CubeSat Model-Based Systems Engineering (MBSE) Reference Model - Development and Distribution – Interim Status #3

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International Council on Systems Engineering (INCOSE)

Space Systems Working Group (SSWG)

Project Objectives

- Demonstrate Model-Based Systems Engineering (MBSE) methodology as applied to a CubeSat mission
- Provide a CubeSat Reference Model (CRM) that CubeSat teams can use as starting point for their mission-specific CubeSat model (MCM)
- Develop the CRM as an Object Management Group (OMG) specification

SSWG Team Composition

Aerospace Students and Professors

Engineers and Software Developers from
NASA Centers, Aerospace Companies, and
Modeling and Simulation Tool Providers

Telecons on Friday at 1pm eastern time

Meeting materials and links to meeting recordings
in Google docs

Model-Based Systems Engineering

Model Based Systems Engineering

Formalized application of modeling to support requirements, design, analysis, validation, and verification

Systems Modeling Language (SysML)

A graphical modeling language for modeling complex systems including hardware, software, information, personnel, procedures, and facilities

- Engineering Methodology
- System Modeling Tools
- Interfaces with Other Models

Systems Engineering Methodology

Logical architecture decomposes the system into components that interact to satisfy system requirements.

The components are abstractions of physical components that perform system functionality but without imposing implementation constraints

Physical architecture defines physical components that interact to satisfy the system requirements.

The physical components of the system include hardware, software, persistent data, and operational procedures

The CubeSat Reference Model will provide the logical architecture.

Project Phases

INCOSE MBSE Challenge Project

Initiated 2007

INCOSE SSWG

2007-2010

Phase 0

Modeled a Space System in SysML

Hypothetical FireSat - SMAD

Phase 1

CubeSat Framework

Prelim. RAX Model [1]

Phase 2

RAX Behavior Modeling Power, Comm, State [2]

Recent Efforts

Phase 3

RAX CubeSat Model

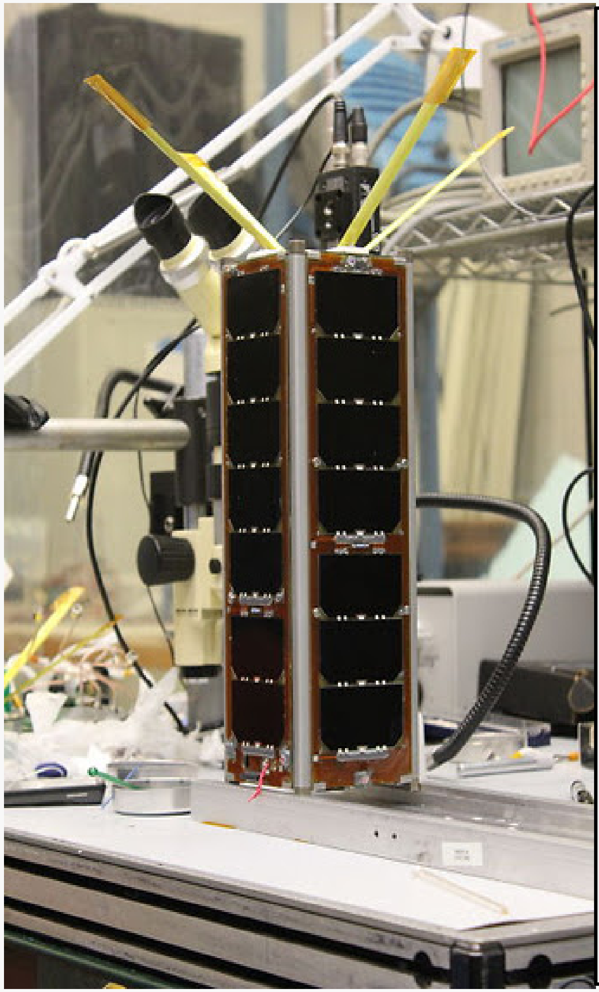
Trade Studies [3]

Current Efforts

Phase 4

Develop a CubeSat MBSE Ref. Model [4] – [9]

Concept Phase Trade Studies



Radio Aurora Explorer (RAX) CubeSat Mission

Michigan Exploration Lab and
SRI International mission

Studies formation of magnetic field aligned plasma irregularities in the lower polar ionosphere

Radar signal is transmitted by Incoherent Scatter Radar site in Poker Flat, Alaska and received by RAX's radar receiver

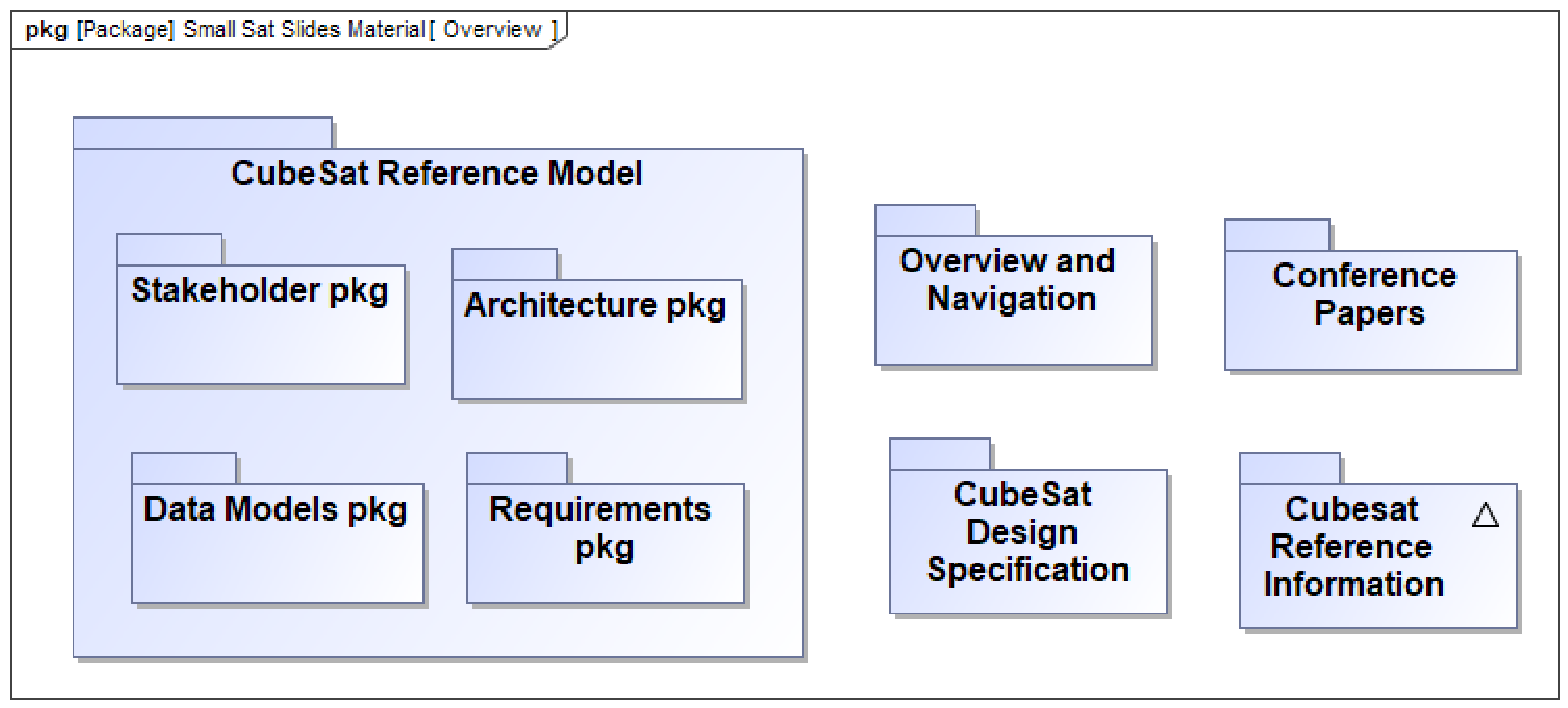
Science data processed on-board, compressed, transmitted to the primary ground station and control center in Ann Arbor, Michigan

Concept Phase Trade Studies

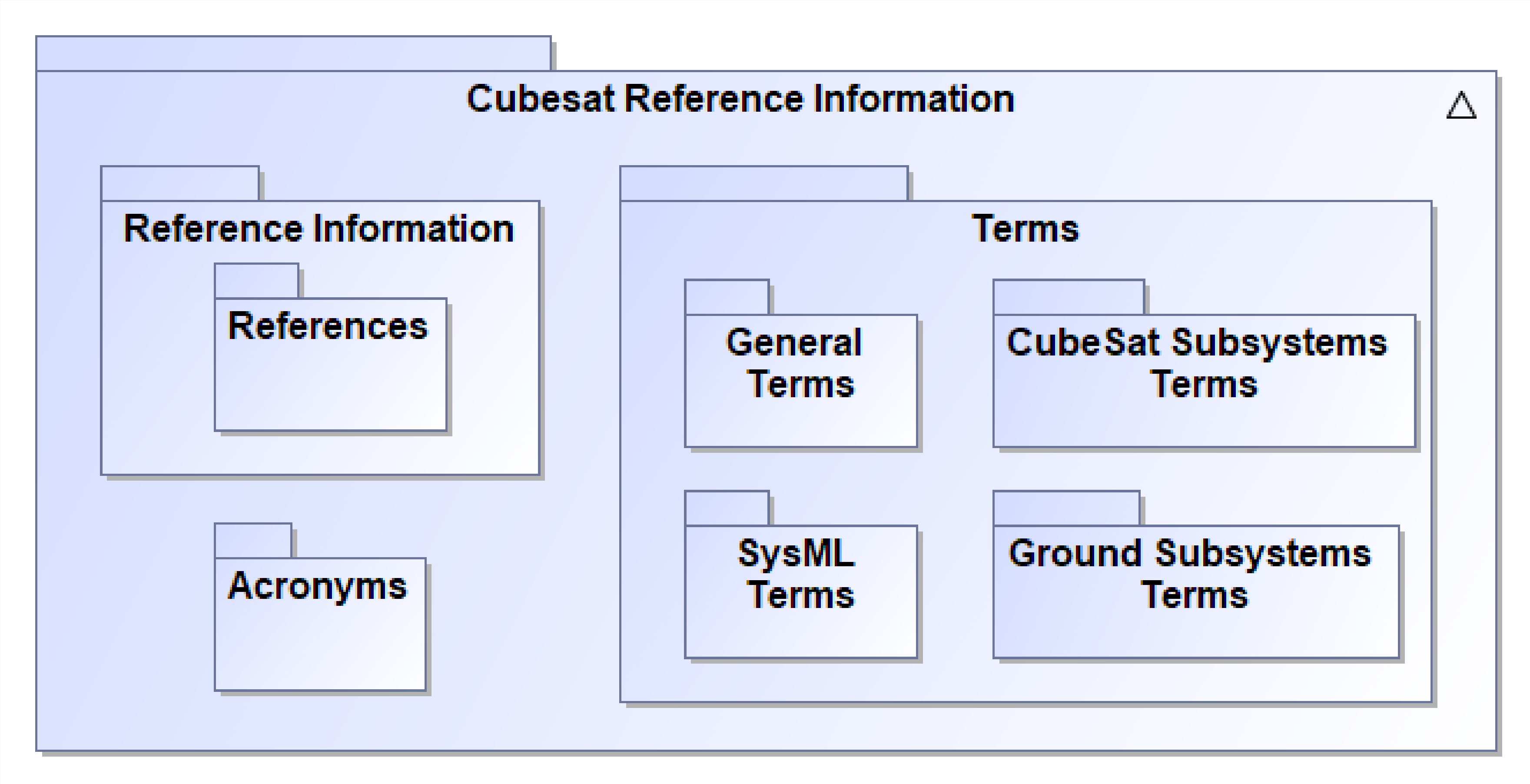
Trade Studies	Trade Space	Performance Metric
Solar panel area	• Nominal:18.2 cm^2/slide • ½ of nominal • ¼ of nominal	On-board energy
Max battery capacity	• Nominal:115,000 J • Reduced: 100,000 J	On-board energy
Orbital altitude	• Nominal: 811 km x 457 km • Low: 593 km x 250 km • High: 1311 km x 932 km	Quantity of data downloaded
Ground station network	• Ann Arbor & Menlo Park • Ann Arbor & Fairbanks • Fairbanks & Menlo Park	Quantity of data downloaded

Current Phase – Develop CubeSat Reference Model

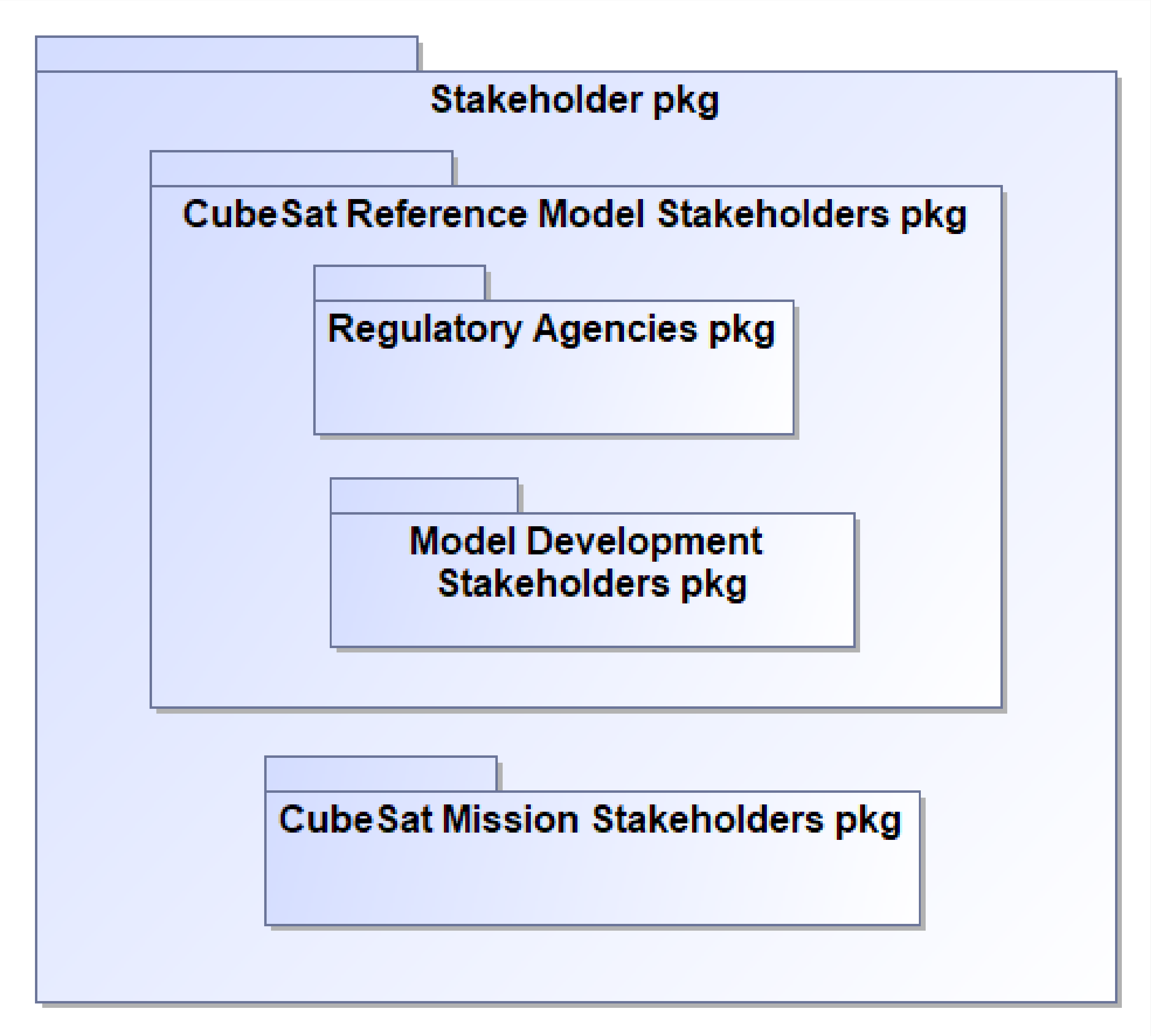
Model Overview



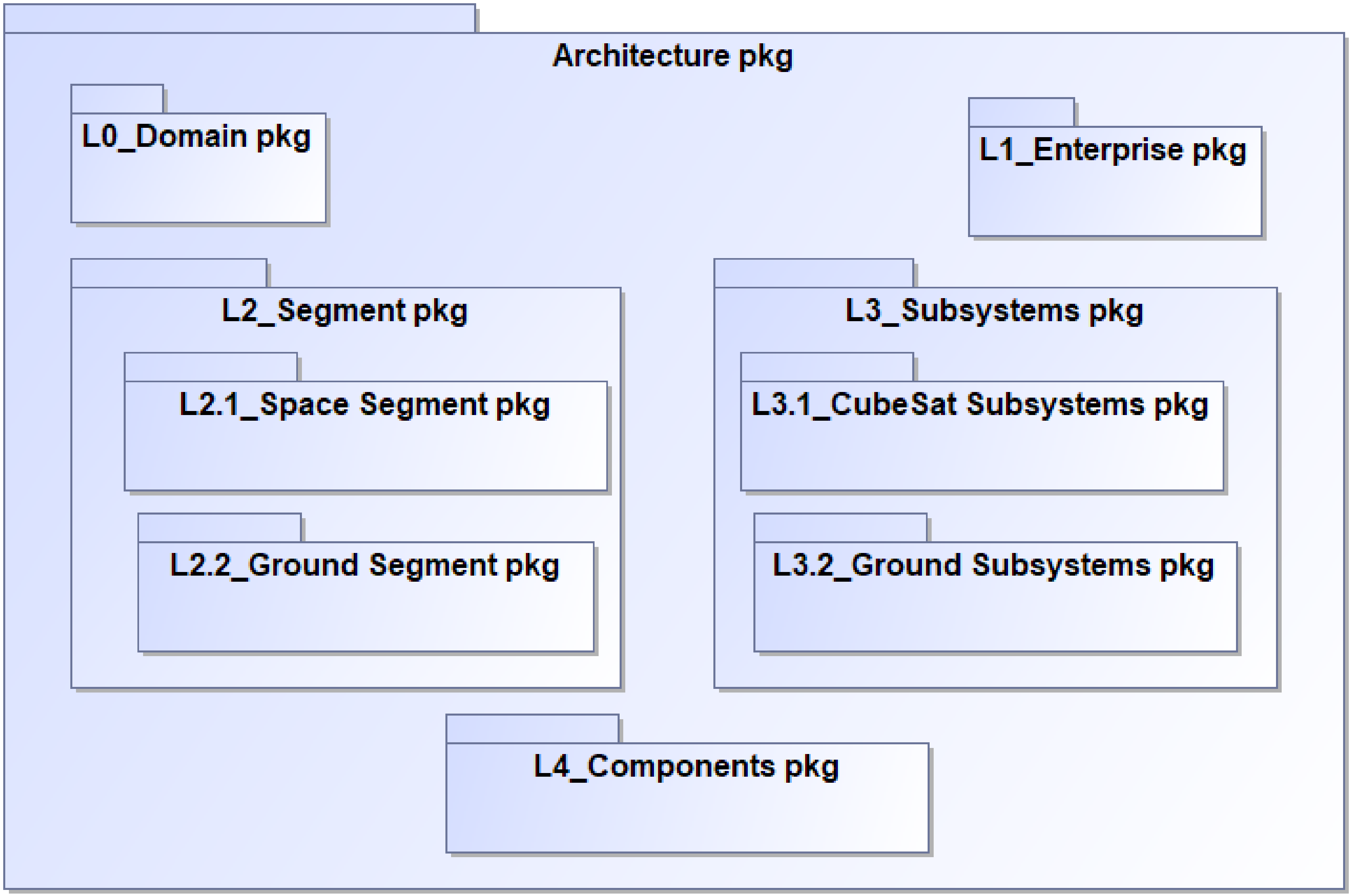
Glossary


Cubesat Reference Information
Reference Information
References
Acronyms
Terms
General Terms
CubeSat Subsystems Terms
SysML Terms
Ground Subsystems Terms

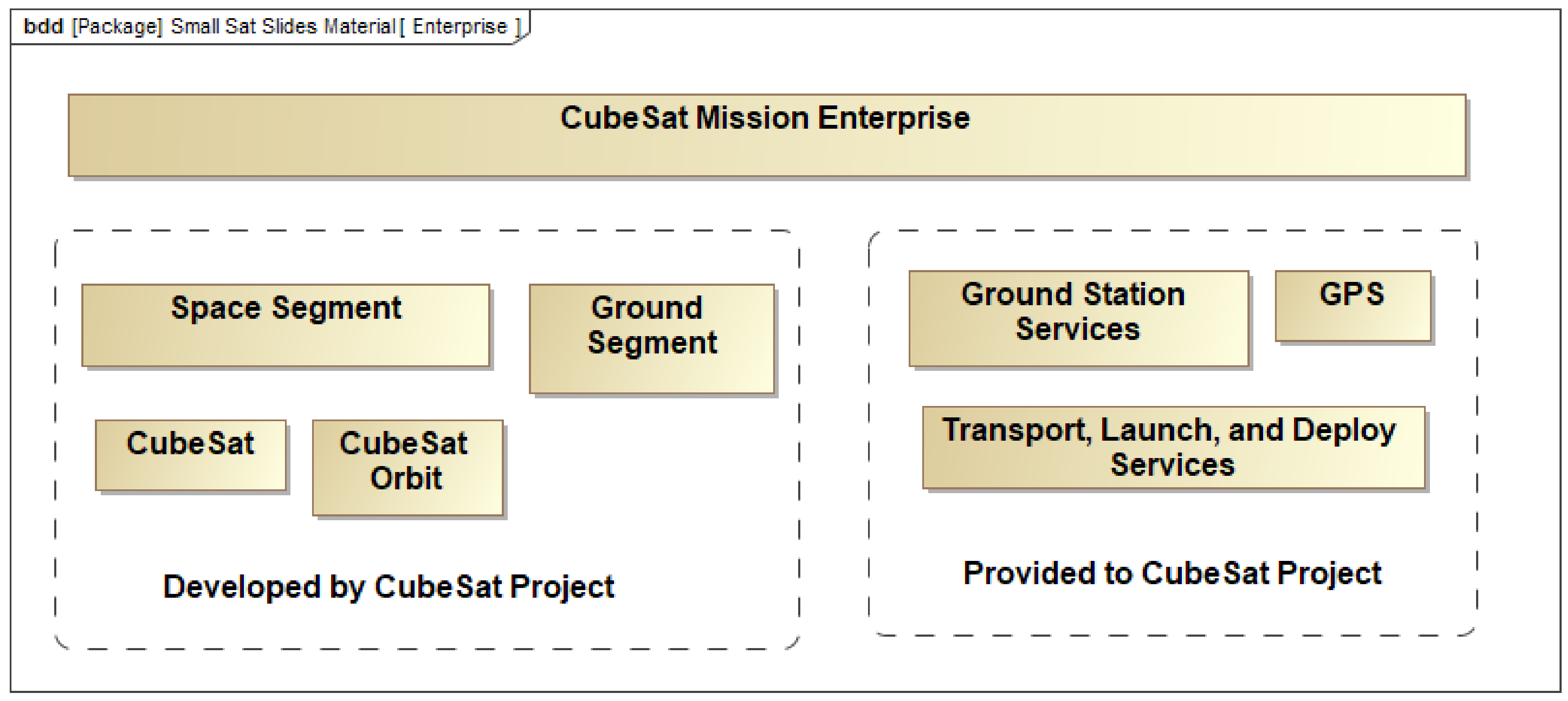
Stakeholders



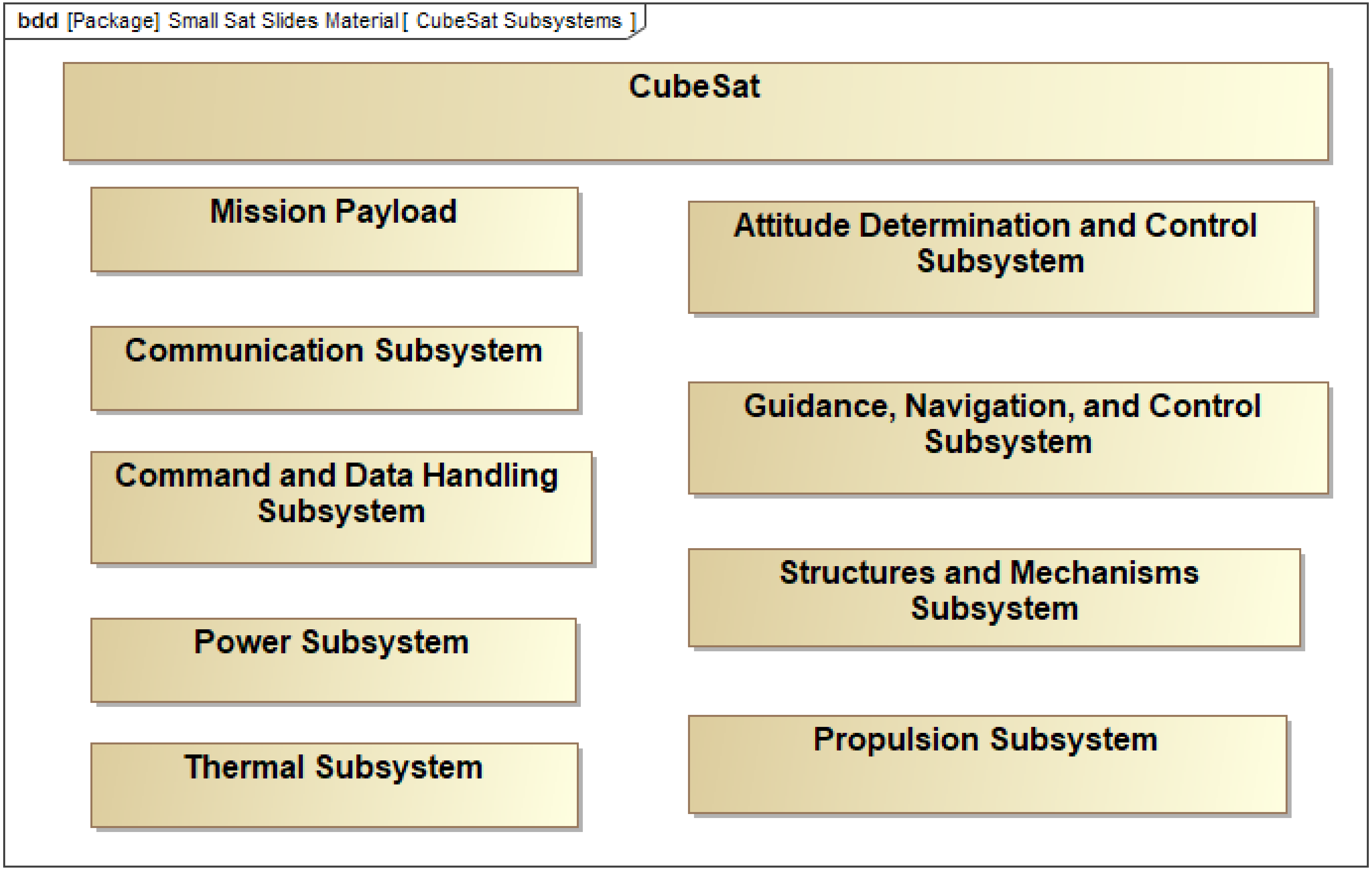
Architecture



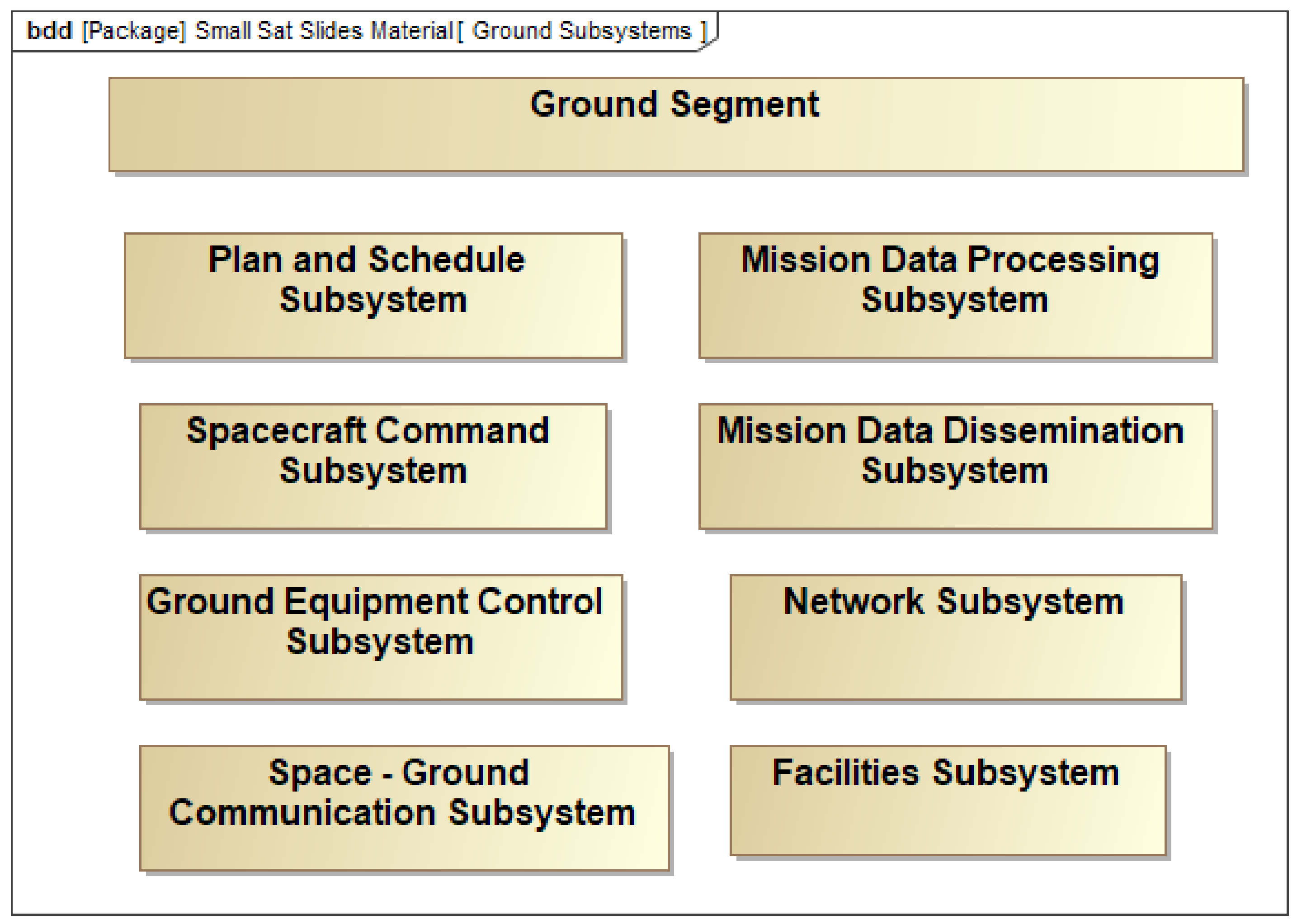
CubeSat Mission Enterprise



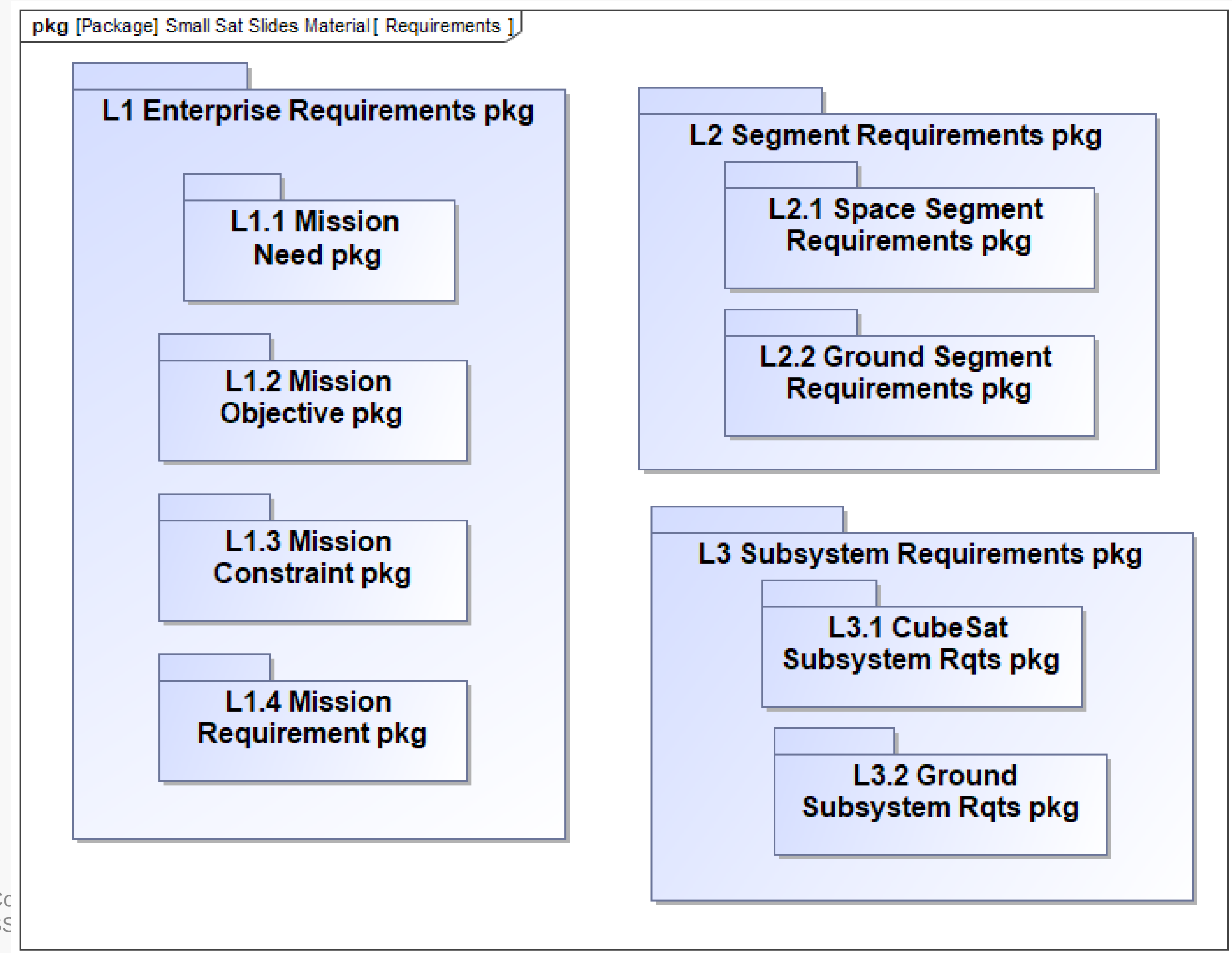
CubeSat Subsystems



Ground Segment

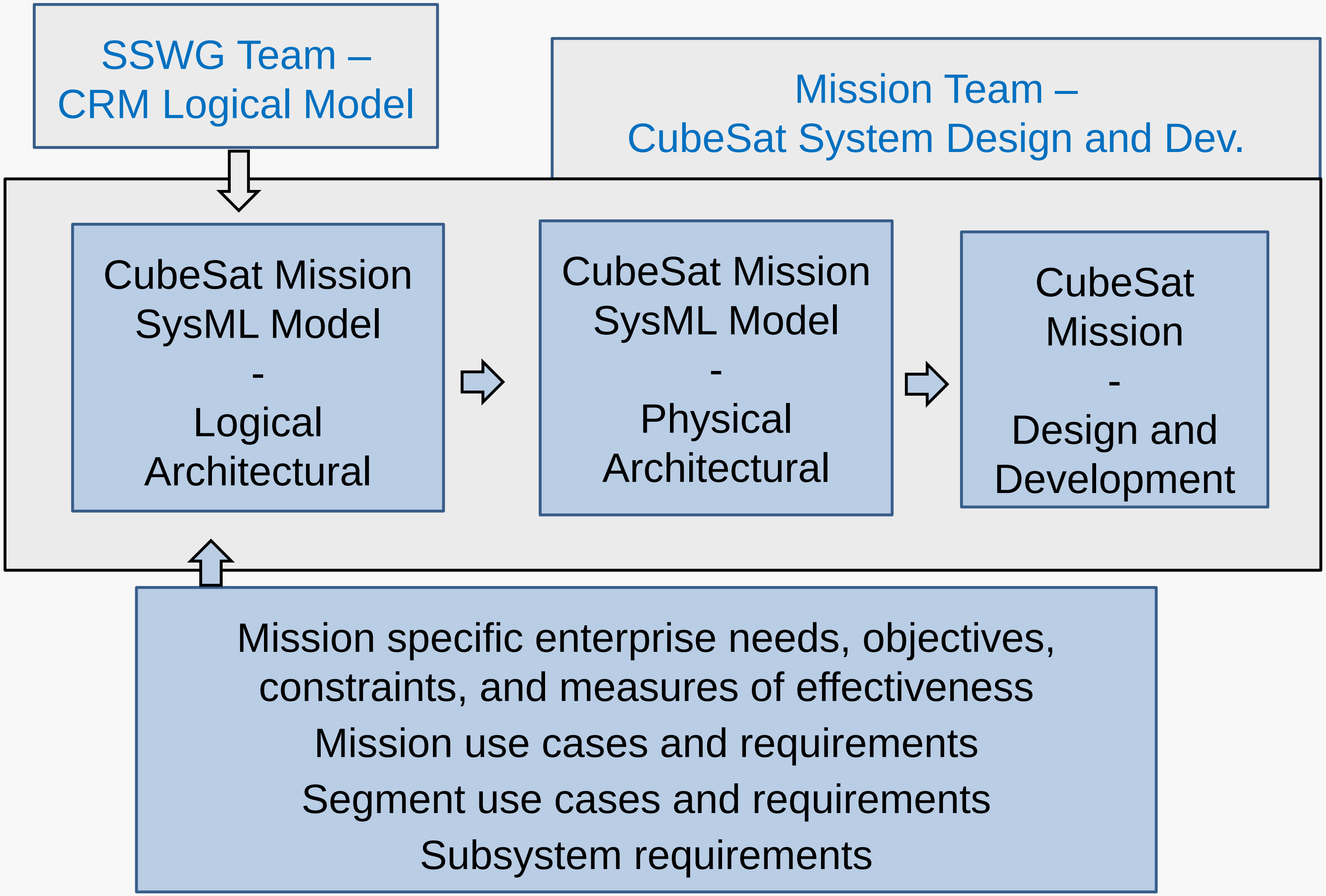


Requirements



Mission Modeler

CRM and Mission Modeler



Architecture and Mission Modeler

- The space and ground architectural elements shall provide the capability of a mission modeler to:
  - Roll-up power, cost, mass starting at the CubeSat component level
  - Create use cases such as mission data collection and distribution
  - Update add, delete, or combine subsystems
  - Populate data model, validation, and verification packages

Requirements and Mission Modeler

- The CRM requirements architecture shall provide the capability for the mission modeler to:
  - Use requirements tables to create and manage requirements starting with the mission stakeholders
  - Modify the predefined requirements prefix and numbering scheme
  - Create requirements diagrams to establish relationships including: traced to, refined by, satisfied by, and verified by
  - Export requirements table

Next Steps, Side Sessions, References

Next Steps

- Populate with an example starting with stakeholder needs, objectives, and constraints

- Incorporate and populate technical measures at enterprise, segment, and subsystem levels

- Initiate OMG process for adopting a CRM as a specification

Side Sessions

Development of a CubeSat Reference Model
as an OMG Specification

Old Main (MAIN) Room #203

Sunday 6:00 – 7:00pm

Monday 9:00 – 10:00am

References

[1] S. Spangelo, D. Kaslow, C. Delp, B. Cole, L. Anderson, E. Fosse, B. Gilbert, L. Hartman, T. Kahn, and J. Cutler, "Applying Model Based Systems Engineering (MBSE) to a Standard CubeSat," in *Proceedings of IEEE Aerospace Conference*, Big Sky, MT, March 2012.

[2] S. Spangelo, L. Anderson, E. Fosse, L Cheng, R. Yntema, M. Bajaj, C. Delp, B. Cole, G. Soremekun, D. Kaslow, and J. Cutler, "Model Based Systems Engineering (MBSE) Applied to Radio Explorer (RAX) CubeSat Mission Operational Scenarios," *Proceedings of IEEE Aerospace Conference*, Big Sky, MT, March 2013.

[3] D. Kaslow, G. Soremekun, H. Kim, S. Spangelo, "Integrated Model-Based Systems Engineering (MBSE) Applied to the Simulation of a CubeSat Mission", *Proceedings of IEEE Aerospace Conference*, Big Sky, MT, March 2014.

[4] D. Kaslow, L. Anderson, S. Asundi. B. Ayres, C. Iwata, B. Shiotani, R. Thompson, "Developing a CubeSat Model-Based System Engineering (MBSE) Reference Model – Interim Status", *Proceedings of IEEE Aerospace Conference*, Big Sky, MT, March 2015.

[5] D. Kaslow, L. Anderson, S. Asundi. B. Ayres, C. Iwata, B. Shiotani, R. Thompson, "Developing and Distributing a CubeSat Model-Based System Engineering (MBSE) Reference Model ", *Proceedings of the 31st Space Symposium*, Colorado Springs, CO, April 2015.

References

[6] D. Kaslow, B. Ayres, M.J Chonoles, S. Gasster, L. Hart, C. Massa, R. Yntema, B. Shiotani "Developing and Distributing a CubeSat Model-Based System Engineering (MBSE) Reference Model – Interim Status #2", *Proceedings of IEEE Aerospace Conference*, Big Sky, MT, March 2016.

[7] D. Kaslow, B. Ayres, P. Cahill, L. Hart, R. Yntema, "Developing a CubeSat Model-Based System Engineering (MBSE) Reference Model – Interim Status #3", *Proceedings of IEEE Aerospace Conference*, Big Sky, MT, March 2017.

[8] D. Kaslow, B. Ayres, P. Cahill, L. Hart, R. Yntema "A Model-Based Systems Engineering (MBSE) Approach for Defining the Behaviors of CubeSats", *Proceedings of IEEE Aerospace Conference*, Big Sky, MT, March 2017.

[9] Madni, A.M. and Sievers, M. Model based Systems Engineering: Opportunities and Challenges, Disciplinary Convergence: Implications for Systems Engineering Research, 2017 CSER, Springer, 2017