Approved, DCN# 543-426-23

POWER ELECTRONIC POWER DISTRIBUTION SYSTEM ARCHITECTURES

Technical Report

Submitted to:
The Office of Naval Research

Contract Number: N00014-21-1-2124

Submitted by:
Carmen E. Araujo, David C. Gross, Michael “Mischa” Steurer, Naqash Ali

March 2023

Approved, DCN# 543-426-23

ELECTRIC SHIP RESEARCH AND DEVELOPMENT CONSORTIUM

ESRDC

MISSION STATEMENT

The Electric Ship Research and Development Consortium brings together in a single entity the combined programs and resources of leading electric power research institutions to advance near- to mid-term electric ship concepts. The consortium is supported through a grant from the United States Office of Naval Research.

Florida State University

Massachusetts Institute of Technology

Mississippi State University

Naval Postgraduate School

Purdue University

University of South Carolina

United States Naval Academy

The University of Texas at Austin

2000 Levy Avenue, Suite 140 | Tallahassee, FL 32310 | www.esrdc.com

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 EXECUTIVE SUMMARY

This report discusses the process, product, and purpose of the PEPDS System Model Version 1.0 which captures diverse stakeholder needs, analyzes black box and white box functions, defines black box and white box context and interfaces, and identifies measures of effectiveness and performance. The foregoing elements distill into a set of system requirements that result in the PEPDS functional architecture. This report is intended to accompany the PEPDS System Model Version 1.0 with the purpose of assisting the reader with navigating and understanding the model.

2 NOMENCLATURE

Nomenclature is defined in the PEPDS System Model Glossary provided in section 11.3, the MagicGrid® Book of Knowledge glossary from reference [1], and the No Magic Inc. Glossary of SysML Concepts from reference [2].

3 INTRODUCTION

The Power Electronic Power Distribution System (PEPDS) is a new power, energy, and control distribution concept enabled by technology development funded by the Office of Naval Research (ONR). "The goal of the PEPDS program is to achieve revolutionary changes to system design and operation by leveraging recent technological advances and developing both the applications to use them and the control and modeling capabilities needed to employ them" [3]. The PEPDS development program has five (5) main areas of science and technology development:

1. Navy Integrated Power Electronics Building Block (NiPEBB),
2. Navy Integrated Power and Energy Corridor (NiPEC),
3. Model is the Specification,
4. Control, and
5. System Simulation.

The technical approach for integrating this work is digital engineering grounded in Model-Based System Engineering (MBSE). The product of this MBSE effort is the PEPDS System Model which is a living document that will change and grow throughout the lifetime of the system.

This report discusses the process, product, and purpose of the PEPDS System Model Version 1.0 which captures diverse stakeholder needs, analyzes black box and white box functions, defines black box and white box context and interfaces, and identifies measures of effectiveness and performance. The foregoing elements distill into a set of system requirements that result in the PEPDS functional architecture. This report is intended to accompany the PEPDS System Model Version 1.0 with the purpose of assisting the reader with navigating and understanding the model.

4 PROCESS

This section discusses the process used for developing the PEPDS System Model Version 1.0.

4.1 Contributors

The authors are chartered to lead the PEPDS functional architecture development. In that role, we established the PEPDS Architecture Team, see Table I, to provide a framework for PEPDS architecture studies and to enable collaborative research. The PEPDS Architecture Team uses the Systems Modeling Language (SysML) to develop the PEPDS System Model with the Cameo

Enterprise Architecture (Version 19) software, explained in detail in section 4.2. Consistent with similar projects at the Naval Sea Systems Command (NAVSEA), the PEPDS System Model follows the MagicGrid® Framework, explained in section 4.3.

Table I: PEPDS Architecture Team Members

Organization	Lead Researcher	Main Research Topic	Supporting Team Members
Florida State University	Michael "Mischa" Steurer (Lead Architect)	Architectures, Abilities, System Integration	Carmen E. Araujo (Lead MBSE & Team Point of Contact), David C. Gross (MBSE), Naqash Ali, Jodie Bell, Karl Schoder, Matthew Bosworth, Sihun Song
Florida State University	Juan Ordonez	Thermal Management	
Massachusetts Institute of Technology	Julie Chalfant	NiPEC, Naval Architecture	Matt Kruse, Drake Platenberg, Avi Chatterjee
University of South Carolina	Herbert L. Ginn	Controls	Aaron De La O Perez
University of Texas at Arlington	David A. Wetz	Energy Storage	Shawn 'Tyler' Scoggin, Hayden Atchison, Alex Johnston
University of Wisconsin-Milwaukee	Robert M. Cuzner	Virtual Prototyping	Jacob David Gudex, Joey Authement, William Joseph Koebel, Jose Antonio Trujillo Parra, Hamed Shabani, Rounak Siddaiah
Virginia Tech	Dong Dong	NiPEBB	Daniel Sathri, Marie Lawson
NSWCPD	Aaron Scherr		
NSWCPD	Nathan Spivey		
NSWCPD	Robert "Bob" Irwin (PI)	Stability Design & Assessment	
NSWCPD	Shawn Plesnick (AI)	Stability Design & Assessment	
Previous Team Members	n/a		Igor Cvetkovic (VT), Rolando Burgos (VT), Richard Zhang (VT), Dushan Boroyevich (VT), Christina DiMarino (VT), Salman Hussain (FSU), Ceca Mijatovic (FSU), James Narey (UTA)

4.2 Model Based Systems Engineering

MBSE is “the formalized application of modeling to support system requirements, design, analysis, verification, and validation activities beginning in the conceptual design phase and continuing throughout development and later lifecycle phases” [4]. The benefits of using an MBSE approach over a traditional document-based approach are enhanced communications, reduced developmental risk, improved quality, increased productivity, and enhanced knowledge transfer [5].

For the PEPDS System Model, the MBSE tool being used is the Cameo Enterprise Architecture Version 19 software. The Cameo Enterprise Architecture, herein referred to as Cameo, is a product of CATIA No Magic owned by Dassault Systems. The Cameo supported modeling language selected for the PEPDS System Model is SysML. “Modeling languages are

specifications which provide standardized guidelines and structures for expressing system information" [6]. SysML is one of the more frequently used modeling languages for MBSE and is a "graphical language that utilizes diagrams and tables in order to express system information and provides a standard set of nine diagram types which can be used to organize and express system information" [6]. The information expressed via a modeling language is often organized via an architecture framework [6]. The PEPDS System Model follows the MagicGrid® Framework which is discussed in section 4.3.

4.3 MagicGrid® Framework

The PEPDS System Model follows the MagicGrid® Framework defined by the first edition of the MagicGrid® Book of Knowledge by NoMagic, Inc. The MagicGrid® Framework is shown in Fig. 1. The MagicGrid® approach "includes the definition of the problem, solution, and implementation domains in the system model. They align with the processes defined by ISO/IEC/IEEE 15288 as follows: problem domain with the Stakeholder Needs Development process, solution domain with the Architecture Definition process, and implementation domain with the Design Definition process" [1]. "Each domain definition includes four different aspects of the system to be considered and captured in the model. These aspects match the four pillars of the SysML, that is, requirements, behavior, structure, and parameters" [1].

	PILLAR					
DOMAIN			**Requirements**	**Behavior**	**Structure**	**Parameters**	**Specialty Engineering** **Integrated Testing** **Analysis**
	Problem	**Black Box**	B1-W1 Stakeholder Needs	B2 Use Cases	B3 System Context	B4 Measurements of Effectiveness	
		White Box		W2 Functional Analysis	W3 Logical Subsystems Communication	W4 MoEs for Subsystems	
	Solution		S1 System Requirements	S2 System Behavior	S3 System Structure	S4 System Parameters	
			SS1 Subsystem Requirements	SS2 Subsystem Behavior	SS3 Subsystem Structure	SS4 Subsystem Parameters	
			...	...	...	...	
			C1 Component Requirements	C2 Component Behavior	C3 Component Structure	C4 Component Parameters	
	Implementation		I1 Physical Requirements	Software, Electrical, Mechanical			

Fig. 1: MagicGrid® Framework [1]

The PEPDS System Model Version 1.0 contains content for the entire Problem Domain and S1 System Requirements. Two modifications to the MagicGrid® Framework occur in the PEPDS System Model Version 1.0. The first is that some structure diagrams in B3 and W3 are combined into one diagram for convenience. These are the B3.1/W3.1 System Context and Logical Architecture diagram and the B3.3/W3.3 Exchange Items diagram. The second modification is in the W4 MoEs for Subsystems section. Here, the PEPDS System Model Version 1.0 provides the Measures of Performance (MoPs) that make up each of the Measures of Effectiveness (MoEs), defined in B4, for PEPDS at a system level. The MoEs and MoPs for each subsystem are not yet defined but will pull from the MoEs and MoPs defined in the B4 and W4 sections.

The PEPDS System Model contains a MagicGrid® Index, shown in Fig. 2, that provides easy access to each section's content. Each section has a package diagram that will contain links to all the diagrams and tables created for that section. A copy of each section's package diagram is provided in section 11.4.

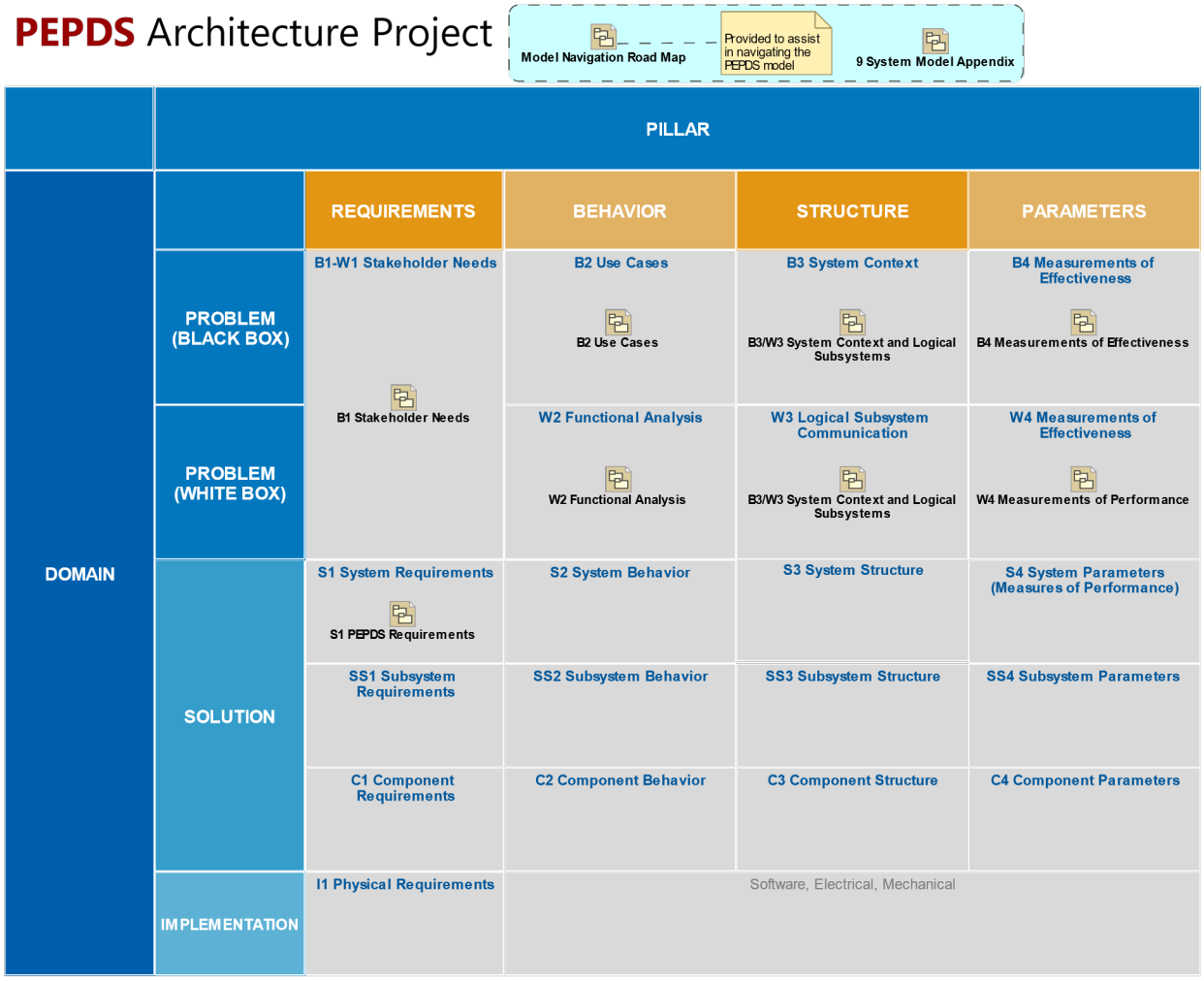


Fig. 2: PEPDS System Model MagicGrid® Index

4.4 PEPDS System Model Navigation Roadmap

To assist the reader in navigating and understanding the PEPDS System Model, a road map for navigating the model was created. Fig. 3 shows a high-level summarized version of the road map. A copy of the road map is provided in section 11.1. The PEPDS System Model can be explored using the MagicGrid® Index or the road map. This report will discuss each diagram in the model in the order suggested by the road map.

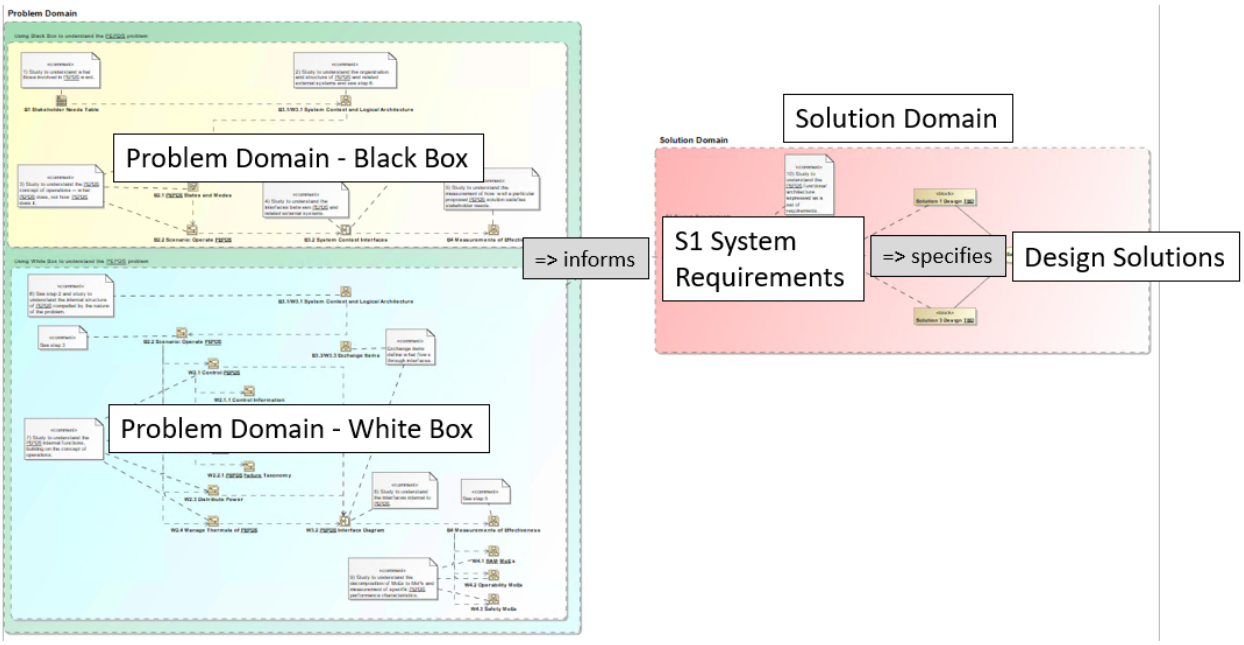


Fig. 3: Explanation of PEPDS System Model Road Map

5 PRODUCT

This section will walk the reader through the PEPDS System Model Version 1.0. The PEPDS System Model Version 1.0 captures diverse stakeholder needs, defines black box and white box context and interfaces, analyzes black box and white box functions, and identifies measures of effectiveness and performance. The foregoing elements are distilled into a set of system requirements that result in the PEPDS functional architecture.

To view the model in Cameo, follow the instructions in section 10 to download, install, and use the Cameo Enterprise Architecture Reader, herein referred to as Cameo Reader. After opening the PEPDS System Model in the Cameo Reader, there will be a road map illustrating how the model developers suggest the reader should review the model. Sections 5.1, 5.2, and 5.3 of the report explain the PEPDS System Model contents in the order of the road map to enhance reader comprehension. A copy of the road map and each of the diagrams and tables reviewed with the road map are provided in Appendix B: PEPDS System Model Contents.

5.1 Black Box Problem Domain

A copy of each of the diagrams and tables reviewed in this section is provided in section 11.2.

5.1.1 B1 Stakeholder Needs Table

The B1 Stakeholder Needs Diagram defines what those involved in PEPDS require and desire. Within the model, they are represented as business requirements. Throughout the model, these business requirements are referenced to provide rationale for certain design choices.

5.1.2 B3.1/W3.1 System Context Interfaces and Logical Architecture

The top section of the B3.1/W3.1 System Context and Logical Architecture diagram shows how PEPDS exists in its environment. PEPDS is an electric system existing on the electric ship. It interacts with other systems on the electric ship as well as external systems. These interfaces are defined in the B3.2 System Context Interfaces diagram discussed in section 5.1.6. The bottom section of the B3.1/W3.1 System Context and Logical Architecture diagram is part of the White Box Problem Domain and is reviewed in section 5.2.1.

5.1.3 B2.1 Use Cases of PEPDS

After gaining an understanding of the system context, proceed to review the PEPDS concept of operations. The PEPDS System Model Version 1.0 defines the concept of operations in three diagrams that express what PEPDS does, but not how PEPDS does it.

The first step is to understand its use cases shown in the B2.1 PEPDS Use Cases diagram. An important requirement of PEPDS is to simplify its operation and maintenance to the point that minimal training on PEPDS is required for the crew. In addition to this, Maintain PEPDS is an included use case within the Operate PEPDS use case. This is because it is required that PEPDS can remain operational while maintenance is performed. The goal is that PEPDS always remains operational while away from the shipyard. This means that PEPDS' ability to operate in nominal and off-nominal conditions is required in addition to its ability to operate during times of maintenance. This concept is further elaborated on in the B2.2 PEPDS States and Modes diagram in section 5.1.4.

PEPDS is also required to have advanced functional control and simple least replaceable unit (LRU) replacement. This is part of the maintenance that must be executable by the crew. The crew is expected to be able to control the component and network functions through programming and reconfiguration as well as replace LRUs that are carriable by a single sailor and require minimal training for installation and removal.

5.1.4 B2.2 PEPDS States and Modes

The B2.2 PEPDS States and Modes diagram shows the states, modes, and transitions that exist for PEPDS. PEPDS states are Off, Operating, and Performing SHIPALT.

The Performing SHIPALT state is needed for the stakeholder need of having PEPDS installable as a unit at the shipyard. This expected PEPDS innovation consists of construction and testing being executable off the ship and avoiding intensive cabling after ship construction.

The operating state reflects the use cases defined in section 5.1.3. The Operating state has the modes of Operating Nominally, Operating Off-Nominally, and Maintaining. The transitions between these modes defined in the diagram reflect multiple stakeholder needs. To minimize the possibilities of failures, condition-based maintenance plus (CBM+) is expected to be fully integrated into the PEPDS design. If a failure does occur, PEPDS is expected to be able to diagnose and prognose failures to autonomously recover when possible. If autonomous recovery is not possible, the crew must perform corrective maintenance. After repairs are completed,

PEPDS is expected to be able to self-adapt to the repairs and upgrades as well as perform a self-check to ensure the system has fully recovered.

5.1.5 B2.3 Scenario: Operate PEPDS

The B2.3 Operate PEPDS Scenario diagram elaborates on select activities that occur while PEPDS is in the operating state defined in section 5.1.4. This diagram shows the exchange items that enter and leave PEPDS, where they come from or go to, and what activities they are used for during the Operate PEPDS scenario. The main functions of PEPDS, shown in gold, are Control PEPDS, Protect PEPDS, Distribute Power, and Manage Thermal Load of PEPDS. These functions occur simultaneously in a loop from when PEPDS is turned on to when it is turned off. The functions (depicted as behaviors in the model) define how the system achieves its capabilities (depicted as structures in the model). These behaviors and structures are further defined in the White Box Problem Domain review in section 5.2.

5.1.6 B3.2 System Context Interfaces

The B3.2 System Context Interfaces diagram displays the exchange items traveling across the PEPDS external interfaces. It shows all possible exchange items, not just the exchange items for one specific scenario like in the B2.3 Scenario: Operate PEPDS diagram discussed in section 5.1.5 . The diagram also shows some of the possible onboard power loads, onboard power sources, and offboard power systems that PEPDS may interact with.

5.1.7 B3.3/W3.3 Exchange Items

The B3.3/W3.3 Exchange Items diagram elaborates on the exchange items that travel in, out, and within PEPDS.

5.1.8 B4 Measurements of Effectiveness

Based on the stakeholder needs defined in the B1 Stakeholder Needs Table discussed in section 5.1.1, three measurements of effectiveness (MoEs) were defined for PEPDS. These are RAM (reliability, availability, maintainability), operability, and safety. The B4 PEPDS MoEs diagram shows these MoEs as well as the measures of performance (MoPs) that are within them. The MoPs are defined further in the White Box Problem Domain review in section 5.2. These MoEs and MoPs measure how well a particular proposed PEPDS solution satisfies stakeholder needs. Review the B4 PEPDS MoEs traced to B1 Stakeholder Needs matrix to see how each MoE and MoP traces back to the stakeholder needs.

5.2 White Box Problem Domain

A copy of each of the diagrams and tables reviewed in this section is provided in section 11.2.2.

5.2.1 B3.1/W3.1 System Context Interfaces and Logical Architecture Part 2

Returning to the B3.1/W3.1 System Context and Logical Architecture diagram discussed in section 5.1.2, review the second half of the diagram containing the PEPDS Logical Architecture.

PEPDS subsystems are defined as capabilities. These capabilities (depicted as structures in the model) represent what the system of interest can do, as contrasted with the functions (depicted as behaviors in the model) introduced in the B2.3 Scenario: Operate PEPDS diagram discussed in section 5.1.5. The PEPDS capabilities are the Control Capability, Protection Capability, Electrical Distribution Capability, and Thermal Management Capability. The Electrical Distribution Capability is split into three sub-capabilities which are the Energy Storage Capability, Power Transportation Capability, and Power Conversion Capability. The goal of making converters part of distribution is "to reduce cost, achieve control, improve performance, enable cyber security, and further reduce size and weight" [3]. The operational paradigms of future warships depend on energy storage creating a need for "integration of both point and distributed energy storage directly into the power distribution system" [3]. This is why the Energy Storage Capability, Power Transportation Capability, and Power Conversion Capability are defined as parts of the Electrical Distribution Capability.

Each PEPDS Capability is made up of components that are defined as either LRUs or Non-LRUs. This approach to defining the components has the purpose of limiting unnecessary restrictions on the Solution Space while also encouraging PEPDS innovations defined in the B1 Stakeholder Needs Table discussed in section 5.1.1. LRUs are defined in the PEPDS Model as components that are easily installed, removed, and transported by a single sailor, have spares onboard, and that some are reprogrammable. Non-LRUs are defined in the PEPDS Model as components that are not easily installed, removed, and transported by a single sailor.

5.2.2 B2.3 Scenario: Operate PEPDS Part 2

Returning to the B2.3 Operate PEPDS Scenario diagram, discussed in section 5.1.5, each of the main functions of PEPDS, shown in gold, are executed by the PEPDS Capabilities defined in the B3.1/W3.1 System Context Interfaces and Logical Architecture diagram, discussed in section 5.2.1. Review the W2.1 Control PEPDS diagram discussed in section 5.2.3, the W2.2 Protect PEPDS diagram discussed in section 5.2.4, the W2.3 Distribute Power diagram discussed in section 5.2.5, and the W2.4 Manage Thermal Load of PEPDS diagram discussed in section 5.2.6 to see the behaviors carried out by each of the PEPDS Capabilities to fulfill these PEPDS functions.

5.2.3 W2.1 Control PEPDS

The W2.1 Control PEPDS diagram shows the behaviors of the control capability and the exchange items that are shared with other PEPDS Capabilities and external systems. The Control Capability has two functions. It controls the information within, entering, and exiting PEPDS and controls all PEPDS capabilities. The activities that occur in W2.1.1 Control Information are discussed in section 5.2.3.1 and the activities that occur in W2.1.2 Control PEPDS capabilities are discussed in section 5.2.3.2.

By controlling and processing information, the Control Capability updates the Control Strategy. The Control Strategy controls electrical power by commanding PEPDS Capabilities. Returning to the B3.3/W3.3 Exchange Items diagram discussed in section 5.1.7, the interface block named Control Strategy defines what is included in the Control Strategy which currently consists of the Operation Strategy, Protection Strategy, Maintenance Strategy, Forecasting Consequences, and

Cybersecurity Operations. These individual strategies and activities were combined under the overarching term “Control Strategy” because when one changes, the others must change as well.

5.2.3.1 W2.1.1 Control Information

The W2.1.1 Control Information diagram shows the behaviors of the Control Capability and the exchange items that enter and exit the Control Information activity. The commands and feedback entering the Control Information activity are used to consistently monitor PEPDS needs and user needs. If feedback from the Protection Capability requires an immediate response, the Control Capability will override other planned activities as needed and proceed to determine a course of action based on the Protection Capability feedback. If the Protection Capability feedback does not show a need for an immediate response, one of three paths will occur based on the Control Strategy. As shown in the B2.3 Scenario: Operate PEPDS diagram discussed in 5.1.5, the PEPDS functions occur in a loop. So, if one Control Information path is dependent on a different one, they will occur in the order needed. Just because one path is chosen does not mean a different one will never occur. They will just proceed in the order necessary for the task at hand.

The Capability Control Path determines a course of action based on the analysis of power load demands, power source supply, and capability needs. After determining a course of action, the Control Strategy is updated. The Functional Control Path programs communication networks, power networks, and PEPDS components. Once the programming is completed, it performs an automated self-check to assess the effects of the changes. The CBM+ Path initiates the CBM+ process. Data is captured and stored locally for internal CBM+ analysis. Select captured data is transmitted to Ship Control which relays it to an external database to support external CBM+ processes. Raw data and externally analyzed data are used to perform an internal CBM+ analysis. If this analysis produces evidence of need for maintenance, the Control Capability will determine a course of action to address this in a future iteration of the looped process. This evidence of need for maintenance can be a system health change or a PEPDS failure. All paths end with the track and improve activity which represents PEPDS’ ability to self-learn by tracking performance and CBM+ data and analyzing control and protection activities. At the end of the Control Information Activity, feedback is provided to the Crew and Ship Control.

5.2.3.2 W2.1.2 Control PEPDS Capabilities

The W2.1.2 Control PEPDS Capabilities diagram shows how the Control Capability executes the Control Strategy. As shown in the diagram, the Control Capability controls interfaces between PEPDS and external power systems, configures PEPDS networks and components, commands how power should be tailored, and addresses all other possible PEPDS Capability needs. It issues prioritized commands to PEPDS Capabilities as directed by the Control Strategy.

5.2.4 W2.2 Protect PEPDS

The W2.2 Protect PEPDS diagram shows the activities that occur for executing continuous protection and handling failures. The Protection Capability determines needs for safety, performance, and resilience based on the analysis of power source and load interfaces, analysis of PEPDS performance, commands by the Control Capability, and protection strategy in the Control Strategy. Based on the former, the Protection Capability will select a protection

response. If a failure occurs, diagnosis and prognosis are performed before selecting a protection response to address the failure. Selected protection responses are sent to the Control Capability for execution. The protection feedback may recommend immediate response of the system because of imminent danger to personnel, PEPDS, or an external system, may require an eventual response, or may require no response.

5.2.5 W2.3 Distribute Power

The W2.3 Distribute Power diagram shows how the Electrical Distribution Capability transports, converts, and stores power. The Electrical Distribution Capability consists of the Power Transportation Capability, Power Conversion Capability, and Energy Storage all of which are commanded by the control capability. Electrical power is transported from the source to the load and undergoes conversion when needed. After going through all necessary power conversions, the electrical power can either be stored or transported. The diagram shows that electrical power must go through the Power Conversion Capability before entering the Energy Storage Capability. This does not mean electrical power will always undergo conversion. If it is in the correct form, then it will be transported directly to the Energy Storage Capability.

5.2.6 W2.4 Manage Thermal Load of PEPDS

PEPDS Capabilities will create environmental loads as an unintended side effect of their functions. The Thermal Management Capability manages these loads and since they are unintended side effects, they are only modeled in the W2.4 Manage Thermal Load of PEPDS diagram. This diagram shows that the Thermal Management Capability regulates PEPDS internal thermal load to facilitate PEPDS continuing operations. One of the stakeholder needs requires that a universal thermal interface is proposed. System designers will create a PEPDS solution that regulates its internal thermal load using the resources available on the ship. A solution should be able to access and use the already existing environmental management services on the ship. The possible environmental management services are defined in the B3.3/W3.3 Exchange Items diagram discussed in section 5.1.7. The currently defined environmental management services are chilled water and forced air.

5.2.7 W3.2 PEPDS Interface Diagram

The W3.2 PEPDS Interface Diagram shows the interfaces and exchange items between PEPDS Capabilities as well as between PEPDS Capabilities and external systems. These are the same exchange items and interfaces defined in the white box behavior diagrams shown in a different view. This view shows the networks needed for PEPDS to execute its functions. These networks are a communication network, electrical power network, and environmental load management network.

5.2.8 B4 Measurements of Effectiveness Part 2

Returning to the B4 Measurements of Effectiveness diagram, discussed in section 5.1.8, each MoE is broken down into its MoPs that are defined in the W4.1 RAM MoEs diagram discussed in section 5.2.9, the W4.2 Operability MoEs diagram discussed in section 5.2.10, and the W4.3

Safety MoEs diagram discussed in section 5.2.11. The MoEs and MoPs for each PEPDS Capability are not yet defined but will pull from the MoEs and MoPs in the W4 diagrams.

5.2.9 W4.1 RAM MoEs

The W4.1 RAM MoEs diagram identifies constraint calculations, thresholds, and goals for each MoP for the RAM MoE.

5.2.10 W4.2 Operability MoEs

The W4.2 Operability MoEs diagram identifies constraint calculations, thresholds, and goals for each MoP for the Operability MoE.

5.2.11 W4.3 Safety MoEs

The W4.3 Safety MoEs diagram identifies constraint calculations, thresholds, and goals for each MoP for the Safety MoE.

5.3 System Level Solution Domain

A copy of each of the diagrams and tables reviewed in this section is provided in section 11.2.3.

5.3.1 S1 PEPDS Requirements

The problem domain elements were distilled into a set of system requirements that result in the PEPDS functional architecture. These system requirements are available in the tables and diagrams contained in the S1 System Requirements package diagram, provided in section 11.2.3.1. The S1 System Requirements diagrams, provided in section 11.2.3.2, show the S1 PEPDS Requirements organized in their respective packages and are traced to stakeholder needs. The tracing between S1 and the Problem Domain is shown in the S1 System Requirements Traceability Matrices, provided in section 11.2.3.3. The S1 System Requirements Table, provided in section 11.2.3.4, shows all of the S1 system requirements along with their tracing, source, verification method, risk level, and revision date.

The PEPDS System Model Version 1.0 ends at the S1 System Requirements.

5.4 PEPDS System Model Future Improvements

The PEPDS System Model is a living document that will change and grow throughout the lifetime of the system. It will continue to support system requirements, design, analysis, verification, and validation activities throughout development and later lifecycle phases [4].

Some aspects lacking in Version 1.0 that will be addressed in Version 2.0 are dynamic behavior, the ability to integrate with focus area models, and the modeling and analysis of the design trade space.

6 PURPOSE

Using an MBSE approach for the PEPDS development process will enhance communication, reduce developmental risk, improve quality, increase productivity, and enhance knowledge transfer [5]. System designers will use the PEPDS System Model to understand the PEPDS functional architecture, propose alternative designs, select a preferred design, and build and qualify implementations. The PEPDS System Model will provide a framework for PEPDS architecture studies and enable collaborative research.

7 CONCLUSION AND RECOMMENDATIONS

The PEPDS Architecture Team has successfully baselined a functional architecture described in terms of needs, functions, structures, and measures transformed into a baselined set of functional requirements. The functional architecture baseline enables initial exploration of the solution space. The system model will transition from its role in framing the problem to enabling exchange of technology research, data, and information and exploration of the PEPDS design trade space.

Forthcoming work includes adding dynamic behavior to the system model, acquiring tools, enabling integration of the system model with focus area models, and exploring the PEPDS design trade space.

8 ACKNOWLEDGEMENTS

The authors gratefully acknowledge the contributions of the Architecture Team shown in Table I.

9 REFERENCES

[1] A. Aleksandraviciene and A. Morkevicius, MagicGrid® Book of Knowledge: A Practical Guide to Systems Modeling using MagicGrid from No Magic, Kaunas, Lithuania: Vitae Litera, 2018.

[2] "Glossary of SysML Concepts," No Magic Product Documentation. [Online]. Available: https://docs.nomagic.com/display/SYSMLP190/Glossary+of+SysML+concepts. [Accessed: 07-Mar-2023].

[3] L. Petersen, C. Schegan, T. S. Ericsen, D. Boroyevich, R. Burgos, N. G. Hingorani, M. Steurer, J. Chalfant, H. Ginn, C. DiMarino, G. C. Montanari, F. Z. Peng, C. Chryssostomidis, C. Cooke, and I. Cvetkovic, "Power Electronic Power Distribution Systems (PEPDS)," Electric Ship Research & Development Consortium, USA, 2020. [Online]. Available: https://www.esrdc.com/library/pepds-plan/

[4] "Systems Engineering Vision 2020," International Council on Systems Engineering, San Diego, CA, USA, TP-2004-004-02, 2007.

[5] S. Friedenthal, A. Moore, and R. Steiner, A Practical Guide to SysML: The Systems Modeling Language, 3rd ed. Amsterdam: Morgan Kaufmann, 2014.

[6] C. Singam, "Model-Based Systems Engineering (MBSE)" in SEBoK Editorial Board, in The Guide to the Systems Engineering Body of Knowledge (SEBoK), v. 2.7, R. J. Cloutier, Ed. Hoboken, NJ: The Trustees of the Stevens Institute of Technology, 2022. [Online]. Available: https://www.sebokwiki.org/wiki/Model-Based_Systems_Engineering_(MBSE). [Accessed: Mar 7, 2023]. BKCASE is managed and maintained by the Stevens Institute of Technology Systems Engineering Research Center, the International Council on Systems Engineering, and the Institute of Electrical and Electronics Engineers Systems Council.

10 APPENDIX A: HOW TO INSTALL AND USE CAMEO ENTERPRISE ARCHITECTURE READER

Cameo Enterprise Architecture Reader is made for reading and previewing models created with Cameo Enterprise Architecture and is free of charge.

10.1 Instructions on Installing Cameo Enterprise Architecture Reader

Follow the instructions to install the Cameo Enterprise Architecture Reader:

1. Go to: https://www.magicdraw.com/main.php
2. Register as a User and Login.
3. Select **Download Reader** from the column on the left near the end.
4. Select **Cameo Enterprise Architecture** product and **19.0 SP1 LTR** version.
5. Select the download file link based on your operating system.
6. Download the file from the mirror site nearest you.
7. Open the file and follow the installation prompts.
    a. If you selected no_install.zip, extract the .zip file and follow the instructions in the **readme** HTML document under section "**Using no-install package**".

The Cameo Enterprise Architecture Reader is now ready for use. Proceed to section 10.2.

10.2 How to use Cameo Enterprise Architecture Reader

Open Cameo Enterprise Architecture Reader then, under file, select "open project" and open the ".mdzip" file of the model you would like to view.

Navigate the model in a fashion similar to a webpage. You can open diagrams/tables by double clicking the diagram/table or by right clicking the diagram/table and selecting "Open in New Tab". The diagrams/tables can be opened from a linked icon/element on a diagram or from the containment tree. To see two diagrams/tables side by side, right click the tab and select "new horizontal/vertical group". You can close diagrams/tables by clicking the back arrow (when applicable) or by clicking the X on the tab.

Utilize the zooming and the vertical and horizontal scrolling in order to increase readability.

You can print diagrams/tables by selecting file → print.

User manuals are available under "help". Resources to help you understand the SysML diagrams are the MagicGrid® Book of Knowledge from reference [1] and the No Magic Inc. Glossary of SysML Concepts from reference [2].

11 APPENDIX B: PEPDS SYSTEM MODEL CONTENTS

The following list provides the sections of Appendix B and defines their content's purpose:

- Section 11.1 Navigation Road Map begins on page 19. The road map, discussed in section 4.4, is used for the product review in section 5 of the technical report.
- Section 11.2 PEPDS System Model Review Contents begins on page 20. The diagrams in this section accompany the product review in section 5 of the technical report.
    - Section 11.2.1 Problem Domain Black Box Review begins on page 20. The diagrams in this section accompany the Black Box Problem Domain review in section 5.1 of the technical report.
    - Section 11.2.2 Problem Domain White Box Review begins on page 30. The diagrams in this section accompany the White Box Problem Domain review in section 5.2 of the technical report.
    - Section 11.2.3 Solution Domain S1 System Requirements Review begins on page 45. The diagrams in this section accompany the System Level Solution Domain review in section 5.3 of the technical report.
        - Section 11.2.3.1 S1 System Requirements on page 45 shows all of the tables, diagrams, and matrices used to define the S1 system requirements.
        - Section 11.2.3.2 S1 System Requirements Diagrams begins on page 46. These diagrams show the S1 system requirements organized in their respective packages and are traced to stakeholder needs.
        - Section 11.2.3.3 S1 System Requirements Traceability Matrices begins on page 59. These matrices show the tracing between S1 and the Problem Domain.
        - Section 11.2.3.4 S1 System Requirements Table begins on page 63. This table provides all of the S1 system requirements along with their tracing, source, verification method, risk level, and revision date.
- Section 11.3 System Model Appendix begins on page 88. The diagrams in this section are not reviewed in the product review in section 5 of the technical report. They are supplementary material that provide information that will enhance the understanding of the PEPDS System Model product, discussed in section 5, and the PEPDS Functional Architecture development process, discussed in section 4.
- Section 11.4 MagicGrid® Index Package Diagrams begins on page 104. The diagrams in this section are the package diagrams from the MagicGrid® Index discussed in section 4.3.

The following is the list of figures for Appendix B: PEPDS System Model Contents:

11.1 Navigation Road Map

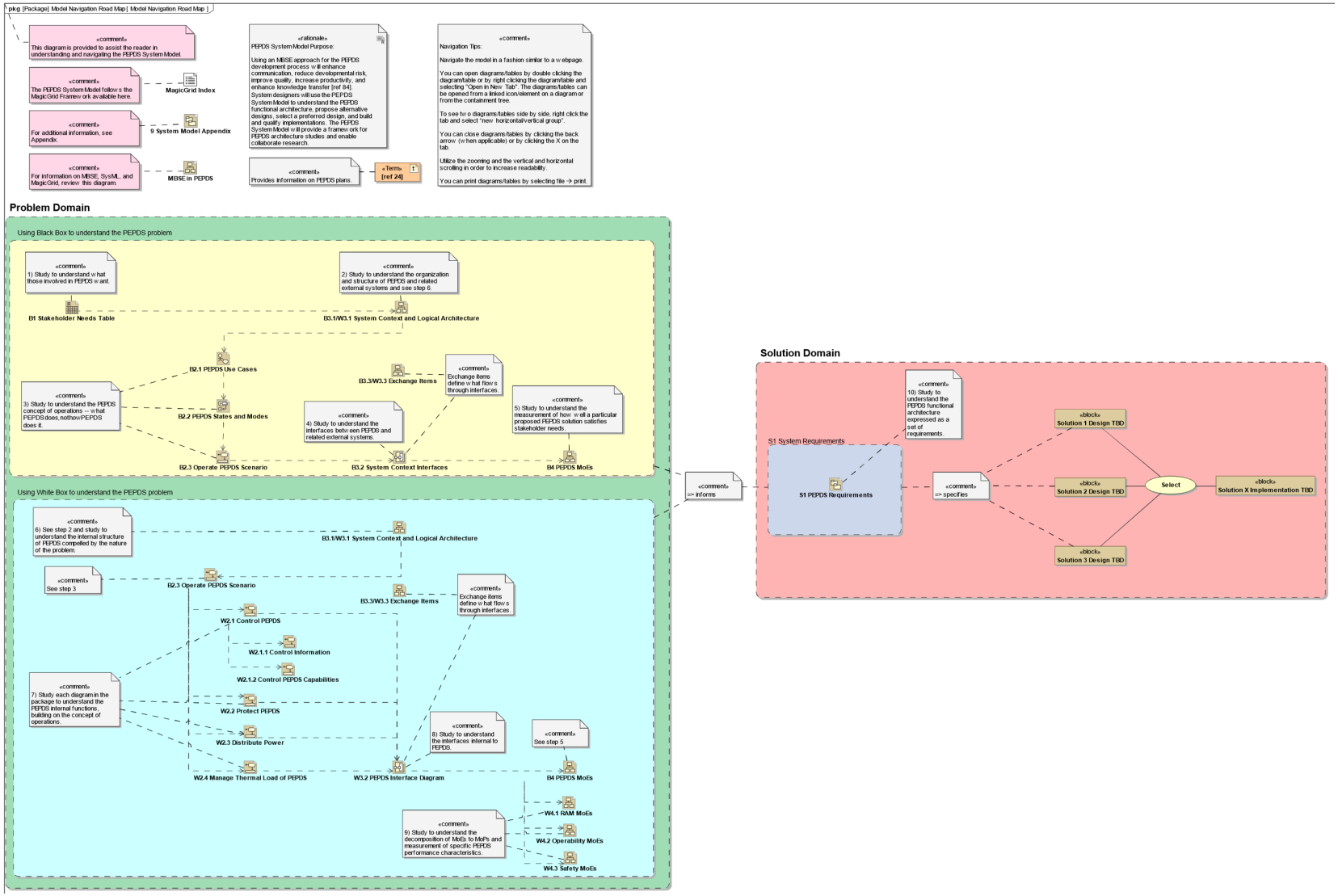


Fig. 4: Navigation Road Map

11.2 PEPDS System Model Review Contents

11.2.1 Problem Domain Black Box Review

#	Id	Source	△ Name	Text
1	1	Navy	1 Power Delivery	Transfers power from power source to power load
2	1.1	Navy	1.1 Power Efficiency	Limit power loss during transmission and conversion
3	1.1.1	Navy	1.1.1 Fuel Efficiency	Reduce amount of fuel consumption
4	1.2	Navy	1.2 Power Density	High power rating relative to volume
5	1.3	Navy	1.3 Reliability	Long online time when measured by MTBF
6	1.4	Navy	1.4 Robustness	Compatible with various operating conditions and set points
7	1.5	Navy	1.5 Resiliency	Tolerant to critical scenarios such as faults and failure of device(s)
8	1.6	Navy	1.6 UPS	If demand is greater than supply (delta power), then provide provisional power for x time
9	2	Navy	2 Operability	System operation accomplished with reduced manning and logistics effort
10	2.1	Navy	2.1 Maintainability	Maintenance with reduced down time
11	2.2	Navy	2.2 Operator Trainability	Low training requirements in regards to time and technical skills
12	2.3	Operator	2.3 Safety	Safe handling conditions
13	2.3.1	Operator	2.3.1 Thermally Touchable	External environment at reasonable handling temperatures
14	2.3.2	Operator	2.3.2 Liftable	Weight and volume at a reasonable range for handling
15	2.3.3	Operator	2.3.3 Electrically Insulated	Insulation to limit current through operator
16	2.4	Navy	2.4 Long Life Expectancy	Long operable lifespan
17	3	Navy	3 Scalability	Greater power requirement met through serial and/or parallel connections
18	3.1	Navy	3.1 Serial Thermal Management	Universal thermal interface should be proposed
19	3.2	Navy	3.2 Parallel Redundancy	Parallel operation to provide continuous power to mission critical loads
20	3.3	Navy	3.3 Controllable	Coordination should allow for extension/addition of devices
21	3.3.1	Navy	3.3.1 Software Reliability	Continuous high performance operation even in disruptive processes
22	3.3.2	Navy	3.3.2 Cyber Security	Resistant to malicious attacks against software and offers security observation
23	3.3.3	Navy	3.3.3 Dynamic response	Can ramp up power in a short time; can provide x time over power in a short time slot
24	3.4	Navy	3.4 Standardizable	Fits in many classes of ship
25	3.5	Navy	3.5 Affordability	Reduce implementation and operation cost for life cycle
26	3.6	Navy	3.6 Hotswappable	Hotswappable "Plug-and-Play" applications
27	4	CAPS Power Systems	4 Model Objectives	PEPDS Model key objectives
28	4.1	CAPS Power Systems	4.1 Program Communication	To become a vehicle to communicate PEPDS work progress and accomplishments
29	4.2	CAPS Power System	4.2 Single Source of Truth	This model is formal representation of PEPDS system in order to make clear: (1) Its structure, interfaces, and internal and external relationships (2) The behaviors exhibited by the entity and its elements, both internally and externally (3) The global rules to which the entity and its elements must conform in order to meet the requirements allocated to them, initially and over the entity's operational lifetime
30	4.3	CAPS Power System	4.3 Program Guideline	To guide and support solutioning of PEPDS modular architecture
31	5	Navy	5 PEPDS Innovations	PEPDS innovations are dependent on using power electronics in an innovative way and utilizing advancements in technology and control capabilities
32	5.1	Navy	5.1 Ease of Installation as a Unit	Reduce installation time and cost by having construction and testing executable off ship and avoiding intensive cabling after ship construction
33	5.2	Navy	5.2 Load Interface Design	Common interface solution for all loads with increased possibilities of load interface spatial arrangement in the ship
34	5.3	Navy	5.3 Power Electronic Interfaces	All source and load interfaces are power electronics based and as such provide the required adaptability, reconfigurability, and fault current limitation
35	5.4	Navy	5.4 Self Learning	Ability to self learn by tracking performance and CBM+ data and analyzing control and protection activities
36	5.5	Navy	5.5 Integrated Control	Integrated electrical, thermal, and mechanical control
37	5.6	Navy	5.6 Functional Control	Control component and network functions through programming and reconfiguration
38	5.7	Navy	5.7 Adaptive Controls	Control algorithms self-adapt to changes in mission requirements, load performance, and system upgrades
39	5.8	Navy	5.8 Automated Self-check	Have self diagnosis or automated self-check after controls upgrades which would be an advanced concept of CHIL with regression tests embedded in PEPDS (integrated "digital twin") – including cybersecurity aspects
40	5.9	Navy	5.9 Integrated CBM+	Condition based maintenance+ fully integrated into design. Diagnosis, prognosis, and health prediction capabilities - down to the device level.
41	5.10	Navy	5.10 Comprehensive Application of the LRU Approach to the Entire System Design	Maximize the dependence on LRUs while minimizing the different types of LRUs
42	5.11	Navy	5.11 Simplified LRU Replacement	Utilize LRUs that are a size and weight carriable by a single sailor, that can fit through hatches, that requires minimal training for installation and removal, and has plug & play capabilities
43	5.12	Navy	5.12 Minimal Redundant Elements	Provide power quality to loads using fewer components by using distributed resources and integrated functionality such as advanced power electronic control across many converters, active filtering across many converters, and distributed storage
44	5.13	Navy	5.13 Integrated Power and Energy Power Distribution System	PEPDS is an integrated power and energy power distribution system which should have integrated power, propulsion, optimization, protection, filtering, storage, and control
45	5.14	Navy	5.14 Distributed Power Conversion	Distributed power conversion provides protection, filtering, and energy storage. It creates an interface for every load meaning there will be no single interface standard for all loads and that ac or dc, frequency, voltage, power, etc. are tailored to meet individual load requirements
46	5.15	Navy	5.15 Reduce Conventional Switchgear	Integrate functionality of switchgear within the power electronics framework in order to reduce or eliminate use of conventional external switchgear and provide current limiting function - thereby reducing risk from high fault currents and hence improving reliability

Fig. 5: B1 Stakeholder Needs Table

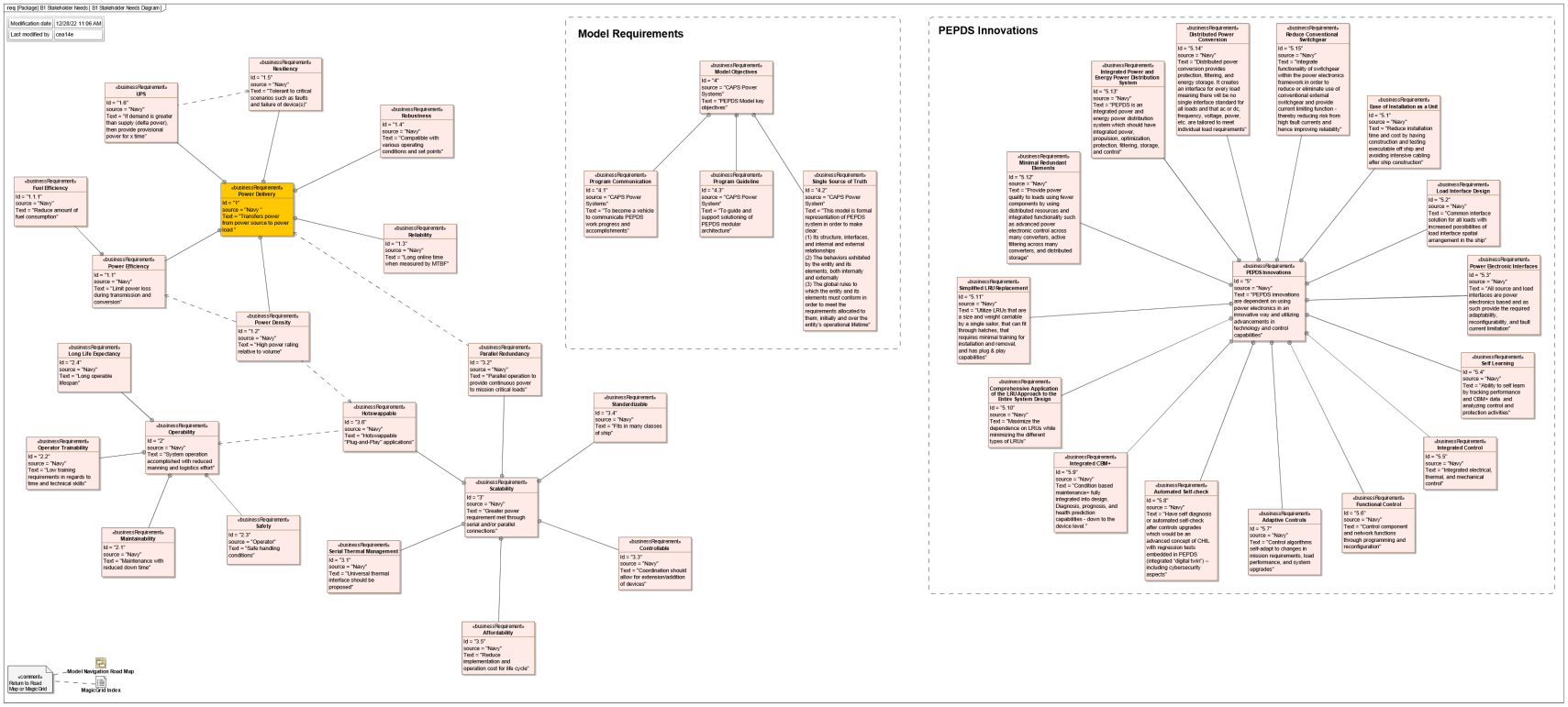


Fig. 6: B1 Stakeholder Needs Diagram

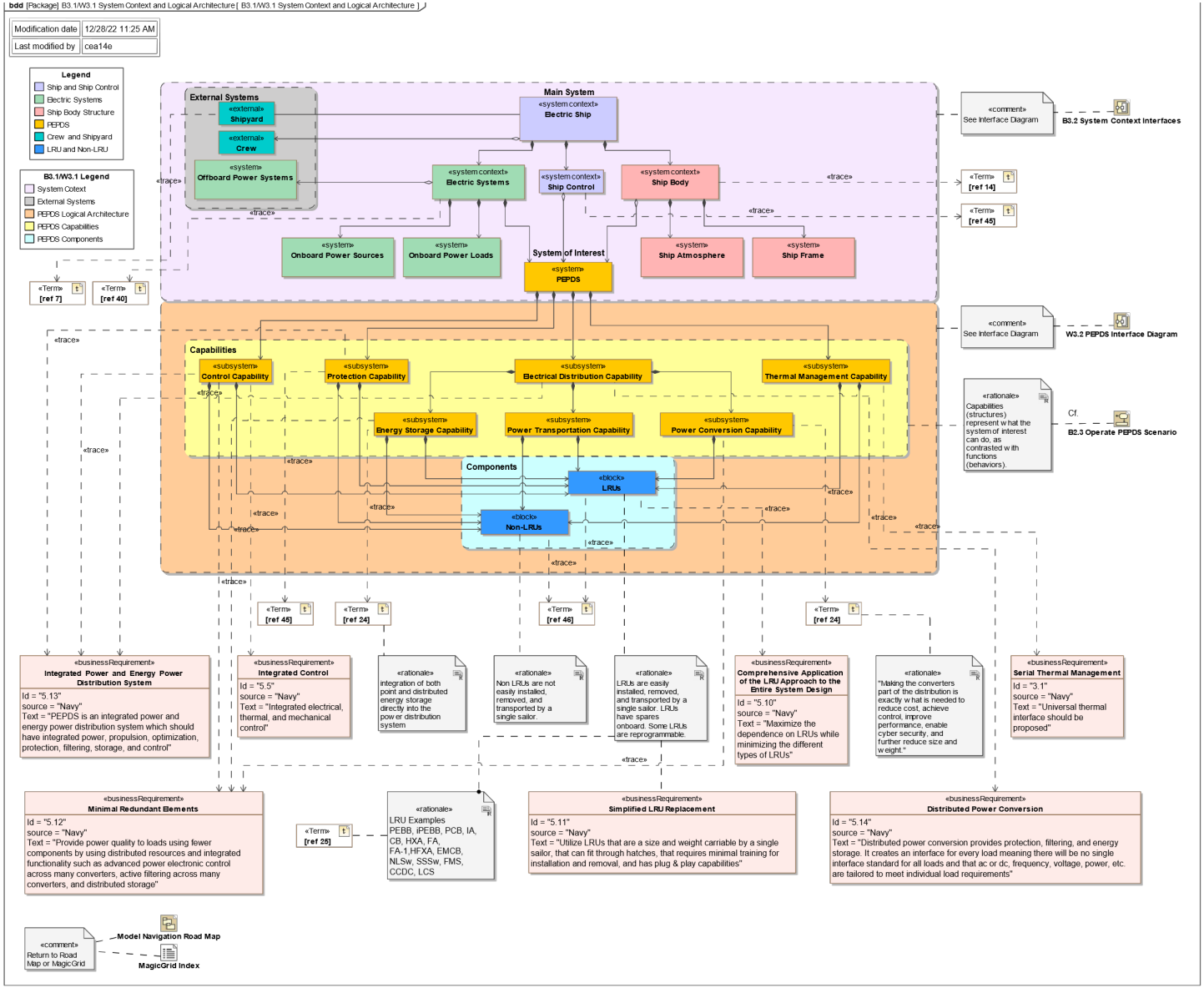


Fig. 7: B3.1/W3.1 System Context and Logical Architecture (Review Part 1)

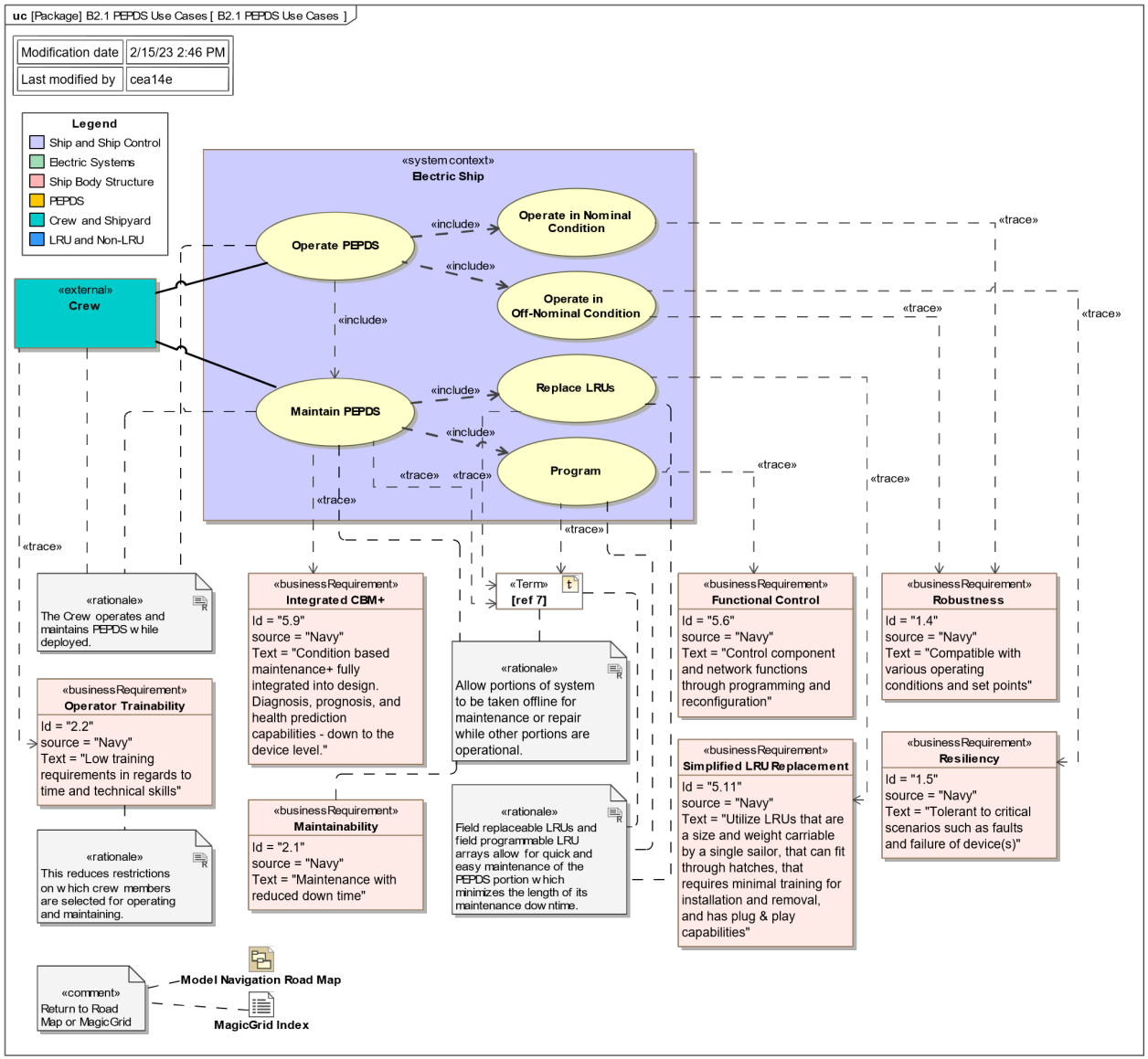


Fig. 8: B2.1 PEPDS Use Cases

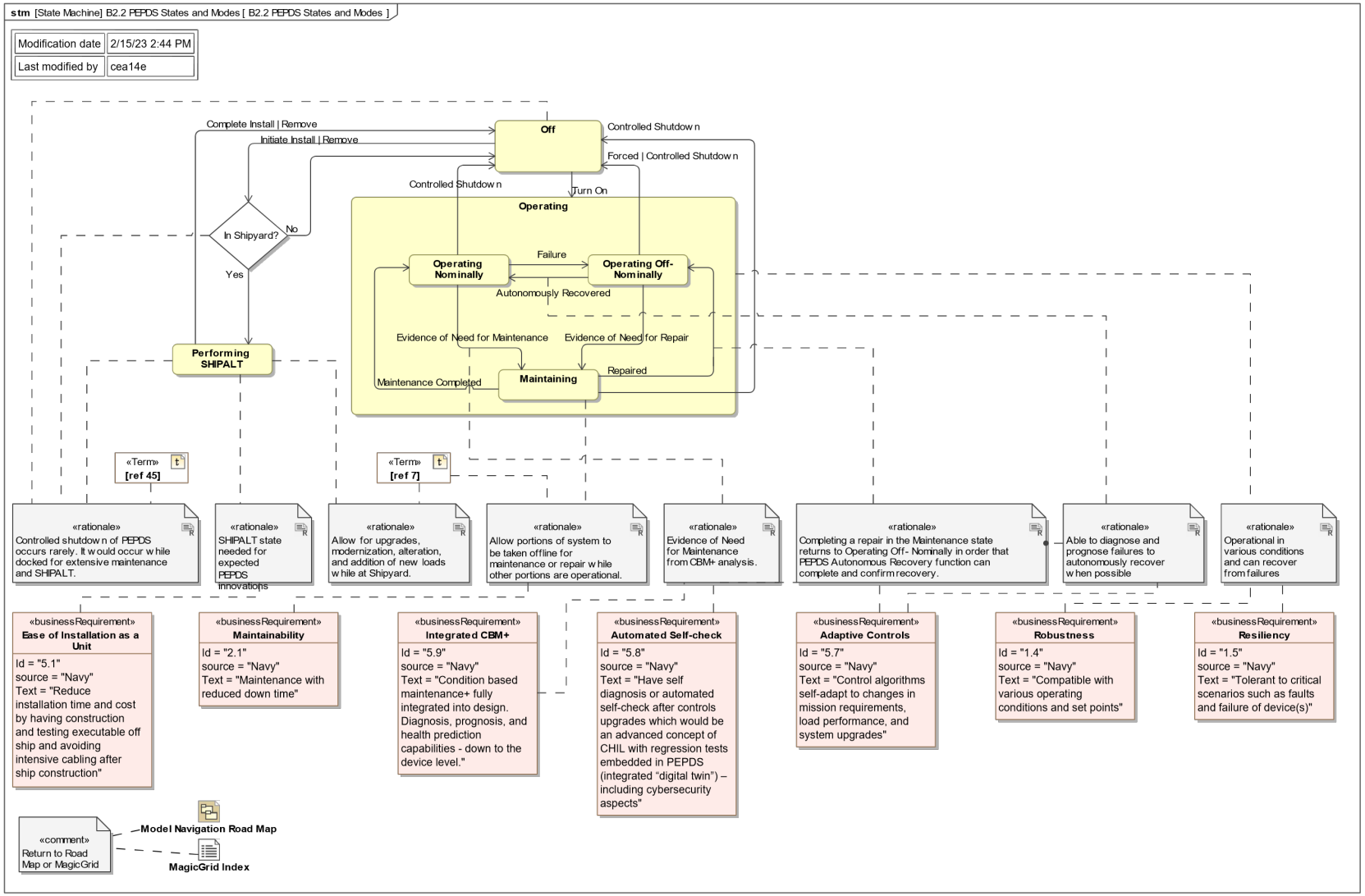


Fig. 9: B2.2 PEPDS States and Modes

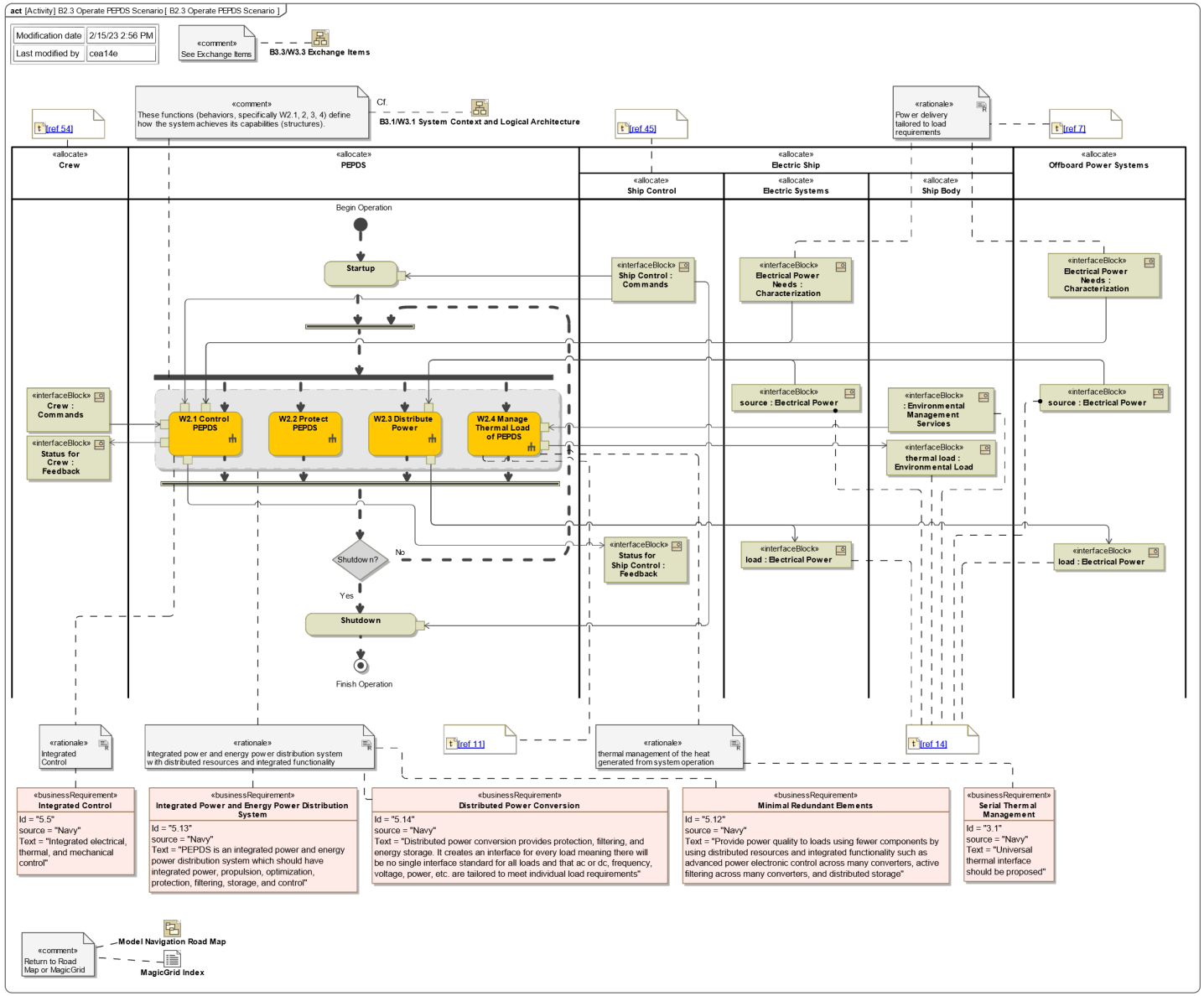


Fig. 10: B2.3 Operate PEPDS Scenario (Review Part 1)

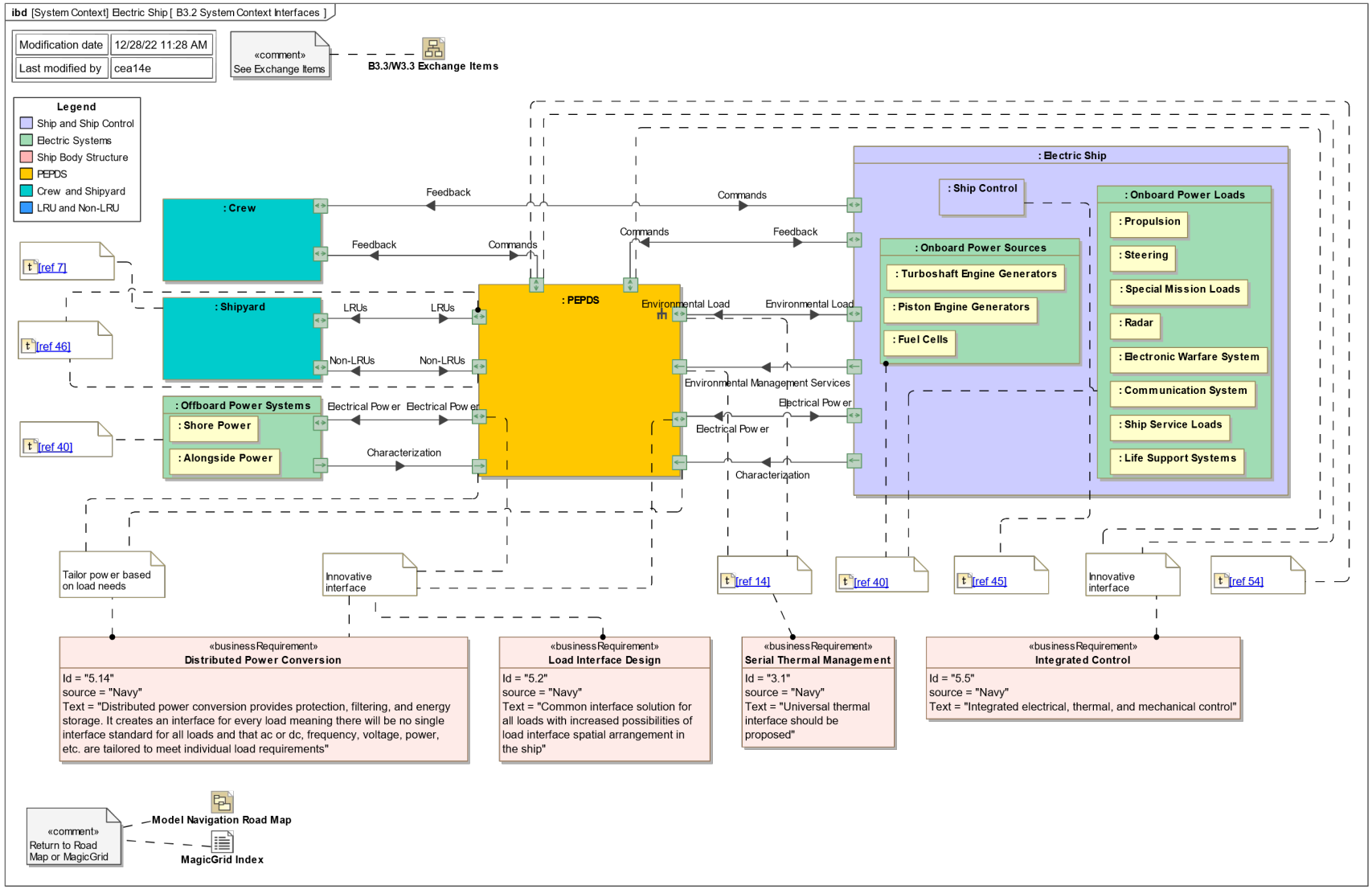


Fig. 11: B3.2 System Context Interfaces

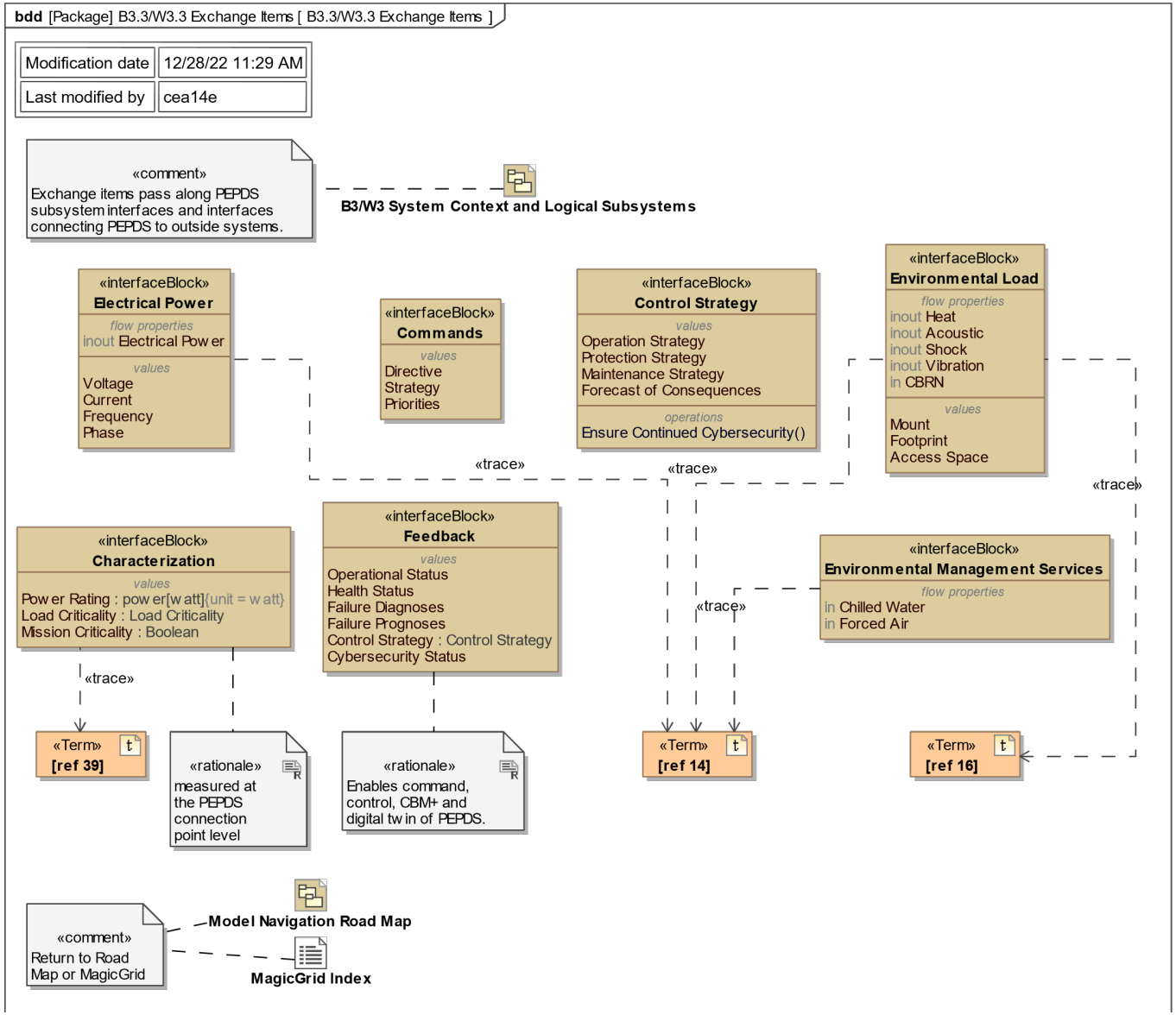


Fig. 12: B3.3/W3.3 Exchange Items

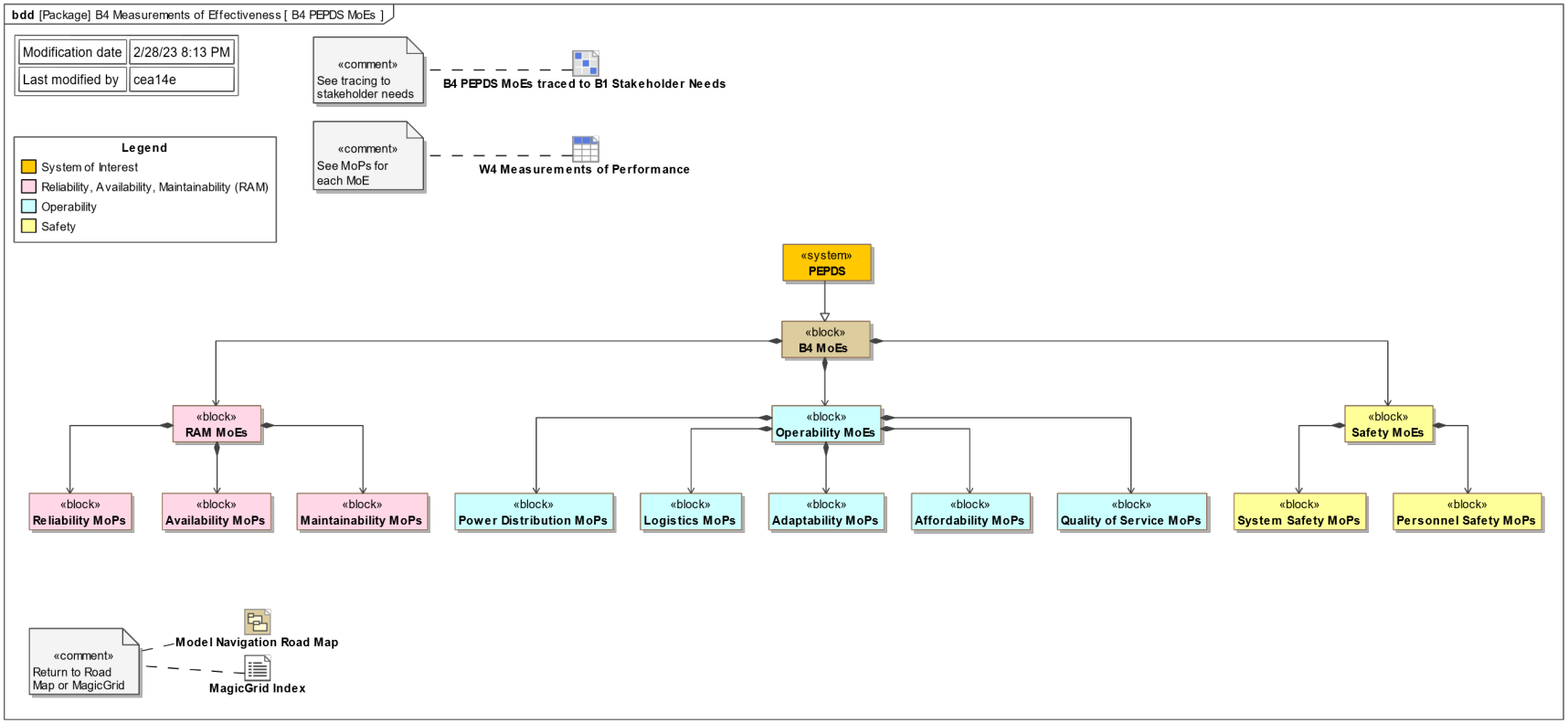


Fig. 13: B4 PEPDS MoEs (Review Part 1)

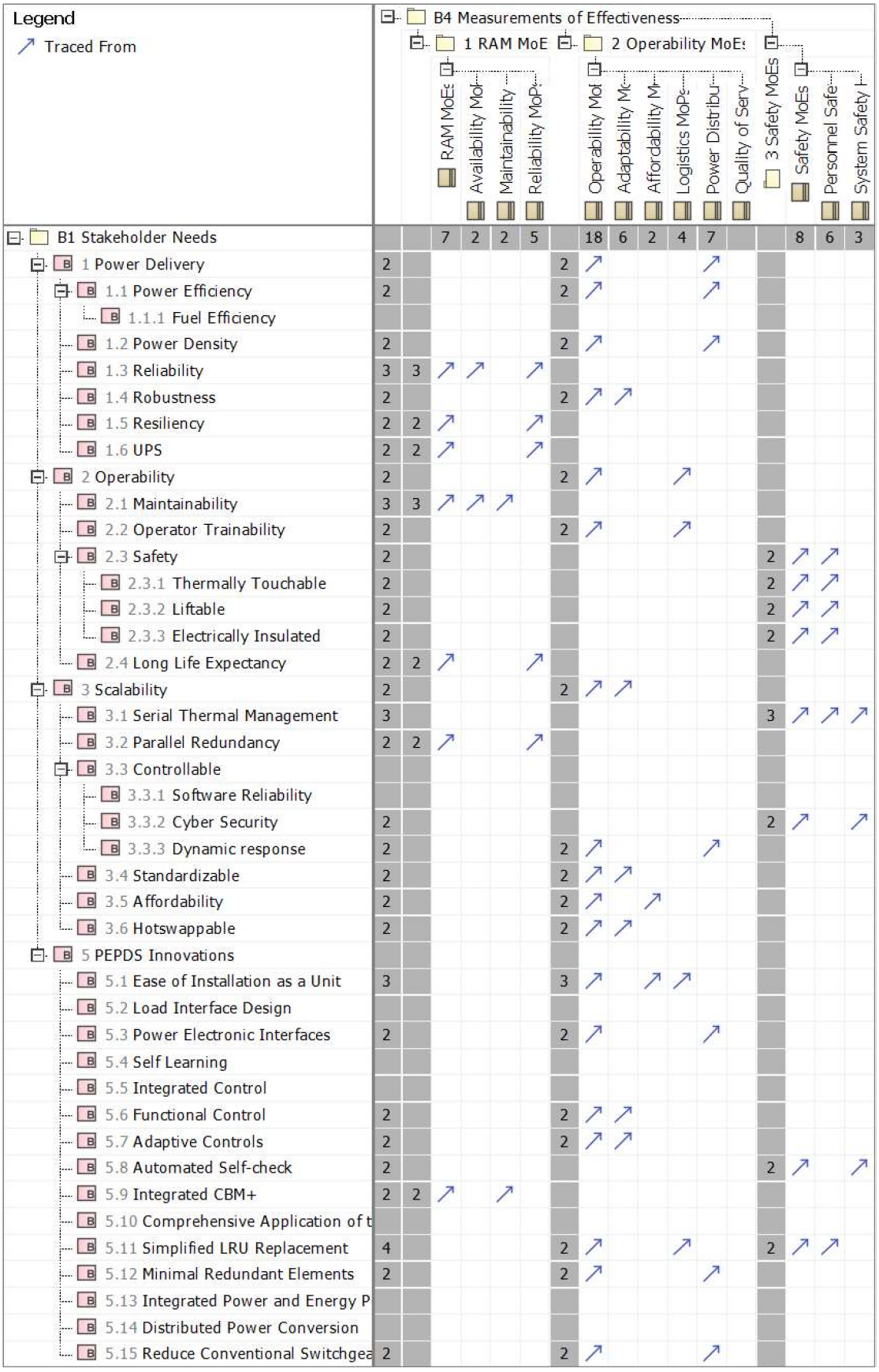


Fig. 14: B4 PEPDS MoEs traced to B1 Stakeholder Needs

11.2.2 Problem Domain White Box Review

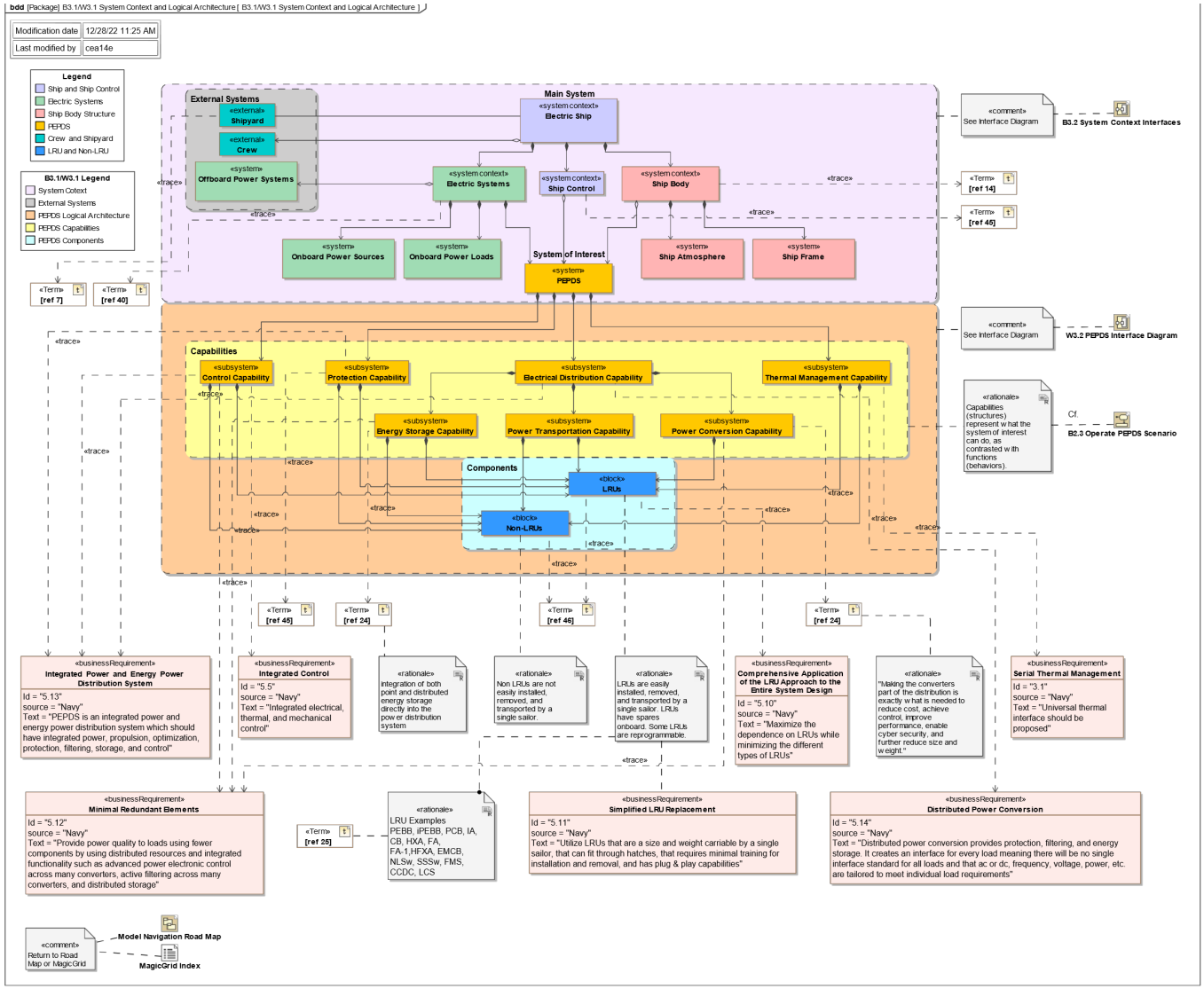


Fig. 15: B3.1/W3.1 System Context and Logical Architecture (Review Part 2)

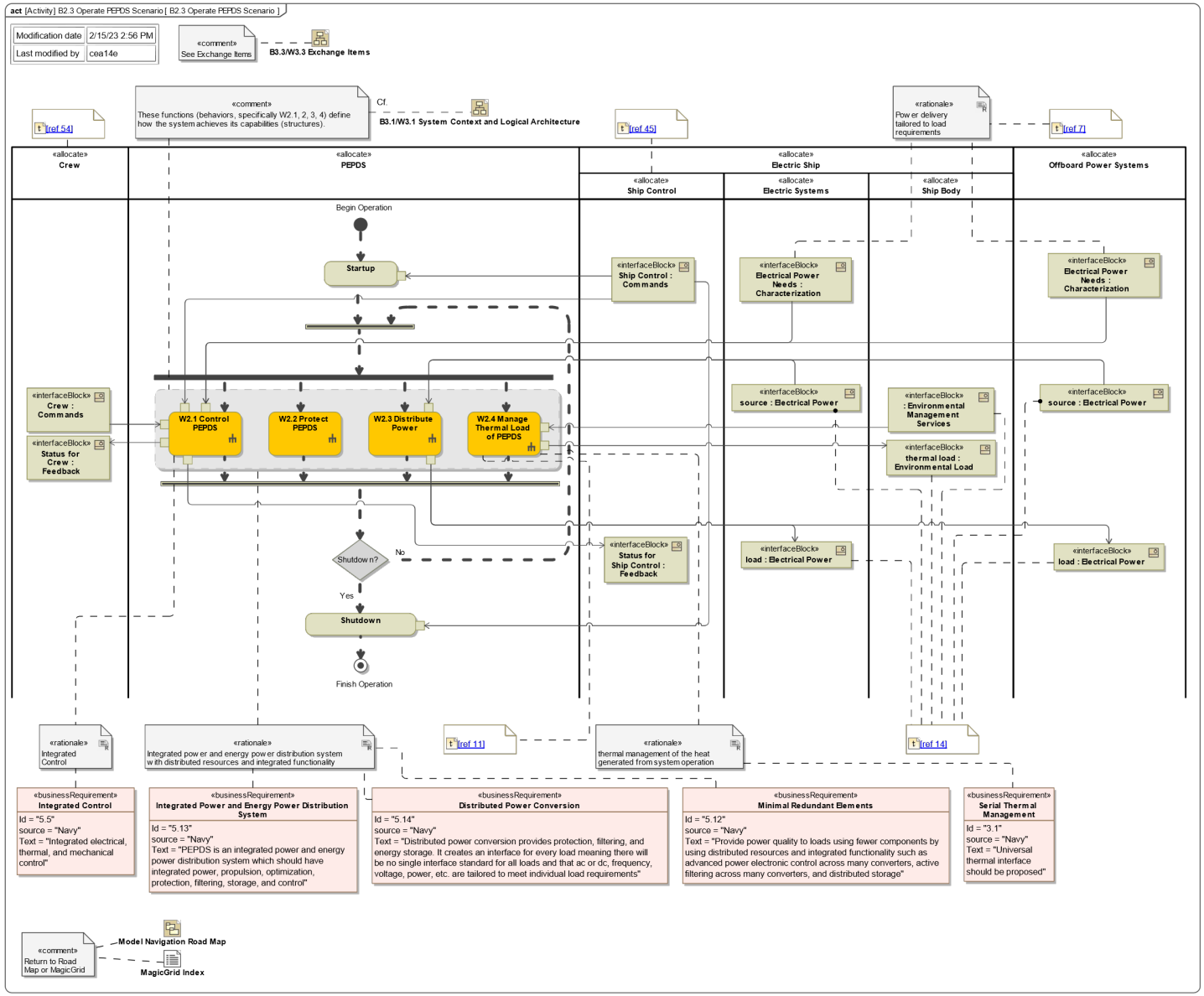


Fig. 16: B2.3 Operate PEPDS Scenario (Review Part 2)

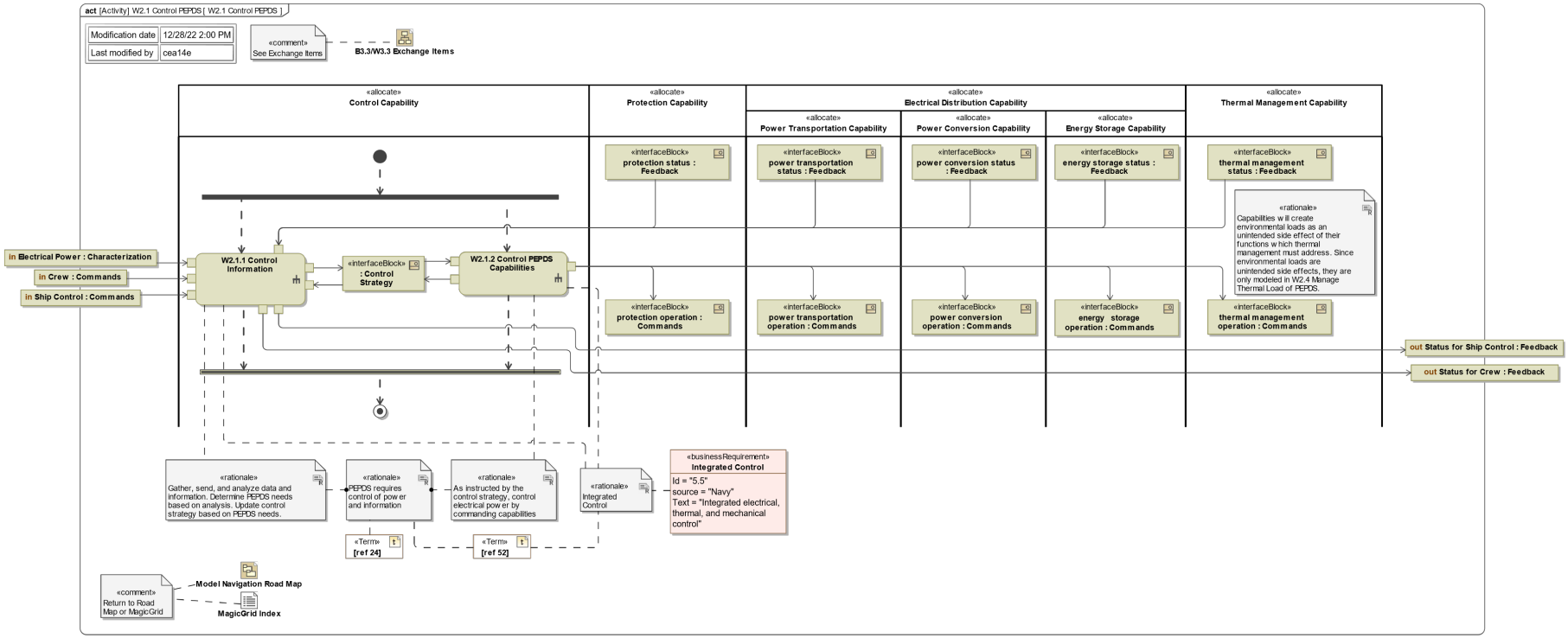


Fig. 17: W2.1 Control PEPDS

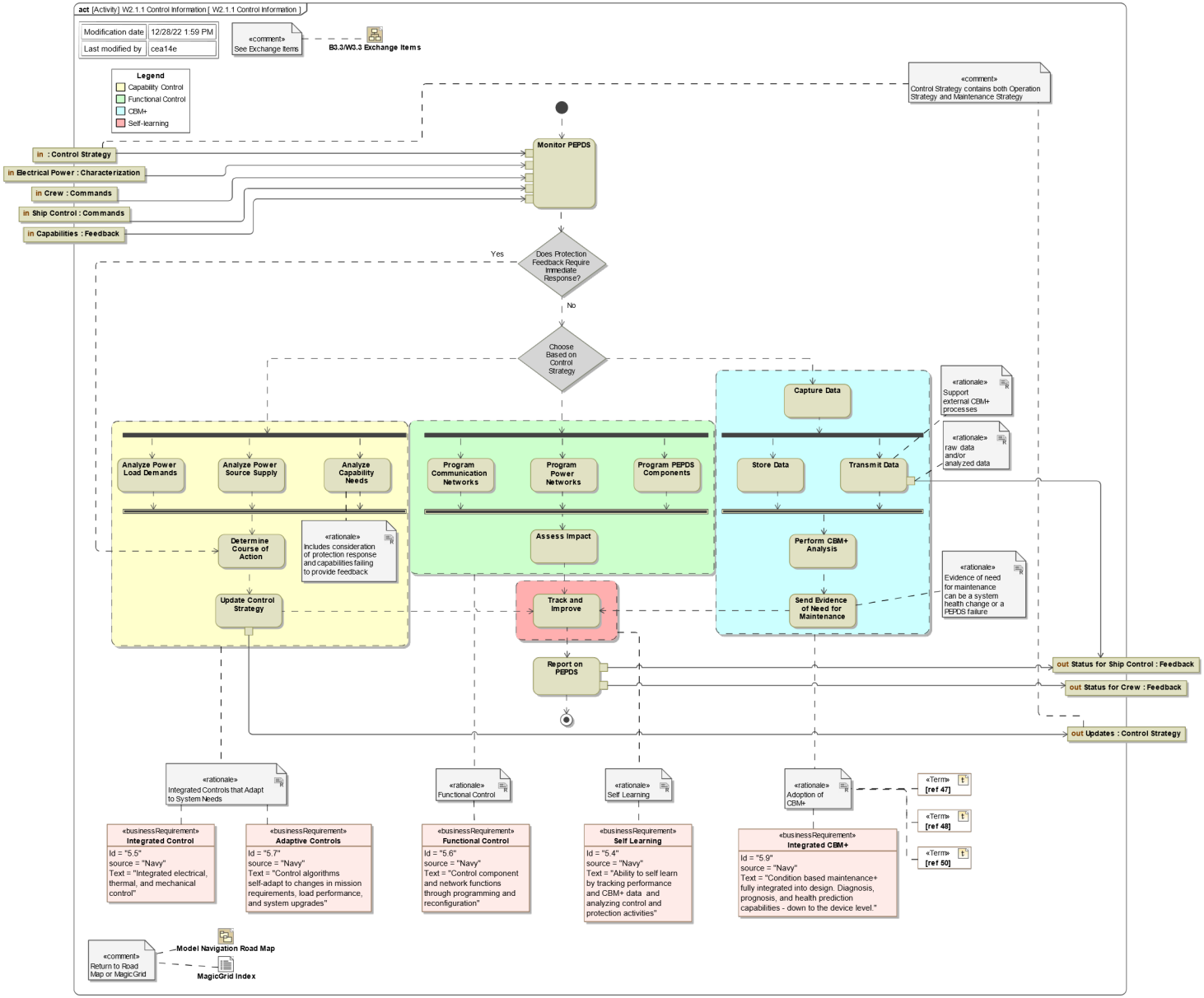


Fig. 18: W2.1.1 Control Information

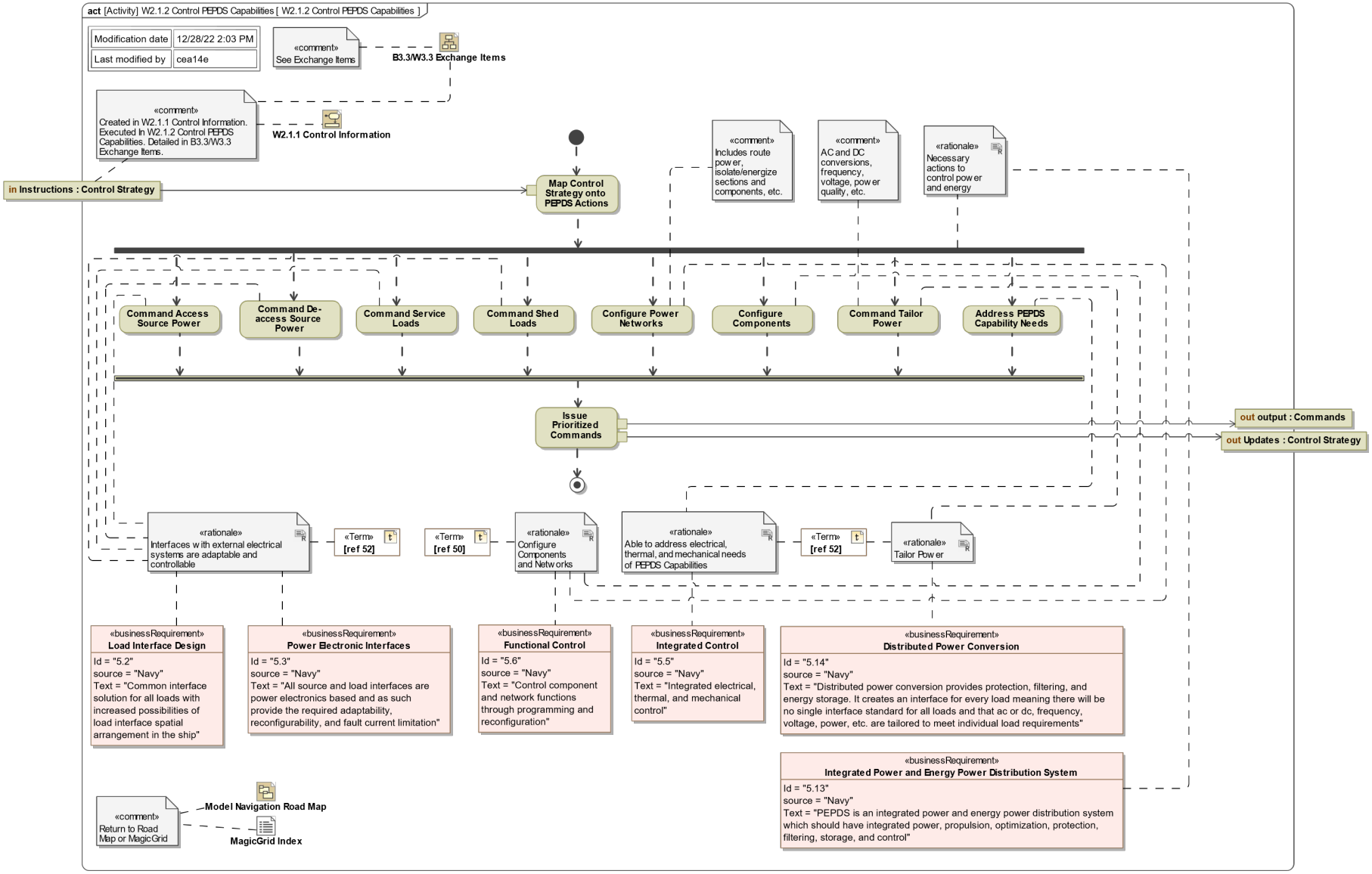


Fig. 19: W2.1.2 Control PEPDS Capabilities

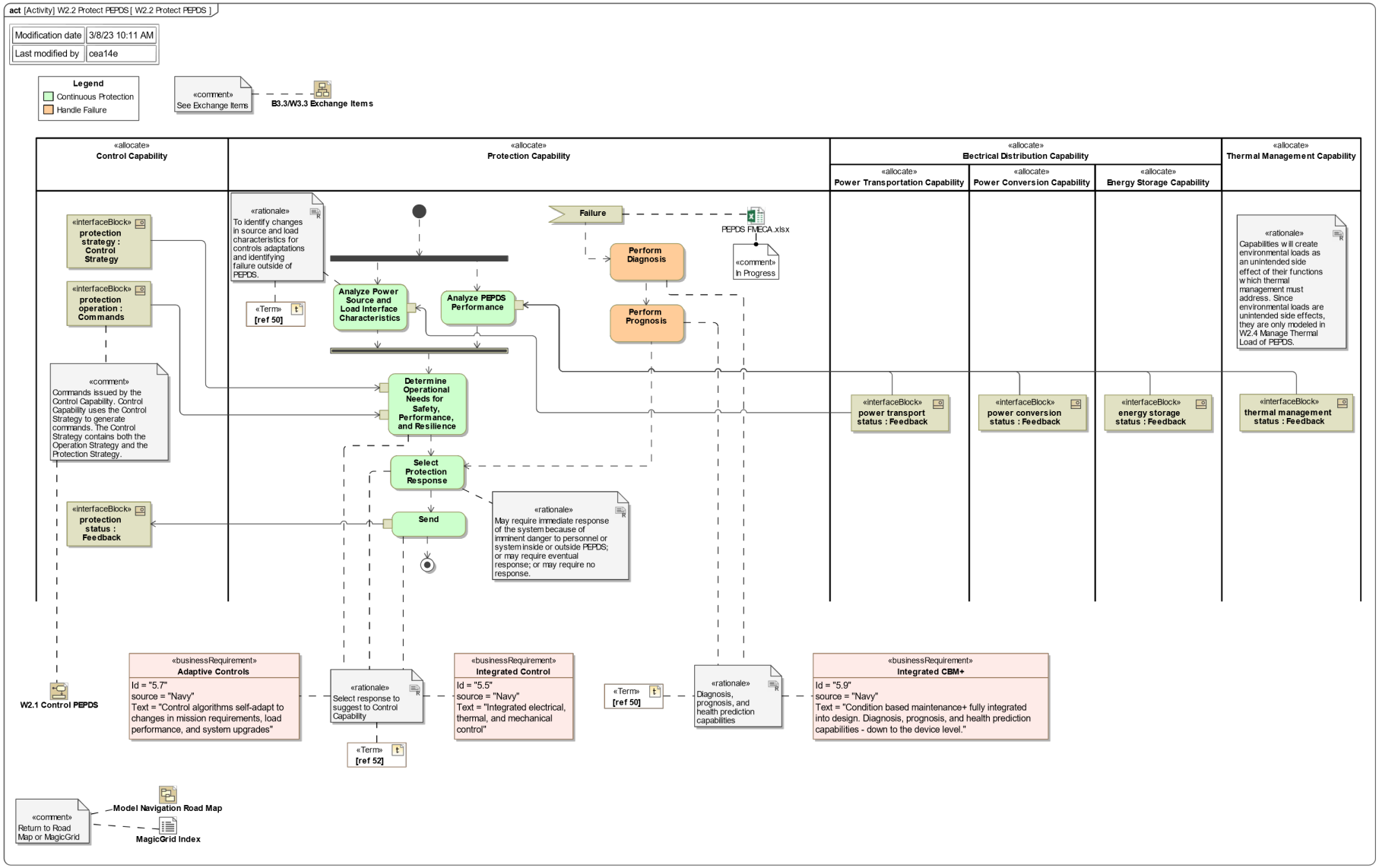


Fig. 20: W2.2 Protect PEPDS

Item	Function	Potential Failure Mode	Potential Effects of Failure	Severity	Potential Causes of Failure	Occurance	Current Controls for Prevention/Detection	Detection	RPN
Control Capability	Control	PEPDS fail to de-energize specific section of system							
		PEPDS fails to analyze capability needs							
		PEPDS fails to analyze power load demands							
		PEPDS fails to analyze power source supply							
		PEPDS fails to assess impact of programming							
		PEPDS fails to command servicing and shedding of the loads							
		PEPDS fails to configure power networks and components							
		PEPDS fails to control source power							
		PEPDS fails to determine the correct course of action							
		PEPDS fails to issue prioritized commands							
		PEPDS fails to map control strategy onto PEPDS actions							
		PEPDS fails to perform CBM+							
		PEPDS fails to program communication networks							
		PEPDS fails to program components							
		PEPDS fails to program power networks							
		PEPDS fails to send feedback to crew and ship control							
		PEPDS fails to tailor power based on need							
		PEPDS fails to track and improve control strategy							
		PEPDS fails to track and improve need for maintenance							
		PEPDS fails to update control strategy							
		The control capability fails to control PEPDS capabilities							
		The control capability fails to establish an interface with the crew							
		The control capability fails to establish an interface with the energy storage capability							
		The control capability fails to establish an interface with the onboard and offboard power sources and loads							
		The control capability fails to establish an interface with the power conversion capability							
		The control capability fails to establish an interface with the power transportation capability							
		The control capability fails to establish an interface with the protection capability							
		The control capability fails to establish an interface with the ship control							
		The control capability fails to interface control strategy in the control activity							
		The control capability fails to monitor PEPDS							
		The control capability fails to receive feedback from all other capabilities							
		The control capability fails to send commands to all other capabilities							
		PEPDS fails to take counter measures to control abnormality in operations							
		PEPDS fails to address electrical power needs							
		PEPDS fails to address ship control commands							
		PEPDS fails to address crew commands							
Energy Storage Capability	Store Energy	Degradation of energy storage devices							
		Energy storage charge rate exceeds acceptable range							
		Energy storage discharge rate exceeds acceptable range							
		Energy Storage Overcharges							
		Energy Storage Overdischarges							
		PEPDS fail to receive power from energy storages							
		PEPDS fails to store energy							
		The energy storage capability fails to address commands from the control capability							
		The energy storage capability fails to address electrical power from the power conversion capability							
		The energy storage capability fails to deliver electrical power to power conversion capability							
		The energy storage capability fails to update energy storage status to the protection capability							
PEPDS	Allow Maintenance	Installation of LRU fails							
		Removal of LRU fails							
		PEPDS fails to perform device level maintenance							
	Establish Interface with External System	LRU fails to establish an interface with PEPDS							
		PEPDS fails to establish an interface with the shipyard							
		PEPDS fails to establish an interface with the onboard power systems							
		PEPDS fails to establish an interface with the crew							
		PEPDS fails to establish an interface with the electric ship							
		PEPDS fails to establish an interface with the offboard power systems							
	Transition States	PEPDS detects a failure but does not go to off-nominal state from nominal state							
		PEPDS fails to go to maintaining state from operating nominally state							
		PEPDS fails to go to maintaining state from operating off-nominally state							
		PEPDS fails to go to off state after maintenance							
		PEPDS fails to go to off state after performing SHIPALT							
		PEPDS fails to operate nominally after maintenance is completed							
		PEPDS fails to operate off-nominally after a repair is performed							
		PEPDS fails to recover autonomously from operating off-nominally							
		PEPDS fails to shutdown							
Power Conversion Capability	Convert Power	PEPDS fail to convert power for problems other than voltage, current, phase and frequency							
		Power conversion fails to meet current specification							
		Power conversion fails to meet frequency specification							
		Power conversion fails to meet phase specification							
		Power conversion fails to meet voltage specification							
		The power conversion capability fails to address commands from the control capability							
		The power conversion capability fails to address electrical power from the energy storage capability							
		The power conversion capability fails to address electrical power from the power transportation capability							
		The power conversion capability fails to establish an interface with the energy storage capability							
		The power conversion capability fails to update power conversion status to the protection capability							
Power Transportation Capability	Transport Power	Ark flashing							
		Conductor to ground short							
		External electrical short detected							
		Fault currents							
		Internal electrical short detected							
		Line to ground short							
		Line to line short							
		PEPDS fail to deliver power to loads							
		PEPDS fail to distribute power							
		PEPDS fail to receive power from off-board power sources							
		PEPDS fail to receive power from on-board power sources							
		The power transportation capability fails to accommodate electrical power from the power conversion capability							
		The power transportation capability fails to deliver electrical power to loads							
		The power transportation capability fails to establish an interface with the energy storage capability							
		The power transportation capability fails to establish an interface with the offboard power systems							
		The power transportation capability fails to establish an interface with the onboard power systems							
		The power transportation capability fails to establish an interface with the power conversion capability							
		The power transportation capability fails to process commands from the control capability							
		The power transportation capability fails to receive electrical power from sources							
		The power transportation capability fails to update power transportation status to the protection capability							
Protection Capability	Provide Protection	Change in System Functions							
		The protection capability fails to address commands from the control capability							
		The protection capability fails to analyze PEPDS performance based on feedback from other capabilities							
		The protection capability fails to analyze power and source interface characteristics							
		The protection capability fails to determine need for safety, performance and resilience based on protection strategy							
		The protection capability fails to diagnose or prognose the failure							
		The protection capability fails to establish an interface with the energy storage capability							
		The protection capability fails to establish an interface with the power conversion capability							
		The protection capability fails to establish an interface with the power transportation capability							
		The protection capability fails to select a protection response on detection of a fault							
		The protection capability fails to send the the protection status to the control capability							
		Uncontained cybersecurity intrusion							
		Undetected cybersecurity intrusion							
		Unresolved cybersecurity intrusion							
Thermal Management Capability	Manage Thermal Load	Inadequate capability to drain used coolant							
		Leakage in coolant system							
		PEPDS fails to maintain thermal situation during continuous operations							
		PEPDS fails to manage external environmental services							
		PEPDS fails to regulate environmental load from capabilities							
		The thermal management capability fails to address commands from the control capability							
		The thermal management capability fails to dissipate thermal load external to PEPDS							
		The thermal management capability fails to establish an interface with the control capability							
		The thermal management capability fails to establish an interface with the electric ship							
		The thermal management capability fails to establish an interface with the energy storage capability							
		The thermal management capability fails to establish an interface with the power conversion capability							
		The thermal management capability fails to establish an interface with the power transportation capability							
		The thermal management capability fails to establish an interface with the protection capability							
		The thermal management capability fails to regulate PEPDS internal thermla load							
		The thermal management capability fails to update thermal management status to the control capability							
		The thermal management capability fails to update thermal management to the protection strategy							
		Thermal degradation							
		Used coolant exposed to oxygen							
		PEPDS fails to address environmental management services							

Fig. 21: W2.2.1 PEPDS FMECA

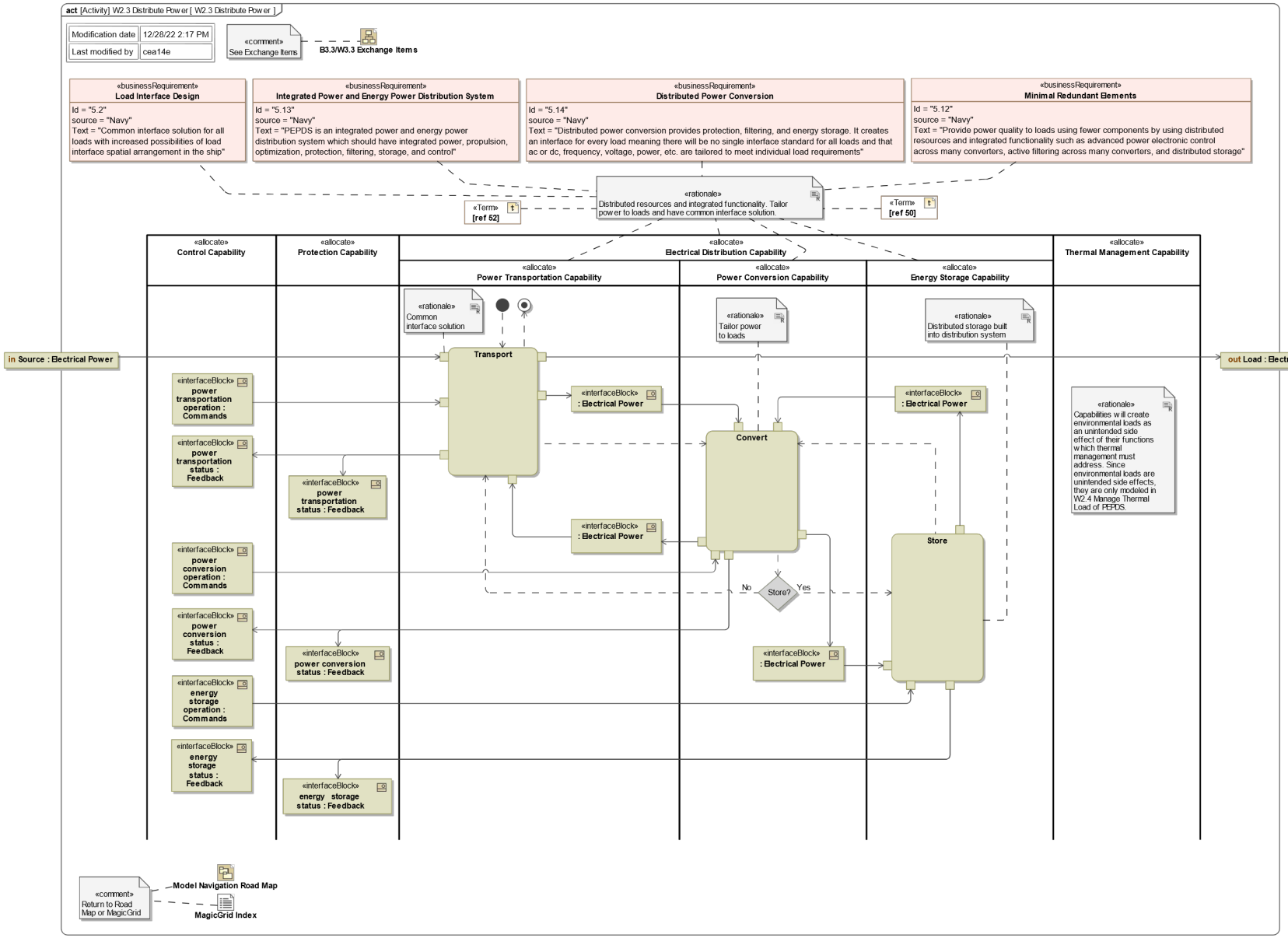


Fig. 22: W2.3 Distribute Power

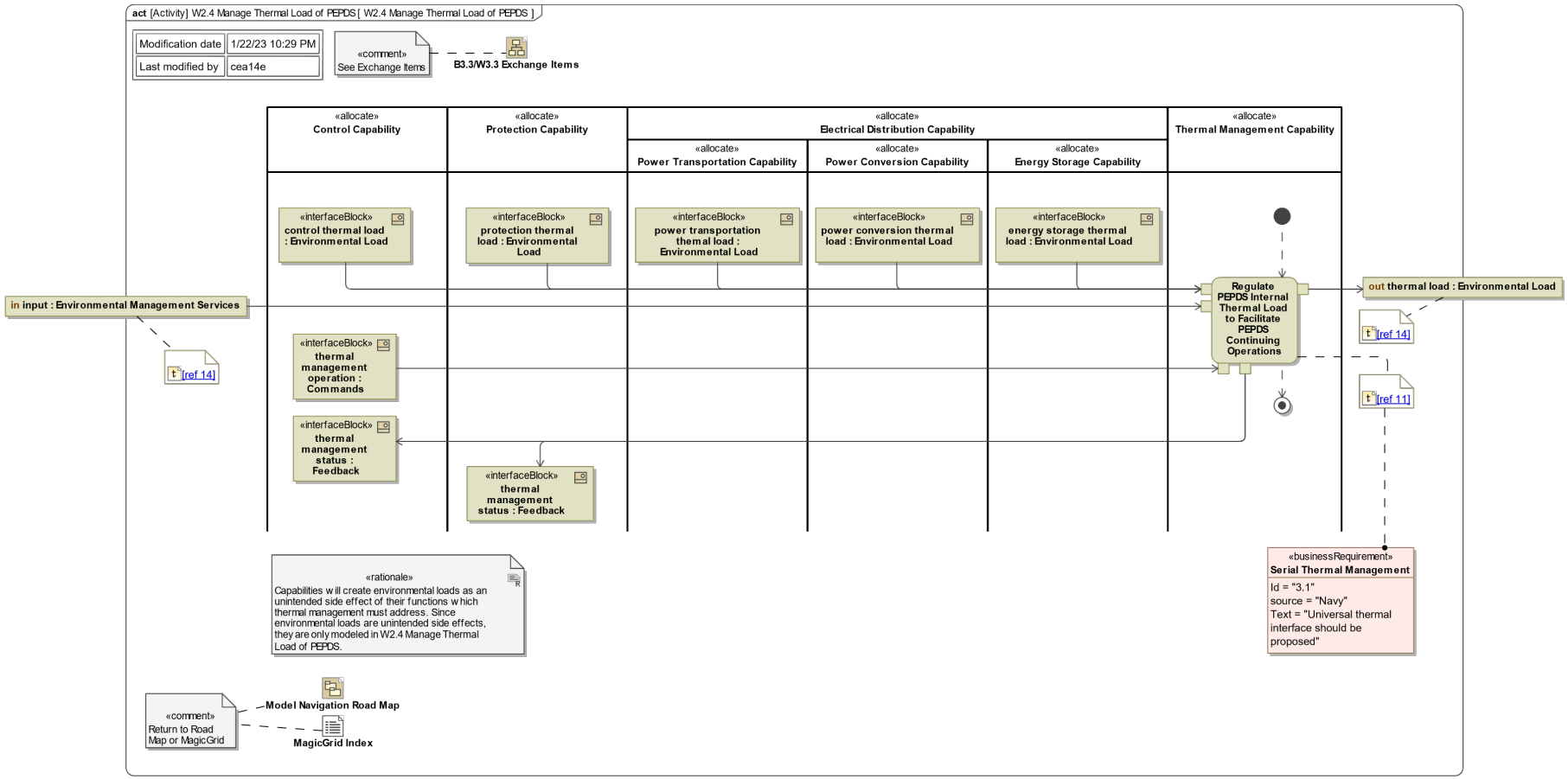


Fig. 23: W2.4 Manage Thermal Load of PEPDS

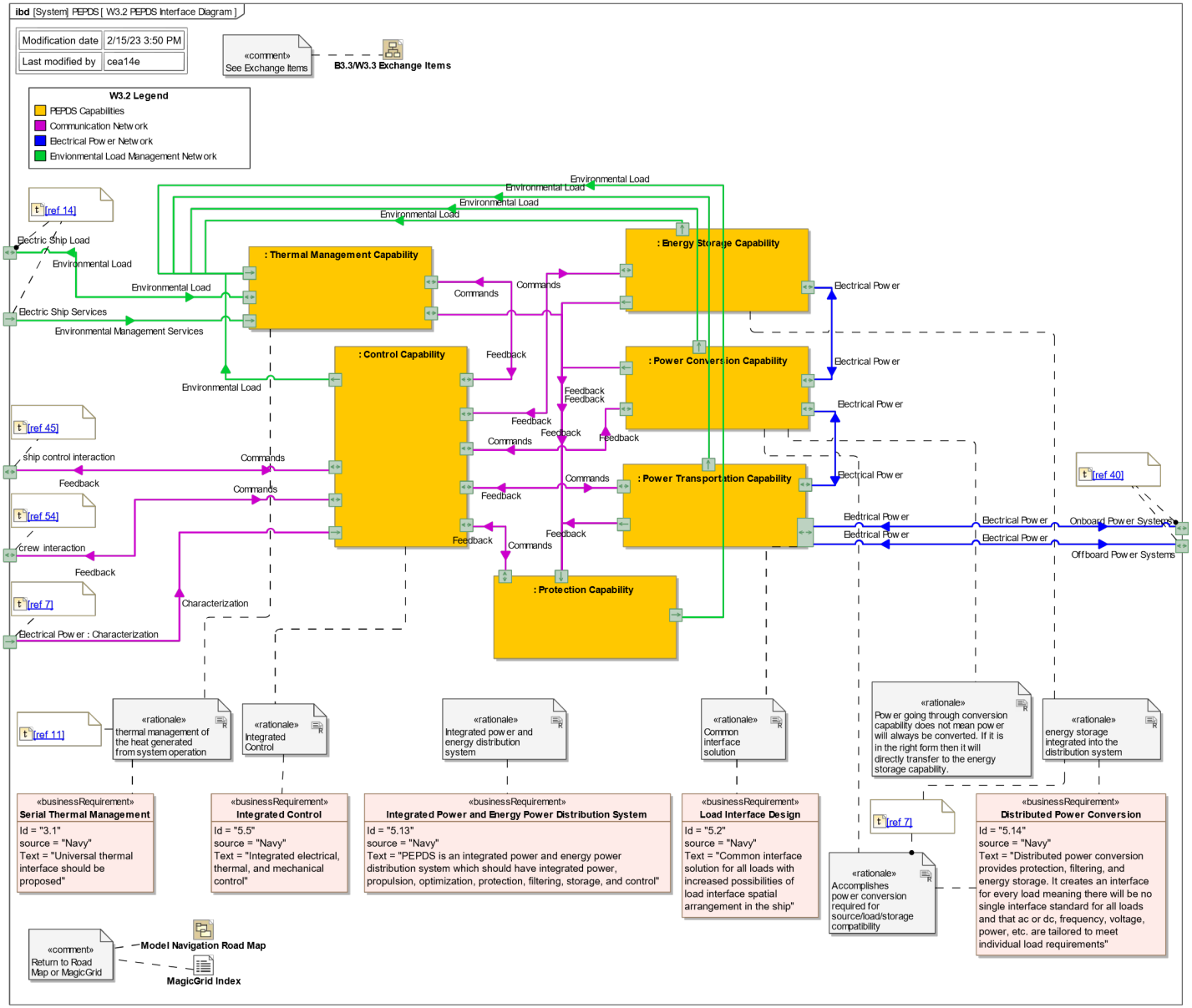


Fig. 24: W3.2 PEPDS Interface Diagram

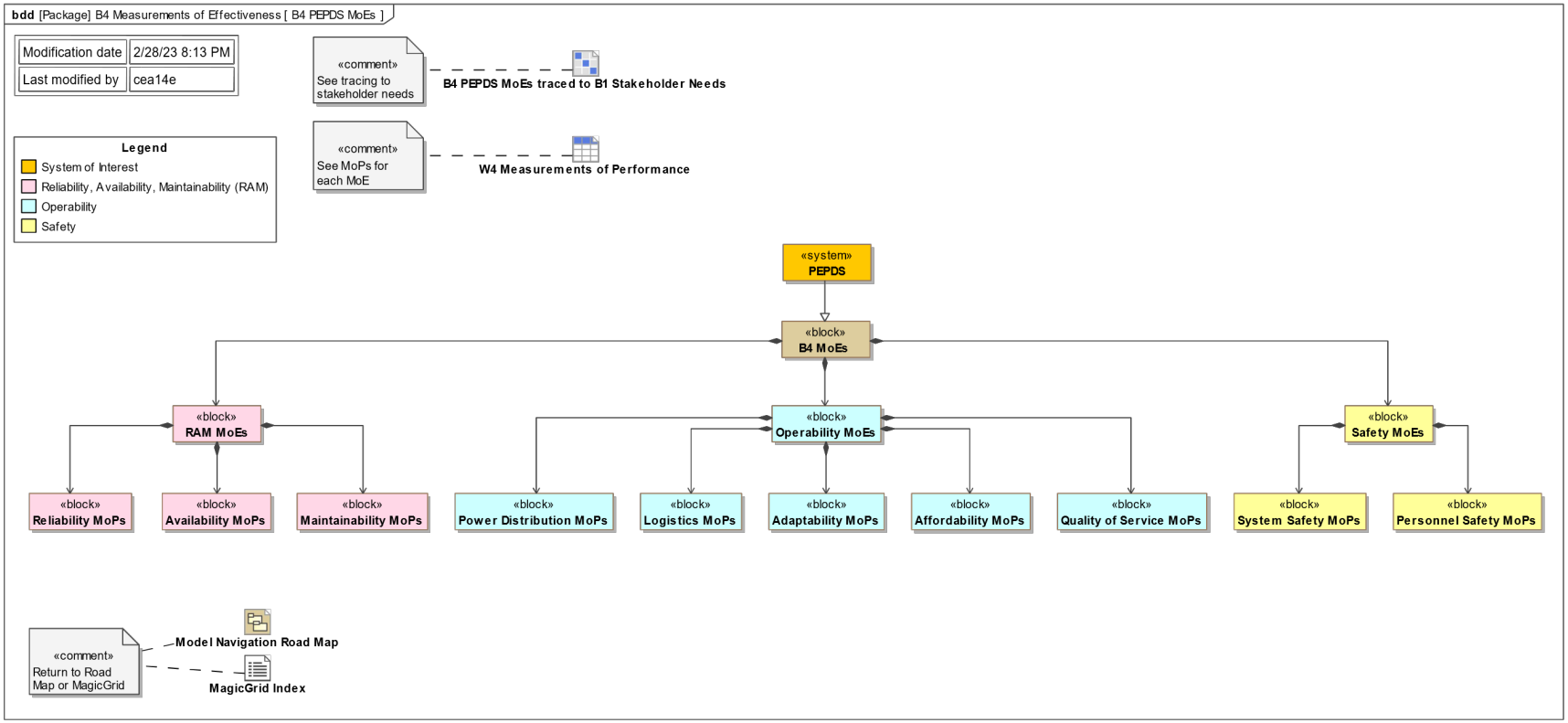


Fig. 25: B4 PEPDS MoEs (Review Part 2)

#	Owner	Name	MoPs
1	Operability MoEs	Adaptability MoPs	Application Adaptability Scalability Robustness Survivability Applicable Ship Classes
2	Operability MoEs	Affordability MoPs	Removal Cost Installation Cost Operation Cost Implementation Cost
3	Operability MoEs	Logistics MoPs	LMS Manning LMS Training Operation Manning Cost for Support Operator Training Effectiveness of Support Capability Removal Time Installation Time
4	Operability MoEs	Power Distribution MoPs	Specific Energy Power Density Response Time Power Electronic Utilization Transmission Efficiency Recharge C Rate Conversion Efficiency Discharge C Rate
5	Operability MoEs	Quality of Service MoPs	Mean Time to Resolve Service Interruption of Un-Interruptible Load Mean Time to Resolve Service Interruption of Short Term Interrupt Load Survival Service Time for Un-Interruptible Load Survival Service Time for Short Term Interrupt Load Mean Time to Resolve Service Interruption Survival Service Time Mean Time to Resolve Service Interruption of Long Term Interrupt Load Survival Service Time for Long Term Interrupt Load
6	RAM MoEs	Availability MoPs	Inherent Availability Operational Availability Achieved Availability
7	RAM MoEs	Maintainability MoPs	Mean Operating Hours between False Alarm Percent BIT Fault Detection Percent BIT Fault Isolation Mean Down Time Maintenance Burden
8	RAM MoEs	Reliability MoPs	Mean Time Between Repairs Mean Time Between Maintenance Resiliency Quality of Service MoPs Power Delivery Reliability Life Expectancy Mean Time Between Failure
9	Safety MoEs	Personnel Safety MoPs	LRU s Transportability LRU s Liftability Electrical Safety Thermal Safety
10	Safety MoEs	System Safety MoPs	Tolerance to Environmental Loads Mean Time to Contain Cybersecurity Intrusion Mean Time to Resolve Cybersecurity Intrusion Mean Time to Detect Cybersecurity Intrusion

Fig. 26: W4 Measurements of Performance

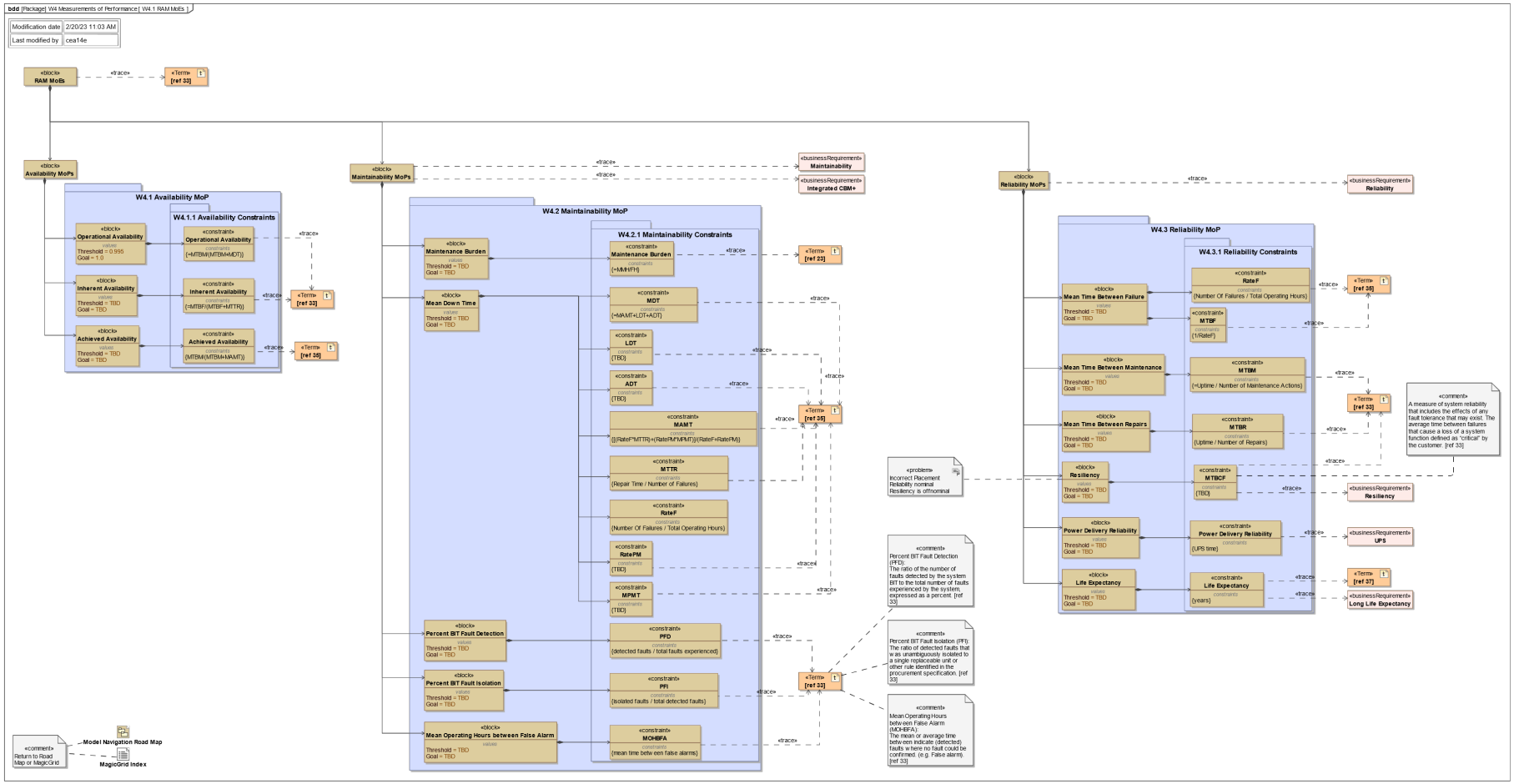


Fig. 27: W4.1 RAM MoEs

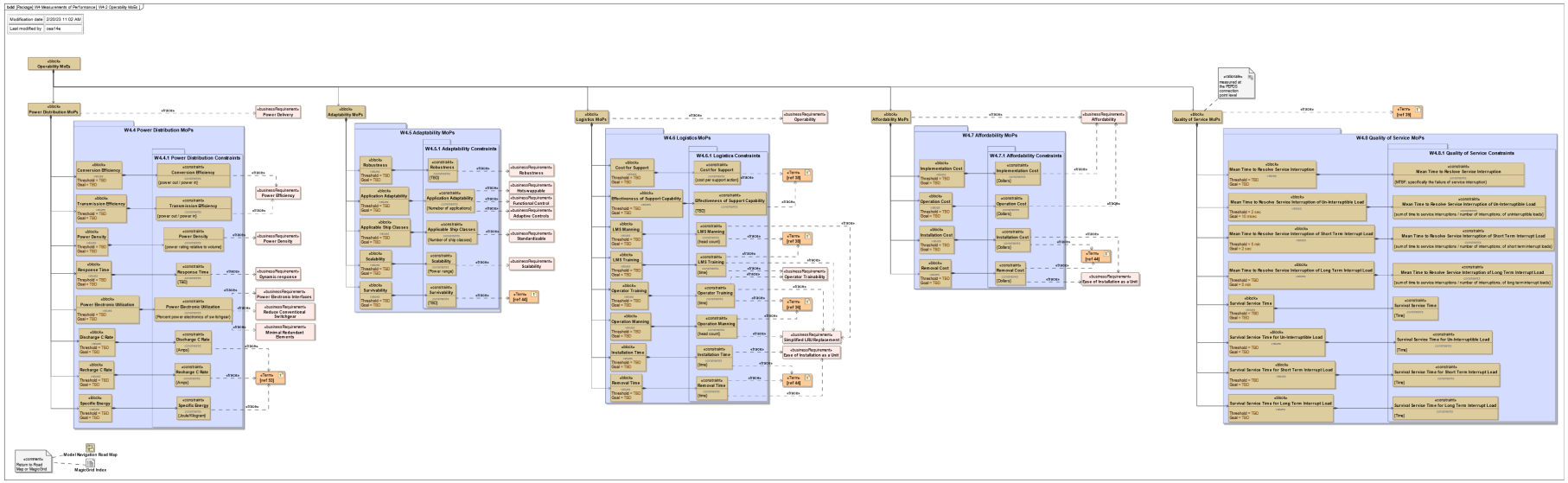


Fig. 28: W4.2 Operability MoEs

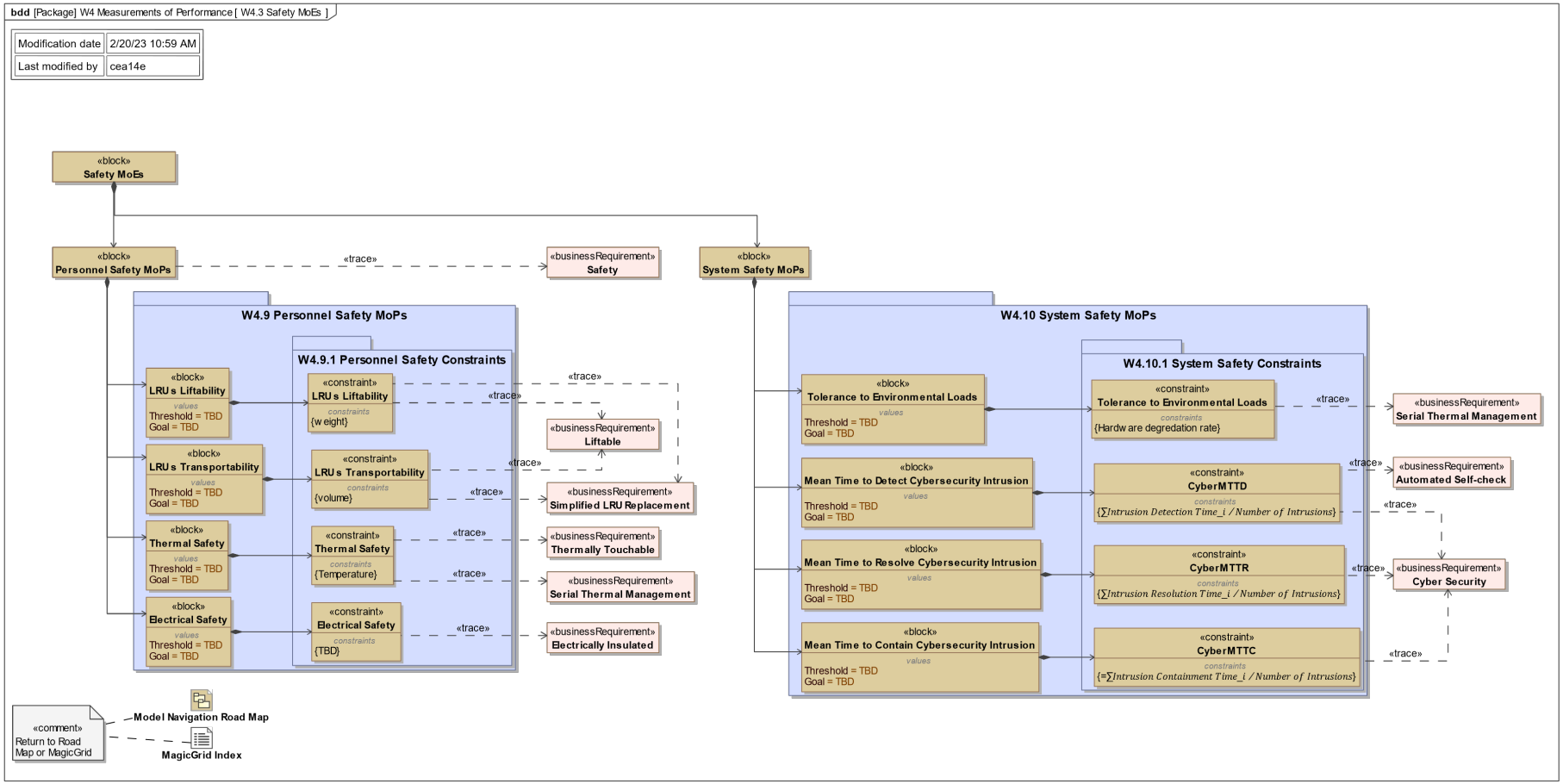


Fig. 29: W4.3 Safety MoEs

11.2.3 Solution Domain S1 System Requirements Review

11.2.3.1 S1 System Requirements

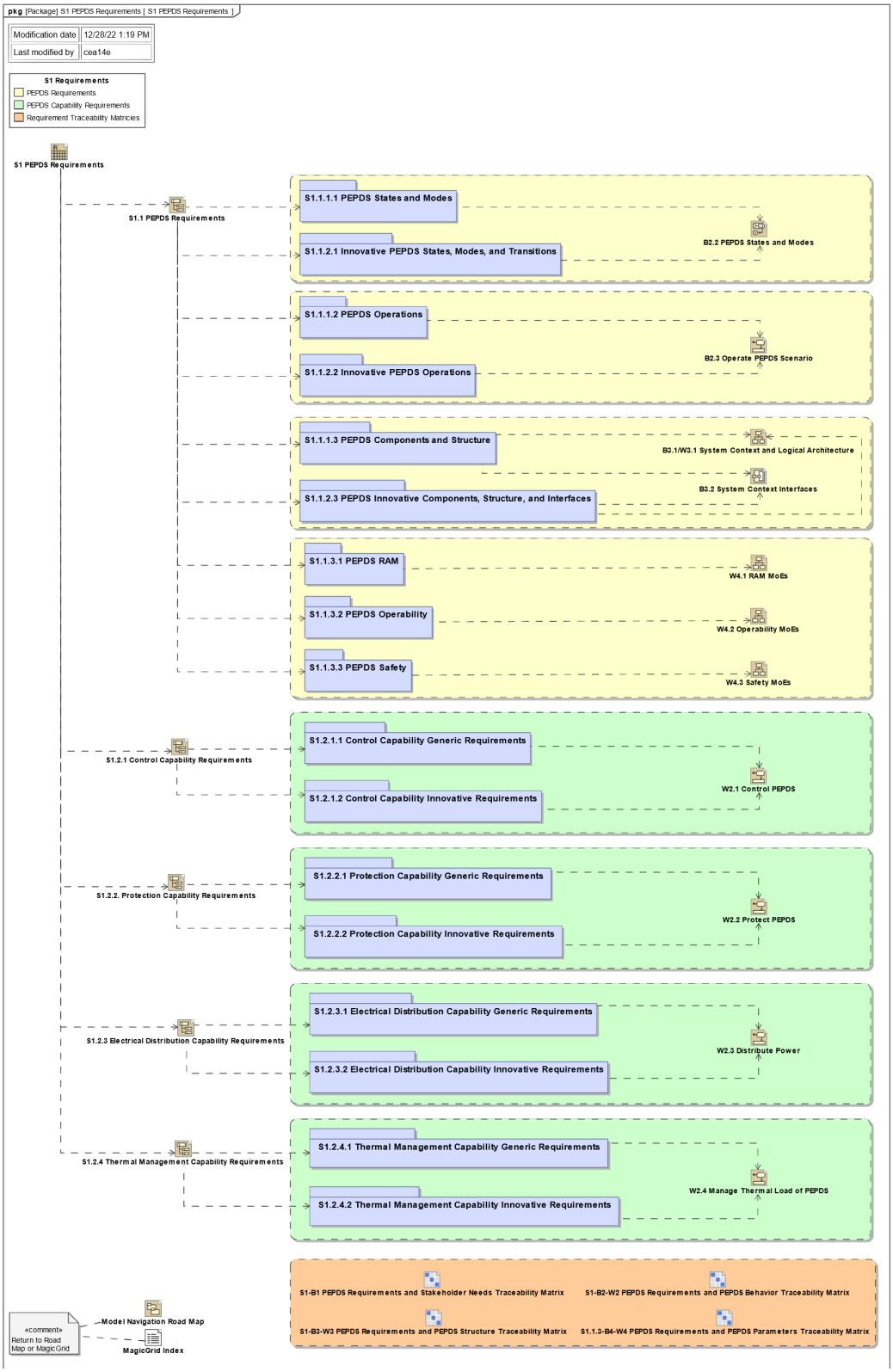


Fig. 30: S1 PEPDS Requirements

11.2.3.2 S1 System Requirements Diagrams

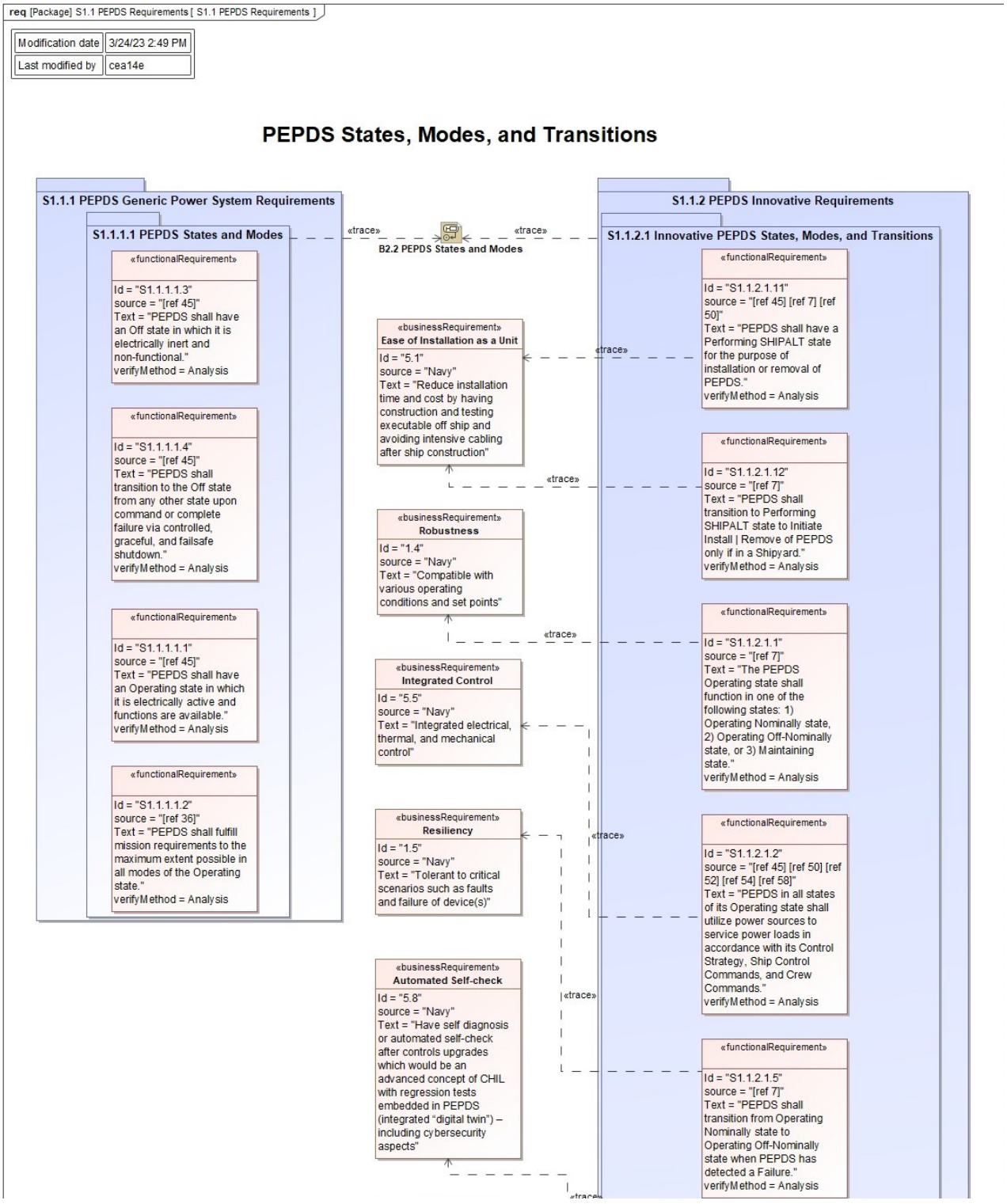


Fig. 31: S1.1 PEPDS Requirements Part 1.1

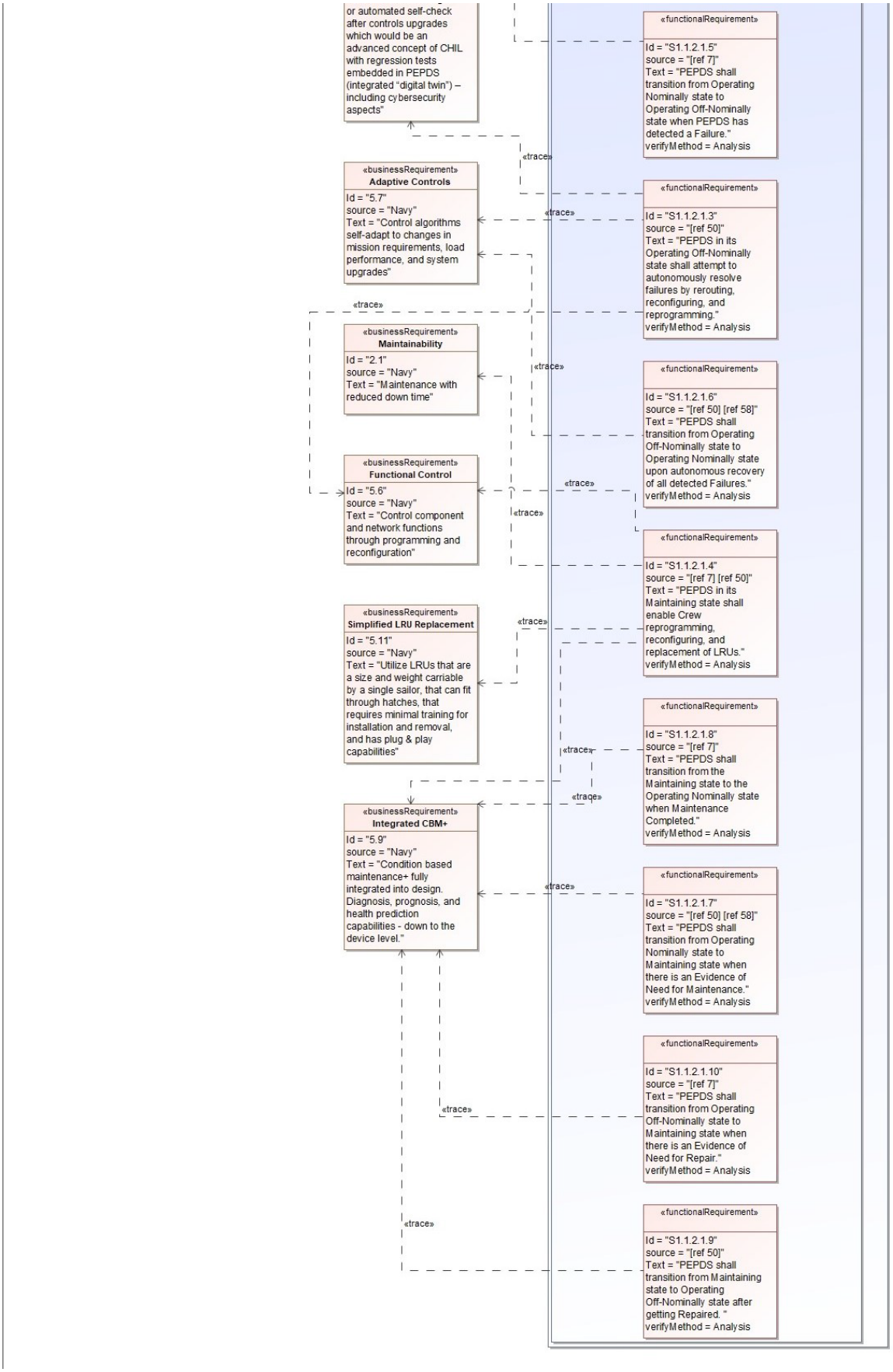


Fig. 32: S1.1 PEPDS Requirements Part 1.2

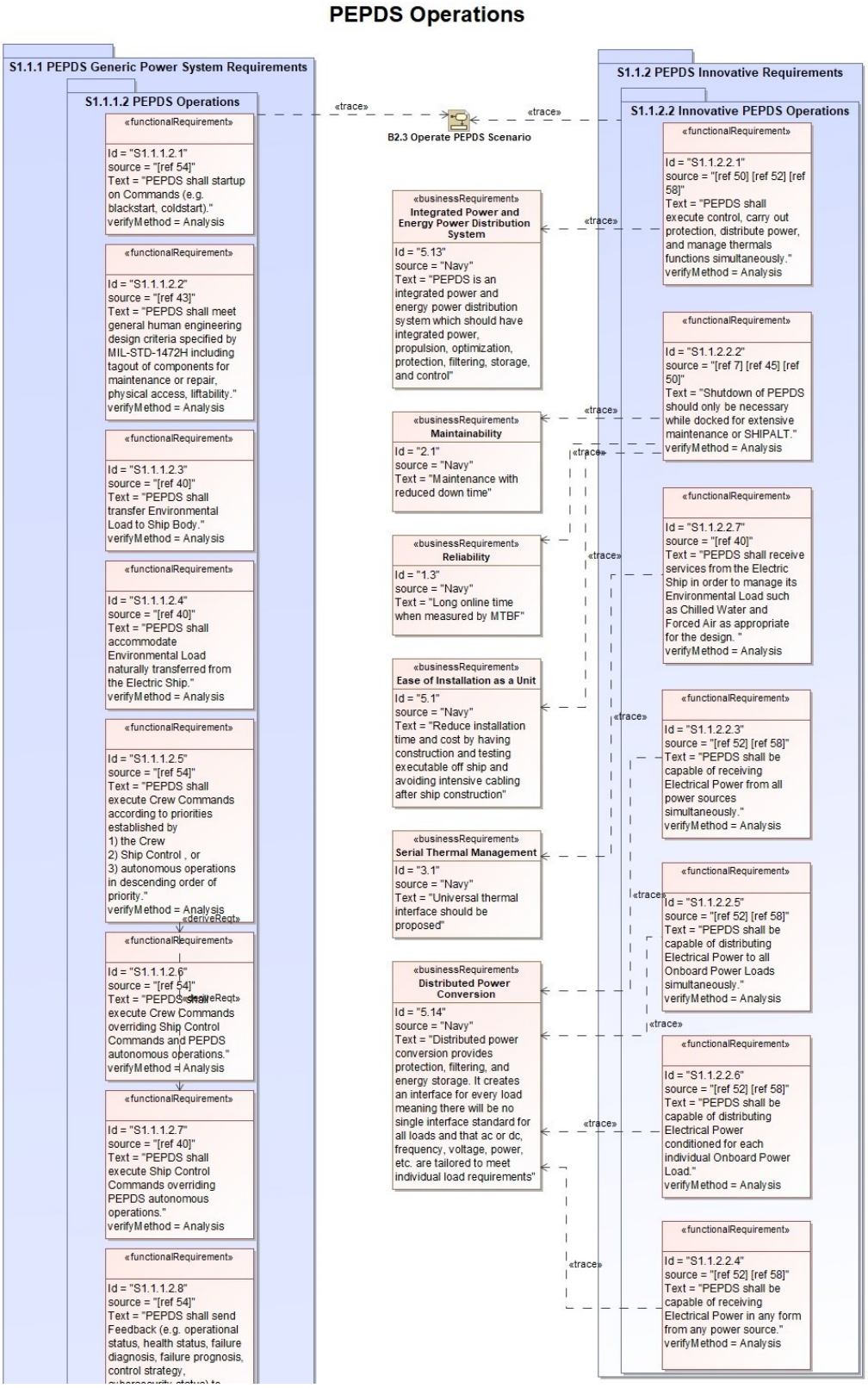


Fig. 33: S1.1 PEPDS Requirements Part 2.1

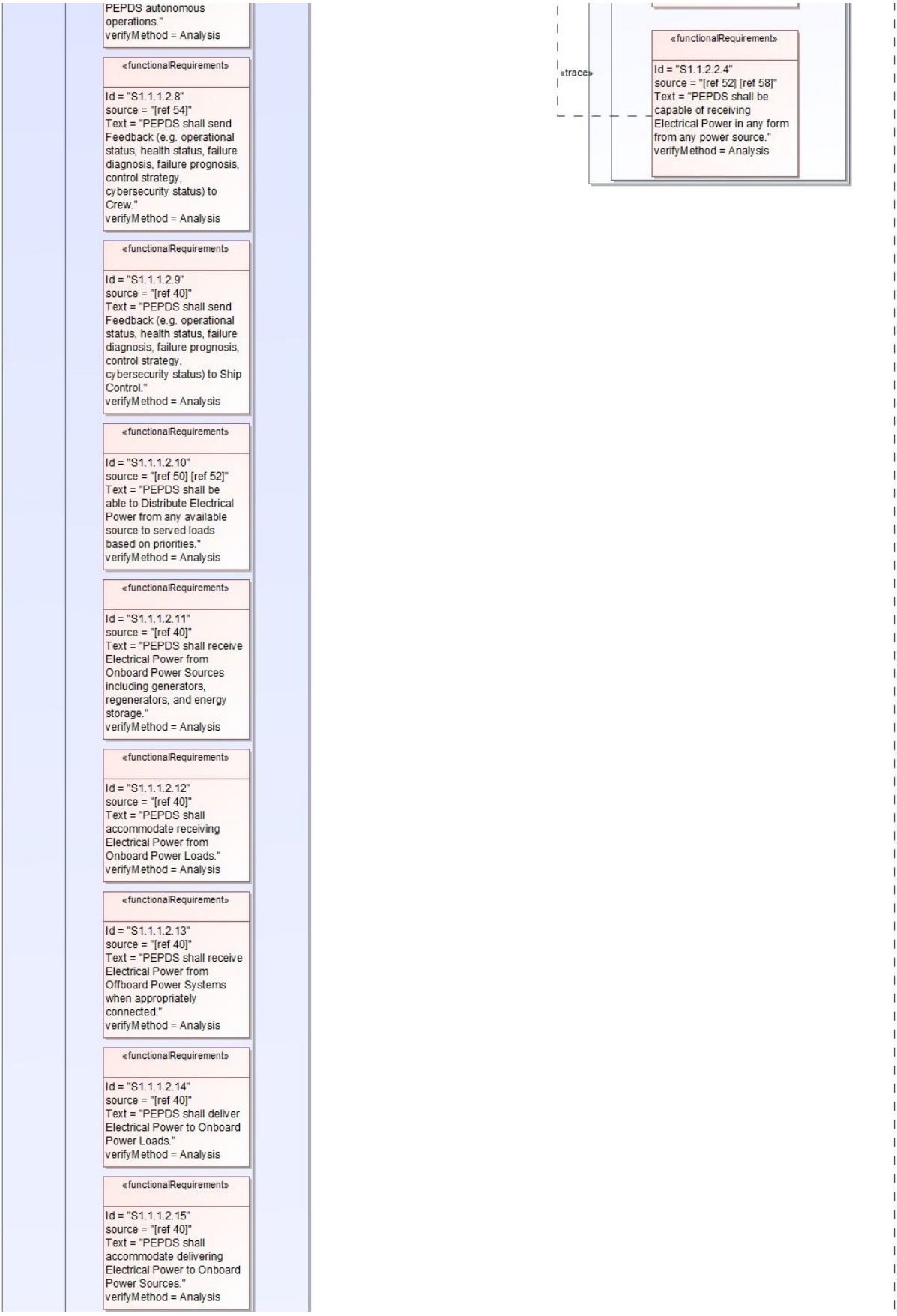


Fig. 34: S1.1 PEPDS Requirements Part 2.2

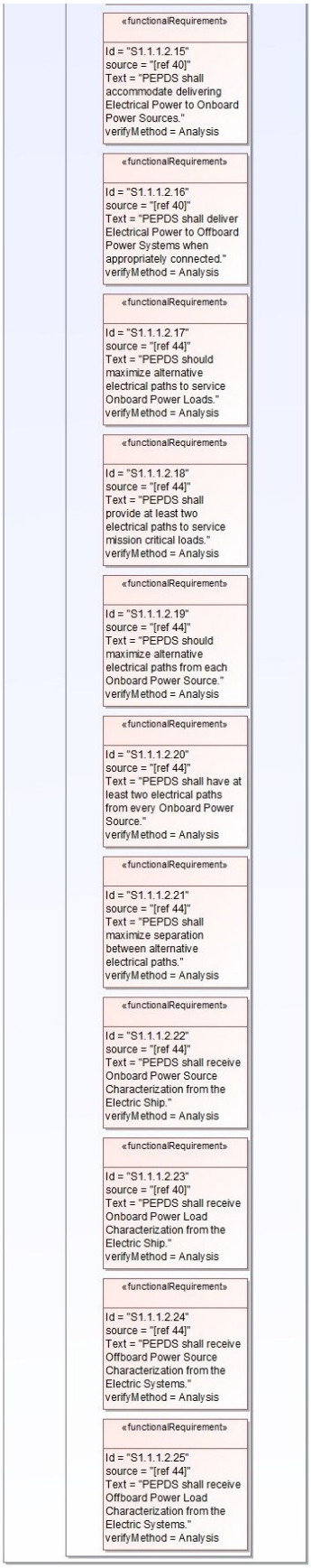


Fig. 35: S1.1 PEPDS Requirements Part 2.3

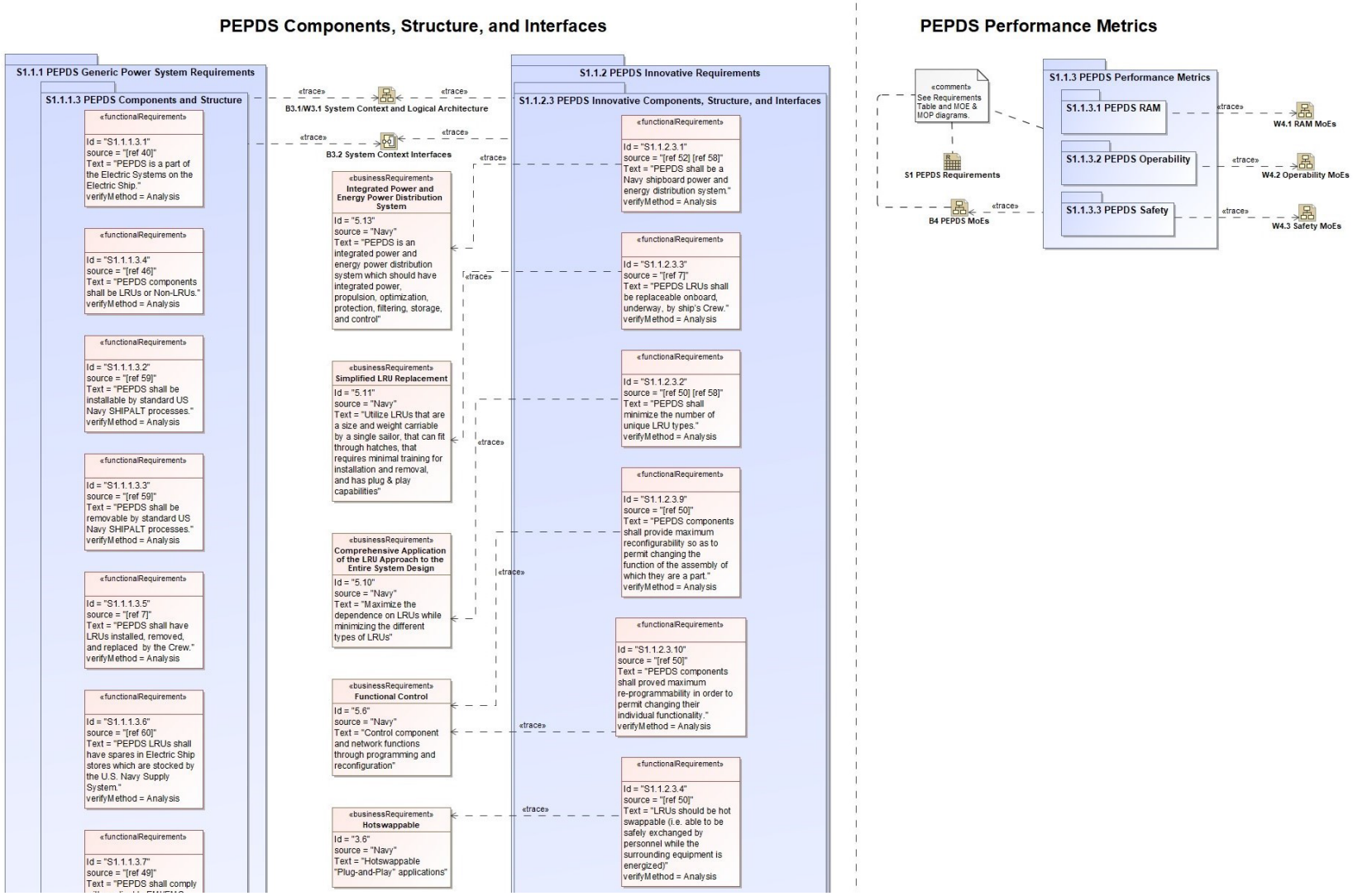


Fig. 36: S1.1 PEPDS Requirements Part 3.1

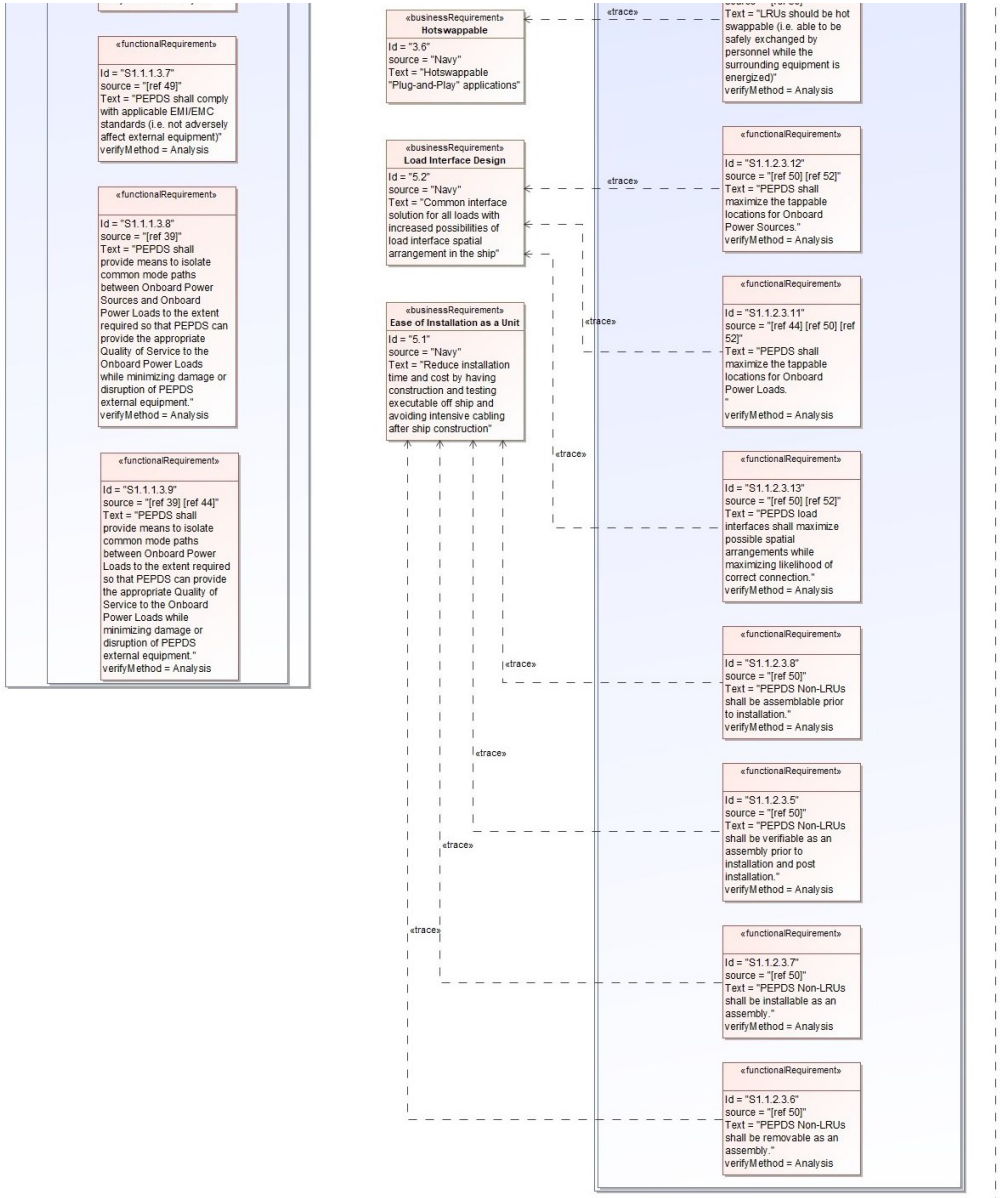


Fig. 37: S1.1 PEPDS Requirements Part 3.2

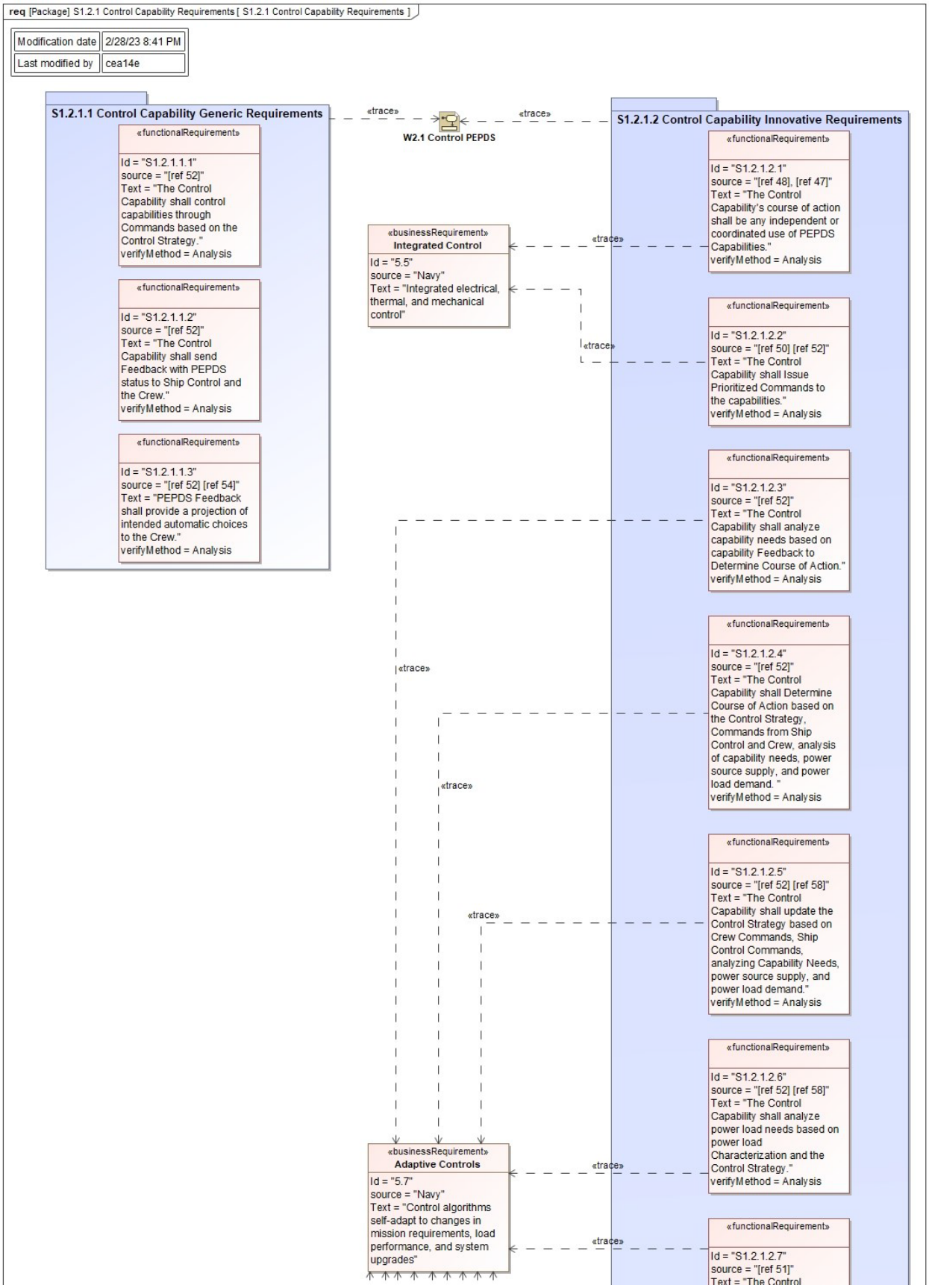


Fig. 38: S1.2.1 Control Capability Requirement Part 1

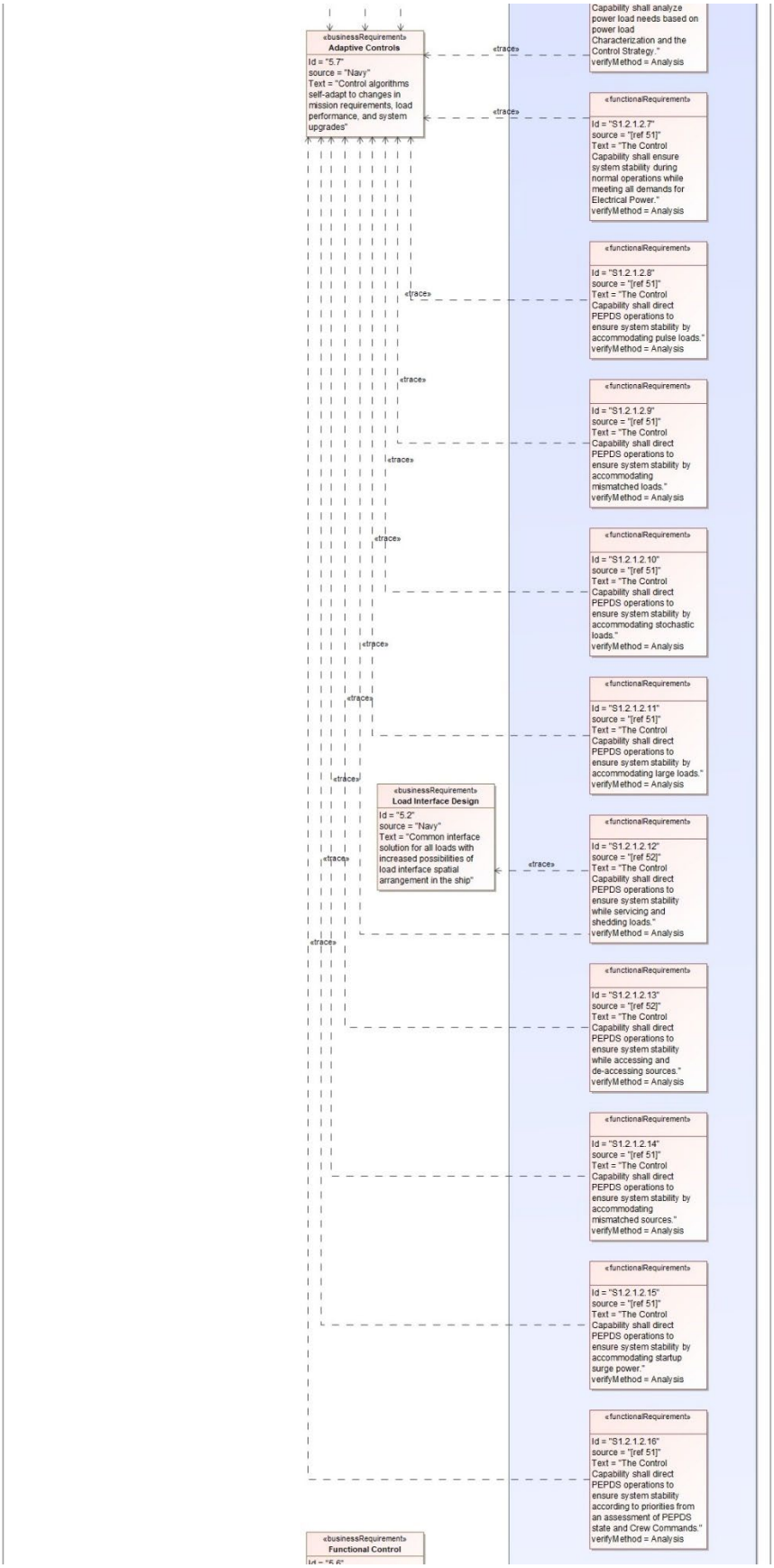


Fig. 39: S1.2.1 Control Capability Requirement Part 2

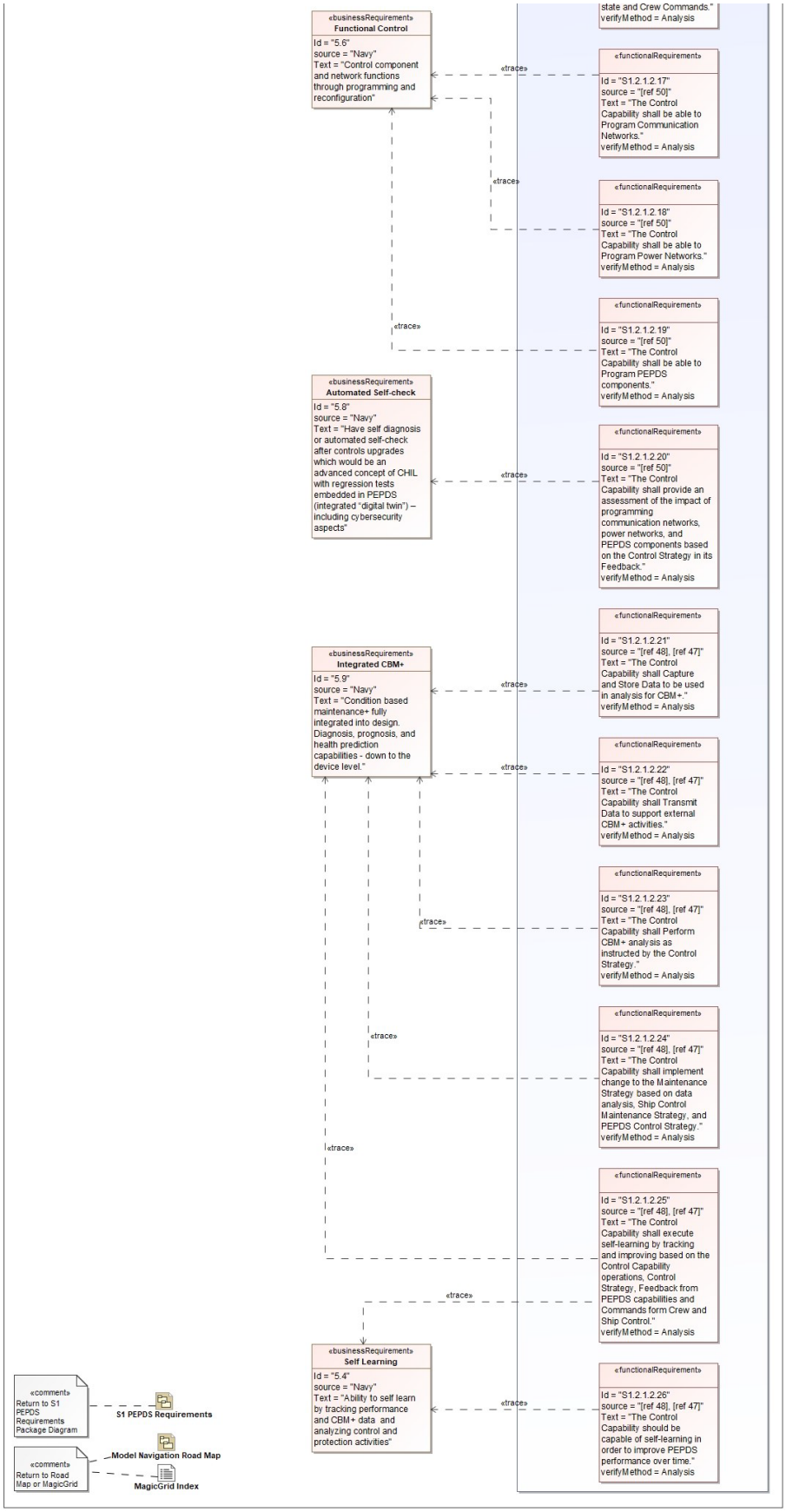


Fig. 40: S1.2.1 Control Capability Requirement Part 3

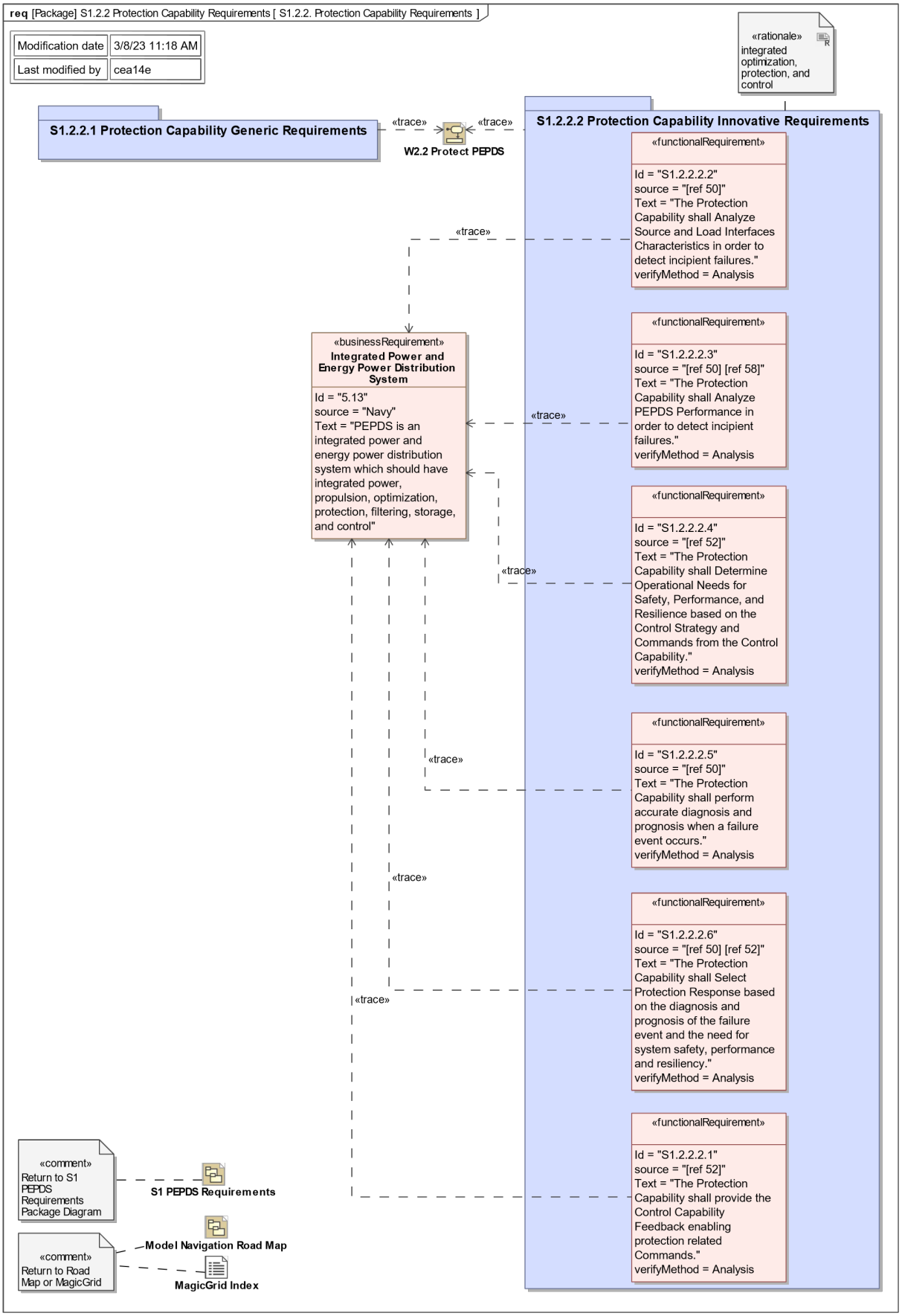


Fig. 41: S1.2.2. Protection Capability Requirements

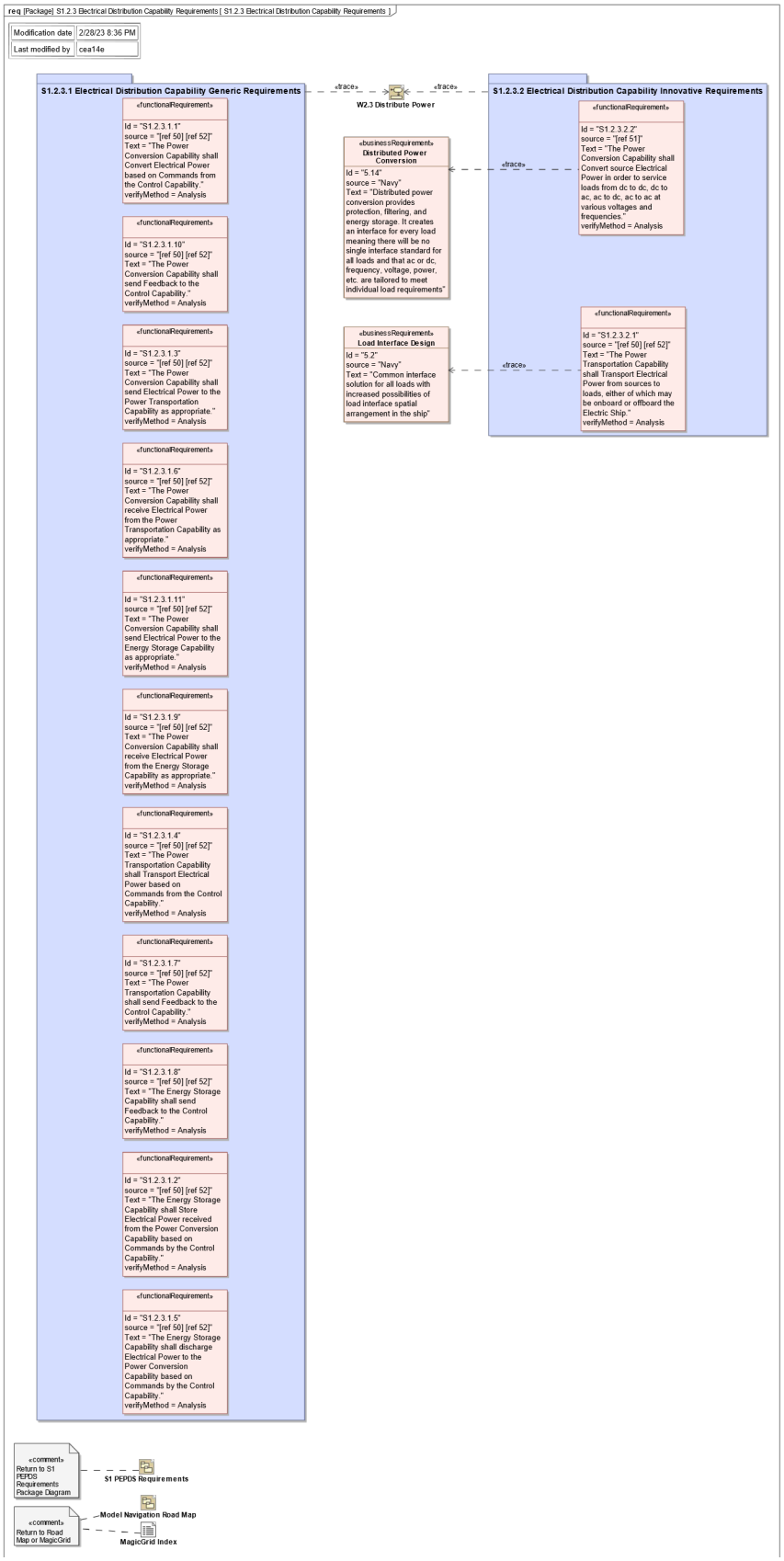


Fig. 42: S1.2.3 Electrical Distribution Capability Requirements

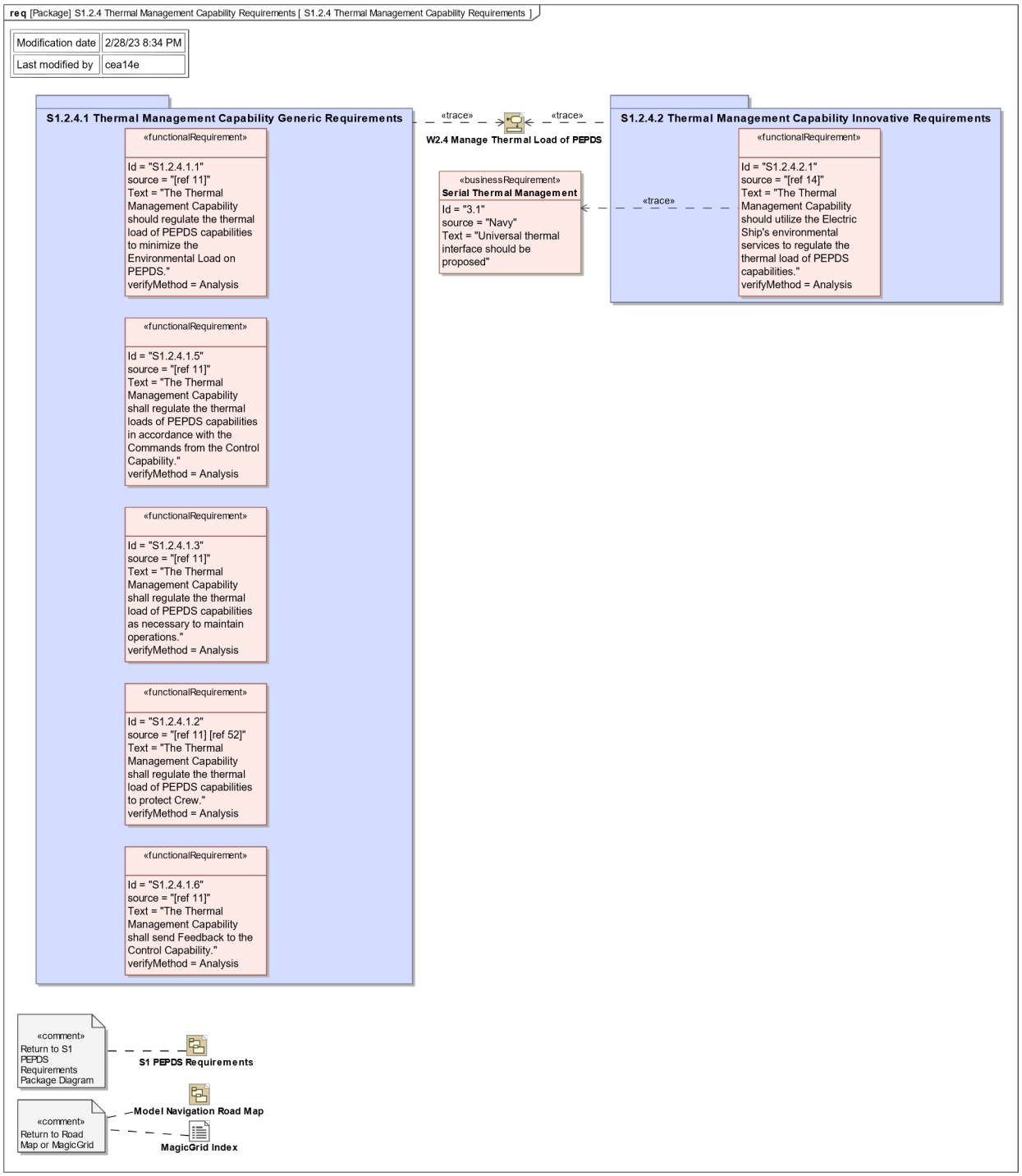


Fig. 43: S1.2.4 Thermal Management Capability Requirements

11.2.3.3 S1 System Requirements Traceability Matrices

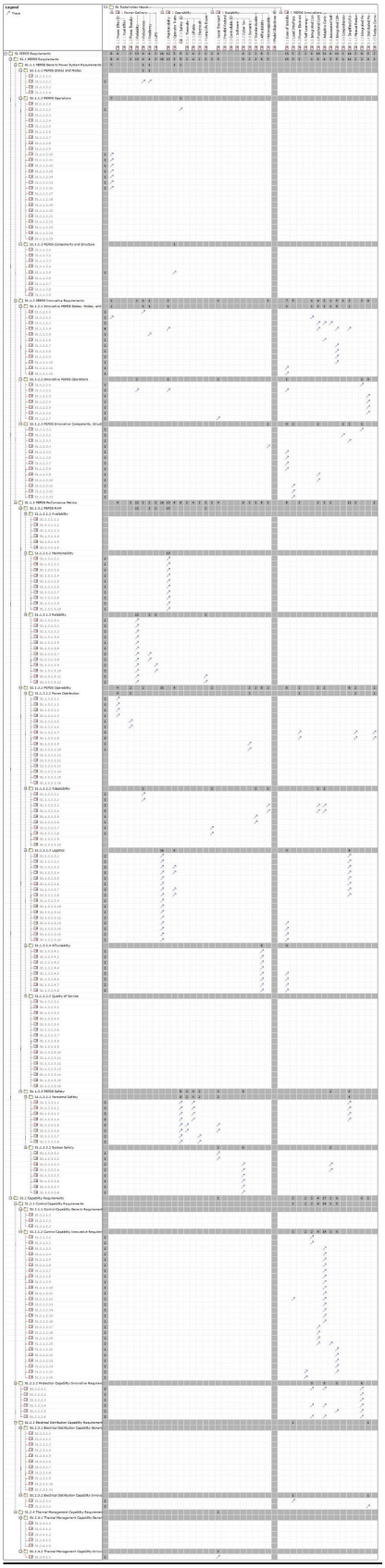


Fig. 44: S1-B1 PEPDS Requirements and Stakeholder Needs Traceability Matrix

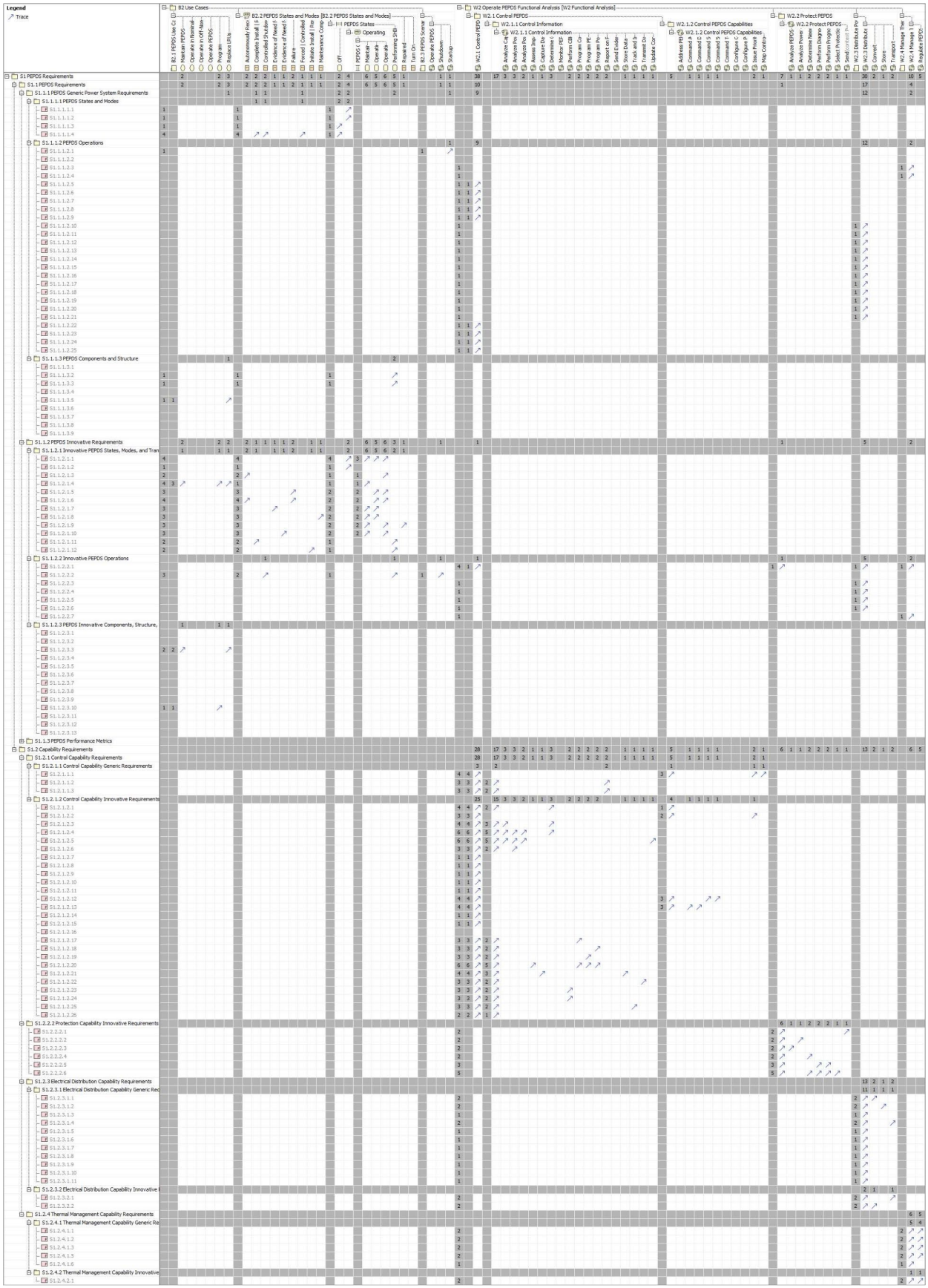


Fig. 45: S1-B2-W2 PEPDS Requirements and PEPDS Behavior Traceability Matrix

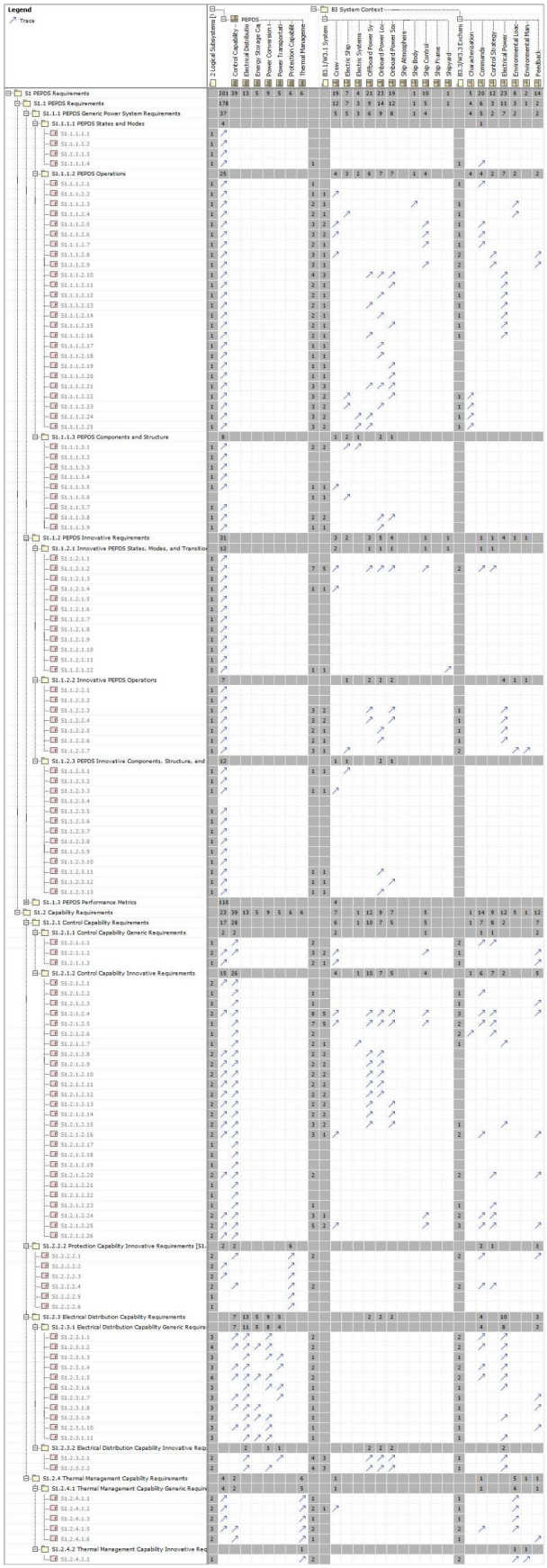


Fig. 46: S1-B3-W3 PEPDS Requirements and PEPDS Structure Traceability Matrix

Fig. 47: S1.1.3-B4-W4 PEPDS Requirements and PEPDS Parameters Traceability Matrix

11.2.3.4 S1 System Requirements Table

#	Name	Text	Traced To	Source	Verify Method	Risk	Revision Date
1	S1.1 PEPDS Requirements						
2	S1.1.1 PEPDS Generic Power System Requirem						
3	S1.1.1.1 PEPDS States and Modes						
4	S1.1.1.1.1	PEPDS shall have an Operating state in which it is electrically active and functions are available.	PEPDS Operating	[ref 45]	Analysis		2022.11.15
5	S1.1.1.1.2	PEPDS shall fulfill mission requirements to the maximum extent possible in all modes of the Operating state.	Operating 1.4 Robustness 1.5 Resiliency PEPDS	[ref 36]	Analysis		2022.11.15
6	S1.1.1.1.3	PEPDS shall have an Off state in which it is electrically inert and non-functional.	PEPDS Off	[ref 45]	Analysis		2022.11.15
7	S1.1.1.1.4	PEPDS shall transition to the Off state from any other state upon command or complete failure via controlled, graceful, and failsafe shutdown.	PEPDS Controlled Shutdown Forced | Controlled Shutdown Off Complete Install | Remove Commands Failure	[ref 45]	Analysis		2022.11.15
8	S1.1.1.2 PEPDS Operations						
34	S1.1.1.3 PEPDS Components and Structure						
44	S1.1.2 PEPDS Innovative Requirements						
80	S1.1.3 PEPDS Performance Metrics						
204	S1.2 Capability Requirements						

Fig. 48: S1.1.1.1 PEPDS States and Modes

#	Name	Text	Traced To	Source	Verify Method	Risk	Revision Date
1	S1.1 PEPDS Requirements						
2	S1.1.1 PEPDS Generic Power System Requirem						
3	S1.1.1.1 PEPDS States and Modes						
8	S1.1.1.2 PEPDS Operations						
9	S1.1.1.2.1	PEPDS shall startup on Commands (e.g. blackstart, coldstart).	PEPDS Startup Commands		Analysis		2022.11.15
10	S1.1.1.2.2	PEPDS shall meet general human engineering design criteria specified by MIL-STD-1472H including tagout of components for maintenance or repair, physical access, liftability.	PEPDS 2.3 Safety Crew	[ref 43]	Analysis		2022.11.15
11	S1.1.1.2.3	PEPDS shall transfer Environmental Load to Ship Body.	Ship Body Environmental Load PEPDS W2.4 Manage Thermal Load of PEPDS	[ref 40]	Analysis		2022.11.15
12	S1.1.1.2.4	PEPDS shall accommodate Environmental Load naturally transferred from the Electric Ship.	PEPDS Environmental Load Electric Ship W2.4 Manage Thermal Load of PEPDS	[ref 40]	Analysis		2022.11.15
13	S1.1.1.2.5	PEPDS shall execute Crew Commands according to priorities established by 1) the Crew 2) Ship Control , or 3) autonomous operations in descending order of priority.	PEPDS Crew Ship Control Commands W2.1 Control PEPDS	[ref 54]	Analysis		2022.11.15
14	S1.1.1.2.6	PEPDS shall execute Crew Commands overriding Ship Control Commands and PEPDS autonomous operations.	PEPDS Crew Commands Ship Control W2.1 Control PEPDS	[ref 54]	Analysis		2022.11.15
15	S1.1.1.2.7	PEPDS shall execute Ship Control Commands overriding PEPDS autonomous operations.	PEPDS Commands Ship Control W2.1 Control PEPDS	[ref 40]	Analysis		2022.11.15
16	S1.1.1.2.8	PEPDS shall send Feedback (e.g. operational status, health status, failure diagnosis, failure prognosis, control strategy, cybersecurity status) to Crew.	PEPDS Feedback Crew Control Strategy W2.1 Control PEPDS	[ref 54]	Analysis		2022.11.15
17	S1.1.1.2.9	PEPDS shall send Feedback (e.g. operational status, health status, failure diagnosis, failure prognosis, control strategy, cybersecurity status) to Ship Control.	Ship Control Feedback PEPDS Control Strategy W2.1 Control PEPDS	[ref 40]	Analysis		2022.11.15
18	S1.1.1.2.10	PEPDS shall be able to Distribute Electrical Power from any available source to served loads based on priorities.	PEPDS Electrical Power Onboard Power Sources Onboard Power Loads 1 Power Delivery W2.3 Distribute Power Offboard Power Systems	[ref 50] [ref 52]	Analysis		2022.11.15
19	S1.1.1.2.11	PEPDS shall receive Electrical Power from Onboard Power Sources including generators, regenerators, and energy storage.	Onboard Power Sources Electrical Power PEPDS 1 Power Delivery W2.3 Distribute Power	[ref 40]	Analysis		2022.11.15
20	S1.1.1.2.12	PEPDS shall accommodate receiving Electrical Power from Onboard Power Loads.	PEPDS Electrical Power Onboard Power Loads 1 Power Delivery W2.3 Distribute Power	[ref 40]	Analysis		2022.11.15
21	S1.1.1.2.13	PEPDS shall receive Electrical Power from Offboard Power Systems when appropriately connected.	Offboard Power Systems Electrical Power PEPDS 1 Power Delivery W2.3 Distribute Power	[ref 40]	Analysis		2022.11.15
22	S1.1.1.2.14	PEPDS shall deliver Electrical Power to Onboard Power Loads.	Onboard Power Loads Electrical Power PEPDS 1 Power Delivery W2.3 Distribute Power	[ref 40]	Analysis		2022.11.15
23	S1.1.1.2.15	PEPDS shall accommodate delivering Electrical Power to Onboard Power Sources.	PEPDS Electrical Power Onboard Power Sources 1 Power Delivery W2.3 Distribute Power	[ref 40]	Analysis		2022.11.15
24	S1.1.1.2.16	PEPDS shall deliver Electrical Power to Offboard Power Systems when appropriately connected.	Offboard Power Systems Electrical Power PEPDS 1 Power Delivery W2.3 Distribute Power	[ref 40]	Analysis		2022.11.15
25	S1.1.1.2.17	PEPDS should maximize alternative electrical paths to service Onboard Power Loads.	PEPDS Onboard Power Loads W2.3 Distribute Power	[ref 44]	Analysis		2022.11.15
26	S1.1.1.2.18	PEPDS shall provide at least two electrical paths to service mission critical loads.	PEPDS W2.3 Distribute Power Onboard Power Loads	[ref 44]	Analysis		2022.11.15
27	S1.1.1.2.19	PEPDS should maximize alternative electrical paths from each Onboard Power Source.	PEPDS Onboard Power Sources W2.3 Distribute Power	[ref 44]	Analysis		2022.11.15
28	S1.1.1.2.20	PEPDS shall have at least two electrical paths from every Onboard Power Source.	PEPDS Onboard Power Sources W2.3 Distribute Power	[ref 44]	Analysis		2022.11.15
29	S1.1.1.2.21	PEPDS shall maximize separation between alternative electrical paths.	PEPDS W2.3 Distribute Power Offboard Power Systems Onboard Power Loads Onboard Power Sources	[ref 44]	Analysis		2022.11.15
30	S1.1.1.2.22	PEPDS shall receive Onboard Power Source Characterization from the Electric Ship.	PEPDS Characterization Onboard Power Sources Electric Ship W2.1 Control PEPDS	[ref 44]	Analysis		2022.11.15
31	S1.1.1.2.23	PEPDS shall receive Onboard Power Load Characterization from the Electric Ship.	PEPDS Characterization Onboard Power Loads Electric Ship W2.1 Control PEPDS	[ref 40]	Analysis		2022.11.15
32	S1.1.1.2.24	PEPDS shall receive Offboard Power Source Characterization from the Electric Systems.	PEPDS Offboard Power Systems Characterization Electric Systems W2.1 Control PEPDS	[ref 44]	Analysis		2022.11.15
33	S1.1.1.2.25	PEPDS shall receive Offboard Power Load Characterization from the Electric Systems.	PEPDS Characterization Offboard Power Systems Electric Systems W2.1 Control PEPDS	[ref 44]	Analysis		2022.11.15
34	S1.1.1.3 PEPDS Components and Structure						
44	S1.1.2 PEPDS Innovative Requirements						
80	S1.1.3 PEPDS Performance Metrics						
204	S1.2 Capability Requirements						

Fig. 49: S1.1.1.2 PEPDS Operations

#	Name	Text	Traced To	Source	Verify Method	Risk	Revision Date
1	S1.1 PEPDS Requirements						
2	S1.1.1 PEPDS Generic Power System Requirem						
3	S1.1.1.1 PEPDS States and Modes						
8	S1.1.1.2 PEPDS Operations						
34	S1.1.1.3 PEPDS Components and Structure						
35	S1.1.1.3.1	PEPDS is a part of the Electric Systems on the Electric Ship.	PEPDS Electric Systems Electric Ship	[ref 40]	Analysis		2022.11.15
36	S1.1.1.3.2	PEPDS shall be installable by standard US Navy SHIPALT processes.	PEPDS Performing SHIPALT	[ref 59]	Analysis		2022.11.15
37	S1.1.1.3.3	PEPDS shall be removable by standard US Navy SHIPALT processes.	PEPDS Performing SHIPALT	[ref 59]	Analysis		2022.11.15
38	S1.1.1.3.4	PEPDS components shall be LRUs or Non-LRUs.	PEPDS LRUs Non-LRUs	[ref 46]	Analysis		2022.11.15
39	S1.1.1.3.5	PEPDS shall have LRUs installed, removed, and replaced by the Crew.	PEPDS LRUs Crew Replace LRUs 2.2 Operator Trainability	[ref 7]	Analysis		2022.11.15
40	S1.1.1.3.6	PEPDS LRUs shall have spares in Electric Ship stores which are stocked by the U.S. Navy Supply System.	LRUs Electric Ship	[ref 60]	Analysis		2022.11.15
41	S1.1.1.3.7	PEPDS shall comply with applicable EMI/EMC standards (i.e. not adversely affect external equipment)	PEPDS	[ref 49]	Analysis		2022.11.15
42	S1.1.1.3.8	PEPDS shall provide means to isolate common mode paths between Onboard Power Sources and Onboard Power Loads to the extent required so that PEPDS can provide the appropriate Quality of Service to the Onboard Power Loads while minimizing damage or disruption of PEPDS external equipment.	PEPDS Quality of Service Onboard Power Loads Onboard Power Sources	[ref 39]	Analysis		2022.11.15
43	S1.1.1.3.9	PEPDS shall provide means to isolate common mode paths between Onboard Power Loads to the extent required so that PEPDS can provide the appropriate Quality of Service to the Onboard Power Loads while minimizing damage or disruption of PEPDS external equipment.	PEPDS Quality of Service Onboard Power Loads	[ref 39] [ref 44]	Analysis		2022.11.15
44	S1.1.2 PEPDS Innovative Requirements						
80	S1.1.3 PEPDS Performance Metrics						
204	S1.2 Capability Requirements						

Fig. 50: S1.1.1.3 PEPDS Components and Structure

#	Name	Text	Traced To	Source	Verify Method	Risk	Revision Date
1	S1.1 PEPDS Requirements						
2	S1.1.1 PEPDS Generic Power System Requirem						
44	S1.1.2 PEPDS Innovative Requirements						
45	S1.1.2.1 Innovative PEPDS States, Modes,						
46	S1.1.2.1.1	The PEPDS Operating state shall function in one of the following states: 1) Operating Nominally state, 2) Operating Off-Nominally state, or 3) Maintaining state.	PEPDS Operating Operating Nominally Operating Off-Nominally Maintaining 1.4 Robustness	[ref 7]	Analysis		2022.11.15
47	S1.1.2.1.2	PEPDS in all states of its Operating state shall utilize power sources to service power loads in accordance with its Control Strategy, Ship Control Commands, and Crew Commands.	PEPDS Operating Control Strategy Offboard Power Systems 5.5 Integrated Control 1 Power Delivery Onboard Power Sources Onboard Power Loads Commands Crew Ship Control	[ref 45] [ref 50] [ref 52] [ref	Analysis		2022.11.15
48	S1.1.2.1.3	PEPDS in its Operating Off-Nominally state shall attempt to autonomously resolve failures by rerouting, reconfiguring, and reprogramming.	PEPDS Operating Off-Nominally Autonomously Recovered 5.7 Adaptive Controls 5.6 Functional Control 5.8 Automated Self-check Failure	[ref 50]	Analysis		2022.11.15
49	S1.1.2.1.4	PEPDS in its Maintaining state shall enable Crew reprogramming, reconfiguring, and replacement of LRUs.	PEPDS Maintaining Crew LRUs 5.9 Integrated CBM+ 5.11 Simplified LRU Replacement 5.6 Functional Control 2.1 Maintainability Program Replace LRUs Maintain PEPDS	[ref 7] [ref 50]	Analysis		2022.11.15
50	S1.1.2.1.5	PEPDS shall transition from Operating Nominally state to Operating Off-Nominally state when PEPDS has detected a Failure.	PEPDS Operating Nominally Operating Off-Nominally Failure 1.5 Resiliency Failure	[ref 7]	Analysis		2022.11.15
51	S1.1.2.1.6	PEPDS shall transition from Operating Off-Nominally state to Operating Nominally state upon autonomous recovery of all detected Failures.	PEPDS Operating Nominally Operating Off-Nominally Autonomously Recovered Failure 5.7 Adaptive Controls Failure	[ref 50] [ref 58]	Analysis		2022.11.15
52	S1.1.2.1.7	PEPDS shall transition from Operating Nominally state to Maintaining state when there is an Evidence of Need for Maintenance.	PEPDS Maintaining Evidence of Need for Maintenance Operating Nominally 5.9 Integrated CBM+	[ref 50] [ref 58]	Analysis		2022.11.15
53	S1.1.2.1.8	PEPDS shall transition from the Maintaining state to the Operating Nominally state when Maintenance Completed.	PEPDS Maintaining Operating Nominally Maintenance Completed 5.9 Integrated CBM+	[ref 7]	Analysis		2022.11.15
54	S1.1.2.1.9	PEPDS shall transition from Maintaining state to Operating Off-Nominally state after getting Repaired.	PEPDS Maintaining Operating Off-Nominally Repaired 5.9 Integrated CBM+	[ref 50]	Analysis		2022.11.15
55	S1.1.2.1.10	PEPDS shall transition from Operating Off-Nominally state to Maintaining state when there is an Evidence of Need for Repair.	PEPDS Operating Off-Nominally Maintaining Evidence of Need for Repair 5.9 Integrated CBM+	[ref 7]	Analysis		2022.11.15
56	S1.1.2.1.11	PEPDS shall have a Performing SHIPALT state for the purpose of installation or removal of PEPDS.	Performing SHIPALT PEPDS Complete Install | Remove 5.1 Ease of Installation as a Unit	[ref 45] [ref 7] [ref 50]	Analysis		2022.11.15
57	S1.1.2.1.12	PEPDS shall transition to Performing SHIPALT state to Initiate Install | Remove of PEPDS only if in a Shipyard.	PEPDS Performing SHIPALT Initiate Install | Remove Shipyard 5.1 Ease of Installation as a Unit	[ref 7]	Analysis		2022.11.15
58	S1.1.2.2 Innovative PEPDS Operations						
66	S1.1.2.3 PEPDS Innovative Components, S						
80	S1.1.3 PEPDS Performance Metrics						
204	S1.2 Capability Requirements						

Fig. 51: S1.1.2.1 Innovative PEPDS States, Modes, and Transitions

#	Name	Text	Traced To	Source	Verify Method	Risk	Revision Date
1	S1.1 PEPDS Requirements						
2	S1.1.1 PEPDS Generic Power System Requirem						
44	S1.1.2 PEPDS Innovative Requirements						
45	S1.1.2.1 Innovative PEPDS States, Modes,						
58	S1.1.2.2 Innovative PEPDS Operations						
59	S1.1.2.2.1	PEPDS shall execute control, carry out protection, distribute power, and manage thermals functions simultaneously.	PEPDS W2.1 Control PEPDS W2.2 Protect PEPDS W2.3 Distribute Power W2.4 Manage Thermal Load of PEPDS 5.13 Integrated Power and Energy Pc	[ref 50] [ref 52] [ref 58]	Analysis		2022.11.15
60	S1.1.2.2.2	Shutdown of PEPDS should only be necessary while docked for extensive maintenance or SHIPALT.	Controlled Shutdown Performing SHIPALT PEPDS Shutdown 2.1 Maintainability 1.3 Reliability 5.1 Ease of Installation as a Unit	[ref 7] [ref 45] [ref 50]	Analysis		2022.11.15
61	S1.1.2.2.3	PEPDS shall be capable of receiving Electrical Power from all power sources simultaneously.	PEPDS Onboard Power Sources Offboard Power Systems 5.14 Distributed Power Conversion W2.3 Distribute Power Electrical Power	[ref 52] [ref 58]	Analysis		2022.11.15
62	S1.1.2.2.4	PEPDS shall be capable of receiving Electrical Power in any form from any power source.	PEPDS Electrical Power Onboard Power Sources Offboard Power Systems 5.14 Distributed Power Conversion W2.3 Distribute Power	[ref 52] [ref 58]	Analysis		2022.11.15
63	S1.1.2.2.5	PEPDS shall be capable of distributing Electrical Power to all Onboard Power Loads simultaneously.	PEPDS Onboard Power Loads 5.14 Distributed Power Conversion Electrical Power W2.3 Distribute Power	[ref 52] [ref 58]	Analysis		2022.11.16
64	S1.1.2.2.6	PEPDS shall be capable of distributing Electrical Power conditioned for each individual Onboard Power Load.	PEPDS 5.14 Distributed Power Conversion W2.3 Distribute Power Onboard Power Loads Electrical Power	[ref 52] [ref 58]	Analysis		2022.11.16
65	S1.1.2.2.7	PEPDS shall receive services from the Electric Ship in order to manage its Environmental Load such as Chilled Water and Forced Air as appropriate for the design.	Electric Ship PEPDS Environmental Load 3.1 Serial Thermal Management Environmental Management Services W2.4 Manage Thermal Load of PEPDS	[ref 40]	Analysis		2022.11.15
66	S1.1.2.3 PEPDS Innovative Components, S						
80	S1.1.3 PEPDS Performance Metrics						
204	S1.2 Capability Requirements						

Fig. 52: S1.1.2.2 Innovative PEPDS Operations

#	Name	Text	Traced To	Source	Verify Method	Risk	Revision Date
1	S1.1 PEPDS Requirements						
2	S1.1.1 PEPDS Generic Power System Requirem						
44	S1.1.2 PEPDS Innovative Requirements						
45	S1.1.2.1 Innovative PEPDS States, Modes,						
58	S1.1.2.2 Innovative PEPDS Operations						
66	S1.1.2.3 PEPDS Innovative Components, S						
67	S1.1.2.3.1	PEPDS shall be a Navy shipboard power and energy distribution system.	Electric Ship PEPDS 5.13 Integrated Power and Energy Pc	[ref 52] [ref 58]	Analysis		2022.11.15
68	S1.1.2.3.2	PEPDS shall minimize the number of unique LRU types.	PEPDS LRUs 5.10 Comprehensive Application of th	[ref 50] [ref 58]	Analysis		2022.11.15
69	S1.1.2.3.3	PEPDS LRUs shall be replaceable onboard, underway, by ship's Crew.	Replace LRUs PEPDS Crew LRUs 5.11 Simplified LRU Replacement Maintain PEPDS	[ref 7]	Analysis		2022.11.15
70	S1.1.2.3.4	LRUs should be hot swappable (i.e. able to be safely exchanged by personnel while the surrounding equipment is energized)	LRUs 3.6 Hotswappable	[ref 50]	Analysis		2022.11.15
71	S1.1.2.3.5	PEPDS Non-LRUs shall be verifiable as an assembly prior to installation and post installation.	PEPDS Non-LRUs 5.1 Ease of Installation as a Unit	[ref 50]	Analysis		2022.11.15
72	S1.1.2.3.6	PEPDS Non-LRUs shall be removable as an assembly.	PEPDS Non-LRUs 5.1 Ease of Installation as a Unit	[ref 50]	Analysis		2022.11.15
73	S1.1.2.3.7	PEPDS Non-LRUs shall be installable as an assembly.	PEPDS Non-LRUs 5.1 Ease of Installation as a Unit	[ref 50]	Analysis		2022.11.15
74	S1.1.2.3.8	PEPDS Non-LRUs shall be assemblable prior to installation.	PEPDS Non-LRUs 5.1 Ease of Installation as a Unit	[ref 50]	Analysis		2022.11.15
75	S1.1.2.3.9	PEPDS components shall provide maximum reconfigurability so as to permit changing the function of the assembly of which they are a part.	PEPDS Non-LRUs 5.6 Functional Control LRUs	[ref 50]	Analysis		2022.11.15
76	S1.1.2.3.10	PEPDS components shall proved maximum re-programmability in order to permit changing their individual functionality.	PEPDS LRUs Non-LRUs 5.6 Functional Control Program	[ref 50]	Analysis		2022.11.15
77	S1.1.2.3.11	PEPDS shall maximize the tappable locations for Onboard Power Loads.	PEPDS Onboard Power Loads 5.2 Load Interface Design	[ref 44] [ref 50] [ref 52]	Analysis		2022.11.15
78	S1.1.2.3.12	PEPDS shall maximize the tappable locations for Onboard Power Sources.	PEPDS Onboard Power Sources 5.2 Load Interface Design	[ref 50] [ref 52]	Analysis		2022.11.15
79	S1.1.2.3.13	PEPDS load interfaces shall maximize possible spatial arrangements while maximizing likelihood of correct connection.	PEPDS 5.2 Load Interface Design Onboard Power Loads	[ref 50] [ref 52]	Analysis		2022.11.15
80	S1.1.3 PEPDS Performance Metrics						
204	S1.2 Capability Requirements						

Fig. 53: S1.1.2.3 PEPDS Innovative Components, Structure, and Interfaces

#	Name	Text	Traced To	Source	Verify Method	Risk	Revision Date
1	S1.1 PEPDS Requirements						
2	S1.1.1 PEPDS Generic Power System Requirem						
44	S1.1.2 PEPDS Innovative Requirements						
80	S1.1.3 PEPDS Performance Metrics						
81	S1.1.3.1 PEPDS RAM						
82	S1.1.3.1.1 Availability						
83	S1.1.3.1.1.1	PEPDS shall maximize Operational Availability achieving a minimum threshold of 0.995.	PEPDS Operational Availability Threshold = 0.995 Operational Availability RAM MoEs Availability MoPs B4 MoEs	[ref 33] [ref 35]	Analysis		2022.11.15
84	S1.1.3.1.1.2	PEPDS should maximize Operational Availability achieving a minimum goal of 1.0.	PEPDS Operational Availability Goal = 1.0 Operational Availability RAM MoEs Availability MoPs B4 MoEs	[ref 33] [ref 35]	Analysis		2022.11.15
85	S1.1.3.1.1.3	PEPDS shall maximize Inherent Availability achieving a minimum threshold of TBD.	PEPDS Inherent Availability Inherent Availability Threshold = TBD RAM MoEs Availability MoPs B4 MoEs	[ref 33] [ref 35]	Analysis		2022.11.15
86	S1.1.3.1.1.4	PEPDS should maximize Inherent Availability achieving a minimum goal of TBD.	PEPDS Inherent Availability Goal = TBD Inherent Availability RAM MoEs Availability MoPs B4 MoEs	[ref 33] [ref 35]	Analysis		2022.11.15
87	S1.1.3.1.1.5	PEPDS shall maximize Achieved Availability achieving a minimum threshold of TBD.	PEPDS Achieved Availability Threshold = TBD Achieved Availability RAM MoEs Availability MoPs B4 MoEs	[ref 33] [ref 35]	Analysis		2022.11.15
88	S1.1.3.1.1.6	PEPDS should maximize Achieved Availability achieving a minimum goal of TBD.	PEPDS Achieved Availability Goal = TBD Achieved Availability RAM MoEs Availability MoPs B4 MoEs	[ref 33] [ref 35]	Analysis		2022.11.15
89	S1.1.3.1.2 Maintainability						
100	S1.1.3.1.3 Reliability						
113	S1.1.3.2 PEPDS Operability						
185	S1.1.3.3 PEPDS Safety						
204	S1.2 Capability Requirements						

Fig. 54: S1.1.3.1.1 Availability

#	Name	Text	Traced To	Source	Verify Method	Risk	Revision Date
1	S1.1 PEPDS Requirements						
2	S1.1.1 PEPDS Generic Power System Requirem						
44	S1.1.2 PEPDS Innovative Requirements						
80	S1.1.3 PEPDS Performance Metrics						
81	S1.1.3.1 PEPDS RAM						
82	S1.1.3.1.1 Availability						
89	S1.1.3.1.2 Maintainability						
90	S1.1.3.1.2.1	PEPDS shall minimize Maintenance Burden achieving a maximum threshold of TBD.	Maintenance Burden PEPDS Maintenance Burden Threshold = TBD 2.1 Maintainability RAM MoEs Maintainability MoPs B4 MoEs	[ref 23] [ref 33]	Analysis		2022.11.15
91	S1.1.3.1.2.2	PEPDS should minimize Maintenance Burden achieving a maximum goal of TBD.	Maintenance Burden PEPDS Maintenance Burden Goal = TBD 2.1 Maintainability RAM MoEs Maintainability MoPs B4 MoEs	[ref 23] [ref 33]	Analysis		2022.11.15
92	S1.1.3.1.2.3	PEPDS shall minimize Mean Down Time achieving a maximum threshold of TBD.	PEPDS MDT Mean Down Time Threshold = TBD 2.1 Maintainability RAM MoEs Maintainability MoPs B4 MoEs	[ref 33] [ref 35]	Analysis		2022.11.15
93	S1.1.3.1.2.4	PEPDS should minimize Mean Down Time achieving a maximum goal of TBD.	PEPDS MDT Mean Down Time Goal = TBD 2.1 Maintainability RAM MoEs Maintainability MoPs B4 MoEs	[ref 33] [ref 35]	Analysis		2022.11.15
94	S1.1.3.1.2.5	PEPDS shall maximize Percent Fault Detection achieving a minimum threshold of TBD.	PEPDS PFD Percent BIT Fault Detection Threshold = TBD 2.1 Maintainability RAM MoEs Maintainability MoPs B4 MoEs	[ref 33]	Analysis		2022.11.15
95	S1.1.3.1.2.6	PEPDS should maximize Percent Fault Detection achieving a minimum goal of TBD.	PEPDS PFD Percent BIT Fault Detection Goal = TBD 2.1 Maintainability RAM MoEs Maintainability MoPs B4 MoEs	[ref 33]	Analysis		2022.11.15
96	S1.1.3.1.2.7	PEPDS shall maximize Percent Fault Isolation achieving a minimum threshold of TBD.	PEPDS PFI Percent BIT Fault Isolation Threshold = TBD 2.1 Maintainability RAM MoEs Maintainability MoPs B4 MoEs	[ref 33]	Analysis		2022.11.15
97	S1.1.3.1.2.8	PEPDS should maximize Percent Fault Isolation achieving a minimum goal of TBD.	PEPDS PFI Percent BIT Fault Isolation Goal = TBD 2.1 Maintainability RAM MoEs Maintainability MoPs B4 MoEs	[ref 33]	Analysis		2022.11.15
98	S1.1.3.1.2.9	PEPDS shall maximize Mean Operating Hours Between False Alarms achieving a minimum threshold of TBD.	PEPDS MOHBFA Mean Operating Hours between False Threshold = TBD 2.1 Maintainability RAM MoEs Maintainability MoPs B4 MoEs	[ref 33]	Analysis		2022.11.15
99	S1.1.3.1.2.10	PEPDS should maximize Mean Operating Hours Between False Alarms achieving a minimum goal of TBD.	PEPDS MOHBFA Mean Operating Hours between False Goal = TBD 2.1 Maintainability RAM MoEs Maintainability MoPs B4 MoEs	[ref 33]	Analysis		2022.11.15
100	S1.1.3.1.3 Reliability						
113	S1.1.3.2 PEPDS Operability						
185	S1.1.3.3 PEPDS Safety						
204	S1.2 Capability Requirements						

Fig. 55: S1.1.3.1.2 Maintainability

#	Name	Text	Traced To	Source	Verify Method	Risk	Revision Date
1	S1.1 PEPDS Requirements						
2	S1.1.1 PEPDS Generic Power System Requirem						
44	S1.1.2 PEPDS Innovative Requirements						
80	S1.1.3 PEPDS Performance Metrics						
81	S1.1.3.1 PEPDS RAM						
82	S1.1.3.1.1 Availability						
89	S1.1.3.1.2 Maintainability						
100	S1.1.3.1.3 Reliability						
101	S1.1.3.1.3.1	PEPDS shall maximize MTBF achieving a minimum threshold of 30,000 hours.	PEPDS MTBF Mean Time Between Failure Threshold = TBD 1.3 Reliability RAM MoEs Reliability MoPs B4 MoEs	[ref 33] [ref 35]	Analysis		2022.11.15
102	S1.1.3.1.3.2	PEPDS should maximize MTBF achieving a minimum goal of TBD.	PEPDS MTBF Mean Time Between Failure Goal = TBD 1.3 Reliability RAM MoEs Reliability MoPs B4 MoEs	[ref 33] [ref 35]	Analysis		2022.11.15
103	S1.1.3.1.3.3	PEPDS shall maximize MTBM achieving a minimum threshold of 7,000 hours.	PEPDS MTBM Mean Time Between Maintenance Threshold = TBD 1.3 Reliability RAM MoEs Reliability MoPs B4 MoEs	[ref 33]	Analysis		2022.11.15
104	S1.1.3.1.3.4	PEPDS shall maximize MTBM achieving a minimum goal of TBD.	PEPDS MTBM Goal = TBD Mean Time Between Maintenance 1.3 Reliability RAM MoEs Reliability MoPs B4 MoEs	[ref 33]	Analysis		2022.11.15
105	S1.1.3.1.3.5	PEPDS shall maximize MTBR achieving a minimum threshold of TBD.	PEPDS MTBR Mean Time Between Repairs Threshold = TBD 1.3 Reliability RAM MoEs Reliability MoPs B4 MoEs	[ref 33]	Analysis		2022.11.15
106	S1.1.3.1.3.6	PEPDS should maximize MTBR achieving a minimum goal of TBD.	PEPDS MTBR Mean Time Between Repairs Goal = TBD 1.3 Reliability RAM MoEs Reliability MoPs B4 MoEs	[ref 33]	Analysis		2022.11.15

Fig. 56: S1.1.3.1.3 Reliability Part 1

107	S1.1.3.1.3.7	PEPDS shall maximize Resiliency achieving a minimum threshold of TBD.	MTBCF PEPDS Resiliency Threshold = TBD 1.3 Reliability 1.5 Resiliency RAM MoEs Reliability MoPs B4 MoEs	[ref 33]	Analysis		2022.11.15
108	S1.1.3.1.3.8	PEPDS should maximize Resiliency achieving a minimum goal of TBD.	MTBCF PEPDS Resiliency Goal = TBD 1.3 Reliability 1.5 Resiliency RAM MoEs Reliability MoPs B4 MoEs	[ref 33]	Analysis		2022.11.15
109	S1.1.3.1.3.9	PEPDS shall maximize Power Delivery Reliability achieving a minimum threshold of TBD.	PEPDS Power Delivery Reliability Power Delivery Reliability Threshold = TBD 1.3 Reliability 1.6 UPS RAM MoEs Reliability MoPs B4 MoEs	[ref 33]	Analysis		2022.11.15
110	S1.1.3.1.3.10	PEPDS should maximize Power Delivery Reliability achieving a minimum goal of TBD.	PEPDS Power Delivery Reliability Power Delivery Reliability Goal = TBD 1.3 Reliability 1.6 UPS RAM MoEs Reliability MoPs B4 MoEs	[ref 33]	Analysis		2022.11.15
111	S1.1.3.1.3.11	PEPDS shall maximize Life Expectancy achieving a minimum threshold of TBD.	PEPDS Life Expectancy Life Expectancy Threshold = TBD 1.3 Reliability 2.4 Long Life Expectancy RAM MoEs Reliability MoPs B4 MoEs	[ref 33] [ref 37]	Analysis		2022.11.15
112	S1.1.3.1.3.12	PEPDS should maximize Life Expectancy achieving a minimum goal of TBD.	PEPDS Life Expectancy Goal = TBD Life Expectancy 1.3 Reliability 2.4 Long Life Expectancy RAM MoEs Reliability MoPs B4 MoEs	[ref 33] [ref 37]	Analysis		2022.11.15
113	S1.1.3.2 PEPDS Operability						
185	S1.1.3.3 PEPDS Safety						
204	S1.2 Capability Requirements						

Fig. 57: S1.1.3.1.3 Reliability Part 2

#	Name	Text	Traced To	Source	Verify Method	Risk	Revision Date
1	S1.1 PEPDS Requirements						
2	S1.1.1 PEPDS Generic Power System Requirem						
44	S1.1.2 PEPDS Innovative Requirements						
80	S1.1.3 PEPDS Performance Metrics						
81	S1.1.3.1 PEPDS RAM						
113	S1.1.3.2 PEPDS Operability						
114	S1.1.3.2.1 Power Distribution						
115	S1.1.3.2.1.1	PEPDS shall maximize Conversion Efficiency achieving a minimum threshold of TBD.	PEPDS Conversion Efficiency Conversion Efficiency Threshold = TBD 1.1 Power Efficiency Operability MoEs Power Distribution MoPs B4 MoEs	[ref 36]	Analysis		2022.11.15
116	S1.1.3.2.1.2	PEPDS should maximize Conversion Efficiency achieving a minimum goal of TBD.	PEPDS Conversion Efficiency Conversion Efficiency Goal = TBD 1.1 Power Efficiency Operability MoEs Power Distribution MoPs B4 MoEs	[ref 36]	Analysis		2022.11.15
117	S1.1.3.2.1.3	PEPDS shall maximize Transmission Efficiency achieving a minimum threshold of TBD.	PEPDS Transmission Efficiency Transmission Efficiency Threshold = TBD 1.1 Power Efficiency Operability MoEs Power Distribution MoPs B4 MoEs	[ref 36]	Analysis		2022.11.15
118	S1.1.3.2.1.4	PEPDS should maximize Transmission Efficiency achieving a minimum goal of TBD.	PEPDS Transmission Efficiency Transmission Efficiency Goal = TBD 1.1 Power Efficiency Operability MoEs Power Distribution MoPs B4 MoEs	[ref 36]	Analysis		2022.11.15
119	S1.1.3.2.1.5	PEPDS should maximize Power Density achieving a minimum goal of TBD.	PEPDS Power Density Power Density Goal = TBD 1.2 Power Density Operability MoEs Power Distribution MoPs B4 MoEs	[ref 36]	Analysis		2022.11.15
120	S1.1.3.2.1.6	PEPDS shall maximize Power Density achieving a minimum threshold of TBD.	PEPDS Power Density Power Density Threshold = TBD 1.2 Power Density Operability MoEs Power Distribution MoPs B4 MoEs	[ref 36]	Analysis		2022.11.15
121	S1.1.3.2.1.7	PEPDS shall maximize Power Electronic Utilization e.g. to characterize loads and sources, increase reliability, reduce response time (e.g. switching), increase reconfigurability, and enable programming achieving a minimum threshold of TBD.	PEPDS Power Electronic Utilization Power Electronic Utilization Threshold = TBD 5.3 Power Electronic Interfaces 5.15 Reduce Conventional Switchgear 5.12 Minimal Redundant Elements Operability MoEs Power Distribution MoPs B4 MoEs	[ref 50] [ref 52] [ref 58]	Analysis		2022.11.15

Fig. 58: S1.1.3.2.1 Power Distribution Part 1

122	S1.1.3.2.1.8	PEPDS should maximize Power Electronic Utilization, e.g. to characterize loads and sources, increase reliability, reduce response time (e.g. switching), increase reconfigurability, and enable programming achieving a minimum goal of TBD.	PEPDS Power Electronic Utilization Power Electronic Utilization Goal = TBD 5.3 Power Electronic Interfaces 5.15 Reduce Conventional Switchgear 5.12 Minimal Redundant Elements Operability MoEs Power Distribution MoPs B4 MoEs	[ref 50] [ref 52] [ref 58]	Analysis		2022.11.15
123	S1.1.3.2.1.9	PEPDS shall minimize Response Time achieving a maximum threshold of TBD.	Response Time PEPDS Response Time Threshold = TBD 3.3.3 Dynamic response Operability MoEs Power Distribution MoPs B4 MoEs	[ref 24]	Analysis		2022.11.15
124	S1.1.3.2.1.10	PEPDS should minimize Response Time achieving a maximum goal of TBD.	Response Time PEPDS Response Time Goal = TBD 3.3.3 Dynamic response Operability MoEs Power Distribution MoPs B4 MoEs	[ref 24]	Analysis		2022.11.15
125	S1.1.3.2.1.11	PEPDS shall achieve [TBD] threshold for Specific Energy.	PEPDS Specific Energy Specific Energy Threshold = TBD Operability MoEs Power Distribution MoPs B4 MoEs	[ref 53]	Analysis		2022.11.15
126	S1.1.3.2.1.12	PEPDS should achieve [TBD] goal for Specific Energy.	PEPDS Specific Energy Specific Energy Goal = TBD Operability MoEs Power Distribution MoPs B4 MoEs	[ref 53]	Analysis		2022.11.15
127	S1.1.3.2.1.13	PEPDS shall minimize Discharge C Rate achieving a maximum threshold of TBD.	PEPDS Discharge C Rate Discharge C Rate Threshold = TBD Operability MoEs Power Distribution MoPs B4 MoEs	[ref 53]	Analysis		2022.11.15
128	S1.1.3.2.1.14	PEPDS should minimize Discharge C Rate achieving a maximum goal of TBD.	PEPDS Discharge C Rate Discharge C Rate Goal = TBD Operability MoEs Power Distribution MoPs B4 MoEs	[ref 53]	Analysis		2022.11.15
129	S1.1.3.2.1.15	PEPDS shall minimize Recharge C Rate achieving a maximum threshold of TBD.	PEPDS Recharge C Rate Recharge C Rate Threshold = TBD Operability MoEs Power Distribution MoPs B4 MoEs	[ref 53]	Analysis		2022.11.15
130	S1.1.3.2.1.16	PEPDS should minimize Recharge C Rate achieving a maximum goal of TBD.	PEPDS Recharge C Rate Recharge C Rate Goal = TBD Operability MoEs Power Distribution MoPs B4 MoEs	[ref 53]	Analysis		2022.11.15
131	S1.1.3.2.2 Adaptability						
142	S1.1.3.2.3 Logistics						
159	S1.1.3.2.4 Affordability						
168	S1.1.3.2.5 Quality of Service						
185	S1.1.3.3 PEPDS Safety						
204	S1.2 Capability Requirements						

Fig. 59: S1.1.3.2.1 Power Distribution Part 2

#	Name	Text	Traced To	Source	Verify Method	Risk	Revision Date
1	S1.1 PEPDS Requirements						
2	S1.1.1 PEPDS Generic Power System Requirem						
44	S1.1.2 PEPDS Innovative Requirements						
80	S1.1.3 PEPDS Performance Metrics						
81	S1.1.3.1 PEPDS RAM						
113	S1.1.3.2 PEPDS Operability						
114	S1.1.3.2.1 Power Distribution						
131	S1.1.3.2.2 Adaptability						
132	S1.1.3.2.2.1	PEPDS shall maximize Robustness achieving a minimum threshold of TBD.	Robustness PEPDS Robustness Threshold = TBD 1.4 Robustness Operability MoEs Adaptability MoPs B4 MoEs	[ref 36]	Analysis		2022.11.15
133	S1.1.3.2.2.2	PEPDS should maximize Robustness achieving a minimum goal of TBD	Robustness PEPDS Robustness Goal = TBD 1.4 Robustness Operability MoEs Adaptability MoPs B4 MoEs	[ref 36]	Analysis		2022.11.15
134	S1.1.3.2.2.3	PEPDS shall maximize Application Adaptability achieving a minimum threshold of TBD.	PEPDS Application Adaptability Application Adaptability Threshold = TBD 3.6 Hotswappable 5.6 Functional Control 5.7 Adaptive Controls Operability MoEs Adaptability MoPs B4 MoEs	[ref 50] [ref 58]	Analysis		2022.11.15
135	S1.1.3.2.2.4	PEPDS should maximize Application Adaptability achieving a minimum goal of TBD.	PEPDS Application Adaptability Application Adaptability Goal = TBD 3.6 Hotswappable 5.6 Functional Control 5.7 Adaptive Controls Operability MoEs Adaptability MoPs B4 MoEs	[ref 50] [ref 58]	Analysis		2022.11.15
136	S1.1.3.2.2.5	PEPDS shall maximize the number of Applicable Ship Classes for which it is suitable achieving a minimum threshold of TBD.	PEPDS Applicable Ship Classes Applicable Ship Classes Threshold = TBD 3.4 Standardizable Operability MoEs Adaptability MoPs B4 MoEs	[ref 36]	Analysis		2022.11.15
137	S1.1.3.2.2.6	PEPDS should maximize the number of Applicable Ship Classes for which it is suitable achieving a minimum goal of TBD.	PEPDS Applicable Ship Classes Applicable Ship Classes Goal = TBD 3.4 Standardizable Operability MoEs Adaptability MoPs B4 MoEs	[ref 36]	Analysis		2022.11.15
138	S1.1.3.2.2.7	PEPDS shall maximize Scalability achieving a minimum threshold of TBD.	PEPDS Scalability Scalability Threshold = TBD 3 Scalability Operability MoEs Adaptability MoPs B4 MoEs	[ref 24]	Analysis		2022.11.15
139	S1.1.3.2.2.8	PEPDS should maximize Scalability achieving a minimum goal of TBD.	PEPDS Scalability Scalability Goal = TBD 3 Scalability Operability MoEs Adaptability MoPs B4 MoEs	[ref 24]	Analysis		2022.11.15
140	S1.1.3.2.2.9	PEPDS shall maximize Survivability achieving a minimum threshold of TBD. (e.g., managing casualty power).	PEPDS Survivability Survivability Threshold = TBD Operability MoEs Adaptability MoPs B4 MoEs	[ref 44]	Analysis		2022.11.15
141	S1.1.3.2.2.10	PEPDS should maximize Survivability achieving a minimum goal of TBD. (e.g., managing casualty power).	Survivability Goal = TBD PEPDS Survivability Operability MoEs Adaptability MoPs B4 MoEs	[ref 44]	Analysis		2022.11.15
142	S1.1.3.2.3 Logistics						
159	S1.1.3.2.4 Affordability						
168	S1.1.3.2.5 Quality of Service						
185	S1.1.3.3 PEPDS Safety						
204	S1.2 Capability Requirements						

Fig. 60: S1.1.3.2.2 Adaptability

#	Name	Text	Traced To	Source	Verify Method	Risk	Revision Date
1	S1.1 PEPDS Requirements						
2	S1.1.1 PEPDS Generic Power System Requirem						
44	S1.1.2 PEPDS Innovative Requirements						
80	S1.1.3 PEPDS Performance Metrics						
81	S1.1.3.1 PEPDS RAM						
113	S1.1.3.2 PEPDS Operability						
114	S1.1.3.2.1 Power Distribution						
131	S1.1.3.2.2 Adaptability						
142	S1.1.3.2.3 Logistics						
143	S1.1.3.2.3.1	PEPDS shall minimize LMS Manning achieving a maximum threshold of TBD.	PEPDS LMS Manning LMS Manning Threshold = TBD 2 Operability 5.11 Simplified LRU Replacement Operability MoEs Logistics MoPs B4 MoEs	[ref 38]	Analysis		2022.11.15
144	S1.1.3.2.3.2	PEPDS should minimize LMS Manning achieving a maximum goal of TBD.	PEPDS LMS Manning LMS Manning Goal = TBD 2 Operability 5.11 Simplified LRU Replacement Operability MoEs Logistics MoPs B4 MoEs	[ref 38]	Analysis		2022.11.15
145	S1.1.3.2.3.3	PEPDS shall minimize LMS Training achieving a maximum threshold of TBD.	PEPDS LMS Training LMS Training Threshold = TBD 2 Operability 2.2 Operator Trainability 5.11 Simplified LRU Replacement Operability MoEs Logistics MoPs B4 MoEs	[ref 38]	Analysis		2022.11.15
146	S1.1.3.2.3.4	PEPDS should minimize LMS Training achieving a maximum goal of TBD.	PEPDS LMS Training LMS Training Goal = TBD 2 Operability 2.2 Operator Trainability 5.11 Simplified LRU Replacement Operability MoEs Logistics MoPs B4 MoEs	[ref 38]	Analysis		2022.11.15
147	S1.1.3.2.3.5	PEPDS shall minimize Operator Manning achieving a maximum threshold of TBD.	PEPDS Operation Manning Operation Manning Threshold = TBD 2 Operability 5.11 Simplified LRU Replacement Operability MoEs Logistics MoPs B4 MoEs	[ref 36]	Analysis		2022.11.15
148	S1.1.3.2.3.6	PEPDS should minimize Operator Manning achieving a maximum goal of TBD.	PEPDS Operation Manning Operation Manning Goal = TBD 2 Operability 5.11 Simplified LRU Replacement Operability MoEs Logistics MoPs B4 MoEs	[ref 36]	Analysis		2022.11.15
149	S1.1.3.2.3.7	PEPDS shall minimize Operator Training achieving a maximum threshold of TBD.	PEPDS Operator Training Operator Training Threshold = TBD 2 Operability 2.2 Operator Trainability 5.11 Simplified LRU Replacement Operability MoEs Logistics MoPs B4 MoEs	[ref 36]	Analysis		2022.11.15
150	S1.1.3.2.3.8	PEPDS should minimize Operator Training achieving a maximum goal of TBD.	PEPDS Operator Training Operator Training Goal = TBD 2 Operability 2.2 Operator Trainability 5.11 Simplified LRU Replacement Operability MoEs Logistics MoPs B4 MoEs	[ref 36]	Analysis		2022.11.15

Fig. 61: S1.1.3.2.3 Logistics Part 1

151	S1.1.3.2.3.9	PEPDS shall minimize Cost for Support achieving a maximum threshold of TBD.	PEPDS Cost for Support Cost for Support Threshold = TBD 2 Operability Operability MoEs Logistics MoPs B4 MoEs	[ref 38]	Analysis		2022.11.15
152	S1.1.3.2.3.10	PEPDS should minimize Cost for Support achieving a maximum goal of TBD.	PEPDS Cost for Support Cost for Support Goal = TBD 2 Operability Operability MoEs Logistics MoPs B4 MoEs	[ref 38]	Analysis		2022.11.15
153	S1.1.3.2.3.11	PEPDS shall maximize Effectiveness of Support Capability achieving a minimum threshold of TBD.	PEPDS Effectiveness of Support Capability Effectiveness of Support Capability Threshold = TBD 2 Operability Operability MoEs Logistics MoPs B4 MoEs	[ref 38]	Analysis		2022.11.15
154	S1.1.3.2.3.12	PEPDS should maximize Effectiveness of Support Capability achieving a minimum goal of TBD.	PEPDS Effectiveness of Support Capability Effectiveness of Support Capability Goal = TBD 2 Operability Operability MoEs Logistics MoPs B4 MoEs	[ref 38]	Analysis		2022.11.15
155	S1.1.3.2.3.13	PEPDS shall minimize its Installation Time achieving a maximum threshold of TBD.	PEPDS Installation Time Installation Time Threshold = TBD 2 Operability 5.1 Ease of Installation as a Unit Operability MoEs Logistics MoPs B4 MoEs	[ref 44]	Analysis		2022.11.15
156	S1.1.3.2.3.14	PEPDS should minimize its Installation Time achieving a maximum goal of TBD.	Installation Time Goal = TBD PEPDS Installation Time 2 Operability 5.1 Ease of Installation as a Unit Operability MoEs Logistics MoPs B4 MoEs	[ref 44]	Analysis		2022.11.15
157	S1.1.3.2.3.15	PEPDS shall minimize its Removal Time achieving a maximum threshold of TBD.	PEPDS Removal Time Removal Time Threshold = TBD 2 Operability 5.1 Ease of Installation as a Unit Operability MoEs Logistics MoPs B4 MoEs	[ref 44]	Analysis		2022.11.15
158	S1.1.3.2.3.16	PEPDS should minimize its Removal Time achieving a maximum goal of TBD.	Removal Time Goal = TBD PEPDS Removal Time 2 Operability 5.1 Ease of Installation as a Unit Operability MoEs Logistics MoPs B4 MoEs	[ref 44]	Analysis		2022.11.15
159	S1.1.3.2.4 Affordability						
168	S1.1.3.2.5 Quality of Service						
185	S1.1.3.3 PEPDS Safety						
204	S1.2 Capability Requirements						

Fig. 62: S1.1.3.2.3 Logistics Part 2

#	Name	Text	Traced To	Source	Verify Method	Risk	Revision Date
1	S1.1 PEPDS Requirements						
2	S1.1.1 PEPDS Generic Power System Requirem						
44	S1.1.2 PEPDS Innovative Requirements						
80	S1.1.3 PEPDS Performance Metrics						
81	S1.1.3.1 PEPDS RAM						
113	S1.1.3.2 PEPDS Operability						
114	S1.1.3.2.1 Power Distribution						
131	S1.1.3.2.2 Adaptability						
142	S1.1.3.2.3 Logistics						
159	S1.1.3.2.4 Affordability						
160	S1.1.3.2.4.1	PEPDS shall minimize Operation Cost achieving a maximum threshold of TBD.	PEPDS Operation Cost Operation Cost Threshold = TBD 3.5 Affordability Operability MoEs Affordability MoPs B4 MoEs	[ref 36]	Analysis		2022.11.15
161	S1.1.3.2.4.2	PEPDS should minimize Operation Cost achieving a maximum goal of TBD.	PEPDS Operation Cost Operation Cost Goal = TBD 3.5 Affordability Operability MoEs Affordability MoPs B4 MoEs	[ref 36]	Analysis		2022.11.15
162	S1.1.3.2.4.3	PEPDS shall minimize Implementation Cost achieving a maximum threshold of TBD.	PEPDS Implementation Cost Implementation Cost Threshold = TBD 3.5 Affordability Operability MoEs Affordability MoPs B4 MoEs	[ref 36]	Analysis		2022.11.15
163	S1.1.3.2.4.4	PEPDS should minimize Implementation Cost achieving a maximum goal of TBD.	PEPDS Implementation Cost Implementation Cost Goal = TBD 3.5 Affordability Operability MoEs Affordability MoPs B4 MoEs	[ref 36]	Analysis		2022.11.15
164	S1.1.3.2.4.5	PEPDS shall minimize Installation Cost achieving a maximum threshold of TBD.	PEPDS Installation Cost Installation Cost Threshold = TBD 3.5 Affordability 5.1 Ease of Installation as a Unit Operability MoEs Affordability MoPs B4 MoEs	[ref 44] [ref 50]	Analysis		2022.11.15
165	S1.1.3.2.4.6	PEPDS should minimize Installation Cost achieving a maximum goal of TBD.	Installation Cost Goal = TBD PEPDS Installation Cost 3.5 Affordability 5.1 Ease of Installation as a Unit Operability MoEs Affordability MoPs B4 MoEs	[ref 44] [ref 50]	Analysis		2022.11.15
166	S1.1.3.2.4.7	PEPDS shall minimize Removal Cost achieving a maximum threshold of TBD.	PEPDS Removal Cost Threshold = TBD Removal Cost 3.5 Affordability 5.1 Ease of Installation as a Unit Operability MoEs Affordability MoPs B4 MoEs	[ref 44] [ref 50]	Analysis		2022.11.15
167	S1.1.3.2.4.8	PEPDS should minimize Removal Cost achieving a maximum goal of TBD.	Removal Cost Goal = TBD PEPDS Removal Cost 3.5 Affordability 5.1 Ease of Installation as a Unit Operability MoEs Affordability MoPs B4 MoEs	[ref 44] [ref 50]	Analysis		2022.11.15
168	S1.1.3.2.5 Quality of Service						
185	S1.1.3.3 PEPDS Safety						
204	S1.2 Capability Requirements						

Fig. 63: S1.1.3.2.4 Affordability

#	Name	Text	Traced To	Source	Verify Method	Risk	Revision Date
1	S1.1 PEPDS Requirements						
2	S1.1.1 PEPDS Generic Power System Requirem						
44	S1.1.2 PEPDS Innovative Requirements						
80	S1.1.3 PEPDS Performance Metrics						
81	S1.1.3.1 PEPDS RAM						
113	S1.1.3.2 PEPDS Operability						
114	S1.1.3.2.1 Power Distribution						
131	S1.1.3.2.2 Adaptability						
142	S1.1.3.2.3 Logistics						
159	S1.1.3.2.4 Affordability						
168	S1.1.3.2.5 Quality of Service						
169	S1.1.3.2.5.1	PEPDS shall minimize Mean Time to Resolve Service Interruption achieving a maximum threshold of TBD.	Mean Time to Resolve Service Interru Threshold = TBD PEPDS Mean Time to Reslove Service Interru Operability MoEs Quality of Service MoPs B4 MoEs	[ref 39]	Analysis		2022.11.15
170	S1.1.3.2.5.2	PEPDS should minimize Mean Time to Resolve Service Interruption achieving a maximum goal of TBD.	Mean Time to Resolve Service Interru Goal = TBD PEPDS Mean Time to Reslove Service Interru Operability MoEs Quality of Service MoPs B4 MoEs	[ref 39]	Analysis		2022.11.15
171	S1.1.3.2.5.3	PEPDS shall minimize Mean Time to Resolve Service Interruption for Un-Interruptible Load achieving a maximum threshold of 2 sec.	Mean Time to Resolve Service Interru Threshold = 2 sec PEPDS Mean Time to Reslove Service Interru Operability MoEs Quality of Service MoPs B4 MoEs	[ref 39]	Analysis		2022.11.15
172	S1.1.3.2.5.4	PEPDS should minimize Mean Time to Resolve Service Interruption for Un-Interruptible Load achieving a maximum goal of 10msec.	Mean Time to Resolve Service Interru Goal = 10 msec PEPDS Mean Time to Reslove Service Interru Operability MoEs Quality of Service MoPs B4 MoEs	[ref 39]	Analysis		2022.11.15
173	S1.1.3.2.5.5	PEPDS shall minimize Mean Time to Resolve Service Interruption for Short Term Interrupt Load achieving a maximum threshold of 5 min.	Mean Time to Resolve Service Interru Threshold = 5 min PEPDS Mean Time to Resolve Service Interru Operability MoEs Quality of Service MoPs B4 MoEs	[ref 39]	Analysis		2022.11.15
174	S1.1.3.2.5.6	PEPDS should minimize Mean Time to Resolve Service Interruption for Short Term Interrupt Load achieving a maximum goal of 2 sec.	Mean Time to Resolve Service Interru Goal = 2 sec PEPDS Mean Time to Resolve Service Interru Operability MoEs Quality of Service MoPs B4 MoEs	[ref 39]	Analysis		2022.11.15
175	S1.1.3.2.5.7	PEPDS shall minimize Mean Time to Resolve Service Interruption for Long Term Interrupt Load achieving a maximum threshold of TBD.	Mean Time to Resolve Service Interru Threshold = TBD PEPDS Mean Time to Resolve Service Interru Operability MoEs Quality of Service MoPs B4 MoEs	[ref 39]	Analysis		2022.11.15

Fig. 64: S1.1.3.2.5 Quality of Service Part 1

176	S1.1.3.2.5.8	PEPDS should minimize Mean Time to Resolve Service Interruption for Long Term Interrupt Load achieving a maximum goal of 5 min.	Mean Time to Resolve Service Interru Goal = 5 min PEPDS Mean Time to Resolve Service Interru Operability MoEs Quality of Service MoPs B4 MoEs	[ref 39]	Analysis		2022.11.15
177	S1.1.3.2.5.9	PEPDS shall maximize Survival Service Time achieving a minimum threshold of TBD.	Survival Service Time Threshold = TBD PEPDS Survival Service Time Operability MoEs Quality of Service MoPs B4 MoEs	[ref 39]	Analysis		2022.11.15
178	S1.1.3.2.5.10	PEPDS should maximize Survival Service Time achieving a minimum goal of TBD.	Survival Service Time Goal = TBD PEPDS Survival Service Time Operability MoEs Quality of Service MoPs B4 MoEs	[ref 39]	Analysis		2022.11.15
179	S1.1.3.2.5.11	PEPDS shall maximize Survival Service Time for Un-Interruptible Load achieving a minimum threshold of TBD.	Survival Service Time for Un-Interrupt Threshold = TBD PEPDS Survival Service Time for Un-Interrupt Operability MoEs Quality of Service MoPs B4 MoEs	[ref 39]	Analysis		2022.11.15
180	S1.1.3.2.5.12	PEPDS should maximize Survival Service Time for Un-Interruptible Load achieving a minimum goal of TBD.	Survival Service Time for Un-Interrupt Goal = TBD PEPDS Survival Service Time for Un-Interrupt Operability MoEs Quality of Service MoPs B4 MoEs	[ref 39]	Analysis		2022.11.15
181	S1.1.3.2.5.13	PEPDS shall maximize Survival Service Time for Short Term Load achieving a minimum threshold of TBD.	Survival Service Time for Short Term I Threshold = TBD PEPDS Survival Service Time for Short Term I Operability MoEs Quality of Service MoPs B4 MoEs	[ref 39]	Analysis		2022.11.15
182	S1.1.3.2.5.14	PEPDS should maximize Survival Service Time for Short Term Load achieving a minimum goal of TBD.	Goal = TBD PEPDS Survival Service Time for Short Term I Survival Service Time for Short Term I Operability MoEs Quality of Service MoPs B4 MoEs	[ref 39]	Analysis		2022.11.15
183	S1.1.3.2.5.15	PEPDS shall maximize Survival Service Time for Long Term Load achieving a minimum threshold of TBD.	Survival Service Time for Long Term Ir Threshold = TBD PEPDS Survival Service Time for Long Term Ir Operability MoEs Quality of Service MoPs B4 MoEs	[ref 39]	Analysis		2022.11.15
184	S1.1.3.2.5.16	PEPDS should maximize Survival Service Time for Long Term Load achieving a minimum goal of TBD.	Survival Service Time for Long Term Ir Goal = TBD PEPDS Survival Service Time for Long Term Ir Operability MoEs Quality of Service MoPs B4 MoEs	[ref 39]	Analysis		2022.11.15
185	S1.1.3.3 PEPDS Safety						
204	S1.2 Capability Requirements						

Fig. 65: S1.1.3.2.5 Quality of Service Part 2

#	Name	Text	Traced To	Source	Verify Method	Risk	Revision Date
1	S1.1 PEPDS Requirements						
2	S1.1.1 PEPDS Generic Power System Requirem						
44	S1.1.2 PEPDS Innovative Requirements						
80	S1.1.3 PEPDS Performance Metrics						
81	S1.1.3.1 PEPDS RAM						
113	S1.1.3.2 PEPDS Operability						
185	S1.1.3.3 PEPDS Safety						
186	S1.1.3.3.1 Personnel Safety						
187	S1.1.3.3.1.1	PEPDS shall minimize LRU s Liftability achieving a maximum threshold of TBD.	PEPDS LRU s Liftability LRU s Liftability Threshold = TBD 2.3 Safety 2.3.2 Liftable 5.11 Simplified LRU Replacement LRUs Crew Safety MoEs Personnel Safety MoPs B4 MoEs	[ref 50]	Analysis		2022.11.15
188	S1.1.3.3.1.2	PEPDS should minimize LRU s Liftability achieving a maximum goal of TBD.	PEPDS LRU s Liftability LRU s Liftability Goal = TBD 2.3 Safety 2.3.2 Liftable 5.11 Simplified LRU Replacement Crew LRUs Safety MoEs Personnel Safety MoPs B4 MoEs	[ref 50]	Analysis		2022.11.15
189	S1.1.3.3.1.3	PEPDS shall maximize LRU s Transportability achieving a minimum threshold of TBD.	PEPDS LRU s Transportability LRU s Transportability Threshold = TBD 2.3 Safety 2.3.2 Liftable 5.11 Simplified LRU Replacement Crew LRUs Safety MoEs Personnel Safety MoPs B4 MoEs	[ref 50]	Analysis		2022.11.15
190	S1.1.3.3.1.4	PEPDS should maximize LRU s Transportability achieving a minimum goal of TBD.	PEPDS LRU s Transportability LRU s Transportability Goal = TBD 2.3 Safety 2.3.2 Liftable 5.11 Simplified LRU Replacement Crew LRUs Safety MoEs Personnel Safety MoPs B4 MoEs	[ref 50]	Analysis		2022.11.15
191	S1.1.3.3.1.5	PEPDS shall maximize Thermal Safety achieving a minimum threshold of TBD.	PEPDS Thermal Safety Thermal Safety Threshold = TBD 3.1 Serial Thermal Management 2.3.1 Thermally Touchable 2.3 Safety Safety MoEs Personnel Safety MoPs B4 MoEs	[ref 24]	Analysis		2022.11.15
192	S1.1.3.3.1.6	PEPDS should maximize Thermal Safety achieving a minimum goal of TBD.	PEPDS Thermal Safety Thermal Safety Goal = TBD 3.1 Serial Thermal Management 2.3.1 Thermally Touchable 2.3 Safety Safety MoEs Personnel Safety MoPs B4 MoEs	[ref 24]	Analysis		2022.11.15
193	S1.1.3.3.1.7	PEPDS shall maximize Electrical Safety achieving a minimum threshold of TBD.	PEPDS Electrical Safety Electrical Safety Threshold = TBD 2.3.3 Electrically Insulated 2.3 Safety Safety MoEs Personnel Safety MoPs B4 MoEs	[ref 36]	Analysis		2022.11.15
194	S1.1.3.3.1.8	PEPDS should maximize Electrical Safety achieving a minimum goal of TBD.	PEPDS Electrical Safety Electrical Safety Goal = TBD 2.3.3 Electrically Insulated 2.3 Safety Safety MoEs Personnel Safety MoPs B4 MoEs	[ref 36]	Analysis		2022.11.15
195	S1.1.3.3.2 System Safety						
204	S1.2 Capability Requirements						

Fig. 66: S1.1.3.3.1 Personnel Safety

#	Name	Text	Traced To	Source	Verify Method	Risk	Revision Date
1	S1.1 PEPDS Requirements						
2	S1.1.1 PEPDS Generic Power System Requirem						
44	S1.1.2 PEPDS Innovative Requirements						
80	S1.1.3 PEPDS Performance Metrics						
81	S1.1.3.1 PEPDS RAM						
113	S1.1.3.2 PEPDS Operability						
185	S1.1.3.3 PEPDS Safety						
186	S1.1.3.3.1 Personnel Safety						
195	S1.1.3.3.2 System Safety						
196	S1.1.3.3.2.1	PEPDS shall maximize Tolerance to Environmental Loads achieving a minimum threshold of TBD.	PEPDS Tolerance to Environmental Loads Tolerance to Environmental Loads Threshold = TBD 3.1 Serial Thermal Management Safety MoEs System Safety MoPs B4 MoEs	[ref 24]	Analysis		2022.11.15
197	S1.1.3.3.2.2	PEPDS should maximize Tolerance to Environmental Loads achieving a minimum goal of TBD.	PEPDS Tolerance to Environmental Loads Tolerance to Environmental Loads Goal = TBD 3.1 Serial Thermal Management Safety MoEs System Safety MoPs B4 MoEs	[ref 24]	Analysis		2022.11.15
198	S1.1.3.3.2.3	PEPDS shall minimize Mean Time to Detect Cybersecurity Intrusion achieving a maximum threshold of TBD.	Mean Time to Detect Cybersecurity Ir Threshold = TBD PEPDS CyberMTTD 3.3.2 Cyber Security 5.8 Automated Self-check Safety MoEs System Safety MoPs B4 MoEs	[ref 50]	Analysis		2022.11.15
199	S1.1.3.3.2.4	PEPDS should minimize Mean Time to Detect Cybersecurity Intrusion achieving a maximum goal of TBD.	Mean Time to Detect Cybersecurity Ir Goal = TBD PEPDS CyberMTTD 3.3.2 Cyber Security 5.8 Automated Self-check Safety MoEs System Safety MoPs B4 MoEs	[ref 50]	Analysis		2022.11.15
200	S1.1.3.3.2.5	PEPDS shall minimize Mean Time to Resolve Cybersecurity Intrusion achieving a maximum threshold of TBD.	Mean Time to Resolve Cybersecurity I Threshold = TBD PEPDS CyberMTTR 3.3.2 Cyber Security Safety MoEs System Safety MoPs B4 MoEs	[ref 24]	Analysis		2022.11.15
201	S1.1.3.3.2.6	PEPDS should minimize Mean Time to Resolve Cybersecurity Intrusion achieving a maximum goal of TBD.	Mean Time to Resolve Cybersecurity I Goal = TBD PEPDS CyberMTTR 3.3.2 Cyber Security Safety MoEs System Safety MoPs B4 MoEs	[ref 24]	Analysis		2022.11.15
202	S1.1.3.3.2.7	PEPDS shall minimize Mean Time to Contain Cybersecurity Intrusion achieving a maximum threshold of TBD.	Mean Time to Contain Cybersecurity I Threshold = TBD PEPDS CyberMTTC 3.3.2 Cyber Security Safety MoEs System Safety MoPs B4 MoEs	[ref 24]	Analysis		2022.11.15
203	S1.1.3.3.2.8	PEPDS should minimize Mean Time to Contain Cybersecurity Intrusion achieving a maximum goal of TBD.	Mean Time to Contain Cybersecurity I Goal = TBD PEPDS CyberMTTC 3.3.2 Cyber Security Safety MoEs System Safety MoPs B4 MoEs	[ref 24]	Analysis		2022.11.15
204	S1.2 Capability Requirements						

Fig. 67: S1.1.3.3.2 System Safety

#	Name	Text	Traced To	Source	Verify Method	Risk	Revision Date
1	S1.1 PEPDS Requirements						
204	S1.2 Capability Requirements						
205	S1.2.1 Control Capability Requirements						
206	S1.2.1.1 Control Capability Generic Require						
207	S1.2.1.1.1	The Control Capability shall control capabilities through Commands based on the Control Strategy.	Control Capability Commands Control Strategy W2.1.2 Control PEPDS Capabilities W2.1 Control PEPDS Map Control Strategy onto PEPDS Act Issue Prioritized Commands	[ref 52]	Analysis		2022.11.15
208	S1.2.1.1.2	The Control Capability shall send Feedback with PEPDS status to Ship Control and the Crew.	PEPDS Control Capability Ship Control Crew Feedback W2.1.1 Control Information W2.1 Control PEPDS Report on PEPDS	[ref 52]	Analysis		2022.11.15
209	S1.2.1.1.3	PEPDS Feedback shall provide a projection of intended automatic choices to the Crew.	PEPDS Crew Feedback W2.1 Control PEPDS W2.1.1 Control Information Report on PEPDS	[ref 52] [ref 54]	Analysis		2022.11.15
210	S1.2.1.2 Control Capability Innovative Req						
211	S1.2.1.2.1	The Control Capability's course of action shall be any independent or coordinated use of PEPDS Capabilities.	Control Capability PEPDS 5.5 Integrated Control Determine Course of Action W2.1.1 Control Information W2.1.2 Control PEPDS Capabilities W2.1 Control PEPDS	[ref 48], [ref 47]	Analysis		2022.11.15
212	S1.2.1.2.2	The Control Capability shall Issue Prioritized Commands to the capabilities.	Control Capability Commands Issue Prioritized Commands W2.1.2 Control PEPDS Capabilities 5.5 Integrated Control W2.1 Control PEPDS	[ref 50] [ref 52]	Analysis		2022.11.15
213	S1.2.1.2.3	The Control Capability shall analyze capability needs based on capability Feedback to Determine Course of Action.	Control Capability Analyze Capability Needs Determine Course of Action W2.1.1 Control Information 5.7 Adaptive Controls Feedback W2.1 Control PEPDS	[ref 52]	Analysis		2022.11.15
214	S1.2.1.2.4	The Control Capability shall Determine Course of Action based on the Control Strategy, Commands from Ship Control and Crew, analysis of capability needs, power source supply, and power load demand.	Control Strategy Control Capability PEPDS Determine Course of Action W2.1.1 Control Information 5.7 Adaptive Controls Feedback Commands Analyze Capability Needs Analyze Power Load Demands Analyze Power Source Supply Crew Ship Control Offboard Power Systems Onboard Power Loads Onboard Power Sources W2.1 Control PEPDS	[ref 52]	Analysis		2022.11.15
215	S1.2.1.2.5	The Control Capability shall update the Control Strategy based on Crew Commands, Ship Control Commands, analyzing Capability Needs, power source supply, and power load demand.	Control Capability Control Strategy Analyze Capability Needs 5.7 Adaptive Controls Update Control Strategy Crew Ship Control Commands W2.1 Control PEPDS W2.1.1 Control Information Analyze Power Load Demands Analyze Power Source Supply Offboard Power Systems Onboard Power Loads Onboard Power Sources	[ref 52] [ref 58]	Analysis		2022.11.15
216	S1.2.1.2.6	The Control Capability shall analyze power load needs based on power load Characterization and the Control Strategy.	Control Capability Characterization Control Strategy W2.1.1 Control Information 5.7 Adaptive Controls Analyze Power Load Demands W2.1 Control PEPDS	[ref 52] [ref 58]	Analysis		2022.11.15
217	S1.2.1.2.7	The Control Capability shall ensure system stability during normal operations while meeting all demands for Electrical Power.	Electrical Power Control Capability 5.7 Adaptive Controls W2.1 Control PEPDS Electric Systems	[ref 51]	Analysis		2022.11.15
218	S1.2.1.2.8	The Control Capability shall direct PEPDS operations to ensure system stability by accommodating pulse loads.	PEPDS Control Capability 5.7 Adaptive Controls W2.1 Control PEPDS Onboard Power Loads Offboard Power Systems	[ref 51]	Analysis		2022.11.15
219	S1.2.1.2.9	The Control Capability shall direct PEPDS operations to ensure system stability by accommodating mismatched loads.	PEPDS Control Capability 5.7 Adaptive Controls W2.1 Control PEPDS Onboard Power Loads Offboard Power Systems	[ref 51]	Analysis		2022.11.15
220	S1.2.1.2.10	The Control Capability shall direct PEPDS operations to ensure system stability by accommodating stochastic loads.	PEPDS Control Capability 5.7 Adaptive Controls W2.1 Control PEPDS Onboard Power Loads Offboard Power Systems	[ref 51]	Analysis		2022.11.15

Fig. 68: S1.2.1 Control Capability Requirements Part 1

221	S1.2.1.2.11	The Control Capability shall direct PEPDS operations to ensure system stability by accommodating large loads.	PEPDS Control Capability 5.7 Adaptive Controls W2.1 Control PEPDS Onboard Power Loads Offboard Power Systems	[ref 51]	Analysis		2022.11.15
222	S1.2.1.2.12	The Control Capability shall direct PEPDS operations to ensure system stability while servicing and shedding loads.	Control Capability PEPDS Command Service Loads W2.1 Control PEPDS W2.1.2 Control PEPDS Capabilities 5.7 Adaptive Controls 5.2 Load Interface Design Command Shed Loads Onboard Power Loads Offboard Power Systems	[ref 52]	Analysis		2022.11.15
223	S1.2.1.2.13	The Control Capability shall direct PEPDS operations to ensure system stability while accessing and de-accessing sources.	Control Capability PEPDS W2.1.2 Control PEPDS Capabilities 5.7 Adaptive Controls Onboard Power Sources Offboard Power Systems W2.1 Control PEPDS Command Access Source Power Command De-access Source Power	[ref 52]	Analysis		2022.11.15
224	S1.2.1.2.14	The Control Capability shall direct PEPDS operations to ensure system stability by accommodating mismatched sources.	Control Capability PEPDS 5.7 Adaptive Controls W2.1 Control PEPDS Onboard Power Sources Offboard Power Systems	[ref 51]	Analysis		2022.11.15
225	S1.2.1.2.15	The Control Capability shall direct PEPDS operations to ensure system stability by accommodating startup surge power.	PEPDS Control Capability 5.7 Adaptive Controls Electrical Power Onboard Power Sources Offboard Power Systems W2.1 Control PEPDS	[ref 51]	Analysis		2022.11.15
226	S1.2.1.2.16	The Control Capability shall direct PEPDS operations to ensure system stability according to priorities from an assessment of PEPDS state and Crew Commands.	Control Capability PEPDS Feedback 5.7 Adaptive Controls Commands Crew	[ref 51]	Analysis		2022.11.15
227	S1.2.1.2.17	The Control Capability shall be able to Program Communication Networks.	Control Capability W2.1 Control PEPDS W2.1.1 Control Information 5.6 Functional Control Program Communication Networks	[ref 50]	Analysis		2022.11.15
228	S1.2.1.2.18	The Control Capability shall be able to Program Power Networks.	Control Capability W2.1 Control PEPDS W2.1.1 Control Information 5.6 Functional Control Program Power Networks	[ref 50]	Analysis		2022.11.15
229	S1.2.1.2.19	The Control Capability shall be able to Program PEPDS components.	Control Capability W2.1 Control PEPDS W2.1.1 Control Information 5.6 Functional Control Program PEPDS Components	[ref 50]	Analysis		2022.11.15
230	S1.2.1.2.20	The Control Capability shall provide an assessment of the impact of programming communication networks, power networks, and PEPDS components based on the Control Strategy in its Feedback.	Control Capability Control Strategy PEPDS Feedback W2.1 Control PEPDS W2.1.1 Control Information 5.6 Functional Control 5.8 Automated Self-check Assess Impact Program Communication Networks Program Power Networks Program PEPDS Components	[ref 50]	Analysis		2022.11.15
231	S1.2.1.2.21	The Control Capability shall Capture and Store Data to be used in analysis for CBM+.	Control Capability W2.1.1 Control Information 5.9 Integrated CBM+ W2.1 Control PEPDS Capture Data Store Data	[ref 48], [ref 47]	Analysis		2022.11.15
232	S1.2.1.2.22	The Control Capability shall Transmit Data to support external CBM+ activities.	Control Capability W2.1.1 Control Information 5.9 Integrated CBM+ W2.1 Control PEPDS Transmit Data	[ref 48], [ref 47]	Analysis		2022.11.15
233	S1.2.1.2.23	The Control Capability shall Perform CBM+ analysis as instructed by the Control Strategy.	Control Capability W2.1 Control PEPDS Control Strategy W2.1.1 Control Information 5.9 Integrated CBM+ Perform CBM+ Analysis	[ref 48], [ref 47]	Analysis		2022.11.15
234	S1.2.1.2.24	The Control Capability shall implement change to the Maintenance Strategy based on data analysis, Ship Control Maintenance Strategy, and PEPDS Control Strategy.	Control Capability W2.1 Control PEPDS Ship Control PEPDS W2.1.1 Control Information 5.9 Integrated CBM+ Control Strategy Perform CBM+ Analysis Commands	[ref 48], [ref 47]	Analysis		2022.11.15
235	S1.2.1.2.25	The Control Capability shall execute self-learning by tracking and improving based on the Control Capability operations, Control Strategy, Feedback from PEPDS capabilities and Commands form Crew and Ship Control.	Control Capability Control Strategy PEPDS W2.1.1 Control Information 5.4 Self Learning 5.9 Integrated CBM+ W2.1 Control PEPDS Track and Improve Commands Feedback Crew Ship Control	[ref 48], [ref 47]	Analysis		2022.11.15
236	S1.2.1.2.26	The Control Capability should be capable of self-learning in order to improve PEPDS performance over time.	Control Capability PEPDS 5.4 Self Learning W2.1.1 Control Information W2.1 Control PEPDS	[ref 48], [ref 47]	Analysis		2022.11.15
237	S1.2.2 Protection Capability Requirements						
245	S1.2.3 Electrical Distribution Capability Require						
261	S1.2.4 Thermal Management Capability Requir						

Fig. 69: S1.2.1 Control Capability Requirements Part 2

#	Name	Text	Traced To	Source	Verify Method	Risk	Revision Date
1	S1.1 PEPDS Requirements						
204	S1.2 Capability Requirements						
205	S1.2.1 Control Capability Requirements						
237	S1.2.2 Protection Capability Requirements						
238	S1.2.2.2 Protection Capability Innovative R						
239	S1.2.2.2.1	The Protection Capability shall provide the Control Capability Feedback enabling protection related Commands.	Protection Capability Control Capability Feedback Commands 5.5 Integrated Control 5.7 Adaptive Controls 5.13 Integrated Power and Energy Pc W2.2 Protect PEPDS Send(context Protection Capability)	[ref 52]	Analysis		2022.11.15
240	S1.2.2.2.2	The Protection Capability shall Analyze Source and Load Interfaces Characteristics in order to detect incipient failures.	Protection Capability PEPDS Failure Analyze Power Source and Load Inter W2.2 Protect PEPDS 5.13 Integrated Power and Energy Pc	[ref 50]	Analysis		2022.11.15
241	S1.2.2.2.3	The Protection Capability shall Analyze PEPDS Performance in order to detect incipient failures.	Protection Capability PEPDS Analyze PEPDS Performance(context W2.2 Protect PEPDS 5.13 Integrated Power and Energy Pc Failure	[ref 50] [ref 58]	Analysis		2022.11.15
242	S1.2.2.2.4	The Protection Capability shall Determine Operational Needs for Safety, Performance, and Resilience based on the Control Strategy and Commands from the Control Capability.	Protection Capability Control Strategy Control Capability Commands 5.5 Integrated Control 5.7 Adaptive Controls 5.13 Integrated Power and Energy Pc W2.2 Protect PEPDS Determine Operational Needs for Safe	[ref 52]	Analysis		2022.11.15
243	S1.2.2.2.5	The Protection Capability shall perform accurate diagnosis and prognosis when a failure event occurs.	Protection Capability W2.2 Protect PEPDS 5.9 Integrated CBM+ 5.13 Integrated Power and Energy Pc Perform Diagnosis(context Protection Perform Prognosis(context Protection Failure	[ref 50]	Analysis		2022.11.15
244	S1.2.2.2.6	The Protection Capability shall Select Protection Response based on the diagnosis and prognosis of the failure event and the need for system safety, performance and resiliency.	Protection Capability 5.5 Integrated Control 5.7 Adaptive Controls 5.13 Integrated Power and Energy Pc W2.2 Protect PEPDS Perform Diagnosis(context Protection Perform Prognosis(context Protection Select Protection Response(context P Determine Operational Needs for Safe Failure	[ref 50] [ref 52]	Analysis		2022.11.15
245	S1.2.3 Electrical Distribution Capability Require						
261	S1.2.4 Thermal Management Capability Requir						

Fig. 70: S1.2.2 Protection Capability Requirements

#	Name	Text	Traced To	Source	Verify Method	Risk	Revision Date
1	S1.1 PEPDS Requirements						
204	S1.2 Capability Requirements						
205	S1.2.1 Control Capability Requirements						
237	S1.2.2 Protection Capability Requirements						
245	S1.2.3 Electrical Distribution Capability Require						
246	S1.2.3.1 Electrical Distribution Capability Ge						
247	S1.2.3.1.1	The Power Conversion Capability shall Convert Electrical Power based on Commands from the Control Capability.	Power Conversion Capability Electrical Power Commands Control Capability Convert W2.3 Distribute Power Electrical Distribution Capability	[ref 50] [ref 52]	Analysis		2022.11.15
248	S1.2.3.1.2	The Energy Storage Capability shall Store Electrical Power received from the Power Conversion Capability based on Commands by the Control Capability.	Control Capability Electrical Power Energy Storage Capability Commands Power Conversion Capability Store W2.3 Distribute Power 1 Problem Domain Electrical Distribution Capability	[ref 50] [ref 52]	Analysis		2022.11.15
249	S1.2.3.1.3	The Power Conversion Capability shall send Electrical Power to the Power Transportation Capability as appropriate.	Power Conversion Capability Electrical Power Electrical Distribution Capability W2.3 Distribute Power Power Transportation Capability	[ref 50] [ref 52]	Analysis		2022.11.15
250	S1.2.3.1.4	The Power Transportation Capability shall Transport Electrical Power based on Commands from the Control Capability.	Power Transportation Capability Electrical Power Commands Control Capability Transport W2.3 Distribute Power Electrical Distribution Capability	[ref 50] [ref 52]	Analysis		2022.11.15
251	S1.2.3.1.5	The Energy Storage Capability shall discharge Electrical Power to the Power Conversion Capability based on Commands by the Control Capability.	Electrical Distribution Capability Commands Control Capability Energy Storage Capability Electrical Power Power Conversion Capability W2.3 Distribute Power	[ref 50] [ref 52]	Analysis		2022.11.15
252	S1.2.3.1.6	The Power Conversion Capability shall receive Electrical Power from the Power Transportation Capability as appropriate.	Power Conversion Capability Electrical Power Power Transportation Capability W2.3 Distribute Power Electrical Distribution Capability	[ref 50] [ref 52]	Analysis		2022.11.15
253	S1.2.3.1.7	The Power Transportation Capability shall send Feedback to the Control Capability.	Power Transportation Capability Feedback Control Capability W2.3 Distribute Power Electrical Distribution Capability	[ref 50] [ref 52]	Analysis		2022.11.15
254	S1.2.3.1.8	The Energy Storage Capability shall send Feedback to the Control Capability.	Energy Storage Capability Feedback Control Capability W2.3 Distribute Power Electrical Distribution Capability	[ref 50] [ref 52]	Analysis		2022.11.15
255	S1.2.3.1.9	The Power Conversion Capability shall receive Electrical Power from the Energy Storage Capability as appropriate.	Power Conversion Capability Energy Storage Capability Electrical Power W2.3 Distribute Power Electrical Distribution Capability	[ref 50] [ref 52]	Analysis		2022.11.15
256	S1.2.3.1.10	The Power Conversion Capability shall send Feedback to the Control Capability.	Power Conversion Capability Control Capability Feedback W2.3 Distribute Power Electrical Distribution Capability	[ref 50] [ref 52]	Analysis		2022.11.15
257	S1.2.3.1.11	The Power Conversion Capability shall send Electrical Power to the Energy Storage Capability as appropriate.	Power Conversion Capability Electrical Power Energy Storage Capability W2.3 Distribute Power Electrical Distribution Capability	[ref 50] [ref 52]	Analysis		2022.11.15
258	S1.2.3.2 Electrical Distribution Capability In						
259	S1.2.3.2.1	The Power Transportation Capability shall Transport Electrical Power from sources to loads, either of which may be onboard or offboard the Electric Ship.	Power Transportation Capability Electrical Power W2.3 Distribute Power 5.2 Load Interface Design Transport Electrical Distribution Capability Onboard Power Loads Onboard Power Sources Offboard Power Systems	[ref 50] [ref 52]	Analysis		2022.11.15
260	S1.2.3.2.2	The Power Conversion Capability shall Convert source Electrical Power in order to service loads from dc to dc, dc to ac, ac to dc, ac to ac at various voltages and frequencies.	W2.3 Distribute Power Electrical Power 5.14 Distributed Power Conversion Convert Offboard Power Systems Onboard Power Loads Power Conversion Capability Onboard Power Sources Electrical Distribution Capability	[ref 51]	Analysis		2022.11.15
261	S1.2.4 Thermal Management Capability Requir						

Fig. 71: S1.2.3 Electrical Distribution Capability Requirements

#	Name	Text	Traced To	Source	Verify Method	Risk	Revision Date
1	S1.1 PEPDS Requirements						
204	S1.2 Capability Requirements						
205	S1.2.1 Control Capability Requirements						
237	S1.2.2 Protection Capability Requirements						
245	S1.2.3 Electrical Distribution Capability Require						
261	S1.2.4 Thermal Management Capability Requir						
262	S1.2.4.1 Thermal Management Capability G						
263	S1.2.4.1.1	The Thermal Management Capability should regulate the thermal load of PEPDS capabilities to minimize the Environmental Load on PEPDS.	Thermal Management Capability PEPDS Environmental Load W2.4 Manage Thermal Load of PEPDS Regulate PEPDS Internal Thermal Loa	[ref 11]	Analysis		2022.11.16
264	S1.2.4.1.2	The Thermal Management Capability shall regulate the thermal load of PEPDS capabilities to protect Crew.	Thermal Management Capability PEPDS Personnel Safety MoPs Crew W2.4 Manage Thermal Load of PEPDS Regulate PEPDS Internal Thermal Loa Environmental Load	[ref 11] [ref 52]	Analysis		2022.11.15
265	S1.2.4.1.3	The Thermal Management Capability shall regulate the thermal load of PEPDS capabilities as necessary to maintain operations.	Thermal Management Capability PEPDS W2.4 Manage Thermal Load of PEPDS Environmental Load Regulate PEPDS Internal Thermal Loa	[ref 11]	Analysis		2022.11.15
266	S1.2.4.1.5	The Thermal Management Capability shall regulate the thermal loads of PEPDS capabilities in accordance with the Commands from the Control Capability.	Thermal Management Capability Control Capability Commands PEPDS W2.4 Manage Thermal Load of PEPDS Environmental Load Regulate PEPDS Internal Thermal Loa	[ref 11]	Analysis		2022.11.16
267	S1.2.4.1.6	The Thermal Management Capability shall send Feedback to the Control Capability.	Thermal Management Capability Control Capability Feedback W2.4 Manage Thermal Load of PEPDS	[ref 11]	Analysis		2022.11.15
268	S1.2.4.2 Thermal Management Capability I						
269	S1.2.4.2.1	The Thermal Management Capability should utilize the Electric Ship's environmental services to regulate the thermal load of PEPDS capabilities.	Thermal Management Capability Environmental Load Environmental Management Services W2.4 Manage Thermal Load of PEPDS 3.1 Serial Thermal Management Regulate PEPDS Internal Thermal Loa	[ref 14]	Analysis		2022.11.15

Fig. 72: S1.2.4 Thermal Management Capability Requirements

11.3 System Model Appendix

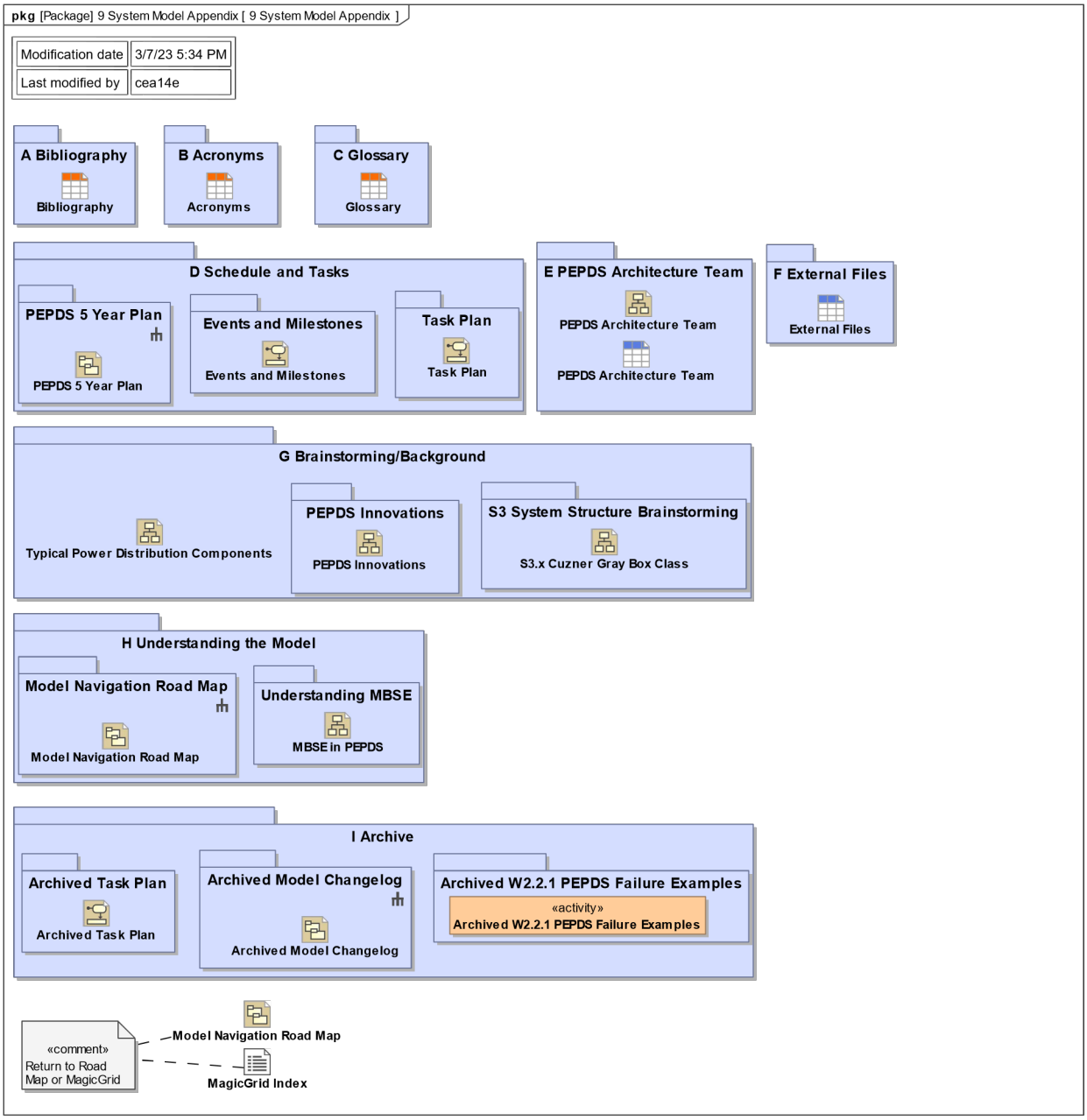


Fig. 73: 9 System Model Appendix

#	Term	Description	Active Hyperlink
1	[ref 1]	R. M. Cuzner, R. Soman, M. M. Steurer, T. A. Toshon and M. O. Faruque, "Approach to Scalable Model Development for Navy Shipboard Compatible Modular Multilevel Converters," in IEEE Journal of Emerging and Selected Topics in Power Electronics, vol. 5, no. 1, pp. 28-39, March 2017, doi: 10.1109/JESTPE.2016.2616222.	https://ieeexplore.ieee.org/document/7587363
2	[ref 2]	R. Soman, M. M. Steurer, T. A. Toshon, M. O. Faruque and R. M. Cuzner, "Size and Weight Computation of MVDC Power Equipment in Architectures Developed Using the Smart Ship Systems Design Environment," in IEEE Journal of Emerging and Selected Topics in Power Electronics, vol. 5, no. 1, pp. 40-50, March 2017, doi: 10.1109/JESTPE.2016.2625030.	https://ieeexplore.ieee.org/document/7736151
3	[ref 3]	C. Mijatovic, "PEPDS Program | MagicDraw Reader for Cameo Enterprise Architecture v19," PEPDS MagicDraw Cameo Reader Instructions, 30-Aug-2021. [Online]. Available: https://rcpc.awsapps.com/workdocs/index.html#/document/f964e4fd12ef45dec2e6d6e97e04924a97d63f2d23661608816bd3478c60abd4. [Accessed: 30-Aug-2021].	https://rcpc.awsapps.com/workdocs/index.html#/folder/60d382205eb7578435d89089352e2b5dccf63f44c9d5f2cd845fbd2620c6ae1d
4	[ref 4]	"Expanded Work Breakdown Structure Weight Classification Guidance - SAWE," SAWE ESWBS RP 03042011, 04-Mar-2011. [Online]. Available: https://www.sawe.org/files/SAWE%20ESWBS%20RP%2003042011.pdf. [Accessed: 08-May-2022].	https://www.sawe.org/files/SAWE%20ESWBS%20RP%2003042011.pdf
5	[ref 5]	NAVSEA, "SHIPBOARD HABITABILITY DESIGN CRITERIA AND PRACTICES MANUAL (SURFACE SHIPS) FOR NEW SHIP DESIGNS AND MODERNIZATION", DIRECTION OF COMMANDER, NAVAL SEA SYSTEMS COMMAND, 2016.	https://habitability.net/WebData/T9640-AC-DSP-010_HAB.pdf
6	[ref 6]	R. Cuzner, 'Functional Architectural Requirements', University of Wisconsin-Milwaukee, 2022.	https://rcpc.awsapps.com/workdocs/index.html#/folder/7d5c804f5dddf7666ad16501634f1b48529470ba46308210caa9995aca1c231
7	[ref 7]	J. Chalfant, 'ANY Navy Ship Power Distribution System | PEPDS', Massachusetts Institute of Technology, 2022.	https://rcpc.awsapps.com/workdocs/index.html#/document/606680bc8de29ad4c0132b34a538ecc1199ef0502fea9ae9b50143426e41bd6b
8	[ref 8]	H. Ginn, 'DDG 1000 IPS Integration - Electric Ship Design Symposium', University of South Carolina, 2009.	https://rcpc.awsapps.com/workdocs/index.html#/document/d998d50c571de3f34c9c05d6105bd9aee3eb56b70775dbe0175daa0ad3720 1b9
9	[ref 9]	K. Kim, G. Roh, W. Kim, and K. Chun, "A Preliminary Study on an Alternative Ship Propulsion System Fueled by Ammonia: Environmental and Economic Assessments," Journal of Marine Science and Engineering, vol. 8, no. 3, p. 183, Mar. 2020, doi: 10.3390/jmse8030183.	https://www.mdpi.com/2077-1312/8/3/183/htm
10	[ref 10]	H. Xing, C. Stuart, S. Spence, and H. Chen, "Fuel Cell Power Systems for Maritime Applications: Progress and Perspectives," Fuel cell sustainability - 13-01213, January 2021. [Online]. Available: https://rcpc.awsapps.com/workdocs/index.html#/document/9db7704328cc4b15eecde298b915c7719a293e6ccb04b4b6d5e5ace29858c588. [Accessed: 08-Sep-2021].	https://www.mdpi.com/2071-1050/13/3/1213/pdf
11	[ref 11]	J. Ordonez, 'Thermal interconnections', University of Wisconsin-Milwaukee, 25 August, 2021.	https://rcpc.awsapps.com/workdocs/index.html#/document/4f78436b73b8e8a91f11a7424206de3ab83ec5751f757a11beb8ead29160dc3c
12	[ref 12]	R. Cuzner, 'Ship Service Loads', University of Wisconsin-Milwaukee, 11 August, 2021.	https://rcpc.awsapps.com/workdocs/index.html#/document/2bbfedd4972c01e69d49a2fd5916a826de92b6dc2b5b9b25c7b438a8207dc607
13	[ref 13]	I. Cvetkovic, 'PEPDS Architecture(s) Brainstorming Meeting', Virginia Tech - Center for Power Electronics Systems, 18 August, 2021.	https://rcpc.awsapps.com/workdocs/index.html#/document/6430732ed18f4be2ff396a88d916b849827a61939e980b21929129aa4468351
14	[ref 14]	J. Chalfant, 'Ship Support', Massachusetts Institute of Technology, 17 September 2021.	https://rcpc.awsapps.com/workdocs/index.html#/document/bef7b270ad76a66a7ab52a39b6255d4316992aea1bec96387bb543d22757fa88
15	[ref 15]	K. Vanska, "Fuel cells in integrated power system of marine vessel", San Francisco, 2019.	https://www.energy.gov/sites/prod/files/2019/10/f68/fcto-h2-at-ports-workshop-2019-v1-vanska.pdf
16	[ref 16]	DEPARTMENT OF DEFENSE TEST METHOD STANDARD, "ENVIRONMENTAL ENGINEERING CONSIDERATIONS AND LABORATORY TESTS," MIL-STD-810G, 31 Oct., 2008.	https://www.atec.army.mil/publications/Mil-Std-810G/Mil-Std-810G.pdf
17	[ref 17]	DEPARTMENT OF DEFENSE DETAIL SPECIFICATION, "ELECTRIC POWER EQUIPMENT, BASIC REQUIREMENTS FOR," MIL-DTL-917F (SH), 05 Aug., 2014.	http://everyspec.com/MIL-SPECS/MIL-SPECS-MIL-DTL/MIL-DTL-917F_51622/
18	[ref 18]	MILITARY SPECIFICATION, "ELECTRIC POWER EQUIPMENT BASIC REQUIREMENTS," MIL-E-917E (SH), 06 Aug., 1993.	http://everyspec.com/MIL-SPECS/MIL-SPECS-MIL-E/MIL-E-917E_10341/#:~:text=%2DDTL%2D917F%5D-,MIL%2DE%2D917E%2C%20MILITARY%20SPECIFIC...
19	[ref 19]	DEPARTMENT OF DEFENSE INTERFACE STANDARD, "REQUIREMENTS FOR THE CONTROL OF ELECTROMAGNETIC INTERFERENCE CHARACTERISTICS OF SUBSYSTEMS AND EQUIPMENT," MIL-STD-461G, 11 December, 2015.	http://everyspec.com/MIL-STD/MIL-STD-0300-0499/MIL-STD-461G_53571/
20	[ref 20]	MILITARY STANDARD, "AIRBORNE AND STRUCTUREBORNE NOISE MEASUREMENTS AND ACCEPTANCE CRITERIA of SHIPBOARD EQUIPMENT," MIL-STD-740B (SHIPS), 13 January, 1965.	http://everyspec.com/MIL-STD/MIL-STD-0700-0799/MIL-STD-740B_10381/
21	[ref 21]	DEPARTMENT OF DEFENSE TEST METHOD, "MECHANICAL VIBRATIONS OF SHIPBOARD EQUIPMENT (TYPE 1 - ENVIRONMENTAL AND TYPE II - INTERNALLY EXCITED)," MIL-STD-167-1 (SHIPS), 01 MAY, 1974.	http://everyspec.com/MIL-STD/MIL-STD-0100-0299/MIL-STD-167-1_22419/
22	[ref 22]	MILITARY SPECIFICATION, "SHOCK TESTS, H.I. (HIGH-IMPACT) SHIPBOARD MACHINERY, EQUIPMENT, AND SYSTEMS, REQUIREMENTS FOR," MIL-S-910D (NAVY), 17 March, 1989.	http://everyspec.com/MIL-SPECS/MIL-SPECS-MIL-S/MIL-S-901D_14581/
23	[ref 23]	"Reliability, availability, maintainability, and cost (RAM-C ... - DDR&E(AC)," RELIABILITY, AVAILABILITY, MAINTAINABILITY, AND COST (RAM-C) RATIONALE REPORT OUTLINE GUIDANCE, 28-Feb-2017. [Online]. Available: https://ac.cto.mil/wp-content/uploads/2019/06/RAMC-Outline-2017-07-07.pdf.	https://ac.cto.mil/wp-content/uploads/2019/06/RAMC-Outline-2017-07-07.pdf
24	[ref 24]	L. Petersen, C. Schegan, T. S. Ericsen, D. Boroyevich, R. Burgos, N. G. Hingorani, M. Steurer, J. Chalfant, H. Ginn, C. DiMarino, G. C. Montanari, F. Z. Peng, C. Chryssostomidis, C. Cooke, and I. Cvetkovic, "Power Electronic Power Distribution Systems (PEPDS)," Electric Ship Research & Development Consortium, USA, 2020. [Online]. Available: https://www.esrdc.com/library/pepds-plan/	https://www.esrdc.com/library/pepds-plan/
25	[ref 25]	R. Cuzner, 'UWM_Ontology_PEPDS', University of Wisconsin-Milwaukee, 2022.	https://rcpc.awsapps.com/workdocs/index.html#/document/1198fbdfdccdcd6e2a4e764e2121bfc11ec6577ffc58e848bb80cfc8c4918977
26	[ref 26]	D. K. Leonard and D. T. Snow, "Electronic warfare," Programs - Electronic Warfare - Office of Naval Research. [Online]. Available: https://www.onr.navy.mil/en/Science-Technology/Departments/Code-31/All-Programs/312-Electronics-Sensors/electronic-warfare. [Accessed: 26-May-2022].	https://www.onr.navy.mil/en/Science-Technology/Departments/Code-31/All-Programs/312-Electronics-Sensors/electronic-warfare
27	[ref 27]	P. Frenz, G. Reader, D. J. Gantzer, and P. Baxter, "Systems engineering measurement primer - december 2010," Systems Engineering Measurement Primer, 05-Nov-2010. [Online]. Available: https://www.incose.org/docs/default-source/ProductsPublications/systems-engineering-measurement-primer---december-2010.pdf?sfvrsn=2&sfvrsn=2. [Accessed: 26-May-2022].	https://www.incose.org/docs/default-source/ProductsPublications/systems-engineering-measurement-primer---december-2010.pdf
28	[ref 28]	M. S. Racine, J. D. Parham and M. H. Rashid, "An overview of uninterruptible power supplies," Proceedings of the 37th Annual North American Power Symposium, 2005., 2005, pp. 159-164, doi: 10.1109/NAPS.2005.1560518.	https://ieeexplore.ieee.org/document/1560518
29	[ref 29]	"Center for Advanced Power Systems," Home | Center for Advanced Power Systems. [Online]. Available: https://www.caps.fsu.edu/. [Accessed: 26-May-2022].	https://www.caps.fsu.edu/
30	[ref 30]	F. Yang, X. Song, F. Xu and K. -L. Tsui, "State-of-Charge Estimation of Lithium-Ion Batteries via Long Short-Term Memory Network," in IEEE Access, vol. 7, pp. 53792-53799, 2019, doi: 10.1109/ACCESS.2019.2912803.	https://ieeexplore.ieee.org/document/8695733
31	[ref 31]	H. Ollhäuser's, "Energy conversion module (ECM) - DC/DC converter with integrated supercaps," Energy Conversion Module (ECM) - DC/DC converter with integrated supercaps, Jan-2008. [Online]. Available: https://www.researchgate.net/publication/293382249_Energy_Conversion_Module_ECM_-_DCDC_converter_with_integrated_supercaps. [Accessed: 26-May-2022].	https://www.researchgate.net/publication/293382249_Energy_Conversion_Module_ECM_-_DCDC_converter_with_integrated_supercaps
32	[ref 32]	"Appendix H - TS9090-310G approved 2015-2-16," ALTERATIONS TO SHIPS ACCOMPLISHED BY ALTERATION INSTALLATION TEAMS, 12-Feb-2015. [Online]. Available: https://www.navsea.navy.mil/Portals/103/Documents/NSWC_Dahlgren/FiberOptics/Appendix_H_TS9090-310G_Approved_2015-2-12.pdf. [Accessed: 26-May-2022].	https://www.navsea.navy.mil/Portals/103/Documents/NSWC_Dahlgren/FiberOptics/Appendix_H_TS9090-310G_Approved_2015-2-12.pdf
33	[ref 33]	"DOD reliability, availability, and maintainability - acqnotes," DOD GUIDE FOR ACHIEVING RELIABILITY, AVAILABILITY, AND MAINTAINABILITY, 03-Aug-2005. [Online]. Available: https://www.acqnotes.com/Attachments/DoD%20Reliability%20Availability%20and%20Maintainability%20(RAM)%20Guide.pdf. [Accessed: 26-May-2022].	https://www.acqnotes.com/Attachments/DoD%20Reliability%20Availability%20and%20Maintainability%20(RAM)%20Guide.pdf
34	[ref 34]	B. Radle and T. Bradicich, "What is serviceability?," NI, 05-Mar-2019. [Online]. Available: https://www.ni.com/en-us/innovations/white-papers/13/what-is-serviceability-.html. [Accessed: 26-May-2022].	https://www.ni.com/en-us/innovations/white-papers/13/what-is-serviceability-.html
35	[ref 35]	B. S. Blanchard, "Reliability, Maintainability, and Availability Measures," in Logistics Engineering and Management, 6th ed., Harlow, Essex: Pearson, 2014, pp. 47–80.	https://rcpc.awsapps.com/workdocs/index.html#/document/d8facb58213d8b962972c7dc69e21be19074d8882b86e2739c1ab86018b7e917
36	[ref 36]	M. Steurer, "PEPDS Architecture," 30-Apr-2021.	https://rcpc.awsapps.com/workdocs/index.html#/document/0442235fe1b3463953665 7f4dab615f07d67e719346cd4276afe13db021f6ab8
37	[ref 37]	"Life Data Analysis (Weibull Analysis)," Reliability Life Data Analysis (Weibull Analysis) - Statistical Analysis Using the Weibull Model and Other Lifetime Distributions. [Online]. Available: https://www.weibull.com/basics/lifedata.htm. [Accessed: 07-Jun-2022].	https://www.weibull.com/basics/lifedata.htm
38	[ref 38]	B. S. Blanchard, "Introduction to Logistics," in Logistics Engineering and Management, 6th ed., Harlow, Essex: Pearson, 2014, pp. 1-46.	https://rcpc.awsapps.com/workdocs/index.html#/document/fad9e9a390312caccbd9f27a07dbe167160614441c23d4e0b3516ba1782c0e17
39	[ref 39]	N. H. Doerry and D. H. Clayton, "Shipboard electrical power quality of service," IEEE Electric Ship Technologies Symposium, 2005., 2005, pp. 274-279, doi: 10.1109/ESTS.2005.1524688.	https://ieeexplore.ieee.org/document/1524688
40	[ref 40]	PEPDS Architecture Team, 'PEPDS Modeling Update', CAPS, 2021.	https://rcpc.awsapps.com/workdocs/index.html#/document/7733b319dd5e90c55987bb7716a1bbcfbf4616542f65359d74636ab1dccfc9f6
41	[ref 41]	M. McCandless et al., "Thermal Analysis of MVDC Power Corridor," 2019 IEEE Electric Ship Technologies Symposium (ESTS), 2019, pp. 106-112, doi: 10.1109/ESTS.2019.8847881.	https://ieeexplore.ieee.org/abstract/document/8847881
42	[ref 42]	J. Padilla, "Cooling power electronic building blocks aboard Navy ships," Cooling Power Electronic Building Blocks Aboard Navy Ships, 15-Jun-2021. [Online]. Available: https://dspace.mit.edu/handle/1721.1/139049. [Accessed: 29-Jun-2022].	https://dspace.mit.edu/handle/1721.1/139049
43	[ref 43]	DEPARTMENT OF DEFENSE DESIGN CRITERIA STANDARD, "HUMAN ENGINEERING," MIL-STD-1472H (SHIPS), 15 September, 2020.	http://everyspec.com/MIL-STD/MIL-STD-1400-1499/MIL-STD-1472H_57041/
44	[ref 44]	"NIPEC Concept," Amazon WorkDocs. [Online]. Available: https://rcpc.awsapps.com/workdocs/index html#/document/dec1e9844e937a4510100fd39abbbbb16ac2cc6a55362829f4379b4f02e2b395. [Accessed: 06-Jul-2022].	https://rcpc.awsapps.com/workdocs/index.html#/document/dec1e9844e937a4510100fd39abbbbb16ac2cc6a55362829f4379b4f02e2b395
45	[ref 45]	"PEPDS Review with Mischa & Jodie" Amazon WorkDocs. [Online]. Available: https://rcpc.awsapps.com/workdocs/index.html#/document/69ea21240f203cd8e2bc487c810689b4183a5f5eddf048d0af382aad594f3aa1. [Accessed: 15-Jul-2022].	https://rcpc.awsapps.com/workdocs/index.html#/document/69ea21240f203cd8e2bc487c810689b4183a5f5eddf048d0af382aad594f3aa1
46	[ref 46]	"Meeting with UTA" Amazon WorkDocs. [Online]. Available: https://rcpc.awsapps.com/workdocs/index.html#/document/74265b77e13832986 1d1a1ad67e162f8ca33e30eda3ccb3f25fd212d2a5da282. [Accessed: 15-Jul-2022].	https://rcpc.awsapps.com/workdocs/index.html#/document/74265b77e13832986 1d1a1ad67e162f8ca33e30eda3ccb3f25fd212d2a5da282
47	[ref 47]	Condition Based Maintenance (CBM +) Guidebook https://www.dau.edu/tools/t/Condition-Based-Maintenance-(CBM+)-Guidebook-#:~:text=%E2%80%8BCondition%20Based%20Maintenance%20Plus,of%20DoD%20systems%20and%20components	https://www.dau.edu/tools/t/Condition-Based-Maintenance-(CBM+)-Guidebook-#:~:text=%E2%80%8BCondition%20Based%20Maintenance%20Plus,of%20Do...
48	[ref 48]	DOD INSTRUCTION 4151.22 CONDITION-BASED MAINTENANCE PLUS FOR MATERIEL MAINTENANCE https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodi/415122p.pdf?ver=2020-08-14-152511-117https://apps.dtic.mil/sti/pdfs/ADA430668.pdf	https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodi/415122p.pdf?ver=2020-08-14-152511-117https://apps.dtic.mil/sti/pdfs/ADA430668.pdf
49	[ref 49]	"PEPDS Failure & Protection Discussion Sept 2022," Amazon WorkDocs. [Online]. Available: https://rcpc.awsapps.com/workdocs/index.html#/document/a9e158e7e2757f34ff96db668b11aba36c8541a722cd8b4539a18b0e0c7ceabe. [Accessed: 21-Oct-2022].	https://rcpc.awsapps.com/workdocs/index.html#/document/a9e158e7e2757f34ff96db668b11aba36c8541a722cd8b4539a18b0e0c7ceabe
50	[ref 50]	"PEPDS Innovations," Amazon WorkDocs. [Online]. Available: https://rcpc.awsapps.com/workdocs/index.html#/document/accd8ffc995664 8ff9f85ba6274ccedfffbad66563c0b4fac79166b2aa70d30c. [Accessed: 22-Sep-2022].	https://rcpc.awsapps.com/workdocs/index.html#/document/accd8ffc995664 8ff9f85ba6274ccedfffbad66563c0b4fac79166b2aa70d30c
51	[ref 51]	"SME feedback excel sheet," Amazon WorkDocs. [Online]. Available: https://rcpc.awsapps.com/workdocs/index.html#/document/defce9a847d18db453d0f6c4e13eba6bb44faa6fc36d383c3ad66d50ff526d31. [Accessed: 22-Sep-2022].	https://rcpc.awsapps.com/workdocs/index.html#/document/defce9a847d18db453d0f6c4e13eba6bb44faa6fc36d383c3ad66d50ff526d31
52	[ref 52]	"ONR Presentation by Lynn Petersen," Amazon WorkDocs. [Online]. Available: https://rcpc.awsapps.com/workdocs/index.html#/document/2d47c7d55c20daa3c8611c5219497d04bbe8b741c8e0c6916cf4f8c3c032fd3. [Accessed: 22-Sep-2022].	https://rcpc.awsapps.com/workdocs/index.html#/document/2d47c7d55c20daa3c8611c5219497d04bbe8b741c8e0c6916cf4f8c3c032fd3
53	[ref 53]	"Meeting with UTA," Amazon WorkDocs. [Online]. Available: https://rcpc.awsapps.com/workdocs/index.html#/document/c2fe947b1de459 1ba8627f3b6e6bdda67b10d89b05b1f001dbf35507040c1d11. [Accessed: 22-Sep-2022].	https://rcpc.awsapps.com/workdocs/index.html#/document/c2fe947b1de459 1ba8627f3b6e6bdda67b10d89b05b1f001dbf35507040c1d11
54	[ref 54]	"Architecture Meeting (07-28-2022)," Amazon WorkDocs. [Online]. Available: https://rcpc.awsapps.com/workdocs/index.html#/document/e9b14ceba516264c9f4d20f445ac14ccc74e51d3798dedbe136f9dcb1b747bfa. [Accessed: 22-Sep-2022].	https://rcpc.awsapps.com/workdocs/index.html#/document/e9b14ceba516264c9f4d20f445ac14ccc74e51d3798dedbe136f9dcb1b747bfa
55	[ref 55]	"Glossary of SysML Concepts," No Magic Product Documentation. [Online]. Available: https://docs.nomagic.com/display/SYSMLP190/Glossary+of+SysML+concepts. [Accessed: 07-Mar-2023].	https://docs.nomagic.com/display/SYSMLP190/Glossary+of+SysML+concepts
56	[ref 56]	L. R. A. Ashman, "Troubleshooting problems in heat transfer systems," Process Heating RSS, 18-Oct-2012. [Online]. Available: https://www.process-heating.com/articles/85373-troubleshooting-problems-in-heat-transfer-systems. [Accessed: 15-Sep-2022].	https://www.process-heating.com/articles/85373-troubleshooting-problems-in-heat-transfer-systems
57	[ref 57]	Cybersecurity, DoD Instruction 8500.01, Department of Defense, Washington, DC, USA, 2012. Available https://www.esd.whs.mil/portals/54/documents/dd/issuances/dodi/850001_2014.pdf.	https://www.esd.whs.mil/portals/54/documents/dd/issuances/dodi/850001_2014.pdf
58	[ref 58]	"Review of PEPDS Innovation Stakeholder Needs," Amazon WorkDocs. [Online]. Available: https://rcpc.awsapps.com/workdocs/index.html#/document/b87da75e8ed25b31cb0aea8e3b166933062fa84df63743613daef347030cb9e6. [Accessed: 21-Oct-2022].	https://rcpc.awsapps.com/workdocs/index.html#/document/b87da75e8ed25b31cb0aea8e3b166933062fa84df63743613daef347030cb9e6
59	[ref 59]	ALTERATIONS TO SHIPS ACCOMPLISHED BY ALTERATION INSTALLATION TEAMS TS9090-310G, APPENDIX H, NAVY MODERNIZATION PROGRAM MANAGEMENT AND OPERATIONS MANUAL, Feb. 12, 2015. Accessed: Oct. 25, 2022. [Online]. Available: https://www.navsea.navy.mil/Portals/103/Documents/NSWC_Dahlgren/FiberOptics/Appendix_H_TS9090-310G_Approved_2015-2-12.pdf	https://www.navsea.navy.mil/Portals/103/Documents/NSWC_Dahlgren/FiberOptics/Appendix_H_TS9090-310G_Approved_2015-2-12.pdf
60	[ref 60]	"Provisioning, Allowance and Fitting Out Support Manual," Amazon WorkDocs. [Online]. Available: https://rcpc.awsapps.com/workdocs/index.html#/document/d50d9b10d5cd2fef219388ce8eb48606b9212a28f8e8589511f2ee78bce2a374. [Accessed: 28-Oct-2022].	https://rcpc.awsapps.com/workdocs/index.html#/document/d50d9b10d5cd2fef219388ce8eb48606b9212a28f8e8589511f2ee78bce2a374

Fig. 74: Bibliography Part 1 of 2

61	[ref 61]	A. Rastegari and M. Bengtsson, "Implementation of Condition Based Maintenance in manufacturing industry - A pilot case study," 2014 International Conference on Prognostics and Health Management, 2014, pp. 1-8, doi: 10.1109/ICPHM.2014.7036377.	https://ieeexplore.ieee.org/document/7036377
62	[ref 62]	S. Crawford , Ed., "Chemical, biological, radiological and nuclear (CBRN) office," FEMA.gov, 30-Aug-2022. [Online]. Available: https://www.fema.gov/about/offices/chemical-biological-radiological-and-nuclear#:~:text=Response-,Chemical%2C%20Biological%2C%20Radiological%20and%20Nuclear%20(CBRN)%20Office,Disaster%20Emergency%20Communications. [Accessed: 22-Nov-2022].	https://www.fema.gov/about/offices/chemical-biological-radiological-and-nuclear#:~:text=Response-,Chemical%2C%20Biological%2C%20Radiological%20and%...
63	[ref 63]	Cyware, "How cyber fusion improves mean time to contain (MTTC)?: Cyware educational guides: Educational guides," Cyware Labs, 19-Apr-2022. [Online]. Available: https://cyware.com/educational-guides/cyber-fusion-and-threat-response/how-cyber-fusion-improves-mean-time-to-contain-mttc-e8c5. [Accessed: 22-Nov-2022].	https://cyware.com/educational-guides/cyber-fusion-and-threat-response/how-cyber-fusion-improves-mean-time-to-contain-mttc-e8c5
64	[ref 64]	"MTTD - mean time to detect," Optiv, 08-Oct-2018. [Online]. Available: https://www.optiv.com/cybersecurity-dictionary/mttd-mean-time-to-detect#:~:text=What%20is%20MTTD%20%2D%20Mean%20Time,done%20by%20a%20cyber%20incident. [Accessed: 22-Nov-2022].	https://www.optiv.com/cybersecurity-dictionary/mttd-mean-time-to-detect#:~:text=What%20is%20MTTD%20%2D%20Mean%20Time,done%20by%20a%20c...
65	[ref 65]	M. Roy, "5 cybersecurity incident response metrics that matter," Axonius, 09-Apr-2021. [Online]. Available: https://www.axonius.com/blog/5-cybersecurity-incident-response-metrics-that-matter. [Accessed: 22-Nov-2022].	https://www.axonius.com/blog/5-cybersecurity-incident-response-metrics-that-matter
66	[ref 66]	V. P. Arafiles and L. L. Turner, "RFI/EMI automated measurement system (REAMS)," IEEE 1991 International Symposium on Electromagnetic Compatibility, 1991, pp. 446-451, doi: 10.1109/ISEMC.1991.148274.	https://ieeexplore.ieee.org/abstract/document/148274
67	[ref 67]	"Immediately dangerous to life or health," Centers for Disease Control and Prevention, 10-May-2019. [Online]. Available: https://www.cdc.gov/niosh/idlh/default.html#:~:text=The%20Immediately%20dangerous%20to%20life,first%20developed%20in%20the%20mid%2D. [Accessed: 22-Nov-2022].	https://www.cdc.gov/niosh/idlh/default.html#:~:text=The%20Immediately%20dangerous%20to%20life,first%20developed%20in%20the%20mid%2D
68	[ref 68]	"Overcome by events[ref 68]:dfdefe," Academic Dictionaries and Encyclopedias. [Online]. Available: https://en-academic.com/dic.nsf/enwiki/1976377. [Accessed: 22-Nov-2022].	https://en-academic.com/dic.nsf/enwiki/1976377
69	[ref 69]	Encyclopædia Britannica. [Online]. Available: https://www.britannica.com/dictionary/TBD. [Accessed: 22-Nov-2022].	https://www.britannica.com/dictionary/TBD
70	[ref 70]	M. B. Raichura, N. G. Chothani, D. D. Patel and K. D. Mistry, "Identification of Inrush and Fault Conditions in Power Transformer using Harmonic Distortion Computation," 2019 IEEE 1st International Conference on Energy, Systems and Information Processing (ICESIP), 2019, pp. 1-6, doi: 10.1109/ICESIP46348.2019.8938308.	https://ieeexplore.ieee.org/document/8938308
71	[ref 71]	"AMTS-2022 Symposia," American Society of Naval Engineers, 20-Jul-2022. [Online]. Available: https://www.navalengineers.org/Symposia/AMTS2022/VideoProceeding. [Accessed: 22-Nov-2022].	https://www.navalengineers.org/Symposia/AMTS2022/VideoProceeding
72	[ref 72]	MAINTAINABILITY PROGRAM FOR SYSTEMS AND EQUIPMENT, MIL-STD-470B, 30-May-1989 [Online]. Available: http://everyspec.com/MIL-STD/MIL-STD-0300-0499/MIL_STD_470B_78/	http://everyspec.com/MIL-STD/MIL-STD-0300-0499/MIL_STD_470B_78/
73	[ref 73]	RELIABILITY PROGRAM FOR SYSTEMS AND EQUIPMENT DEVELOPMENT AND PRODUCTION, MIL-STD-785B, 15-Sep-1980 [Online]. Available: http://everyspec.com/MIL-STD/MIL-STD-0700-0799/MIL-STD-785B_23780/	http://everyspec.com/MIL-STD/MIL-STD-0700-0799/MIL-STD-785B_23780/
74	[ref 74]	Matthew J. White, "AN ANALYSIS OF CNO AVAILABILITY PERFORMANCE METRICS AND THEIR RELATION TO AVAILABILITY PERFORMANCE," M.S. thesis, Dept. of Natl. Sec. Aff., NPS, Monterey, CA, USA, 2013 [Online]. Available: https://calhoun.nps.edu/handle/10945/34762	https://calhoun.nps.edu/handle/10945/34762
75	[ref 75]	"Cost variance," AcqNotes, 17-Nov-2022. [Online]. Available: https://acqnotes.com/acqnote/tasks/cost-variances. [Accessed: 28-Nov-2022].	https://acqnotes.com/acqnote/tasks/cost-variances
76	[ref 76]	"Schedule variances," AcqNotes, 25-Sep-2022. [Online]. Available: https://acqnotes.com/acqnote/tasks/schedule-variances. [Accessed: 28-Nov-2022].	https://acqnotes.com/acqnote/tasks/schedule-variances
77	[ref 77]	"Availability and the different ways to calculate it," weibull.com -- Free Data Analysis and Modeling Resources for Reliability Engineering. [Online]. Available: https://www.weibull.com/hotwire/issue79/relbasics79.htm. [Accessed: 30-Nov-2022].	https://www.weibull.com/hotwire/issue79/relbasics79.htm
78	[ref 78]	Www.nrel.gov. [Online]. Available: https://www.nrel.gov/docs/fy22osti/80312.pdf. [Accessed: 08-Dec-2022].	https://www.nrel.gov/docs/fy22osti/80312.pdf
79	[ref 79]	"Measuring agility - AAU." [Online]. Available: https://projekter.aau.dk/projekter/files/61070870/1181300194.pdf. [Accessed: 08-Dec-2022].	https://projekter.aau.dk/projekter/files/61070870/1181300194.pdf.
80	[ref 80]	A. Aleksandraviciene and A. Morkevicius, MagicGrid® Book of Knowledge: A Practical Guide to Systems Modeling using MagicGrid from No Magic, Kaunas, Lithuania: Vitae Litera, 2018.	https://discover.3ds.com/magicgrid-book-of-knowledge
81	[ref 81]	C. Singam, "Model-Based Systems Engineering (MBSE)" in SEBoK Editorial Board, in The Guide to the Systems Engineering Body of Knowledge (SEBoK), v. 2.7, R. J. Cloutier, Ed. Hoboken, NJ: The Trustees of the Stevens Institute of Technology, 2022. [Online]. Available: https://www.sebokwiki.org/wiki/Model-Based_Systems_Engineering_(MBSE). [Accessed: Mar 7, 2023]. BKCASE is managed and maintained by the Stevens Institute of Technology Systems Engineering Research Center, the International Council on Systems Engineering, and the Institute of Electrical and Electronics Engineers Systems Council.	https://www.sebokwiki.org/wiki/Model-Based_Systems_Engineering_(MBSE)
82	[ref 82]	S. Friedenthal, A. Moore, and R. Steiner, A Practical Guide to SysML: The Systems Modeling Language, 3rd ed. Amsterdam: Morgan Kaufmann, 2014.	https://www.sciencedirect.com/book/9780128002025/a-practical-guide-to-sysml#book-description
83	[ref 83]	"Enterprise Architecture," Integrated Enterprise Architecture (EA) Models - CATIA - Dassault Systèmes®. [Online]. Available: https://www.3ds.com/products-services/catia/products/no-magic/solutions/enterprise-architecture/#:~:text=Cameo%20Enterprise%20Architecture%20%2D%20Cameo%20Enterprise,SoaML%2C%20and%20UML%20modeling%20standards. [Accessed: 26-Aug-2022].	https://www.3ds.com/products-services/catia/products/no-magic/solutions/enterprise-architecture/#:~:text=Cameo%20Enterprise%20Architecture%20%2D%2...
84	[ref 84]	"Systems Engineering Vision 2020," International Council on Systems Engineering, San Diego, CA, USA, TP-2004-004-02, 2007.	

Fig. 75: Bibliography Part 2 of 2

#	Term	Description	References
1	ACWP	Actual Cost of Work Performed	[ref 75]
2	ADT	Administrative Delay Time	[ref 35]
3	BCWP	Budgeted Cost of Work Performed	[ref 75]
4	BCWS	Budgeted Cost of Work Scheduled	[ref 76]
5	BIT	built-in test	[ref 33]
6	CAPS	Center for Advanced Power Systems	[ref 29]
7	CB	Capacitor Bank	[ref 25]
8	CBM+	Conditioned Based Maintenance Plus	[ref 61]
9	CBRN	Chemical, Biological, Radiological, and Nuclear	[ref 62]
10	CCDC	Current Commutating Drive Circuit	[ref 25]
11	CHIL	Controller Hardware-in-the-Loop	[ref 24]
12	CPI	Cost Performance Index	[ref 75]
13	CV	Cost Variance	[ref 75]
14	CyberMTTC	Mean Time to Contain Cybersecurity Failure	[ref 63]
15	CyberMTTD	Mean Time to Detect Cybersecurity Failure	[ref 64]
16	CyberMTTR	Mean Time to Resolve Cybersecurity Failure	[ref 65]
17	DRTS	Digital Real Time Simulator	[ref 24]
18	ECM	Energy Conversion Module	[ref 31]
19	EMC	Electromagnetic Compatibility	[ref 66]
20	EMCB	Electro-Mechanical Circuit Breaker	[ref 25]
21	EMI	Electromagnetic Interference	[ref 66]
22	ESM	Energy Storage Module	[ref 25]
23	EWS	Electronic Warfare System	[ref 26]
24	FA	Fan Assembly	[ref 25]
25	FA-1	Filter Assembly	[ref 25]
26	FH	Flight Hours (i.e., Functional Hours)	[ref 23]
27	FMS	Fast Mechanical Switch	[ref 25]
28	HFXA	High Frequency Transformer Assembly	[ref 25]
29	HXA	Heat Exchanger	[ref 25]
30	IA	Inductor Assembly	[ref 25]
31	IDLH	Immediately Dangerous to Life or Health	[ref 67]
32	iPEBB	integrated Power Electronic Building Blocks	[ref 24]
33	IPEC	Integrated Power and Energy Corridor	[ref 41]
34	IPES	Integrated Power and Energy System	[ref 24]
35	LCC	Life Cycle Cost	[ref 38]
36	LCS	Load Commutating Switch	[ref 25]
37	LDT	Logistics Delay Time	[ref 35]
38	LMS	Logistics, Maintenance, and Support	[ref 38]
39	LRU	Line Replaceable Unit	[ref 6]
40	LRUs	Line Replaceable Units	[ref 6]
41	MAMT	Mean Active Maintenance Time	[ref 35]
42	MCD	Most Common Denominator	[ref 24]
43	MCMT	Mean Corrective Maintenance Time	[ref 35]
44	MDT	Mean Downtime	[ref 35]
45	MMH	Maintenance Man Hours	[ref 23]
46	MoE	Measurement of Effectiveness	[ref 27]
47	MOHBFA	Mean Operating Hours Between False Alarm	[ref 33]
48	MoP	Measurement of Performance	[ref 27]
49	MPMT	Mean Preventative Maintenance Time	[ref 35]
50	MTBCF	Mean Time Between Critical Failure	[ref 33]
51	MTBF	Mean Time Between Failure	[ref 23]
52	MTBM	Mean Time Between Maintenance	[ref 33]
53	MTBOMF	Mean Time Between Operational Mission Failure	[ref 33]
54	MTBR	Mean Time Between Repair	[ref 33]
55	MTTR	Mean Time to Repair	[ref 24]
56	MVAC	Medium Voltage Alternating Current	[ref 24]
57	MVDC	Medium Voltage Direct Current	[ref 24]
58	NiPEBB	Navy iPEBB	[ref 71]
59	NiPEC	Navy integrated Power and Energy Corridor	[ref 42]
60	NLSw	No Load Switch/DC Disconnect	[ref 25]
61	OBE	Overcome By Events	[ref 68]
62	PCB	Printed Circuit Board	[ref 25]
63	PCM	Power Conversion Module	[ref 25]
64	PDM	Power Distribution Module	[ref 25]
65	PEBB	Power Electronic Building Block	[ref 24]
66	PEPDS	Power Electronic Power Distribution System	[ref 24]
67	PFD	Percent Fault Detection	[ref 33]
68	PFI	Percent Fault Isolation	[ref 33]
69	PGM	Power Generation Module	[ref 25]
70	PHIL	Power Hardware-in-the-Loop	[ref 24]
71	PMM	Propulsion Motor Module	[ref 25]
72	RAM	Reliability, Availability, and Maintainability	[ref 23]
73	RateCM	Corrective Maintenance Rate	[ref 35]
74	RateF	Failure Rate	[ref 35]
75	RatePM	Preventative Maintenance Rate	[ref 35]
76	RTS	Real Time Simulator	[ref 24]
77	SHIPALT	Ship Alteration	[ref 32]
78	SoC	State of Charge	[ref 30]
79	SPI	Schedule Performance Index	[ref 76]
80	SSSw	Solid State Switch	[ref 25]
81	SV	Schedule Variance	[ref 76]
82	TBD	To Be Determined	[ref 69]
83	TEM	Tactical Energy Management	[ref 24]
84	THD	Total Harmonic Disorder	[ref 70]
85	TPM	Technical Performance Measure	[ref 38]
86	UPS	Uninterruptible Power Supply	[ref 28]

Fig. 76: System Model Acronyms

#	Term	Description	Active Hyperlink
1	Electrical Load	An electrical load is an electrical component of a circuit that consumes electrical power.	
2	Electrical Source	An electrical source is a device that dissipates electrical power.	
3	Failure	Anything that degrades or disrupts the operation of the system. Response time varies. Includes Faults.	
4	Fault	Disruptive event to the normal operation of the system that requires immediate response of the system because of imminent danger to personnel or system inside or outside PEPDS. Is a type of Failure.	
5	Tappable	Points at which Electrical Power provided by PEPDS may be accessed.	
6	Reconfigurability	Changing system behavior by altering interconnections between components and/or selection of predefined options available for components, thereby treating components as black boxes.	
7	Reconfiguration	see reconfigurability	
8	Re-programmability	Changing system behavior by altering internal functions of components, e.g. through firmware or software, thereby treating components as white boxes.	
9	Programming	see re-programmability	
10	Program	see re-programmability	
11	Diagnosis	identification of the nature and cause of a failure	
12	Prognosis	a forecast of the consequences of a failure if not addressed	
13	Prognoses	see prognosis	
14	Diagnoses	see diagnosis	

Fig. 77: System Model Glossary

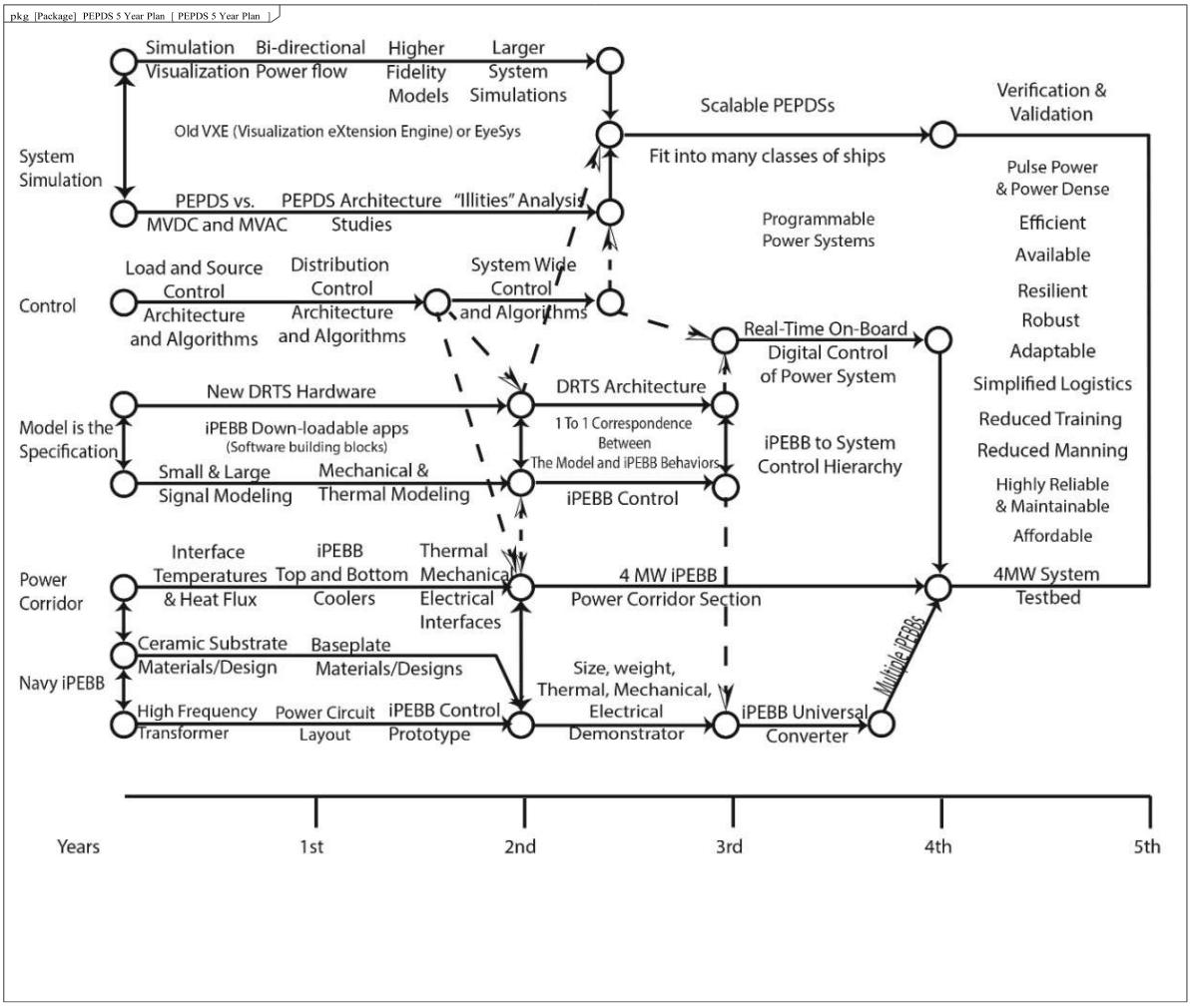


Fig. 78: PEPDS 5 Year Plan

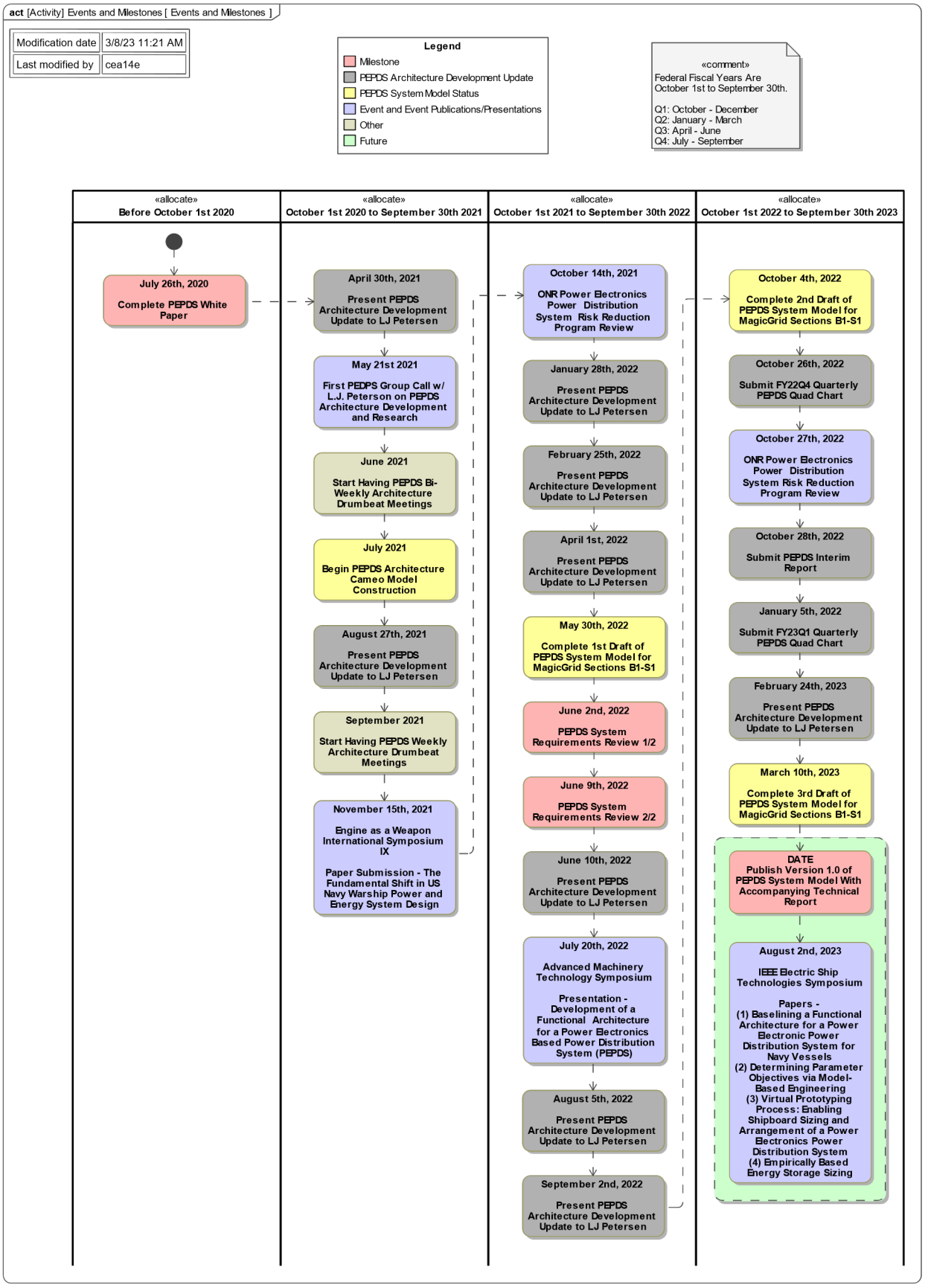


Fig. 79: Events and Milestones

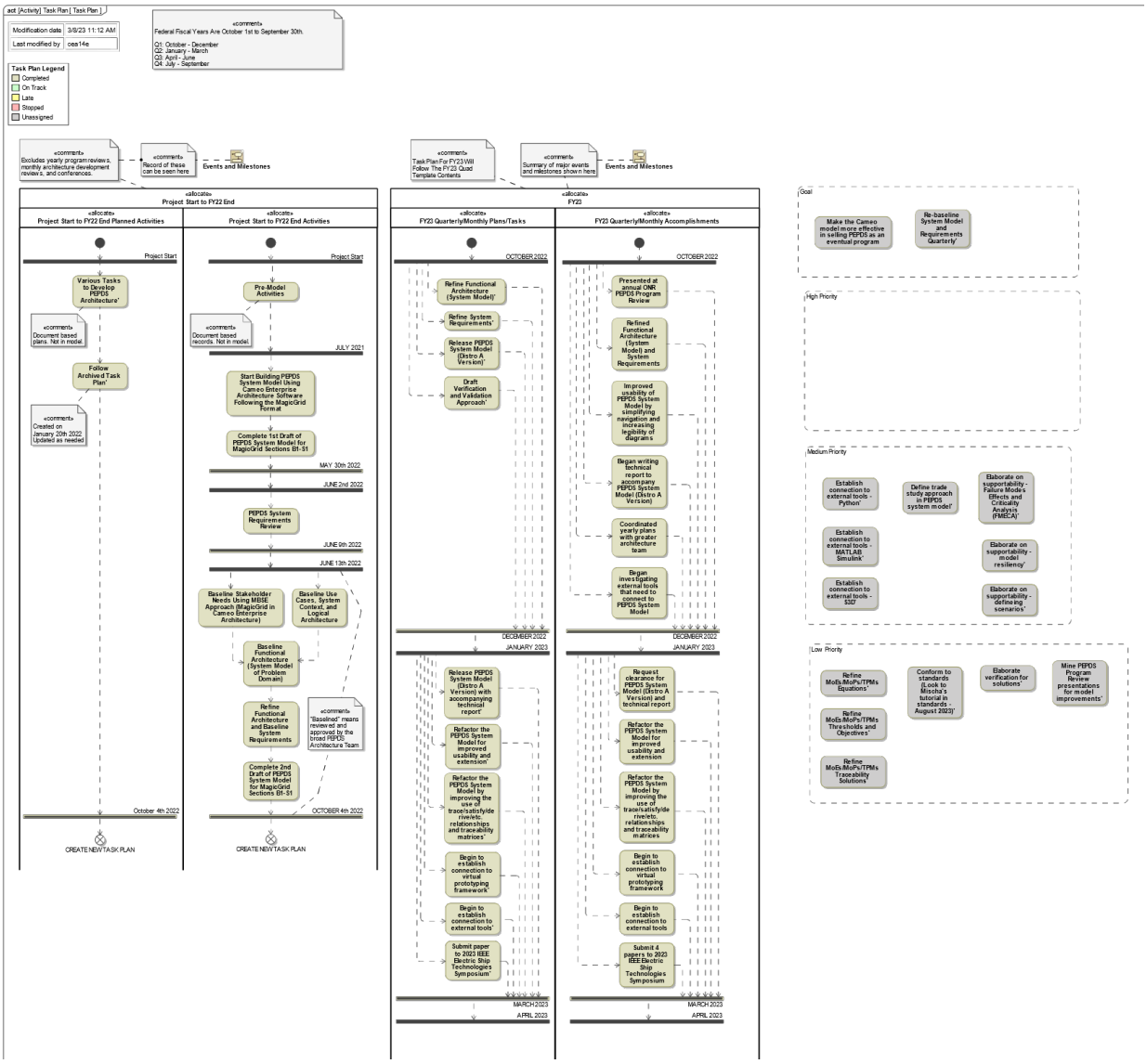


Fig. 80: Task Plan

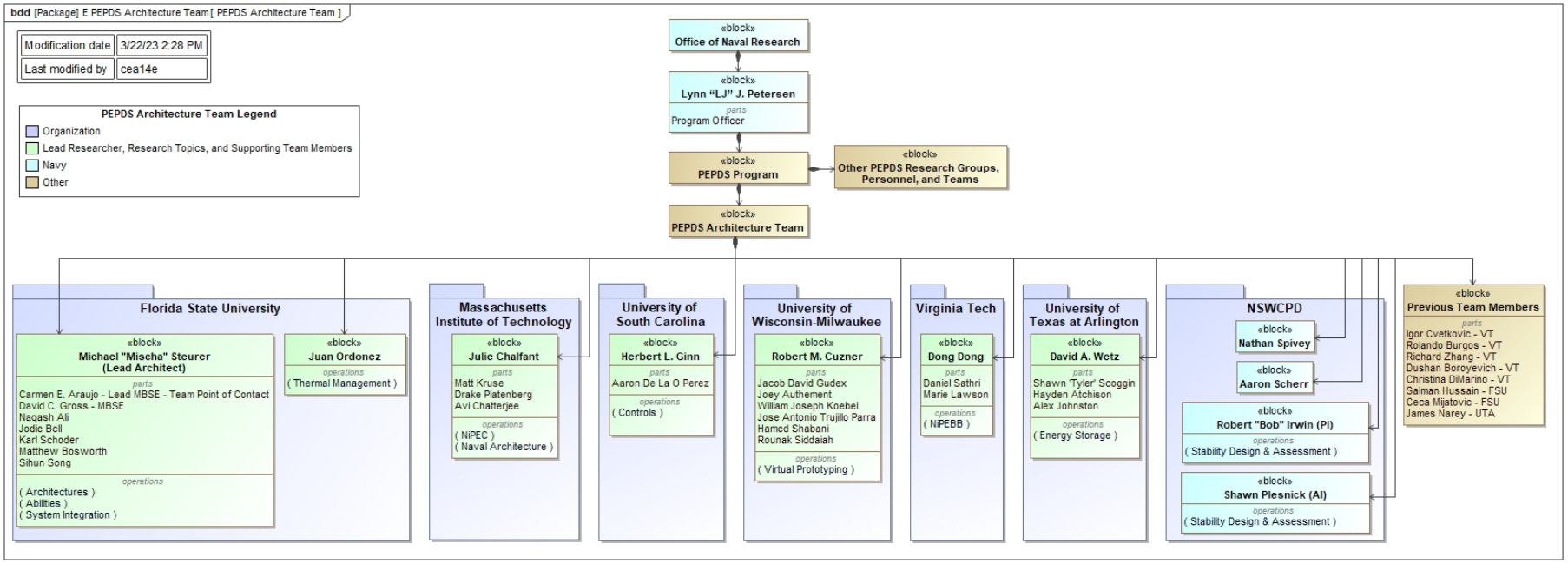


Fig. 81: PEPDS Architecture Team Diagram

#	Organization	Name	Main Research Topic	Supporting Team Members
1	Florida State University	Michael "Mischa" Steurer (Lead Architect)	(Architectures) (Abilities) (System Integration)	Carmen E. Araujo - Lead MBSE - Team Point of Contact David C. Gross - MBSE Naqash Ali Jodie Bell Karl Schoder Matthew Bosworth Sihun Song
2	Florida State University	Juan Ordonez	(Thermal Management)	
3	Massachusetts Institute of Technology	Julie Chalfant	(NiPEC) (Naval Architecture)	Matt Kruse Drake Platenberg Avi Chatterjee
4	University of South Carolina	Herbert L. Ginn	(Controls)	Aaron De La O Perez
5	University of Texas at Arlington	David A. Wetz	(Energy Storage)	Shawn 'Tyler' Scoggin Hayden Atchison Alex Johnston
6	University of Wisconsin-Milwaukee	Robert M. Cuzner	(Virtual Prototyping)	Jacob David Gudex Joey Authement William Joseph Koebel Jose Antonio Trujillo Parra Hamed Shabani Rounak Siddaiah
7	Virginia Tech	Dong Dong	(NiPEBB)	Daniel Sathri Marie Lawson
8	NSWCPD	Aaron Scherr		
9	NSWCPD	Nathan Spivey		
10	NSWCPD	Robert "Bob" Irwin (PI)	(Stability Design & Assessment)	
11	NSWCPD	Shawn Plesnick (AI)	(Stability Design & Assessment)	
12	Other	Previous Team Members		Igor Cvetkovic - VT Rolando Burgos - VT Richard Zhang - VT Dushan Boroyevich - VT Christina DiMarino - VT Salman Hussain - FSU Ceca Mijatovic - FSU James Narey - UTA

Fig. 82: PEPDS Architecture Team Table

#	Owner	Name
1	Submit Feedback	PEPDS Feedback Log.docx
2	W2.2 Protect PEPDS	PEPDS FMECA.xlsx

Fig. 83: External Files

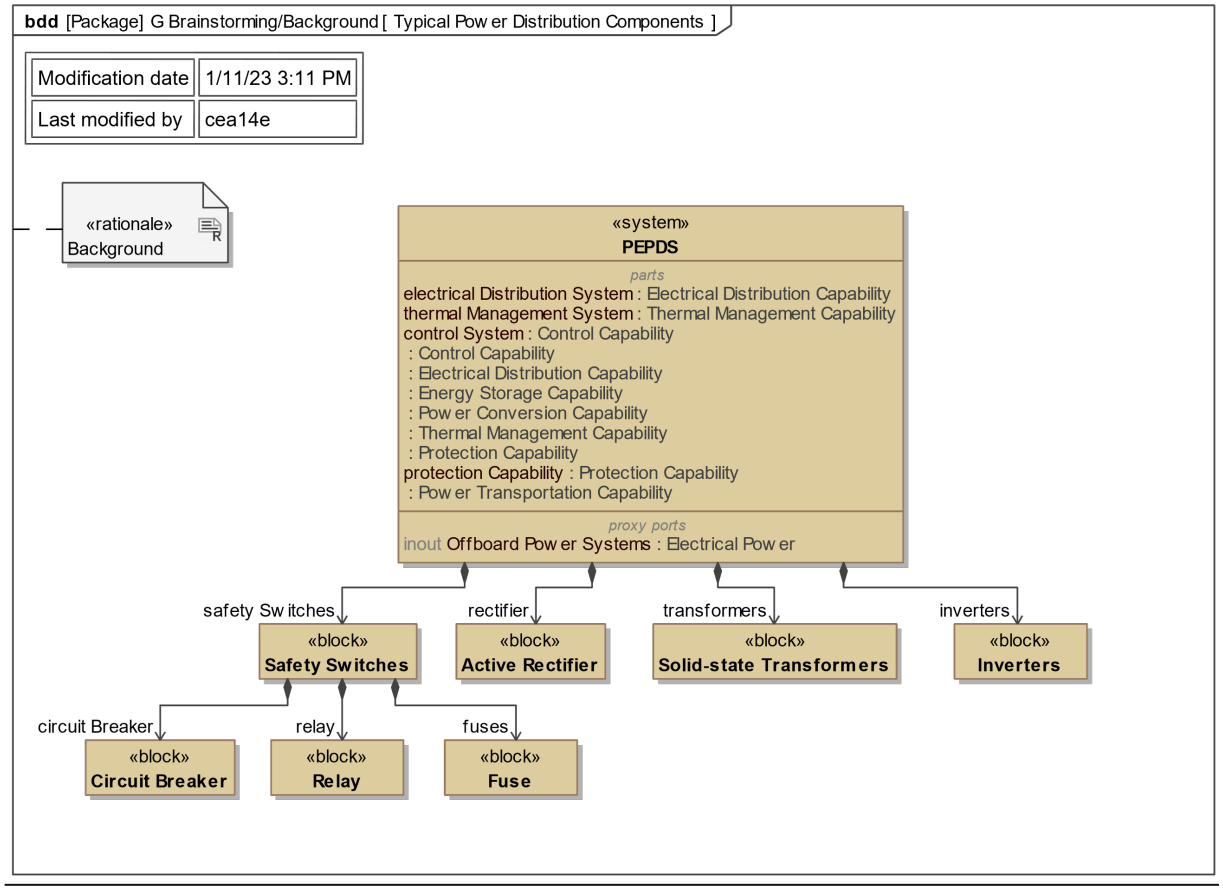


Fig. 84: Typical Power Distribution Components

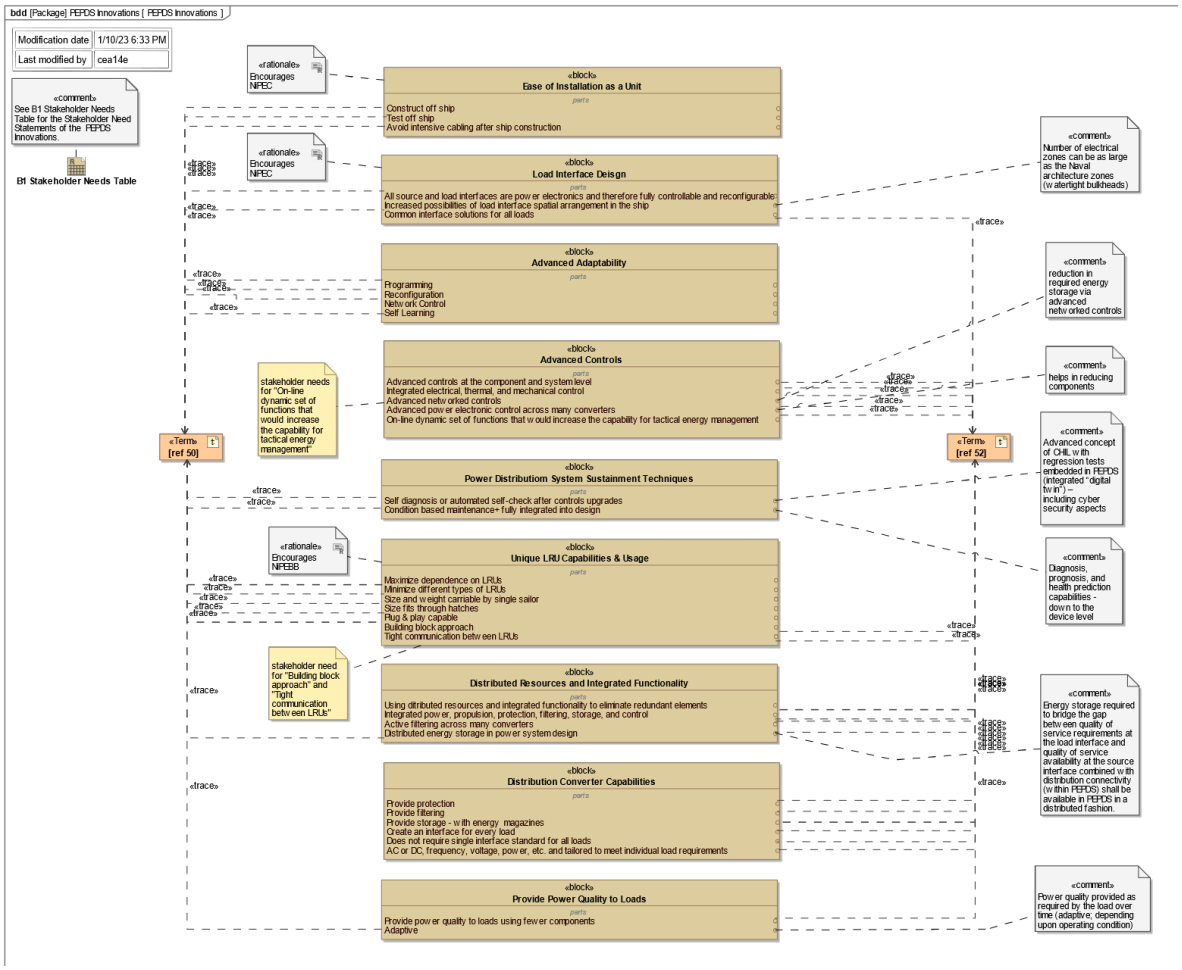


Fig. 85: PEPDS Innovations

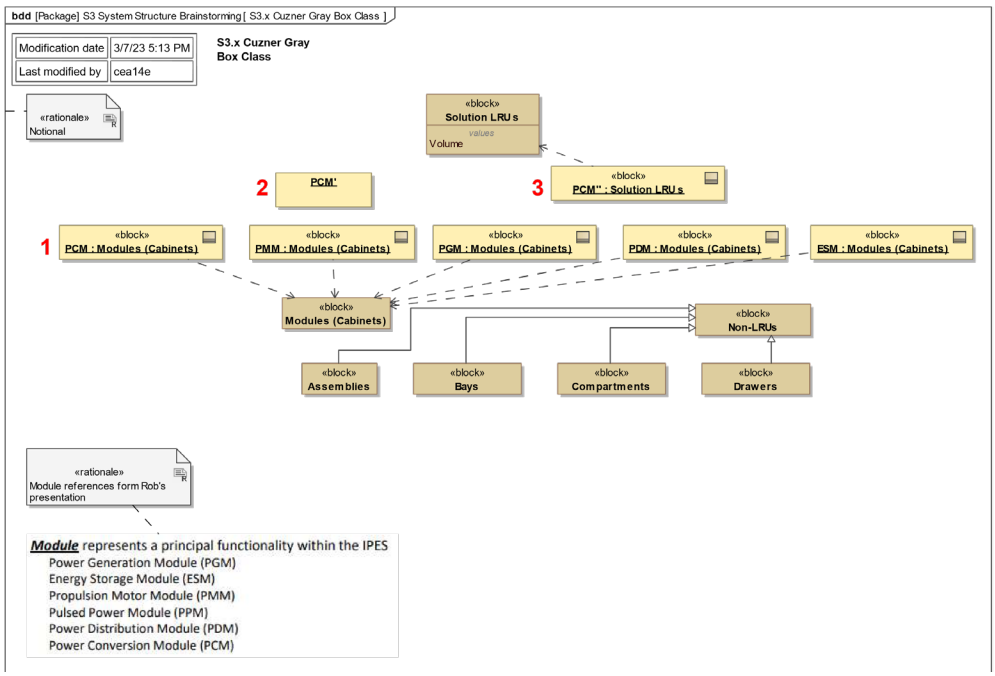


Fig. 86: S3.x Cuzner Gray Box Class

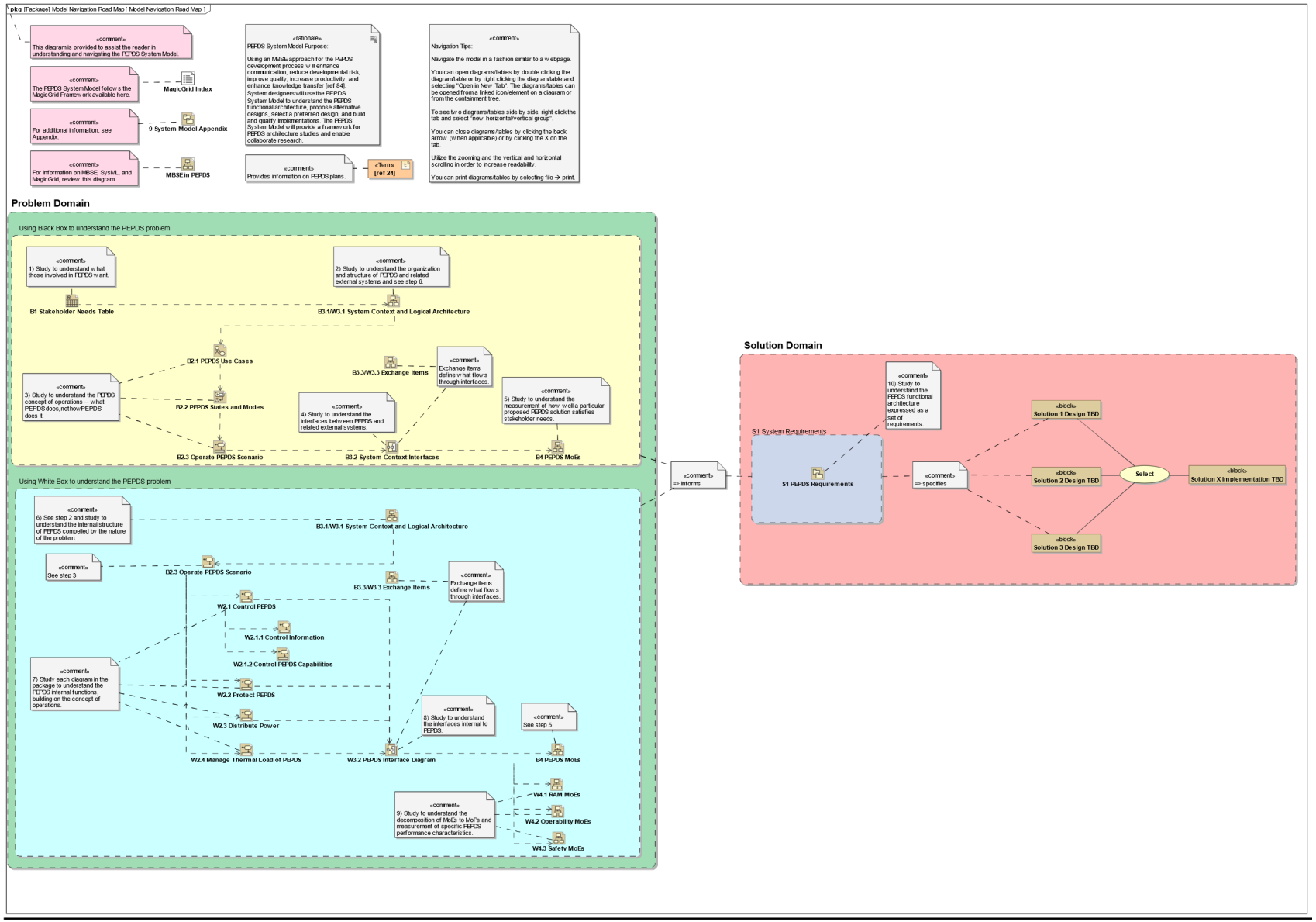


Fig. 87: Model Navigation Road Map

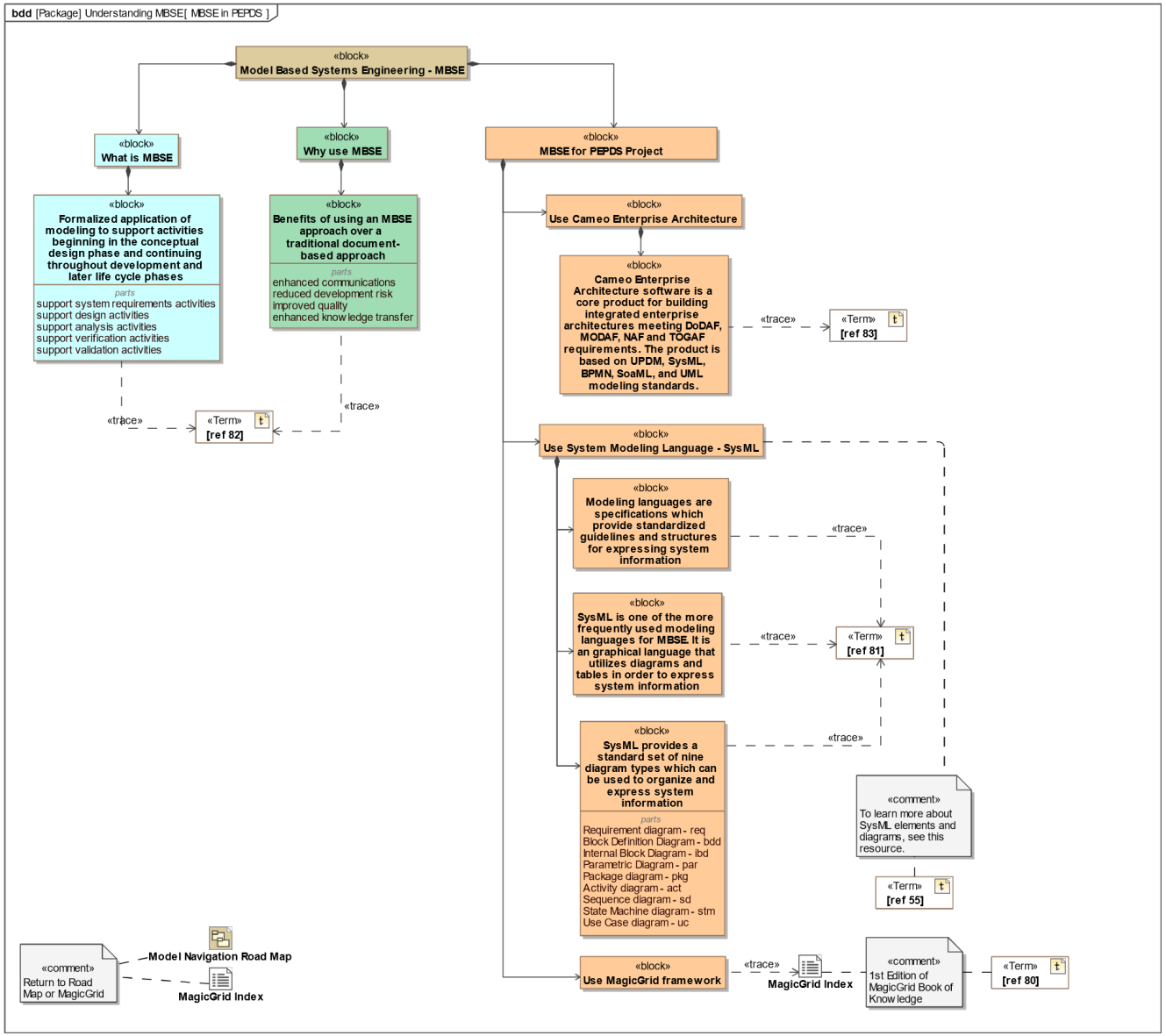


Fig. 88: MBSE in PEPDS

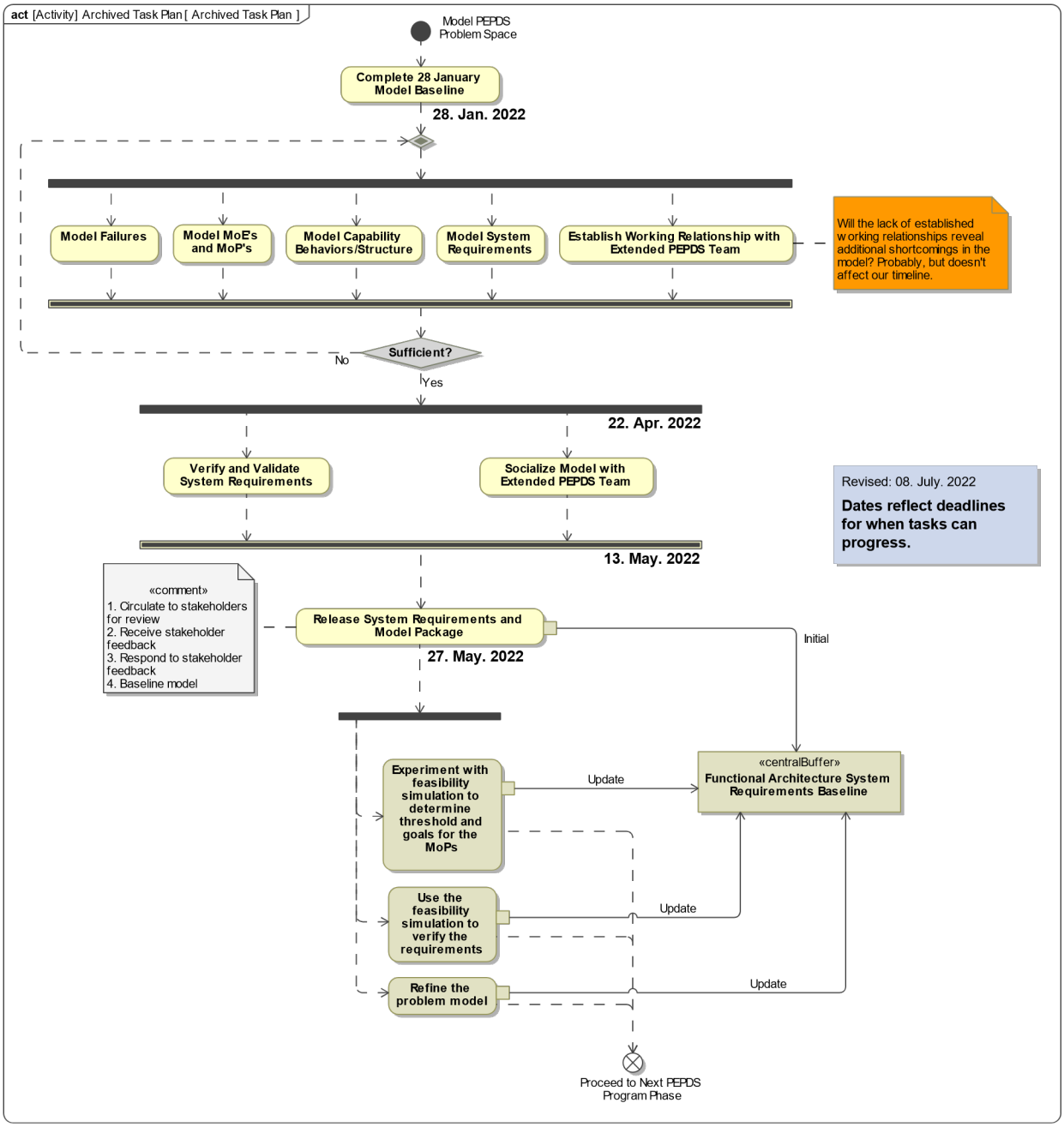


Fig. 89: Archived Task Plan

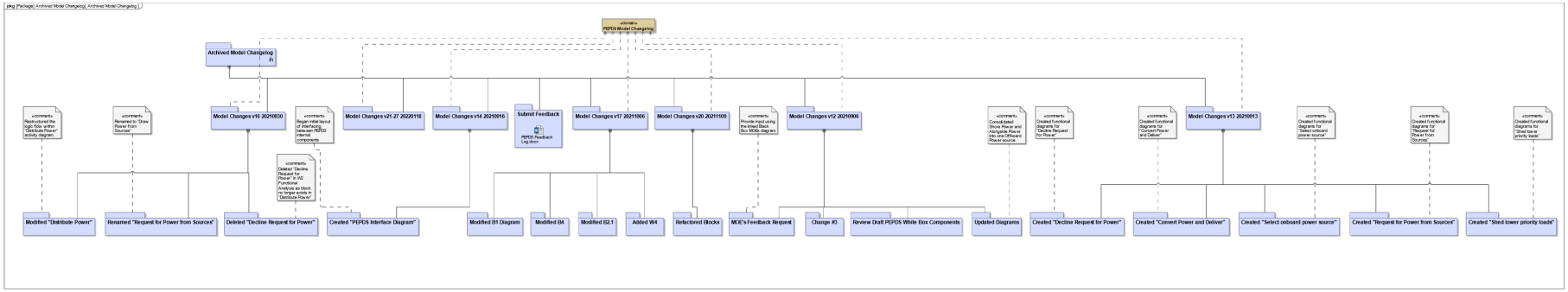
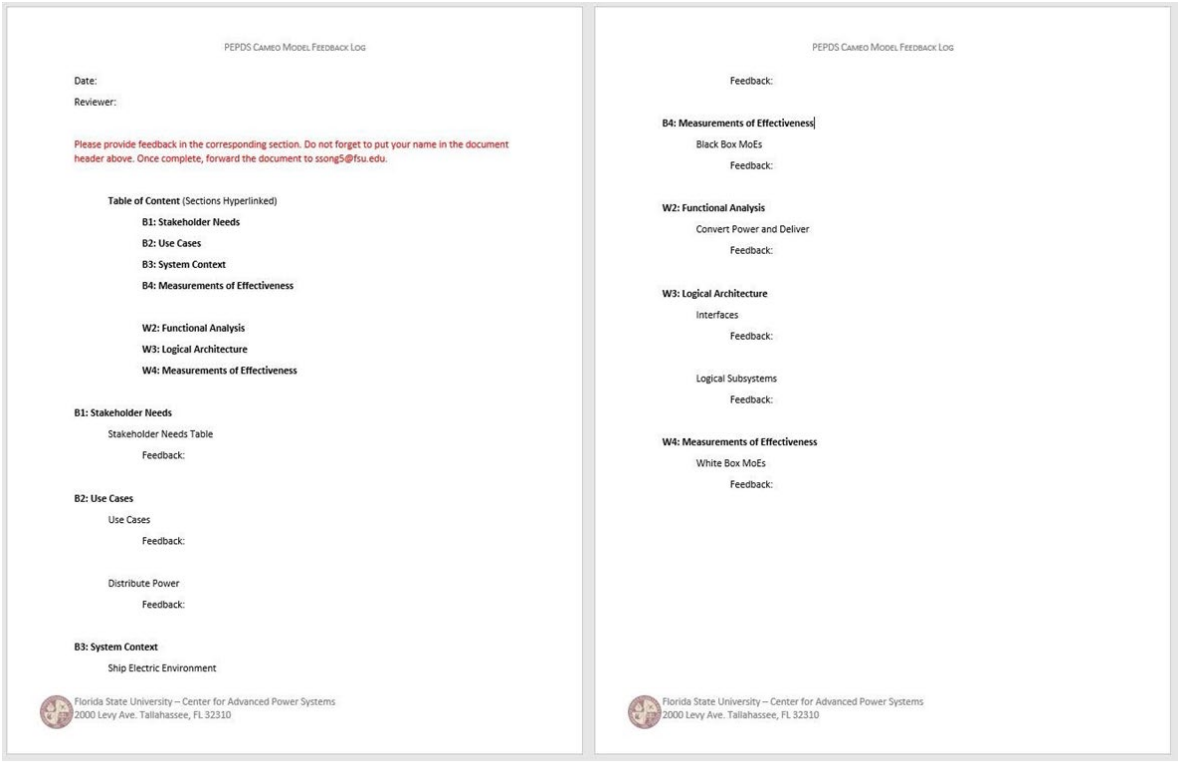


Fig. 90: Archived Model Changelog



PEPDS Cameo Model Feedback Log

Date:

Reviewer:

Please provide feedback in the corresponding section. Do not forget to put your name in the document header above. Once complete, forward the document to ssong5@fsu.edu.

Table of Content (Sections Hyperlinked)

- **B1: Stakeholder Needs**
- **B2: Use Cases**
- **B3: System Context**
- **B4: Measurements of Effectiveness**
- **W2: Functional Analysis**
- **W3: Logical Architecture**
- **W4: Measurements of Effectiveness**

B1: Stakeholder Needs

Stakeholder Needs Table

Feedback:

B2: Use Cases

Use Cases

Feedback:

Distribute Power

Feedback:

B3: System Context

Ship Electric Environment

Florida State University – Center for Advanced Power Systems
2000 Levy Ave. Tallahassee, FL 32310

PEPDS Cameo Model Feedback Log

Feedback:

B4: Measurements of Effectiveness

Black Box MoEs

Feedback:

W2: Functional Analysis

Convert Power and Deliver

Feedback:

W3: Logical Architecture

Interfaces

Feedback:

Logical Subsystems

Feedback:

W4: Measurements of Effectiveness

White Box MoEs

Feedback:

Florida State University – Center for Advanced Power Systems
2000 Levy Ave. Tallahassee, FL 32310

Fig. 91: Archived Feedback Log

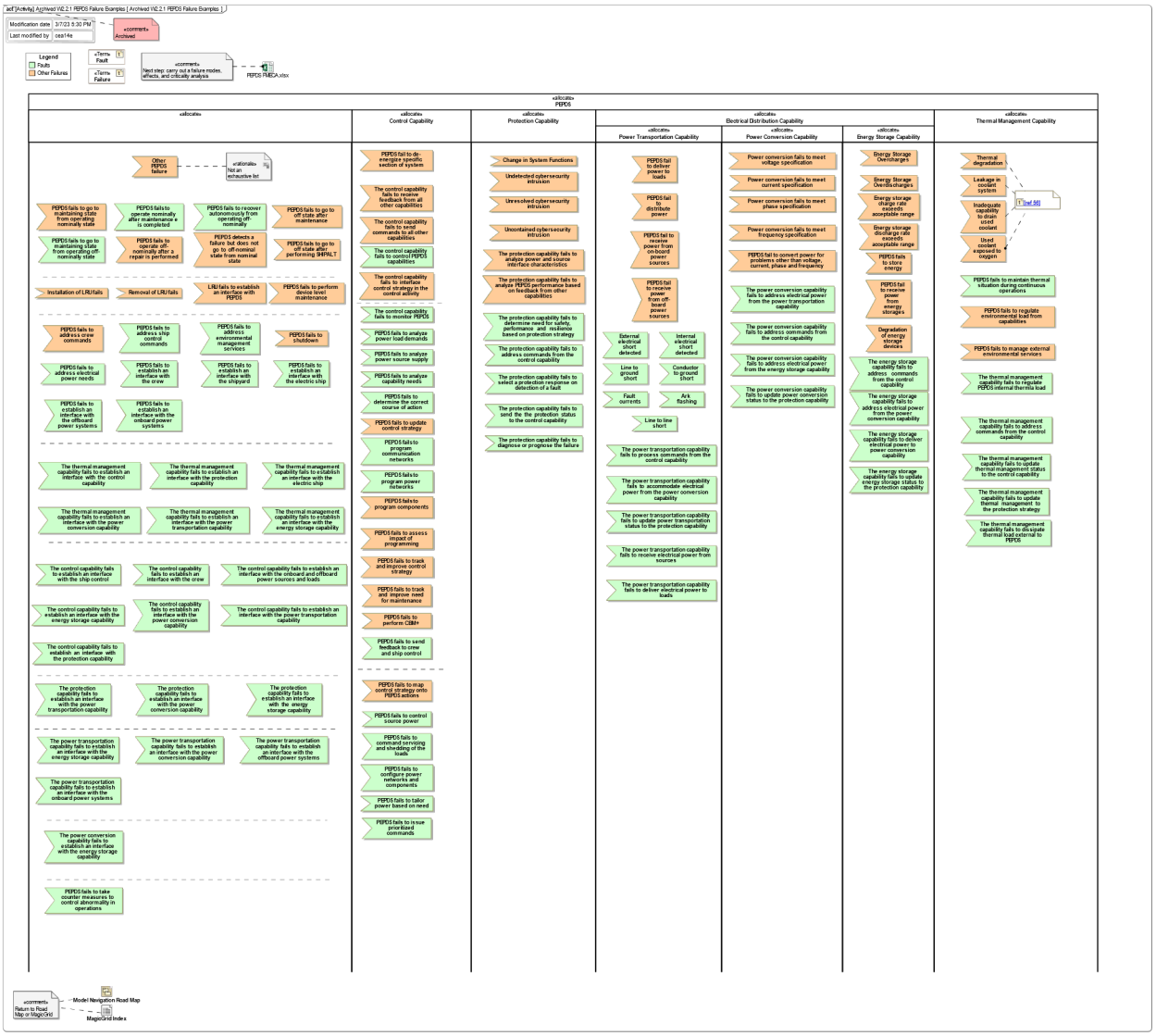


Fig. 92: Archived W2.2.1 PEPDS Failure Examples

11.4 MagicGrid® Index Package Diagrams

11.4.1 MagicGrid® Index Package Diagrams for Problem Domain Requirements

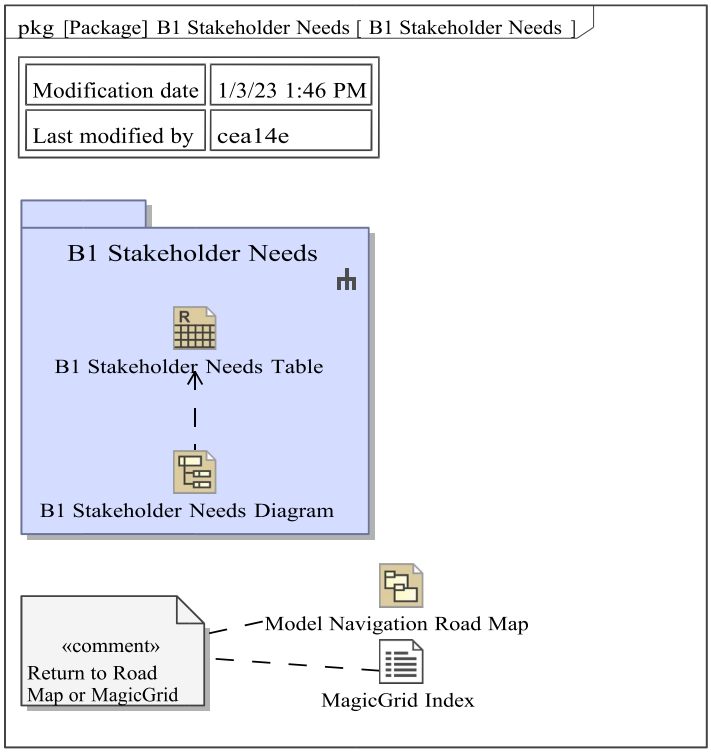


Fig. 93: B1 Stakeholder Needs Package Diagram

11.4.2 MagicGrid® Index Package Diagrams for Problem Domain Behavior

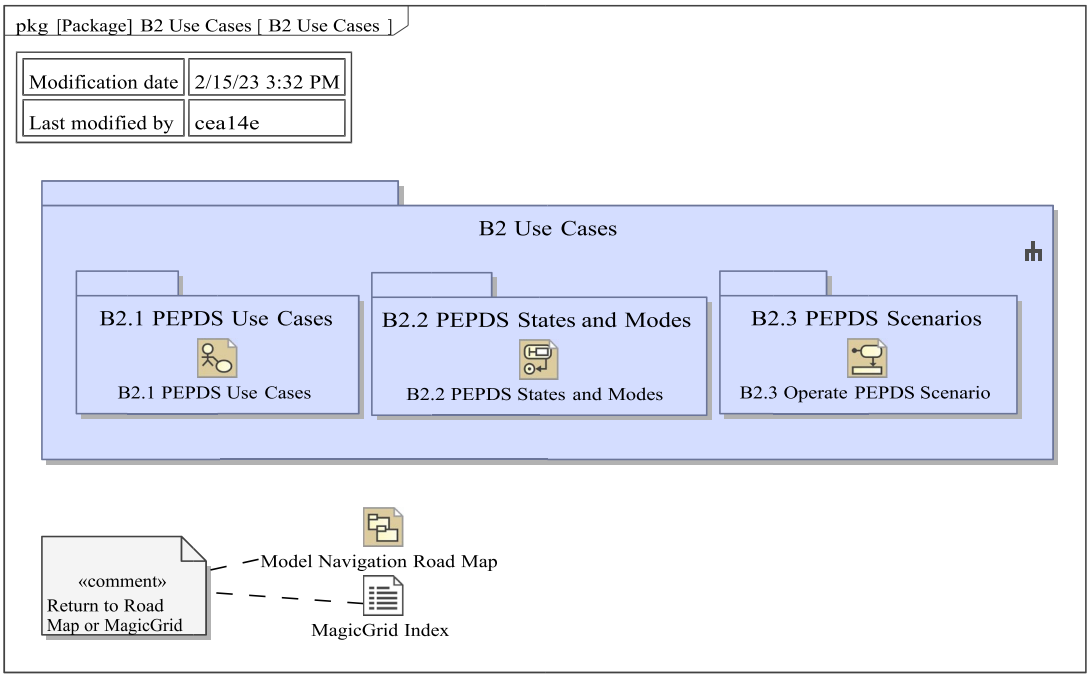


Fig. 94: B2 Use Cases Package Diagram

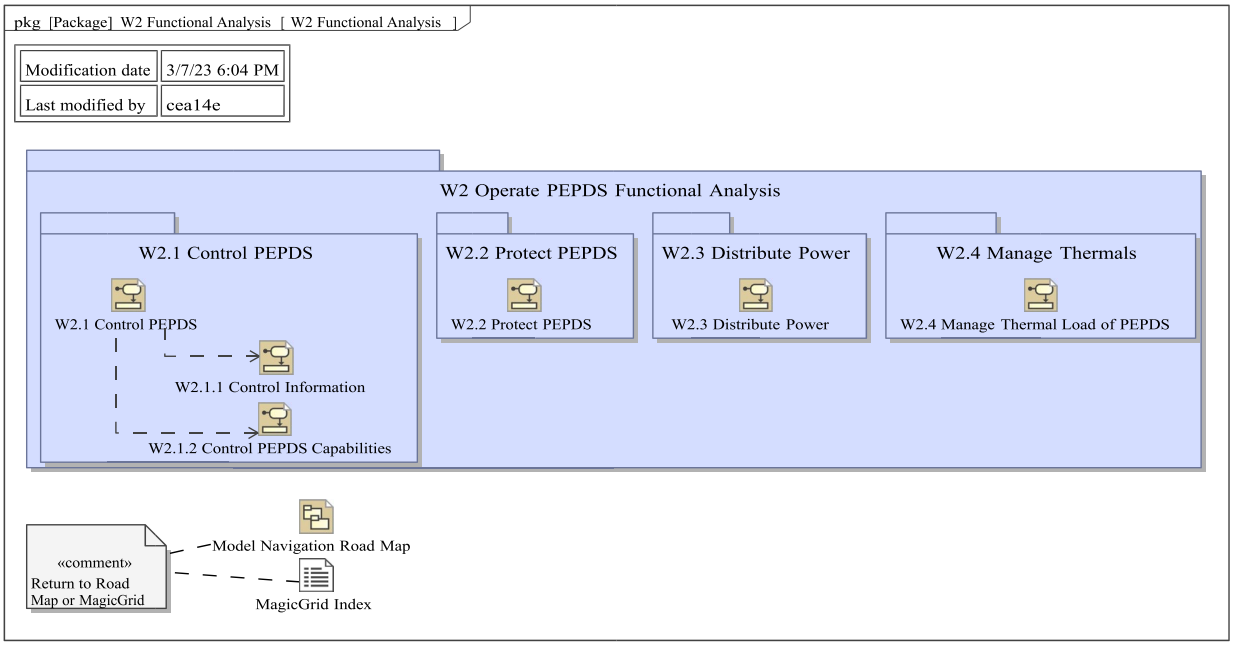


Fig. 95: W2 Functional Analysis Package Diagram

11.4.3 MagicGrid® Index Package Diagrams for Problem Domain Structure

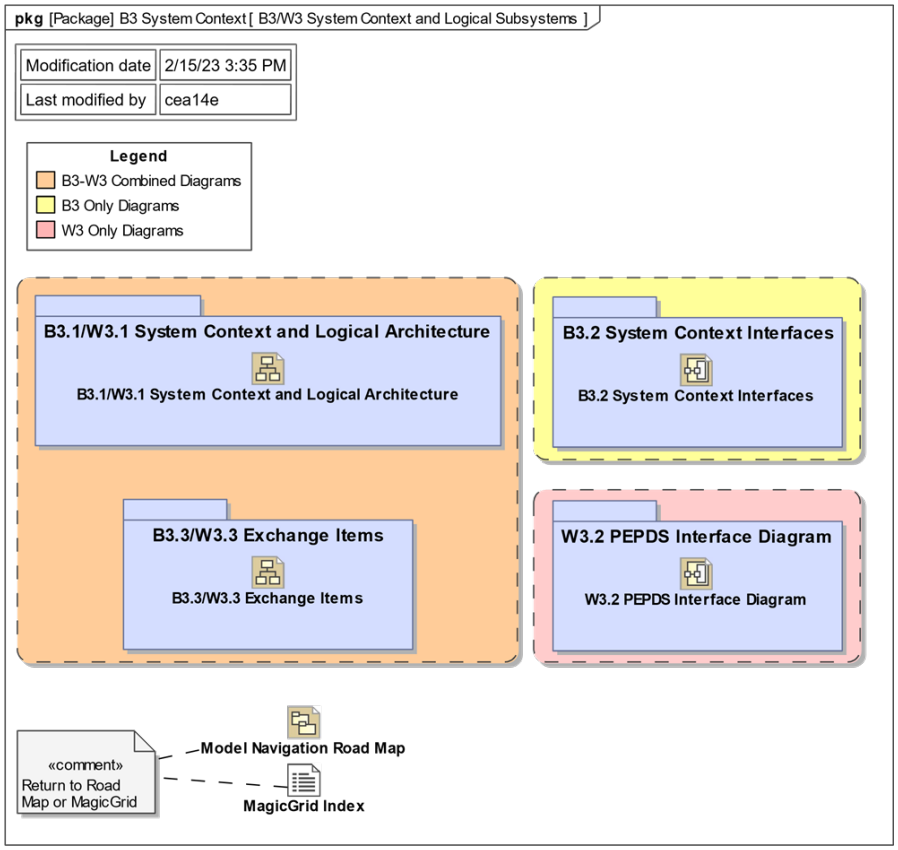


Fig. 96: B3 System Context and Logical Architecture Subsystems

11.4.4 MagicGrid® Index Package Diagrams for Problem Domain Parameters

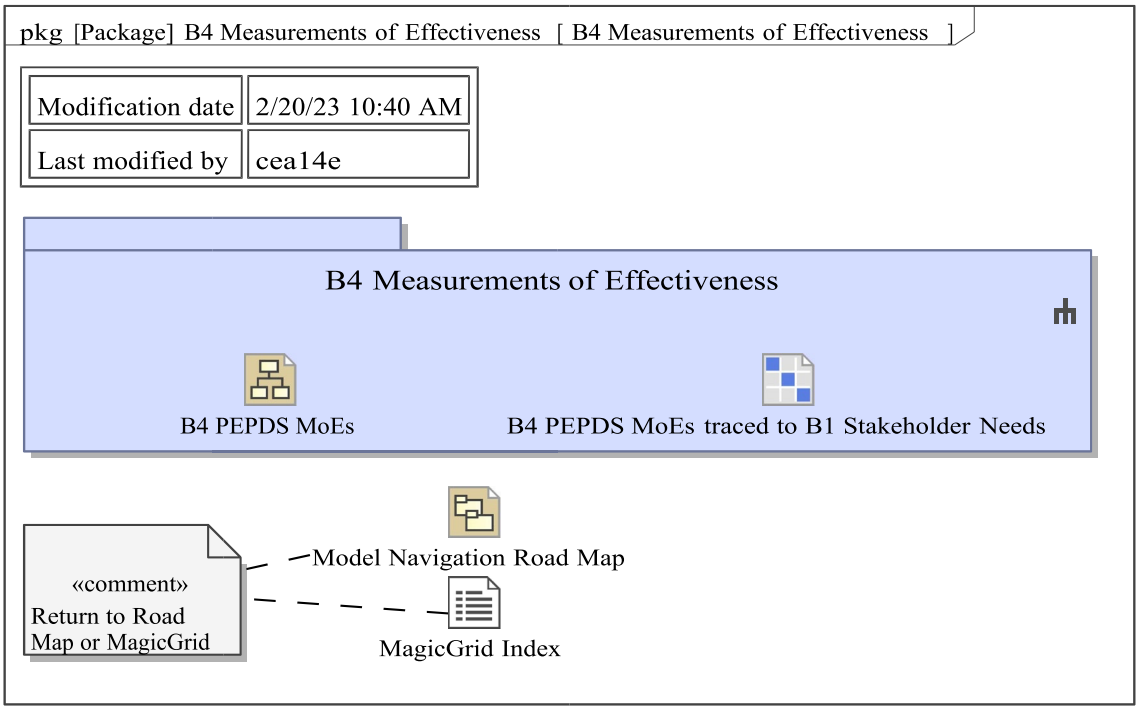


Fig. 97: B4 Measurements of Effectiveness Package Diagram

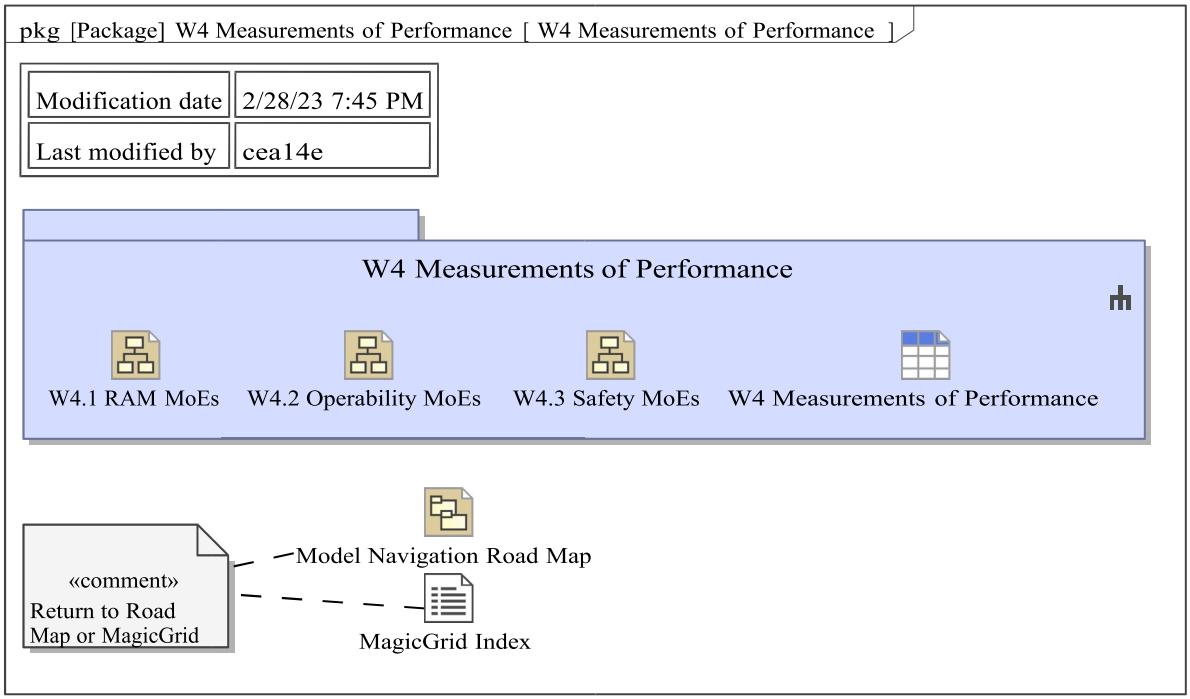


Fig. 98: W4 Measurements of Performance Package Diagram

11.4.5 MagicGrid® Index Package Diagrams for Solution Domain Requirements

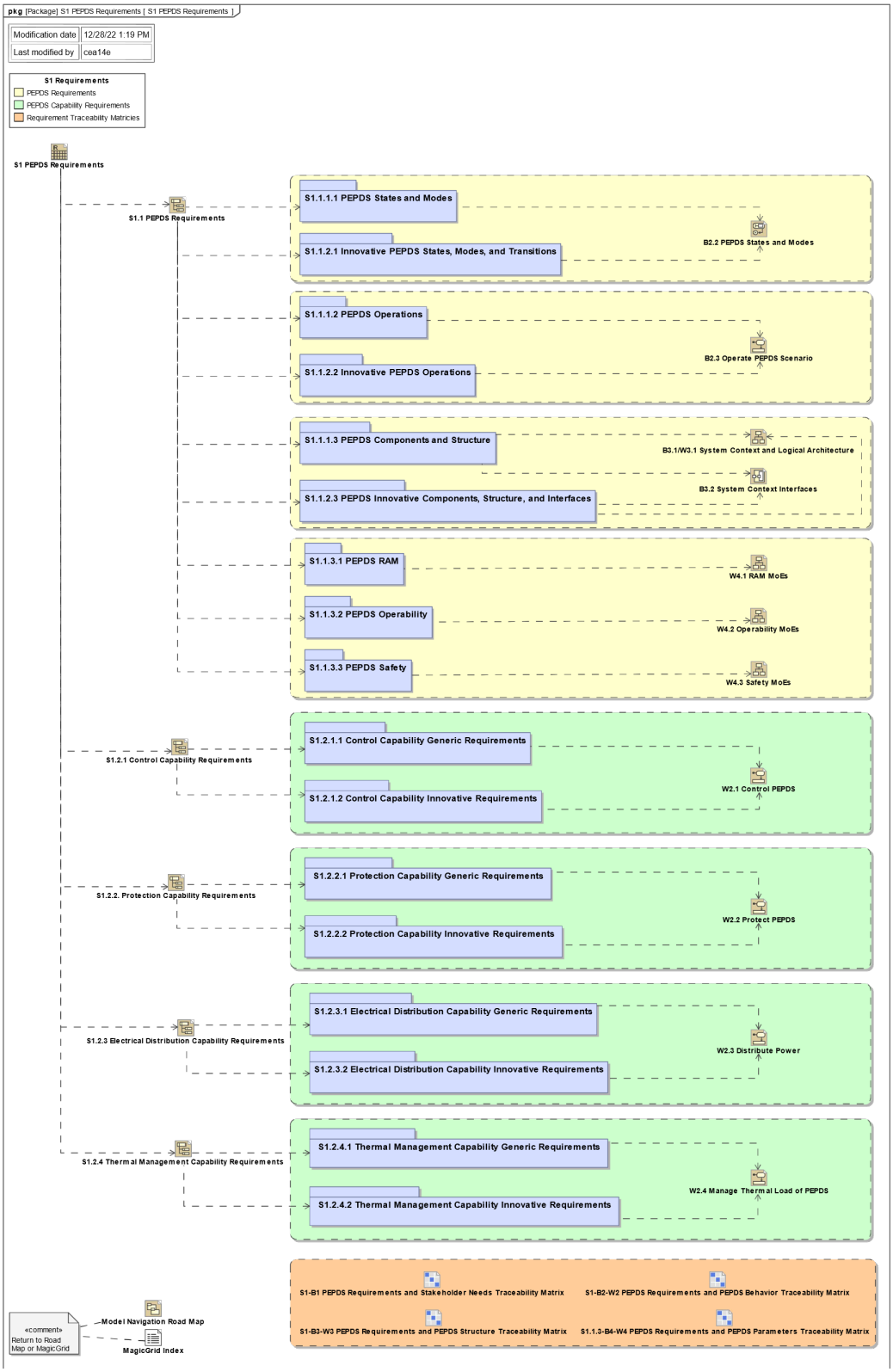


Fig. 99: S1 PEPDS Requirements Package Diagram

11.4.6 MagicGrid® Index Package Diagrams for System Model Appendix

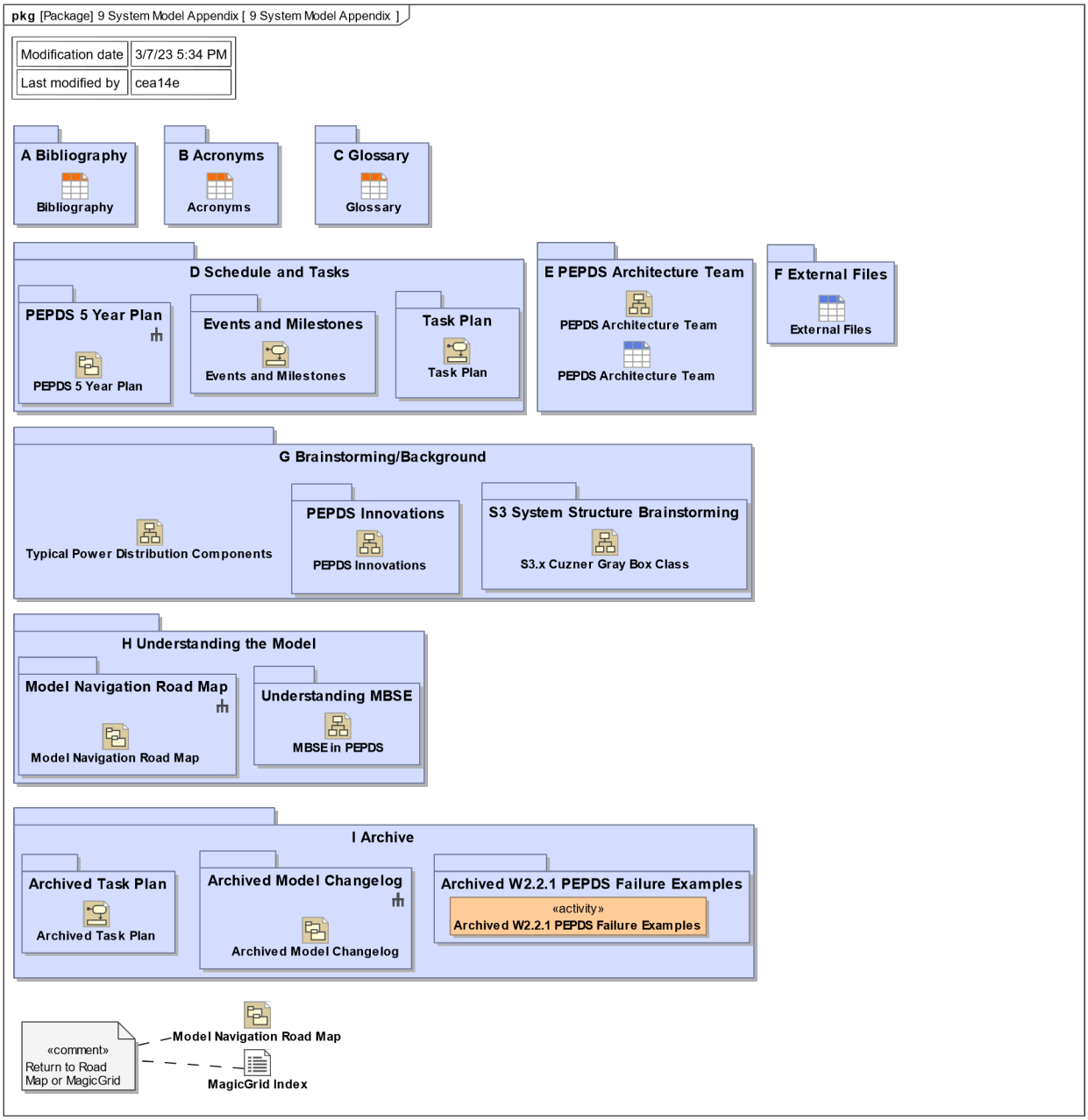


Fig. 100: System Model Appendix Package Diagram