act [Activity] Title [Title]

Developing and Distributing a Model-Based Systems Engineering (MBSE) CubeSat Reference Model

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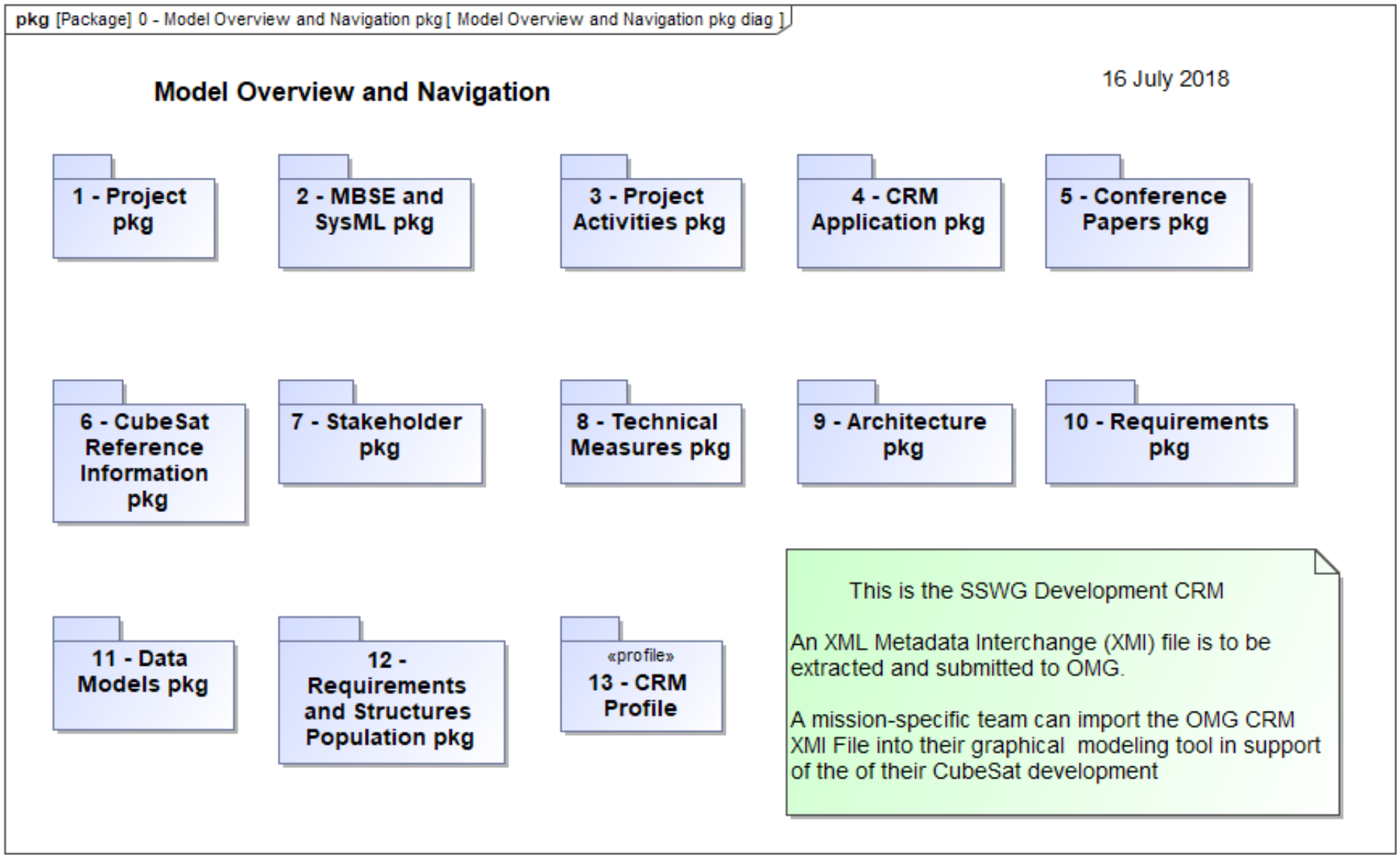
International Council on Systems Engineering (INCOSE)

Space Systems Working Group (SSWG)



act [Activity] Project [Project]

7 Nov 2017

Project

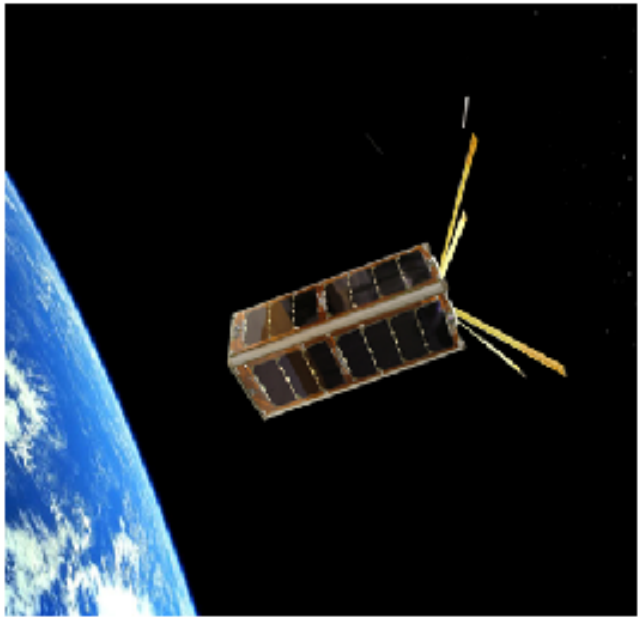
Develop and Distribute a CubeSat Model-Based Systems Engineering (MBSE) Reference Model

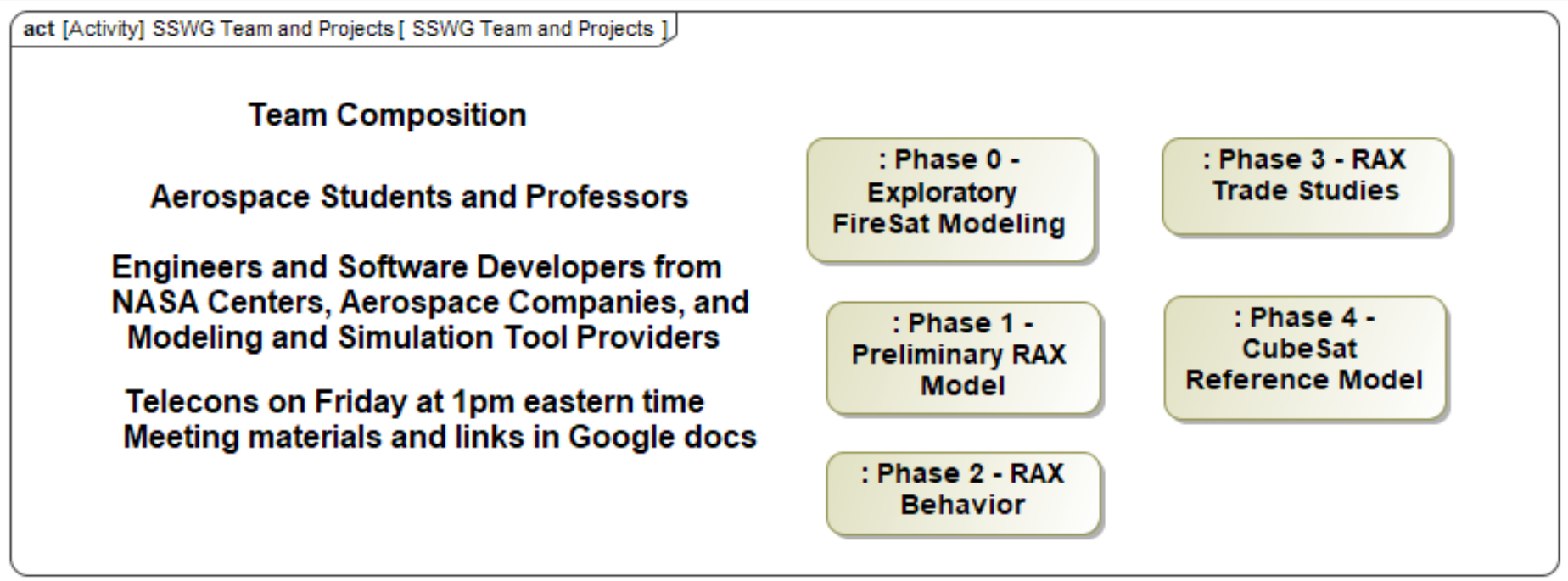
Objectives

Demonstrate Model-Based Systems Engineering (MBSE) methodolgy as applied to a CubeSat Mission

Develop a CubeSat Reference Model (CRM) that a university team can use as a starting point for their mission-specific model

Develop the CRM as an Object Management Group (OMG) specification





act [Activity] MBSE and SysML [MBSE and SysML]

Model Based Systems Engineering (MBSE)

MBSE creates a system model that helps integrate other discipline specific engineering models and simulations

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

SysML diagrams are used to describe requirements, structures, behaviors, and parametrics from the system down to the component level.

Requirements and design are contained and integrated in the model rather than in a series of independent engineering artifacts.

act [Activity] Methodology [Methodology]

CubeSat Reference Model

SysML model elements that can be populated to specify the logical architecture of a CubeSat enterprise space and ground system

Logical architecture decomposes the system into components that interact to satisfy system requirements

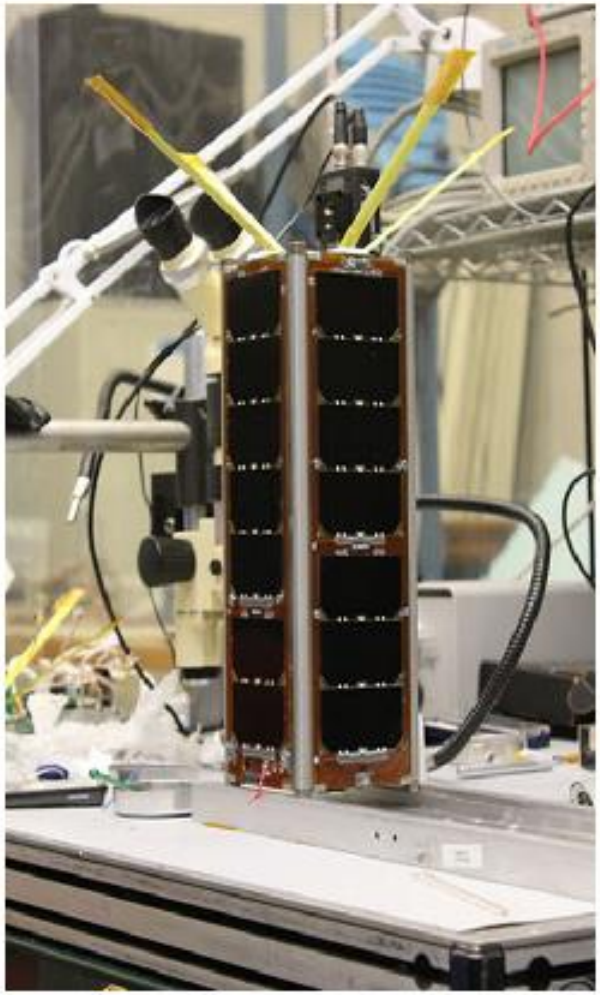
The components are abstractions of physical components that perform system functionality but without imposing implementation constraints

The CRM is systems engineering methodology agnostic

A mission-specific team will import the CRM into their graphical modeling tool to initiate their process for architecting, designing, and developing their Mission-specific Cubesat Model (MCM)

The MCM will be a repository for the systems engineering artifacts created by the mission-specific team

act [Activity] RAX Trade Studies 1 of 2 [RAX Trade Studies 1 of 2]



Radio Aurora Explorer (RAX) CubeSat Mission

Michigan Exploration Lab and SRI International

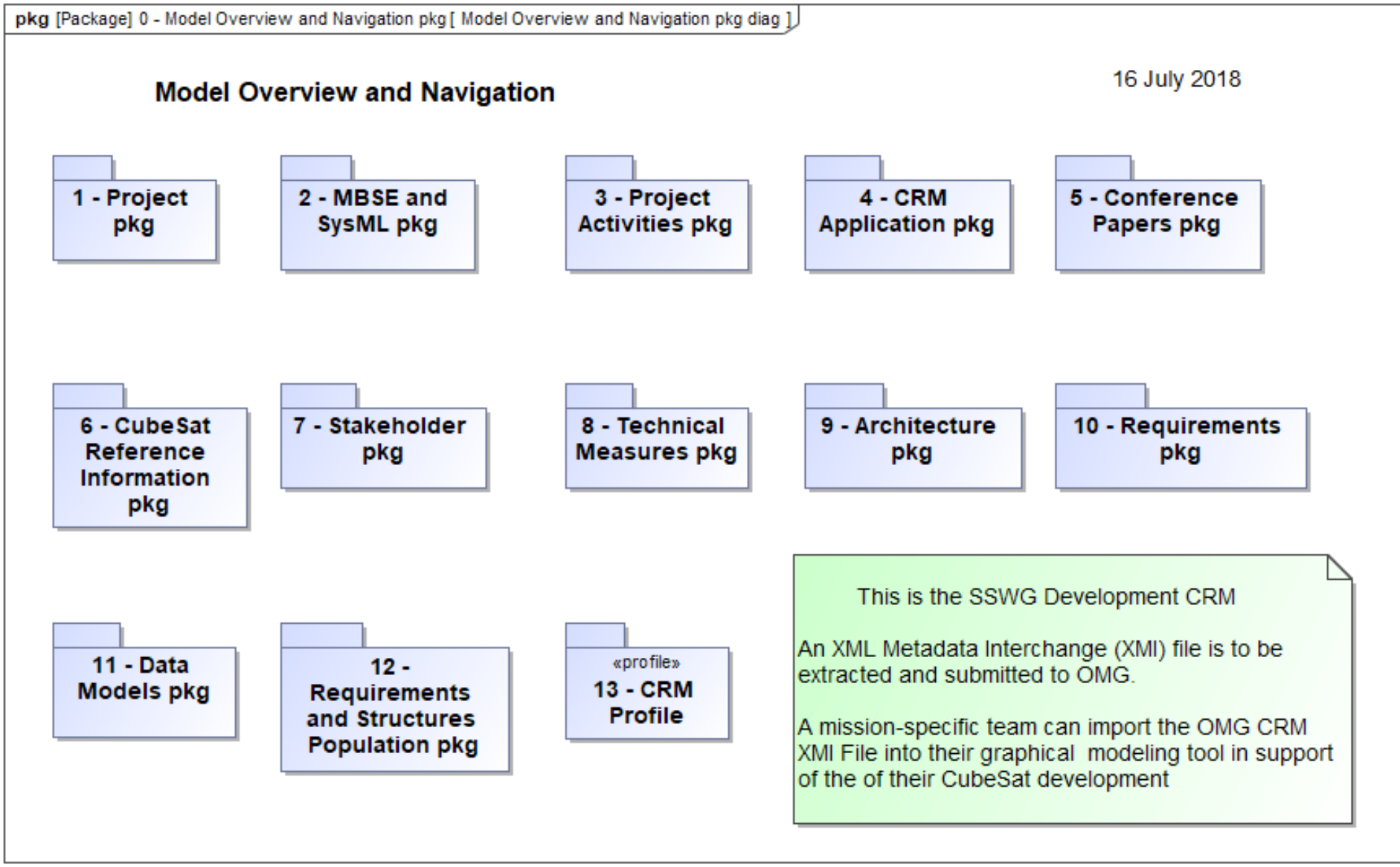
Studies formation of magnetic field aligned plasma irregularities in the lower polar ionosphere

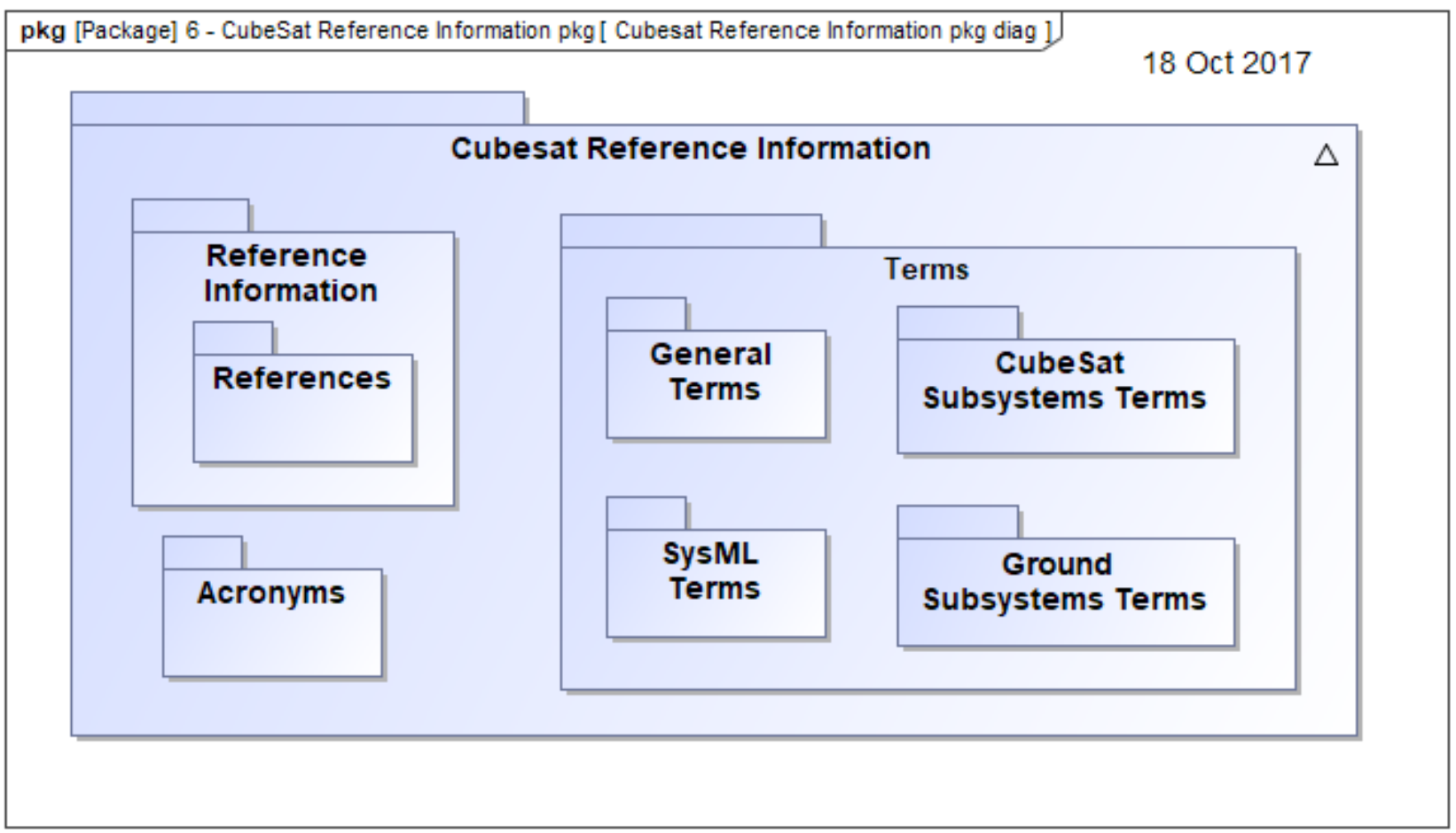
Radar signal is transmitted by Incoherent Scatter Radar site in Poker Flat, Alaska and received by RAX's radar receiver

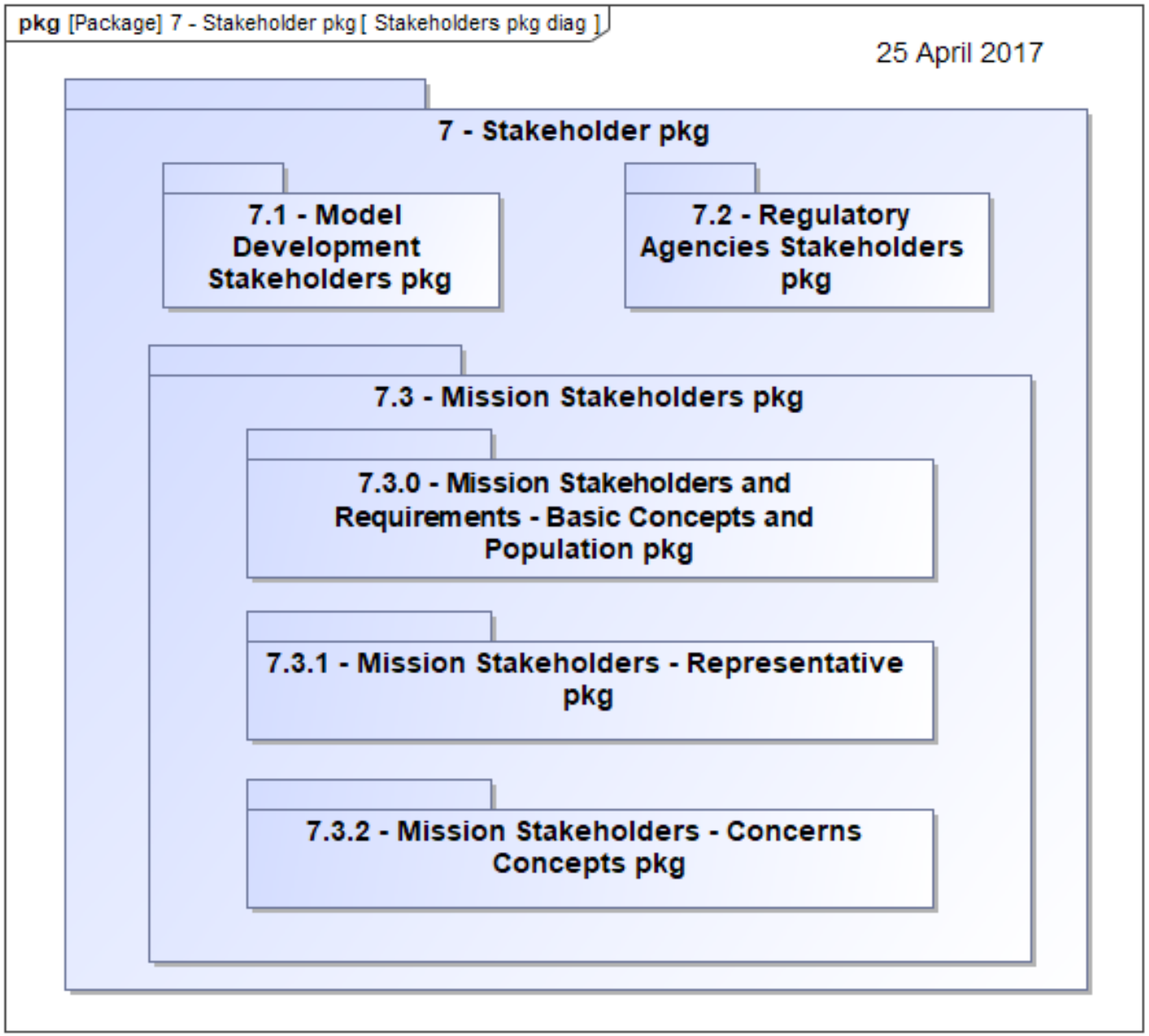
Science data processed on-board, compressed, transmitted to the primary ground station and control center in Ann Arbor, Michigan

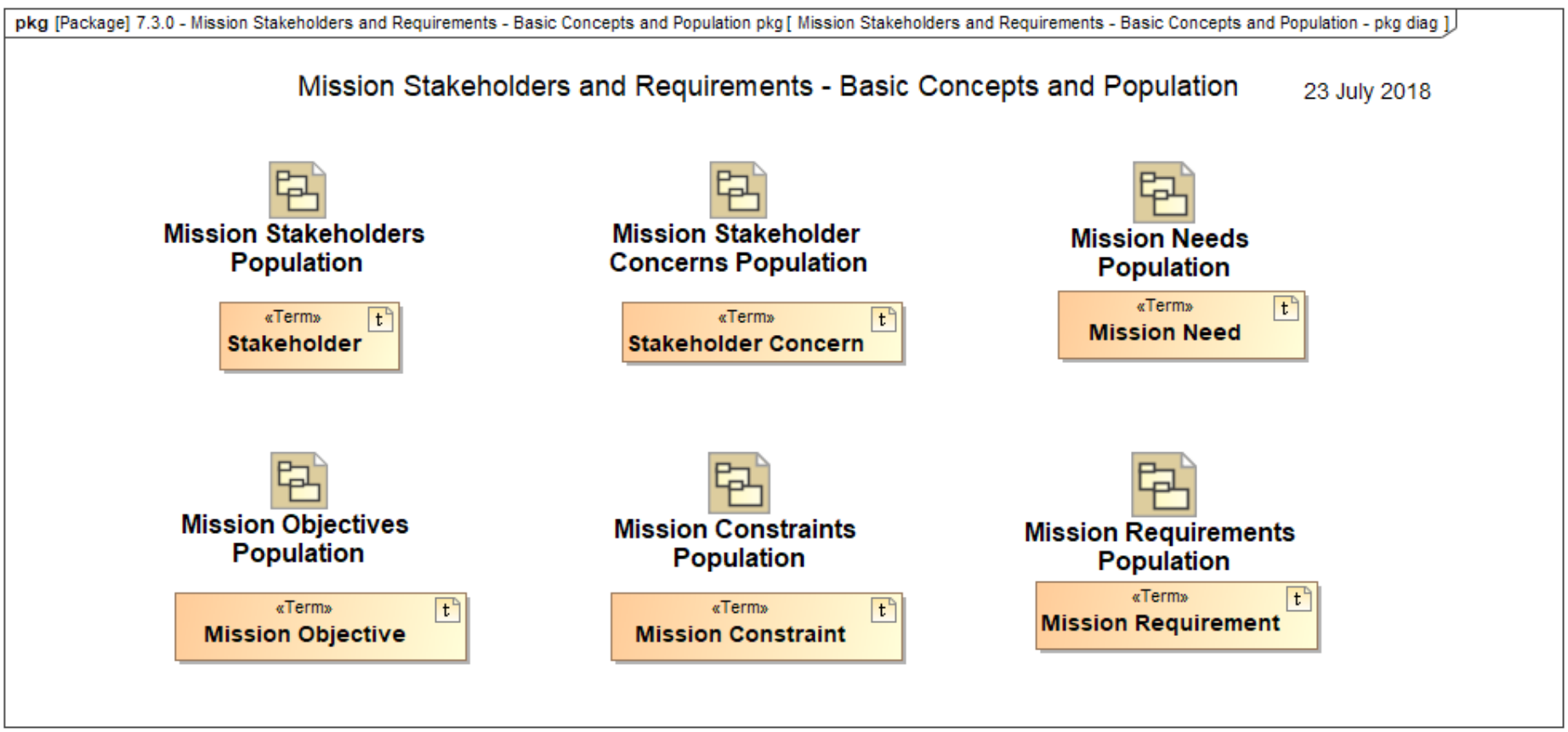
act [Activity] 1 - Project pkg1 [1 - Project pkg1]

Trade Studies	Trade Space	Performance Metric
Solar panel area	• Nominal: 18.2 cm^2/slide • ½ of nominal • ¼ of nominal	On-board energy
Max battery capacity	• Nominal: 115,000 J • Reduced: 100,000 J	On-board energy
Orbital altitude	• Nominal: 811 km x 457 km • Low: 593 km x 250 km • High: 1311 km x 932 km	Quantity of data downloaded
Ground station network	• Ann Arbor & Menlo Park • Ann Arbor & Fairbanks • Fairbanks & Menlo Park	Quantity of data downloaded



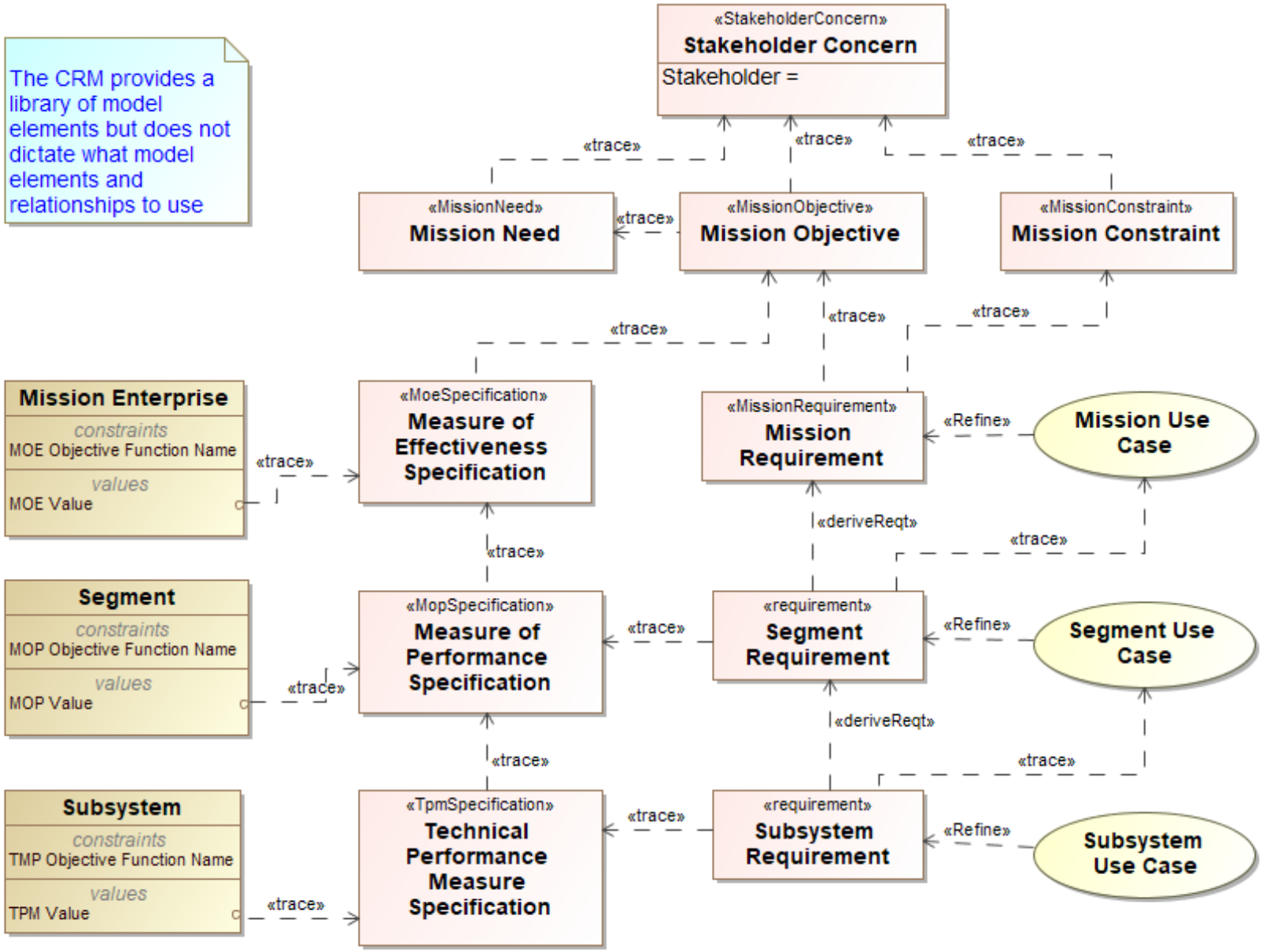






Mission Stakeholder - Concerns Concepts

18 Aug 2018



pkg [Package] Use Cases pkg [Enterprise Use Cases Population]

Enterprise Use Cases Population

22 July 2018

Enterprise Use Cases Table

Use Case Population - Instructions.docx

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Refines = Mission Rqt A

«MissionRequirement»
Mission Rqt A

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Use Case A Description.docx

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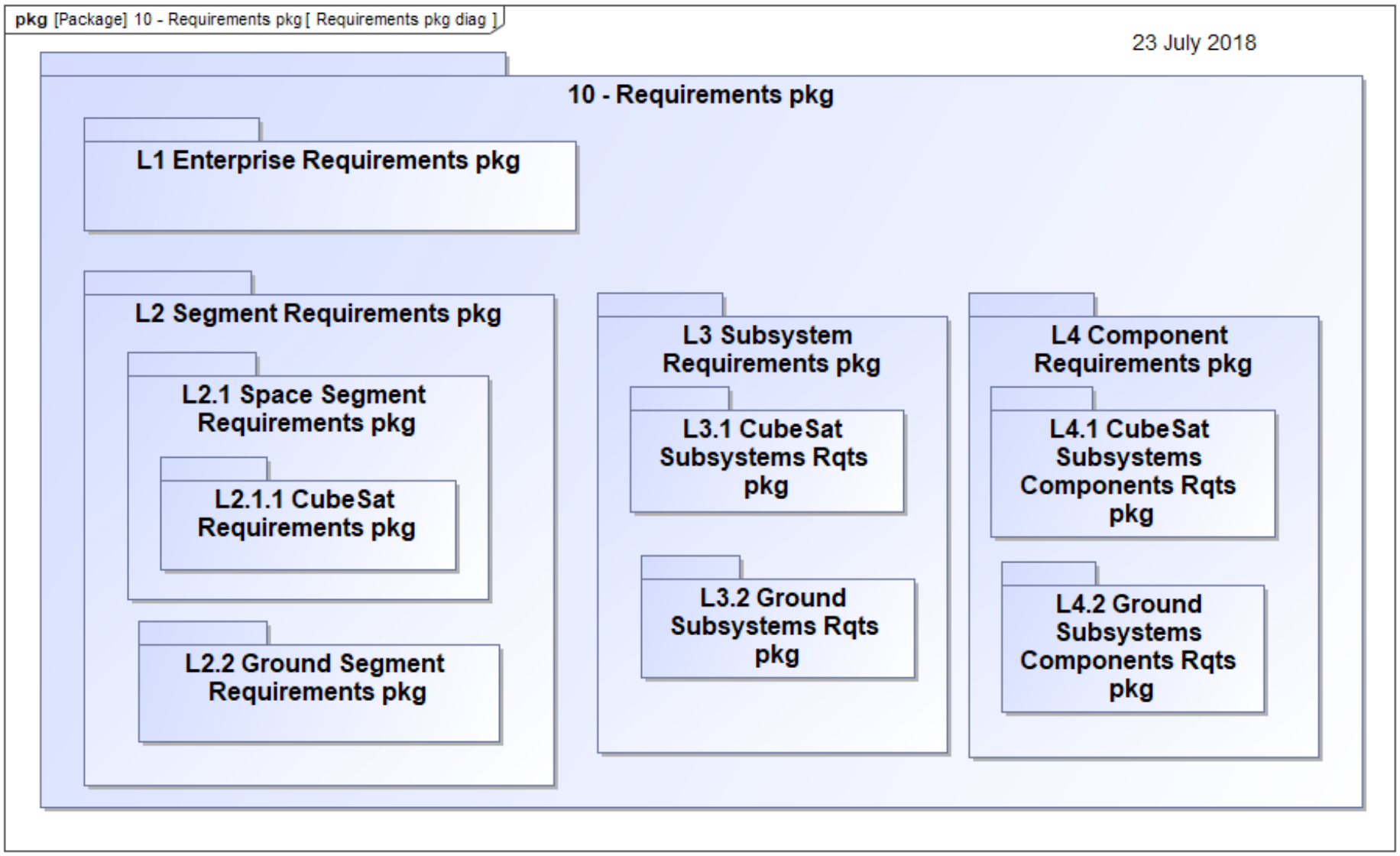
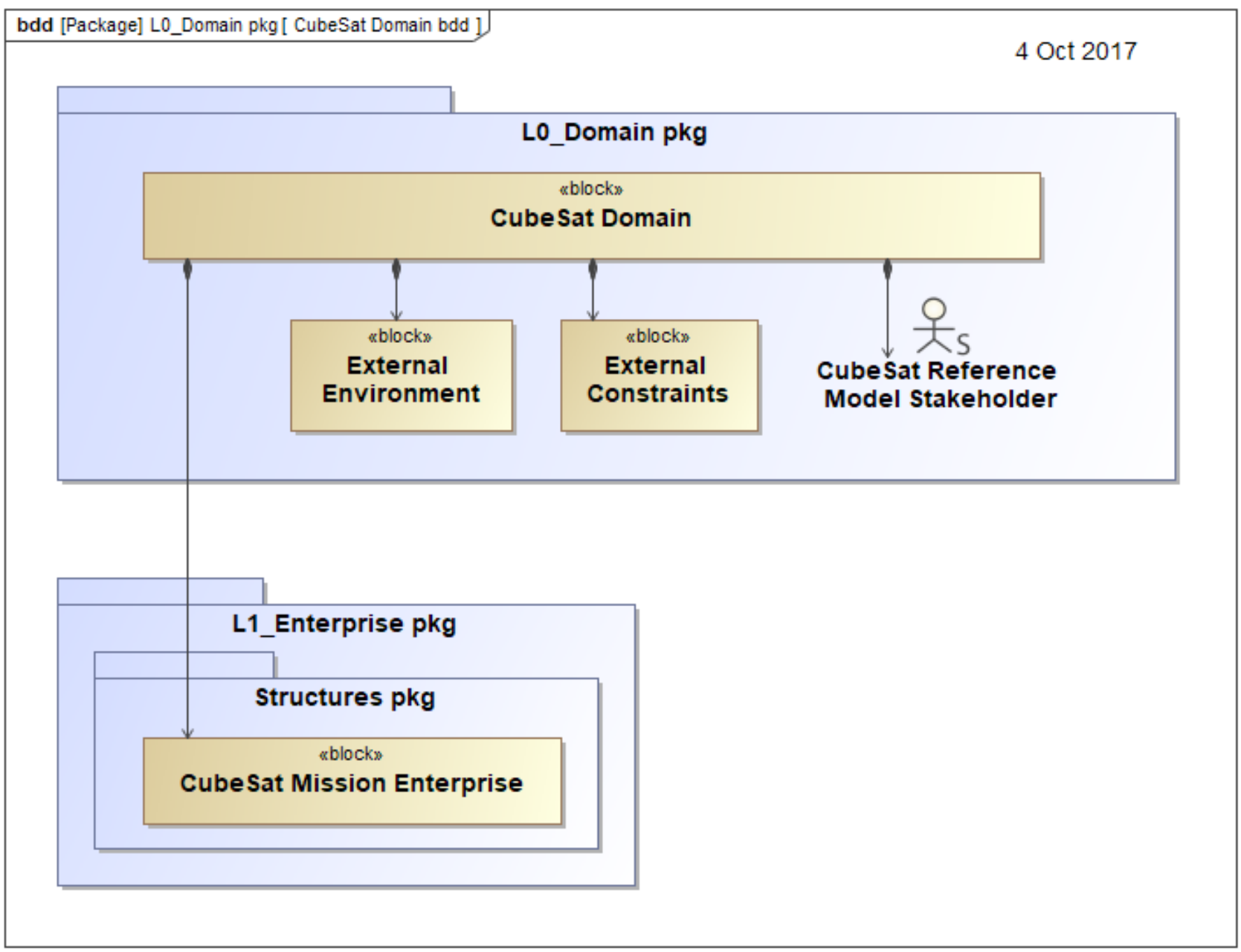
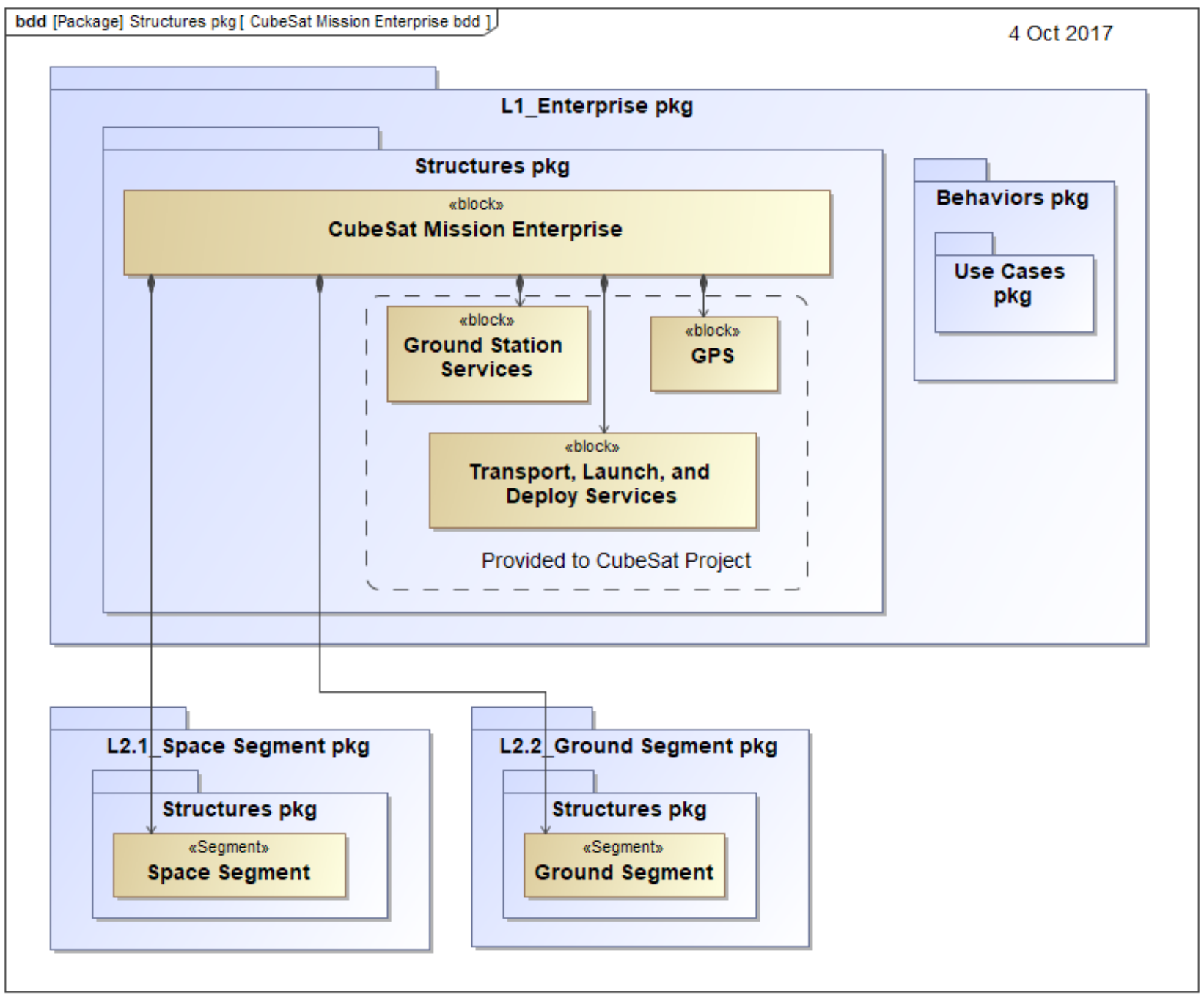
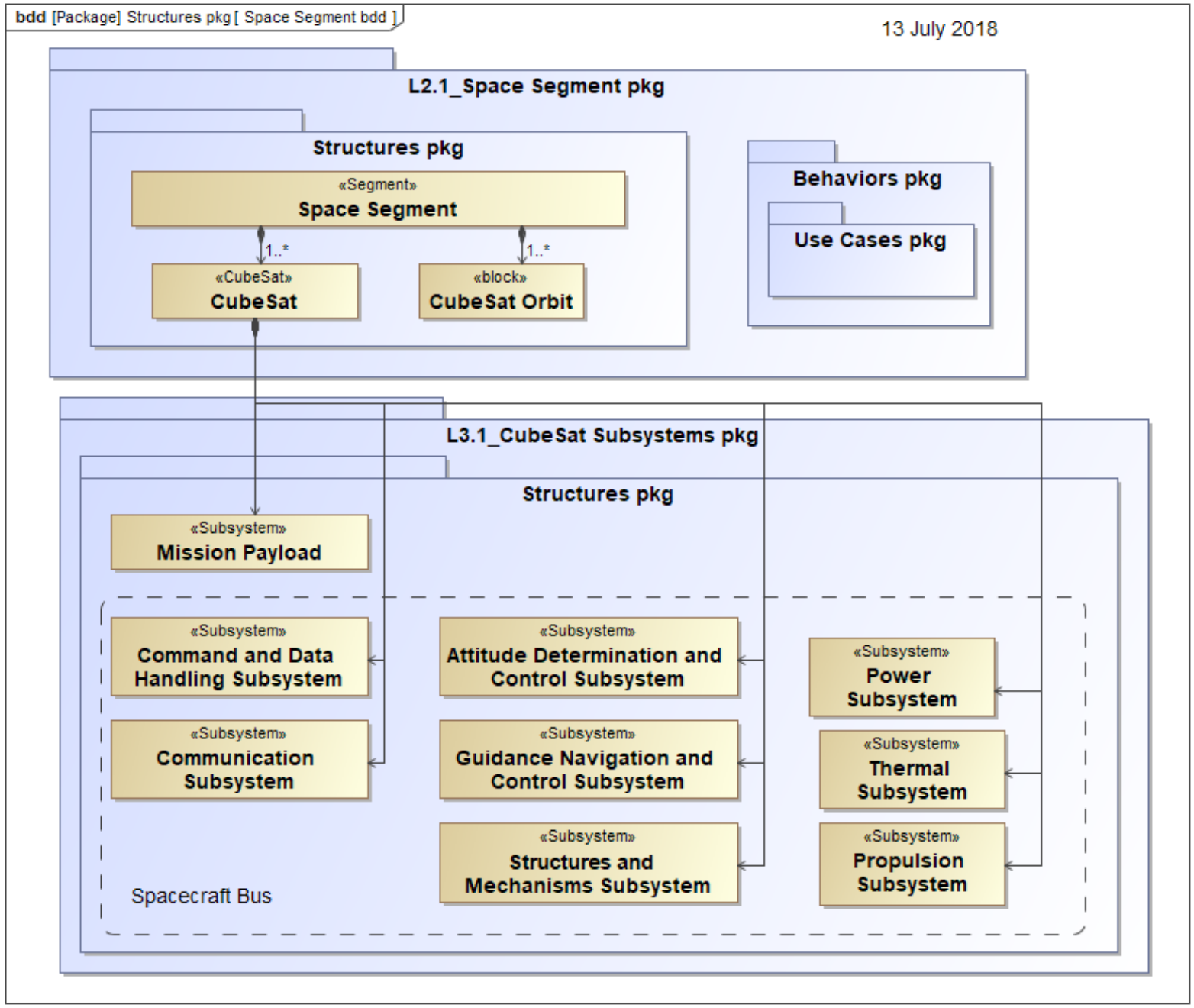
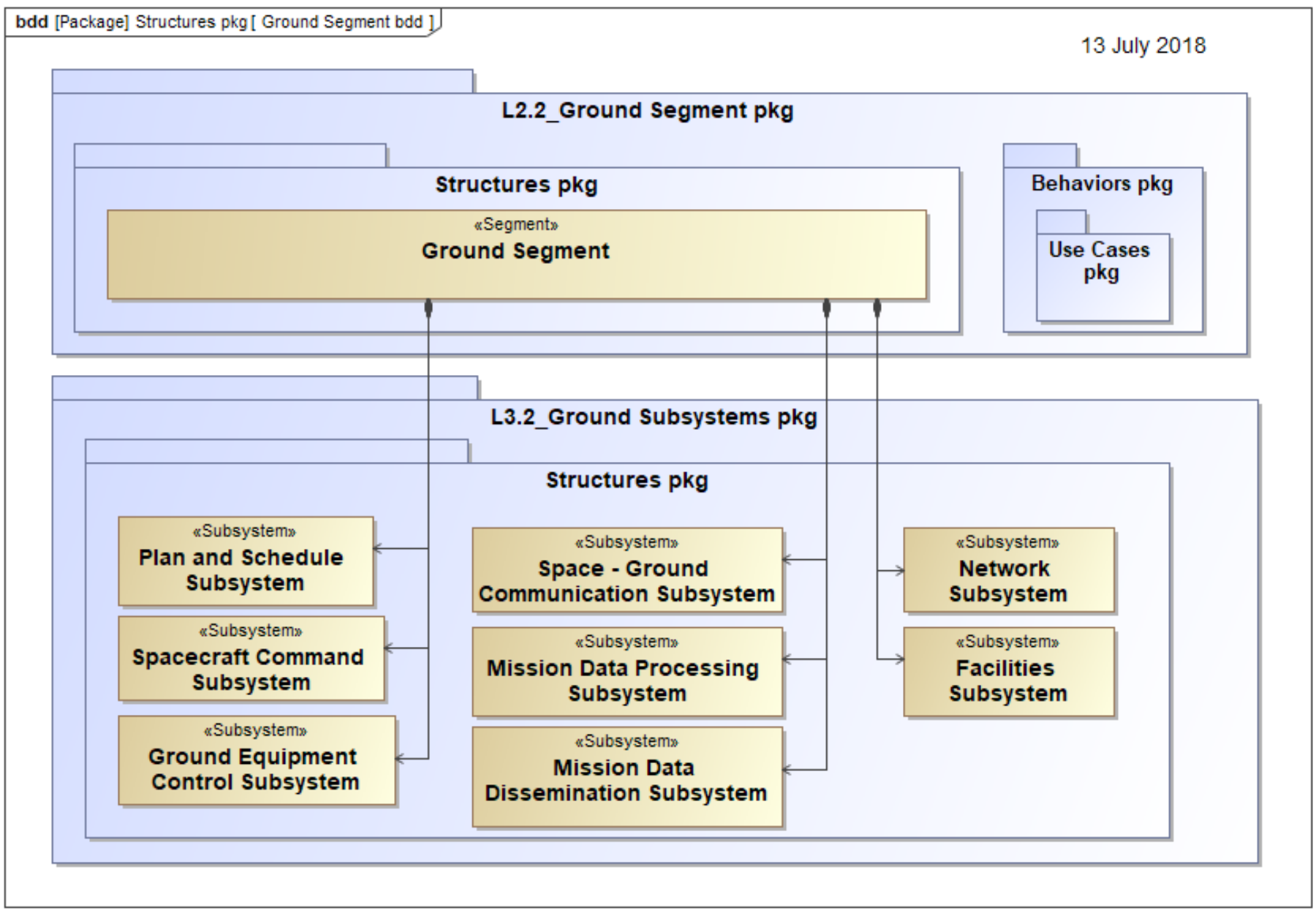
2	Use Case A		1 Mission Req A	Use Case A Description.docx

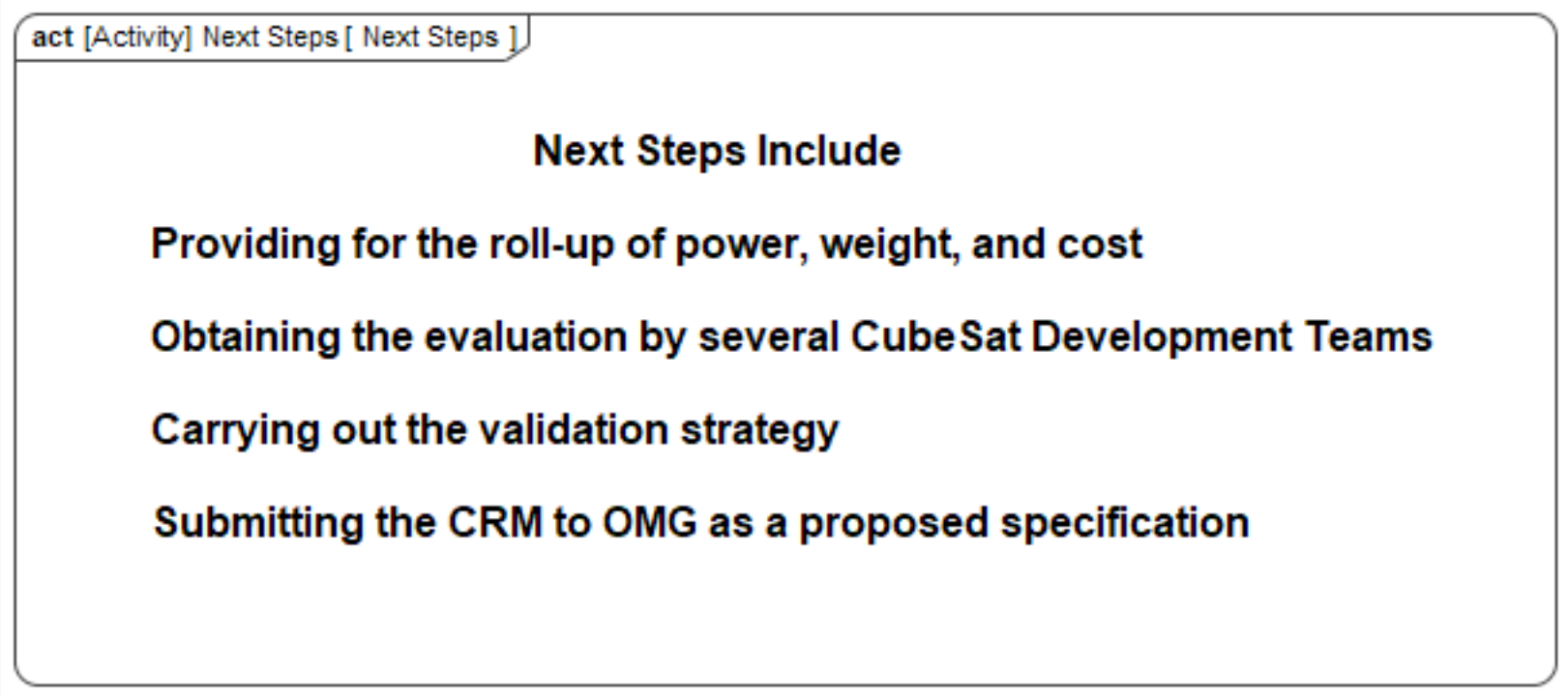





bdd [Package] Structures pkg [CubeSat Mission Enterprise bdd]
4 Oct 2017
L1_Enterprise pkg
Structures pkg
«block»
CubeSat Mission Enterprise
«block»
Ground Station Services
«block»
GPS
«block»
Transport, Launch, and Deploy Services
Provided to CubeSat Project
Behaviors pkg
Use Cases pkg
L2.1_Space Segment pkg
Structures pkg
«Segment»
Space Segment
L2.2_Ground Segment pkg
Structures pkg
«Segment»
Ground Segment







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[2] S. Spangelo, L. Anderson, E. Fosse, L Cheng, R. Yntema, M. Bajaj, C. Delp, B. Cole, G. Soremekun, D. Kaslow, and J. Cutler, “Model Based Systems Engineering (MBSE) Applied to Radio Explorer (RAX) CubeSat Mission Operational Scenarios,” *Proceedings of IEEE Aerospace Conference*, Big Sky, MT, March 2013.

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[5] D. Kaslow, L. Anderson, S. Asundi. B. Ayres, C. Iwata, B. Shiotani, R. Thompson, “Developing and Distributing a CubeSat Model-Based System Engineering (MBSE) Reference Model ”, *Proceedings of the 31st Space Symposium*, Colorado Springs, CO, April 2015.

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