Applying the *'Spacecraft Early Analysis Model'* to the Biomass Mission

ESA MBSE Workshop
28th September 2020

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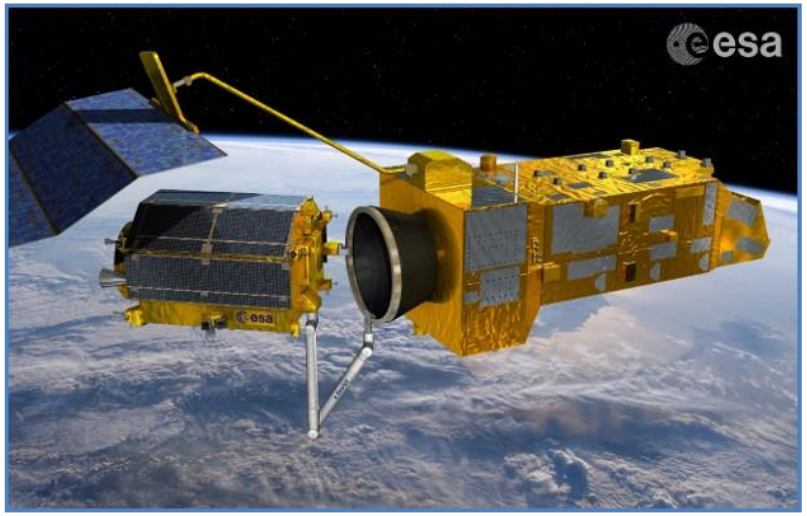
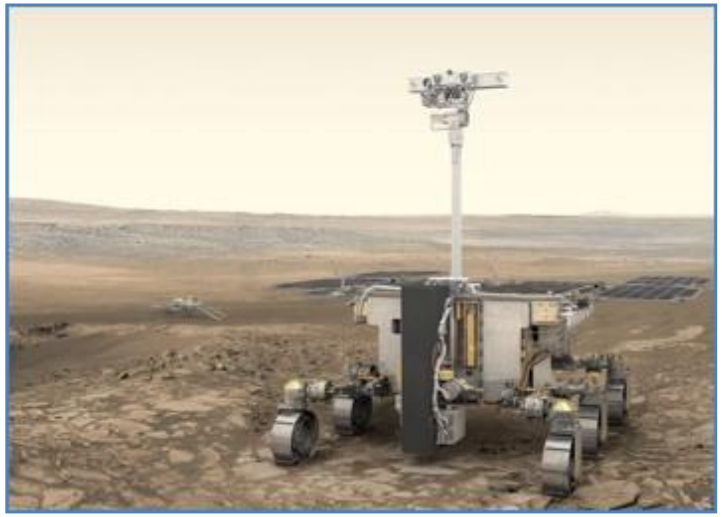
1. Previous Work
2. Spacecraft Early Analysis Model
3. Biomass – Payload Deployment
4. ExoMars – Egress from Lander
5. Summary

Airbus Space MBSE Projects



- **eDeorbit**
- Bremen, Germany
- Autonomous fail-safe reaction



- **ExoMars Rover**
- Stevenage, UK
- Communication of requirements

- **JUICE**
- Toulouse, France
- Science data allocation

eDeorbit is the largest effort so far – methodology and model template developed

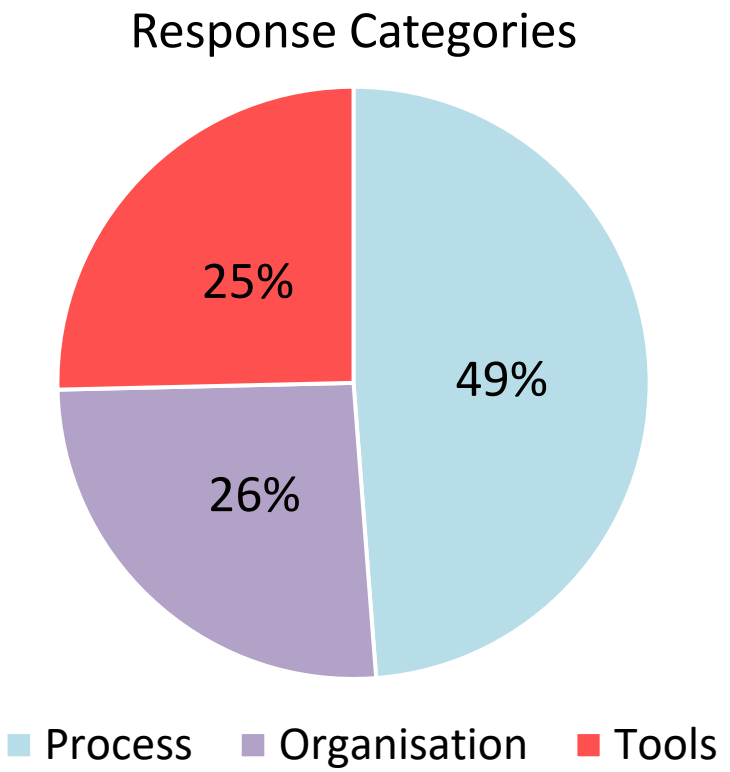
Images courtesy of European Space Agency (ESA)

Airbus Space Interviews

Questions:
- Where are the issues with Systems Engineering?
- Where might models help?

Response Themes:
- Process
- Organisation
- Tools

Topics of interest:
- **Early Functional Validation (ConOps)**
- **Template Model Framework**



Airbus Interviews Publication

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journal homepage: www.elsevier.com/locate/jss

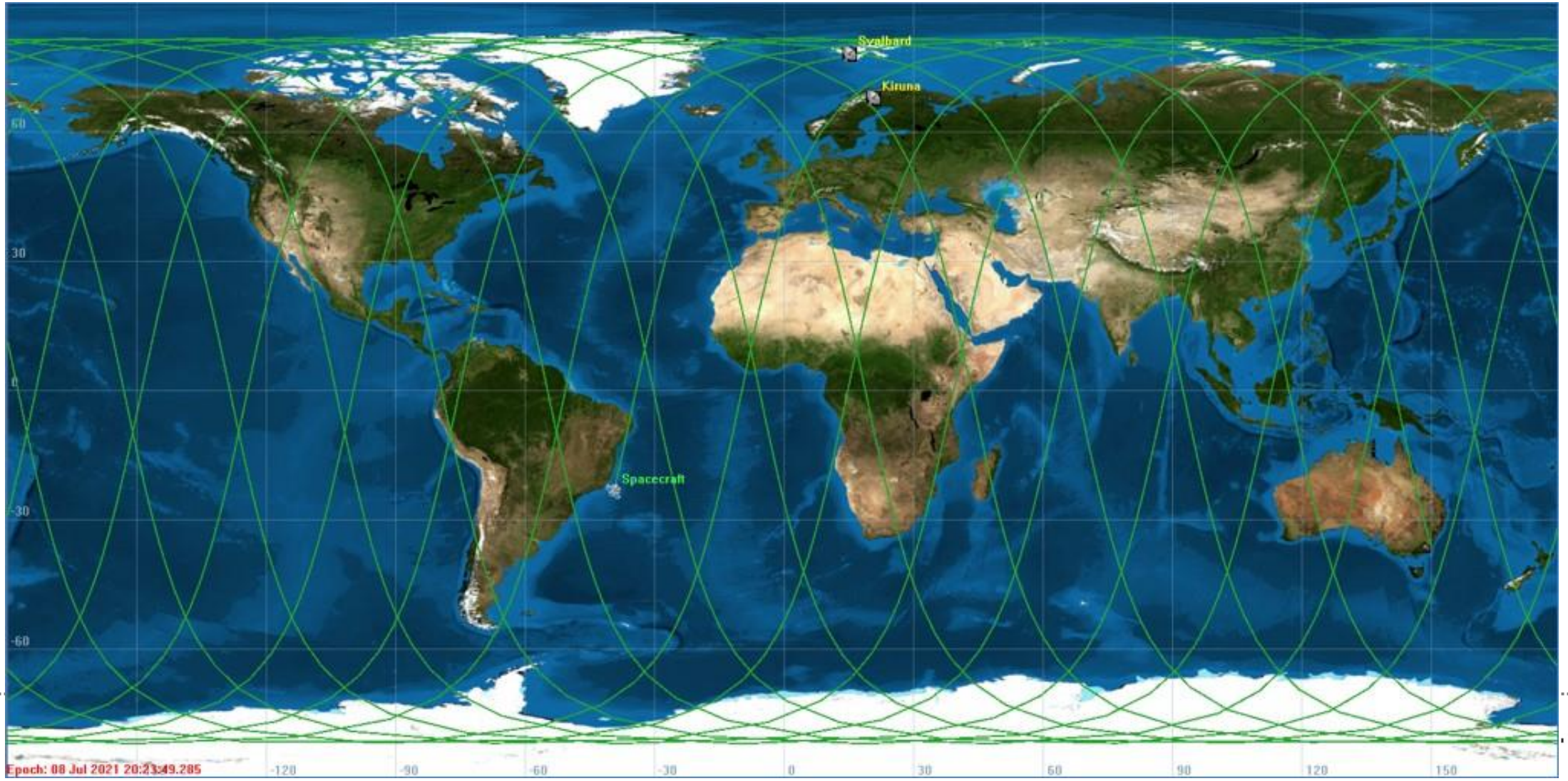
The long and winding road: MBSE adoption for functional avionics of spacecraft

Joe Gregory[a,*], Lucy Berthoud[a], Theo Tryfonas[b], Alain Rossignol[c], Ludovic Faure[d]

DOI: 10.1016/j.jss.2019.110453

J. Gregory, L. Berthoud, T. Tryfonas, A. Rossignol, and L. Faure, “The long and winding road: MBSE adoption for functional avionics of spacecraft,” Journal of Systems and Software, vol. 160 (110453), 2019.

Biomass – Mass Memory Sizing

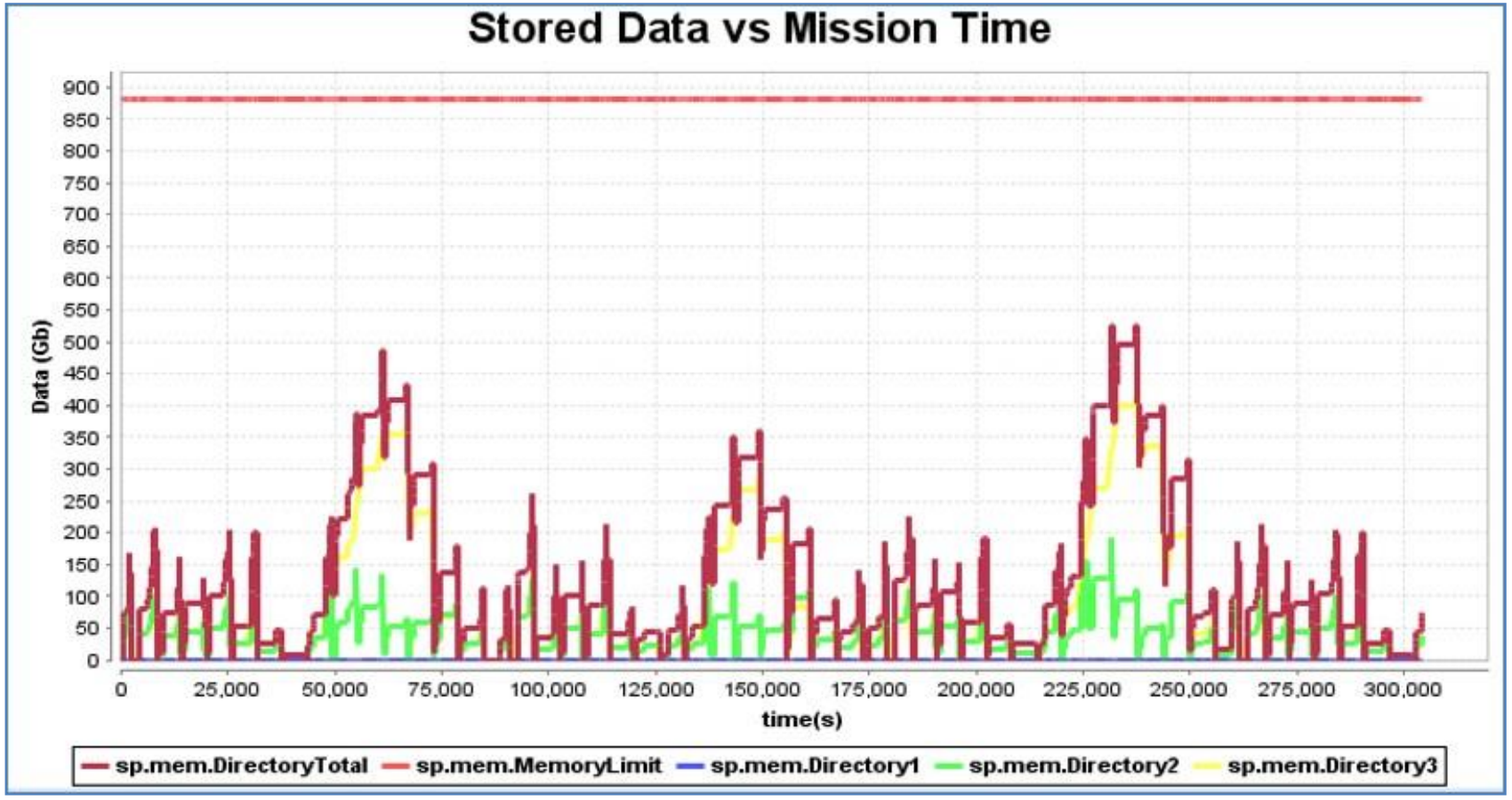


Biomass – Mass Memory Sizing

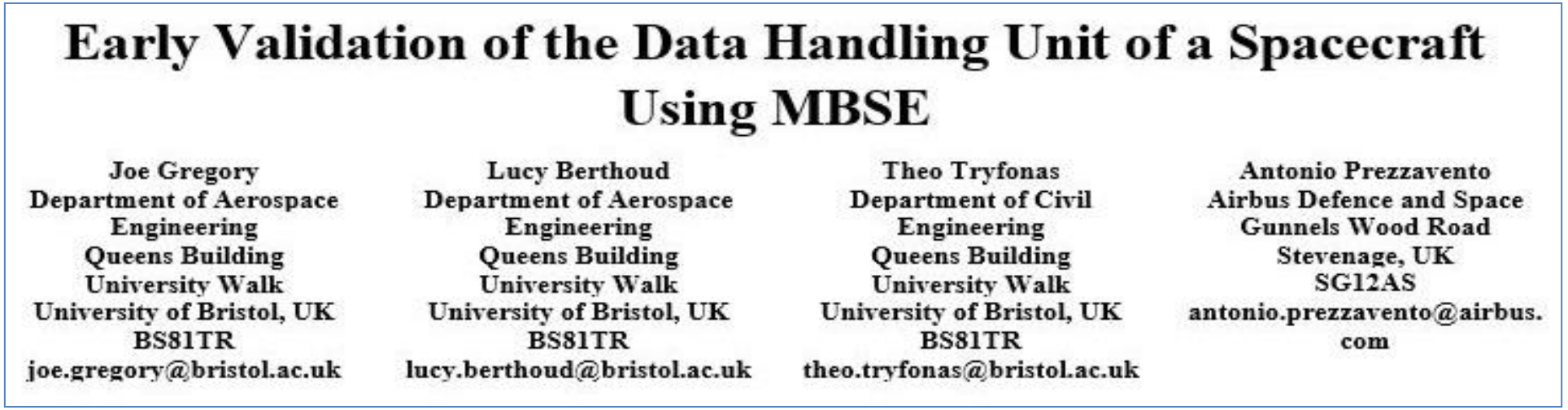
1. Simulation Demo:
   We demonstrated possibility of model execution

2. Memory allocation:
   We showed that the requirement was met

3. Optimise directory sizes:
   We proposed a suitable directory division



Biomass – Mass Memory Sizing



Early Validation of the Data Handling Unit of a Spacecraft Using MBSE

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DOI: 10.1109/AERO.2019.8741767

J. Gregory, L. Berthoud, T. Tryfonas, and A. Prezzavento, “Early Validation of the Data Handling Unit of a Spacecraft Using MBSE,” in *IEEE Aerospace Conference*, Big Sky, MT, 2019.

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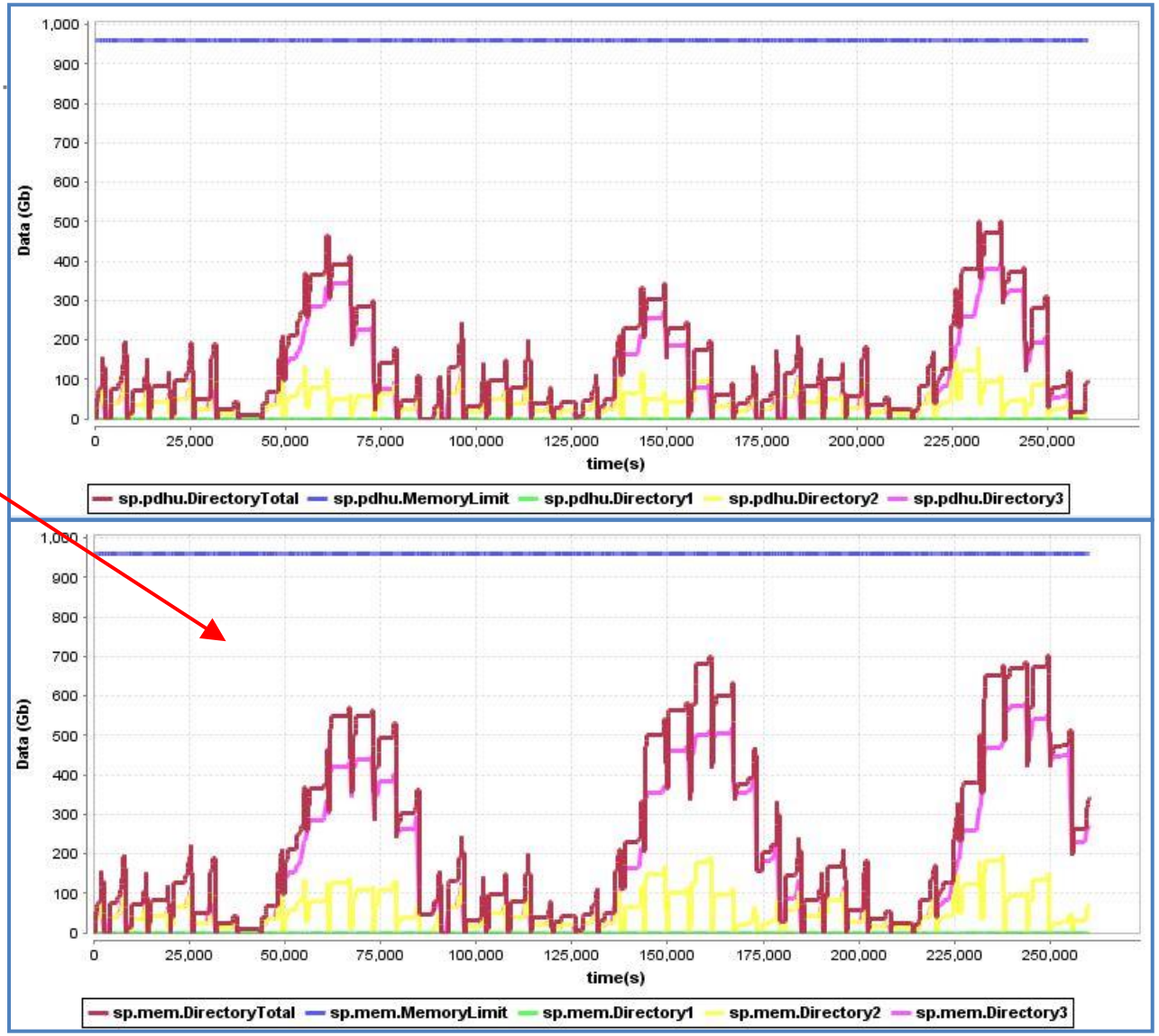
Biomass – Mass Memory Sizing

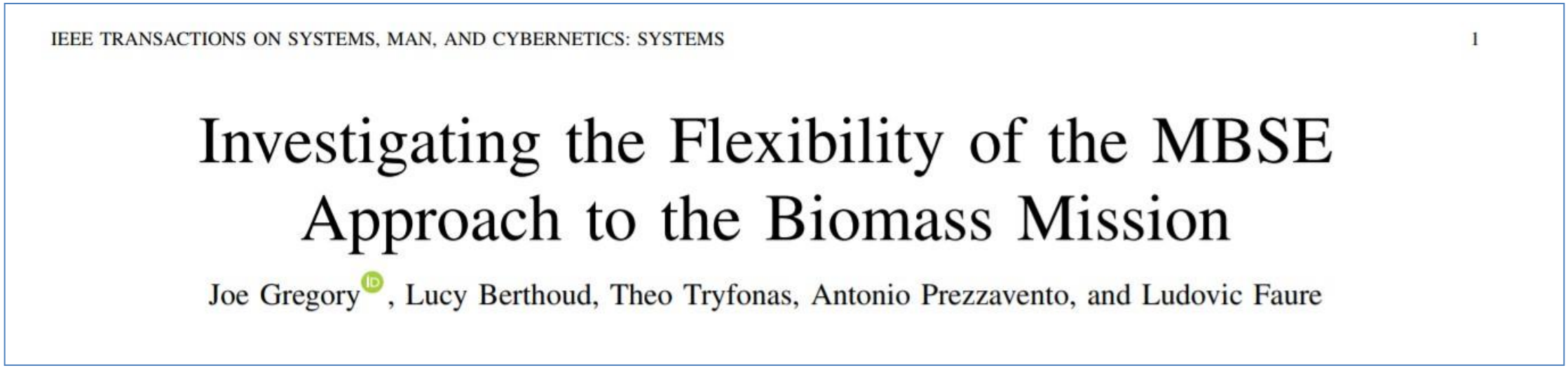
How flexible / adaptable is the model to:

1. Changes to the requirements?
2. Changes to the functional behaviour?
3. Change to the logical architecture?
4. Contingency Analysis
5. Mission Updated

The model introduces flexibility into the system definition.
But work is needed to streamline the process



Biomass – Mass Memory Sizing



IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS: SYSTEMS 1

Investigating the Flexibility of the MBSE Approach to the Biomass Mission

Joe Gregory, Lucy Berthoud, Theo Tryfonas, Antonio Prezzavento, and Ludovic Faure

DOI: 10.1109/TSMC.2019.295875
J. Gregory, L. Berthoud, T. Tryfonas, A. Prezzavento, and L. Faure, “Investigating the Flexibility of the MBSE Approach to the Biomass Mission,” IEEE Transactions on Systems, Man, and Cybernetics: Systems, 2019.

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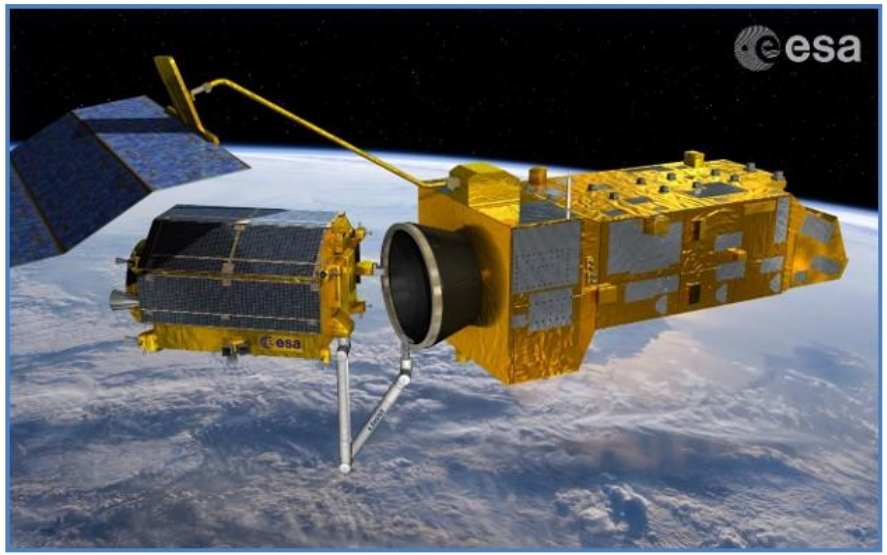
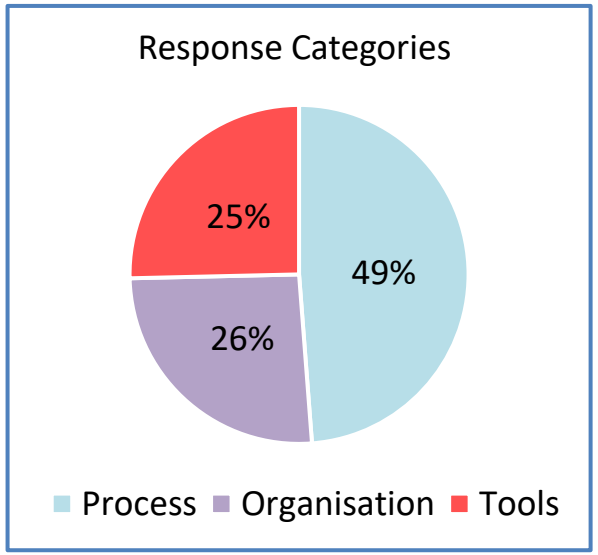
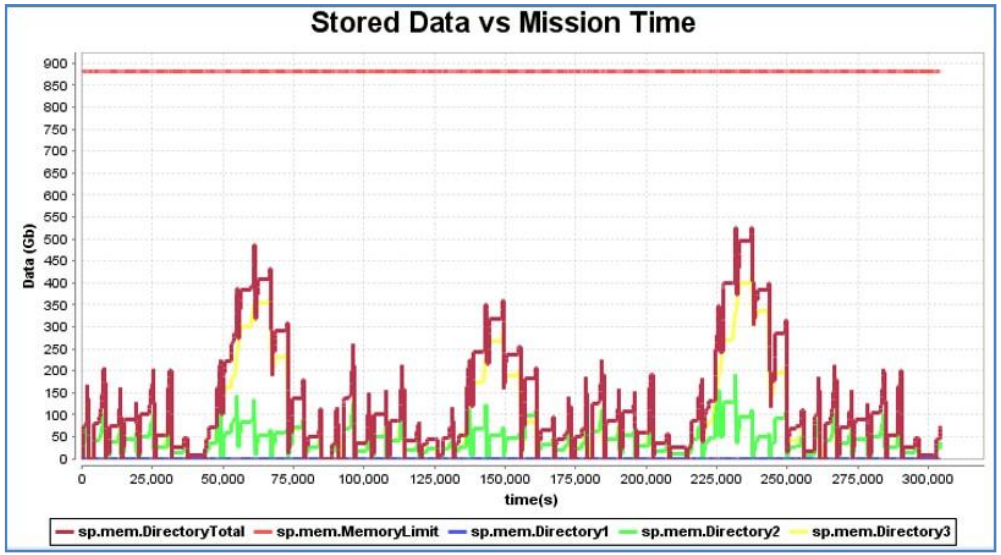
Spacecraft Early Analysis Model - Objectives

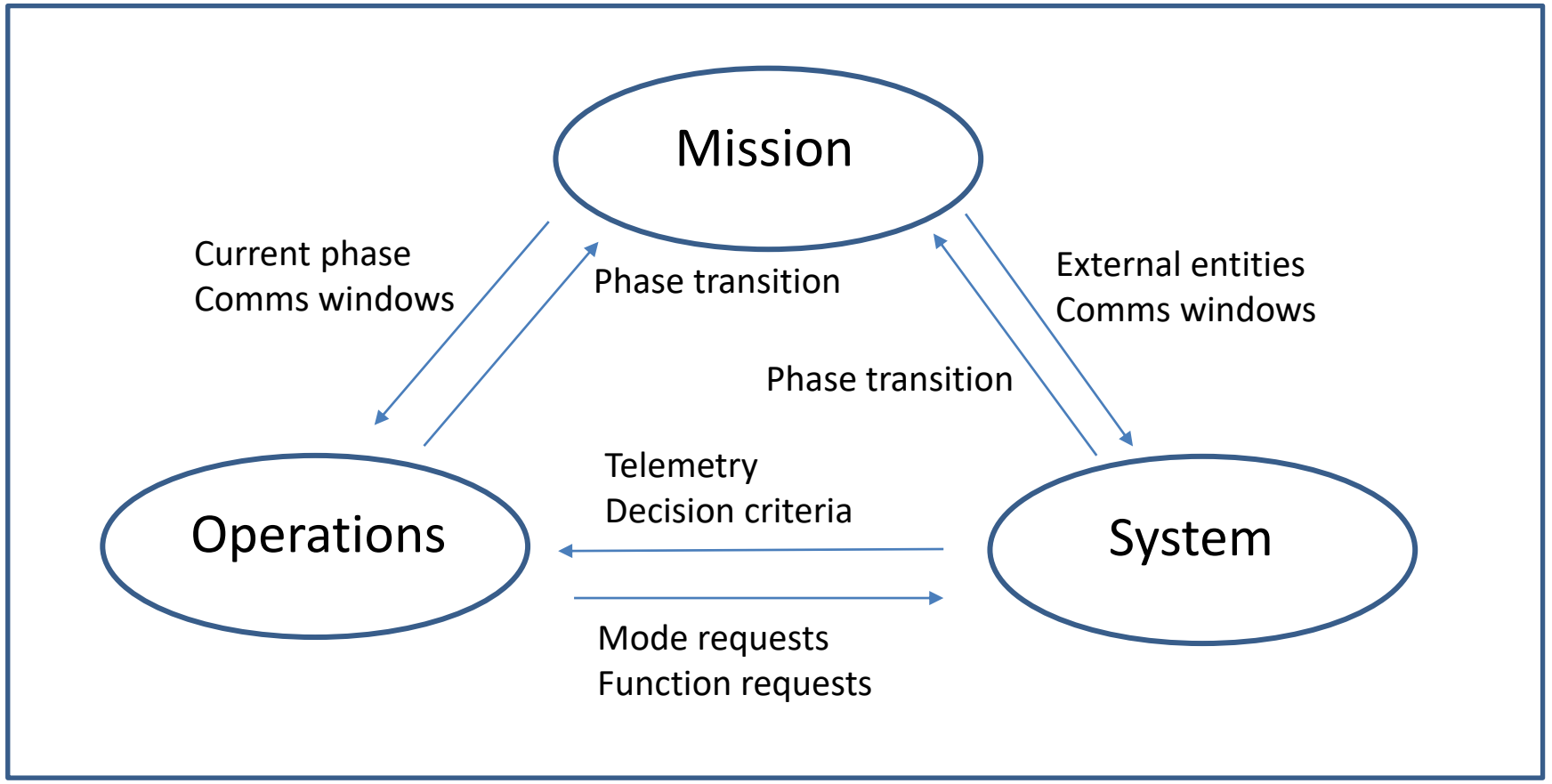




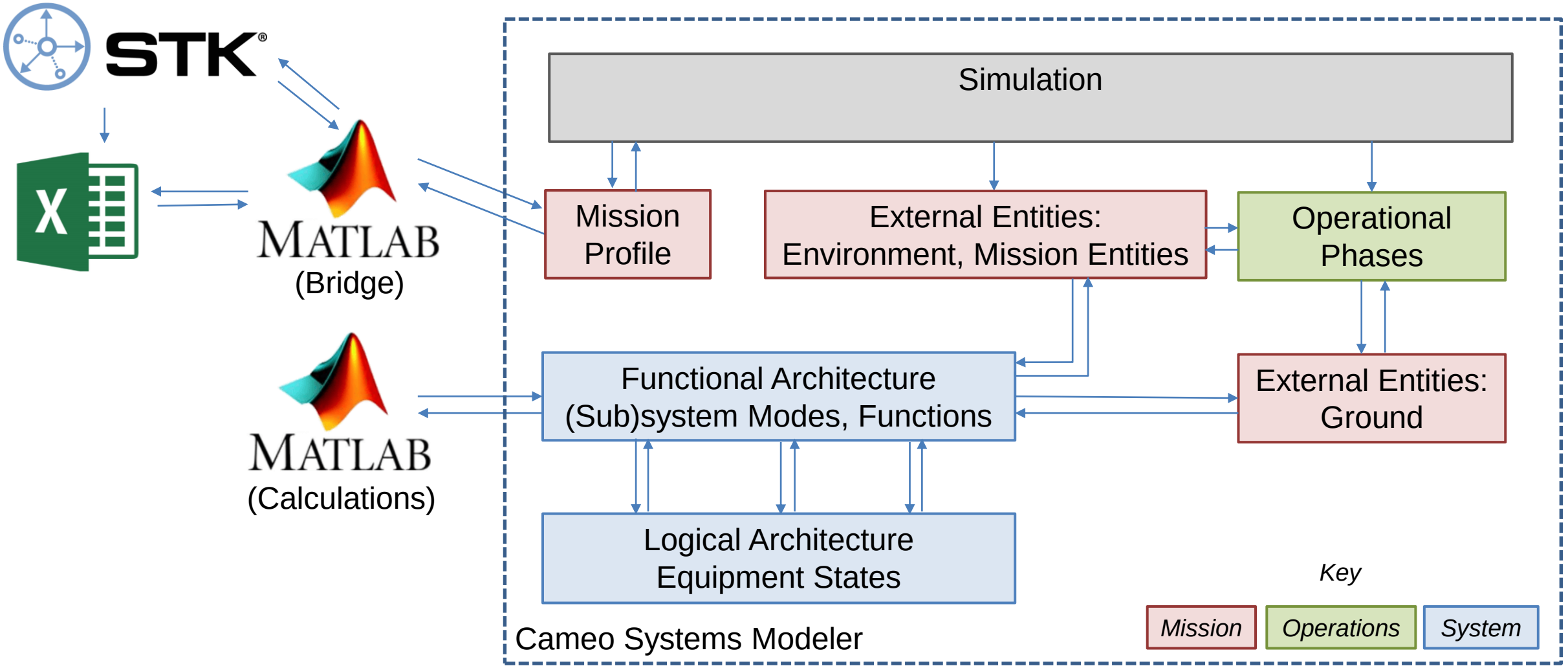


- Develop a template (the SEAM) to be used for **early functional definition and analysis** of spacecraft.
- Demonstrate the flexibility of the SEAM by applying it to real space-based missions.

Spacecraft Early Analysis Model - Separation between M, O, S



Spacecraft Early Analysis Model - Structure



Spacecraft Early Analysis Model – Interim Report

There's no 'I' in SEAM – An Interim Report on the 'Spacecraft Early Analysis Model'

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J. Gregory, L. Berthoud, T. Tryfonas, and L. Faure, "There's no 'I' in 'SEAM': An Interim Report on the 'Spacecraft Early Analysis Model'", in *IEEE Aerospace Conference*, Big Sky, MT, 2020.

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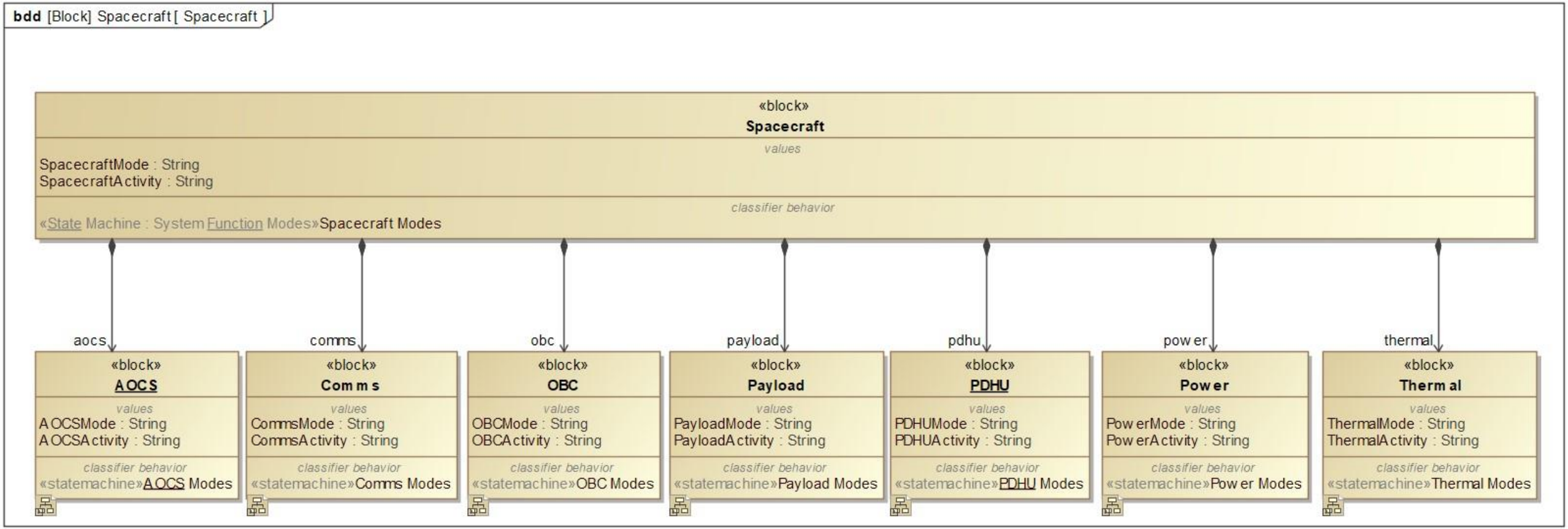
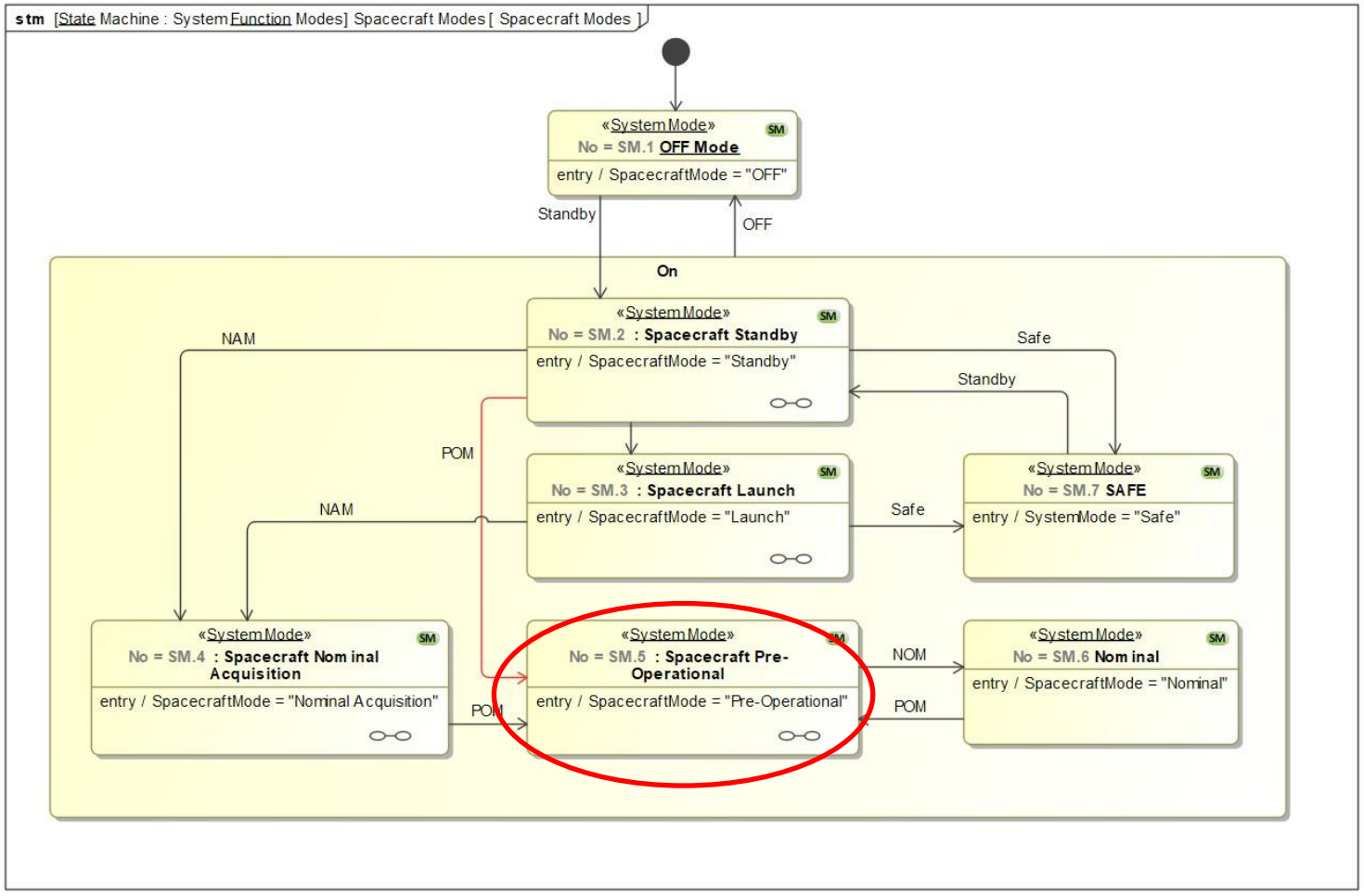
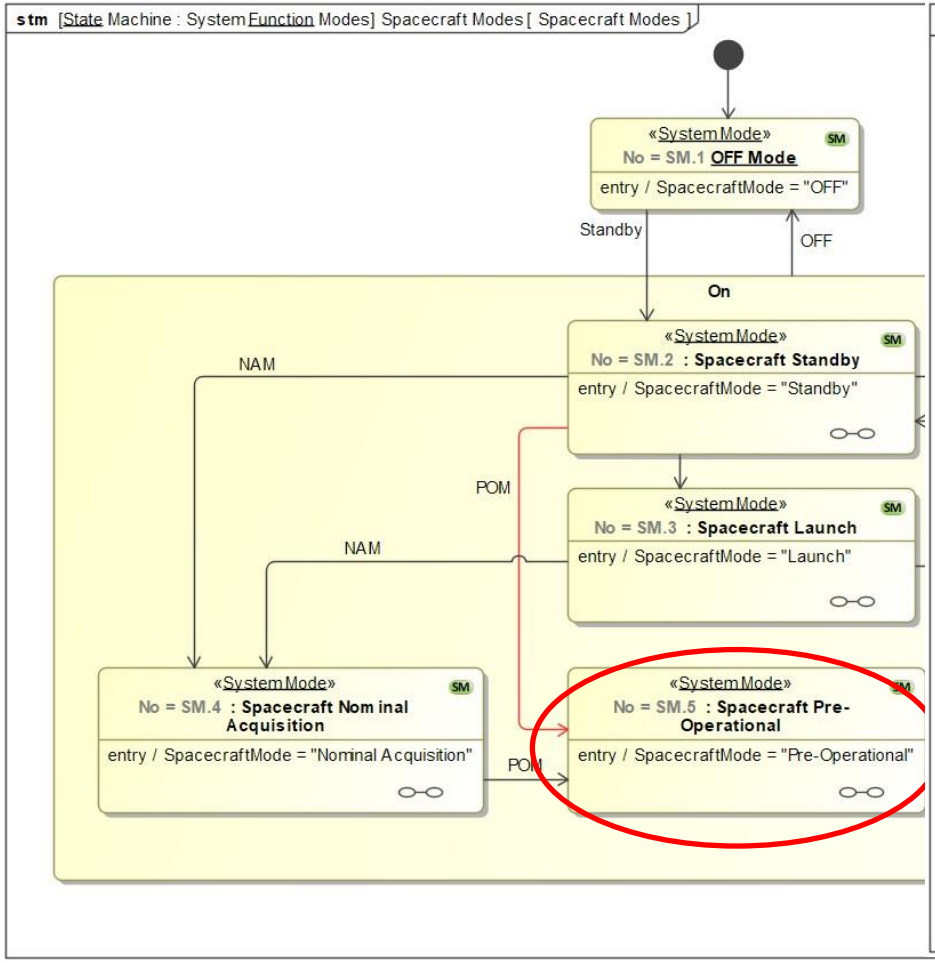
Biomass Model – Logical Architecture

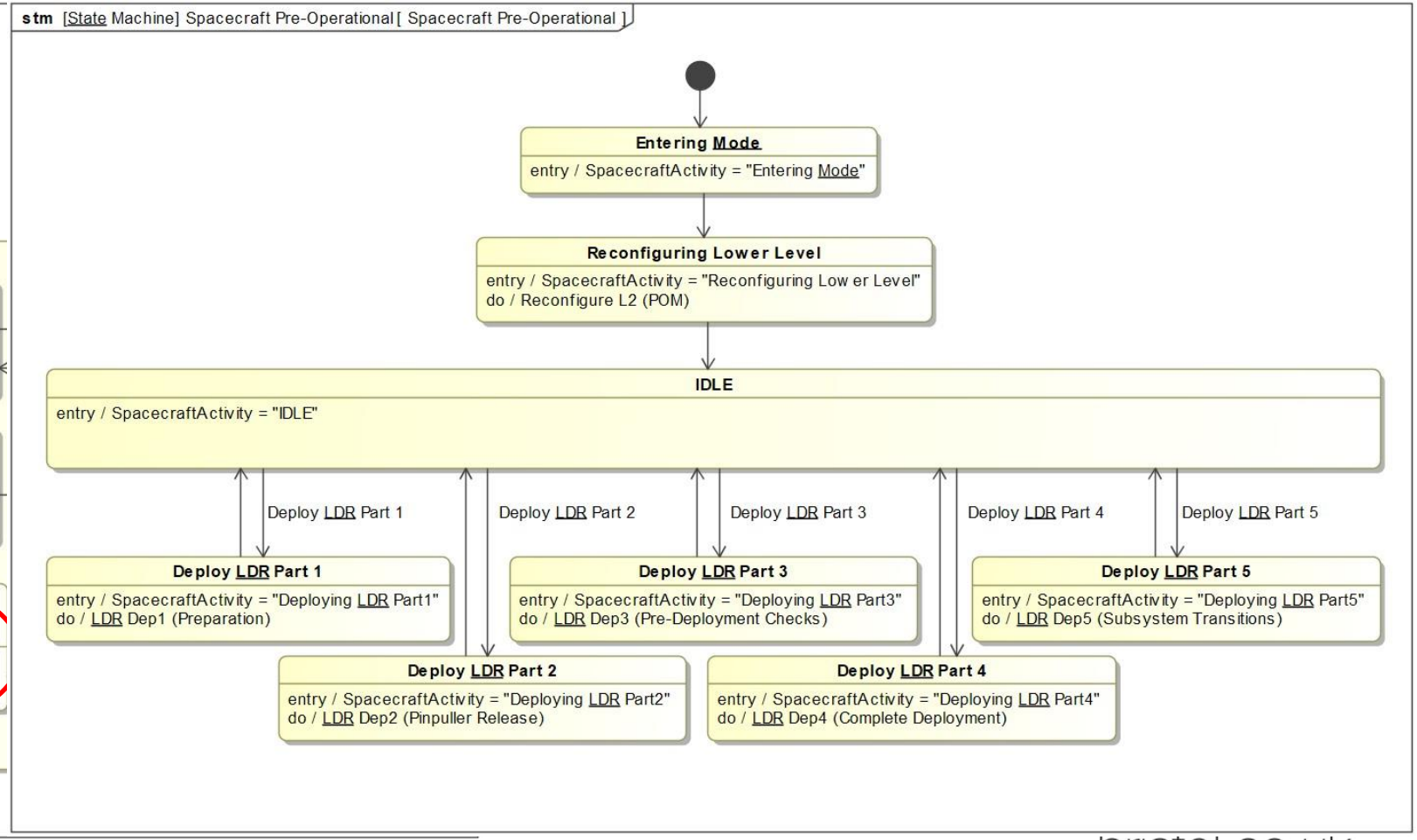


Biomass Model – Functional Definition

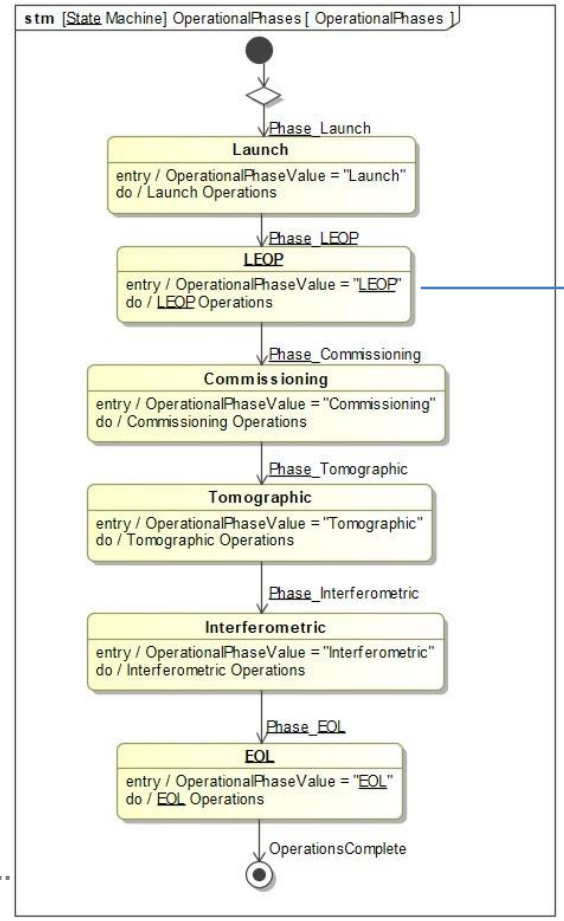


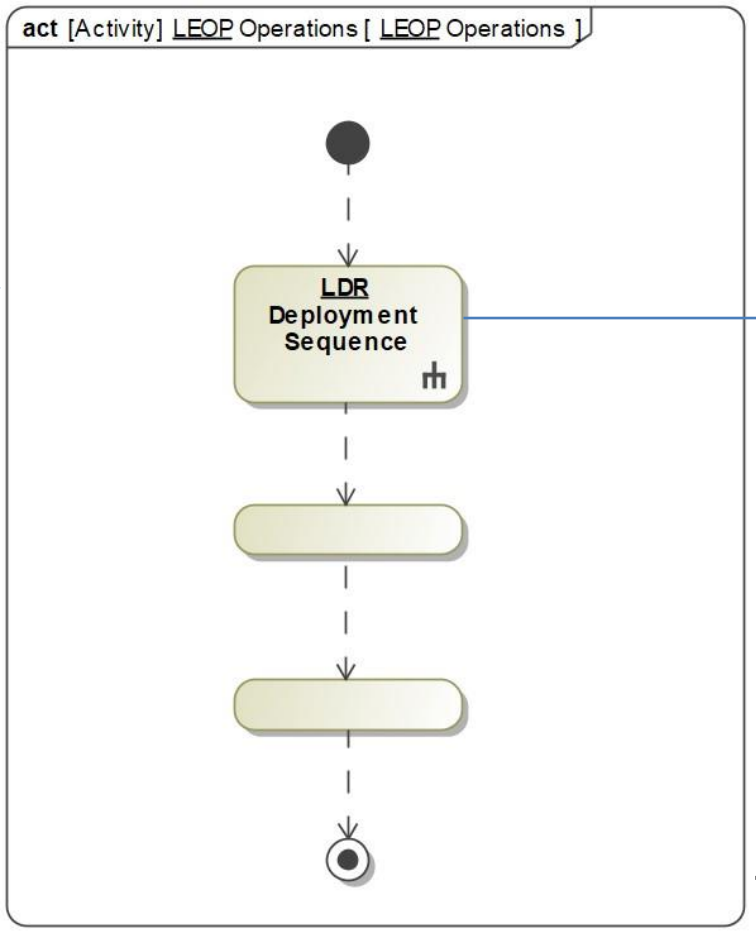
Biomass Model – Functional Definition

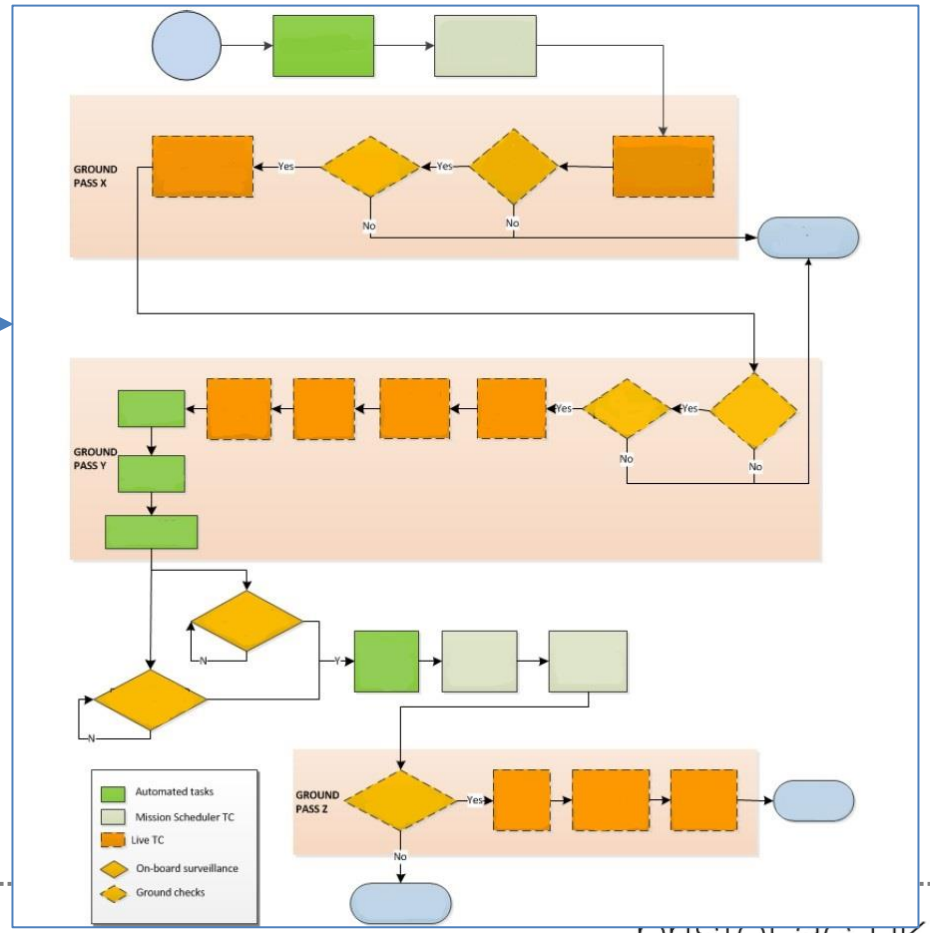




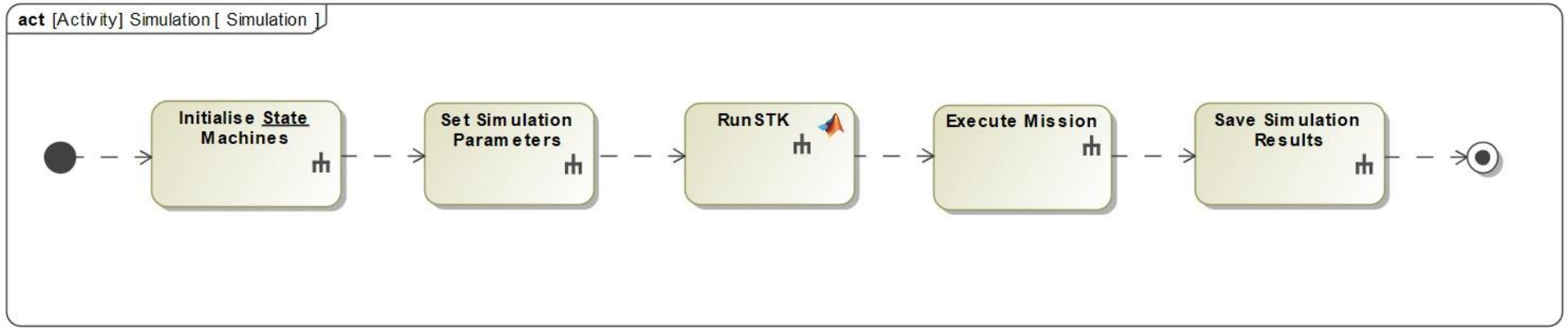
Biomass Model - Operations







Biomass Model – Results



Biomass Simulation

Biomass Simulation

SIMULATION

Filename	BiomassDeploymentModel

MISSION TIMES (min)

Waiting Time	175.4800
Transmission Time	27.6000
Function Time	52.2000
Decision Time	480.0000
Mission Time	735.2800

EXTERNAL ENTITIES

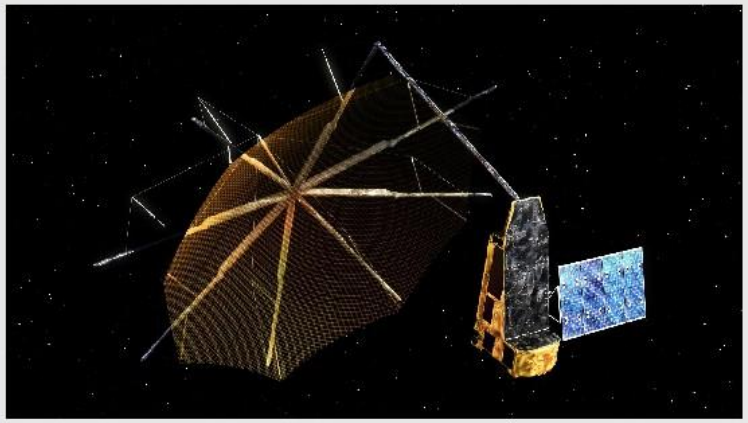
Launcher	Separated
Sun	InView

GROUND STATIONS

		TC	TM
Svalbard	IDLE	0	2
Kiruna	IDLE	1	2
Troll	IDLE	2	0
ESOC	Routing TC		

SPACECRAFT

Operational Phase	LEOP
Spacecraft Mode	Pre-Operational
Spacecraft Activity	IDLE



SUBSYSTEMS

AOCS Mode	NM - GAP
AOCS Activity	IDLE
Comms Mode	Operational
Comms Activity	IDLE
OBC Mode	Operational
OBC Activity	IDLE
Payload Mode	Standby
Payload Activity	IDLE
PDHU Mode	Operational
PDHU Activity	IDLE
Power Mode	Operational
Power Activity	IDLE
Thermal Mode	Operational
Thermal Activity	IDLE

ASSEMBLIES

RCS Mode	Operational	STRA Mode	Operational
RCS Activity	IDLE	STRA Activity	IDLE
GNSS Mode	Operational	RWA Mode	Operational
GNSS Activity	IDLE	RWA Activity	IDLE
SSN Mode	OFF	MTO Mode	OFF
SSN Activity	IDLE	MTO Activity	IDLE
MTQ Mode	OFF		
MTQ Activity	IDLE		
S-Band TT&C Mode	Operational		
S-Band TT&C Activity	IDLE		
RDIU Mode	Operational	Clock Mode	Operational
RDIU Activity	IDLE	Clock Activity	
Processor Mode	Operational		
Processor Activity	IDLE		
LDR Boom Mode	Operational	SAR Mode	OFF
LDR Boom Activity	IDLE	SAR Activity	
LDR Reflector Mode	OFF	MCA Mode	Operational
LDR Reflector Activity		MCA Activity	IDLE
Directory1 Mode	Operational	Directory3 Mode	Operational
Directory1 Activity	IDLE	Directory3 Activity	IDLE
Directory2 Mode	Operational	XDA Mode	Operational
Directory2 Activity	IDLE	XDA Activity	IDLE
Battery Mode	Operational	PCDU Mode	Operational
Battery Activity	IDLE	PCDU Activity	IDLE
SAA Mode	Operational		
SAA Activity	IDLE		
Therm. Assy Mode	OFF	Heater Assy Mode	Operational
Therm. Assy Activity	IDLE	Heater Assy Activity	IDLE

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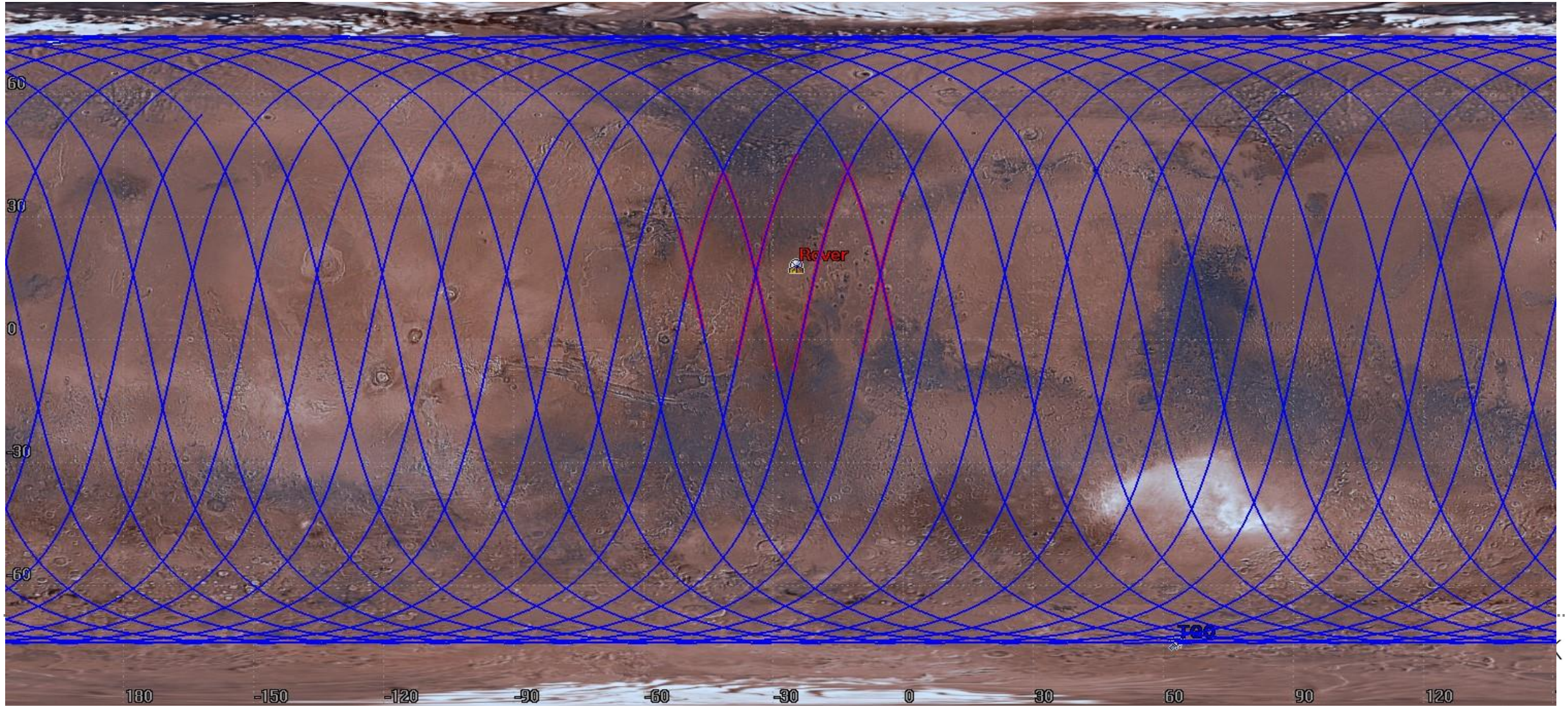
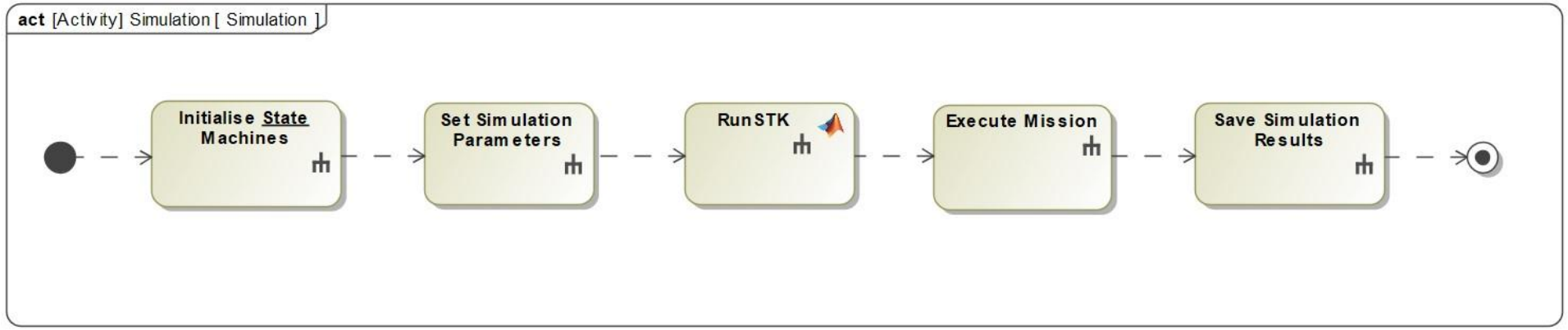
ExoMars Model - STK



ExoMars Model - Results



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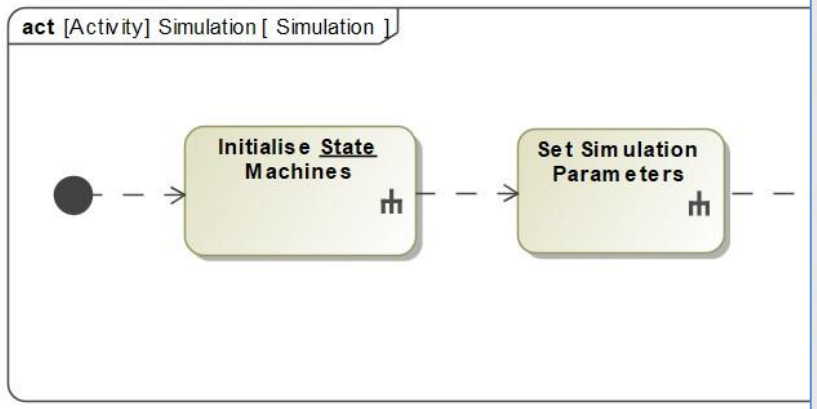
ExoMars Model - Results



SIMULATION

Filename: ExomarsEgressModel

MISSION TIMES (min)

Waiting Time	4690.4660
Transmission Time	300.8040
Function Time	453.3500
Decision Time	720.0000
Mission Time	6164.6200

EXTERNAL ENTITIES

Lander: Separated

COMMUNICATIONS

Estrack: IDLE — TC 6 — TM 6

Orbiter: IDLE

ESOC: IDLE

SPACECRAFT

Operational Phase	PLTE
Spacecraft Mode	Nominal
Spacecraft Activity	Egressing from Lander
Distance Travelled (m)	1.1055
Power Generation (W)	1180.0000

SUBSYSTEMS

Mechanisms	Operational	Switching on Equipment	
Mobility	Standby	IDLE	
Comms	Operational	IDLE	
OBC	Operational	IDLE	
Payload	Operational	IDLE	
Power	Operational	IDLE	
Thermal	Operational	IDLE	

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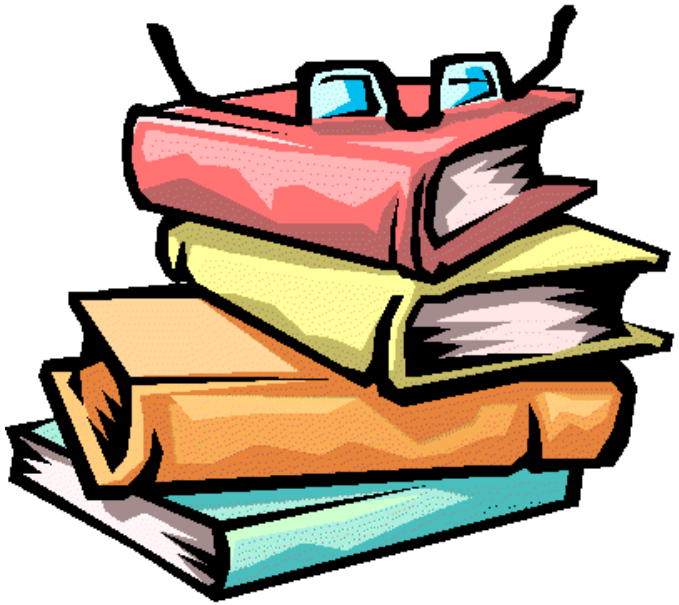
Lessons Learned

- Separation between **Descriptive** and **Analytical** aspects of the model is crucial
- Separation between **Mission**, **Operations** and **System** introduces flexibility in definition and analysis
  - does not prescribe system behaviour
- Application to multiple missions and use cases can demonstrate flexibility



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Summary

- Interviews within Airbus indicated:
  - we should focus on ‘Early Functional Validation’ against ‘Concept of Operations’
  - we should develop a ‘Model Template’
- MBSE techniques have been applied to three case studies:
  1. Biomass, **Mass Memory Sizing** (previous work)
  2. Biomass, **Payload Deployment** Sequence
  3. ExoMars, **Egress from Lander** Sequence
- A model-based framework, the ‘Spacecraft Early Analysis Model’ has been developed
  - This links CSM, MATLAB, Excel, STK to define and simulate system behaviour
- Development of the **SEAM Guide** and **SEAM Ontology** is ongoing

Thank you for listening

Questions / Feedback gratefully received!

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