CubeSat Model-Based Systems Engineering (MBSE) Reference Model – Model Distribution and Application in the Concept Lifecycle Phase – Interim Status

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

Project Objectives

Demonstrate MBSE methodology 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

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

Team Meeting

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

From Document-Centric to Model-Centric

Document Based Design

Create, Update, Review, Config Control, …

System Specs: Rqts, Ops Con, Interfaces, …

Subsys. Specs

…

Ad Hoc Modeling

In support of:

Rqts analysis

Payloads

Mission data collect

…

Traditional Systems Engineering

INCOSE Object-Oriented Systems Engineering Methodology

System Modeling Tools

Interfaces with Other Models

Systems Modeling Language (SysML)

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

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

The Model

SysML Model Elements: Blocks, Actors, Flow, Signals, Ports, …

Block Properties: Parts, Values, Operations, …

System design resides in the model not in documents

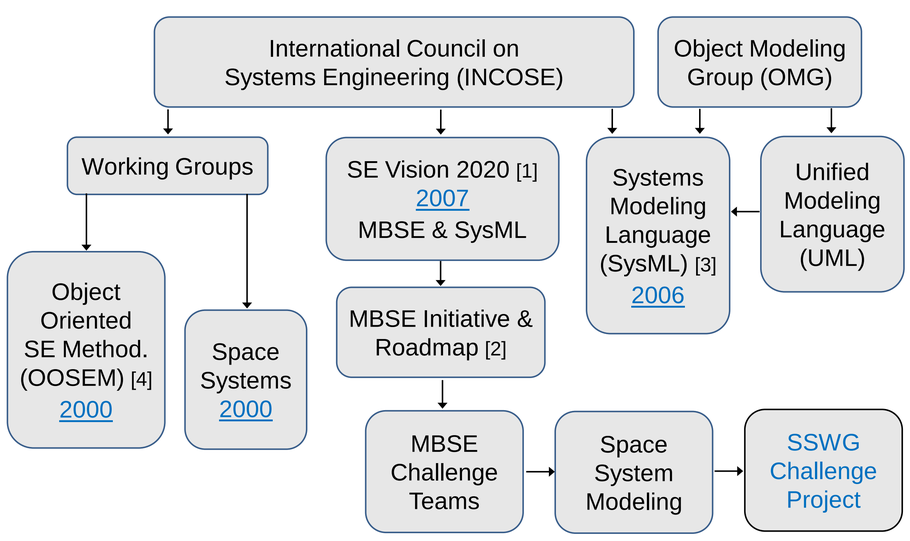
Model updates are automatically populated into the system views

Diagrams are views of the underlying system model

- Structures
- Requirements
- Behaviors
- Parametrics

Traditional documents can be generated from the model as needed

Authoritative, integrated repository of information that evolves from procurement through retirement



INCOSE MBSE Initiative and SSWG Challenge Project

MBSE CubeSat Project

Phase 1 [5]
CubeSat Framework
Preliminary RAX Model

Phase 2 [6]
RAX Behavior Modeling
Power, Comm, State

Recent Efforts (Phase 3)

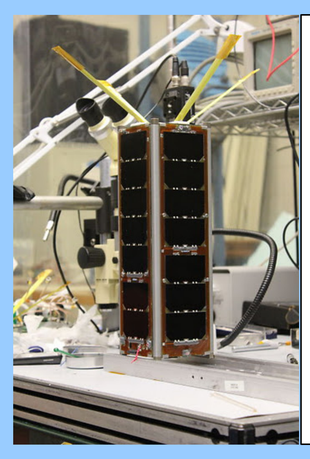
- Enterprise Modeling for CubeSats [7]
- RAX CubeSat Model Trade Studies [8]

Current Efforts (Phase 4)

- Develop a CubeSat MBSE Reference Model [9] [10]

SSWG Challenge Project

Concept Phase Trade Studies – Phase 3 [8]



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

State Diagrams

- Orbit
- Solar
- Experiment
- Download

Models behavior in response to internal and external events

Parametric Diagrams

- Get States
- Power Collection
- Update Energy
- Update Data
- Update Download

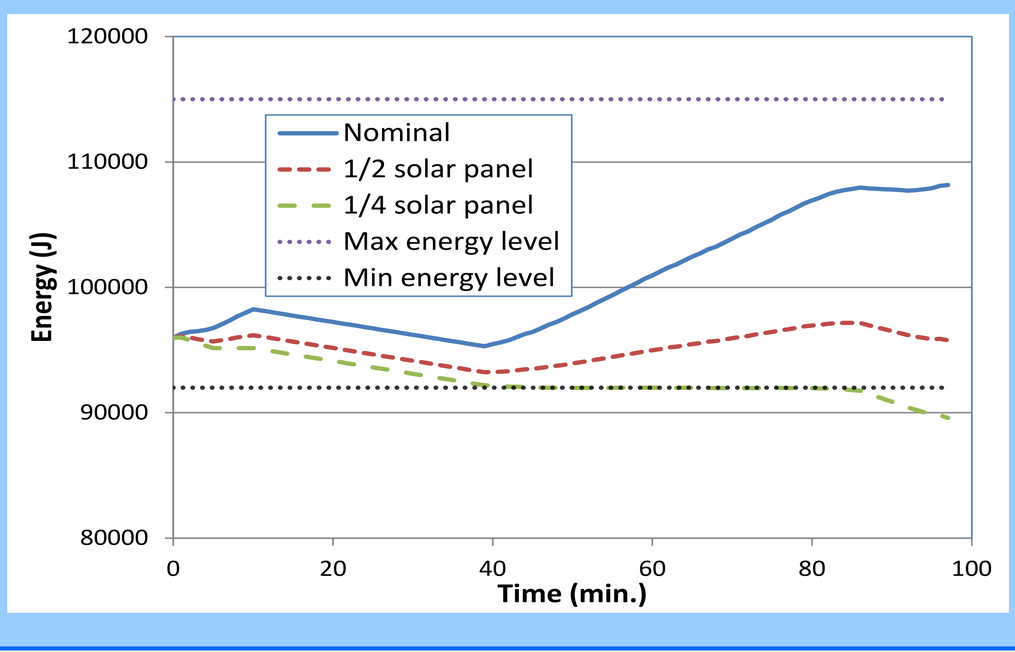
Mapped to analytical and simulation models that estimate RAX performance

Activity Diagrams

- Run Operation
  - Steps through time
- Update States
- Send Signals
  - Controls update of state values
- Update State Values

Defines actions in the activity along with the flow of input, output, and control

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



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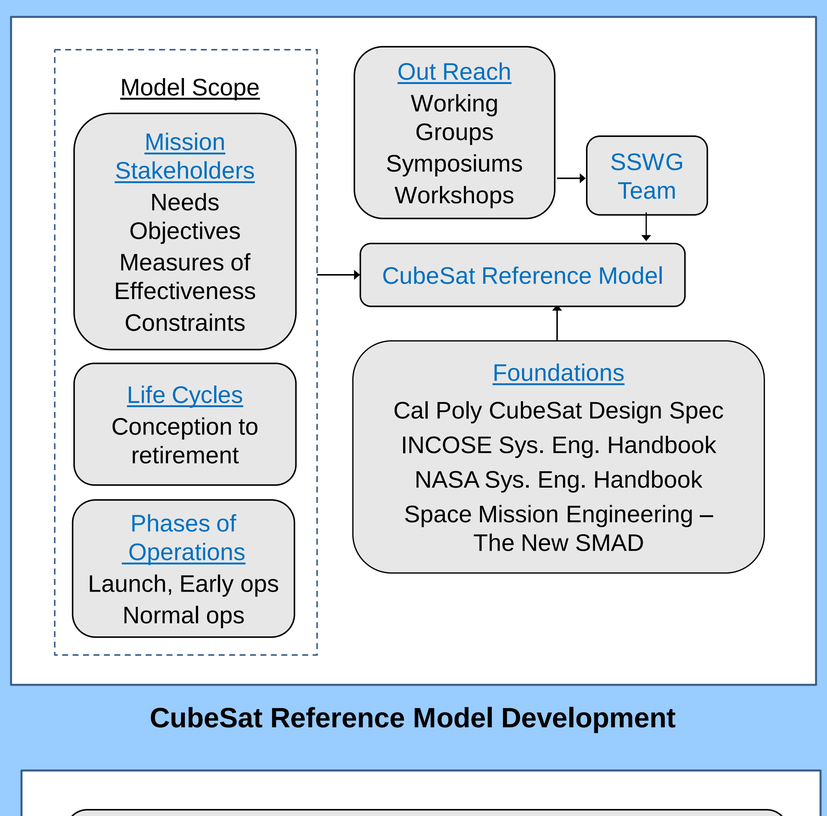
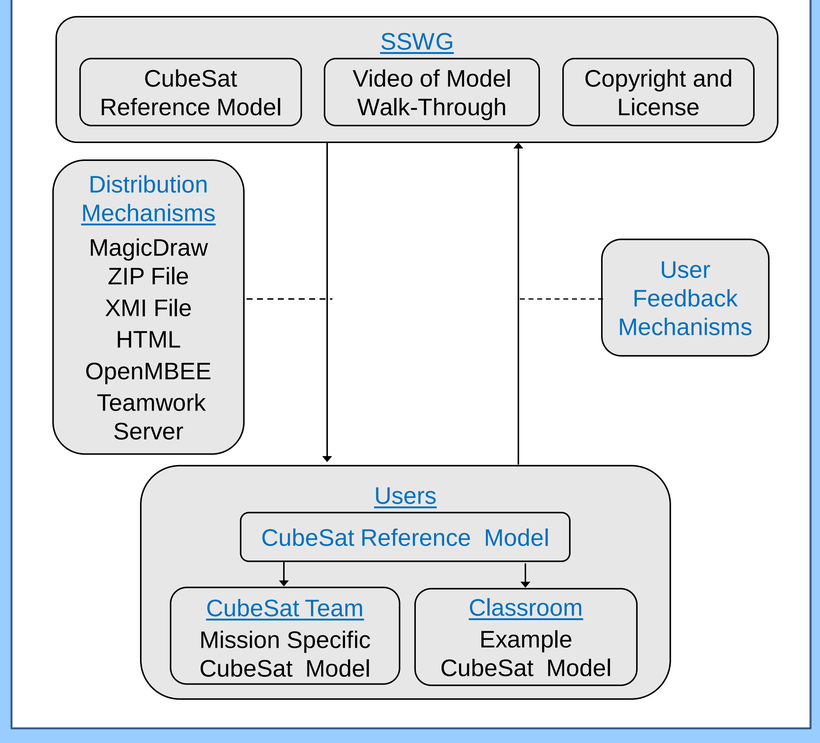
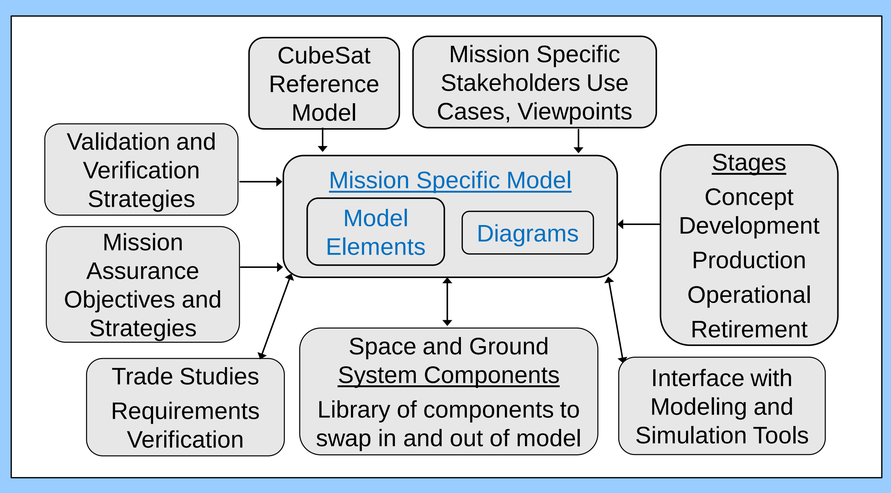
CubeSat Reference Model Logical Design to Mission Specific CubeSat Model



CubeSat Reference Model Development



Model Distribution



Development of a Mission Specific CubeSat Model

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[6] 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.

[7] 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.

[8] 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.

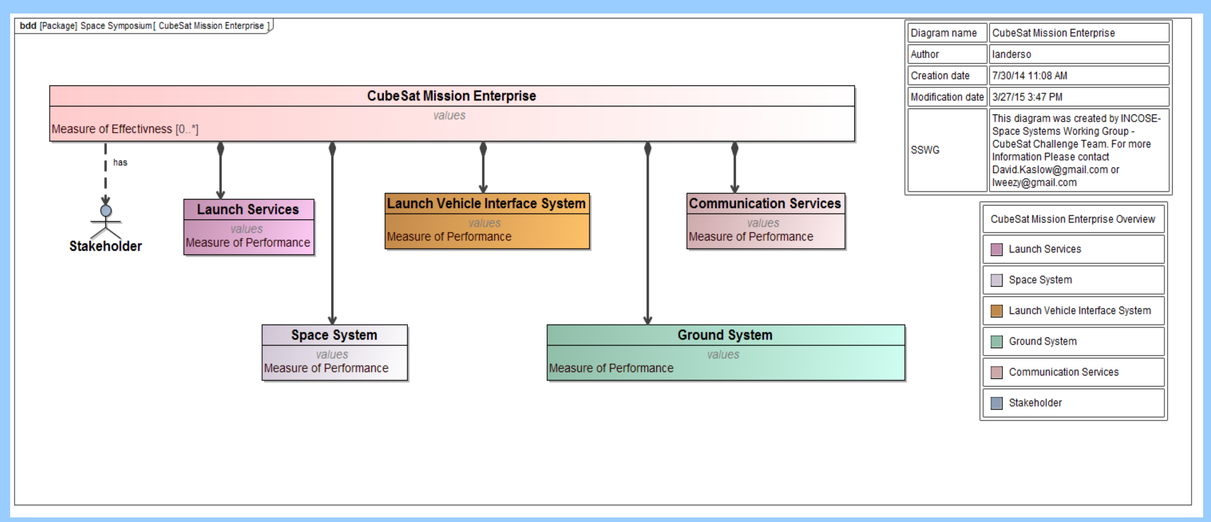
[9] D. Kaslow, L. Anderson, S. Asundi. B. Ayres, C. Iwata, B. Shiotani, R. Thompson, "Developing a CubeSat Model-Based System Engineering (MBSE) Reference Model – Interim Status", *Proceedings of IEEE Aerospace Conference*, Big Sky, MT, March 2015.

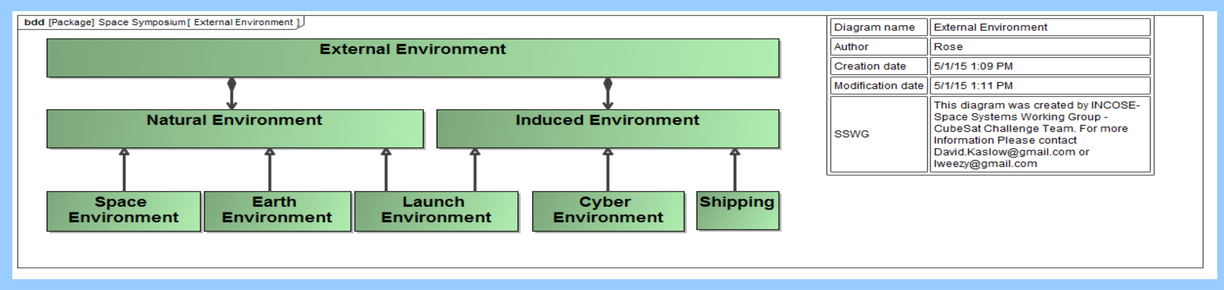
[10] D. Kaslow, L. Anderson, S. Asundi. B. Ayres, C. Iwata, B. Shiotani, R. Thompson, "Developing and Distributing a CubeSat Model-Based System Engineering (MBSE) Reference Model ", *Proceedings of the 31st Space Symposium*, Colorado Springs, CO, April 2015.

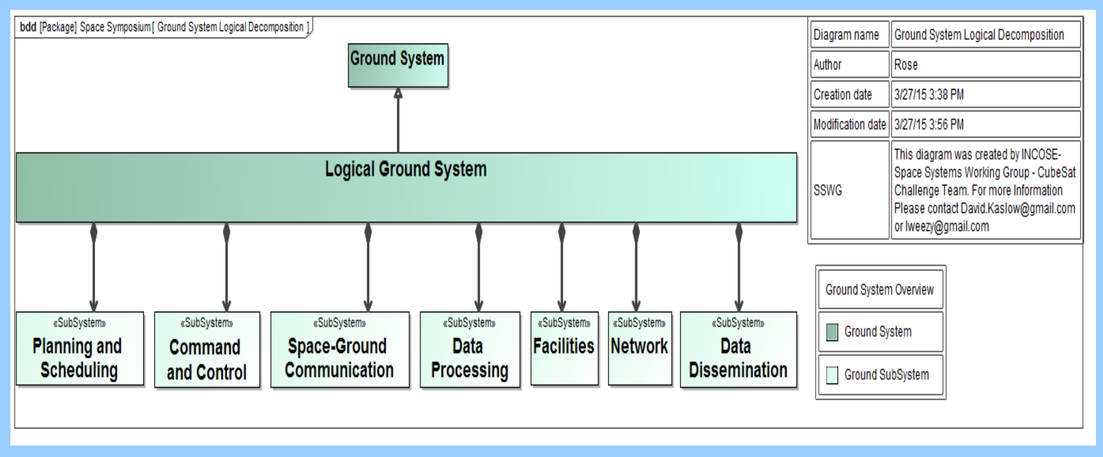
CubeSat Reference Model Views – Phase 4 [10]

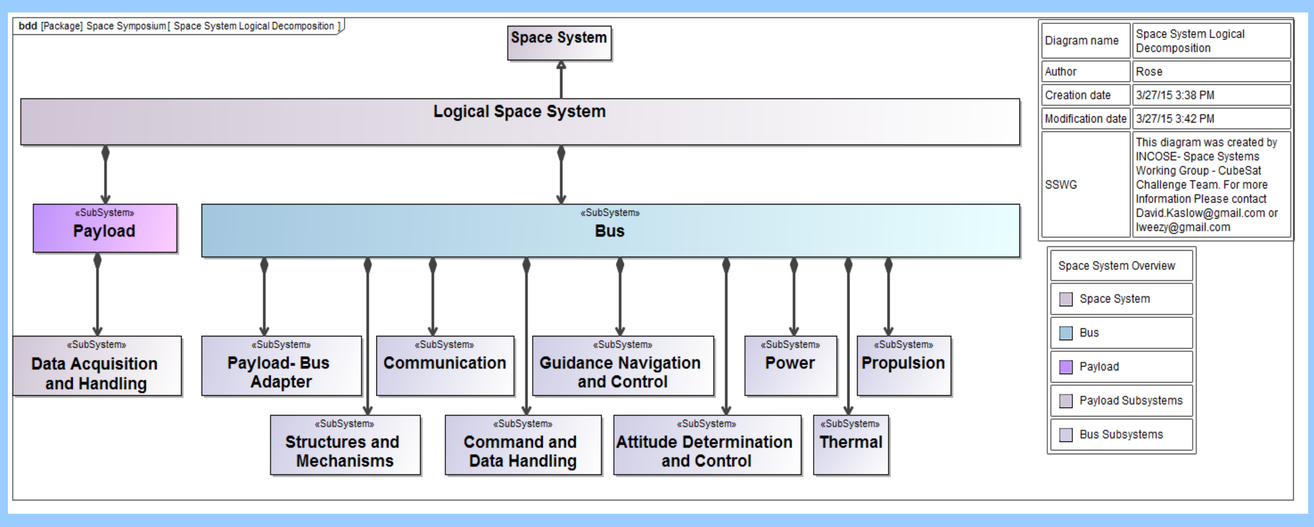
Stakeholders

Sponsor End User Project Manager Project Engineer …
Developer Tester Procurer Supplier …
Launch Servicer Integrator Communication Integrator
Regulatory Agencies: FCC , ITU …









Next Steps

Develop model glossary / ontology

Develop a Space Domain Reference model

Develop a model containing the Cal Poly CubeSat Design Specification

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

Provide the model to university aerospace program

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