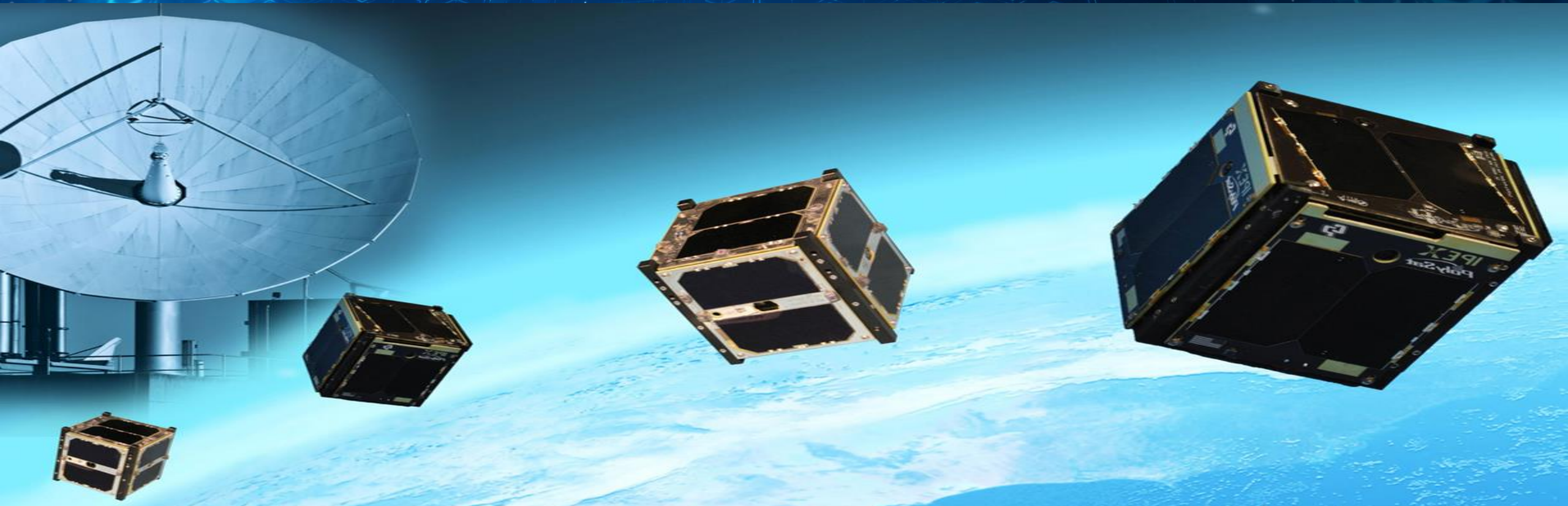
Driving Innovation for Enterprise Integration (Through Architectures, AI, Communications, Frameworks, Modeling, Ontologies, & Standards)

OMG Standards Development Organization®



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February 23, 2022

Overview

- OMG Introduction Highlights
- Unified Architecture Framework® (UAF®)
- Systems Modeling Language® (SysML®) Background & Way Forward
- CubeSat Systems Reference Model™ (CSRM™) and INCOSE CSRM Mission Engineering Initiative
- Translating CSRM Logical Model into a Physical Model (**a "Real World" Capability**)
- Other OMG Space Standards of Interest

OMG Managed Programs

The Object Management Group (OMG) mission is to develop technology standards that provide real-world value for dozens of vertical industries. OMG is dedicated to bringing together its international membership of end-users, vendors, government agencies, universities and research institutions to develop and revise these standards as technologies change throughout the years.

33 Years of Excellence

OMG Standards Development Organization

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OMG Vertical Markets

OMG Standards Development Organization

About OMG

- Founded in 1989
- International Standards Development Organization
- 250+ Specifications
- 240 Member Organizations
- 11 Specifications Ratified As ISO Standards

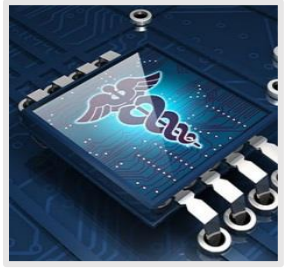
www.omg.org

Standards are developed by OMG using a mature, worldwide, open development process. With more than 33 years of standards work, the OMG one-organization, one-vote policy ensures that every vendor and end-user, large and small, has an effective voice in the process.

Finance

Government

Healthcare



Manufacturing

Military

Retail

Robotics

Space

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Who are OMG Members?

C4I Focused
Space Focused
SysML Focused

88solutions
Advanced Systems Management Group Ltd.
Airbus Group
AIST
Amergint Technologies
Analytical Graphics, Inc.
Appian Corporation
Auxilium Technology Group
BAE SYSTEMS
Bloomberg LP
BOC Products & Services AG
Boeing
BookZurman
Braxton Technologies, LLC
Caltech CTME
Camunda Services GmbH
Capsifi
Carnegie Mellon University
CAST Software
CCSDS
Collibra
Commissariat a l Energie Atomique-CEA
CONTACT Software
Dassault Systemes
Decision Management Solutions
Decisions
Dell Technologies
Delligatti Associates, LLC
Department of Navy
Department of Veterans Affairs
EASC e.V.
Elbit Systems of America
Elparazim
eProsima
FICO
Ford Motor Company
Fraunhofer FOKUS
Fujitsu
Georgia Institute of Technology
GfSE e.V.
GurumNetworks, Inc.
INCOSE
InterCAX
International Business Machines
JARA
K.U. Leuven
Kaiko
KDM Analytics
Kongsberg Defence & Aerospace
Kratos RT Logic, Inc.
Lockheed Martin
Mantech International Corporation
Maplesoft
Mayo Clinic
MEGA International
Mercury Systems
Micro Focus
Microsoft
MIT/Lincoln Laboratory
MITRE
Model Driven Solutions
NASA
Naval Surface Warfare Center
NIST
Northrop Grumman
OAR Corporation
Object Computing, Inc. - OCI
Objective Interface Systems
Office of the Secretary of Defense
oose Innovative Informatik eG
Open Geospatial Consortium
Peraton
processCentric GmbH
PROSTEP AG
ProSTEP iViP Association
PTC
QualiWare
Real-Time Innovations
Red Hat
Rolls-Royce Corporation
Sapiens Decision NA
Security Compass
Siemens
Signavio GmbH
Simula Research Laboratory
SimVentions
Softeam
Space Dynamics Laboratory
Sparx Systems Pty Ltd
Syntell AB
TCS
THALES
The Aerospace Corporation
The MathWorks
The Open Group
Thematix Partners LLC
Tom Sawyer Software
Trisotech
Twin Oaks Computing, Inc.
UML Technology Institute
Vanderbilt University
Visible Systems Corporation
Vitech Corporation
W3 Consortium
Webel IT Australia

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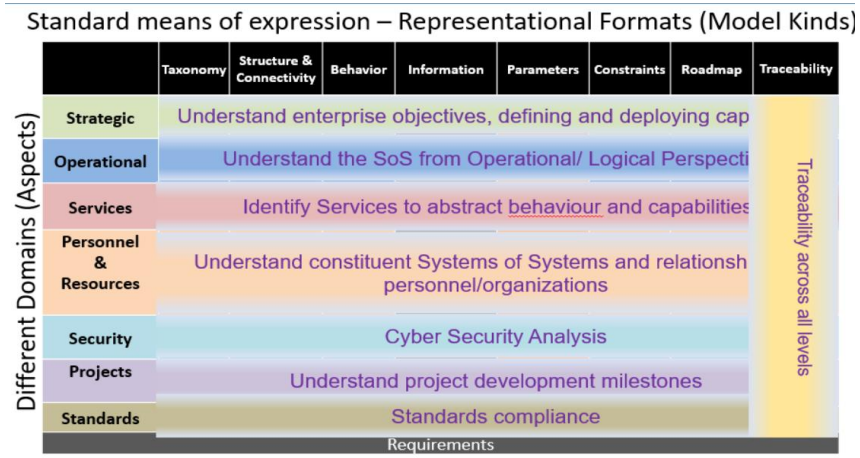
Why Use Frameworks ?

Frameworks such as Unified Architecture Framework (UAF)
represents the unification & demilitarization of a proliferation of defense AFs

- Supports semantic interoperability by using a common vocabulary enabling:
  - Portfolio and capability management
  - SoS Operational planning and Mission Engineering
- UAF is method agnostic (structured, OO, etc.)
- Extends DoDAF v2.2 and Unified Profile for DoDAF and MODAF (UPDM) with additional architectural dimensions: Security, Personnel, Requirements, Analysis, Simulation with full cross-cutting Traceability using a common semantic vocabulary & utilizes DoD Digital Engineer's Model of Choice – SysML®



Architecture Framework: Conventions, principles and practices for the description of architectures established within a specific domain of applications and/or community of stakeholders. ISO/IEC/IEEE 42010:2011

DoD Architecture Framework (DoDAF) v2.2 & Unified Architecture Framework (UAF®)

Standards Development Organization

DoDAF v2.2

- OMG Developed DoDAF in conjunction with DoD and Service Support, migrated it to v2.2, followed by MoDAF, NAF, Unified Profile for DoDAF and MoDAF (UPDM) – DoD CIO on record to support only DoDAF 2.2

- NATO requested one common architecture framework to aid in coalition warfare – UPDM migrated to UAF

- UAF **is** DoDAF 2.2 with UML / SysML applications

Unified Architecture Framework (UAF)

- **Is a profile extension of UML and SysML** developed by OMG with DoD, MoD & NATO involvement

- **Provides a common language and notations** for **model elements views** and viewpoints across multiple frameworks for describing an enterprise architecture

- **Provides element stereotypes for each domain for concepts** that are not supported by SysML

- **Includes elements such as timelines, milestones, and dates**

- **Provides Semantics & Ontologies** to drive **SoS coordination**

DoD DE's & NASA's Model of Choice

Program Description

SysML is a modeling standard that supports an open systems approach. Enables a common approach for specifying & architecting complex systems.

SEBoK GUIDE TO THE SYSTEMS ENGINEERING BODY OF KNOWLEDGE

https://www.sebokwiki.org/wiki/Guide_to_the_Systems_Engineering_Body_of_Knowledge_(SEBoK)

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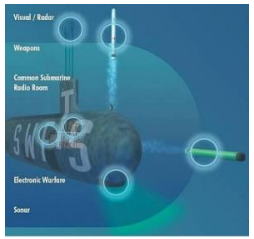
OMG SYSTEMS MODELING LANGUAGE SysML

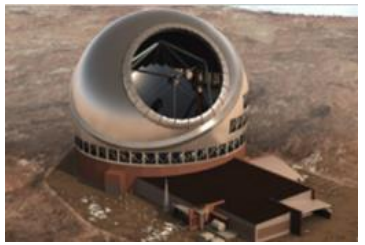
http://www.omgsysml.org/

Program Capabilities

- Modeling to automate requirements verification & generate SE products
- Benefits over a traditional document-based approach is that disconnected artifacts become related in the model, enabling the production of consistent model-based documentation.
- Allows req'ts verification analysis to be conducted in the context of MBSE.
- To perform this analysis, the requirements, executable behavior, and models predicting the system's performance is integrated.



Submarine Warfare Federated Systems



Thirty Meter Telescope

Program Modular and Open System Approach

Submarine Warfare Federated Tactical Systems

The submarine combat system SE&I program delivers updated annual production baselines, along with product line variants for each submarine class or subclass being built or upgraded that year.

Thirty Meter Telescope (TMT)

The MBSE approach applied the Executable Systems Engineering Method (ESEM) and the Open-source Engineering Environment (OpenMBEE) to specify, analyze, & verify requirements of TMT's Alignment & Phasing System (APS) and the Narrow Field Infrared Adaptive Optics System (NFIRAOS).

Key Accomplishments/Status

- Production systems implementing this baseline are delivered to new-build submarines, and to in-service submarines being upgraded on a roughly 6-year cycle. The common combat system product line is referred to as the Submarine Warfare Federated Tactical Systems (SWFTS).

- The value proposition for applying this MBSE approach to was to establish precise requirements and fine-grained traceability to system designs, and to verify key requirements using executable SysML models beginning early in development for Large Telescopes.

- **SysML v2 is the Next Generation Systems Modeling Language that provides significant upgrades** and a standardized API for improved interoperability amongst models

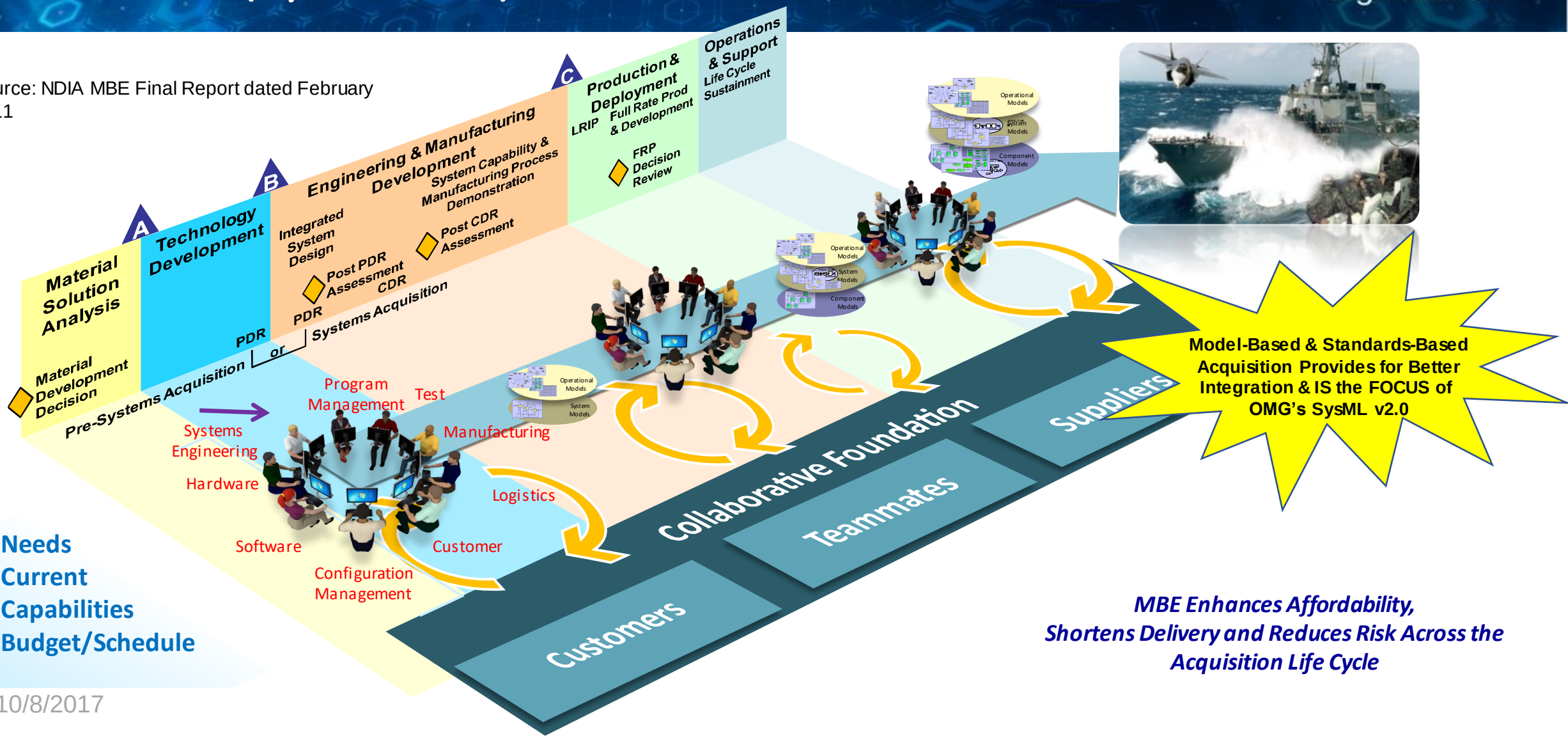
Key Milestones – SysML Historical Updates

SysML v1.0	2007	SysML v1.4	2015	**SysML 2.0 In Development**
SysML v1.1	2008	SysML v1.5	2017	**Final Submission**
SysML v1.2	2010	SysML v1.6	2019	
SysML v1.3	2012	SysML v1.7	2021	**Q3 2022**

Model Based Engineering To Be State (SysML v2.0)

Standards Development Organization

Source: NDIA MBE Final Report dated February 2011



- Needs
- Current Capabilities
- Budget/Schedule

MBE Enhances Affordability, Shortens Delivery and Reduces Risk Across the Acquisition Life Cycle

10/8/2017

CubeSat Systems Reference Model™ (CSRM™)

OMG Standards Development Organization

The International Council of Systems Engineers (INCOSE)

- Utilized OMG's Systems Modeling Language to Develop
- A CubeSat Systems Reference Model that provides information
  - **For universities, students, businesses and developers of CubeSats & Satellites**
  - Provides Behavior modeling between subsystems
  - Validation & Verification (V&V) processes
  - Coordination points for launch

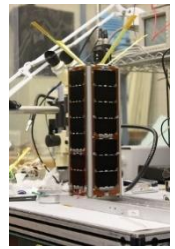
[Model Based Systems Engineering](#) (MBSE)

Formalized application of modeling to support requirements, design, analysis, validation, and verification

[Systems Modeling Language®](#) (SysML®)

A graphical modeling language for modeling complex systems including hardware, software, information, personnel, procedures, facilities and Coordination's

Systems Engineering Methodology	System Modeling Tools	Interfaces with Other Models



Purpose: Provides a [CubeSat Systems Reference Model](#) that CubeSat Teams can use as a starting point for their mission-specific CubeSat

CSRM™ Attributes

What CSRM Does & Doesn't Do

- Provides a CubeSat **logical space-ground architecture**
  - Logical components are:
    - **Abstractions of physical components** that perform system functionality w/o imposing implementation constraints.
    - **Starting points** for a mission-specific CubeSat logical architecture, followed by the physical architecture and the CubeSat development
  - **Establishes a foundation for a Physical architecture that defines physical components** of the system including hardware, software, persistent data, and operational procedures.
- **Integrates five overarching elements**: stakeholders, technical measures, behaviors, requirements, and architecture.
- Provides for **defining and tracing requirements** from stakeholders, to behaviors, technical measures down to subsystems and components to be certified through validation and verification activities.
- **A repository** for systems engineering artifacts. However, it is not pre-populated with specific stakeholders, technical measures, behaviors, and requirements.
  - **It's the CubeSat mission development team's responsibility to populate** based upon their needs and objectives.
  - Development of a mission-specific CubeSat utilizing the CSRM™ establishes a mechanism to share and reuse components with other design activities.

CSRM Attributes (Cont'd)

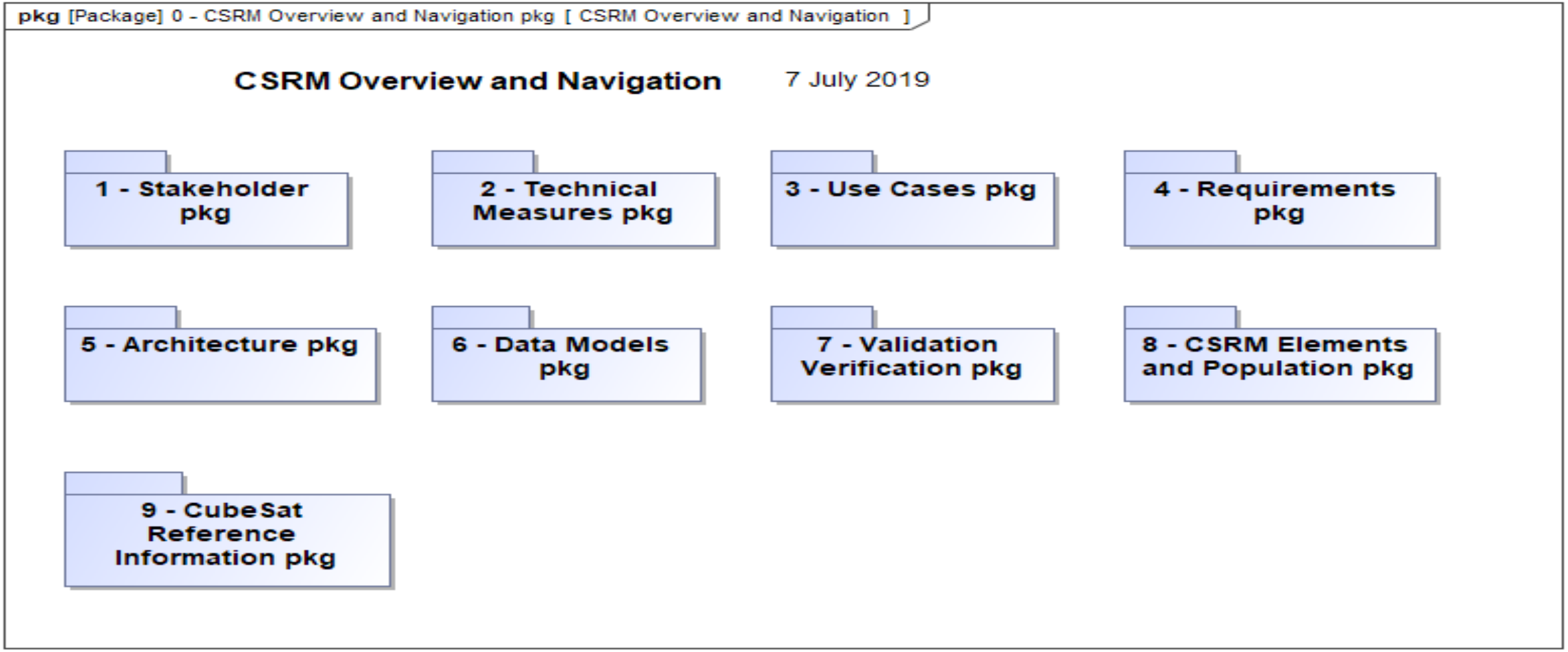
- A mission-specific CubeSat team **downloads the CSRM Specification and files from OMG (Free)** for import it into their own graphical modeling tool.
- The mission team identifies the systems engineering methodology to be followed and revises the model, elements, relationships, and diagrams as needed.

KEY Take Aways:

- The CSRM™ is based on MBSE principles, is SysML v1.6 compliant, and is hosted in a graphical modeling tool.
- The CSRM™ is a Reference Architecture in accordance with the Mission Engineering Approach and Methodology delineated in the DoD Mission Engineering (ME) Guide.
- The mission-specific team is free to adopt a different logical architecture and modify the CSRM™ to accommodate this change.
- INCOSE & OMG are developing an extended ME Capability to address detailed ME Operations for the future

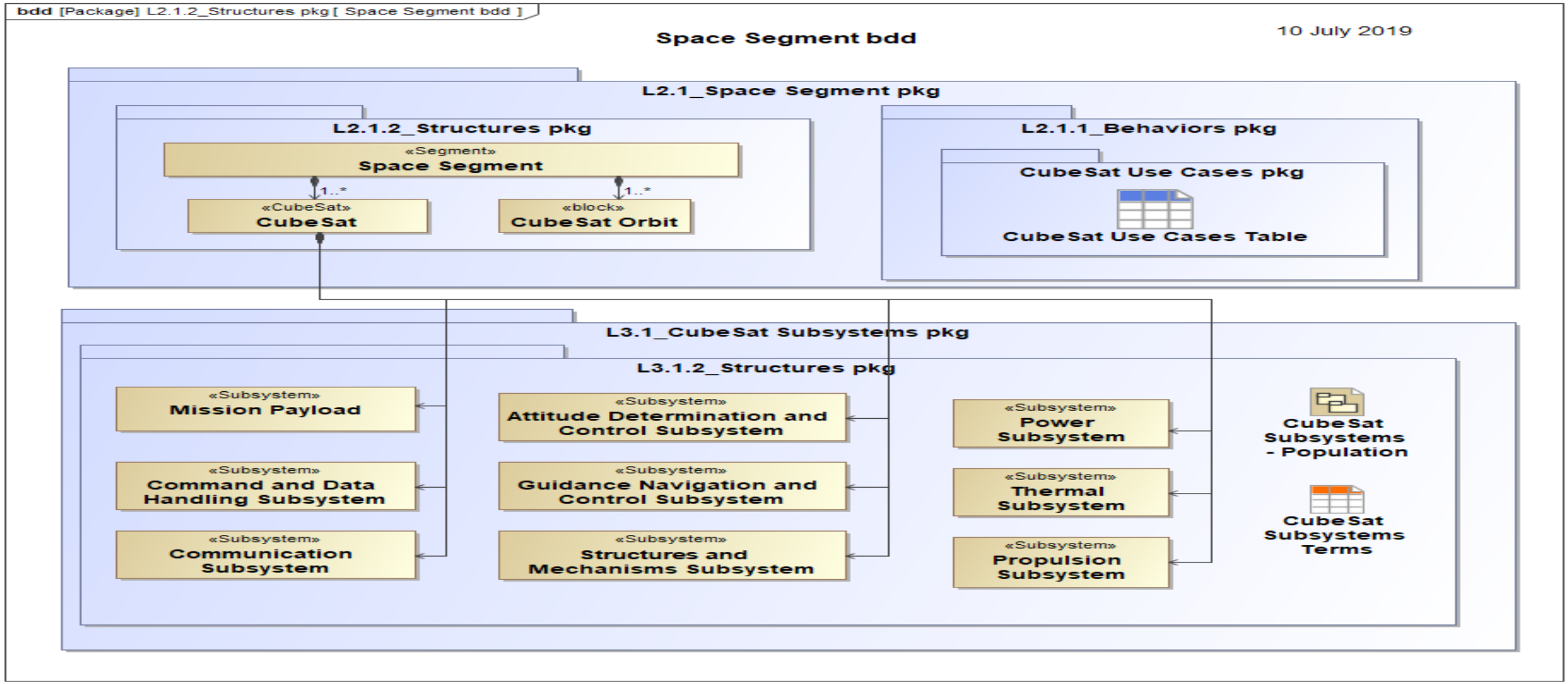
CubeSat Systems Reference Model™ (CSRM™)

Model Overview & Navigation Package



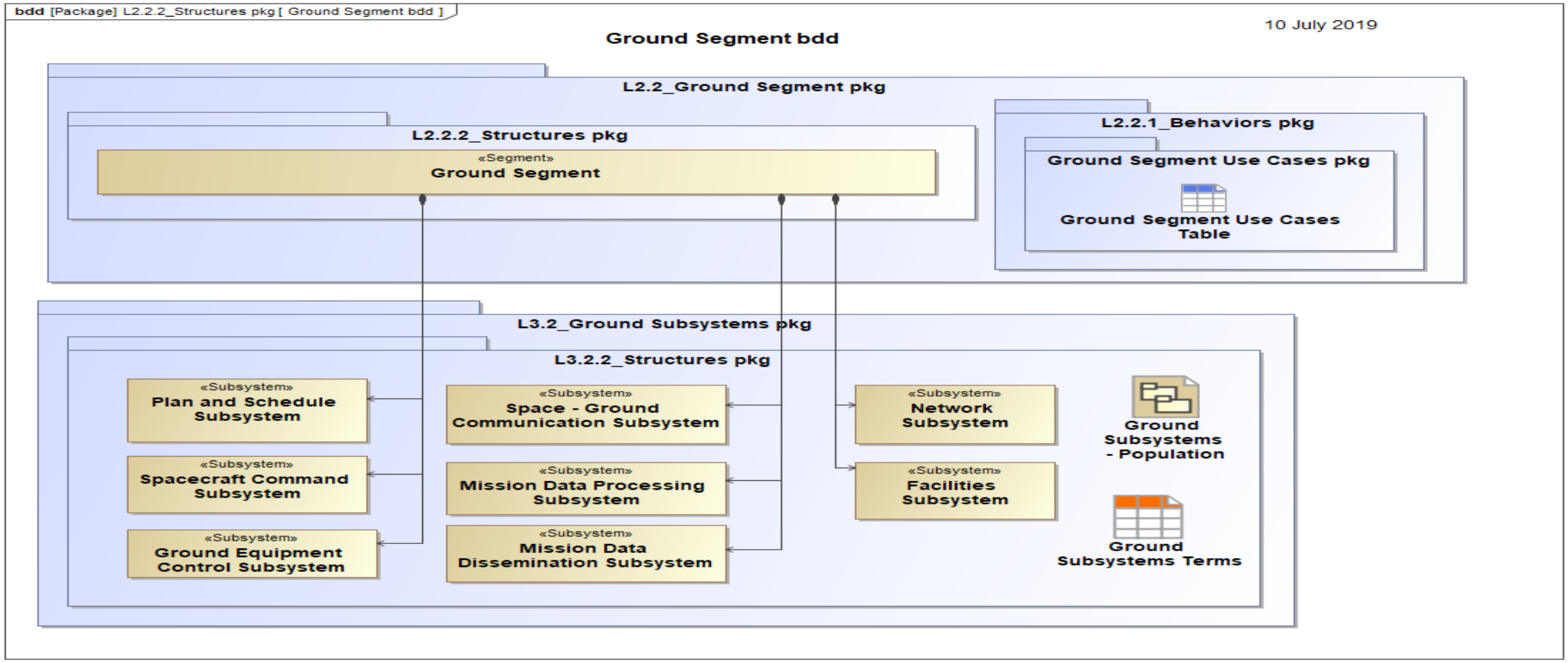
CubeSat Systems Reference Model™ (CSRM™)

Space Segment Structures Package

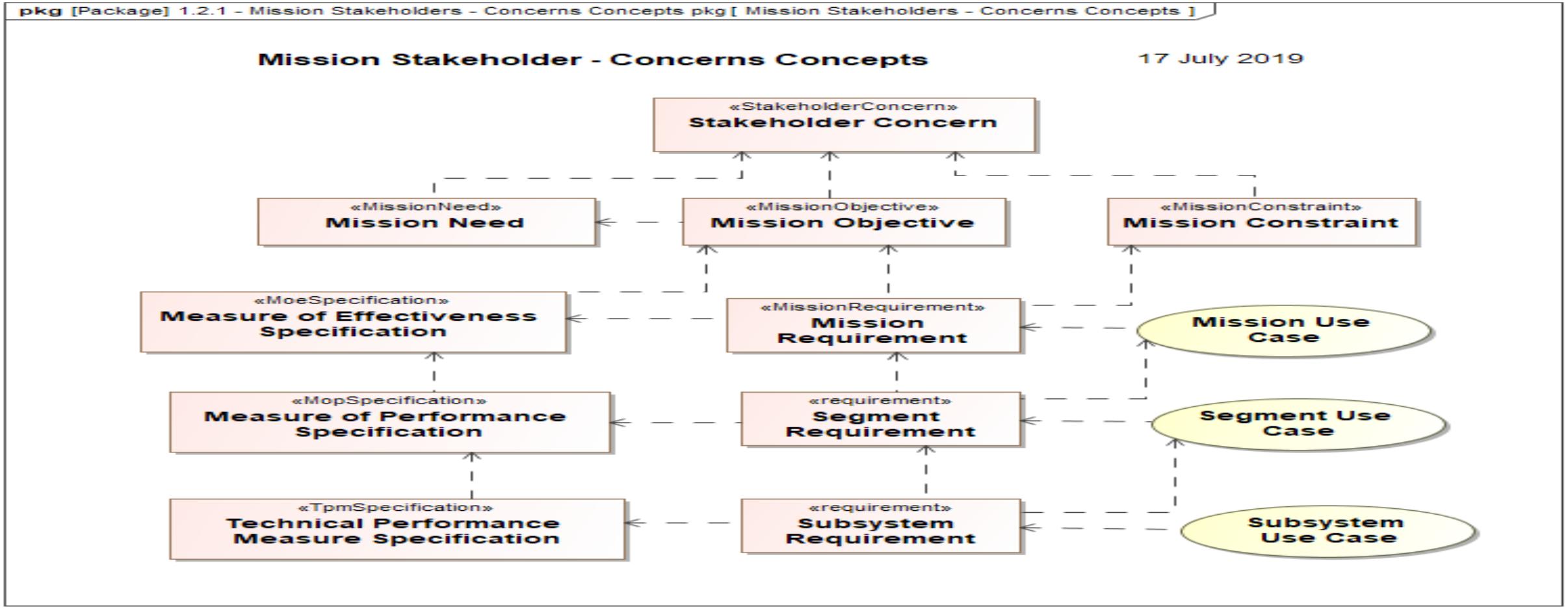


CubeSat Systems Reference Model™ (CSRM™)

Ground Segment Structures Package

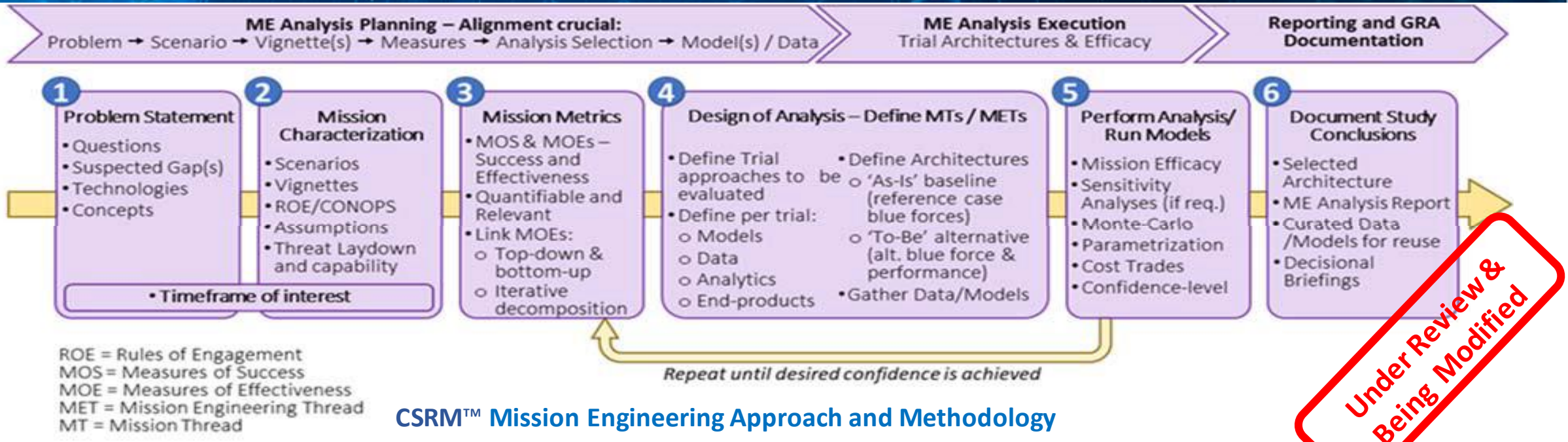


CubeSat Mission Stakeholders & Requirements



OMG Members (DoD, NASA, Industries & Universities) Were Utilizing this Model on Missions Prior to Adoption & Publishing

CSRM™ Mission Engineering Initiative



CSRM™ Mission Engineering Approach and Methodology

Under Review & Being Modified

Step 1. **Problem Statement Artifacts** includes stakeholders and their needs and objectives.

Step 2. **Mission Characterization Artifacts** include mission, segment, and subsystem use cases. in support of mission data tasking, collection, and distribution thread.

Step 3. **Mission Metrics Artifacts** include measure of effectiveness, measures of performance, and technical performance measures.

Steps 4-6 are carried out using:

- **Mission Specific Model (MSM)** based on the CSRM™ descriptive model
- **Time-Based Dynamic Model (TBDM)** needed for trade studies

CSRM™ Mission Engineering Process

Standards Development Organization

1 Identify Mission Engineering Methodologies

Space Mission Analysis and Design

Space Mission Engineering is the refinement of requirements and definition of mission parameters to meet the broad objectives of a space mission in a timely manner at minimum cost and risk

DoD Mission Engineering Handbook

Mission Engineering is the deliberate planning, analyzing, organizing, and integrating of current and emerging operational and system capabilities to achieve desired warfighting mission effects

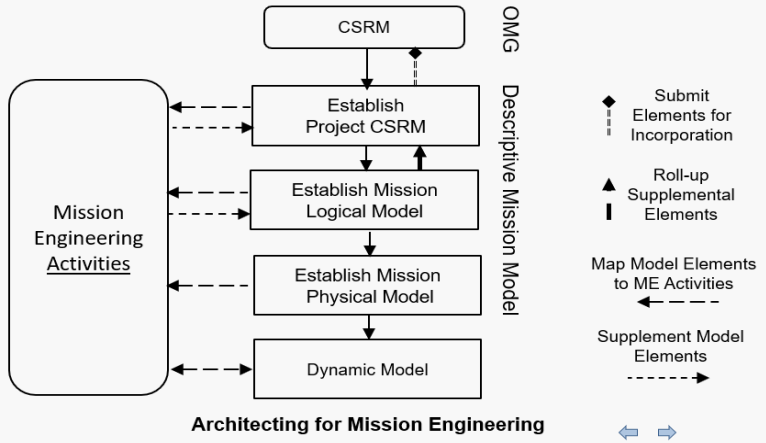
INCOSE Systems Engineering Book of Knowledge

Mission Engineering describes the application of systems engineering to the planning, analysis, and designing of missions where the mission is the System of Interest

Mission Engineering analyzes the mission goals and threads, analyzes the available as well as emerging operational and system capabilities, and designs a mission architecture to achieve the mission goal

Different domains have different mission engineering methodologies

2 Mission Engineering Scope



Architecting for Mission Engineering

3 Map and Supplement CSRM Elements

INCOSE ME Activities

- Mission Capability Analysis and Definition
- Mission Thread Definition
- Tradeoff Analysis
- Mission Architecting
- Requirements Engineering
- Interoperability Analysis
- Mission-oriented SoS Implementation
- Mission Verification and Validation

Map

Supplement

CSRM Elements

- Stakeholders
- Mission Objectives
- Mission Constraints
- Requirements
- Behaviors
- Technical Measures
- Architecture
- Validation Activities
- Verification Activities

The focus is on logical model that will be populated as a physical model

AN OMG STANDARD
CSRM
CubeSat System Reference Model

INCOSE

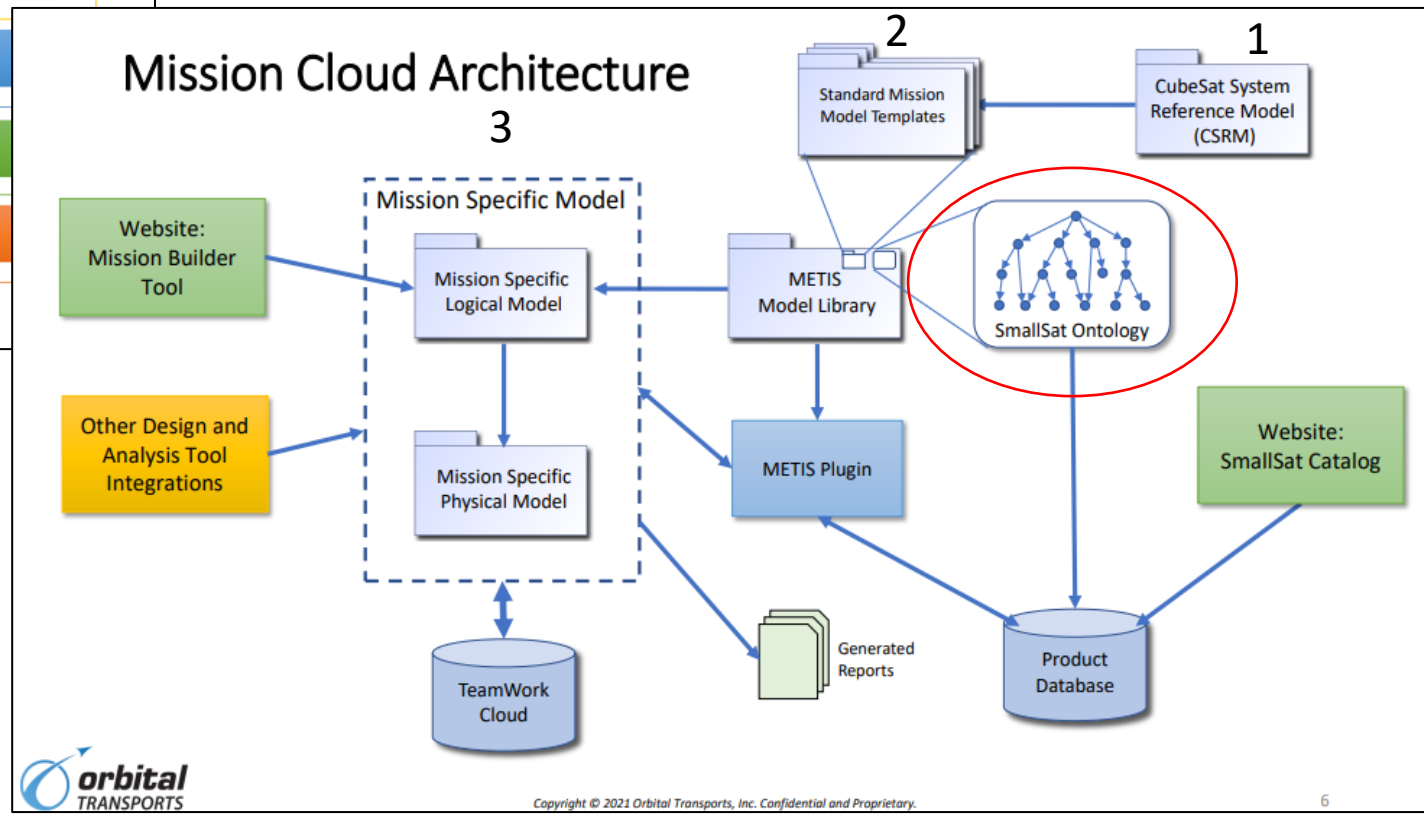
Orbital Transport's (OT) Work is built upon CSRM but extends CSRM significantly

Orbital Transports Mission Cloud

- Cloud-based, integrated digital engineering system
- Simplifies and accelerates SmallSat mission life cycle
- Rapidly select and develop mission models
- Mission Design Tool: web-based front end
- Access to OT SmallSat Catalog of partner products and services
- Perform trade analyses and price comparisons

orbital TRANSPORTS

Mission Cloud Architecture



orbital TRANSPORTS

6

Primary Model Elements Provided by Mission Template Models

- Stakeholders
- Technical Measures
- Use Cases
- Requirements
- Logical Architecture
- Validation and Verification
- Physical Design
- Project Plan and Schedule

} CSRM

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Orbital Transportation – Mission Cloud Concept – Transitioning from Logical to Physical Architecture

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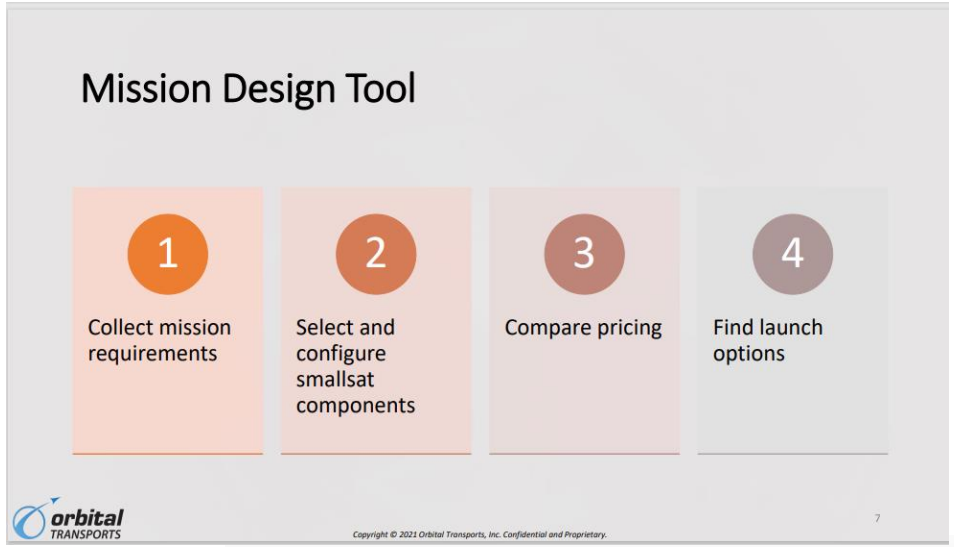
CSRM

CubeSat System Reference Model

INCOSE



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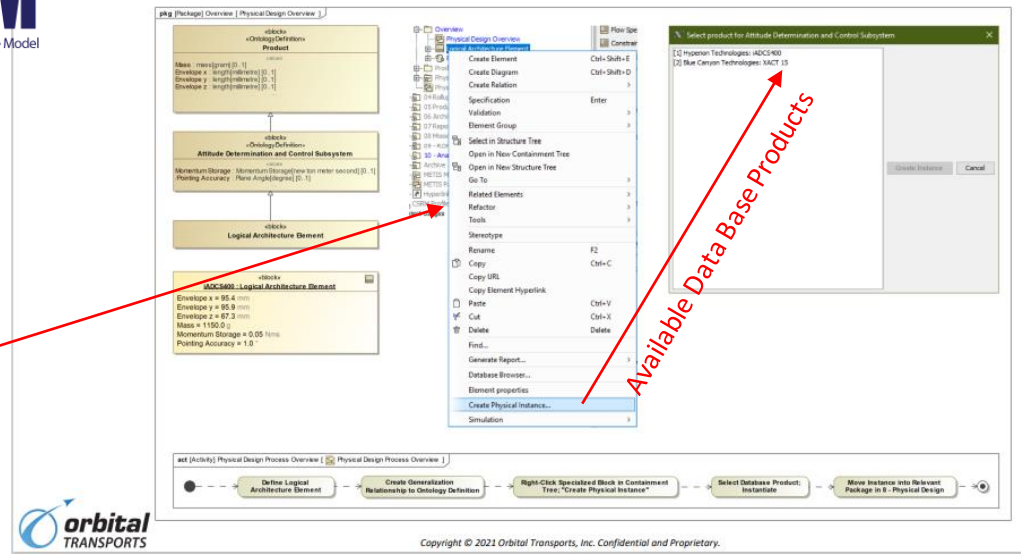
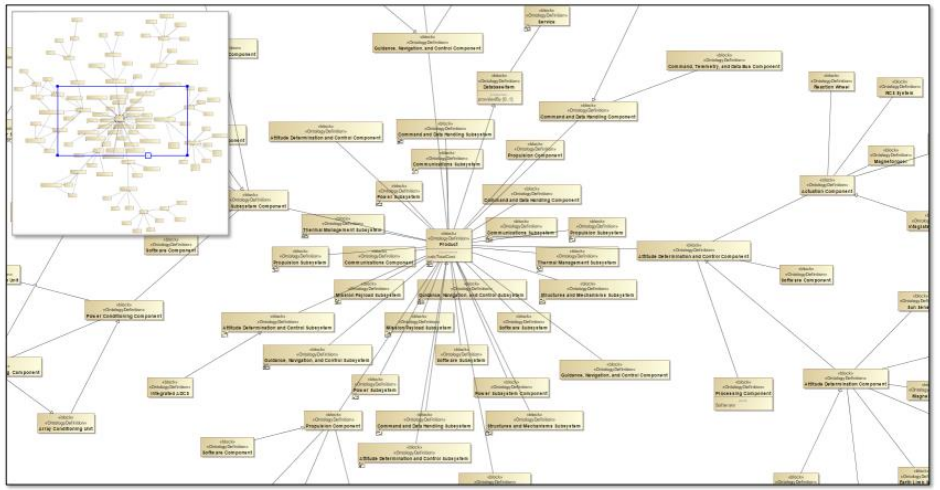
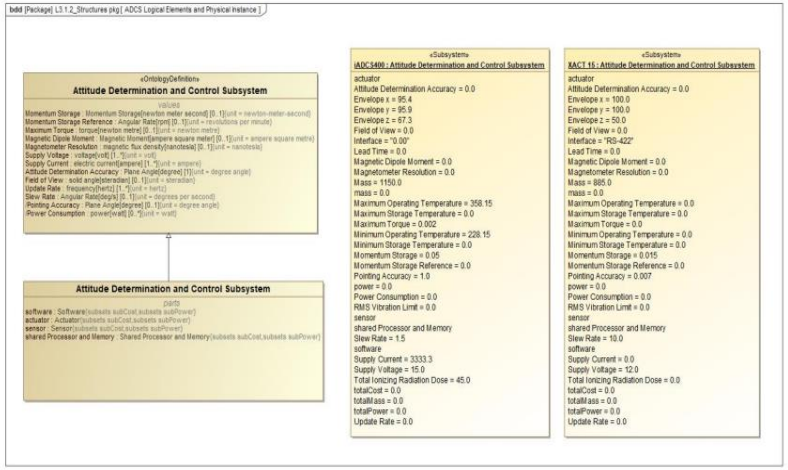
Logical Architecture to Physical Design Process



Product Ontology



Logical Elements and Physical Instances



What is the story here ?

- The logical architecture defines logical elements corresponding to an abstract architecture.
- The block elements describe relatively generic subsystems and components (e.g., OBC, ADCS, etc.). These items are linked by generalization relationships to corresponding definitions in the Ontology, so they inherit the attributes and properties from the Ontology definitions.
- Physical instances are created from the logical elements to represent a specific physical implementation (e.g. Hyperion iADCS 400). The instance properties are defined by the ontology definitions and their values are populated with data retrieved from the product database.
- The Logical Architecture to Physical Design slide is representative of the process of selecting an element from the Logical Architecture, choosing a product from the product database corresponding to the selected architecture element, and automatically creating the physical instance using the product data retrieved from the database.
- The Logical Elements and Physical Instances slide shows the ontology and logical architecture block defining the ADCS subsystem and two physical instances with the property values populated for two different products.

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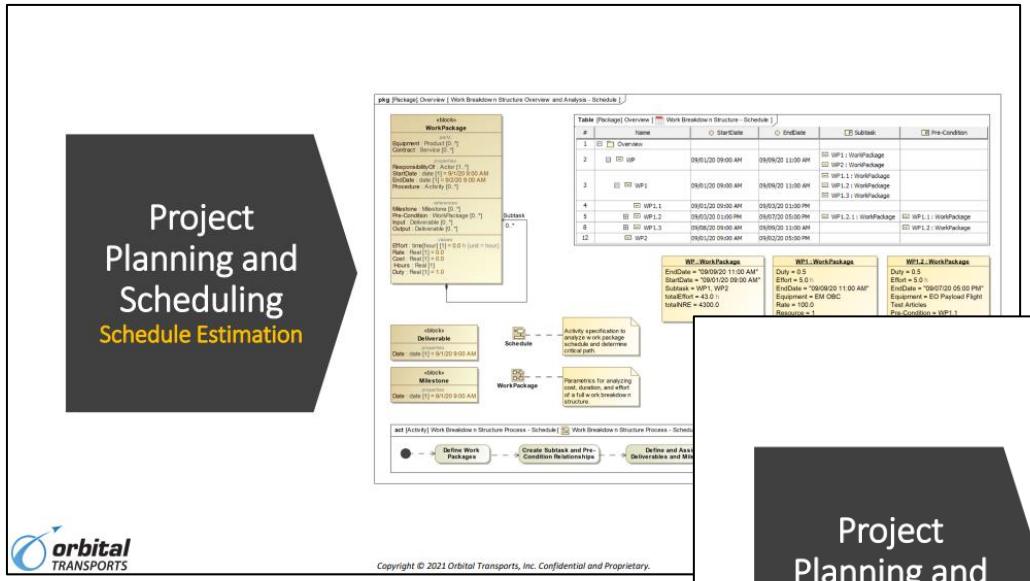
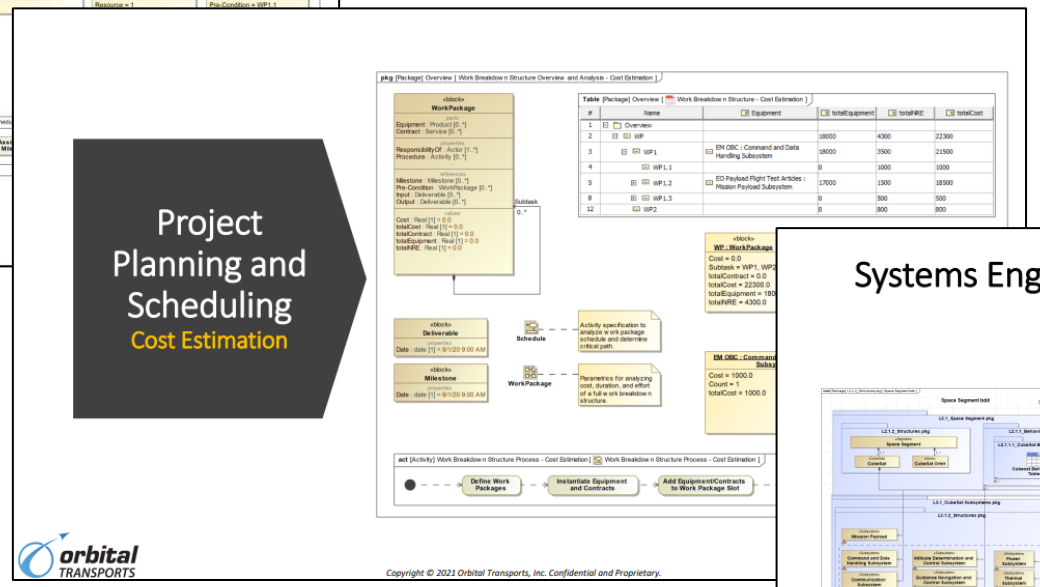
CSRM
CubeSat System Reference Model

INCOSE

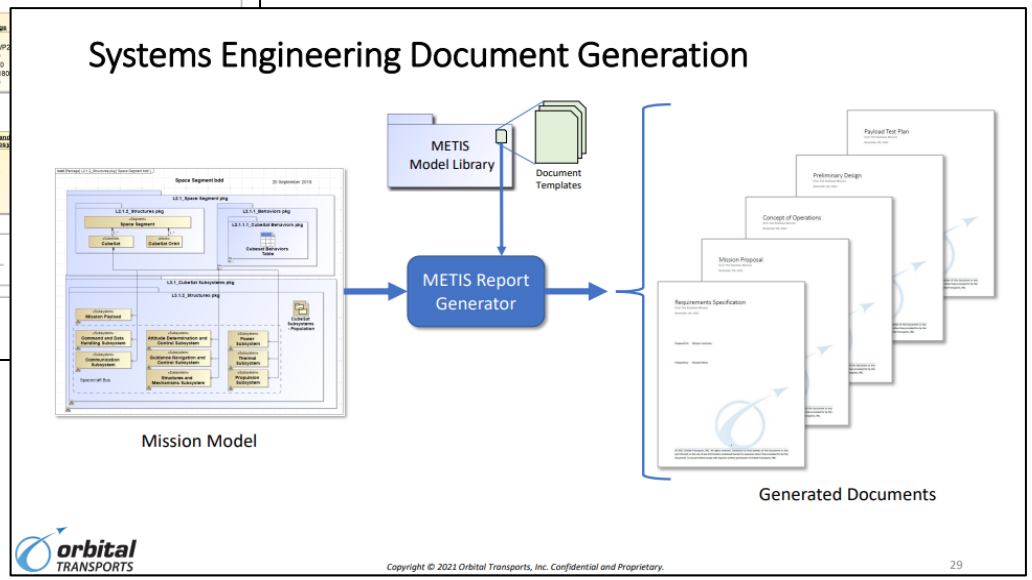
The Model is the Source of Truth

Once the previous SE steps are completed, then cost & schedule are estimated, Document Generation is printed for review





OT's Mission Model Drives the Documents
(Docs do NOT Drive the Process)



OMG Standards Development Organization

First Projected Launch October 2022

Once QAE Council Review Completed – Documents are Submitted to Customer

OMG's Space Domain Task Force (SDTF)

OMG Standards Development Organization

What is it ?

And What does it Do?

Specifically chartered to foster the development of space-related standards

The OMG Space Domain Task Force (DTF)

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- Space professionals committed to greater interoperability, reduction in costs, schedule, and risk for space applications through increased standardization

- The SDTF works cooperatively with the CCSDS to ensure consistent space standards are developed.

- OMG's Space DTF is Fast but not too fast : 9 - 24 months to deliver a standard
- Final Results are specifications and interfaces NOT products
  - Implementations of OMG specifications by users
  - Those implementing specifications need not be OMG members
  - Specifications are *freely* available
- Collective Wisdom - Broad Range of Input
- Standards/Specifications based upon Gov't & Industry Consensus

Space DTF Specifications (Freely Available)

https://www.omg.org/space/

OMG Space Domain Task Force (DTF) Delivered Specifications

- XTCE (XML Telemetry and Command Exchange) (1.1)
- GEMS (Ground Equipment Monitoring Service)
- SOLM (Spacecraft Operations Language Metamodel)
- C2MS (Cmd & Control Mission Services)
- CSRM (CubeSat Systems Reference Model) (INCOSE & OMG Product)

Work-In-Process

- Display Page Exchange
- CubeSat Mission Engineering

Space & Other Relevant Specifications Being Initiated

Future Work being Considered

- archiving, display, & Ontology
- Ground Station Ontology (Spacecraft Operations Language Metamodel),
  - http://www.omg.org/hot-topics/spacecraft-ground-systems-rfi.htm
- Data Archiving
- Cyber Security
- Telescope Reference Model

Other OMG Relevant Specifications to Consider

- Middleware and Related Services (MARS) Secure Networking Communications WG
  - **Space Telecommunications Interface (STI) – OMG AB Approved Beta Spec – Available NOW**
  - Data Distribution Services (DDS)
- C4I:
  - Information Exchange Framework (IEF)
  - Cyber Security for Front Line Systems
  - **Alert Management Service (ALMAS)** Alarms & Event Notification and Scheduling

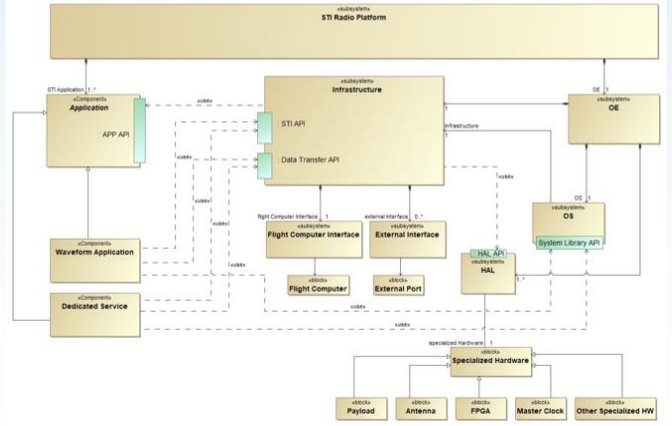
- **Hybrid Adaptive Networking – 2022 ??**

Space Telecommunications Interface (STI) (Beta)
OMG Middleware and Related Services (MARS)
Platform Task Force (PTF)

Standards Development Organization

- **Space Telecommunications Interface (STI) v1.0 Beta is developed to be Software Communications Architecture (SCA) v4.1 Compliant – Developed from NASA's Space Telecommunications Radio Service (STRS)**
- **Moves from UML based SCA to SysML based (backward Compatible)**
- **The Finalization Task Force (FTF) is expected to be Complete by Mar 2022**

STI System Architecture Overview

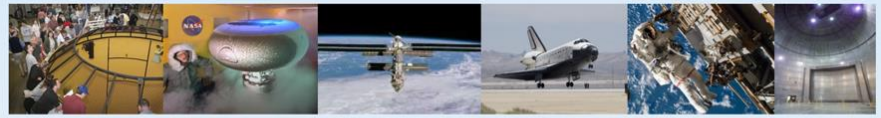


National Aeronautics and Space Administration

System Architecture

- STI defines the various roles and responsibilities of the stakeholders
  - Defined roles and integration points allows for more parallel development efforts, vendor independence
- Emphasis of standard is different for different system roles
  - Focus on a specific software interface (i.e. API) to ensure portability
  - Focus on documentation of system capabilities rather than prescribing a specific set
- This approach allows some component re-use while still allowing the overall system to be tailored to the specific deployment environment and requirements

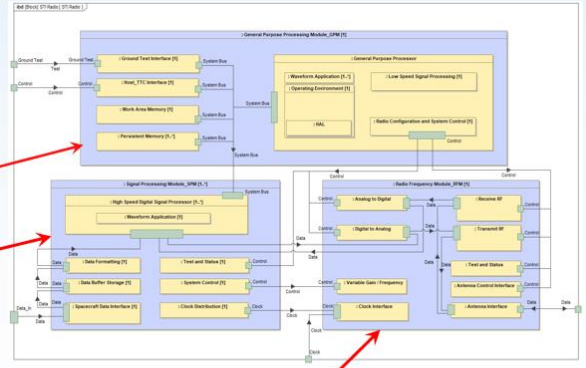
National Aeronautics and Space Administration



STI Overview – Hardware Architecture

STI defines fundamental blocks of a generic SDR platform

- General Processing Module (GPM) hosts the control plane
- Signal Processing Module (SPM) hosts the data plane
- Radio Frequency Module (RFM) provides the radio interface



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Space Telecommunications Interface (STI) (Beta) (Cont'd)

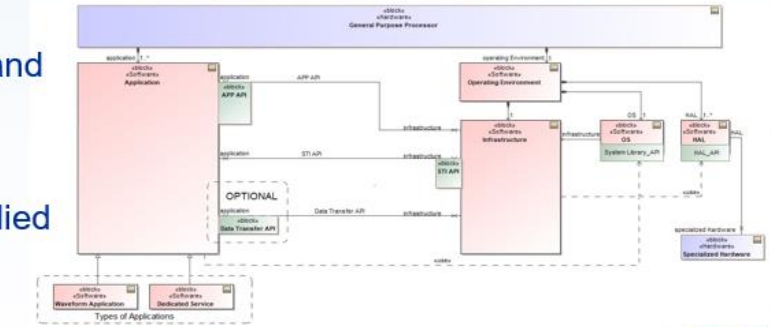
STI Software Operating Environment Model

Proposal prescribes specific API requirements for items between the STI Infrastructure and waveform/application services layers

- Allows portability of software elements between different OE implementations

Proposal prescribes documentation requirements for layers below the STI Infrastructure

- Specialized hardware and hardware system limitations/capabilities defined in vendor-supplied documentation.



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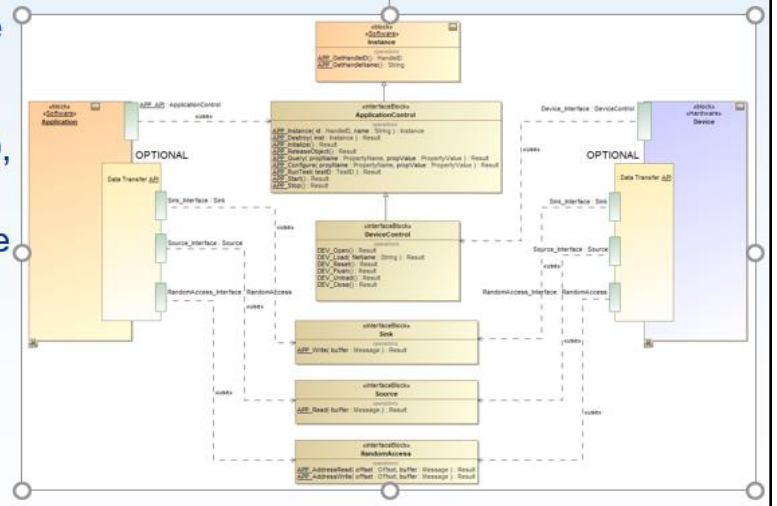
STI Application Software Interface Structure

- Proposes a SW Interface structure similar to existing SDR standards (NASA STRS, SWRADIO, SCA)
- Software written for these other environments should be usable without extensive rewrites or refactoring



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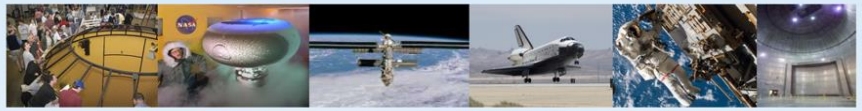
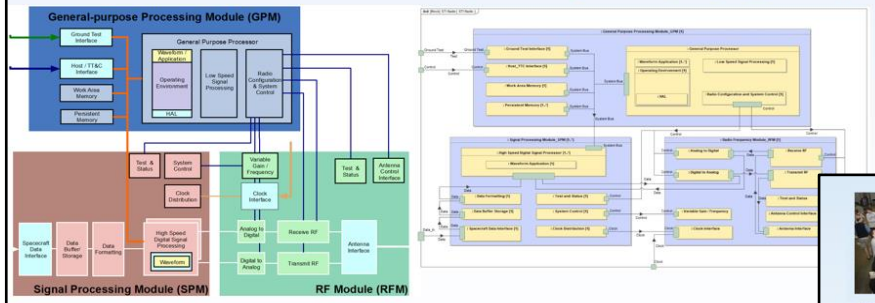
Changes Made From STRS to STI



Changes to Figure 3: Notional STI Hardware Architecture

Before:

After:
(Deleted figure 2 specifying colors)



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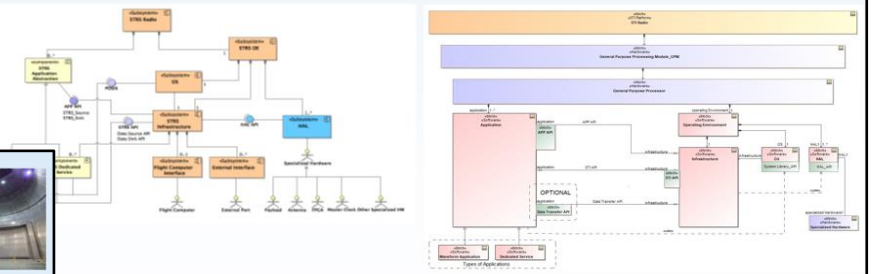
Changes to Figure 10: Layered Structure

Before:

After:
(Became figure 7)



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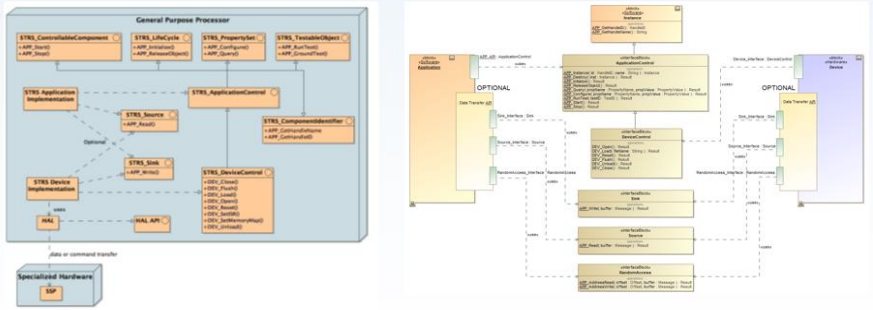
Changes to Figure 14: Application and Device Structure

Before:

After:
(Became figure 9)



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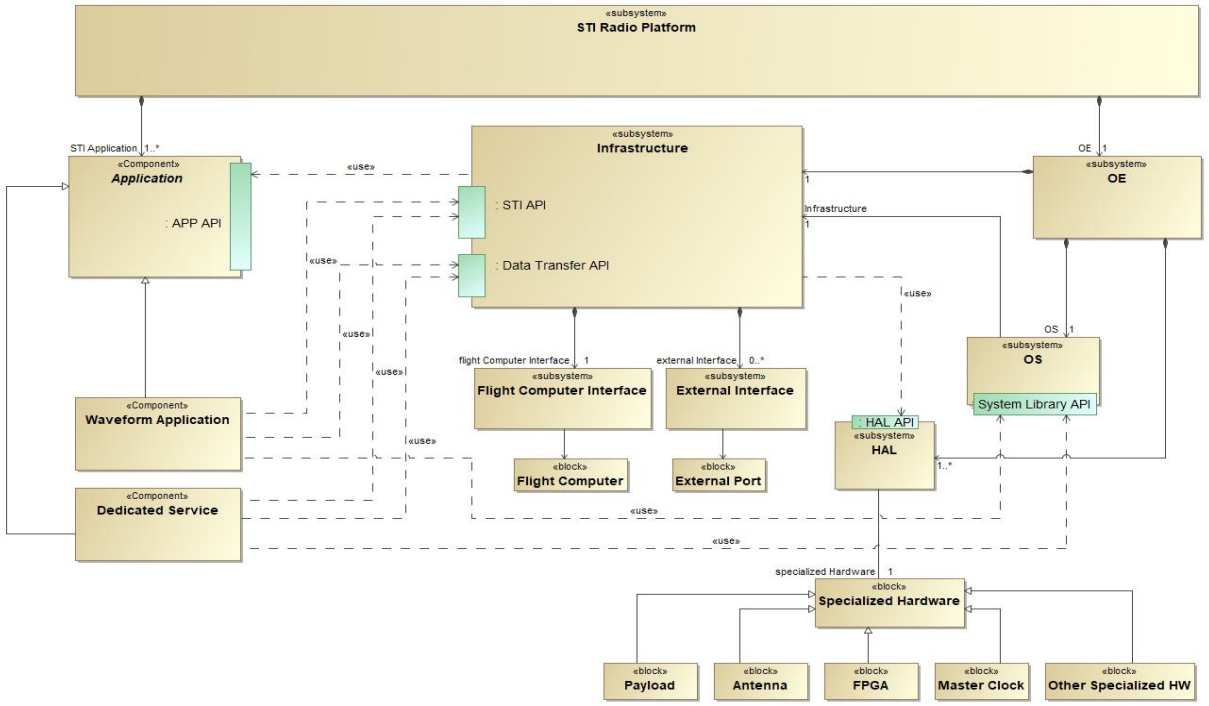
Space Telecommunications Interface (STI)

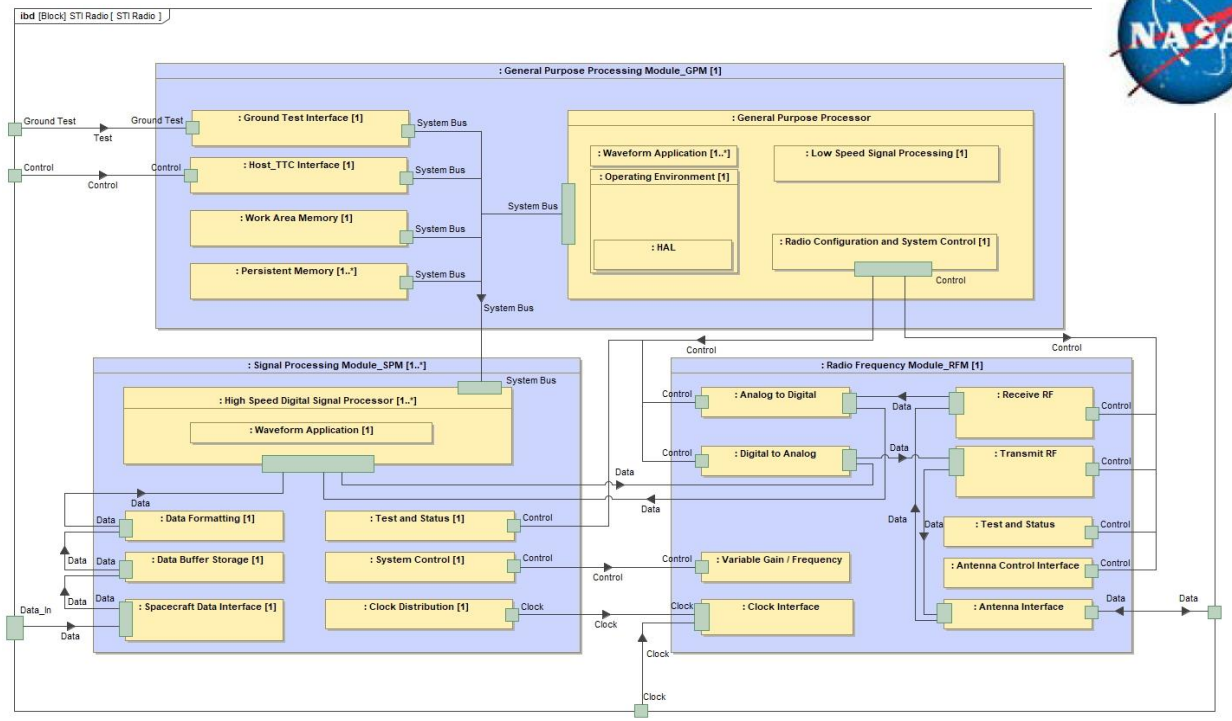
OMG Middleware and Related Services (MARS)

Platform Task Force (PTF)

OMG Standards Development Organization

STI System Architecture Overview – Extends SCA from UML to SysML v1.6





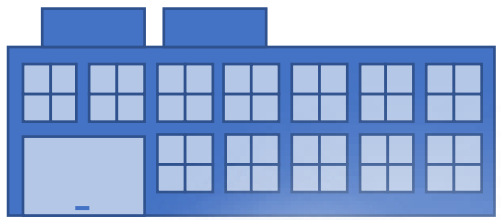
- Proposes a SW Interface structure similar to existing SDR standards (NASA STRS, SWRADIO, **SCA v4.1**)
- Software written for these other environments should be usable without extensive rewrites or refactoring

NASA Optical Comm Porting Complete

& Very Successful !!

Where Do OMG Standards Fit ?

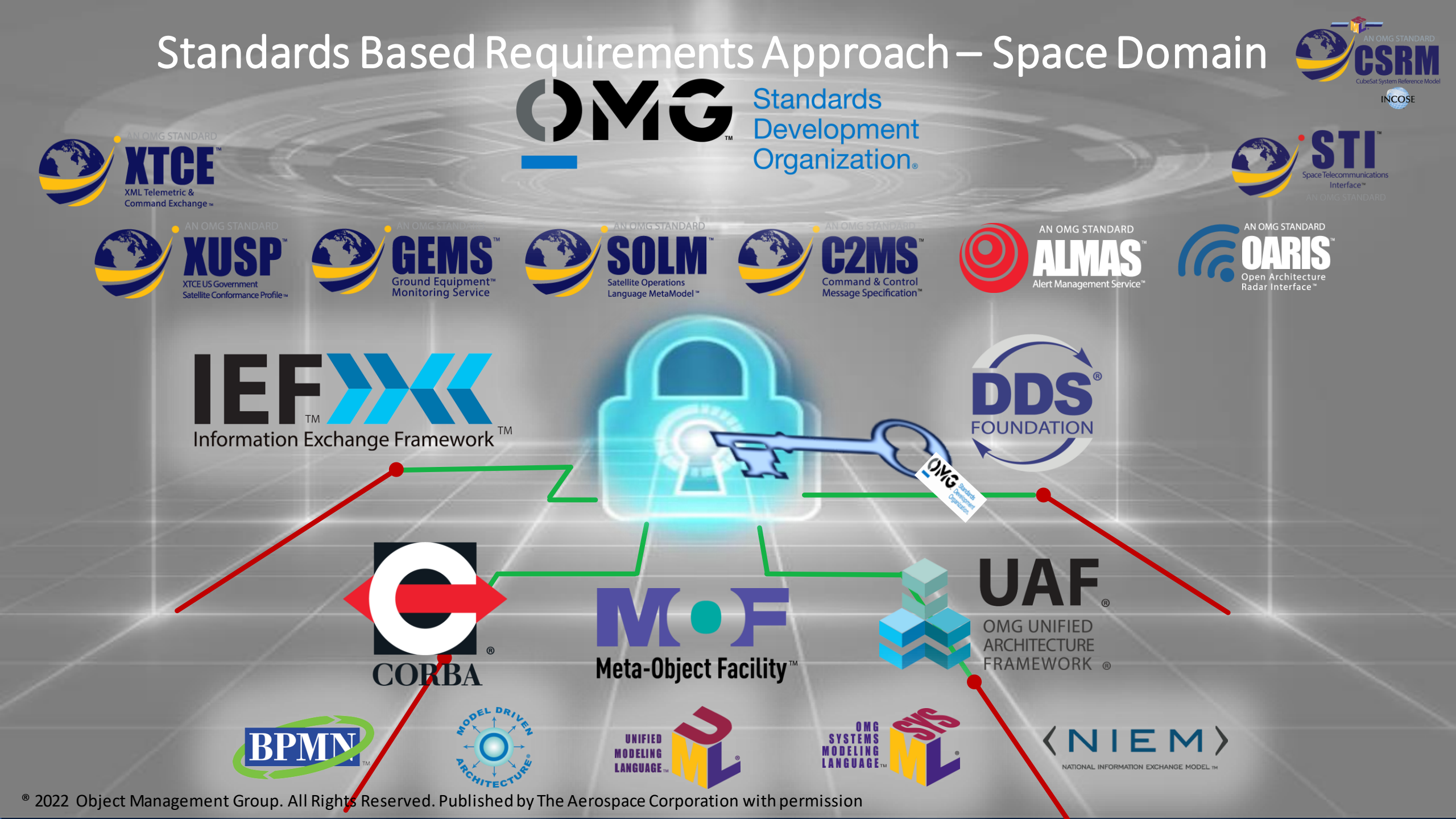
- Satellite link (commands & telemetry)
- Ground Equipment Monitor and Control
- Inter-center real-time messaging
- Intra-center real-time messaging
- Operations artifacts



Other OMG Standards of Choice

- CORBA — Common Object Request Broker Agent
- DDS Foundation — Data Distribution Service
- IEF Information Exchange Framework — Information Exchange Framework
- MOF Meta-Object Facility — Meta Object Facility
- OMG SysML — Systems Modeling Language
- UAF — Unified Architecture Framework
- ALMAS — Alert Mgt Service
- DARIS — Open Architecture Radar Interface Standard

Standards Based Requirements Approach – Space Domain



If Any of You Space Cat's Have Questions - You Can Be Directed To:

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Note Pages & Back Up Charts Available Upon Request

Thank You