SOURCE

Subsurface Observation of Underground Reservoirs in the Ceres Environment

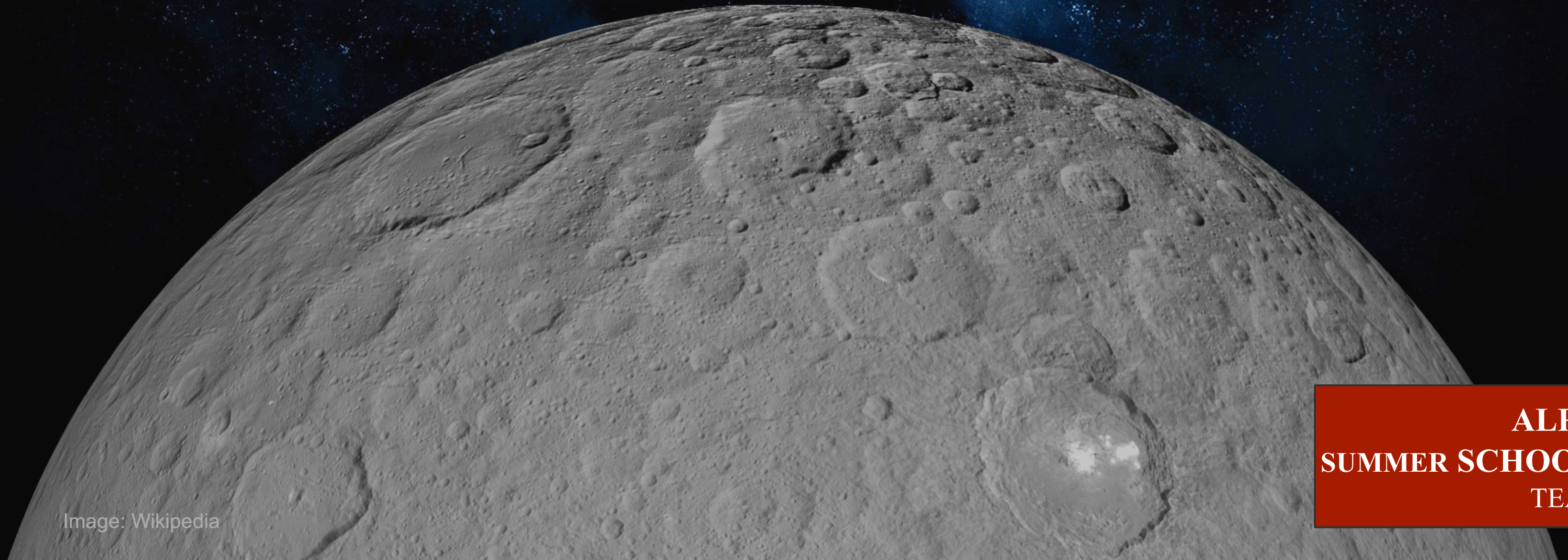


Image: Wikipedia

ALPBACH
SUMMER SCHOOL 2025
TEAM RED

WHY

WHERE

Subsurface Observation of Underground Reservoirs in the Ceres Environment

esa

WHAT

HOW

WHY

WHERE

WHAT

HOW

Importance of H_2O

Habitability = Presence of H_2O and organics

Fundamental question:

HOW DID WATER ORIGINATE ON EARTH?

Sources: endo- or exogenous

Most possible exogenous source:

Small bodies bombardment

Solar System H_2O Reservoirs

Mercury, Moon: ice only

Mars: Liquid and ice

Comets: ice and vapour

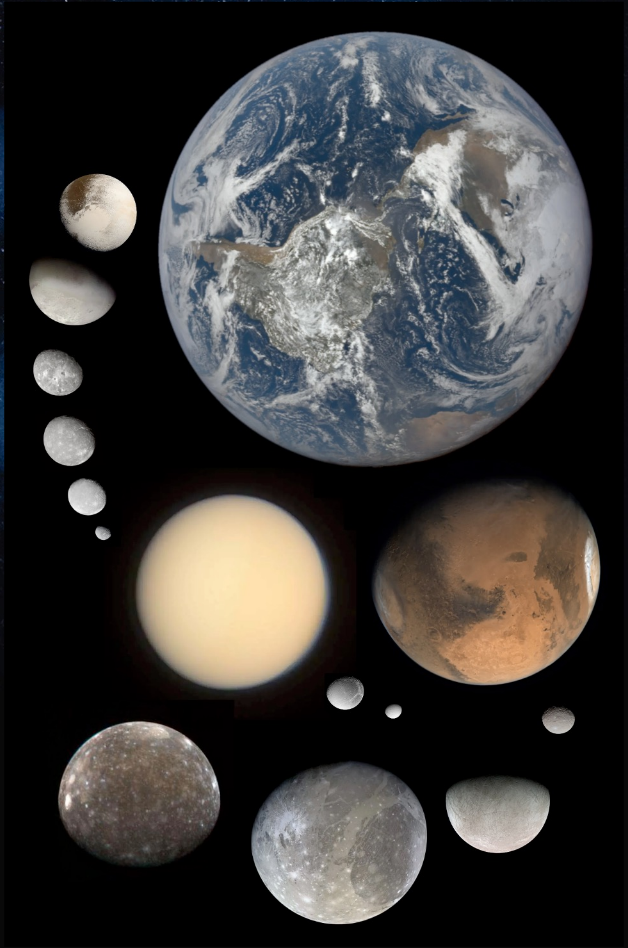
Moons of gas giants + Pluto: subsurface liquid oceans

Europa, Enceladus, Ganymede, Titan, Mimas, Miranda

Formed in the outer Solar System

But: migration of giant planets

Further sources of *liquid* H_2O in inner Solar System?



Ceres – The Best Target?

Ceres = 25% of the total mass of the Main Belt

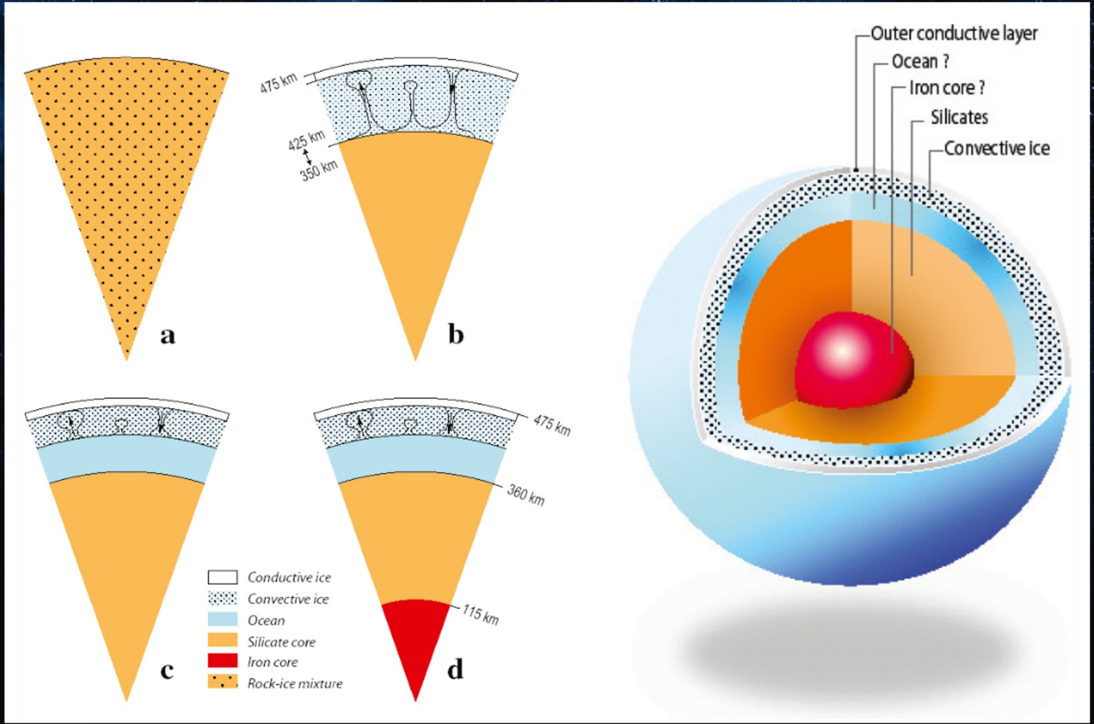
Larges Main Belt object

Visited by Dawn (2015-2018)

Mapping surface topography, gravitational field

Reasonably well-known body

Ceres – The Best Target?



Source: Ceres's internal evolution: The view after Dawn
T. B. McCord et al. 2018

The Dawn of Ceres Exploration

Geological activity in bright spots (faculae)
(De Sanctis et al. 2017, Nathues et al. 2020)

Recent exposures of material (upwellings):
Brines (salt-rich *fluid* water)
Hydrated minerals
Organics

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Subsurface liquid water – global or ponds
(Raymond et al. 2018, Nathues et al. 2020)

H_2O reservoir from surface to 117 km deep

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H_2O reservoir from surface to 117 km deep

Internal structure is likely differentiated (Zolotov 2020)

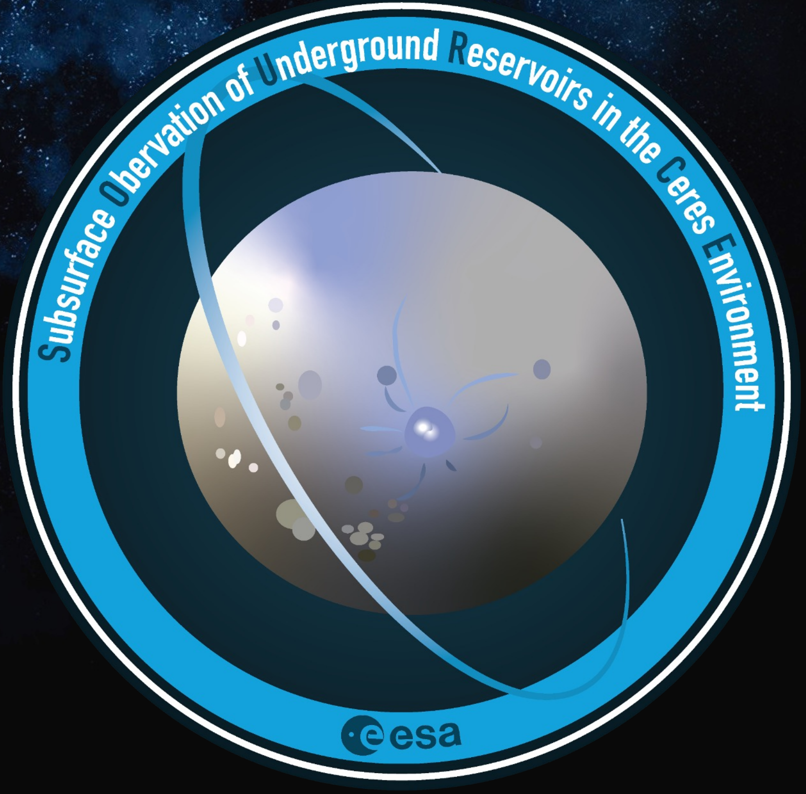
A transient exosphere emerges due to activity
(Schorghofer et al. 2017)

What Can We Learn Through SOURCE?

How to answer open questions from Dawn:

- Measure perturbation of local magnetic field
- Take surface and subsurface samples
- Localize, characterise H_2O & organics reservoirs
- Characterise the composition of upwellings
- Qualitatively describe inner structure

A key to understanding the origin of Earth's water and prebiotic organics



WHY

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Science Objectives

Investigating the origin of water and life on the Earth by landing on Ceres, the largest extraterrestrial H_2O reservoir in the inner Solar System.

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SO2. Assess the current and past habitability potential of Ceres with relation to origin of life on Earth.

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SO3. Determine the origin of observed surface activity on Ceres.

SO4. Determine the internal structure and differentiation of Ceres.

Science Goals

SO1. Characterize the H_2O on Ceres and its relation to origin of water on Earth.

– Detect and localise the putative liquid ocean

– Compare of D/H isotopic ratio to Earth and other Solar System bodies

– Determine the molecular composition of putative liquid ocean

– Infer the formation and origin history of Ceres

SO2. Assess the current and past habitability potential of Ceres with relation to origin of life on Earth.

– Detect of the basic building blocks of life

– Determine of crystallographic makeup of ice in Ceres

Science Goals

SO3. Determine the origin of observed surface activity on Ceres.

– Confirm presence of endogenic activity

– Evaluate evolution of the surface since Dawn mission

– Identify causes of activity

– Induce endogenic activity with an impact

SO4. Determine the internal structure and differentiation of Ceres.

– Characterize internal layers

– Characterise local magnetic fields

– Describe the spatial distribution and phase of H_2O

– Determine of the source of phase change of H_2O

Maximizing Science Return: Architecture Rationale

ORBITER

Localize activity → Surface changes since Dawn → Global mapping

Characterising the transient exosphere

IMPACTOR

Induce artificial impact and characterise subsurface

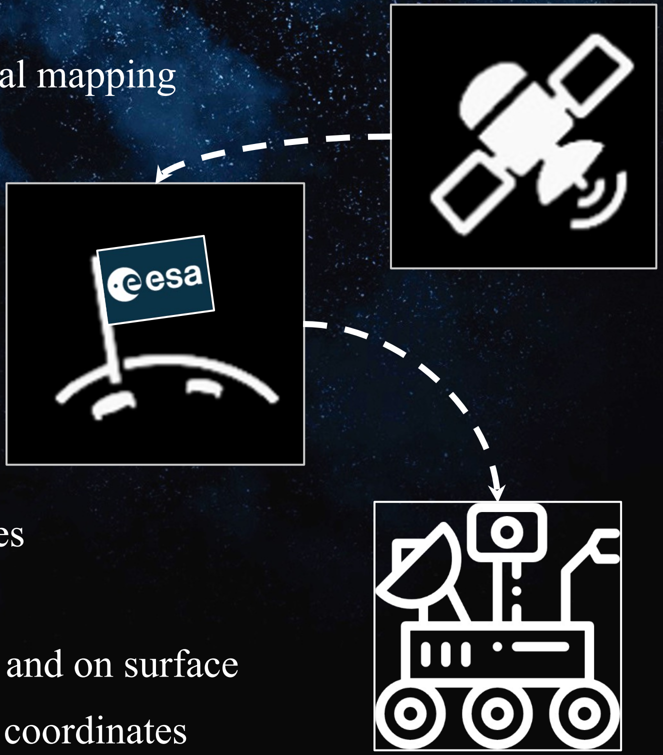
LANDING AND ROVER

Surface and subsurface sampling → Local mapping of sites

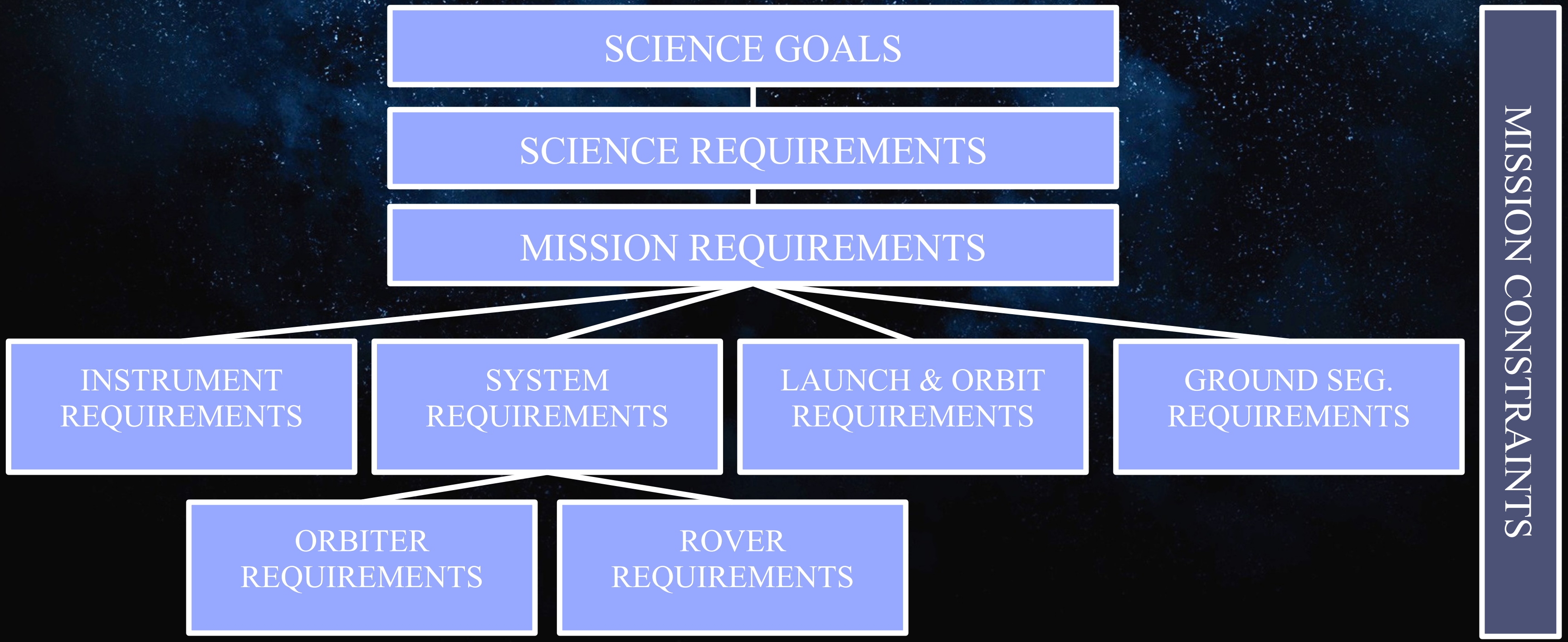
Analysis of samples in-situ

3D mapping with magnetometer → Multiple sites in orbit and on surface

Horizontal variations in subsurface → Sampling different coordinates



Requirement Flow-Down



→ Further flow-down into subsystems

Traceability - STM

Sci. Objective	Sci. Goal	Observable	Measurement		Sci. Req.	Mission Req.	Instrumentation
3. Determine the origin of observed surface activity on Ceres	Is there endogenic activity?	Identify and localize signs of endogenic activity through characterising topography	lidar resolution of 1cm, pressure sensor resolution TBD, NIRCam TDB resolution, wavelength range TBD based on what temperature fluctuations are expected from outgassing/upwelling Precision for Temperature: 1K, Spectral observation at 3 microns; spectral resolution 0.1 µm	Global mapping. Exosphere measurement at an standard star or the sun that is apparently close to Ceres. Exosphere measurement at Ceres from high orbit in the forward scattering direction (θ=180°).	23. The mission shall allow to determine the global topography with a precision of 1m/pixel at 10km of altitude and 40m/pixel at 396 km altitude. 24. The mission shall allow to determine the local topography with a precision of 1cm with a radius of TBD m around the landing site .	The mission shall allow for landing site corrections of up to TBD km post launch.	Laser altimeter, Ground penetrating radar, hyperperspectral camera, pressure sensors
		Identify and localize signs of endogenic activity through characterising subsurface movements			25. The mission shall be able to determine the surface temperature with a precision of 1 K, globally. 26. The mission shall be able to determine temperature fluctuations with a precision of 1 K, locally. pressure sensors accuracy and justification missing!		
		Identify endogenic activity by observing the possible exosphere			27. The missions shall be able to determine the presence of water and oxygen in the exosphere with a precision of 0.1 µm, locally.		
		Identify and localize signs of endogenic activity through characterising temperature fluctuations			28. The mission should be able to characterise global subsurface movement and layering with a depth of 8m and vertical resolution of 10cm.		
	Evolution of the surface since Dawn mission possibly due to activity	Compare previous images from Dawn to newer ones, and identify locations of change.	Resolution of 1m/pixel at 10 km altitude and 40m/pixel at 396 km altitude.	Global mapping	See Req. 22.		Visual camera on orbiter, rover wide-field camera
	What causes the activity seen on Ceres?	Determine composition of active regions, upwellings and outgassings	See 3., and low altitude orbit images at TDB altitude. TBD rover cameras	Global mapping to find target, local spectra when target found	See Req. 5-21		XRD L Chip, mass spectrometer, Raman-LIBs, IR spectrometer
	Can we induce endogenic activity with an impact/collision?	Activity and surface deformations caused by an impactor	Resolution of 1m/pixel at 10 km altitude and, 20nm resolution of spectrometer	Locally on the impact target	29. The mission shall be able to deploy ballistic projectiles at the Cerean surface. 30. The mission shall provide visual imagery of the impact site of the ballistic projectiles with a resolution of TBD m. 31. The mission shall allow for the spectral decomposition of the ejecta at the impact site of the ballistic projectile with a resolution of 20 nm (TBC).	The mission shall allow for active orbit maneuvers between mission phases.	Copper impactor, hyperspectral camera, visual camera on orbiter

Flow-Down: Example

Sci. Objective

Characterise H_2O on Ceres and its relation to water on Earth

Sci. Goal

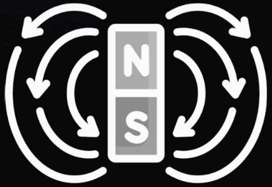
Detection and localisation of subsurface liquid water

Observable

Global and local magnetic field and perturbations

Measurement

- Accuracy of 0.01 nT
- Continuous mea–surements for 27 hrs
- Different locations to map in 3D



Sci. Req.

Mission shall determine global and local magnetic field strength

Mission Req.

Mission shall include a rover

Allow up-and downlink between rover and Orbiter

Rover shall move between different sampling sites

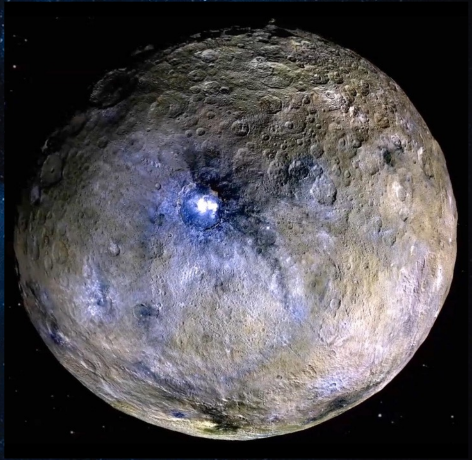
Orbit shall allow for global mapping of magnetic field

Instrument

Magnetometer (Orbiter & lander)

Mission Requirements

Source: NASA Dawn



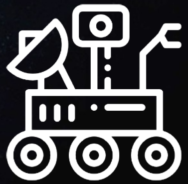
ORBITER

Nominal orbit around Ceres for global coverage

Orbiter nominal lifetime of min. 12 months

Direct communication to Earth and rover (up- and downlink)

Active maneuvers between orbits



ROVER

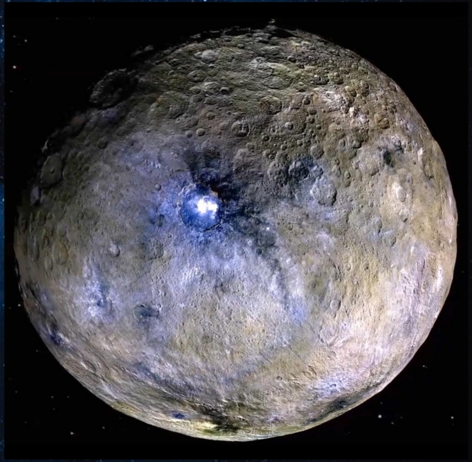
Landing within an area of interest (Occator Crater, 19.8 N lat / 239.3 long)

Rover nominal lifetime of 6 months after landing

Sampling of the surface in areas of 6 m^2 around the landing site for 100 mg/sample

Mission Drivers and Constraints

Source: NASA Dawn

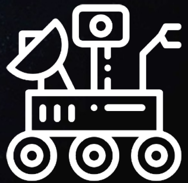


DRIVERS

Landing on the surface

Sampling of the surface

Transfer regime (transfer trajectory and propulsion system)



CONSTRAINTS

Usage of Ariane launcher with given mass and dv

WHY

WHERE

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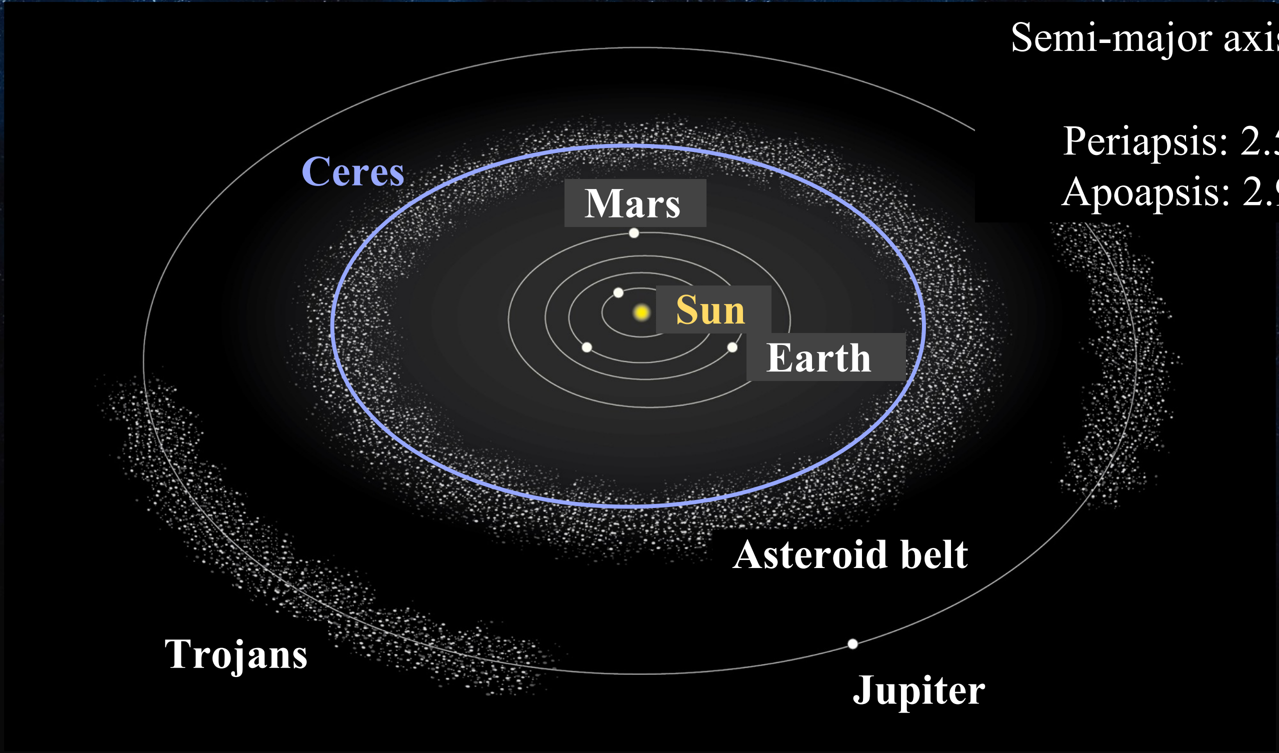
Mission Analysis – Where is Ceres?



Semi-major axis: 2.77 au

Periapsis: 2.544 au
Apoapsis: 2.987 au

Image: gasow.org

Mission Analysis – Orbit Requirements

Interplanetary travel time < 15 years

Global surface mapping (75 % coverage) with altitude < 400 km

Local surface mapping of regions of interest with altitude < 10 km

Communication window with the rover > 30 minutes every Ceres-Day

Stationkeeping on low elliptical orbit

Mission Profile

Launch & LEOP
2036 July 23

Transfer Leg 1
6.3 year

Mars Flyby
November 2042

Transfer Leg 2
7.7 year

Ceres Orbit Insertion
July 2050

Commissioning
~ 3 months

Global Mapping Orbit
~ 3 months

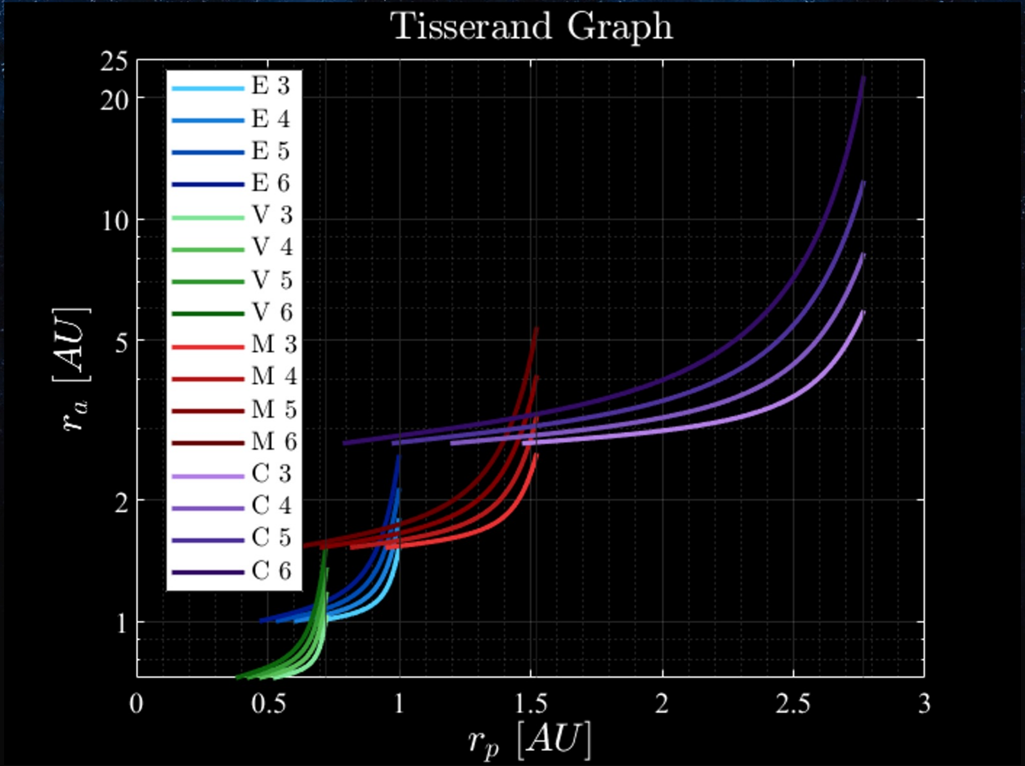
Remote sensing
Selection of landing sites

~ 6 months
Separation & Landing
Relay orbit
End of Life
Local Mapping Orbit
~ 30 days
~ 5 months
Rover Commissioning
On-ground Science
End of Life
~ 3 months
First Orbiter-rover Contact
Sampling
Deployment of Impactor

Transfer Sequence

Transfer Sequence:

Earth
→ **Mars swingby**
→ Ceres



E = Earth, V = Venus, M = Mars, C = Ceres

Launch

Image: Wikipedia

Launcher: **Ariane 64**
Launch site: Kourou, French Guiana
Launch mass: **5.3 t**

Ariane 64 performance (5.65 t)

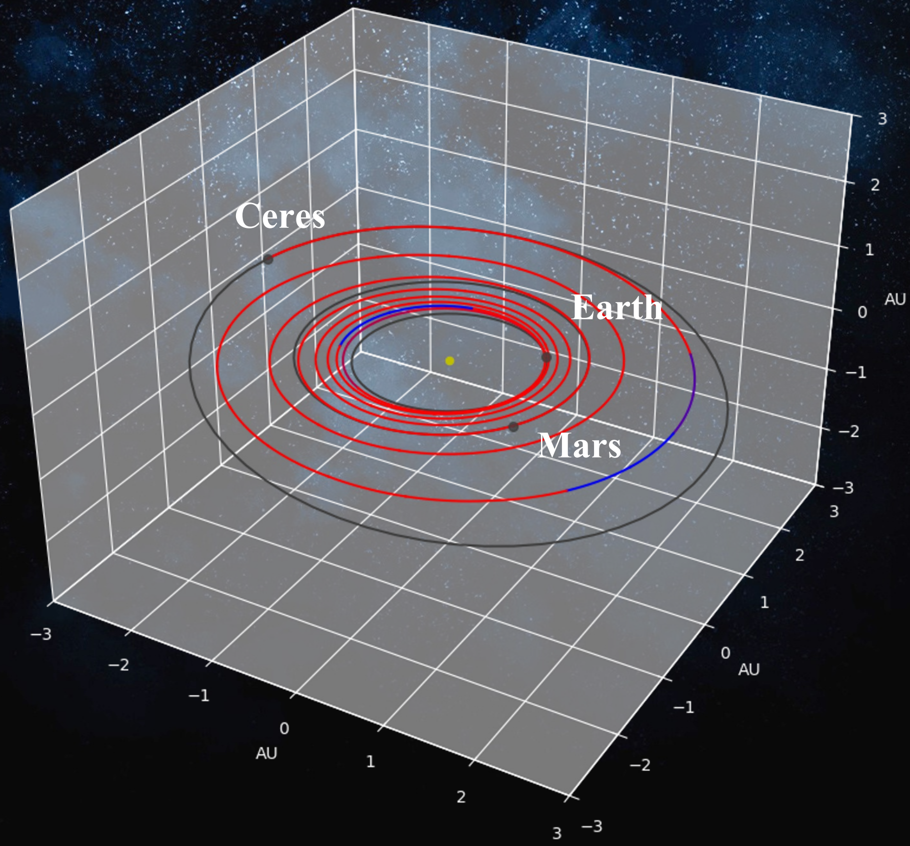
> Launch mass (5.3 t) !

Launch opportunities:

Launch Date	Window	Travel time [y]	Fuel Mass [kg]	C3 [km²/s²]	Ariane 64 Performance [kg]
2036-07-23	early 07 to early 09	14.0	1530	12	5650
2037-05-17	end 05 to end 06	13.1	1580	12	5650

Launch → Transfer + Mars flyby → Ceres Orbit Insertion → Global Mapping Orbit → Local Mapping Orbit → Separation and Landing → Relay Orbit → End of Life

Orbit Transfer



Electric Propulsion

- 4× RIT 2X ion thrusters (2 at time, 2 redundant)
- Total 150 mN @ 5 kW power
- Propellant: 1.65 t Xenon (incl. 2% margin for residuals)
- Total **Δv = 14.64 km/s**

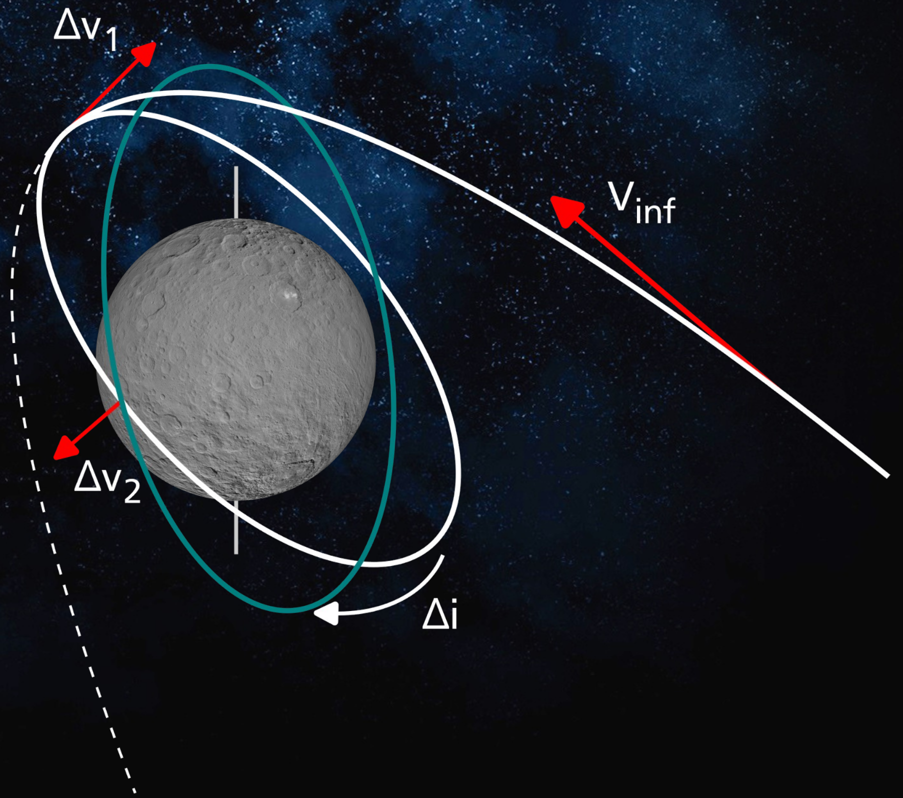
Launch → **Transfer + Mars flyby** → Ceres Orbit Insertion → Global Mapping Orbit → Local Mapping Orbit → Separation and Landing → Relay Orbit → End of Life

Ceres Orbit Insertion

Chemical propulsion

$\Delta v1 = 0.110$ km/s for COI (Ceres Orbit Insertion)

$\Delta v2 = 0.092$ km/s for change of plane of 20 deg



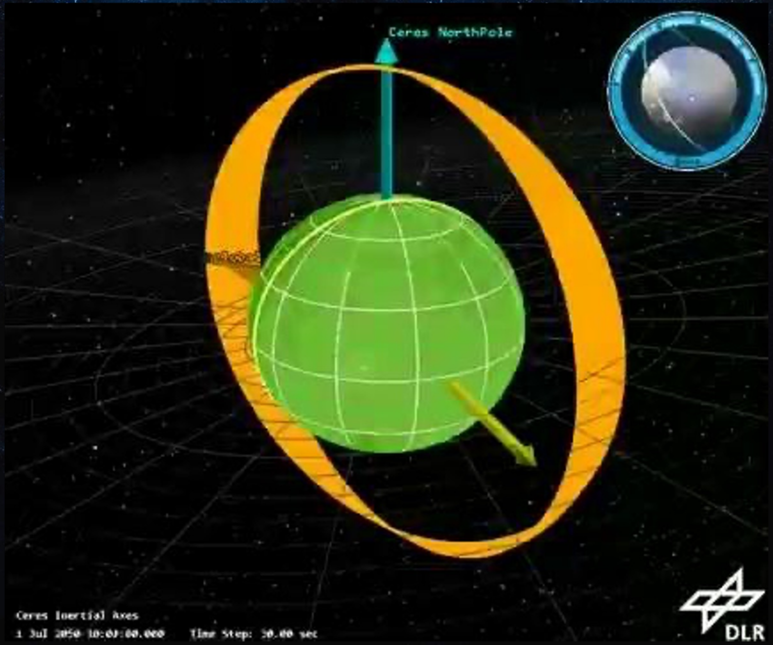
Launch → Transfer + Mars flyby → Ceres Orbit Insertion → Global Mapping Orbit → Local Mapping Orbit → Separation and Landing → Relay Orbit → End of Life

Global Mapping Orbit

Requirement: global mapping **40 m/px**

- Polar orbit
- Altitude = **396 km**
- **Period = 5.65 hr**
  - 1 image every 10 minutes
  - **80 orbits** needed for global coverage

(160 incl. 100% margin)
→ **38 Earth days** ~ 100 Ceres days



Launch → Transfer + Mars flyby → Ceres Orbit Insertion → **Global Mapping Orbit** → Local Mapping Orbit → Separation and Landing → Relay Orbit → End of Life

Local Mapping Orbit

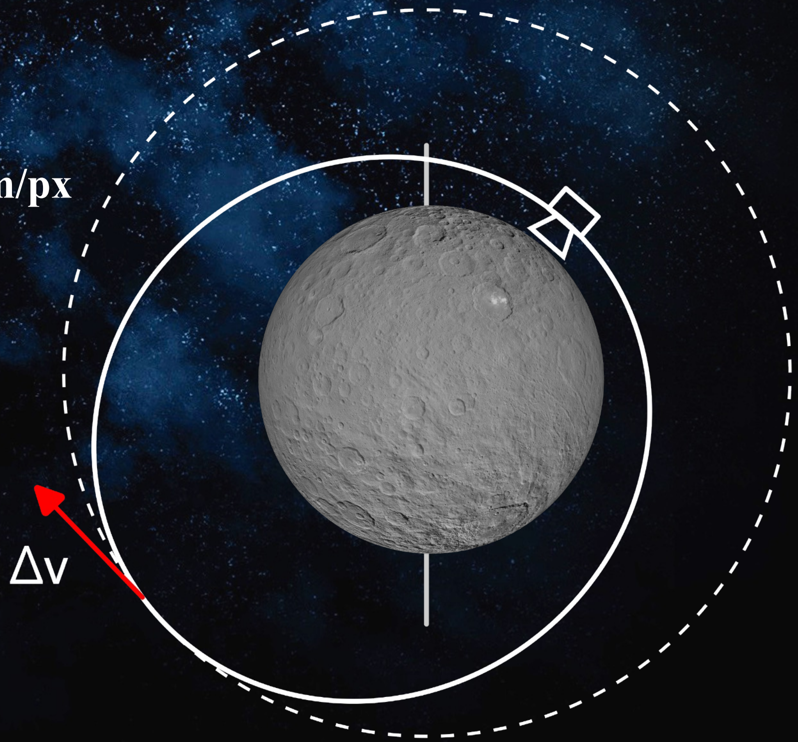
<u>Requirement</u>:

Local mapping of potential **landing sites**: **1 m/px**

→ Pericenter altitude = **10 km**

Period = 3.88 hr

Δv = 41.55 m/s for pericenter decrease



→ Deployment of impactors

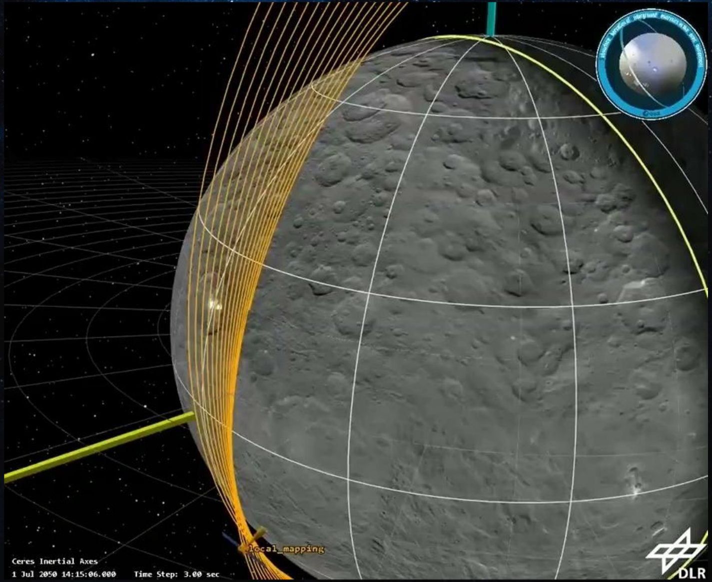
Launch → Transfer + Mars flyby → Ceres Orbit Insertion → Global Mapping Orbit → **Local Mapping Orbit** → Separation and Landing → Relay Orbit → End of Life

Local Mapping Orbit

Perturbations and Stationkeeping

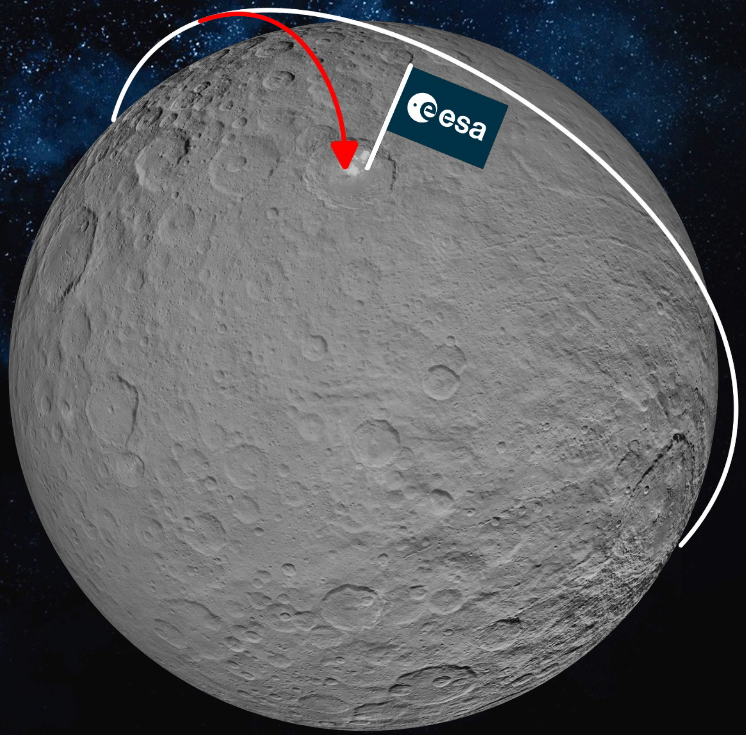
Orbit perturbation	Order of magnitude
J2 effect	~1e-6/1e-7 km/s^2
SRP	~1e-10 km/s^2

→ **Δv_{SK} ~ 30 m/s** (Station Keeping)



Launch → Transfer + Mars flyby → Ceres Orbit Insertion → Global Mapping Orbit → **Local Mapping Orbit** → Separation and Landing → Relay Orbit → End of Life

Separation & Landing



- Deployment of rover at pericenter
- Need to break for soft landing

→ Landing:
Δv = 510 m/s

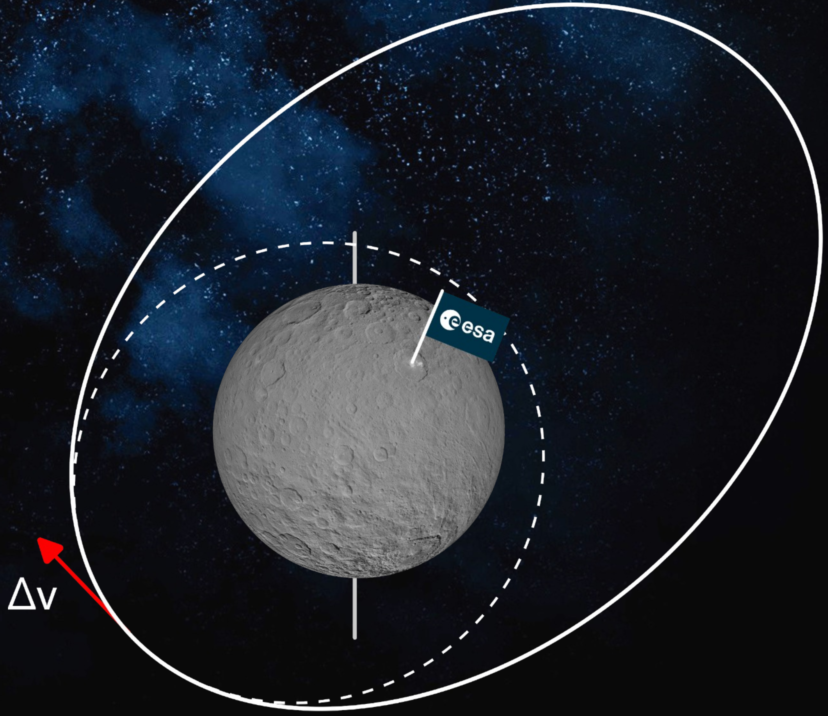
Launch → Transfer + Mars flyby → Ceres Orbit Insertion → Global Mapping Orbit → Local Mapping Orbit → **Separation and Landing** → Relay Orbit → End of Life

Relay Orbit

<u>Driver</u>: **Communication** with rover and Earth

⟶ Change of semi-major axis and argument of pericenter → **Δv = 75.7 m/s**

- Target period: **9.07 h** (1:1 resonance)
- **Phasing** with **dayside** of rover
- New apocenter: altitude **1040.98 km**

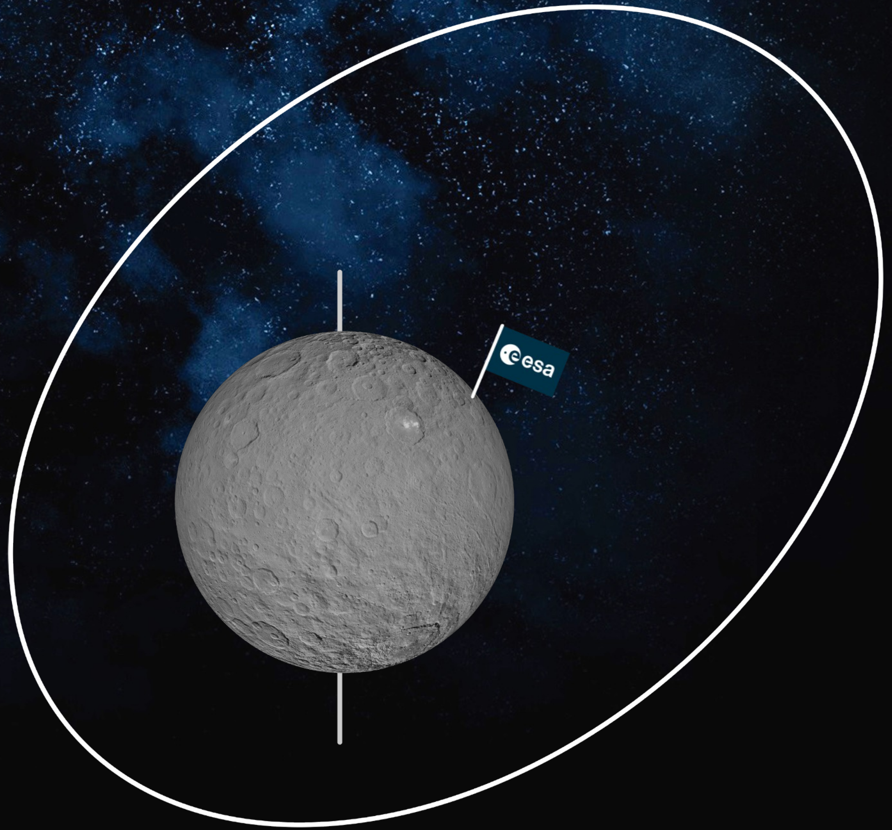


Launch → Transfer + Mars flyby → Ceres Orbit Insertion → Global Mapping Orbit → Local Mapping Orbit → Separation and Landing → Relay Orbit → End of Life

End of Life

- **Orbiter shutdown → uncontrolled**
- Stable orbit for at least **20 years**

- → Mission could be extended



Δv Budget

Orbiter

Maneuver	Δv [m/s] (w/o margins)	ECSS Margins
Transfer	14640	5% + 35 m/s per GAM + 30 m/s for launcher inaccuracy
Orbit insertion	205	5%
Local mapping Orbit	41.55	5%
Semi-major Axis and Argument of Pericenter Change	75.7	5%
Station Keeping	30	100%

Lander

Maneuver	Δv [m/s]	ECSS Margin
Landing	510	20%

Lander
Total Δv (incl. margins) = **612 m/s**

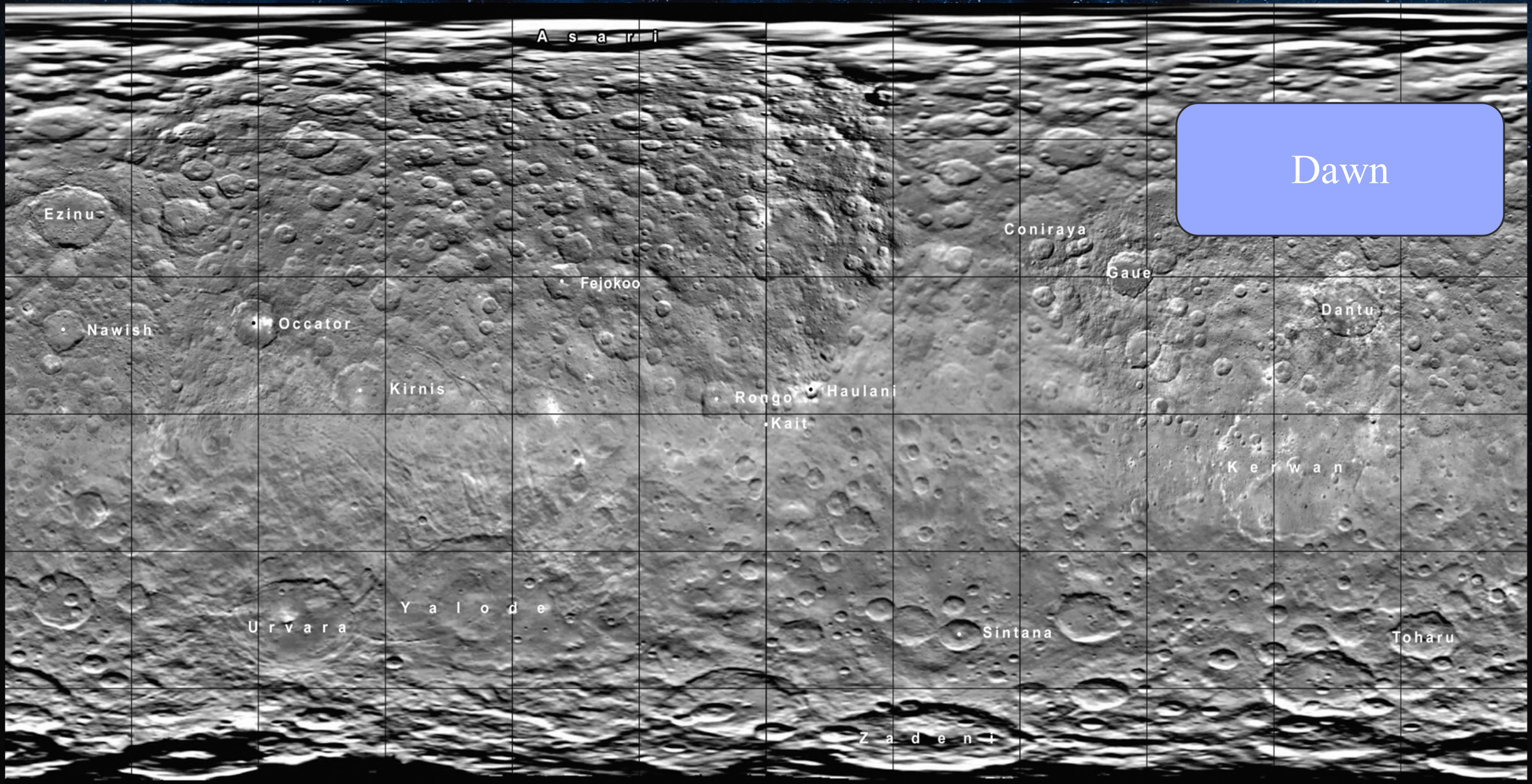
+

Orbiter Electric Propulsion
Total Δv (incl. margins) = **15.437 km/s**

+

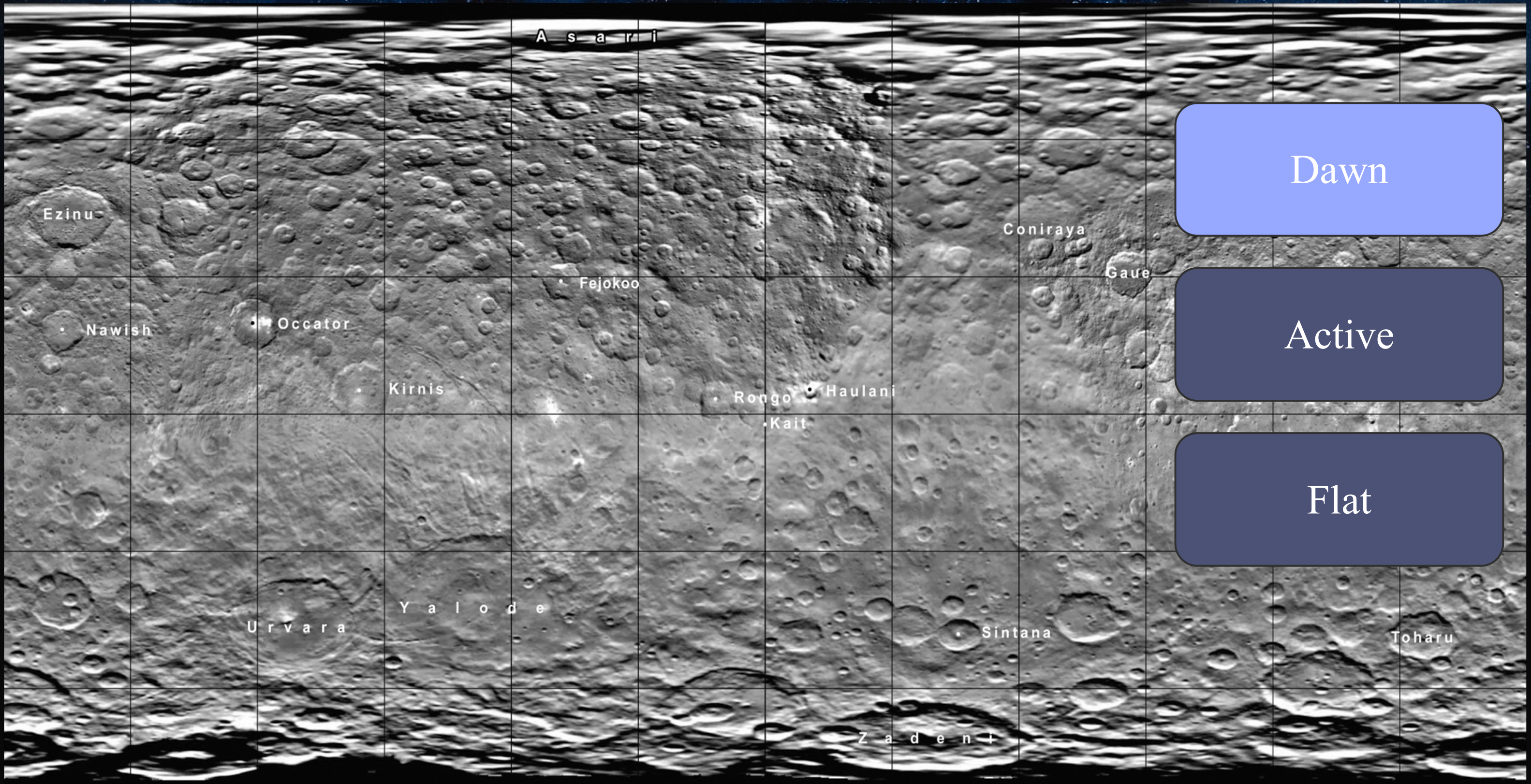
Orbiter Chemical Propulsion
Total Δv (incl. margins) = **442 m/s**

Landing Site Selection



Map of Ceres *(NASA/JPL-Caltech/UCLA/MPS/DLR/IDA)*

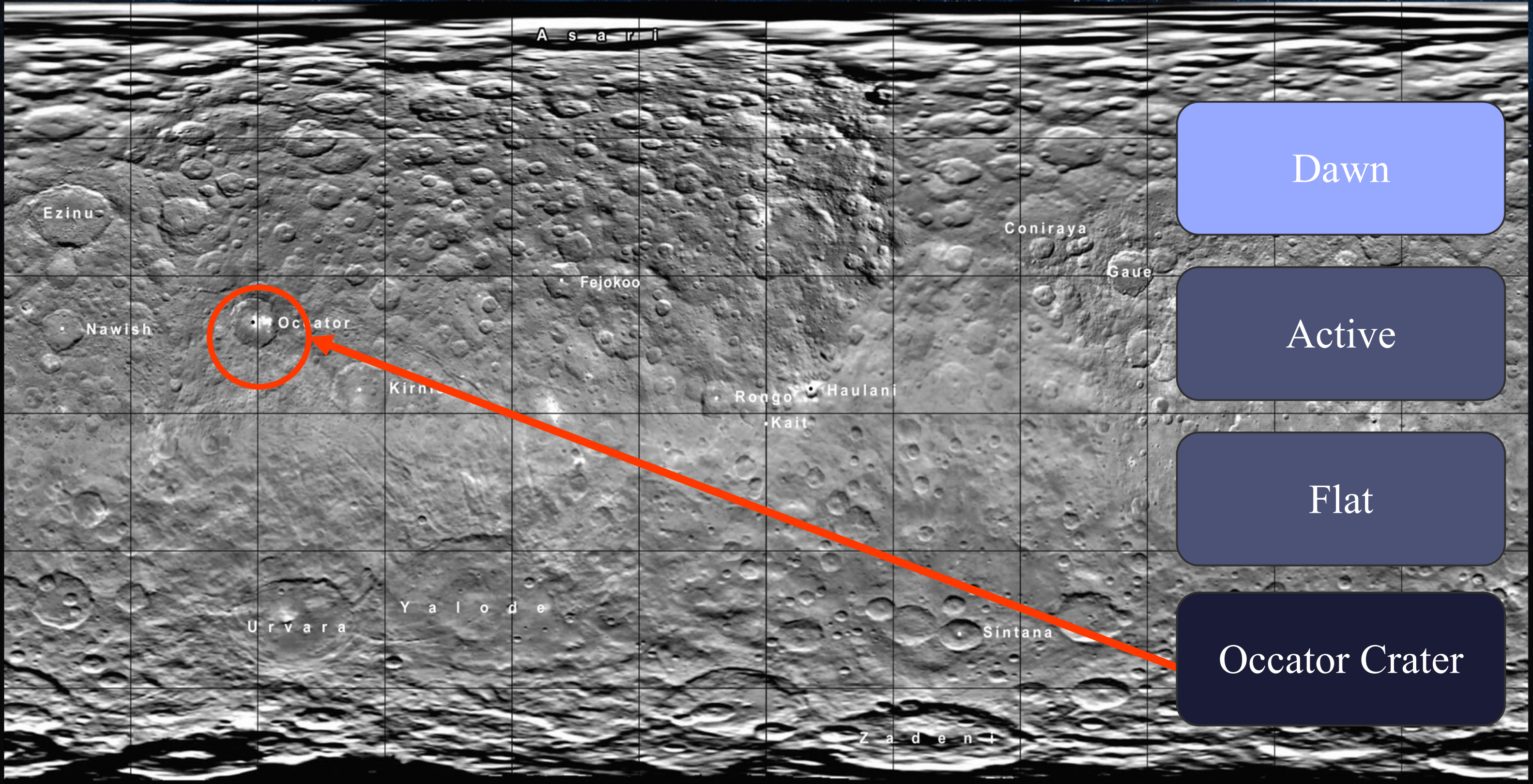
Landing Site Selection



Map of Ceres *(NASA/JPL-Caltech/UCLA/MPS/DLR/IDA)*

- Dawn
- Active
- Flat

Landing Site Selection



Dawn

Active

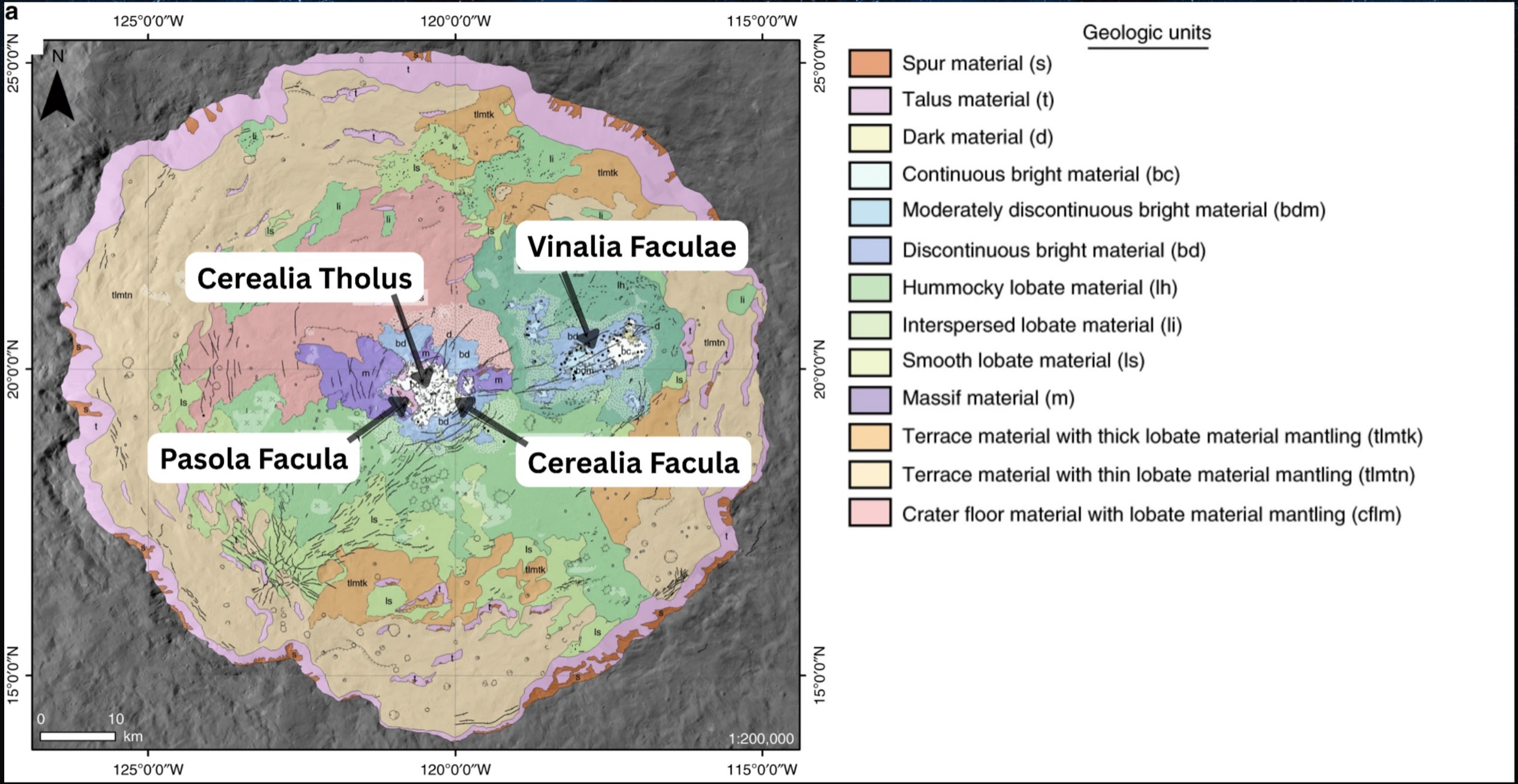
Flat

Occator Crater

Map of Ceres *(NASA/JPL-Caltech/UCLA/MPS/DLR/IDA)*

Occator: The Most Active Site

Scully et al. 2020



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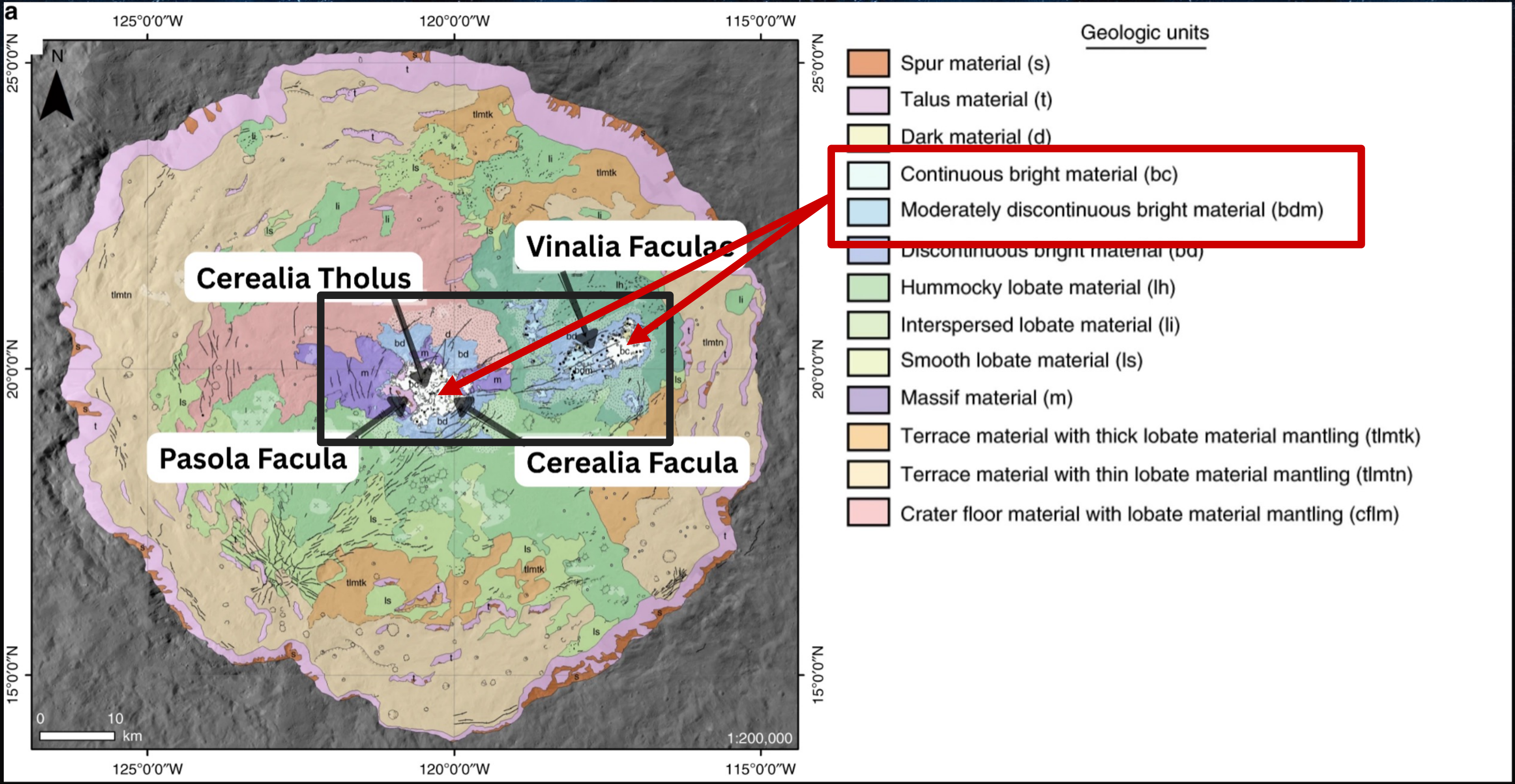
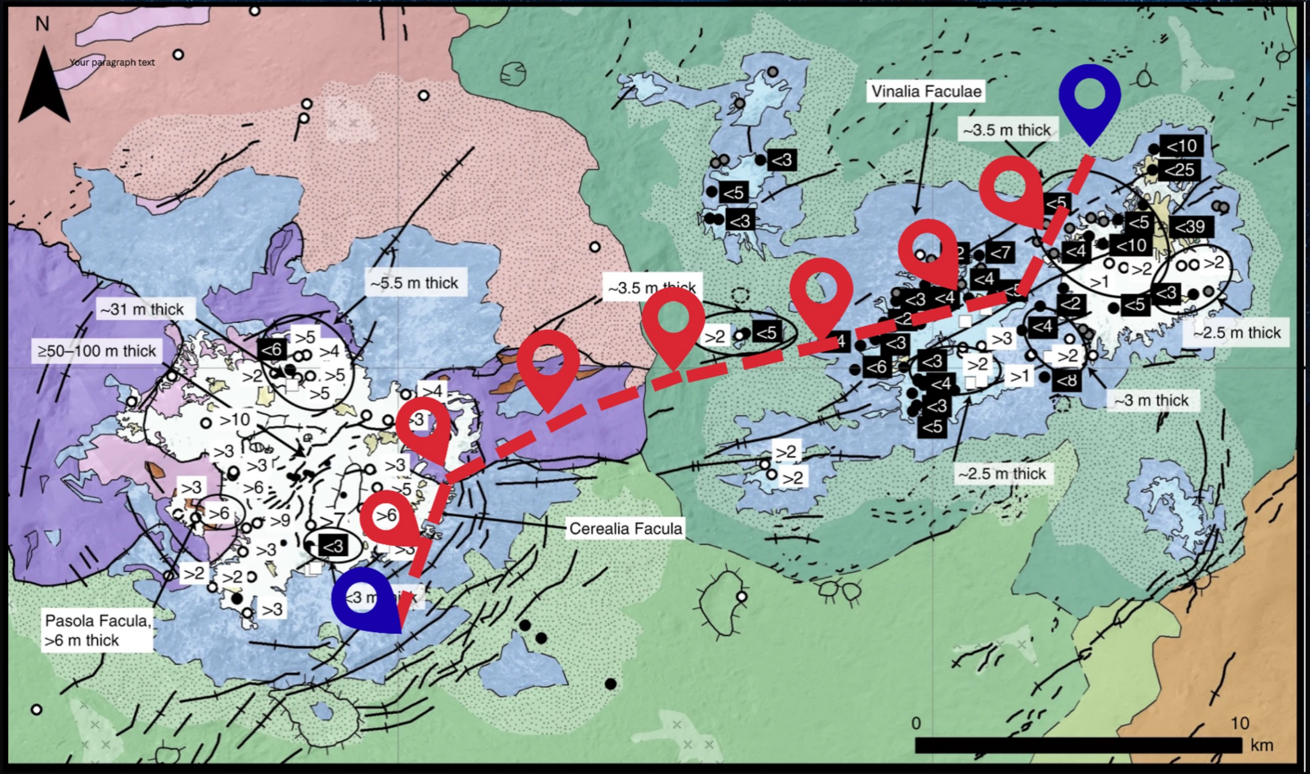


Potential Landing & Sampling Sites



Potential landing site

Potential sampling site

Further constrained by laser altimetry

Prioritised based on roughness, slope, travel time

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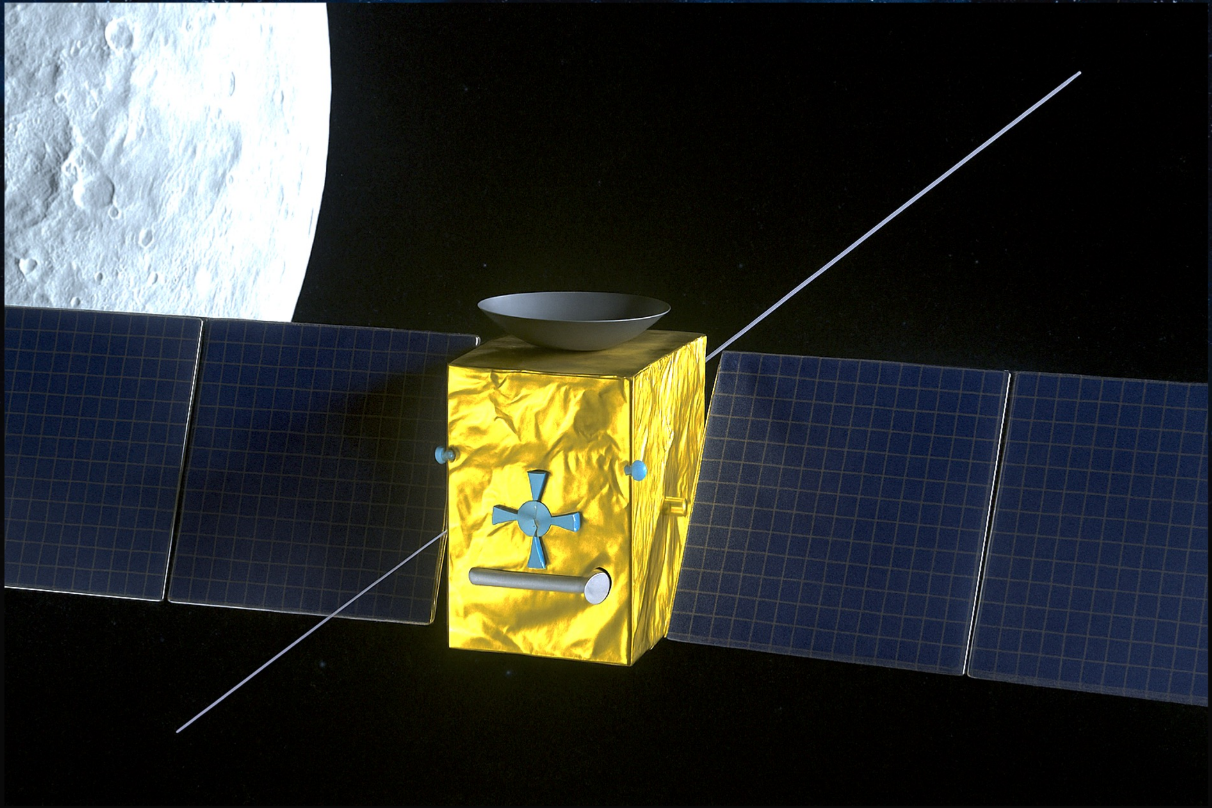
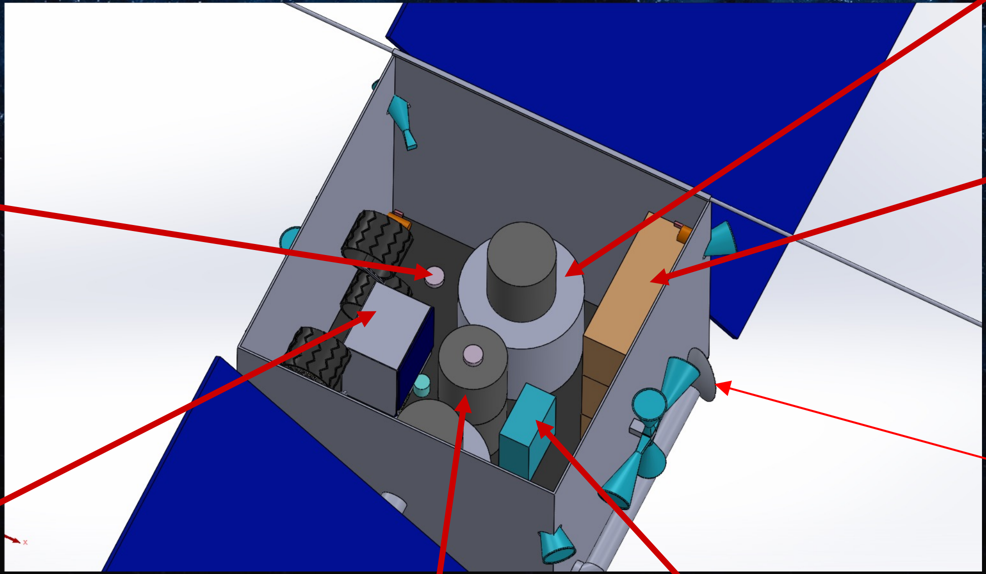
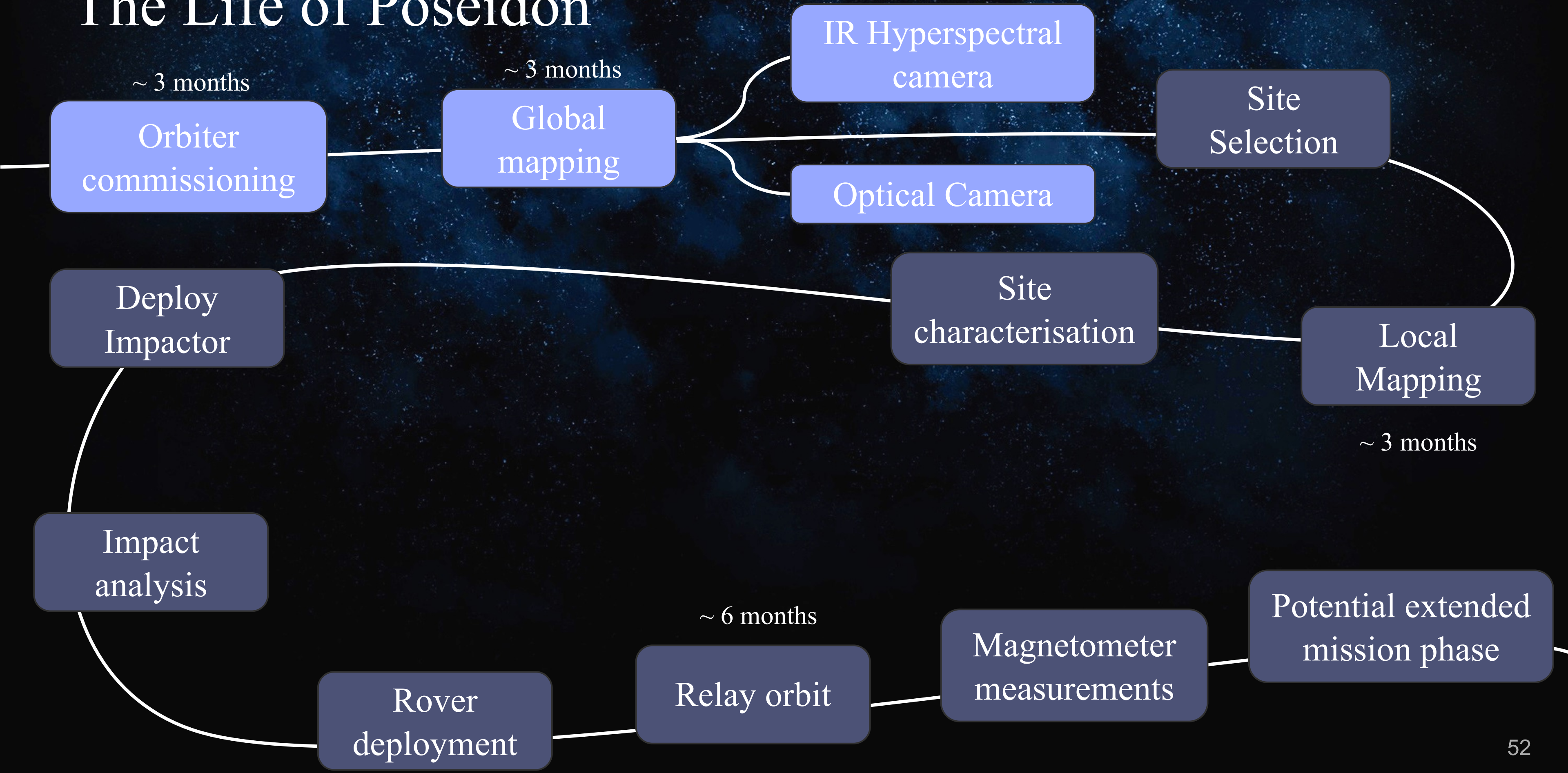
Our Orbiter - Poseidon



Poseidon - Instruments



The Life of Poseidon



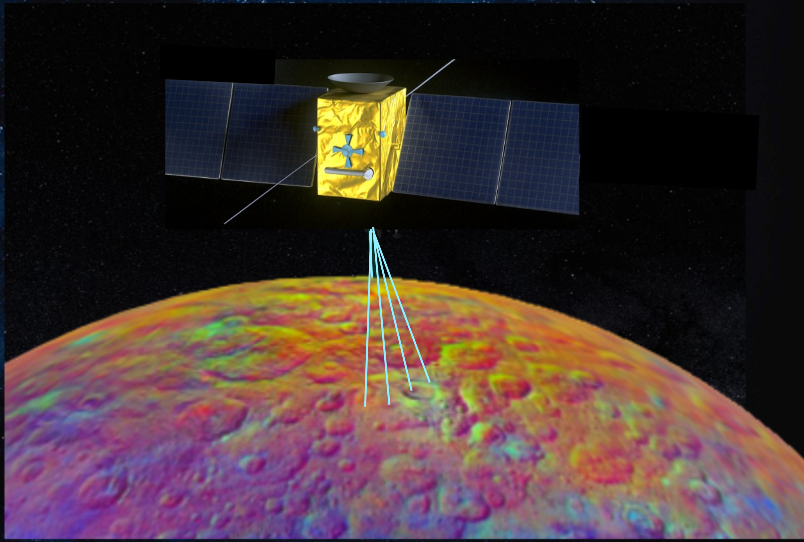
Infrared HyperSpectral Camera

SO2: Complex organics distribution (bands 3 µm)

SO3: Detection of the exosphere using the Sun and standard stars

SO3: Global temperature fluctuation

SO3/4: Analysis of impact site



- Spectral range: **0.9-5 µm**
- Spectral resolution **0.20 µm**
- Temperature precision 1 K

Mass (kg)	Power (W)	Dimensions (mm)	Data consumption	TRL	Heritage	Op. Temp. (ºC)
35	27	780 × 760 × 550	0.02 MB/s	6	VIMS (CASSINI)	-218.15 to -213.15

Visible Cameras (x2)

SO3: Topographical evolution since Dawn

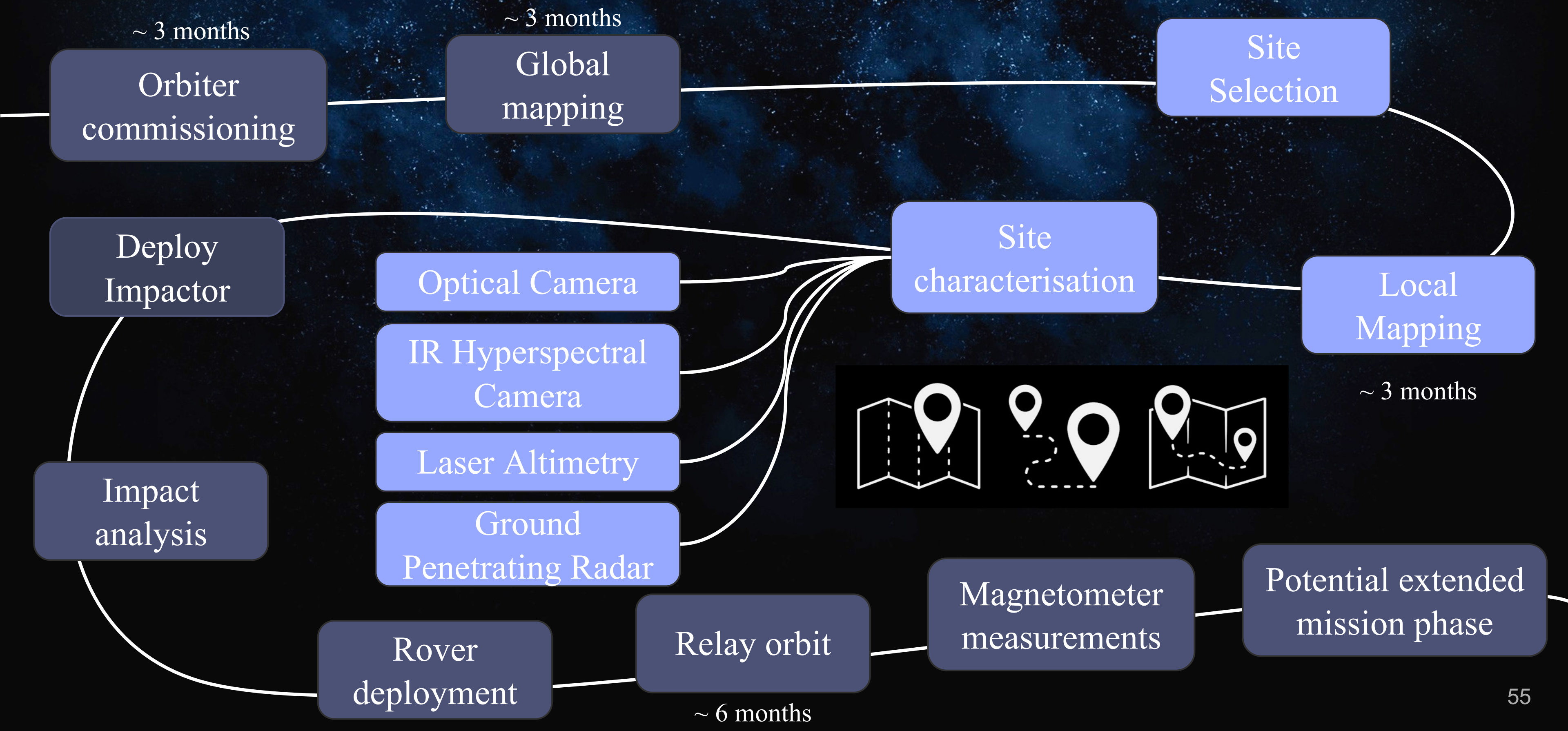
SO3: Visual analysis of impact site

- 40 m/pixel at 396 km altitude
- Resolution: 1 m/pixel at 10 km altitude
- 2048 × 2048 pixel CCD detector
- FoV: 12x12°
- 240 to 720 nm

NASA/JPL-Caltech/UCLA/MPS/DLR/ID

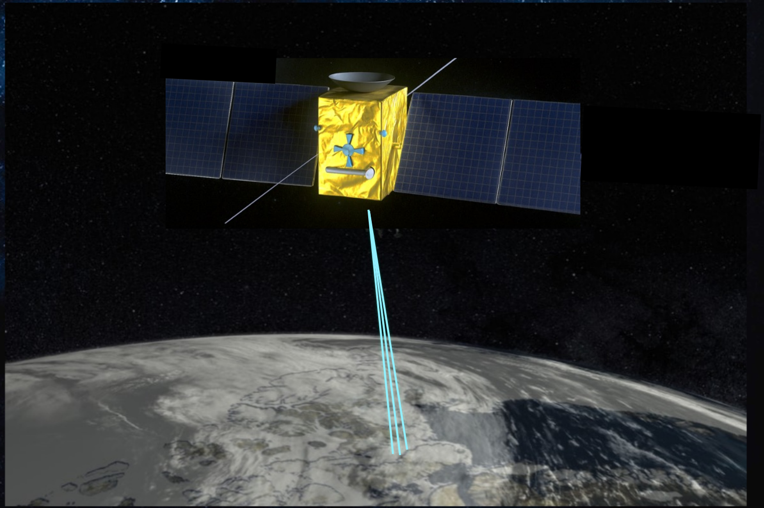
Mass (kg)	Power (W)	Dimensions (mm)	Data	TRL	Heritage	Op. Temp. (ºC)
9 x2	12 x 2	(80×80×80) ×2	16.8 MB/image	8	OSIRIS Wide Angle Camera (Rosetta - ESA)	-30 to 60

The Life of Poseidon



Laser Altimeter

SO3: Detailed topography



- Landing site mapping
- Accuracy: 7 cm horizontal, 1 cm vertical

Mass (kg)	Power (W)	Dimensions (mm³)	Data consumption	TRL	Heritage	Op. Temp. (º C)
6.5	50	98 × 105 × 83	38.5 kB/s	6	RAX (MMX -JAXA)	0 to 40

Ground-Penetrating Radar

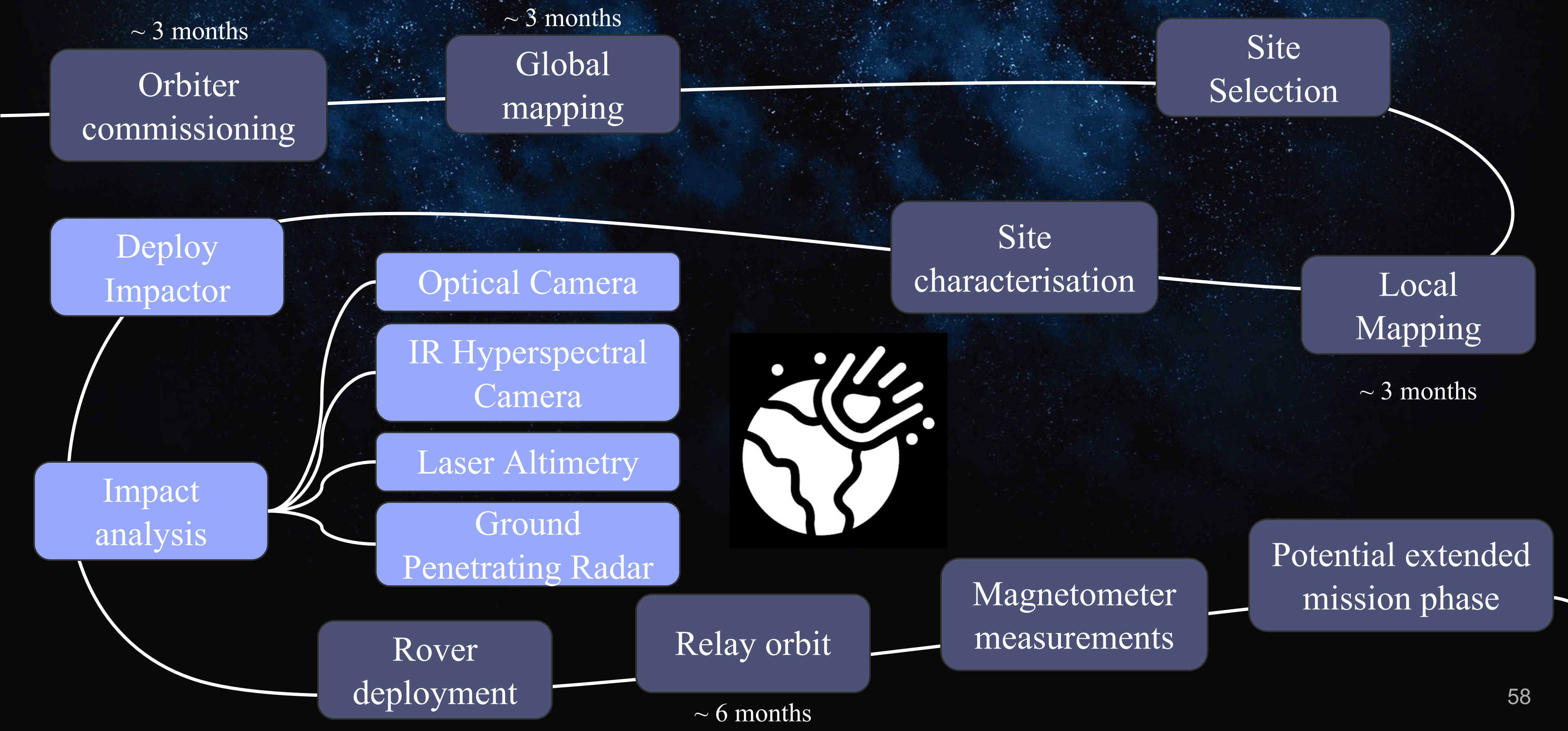
SO3/4: Analysis of impact site

SO4: Subsurface differentiation

- Vertical resolution locally: 150 m
- Depth: 5 km

Mass (kg)	Power (W)	Dimensions (mm)	Data consumption	TRL	Heritage	Op. Temp. (º C)
17	60	length: 40000 diameter: 38	20.1 kB/s	6	MARSIS, Mars Express	0 to 60

The Life of Poseidon



Copper Impactor

SO1/2: Expose new pristine material

SO3: Perturbations in subsurface activity

- Pneumatic launch system
- Laser altimetry, ground penetrating radar, images
- Precision: 3 m crater

Mass (kg)	Power (W)	Dimensions	Data Consumption	TRL	Op. Temp. (° C)
4	0	Radius: 3.76 cm	0	1	–

The Life of Poseidon

~ 3 months

Orbiter commissioning

~ 3 months

Global mapping

Site Selection

Local Mapping

~ 3 months

Site characterisation

Deploy Impactor

Impact analysis

Rover deployment

Relay orbit

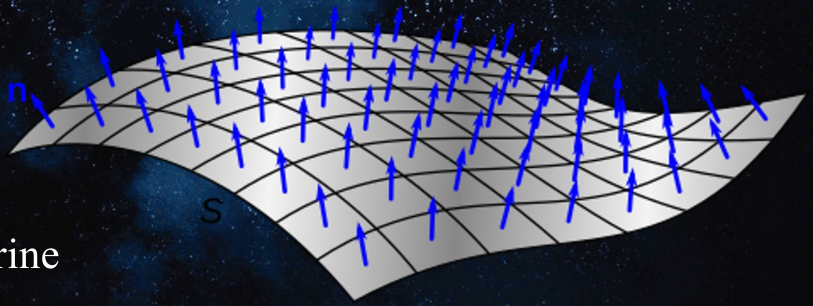
~ 6 months

Magnetometer measurements

Potential extended mission phase

Magnetometer (Orbiter and Rover)

SO1/4: Detect subsurface water reservoirs

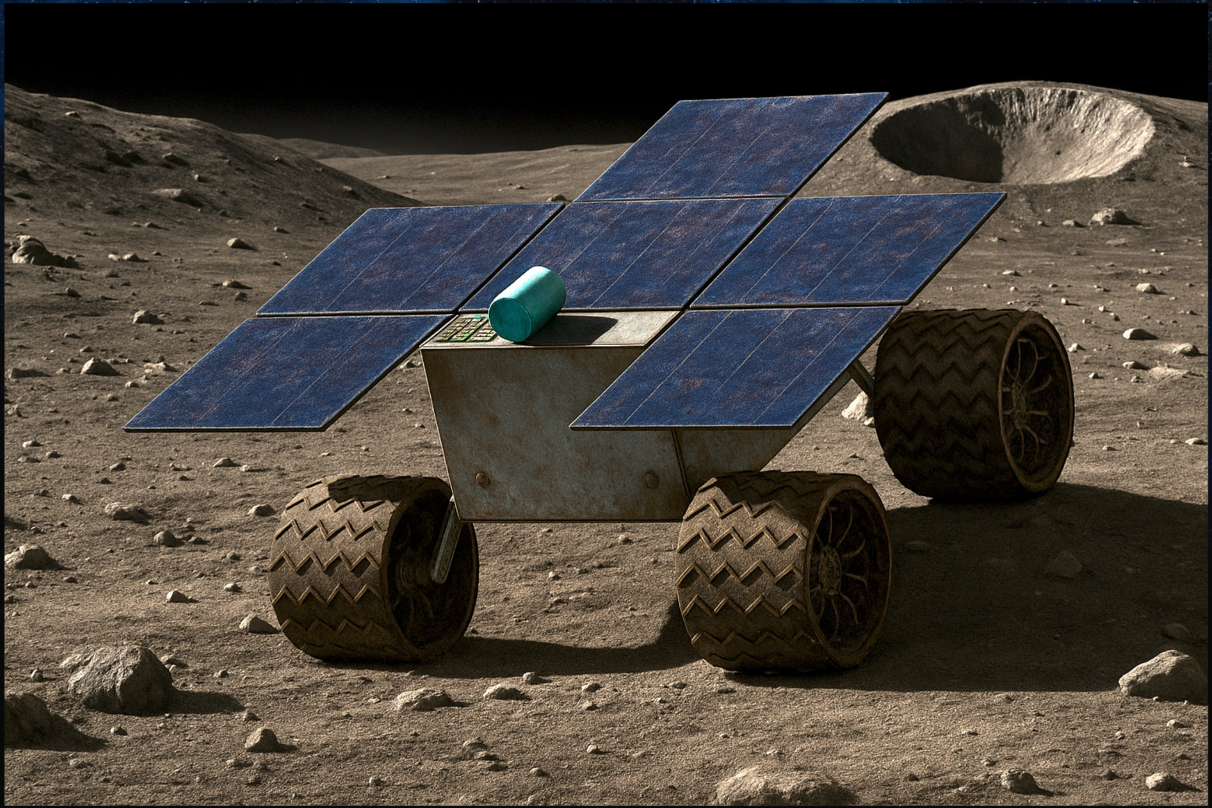


- 10 - 200 m thick silicate/ice layers containing brine
- Accuracy: 0.01 nT for 27 h

Mass (kg)	Power (W)	Dimensions (mm^3)	Data consumption	TRL	Heritage	Op. Temp. (ºC)
1.54	0,9	70 × 70 × 45	500 bits/s	6	THEMIS fluxgate magnetometer	-55 to 60

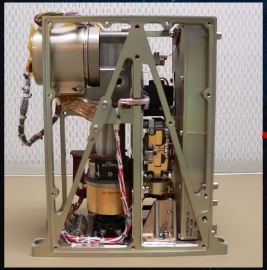
Our Rover - Percy

Sample Preparation



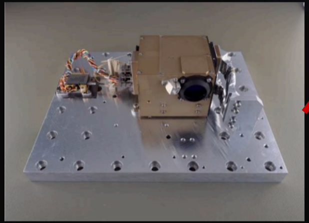
Percy - Instruments

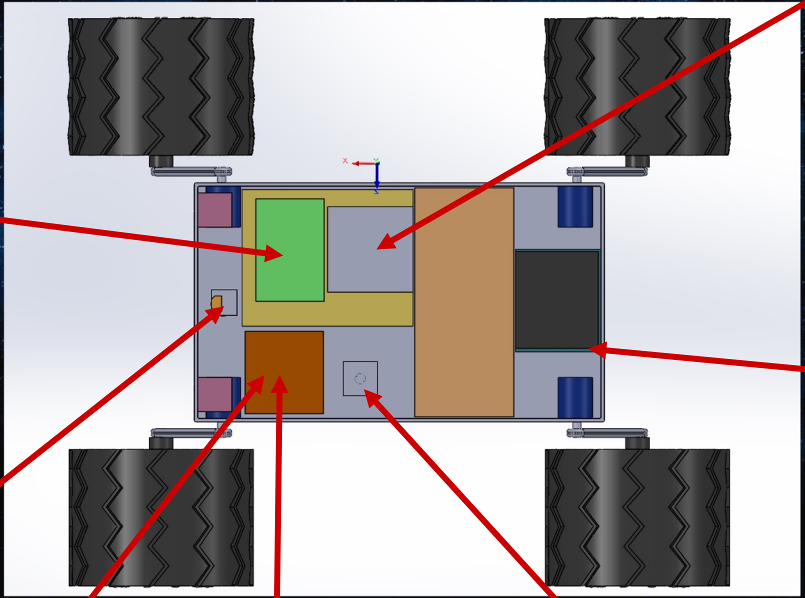
IR Spectrometer



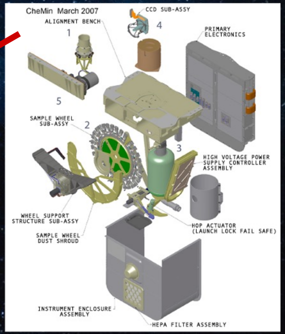
Magnetometer

Raman

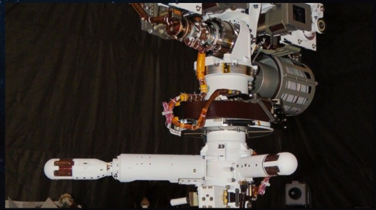




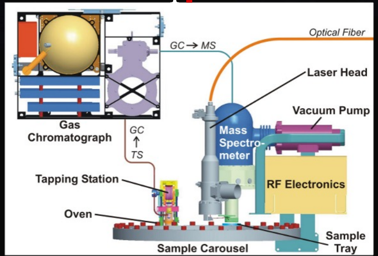
XRD L chip



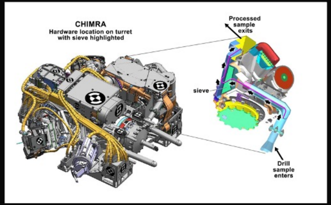
Pressure Sensor



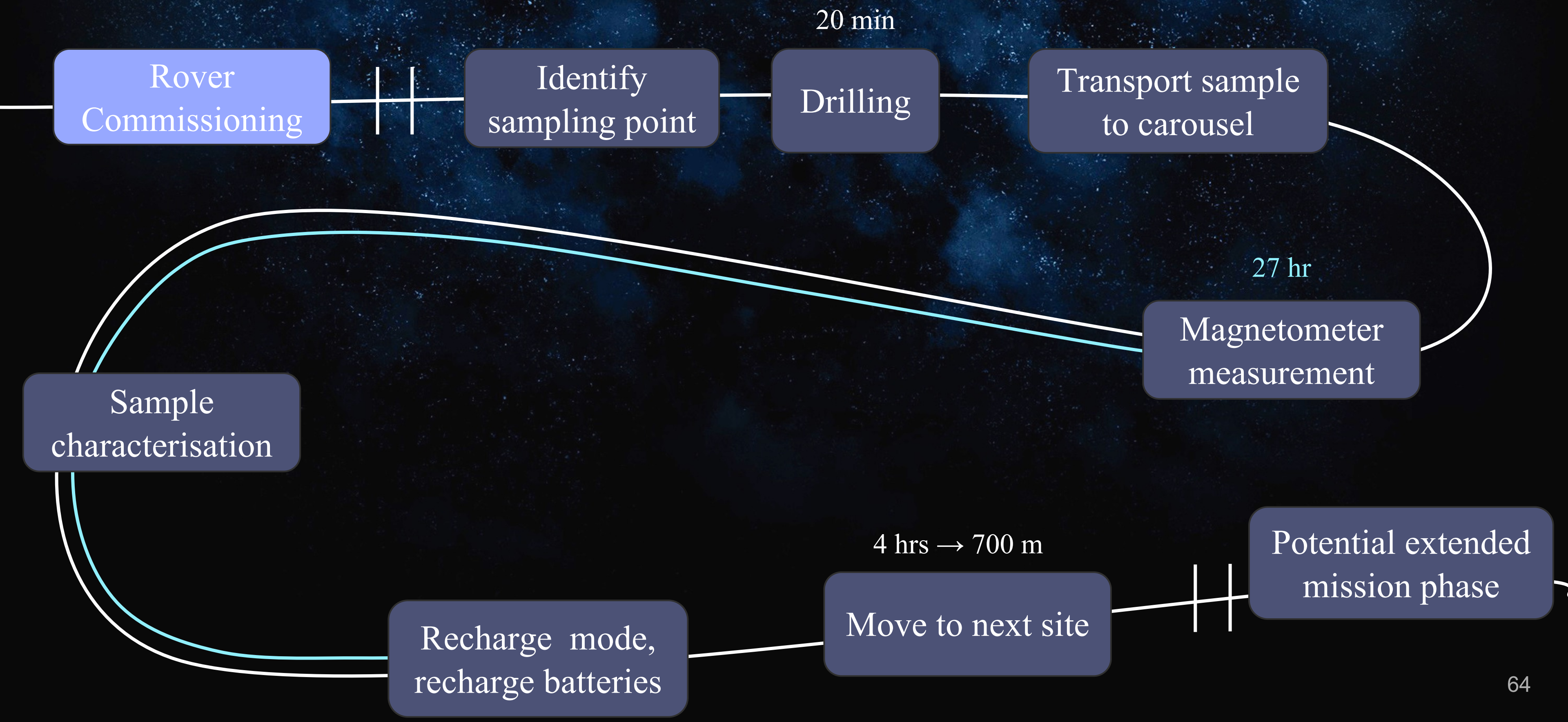
Mass Spectrometer



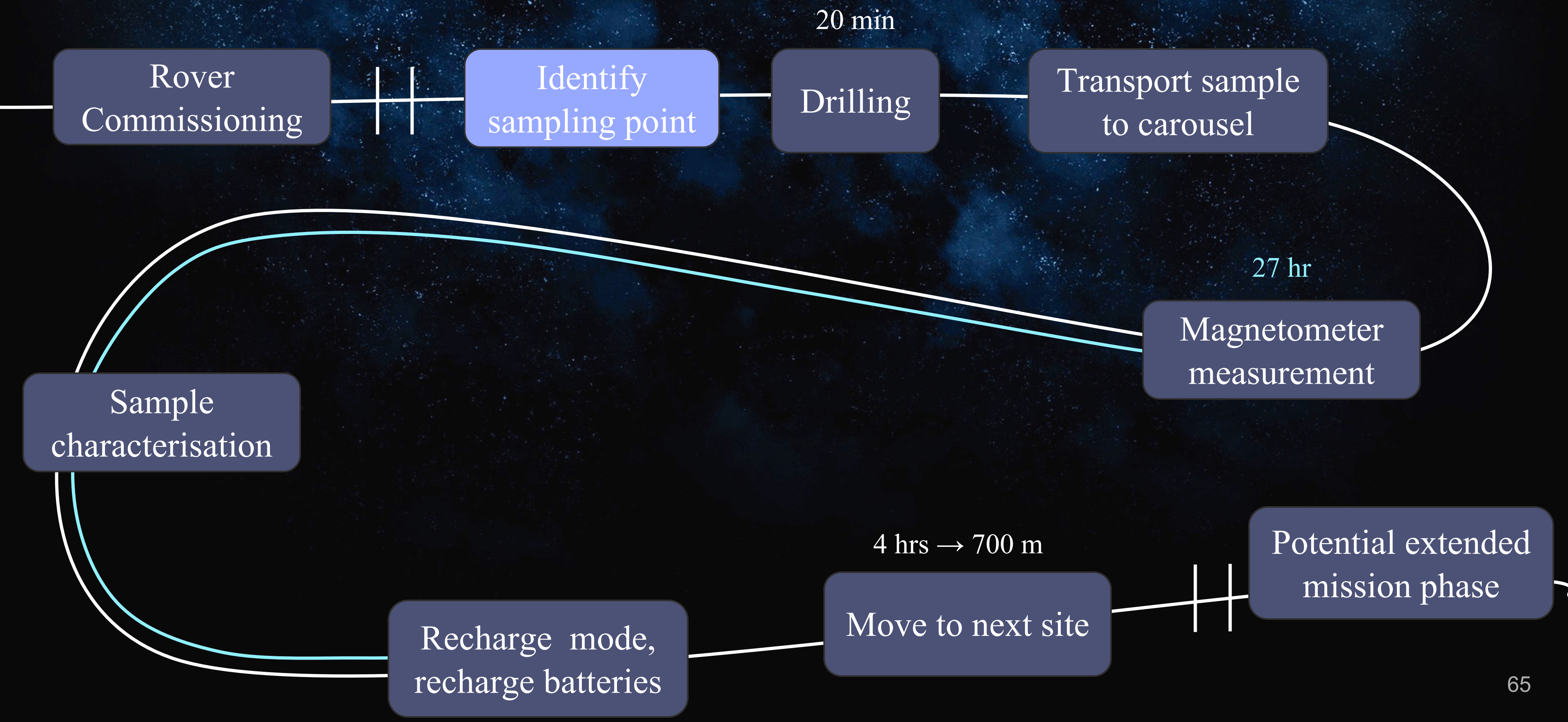
Drill



A "Day" in the Life: Percy

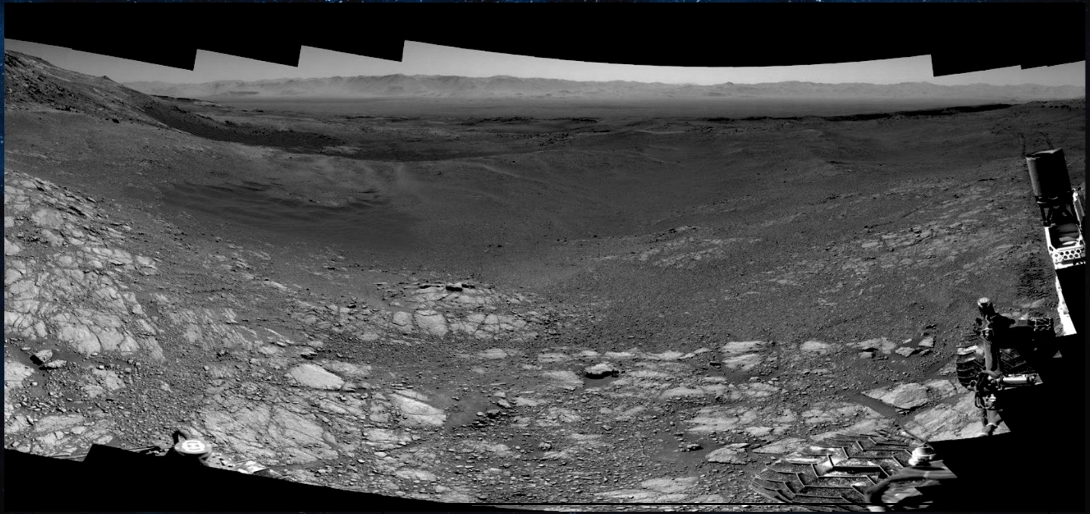


A “Day” in the Life: Percy



Panoramic Camera

- Navigation
- Resolution: 1 m/pixel



Martian panorama from Curiosity rover

Mass (kg)	Power (W)	Dimensions (mm)	Data consumption	TRL	Heritage	Op. Temp. (ºC)
2.13	9.2	200x150x180	8.789 GB/image	6	PanCam (ExoMars)	-55 to 40

Pressure Sensor

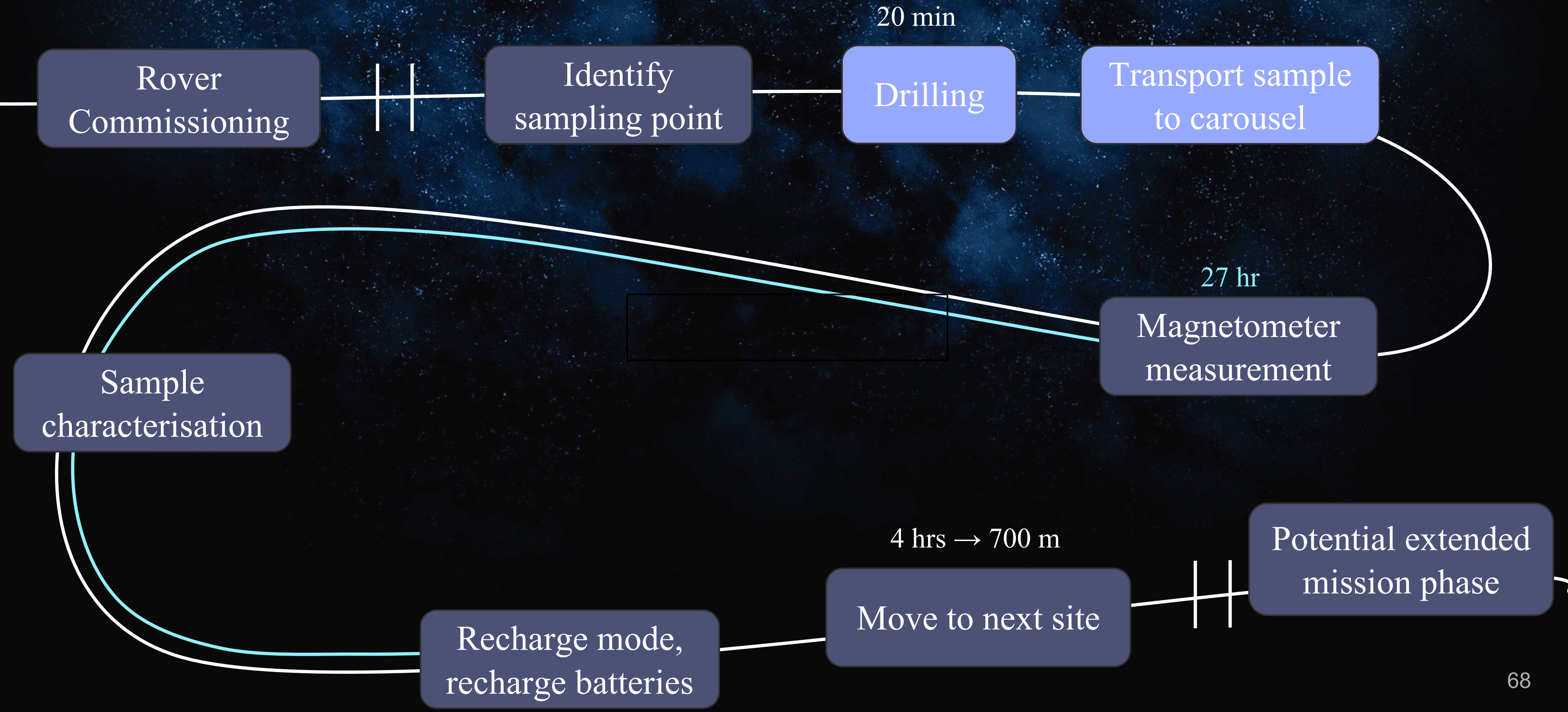
SO3: Upwelling detection

SO3: Outgassing detection

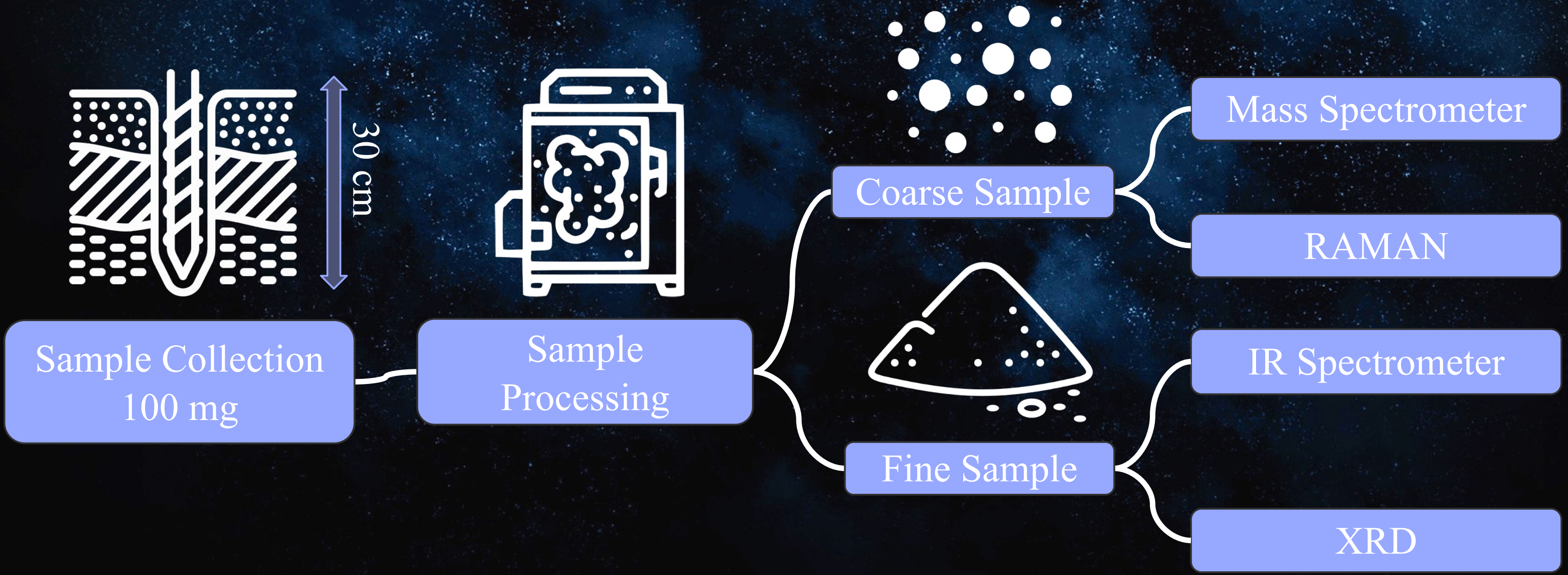
- Accuracy: 10 Pa
- Precision: 1 Pa

Mass (kg)	Power (W)	Dimensions (mm)	Data consumption	TRL	Heritage	Op. Temp. (ºC)
5.5	17	140x140x130	0.01 GB	6	MEDA (Perseverance)	-44 to 55

A "Day" in the Life: Percy

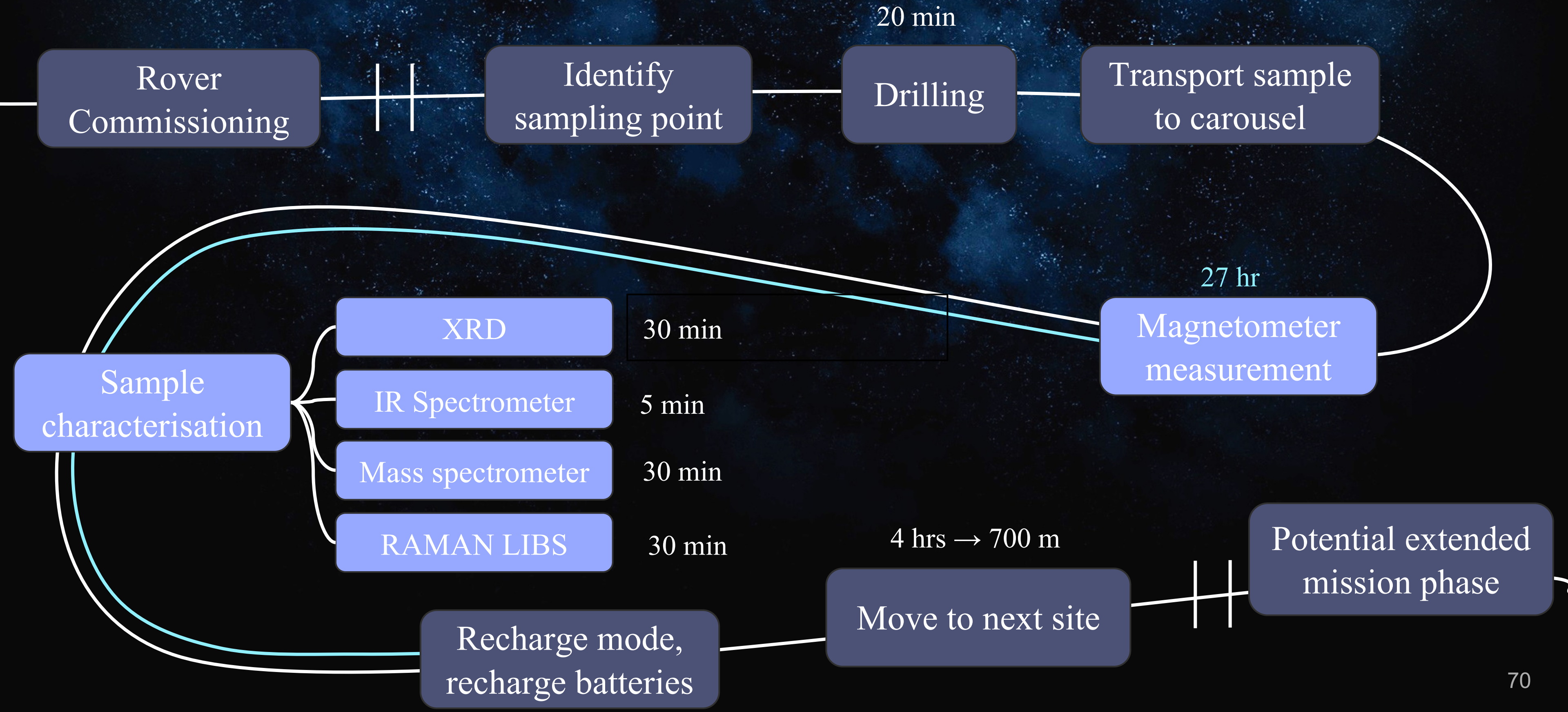


Drilling Process



Mass (kg)	Power (W)	Dimensions (mm)	Data consumption	TRL	Heritage	Op. Temp. (º C)
5	20	158 × 760 × 399	NA	7	SD2 (Rosetta Philae)	-160 to 40

A "Day" in the Life: Percy



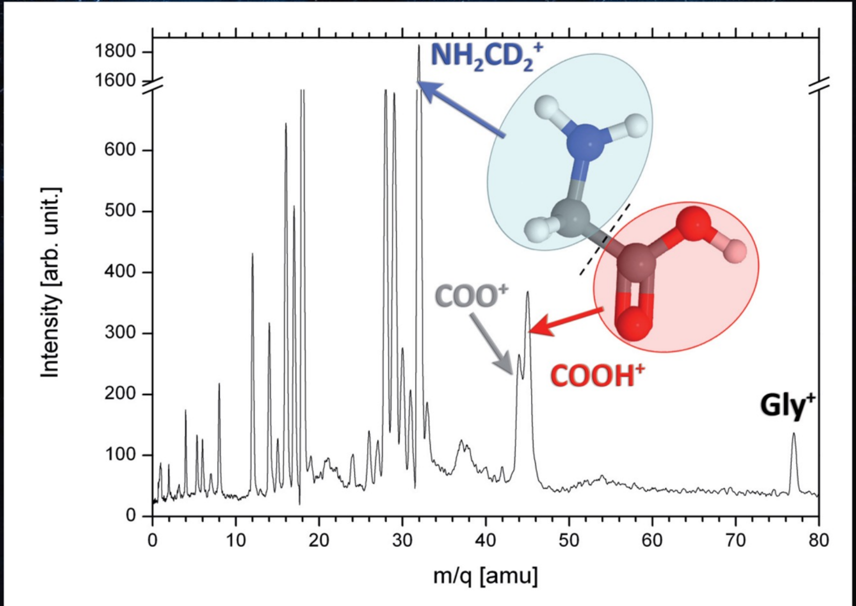
Gas Chromatograph Mass Spectrometer

SO1: Measure D/H in water

SO2: Identify Complex organics

SO1/3: Hydrated minerals

- Range: 10 - 1000 amu
- Resolution: 1 amu
- Sensitivity: 10 ppb



Mass (kg)	Power (W)	Dimensions (mm)	Data consumption	TRL	Heritage	Op. Temp. (ºC)
8	13	240 × 230 × 180	8 MB each 30 min	6	MOMA / COSAC	-40 to 40

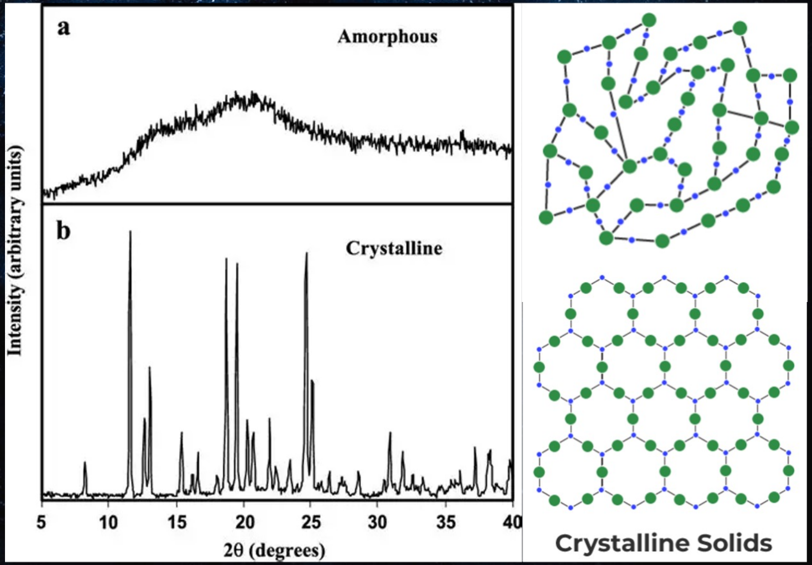
X-Ray Diffraction with L-Chip

SO1: Phase differentiation

SO1: Degree of crystallinity

SO1/3: Composition of active regions

- X-ray diffraction from 4 to 55 degrees
- 0.3º resolution

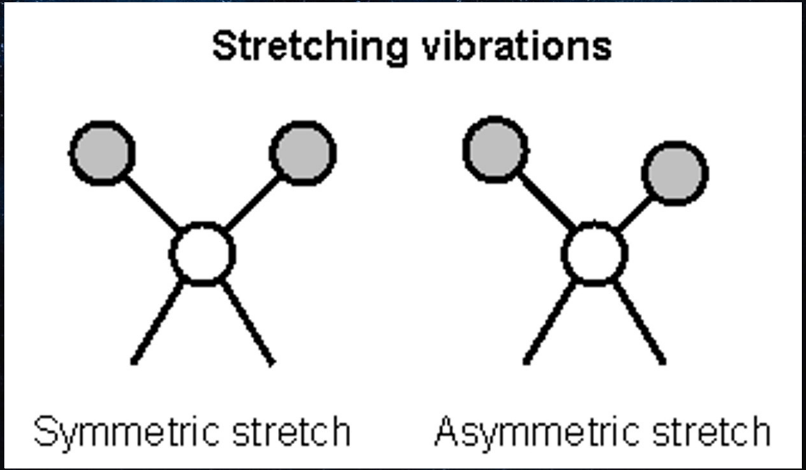


Mass (kg)	Power (W)	Dimensions (mm)	Data	TRL Xray	TRL Chip	Heritage	Op. Temp. (ºC)
5	18.8	241 × 229 × 178	0.745 GB in 5 h	6	4	CheMin Curiosity	-40 to 40

IR Spectrometer

SO1/3: Detection of volatiles, salt hydrates and ices.

SO2: Detection of volatiles, salt hydrates and ices.



- Spectral resolution: 20 cm^{-1}
- Spectral Range: 0.9-3.6 µm

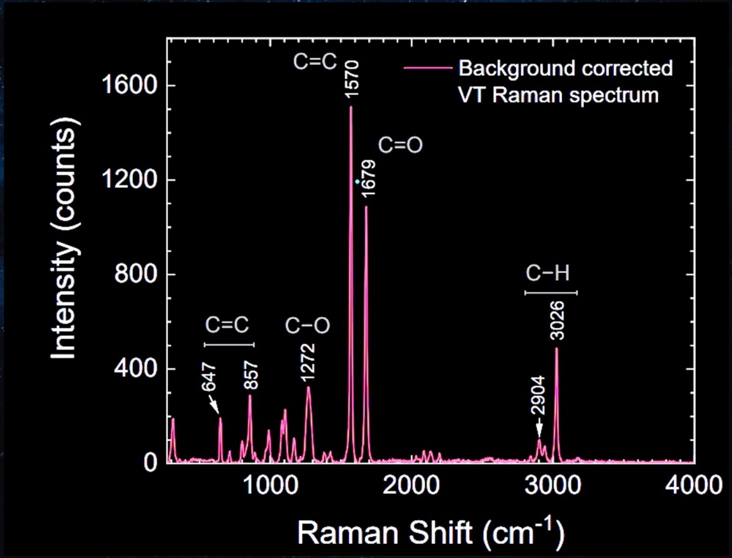
Mass (kg)	Power (W)	Dimensions (mm)	Data consumption	TRL	Heritage	Op. Temp. (º C)
2	11.5	300 × 200 × 200	8 MB each 500 s	6	MicrOmega-IR ExoMars	-40 to 40

Raman Spectrometer

SO1/2: Phase identification

SO2: Mineralogical composition of brine/surface geology.

SO2: Elemental Abundance

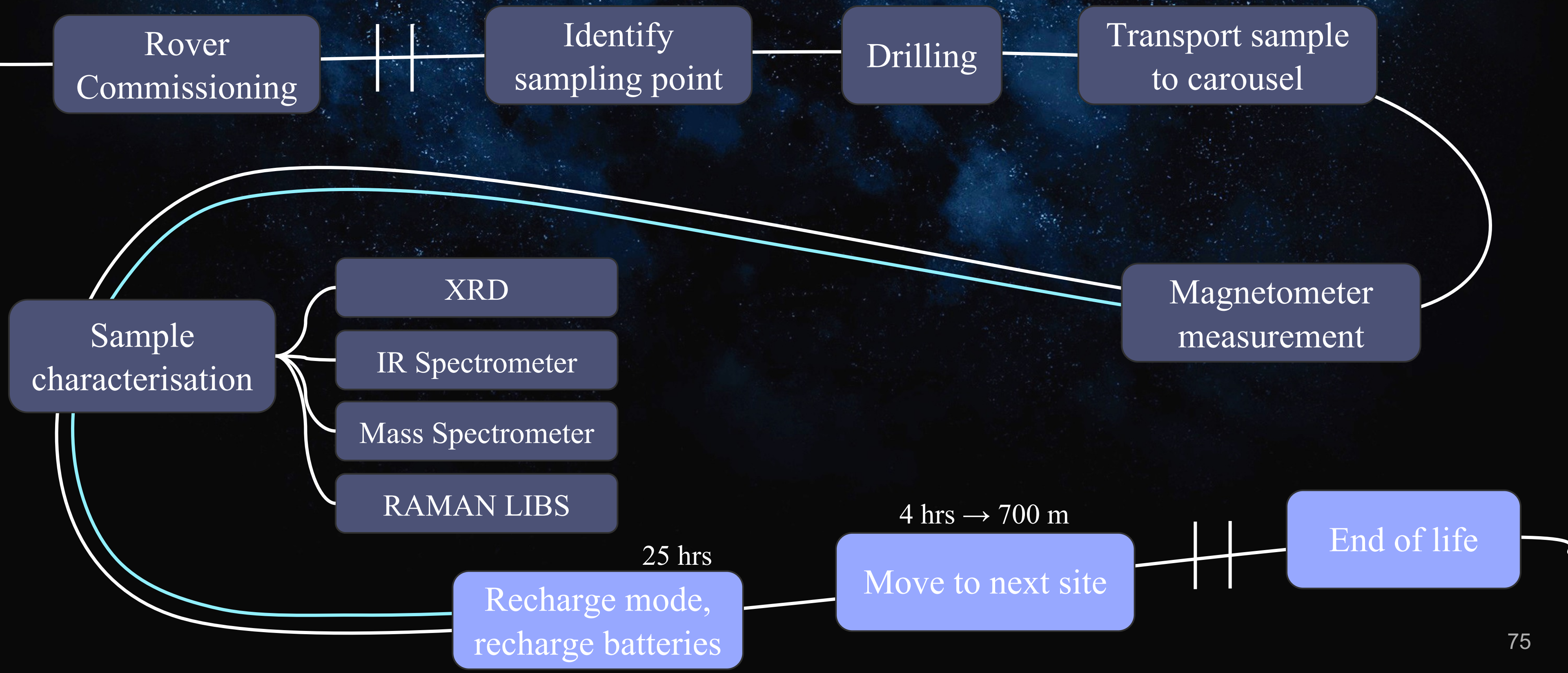


IAC-22-A3.4A.8 RAX: The Raman Spectrometer for the MMX Phobos Rover

- Spectral resolution: 10 cm^{-1}
- Spectral Range: 90 to 4000 cm^{-1}

Mass (kg)	Power (W)	Dimensions (mm)	Data consumption	TRL	Heritage	Op. Temp. (º C)
1.5	25	98 × 105 × 83	675 kB each 30 min	6	RAX (MMX - JAXA)	-40 to 5

A "Day" in the Life: Percy



WHY

WHERE

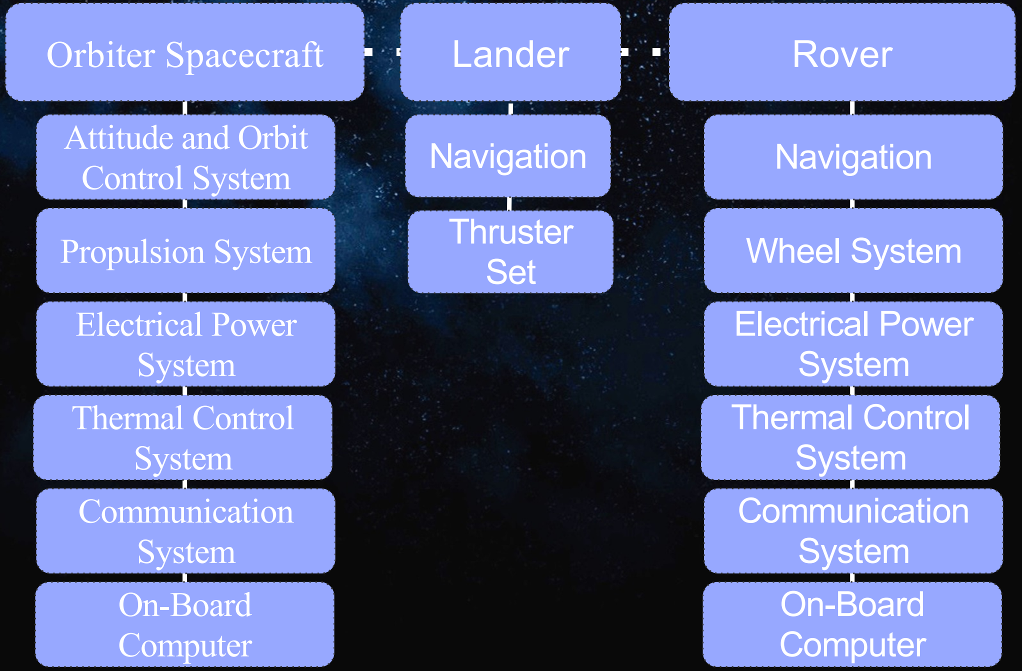
WHAT

HOW

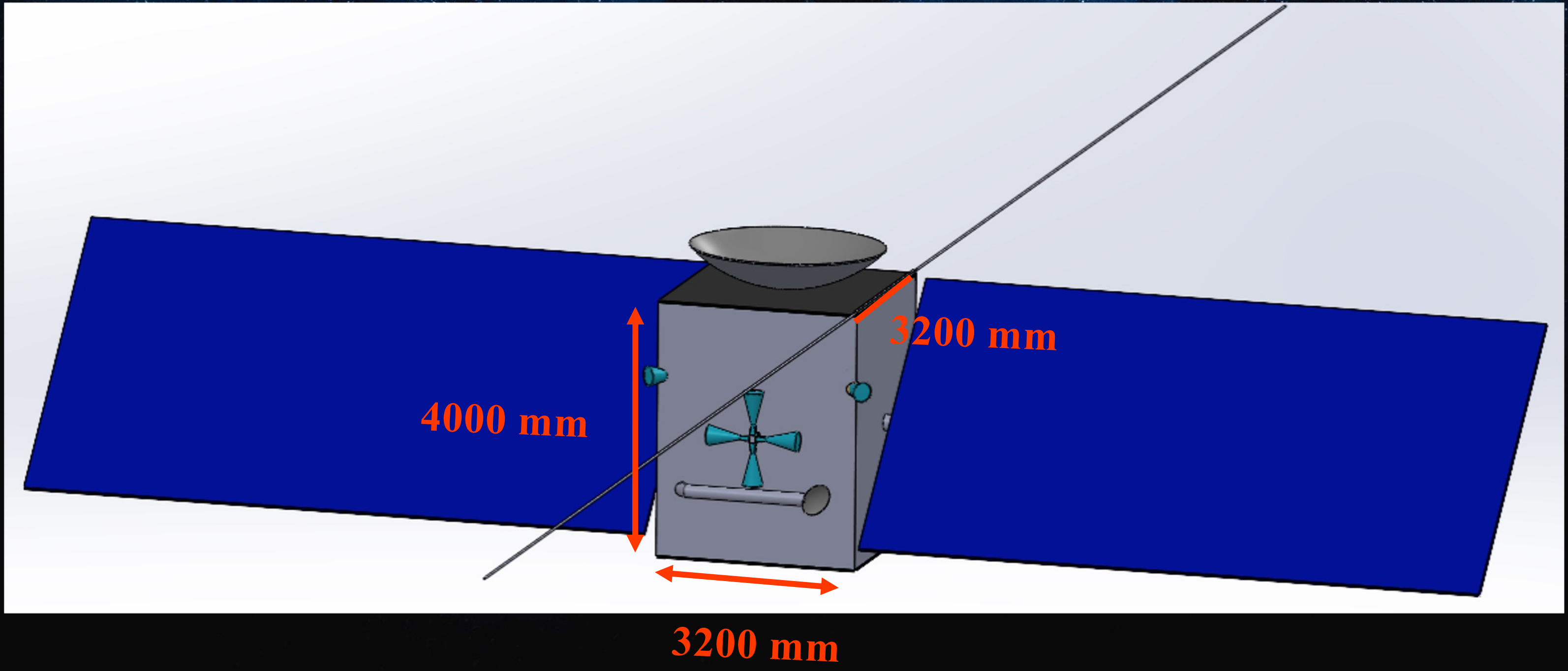
System Design - Overview

MAIN DESIGN CONSIDERATIONS

- Maximization of scientific output and instrument duty cycles
- Preference on high TRL and space-graded components
- Redundancy in critical components
- Overall volume envelope must fit Ariane 64



System Design - Overview



Orbiter - Attitude and Orbit Control System

ATTITUDE SENSORS

- 2x Star trackers
- 12x Sun sensor
- 2x Visual cameras
- 2x Inertial Measurement Unit

ACTUATORS

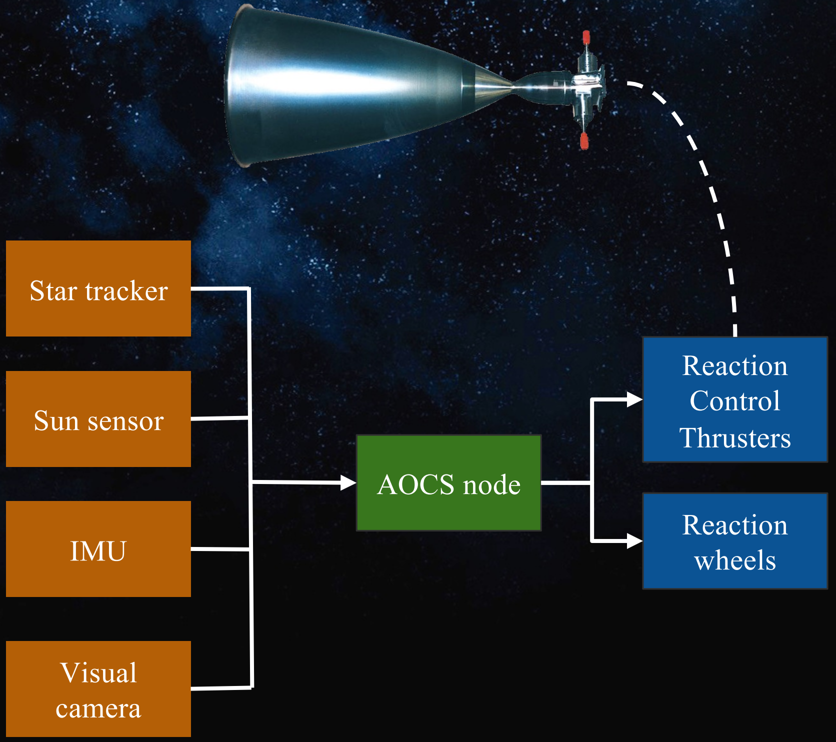
- 4x Reaction wheels (RW) in 3+1 assembly
- (Desaturation via Reaction Control Thrusters)

ORBIT CONTROL

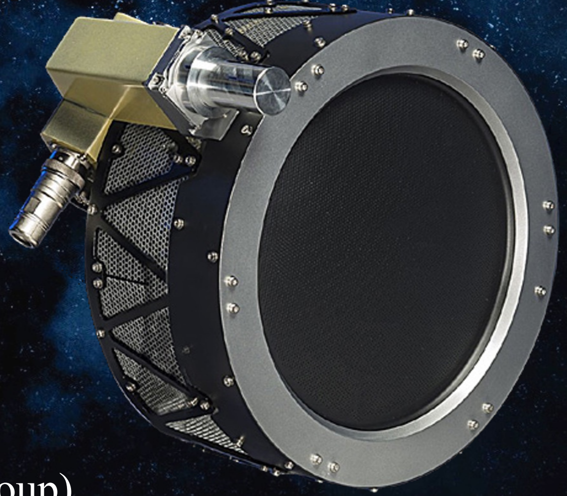
- 12x Reaction Control Thrusters (RCS)

POSITIONING

- Radio-ranging + visual based positioning



Orbiter - Propulsion System



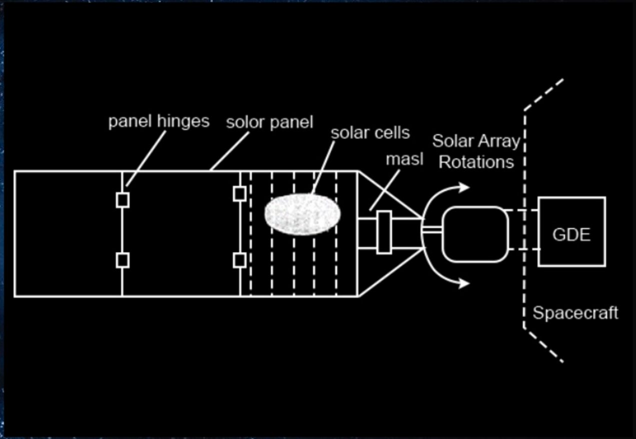
CONSIDERATIONS:

- Thrust level
- Specific impulse
- Maximum thrusting duration & lifetime

BASELINE COMPONENT: RIT-2x Thrusters (ArianeGroup)

	Units	Model	Mass [kg]	TRL	Thrust
Thruster	2+2	RIT 2x	40	4	150mN
Fuel	-	Xenon	1650	-	-

Orbiter - Electrical Power System



CONSIDERATIONS:

- Power consumption @ transfer: ~ 5 kW
- Power consumption in orbit: ~560W (avg. for most consuming mode)
- Power consumption during eclipse (max 100 min): ~520W (avg.)
- Energy budget during LEOP < Science Modes

BASELINE COMPONENTS:

Solar Panels (steerable)	
Design scenario: fully solar powered transfer (5kW)	
Type	Azur 3G28 (Juice Heritage)
Efficiency	35% (BOL)
Degradation	2.5% per year
Margin	20%
Total Solar Array	126 m²

Batteries	
Design scen.: npower production during transfer (5 kW)	
Type	NiH2
Depth of discharge	50 %
Number of batteries	3 (+ 3)
Margin	20%
Total Capacity	~ 15 000 Wh

Orbiter - Thermal Control System

CONSIDERATIONS

- Hot Case: 30°C (Driver: Laser altimeter & Accelerometer)
- Cold Case: 10°C (Driver: Laser altimeter)

BASELINE COMPONENTS

- Radiators: total radiator area amounts to 6.4 m^2
- Cryocoolers for infrared hyperspectral camera
- Electric Heaters (producing up to 104 W of power for thermal energy generation)
- Temperature Sensors and Thermostats: to control and determine the temperature value
- Multi Layer Insulation (MLI), 20-layer

Orbiter-Ground Station: Communication

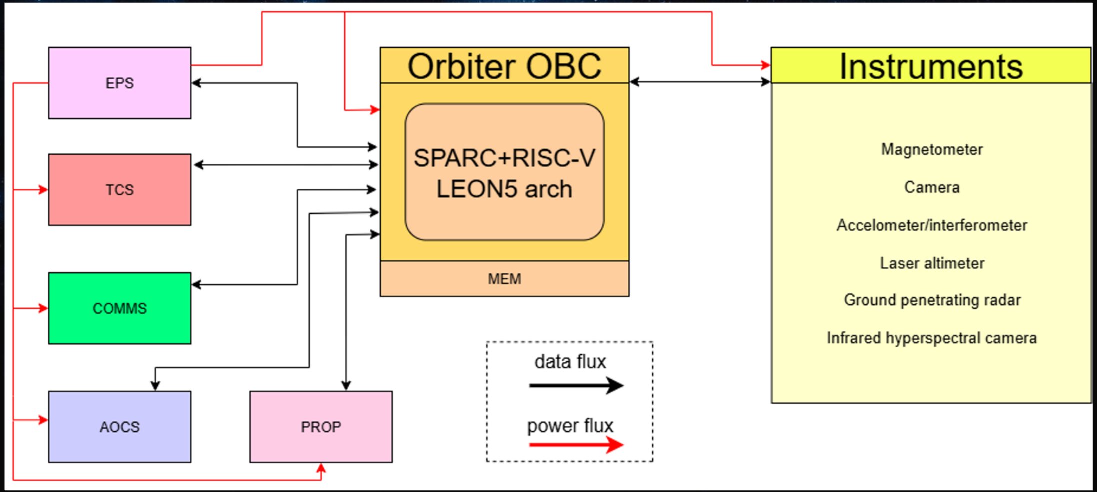
- High Gain Antenna (3 Meter Diameter):
  - X-Band (Downlink, Uplink), Bandwidth: 5 MHz
  - Ka-Band (Downlink), Bandwidth: 100 MHz
- Medium Gain Antenna (0.5 Meter Diameter):
  - X-Band (Downlink, Uplink), Bandwidth: 5 MHz

	Ka-Band Downlink (HGA)	**X-Band Downlink (HGA)**	**X-Band Uplink (HGA)**	**X-Band Downlink (MGA)**
f [GHz]	32	8.7	7.2	8.7
Data Rate [Mbps]	1	0.1	0.5	0.08
Link Margin [dB]	2.6	2.6	10.5	7.8

Orbiter - On-Board Computer and Data Handling

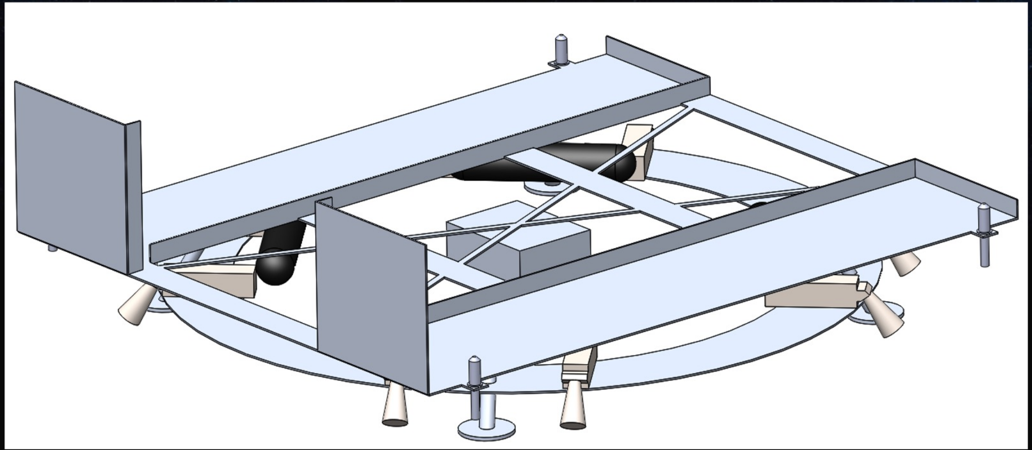
CONSIDERATIONS

- Responsible for operating both platform and instruments
  → Processing of TC and TM
  → Processing and storing of payload data
- Memory storage capacity of Orbiter + rover for 72h
- Redundant and fault tolerant system design to counter anomalies
- Ensure radiation hardness for whole mission duration



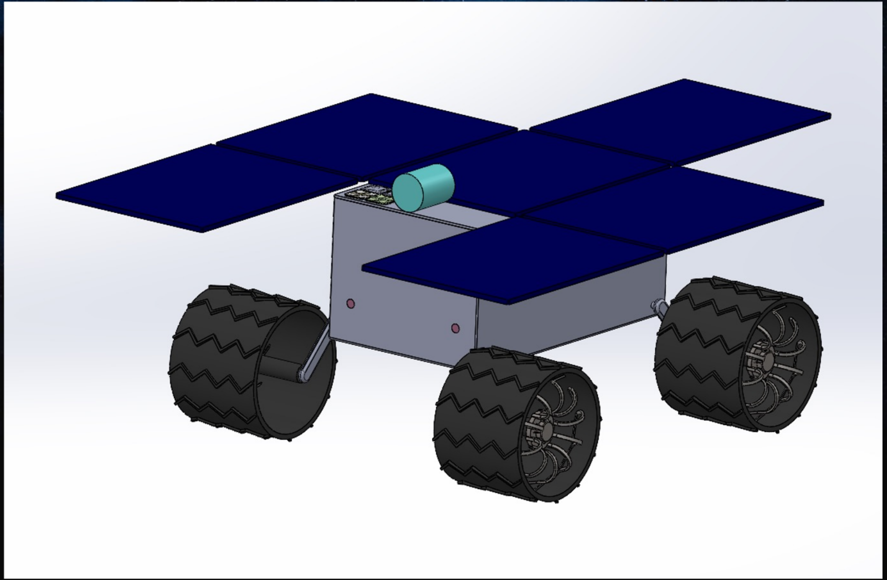
Lander

- **Disposable lander**
  - Only used for landing
  - No power generation
  - Batteries of 1842.5 Wh
- **Roll off lander type**
  - Rover stowed on top of ramp in flight
- **Flight system**
  - 12x monopropellant thrusters
- **Sensors**
  - 2x Inertial Measurement Units
  - (2+1)x Navigation cameras
  - 1x Flash LiDAR altitude determination
- **Mass**
  - 116.3 kg
  - 139.6 kg incl. margin
  - Propellant: 136.7 kg (without margin)



Rover - System Design

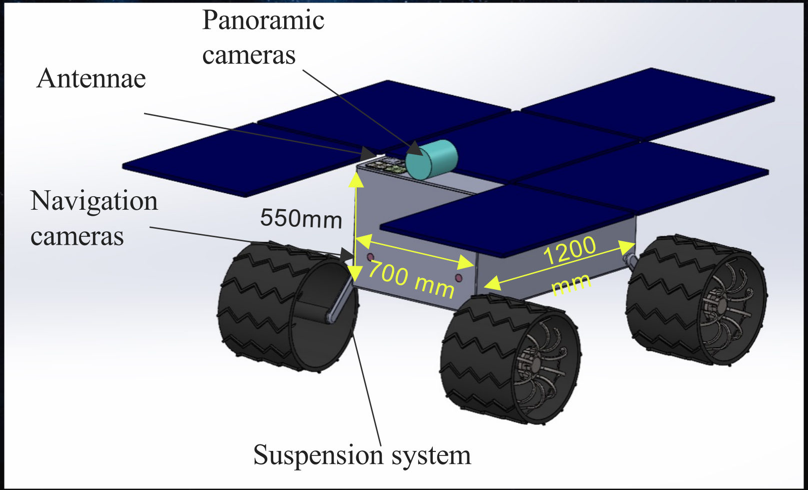
- Rover
  - Navigation
  - Wheel System
  - Electrical Power System
  - Thermal Control System
  - Communication System
  - On-Board Computer



Rover - Navigation & Wheel System

NAVIGATION & DRIVING

- Navigation using cameras, LiDARs, IMUs
- Off-line path planning on ground using both orbiter and rover data
- Autonomous driving given a path
- Moving speed: 5 cm/s
- Wheels with damping mechanism



Rover - Electrical Power System

CONSIDERATIONS:

- Power consumption for science modes in daylight (~4h): ~ 208W (incl. 20% margin)
- Power consumption for driving mode in daylight: ~192W
- Power consumption in nighttime (~5h): 62W

BASELINE COMPONENTS:

Solar Panels (non steerable)	
Design scenario: most power demanding science mode	
Type	Azur 3G28 (Juice Heritage)
Efficiency	35% (BOL)
Degradation	2.5% per year
Margin	20%
Total Solar Array	4 m^2

Batteries	
Design scen.: safe mode for 3 Ceres days (27h)	
Type	NiH_2
Depth of discharge	50 %
Number of batteries	3 (+ 3)
Margin	20%
Total Capacity (3 batteries)	~ 5581 Wh

Rover - Thermal Control System

CONSIDERATIONS:

- Hot Case: 0°C (Driver: Raman Spectrometer + 5K margin)
- Cold Case: -33°C (Driver: IR and Mass Spectrometer, Raman)

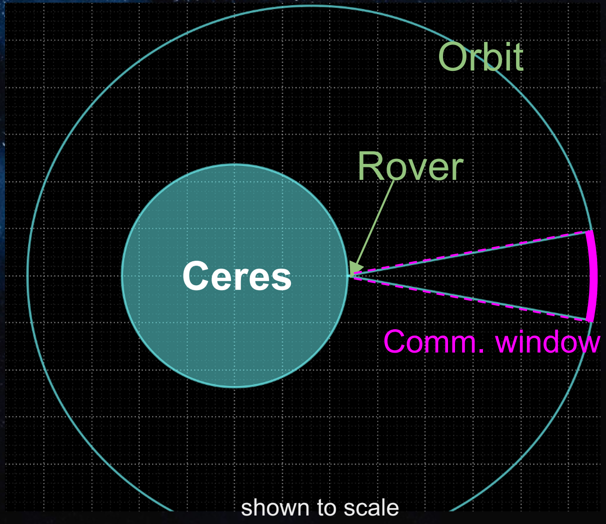
BASELINE COMPONENTS:

- Radiators: The total radiator area amounts to 2.9 m^2
- Electric Heaters (producing up to 50 W of power for thermal energy generation)
- Temperature Sensors and Thermostats to control and determinate the temperature value
- Multi Layer Insulation (MLI)

Rover - Communication

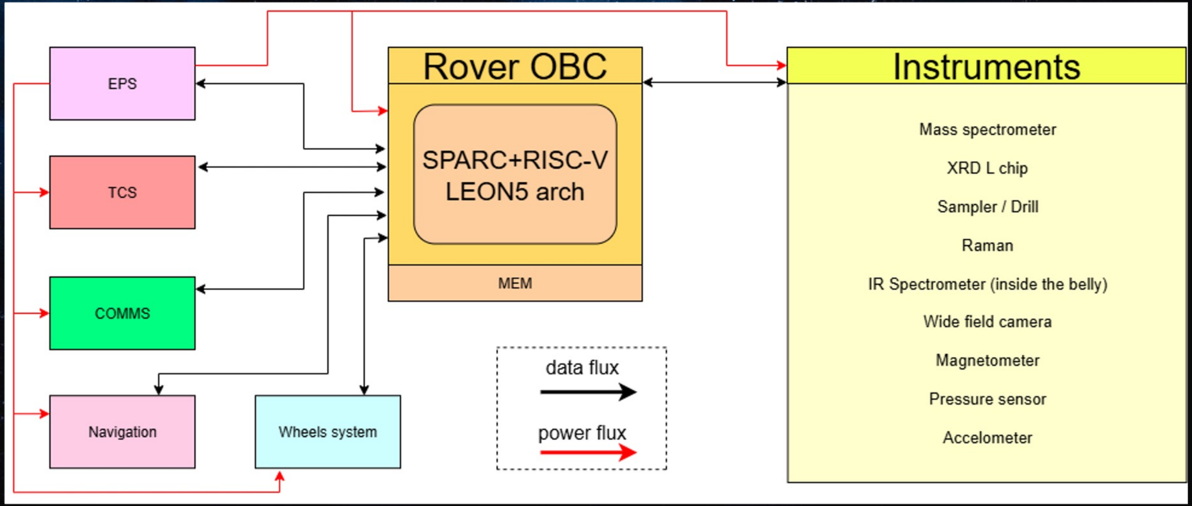
- Patch-Antennas:
  - X-Band (Uplink 7.2 GHz), Bandwidth: 100 MHz
- Communication Window:
  - Antenna Beamwidth = 21°
  - → Δt = 35 minutes per Orbit → 1.4 GB per Orbit

	X-Band Downlink (Orbiter to Rover)	X-Band Uplink (Rover to Orbiter)
f [GHz]	8.7	7.2
Data rate [Mbps]	0.5	5
Link Margin [dB]	18.7	13.1



Rover - On-Board and Data Handling

- Responsible for operating both platform and instruments
  → processing TC and TM
  → processing and storing of payload data
- Redundant and fault tolerant system design to counter anomalies
- Ensure radiation hardness for whole mission duration
- Memory storage capacity of rover data for 18h (2 Ceres days)



System Budget: Mass

A. Orbiter

Subsystems (without margin)	Mass [kg]
ADCS + Propellant	209.9 +754
Coms	38.6
OBC + Harness (5% of Sys. Dry Mass)	81
Thermal	95
EPS	434.5
Propulsion + Propellant	230 + 1650
Structure	400
Mechanisms (Solar Array)	16.6
Total Dry Mass (incl. 20% margin)	1 806
Total Wet Mass (incl. 20% system margin)	**4 210**

B. Rover

Subsystems (without margin)	Mass [kg]
Coms	1
OBC + Harness(5% of Sys. Dry)	26
Thermal	40
EPS	91
Structure + Wheel System	47
Mechanisms	10
Instruments	27
Lander system + Propellant	143 + 139
Total Dry (incl. 20% system margin)	462
Total Wet (incl. 20% margin)	**601**

Total marg. Instr. mass: 149 kg

→ **Total Wet Mass incl. Instr.: ~4961 kg**

System Budget: Power

A. Orbiter

Subsystems	Average Power [W]	
	Daylight	Eclipse
ADCS	120	120
Coms	100	10
OBC	30	30
Thermal	25	200
Solar Panel Steering Mech.	10	0
Instruments	185	55
Total (incl. margin)	**564**	**498**

B. Rover

Subsystems	Average Power [W]		
	Moving	Science	Night
Wheels Motors	67	3,3	0
Coms	10	50	10
OBC	15	15	15
Thermal	35	35	14
Solar Drive Mechanism	10	10	0
Instruments	24	60	12
Total (incl. margin)	**193**	**208**	**62**

System Budget: Data

System	DATA GB per 24h
Orbiter (Total incl. 20% margin)	1.3
Instruments	0.9
Platform	0.2
Rover (Total incl. 20% margin)	0.8
Instruments	0.6
Platform	0.1

Examples:

- **Orbiter global imagery:**

  → 18 GB of data
  - global mapping

- Rover example day:

  → 0.6 GB of data
  - 1h driving with imagery (0.1fps) + sampling afterwards

Ground Segment

Ground Stations

- ESTRACK ground stations: CEBREROS (Spain), MALARGUE (Argentina), both 35m, Ka-band
- Additional stations: Goonhilly (35m, Ka-band, UK) could be considered

Mission Control Center

- ESOC (Darmstadt, Germany)

Science Operations Center

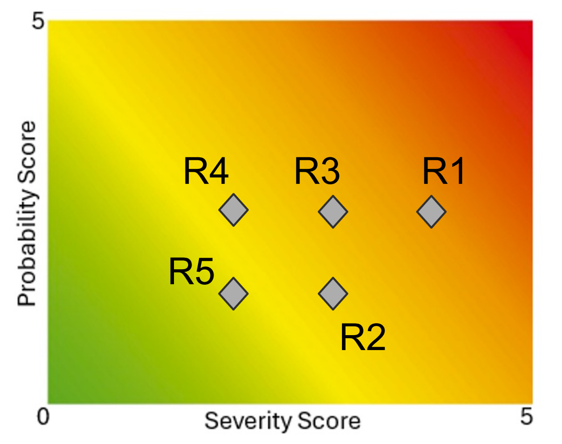
- (depending on science/instrument leads)

Science Data Archive

- ESAC (Madrid, Spain)

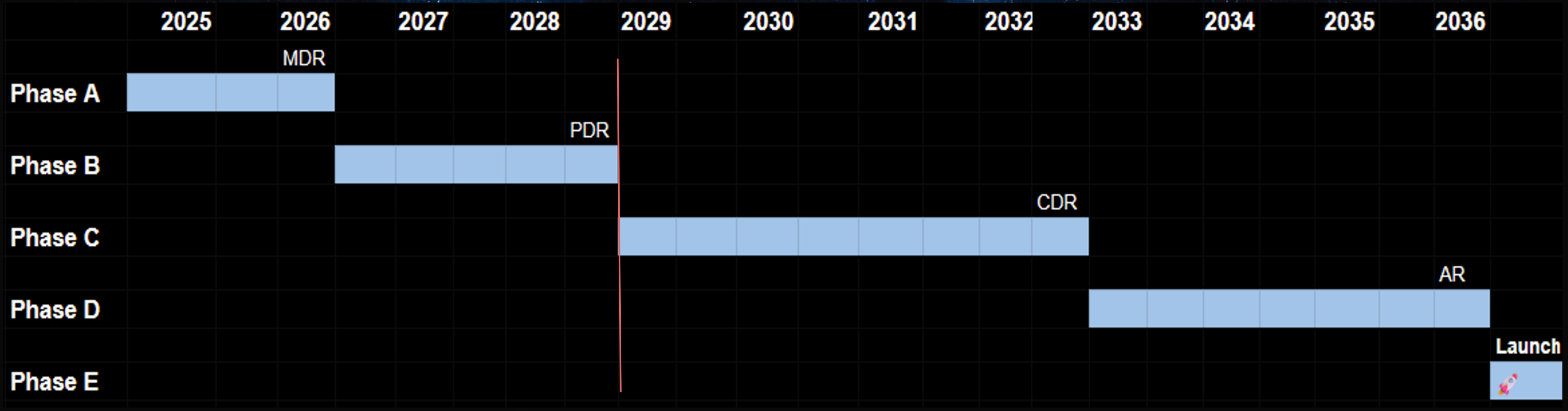
Risk Assessment

ID	Description	Impact	Prob	Sev	Mitigation
R1	Delays in project timeline	Missing of launch window, cost rise	3	4	Contingency margins on both cost and transfer options
R2	Orbit insertion inaccuracies	higher dv for corrections	2	3	Margins in dv budget
R3	Expedited Degradation of solar cells	lower power generation	3	3	Margin on power budget
R4	Expedited Degradation of batteries	reduced performance (esp. in eclipse)	3	2	Redundant batteries
R5	Faults with sample collection	no sub-surface sampling	2	2	Tests in appropriate test facilities (e.g. LUNA Lunar analogue facility)



Development Plan

Target: all instruments shall reach TRL 6 by PDR (end of phase B)



Min. TRL 6

Cost Estimate and Descoping Options

Mission category: ESA Class L

Main descoping options:

- Reduce number of sampling sites to 1
  - No moving rover
- Exclude subsurface sampling
  - Reduce system complexity
- exclude the instrument suite further
  - Change of mission profile

Element	Cost in M€	Nat. Contr. in M€
Launch (Ariane 64)	130	
Spacecraft + Lander	650	
Rover	300	
Instruments (Orbiter)		70
Instruments (Rover)		80
Mission Operations	90	
Science Operations	60	
ESA Mngt.	190	
Contingency	213	
Total CaC	**1 633**	**150**

Summary

PROGRAM SEGMENT

Investigating the origin of H_2O and on the Earth by landing on the largest extraterrestrial reservoir in inner Solar System.

SPACE SEGMENT: SYSTEM

Orbiter → global measurements

Rover → surface / subsurface sampling

SPACE SEGMENT: ORBIT

Transfer with SEP

Circular orbit → global coverage

Elliptical orbit → support rover

LAUNCH SEGMENT

From Kourou with an Ariane 64

GROUND SEGMENT

ESTRACK 35m dishes Operated from ESOC


Subsurface Obervation of Underground Reservoirs in the Ceres Environment
esa
#TEAMRED
#TEAMRED
SOURCE
esa
Image: Wikipedia

Extra slides

Science Requirements

1. Characterize the H_2O on Ceres and its relation to origin of water on Earth.

1-2: Global induced magnetic field strength, and local magnetic perturbations with an accuracy of 0.02 nT

3-4: Local D/H isotopic ratio from (sub)surface sample spectra with an accuracy of 10^{-4} and a precision of 10^{-5}

5-10: Detect complex organics, amino acids, carboxylic acids, salt hydrates, ammonium-bearing minerals, volatiles, non-volatile organics and ices in surface and subsurface samples with an accuracy of 50 - 1000 amu.

11-14: Confirm the presence of complex organics, hydrated minerals and sulphates on local surface and subsurface samples with a coverage of 9 - 4000 1/cm (is this cm^{-1} ?)

15: Attain spectra at 0.9-3.6 µm with a resolution of 0.2 µm.

16-21: Determine mineral crystal structure, degree of crystallinity and differentiate between crystalline, amorphous phases and distinguish polymorphs of crystals in local surface and subsurface samples with accuracy of 0.3° 2ϴ form 4° to 55°

Science Requirements

2. Assess the current and past habitability potential of Ceres with relation to origin of life on Earth.

See Req. 5-21, AND

22: Map the global distribution of different species of complex organic molecules

Science Requirements

3. Determine the origin of observed surface activity on Ceres.

See Req. 5-22. AND

23-24: Determine the global topography with a precision of 40 m/pixel at 396 km of altitude and the local topography with a precision of 1 m/pixel in a radius of (TBD) km around the landing site

25-26: Surface temperature globally, and temperature fluctuations locally, both with a precision of 1 K

27: Determine the presence of water and oxygen in the exosphere with a precision of 0.1 μm, locally

28: Characterise global subsurface movement and layering at a depth of 8 m and vertical res. of 10 cm .

29: Provide visual imagery of the impact site of the ballistic projectiles with a resolution of 1 m

30: Spectral decomposition of the ejecta at the impact site of the ballistic projectile with a res. of 20 nm

Science Requirements

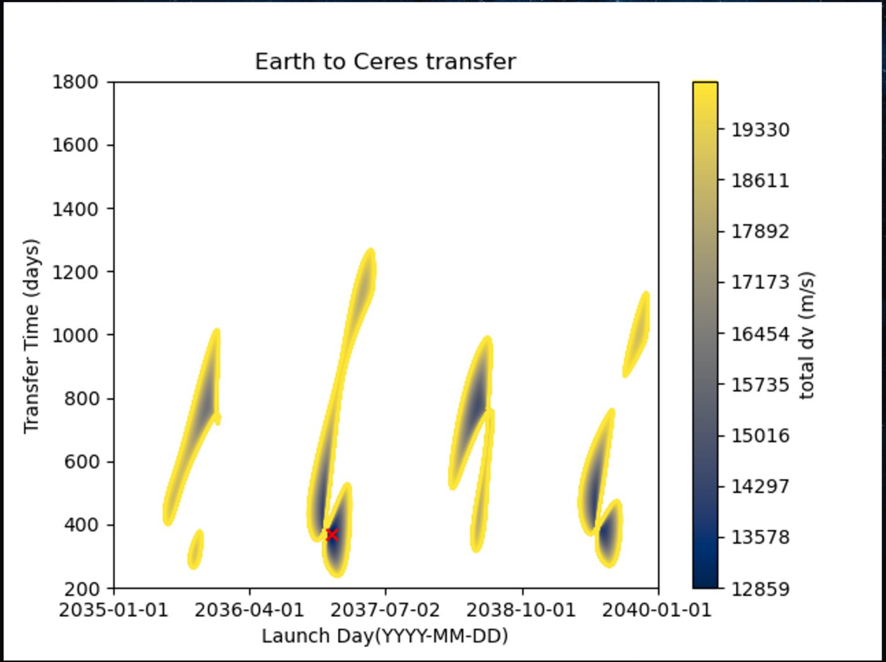
4. Determine the internal structure and differentiation of Ceres.

See Req. 1, 5-21 and 22

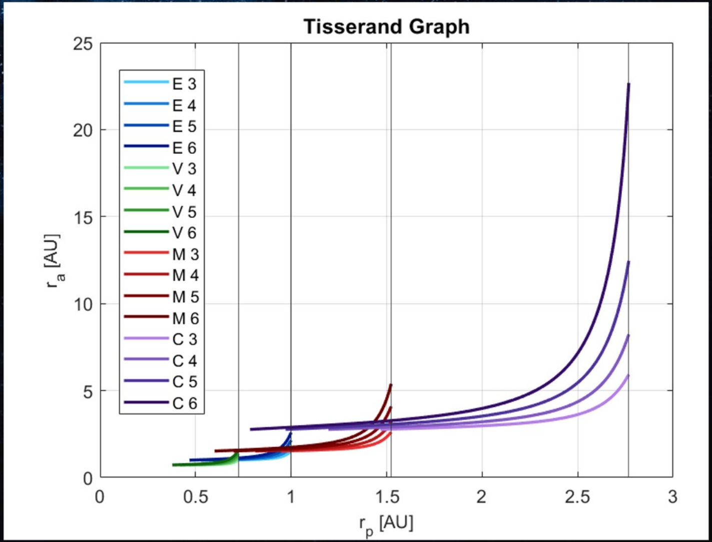
Orbiter - Attitude & Orbit Control System

	Model	Units	Mass [kg]	Size [mm]	Power [W]
Star tracker	ASTRO APS	2	2	154x154x237	23
Sun tracker	BASS	12	0.5	70x82x23	Passive
Visual camera	???	?	?	?	?
IMU	Astrix 1090	2	4.5	ø263x192	13.5
RW (assembly)	RW250	4	5	~270x270x270	52+
RCS	S400-15	12	3.6	ø316x669	-
Propellant	$MMH+N_2O_4$	-	480	ø625x915	-

Mission Analysis

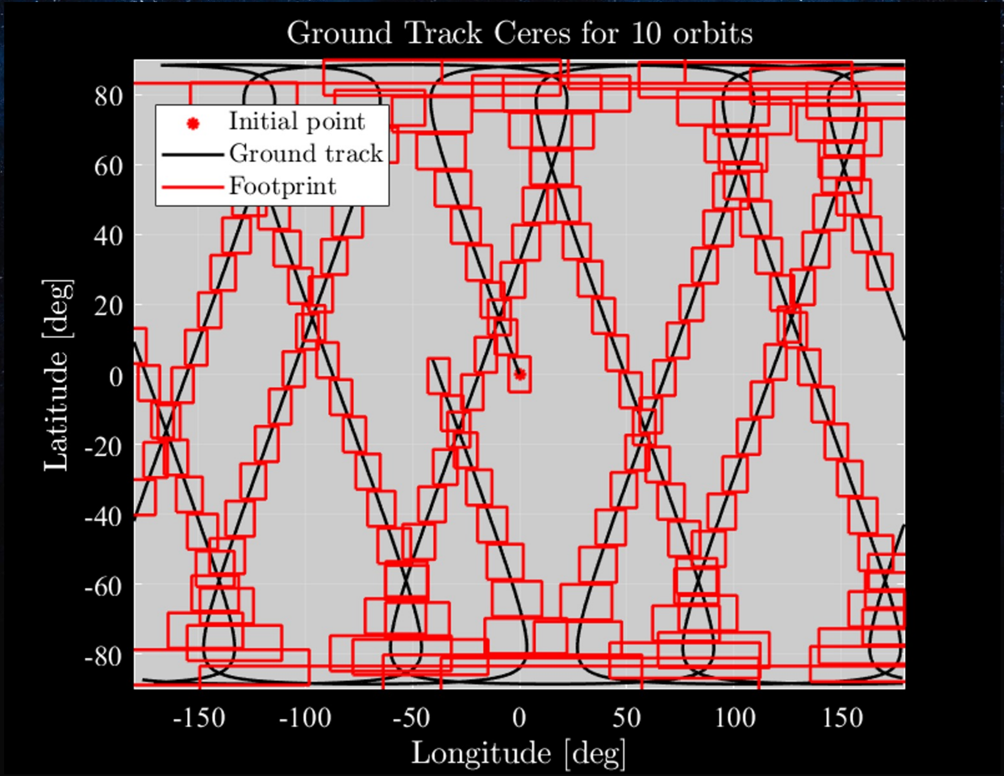


Transfer Sequence: Earth-**Mars**-Ceres



E = Earth, V = Venus, M = Mars, C = Ceres

Global Mapping



Propulsion

vinf,dep = 6.468 km/s

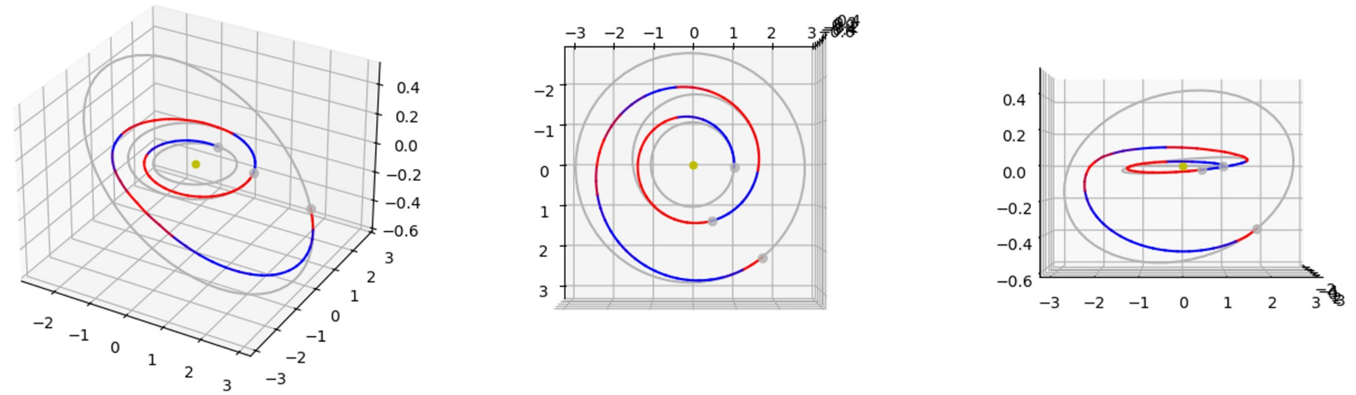
→ with **Ariane 64** only launchable mass = 1320.98 kg

vinf,arr = 5.613 km/s

→ dv = 5.37 km/s for insertion at altitude = 500 km

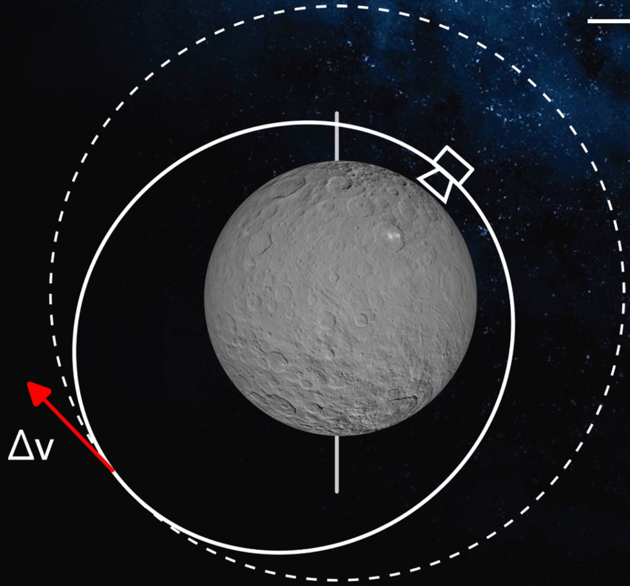
if chemical propulsion 82% of wet mass propellant

Alternative mission profile



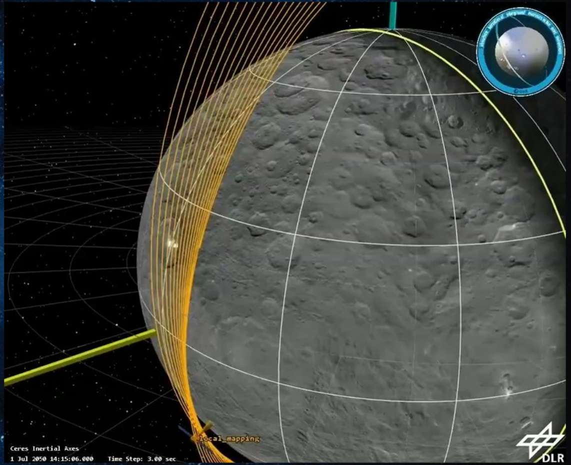
Local Mapping Orbit

Requirement: Local mapping of potential **landing sites**: **1 m/px**



→ Pericenter altitude = **10 km**
Period = 3.88 hr

Δv = 41.55 m/s for pericenter decrease



Orbit perturbation	Order of magnitude
J2 effect	~1e-6/1e-7 km/s^2
SRP	~1e-10 km/s^2

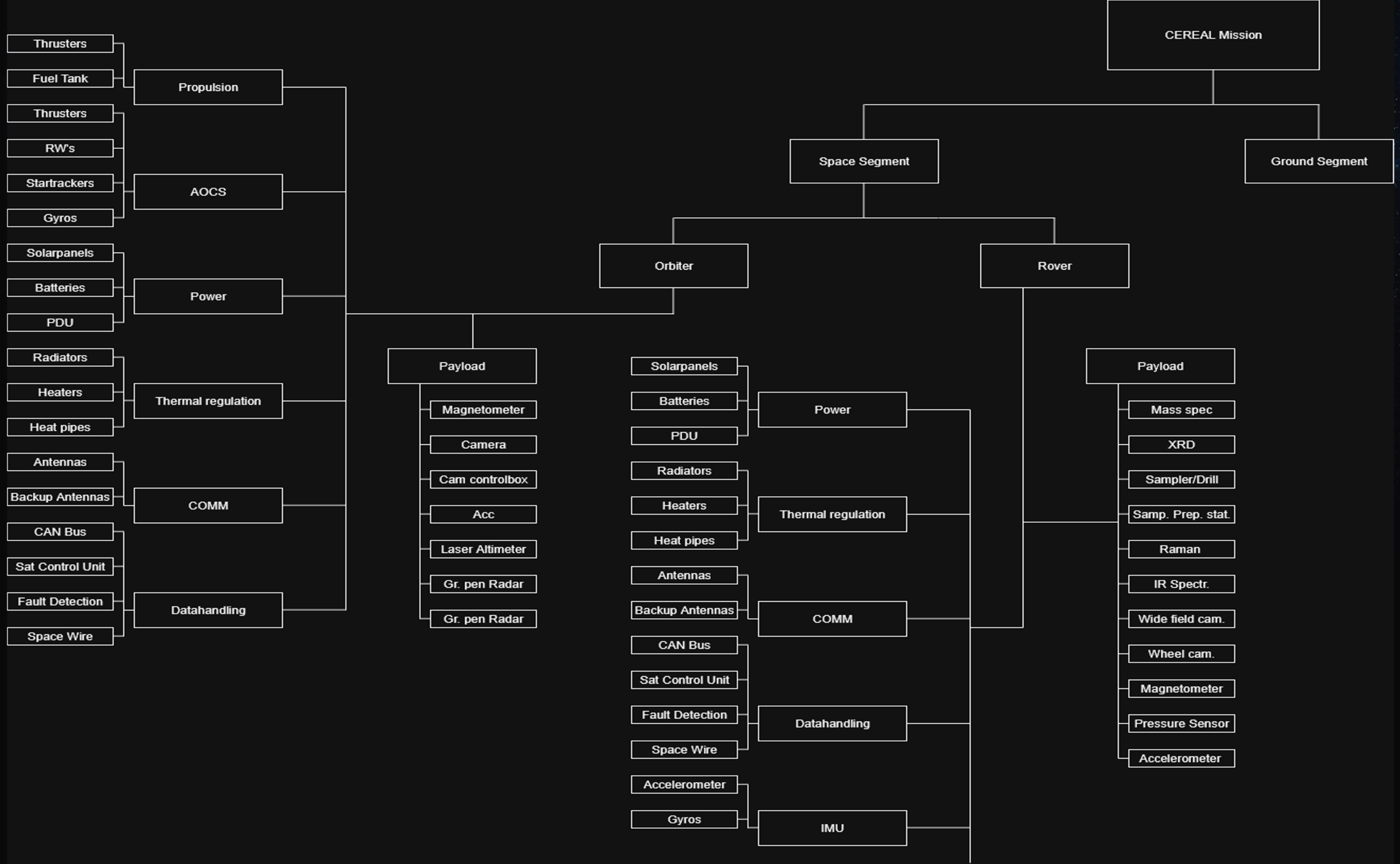
→ **Δv_{SK} ~ 30 m/s** for 10 days

→ Deployment of impactors

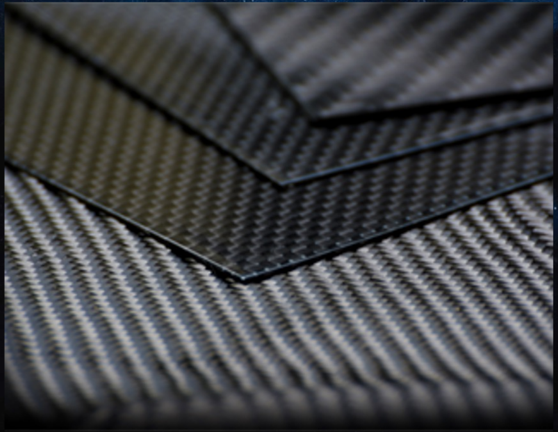
Launch → Transfer + Mars flyby → Ceres Orbit Insertion → Global Mapping Orbit → **Local Mapping Orbit** → Separation and Landing → Relay Orbit → End of Life

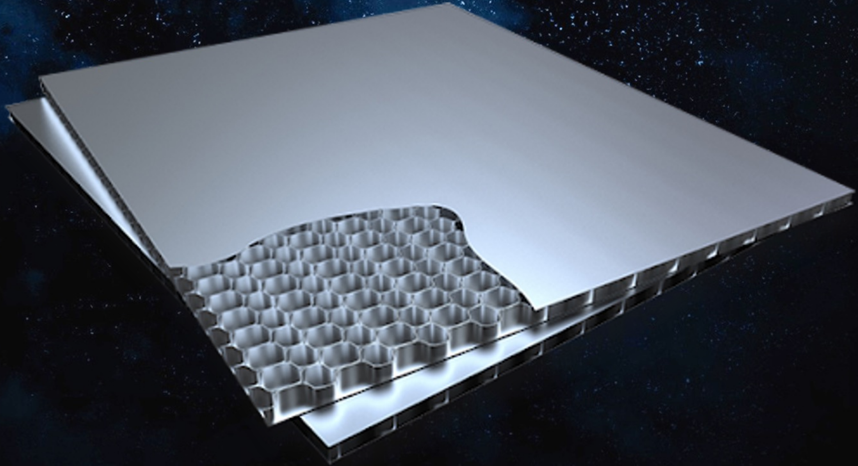
Mars flyby

Phobos Deimos ?


CEREAL Mission
Space Segment
Ground Segment
Orbiter
Rover
Propulsion
Thrusters
Fuel Tank
AOCS
Thrusters
RW's
Startrackers
Gyros
Power
Solarpanels
Batteries
PDU
Thermal regulation
Radiators
Heaters
Heat pipes
COMM
Antennas
Backup Antennas
Datahandling
CAN Bus
Sat Control Unit
Fault Detection
Space Wire
Payload
Magnetometer
Camera
Cam controlbox
Acc
Laser Altimeter
Gr. pen Radar
Gr. pen Radar
Power
Solarpanels
Batteries
PDU
Thermal regulation
Radiators
Heaters
Heat pipes
COMM
Antennas
Backup Antennas
Datahandling
CAN Bus
Sat Control Unit
Fault Detection
Space Wire
IMU
Accelerometer
Gyros
Payload
Mass spec
XRD
Sampler/Drill
Samp. Prep. stat.
Raman
IR Spectr.
Wide field cam.
Wheel cam.
Magnetometer
Pressure Sensor
Accelerometer

Orbiter Structure - Material Choices





Link-Budgets

Orbiter-Earth:	PARABOLIC ANTENNAS			
Ka-Band	Downlink			
	HGA:	**Inputs**	**Calculations**	**Units**
	freqency	3,20E+10	32000000000	**Hz**
	Transmit Power	100	20	**W, dBW**
	Gain		57,03730361	**dBi**
	Opening Angle			**deg**
	Size	3	3	**m**
	Efficiency	50	0,5	**%, %/100**
	Antenna Beamwidth		0,2185986673	**deg**
	Ground Station:			
	freqency	32000000000	32000000000	**Hz**
	Transmit Power			**W, dBW**
	Gain		79,58197871	**dBi**
	Opening Angle			**deg**
	Size	35	35	**m**
	Efficiency	66	0,66	**%**
	Antenna Beamwidth		0,01873702863	**deg**
	EIRP		77,03730361	**dBW**
	Distance	4,04E+11	404000000000	**m**
	Free Space Loss		−294,6740056	**dB**
	Receiver Noise Figure		-0,34	**dB**
	Line Loss		-0,5	**dB**
	Atmospheric Loss		-1	**dB**
	Isotropic Signal Power at Antenna		−219,476702	**dBW**
	System Noise te	100	1,286666091	**K,dBK**
	G/T (NGS-1)		78,29531262	**dB/K**
	RX Signal Power		**−139,8947233**	**dBW**
	RX Noise Power		**−152,4425643**	**dBW**
	Bit Rate	100E6	80	**bps**
	Equivalent Noise Bandwidth		74,87197871	**dBHz**
	C/N		12,54784105	**dB**
	E_b/N_0		7,419819765	**dB**
	Required E_b/N_	11	11	**dB**
	Coded Required	4,9	4,9	**dB**
	Coding Gain		**6,1**	**dB**
	Downlink Margin		**1,319819765**	**dB**

Earth-Orbiter:	PARABOLIC ANTENNAS			
X-Band	Uplink			
	Ground Station	**Inputs**	**Calculations**	**Units**
	freqency	7,2E9	7,2E9	**Hz**
	Transmit Power	20000	43,01029996	**W, dBW**
	Gain		65,41988976	**dBi**
	Opening Angle			**deg**
	Size	35	35	**m**
	Efficiency	50	0,5	**%, %/100**
	Antenna Beamwidth		0,08327568278	**deg**
	HGA:			
	freqency	7,2E9	7,2E9	**Hz**
	Transmit Power			**W, dBW**
	Gain		45,28669328	**dBi**
	Opening Angle			**deg**
	Size	3	3	**m**
	Efficiency	66	0,66	**%**
	Antenna Beamwidth			**deg**
	EIRP		108,4301897	**dBW**
	Distance	4,04E+11	404000000000	**m**
	Free Space Loss		−281,717656	**dB**
	Receiver Noise Figure		-2,5	**dB**
	Line Loss		-0,5	**dB/m**
	Atmospheric Loss		-1	**dB**
	Isotropic Signal Power at Antenna		−177,2874662	**dBW**
	System Noise te	200	23,01029996	**K,dBK**
	G/T (NGS-1)		22,27639332	**dB/K**
	RX Signal Power		**−132,000773**	**dBW**
	RX Noise Power		**−165,0142159**	**dBW**
	Bit Rate	500E3	56,98970004	**bps**
	Equivalent Noise Bandwidth		40,57669328	**dBHz**
	C/N		33,01344294	**dB**
	E_b/N_0		16,60043618	**dB**
	Required E_b/N_	11	11	**dB**
	Coded Required	4,9	4,9	**dB**
	Coding Gain		**6,1**	**dB**
	Uplink Margin		**10,50043618**	**dB**

Link-Budgets

Orbiter-Earth	PARABOLIC ANTENNAS			
X-Band	Downlink			
	HGA:	Inputs	Calculations	Units
	freqency	8,70E+09	8700000000	Hz
	Transmit Power	100	20	W, dBW
	Gain		46,93042841	dBi
	Opening Angle			deg
	Size	3	3	m
	Efficiency	66	0,66	%, %/100
	Antenna Beamwidth		0,8040410751	deg
	Ground Station:			
	freqency	8700000000	8700000000	Hz
	Transmit Power			W, dBW
	Gain		68,2693642	dBi
	Opening Angle			deg
	Size	35	35	m
	Efficiency	66	0,66	%
	Antenna Beamwidth			deg
	EIRP		66,93042841	dBW
	Distance	4,04E+11	404000000000	m
	Free Space Loss		−283,3613911	dB
	Receiver Noise Figure		-0,26	dB
	Line Loss		-0,5	dB/m
	Atmospheric Loss		-1	dB
	Isotropic Signal Power at Antenna		−218,1909627	dBW
	System Noise te	100	20	K,dBK
	G/T (NGS-1)		48,2693642	dB/K
	RX Signal Power		**−149,9215985**	dBW
	RX Noise Power		**−145,0418449**	dBW
	Bit Rate	100E3	50	bps
	Equivalent Noise Bandwidth		63,5593642	dBHz
	C/N		−4,879753543	dB
	E_b/N_0		8,679610655	dB
	Required E_b/N_	11	11	dB
	Coded Required	4,9	4,9	dB
	Coding Gain		**6,1**	dB
	Downlink Margin		**2,579610655**	dB

Orbiter-Earth	PARABOLIC ANTENNAS			
X-Band	Downlink			
	MGA:	Inputs	Calculations	Units
	freqency	8,70E+09	8700000000	Hz
	Transmit Power	50	16,98970004	W, dBW
	Gain		30,16166409	dBi
	Opening Angle			deg
	Size	0,5	0,5	m
	Efficiency	50	0,5	%, %/100
	Antenna Beamwidth		4,824246451	deg
	Ground Station:			
	freqency	8700000000	8700000000	Hz
	Transmit Power			W, dBW
	Gain		68,2693642	dBi
	Opening Angle			deg
	Size	35	35	m
	Efficiency	66	0,66	%
	Antenna Beamwidth			deg
	EIRP		47,15136413	dBW
	Distance	4,04E+11	404000000000	m
	Free Space Loss		−283,3613911	dB
	Receiver Noise Figure		-2,5	dB
	Line Loss		-0,5	dB/m
	Atmospheric Loss		-1	dB
	Isotropic Signal Power at Antenna		−240,210027	dBW
	System Noise te	400	3,764510928	K,dBK
	G/T (NGS-1)		64,50485327	dB/K
	RX Signal Power		**−171,9406628**	dBW
	RX Noise Power		**−161,277334**	dBW
	Bit Rate	8E3	39,03089987	bps
	Equivalent Noise Bandwidth		63,5593642	dBHz
	C/N		−10,66332875	dB
	E_b/N_0		13,86513558	dB
	Required E_b/N_	11	11	dB
	Coded Required	4,9	4,9	dB
	Coding Gain		**6,1**	dB
	Downlink Margin		**7,76513558**	dB

Link-Budgets

Orbiter-Rover:	MGA to Patchantennas			
X-Band	Downlink			
	MGA Orbiter:	Inputs	Calculations	Units
	freqency	8,70E+09	8700000000	Hz
	Transmit Power	30	14,77121255	W, dBW
	Gain		30,16166409	dBi
	Opening Angle			deg
	Area	0,5	0,5	m^2
	Efficiency	50	0,5	%, %/100
	Antenna Beamwidth		4,824246451	deg
	LGA Rover:			
	freqency	8700000000	8700000000	Hz
	Transmit Power			W, dBW
	Gain		17,23356743	dBi
	Opening Angle			deg
	Area	0,05	0,0025	m^2
	Efficiency	50	0,5	%
	Antenna Beamwidth E-Plane		34,45890322	deg
	Antenna Beamwidth H-Plane		55,13424515	deg
	EIRP		44,93287663	dBW
	Distance	1,04E+06	1040000	m
	Free Space Loss		−171,5744306	dB
	Receiver Noise Figure		-2,5	dB/m
	Oxygen Loss			dB/m
	Atmospheric Loss		-1	dB
	Isotropic Signal Power at Antenna		−130,1415539	dBW
	System Noise te	400	26,02059991	K,dBK
	G/T (NGS-1)		−8,787032482	dB/K
	RX Signal Power		**−112,9079865**	dBW
	RX Noise Power		**−135,5909092**	dBW
	Bit Rate	1000E3	60	bps
	Equivalent Noise	5E6	66,98970004	dBHz
	C/N		22,68292268	dB
	E_b/N_0		29,67262272	dB
	Required E_b/N_	11	11	dB
	Coded Required	4,9	4,9	dB
	Coding Gain		**6,1**	dB
	Downlink Margin		**18,67262272**	dB

Rover-Orbiter:	PATCHANTENNAS to MGA			
X-Band	Uplink			
	LGA Rover:	Inputs	Calculations	Units
	freqency	7,20E+09	7200000000	Hz
	Transmit Power	30	14,77121255	W, dBW
	Gain		17,17345723	dBi
	Opening Angle			deg
	Length/Area	0,06	0,0036	m^2
	Efficiency	50	0,5	%, %/100
	Antenna Beamwidth E-Plane		34,69820116	deg
	For Linear arrays Beamwidth		23,31190817	deg
	MGA Orbiter:			
	freqency	7200000000	7200000000	Hz
	Transmit Power			W, dBW
	Gain		28,51792896	dBi
	Opening Angle			deg
	Size	0,5	0,5	m
	Efficiency	50	0,5	%
	Antenna Beamwidth		5,829297794	deg
	EIRP		31,94466978	dBW
	Distance	1,04E+06	1040000	m
	Free Space Loss		−169,9306954	dB
	Receiver Noise Figure		-2,5	dB
	Line Loss		-0,5	dB
	Atmospheric Loss		0	dB
	Isotropic Signal Power at Antenna		−140,9860257	dBW
	System Noise te	400	26,02059991	K,dBK
	G/T (NGS-1)		2,497329048	dB/K
	RX Signal Power		**−112,4680967**	dBW
	RX Noise Power		**−122,5806092**	dBW
	Bit Rate	5E6	66,98970004	bps
	Equivalent Noise	100E6	80	dBHz
	C/N		10,11251252	dB
	E_b/N_0		23,12281247	dB
	Required E_b/N_	11	11	dB
	Coded Required	4,9	4,9	dB
	Coding Gain		**6,1**	dB
	Downlink Margin		**12,12281247**	dB

Power Budget - Orbiter

Power Budget of the ORBITER

Subsystems	Power [W]	Daylight		Eclipse	
		Duty Cycle	Average Power [W]	Duty Cycle	Average Power [W]
ADCS	400	0,3	120	0,3	120
Communications	100	1	100	0,1	10
OBC	30	1	30	1	30
Thermal	250	0,1	25	0,8	200
Instruments	185	1	185	0,3	55,5
Solar Array Drive Mechanism	10	1	10	0	0
			0		
			0		
			0		
			0		
TOTAL Power Consumption [W]			470		415,5
+ Margin [W]			564		498,6

Power Budget - Rover

Power Budget of the ROVER

Subsystems	Power [W]	Daylight (Moving)		Daylight (Science)		Eclipse (safemode)	
		Duty Cycle	Average Power [W]	Duty Cycle	Average Power [W]	Duty Cycle	Average Power [W]
Motors for the Wheels	66,7	1	66,7	0,05	3,33	0,01	0,67
Communications	100	0,1	10	0,5	50	0,1	10
OBC	30	0,5	15	0,5	15	0,5	15
Thermal	70	0,5	35	0,5	35	0,2	14
Instruments	120,1	0,2	24,02	0,5	60,05	0,1	12,01
Solar Array Drive Mechanism	10	1	10	1	10	0	0
			0		0		0
			0		0		0
			0		0		0
TOTAL Power Consumption [W]			160,7		173,38		51,68
+ Margin [W]			192,8		208,1		62,012

Orbiter System Modes

System Mode	Global Mapping	Impacter Observation	Local Mapping	Communic.	Maneuver	Safe Mode
Magnetometer	A	Idle	Idle	Idle	Idle	Off
Visual Camera	A	A	A	Idle	Idle	Off
Accelerometer	A	Idle	Idle	Idle	Idle	Off
Laser altimeter	A	Idle	A	Idle	Idle	Off
GPR	Idle	A	A	Idle	Idle	Off
Hyperspec. cam.	A	A	A	Idle	Idle	Off
AOCS	A (Nadir P.)	A (Target P.)	A (Nadir/Target)	A Earth Point.	A	Inertial Point.
PROP	Off	Off	Off	Off	A	Off
COMS	Idle	Idle	Idle	A	(TM/TC, TBC)	Receive
OBC	A	A	A	A	A	Safe
TCS	A	A	A	Off	Off	Off

Rover System Modes

System Modes	Nominal Science Modes				Comms. Mode	Maneuver Mode	Hybernation Mode	Safe Mode
	Magnet.	Drilling	Sampling Processing	Static measurement				
Mass Spectrometer	Idle	Idle	A	Idle	Idle	Idle	Idle	Off
IR Spectrometer	Idle	Idle	A	Idle	Idle	Idle	Idle	Off
Raman–LIBS	Idle	Idle	A	Idle	Idle	Idle	Idle	Off
XRD L Chip	Idle	Idle	A	Idle	Idle	Idle	Idle	Off
Pano. Camera	Idle	Idle	Idle	A	Idle	A	Idle	Off
Magnetometer	A	Idle	Idle	Idle		Idle	Idle	Off
Pressure Sensor	Idle	A	A	A	Idle	Idle	Idle	Off
Sampler / Drill	Idle	A	Idle	Idle	Idle	Idle	Idle	Off
Accelerometer	Idle	A	Idle	A	Idle	Idle	Idle	Off

Rover System Modes (cont.)

	Nominal Science Modes				Comms. Mode	Maneuver Mode	Hybernation Mode	Safe Mode
	Science Mode 1	Science Mode 2	Science Mode 3	Science Mode 4				
NAV	A	A	A	A	A	A	Idle	A
MOTOR	Off	Off	Off	Off	Off	A	Idle	Off
COMS	Receive	Receive	Receive	Receive	A	Receive	Receive	Receive
OBC	A	A	A	A	A	A	Hyber	A
TCS	A	A	A	A	A	Off	Off	Off

Launch windows

Max v_inf	v_inf	Max T [m	Launch Ma	Launch Da	Launch Date (est	Dur	Duration [	Final Mas	Propella	Δv [km/s]	launchable m [kg]	usable mass	Launchable?
3.46	2.70	150.00	5300.00	13669.84	6/4/2037	4858.13	13.30	3694.5	1605.50	14.16	6,333.68	3,662.39	TRUE
3.46	3.46	150.00	5300.00	13639.7	5/5/2037	4855.01	13.29	3695.53	1604.47	14.15	5,651.01	3,663.44	TRUE
3.46	2.29	150.00	5300.00	13683.44	6/18/2037	4850.24	13.28	3697.11	1602.89	14.13	6,631.39	3,665.05	TRUE
3.46	3.46	150.00	5300.00	13675.61	6/10/2037	4826.74	13.21	3704.88	1595.12	14.05	5,651.01	3,672.98	TRUE
3.46	3.46	150.00	5300.00	13651.56	5/17/2037	4781.64	13.09	3719.79	1580.21	13.89	5,651.01	3,688.19	TRUE
3.46	3.46	150.00	5300.00	13741.79	8/15/2037	4776.86	13.08	3721.39	1578.61	13.88	5,651.01	3,689.82	TRUE
3.46	2.30	150.00	5300.00	13207.33	2/28/2036	5305.99	14.53	3722.56	1577.44	13.86	6,626.06	3,691.01	TRUE
3.46	3.07	150.00	5300.00	13400.97	9/8/2036	5049.21	13.82	3771.21	1528.79	13.35	6,025.52	3,740.63	TRUE
3.46	1.69	150.00	5300.00	13669.66403	6/4/2037	5599.90	15.34	3612.797138	1687.20	15.04	6,977.08	3,579.05	TRUE
3.46	2.74	150.00	5300.00	13759.82412	9/2/2037	5456.72	14.95	3600.227147	1699.77	15.17	6,301.78	3,566.23	TRUE
3.46	3.46	150.00	5300.00	13686.99189	6/21/2037	5578.69	15.28	3600	1700.00	15.18	5,651.01	3,566.00	TRUE
3.46	3.46	150.00	5300.00	13637.35153	5/3/2037	4887.28	13.38	3684.864309	1615.14	14.26	5,651.01	3,652.56	TRUE
3.46	3.43	150.00	5300.00	13797.13165	10/10/2037	5588.41	15.31	3600	1700.00	15.18	5,681.54	3,566.00	TRUE
3.46	3.46	150.00	5300.00	13647.86497	5/13/2037	4888.48	13.38	3684.466865	1615.53	14.27	5,651.01	3,652.16	TRUE
3.46	0.99	150.00	5300.00	13789.5295	10/2/2037	5515.99	15.11	3600	1700.00	15.18	7,251.27	3,566.00	TRUE
3.46	2.31	150.00	5300.00	13660.03845	5/26/2037	5494.13	15.05	3633.844505	1666.16	14.81	6,619.17	3,600.52	TRUE
3.46	2.63	150.00	5300.00	13695.86234	6/30/2037	5548.07	15.20	3600	1700.00	15.18	6,385.42	3,566.00	TRUE
3.46	3.06	150.00	5300.00	13769.20006	9/12/2037	5500.17	15.07	3606.108437	1693.89	15.11	6,033.68	3,572.23	TRUE
3.46	2.57	150.00	5300.00	13693.12132	6/28/2037	4831.26	13.23	3703.386866	1596.61	14.07	6,436.17	3,671.45	TRUE
3.46	3.42	150.00	5300.00	13680.2855	6/15/2037	4829.66	13.22	3703.911662	1596.09	14.06	5,692.50	3,671.99	TRUE
3.46	2.04	150.00	5300.00	13718.64602	7/23/2037	5563.84	15.24	3645.325323	1654.67	14.69	6,791.01	3,612.23	TRUE
3.46	1.03	150.00	5300.00	13747.36331	8/21/2037	5561.38	15.24	3600.067092	1699.93	15.18	7,237.42	3,566.07	TRUE

Rover - Electrical Power System