

**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

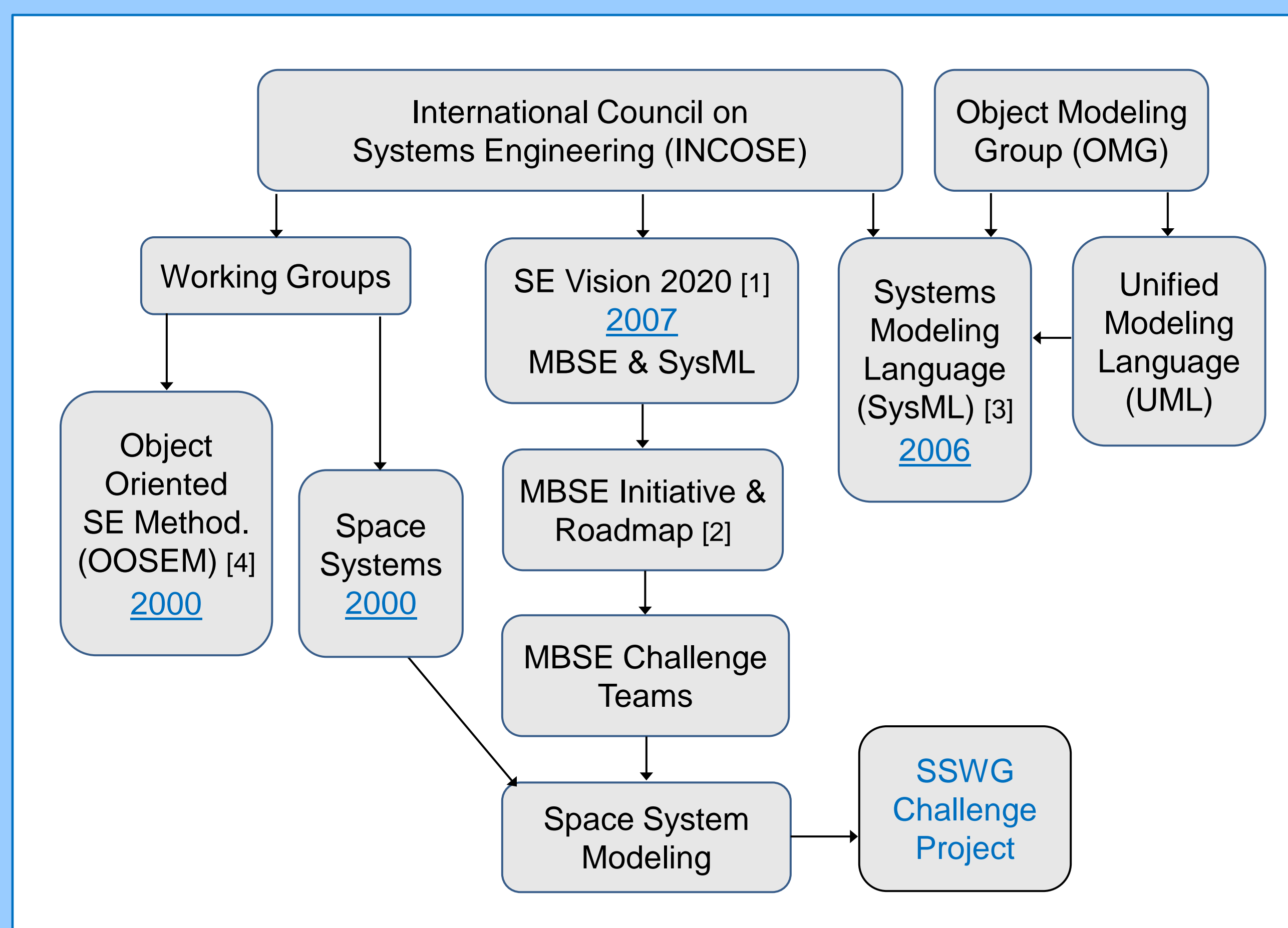
Team Composition

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

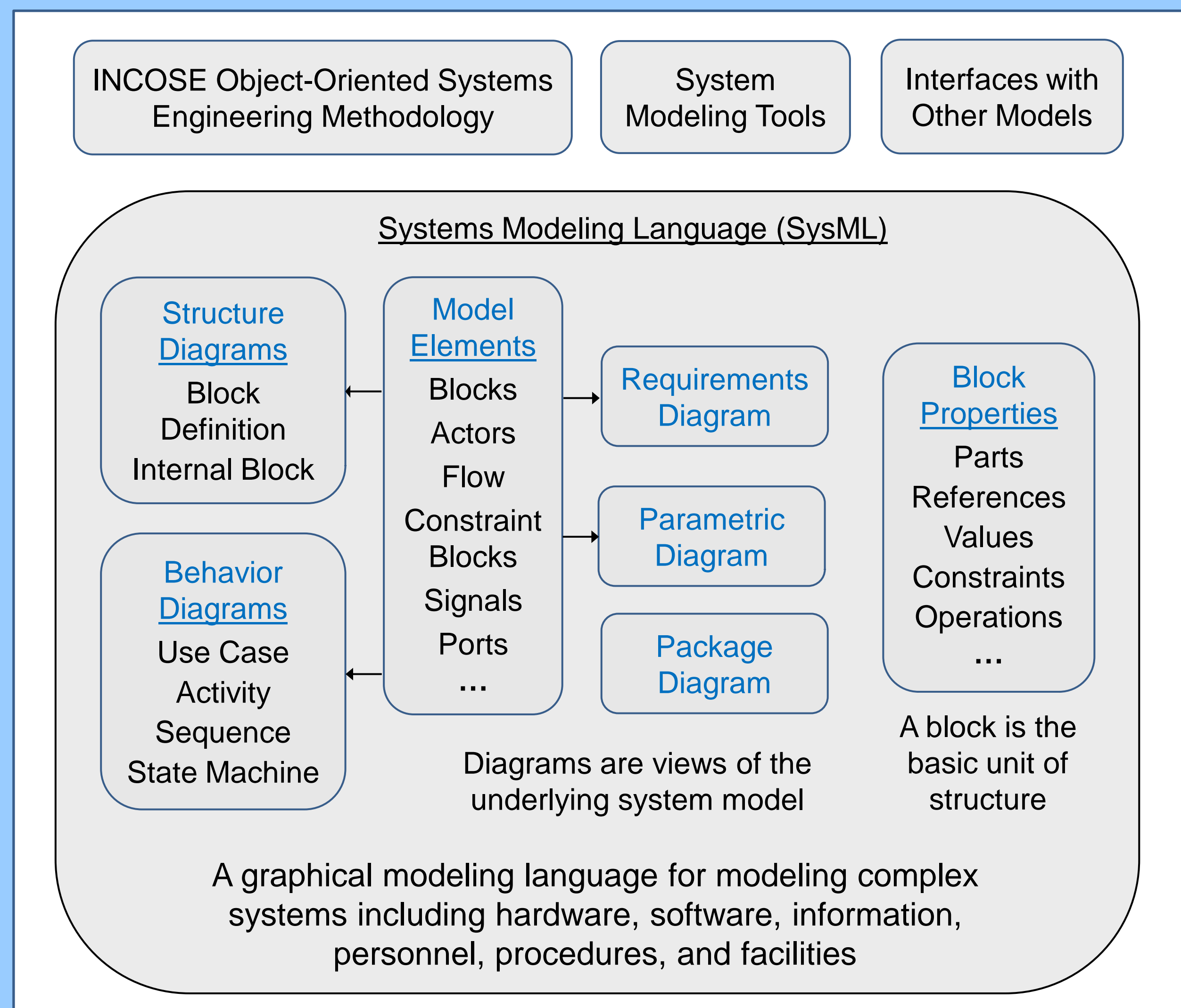
Team Meeting

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/Chapters/WorkingGroups/government/space-systems>

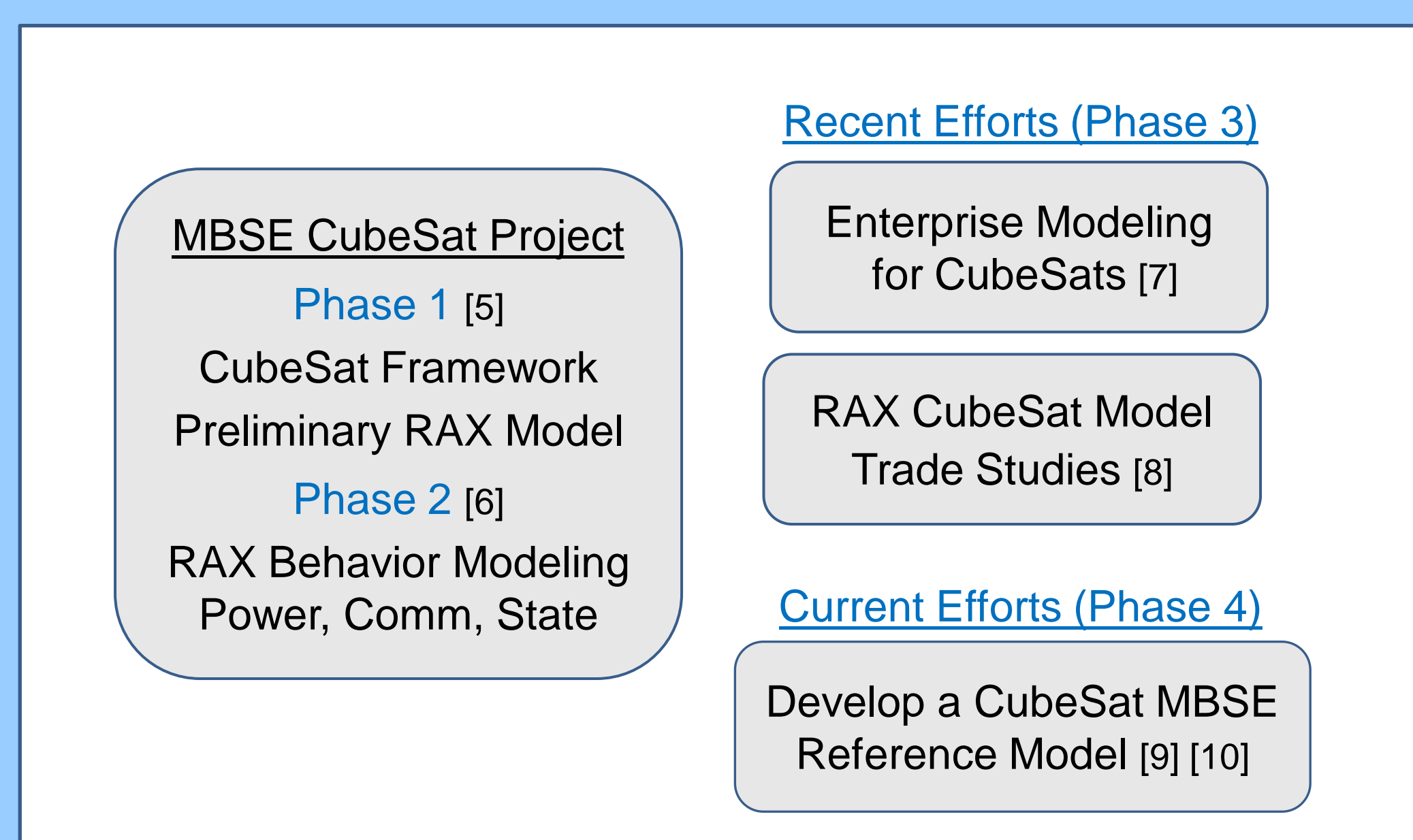
MBSE – Formalized application of modeling to support requirements, design, analysis, validation and verification
Authoritative, integrated repository of information from procurement through operations



INCOSE MBSE Initiative and SSWG Challenge Project

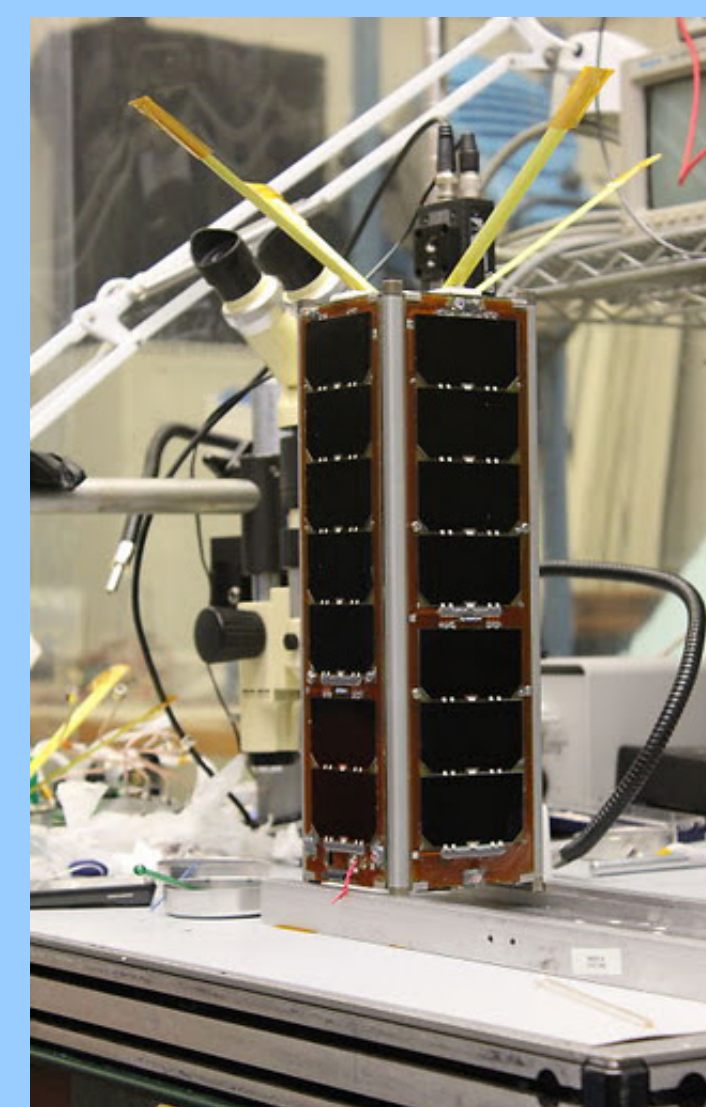


MBSE Methodology



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

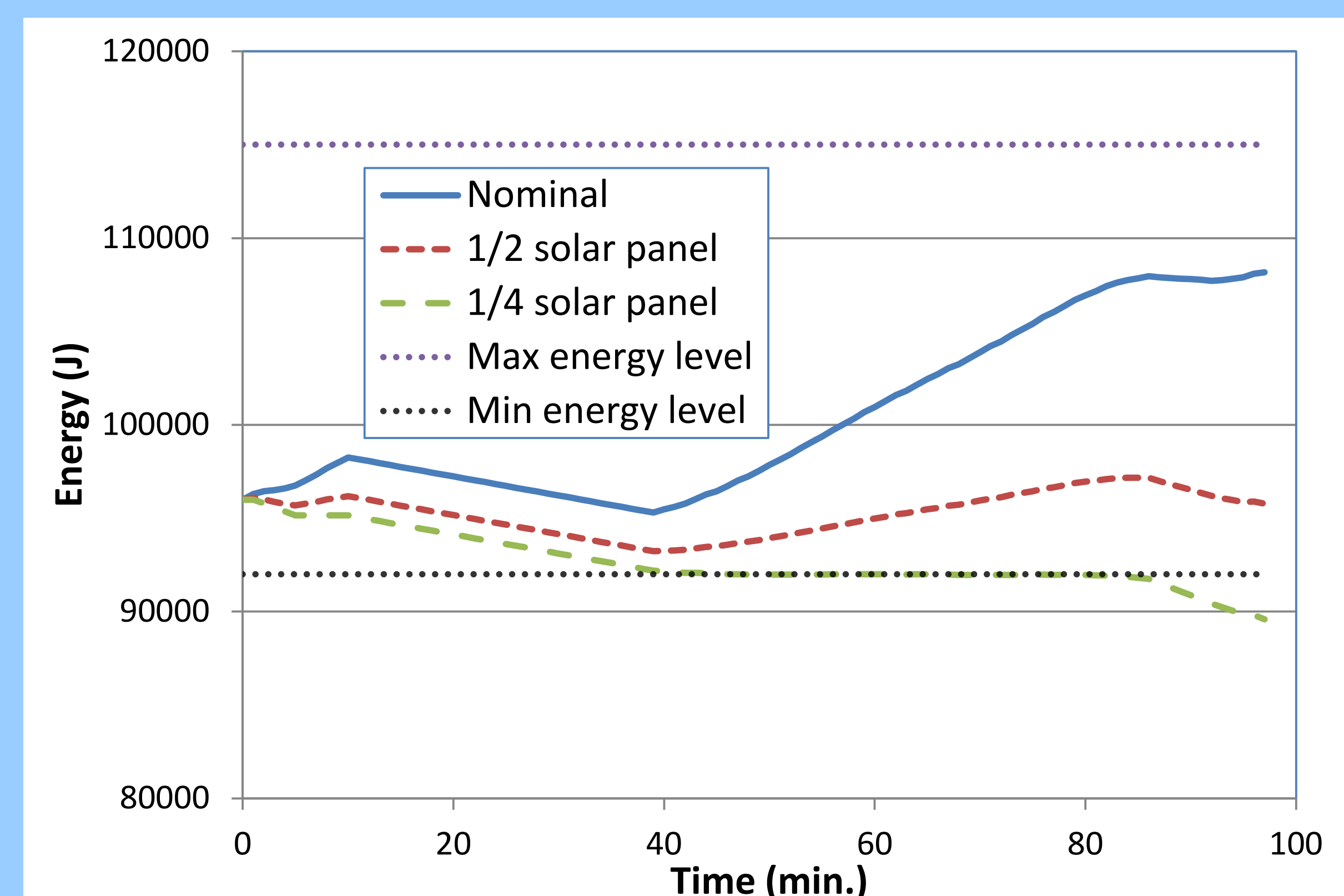
Mapped to analytical and simulation models that estimate RAX performance

Activity Diagrams

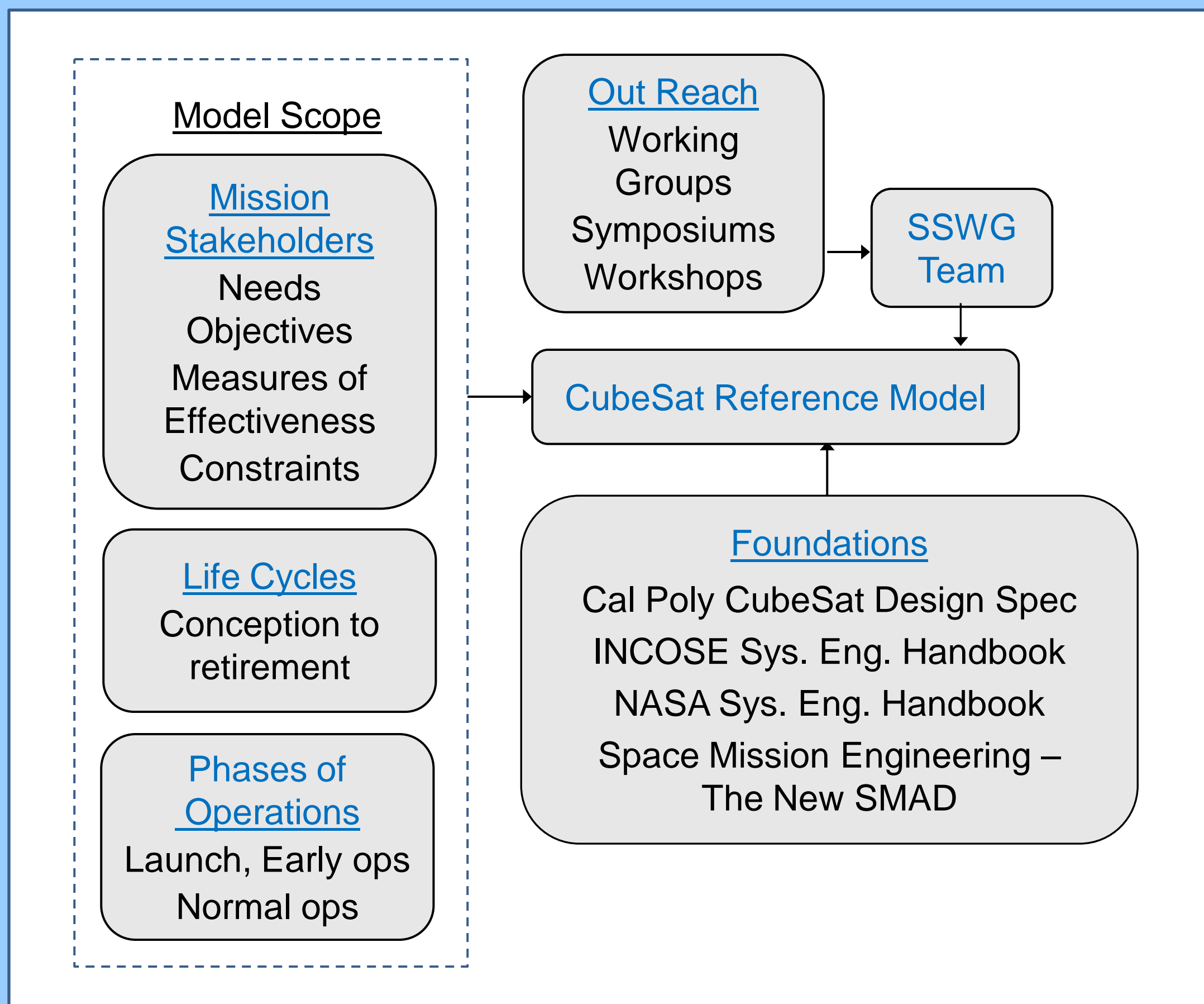
- Run Operation
 - Steps through time
- Update States
- Send Signals
 - Controls update of state values
- Update State Values

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

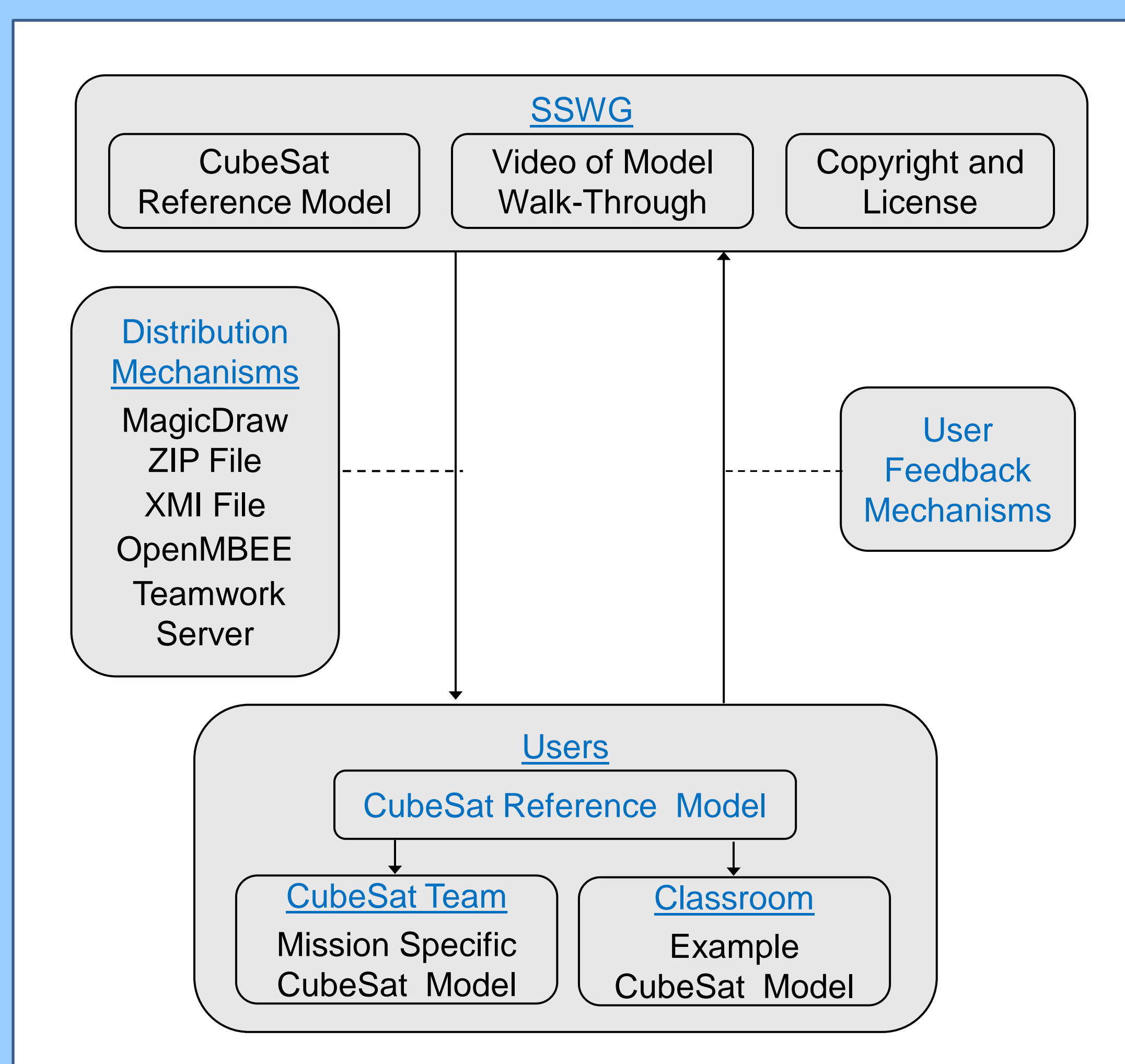
Trade Studies	Values Studies	Performance Metric
Solar Panel Area	<ul style="list-style-type: none"> Nominal: 18.2 cm²/slide ½ of nominal ¼ of nominal 	On-board energy
Max Battery Capacity	<ul style="list-style-type: none"> Nominal: 115,000 J Reduced: 100,000 J 	On-board energy
Orbital Altitude	<ul style="list-style-type: 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



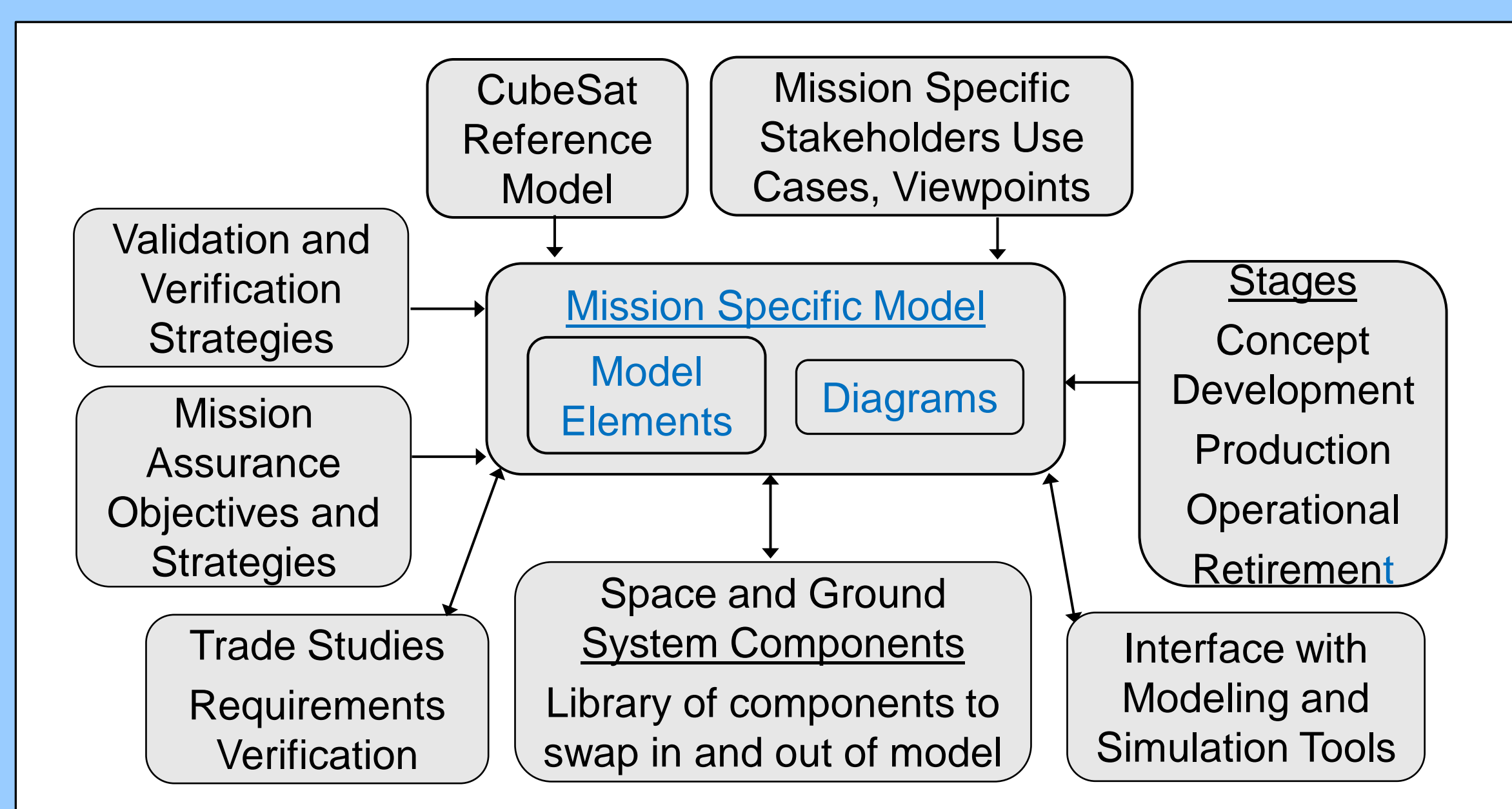
CubeSat Reference Model Logical Design to Mission Specific CubeSat Model



CubeSat Reference Model Development



Model Distribution

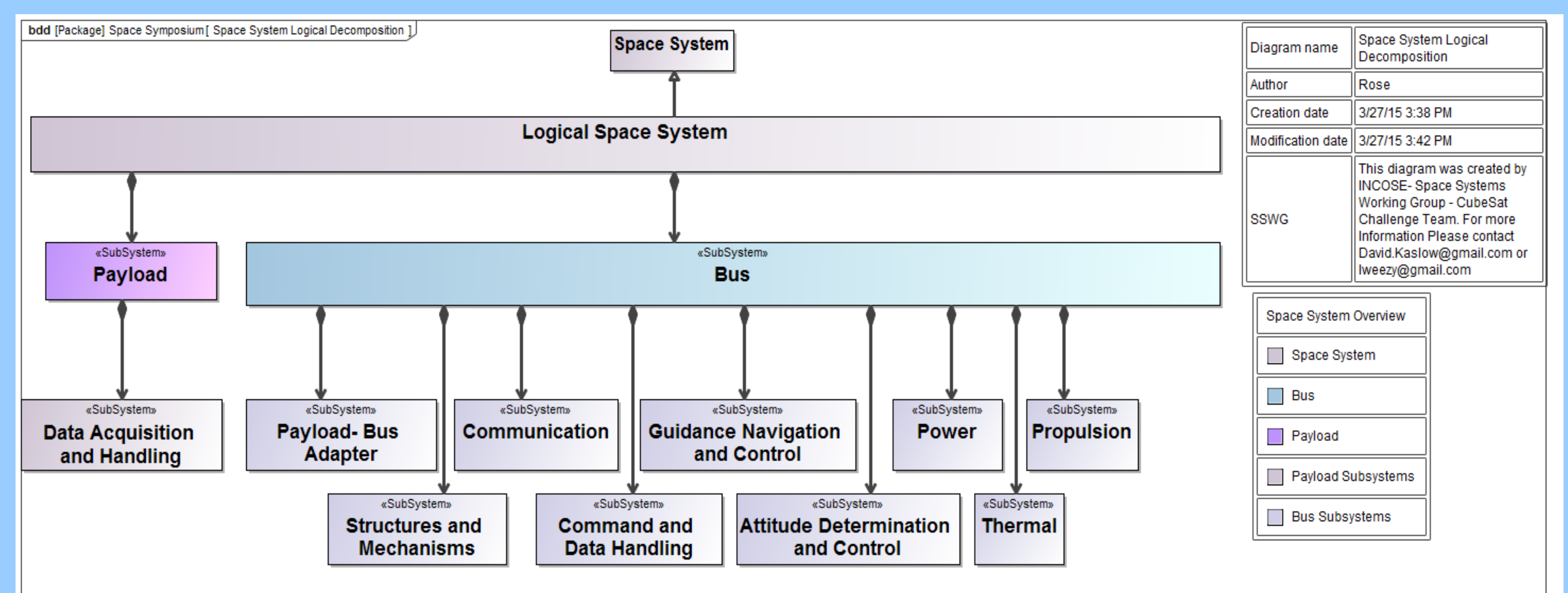
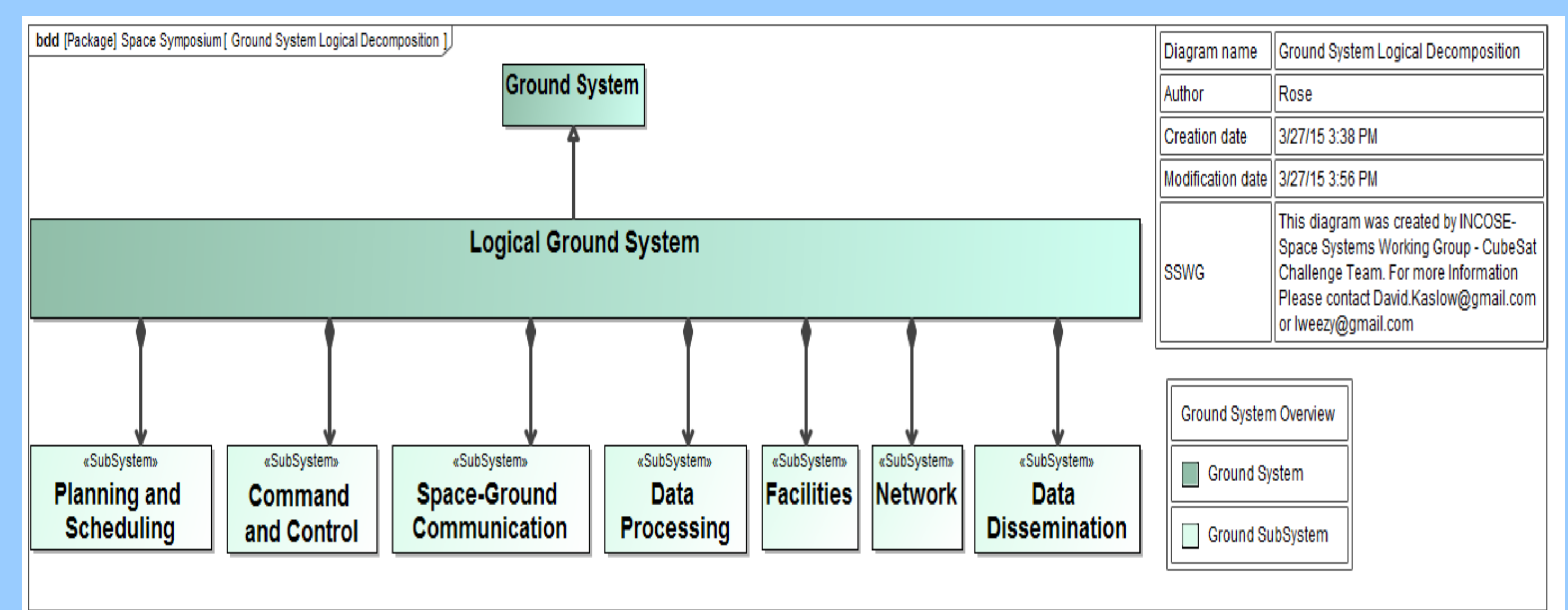
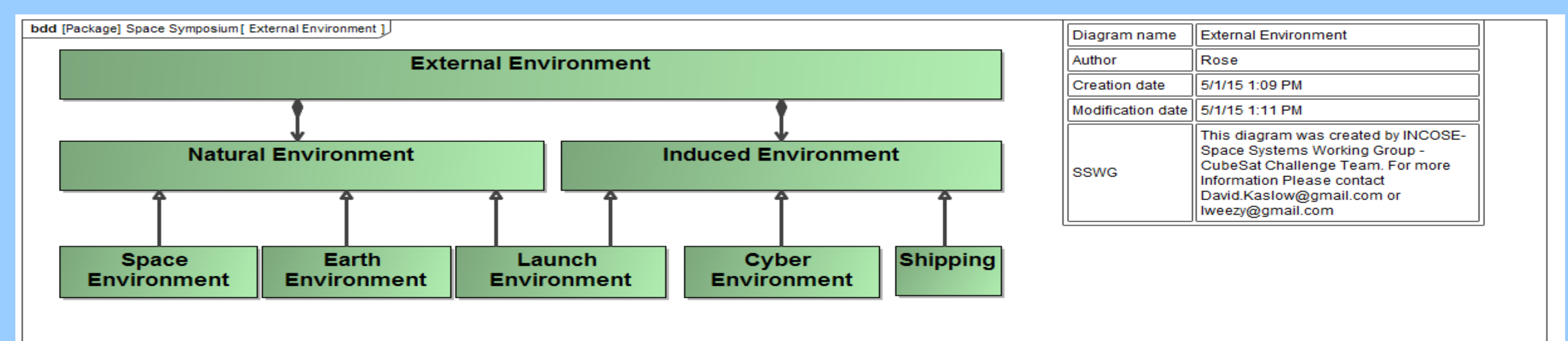
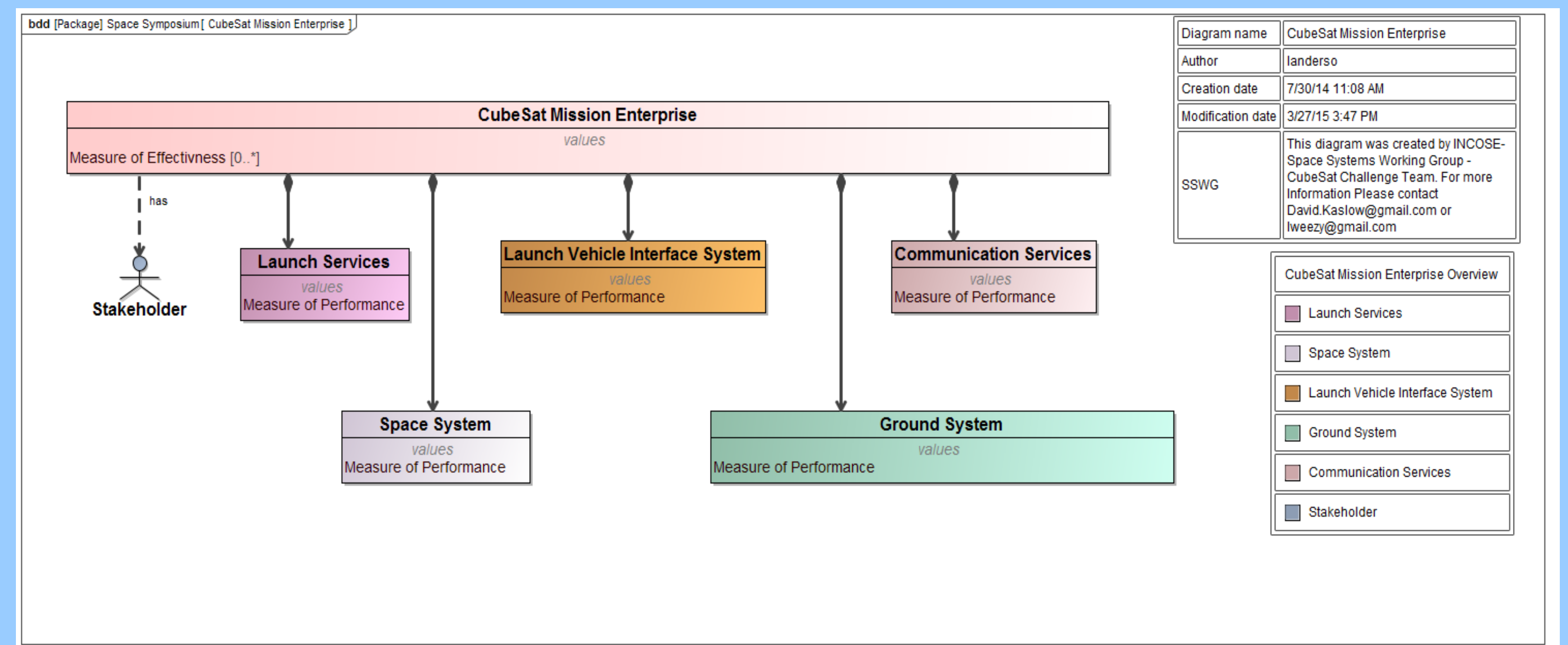


Development of a Mission Specific CubeSat Model

- [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] Object Management Group (OMG), OMG Website. [Online]. Available: <http://www.omgysml.org/>
- [4] Object Management Group (OMG), OMG Wiki. [Online]. Available: <http://www.omgwiki.org/MBSE/doku.php?id=mbse:incoseosem>
- [5] 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.
- [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
- Populate model with example:
 - 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