Rosetta:

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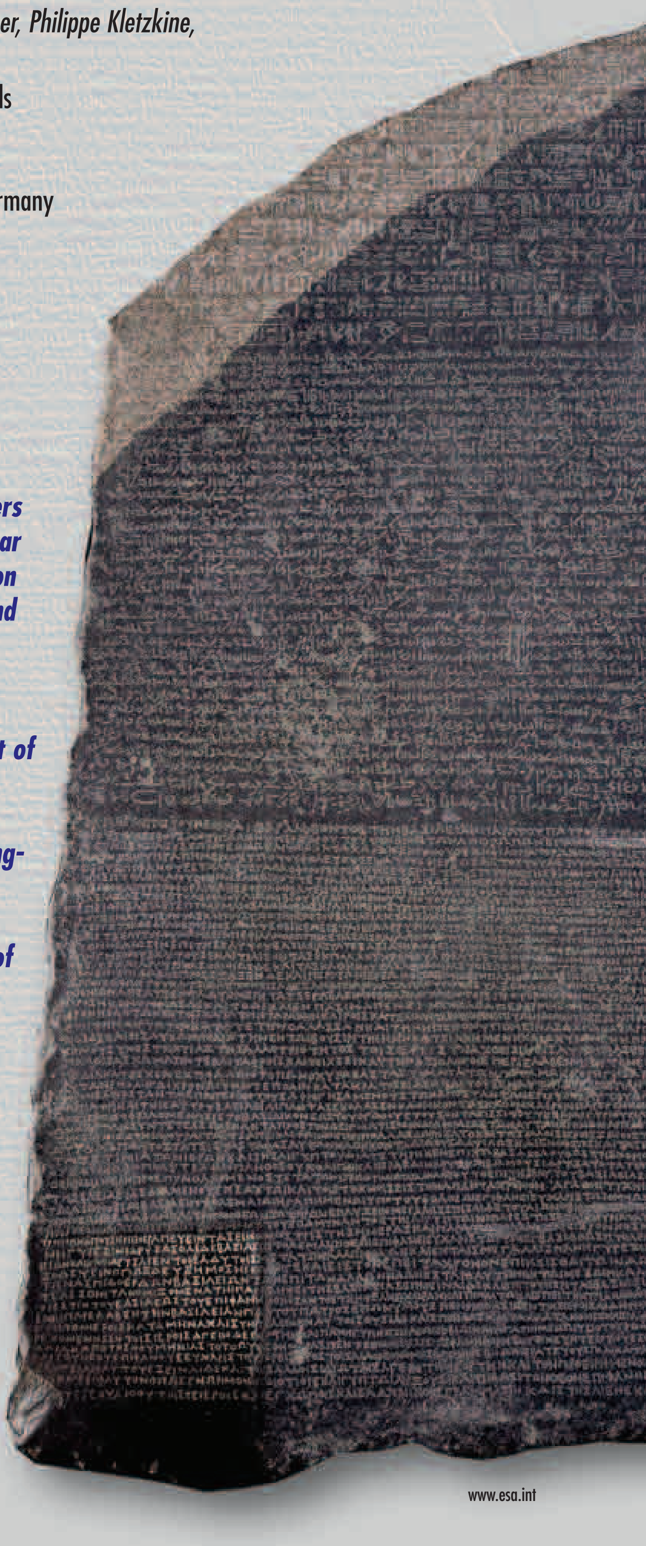


Why 'Rosetta'?

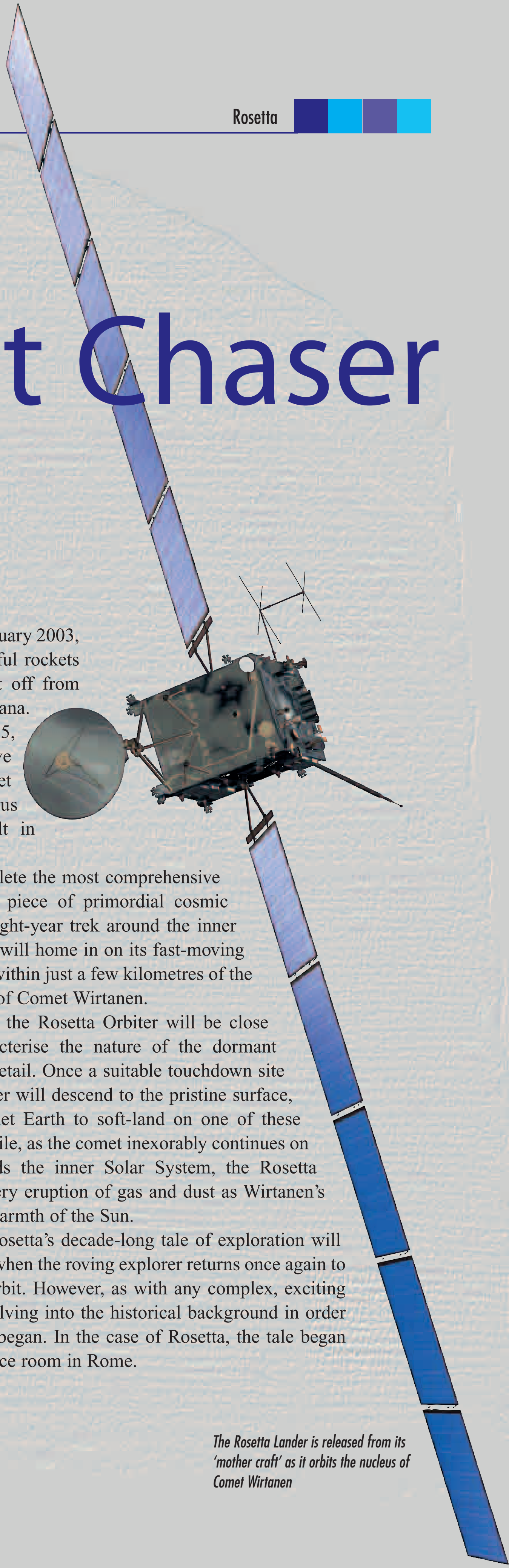
The Rosetta spacecraft is named after the famous Rosetta Stone, a slab of volcanic basalt now on display in the British Museum in London. French soldiers discovered the unique Stone in 1799, as they prepared to demolish a wall near the village of Rashid (Rosetta) in Egypt's Nile delta. The carved inscriptions on the Stone included hieroglyphics – the written language of ancient Egypt – and Greek, which was readily understood.

By comparing the inscriptions, it eventually became possible to decipher the mysterious figures that had been carved several thousand years earlier. 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 able to piece together the history of a long-lost culture for the first time.

Just as the discovery of the Rosetta Stone eventually led to the unravelling of the mysterious hieroglyphics, so Rosetta will help scientists to unravel the mysteries of comets. Whereas hieroglyphics were the building blocks of the Egyptian language, comets are considered to be the most primitive objects in the Solar System, the building blocks from which the planets formed.

Billions of these giant chunks of ice still linger in the depths of space, the remnants of a vast swarm of objects that once surrounded our Sun and eventually came together to form planets. Virtually unchanged after 5 billion years in the deep freeze of the outer Solar System, they still contain ices and dust from the original solar nebula. They also contain complex organic compounds which some scientists believe may have provided the raw material from which life on Earth evolved.

ESA's Comet Chaser



On the night of 12-13 January 2003, one of the most powerful rockets in the world will blast off from Kourou spaceport in French Guiana. On top of the giant Ariane-5, cocooned inside a protective fairing, will be the Rosetta comet chaser, the most ambitious scientific spacecraft ever built in Europe.

Rosetta's mission is to complete the most comprehensive examination ever made of a piece of primordial cosmic debris – a comet. After an eight-year trek around the inner Solar System, the spacecraft will home in on its fast-moving target, eventually edging to within just a few kilometres of the solid nucleus, the icy heart of Comet Wirtanen.

By the summer of 2012, the Rosetta Orbiter will be close enough to map and characterise the nature of the dormant nucleus in unprecedented detail. Once a suitable touchdown site is identified, a small Lander will descend to the pristine surface, the first object from planet Earth to soft-land on one of these primitive worlds. Meanwhile, as the comet inexorably continues on its headlong rush towards the inner Solar System, the Rosetta Orbiter will catalogue every eruption of gas and dust as Wirtanen's volatiles vaporise in the warmth of the Sun.

The final chapter in Rosetta's decade-long tale of exploration will take place in July 2013, when the roving explorer returns once again to the vicinity of Earth's orbit. However, as with any complex, exciting adventure, it is worth delving into the historical background in order to understand how it all began. In the case of Rosetta, the tale began 17 years ago in a conference room in Rome.

The Rosetta Lander is released from its 'mother craft' as it orbits the nucleus of Comet Wirtanen

Comet Nucleus Sample Return

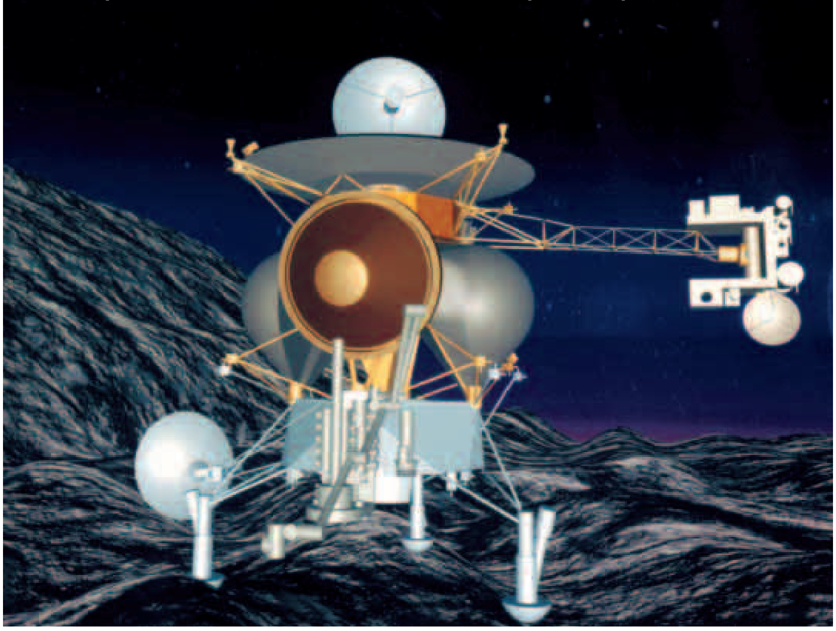
In January 1985, Ministers responsible for space matters in ESA's Member States came together to approve an ambitious and far-seeing programme of scientific and technological research. One of their most significant decisions involved approval of a long-term science plan, which was then named 'Horizon 2000'. A Resolution drafted by the Ministers stated, "The Council agrees to reinforce space-science activities in Europe during the next decade with a view to enabling the scientific community to remain in the vanguard of space research."

Based on inputs from the European space-science community, the revolutionary plan included ground-breaking missions that would be launched between the mid-1990s and the early years of the 21st century. The proposed programme was founded on four major Cornerstones, one of which was described as "a mission to primordial bodies including return of pristine materials". Even before its Giotto spacecraft reached Comet Halley, ESA was looking forward to establishing a leading role in the exploration of the smaller bodies of the Solar System by bringing back samples of material from either a comet or an asteroid.

After Giotto's remarkably successful Halley flyby in March 1986, the emphasis switched to comet sample return, but it soon became clear that the cost of such a mission would be too prohibitive for Europe to carry out alone. As a result, the ESA Science Executive began to investigate the possibility of conducting the Planetary Cornerstone as a collaborative venture with NASA, which was already pursuing its own Comet Rendezvous and Asteroid Flyby (CRAF) mission.

At this stage, scientists on both sides of the Atlantic were excitedly anticipating sending a mission to land on a relatively active, 'fresh' comet that did not approach too closely to the Sun. Apart from characterising the surface of the nucleus and obtaining high resolution imagery of the landing site, it was hoped to obtain three types of sample: a 'core' drilled to a depth of at least one metre; a sealed sample of volatile, icy material; and a sample of non-volatile surface material. Stored at the same frigid temperatures experienced on the comet, the samples would be returned for comprehensive analysis in laboratories on Earth.

Artist's impression of the ESA-NASA Rosetta Comet Nucleus Sample Return spacecraft



By 1991, a joint ESA-NASA Rosetta Comet Nucleus Sample Return mission had been defined, with launch anticipated in December 2002. The spacecraft was to comprise three modules. A large NASA Mariner Mark II Cruiser would provide attitude control, navigation, power, propulsion and communications. Attached to the main bus would be a Lander, which was to carry a drill and surface sampling tool, and an Earth-Return Capsule. Once the samples were safely transferred to a container in the Capsule, the spacecraft would lift off, leaving the Lander behind on the comet. Two and a half years later, the Capsule would parachute into the ocean with its precious cargo, ready for collection by helicopter and ship.

A Revised Rosetta

Within two years, NASA's financial difficulties and resultant cutbacks in its space-science programme (notably the cancellation of the CRAF mission) forced ESA to reconsider its options for Rosetta. The prime consideration was to define a core mission that could be performed by ESA alone, using European technology – although the door was left open for other agencies to participate. The revised baseline mission that emerged involved a rendezvous with a comet and at least one asteroid flyby. It was hoped that a small Lander would be added as an additional experiment provided by one or more scientific institutions.

To all intents and purposes, that is the mission that has survived to the present. The Rosetta that will be launched towards Comet Wirtanen in January 2003 comprises two spacecraft: a 3 ton Orbiter, including 165 kg of scientific instruments, and a 100 kg Lander provided by a consortium including ESA and institutes from Austria, Finland, France, Germany, Hungary, Ireland, Italy and the United Kingdom, under the leadership of the German Space Agency (DLR).

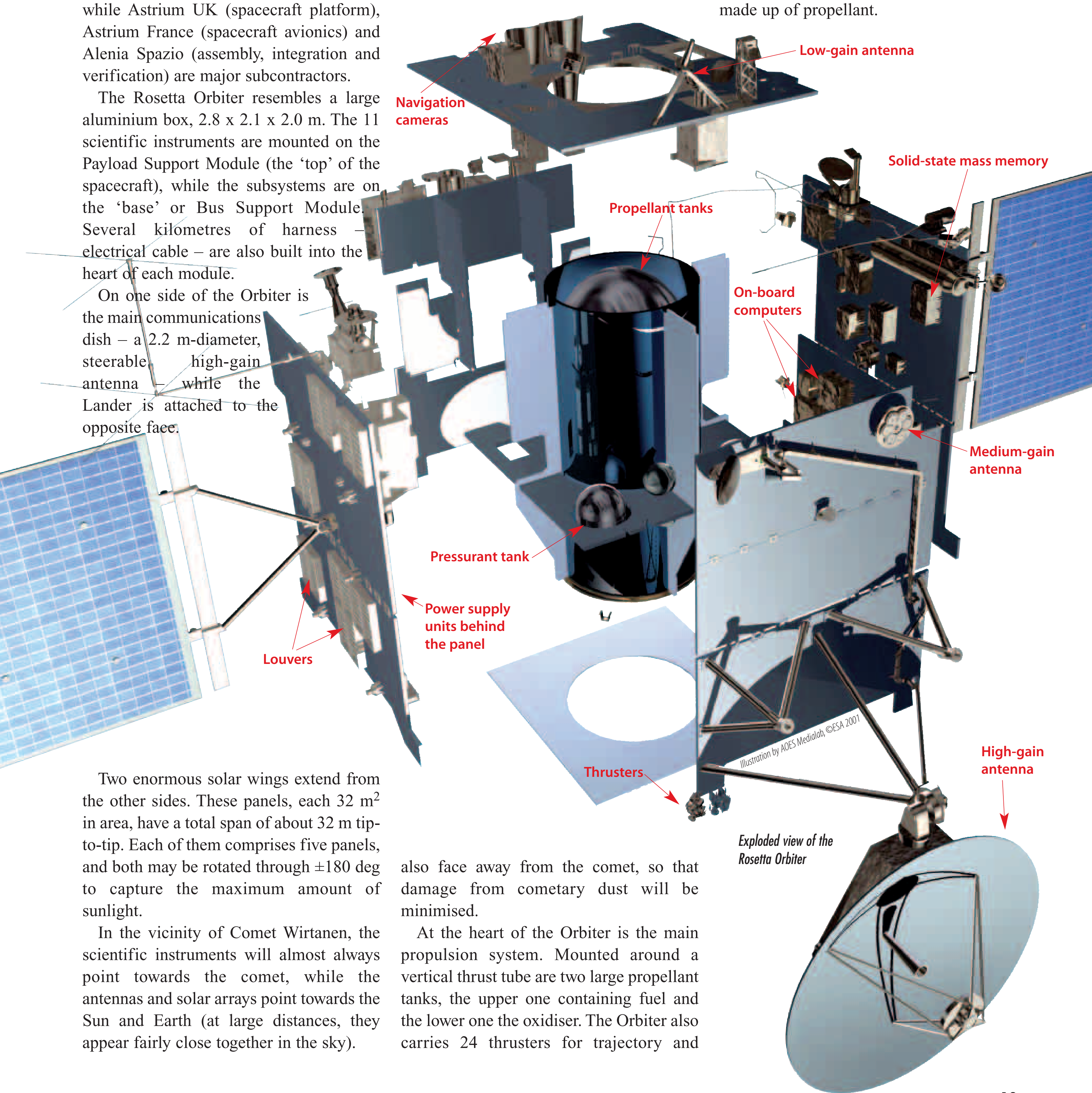
"That such a complex mission can be built in partnership and delivered on time is a great tribute to the management and cooperative spirit of industry, the scientists and the many agencies involved, as well as ESA's staff," says John Ellwood, Rosetta Project Manager.

Anatomy of a Spacecraft

Rosetta is truly an international enterprise, involving more than 50 industrial contractors from 14 European countries and the United States. The prime spacecraft contractor is Astrium Germany, while Astrium UK (spacecraft platform), Astrium France (spacecraft avionics) and Alenia Spazio (assembly, integration and verification) are major subcontractors.

The Rosetta Orbiter resembles a large aluminium box, 2.8 x 2.1 x 2.0 m. The 11 scientific instruments are mounted on the Payload Support Module (the 'top' of the spacecraft), while the subsystems are on the 'base' or Bus Support Module. Several kilometres of harness – electrical cable – are also built into the heart of each module.

On one side of the Orbiter is the main communications dish – a 2.2 m-diameter, steerable, high-gain antenna – while the Lander is attached to the opposite face.



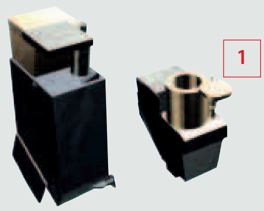
Exploded view of the Rosetta Orbiter

Two enormous solar wings extend from the other sides. These panels, each 32 m^2 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 deg to capture the maximum amount of sunlight.

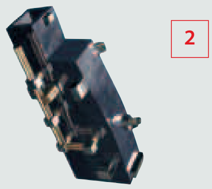
In the vicinity of Comet Wirtanen, the scientific instruments will almost always point towards the comet, while the antennas and solar arrays point towards the Sun and Earth (at large distances, they appear fairly close together in the sky).

By 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 which regulate its internal temperature. They will also face away from the comet, so that damage from cometary dust will be minimised.

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 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 – more than 1.7 tonnes – is made up of propellant.

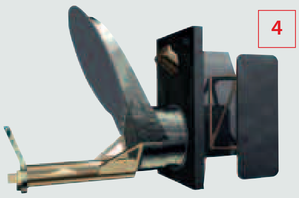


OSIRIS (Optical, Spectroscopic, and Infrared Remote Imaging System): A Wide Angle Camera and a Narrow Angle Camera to obtain high-resolution images of the comet's nucleus and asteroids Siwa and Otawara.

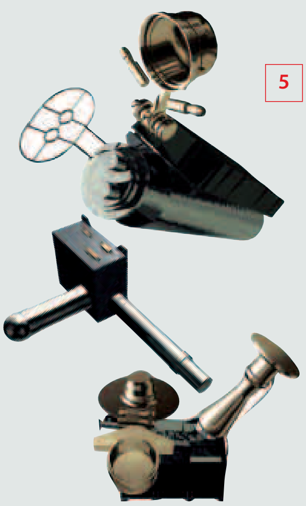


ALICE (Ultraviolet Imaging Spectrometer): Analyses gases in the coma and tail and measures the comet's production rates of water and carbon monoxide/dioxide. Also provides information on the surface composition of the nucleus.

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.



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 sub-surface temperatures of Siwa and Otawara, and search for gas around them.



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.

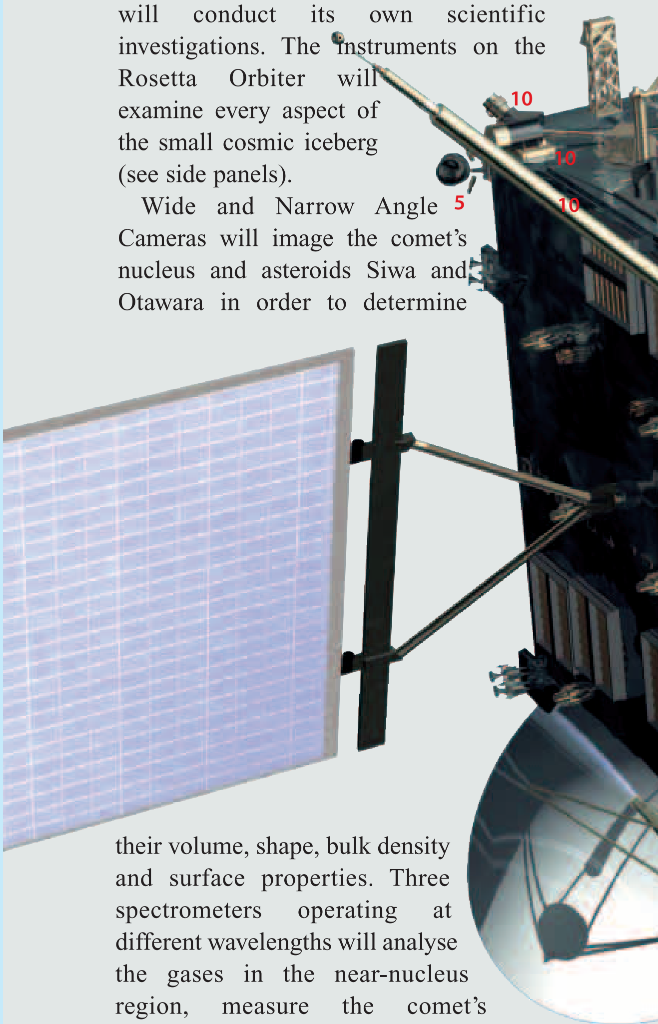
The Rosetta Payload

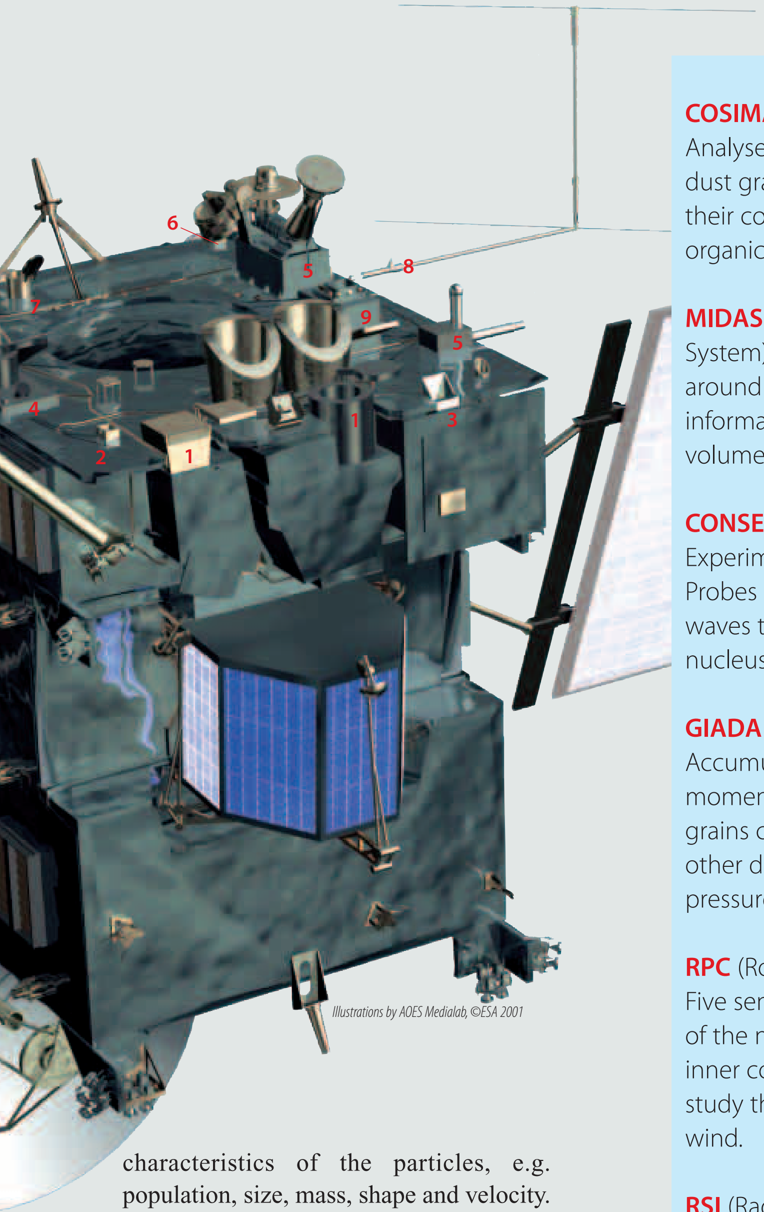
The Orbiter's scientific payload includes 11 experiments and a small Lander, which will conduct its own scientific investigations. The instruments on the Rosetta Orbiter will examine every aspect of the small cosmic iceberg (see side panels).

Wide and Narrow Angle Cameras will image the comet's nucleus and asteroids Siwa and Otawara in order to determine their volume, shape, bulk density and surface properties. Three spectrometers operating at different wavelengths will analyse the gases in the near-nucleus region, measure the comet's production rates of water and carbon monoxide/dioxide, and map the temperature and composition of the nucleus.

Our knowledge of the nucleus should be revolutionised by the CONSERT experiment, which will probe the comet's interior by transmitting and receiving radio waves that are reflected and scattered as they pass through the nucleus.

Four more instruments will examine the comet's dust and gas environment, measuring the composition and physical





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characteristics of the particles, e.g. population, size, mass, shape and velocity.

The comet's plasma environment and interaction with the electrically charged particles of the solar wind will be studied by the Rosetta Plasma Consortium and the Radio Science Investigation.

The 100 kg Rosetta Lander carries a further nine experiments, as well as a drilling system to take samples of sub-surface material. The Lander instruments are designed to study in situ for the first time the composition and structure of the surface and subsurface material on the nucleus.

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 nucleu; define the comet's orbit; and study the inner coma. 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.

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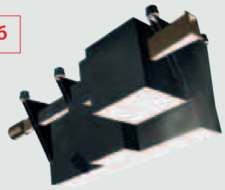

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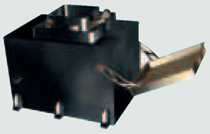

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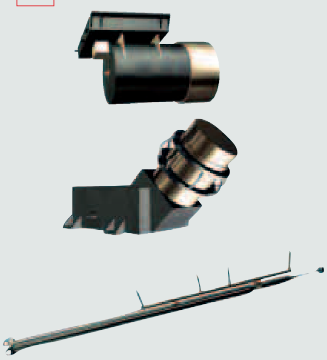


Illustration by AOES Medialab, ©ESA 2001

The Rosetta Lander

The box-shaped Lander piggybacks on the Orbiter until it arrives in close orbit around Comet Wirtanen. Once the 'mother craft' is aligned correctly, the ground commands the Lander to push off and unfold its three legs, ready for a gentle touch down at the end of the slow 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 65 hours, but surface operations may continue for many months.

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 for power generation. An antenna transmits data from the surface to Earth via the Orbiter.

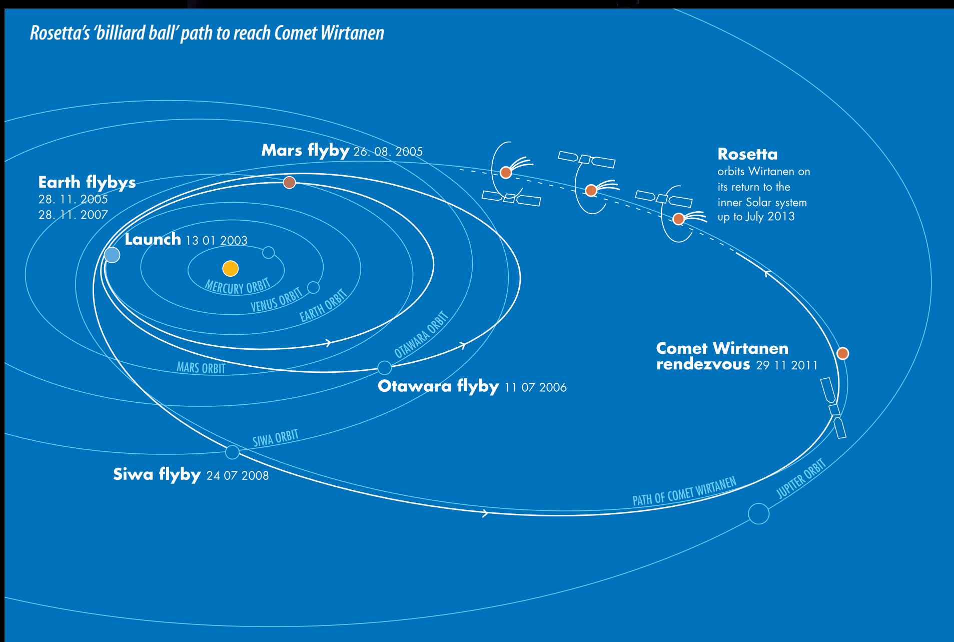
A Space Odyssey

Although its cometary target has changed since Rosetta was first envisaged, the launch date has altered very little. Rosetta's 10-year odyssey will begin in January 2003, when an Ariane-5 launcher boosts the spacecraft into an elliptical (4000 km x 200 km) trajectory around the Earth. After about two hours, Ariane's upper stage re-ignites to send Rosetta on its way towards the asteroid belt.

The hardy spacecraft will then 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. Along this roundabout route, Rosetta will enter the asteroid belt twice, enabling it to glimpse the ancient, battered surfaces of two contrasting rocky objects, Siwa and Otawara. It will also receive a boost in speed from gravitational 'kicks' provided by close flybys of Mars in 2005 and Earth in 2005 and 2007.

After a large deep-space manoeuvre, Rosetta will break the record for a solar cell-powered spacecraft as its elongated path carries it some 800 million km from the Sun. It will then be re-activated for the most difficult phase of the mission – the final rendezvous with the fast-moving comet.

Arriving in the comet's vicinity in November 2011, Rosetta's thrusters will brake the spacecraft so that it can match Comet Wirtanen's orbit. Over the next six months, it will edge closer to the black,



Rosetta's 'billiard ball' path to reach Comet Wirtanen

Rosetta Lander 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.

MUPUS (Multi-Purpose Sensors for Surface and Subsurface Science): Uses sensors on the Lander's anchor, probe and exterior to measure the 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 the dust environment to the surface.

APXS (Alpha X-ray Spectrometer): Lowered to within 4 cm of the ground, it detects back-scattered alpha particles and alpha-induced 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: Seven micro-cameras - six mono and one stereo pair - take panoramic pictures of the surface. A visible-light microscope and coupled infrared 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 of the nucleus surface below the Lander and of the 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.

dormant nucleus until it is only a few dozen kilometres away. The first camera images will dramatically improve calculations of the comet's position and orbit, as well as its size, shape and rotation.

By the summer of 2012, Rosetta will enter orbit around the comet, sweeping to within a few kilometres of the coal-black surface. However, the almost imperceptible gravitational pull of the 'dirty snowball' will mean that Rosetta need only circle Wirtanen at a snail's pace – a few centimetres per second. With the alien landscape now looming large, the Orbiter's cameras will start to map the nucleus in great detail. Eventually, a number of potential landing sites will be selected for close observation.

Once a suitable site is chosen, the Lander will be released from a height of about 1 km. Touching down gently at walking speed – less than 1 metre per second – the ambassador from Earth will anchor itself to the nucleus before sending back high-resolution pictures and other information on the nature of the comet's ices and organic crust. Scientists back on the distant Earth will eagerly await the treasure trove of data from the pristine surface as it is relayed to ground stations via the Orbiter.

The way will then be clear for the exciting comet chase towards the Sun. Over a period of 12 months, the Orbiter will continue to orbit Wirtanen, observing the dramatic changes that take place as the icy nucleus begins to warm and vaporise during the headlong rush towards the Sun. The escort mission will end in July 2013, at the time of the comet's closest approach to the Sun (perihelion). More than 3800 days will have elapsed since Rosetta's dramatic space odyssey began.

"The Rosetta mission is something that we could only dream about 17 years ago, and now it is becoming an exciting reality", says Gerhard Schwehm, Rosetta Project Scientist.