Integrating Mission Engineering and Model-Based Systems Engineering: An ARCADIA-Capella Approach

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CAPELLA DAYS 2025

Where the Capella Community Meets

November 18-22, 2025

Online Forum

Capella™

Agenda

- Mission Engineering
- Mission Engineering Architecture Meta-Model (MEAM)
- MEAM Implementation with Capella Arcadia
- Case study
- Conclusion & Learned lessons

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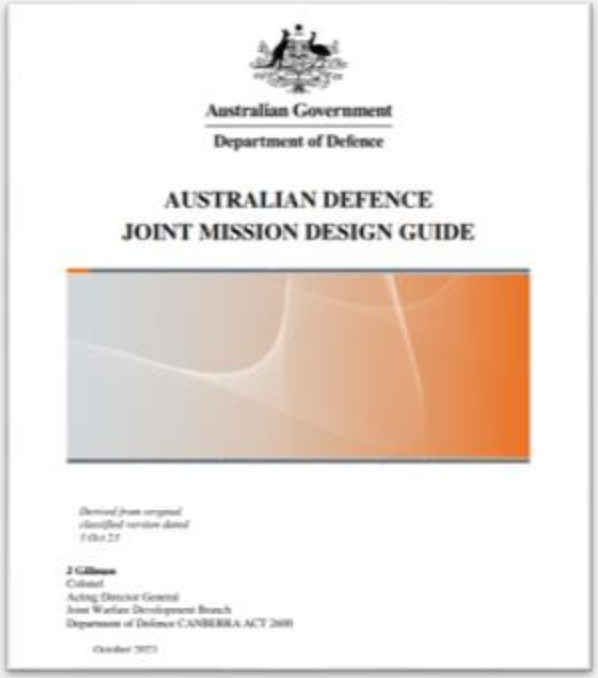
Mission Engineering

- ***Mission Engineering (ME)*** *is a methodology that focuses on optimising the mission itself, treating the entire system of systems as a single unit to achieve desired outcomes.*
- ME helps decision-makers understand what capabilities are needed, the level of performance they need to deliver, the capacity of each capability and interoperability needs.
- The Joint Mission Design is the logical thread between Government's guidance and the fielded force.
- The primary sources for the Mission Engineering processes presented are:
  - US DoD Mission Engineering Guide (MEG)
  - Australian Defence Joint Mission Design Guide (JMDG)
- These were developed into the meta-model concept presented at SETE 2024



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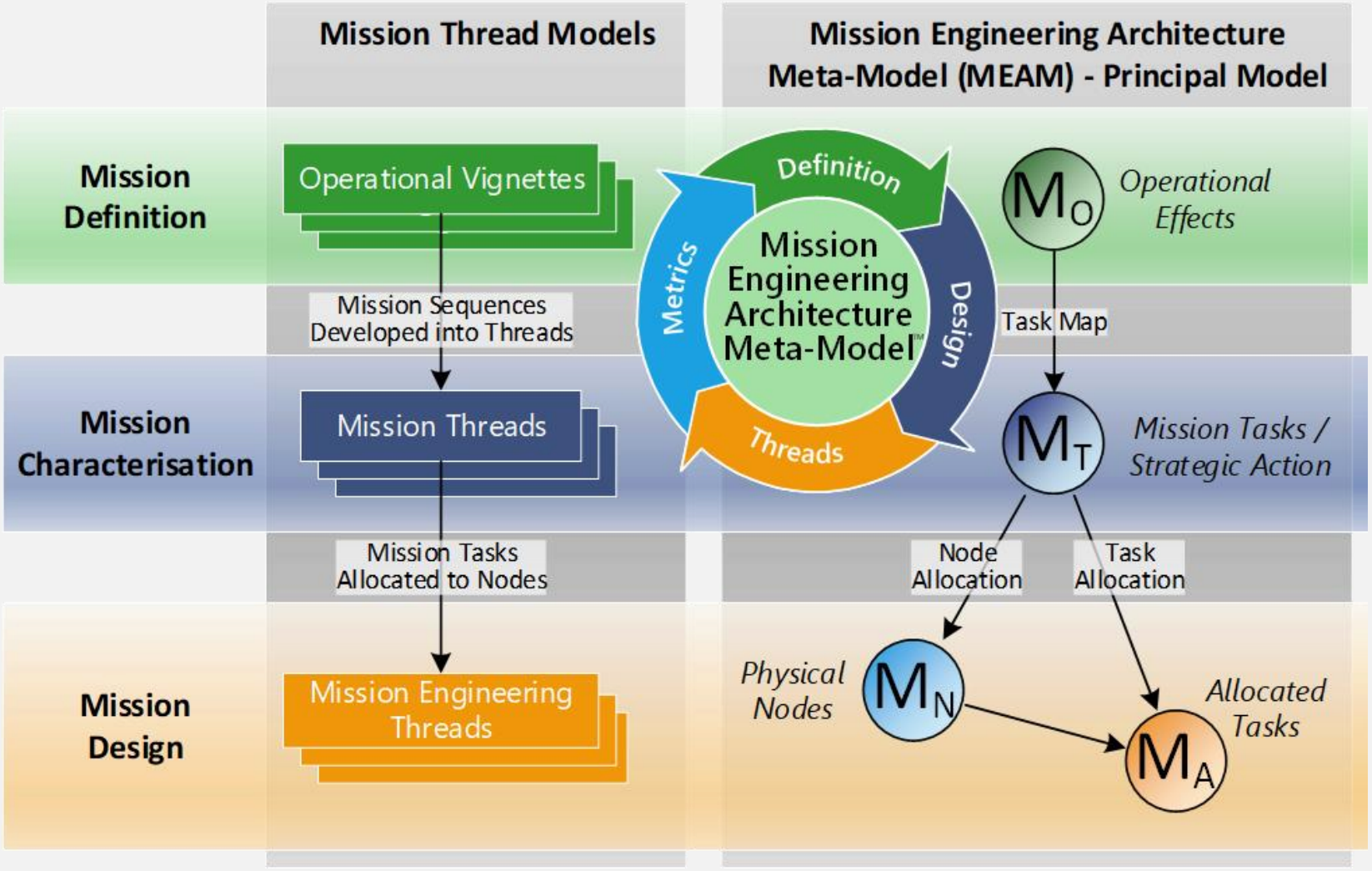
Mission Engineering Architecture Meta-Model (MEAM)

- MEAM is a key enabler in the integration of ME and Systems Engineering and Architecture.
- Can be implemented using any UML / SysML modelling system (tool agonistic).
- MEAM can capture outputs from various ME processes and aims to document in such a way that it will be useful for capability acquisition and systems integration.
- Process derived from US Mission Engineering Guide (MEG), but also usable with the AUS Joint Mission Design Guide (JMDG).



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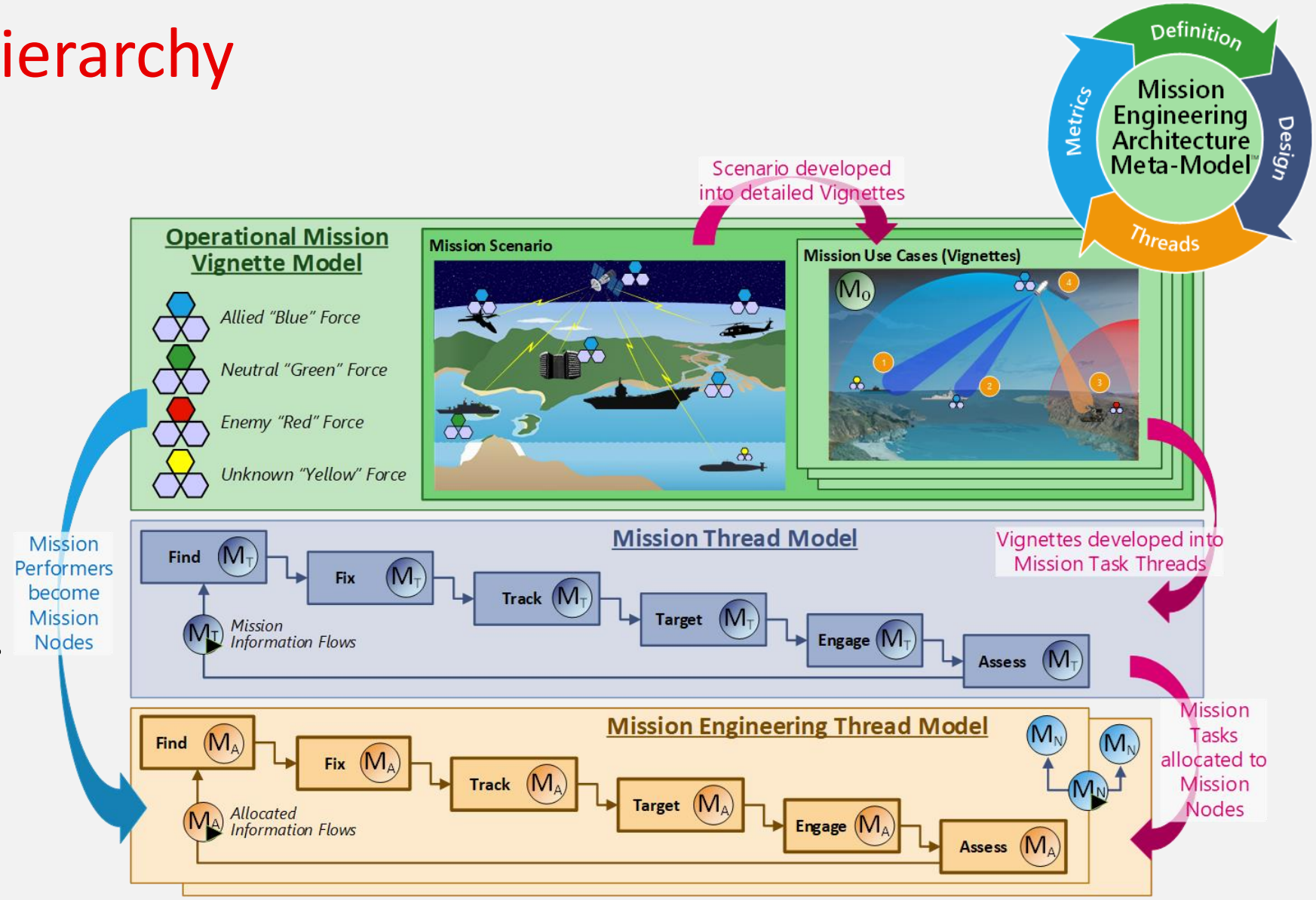
Mission Thread Hierarchy

- Mission Scenario is decomposed into the Mission Thread (MT), which is allocated to Physical Nodes in a Mission Engineering Thread (MET).
- Mission Tasks are managed holistically by Defence (represented by the AUS Functional Library) and adjust in line with missions' changes.
- Physical Node architecture is analysed and trade offs are performed prior to capability investment.



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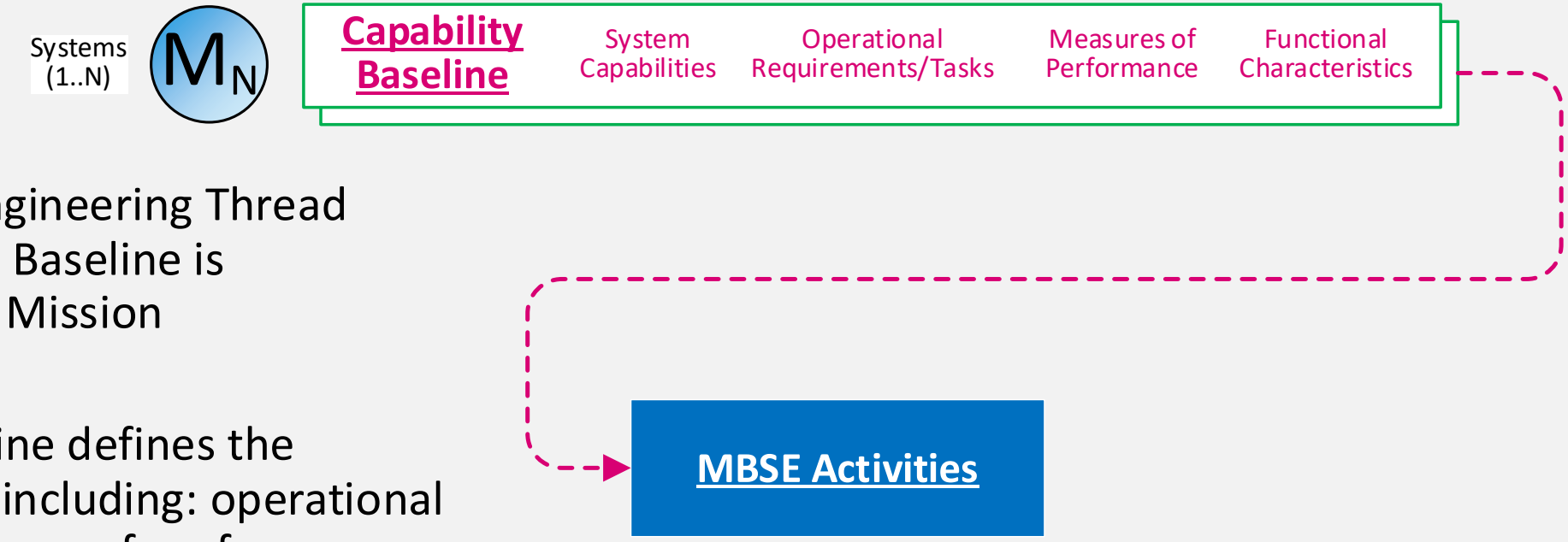
Mission Engineering to MBSE



- From the Mission Engineering Thread Process, a Capability Baseline is established for each Mission System/Node.
- The Capability Baseline defines the System Capabilities, including: operational requirements, measures of performance and other functional characteristics.
- The Mission Engineering defined Capability Baseline is then implemented through standard MBSE Activities, such as the Capella Arcadia method.

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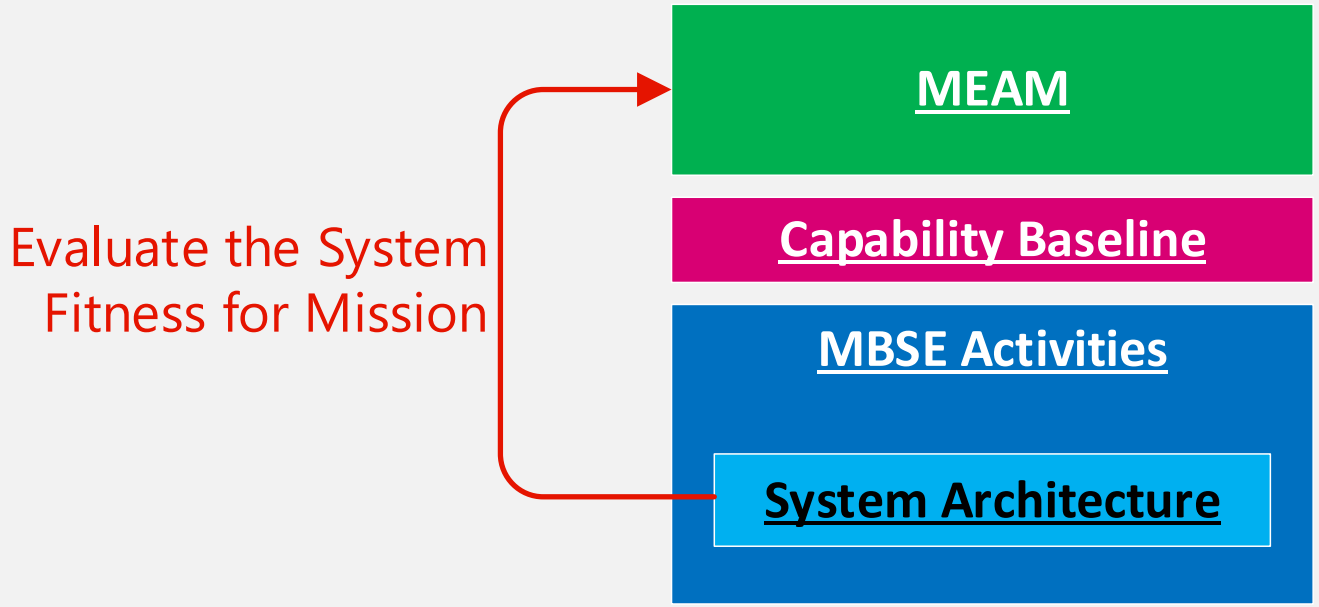
MBSE Solution Meets Mission Needs

- Using the MEAM defined Capability Baseline, System Architecture solutions can be compared and contrasted to evaluate which solution best meets the Mission Needs.
- The advantages and potential limitations for the System Architecture solutions can be evaluated against the Mission impact.
- Having this broader mission perspective provides a more end-user focused standpoint when making trade-off decisions, rather than just a cost/schedule or otherwise programmatic evaluation.



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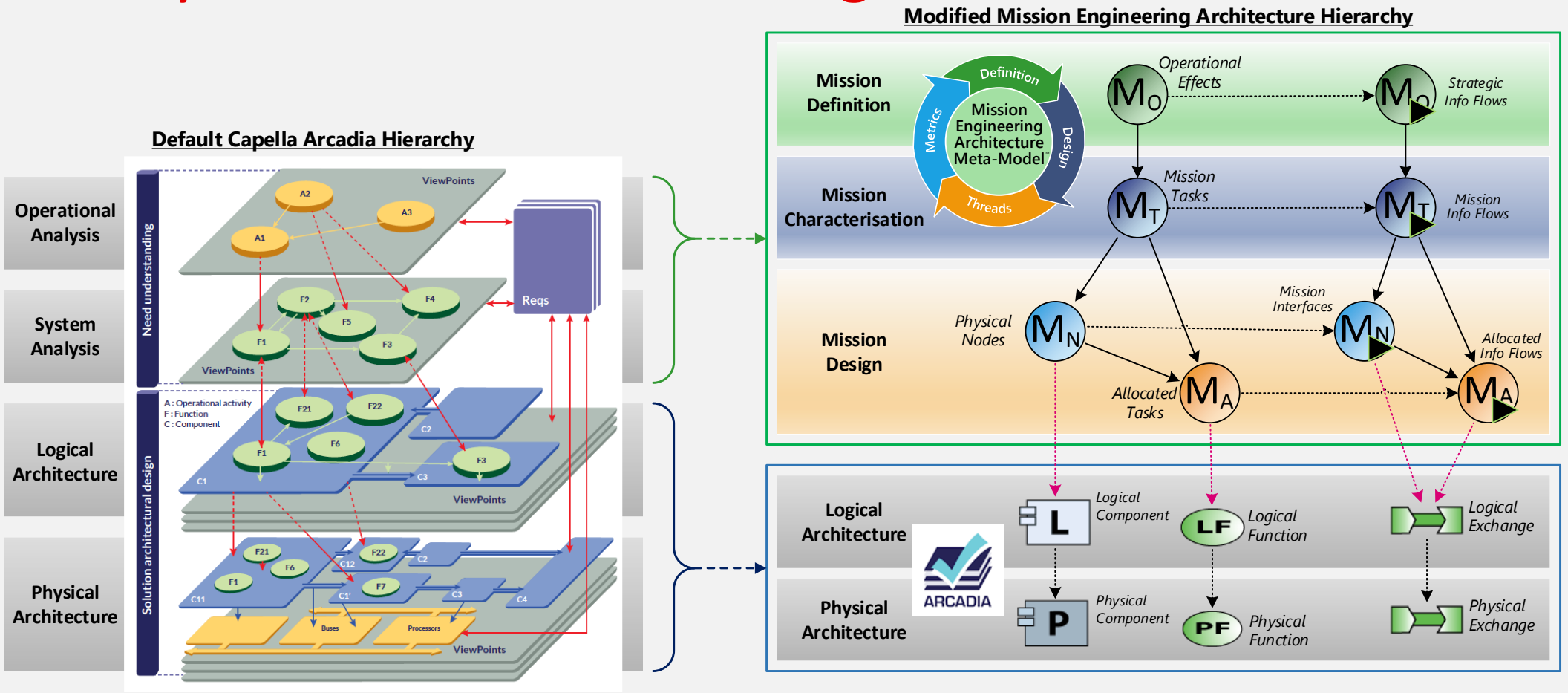
Mission Systems Architecture Alignment



- Mission Engineering is modelled to capture the Mission Needs, which is then traceable into the Arcadia Logical and Physical Solution Architecture Designs.
- Logical and Physical Solutions are able to adapt to new and modified mission needs.

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MEAM to Capella Arcadia Mapping

ARCADIA Element	Capella Diagram	MEAM Element
Operational Capabilities	OCB	Operational Effects / Mission objectives
Operational Entity Breakdown	OEBD	Mission Context
Operational activities	OAIB	Mission (essential) Tasks
Operational activities / Operational Processes	OAIB / OPD	Mission Thread
Operational activity Breakdown	OABD	Mission Tasks Taxonomy
Operational Actors / Entities	OEBD	Operational Roles Mission Performers Physical Node
Operational Entity Scenario / Operational activity scenario	OES / OAS	Scenarios / Vignettes (Use Case)
Operational Architecture	OAB	Mission Engineering Thread Allocated Task

Problem

- In most SysML based modelling tools, stereotypes can be applied to extend an existing SysML element into a MEAM element, however Capella doesn't offer stereotyping as a configuration in the same way as it is offered in other tools.
- There is a PVMT add-on that defines properties and changes graphical aspects of Arcadia elements, however this has limited functionality at the higher level (e.g. it doesn't allow for complete re-assignment of Arcadia elements).

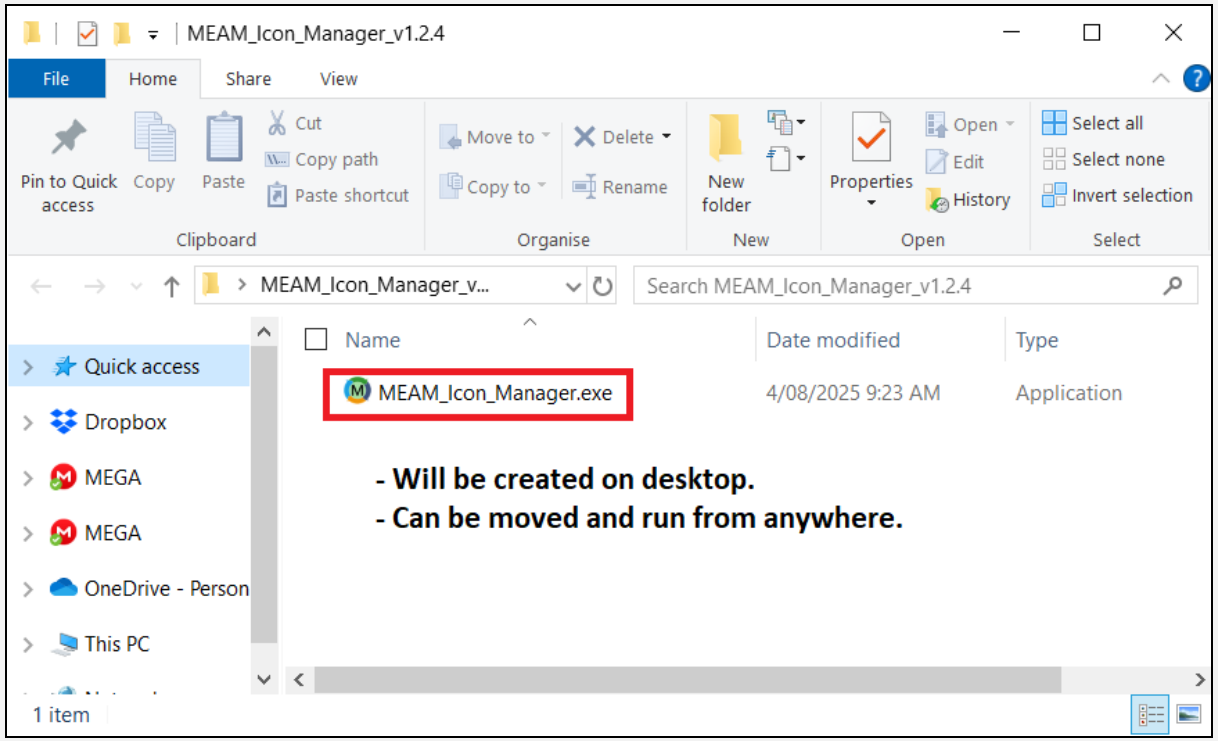
Solution Approaches

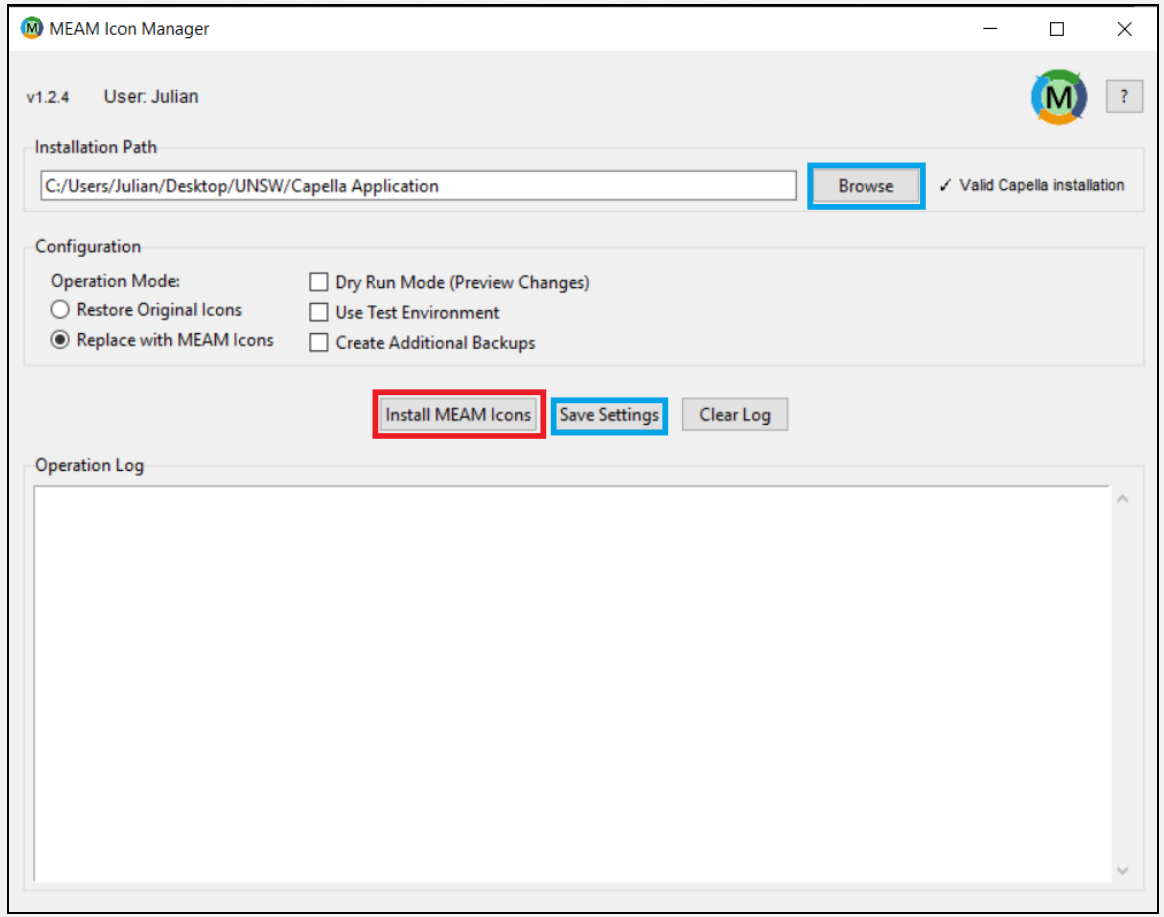
Following consultation with OBEO, two solutions were offered for consideration:

- An Advanced Approach, using Sirius, which consisted of creating an Add-On (like the Basic Mass / Requirements Viewpoint Add-Ons).
- An Expedited Approach, which consisted of replacing Capella icons in existing .jar files to the relevant MEAM icons.

MEAM Installation in Capella Arcadia

- The MEAM Icon Manager was created to automatically apply MEAM to a Capella 7.0.0 installation.





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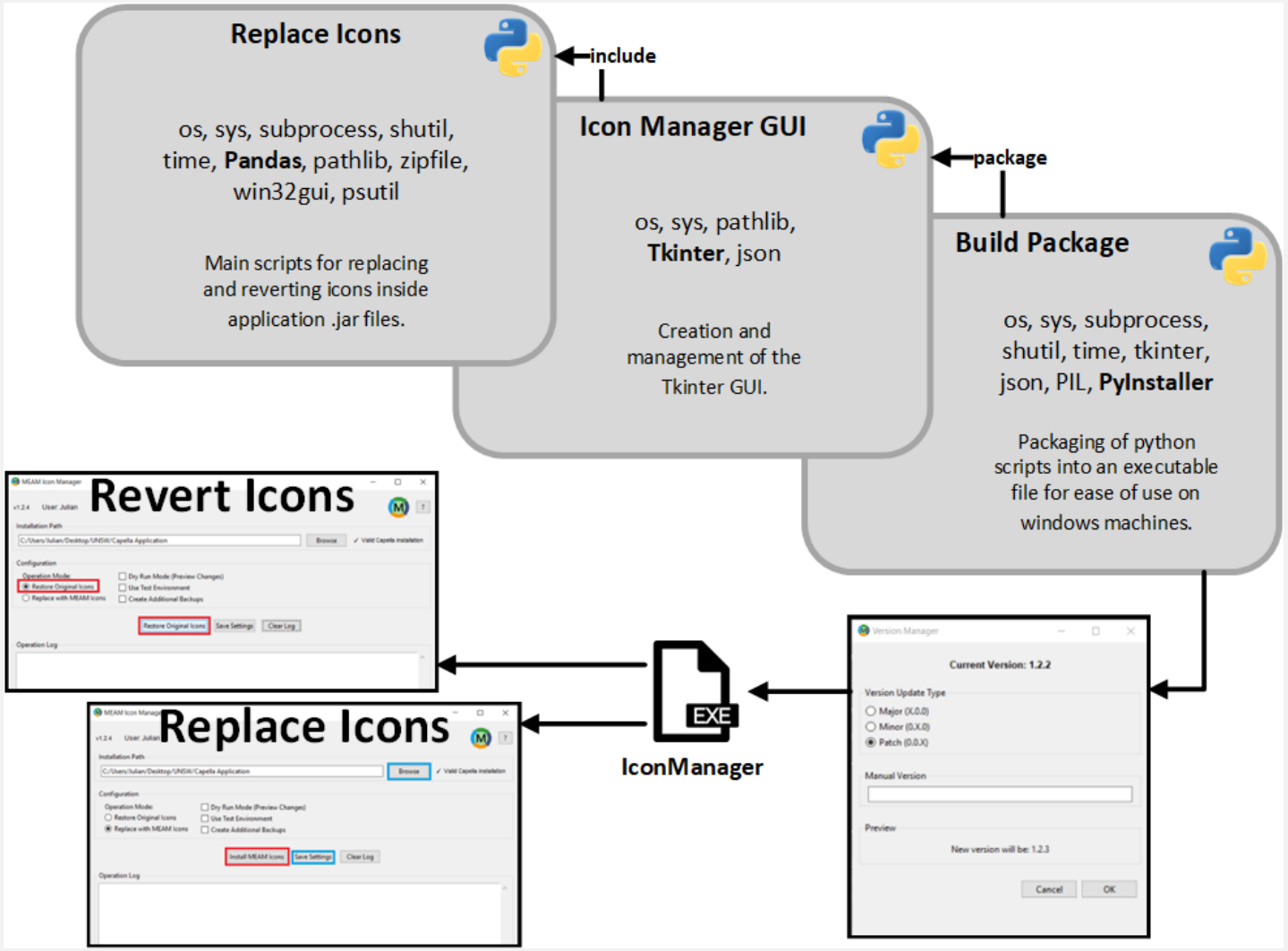
Script Layout

- The script is primarily contained in replace_icons.py which uses Pandas to read CSV mapping and pathlib/shutil to process .jar files and move icons to desired locations.
- A Tkinter GUI helps the user manage the Capella installation and the various icon manager functions.
- PyInstaller is used to package scripts and maps into an executable file for ease of use on windows machines.



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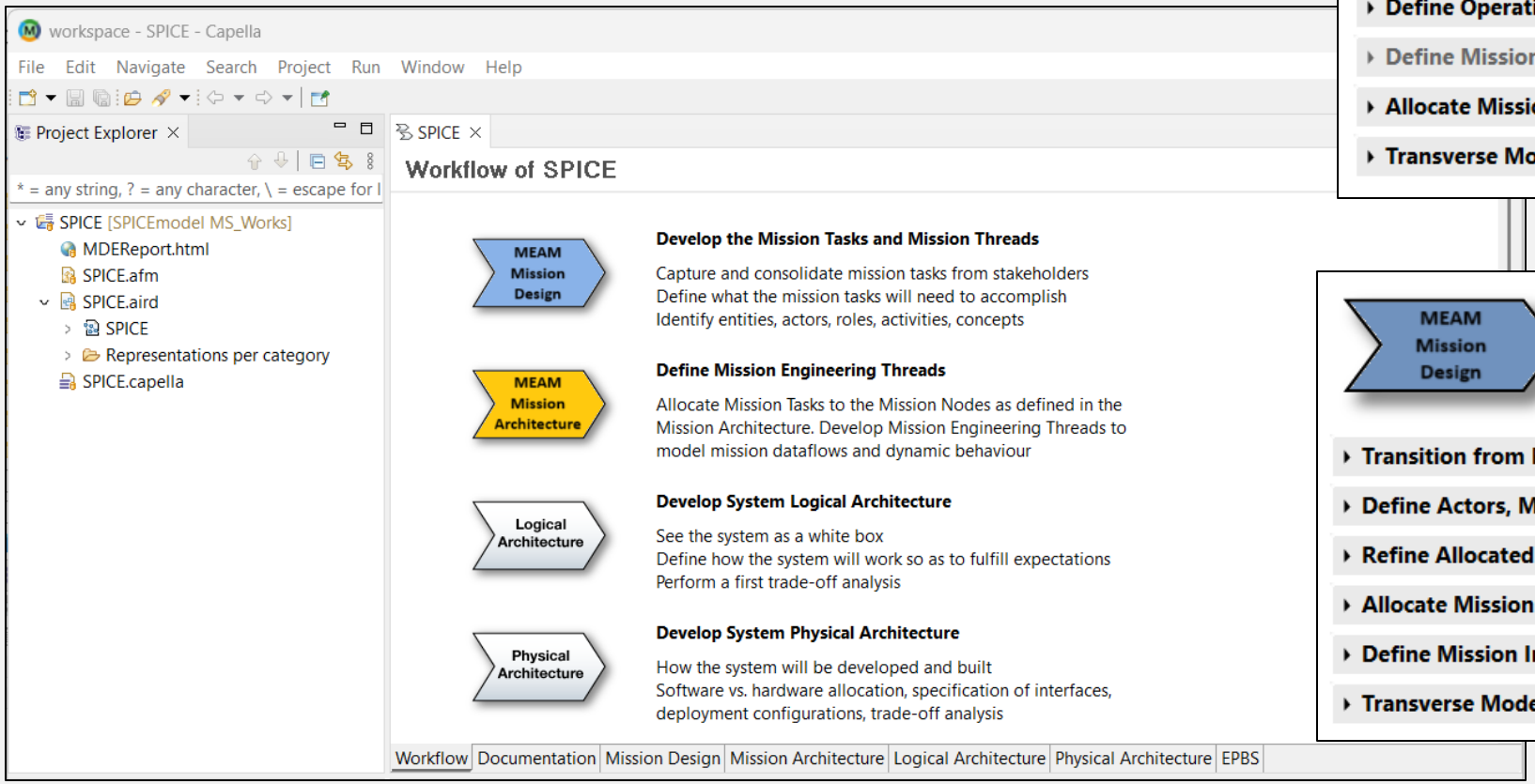
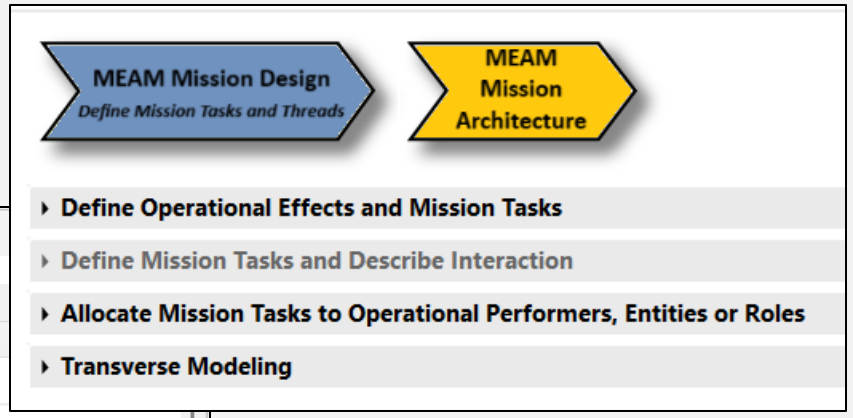
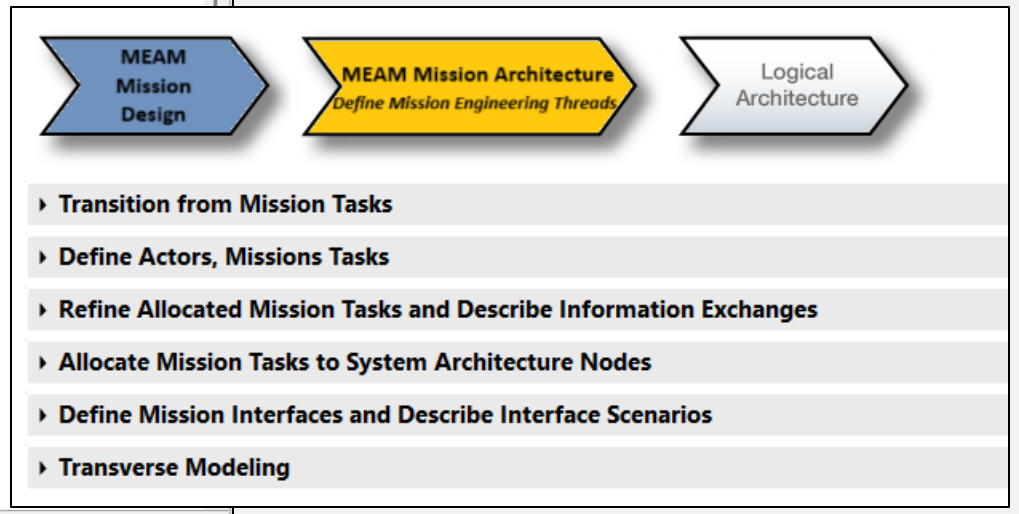
MEAM Implemented in Capella Arcadia Workflow

- The MEAM Workflow has been implemented in Capella and aligned to the Logical and Physical Architecture layers.







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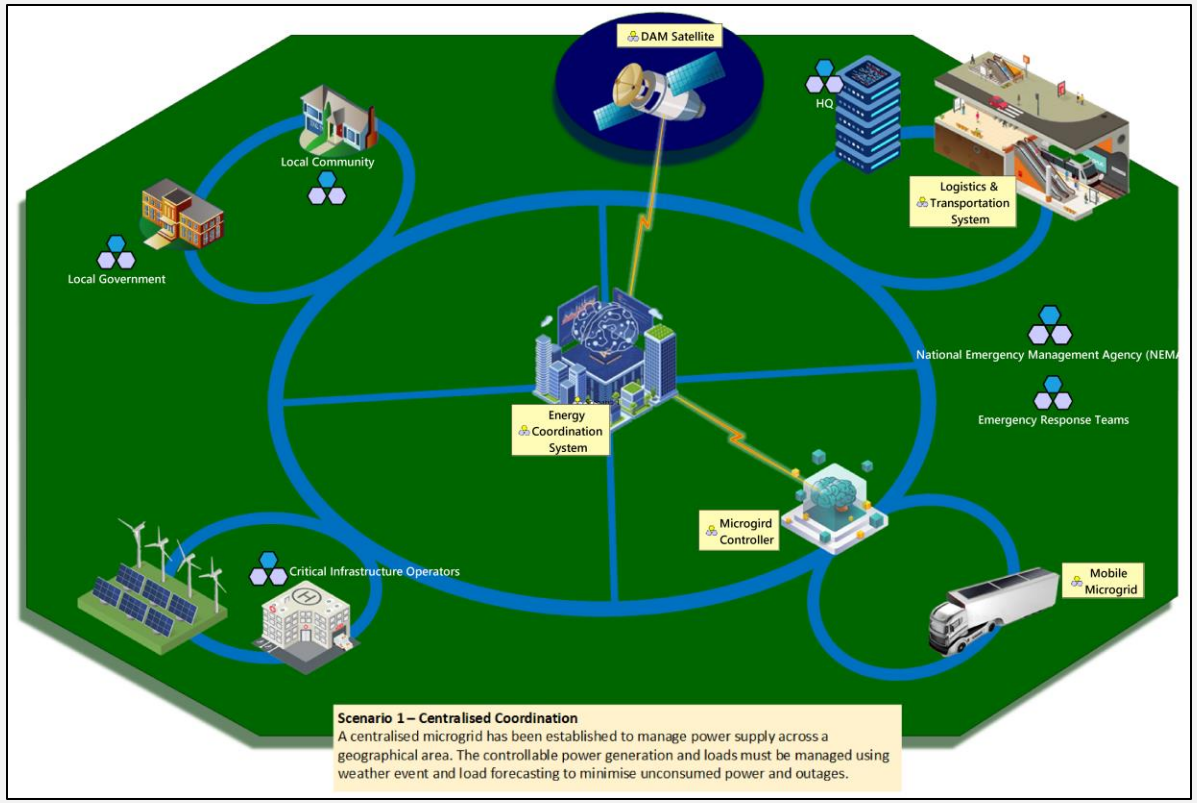
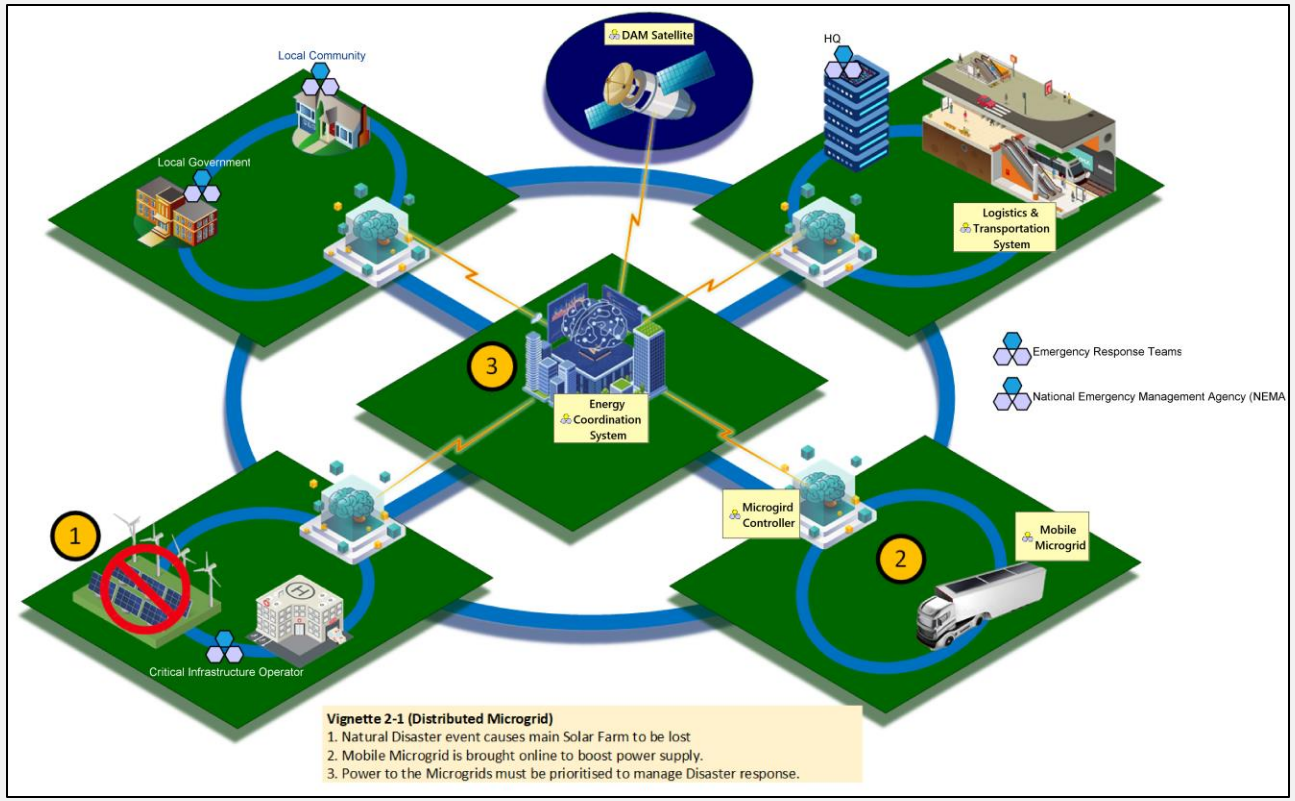
Introduction to our mission

- **Case Study System:** SPICE (Sustainable Power Integration for Crisis Events)
- **Mission:** Enhance energy resilience and disaster response capability in vulnerable regions during extreme events.
- **Constituent Systems:**
  - Mobile Microgrid
  - Disaster Alarm & Monitoring Satellite
  - Critical Infrastructure operators
  - HQ
  - Local government
  - National Emergency Management Agency (NEMA)
  - Logistics & Transportation System
  - Energy coordination system

MEAM in Capella – Mission Scenarios



- The MEAM Mission Scenarios have also been implemented in Capella using Mission Performer icons and relationships.



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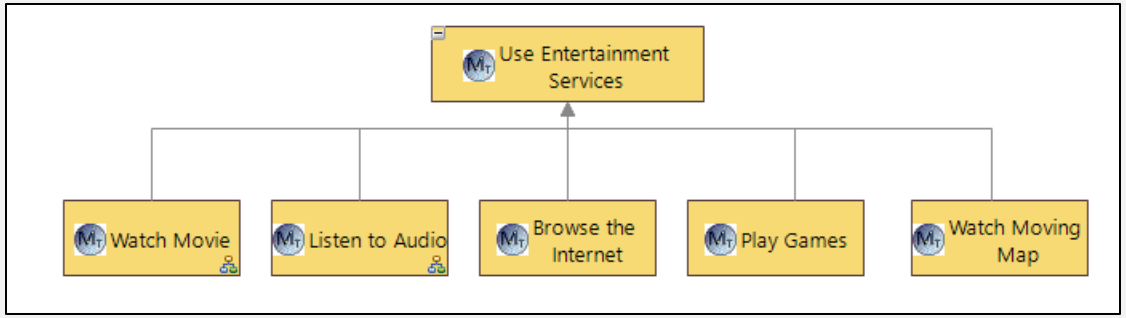
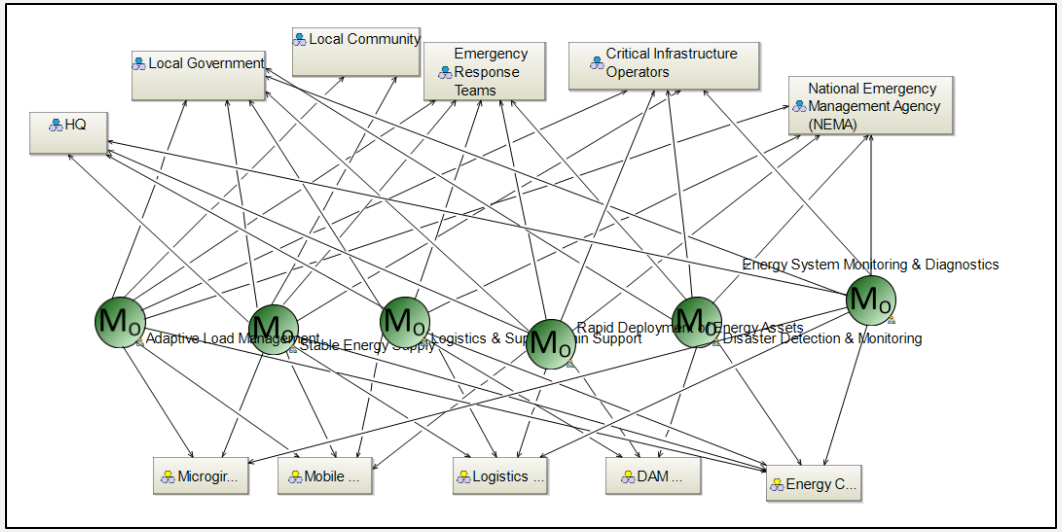
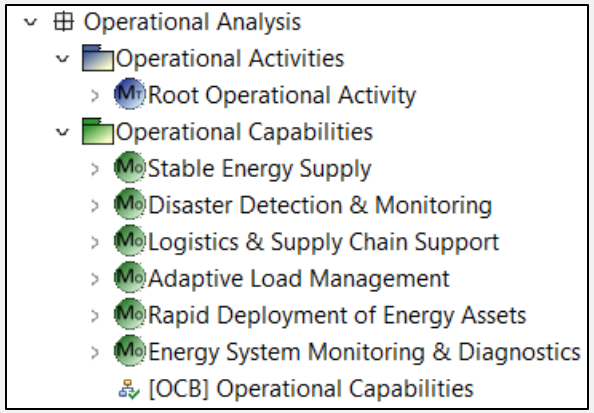
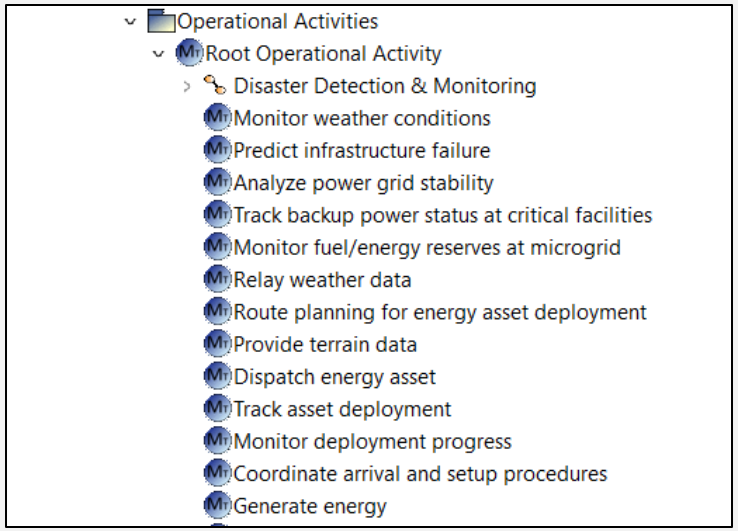
MEAM in Capella Arcadia - Views

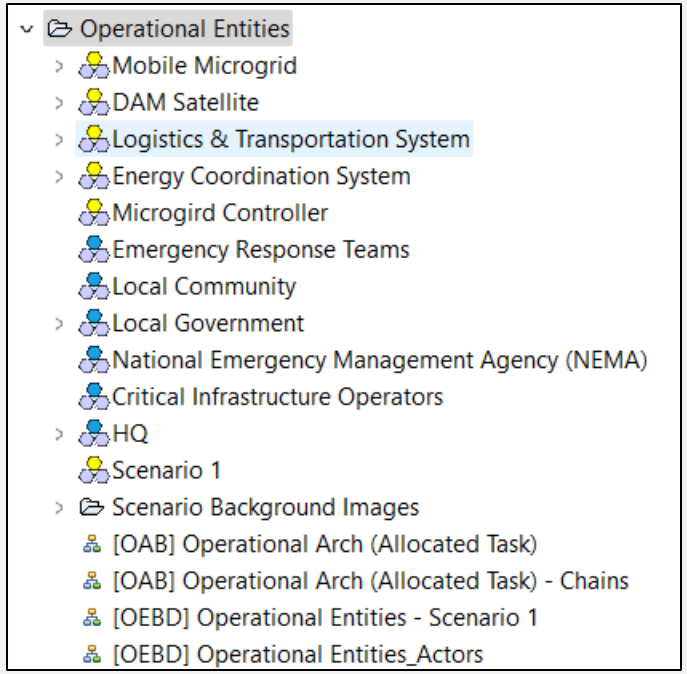
- The MEAM Icons have been implemented in Capella, enabling a range of Mission Engineering diagrams to be developed.











MEAM in Capella Arcadia - Mission

Mission & Operational Effects

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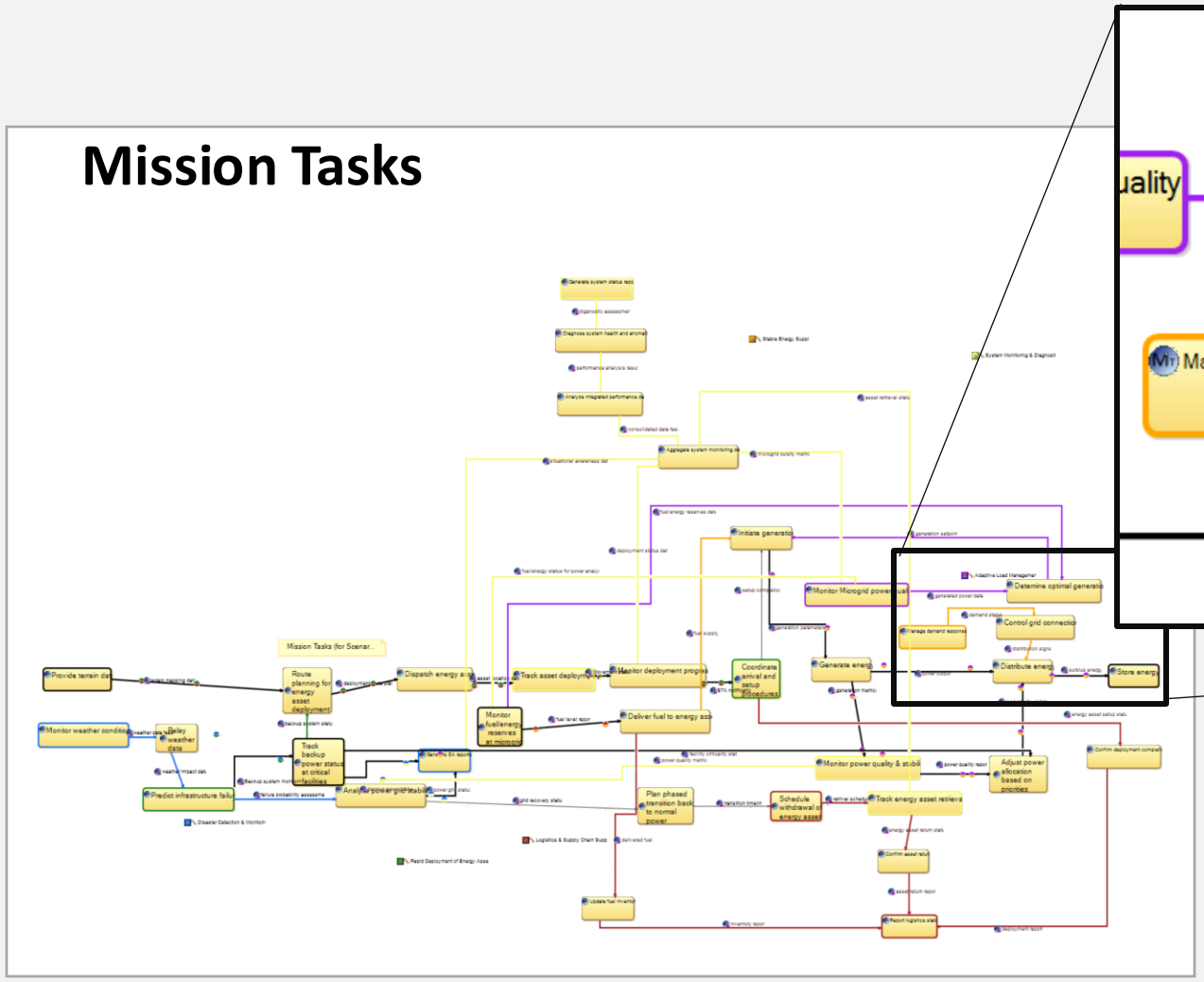
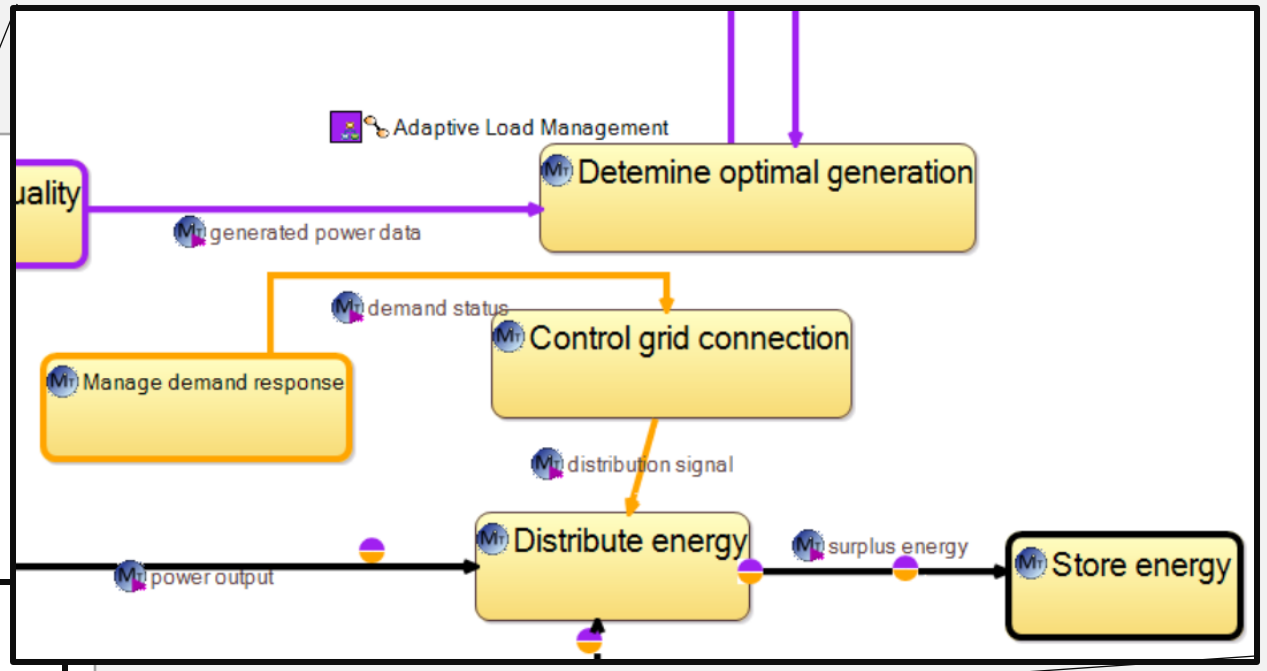
MEAM in Capella Arcadia - Tasks





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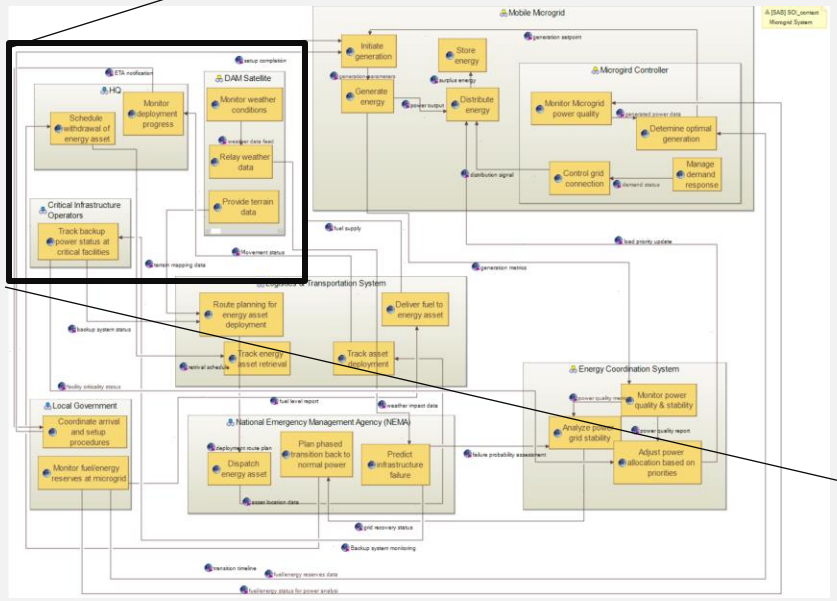
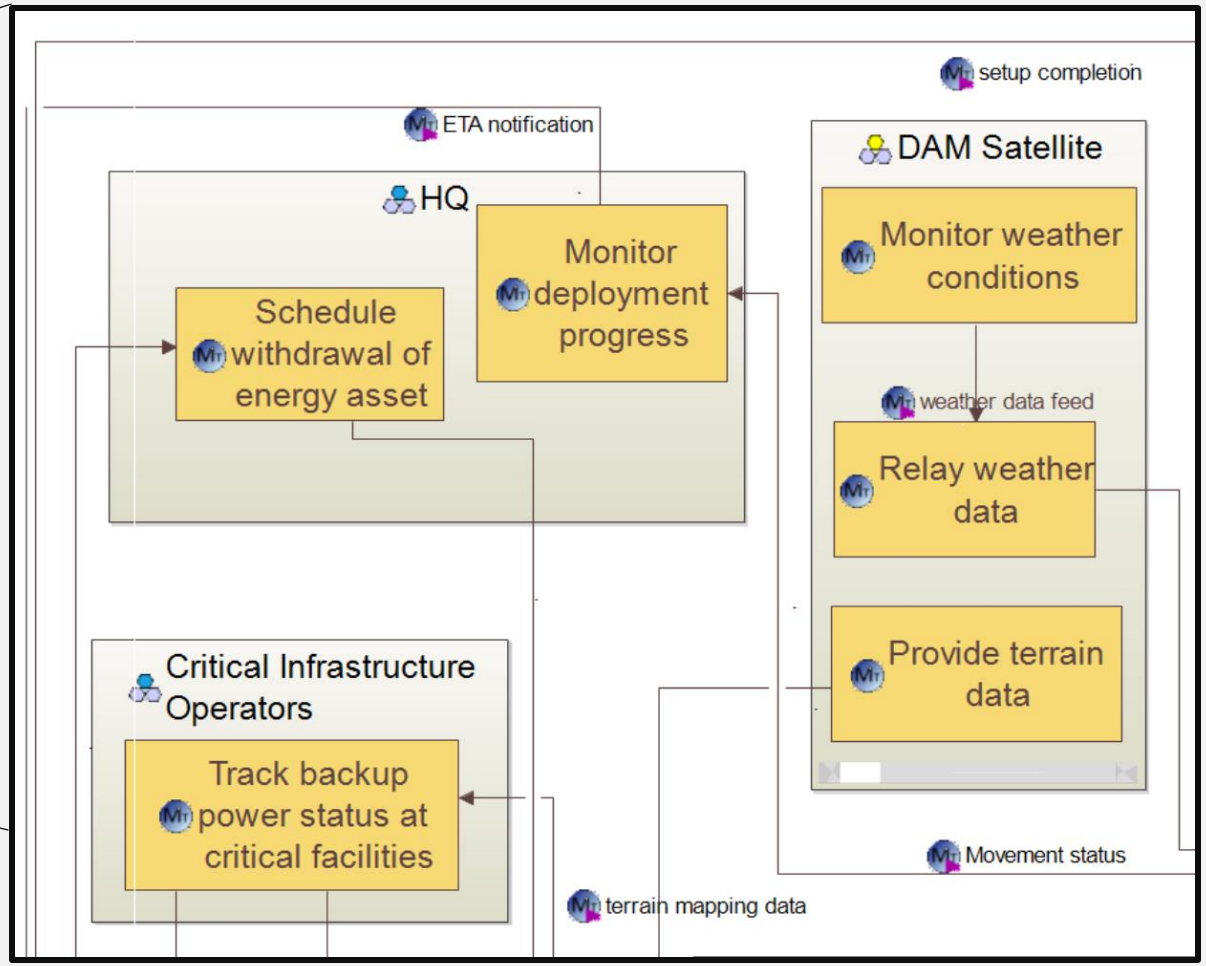
MEAM in Capella Arcadia - Nodes

Mission Nodes
& Task Allocation





Lessons Learnt

- Developing plugins required more software expertise than initially anticipated, which led us to adopt a faster workaround rather than a full custom extension.
- Capella's add-in architecture offers considerable flexibility. With the right knowledge, major parts of the tool can be modified. However, this level of customization increases complexity.
- Mission engineering is increasingly fundamental to modern systems development. Tools should better support mission-oriented workflows to make their application smoother and more accessible.
- There is strong value in enhanced stereotyping support within Capella. A plugin that allows advanced customization—like Cameo's profile mechanism—without requiring deep code changes would be a major enabler.

Lessons Learnt (2)

- When adapting tools for new domains, it is important not to underestimate the limitations or possibilities. Assumptions can lead to incorrect expectations about what is feasible.
- Although quick fixes may be appealing, it is more effective and sustainable to invest in a solution that is repeatable and scalable. The additional effort pays off in the long term.
- There is a clear need for ontologies to enable communication between different domains. Without a shared understanding, integration challenges will emerge during implementation.
- A clear understanding of the difference between languages, methods, and tools can improve the adaptability of MBSE practices. For instance, the ARCADIA method remains valuable for mission engineering even if Capella is not the tool of choice.

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