

Reaching for Planets and Comets

ESA's Challenges of Operating Deep Space Missions

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Extreme conditions in space



launch

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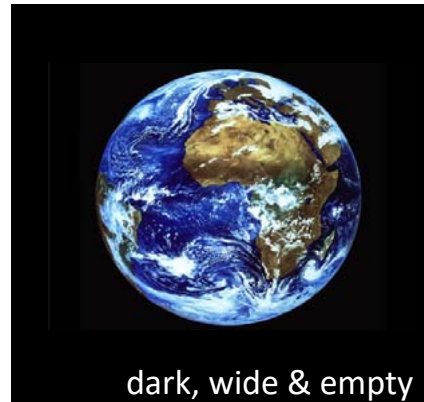


zero gravity

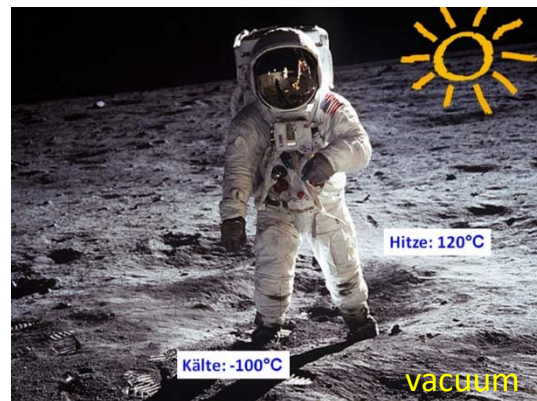


zero gravity

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dark, wide & empty



Hitze: 120°C

Kälte: -100°C

vacuum

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Complex but reliable



Telecommands: < 10
Telemetry Parameters $= 0$



Telecommands: ~ 25
Telemetry Parameters ~ 100



Telecommands: < 100
Telemetry Parameters ~ 1000



Telecommands: ~ 5000
Telemetry Parameters ~ 30.000

Mission operations in a nutshell



Interplanetary missions

Main challenges

- Long cruise phase
- Long signal travel times
- Energy generation
- Scarce knowledge of target



Mission control approach

- Primarily off-line control & on-board autonomy
- Flexibility in team-staffing
- Training of critical activities
- Incremental, adaptive operations concept



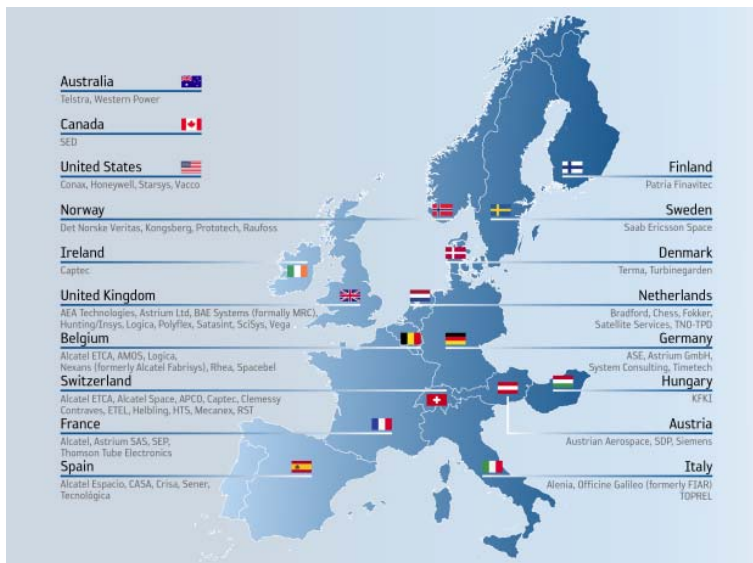
ROSETTA – Europe's Comet Chaser



- Leaving the Earth
- Very long cruise phase: **10 years**
- Long hibernation period driven by power budget: **2.5 years**
- Reaching the comet
- Getting into orbit
- Delivering the lander
- Slow descent onto the comet



A collaborative endeavour



ROSETTA Landing Operations Mission Control Team



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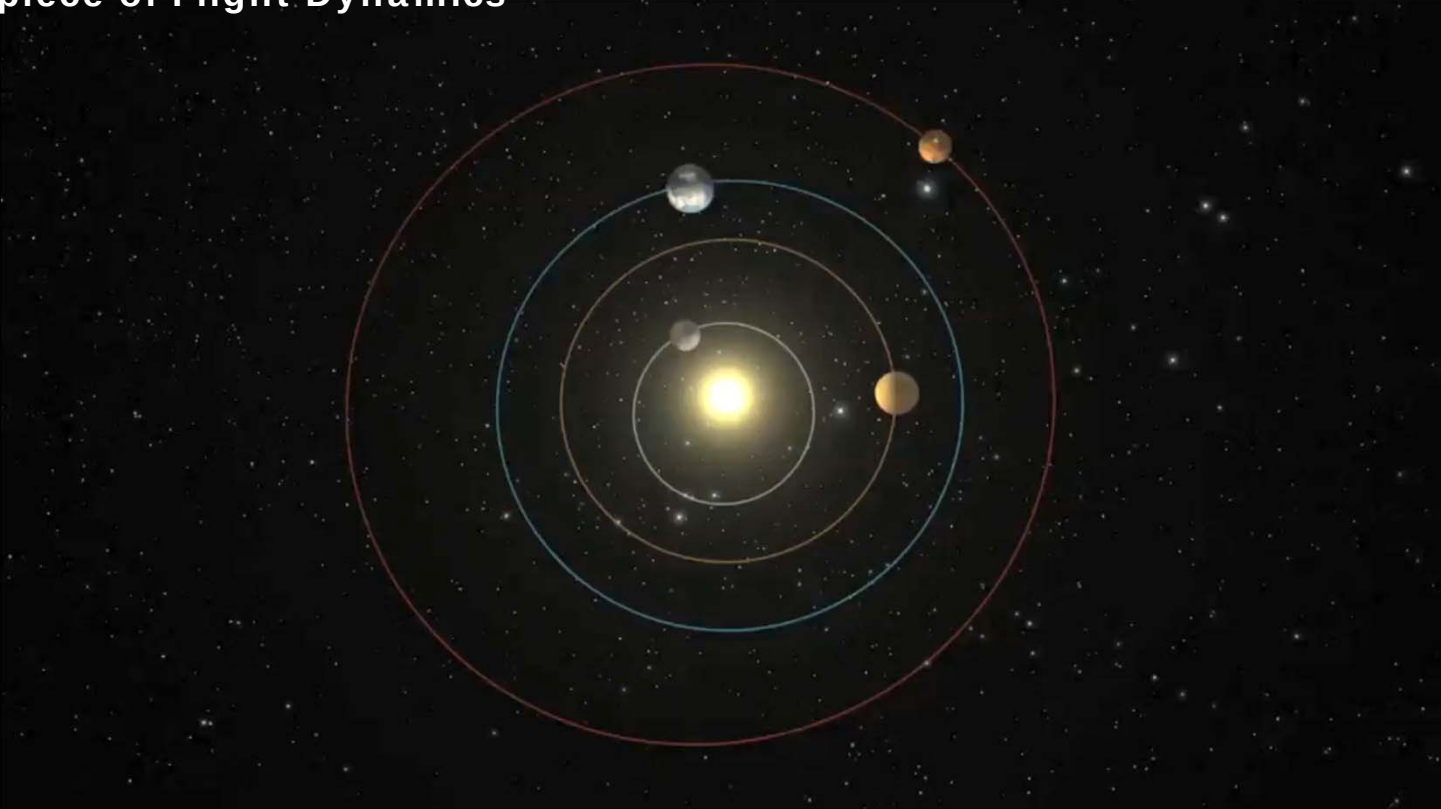
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European Space Agency

Long-distance flight

A Masterpiece of Flight Dynamics

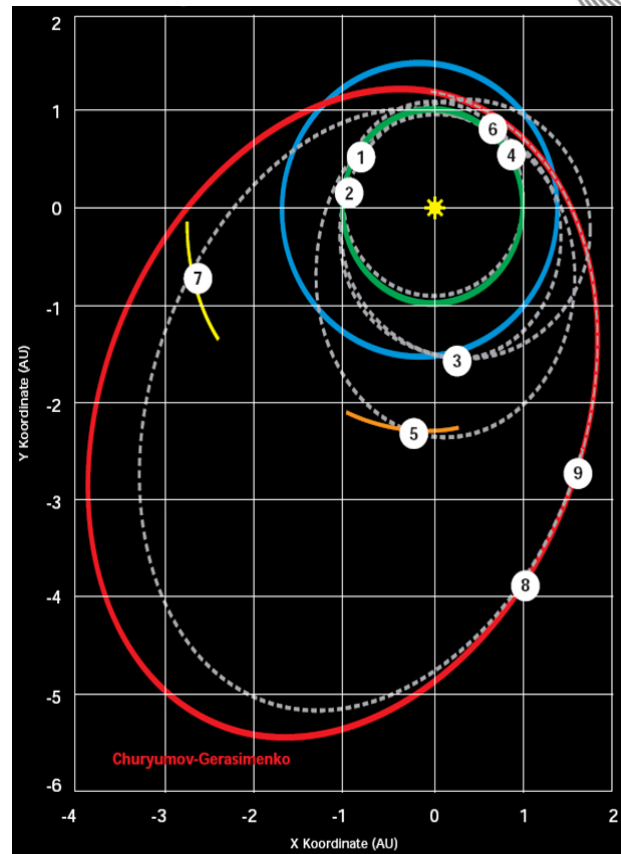


ROSETTA's complex manoeuvres

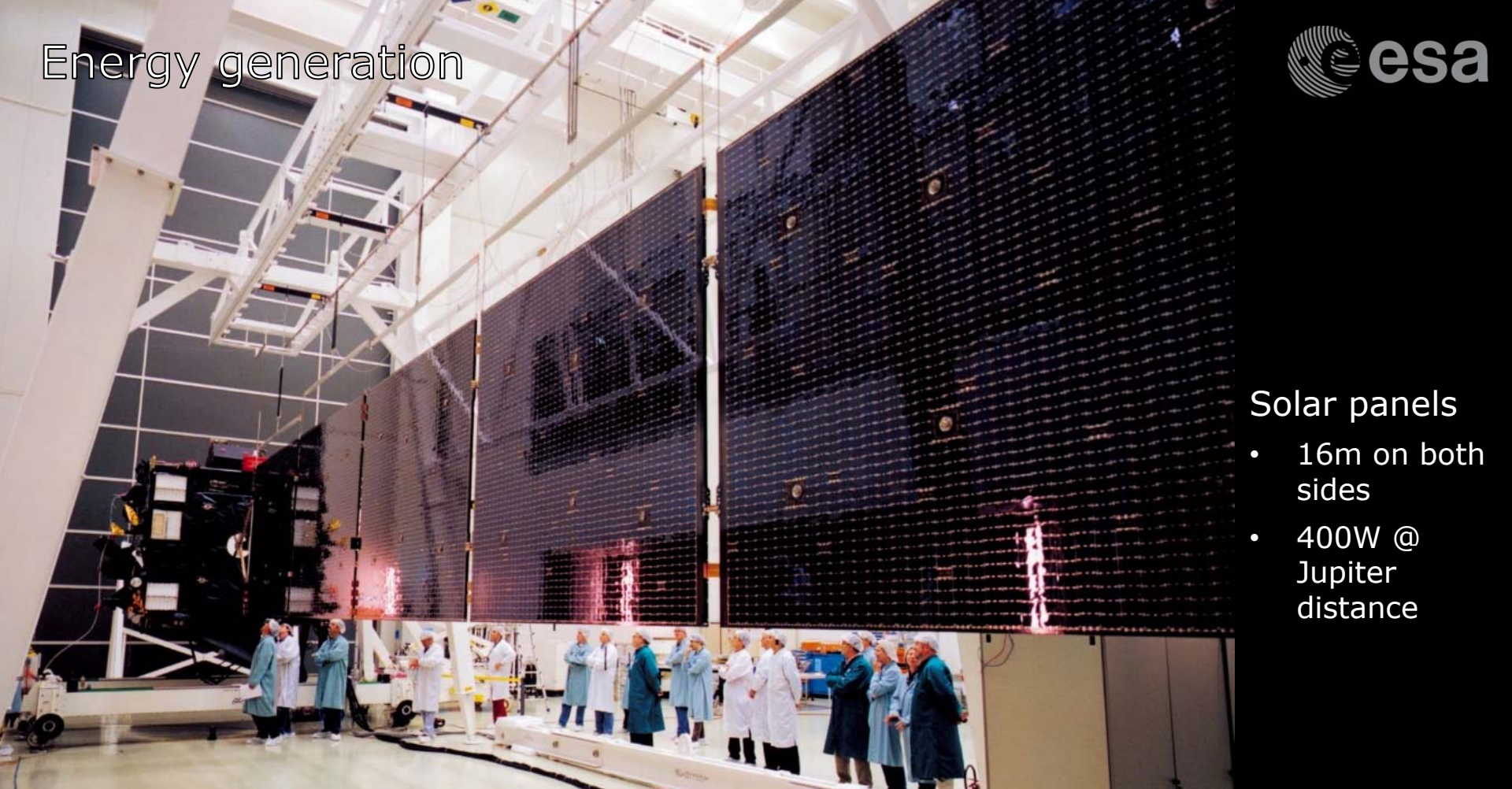
- ① Launch
- ② 1st Earth swing-by 5.9 km/s
- ③ Mars swing-by 2.3 km/s
- ④ 2nd Earth swing-by 5.2 km/s
- ⑤ Flyby asteroid Šteins
- ⑥ 3rd Earth swing-by 6.35 km/s
- ⑦ Flyby asteroid Lutetia
- ⑧ Orbit around comet
- ⑨ Landing of Philae

Gravity assist via planet swing-bys:

- Total Δv -gain 19.75 km/s
- 1700 kg fuel on-board ~2.2 km/s



Energy generation



Solar panels

- 16m on both sides
- 400W @ Jupiter distance

Unknown & little explored territory

The big surprise



Comet Chury

Darker than coal



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Navigation

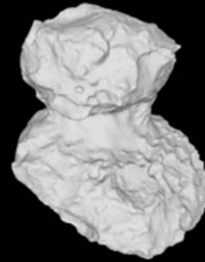
Long signal travel times & orbit perturbations due to gasses



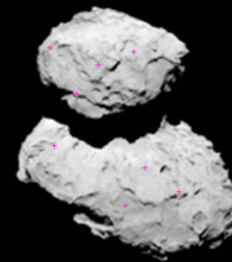
Real picture



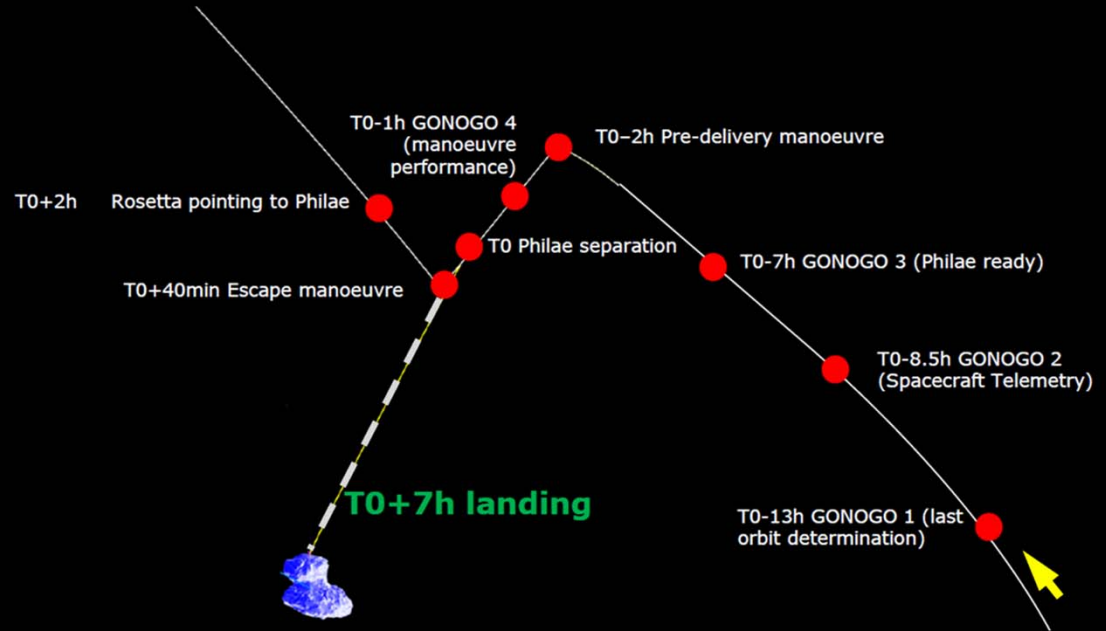
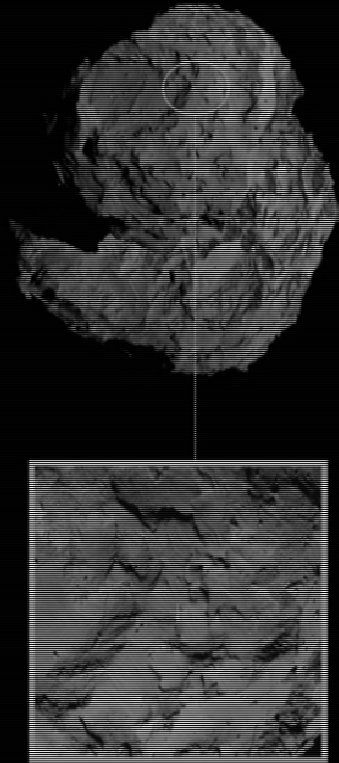
Reconstructed model



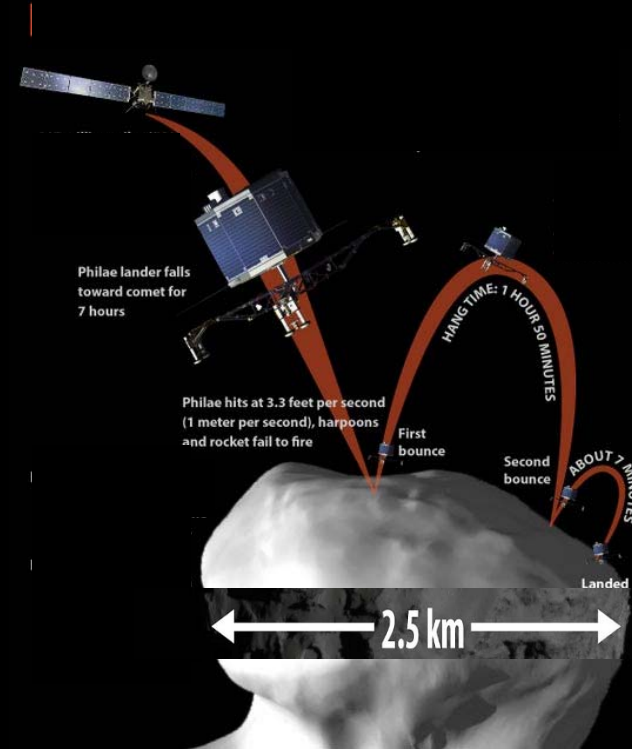
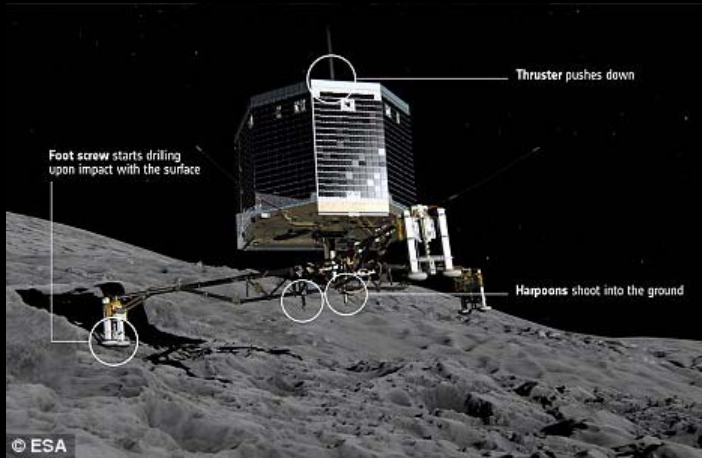
Navigations land marks



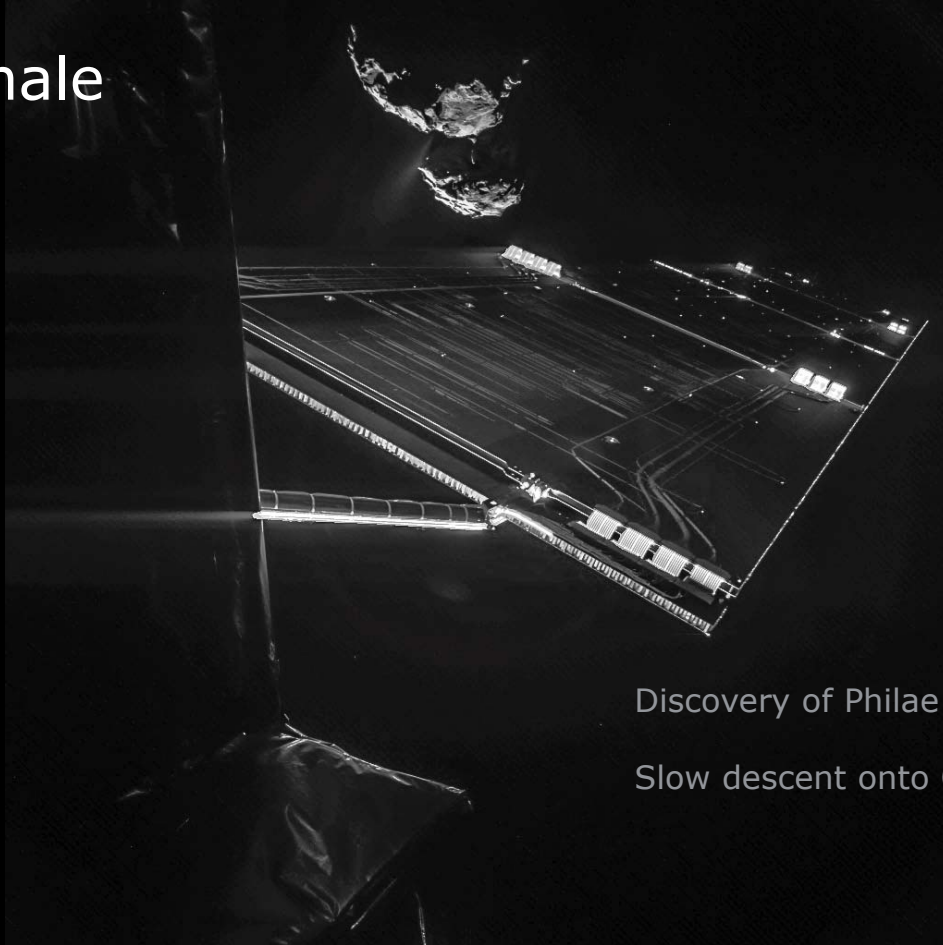
Risky landing



PHILAE bounces



Grand finale



Discovery of Philae @ 2.7km

Slow descent onto Chury with scientific data collection

BepiColombo – ESA's Mission to Mercury

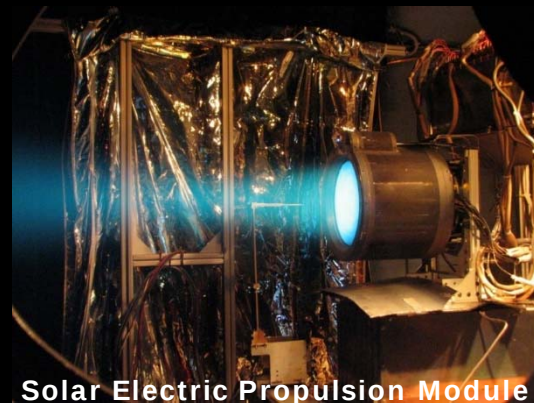
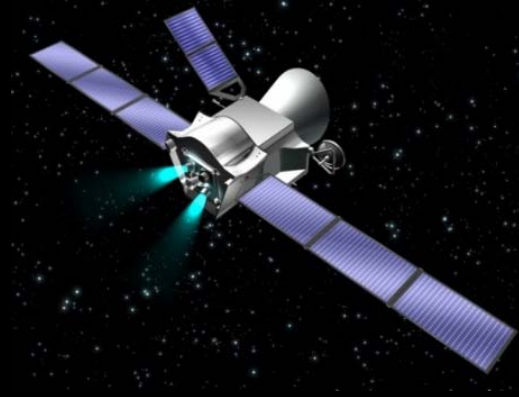


Transfer: electric propulsion & planetary swing-bys (7.5 years)

Separation of 3 modules within 3 months, 7.5 years after launch

Mercury orbit insertion: 15 manoeuvres as frequently as every 3 days

Thermal & power constraints: solar arrays
 $T < 190^{\circ}\text{C}$ → off-pointing from Sun $> 70^{\circ}$



Propellant:
Xenon

Low thrust:
290mN (10.3kW)
250mN (9kW)

-



Operations of the future





Thanks for your interest!

Credit: J. Mai (ESA)