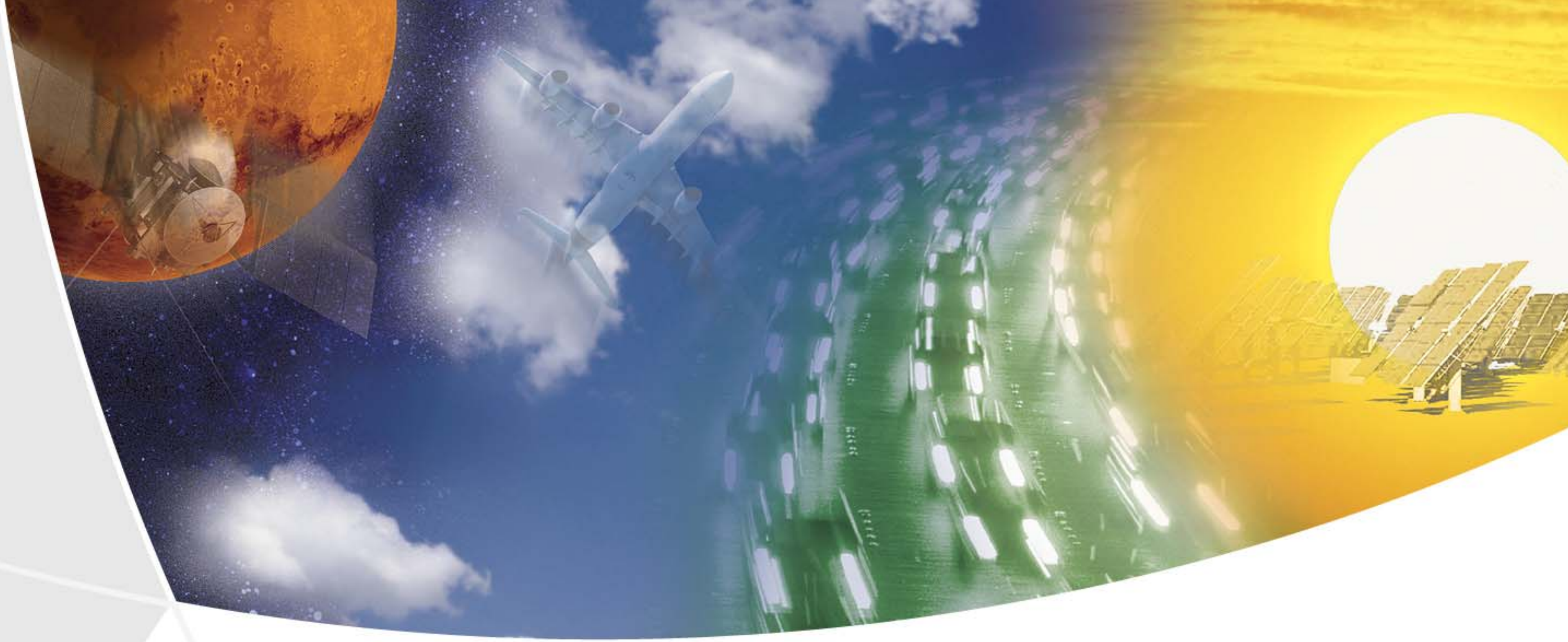

MASCOT – Marco Polo Surface Scout

Progress Report on Lander Package Study for Marco Polo

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In situ science lander + Marco Polo S/C

Brief history of MASCOT study

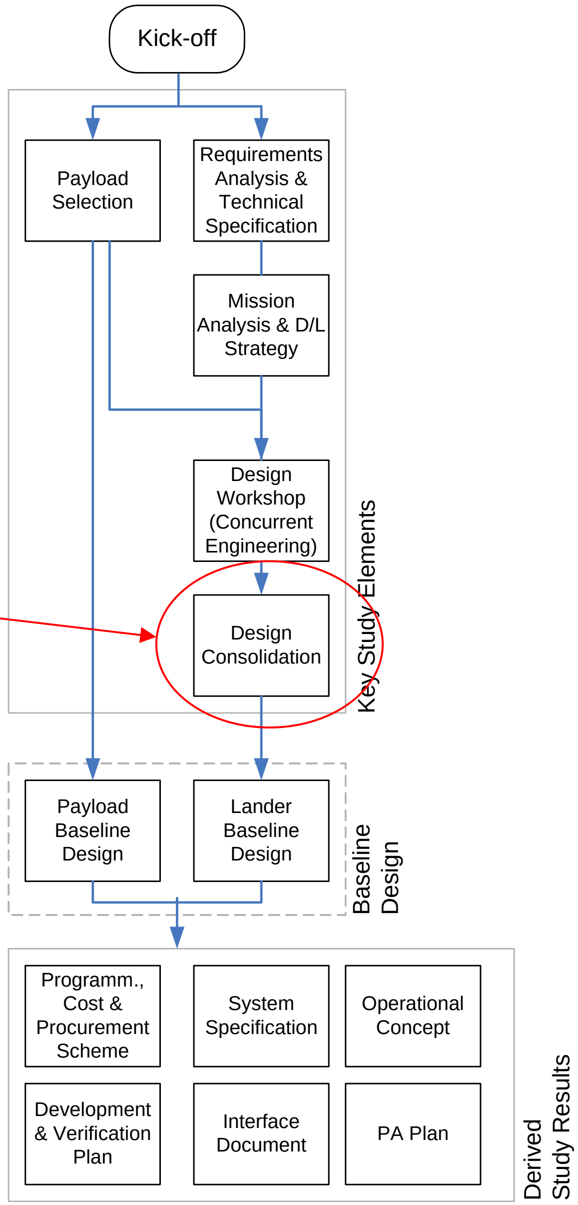
- Marco Polo mission proposal: showed interest in dedicated lander for in situ science
- ESA: ‚Declaration of Interest‘ (DOI) in summer 2008
- Max Planck Lindau: approached DLR Inst. of Space Systems (Bremen) (now reponsible for lander technology in DLR R&D) to jointly propose lander for Marco Polo
- DLR Bremen: proposed a dedicated lander (Marco Polo Surface Scout, MASCOT)
- MASCOT favorably reviewed by ESA
  - We are now doing the study (different-sized lander options)
  - Funded internally by DLR R&D
  - Synchronized with MP mission study

Science case for MASCOT lander

- Needs to be complementary to remote sensing from main S/C and to analysis of returned samples
- MASCOT objectives:
  - In situ observations of undisturbed materials
  - Microscopic scale observations not possible from main S/C
  - Study of internal structure/geophysics
- Allow for coordinated mission operations: MASCOT results ideally to guide selection of sampling spot(s) of main S/C

Course of study

we are here now
(May 2009)

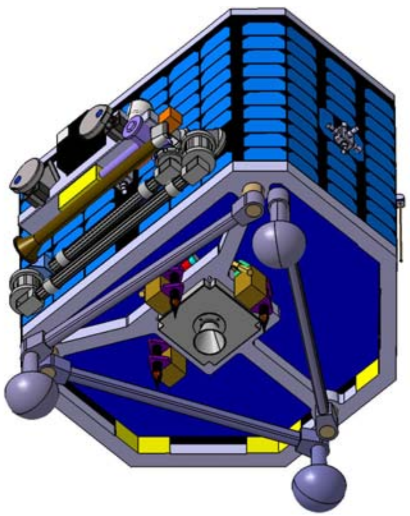


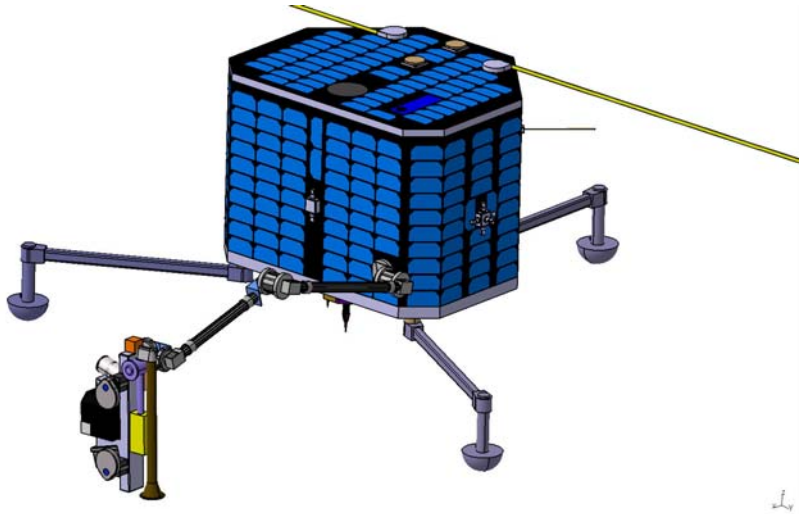
Study programmatics

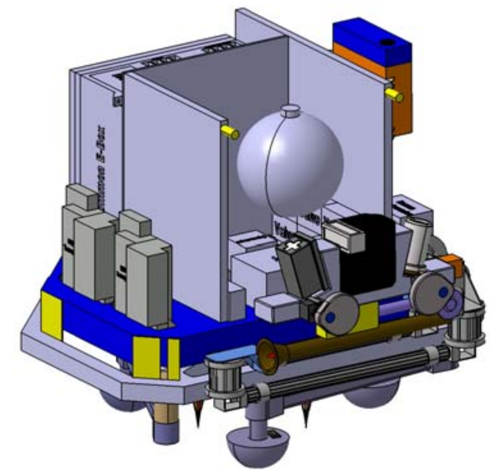
- Coordination with both ESA and JAXA
- Worked with the science community to define model payload(s)

Different lander options considered in CDF study of DLR Bremen

- Option 1: ~95 kg, strong heritage from Philae, 3-axis attitude control, hazard avoidance, post-landing mobility



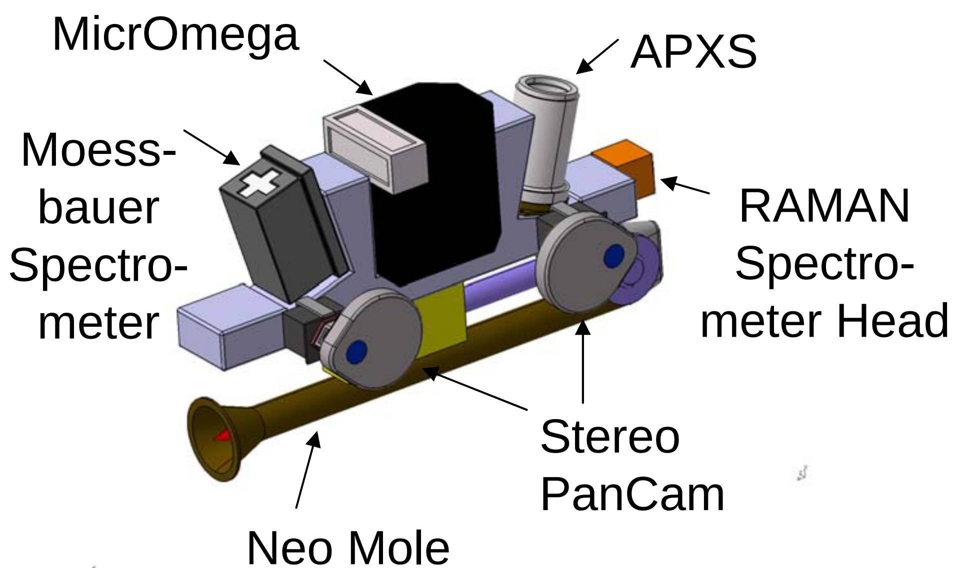




Different lander options considered in CDF study of DLR Bremen

- Option 1 P/L:

Arm-mounted P/L



Instruments	**Mass [kg]**
APXS (Alpha-Particle-X-ray Spectrometer)	0.7
Raman Spectrometer	1.2
Mössbauer Spectrometer	0.5
Neo-Mole	0.9
EVITA (Evolved Volatiles Ion Trap Analyzer)	0.6
Voldet (Mid-IR ATR spectr., volatile detect., microsc.)	0.2
ILMA (Ion Laser Mass Analyzer)	2.5
XRD (X-ray diffractometer)	2
MicrOmega (Optical microscope & IR spectr.)	0.5
Mikroseismometer	0.3
Stereo/panoramic camera (WAC)	0.8
New Consert	1.8
MPBeacon	1
Laser Retroreflectors	0.5
Σ	**13.5**

Different lander options considered in CDF study of DLR Bremen

Element 1	MASCOT_Full_Mobility							
				Target Spacecraft Mass at Launch			100,00	kg
				Below Mass Target by:			8,94	kg
	Input Mass	Input Margin	Dry mass contributions	Without Margin	Margin %	kg	Total kg	% of Total
EL			Structure	8,30 kg	10,17	0,84	9,14	12,12
EL			Thermal Control	2,54 kg	8,42	0,21	2,75	3,65
EL			Mechanisms	14,00 kg	15,71	2,20	16,20	21,48
EL			Communications	2,80 kg	5,00	0,14	2,94	3,90
EL			Data Handling	0,98 kg	5,00	0,05	1,03	1,37
EL			GNC	5,10 kg	20,00	1,02	6,12	8,12
EL			Propulsion	4,00 kg	10,67	0,43	4,42	5,86
EL			Power	10,67 kg	18,88	2,01	12,68	16,82
EL			Harness	5,00 kg	5,00	0,25	5,25	6,96
EL			Instruments	13,52 kg	10,00	1,35	14,87	19,72
			Total Dry(excl.adapter)	66,90			75,41	kg
			System margin (excl.adapter)		20,00	%	15,08	kg
			Total Dry with margin (excl.adapter)				90,49	kg
			Other contributions					
			Wet mass contributions					
DI	0,55	5,00	Propellant	0,55 kg	5,00	0,03	0,58	0,63
			Adapter mass (including sep. mech.), kg	0,00 kg	0,00	0,00	0,00	0,00
			Total wet mass (excl.adapter)				91,06	kg
			Launch mass (including adapter)				91,06	kg

Different lander options considered in CDF study of DLR Bremen

- Option 2: ~70 kg, flywheel for attitude stabilization, post-landing mobility by hopping

Instruments	Mass [kg]
APXS (Alpha-Particle-X-ray Spectrometer)	0.7
Raman Spectrometer	1.2
Neo-Mole	0.9
Voldet (Mid-IR ATR spectr., volatile detect., microsc.)	0.2
ILMA (Ion Laser Mass Analyzer)	2.5
MicrOmega (Optical microscope & IR spectr.)	0.5
Mikroseismometer	0.3
Stereo/panoramic camera	0.8
New Consert	1.8
MPBeacon	1
Σ	**9.8**

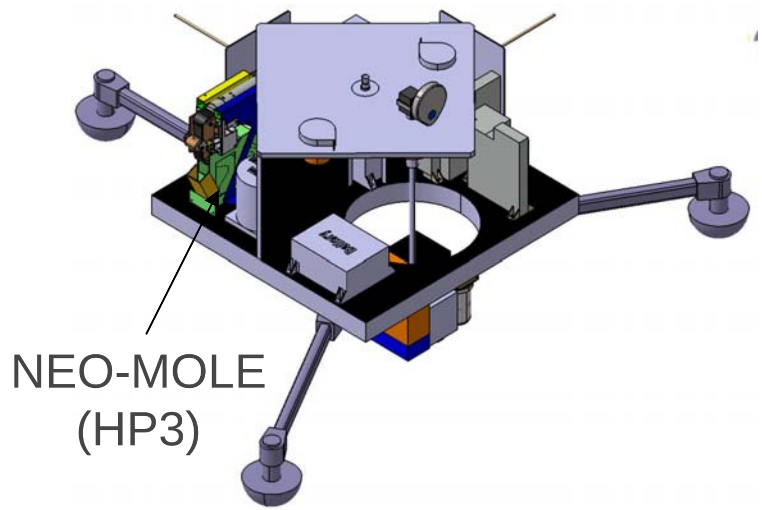
Different lander options considered in CDF study of DLR Bremen

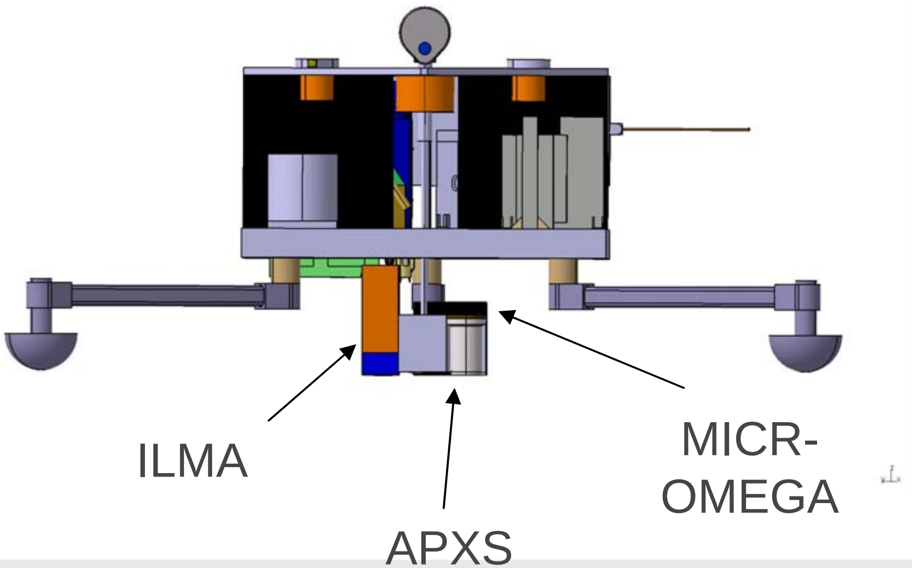
Element 2 MASCOT_Medium_Mobility

				Target Spacecraft Mass at Launch				70,00	kg
				ABOVE MASS TARGET BY:				-3,89	kg
	Input Mass	Input Margin	Dry mass contributions	Without Margin		Margin %	Margin kg	Total kg	% of Total
EL			Structure	8,30	kg	10,17	0,84	9,14	14,84
EL			Thermal Control	2,54	kg	8,42	0,21	2,75	4,47
EL			Mechanisms	12,70	kg	16,30	2,07	14,77	23,99
EL			Communications	2,80	kg	5,00	0,14	2,94	4,77
EL			Data Handling	0,89	kg	5,00	0,04	0,93	1,51
EL			GNC	2,00	kg	20,00	0,40	2,40	3,90
EL			Propulsion	3,68	kg	9,86	0,36	4,04	6,56
EL			Power	8,10	kg	17,28	1,40	9,50	15,43
EL			Harness	4,00	kg	5,00	0,20	4,20	6,82
EL			Instruments	9,92	kg	10,00	0,99	10,91	17,71
			Total Dry(excl.adapter)	54,91				61,58	kg
			System margin (excl.adapter)			20,00	%	12,32	kg
			Total Dry with margin (excl.adapter)					73,89	kg
			Other contributions						
			Wet mass contributions						
EL	0,30	5,00	Propellant	-	kg	-	-	-	-
			Adapter mass (including sep. mech.), kg	0,00	kg	0,00	0,00	0,00	0,00
			Total wet mass (excl.adapter)					73,89	kg
			Launch mass (including adapter)					73,89	kg

Different lander options considered in CDF study of DLR Bremen

- Option 3: ~35 kg, battery powered, flywheel for attitude stabilization, no post-landing mobility





Different lander options considered in CDF study of DLR Bremen

- Option 3 P/L:

Instruments	**Mass [kg]**
APXS (Alpha-Particle-X-ray Spectrometer)	0.7
Neo-Mole/HP3	0.9
ILMA (Ion Laser Mass Analyzer)	2.5
MicrOmega (Optical microscope & IR spectr.)	0.5
Mikroseismometer	0.3
Stereo/panoramic camera	0.8
New Consert	1.8
Σ	**7.5**

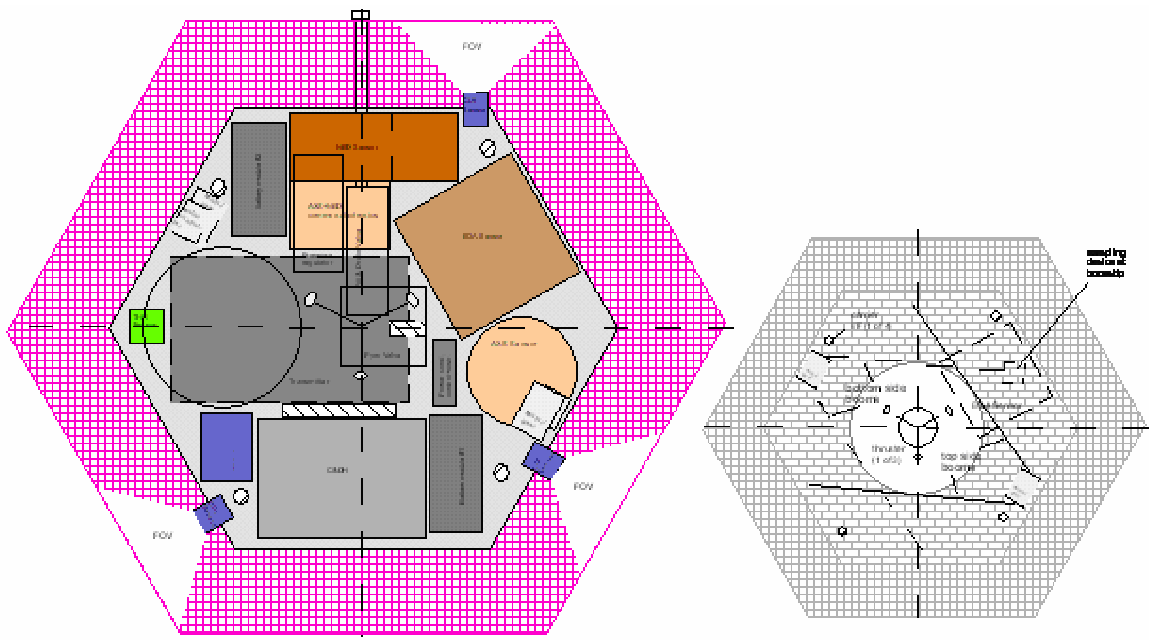
Different lander options considered in CDF study of DLR Bremen

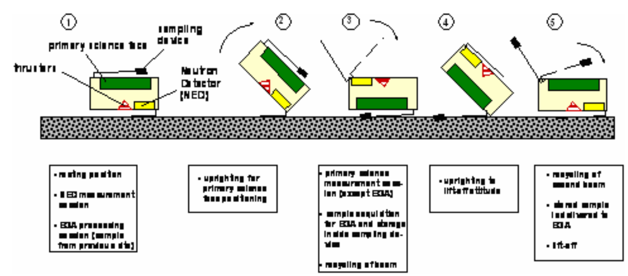
Element 3 MASCOT_Zero_Mobility

				Target Spacecraft Mass at Launch				30,00	kg
				ABOVE MASS TARGET BY:				-13,47	kg
	Input Mass	Input Margin	Dry mass contributions	Without Margin		Margin %	Margin kg	Total kg	% of Total
EL			Structure	2,58	kg	15,64	0,40	2,98	8,24
EL			Thermal Control	1,45	kg	8,28	0,12	1,57	4,33
EL			Mechanisms	8,20	kg	18,41	1,51	9,71	26,80
EL			Communications	2,80	kg	5,00	0,14	2,94	8,12
EL			Data Handling	0,79	kg	5,00	0,04	0,83	2,30
EL			GNC	1,00	kg	20,00	0,20	1,20	3,31
EL			Propulsion	0,20	kg	20,00	0,04	0,24	0,66
EL			Power	5,50	kg	16,36	0,90	6,40	17,67
EL			Harness	2,00	kg	5,00	0,10	2,10	5,80
EL			Instruments	7,50	kg	10,00	0,75	8,25	22,77
			Total Dry(excl.adapter)	32,02				36,23	kg
			System margin (excl.adapter)			20,00	%	7,25	kg
			Total Dry with margin (excl.adapter)					43,47	kg
			Other contributions						
			Wet mass contributions						
EL			Propellant	-	kg	-	-	-	-
			Adapter mass (including sep. mech.), kg	0,00	kg	0,00	0,00	0,00	0,00
			Total wet mass (excl.adapter)					43,47	kg
			Launch mass (including adapter)					43,47	kg

Different lander options considered in CDF study of DLR Bremen

- Option 4 (‚MASCOT-XS‘): ~10 kg, based on prior DLR concept study for ESA, ballistic descent with selfrighting, optional post-landing mobility





Size of lander: link to MP S/C and mission design

- Marco Polo (MP) S/C design strongly depends on mission target
  - For Wilson-Harrington: need more Δv, larger solar distance -> larger solar array, larger S/C (~1.3 tons vs. 0.5 tons for Hayabusa) -> could have ~50 kg lander (plus remote sensing science)
  - For 1999 JU3 (C-type NEO asteroid): for a solar-electric mission, could re-use Hayabusa S/C with small upgrades -> could have ~10 kg lander (plus some remote sensing science)

Size of lander: link to MP S/C and mission design

Target-Spacecraft Trade-Offs: Summary

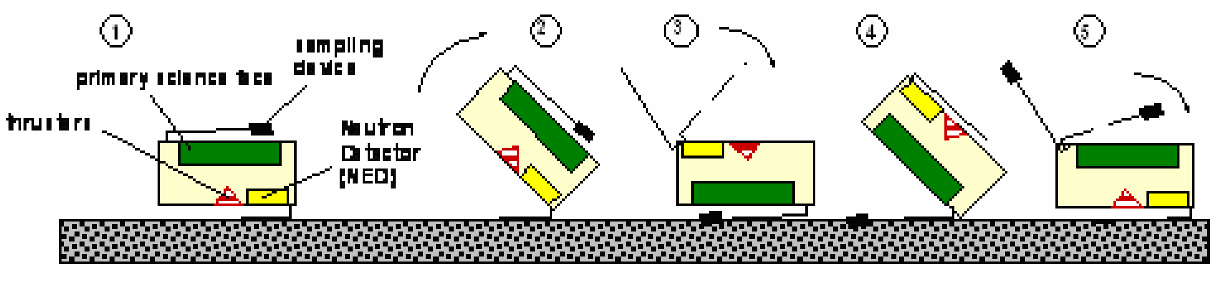
Target Objects	W-H (Dormant Comet), D-type	1999 JU3 (C-Type)
Earliest Launch Windows	2018-20	2014-16
Capsule Re-entry Velocity	~14 km/s (Out of ESA TRL)	~12 km/s (Within ESA TRL)
Ion Engines	Mu-20 (30mN@1kW)	Mu-10 (8~10mN@350W)
SAP	2~4 times as large as Hayabusa (JU3 Class)	2575W@1AU (1.36 x 4.22) x2 m^2
Total Mass	1.0 ~1.3 ton class	500kg+alpha class
MASCOT Accommodation Mass (Release Mech. included)	Option 2-4 (70-10 kg) Possible Option 1 (100 kg) needs to be reduced	Option 4 (10 kg) Possible Option 3 (30 kg) needs to be reduced
MASCOT Accommodation Envelope (Release Mech. included)	600 x 600 x 600 mm Cube on the asteroidal face	(1) 300 x 300 x 300 mm Cube on side face (2) >400 mm dia. x TBD height on capsule face
Surface Science Sub-system	MASCOT Option (1), 2, 3, or 4 MINERVA-class robot (Networking) Sampling System / Monitor Camera	MASCOT Option (3) or 4 MINERVA-class robot (Networking) Sampling System / Monitor Camera
Sampling System	(1) Impact ejecta by projectiles, (2) Stratigraphic samples by corer, (3) Top surface size distribution by sticky pad	Impact ejecta increased by projectile shape & ang. momentum

JAXA perspective!

Courtesy: JAXA/JSPEC

Is a 10 kg package feasible?

- Studied by DLR for ESA in 1995: hopping/tumbling probe (12 kg) for small body surface science
- Ballistic descent to surface
- Impact attenuation by layer of soft honeycomb
- Self-righting mechanism: may be used for tumbling mobility
- Primary battery as power source
- Payload: about 3 kg appear doable



Next steps

- Continue MASCOT study at DLR Bremen (next CDF session in July)
  - Trades on power (battery, Russian small RTG, solar cells)
  - P/L accommodation
  - Thermal design
- Contribute to ESA/JAXA ‚yellow book‘ for MP: describe two different-sized options: ~50 kg and ~10 kg
- Prepare the programmatic ground: e.g., held a first CNES/DLR R&D meeting yesterday

Conclusions

- Strong science case for an in-situ science lander
  - Guiding the choice of sampling site
  - Science complementary to that of SR
- European heritage of small body lander: Rosetta-Philae
- Lander study team will pursue two different sized options to be prepared for emerging flight opportunities

Backup material