A combined Exobiology and Geophysics Mission to Mars 2009

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European Programme of Mars Exploration

Mars Express
Beagle 2
Netlanders
Earth re-entry capsule
ExoMars
Mars Sample Return

Entry, Descent and Landing Demonstrator

Entry, Descent and Landing Demonstrator

This study is based on lessons learned from Beagle 2

With particular regard to the ESA Inquiry Board “Recommendations”

Entry, Descent and Landing Demonstrator

Mission should:

(i) recover the science lost on Beagle 2

(ii) provide the long desired network of geophysical measurements

(iii) act as a precursor for the Aurora programme – mobility/sample return

Why Two Landers ?

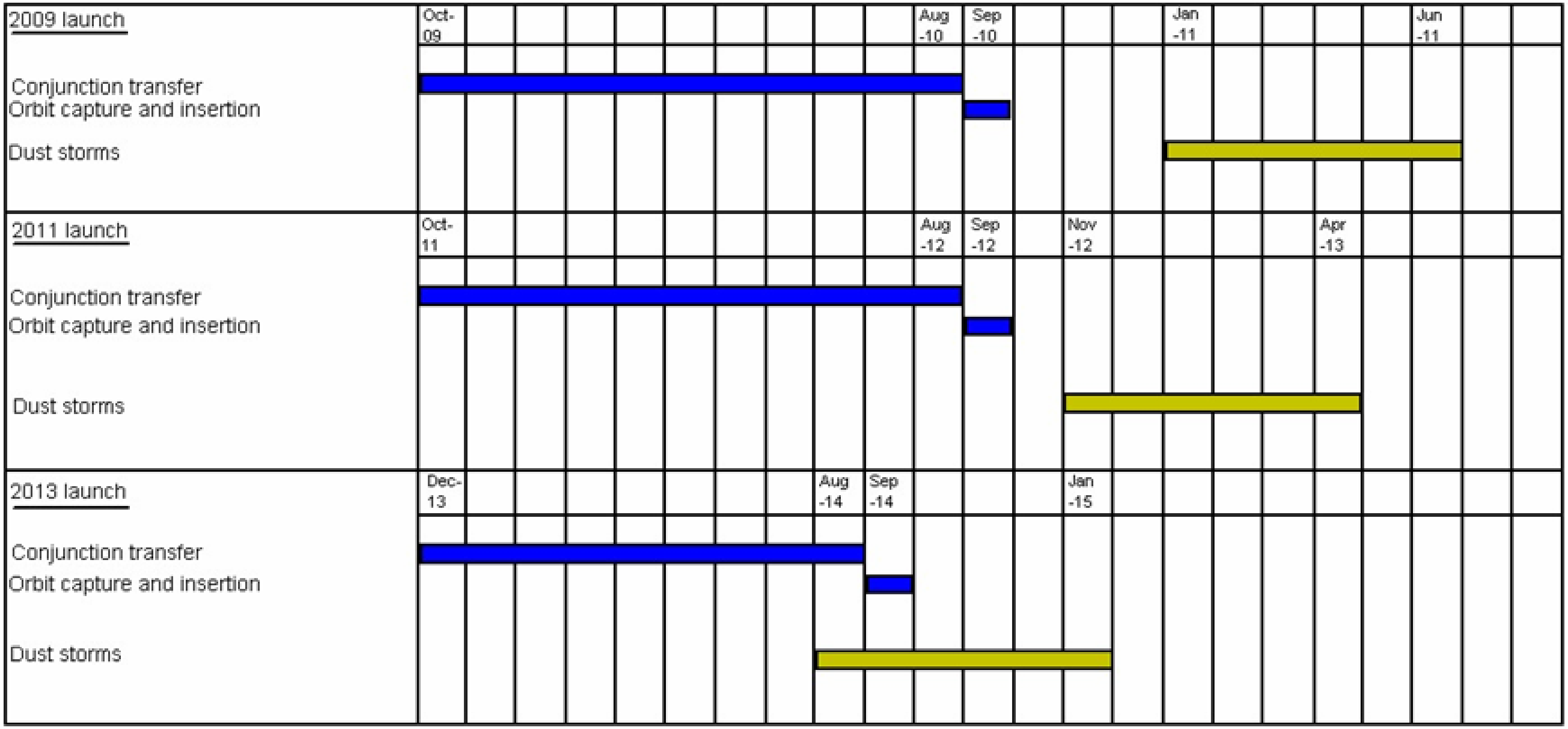
- - I don't care how much testing you do - you cannot build a perfectly safe Mars lander.
- - we built two of everything. Two rockets, two landers, two rovers, two payloads, identical up and down the line, but we built two of everything. …..
- - if you have a robotic mission that must succeed, if you don't send two, you're crazy, in my personal opinion.

Steve Squyres (MER Rover PI) 18th Oct 2004

Transfer opportunities 2009 and later

Earth-Mars Opportunity	Launch Date	Trans Time (days)	Arrival Date	Vinf Depart (m/s)	Vinf Arrive (m/s)	Total Vinf (m/s)
2009	14-Oct-09	324	2-Sept-10	3207	2464	5671
2011	10-Nov-11	306	11-Sep-12	2990	2707	5698
2013/14	7-Dec-13	294	27-Sep-14	3066	3177	6244

Dust Storm Avoidance
(90 day science mission)



Dust Storm Avoidance
(90 day science mission)

- **A mission post 2009 loses the impetus gained by MeX**
- **The unique science proposed for Europe would be lost to other missions**

	2009	2011	2013/4
1. Conjunction transfer	yes	no	no
2. Accelerated conjunction transfer	yes	yes	no
3. Long duration transfer	yes	yes	yes

2009 Mission Characteristics

Launch date	October 2009
Launch vehicle	Soyuz-Fregat (from Kourou)
Arrival date	September 2010 (Ls 140)
Orbiter type	Eurostar 2000 class (4 tanks)
Landing locations	45°N to 45°S
Landing site altitude	Up to 0km MOLA with margin
Landing site accuracy	Ellipse size ~ 60km
Orbiter comms relay	Elliptical orbit; ~ 12hr (6 or 24hr ?)
Science mission duration	90 Sols+ (outside dust storm season)
Two probes/landers both from orbit	Two de-orbit and re-orbit manoeuvres
One hyperbolic entry and one from orbit	Single de-orbit re-orbit manoeuvre

Spacecraft Description

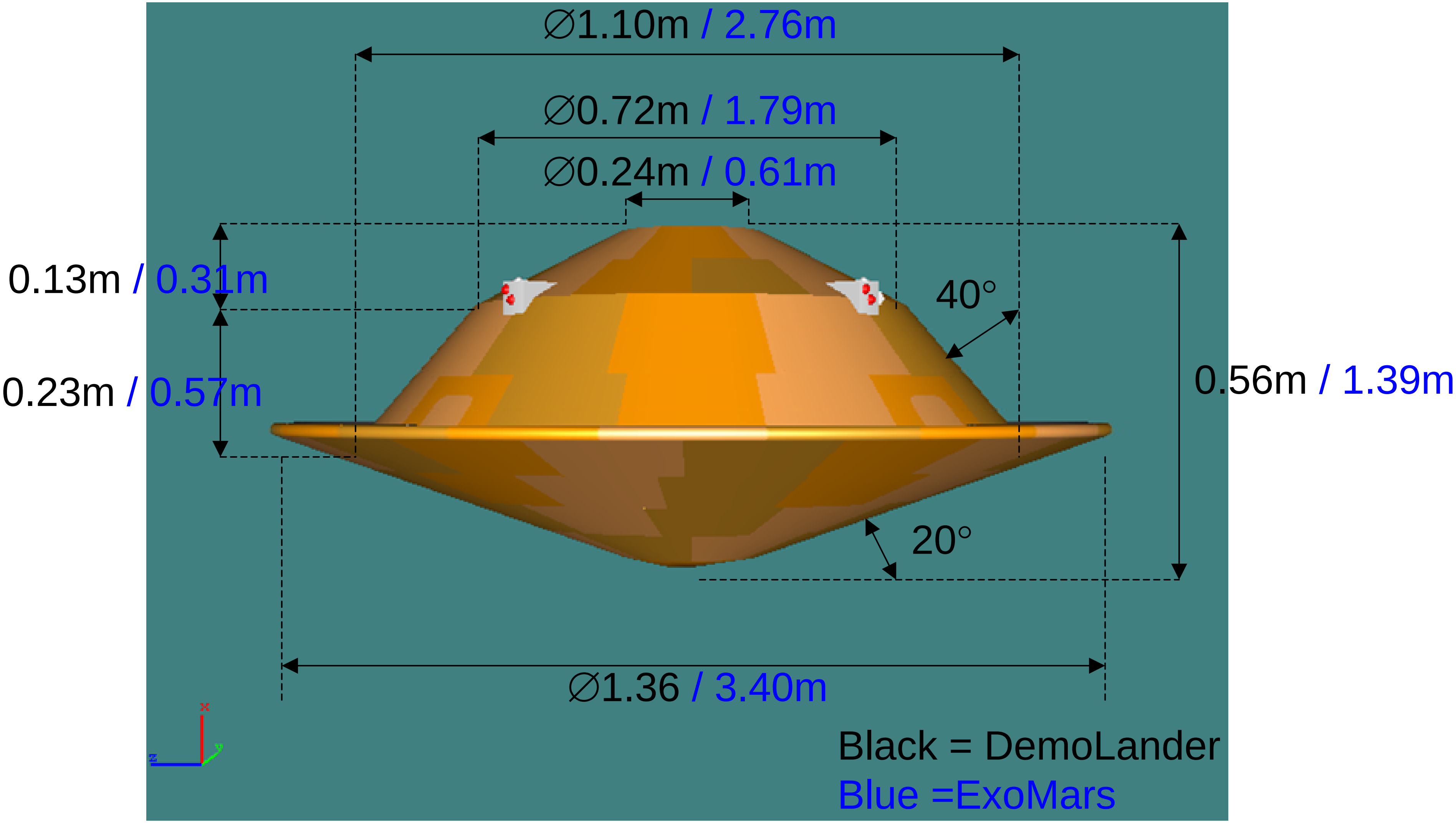
- Probe Aeroshape
- Configuration
- EDLS
- Communications
- Power
- Accommodation on Orbiter
- Mass budgets and analysis
- Risk reduction recommendations
- Planetary Protection
- Technology status

Aeroshell and Overall Configuration

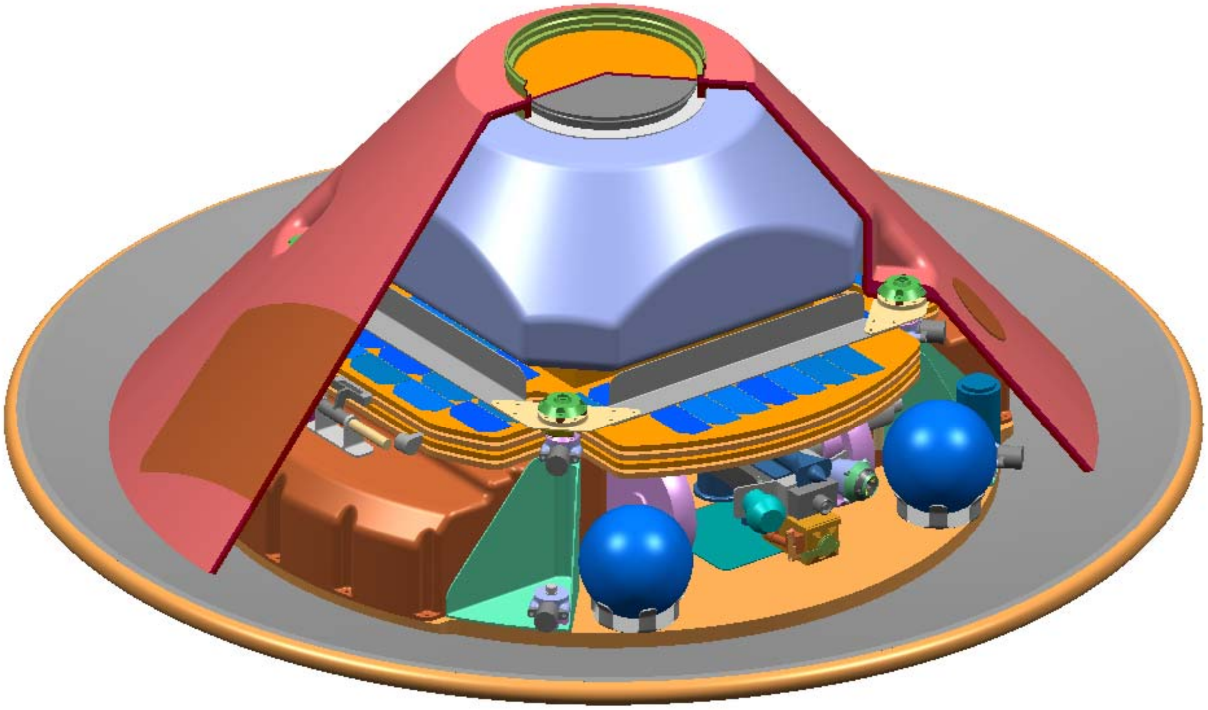
Probe Aeroshape

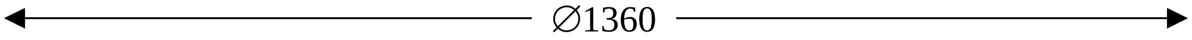
- ExoMars DM aeroshape expected to be based on Viking
- EDLS demonstrator mission, requires:
  1. Viking shape front shield (70° half-cone) geometry
  2. ExoMars stepped / bi-conical back cover geometry
  3. Similar ballistic coefficient to ExoMars DM
- Adopting 40% scaled Astrium ExoMars aeroshape design:
  - Front Shield ∅1.36m
  - Back Cover ∅1.1m
  - Ballistic Coefficient ~ 55kg/m^2 (ExoMars = 58kg/m^2)

Aeroshell Geometry



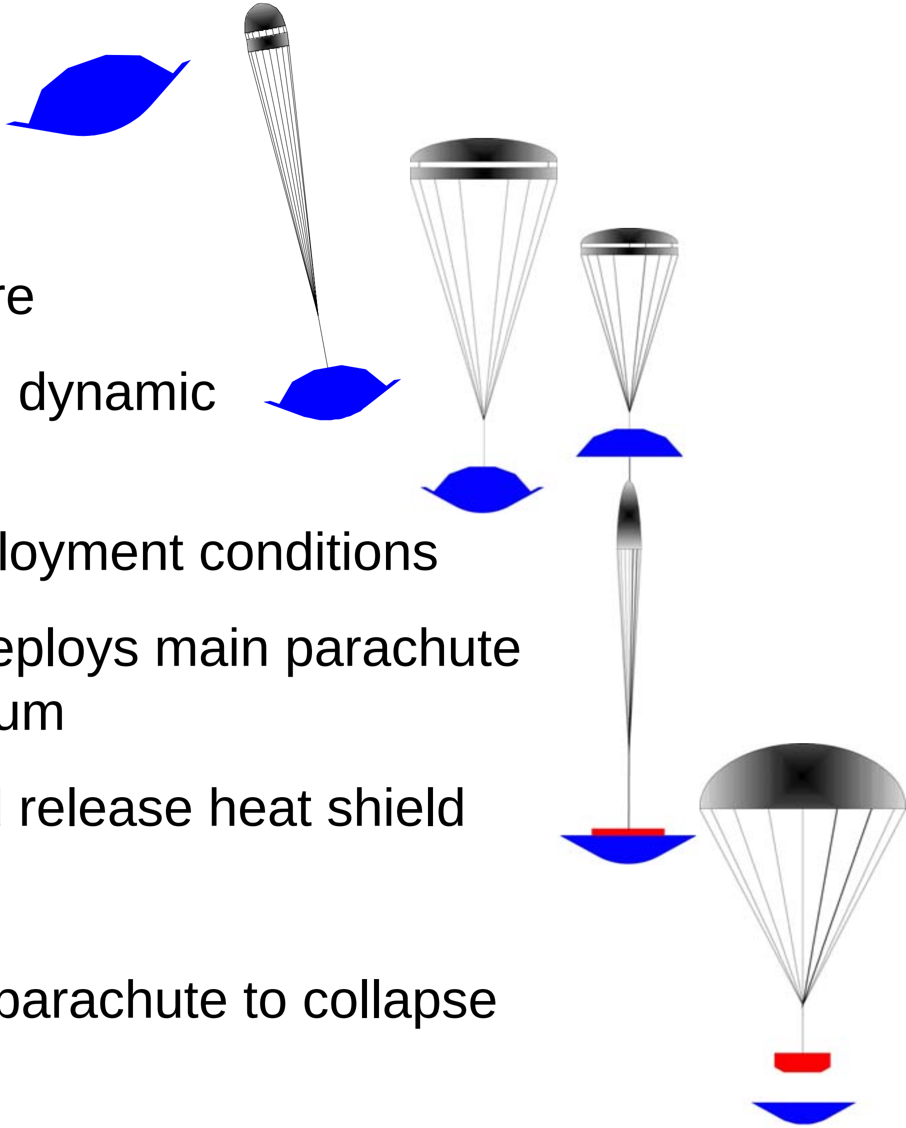
Internal View





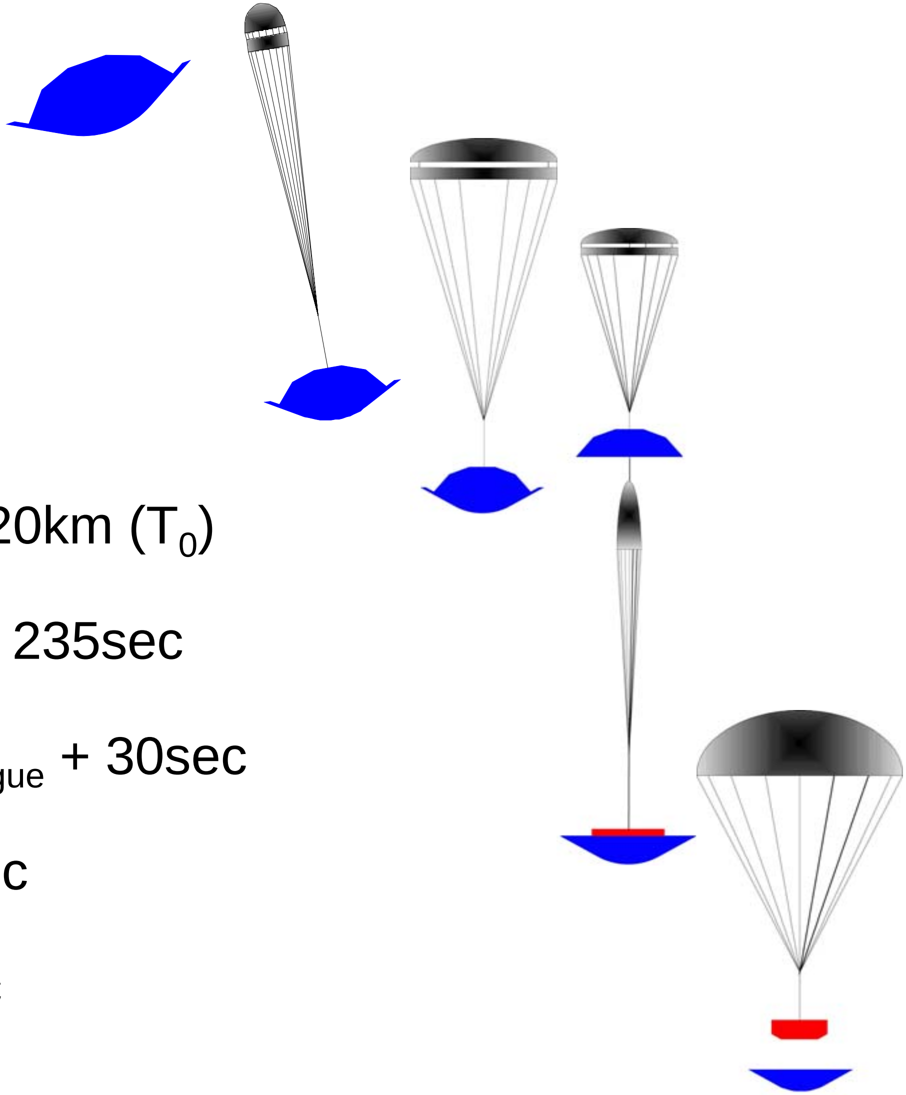
EDL System and Comms

EDL Sequence



- Entry detected by dynamic pressure
- Deploy drogue at 1.8<M<1.6 when dynamic pressure below drogue maximum
- Drogue retards lander to main deployment conditions
- Drogue removes backcover and deploys main parachute at dynamic pressure below maximum
- When main parachute fully inflated release heat shield
- Inflate gas bags at chosen altitude
- Vent gas bags on impact, release parachute to collapse down wind
- Data sources, accelerometers, LIDAR, radar altimeter, clock

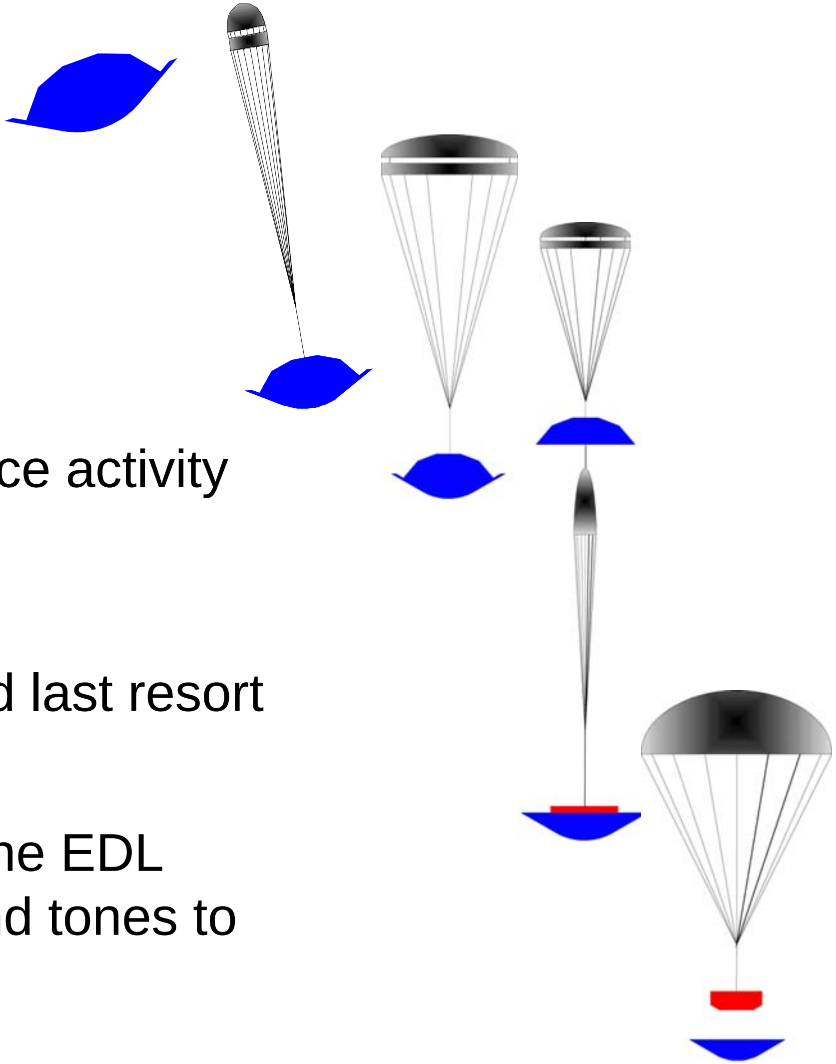
EDL Sequence



Typical:

- Atmospheric entry detected at ~ 120km (T_0)
- Last ditch drogue deployment T_0 + 235sec
- Main parachute deployment ~ T_{drogue} + 30sec
- Heat shield released ~ T_{main} +15sec
- Gasbags inflated $T_{touchdown}$ – 10sec
- Touchdown

EDLS Compliance with Requirements



- Safe landing
  - 700m/s^2 limit
  - lands upright with access for science activity
  - no contamination
- Closed-loop operation based on direct measurements of the environment (and last resort decision capability)
- Feedback measurements throughout the EDL sequence to orbiter (back-up carrier and tones to Earth-based telescopes)

EDL System Parameters

Drogue Parachute

Type	Viking geometry Disk Gap Band
Deployment method	Mortar
Diameter	3.5 m
Mass	4.2 kg

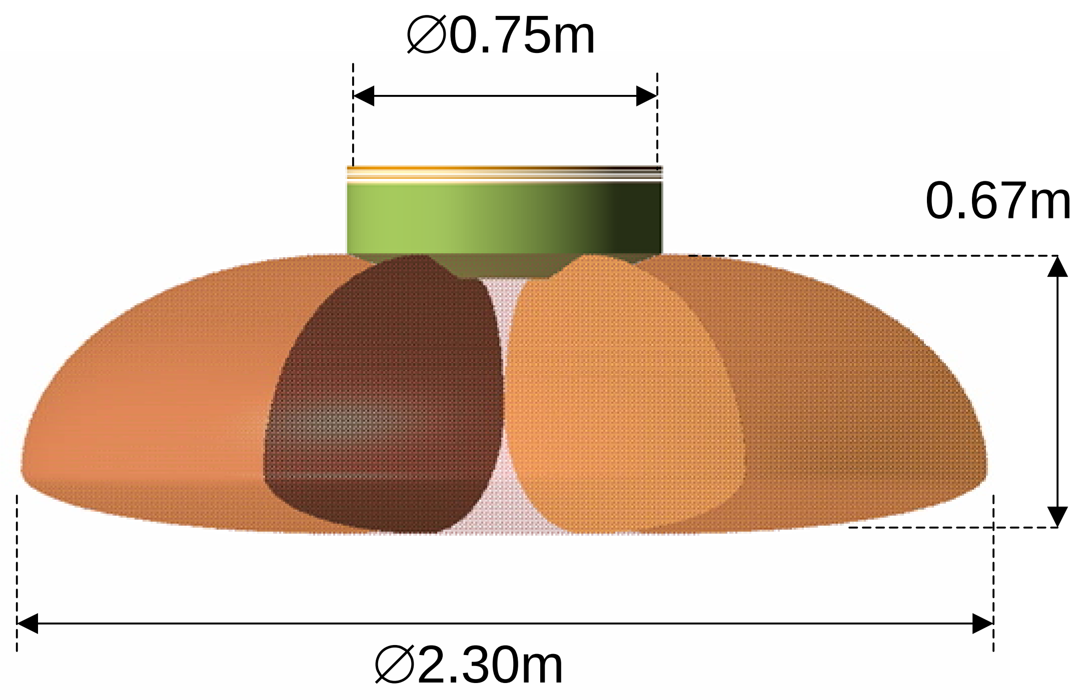
Main Parachute

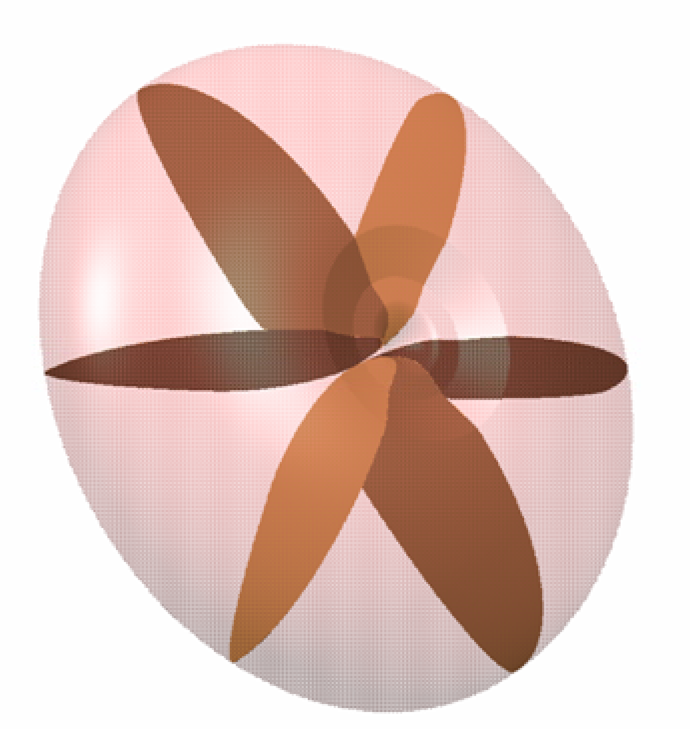
Type	Beagle type Ringsail
Deployment method	Extracted by drogue
Ballistic coefficient ratio at heatshield separation	30
Diameter	15.2 m
Mass	7.8 kg
Terminal descent speed	15 m/s

Airbag

Type	Vented multi-chamber with anti-bottoming bag
Diameter	2.6 m
Height	0.9m
Maximum deceleration at impact	$70\ g_{earth}$

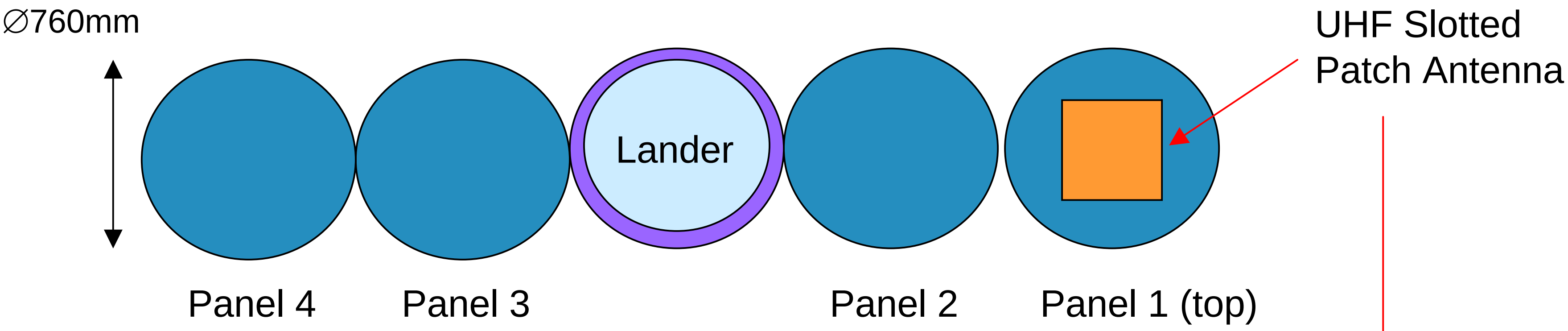
Dead-beat Gasbag – Inflated Geometry





- 70g max impact deceleration
- 6 compartments
- Anti-bottoming airbag (not shown for clarity)
- Uses stored N_2 gas (minimises surface contamination)

Solar Panels - Deployment

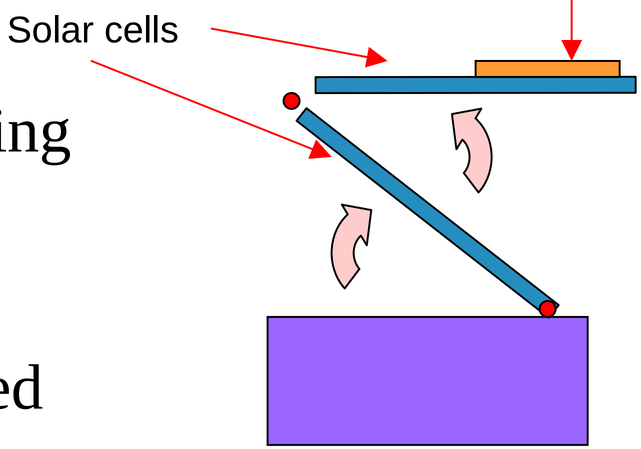


∅760mm

UHF Slotted
Patch Antenna

Lander

Panel 4 Panel 3 Panel 2 Panel 1 (top)



Solar cells

- Cells and antenna ‘face-up’ during descent, on landing, during/post deployment
- Deployment via two synchronised panel motors

EDLS Advantages

- Low complexity solution
- Tolerant to discrepancies between expected and actual conditions
- Minimise single point failures
- Removes areas of random unpredictable risk
- Heritage from Huygens
- Provides feedback for future landing attempts
- Significant design margins

Lander Design Features

- Fits in 40% scaled ExoMars aeroshell
- X-band DTE comms during entry
- UHF Comms (relay to Orbiter and DTE) throughout descent and landing (can command procedure after landing from Earth)
- Some solar power during descent and landing
- No self-righting mechanism required (vented gasbags)
- Minimum operations to expose full solar panel area

Power

Solar Cell Area

- Assume European RWE cells : 80 x 40 mm; area 30.18 cm^2
- Assume Ls 140 (pm) and Ls 325 (am) landings - (2009 launch Option)
- Worst-case daily total energy required = 600 Whr (incl. 10% margin)
- Total solar cell area required = 1.138 m^2 (incl. losses)
- Number of solar cells = 377 (29 strings of 13 cells)
- Top panel = 65 cells (5 x 13)
- Lower panels = 104 cells (8 x 13)
- Coverage efficiency = 67%

Energy Balance Analysis (4 panels)

Season	20 - 45° S	0 - 15° S	0 - 15° N	20 - 45° N
Ls140 (BOL)	-243	+284	+420	+432
Ls185 (EOL)	+113	+415	+200	+209
Ls325 (BOL)	+550	+532	+339	-260
Ls10 (EOL)	-230	-137	-61	+245

Values are in Watt-hours

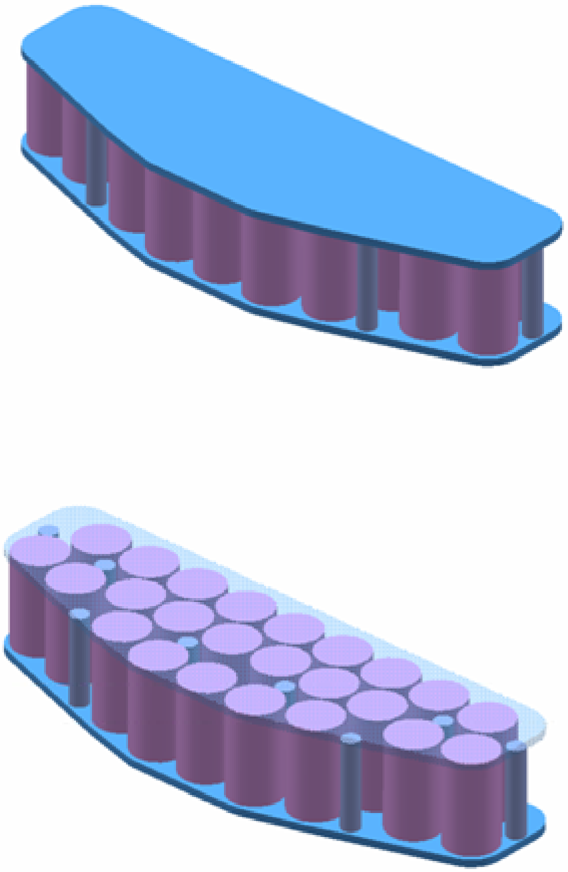
+ denotes power in excess of 600Whr

- denotes power deficit compared to 600Whr

Battery - Size

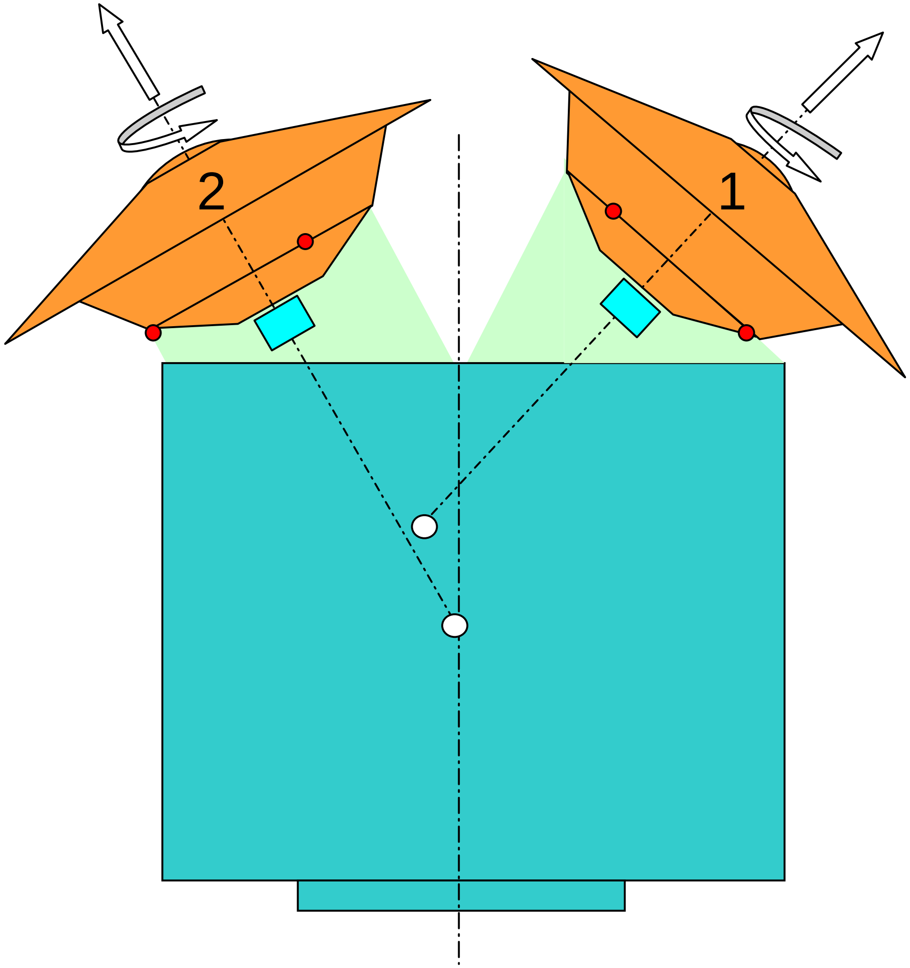
- Low temperature D-type (R20): ∅34mm x 62mm Li-ion cells
- Number of cells = 4 strings x 6 cells = 24 cells
- Pack shape not critical
- Capacity = 20 Ah

- Margin = 26% on worst-case



Accommodation on Orbiter

Twin Lander Orbiter Accommodation



Twin Lander Orbiter Accommodation

- On Eurostar – type Orbiter
- Upper floor mounting via adaptors
- Inclined with axis ~ through Orbiter CoM to minimise disturbance torques
- Beagle 2-type SUEM (locking ring / helical guide cylinder / spring)
- 4 Pyro hold-downs at outer adaptor diameter
- CFRP slant cylinder adaptor structures with ‘flexible’ central SUEM mount
- Bioshield around aeroshell back cover for category IVa+/ IVc?

Risk Reduction

Risk Reduction

- All “Recommendations” by ESA Inquiry Board accepted
- Two lander philosophy increases chances of success
- Continuous Comms strategy means lander never out of touch

Mass Budgets

Lander Mass Breakdown

LANDER MASS

Item	Mass (kg)
Science Payload	
GAP	6.0
Rover (inc. PAW & Seismometer)	9.9
Camera / Arm	2.5
Other Instruments	2.0
	20.4
Lander Systems	
Structure	13.8
Mechanisms	2.2
Thermal Control	0.5
Solar Panels	5.9
Battery	3.0
Common Electronics	2.9
UHF Comms	1.6
EDLS Sensors	1.6
Harness	2.3
	33.8
Total exc. margin	**54.1**
System Margin @ 20%	10.8
Total inc. system margin	**65.0**

Mass of Lander

- **54 kg w/o margin**
- **65 kg with margin**

Probe Mass Breakdown

PROBE ENTRY MASS

Item	**Mass (kg)**
Lander	
Science Payload	20.4
Lander Systems	33.8
	54.1
EDLS	
Front Shield	20.4
Back Cover	13.5
Mortar/Drogue Chute	5.9
Main Chute	5.4
Airbag System	14.6
X-Band Comms	0.6
Sensors	0.1
Harness	0.7
Aeroshell MLI	1.9
	63.1
Total exc. margin	**117.2**
System Margin @ 20%	23.4
Total inc. system margin	**140.7**

Mass of Probe at Entry

- **117 kg w/o margin**
- **141 kg with margin**

System Mass Breakdown

TOTAL SYSTEM MASS

Item	**Mass (kg)**
Probe	
Lander	54.1
EDLS	63.1
	117.2
Orbiter Systems	
SUEM & Hold-Downs	4.2
Adaptor Structure	9.1
Thermal	0.7
Electrical Interface Unit & Harness	2.0
	16.0
Total exc. margin	**133.2**
System Margin @ 20%	26.6
Total inc. system margin	**159.9**

Total Mass of 2 Lander Systems

- **266 kg w/o margin**
- **320 kg with margin**

Mission Useful Mass

Maximum useful mass =

Launch capability
- propellant inc. 5% on ΔV
- propulsion system (engine; tanks, pipework etc)
- launch vehicle adaptor
- 20% margin

= spacecraft dry mass + payload

Launch Mass Margins – GTO-like Transfer

	GTO-like Inter-Planetary Transfer					
	Both Landers Released from Orbit			**1st Lander Released on Approach, 2nd from Orbit**		
Mars Orbital Period (hrs)	**6**	**12**	**24**	**6**	**12**	**24**
	Mass (kg)	**Mass (kg)**	**Mass (kg)**	**Mass (kg)**	**Mass (kg)**	**Mass (kg)**
"Useful Mass"	**768**	**860**	**922**	**817**	**901**	**960**
Payload (without system margin)						
2 Lander Systems	266	266	266	266	266	266
Remote Sensing	20	20	20	20	20	20
Monitoring Cameras	1	1	1	1	1	1
UHF Comms Relay	12	12	12	12	12	12
	299	**299**	**299**	**299**	**299**	**299**
Orbiter						
Dry mass - less prop'n related	477	477	477	477	477	477
Structure reinf. for lander payload	8	8	8	8	8	8
	485	**485**	**485**	**485**	**485**	**485**
Total	**784**	**784**	**784**	**784**	**784**	**784**
Margin (in excess of 20%)	**-16**	**76**	**138**	**33**	**117**	**176**

12hr+ Orbits give satisfactory launch mass margin over and above 20%

Science

Science Aims

- Detection of carbon on Mars
- Biogeochemical cycles
- Methane - at what concentration does it exist ?
  - recognisable production locations ?
  - biological *vs* volcanic origin ?
- Other trace atmospheric constituents
- Is Mars geologically active ?
- Mars internal structure
- Dating processes on Mars
- Electrical and magnetic properties
- UV and radiation environment
- Meteorology, climate

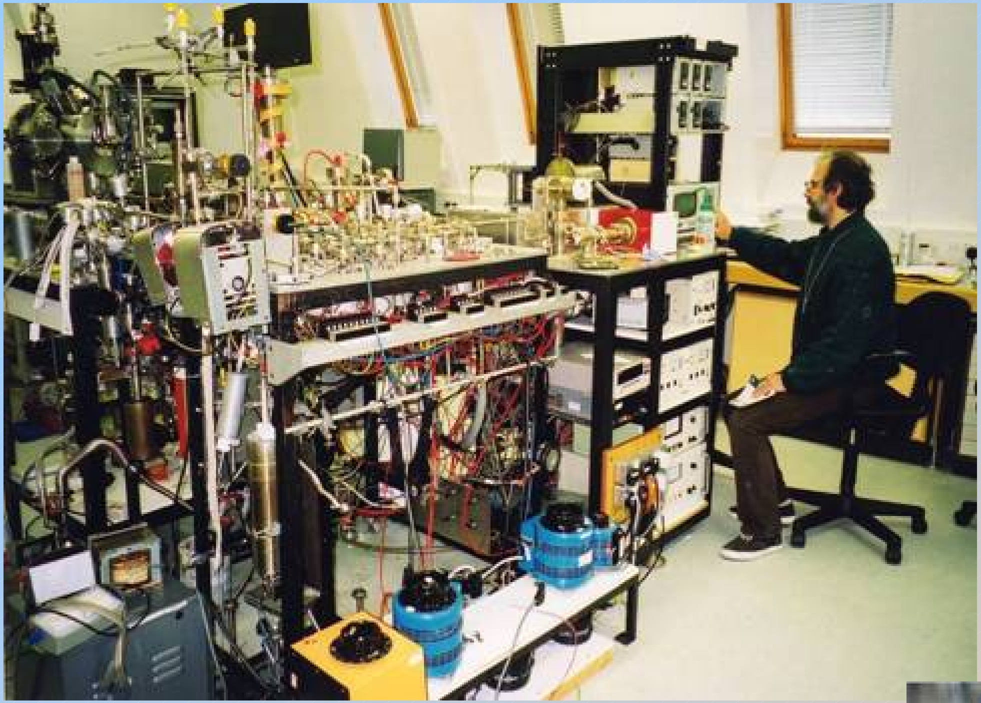
Science Payload

Gas analysis package	Solid and atmospheric samples
Seismometer	High and low frequency modes
Cameras	Panoramic and navigational
Other geochemical analysis	XRF, Mossbauer, microscope
Other geophysics	Magnetometer, radioscience, radar
Sample handling systems	Robotic arm, corer grinder, mole
Mobility	Small rover

Mass Budget for Payload

	kg	weighed
Gas analysis package (mass spectrometer etc)	6.0	90%
Rover (structure, drive systems, tether, seismometer, geochemistry, sample handling	10.0	50%
Camera systems (robot arm, panoramic camera, some sensors)	2.5	90%
Other (geophysics, remaining sensors)	2.0	25%

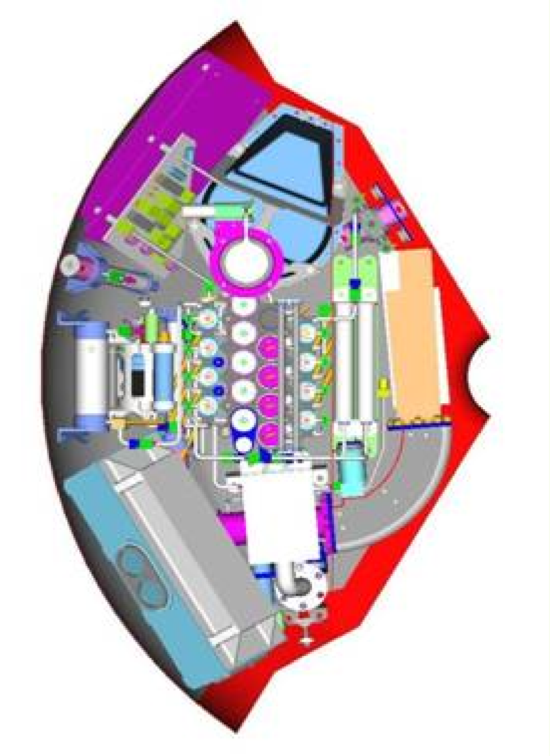
Total mass **20.5 kg**

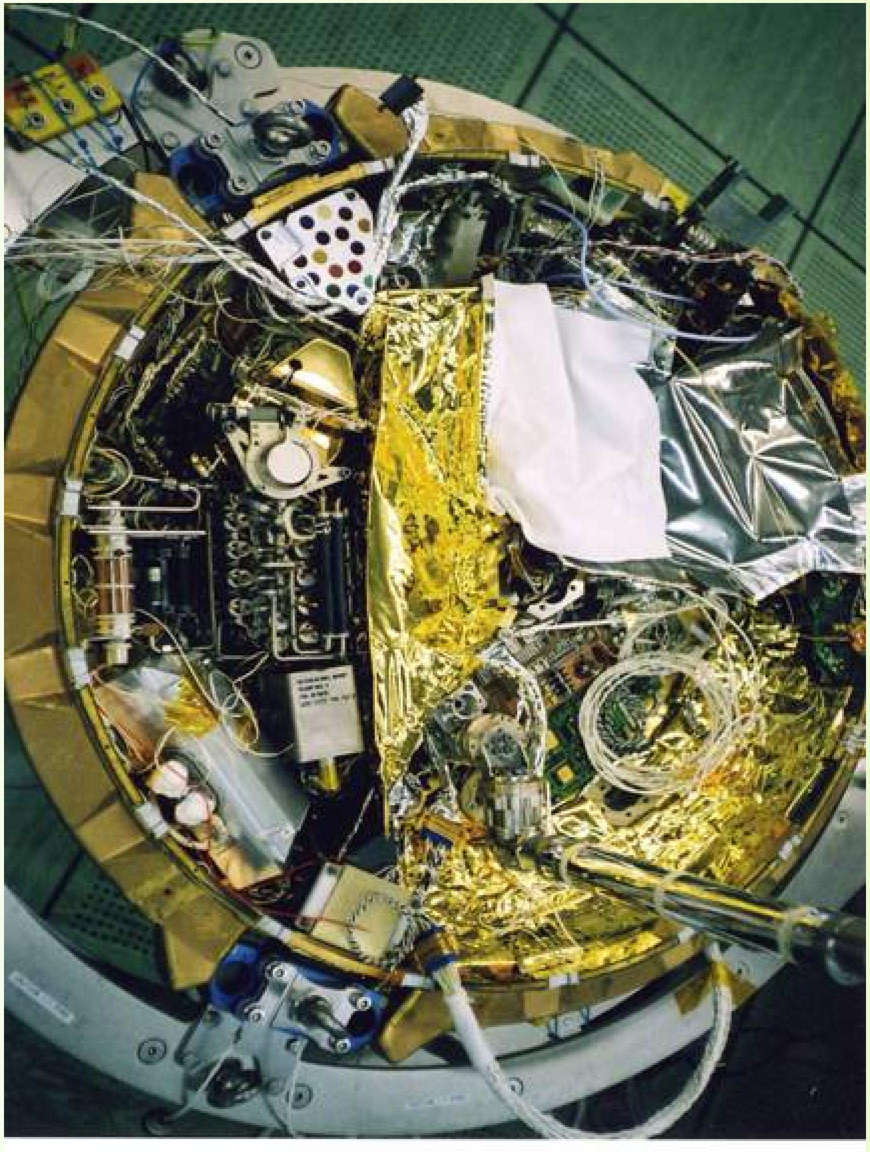


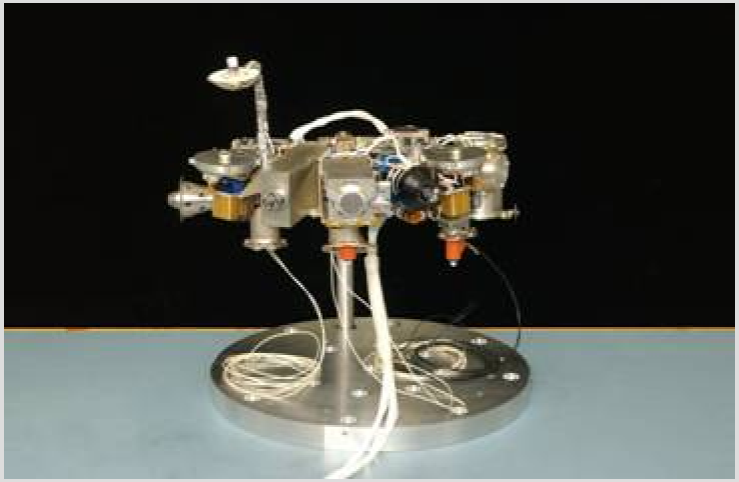
Beagle 2
Gas Analysis Package

A room full of equipment shrunk to 5.5 kg

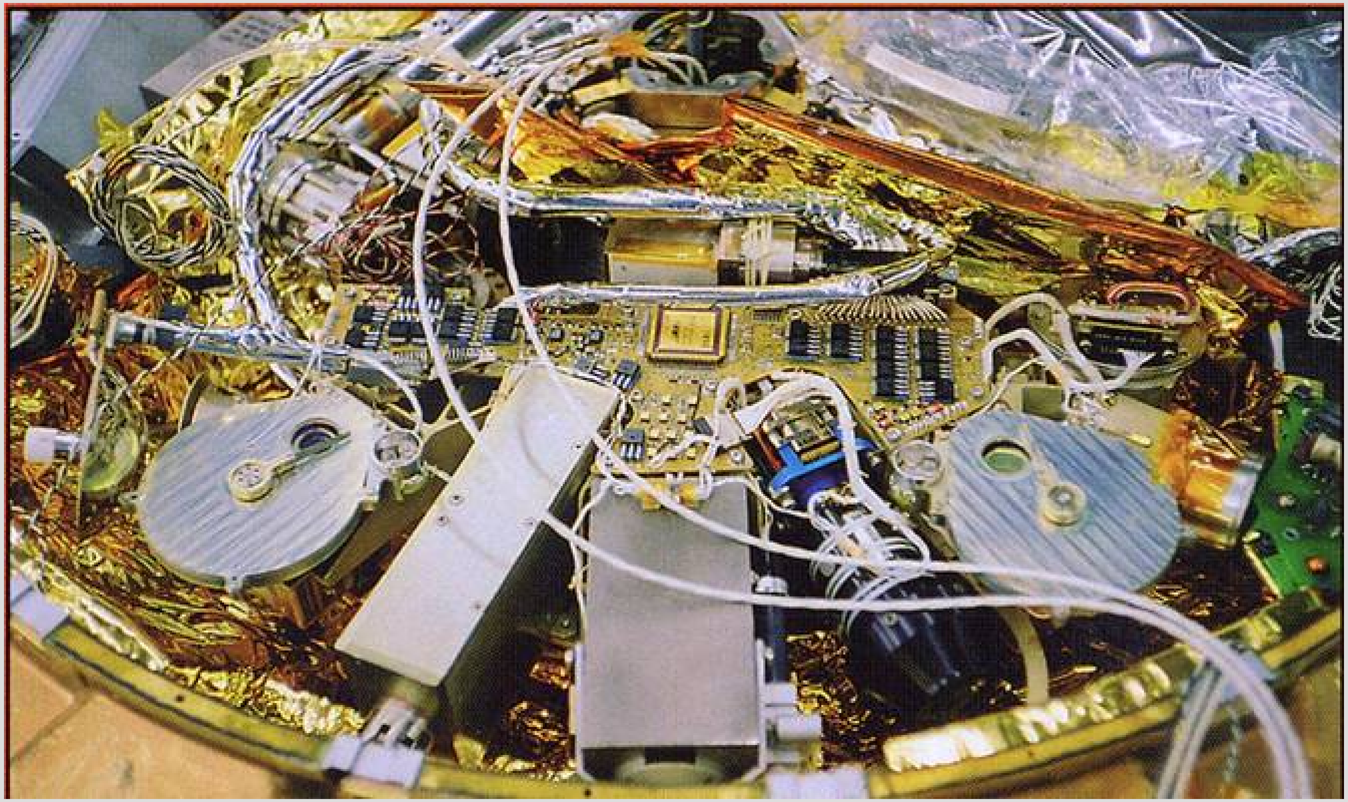
The life detection instrument inside the lander

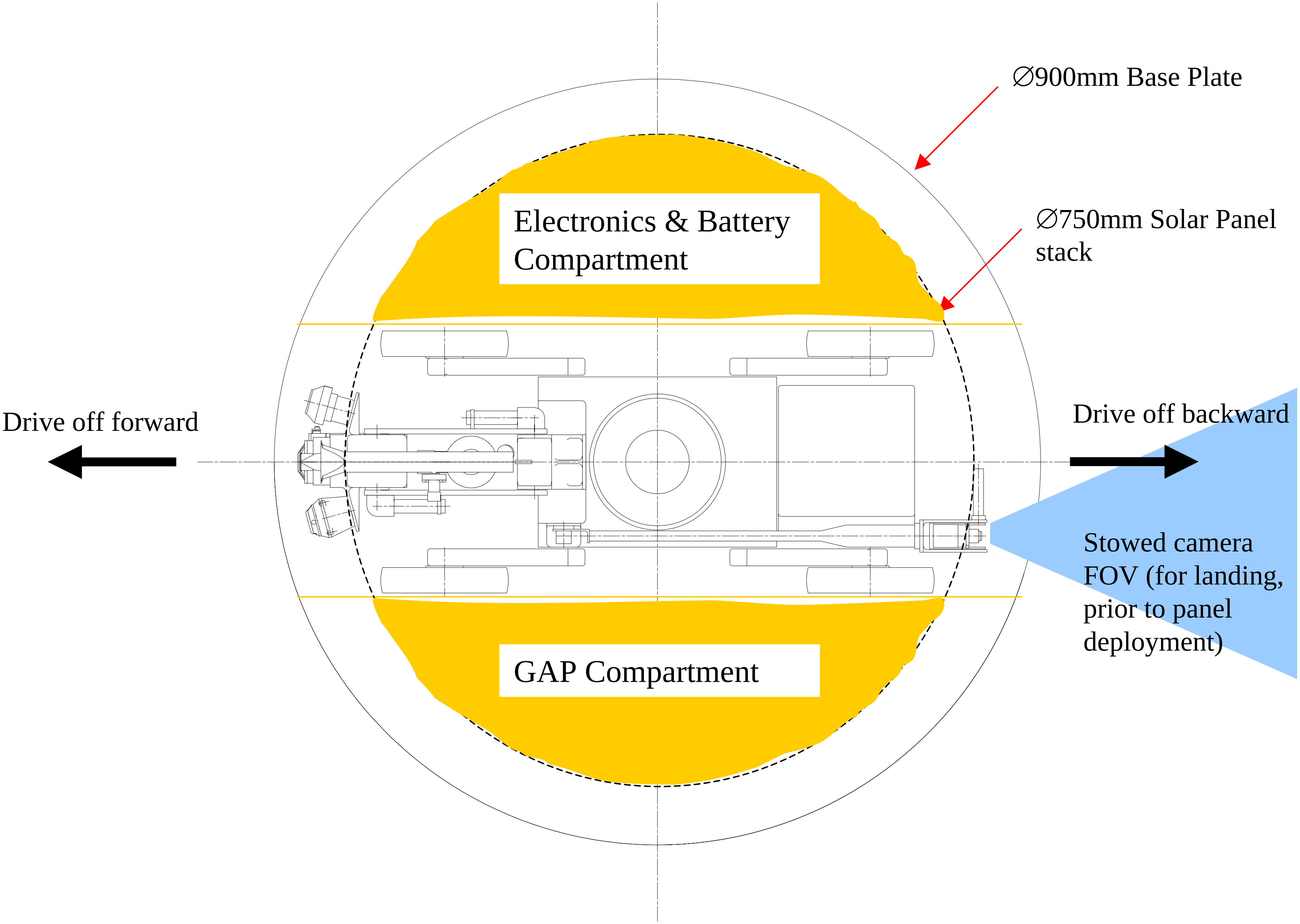






The Beagle 2 Position Adjustable Workbench (PAW)





∅900mm Base Plate

∅750mm Solar Panel stack

Electronics & Battery Compartment

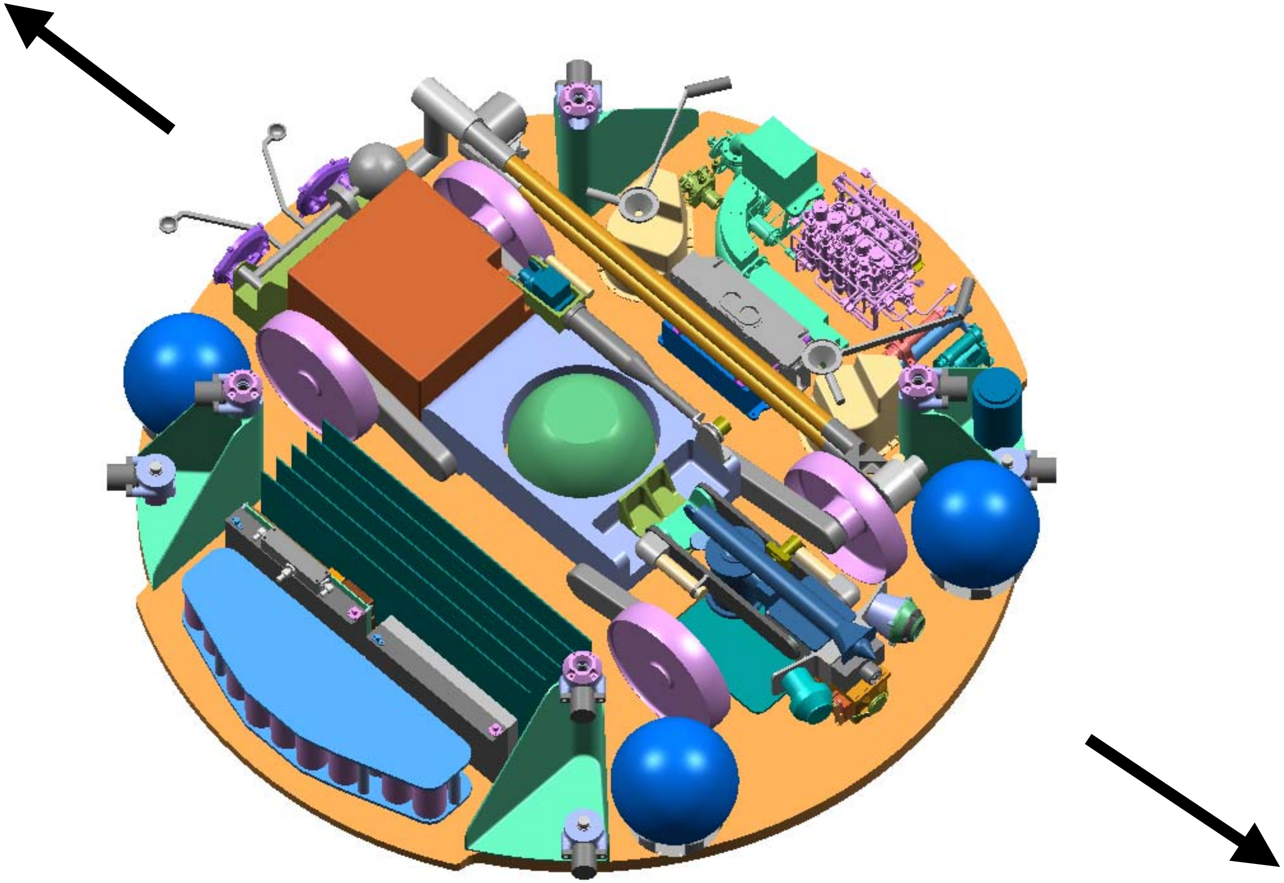
Drive off forward

Drive off backward

Stowed camera FOV (for landing, prior to panel deployment)

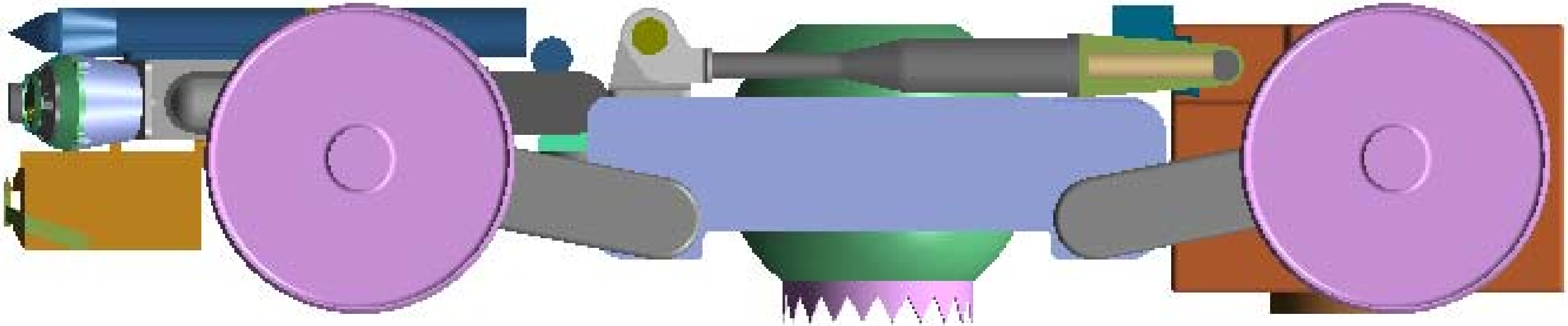
GAP Compartment

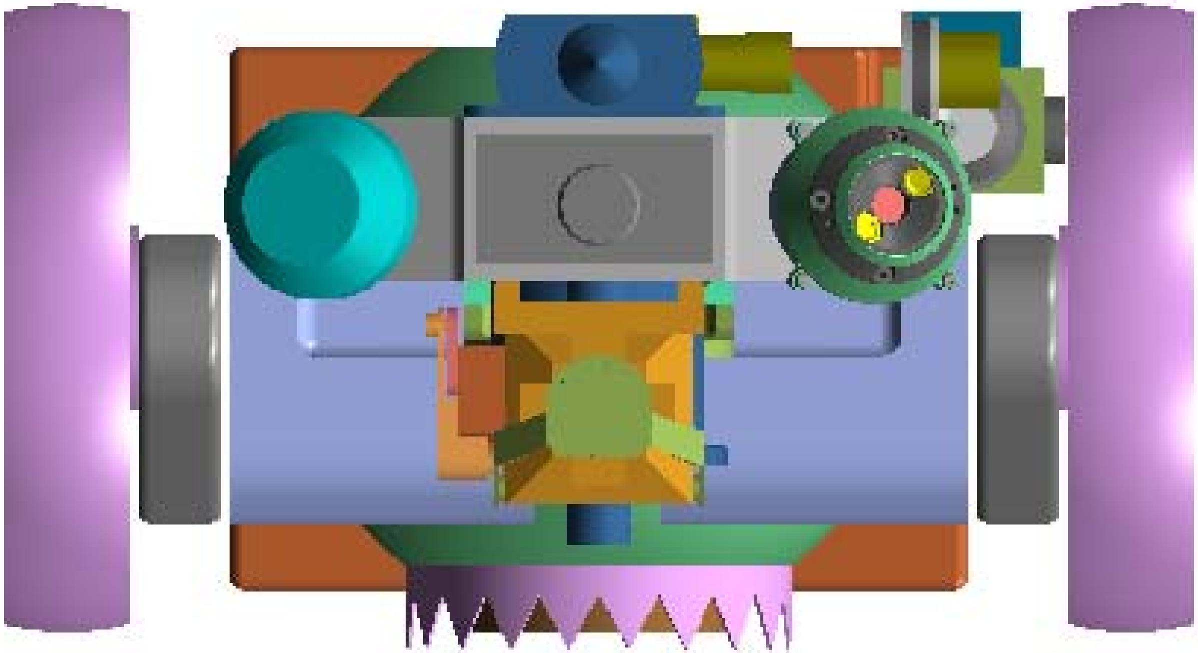
Rover and equipment accommodation on Lander



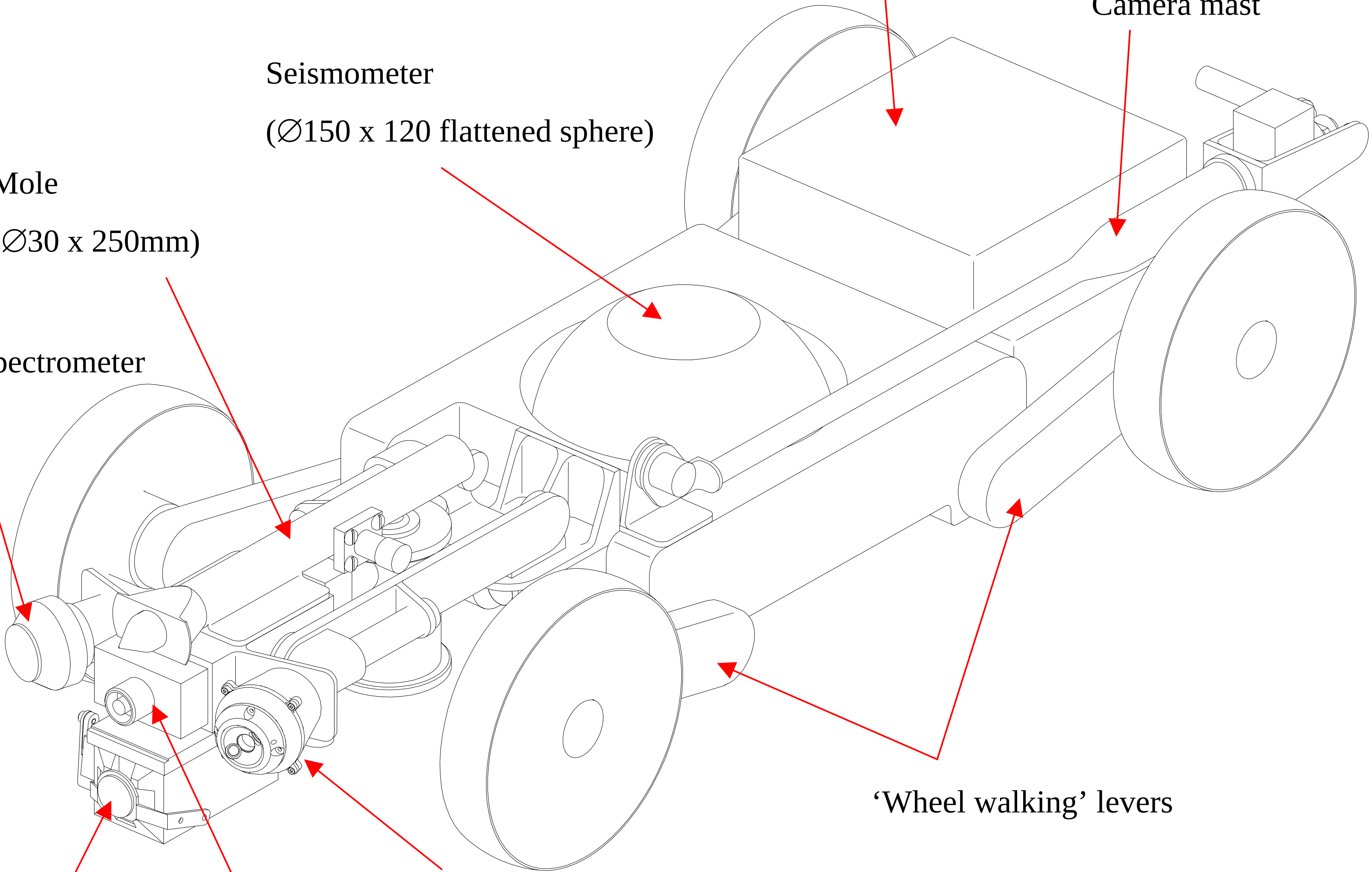
Drive off backward

Drive off forward





Stowed Rover



Rover Electronics warm enclosure

Camera mast

Seismometer

(∅150 x 120 flattened sphere)

Mole

(∅30 x 250mm)

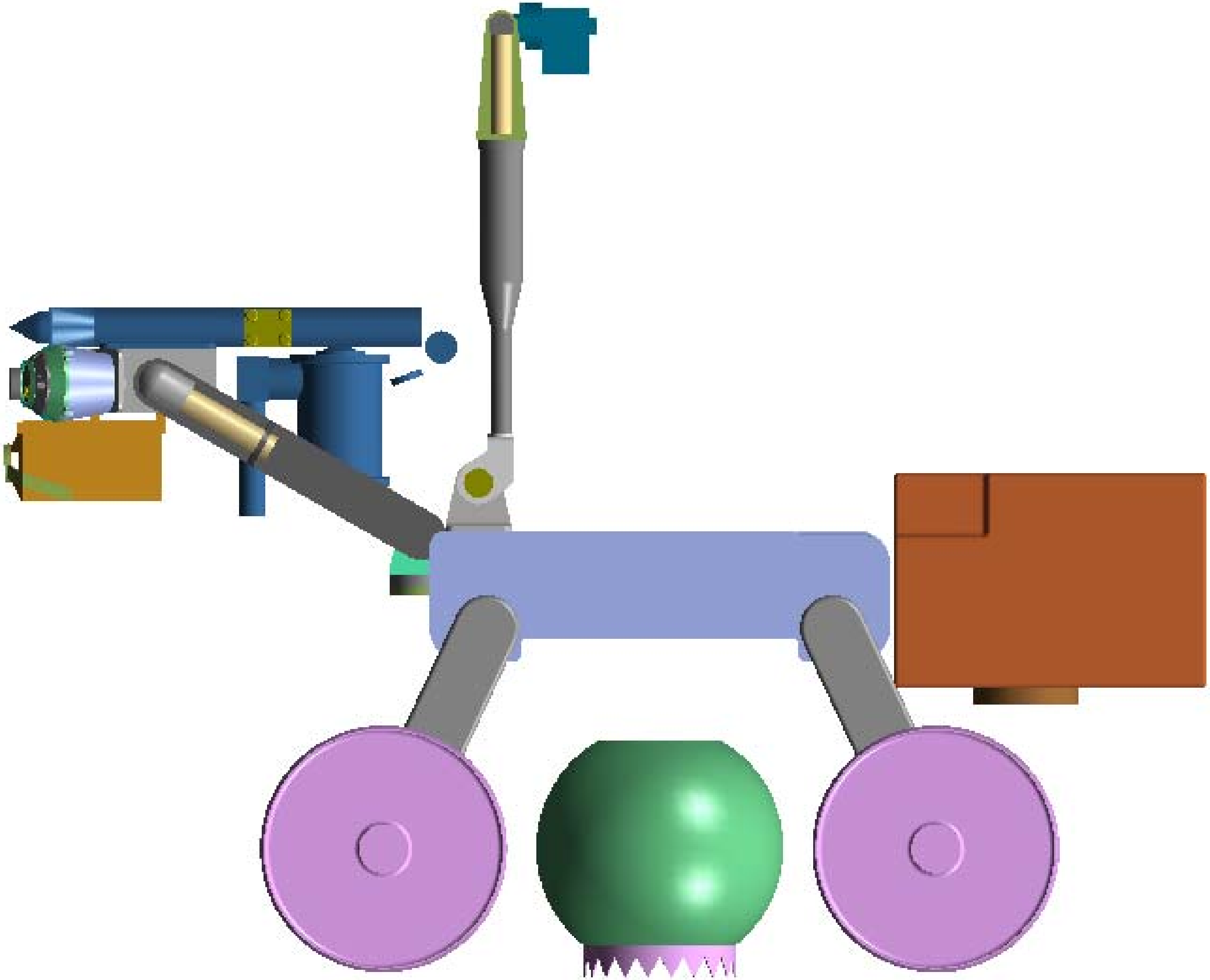
X-Ray Spectrometer

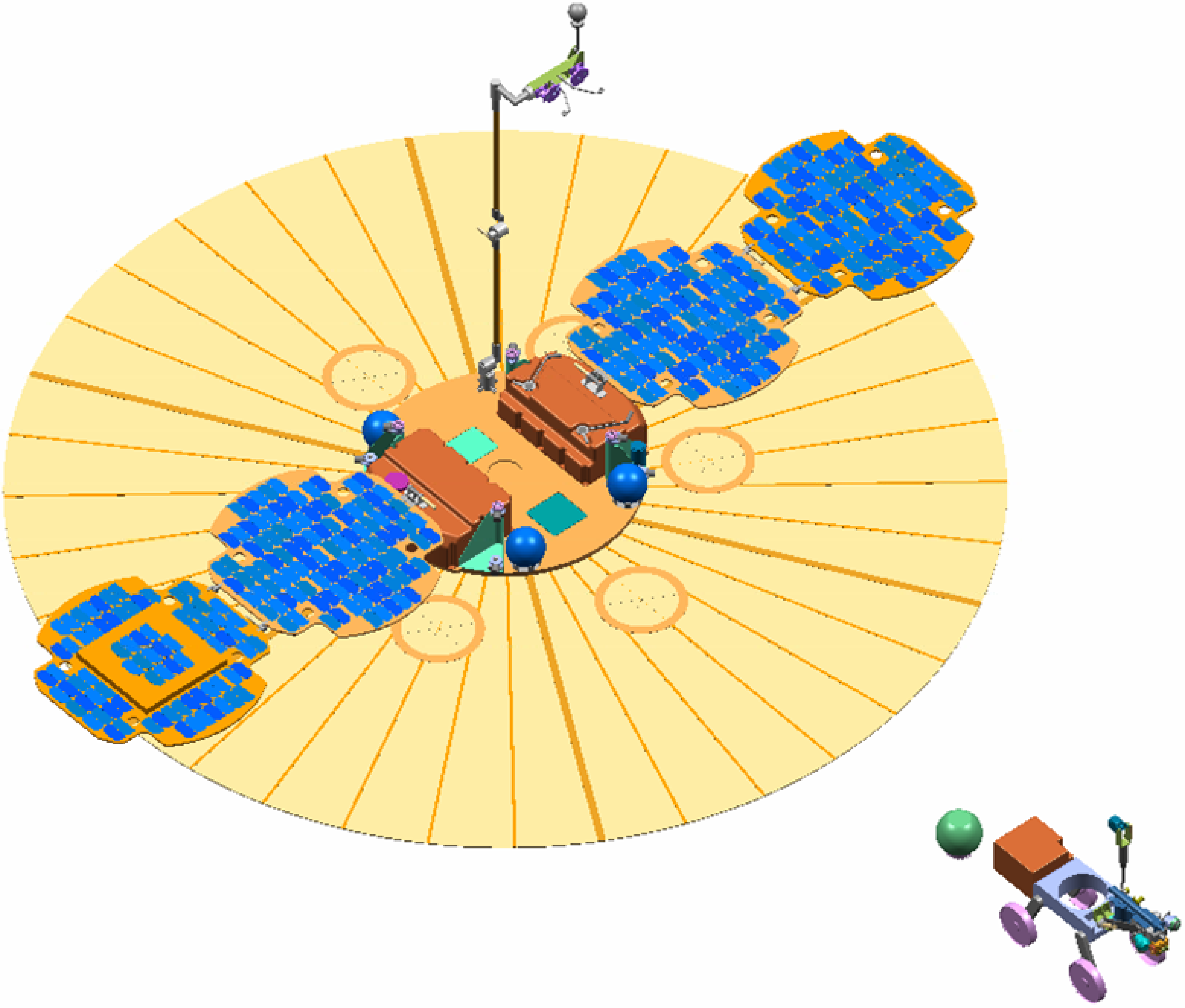
‘Wheel walking’ levers

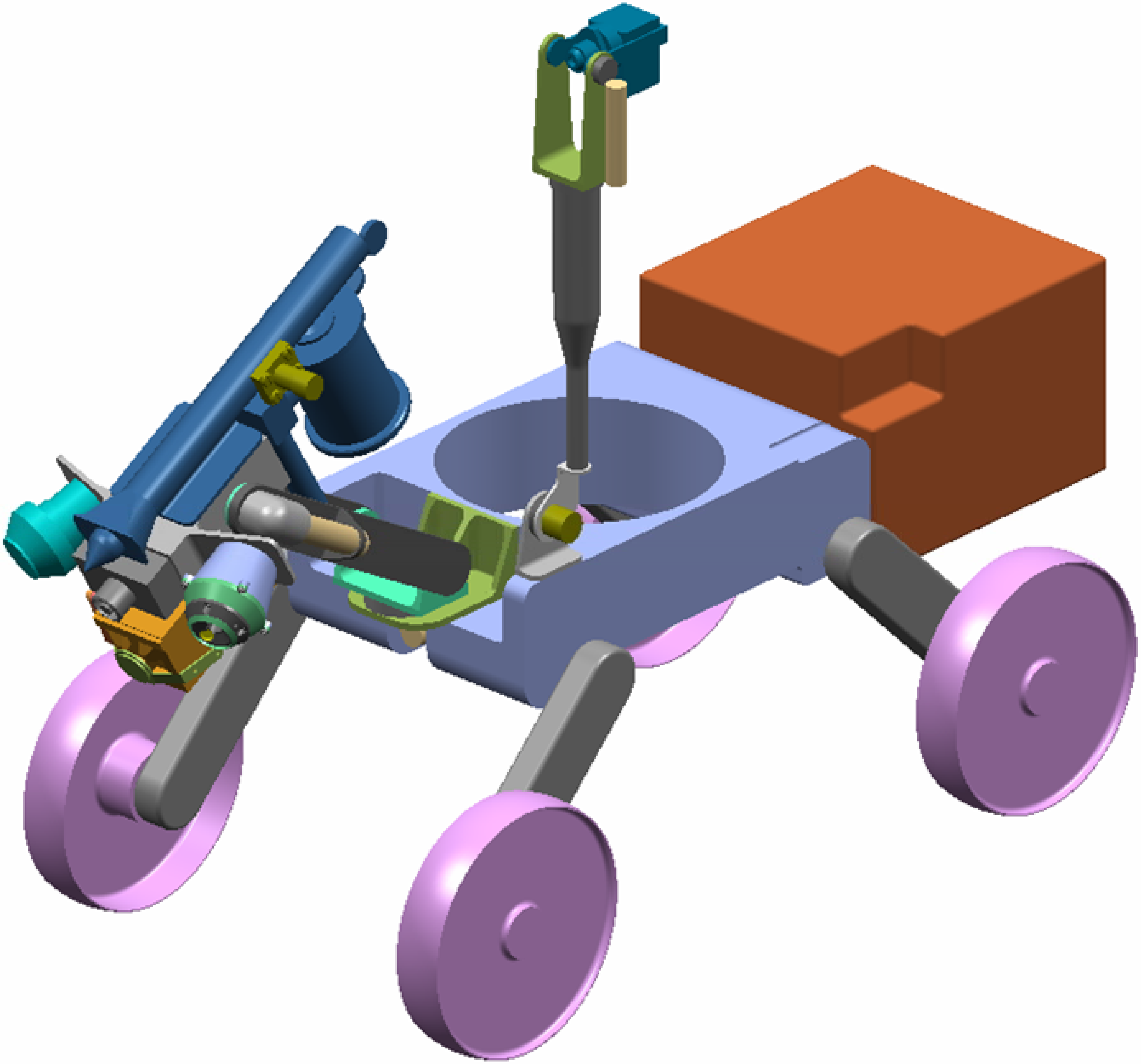
Mössbauer head

Microscope

Corer-Grinder







Mole Configuration

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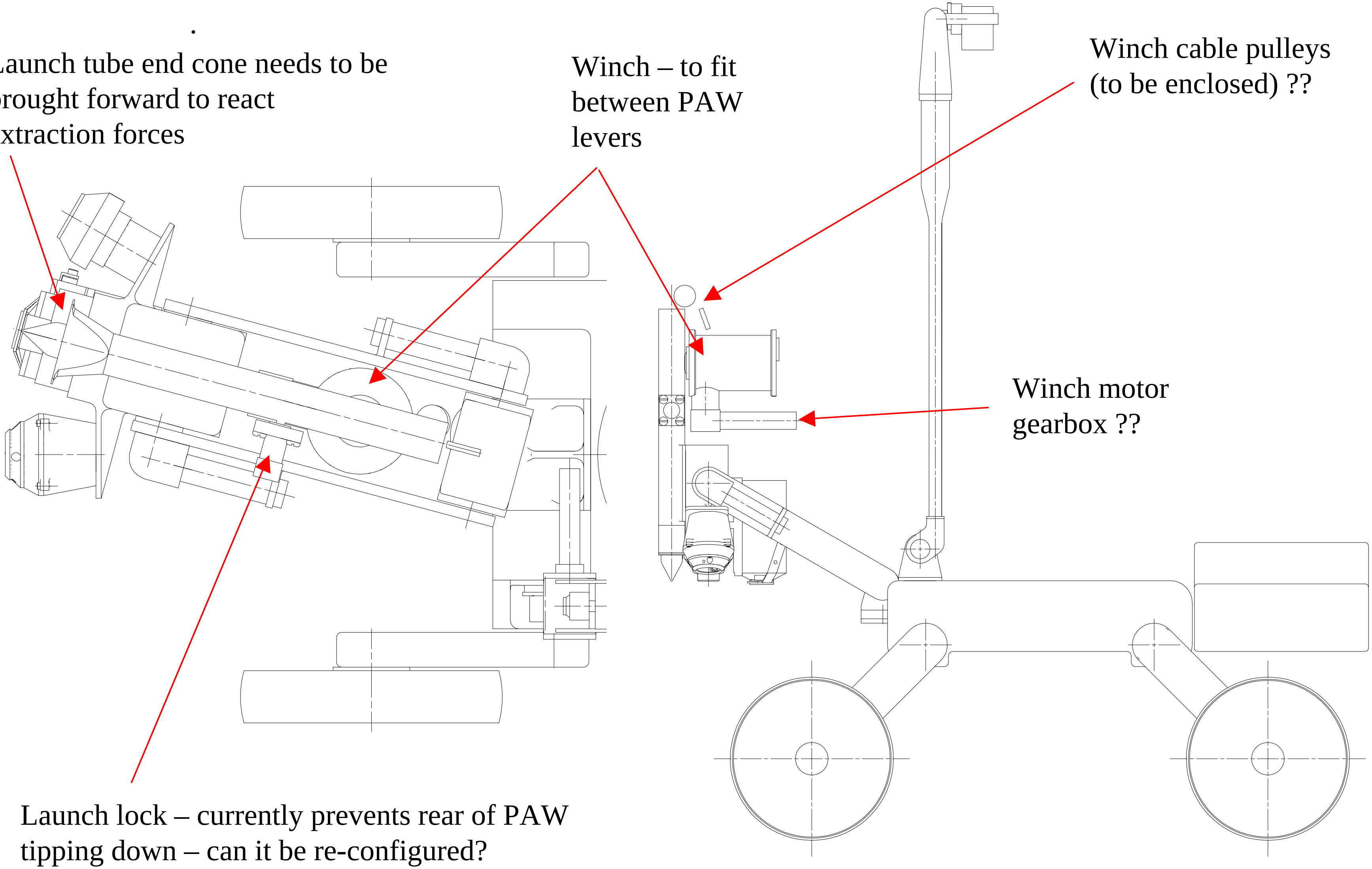


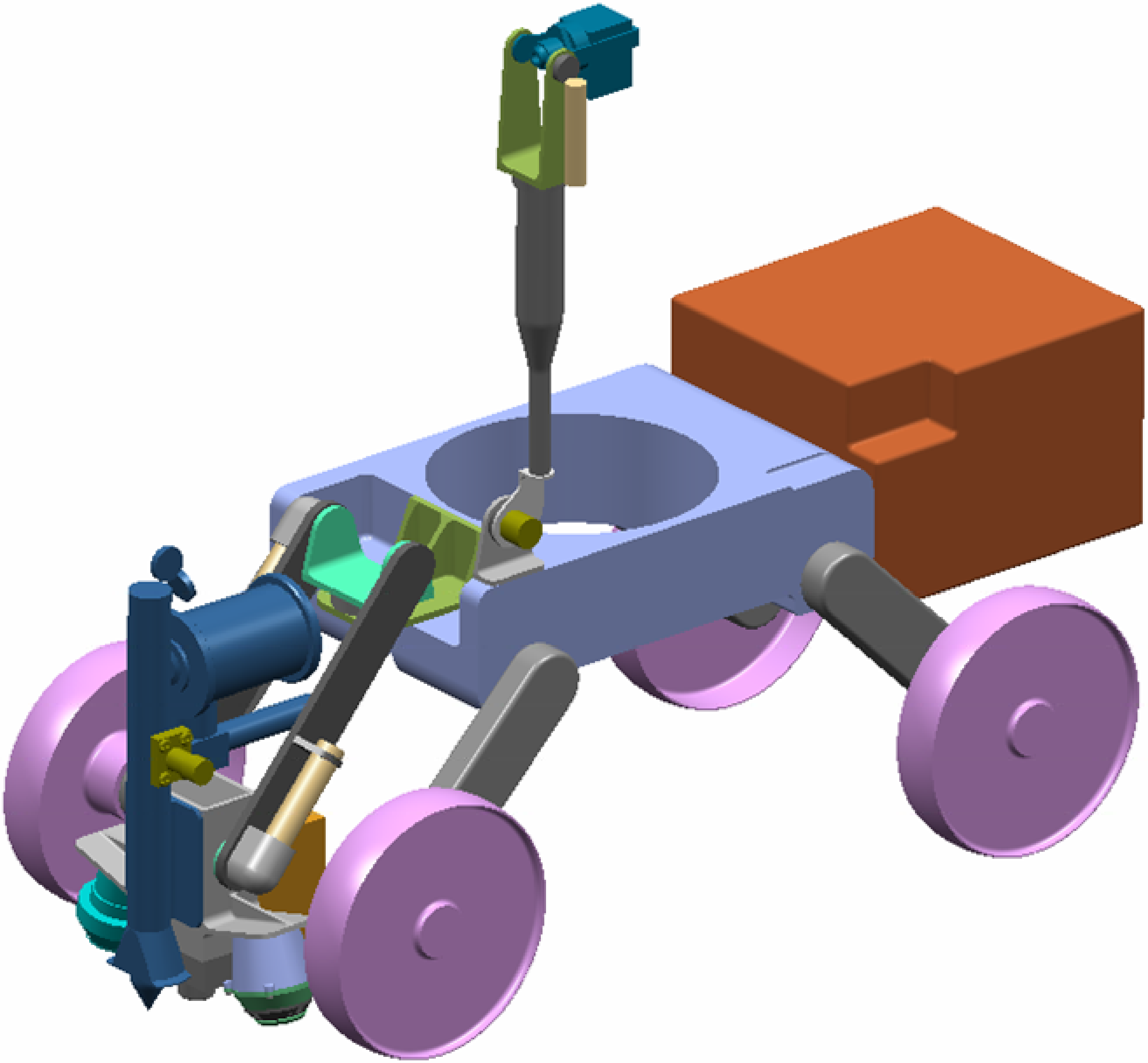
Launch tube end cone needs to be brought forward to react extraction forces

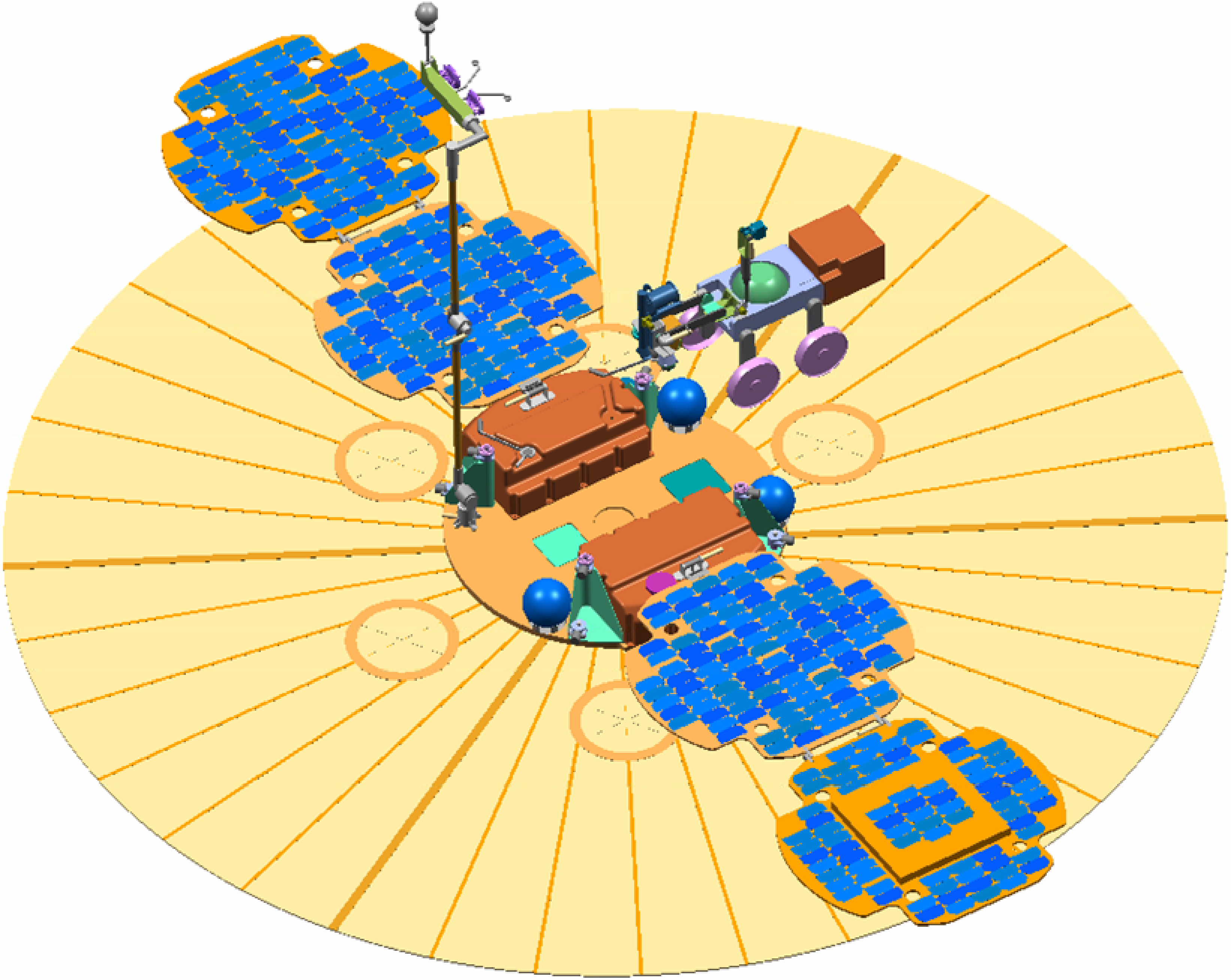
Winch – to fit between PAW levers

Winch cable pulleys (to be enclosed) ??

Winch motor gearbox ??

Launch lock – currently prevents rear of PAW tipping down – can it be re-configured?





Planetary Protection

Planetary Protection

- Battery can be integrated after heat sterilisation
- Lander systems compatible with terminal heat sterilisation (No frangibolts, SMAs) (COSPAR IVc)
- Rover, lander systems and instruments can be built and cleaned separately
- Aseptic build followed by heat sterilisation and battery integration
- Bioshield required between lander and Orbiter ?

Technology Status

Technology Status

- Heritage from Huygens, Netlander and Beagle 2 development and test programmes
- Large proportion of payload developed and qualified
- New technology within European capabilities

<u>The added value</u> of a combined Exobiology Geophysics Mission to Mars in 2009

- Original goals of the Beagle 2 and Netlander programmes
- Demonstration of small lander capability
- New high priority science objectives (methane, recent volcanism)
- Rehearsals for ExoMars and MSR
- More extensive coverage of martian surface
- Experience relevant for targetted exploration

Completing the Network

- third seismometer on MSL ?

alternatively/additionally

- third spacecraft delivered by Phobos-Grunt (Russian Phobos sample return mission 2009)

Redundancy

4 seismometers

3 landers

2 launches / 2 orbiters

1 Big Idea

Unique to ESA
complementary to NASA

And Finally

The project name:

Beagle**NET**