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ARTIFICIAL INTELLIGENCE FOR MODEL-BASED SYSTEMS ENGINEERING - AIM

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08/13/25

U.S. DEPARTMENT of ENERGY | NNSA National Nuclear Security Administration

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SAND2025-09606PE

ABSTRACT

- In the rapidly evolving landscape of systems engineering, the integration of Artificial Intelligence (AI) with Model-Based Systems Engineering (MBSE) offers unprecedented opportunities for enhancing system design, analysis, and validation.
- This presentation explores the innovative use of MagicDraw CAMEO as a robust MBSE platform, showcasing its capabilities in facilitating complex system modeling through the application of Systems Modeling Language (SysML).
- We will introduce an embedded AI Graphical User Interface (GUI) designed to interpret user prompts and generate insightful outputs in SysML

MODEL-BASED SYSTEMS ENGINEERING OVERVIEW

The application of digital tools to effectively allocate and manage requirements, integrate design, conduct analysis, and perform qualification, verification, and validation throughout the entire product lifecycle.

Three Pillars of MBSE

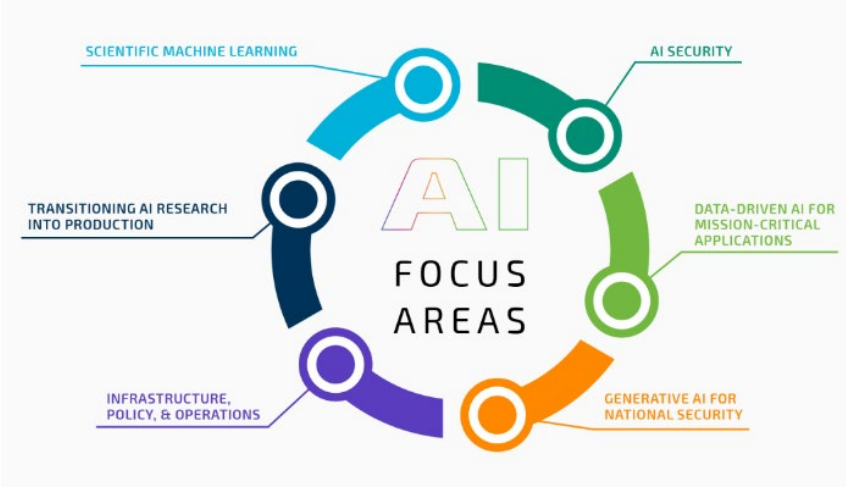
Modeling Language

Modeling Methods

Modeling Tools

MOTIVATION / ROLE OF AI IN MBSE

- The scope of work at Sandia National Labs has expanded in recent years. There is a demand for Systems Engineering application. We need to be more efficient without reducing quality.
- The integration of AI into Model-Based Systems Engineering at Sandia National Laboratories aims to achieve "More Systems Engineering with Less."
  - increasing accessibility to system data
  - improving accuracy and efficiency in system model validation
  - improving efficiency in system architecture generation and creation



AIM PROJECT OVERVIEW

Objectives

- To provide world class systems engineering enabled through the integration and utilization of Model Based Systems Engineering (MBSE) and Artificial Intelligence (AI)
- To provide seamless interaction between MagicDraw users and AI

Scope

- Focus on interpretation of SysML MBSE Models
- Process SysML documents pertaining to modeling methodology and model review
- Process project-level and program-level documents leveraging specific data for enhanced modeling

Key Components

- Graphical User Interface embedded in MagicDraw
- Interface to on-premises Large Language Model (LLM)
- Local Vector Database
- Interface between MBSE Data and Vector Database

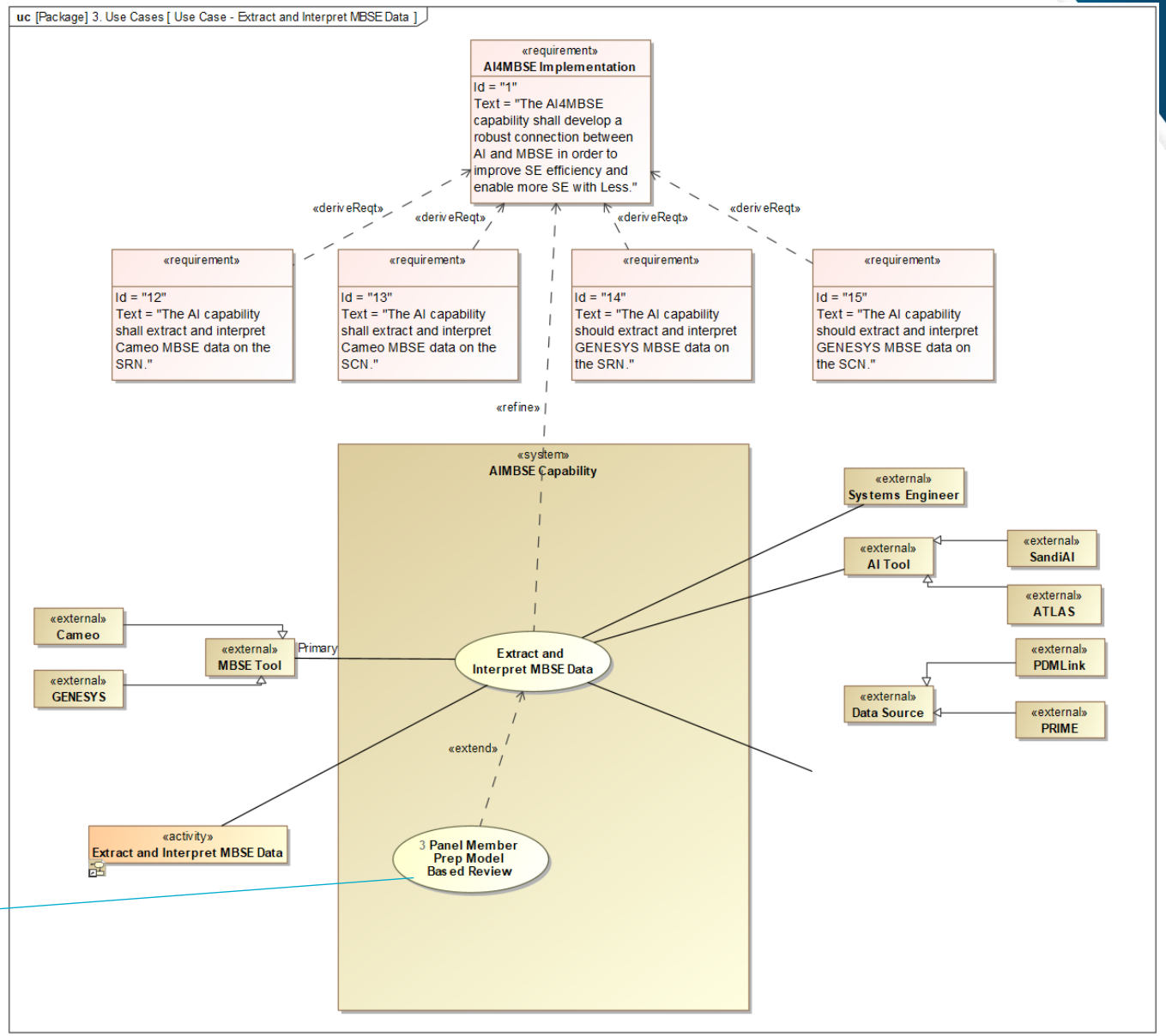
Note: We have explored integrating AI into GENESYS in the past but have focused on completing the MagicDraw integration for this FY

AIM USE CASES

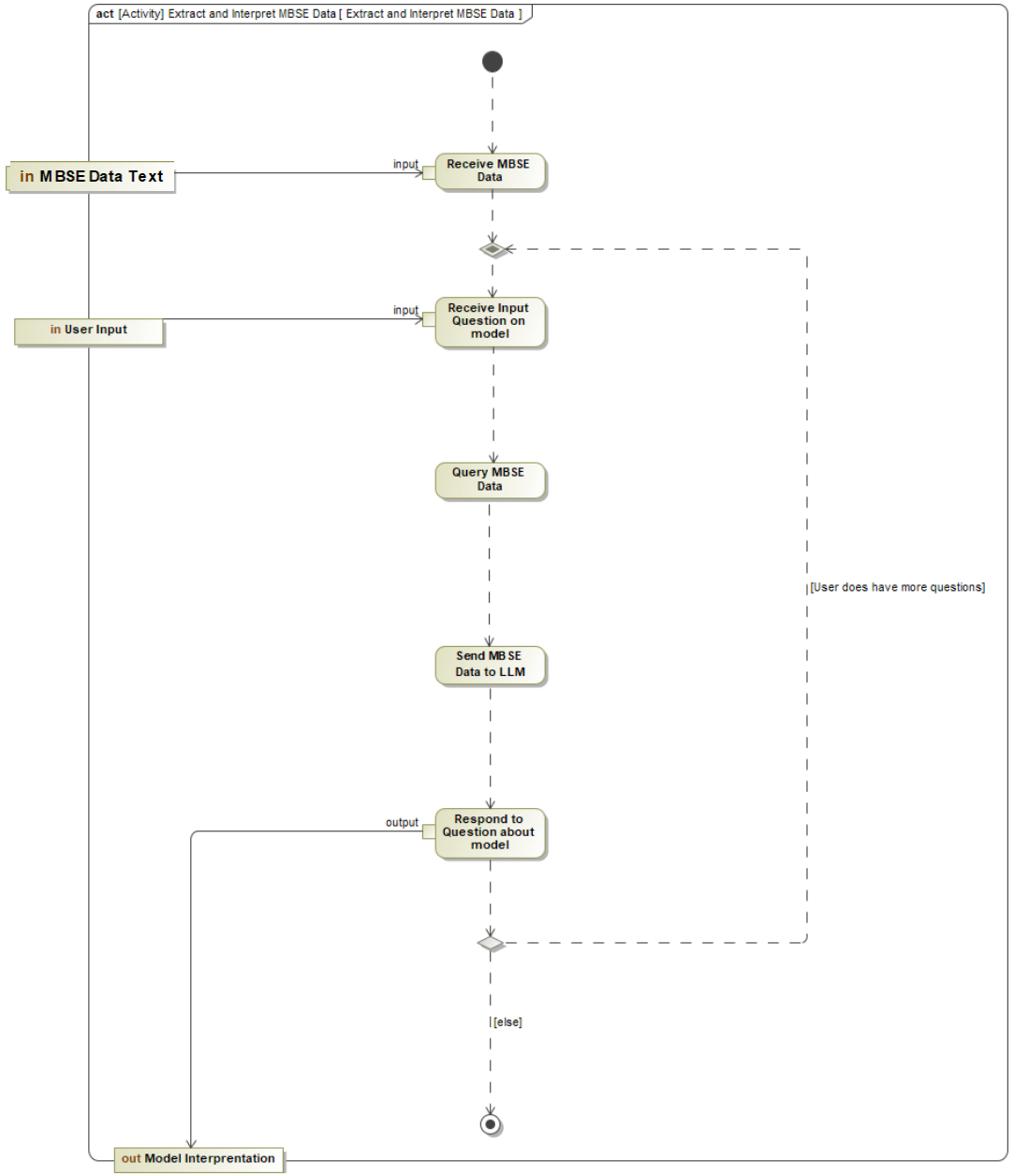
USE CASE #1 – MBSE INTERPRETATION ASSISTANT

- First desire is to interrogate MBSE data using AI
  - Enables **increased data accessibility**
  - **Improved SE efficiency**

Out-standing Issue	Panel Prep takes weeks. It is a manual process that involves sifting through large amounts of information while panel members have other jobs.
Pre Condition	Panel members prepare themselves manually.
Post Condition	Panel members utilize AI to interrogate MBSE system or component architectures to quickly prepare themselves.

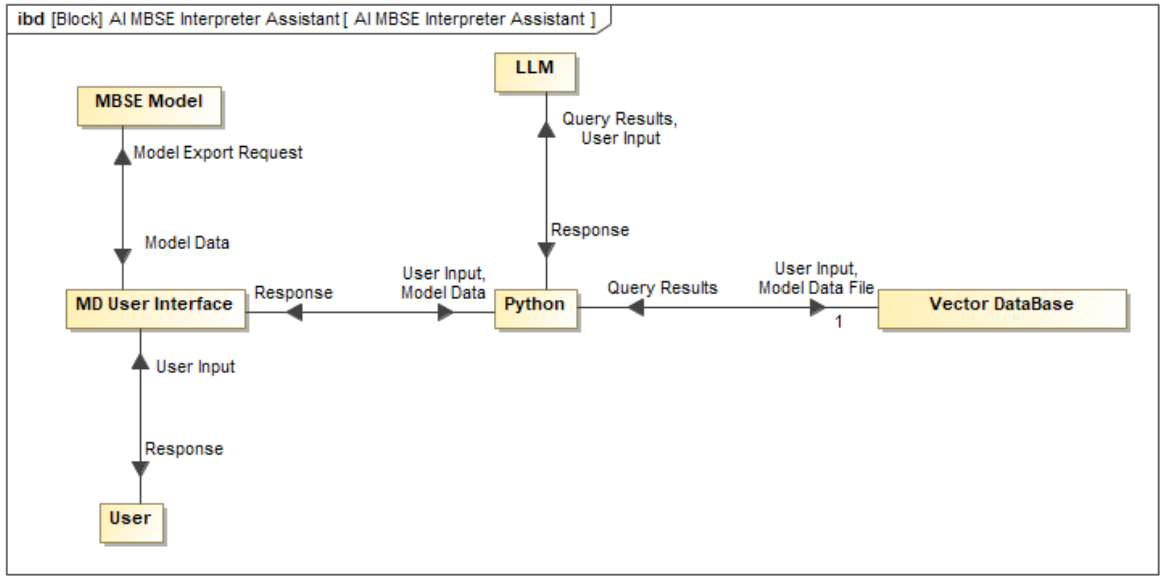


INFRASTRUCTURE/IMPLEMENTATION - INTERPRETER



Example Prompts:

1. What evidence exists for this requirement?
2. What upcoming testing do we have for these requirements?
3. Describe to me the Nuclear Safety Theme.

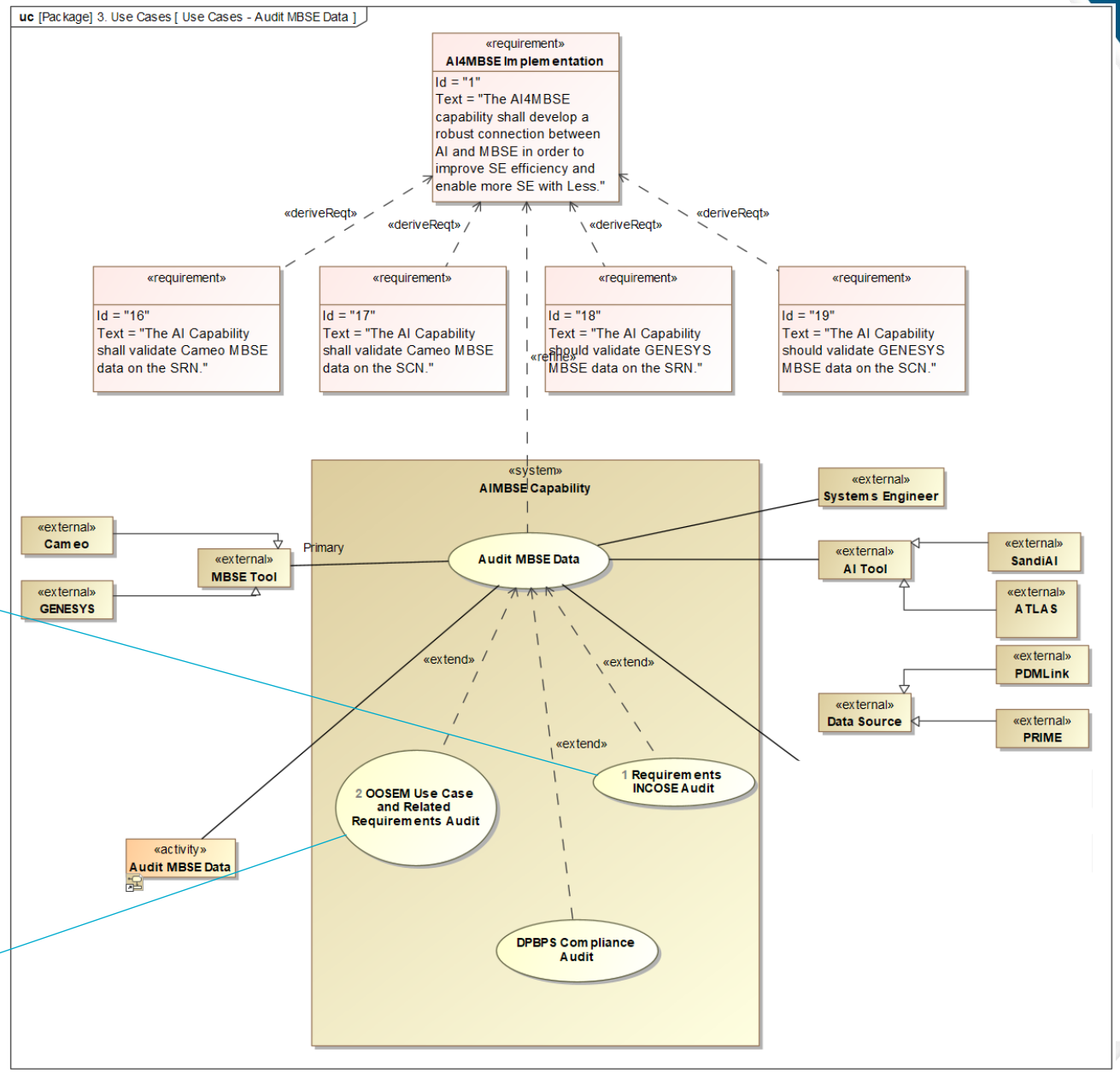


USE CASE #2 – MBSE VALIDATION ASSISTANT

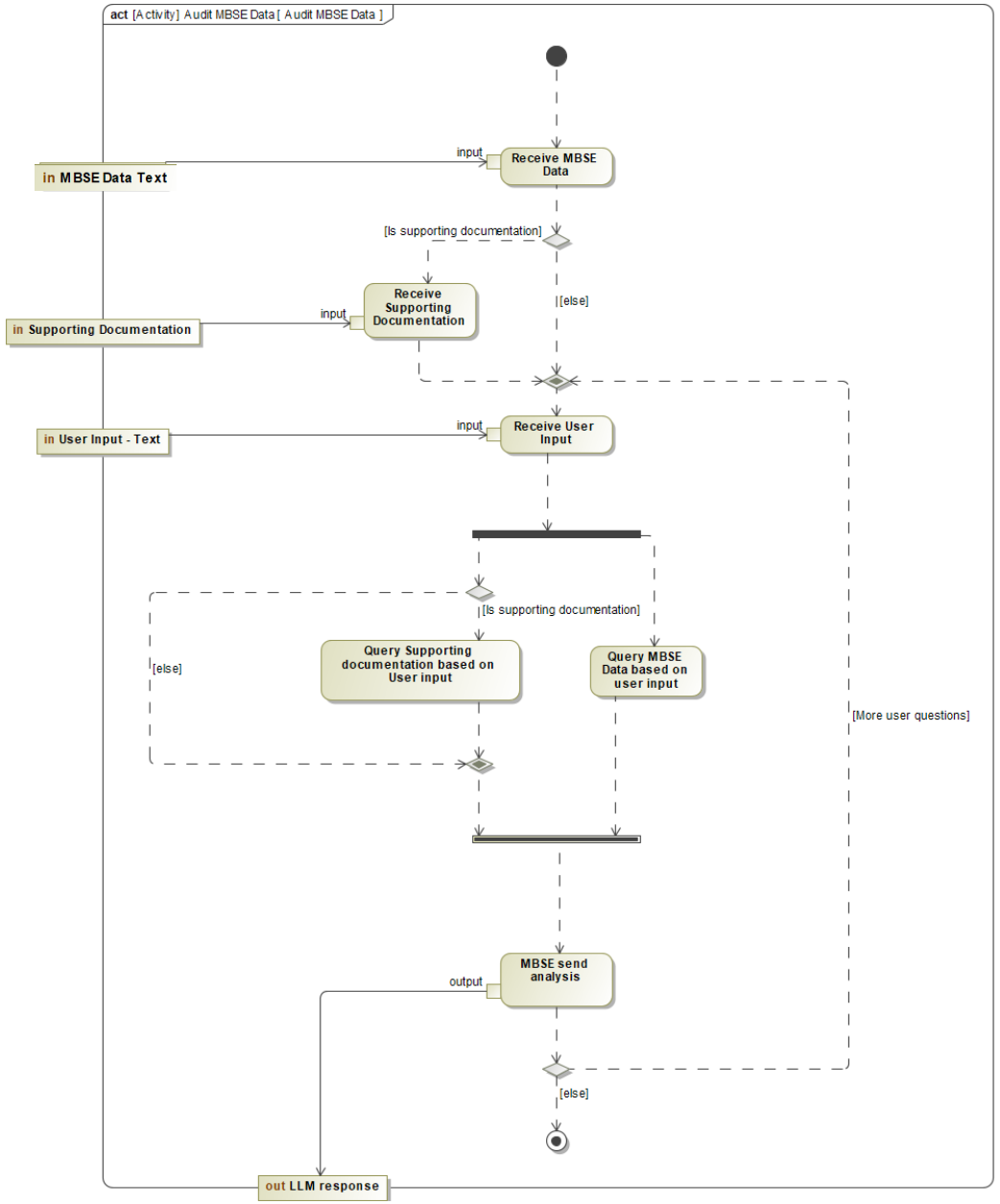
- Second desire is to Audit MBSE data using AI for model verification.
  - Enables **Improved quality and efficiency** of system model validation

Out-standing Issue	Fagan Reviews are done by hand and when conducted on requirements it is very difficult to take all 43 requirement writing guide principles into consideration.
Pre Condition	Fagan of CDs done manually by hand.
Post Condition	AI and MBSE used to audit program requirements with improved efficiency and quality. Defects are eliminated quicker and easier.

Out-standing Issue	Requirements decompostion has been conducted on programs simply using requirements. Consideration from the user in properly and complete use cases is not utilized.
Pre Condition	Requirements decomposition conducted manually in a spread sheet not following external standards.
Post Condition	Requirements decomposition conducted following OOSEM modeling methodology and AI to quickly audit content.

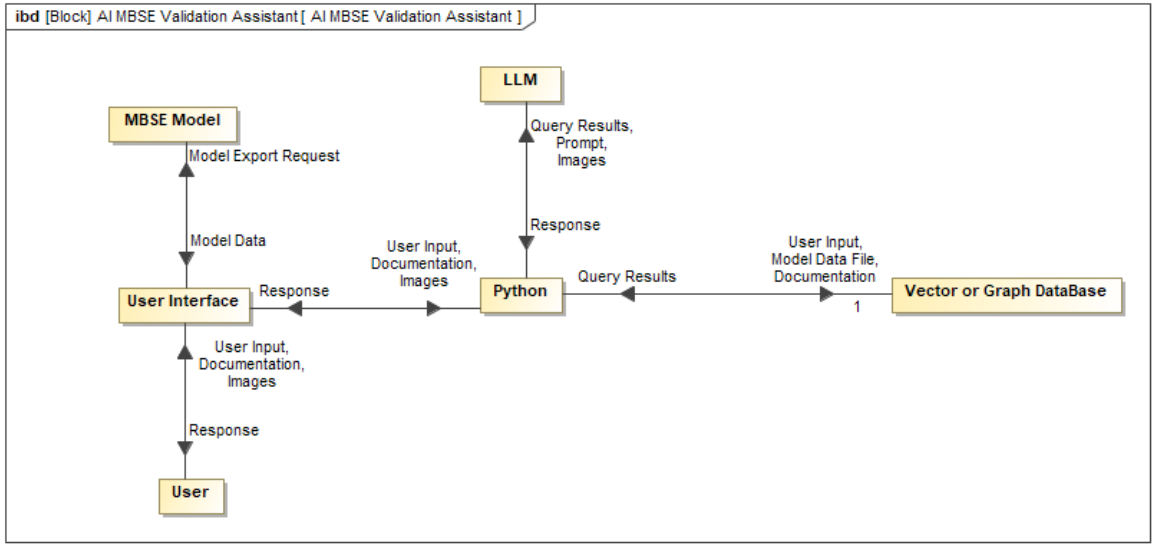


INFRASTRUCTURE/IMPLEMENTATION - AUDIT



Example Questions:

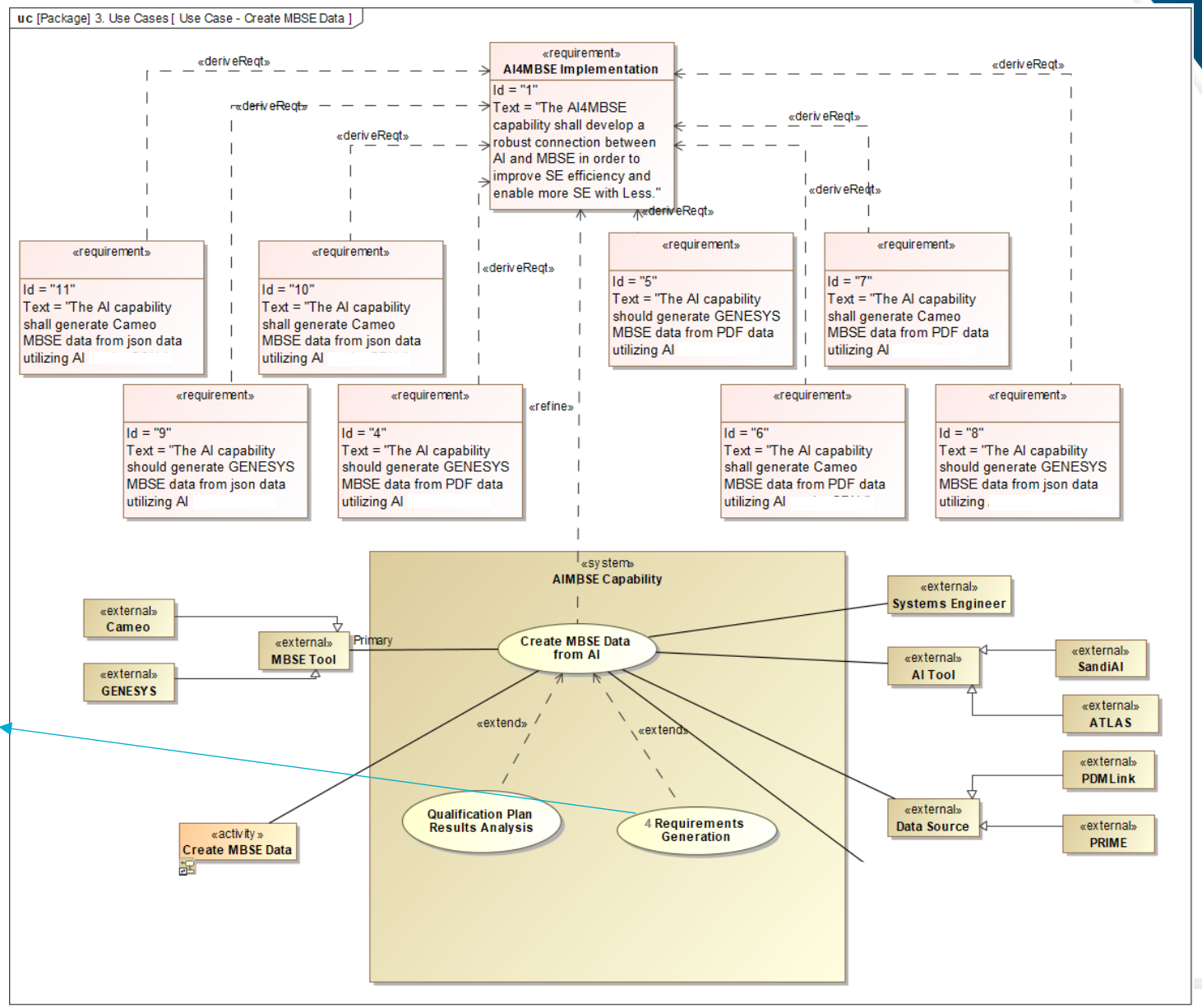
1. Based on data from previous systems, are there any functional oversights in my system?
2. Assess my requirements against the INCOSE Requirement Writing Standards in a Fagan like assessment.
3. Is my current verification plan implementing lessons learned?



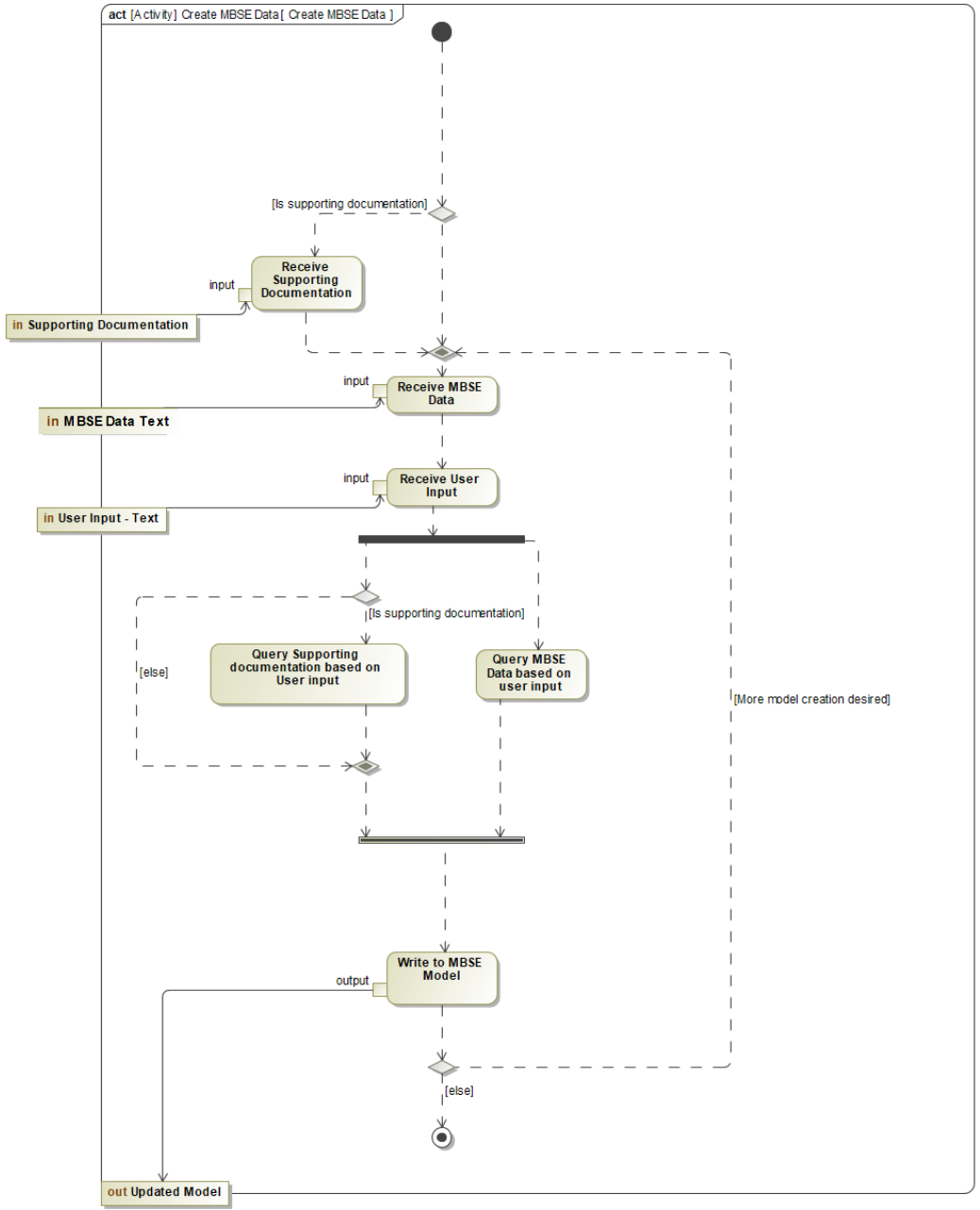
USE CASE #3 – MBSE MODEL GENERATION

- Third desire is to Generate MBSE data using AI for improved modeling efficiency.
  - **improved efficiency** in system architecture generation and creation

Out-standing Issue	Identifying requirement gaps or redundacies is a time consuming process. Because of this our programs often are changing requirements late in the program (Post BDR). There is no formal analysis method applied to identify gaps.
Pre Condition	Requirement analysis is conducted manually and issues are identified late in the program.
Post Condition	MBSE is used to model requirements and relate to other architectures. Auditing with AI and MBSE connection allows for quicker gap analysis. Seemless integration between AI and MBSE to add missing requirements directly to the MBSE tool.

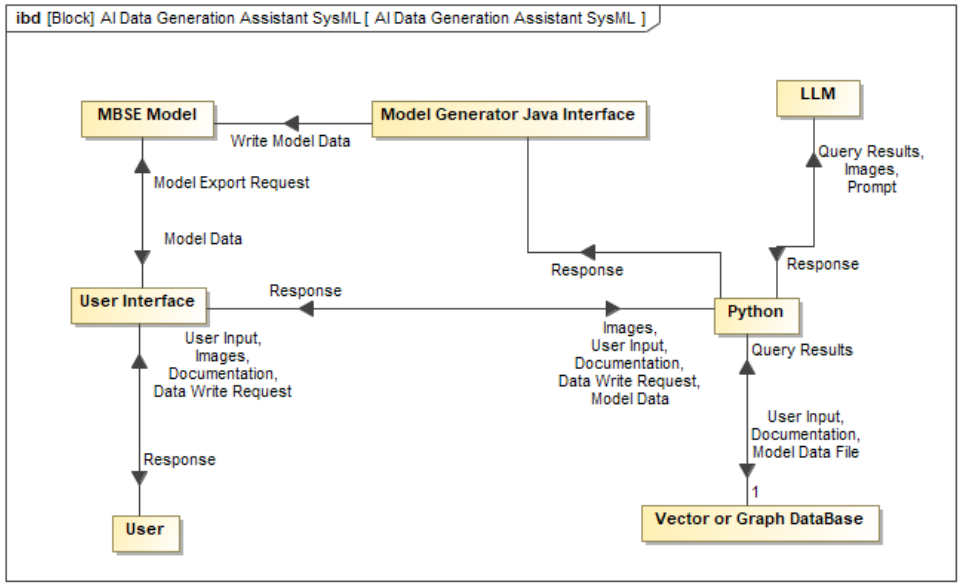


INFRASTRUCTURE/IMPLEMENTATION – DATA GENERATION



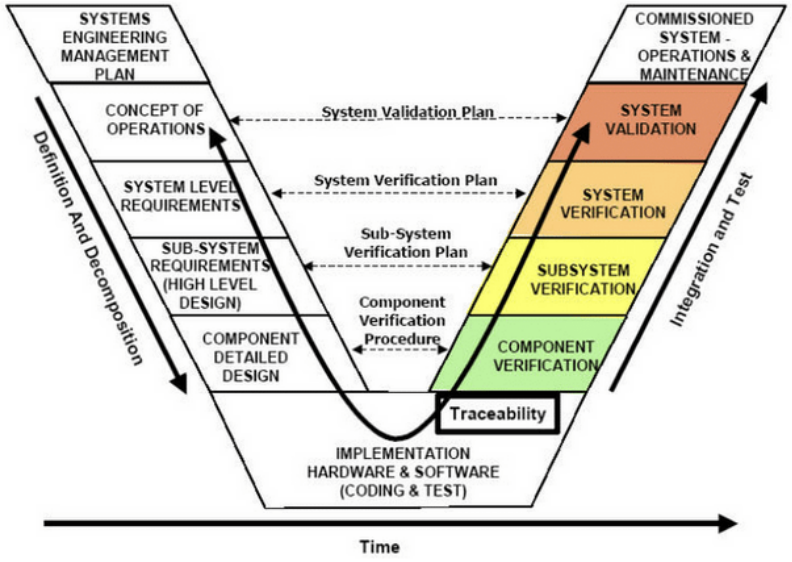
Example prompt:

1. Please make all updates from this Fagan like review to my model.
2. Please add the missing functionality to my system.
3. Please implement these lessons learned to my V&V strategy.



APPROACH

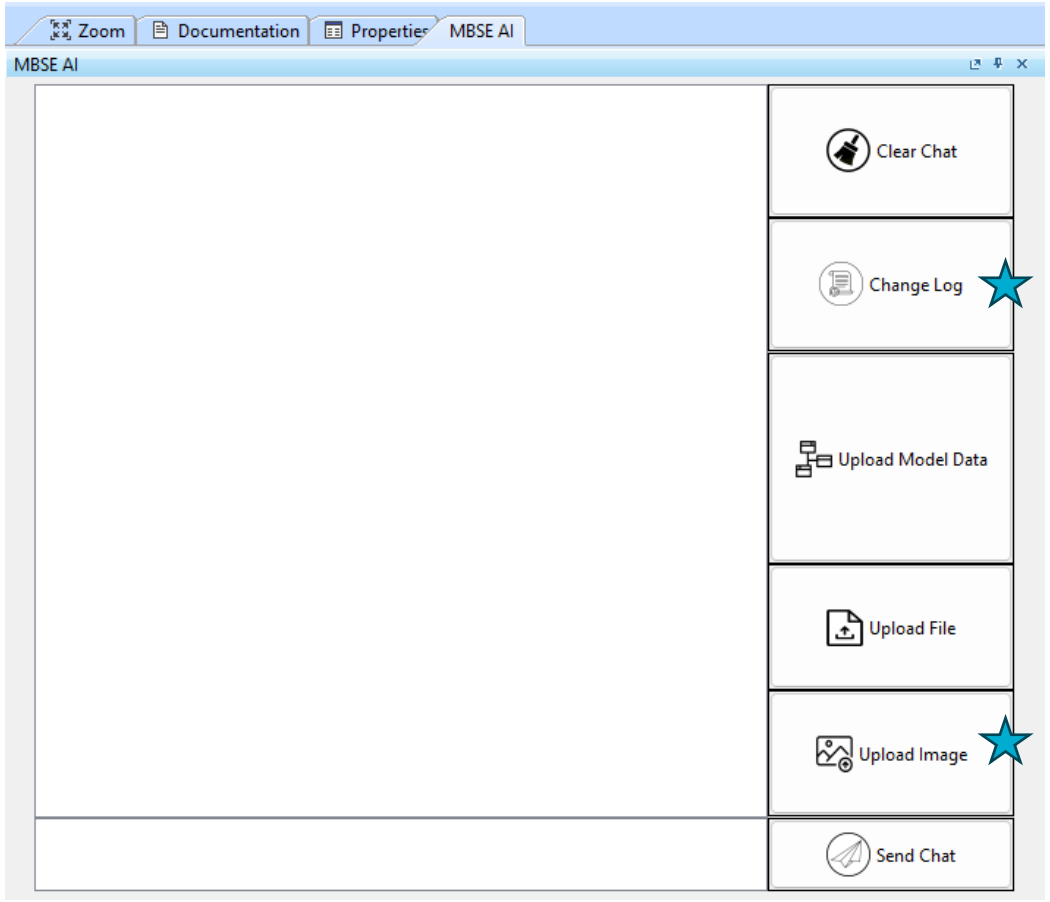
- We implemented on a phased approach. Each phase built off the next in terms of infrastructure and capability.
  - Phase 1 – Interpret MBSE Model Data
  - Phase 2 – Validate MBSE Model Data
  - Phase 3 – Generate MBSE Model Data



AIM CURRENT STATUS

AIM CURRENT STATUS AND SUCCESSES

- Embedded MagicDraw GUI
- Interface between MagicDraw Java API and Python Scripts
  - Interface to LLM
  - Interface to Vector Database
- Retrieval Augmented Generation (RAG) Pipeline
  - Utilization of Vector Database as context for AI Responses
- File uploading to custom local database
- Basic model data exports to database
  - Requirements and block data
- Basic model generation
  - Creation of “Class” elements

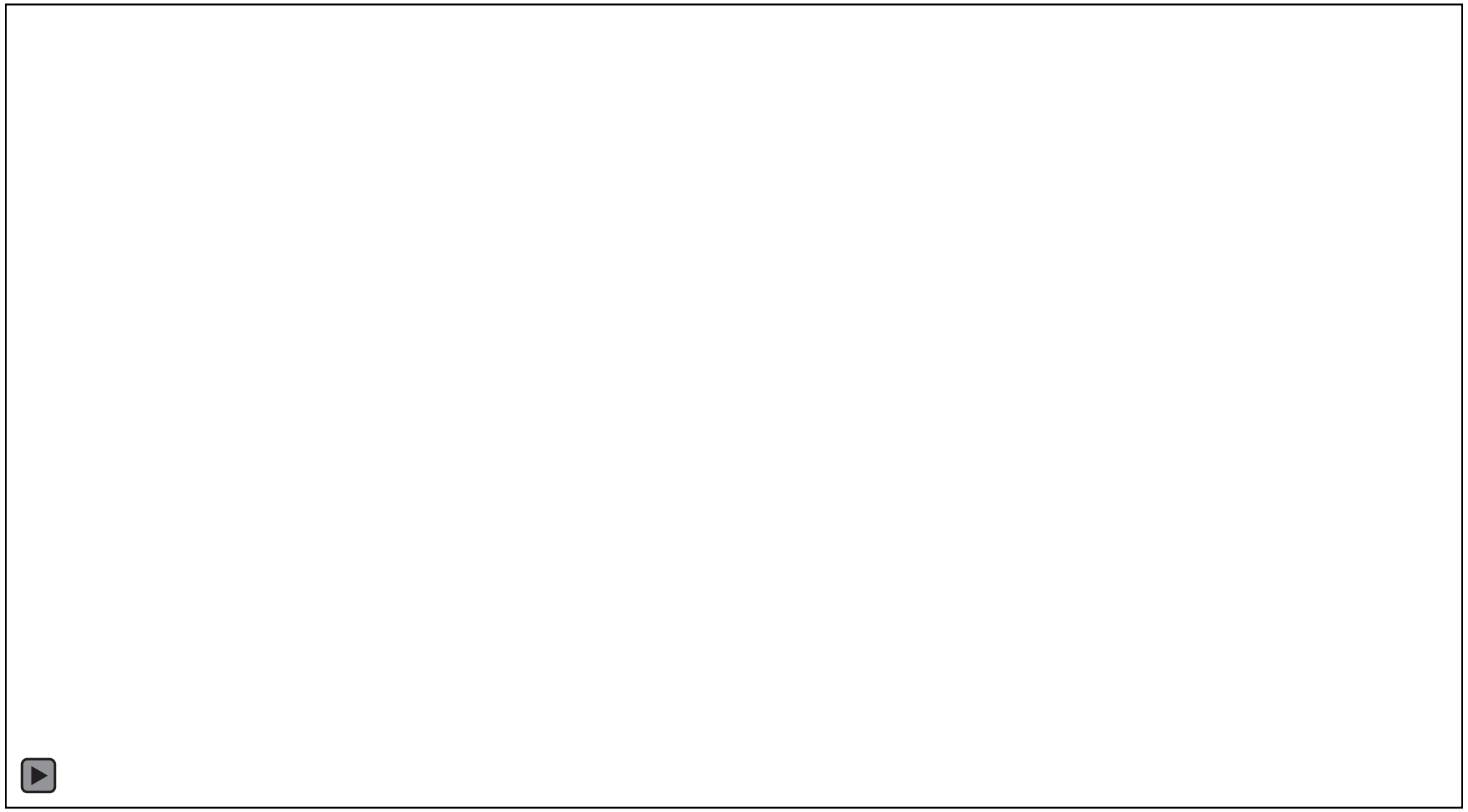


★ - Needs development

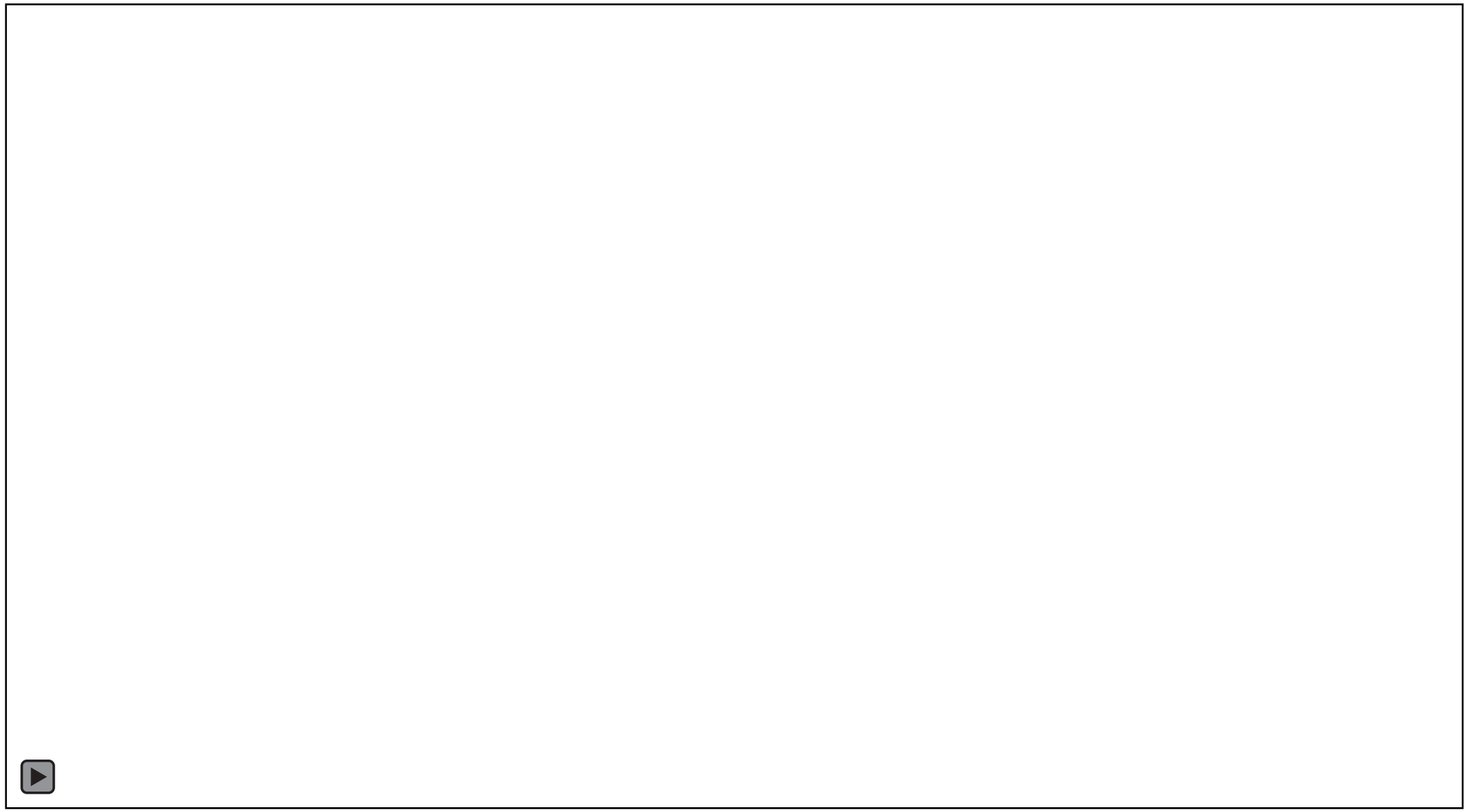
AIM DEMOS

DEMO MBSE INTERPRETATION ASSISTANT

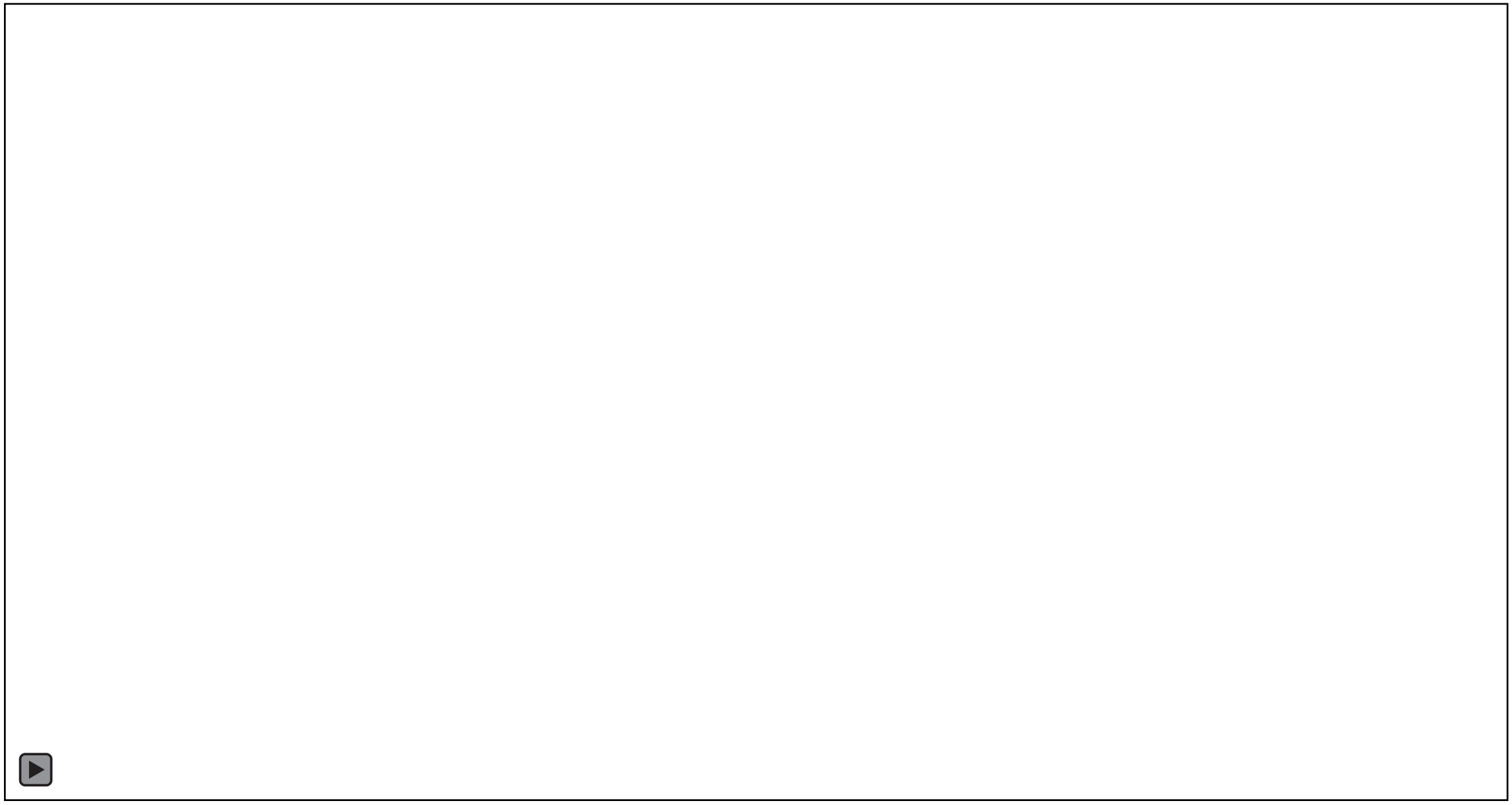
DEMO MBSE VALIDATION ASSISTANT



DEMO MBSE MODEL GENERATION



CALIBRATION REQUIREMENTS FOR KEYSIGHT DSOX3104G OSCILLOSCOPE



INDUSTRY CONTEXT

- Digital Thread:
  - At SNL, we are developing acceptance of modeling language, methods, and tools
    - This requires some thought into how much we want to model
    - How are the various models related and what standard is going to be required
  - Once we have an established understanding of common modeling architecture, AI will be a force multiplier for assessing federal requirements and local requirements and ensuring me meet the current standards for design engineering
- AI in Engineering:
  - The drive is to reduce (and eventually end) the reliance on document based artifacts. AI can help us asses necessary information within repositories for rapid inclusion into models.
  - Hope is to build an understanding for rapid assistance – take for instance equipment calibration

AIM TRAINING

- Prompt Engineering:
  - Importance of crafting effective prompts for AI to yield useful outputs
  - What does our AI tool know? What do you want it to do? Is it providing valued results?
- Challenges:
  - It's like training a young individual – with ambiguity, it generates what it thinks you want
  - I've learned that it's best to understand what the tool can do and to "guide it" to the result you want
    - Example: Can it do X – if yes, can it do Y, if yes, can it combine X and Y
- Feedback Mechanism:
  - We've learned to expand the context to give the tool better understanding of its purpose
  - Employing "use cases" enhances the reality of how this tool will assist the user

REVIEW OF UNIQUE DIFFERENTIATORS

- Integration Depth:
  - By developing specific user databases, we're able to focus on what MBSE and AI are doing
    - Interconnecting with Sandia built tools or other industry tools such as DOORS NextGen
  - Integrating specific program-related documents and requirements into the modeling process
- Specificity:
  - User specific RAG, local databases
  - Emphasize the ability to work with detailed program-specific data, enhancing the relevance and accuracy of AI-generated models.
- Real-World Applications:
  - Beta-testing and internal approval
  - Deployable to users

POSSIBLE FUTURE WORK

- Model Generation
  - Creation of more elements
  - Current element manipulation
  - Diagram creation
- Refined Model Exports
  - More detailed data exported from models
  - Increased scope of exported elements
- Diagram Picture Analysis
  - AI Analysis on current open diagram
  - Upload pictures to AI
- SysML V2 Integration

AIM DEVELOPMENT AND LESSONS LEARNED

- Hurdles:
  - Transition from standalone application to embedded application
    - Enabling model generation
    - Smooth MBSE model data transfer
  - Difficulties interfacing MagicDraw with a Python Application
- Configuration Control:
  - We will need to have a centralized approach to data management to maintain configuration control.
- Continuous Improvement:
  - Additional research and testing will be needed to further refine the accuracy of our AI implementation
    - Understanding vector databases and AI prompt engineering
  - GUI improvements to enhance user experience

SPECIAL THANKS

- Brian Mileshosky
- Casey Noll
- Aaron McCommon
- Kahlil Stoltzfus
- David Ruddell
- Ethan Pardieu
- Julia Marsh
- Cobe Haddock
- Bill Gruner
- Marissa Conroy
- Jessica Domrzalski
- And anyone we missed!

THANK YOU!
Q&A?