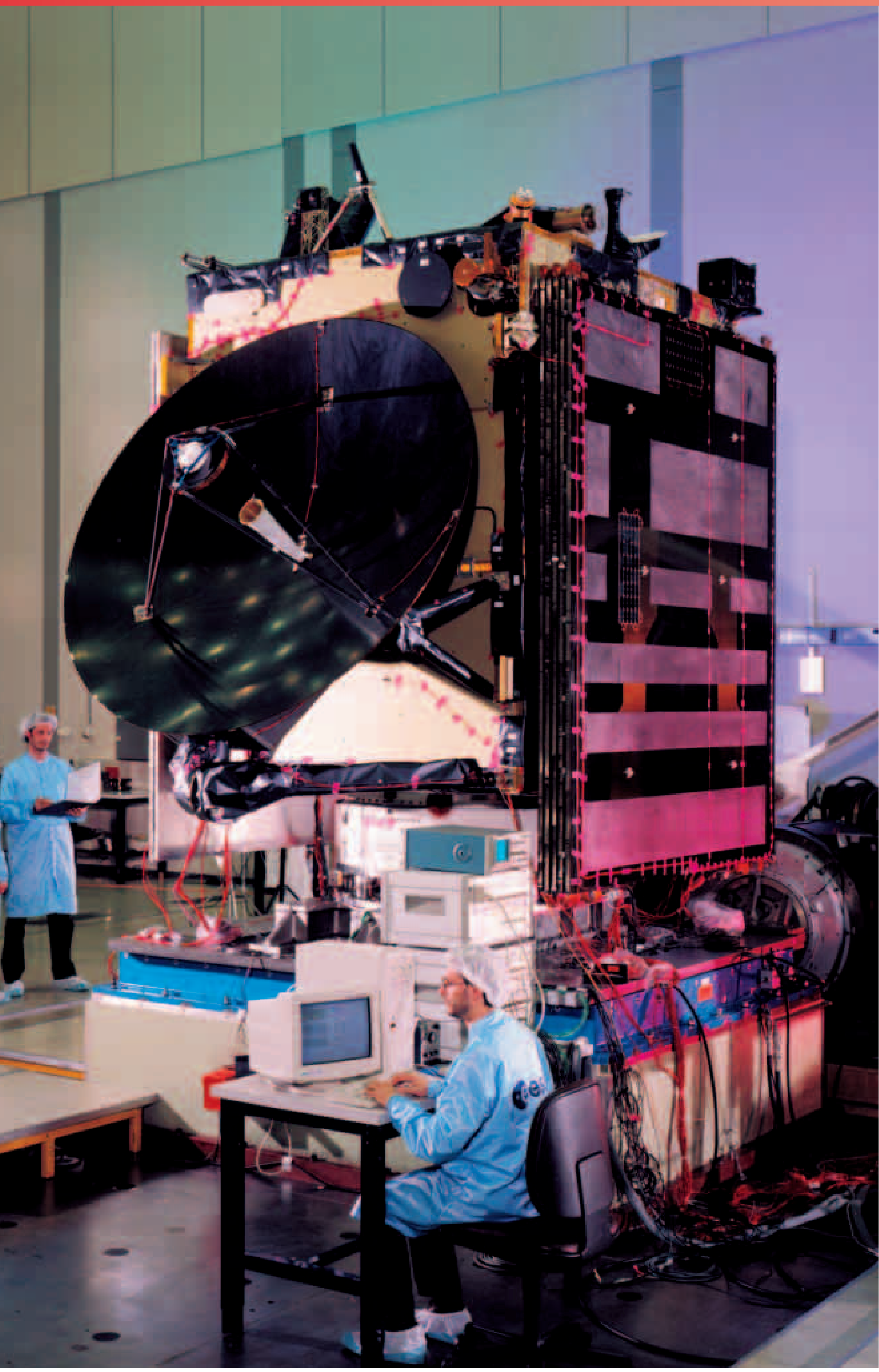
A Race Against Time



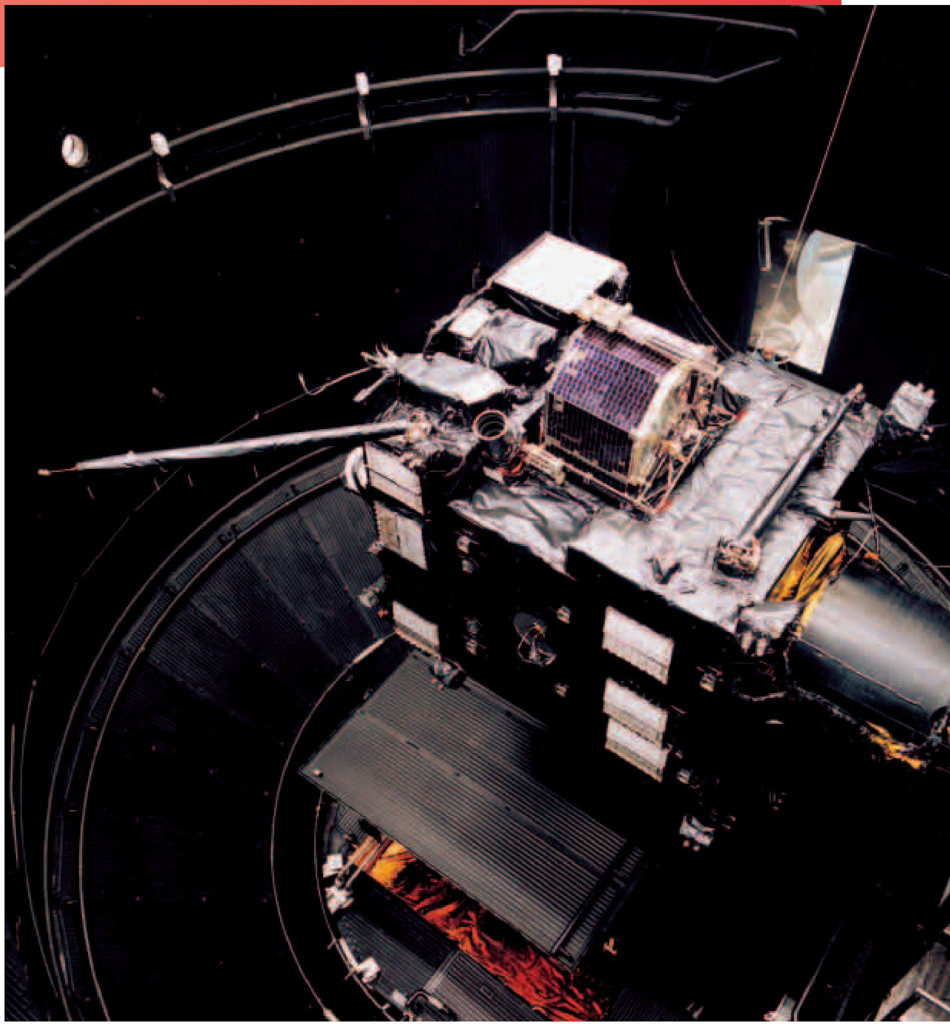
The International Rosetta Mission was approved as a Cornerstone mission within ESA's Horizon 2000 Science Programme in November 1993. Even at this early stage, it was envisaged that the ambitious mission would be scheduled for launch in the 2003 timeframe and a number of comet-rendezvous opportunities were identified. Although the original target, Comet Schwassman Wachmann 3, has since been superseded by another periodic intruder into the inner Solar System, Comet Wirtanen, there has been little shift in the original launch schedule. Rosetta is now set for lift-off from Kourou on the night of 12-13 January 2003.

Ever since the mission was accepted and given a slot in the long-term Horizons 2000 programme, the teams of ESA engineers and scientists have been engaged in a race against time. Once the design and specifications of the spacecraft and its payload were fixed in 1998, just four years remained for the Assembly, Integration and Verification phase.

Following the conventional spacecraft development philosophy, the Rosetta project team and its industrial partners were first required to build a Structural and Thermal Model in order to evaluate the design and thermal characteristics of the satellite. This was to be followed about seven months later by the delivery of an Engineering and Qualification Model that would be used to demonstrate that Rosetta's electrical and other subsystems would operate correctly in the extreme environment of deep space. Only then would the Flight Model be assembled and put through a final series of exhaustive tests that would check out overall performance and flight readiness.

Rosetta Structural and Thermal Model undergoing vibration testing at ESTEC in January 2001

Rosetta Flight Model in the Large Space Simulator (LSS) at ESTEC in March 2002



Meanwhile, teams from many countries were also required to deliver a Structural and Thermal Model, an Engineering and Qualification Model and a Flight Model of each of their instruments that would be used to survey the comet. With a three-month launch campaign scheduled to begin in early September, there was no time to pause for breath and 24-hour shifts became commonplace for the engineers and scientists who endeavoured to ensure that Rosetta would leave the pad on time.

"The heavens have their own timetable and the comet won't wait for us if we're late," said John Ellwood, Rosetta Project Manager.

The Flying Italian

Preparing a 3 tonne spacecraft for a series of endurance tests is far from easy. Before the thermal vacuum checks could take place, intrepid Alenia Spazio engineer Natalino Zampirolo was required to imitate an acrobat on a high wire. Suspended from an electric hoist, the engineer was required to 'fly' alongside the spacecraft at a height of 5 metres above the floor of the giant test chamber.

Dangling next to the Rosetta orbiter, Zampirolo gingerly removed the 'red tag' items – protective covers, arming plugs on the explosive connectors etc. – that were fitted as a safety precaution during normal work on the spacecraft. With his task successfully accomplished, the flying Italian was relieved to retreat to safety, leaving the spacecraft armed and ready to start its thermal trial.

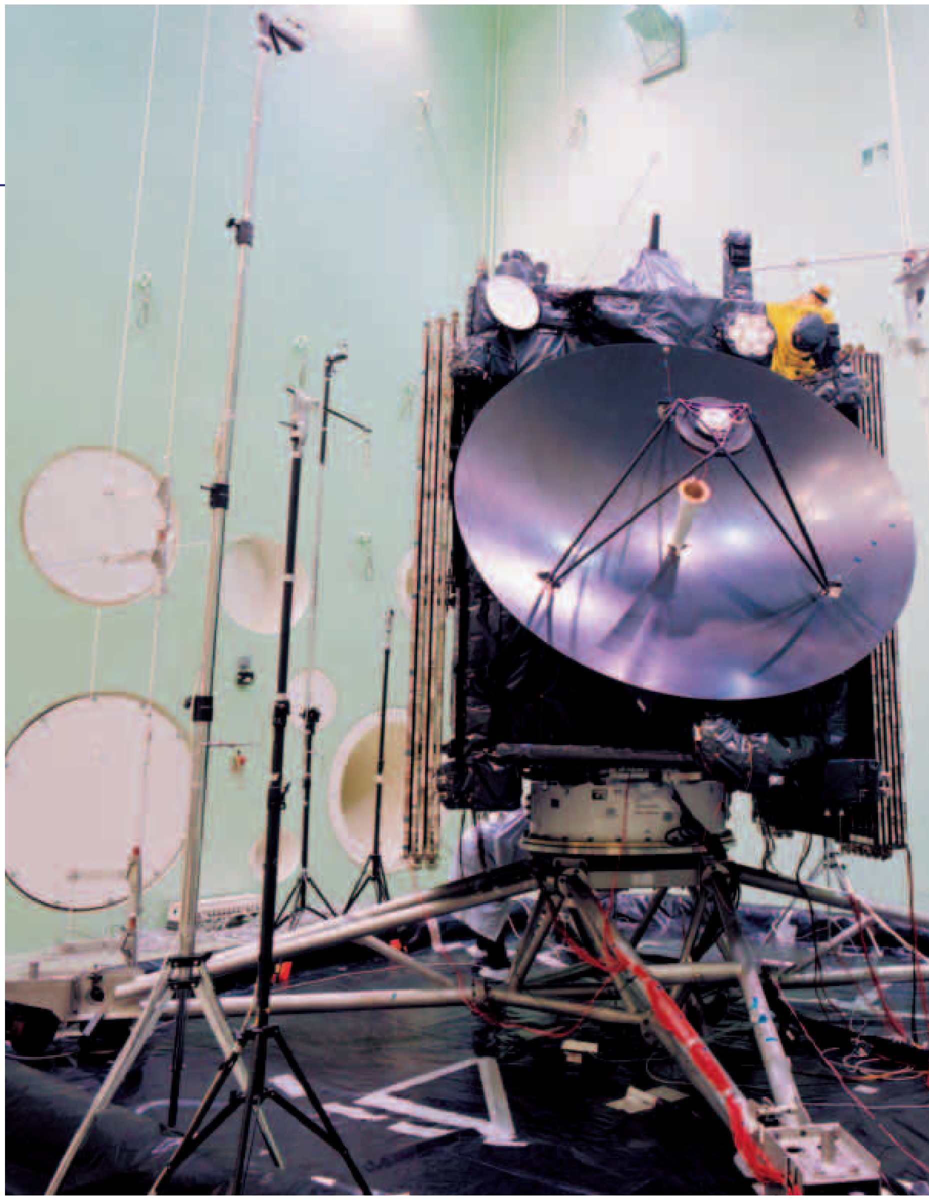
Rosetta Runs Hot and Cold

One of the key stages in the test programme was to establish whether Rosetta could maintain reasonable working temperatures throughout its circuitous trek to the orbit of Jupiter and back. In order to check the efficiency of Rosetta's thermal-control system, engineers at the European Space Research and Technology Centre (ESTEC) in the Netherlands placed the spacecraft in a thermal-vacuum chamber where the wildly fluctuating temperatures that Rosetta will experience could be replicated.

Imprisoned in the giant airless chamber, the Rosetta Orbiter, the Lander and their complement of 20 scientific instruments were alternately baked and frozen. In order to simulate the warmth of the inner Solar System, the exterior of the spacecraft was heated to a sizzling 150°C by a solar simulator comprised of 12 lamps each radiating 25 kW. During subsequent tests, liquid nitrogen was pumped through pipes in the chamber, causing the temperature inside to plummet to -180°C.

Sensors indicated that the spacecraft's insulation and heat control systems enabled Rosetta to survive these thermal tortures in fine shape, with internal temperatures restricted to between 40°C and -10°C. ESTEC engineers confidently predicted that, with the aid of its radiators and reflective louvers, Rosetta will be the 'coolest spacecraft' around.

"These tests show that Rosetta can survive the tremendous temperature contrasts it will endure as it flies from the vicinity of the Sun to the orbit of Jupiter," says Claude Berner, Payload and Operations Manager. "This gives us great confidence that the spacecraft will be able to survive its long exposure to the harsh environment of space."



Rosetta Breaks the Sound Barrier

Even before Rosetta has left the planet, the spacecraft has managed to break the sound barrier. In April 2002, the Flight Model was removed from the thermal vacuum chamber and prepared for the next stage of its pre-launch punishment. Once the high-gain antenna and huge solar arrays were mounted, the Orbiter was subjected to a series of deafening vibration tests in order to check whether it can survive the stresses it will experience during launch.

"The spacecraft was powered on, while the Lander, the high-gain antenna and the solar arrays were all in launch configuration," explained Claude Berner. "Even the propellant tanks were filled with 'dummy fuel'."

Placed in a giant acoustic/vibration chamber, a barrage of sound was directed at Rosetta from a huge amplifier in order to simulate the noise expected during lift-off. Soaring to a maximum of 135 decibels – ten times louder than Concorde at take-off – the sound levels were so severe that anyone straying into the chamber would have been killed within seconds.

Following these not-so-good vibrations, Rosetta returned to the clean room to complete a rock-and-roll ride on a giant shaker in order to simulate its ride into orbit aboard an Ariane-5 rocket. Attached to a table capable of moving the 3 tonne spacecraft from side to side like a metallic toy being mauled by a mastiff, Rosetta was severely shaken, first horizontally and then vertically, over a wide range of frequencies. Several hundred accelerometers on the structure were used to monitor the spacecraft's performance during each three-minute simulation. The results confirmed that the launch by the powerful Ariane-5 would leave Rosetta shaken but not stirred.

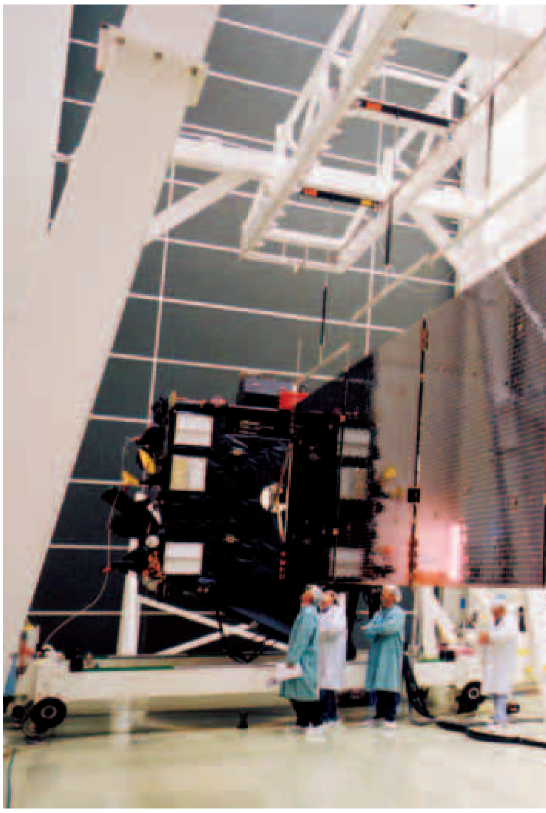
Solar Wings

Once the engineers at ESTEC had verified that all of the spacecraft's electronics had survived intact, it was time to check whether the pair of 14 m-long solar arrays and the delicate instrument booms had survived their potentially shattering ordeal.

Most critical of all were the deployment tests on the two giant 'wings' that will power Rosetta throughout its 10-year mission to deep space and back. These arrays, stretching one and a half times the length of a tennis court, must gently unfold to expose the special silicon cells that will generate electricity for the spacecraft to sunlight.

The 'minus-y' array, located to the left of the dish-shaped high-gain antenna, was the first to be unfolded. This was followed a day later by deployment of the 'plus-y' array on the opposite side of the spacecraft. Held in place by six Kevlar cables that will embrace the arrays during launch, each solar array was released after commands sent via the spacecraft activated the deployment sequence. 'Thermal knives' then severed each cable in turn by heating it to a temperature of several hundred degrees Celsius.

After the sixth cable was cut, the array began to unfold like a giant accordion. Attached to a huge, specially developed, deployment rig, the five panels in each array were gradually extended to their full



Rosetta Flight Model in the Acoustic Chamber at ESTEC

length across the clean room. To simulate the zero-gravity conditions of outer space, the weight of the arrays was counterbalanced by a mass-compensation device equipped with dozens of springs.

"Both tests went very well and there was a big round of applause when they were successfully completed," said Walter Pinter-Krainer, Principal AIV Systems Engineer for Rosetta.

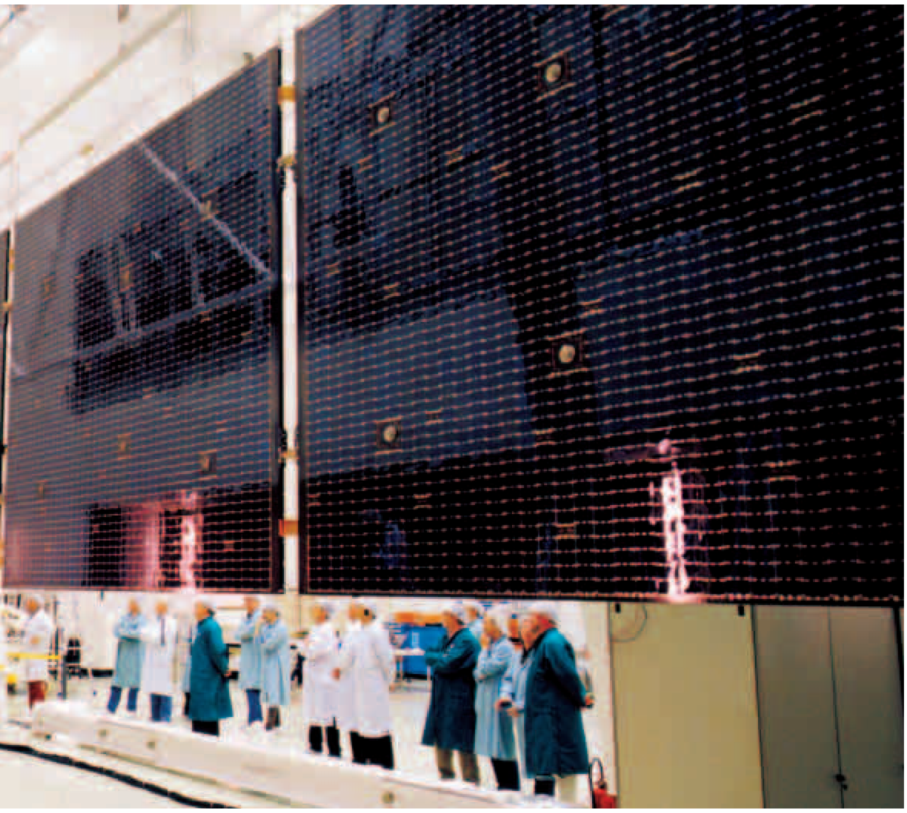
Checking the Booms

Confident that their spacecraft's powerhouse would deploy properly after launch, the engineers went on to check out Rosetta's other movable parts. First came a partial deployment of the orbiter's 2.2 m-diameter high-gain antenna, when three pyros (explosive charges) were fired to release the dish from its stowed launch position.

The engineers also had to retreat to the safety of an observation area in the clean room for the firing of more pyros during the deployment of the upper and lower experiment booms on the Orbiter. Each 2 m-long boom carries probes and other equipment that will investigate the magnetic field and particle environment around Comet Wirtanen.

The fifth and final deployment test involved the release of a wire antenna to be used by the CONSERT experiment. After another explosive charge was fired, this unusual, H-shaped aerial was gently unfolded, suspended beneath five helium balloons to simulate the weightlessness of space.

The CONSERT experiment unfolded



Unfurling of the spacecraft's solar array

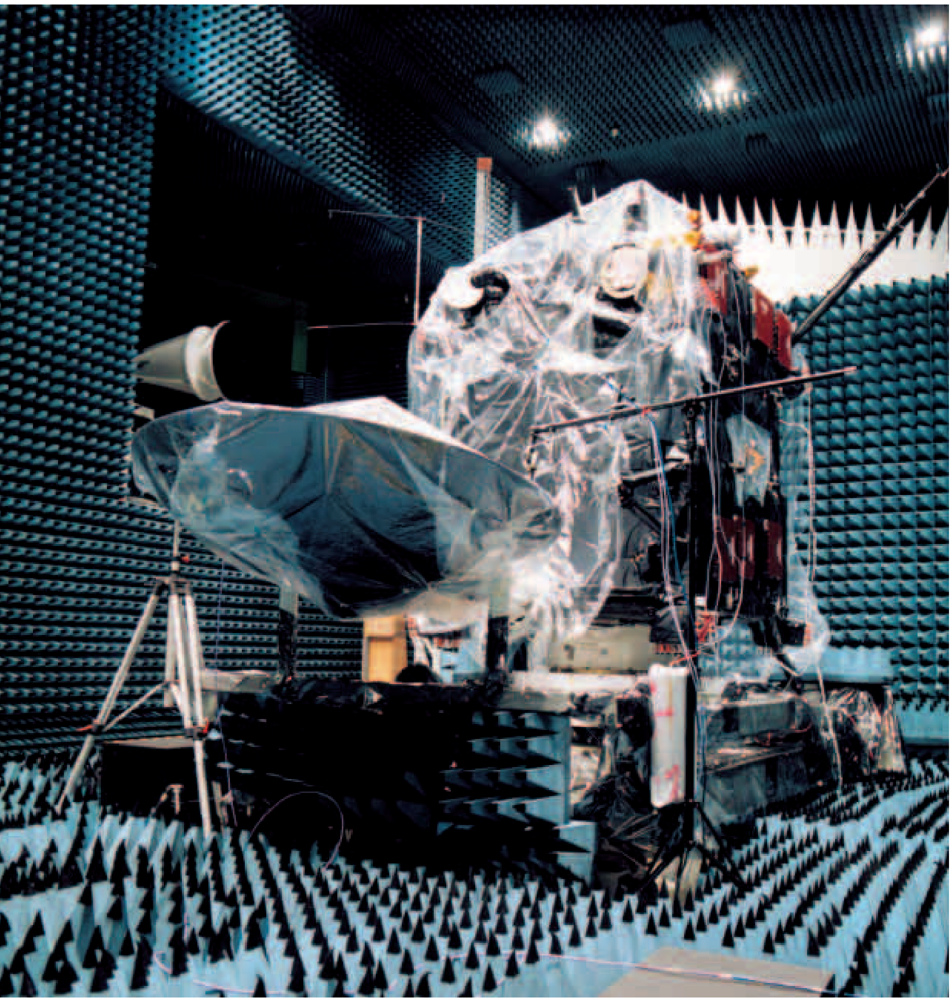
"Once again, the trial was completed without a hitch," announced a proud Marc Schwetterle, one of the payload engineers responsible for the tests.

"All of the deployment tests were very successful," commented Walter Pinter-Krainer. "These were crucial moments in our test programme and we were very happy to see everything working so well."

Rosetta Cleared of Interference

The hectic schedule continued in June when Rosetta was moved into another large test chamber at ESTEC, known as the Compact Test Range, where it was subjected to an extensive electromagnetic-compatibility (EMC) check.

In order to simulate the EMC environment during its long trek through deep space, Rosetta was placed inside a



A 'cocooned' Rosetta Flight Model in the Compact Test Range facility at ESTEC

chamber lined with cones that absorb radio signals and prevent reflections. To avoid TV or radio interference, the chamber walls form a steel 'Faraday cage', impenetrable to electromagnetic signals from the outside world. In this radiation-free environment, the ESTEC team was able to study the radio signals and electrical noise coming from the various systems on the spacecraft and to check whether they caused any electromagnetic interference with each other.

"Before a satellite is launched it is essential to ensure that the electrical and electronic equipment within a spacecraft functions correctly," explains Flemming Pedersen, a senior AIV engineer for Rosetta. "For example, it could be fatal if, when switching on one unit, other instruments or systems such as the telecommunication link, were disturbed or even disrupted."

Like some alien creation, the spacecraft was cocooned in protective plastic foil while the engineers and scientists painstakingly prepared to switch on Rosetta's systems and payloads. At first, the see-through wrapping proved to be too tight, causing the spacecraft's temperature to rise. Once this was remedied and the staff vacated the chamber, all was set to simulate the various phases of Rosetta's 10-year mission.

"For some of the time we were measuring the energy emitted by the spacecraft's high-gain antenna, and this is hazardous, so the chamber was completely closed and everyone had to remain outside it whilst the measurements were made," said Flemming Pedersen. "It would be like exposing the engineers to the radiation from thousands of mobile phones simultaneously."

The first series of tests studied how the spacecraft behaved in 'launch mode'. At this time Rosetta was in its launch configuration, with a minimum of systems active while awaiting the lift-off of the Ariane-5 rocket. This was to ensure that signals from the spacecraft would not interfere with communications between the rocket and ground control during the launch phase.

Subsequent EMC tests took place when the spacecraft was at various levels of activity – from quiet periods when no science payloads were operating, to spells of hectic scientific investigation.

"We could switch on each instrument individually and measure the electromagnetic waves coming from it," explains Bodo Gramkow, Principal Payload engineer and EMC expert. "The rest of the instruments were put into listening mode to see if any of them detected any disturbance."

"On other occasions we switched on all of the instruments, including those on the Lander, in order to see whether we got any unexpected 'noise' or interference," he says. "From this we could determine whether we will need to switch a particular instrument off when we are making a very sensitive measurement with another one."

"All of the EMC tests proved to be very successful," says Bodo Gramkow. "This was the last of the three big system-validation tests and Rosetta passed with flying colours."

Ironing-out the 'Bugs' (from the Pilot's Seat)

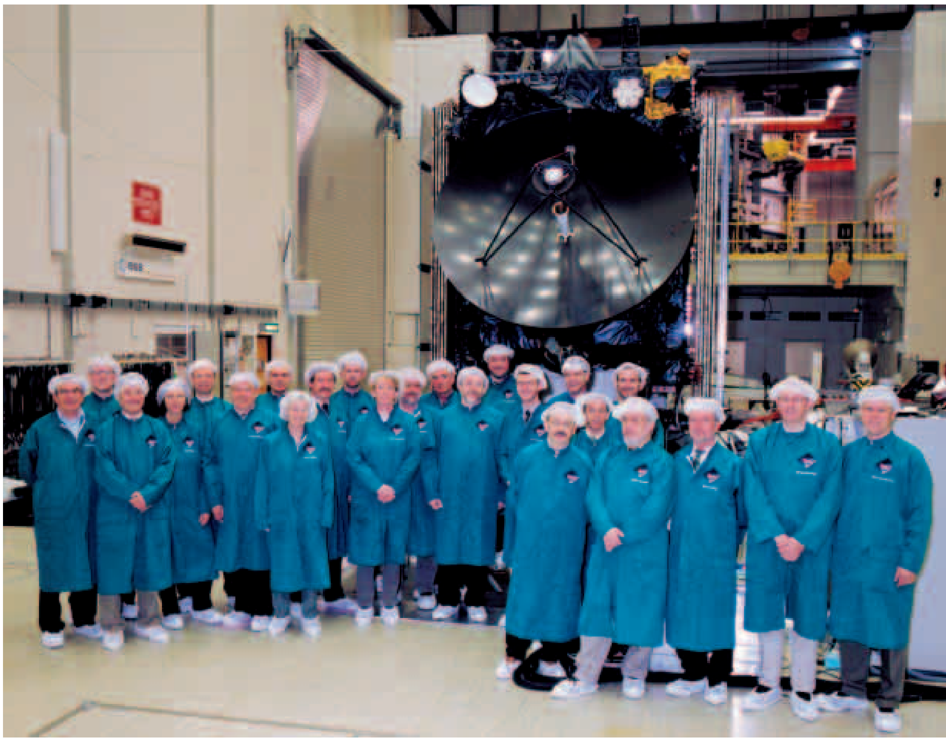
One key question that needs answering with confidence is: "Will Rosetta fly?" If the onboard computers are receiving all the right signals to convince them that the spacecraft is flying, will they react correctly? That question was asked and answered several times throughout 2002 in the form of an extensive set of Mission Simulation Tests.

It's 6 a.m. and a new shift starts. Into the control room come the software experts and they take up their positions in front of large, crowded, computer screens. Two sets of computers are synchronised: one set, on the ground, simulating a 'real-space' environment for their counterparts

onboard. The ground equipment feeds the Spacecraft Star Tracker with a simulated star-field image, and the onboard computers react and command a small attitude change for the spacecraft body.

Standing in the clean room and watching from the outside, nothing changes, but on the inside, from the perspective of the many onboard computers .... Yes! Rosetta is flying! So it goes on. For each mission phase the spacecraft computers are put through their paces.

"The functional testing of such a complex spacecraft as Rosetta should not be underestimated," says Mark Nesbit, the ESA engineer responsible for defining much of the functional test programme. "We test the spacecraft system in many closed-loop simulations, with the full scientific payload on-line, performing comet observations just as it will during the actual mission."



The Rosetta Team, with the Flight Model spacecraft in the background

"But for Rosetta," Mark continues, "we have to go a few steps further and we give the onboard computers a hard time. We feed them with unexpected situations, where the onboard autonomy has to take over and automatically recover the spacecraft into a safe mode. The variety in the mission profile and the long periods without ground contact mean that Rosetta has to be able to take care of itself, and on the ground we have to convince ourselves that it can."

The Trip to the Tropics

With the completion of the AIV programme, the final leg of Rosetta's race to the launch pad could get under way. It was time to transport ESA's comet chaser to the Kourou spaceport on the other side of the world. First to be packed was the ground-support equipment, which was loaded onto transporters for the short road journey to Rotterdam. There, the containers were transferred onto a regular Arianespace supply ship for the two-week voyage to French Guiana.

This was followed in early September by the Rosetta spacecraft itself, minus the large high-gain antenna and the twin solar arrays. Cocooned inside a protective container and purged with nitrogen to prevent contamination, the Orbiter and the attached Lander were loaded onto a Russian Antonov-124 air freighter at Amsterdam airport for the flight to Cayenne.

Over the next four months, the spacecraft would be prepared for launch in the specialist facilities at Kourou. After installation of the high-gain antenna, the folded solar wings, the explosive pyros and the spacecraft batteries, Rosetta is to be moved to another building for hazardous operations where its propellant tanks will be filled and pressurised. By early January 2003, it is scheduled for mating with the upper stage of the Ariane-5 launch vehicle. Five days after the fairing installation on 6 January, the huge rocket and its precious payload will inch along the causeway to the launch pad.

If all goes well, Rosetta's long, hard road from initial acceptance to successful launch will take place on the night of 12-13 January. Eight years later, the odyssey will be completed when Comet Wirtanen sails into view and the expedition to explore this small, primordial world begins in earnest.

The Rosetta Lander undergoing testing at ESTEC