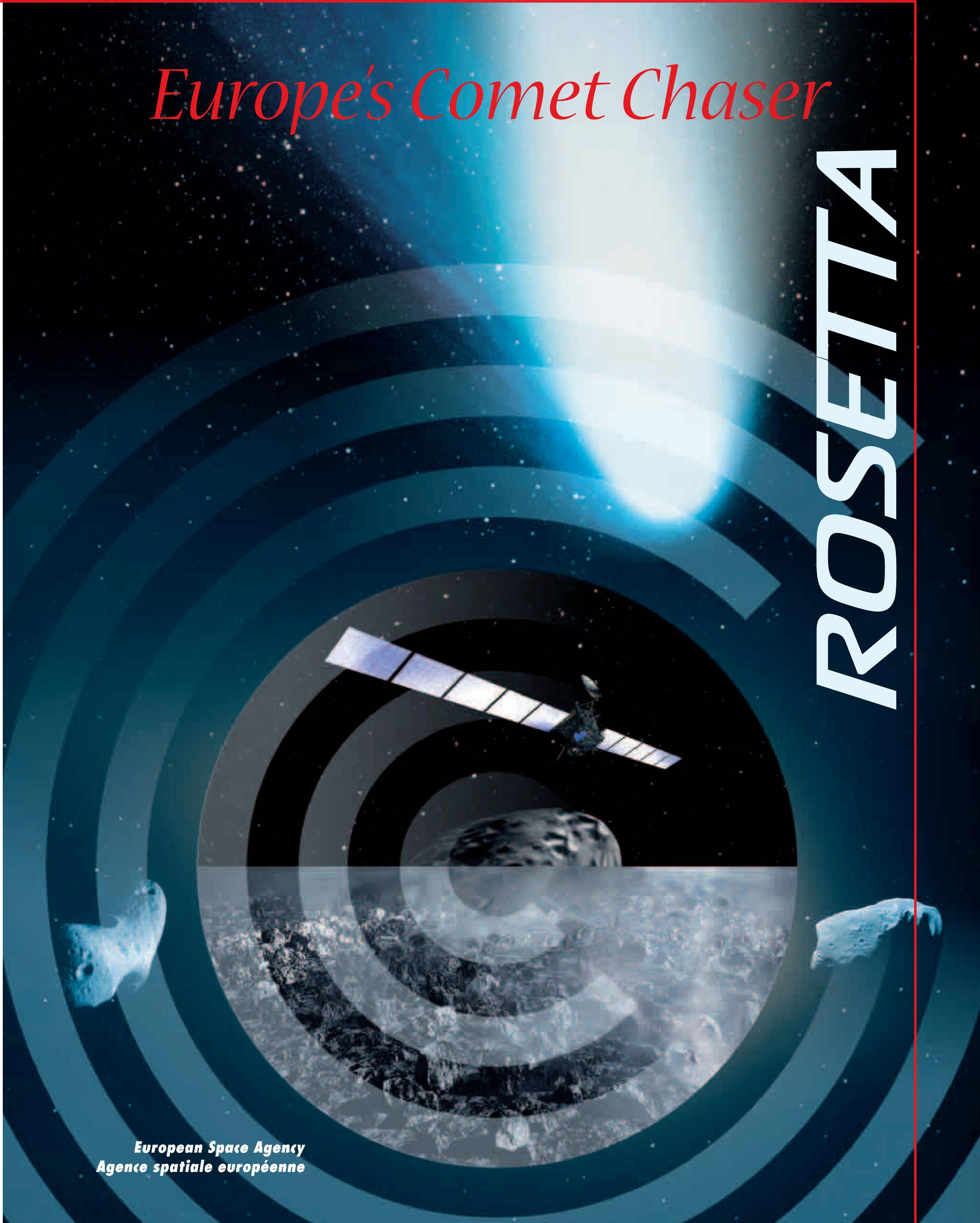
esa

BR-179
September 2001

Europe's Comet Chaser

ROSETTA

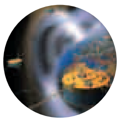


European Space Agency
Agence spatiale européenne

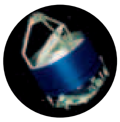
About ESA

The European Space Agency (ESA) was formed on 31 May 1975. It currently has 15 Member States: Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom. Canada is also a partner in some of the ESA programmes.

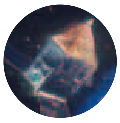
The ESA Science Programme has launched a series of innovative and successful missions. Highlights of the programme include:



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

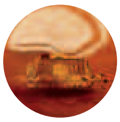


Giotto, which took the first close-up pictures of a comet nucleus (Halley) and completed flybys of Comets Halley and Grigg-Skjellerup.



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

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://sci.esa.int

Prepared by: Science Programme Communication Service
Text by: Peter Bond
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
Copyright: © 2001 European Space Agency
ISSN No.: 0250-1589
ISBN No.: 92-9092-698-8
Price: 15 Dfl/7 Euros
Printed in The Netherlands

Illustrations by AOES Medialab, ©ESA 2001

Rosetta

Europe's Comet Chaser

Contents

Rosetta:

Europe's Comet Chaser

In November 1993, the International Rosetta Mission was approved as a Cornerstone Mission within 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.

The adventure will begin in January 2003, when a European Ariane-5 rocket lifts off from Kourou in French Guiana. During a circuitous eight-year trek through the Solar System, Rosetta will cross the asteroid belt and travel into deep space, to more than five times Earth's distance from the Sun. Its destination will be a periodic comet known as 46P/Wirtanen.

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

The Rosetta Orbiter will rendezvous with Comet Wirtanen 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. Two more years will pass before the remarkable mission draws to a close in July 2013. By then, both the spacecraft and the comet will have returned to the inner Solar System.

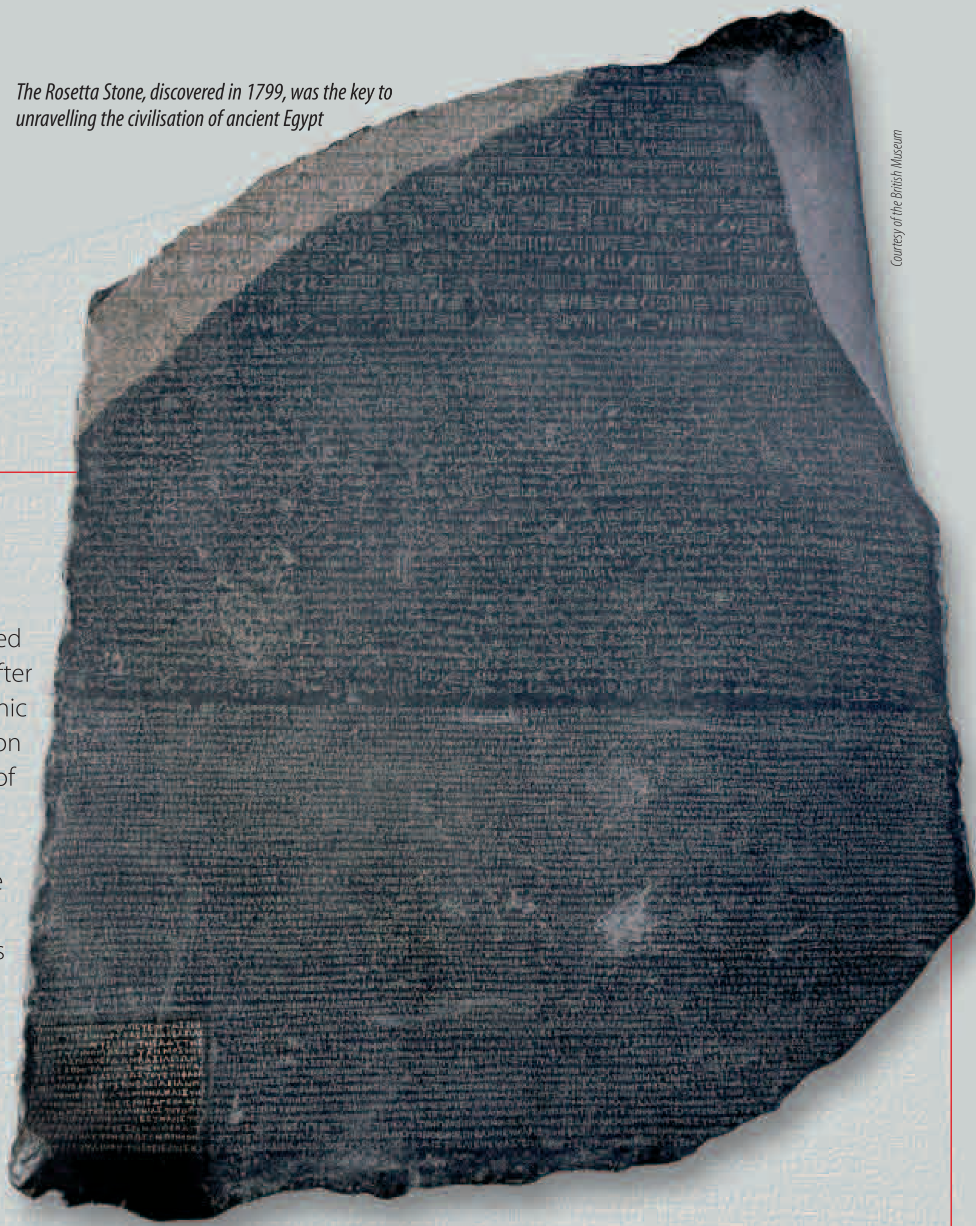
An Historic Mission

The Rosetta mission will achieve many historic landmarks:

- **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 Wirtanen, the Rosetta Orbiter will dispatch 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 Wirtanen, Rosetta will make the first flybys of the main-belt asteroids Siwa and Otawara.**
- **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, essential ingredients for life as we know it. **Did life on Earth begin with the help of comet seeding? Rosetta will help us to find the answer to this fundamental question.**

The Rosetta Stone, discovered in 1799, was the key to unravelling the civilisation of ancient Egypt



Courtesy of the British Museum

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 unravelling the civilisation of ancient Egypt.

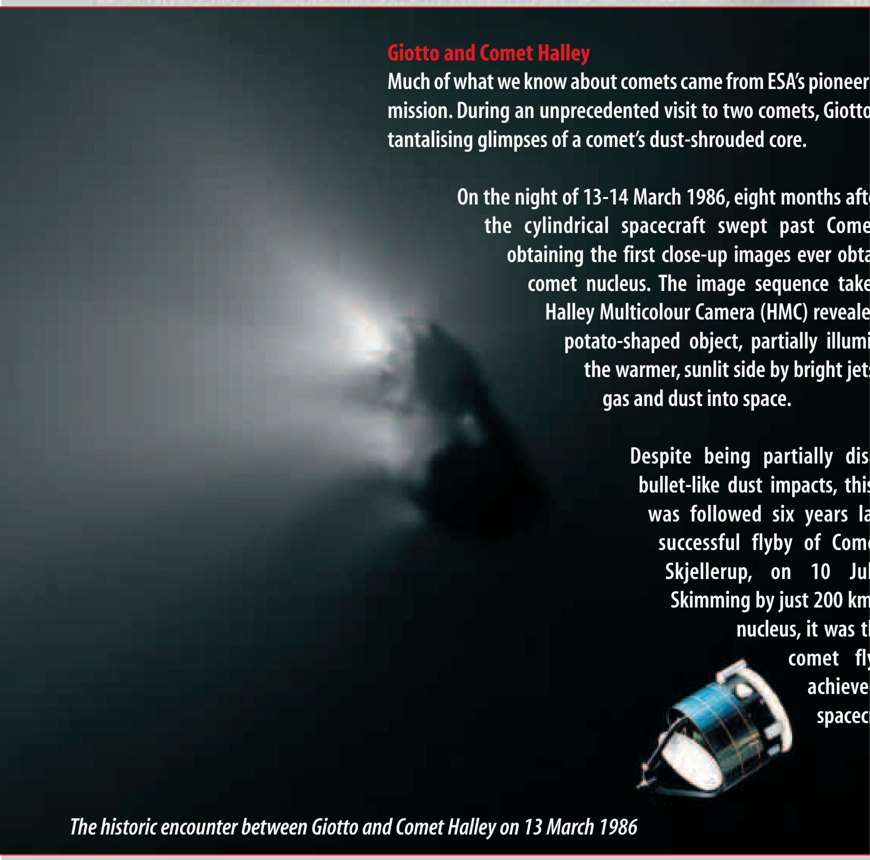
French soldiers discovered the unique Stone in 1799, as they prepared to demolish a wall near the village of Rashid (Rosetta) in Egypt's Nile delta. The carved inscriptions on the Stone included hieroglyphics – the written language of ancient Egypt – and Greek, which was readily understood. After the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

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 taken by the Halley Multicolour Camera (HMC) 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 six years later by a successful flyby of Comet Grigg-Skjellerup, on 10 July 1992. Skimming by just 200 km from the nucleus, it was the closest comet flyby ever achieved by any spacecraft.



The historic encounter between Giotto and Comet Halley on 13 March 1986

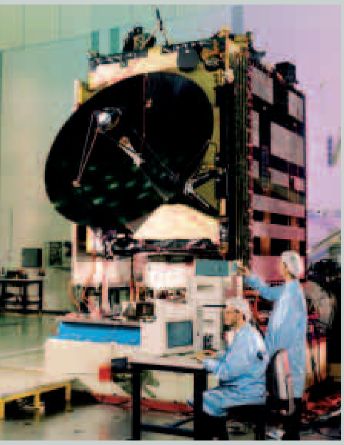
Image composite: ©ESA 2001/Giotto HMC image: MPAe, Lindau

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 the 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.

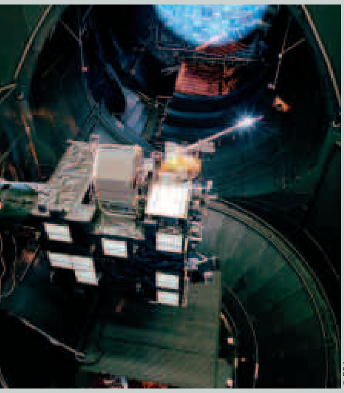
Just as the Rosetta Stone provided the key to an ancient civilisation, so ESA's Rosetta spacecraft will unlock the mysteries of the oldest building blocks of our Solar System – the comets. As the worthy successor of Champollion and Young, Rosetta will allow scientists to look back 4.6 billion years to 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 two asteroids. Ensuring that the spacecraft survives the hazards of travelling through deep space for more than 10 years is therefore one of the great challenges of the Rosetta mission.



©ESA



©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

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

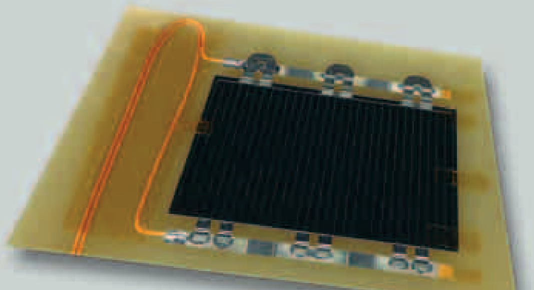
Instructions from the ground take up to 50 minutes to reach the spacecraft and so Rosetta must have the 'intelligence' to look after itself. This is done by its onboard computers, whose tasks include data management and attitude and orbit control. In case any problems arise during the lengthy cruise,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

Hot and Cold

Temperature control was a major headache for the 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 (e.g. fuel tanks, pipework and thrusters), placing louvers over the radiators, and wrapping the spacecraft in multi-layered insulation blankets to cut down 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 km from the Sun, where sunlight levels are only 4% those on Earth. Hundreds of thousands of specially developed, non-reflective, silicon cells generate up to 8700 W in the inner Solar System and around 400 W for the deep-space comet encounter.



Close-up of a single solar-array cell

©ESA

The cosmic billiard ball

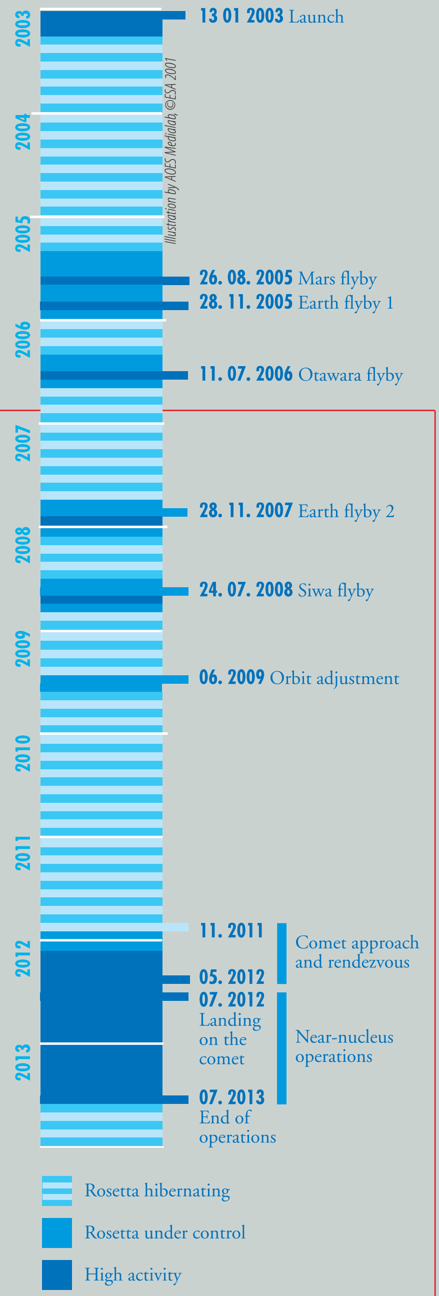
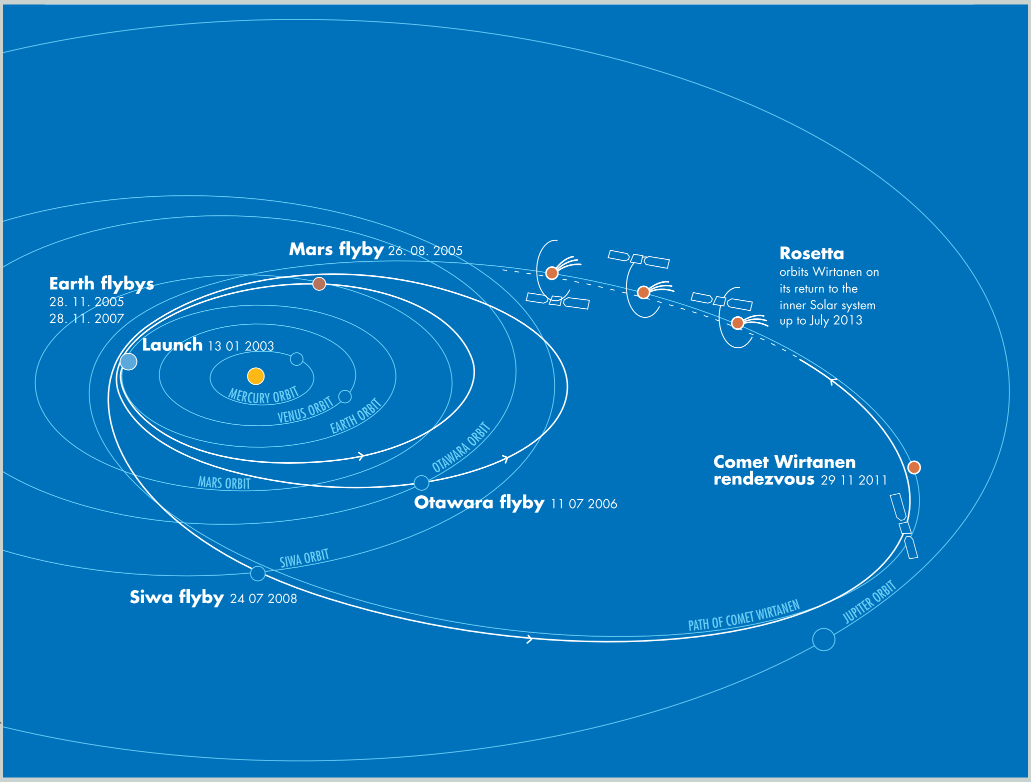


Illustration by AOES Medialab, ©ESA 2001

Rosetta's 10 year expedition will begin in January 2003, with an Ariane-5 launch from Kourou in French Guiana. The three-tonne spacecraft will first be inserted into a parking orbit, before being 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 Wirtanen. Instead, Rosetta will bounce around the inner Solar System like a cosmic billiard ball, circling the Sun almost four times during its eight-year trek to Comet Wirtanen. Whilst following this roundabout route, Rosetta will enter the asteroid belt twice and gain velocity from gravitational 'kicks' provided by close flybys of Mars (2005) and the Earth (2005 and 2007).

The spacecraft will eventually arrive in the comet's vicinity in November 2011. Rosetta's thrusters will then brake the spacecraft, so that it can match Comet Wirtanen's orbit. Over the next six months, it will edge closer to the black, dormant nucleus until it is only a few dozen km 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 eight-year trek to Comet Wirtanen, Rosetta will bounce around the inner Solar System like a cosmic billiard ball

The long trek

1 Launch (13 January 2003 – Central European Time): 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.

2 Commissioning (January – April 2003): The spacecraft deploys its solar arrays and turns toward the Sun. Over the next three months, all systems are checked and the scientific payload is commissioned. Rosetta then goes into a low activity mode for the cruise to Mars.

3 Mars Flyby (26 August 2005):

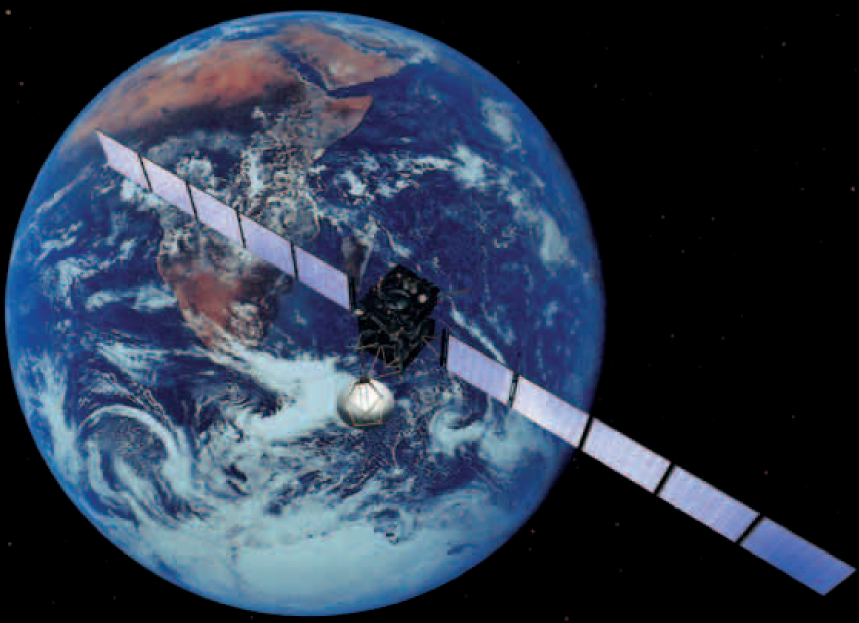
Rosetta flies past Mars at a distance of about 200 km, obtaining some science observations. An eclipse of the Earth by Mars lasts for about 37 minutes, causing a communications blackout.

4 First Earth Flyby (28 November 2005):

Rosetta remains active during the cruise to Earth. The flyby distance is about 4500 km. Operations mainly involve tracking and orbit determination. Orbit-correction manoeuvres take place before and after the flyby.

5 Otawara Flyby (11 July 2006):

The spacecraft goes into passive cruise mode on the way to asteroid Otawara. Rosetta observes the tiny asteroid from a distance of about 2200 km. Science data recorded onboard are transmitted to Earth after the flyby.

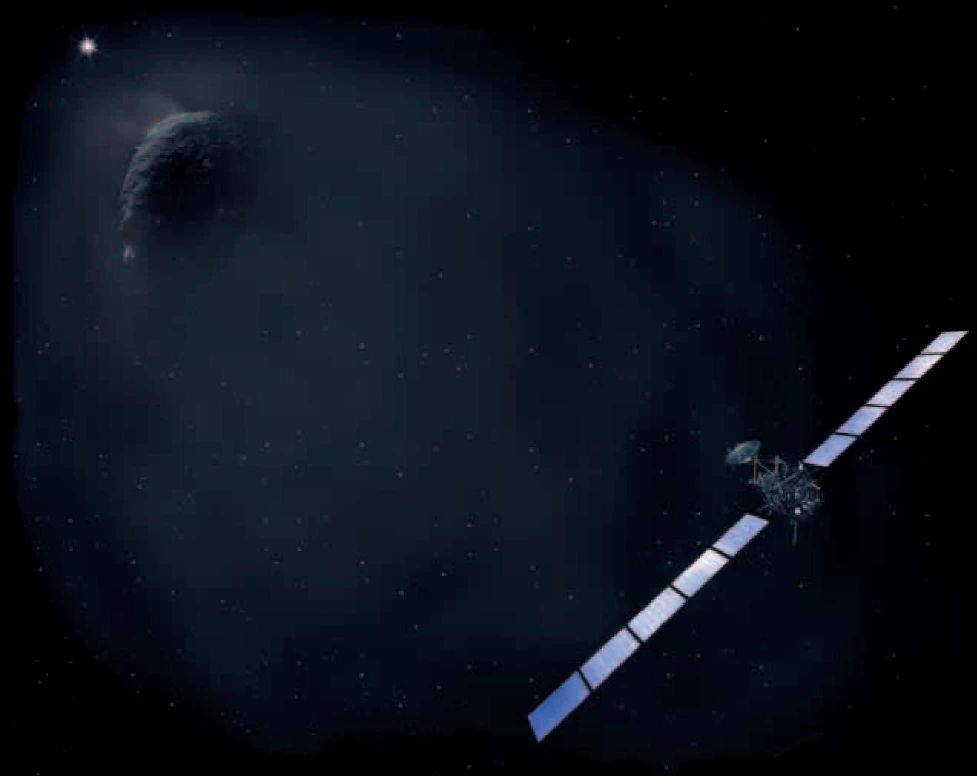


6 Second Earth Flyby (28 November 2007):

The spacecraft is once again in passive cruise mode prior to the second Earth gravity assist. This time, Rosetta passes about 1370 km above our planet. Operations are similar to those during the first Earth flyby.

7 Siwa Flyby (24 July 2008):

Once again, the spacecraft is put back into passive cruise mode on its way to the large asteroid Siwa. Flyby operations are similar to the Otawara flyby, although at a greater distance (about 3500 km).



8 Deep Space Hibernation and Comet Rendezvous (June 2009 – November 2011):

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 km) and Earth (about 1 billion km). The spacecraft is reactivated 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 m/s.

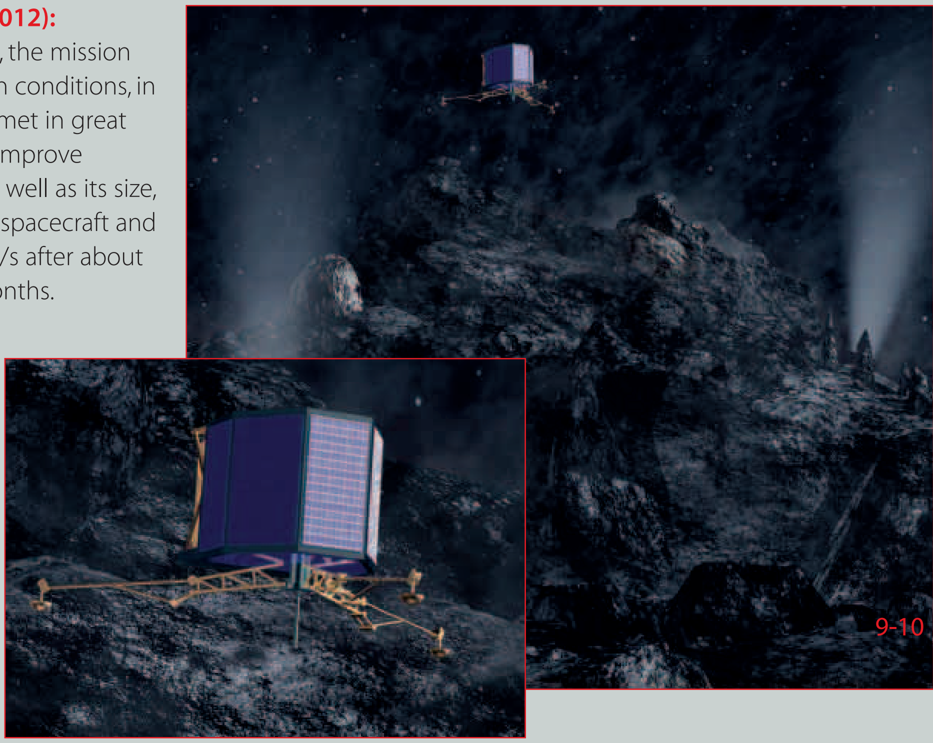
The Rosetta Lander is released towards comet Wirtanen

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 November 2011, the priority will be to edge closer to the nucleus. Since this takes place before Rosetta's cameras have imaged the comet, accurate calculations of Wirtanen's orbit, based on ground-based observations, are essential.

9 Comet Approach (November 2011 – May 2012):

As Rosetta drifts towards the heart of the comet, the mission team will try to achieve good comet illumination conditions, in order to study the dynamic properties of the comet in great detail: 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 velocities of the spacecraft and comet will gradually be reduced, slowing to 2 m/s after about 90 days. This phase could be reduced to four months.



9-10

10 Comet Mapping / Characterisation (May – June 2012):

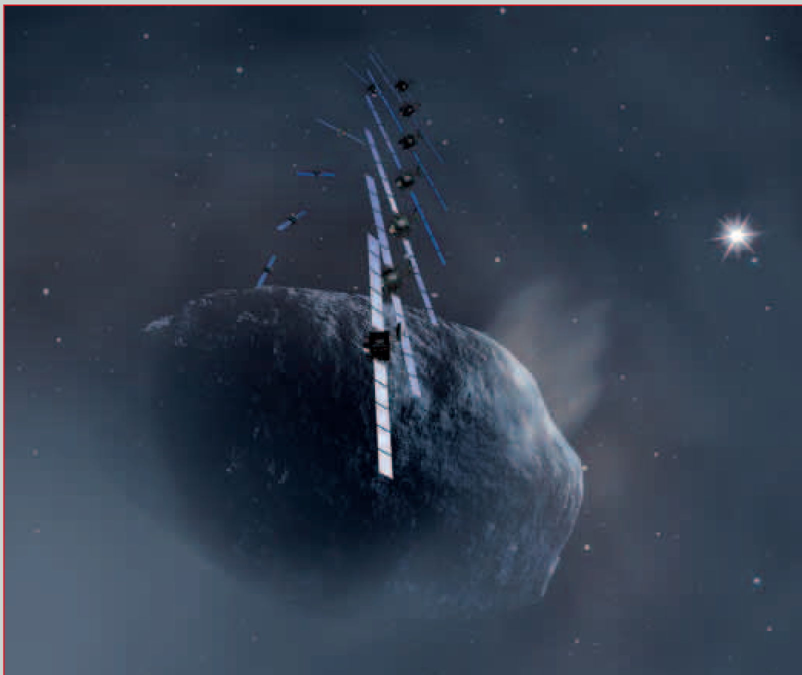
Less than 200 km from the nucleus, images from Rosetta show the comet's attitude, angular velocity, major landmarks and other basic characteristics. Eventually, the spacecraft is inserted into orbit around the nucleus at a distance of about 35 km. Their relative velocity is now down to a few cm/s. The Orbiter starts to map the nucleus in great detail. Eventually, five potential landing sites are selected for close observation.

11 Landing on the Comet (July 2012):

Once a suitable landing site is chosen, the Lander is released from a height of about 1 km. Touch-down takes place at walking speed – less than 1 m/s. 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 organics in the crust. The data are relayed to the Orbiter, which stores them for downlinking to Earth during the next ground-station contact.

12 Escorting the Comet (July 2012 – July 2013):

The Orbiter continues to orbit Comet Wirtanen, observing what happens as the icy nucleus approaches the Sun. The mission ends in July 2013, at the time of the comet's closest approach to the Sun (perihelion). Rosetta will once again be close to Earth's orbit, more than 3800 days after its adventure began.



Debris of the Solar System:

asteroids Otawara and Siwa

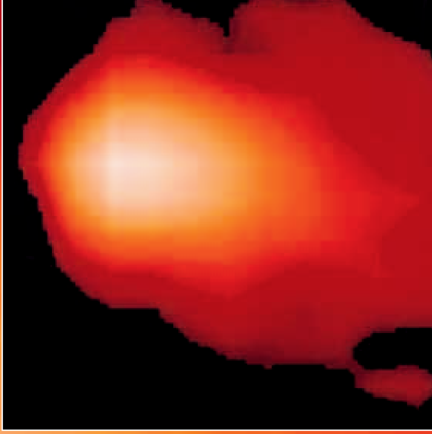
Our tiny corner of the Universe – the Solar System – is home to one star, nine planets, and dozens of planetary satellites. It also contains untold billions of asteroids and comets – the left-over debris from the cosmic construction site that created the planets and their moons. Rosetta's task is to study three of these primitive building blocks at close quarters so that scientists may gain new insights into the events that took place 4.6 billion years ago, during the birth of the Earth and its planetary neighbours.

Two Asteroid Flybys

On the outward leg of its eight-year trek to Comet Wirtanen, Rosetta will make two excursions into the main asteroid belt that lies between the orbits of Mars and Jupiter. On each visit, Rosetta will send back the first detailed pictures of and scientific data on the asteroids 4979 Otawara and 140 Siwa.

Asteroid Vital Statistics	4979 Otawara	140 Siwa
Average distance from Sun (million km)	324	409
Orbital period	3.19 years	4.52 years
Size (estimated)	2.6 – 4 km	110 km
Rotation period (estimated)	2 h 42 m	4 h 38 m
Orbital inclination (degrees)	0.91	3.19
Orbital eccentricity	0.1449	0.2157
Asteroid type	V or SV	C
Date of discovery	2 Aug. 1949	13 Oct. 1874
Discoverer	K. Reinmuth	J. Palisa

Comet 46P/Wirtanen



These primordial rocks could hardly be more different. Siwa will be the largest asteroid ever encountered by a spacecraft, while (apart from a tiny asteroid moon called Dactyl) Otawara will be the smallest. Otawara is suspected to be a chunk of once-molten basalt (a type V or SV asteroid), and Siwa seems to be a carbon-rich object, which is blacker than coal (a type C asteroid).

Rosetta's flyby of Otawara will take place on 12 July 2006, when the asteroid is 283 million km from the Sun. Travelling at a relative velocity of more than 10 km/sec, the spacecraft will pass by Otawara's sunlit side at a distance of about 2200 km. Otawara rotates faster than any asteroid so far visited by spacecraft (about once every 3 hours), which should allow Rosetta to image most of its surface during the flyby.

Rosetta will also obtain spectacular images as it flies to within 3500 km of Siwa on 24 July 2008. The spacecraft will fly past at a relative velocity of 17 km/sec, approaching on the sunlit side and then looking at a crescent phase as it moves away. At this time, Siwa will be about 470 million km from the Earth, so that signals from the spacecraft will take 26 minutes to reach ground stations.

Relative sizes of Otawara, Siwa and other known asteroids

Illustrations by AOES Medialab, original photos NASA/JPL, JHU/APL

Comet 46P/Wirtanen

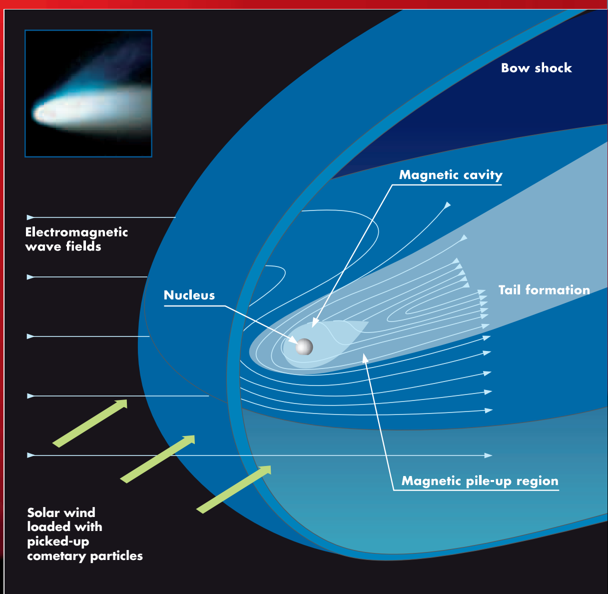
Comet 46P/Wirtanen	
Diameter of nucleus – estimated (km)	1.2 km
Orbital period (years)	5.45
Minimum distance from Sun (million km)	159
Maximum distance from Sun (million km)	768
Orbital eccentricity	0.657
Orbital inclination (degrees)	11.72
Year of discovery	1948
Discoverer	Carl Wirtanen (Lick Observatory, USA)

ISOCAM – P. Lamy & B. Altieri

After its brief encounters with Otawara and Siwa, Rosetta will travel far beyond the asteroid belt to reach its main target, Comet Wirtanen. Wirtanen is a large dirty snowball that orbits the Sun once every 5.5 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.

Rosetta will study the changes in Wirtanen's activity as it approaches the Sun

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 the surrounding space. Unfortunately, although this enveloping 'coma' of dust and gas increases Wirtanen's brightness, it also completely hides the comet's nucleus.

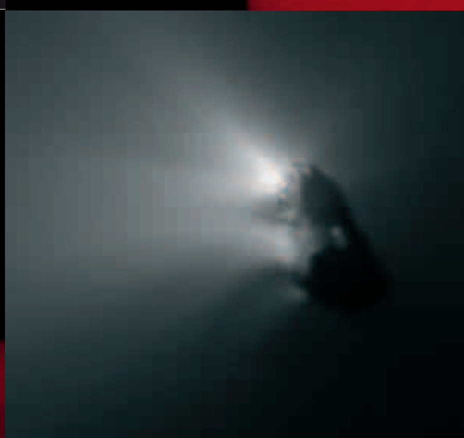


Structure of a comet

Illustrations by AOES Medialab, ©ESA 2001

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 chase Wirtanen as it charges headlong towards the inner Solar System at speeds of up to 135 000 km/h.

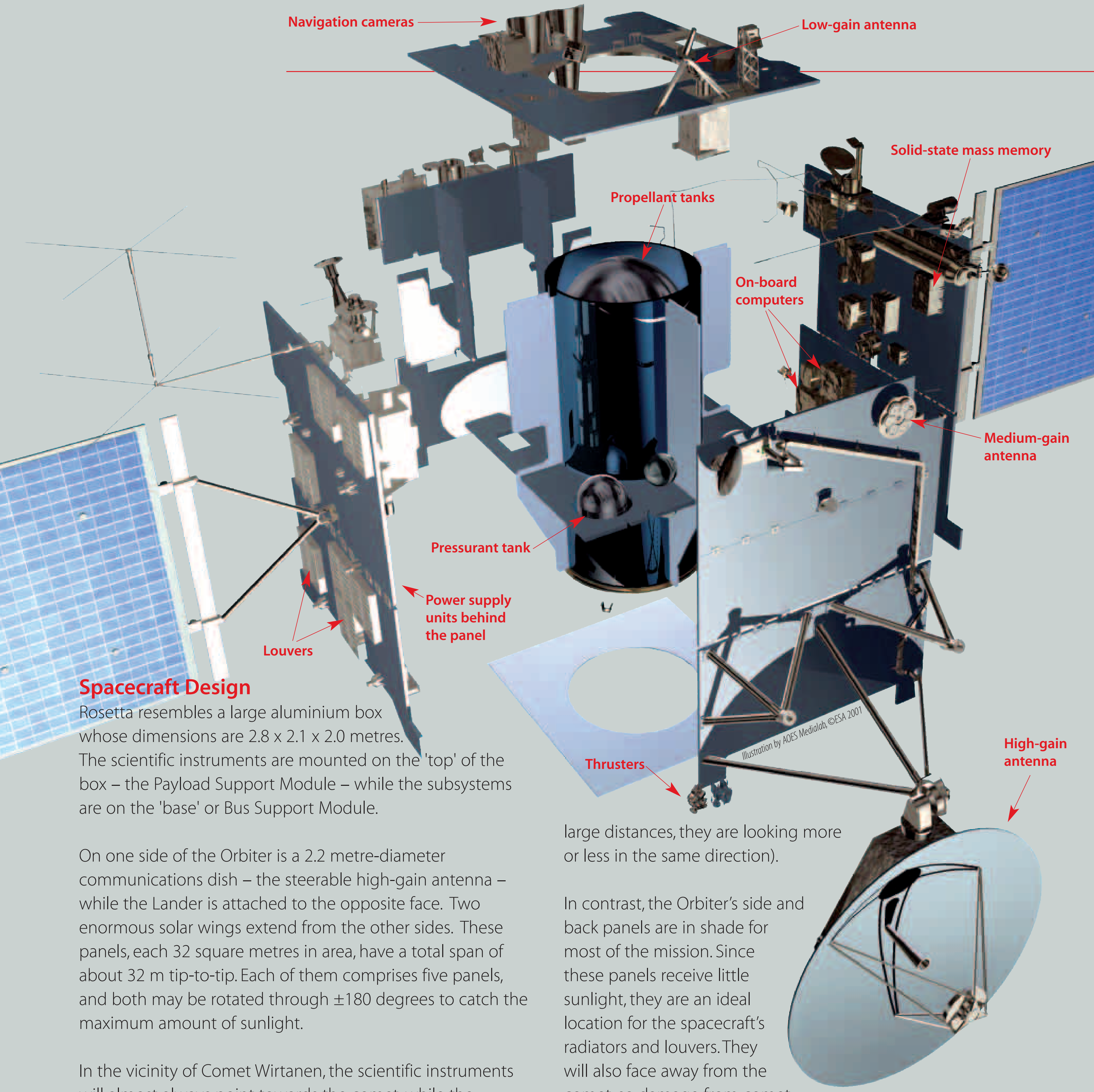
Over an entire year, as it approaches the Sun, Rosetta will orbit the comet, mapping its surface and studying changes in its activity. As its ices evaporate, instruments onboard the Orbiter will study the dust and gas particles that surround the comet and trail behind it as streaming tails, as well as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



The nucleus of Comet Halley as seen from the Giotto spacecraft by the Halley Multicolour Camera

Courtesy of MPAe, Lindau

The Rosetta Orbiter



Spacecraft Design

Rosetta resembles a large aluminium box whose dimensions are 2.8 x 2.1 x 2.0 metres. The scientific instruments are mounted on the 'top' of the box – the Payload Support Module – while the subsystems are on the 'base' or Bus Support Module.

On one side of the Orbiter is a 2.2 metre-diameter communications dish – the steerable high-gain antenna – while the Lander is attached to the opposite face. Two enormous solar wings extend from the other sides. These panels, each 32 square metres in area, have a total span of about 32 m 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 Wirtanen, the scientific instruments will almost always point towards the comet, while the antennas and solar arrays point towards the Sun and Earth (at large distances, they are looking 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 louvers. 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 metres
span of solar arrays	32 metres.
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 bi-propellant 10 N thrusters
Operational mission	10.5 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 Newton, equivalent to that experienced by someone holding a bag of 10 apples. Over half the launch weight of the entire spacecraft is taken up by propellant.

An International Enterprise

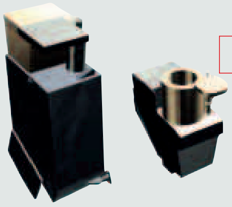
Rosetta's industrial team involves more than 50 contractors from 14 European countries, Canada and the United States. The prime spacecraft contractor is Astrium Germany. Major subcontractors are Astrium UK (spacecraft platform), Astrium France (spacecraft avionics) and Alenia Spazio (assembly, integration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

Companies involved in building the Rosetta Orbiter and the ground antenna

Illustration by AOES Medialab, ©ESA 2001

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

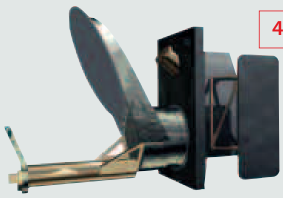
OSIRIS (Optical, Spectroscopic, and Infrared Remote Imaging System): A Wide Angle Camera and a Narrow Angle Camera to obtain high-resolution images of asteroids Otawara and Siwa and of the comet nucleus, and to help in identifying the best landing sites.

2

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.

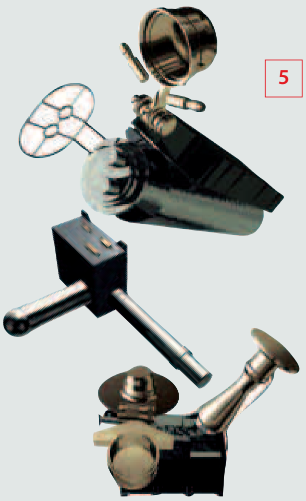
3

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.



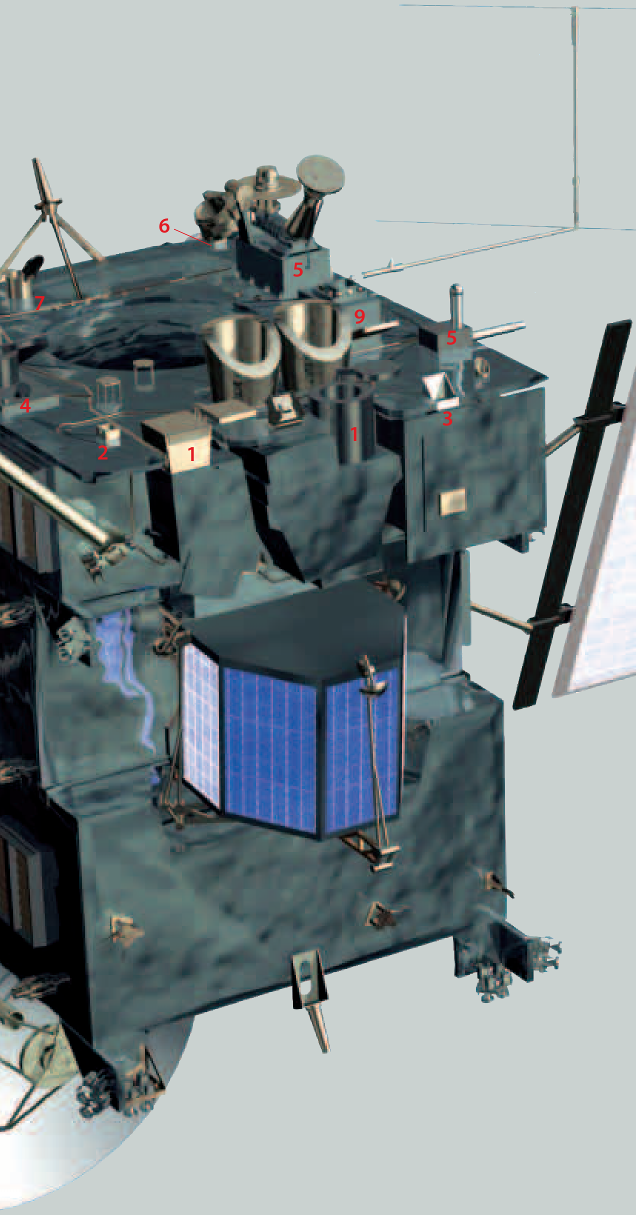
4

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 Siwa and Otawara, and 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.

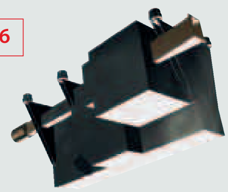
CONSERT (Comet Nucleus Sounding Experiment by Radiowave Transmission): Probes the comet's interior by studying radio waves that are reflected and scattered by the nucleus.

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).

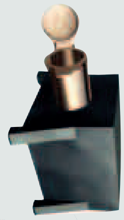
RPC (Rosetta Plasma Consortium): Five sensors measure the physical properties of the nucleus, examine the structure of the inner coma, monitor cometary activity, and study the comet's interaction with the solar wind.

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

6

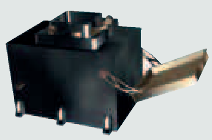


7

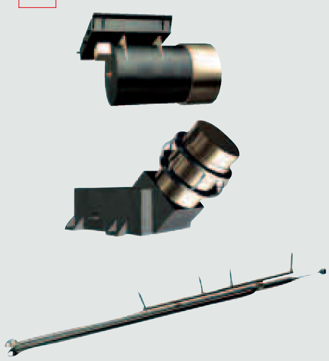


8

9



10



The Rosetta Lander

The 100 kg 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 Wirtanen. Once the Orbiter is aligned correctly, the ground commands the Lander 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 from escaping from the comet's extremely weak gravity. The minimum mission target is 65 hours, 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, which 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 kg. It also carries a drilling system to take samples of subsurface material.

The Rosetta Lander, anchored to Wirtanen's surface, will work for a minimum mission target of 65 hours, but its operations may continue for many months

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 nucleus of Comet Halley as seen from the Giotto spacecraft by the Halley Multicolour Camera
(Courtesy of MPAe, Lindau)

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 study the local magnetic field and the comet/solar-wind interaction.

SESAME (Surface Electrical, Seismic and Acoustic Monitoring Experiments): Three instruments measure properties of the comet's outer layers. The Cometary Acoustic Sounding Surface Experiment measures the way in which 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 cm 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 cm into the surface, collects samples and delivers them to different ovens or for microscope inspection.

Illustration by AOES Medialab, ©ESA 2001

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 onboard 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 control centre for Rosetta's entire 10-year journey will be 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.

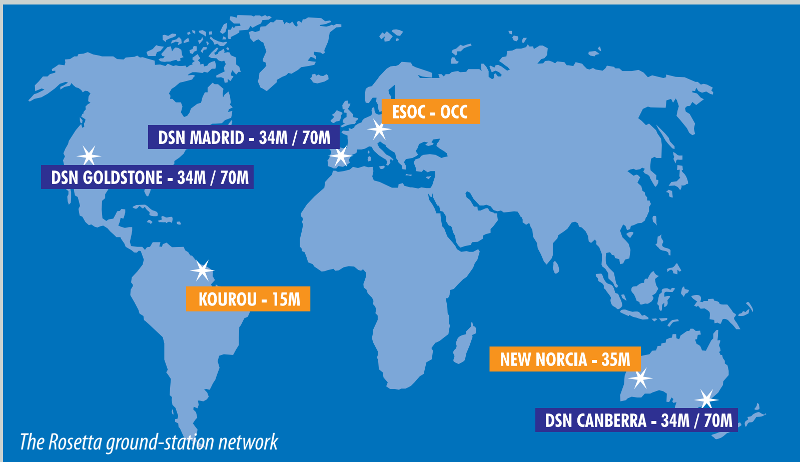
Ground control at the European Space Operations Centre (ESOC) in Darmstadt, Germany.

©ESA

Quite a Dish

©ESA

Radio communications between Rosetta and the ground will use a newly developed deep-space antenna, which is being built by ESA at New Norcia, near Perth in Western Australia. This 35 metre-diameter parabolic antenna concentrates the energy of the radio signal into a narrow beam, allowing it to reach distances of more than 1 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!



The Rosetta ground-station network

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 communication 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 communication-blackout periods 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 it to Earth at the next opportunity.

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: 13 January 2003 (02:12 GMT)

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 metres, on which all subsystems and payload equipment are mounted. Two 14 metre-long 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; A. Balogh, UK)
RSI - Radio Science Investigation (M. Pätzold, Germany)
VIRTIS - Visible and Infrared Mapping Spectrometer (A. Coradini, Italy)

Scientific Payload - Lander:
APXS - Alpha 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)

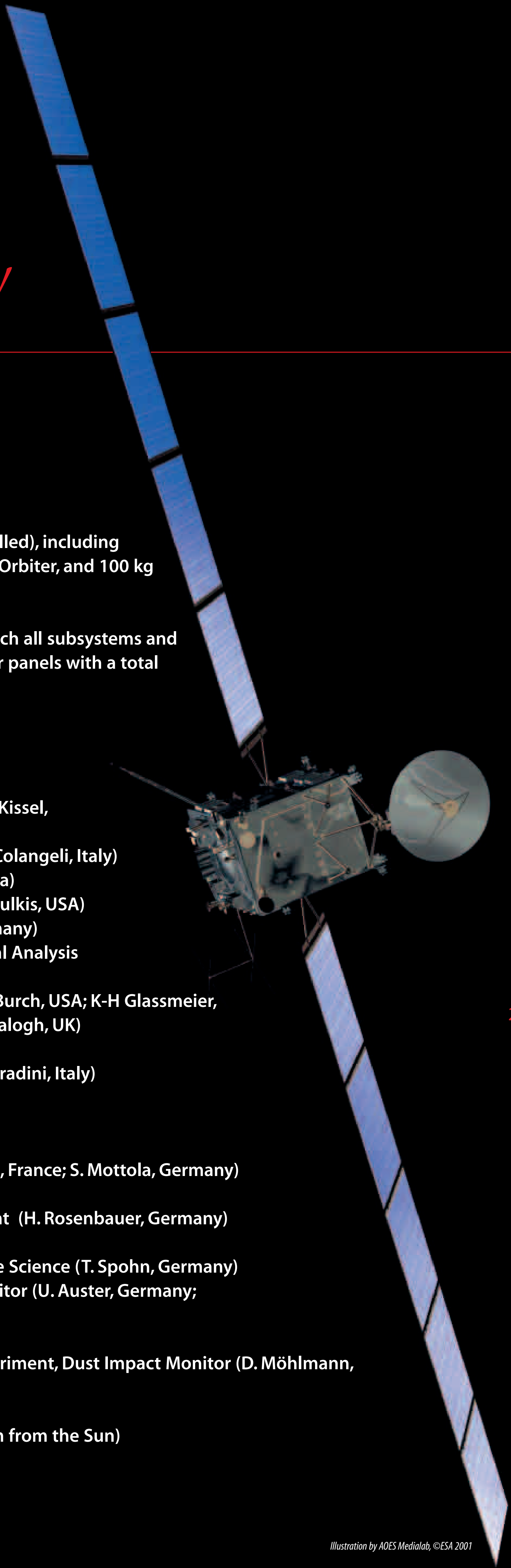


Illustration by AOES Medialab, ©ESA 2001

- ESA Headquarters
  8-10 rue Mario-Nikis
  75738 Paris Cedex 15
  Tel. (33) 1.53.69.71.55
  Fax (33) 1.53.69.76.90

- ESTEC Noordwijk
  The Netherlands
  Tel. (31) 71.565.3006
  Fax (31) 71.565.6040

- ESOC Darmstadt
  Germany
  Tel. (49) 6151.90.2696
  Fax (49) 6151.90.2961

- EAC Cologne
  Germany
  Tel. (49) 2203.60.010
  Fax (49) 2203.60.0166

- ESRIN Frascati
  Italy
  Tel. (39) 6.94.18.02.60
  Fax (39) 6.94.18.02.57

ESA Science Programme Communication Service
Tel: +31 71 565 3223
Fax: +31 71 565 4101
http://sci.esa.int

European Space Agency
Agence spatiale européenne

Contact: ESA Publications Division
c/o ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands
Tel. (31) 71 565 3400 - Fax (31) 71 565 5433