INCOSE MBSE Activities

20 May 2009

Presented by the INCOSE OOSEM WG:

L. Mark Walker, loren.m.walker@lmco.com

Mike Pafford, mike.pafford@jhuapl.edu

Larry McGovern, lawrence.mcgovern@ngc.org

Other Briefing Contributors:

Sandy Friedenthal, sanford.friedenthal@lmco.com

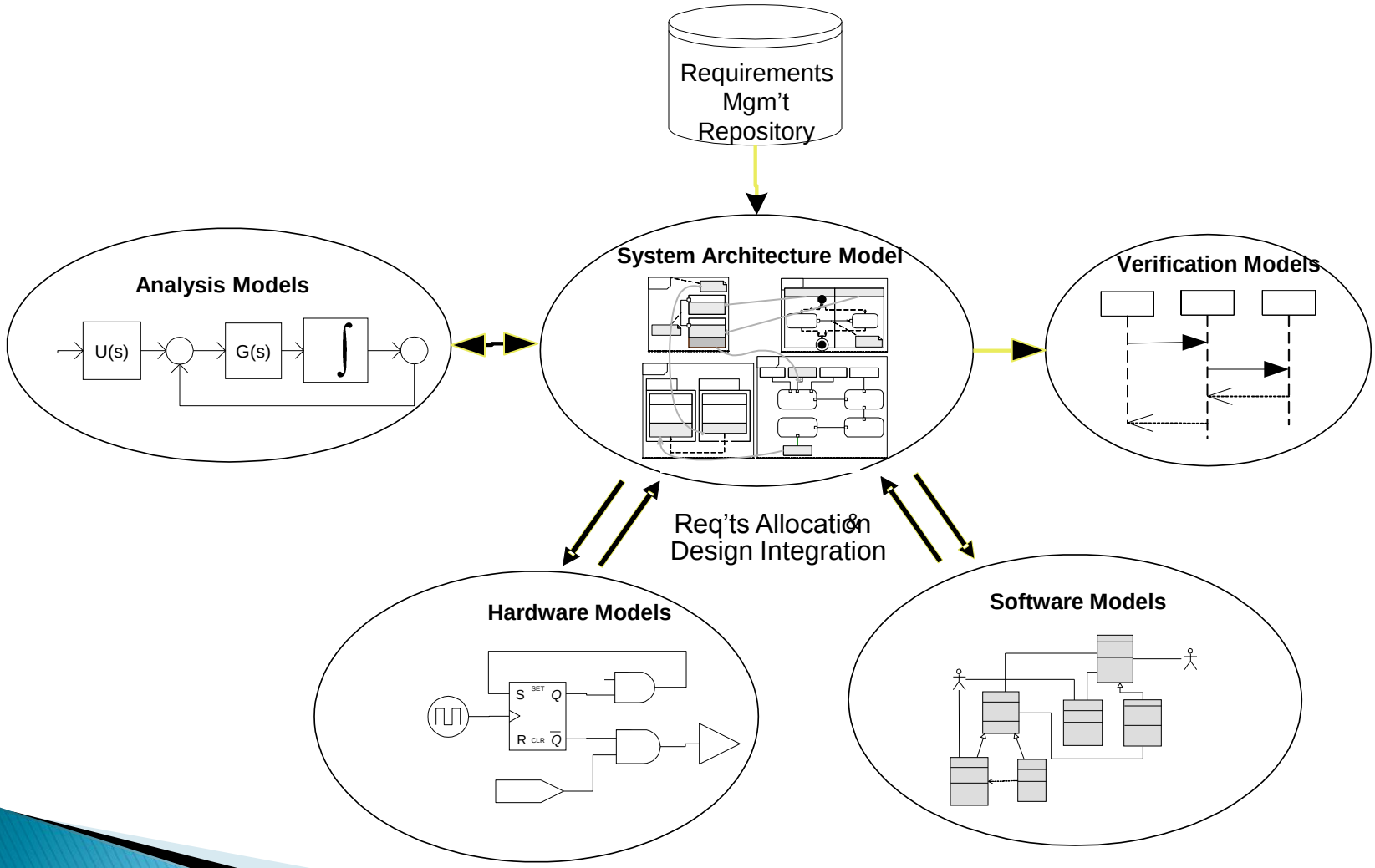
Howard Lykins, Howard.Lykins@hq.doe.gov

Outline

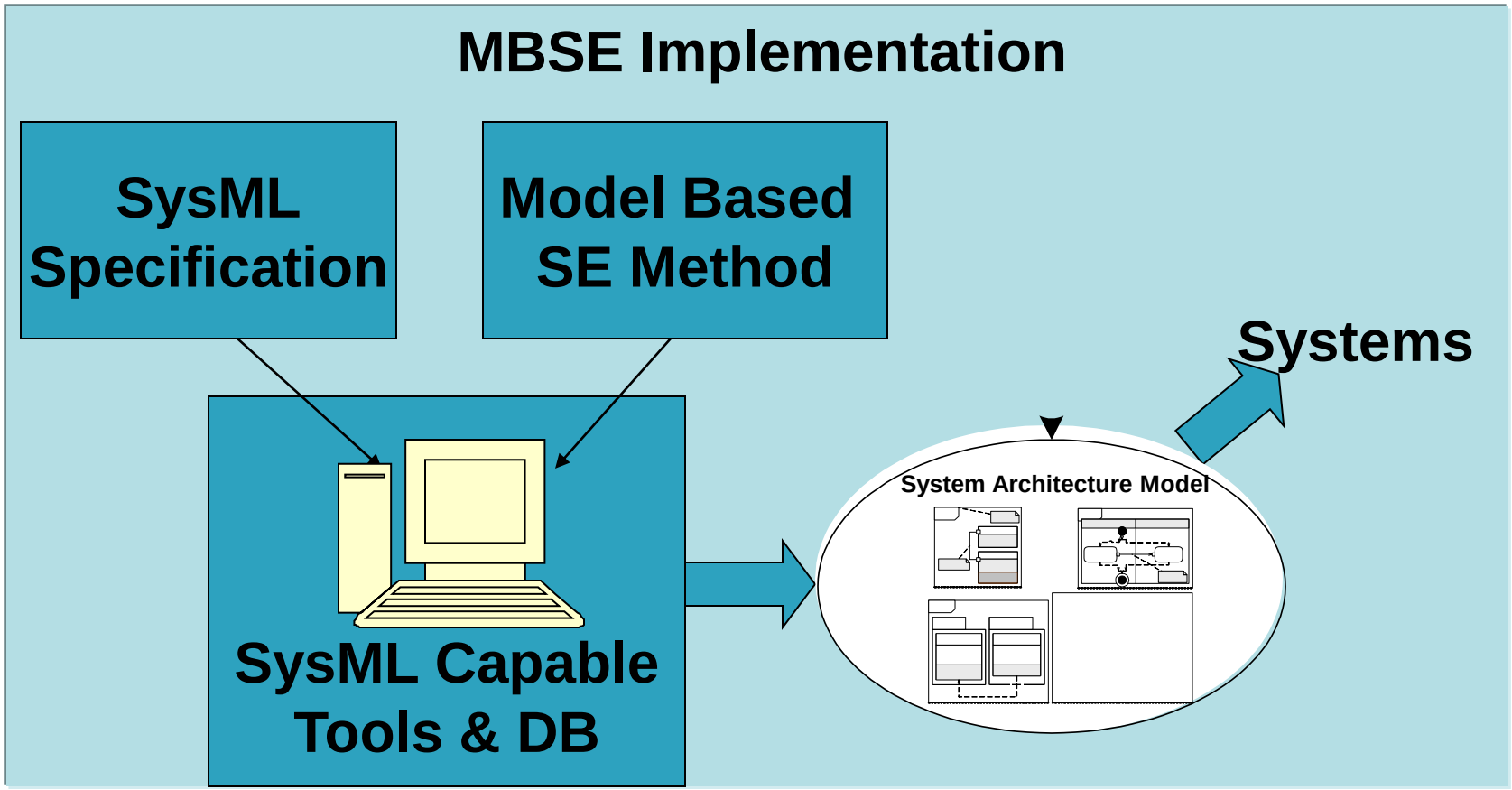
- Introduction- Mark Walker
- Status of INCOSE MBSE Committee Activities- Sandy Friedenthal/Mark Walker
- Status of OMG SysML- Sandy Friedenthal/Mark Walker
- OOSEM WG Status- Howard Lykins/Mark Walker
- Procedure Documentation System Project & Method Issues - Howard Lykins/Mark Walker
- APL/John Hopkins Univ. - Mike Pafford
- GEOSS Structure & Opportunity Challenge Team - Larry McGovern
- Fire Satellite Challenge Team - Mark Walker
- Closing Discussion

SysML & MBSE Background and Motivation

System Architecture Model as Integrating Model

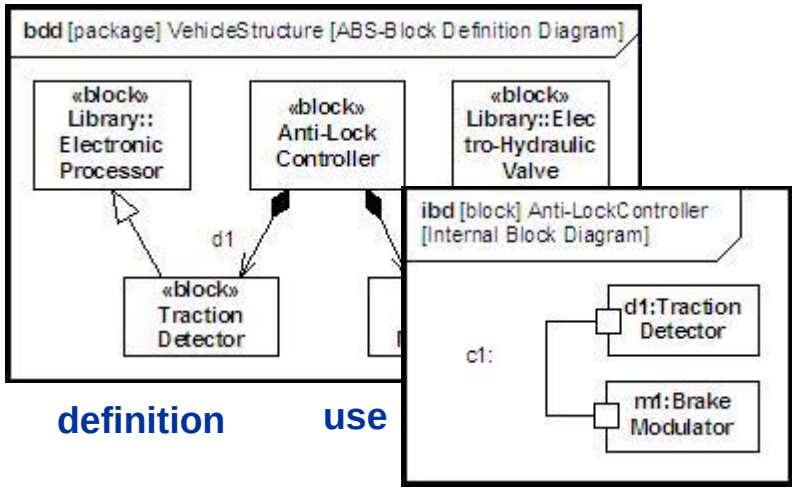


Key Elements for Implementing MBSE



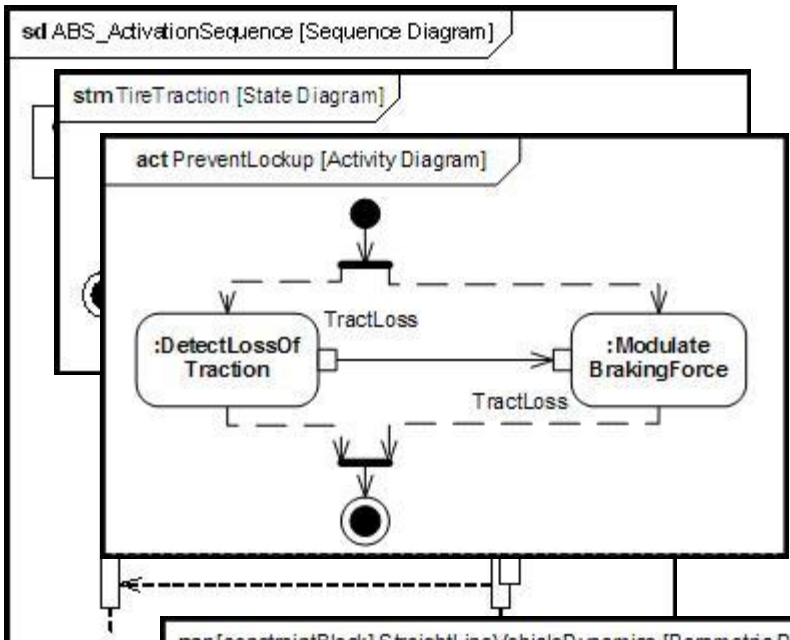
4 Pillars of SysML

1. Structure



definition use

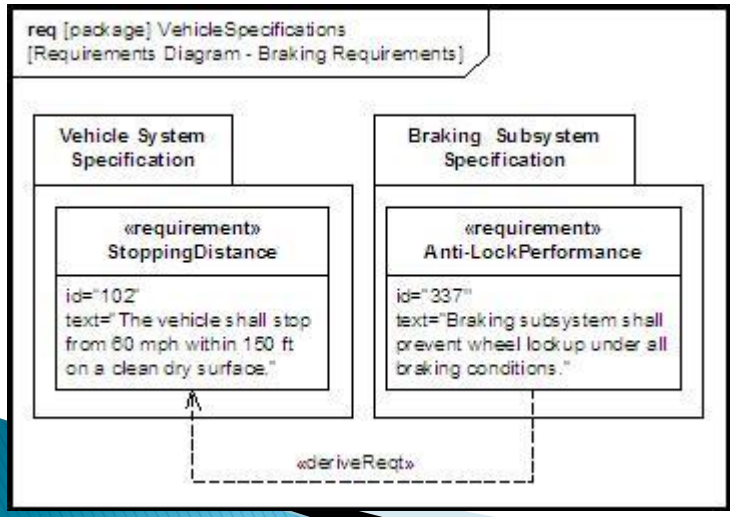
2. Behavior



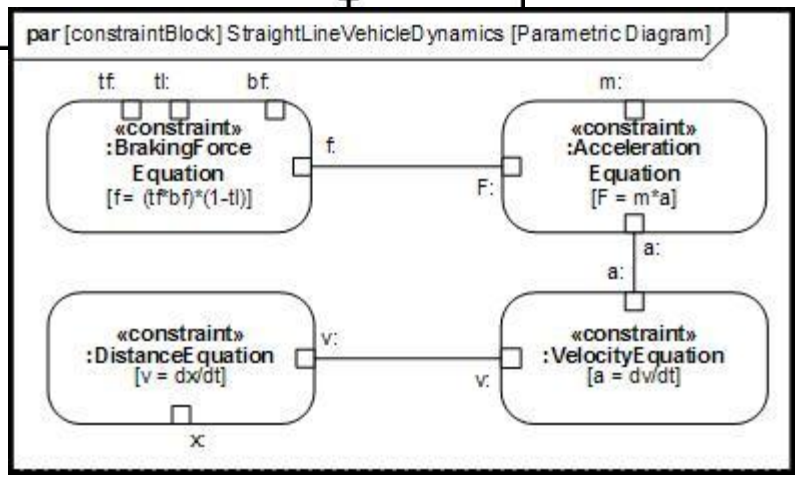
interaction

state machine

activity/ function



3. Requirements



4. Parametrics

Applying the Model Based Approach (MBSE Method)

- Model based approach
  - More rigorous and precise based on SysML Specification for 9 key diagram types
  - Diagrams are integrated via Tools
  - ReUse of common library of terms, equations, parameter, definitions, etc.
  - ReUse results in reduced errors, cost savings, improved schedules and more time for system model development
- Implementation
  - Takes time to get basics, tools and training
  - Provide adequate tool and training support (SysML, MBSEM, Tool)
  - Use an incremental method to evolve the system models and manage the scope of the effort
  - Manage level of model abstraction so you don't get too detailed too early

UML Profile for DoDAF/MODAF (UPDM) Overview

- OMG initiative underway to develop tool specification for representing & exchange of DODAF and MODAF products
- Goal:
  - provide robust architecture modeling capability,
  - improve communications and tool interoperability,
  - reduce re-training
- Multiple tool vendors and users participating
- Should leverage SysML, UML and BPMN and experience gained from existing tools

DoD & UK MOD are supporting and hope to adopt!

INCOSE MBSE Initiative Status May 20, 2009

Sanford Friedenthal
(briefed by Mark Walker)

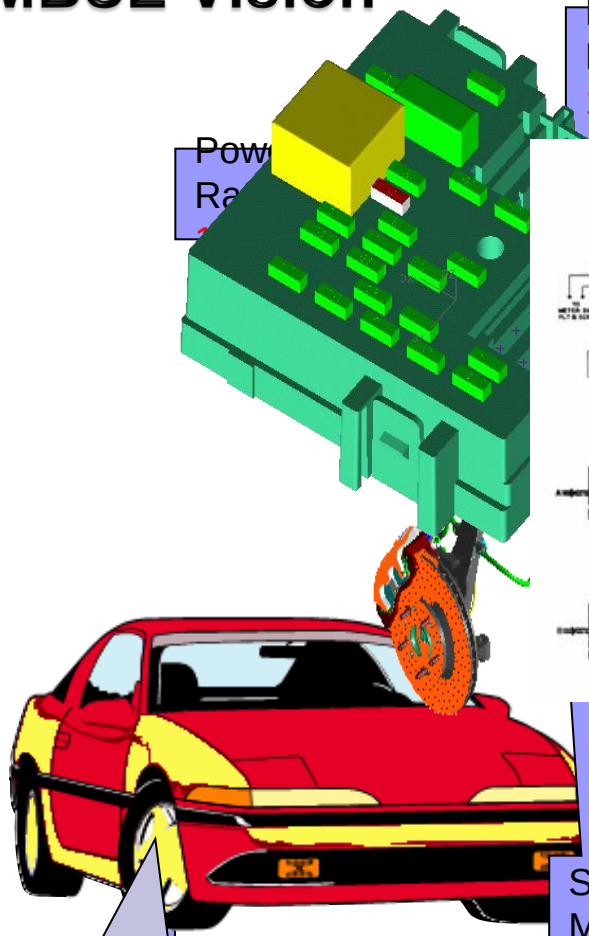
INCOSE MBSE Initiative Charter

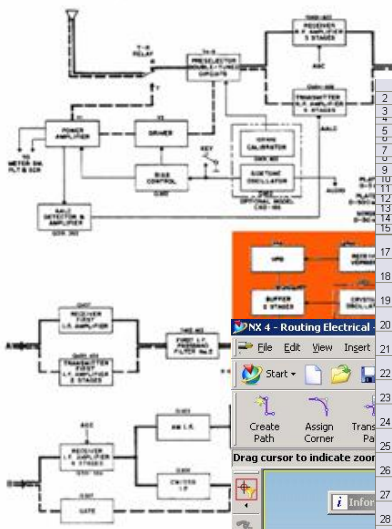
- **Promote, advance, and institutionalize the practice of MBSE to attain the MBSE 2020 Vision through broad industry and academic involvement in:**
  - **Research**
  - **Standards**
  - **Processes, Practices, & Methods**
  - **Tools & Technology**
  - **Outreach, Training & Education**

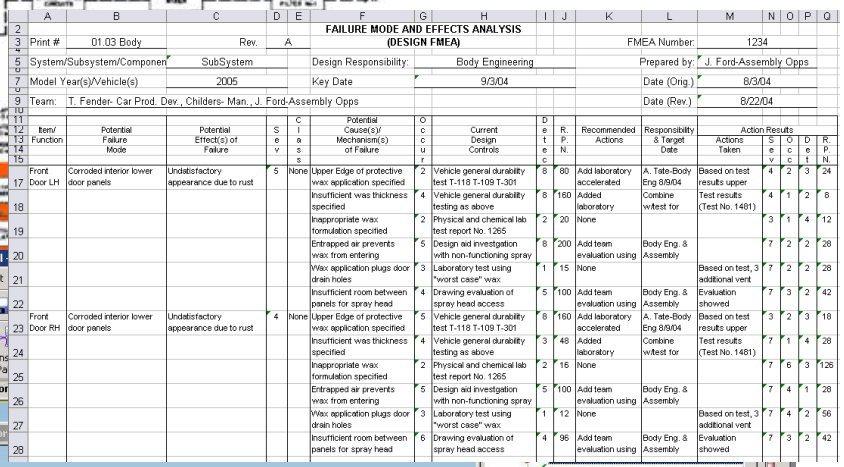
MBSE Vision

Hydraulic Fluid: SAE 1340 not-

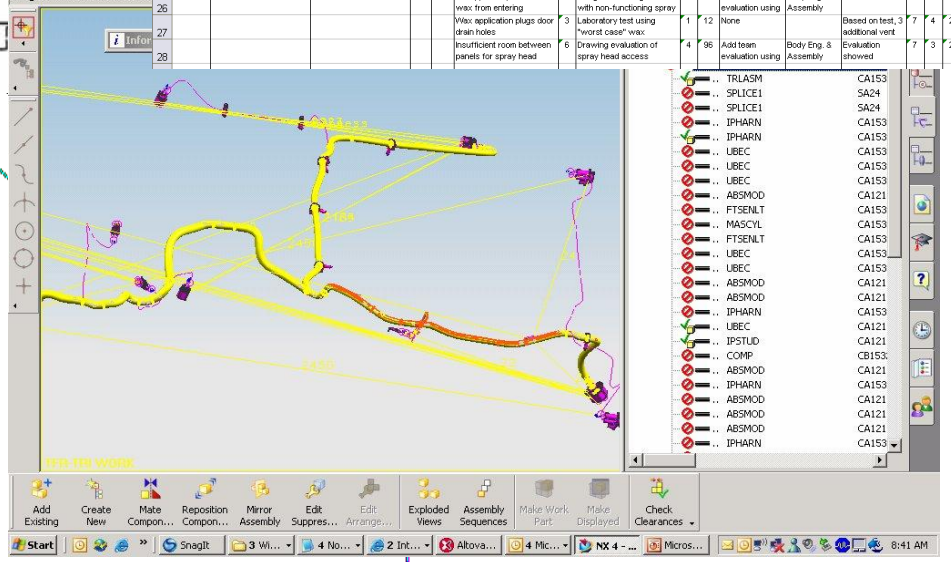
Pow
Ra







	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
2	FAILURE MODE AND EFFECTS ANALYSIS																
3	Print #	01.03 Body		Rev.	A	(DESIGN FMEA)						FMEA Number:	1234				
5	System/Subsystem/Componen		SubSystem			Design Responsibility:		Body Engineering				Prepared by:	J. Ford-Assembly Opps				
7	Model Year(s)/Vehicle(s)		2005			Key Date		9/3/04				Date (Orig.)	8/3/04				
9	Team:	T. Fender- Car Prod. Dev., Childers- Man., J. Ford-Assembly Opps										Date (Rev.)	8/22/04				
12	Item/ Function	Potential Failure Mode	Potential Effect(s) of Failure	S e v	C l a s s	Potential Cause(s)/ Mechanism(s) of Failure	O c c u r	Current Design Controls	D e t e c	R. P. N.	Recommended Actions	Responsibility & Target Date	Actions Taken	S e v	O c c	D e t	R. P. N.
17	Front Door LH	Corroded interior lower door panels	Undatisfactory appearance due to rust	5	None	Upper Edge of protective wax application specified	2	Vehicle general durability test T-118 T-109 T-301	8	80	Add laboratory accelerated	A. Tate-Body Eng 8/9/04	Based on test results upper	4	2	3	24
18						Insufficient was thickness specified	4	Vehicle general durability testing as above	8	160	Added laboratory	Combine w/test for	Test results (Test No. 1481)	4	1	2	8
19						Inappropriate wax formulation specified	2	Physical and chemical lab test report No. 1265	2	20	None			3	1	4	12
20						Entrapped air prevents wax from entering	5	Design aid investgation with non-functioning spray	8	200	Add team evaluation using	Body Eng. & Assembly		7	2	2	28
21						Wax application plugs door drain holes	3	Laboratory test using "worst case" wax	1	15	None		Based on test, 3 additional vent	7	2	2	28
22						Insufficient room between panels for spray head	4	Drawing evaluation of spray head access	5	100	Add team evaluation using	Body Eng. & Assembly	Evaluation showed	7	3	2	42
23	Front Door RH	Corroded interior lower door panels	Undatisfactory appearance due to rust	4	None	Upper Edge of protective wax application specified	5	Vehicle general durability test T-118 T-109 T-301	8	160	Add laboratory accelerated	A. Tate-Body Eng 8/8/04	Based on test results upper	3	2	3	18
24						Insufficient was thickness specified	4	Vehicle general durability testing as above	3	48	Added laboratory	Combine w/test for	Test results (Test No. 1481)	7	1	4	28
25						Inappropriate wax formulation specified	2	Physical and chemical lab test report No. 1265	2	16	None			7	6	3	126
26						Entrapped air prevents wax from entering	5	Design aid investgation with non-functioning spray	5	100	Add team evaluation using	Body Eng. & Assembly		7	4	1	28
27						Wax application plugs door drain holes	3	Laboratory test using "worst case" wax	1	12	None		Based on test, 3 additional vent	7	4	2	56
28						Insufficient room between panels for spray head access	6	Drawing evaluation of spray head access	4	96	Add team evaluation using	Body Eng. & Assembly	Evaluation showed	7	3	2	42



Sensor MTBF: 3000 hrs

Minimum Turn Radius: 24 ft.
Dry Pavement Braking Distance at 60 MPH: 110 ~~ft.~~ 90 ft

FIGURE NOT INCLUDED IN VISION
Provided by Mark Sampson

INCOSE MBSE Roadmap

MBSE Capability: Reduced cycle times; System of systems interoperability; Design optimization across broad trade space; Cross domain effects based analysis

June 15, 2008

Institutionalized MBSE across Academia/Industry

Well Defined MBSE

Ad Hoc MBSE Document Centric

Maturity

- Distributed & secure model repositories crossing multiple domains
- Defined MBSE theory, ontology, and formalisms
- Architecture model integrated with Simulation, Analysis, and Visualization
- Matured MBSE methods and metrics, Integrated System/HW/SW models
- Emerging MBSE standards

Refer to activities in the following areas:

- Planning & Support
- Research
- Standards Development
- Processes, Practices, & Methods
- Tools & Technology Enhancements
- Outreach, Training & Education

2010 2020 2025

MBSE Workshop Agenda INCOSE IW 2009

- 3rd MBSE Workshop
  - 3.5 days
  - Good attendance – 40+
- Activity Sessions
  - Model Management
  - MBSE Methodologies
  - Human System Integration (HSI)
  - Ontology
  - SoS modeling
- Special Topics
  - Data link semantics – Julian Johnson
  - Domain specific modeling – George Sawyer
  - Systems analysis framework and semantic – Claude Feliot
- Challenge Teams

Challenge Teams

- ***Telescope System Modeling*** ***– Robert Karban (ESO)**
- ***Space Systems (FireSat)*** ***– Chris Delp**
- **Mechatronics / Model Interoperability Team – Russell Peak (GIT)**
- ***GEOSS Architecture Modeling *– Larry McGovern***
- **Intelligent Enterprises – Jack Ring**
- **INCOSE Enterprise Model – Michael Dee (Regina Griego)**
- **MBSE Applied to Urban Transportation – Larry Head (UofA)**
- **Avionics Systems and Software Integration – Leon Corley**

*** Presented later in briefing**

Observations (partial list)

- Good participation and enthusiasm from practitioners
- Good progress across the board
- Possible new efforts
  - Considering new HSI standard through the OMG
  - Potential new challenge team from Biomedical WG
- MBSE state of practice is progressing from ad hoc MBSE
  - Continued emergence of new standards (UPDM, executable UML, ontology) and maturity of existing standards (AP233, SysML) and tools
  - MBSE is being successfully applied on large projects
  - Industry requesting academia to include MBSE in curriculum
  - Some indicators of higher quality and wider spread MBSE in companies
  - MBSE part of RFP
- Over 10 offers to contribute to INSIGHT MBSE Themed Edition for Dec 09

OMG Systems Modeling Language Status
May 20, 2009

Sanford Friedenthal
(briefed by Mark Walker)

OMG SysML™

- Specification status
  - OMG Beta Specification in May ’06
  - Available Specification v1.0 in Sept ’07
  - Available Specification v1.1 in Nov ‘08
  - Revision task force for v1.2 in process
- Adoption
  - Multiple vendor implementations available
  - Increasing number of early adopters across industry
  - Being introduced into academia
  - Books available (3)
  - SysML Certification being planned: OMG-Certified Systems Modeling Professional (OCSMP)
- Information can be found on the OMG SysML Website at http://www.omgsysml.org/

OMG SysML™ (cont.)

- On-going Efforts
  - SysML/AP233 Integration
  - SysML/Modelica WG (Modelica is a very powerful and standardized simulation language)
  - Model interchange WG
- Leveraging SysML in other OMG Specifications
  - UPDM, MARTE (Modeling and Analysis of Real-time and Embedded systems)
- University Courses
  - Fachhochschule Vororlberg
    - www.fhv.at – Bernd Wenzel
  - George Mason University
  - Georgia Institute of Technology
  - University of Arizona
  - University of California at San Diego Extension
  - Others ?

Summary

- **Standards such as SysML are critical enablers of MBSE**
- **Multiple tool vendors implementing the standard**
- **System architecture model and standards based approach facilitate Integration across modeling domains**
- **Growing interest and application of MBSE**
- **INCOSE MBSE helping to advance and promote MBSE**

OOSEM WG Background & Status

OOSEM WG Status

- Started 2000
- Currently supporting OOSEM application to MBSE Initiatives
- Supporting development of JHU/APL MBSE Course
  - Initially targeted toward professional staff at APL
  - Will evolve to course for JHU engineering students
- Continuing contribution to SysML & MBSE activities
  - Understanding, application and standardization
  - Tutorials, Standard updates, articles, book support
- Meeting monthly in the APL Kossiakoff Center

JHU/APL IN-HOUSE "STRATEGIC EDUCATION PROGRAM (SEP)"

(Mike Pafford)

JHU/APL MBSE with SysML Practitioners Course

- JHU/APL IN-HOUSE "STRATEGIC EDUCATION PROGRAM (SEP)"
  - 2-hour Classroom Sessions; Weekly; 12 Weeks; Fall 2009
  - Target Audience: JHU/APL Systems & Software Engineers and Systems & Software Project/Program Managers
- INTRO TO MBSE, INTRO TO SYSML, PRACTICE WITH MBSE TOOL
- TEXT: "A Practical Guide to SysML; The Systems Modeling Language"; Friedenthal, Moore, and Steiner; 2008
- MBSE TOOL: Sparx EA™
- INSTRUCTORS:
  - **Mr. Joe Wolfrom (JHU/APL), (240) 228-0719, joe.wolfrom@jhuapl.edu**
  - **Mr. Mike Pafford (JHU/APL), (240) 228-3174, mike.pafford@jhuapl.edu**

Specific SysML & MBSE Applications

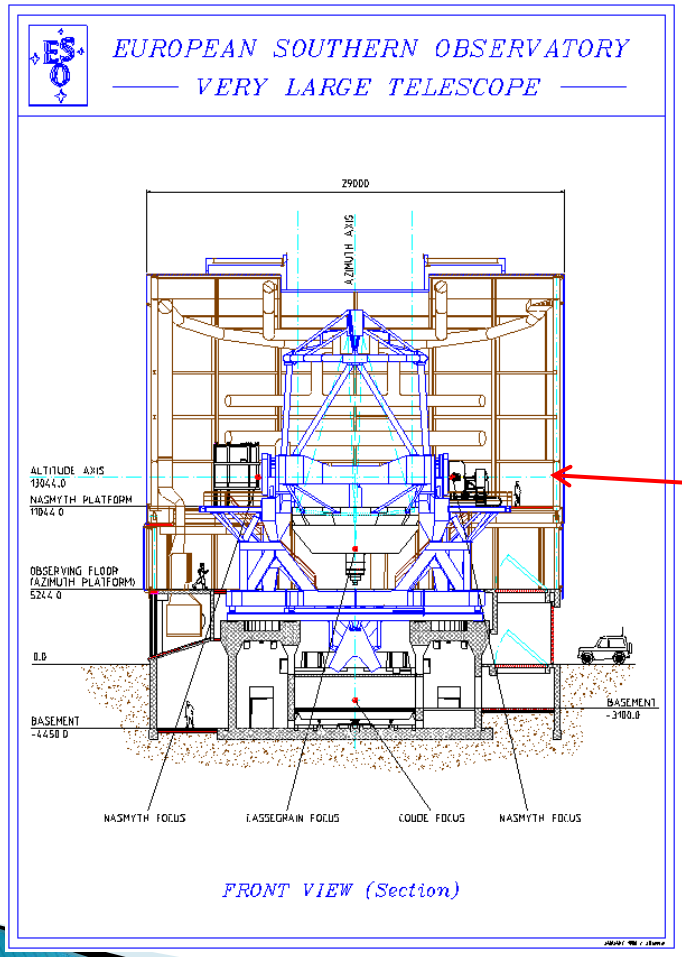
Small System Project & Team

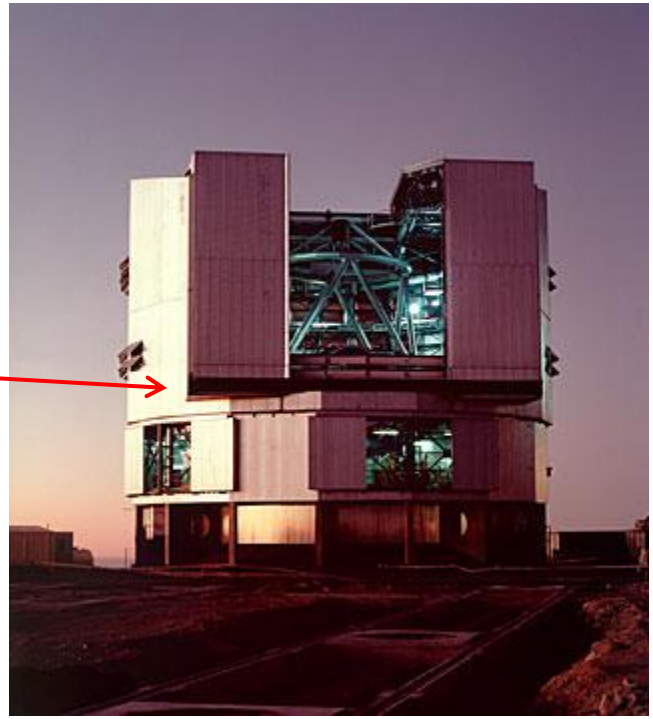
Howard Lykins

Small System Project/Teams & Method Issues

- Challenge: Apply OOSEM to development of small information systems
  - Specific application: web-based information system for standard operating procedures (SOPs)
  - Two versions of system for two clients
- Issues: How to…
  - Select most important work products (what to concentrate on)
    - Avoid eliminating something critical
  - Involve customer (who is not an expert)
  - Model variation between system versions
    - Decide if and when to split into two separate projects
- Desired outcomes for small projects & teams:
  - Guidelines and work product templates
- Status: Completing Logical Architecture

INCOSE Telescope Modeling Challenge Team
Robert Karban – Lead APE Project

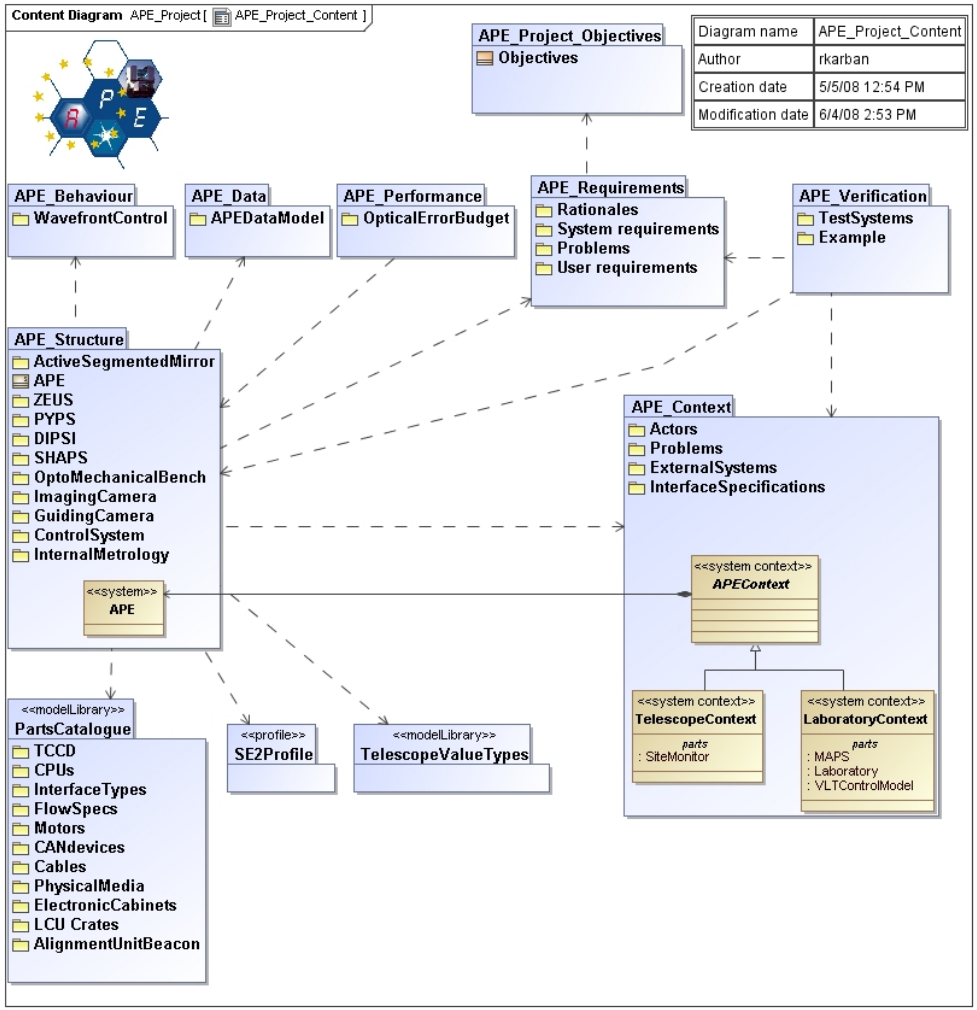




APE will be installed at the telescope in the Chile desert.

OOSEM WG Presentations- May 09

Model Organization



Telescope MBSE Challenge Team Site
http://mbse.sysmod.de/

Presented to the INCOSE 2008 Symposium by Robert Karban

GEOSS Architecture Modeling Team Status Report

Lawrence E. McGovern, PhD
Team Lead

20 May 2009

Description of the Problem

- Tasked to express the GEOSS Architecture using UML IAW ISO/IEC Standard 19793:2006 and Reference Model for Open Distributed processing RM-OTP

Technical Approach

- Conform to the ISO/IEC 19793 Viewpoint correspondences for the information language and profiles provided for each specification type.
- Develop a Use Case For each scenario in the Enterprise Specification and associate at a minimum a SysML Activity Diagram and Sequence Diagram to each use case. Use this a basis for other specifications
- Develop Entity Relationship diagram for each information view
- Develop Component Diagram for each Computational View
- Develop in a UML Capable tool in one repository
- Capture inputs from each contributor in the repository and integrate into the model
- Produce each view in HTML Format

References and Additional Information

- The rapid growth of distributed processing has led to the adoption of the Reference Model of Open Distributed Processing (RM-ODP), which provides a coordinating framework for the standardization of open distributed processing (ODP).
- RM-ODP creates an architecture within which support of distribution, inter-working, and portability can be integrated.
- This architecture provides a framework for the specification of ODP systems.

GEOSS Architecture Scenarios

- Disaster Scenarios:
  - Air Quality and Health Scenario: Wildfire
  - Disaster Scenario: Flood Disaster Management
  - Climate Change & Biodiversity Scenario: Arctic Food Chain Chain / Pika Distribution/ Polar Echosystems
  - Renewable Energy: Facility Management

Collaboration Approach

- Current
  - Use Artisan for repository
  - Use CITRIX and Artisan VDS on line with central repository
  - Weekly team meetings

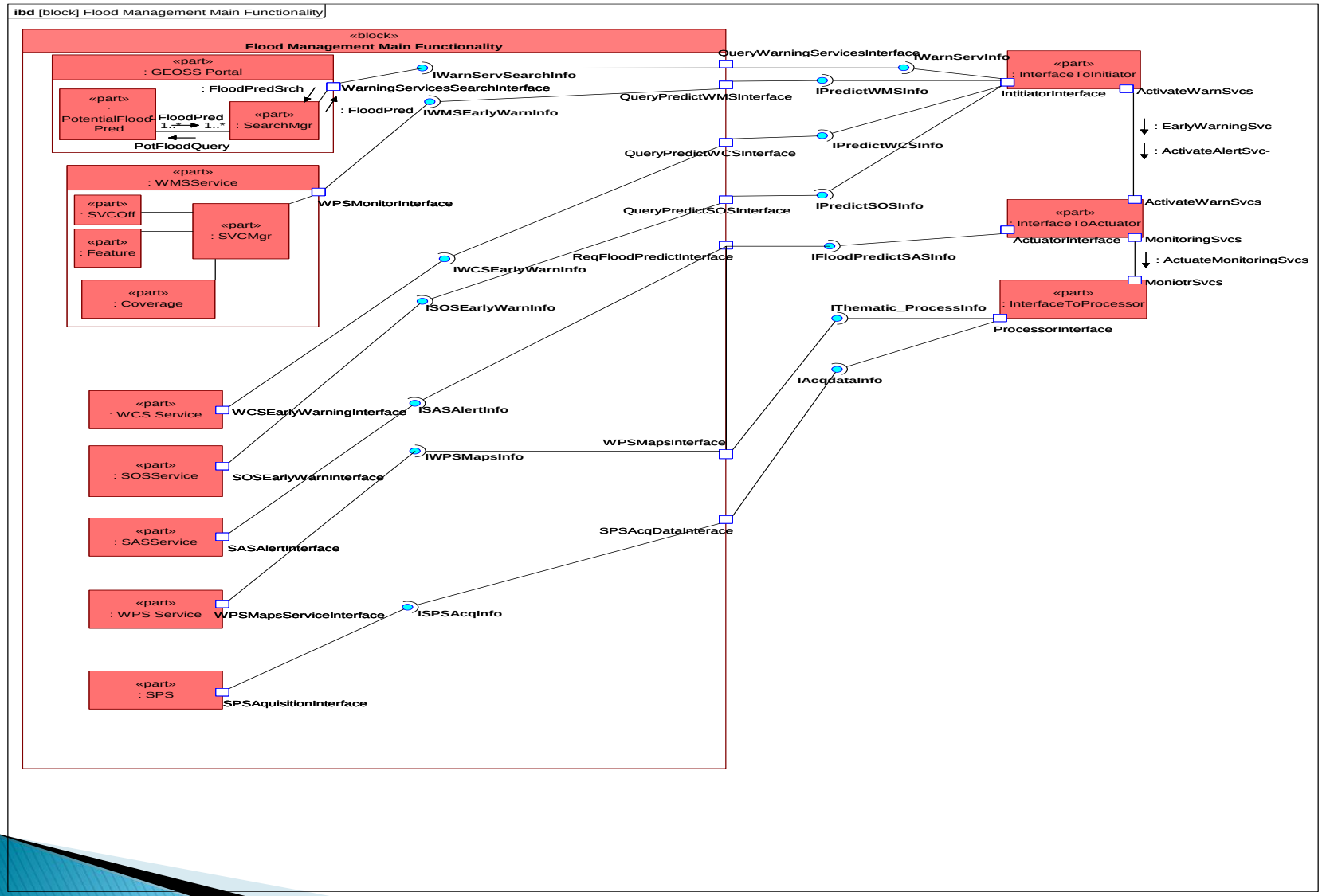
Interim Progress and Results

- Model of Eight total Disaster Scenario Views completed by end of May 2009
- Examples presented in Sestra, Italy May 3, 2009
- Two of eight Computational diagrams completed as of today. Remainder will be completed by end of May 2009 and final report submitted

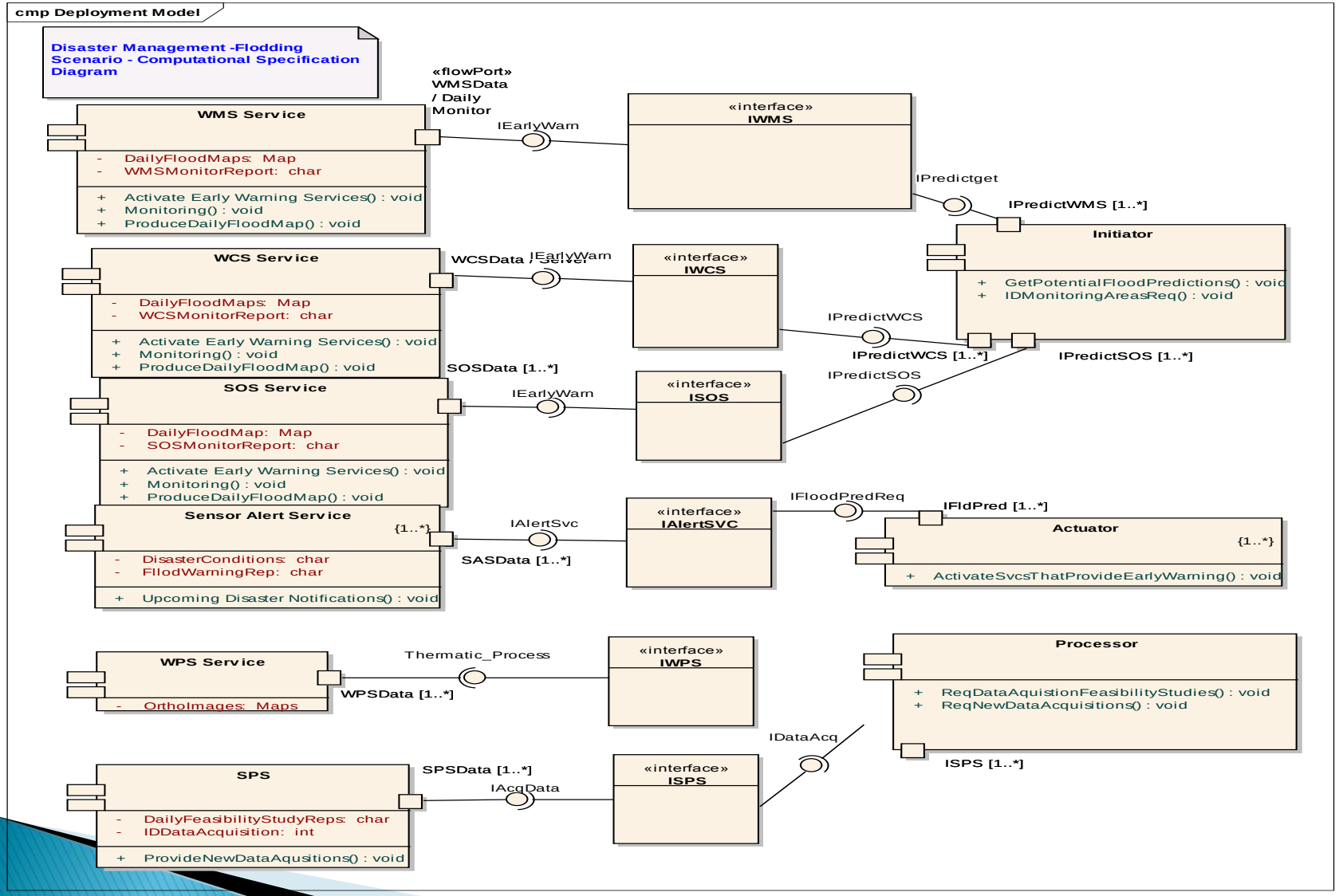
General Assessment and Gap Analysis

- General Assessment: On schedule, Enterprise, Information and Computational Views completed for all eight scenarios
  - Gap Analysis: Need to prepare AIP2 Final Report
  - Plan for completion of Engineering and Technical Views all eight scenarios in AIP3

DM-Flood Mgmt Computational View



Flood Management



INCOSE MBSE Grand Challenge

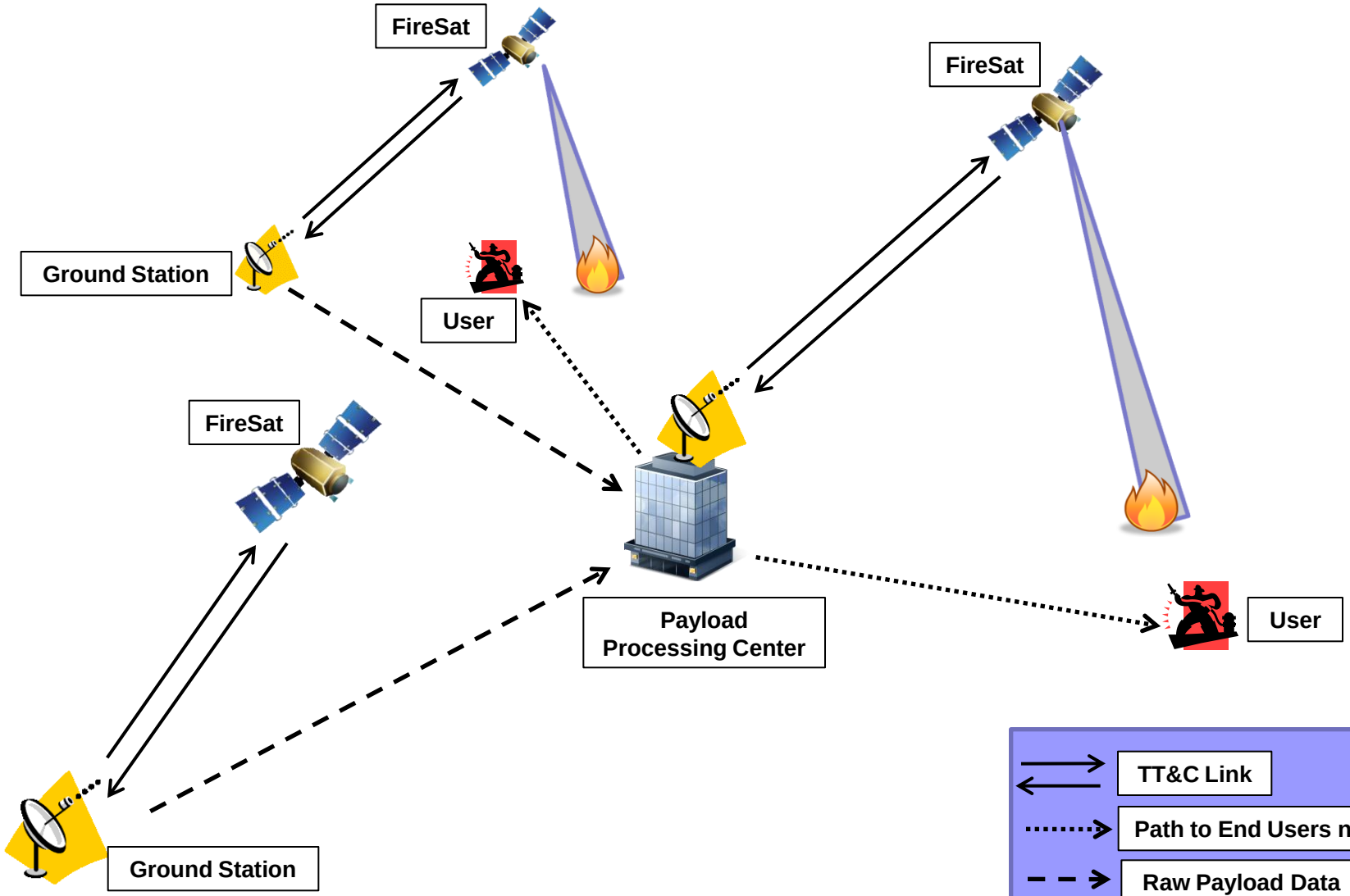
Space Systems Working Group Entry
INCOSE International Workshop 2009

Christopher L. Delp
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California, U.S.A.
Chris.Delp@jpl.nasa.gov

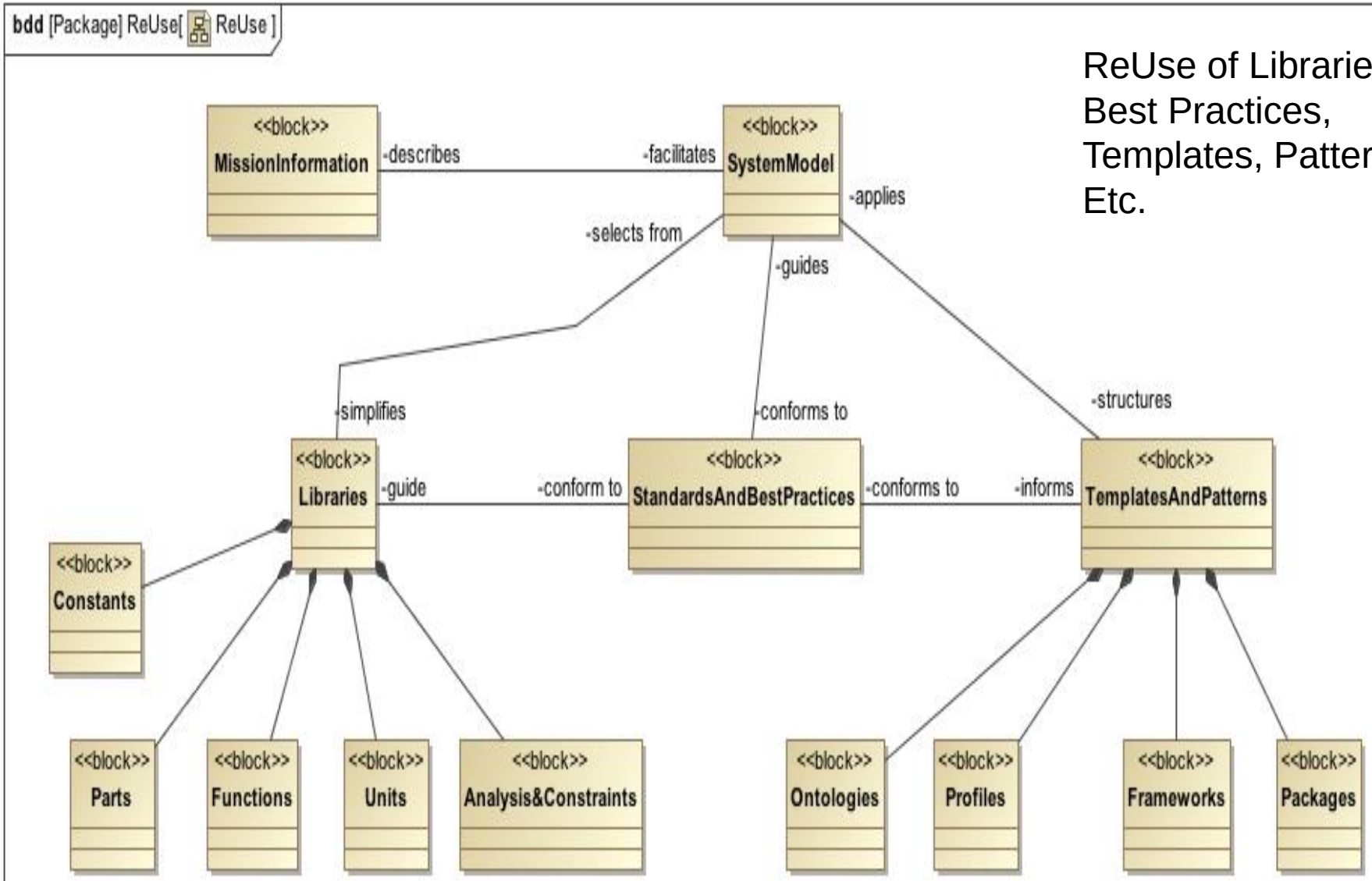
Challenge Team Approach

- Largely volunteer from industry and academia.
  - SSWG Industry professionals (JPL, etc.)
  - MIT/GaTech Student Team
- Reference:
  - Space Mission Analysis & Design [SMAD] is a globally recognized authorative text
  - FireSat mission: running example to illustrate all aspects of space system development.
- Focus for Project
  - INCOSE OOSEM/MBSE & SysML
  - JPL developed State Analysis
  - Numeric Trade-space Models

Operations Concepts (OV-1)

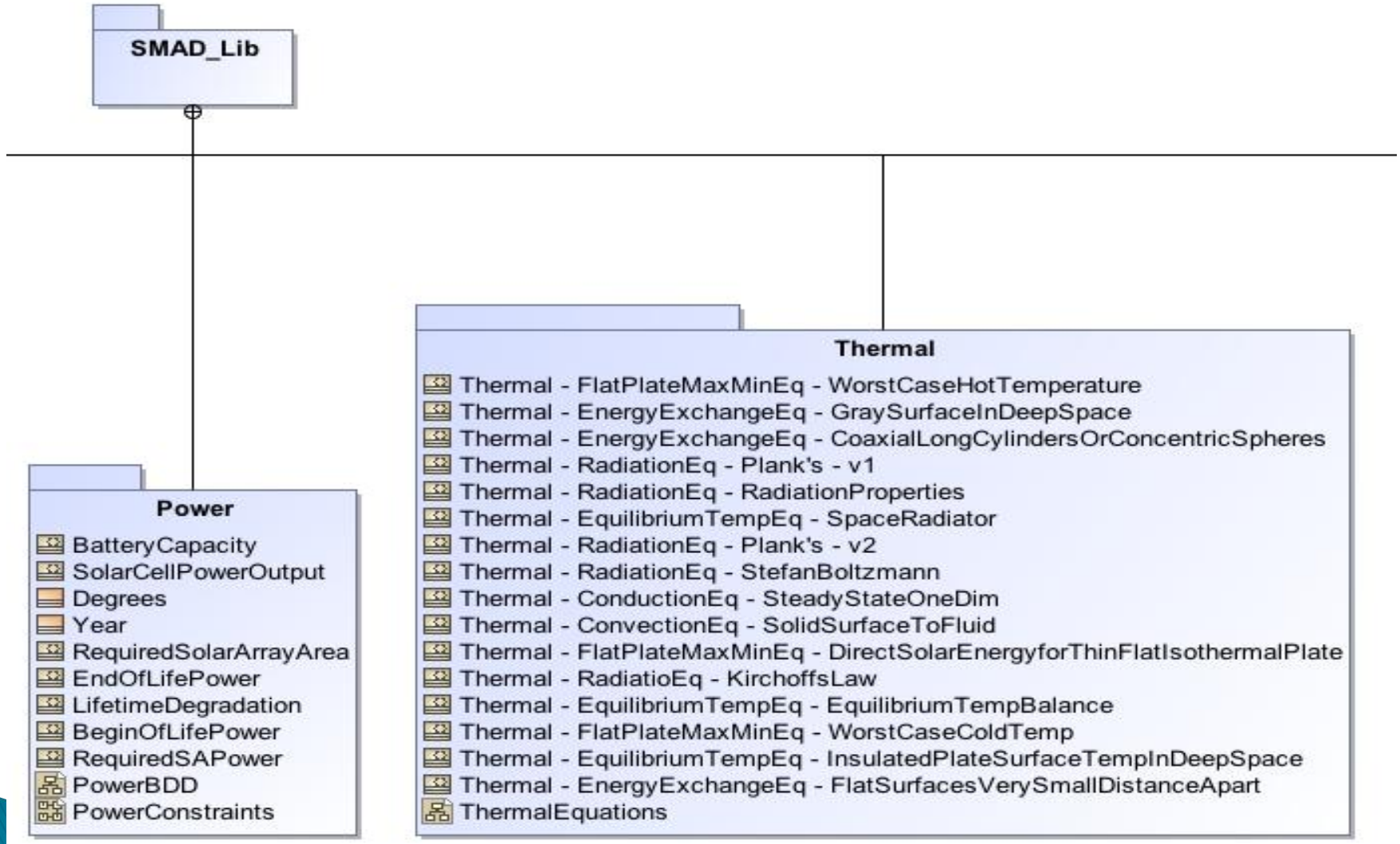


Model Reuse (Meta Model)

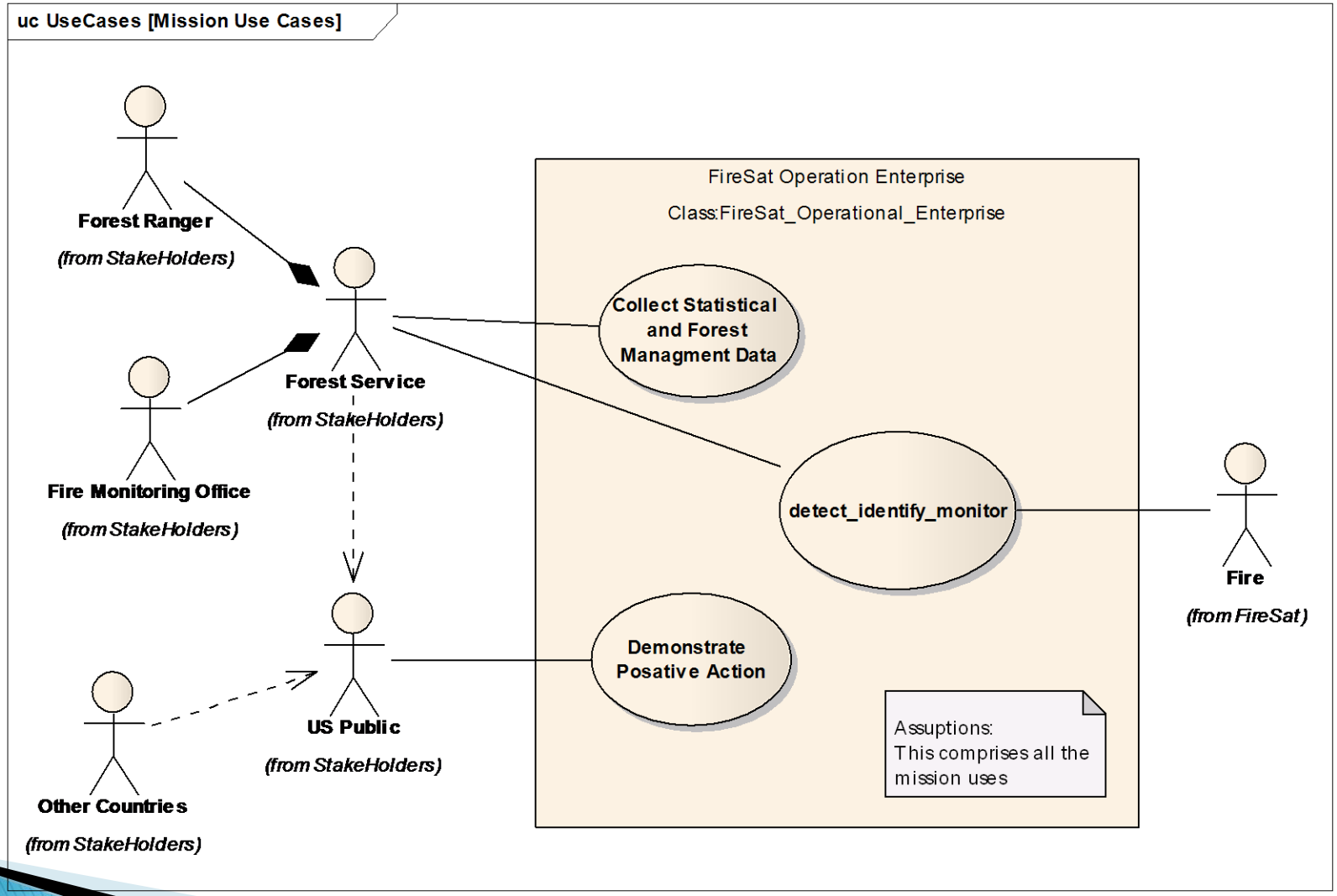


ReUse of Libraries, Best Practices, Templates, Patterns, Etc.

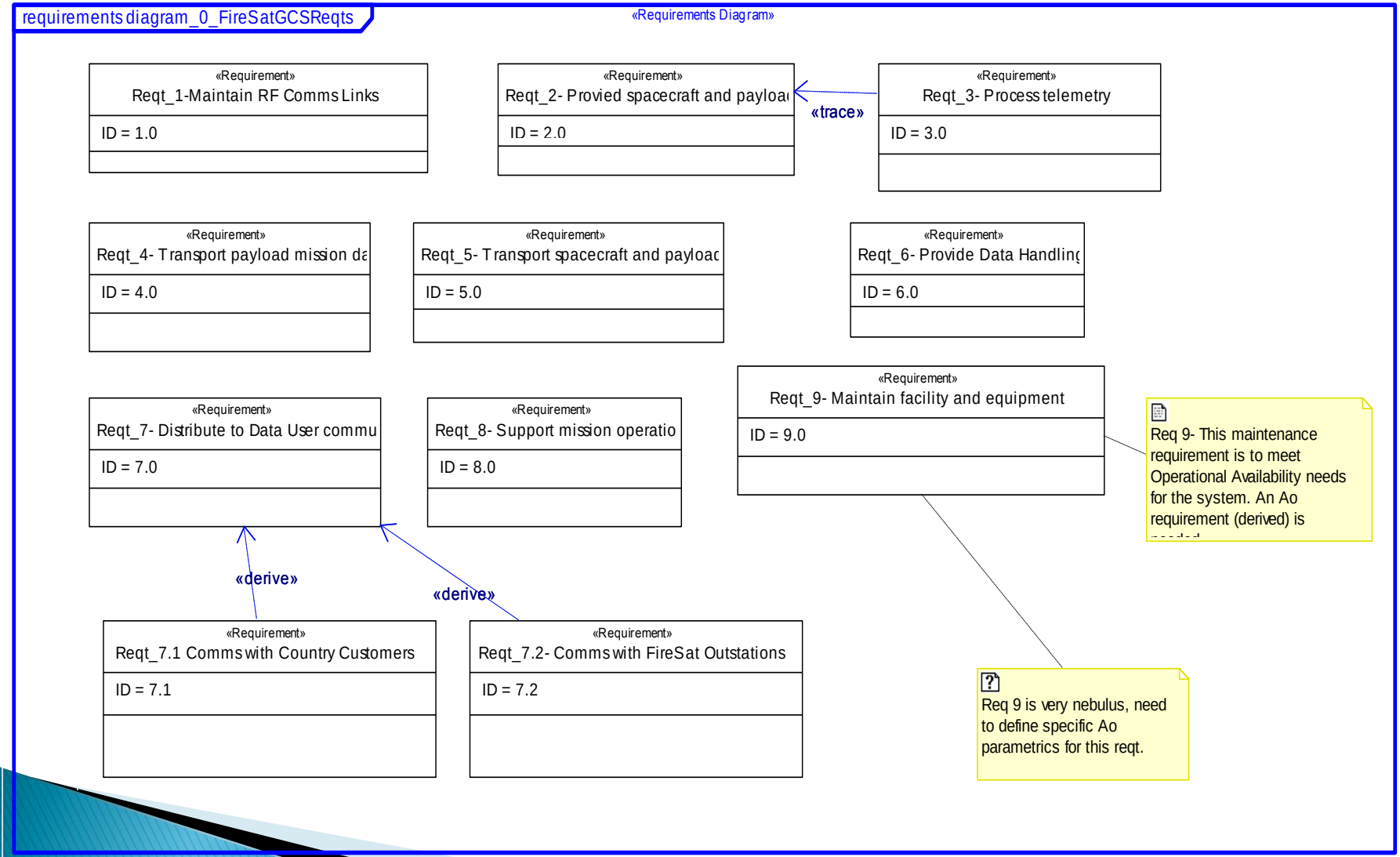
Use of Library Parameters, Equations, etc.



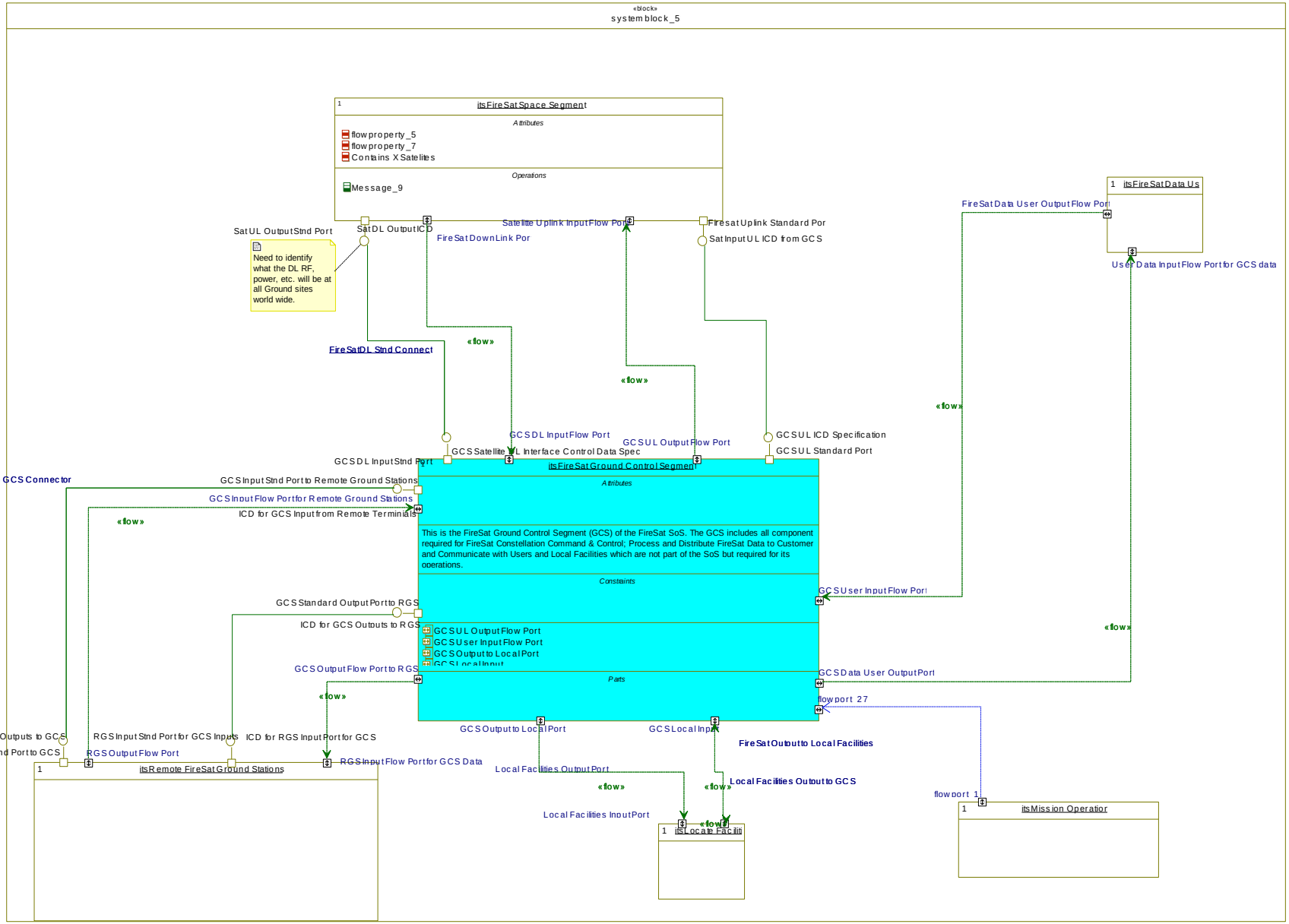
Use cases


uc UseCases [Mission Use Cases]
Forest Ranger
(from StakeHolders)
Forest Service
(from StakeHolders)
Fire Monitoring Office
(from StakeHolders)
US Public
(from StakeHolders)
Other Countries
(from StakeHolders)
FireSat Operation Enterprise
Class:FireSat_Operational_Enterprise
Collect Statistical and Forest Managment Data
detect_identify_monitor
Demonstrate Posative Action
Assuptions:
This comprises all the mission uses
Fire
(from FireSat)

Requirements Diagram

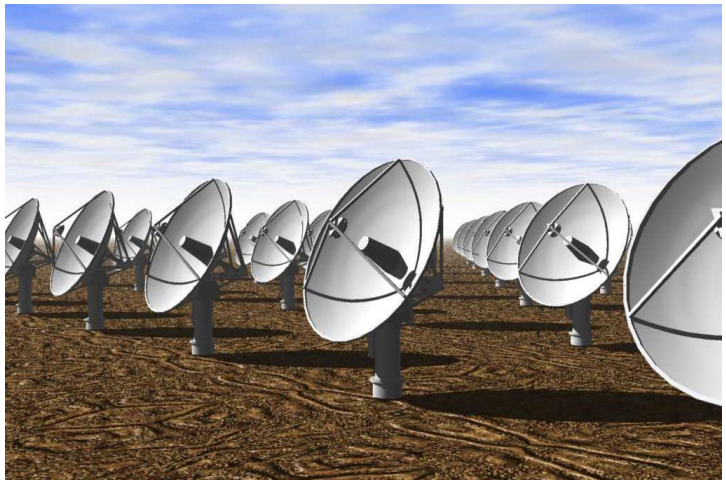


FireSat GroundStation Context (ibd)

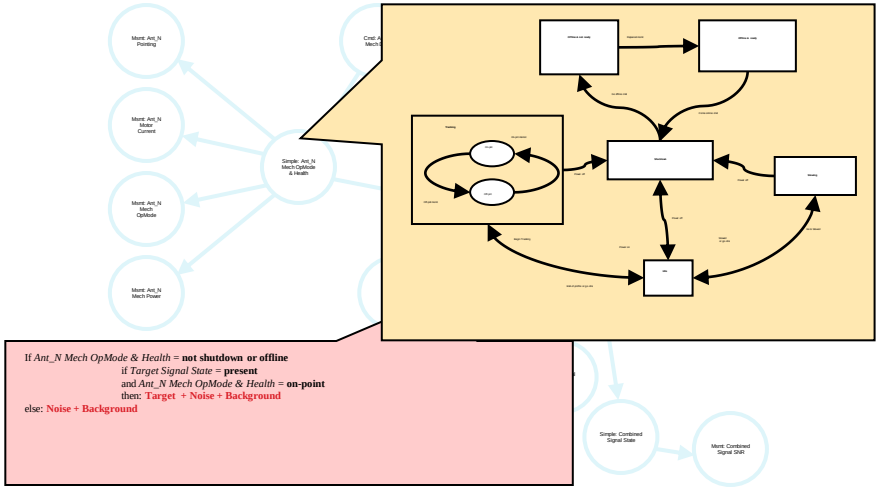


Overview of State Analysis

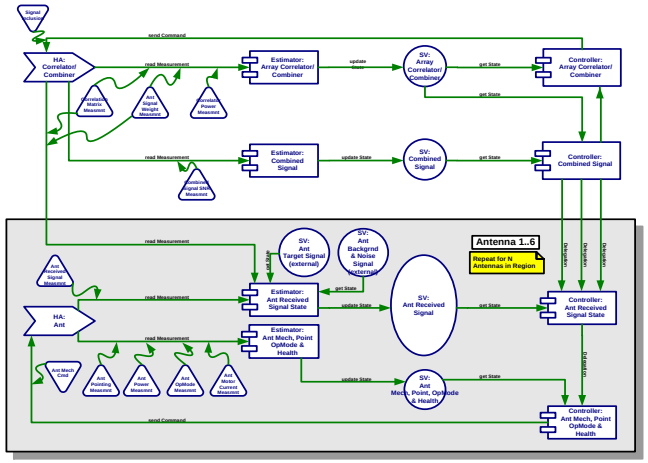
1. System to be controlled



2. State Analysis produces model

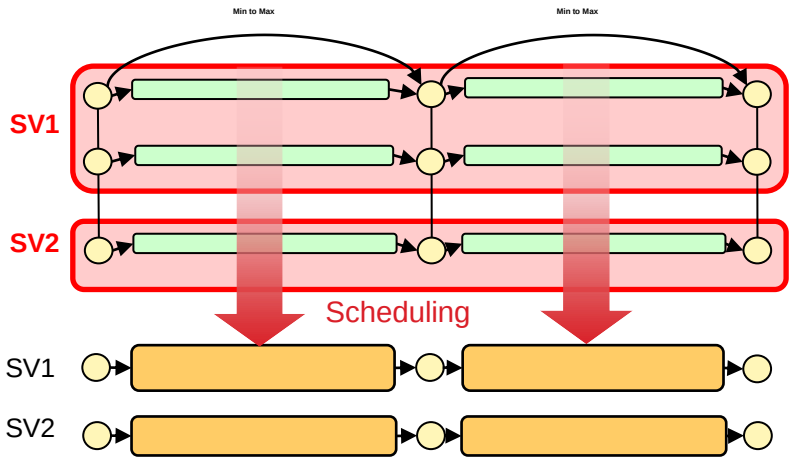


3. Model informs software design



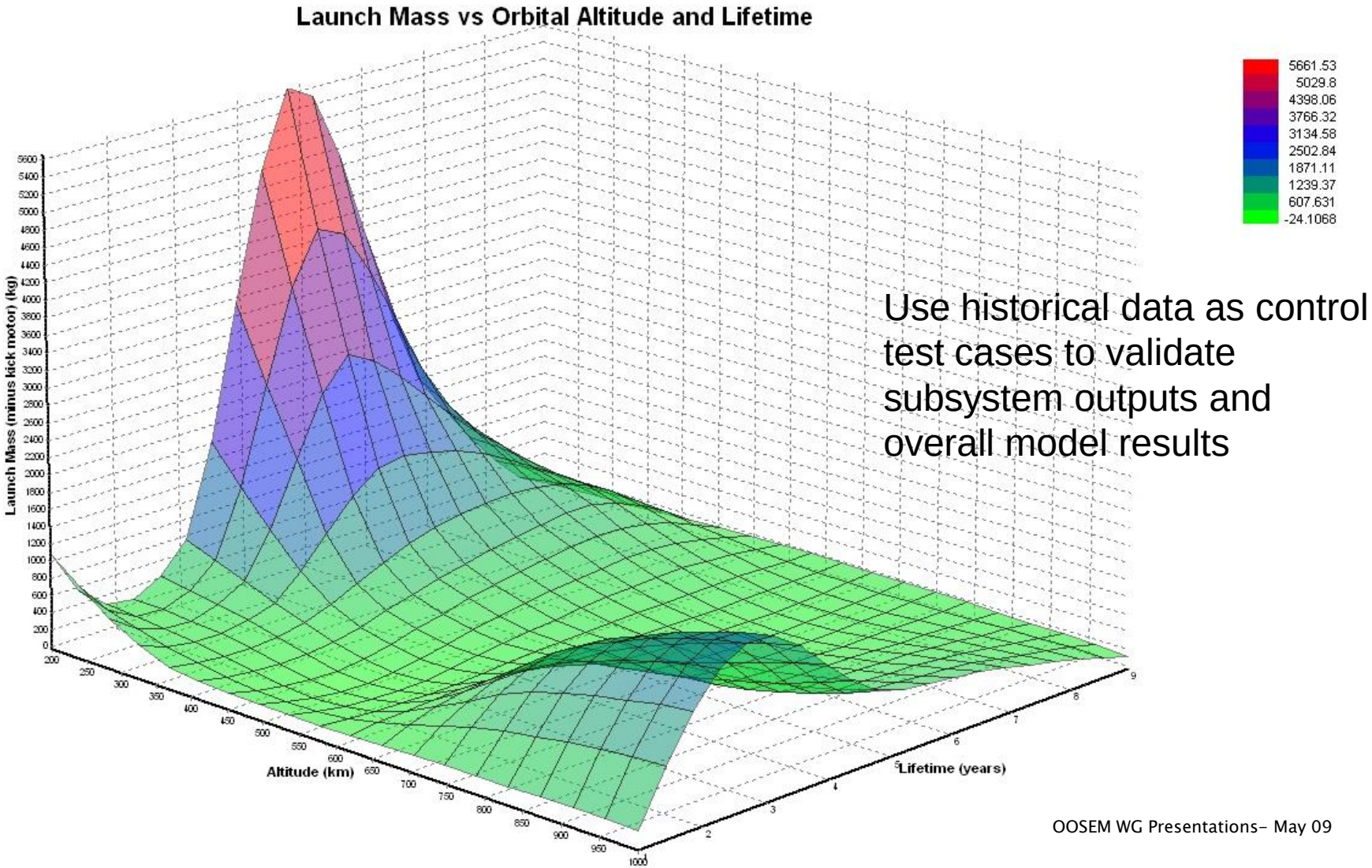
DSAN Collaboration Diagram

4. Model informs operations



OOSEM WG Presentations- May 09

System Results (MIT)



Use historical data as control test cases to validate subsystem outputs and overall model results

2009-10

- Integrate SMAD_Library & FireSat models
  - do example trade
- Continue to refine FireSat Models
  - State Analysis profile/artifacts
- Add Consultative Committee for Space Data Systems (CCSDS) & Reference Architecture for Space Data Systems (RASDS) views
- Continue to explore opportunities with future student teams
- Find real-mission example opportunities

Contacts and Websites

Presented by **the INCOSE OOSEM WG:**

L. Mark Walker, 301-543-5257, loren.m.walker@lmco.com

Mike Pafford, (240) 228-3174, mike.pafford@jhuapl.edu

Larry McGovern, lawrence.mcgovern@ngc.org

Sandy Friedenthal, sanford.friedenthal@lmco.com

Howard Lykins, Howard.Lykins@hq.doe.gov

Joe Wolfrom, joe.wolfrom@jhuapl.edu

Websites:

http://www.incose.org/

http://www.omgsysml.org/

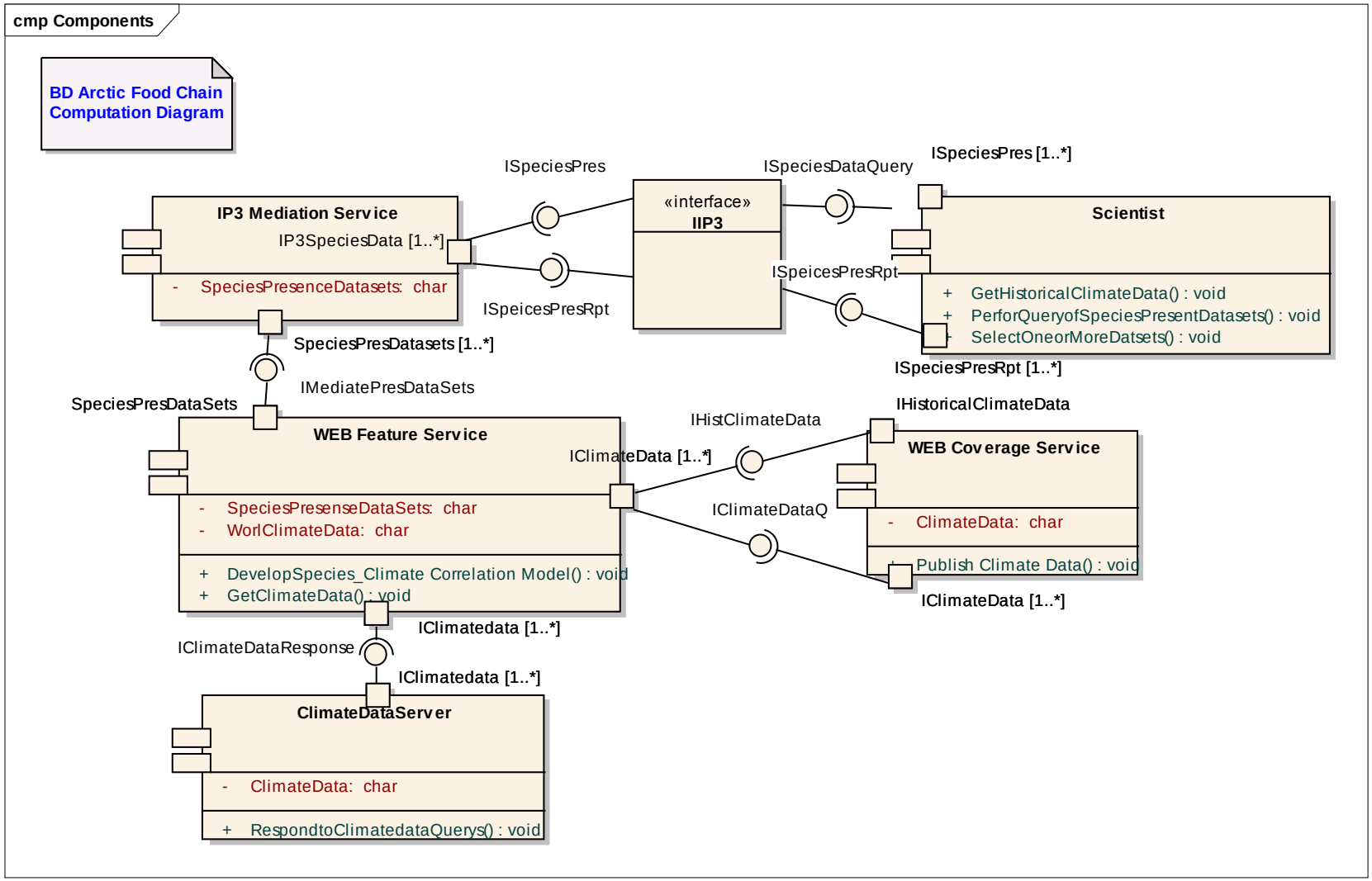
http://syseng.omg.org/

http://www.epa.gov/geoss/

Questions?

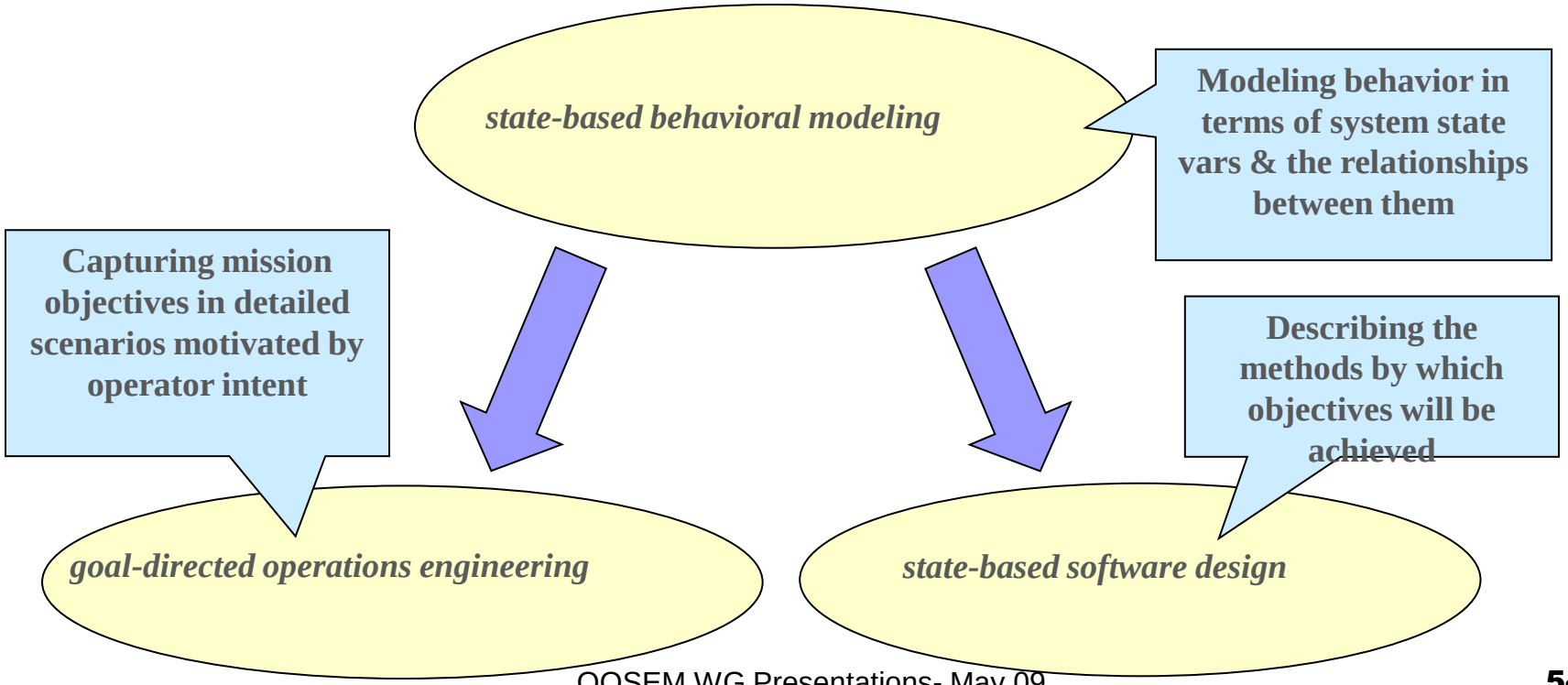
Backups

Arctic Food Chain

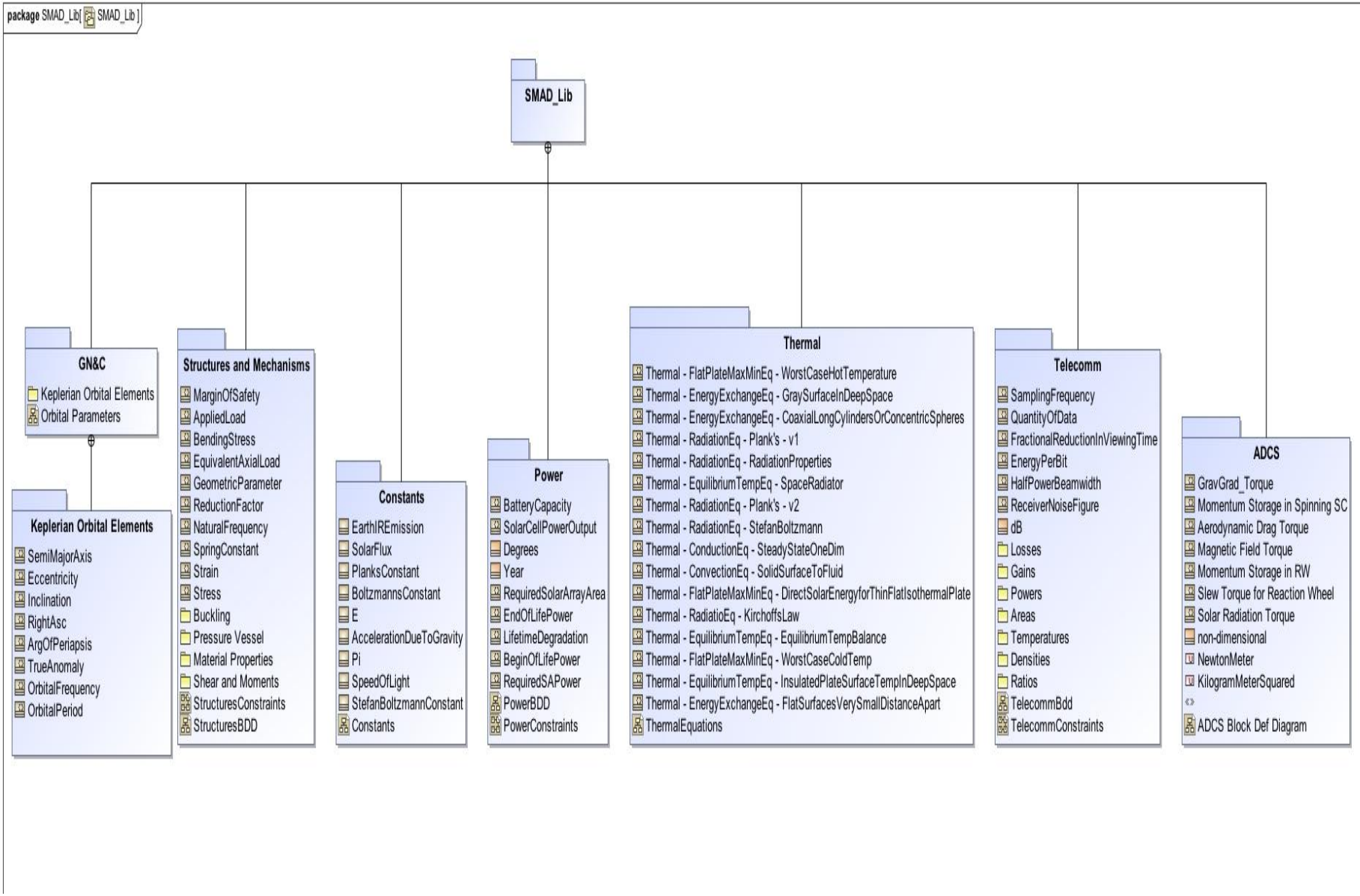


What is State Analysis?

- A model-based systems engineering methodology
  - Based on familiar principles from control theory
  - Complementary to the functional decomposition approach
  - Intended to help address the complexity challenge
- It provides a methodical and rigorous approach for:



Packages & Contents



FireSat Documented Examples

- requirements

FireSat
Mission Statement

Because forest fires have an increasing impact on recreation and commerce and ever higher public visibility, the United States needs a more effective system to identify and monitor them. In addition, it would be desirable (but not required) to monitor forest fires for other nations; collect statistical data on fire outbreaks, spread, speed, and duration; and provide other forest management data.

Ultimately, the Forest Service's fire-monitoring office and rangers in the field will use the data. Data flow and formats must meet the needs of both groups without specialized training and must allow them to respond promptly to changing conditions.

FireSat
Mission Objectives

Primary Objective:

To detect, identify, and monitor forest fires throughout the UnitedStates, including Alaska and Hawaii, in near real time.

Secondary Objectives:

To demonstrate to the public that positive action is underway to contain forest fires.

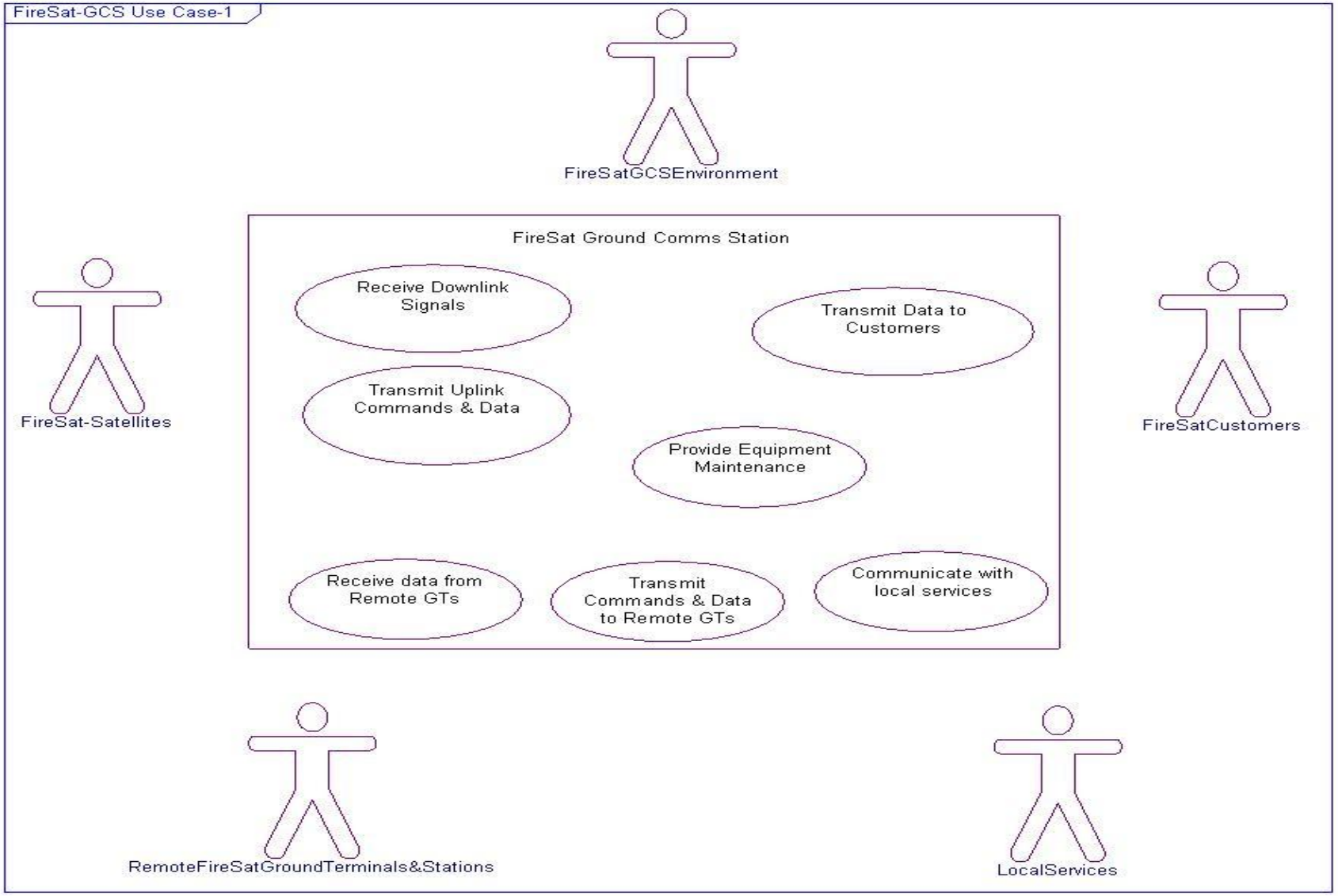
To collect statistical data on the outbreak and growth of forest fires.

To monitor forest fires for other countries.

To collect other forest management data.

From Space Mission Analysis and Design (SMAD), Third Edition, by Wiley J. Larson and James R. Wertz (editors).

Use Case- FireSat Ground



OOSEM WG Presentations- May 09

Complexity Controlled Through Simplification

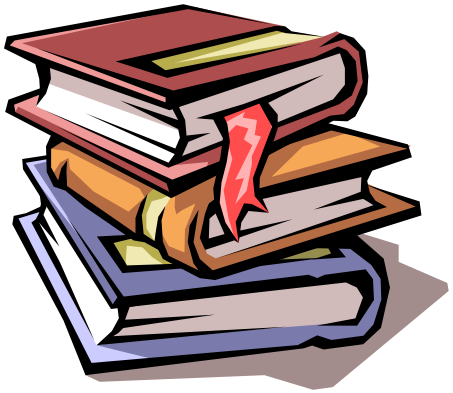
- MBSE provides a centralized repository for mission information.
- A modeling tool can present a project element (e.g., a requirement, a subsystem) and associated relationships
  - Avoid searching for information distributed over multiple documents.
- This greatly simplifies creating and changing project elements and propagating changes to related elements.

References

1. Estefan, J. *Survey of Model-Based Systems Engineering Methodologies.* INCOSE MBSE Focus Group Document. May 25, 2007.
2. Hassan, R. “Comparison of Sampling Techniques for Reliability-based Optimization of Communication Satellites Using Genetic Algorithms”. AIAA 2003-1332. Jan 2003.
3. Ingham M., Rasumessen, R. “Generating Requirements for Embedded Systems Using State Analysis”. IAC-04-IAF-U.3.A.05
4. De Koning H. P. “INCOSE Model Based Systems Engineering Grand Challenge. Proposed Contribution of the Space Systems Working Group”. V1.0, 2007, May 17.
5. Kordon M., Wall, S. “Model-Based Engineering Design Pilots at JPL.”
6. Kordon M. , Wood E. “Multi-Mission Space Vehicle Subsystem Analysis Tools”. Vol. 8-3699. IEEE Aerospace Conference Proceedings, Big Sky, MT., March 2003.
7. Martin J., Simpson T. “A Monte Carlo Method for Reliability-Based Design Optimization.” AIAA 2006-2146.
8. Terrile, R. “Automated Design of Spacecraft Telecommunications using Evolutionary Computational Techniques”.
9. Satellite Systems Engineering 16.851 MIT Aero/Astro Dept. ”FireSAT: A Description of a Systems Based Satellite Optimization Model” INCOSE International Workshop, January 2008.

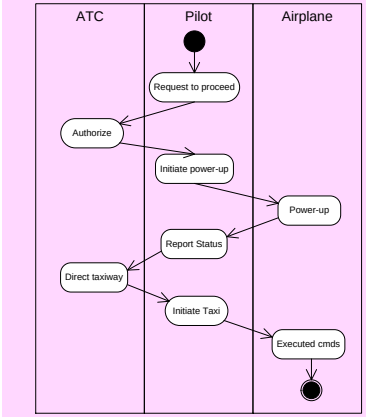
SE Practices for Describing Systems

Past



- Specifications
- Interface requirements
- System design
- Analysis & Trade-off
- Test plans

Future



Moving from Document centric to Model centric

SysML Diagram Taxonomy