Plant Systems Design System MBSE Approach Case Study

developed by

SPEC Innovations 2022

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Why ASME Took a Systems Approach?

American Society of Mechanical Engineers (ASME), "promotes the art, science and practice of multidisciplinary engineering and allied sciences around the globe." ASME is formed by volunteers to develop compatible standards. More than 5500 dedicated volunteers — engineers, scientists, government officials, etc. — contribute their technical expertise to develop voluntary standards that enhance public safety, health, and quality of life, as well as facilitate innovation, trade, and competitiveness. ASME standards are accepted for use in more than 100 countries around the world.

Generally, ASME standards are not system-based. Ralph Hill took the lead in developing the first systems-based standard for plant systems design. Mr. Hill has been volunteering at ASME for 45 years. ASME develops standards and guidance documents for the design, construction and operation of plants and facilities to ensure safety and quality. However, Mr. Hill recognized a missing element in the system. There are no standards addressing design activities that produce the design and construction specifications, which provide the basis for design and construction addressed by ASME standards. Each design and engineering organization has its own internal procedures, but there is no standard to provide a benchmark to provide assurance of accuracy and quality.

Since the Plant Systems Design standard is systems-based, that makes it processed based as well. Viewing the standard as process-based allows the authors to break design development stages into multiple activities and connect them through inputs and outputs (I/O's) for each process.

Members of the Committee for Plant Systems Design consist of geographically dispersed volunteers across many industries: bio, research and development, oil and gas, etc. The committee identified the need for a model-based systems engineering tool that was cloud-native so that they could simultaneously work together and easily share information. ASME found that the MBSE tool, Innoslate, met these needs.

What Are Their Goals and Objectives?

ASME's goal is to develop a technology-neutral standard for the design of plant systems for nuclear facilities, including power generation; fossil power generation facilities (e.g., coal, natural gas); oil refining; oil and natural gas production; petrochemical; chemical; and hazardous waste plants and facilities. It prioritizes the health and safety of the public, the worker, and the environment.

The Standard provides a framework, including requirements and guidance, for design organizations to:

- Incorporate systems engineering practices and tools with traditional architect engineering design processes, practices, and tools.
- Conduct plant process hazard analysis in the early stages of plant design that (a) advances as the design matures and (b) provides structure to the initial development of a quantitative risk assessment.
- Incorporate risk-informed probabilistic design methodologies with traditional deterministic design methods using reliability and availability targets.

ASME's objectives are:

- Safer, more efficient designs and design alternatives
- More effective requirements management
- Knowledge in how the design affects the entire lifecycle of a plant: design, construction, operation, and decontamination/decommission

The Process of Developing the Standard

1st Year Planning

The focus of the 1st year was detailed planning of the contents of the standard.

Being system-based is a fundamental change for ASME. Being system-based means, it is process-based, another fundamental change. Because it is process-based, a model-based systems engineering tool becomes an ideal platform for promulgating the standard.

The MBSE tool, Innoslate, was chosen for this. They found that cloud-based was necessary to get such a geographically dispersed committee on the same page. Their work needed to be transparent and current and MS Office tools are just not up to the task.

The ASME author volunteers met via zoom to develop the roadmaps used for work breakdown structures, datasheets, block flow diagrams, and N^2 diagrams to integrate activities of each technical area. After which, they entered this information directly into Innoslate to plan and organize parts of the standards.

2nd Year Begin Writing

ASME began writing sections of the standard. Authors are writing sections of the standard directly in Innoslate. They are utilizing the table notation within the tool to ensure proper change control of requirements and I/O's.

Within Innoslate, they developed the *Writer's Guide*.

Within the tool, they created a writing guide for the authors. The guide instructs how to write a good requirement, specific terminology, and how to properly number requirements, along with other instructions. This helps the globally disperse volunteers maintain consistency in writing the different sections of the standard.

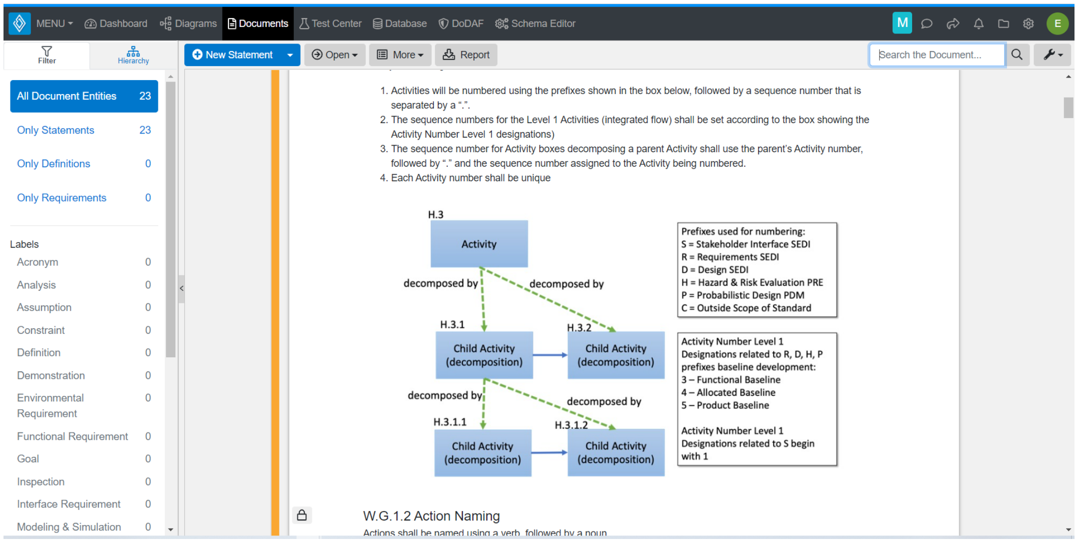

Figure 1 Writer's Guide

The standard has two parts: Part 1, General Principles and Design Development Process. The General Principles part provides scope and applicability. It also describes the boundaries of the design activities that are included. Provides detailed descriptions of the taxonomy and baselines that are used. It also describes licensing, regulatory conformance, occupational health and safety, performance-based design, etc. Design process overviews are provided for the three technical focus areas: systems engineering, risk evaluation, and probabilistic design.

In parallel with writing Part 1, the ASME volunteers began writing Part 2, the Design Development Processes section. This section provides guidance for the three technical focus areas, including methodologies and tools. "This [part] is the heart of the standard" – Mr. Ralph Hill.

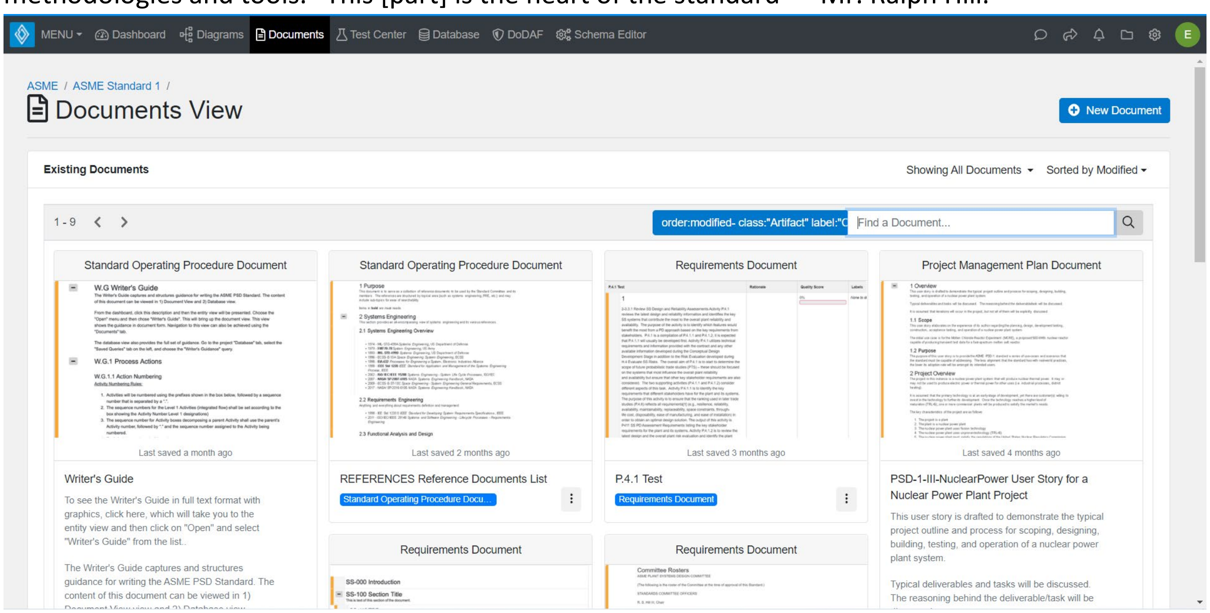

Figure 2 Innoslate Documents View

Part 1 General Principles

(1) **Boundaries** –From *Figure 3*, you can see in the boundary diagram that ASME is influenced by ISO 15288, but many of the ISO process groups are not included in scope. This standard only addresses a subset of the technical processes that is seen outlined in the red box. There are multiple points of entry into this box depicted with the red dash. The red dash can move up and down depending on the contractual point of entry.

ISO 15288 Process Groups	INCOSE Stages (Note 1)	A/E Design Stages (Note 3)	DOE	PSD Baselines (Note 2)
Technical Management Processes	project planning, project assessment & control, decision management, [project] risk management, configuration management, measurement, and quality assurance.			
Technical Processes				
Business/Mission Analysis			Pre-Conceptual Design	Pre-Conceptual Design Package
Stakeholder Needs & Requirements Definition	Concept	Conceptual Design	Conceptual Design	Functional
System Requiremets Definition				
Architecture Definition	Development	Preliminary Design	Preliminary Design	Allocated
Design Definition				
System Analysis				
Implementation		Detail Design	Final Design	Product
Integration				
SSC Verification (Note 4)				
SSC Validation (Note 4)	Production	SSC Construction	Construction	As-Constructed (Note 5)
Plant Verification (Note 4)				
Plant Transition (Note 4)		Plant Construction		
Plant Validation (Note 4)				
Operation	Utilization	Operation	Operation	
Maintenance	Support			
Disposal	Retirement	Decontamination & Decommissioning	Decontamination & Decommissioning	
Agreement Processes	acquisition and supply			
Organizational Project-Enabling Processes	life cycle model management, infrastructure management, portfolio management, human resource management, quality management, and knowledge management			

Figure 3 Boundary Diagram

(2) **Taxonomy** - This standard is meant for a wide-range of plant systems; it was important to define a common taxonomy. The site is the highest level and consists of infrastructure and plant.

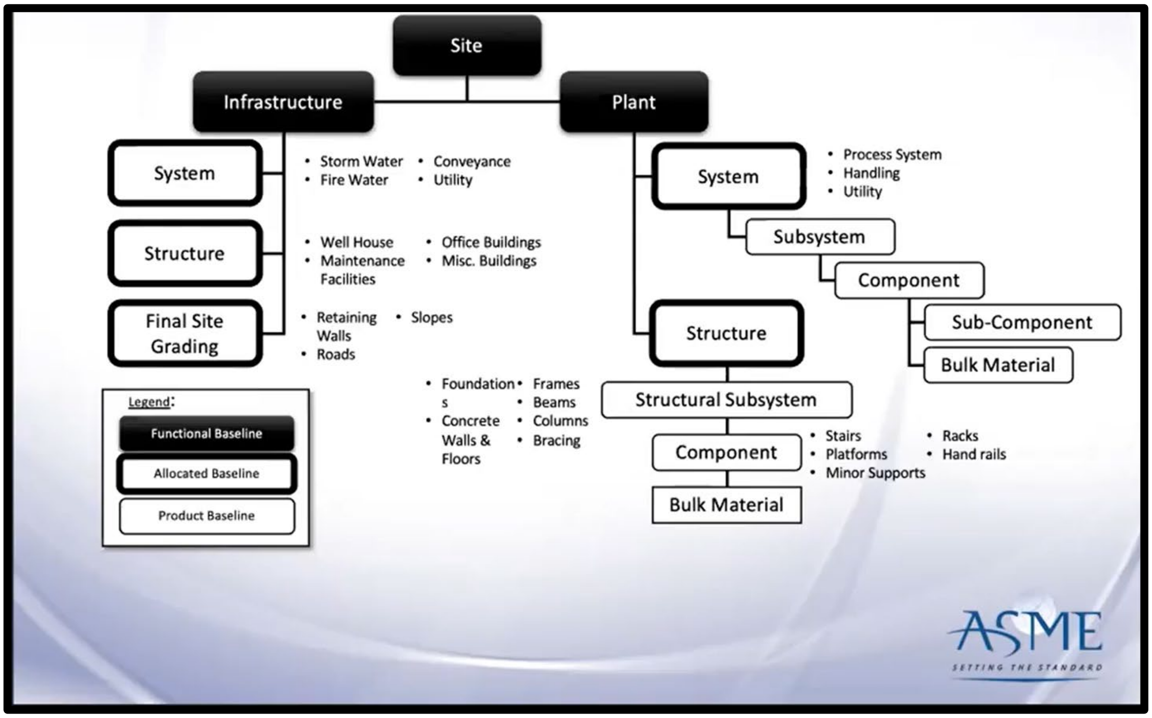

Figure 4 Taxonomy for Plant System Design

(3) **The Plant System Design Process Overview** shows the design development stages; the process begins with the receipt of the contract's technical requirements. Conceptual Design activities are in yellow, Preliminary Designs are in blue, and Detailed Designs are in green. At the conclusion of each design stage, a baseline is established as the basis for the next design stage. These baselines are shown shaded in grey. The detailed design focuses on the product: pumps, valves, pressure tanks, firmware, software, etc.

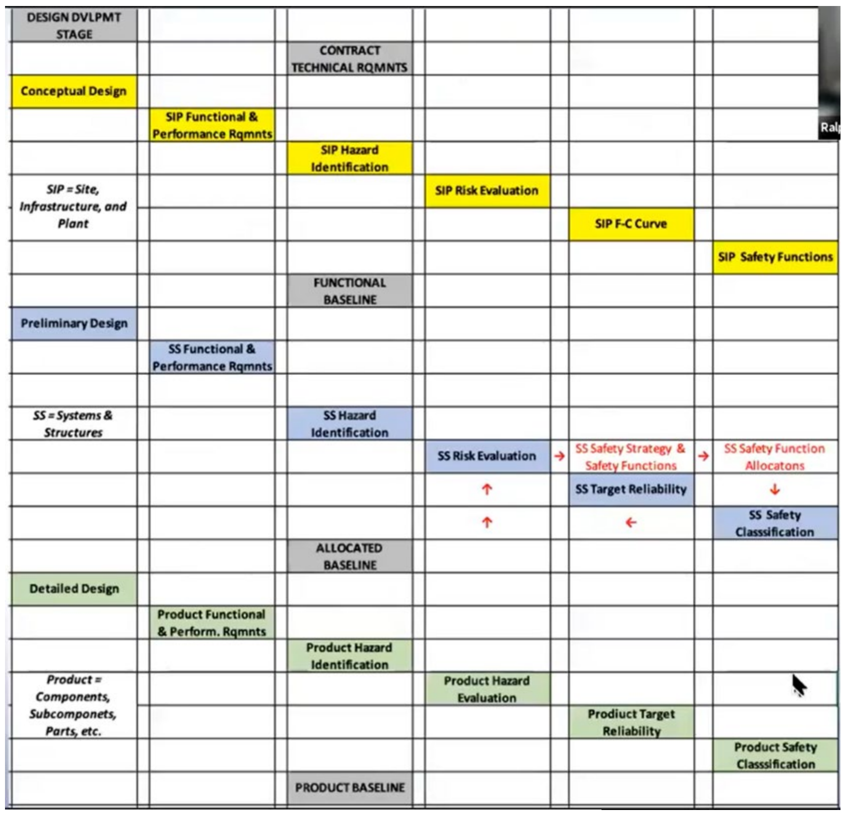

Figure 5 Plant System Design Process Overview

Part 2 Design Development Processes: Methodologies and Tools

Project Dashboard

Each ASME volunteer can tailor their Innoslate project dashboard using widgets. Mr. Hill has his set up to show the comment feed, root diagram, activity feed, and the writer's guide that was mentioned earlier.

Data Entry

The authors enter data in two different ways either by manually adding data into the database through Database View or graphically by adding new actions, inputs/outputs, actors (assets), and more into a diagram.

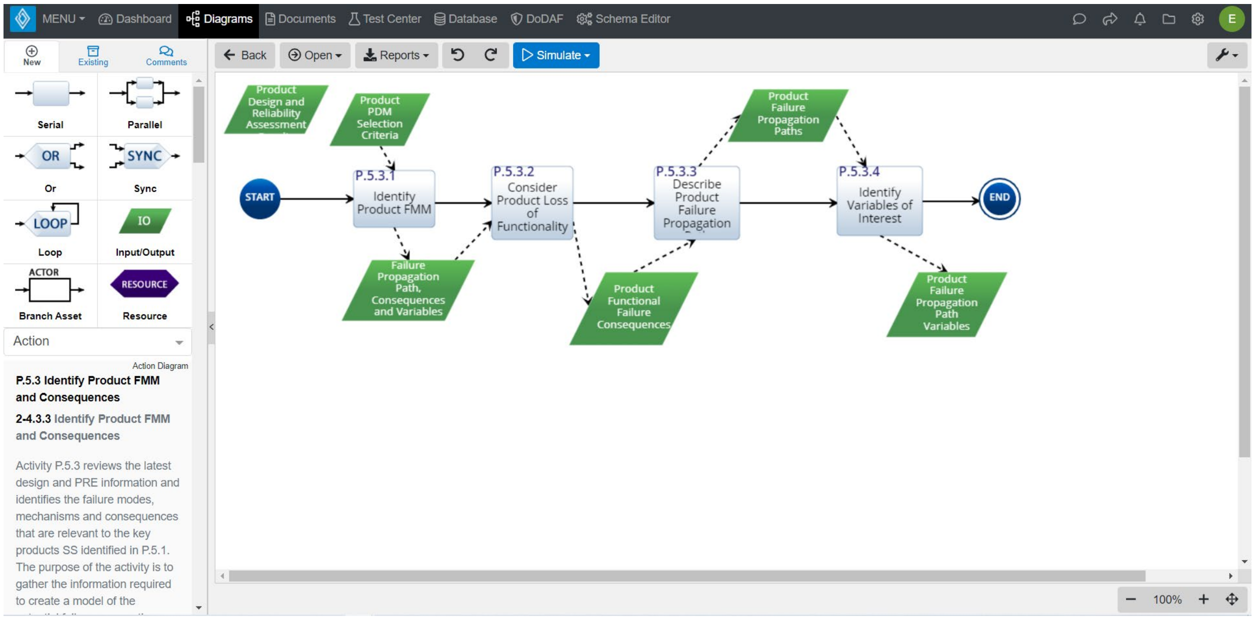

Figure 6 Innoslate Drag and Drop Diagram Functionality

Viewing Data

There are many ways to view the data graphically: Action Diagram, Spider Diagram, N^2 Diagram, Activity Diagram, etc., to give you the most insight. Since Innoslate is a single-source of truth, the data in one diagram can be used to auto-generate many different diagrams. This is demonstrated in Figure 7. You can see that the information in the Root action diagram created a hierarchy diagram, n-squared diagram, and a spider diagram.

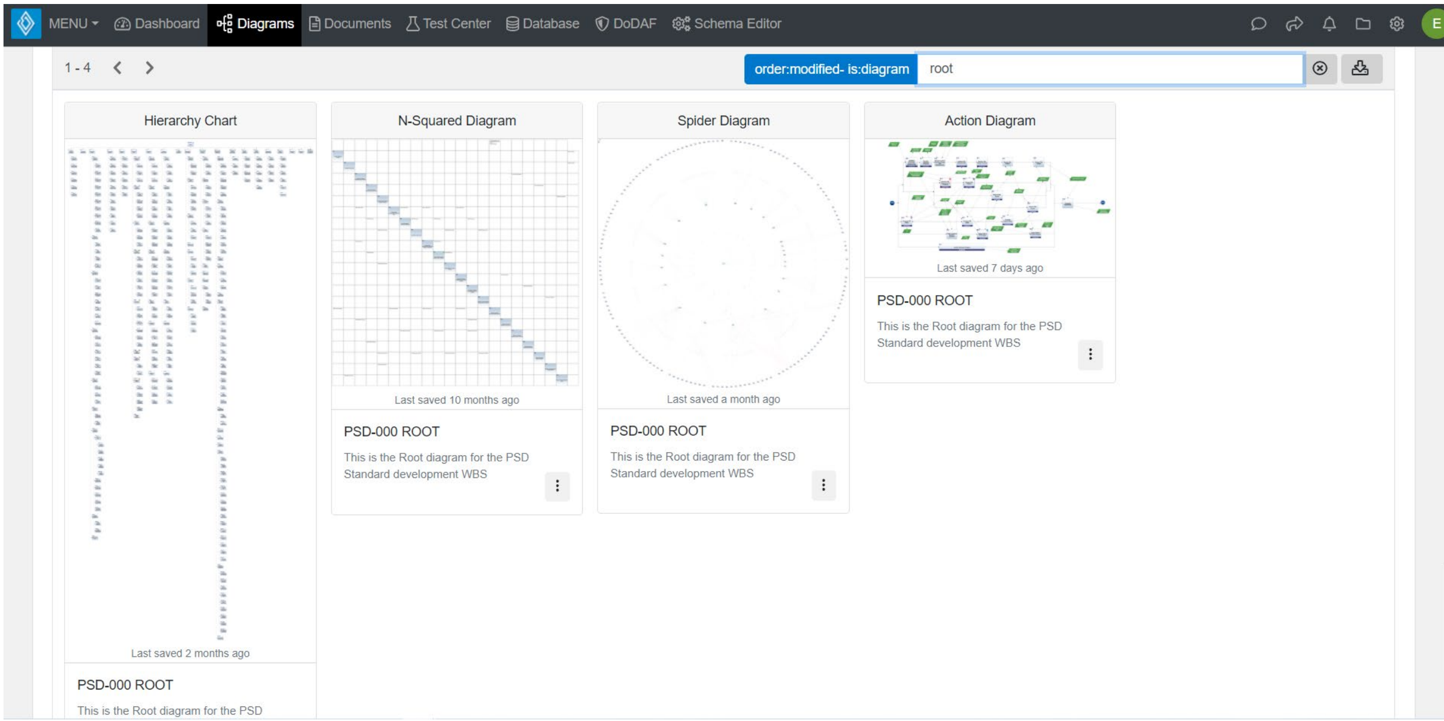

Figure 7 Auto-generated Diagrams: Hierarchy Chart, N-Squared Diagram, Action Diagram, Spider Diagram

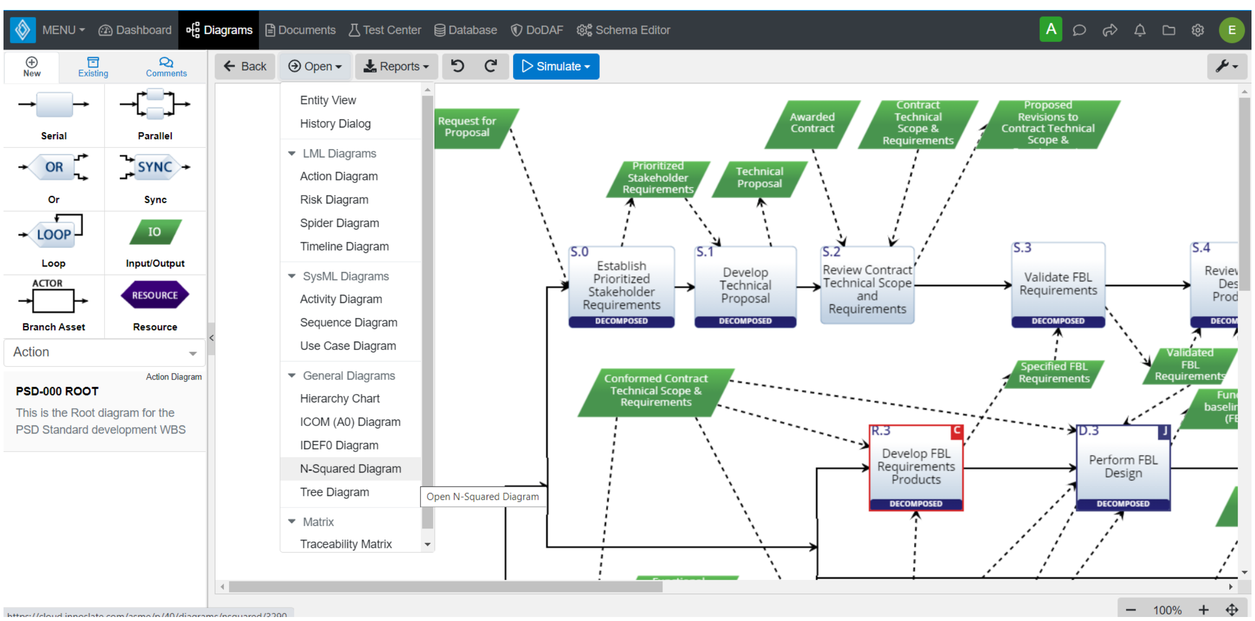

Figure 8 Innoslate Diagrams Allow You to View Multiple Types of Diagrams from the Same Data

There are also many ways to report the data. Innoslate offers different types of reports by content and format.

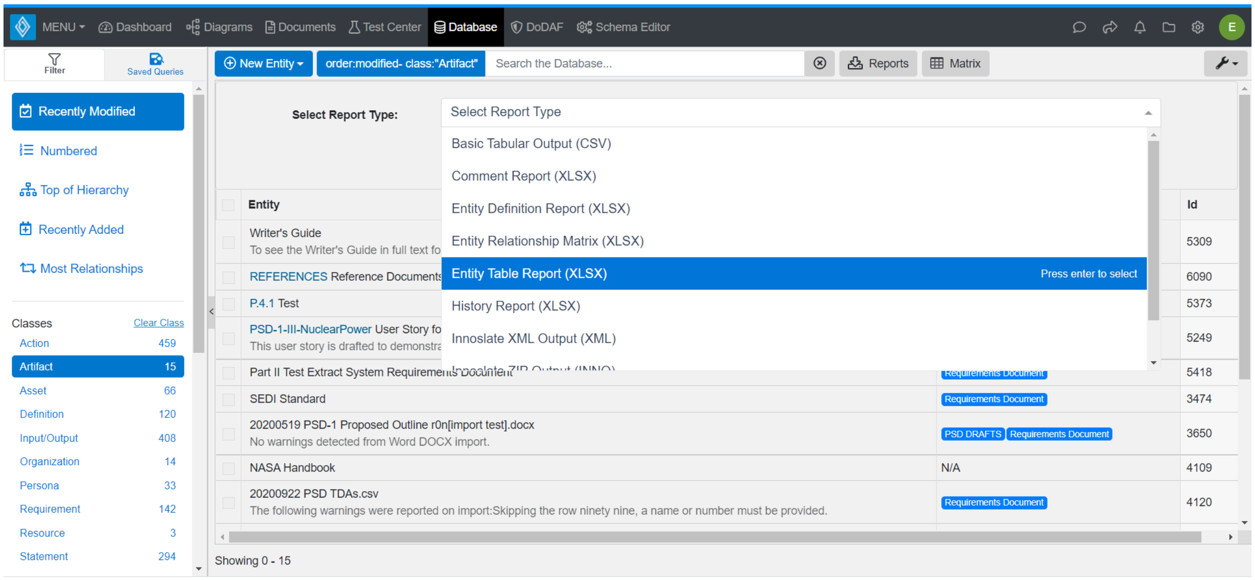

Figure 9 Innoslate Report Options in Database View

Mr. Hill prefers the entity table report. This report allows him to preselect the data fields he wants to see. The entity table report is a table of the selected entities' attributes and optionally its selected related entities.

	Source Entity Attributes		
Class	Number	Name	Description
Action	H.3.1	Identify SIP Hazards and Causes	2-2.2.1 Identify SIP Hazards and Causes
	H.3.1.1	Identify SIP Process H&C	Identify the physical and health hazards and causes
	H.3.1.2	Identify SIP Production H&C	Identify the physical and health hazards and causes
	H.3.1.3	Identify SIP External H&C	Identify the external hazards and causes with
Requirement	H.3.1-1	Generate Lists of SIP Hazards and	The RO shall GENERATE lists of SIP hazards and their
	H.3.1-1.1	Identify SIP Hazards Assumptions	The RO shall IDENTIFY any assumptions, open items
	H.3.1-2	Compilation of SIP Event Hazards and	The RO shall COMPILE the lists of event consequences

Figure 10 Entity Table Reported Generated in Innoslate

Mr. Hill - "As far as we know this is the first project to promulgate a standard using an MBSE tool."

SPEC Innovations is proud that ASME has chosen Innoslate to develop this important standard for plant systems design and is looking forward to viewing the finished product.

About Mr. Ralph Hill

ASME Fellow
Chair, ASME Plant Systems Design Standard Committee

Although retired, Ralph continues his volunteer activities in support of ASME codes and standards. He has been actively involved as a contributor and a leader in the promulgation of ASME nuclear codes and standards for over 40 years. He is an ASME Fellow and recipient of several ASME honors and awards. Ralph is the current Chair and champion for the development of the new ASME Plant Systems Design standard. He is actively involved in bringing risk-informed probabilistic design methods into the ASME Code as well as initiatives to support both advanced and next-generation nuclear reactors.