Utilizing CSRM for NASA Mission Ground Segment (GS) Design.

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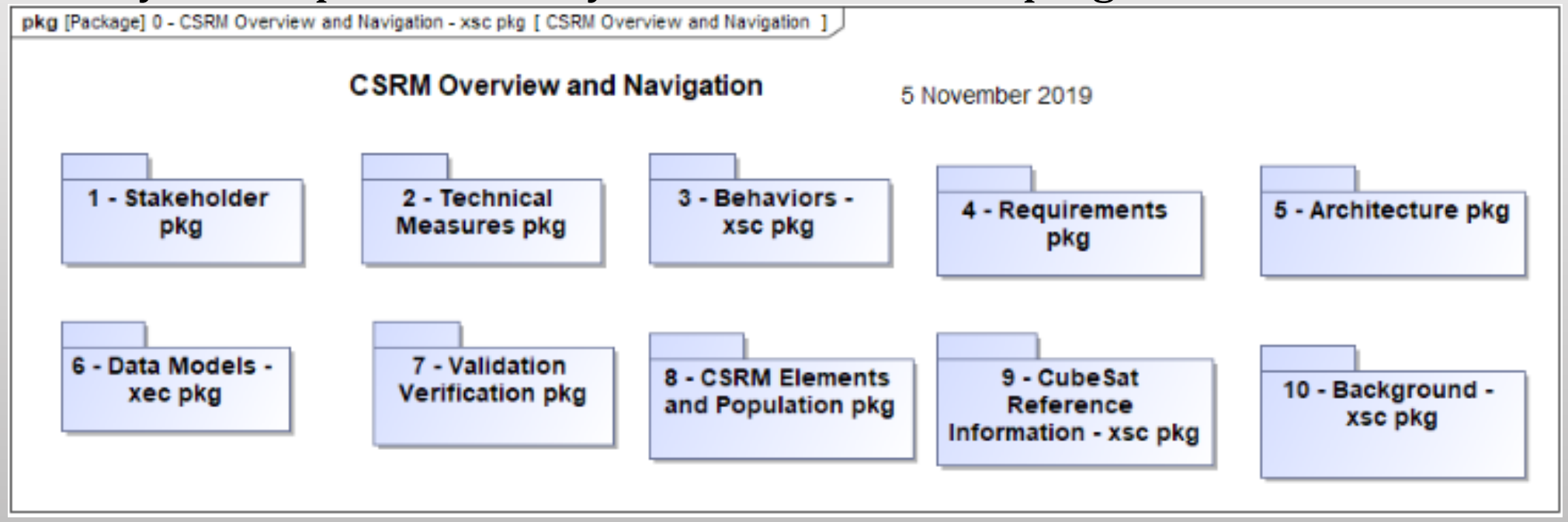
Agenda

- What is CSRM
- HERMES
- Application of CSRM on a NASA Hosted Payload GS
- Using CSRM in a DBSE Environment

MBSE & CSRM

MTi SYSTEMS

- The CubeSat System Reference Model (CSRM) is a Model-Based Systems Engineering (MBSE) modeling template intended for use by spacecraft systems engineers to develop flight segment and ground segment architectures.
  - Primarily developed for use by universities developing CubeSats.

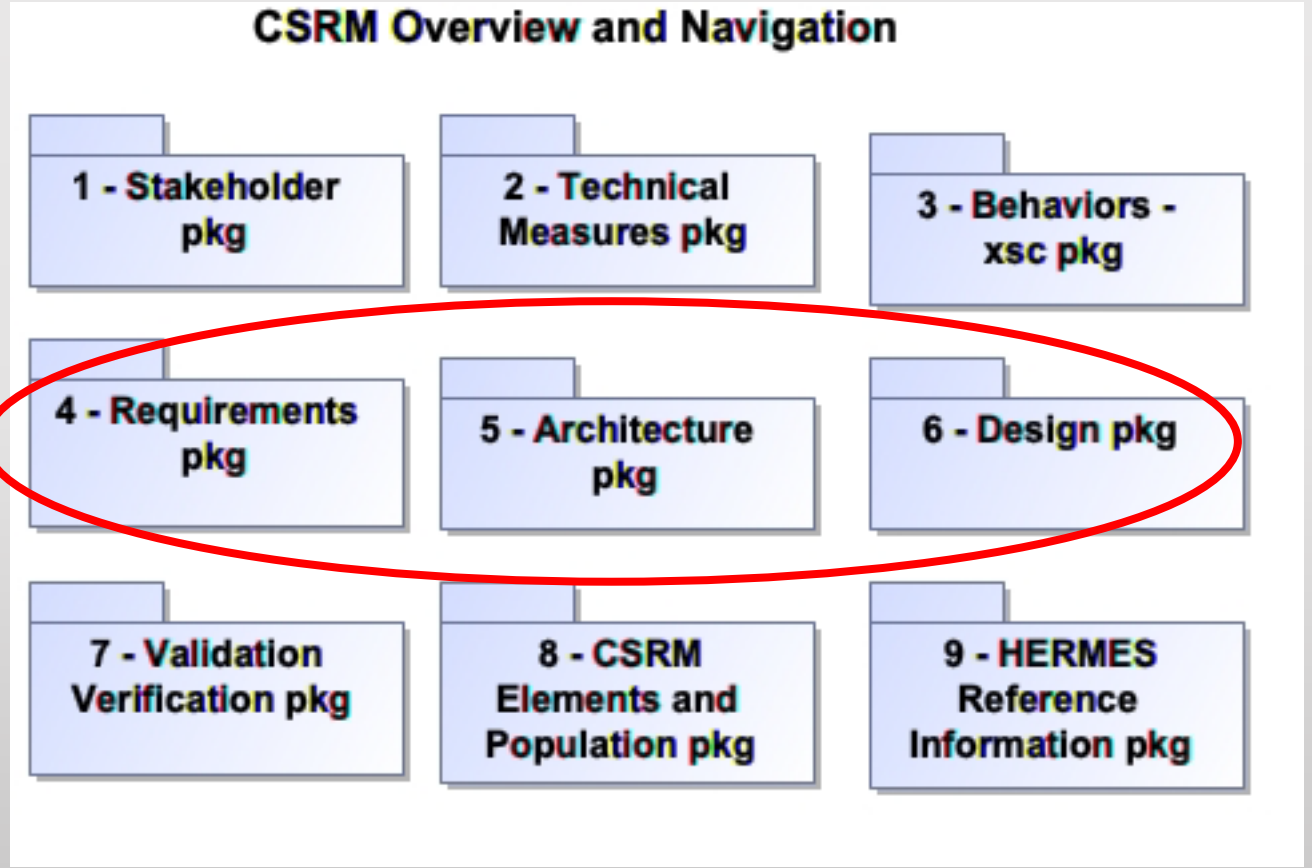


About HERMES

- The Heliophysics Environmental and Radiation Measurement Experiment Suite (HERMES) is a hosted payload that will fly aboard the Gateway, NASA's orbital outpost to support Artemis lunar operations.
  - Instrument suite consists of 4 instruments: EEA built by NASA GSFC, MERiT built by NASA GSFC, NEMISIS built by NASA GSFC, and SPAN-I built by UC Berkeley
- NASA Class D Payload – low cost, high risk.
- Currently in Phase C, but in a bathtub period.
- Expected launch date: No Earlier Than End of 2025

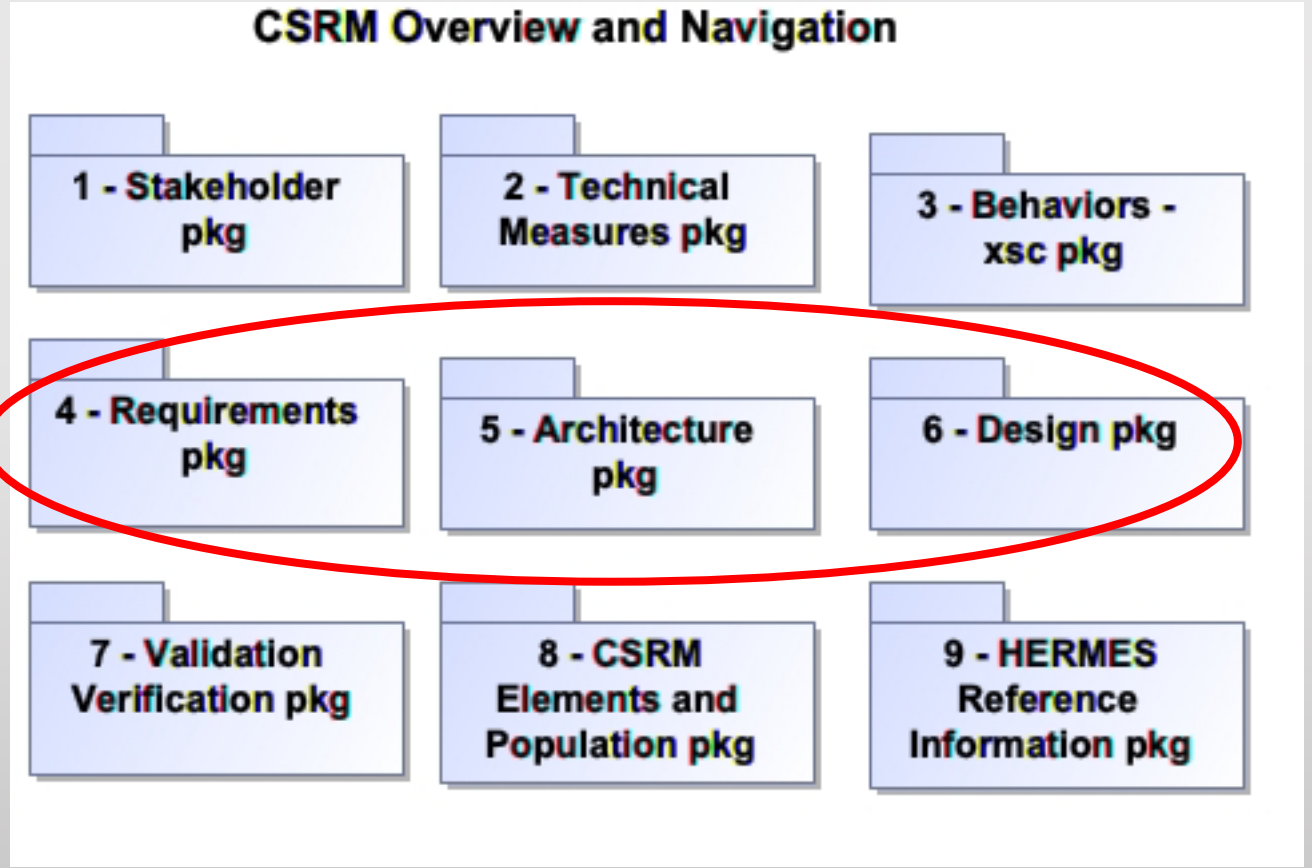
Using CSRM on HERMES

- CSRM template in MagicDraw format used as a starting point for the HERMES ground segment development.
- HERMES MOC Lead started model, but it's now maintained in a collaborative fashion by the MOC and SOC Leads using Teamwork Cloud (No Magic's model version-controlled repository).



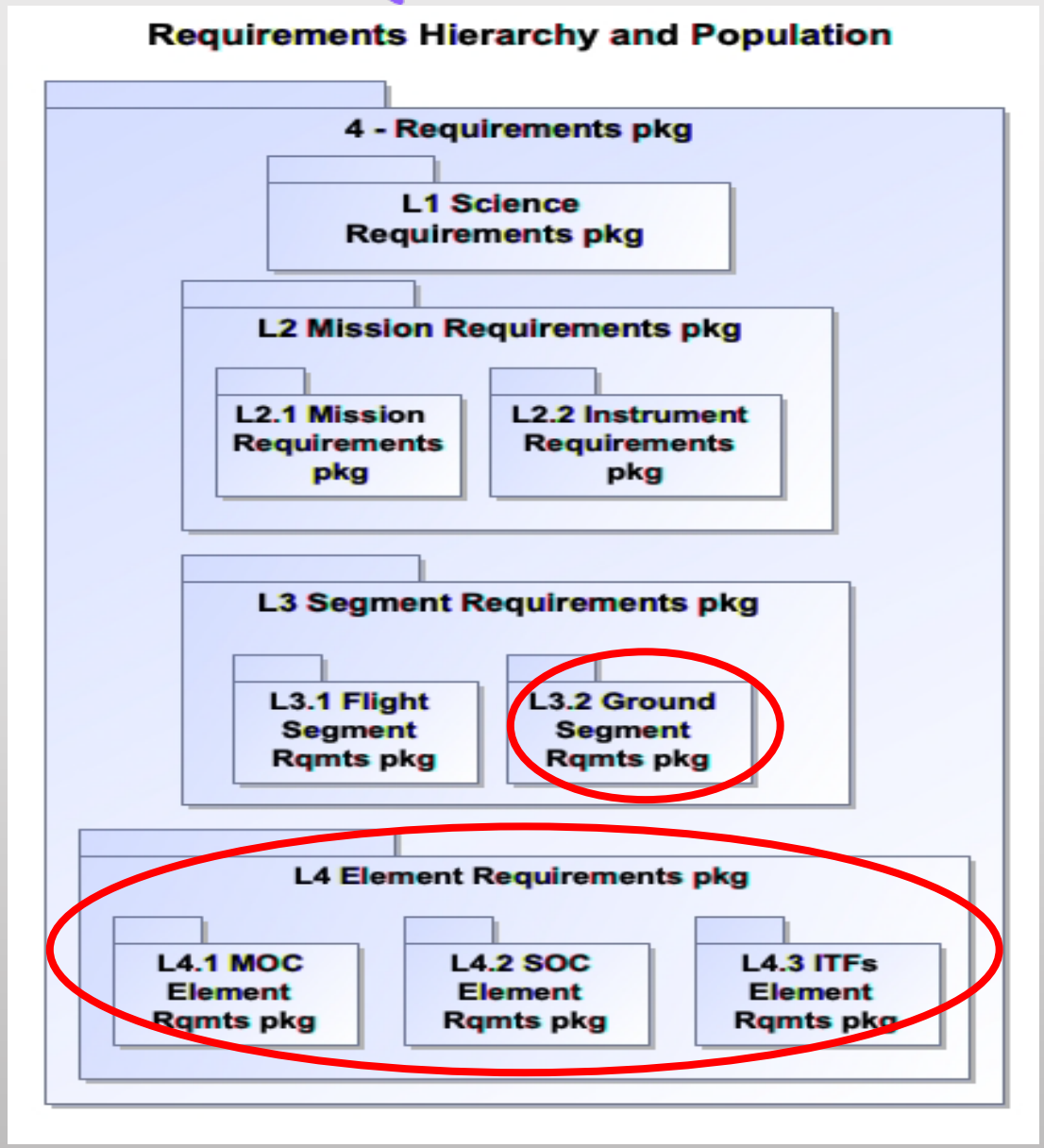
Using CSRM on HERMES

- Contains some HERMES flight segment information for reference purposes only and updated whenever a change directly affects the ground segment.
- Gateway's HALO Module related content, but it's also for reference purposes.
  - Gateway teams maintain their own models
  - Ingestion is possible, but it would add more bloat than information critical to the HERMES Ground Segment teams.



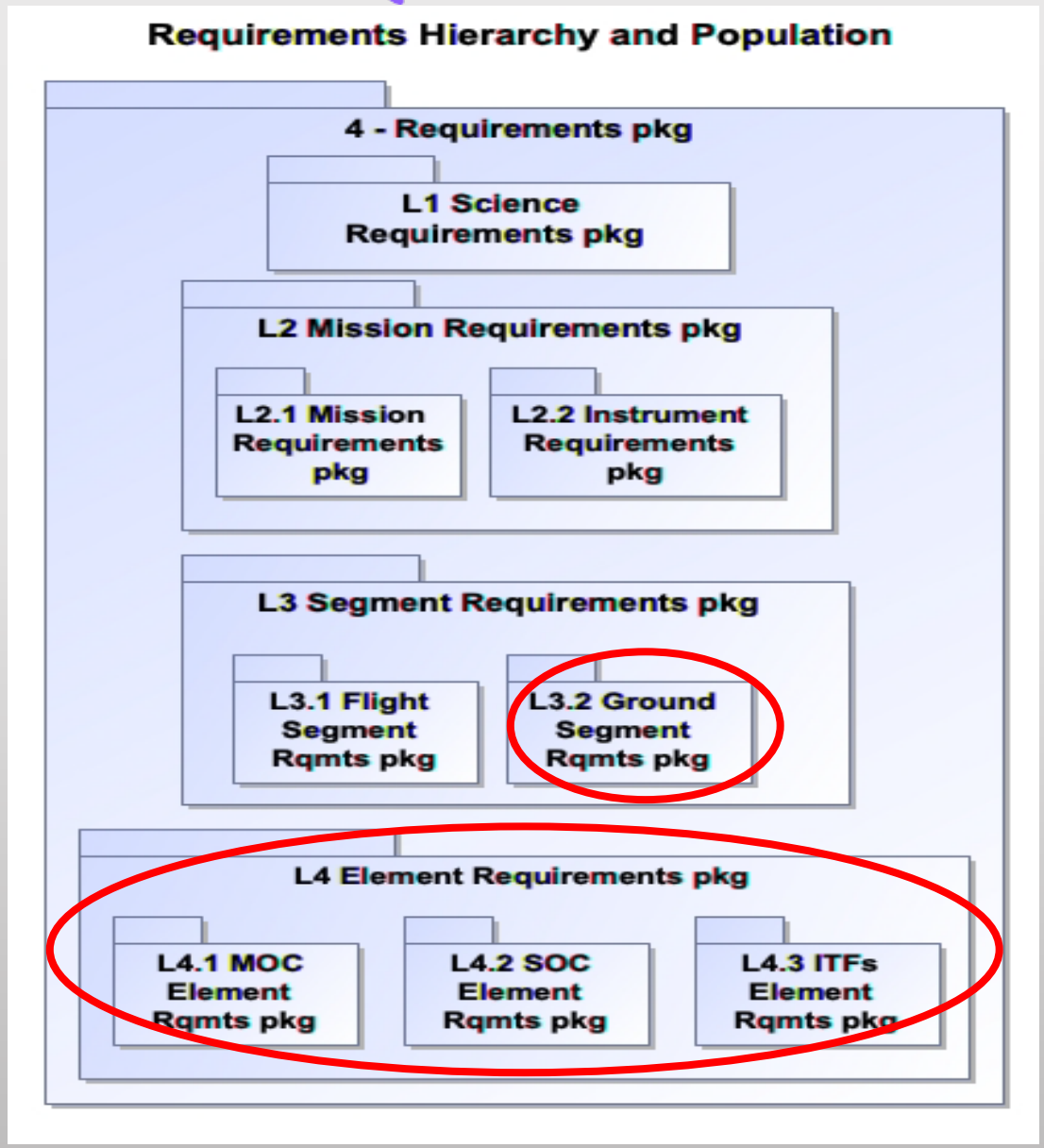
Using CSRM on HERMES

- As a Class D payload, the HERMES Project Management Office (PMO) decided against the use of IBM's Rational DOORS so each team within the flight segment uses a different method to track their requirements.
- The HERMES GS team uses the CSRM based HERMES model to manage its:
  - Ground Segment level 3 requirements
  - Mission Operations Center (MOC) level 4 requirements
  - Science Operations Center (SOC) level 4 requirements
  - Instrument Team Facilities (ITFs) level 4 requirements



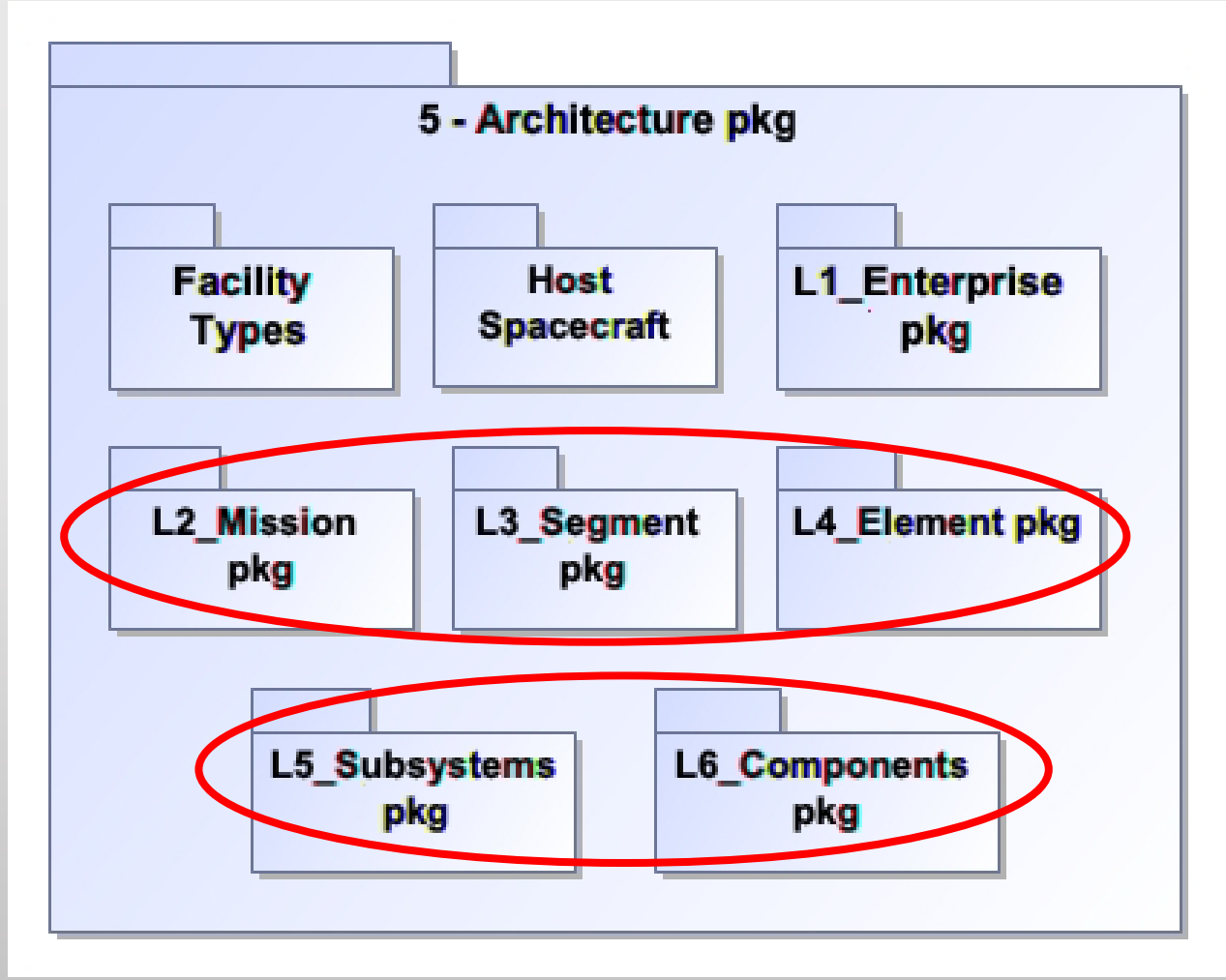
Using CSRM on HERMES

- Ground Segment requirements document exported from MagicDraw and posted to NASA GSFC's Technical Data Management System (TDMS).
- Following the CSRM template ensures the location of information is kept consistent among the MOC team and the SOC team.
- Consistency is what allows the HERMES GS teams to successfully export the requirements information each time a new document revision is needed.

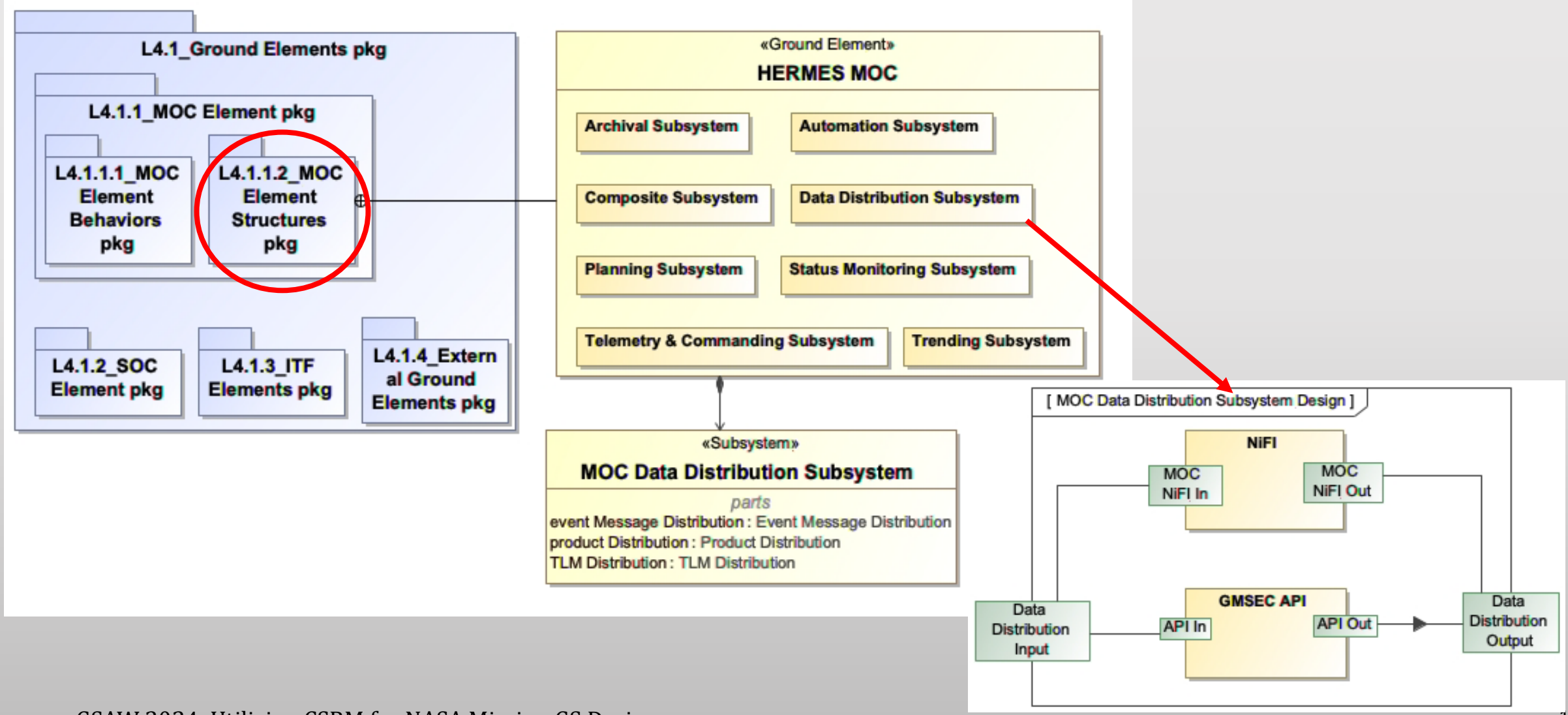


Using CSRM on HERMES

- The use of the architecture area to define ground segment behaviors and structures.
- Structures packages contain block types with HERMES specific stereotypes for the HERMES mission, its flight and ground segments, the seven major ground elements, and the many subsystems and components within each.
- It also contains block definition diagrams and internal block diagrams

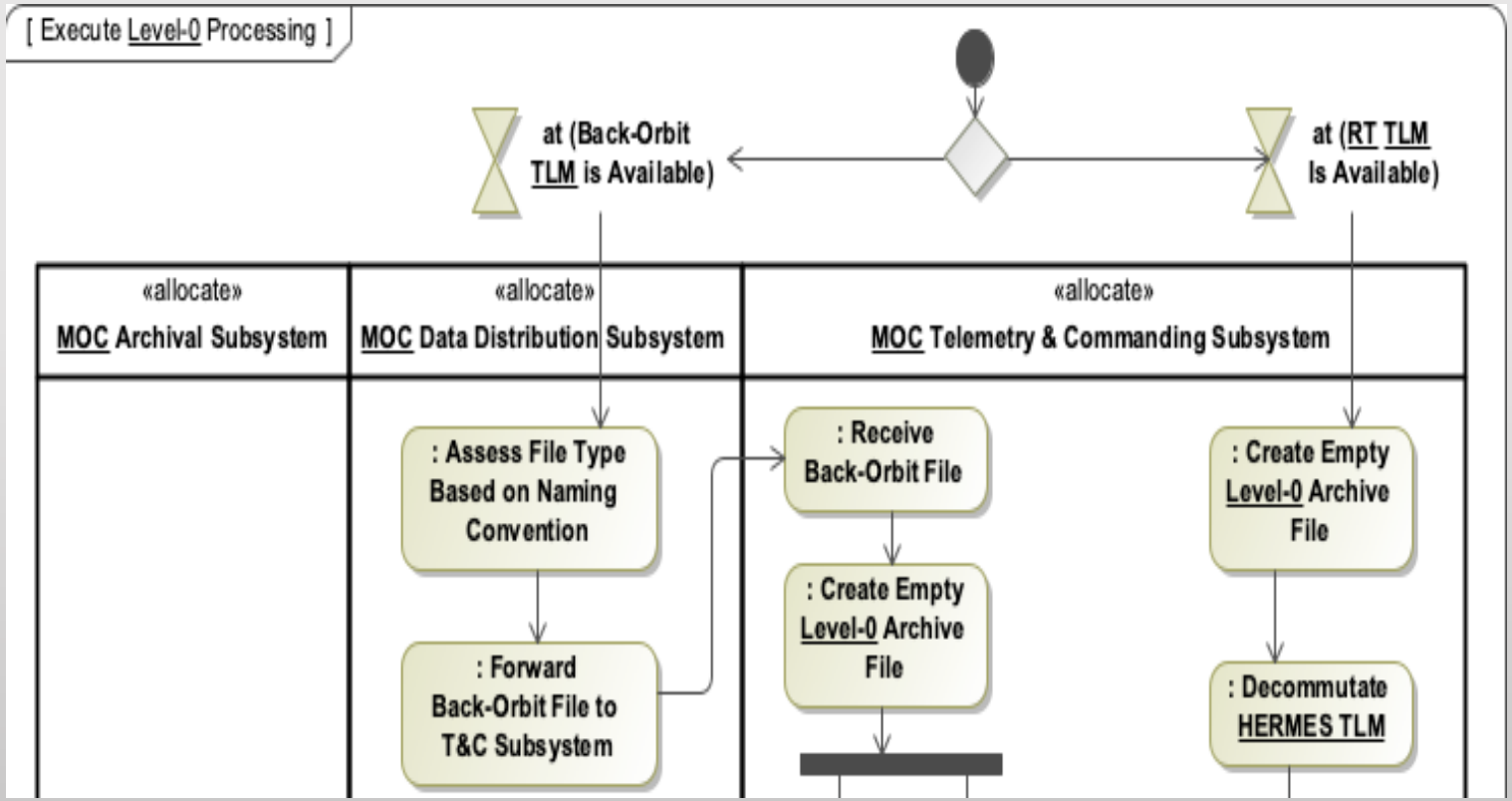


HERMES GS Structures



Using CSRM on HERMES

- Behaviors packages contain SySML activity diagrams detailing concepts of operations and operational concepts for the HERMES mission, its flight and ground segments, the seven major elements, and the many subsystems.

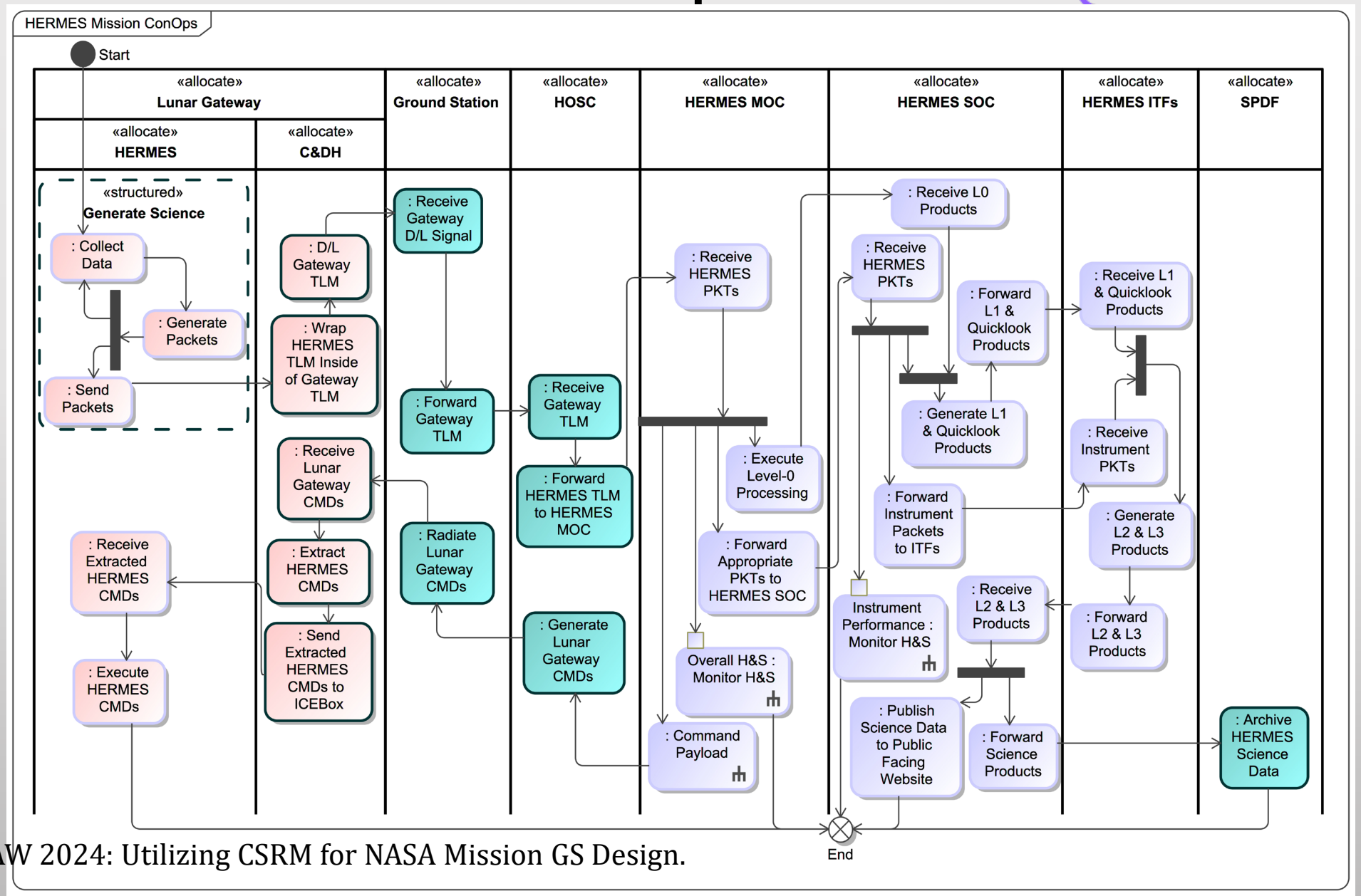


Using CSRM on HERMES

- HERMES specific stereotypes to add verification information to requirements.
- Requirements table that doubles as RTVM
- Clear digital thread tying the HERMES ground segment requirements all the way through to the verification and validation activities for each one as well as their respective artifacts.

Id	Verification Approach	Allocated To	Capability Deployment	Verification Event	Derived From	Verification Status	Satisfied By	Verified By
L4-MOC-2	Submit real-time commands using an ICEBox emulator. Capture screenshots of the command counter before and after submittal of commands.	MOC Telemetry & Commanding Subsystem	MOC Build 3	MOC SAT 3	L3-HGS-1 GS RT Commanding	Untested	MOC Telemetry & Command Subsystem Design	RT CMDing

HERMES Mission ConOps



CSRM in a DBSE Culture

- Slow adoption of MBSE processes in the NASA GSFC's Flight Projects Directorate, except for within the Exploration & Space Communications Projects Division.
- Word documents are still contractually required, and deviation is not allowed.
- Relies on MagicDraw's Report Wizard functionality to export model data in Word document format.
  - Requires knowledge of Velocity Template Language to generate document templates for each mission artifact.
  - Each systems engineering lifecycle artifact requires its own document template.
  - Personally, the most time-consuming part.

CSRM in a DBSE Culture

- The generation of a new document template for a lifecycle artifact takes nearly as long it would to write the document without MBSE.
- On average, follow on revisions take about a quarter of the time normally required.
- All HERMES Ground Segment documents are now exported directly from MagicDraw:
  - HERMES Ground Segment Requirements Document
  - HERMES Mission Concept of Operations Document
  - HERMES GS Internal Interface Description Document
  - HERMES GS External Interface Description Document*
  - HERMES Ground Segment Description Document*

*Document template is still under development

CSRM in a DBSE Culture

- For ground segment systems engineering lifecycle reviews PowerPoint presentations are still king.
- Slide content is manually pulled from the HERMES model
- Content almost exclusively made up of:
  - SysML block definition diagrams,
  - SysML internal block diagrams,
  - SysML activity diagrams,
  - SysML use case diagrams,
  - Requirement tables
  - SysML allocation matrices
- Tedious, but ensures consistency between all ground system documents and what is being presented.
- Avoids mad scramble to generate Visio or PowerPoint diagrams that is commonly experienced when preparing for a lifecycle review.

Acronyms

- BDD – Block Definition Diagram
- C&DH – Command & Data Handling
- CSRM – CubeSat System Reference Model
- DBSE – Document-Based Systems Engineering
- GS – Ground System
- HALO – Habitation & Logistics Outpost
- HERMES - Heliophysics Environmental and Radiation Measurement Experiment Suite
- HOSC – Huntsville Operations Support Center
- ITF – Instrument Team Facility
- MBSE – Model-Based Systems Engineering
- MOC - Mission Operations Center
- NASA
- PKG – Package
- PMO – Project Management Office
- RTVM – Requirements Traceability Verification Matrix
- SEBoK – Systems Engineering Book of Knowledge
- SOC – Science Operations Center
- SysML – Systems Engineering Modeling Language
- VTL – Velocity Template Language

References

1. Kaslow, D., Cahill, P., & Ayres, B. (n.d.). *Development and Application of the CubeSat System Reference Model*. Retrieved November 2, 2023, from https://www.incose.org/docs/default-source/space-systems-working-group/2020-ieee-aerospace-conf---development-and-application-of-the-cubesat-system-reference-modeld119158572db67488e78ff000036190a.pdf?sfvrsn=5cc272c7_2
2. *HERMES - NASA Science*. (n.d.). Science.nasa.gov. Retrieved November 2, 2023, from https://science.nasa.gov/mission/hermes/