Developing and Distributing a Model-Based Systems Engineering(MBSE) CubeSat Reference Model – Status

Dave Kaslow

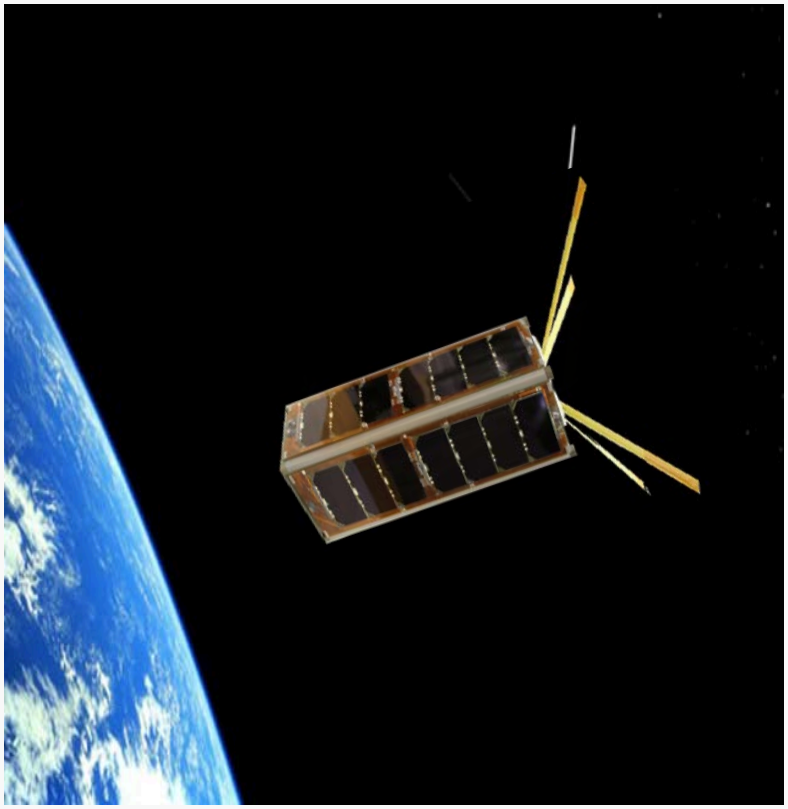
Chair: International Council on Systems Engineering (INCOSE)
Space Systems Working Group (SSWG)

NDIA Systems Engineering Conference

October 26-29

Agenda

- Project Objectives and Team
- INCOSE MBSE Initiative
- SSWG Challenge Project
- CubeSat Reference Model Development and Distribution
- CubeSat Reference Model Diagrams
- Next Steps
- References



Project Objectives

Demonstrate MBSE methodology as applied to a CubeSat mission

Demonstrate Object Oriented Design Method (OOSEM)
as applied to a CubeSat mission

Provide a CubeSat Reference Model that CubeSat teams
can use as a starting point for their mission-specific CubeSat model

Demonstrate the application of the model in assessing
measures of performance in the concept life cycle phase

SSWG Team Composition

Aerospace Students and Professors

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

Email to be included on the email reflector list:
david.kaslow@gmail.com

SSWG Team Meetings

Telecons every Friday at 1pm east coast time

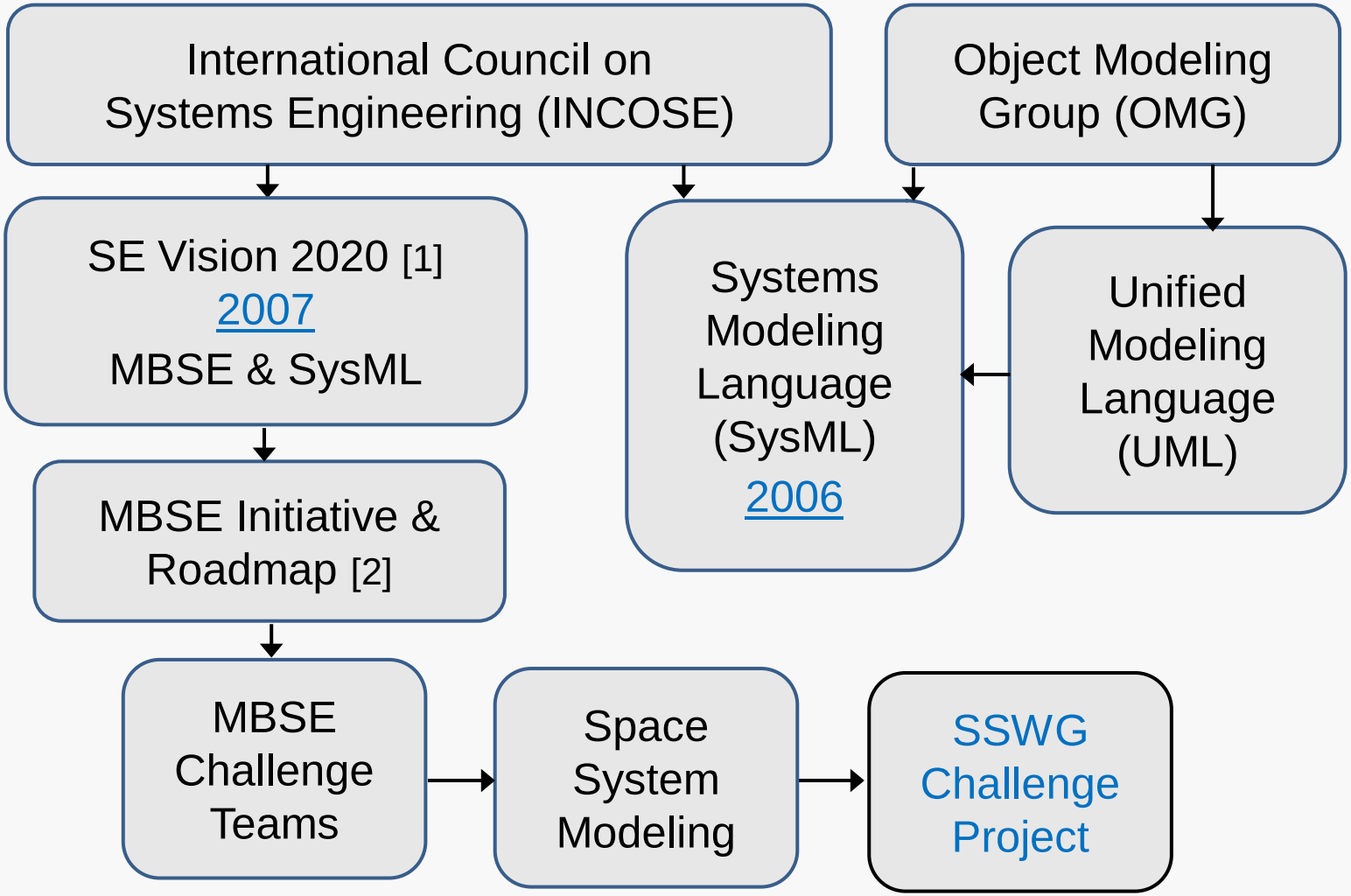
Meeting materials and links to meeting recordings in Google docs

Conference papers posted in INCOSE SSWG Web Site

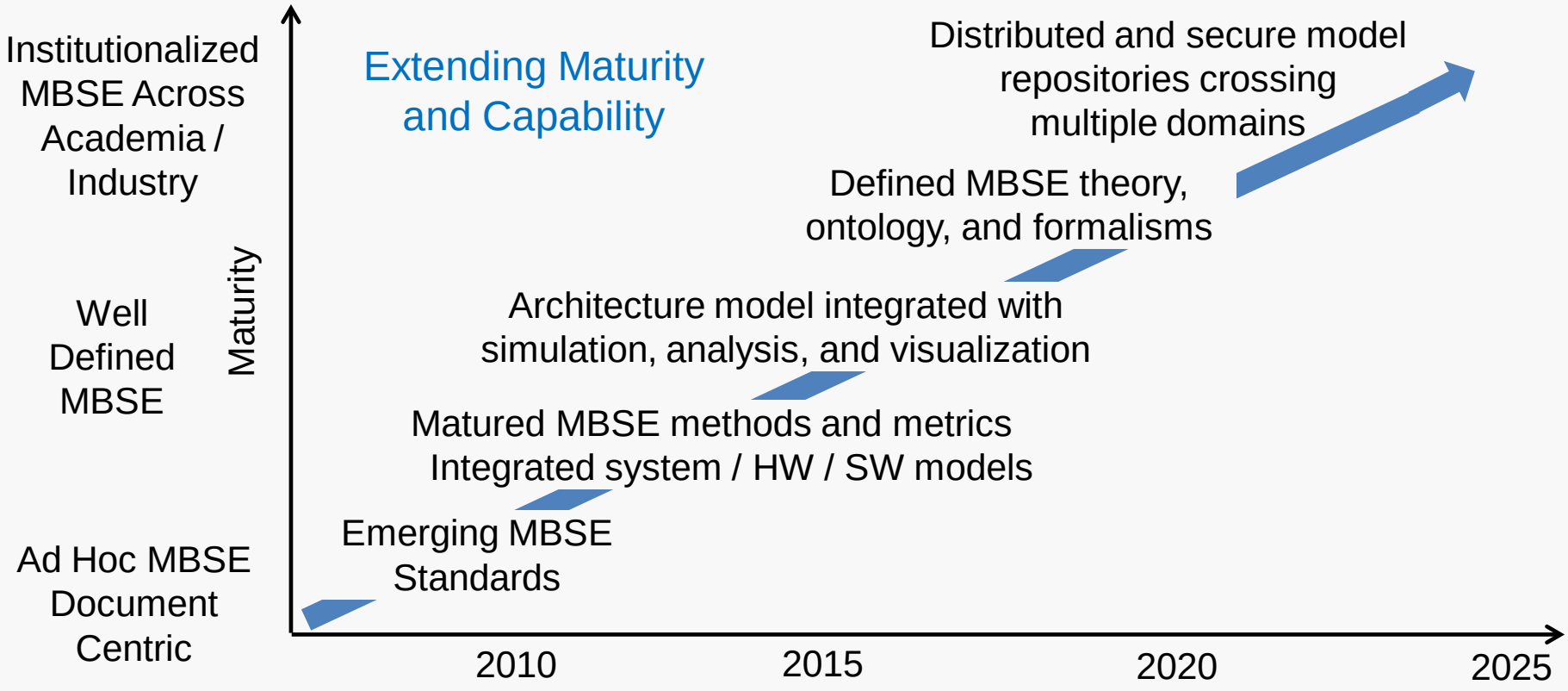
http://www.incose.org/ChaptersGroups/WorkingGroups/government/space-systems

INCOSE MBSE Initiative

INCOSE MBSE Initiative - Genesis, Flow, Interaction



MBSE Roadmap



Adapted from ref. [2]

Model-Based Systems Engineering (MBSE)

INCOSE Systems Engineering Vision [1]

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

Survey of MBSE Methodologies [3] [4]

A collection of related processes, methods, and tools

Performing Systems Engineering with Models

System, subsystem, and component level models

Integration of models and simulations

Authoritative, integrated repository of information from procurement through operations

e

Model-Based Systems Engineering (MBSE)

Systems Modeling Language (SysML) [5]

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

INCOSE Object-Oriented Systems Engineering Method [6]

System Modeling Tools

Interfaces with Other Models

Systems Modeling Language (SysML)

The Model

SysML Model Elements

Blocks, Actors, Flow, Signals, Ports, …

Diagrams

Views of the underlying system model

Structure

Block Definition

Internal Block

Requirement

Parametric

Behavior

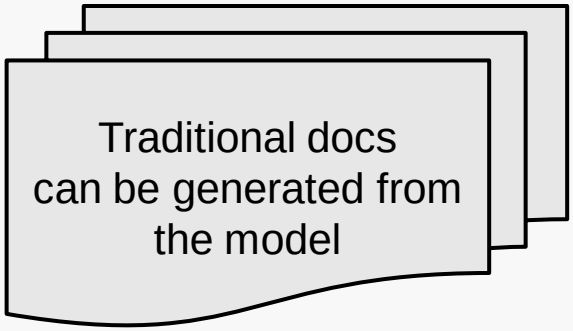
Activity

Sequence

State

Use Case

System design resides in the model not in documents



Model updates are automatically populated into the system views

Model-Based Systems Engineering (MBSE)

Block

Logical, Conceptual, Physical Entity

Hardware, Software, Data

Person, Facility, Item Flow …

Properties

Parts, Behaviors, Values, …

Requirement

Properties

id, text

Derived from requirement

Traced from element

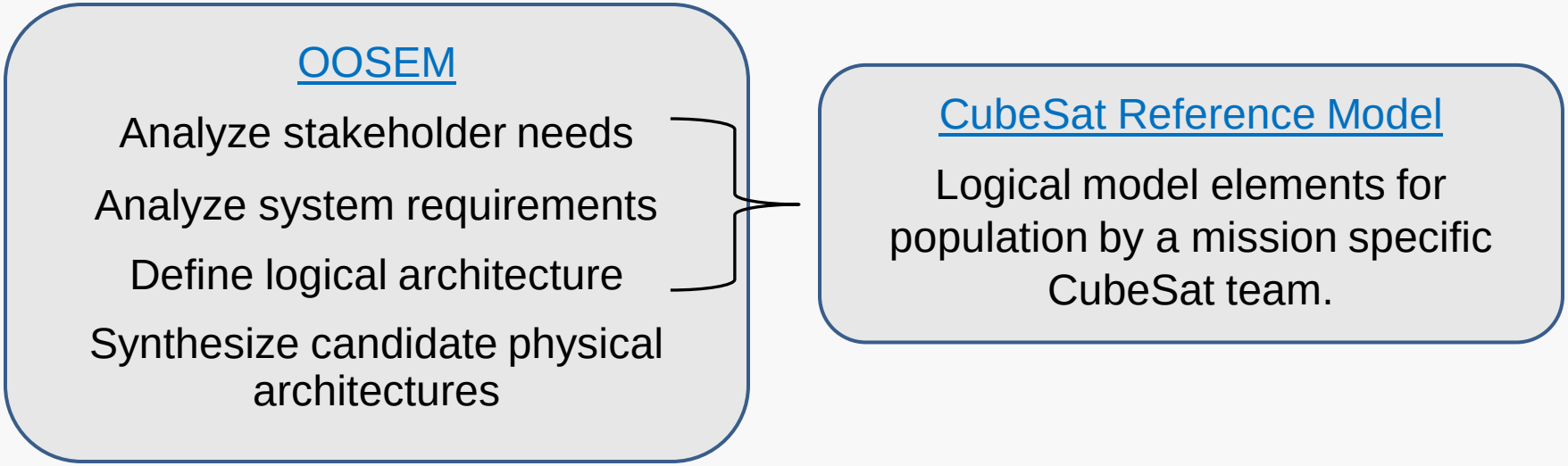
Refined by element

Satisfied by element

Verified by test case

…

Object Oriented Systems Engineering Method (OOSEM)



SSWG Challenge Project

SSWG Challenge Project

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 [7]

Phase 2

RAX Behavior Modeling Power, Comm, State [8]

Recent Efforts

Phase 3

Enterprise Modeling for CubeSats [9]

RAX CubeSat Model Trade Studies [10]

Current Efforts

Phase 4

Develop a CubeSat MBSE Ref. Model [11] [12]

Phase 3 - 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

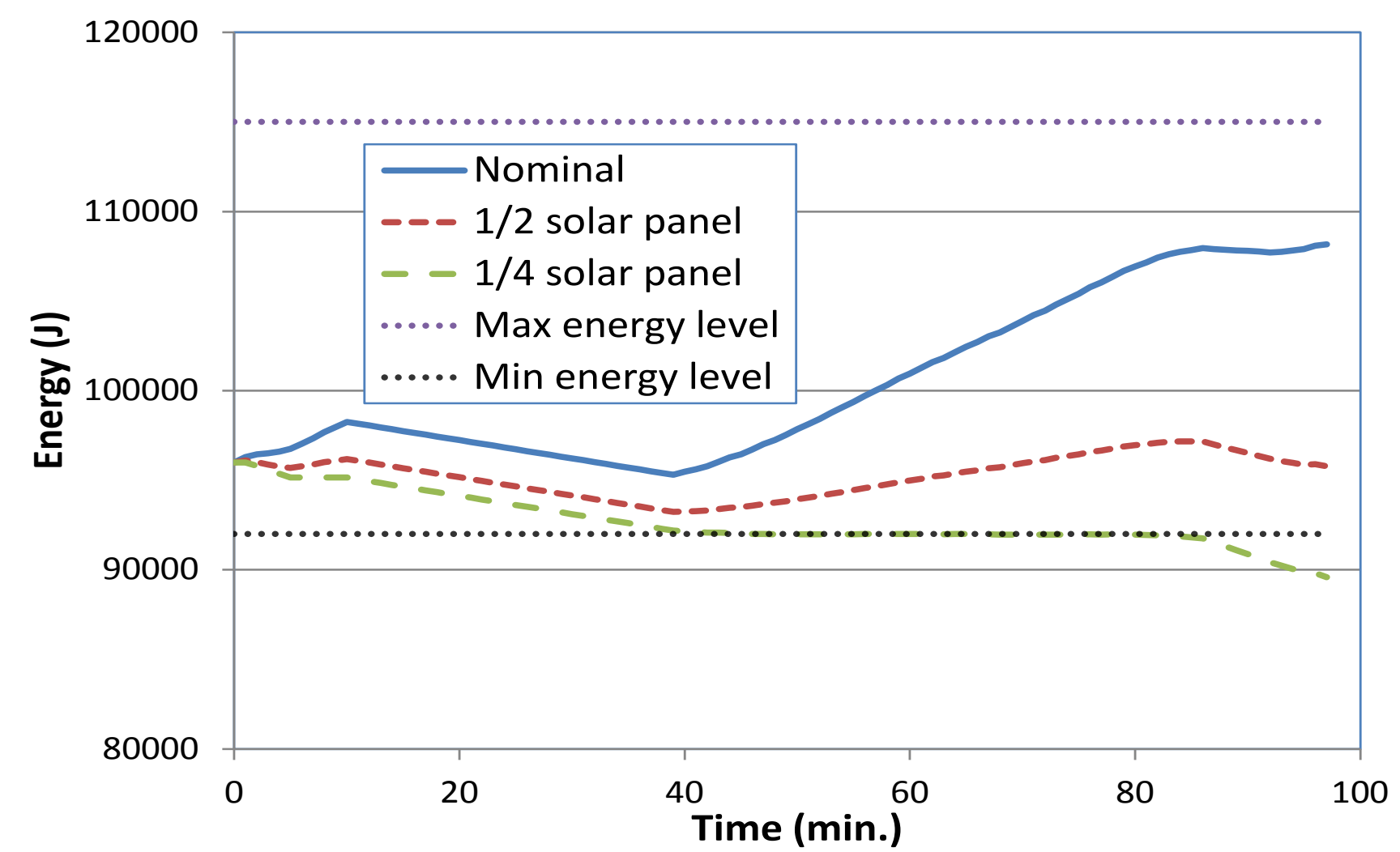
Radar signal is transmitted by Incoherent Scatter Radar site in Poker Flat, Alaska and received by RAX's radar receiver

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

Phase 3 - RAX CubeSat Model Trade Studies

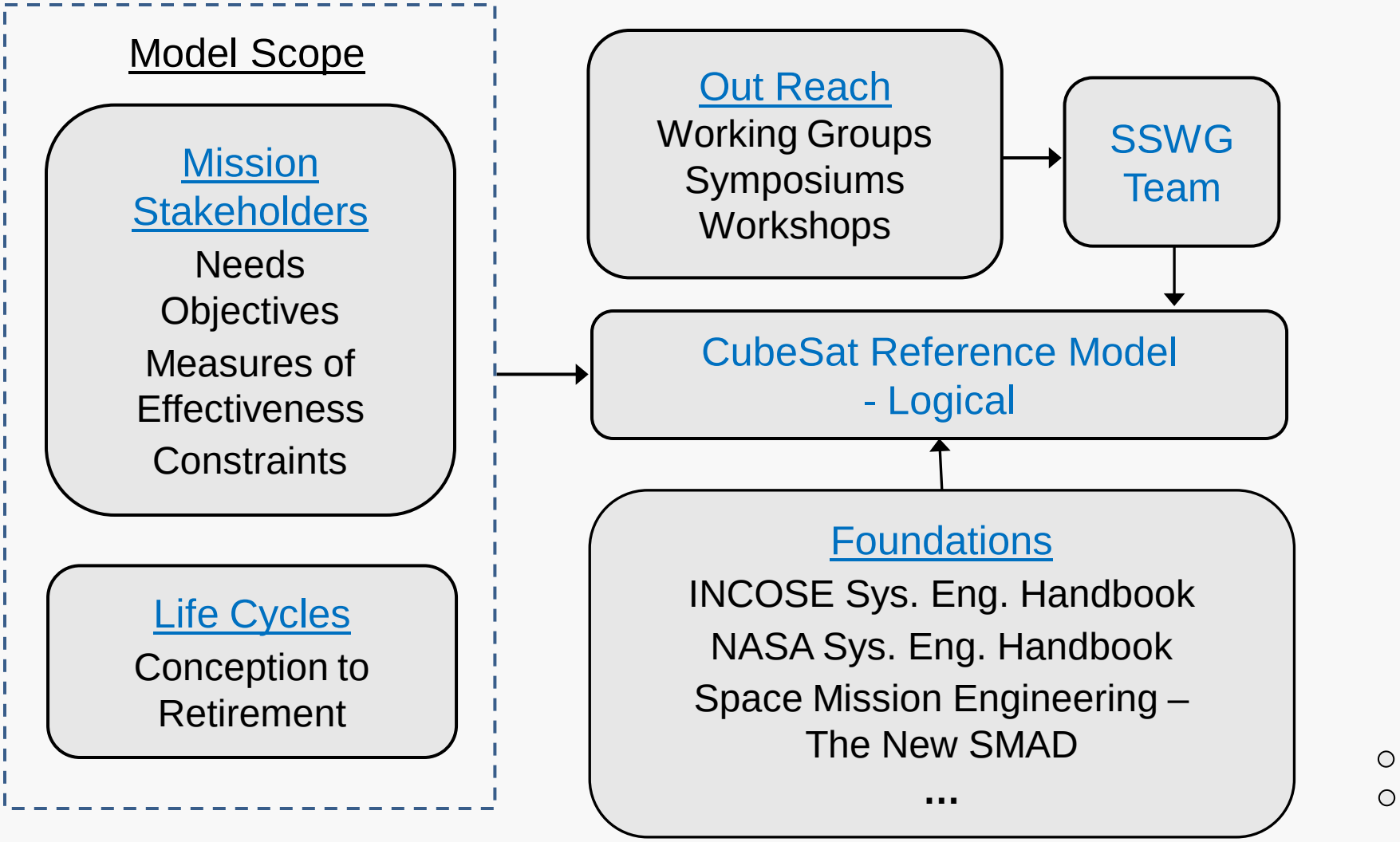
Trade Studies	Trade Space	Perf. Metric
Solar Panel Area	• Nominal:18.2 cm^2/slide • ½ of nominal • ¼ of nominal	On-board energy
Max Battery Capacity	• Nominal:115,000 J • Reduced: 100,000 J	On-board energy
Orbital Altitude	• Nominal: 811 km x 457 km • Low: 593 km x 250 km • High: 1311 km x 932 km	Quantity of data downloaded
Ground Station Network	• Ann Arbor & Menlo Park • Ann Arbor & Fairbanks • Fairbanks & Menlo Park	Quantity of data downloaded

Phase 3 - RAX CubeSat Model Trade Studies

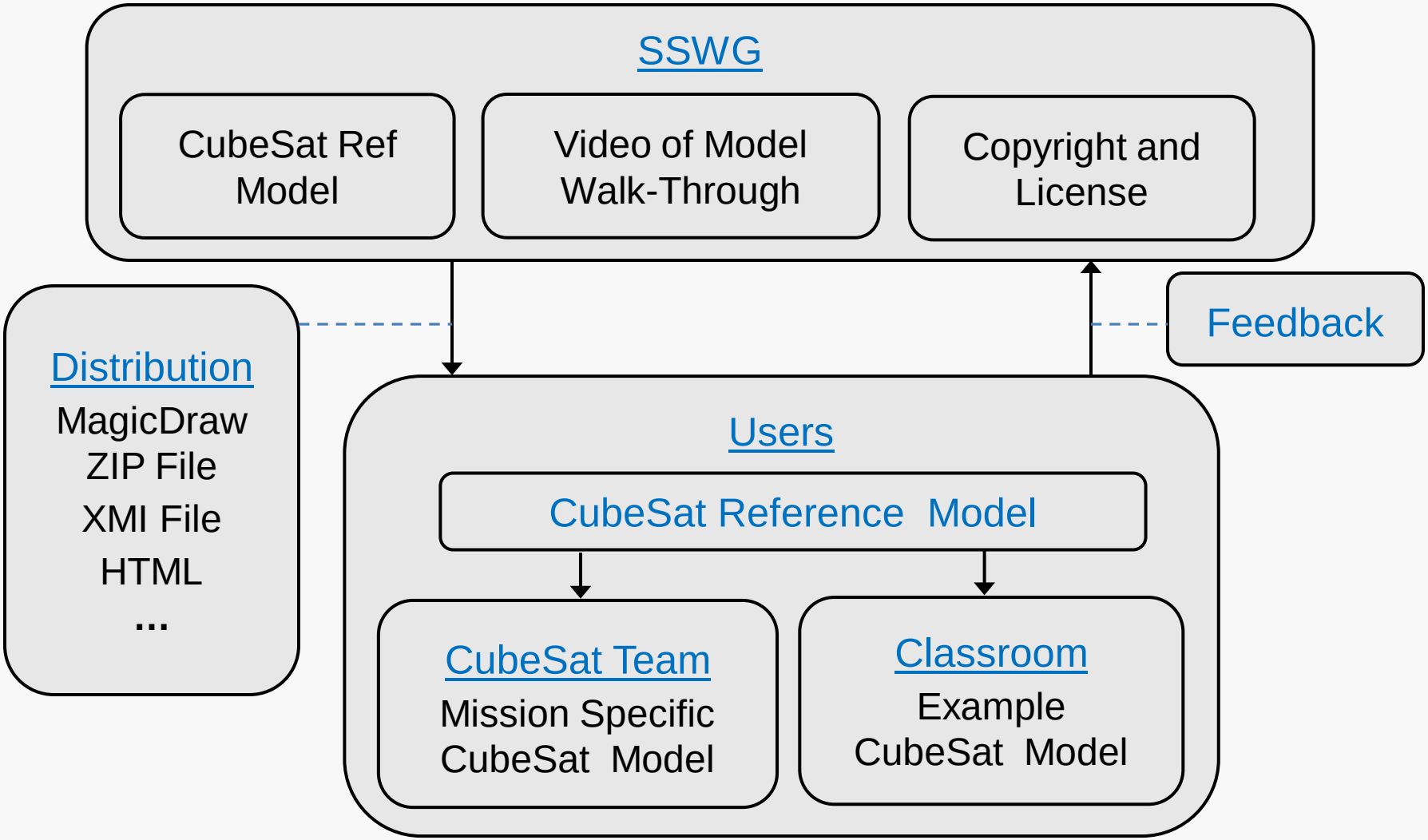


CubeSat Reference Model Development and Distribution

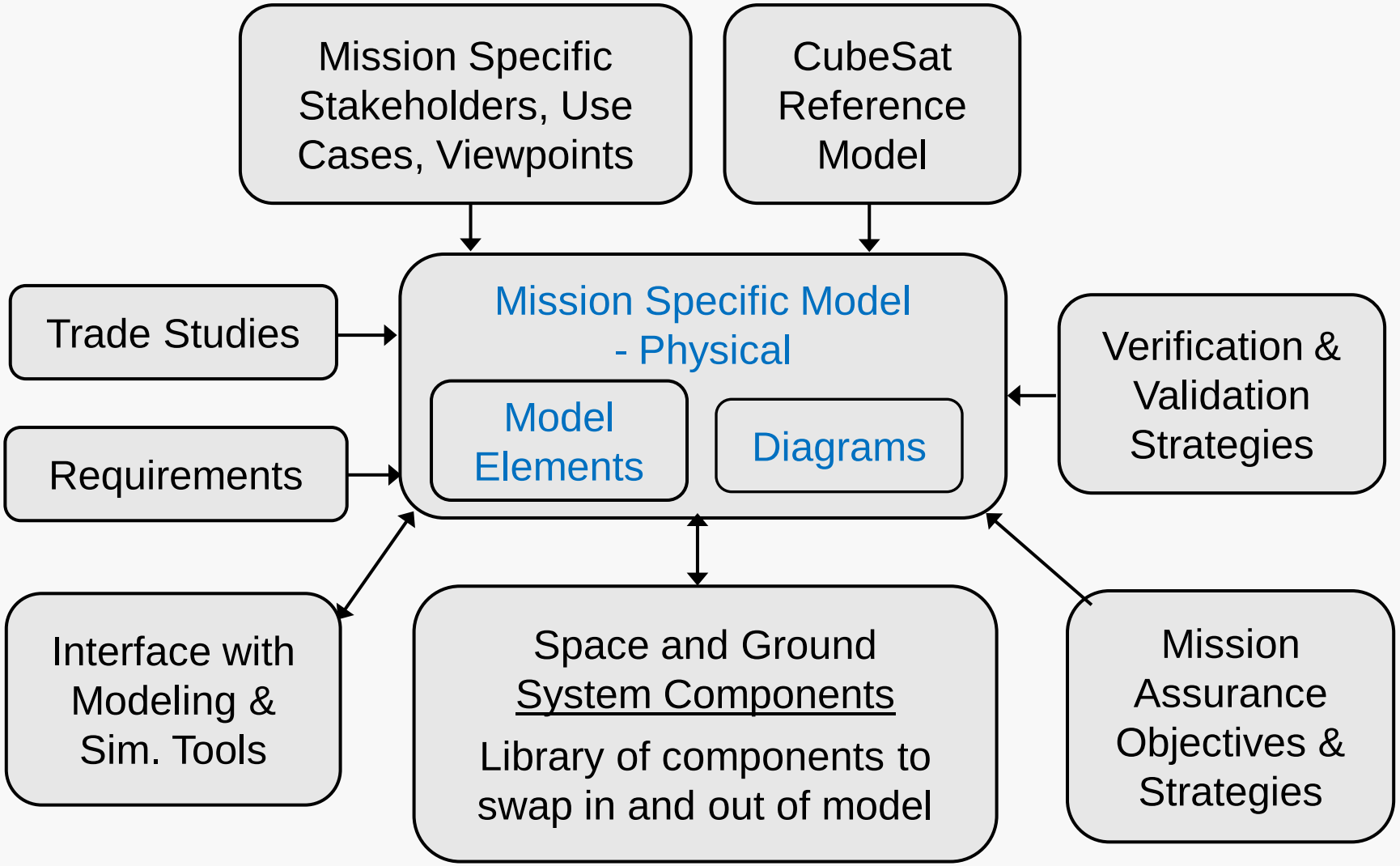
CubeSat Reference Model Development



Model Distribution

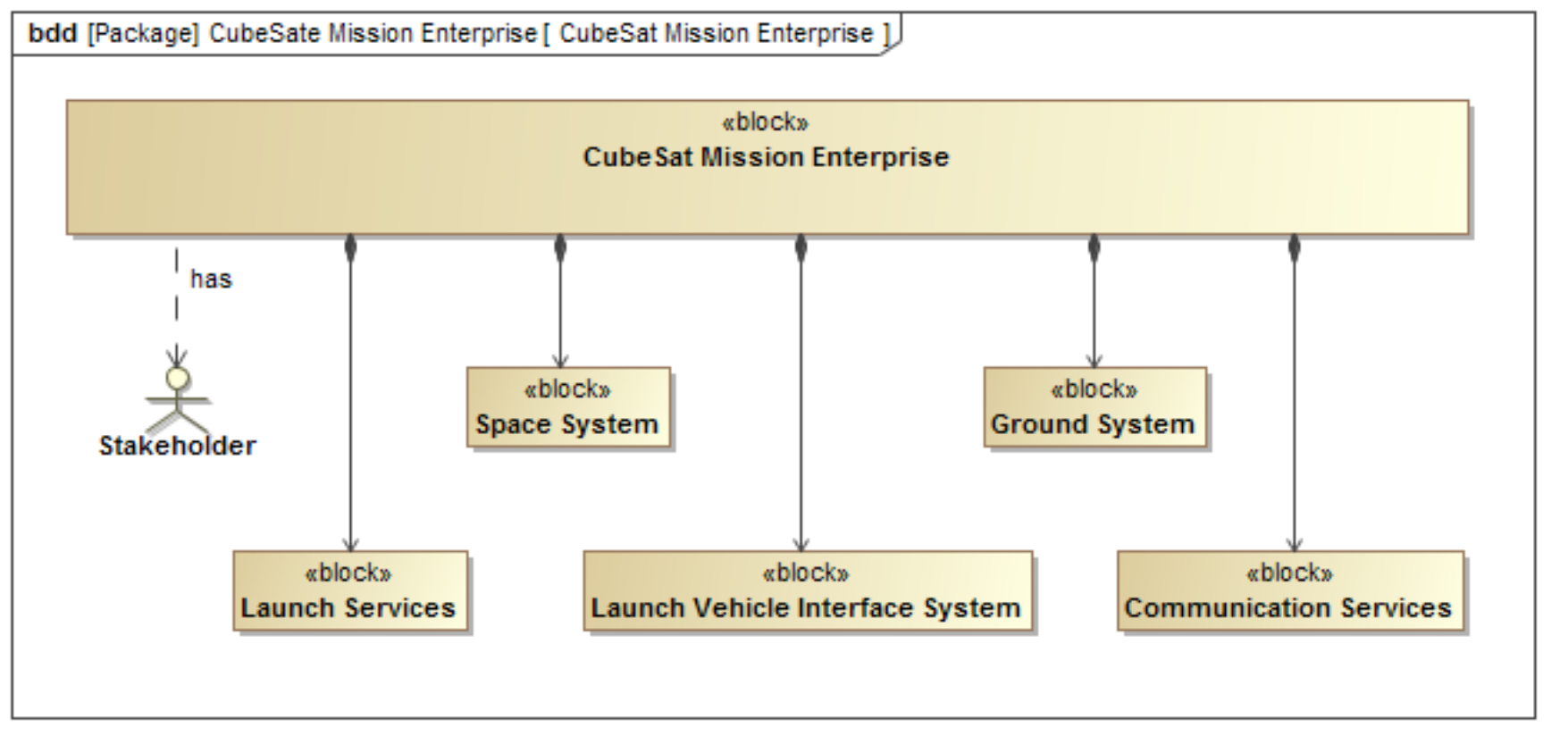


Development of a Mission Specific CubeSat Model

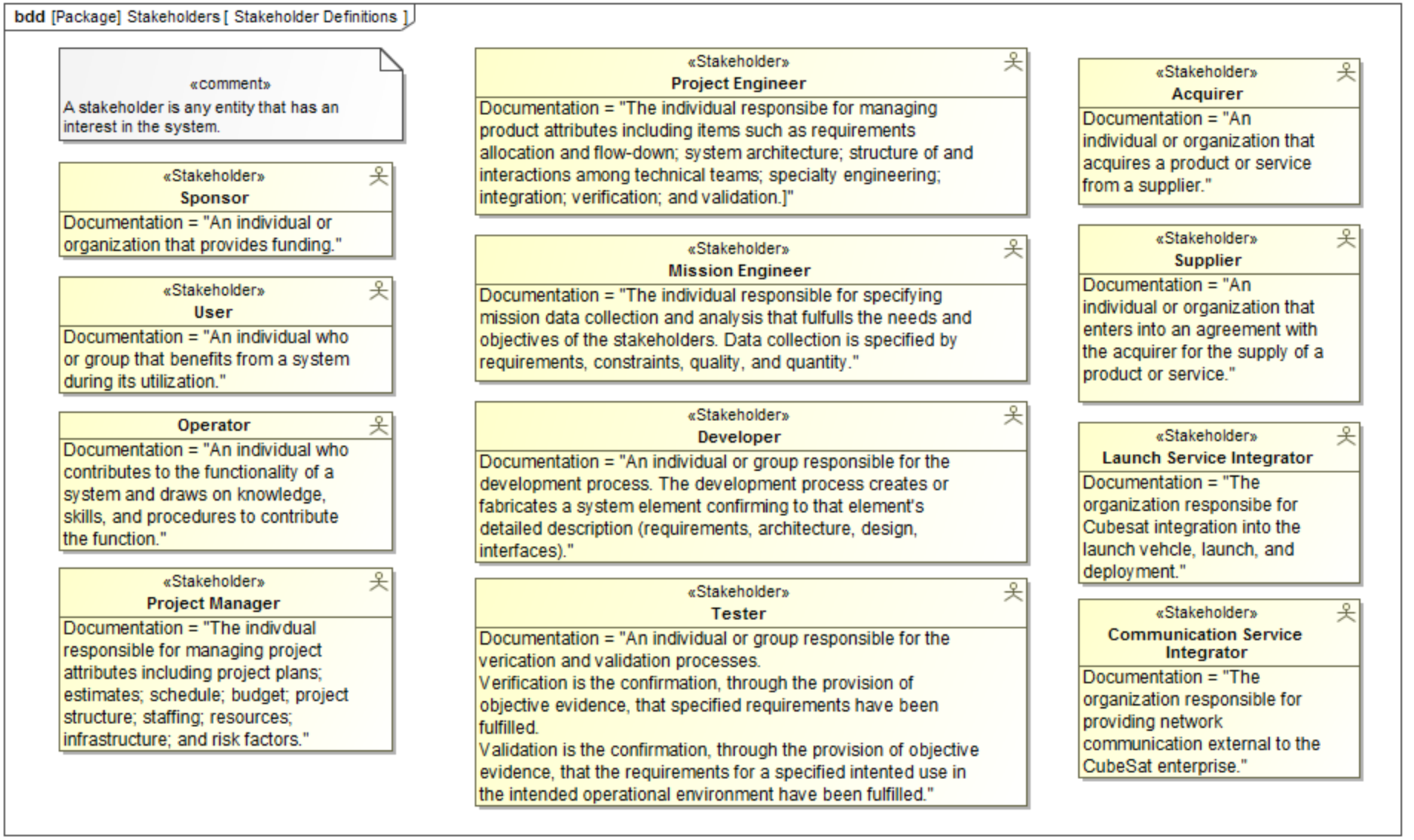


CubeSat Reference Model Diagrams

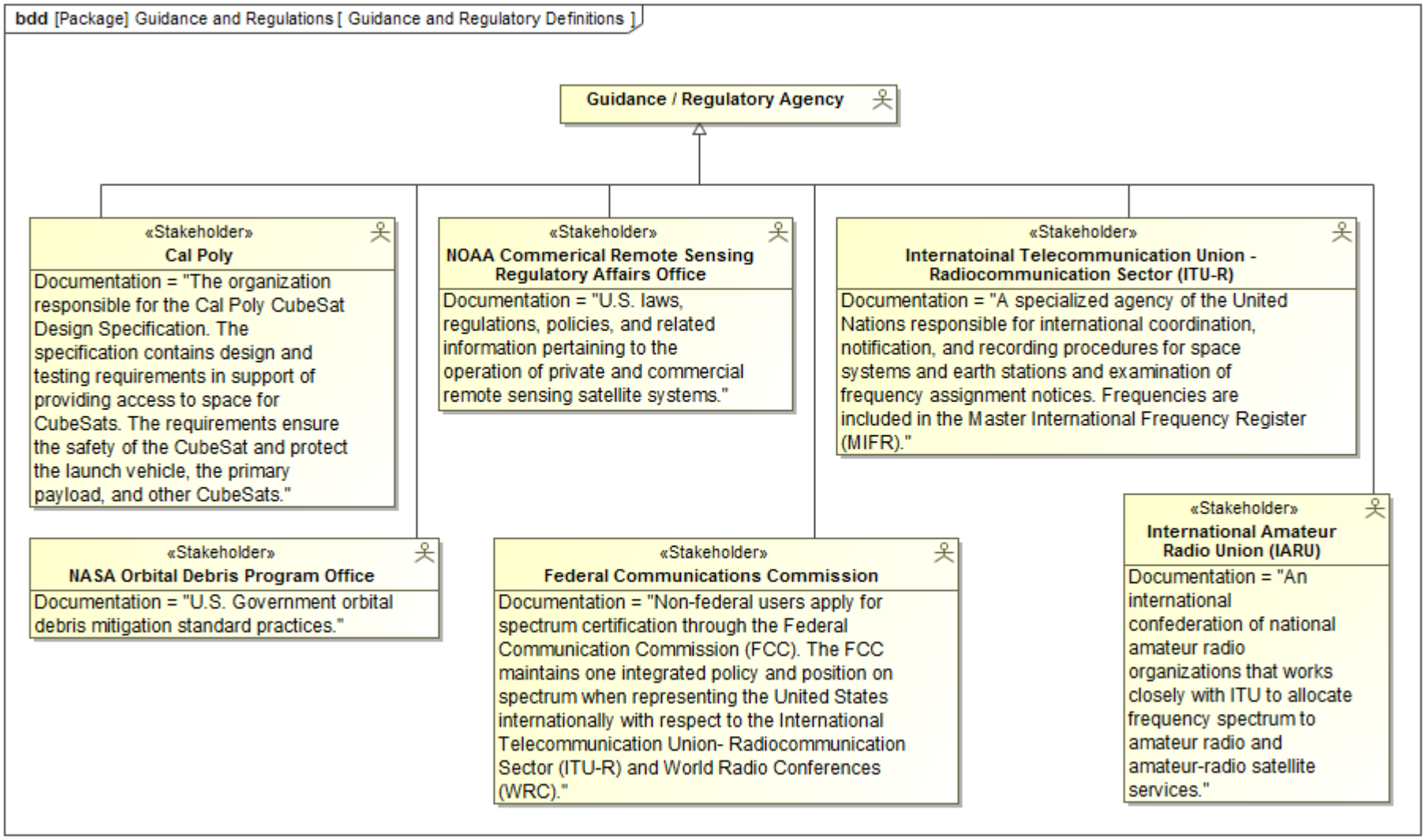
CubeSat Mission Enterprise



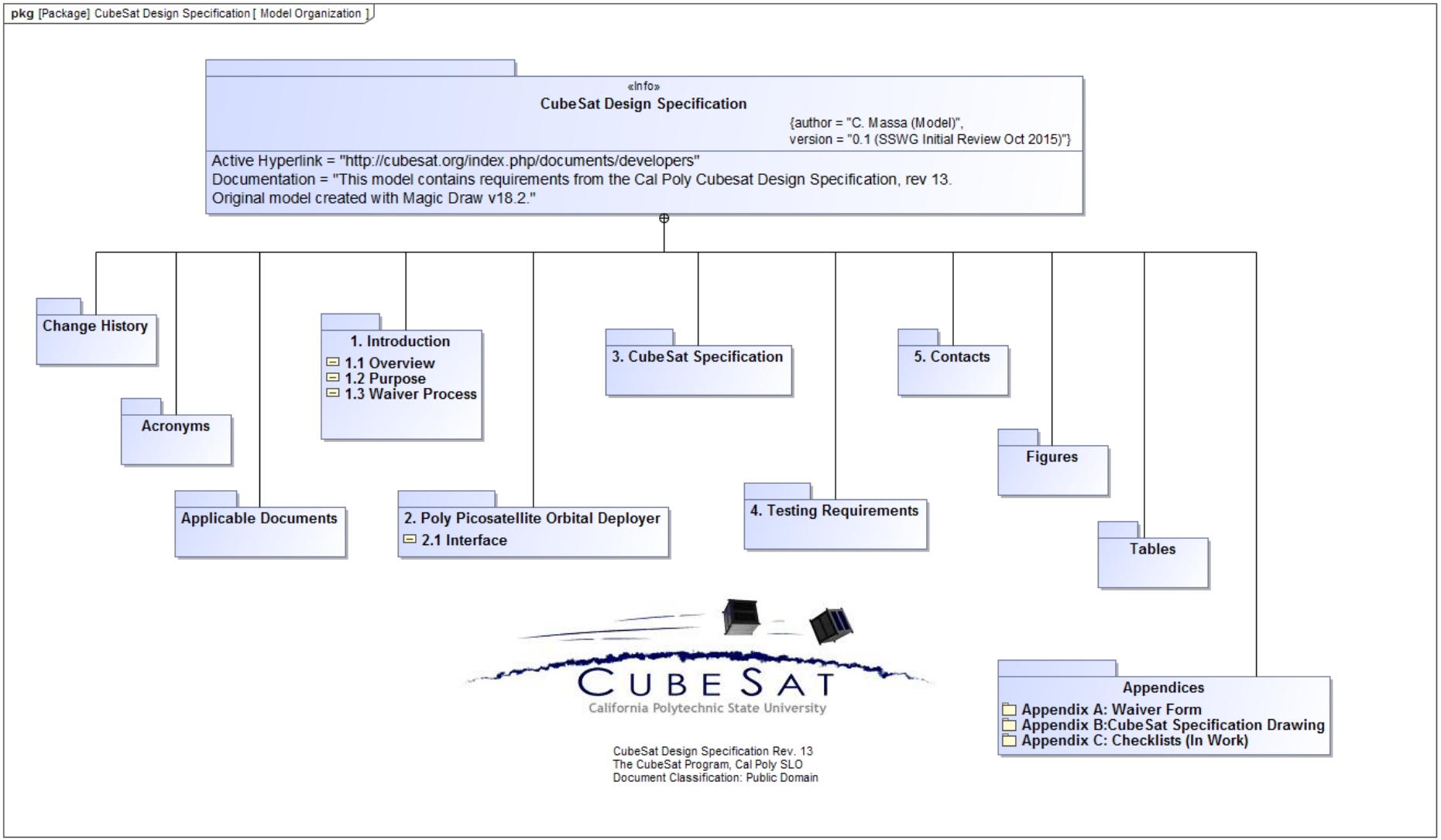
Stakeholders



Stakeholders: Guidance and Regulations



Cal Poly CubeSat Design Specification



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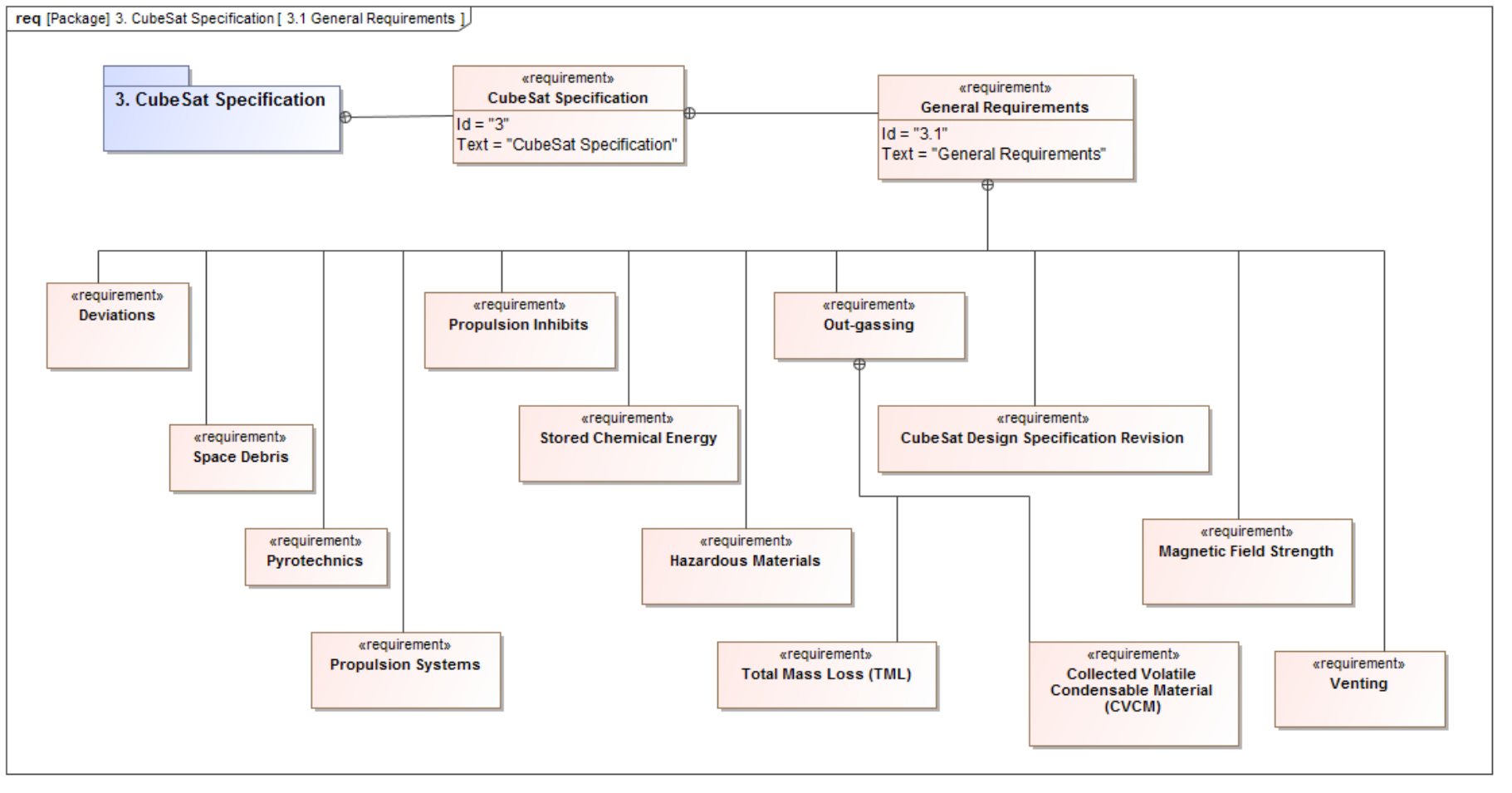
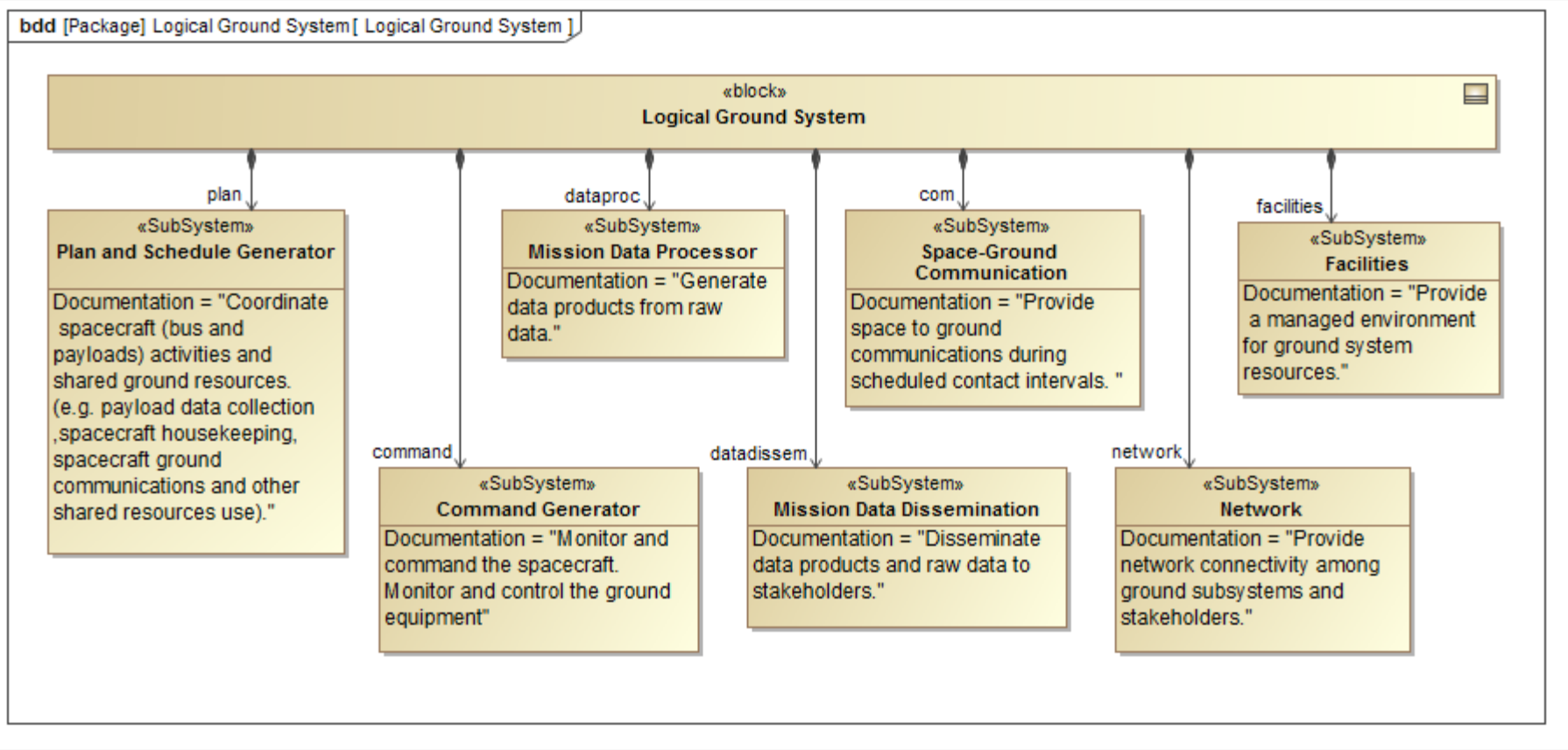
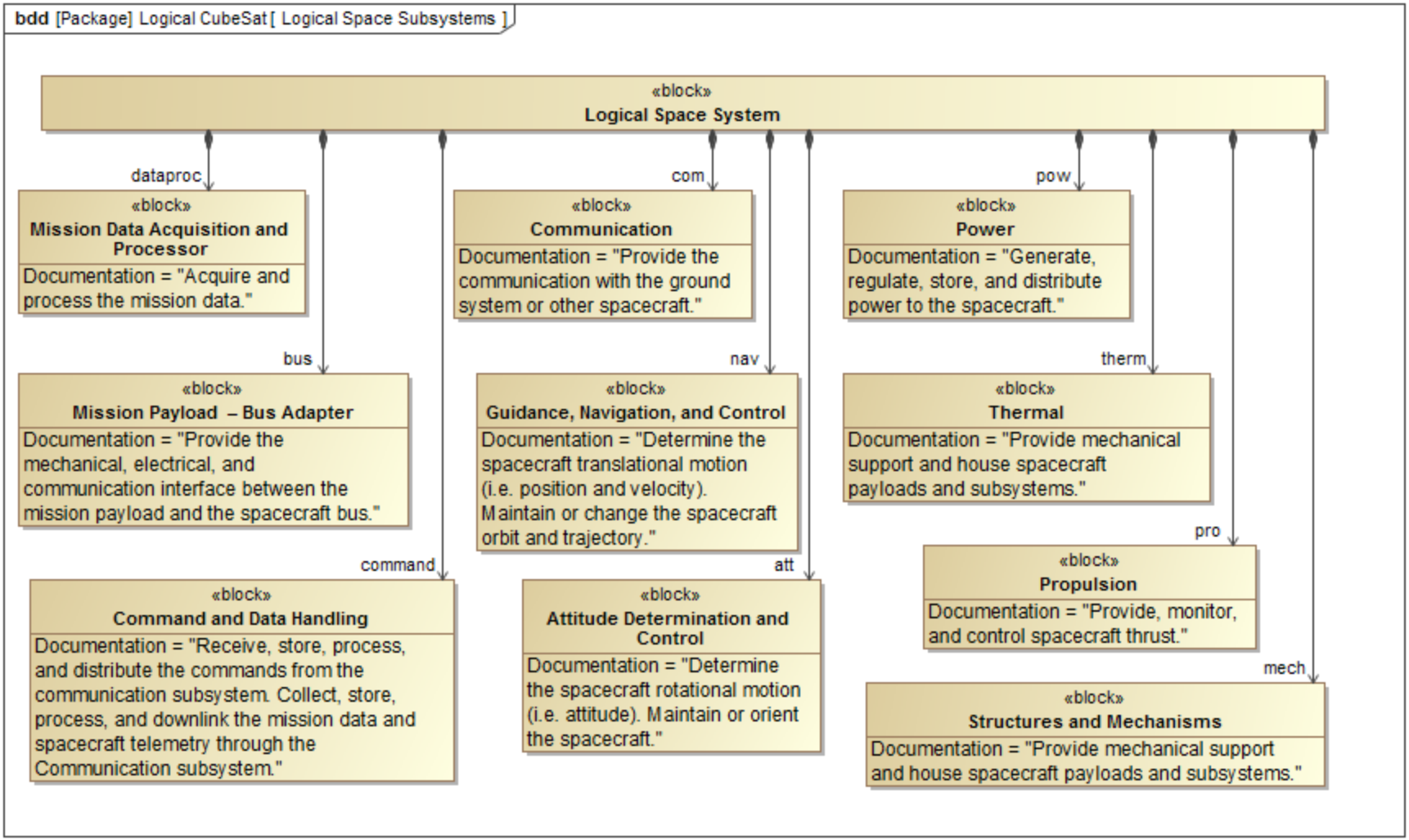


Logical Ground System



Logical Space System



Next Steps and References

Next Steps

Create example mission specific model:

Stakeholder needs, objectives, constraints

Mission and system requirements

Measure of Effectiveness (MOE)

Measure of Performance (MOP)

Demonstrate validation of MOEs and MOPs

References

[1] Systems Engineering Vision 2020, INCOSE –TP_2004-004-02, ver. 2/03,September 2007. [Online]. Available: http://oldsite.incose.org/ProductsPubs/pdf/SEVision2020_20071003_v2_03.pdf

[2] MBSE Roadmap. MBSE Wiki, INCOSE MBSE IW 2012. MBSE Wiki. [Online} Available: http://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:mbse_iw_2012-introduction-2012-01-21-friedenthal-c.pptx

[3] *Survey of Model-Based Systems Engineering (MBSE) Methodologies.* INCOSE-TD-2007-003-01, Ver. B. 10 June 2008. [Online]. Available: https://oldsite.incose.org/ProductsPubs/pdf/techdata/MTTC/MBSE_Methodology_Survey_2008-0610_RevB-JAE2.pdf

[4] *Additional Methodologies Identified as Gaps since 2008 INCOSE Survey*. MBSE Wiki, Metrics and Methodologies [Online]. Available: http://www.omgwiki.org/MBSE/doku.php?id=mbse:methodology

[5] Object Management Group (OMG), OMG Website. [Online]. Available: http://www.omgsysml.org/

[6] Object Management Group (OMG), OMG Wiki. [Online]. Available: http://www.omgwiki.org/MBSE/doku.php?id=mbse:incoseoosem

References

[7] 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.

[8] 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.

[9] L. Anderson, B. Cole, R. Yntema, M. Bajaj, S. Spangelo, D. Kaslow, C. Lowe, E. Sudano, M. Boghosian, R. Reil, S. Asundi, and S. Friedenthal, “Enterprise Modeling for CubeSats,” *Proceedings of IEEE Aerospace Conference*, Big Sky, MT, March 2014.

[10] 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.

[11] 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.

[12] 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.