VT National Security Institute

-

Complex Systems Division

GenGroves:
A Bridge Between Systems Engineers and Domain Experts

Paul Wach, PhD, Research Assistant Professor

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SERC Workshop on AI4SE

Some Upfront Thank You(s)!

General
Leslie Groves
Director, Manhattan Project

Image from: Wikipedia

- The work has been realized thanks to several contributors and sponsors

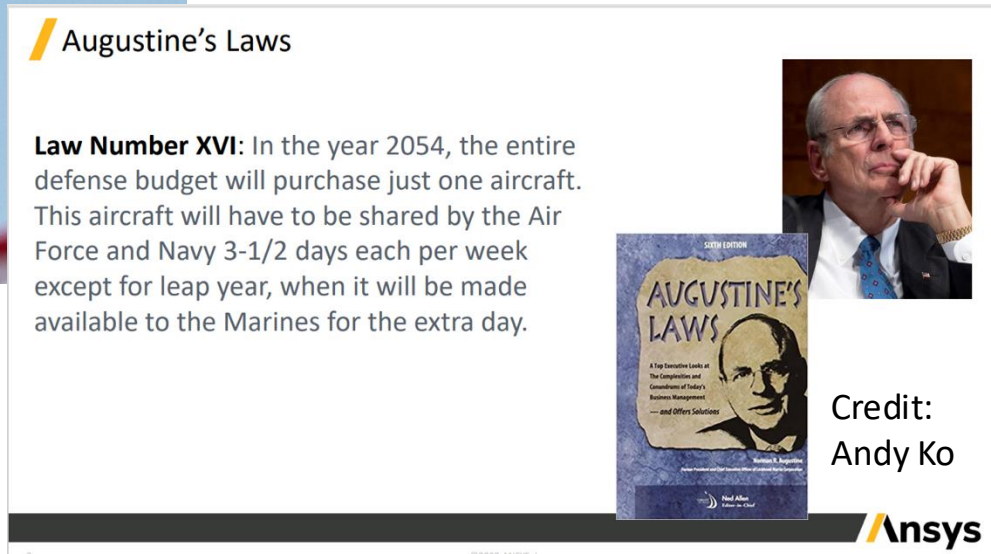
- Collaborators include:
  - **The Remarkable Ms. Mary Nerayo!!!**
  - Peter Beling, Taylan Topcu, Rohan Anand, Brady Jugan, Caleb Anderson

Setting the Stage

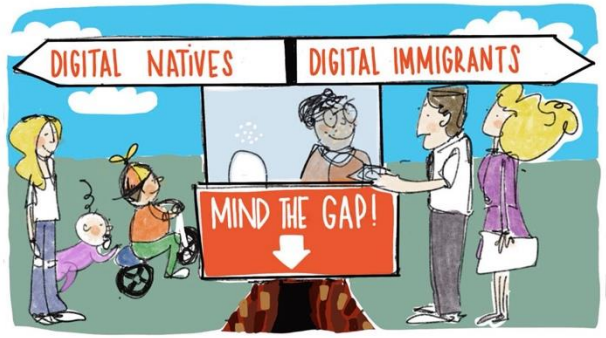
- Challenge:

  From empirical evidence and individual experience, **our current approach is not sufficient**

- Example Solution(s):
  - **Digital engineering (DE)**: connecting the right data right to enable effective and efficient decisions and communication
  - **Model-based systems engineering (MBSE)**: the application of DE to enhance systems engineering (SE)



Credit: Andy Ko



Spectrum of workforce

Generative Artificial Intelligence (GenAI) & Digital Transformation

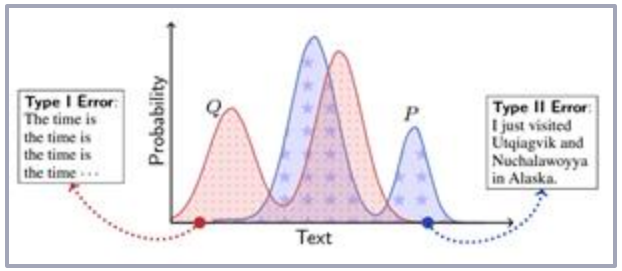
- Challenge:
  - **Adoption** of digital engineering has been **slow**er than expected and the benefits have not yet been realized
- Goal:
  - **Expedite & reimagine** the digital transformation
- Large language models (**LLM**) and the systems modeling language version 2 (**SysMLv2**)
  - Serve as a **workforce bridge** between seasoned generation and incoming digital natives, among other applications
- Thrusts
  1. Text to text
  2. Text/image to SysMLv2 code
  3. SysML image/code to text

Text to text

Human expert

vs

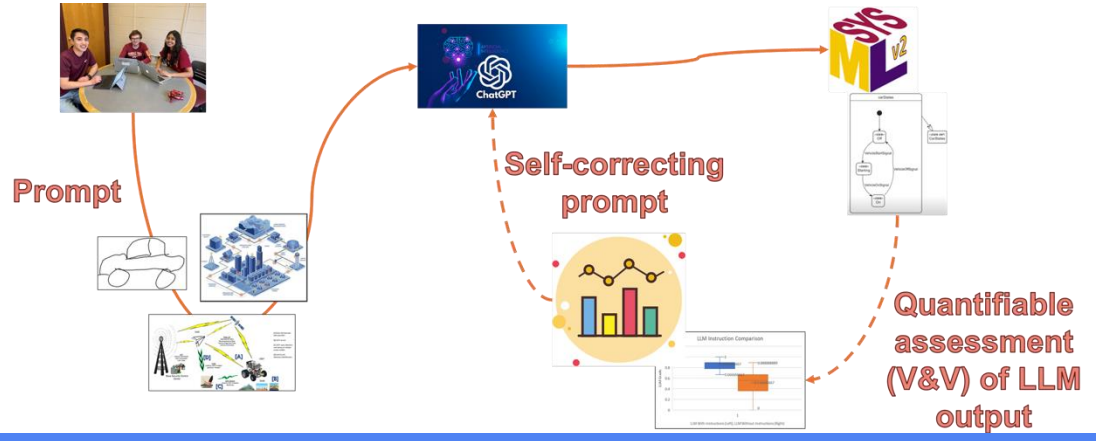
LLM



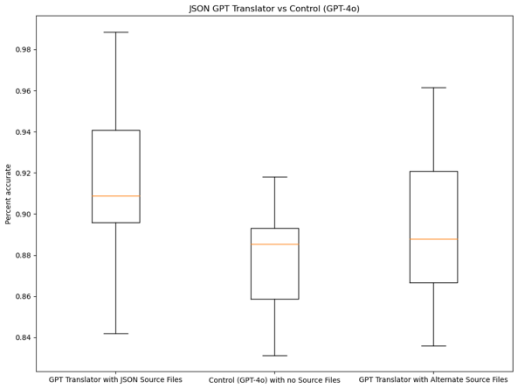
	MAUVE Scores		
Model	Prompt 1	Prompt 2	Prompt 3
GPT-4 (OpenAI)	0.0000	0.0000	0.9137
GPT-3.5 Turbo (OpenAI)	0.0000	0.0001	0.9749
Claude (Anthropic)	0.0000	0.0003	0.9932

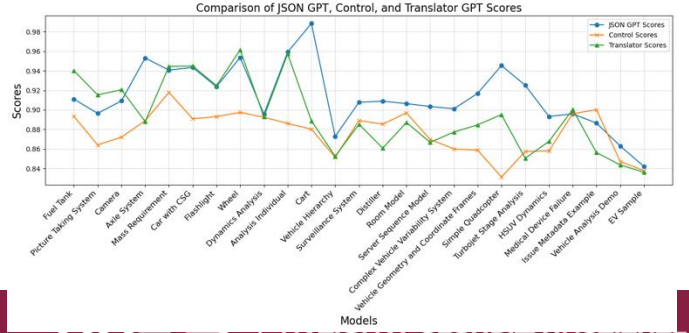
Text/Image to SysMLv2

Notional Prompt with self-correcting V&V of output



SysMLv2 image to text





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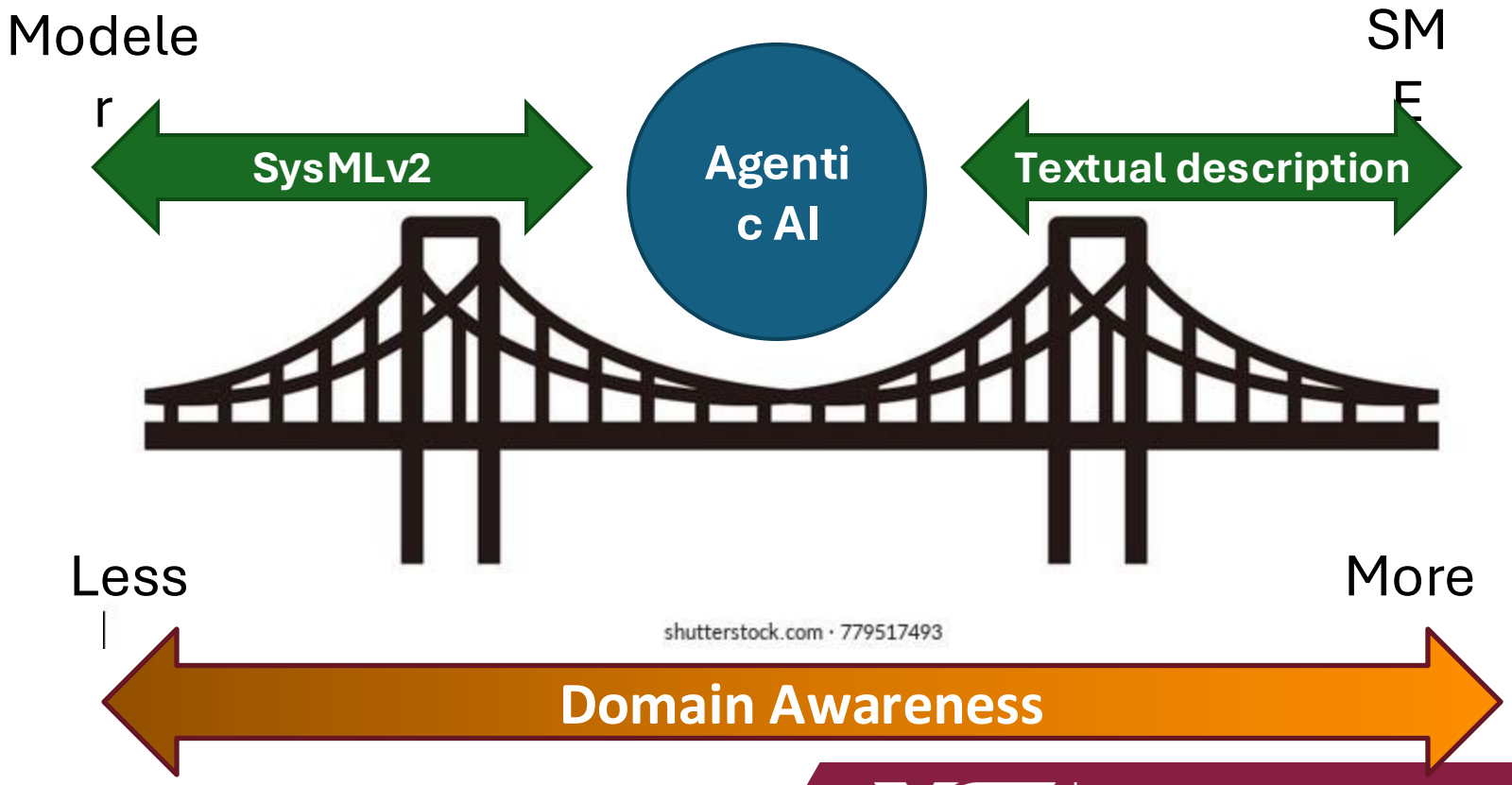
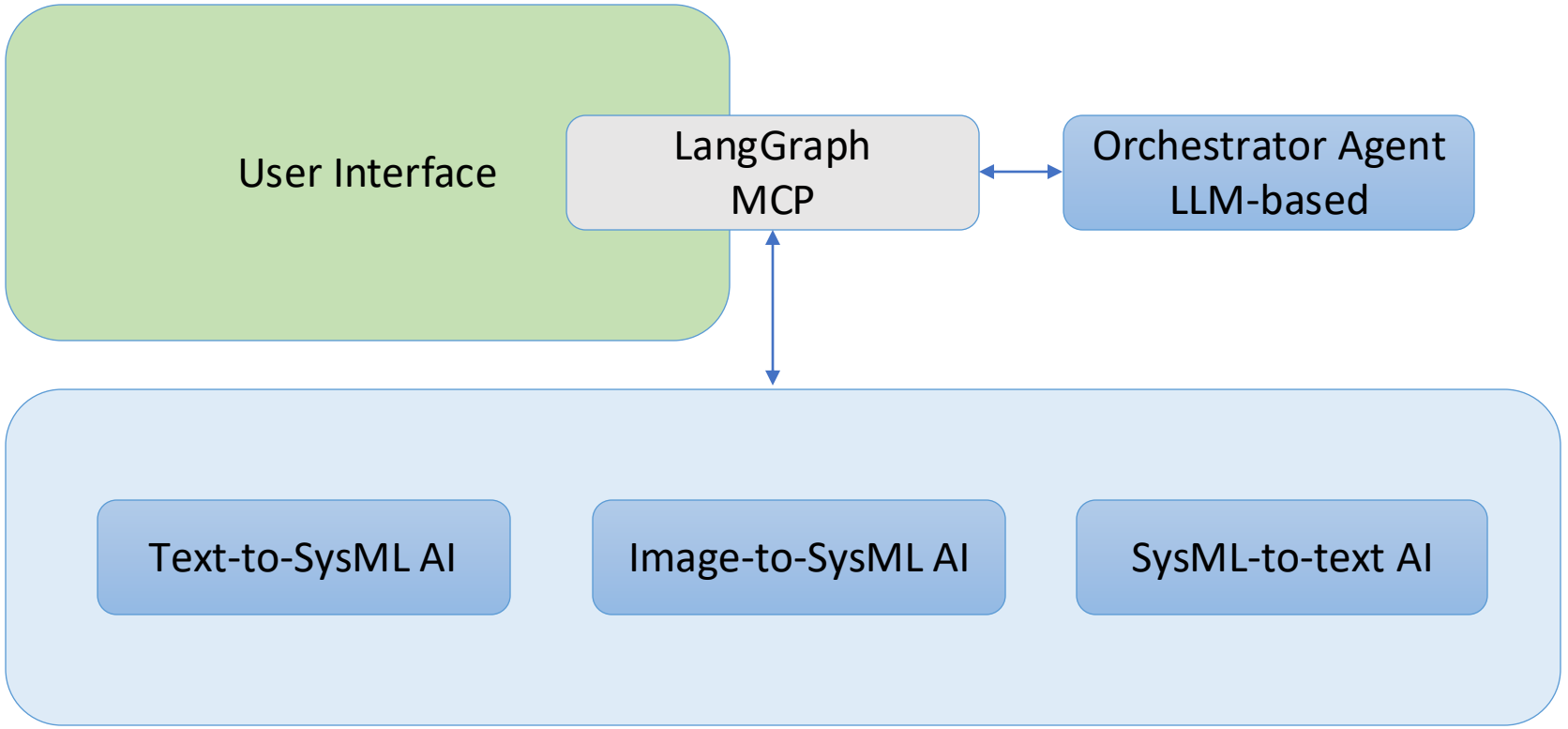
So, Who is the Bridge Really for?!

- Just systems engineering?
- Just domain experts?
- OR
  - Systems engineering modelers (e.g., those that model in MBSE tools)
  - + Subject matter experts
    - Senior systems engineers
    - Mechanical engineers
    - Electrical engineers
    - Aerospace engineers
    - Physicist!!!
    - Business managers



Overview of Agentic AI Framework for GenGroves



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Selecting the Right Parts: Experimentation

Prompt 1 -

- The drone system must perform regular patrols. It should cover a 5 km² area and complete each patrol within 30 minutes.
- The drone must ensure operational safety. Specifically, it should return to base when the battery level falls below 20%, and it must avoid entering pre-specified no-fly zones based on GPS coordinates.
- The communication system must report the drone's status every 2 minutes and issue alerts if it detects anomalies such as intrusion or GPS jamming.
- Using the description above for a drone system, provide the requirements of this system in a simple list format

Criteria	Rank 1 (Best)	Rank 2	Rank 3
Clarity & Organization	Mistral	Gemma	LLama
Depth of Explanation	Gemma	Mistral	LLama
Tone	Mistral	Gemma	LLama
User-Friendliness	Gemma	Mistral	LLama
Use of Examples/Scenarios	Gemma	Mistral	LLama
Scalability & Reusability	Mistral	Gemma	LLama

*Kudos to Rohan Anand

Selecting the Right Parts: Experimentation

Prompt 2 -

- Provide the requirements for a drone system that does surveillance in a small area.

Criteria	Rank 1 (Best)	Rank 2	Rank 3
Clarity & Organization	**Gemma**	**Mistal**	**Llama**
Depth of Explanation	**Gemma**	**Llama**	**Mistal**
Tone	**Gemma**	**Mistal**	**Llama**
User-Friendliness	**Mistal**	**Gemma**	**Llama**
Use of Examples/Scenarios	**Gemma**	**Llama**	**Mistal**
Scalability & Reusability	**Gemma**	**Mistal**	**Llama**

*Kudos to Rohan Anand

Selecting the Right Parts: Experimentation

Prompt 3 -

```
package 'Requirement Hierarchy Example' {
    import ScalarValues::*;

    // Top-level requirement definition
    requirement def SystemPerformance {
        attribute id : String;
        attribute description : String;
    }

    // Sub-requirements
    requirement def HighSpeed :> SystemPerformance {
        attribute id : String;
        attribute description : String;
    }

    requirement def LowPower :> SystemPerformance {
        attribute id : String;
        attribute description : String;
    }

    // Usage of the top-level requirement
    requirement sysPerfReq : SystemPerformance {
        attribute :>> id = "REQ-000";
        attribute :>> description = "The system shall optimize performance characteristics."
    }

    // Usage of sub-requirements
    requirement speedReq : HighSpeed {
        attribute :>> id = "REQ-001";
        attribute :>> description = "The system shall operate at speeds greater than 100
units/sec.";
    }

    requirement powerReq : LowPower {
        attribute :>> id = "REQ-002";
        attribute :>> description = "The system shall consume less than 50 watts under normal
load.";
    }
}
```

- Using the above SysMLv2 diagram explain the system the diagram describes.

Criteria	Rank 1 (Best)	Rank 2	Rank 3
Clarity & Organization	**Gemma**	Llama	Mistral
Depth of Explanation	**Gemma**	Llama	Mistral
Tone	**Llama**	Gemma	Mistral
User-Friendliness	**Gemma**	Llama	Mistral
Use of Examples/Scenarios	**Gemma**	Llama	Mistral
Scalability & Reusability	**Gemma**	Llama	Mistral

*Kudos to Rohan Anand

Selecting the Right Parts: Experimentation

Prompt 4 -

```
package 'Requirement Hierarchy Example' {
    import ScalarValues::*;

    // Top-level requirement definition
    requirement def SystemPerformance {
        attribute id : String;
        attribute description : String;
    }

    // Sub-requirements
    requirement def HighSpeed :> SystemPerformance {
        attribute id : String;
        attribute description : String;
    }

    requirement def LowPower :> SystemPerformance {
        attribute id : String;
        attribute description : String;
    }

    // Usage of the top-level requirement
    requirement sysPerfReq : SystemPerformance {
        attribute :>> id = "REQ-000";
        attribute :>> description = "The system shall optimize performance characteristics."
    }

    // Usage of sub-requirements
    requirement speedReq : HighSpeed {
        attribute :>> id = "REQ-001";
        attribute :>> description = "The system shall operate at speeds greater than 100 units/sec.";
    }

    requirement powerReq : LowPower {
        attribute :>> id = "REQ-002";
        attribute :>> description = "The system shall consume less than 50 watts under normal load.";
    }
}
```

- Above is an example of SysMLv2 requirements diagrams. Using the description of a system below create the entire SysMLv2 requirements diagram.
- The drone system must perform regular patrols. It should cover a 5 km² area and complete each patrol within 30 minutes.
- The drone must ensure operational safety. Specifically, it should return to base when the battery level falls below 20%, and it must avoid entering pre-specified no-fly zones based on GPS coordinates.
- The communication system must report the drone's status every 2 minutes and issue alerts if it detects anomalies such as intrusion or GPS jamming.

Criteria	Rank 1 (Best)	Rank 2	Rank 3
Clarity & Organization	**Gemma**	Mistral	Llama
Depth of Explanation	**Gemma**	Mistral	Llama
Tone	**Gemma**	Mistral	Llama
User-Friendliness	**Gemma**	Llama	Mistral
Use of Examples/Scenarios	**Gemma**	Mistral	Llama
Scalability & Reusability	**Gemma**	Mistral	Llama

*Kudos to Rohan Anand

Demo of Current Version of GenGroves

Artifact

Download

Artifact content...

Hello! I'm here to assist you. As we collaborate, I'll update the artifact on the left in real time. Feel free to provide an artifact for editing or ask me to create a new one for you.

Artifact used: Artifact

Editing SysMLv2

Submit

Questions?

Contact:
Paul Wach, paulw86@vt.edu

*A year of iterating on the image for GenGroves

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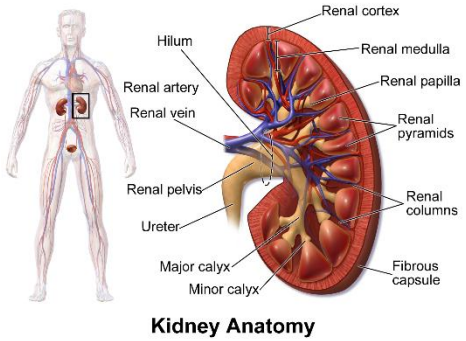
Who is Paul? (or Professor Paul or Doc Wach)

BS in Biomedical Engineering 2009



Kidney Anatomy

MS in Mechanical Engineering 2013

PhD in Industrial and Systems Engineering 2022

Research Faculty in Intelligent Systems Division 2023-present

Virginia Tech – National Security Institute (NSI)

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