CubeSat Model-Based Systems Engineering (MBSE) Reference Model – Model Distribution and Application – Interim Status #2

International Council on Systems Engineering (INCOSE) Space Systems Working Group (SSWG)
Chair: David Kaslow
Object Management Group (OMG) Space Domain Task Force

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.
- Obtain International Specification Standard & Create Testbed

Team Composition

Aerospace Students and Professors Engineers and Software Developers from NASA Centers, Aerospace Companies, Modeling and Simulation Tool Providers
Email to be included on the email reflector list: david.kaslow@gmail.com
Standards to be worked through OMG Space Domain Task Force

Team Meeting

Telecons every Friday at 1 pm ET
Meeting materials and links to recordings in Google docs
Conference papers posted in INCOSE SSWG Web Site
http://www.incose.org/ChaptersGroups/WorkingGroups/government/sswg
Anticipated Standards Task Planned for Dec 2016 – Jun 2018

SSWG Challenge Project

- INCOSE MBSE Challenge Project
  - Phase 0: Initiated 2007
  - Phase 1: CubeSat Framework Prelim. RAX Model [3]
- INCOSE SSWG
  - Phase 2: 2007-2010 Modeled a Space System in SysML Hypothetical Firesat - SNAP
- Recent Effects
  - Phase 3: RAX CubeSat Model Trade Studies [5]
- Current Effects
  - Phase 4: Develop a CubeSat MBSE Ref. Model [6] [7] [8] [9]

Concept Phase Trade Studies – Phase 3 [5]

Radio Aurora Explorer (RAX) CubeSat Mission
Michigan Exploration Lab and SRI International mission
Studied 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

Ad Hoc Modeling

- System Specs: Reqts, Ops Con., Interfaces, ...
- Subsys. Specs
- Ad Hoc Modeling in support of:
  - Reqts analysis
  - Payloads
  - Mission data collect

Traditional Systems Engineering

- Systems Engineering Methodology
- System Modeling Tools
- Interfaces with Other Models

Systems Modeling Language (SysML) [1]
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 [2]

- The Model
  - SysML Model Elements
  - Block Properties
  - Blocks, Actors, Flow, Signals, Ports, ...
  - Parts, Values, Operations, ...

Model updates are automatically populated into the system views

Traditional documents can be generated from the model as needed

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


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**CubeSat Reference Model Logical Design to Mission Specific CubeSat Model**

Logical architecture decomposes the system into components that interact to satisfy system requirements. The components are abstractions of physical components that perform system functionality but without imposing implementation constraints.

Physical architecture defines physical components that interact to satisfy the system requirements. The physical components of the system include hardware, software, persistent data, and operational procedures.

The CubeSat Reference Model provides the logical architecture.

### Logical and Physical Architectures

**SSWG Team – CubeSat System SysML Model Development**

**Stakeholders**
- University CubeSat Team
- INCOSE
- OMG
- Cal Poly – CubeSat Spec
- NOAA – Remote Sensing
- NASA – Orbital Debris
- FCC – Comm. Spectrum

**Model Release**
- Validation Verification
- Accreditation
- Approval Mechanism
- Maintenance

**OMG**
- Repository
- Configuration Management
- Intellectual Property
- Distribution

**Typical Stakeholders**
- Sponsor
- User
- Operator
- Project Manager
- Mission Engineer
- Developer
- Tester

### Two Teams – Two Groups of Stakeholders

**SSWG CubeSat Reference Model Development**

**Actors**
- Stakeholders
- Guidance and Regulations
- Domain Enterprise

**Ground Segment**
- Ground Subsystems

**Space Segment**
- CubeSat Subsystems

**Technical Measures**
- Requirements
- Use Cases
- Data Flow Validation
- Verification

**Ground Station Services**
- Transport, Launch, and Deploy Services

**Mission Team – CubeSat System Design and Development**

**CubeSat SysML Model**
- Logical Architectural Elements

**CubeSat Mission**
- Logical Architectural Elements

**CubeSat**
- Physical Architectural Elements

**CubeSat Mission Design and Development**

Mission specific enterprise needs, objectives, constraints, and measures of effectiveness.

Mission use cases and requirements.

Segment use cases and requirements.

**Subsystem requirements**

**Best-Known Successes**
- Architecture Frameworks: Unified Profile for DO-178 and Modelica (MDO), evolving into the Architecture Framework (AF)
- Business Process Modeling Notation: BPMN™ provides businesses with the capability of understanding their internal business processes
- Common Object Request Broker Architecture: CORBA® remains the only language-and platform-neutral interoperability standard
- Data Distribution Service: DDS, real-time, data-centric, publish-subscribe OMG specification for data distribution
- Meta-Object Facility: MOF™, the repository standard and the basis for non-proprietary tool usage. A central way to query, view, and transform languages.
- Model Based Systems Engineering (MBSE) – with INCOSE: Provides processes & methods used in industry with specific emphasis on methodology and develops useful metrics that can be used on MBSE related programs & projects; more specifically, tool metrics & process metrics.
- Systems Modeling Language: SysML™ supports the specification, analysis, design, and verification and validation of a broad range of complex systems.
- Unified Modeling Language: UML™ remains the world’s only standardized modeling language
- XML Metadata Interchange: XMI®, the XML-UML standard purpose is to enable easy interchange of metadatas between UML-based modeling tools & MDO-based metadata repositories.

### CubeSat Domain and Mission Enterprise

**CubeSat Logical Architecture**

**CubeSat Ground System Logical Architecture**

**Cal Poly Design Spec SysML Model Organization**

### Next Steps

**Continue Development of Model**

- Engage University CubeSat Team and Update Model
- Provide Model to University Team and Refine Model

**OMG Process for Adopting a CubeSat Reference Model**

- Develop a Request for Proposal (RFP) which specifies the requirements for a CubeSat Reference Model
- OMG issue RFP
- OMG evaluates submitted CubeSat Reference Models and adopts one

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