# Using MBSE Methods to Design Generic System Platforms and Derivatives: A Methodology Applied to the Mobile Asteroid Surface Scout

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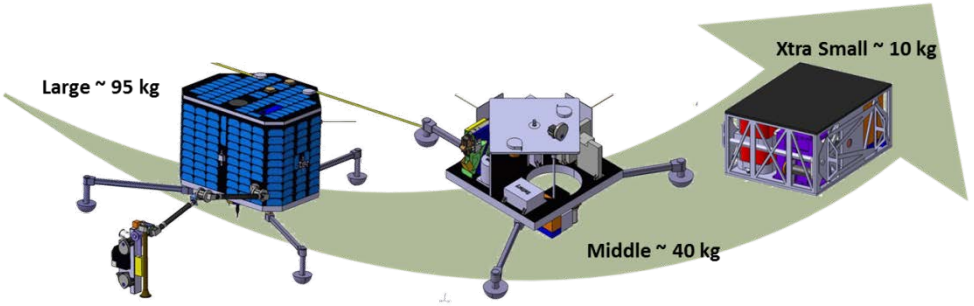
# Outlook

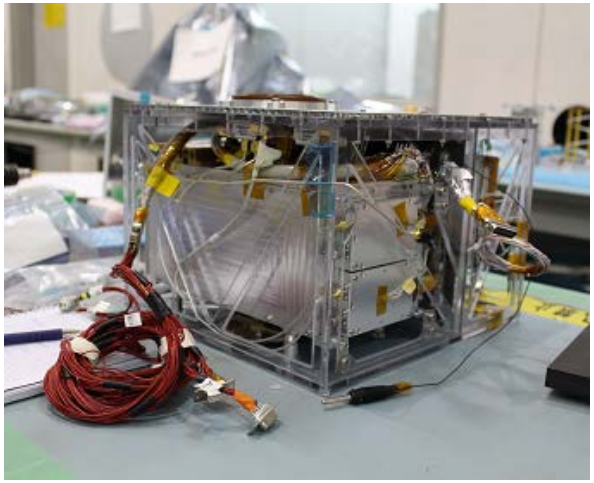
- **MASCOT**
  - The mission
  - The system
  - The model
- **MBSE**
  - Approach
  - Tools
- **Variants**
  - Market Analysis
  - Model implementation

# MASCOT: A short historical excurs

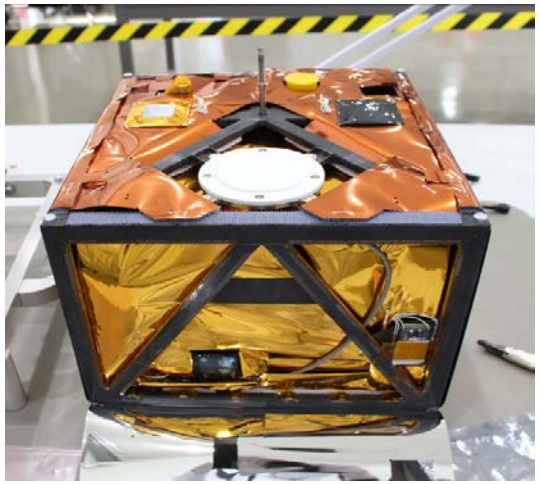
- ‘Marco Polo’: proposed **(2008)** near Earth asteroid sample return mission of ESA as follow up to Hayabusa; studied in the Cosmic Vision Framework
  - DLR Bremen proposed MASCOT (= “Marco Polo Surface Scout”)
- JAXA/ISAS: planning to launch ‘Hayabusa-2’ in 2014/15
- December 2008 – September 2009: feasibility study, with CNES, in context of Marco Polo and Hayabusa-2, with common requirements:
  - 3 iterations in DLR-CEF
- After Marco Polo failed Cosmic Vision Selection: focussing more than ever on Hayabusa opportunity
  - **MASCOT = “ Mobile Asteroid Surface Scout“**

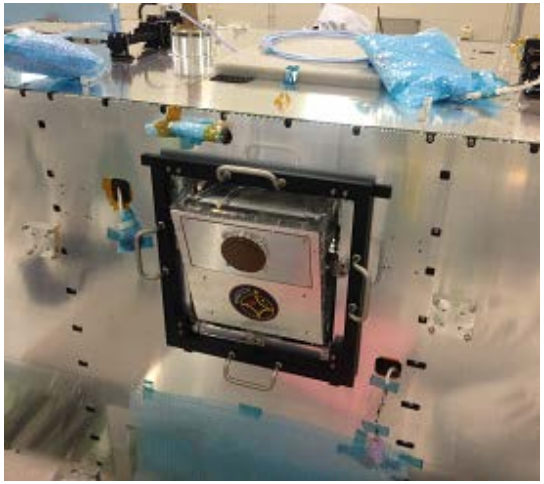



## HY-2 Subsystem Functional Test (FNC-D) [@ JAXA / ISAS]

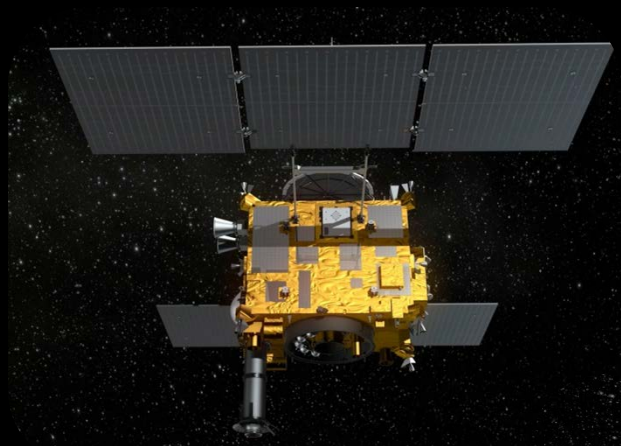




## HY-2 Integration [@ JAXA / ISAS]

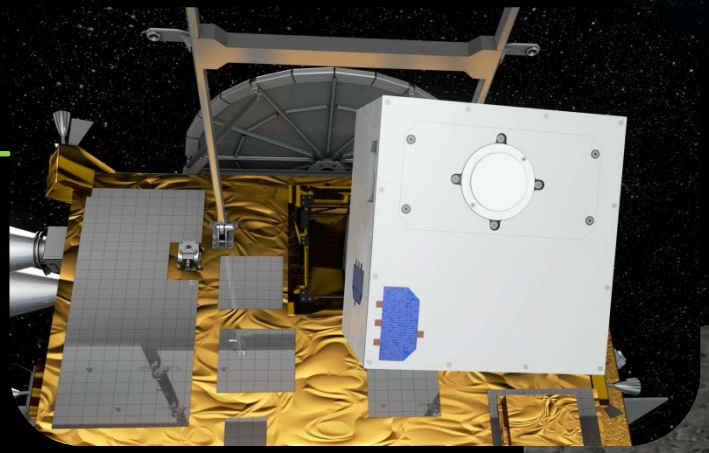




# The MASCOT mission



Transfer by Hayabusa-II spacecraft



Deployment at the asteroid

1999 JU3

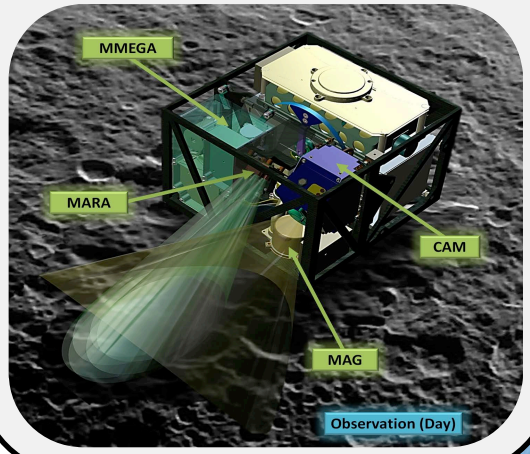
Landing, Hopping

- Surface lifetime > one Asteroid rotation
- 1-2 Landing sites

# MASCOT system

## Instruments

- 4 instruments with 3 kg mass in total
- Camera (CAM, DLR-PF), Infrared Spectrometer (MMEGA, ISAS), Radiometer (MARA, DLR-PF), Magnetometer (MAG, TU BS)

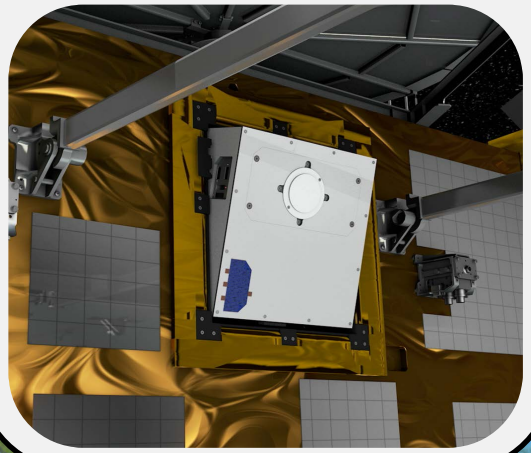



## System Features

- **Configuration/Structure**: highly integrated carbon-fibre composite structure
- **Power**: Primary battery; **Communication:** omnidirectional, redundant UHF link based on Minerva transceiver
- **OBC:** Warm redundant, autonomous on-surface operation
- **Mechanisms:** ”up-righting” & “hopping”
- **GNC (attitude):** proximity sensors (baseline: optical sensors + photocells)
- **Thermal:** ”semi-active”

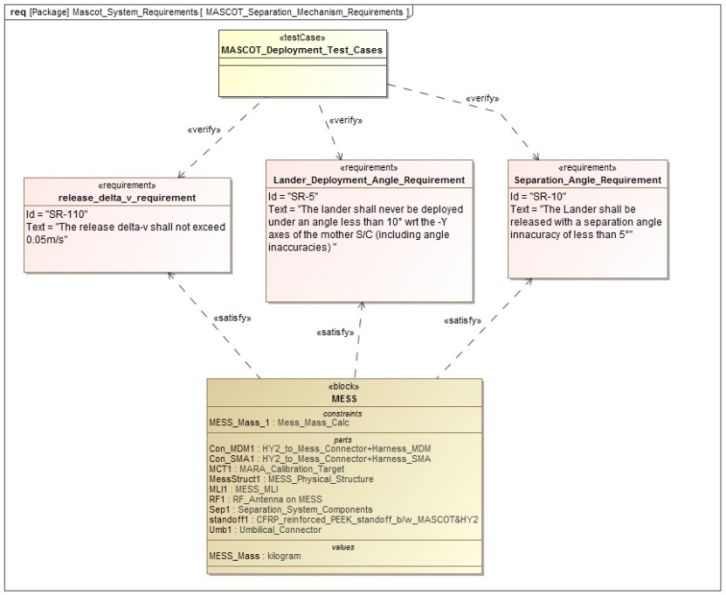
## Interfaces with the main-S/C

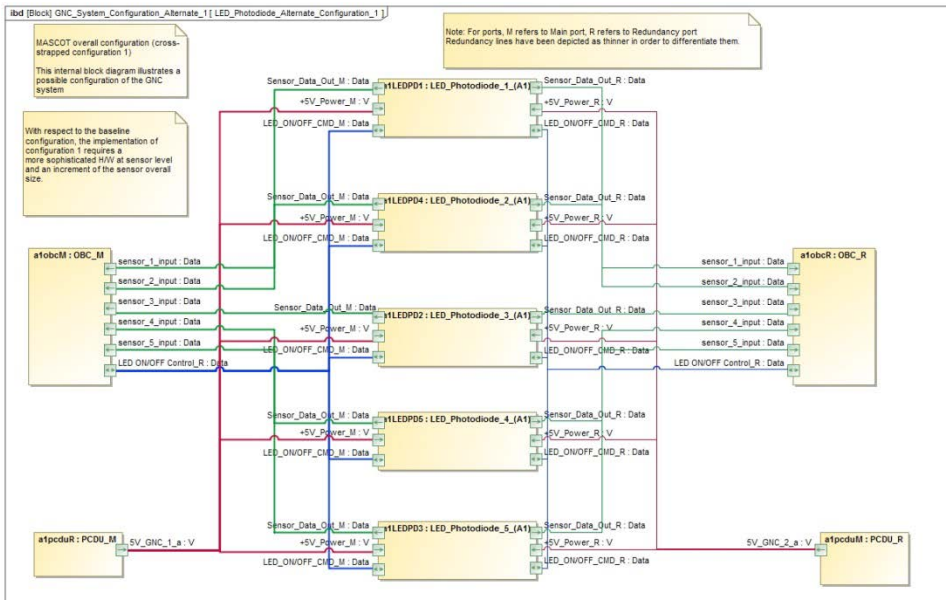
- RF Data Interface during cruise
- Thermal Control during Sleep Mode
- Redundant Power Supply
- Mechanical IF (MESS)
- Separation mechanism on MSC-side



# MBSE in the MASCOT project

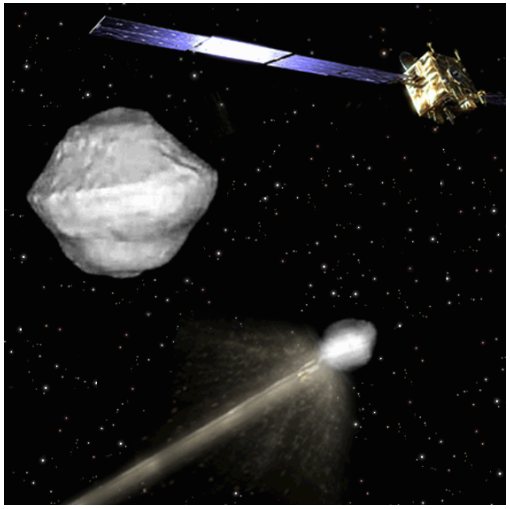
- Has started as a case (shadow) study investigating fragmented aspects of MBSE for a space mission project using MagicDraw + SysML



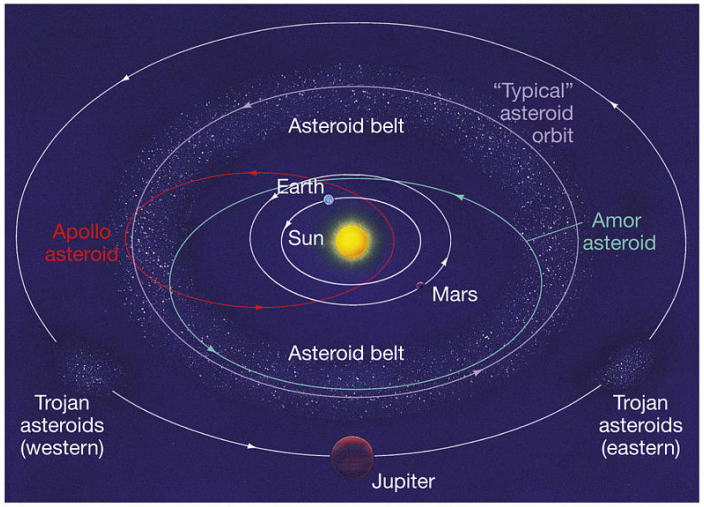




- Having put some effort and understanding into the built-up of a model, why not reuse it?

# What for?



Credit: ESA

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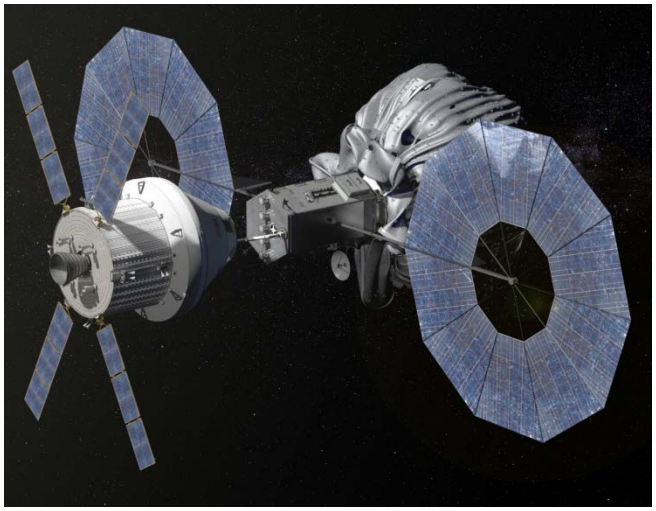
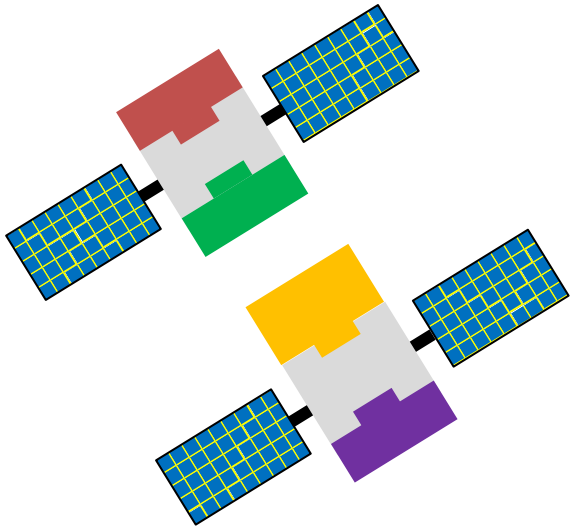


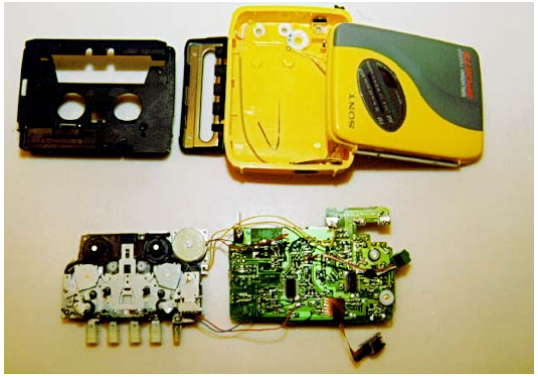
Credit: NASA

- A small versatile carry-on instrument package such as MASCOT can greatly enhance any kind of main missions scientific objectives
- The variations in possible future missions are large, thus requiring each time a modification of the existing MASCOT system → **MASCOT variants / a next generation MASCOT platform**
- If this variant design is managed systematically, much cheaper mission realization is possible, leading to affordable mission participation for a much wider range of users
  - Fast operational readiness
  - Decreased development risk by successful knowledge management and applying lessons learned

# The platform design aspect - Definitions

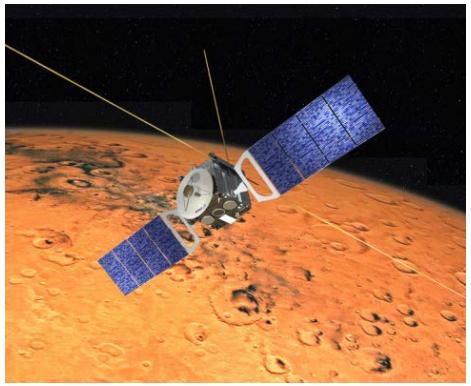
- A […] **platform** is a set of parts, subsystems, interfaces […] that are **shared** among **a set of products** and allow the development of derivative products with cost and time savings. (adopted from Meyer and Lehnerd (1997))
- Each different mission based on the platform = **variant**
- The set of all variants = **product family**



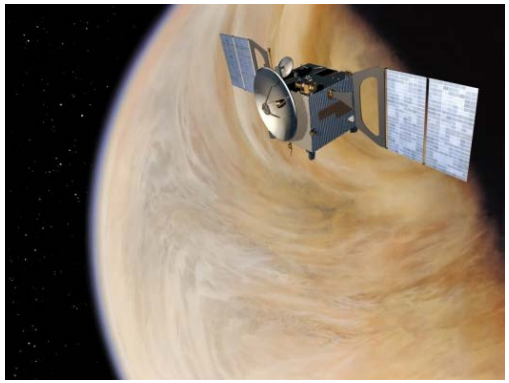


Sony Walkman


B&D Versapack®Toolkit



Mars Express, Credit: ESA



Venus Express, Credit: ESA

DLR

# Underlying objectives of this study

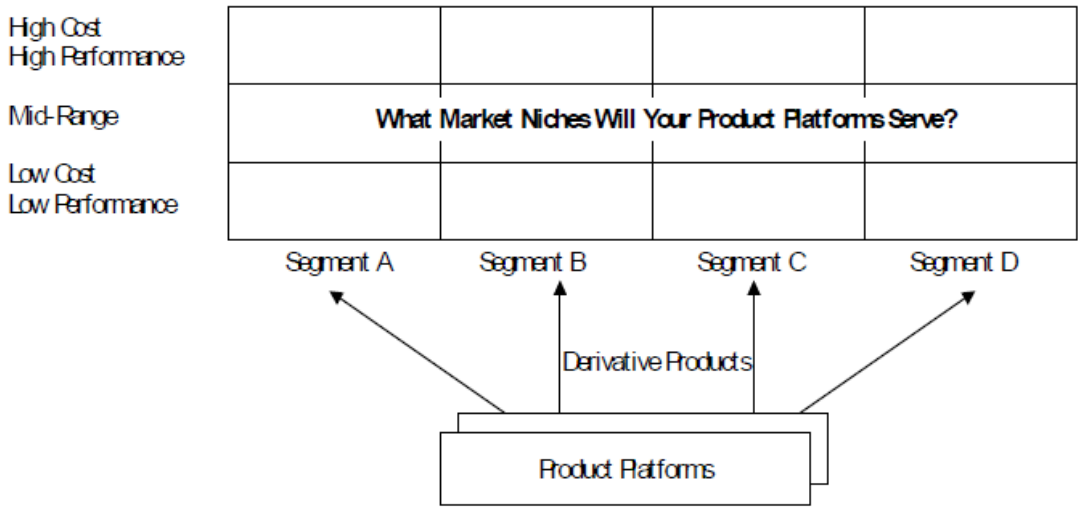
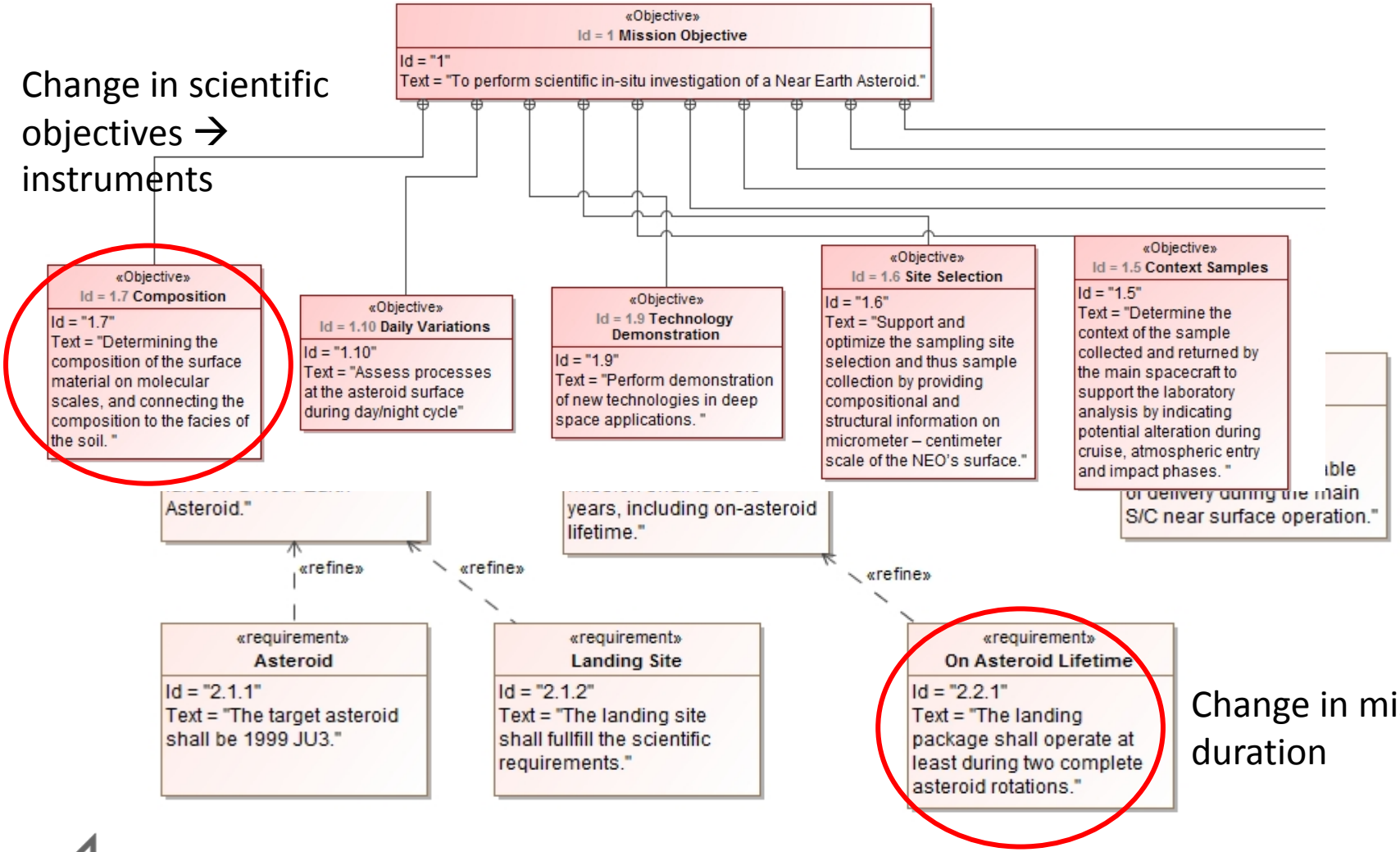



*Figure 5. Market segmentation grid (Meyer and Lehnerd, 1997a, p.54).*

- To investigate how far new methods can speed-up/simplify the design phase of MASCOT variants / a next generation MASCOT platform
- To investigate the application of product family and product platform methods to the range of MASCOT variants with the goal of optimizing/streamlining future developments

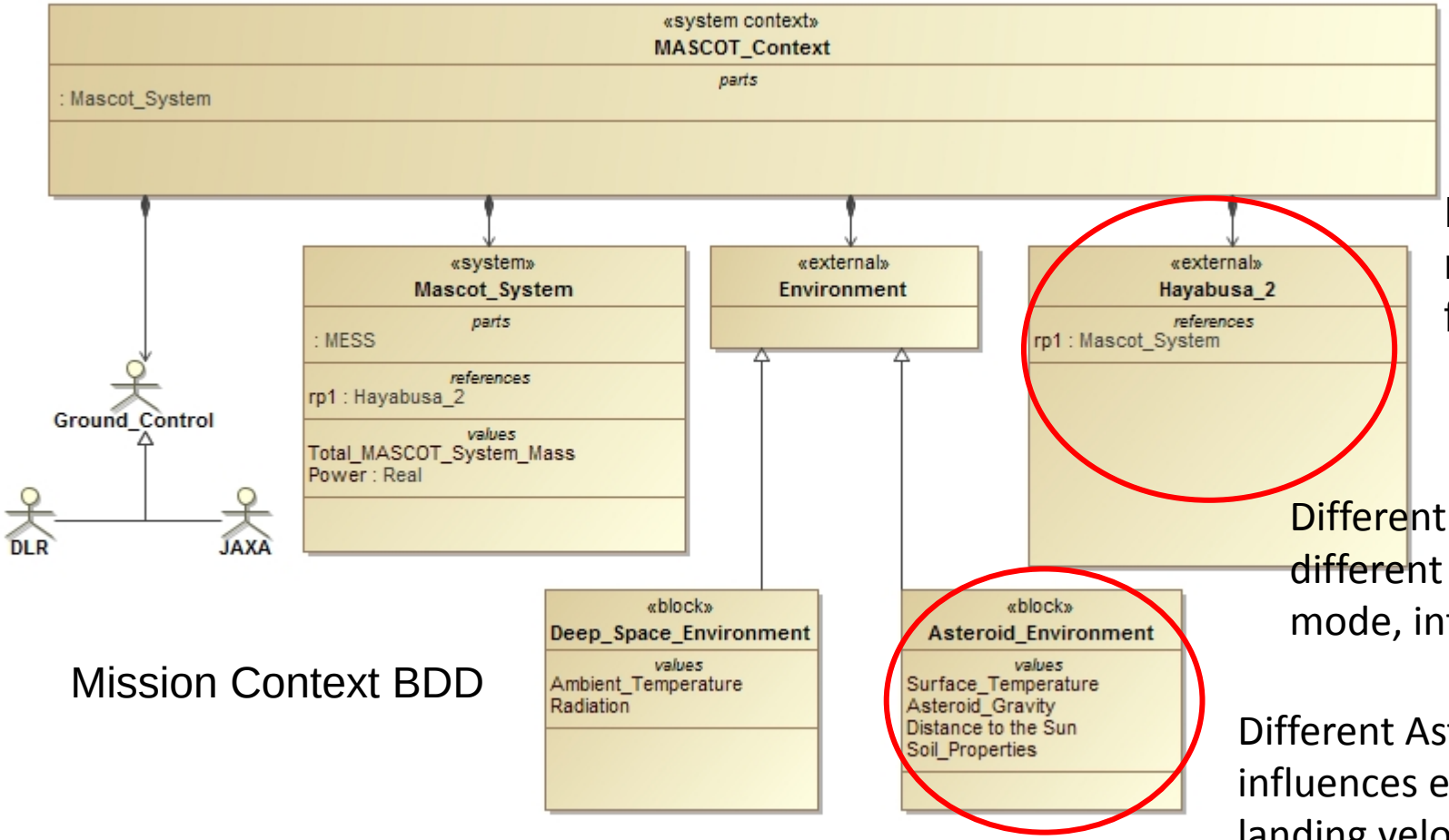
# MASCOT variations – market analysis

Change in scientific objectives → instruments




Change in mission duration

# MASCOT variations – market analysis




Mission Context BDD

From flyby; robotically from lander

Different carrier, different deployment mode, interfaces

Different Asteroid → influences e.g. landing velocity, thermal behaviour

Trojans, Earth and Mars Moon ←

# The approach: theoretical overview

**Step 1**

- create a MASCOT system model which includes
  - the interfaces view (to HY-II and to the instruments)
  - the environmental context of the mission

**Step 2**

- Generalize the model

**Step 3**

- Introduce the variation points as per market analysis
  - Change requirements, components, interface constraints

**Step 4**

- Analyze the influences of the variation points on the system

**Step 5**

- Derive common platform elements and system variants

# Discussion Points - I

- In theory: **SysML requirements are perfectly suited to visualize the impact of requirements on the architecture.**
- In practice: requirements (especially the breakdown) in MASCOT have not been analyzed and modeled properly for future reuse
  - → 1. the requirements model must thoroughly include how the requirement is satisfied by other model elements
  - → 2. the requirements analysis must be revisited, especially the breakdown
- (Changing) Interface requirements can be modelled better using constraints which make them satisfiable
- Can there be requirements variants? Or what happens when you change requirements?

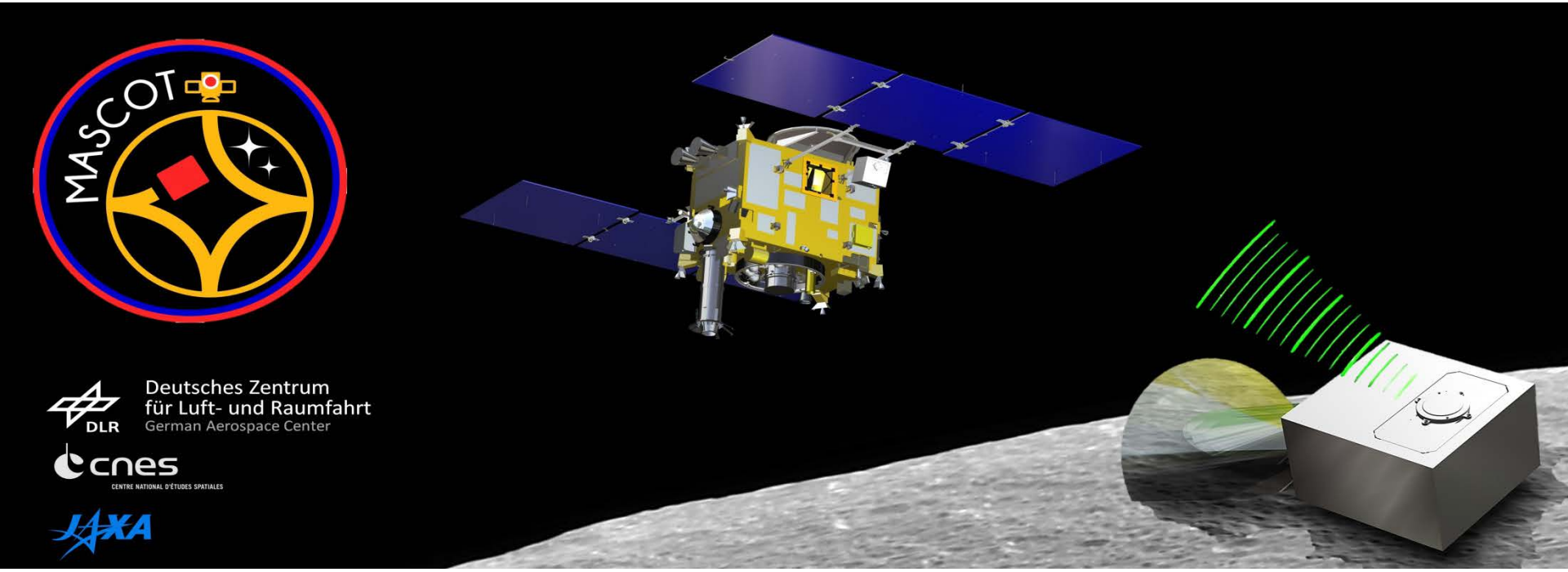
# Discussion Points - II

- Some aspects can be modeled using the SYSMOD or SE2 Variant modeling approach
  - Different context for different variants leads to the manual creation of different Product Trees → what is required to automatically derive the latter from the change in context?
- As far as can be seen from the current state of the art, an automatic change impact analysis is not implemented in any kind of tool
- The learning curve
  - Time it takes to create a coherent model, become familiar with the tools and language

# Conclusions and Outlook

- The current state of the model is more suited for documentation and communication (model level of detail/abstraction)
- Potential approaches / methods / tools have been identified in the MBSE environment to facilitate future MASCOT generations developments
- Open issues: (a lot)
  - Remodel requirements and constraints; Add change propagation analysis
  - Integrate existing and already generalized system level performance models from MATLAB into SysML-Model
  - Integrate product  platform design methods
  - …

**Looking at upcoming missions and high demand of MASCOT-variations we will have a lot of reasons to solve these issues**




# Thank you

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