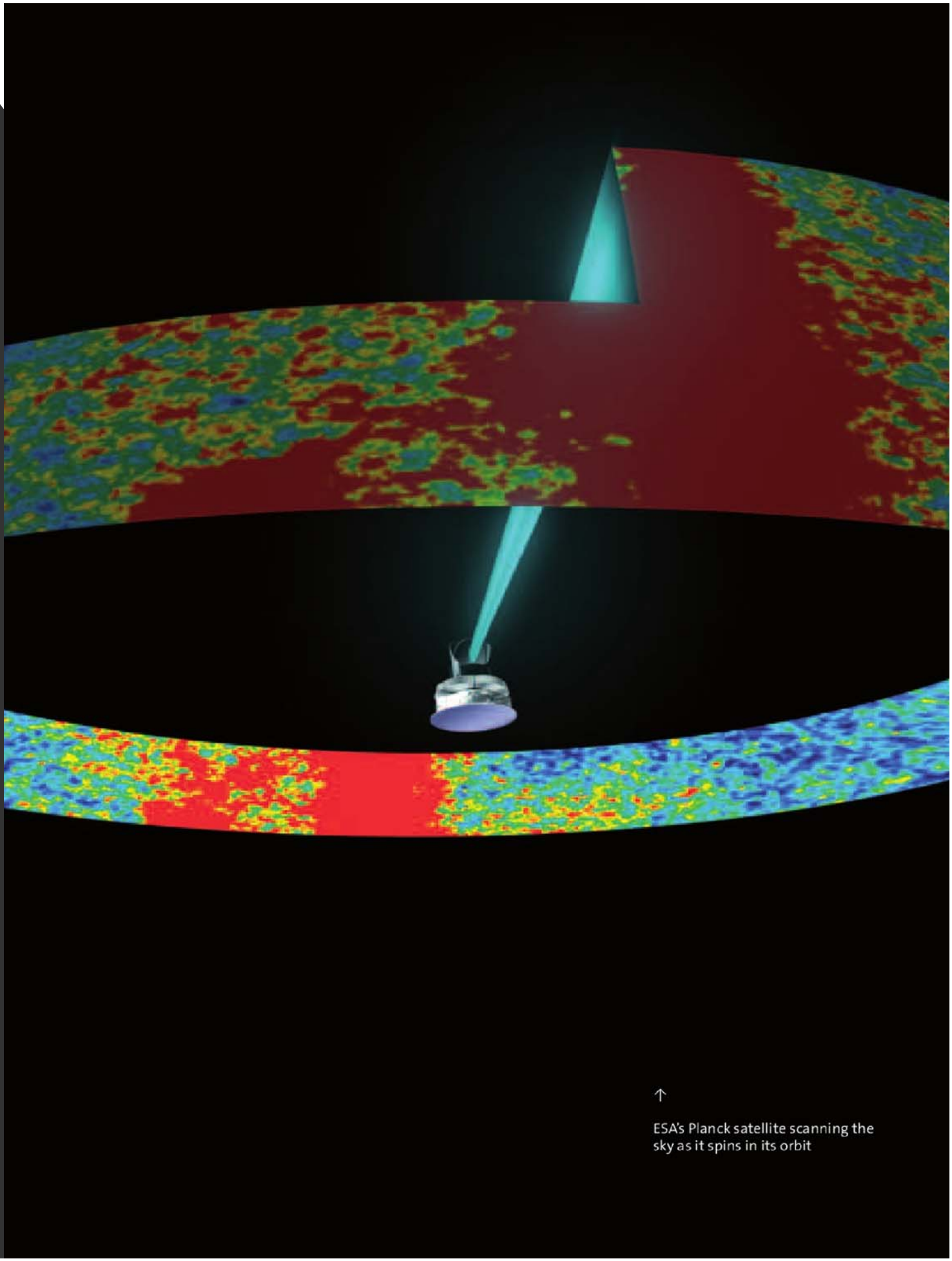

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ESA's Planck satellite scanning the sky as it spins in its orbit

→ HOW WE MAP THE FIRST LIGHT

The Science Ground Segment of Planck

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For any space mission, the 'ground segment' is vital for operating a spacecraft and processing data received from its instruments. Planck is no different, with hardware, software, telecommunications and other operations reaching from Spain to Australia.

The Planck satellite will observe the Cosmic Microwave Background (CMB), which is the cooled remnant of the light emitted around 400 000 years after the Big Bang, when hydrogen atoms combined and the Universe became transparent. It will measure the temperature variation across this microwave background with much better sensitivity, angular resolution and frequency range than any previous satellite. By observing the 'oldest' detectable radiation, Planck will be seeing the Universe as it was almost at its origin.

The ground segment of Planck is composed of the Operations Ground Segment, comprising all the elements under the responsibility of the European Space Operations Centre (ESOC), which includes the Mission Operations

Centre, the ground stations and the communications network, and the Scientific Ground Segment.

The latter is distributed between the following centres: the Planck Science Office, taking care of the scheduling of the survey strategy, and the two instrument teams' Data Processing Centres and Instrument Operations Teams, responsible for each instrument to process the telemetry and monitor the instrument operations respectively. The 35 m deep-space antenna at New Norcia in Australia is the prime ground station for Planck, with Cebreros in Spain as back-up.

DPCs and IOTs

Planck carries a 1.5 m telescope which focuses radiation from the sky on two arrays of highly sensitive radiodetectors, the High Frequency Instrument (HFI) built by a consortium of scientists led by the Institut d'Astrophysique Spatiale in Orsay, France, and the Low Frequency Instrument (LFI), led by the Istituto di Astrofisica Spaziale e Fisica Cosmica (IASF) in Bologna, Italy.

For each of these instruments, two operational centres have been put in place. The first one is the Data Processing Centre (DPC), responsible for (i) taking the raw payload telemetry received at ESOC, (ii) processing the telemetry until the generation of the final scientific products to be delivered to the Planck Science Office, (iii) providing the infrastructure, tools and resources for supporting the scientific data analysis during the proprietary phase and (iv) the operation and maintenance of a software maintenance facility.

The second one is the Instrument Operations Team (IOT) responsible for (i) commanding, calibrating and monitoring the instrument to ensure the optimum payload configuration is used, (ii) daily assessment of instrument health and (iii) providing payload expertise when needed for operations.

For HFI, the DPC is at the Institut d'Astrophysique de Paris in France, and the IOT is at the Institut d'Astrophysique

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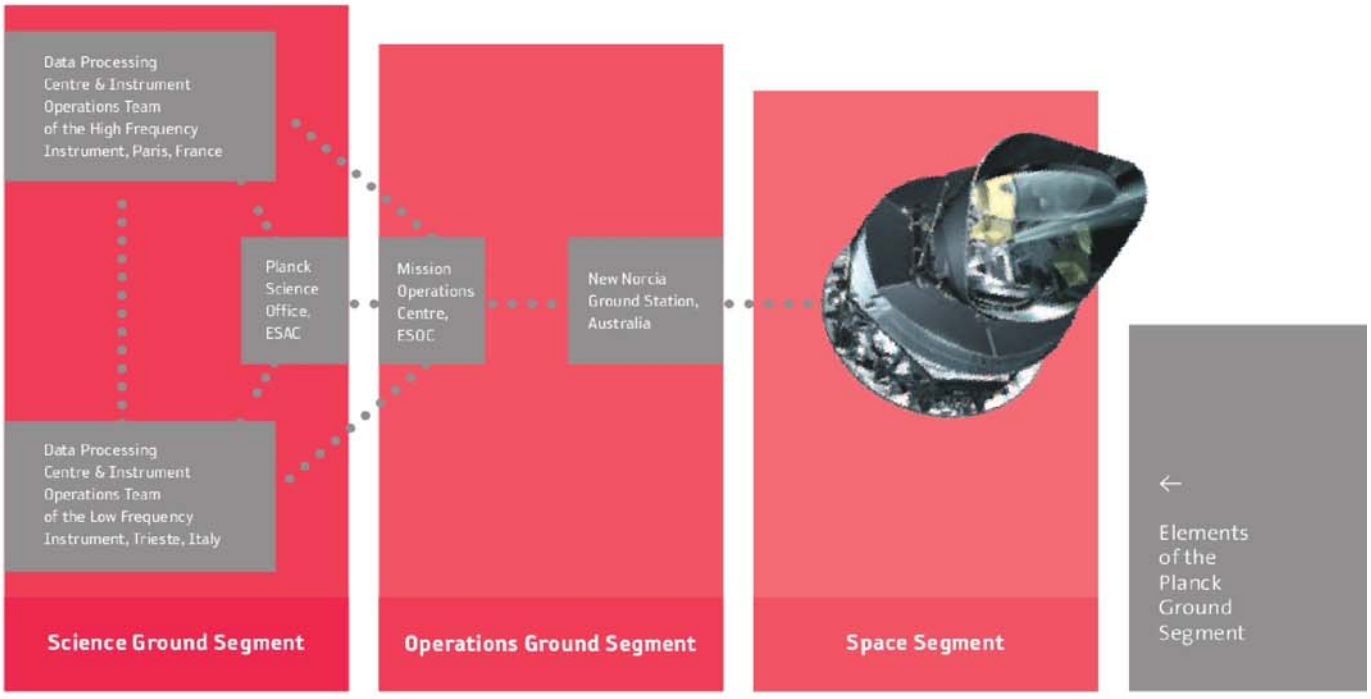
The deep-space station at New Norcia in Australia is the prime ground station for Planck



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Elements of the Planck Ground Segment

Spatiale in Orsay. For LFI, both the DPC and the IOT are at the Osservatorio Astronomico di Trieste, Italy.

Planck Science Office

The Planck spacecraft is spinning at a constant rate of one revolution per minute, and the line of sight of the telescope is at an angle of 85° to the spin axis, so that the observed sky region will trace a large circle on the sky. As the spin axis follows the Sun, the circle observed by the instruments sweeps through the sky at a rate of 1° per day.

Planck will take about six months to complete a full scan of the sky, charting two complete sky maps during its nominal lifetime (about 15 months). To maximise the sky coverage and optimise the science output of the mission, it is possible to change the spin axis while staying away from pointing at the Sun, Earth and Moon (called the 'survey strategy').

The Planck Science Office, located at the European Space Astronomy Centre (ESAC), near Madrid, Spain, is responsible for the scheduling of the pointing to be followed by the Planck spacecraft in order to implement the agreed survey strategy. This is done using the Survey Planning and Performance Tool (SPPT) developed by the PSO. This tool can simulate a given scanning law (i.e. a set of spin axis pointings) over a period of time to plan the course of the survey.

During operations, the Planck Science Office will continuously monitor the progress of the survey by visualising the accumulated coverage and quality of the Planck survey at any time in the mission. This will allow the Planck Science Office to quickly trigger the recovery of gaps in the survey coverage before the area ceases to be visible, as well as to carry out longer term modifications in the plan geared to improve the mission output.

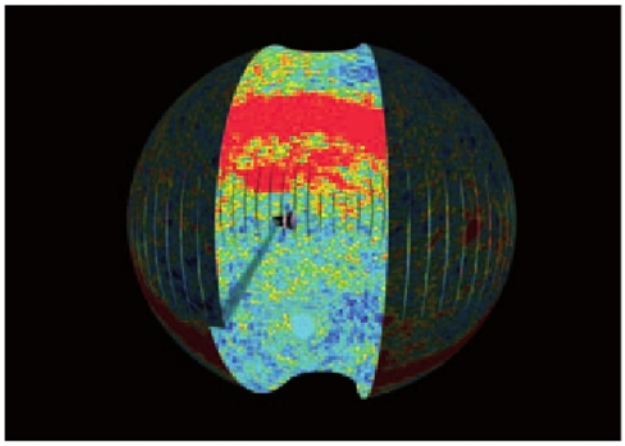
The Planck Science Office is also responsible for a number of coordination activities within the Science Ground Segment, for example, to: a) establish and maintain the scanning law in order to survey the sky is as efficient and effective a manner as possible, b) support the Instrument Operations Teams in maximising the scientific value of the data acquired by the Planck spacecraft and instrument, c) support the efforts of the DPCs to process the science data acquired by Planck and the usability of this data within the scientific community, and d) lead the preparation and execution of the calibration to be performed by the Planck payload prior to the start of the survey operation in order to tune the instruments in their optimum setups.

ESAC will also develop and host the archive system to be used during operation to exchange the data among all the groups involved in the data analysis effort (the first exchanges of data between the DPCs are planned around six months after launch with the data of the first three months), and after operations to become the Planck Legacy Archive. From here, Planck data will be made available to the worldwide scientific community (to be used at the expiration of the proprietary period of two years after the end of the nominal operations phase). These archives are developed by the Science Archive Team at ESAC based on the experience and technology used for the other science archives (ISO and XMM-Newton, for example).

Science Ground Segment operations

The nominal routine phase of the mission will last 15 months (allowing the sky to be surveyed twice) and can be extended by another 12 months. The Planck Science Office provides to the MOC in Darmstadt the sequence of pointing to be followed by the spacecraft in order to perform the surveys.

Although the Planck payload configuration is kept as stable as possible during the surveys, it is expected that some limited instrument commanding will be needed. The HFI and LFI IOTs are responsible for giving the MOC the detailed instruments commanding required. MOC will then take the pointing information from the Planck Science Office and the payload commands from the IOTs to generate the timeline to be uploaded every day to the spacecraft via the New Norcia ground station in Australia.



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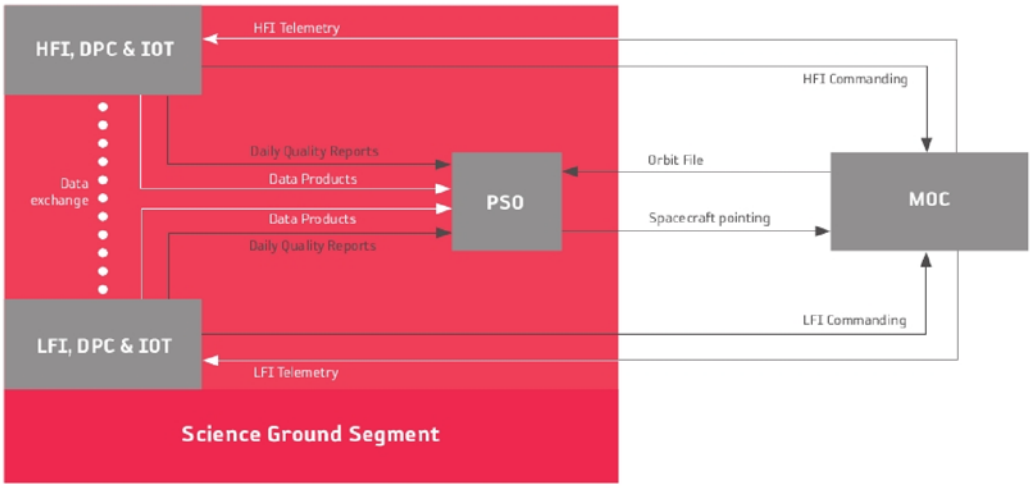
How Planck builds up its survey of the sky – completing two sky maps in 15 months (rotating 1° per day)

The telemetry downloaded each day during a ground station pass is made available at the MOC from where it is retrieved by the DPCs. The data processing is carried out by the DPCs in several steps, the first being the assessment of the performed observations. A report indicating the quality of all the performed pointings is generated every day by the DPCs and sent to the Planck Science Office.

Based on these reports, the Science Survey Planning and Performance Tool (SPPT) will be used to assess the survey quality and coverage and trigger when needed changes such as the recovery of the pointings which have not been observed. The data processing at the DPCs continues with the generation of the data products that will be ingested



Interfaces in the Planck Science Ground Segment during operations

in the Planck Archive at ESAC, from where they are made available to the scientific community.

The various elements of the Planck Science Operations Ground Segment completed their development at the end of 2008, culminating in the validation of all the processes and interfaces during the System Operations and Validation Test (SOVT) and declaring it ready to support Planck mission operations.

Acknowledgements

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