the rest of the PDM data model. AP212 Usage Guide, Section 5.1.1, Item and related entities, indicated the AP212 Item entity maps to the PDM npd:Design_part since both represent a part that could be used in the design of an electrical system. The application of a design part to a specific purpose is specified the by AP212 entity Design_discipline_item_defintion. An instance of a part fulfilling this specification is a Device. In PDM this is a Design_occurence. Hence, Device is subtyped from PDM entity npd:Design_occurence.

Sometimes a design part is fulfilled from a catalog part. On page 56 of the AP212 Usage Guide, Figure A.18 shows the transformer T1 is represented by an instance (#291) of the Single_device entity (a subtype of Device). The definition for the Single_device is given by Design_discipline_item_definition, which points to a catalog description of transformer T1. Figure A.18 shows this "catalog description" as an Item_version instance. On page 132 of the AP212 Usage Gude, it states, "Recall that a Design_discipline_item_definition represents the typical or "catalog" item." Thus the concept of catalog part is shared between two AP212 entities. PDM entity npd:Catalog_part, which provides access to the SCIM Chapter 8, Common Parts Procurement (CPP), is integrated with AP212 via two assocations: npd:Design_disipline_item_defintion.catalog_part and npd:Item_version.catalog_part. The SCIM CPP Chapter is a logical model of the shipyard Common Parts Catalog.

In PDM a Physical_part is the physical manifestion of a Design_part. In AP212 a Physical_instance is a physically realized Item. As described above, an Item maps to a PDM Design_part. Thus the PDM Physical_part corresponds to the AP212 Physical_instance. Integration is by subtyping AP212 Physical_instance from PDM Physical_part.

The PDM Part Lifecycle Views functional group addresses several aspects of the lifecycle. The design aspect (Design_occurence) was discussed above. The other aspects do not have a direct correspondence with AP212 as follows:

- AP212 does not have a concept that maps to npd:Physical_occurrence. However, the user can associate AP212 npd:Physical_instance to npd:Physical_occurence via the generalization to PDM npd:Physical_part

- AP212 does not contain a logistics component to subtype from npd:Logistics_occurrence. Hence, electrical logistics must come from PDM logisitics relationships to PDM supertypes of AP212 entites.
- AP212 has built in electical analysis functionality. Some excellent examples of this is reviewed in the AP212 Usage Guide use cases. While PDM offers the npd:Analysis_occurrence entity, SCIM Chapter 11 does not subtype from npd:Analysis_occurence. If PDM npd:Analysis_occurence is desired, it can be accessed via npd:Design_occurence.

The AP 212 Organizational_data UoF was descoped to the following entities: Approval, Certification, Security_classification, and Security_level. Approval, Certification, and Security_classification were subtyped from the correspondingly named PDM entity and renamed npd:Approval_electrical, npd:Certification_electrical, and npd:Security_classification_electrical. Properties with name clashes between PDM and AP212 were subsumed by PDM. The documentation below has the details. Each AP212 entity was retained to ensure the associations with the AP212 data model was maintained. Thus, for example, the AP212 approval relationships with the rest of the AP212 data model are maintained while the organizational information is obtained from PDM through the npd:Approval relationships.

The AP 212 Work_management UoF was descoped to the following entities: Contract, Organization_in_contract. Contract was subtyped from the correspondingly named PDM entity and renamed npd:Contract_electrical. Again, the relationships between Contract, Organization_in_contract, and the reast of the AP212 data model was maintained. PDM entity npd:Contract allows access to PDM contract functionality.

The AP 212 Conditions UoF was implemented in full. However, AP212 entity Requirement was subtyped from the PDM entity Design_requirement and renamed npd:Requirement_electrical. Thus, either the PDM or AP212 requirement data models can be used depending on the need. The PDM model is lighter and may meet most needs.

The AP 212 Documentation UoF and External_reference UoFs were both downscoped. UoF Documentation provides the drawings data model. It was downscoped to focus on the drawing as an object; the internal details of the drawing were removed. UoF External_reference provides the references data model to external documents that may or may not be AP212 compliant . It was downscoped to replace the document properties application objects with the PDM entity npd:Document_metadata, which contains most of the removed functionality. The SCIM adds associations between PDM entity npd:Document_metadata and npd:Drawing_electrical (npd:Drawing.document_metadata) as well as npd:Document (npd:Document.document_metadata) in support of this functionality. AP212 application object Drawing was renamed npd:Drawing_electrical to avoid a name clash with Chapter 7, PLCS, entity npd:Drawing. In addition, AP212 entity Digital_file was retained and subtyped from the correspondingly named PDM entity and renamed npd:Digital_file_electrical in the External_reference UoF. This permits access to the PDM external reference model to other SCIM chapter instance files. See the PDM Chapter for details

5 DELIVERY OF THE SCIM

5.1 Make Available on NSRP Website

The SCIM is approved for public release with unlimited distribution, and there will be no restrictions as to its availability. The ILE Team feels that easy access and widespread availability are essential to enable a data exchange standard to be accepted and extensively implemented.

The SCIM is currently located on the www.isetools.org Website, and, in addition, will shortly be placed on the NSRP Website at www.nsrp.org, where it should be easily accessible and widely available.

5.2 Publicize

The ILE Team has made every effort to publicize the SCIM and encourage its adoption as the standard for data exchange among U.S. shipyards and the Navy.

Formal presentations have been given at the Ship Production Symposium (SPS) and SNAME Annual Meeting for the last two years, and at ShipTech in 2011 and 2012.

In addition regular presentations were given at NSRP Joint Panel Meetings throughout the ILE Project to update the audience on the status of the ILE Project and the content of the SCIM.

5.3 SCIM Implementation Video

A video presentation describing the requirements of shipbuilding data exchange and how the SCIM meets these needs has been developed by the ILE Team in conjunction with the NSRP Workforce Development Panel. It was produced by the "Panel Project Technology Transfer Templates", which was an NSRP Panel Project under the Workforce Development Panel.

It is hoped that this video can be shown to as wide an audience as possible within the U.S. shipbuilding community and the Navy to encourage the adoption of the SCIM as the standard information model to be used for data exchange of future ship design, manufacturing, and lifecycle support efforts.

6 SUMMARY

The idea for the SCIM as an information model to support data exchange and interoperability in shipbuilding came from the NPDI effort and the numerous Integrated Shipbuilding Environment (ISE) Projects run through NSRP.

In order to make the SCIM a viable document that would be of value to the Navy and the shipyards, it had to be completed and validated. The capabilities of the SCIM to support interoperability for the next generation IPDE needed to be demonstrated before it could be invoked as a contractual requirement.

The Integrated Logistics Environment (ILE) Project has addressed both of these requirements. As ILE concludes, it leaves a SCIM document whose use has been prototyped and thereby validated, and which represents the best efforts at defining an information model for the product data required to support U.S. shipbuilding for design, manufacture, and lifecycle support.

It is the hope of the ILE Team that the SCIM can become a requirement on future Navy contracts, and that the SCIM can provide the basis for successful data exchange and interoperability among U.S. shipyards and the Navy.

REVISION HISTORY

Rev	Rev Date	Revised By	Description	Reason
1.0	11/21/12	BFG	Initial Release	
2.0	11/26/12	BFG	Minor Editorial Changes	Fixed minor errors identified by Doug Martin