34th Annual INCOSE international symposium

hybrid event

Dublin, Ireland
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Model-Based Architectural Patterns for Teaching Systems Engineering

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The Problem

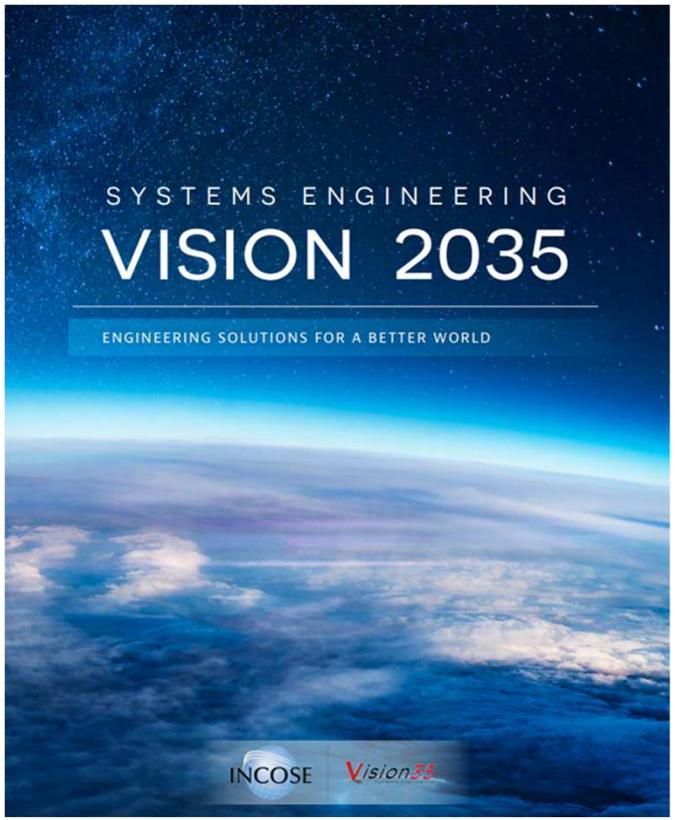
- The technological innovations are **challenging** the practices of **Systems Engineering** to adapt
  - **MBSE**
  - **Architectural Patterns**
- It **takes too long** for systems engineers and mission architects **to develop** a new **system from scratch**, particularly new space-based systems derived from the existing space systems architectures

The Purpose and Approach

- **Academic coursework** for teaching MBSE using a space-based architectural patterns library (the pattern language)
- The method - **NASA pattern library**
- SE graduate students
- **Ease the development** of new space-based **systems architectures**

Objective

- The objective is to incorporate "**INCOSE Vision 2035**" into academia using Model-Based Architectural Patterns (MBAP) to teach SE
- Benefit – **reduce development and validation time**



Scope and Opportunity

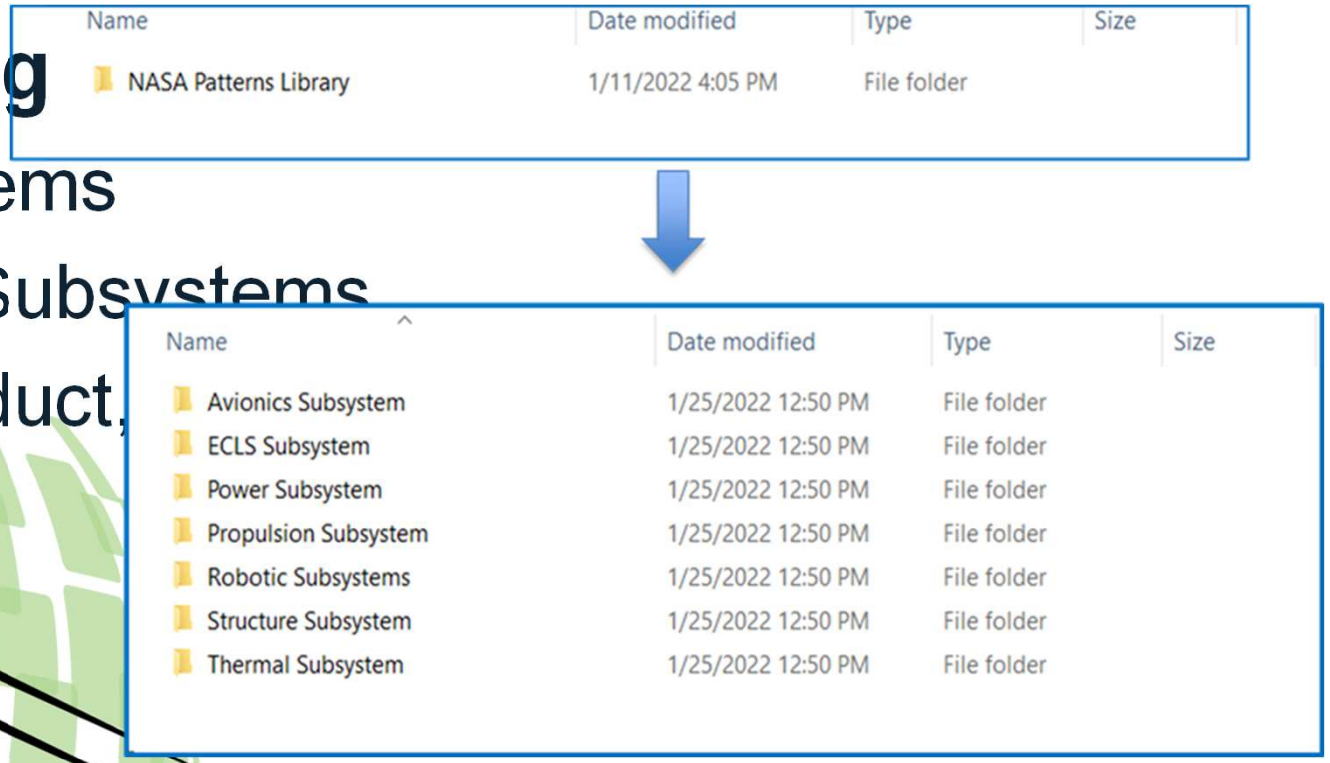
- **NASA – Marshall Space Center** – Advanced Concepts Office on MBSE
- **Architectural Pattern Project** – 2020
- An opportunity to develop and prove **methodology**
- Develop new space systems architectures within a **short period** while allocating the top-level system **verification, validation,** and **testing requirements**

Research Application

- Paper - **incremental addition** to existing work
- Extended **novel application** of a space-based pattern library for
  - Teaching MBSE and
  - Architectural Patterns
  - Using System Modeling Language (SysML)
  - In SE graduate classroom

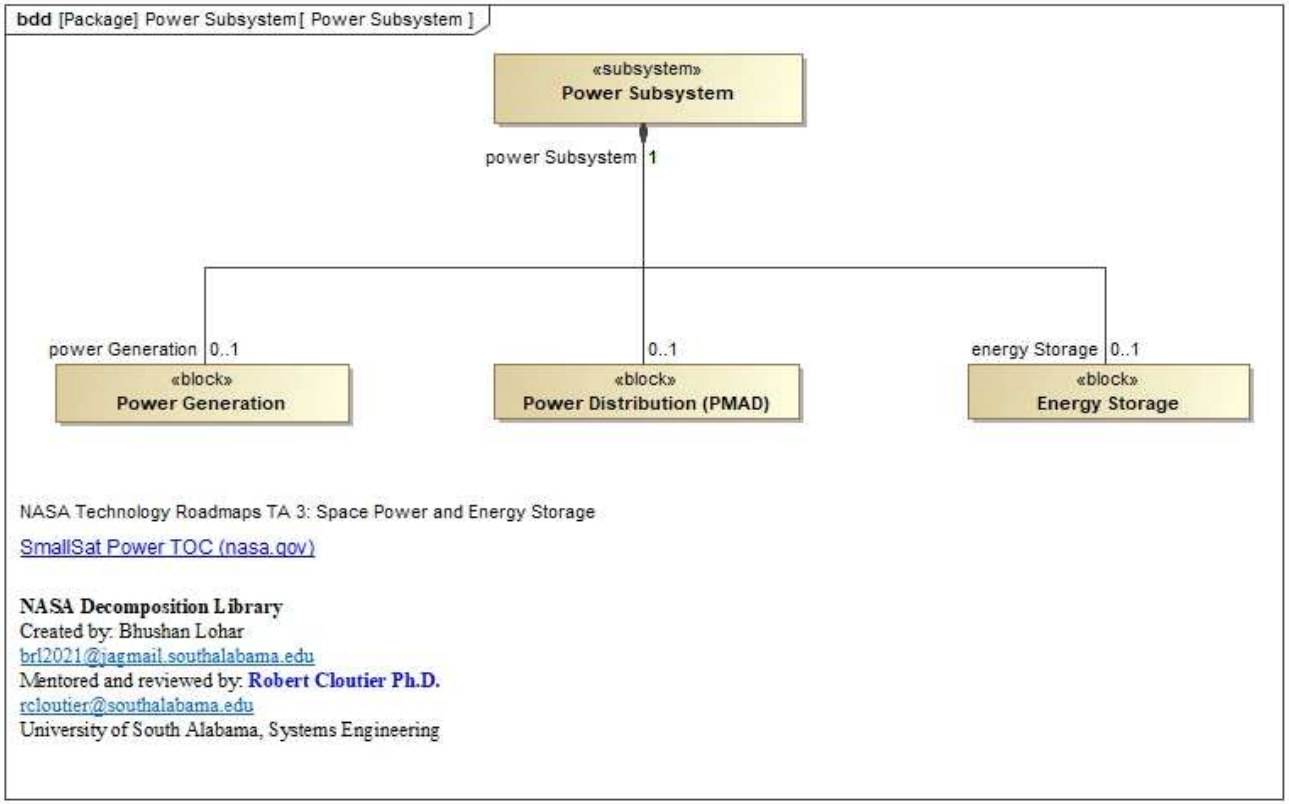
Methods

- Pattern library **org**
  - Top-level – Systems
  - Second-level – Subsystems
  - Third-level - product, components



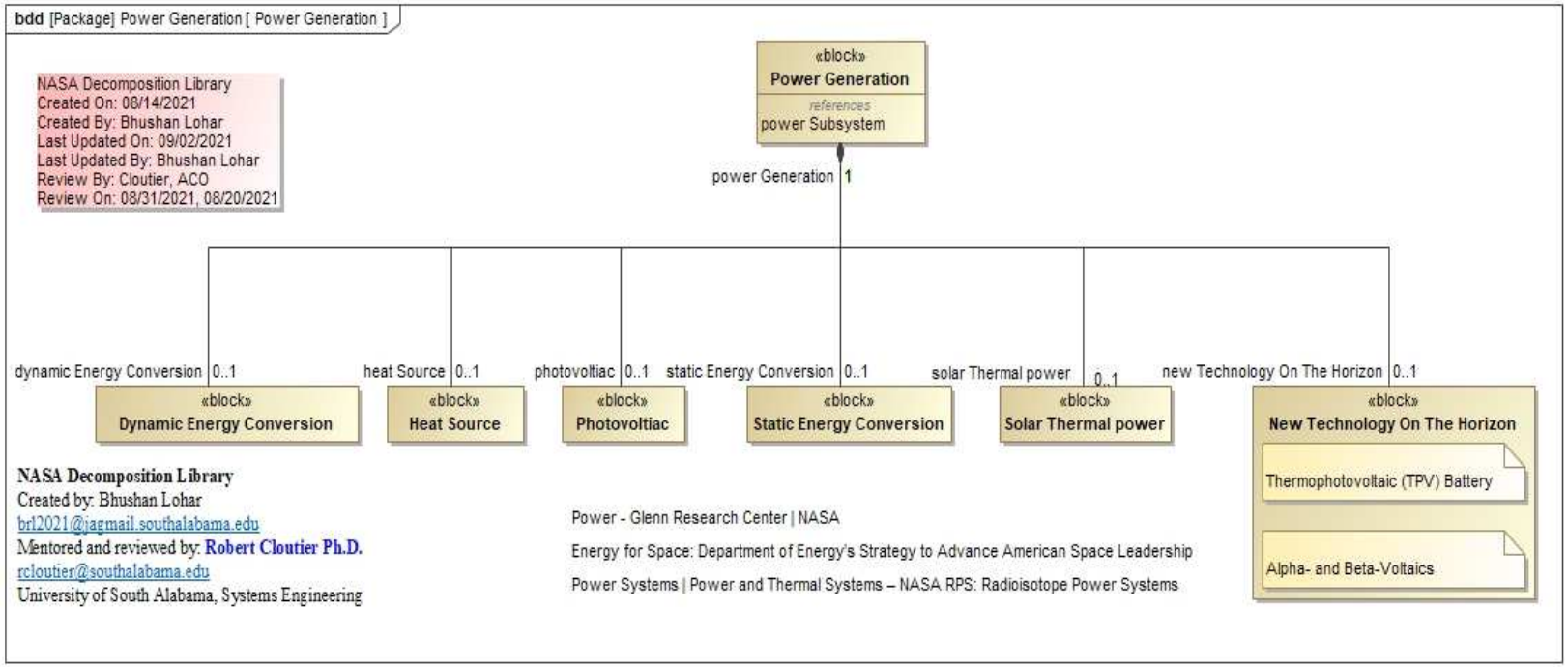
Methods

- Each pattern ha
  - **Small patterns**
    the **requiremer**
    specific interfa
  - Relationship
  - **Multiplicity**
  - **74 patterns**



Proof of Concept (PoC)

- **Any coll**
  create a
- **Power to**
- With **thou**
- This **sma**
  archite
  rovers, and gateways.



Application to Academia

- The **SE Vision 2035** defines
  - *“by 2035, the SE practices will be based on a set of theoretical foundations and other general principles that are continuously taught as part of a Systems Engineering curriculum”*
- **Advanced graduate-level SE course** using the subject space systems architectural pattern library
- SE 617 – Space Systems Architecting
  - Summer 2023 and 2024

Curriculum

- Mission objectives and requirements
- Stakeholders and needs
- Key space SE concepts, systems thinking
- Modeling and Simulations
- Flight and ground systems and subsystems for systems of interest (SoI)

Patterns speed up the logical architecture development and requirement allocations

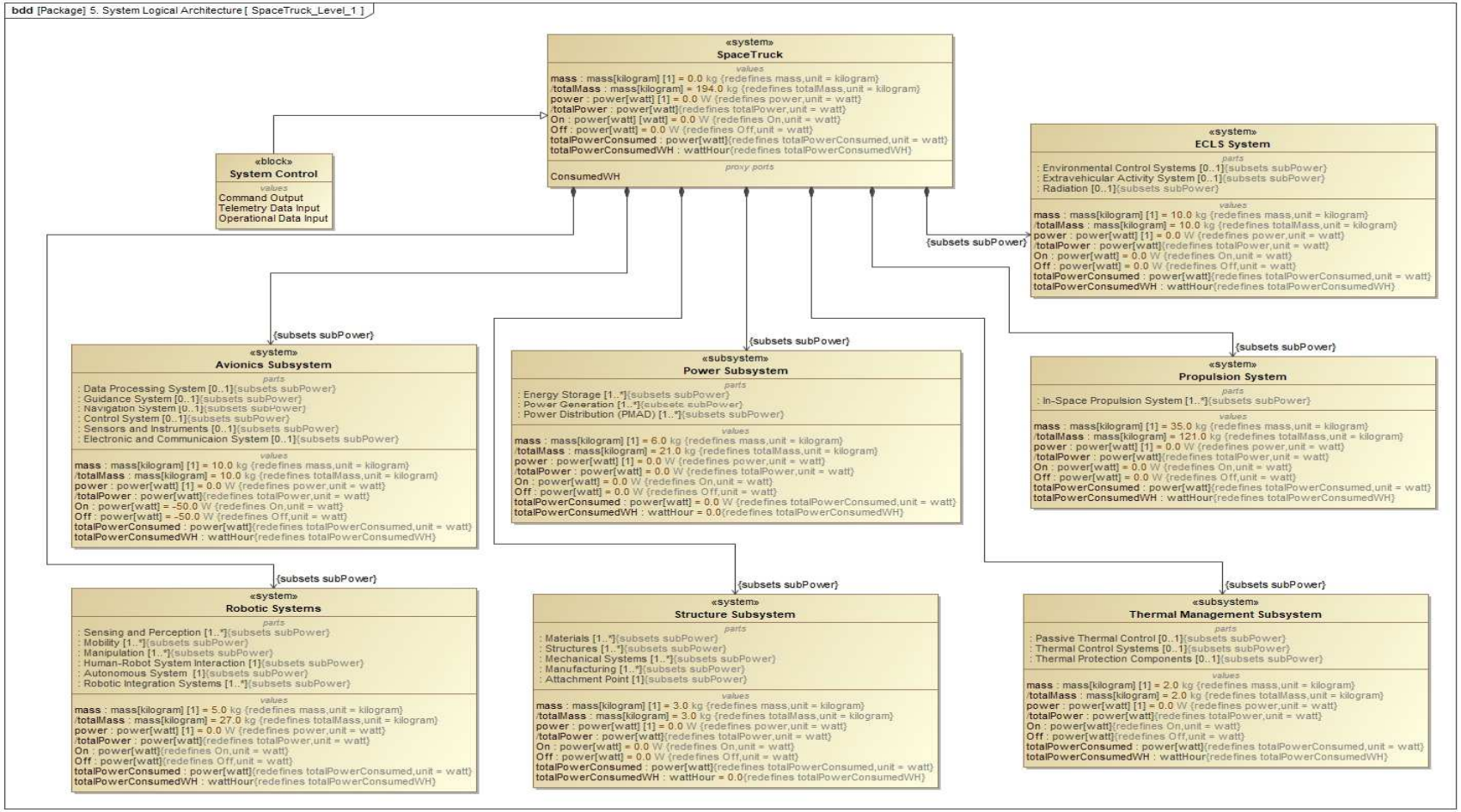
Outcomes

- The teaching methods and outcomes produced
  - **In line with the INCOSE Future of Systems Engineering (FuSE)** program's mission and streams.
- Student 4 (Summer 2023)

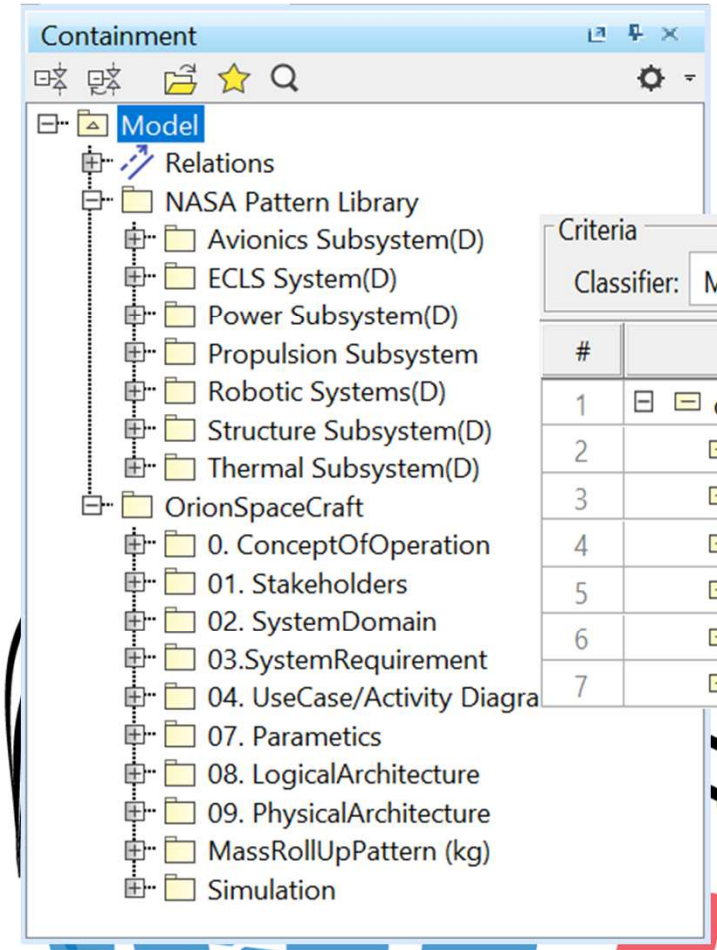
"As the logical architecture for AMAL began to take shape by using the pattern library, it became clear that the original propulsion system that I had in mind would no longer work".

AMAL - Asteroid Mineral Analysis Laboratory

Logical Architecture – Space truck



Orion – System and Mass Roll-up Patterns



Criteria

Classifier: MassRollUpPattern(kg) ... Scope (optional): MassRollUpPattern (kg)

#	Name	mass : mass[kilogram]	totalMass : mass[kilogram]
1	orion	0 kg	32658.6506 kg
2	orion .avionics Subsystem	1723.651 kg	1723.651 kg
3	orion .ecls system	9344.0028 kg	9344.0028 kg
4	orion .propulsion System	14016.0042 kg	14016.0042 kg
5	orion .robotic Systems	360 kg	360 kg
6	orion .structure Subsystem	5934.9926 kg	5934.9926 kg
7	orion .thermal Management Subsystem	1280 kg	1280 kg

Conclusion - Analytics - Time Saving

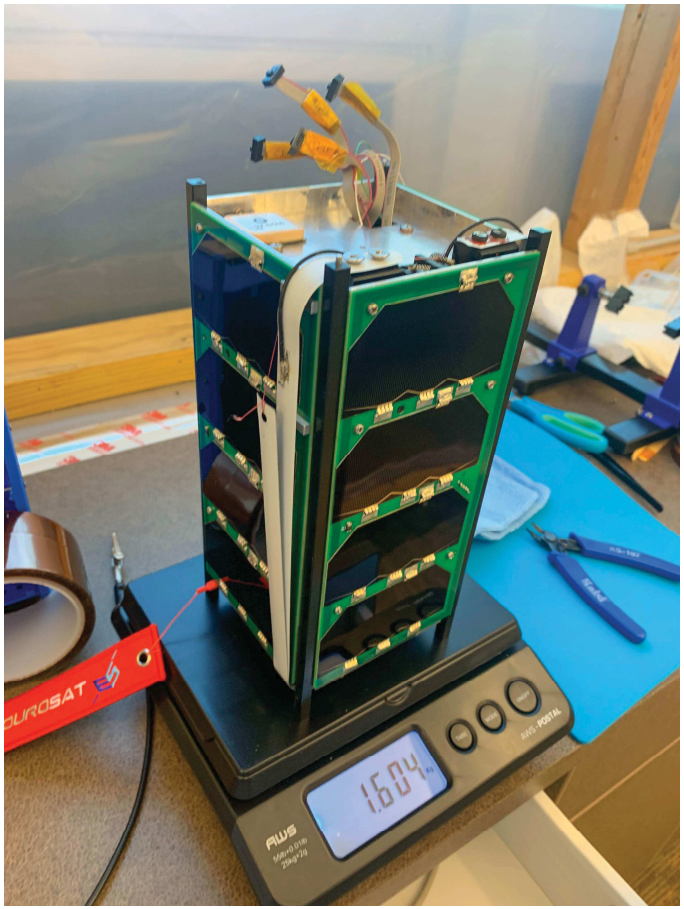
- All students used the majority of top-level patterns, with a minimum of four top-level patterns for Cygwin spacecraft (Student 3) and all seven for AMAL (Student 4) and Orion spacecraft (Student 2)
- Most common four top-level patterns
  - **Power, Structure, Propulsion, and Avionics** systems.
  - **56 patterns** were used in a complete or partial form
  - **19 patterns** are common among all spacecraft
  - Guidance, Navigation, Control, Power Generation, Power Storage, In-space Propulsion, Communications Systems, etc.

Conclusion

- Our SE students should be **learning techniques** that will **help them in the future**, not practices that are being retired
- **One example** of applying research to graduate curricula
- Authors agree with the list of **the implications for education and lifelong learning by 2035** described in the INCOSE Vision 2035
- The academia certainly offers an **educational, training, mentoring, and life-long** learning pipeline to **empower more systems engineers** with strong multi- and transdisciplinary **competencies**

Conclusion - Applications

- The University of South Alabama – “**JagSat I**”
- “JagSat II” & “SolarSailSat I” missions **using patterns**
- Went back to “JagSat I” - as-built architecture and **requirements V&V**



Conclusion – Most Viable Products (MVP)

- **Pattern** library in **various domains** (by author)
  - Fire Protection Systems
  - Home Security Systems (Z-Wave)
  - Sustainable Aviation Fuels Ecosystem (SAF)
  - EV Batteries – Repurpose decision-making
  - Cancer Research – Pattern recognition
  - Virtual Patient – Medical (Ob/gyn) treatment decision-making

Conclusion and Summary

- Teaching Systems Engineering - data
- Speed up architecture development
- Most viable logical architecture
- Advanced MBSE
- Modeling and Simulations teaching
- AI/ML to aid simulations and MVP decisions
- INCOSE FuSE and Vision 2035

Questions

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