

Gaia Launch on 19 December 2013 - Credits: C. Cesarski, S. Jousseume, P. Kosuth, F. Mignard, S. Pireaux.

Editorial by DPAC chair, Anthony Brown

And we had lift-off!

On January 14 the final manoeuvre has been executed to insert Gaia into its orbit around the second Lagrange point of the Sun-Earth system.

The pictures above give an impression of the Gaia launch, an emotional moment for DPAC members, who have often spent many years working on the Gaia mission.

Following the launch from and outside viewing point at Kourou it was strange to realize that at the end of the smoke trail there was Gaia ready to be released in space.

The launch was celebrated throughout Europe at various launch events which were well attended and at-

tracted plenty of attention from the media and general public. Thanks to all the DPAC members who put a lot of effort into organizing or taking part in these events.

The DPAC in collaboration with Astrium and ESA (in particular the teams at ESOC and ESAC) is now engaged in the commissioning of Gaia and its scientific instruments. The commissioning period is expected to last until early May, after which the nominal Gaia mission will start. More on the commissioning can be found in the DPAC news section.

For later this year we can look forward to the first publications providing an early performance assessment of Gaia and hopefully also the first Gaia data in the form of science alerts. 2014 will be an exciting year for DPAC!

Although launch took place only a month ago, a lot has already happened in the meantime as part of the commissioning of the spacecraft and the scientific instruments on board. Below is an impression of the first weeks of commissioning.

- The launch was executed quite accurately which means that Gaia was inserted almost perfectly into its trajectory toward L2. This translates into larger margins on the fuel consumption of the spacecraft. The sun shield deployment and the release of the payload module support structures was successful, a critical operation that took place within hours after launch!

- The two pictures were taken from within the main control room at ESOC. The first one shows that Gaia is "on the board" and the second picture shows the first spectrum of the signal from Gaia's phased array antenna. This is a crucial piece of equipment which we need in order to get the vast amount of data that Gaia collects to the ground stations.

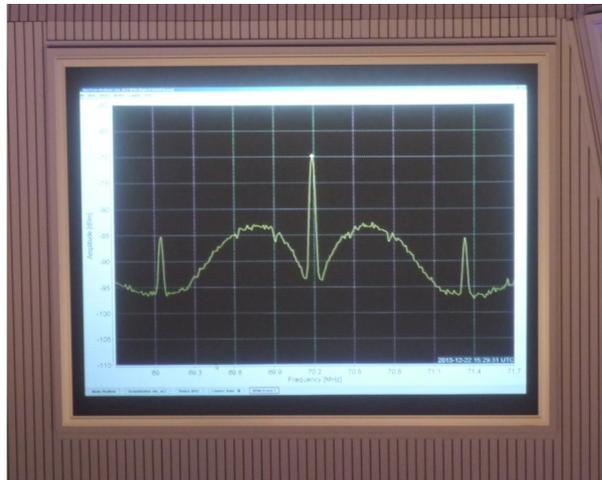
- The DPAC outreach group has contacted amateur astronomers throughout Europe about the possibility to

SPACECRAFT	DATE	LAUNCHER
HERSCHEL	14 5 09	ARIANE 5
PLANCK	14 5 09	ARIANE 5
CRYOSAT-2	8 4 10	DNEPR
MSG-3	5 7 12	ARIANE 5
METOP-B	17 9 12	SOYUZ
SWARM A-B-C	22 11 13	ROCKOT
GAIA	19 12 13	SOYUZ

find out where Gaia is on the sky (using a website provided by the Meudon GBOT team) and to encourage them to take pictures of Gaia on its way to L2. This was successful and several pictures and videos were received of Gaia during its first days in space. You can find this (very cool!) material via the ESA Gaia web pages. The pictures also gave the GBOT team an early warning that Gaia is a lot fainter than hoped for. We are currently working on addressing this issue.

- The focal plane array of Gaia was switched on on Jan-

uary 3. This was an exciting moment as all 7 VPUs and all 106 CCD-PEM combinations were switched on! All seems to work fine and the very first images from Gaia have been arriving over the past 10 days, containing the first stars observed. Of course these represent test images only.



- The data processing centre (DPC) at ESAC started receiving housekeeping telemetry as the spacecraft was still on the launchpad and has been receiving Gaia telemetry ever since. The telemetry is archived and also backed up at the CNES DPC in Toulouse. The DPAC systems so far work very well, with data flowing from ESOC to ESAC and from there to the other DPCs and also to Astrium. The DPCE team together with the payload experts and the IDT/FL developers have been working hard to quickly and effectively fix many small issues encountered, showing how effective the operations rehearsals have been!

After Gaia has been firmly stationed in its orbit around L2 the next major activity is to align the telescopes with the aid of the movable secondary mirrors and the wave-front sensors, as well as to find the optimal focus and spacecraft spin rate. This is expected to take up to seven weeks. Thereafter a detailed performance assessment and fine tuning of the Gaia instruments will take place. The current planning is to have the commissioning activities end early May and then start the nominal Gaia mission.

Keep an eye on the ESA and DPAC web pages for further news during the coming months!

From the Editor,

We are sure that you noticed with disappointment (at least allow us to hope !) that your favourite NewsLetter did not reach your mailbox as expected at the end of October. This was planned indeed until we realised that this normal schedule went into conflict with a special launch issue to be released less than a month later. After consultation with the DPAC Chair we decided to postpone the release at launch time, scheduled on 20th November. Then the launch was delayed by one further month, and the NL schedule collided with the Christmas and New Year break. We are back now with the awaited launch issue and expect to resume the regular quarterly release.

The highly successful operational phase of Hipparcos ended in 1993, with the catalogue published in 1997. By then, several groups were thinking about future astrometric possibilities from space. In the US, interest was focused on pointed interferometers, ranging from the operational HST-FGS, the proposed POINTS, and later SIM in its various forms. Three Russian plans were presented at IAU191 in 1989: the pointed Lomonosov at L2, and the scanning missions Regatta-Astro and AIST. They targeted accuracies of 1-10 mas (around 1997), with a view to measuring accurate proper motions for the Hipparcos stars.

Erik Hoeg's early involvement with the Russian missions led to his preliminary 1992 concept using CCDs as a modulation detector (referred to as Hipparcos-2) and, soon after, to a TDI-based direct imaging design, Roemer. Submitted as an ESA M3 candidate in May 1993, Roemer was a Hipparcos-like scanning mission with beam combiner and a 0.34-m aperture, aiming for 100 million stars with 0.2 mas accuracy at 13 mag.

Rated highly, but not scientifically ambitious enough, it was rejected by the AWG/SSAC in favour of Planck for Phase A study in 1999.

ESA Horizon 2000+

Around this time, ESA started to formulate a long-term planning, referred to as Horizon 2000+. Decision time-scales were unknown, and it was unclear how many 'cornerstone missions' would be selected. Although we were therefore working somewhat in the dark, all knew that the competition would be intense.

Meanwhile, there had been ESA study teams devoted to space interferometry since the early 1980s. Interferometry appeared in the earlier Horizon 2000 planning as a 'Green Dream': widely considered as a technique of potential strategic interest, but lacking a compelling scientific application. Capitalising on the favourable technical interest in interferometry, with ambitious science underpinned by astrometry, we submitted an outline proposal for the Horizon 2000+ planning on 12 Oct 1993. Naming it Gaia, scientific goals included stellar distances and motions, spectral types from intermediate band photometry, variability from epoch photometry, general relativity, and a 100,000 star survey to 100 pc for Jupiter mass companions.

The Horizon 2000+ planning exercise got underway during the summer of 1994. With Lo Woltjer as commit-

tee chair, and various topical teams to set priorities in different areas, a phase of intense lobbying began.

Informal feedback from the Capri meeting (of the AWG, SPC, and H2000+ teams) made it clear that more convincing arguments would be needed from the Gaia community. Accordingly, on 15 Sep 1994, we submitted a more detailed, unsolicited, report to the Director of Science, Roger-Maurice Bonnet, in time for his next meeting with the key decision makers (L. Woltjer, S. Beckwith, J. Bleeker).

By early October 1994, Gaia was being spoken of as a serious future cornerstone contender, although over the next few years both the infrared (Edison, later IRSI/Darwin), the Mercury-BepiColombo, and the LISA teams, would continue to press their cases. To keep momentum going, and to help technical and scientific ideas to develop and converge, the Gaia community organised a symposium in Cambridge in June 1995, (see picture on page 5). The highly-productive meeting was organised around 5 technical sessions, and the proceedings were out in record time, in early October 1995.

Pathway to selection

National communities (in France, Germany, Spain, Italy and elsewhere) organised meetings to formulate their own priorities. Within ESA, Oscar Pace was appointed as study manager, financing of various system studies was petitioned, and a target launch date of 2012 adopted. A Science Advisory Group (SAG) was established under the authority of the Director of science (R. Bonnet). It was chaired by M. Perryman and comprised at various times K. de Boer, G. Gilmore, E. Hoeg, M.G. Lattanzi, L. Lindegren, X. Luri, F. Mignard, S. Roeser, P.T de Zeeuw, and was supported by an expert group from ESA. It met for the first time in March 1997. Parallel system studies got underway with MMS-Astrium and Alenia in September 1997.

Over the next three years, the technical baseline advanced and converged, with regular industrial progress meetings, numerous technology studies, and 12 further meetings of the SAG. A 5-day Lorentz Workshop (Leiden, November 1998) brought together 68 participants to discuss and prioritise the numerous scientific aspects. The end result of this three year study was a 350 page document issued in July 2000 (ESA-SCI (2000)4) and detailing the instrument baseline and error budget, the technical baseline, and the detailed sci-

entific case (itself running to more than 100 pages, with inputs from 100 scientists).

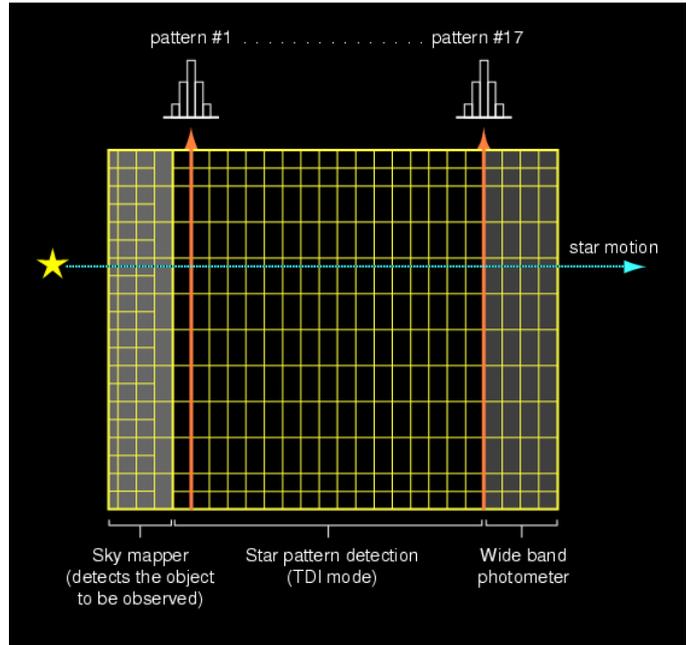
But uncertainties proliferated as the next major round of ESA decision-making drew nearer. Key meeting dates moved, cost envelopes changed, and rumours circulated as to the prospects of the competitors: IRSI -Darwin, BepiColombo and LISA. Competition from the former diminished after the presentation of both projects to the AWG in September 1999 (the Gaia presentation was made by L. Lindegren). Again, national meetings were held to discuss priorities, while the work on FAME in the US and DIVA in Germany introduced some further uncertainties in the political landscape.

The deciding presentations of Darwin, Gaia, LISA, and Mercury were made to the combined ESA advisory groups at UNESCO, Paris (13 Sep 2000), with Gaia presentations made on the payload and accuracy (L. Lindegren), science case (T. de Zeeuw), community involvement (G. Gilmore) and mission implementation (O. Pace).

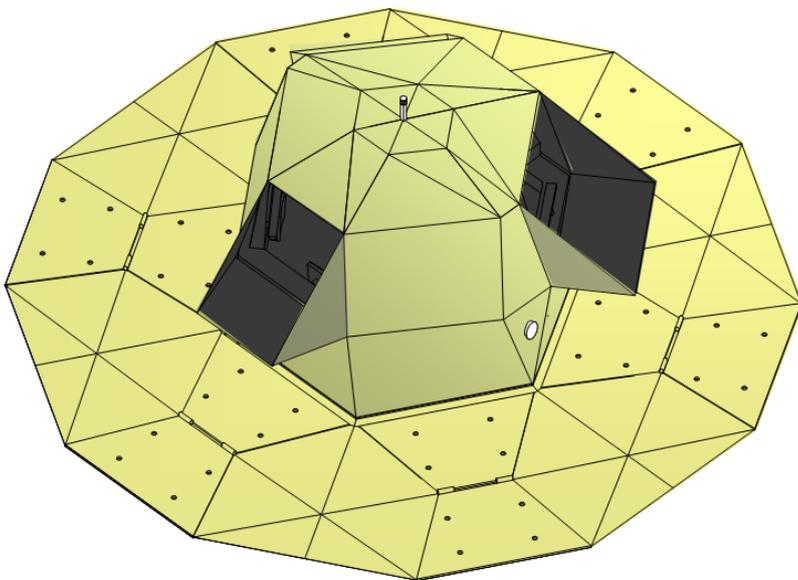
The AWG met on 14 Sep, and the influential SSAC on the 15 Sep, at which the AWG chair, Martin Ward,

described Gaia as 'an amazing mission of almost mind-boggling extent'. The SSAC finally recommended the adoption of BepiColombo as CS5, and Gaia as CS6, with launch dates in 2009(!) and 2012 respectively.

The confirmation of Gaia as Cornerstone 6, and the start of a new chapter in space astrometry, was formalised by the SPC at its meeting of 12 Oct 2000.



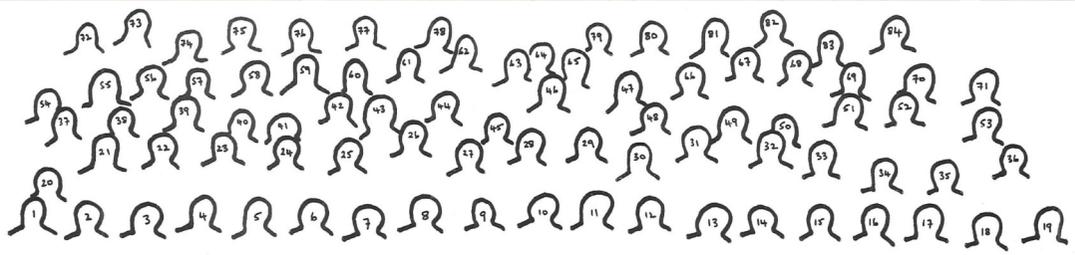
Gaia astro focal plane in 2000. There was one for each field of view with 250 CCDs already operated in TDI mode but with a scan period of 3 hours.



This is what Gaia looked like at the end of the Concept and Technology Study in 1999. Not so much different of what it is today: the flying saucer-shaped craft just morphed into a more sombrero alike (from GAIA/MMS/TN/037, March 1999).

To be continued page 5

R.G.O. / E.S.A. Workshop, Cambridge, United Kingdom
 19-21 June 1995
 Future Possibilities For Astrometry in Space



RGO/ESA Workshop on 'Future Possibilities for Astrometry from Space', Cambridge, 19-21 June 1995

- 1 F. Mignard; 2 U. Bastian; 3 G. Gilmore; 4 R. Mundt; 5 M.J. Penston; 6 L. Lindegren; 7 G. Harrison; 8 M.A.C. Perryman; 9 A. Peake; 10 J.-W. Pel;
- 11 F. van Leeuwen; 12 S. Volonté; 13 F. Crifo; 14 L. Morrison; 15 M. Miyamoto; 16 T. Tsujimoto; 17 N. Argue; 18 D.W. Evans; 19 C.A. Murray; 20 M.O. Mennessier;
- 21 F. Favata; 22 H. Jenkner; 23 B. Taylor; 24 C. Martin; 25 A. Quirrenbach; 26 J. Noordam; 27 I. Platais; 28 P. Hemenway; 29 H.-J. Tucholke; 30 P. Bely;
- 31 S. Loiseau; 32 R. Laurance; 33 E. Hog; 34 V. Straizys; 35 E. Schilbach; 36 L. Taff; 37 A. Emanuele; 38 A.-M. Hubert; 39 W. Flury; 40 B. Morando; 41 A. Gomez;
- 42 S. Casertano; 43 A. Wicene; 44 R. Fakir; 45 C. Turon; 46 A. Penny; 47 M. Gai; 48 R. Pannunzio; 49 B. Lasker; 50 B. Bucciarelli; 51 R. Wielen; 52 K. Seidlmann;
- 53 B. McLean; 54 P. Gray; 55 D. Cardini; 56 S. Shaklan; 57 J.-L. Falin; 58 M. Froeschlé; 59 D. Gulberg; 60 C. Quist; 61 H. Saint; 62 C. Burrows; 63 J.-L. Halbwegs;
- 64 D. Briot; 65 F. Vakili; 66 G. Daigne; 67 V. Yershov; 68 V. Makarov; 69 C. Maccone; 70 J. Torra; 71 J. LaSala; 72 R. Burnage; 73 D. Simeoni; 74 R. Le Poole;
- 75 M. Haywood; 76 D. Hestroffer; 77 F. Arenou; 78 M. Crézé; 79 Y. Rabbia; 80 P. Assus; 81 R. Argyle; 82 C. Fabricius; 83 E. Griffin; 84 S. Röser.

Gaia Tracking and Orbit Determination

Frank Budnik, Flight Dynamics, ESOC, ESA

In order to fulfill the scientific objectives the Gaia orbit has to be known a posteriori to a precision that is unprecedented for ESA's space observatories. The requirement on the reconstruction accuracy of the spacecraft position is 150 m in each position and 2.5 mm/s in each velocity component. Can these orbit reconstruction requirements be fulfilled with traditional orbit determination methods?

How is Gaia tracked by ESA ?

For ESA missions to the Lagrange points the orbit is determined by using ESOC's interplanetary orbit determination system. Interplanetary orbit determination is mainly relying on 2-way range and Doppler tracking observables. With the existing tracking systems that are installed in ESA's deep-space stations in New Norcia, Cebreros and Malargüe an end-to-end measurement precision of better than 5 m and 0.1 mm/s for 2-way range and range-rate (derived from Doppler observables integrated over a 1 minute count time) respectively is achieved. With these measurements the Gaia orbit reconstruction requirements appear to be easily fulfillable. However, they measure only one component of the Gaia position and one component of the Gaia velocity, the so-called line-of-sight components. The so-called plane-of-sky components perpendicular to the line-of-sight can only be derived indirectly via the sinusoidal modulation on the range and Doppler observables over one tracking pass that is induced by the rotational motion of the tracking station on Earth. Unfortunately this indirect method is not precise enough to fulfill the Gaia orbit reconstruction requirements.

The accuracy issue

The solution is to augment the line-of-sight measurement with direct measurements of the plane-of-sky components, i.e. with angular measurements of the spacecraft position. The tracking antenna being in auto-track with the spacecraft could supply these kinds of measurements but only with an accuracy of about 180 arcsec (corresponds to more than 1000 km at L2) which makes them unusable for Gaia. Delta Differenced One-Way Range (Delta-DOR) measurements, which are a VLBI type measurement that uses two widely separated stations on Earth would be another option. These measurements are very precise (better than 3 mas which corre-

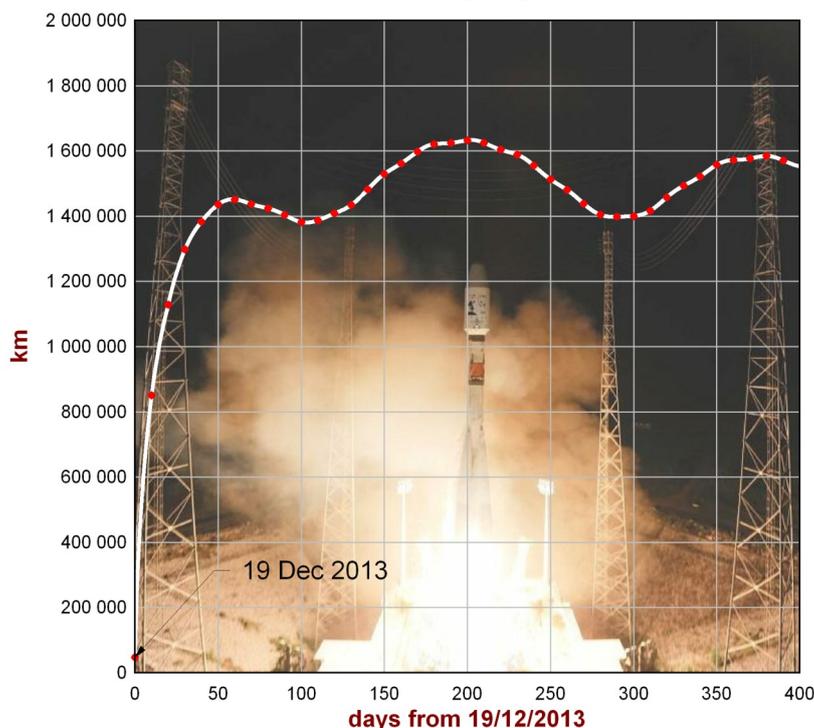
sponds to 22 m at L2) and often used for planetary approach navigation. But they are also very resource demanding by needing at least 3 deep space stations for about 2 hours every night over the full duration of the Gaia mission. This is considered not being affordable and would lead unavoidably to major conflicts with other missions that rely on ESA's deep space network.

Optical astrometry will help

The solution of the problem is the use of astrometric measurements of Gaia by ground based optical telescopes. The precision of these measurements depends on the quality of the star catalogue that is used to reduce the optical images to angular measurements. It is expected that with the first Gaia star catalogue angular precision of better than 10 mas (corresponds to 70 m at L2) can be achieved. These measurements could therefore be used to meet the Gaia orbit reconstruction requirements and this has been confirmed by simulations provided that measurements are available approximately every night.

The acquisition and reduction of ground based optical images of Gaia is the responsibility of a group within DPAC called GBOT (Ground Based Optical Tracking). The reduced data are delivered to ESOC where they are included in a second orbit reconstruction process which result serves as input for the generation of the final Gaia science products.

Distance of Gaia to the Earth barycentre in 2014
Dot every 10 days



Distance of Gaia to the centre of the Earth in 2014. The cruise to L2 is well visible over the first month until the distance oscillates about its mean as Gaia completes its first two Lissajous loops with a 6-month period.

The orbit of Gaia is a complex 3D path not easily represented with a single projection. You may have seen several depictions of it, generally in the form of more or less regular loops around the L2 point, a virtual point in space at 1.5 millions km away from the Earth along the Sun-Earth direction. To represent the orbit as a 2D projected path, one must select:

- an origin in space, the most common being the centre of the Earth or L2 itself
- a system of axes fixing where the x- and y-axis are pointing. This could be a non rotating frame, say x-axis pointing to the vernal equinox, or a rotating frame with x-axis constantly directed toward L2, at least approximately.

Given the definition of L2 involving the Earth-Moon barycenter and the eccentricity of the Earth orbit, the distance separating the Earth from L2 is not constant with about 50,000 km between the smallest and the largest distances. Therefore in a plot with the Earth at the origin, L2 is not fixed and reciprocally. These assumptions must be known when comparing different

representations of the Gaia orbit.

In the following plots I have adopted some compromises to illustrate the Gaia position from an earth based perspective and using a rotating frame. The orbit is projected on the ecliptic plane and the projected L2 is always on the x-axis at a distance between 1,475,000 and 1,525,000 km. Therefore in this image the loops move back and forth around a swinging L2, unlike the more classical view centred at L2.

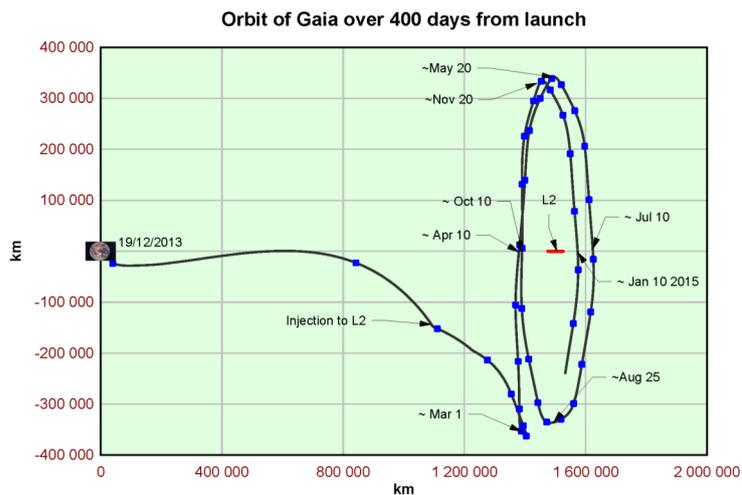


Fig.1(above) - Orbit of Gaia projected on the ecliptic plane over 400 days from launch. The x-axis rotates with L2 and the Earth is fixed at the origin of coordinates. Blue marks are plotted every 10 days in 2014. The motion of L2 in this frame is shown with the small red line of length about 50,000 km.

Where is Gaia in 2014 ?

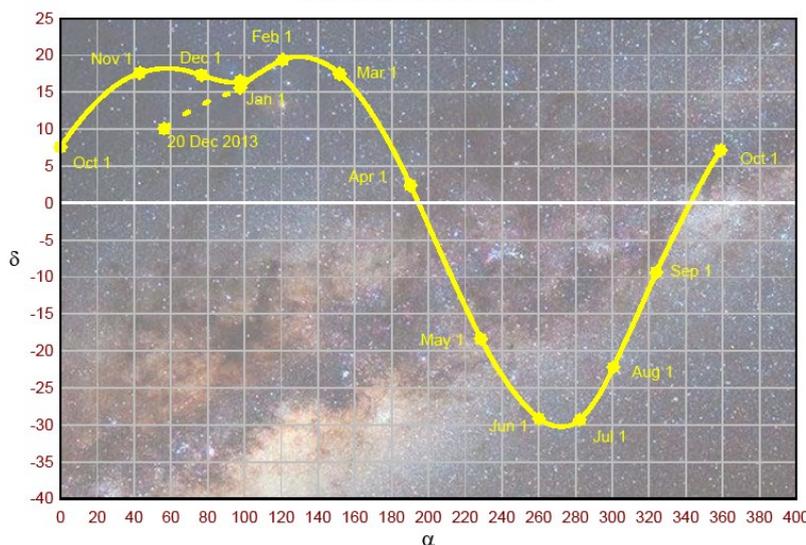


Fig 2. Where to look among the stars to see (or imagine) Gaia in 2014 ? This low resolution plot shows the equatorial coordinates of Gaia over one year. The main circulation among the zodiacal constellations is just the annual motion of the Sun, shifted by 6 months (180 degrees) for L2, which is opposite to the Sun. One might expect that L2 would reach the extreme declinations ± 23.5 deg, respectively at winter and summer solstice. This is approximately true, but the interplay with the 6-month period Lissajous loops complicates the feature, especially when combined with the fact that the Lissajous motion starts around the spring equinox in 2014. Therefore Gaia explores much southern declinations than it does in the north and the curve is a far cry from a symmetric sine wave with respect to the celestial equator. For more details, see the very nice tool (<http://gaiainthesky.obspm.fr/>) developed by T. Carlucci and S. Bouquillon from the GBOT group in Paris Observatory.

Following the successful flight of Soyuz VS06, which sent the spacecraft towards its orbit around L2, the commissioning phase of Gaia has begun. This phase is a great challenge and will certainly be with lots of excitement: It is the first time that the people who have been working on Gaia for so long, will see "their" mission produce real data on the real sky.

How to assess the scientific performances ?

The commissioning phase of Gaia is planned to last more than five months.

During the first three months the industrial partner will activate the various satellite subsystems, and carefully tune the numerous on-board settings, like focus, spin rate, etc., to achieve best scientific performance.

During the remaining two months the overall scientific performance shall be verified. Of course, the question arises what does best scientific performance mean and how is it measured. This is the area in which DPAC will provide important input and play an active role in commissioning. Over the past two years the DPAC Initial In-Orbit Calibration group has developed methods and ways to provide answers to these questions. This group ultimately turned into the "Payload Experts", by now containing more than 20 DPAC members from almost all CUs and whose expertise covers all areas of the scientific payload. They will assess the first Gaia data using the tools they have developed to analyze the data interactively but also, and foremost, employing the DPAC daily processing systems.

It is primarily the scientific performance and health monitoring system, "First Look (FL)", which will conduct a wide range of analyses covering all Gaia instruments and which was designed to do so on a daily basis. As they successively will start to process data, also all other DPAC short term calibration systems can be expected to provide important

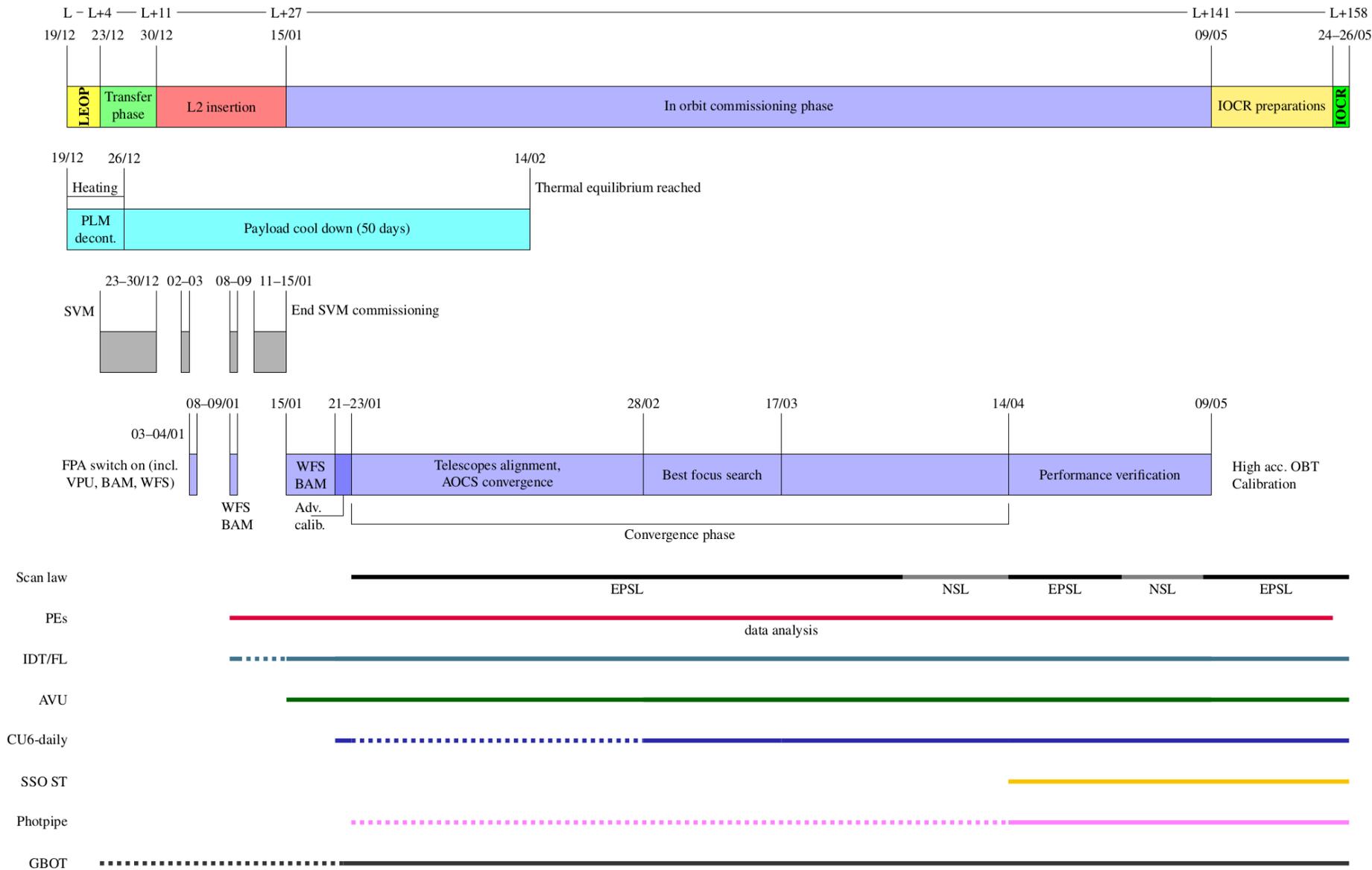
input to the commissioning activities by determining the detailed calibrations for the various Gaia components. These performance assessments depend largely on the availability of external references in the form of well known regions in the sky. In addition, a sufficiently "simple" scanning law has been selected to be used during this early phase: the Ecliptic Pole Scanning Law (EPSL), which enables repeated observations of the same stars near the ecliptic poles, many times over the few weeks of the commissioning activities. A very valuable feature for early calibrations.

Scanning the sky with the EPSL

To provide the necessary reference data, the two areas covering each 1 degree by 1 degree centered on each of the Ecliptic poles, were observed in the GBOG (Ground-Based Observations for Gaia) framework. The results have been compiled in the Ecliptic Pole Catalogue (EPC). The EPC, as part of the IGSL which is DPAC's main reference catalogue, forms the basis for the quantitative analysis of a wide range of instrument parameters. During its use in the commissioning period, the EPSL will result in a total number of observations of the ecliptic pole areas which will be comparable to the end of the Gaia mission, i.e., after five years. This holds the amazing possibility to derive some true end of mission performance estimations, for example in the case of RVS. The methods and infrastructure within DPAC have been setup and trained over the past year, to support effectively the commissioning which will be conducted by industry.

This will allow DPAC to support the initial setup of Gaia and to obtain its own initial calibrations, needed to start the routine phase. This will be the initial culmination of the work put forward by all the dedicated people in the CUs and DPCs.

To be continued page 9



The top line indicates the schedule in days after launch. The true commissioning starts immediately after the second burns to insert Gaia onto its final L2 orbit and will last until early May 2014 and is followed by the IOCR (Commissioning Review), after which the nominal mission will officially commence. The commissioning is decomposed into the Service Module (SVM on the diagram) and the payload commissioning, where the different subsystems are indicated horizontally while the DPAC S/W activated are on the vertical left columns. The black lines tells how the sky is scanned during the different phases. (EP SL : Ecliptic Pole SL, NSL : nominal scanning law with precession of the spin axis). More details on the DPAC wiki (restricted access) http://wiki.cosmos.esa.int/gaia-dpac/index.php/Gaia_Commissioning:Timeline.

Chart: A. Brown.

A busy Christmas period for Gaia on its way to L2

Vincent Poinsignon, Astrium



Gaia enters in 2014

The way toward the operational orbit around L2 is not a bed of roses. No long Christmas break for the teams. The payload decontamination heaters were settled. The star trackers were activated a few hours after launch so as to acquire a three axis attitude knowledge and allow Ground Segment to prepare a first orbit control manoeuvre aiming at correcting launcher injection errors as early as possible, nominally on December 20th. Spacecraft servitudes were then exercised and commissioned. Starting from December 26th, the payload decontamination heaters were gradually switched

Launch is a very peculiar milestone of a space mission. It is more or less the only hour of the program during which the spacecraft teams have no control of their baby. It marks the end of several years of activity for the assembly, integration and test teams who properly celebrated the event on the launch site, and the beginning of the in orbit life of the spacecraft for the operation teams who are waiting under the highest stress level to take control of the spacecraft delivered in orbit.

Early minutes in Gaia life

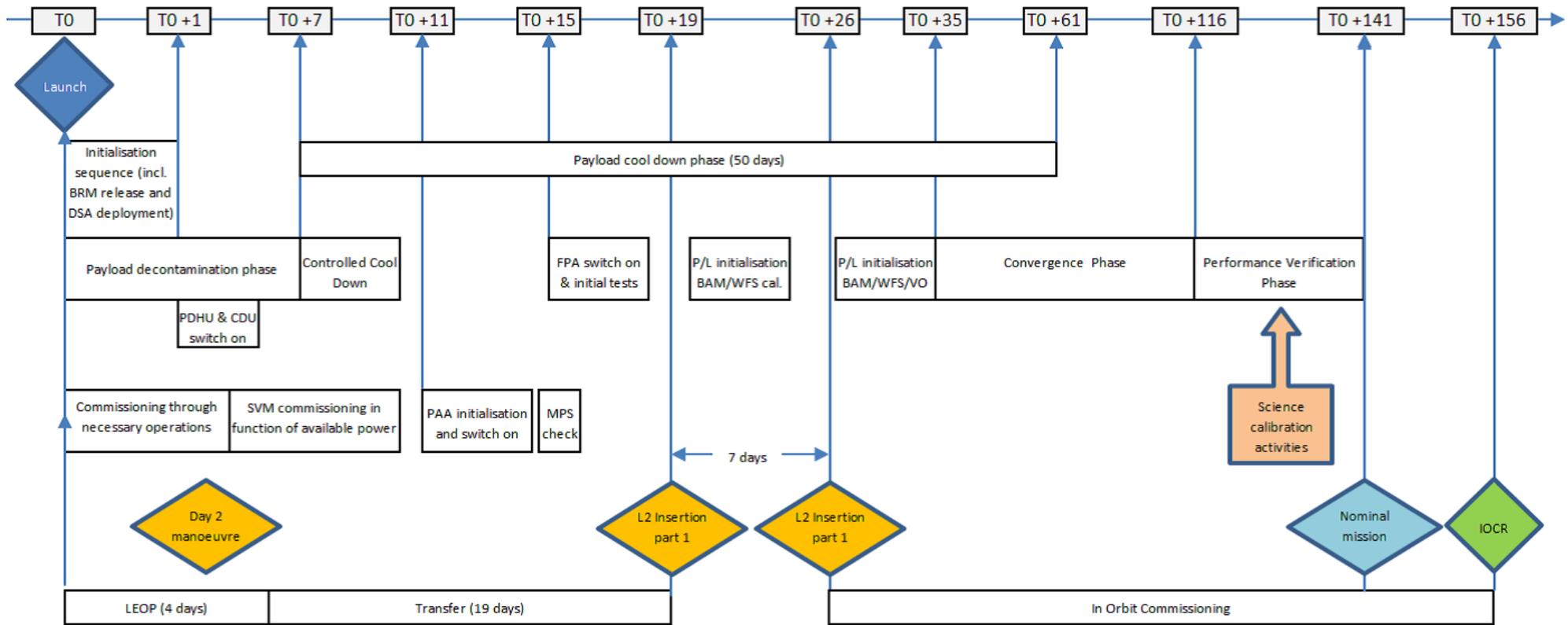
For Gaia, the operation teams located in the European Space Operation Center (ESOC) of Darmstadt near Frankfurt in Germany received the first signal from the spacecraft after separation from Fregat, the launcher restartable upper stage. This separation marked the start of an autonomous deployment sequence. Upon detection of the separation switches and within a few seconds, the transmitter was switched on to enable telemetry to the ground station, then the gyros were activated to measure the tumbling rates of the spacecraft, the launch bipods supporting the instrument loads during ascent were released and thermal control lines authorized. Twenty minutes are needed to prime the chemical propulsion system. Afterwards, attitude control was enabled and the spacecraft started to orient itself its lower face equipped with solar panels toward the Sun. The sunshield deployment occurred, followed by another sun attitude acquisition to complete the autonomous sequence, leaving a spacecraft ready to receive ground commands on its way to L2.

off in a controlled way over four days so as to avoid contamination of sensitive optical surfaces. The phased array active antenna was switched on just before New Year's eve. This antenna is used to download the large science telemetry flow of Gaia. After a short break for the New Year day, commissioning operations resumed on January 2nd with the first characterization tests of the cold gas micro-propulsion that will enable Gaia to achieve its finest attitude pointing stability. The instrument focal plane assembly was powered on January 3rd.

Gaia opens its eyes

An activity break of three days without disturbances was implemented to secure the main leg of the L2 insertion manoeuvre planned on January, 7th. About 80% of the required velocity increment was actuated. The 20% remaining were performed one week later, after fine orbit restitution and manoeuvre programming by ESOC flight dynamics teams. In between these two legs, the first attempts of scanning laws (actually the Ecliptic Polar Scanning Law) was implemented and the in-orbit tests of the two metrology systems of the instrument for wave front sensing and basic angle monitoring initiated. First stars were even be acquired in the coarsest "zoom + gate" payload mode.

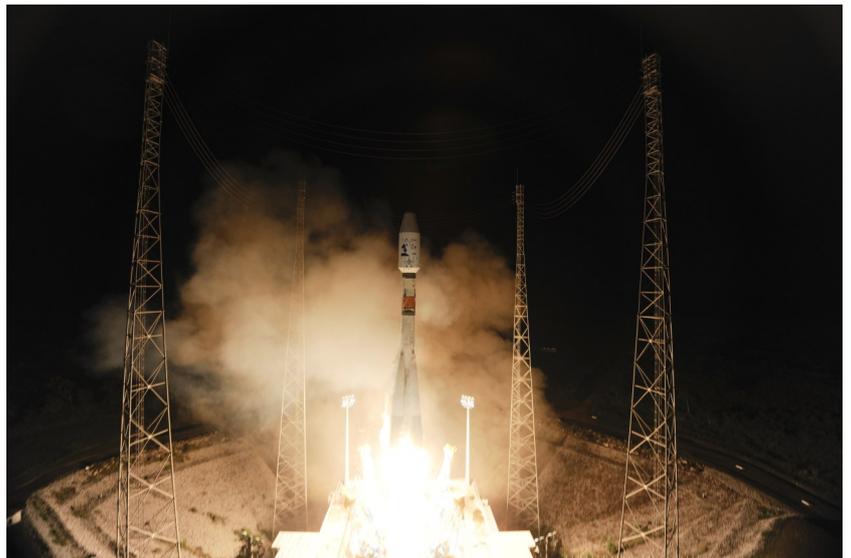
Thanks to these initial activities, the complete in orbit commissioning operations can carry on full speed once the spacecraft is inserted around L2. The nominal stellar census will then proceed before mid of 2014, after the In Orbit Commissioning Review.



Overall chart timelines of commissioning.



19 December 2013



Credit: ESA - C. Carreau, Joël Schopfer