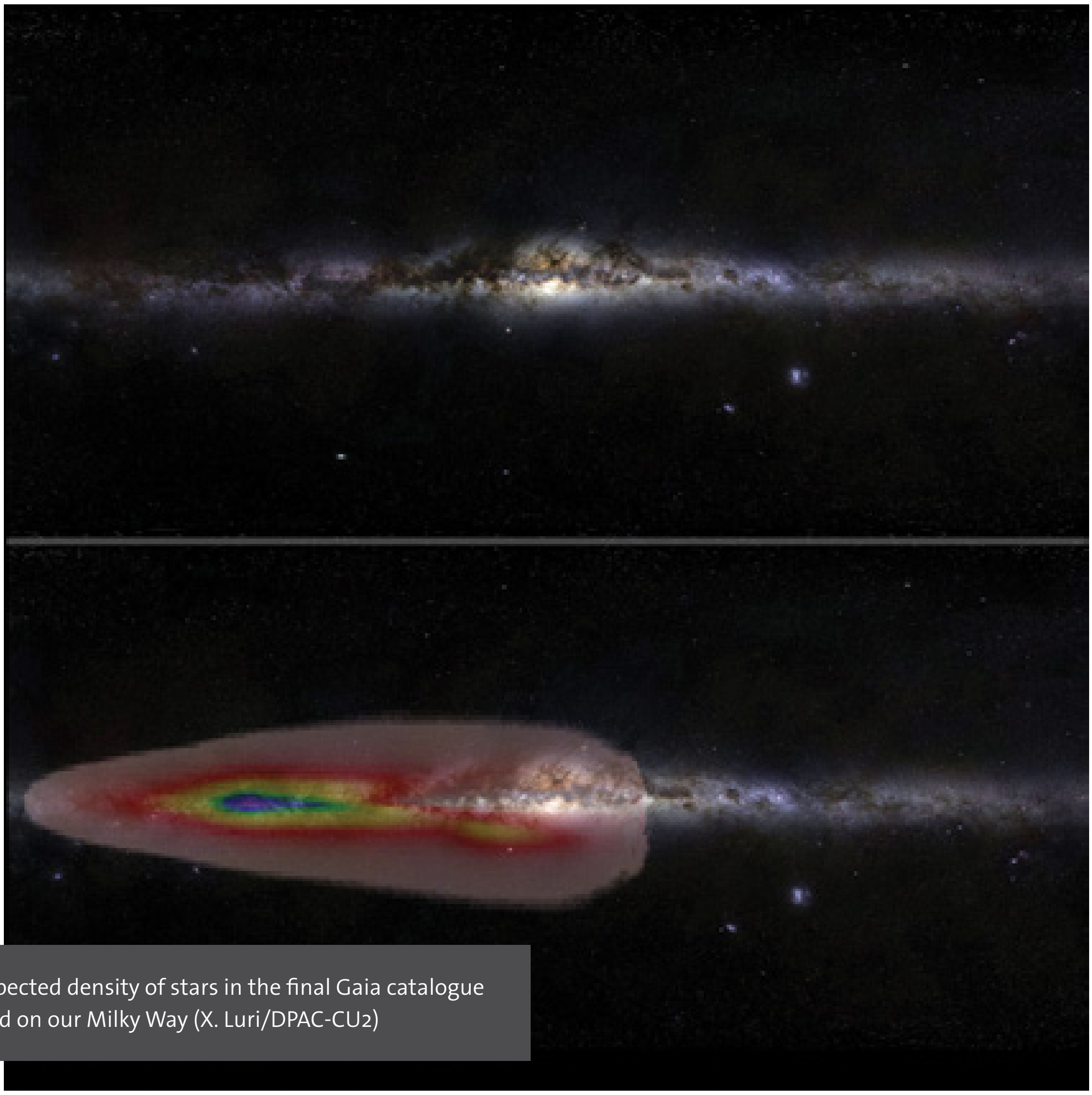
→ ESA'S BILLION-STAR SURVEYOR

Gaia ready for launch campaign

Giuseppe Sarri, Timo Prusti and Ared Schnorhk
Directorate of Science and Robotic Exploration, ESTEC, Noordwijk, the Netherlands



↗ The expected density of stars in the final Gaia catalogue overlaid on our Milky Way (X. Luri/DPAC-CU2)

ESA's billion-star surveyor, Gaia, has completed final preparations in Europe and is ready to depart for its launch site in French Guiana, set to embark on a five-year mission to map the stars with unprecedented precision.

Cataloguing the night sky is an essential part of astronomy. Before astronomers can investigate a celestial object, they must know where to find it. Without this knowledge, astronomers would wander helplessly in what Galileo once termed a 'dark labyrinth'. ESA's Gaia mission will create a detailed map of this labyrinth, finding clues to the origin, structure and evolution of our home galaxy, the Milky Way.

Gaia will take a census of one thousand million stars, roughly 1% of all of the stars in our Galaxy. During the satellite's expected lifetime of five years, Gaia will observe each star about 70 times, each time recording its brightness, colour and, most importantly, its position. The precise measurement of a celestial object's position is known as astrometry, and since humans first started studying the sky, astronomers have devoted much of their time to this art. However, Gaia will do so with extraordinary precision, far beyond the dreams of those ancient astronomers.

By comparing Gaia's series of precise observations, today's astronomers will soon be able to make precise measurements of the apparent movement of a star across the heavens, enabling them to determine its distance and motion through space. The resulting database will allow astronomers to trace the history of the Milky Way.

In the course of charting the sky, Gaia's highly superior instruments are expected to uncover vast numbers of previously unknown celestial objects, as well as studying normal stars. Its expected haul includes asteroids in our Solar System, icy bodies in the outer Solar System, failed stars, infant stars, planets around other stars, far-distant stellar explosions, black holes in the process of feeding and giant black holes at the centres of other galaxies. Gaia will be a discovery machine.

Origin of the Milky Way

Our galaxy is a disc of some one hundred billion stars in a spiral structure surrounding a central bulge. While many of the stars were born in our Milky Way, many others originated in small external galaxies that have subsequently merged with ours. Gaia will make it possible to discover families of stars that share peculiar motions around the galaxy or anomalous compositions. Each family could be the remnants of a once-separate galaxy that the Milky Way has consumed.

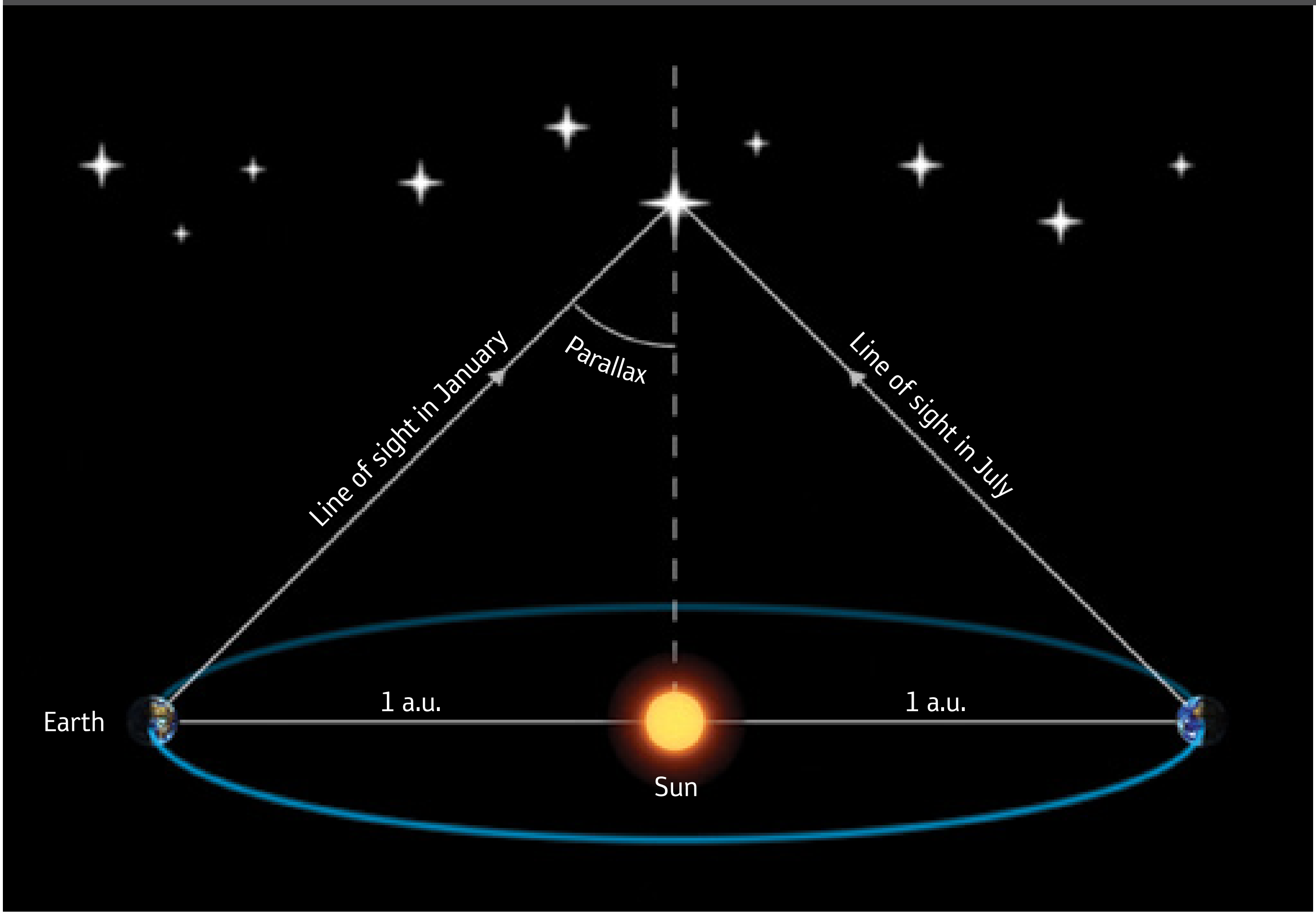
Understanding the history of our galaxy requires the measurement of stellar distances and motions for large samples of stars of different masses, ages and compositions. Gaia's survey of stars across the entire sky, down to extremely faint limits with a level of precision never accomplished before, will provide such a sample. By revealing the structure and motions of stars in our galaxy, Gaia will revolutionise our understanding of the history of the Milky Way.

Stars as individuals and collectives

To understand fully the physics of a star, its distance from Earth must be known. This is more difficult than it sounds because stars are so remote. Even the closest one is 40 trillion kilometres away, and we cannot send spacecraft out to them to measure as they go. Nor can we bounce radar signals off them, which is the method used to measure distances within the Solar System. Instead, astronomers have developed other techniques for measuring and estimating distances.

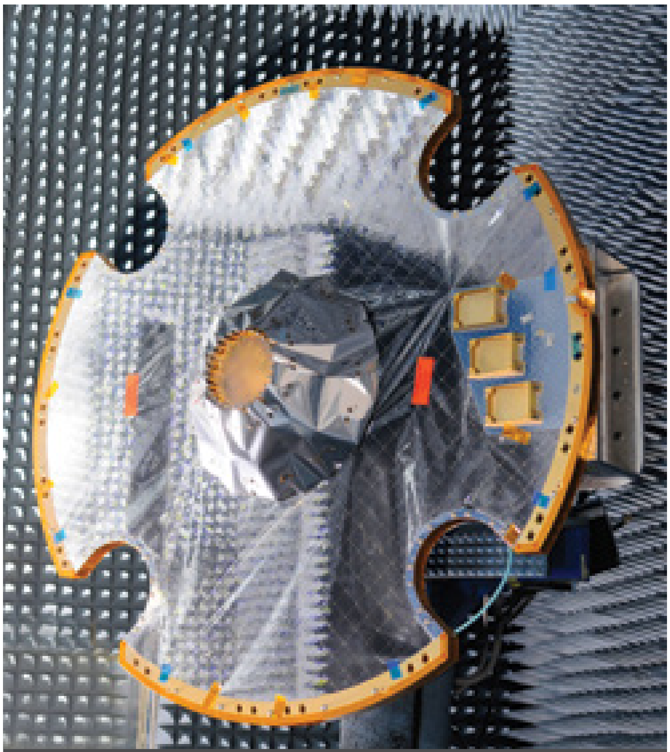
The most reliable and only direct way to measure the distance of a star is by determining its 'parallax'. By obtaining extremely precise measurements of the positions of stars, Gaia will yield the parallax for one billion stars; more than 99% of these have never had their distances measured accurately. Gaia will also deliver accurate measurements of other important stellar parameters, including the brightness, temperature, composition and mass. The observations will cover many different types of stars and many different stages of stellar evolution.

↓ Distance to a star can be calculated with simple trigonometry from the measured parallax angle. 1 a.u. is 1 Astronomical Unit, or 149.6 million km (ESA/Medialab)



→

The Gaia Payload Module in its final configuration during the mechanical acceptance test at Intespace in September 2012 (Astrium)



↑

The 1.5m wide Gaia Antenna Panel, which contains the satellite's Phased Array Antenna, is seen here inside the EADS CASA test facility in Madrid, 2012 (Astrium)

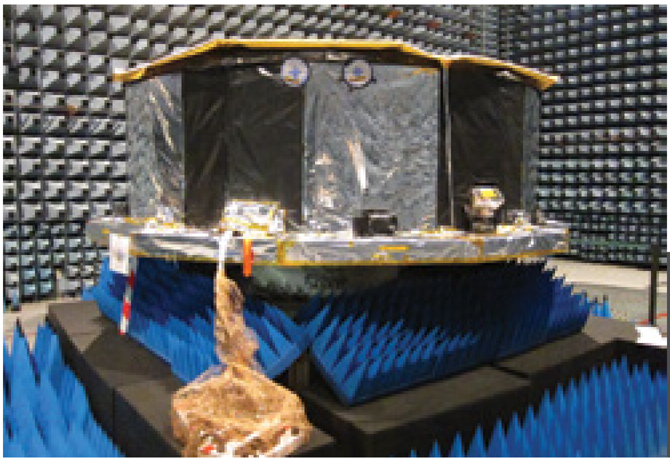
The principles of Gaia

At its heart, Gaia is a space telescope – or rather, two space telescopes that work as one. These two telescopes use ten mirrors of various sizes and surface shapes to collect, focus and direct light to Gaia's instruments for detection. The main instrument, an astrometer, precisely determines the positions of stars in the sky, while the photometer and spectrometer spread their light out into spectra for analysis.

Gaia's telescopes point at two different portions of the sky, separated by a constant 106.5°. Each has a large primary mirror with a collecting area of about 0.7 m^2. On Earth we are used to round telescope mirrors, but Gaia's will be rectangular to make the most efficient use of the limited space within the spacecraft. These are not large mirrors by modern astronomical standards, but Gaia's great advantage is that it will be observing from space, where there is no atmospheric disturbance to blur the images. A smaller telescope in space can yield more accurate results than a large telescope on Earth.

Gaia is just 3.5 m across, so three curved mirrors and three flat ones are used to focus and repeatedly fold the light beam over a total path of 35 m before the light hits the sensitive, custom-made detectors. Together, Gaia's telescopes and detectors will be powerful enough to detect stars up to 400 000 times fainter than those visible to the naked eye.

To cover the whole sky, Gaia spins slowly, making four full rotations per day and sweeping swathes across the celestial sphere. In addition the satellite rotation axis has a precession with a period of about 63 days. As it moves around the Sun, different parts of the sky are covered. Over the five-year mission, each star will be observed and measured an average of 70 times.



←

The Gaia Service Module at Intespace, Toulouse, France, during launcher electromagnetic-compatibility testing in May (Astrium)

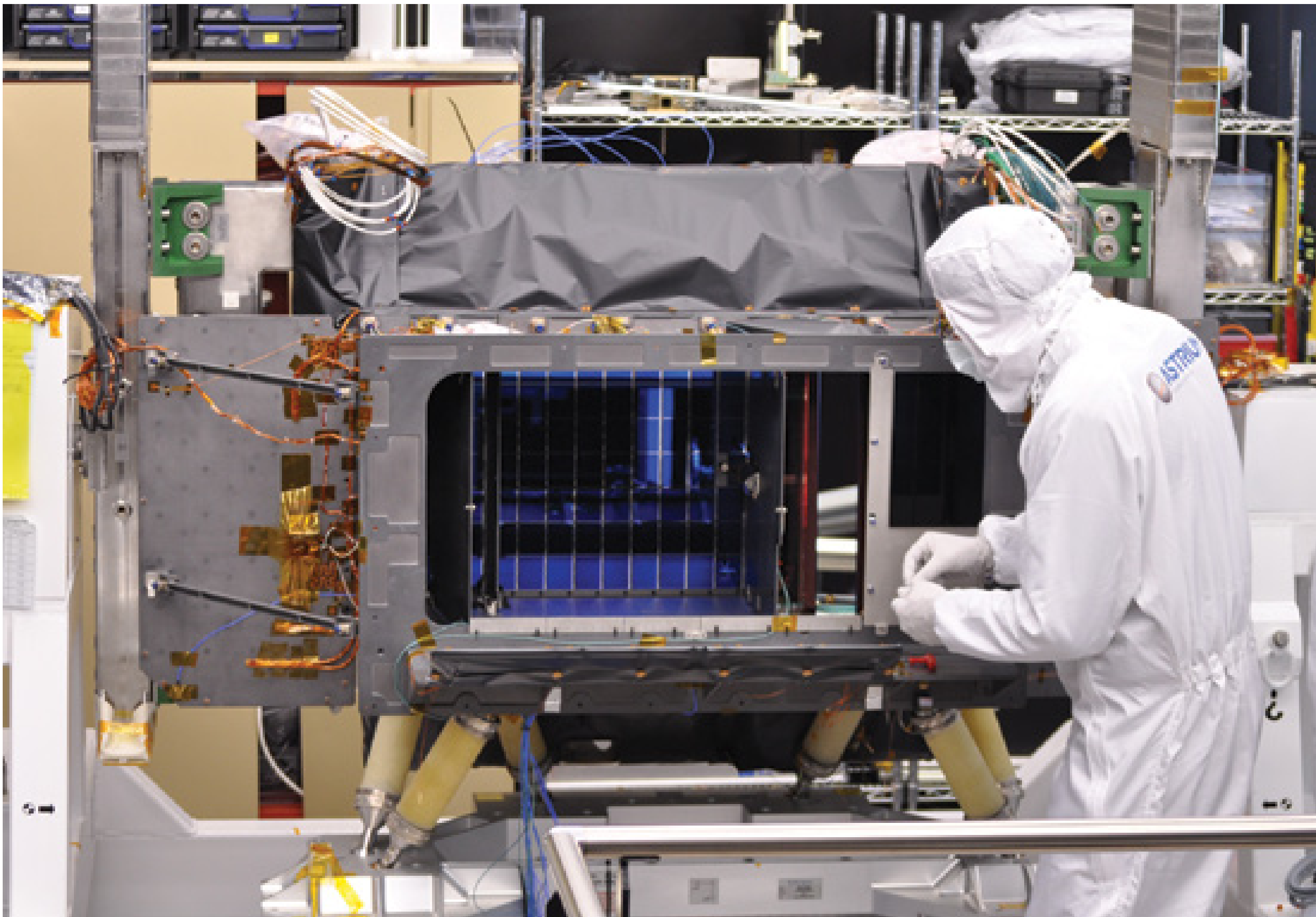
Spacecraft configuration

Gaia is composed of two sections: the Payload Module and the Service Module. The Payload Module is housed inside a protective dome and contains the two telescopes and the three science instruments. They are all mounted on a torus made of a ceramic material called silicon carbide. The extraordinary measurement accuracy required from Gaia calls for an extremely stable Payload Module that will barely move or deform once in space; this is achieved thanks to the extensive use of this material.

Underneath the Payload Module, the Service Module contains electronic units to run the instruments, as well as the propulsion system, communications units and other essential components. These components are mounted on carbon-fibre-reinforced plastic panels in a conical framework.

Finally, beneath the Service Module, a large sunshield keeps the spacecraft in shadow, maintaining the Payload Module at an almost constant temperature of around –110 °C, to allow the instruments to take their precise and sensitive readings. The sunshield measures about 10 m across, too large for the launch vehicle fairing, so it comprises a dozen folding panels that will be deployed after launch. Some of the solar array panels that are needed to generate power are fixed on the sunshield, with the rest on the bottom of the spacecraft.

Gaia is an exceptionally complex space observatory. ESA awarded Astrium SAS (Toulouse, France) the prime contract in May 2006 to develop and build the spacecraft. Together with the German and British branches of Astrium, more than 50 industrial subcontractor companies from across Europe were involved in building the spacecraft.



↑

Completion of the thermal hardware installation of the Gaia Focal Plane Assembly in the Class 100 cleanroom at Toulouse (Astrium)

Deployment sequence of the sun shield Assembly (Astrium)

Detection system

Three instruments will detect the light collected by Gaia's telescopes. Each one uses a set of digital detectors known as charge coupled devices (CCDs) to record the starlight falling onto them. Added together, the Gaia CCDs make the largest focal plane ever flown in space, a total of almost one billion pixels covering an area of about 0.38 m^2.

The astrometric instrument is devoted to measuring stellar positions on the sky. By combining all measurements of a given star over the five-year mission, it will be possible to deduce its parallax and thus its distance, as well as the velocity of the star as it moves across the plane of the sky.

The third dimension is provided by the Radial Velocity Spectrometer, which reveals the velocity of the star along the line of sight by measuring the Doppler shift of absorption lines in a high-resolution spectrum covering a narrow wavelength range.

The photometric instrument provides colour information for celestial objects by generating two low-resolution spectra, one in the blue and one in the red range of the optical spectrum. These data help to determine key stellar properties such as temperature, mass and chemical composition.

Launcher and launch campaign

Gaia will be carried into space later in 2013 by a Soyuz ST-B launch vehicle with a Fregat-MT upper stage, from Europe's Spaceport in French Guiana. This Soyuz is the most recent of a long line of vehicles that have proved their reliability with more than 1700 launches since launching the first satellite Sputnik in 1957. The three-stage version that will be used for Gaia was introduced 45 years ago and has been launched more than 850 times. It is by far the world's most-used launch vehicle.

After the early feasibility analyses, contact with the launcher provider has been maintained regularly in the frame of the project reviews. Detailed definition of launcher interface parameters started three years before the actual launch date. This early contact allowed the context to be set of a launch from French Guiana with a team more experienced with Soyuz launches from Baikonur and to prepare a first version of the Spacecraft Operation Plan.

Potential difficulties were identified and proper measures requiring relatively long preparation could be studied with commonly agreed solutions. The Gaia launch campaign preparation began with a visit to Europe's Spaceport in Kourou in the beginning of 2012.

In January, a second visit to Kourou verified the applicability of the chosen options. In the meantime, the definition of

↓ The Gaia Flight Model spacecraft undergoing final electrical tests at Astrium Toulouse in June (Astrium)

↓ Gaia being prepared for leak testing in June (Astrium)

the spacecraft interfaces had improved. This was reflected in the updates of the interface control documents and the Spacecraft Operation Plan. Trajectory definition, parameter exchange and verification between ESA's flight operations team at ESOC and the Russian partner NPO-Lavochkin responsible for Soyuz missions are now finalised.

Gaia mechanical and thermal peculiar verification strategies put in place to allow as much as possible a parallel development of the Service and Payload Modules also required agreement from the launcher side. Regular and clear exchanges over the progress and necessary evolutions of the verification process allowed successful implementation.

The Gaia launch campaign is organised over a period of ten weeks. Considering that almost no activity can be performed on the payload, this may seem rather long. However, after installing the deployable sun shield on the spacecraft, a deployment test is implemented to complete its final verification after transport to the launch site.

This very specific activity, already performed once at spacecraft level, will require just over a month. It will be

A Soyuz upper composite at the launchpad is lifted on top of a Soyuz rocket

↑ When moving between the different buildings and launch sites at Kourou, strict thermal, humidity and clean conditions must be maintained during the moves. Here, the CCU-3 (Container Charge Utile) is a cleanroom on wheels

performed in the S1B spacecraft integration facility at Kourou after the standard post-transport propulsion and electrical checks. In its deployed configuration, the sun shield has a diameter of 10 m; in the cleanroom, with the various stands installed, the sun shield requires a 12 m diameter surface to be kept free.

Following sun shield deployment, the spacecraft will be moved to the S5B facility for final pressurisation and propellant fuelling. In the same cleanroom, the launcher adaptor system will be ready to receive the satellite on top. This set-up will then be taken to another building, the S3B, for the mating on top of the fuelled Fregat-MT upper stage and for fairing installation. These operations are performed on a special scaffold that allows full access around the spacecraft at different levels.

The launcher fairing has been adapted to fit Gaia inside with sufficient margin. Once under the fairing, contact with the spacecraft will only be visual or via the electrical support equipment through umbilical lines. Four days before launch, the complete upper composite will be transferred to the launch pad, where the three lower stages of the Soyuz launcher await. Overnight, the upper composite is then lifted on top and connected to the launcher third stage. The last activities take place in the Soyuz gantry protecting the launcher from the Guianese weather conditions until launch day. ■

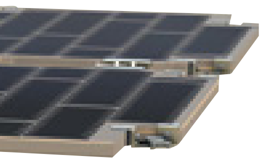
↑ The scaffolding used to prepare the upper composite. A Fregat upper stage, attached to a section of the launcher, is inside the scaffolding. The halves of the fairing are shown on the left

The 2018 ExoMars rover

→ EXOMARS

ESA's next step in Mars exploration

Jorge Vago, Olivier Witasse, Pietro Baglioni, Albert Haldemann, Giacinto Gianfiglio, Thierry Blancquaert, Don McCoy, Rolf de Groot and the ExoMars team
Directorate of Science and Robotic Exploration, ESTEC, Noordwijk, the Netherlands



Establishing if life ever existed on Mars is one of the outstanding scientific questions of our time. To do this, ESA is launching two missions to Mars, in 2016 and 2018.

ESA and Russia's space agency Roscosmos have signed an agreement to work in partnership to develop and launch two ExoMars missions. The first mission will study Mars' atmospheric composition and deliver a lander. The second mission will land, operate a static surface platform and put a large rover on the surface with the objective of searching for signs of life.

Both missions will use novel technologies needed to accomplish their goals and extend Europe and Russia's planetary exploration capabilities.

The missions

The first ExoMars mission consists of two elements: the Trace Gas Orbiter (TGO) and the Entry, descent, and landing Demonstrator Module (EDM). The TGO will first deliver the EDM, which will land on Mars to validate key technologies for the 2018 mission. The orbiter will then begin an aerobraking