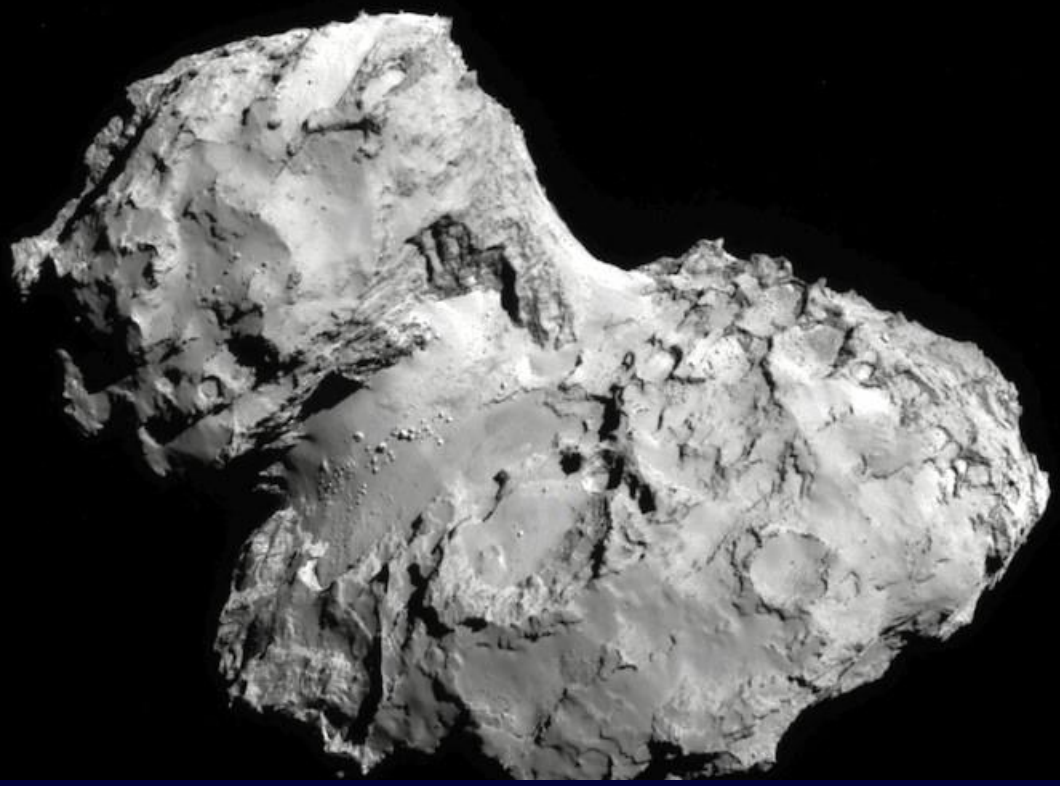
Rosetta

Ako sme pristáli na kométe...



NASA, Apollo 8

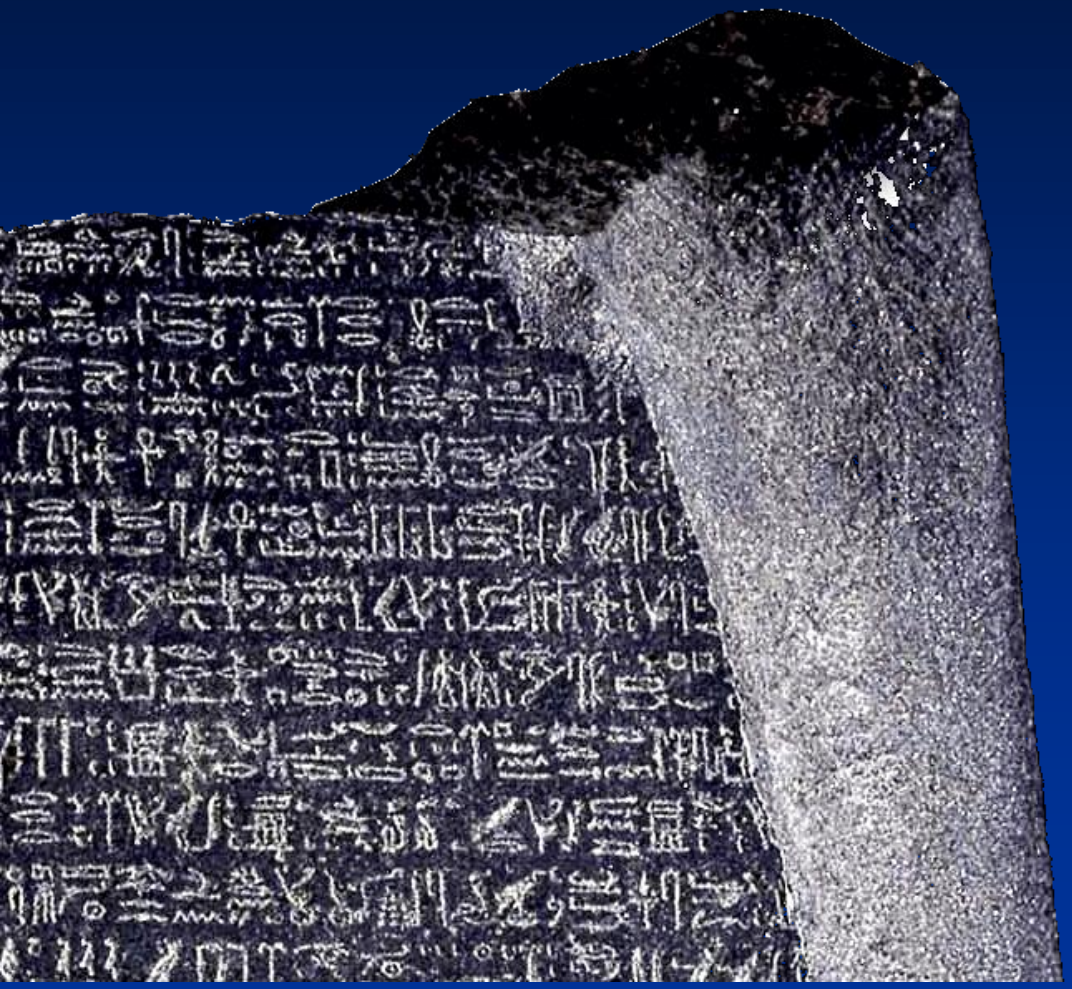
- *Čo sú kométy a odkiaľ prichádzajú ?*
- *Prečo sa sonda volá Rosetta ?*
- *Prečo sme pristáli na kométe ?*

1577

1680

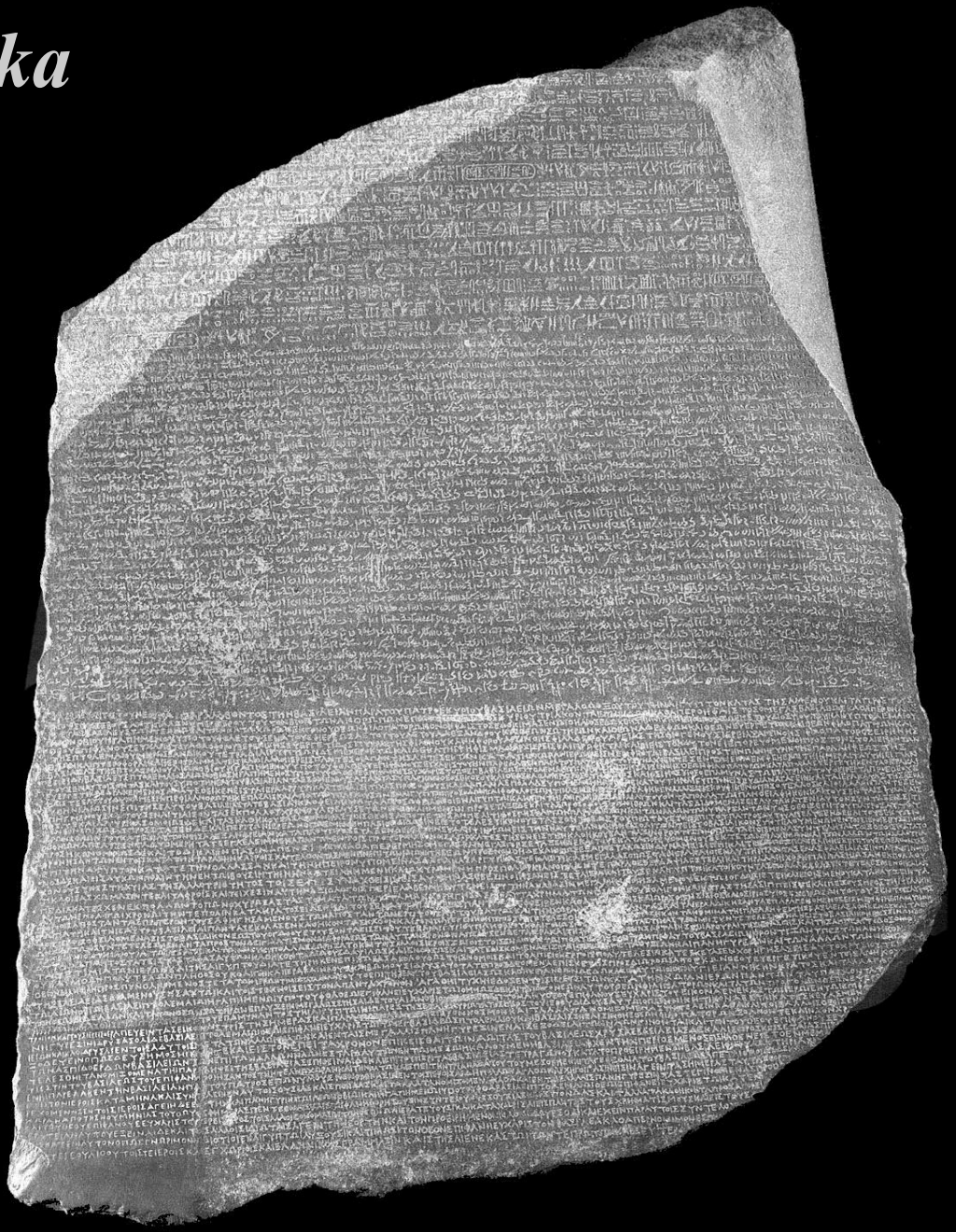
Prečo Rosetta ?

Rosettská doska, nájdená v r. 1799, pomohla rozlúštiť egyptské hieroglyfy, čím poodhalila dejiny našej civilizácie o tisícročia dozadu.



Sonda Rosetta odhaľuje dejiny Slnečnej sústavy a tajomstvá jej vzniku pred 4.6 miliardami rokov – a to najmä analýzou „primitívnej“ kometárnej hmoty, ktorá sa od tých čias nezmenila.

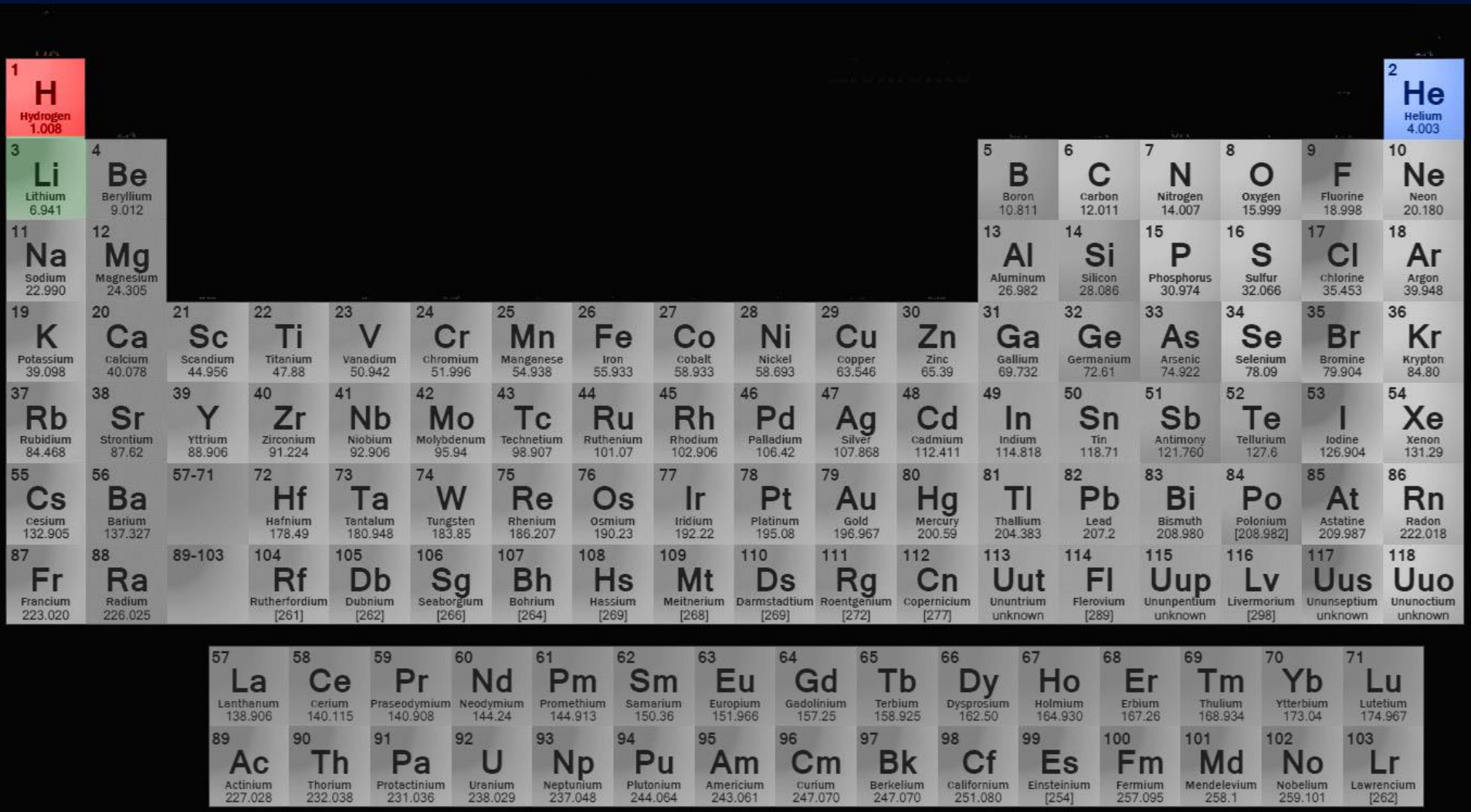
osettská doska



Veľký tresk (Big Bang) *pred 13,8 miliardami rokov*

...o 350 000 rokov neskôr ...

Chemické prvky po Big Bangu



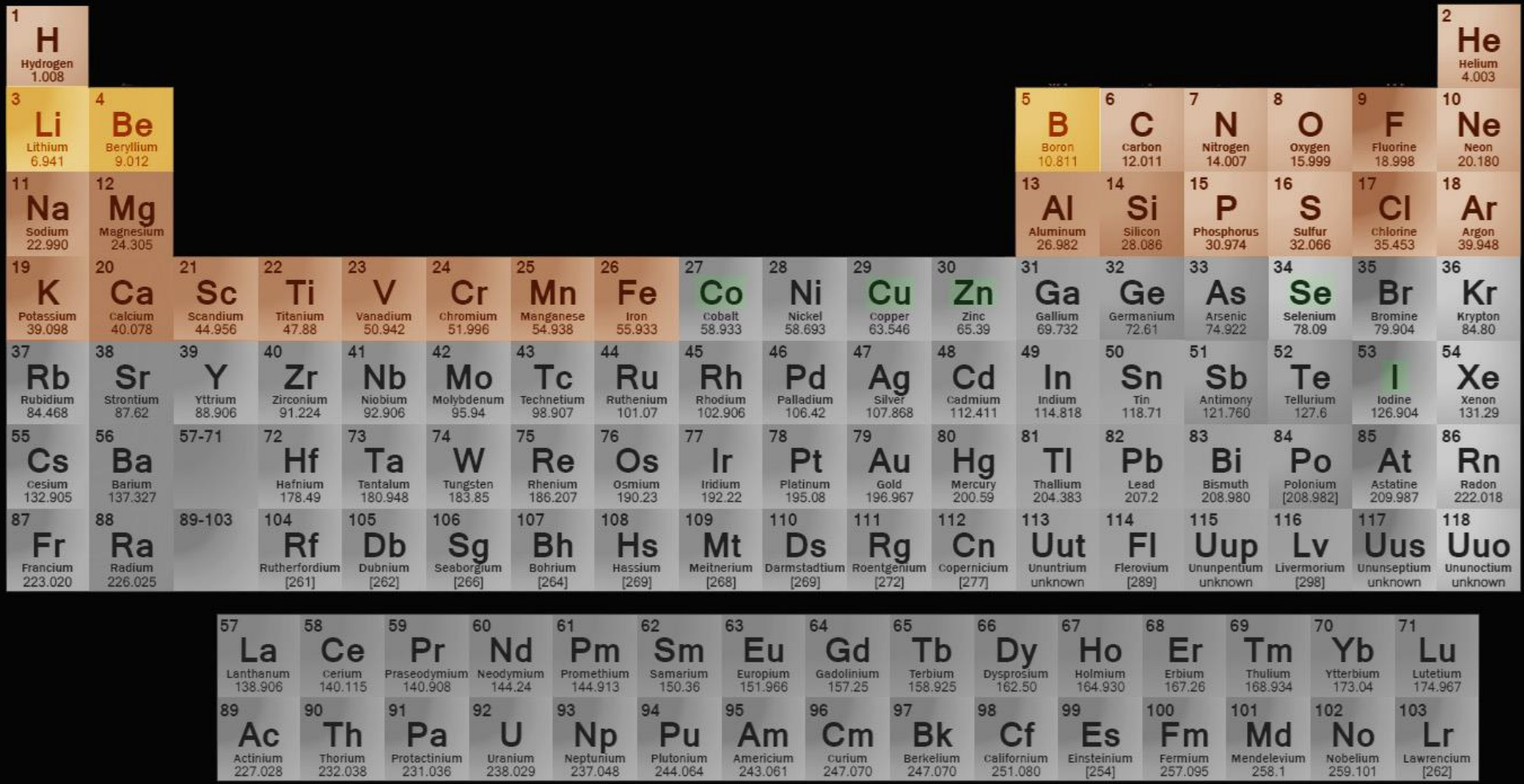
Vodík: plyn bez farby a zápachu, ktorý

– ak má dosť času –

premení sa na ľudí...

Prvé hviezdy (~ 100 000 000 rokov po Big Bangu)

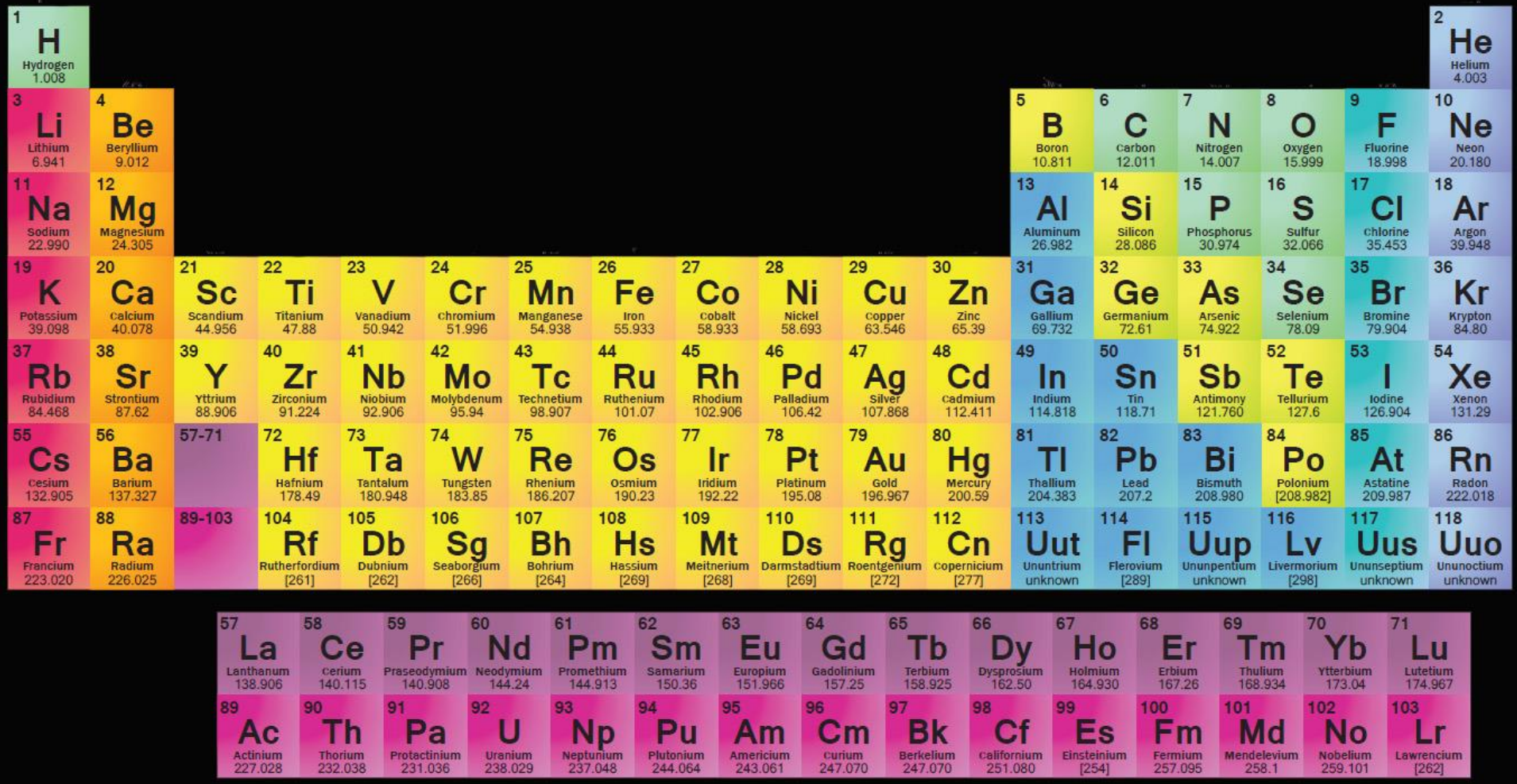
Chémia štandardných hviezd



Supernova

Krabia hmlovina dnes
(výbuch supernovy bol v r. 1054)

Chémia supernovy



„Piliere stvorenia“(Eagle Nebula)

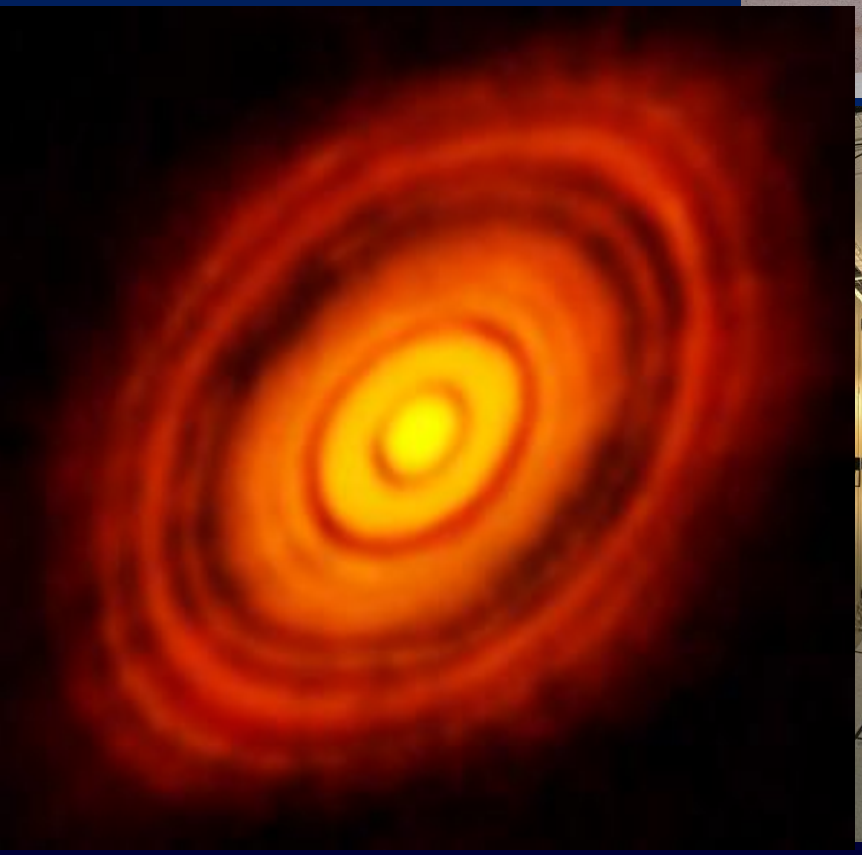
Od proto-solárnej nebuly k dnešnej Slnečnej sústave

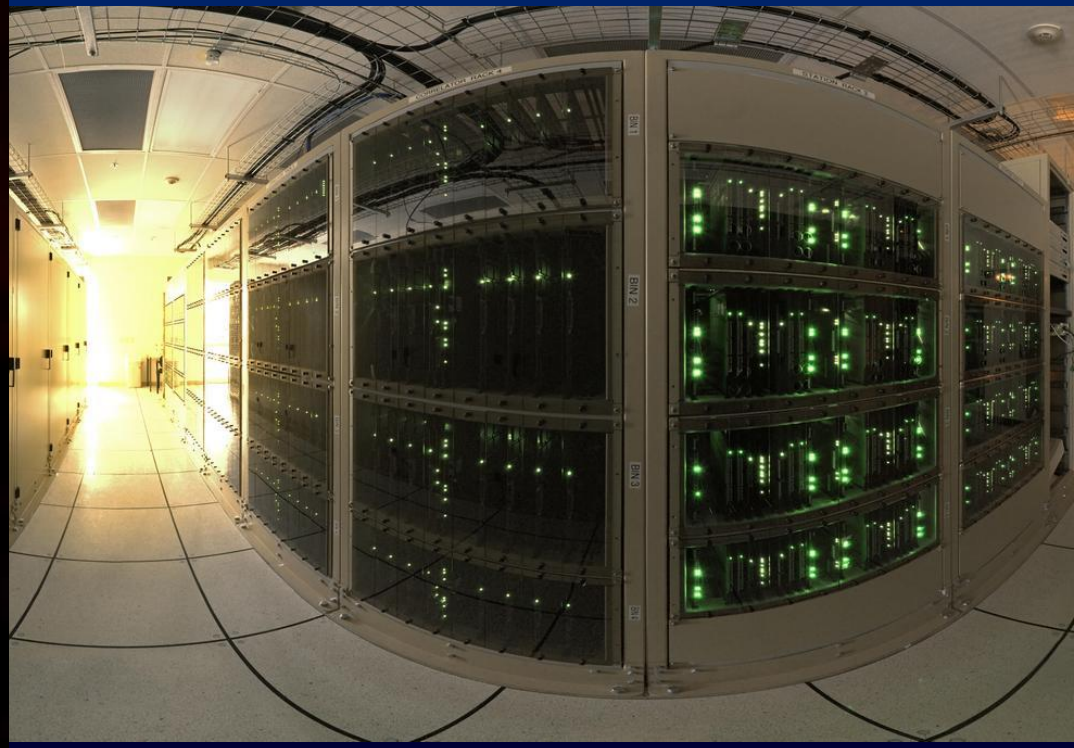
Kometárny materiál je unikátnou pokladnicou cenných informácií o zložení proto-solárnej nebuly z ktorej sa vyvinula Slnečná sústava.

ALMA

(Atacama Large Millimeter Array - Chile)

Protoplanetárny Disk
HL Tauri (450 ly)
5.11.2014



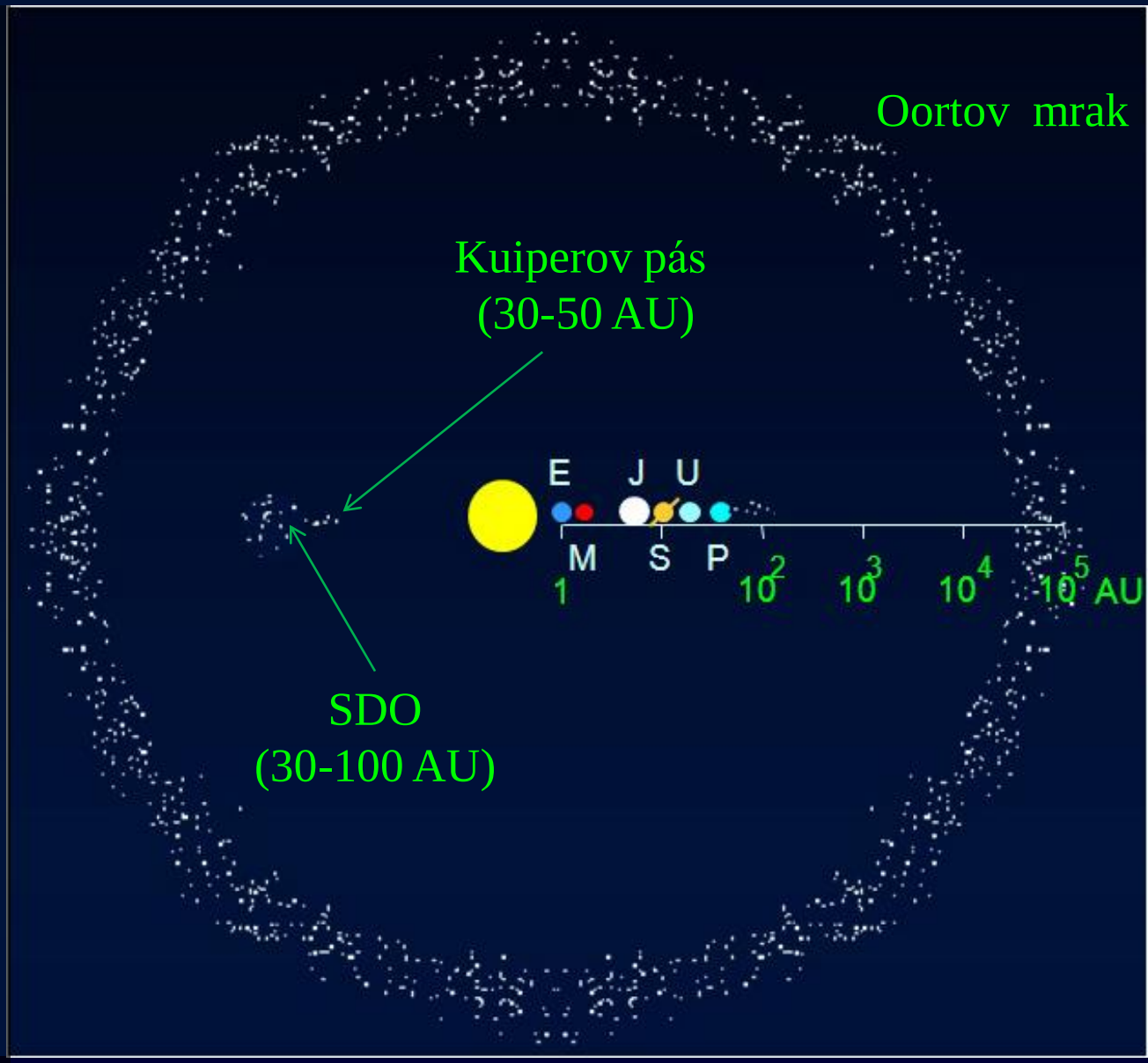


Odkiaľ prichádzajú kométy...

Krátkoperiodické z relatívne bližšieho Kuiperovho pásu (30-50AU) a Rozptýleného disku SDO (30-100 AU).

Dlhoperiodické a neperiodické z Oortovho mraku (~ 10^5 AU) .

Vďaka hlboko zmrazenému stavu (5 - 20 K) ich materiál pretrváva v (takmer) nezmenenom stave od čias protosolárneho disku.



Cieľ Rosetty: Kométa 67P-Čurjumov-Gerasimenko

1975

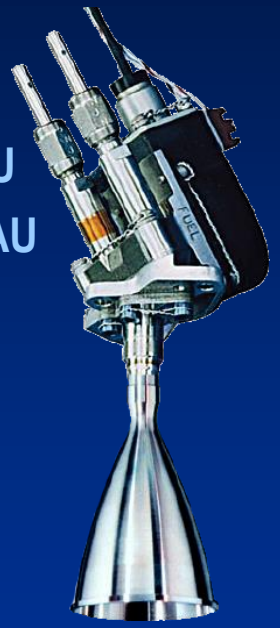
Rozmery jadra (odhad): ~ 4 km
Doba rotácie okolo vlastnej osi: 12,3 hodín
Obežná doba okolo Slnka: 6.57 roka
Perihélium : 194 mil. km (1.29 AU)
Afélium : 858 miliónov km (5.74 AU)
Albedo: 0,04
Rok objavu: 1969
Objavitelia: Klim Čurjumov
Svetlana Gerasimenko (UA)

2004

Základné technické údaje sondy Rosetta

Rozmery:

hlavná štruktúra	2.8 x 2.1 x 2.0 m
rozpätie sol. panelov	32 m
plocha sol.panelov	64 m^2
výkon sol. panelov	8700 W - 1AU
	850 W - 3.4 AU
	395 W - 5.25 AU



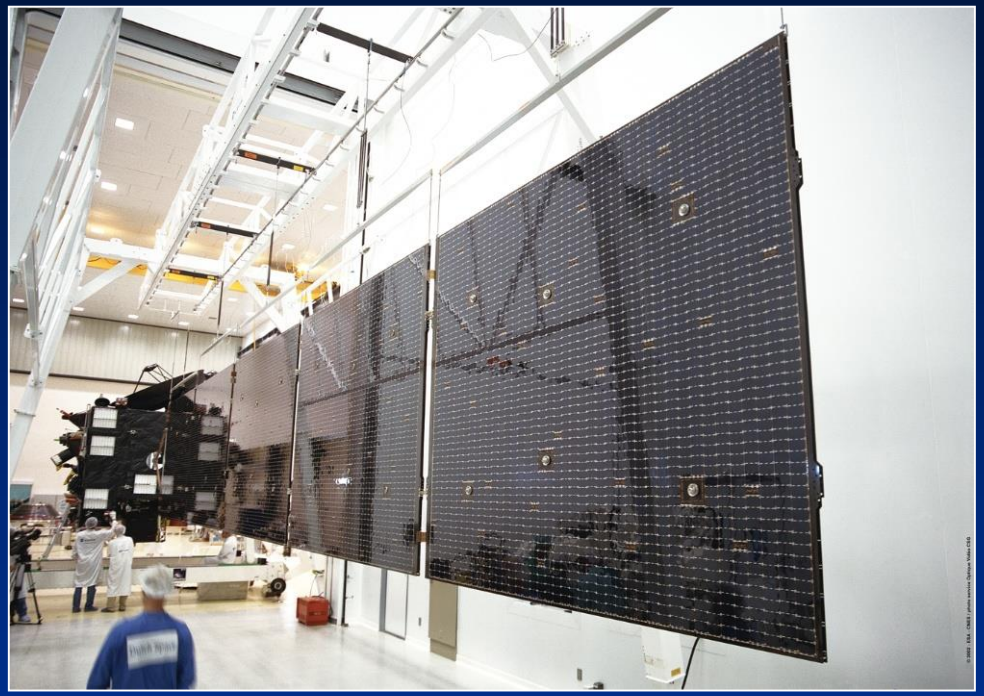
Hmotnosť pri štarte:

celková:	2900 kg
palivo	1720 kg
vedecký náklad	165 kg
Lander Philae	100 kg

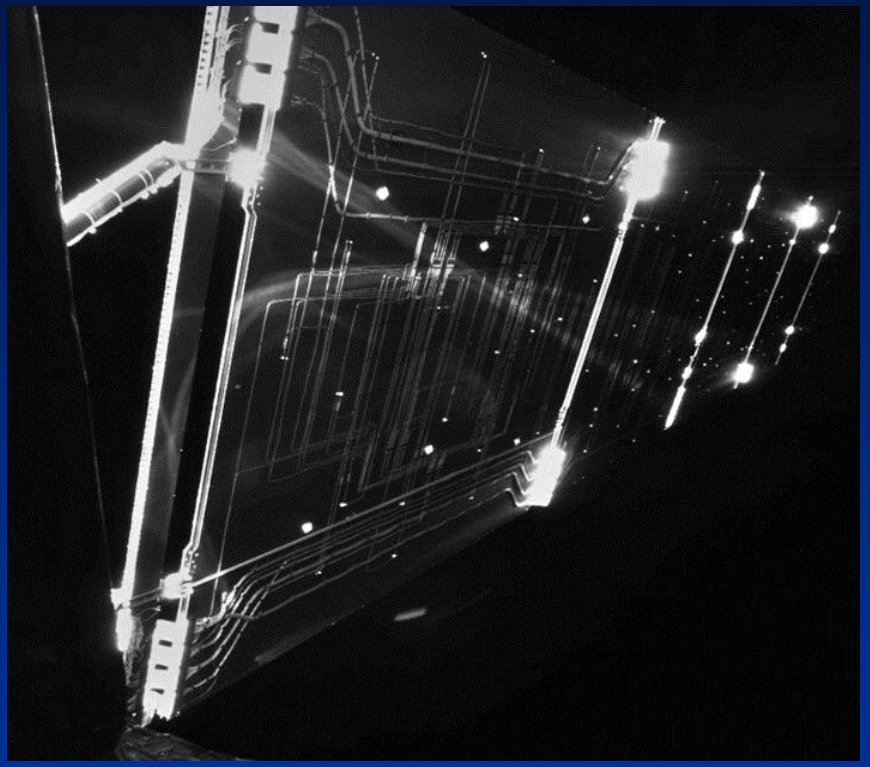
Propulzný systém: 24 thrusterov 10N
palivo MMH + N_2O_4

Operačná doba: 12 rokov (2004-2016)

Solárne panely *(rozpätie 32m, plocha 64m^2)*

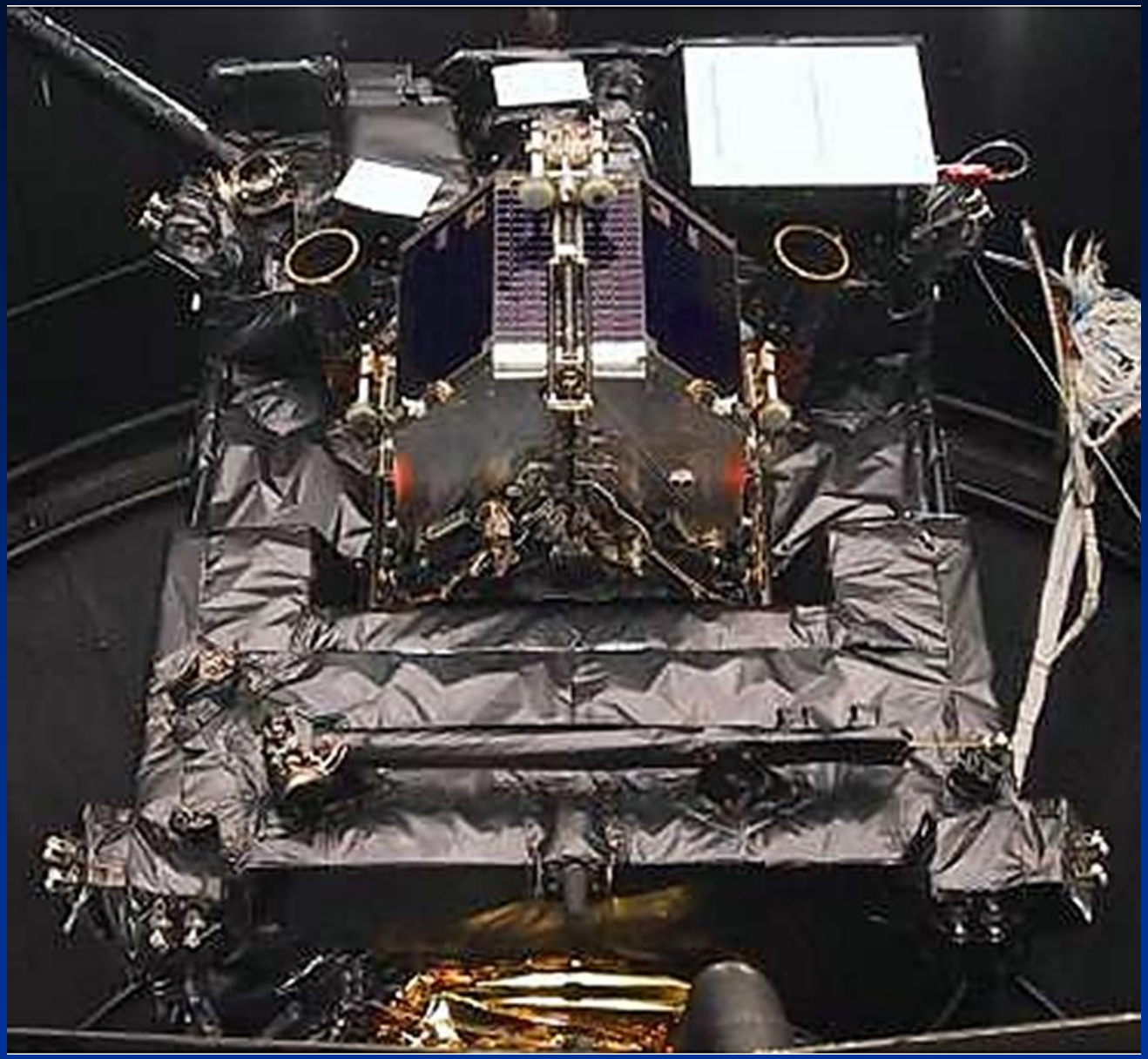


v **ESA-ESTEC**



za letu (CIVA-P)

ROSETTA a Philae v laboratóriách ESA-ESTEC

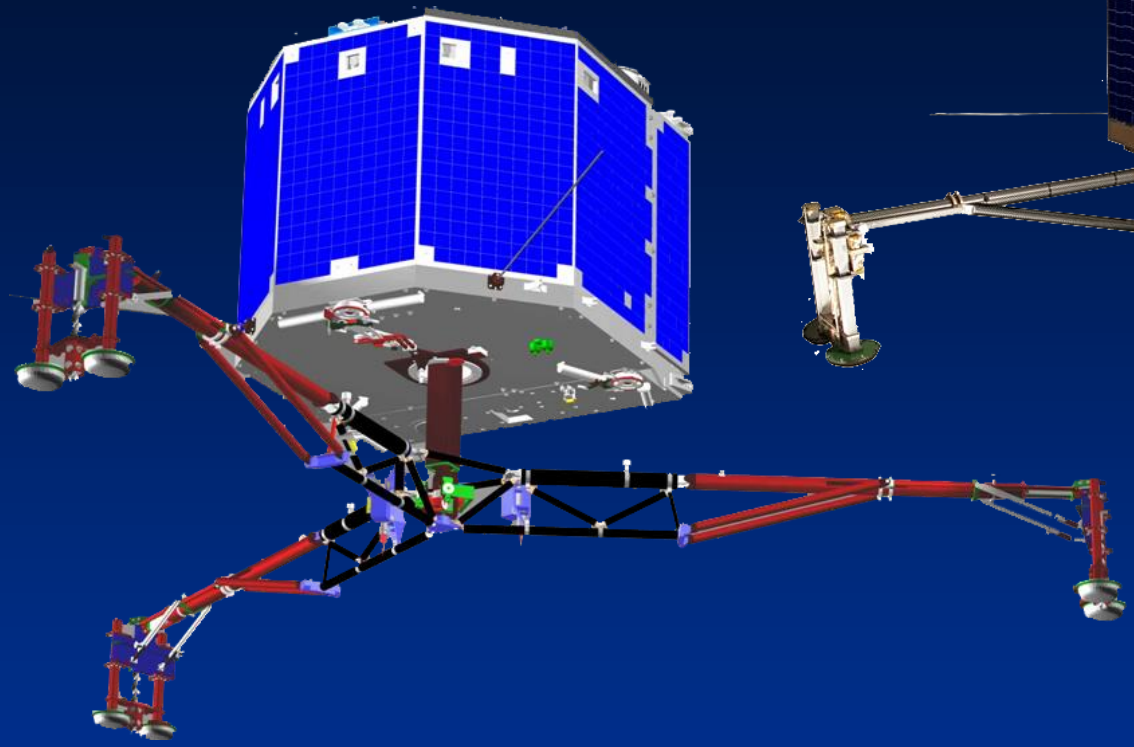


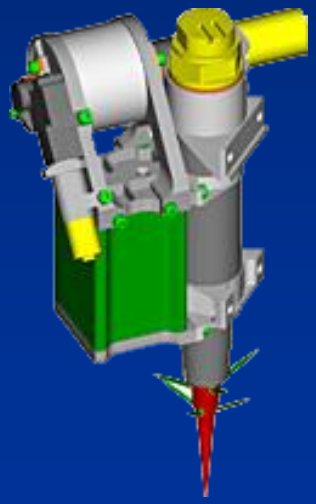
Sonda ROSETTA pozostáva z dvoch častí:

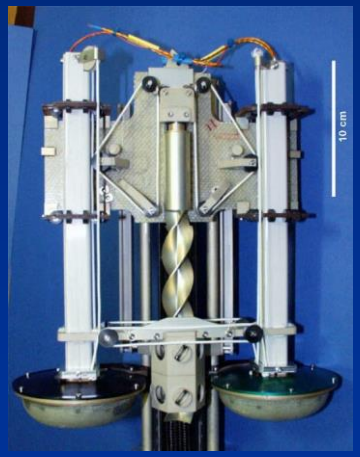
Orbiter – v súčasnosti na orbite v blízkosti kometárneho jadra,

Lander – pristál priamo na povrchu jadra.

Lander (Philae)

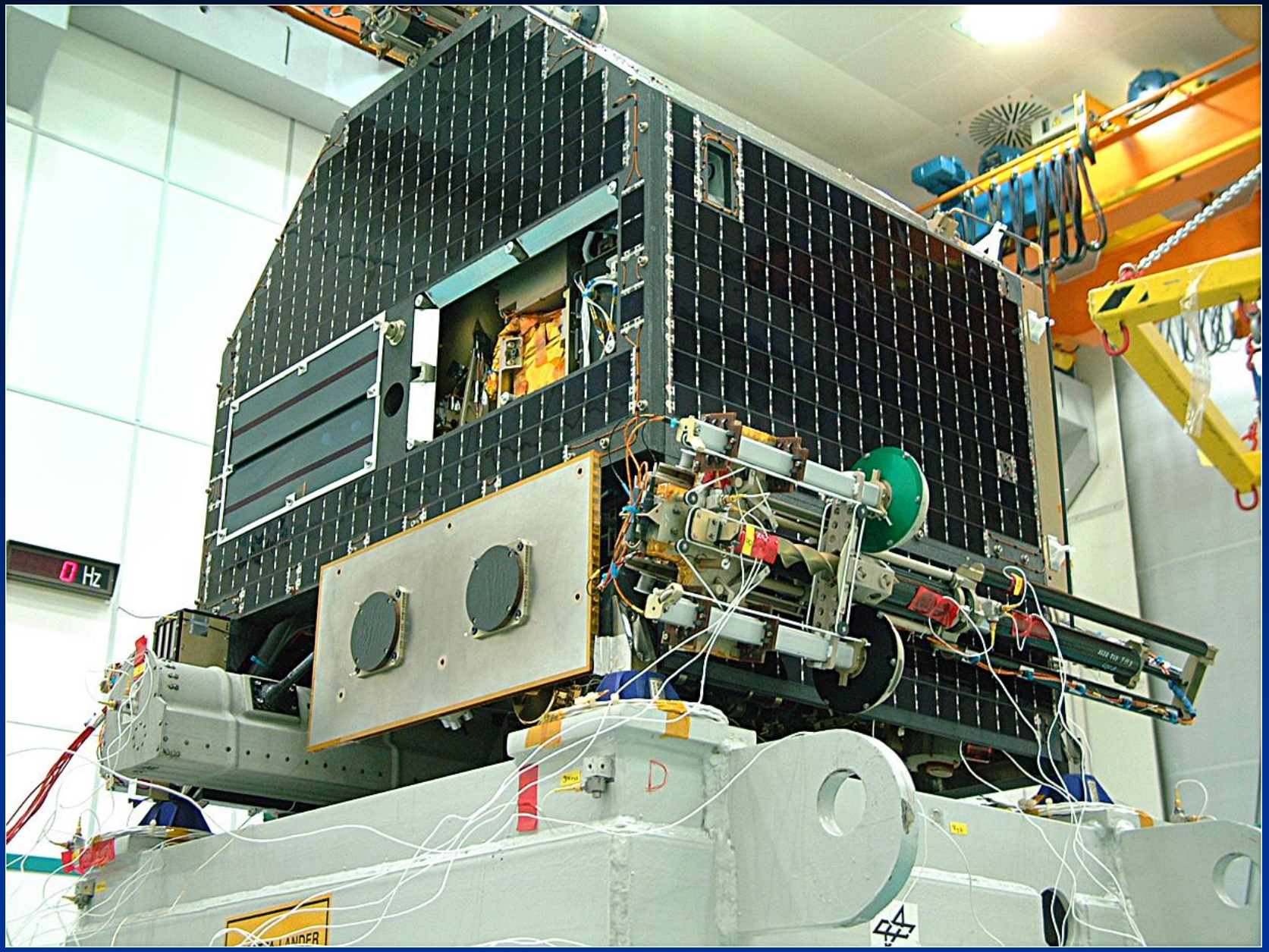




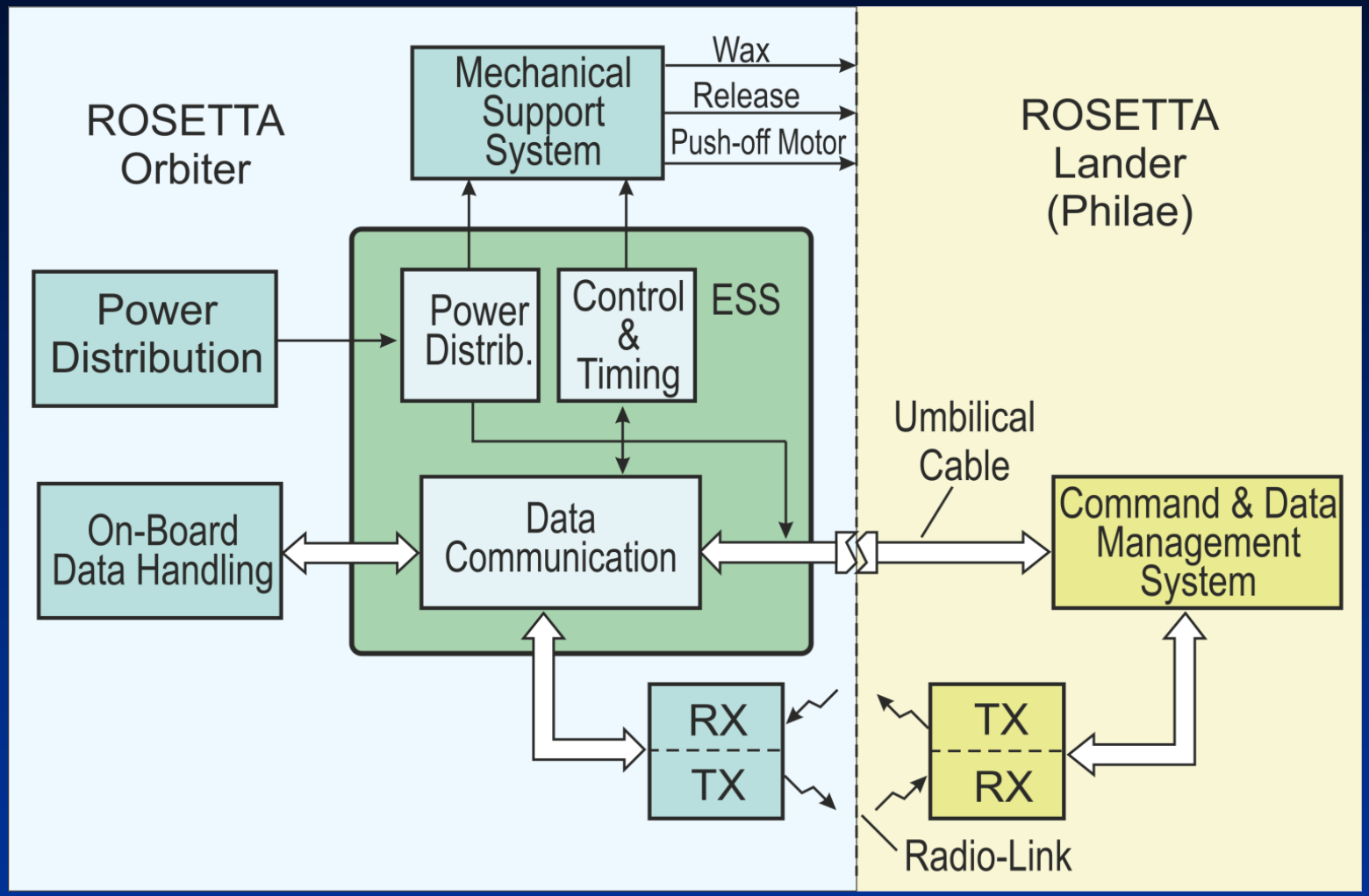


Hmotnosť: **100 kg**
Vypustenie z výšky: **ca 22 km**
Rýchlosť oddelenia: **0,05 – 0,52 m-s**
Odpruženie: **Trojnohý podvozok,**
Ukotvenie: **2 harpúny + 3 snežné skrutky,**
Korekcie náklonu, Rotácia 360°

Lander Philae - vibračné akceleračné testy

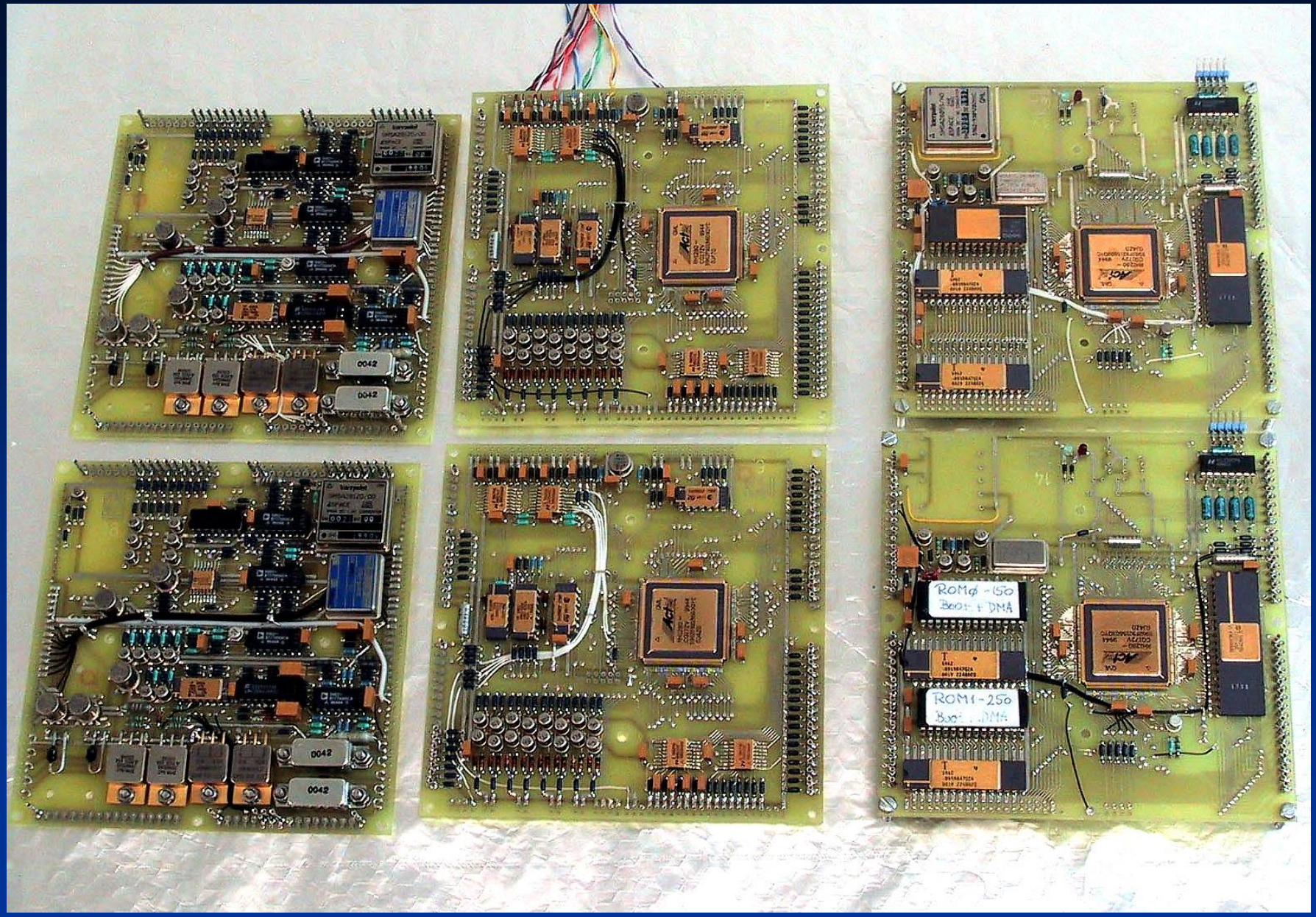


ESS-processor (Interface Orbiter – Lander)



ESS-processor zabezpečil oddelenie pristávacieho modulu Lander (Philae) od Orbitera a obojsmernú dátovú komunikáciu medzi nimi.

Z realizácie ESS-procesora (2000 - 2001)

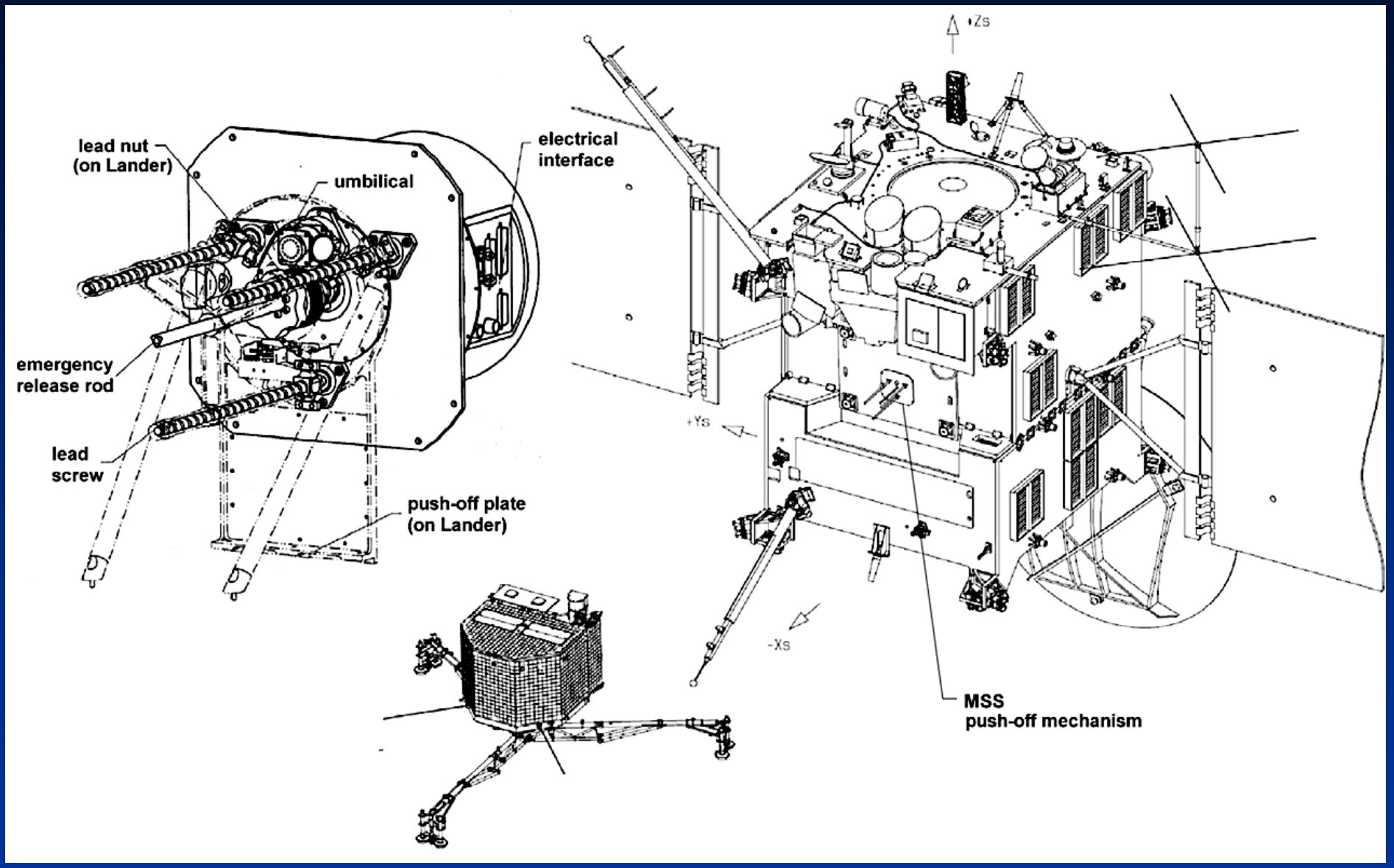


Záverečné práce na ESS procesore (STIL 2001)

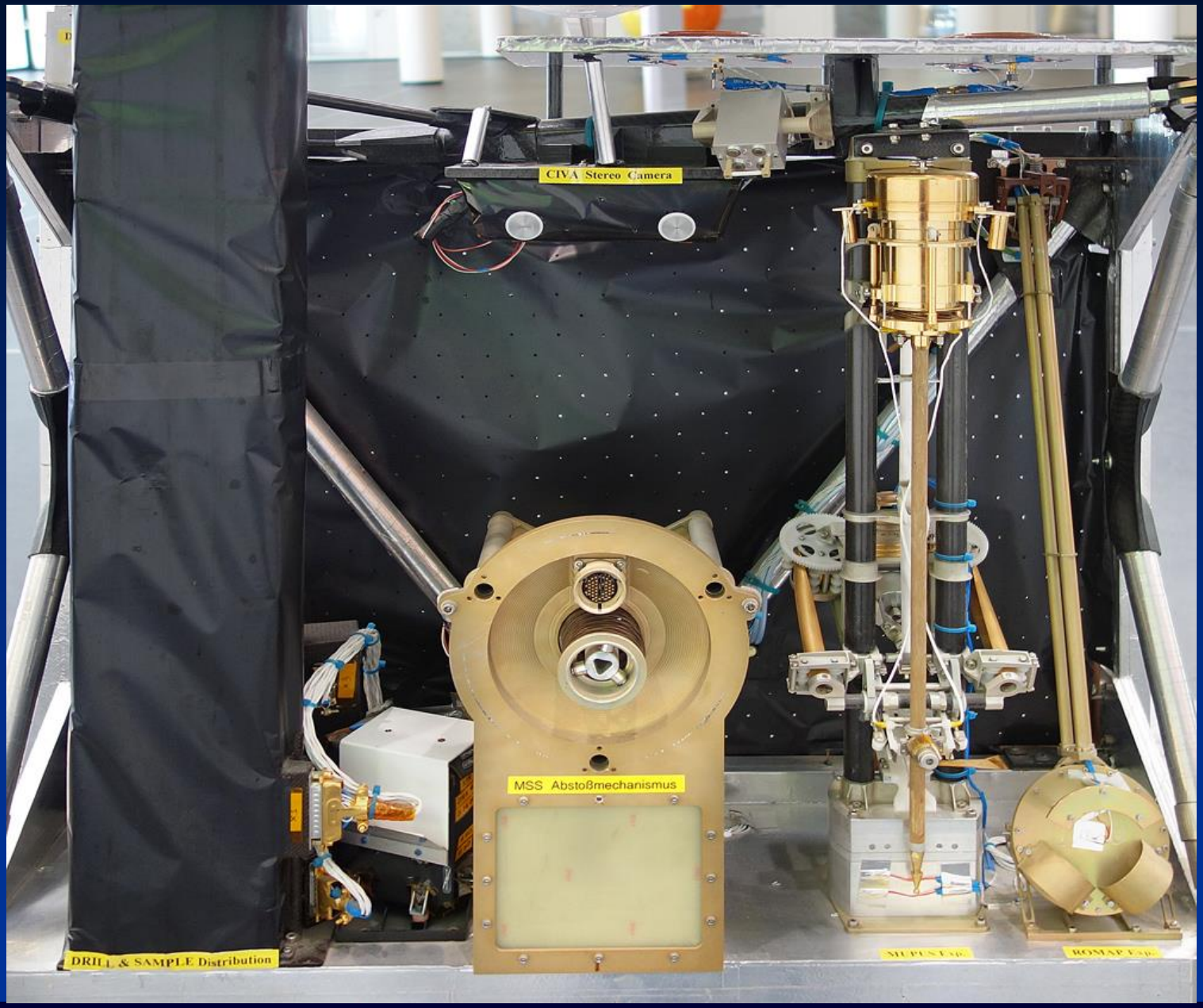
Záverečné práce na ESS procesore (STIL 2001)

Úplný ESS procesor – vibračné testy

Lander - oddeľovací mechanizmus (MSS)



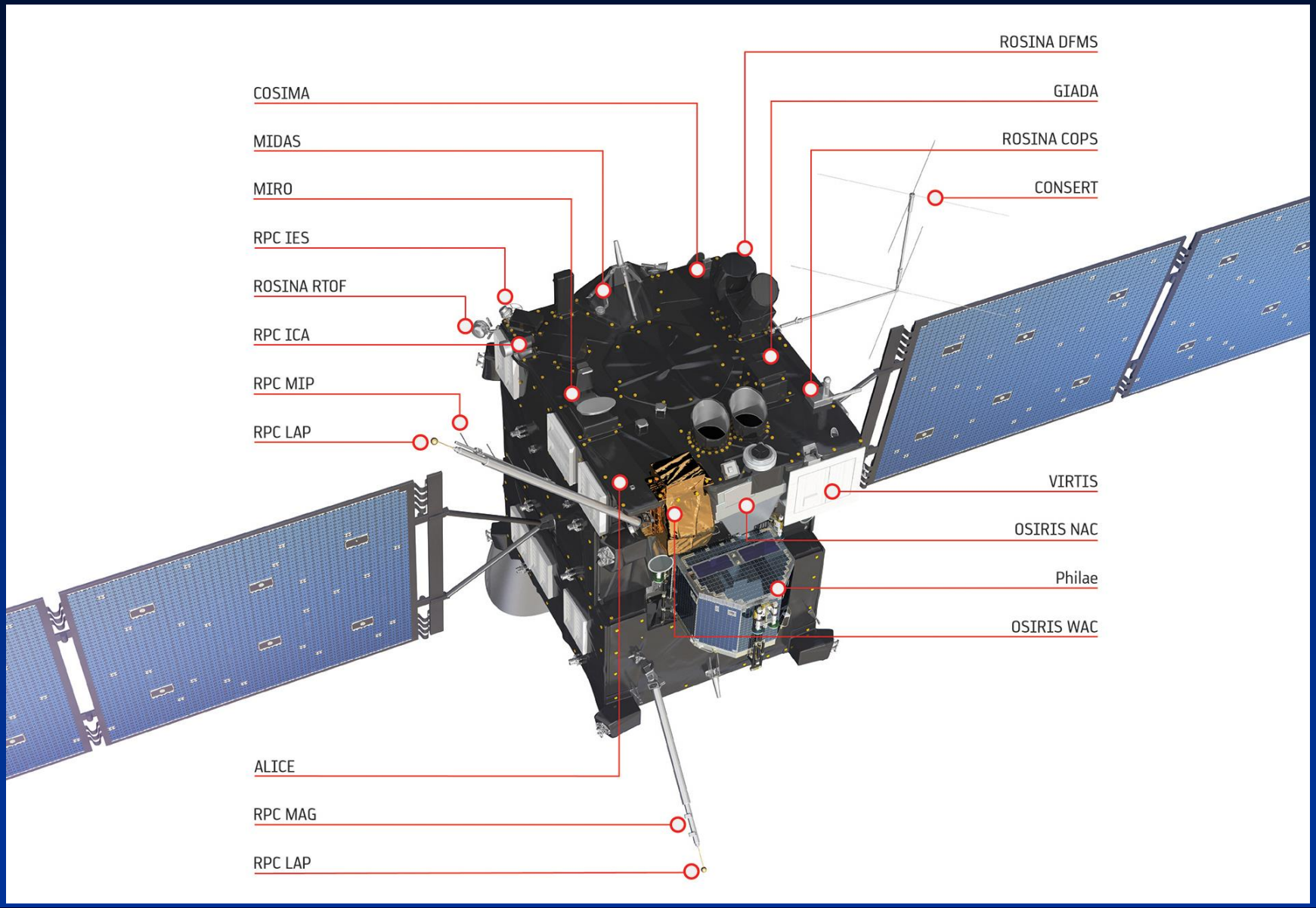
Lander - oddeľovací mechanizmus



Orbiter – Vedecký náklad (payload)

1. **ALICE** Ultraviolet Imaging Spectrometer
2. **CONSERT** Comet Nucleus Sounding Experim. by Radio Transmission
3. **COSIMA** Cometary Secondary Ion Mass Analyser
4. **GIADA** Grain Impact Analyser and Dust Accumulator
5. **MIDAS** Micro-Imaging Dust Analysis System
6. **MIRO** Microwave Instrument for the Rosetta Orbiter
7. **OSIRIS** Rosetta Orbiter Imaging System
8. **ROSINA** Rosetta Orbiter Spectrometer for Ion and Neutral Analysis
9. **RPC** Rosetta Plasma Consortium
10. **RSI** Radio Science Investigation
11. **VIRTIS** Visible and Infrared Mapping Spectrometer

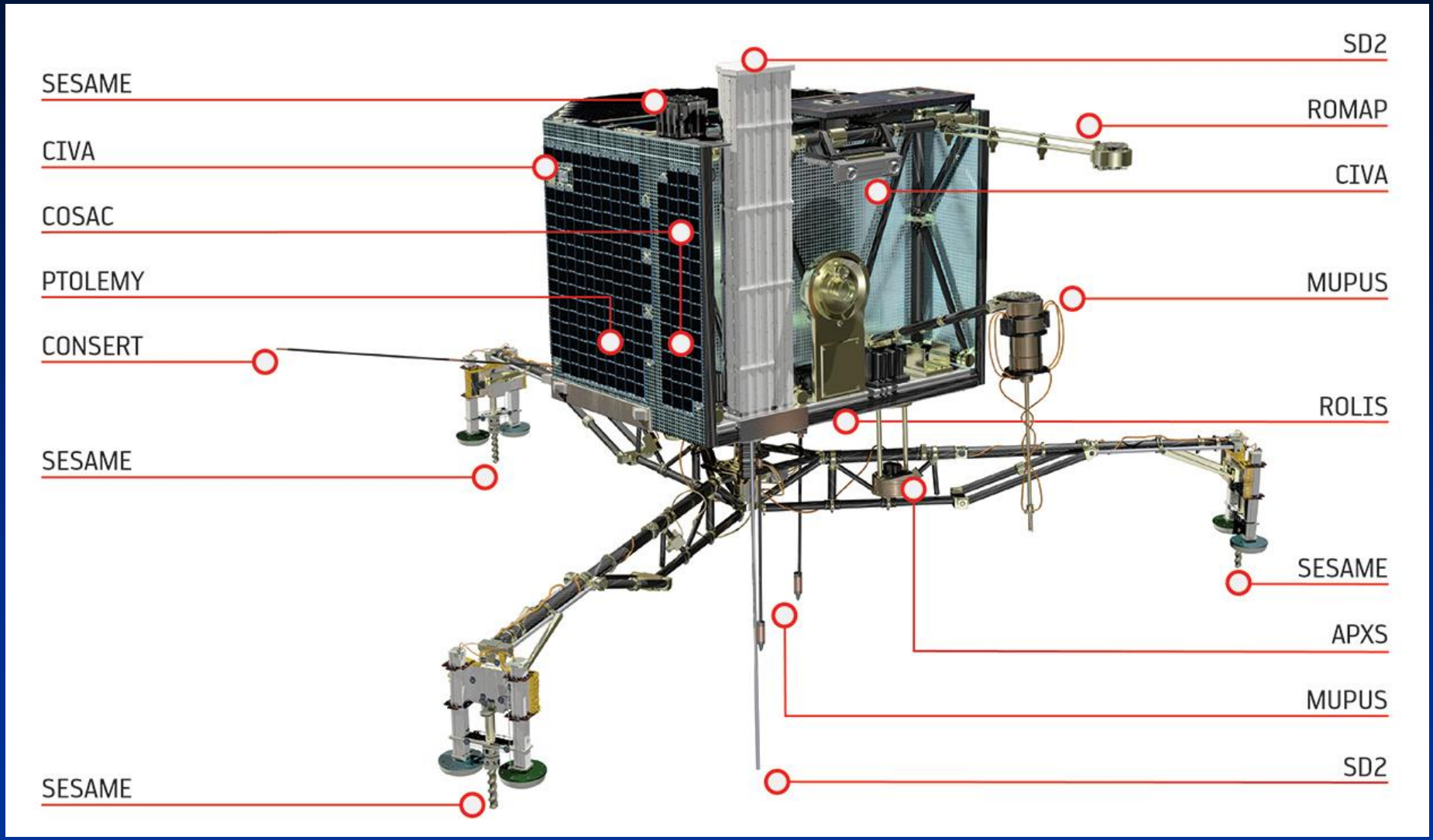
Orbiter – rozmiestnenie vedeckého nákladu



Lander Philae - Vedecký náklad

1. **APXS** Alpha-X-ray spektrometer
2. **ÇIVA** Panoramatická a mikroskopické stereo-kamery
3. **CONSERT** Rádiová tomografia jadra (s CONSERT – orbiter)
4. **COSAC** Analyzátor plynov - prvková a molekulárna analýza (chiral.)
5. **PTOLEMY** Analyzátor plynov - izotopová analýza
6. **MUPUS** Meranie podpovrchových vlastností (penetrátor)
7. **ROLIS** „Down looking camera“ – detailné snímkovanie povrchu
8. **ROMAP** Magnetometer a plazmový monitor
9. **SD2** Vŕtací systém a transport vzoriek na analýzu
10. **SESAME** Seizmický, elektrický, akustický a prachový monitoring

Lander - rozmiestnenie vedeckého nákladu



Hlavné vedecké ciele Rosetty :

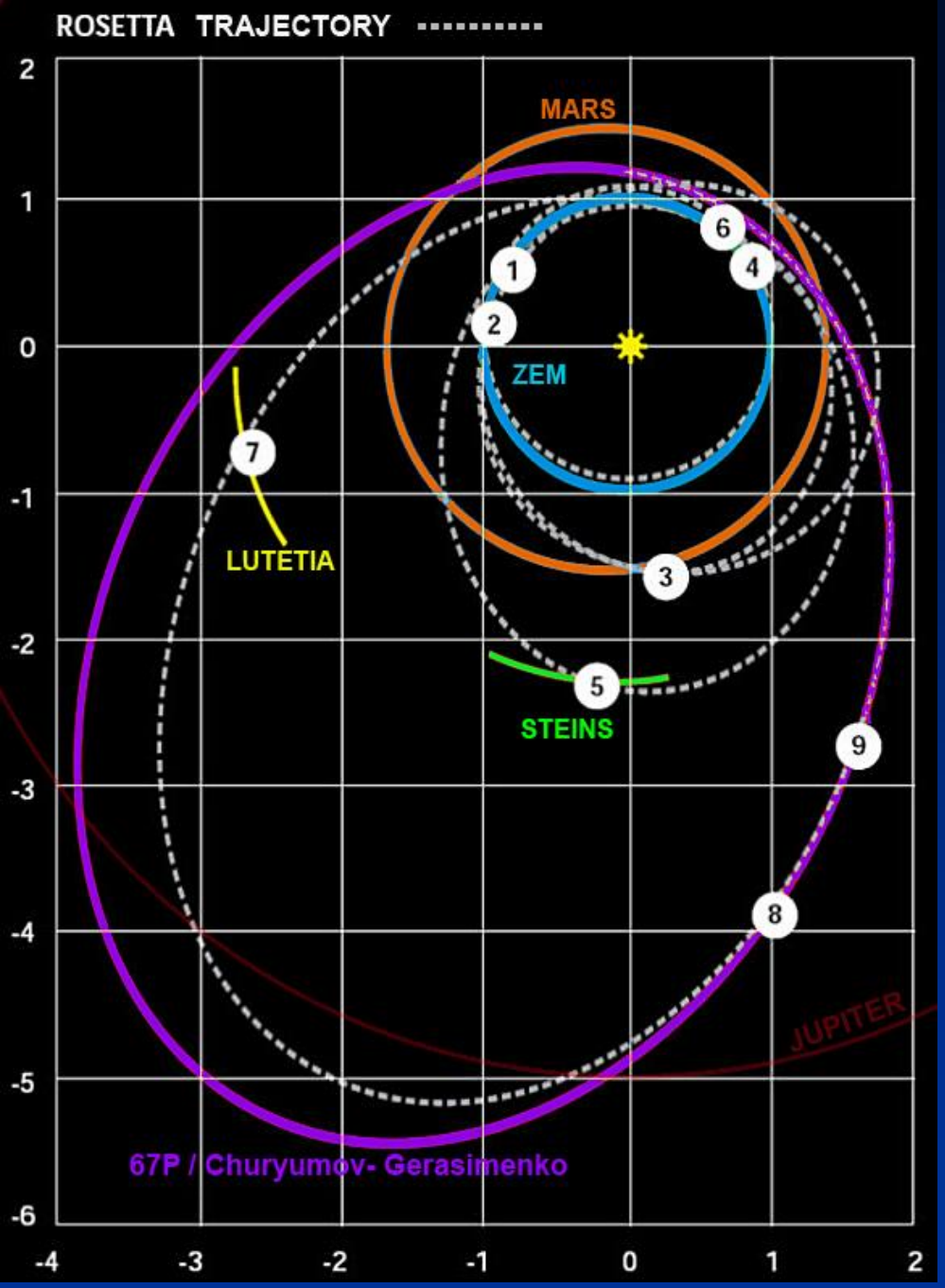
- **Vývoj aktivity jadra vplyvom slnečnej radiácie od veľkej heliocentrickej vzdialenosti, cez maximum v perihéliu a jej útlm počas vzďaľovania sa od Slnka.**
- **Analýzy chemického, mineralogického a izotopového zloženie jadra a komy a chemických reakcií v nej.**

Štart sondy ROSETTA

02. 03. 2004

(kozmodróm ESA Kourou, Francúzska Guyana)

Ariane 5G+

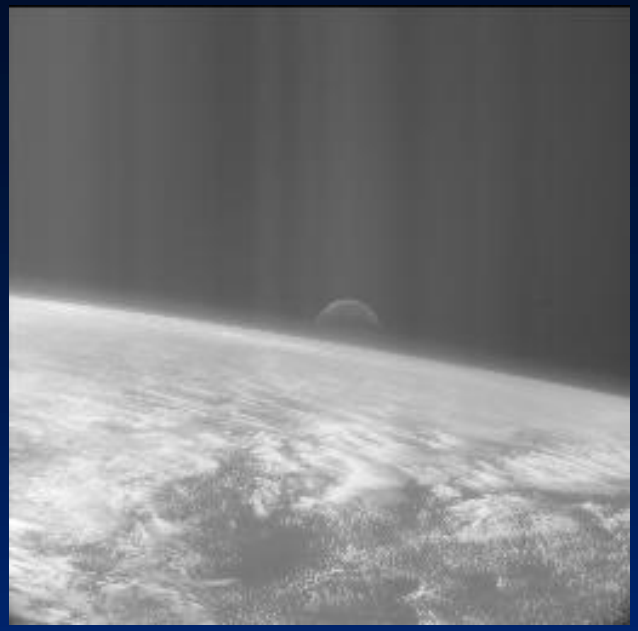


Letový plán sondy ROSETTA

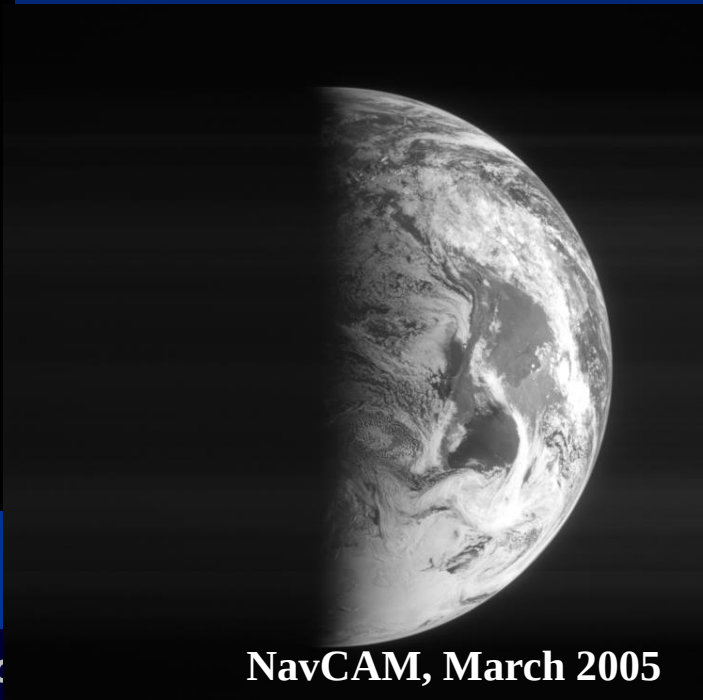
1. **2004-03-02 Štart (Kourou)**
2. **2005-03-04 Zem (prelet 1950km)**
3. **2007-02-25 Mars (prelet 250km)**
4. **2007-11-13 Zem (prelet 5300km)**
5. **2008-09-05 Steins (prelet 802km)**
6. **2009-11-13 Zem (prelet 2481km)**
7. **2010-07-10 Lutetia (prelet 3162km)**
8. (2011-06-08 - 2014-01-20) – hibernácia
9. **2014-08-06 67P (priblíženie ~100km)**
10. **2014-11-12 67P (pristátie Philae)**
11. **2015-08-13 Perihélium** (1.2432AU)

Prvý prelet nad planétou Zem

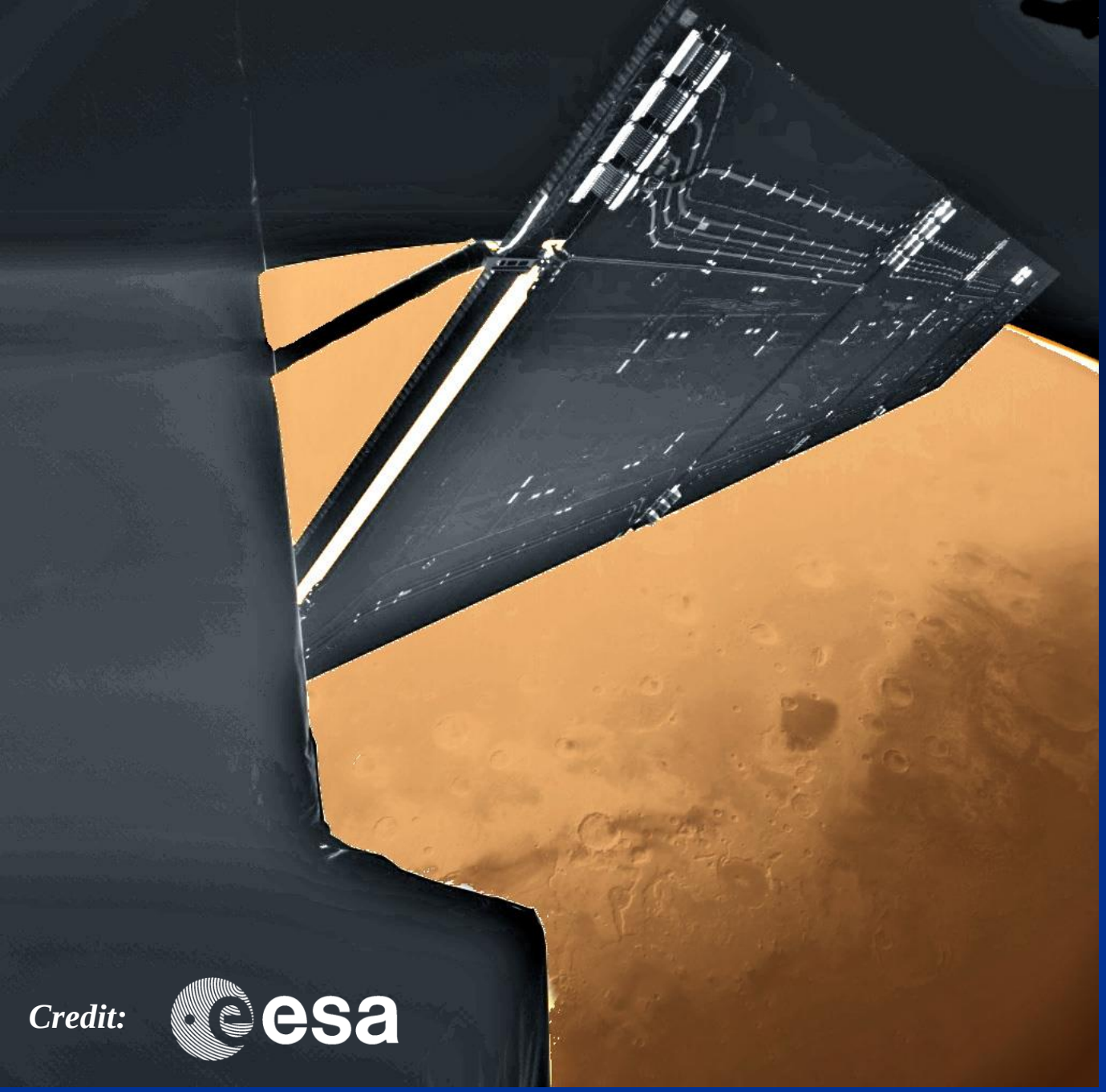
(04. 03. 2005, 1950 km)



NavCAM, March 2005



NavCAM, March 2005



Credit: esa

Rosetta nad planétou Mars

(25. 02. 2007, 250.6 km)

“One-Billion Gamble”

(Mawrth Vallis region)

foto: CIVA-P

Autonómne operácie Landera, Napájanie z Batérií

Druhý prelet nad planétou Zem

(13. 11. 2007, 5300km , Catalina Sky Survey: 2007 VN_{84} !!!)

Asteroid 2867 Steins *(05. 09. 2008, 802km, 8,6 km-s)*

„Diamantový tvar“,

Rozmery 6.67 × 5.81 × 4.47 km^3

Pokrytý plytkými krátermi

Posledný prelet nad planétou Zem *(13.11.2009, 2481 km)*

Asteroid 21 Lutetia

(10. 07. 2010, 3162 km, 15km-s)

OSIRIS *imaging (1px = 60m)*

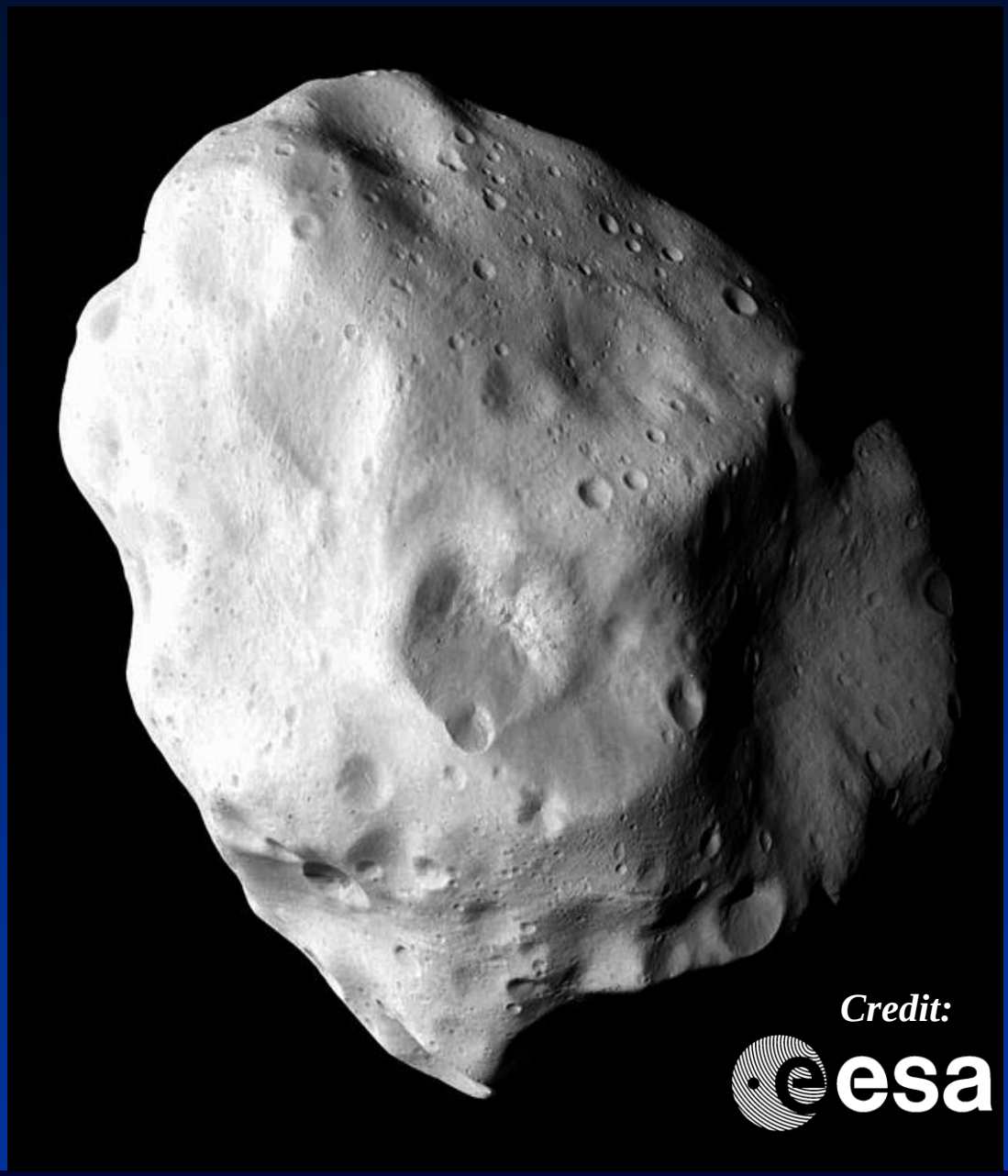
Hmotnosť 1.7 x 10^{18} kg,

Hustota ~ 3.4 g-cm^3 - pomerne vysoká, obsah Fe

Povrch chondritický

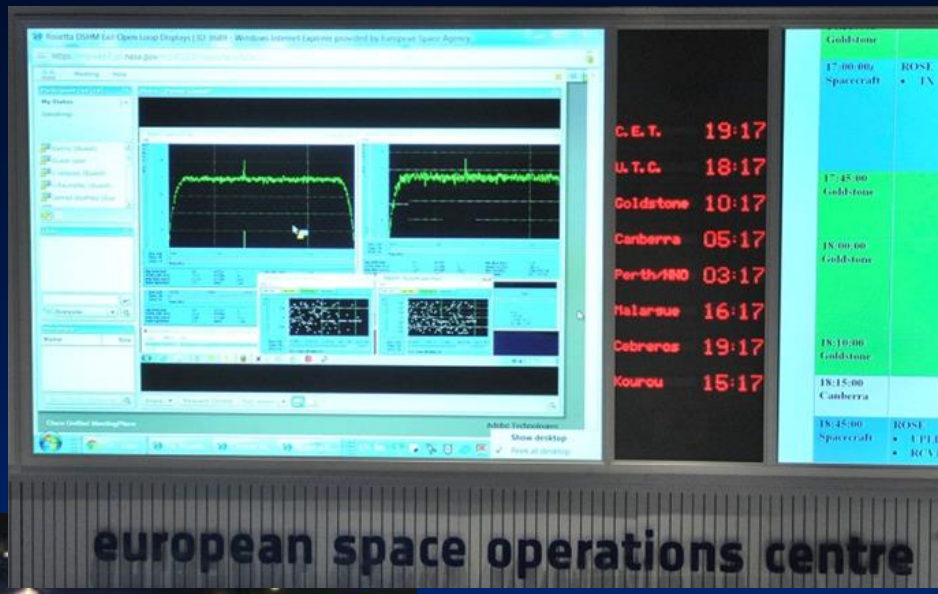
Vnútro asi bolo kedysi pretavené.

Lutetia je pravdepodobne primordiálna planetezimála.

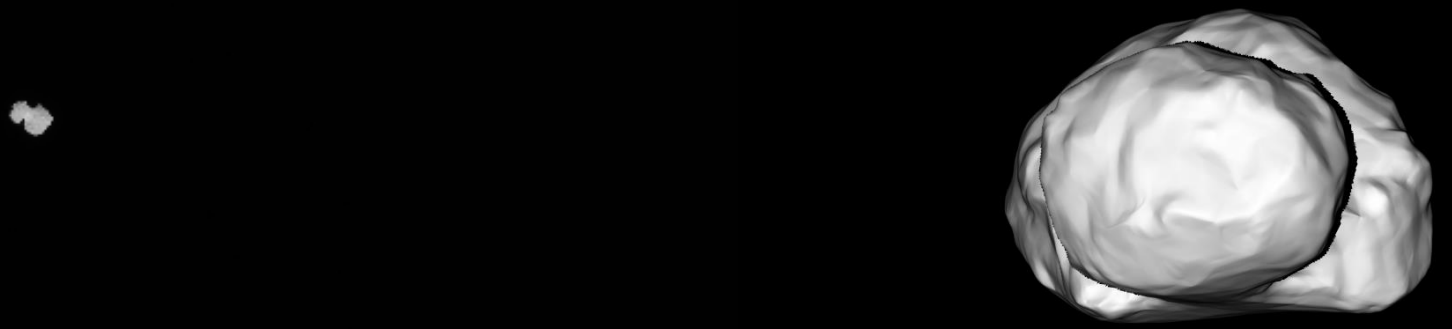


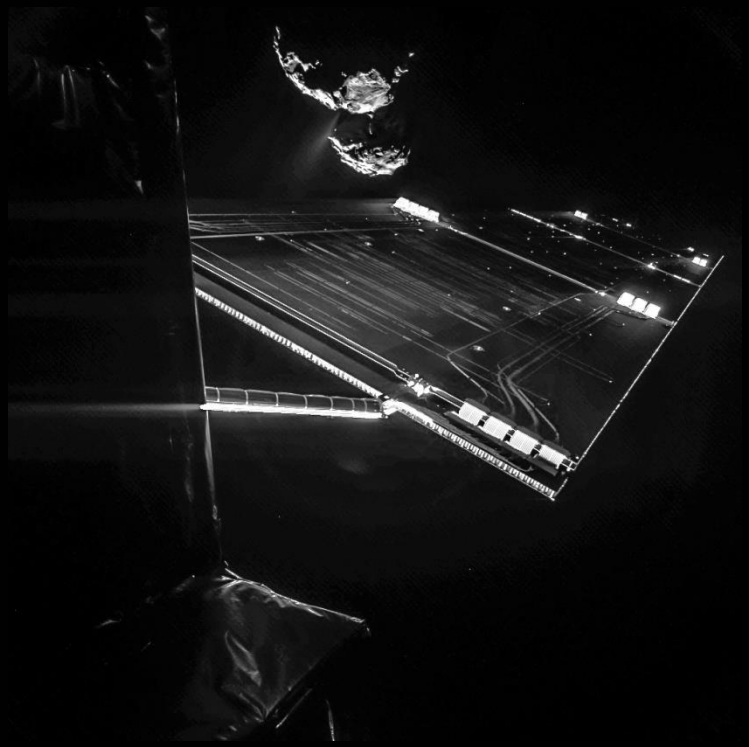
Prebudenie z hibernácie

20. 01. 2014



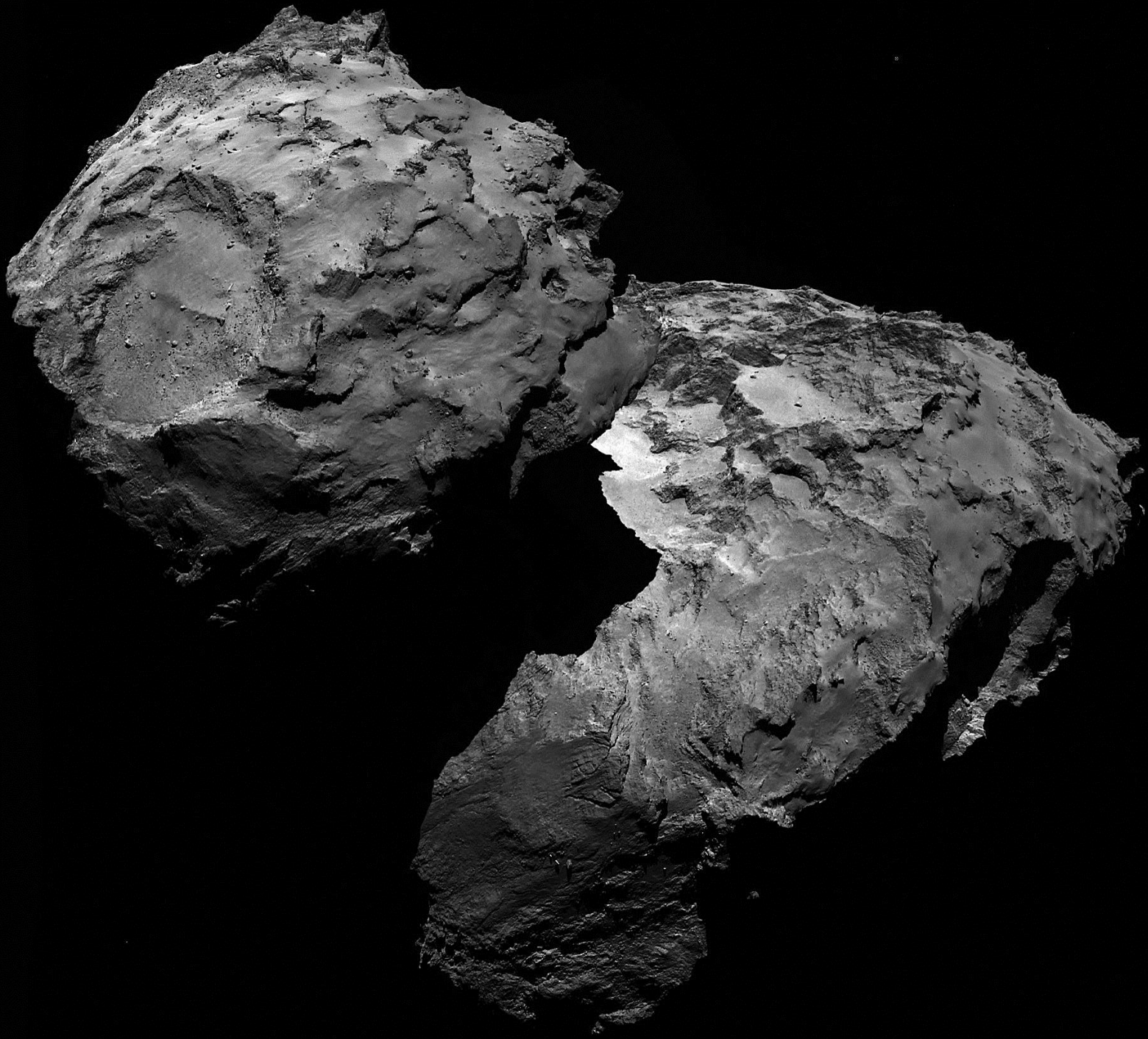
Rendezvous s 67P (august 2014)

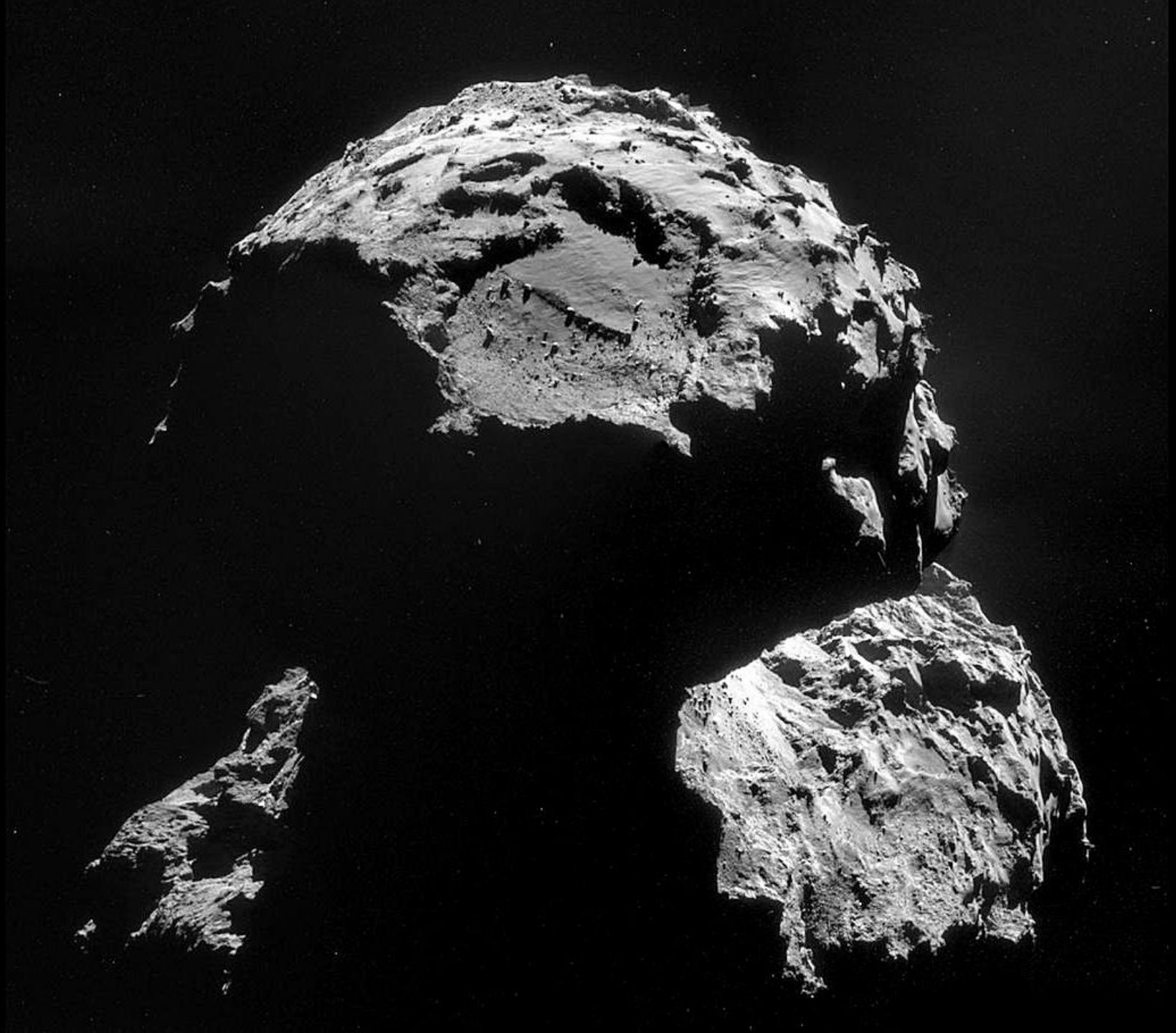


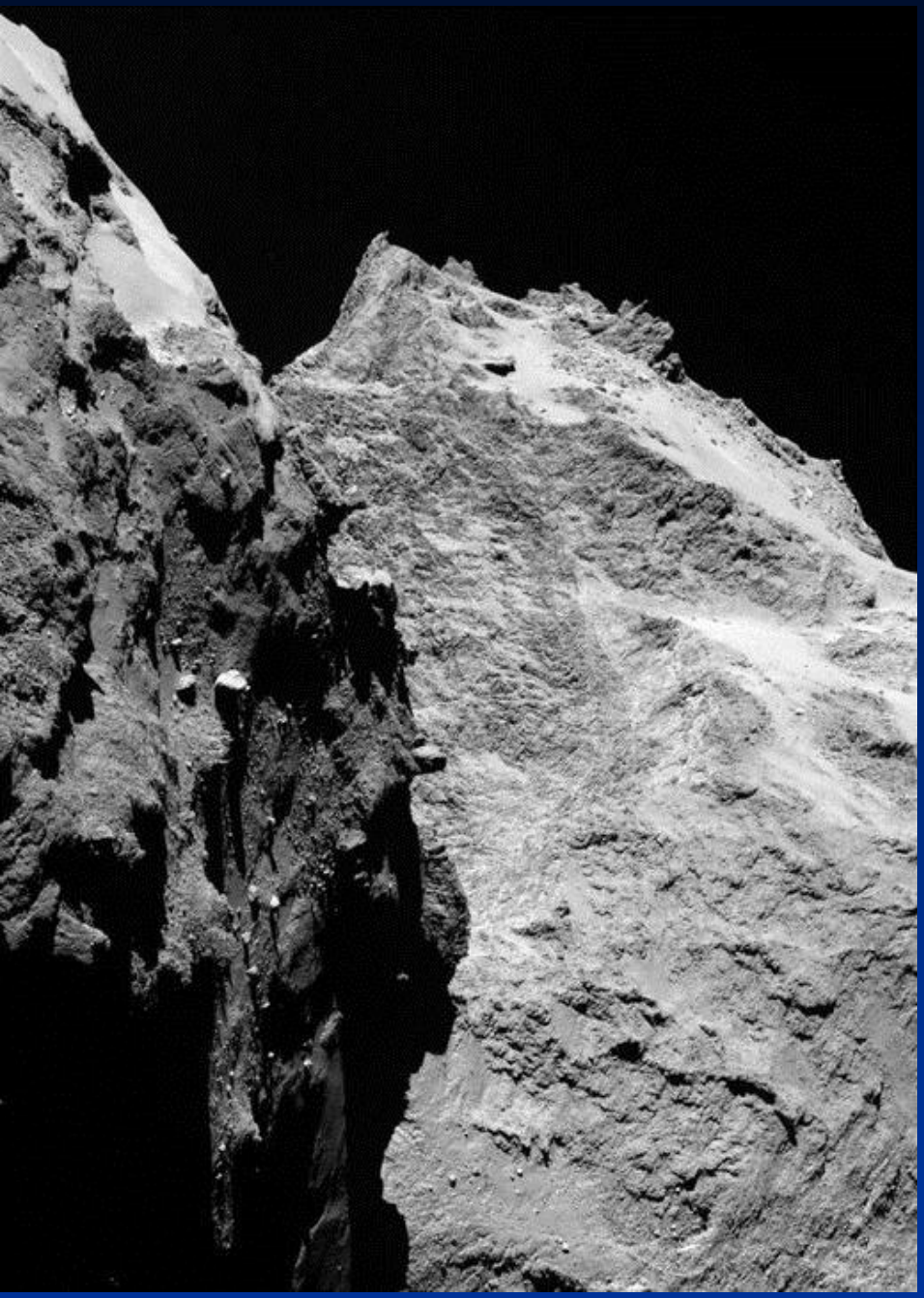


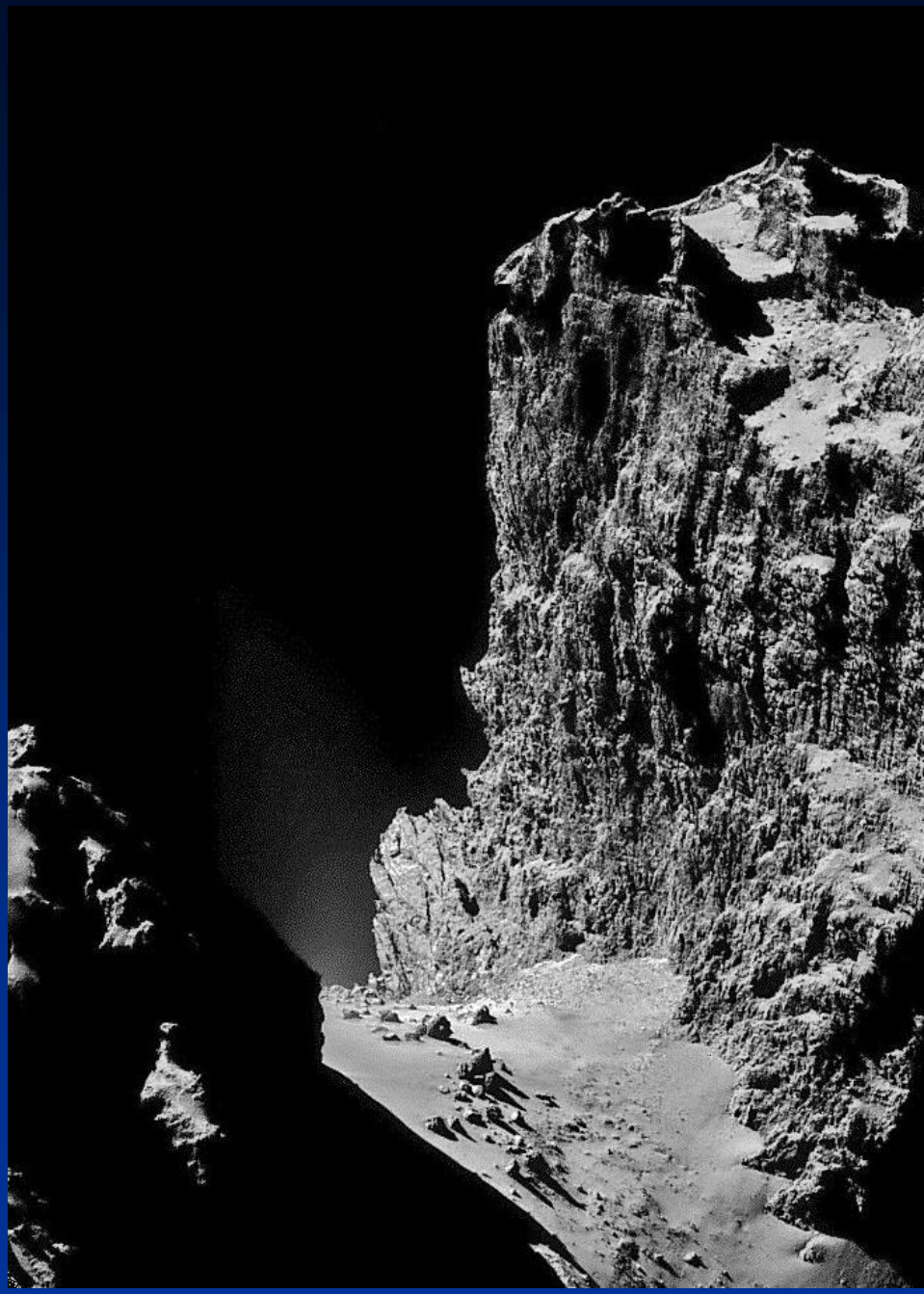
Comet 67P/Churyumov-Gerasimenko from Rosetta - 31 August 2014
ESA/Rosetta/NAVCAM/Ken Kremer/Marco Di Lorenzo

Rendezvous s 67P (6 august 2014)









Nové dáta o 67P/C-G z „Blízkeho stretnutia“

Rozmery (malý lalok)	2,5 × 2,5 × 2,0 km	OSIRIS
Rozmery (veľký lalok)	4,1 × 3,2 × 1,3 km	OSIRIS
Perióda rotácie	12,4043 hod	OSIRIS
Orientácia osi rotácie	RA: 69°; DE: 64°	OSIRIS
Hmotnosť	10^{13} kg (10 miliárd ton)	RSI
Objem	25 km^3	OSIRIS
Hustota	0,4 $g\text{-}cm^3$	RSI- OSIRIS
Rýchlosť odparovania	0,3 l-s (6-2014); 1–5 l-s (7-8-2014)	MIRO
Povrchová teplota	205–230 K (−68-−93°C, 7-8-2014)	VIRTIS
Podpovrchová teplota	30–160 K (−113-−243 °C, 8-2014)	MIRO
Detekované plyny	CO, CO_2, CH_3OH (methylalk.), CH_4(metán) NH_3 (amoniak), H_2S (sírovodík)	ROSINA
Veľkosť prach. častíc	~ 0.1 µm - ~0.01µm	COSIMA-GIADA

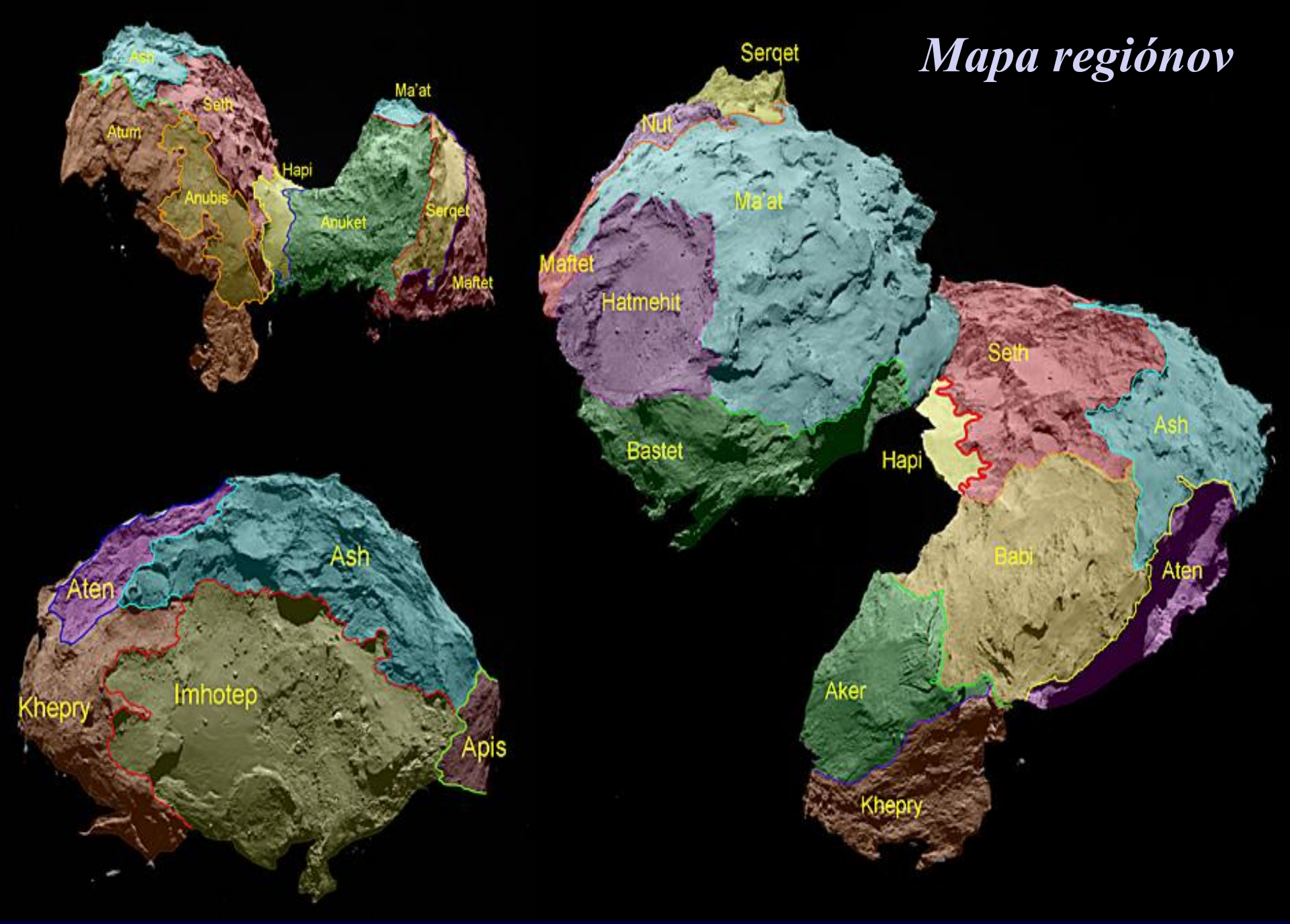
Nové dáta o 67P/C-G z „Blízkeho stretnutia“

ROSINA (Rosetta Orbiter Sensor for Ion and Neutral Analysis)

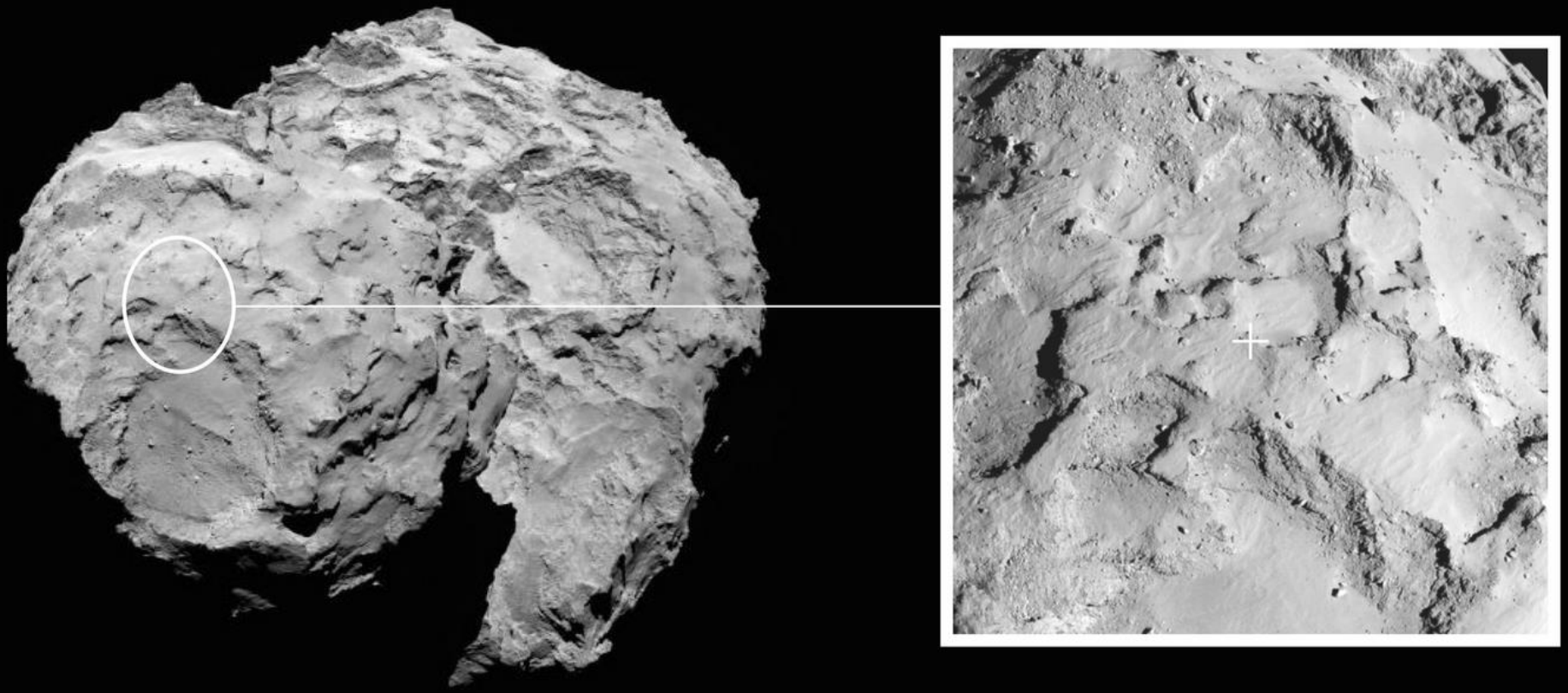
Detected gases, organic compounds and radicals in the coma

$H_2{}^{16}O$	HDO	HCl	C_2H_6O	and
$H_2{}^{17}O$	N_2	$H^{37}Cl$	C_6H_4	many
$H_2{}^{18}O$	CO	CH_3OH	N_2H_4	more
CO_2	C_2H_2	OCS	$N^{18}O$	
H_2S	C_2H_4	CH_2O_4	H_2NO	
$H_2{}^{34}S$	C_2H_6	C_6H_6	$H^{15}NO$	
SO_2	CH_2N	C_3H_2	O_2	
CS_2	C_2HN	OH	H_2O_2	
HCN	C_2	$C^{34}S$	PH_3	
Ar^{36}	C_3	NO_2	CH_3CN	
Ar^{38}	C_2N	$C^{18}O^{16}O$	SO	

Mapa regiónov



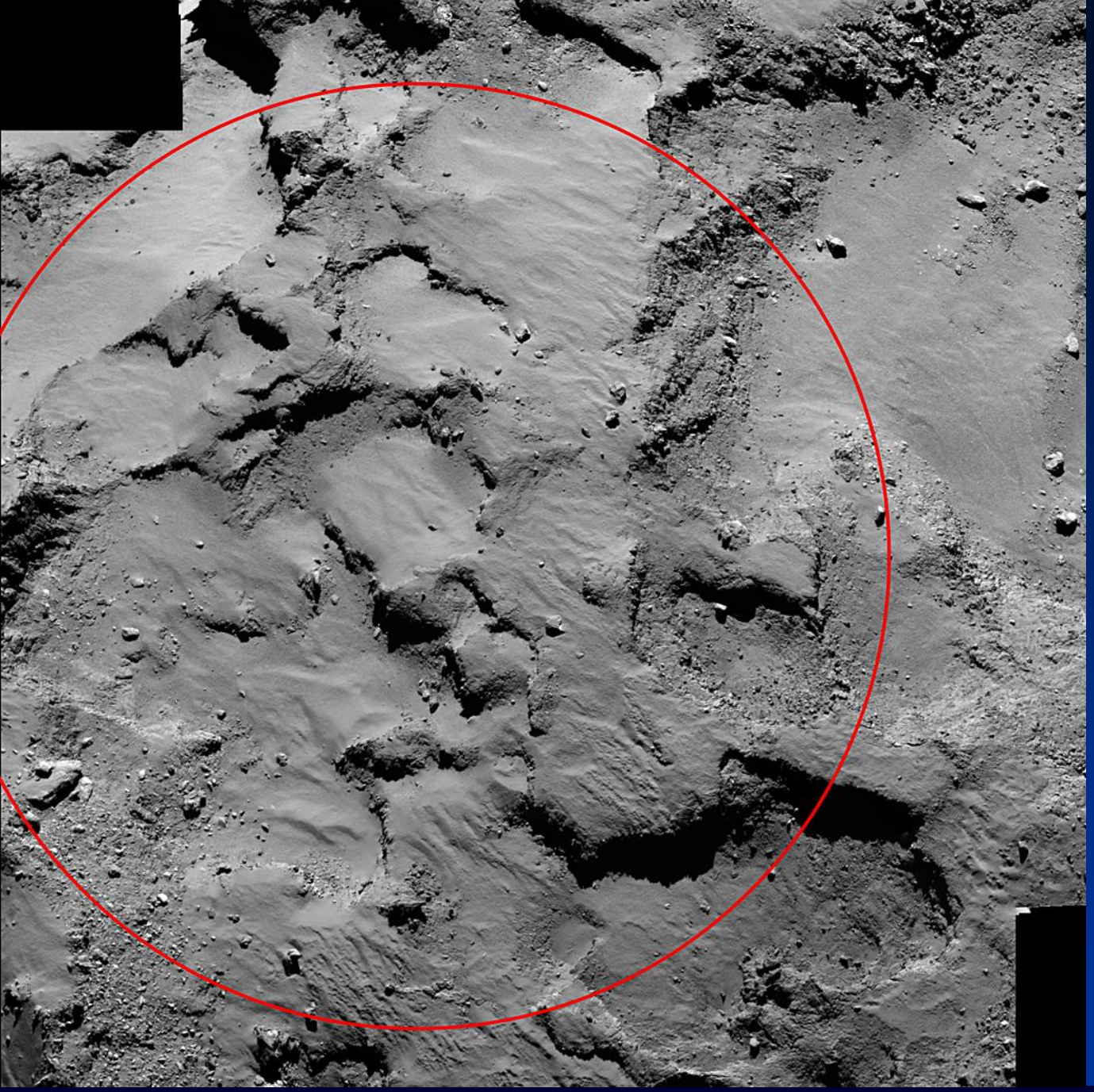
Výber miesta na pristátie (sep. 2014) vybraný bod „J“ Agilkia



Bezpečnostné kritériá: Plochý terén s malým sklonom a bez väčších balvanov.

Technické kritériá: Profil osvetlenia, teplota povrchu, kompaktnosť povrchu, spoľahlivá komunikácia s orbiterom.

Vedecké kritériá: Reprezentatívne materiálové zloženie, primeraná povrchová aktivita po priblížení k Slnku.



AGILKIA

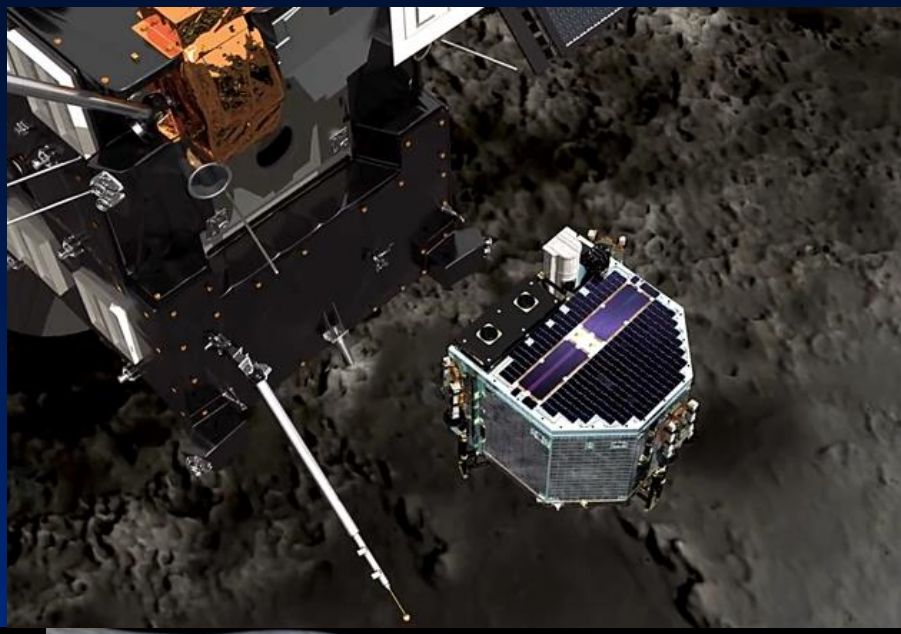
OSIRIS telefoto

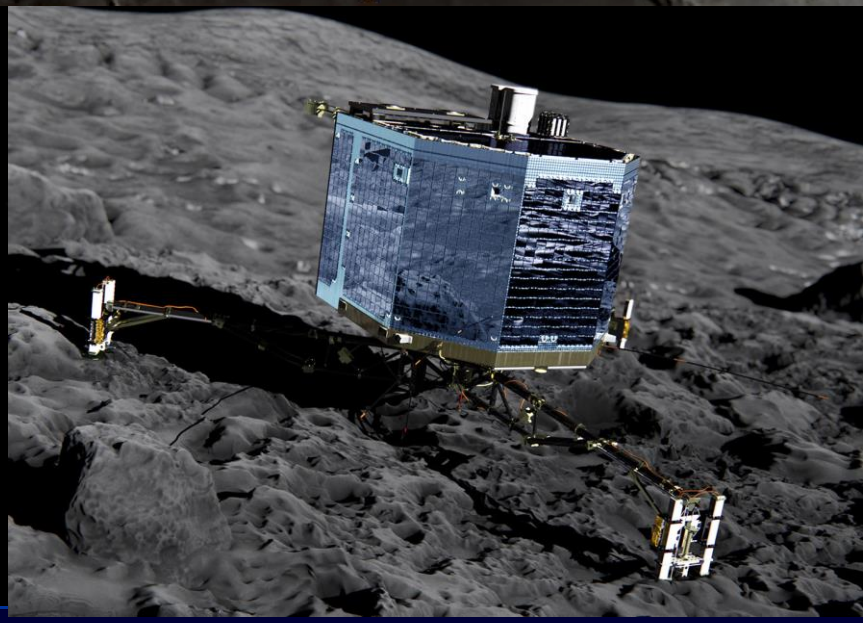
14 September 2014

Záber z výšky 30 km.

Polomer kruhu 500 m.

Pristátie na kométe 67P (12 november 2014)

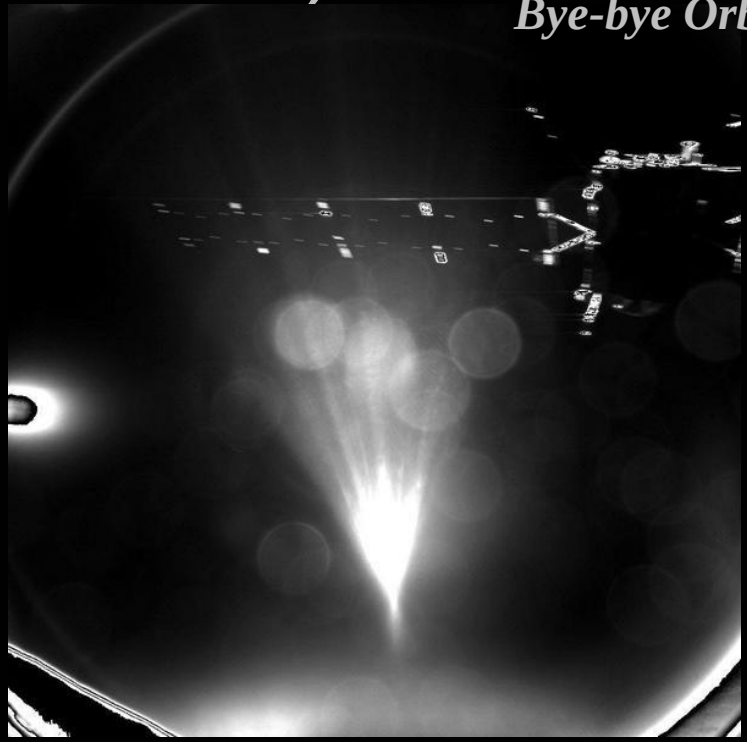




Pristátie na kométe 67P (12 november 2014)

Bye-bye Philae

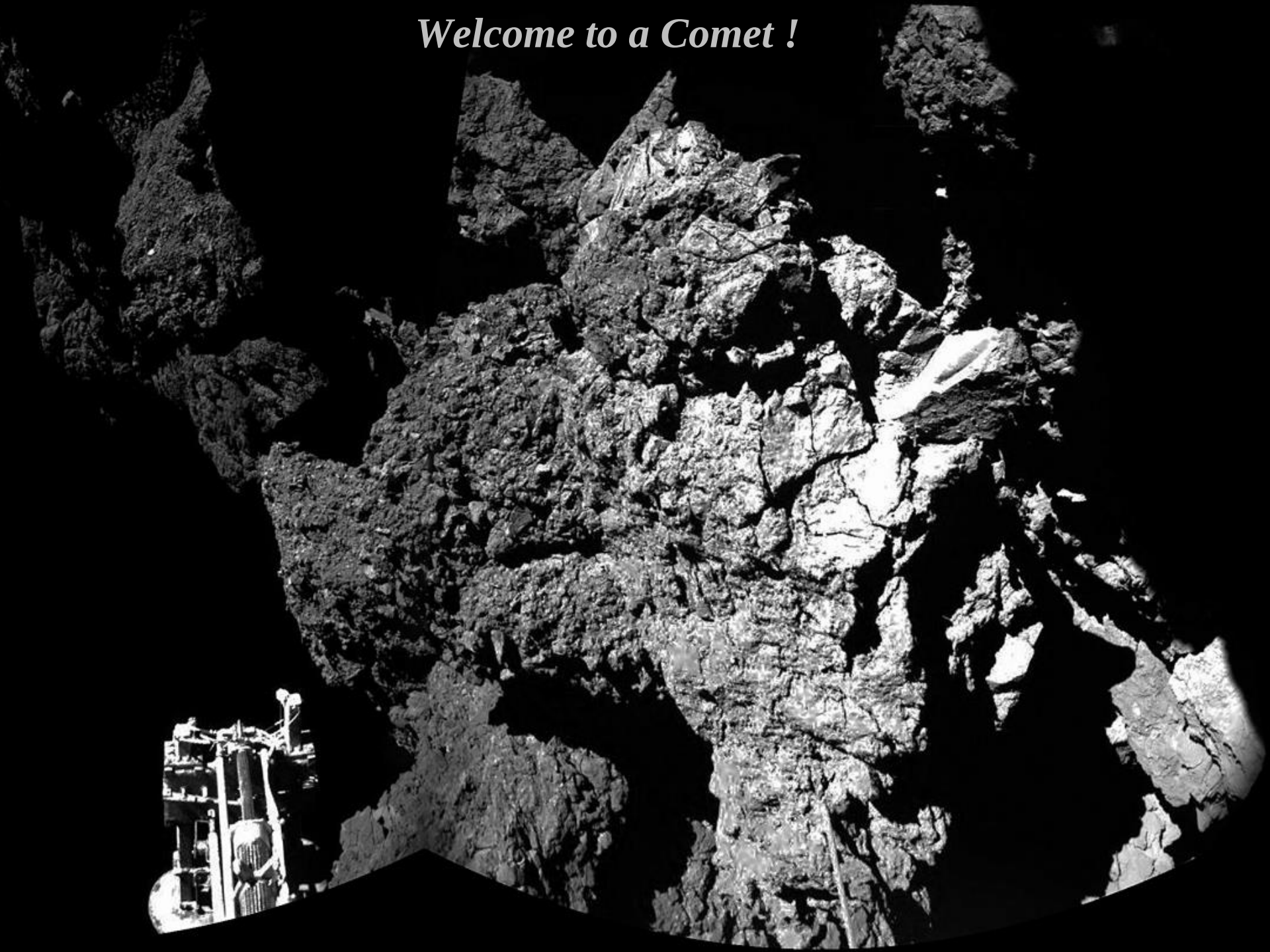
Bye-bye Orbiter



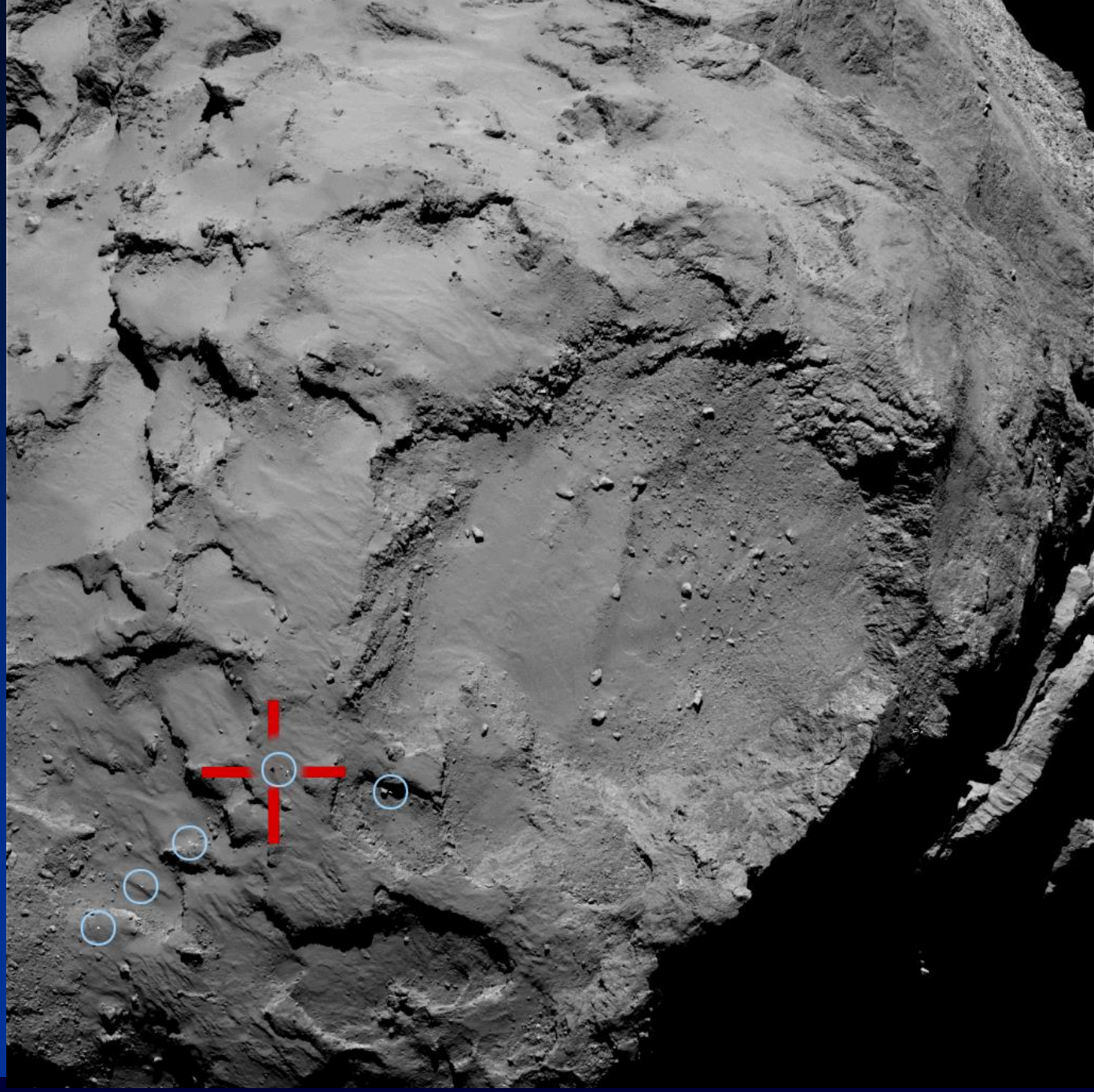
ROLIS 3 km

ROLIS 40m

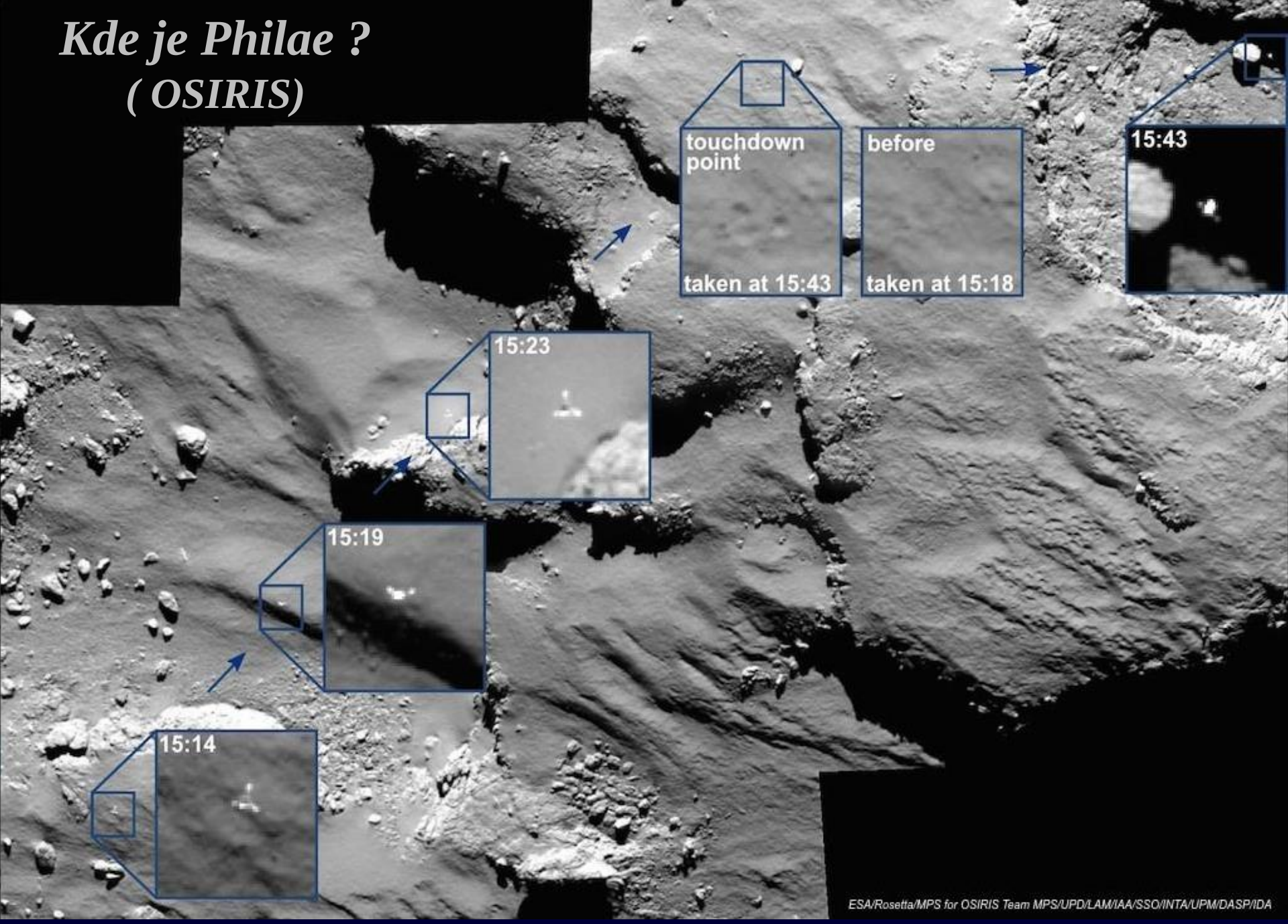
Welcome to a Comet !



Kde je Philae ?
(NavCAM)



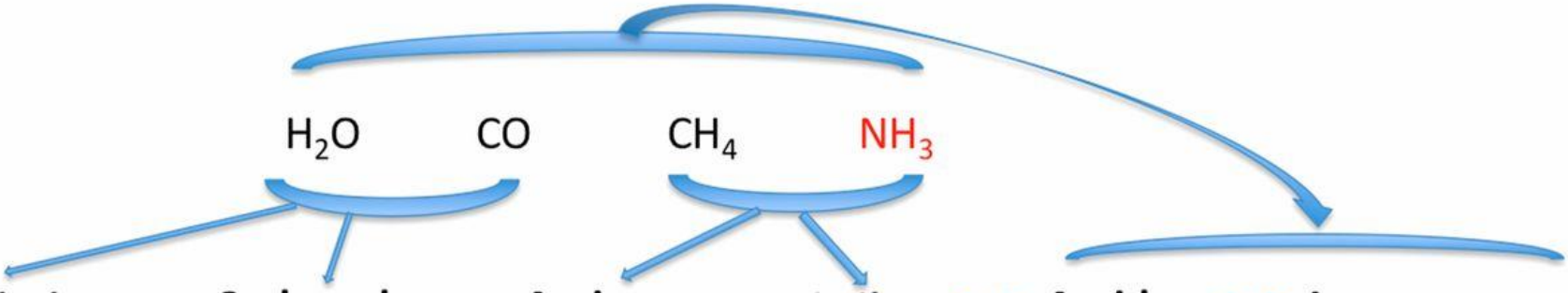
Kde je Philae ? (OSIRIS)



Kde je Philae ?
(NavCam)

Chemické rodiny detegované aparatúrou COSAC

(pre-biotické zlúčeniny)



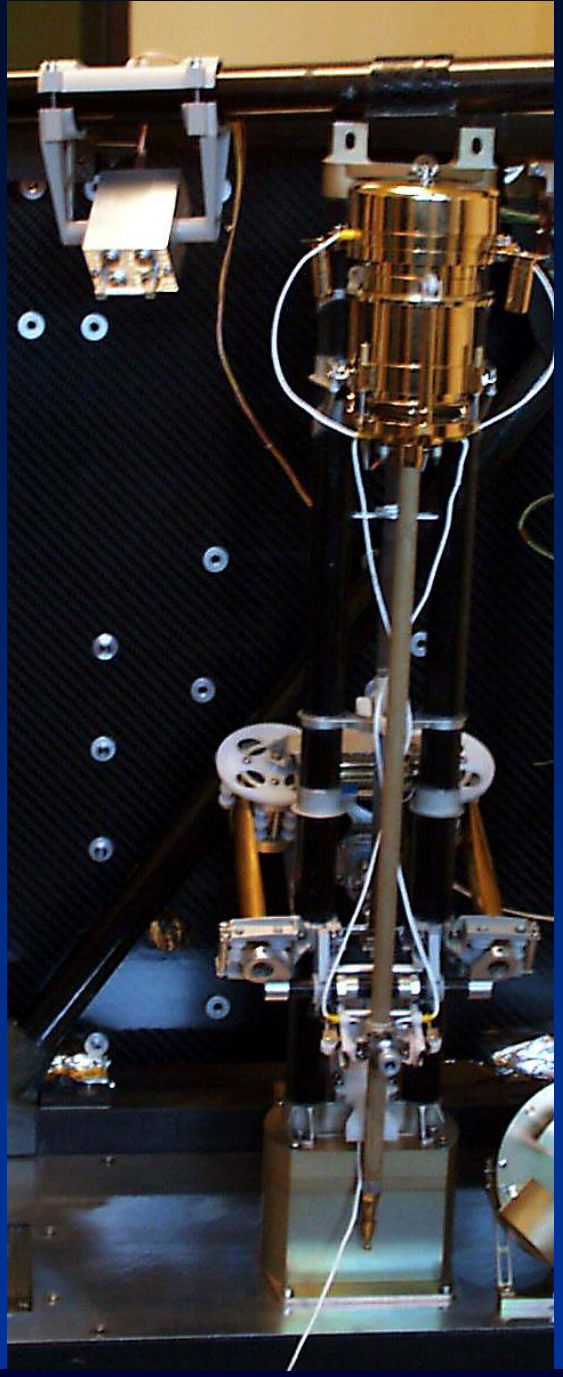
Alcohols	Carbonyls	Amines	Nitriles	↔ Amides	↔ Isocyanates
1,2-Ethanediol $(CH_2OH)_2$	Ethanal CH_3CHO	Methylamine CH_3NH_2	Methanenitrile HCN	Methanamide $HCONH_2$	Isocyanic acid HNCO
2-Hydroxyethanal CH_2OHCHO		Ethylamine $C_2H_5NH_2$	Ethanenitrile CH_3CN	Ethanamide CH_3CONH_2	Isocyanatomethane CH_3NCO
2-Propanol $(CH_3)_2CHOH$	Propanal C_2H_5CHO				
	Propanone $(CH_3)_2CO$				

MUPUS, SESAME, CONSERT

„Vŕtacie kladivo“ MUPUS nedokázalo pri obmedzenom napájaní preraziť tvrdú krustu, ktorá je pokrytá len tenkou vrstvou prachu. Zrejme tvrdý ľad. Dáta sa analyzujú.

Podobné vlastnosti potvrdil SESAME.

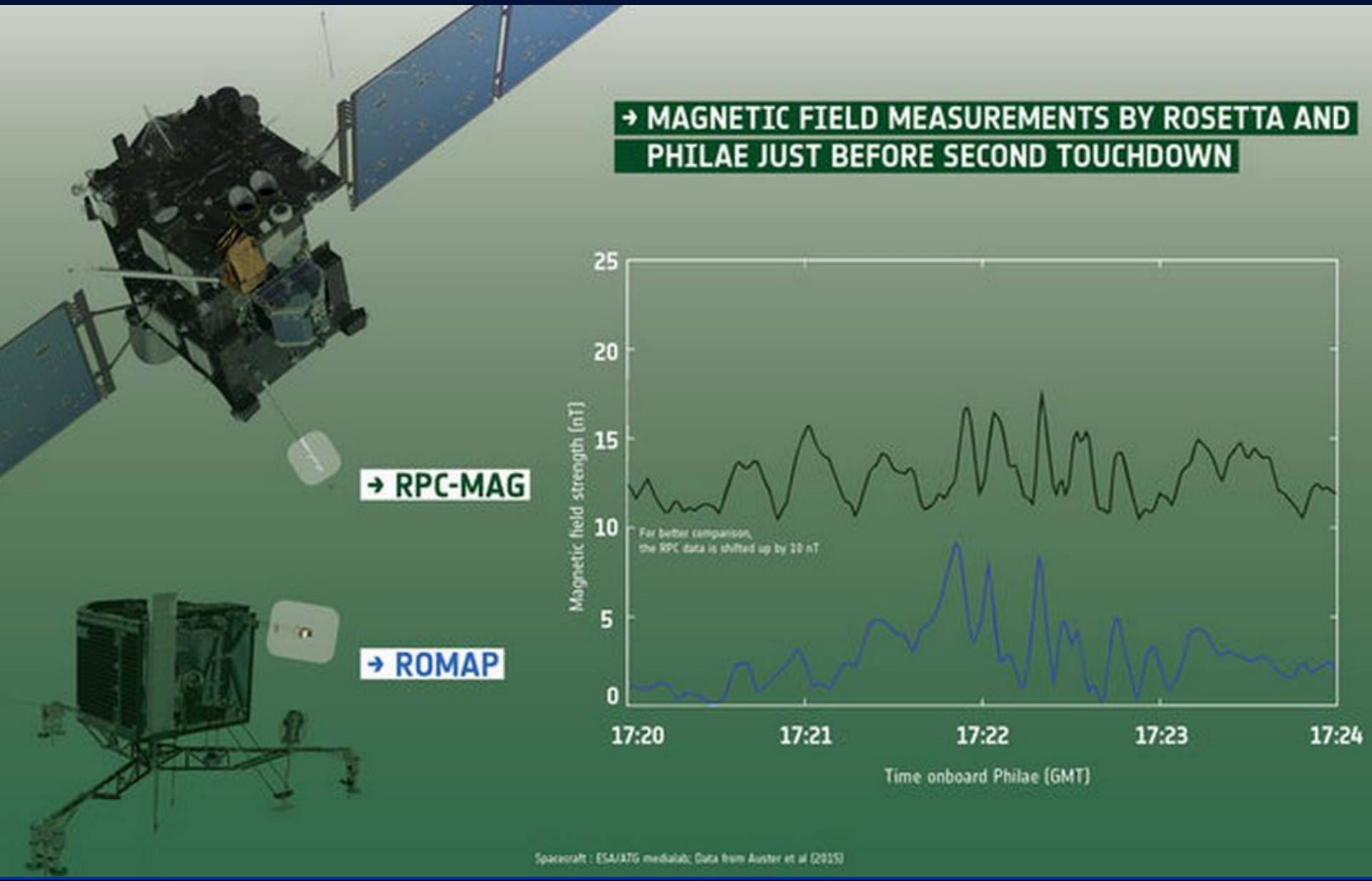
CONSERT urobil tomografiu jadra rádiovými vlnami (spolupráca s Orbiterom). Počas jeho aktivity došli batérie. Dáta sa analyzujú, zistilo sa napr. pomerne homogénne vnútro jadra kométy.



Spojenia s Philae

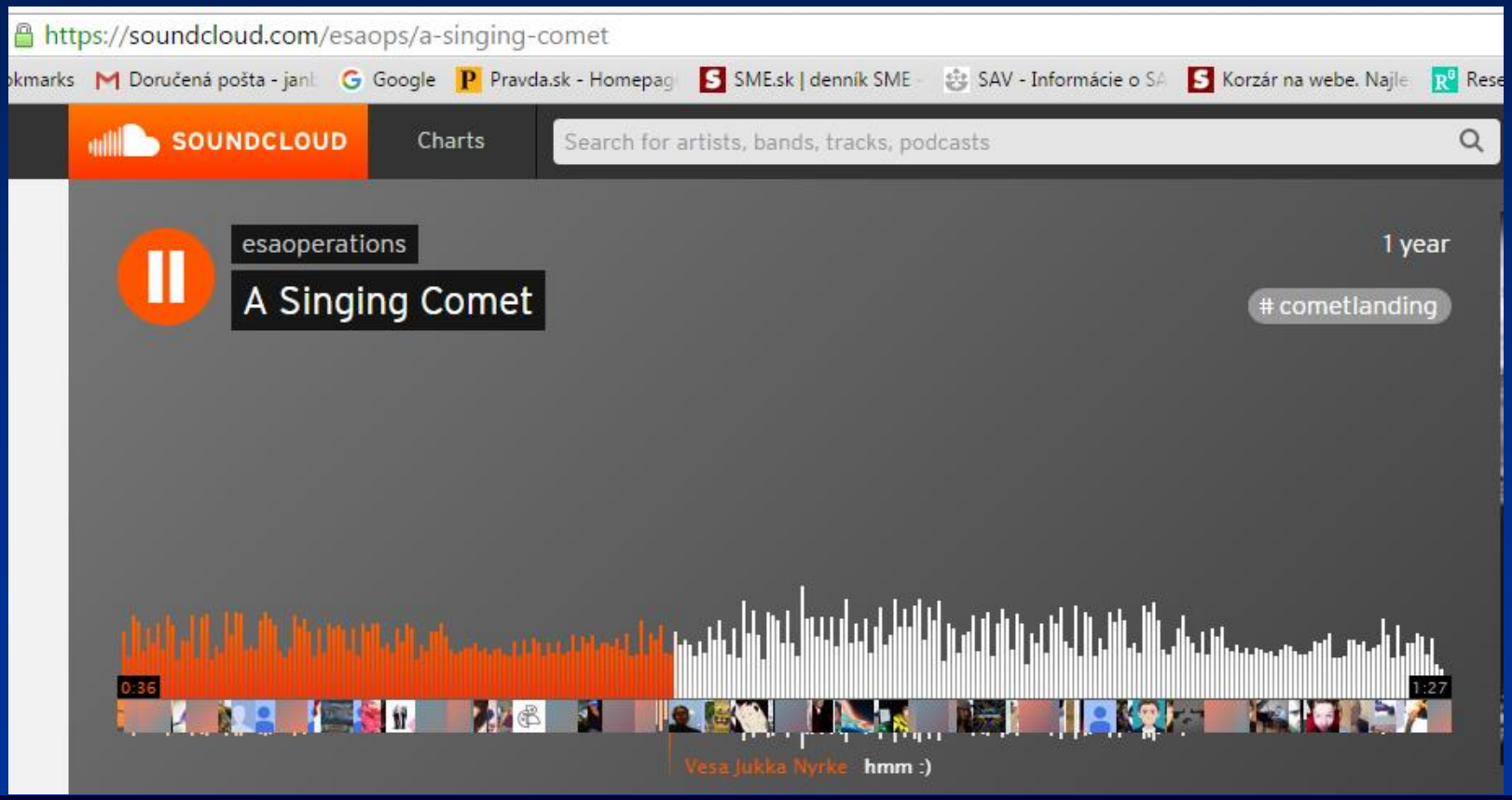
Connection	Date	Duration
nominal	12-Nov-2014	2,5 days
1	13-Jun-2015	78 sec
2	14-Jun-2015	4:04 min
3	19-Jun-2015	18:53 min
4	20-Jun-2015	31:01 min
5	21-Jun-2015	11:25 min
6	24-Jun-2015	17:11min
7	09-July-2015	22 min

Skoro žiadne magnetické pole

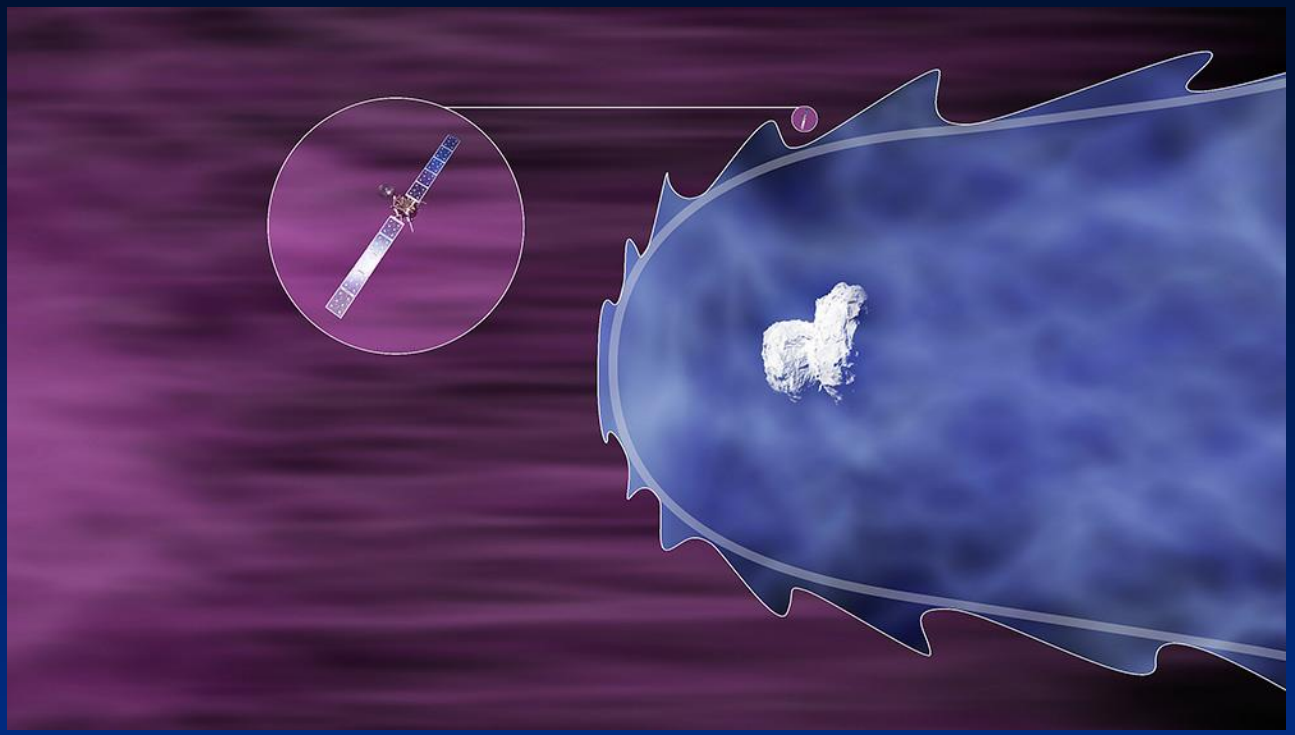


„Spievajúca kométa“

Variácie magnetického poľa v blízkom okolí kométy transponované z milihertzovej oblasti (40-50mHz) do počuteľného rozsahu (20Hz-20kHz) jej vyniesli prezývku „spievajúca kométa“. Pravdepodobne ide o interakciu slnečného vetra s ionizovaným plynom a prachom z kométy.

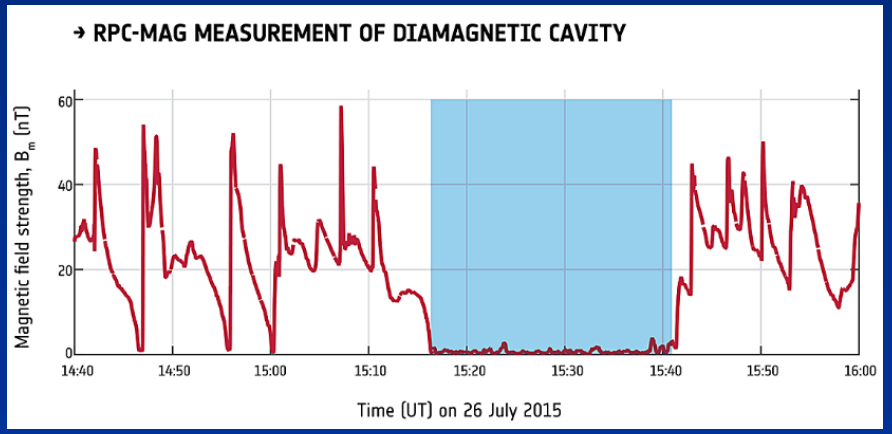


Veľká diamagnetická kavita (bublina) okolo kométy



Rosetta detegovala podstatne väčšiu kavitu než bola predpovedaná modelmi.

Diamagnetická kavita vzniká reakciou slnečného vetra a plynovo-plazmového prostredia okolo kométy v perihéliu.



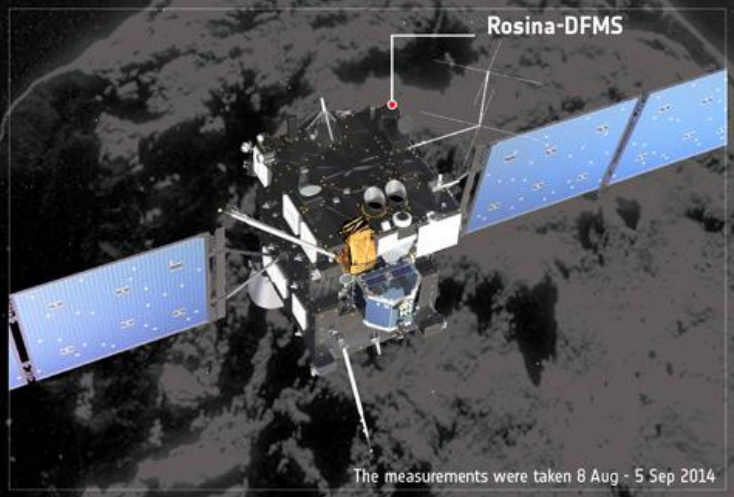
Voda z kométy 67P je iná... (Iné izotopové zloženie - D/H pomer)

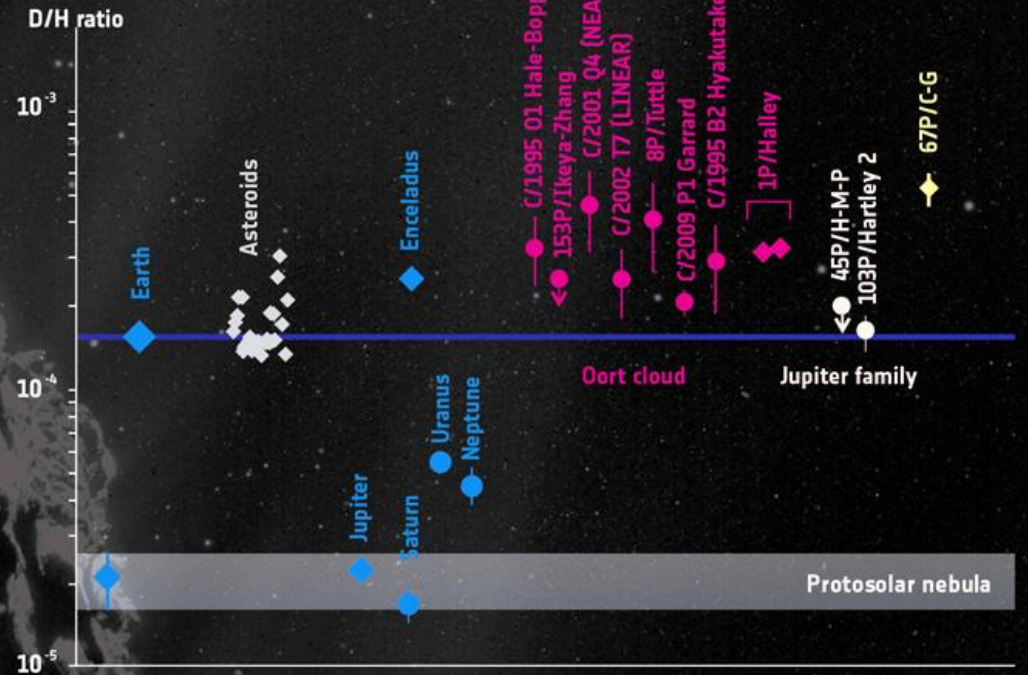
Rosetta's ROSINA instrument finds Comet 67P/Churyumov-Gerasimenko's water vapour to have a significantly different composition to Earth's oceans.

Zem: 1.56×10^{-4} (0.0156 %)

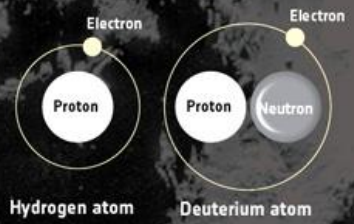
67P: 5.3×10^{-4} (0.053 %)

esa





The ratio of deuterium to hydrogen in water is a key diagnostic to determining where in the Solar System an object originated and in what proportion asteroids and comets may have contributed to Earth's oceans



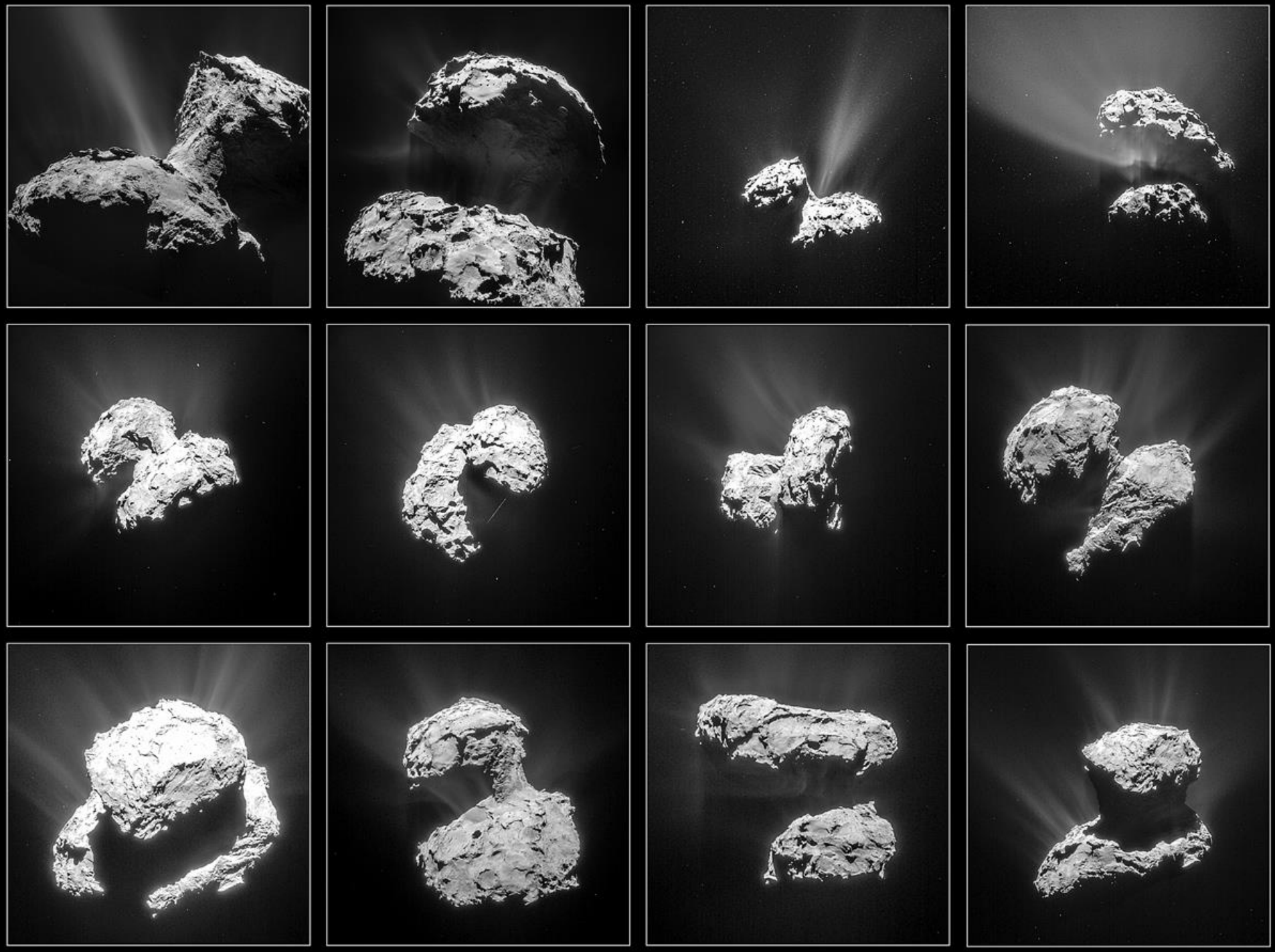
D/H ratio for different Solar System objects, grouped by colour as planets and moons (blue), chrondritic meteorites from the Asteroid Belt (grey), comets originating from the Oort cloud (purple) and Jupiter family comets (pink). Comet 67P/C-G, a Jupiter family comet, is highlighted in yellow. ◆ = data obtained in situ ● = data obtained by astronomical methods

www.esa.int

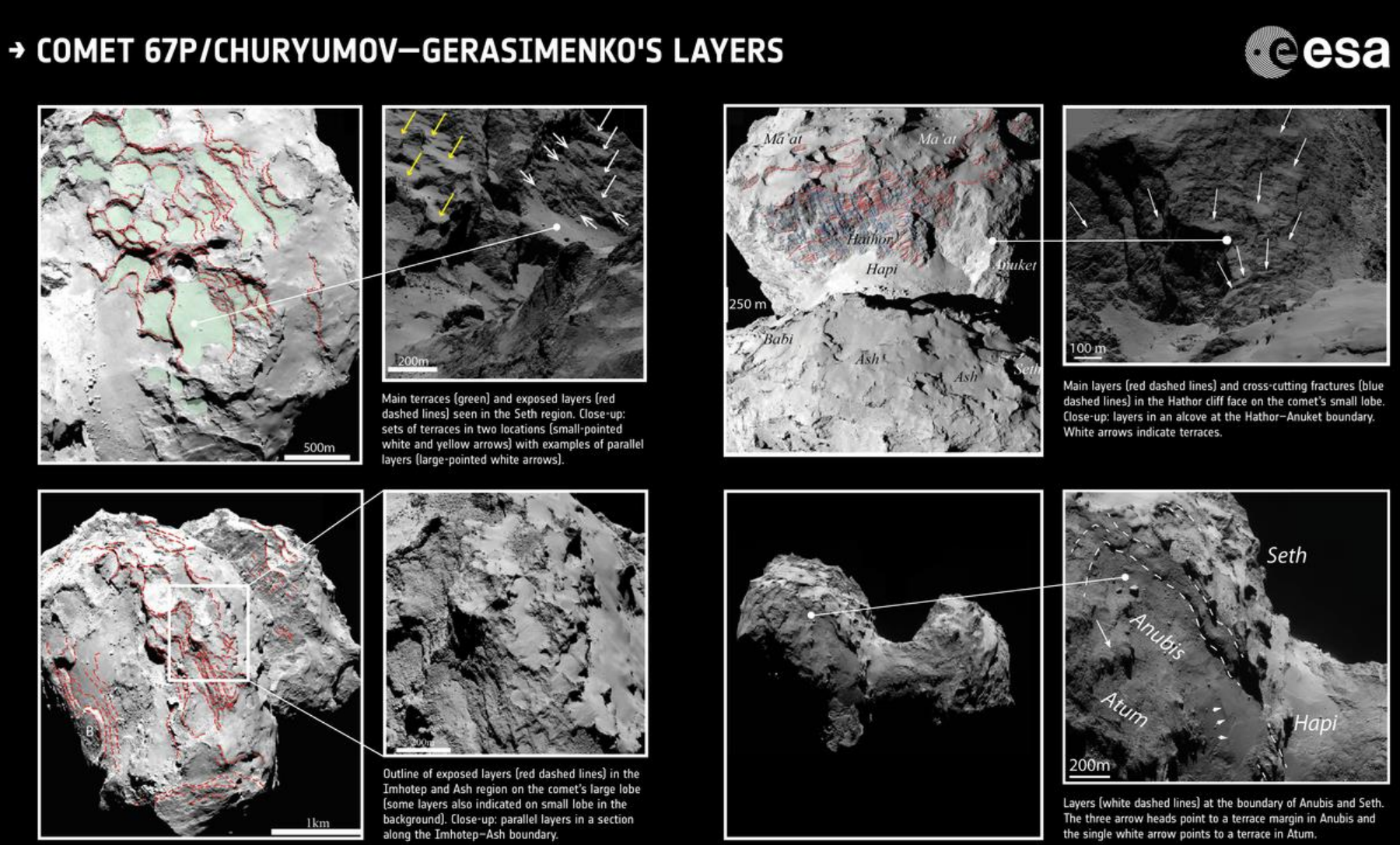
Spacecraft: ESA/ATG medialab; Comet: ESA/Rosetta/NAVCAM; Data: Altwegg et al. 2014 and references therein.

European Space Agency

Prebúdzanie kométy...



67P vznikla „pomalou zrážkou“ dvoch telies



67P v perihéliu *(13. 8.2015)*

Prachové prostredie v perihéliu (Osiris)

Pohľad na kométu z jej chvosta...(27. 3. 2016)

Plánované „pristátie“ Rosetty na kométe 30 septembra 2016

Možno uvidíme Philae…

Nespočet prestížnych vedeckých publikácií... (doposiaľ, aj v budúcnosti)

Report

67P/Churyumov-Gerasimenko, a Jupiter family comet with a high D/H ratio

K. Altwegg *et al.*

In situ mass spectrometry reveals a deuterium-to-hydrogen ratio three times that of Earth, which is suggestive of diverse origins for comets in this class.

Report

The organic-rich surface of comet 67P/Churyumov-Gerasimenko as seen by VIRTIS/Rosetta

F. Capaccioni *et al.*

The reflectance behavior of an illuminated comet is consistent with the presence of nonvolatile organics and sparse water ice.

Report

Time variability and heterogeneity in the coma of 67P/Churyumov-Gerasimenko

M. Hässig *et al.*

Mass spectrometry performed in situ shows a highly heterogeneous coma with large diurnal and possibly seasonal variations.

RELATED PODCAST

Report

Birth of a comet magnetosphere: A spring of water ions

H. Nilsson *et al.*

The interaction of the solar wind and a comet atmosphere is characterized through detection of the energetic ion environment.

Report

Subsurface properties and early activity of comet 67P/Churyumov-Gerasimenko

S. Gulkis *et al.*

Measurements at a comet yield water production rates and an assessment of low thermal inertia.

Research Article

On the nucleus structure and activity of comet 67P/Churyumov-Gerasimenko

H. Sierks *et al.*

A comet with an unusual shape has an array of surface features and high porosity, with early outgassing between its two lobes.

Research Article

The morphological diversity of comet 67P/Churyumov-Gerasimenko

N. Thomas *et al.*

Images with better than 1-meter-per-pixel resolution shows a comet's morphology with evidence for complex active processes.

Research Article

Dust measurements in the coma of comet 67P/Churyumov-Gerasimenko inbound to the Sun

A. Rotundi *et al.*

Observations of the dust outflow show bound and unbound grains and imply a comparatively high dust-to-gas ratio of 4.

Latest News

Close-ups of comet Churyumov-Gerasimenko/67P reveal an actively sculpted surface

E. Hand

Diversity of features points to a more complicated cometary birth.

The presence of clathrates in comet 67P/Churyumov–Gerasimenko

Article *in* Science Advances · April 2016

DOI: 10.1126/sciadv.1501781

Contents lists available at ScienceDirect

Acta Astronautica

journal homepage: www.elsevier.com/locate/actaastro

Invited Paper

Performance of the mission critical Electrical Support System (ESS) which handled communications and data transfer between the Rosetta Orbiter and its Lander Philae while en route to and at comet 67P/Churyumov-Gerasimenko

Susan McKenna-Lawlor[a,*], Peter Rusznyak[a], Jan Balaz[a,d], Walter Schmidt[b], Cinzia Fantinati[c], Oliver Kuechemann[c], Koen Geurts[c]

Záverom

- **ROSETTA sa ako prvá sonda v histórii stala spolu-pútnikom kométy. Pripojila sa k nej v studenej oblasti Slnečnej sústavy a zblízka pozorovala jej aktivitu pri približovaní sa k Slnku, pri prechode perihéliom a pri jej postupnom návrate do zmrznutého stavu.**

- **Prvýkrát v histórii dielo vytvorené človekom kontrolovane pristálo na jadre kométy, a analyzovalo vzorky neznámeho materiálu, z ktorého sa kedysi zrodila naša Slnečná sústava.**

- **ROSETTA sa zaradila medzi najväčšie počiny ľudstva vo výskume vesmíru a už dnes zmenila naše poznatky o Slnečnej sústave.**

Ďakujem za pozornosť !