
Applying Model-Based Systems Engineering (MBSE) to Develop an Executable Model for the RAX CubeSat Mission

Sara Spangelo

Spangelo.sara@gmail.com

JPL – Univ of Michigan

Hongman Kim

hkim@phoenix-int.com

Grant Soremekun

grant@phoenix-int.com

Phoenix Integration

Mike Bruchanski

mbruchanski@agi.com

Greg Haun

ghaun@agi.com

Dave Kaslow

dkaslow@agi.com

Analytical Graphics

Lonnie VanZandt

[lonnie.vanzandt](mailto:lonnie.vanzandt@nomagic.com)

@nomagic.com

No Magic

John Springmann

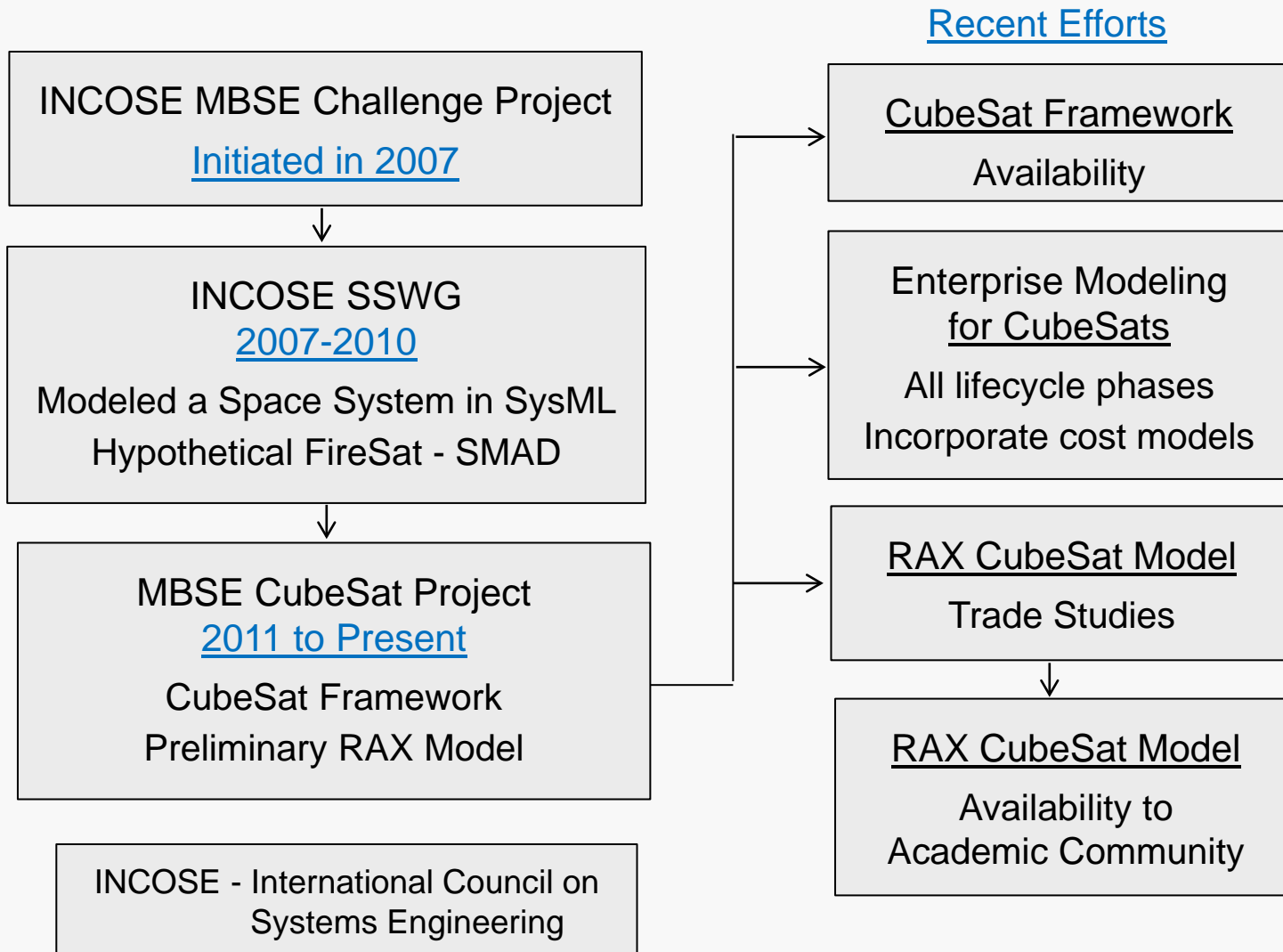
jspringm@umich.edu

James Cutler

jwculter@umich.edu

University of Michigan

MBSE Project Overview and Roadmap



INCOSE MBSE Challenge Project

INCOSE MBSE Roadmap Out to 2020 Time Frame

Maturation / incorporation of MBSE
Academic and industry.

INCOSE / Object
Management Group (OMG)
project – UML based

Model Based Systems Engineering (MBSE)

System level model
Integration of models and simulations
Authoritative, integrated repository of
information from procurement
through operations

Systems Modeling Language (SysML) Diagrams

Requirements

Parametrics

Structures

Block Definition
Internal Block

Behaviors

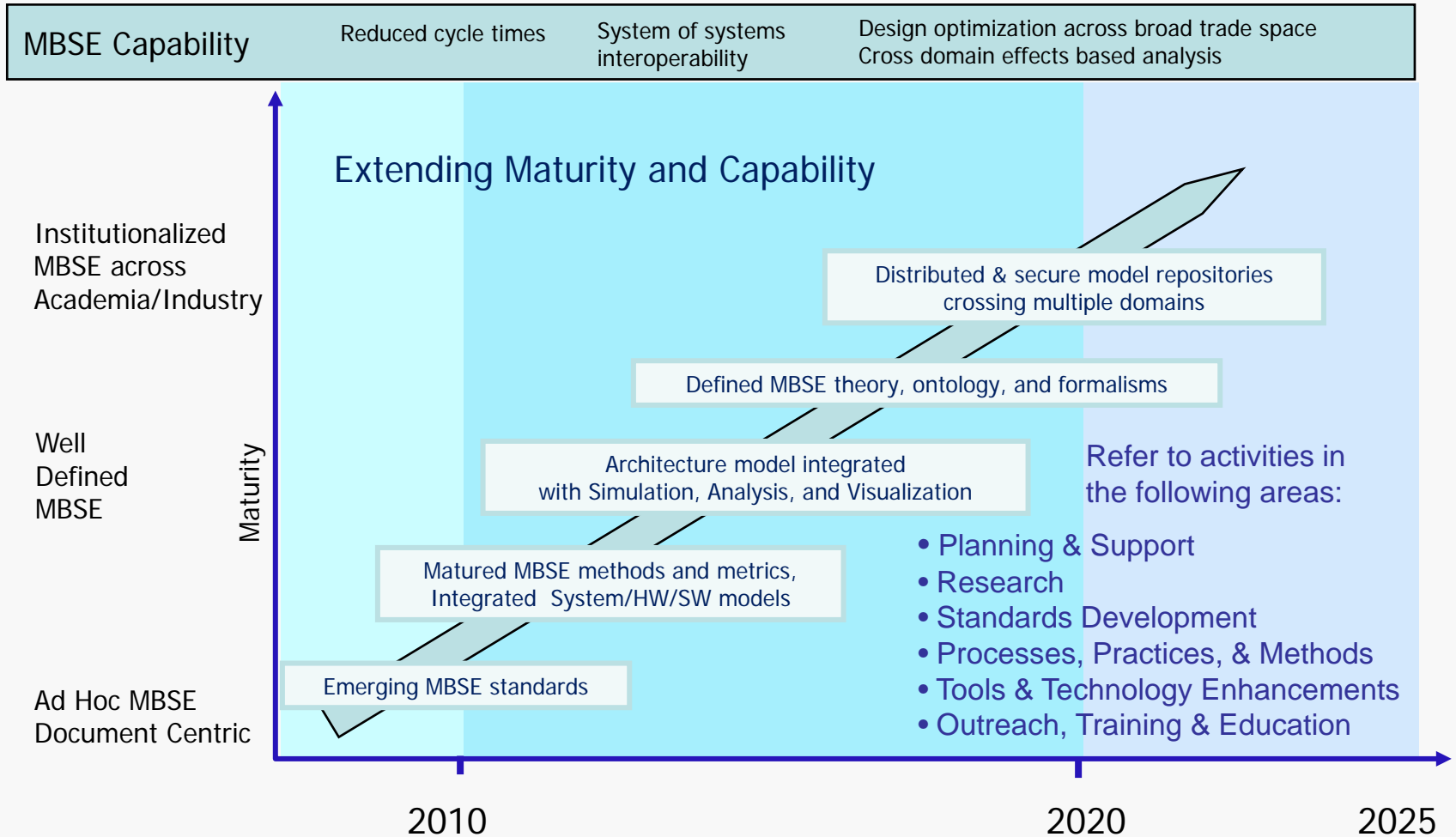
Activity
Sequence
State
Use Case

Interactions

Data, Control,
Messages

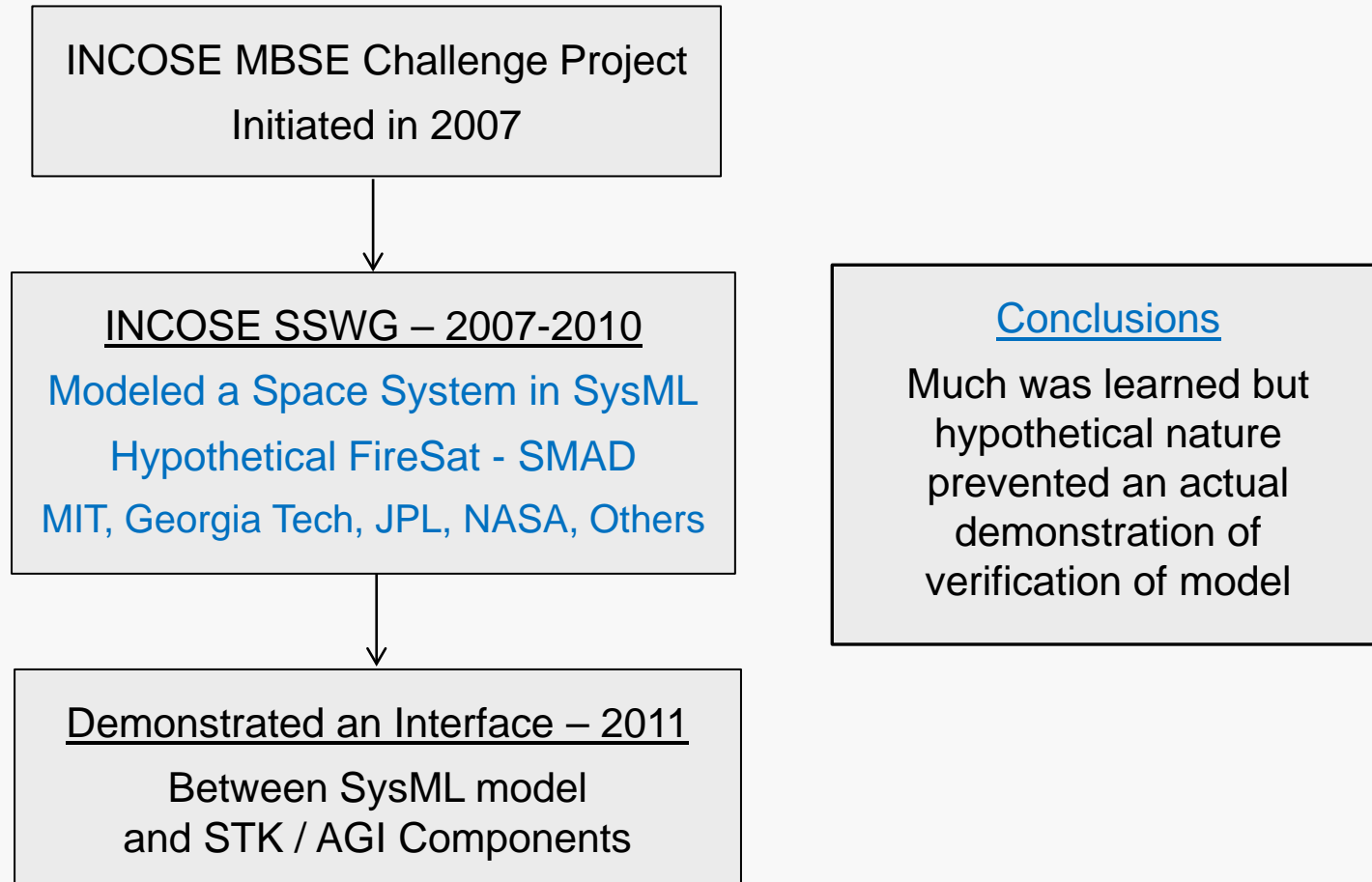
SysML is a modeling
language not an
engineering methodology

INCOSE MBSE Challenge Project - Roadmap



From Sandy Friedenthal. INCOSE MBSE IW 2012. MBSE Wiki. <http://www.omgwiki.org/MBSE/doku.php>

INCOSE SSWG – 2007-2010



MBSE CubeSat Project – 2011 to Present

CubeSat Framework / Preliminary RAX Model

SSWG, Univ of Michigan, JPL,
AGI, InterCAX, Others

Project Goals

- Demonstrate the practical application of MBSE and SysML
- CubeSat modeling framework
- Interface CubeSat SysML with COTS modeling, analysis, visualization tools
- Apply framework to realistic mission

MBSE and SysML Enable

- Connecting system level model to analytical tools
- Executing dynamic simulation of end-to-end mission
- Identifying failure to satisfy requirements, sub-optical designs
- Accommodating re-evaluation when design changes occur
- Operational mission planning / execution and responding to component degradation

Capture subsystem functions in the form of behaviors and allowing for time-dependent execution of these behaviors

MBSE CubeSat Project – 2011 to Present

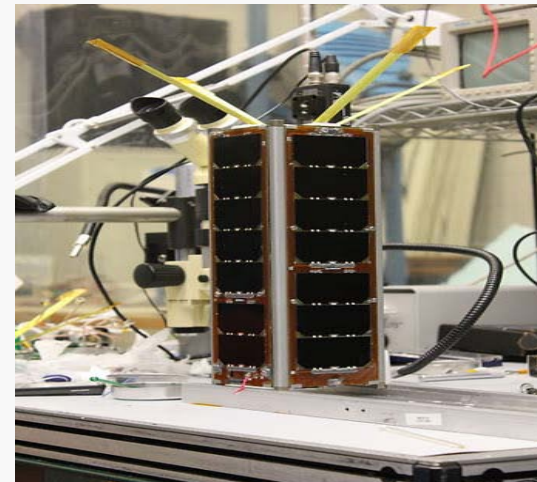
RAX Mission

- Michigan Exploration Lab and SRI International
- 3U CubeSat
- Study ionosphere plasma irregularities that disturbs space – grd comm and navigation
- Radar signal transmitted from a site in Poker Flat and received by RAX
- Data processed, compressed, transmitted to ground station / control center

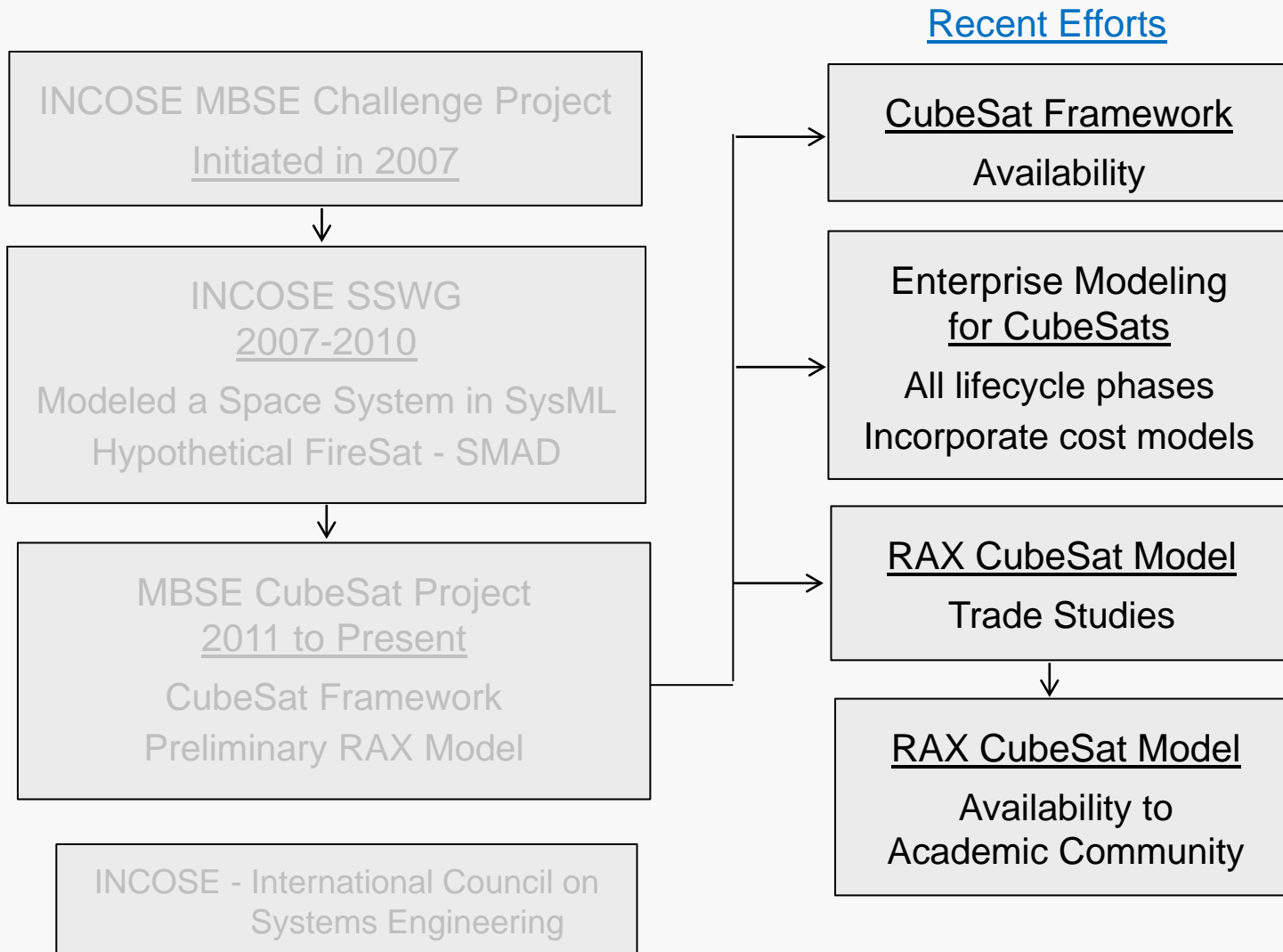
Conclusions

- Successfully demonstrated application of MBSE and SysML to create CubeSat framework
- Lacking in ability to execute realistic behavioral scenarios

RAX is an Operating On-Orbit Mission



MBSE Project Overview and Roadmap



RAX CubeSat Model – Recent Effort

Develop a Executable RAX Model / Execute Trade Studies
Analytical Graphics, Phoenix Integration, S. Spangelo (Consultant)

Scope of Effort

Code developed from scratch
based on CubeSat framework
published documentation

Focus on capturing characteristics of RAX
design and operations
Not a detailed representation of actual
design and operations

**A practical demonstration
of MBSE and SysML**

Intended as a demonstration of interfacing
with COTS capabilities
That is, some STK capabilities were not
activated, e.g. solar power calculations

RAX CubeSat Model – Recent Effort

Model Elements

Model the science data collection / management and power collection / management aspects of the RAX mission

System Model

S/C Vehicle
Orbit
Attitude Scheme
Operations
Ground Network
External Environment
Experimental Zone

Spacecraft Subsystems

Mission Payload
Communication
Power Collection
Power Management
Data Management
Bus

Requirements

Data Collection
Data Storage
Data Download
Battery Capacity
Battery Margin

RAX CubeSat Model – Recent Effort

Model Diagrams

State Diagrams

- Orbit
- Solar
- Experiment
- Download

Models behavior in
respond to internal
and external events.

Parametric Diagrams

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

Defines equations that
constrain properties of
blocks

Activity Diagrams

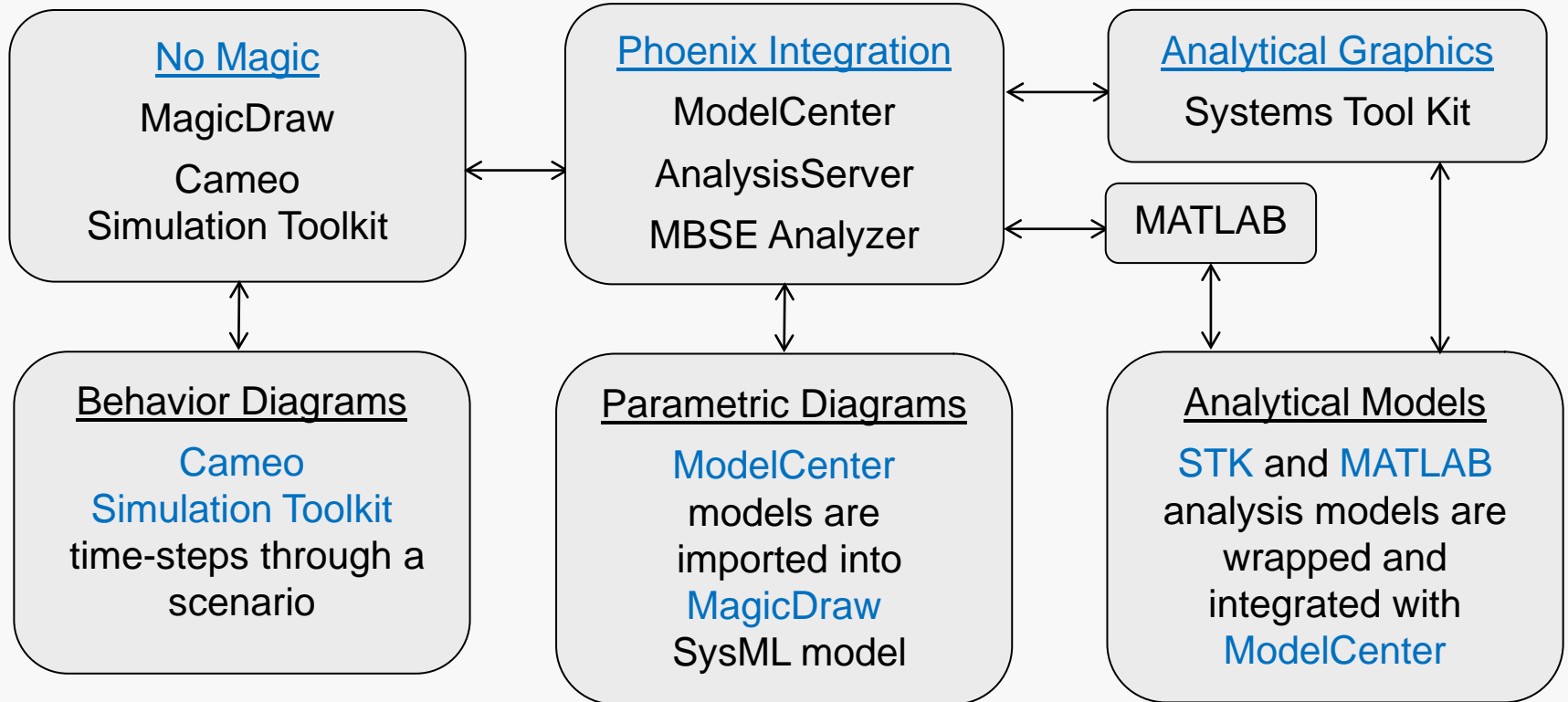
- Run Operation
 - Steps through timeline
- Update States
- Send Signals
 - Controls update of state values
- Update State Values

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



RAX CubeSat Model – Recent Effort

Model Interaction



Capture dynamics of operations

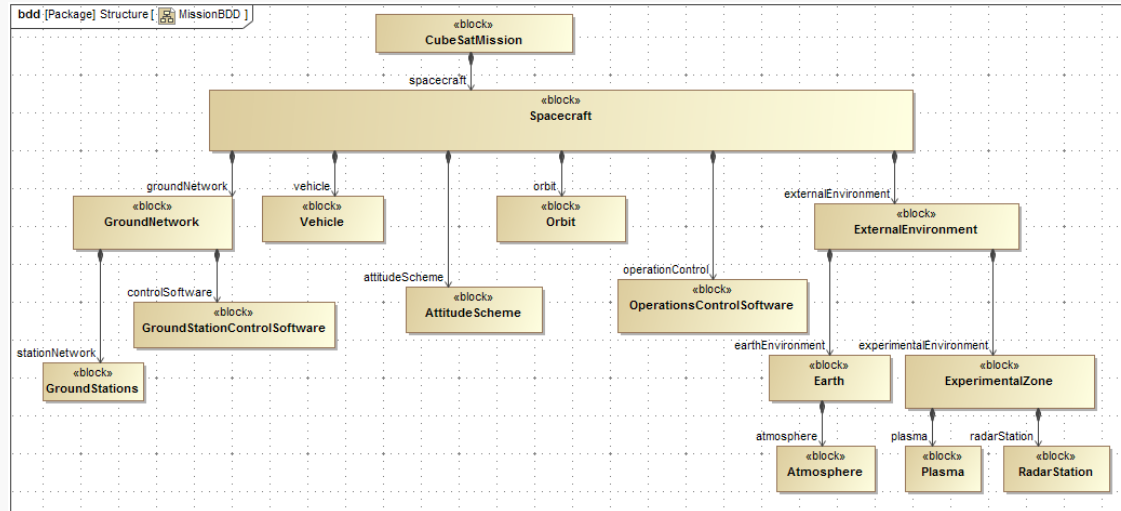
Capture analytical relationships

Capture solar state, access to exper. zone, access to grd stations

RAX CubeSat Model – Recent Effort

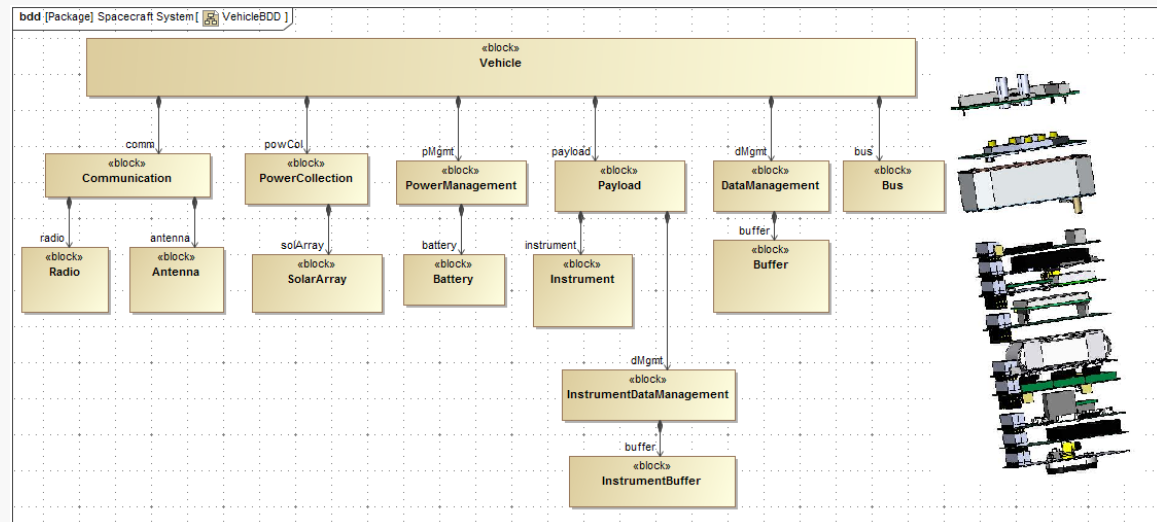
Structural Diagrams

Mission Level



Captured from MagicDraw

Vehicle Level



RAX CubeSat Model – Recent Effort

Trade Space

Solar panel area
Battery capacity
Orbit Altitude
Ground Station
Network

Requirements

Data Collection
Data Storage
Data Download
Battery Capacity
Battery Margin

Next Step

Free distribution to academic
CubeSat community
Provides a start at
modeling their CubeSats
Evaluate benefit of
expanding model

Conclusions

Successfully demonstrated
using MBSE / SysML to:

- Develop a model
- Interface with COTS tools
- Carry out trade studies

**First known integration of a
space system SysML model with:**

- **Diverse analytical models**
- **Simulation engines**
- **Special-purpose high-fidelity
space system model**

Resources

[INCOSE MBSE Workshops](#)

- 2011 - Demo of SysML model - STK interface
- 2012 - Working Through System Models
- 2013 - Using MBSE for Operational Analysis

[IEEE Aerospace Conferences](#)

- 2012 - Applying Model Based Systems Engineering (MBSE) to a Standard CubeSat
- 2013 - Model Based Systems Engineering (MBSE) Applied to Radio Aurora Explorer (RAX) CubeSat Mission Operational Scenarios
- 2014 - Enterprise Modeling for CubeSats (submitted)
- 2014 - Integrated Model-Based Systems Engineering (MBSE) Applied to the Simulation of the RAX CubeSat Mission (submitted)

Open to all to actively participate or just monitor

[SSWG Bi-Weekly Telecons](#)

Louise Anderson

louise.anderson@jpl.nasa.gov

[Google Group and Docs CubeSat MBSE](#)

Dave Kaslow

dkaslow@agi.com

[AGI blog and video](#)

<http://blogs.agi.com/inview/spring2013/?p=55>