



22nd Annual Conference on Systems Engineering Research

March 18-21 2025, Long Beach, CA

Cognitive Assistants for Integrated System and
Software Engineering

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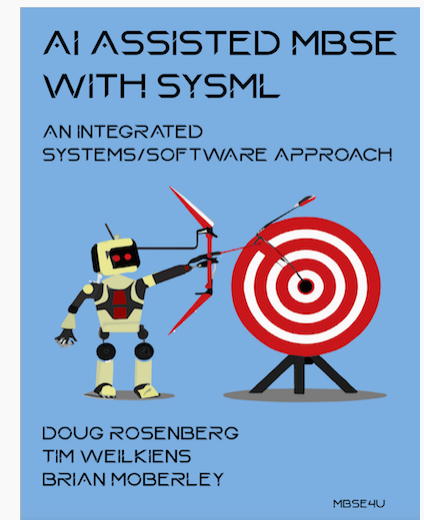
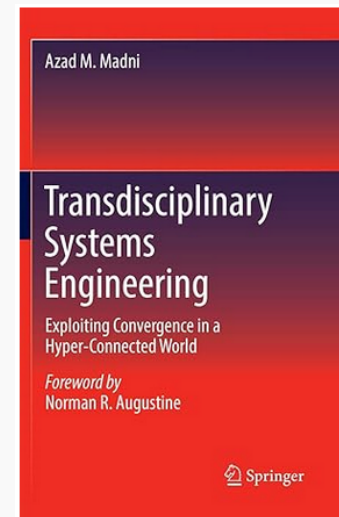


Introduction

- ☐ Theory meets Practice
- ☐ Increasing complexity in modern systems (e.g., aerospace, defense)
- ☐ The challenge of integrating Systems Engineering (SE) and Software Engineering (SwE)
- ☐ Example: Boeing's Starliner issues highlighting integration failures
- ☐ Need for AI tools to support engineers in handling complex integrations

Theory meets Practice

- ❑ Normally, the difference between Theory and Practice is that in Theory, there is no difference between Theory and Practice, but in practice there is.
- ❑ This is a rare occasion where Theory aligns perfectly with Practice.
- ❑ The disciplines in question for this talk are Systems Engineering and Software Engineering
- ❑ Concepts of Augmented Intelligence and Cognitive Assistants are realized as AI Personas and AI Agents



Cognitive Assistants & AIM Process

❑ What's a Cognitive Assistant?

❑ Role in augmenting the performance of engineers:

- Automating requirements discovery (AI as Subject Matter Expert)
- Object-oriented analysis and design
- Use case generation
- Wireframe and prototype code generation
- Assisting with parametric simulation
- Database design and code generation

❑ Personas and Agents boost the cognitive capacity of engineers, with a focus on making system engineers more fluent with software concepts.

What's a Cognitive Assistant?

- ❑ **Cognitive Assistant:** AI software that aids humans in understanding and interacting with the world, while offloading them in routine tasks such as search and information retrieval.
- ❑ **Augmented Intelligence (AugI)** Also called Intelligence Amplification, is the use of AI to enhance human-AI team performance while circumventing their respective limitations (Madni, 2019)

Working definitions for Persona and Agent

❑ In this talk, we will be using the following definitions for these terms:

- **AIM Process:** a process that uses AI to accelerate many tasks within systems and software engineering, using personas to encapsulate related sets of prompts for topics like code generation from state machines and parametric simulation. A key focus is to improve the software literacy of systems engineers.
- **AI Persona:** a device to make it easier for humans to communicate with AI by defining a “personality” that encapsulates a specific set of related prompts (e.g. prompts related to parametric simulation).
- **AI Agent:** A persona that has received custom training in a specific domain, such as parametric simulation or object-oriented design, realized via a “custom GPT file” or similar mechanism.

❑ Both Personas and Agents are Cognitive Assistants which leverage AugI.

Challenges in SE and SwE Integration

- ❑ Disconnects in traditional SE and OOD methodologies
 - OOD replaced Functional Decomposition in Software in the 1990s
 - Many Systems Engineers still embrace Functional Decomposition
 - Software Engineers don't know what to do with functionally decomposed models
- ❑ Agile methodologies cause issues, especially in large-scale projects
 - Agile/Scrum practitioners generally dislike formal requirements
- ❑ Misalignment between system requirements and software implementations
 - When Systems Engineers and Software Engineers are in different silos, there are issues
 - Software and Systems are inseparable
- ❑ Cognitive assistants as a solution to enhance communication and reduce errors
 - Without Software there is no System

Starliner is not unique, but exemplifies SE/SwE issues

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Starliner investigation finds numerous problems in Boeing software development process

by Jeff Foust February 7, 2020



Boeing's CST-100 Starliner spacecraft after its Dec. 22 landing that ended a truncated uncrewed test flight. Credit: NASA/Bill Ingalls



Transdisciplinary as in “software AND systems”

In AIM Process, Hardware and Software design are inseparable

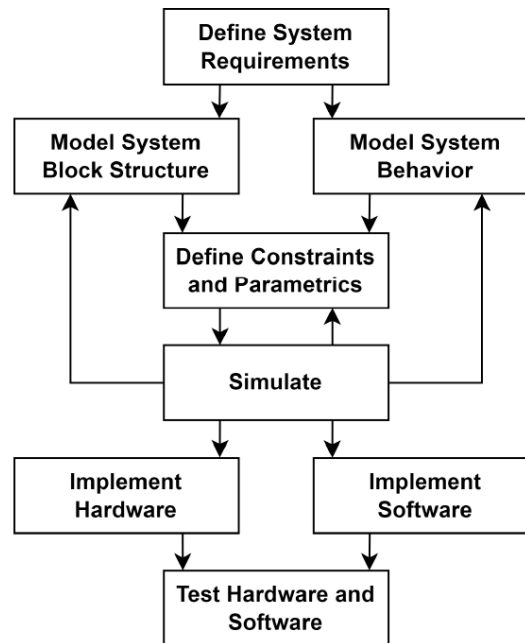
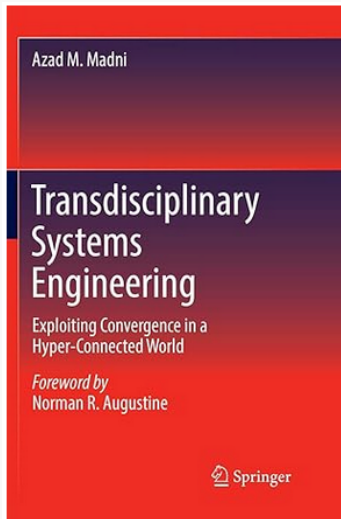
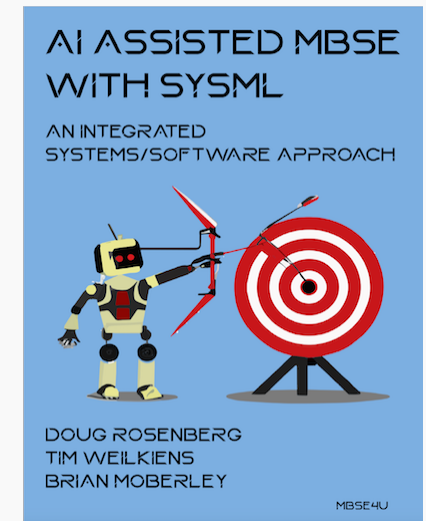


Figure 2.19. System and Software models are still inseparable

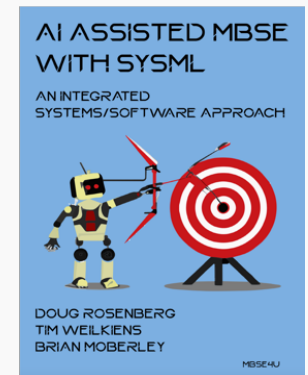


The Role of Augmented Intelligence (AugI)

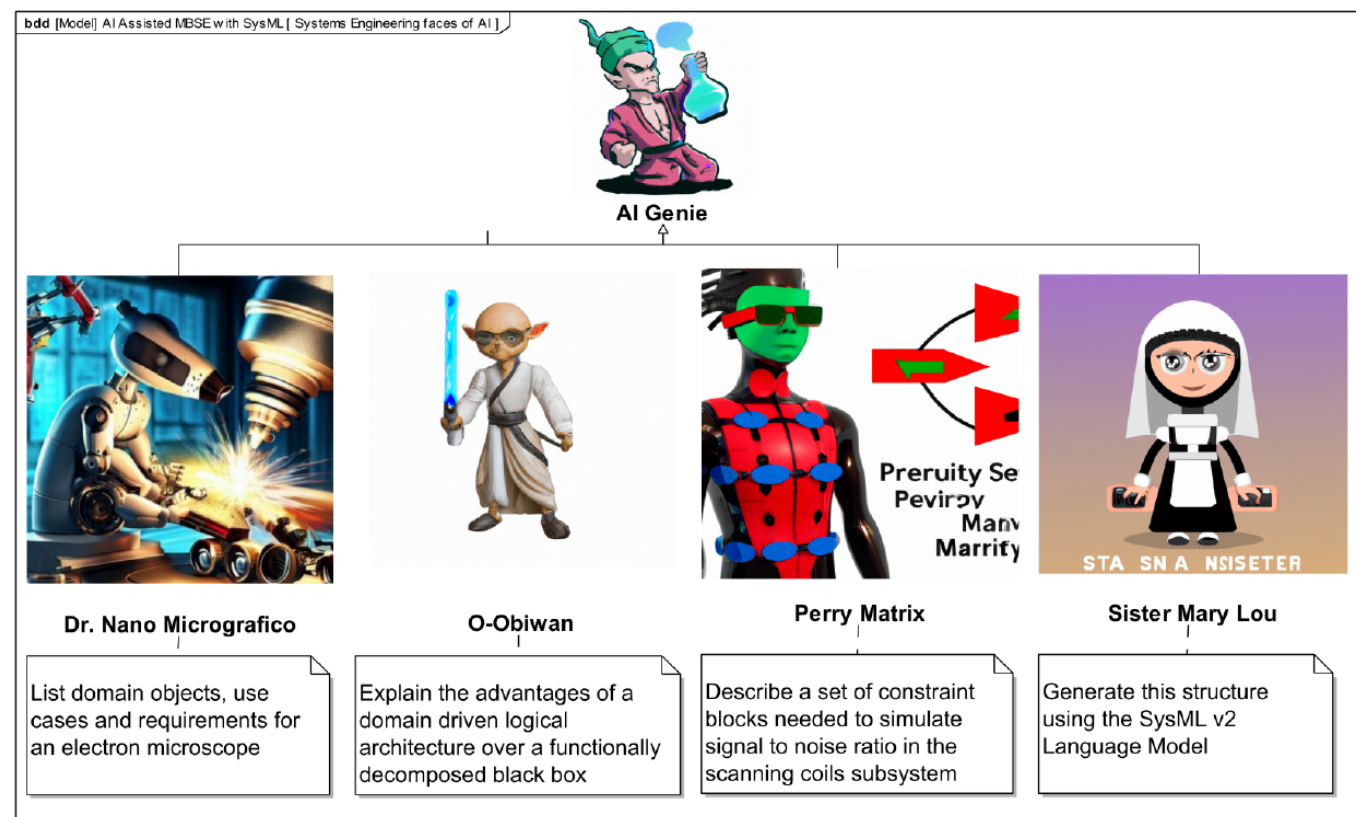
- ❑ AugI as a bridge between SE and SwE
 - AI can generate microcontroller code from SysML State Machines
 - AI can help Systems Engineers produce more object-oriented models
- ❑ Key tasks automated by cognitive assistants:
 - Requirements analysis
 - Use case generation
 - Failure mode analysis
 - Wireframe creation
 - Parametric Simulation
 - Database design and coding
 - User Interface design and coding
- ❑ Enhanced collaboration between SE and SwE teams
 - Systems Engineers can write better requirements for software functionality

Example: Scanning Electron Microscope (SEM)

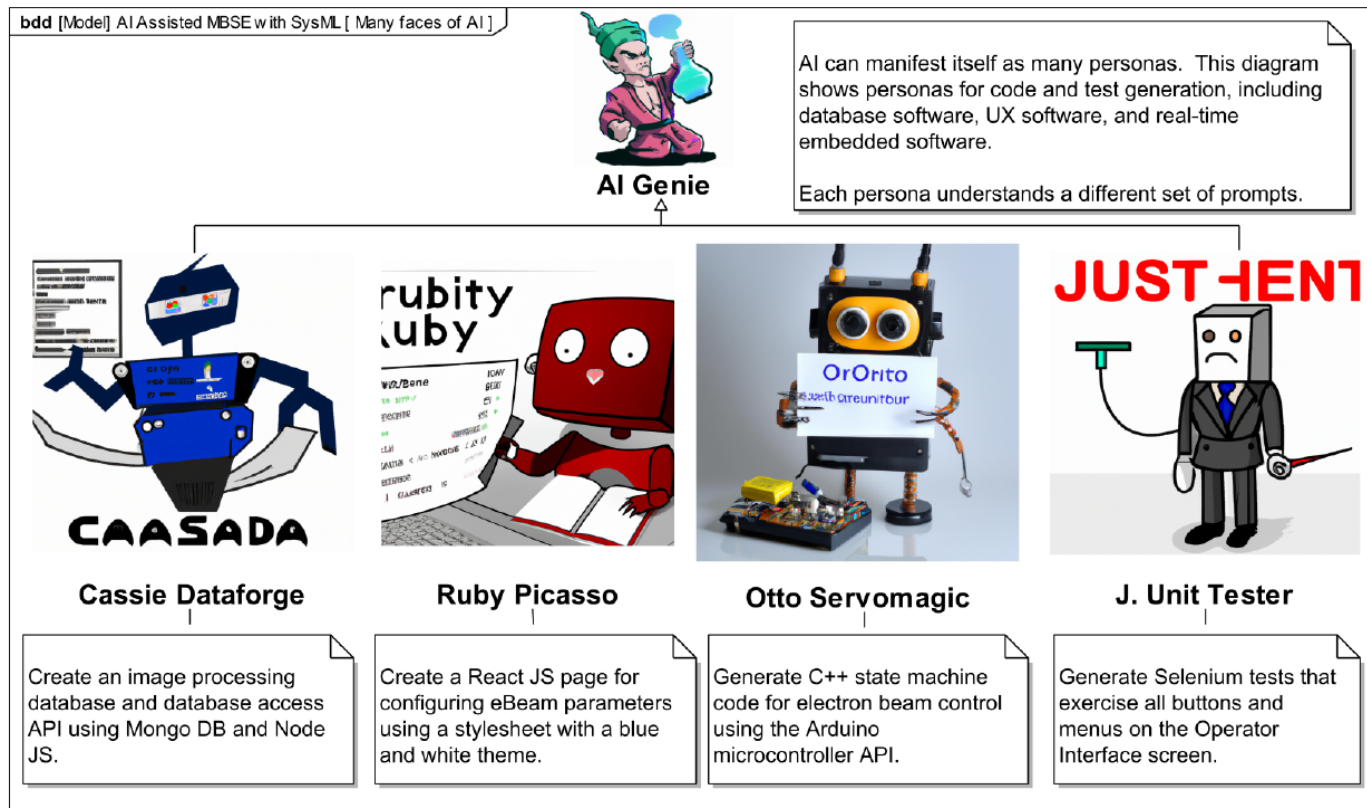
- ❑ Case study (book example) of SEM development: integrating hardware and software models
- ❑ Role of Cognitive Assistants in:
 - Automating requirements discovery
 - Ensuring system and software model alignment
 - Failure mode analysis and early issue detection
 - Embedded code generation



AI Personas for Systems Engineering



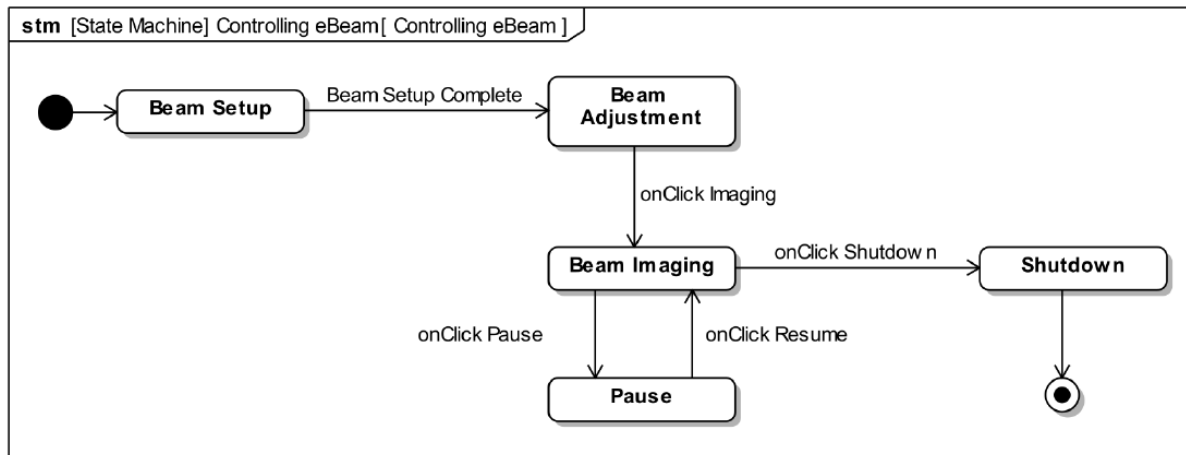
AI Personas for Software Engineering



Key Results from SEM Case Study

- ☐ Demonstrated the use of AI as a subject matter expert
- ☐ Demonstrated the use of AI to generate microcontroller C++ code from state machines
- ☐ Demonstrated the use of AI to write use cases, wireframe screens, develop UI code
- ☐ Demonstrated the use of AI to generate database code for image processing
- ☐ Developed custom-trained agents for parametric simulation and O-O design

“Otto Servomagic” persona generated both state machine and embedded C++ code



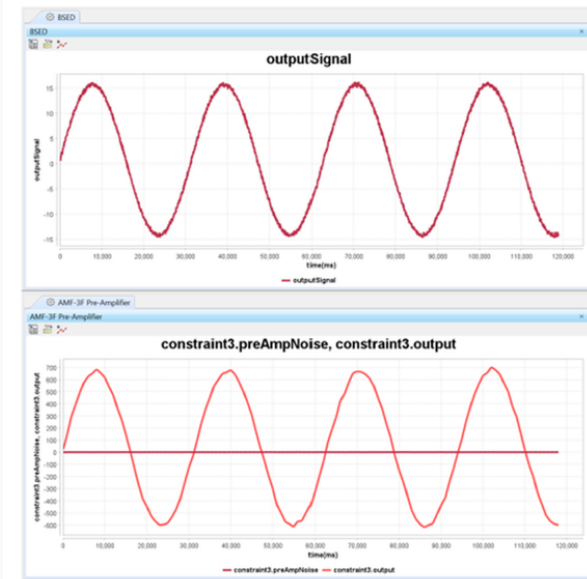
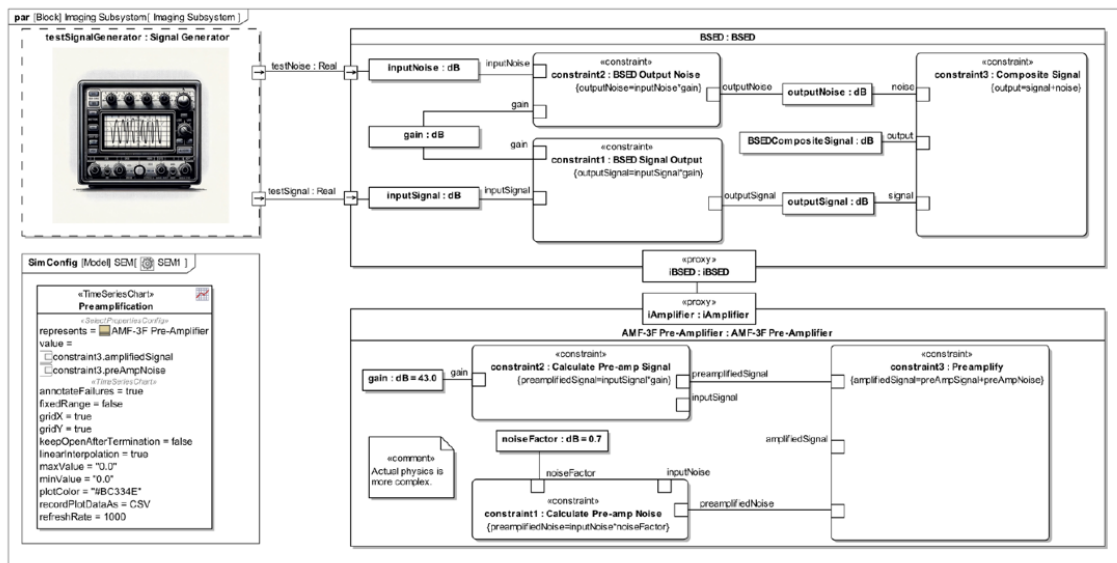
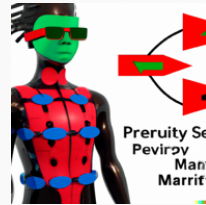
```

// Define states
enum BeamControlState {
    IDLE_STATE,
    BEAM_SETUP_STATE,
    BEAM_ADJUSTMENT_STATE,
    BEAM_IMAGING_STATE,
    PAUSE_STATE,
    SHUTDOWN_STATE
};

// Initialize the state variable
BeamControlState currentState = IDLE_STATE;

// Define state transition functions
void transitionToSetupState() {
    // Logic for transitioning to BEAM_SETUP_STATE
    currentState = BEAM_SETUP_STATE;
}
  
```

“Perry Matrix agent helped with parametric simulation of Signal to Noise Ratio (SNR)”



“Ruby Picasso” persona generated both UI Wireframe and functional Image Processing code



Image Enhancement

Image Preview

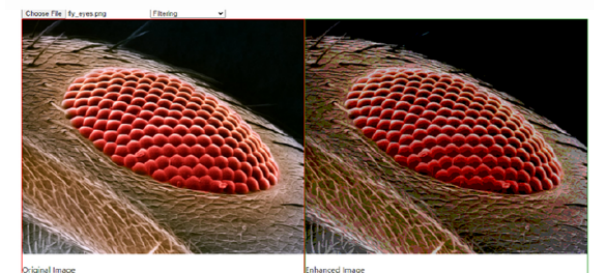
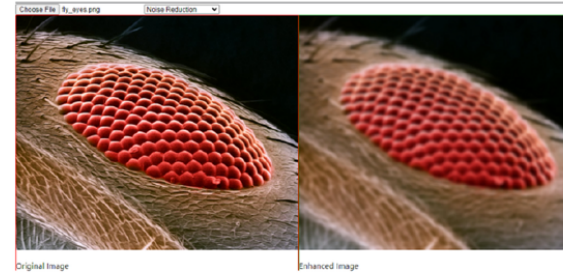
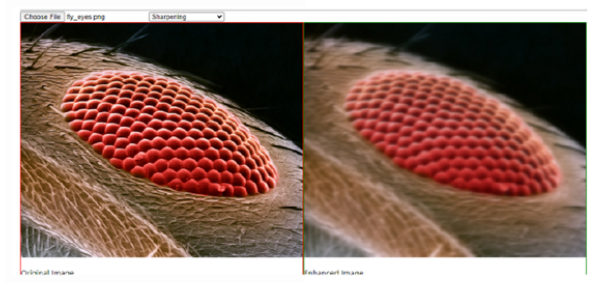
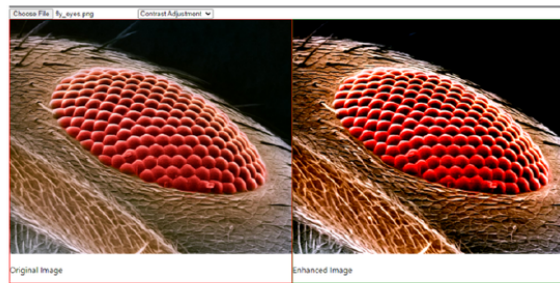
Enhancement Options

- ✓ Brightness
- Contrast
- Sharpen
- Blur
- Noise Reduction
- Color Correction
- Exposure
- Saturation
- Vignette
- Resize
- Rotate

Material Analysis ○ Biological Imaging

Preview Reset

- Choose a preset filter or adjust settings manually.
- Click "Apply Enhancement" to enhance the image.
- Use "Preview" to see the changes, or "Reset" to revert.



Future Directions for Augmented Intelligence

- ❑ Integration with emerging technologies:
 - Digital twins
 - Edge computing
- ❑ Expanding the role of AI in real-time systems, autonomous vehicles, and aerospace
- ❑ The growing importance of AI-driven collaboration in system/software engineering

Conclusion - From Theory to Practice

❑ Augmented Intelligence in System and Software Engineering

- Madni's theoretical work on Augmented Intelligence (AugI) has been realized through AIM Process, which transforms complex systems engineering and software development tasks through AI-driven cognitive assistants.

❑ AIM Process – Seamless Integration of SE and SwE

- Leveraging AI to bring theory into real-world applications by automating key engineering tasks and improving collaboration between systems and software teams
- Implementing AI Personas and Custom Agents to boost software literacy among systems engineers and automate critical tasks, such as code generation, requirements analysis, and parametric simulation.

❑ The Future of Engineering is Augmented by AI

- Use of AugI will continue to expand, integrating emerging technologies like digital twins, edge computing, and autonomous systems to enhance real-time decision-making and system reliability.



Questions?

❑ Thanks for your interest!

❑ Feel free to email us with questions

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