Improving the Satellite Development Process: What Does it Take?

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Outline

- ESA's Motivation
- Approach and Vision
- Achievements: Simulation-Based design
- Final Remarks

Motivation for
Space System Design Process Improvements

- **Increase Cost effectiveness of development process**
  - **Who owns the process?**
  - **What is ESA’s role?**
- **Manage growing complexity of future missions**
- **Boost industrial competitiveness**

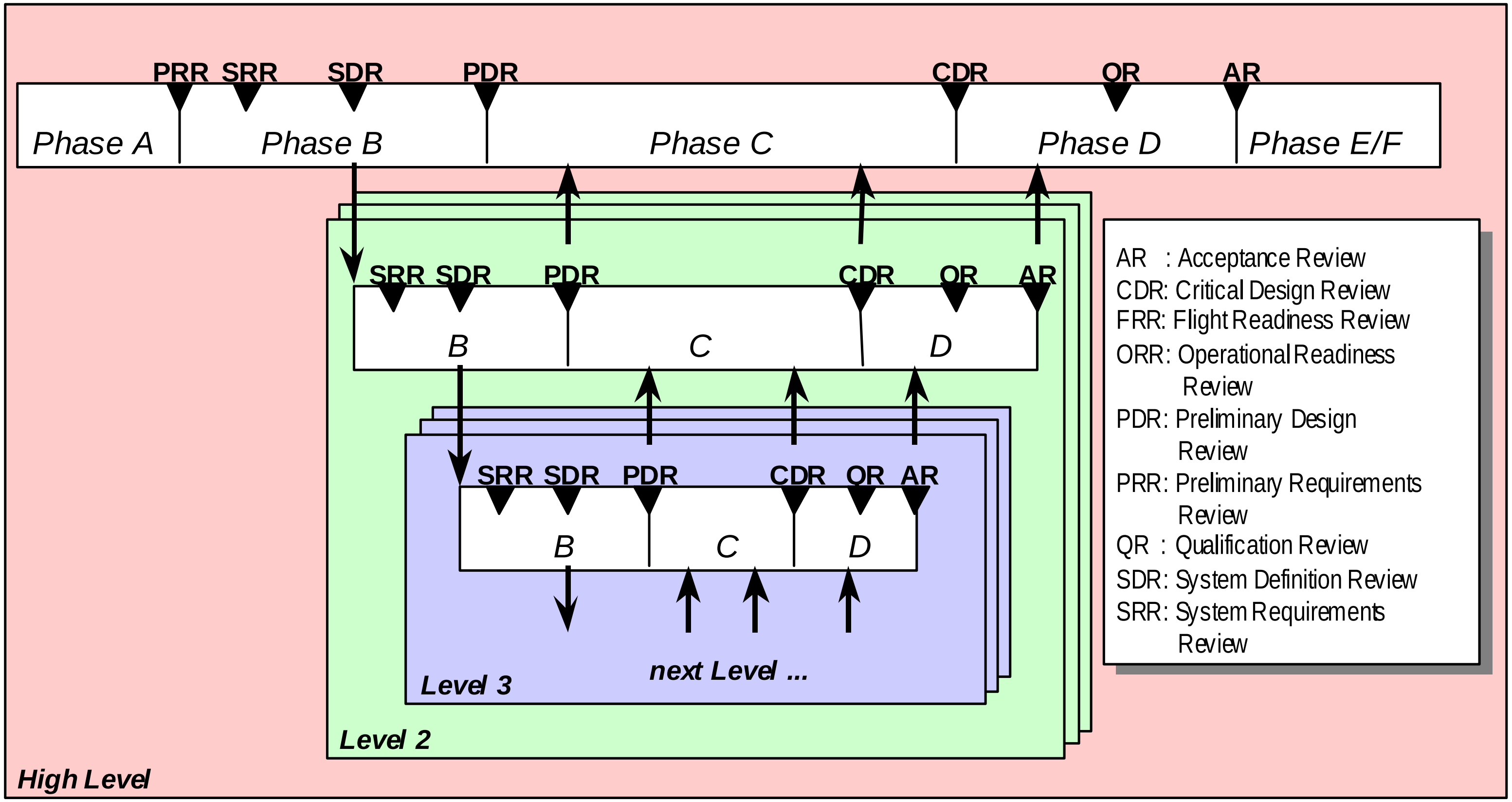
ESA past and current activities

- Studies
- Engineering Data Exchange Standards
- Multi-Disciplinary Engineering Analysis Tools
- Concurrent Design Facility
- Project Test Bed
- Virtual Prototyping
- Tele-testing
- Distributed Collaborative Engineering
- Software (Requirements) Engineering

Renewed Approach

- Process before tools
- Life-cycle before individual phases
- System before sub-system/discipline
- Standardisation before diversification
- Federation before segmentation

Development Life-Cycle and Related Activities



Requirements Engineering Process

- Generate "system" model using methodology from software systems (e.g. XML, UML, Statemate, Stateflow) Stateflow)
- Reuse of RE system model for analysis and simulation tools (e.g. Matlab/Simulink)
- Innovative methods for Requirements Generation and Management Functions
- Formal methods to generate system spec

Design & Development Process

Simulation-Based Design

- Life-Cycle Approach: the Project Test Bed concept
- Seamless migration from analysis to simulation
- Automatic Code and Simulation Generation
- Generic satellite simulator architectures
- Simulation Model Repositories
- Virtual Prototyping (i3D)

Design & Development Process
Collaborative Engineering

- **Distributed access to project data (PDM, Federated Databases)**
- **Concurrent Engineering (PDC, CDF)**
- **Distributed Concurrent Development**
- **Geographically distributed supply chain**
- **Distributed Interactive Simulation**
- **Geographically distributed satellite pre-integration**

AIV Process

- Tailored to specific model philosophy (e.g. Protoflight)
- Based on operational experience
- Test languages
- Generation and validation of test procedures
- Modular low-cost EGSE systems
- Teletesting (remote participation, 3D visualisation)

Process Reinforcing Tools

- **STEP Tools (Plug-ins, viewer etc.)**
- **Interface to PDM Tool**
- **Interface to Distributed databases or Repositories**
- **Code Generators**
- **Support Migration from Analysis to Simulation tools**
- **Facilitate adoption of standards**

Standards

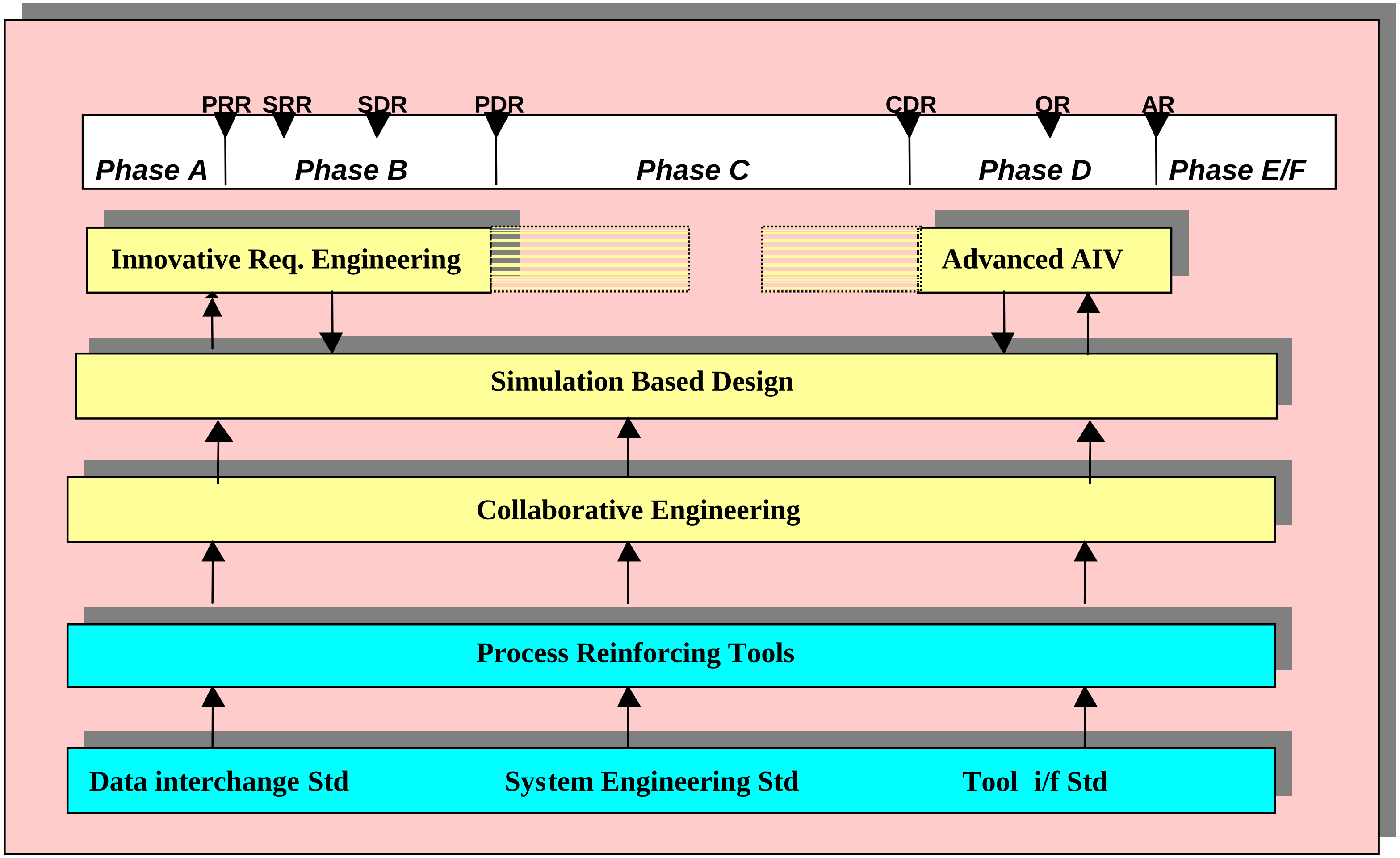
- **System Engineering Standards**
  - **European Co-operation for Space Standardisation (ECSS)**
  - **Define the Spacecraft Development Process**
  - **Promote good practice**

- **Standard Components**
- **Data exchange Standards**
- **Tool Interface Standards**
  - **provide independence from tools**

Tool I/F Standards

- Engineering tools
  - STEP,
  - XML, UML
- Simulation
  - Model portability (SMP)
  - interoperability (HLA, CORBA)
- EGSE
  - simulator, flight model, core-EGSE, synchronisation
  - test language,
- Databases
  - engineering components
  - spacecraft database

Mapping to Project Life-Cycle



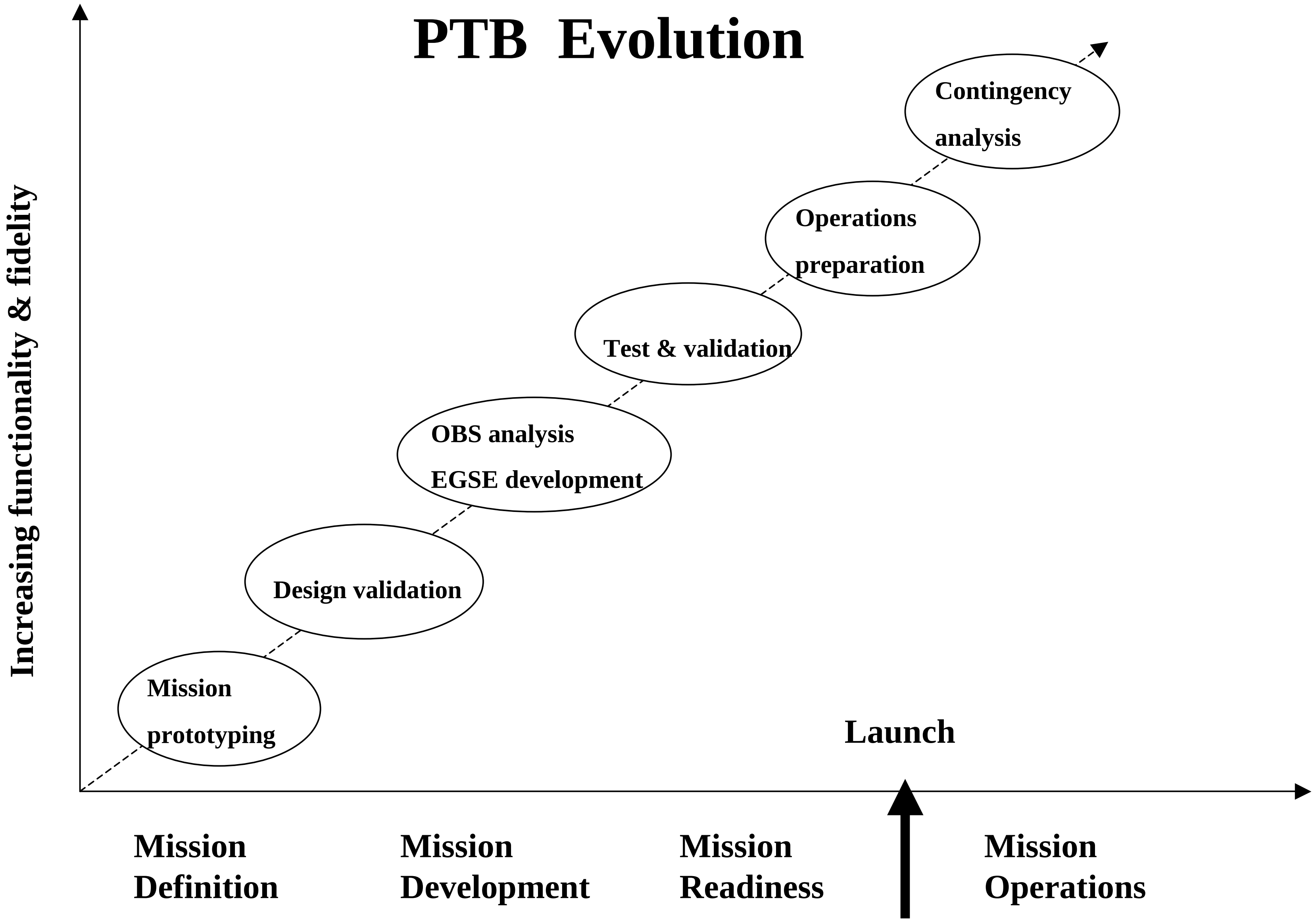
Simulation-Based Design

"VIRTUAL SATELLITE"

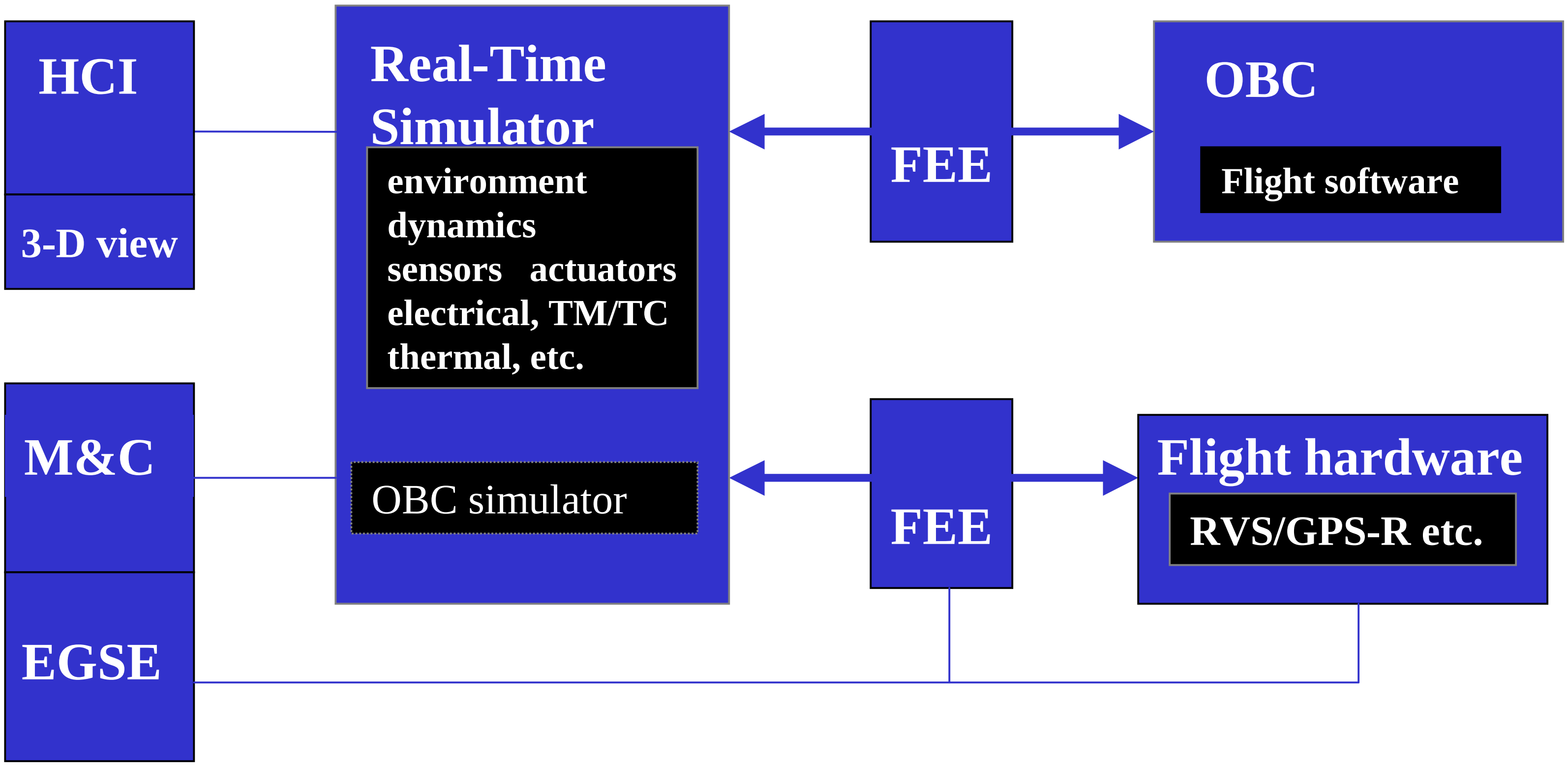
Project Test Bed (PTB)

- Approach based on a “Virtual” representation of the spacecraft, its environment and its mission
- Life Cycle Approach
  - starts with mission and system definition
  - covers Specification, Design, Qualification, AIV, Operations
  - exploits synergy /commonality across phases
- System Level
  - supports Systems Engineering function
  - does not replace s/s or discipline specific simulation
  - focuses on system “overall” optimisation
  - allows for verification of s/s interfaces
  - complements/replaces electrical test models (ETM, EQM)

PTB Evolution

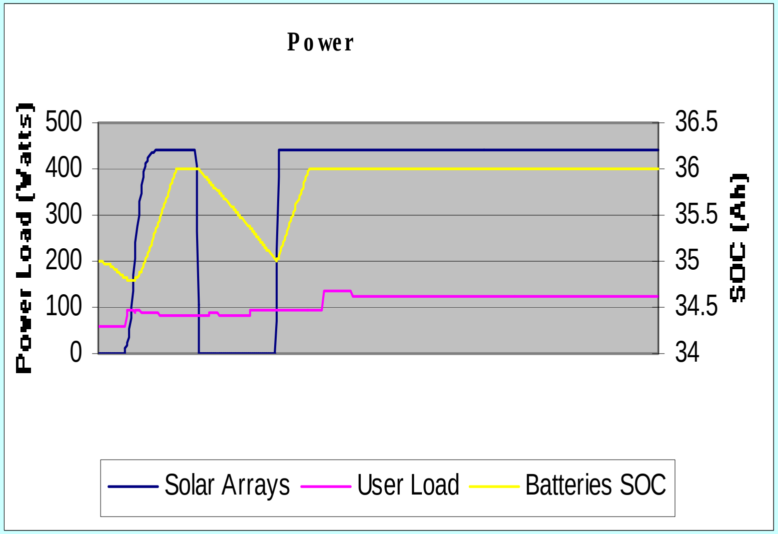


PTB Architecture



Application of PTB

- **Phase 0/A Mission and System Definition**
  - **within Concurrent Design Facility**
  - **e.g. LEO, Interplanetary missions (BepiColombo)**
- **Phase B/C**
  - **Galileo Constellation**
  - **SMART-1**
- **Phase D**
  - **Grace**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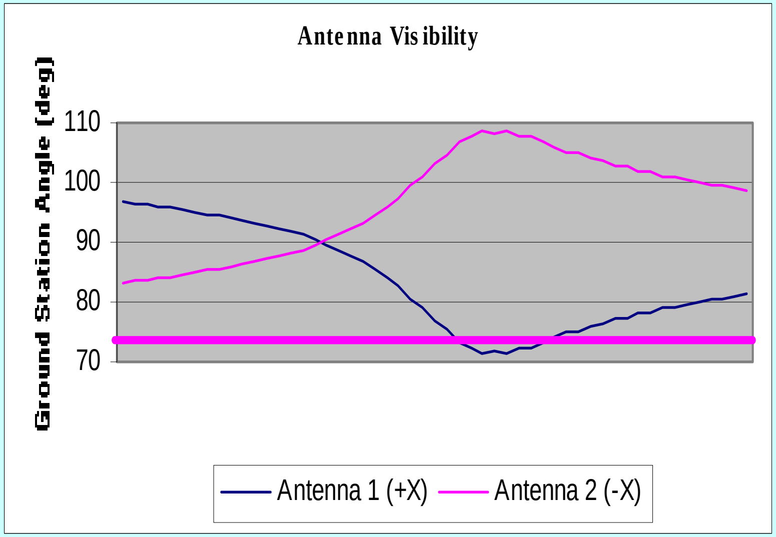
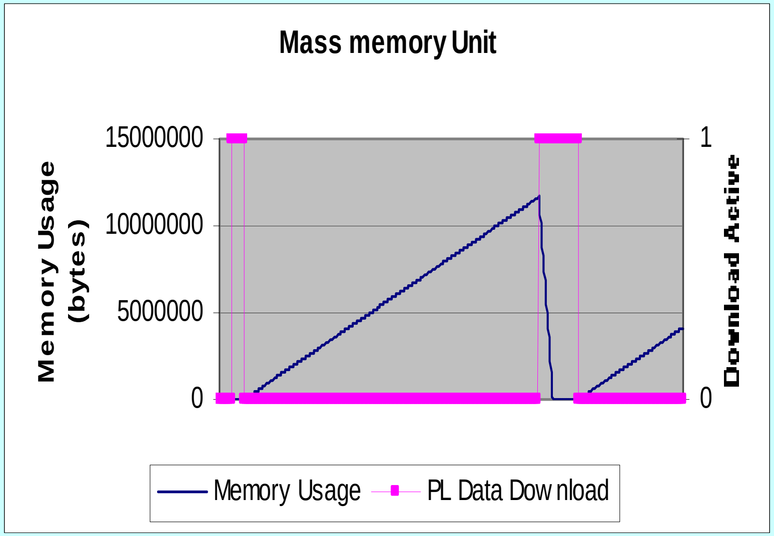
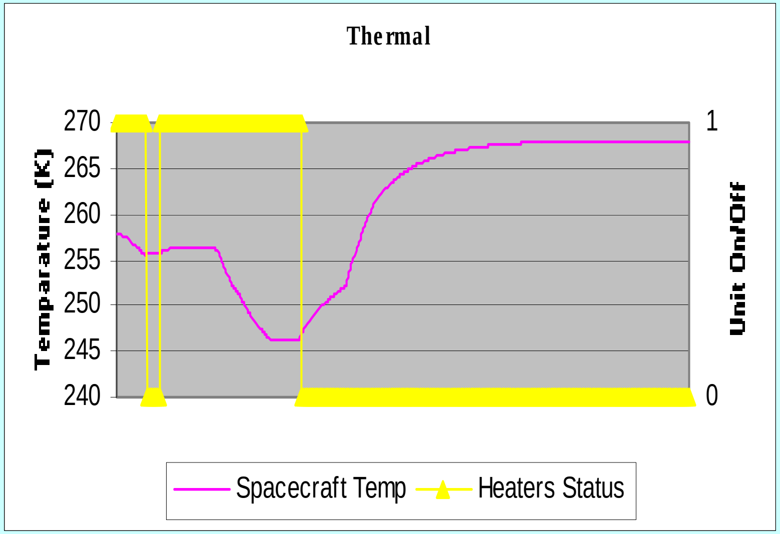
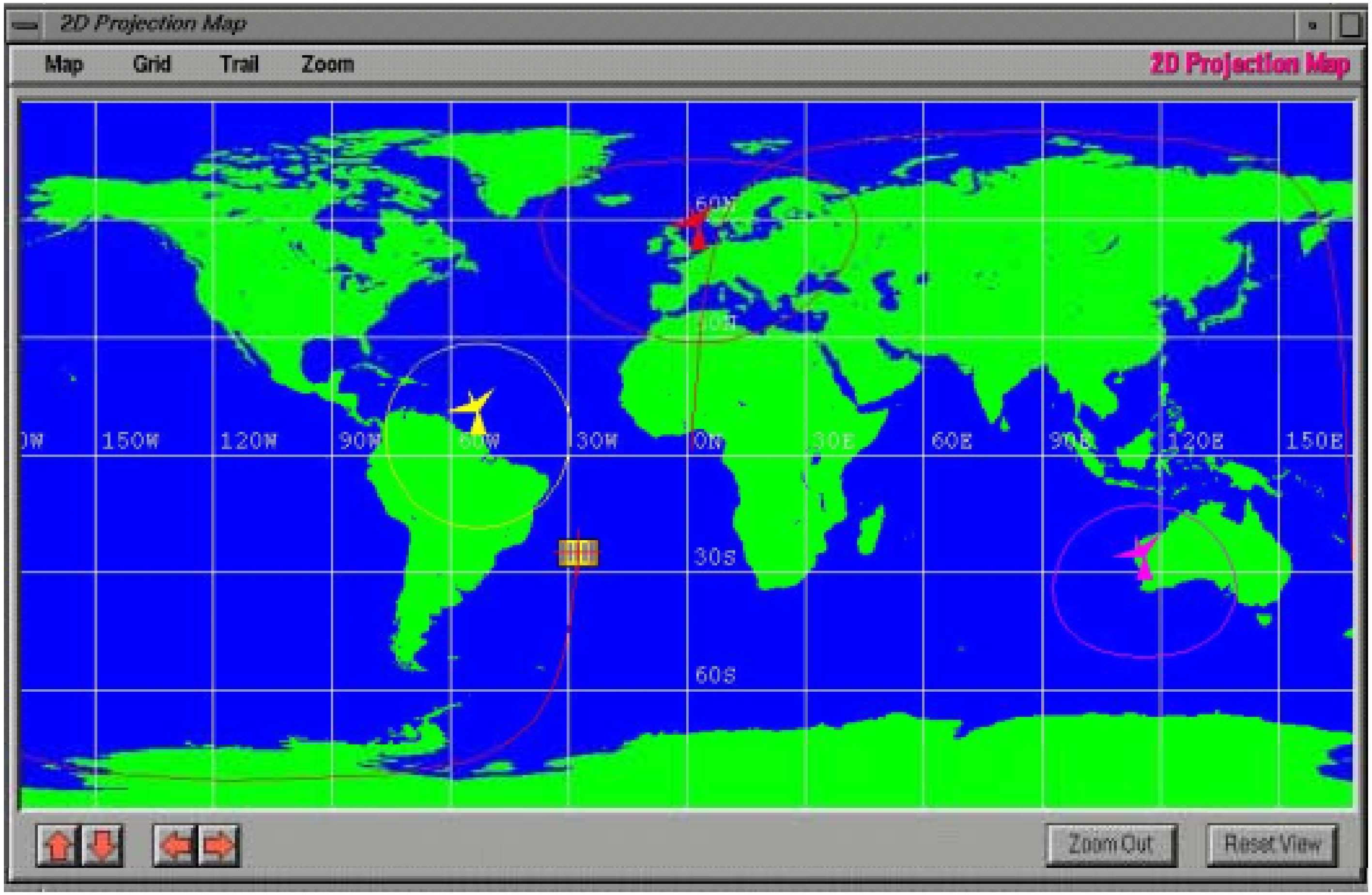
Power Load [Watts]
500
400
300
200
100
0
36.5
36
35.5
35
34.5
34
SOC [Ah]
Solar Arrays
User Load
Batteries SOC


Antenna Visibility
Ground Station Angle [deg]
110
100
90
80
70
Antenna 1 (+X)
Antenna 2 (-X)


Mass memory Unit
Memory Usage (bytes)
15000000
10000000
5000000
0
1
0
Download Active
Memory Usage
PL Data Download


Thermal
Temparature [K]
270
265
260
255
250
245
240
1
0
Unit On/Off
Spacecraft Temp
Heaters Status


2D Projection Map
Map
Grid
Trail
Zoom
2D Projection Map
60N
30N
150W
120W
90W
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0N
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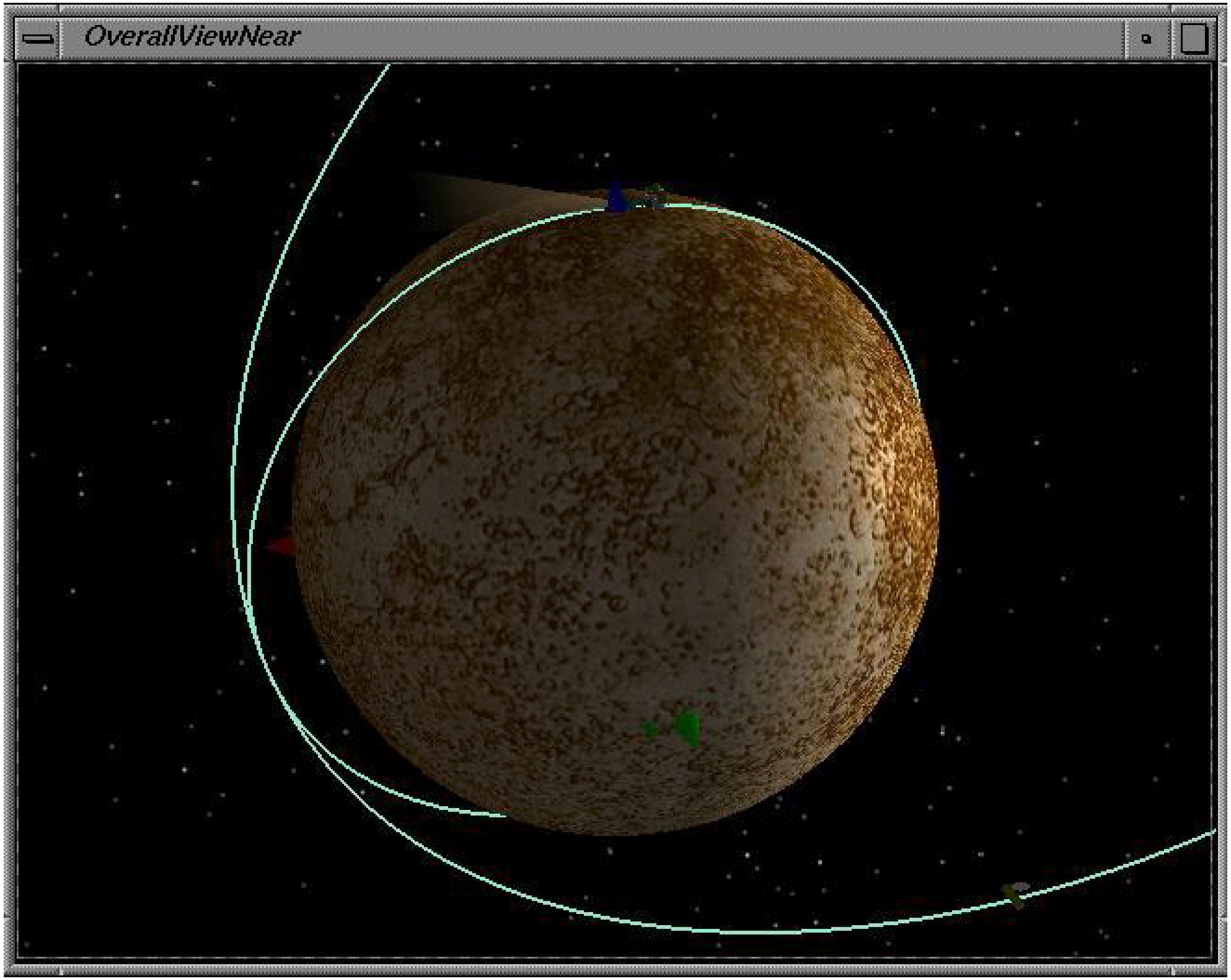
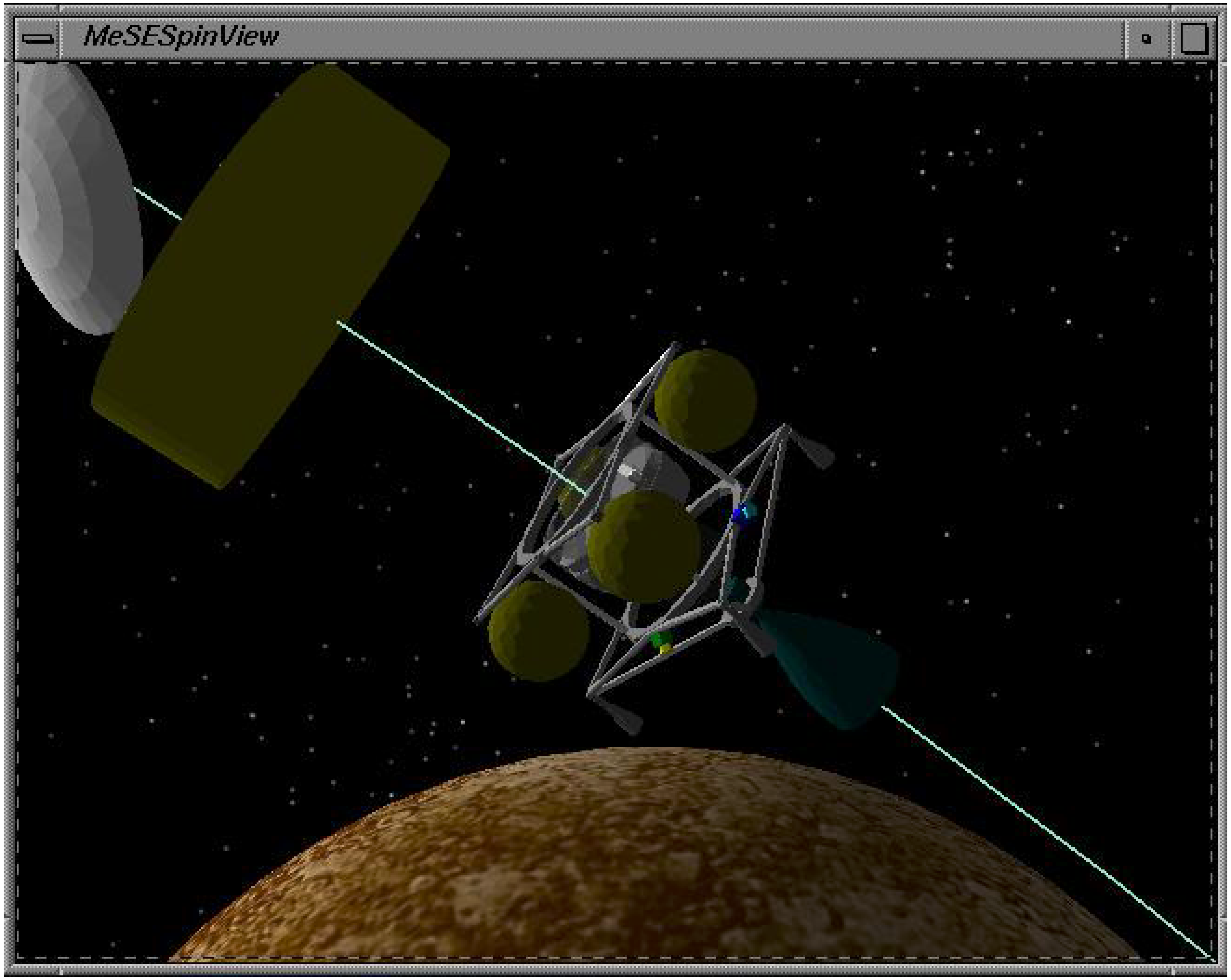
60E
90E
120E
150E
30S
60S
Zoom Out
Reset View

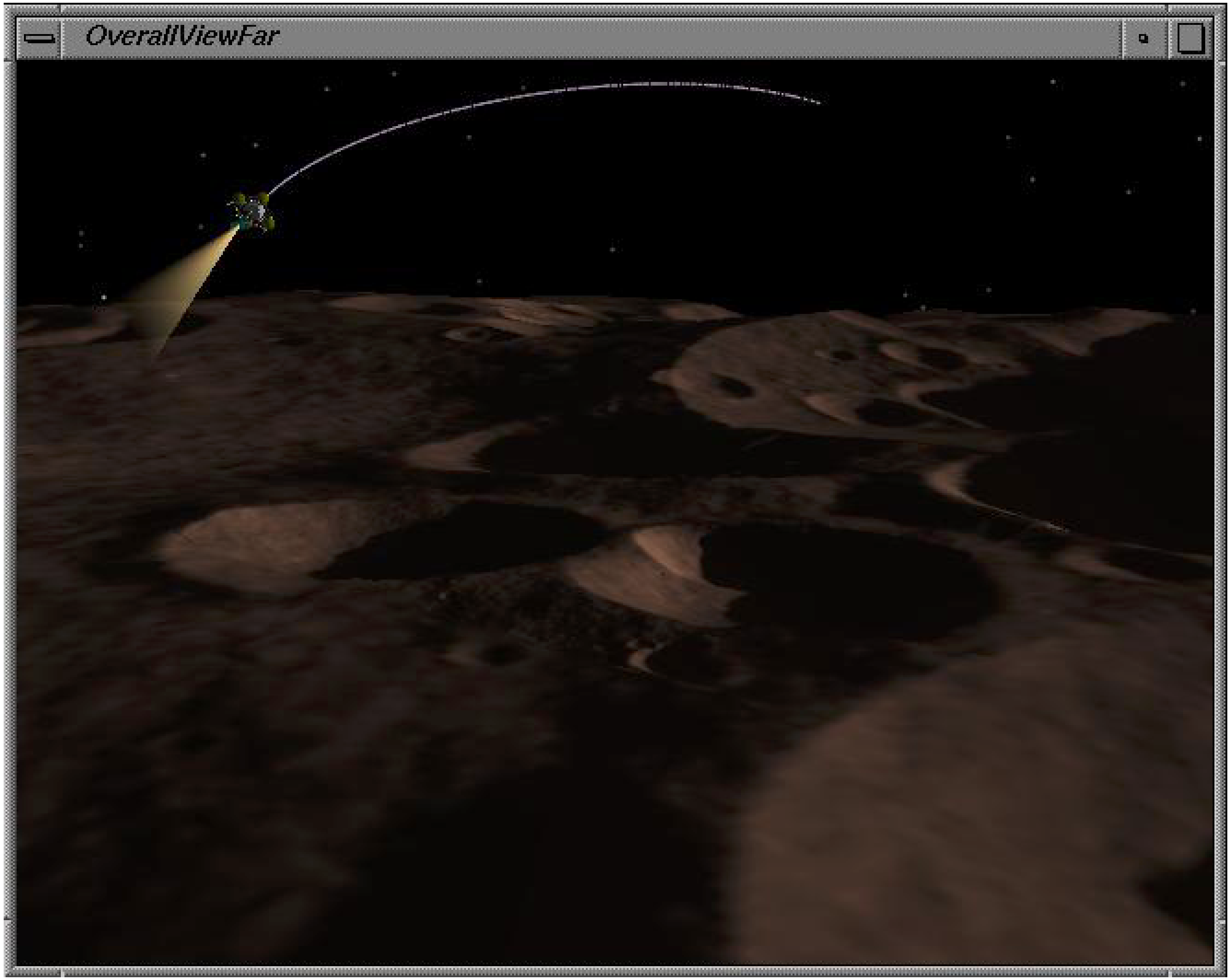
BepiColombo



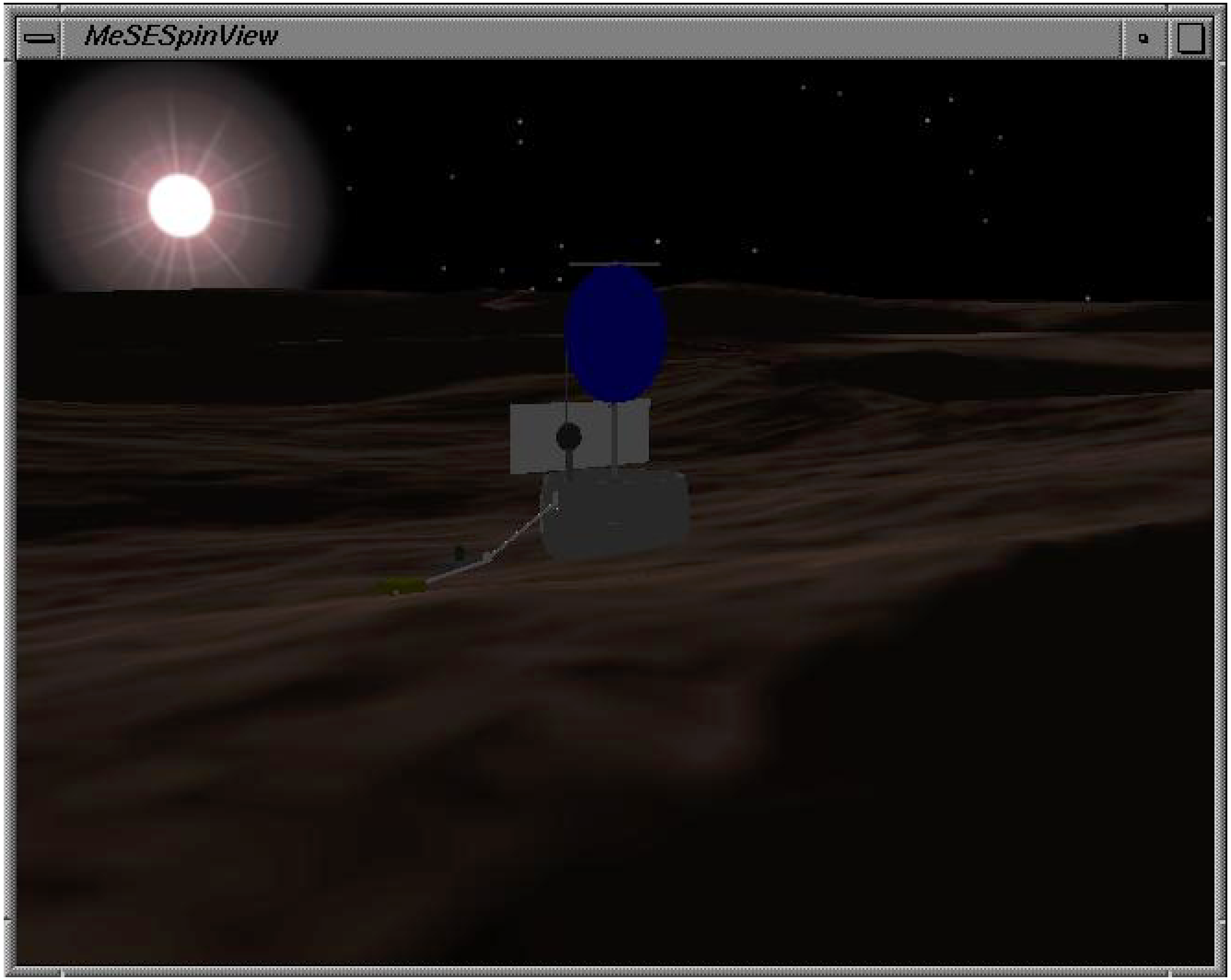
BepiColombo



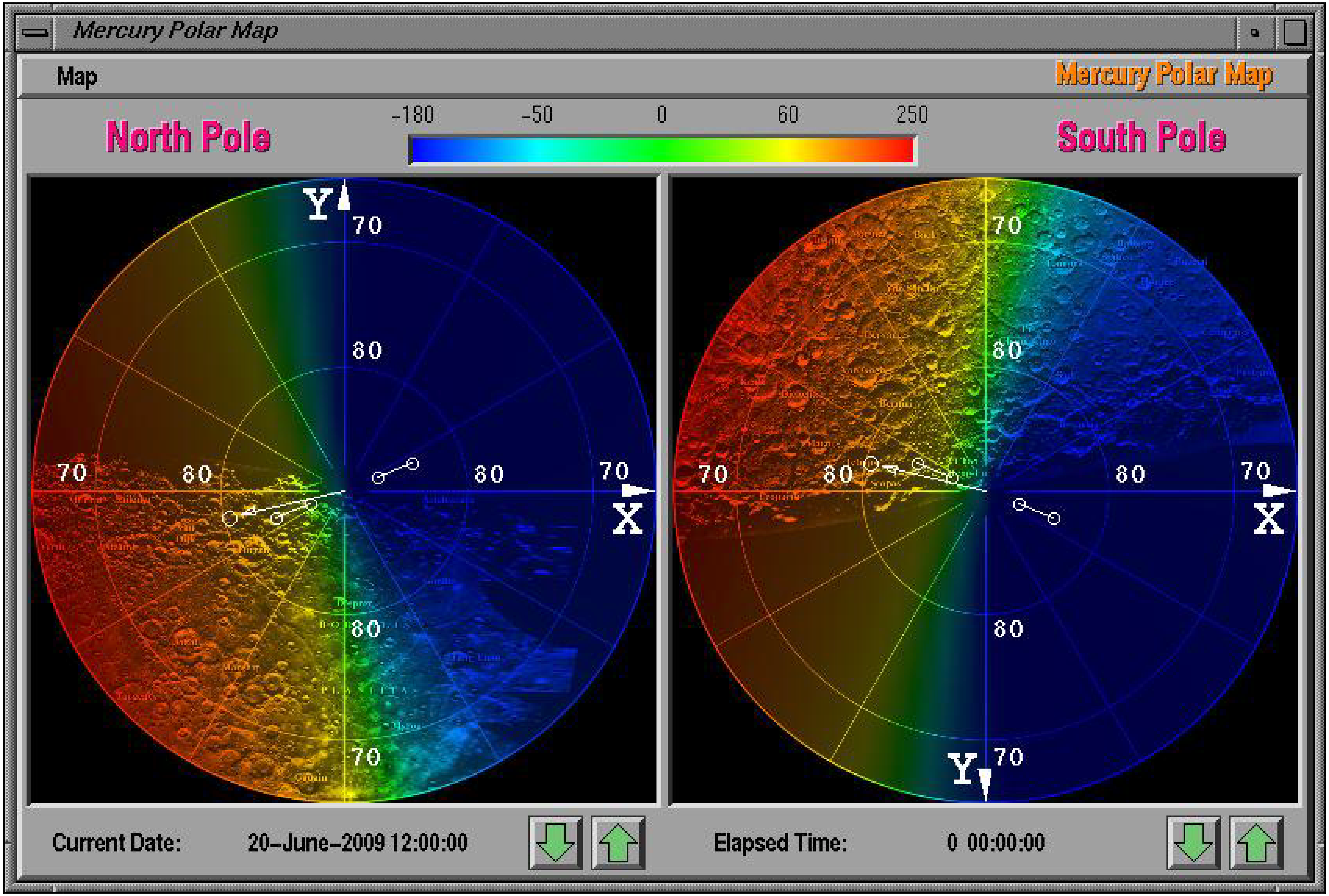
BepiColombo



BepiColombo



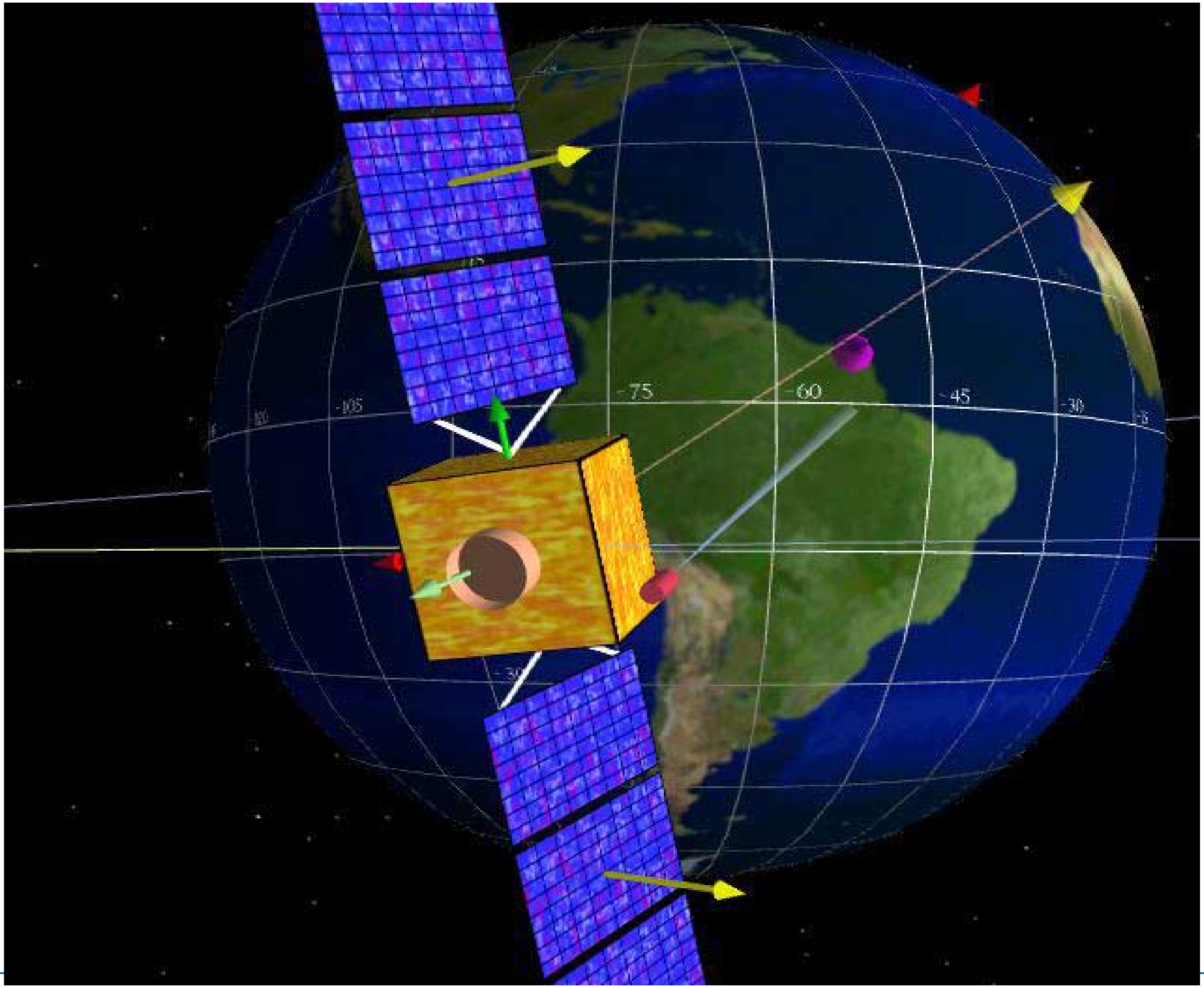
BepiColombo



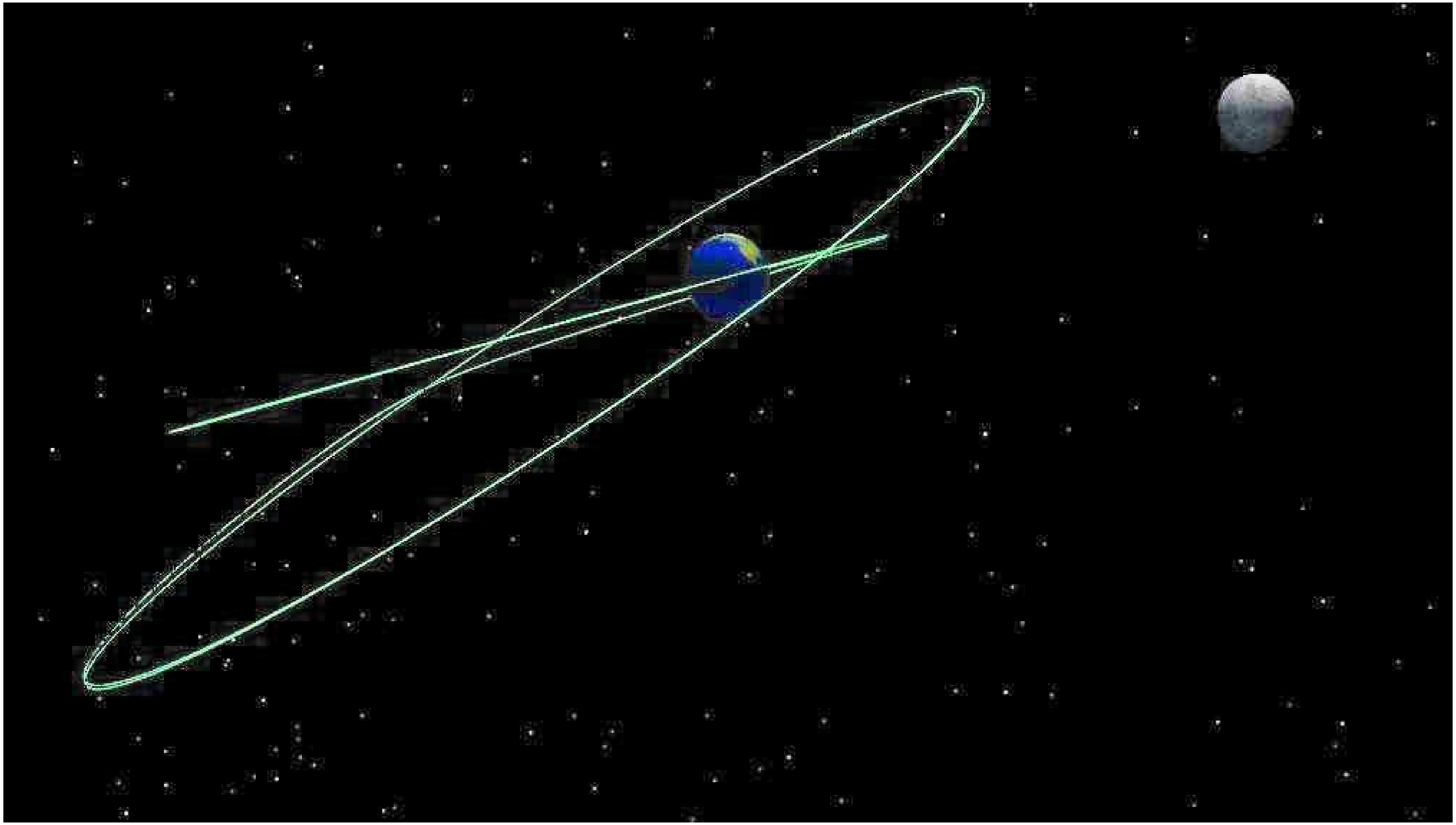
Phase B/C

- **Supports early prototyping**
  - **critical design issues**
  - **assessment of functional requirements**
  - **assessment of performance requirements**

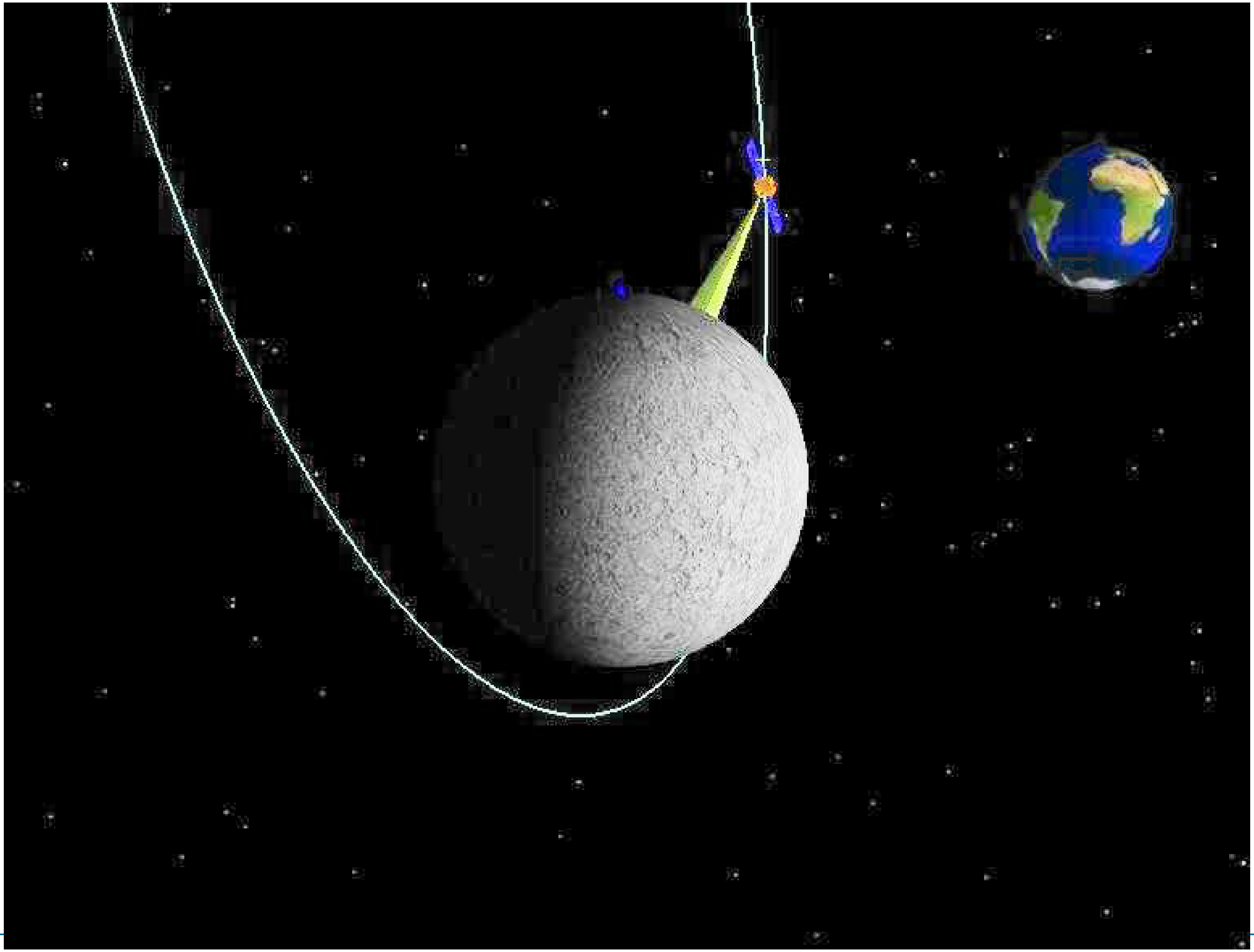
SMART-1



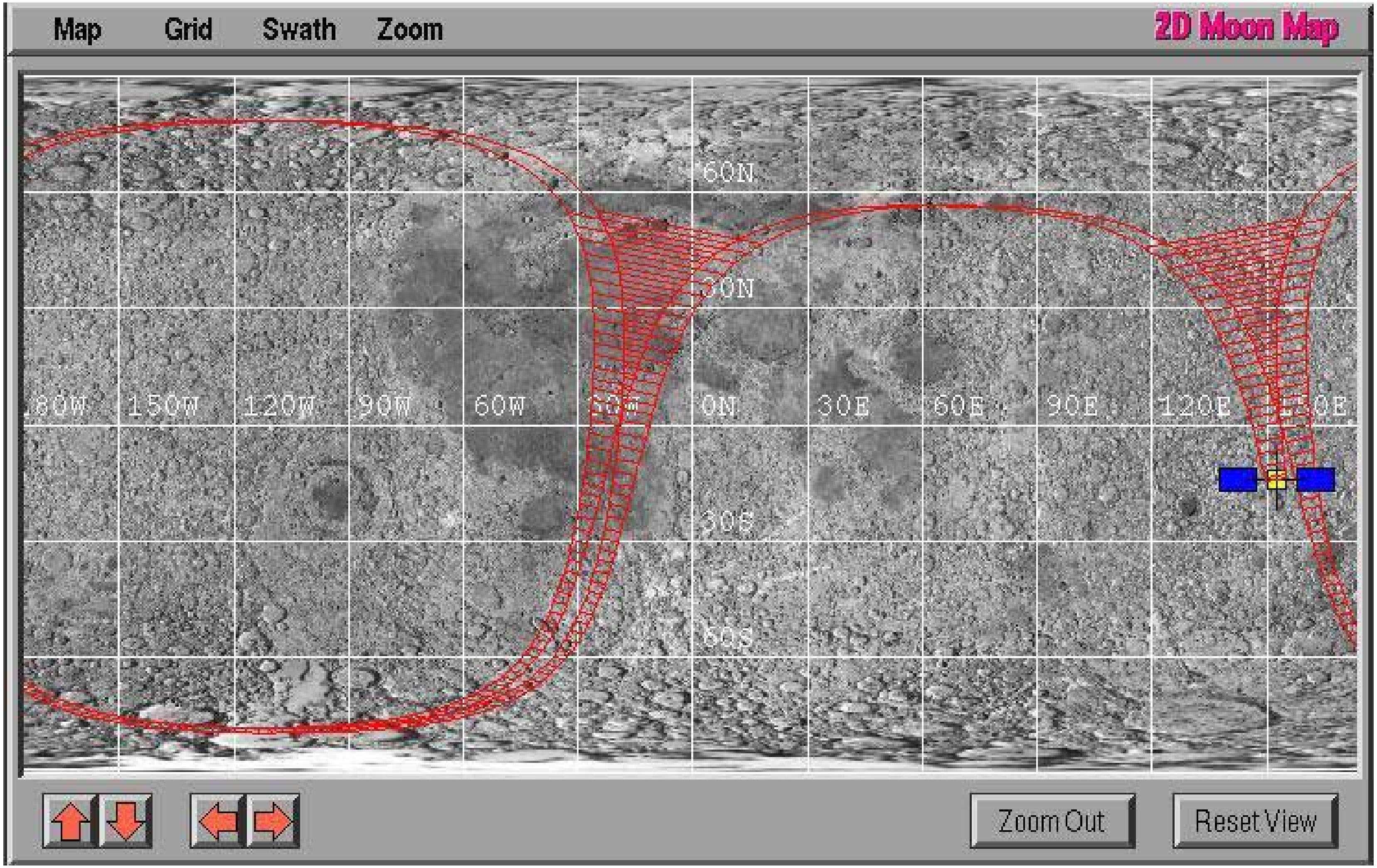
SMART-1



SMART-1



SMART-1


Map
Grid
Swath
Zoom
2D Moon Map
60N
30N
180W
150W
120W
90W
60W
0N
30E
60E
90E
120E
150E
30S
60S
Zoom Out
Reset View

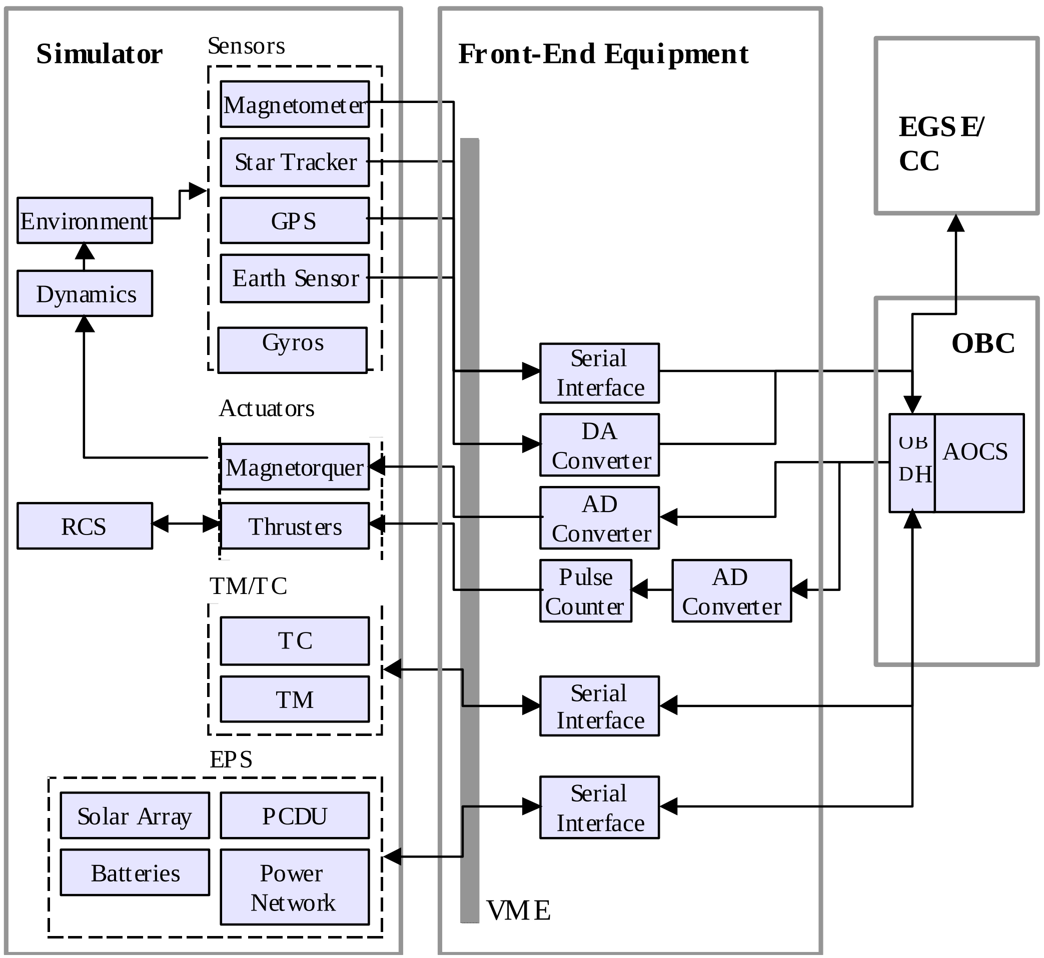
Phase D
System AIV

- **Supports system verification**
  - **design validation**
  - **software verification**
  - **system qualification**
  - **end-to-end system validation**

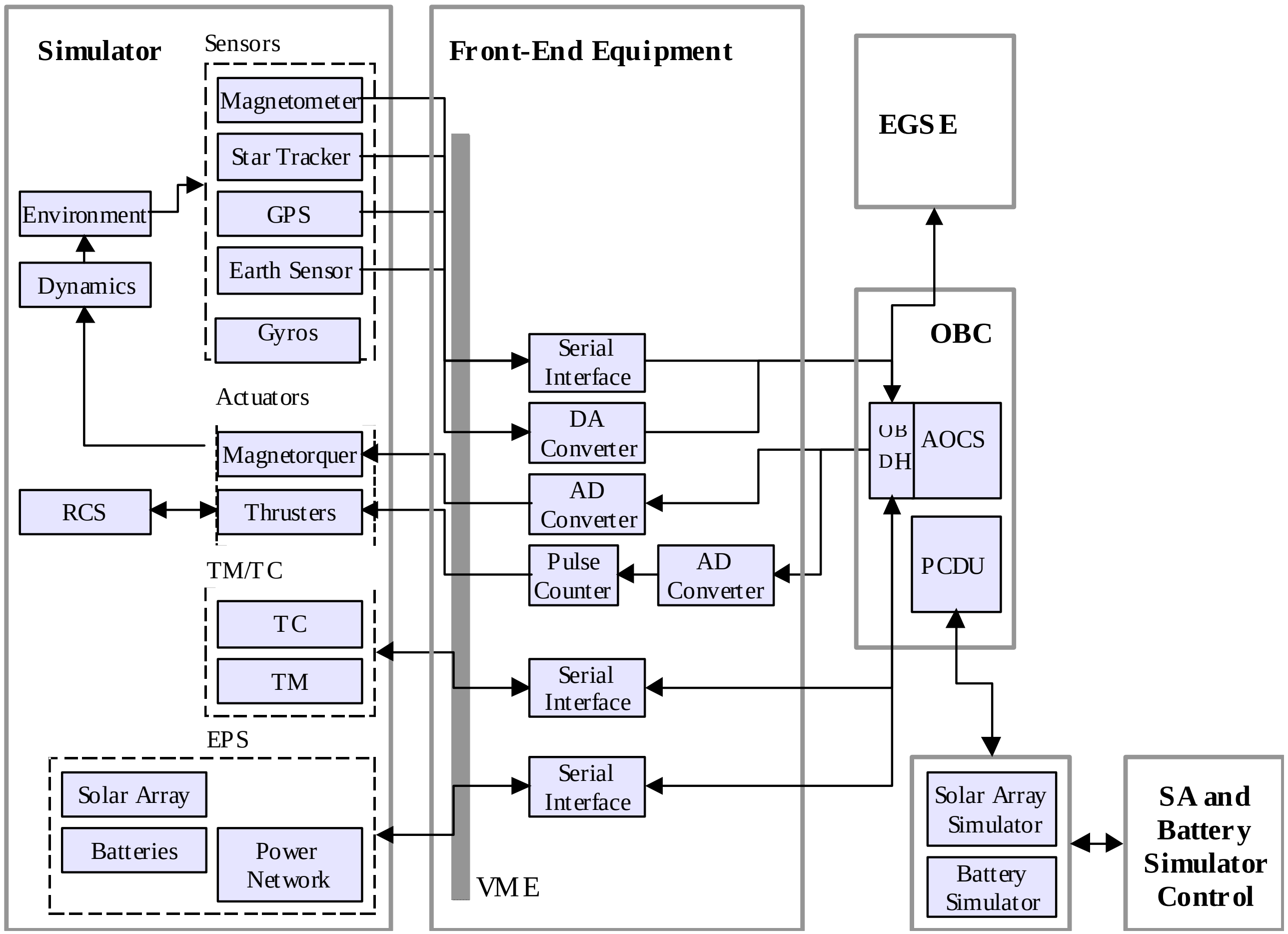
PTB concept focuses on AIV

- **Demonstrates concurrent Engineering during phase D activities**
- **Shows improved AIV process**
- **Replaces the Engineering Models (ETM and EQM) by simulation testbed**
- **Achieves harmonisation between AIV and Operations**

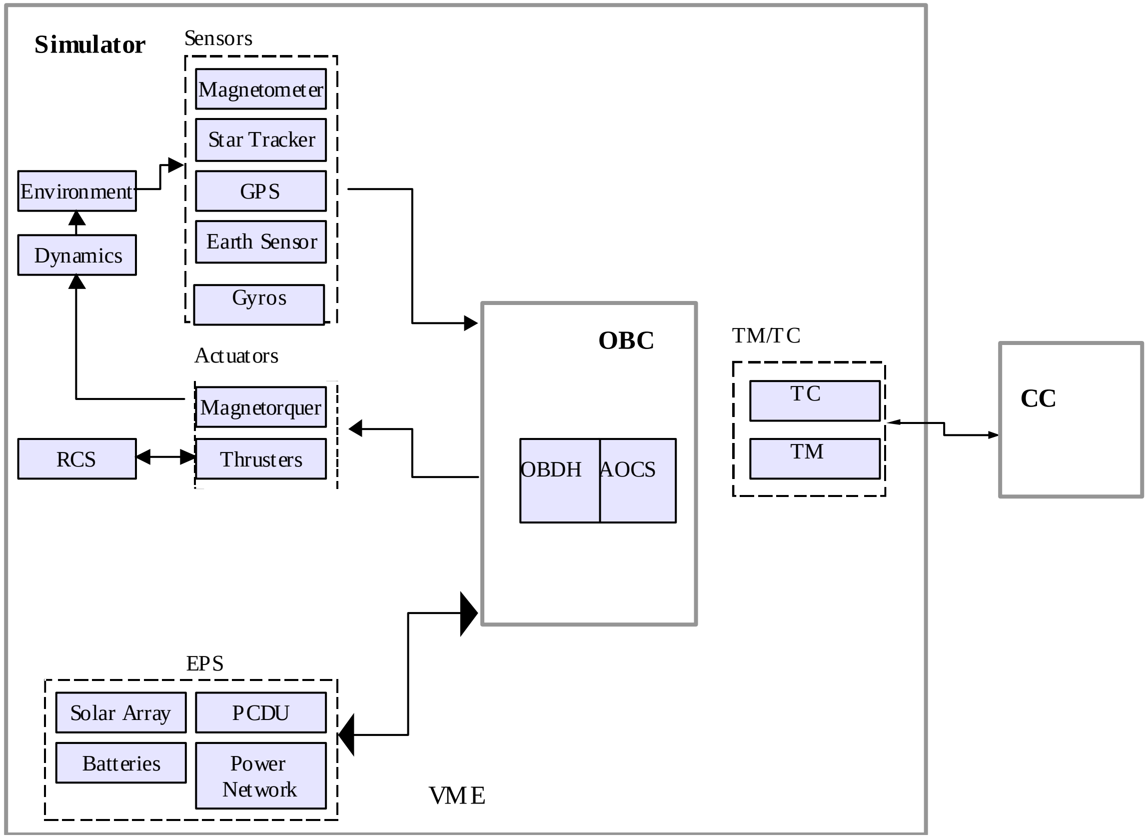
PTB Configuration with Flight Computer in the Loop



Engineering Model based on PTB



Operations Simulator based on PTB



Final Remarks

- **Improving the Process is a Multidisciplinary Task**
- **Demonstration of Added Value is Key for Adoption**
- **Pilot Projects**
- **Exchange with industry/projects**
- **Emphasis on Process rather than Tools**
- **Must be Well Supported by Standards**

Required Paradigms, Methods and Tools