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

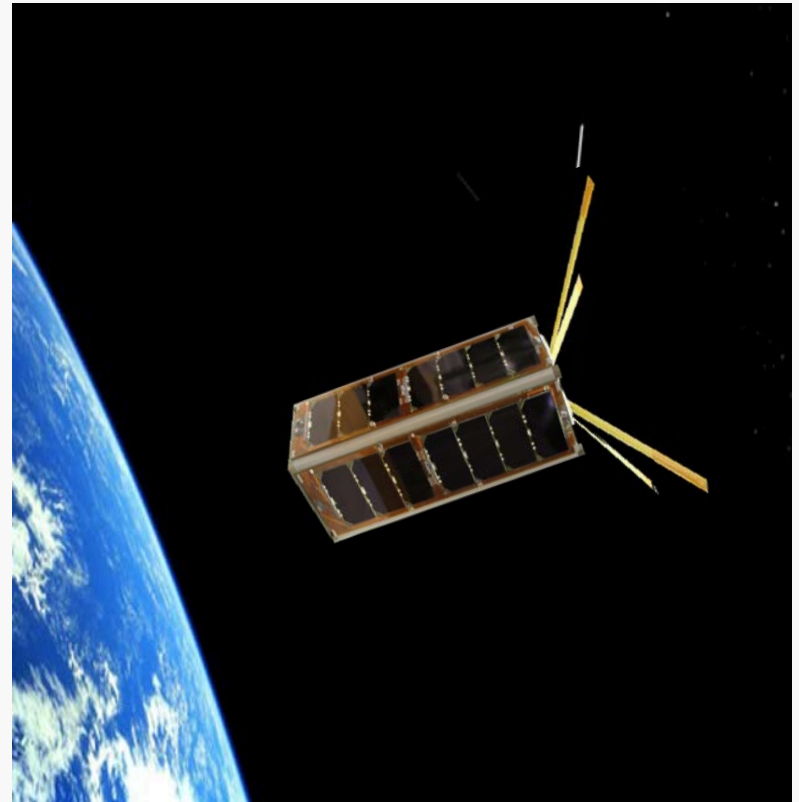
Dave Kaslow

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

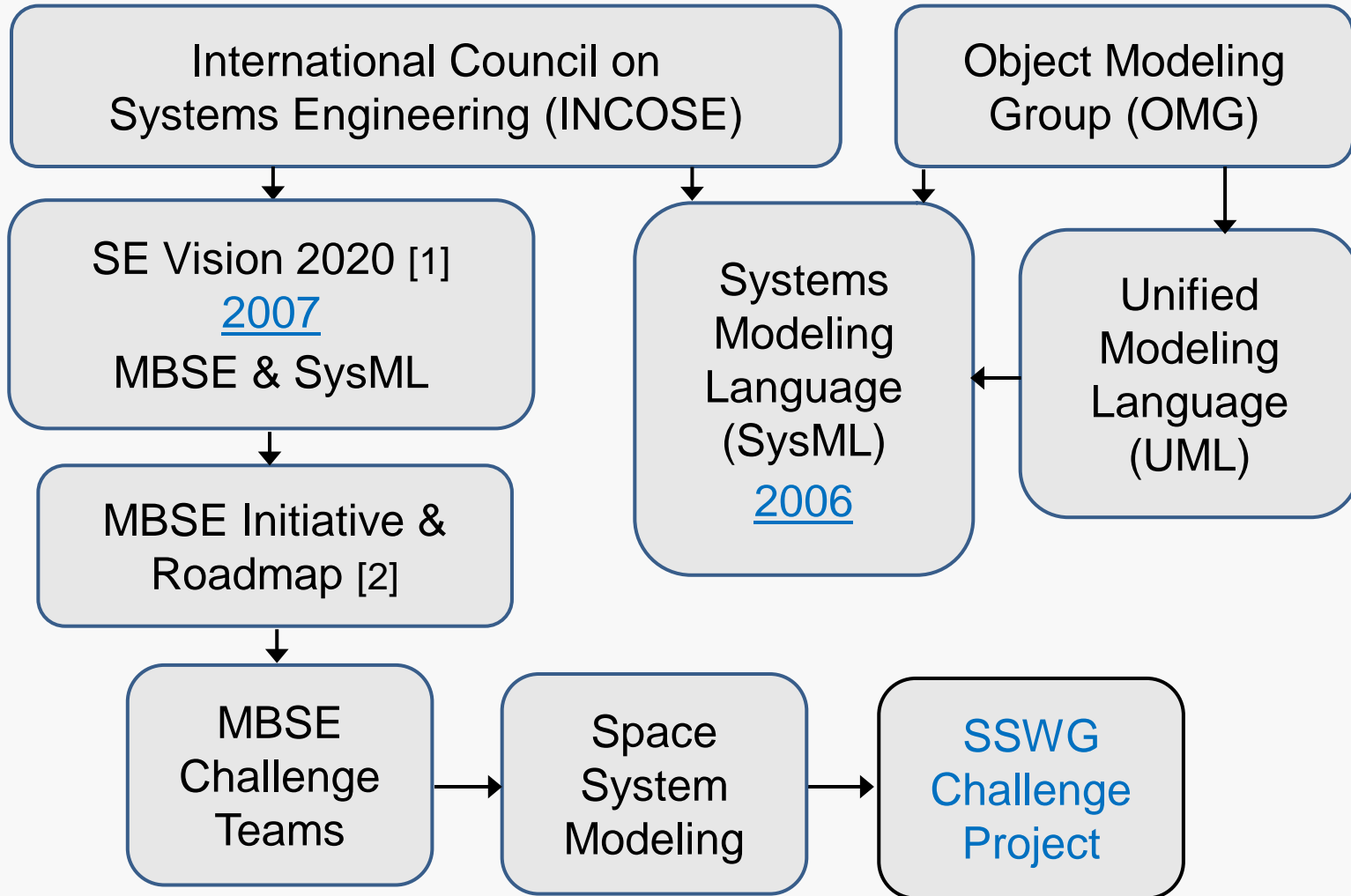
Meeting materials and links to meeting recordings
in Google docs

Conference papers posted in INCOSE SSWG Web Site

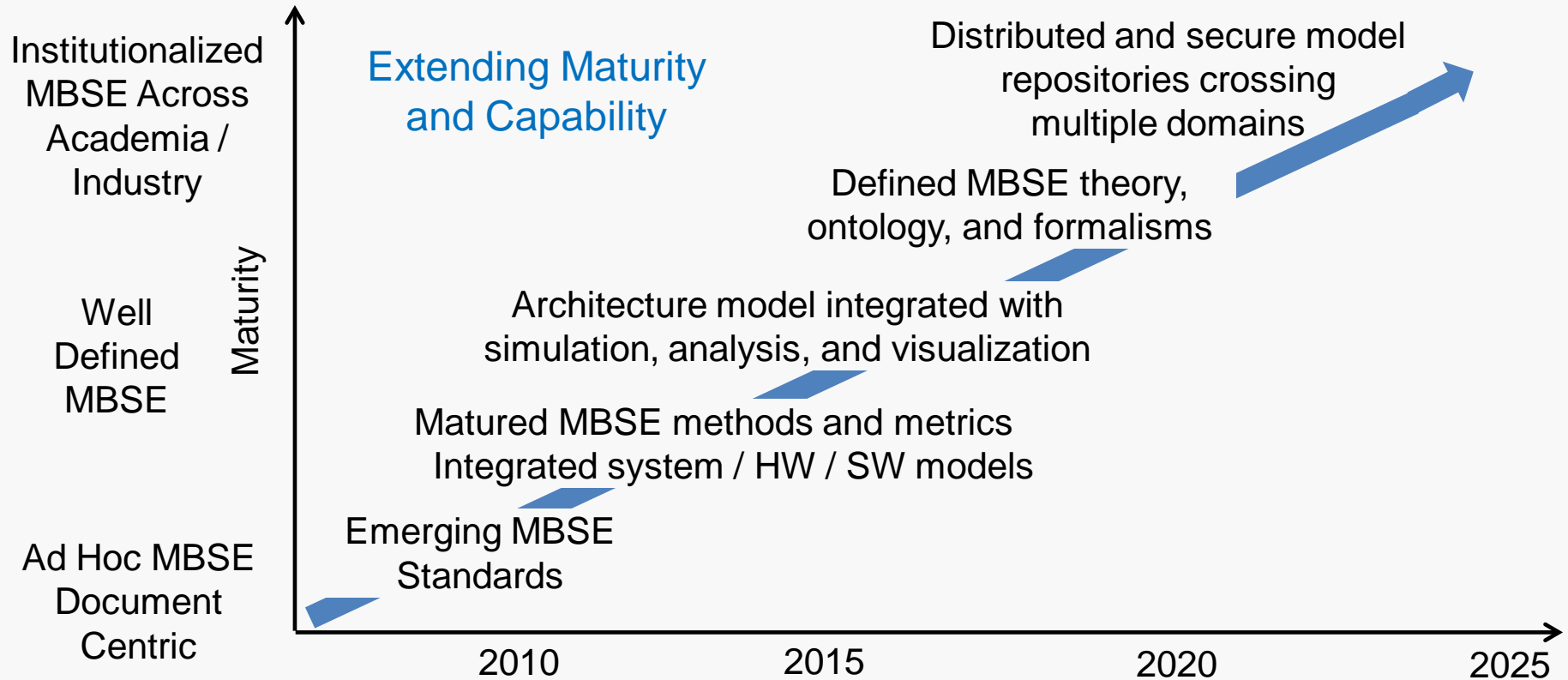
<http://www.incose.org/ChaptersGroups/WorkingGroups/government/space-systems>

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

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

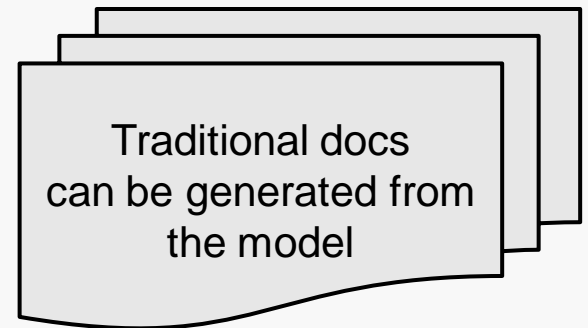
Requirement

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)

OOSEM

Analyze stakeholder needs
Analyze system requirements
Define logical architecture
Synthesize candidate physical architectures

CubeSat Reference Model

Logical model elements for population by a mission specific CubeSat team.

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

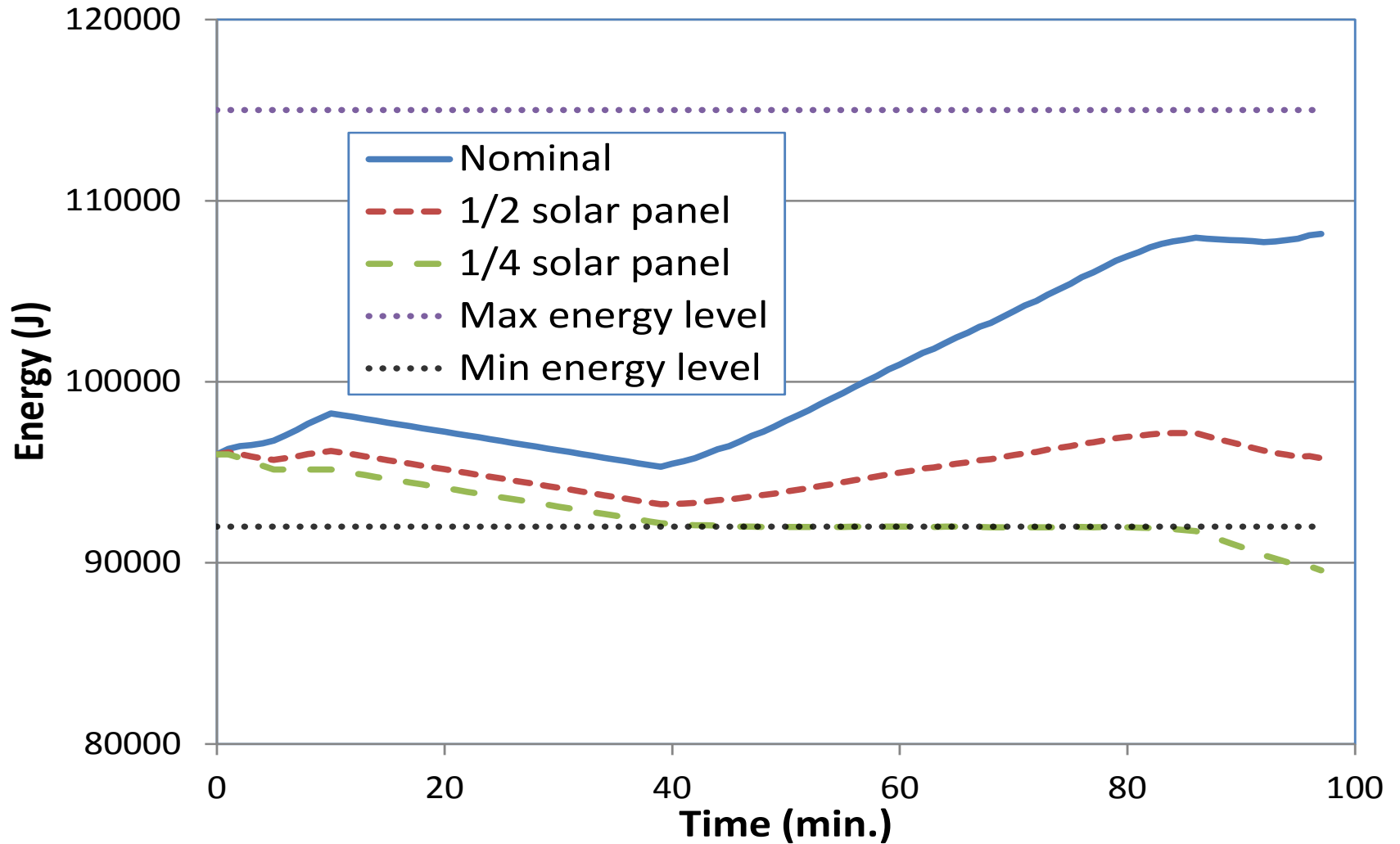
Radar signal is transmitted by Incoherent Scatter Radar site in
Poker Flat, Alaska and received by RAX's radar receiver

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

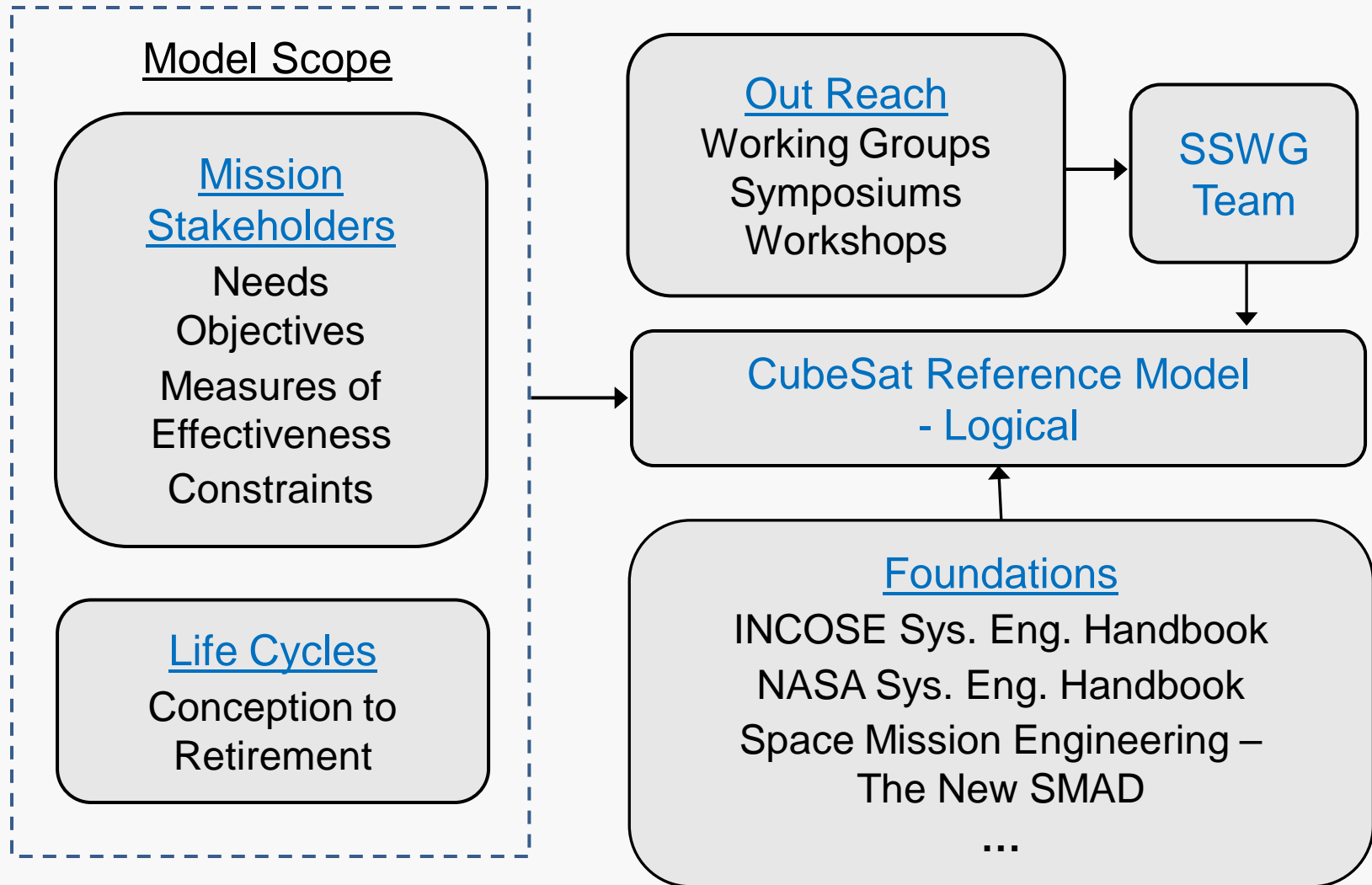
Trade Studies	Trade Space	Perf. Metric
Solar Panel Area	<ul style="list-style-type: none"> • Nominal: 18.2 cm²/slide • ½ of nominal • ¼ of nominal 	On-board energy
Max Battery Capacity	<ul style="list-style-type: none"> • Nominal: 115,000 J • Reduced: 100,000 J 	On-board energy
Orbital Altitude	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • Ann Arbor & Menlo Park • Ann Arbor & Fairbanks • Fairbanks & Menlo Park 	Quantity of data downloaded

Phase 3 - RAX CubeSat Model Trade Studies

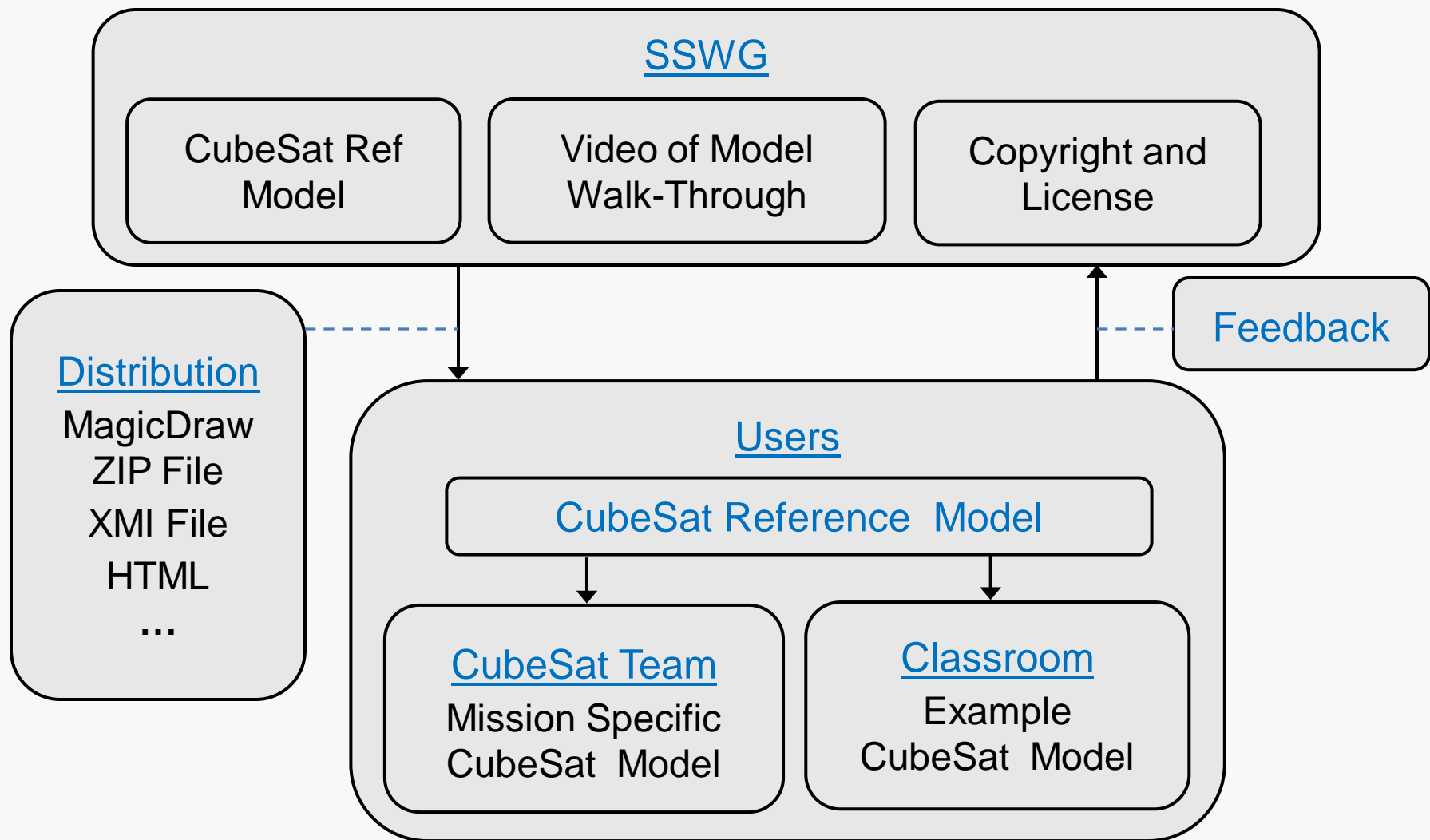


CubeSat Reference Model Development and Distribution

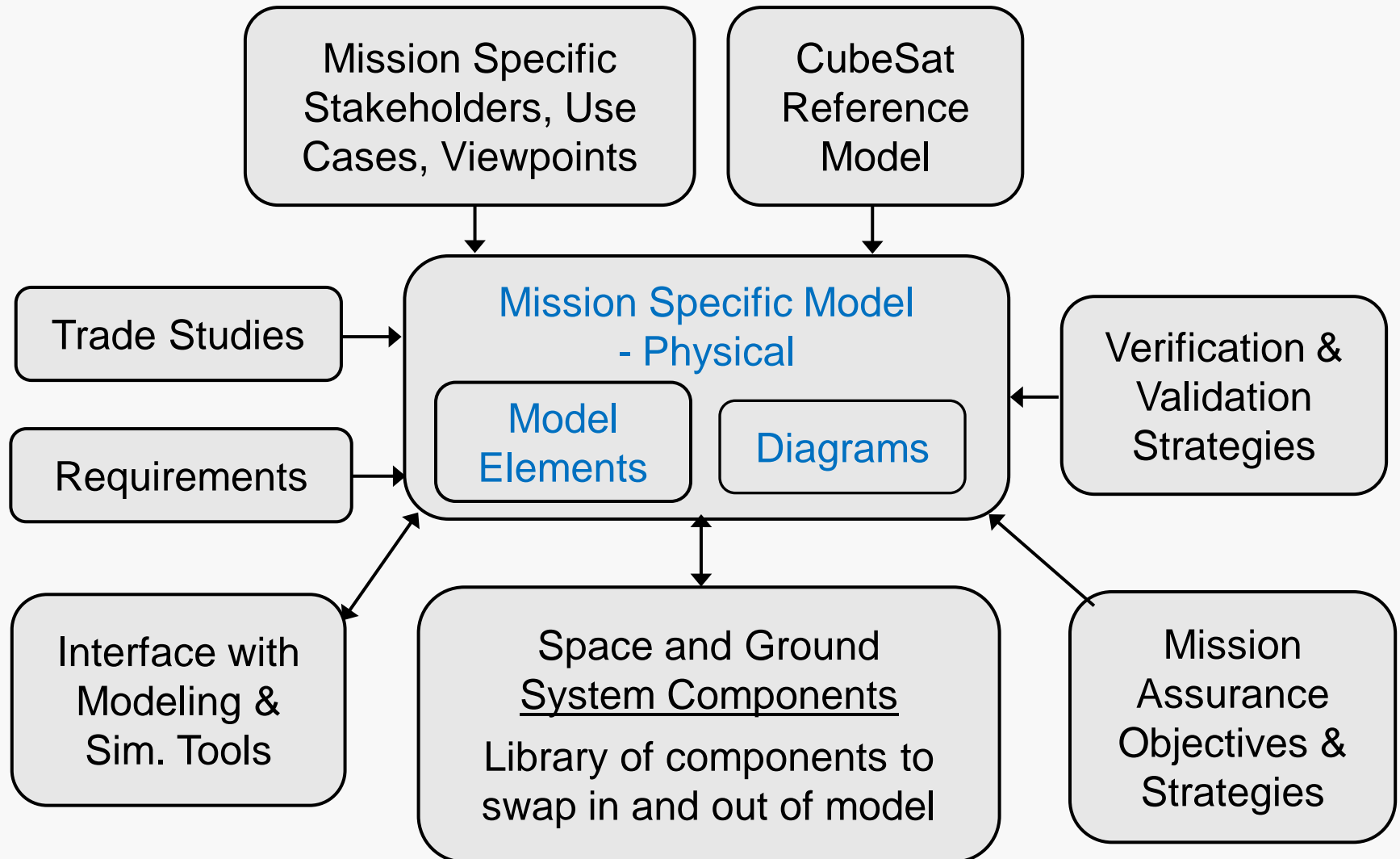
CubeSat Reference Model Development



Model Distribution

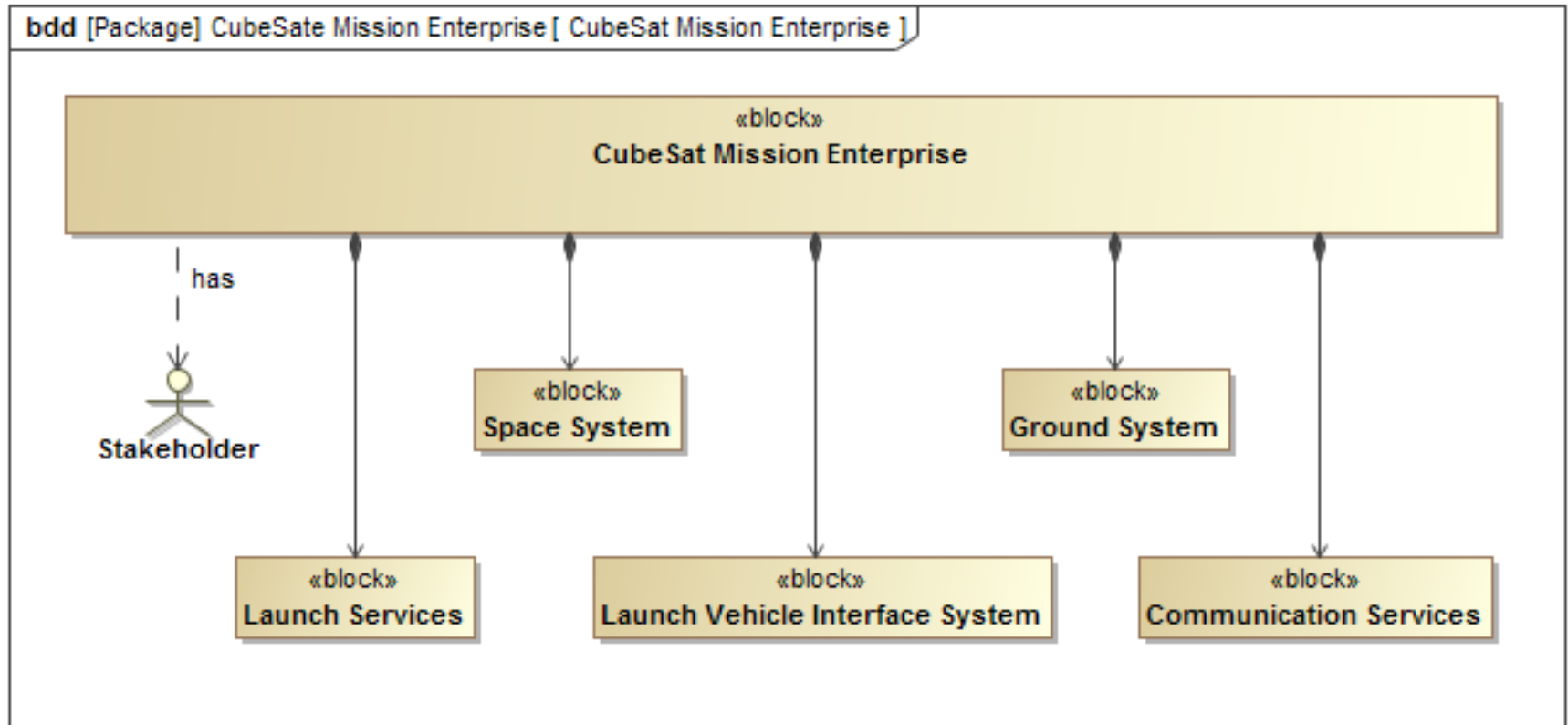


Development of a Mission Specific CubeSat Model



CubeSat Reference Model Diagrams

CubeSat Mission Enterprise



Stakeholders

bdd [Package] Stakeholders [Stakeholder Definitions]

«comment»

A stakeholder is any entity that has an interest in the system.

«Stakeholder»

Sponsor

Documentation = "An individual or organization that provides funding."

«Stakeholder»

User

Documentation = "An individual who or group that benefits from a system during its utilization."

Operator

Documentation = "An individual who contributes to the functionality of a system and draws on knowledge, skills, and procedures to contribute the function."

«Stakeholder»

Project Manager

Documentation = "The individual responsible for managing project attributes including project plans; estimates; schedule; budget; project structure; staffing; resources; infrastructure; and risk factors."

«Stakeholder»

Project Engineer

Documentation = "The individual responsible for managing product attributes including items such as requirements allocation and flow-down; system architecture; structure of and interactions among technical teams; specialty engineering; integration; verification; and validation.]"

«Stakeholder»

Mission Engineer

Documentation = "The individual responsible for specifying mission data collection and analysis that fulfills the needs and objectives of the stakeholders. Data collection is specified by requirements, constraints, quality, and quantity."

«Stakeholder»

Developer

Documentation = "An individual or group responsible for the development process. The development process creates or fabricates a system element conforming to that element's detailed description (requirements, architecture, design, interfaces)."

«Stakeholder»

Tester

Documentation = "An individual or group responsible for the verification and validation processes.
Verification is the confirmation, through the provision of objective evidence, that specified requirements have been fulfilled.
Validation is the confirmation, through the provision of objective evidence, that the requirements for a specified intended use in the intended operational environment have been fulfilled."

«Stakeholder»

Acquirer

Documentation = "An individual or organization that acquires a product or service from a supplier."

«Stakeholder»

Supplier

Documentation = "An individual or organization that enters into an agreement with the acquirer for the supply of a product or service."

«Stakeholder»

Launch Service Integrator

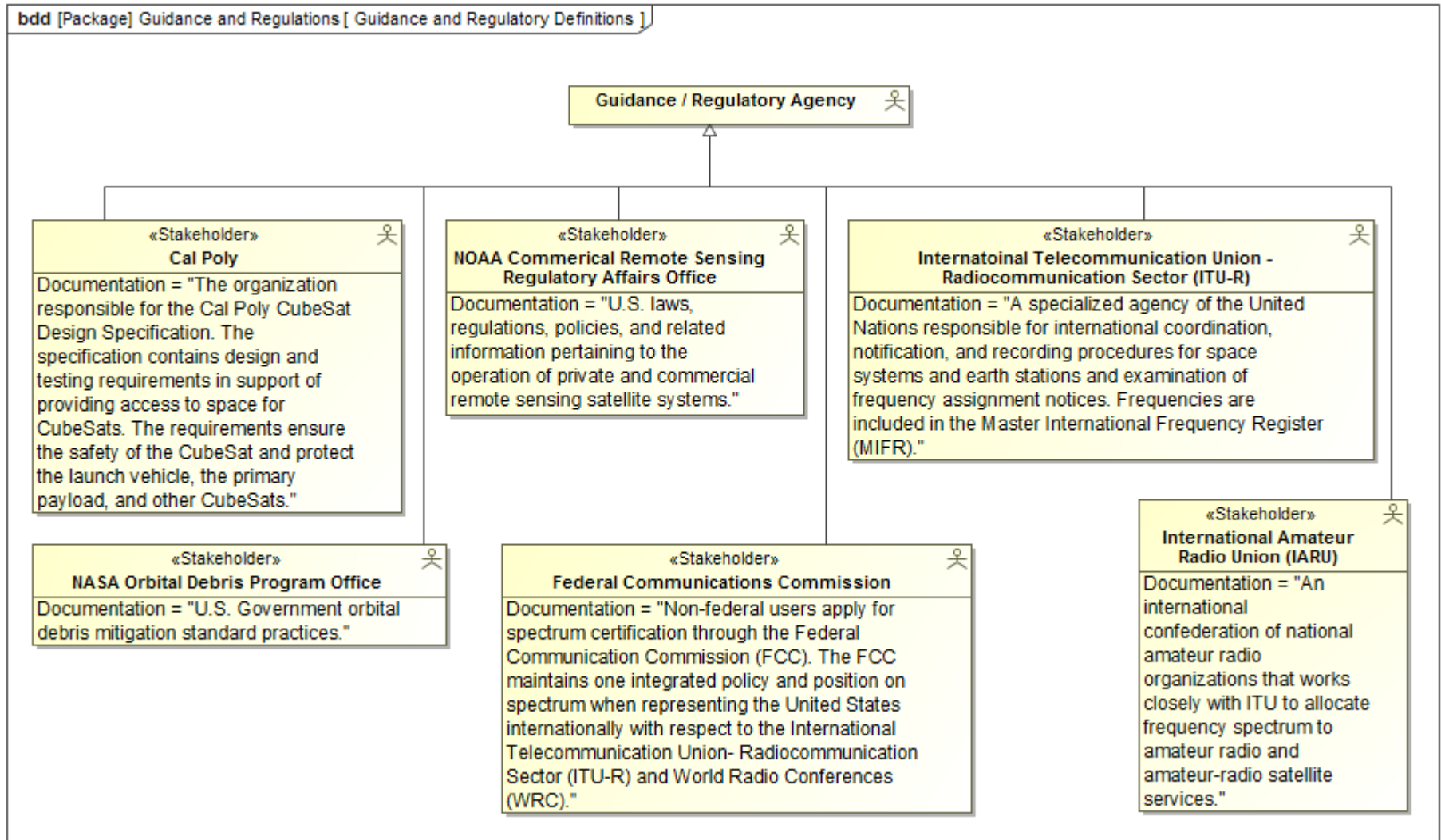
Documentation = "The organization responsible for Cubesat integration into the launch vehicle, launch, and deployment."

«Stakeholder»

Communication Service Integrator

Documentation = "The organization responsible for providing network communication external to the CubeSat enterprise."

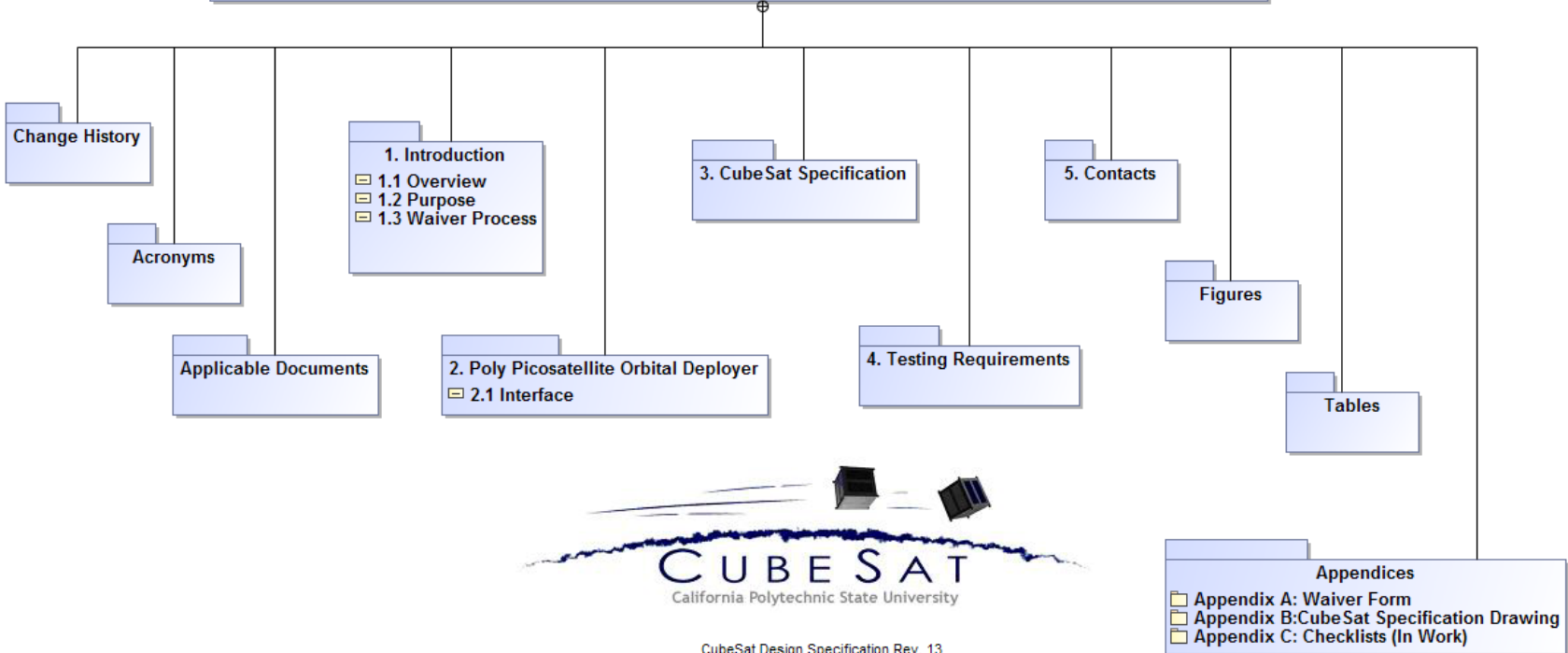
Stakeholders: Guidance and Regulations



Cal Poly CubeSat Design Specification

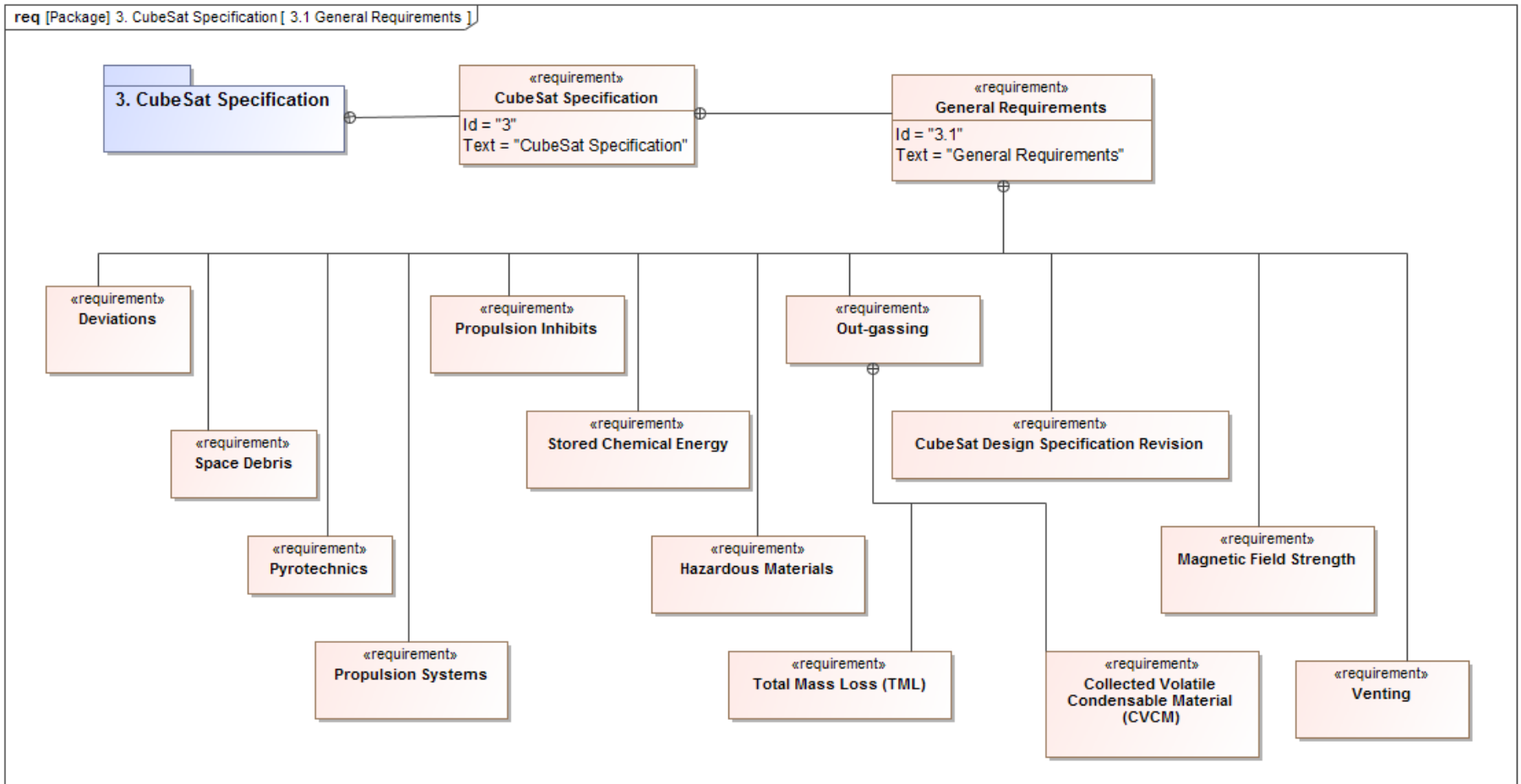
pkg [Package] CubeSat Design Specification [Model Organization]

«Info»
CubeSat Design Specification
{author = "C. Massa (Model)",
version = "0.1 (SSWG Initial Review Oct 2015)"}
Active Hyperlink = "<http://cubesat.org/index.php/documents/developers>"
Documentation = "This model contains requirements from the Cal Poly Cubesat Design Specification, rev 13.
Original model created with Magic Draw v18.2."

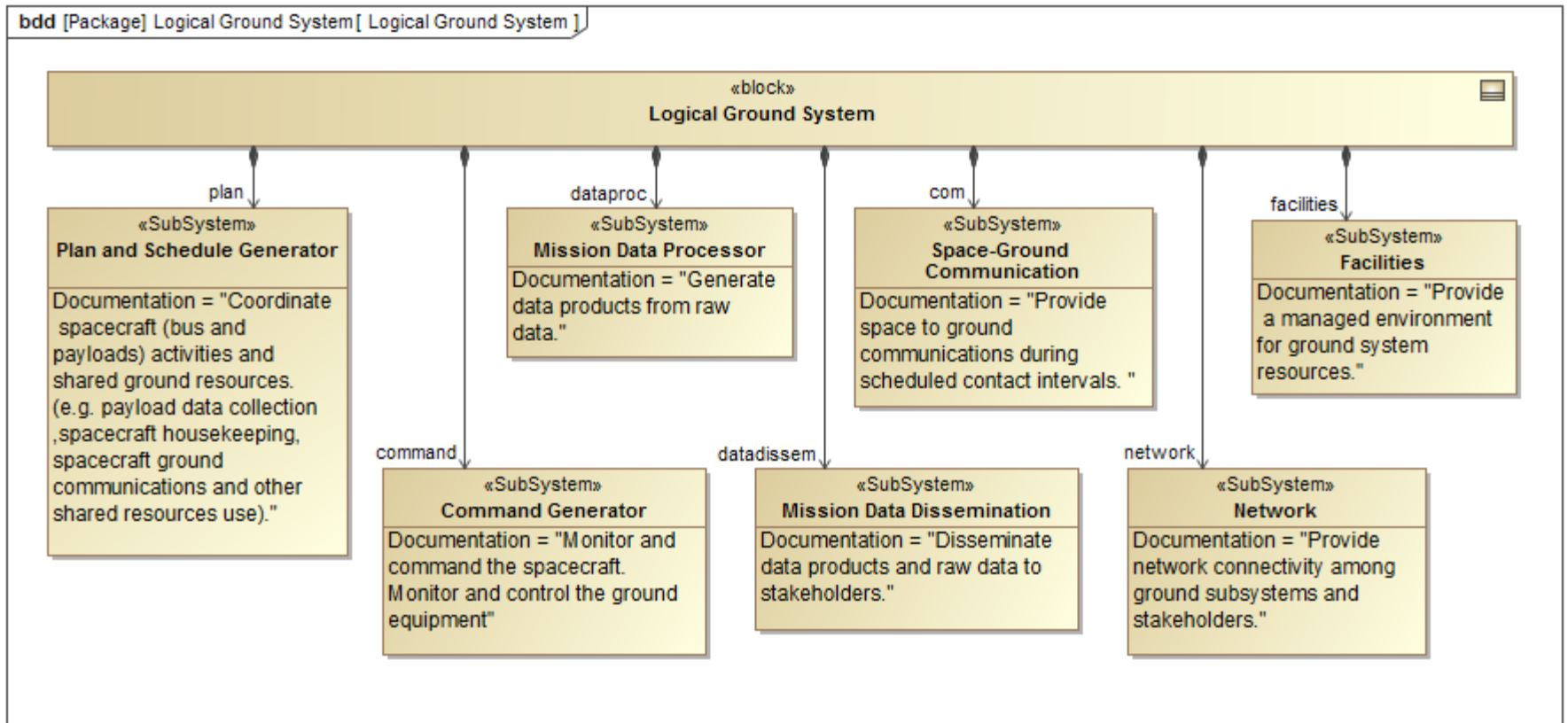


CubeSat Design Specification Rev. 13
The CubeSat Program, Cal Poly SLO
Document Classification: Public Domain

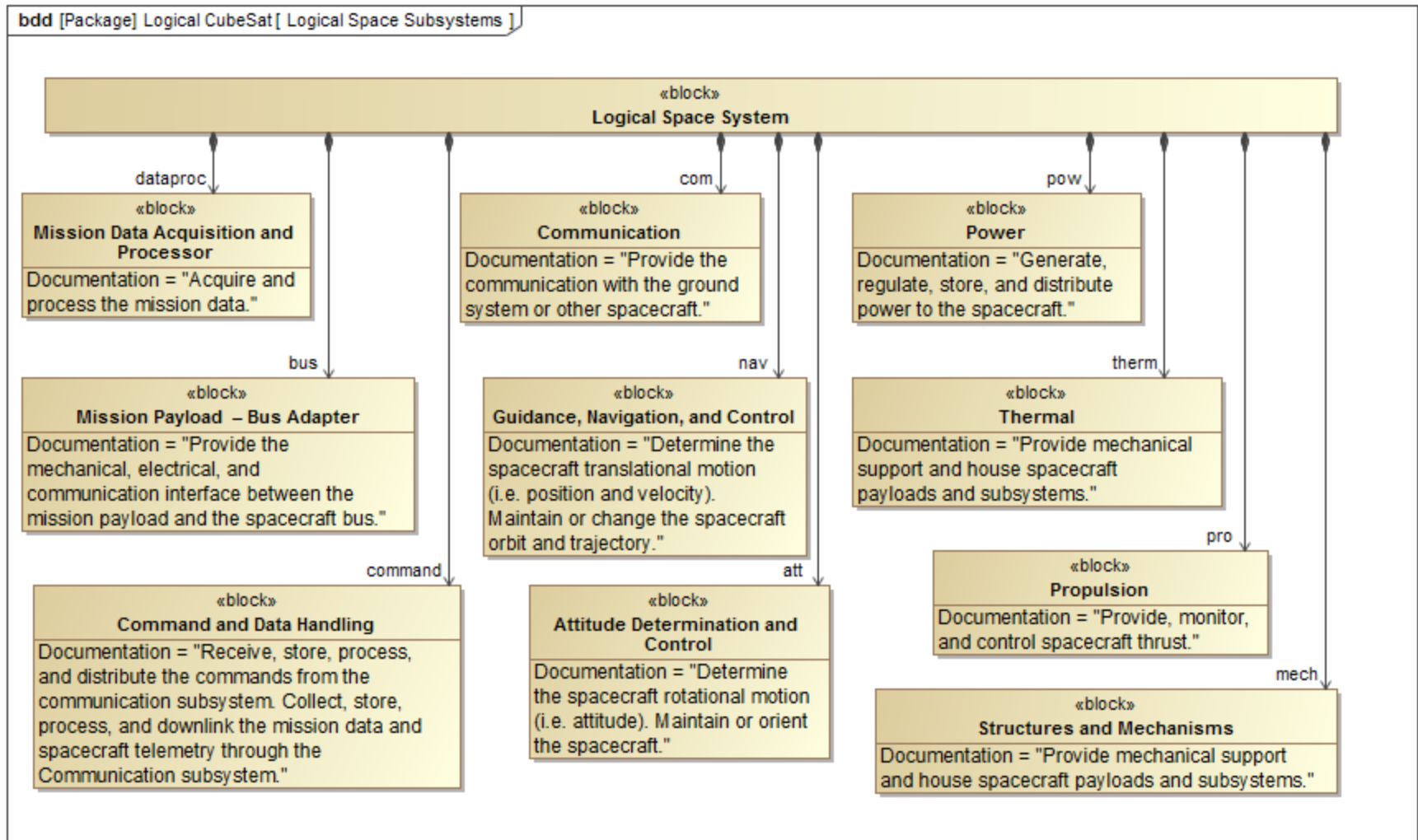
Cal Poly CubeSat Design Specification



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:
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- [5] Object Management Group (OMG), OMG Website. [Online]. Available:
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- [6] Object Management Group (OMG), OMG Wiki. [Online]. Available:
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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.