Development and Application of the CubeSat System Reference Model

Space Systems Working Group (SSWG)

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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

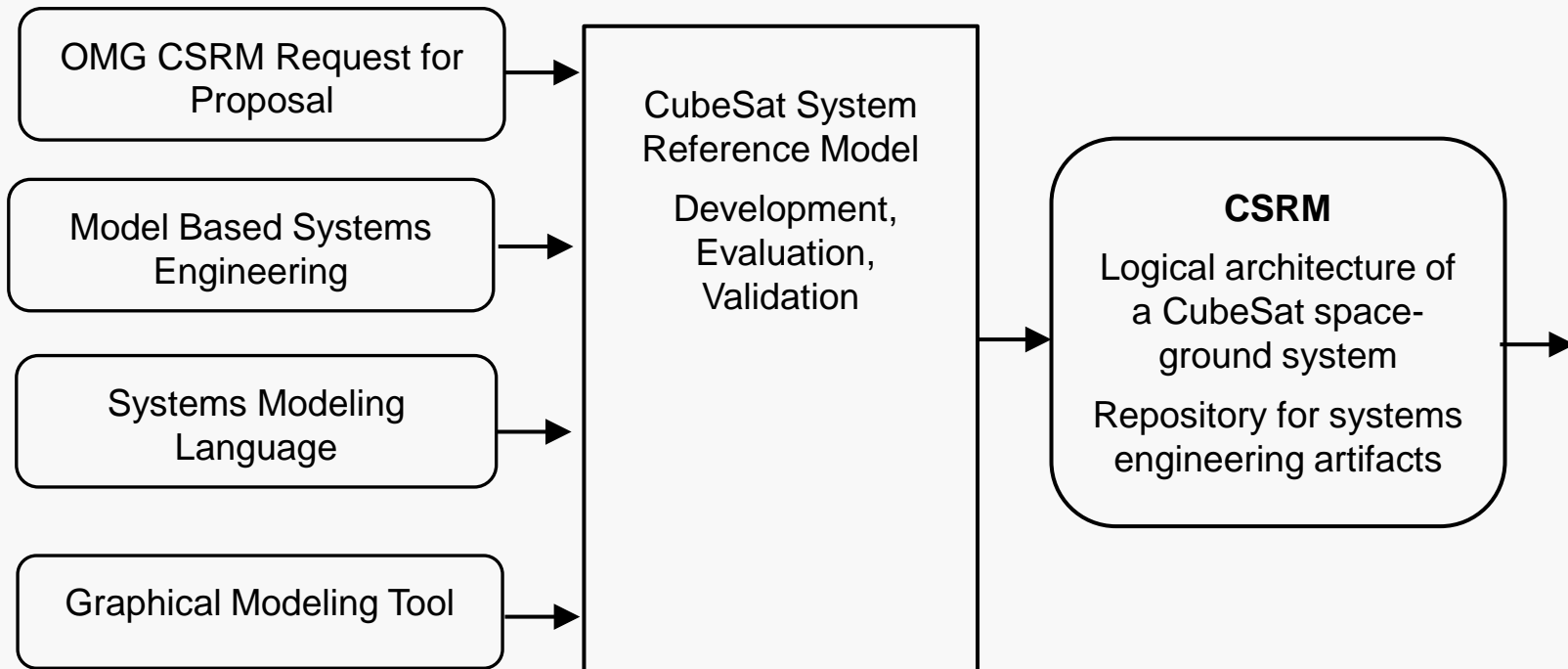# CSRM Project Objectives

- 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 uses as 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
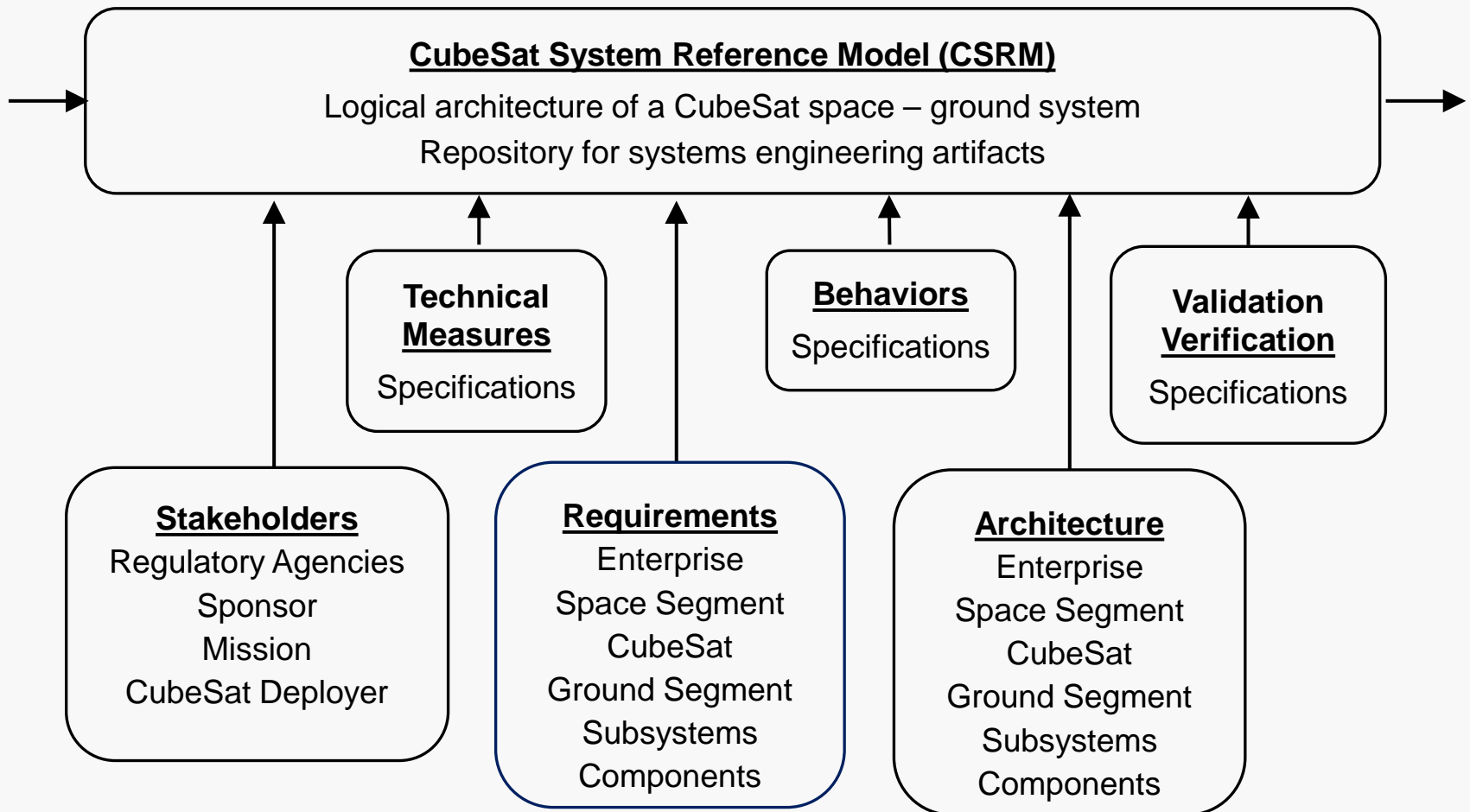
Can the CSRM concept be extended to Mission Engineering?

CSRM Foundation

OMG CSRM Request for Proposal →		
Model Based Systems Engineering →	**CubeSat System Reference Model** Development, Evaluation, Validation	**CSRM** Logical architecture of a CubeSat space-ground system Repository for systems engineering artifacts
Systems Modeling Language →		
Graphical Modeling Tool →		

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

Technical Measures

Specifications

Behaviors

Specifications

Validation Verification

Specifications

Stakeholders
Regulatory Agencies
Sponsor
Mission
CubeSat Deployer

Requirements
Enterprise
Space Segment
CubeSat
Ground Segment
Subsystems
Components

Architecture
Enterprise
Space Segment
CubeSat
Ground Segment
Subsystems
Components

An exo-structure for population with mission-specific elements

CSRM as an OMG Specification

Object Management Group (OMG)

An International Standards Organization

Issue CSRM RFP

Evaluation and Down Selection

Compliance Criteria

Approve and Distribute

Normative

CSRM Specification Document

CSRM Profile XMI File

Non-Normative

CSRM Model File

CSRM HTML File
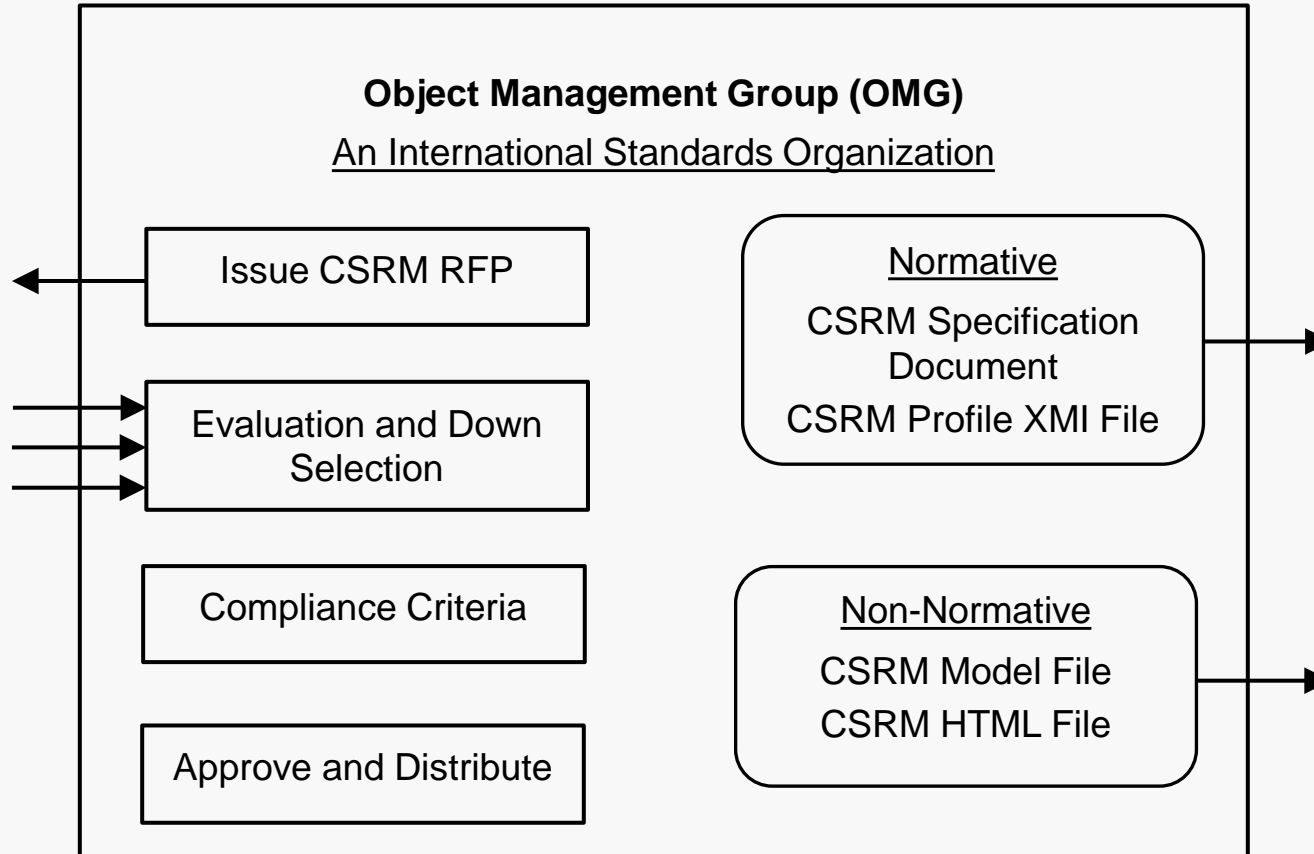
In the past, OMG Specifications have been entirely document-based

CSRM Application

Mission-specific CubeSat Model (MSM)

Logical architecture, Physical architecture, Development

Project –specific Stakeholders and Needs	→ Download CSRM and Populate Graphical Modeling Tool
Project Engineering Methodology	→ Establish Project-specific CubeSat Reference Model
Mission–specific Stakeholders and Needs	→ Establish Mission-specific Logical Architecture
Design and Develop Mission CubeSat ←	Establish Mission-specific Physical Architecture

The CSRM has sufficient flexibility for the mission team to modify the logical architecture for the mission and systems engineering methodology

CSRM Architecture

INCOSE IW
January 2021
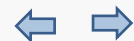
CSRM Landing Page
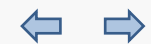
The CSRM landing page provides for an overview and navigation including the requirements and architecture hierarchies
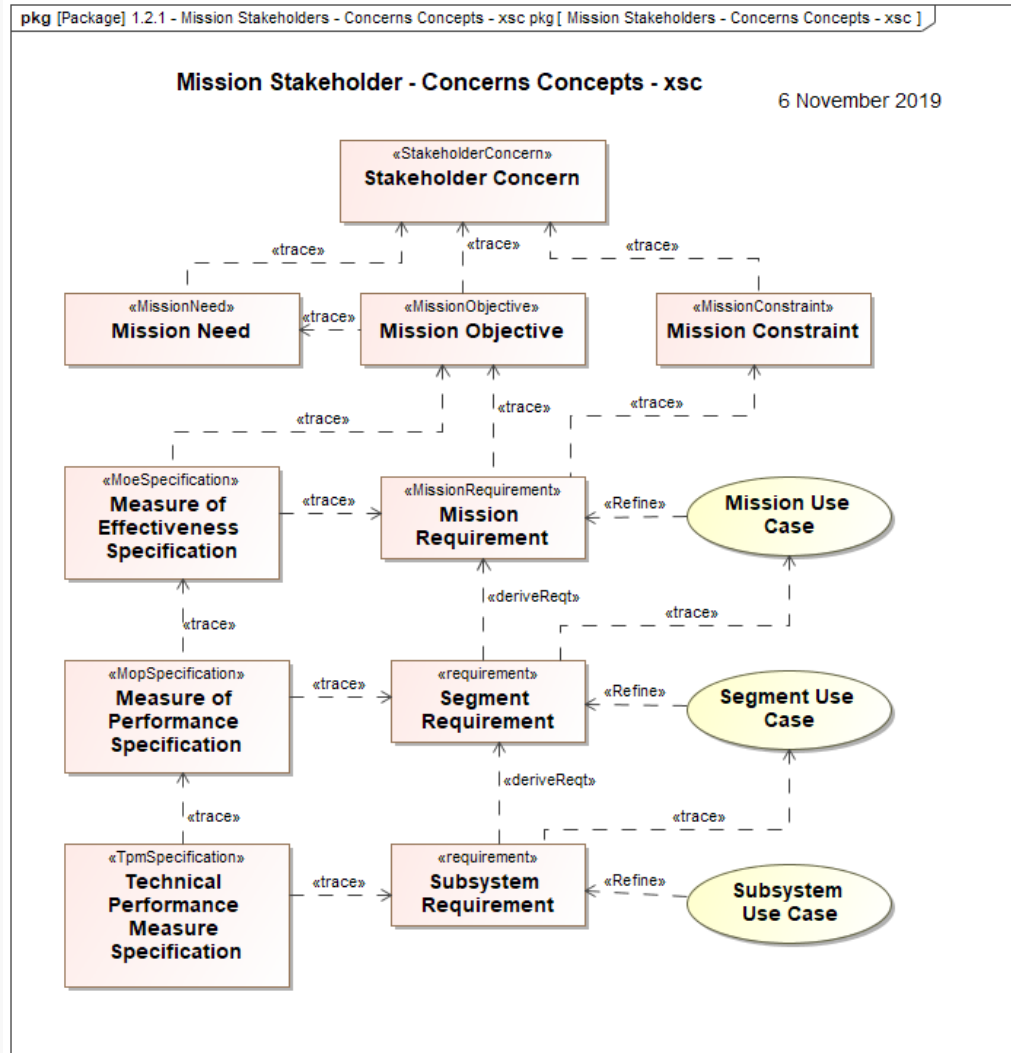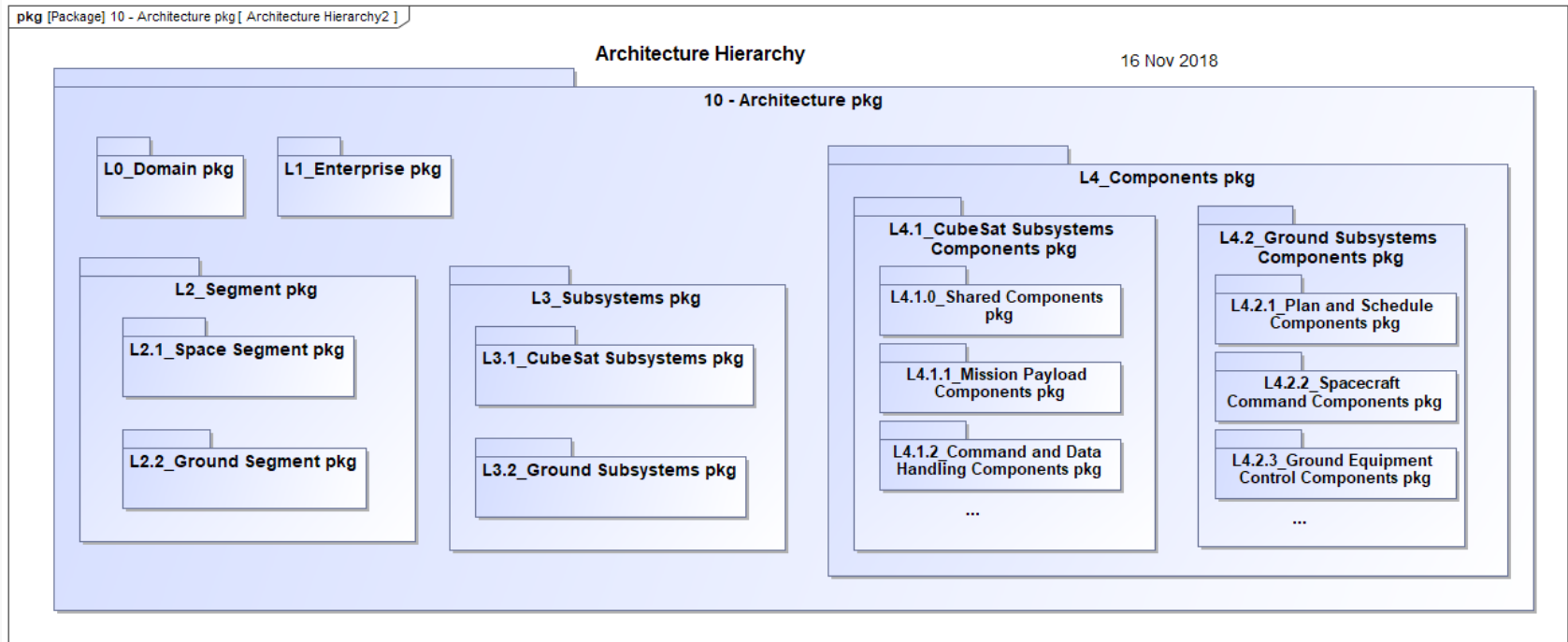
Requirements Hierarchy
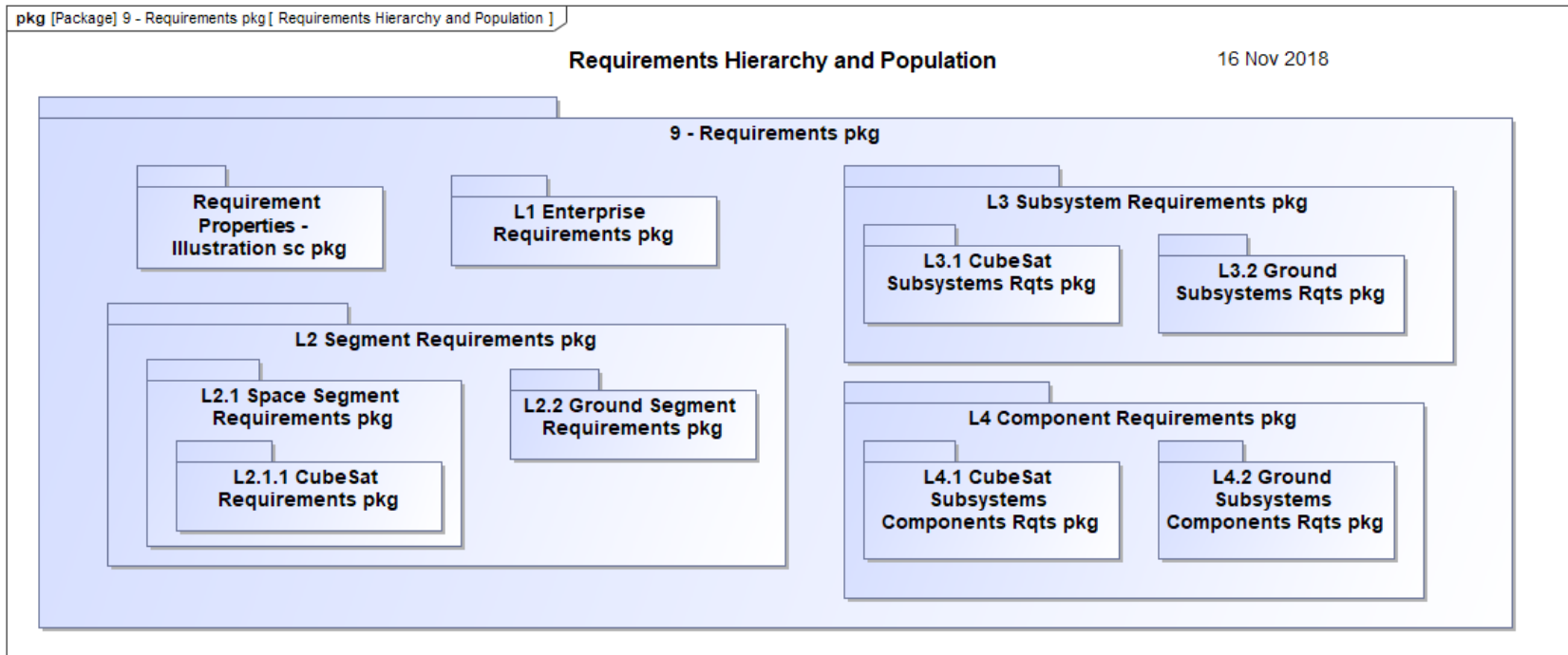
CSRM provides for defining and tracing requirements from stakeholders, use cases, technical measures down to subsystems and components and to validation and verification activities

Requirements Hierarchy

pkg [Package] 1.2.1 - Mission Stakeholders - Concerns Concepts - xsc pkg [Mission Stakeholders - Concerns Concepts - xsc]

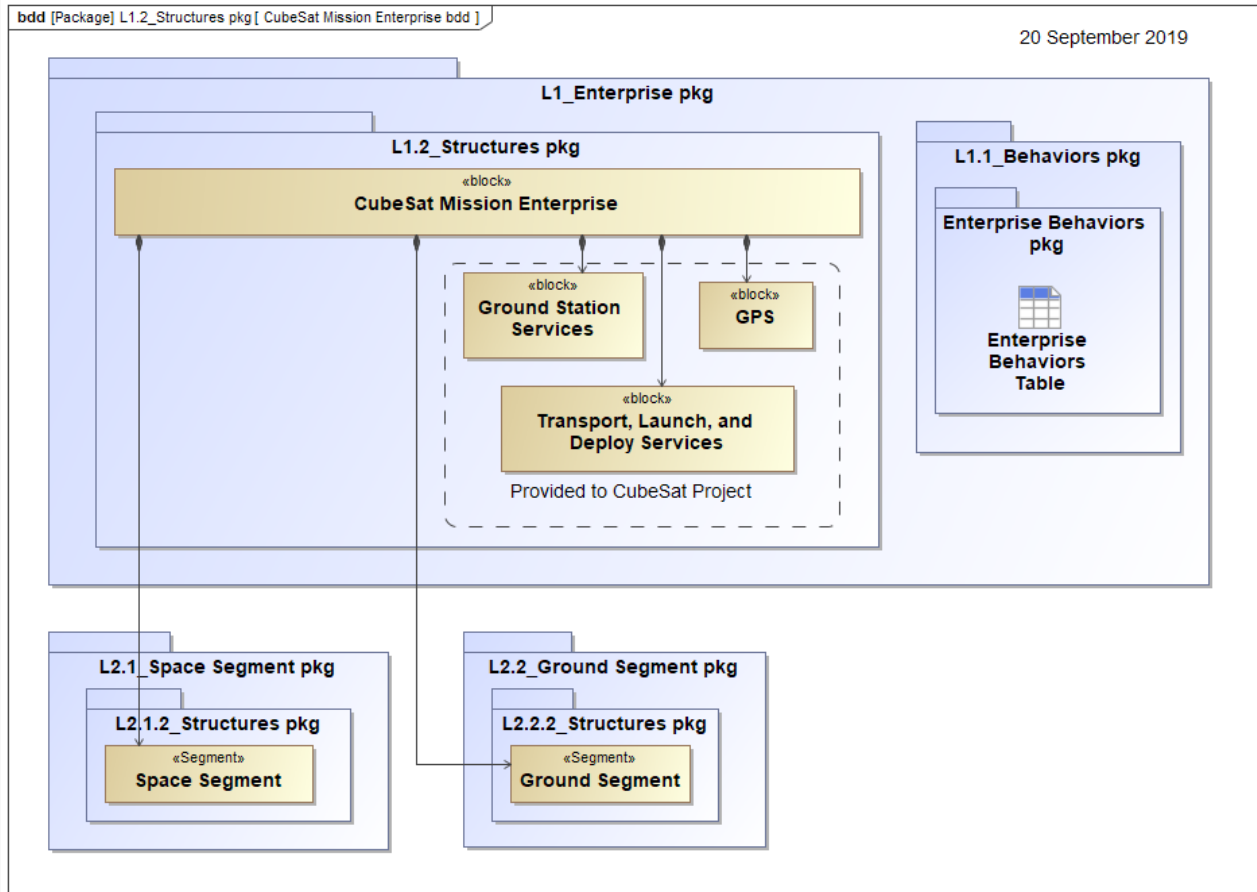**Mission Stakeholder - Concerns Concepts - xsc**

6 November 2019

Architecture Hierarchy

**CSRM logical architecture provides the starting point for a
mission-specific team establishing their logical and physical architectures**
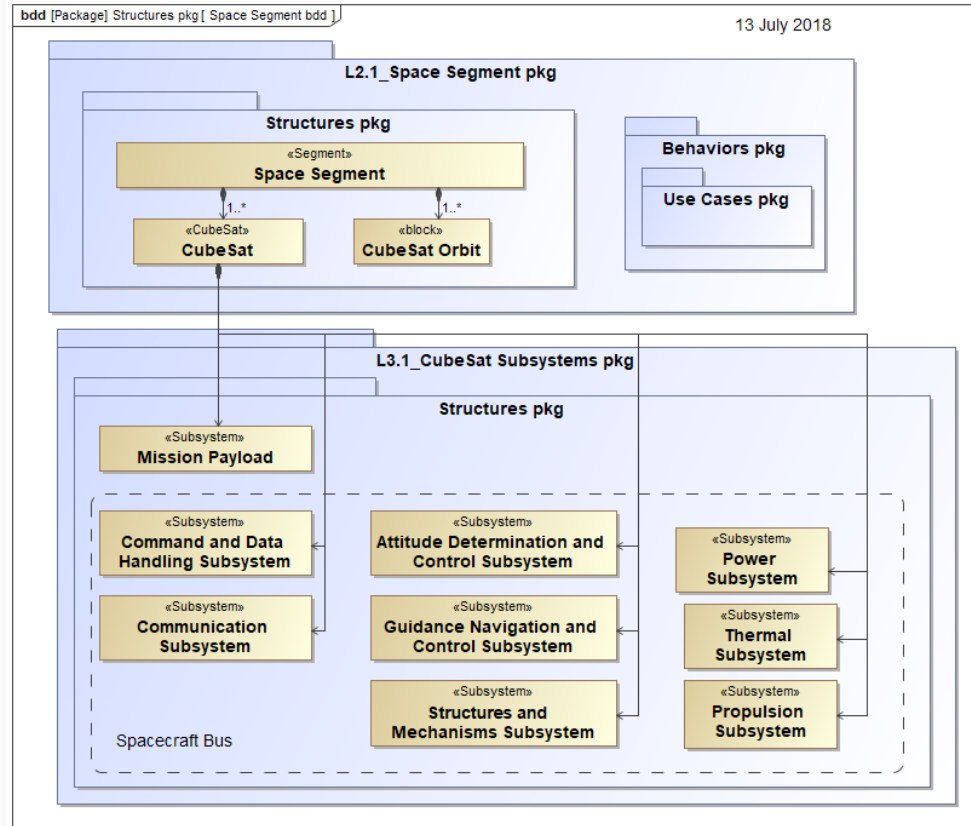
CubeSat Mission Enterprise

CSRM provides for both space and ground capabilities and external services

Space Segment and CubeSat Subsystems

The mission team specifies subsystem capabilities and whether they are provided by software, hardware, persistent data, or operator procedures
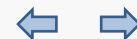
Next Steps - Mission Engineering

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

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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
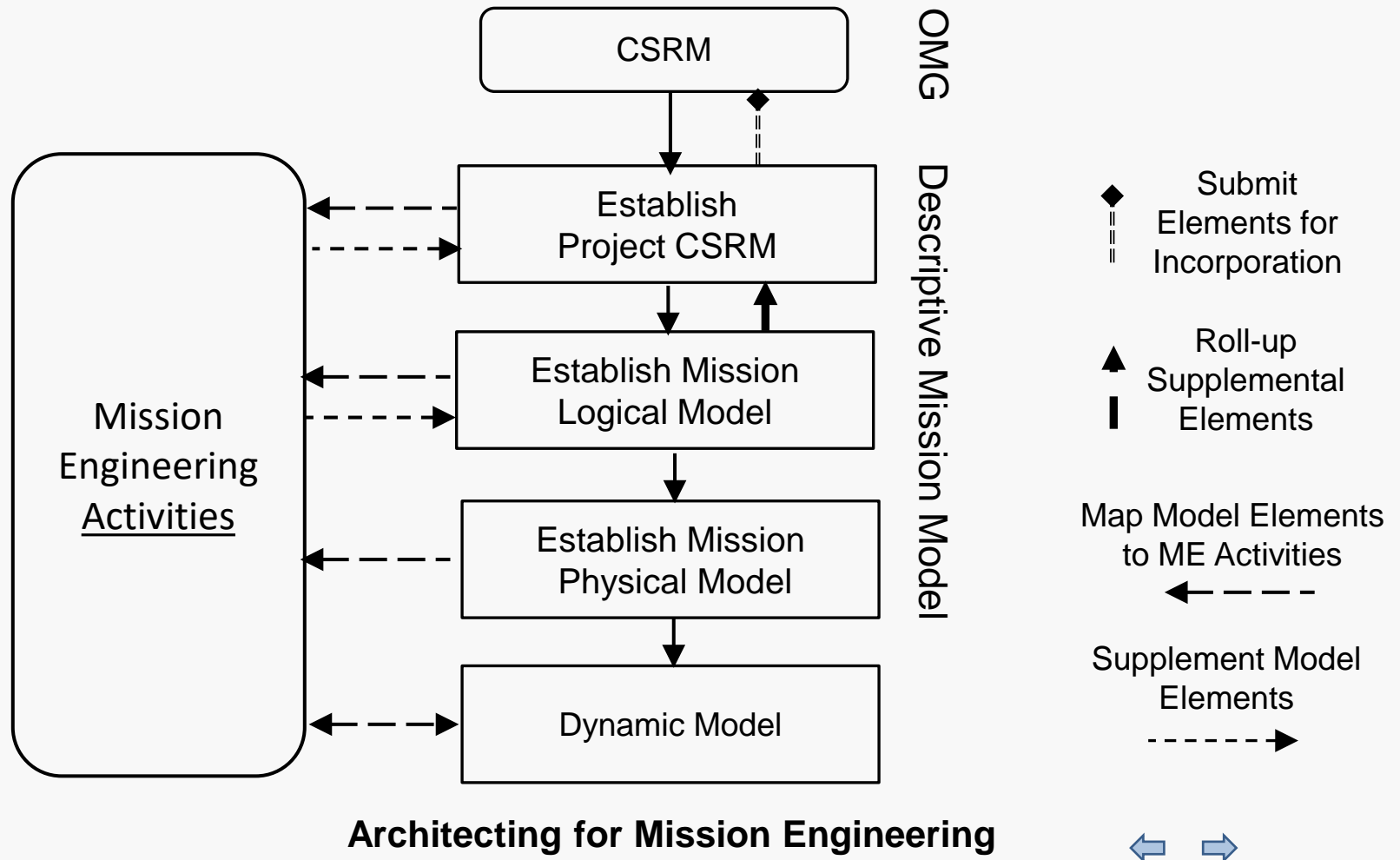
INCOSE Systems Engineering Book of Knowledge

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

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Mission Engineering Scope

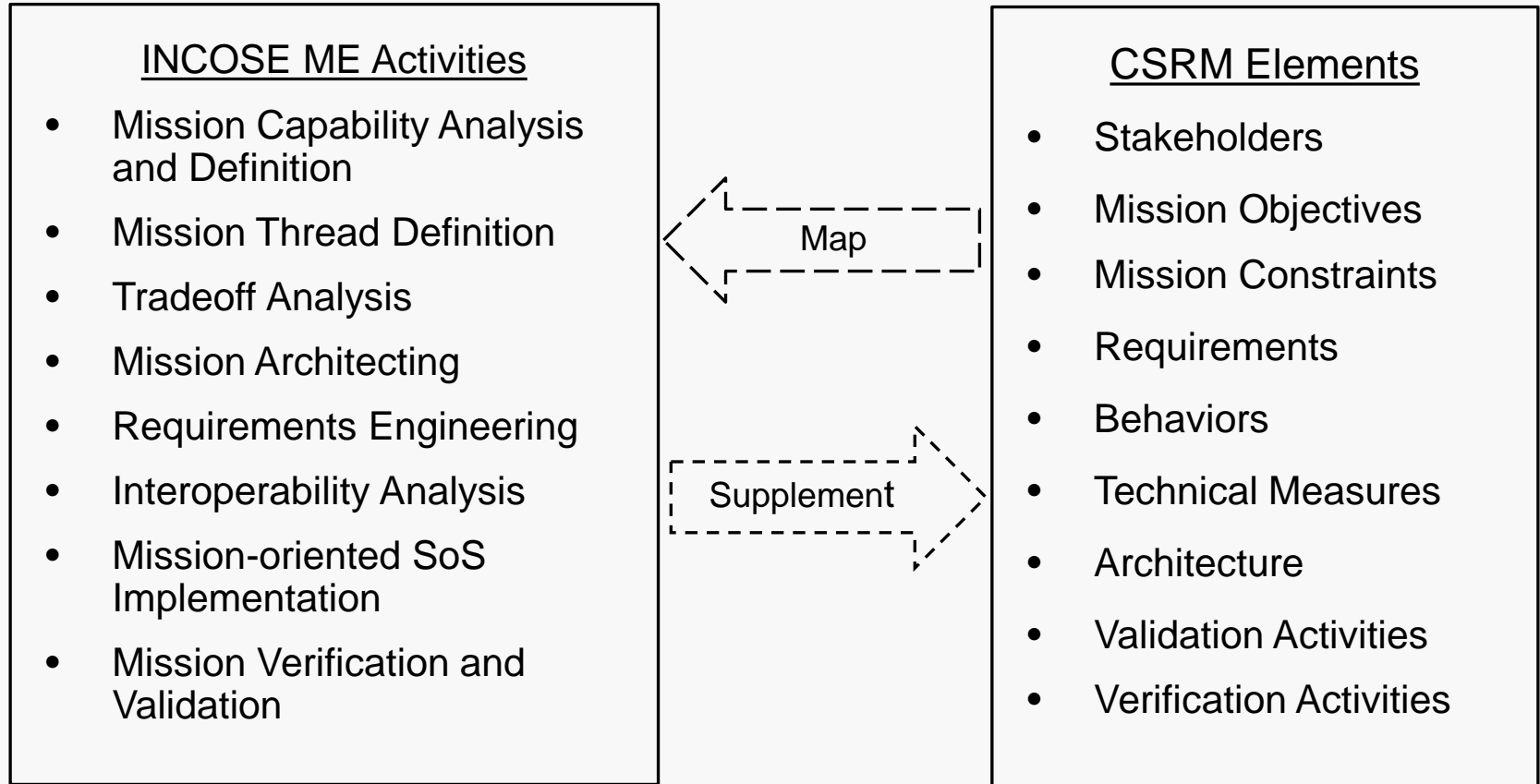**Architecting for Mission Engineering**
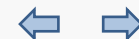
INCOSE Mission Engineering

- The INCOSE Systems Engineering Body of Knowledge (SEBoK) defines Mission Engineering as:

  "the application of systems engineering to the planning, analysis, and designing of missions where the mission is the system of interest".

- Where Mission Engineering:
  - Analyzes the mission goals and threads
  - Analyzes the available as well as emerging operational and system capabilities
  - Designs a mission architecture to achieve the mission goal

  INCOSE Mission Engineering Activities will be used to kick-off this process

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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

Map

Supplement

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

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Thank You

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

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