Past and present missions:
Mobile Asteroid Surface Scout (MASCOT)

Jens Biele

DLR

Who am I?

- After some fun with chemistry (<18), became clear to study physics
- (Experimental) physics 1985-93 Univ. K-Town/Germany, Imperial College/London, Diploma (~masters), laser spectroscopy&molecular physics. Some hesitation what to do next..
- PhD 1995-98 at AWI institute, Potsdam/Berlin (polar atmospheric research in the Arctic, LIDAR, expeditions and all)
- Some hesitation what to do next..
- Moved to Cologne. Found job at DLR by chance: payload manager for Rosetta/Philae, liked it, stayed on, moved to other projects like MASCOT..
- Broad range of interests and, luckily, quite some freedom to pursue scientific interests even if not immediately necessary for project task at hand

- Explorations and science mission specialist for the business development group of the DLR-RB institute.
- Key experience and focus: testing and operations of science instruments in space, Solar system exploration in general, geophysics (atmosphere, solar system ices), thermodynamics, systems and subsystems fors mall spacecraft and surface science packages.
- Thesis supervisor for several master and diploma theses at DLR
- Occasional lectures at the University of Cologne, Department of Geophysics (Celestial mechanics and Coordinate Systems; Geodynamics/Rotation of the Earth)

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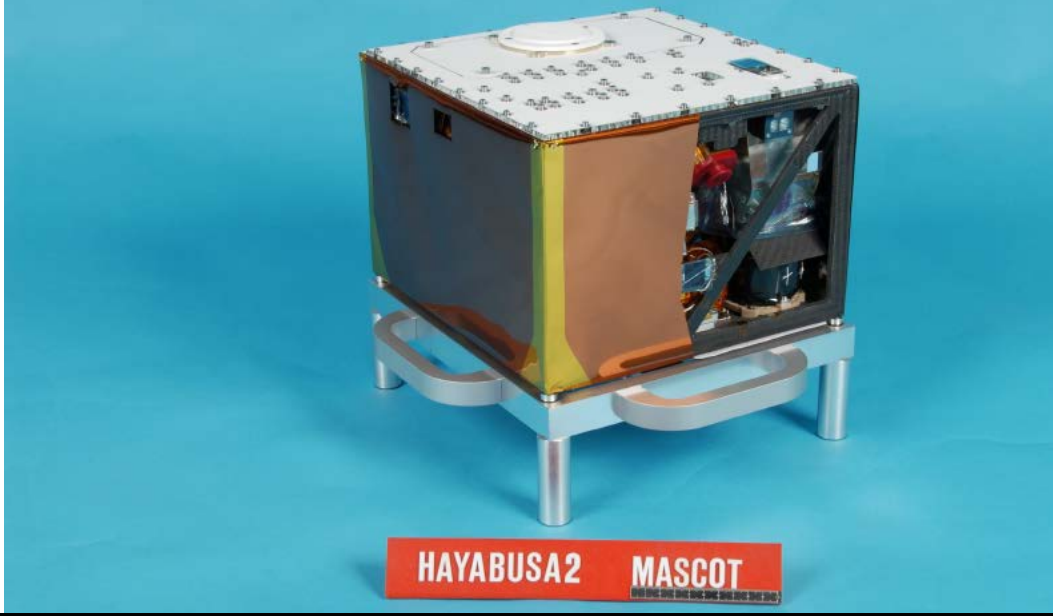
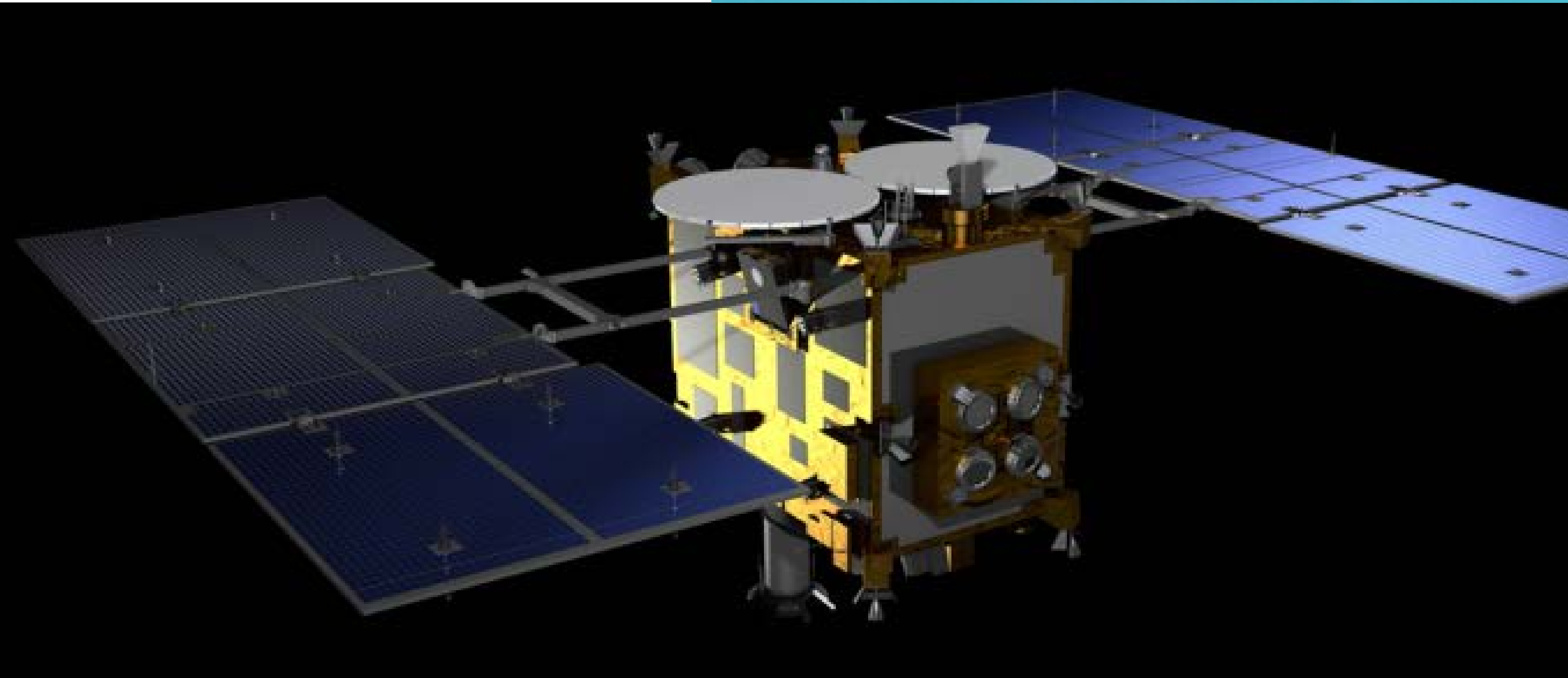
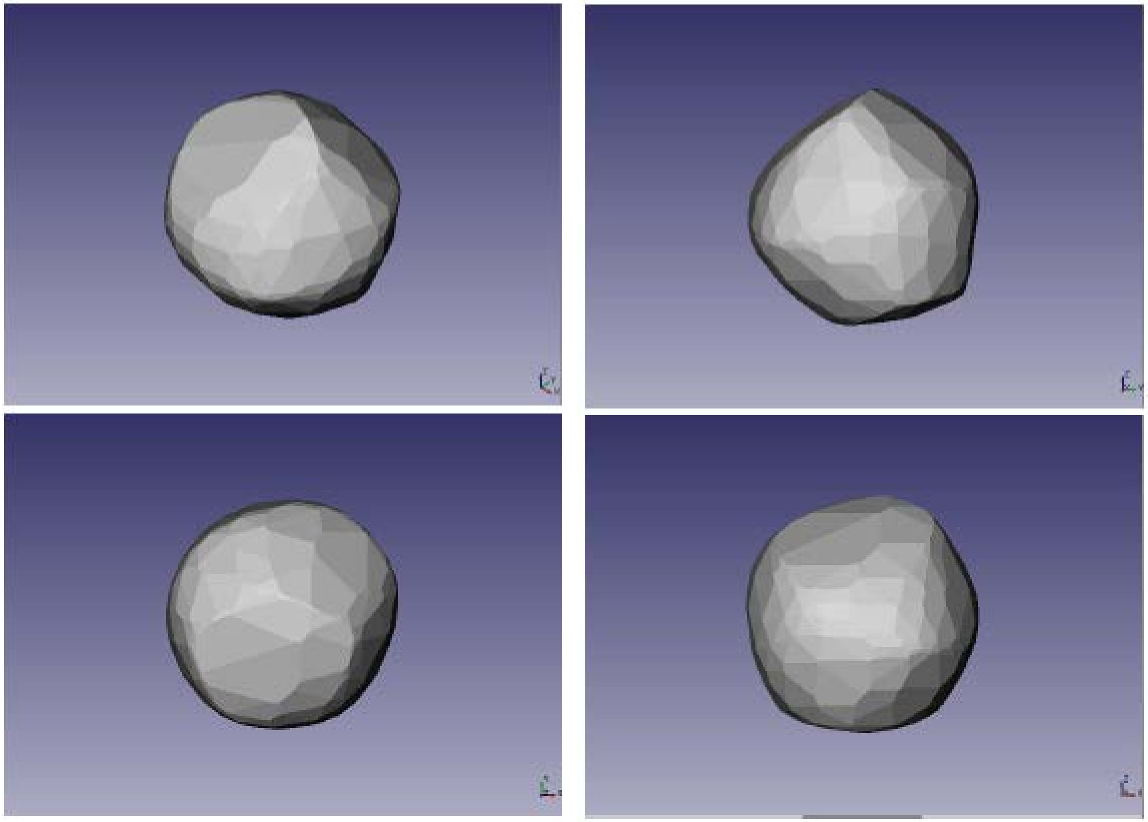
MASCOT

= Mobile Asteroid Surface Scout with a suite of 4 scientific instruments onboard Hayabusa2





Target Object: NEA Ruygu/1999JU3 (C-Typ)



JAXA Design Reference

Parameters	
Mean volume-equivalent diameter (km)	0.87±0.03
Bulk density (kg/m^3)	1300
Spin period (hrs)	7.63±0.01
Spin axis (J2000), positive pole	λ_ecl = 73.1° β_ecl=-62.3° retrograde rotation Obliquity=151.6°
V_{esc} (m/s)	0.37±0.03
Thermal inertia (global average) (Jm^{-2} s$^{-0.5}$ K^{-1})	Notional: 400
Emissivity	0.9 (assumed)
g (m/s^2)	1.5×10^{-4}
Surface fraction covered with craters	0.4 – 0.9

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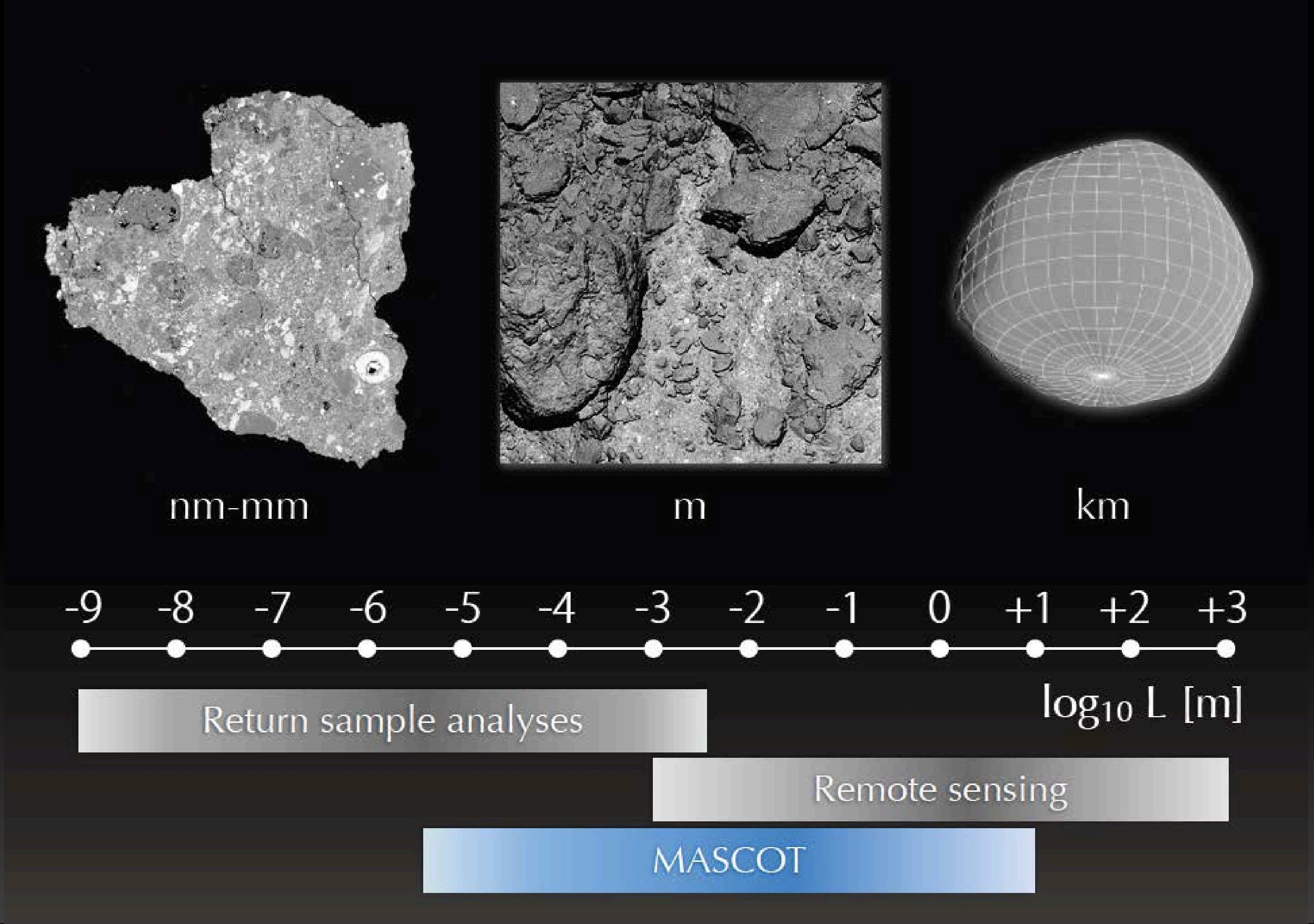
MASCOT will serve as ground truth tie point between sample science (10^{-3}-10^{-6}m) & remote sensing sciences (10^{3} – 10^{-3}m)



The MASCOT Concept, Requirements and Technical Realization

Top Level Requirements:

- The maximum mass is 11 kg
- The maximum volume is 0.3 x 0.3 x 0.2m³
- Separation & descent during a sampling dress rehearsal
- Operation during two asteroid rotations
- Autonomous operations on asteroid surface
- Self right and relocation ability via mobility

… that have implication on the system design & development

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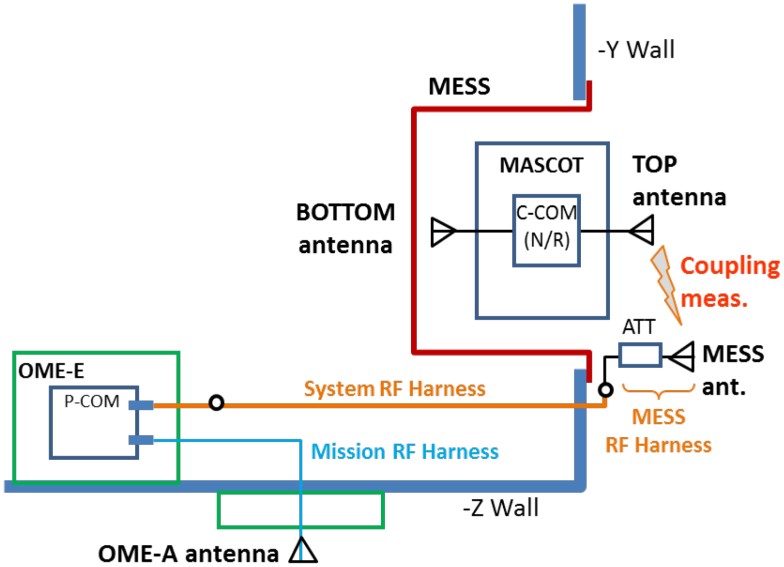
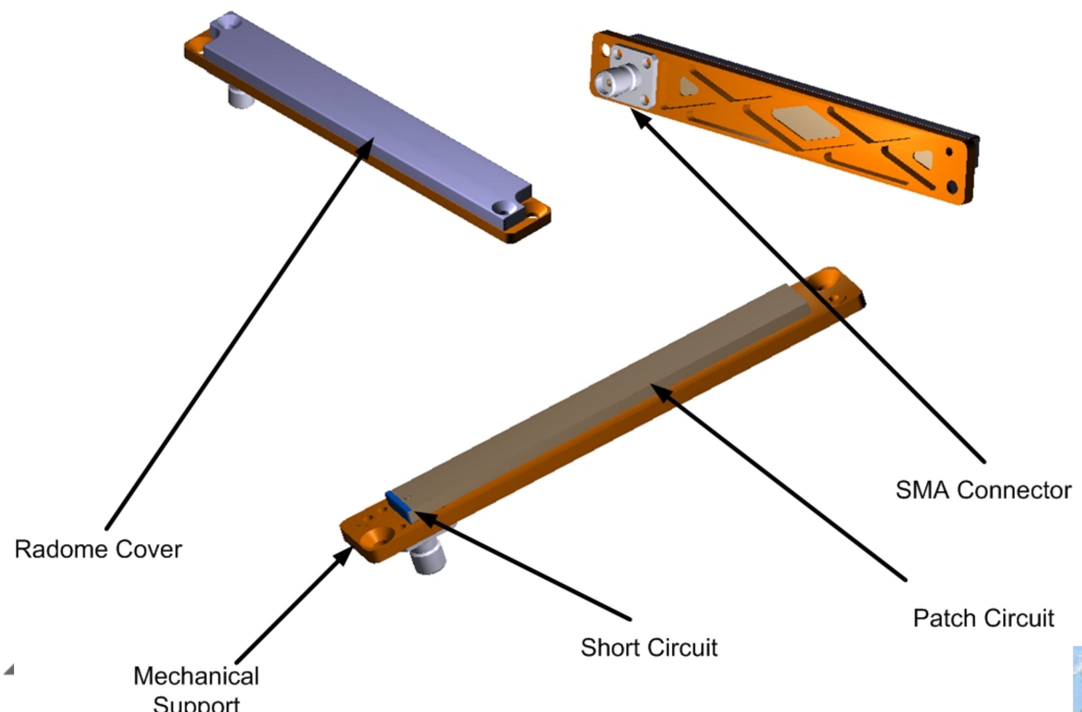
⇒ Shared communication with Minerva Rovers (via CCOM & OME-A Antenna)

⇒ During cruise: „wireless“ communication with MESS antenna

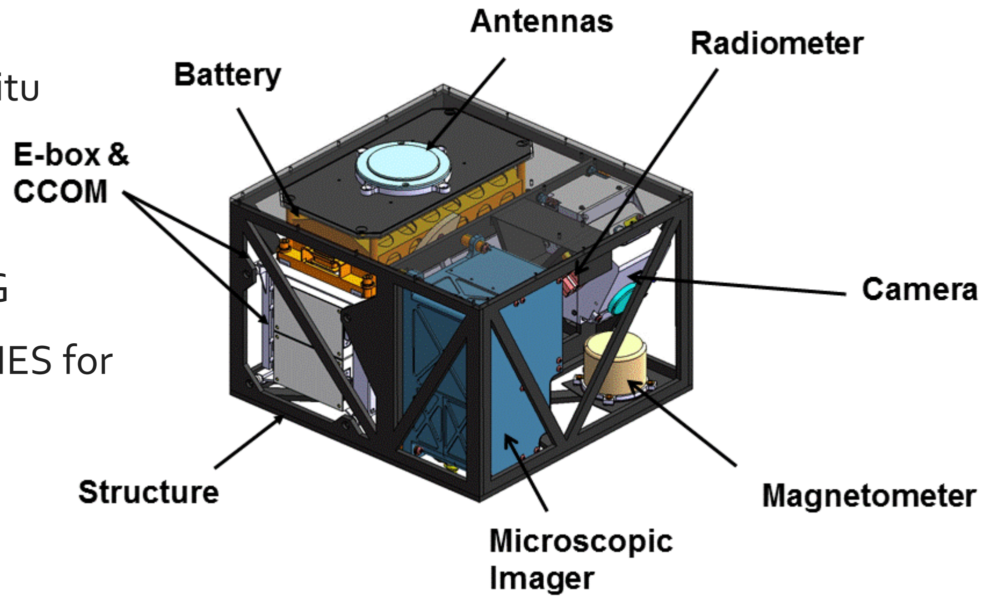
⇒ On asteroid: shared communication with OME-A

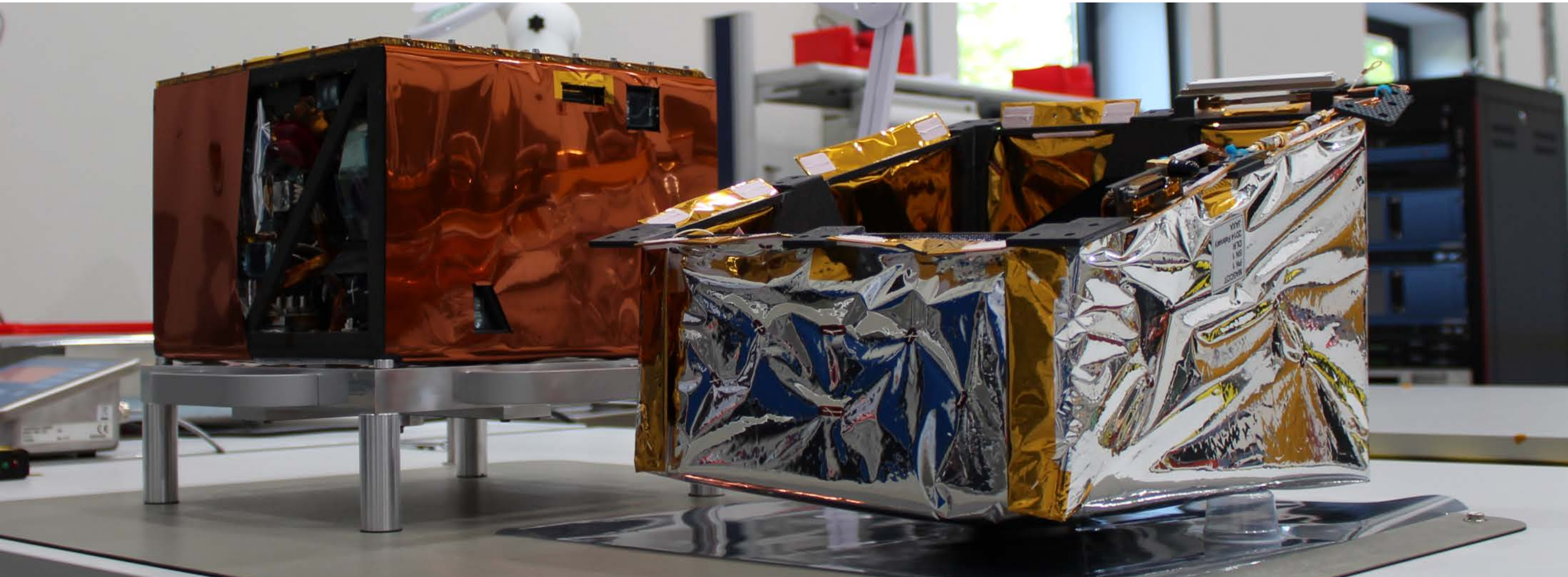




MASCOT Concept

- Agile, light & compact nano-lander for in-situ asteroid research
- Total mass: ~10 kg
- PLs: MASCAM, μOmega, MARA, MASMAG
- Developed by DLR in collaboration with CNES for the Hayabusa 2 Mission
- On-Asteroid ops: ~Oct 3, 2018

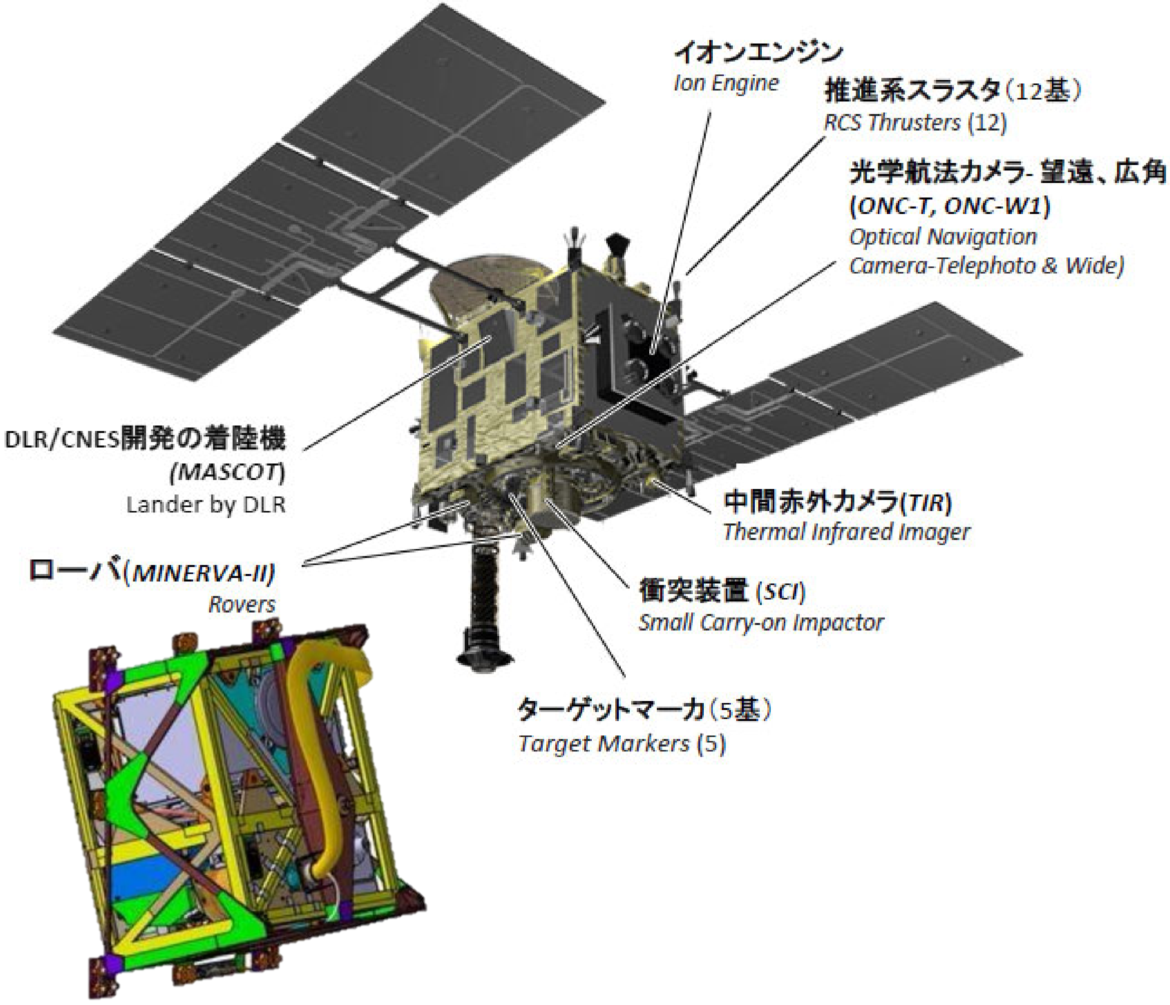




Hayabusa2 (HY2)

= Hayabusa Immediate follow-on Asteroid Sample Return Mission (JAXA/ISAS)

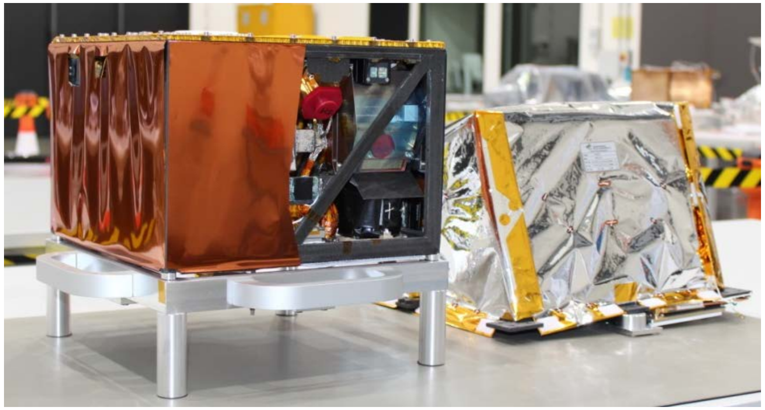
- Launch: Dec 2014
- Arrival + Ops: 2018/2019
- Return to Earth: 2020
- Mass ~ 600 kg
- Dimensions of main structure: 1.0m x 1.6m x 1.4m (Paddle span: 6.0m)
- PL: Four orbiter experiments, impactor, sampler, 3 Minerva rovers + MASCOT (DLR/CNES)



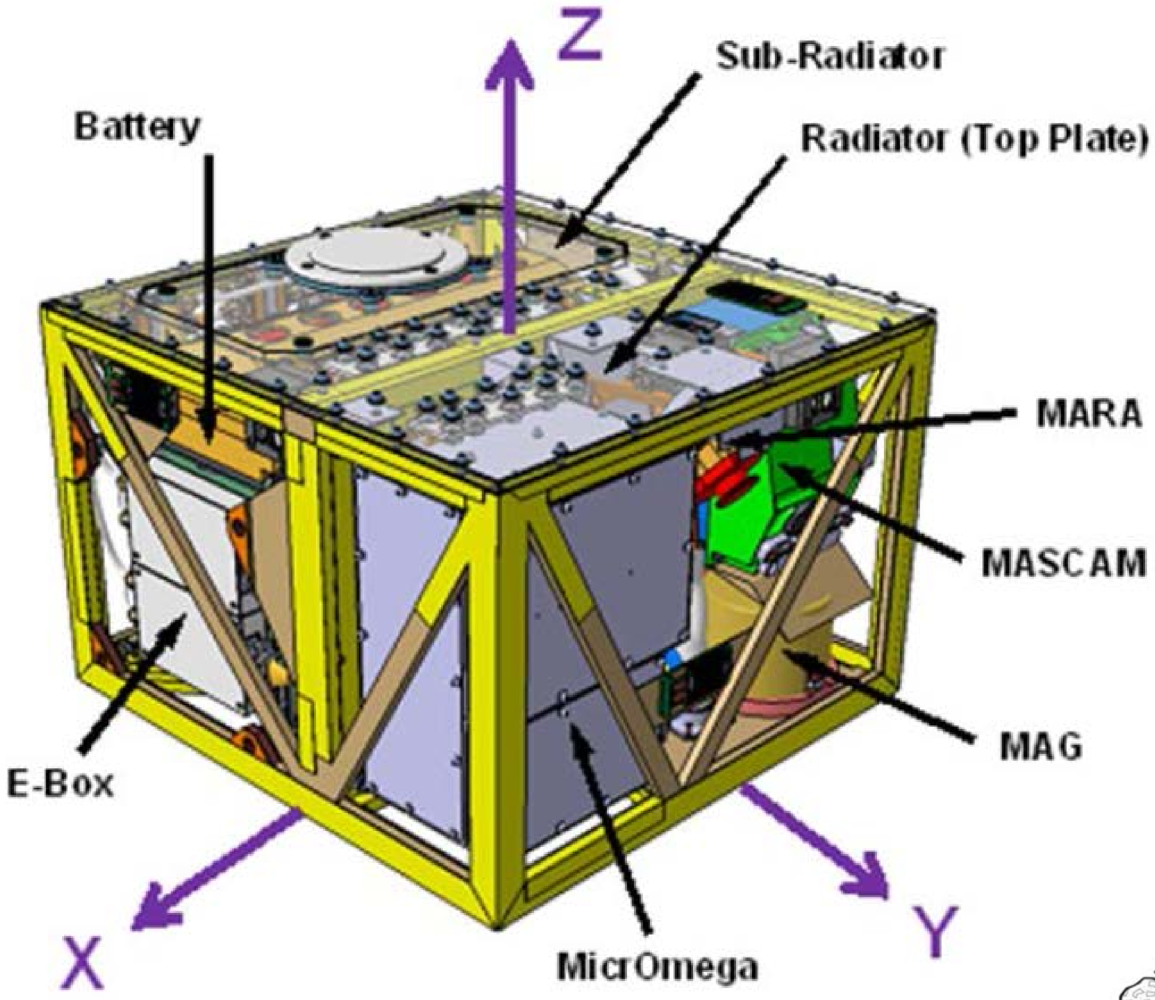
MASCOT Baseline Design - Summary

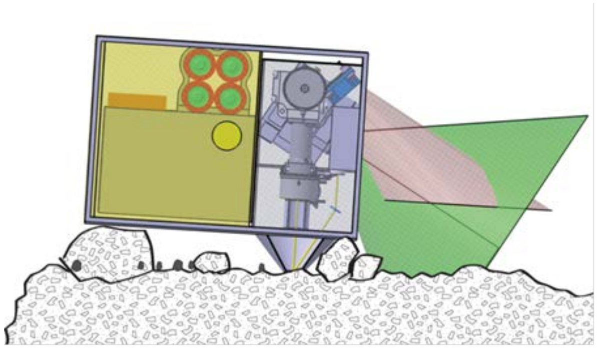
- Configuration/Structure: highly integrated carbon-fibre composite structure with separate payload and warm compartment (including common E-box for all instrument electronics)
- Power: Primary battery only; redundant power supply from main-S/C during cruise
- Communication: common communication based on Minerva transceiver, on MASCOT: omnidirectional, redundant link with one antenna on each side
- DHS/OBC: Redundant on-board computer, Mascot Autonomy Manager (MAM)
- Mechanisms: uprighting and hopping using motor/drive/excenter
- GNC (attitude): using proximity sensors (baseline optical + backup)

- Thermal: semi-active;
- Cruise: active (heater power and control from HY2)
- On surface: passive (MLI and coatings)
- MESS: physical interface to HY2

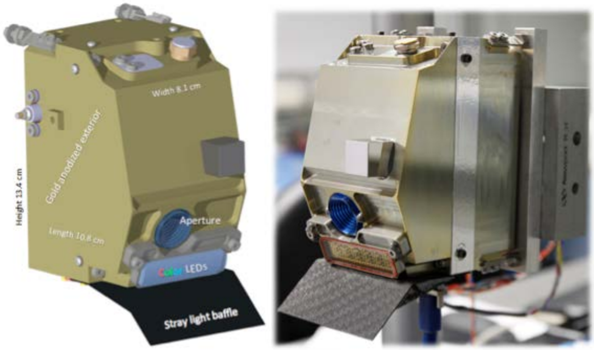


Payload Accomodation





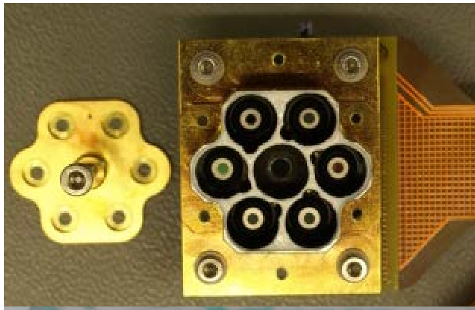
MASCOT Science Payload



Camera (MasCam)/DLR PF

- *Ground truth* for orbital measurements of the HY2 instruments and the in-situ MSC sensor suite
- Geological context of the samples

Radiometer (MARA)/DLR PF

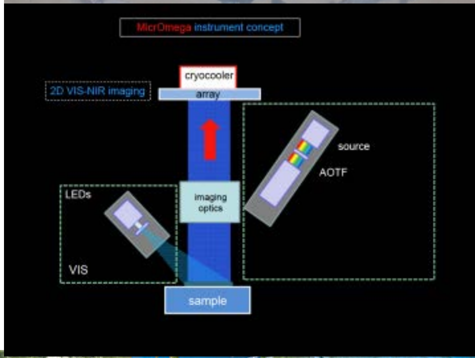


- Surface brightness temperature for a full asteroid rotation
- Surface inertia and spectral slope in the IR

Magnetometer (MasMag)/TU Braunschweig

- Observe the magnetic field profile during descent and hopping
- Identification of global and local magnetization of asteroid and reconstruct the coordinate system of the magnetic field vector

IR Hyper-Spectral Imager (MicrOmega)/IAS Paris



- Composition of the asteroid’s surface, at grain scale in terms of minerals (pristine, altered), ices/frosts, organics
- Microscopic structure of the soil, and the relation between the various phases of distinct compositions.

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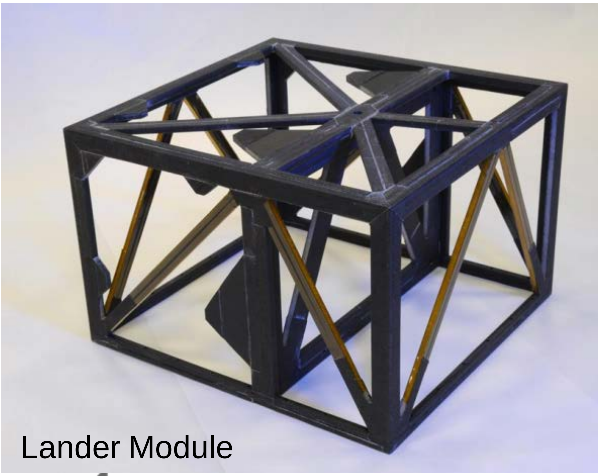
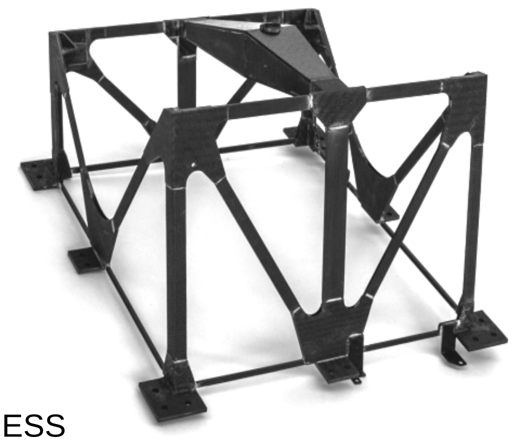
The Mass and Volume Requirements

- Maximum mass (incl. MESS) ≤11 kg!
- Maximum volume (incl. antenna, etc..) ≤ 0.3x0.3x0.2m³!
  - ⇒ Lander structure (CFRP) ≈ 0,56 kg
  - ⇒ MESS structure (CFRP) ≈ 0,7 kg
  - ⇒ Payload/System Mass Ratio ≈ 3:7

MASCOT Lander	Mass [kg]
Mobility	0,52
GNC	0,26
OBC	0,49
Communication	0,52
Power (Batteries and PCDU)	1,82
Structure (incl. Ebox)	2,13
Thermal	0,41
Harness	0,55
Payload	
MicrOmega	2,1
MAG	0,24
MARA	0,26
MASCAM	0,46
MASCOT MESS	1,23
Total	11,02

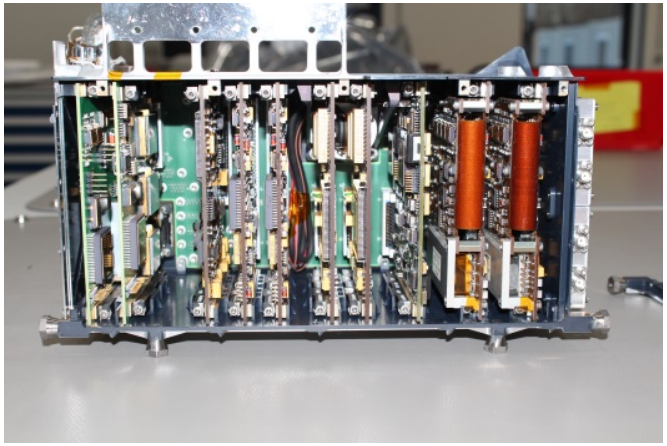


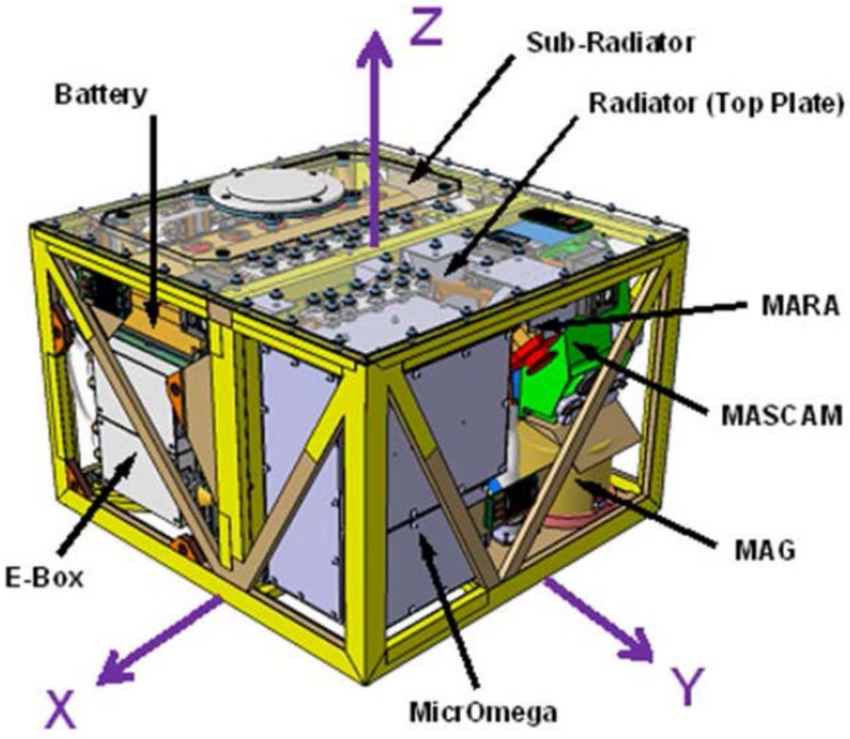
Lander Module

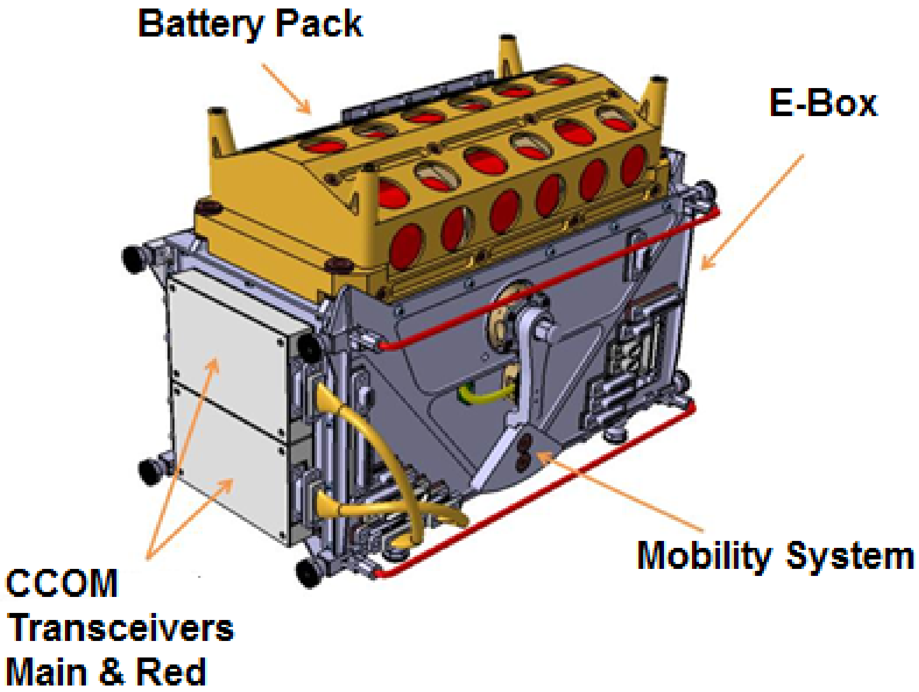


MESS

⇒ High integration density:
- Most harness is replaced by a backplane
- E-box (Al, thickness ≈ 1,5 mm) contains nearly all PCBs & Mobility S/S

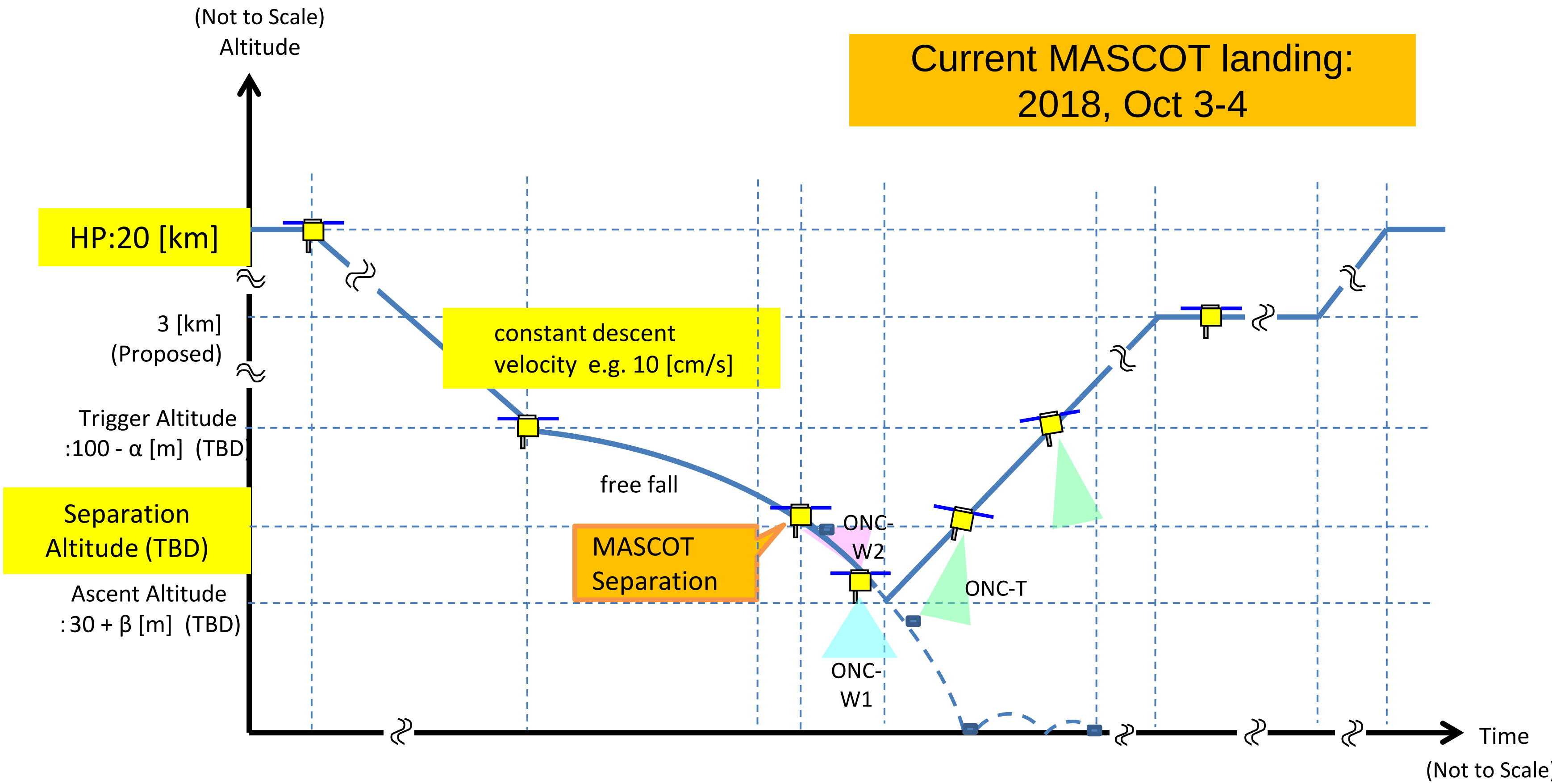






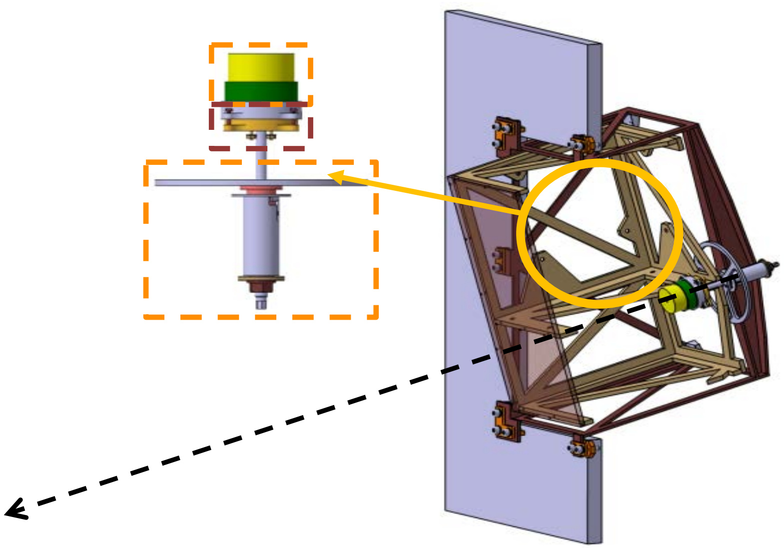
Separation and Landing

- MASCOT will be separated during a 'Touch and Go' maneuver of HY2 at an altitude of ~100m and free fall on asteroid surface

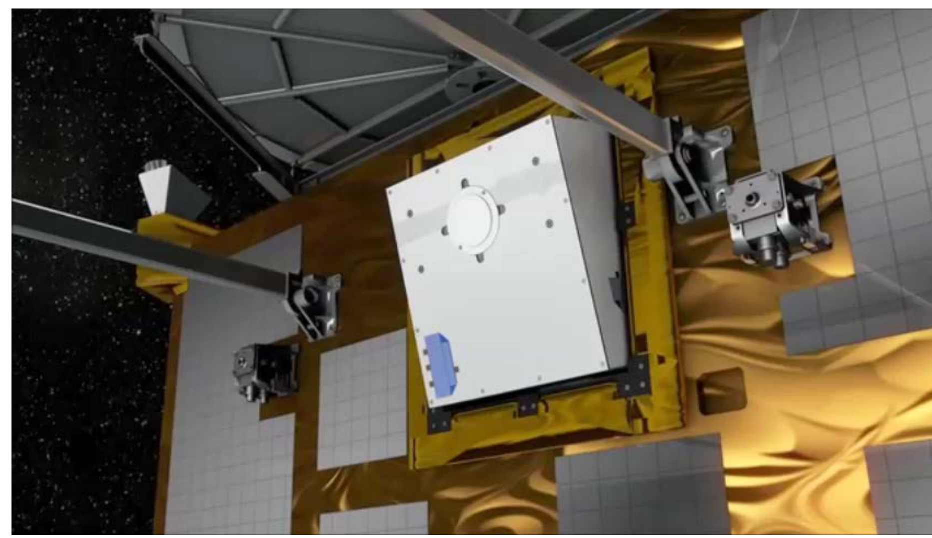


⇒ MASCOT will be ejected via separation mechanism (NEA, push plate, spring) from HY2 & MESS

- Relative separation velocity ≈ 5 cm/s
- V_{impact} < 50% then asteroid escape velocity(≈ 32 cm/s)



Separation direction

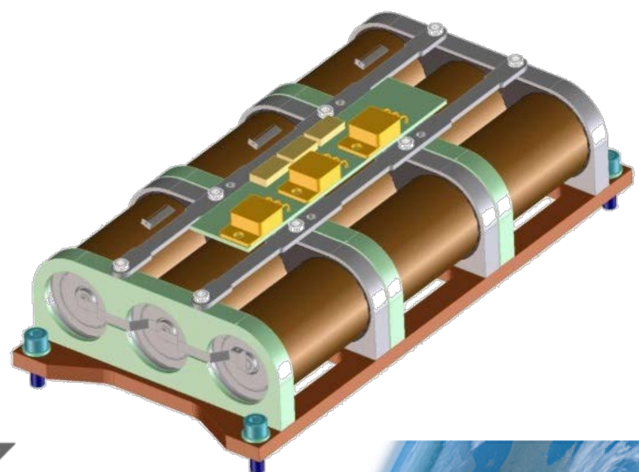


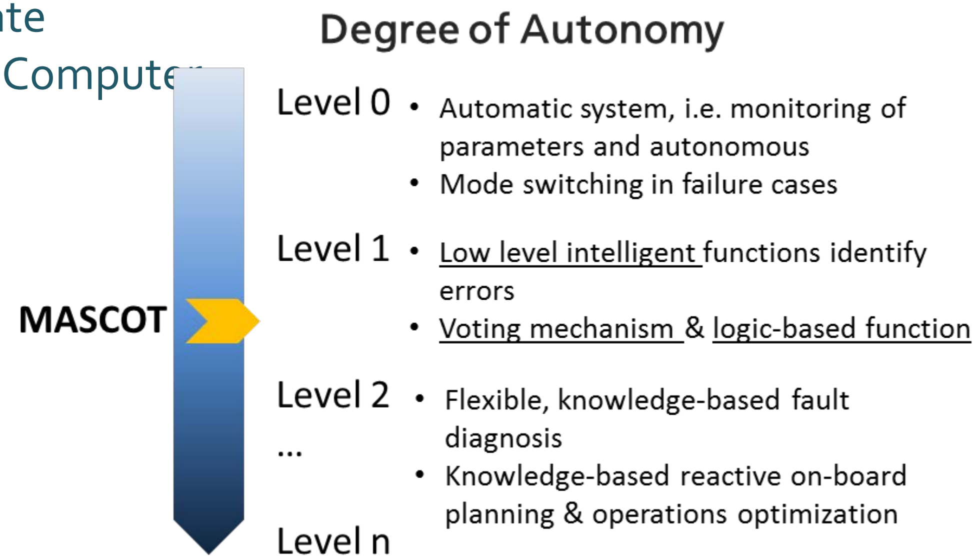
Operational Requirements

- The landing package shall operate at least during two complete asteroid rotations
- The landing package shall autonomously perform nominal operations when ground intervention is not possible

⇒ Primary batteries (i.e. LSH20 SAFT; Philae/Rosetta)

⇒ MSC Autonomy Manager: State Machine as App on On-Board Computer





From: Eickhoff, J.; Simulating Spacecraft Systems, Springer-Verlag Berlin Heidelberg, 2009

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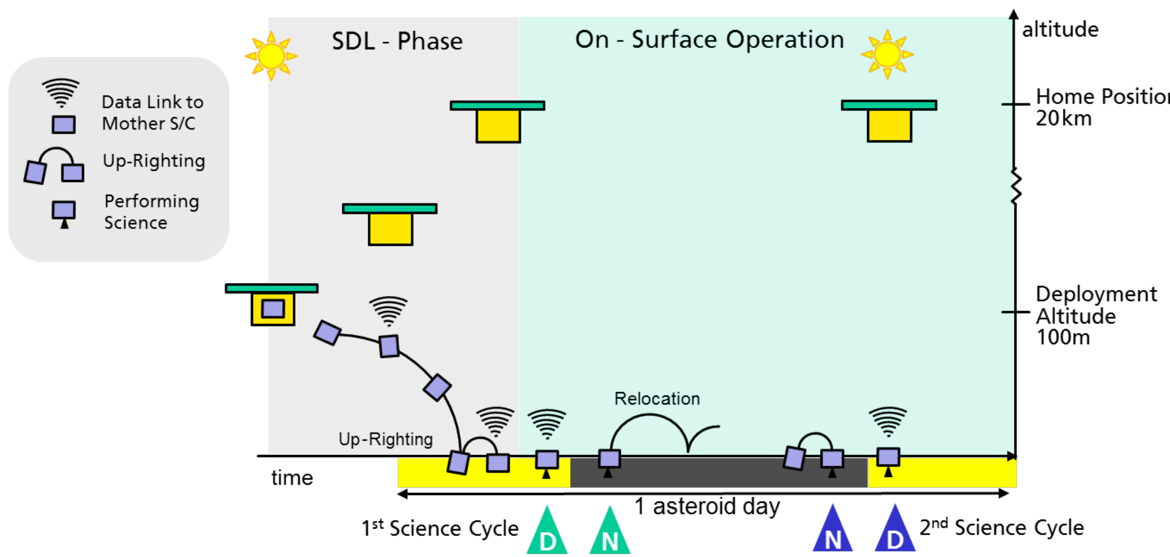
Mobility

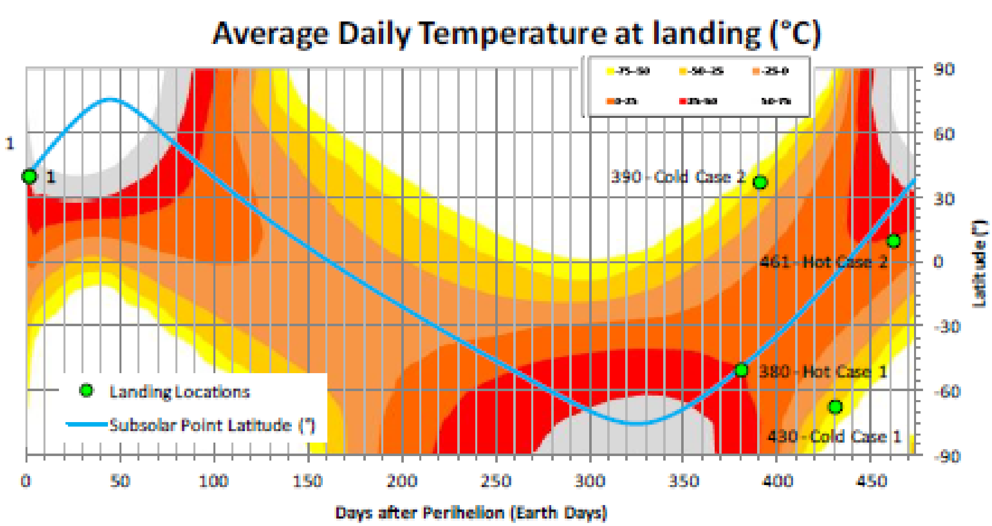
- Upright capability & change of surface site
  - ⇒ Upright and hopping mechanism via mobility s/s (motor/control electronics/excenter arm)
  - ⇒ OPS to detect asteroid surface
  - ⇒ Redundancy via PEC to detect Sun vector

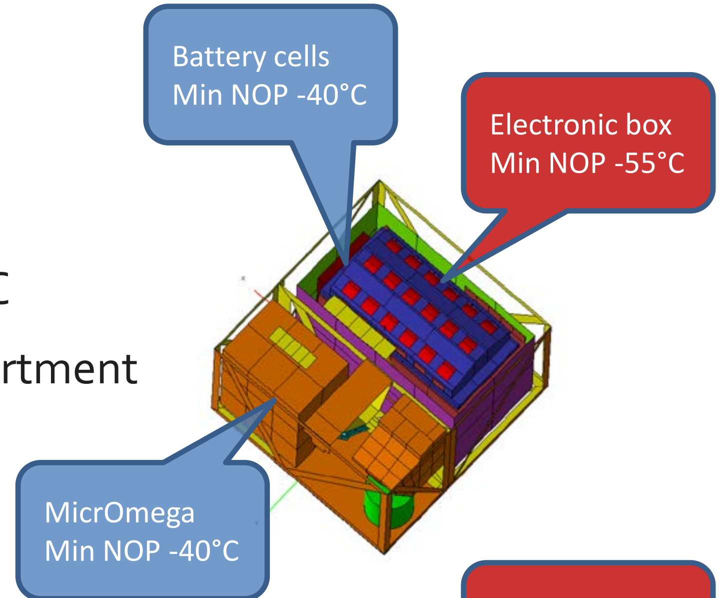


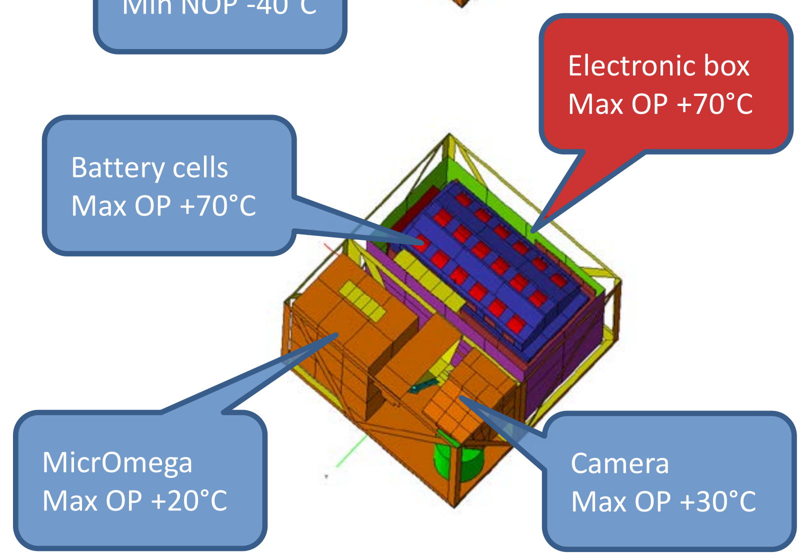
Thermal Requirements

- Temperatures during cruise (4 years): -30 < t < +60 °C
  - Max. heat transfer between MSC & HY2 ~ 5W
- Temperatures on the asteroid surface : -60 < t < +77 °C
- Warm compartment (Ebox, batteries) ⇔ Cold compartment (PL)

⇒ Semi-active Thermal Control System

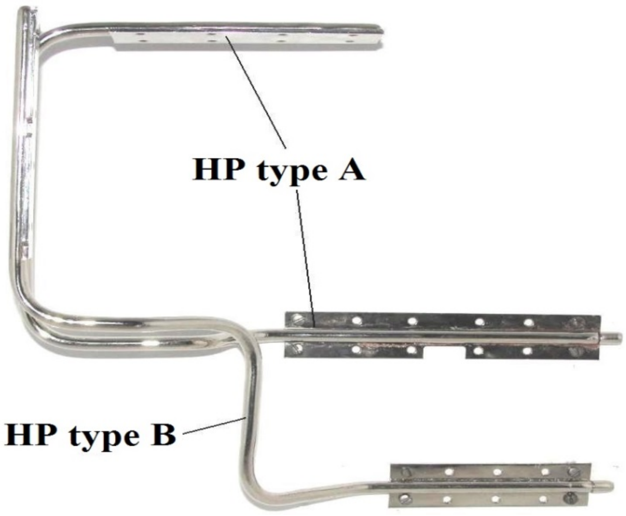


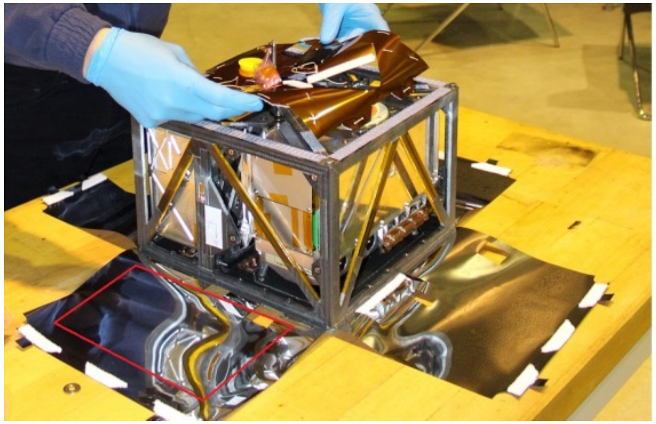


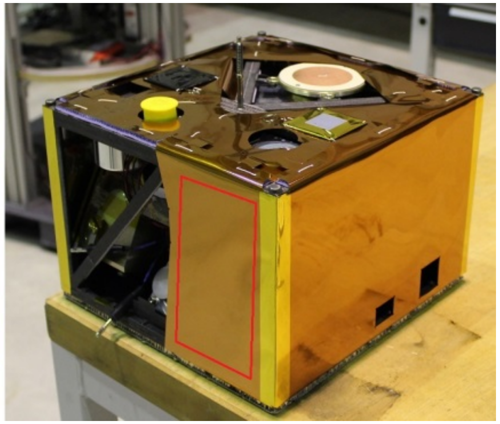


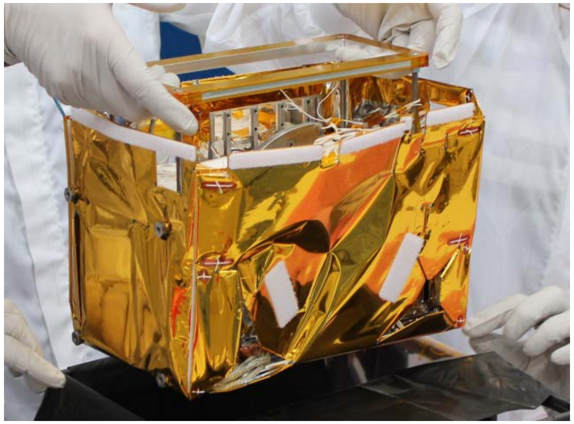
Passive Thermal Control Part

- ⇒ Super-insulation (MLI) on MESS
- ⇒ E-box & batteries in super-insulating layers (MLI)
- ⇒ SLI: Insulated sides to reduce heat input from ground (landed) or heat exchange to HY2 (cruise)
- ⇒ Radiator & Heat Pipes (Main Actor during In-flight switch on)









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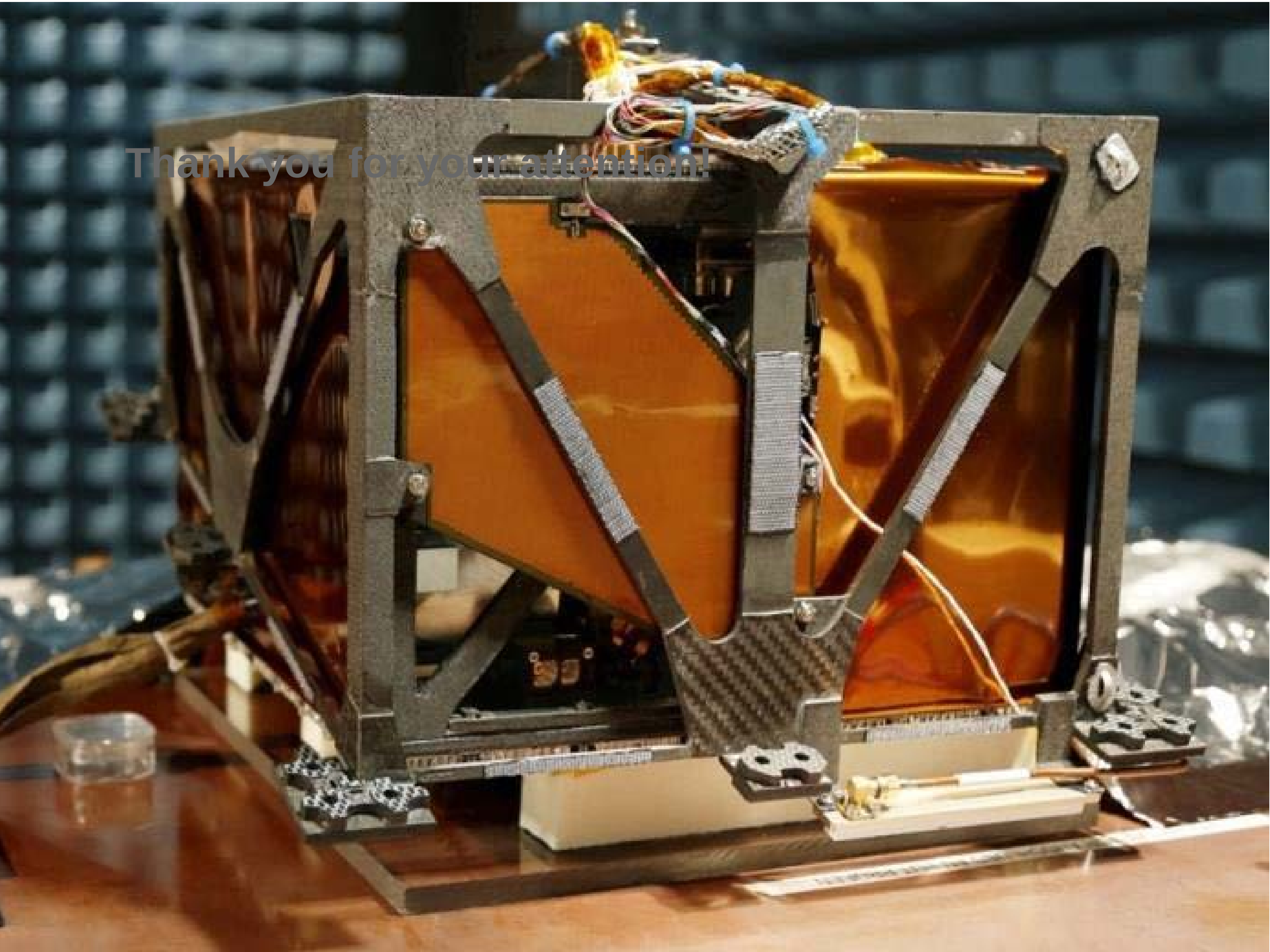
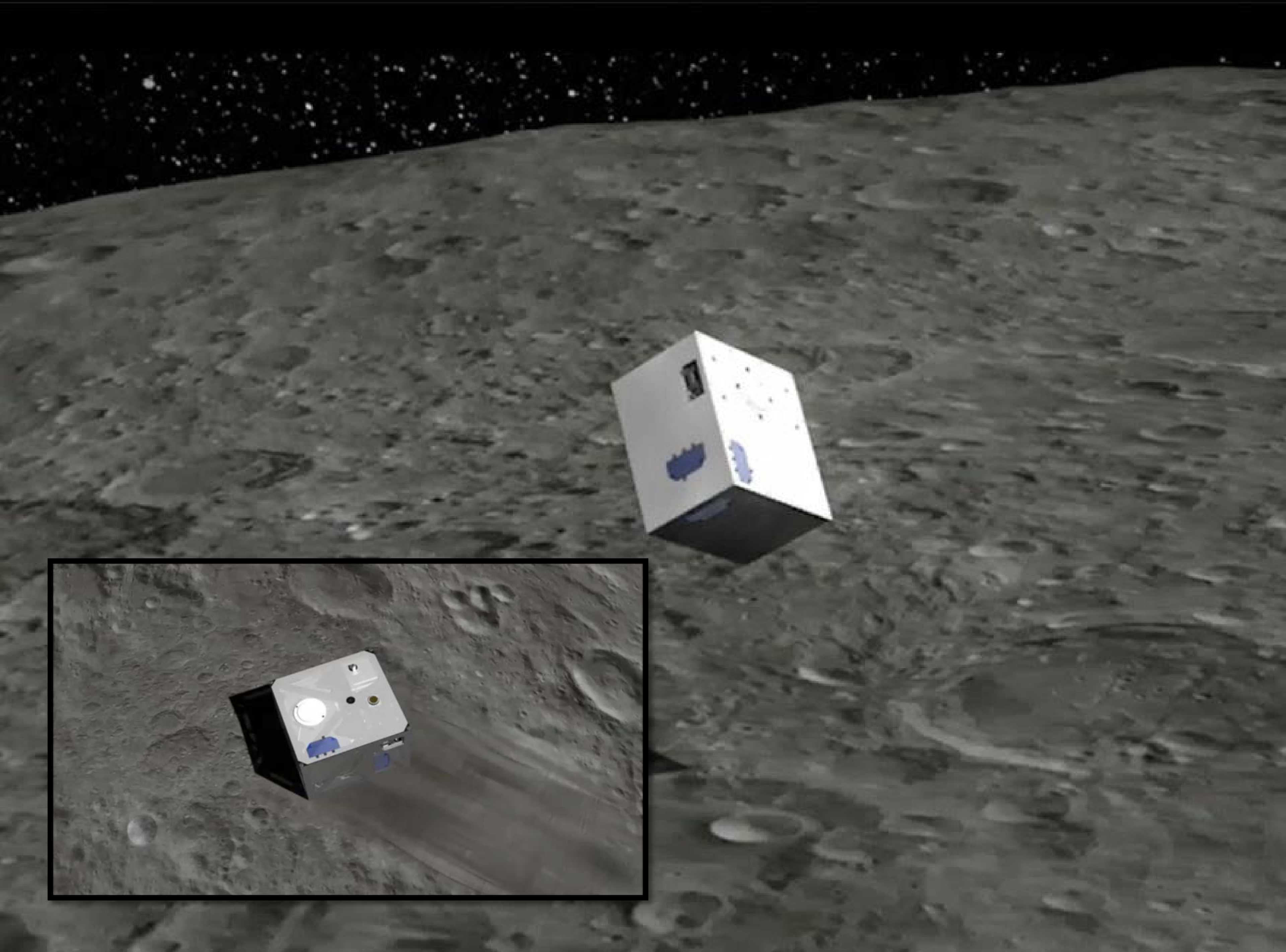
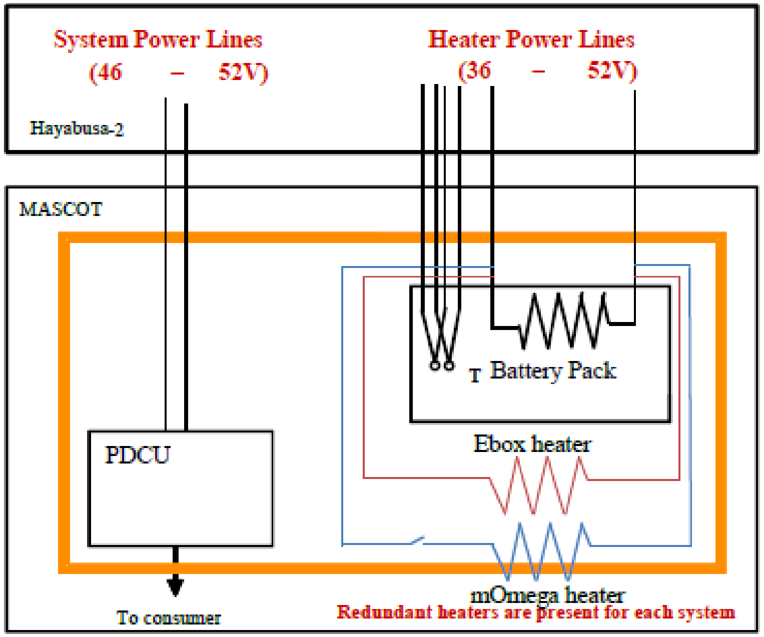
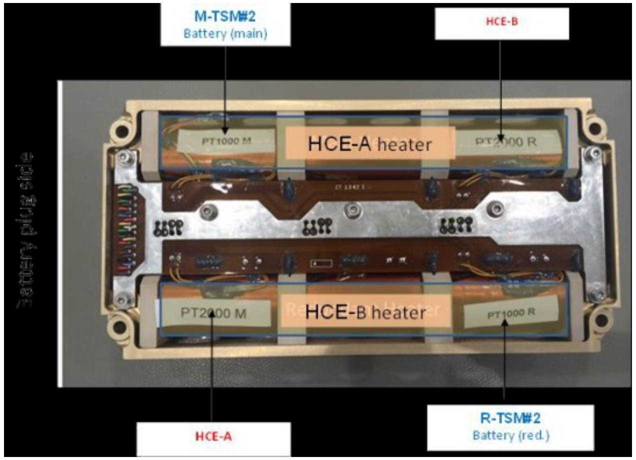




Thermal Control via HY2 S/C

⇒ Redundant heater on MASCOT for thermal control of batteries (+ Ebox and MMEGA)
- grant survival temperature of batteries during cruise
- preheat MASCOT before commissioning phases & shortly before landing.





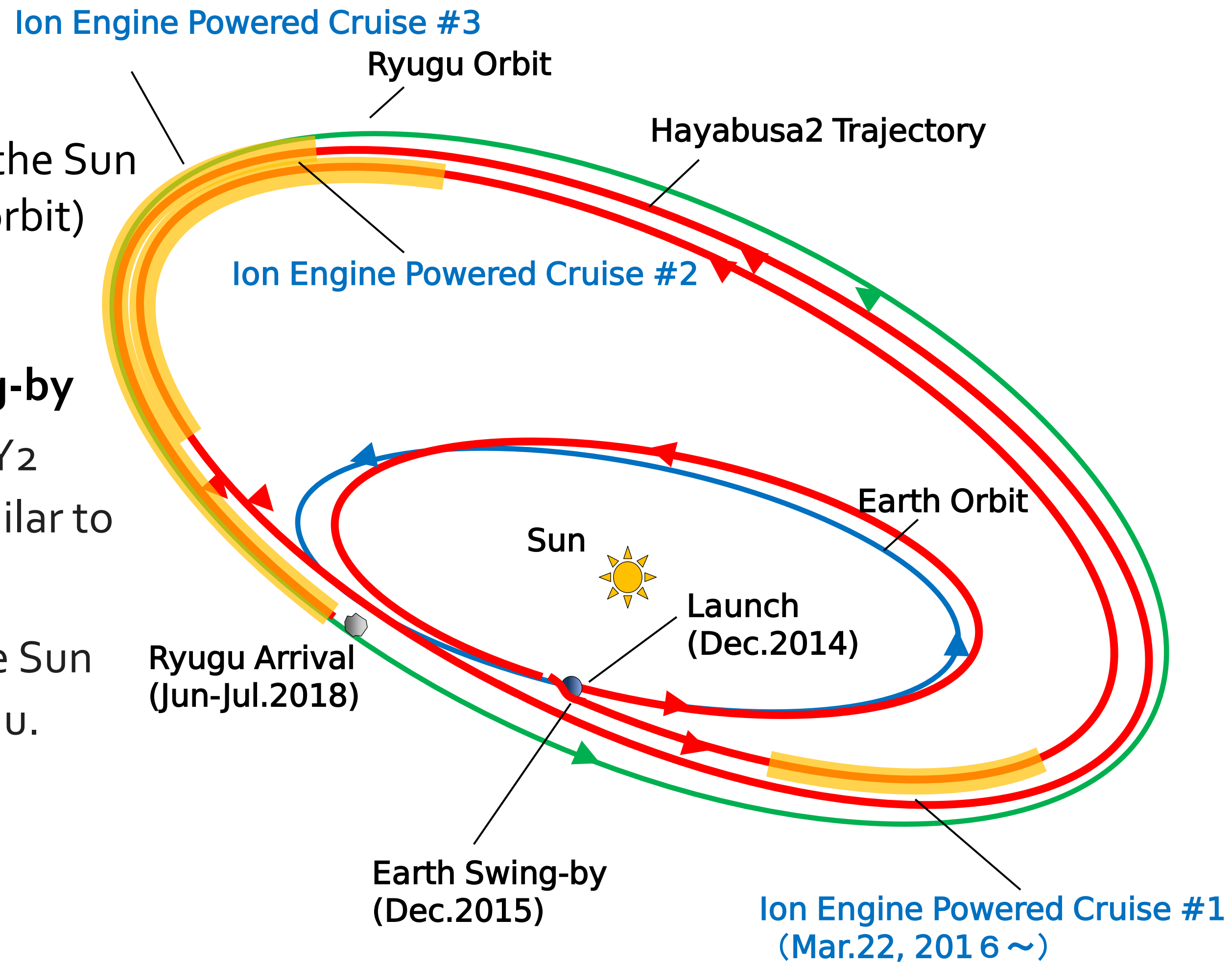
S/C Requirements: Heat Transfer to the S/C		
	Cold Case	Hot Case
Maximum Heat Transfer	-5W	5W

Hayabusa2 Mission Baseline

Dec 3, 2014: Launch
HY2 will fly once around the Sun
(Note: similar to Earth's orbit)

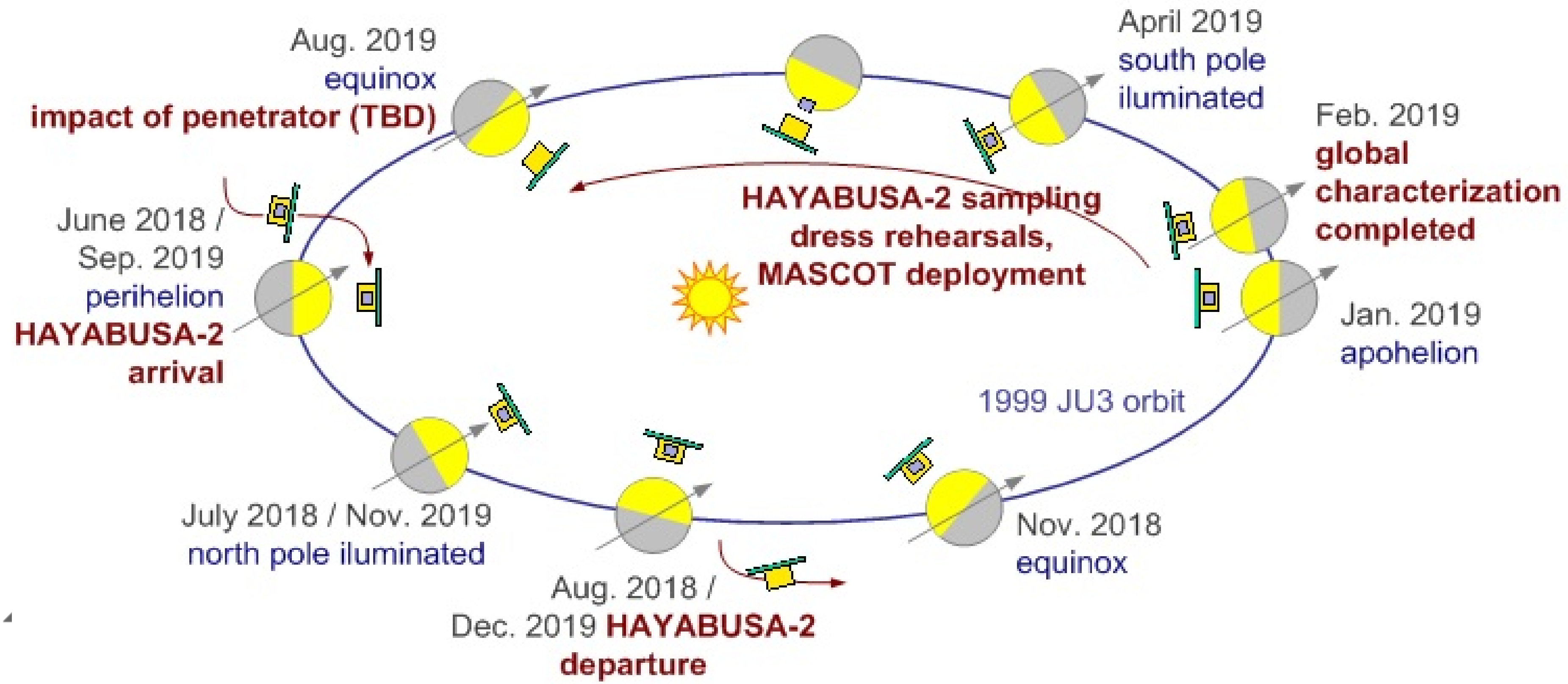
End of 2015: Earth swing-by

- After the swing-by HY2 goes into an orbit similar to NEA Ryugu.
- ~ 2 rounds around the Sun to arrive at NEA Ryugu.



Summer 2018: Arrival at the asteroid – Stay there for about 18 months.

- Remote observation incl. Near InfraRed Spectrometer (NIRS3) and Thermal Infrared Imager (TIR).
- Separation of small rovers "MINERVA" and small lander "MASCOT".
- Sampling surface of the asteroid.
- Small Carry-on Impactor (SCI) separation → artificial crater, touch down & sampling



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Questions?