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

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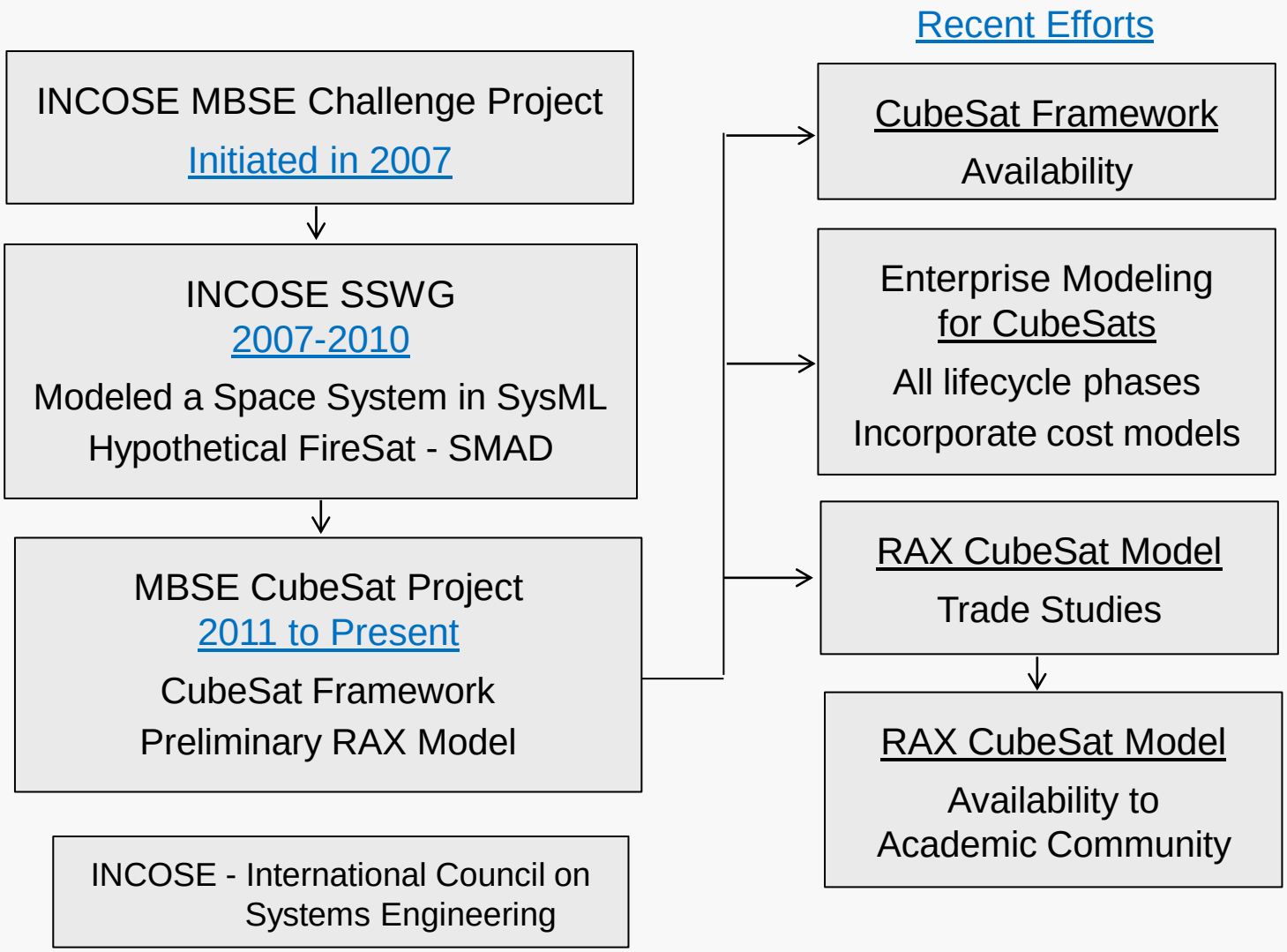
MBSE Project Overview and Roadmap



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 though operations

Systems Modeling Language (SysML) Diagrams

Requirements

Parametrics

Structures

Block Definition

Internal Block

Behaviors

Activity

Sequence

State

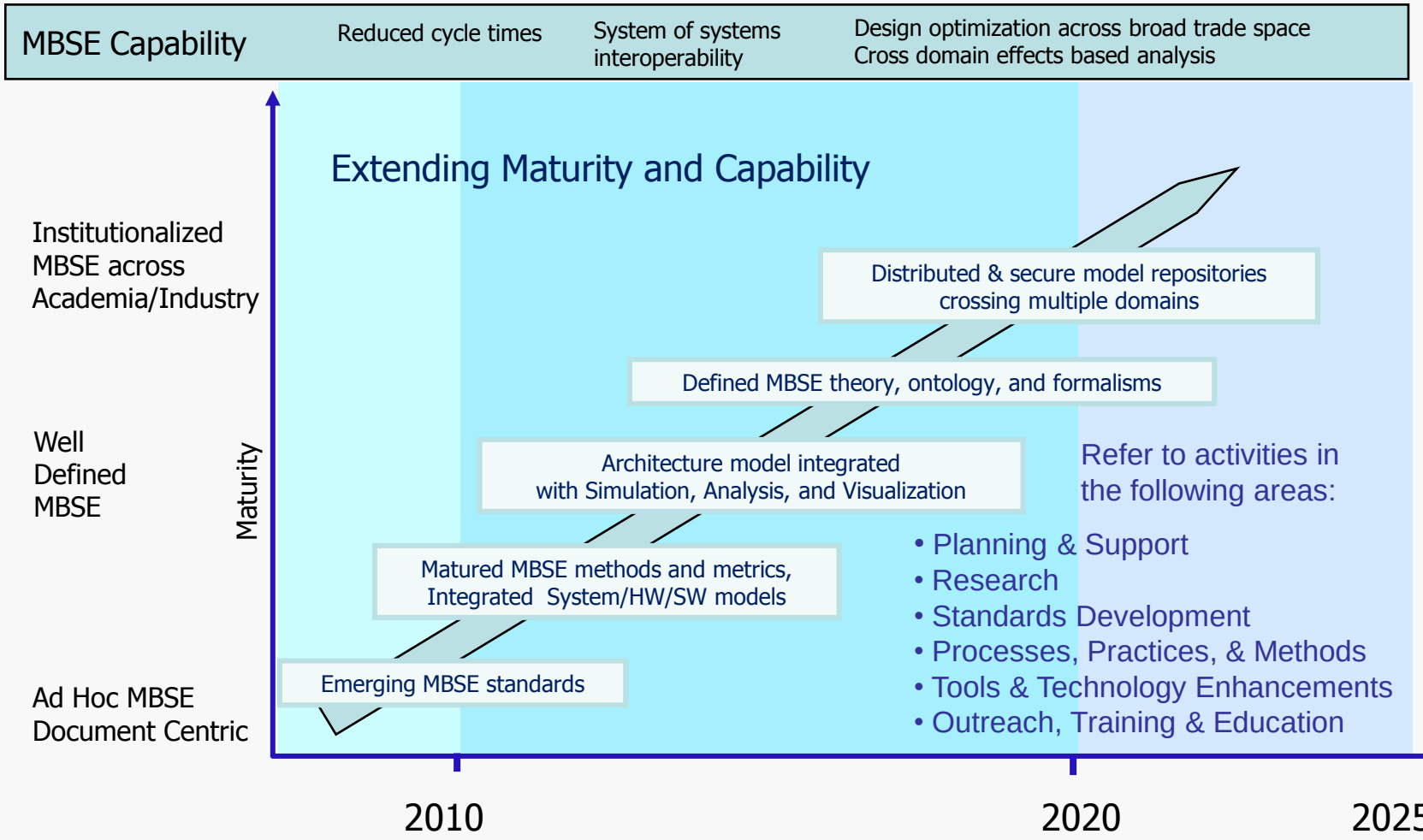
Use Case

Interactions

Data, Control, Messages

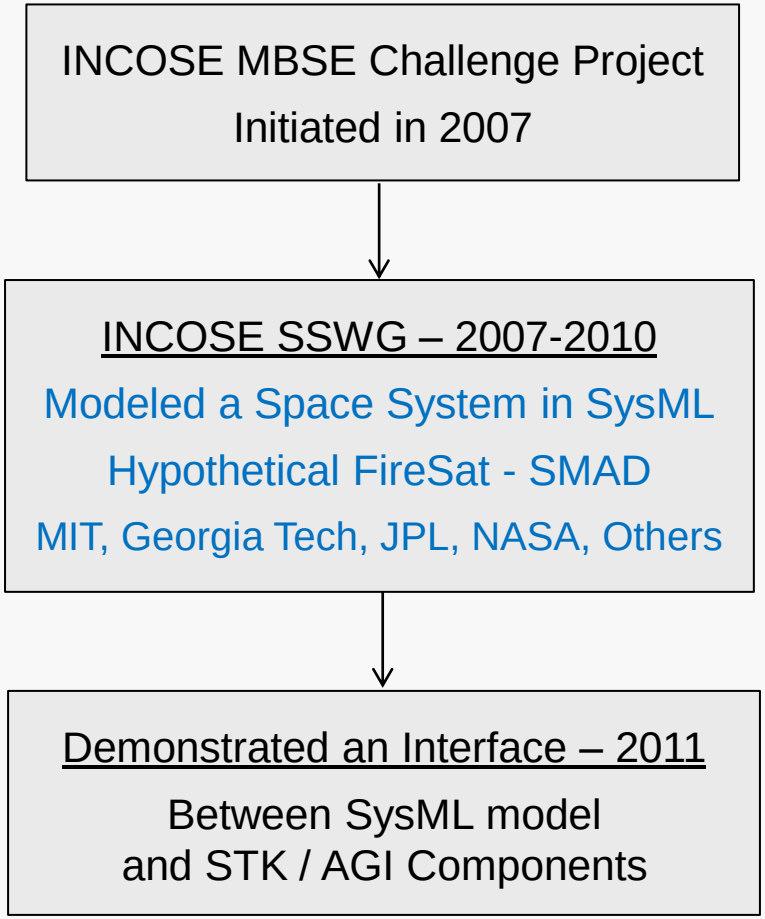
SysML is a modeling language not an engineering methodology

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



Conclusions

Much was learned but hypothetical nature prevented an actual demonstration of verification of model

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

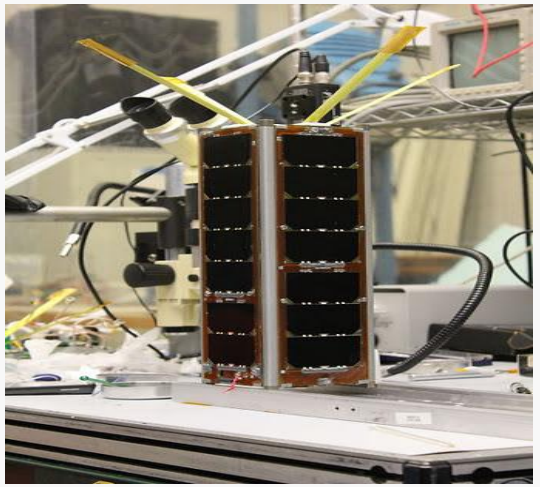
RAX Mission

- 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

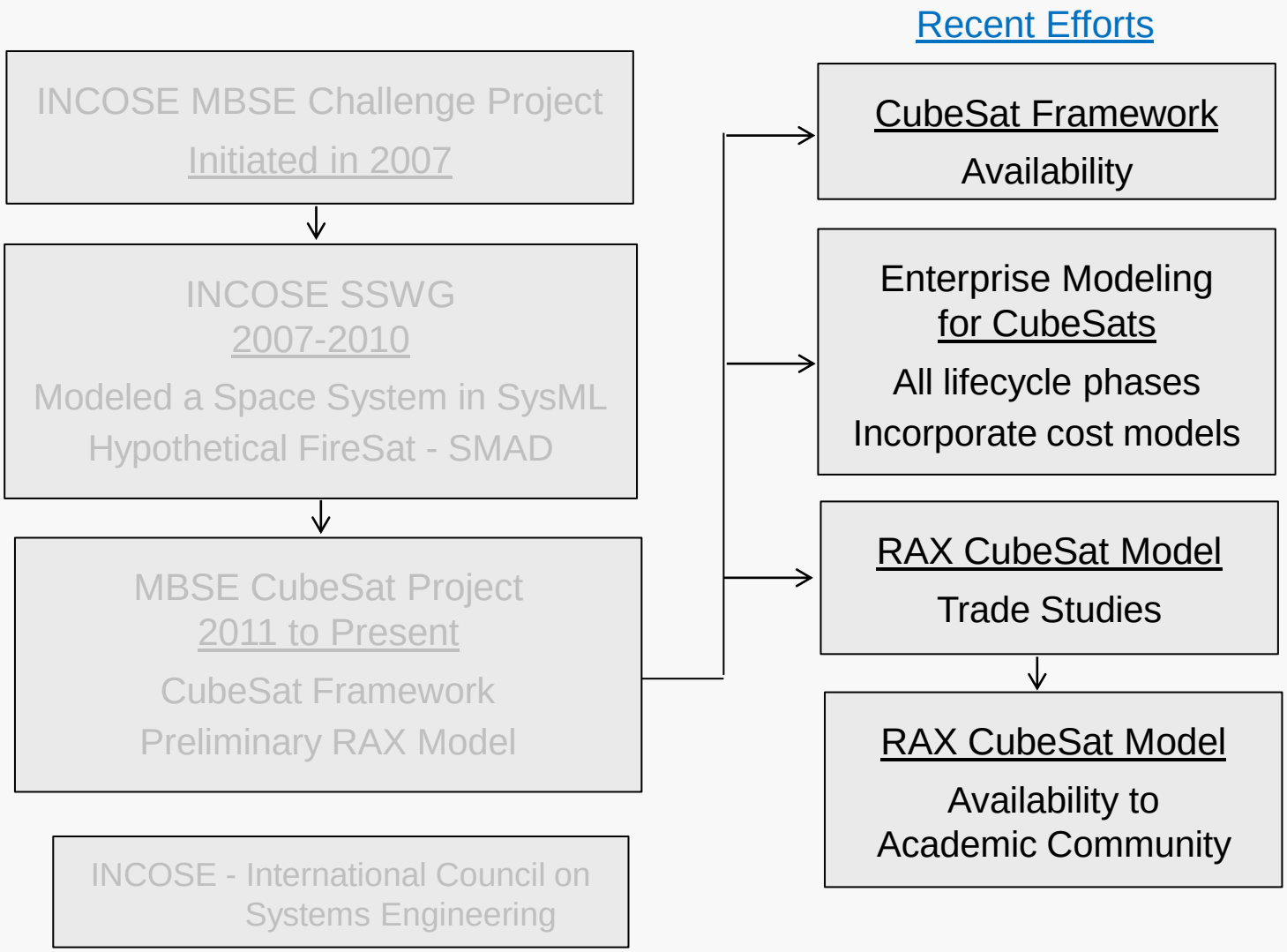
RAX is an Operating On-Orbit Mission

Conclusions

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



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

Intended as a demonstration of interfacing with COTS capabilities

That is, some STK capabilities were not activated, e.g. solar power calculations

A practical demonstration of MBSE and SysML

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

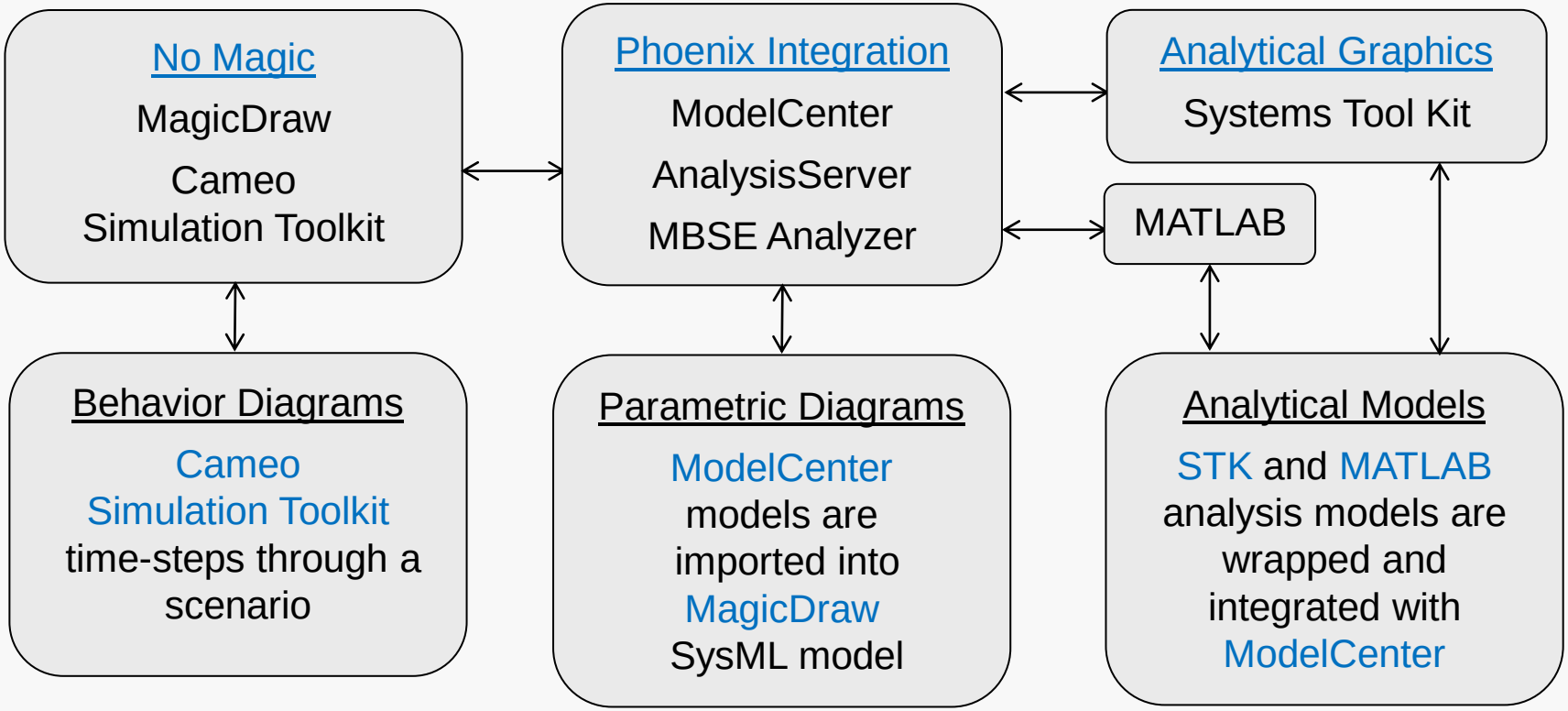
Activity Diagrams

- 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

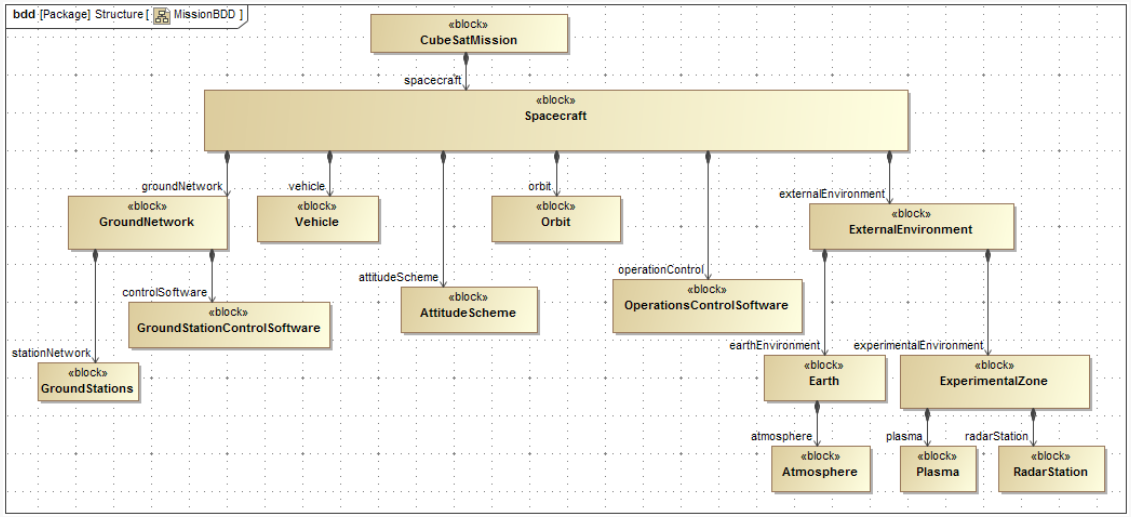
Capture analytical relationships

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

RAX CubeSat Model – Recent Effort

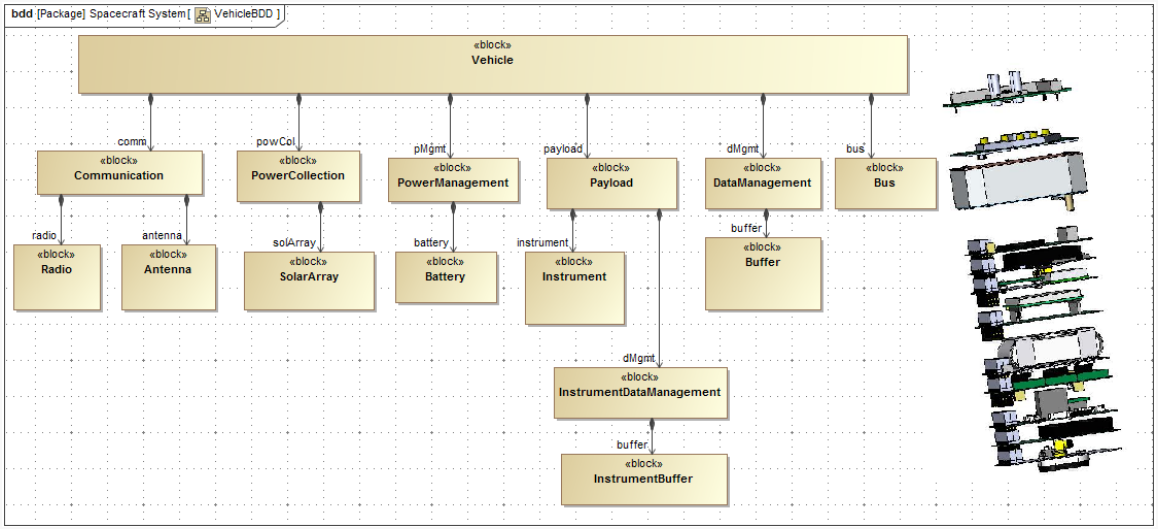
Structural Diagrams

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

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Google Group and Docs
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AGI blog and video

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