

Europe's Comet Chaser

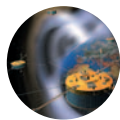
ROSETTA

About ESA

The European Space Agency (ESA) was formed on 31 May 1975. It now has 15 Member States: Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

The ESA Science Programme has launched a series of innovative and successful missions.

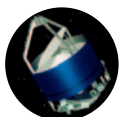
Highlights of the programme include:



Cluster, which is a four-spacecraft mission to investigate in unprecedented detail the interaction between the Sun and the Earth's magnetosphere.



Integral, which is the first space observatory that can simultaneously observe celestial objects in gamma rays, X-rays and visible light.



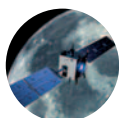
Giotto, which took the first close-up pictures of a comet nucleus (Halley) and completed flybys of Comets Halley and Grigg-Skjellerup.



Mars Express, Europe's first mission to Mars, which consists of an orbiter and a lander looking for signs of water and life on the Red Planet.



Hipparcos, which fixed the positions of the stars far more accurately than ever before and changed astronomers' ideas about the scale of the Universe.



SMART-1, Europe's first mission to the Moon, which will test solar-electric propulsion in flight, a key technology for future deep-space missions.



Hubble Space Telescope, a collaboration with NASA on the world's most important and successful orbital observatory.



Huygens, a probe to land on the mysterious surface of Saturn's largest moon, Titan, in 2004. Part of the international Cassini mission.



ISO, which studied cool gas clouds and planetary atmospheres. Everywhere it looked, it found water in surprising abundance.



IUE, the first space observatory ever launched, marked the real beginning of ultraviolet astronomy.



SOHO, which is providing new views of the Sun's atmosphere and interior, revealing solar tornadoes and the probable cause of the supersonic solar wind.



Ulysses, the first spacecraft to fly over the Sun's poles.



XMM-Newton, with its powerful mirrors, is helping to solve many cosmic mysteries of the violent X-ray Universe, from enigmatic black holes to the formation of galaxies.

For further information on the ESA Science Programme please contact the Science Programme Communication Service on (tel.) +31-71-5653223; (fax) +31-71-5654101

More information can also be obtained via the ESA Science Web Site at: <http://www.esa.int/science>

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Published by: ESA Publications Division

ESTEC, PO Box 299
2200 AG Noordwijk
The Netherlands

Editors: Bruce Battrick & Monica Talevi

Design & Layout: Carel Haakman

Cover: concept and graphics by AOES Medialab and C. Haakman
photos: courtesy of NASA/JPL

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ISSN No.: 0250-1589

ISBN No.: 92-9092-687-2

Price: 7 Euros

Printed in The Netherlands

The background of the entire page is a deep space scene. In the upper left, the Rosetta spacecraft is shown in profile, with its long boom and various instruments. Below it, the lander Philae is depicted as a small, white, three-legged object. In the lower right, a large, dark, and heavily cratered comet nucleus (67P/Churyumov-Gerasimenko) is visible. A bright star with a diffraction pattern is located in the upper right quadrant.

Rosetta

Europe's Comet Chaser

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Rosetta:

Europe's Comet Chaser

In November 1993, the International Rosetta Mission was approved as a Cornerstone Mission in ESA's Horizons 2000 Science Programme. Since then, scientists and engineers from all over Europe and the United States have been combining their talents to build an orbiter and a lander for this unique expedition to unravel the secrets of a mysterious mini ice world – a comet.

Initially scheduled for January 2003, the launch of Rosetta had been postponed due to a failure of an Ariane rocket in December 2002. The adventure will now begin in February 2004, when a European Ariane-5 rocket lifts off from Kourou in French Guiana. During a circuitous ten-year trek across the Solar System, Rosetta will cross the asteroid belt and travel into deep space, more than six times Earth's distance from the Sun. Its destination will be a periodic comet known as 67P/Churyumov-Gerasimenko.

The Rosetta orbiter will rendezvous with 67P/Churyumov-Gerasimenko and remain in close proximity to the icy nucleus as it plunges towards the warmer inner reaches of the Sun's domain. At the same time, a small lander will be released onto the surface of this mysterious cosmic iceberg. More than a year will pass before the remarkable mission draws to a close in December 2015. By then, both the spacecraft and the comet will have circled the Sun and be on their way out of the inner Solar System.

A historic mission

The Rosetta mission will achieve many historic firsts.

- **Rosetta will be the first spacecraft to orbit a comet's nucleus.**
- **It will be the first spacecraft to fly alongside a comet as it heads towards the inner Solar System.**
- **Rosetta will be the first spacecraft to examine from close proximity how a frozen comet is transformed by the warmth of the Sun.**
- **Shortly after its arrival at Comet 67P/Churyumov-Gerasimenko, the Rosetta orbiter will despatch a robotic lander for the first controlled touchdown on a comet nucleus.**
- **The Rosetta lander's instruments will obtain the first images from a comet's surface and make the first in-situ analysis to find out what it is made of.**
- **On its way to Comet 67P/Churyumov-Gerasimenko, Rosetta will pass through the main asteroid belt, with the option of a first close encounter with one or more of these primitive objects.**
 - **Rosetta will be the first spacecraft ever to fly close to Jupiter's orbit using solar cells as its main power source.**

Scientists will be eagerly waiting to compare Rosetta's results with previous studies by ESA's Giotto spacecraft and by ground-based observatories. These have shown that comets contain complex organic molecules - compounds that are rich in carbon, hydrogen, oxygen and nitrogen. Intriguingly, these are the elements that make up nucleic acids and amino acids, the essential ingredients for life as we know it.

Did life on Earth begin with the help of comet seeding? Rosetta may help us to find the answer to this fundamental question.

Rosetta will be the first spacecraft to orbit a comet's nucleus

The Rosetta stone, discovered in 1799, was the key to unraveling the civilisation of ancient Egypt

Why 'Rosetta'?

The European Space Agency's unprecedented mission of cometary exploration is named after the famous 'Rosetta Stone'. This slab of volcanic basalt – now in the British Museum in London – was the key to unraveling the civilisation of ancient Egypt.

French soldiers discovered the unique stone in 1799, as they prepared to demolish a wall near the village of Rashid (Rosetta) in Egypt's Nile delta. The carved inscriptions on the stone included hieroglyphics – the written language of ancient Egypt – and Greek, which was readily understood. After the French surrender in 1801, the 762-kilogram stone was handed over to the British.

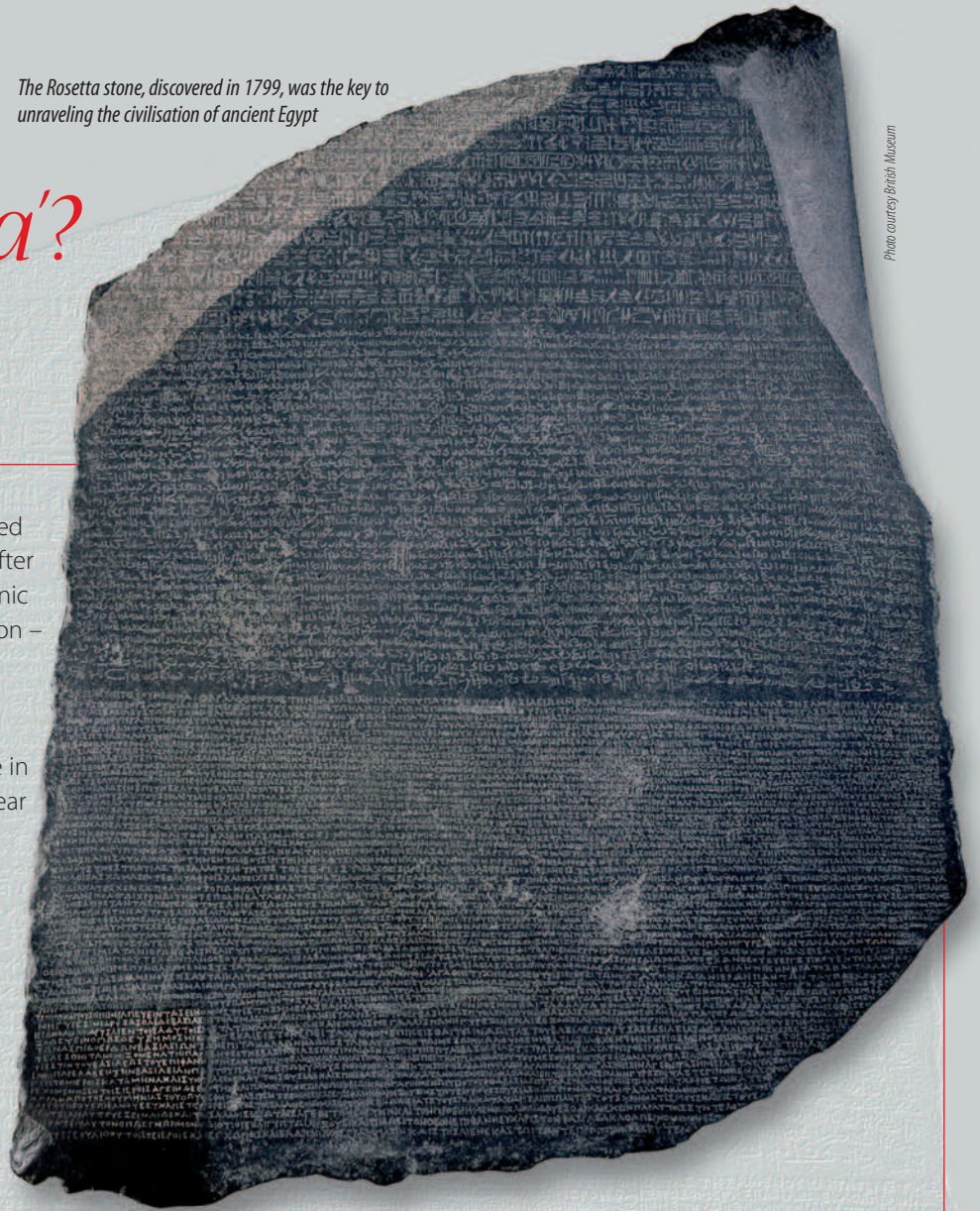


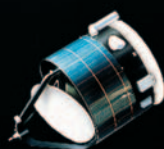
Photo courtesy British Museum

Giotto and Comet Halley

Much of what we know about comets came from ESA's pioneering Giotto mission. During an unprecedented visit to two comets, Giotto provided tantalising glimpses of a comet's dust-shrouded core.

On the night of 13/14 March 1986, eight months after launch, the cylindrical spacecraft swept past Comet Halley, obtaining the first close-up images ever obtained of a comet nucleus. The image sequence revealed a black, potato-shaped object, partially illuminated on the warmer, sunlit side by bright jets spewing gas and dust into space.

Despite being partially disabled by bullet-like dust impacts, this triumph was followed by a successful fly-by of Comet Grigg-Skjellerup on 10 July 1992. Skimming by just 200 kilometres from the nucleus, it was the closest comet fly-by ever achieved by any spacecraft.



The historical encounter between Giotto and Halley's Comet on 13 March 1986

By comparing the inscriptions on the stone, historians were able to begin deciphering the mysterious carved figures. Most of the pioneering work was carried out by the English physician and physicist Thomas Young, and French scholar Jean François Champollion. As a result of their breakthroughs, scholars were at last able to piece together the history of a long-lost culture.

Just as the Rosetta Stone provided the key to an ancient civilisation, so ESA's Rosetta spacecraft will unlock the mysteries of the oldest building blocks of our Solar System – the comets. As the worthy successor of Champollion and Young, Rosetta will allow scientists to look back 4600 million years to an epoch when no planets existed and only a vast swarm of asteroids and comets surrounded the Sun.

Life and survival in deep space

Rosetta's deep-space odyssey will comprise lengthy periods of inactivity, punctuated by relatively short spells of intense activity – the encounters with Mars, Earth and one or more asteroids. Ensuring that the spacecraft survives the hazards of travelling through deep space for more than 10 years is one of the great challenges of the Rosetta mission.

Spacecraft hibernation

For much of the outward journey, the spacecraft will be placed in 'hibernation' in order to limit consumption of power and fuel, and to minimise operating costs. At such times, the spacecraft spins once per minute while it faces the Sun, so that its solar panels can receive as much sunlight as possible. Almost all of the electrical systems are switched off, with the exception of the radio receivers, command decoders and power supply.

On-board autonomy

Instructions from the ground take up to 50 minutes to reach the spacecraft, so Rosetta must have the 'intelligence' to look after itself. This is done by its on-board computers, whose tasks include data management, attitude and orbit control. In case any problems arise during the lengthy cruise, back-up systems have been added to ensure that the spacecraft can remain operational during critical mission phases.

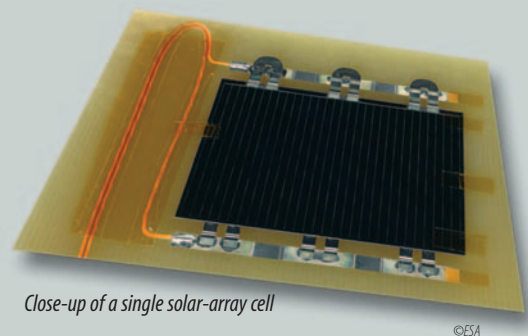
Hot and cold

Temperature control is a major headache for designers of the Rosetta spacecraft. Near the Sun, overheating has to be prevented by using radiators to dissipate surplus heat into space. In the outer Solar System, the hardware and scientific instruments must be kept warm

(especially when in hibernation) to ensure their survival. This is achieved by using heaters located at strategic points (for example, fuel tanks, pipework and thrusters), placing louvres over the radiators and wrapping the spacecraft in multi-layered insulation blankets to cut back on heat losses.

Solar Power

Rosetta will be the first space mission to journey beyond the main asteroid belt and rely solely on solar cells for power generation rather than the traditional radio-isotope thermal generators. The new solar cell technology used on the orbiter's two giant solar panels allows it to operate over 800 million kilometres from the Sun, where levels of sunlight are only 4% of those on Earth. Hundreds of thousands of specially developed, non-reflective, silicon cells generate up to 8700 Watts in the inner Solar System and around 400 Watts for the deep-space comet encounter.



Close-up of a single solar-array cell

©ESA



The Rosetta spacecraft without thermal blankets ready for vibration testing on the shaker (top), and with thermal blankets ready for testing in the Large Space Simulator (bottom), at ESTEC in The Netherlands

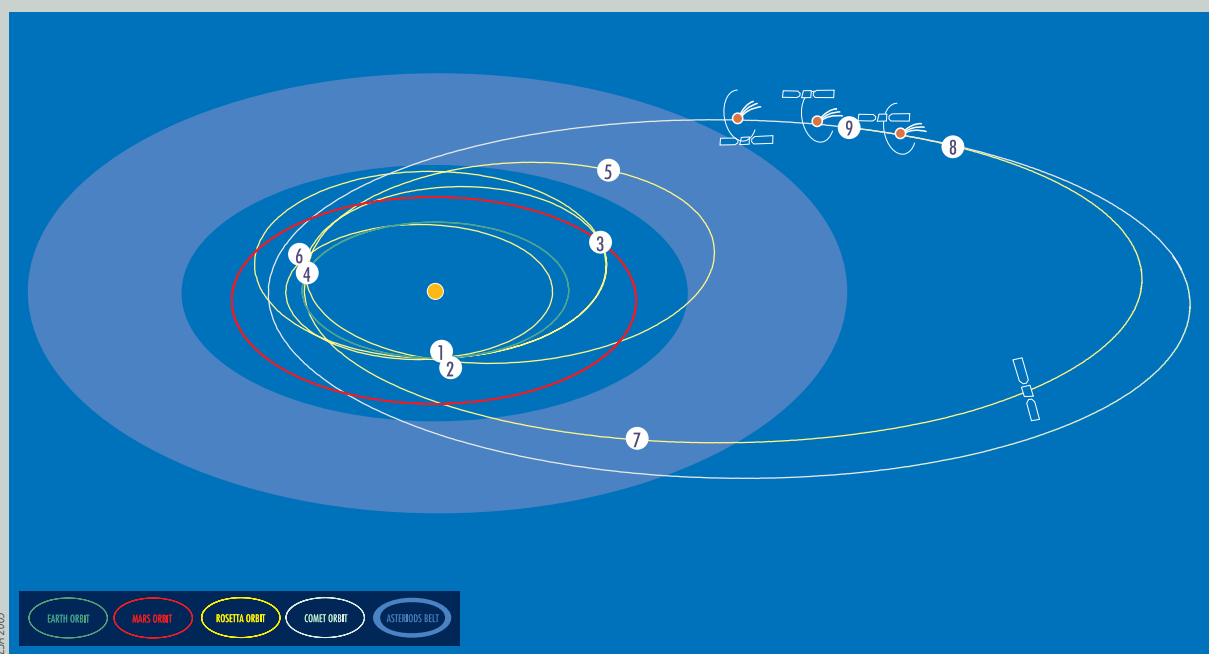
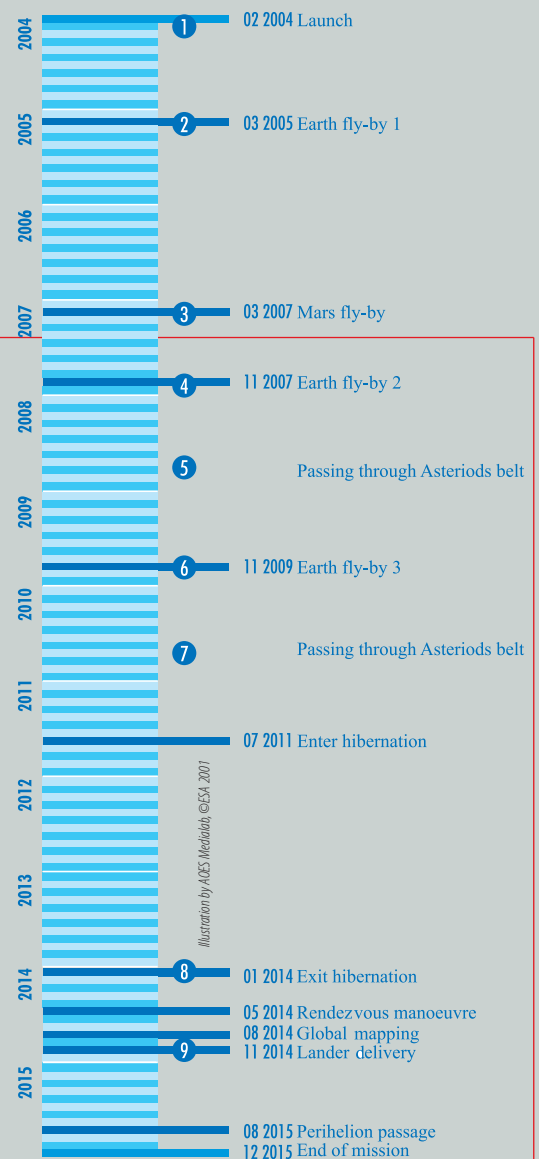
The cosmic billiard ball

Rosetta's 12-year expedition will begin in February 2004, with an Ariane-5 launch from Kourou in French Guiana. The three-tonne spacecraft will be inserted into a parking orbit, then sent on its way towards the outer Solar System.

Unfortunately, no existing rocket, not even the powerful European-built Ariane-5, has the capability to send such a large spacecraft directly to Comet 67P/Churyumov-Gerasimenko. Instead, Rosetta will bounce around the inner Solar System like a 'cosmic billiard ball', circling the Sun almost four times during its ten-year trek to Comet 67P/Churyumov-Gerasimenko. Along this roundabout route, Rosetta will enter the asteroid belt twice and gain velocity from gravitational 'kicks' provided by close fly-bys of Mars (2007) and the Earth (2005, 2007 and 2009).

The spacecraft will eventually arrive in the comet's vicinity in May 2014. Rosetta's thrusters will then brake the spacecraft, so that it can match Comet 67P/Churyumov-Gerasimenko's orbit. Over the next six months, it will edge closer to the black, dormant nucleus until it is only a few dozen kilometres away. The way will then be clear for the exciting transition to global mapping, lander deployment and the comet chase towards the Sun.

During its ten-year trek to Comet 67P/Churyumov-Gerasimenko, Rosetta will bounce around the inner Solar System like a 'cosmic billiard ball'



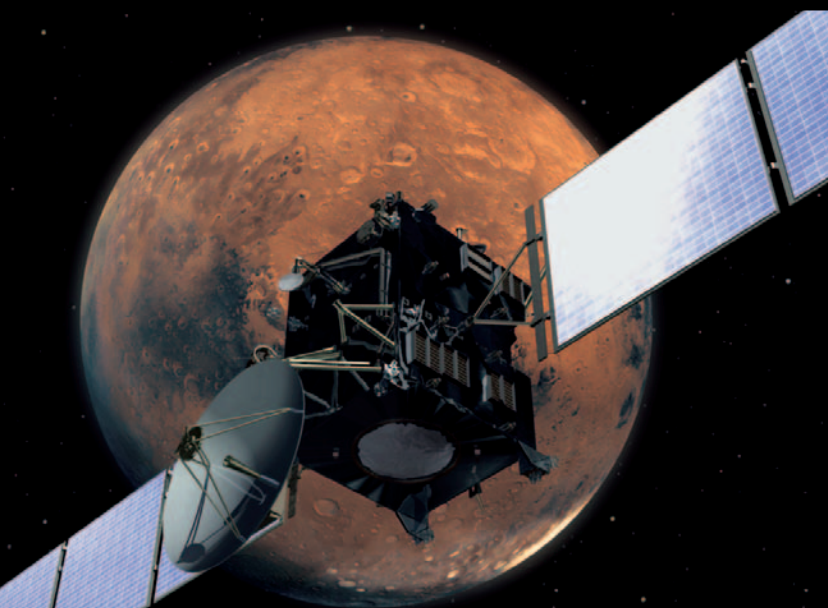


The long trek



Launch (February 2004): The Ariane-5 rocket lifts off from Kourou. After burnout of the lower stage, the spacecraft and upper stage remain in Earth parking orbit (4000 km x 200 km) for about two hours. Ariane's upper stage then ignites to boost Rosetta onto its interplanetary trajectory, before separating from the spacecraft.

Earth fly-bys (March 2005, November 2007 and 2009): Rosetta remains active during the cruise to Earth. Fly-by distance is between 300 and 14 000 kilometres. Operations mainly involve tracking, orbit determination and payload check-out. Orbit correction manoeuvres take place before and after each fly-by.



Mars fly-by (February 2007): Rosetta flies past Mars at a distance of about 200 kilometres, obtaining some science observations. An eclipse of the Earth by Mars lasts for about 37 minutes, causing a communication blackout.

Asteroids fly-bys: The spacecraft goes into passive cruise mode on the way to the asteroid belt. Rosetta observes the asteroids from a distance of a few thousand kilometres. Science data recorded on board are transmitted to Earth after the fly-by.

Deep-space hibernation (July 2011 - January 2014):


After a large deep-space manoeuvre, the spacecraft goes into hibernation. During this period, Rosetta records its maximum distances from the Sun (about 800 million kilometres) and Earth (about 930 million kilometres).



Illustrations by ADIS Medialab, © ESA, 2007

<http://www.esa.int/science>

Rendezvous with a comet



The most difficult phase of the Rosetta mission is the final rendezvous with the fast-moving comet. After the braking manoeuvre in May 2014, the priority will be to edge closer to the nucleus. Since this takes place before Rosetta's cameras have imaged the comet, accurate determination of 67P/Churyumov-Gerasimenko's orbit, based on observations from the ground, is essential.

Comet approach (January–May 2014):

The spacecraft is re-activated prior to the comet rendezvous manoeuvre, during which the thrusters fire for several hours to slow the relative drift rate of the spacecraft and comet to about 25 metres per second. As Rosetta drifts towards the heart of the comet, the mission team will try to avoid any comet dust and achieve good comet illumination conditions. The first camera images will dramatically improve calculations of the comet's position and orbit, as well as its size, shape and rotation. The relative speeds of the spacecraft and comet will gradually be reduced, slowing to 2 metres per second after about 90 days.

Comet mapping/characterisation (August–October 2014):

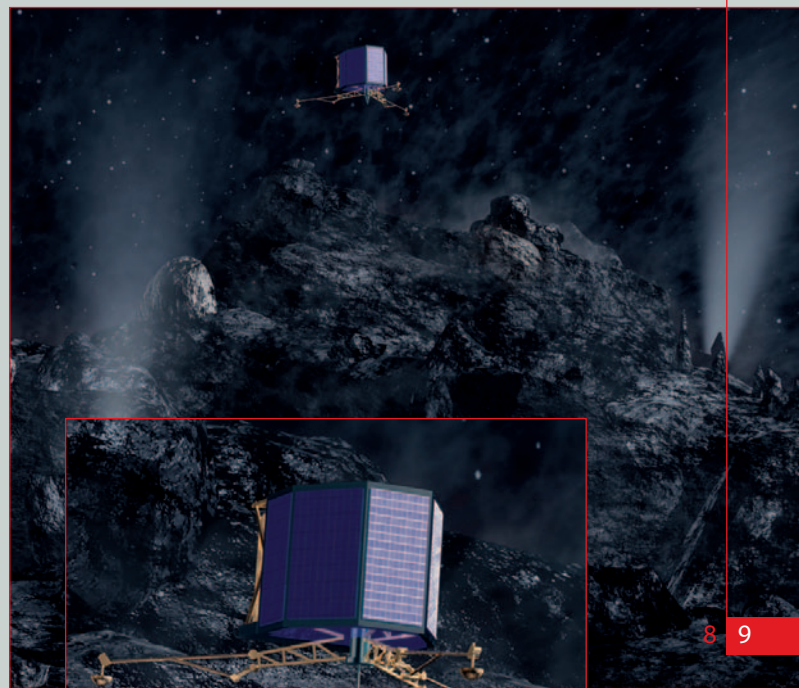
Less than 200 kilometres from the nucleus, images from Rosetta show the comet's spin-axis orientation, angular velocity, major landmarks and other basic characteristics. Eventually, the spacecraft is inserted into orbit around the nucleus at a distance of about 25 kilometres. Their relative speed is now down to a few centimetres per second. The orbiter starts to map the nucleus in great detail. Eventually, five potential landing sites are selected for close observation.

Landing on the comet (November 2014):

Once a suitable landing site is chosen, the lander is released from a height of about 1 kilometre. Touchdown takes place at walking speed — less than 1 metre per second. Once it is anchored to the nucleus, the lander sends back high-resolution pictures and other information on the nature of the comet's ices and organic crust. The data are relayed to the orbiter, which stores them for transmission back to Earth during the next period of contact with a ground station.

Escorting the comet around the Sun (November 2014 – December 2015):

The orbiter continues to orbit Comet 67P/Churyumov-Gerasimenko, observing what happens as the icy nucleus approaches the Sun and then travels away from it. The mission ends in December 2015. Rosetta will once again pass close to Earth's orbit, more than 4000 days after its adventure began.



Debris of the Solar System: asteroids

Our tiny corner of the Universe - the Solar System - is home to one star, nine planets and dozens of planetary satellites. It also contains millions of asteroids and comets – the left-over debris from the cosmic construction site that created the planets and their moons.

Rosetta's task is to study these primitive building blocks at close quarters so that scientists may gain new insights into the events that took place 4600 million years ago, during the birth of the Earth and its planetary neighbours.

Asteroid fly-bys

On the outward leg of its ten-year trek to Comet 67P/Churyumov-Gerasimenko, Rosetta will make two excursions into the main asteroid belt that lies between the orbits of Mars and Jupiter. Scientists have identified a number of possible target asteroids along Rosetta's path. One or more of them will be selected in the course of the mission for a close fly-by.

Only a few asteroids have been observed so far from nearby. Rosetta will obtain spectacular images as it flies by within several thousand kilometres of these primordial rocks. The relative speed will be less than 15 kilometres per second.

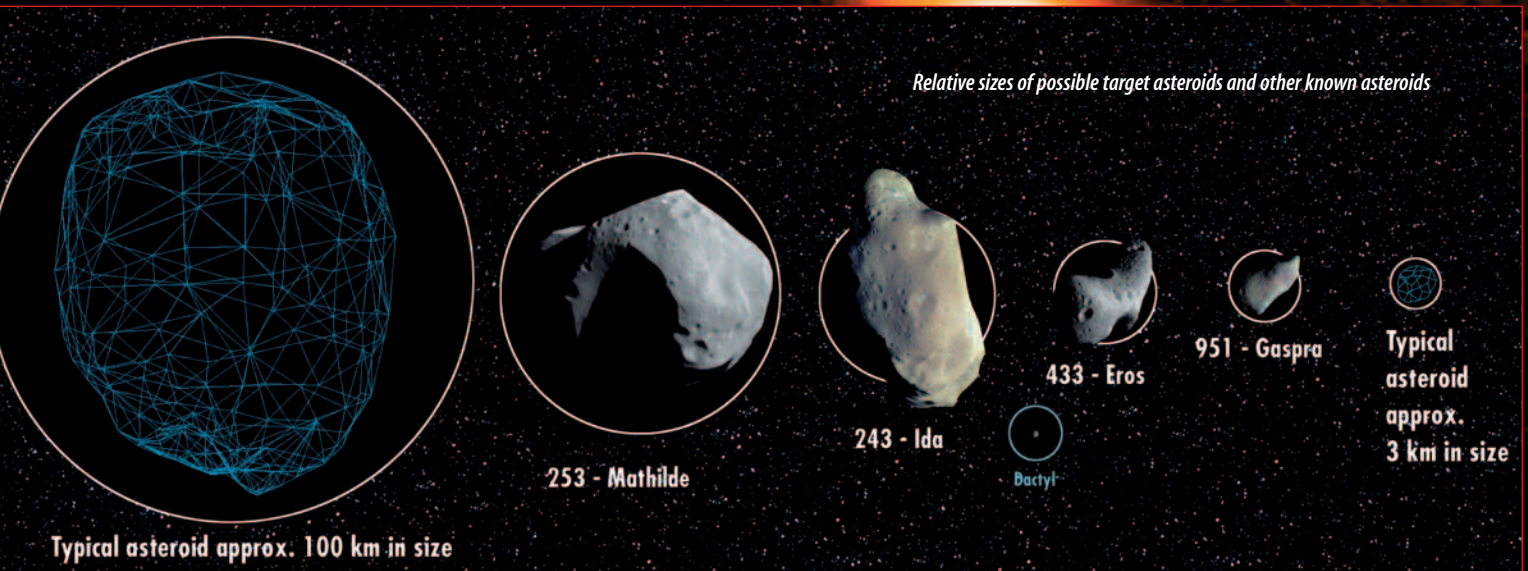
Image of Comet 67P/Churyumov-Gerasimenko

ESA and European Southern Observatory

Comet 67P/Churyumov-Gerasimenko

Diameter of nucleus – estimated (km)	4
Orbital period (years)	6.6
Minimum distance from Sun (million km)	186
Maximum distance from Sun (million km)	857
Orbital eccentricity	0.6
Orbital inclination (degrees)	7.1
Year of discovery	1969
Discoverer	K. Churyumov, University of Kiev, Ukraine S. Gerasimenko, Institute of Astrophysics Dushanbe, Tajikistan

Asteroids are very different in shape and size (ranging from a few kilometres to more than 100 kilometres) as well as in their composition. Rosetta will provide information on the mass and density of the asteroids that it approaches, thus telling us more about their composition. It will also measure their subsurface temperature and look for gases and dust around them.



Comet 67P/Churyumov-Gerasimenko

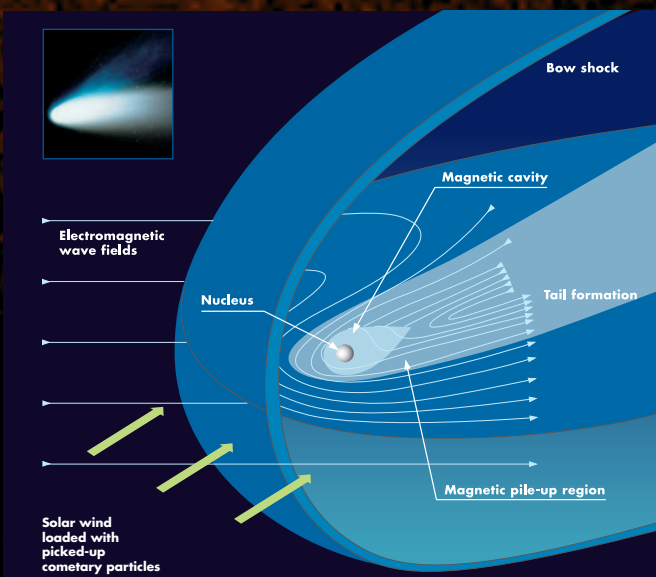
Rosetta will travel far beyond the asteroid belt to reach its main target, Comet 67P/Churyumov-Gerasimenko.

67P/Churyumov-Gerasimenko is a large dirty snowball that orbits the Sun once every 6.6 years. During this time, it commutes between the orbits of Jupiter and the Earth. However, little is known about it, despite its regular visits to the inner Solar System.

Most of the time, its faint image is drowned in a sea of stars, making observations with Earth-based telescopes extremely difficult. However, during its short-lived excursions to the inner Solar System, the warmth of the Sun causes ices on its surface to evaporate and jets of gas to blast dust grains into the surrounding space. Unfortunately, although this enveloping 'coma' of dust and gas increases 67P/Churyumov-Gerasimenko's brightness, it also completely hides the comet's nucleus.

Rosetta's task is to rendezvous with the comet while it still lingers in the cold regions of the Solar System and shows no surface activity. After releasing a lander onto the dormant nucleus, the orbiter will then chase Churyumov-Gerasimenko as it charges headlong towards the inner Solar System at speeds of up to 135 000 kilometres per hour.

Structure of a comet



Rosetta will study the changes in 67P/Churyumov-Gerasimenko's activity as it approaches the Sun



Over an entire year, as it approaches the Sun, Rosetta will orbit the comet, mapping its surface and studying changes in its activity. As its ices evaporate, instruments on board the orbiter will study the dust and gas particles which surround the comet and trail behind it as streaming tails, as well as their interaction with the solar wind.

The nucleus of Halley's Comet as seen from the Giotto spacecraft. Image taken by the Halley Multicolour Camera

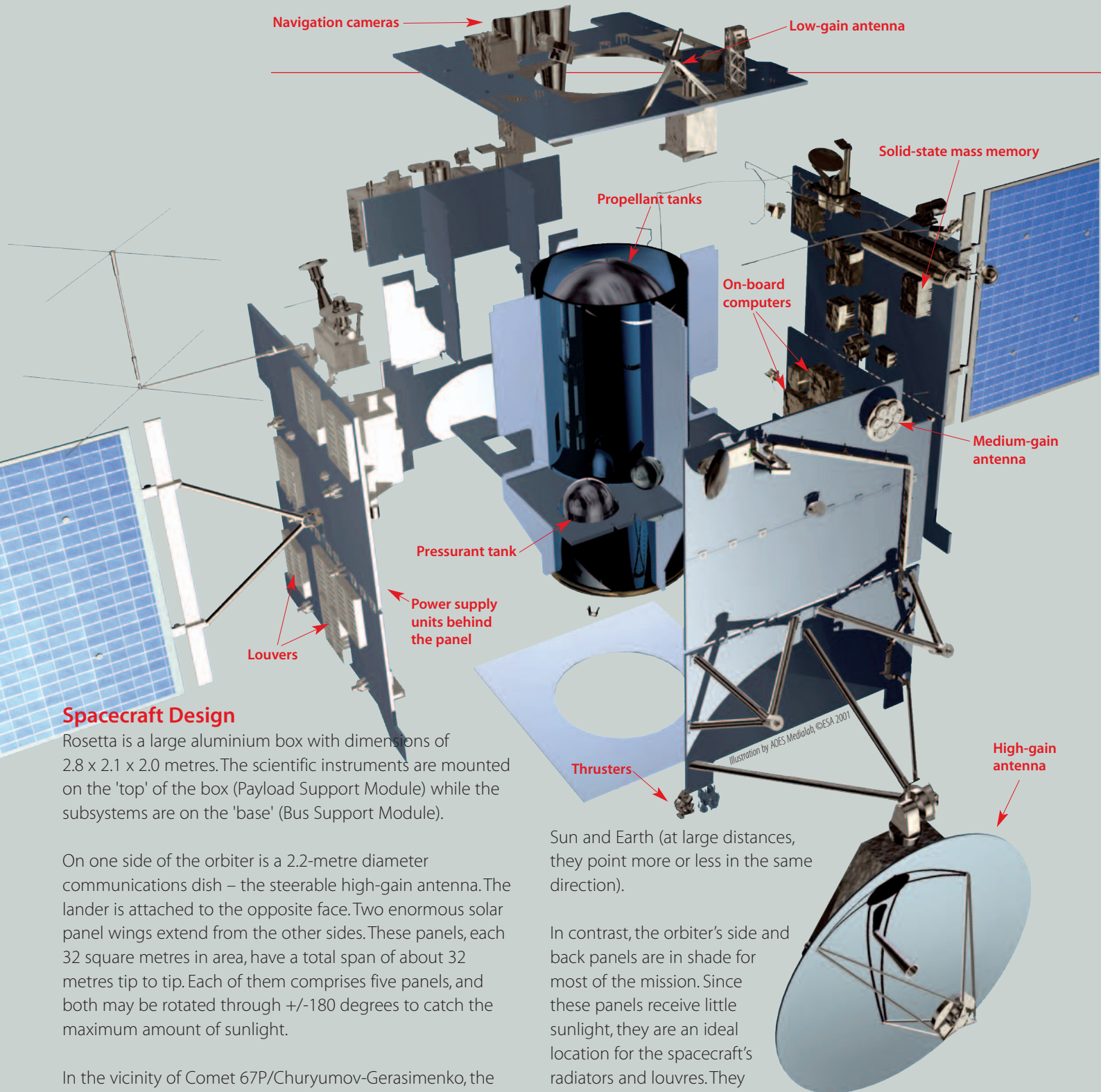


Illustrations by A. OES Medialab, © ESA 2001

Illustrations by A. OES Medialab, © ESA 2001

Courtesy of MPAE, Linde

The Rosetta orbiter



Spacecraft Design

Rosetta is a large aluminium box with dimensions of 2.8 x 2.1 x 2.0 metres. The scientific instruments are mounted on the 'top' of the box (Payload Support Module) while the subsystems are on the 'base' (Bus Support Module).

On one side of the orbiter is a 2.2-metre diameter communications dish – the steerable high-gain antenna. The lander is attached to the opposite face. Two enormous solar panel wings extend from the other sides. These panels, each 32 square metres in area, have a total span of about 32 metres tip to tip. Each of them comprises five panels, and both may be rotated through ± 180 degrees to catch the maximum amount of sunlight.

In the vicinity of Comet 67P/Churyumov-Gerasimenko, the scientific instruments almost always point towards the comet, while the antennas and solar arrays point towards the

Sun and Earth (at large distances, they point more or less in the same direction).

In contrast, the orbiter's side and back panels are in shade for most of the mission. Since these panels receive little sunlight, they are an ideal location for the spacecraft's radiators and louvres. They will also face away from the comet, so damage from comet dust will be minimised.

Spacecraft Vital Statistics

Size: main structure	2.8 x 2.1 x 2.0 m
span of solar arrays	32 m
Launch mass - total	3000 kg (approx.)
- propellant	1670 kg (approx.)
- science payload	165 kg
- lander	100 kg
Solar array output	850 W at 3.4 AU, 395 W at 5.25 AU
Propulsion subsystem	24 bipropellant 10 N thrusters
Operational mission	12 years

Propulsion

At the heart of the orbiter is the main propulsion system. Mounted around a vertical thrust tube are two large propellant tanks, the upper one containing fuel, and the lower one containing the oxidiser. The orbiter also carries 24

thrusters for trajectory and attitude control. Each of these thrusters pushes the spacecraft with a force of 10 Newtons, about the same as experienced by someone holding a large bag of apples. Over half the launch weight of the entire spacecraft is taken up by propellant.

An International Enterprise

Rosetta's industrial team involves more than 50 contractors from 14 European countries and the United States. The prime spacecraft contractor is Astrium Germany. Major subcontractors are Astrium UK (spacecraft platform), Astrium France (spacecraft avionics) and Alenia Spazio (assembly, integration and verification).

 **Canada (CDN)** - SED

 **Australia (AUS)** - Telstra, Western Power

 **United States (US)** - Conax, Honeywell, Starsys, Vacco

 **Norway (N)** - DNV, Kongsberg, Prototech, Raufoss

Finland (FIN) 

Patria Finavitte

Saab Ericsson Space - **Sweden (S)** 

 **Ireland (IRL)** - CAPTEC

TERMA - **Denmark (DK)** 

 **United Kingdom (UK)** - AEA,

Astrium Ltd, MRC, Polyflex

Chess, Fokker, - **The Netherlands (NL)** 

Satellite Services, TNO-TPD

 **Belgium (B)** - Alcatel ETCA, Amos,

Logica, Nexans, RHEA, Spacebel

ASE, Astrium GmbH, - **Germany (D)** 

ND Satcom, Timetech, Vertex

 **France (F)** - Alcatel Space, Astrium SAS, EADS-IV, Snecma, Thomson

AAE, Siemens, - **Austria (A)** 

Steyr Daimler Puch

 **Switzerland (CH)** - Alcatel Space, APCO, Clemessy, Contraves, Captec SIW,

ETEL, Helbling, HTS, Mecanex, RST

 **Spain (E)** - Alcatel Espacio, CASA,

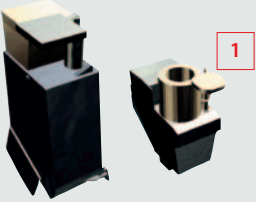
CRISA, Sener, Tecnológica

Alenia Spazio, O. Galileo, Top-Rel - **Italy (I)** 

Companies involved in building the Rosetta orbiter and the ground antenna

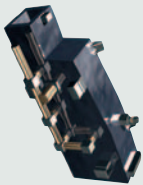
Science from the orbiter

The orbiter's scientific payload includes 11 experiments, in addition to the lander. Scientific consortia from institutes across Europe and the United States have provided these state-of-the-art instruments. All of them are located on the side of the spacecraft that will permanently face the comet during the main scientific phase of the mission.



1

OSIRIS (Optical, Spectroscopic, and Infrared Remote Imaging System): A wide-angle camera and a narrow-angle camera to obtain high-resolution images of the comet's nucleus and asteroids.



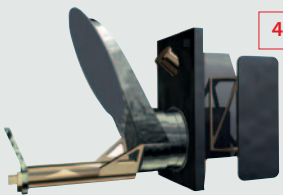
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ALICE (Ultraviolet Imaging Spectrometer): Analyses gases in the coma and tail and measures the comet's production rates of water and carbon monoxide/dioxide. Also provides information on the surface composition of the nucleus.



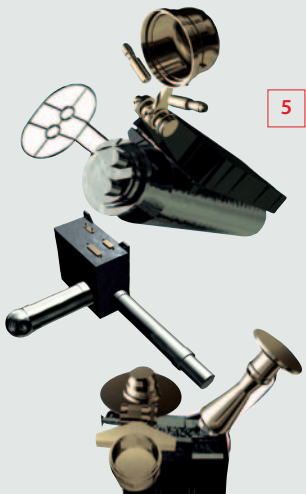
3

VIRTIS (Visible and Infrared Thermal Imaging Spectrometer): Maps and studies the nature of the solids and the temperature on the surface of the nucleus. Also identifies comet gases, characterises the physical conditions of the coma and helps to identify the best landing sites.



4

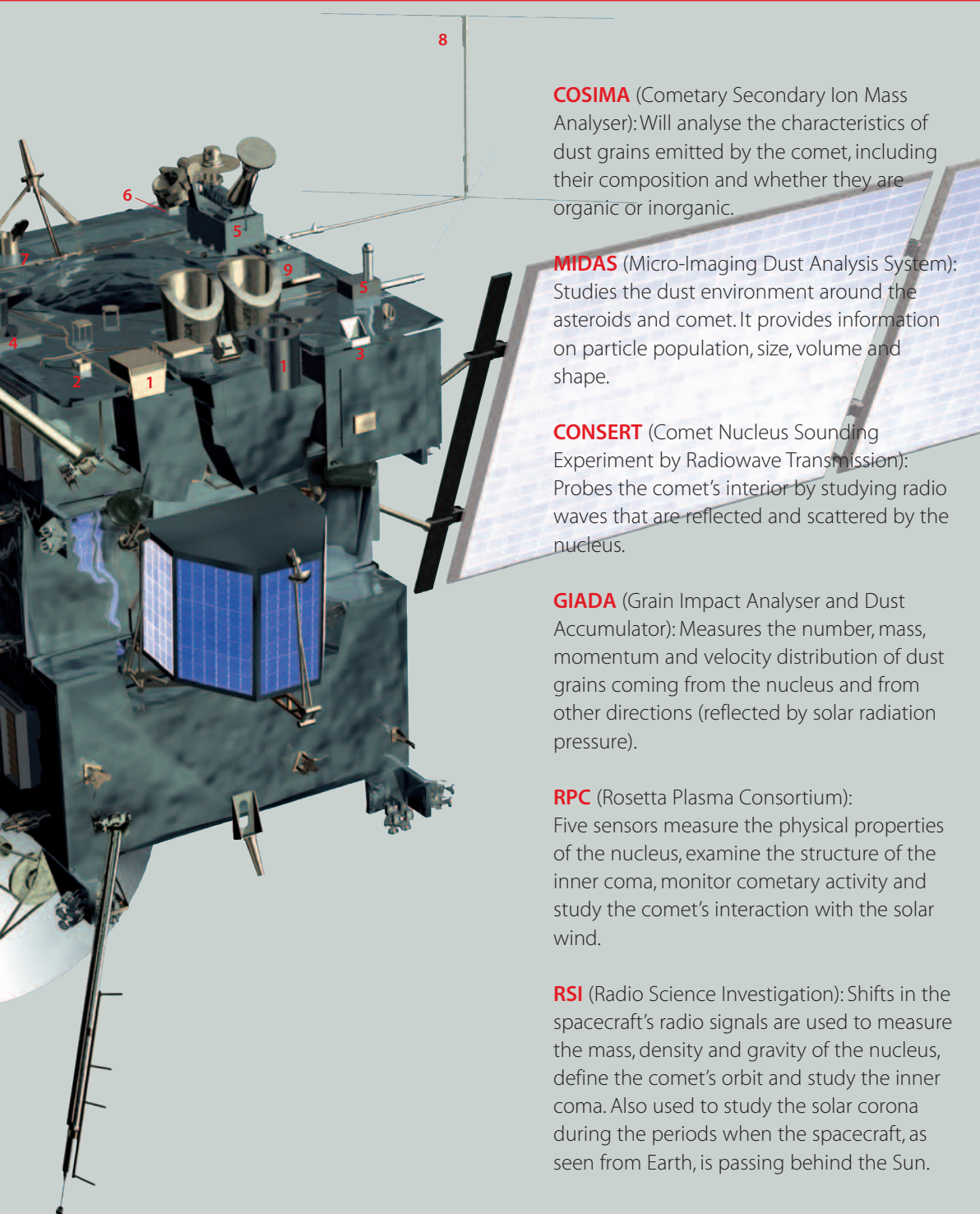
MIRO (Microwave Instrument for the Rosetta Orbiter): Used to determine the abundances of major gases, the surface outgassing rate and the nucleus subsurface temperature. It will also measure the subsurface temperatures of the asteroids that it approaches and will search for gas around them.



5

ROSINA (Rosetta Orbiter Spectrometer for Ion and Neutral Analysis): Two sensors will determine the composition of the comet's atmosphere and ionosphere, the velocities of electrified gas particles, and reactions in which they take part. It will also investigate possible asteroid outgassing.





COSIMA (Cometary Secondary Ion Mass Analyser): Will analyse the characteristics of dust grains emitted by the comet, including their composition and whether they are organic or inorganic.

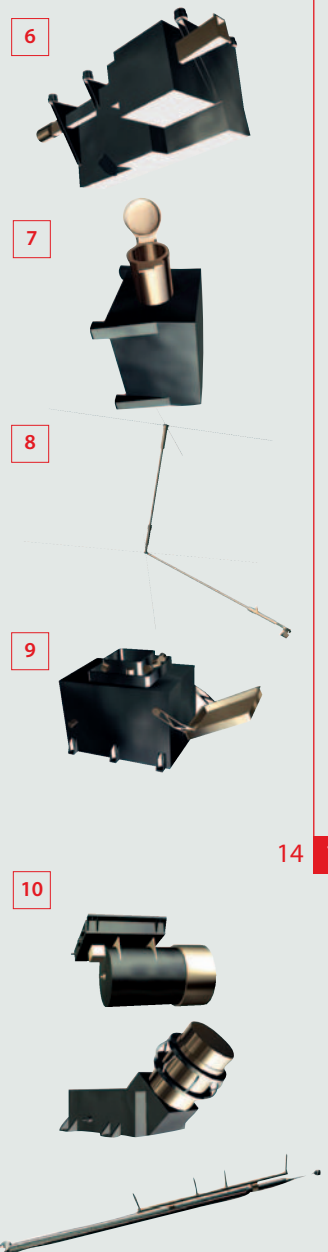
MIDAS (Micro-Imaging Dust Analysis System): Studies the dust environment around the asteroids and comet. It provides information on particle population, size, volume and shape.

CONSERT (Comet Nucleus Sounding Experiment by Radiowave Transmission): Probes the comet's interior by studying radio waves that are reflected and scattered by the nucleus.

GIADA (Grain Impact Analyser and Dust Accumulator): Measures the number, mass, momentum and velocity distribution of dust grains coming from the nucleus and from other directions (reflected by solar radiation pressure).

RPC (Rosetta Plasma Consortium): Five sensors measure the physical properties of the nucleus, examine the structure of the inner coma, monitor cometary activity and study the comet's interaction with the solar wind.

RSI (Radio Science Investigation): Shifts in the spacecraft's radio signals are used to measure the mass, density and gravity of the nucleus, define the comet's orbit and study the inner coma. Also used to study the solar corona during the periods when the spacecraft, as seen from Earth, is passing behind the Sun.



The Rosetta lander

The 100-kilogram Rosetta lander is provided by a European consortium under the leadership of the German Aerospace Research Institute (DLR). Other members of the consortium are ESA and institutes from Austria, Finland, France, Hungary, Ireland, Italy and the UK.

The box-shaped lander is carried on the side of the orbiter until it arrives at Comet 67P/Churyumov-Gerasimenko. Once the orbiter is aligned correctly, the lander is commanded to self-eject from the main spacecraft and unfold its three legs, ready for a gentle touchdown at the end of the ballistic descent. On landing, the legs damp out most of the kinetic energy to reduce the chance of bouncing, and they can rotate, lift or tilt to return the lander to an upright position.

Immediately after touchdown, a harpoon is fired to anchor the lander to the ground and prevent it escaping from the comet's extremely weak gravity. The minimum mission target is one week, but surface operations may continue for many months.

Lander Design

The lander structure consists of a baseplate, an instrument platform, and a polygonal sandwich construction, all made of carbon fibre. Some of the instruments and subsystems are beneath a hood that is covered with solar cells. An antenna transmits data from the surface to Earth via the orbiter. The lander carries nine experiments, with a total mass of about 21 kilograms. It also carries a drilling system to take samples of subsurface material.

Scientific Experiments

COSAC (Cometary Sampling and Composition experiment): One of two evolved gas analysers. It detects and identifies complex organic molecules from their elemental and molecular composition.

MODULUS PTOLEMY: Another evolved gas analyser which obtains accurate measurements of isotopic ratios of light elements.



The Rosetta lander, anchored to 67P/Churyumov-Gerasimenko's surface, will work for a minimum mission target of one week, but its operations may continue for many months

MUPUS (Multi-Purpose Sensors for Surface and Subsurface Science): Uses sensors on the lander's anchor, probe and exterior to measure the density, thermal and mechanical properties of the surface.

ROMAP (Rosetta Lander Magnetometer and Plasma Monitor): A magnetometer and plasma monitor to study the local magnetic field and the comet/solar wind interaction.

SESAME (Surface Electrical, Seismic and Acoustic Monitoring Experiments): Three instruments to measure properties of the comet's outer layers. The Cometary Acoustic Sounding Surface Experiment measures the way sound travels through the surface. The Permittivity Probe investigates its electrical characteristics and the Dust Impact Monitor measures dust falling back to the surface.

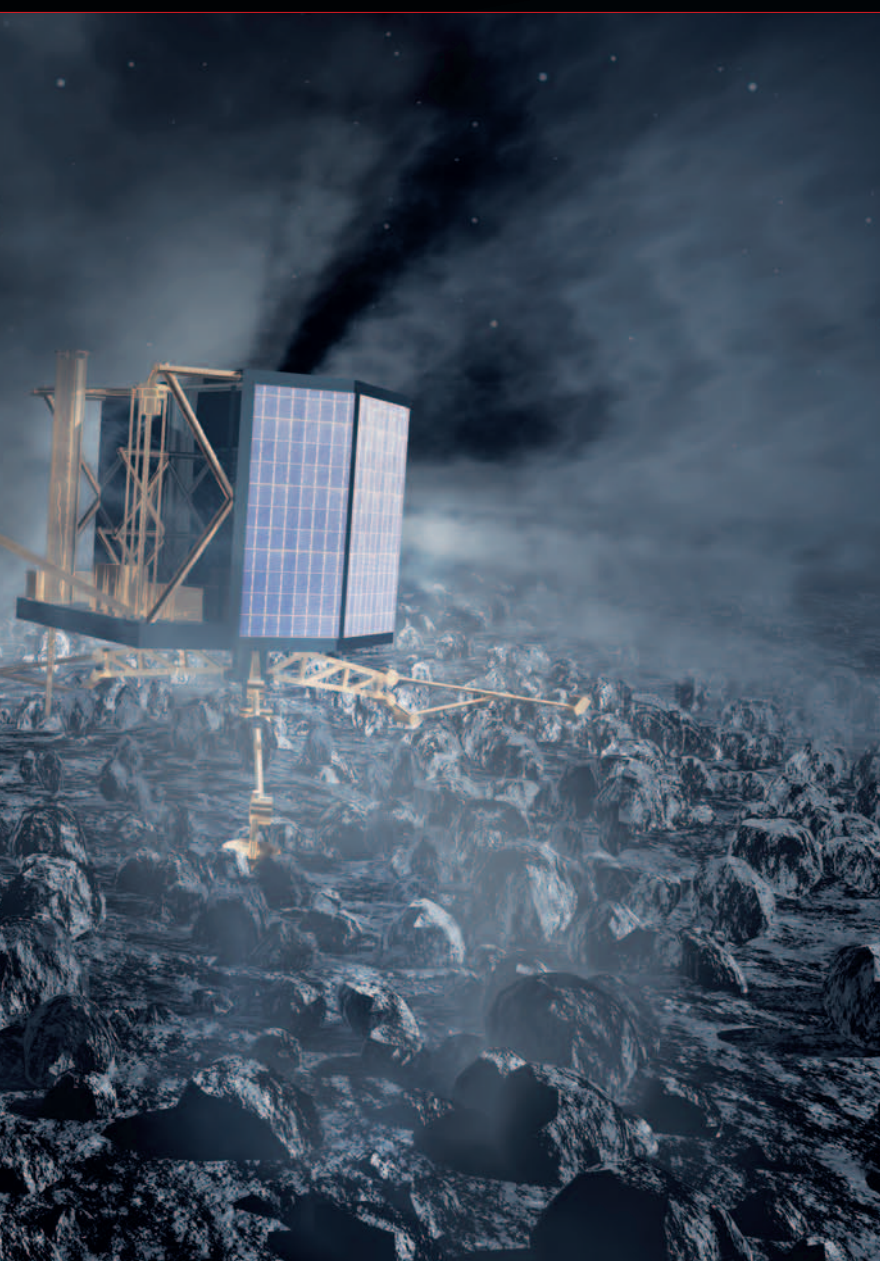
APXS (Alpha X-ray Spectrometer): Lowered to within 4 centimetres of the ground, it detects alpha particles and X-rays which provide information on the elemental composition of the comet's surface.

CONSERT (Comet Nucleus Sounding Experiment by Radiowave Transmission): Probes the internal structure of the nucleus. Radio waves from the CONSERT experiment on the orbiter travel through the nucleus and are returned by a transponder on the lander.

ÇIVA: Six identical micro-cameras take panoramic pictures of the surface. A spectrometer studies the composition, texture and albedo (reflectivity) of samples collected from the surface.

ROLIS (Rosetta Lander Imaging System): A CCD camera to obtain high-resolution images during descent and stereo-panoramic images of areas sampled by other instruments.

SD2 (Sample and Distribution Device): Drills more than 20 centimetres into the surface, collects samples and delivers them to different ovens or for microscope inspection.



Long-distance communication

During Rosetta's prolonged interplanetary expedition, reliable communications between the spacecraft and the ground will be essential. All of the scientific data collected by the instruments on board the spacecraft are sent to Earth via a radio link. The operations centre, in turn, remotely controls the spacecraft and its scientific instruments via the same radio link.

Down to Earth

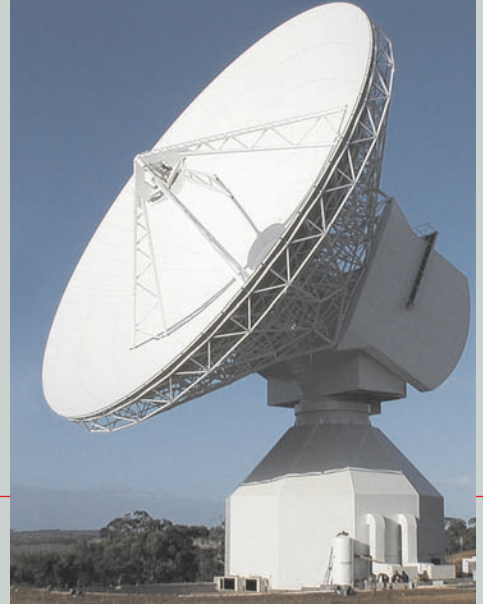
The Mission Operations Centre during Rosetta's entire 12-year journey is the European Space Operations Centre (ESOC) in Darmstadt, Germany. ESOC is responsible for all mission operations, including:

- mission planning, monitoring and control of the spacecraft and its payload;
- determination and control of the spacecraft trajectory;
- distribution of the scientific data received from the spacecraft to the Rosetta scientific community and the Principal Investigators.

A Science Operations Centre will also be located at ESOC during the active phases of the mission. Its task will be to coordinate the requests for scientific operations received from the scientific teams supporting both the orbiter and the lander instruments.

Lander operations will be coordinated through the German Aerospace Research Centre (DLR) control centre in Cologne, and the scientific control centre of CNES, the French space agency, in Toulouse.

Ground control at the European Space Operations Centre (ESOC) in Darmstadt, Germany.



Quite a Dish

Radio communications between Rosetta and the ground will use a newly developed deep-space antenna which has been built by ESA at New Norcia, near Perth in Western Australia. This 35-metre diameter parabolic antenna concentrates the energy of the radio signal in a narrow beam, allowing it to reach distances of more than 1000 million kilometres from Earth. Signals are transmitted and received in two radio frequency bands: S-band (2 GHz) and X-band (8 GHz). The radio signals, travelling at the speed of light, will take up to 50 minutes to cover the distance between the spacecraft and Earth!

ESA is building another 35-metre parabolic antenna at Cerebros in Spain. It will begin to operate in 2005 providing further coverage for Rosetta.



Illustration by AOES Medialab, ©ESA 2001

What a Memory!

During the mission, the rate at which data can be sent from Rosetta to Earth will vary from 10 to 22 000 bits per second. However, the rotation of the Earth means that real-time communications will not always be possible. The spacecraft will be visible from the New Norcia antenna for an average of 12 hours per day. In addition, there will be several periods of communications blackout when the spacecraft passes behind the Sun. To overcome these breaks in communication, Rosetta's solid-state memory of 25 Gbits capacity is able to store all scientific data and then transmit them to Earth at the next opportunity.

<http://www.esa.int/science>

To communicate with Earth, Rosetta will use the impressive 35 metre parabolic antenna recently built by ESA in New Norcia near Perth, W. Australia

Rosetta overview

Launch: Early 2004

Launcher: Ariane-5

Spacecraft Launch Mass: Approximately 3000 kg (fully fuelled) including 1670 kg of propellant, 165 kg of scientific payload for the orbiter and 100 kg for the lander

Dimensions: Main spacecraft 2.8 x 2.1 x 2.0 m, on which all subsystems and payload equipment are mounted. Two 14 m solar panels with a total area of 64 square metres

Scientific Payload - Orbiter:

ALICE - Ultraviolet Imaging Spectrometer (S.A. Stern, USA)
CONSERT - Comet Nucleus Sounding (W. Kofman, France)
COSIMA - Cometary Secondary Ion Mass Spectrometer (J. Kissel, Germany)
GIADA - Grain Impact Analyser and Dust Accumulator (L. Colangeli, Italy)
MIDAS - Micro-Imaging Analysis System (W. Riedler, Austria)
MIRO - Microwave Instrument for the Rosetta Orbiter (S. Gulkis, USA)
OSIRIS - Rosetta Orbiter Imaging System (H.U. Keller, Germany)
ROSINA - Rosetta Orbiter Spectrometer for Ion and Neutral Analysis (H. Balsiger, Switzerland)
RPC - Rosetta Plasma Consortium (A. Eriksson, Sweden; J. Burch, USA; K.-H. Glassmeier, Germany; R. Lundin, Sweden; J.G. Trotignon, France; C. Carr, UK)
RSI - Radio Science Investigation (M. Pätzold, Germany)
VIRTIS - Visible and Infrared Mapping Spectrometer (A. Coradini, Italy)

Scientific Payload - Lander:

APXS - Alpha Proton X-ray Spectrometer (R. Rieder, Germany)
ÇIVA/ROLIS - Rosetta Lander Imaging System (J.P. Bibring, France; S. Mottola, Germany)
CONSERT - Comet Nucleus Sounding (W. Kofman, France)
COSAC - Cometary Sampling and Composition experiment (H. Rosenbauer, Germany)
MODULUS PTOLEMY - Evolved Gas Analyser (I. Wright, UK)
MUPUS - Multi-Purpose Sensor for Surface and Subsurface Science (T. Spohn, Germany)
ROMAP - Rosetta Lander Magnetometer and Plasma Monitor (U. Auster, Germany; I. Apathy, Hungary)
SD2 - Sample and Distribution Device (A. Ercoli Finzi, Italy)
SESAME - Surface Electrical and Acoustic Monitoring Experiment, Dust Impact Monitor (D. Möhlmann, Germany; W. Schmidt, Finland; I. Apathy, Hungary)

Orbit: Interplanetary, out to 5.25 AU (about 790 million km from the Sun)

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