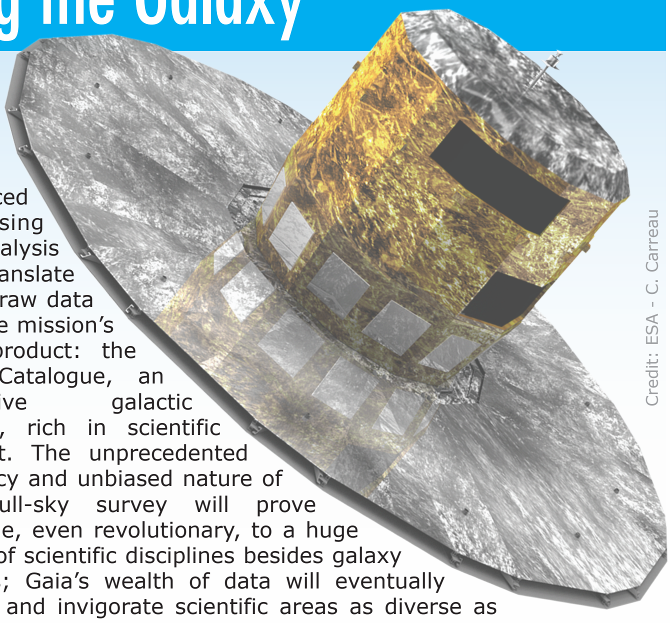
Gaia: Surveying the Galaxy

Overview

Gaia is a pioneering ESA astronomy mission set to revolutionise our view of the Galaxy with a precise, detailed stereoscopic survey of the billion brightest celestial objects. High-accuracy astrometry will allow Gaia to pinpoint the 3D position of a star and to measure its movement across the sky. Gaia will also gather spectroscopic data, allowing radial velocitites to be determined, and photometric data, measuring the brightness of a star in a few dozen colours. This array of data will reveal a moving, three-dimensional Milky Way map of unprecedented scope and precision, as well as providing profiles of the physical properties of each star, including luminosity, surface gravity, temperature and elemental composition.

By surveying all celestial bodies down to the very faint magnitude 20, Gaia will take in a representative fraction of the Milky Way's population, providing scientists with the data to tackle unanswered questions about our home galaxy, potentially revealing its formation history, current state and future evolution, and advancing galaxy studies in general. Furthermore, this catch-all survey will naturally include exotic stars and stars in short-lived phases of stellar evolution, as well as several thousand brown dwarfs and extra-solar planets. Gaia will map out our immediate neighbourhood in great detail, detecting hundreds of thousands of minor Solar System bodies. Beyond the Milky Way, Gaia will also observe bright extra-galactic objects like supernovae and quasars, and resolve many distant galaxies.

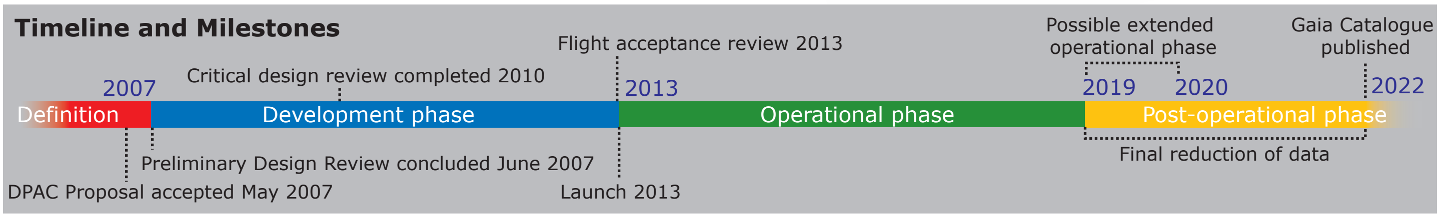
Selected as an ESA Cornerstone mission in 2000, this mission is currently set to launch in 2013. Gaia continues a European tradition for pioneering astrometry, building on expertise generated by the first space-based astrometry mission, Hipparcos. Gaia will outdo its predecessor by orders of magnitude in terms of accuracy, limiting magnitude and sample size, and whilst Hipparcos had a pre-selected programme of objects to observe, Gaia's survey is complete and unbiased.



Credit: ESA - C. Carreau

Advanced processing and analysis will translate Gaia's raw data into the mission's final product: the Gaia Catalogue, an extensive galactic census, rich in scientific content. The unprecedented accuracy and unbiased nature of this full-sky survey will prove valuable, even revolutionary, to a huge range of scientific disciplines besides galaxy studies; Gaia's wealth of data will eventually inform and invigorate scientific areas as diverse as stellar life cycles, dark matter distribution and general relativity. As a complete sky survey without pre-programmed targets, the discovery potential of Gaia is also profound.

Timeline and Milestones



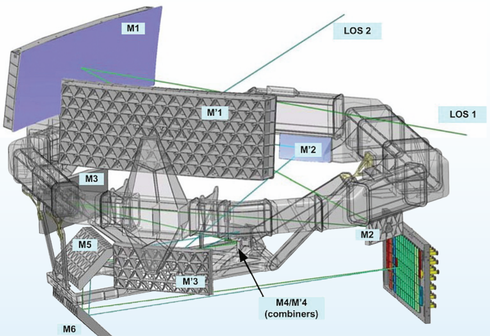
Credit: R. Hurt (SSC), JPL-Caltech, NASA

Gaia will survey the Milky Way with extraordinary precision

Spacecraft and Astrometric Instrument

Inside the satellite, Gaia's instruments are mounted on a hexagonal optical bench. The payload features two telescopes sharing a common focal plane, each looking out through an aperture in the payload housing. The two viewing directions are each 1.7° by 0.6° in size, and separated by a highly stable basic angle of 106.5°.

Light from a celestial object enters the arrangement through one of the two apertures, striking the large primary mirror opposite (M1 and M'1 in the payload illustration). The light is reflected by the primary mirror and bounced by a series of further mirrors along a total focal length of 35 m, with the two light paths meeting at the M4/M'4 beam combiner before finally reaching the shared focal plane. At the focal plane is a large mosaic of sophisticated, custom-built charge coupled devices (CCDs), light detectors of essentially the same kind as found in a digital camera. Containing 106 CCDs, the focal plane assembly comprises a total of nearly one billion pixels (a 'gigapixel'), compared to the few million of a typical digital camera.



The Gaia Payload

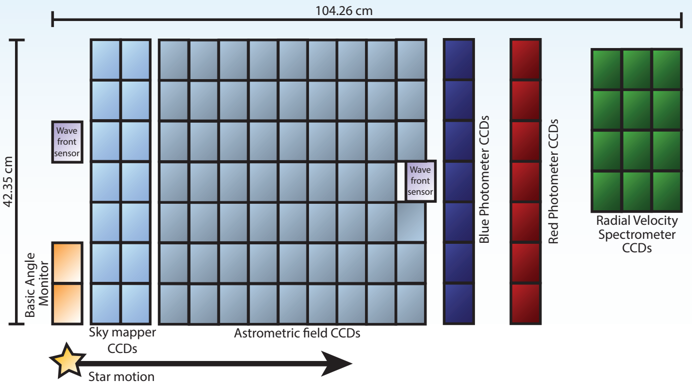
Credit: EADS Astrium

As the craft slowly rotates, the light from the celestial object (that is, the image of the object) passes across the focal plane. In this way, Gaia steadily scans the whole sky as the satellite spins and gradually precesses, with each part being observed around 70 times in the course of the operational lifetime.

Gaia's astrometric measurements are made using the global astrometry concept successfully demonstrated by Hipparcos.

By measuring the instantaneous image centroids, Gaia measures the relative separations of the thousands of stars simultaneously present in the combined fields. The craft's continuous scanning motion means that a constant stream of relative angular measurements is built up as the fields of view sweep across the sky. High angular resolution (and hence high positional precision) in the scanning direction is provided by the primary mirror of each telescope, of dimension 1.45 x 0.5 m^2, and the 35 m focal length. The wide-angle measurements provide the high rigidity of the resulting reference system.

Credit: ESA - A. Short



The Focal Plane Assembly

The astrometric field in the focal plane is sampled by an array of 62 CCDs, each read out in time-delayed integration mode synchronized to the scanning motion of the satellite. Stars entering the combined field of view first pass across dedicated CCDs which act as a 'sky mapper' — each object is detected on board, and information on its position and brightness is processed in real-time to define the windowed region read out by the following CCDs. Gaia's limiting magnitude is about 20 in its own white-light band (V=20 for blue stars, V=22 for red stars), and all objects brighter than this limit at the epoch of observation will be measured.

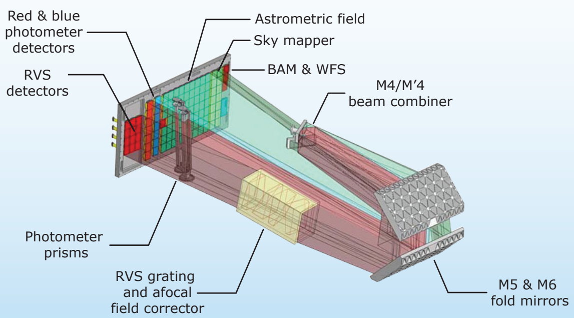
Astrometric Accuracies

Magnitude \ Star	B1V	G2V	M6V
V < 10	< 7µas	< 7µas	< 7µas
V = 15	< 25µas	< 24µas	< 12µas
V = 20	< 300µas	< 300µas	< 100µas

Photometric and Spectroscopic Instruments

Gaia's photometric instrument consists of two low-resolution fused-silica prisms dispersing all the light entering the field of view, both located between the last telescope mirror (M6) and the focal plane. One disperser, the blue photometer (BP), operates in the wavelength range 330–680 nm; the other, the red photometer (RP), covers the wavelength range 640–1050 nm. The dispersion of the prisms ranges from 3 to 29 nm/pixel for BP and from 7 to 15 nm/pixel for RP. These simultaneous measurements of the spectral energy distribution yield key astrophysical information, such as temperatures, gravities, and metallicities for each of the vast number of stars observed.

Credit: EADS Astrium



The Gaia Instruments

In addition to the photometric instrument, Gaia features the Radial Velocity Spectrometer (RVS) instrument. The RVS provides the third component of the space velocity of each star down to about 17th magnitude. The instrument is a near-infrared (847–874 nm), medium-resolution, integral-field spectrograph dispersing all the light entering the field of view. The spectral dispersion of objects in the field of view is achieved by means of an optical module located between M6 and the focal plane. This module contains a grating plate and an afocal field corrector lens, composed of four fused-silica prisms.

The photometers and RVS are integrated with the astrometric instrument and telescopes, so that light from the two viewing directions is superimposed on the photometric and RVS CCDs. The RVS and photometers use the (astrometric) sky mapper function for object detection and confirmation. Objects will be selected for RVS observation based on measurements made slightly earlier in the red photometer.

The Data Processing and Analysis Consortium

The nature of the Gaia mission leads to the acquisition of an enormous quantity of complex, extremely precise data, representing the multiple observations of a billion diverse objects by a 'double vision' instrument that is spinning and precessing. The Gaia data challenge - processing raw satellite telemetry into valuable science products - is therefore a huge task in terms of expertise, effort and dedicated computing power.

In late 2006, ESA's Announcement of Opportunity for Gaia's data processing was released, calling for a proposal to build and operate Gaia's ground segment data processing, a single processing pipeline leading to the intermediate and final mission products. In response to the announcement, a large pan-European team of expert scientists and software developers submitted their proposal for a comprehensive system capable of handling the full size and complexity of the Gaia data. In May of 2007, ESA's Science Programme Committee approved this proposal put forward by the Data Processing and Analysis Consortium (DPAC), at which point DPAC became officially responsible for Gaia data processing and analysis.

Key People at Gaia

Project Scientist:	Timo Prusti (ESA)
SOC Manager:	William O'Mullane (ESA)
Project Manager:	Giuseppe Sarri (ESA)
DPAC Project Coordinator:	Sebastian Els
DPAC Executive Chair:	Anthony Brown (Leiden Observatory)
DPAC Executive Deputy Chair:	Antonella Vallenari (Padova Astronomical Observatory)
EADS Astrium Project Manager:	Vincent Poinsignon

DPAC is a collaboration that draws its membership from all over Europe, including a diverse community of about 450 scientists and software engineers, spread throughout 22 countries, and six large Data Processing Centres. The consortium brings together skills and expertise from across the continent; its international nature and cooperative spirit reflects that of ESA itself.

Coordinated by the DPAC Executive, the consortium is sub-divided into nine smaller, specialist units known as Coordination Units, or CUs, with each unit being assigned a unique set of data processing tasks. The CUs are supported by the six Data Processing Centres, or DPCs. These are the centres at which the actual computer hardware for processing is available.

The day-to-day management of the overall DPAC development and operations is delegated to the DPAC Project Office (PO).

EADS Astrium

In May 2006, European satellite system specialist EADS Astrium signed a contract with ESA to develop and build the Gaia satellite. The cutting-edge technology employed in the Gaia craft and instruments draws on Astrium's considerable expertise, particularly with silicon carbide telescopes, as used on the Herschel Space Observatory. Moreover, as the makers of Gaia's predecessor, Hipparcos, EADS Astrium bring much valuable experience to the project.

For more information on Gaia: http://www.rssd.esa.int/gaia
For more on DPAC: http://www.rssd.esa.int/gaia/dpac