211. The end of Gaia operations

IN JUST TWO DAYS from today, on 15 January 2025, the Gaia satellite will cease its science operations. More than 10 years of spectacular astrometric (and related) observations of unprecedented accuracy, number, and magnitude range, will come to an end.

In an information note two months ago, ESA announced the planned end of observations. I quote:

"The Gaia spacecraft relies on a cold gas propellant to keep it spinning and scanning the sky. The amount of remaining cold gas decreases by about a dozen grams per day and is reaching its end in early 2025. The Gaia science observations will therefore end on 15 January 2025, meaning that no more nominal science data will be acquired by Gaia after that date. This is, however, far from being the end of this transformative mission.

"The Gaia scientific and engineering teams will continue to work full steam on the preparations for Gaia Data Release 4, which is not 'more of the same' but will make new groundbreaking science possible by including a much larger data volume, many more data products, and data of overall better quality compared to Gaia Data Release 3.

"In 2025, once all of Gaia's nominal science data have been downlinked to Earth, the processing for the final Gaia Data Release 5 will ramp up to full speed and run in parallel to the processing of Gaia Data Release 4. Gaia Data Release 4, covering 5.5 years of mission data, is expected in 2026 and Gaia Data Release 5, covering the full 10.5 years of mission data, around the end of the decade.

"After Gaia's science observations end on 15 January 2025, a period of technology tests will commence. These will allow us to study in more detail the behaviour of some spacecraft and instrument components, with the potential of further improving the Gaia calibrations and aiding the design of future space missions.

"After these tests, which will last several weeks, the Gaia spacecraft will leave its orbit around the Lagrange point L2 to be put into its final heliocentric orbit, away from Earth's sphere of influence. Eventually, the Gaia spacecraft will be passivated in March/April 2025 and reach its well-deserved retirement."

LET ME RECALL the timeline of the Gaia data releases up to now, and the current plans for the future, as given in the above announcement.

Gaia DR1 was released on 14 September 2016, and the ESA Gaia www pages provide both an overview, and a description of the catalogue contents.

Gaia DR2 was released on 25 April 2018, and the ESA Gaia www pages provide both an overview, and a description of the catalogue contents.

Gaia EDR3 (Early Data Release 3) was made available on 3 December 2020, and the ESA Gaia www pages provide both an overview, and a description of the catalogue contents.

Gaia DR3 was released on 13 June 2022, and the ESA Gaia www pages provide both an overview, and a description of the catalogue contents.

Gaia FPR (Focused Product Release) was issued on 10 October 2023, and the ESA Gaia www pages provide both an overview, and a description of the contents.

In previous essays, I have given my own summaries of these various releases, covering DR1–EDR3 (essay 10), DR3 (essay 76), and the various topics covered by the Focused Product Release (essays 157–161).

FOR THE FUTURE, the current plan is for Gaia DR4, based on 66 months of data, to be released not before mid-2026. This will consist of the full astrometric, photometric, and radial-velocity catalogues; all available variable-star and non-single-star solutions; source classifications plus astrophysical parameters (from BP/RP, RVS, and astrometry) for stars, unresolved binaries, galaxies, and quasars; an exoplanet list; and the epoch and transit data for all sources.

Gaia DR5, based on all 10.5 years of mission data, will not be available before the end of 2030, when it will consist of the complete Gaia Legacy Archive of all data.

Recalling that the latest full catalogue, DR3, covers just the first 34 months of mission data, those who have worked with the Gaia catalogues will have some appreciation for the harvest expected once the full mission data set, covering more than 10 years, becomes available.

FOR THOSE INVOLVED in the early ideas for Gaia, and in my own case as ESA's Project Scientist for the first 15 years of the mission, the acquisition of 10+ years of mission data is a wonderful achievement… but also one for which provisions were carefully made!

Our top-level specifications, presented in the 380-page Concept and Technology Study Report of July 2000, called for a 5-year design life, with an extended lifetime of a further 5 years. Specifying a 10-year *design* lifetime would have come with additional industrial costs, considered unnecessary for the basic mission objectives. But many scientific and technology studies underpinned arguments for an extended operation period. Let me quote our summary from the 2000 study report.

"Although the many advantages of the space environment permit significant measurements to be made in a relatively short time, some of the more complex motions cannot be properly explored on a time scale of 2–3 years. This concerns, in particular, binaries with periods up to several years. The instrument is also ideal for planetary detection, but measurements extending over a significant fraction of the orbital period are mandatory.

"Additional motivations for a longer temporal baseline are for the dynamical studies of asteroids, and for photometric variability studies. The design lifetime is used for the assessment of the astrometric and photometric accuracies, and for the evaluation of all instrument and system performances, including the reliability analysis. The design lifetime was subject to a major system trade-off, since a longer design lifetime could actually minimise the satellite complexity.

"An extended design lifetime of 5 further years has also been considered, during which the satellite's design features will permit additional measurements to be made. The extended lifetime has been used for the sizing of all consumables (propellant) as well as for the sizing of items which suffer from aging and radiation effects, including the solar cells and thermal surfaces."

THE TECHNOLOGY TESTS that are planned for the Gaia satellite, after 15 January, are detailed in the above referenced information note. I will summarise:

On 15 January 2025, the last of the remaining cold gas, estimated to be an equivalent of about 15 days of nominal operations, will be used for technology tests.

The goal of these technology tests is to learn more about the instruments. This could help to improve Gaia calibrations for future data releases, but also the design of future space missions. Some of the Gaia technologies have already been re-used, for example the mirror-drive electronics and cold-gas thrusters on EUCLID. Future science missions such as the gravitational wave observatory LISA or the potential next generation Gaia–NIR are going to be ever more sensitive and are good candidates that might profit from the Gaia experience.

Some specific payload calibrations are also planned. The special virtual object patterns on-board will be used for an extended period to map the straylight, CCD response, and wings of the point spread function. Additionally, high-rate pre-scan pixel sampling will be undertaken to probe some known issues, and to map the temperature variations across the focal plane.

To better understand the cause of the tiny variations in the 'basic angle' between the two fields of view (as measured by the 'basic angle monitor'), and so provide important information for the design of future space missions, tests will study how it varies following certain changes in the spacecraft configuration.

AS THE operations end, let me express my own deep appreciation to all the individuals and teams involved: scientists and engineers who worked since the early 1990s on the early designs, the ESA advisory groups responsible for Gaia's selection in 2000, the ESA and industrial teams, and the launch authorities. The ESOC satellite operations team merit special recognition for keeping Gaia operating efficiently throughout. As do all members of the Gaia Data Processing and Analysis Consortium, DPAC, who are working with intensity and dedication to create the remarkable mission products.

I ASKED JUST a few of those involved for their thoughts. 65 years after his first contributions to astrometry, and 35 years after his first designs of a Hipparcos successor, Erik Høg, now 92, said: *'It is like a dream to witness the mission's success'*. Lennart Lindegren, now 74 and a central scientific figure in both Hipparcos and Gaia, said: *'Coming to the end of the science data gathering is a bit sad, but also deeply satisfying, because we know that something truly extraordinary has been achieved'*.

Vincent Poinsignon, industrial project manager said: *'Gaia was one of our biggest satellite challenges, and probably our biggest scientific success. Airbus is proud to have contributed to this major advance'*.

David Milligan, the satellite operations manager at ESOC for most of the mission, said: *'Our operations team started work several years before launch, preparing for both routine operations and unexpected contingencies. It is wonderful to see its success'*.

Uwe Lammers, Gaia's mission manager, said: *'Ten and a half years of observing have given us a treasure trove of trillions of measurements which will be turned into a final legacy dataset (DR5) that is likely to remain a standard for astrophysical research in the coming decades. So, although satellite operations will, sadly, end soon, the best is yet to come!'*.

Anthony Brown, chair of the DPAC Consortium, said: *'Our 400-strong scientific consortium joins in celebrating over 10 years of surveying the Milky Way and beyond, and looks forward to delivering data releases DR4 and DR5'*.