rosetta

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AUGUST 2014

ARRIVAL AT COMET 67P/CHURYUMOV-GERASIMENKO

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#RosettaAreWeThereYet

Rosetta is one of the most complex and ambitious missions ever undertaken.

It will perform unique science. No other mission has Rosetta's potential to look back to the infant Solar System, when our planet was forming, and investigate the role comets may have played in seeding Earth with water, perhaps even the ingredients for life.

To do this, Rosetta will be the first mission to orbit and land on a comet. To get there, scientists had to plan in advance, in the greatest possible detail, a ten-year trip through the Solar System.

Approaching, orbiting, and landing on a comet require delicate and spectacular manoeuvres. Rosetta's target, comet 67P/Churyumov-Gerasimenko, is a relatively small object, about 4 kilometres in diameter, moving at a speed as great as 120,000 kilometres per hour with respect to the Sun.

Very little is known about its surface properties or the close environment. Only when we arrive at the comet will we be able to explore the comet in such detail that we can safely orbit it and deploy the lander.

Rosetta's lander will obtain the first images from a comet's surface and make the first in-situ analysis of a comet's composition.

Rosetta will also be the first mission to investigate a comet's nucleus and environment over an extended period of time. It will witness, at close proximity, how a comet changes as it approaches the increasing intensity of the Sun's radiation and then returns to the outer Solar System.

Rosetta is an ESA mission with contributions from its member states and NASA. Rosetta's Philae lander is provided by a consortium led by DLR, MPS, CNES and ASI.

Cover image: Artist's impression of Rosetta arriving at comet 67P/ Churyumov-Gerasimenko
Credit: ESA - C. Carreau / ATG medialab

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Online transmission of press events

The press event covering the arrival of Rosetta at comet 67P/C-G will be streamed live on:

www.esa.int
&
www.livestream.com/eurospaceagency

ESA TV productions

ESA TV productions are made available via: television.esa.int

Press conference schedules for Rosetta

6 August 2014, ESOC, Germany – Arrival at comet
The final schedule for the press event to be held at ESA's Spacecraft Operations Centre in Darmstadt, Germany, will be published on www.esa.int. A provisional programme can be found in Appendix A.

15 September, Paris, France [TBC] – Announcement of landing site
Details of the primary landing site for Rosetta's lander Philae will be announced at a press event on 15 September in Paris, France. Date and location are still to be confirmed. Details will be published on the ESA Portal www.esa.int.

11 November, ESOC, Germany [TBC] – Landing on comet
Members of the media are invited to cover Rosetta's delivery of the lander Philae to the surface of the comet at a press event in ESOC, currently foreseen for 11 November. Date to be confirmed. Details will be published on the ESA Portal www.esa.int.

Requests for interviews at press events at ESOC

Members of the media wishing to conduct interviews with participants at press events at ESOC should contact:

Corporate Communications Office
European Space Agency, ESA/ESOC
Robert-Bosch-Strasse 5
D-64293 Darmstadt
Email: esoc.communication@esa.int
Phone: +49 6151 902516

There is also a dedicated Rosetta media requests phone line:
+49 6151 90 4356

Accreditation to press events

Members of the media wishing to attend Rosetta press events must register for each event using the link provided in the related Call for Media published on the ESA Portal (www.esa.int).

Rosetta online

Information about the mission and the role of the partners can be found on the following websites:

European Space Agency
www.esa.int/rosetta - the entry point for all ESA web pages covering the Rosetta mission.
sci.esa.int/rosetta – detailed information about the Rosetta mission
blogs.esa.int/rosetta – regular updates, behind-the-scenes reports, contributions from guest writers.

The Rosetta pages on our partners' websites are at:
NASA rosetta.jpl.nasa.gov/
DLR www.dlr.de/rosetta and www.dlr.de/en/rosetta
CNES www.cnes.fr/rosetta and www.cnes.fr/rosetta-blog
ASI www.asi.it/it/attivita/sistema_solare/rosetta

Rosetta is also present on social media platforms:
Twitter: @ESA_Rosetta
FaceBook: www.facebook.com/RosettaMission
YouTube: bit.ly/rosettaYT
Flickr: bit.ly/rosettaFlickr

Pictures, illustrations and animations

A variety of photographs, illustrations and animations are available for non-commercial use. They cover a broad range of topics including: images of comet 67P/Churyumov-Gerasimenko taken with the cameras on Rosetta; pictures and animations to illustrate the science of Rosetta; and photographs documenting the different phases of the mission.

Links to a selection of recommended illustrations can be found in Appendix C.

An extensive collection of illustrations can also be found online:

All Rosetta images and videos: www.esa.int/spaceinimages/Missions/Rosetta/

Images of 67P/C-G from Rosetta: sci.esa.int/rosetta_comet_67P_images
Images of asteroid Lutetia: sci.esa.int/rosetta_lutetia_images
Images of asteroid Steins: sci.esa.int/rosetta_steins_images

ROSETTA ARRIVES AT COMET 67P/CHURYUMOV-GERASIMENKO

Key messages for today

- Rosetta is the first spacecraft to rendezvous with a comet
- Even greater risks and challenges lie ahead as the spacecraft will enter close orbit and deploy lander Philae to the comet's surface.
- Landing site selection for Philae begins now that Rosetta is close enough to characterise the comet in detail
- The mission will yield most of its scientific return as the spacecraft follows the comet on its orbit around the Sun through 2014 and 2015.

Key science themes of the Rosetta mission

- What are the comet nucleus constituents, composition and structure?
- How does the comet nucleus and coma change, on a daily basis and as it orbits the Sun?
- How does a comet "work"? For example, how is its activity generated?
- What role did comets play in the evolution of the Solar System?
- What role did comets play in delivering water to Earth during the evolution of the Solar System?
- Do comets contain the ingredients that helped spark life on Earth?

To answer these questions, Rosetta will

- Characterise the comet's surface morphology and composition, with instruments on the orbiter and on the lander, Philae
- Study the processes in the surface layers of the nucleus and the relationship to the development of activity and the growth of the coma
- Study the comet's plasma environment and how it interacts with the solar wind

Key quotes on the occasion of arrival

Alvaro Giménez, ESA's Director of Science and Robotic Exploration:

"The mission is a result of a huge international endeavour spanning several decades. It is a tribute to the expertise of hundreds of people that Rosetta has successfully navigated a 6.4 billion kilometre journey to bring the spacecraft to within reach of the comet."

"We've come an extraordinarily long way since the mission concept was first discussed in the late 1970s and approved in 1993, and now we are ready to open a treasure chest of scientific discovery that is destined to rewrite the textbooks on comets for even more decades to come."

Fred Jansen, ESA's Rosetta mission manager:

"Rosetta has clocked up many successes during its 10-year journey to comet 67P/Churyumov-Gerasimenko: the spacecraft has travelled five times round the Sun, completed four flybys –three at Earth and one at Mars –and has studied two asteroids along the way. It travelled out beyond the orbit of the asteroid belt on solar energy alone, survived 31-months in deep space hibernation, and woke up autonomously in January as planned. But only now are we about to start doing what the spacecraft was really built for: addressing the mission's main objectives at the comet."

Matt Taylor, ESA's Rosetta project scientist:

"Our first clear views of the comet have given us plenty to think about. Is this double-lobed structure built from two separate comets that came together in the Solar System's history, or is it one comet that has eroded dramatically and asymmetrically over time? Rosetta, by design, is in the best place to study one of these unique objects."

"Over the next few months, in addition to characterising the comet nucleus and setting the bar for the rest of the mission, we will begin final preparations for another space history first: landing on a comet. After landing, the spacecraft will continue to accompany the comet until its closest approach to the Sun in August 2015 and beyond, watching its behaviour from close quarters to give us a unique insight and real-time experience of how a comet works as it hurtles around the Sun."

Sylvain Lodiot, ESA's Rosetta spacecraft operations manager:

"Arriving at the comet is really only just the beginning of an even bigger adventure. Greater challenges lie ahead as we learn how to operate in this unchartered environment, start to orbit and, eventually, land."

Andrea Accomazzo, ESA's Rosetta flight director:

"Operations in the vicinity of the comet will be extremely challenging, especially if there are rapid changes in its activity. Our top priority is to keep the spacecraft safe as we follow the comet through the inner Solar System for over a year."

QUICK REFERENCE MISSION FACTS

Fast facts

Launch: 07:17 GMT on 2 March 2004, on an Ariane 5 G+ from ESA's spaceport at Kourou, French Guiana

Launch mass: 3000 kg (fully fuelled) of which the Orbiter accounted for 2900 kg (including 1670 kg propellant and 165 kg science payload), and the Lander 100kg (with 26.7 kg of science payload).

Orbiter dimensions: 2.8m x 2.1m x 2.0m with two 14m long solar wings

Orbiter payload: 11 experiments (ALICE, CONSERT, COSIMA, GIADA, MIDAS, MIRO, OSIRIS, ROSINA, RPC [ICA, IES, LAP, MAG, MIP, PIU], RSI and VIRTIS) to study the comet's global and local environment, surface, and sub-surface.

Lander dimensions: 1 m x 1 m x 1 m (before deployment of landing gear)

Lander payload: 10 experiments (APXS, CIVA, CONSERT, COSAC, PTOLEMY, MUPUS, ROLIS, ROMAP, SD2, SESAME) to investigate the local comet environment, surface and sub-surface.

Distance travelled (as of 6 August*): 6.5 billion km

One-way signal travel time (on 6 August*): 1349 seconds

Ground communications: ESA's New Norcia ground station (07:59-19:43 UTC), with ESA's Malargüe and NASA's Goldstone ground stations (outside the New Norcia coverage)

Distance of Rosetta from Sun (on 6 August*): 538,671,000 km

Distance of Rosetta from Earth (on 6 August*): 404,551,000 km

Speed of spacecraft and comet with respect to Sun: 15.3 km/s

** See Appendix E for equivalent numbers for other key periods of the mission*

Cost: The total cost of the mission is 1.3 thousand million Euro. This includes the launch, the spacecraft, the science payload (instruments and lander), and mission and science operations.

Industrial contributions: The Rosetta spacecraft was built by an industrial team led by prime contractor Astrium GmbH, Friedrichshafen, Germany, and involving more than 50 contractors from 14 European countries and the USA. Major subcontractors were Astrium Ltd. who built the spacecraft platform, Astrium France who supplied the spacecraft avionics and Alenia Spazio, Turin, Italy, for assembly, integration and verification. Canada participated in the construction of ESA's first 35 m-diameter Deep Space Antenna in Australia, which was built for Rosetta. Scientific consortia from institutes across Europe and the United States provided the 11 experiments for the orbiter.

Rosetta is an ESA mission with contributions from its member states and NASA. Rosetta's Philae lander is provided by a consortium led by DLR, MPS, CNES and ASI.

What’s in a name?

For the people charged with naming one of the most ambitious missions in planetary science this decade there was one name that seemed to have been destined for it: Rosetta.

The Rosetta Stone, an ancient Egyptian stone tablet from the second century BC was unearthed near Rashid (Rosetta) on the Nile delta in 1799. Famous for carrying the same text inscribed in three different languages – ancient Egyptian hieroglyphics, Demotic script (an everyday form of Egyptian) and ancient Greek - the stone allowed archeologists to decipher hieroglyphics for the first time. This in turn provided the key to understanding an ancient civilisation. In a similar manner, ESA’s Rosetta mission will allow scientists to unlock the mysteries of the oldest building blocks of our Solar System: comets.

Rosetta's lander Philae is named after an island in the Nile river, where archeologists found an inscription on an obelisk that confirmed their interpretation of the Rosetta Stone texts.

Mission milestones

Date	Event	Comment
2 March 2004	Launch	
4 March 2005	1st Earth swingby	Distance from Earth: 1950 km. Purpose: Gravity assist from Earth
25 February 2007	Mars swingby	Distance from Mars: 250 km. Purpose: Gravity assist from Mars
13 November 2007	2nd Earth swingby	Distance from Earth: 5300 km. Purpose: Gravity assist from Earth
5 September 2008	Steins flyby	Distance from Steins: 803 km. Purpose: Scientific investigation of asteroid (2867) Steins
13 November 2009	3rd Earth swingby	Distance from Earth: 2480 km. Purpose: Gravity assist from Earth
10 July 2010	Lutetia flyby	Distance from Lutetia: 3162 km. Purpose: Scientific investigation of asteroid (21) Lutetia
8 June 2011	Enter deep space hibernation	Distance from Sun: 667 million km. Purpose: To conserve energy while far from the Sun
20 January 2014	Exit deep space hibernation	Distance from Sun: 672 million km. Purpose: To prepare for comet rendezvous.
May to August 2014	Comet rendezvous manoeuvres – see Appendix D	Distance from comet: 230,000 km to 100 km. Purpose: To approach the comet for scientific investigations
6 August	Arrival at comet	Distance from comet: 100 km. Purpose: To enter close orbit around comet
11 November 2014 *Date to be confirmed*	Delivery of Philae lander to comet and start of First Scientific Sequence of Lander	Distance from comet: less than 10 km Distance from Earth: 509 million km Distance from Sun: 449 million km. Purpose: To deliver the lander on the comet surface.
November 2014 – December 2015	Accompany comet through perihelion (August 2015) and back towards outer Solar System	Distance from Sun at perihelion: 186 million km. Purpose: To study how a comet changes as it approaches and recedes from the Sun.

HIGHLIGHTS FROM THE ROSETTA MISSION THUS FAR

There are many highlights from the Rosetta mission because there is nothing routine about the endeavour. It is a daring mission that demanded world-class ambition and technological development to match.

When Rosetta is placed in orbit around comet 67P/Churyumov-Gerasimenko on 6 August 2014, the mission will already have accumulated a significant number of successes.

The idea that became Rosetta was conceived in the early 1980's even before ESA's Giotto mission flew by comet 1P/Halley, returning the first detailed picture of a comet's nucleus ever seen. The success of Giotto meant that plans for a follow-on mission were enthusiastically considered.

Almost 20 years later, Rosetta was built, tested and ready to launch. But disaster struck just one month before the planned liftoff. In December 2002, an Ariane 5, similar to the one designated to launch Rosetta, failed while lifting a communications satellite into orbit. With one billion Euros of tax-payers money and the hopes of the world's comet scientists resting on the successful launch of Rosetta, the difficult decision was made to postpone the attempt until the launcher failure was understood.

This robbed the mission of its original target, comet 46P/Wirtanen. While the engineers worked to understand and prevent the loss of another Ariane 5, scientists and engineers searched for a replacement target. Eventually they settled on comet 67P/Churyumov-Gerasimenko, a somewhat more massive comet than Wirtanen. This led to the strengthening of the legs on Rosetta's lander Philae, to cope with the slightly faster landing speed now expected.

With all this drama behind it, the first highlight of the mission was simply to leave the surface of the Earth behind and begin its interplanetary journey. The launch took place on 2 March 2004.

A complex journey

Rosetta could not head straight for the comet. Instead it began a series of looping orbits around the Sun that brought it back for three Earth fly-bys and one Mars fly-by. Each time, the spacecraft changed its velocity and trajectory as it extracted energy from the gravitational field of Earth or Mars. During these planetary fly-bys, the science teams checked out their instruments and, in some cases, took the opportunity to carry out science observations coordinated with other ESA spacecraft such as Mars Express, ENVISAT and Cluster.

Each of the fly-bys required months of intense preparation. In particular the fly-by of Mars in February 2007 was a critical operation: the new mission trajectory to 67P/Churyumov-Gerasimenko required that Rosetta fly past Mars at just 250 km from the surface, and spend 24 minutes in its shadow.

The spacecraft had been designed for the mission to Wirtanen, which did not include a period in Mars's shadow. The flight team had to re-programme the spacecraft completely in the months preceding the Mars fly-by, teaching Rosetta "not to worry" and to avoid potentially catastrophic autonomous reactions to the absence of sunlight on the solar panels and Sun-sensors.

When the Rosetta signal reappeared after the passage behind Mars, shortly after the end of the "shadow" period, there was a collective sigh of relief.

Getting to know Rosetta

A decade has passed since Rosetta was launched. This means that as it arrives at the comet, Rosetta is now an old-timer in terms of starting its main mission phase. Nevertheless, it must work at peak efficiency to make the most use of the months it will have at the comet.

One advantage of the mission's 10-year cruise phase is that the flight team has had plenty of opportunities to become familiar with many aspects of the spacecraft's personality. No matter how precisely designed and constructed, all complex machinery takes on a life of its own once it starts working. Spacecraft are no different.

In the case of Rosetta, the flight team has learned to use the thrusters at slightly reduced efficiency to compensate for the fact that the fuel tanks cannot be re-pressurized. This is due to a leak in the Reaction Control System that manifested itself in 2006.

They have also learned to operate the reaction wheels at lower speeds than originally designed. The reaction wheels are critical to the mission. They are used to orient the spacecraft such that the instruments can point to the comet, the solar arrays to the Sun, and the main antenna to the Earth. Well into the mission, two out of the four reaction wheels started showing signs of vibrations when operated at their normal operating speed. An alternative software has been devised that uses only two wheels; this is ready to be uploaded and used in case the two reaction wheels completely fail.

The cruise phase has not been all quiet. Even in the periods of low activity, during the long arcs between fly-bys, the spacecraft had to be monitored once a week, and its flight plan continuously updated.

Science along the way

En-route to the comet, Rosetta encountered two asteroids. These allowed the scientists and flight team to practise with the instruments and to gain more valuable experience about how to navigate the spacecraft. A highlight from the first encounter was Rosetta executing a manoeuvre that had originally been termed too risky.

Asteroid Steins is tiny, just 5 kilometres across; about the size of a large village. On 5 September 2008, Rosetta was to fly past at a distance of 800 kilometres, roughly the distance between Paris and Munich, and keep everything in the sharpest focus possible. To do this throughout the fly-by would have meant exposing one face of the spacecraft to the Sun for longer than allowed.

The original strategy defined by the spacecraft manufacturer, taking into account Rosetta's thermal and mechanical constraints, involved stopping before the closest approach to turn the spacecraft back to its nominal attitude. This would have led to significant loss of data. Naturally, the data-hungry scientists wanted to take observations all the way through.

So the flight control team invented and tested a new strategy, such that Rosetta tracked the asteroid autonomously all the way through the encounter, boosting confidence in the spacecraft enormously.

However, not everything went according to plan. The OSIRIS science camera and the navigation cameras did not work exactly as expected during the fly-by revealing another quirk of the spacecraft's personality. The team worked out how to ensure this did not happen again so that the next fly-by would be a success.

This paved the way for the mission's most celebrated science highlight so far: the fly-by of asteroid Lutetia in July 2010.

Whereas Steins was a small jumble of rocky debris that resembled a solid object, Lutetia was a miniature world, with a diameter of 130 kilometres. At the time, it was the largest asteroid ever seen in close-up.

Rosetta was going to fly past at a greater distance, 3,162 kilometres this time in order to allow the full asteroid to appear in the field of view of the scientific cameras. Nevertheless, the spacecraft would be out of communications with Earth for about 40 minutes as it turned its attention to Lutetia.

The vigil was worth it. Rosetta began streaming back its data, revealing a mini-world of the most complex geology. Its pulverised surface appeared to be poor in metals but showed the presence of hydrated minerals. There were rockslides and giant craters covering this battered relic from the formation of the Solar System.

In terms of aesthetics, the beauty-shot was an image that Rosetta had snapped on approach, showing the looming bulk of the asteroid in the foreground. In the distance, more than ten thousand times further away from the spacecraft, was the unmistakable shape of Saturn and her rings.

Rosetta sped on. It had charged past the asteroid at a relative speed of 54,000 kilometres per hour and was heading for the comet. Even at that great speed, there were still four more years to go. This meant that the moment many of the mission team dreaded was almost upon them: hibernation.

Hibernation and then …

Putting Rosetta to sleep for two years, seven months and twelve days was forced on the mission because it had to go so far out into the Solar System. Rosetta carries large solar panels based on completely new technology that makes them exceptionally efficient. But so far from the Sun, where no solar-powered spacecraft has gone before, there would not be enough power to keep all the spacecraft's systems operating. So everything was shut down, except for the on-board computer, some internal heaters and a few clocks to count down until 10:00 UTC on January 20th 2014. Then it was time for Rosetta to wake up, reactivate its communications system and phone home.

It did so, after a tense 18 minute delay, caused by the on-board computer rebooting. A memorable moment for the assembled scientists, flight team, officials and press, and a significant highlight ticked off the list. The mission was alive and ready for business. Next stop: the comet itself. Not that the flight team could relax. There was still a lot to do.

Preparing for arrival

Between wake-up and rendezvous, all twenty-one instruments had to be brought online and checked out. Software was updated and the spacecraft had to perform a series of 10 manoeuvres to reduce its speed sufficiently to rendezvous with the comet rather than fly by it.

Just by arriving at the comet, Rosetta has proved itself a remarkable space mission. By any standard it is a world-leading success to get this far.

Now the flight team will have to learn how to steer Rosetta round the comet. In the comet's weak gravitational field this will mean masterminding a series of complex manoeuvres that will last for more than a year, as Rosetta deploys a lander on the surface and follows the comet through its closest approach to the Sun in August 2015.

For the scientists, it is time to collect data in earnest. They must get to know the comet, and understand its behavior now, as a benchmark for the remainder of the mission. And they must choose a location for the landing attempt.

In contrast to previous missions to comets, this is not a quick fly by, but a chance to study a comet in detail, to monitor its transformation over the course of more than a year, and to learn its secrets.

As comet 67P/Churyumov-Gerasimenko is accelerating towards its encounter with the Sun its surface will become more active, more challenging to the spacecraft.

Rosetta will be there every step of the way.

It has already been a wild ride for this spacecraft, and it is set to get even wilder.

HOW ROSETTA ARRIVES AT AND ORBITS COMET 67P/C-G

ESA's Rosetta spacecraft has been travelling towards comet 67P/Churyumov-Gerasimenko for over ten years. Following launch on 2 March 2004, Rosetta has had to orbit around the Sun five times, and change speed and direction through four essential gravity assist manoeuvres – three at Earth and one at Mars – to put the spacecraft on a trajectory which brings it in line to rendezvous with the comet.

Comet 67P/C-G is on an elliptical 6.5-year orbit. At its furthest point, it travels beyond the orbit of Jupiter to nearly 850 million kilometres (5.68 AU) from the Sun. At its closest to the Sun, it comes between the orbits of Mars and Earth, at a distance of 186 million km (1.24 AU).

Rosetta too has been out close to the orbit of Jupiter and is now closing in on the comet while it is still between Jupiter and Mars: it will accompany the comet through closest approach to the Sun in August 2015 and as starts to travel back out from the inner Solar System again.

But first, Rosetta must rendezvous with the comet, currently travelling with a speed of about 55 000 km/hour in its orbit about the Sun. In order to achieve this space-history first, Rosetta must 'arrive' at a distance of 100 km from the comet's surface on 6 August, and with the same velocity and trajectory as the comet. Rosetta will then travel alongside the comet and manoeuvre around it with a relative velocity of less than 1 metre per second or 3.6 km/hour, roughly equivalent to walking pace.

After Rosetta woke up from deep space hibernation on 20 January 2014, the relative speed between the spacecraft and comet was 2790 km/hour (775 m/s) and Rosetta had to close a gap of nine million kilometres. At the same time, both Rosetta and the comet continued to move on their respective trajectories around the Sun, covering over a million kilometres each day.

Since early May, Rosetta has completed a series of ten orbital correction manoeuvres to slow the spacecraft's velocity – with respect to the comet – from 775 m/s to 1 m/s, and to alter its trajectory towards the comet's orbit. The first four burns were conducted every two weeks, providing adequate time to assess how well they were carried out, determine Rosetta's resulting orbit, and to ascertain the position of the comet. With this information, the magnitude and duration of the next manoeuvre could be tweaked accordingly.

The three largest burns, one exceeding seven hours, were some of the longest ever performed by an ESA spacecraft. Then in July, four more burns – the so-called 'far approach trajectory' burns – were conducted on a weekly basis.

Each burn was critical. If any of the burns had not completed successfully, or there was some delay in relaying the commands to Rosetta, orbital mechanics dictated that there would only be a matter of days to fix the problem, re-plan the burn and carry it out again. The ‘recovery time’ between burns became shorter and shorter as arrival day got closer.

If any of these burns were missed, the spacecraft would not be able to rendezvous with the comet. Instead of a year or more studying the comet from close quarters as planned, Rosetta would have only made a brief flyby.

All eight of the main manoeuvres were successfully completed within their expected tolerances. But no-one can rest easy just yet. The final two ‘close approach trajectory’ manoeuvres are scheduled for 3 and 6 August, respectively, the critical finishing touches to a successful rendezvous.

The short burn on 6 August will not only signal Rosetta’s safe arrival at the comet, but will also kick the spacecraft onto the first of three ‘arcs’ of a triangular-shaped trajectory, on its sunward side. Each arc will take about 3 or 4 days to complete, during which time the spacecraft will be between about 90 and 120 km from the comet surface. Eleven days later, and over a period of about a week, the spacecraft will slowly be brought down to a distance of about 50–70 km from the comet, and three more arcs will be flown, making another triangular-shaped trajectory in front of the comet. Small thruster burns providing a change in velocity of some tens of cm/s will be used to control these trajectory changes.

Each of these trajectory changes is crucial and carries with it an element of risk, with extremely short turnaround times – a matter of hours – to rectify any problems. At this stage, the risk is not that the spacecraft would miss the comet but that more time would be needed to reach the desired orbit, and time is now of the essence as observations are gathered to support the landing site selection activities. Changing the spacecraft’s trajectory with these manoeuvres allows data to be collected from different viewing angles, vital to the study of the comet and for planning what comes next.

The spacecraft’s navigation camera and scientific instruments will assess the comet’s characteristics, map its surface, observe any activity, and refine mass and gravity models, while mission controllers continue to learn how to operate in uncharted territory. A significant challenge will arise from the comet’s irregular shape and therefore determining its physical properties is absolutely critical for determining the eventual orbit around it.

Based on images and Doppler tracking performed while approaching the comet, the flight dynamics team have begun to develop models for the comet’s gravity potential, its shape and its rotational motion. Similarly, the high resolution OSIRIS narrow angle camera has also been used during the approach phase to deliver shape models to the lander team, to not only aid navigation around the comet, but also to start planning how and where the lander Philae can be deployed.

A lot will be known about 67P/C-G before Rosetta enters a true orbit around the comet in early September, when the spacecraft will be transferred to a global mapping orbit at roughly 30 km from the surface. At this distance, the comet's own weak gravity, several hundred thousand times weaker than that of Earth, should be sufficient to keep Rosetta in a closed orbit.

Depending on the activity of the comet, the ultimate aim is to orbit even closer, perhaps as close as 10 km by mid-October. The orbital period of Rosetta around the comet will depend on how close it is, but will typically be on the order of several days. During these closer periods, Rosetta will fly over dayside regions, and will image the chosen landing site at higher resolution still.

Operating Rosetta in this environment will present challenges on a daily basis; the unpredictability of the comet environment will require both care and flexibility in planning the short-term operations. Orbit profiles will have to be re-planned and adjusted on a very short cycle if there are rapid variations in the comet activity level. Keeping the spacecraft safe will be of primary importance in order to achieve the goal of accompanying the comet on its orbit around the Sun throughout 2015 and beyond.

Summary of rendezvous manoeuvres

Note: At wake-up, 20 January 2014, the separation between Rosetta and the comet was nine million km, and the relative velocity between Rosetta and the comet was 775 m/s.

Date (2014)	Reduction in velocity relative to comet (m/s)	Length of burn (mins)	Comet distance on day of burn (km)	"Flyby" date/ distance if burns not completed
7 May	20	41	1 921 331	3 June / 50304 km
21 May	291	441	1 007 849	5 June / 47510 km
4 June	271	406	428 208	14 June / 27298 km
18 June	91	140	178 913	28 June / 13804km
2 July	59	94	50 154	7 July / 10093km
9 July	25	46	21 300	14 July/ 4912 km
16 July	11	26	9 134	21 July / 2415km
23 July	5	17	3 920	28 July / 1010 km
3 August	3	13	534	4 August / 219 km
6 August	1	7	120	n/a

SELECTING A LANDING SITE FOR ROSETTA'S LANDER, PHILAE

The landing site selection process will identify a safe and scientifically interesting landing site for Rosetta's lander, Philae. The process began in late July and will culminate in mid-October with the formal go-ahead for landing.

Responsibility for the selection lies with the Landing Site Selection Group (LSSG). This is composed of engineers and scientists from Philae's Science, Operations and Navigation Centre (SONC/CNES), the Lander Control Centre (LCC/DLR), scientists representing the Philae Lander instruments, and the ESA Rosetta team.

Since comet 67P/Churyumov-Gerasimenko has never been seen up close before, a meaningful selection can only be made once the spacecraft is close enough to be able to characterise it.

In this context, characterising the comet means determining the shape, rotation rate and orientation, gravity field, albedo (reflectivity), surface features and surface temperature of the nucleus. It also means measuring outgassing and quantifying the density and velocity distribution of particles in the coma, the envelope of gas and dust surrounding the comet nucleus.

The selection of the landing site is a race against time in a brief window of opportunity, and must find a balance between competing needs. The comet's activity is driven by the increase in heat as it heads closer to the Sun every day. The lander must be deployed before this activity rises to levels that could jeopardise a safe landing.

On the other hand, the landing cannot take place too early because there must be sufficient sunlight for Philae's solar cells to generate enough power to operate the lander in the weeks after landing. Also, the surface temperature should be suitable for the lander to operate: not to cold or too hot.

Combined, these factors dictate that the landing should take place when the comet and Rosetta are about 3 Astronomical Units (450 million km) from the Sun – this is where the comet will be by mid-November.

Those involved in the selection process must therefore make the best use of the limited time following the rendezvous on 6 August to gather critical data and make informed decisions. A detailed rehearsal to test the selection process was carried out with simulated data in the period between January and May 2014. Now it is time to do it for real.

As the distance between Rosetta and the comet decreased rapidly between May and August, the onboard scientific and navigation cameras began to resolve the comet and identify features on its surface. Rosetta's other instruments are also beginning to 'sense' the comet's environment in more and more detail as the spacecraft draws close.

In July 2014, images from the OSIRIS cameras began to reveal the shape of comet 67P/C-G. It appears to have two distinct lobes, reminiscent of a contact binary – a body composed of two separate entities that combined during a collision. Although no definitive conclusions about the nature, origin and evolution of the comet can be drawn from these early images, what is certain is that the distinctive shape will add to the challenges involved in selecting a safe landing site.

The first step in the selection process is to gather the crucial technical information needed by the LSSG to identify suitable candidate landing sites.

Initially, the primary driver is whether or not landing on a given site is technically feasible, independent of scientific desirability.

'Feasibility' is based on many factors relating to where a site is on the comet. Some of these are specific to the descent phase after Rosetta has deployed the lander: its duration and the illumination conditions and radio communications with Rosetta during descent.

Others relate to the conditions at touchdown, such as the speed at which the lander reaches the site, the slope of the surface and the orientation of the lander.

The physical nature of the site is also an important factor: are there hazards such as large boulders or deep crevasses on the surface? Is the topography of the landing site suitable for the science experiments?

Periodic communications between the lander and the orbiter must be maintained as much as possible during the lander's First Science Sequence (FSS; the first intensive phase, lasting about 3 days) and its Long Term Science Sequence (LTS; up to about March 2015).

There must also be a balance between comet day and comet night to cater for the scientific needs of the instruments, as well as ensuring that the solar cells can recharge the battery to power the lander instruments, while not overheating the lander.

Finally, sites should allow for operations of the CONSERT experiment, which requires radio signals to be transmitted between the orbiter and lander through the body of the comet.

The scientific value of the potential sites is also taken into account. To help judge this, essential observations will be made by Rosetta's scientific instruments, in particular OSIRIS, MIRO, and VIRTIS, with additional contributions from ALICE and ROSINA, and from the navigation camera, NAVCAM.

NAVCAM and OSIRIS images are used not only to model the shape and rotation of the comet. They also allow the flight team to compute the spacecraft's trajectory and so deduce the comet's gravitational field. MIRO and VIRTIS measurements of the comet's surface temperature will be used to predict the temperature at the comet three months into the future, during lander operations. Measurements from MIRO, VIRTIS, ROSINA and ALICE of the pressure and density of gas surrounding the nucleus will be used to indicate the environment in which the spacecraft will be operating.

Scientific measurements of the comet surface and environment are also gathered by other orbiter experiments. These will also be used in assessing the scientific merit of the candidate sites.

A preliminary selection of up to 10 landing sites will be made by a subset of the LSSG, meeting on 20 August, just two weeks after rendezvous. For each of these sites, the LCC and the SONC will carry out a technical analysis to be presented at the first full meeting of the LSSG, on 22-24 August.

At this meeting, participants will review the results from the technical analysis and discuss the scientific merits of the candidate sites. By the end of the meeting, the group will select no more than five of the sites for detailed investigation.

From 25 August to 13 September, the ESA Rosetta Mission Operations Centre (RMOC) at ESOC will carry out a comprehensive analysis to identify possible trajectories to deliver the lander, and to confirm that the proposed landing sites can be reached with the required accuracy. It is possible that some of the landing sites will be rejected at this point.

During this period, more detailed measurements will be taken from the orbiter, as it approaches to within 50km of the comet.

At this stage the shape model of the comet will have a resolution of 3.6m on the surface of the comet and 0.5m in elevation. The model will be used to simulate a view of the horizon as seen from Philae's panoramic cameras, which may also be a factor in the selection of the primary site.

At the second meeting of the LSSG, on 13-14 September, the latest data will be scrutinised. Technical aspects, such as flight dynamics analyses for the orbiter and the lander, and scientific aspects, for example, new measurements from orbiter instruments, will be considered. The possible landing scenarios and their implications on the science programme of the lander will be discussed.

Finally, the remaining candidate sites will be ranked, and from this the primary and possibly backup landing sites will be selected.

From 16 September to 11 October, detailed analysis and operational preparation for the landing will take place. During this period the spacecraft will be close enough to the comet to allow the OSIRIS Narrow Angle Camera to map the boulder distribution at the primary and backup landing sites.

On 12 October the LSSG meet to make the crucial Go/No Go decision for Philae to land on the primary site. While the primary site coordinates define the location where the lander is envisaged to land, the actual landing can take place within a landing ellipse measuring some hundreds of metres across. The precise dimensions of the actual landing area will depend on a number of factors, including the precision with which the orbiter's location is known at the time the lander is released and on where along the delivery trajectory the lander is released. In preparation for this Go/No Go meeting, OSIRIS will deliver its high resolution images and information about the distribution of boulders on the primary and backup landing sites which are used as an input to the risk analysis. This information serves to support slight adjustments to be made to the target coordinates within the landing area with the aim to reduce the overall risk of landing in a section which has a higher fraction of boulders.

Final scientific measurements from orbiter instruments will also be used to support the risk analysis, although these will not be considered as an essential part for the Go/No Go decision.

Two days later, on 14 October, the formal Lander Operations Readiness Review takes place, to give the official go-ahead for the landing.

Then from 13 October to 3 November the SONC and LCC work to adapt the Separation, Descent and Landing (SDL) and First Scientific Sequence (FSS) operations of Philae based on the chosen landing site. The fine-details of these operations can be adapted at this stage.

In parallel, the spacecraft operators at ESOC prepare the command sequences for the deployment of Philae onto the surface of comet 67P/Churyumov-Gerasimenko. Due to the extremely high precision required for this manoeuvre, the spacecraft's trajectory and commands will be continually updated as the days count down. The final separation and landing sequence will only be transmitted to Rosetta a few hours before separation.

Then, the world waits. The landing, currently planned for 11 November, will take place entirely automatically.

Key dates

19 August: Due date for all data needed for the Landing Site Selection Group (LSSG) meeting of 20 August

20 August: LSSG meeting to pre-select up to 10 candidate sites: Lander Control Centre (LCC) and Science Operations and Navigation Centre (SONC) carry out technical analysis

22-24 August: Meeting of LSSG to select a maximum of five of the candidate landing sites; Coordinates of sites are sent to Rosetta Mission Operations Centre (RMOC)

25 August: Delivery of OSIRIS Digital Terrain Models of the candidate sites

5 September: RMOC experts report on first analysis of landing sites

13-14 September: Meeting of LSSG to select primary and backup landing sites; Landing Site coordinates are sent to RMOC

23 September: Delivery of OSIRIS high-resolution images and boulder distribution file for primary and backup landing sites

26 September: RMOC report on final analyses and operational scenario of primary landing site

12 October: Meeting of LSSG for final Go/No Go decision primary landing site

14 October: Lander Operations Readiness Review

7 November: Final landing sequences are sent from LCC to RMOC

9 November: Final landing sequences are uploaded to the Lander

11 November: Currently planned landing date

LANDING ON A COMET

Beyond the significant first rendezvous with and escort of a comet, Rosetta will attempt another first: landing on a comet.

The race to find a safe and scientifically interesting landing site begins as soon as Rosetta arrives at comet 67P/Churyumov-Gerasimenko in August. Only then will the experts be able to study the comet in sufficient detail to choose a landing site. By mid-October the site will have been selected.

Why the rush? The date chosen for landing is a delicate balance between competing issues. On one hand, the lander must receive enough sunlight to generate power with its solar cells and recharge its batteries, and thus the landing cannot take place when the comet is too far from the Sun. The surface must be a reasonable temperature to ensure lander survival as well.

On the other hand, landing cannot occur too close the Sun either, because as the comet heads into the inner Solar System, the heat of the Sun becomes an increasingly powerful influence on its surface. Ices in and under the surface will sublimate, turning straight into gas, while previously trapped gas escapes through fissures opened in the comet's rock-ice nucleus. This gas escapes from the surface, dragging dust grains with it.

As activity builds up, this makes for an increasingly hostile and risky environment in which to operate the orbiter and deploy the lander. Already, comet 67P/C-G has given hints of such activity with an apparent outburst between late April and early June this year, and such events will likely grow in frequency and intensity as the comet draws nearer to the Sun.

Taking all of these factors into account, the most suitable time for landing is thought to be when the comet is about 3 Astronomical Units (450 million km) from the Sun. This is where it will be by mid-November.

Between August and October, Rosetta will have edged closer to the comet. If the activity is not too high by mid-October, Rosetta will be orbiting the comet at an altitude of about 10 km. A series of small manoeuvres will then place the spacecraft into the pre-delivery orbit. The delivery manoeuvre requires extremely high precision, so Rosetta will remain in this orbit for a few days to give the spacecraft operators time to verify the position and velocity of the spacecraft with great accuracy. Once this is done, the landing attempt can begin.

From the pre-delivery orbit, Rosetta will manoeuvre to a hyperbolic trajectory flying in front of the comet, on the Sun side. Two hours later, the lander will be automatically released. It can be pushed away from the orbiter at a selectable speed of between 0.05 m/s and 0.51 m/s. The exact value will depend on the properties of the comet, and on the chosen separation and descent scenarios. If the initial deployment is not successful, a backup spring mechanism will ensure that the lander is released at a speed of about 0.18 m/s. For obvious reasons then, a separation and descent strategy with this value is favoured.

Once released, Philae is on its own. A signal will take about 30 minutes to cross the distance between Earth and the comet at that point, which is far too long to allow any kind of manual intervention.

The descent could be as short as 2 hours or as long as 12 hours, depending on the particular landing scenario chosen to get to the selected landing site. The lander will touchdown somewhere inside a “landing ellipse”, roughly a few hundred metres across. The landing ellipse will have been selected to be as free as possible of hazards such as large boulders, but there will nevertheless be a degree of risk involved.

As Philae descends it will fall slowly without propulsion or guidance, gradually gathering speed in the comet’s weak gravitational field, although its attitude will be stabilised via an internal flywheel.

During the descent, images will be recorded with the downward looking camera and some of the science experiments on the lander will be active too. Meanwhile, the orbiter will continue on its trajectory away from the comet’s nucleus. A small manoeuvre will allow it to look back and monitor Philae’s descent using cameras. This manoeuvre also ensures that there can be communication between the orbiter and lander during the descent and up to 90 minutes after landing.

Philae will reach the surface at roughly walking pace, around 1 m/s. That may not sound like much, but as the comet’s surface gravity is roughly one hundred thousand times weaker than Earth’s, a sophisticated system must be used to prevent it from rebounding into space. The three-legged landing gear will absorb the momentum and use it to drive an ice screw in each foot into the surface. At the same time, two harpoons will fire to lock the probe onto the surface, and a small thruster on top may be used to counteract the recoil of the harpoon.

Once anchored to the nucleus, Philae’s primary science mission will begin and must happen quickly. Its initial battery life is only 64 hours, and while it also has solar cells with which to recharge the batteries and extend its lifetime, this will depend on the landing site location and illumination, and how much dust collects on the panels.

Philae will take panoramic images of its surroundings, with a section in 3D, and high-resolution images of the surface immediately underneath it. It will perform on-the-spot analysis of the composition of the comet’s ices and organic material, and a drill will take samples from a depth of 23 cm and feed them to the on-board laboratory for analysis. The lander will also make measurements of the electrical and mechanical characteristics of the nucleus surface.

The data will be relayed to the orbiter, ready for transmission back to Earth at the next period of contact with a ground station. For the first five Earth days, there will be regular contact between the orbiter and lander when the two can see each other as the comet rotates with its 12.4 hour period. In addition, low-frequency radio signals will be beamed between Philae and the orbiter through the nucleus, to probe its internal structure.

The detailed in-situ surface measurements that Philae makes at its landing site will be used to complement and calibrate the extensive remote observations made by the orbiter covering the whole comet. Once the primary science mission has been completed, the lander will continue to monitor the physical and chemical properties of the comet's surface as it continues on its journey towards the Sun and for as long as the batteries are able to recharge.

In the meantime, Rosetta will begin the next major part of its mission, the escort phase. The orbiter will continue to manoeuvre around the comet at walking pace, collecting dust and gas samples and making remote sensing observations as the comet warms up and the nucleus and its environment evolve. The comet will reach its closest point to the Sun (perihelion) in August 2015, at 186 million kilometres. Rosetta will then track the waning of activity as the comet heads back towards the outer Solar System, at least until the end of 2015.

COMETS – AN INTRODUCTION

What is so special about comets that ESA has spent ten years flying a spacecraft towards one?

These small icy bodies are the most primitive objects in our cosmic neighbourhood, preserving pristine material left over from the formation of the Solar System, 4.5 billion years ago. For this reason, studying the chemical composition of comets may help scientists to answer some of the open questions about the Solar System's formation, including the way Earth came together.

Comets may have played an important role in delivering water to the young Earth, as well as bringing carbon-based molecules that may have been key to the development of life. Locked up in their rock-ice interiors are frozen water and other volatiles, including carbon monoxide, carbon dioxide, methane, and ammonia.

When comets approach the Sun these frozen worlds are gently heated, releasing these ices into space to produce a vast envelope of dust and gas around the nucleus. This 'coma' results from ices on the nucleus sublimating – changing directly from a solid to a gas – and carrying tiny dust particles into space. Sunlight reflecting off these particles makes the coma visible.

For observers on Earth, the result of this process can be spectacular: the coma can grow to millions of kilometres in diameter and, eventually, pressure from solar radiation and the solar wind is enough to cause some of the material to stream out in the opposite direction to the Sun to form two tails. One tail is made of gas and plasma and points in a direction directly opposite to the Sun, and the other is made primarily of dust, following a slightly curved path that points back along the comet's orbit.

Humans have observed comets since ancient times, but only in the past few centuries have scientists started to grasp the nature of these fascinating bodies. And it wasn't until the second half of the twentieth century that a clear picture began to emerge.

The most famous of all comets is undoubtedly Halley, a so-called periodic comet that returns to our skies once every 76 years. In general, short-period comets have periods up to two hundred years; their orbits are elliptical and occupy a very similar region in the Solar System to the one where the giant planets are found.

But the majority of comets have longer periods, spend most of their time in the far reaches of the Solar System and have highly eccentric elliptical orbits that only bring them to our skies once every few hundreds of thousands of years or so. There are also non-periodic comets. As these fall towards the inner Solar System, the gravitational pull of the giant planets places them on 'open orbits'. This means that they only pass by the Sun once.

Two reservoirs supply the Solar System with comets: the Kuiper belt a flattened, ring-like distribution that begins just outside Neptune's orbit, and the Oort cloud, a huge spherical cloud that extends over a thousand times farther than the orbits of Neptune and Pluto. These two reservoirs are named after Dutch astronomers Gerard Kuiper and Jan Oort, respectively, who predicted their existence in the 1950s.

Comets in the Kuiper belt and Oort cloud are gravitationally bound to the Solar System. They originated from the same primordial nebula that gave birth to the Sun and the planets. It is likely that these comets formed closer to the Sun and were later expelled outwards as a consequence of repeated interactions with the giant planets.

As the Sun moves through the Galaxy, stars or gas clouds passing near the outer boundaries of the Oort cloud may perturb the motion of some of these “dormant” comets just enough to modify their orbits. This can kick them into the inner Solar System, where they eventually develop the characteristic coma and tails. Then, as a comet leaves the inner Solar System, the rate of sublimation decreases significantly and the coma and tails disappear. But the comet’s activity does not die down, and occasional outbursts may occur also at larger distances from the Sun.

In some cases, the comet plunges back along its highly eccentric orbit into the far reaches of our planetary system (for long period comets) or even beyond (for non-periodic comets). In other cases, it may be affected by the gravitational pull of one or more of the giant planets and remain “trapped” in a more regular, less eccentric orbit that keeps it closer to the Sun on a short-period orbit. For example, Rosetta’s target comet 67P/Churyumov-Gerasimenko is trapped on a 6.5 year commute around the Sun between the orbits of Jupiter and Earth.

Sometimes a comet meets a dramatic fate. If the comet comes too close to the Sun, the gravity of our parent star may tear it apart. This can happen either at a comet's first passing by the Sun (as in the case of comet ISON, a “sungrazer” that disintegrated in late 2013) or after many orbits (as for the short-period comet known as Biela's Comet, which was seen to split in two pieces in 1852). Other Solar System bodies can also cause a comet's demise, as witnessed by the collision of comet Shoemaker-Levy 9 with Jupiter in 1994. Or a comet can simply ‘fade away’, having exhausted its ices or developed a thick layer of dust.

Scientists have been observing comets remotely using ground-based telescopes for the past four centuries, but the advent of the space age revolutionised the field. Now, spacecraft can fly past comets and study them up close. Five comets have been visited by spacecraft since Giotto flew past comet 1P/Halley in 1986, setting the stage for ESA's Rosetta mission, the first spacecraft to rendezvous with a comet, attempt a landing on its nucleus, and accompany it as it moves closer to the Sun.

ROSETTA'S COMET - AT A GLANCE

After a ten-year journey, ESA's Rosetta mission is arriving at its destination: comet 67P/Churyumov–Gerasimenko, or 67P/C-G for short. The name acknowledges the Ukrainian astronomers Klim Churyumov and Svetlana Gerasimenko, who first spotted the comet in 1969. The '67P' refers to it being the 67th short-period comet discovered.

Comet 67P/C-G is on an elliptical 6.5-year orbit. Its closest approach to the Sun (perihelion) is in the region between the orbits of Earth and Mars, while its farthest point from the Sun (aphelion) is slightly beyond the orbit of Jupiter. It belongs to the "Jupiter Family" of comets, whose motion is strongly affected by Jupiter's gravity. Close encounters with Jupiter in 1840 and 1959 reduced the perihelion from a distance of almost 600 million to 186 million kilometres.

Using ground-based telescopes the comet has been observed from Earth on seven approaches to the Sun: 1969 (discovery), 1976, 1982, 1989, 1996, 2002 and 2009. This time around astronomers are paying particular attention. More than 70 professional astronomers are observing 67P/C-G using telescopes at major observatories all over the world. These ground-based observations complement the unique results that will come from Rosetta. While Rosetta investigates the nucleus and inner core of the coma, observations from Earth get a wider view, taking in the entire coma and tails of the comet. This provides valuable context information for scientists and for mission planners.

As 67P/C-G approaches the Sun, it will brighten, bringing it within reach of amateur astronomers and their telescopes. A ProAm collaboration to monitor activity on the comet is already underway and will continue for the duration of the mission.

Year of discovery	1969
Discoverers	Klim Churyumov & Svetlana Gerasimenko
Size	Irregular, approximately 4 km across
Rotation period (hours)	12.4
Orbital period (years)	6.5
Perihelion (million km)	186 (1.243 AU)
Aphelion (million km)	849.7 (5.68 AU)
Orbital eccentricity	0.640
Orbital inclination (degrees)	7.04
Surface temperature	-70°C (average surface temperature measured by VIRTIS from a distance of 14 000-5000km)

MISSIONS TO COMETS – ROSETTA IN CONTEXT

For much of history, humans have been fascinated by comets. Evidence for this can be found in Scottish rock carvings dating back to the second millennium BC, on clay tablets from ancient Babylon, and on an 11th century BC Chinese almanac transcribed on silk.

Comets were seen as omens of portent, and thought by many to be atmospheric phenomena rather than celestial. Gradually, astronomers realised that these apparitions were visitors from the distant reaches of outer space. In doing so, mere curiosity evolved over the centuries into scientific study.

Where did comets come from? How did they move through space? What were they made from? All of these became key drivers in the astronomers' pursuit of knowledge throughout the 18th century Age of Enlightenment.

Towards the end of the twentieth century, advances in space technology provided exciting new possibilities for comet scientists. Before they had relied solely on naked-eye observations or ground-based telescopes to study these ghostly messengers. Now it was possible to approach them with spacecraft, catching them as they journeyed towards the inner regions of the Solar System, relatively close to Earth.

In 1985, NASA's International Cometary Explorer (ICE) became the first space mission to pass through the tail of a comet. It flew past at a distance of 7800 kilometres from the nucleus of comet 21P/Giacobini-Zinner.

Just one year later, when Halley's Comet returned to our skies, an armada of spacecraft was sent to study the comet up close: these included two probes from Russia (Vega-1 and Vega-2), two from Japan (Sakigake and Suisei), and ESA's Giotto spacecraft.

Giotto flew within 600 kilometres of comet 1P/Halley, closer than any other spacecraft, and sent back detailed images of the icy nucleus at the heart of the comet. This was a world-leading first. Giotto's unique data showed, among other things, that comets contain complex organic molecules. Studying these may help us understand if comets helped to 'seed' life on Earth.

After Halley, the spacecraft continued its journey. It was revived in 1992 to fly past comet 26P/Grigg-Skjellerup. Giotto's camera had been blinded by dust particles during its encounter with Halley, but nonetheless it's other instruments could sense 26P's nucleus as it flew within 200 km of it. It confirmed the picture from Halley that comets were solid objects rather than mere rubble piles or conglomerates of small fragments.

Other missions to comets followed. These include a trio of NASA probes: Deep Space 1, which flew by comet 19P/Borelly in 2001; Stardust, which flew past comet 81P/Wild in 2004 collecting samples from the comet's coma, the envelope of gases that surrounds the nucleus, that it returned to Earth two years later; and Deep Impact, which in 2005 shot a block of copper onto the nucleus of comet 9P/Tempel to investigate the subsurface.

The Stardust mission was extended and as Stardust-NExT it flew by comet 9P/Tempel in 2011 and imaged the crater created six years earlier by Deep Impact. The latter mission was also extended and as the EPOXI mission flew by comet 103P/Hartley in 2010 and imaged comet C/2009 P1 (Garradd) in April 2012 and comet C/2012 S1 (ISON) in January 2013. Another NASA mission, Contour, launched in Summer 2002, failed when it was incorrectly inserted into its interplanetary trajectory.

Rosetta is much more ambitious and advanced than Giotto or any of the previous comet explorers. Its observation phase will last much longer and will not be limited to "snap-shots" from flybys.

Unlike all previous missions, Rosetta is capable of investigating both the nucleus and the coma over an extended period of time. The mission includes both an orbiter and a lander, so observations made from orbit can be correlated with in-situ measurements made on the surface.

It carries a much more advanced payload than any of its predecessors. The suite of eleven experiments on the orbiter will observe all aspects of the comet from close range over more than a year as it moves along its orbit towards the inner Solar System. The ten experiments on the lander, including spectrometers, high-resolution cameras and drill, will provide ground-truth measurements of the nucleus.

Rosetta is unique. It will be the first mission to rendezvous with a comet, deploy a lander and then accompany the comet as it reaches its closest approach to the Sun.

TIMELINE OF MISSIONS TO COMETS

LAUNCH DATE	MISSION NAME	COMET
12 August **1978**	**International Cometary Explorer**	**Comet 21P/Giacobini-Zinner** Flew past the comet at a distance of 7,860 km on 11 September 1985. First spacecraft to fly in the vicinity of a comet. **Comet 1P/Halley** Flew through the coma at a distance of 31 million km from comet nucleus on 28 March 1986.
15 December **1984**	**Vega-1**	**Comet 1P/Halley** Flew past the comet at a distance of 8,890 km on 6 March 1986. Part of international fleet to study 1P/Halley.
21 December **1984**	**Vega-2**	**Comet 1P/Halley** Flew past the comet at a distance of 8,030 km from comet on 9 March 1986. Part of international fleet to study 1P/Halley.
7 January **1985**	**Sakigake**	**Comet 1P/Halley** Flew past the comet at a distance of 151,000 km on 8 March 1986. Part of international fleet to study 1P/Halley.
2 July **1985**	**Giotto**	**Comet 1P/Halley** Flew within 600 km of comet on 13 March 1986. Closest approach to 1P/Halley. First resolved image of comet nucleus. Part of international fleet to study 1P/Halley.
18 August **1985**	**Suisei**	**Comet 26P/Grigg-Skjellerup** Flew within 200 km of comet on 10 July 1992. **Comet 1P/Halley** Flew 7 million km past the comet on 11 March 1986. Part of international fleet to study 1P/Halley.
24 October **1998**	**Deep Space 1**	**Comet 19P/Borrelly** Flew past the comet at a distance of 2,200 km on 22 September 2001. Main mission was technology demonstrator of ion engines, main target was asteroid Braille. Extended to go to 19P/Borelly.
7 February **1999**	**Stardust**	**Comet 81P/Wild** Flew within 240 km on 2 January 2004. Mission to collect samples of comet atmosphere and to sample comet grains. Samples returned to Earth on 15 January 2006.
7 February **1999**	**Stardust-NExT**	**Comet 9P/Tempel** Flew within 181 km of the comet on 14 February 2011.
3 September **2002**	**Contour**	**Comet 2P/Encke & Comet 73P/Schwassmann-Wachmann** Contact lost shortly after launch.
2 March **2004**	**Rosetta**	**Comet 67P/Churyumov-Gerasimenko** Orbit comet, deploy lander to surface and escort comet though perihelion. Asteroids Steins and Lutetia were studied along the way.
12 January **2005**	**Deep Impact**	**Comet 9P/Tempel** Flew within 500 km of the comet on 4 July 2005 before releasing impactor to study comet's interior.
12 January **2005**	**EPOXI**	**Comet 103P/Hartley** Flew past the comet at a distance of 700 km on 4 September 2010. Mission to study a hyper-active comet. Deep Impact was reassigned as EPOXI, a combination of two missions: DIXI, Deep Impact Extended Investigation, and EPOCh, Extrasolar Planet Observation and Characterisation. **Comet C/2009 P1 (Garradd)** Imaged from a distance of 210 million km between February and April 2012. **Comet C/2012 S1 (ISON)** Imaged from a distance of 793 million km in January 2013.

APPENDIX A: DRAFT PROGRAMME FOR PRESS EVENT

On 6 August, after a decade-long journey through space, ESA's Rosetta will become the first spacecraft in history to rendezvous with a comet. Members of the media are invited to join ESA's science and mission control experts and partners on Wednesday 6 August, from 09:30 CEST, at ESA's Operations Centre in Darmstadt, Germany, for the day-long event celebrating the arrival and presenting the latest, high-resolution images of the comet's nucleus.

The press briefings will be live-streamed at www.esa.int/rosetta and www.livestream.com/eurospaceagency.

Provisional programme - subject to change.

09:30 Doors open at ESOC H-building (1st floor)

10:00 Welcome, by Thomas Reiter, ESA's Director of Human Spaceflight and Mission Operations and Head of the European Space Operations Centre, ESOC

10:05-10:45 Addresses by:
Jean-Jacques Dordain, ESA Director General
Brigitte Zypries, Parliamentary State Secretary, Air and Space Coordinator for the German Federal Government (BMWE)
Johann-Dietrich Wörner, Chairman of the DLR German Aerospace Center
Jean-Yves Le Gall, President of the French space agency, CNES
Roberto Battiston, President of the Italian space agency, ASI
Alvaro Giménez, ESA's Director of Science and Robotic Exploration

10:45-11:00 First scientific findings and images from Rosetta's approach:
Matt Taylor, ESA Rosetta project scientist
Holger Sierks, MPS Göttingen, Germany (PI, OSIRIS instrument)
Samuel Gulkis, NASA JPL, Pasadena, USA (PI, MIRO instrument)
Fabrizio Capaccioni, IAPS, Rome, Italy (PI, VIRTIS instrument)

11:00 Beginning of orbit insertion manoeuvre

11:10-11:35 Mission operations and expected arrival at the comet
Paolo Ferri, Head of Mission Operations, ESA
Andrea Accomazzo, ESA Rosetta Flight Director
Frank Budnik, ESA Rosetta Flight Dynamics expert
Laurence O'Rourke, Rosetta Science Operations, ESA

~11:35 Announcement of successful comet insertion by **Sylvain Lodiot**, Rosetta Spacecraft Operations Manager

11:40 Statement by ESA Director General **Jean-Jacques Dordain**

11:50 Lunch break, opportunities for further interviews

13:00 Press briefing at the new press centre, ESOC H building, (Ground floor)
Moderated by **Mark McCaughrean**, Senior Scientific Advisor, ESA Directorate of Science and Robotic Exploration

Short interactive presentations with Rosetta scientists and mission experts to set the scene for upcoming science operations and preparations for the landing:

Andrea Accomazzo, Head of Planetary Missions Division, ESA
Stephan Ulamec, Philae Lander Project Manager, German Aerospace Center, DLR
Laurence O'Rourke, Rosetta Science Operations, ESA
Frank Budnik, Flight Dynamics expert, ESA
Samuel Gulkis, NASA JPL, Pasadena, USA (Instrument MIRO)
Fabrizio Capaccioni, IAPS, Rome, Italy (Instrument VIRTIS)

Presentation of the latest comet images by **Holger Sierks**, MPS Göttingen, Germany

14:30 Q & A opportunities for media; further interview possibilities

15:30 End of event

Appendix B: SPEAKERS AT THE 6 AUGUST PRESS EVENT


Jean-Jacques Dordain,
ESA Director General


Thomas Reiter,
Director of Human Spaceflight and Operations, and Head of ESOC


Alvaro Giménez,
Director of Science and Robotic Exploration


Brigitte Zypries,
German Parliamentary Secretary of Space, Federal Coordinator for Space Matters

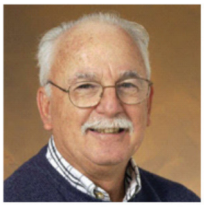

Johann-Dietrich Wörner, CEO DLR

Jean-Yves Le Gall,
President of the French space agency, CNES


Roberto Battiston,
President of the Italian space agency, ASI

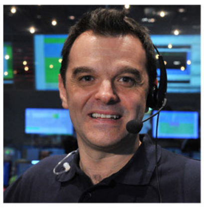

Matt Taylor,
Rosetta Project Scientist, ESA


Holger Sierks,
Principal Investigator OSIRIS, MPS


Sam Gulkis,
Principal Investigator MIRO, NASA JPL


Fabrizio Capaccioni,
Principal Investigator VIRTIS, INAF-IAPS


Paolo Ferri,
Head of Mission Operations Department, ESA


Andrea Accomazzo,
Rosetta Mission Director, ESA


Sylvain Lodiot,
Spacecraft Operations Manager, ESA


Frank Budnik,
Flight Dynamics expert, ESA

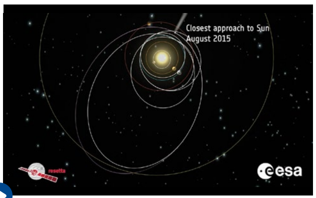

Mark McCaughrean,
Senior Scientific Advisor, ESA


Alan Stern,
Principal Investigator ALICE


Stefan Ulamec,
Rosetta Lander Manager, DLR

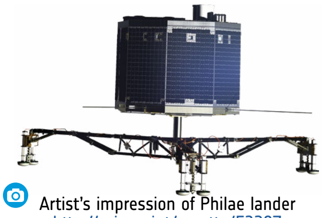

Laurence O'Rourke,
Rosetta science operations coordinator, ESA

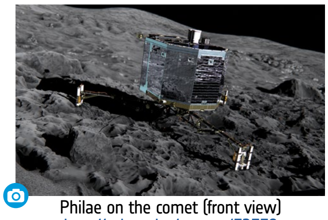
Appendix C: SELECTED ROSETTA IMAGES & VIDEOS

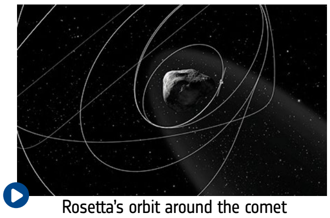


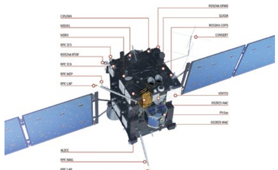
Rosetta's twelve-year journey in space
http://sci.esa.int/rosetta/52838

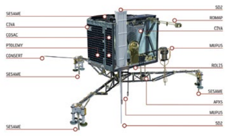

Artist's impression of Rosetta spacecraft
http://sci.esa.int/rosetta/5329

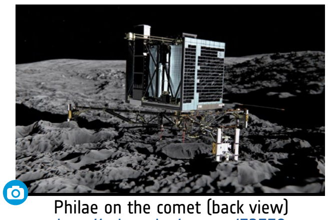

Artist's impression of Philae lander
http://sci.esa.int/rosetta/53297

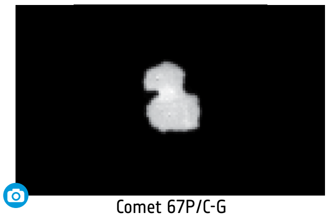

Philae on the comet (front view)
http://sci.esa.int/rosetta/53558

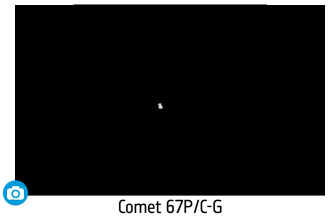

Rosetta's orbit around the comet
http://sci.esa.int/rosetta/53595

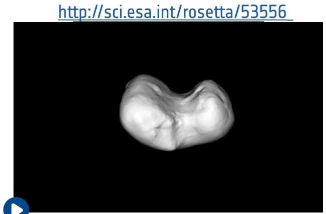

Artist's impression of Rosetta orbiter with instruments
http://sci.esa.int/rosetta/53555

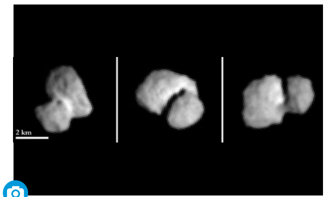

Artist's impression of Philae lander with instruments
http://sci.esa.int/rosetta/53556


Philae on the comet (back view)
http://sci.esa.int/rosetta/53559


Comet 67P/C-G on 29 July 2014 - NAVCAM
http://sci.esa.int/rosetta/54424

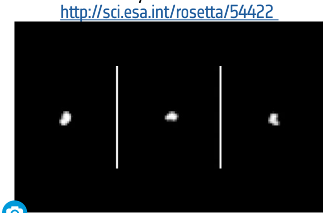

Comet 67P/C-G on 29 July 2014 - NAVCAM
http://sci.esa.int/rosetta/54422

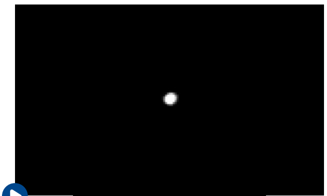

Shape model of comet 67P/C-G
http://sci.esa.int/rosetta/54389

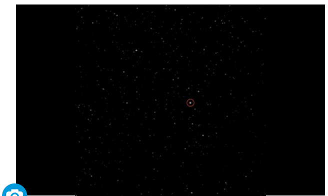


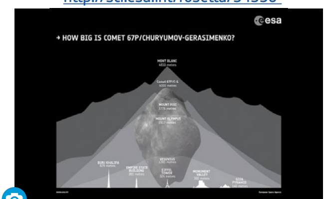
Comet 67P/C-G on 20 July 2014
http://sci.esa.int/rosetta/54388

Rotating view of comet 67P/C-G on 14 July 2014
http://sci.esa.int/rosetta/54356

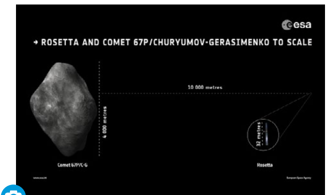

Comet 67P/C-G on 4 July 2014
http://sci.esa.int/rosetta/54318


Rotating comet 67P/C-G on 27-28 June 2014
http://sci.esa.int/rosetta/5428


Comet 67P/C-G on 4 June 2014
http://sci.esa.int/rosetta/54193



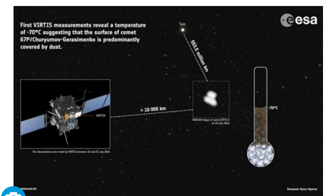
How big is 67P?
http://sci.esa.int/rosetta/54245



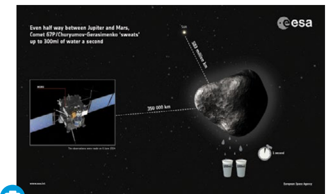
Rosetta and 67P to scale
http://sci.esa.int/rosetta/54349

Rosetta and 67P to scale
http://sci.esa.int/rosetta/54350

Anatomy of a comet
http://sci.esa.int/rosetta/54420

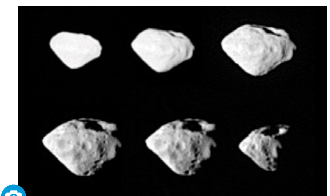


First measurement of surface temperature
http://sci.esa.int/rosetta/54426



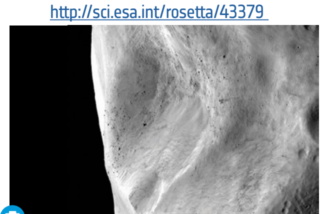
First detection of water vapour at 67P
http://sci.esa.int/rosetta/54251

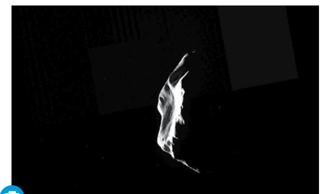

Video sequence from OSIRIS WAC of asteroid Steins
http://sci.esa.int/rosetta/43379


OSIRIS WAC images of asteroid (2867) Steins
http://sci.esa.int/rosetta/43363


Lutetia with Saturn
http://sci.esa.int/rosetta/47423


Lutetia at closest approach
http://sci.esa.int/rosetta/47446

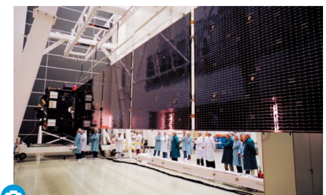

Landslides and boulders on Lutetia
http://sci.esa.int/rosetta/49541


Farewell Lutetia
http://sci.esa.int/rosetta/47424


Photograph of the Rosetta Stone
http://sci.esa.int/rosetta/54397

Rosetta mission poster
http://sci.esa.int/rosetta/53294


Rosetta lift-off
http://sci.esa.int/rosetta/53348


Rosetta spacecraft
http://sci.esa.int/rosetta/54421

Appendix D: MISSION TIMELINE FOR AUGUST TO NOVEMBER

[Regular updates on the mission will be published on www.esa.int/rosetta]

Date (2014)	Flight activity	Distance from comet	Notes & key mission events
3 August	Pre-insertion manoeuvre to bend Rosetta's trajectory towards the comet executed at 09:00 UTC. DV = 3 m/s Duration = 13 minutes	534 km	*Comet diameter covers 500 OSIRIS NAC pixels*
6 August	Close approach trajectory insertion manoeuvre executed at 09:00 UTC. DV = 1 m/s Duration = 7 minutes Spacecraft begins first arc of 100 km distant pyramid	150-100 km	*Comet diameter covers 1766 OSIRIS NAC pixels* **ESA Press Release**
10 August	Start second arc of pyramid	100 km	*Comet larger than OSIRIS NAC field of view (500 pixels in OSIRIS WAC and NAVCAM)*
13 August	Start third arc of pyramid	100 km	
17 August	Start move 'down' to second pyramid	100 km	
18 August			First delivery of ESA's NAVCAM comet models
19 August			Due date for all data needed for the Landing Site Selection Group (LSSG) meeting of 20 August
20 August	Continue to move down to second pyramid	80 km	LSSG meeting to pre-select up to ten landing site candidates. Lander Control Centre (LCC) and Science Operations and Navigation Centre (SONC) carry out technical analysis

Date (2014)	Flight activity	Distance from comet	Notes & key mission events
22-24 August			Meeting of LSSG to select five candidate landing sites; Coordinates of sites are sent to Rosetta Mission Operations Centre (RMOC)
24 August	Start first arc of 50 km pyramid	50-60 km	
25 August			Delivery of OSIRIS Digital Terrain Models of the five candidate sites.
27 August	Start second arc of 50 km pyramid	50-60 km	
31 August	Start third arc of 50km pyramid	50-60 km	
3 September	Start transfer to global mapping orbit		
5 September			RMOC experts report on first analysis of landing sites
10 September	Global mapping orbit begins	30 km	
13-14 September			Meeting of LSSG to select primary and backup landing sites; Landing Site coordinates are sent to RMOC. **ESA Press Release** **Announcement of landing site (15 September)**

Date (2014)	Flight activity	Distance from comet	Notes & key mission events
23 September			Delivery of OSIRIS high-resolution images and boulder distribution for primary and backup landing sites
26 September			RMOC report on final analyses of primary landing site
8 October	Close orbit phase begins	20 km	
12 October			Meeting of LSSG for final Go/No Go decision for primary landing site
14 October		10 km	Lander Operations Readiness Review
26 October	Landing preparations	10 km	
27 October	Move to delivery orbit	orbit 10 x 20 km	
7 November			Updated landing sequences are sent from LCC to RMOC
9 November			Final landing sequences are uploaded to the spacecraft
11 November	Provisional landing date		Landing **ESA Press Release**

Appendix E: MISSION MILESTONES -DISTANCES, DATES, TIMES

Date	Event	Distance Rosetta – Earth	Distance Rosetta – Sun	Distance Rosetta –comet	Distance travelled by Rosetta	One-way signal travel time
2 March 2004	Launch	—	148 million km	585 million km	—	1 s
4 March 2005	Earth swingby	1950 km (at closest approach)	148 million km	777 million km	941 million km	1 s
25 February 2007	Mars swingby	316 million km (250 km from Mars)	216 million km	553 million km	2.5 billion km	1053 s
13 November 2007	Earth swingby	5300 km (at closest approach)	148 million km	721 million km	3 billion km	1 s
5 September 2008	Steins flyby	359 million km	319 million km	393 million km	3.7 billion km	1197 s
13 November 2009	Earth swingby	2480 km (at closest approach)	148 million km	537 million km	4.5 billion km	1 s
10 July 2010	Lutetia flyby	454 million km	406 million km	276 million km	5 billion km	1514 s
8 June 2011	Enter deep space hibernation	549 million km	667 million km	141 million km	5.5 billion km	1831 s
20 January 2014	Exit deep space hibernation	807 million km	672 million km	9.2 million km	6.2 billion km	2693 s
7 May 2014	Start of manoeuvres towards comet	538 million km	609 million km	1.9 million km	6.3 billion km	1796 s
6 August 2014	Arrival at comet	404 million km	539 million km	100 km	6.5 billion km	1349 s
11 November 2014 *Date to be confirmed*	Deploy lander	509 million km	449 million km	—	6.6 billion km	1697 s
13 August 2015	Closest approach to the Sun (Perihelion)	265 million km	186 million km	—	7.2 billion km	884 s
December 2015	End of nominal mission	244 million km	301 million km	—	7.5 billion km	813 s

Prepared by the Communication, Outreach and Education Group
Directorate of Science and Robotic Exploration
European Space Agency

SRE-A-COEG-2014-001 August 2014

Corrections and updates to this media kit can be found at: sci.esa.int/rosetta/54429