Marco Polo: A sample return mission to a primitive NEO

Session IX: Sample Return Challenges

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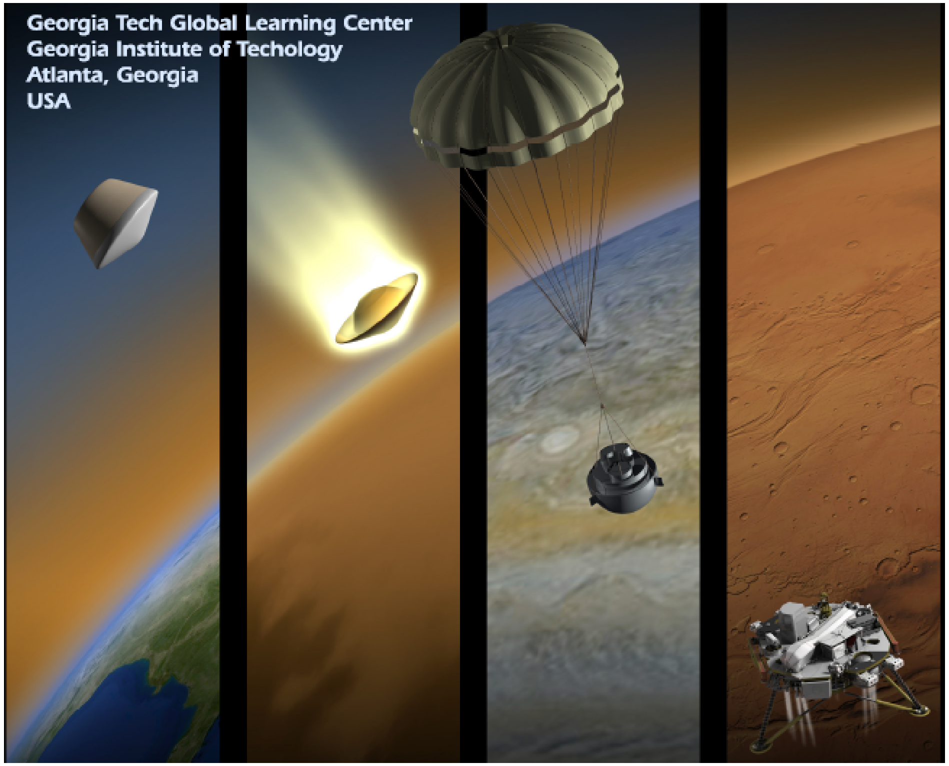

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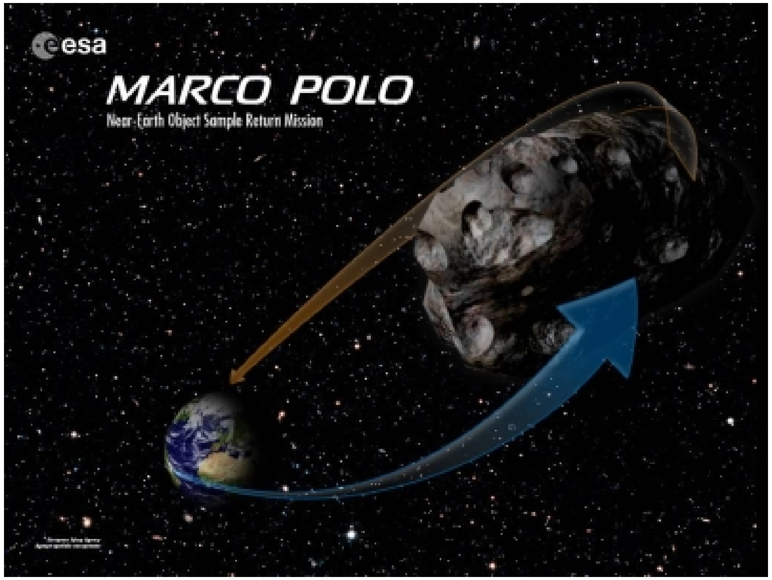
Outline

- Cosmic-Vision context
- Marco Polo science requirements
- Scope of the CDF study
- NEO target selection and baseline mission profile
- Sampling strategy, sample acquisition and transfer system
- Orbiting, descent and landing on a NEO
- High-speed Earth re-entry
- Overall spacecraft design
- Technology development approach



ESA Cosmic-Vision

- ❑ Future of the ESA Scientific programme 2017-202X
- ❑ Cosmic Visi
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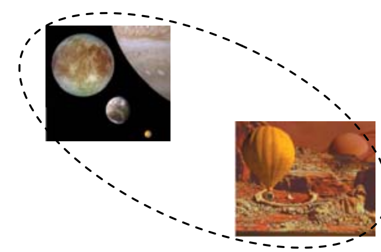
- ❑ 50 proposal
- ❑ 9 proposals structures → assessment M€ budget)

Cross-Scale

Euclid

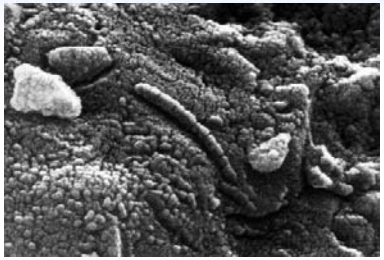
Marco Polo

Plato



- ❑ Down selection of 2 M missions to enter definition phase ~ mid-2009
- ❑ Final M mission selected in 2011 for implementation

Requirements and payload



- Defined by US, European and Japanese scientists
- Go to a D, T, C or B type NEO (most primitive)
- Return > 30 g sample (goal 100 g)
- Place sample in their global/local context
- Provide complementary info not available from the samples
- Multiple sampling locations (non-uniform composition)
- Maximum sample temperature: + 40ºC (organics)
- Sample composition (cm-sized pebbles + small particles)
- Avoid contamination of the sample
- Instruments: wide & narrow angle camera, Vis-NIR & mid-IR spectrometer, laser altimeter, neutral particle analyzer, radio science experiment

	Spatial resolution for imaging in the visual	Spatial resolution for VIS/IR spectrometer	Spatial resolution for mid-IR instrument
Global characterisation	**Order of dm**	**Order of m**	**Order of 10 m**
Local characterisation x 5	**Order of mm**	**Order of dm**	**Order of dm**
Context measurements	**Tens of µm**	-	-

Scope of the ESA CDF Study

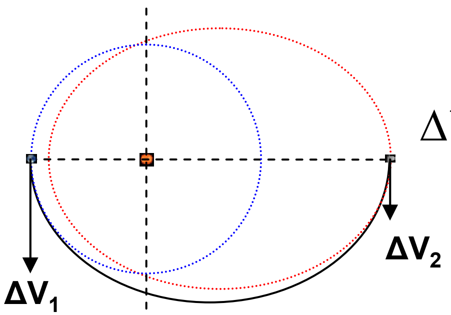
- **Internal ESA pre-assessment study (similar to NASA JPL Team X)**
- **Objectives:**
  - Critical assessment of initial Marco Polo proposal
  - Establish a feasible & cost-efficient mission profile option
  - Fulfil science objectives & requirements
  - Feed forward upcoming industry studies
  - Help define required technology development
- **Discussions with JAXA ongoing**

  → As a starting point CDF study focuses on European expertise : NOT meant to be representative of selected Phase A scenario
- **M-mission Cosmic-Vision technology constraints:**
  - No major development can be undertaken until definition phase unless strong generic interest
  - TRL 5/6 by 2011

  → build on ongoing development and off-the-shelf equipment

NEO selection

- Preliminary global screening (> 5000 known NEO!)
- Global optimization algorithms run over ~ 15 targets based on specific optimization criteria
- More in-depth mission analysis + design iterations for 4 targets



$$\Delta V_1 + 2 \times \Delta V_2 + \Delta V_i$$

NEW TARGET PROPOSALS WELCOME !!!

Provisional designation	Number	Type	q (AU)	Q (AU)	i (deg)	HV	D (km) assumes p=0.06	Prot (hrs)
1989 UQ	65679	C	0.67	1.16	1.3	19.28	0.76	7.733
1999 JU3	162173	Cg	0.96	1.42	5.9	19.2	0.78	7.5
2001 SK162	162998	T	1.01	2.84	1.7	17.77	1.52	68
2001 SG286		D	0.89	1.83	7.8	20.93	0.35	?
1999 RQ36	[illegible]	[illegible]	0.9	[illegible]	[illegible]	[illegible]	0.37	2.146
1996 FG3	[illegible]	[illegible]	0.69	1.42	[illegible]	[illegible]	1.23	3.5942
2001 AE2	138911	T	1.24	1.46	1.66	19	0.86	?
2001 FC7	[illegible]	Cg[1]	[illegible]	[illegible]	[illegible]	[illegible]	1.26	?
1977 VA	[illegible]	[illegible]	[illegible]	2.6	[illegible]	[illegible]	0.84	?
1998 KU2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.76	?
1960 UA = Anza	[illegible]	TCG	[illegible]	[illegible]	[illegible]	16.56	2.65	5.75, 11.5
1979 VA = Wilson-Harrington	4015	Dormant comet	0.99	4.28	2.8	15.99	3.44	3.56, 6.1
1991 DB	14402	C	1.03	2.41	11.4	18.4	1.13	2.266
2000 RW37	162567	C	0.94	1.56	13.7	19.74	0.61	?
1998 UT18	85774	C	0.94	1.87	13.6	19.07	0.83	34

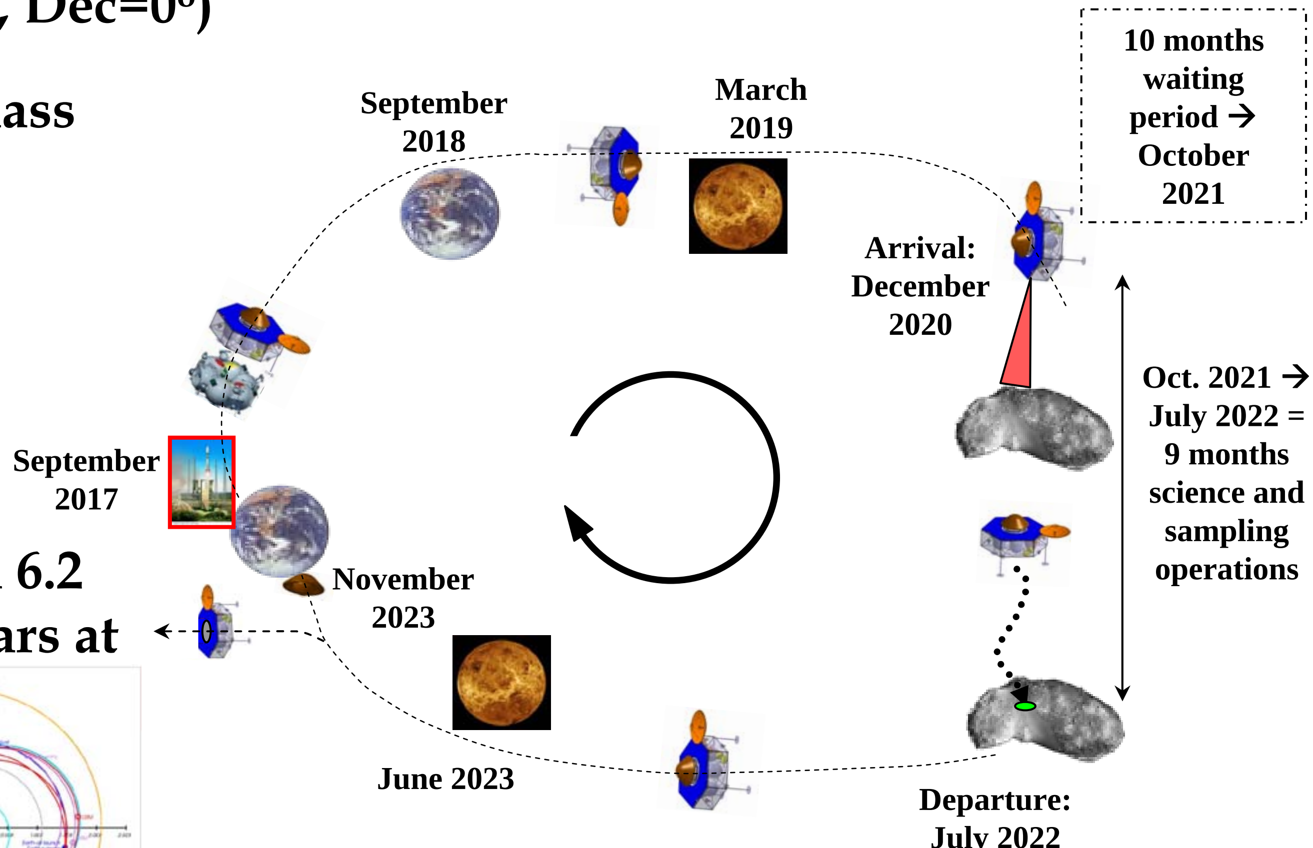
[1] To be confirmed by observations

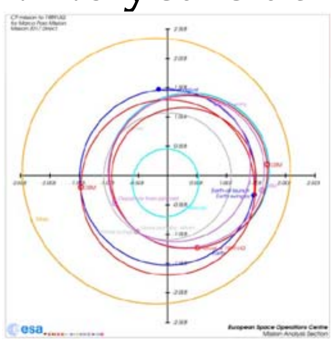
NEO	LAUNCH			CRUISE			ARRIVAL		SCI	DEPARTURE	CRUISE	ENTRY			TOTAL	
name	escape	V-inf	dec	swb1	swb2	swb3	date	kg	yea	date	swb	date	V-ent	kg	m/s	years
1999 JU3	19/11/30	4.000	-10	20/12/04			22/01/20	1550	1.5	23/07/18		24/12/03	12.13	1303	2665	5.0
	17/12/28	3.466	10	20/08/17	20/12/05		22/04/28	1759	1.2	23/07/18		24/12/04	12.13	1471	2288	6.9
2001 SK162	18/08/27	3.394	-45	19/02/13	20/12/10		23/03/07	1294	0.8	23/12/06		26/01/08	12.75	1188	2951	7.4
	17/08/25	3.396	0	18/08/25	19/02/12	20/12/09	23/04/04	1444	0.7	23/12/06		26/01/08	12.75	1324	2615	8.4
1989 UQ	18/09/19	3.490	-30	19/03/05			20/12/07	1610	1.7	22/08/04	23/06/24	23/11/16	11.83	1366	2517	5.2
	17/09/20	3.492	0	18/09/20	19/03/05		20/12/20	1702	1.6	22/08/04	23/06/24	23/11/16	11.83	1444	2345	6.2
2001 SG286	18/01/28	3.889	6	19/03/27	20/12/25		22/07/19	1041	1.3	23/10/24		25/05/22	15.13	903	3803	7.3
	18/03/24	3.553	0	19/04/14	20/05/21		22/03/22	1380	1.6	23/10/24		25/05/22	15.13	1195	2932	7.2

Venus Earth Mars

Baseline mission analysis

- Launch by Soyuz-Fregat 2-1b from Kourou on direct escape (V_{inf} = 3.49 km.s^{-1}, Dec=0º)
- 1566 kg launch mass capability
- Total mission $\Delta V \sim 1143$ m.s^{-1}
- Re-entry velocity ~ 11.8 km.s^{-1}
- Mission duration 6.2 years, incl. 1.6 years at NEO

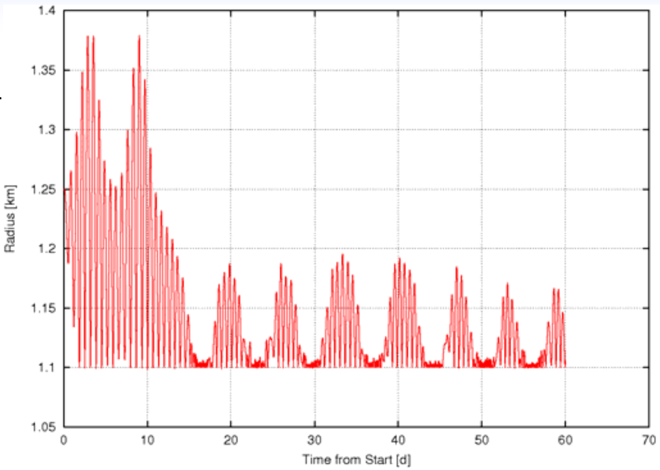




Proximity operations

Both uncontrolled (for radio science) and controlled orbits have been analyzed assuming:

- 1989 UQ physical properties (tumbling, 4:2:1 shape, ~ 760 m diameter, 7.7 h rotation, 1300 kg/m^3, etc.)
- Solar radiation pressure
- Sun's gravity influence (influence of planets' negligible)



Activity	Instruments	Orbit	Distance [km]	Duration [weeks]	Comment
Initial Fly bys	WAC, NAC RSE, Laser Alt.	Fly by	TBD	2	Initial estimation of the mass of the Asteroid
Far Global Characterisation	WAC, NAC RSE, Laser Alt Vis IR, Mid IR	5 km formation flying	5	2	Spin axis and rotational period
Detailed Gravity Field	RSE, WAC Laser Alt.	Terminator orbit	3	4	Detailed gravity field
Global Characterisation	WAC, NAC RSE, Laser Alt Vis IR, Mid IR NPA	1.25 km 9 AM orbit	1.25	8	Low resolution mapping of the Asteroid
Local Characterisation	WAC, NAC RSE, Laser Alt Vis IR, Mid IR	Descent to 100 m	0.1	5	High resolution characterisation of potential landing sites
Landing	Cl'e up imager APXS, Volatile Temperature	Landing	0	10	Sample collection

1 month

7 months

Sampling strategy, sample acquisition and transfer system

- ❑ **Possible strategies:**
  - Hover & go
  - Touch & go
  - Short-term landing
  - Long-term landing
- ❑ **Rotating corer used as sample vessel**
- ❑ **Mounted at the tip of telescopic boom**
- ❑ **Inserted into rotating corer holder (ERC backcover) further transferred to ERC via elevator**
- ❑ **20 N down-thrust during sampling operations**
- ❑ **20-30 minutes operations**

→Smooth landing

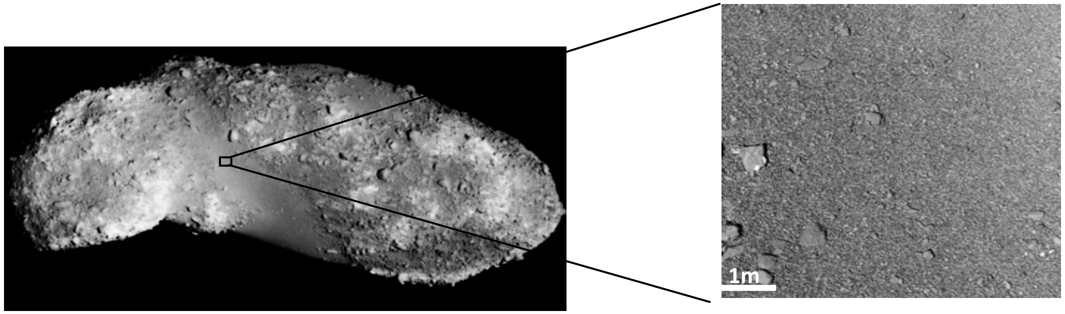
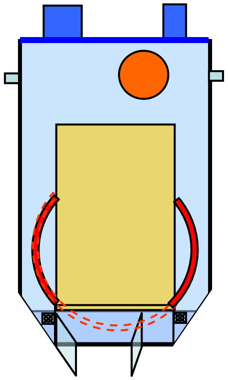
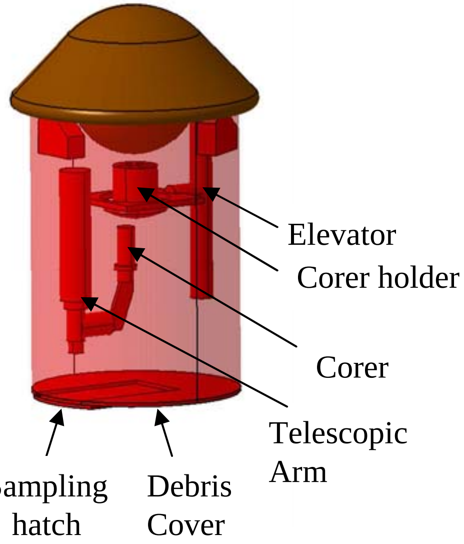


Image courtesy: JAXA





Descent and landing

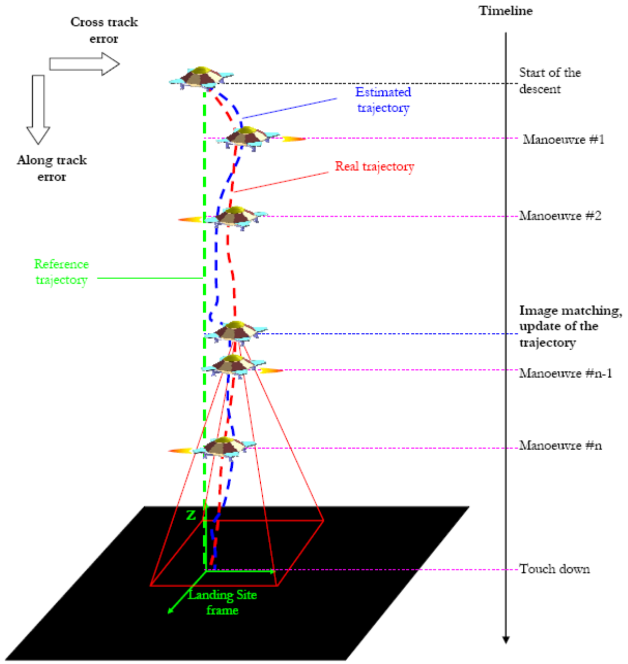
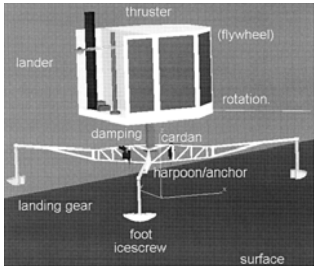
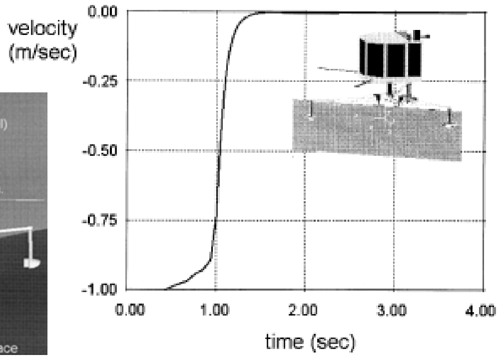


Image courtesy: Astrium Ltd

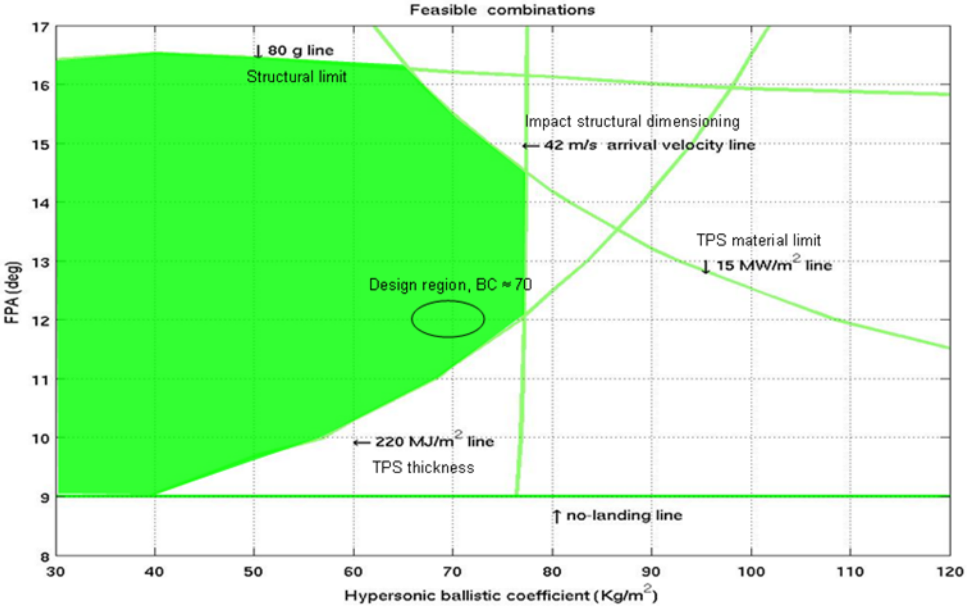
- **Navigation strategy (vision-based)**
  - Get a good shape/gravity model and map hazards from orbit
  - Descent down to 150 m
  - "Go" decision → Autonomous + 90º slew
  - Controlled descent (lateral)
  - Landing conditions: $V_V < 20$ cm.s^{-1}, $V_H < 5$ cm.s^{-1}, $\theta < 10^o$
  - Landing accuracy < 5 m → safe site
  - Autonomous battery-powered descent, landing, sampling and ascent operations (~ 2 hours)

- **Landing structure/mechanism**
  - Philae damping system or multistage crushable
  - Much higher clearance requirement
  - No anchoring



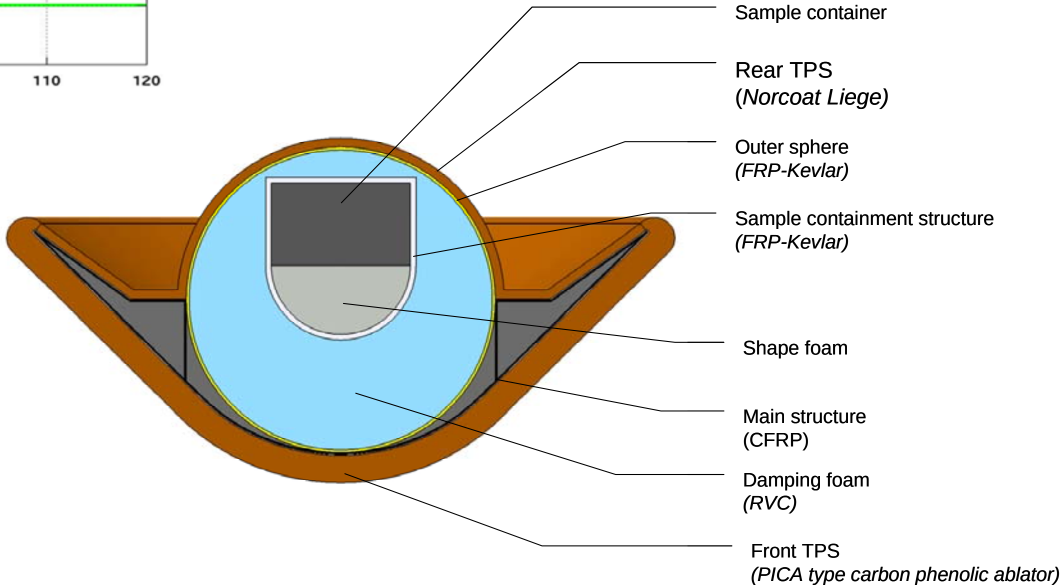


High-speed Earth re-entry



- 11.8 km.s^{-1}, FPA~-12°
- Landing load on the sample: 800 g
- Peak heat flux: 11.3 MW.m^{-2}
- Heat load: 209 MJ.m^{-2}
- Entry duration: 484 s

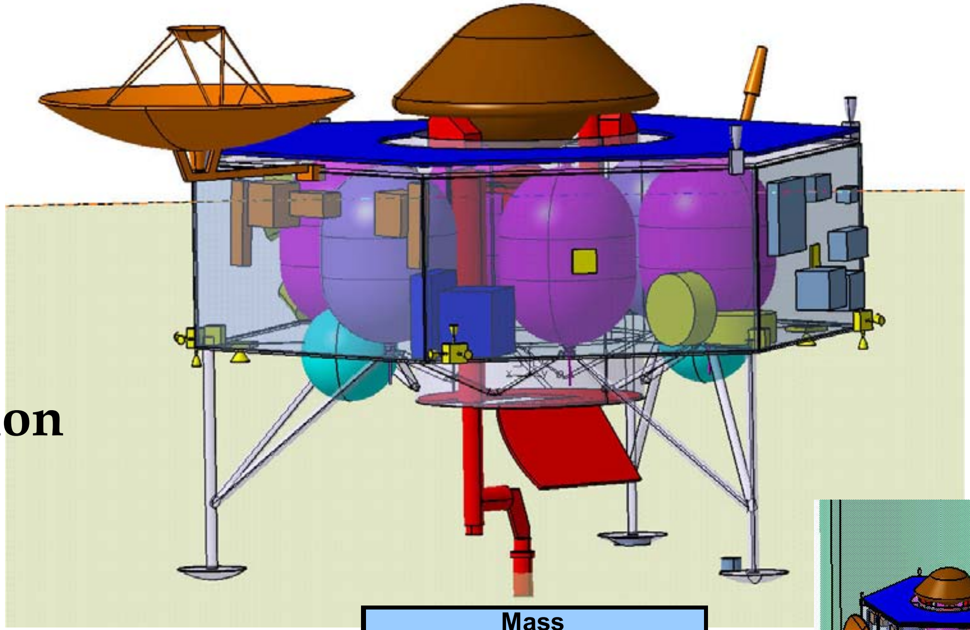
- PICA-like (260 kg.m^{-3}) front TPS, Norcoat-Liege rear TPS
- 45° half-cone angle
- 1.1 m base diameter
- 200 mm RVC foam
- 76 kg capsule



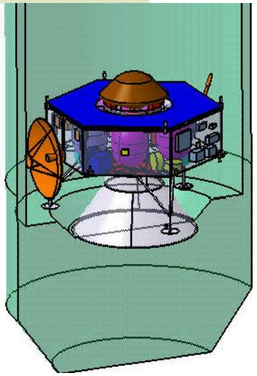
Spacecraft design

Outbound propulsion Module	Orbiter	Descent Module	Sampling Module	Earth Return Vehicle	Earth Re-entry Capsule

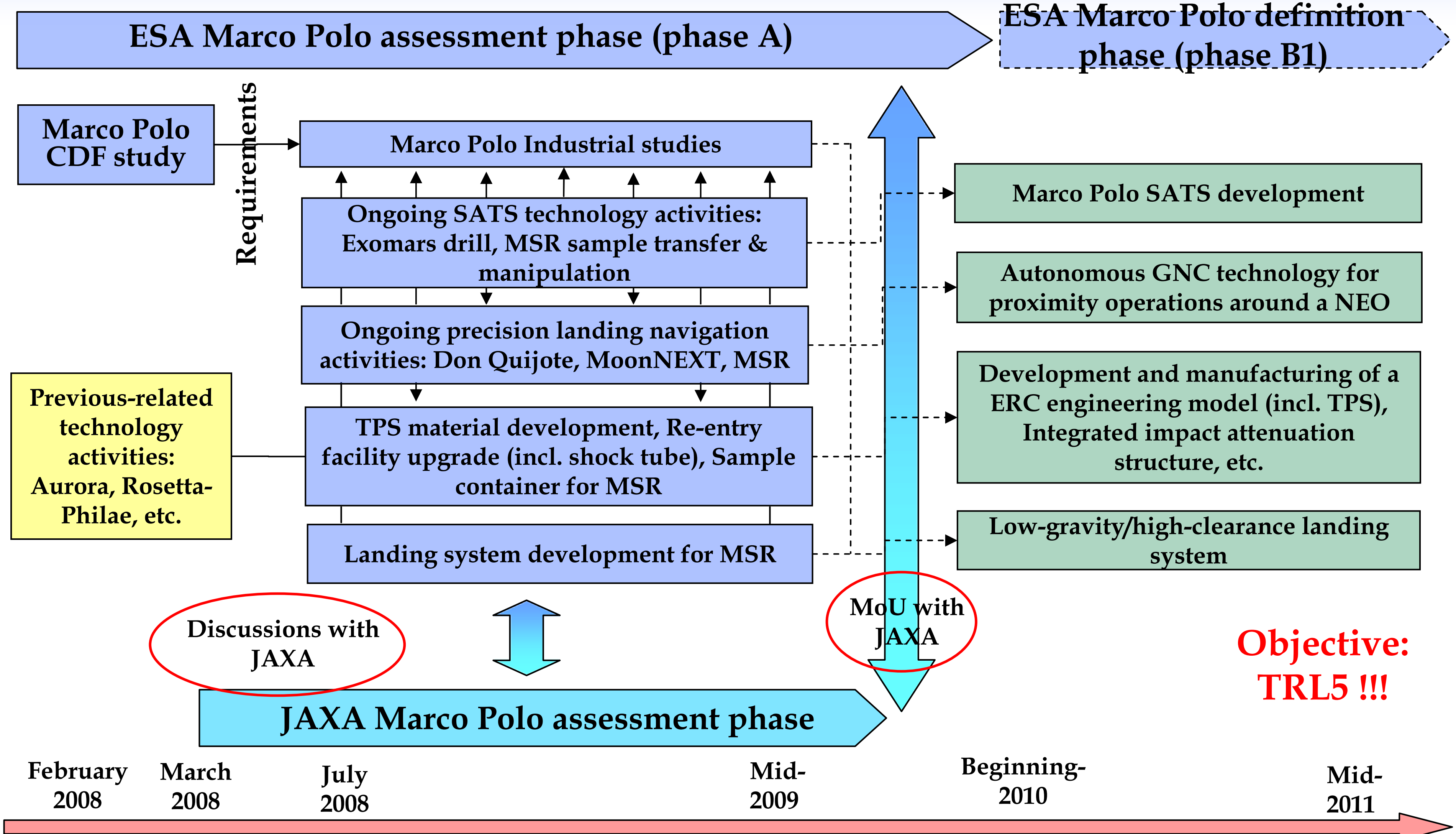
- Body-mounted solar arrays (485 W)
- Low-thrust dual mode propulsion system
- 3-axis controlled
- 3 landing legs
- Central SATS accommodation
- Surface thermal control to be further analyzed (i.e. keep sample cold & high temperature mechanisms)



	Mass
Orbiter-lander dry mass incl. system margin	646 kg
Orbiter-lander wet mass	1191 kg
ERC	76 kg
Orbiter-lander propellant mass	545 kg
Launch mass	1267 kg
Launch mass incl. adapter	1312 kg
Launch vehicle performance	1566 kg
Below mass target by	- 254 kg



Technology development



Summary and way forward

- ESA pre-phase A feasible mission design taking advantage of past/ongoing European technology development
- ESA industrial assessment studies (In // to JAXA study)
  - Kick-off: Sept. 08
  - Conceptual Design: Sept. 08 – Dec. 08
  - Selection of baseline design together with JAXA
  - Detailed Mission Design: Jan. 09 - Jun. 09
  - Programmatics data: Jul. 09

  → *Re-opened assessment (target, architecture, S/C design, etc.) to be iterated and converged with JAXA*
- Parallel instrument studies
- Planetary protection working group
- Set of technology activities defined and proposed + planned workshops/working Groups (e.g. Navigation around low-gravity bodies end of this year)