An Introduction to the

Template for Early Functional Definition and Analysis

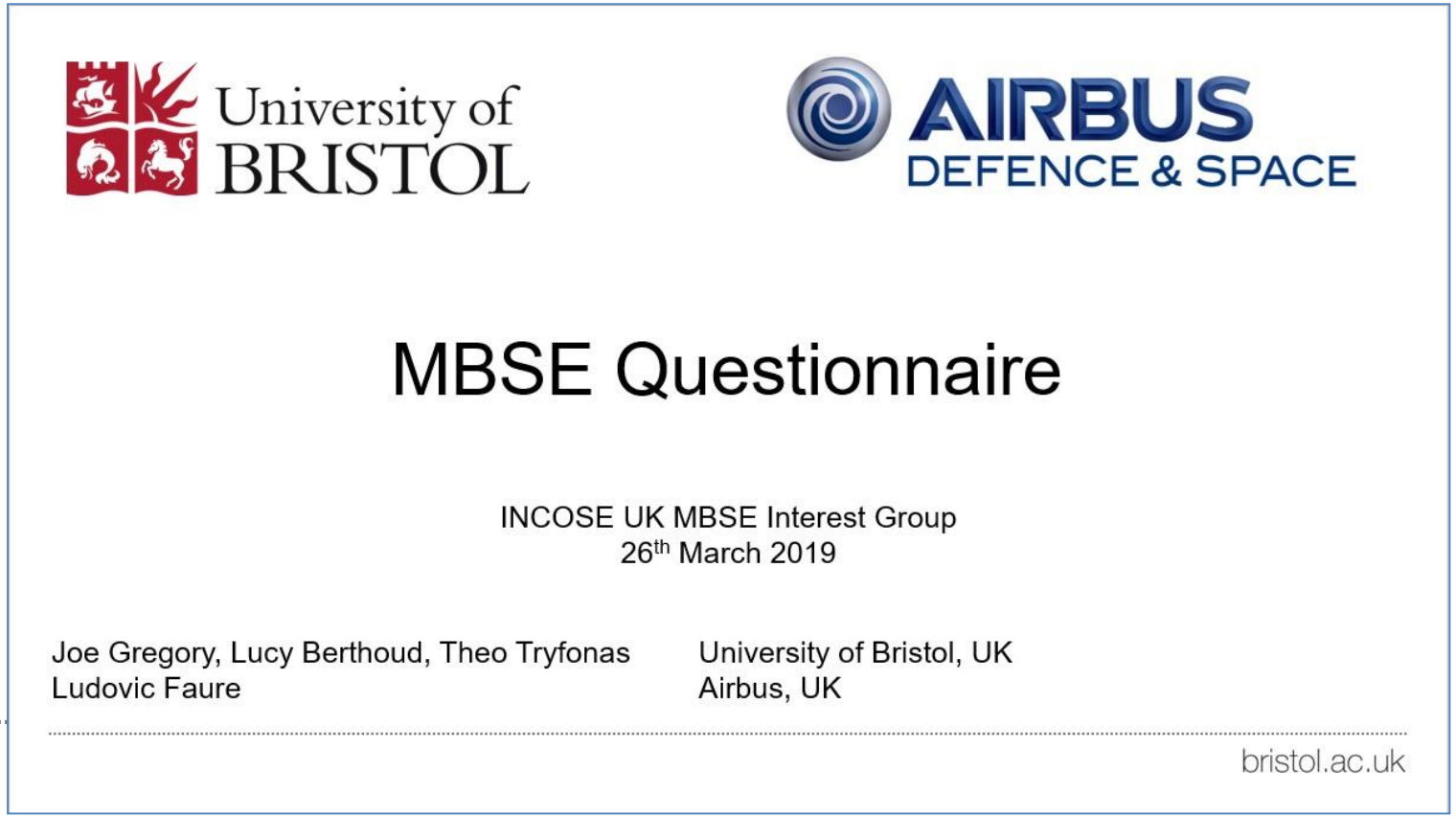
INCOSE UK MBSE Interest Group
17th September 2019

Joe Gregory, Lucy Berthoud, Theo Tryfonas — University of Bristol, UK
Ludovic Faure — Airbus, UK

But first…

- Last time I was here I asked some of you for help with an MBSE Questionnaire

- Work is ongoing
- Finishing off a paper on a previous set of interviews
- I will explain where this fits in



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1. Background

2. Airbus Interviews

3. Mass Memory Sizing

4. Critical Sequences

5. Template for Early Functional Definition and Analysis

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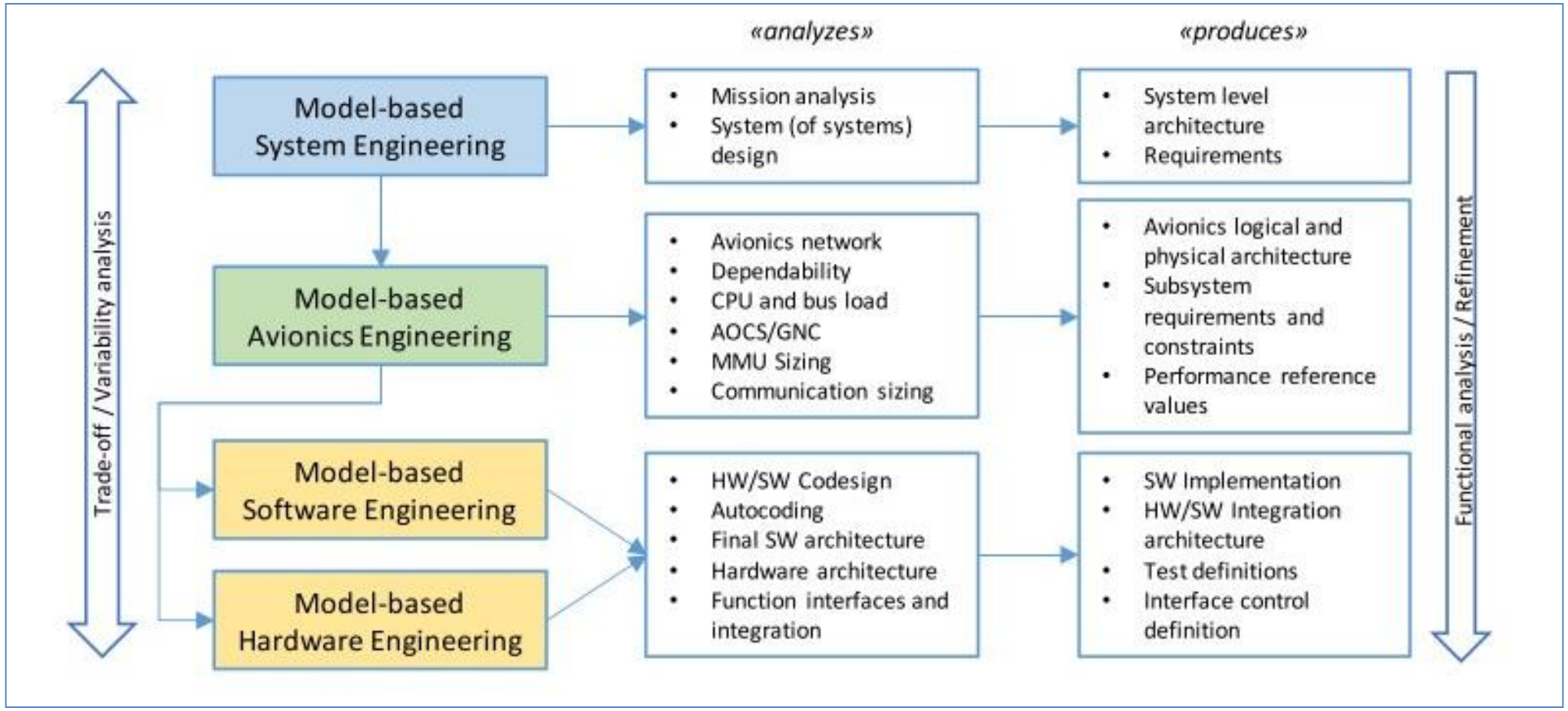
Functional Avionics – A quick look at MBAE



S. Feo-Arenis, "SAVOIR-TN-003: Model-Based Avionics Roadmap," Iss 1, Rev 0. ESTEC, ESA. Noordwijk, The Netherlands, 2018

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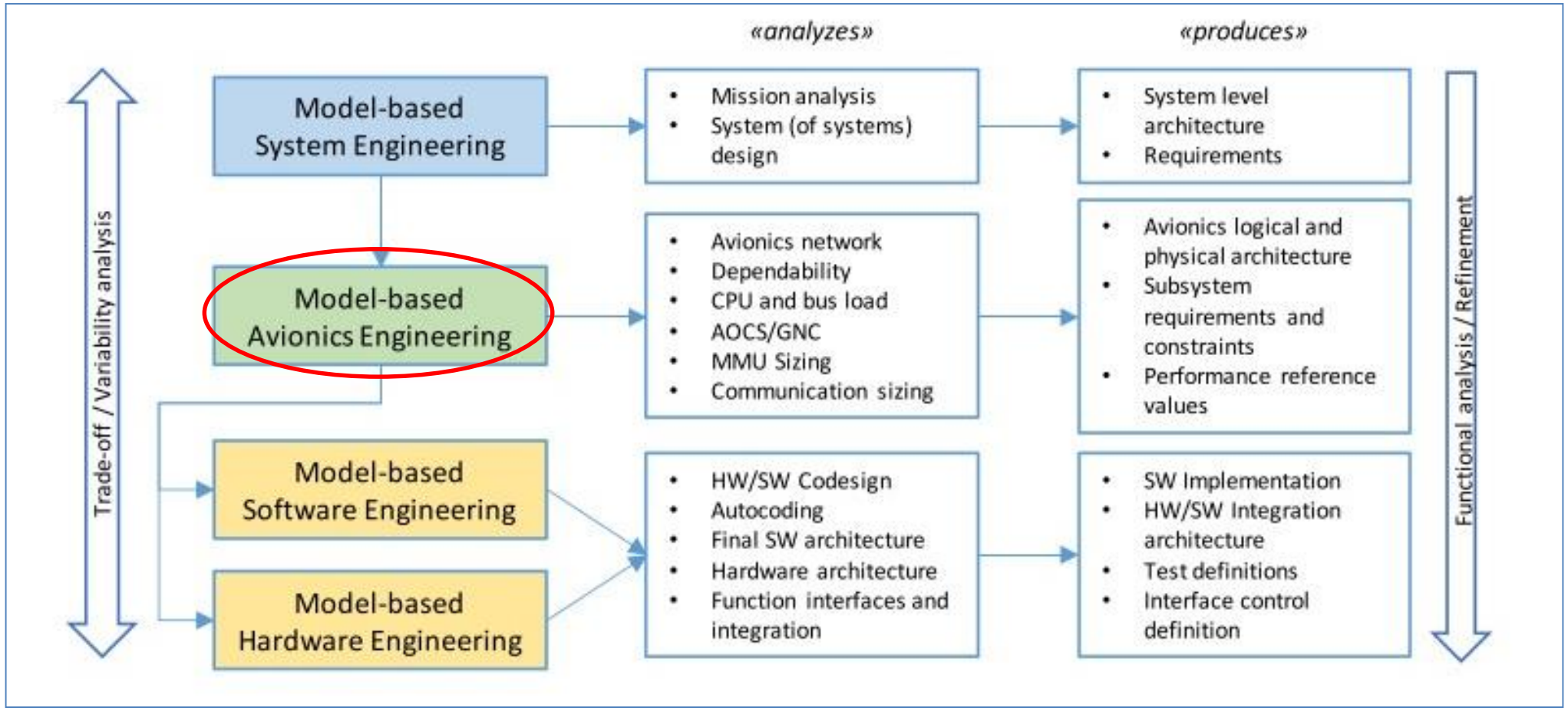

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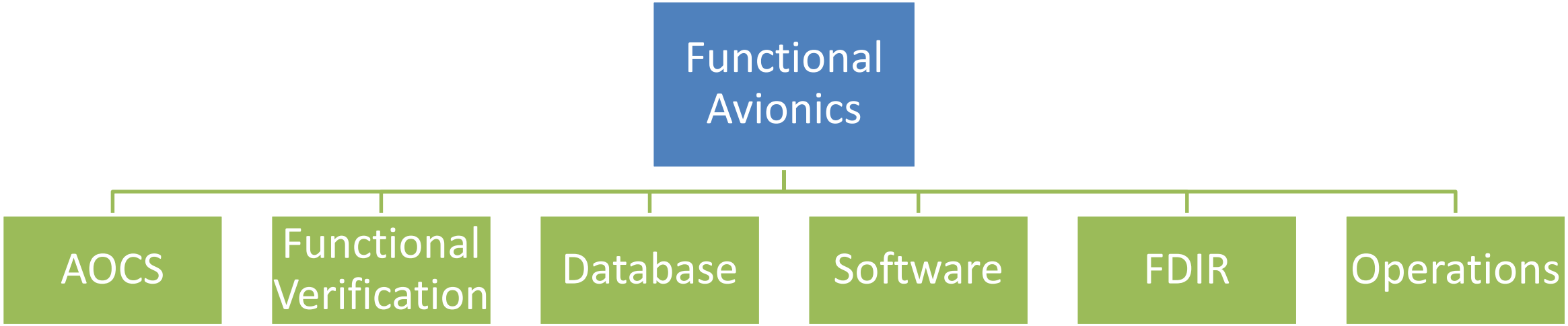
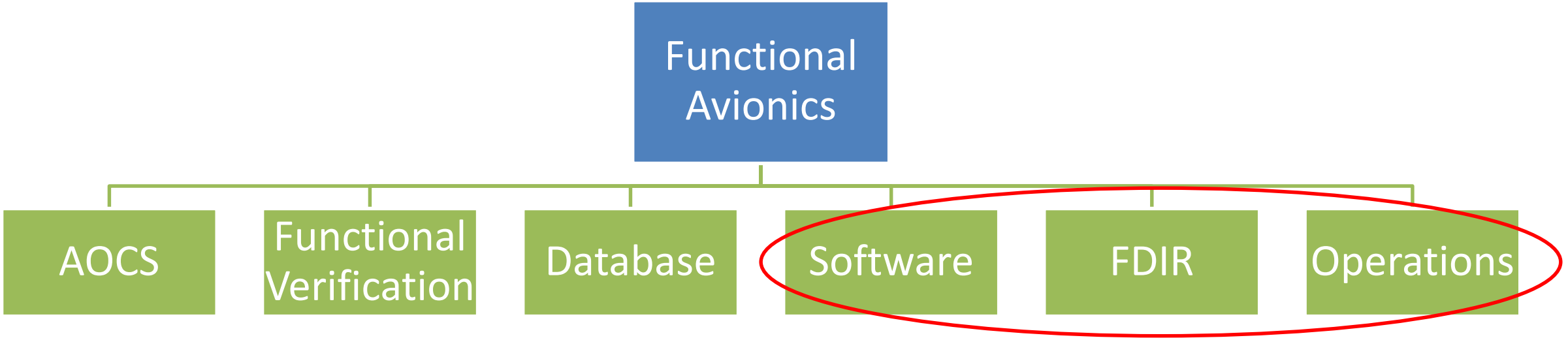
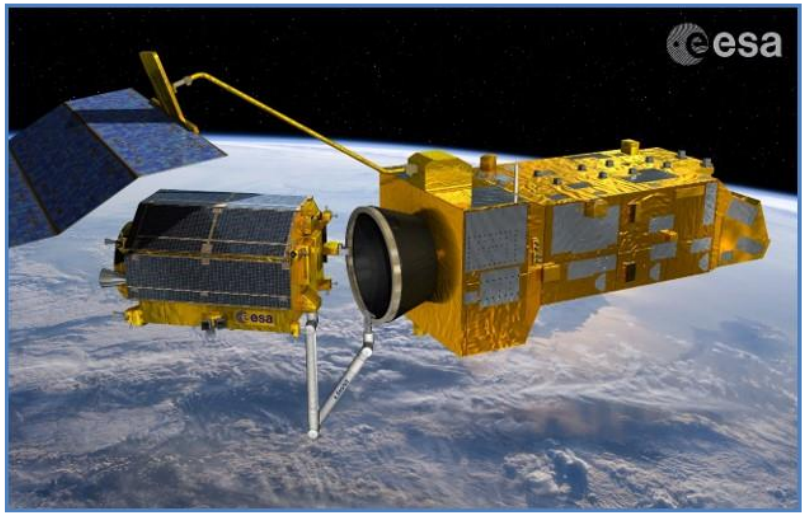
Airbus Space Functional Avionics: UK



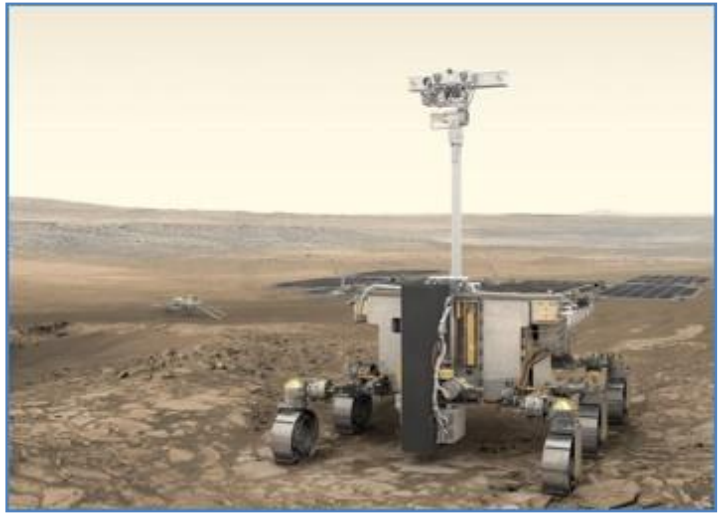
Airbus Space Functional Avionics: UK



Airbus Space MBSE Projects



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



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

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

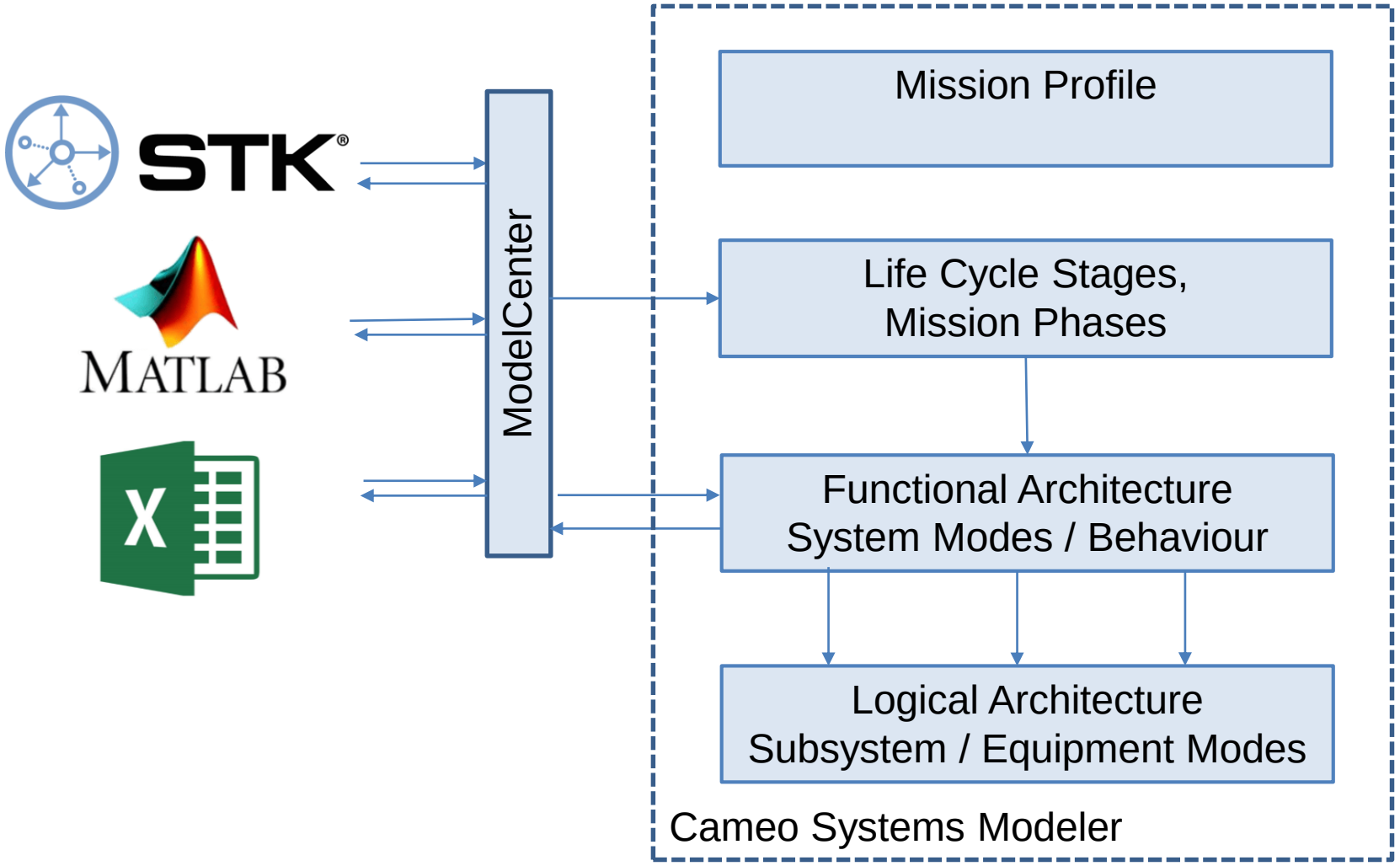
eDeorbit is the largest effort so far – methodology and model template developed

Images courtesy of European Space Agency (ESA)

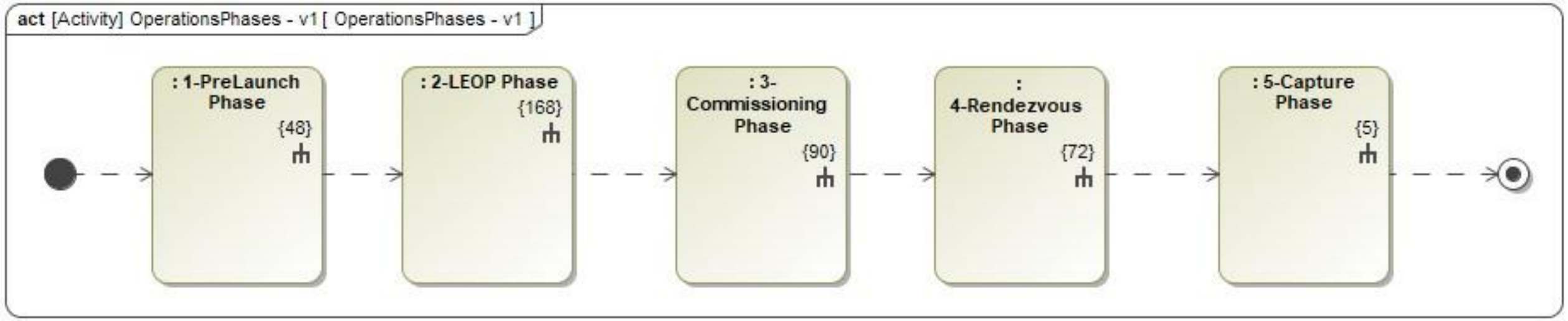
eDeorbit

- Safety-critical rendezvous Deorbit Envisat
- Phase B1-B2
  Concept exploration
  System definition
- Developed using the ‘Federated and Executable Models’ approach
  Stephane Estable, Airbus

eDeorbit Model Structure



eDeorbit - Phases



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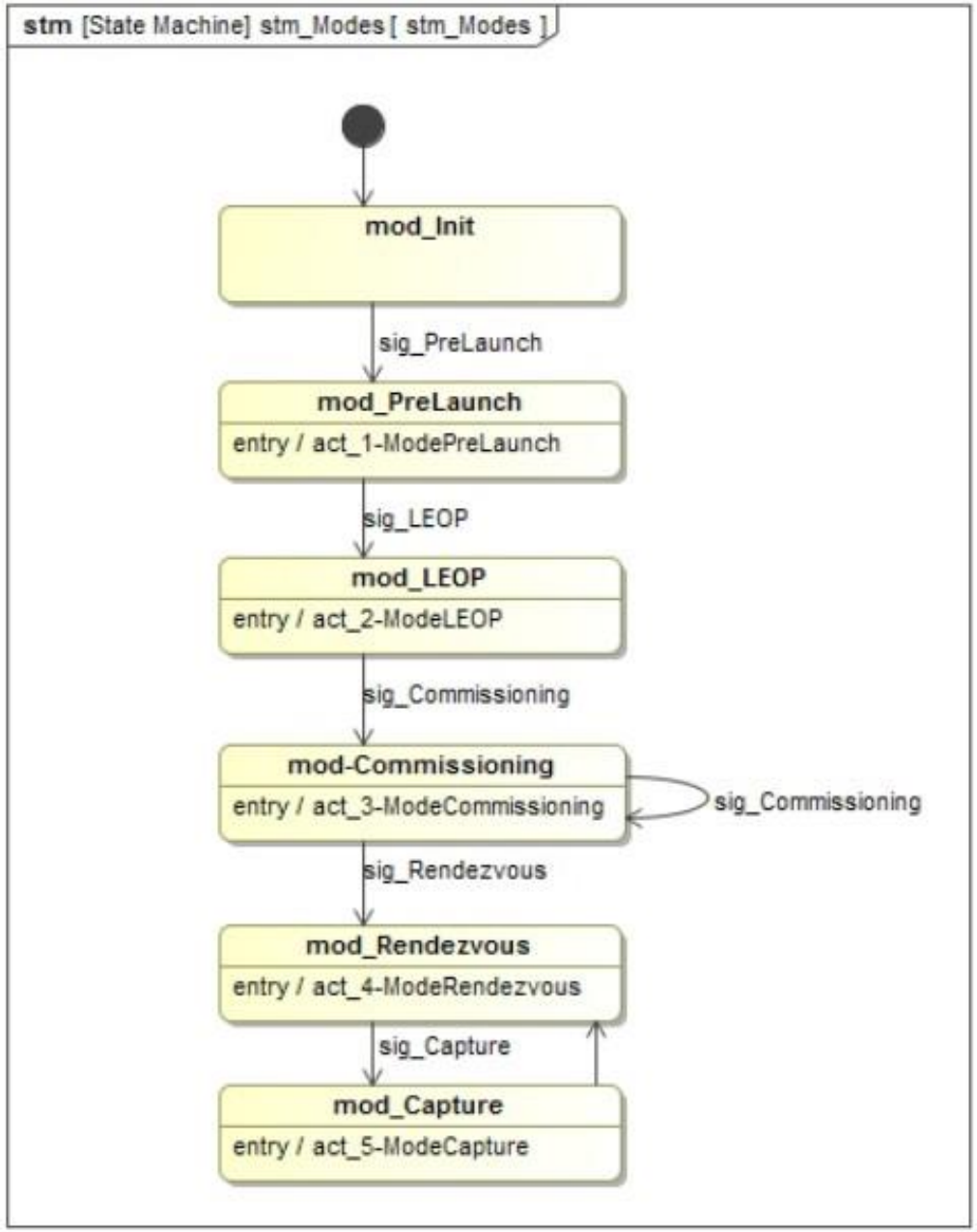
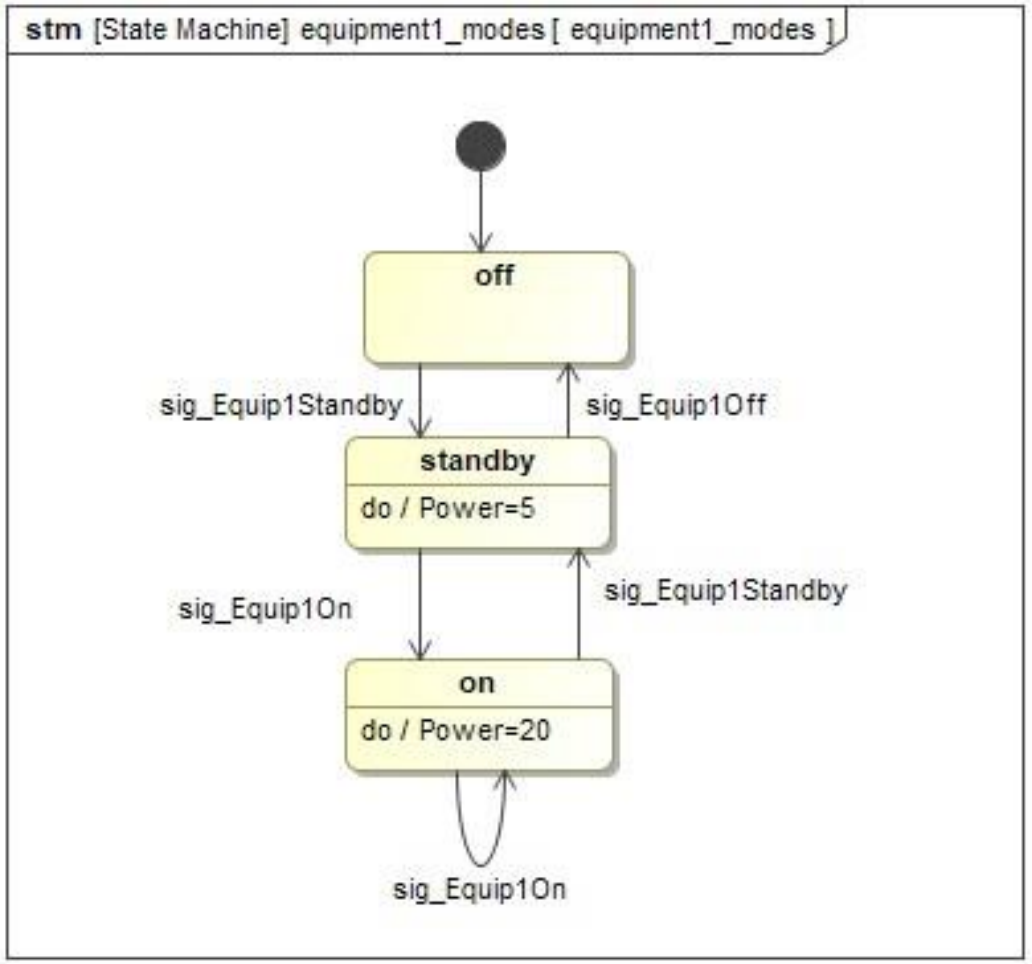
eDeorbit - Modes



S. Estable, "Application of the 'Federated and Executable Models' MBSE Process to Airbus Orbital Servicing Missions," in Phoenix Integration International Users' Conference, Annapolis, MD, 2018

eDeorbit – Subsystem (Modes)



Modelling Objectives:

- Can we add simulation capabilities to the *Federated and Executable Models* approach?
- Can we do so without using ModelCenter (by Phoenix Integration)?
- Can we do so while maintaining the model's primary use a System *Description*

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Airbus Functional Avionics Interviews

Operations
Failure Detection, Isolation and Recovery (FDIR)
Software

Introductory Airbus interviews
- Two sites (UK, France)
- 28 interviewees

Detailed Airbus interviews
- Three sites (UK, France, Germany)
- 23 interviewees

"What other domains do you interact with, and what does your work consist of?"

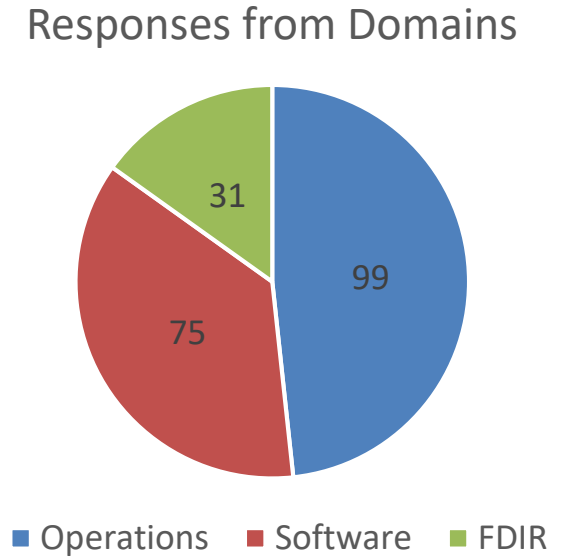
"What causes redo or non-quality in projects, and can this be resolved by use of models?"

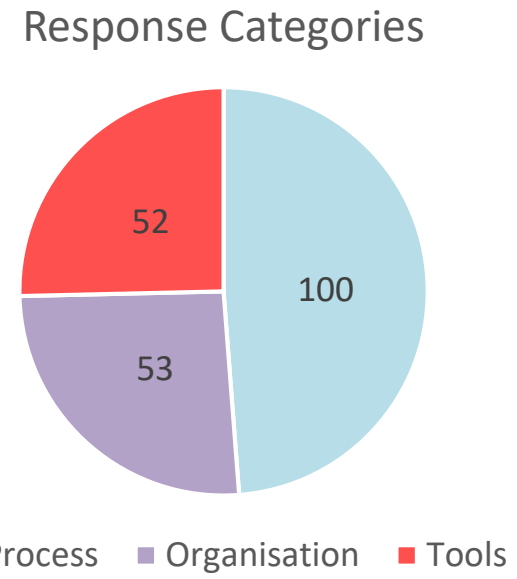
Airbus Functional Avionics Interviews - Outcomes

- 205 answers
- Process, Organisation, Tools
- Operations, FDIR, Software

Areas increasing the Cost of Non-Quality
- Interfaces between domains (e.g. SW – Ops)
- Lack of integrated toolset
- Lack of early validation of Concept of Operations

Topics of interest
- **System-level early validation of Concept of Operations (ConOps)**
- **Model template development**





Airbus Interviews Publication

The Long and Winding Road:
MBSE Adoption for Functional Avionics of Spacecraft

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- *Currently under review*

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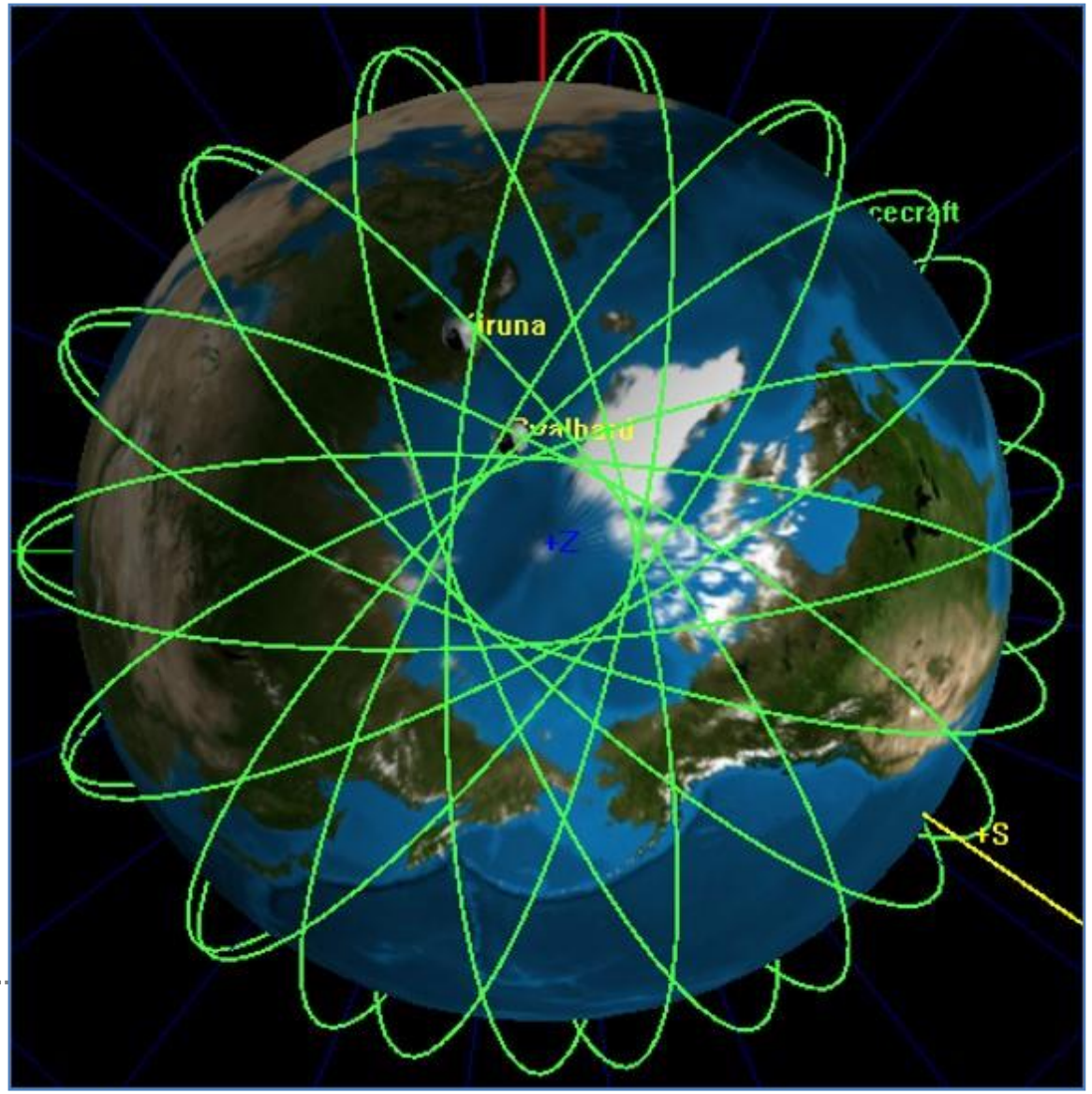
Mass Memory Sizing

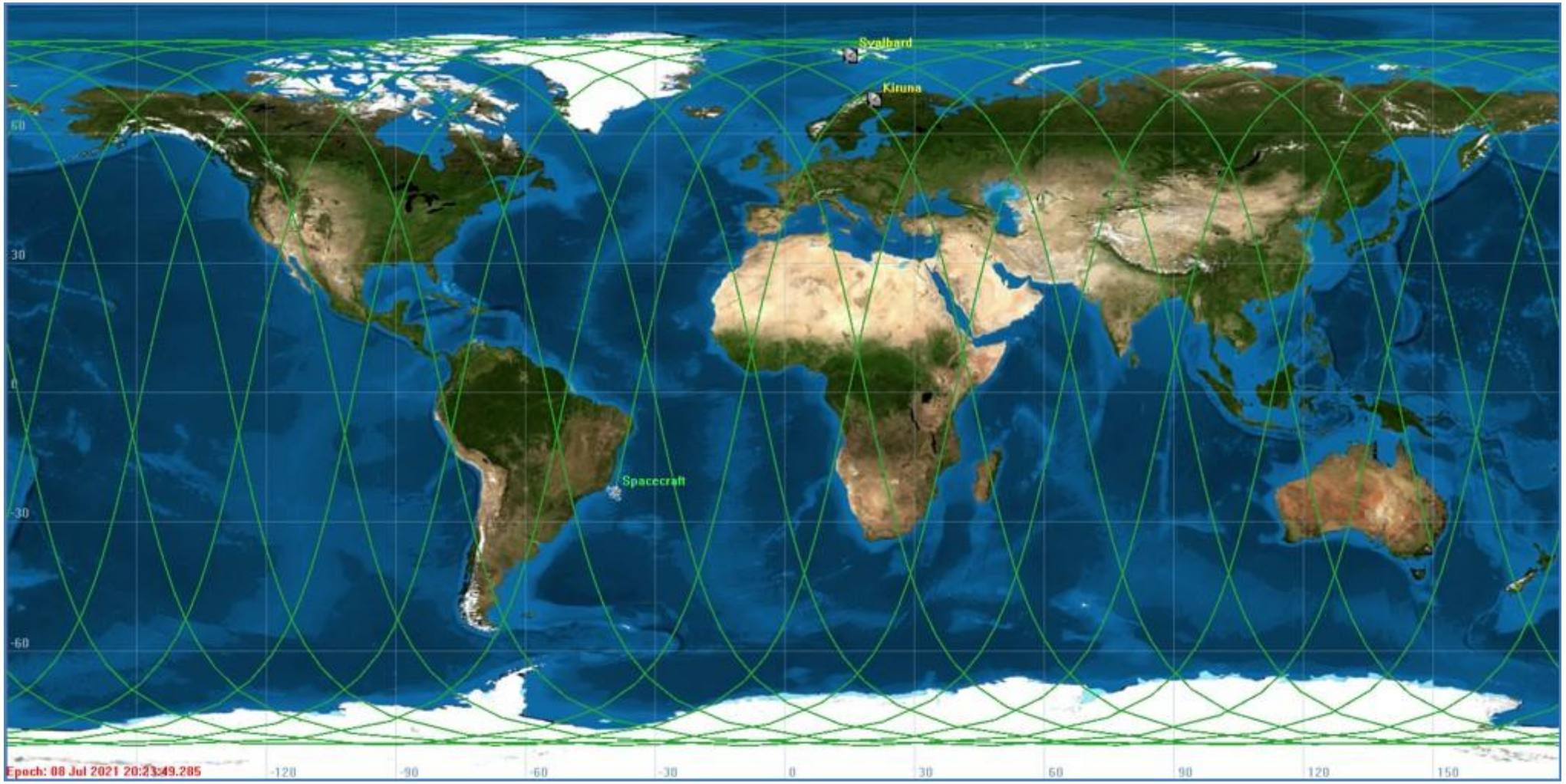
Biomass Spacecraft

Instrument (Radar)
- On over land
- Off over ocean

Antenna
- On over ground station
- Off when not over ground station

Memory Unit – 3x Directories
- Reading (when Antenna on: downlinking)
- Writing (when Instrument on: recording)
- Both (when Antenna and Instrument on)

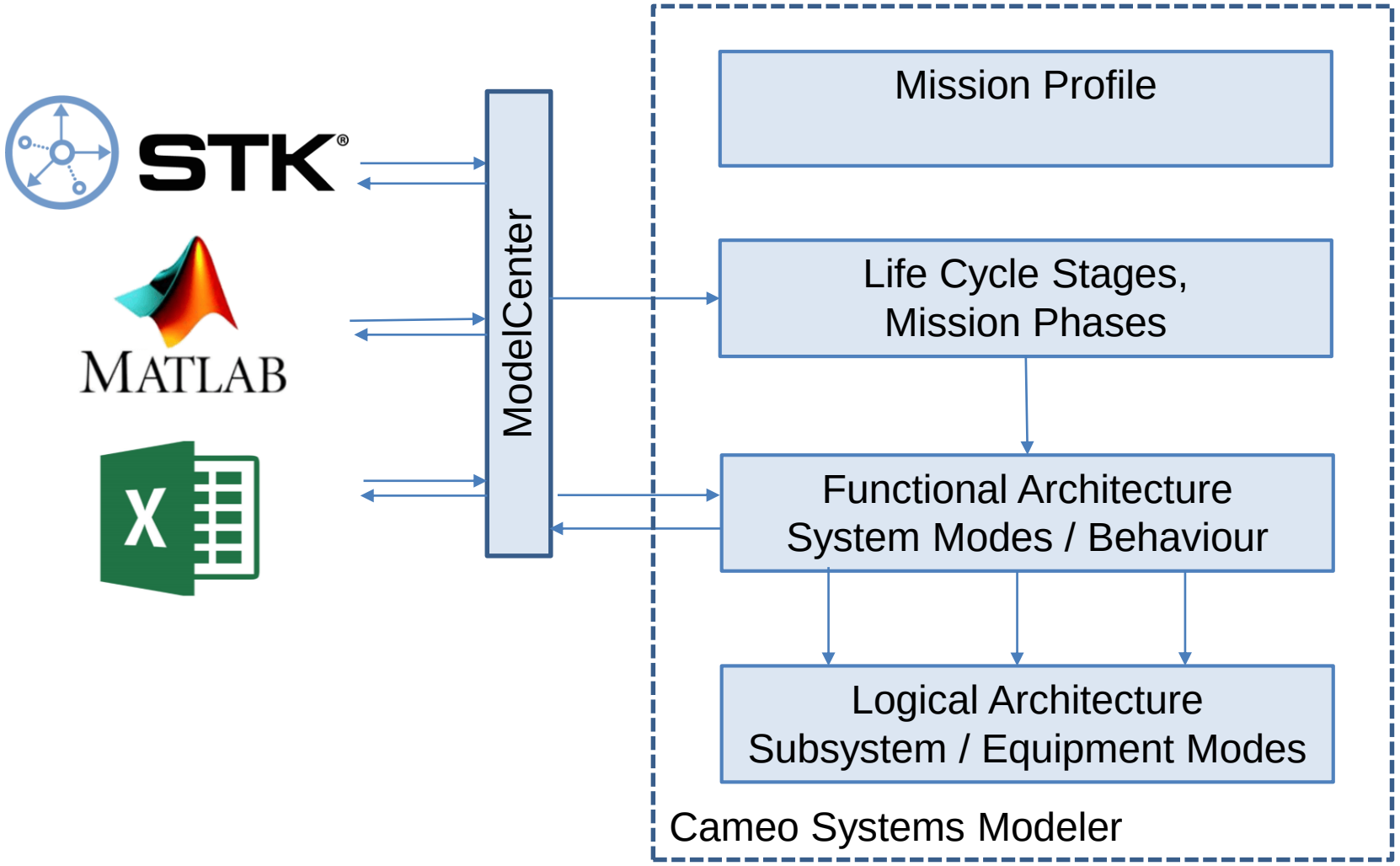



Svalbard
Kiruna
Spacecraft
60
30
0
-30
-60
-120
-90
-60
-30
0
30
60
90
120
150

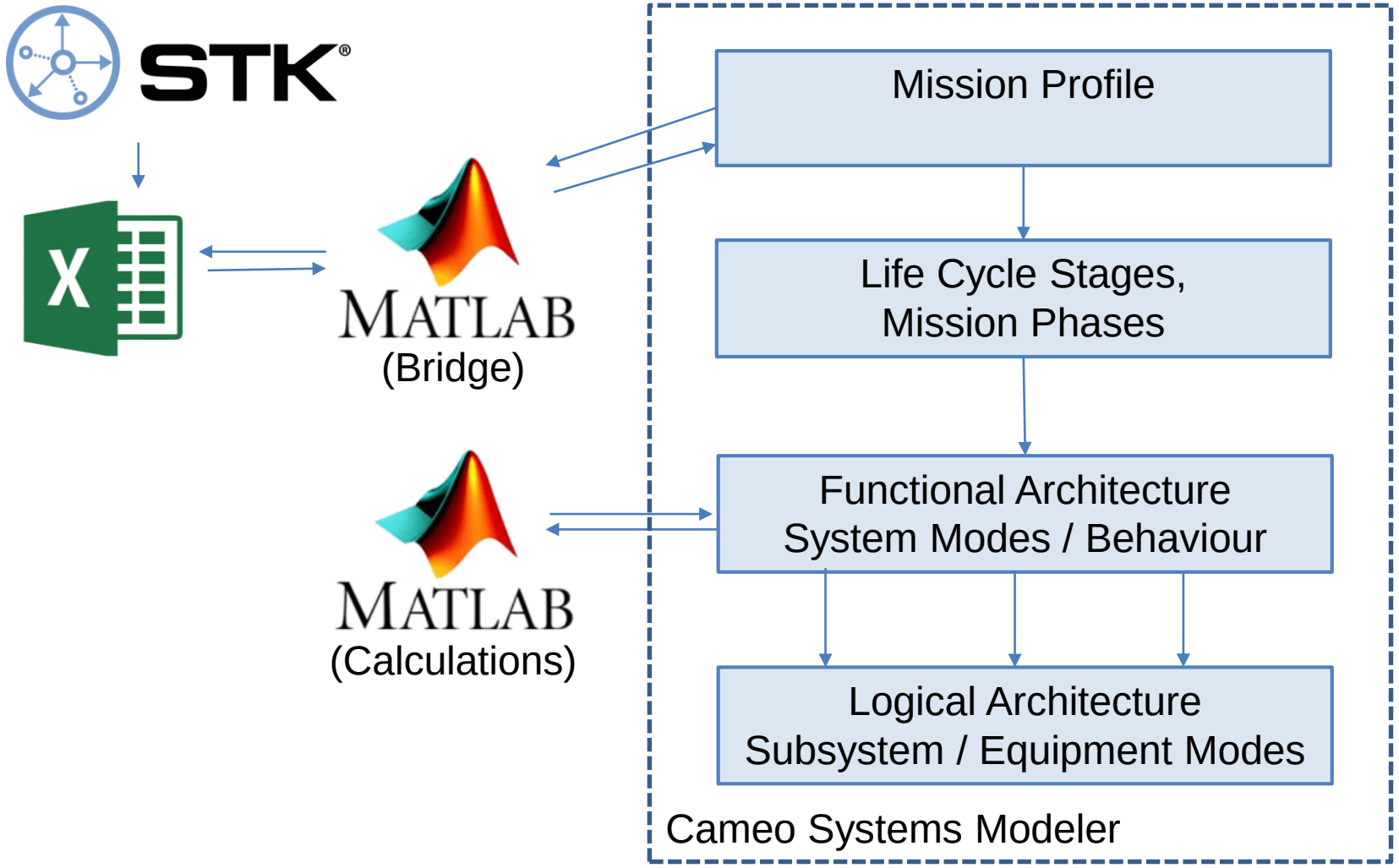
Mass Memory Use Case Objectives

1. Validate spacecraft memory unit design
    - Validate total memory allocation (880Gb)
    - Optimise Memory Unit directory sizes
    - Validate model against Excel results

eDeorbit Model Structure

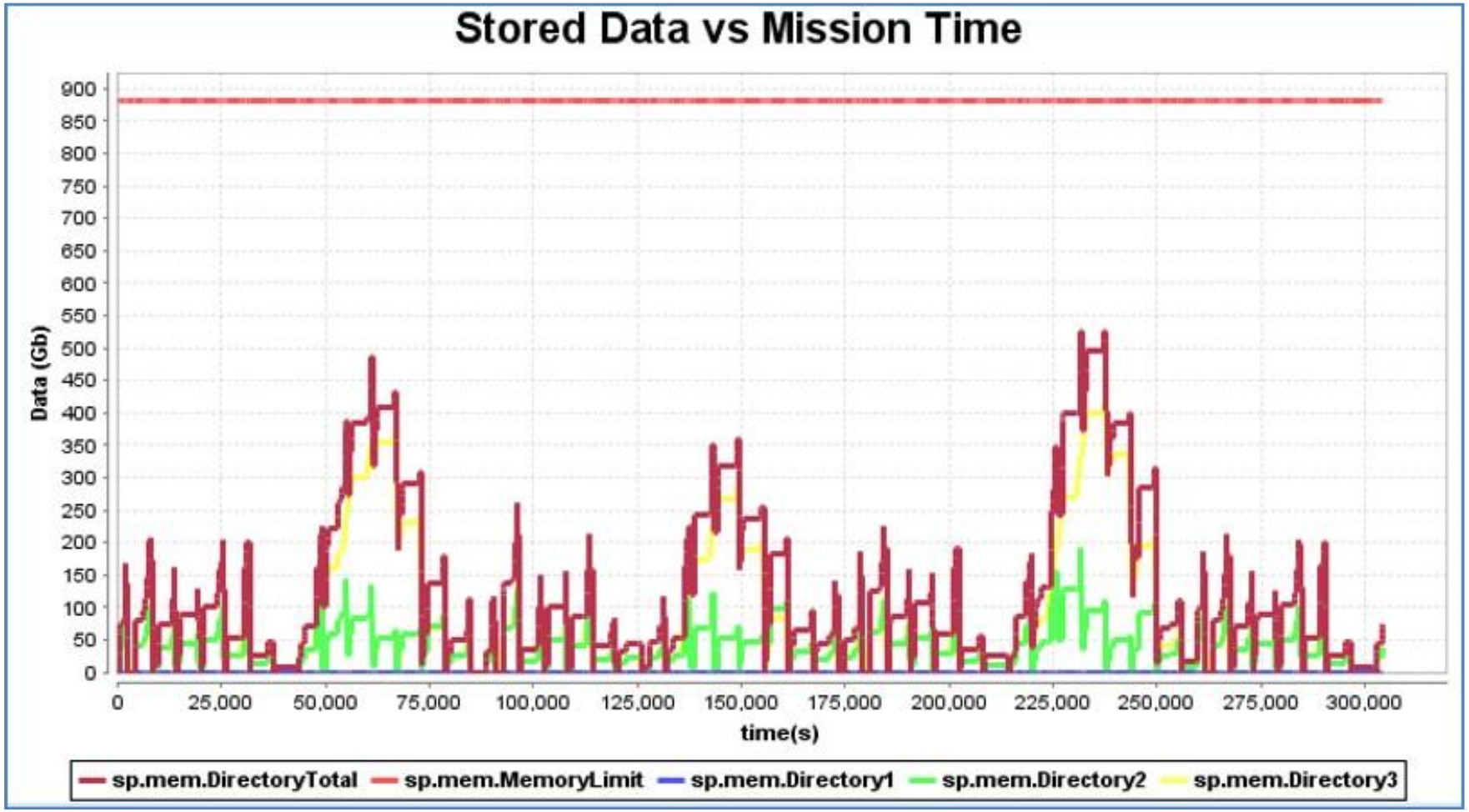


Biomass Model Structure 1



Mass Memory Use Case Results

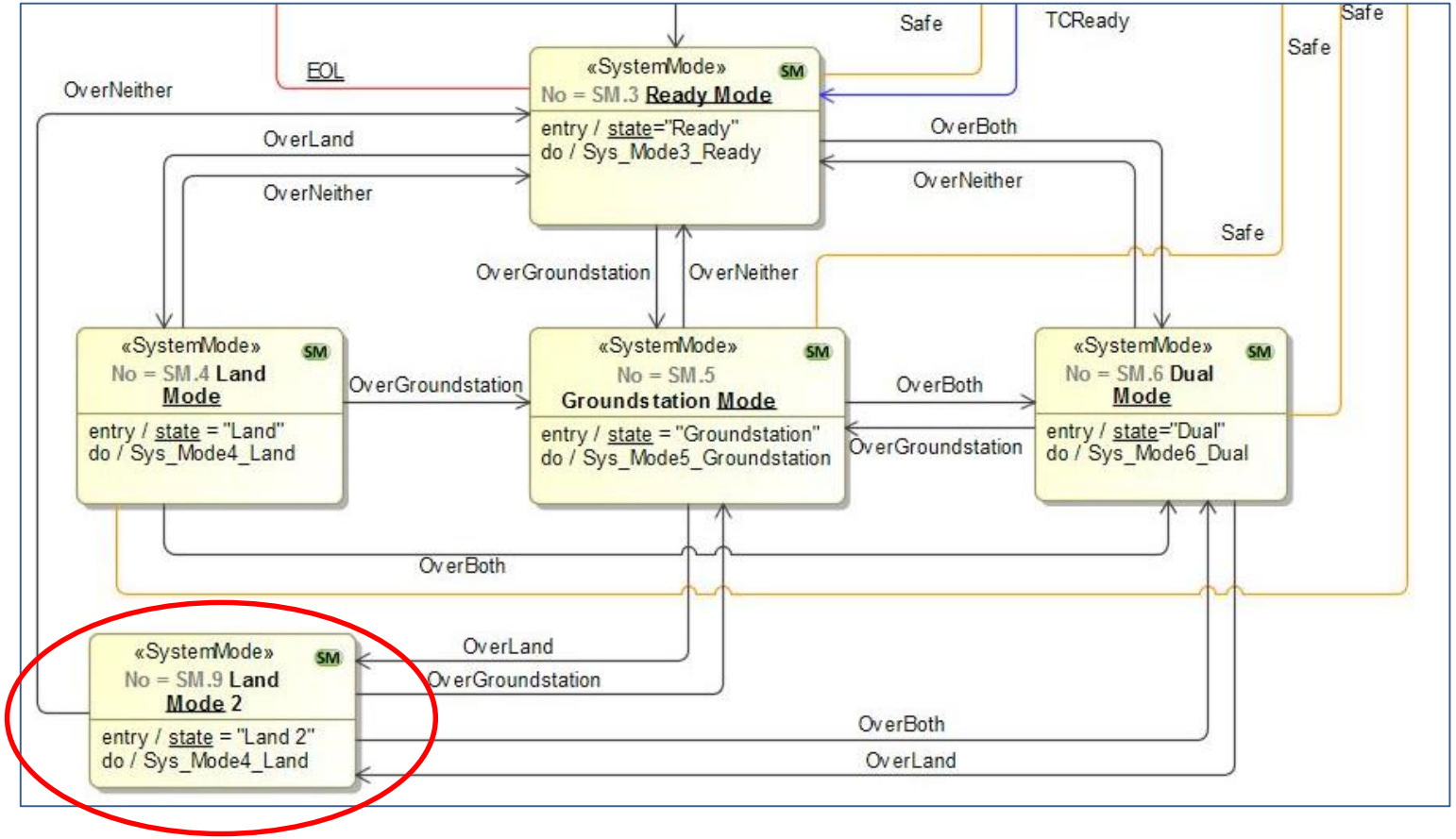
1. Memory allocation
   - Full simulation results show a ~40% margin
2. Optimised directory sizes
3. Validated model against subcontractor Excel data



Biomass Model Flexibility

1. Changes to Requirements
2. Additional Mode
3. Change no. of Directories
4. Contingency Analysis
5. Mission Updated

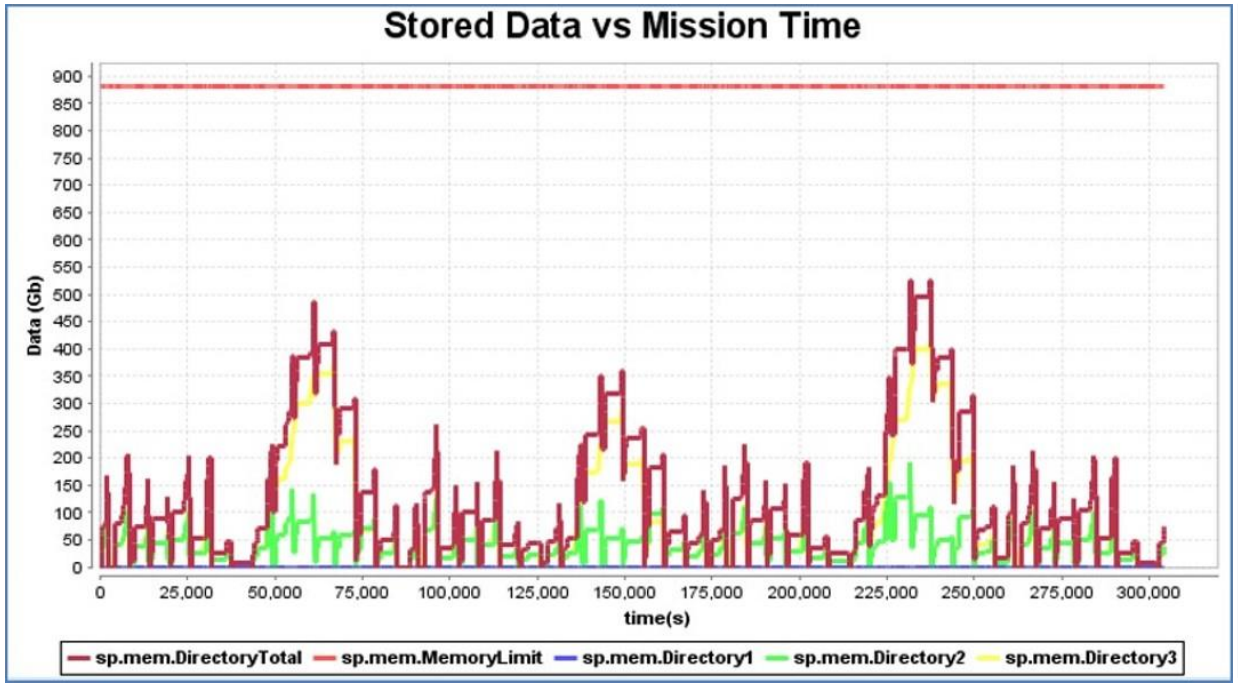
E.g. Additional Mode

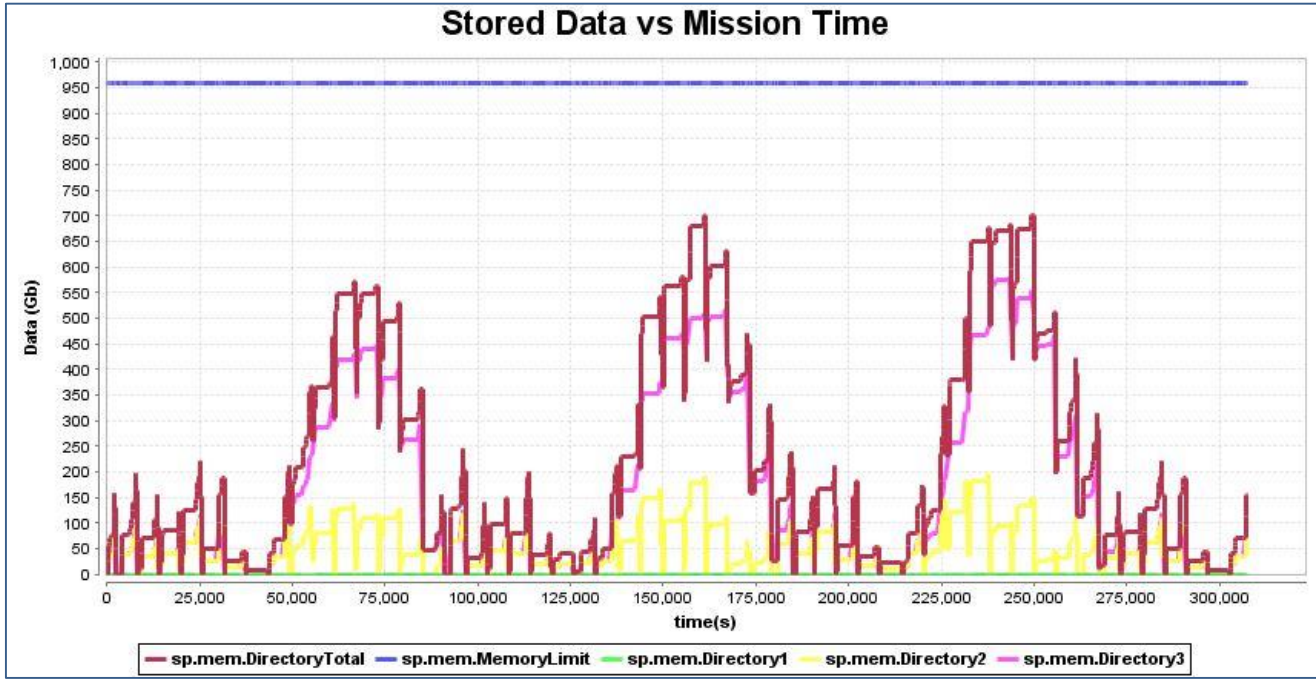


Introduce another mode

- Increased Land Mode
- Increased capability (4 x rate)
- Effective after downlink
- Observe effect on mass memory
- Effectively changing system response

E.g. Additional Mode





Mission not changed, System response has been updated
Effects immediately observable

Time Taken:
Add Mode in Mode Diagram: *minutes*
Produce Mode Activities: *~day*

Mass Memory Use Case Outcomes – in terms of Template

- Demonstrated key features of the model structure
  - Maintained separation of *Mission* and *System*
    Allocated system functionality to system logical architecture

- Added simulation capabilities to the original model – *Federated and Executable Models*
  - Mass memory sizing calculations
  - Removed ModelCenter – uses MATLAB as bridge to connect to Excel, AGI STK

- *Mission Operations Concept Document* to *Mission Operations Concept Model*
  - Maintained the model's primary purpose as a system description
  - The underlying structure that allows the model to be executed can be seen as a *bonus*

Mass Memory Sizing Use Case Publications

No Magic WORLD SYMPOSIUM
MODELING SIMULATION ANALYSIS

Using MBSE Techniques to perform Early Validation on the Data Handling Unit of an Earth-Observation Spacecraft

22nd May 2018

Joe Gregory, Lucy Berthoud, Antonio Prezzavento, Joanna O'Rourke, Stephane Estable, Alexandre Cortier

University of Bristol, funded by **Airbus**

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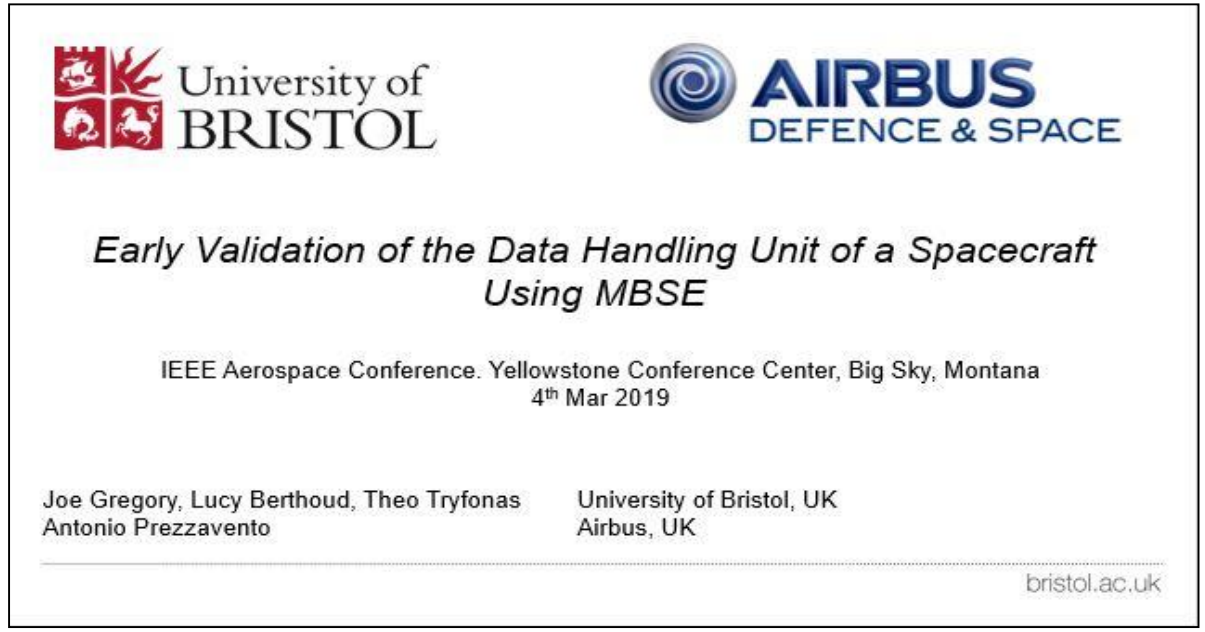

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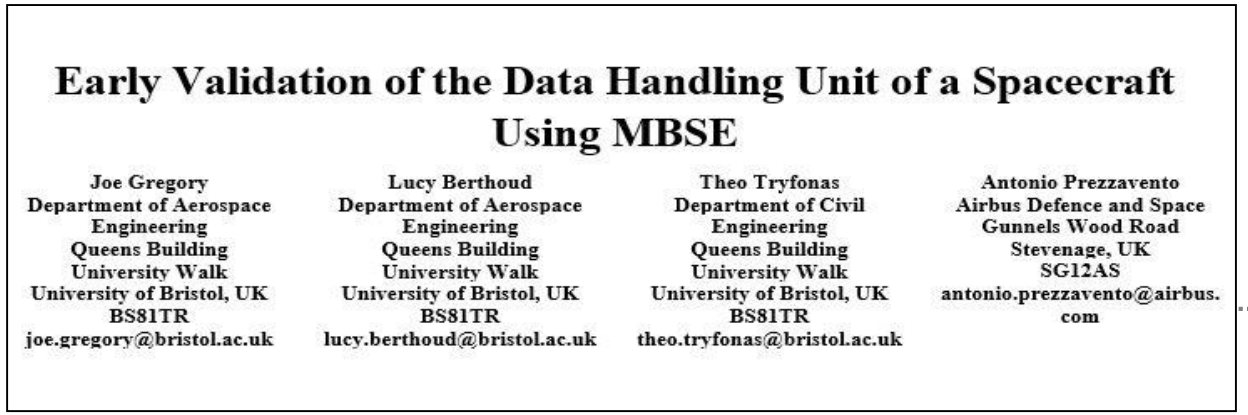
AIRBUS DEFENCE & SPACE

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

IEEE Aerospace Conference. Yellowstone Conference Center, Big Sky, Montana
4th Mar 2019

Joe Gregory, Lucy Berthoud, Theo Tryfonas — University of Bristol, UK
Antonio Prezzavento — Airbus, UK

bristol.ac.uk



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

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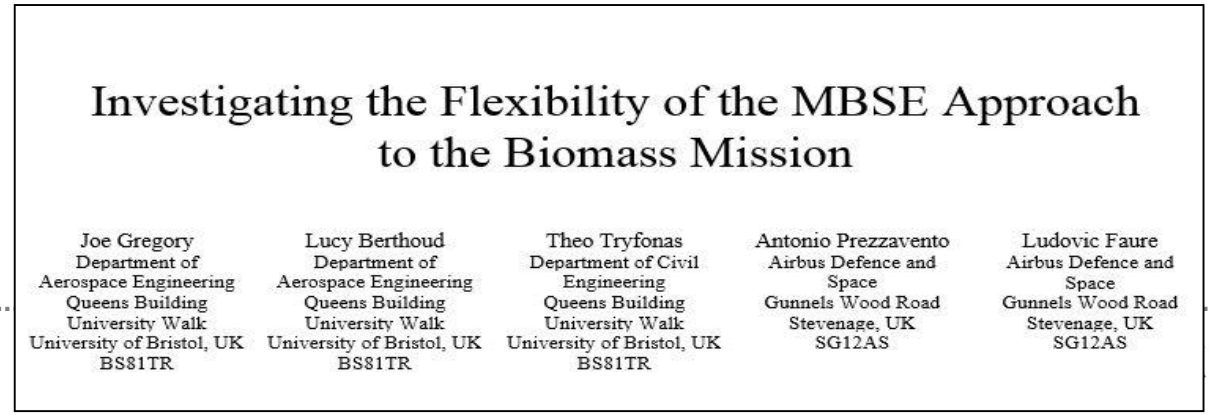

Investigating the Flexibility of the MBSE Approach to the Biomass Mission

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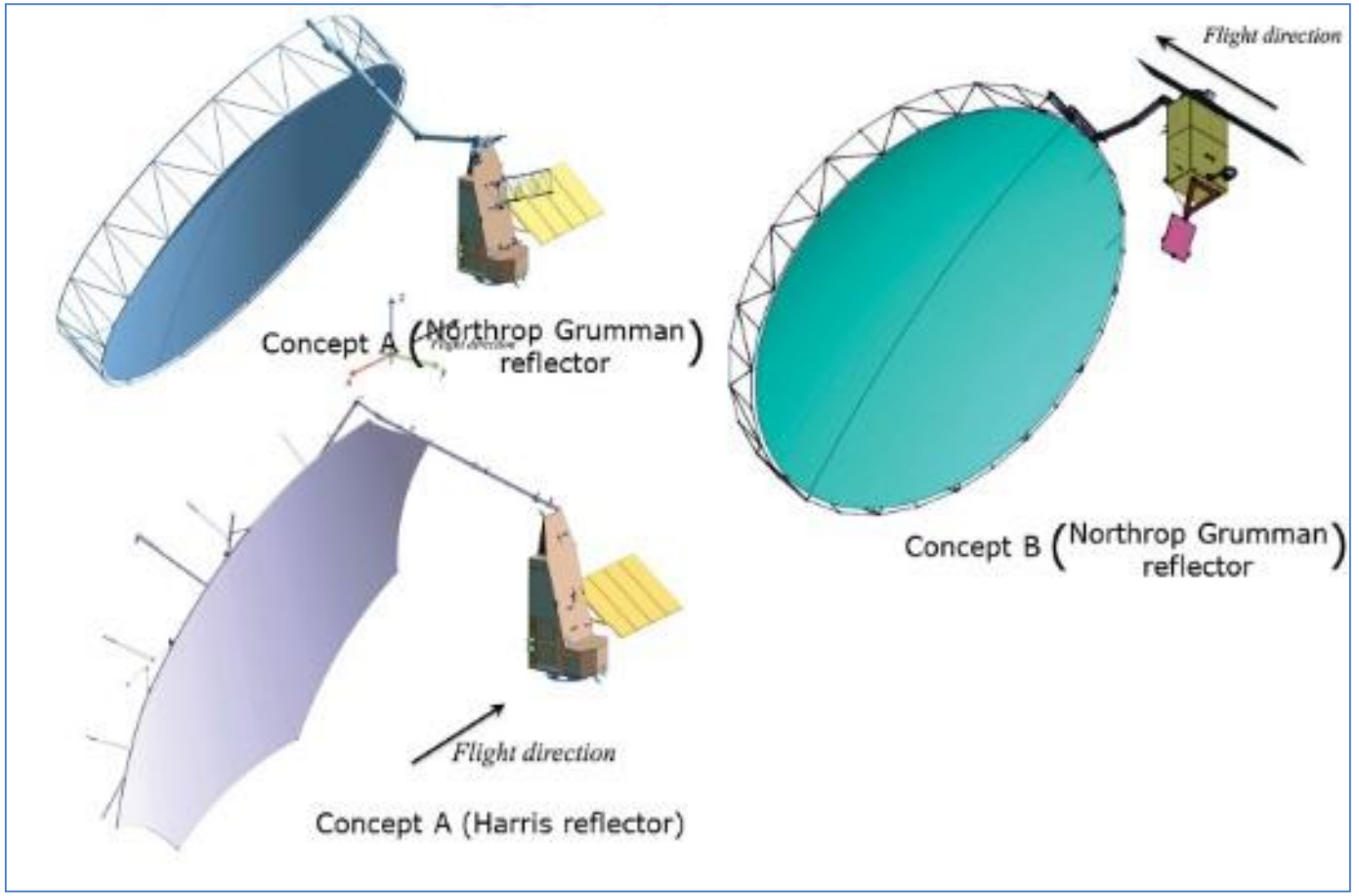
Critical Sequences

Biomass Spacecraft

Deployable Reflector
- Deployed soon after launch
- Critical procedure
- Must be in contact with ground

Considerations
- Communication with ground
- Modes / states of system, subsystems and equipment
- Multiple decision nodes

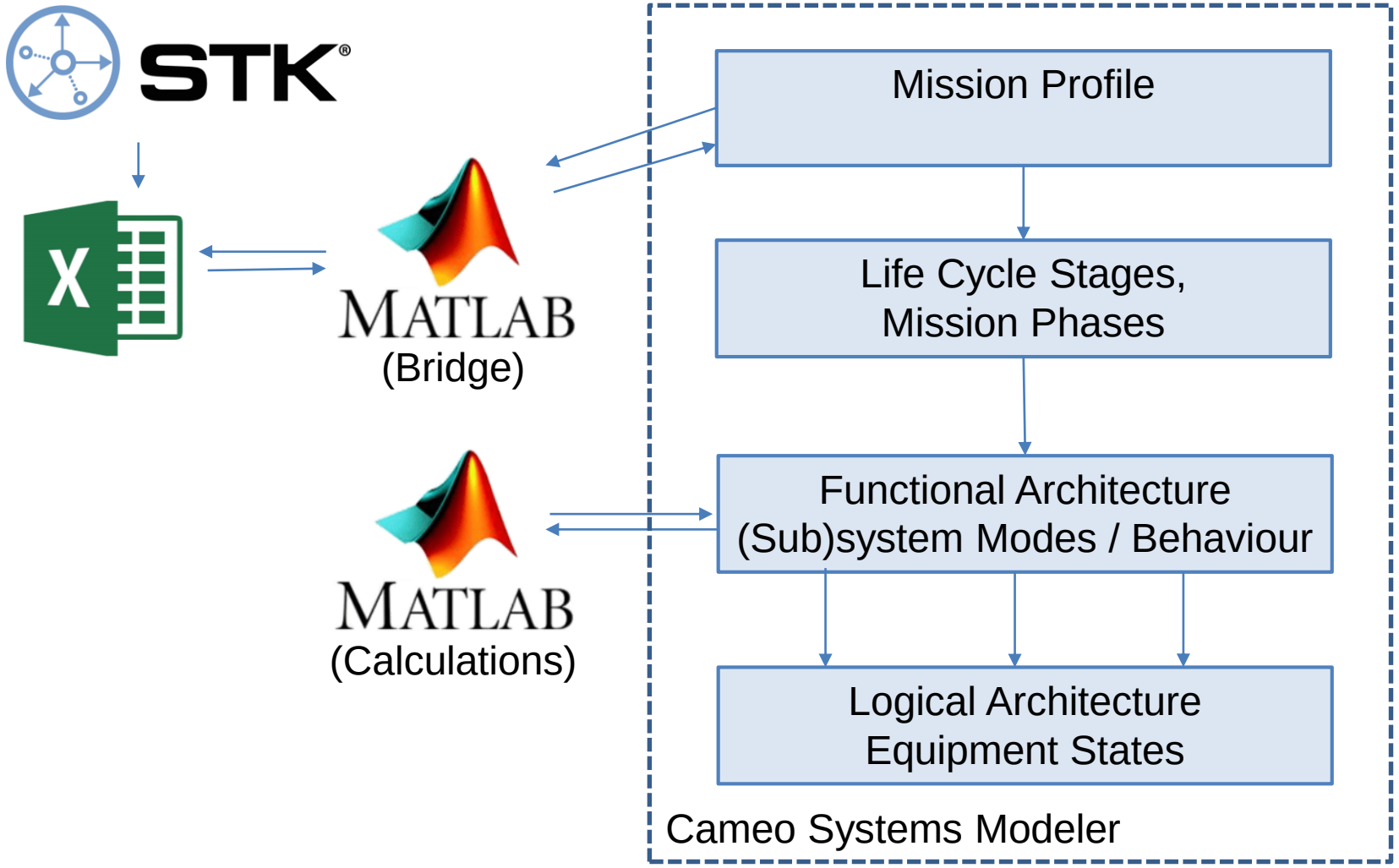


F. Hélière, F. Fois, M. Arcioni, P. Bensi, M. Fehringer, and K. Scipal, "Biomass P-band SAR interferometric mission selected as 7th Earth Explorer Mission," in *Proceedings of 10th European Conference on Synthetic Aperture Radar, EUSAR 2014*

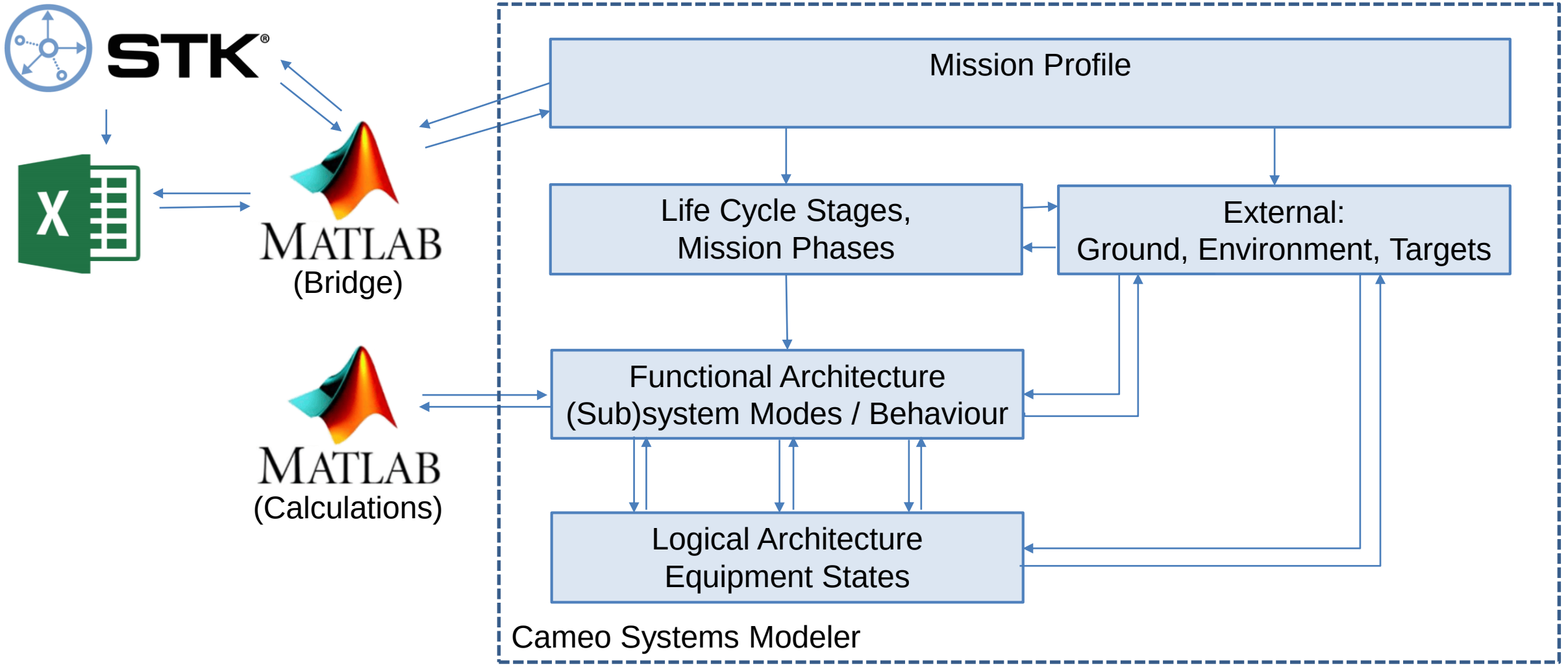
Critical Sequences Use Case Objectives

1. Validate the reflector deployment sequence
    - Ensure that deployment sequences fully describe all possible scenarios.
    - Demonstrate flexibility of the system by postponing launch, altering orbit, etc.
    - Demonstrate that all system modes, subsystems modes and equipment states have been described.
    - Begin assigning functions to logical architecture

Biomass Model Structure 1



Biomass Model Structure 2



Critical Sequences Use Case Results

Not quite there yet…

Critical Sequences Use Case Outcomes – in terms of Template

Outcomes so far…

- Can run STK from Cameo Systems Modeler (with *Katy Pugh, University of Bristol*)
  - Previously limited to reading Excel-based results into Cameo Systems Modeler.
  - Now can do the following:
    1. Define the parameters of an STK scenario in Cameo Systems Modeler
    2. Open STK and run the scenario from Cameo Systems Modeler
    3. Generate results in STK and output these to Cameo Systems Modeler

- Made behaviour *Modular*
  - E.g. added ‘External’ block - Can now add external behaviour (e.g. Environment, Targets)
  - Can follow patterns to add system behaviour and choose which to include in simulation

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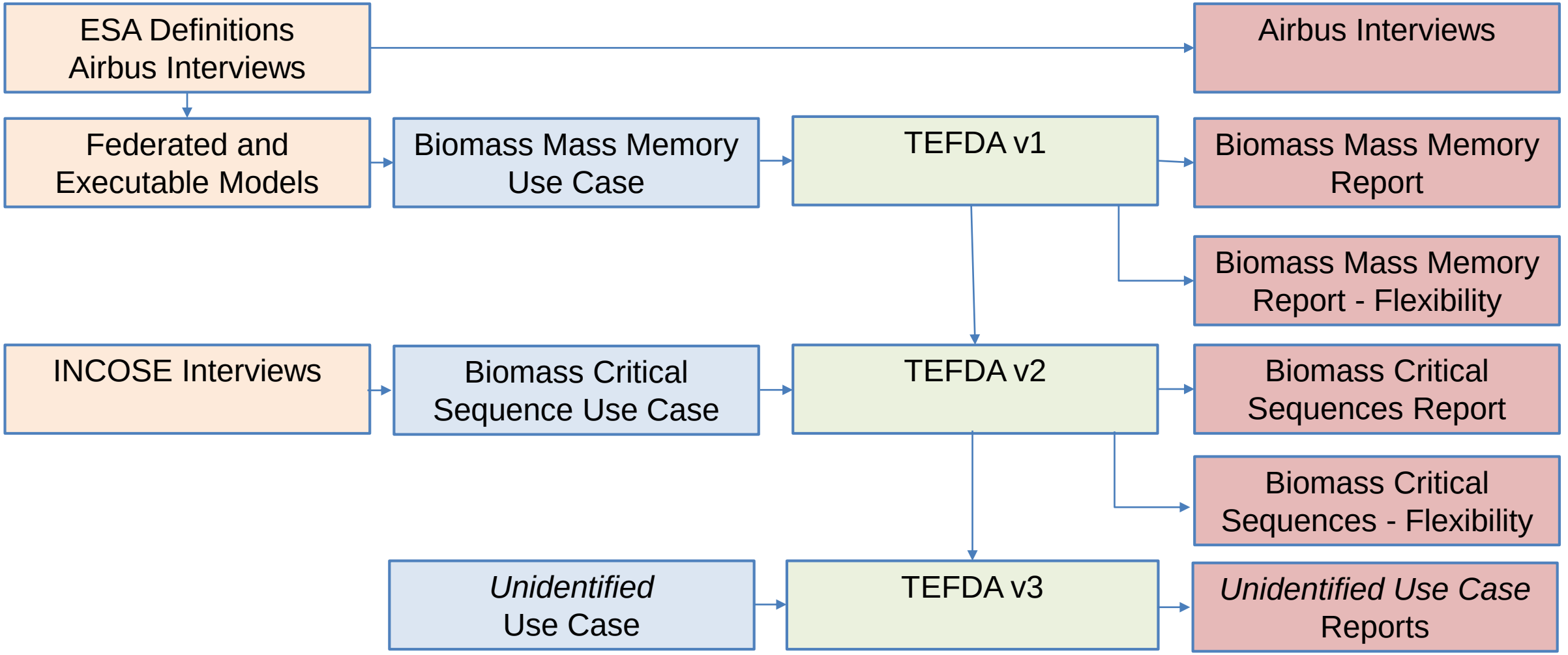
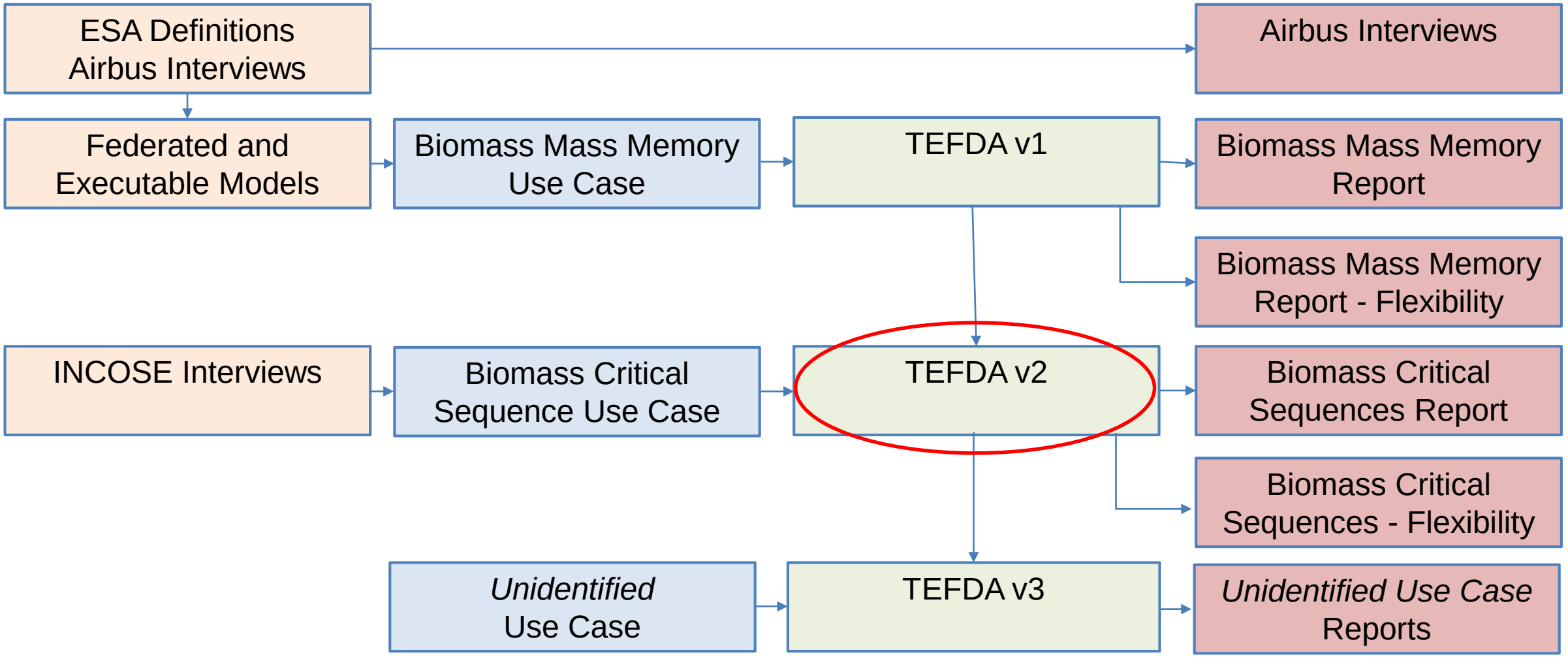

ESA Definitions
Airbus Interviews
Airbus Interviews
Federated and Executable Models
Biomass Mass Memory Use Case
TEFDA v1
Biomass Mass Memory Report
Biomass Mass Memory Report - Flexibility
INCOSE Interviews
Biomass Critical Sequence Use Case
TEFDA v2
Biomass Critical Sequences Report
Biomass Critical Sequences - Flexibility
Unidentified Use Case
TEFDA v3
Unidentified Use Case Reports
Inputs
Use Cases
Models
Reports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Sequence Use Case
TEFDA v2
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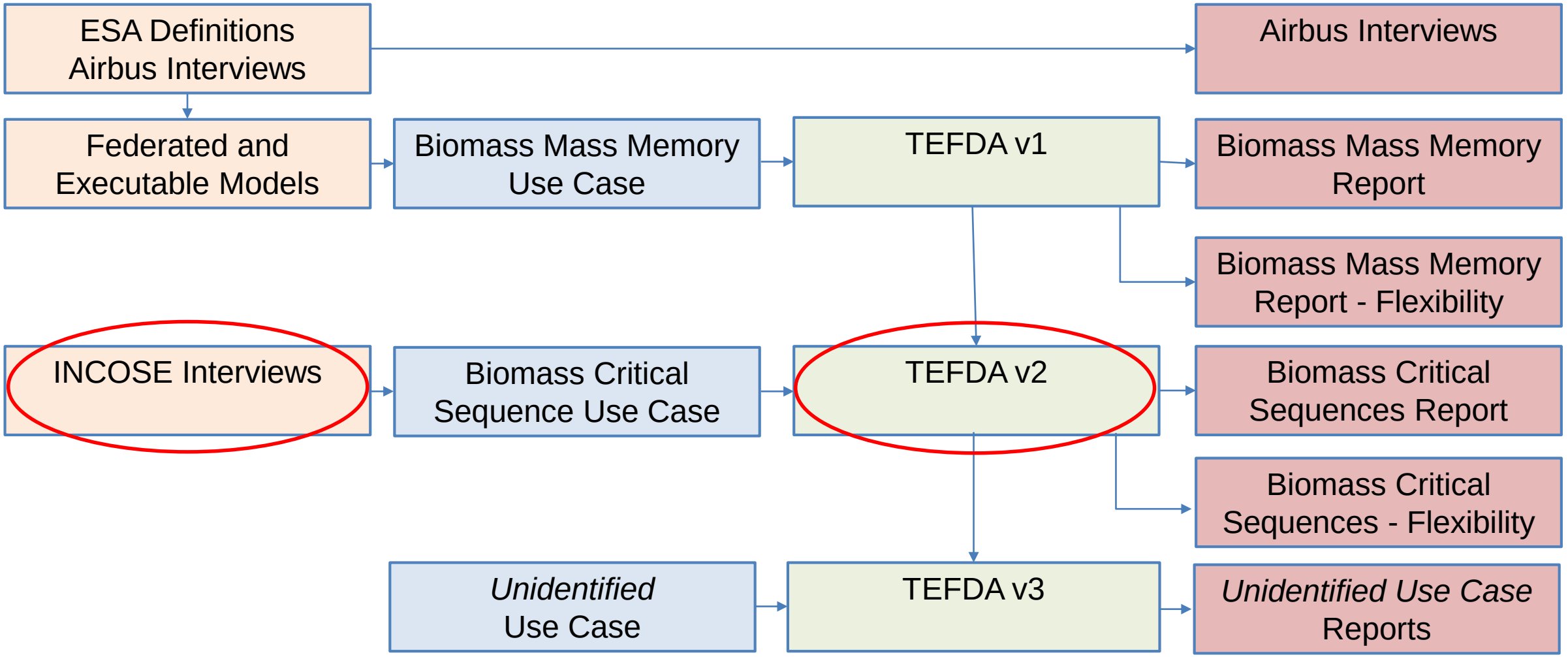
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Report - Flexibility
INCOSE Interviews
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Sequence Use Case
TEFDA v2
Biomass Critical
Sequences Report
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Sequences - Flexibility
Unidentified
Use Case
TEFDA v3
Unidentified Use Case
Reports
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Modelling Objectives:

- Can we add simulation capabilities to the *Federated and Executable Models* approach?
- Can we do so without using ModelCenter (by Phoenix Integration)?
- Can we do so while maintaining the model's primary use a System *Description*
- Can we tailor our simulation capabilities towards early validation of the ConOps?
- Can we generalise and produce a model template for use on other missions?

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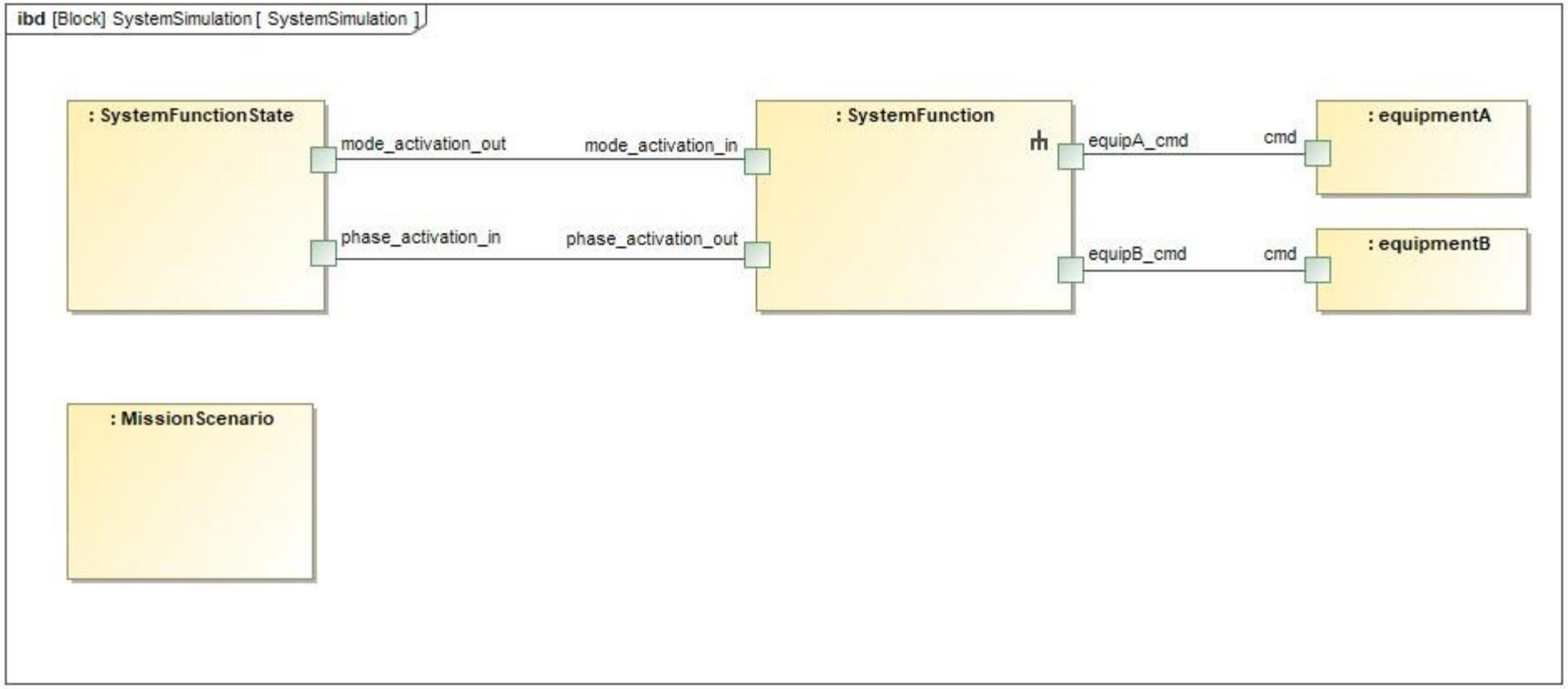
Can we generalise and produce a model template for use on other missions?

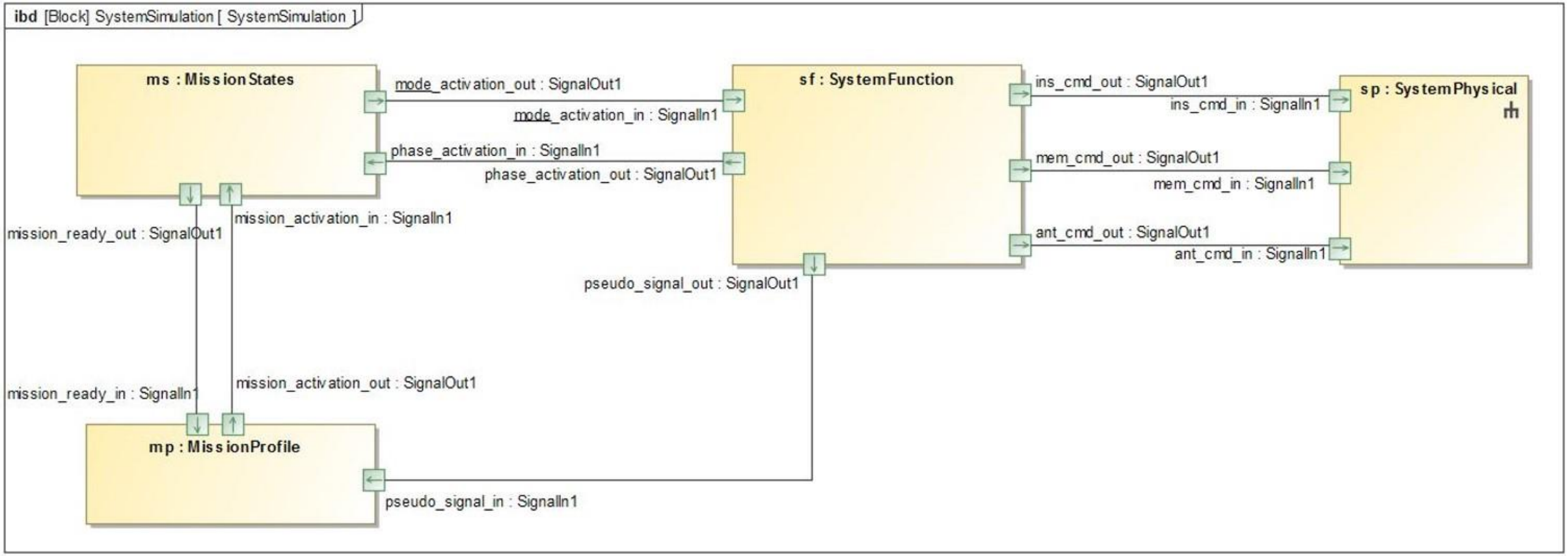
In Progress!

- **Manage complexity**
- Separate *descriptive* and *analytical* aspects of the model
- Measure success

Top-Level Internal Block Diagram - Initial



Top-Level Internal Block Diagram – Mass Memory Use Case



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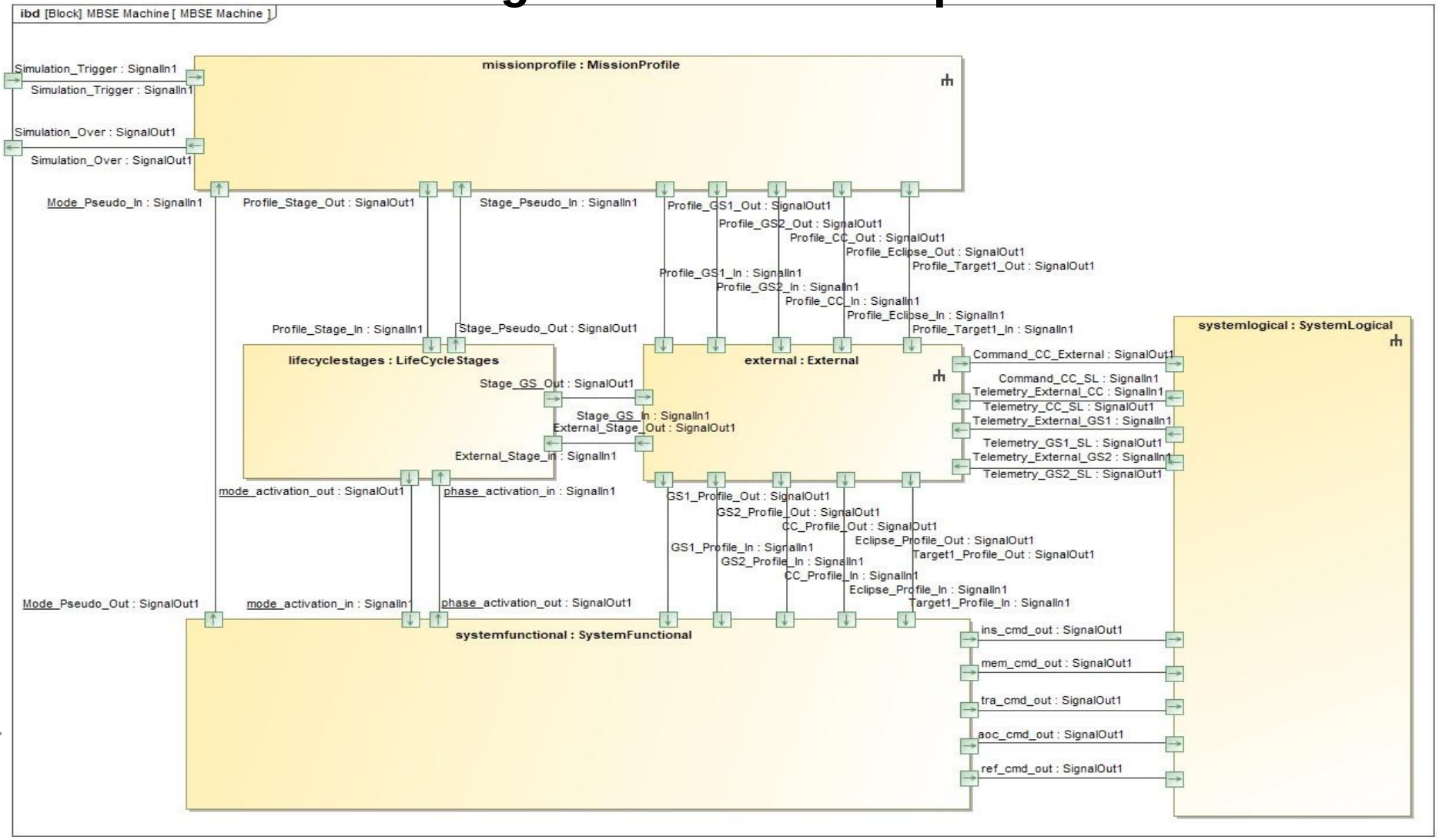
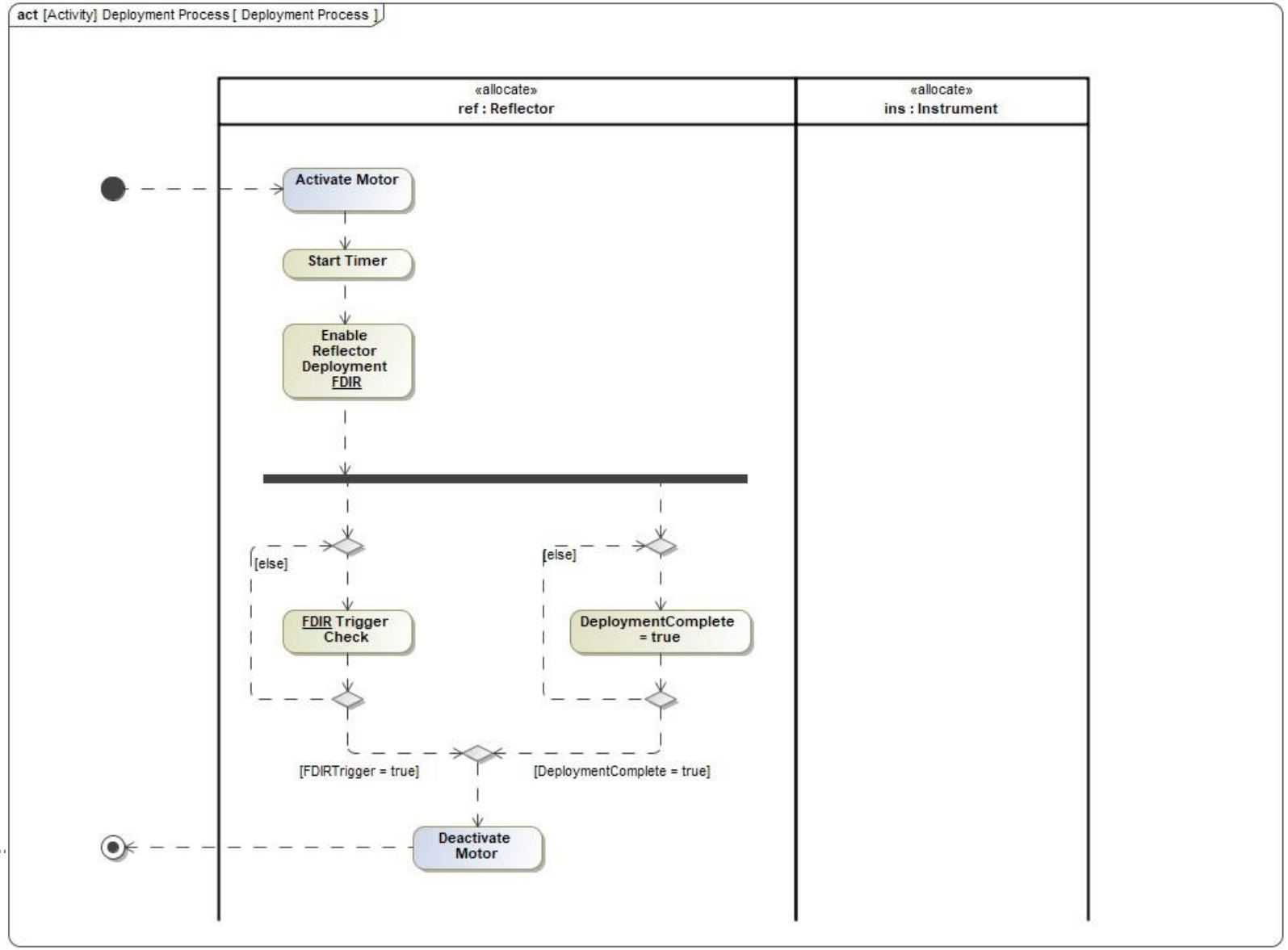
Top-Level Internal Block Diagram – Critical Sequences Use Case

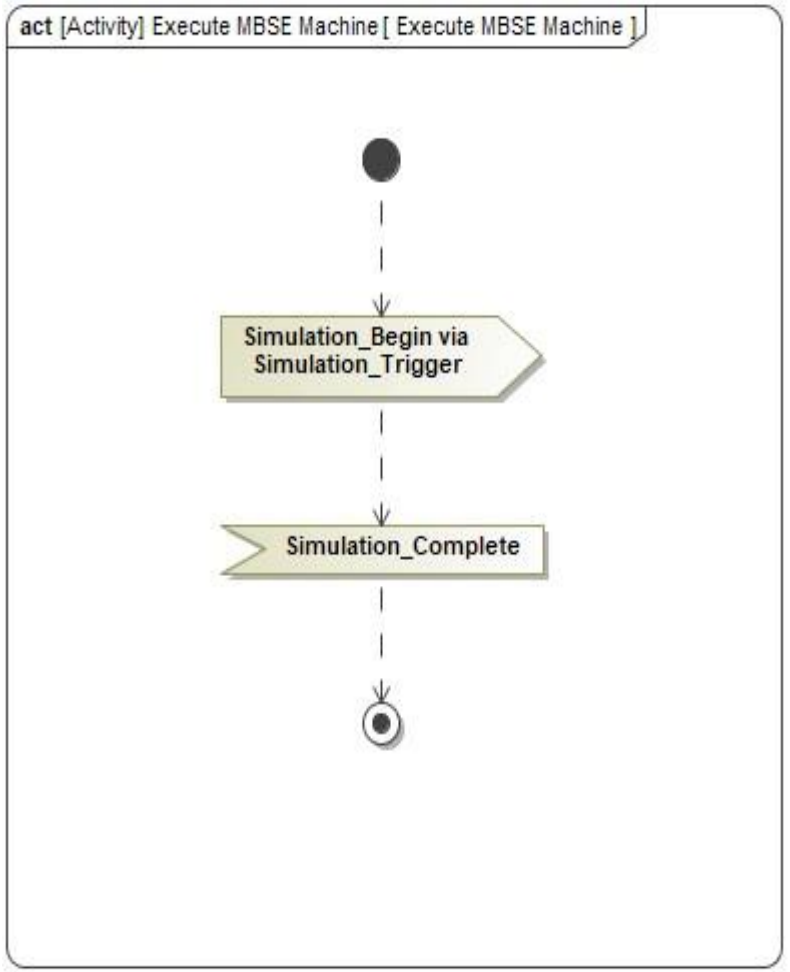


Can we generalise and produce a model template for use on other missions?

In Progress!

- Manage complexity
- **Separate *descriptive* and *analytical* aspects of the model**
- Measure success


act [Activity] Deployment Process [Deployment Process]
«allocate»
ref : Reflector
«allocate»
ins : Instrument
Activate Motor
Start Timer
Enable Reflector Deployment FDIR
[else]
FDIR Trigger Check
[else]
DeploymentComplete = true
[FDIRTrigger = true]
[DeploymentComplete = true]
Deactivate Motor


act [Activity] Execute MBSE Machine [Execute MBSE Machine]
Simulation_Begin via Simulation_Trigger
Simulation_Complete

Can we generalise and produce a model template for use on other missions?

In Progress!

- Manage complexity
- Separate *descriptive* and *analytical* aspects of the model
- **Measure success**

Measuring Success

Possible Metrics

- Communicability
- Consistency
- Traceability
- Reusability
- Accuracy

Possibility of MBSE / DBSE experiment to come

Thank you for listening

Questions / Feedback gratefully received!