POLITECNICO DI MILANO





Missione Rosetta: come raggiungere ed esplorare una cometa

Politecnico di Milano

Dipartimento di Scienze e Tecnologie Aerospaziali

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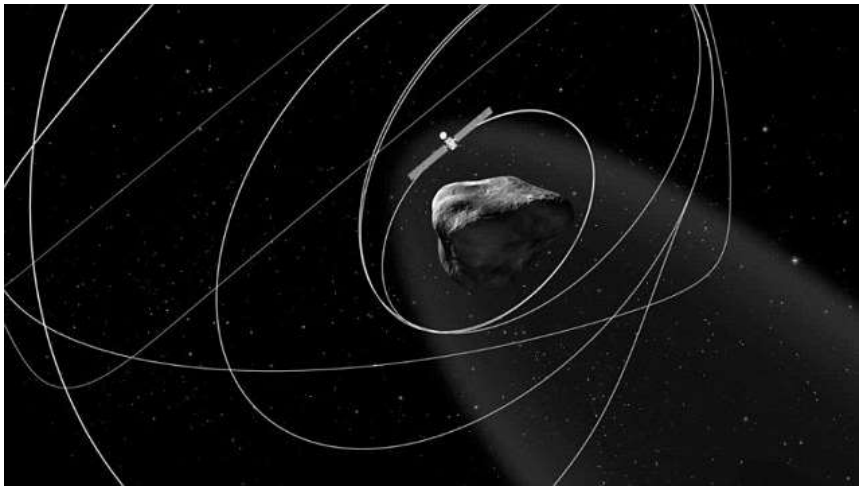
The Rosetta mission
A «staggeringly ambitious plan»

- It's the first space mission ever launched to:
  - chase
  - orbit around
  - land on
  - sample

  } ***a comet***

  - perform scientific observation of:
    - ***comet's nucleus***
    - ***coma***



Courtesy of ESA

The Rosetta mission
A «staggeringly ambitious plan»

Why targetting a comet?

Because…

- Comets are made of ***primordial materials***
- Comets remain ***inert*** for a very long time → small changes expected in their original formation
- Comets transport materials (*organic*? *life building blocks*?) from one side to the other of the Solar System

They may represent a key element to step forward in the life formation understanding

The Rosetta mission
A «staggeringly ambitious plan»

The Rosetta space mission **main objective**

(citation from sci.esa.int/rosetta)

To study the origin of comets, the relationship between cometary and interstellar material, and its implications with regard to the origin of the Solar System

translates into…

1. "Global **characterisation of the nucleus**, determination of dynamic properties, surface morphology and composition
2. determination of the **chemical, mineralogical and isotopic compositions** of volatiles and refractories in a cometary nucleus"

The Rosetta mission
A «staggeringly ambitious plan»

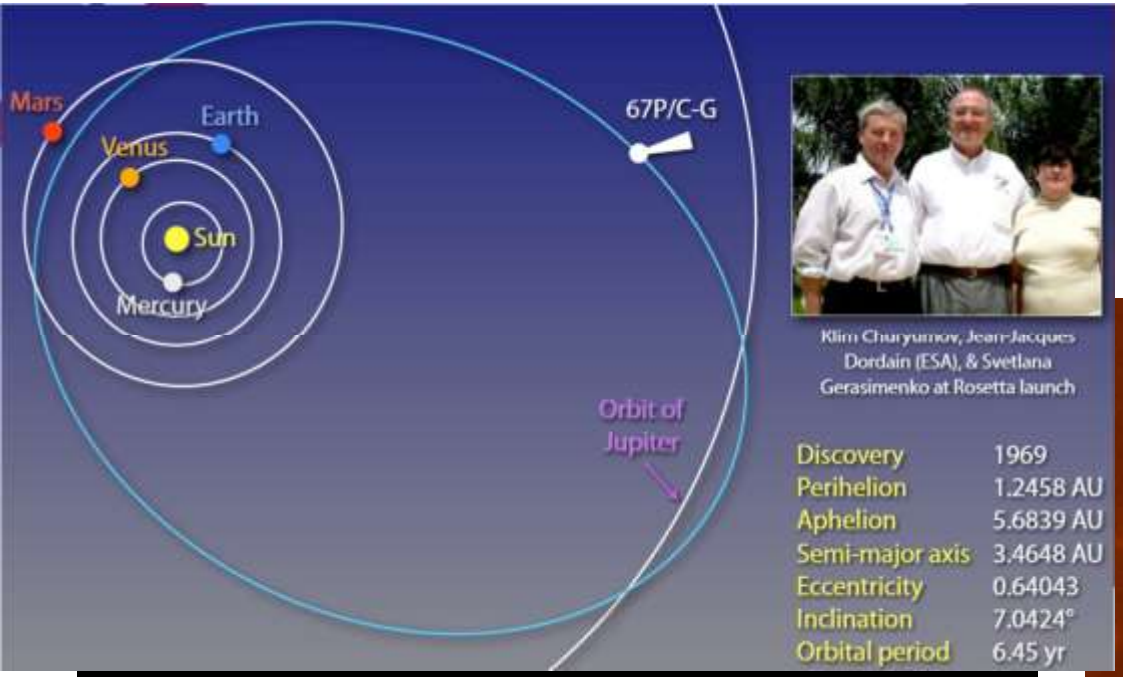
3. “Determination of the **physical properties and interrelation of volatiles and refractories** in a cometary nucleus

4. Study of the **development of cometary activity** and the processes in the surface layer of the nucleus and the inner coma (dust/gas interaction)

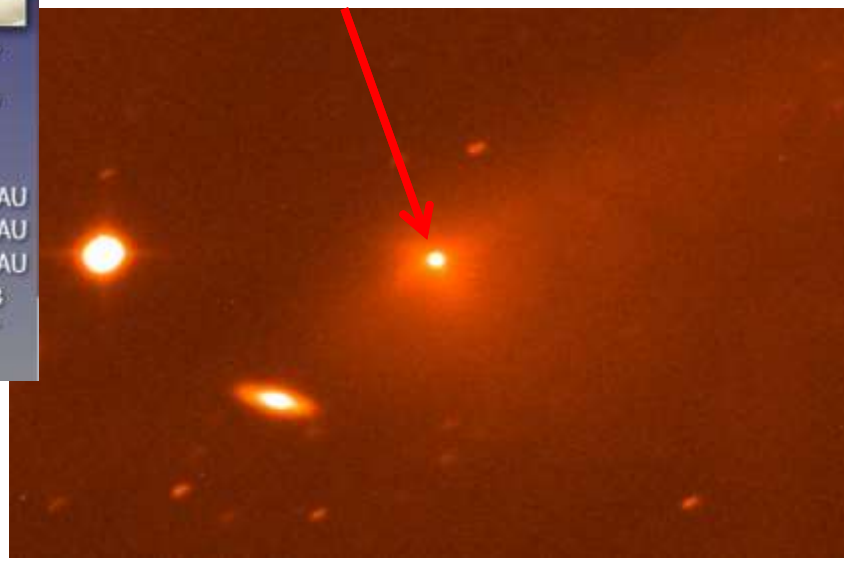
5. Global **characterisation of asteroids,** including determination of dynamic properties, surface morphology and composition.”

(citation from sci.esa.int/rosetta)

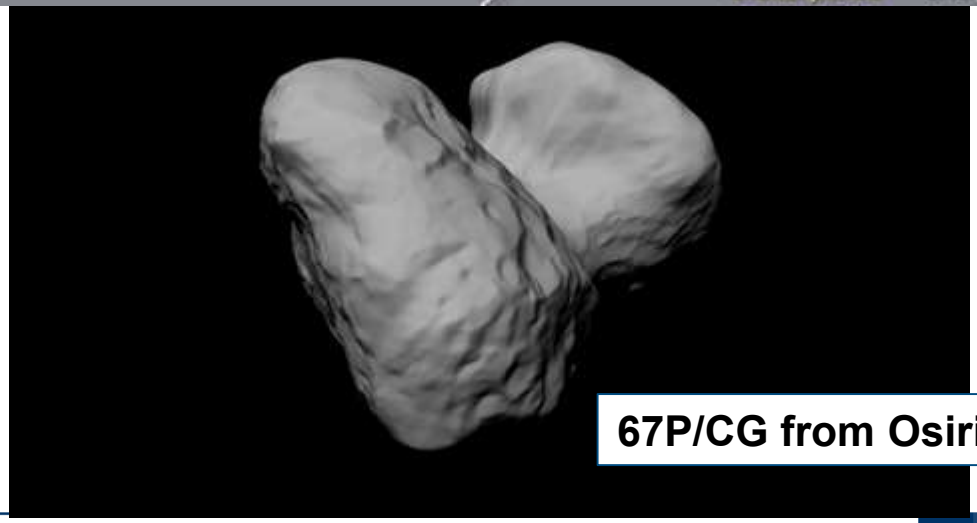
Rosetta's final target
Comet Churymov-Gerasimenko (C-G) / 67P



67P/CG from Hubble



Courtesy of ESA

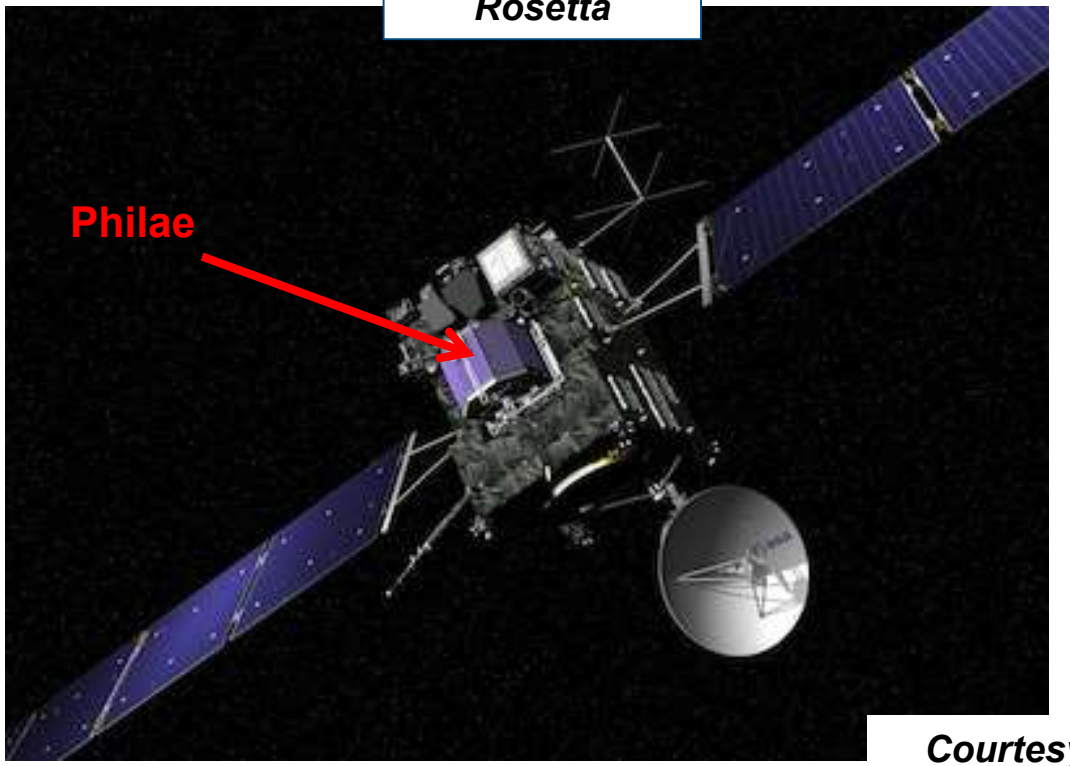


67P/CG from Osiris camera on board Rosetta, July2014

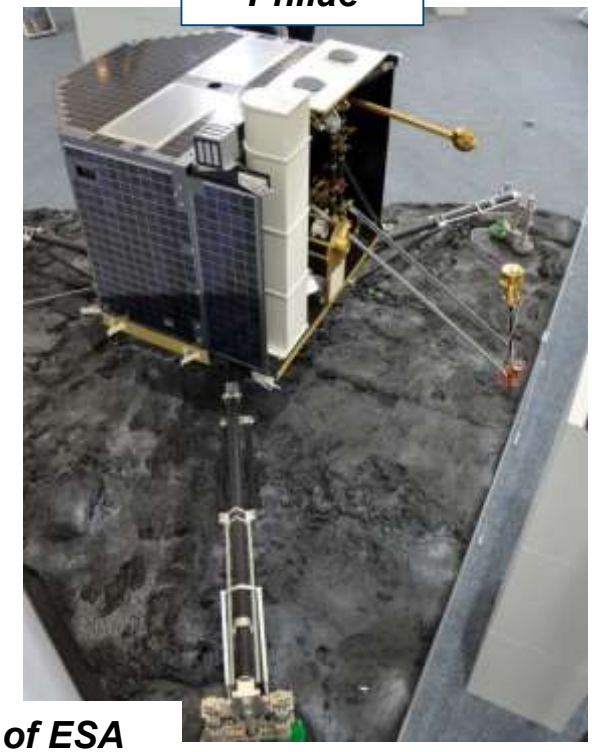
The Rosetta mission
What is needed to achieve the goal?

- ✓ an **orbiter** → ***Rosetta***, with 11 scientific experiments
- ✓ a **lander** → ***Philae***, with 10 scientific instruments for in situ analysis of the comet surface

Rosetta



Philae



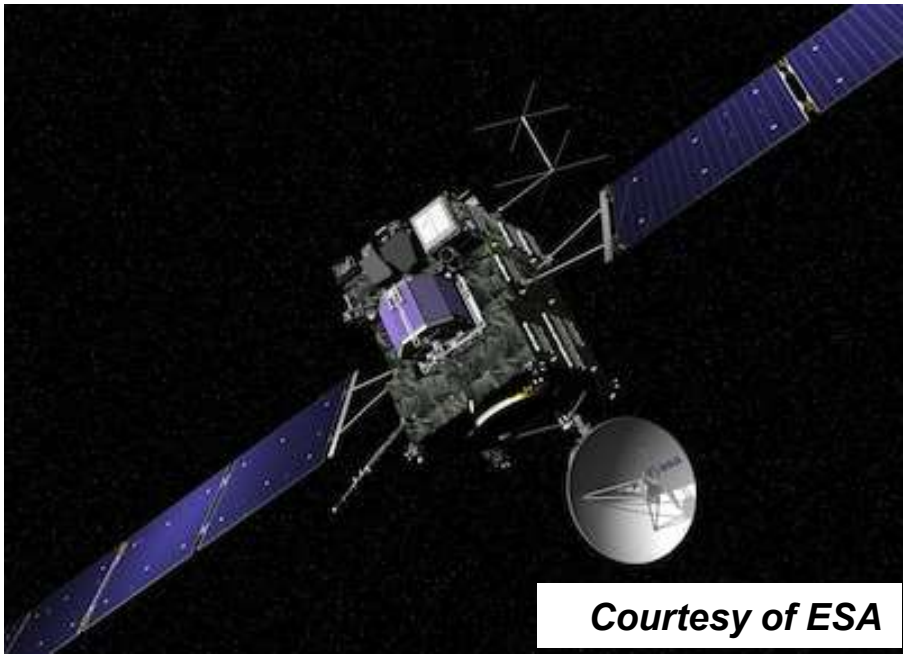
Courtesy of ESA

The Rosetta space system main facts

The orbiter

- ✓ The case to protect → body size: 2.8 x 2.1 x 2.0 m
- ✓ To talk → high gain antenna diameter: 2.2 m
- ✓ The energy source → photovoltaic Si cells: 2wings, 32m^2 wide each, still providing 400W at ~760000000 km from the Sun!!

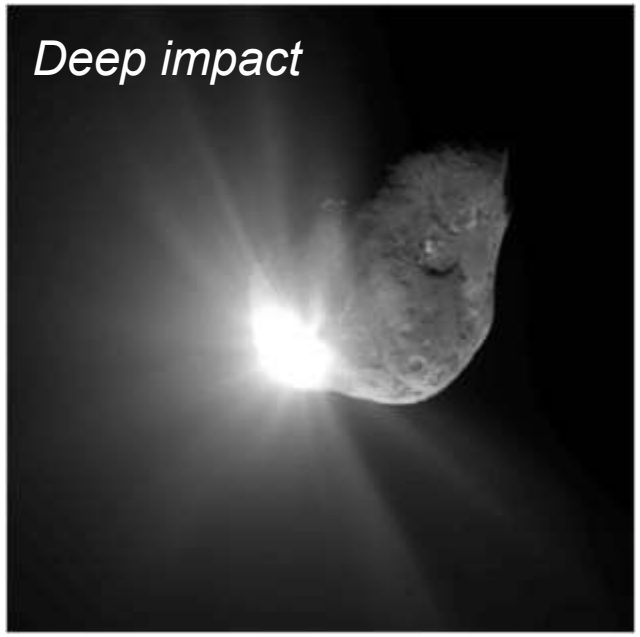
- ✓ Launch mass ~ 3000 kg:
  - Propellant: 1670 kg
  - Science payload: 165 kg
  - Lander: 100 kg
- ✓ Max power demand 900W

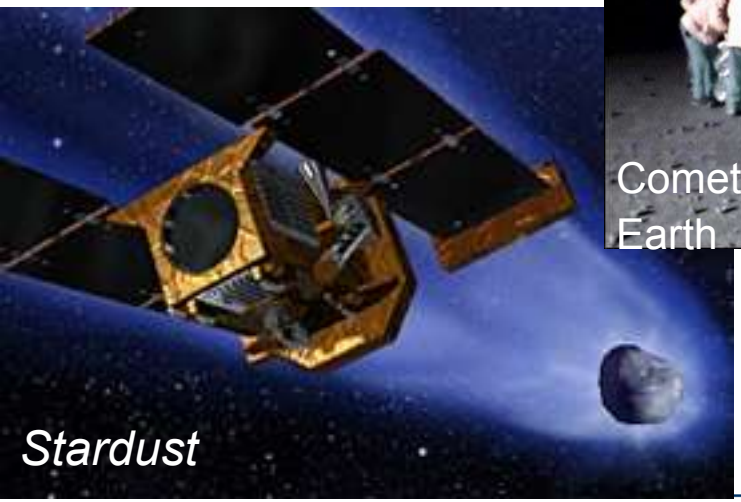


Courtesy of ESA

Missions to comets

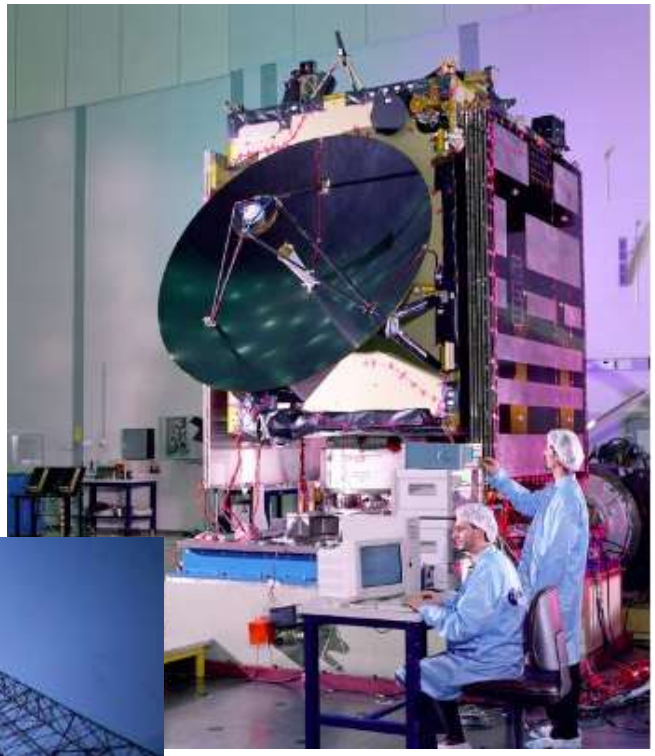
- ISEE-3/ICE ⇨ Giacobini-Zinner (1985)
- Vega 1 and 2
- Sakigake
- Suisei
- Giotto ⇨ Halley (1986)
- Stardust ⇨ Wild 2 (2004)
- Deep Impact ⇨ Tempel 1 (2005)





Rosetta mission conception and design phase

- Rosetta mission was:
  - conceived in the late 1970s
  - approved in 1993 as a Cornerstone Mission
  - Launched in 2004 by Ariane 5 rocket, form Kourou French Guiana

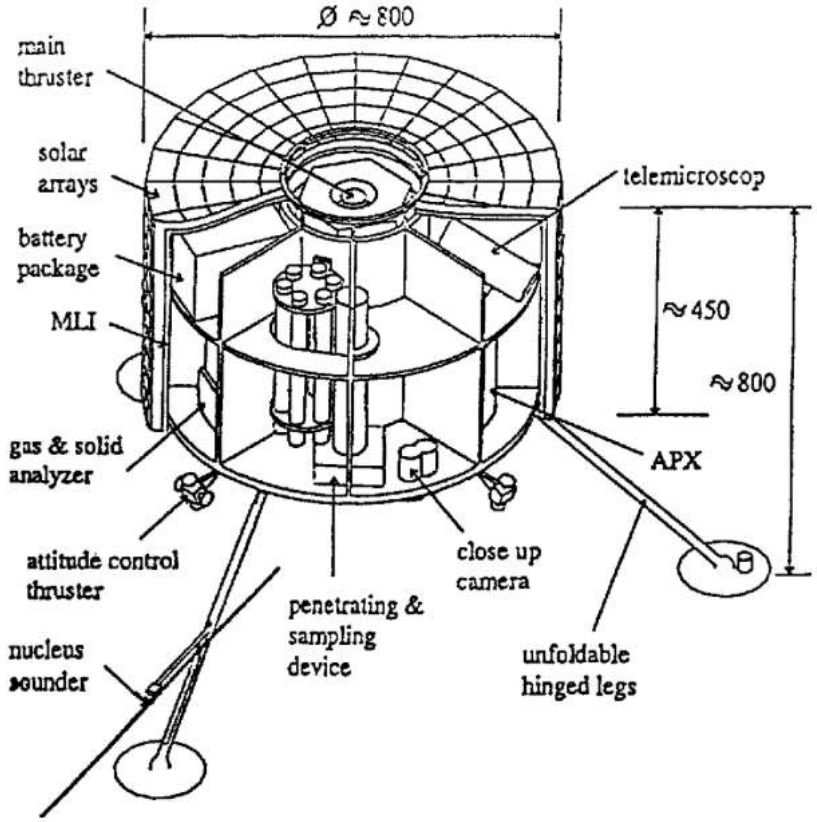


Courtesy of ESA

Rosetta Mission: history

- First conceived in the late ‘70s to explore comet 46P/Wirtanen

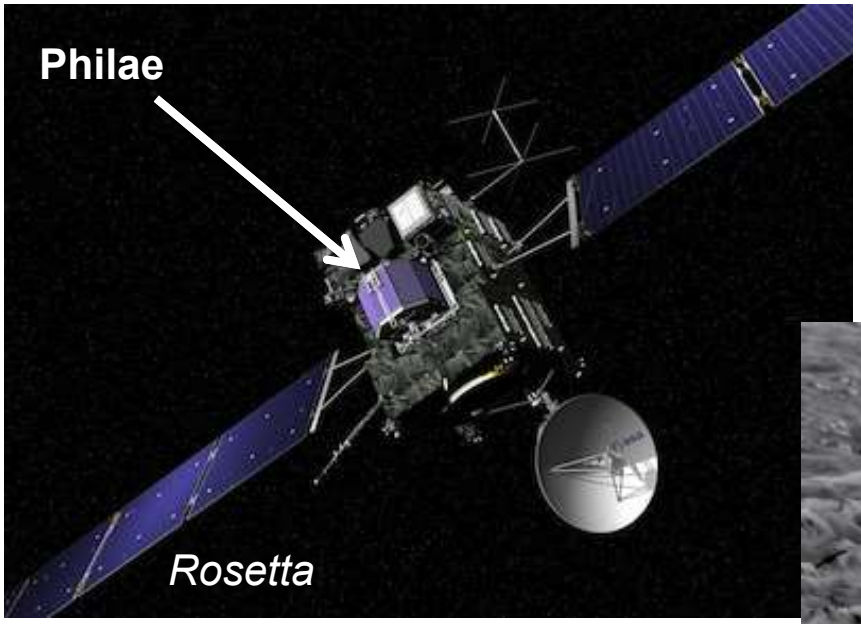
Champollion (France, ~~USA~~)



RoLand (Germany, Italy)

Rosetta Mission: history

- Approved by ESA in the early ‘90s to explore comet 46P/Wirtanen



Philae (Germany, France, Italy)

Rosetta Mission: launch

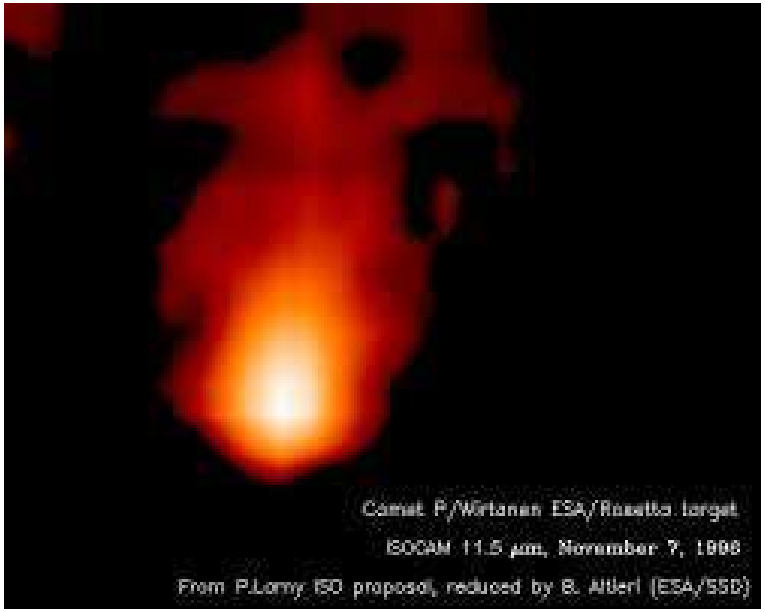
- Planned launch: March 2003

Ariane 5 failure: 11 December 2002

Rosetta Mission: launch

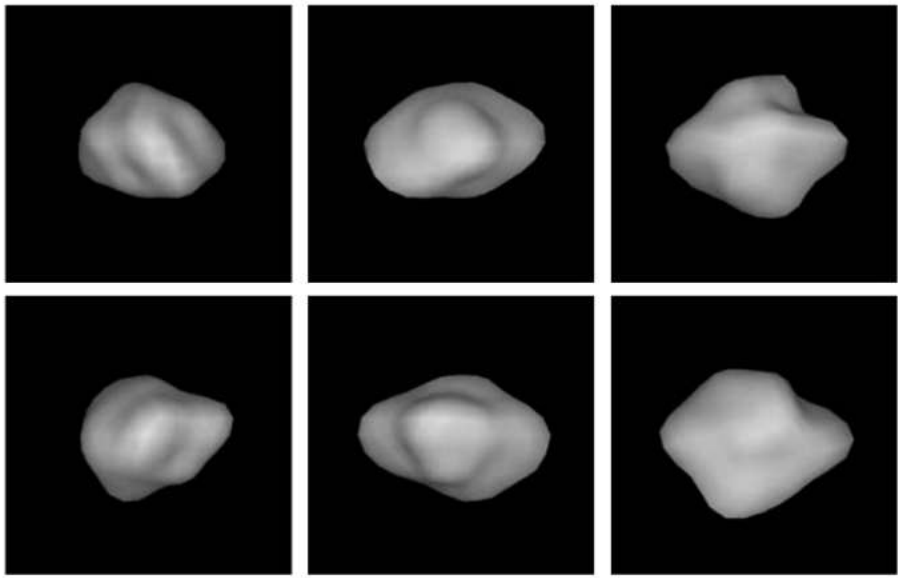
- Planned launch: March 2003

46P / Wirtanen



- Actual launch: 02/03/2004

67P/Churyumov-Gerasimenko

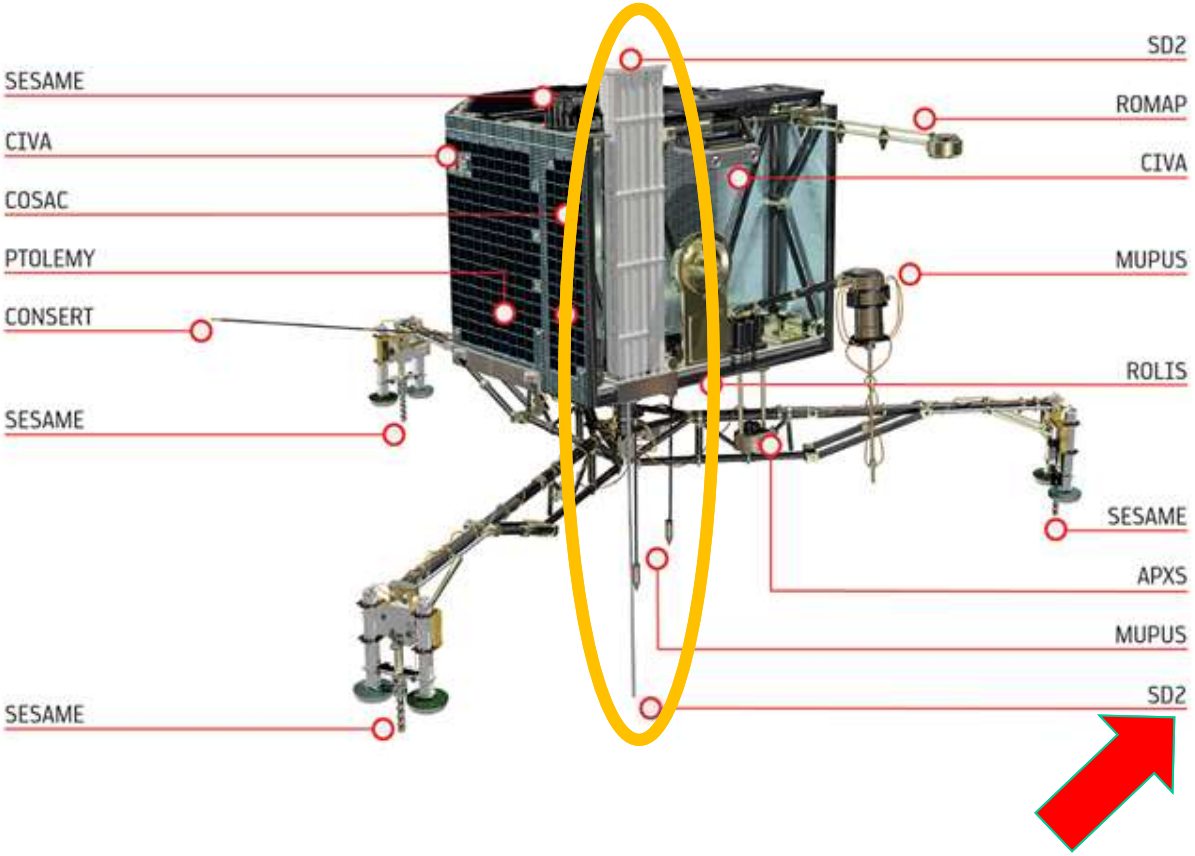


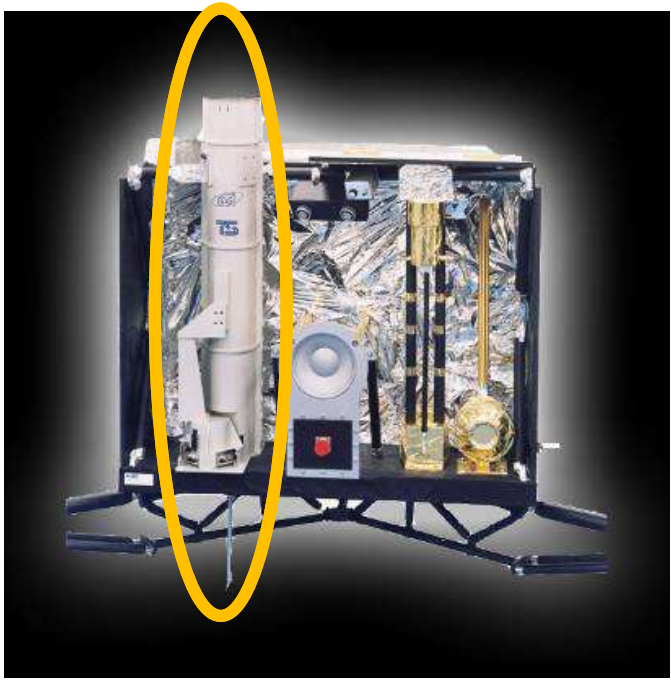
The consortium for the design and construction phases

Solar Array Assembly

Courtesy of Selex ES

Philae Lander: scientific instruments



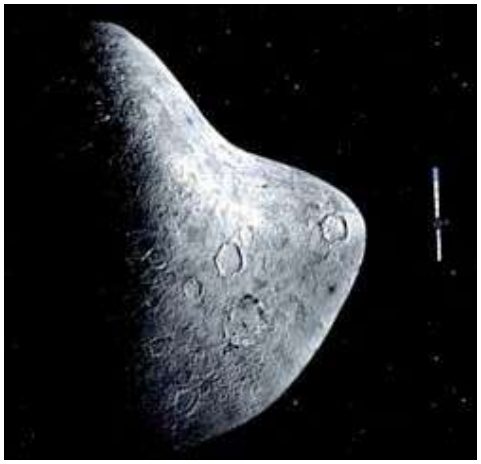


Philae Lander: SD2 drill … a long history

Drill prototype test, Etna, 2002

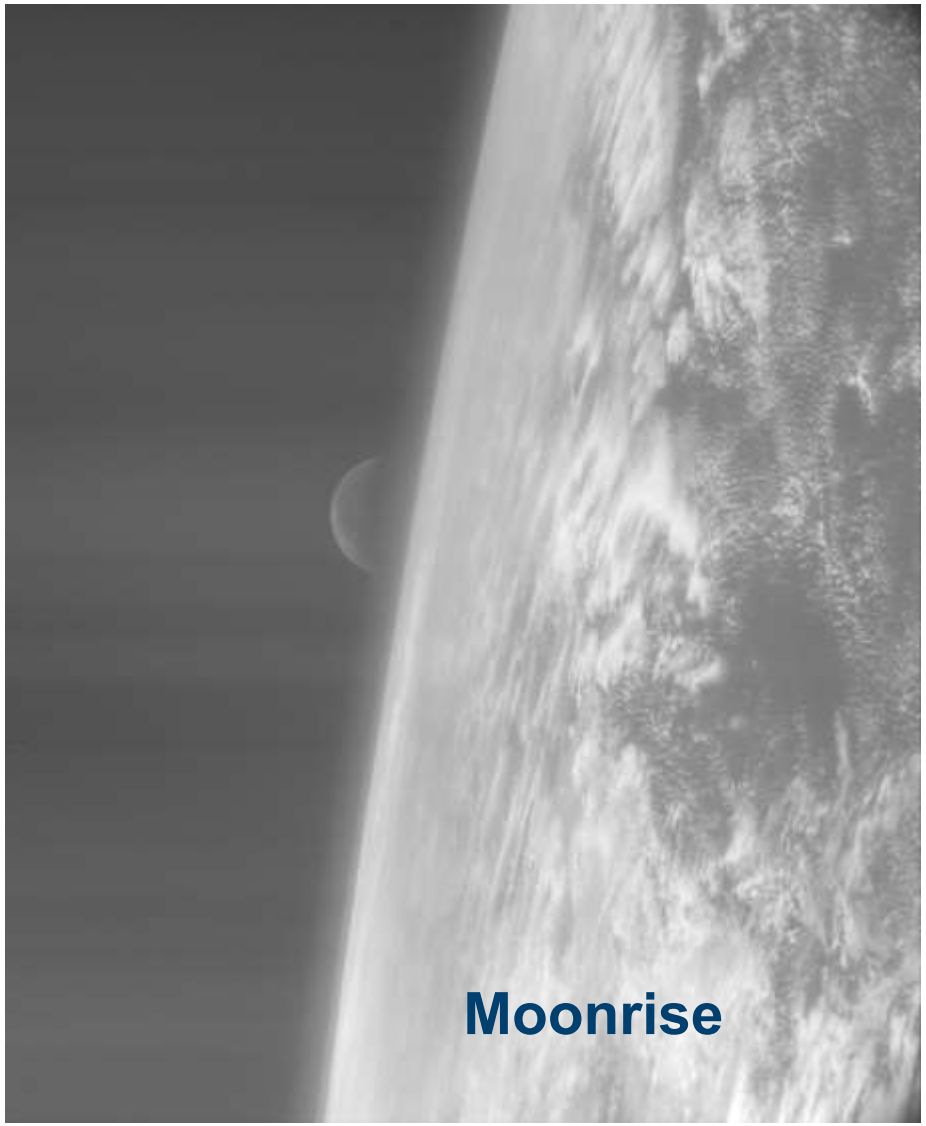
Rosetta mission timeline

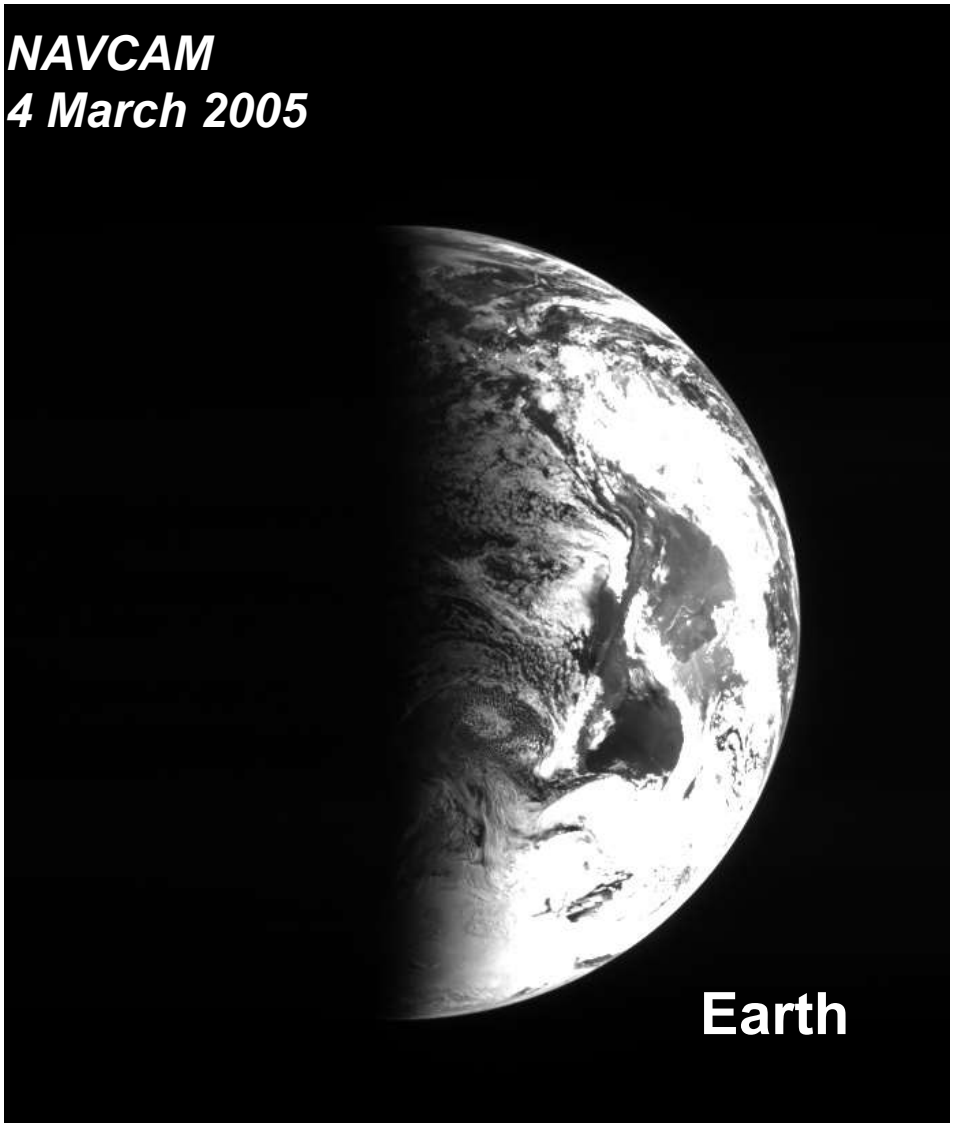
Event	Date
Launch	March 2004
1st Earth Gravity Assist (GA)	March 2005
Mars GA	February 2007
2nd Earth GA	November 2007
Flyby of Asteroid Steins	September 2008
3rd Earth GA	November 2009
Flyby of Asteroid Lutetia	July 2010
Hybernation	July 2011
Wake-up	January 2014
Comet rendezvous	May 2014
Philae Landing	November 2014
Comet Closest Approach to the Sun	August 2015
Nominal Mission End	December 2015

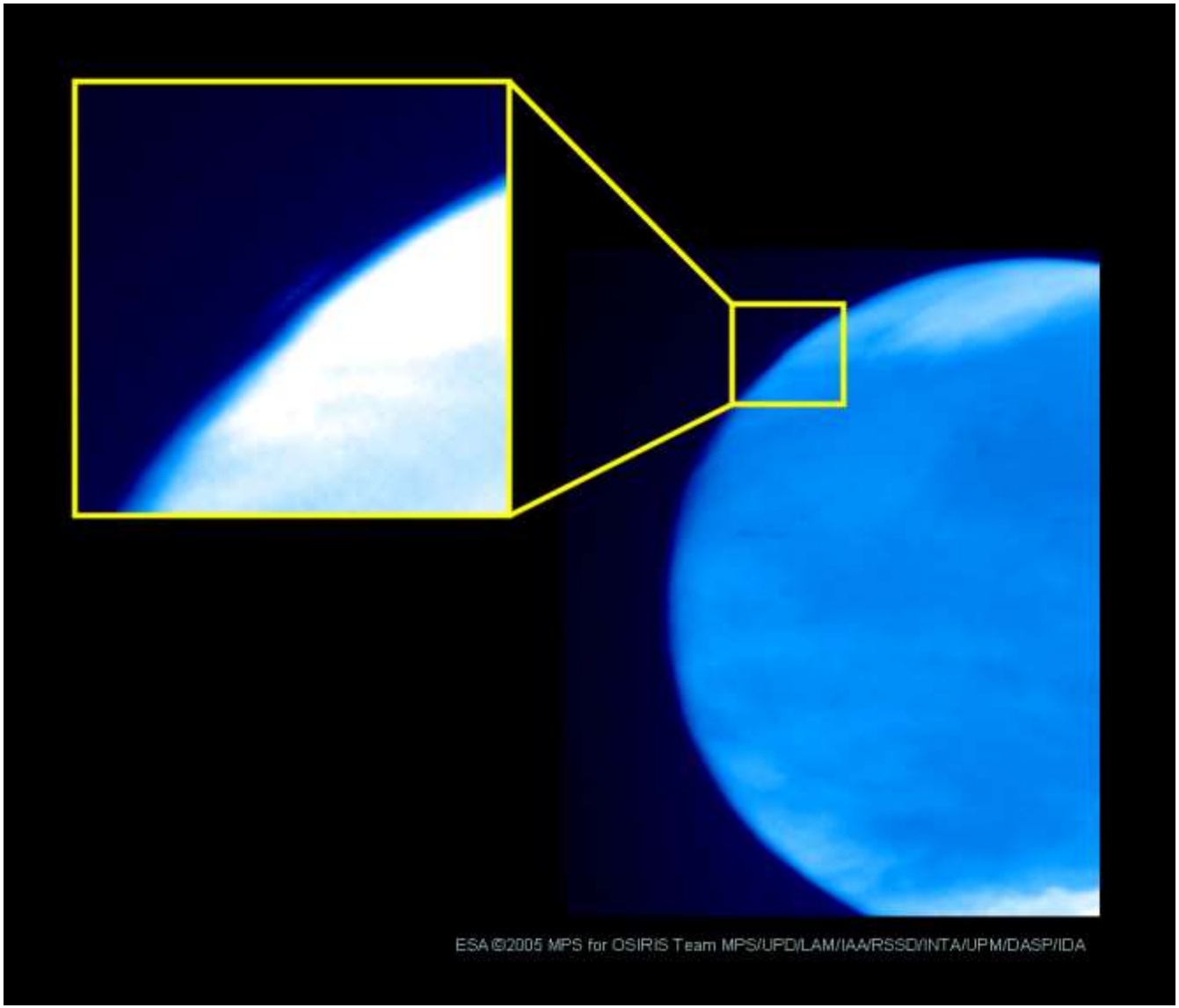


Rosetta Mission
The long journey

Rosetta
first Earth flyby



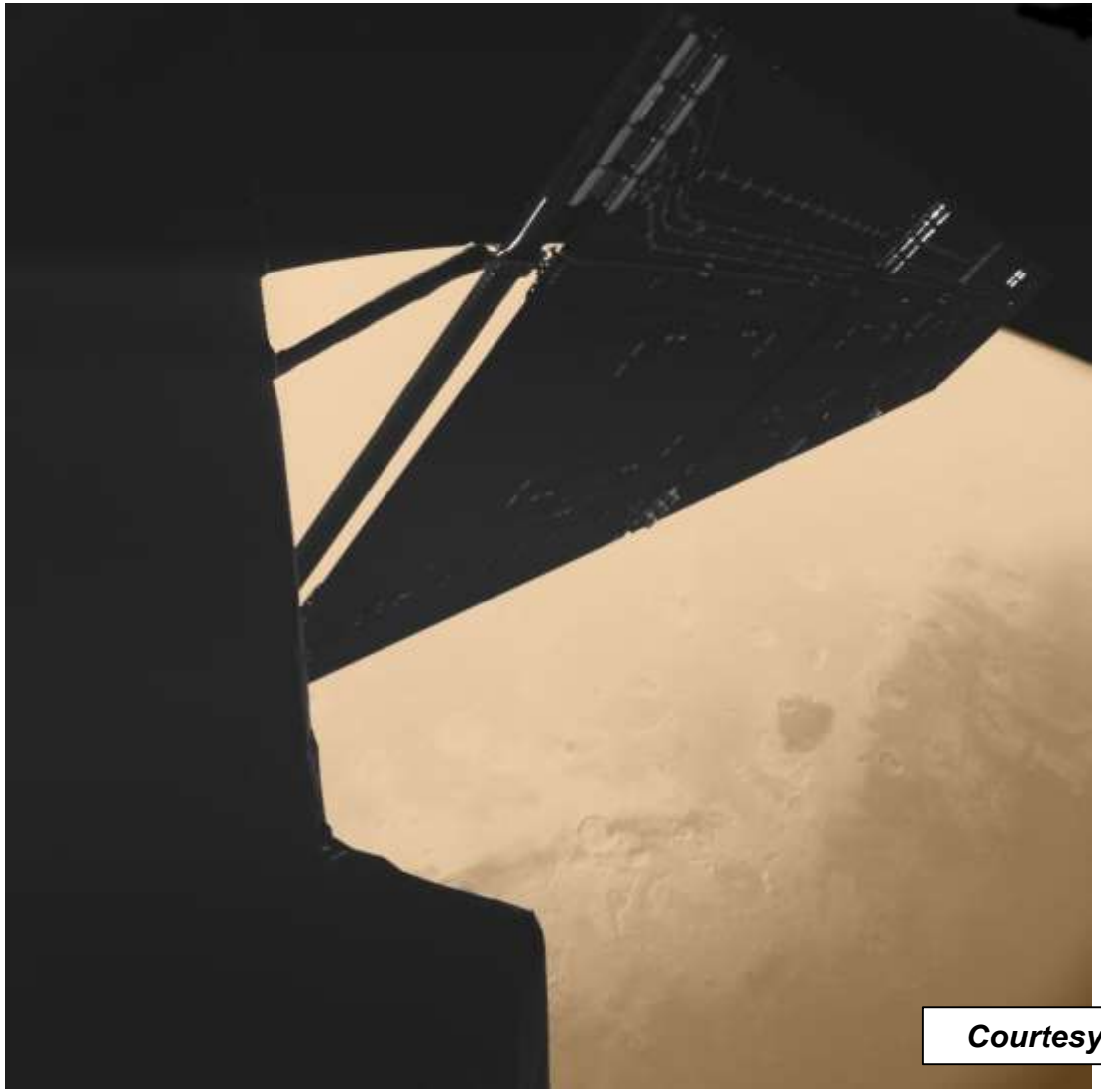




OSIRIS WAC
Ultraviolet image
24 February 2007

Clouds in Mars atmosphere

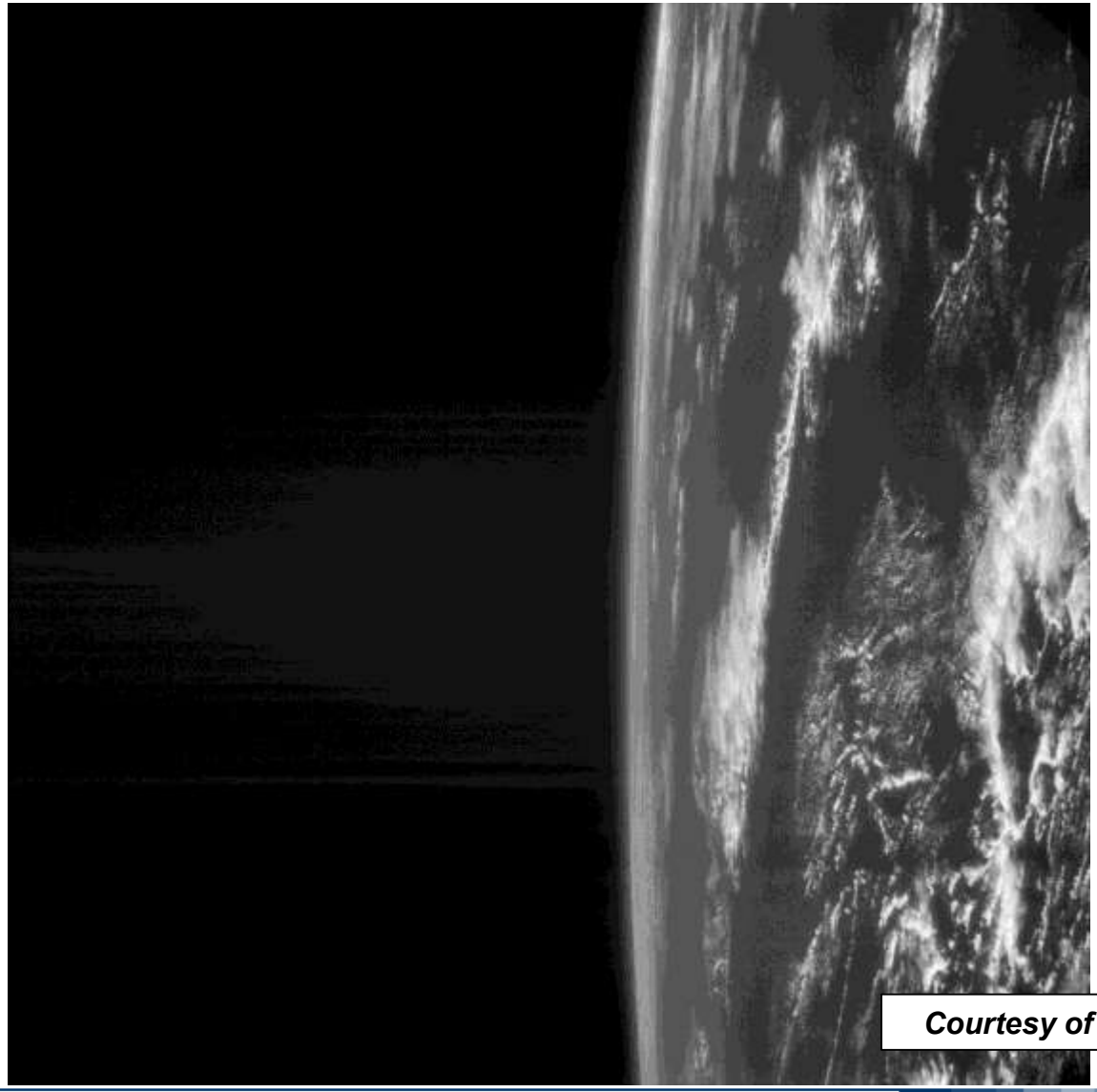
Rosetta
«selfie» during Mars flyby



Courtesy of ESA

CIVA Image
25 February 2007
About 1000 km distance

Rosetta
second Earth flyby



Courtesy of ESA

NAVCAM image
13 November 2007
About 6250 km from surface

Rosetta
close encounter with asteroid Steins

A diamond in space
OSIRIS image – 5 September 2008 – 800 km distance

Courtesy of ESA

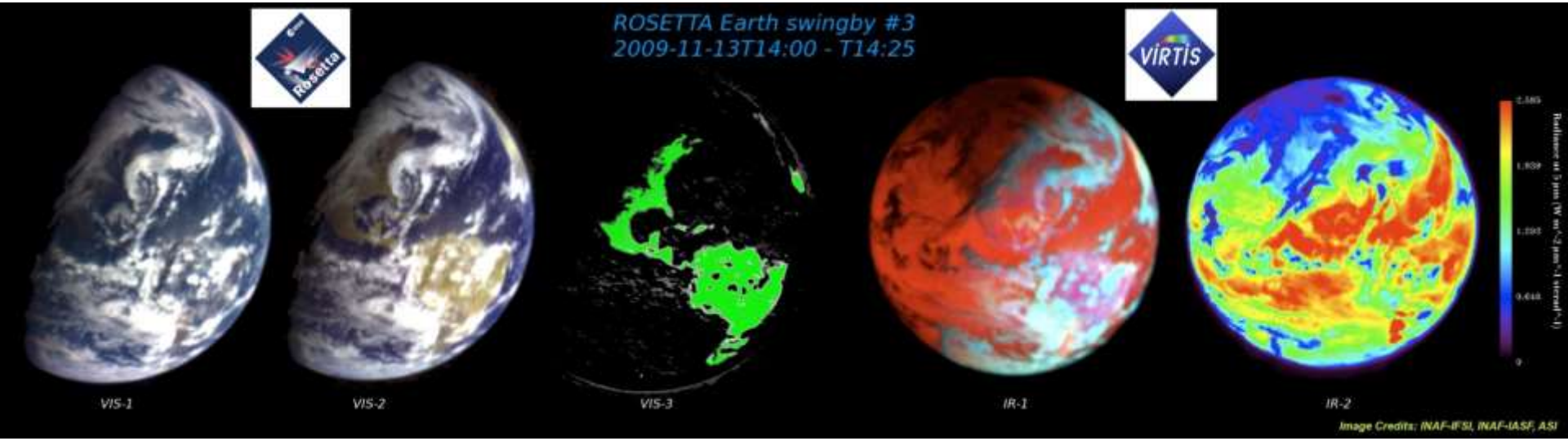
Rosetta
third Earth flyby

OSIRIS image
November 2009
About 350000 km distance

Courtesy of ESA

Rosetta
third Earth flyby

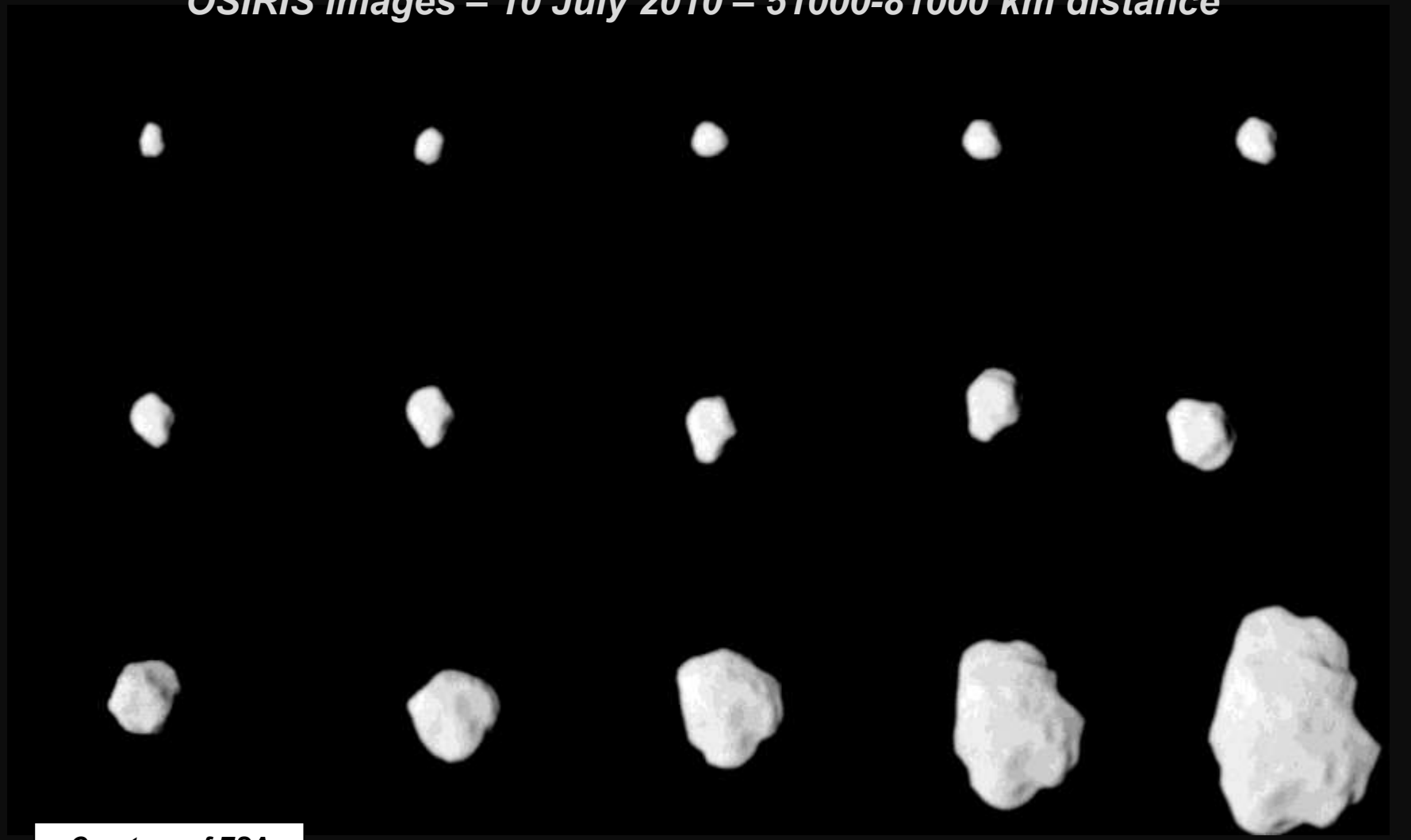
VIRTIS images
13 November 2009
About 230000 km distance



Courtesy of ESA

Rosetta
close encounter with asteroid Lutetia

OSIRIS images – 10 July 2010 – 51000-81000 km distance



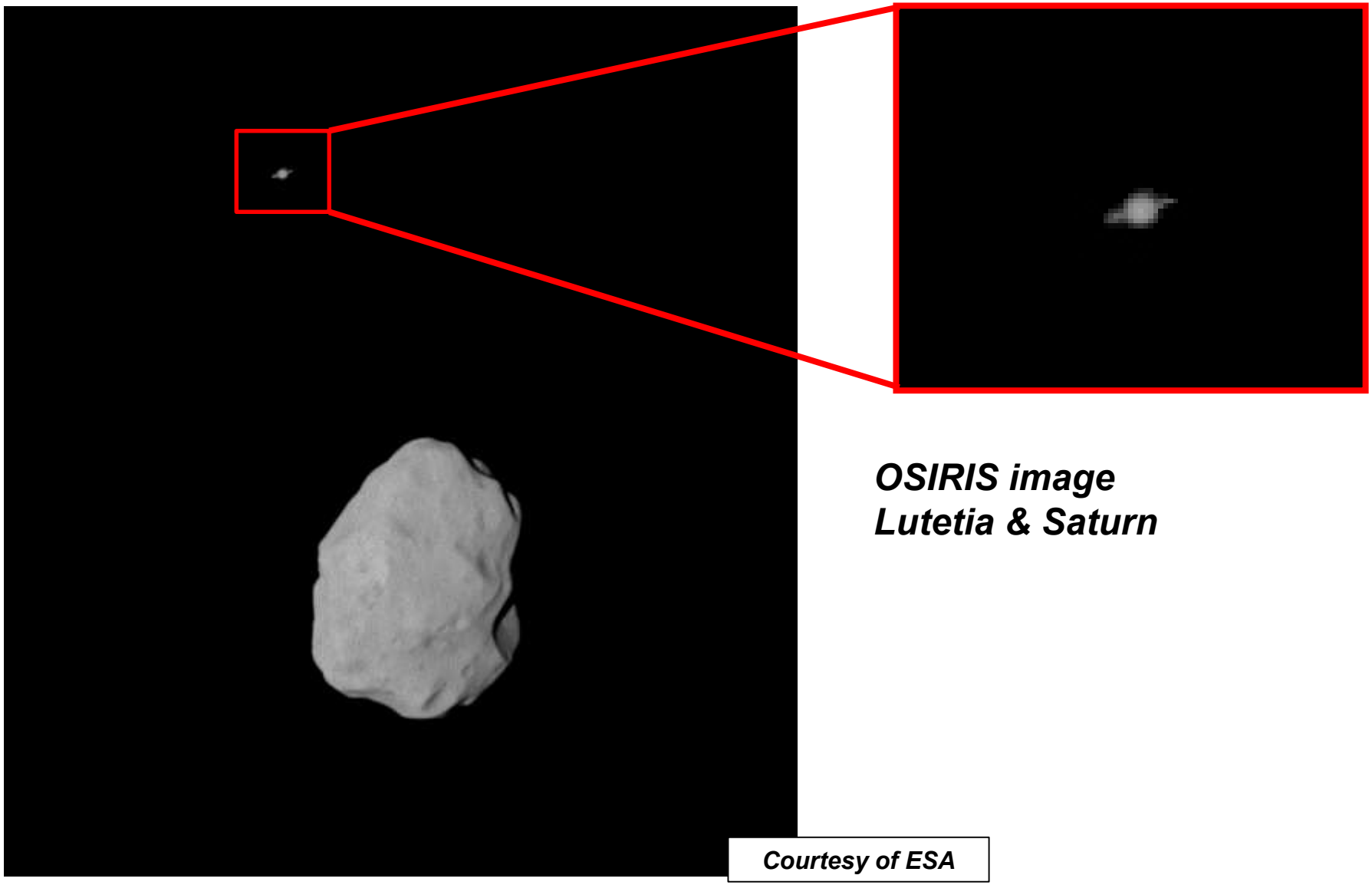
Courtesy of ESA

Rosetta
close encounter with asteroid Lutetia

OSIRIS images
10 July 2010
Closest approach – 3160km

Courtesy of ESA

Rosetta
close encounter with asteroid Lutetia



OSIRIS image
Lutetia & Saturn

Courtesy of ESA

Lamy et al., 2007

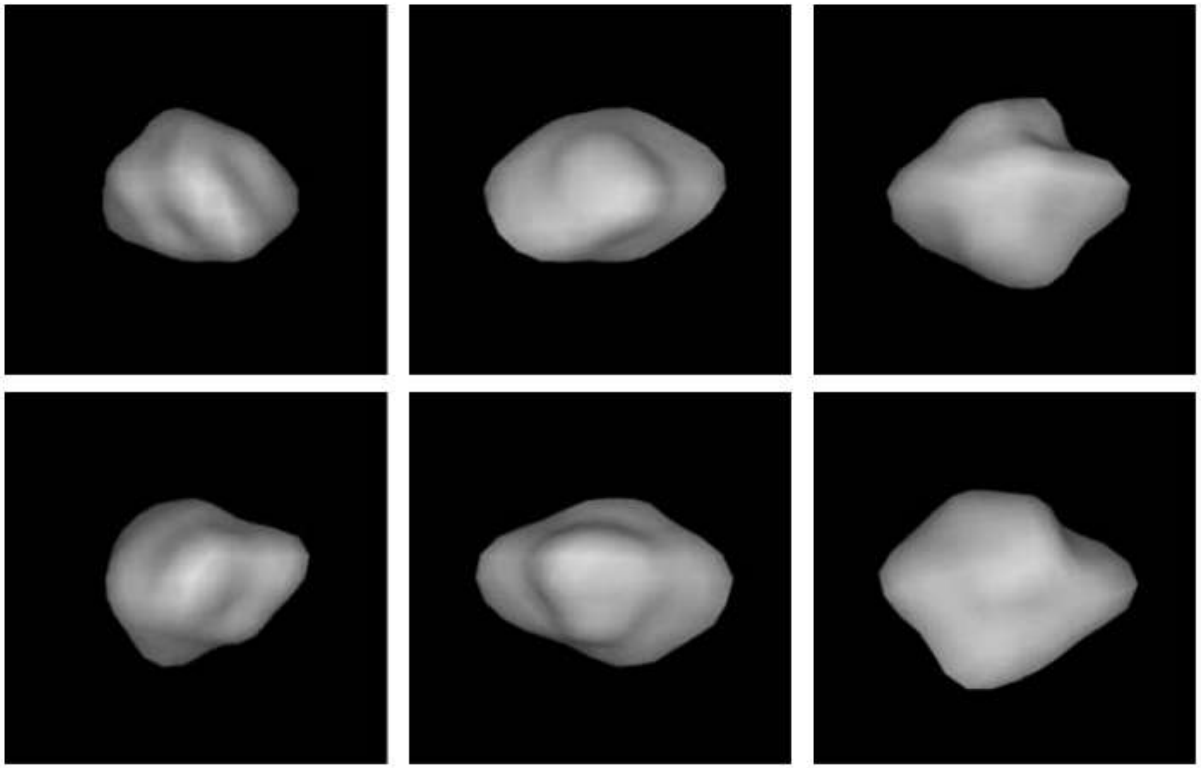
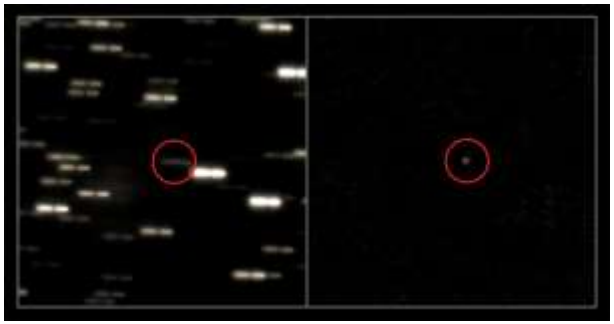


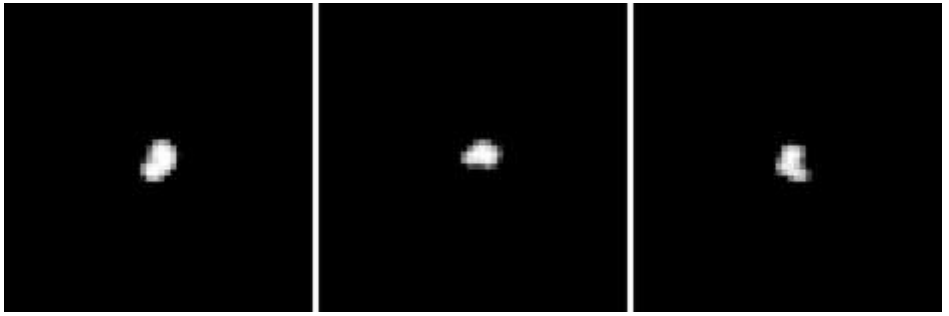
Figure 5. The prograde A1 (top row) and the retrograde B2 (bottom row) solutions for the three-dimensional shape of the nucleus of comet 67P/Churyumov–Gerasimenko reconstructed from the inversion of the 2003 HST and 2005 NTT light curves. For each solution, three views of the reconstructed 3-D shape model are displayed at three different rotational phase angles: 350° (left-panel), 80° (mid-panel), and pole-on view of the 80° model (right-panel).

Rosetta
… and the actual shape!

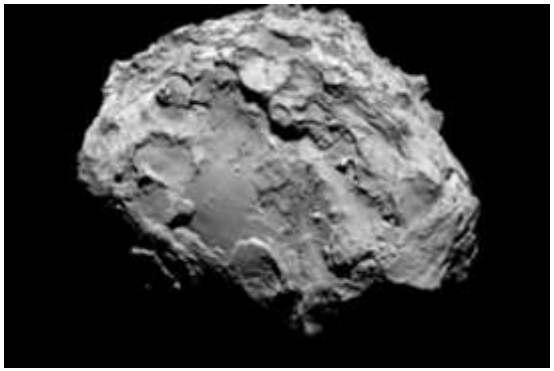
2014

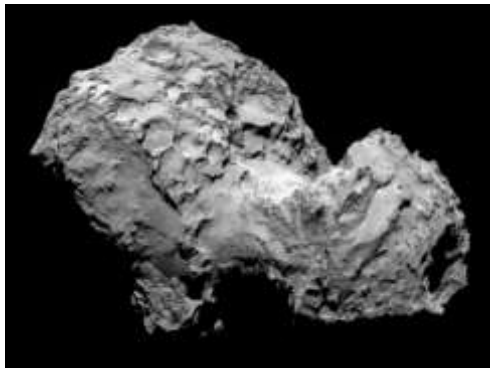


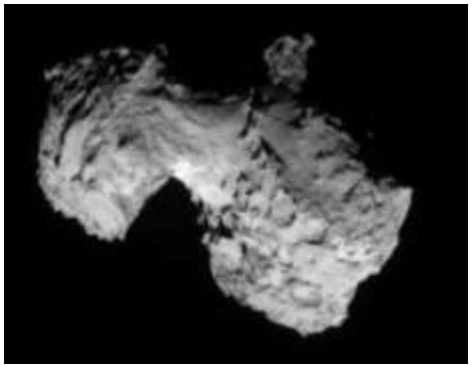
February 2



July 4







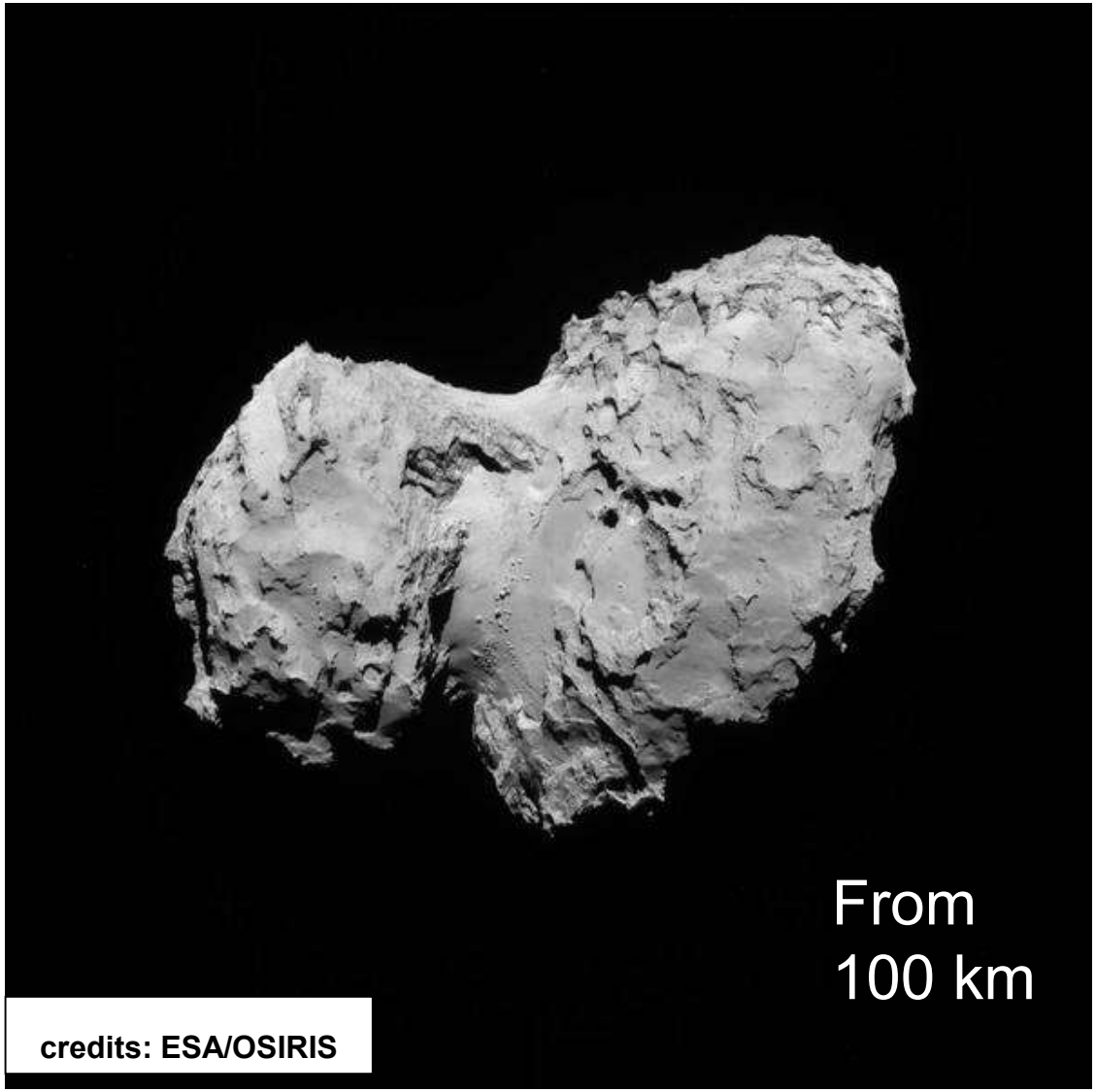
August 3

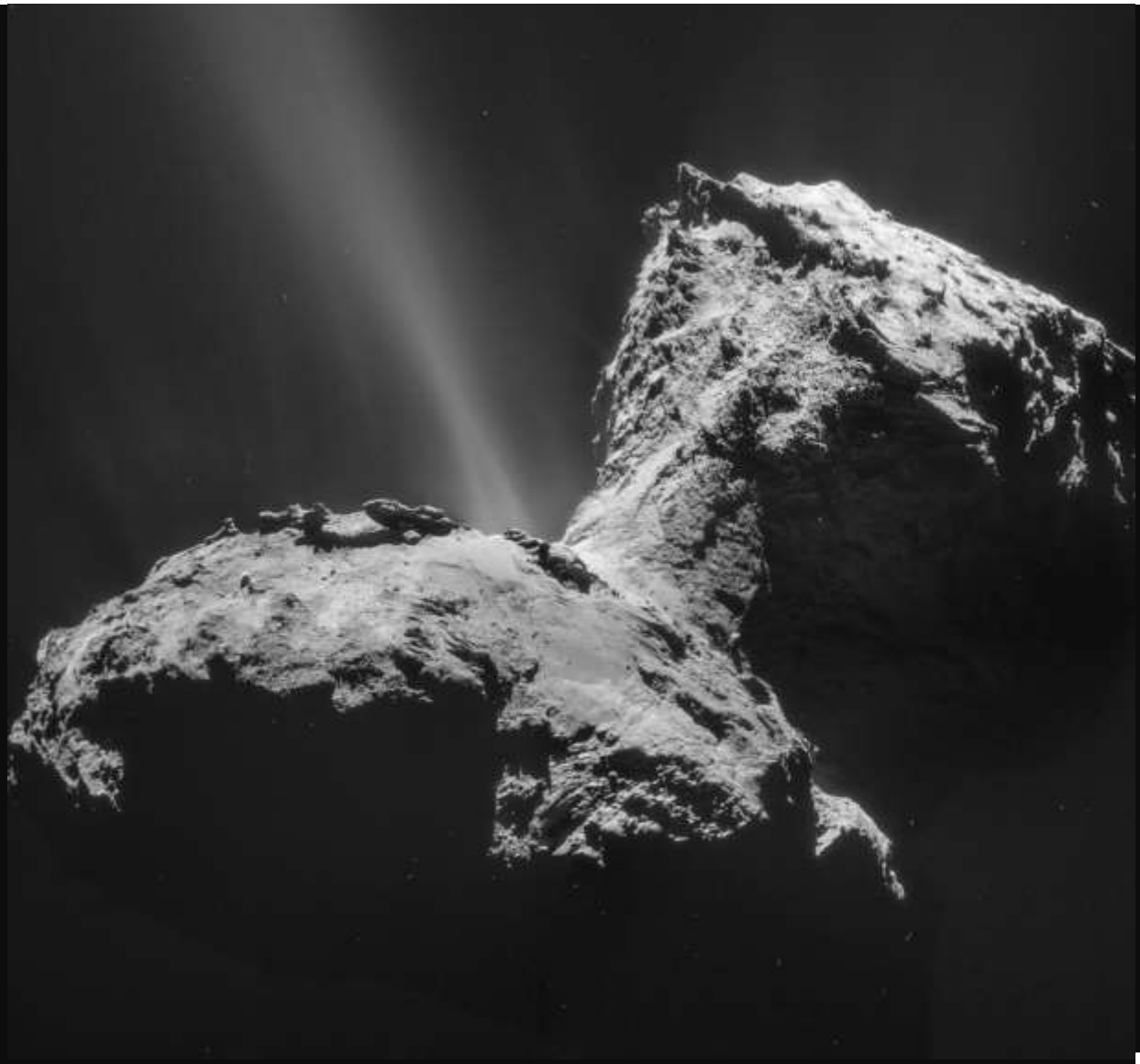
credits: ESA/OSIRIS

Rosetta
Comet fact sheet

From on acquired scientific data, preliminary infos on the target have been obtained

- Mass: 10^{13} kg
- Volume: 25 km^3
- Density: 0.4 g/cm^3
- Rotational period: 12.4 hours



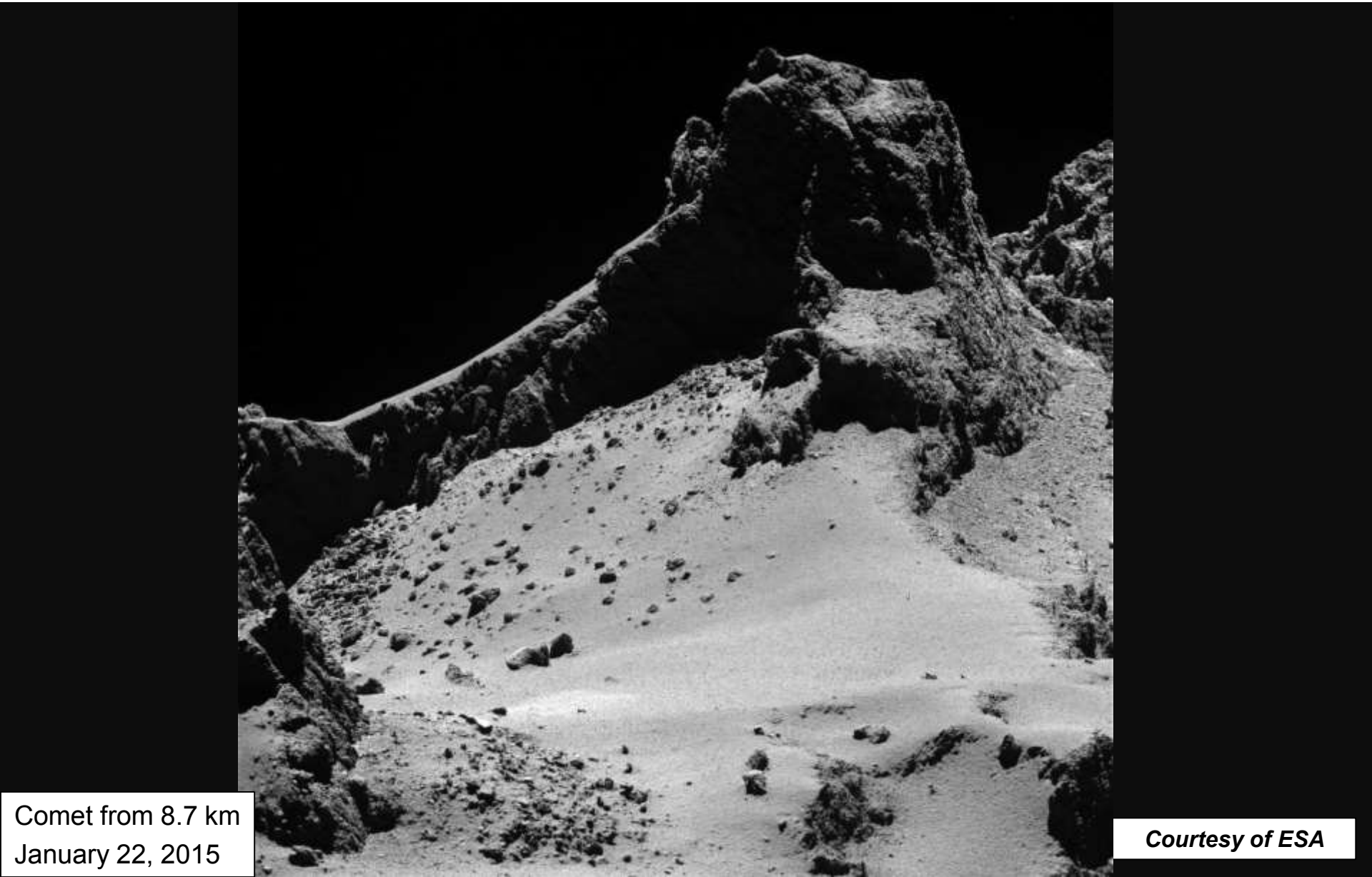


From the NAVCAM

Courtesy of ESA

Comet from 8.7 km
February 14, 2015

Courtesy of ESA



Comet from 8.7 km
January 22, 2015

Courtesy of ESA

Rosetta
hovering around the comet

Rosetta *Selfie*

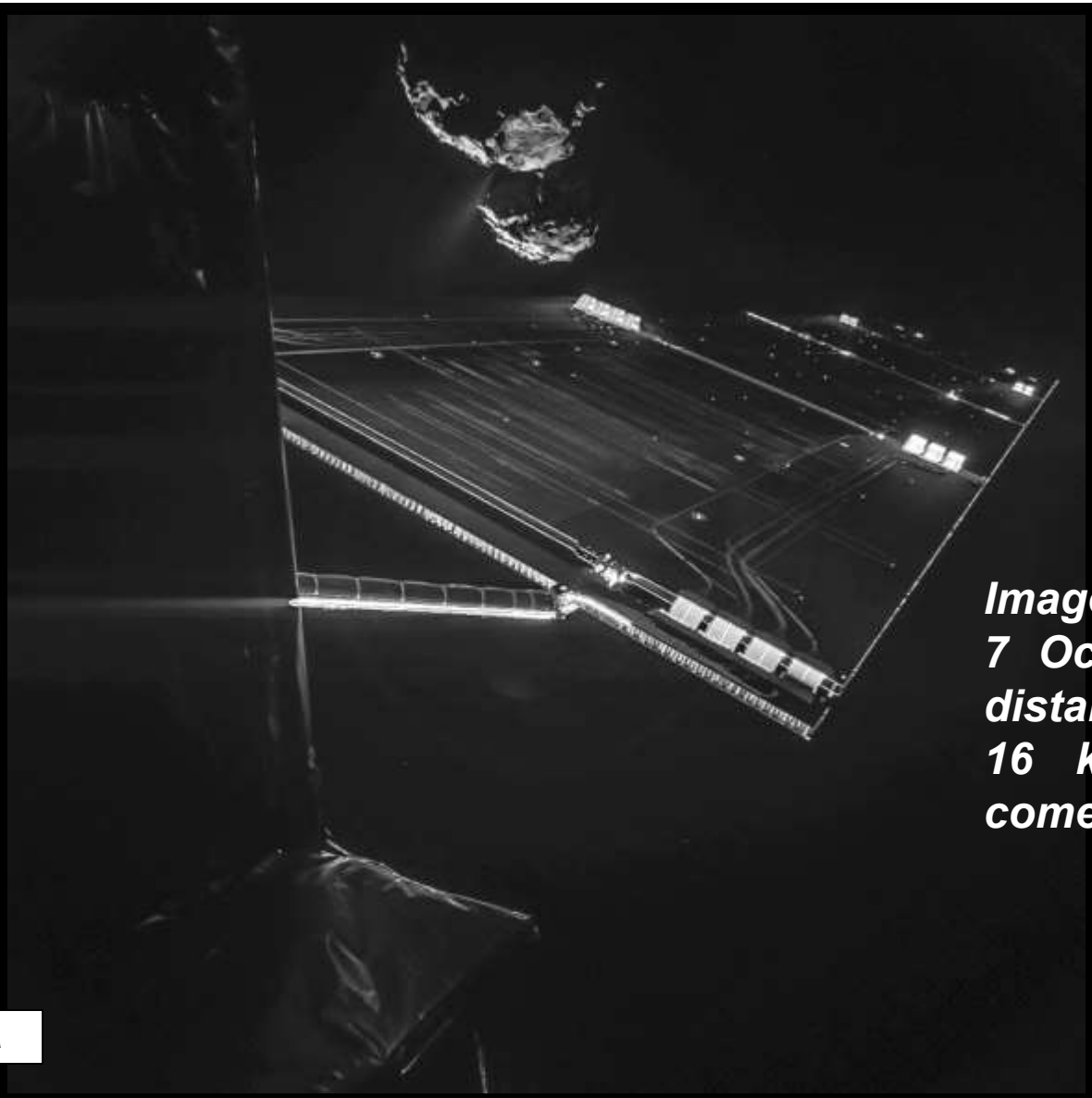
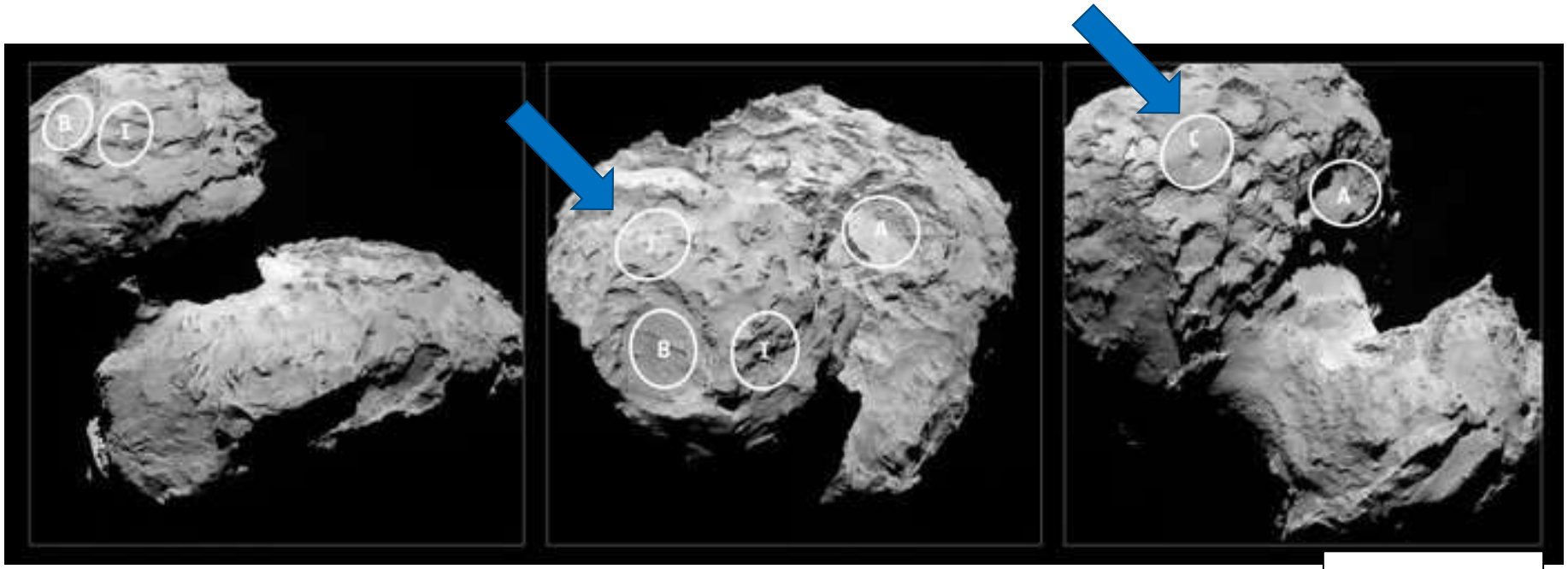


Image from CIVA - 7 October from a distance of about 16 km from the comet

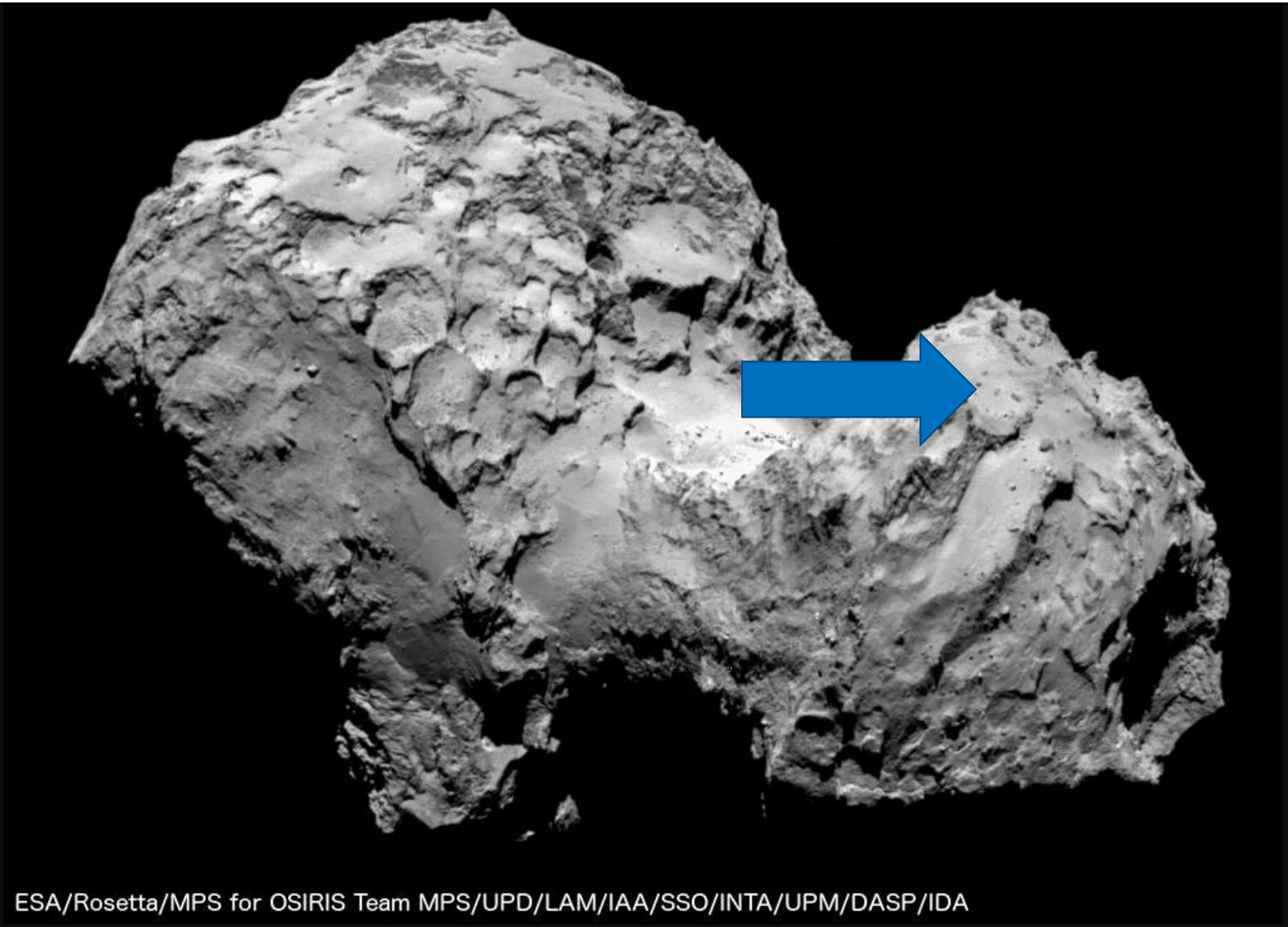
Courtesy of ESA

Rosetta
landing site selection

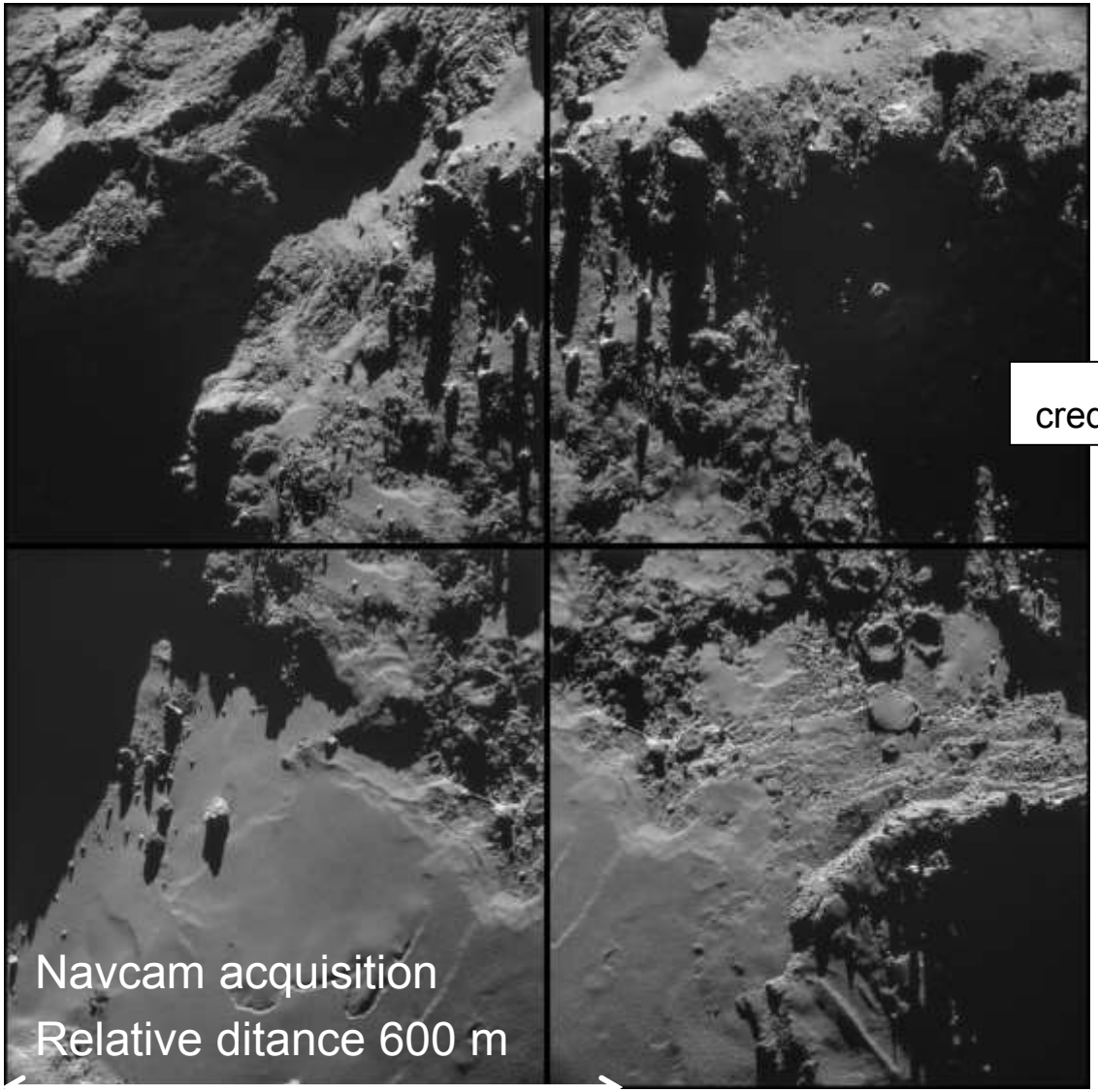


credits: ESA

Rosetta landing site

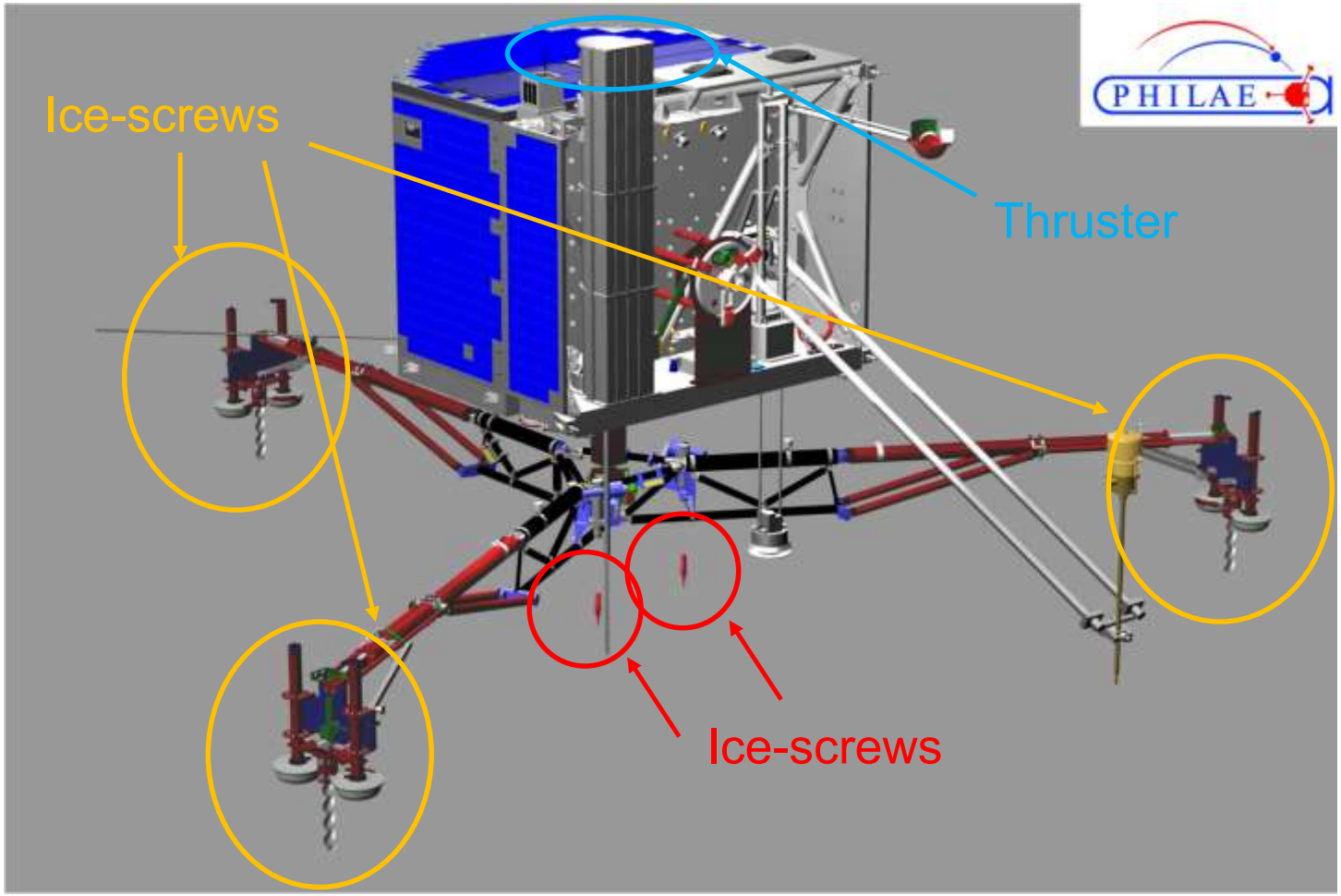


Rosetta landing site

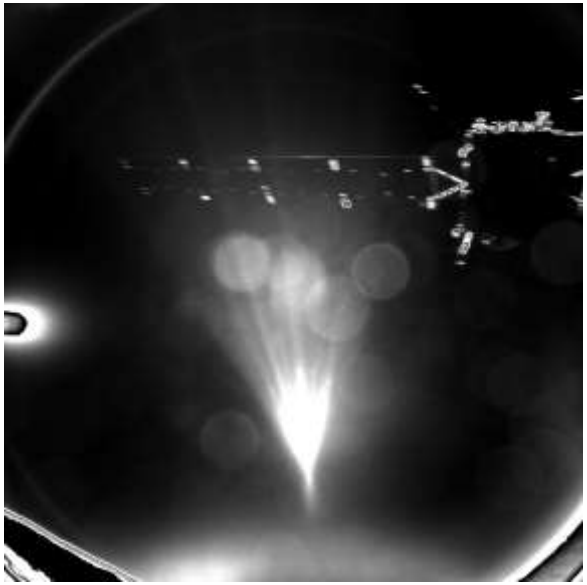


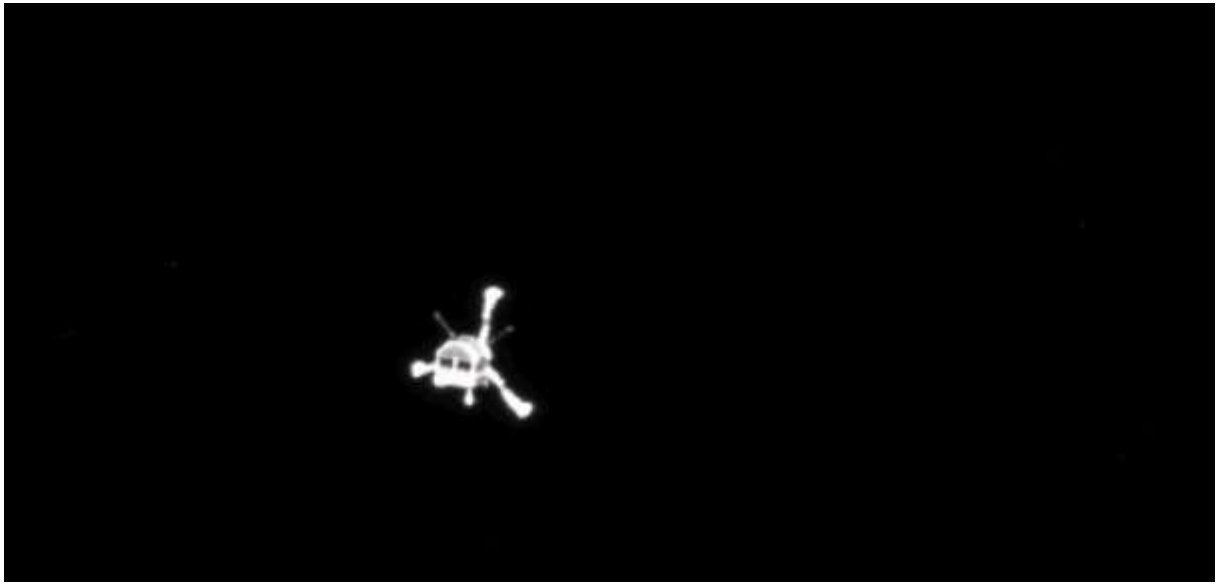
credits: ESA

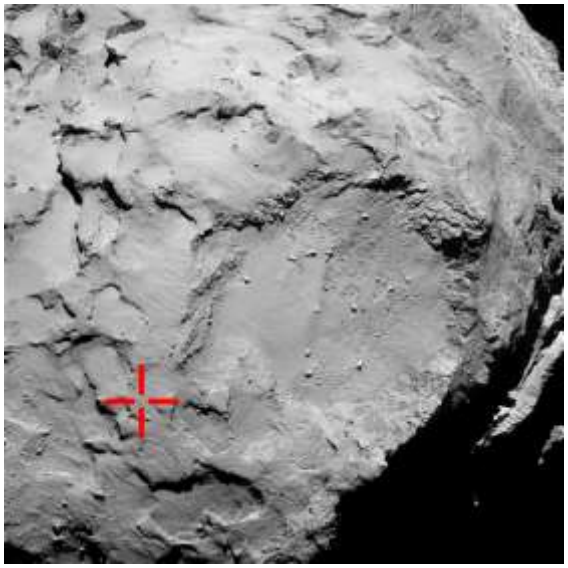
Rosetta
How does Philae harpoon the comet?



Rosetta
Close orbit to lander deployment

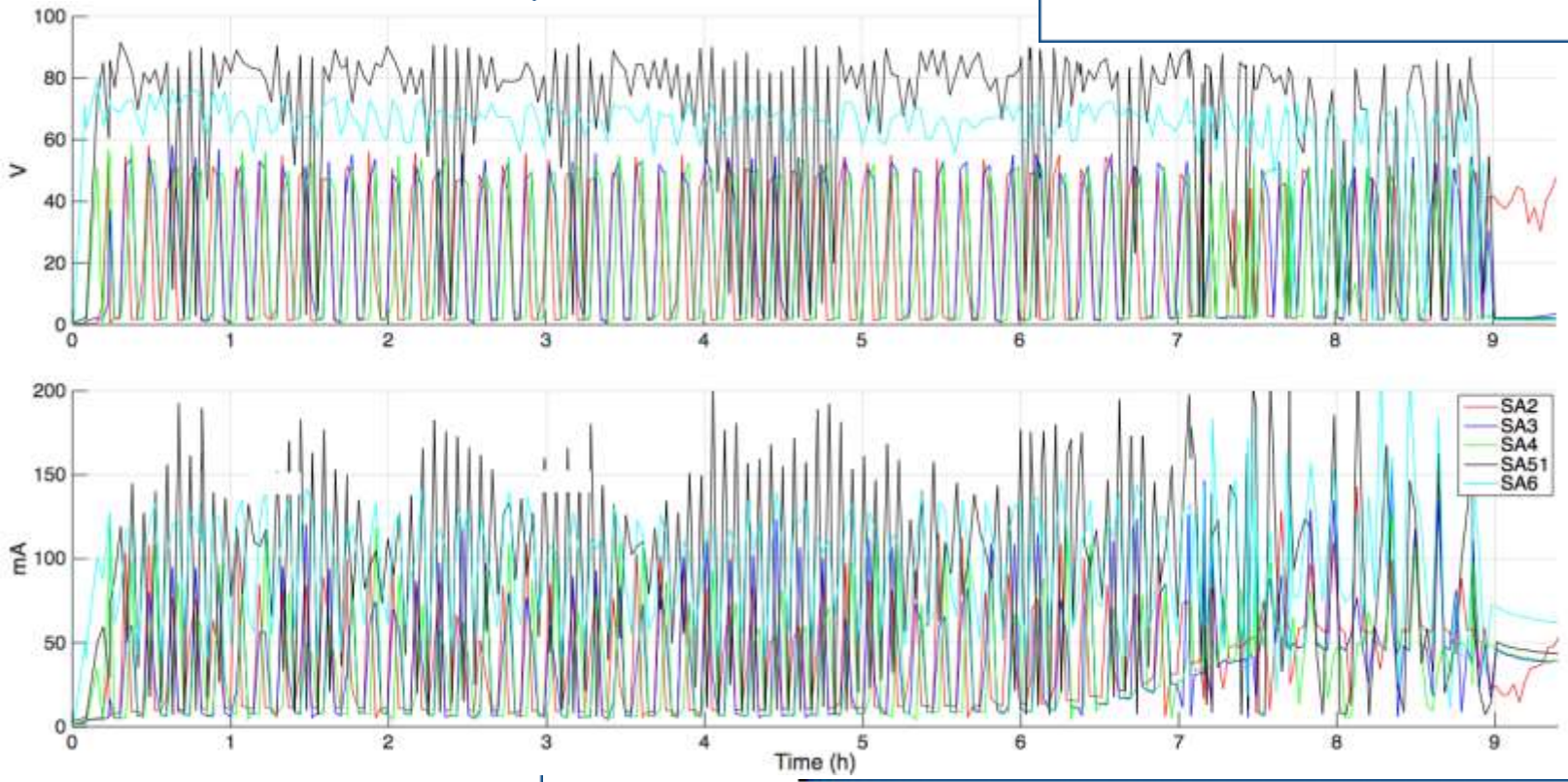




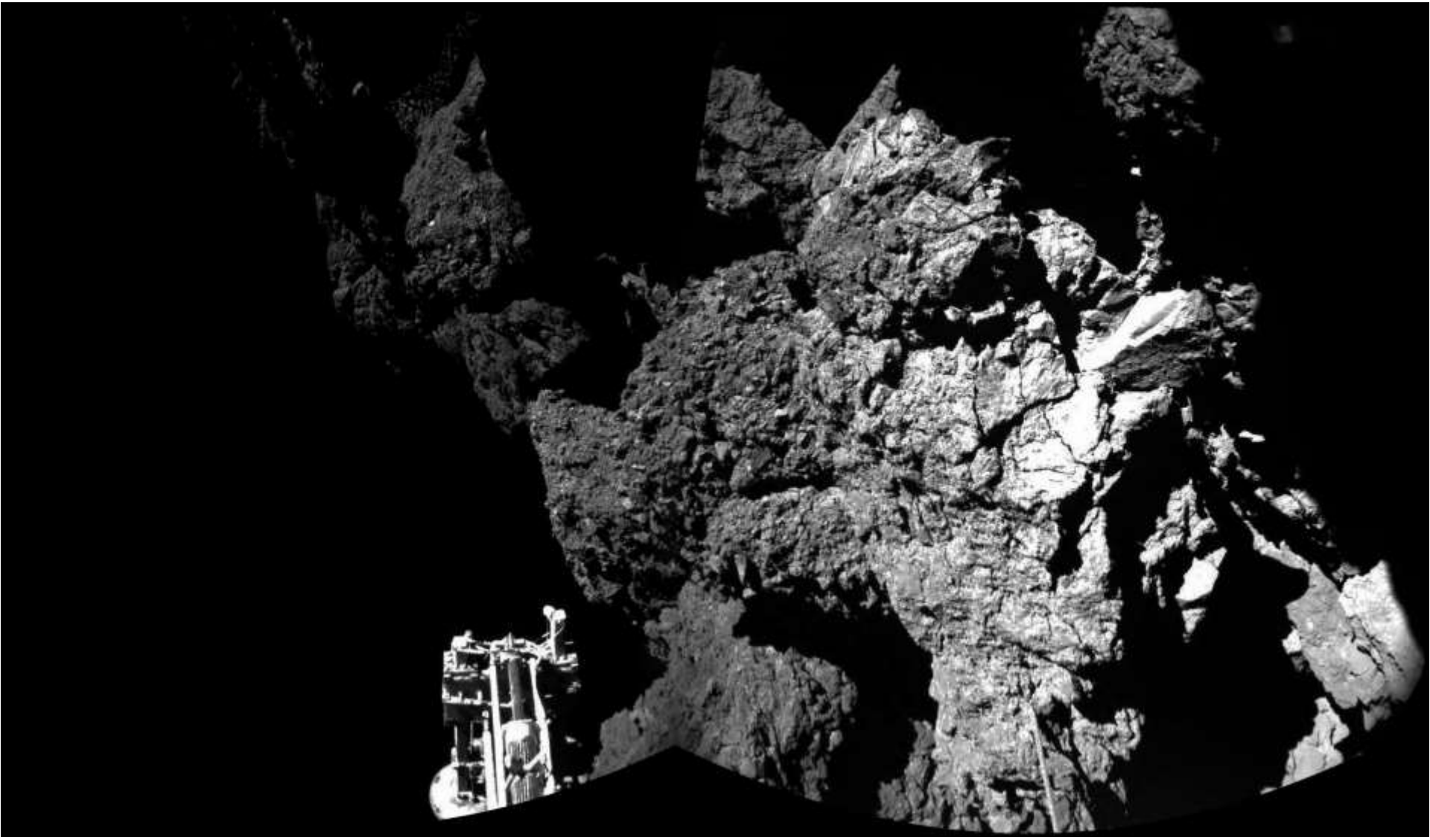


Rosetta Mission Control Center (Darmstatd) …

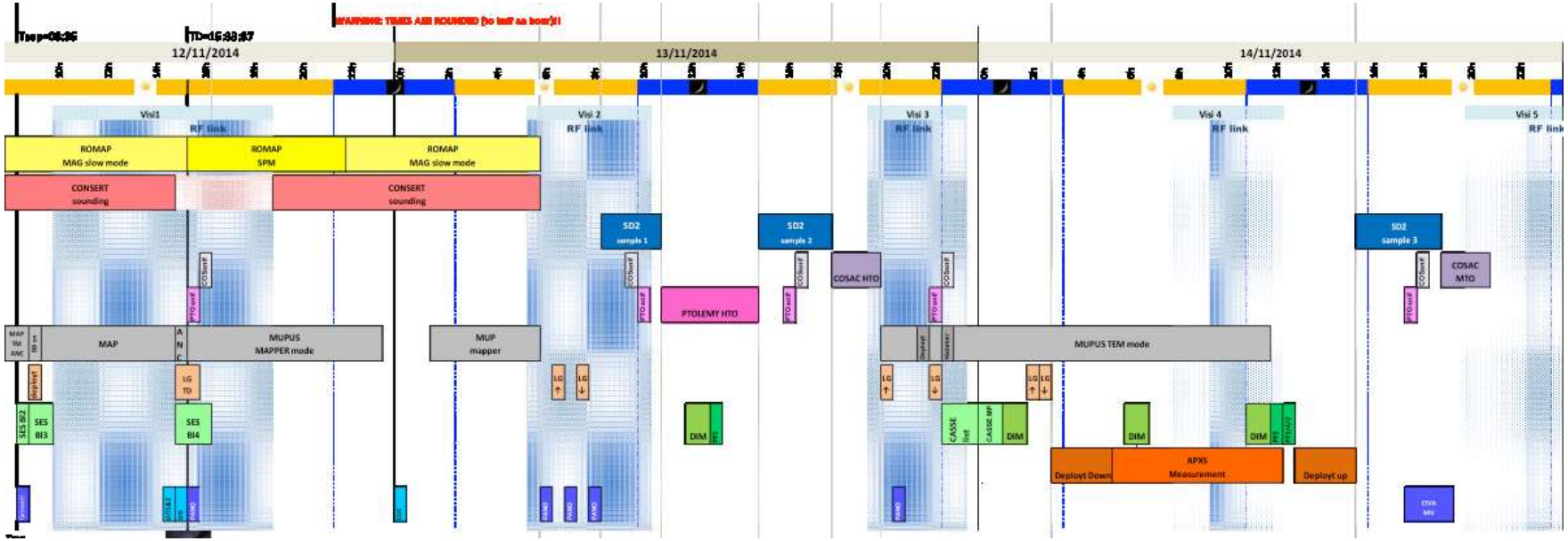
Evening of November 12, 2014 …



November 13, 2014 – the first image

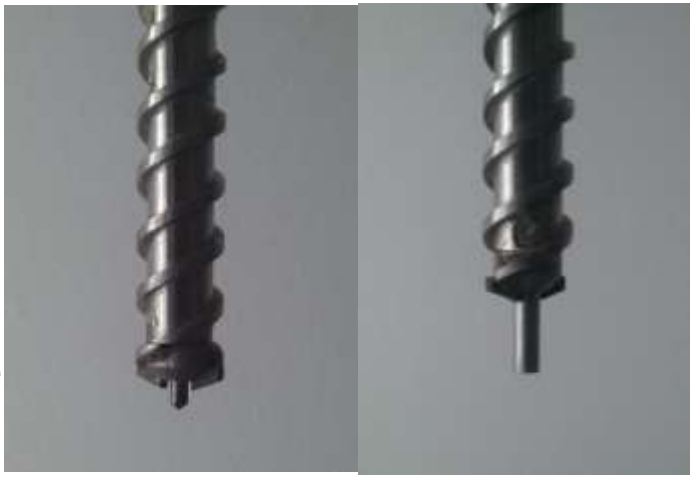


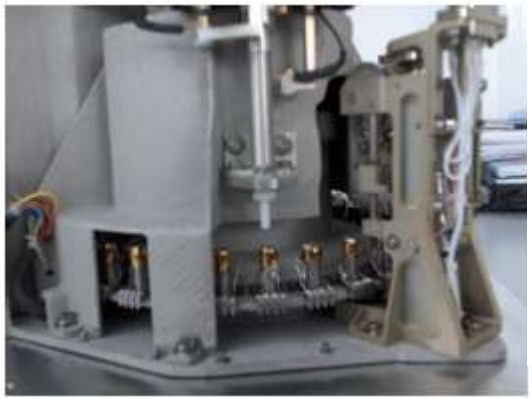
November 13, 2014: the planned operations

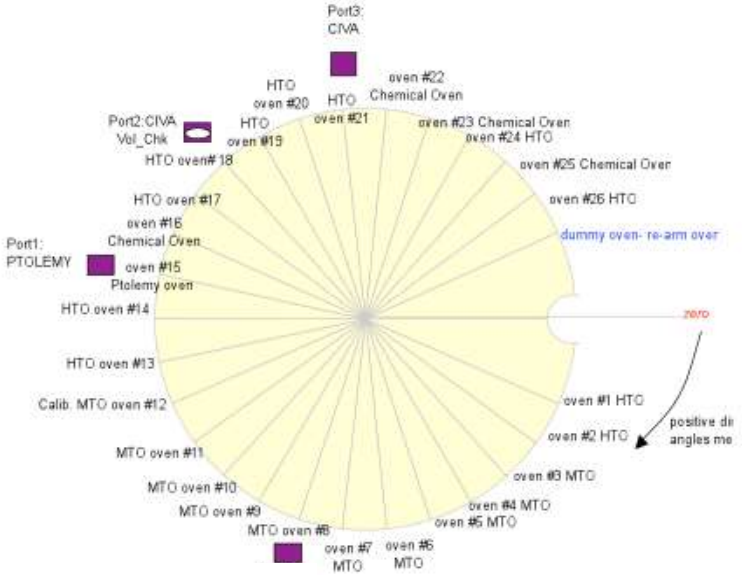


SD2 procedure:

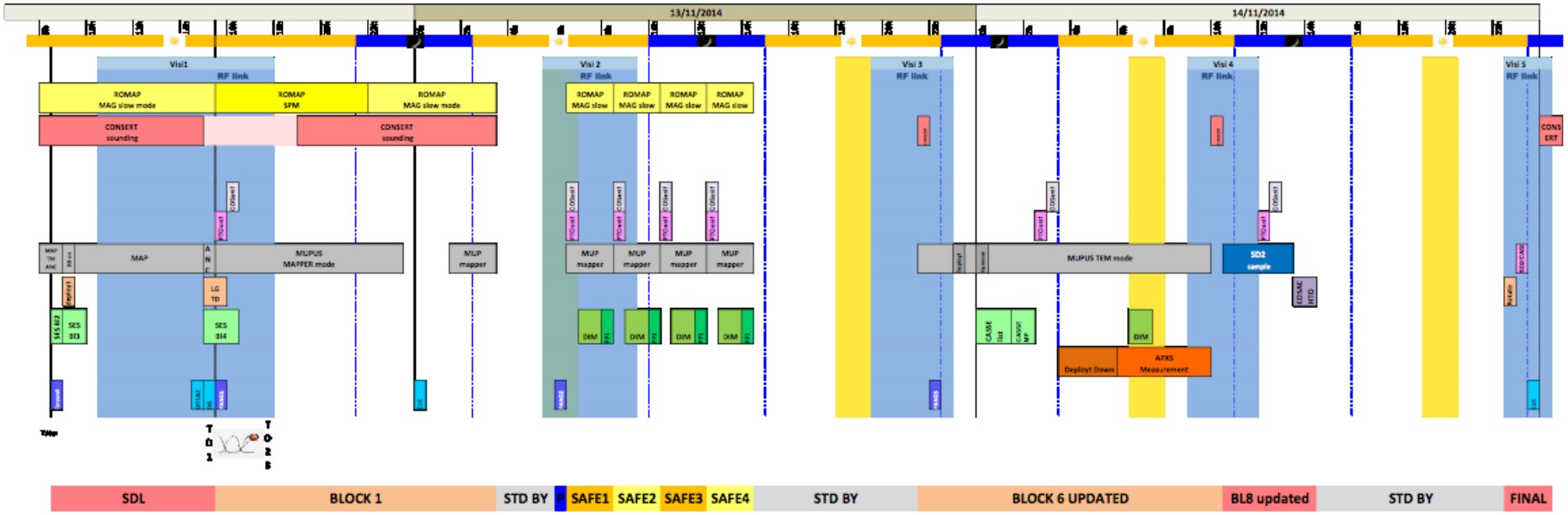
1. Drill to the position 250 mm
2. Extract the sampling tube and rotate to perform a coring
3. Translate back to home position
4. Rotate Carousel to move the desired oven under the drill
5. Discharge the sample into the oven
6. Rotate Carousel to move the oven with its sampl under **COSAC**
7. Rearm the drill bit before the next drilling and sampling activity



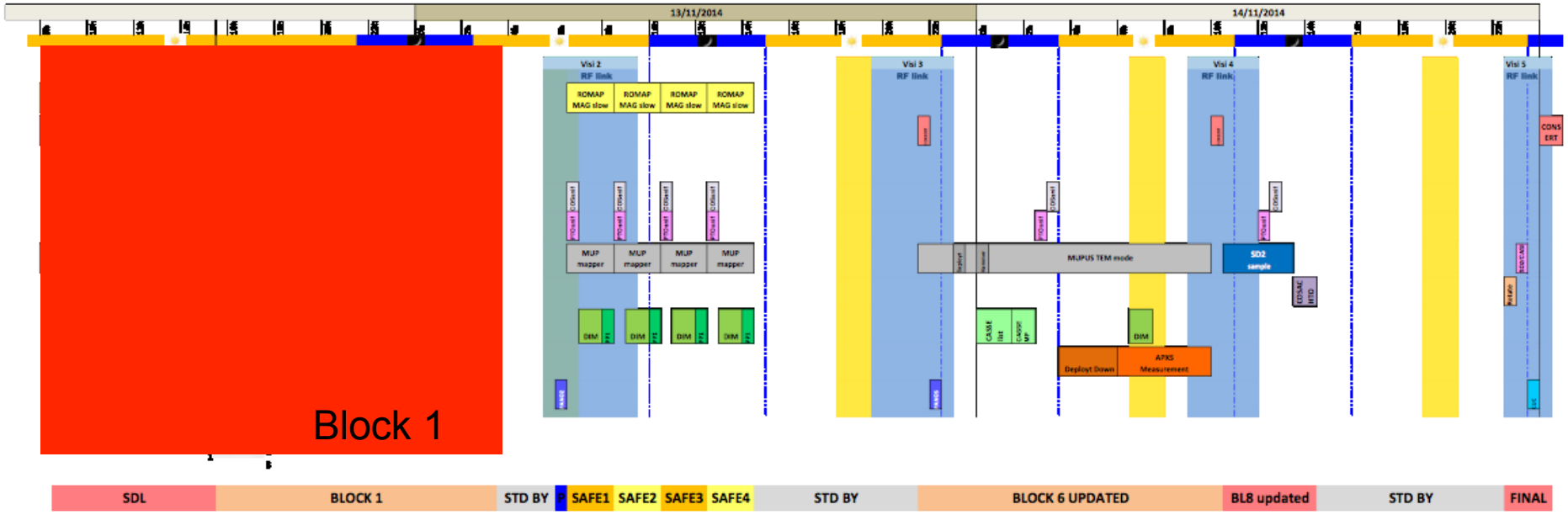




Final sequence of operations

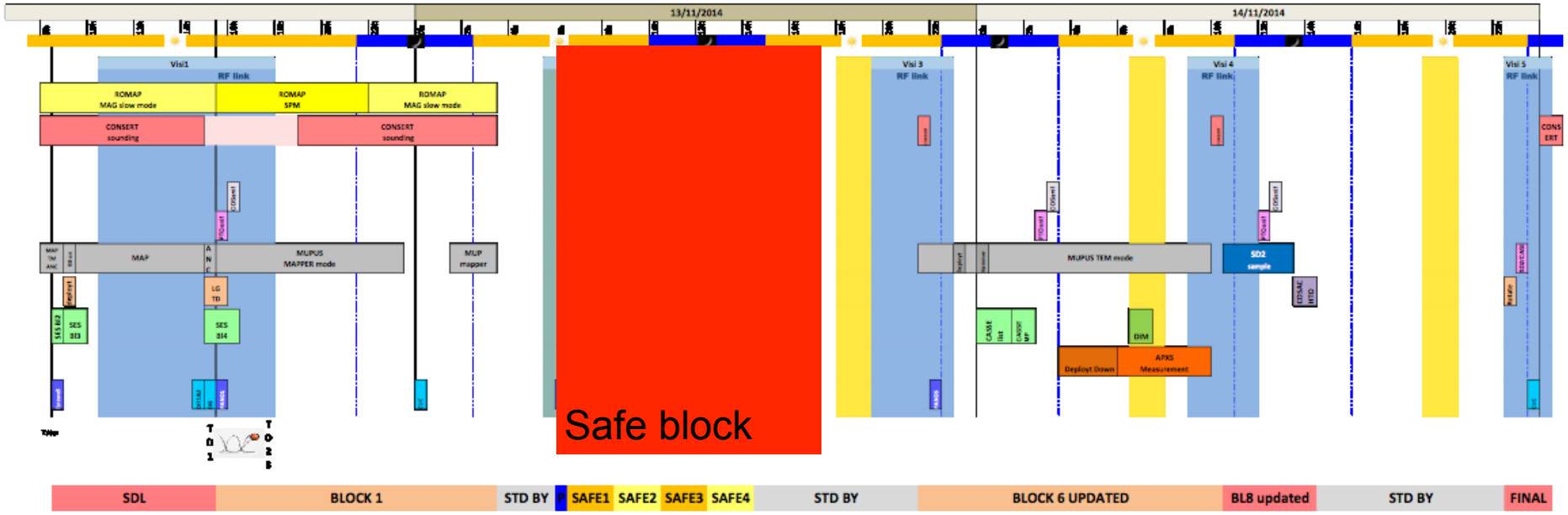


Final sequence of operations



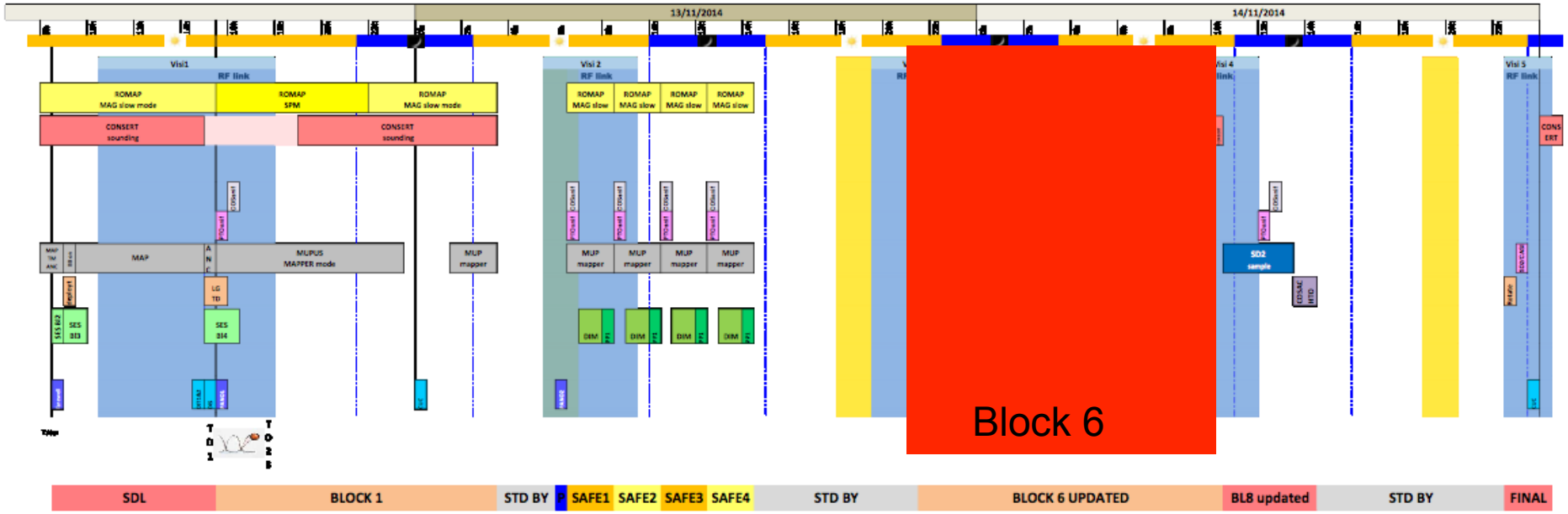
- No mechanical movements
  - ROMAP: Magnetometer
  - CONSERT: Sounding Experiment by Radiowave Transmission
  - MUPUS: temperature mapping

Final sequence of operations



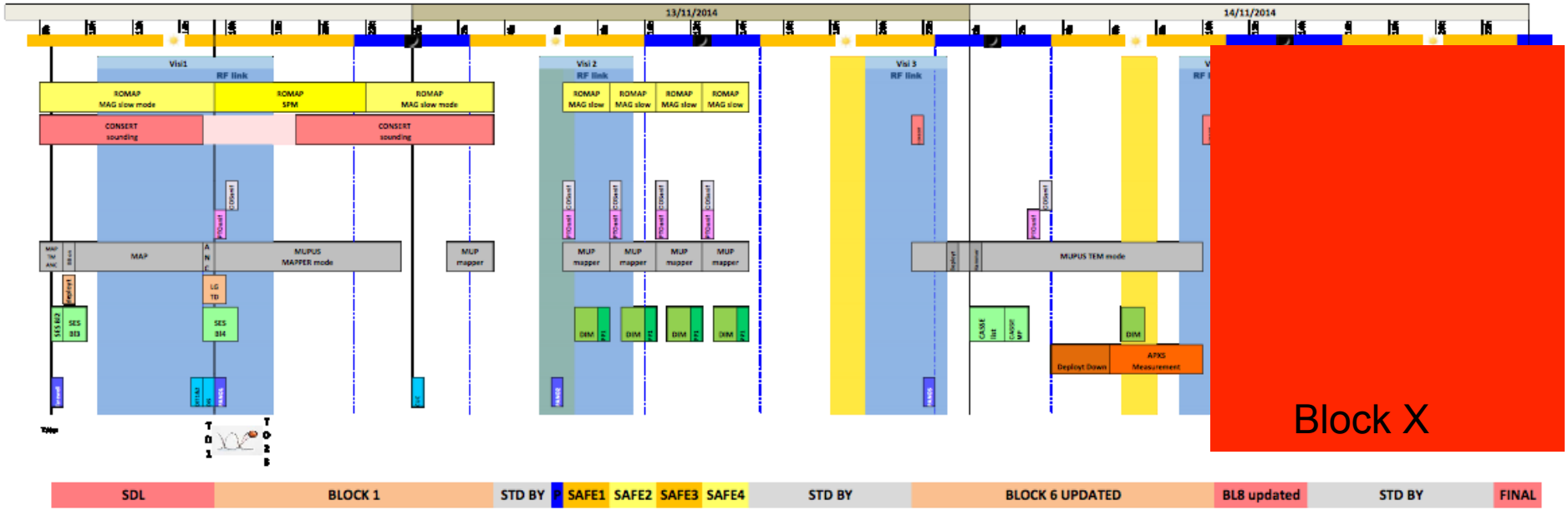
- No mechanical movements
  - ROMAP: magnetometer
  - MUPUS: temperature mapping
  - SESAME-DIM: dust impacts monitor
  - COSAC and PTOLEMY sniffing

Final sequence of operations



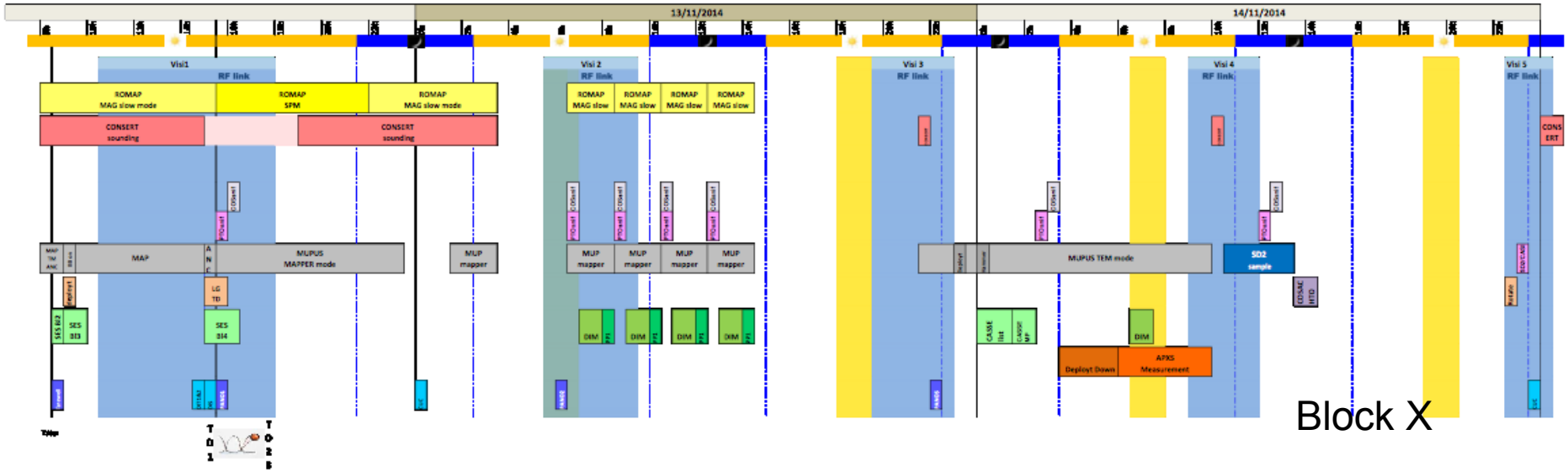
- Mechanical movements
  - MUPUS: hammering mode to measure compressive strength
  - APXS: Alpha proton X-ray spectrometer to measure composition
  - SESAME-CASSE: sounding experiment (seismograph and sonar)

Final sequence of operations

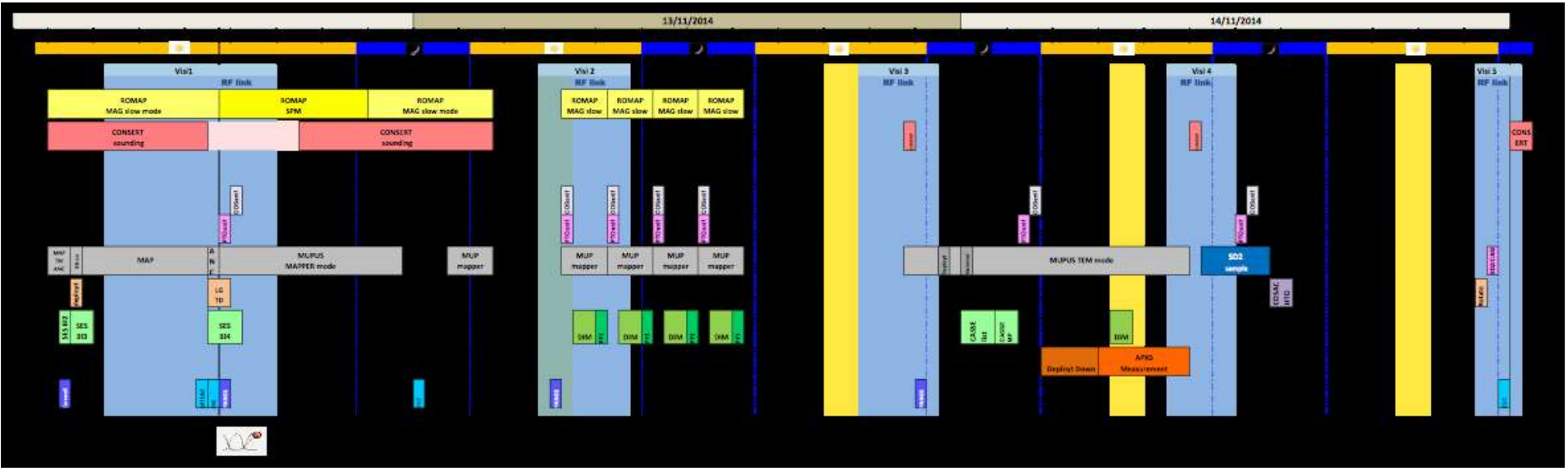


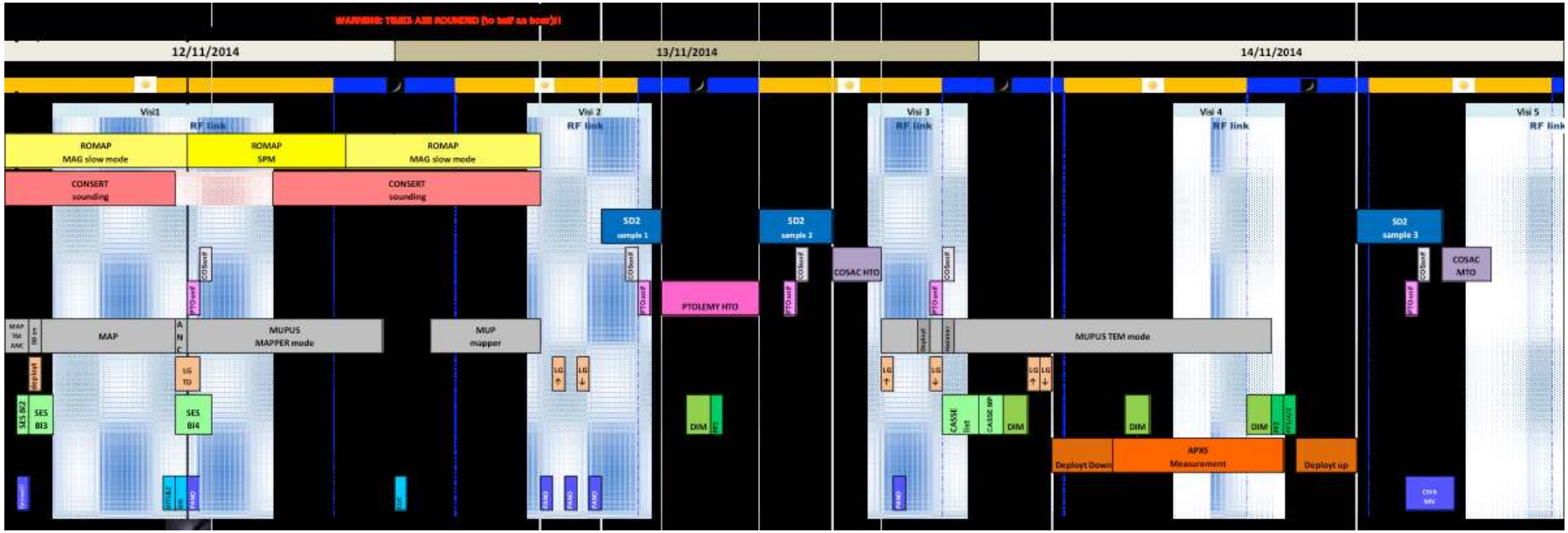
- Mechanical movements
  - SD2: drilling and sample collection
  - COSAC: sample analysis
  - Lander rotation to increase power production
  - PTOLEMY: sniffing of the Carbosphere oven
  - ROLIS: image of the soil after lander rotation
  - CONCERT: sounding experiment by radiowave transmission

Communications with Philae



Actual and planned operations





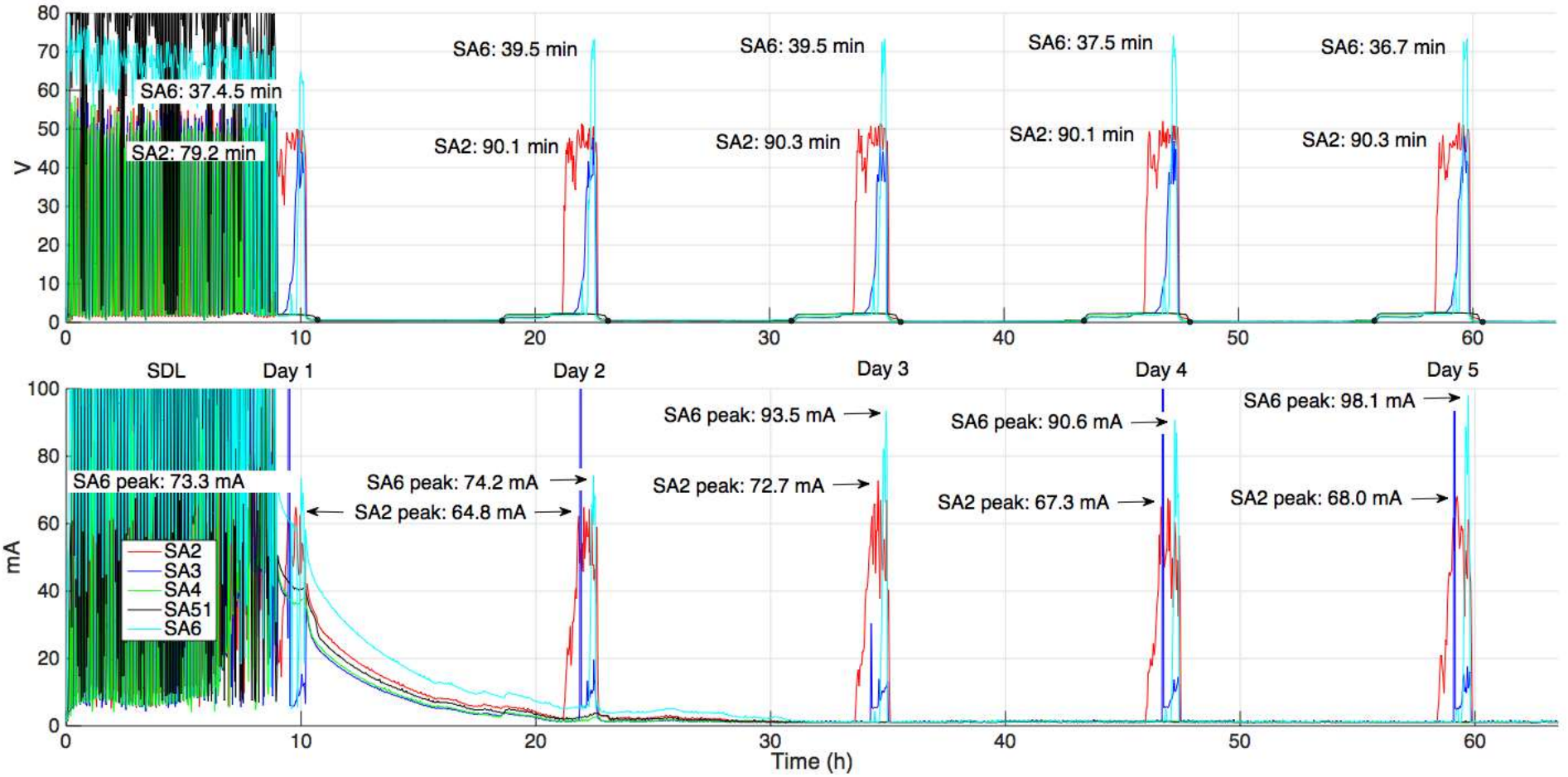
The end of the first science sequence

Increase of scientific activity

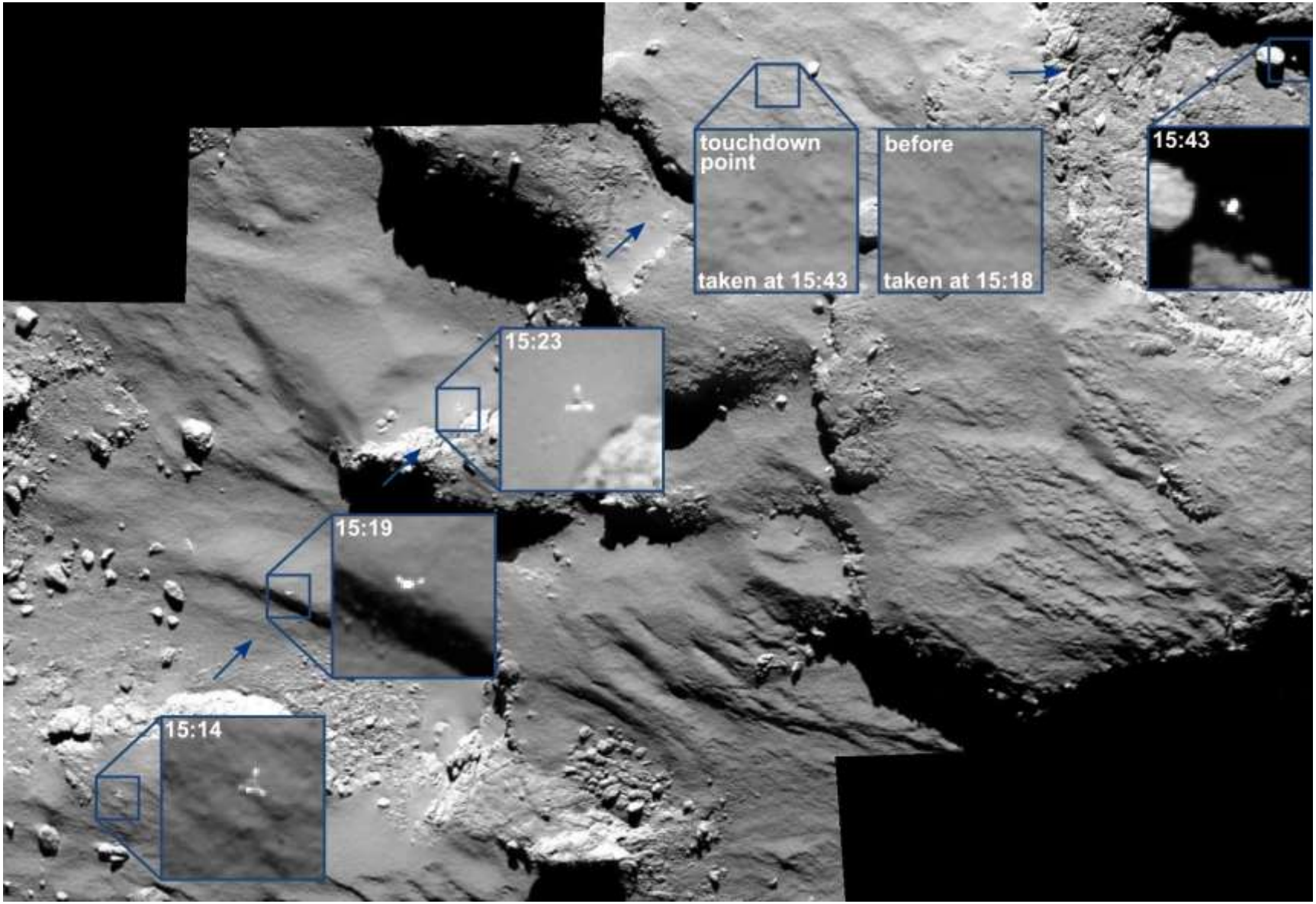
Decrease of energy stored in the battery

November 14, 2014

5 cometary days



But where is Philae?



The staff behind Philae


JRehling
@JRehling
Follow
Fox: "Why did America waste money landing on a comet?"
Scientist: "This is a European mission."
Fox: "Why didn't America get there first?"