Development and Application of the CubeSat System Reference Model

Space Systems Working Group (SSWG)

Co-Chairs

David Kaslow
david.kaslow@gmail.com

Alejandro Levi
alejandro.g.levi@ieee.org
CubeSat System Reference Model Project

- CSRM Project Objectives
- CSRM Foundation
- CSRM Fundamental Elements
- CSRM as an OMG Specification
- CSRM Application
- CSRM Architecture
- CSRM and Mission Engineering
- References

CubeSat unit is 10x10x10 cm and about 1.3 kg
Originated 1999 – Stanford Univ and Cal Poly Univ
CSRM Project Objectives

- International Council on Systems Engineering (INCOSE) Space Systems Working Group (SSWG) project

- Objectives of CSRM Project
  - Demonstrate Model-Based Systems Engineering (MBSE) as applied to a CubeSat Mission
  - Develop a CSRM that a university team can use as a starting point for their mission-specific model
  - Develop the CSRM as an Object Management Group (OMG) Specification

The CSRM architecture can be applied to SmallSats

Can the CSRM concept be extended to Mission Engineering?
CSRM Foundation

OMG CSRM Request for Proposal
Model Based Systems Engineering
Systems Modeling Language
Graphical Modeling Tool

CubeSat System Reference Model
Development, Evaluation, Validation

CSRM
Logical architecture of a CubeSat space-ground system
Repository for systems engineering artifacts

A foundation for a mission-specific logical model
CSRM Fundamental Elements

CubeSat System Reference Model (CSRM)
Logical architecture of a CubeSat space – ground system
Repository for systems engineering artifacts

Stakeholders
Regulatory Agencies
Sponsor
Mission
CubeSat Deployer

Requirements
Enterprise
Space Segment
CubeSat
Ground Segment
Subsystems
Components

Behaviors
Specifications

Validation
Verification
Specifications

Technical Measures
Specifications

Architecture
Enterprise
Space Segment
CubeSat
Ground Segment
Subsystems
Components

An exo-structure for population with mission-specific elements
In the past, OMG Specifications have been entirely document-based
The CSRM has sufficient flexibility for the mission team to modify the logical architecture for the mission and systems engineering methodology.
CSRM Architecture
The CSRM landing page provides for an overview and navigation including the requirements and architecture hierarchies.
CSRM provides for defining and tracing requirements from stakeholders, use cases, technical measures down to subsystems and components and to validation and verification activities.
Requirements Hierarchy
CSRMM logical architecture provides the starting point for a mission-specific team establishing their logical and physical architectures.
CSRMA provides for both space and ground capabilities and external services
The mission team specifies subsystem capabilities and whether they are provided by software, hardware, persistent data, or operator procedures.
Next Steps - Mission Engineering

The SSWG will explore how the approaches and methodologies used in the development of the CSRM can be applied to Mission Engineering.
CSRM and Mission Engineering

The following activities are proposed:

- Identify Mission Engineering MBSE methodologies
- Identify the key elements of terminology, and map/align with the CSRM terminology for each methodology
- Analyze the CSRM for additional artifacts which could be added to the containment tree for the key elements that do not map to the CSRM
- Assess whether the CSRM is the right tool to support this aspect of the methodology
- Provide the results of the above analysis to INCOSE and OMG with recommendations for implementation

**Carry-out a CSRM gap-like analysis relative to accommodating mission engineering threads**
Identify Mission Engineering Methodologies

Space Mission Analysis and Design
Space Mission Engineering is the refinement of requirements and definition of mission parameters to meet the broad objectives of a space mission in a timely manner at minimum cost and risk

DoD Mission Engineering Handbook
Mission Engineering is the deliberate planning, analyzing, organizing, and integrating of current and emerging operational and system capabilities to achieve desired warfighting mission effects

INCOSE Systems Engineering Book of Knowledge
Mission Engineering describes the application of systems engineering to the planning, analysis, and designing of missions where the mission is the System of Interest

Mission Engineering analyzes the mission goals and threads, analyzes the available as well as emerging operational and system capabilities, and designs a mission architecture to achieve the mission goal

Different domains have different mission engineering methodologies
Mission Engineering Scope

Mission Engineering Activities

OMG

CSRM

Establish Project CSRM

Establish Mission Logical Model

Establish Mission Physical Model

Dynamic Model

Map Model Elements to ME Activities

Submit Elements for Incorporation

Roll-up Supplemental Elements

Supplement Model Elements

Architecting for Mission Engineering
INCOSE Mission Engineering Activities will be used to kick-off this process
Map and Supplement CSRM Elements

**INCOSE ME Activities**
- Mission Capability Analysis and Definition
- Mission Thread Definition
- Tradeoff Analysis
- Mission Architecting
- Requirements Engineering
- Interoperability Analysis
- Mission-oriented SoS Implementation
- Mission Verification and Validation

**CSRM Elements**
- Stakeholders
- Mission Objectives
- Mission Constraints
- Requirements
- Behaviors
- Technical Measures
- Architecture
- Validation Activities
- Verification Activities

*The focus is on logical model that will be populated as a physical model*
Mission Engineering – CSRM and System of Systems

- Two of the mission Engineering Activities will be particularly challenging to explore
  - Interoperability Analysis
  - Mission-oriented SoS Implementation Activities
- Our paper outlines the SoS issues as presented in the INCOSE SoS Primer
- SoS architecture issues can be broadly categorized as to the roles of the constituent system
  - The constituent system provides technical data and an interface must be established
  - The constituent system provides a capability that needs to be modeled and integrated with the operations of other constituent systems.
Mission Engineering - Next Steps

- Outreach for additional Mission Engineering Methodologies:
  - 2021 INCOSE International Workshop
  - 2021 IEEE Aerospace Conference
  - 2021 Small Sat Conference

- Coordination with INCOSE Working Groups:
  - Enterprise Systems
  - System of Systems
  - Model-Based Conceptual Design
References
References


References

- INCOSE Systems of Systems Primer, INCOSE-TP-2018-003-01.1, 2018
Thank You

If you have any questions, please feel free to contact us

David Kaslow
david.kaslow@gmail.com

Alejandro Levi
alejandro.g.levi@ieee.org