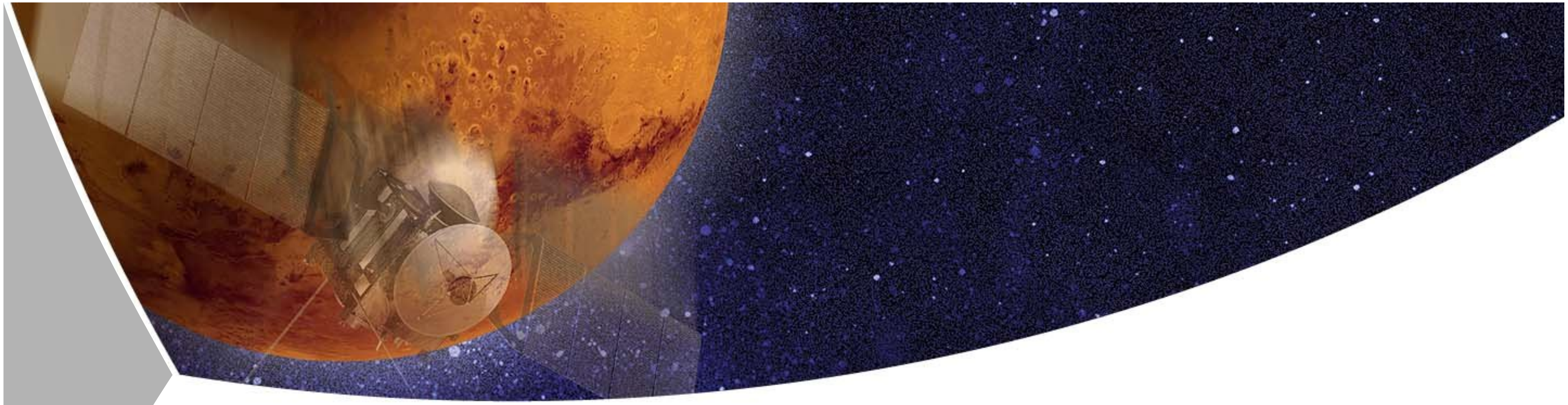


Baseline Design of a Mobile Asteroid Surface Scout (MASCOT) for the Hayabusa-2 mission

IPPW-7, 2010, Barcelona, Spain

C. Lange, J. Biele, J. Block, A. Braukhane, C. Dietze, M. Drobzyck, F. Herrmann, T.-M. Ho, M. Lange, O. Kroemer, M. Schlotterer, T. Sproewitz, S. Ulamec, B. Vogel, S. Wagenbach, L. Witte (DLR), J. Bellerose, T. Okada, H. Yano (JAXA/JSPEC), J.-P. Bibring (IAS), P. Bousquet (CNES), R. Nadalini (AST)

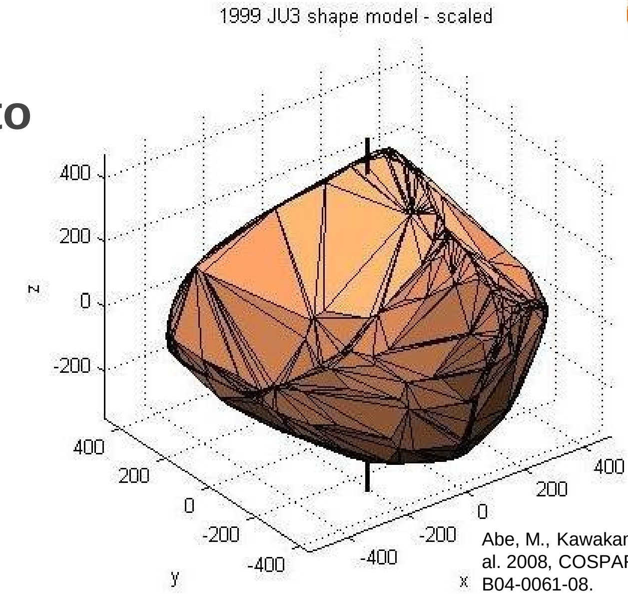
DLR Deutsches Zentrum für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

What is MASCOT?

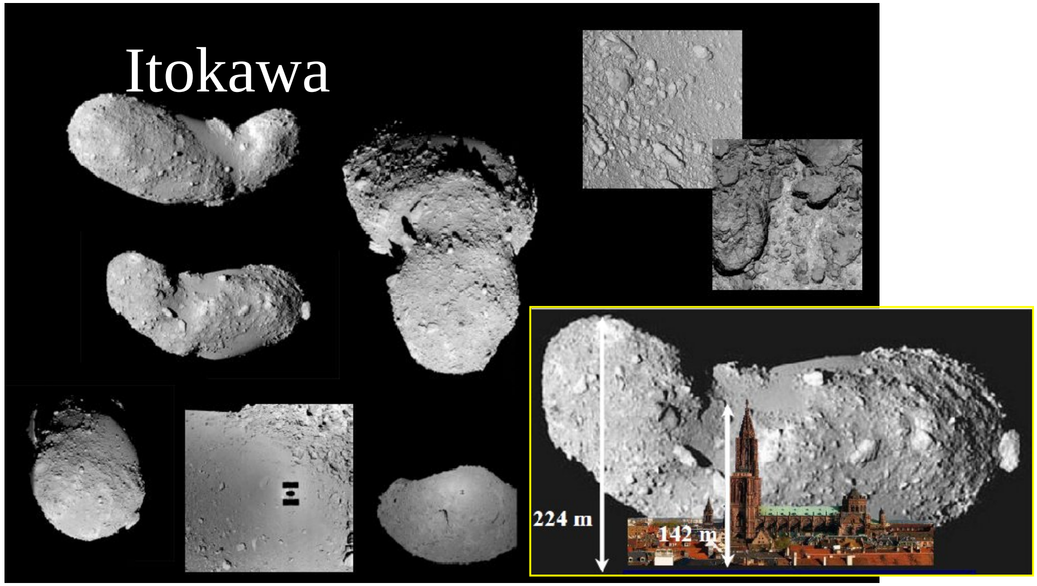
- Originally proposed as "**Marco Polo Surface scout**"
- 'Marco Polo': proposed near Earth asteroid sample return mission of ESA as follow up to Hayabusa; studied in the Cosmic Vision Framework
- Marco Polo mission proposal identified interest in a dedicated lander for in-situ science → DLR Bremen proposed **MASCOT as a dedicated lander** → selected for study
- JAXA/ISAS: planning to launch 'Hayabusa-2' in 2014/15
- After Marco Polo failed Cosmic Vision Selection: focussing more than ever on Hayabusa opportunity
  - **MASCOT = " Mobile Asteroid Surface Scout"**

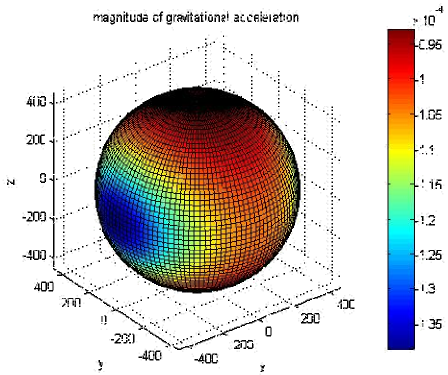
Target Body of Hayabusa-2: 1999JU3

- 1999 JU3 as C-type asteroid is likely to be a rubble-pile
- size of 1999 JU3 comparable to ITOKAWA



Abe, M., Kawakami, K., Hasegawa, S. et al. 2008, COSPAR Scientific Assembly, B04-0061-08.
Kawakami, K. 2009, Master's thesis, University of Tokyo





Taxonomic Type	Estimated Diameter	Rotation Period
Cg	0.9 - 0.98 km	0.3178 d / 7.6272 h

MASCOT Science Objectives

Mothership:

GLOBAL study of the target body

Link to telescopic data

Sampling site selection

MASCOT lander:

LOCAL study of the target body

Cross-scale link between mother-S/C data and sample analyses

Sampling site investigation in-situ

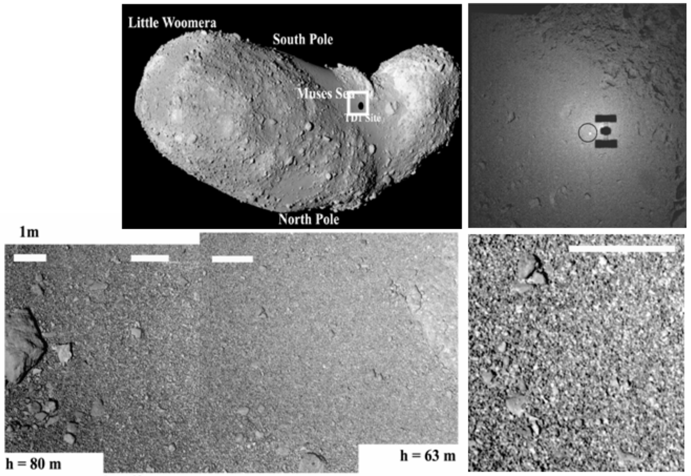
Direct exploration of sub-surface information

Returned samples:

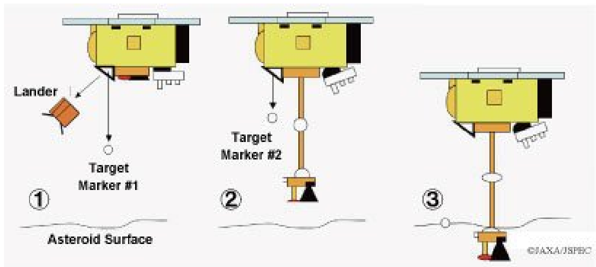
MICROSCOPIC study of the target body

Link to meteorite/cosmic dust collection data

Can use the most updated analytical facilities at return



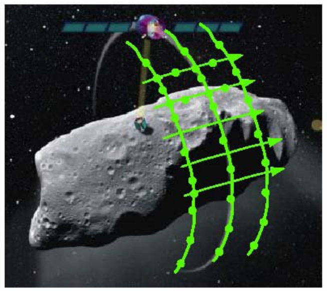
[Yano H. et al., 2006. Science 312, 1350]



http://b612.jspec.jaxa.jp/mission/e/marco_spacecraft_e.html

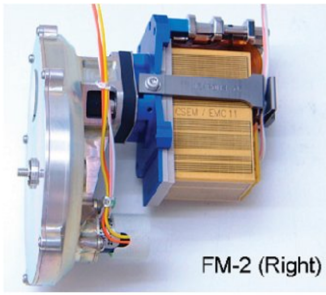
Potential Payload

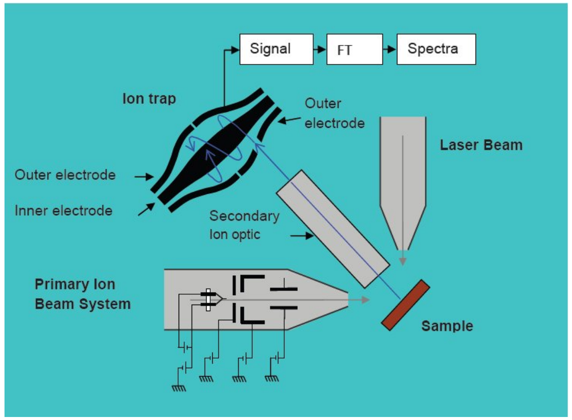
- **Model Payload selected according to the compliance with the science requirements**
  - ILMA (Ion Trap Mass Spectrometer) or XRD/XRF or Bi-static radar of 2 kg
  - VIS and Infrared Microscope of 0.7 kg
  - Wide Angle Camera of 0.3 kg
- **Ideal P/L combination is to be defined**
- **P/L selection is scheduled for start in late 2010**



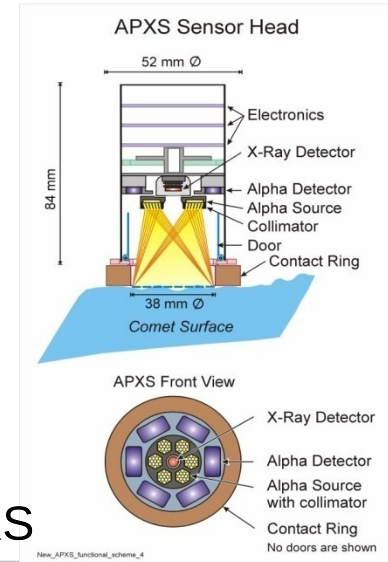
New Consert

Camera





ILMA



APXS

Concept Selection for Suggested Landing Package

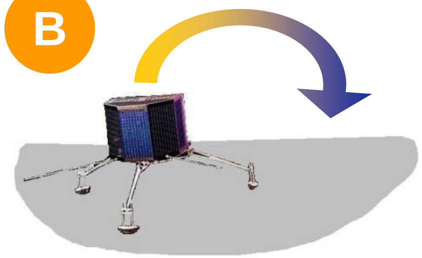
MASCOT

Lander Type

- **Soft Lander**
  - Target Sites
    - **single**: Attitude / Landing Stability controlled device
    - **multiple**: Attitude / Stability controlled device plus mobility
- **(Semi-)Hard Lander**
  - Target Sites
    - **single**: Penetrator or Impactor
    - **multiple**: Frog-type landing device

A

B



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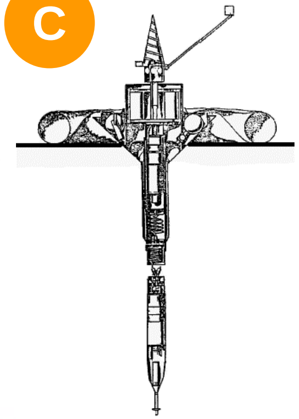
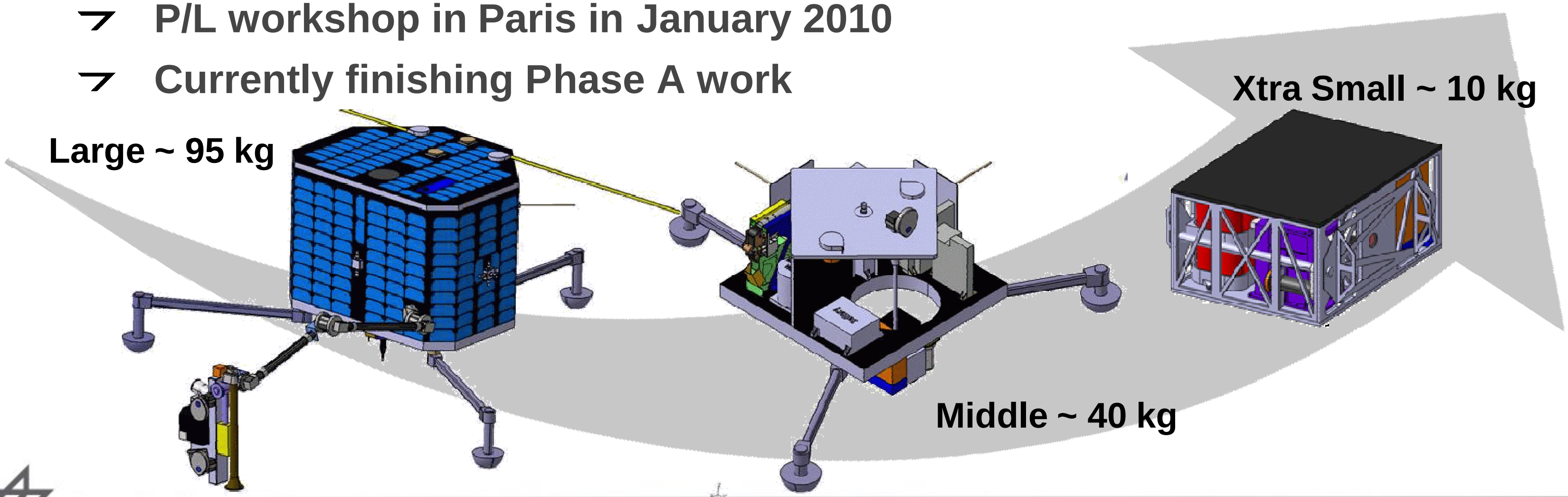


D

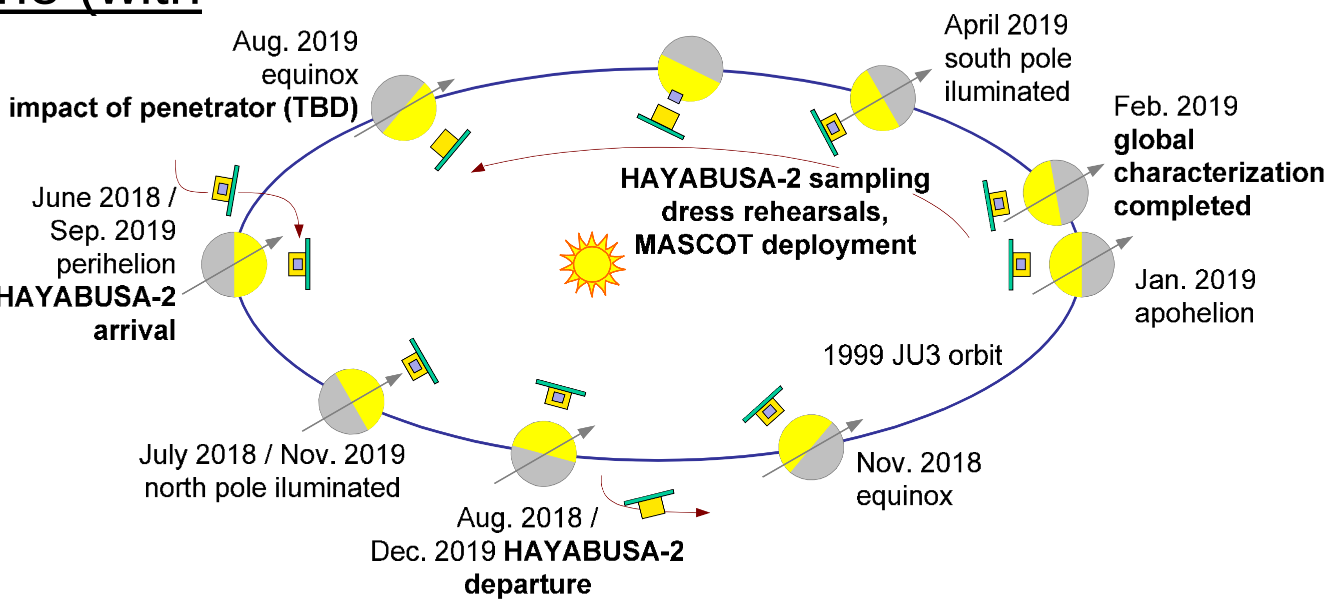
MASCOT Study flow / History

- **December 2008 – September 2009: feasibility study, with CNES, in context of Marco Polo and Hayabusa-2, with common requirements:**
  - 3 iterations of different mass and P/L
- **Settled on 10 kg lander package having 3 kg of P/L**
- **Started detailed definition of concept XS:**
  - Close exchange with JAXA/JSPEC
  - 2 CEF sessions (March & July 2009) for baseline-design
  - January 2010: CEF session for design consolidation
- **P/L workshop in Paris in January 2010**
- **Currently finishing Phase A work**



Mission Requirements and Constraints (1)

Mission Timeline (with 2014 Launch)



Constraints and Interfaces to the main-S/C

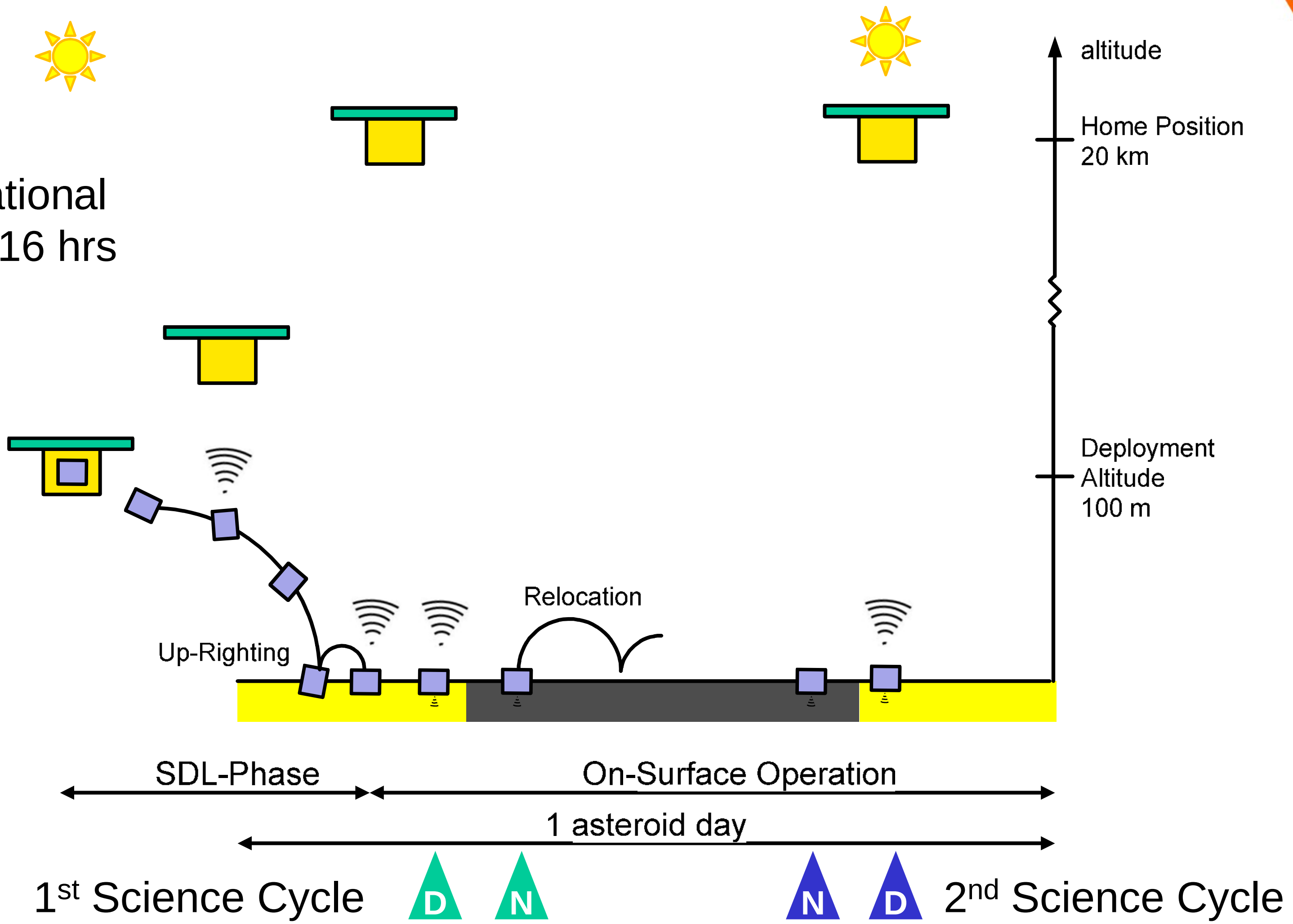
Mass restriction of 10 kg (including all IF)

Envelope of 0.3 x 0.3 x 0.2 m

Stowage on +Y-Panel

Mission Operation Timeline

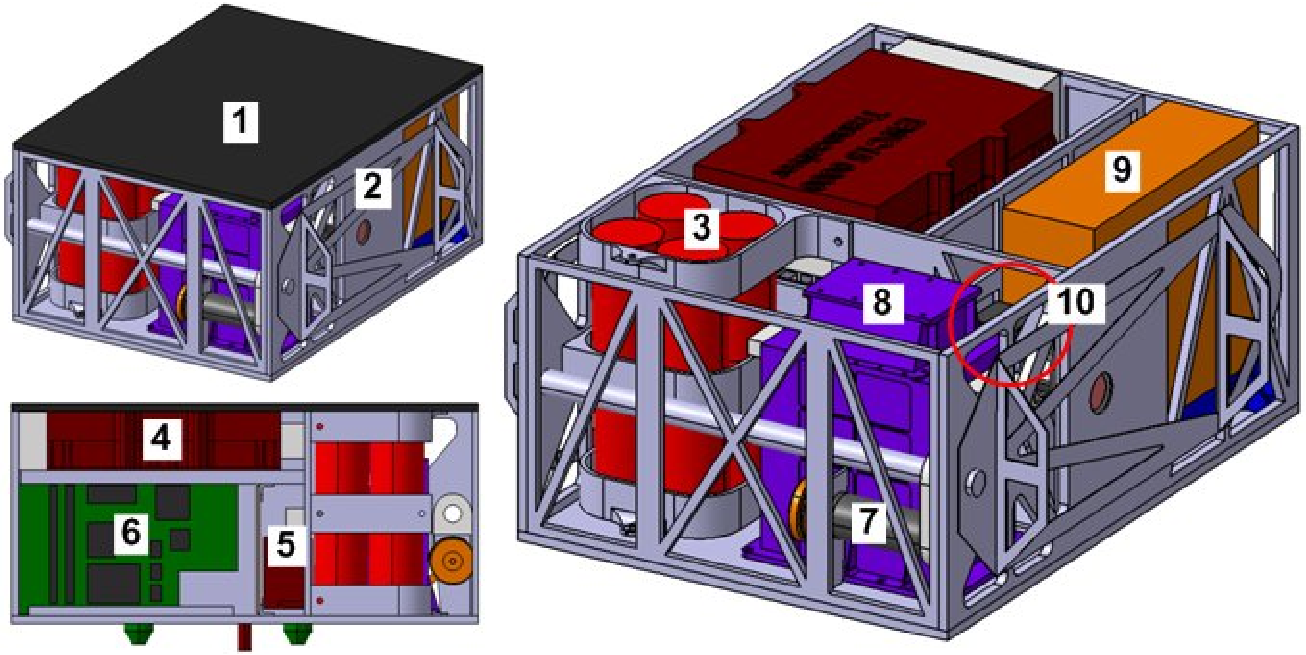
total operational lifetime of 16 hrs



MASCOT Concept Baseline Design

- **Mission: Launch 2014/15; Deployment November 2018, release alt. 100m**
- **Mission duration: 16 hrs of on-asteroid operation**
- **Model Payload: 3 instruments with 3 kg total mass including margins**
- **Configuration: Prismatic body with fixed instrument accommodation**
- **Structure: no boxes, but integrated structure (including common electronics accommodation)**
- **Subsystems: highly integrated approach for all subsystems, passive and low risk system, communication using synergies with the mother-spacecraft**
- **Main Functions:**
  - On-Surface up-righting and mobility
  - Mainly Autonomous operation without ground interference
- **Redundancy concept: consider redundancy for onboard computer**

Design Baseline - Structure



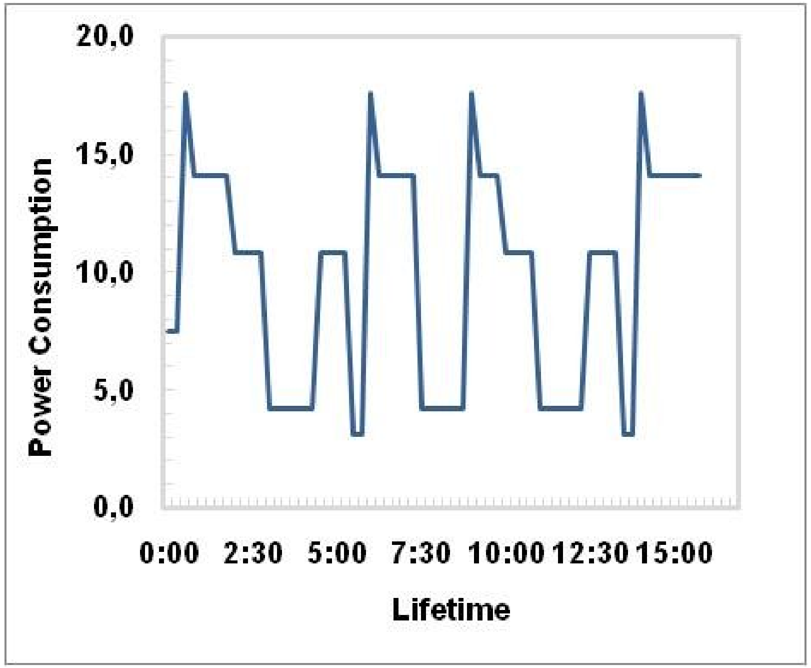
(1) sandwich top plate
(2) main Al structure
(3) battery pack
(4) transceiver unit
(5) Rx-filter
(6) common E-box
(7) motor and gear
(8) Instrument 1
(9) Instrument 2
(10) Camera

- **Highly bending stiff and load bearing base plate with mounted P/L**

  → Critical load area in base plate center
- **Material: aluminium implicated by the science objectives / asteroid type**

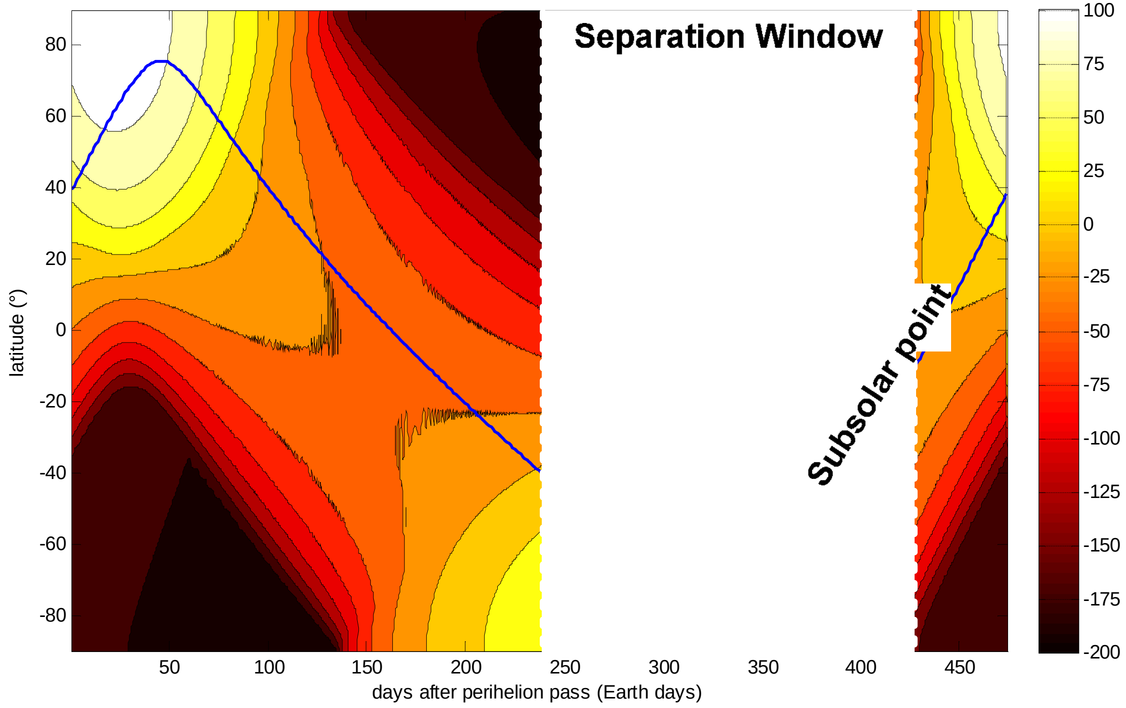
Design Baseline - Power

- **Powered by carrier during cruise**
- **For on-surface operation:**
  - Primary battery only
  - 160 Wh for 16 hrs of operation
  - Power consumption profile →



- **SAFT LSH-20 (Li-thionyl-cloride) with total S/S mass of 0.8 kg**
- **2p3s or 3p2s → Bus voltage 6 or 9 V approx.**
- **Degradation of 3% per year considered (pessimistic)**

Design Baseline - Thermal



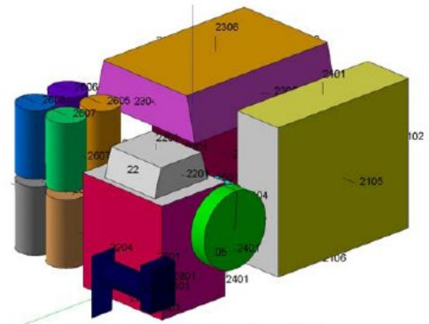
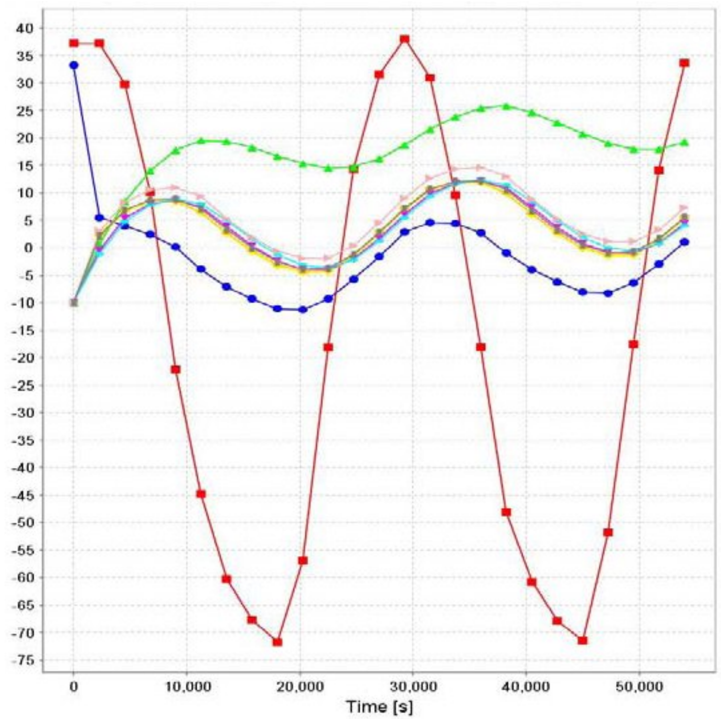


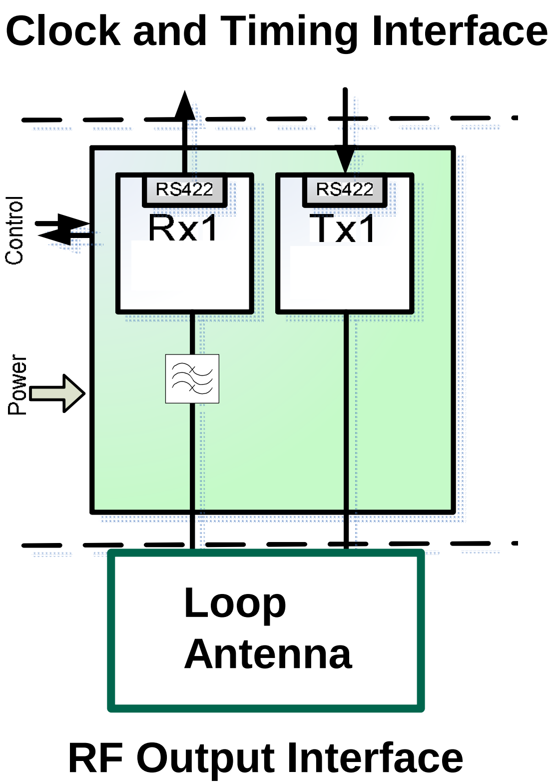
Figure 13: Payload modeling



- Thermal design basically passive: painting and coatings, spacers and feet-mounted housings for instruments for decoupling of equipment from the bottom shell; Multi-Layer Insulation (MLI) is used
- Active part: heating unit before wake-up

Design Baseline - Communication

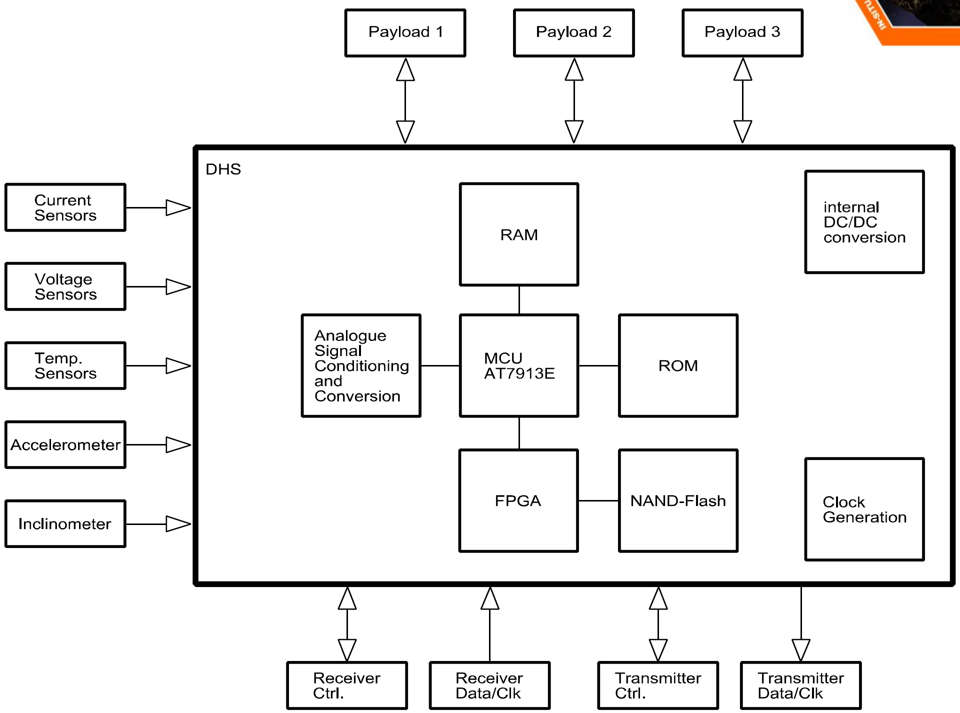
- <u>Requirements:</u>
- Communication is required during SDL-phase and on the surface and relayed through the main S/C
- Commandability shall be possible, but is only foreseen in hazardous cases; handshaking for signal validation and access knowledge will be used
- Omnidirectional communication



- <u>Current baseline:</u>
- UHF with 32 kbps for 0.7 Gbit total science data volume
- Configuration: 1 transmitter and 1 receiver on the main-S/C and the lander; no redundancy foreseen otherwise
- Full-duplex communications
- Loop antenna
- A local protocol will be used that still has to be defined

Design Baseline - Onboard Computing

- <u>Main tasks of OBC:</u>
- gathering, storing, and processing housekeeping data from the lander's equipments
- providing data processing and data storing capabilities for the scientific instruments (including commanding, if required) → onboard mass memory designed to store all acquired data
- monitoring of the health of the spacecraft
- autonomous control of the lander



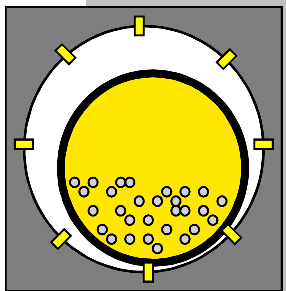
- <u>Baseline-Design:</u>
- Atmel AT7913E SpaceWire
- fault tolerant LEON2 processor with a floating point unit, RS422 and SpaceWire interfaces

Design Baseline – Attitude Determination and Mobility

Attitude

Detect landing shock and final rest position

Determine the position on the surface wrt. to distance, angle to the surface and orientation

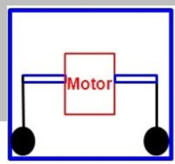


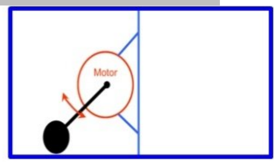
Mobility / Relocation

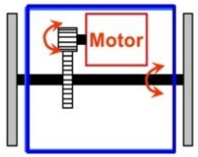
Correct the position or orientation (if necessary)

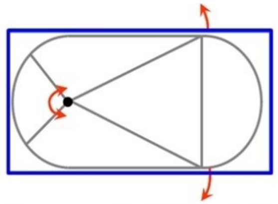
Change location after one complete measurement cycle

Perform support measurements (e.g. measurement of attitude rates)



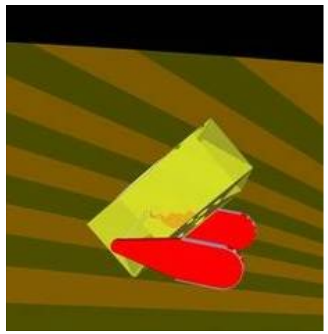






Opportunity Science

Measure the magnitude of the bouncing shock (depends on surface properties)

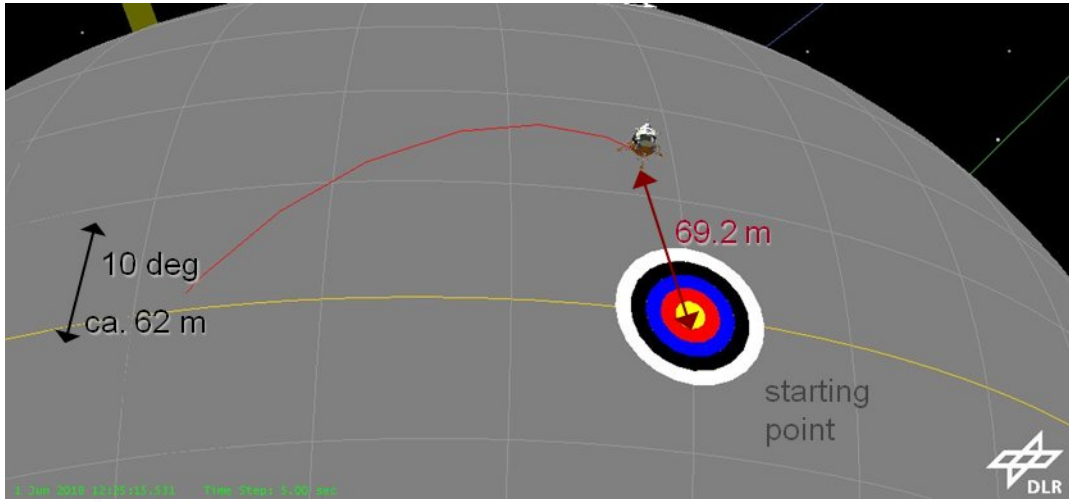


MASCOT design – Post Landing Mobility Analysis

alpha 60 deg, jumping in direction of (nearest) pole
-> best case

starting point		distance *	max. altitude	duration
equator (latitude 0 deg)	longitude 0 deg, r = 460 m	69.2 m	31.6 m	1515 s (25 min)
	longitude 90 deg, r = 390 m	45.4 m	20.8 m	974 s (16 min)
latitude 45 deg	longitude 0 deg, r = 423 m	53.2 m	29.4 m	1284 s (21 min)
	longitude 90 deg, r = 373 m	37.8 m	19.8 m	881 s (15 min)

* linear distance, not real ellipsoidal segment



- note: hopping along equator with 60 deg or 120 deg against surface results in similar distances

snapshot from STK scenario: MASCOT landed after hopping
latitude = longitude = 0 deg
angle = 60 deg in direction of pole, delta-v = 10 cm/s

Mass Budget

- Mass budget includes all S/S and interfaces to the mother S/C
- Still significant amount of margin included, unable to reduce prior to P/L selection

	Dry Mass [kg]	**Eff. Margin %**	**Wet Mass [kg]**
Structure	2.90	0.0	2.90
Thermal Control	0.41	15.4	0.47
Mechanisms	0.48	17.8	0.57
Communications	0.36	10.0	0.40
DHS	0.40	20.0	0.48
Power	1.00	12.0	1.12
Harness	0.30	20.0	0.36
Payload	3.00	0.0	3.00
Attitude Determination	0.20	20.0	0.24
Landed Mass	9.1		9.5
Interface Parts	1.5	13.0	1.7
Subtotal			11.3
Total incl. 20% System Margin			**13.5**

Summary / Outlook

- **Technology:**
  - A 10 kg landing package with 3 kg of payload has been demonstrated as being not out of this world due to the fact that main S/C provides most of the maneuvering and control for landing sequence
  - Phase B study work including breadboarding will start for high risk subsystems to mitigate risk (using FE2E-Simulator and HiL/SiL)
  - Early start in testing and qualification for COTS parts
- **Politics:**
  - Systems Lead is at DLR Bremen Institute of Space Systems with close collaboration with other DLR Institutes (Robotics, MUSC) and CNES
  - Close technical and scientific exchange between JAXA and study team

Thank you!


MASCOT
LANDER STUDY
MOBILE ASTEROID
SURFACE SCOUT
IN-SITU SCIENCE