MBSE 2022
A model based approach to budget management on the Earth Return Orbiter

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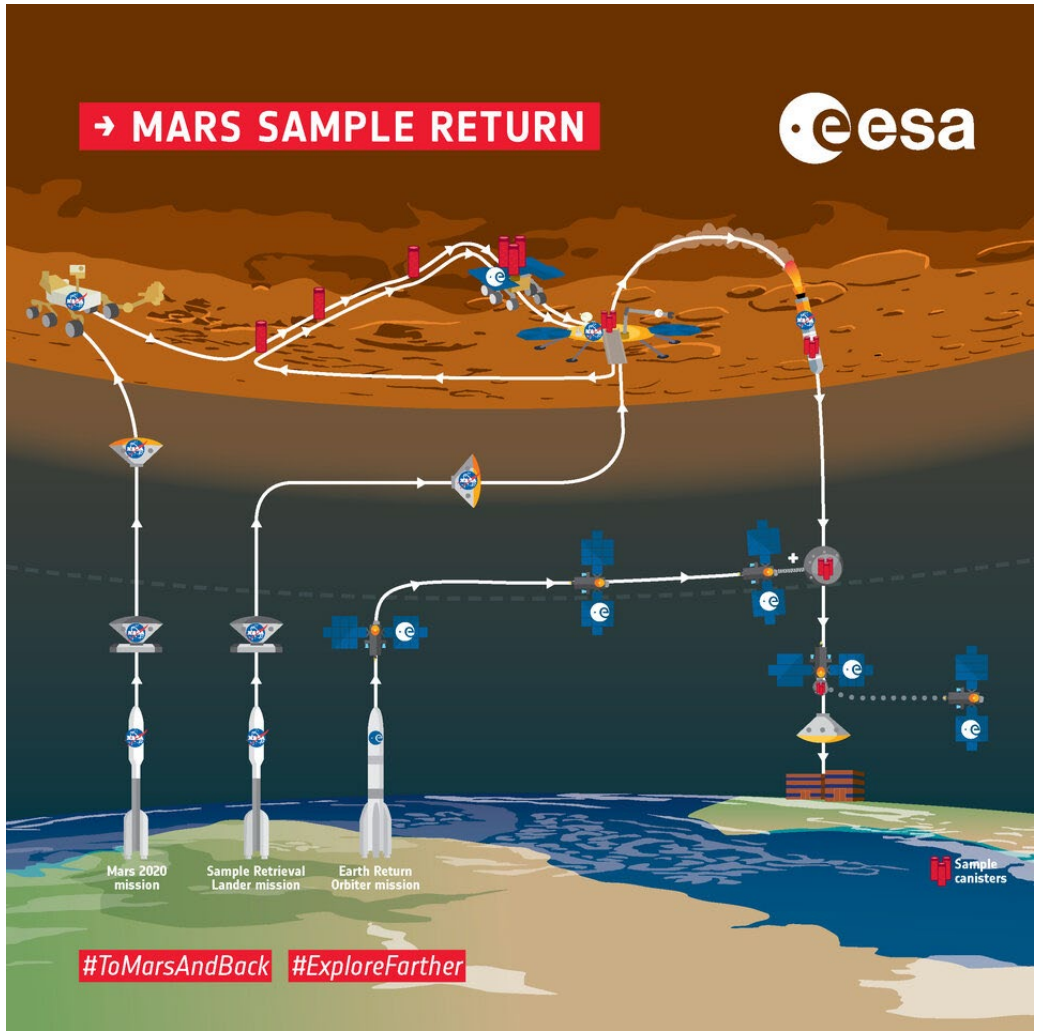
Agenda

- The Earth Return Orbiter
- MBSE implementation within ERO
- Budget management: MBSE
- Budget management: Dashboard
- Conclusion and Way forward
- Q&A

The Earth Return Orbiter (ERO)



MSR Campaign goal	• Bring back Martian samples to be studied on Earth
ERO Mission goals	• Capture and contain samples in Martian Orbit • Deliver samples to Earth
Organisation	• ESA's Human and Robotic Exploration Directorate (HRE) • Airbus Defence and Space (ADS) as Prime contractor
Challenges	• Cross-agency program • Complex technical challenges
Needs	• Robust systems engineering • Effective communication between stakeholders and all disciplines involved

Model Based System Engineering within ERO

Model content:

Pilar I: Requirements

Pilar II: Operation Analysis

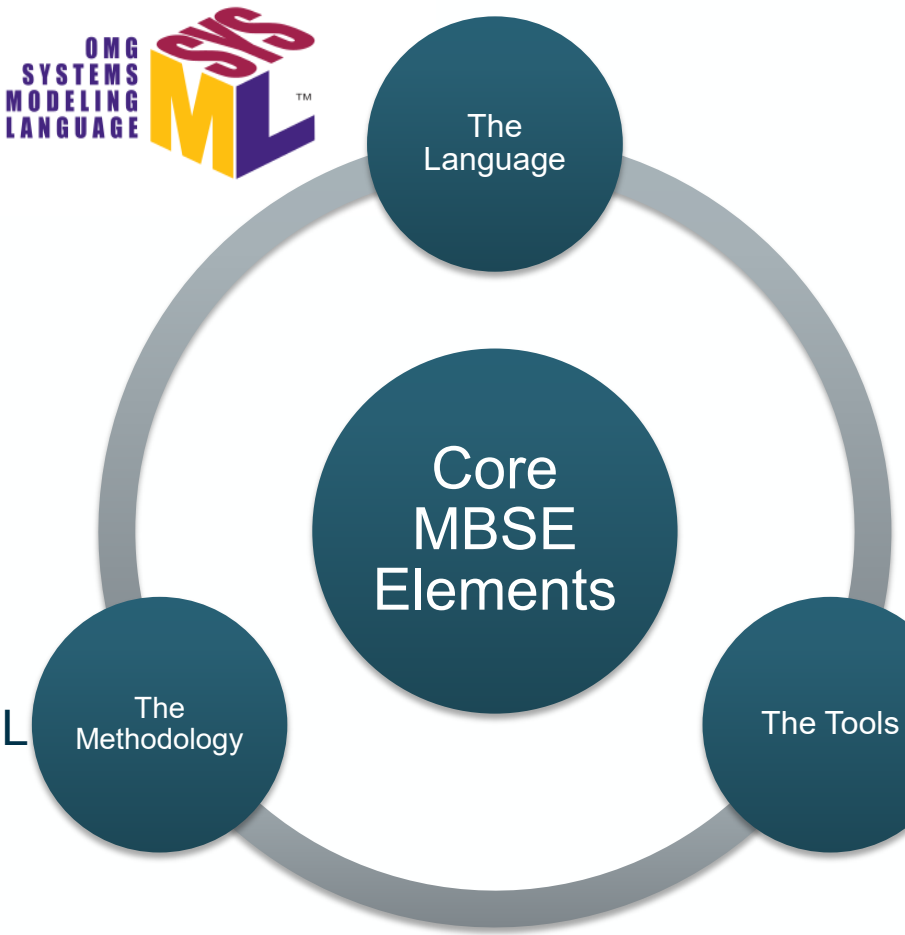
Pilar III: Functional architecture

Pilar IV: Logical Architecture

Pilar V: Model traceability

Workflow:

- Modeling activities started in Phase B2
- First model delivered for S-PDR
- User need identification
- Model based mass budget management pilot



1) ESA SysML solution
2) Airbus MOFL(T)

The proposed solution

CAMEO

- Extension of methodology
- Formalized mass budget
- Version controlled and working views
- Connectivity to rest of the model

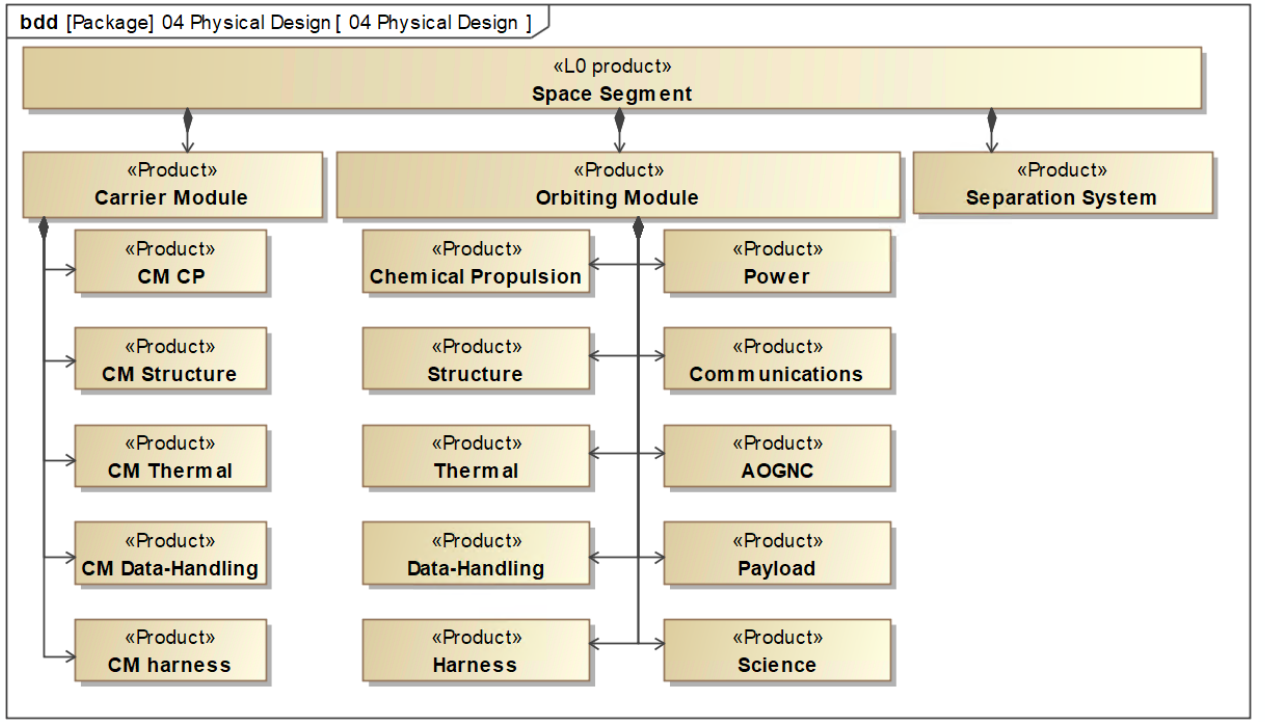
Dashboard

- Visual aid
- Communication tool
- Ease of access throughout stakeholder
- Output from CAMEO
- Consistency of information

Logical/Physical Architecture

Logical Decomposition

- SysML block
- Association links
- Hierarchical decomposition of system



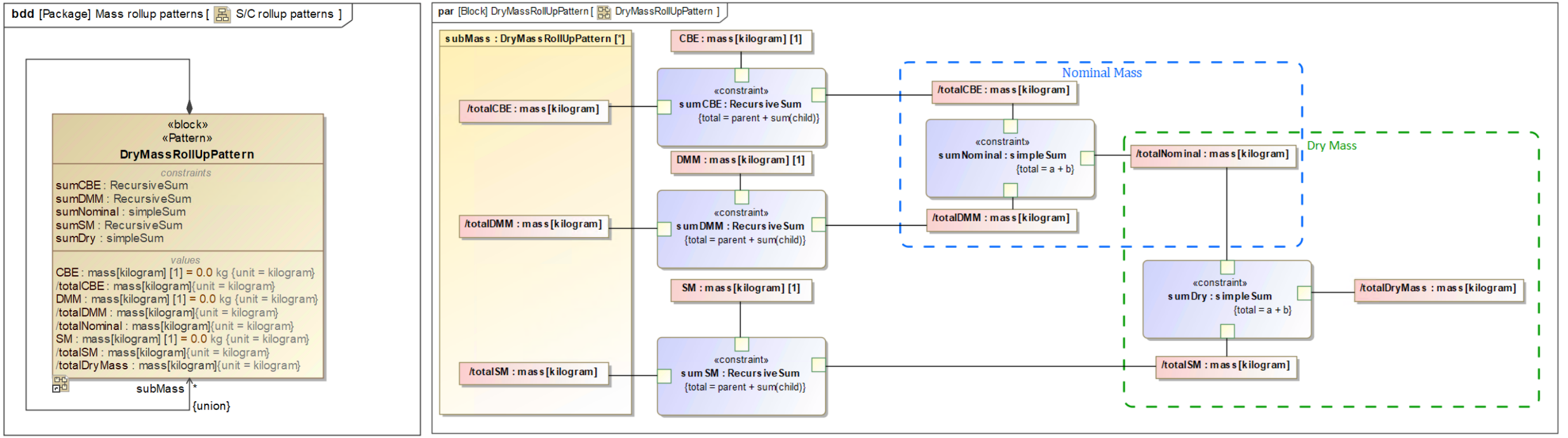
Both *ESA's SysML Solution* and ADS's *MOLF(T)* methodology use this approach

Mass properties I

SysML Parametrics

- Patterns
- Parametric diagrams

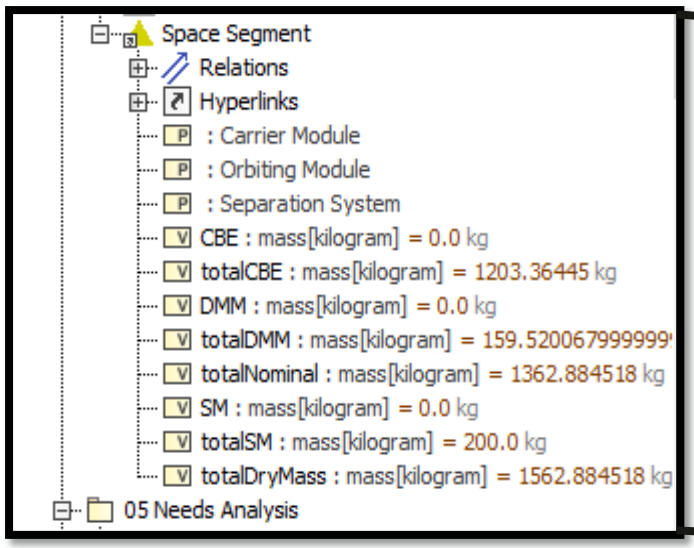
- Formalised budget management
- Visualisation of information flow
- Automated application to Architecture
- SysML inheritance hierarchy

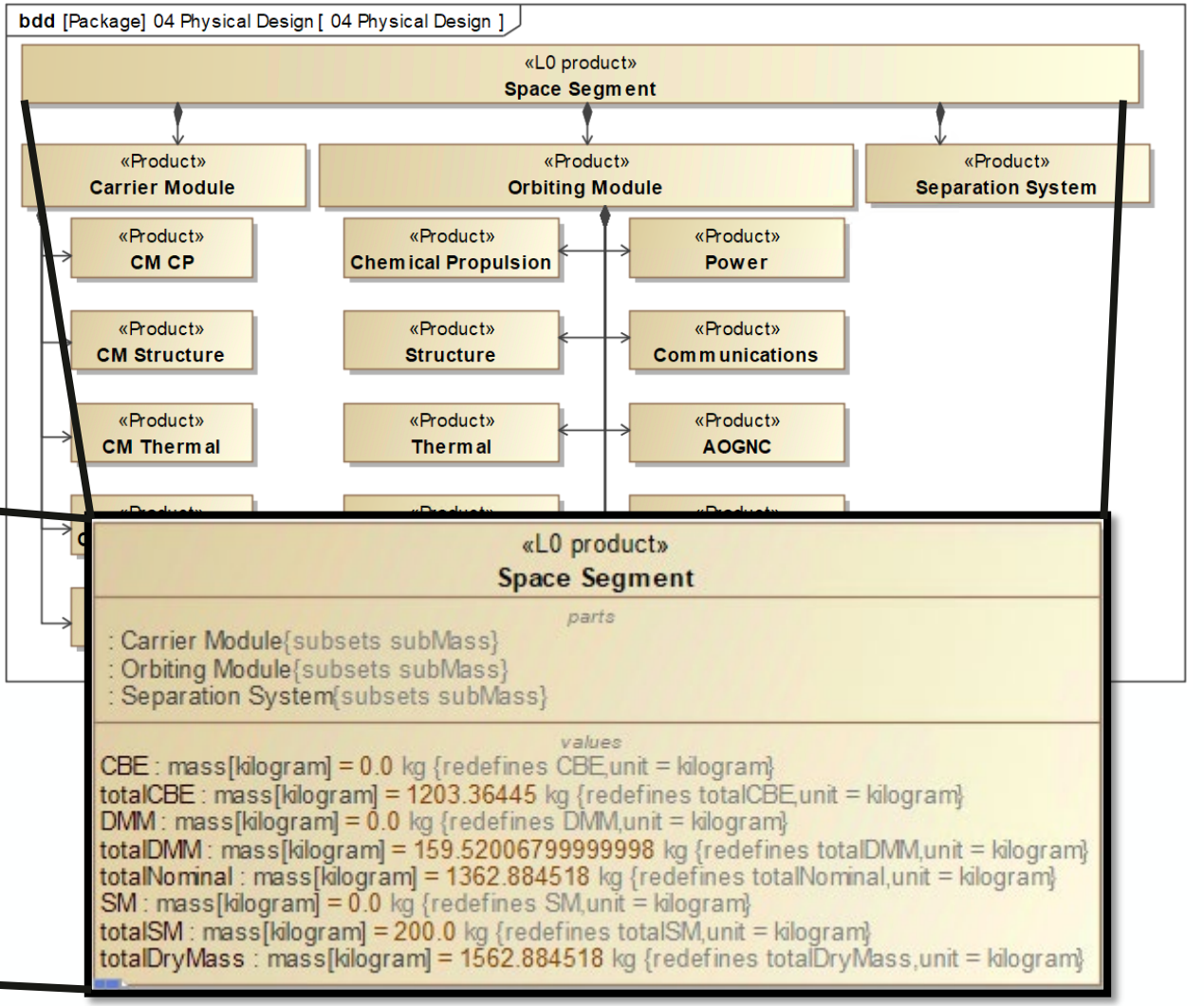


Mass properties II

SysML Parametrics

- Patterns
- Parametric diagrams



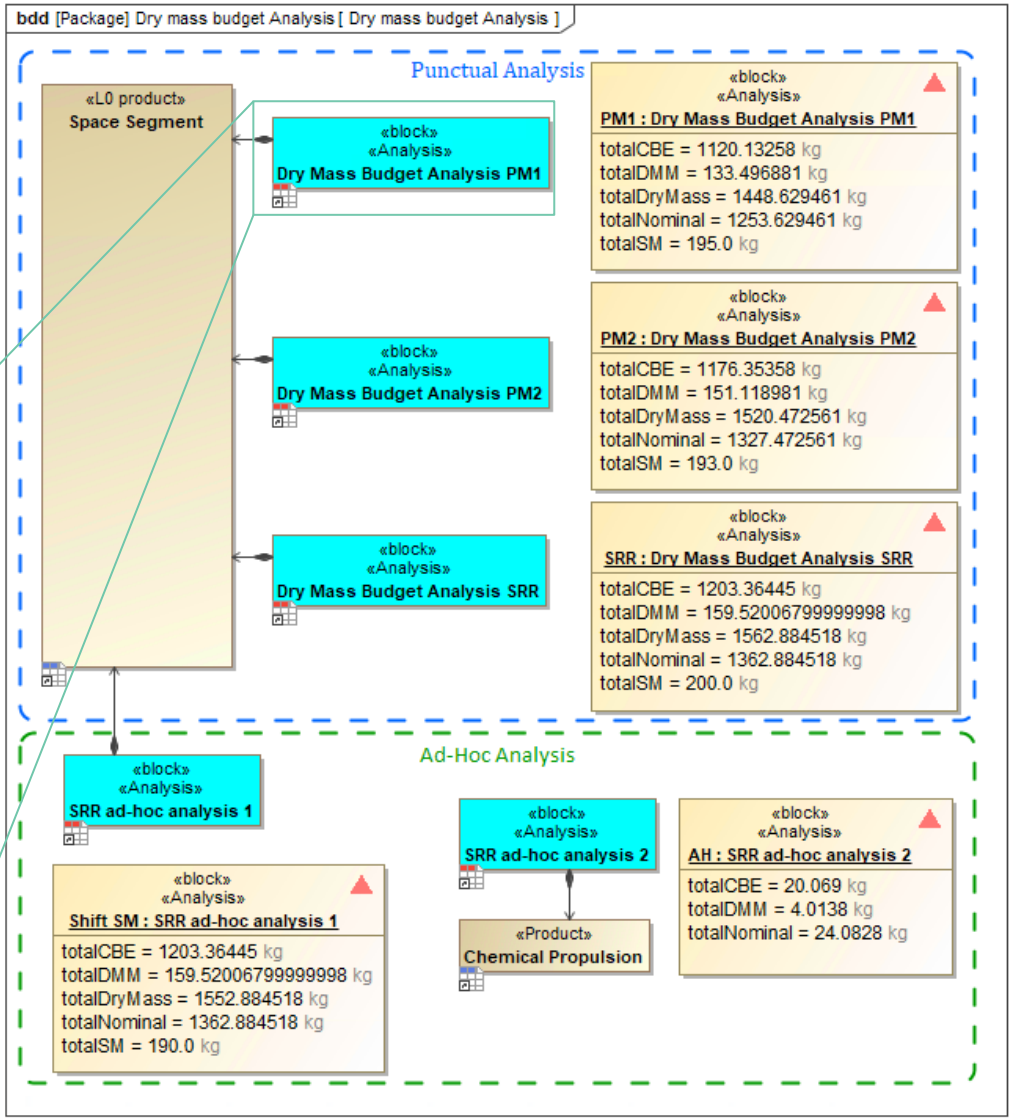


CAMEO Budget Management

SysML instances

- Virtual copy of S/C
- Store information of past baselines
- Ad-Hoc analysis between milestones

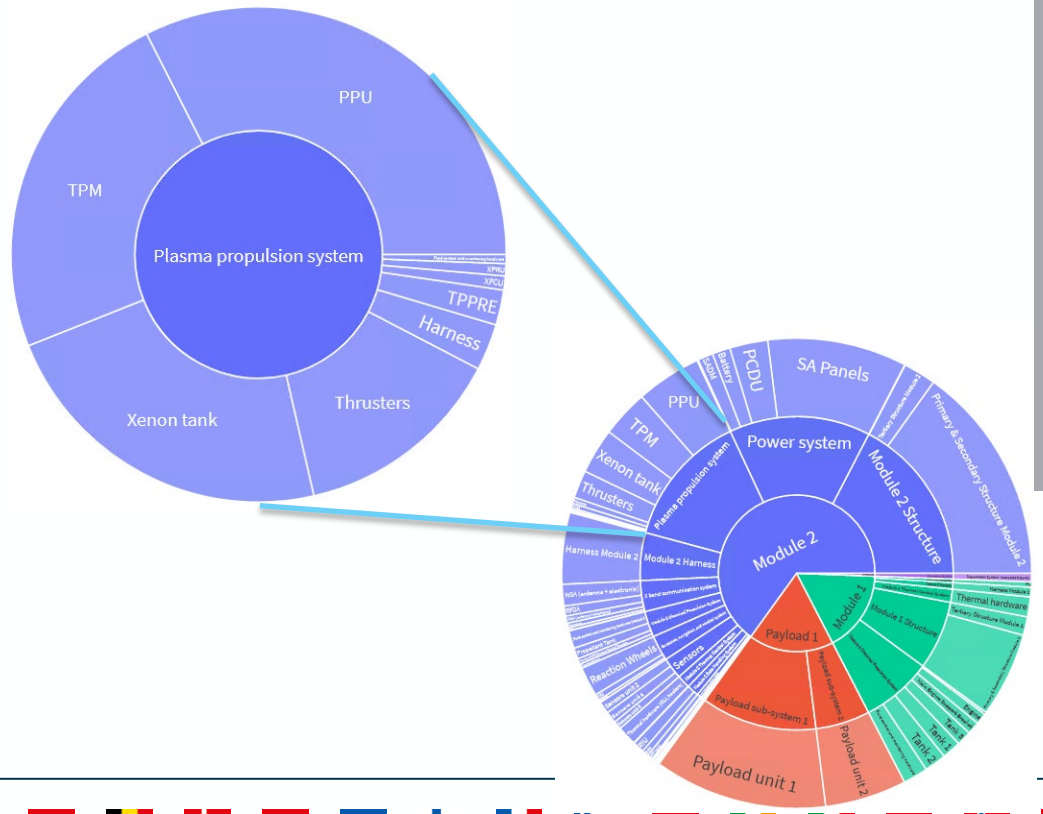
#	Name	Classifier	totalCBE (kg)	totalDMM (kg)	totalNominal (kg)	totalSM (kg)	totalDryMass (kg)
1	PM1	Dry Mass Budget Analysis PM1	1120.1326	133.4969	1253.6295	195	1448.6295
2	dry Mass Budget Analysis PM1.space Segment	Space Segment	1120.1326	133.4969	1253.6295	195	1448.6295
3	dry Mass Budget Analysis PM1.space Segment.carrier Module	Carrier Module	448.9716	43.8684	492.84	50	542.84
12	dry Mass Budget Analysis PM1.space Segment.orbiting Module	Orbiting Module	651.161	87.6285	738.7894	141	879.7894
13	dry Mass Budget Analysis PM1.space Segment.orbiting Module.aognc	AOGNC	30.612	4.5918	35.2038	0	35.2038
18	dry Mass Budget Analysis PM1.space Segment.orbiting Module.chemical Propulsion	Chemical Propulsion	20.069	4.0138	24.0828	0	24.0828
22	dry Mass Budget Analysis PM1.space Segment.orbiting Module.communications	Communications	43.47	4.347	47.817	0	47.817
27	dry Mass Budget Analysis PM1.space Segment.orbiting Module.data-Handling	Data-Handling	42.72	4.272	46.992	0	46.992
29	dry Mass Budget Analysis PM1.space Segment.orbiting Module.harness	Harness	35.702	5.3553	41.0572	0	41.0572
30	dry Mass Budget Analysis PM1.space Segment.orbiting Module.payload	Payload	100	20	120	0	120
32	dry Mass Budget Analysis PM1.space Segment.orbiting Module.power	Power	95.4	9.54	104.94	0	104.94
37	dry Mass Budget Analysis PM1.space Segment.orbiting Module.science	Science	75.528	15.1056	90.6336	0	90.6336
41	dry Mass Budget Analysis PM1.space Segment.orbiting Module.structure	Structure	200.4	20.04	220.44	0	220.44
42	dry Mass Budget Analysis PM1.space Segment.orbiting Module.thermal	Thermal	7.26	0.363	7.623	0	7.623
46	dry Mass Budget Analysis PM1.space Segment.separation System	Separation System	20	2	22	4	26

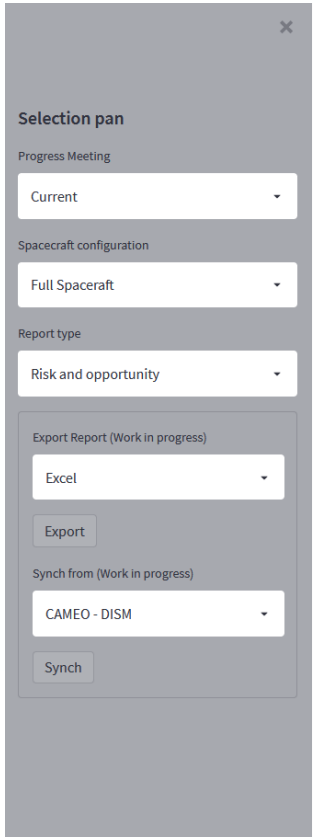


Dashboard

Python webapp

- Outputs from CAMEO
- Python based (modular implementation)
- User defined views





Conclusion and Way forward

Conclusion — First iteration implemented

- ✓ Tailoring of MBSE methodology to include parametrics
- ✓ Version controlled budget and work environment in CAMEO
- ✓ Dashboard for data viewing and sharing
- ✓ Initial versions well received within project

Way Forward — Deployment

- ❑ Pilot roll-out within the project pending
- ❑ Tracing of requirements to budget

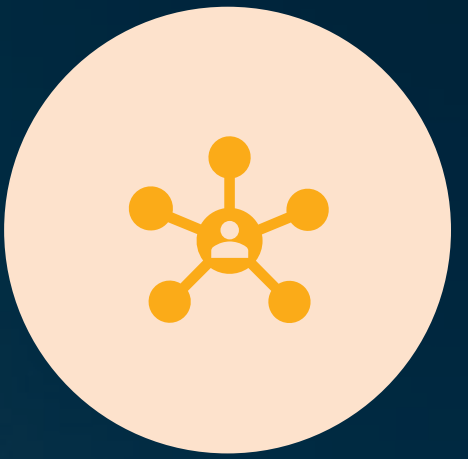
Future Work — Capabilities

- ➢ Expand to other budgets (power, …)
- ➢ Converter between budget philosophies
- ➢ User experience

Open discussion

THANK YOU FOR YOUR ATTENTION

QUESTIONS ARE WELCOMED



POINT OF CONTACTS:

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Additional materials

ERO at a glance

Earth Return Orbiter

Round trip to Mars Design
Stacked S/C (1/3 jettisoned mass)
-> Launch mass: 7.2T
-> Departure mass: 3.6T
-> Return mass: 3T

High Reliability
2-FT design for safety critical phases

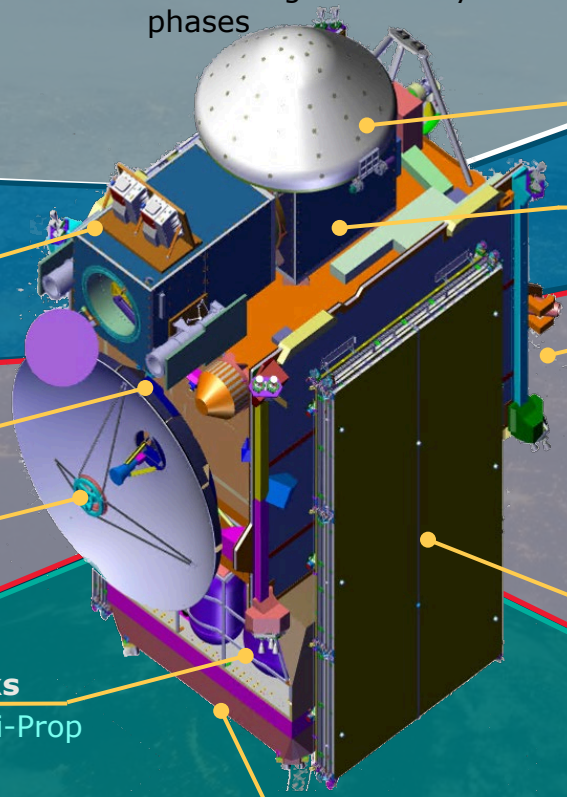
CCRS

Earth Entry System
Deliver OS back to Earth surface

Capture, Contain & return System

Rendezvous Sensor Suite

LIDAR & NAC
Locate samples in Martian Orbit
Jettisoned at Mars



Electric Propulsion
5 electrical thruster
High thrust & Isp:
250mN - 4000s
1203 kg of Xenon

Return Module

UHF Payload
Relay capability for Mars assets,
EDL & MAS ascent
2 Mbits/s

Return Module

X-Band Communication
2-axis steerable HGA & MGA
2 x LGA
2.5Mbits/s @ 1AU –
150kbits/s @ 2.2 AU

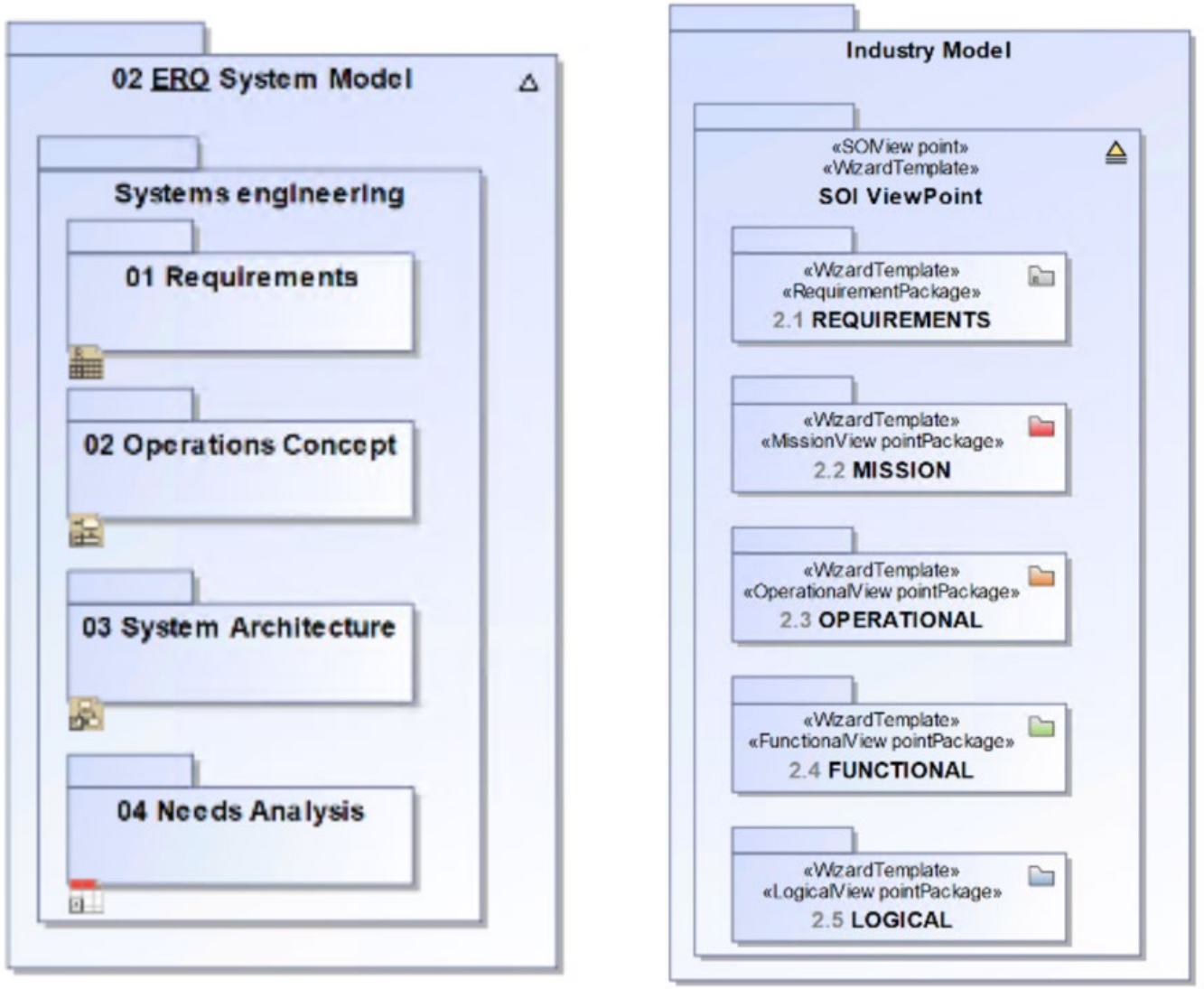
Solar Array
Deployable 2 x 72m2
Power: 42 kW

CP Tanks
2025 kg of Bi-Prop

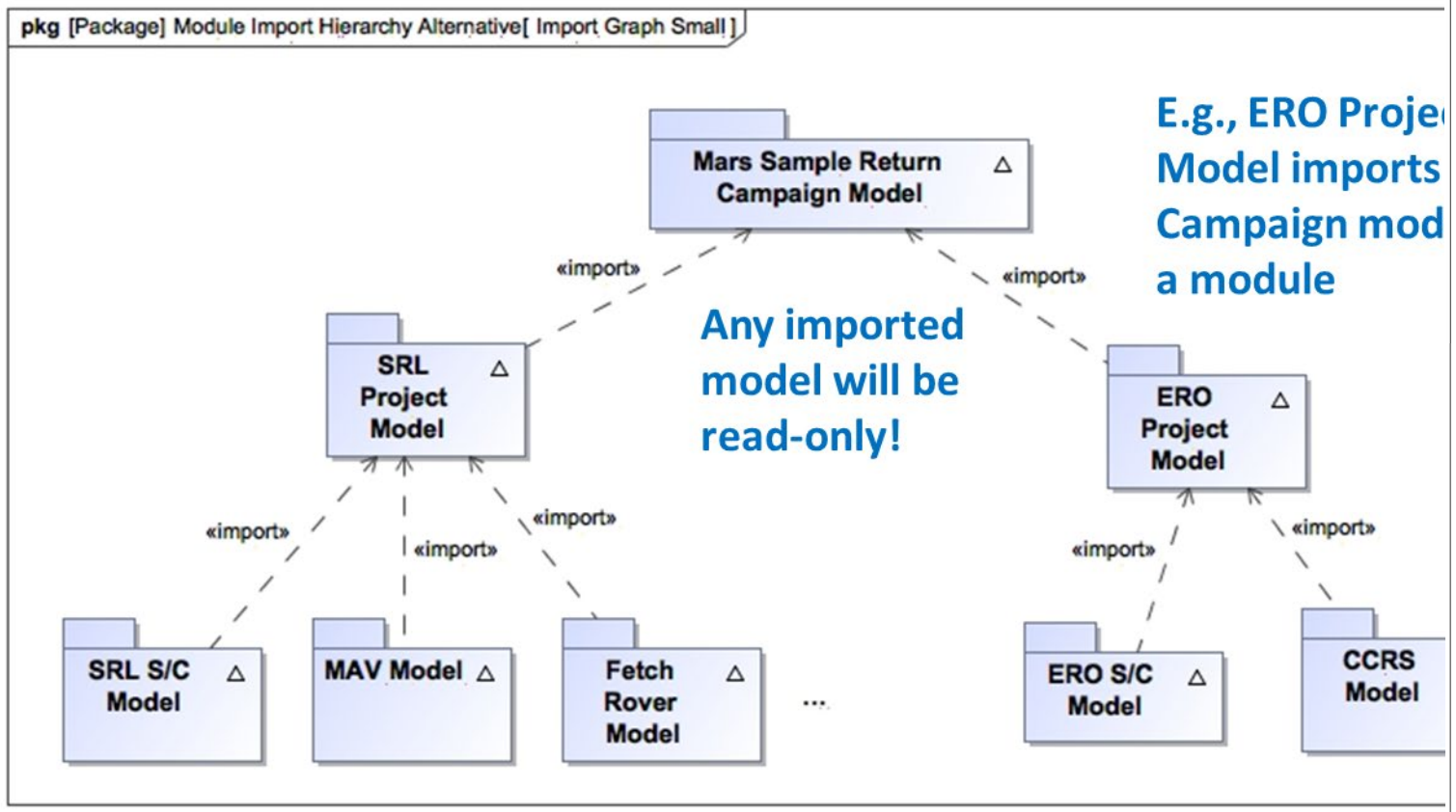
Main Engines
2 x 2 main insertion engines
400N

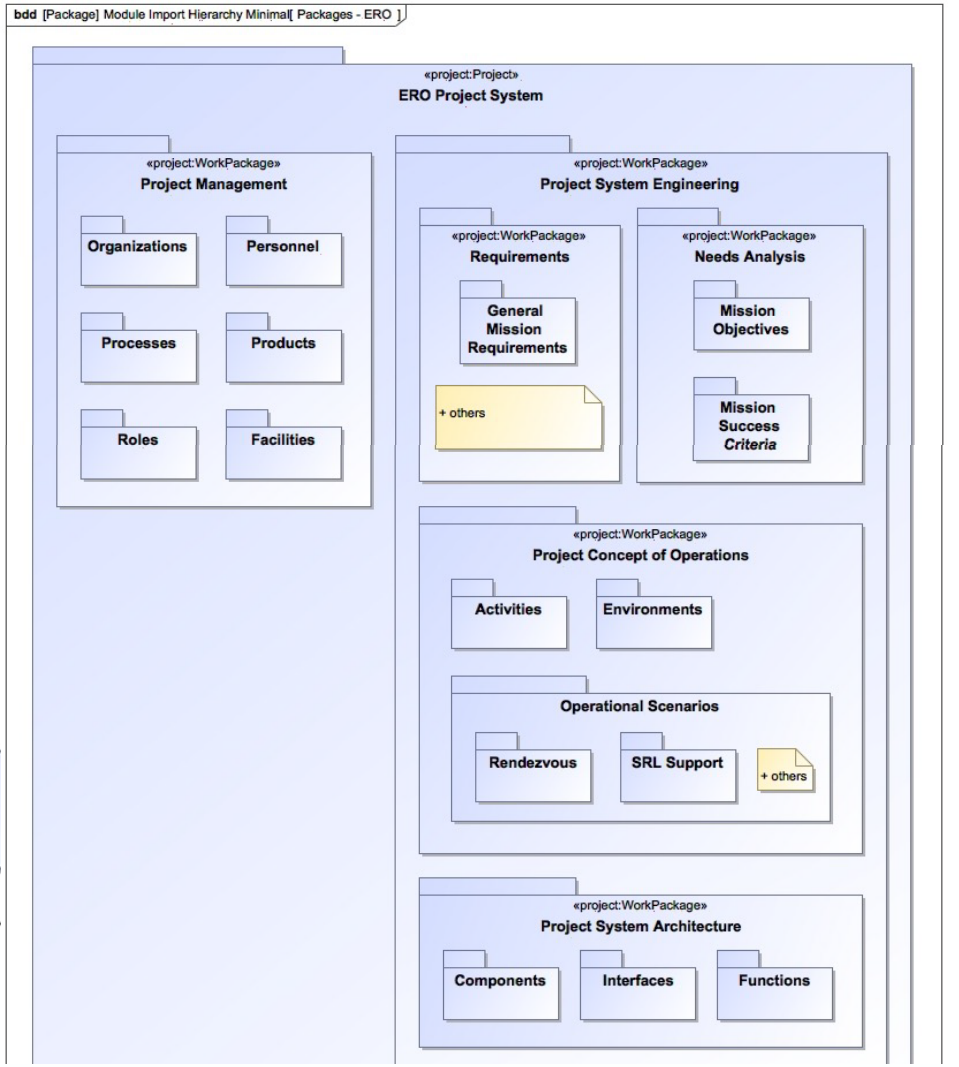
Orbit Insertion Module

DISM Organisation

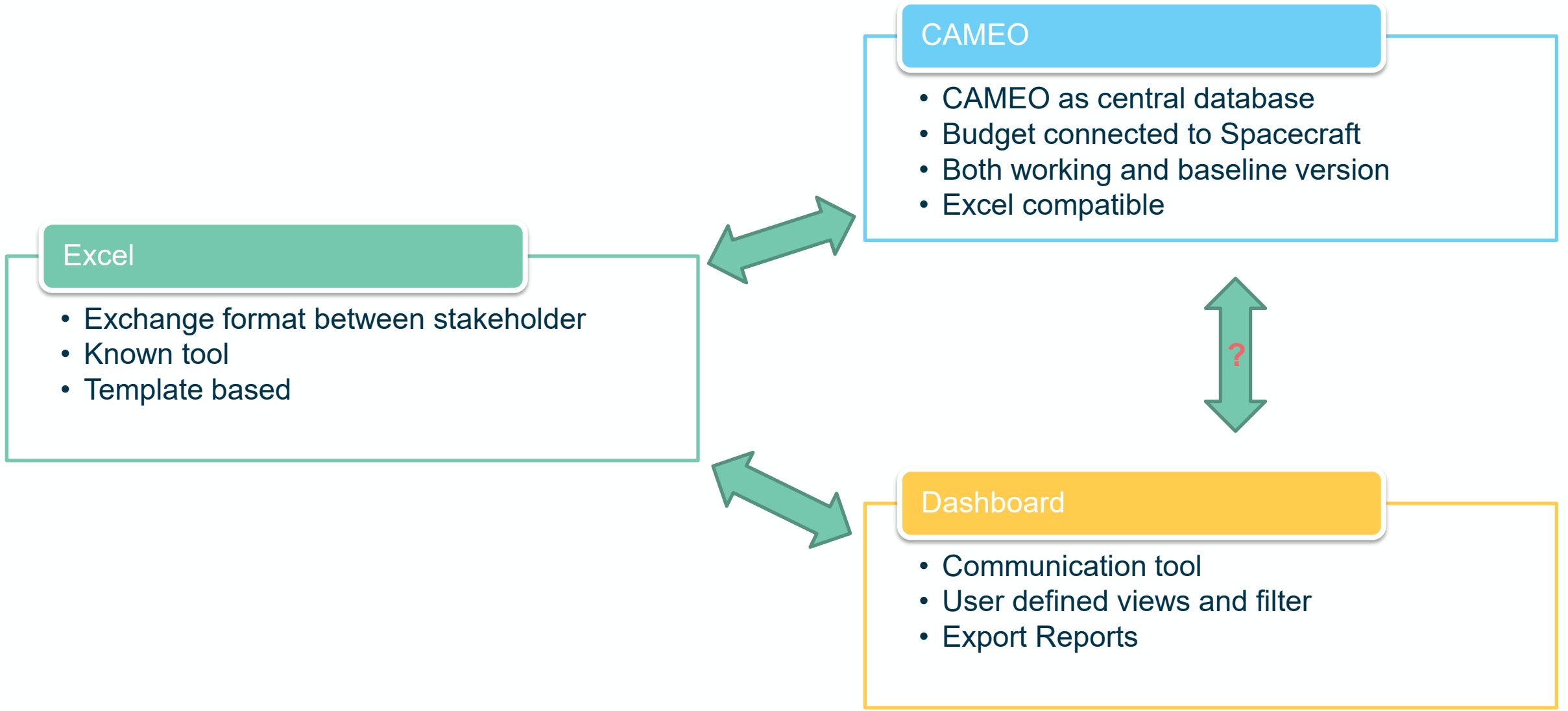


DISM History





Connectivity



Model Based Review

Online Aspects

General Introduction to MBSE

- Familiarize stakeholders to MBSE environment
  - SysML
  - CAMEO
  - MOFL

Online Review

- Consistency, Completeness and Correctness (3 c's)
- Specific model aspect mapped to relevant expert
- Issue raised directly into the model

Colocation

- Discussion of review comments generated offline
- Incorporate changes in the model

Offline Aspects

Definition of review scope and delivery of DISM

- Similar to classic review format
- Accessibility of delivery
  - CAMEO model
  - HTML – web access
  - Excel (capture raised issues)

Offline Review

- Offline reviewer have access to current model review status
- Raise issues:
  - Directly in the model
  - Excel (capture raised issues)