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Extract of Planck section

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4.3 Planck

Scientific goals

In late 1992, the NASA COBE team announced the detection of intrinsic temperature fluctuations in the Cosmic Background Radiation Field (CBRF), observed on the sky at angular scales larger than ~10º, and at a brightness level $\Delta T/T$~10^{-5}. In February 2003, the NASA WMAP team announced results on scales of about 15 arcmin with a similar sensitivity (see *http://lambda.gsfc.nasa.gov* for detailed descriptions of COBE and WMAP). These fluctuations have been interpreted as due to differential gravitational redshift of photons scattered out of an inhomogeneously dense medium, thus mapping the spectrum of density fluctuations in the Universe at a very early epoch. This long-sought result established the Inflationary Big Bang model of the origin and evolution of the Universe as the theoretical paradigm. However, in spite of the importance of the COBE and WMAP measurements (and those made by many other ground- or balloon-based experiments), many fundamental cosmological questions remain open. Building on the pioneering work of COBE and WMAP, the main objective of the Planck mission is to map the fluctuations of the CBRF with an accuracy that is set by fundamental astrophysical limits, allowing these fundamental questions to be addressed effectively.

Mapping the fluctuations of the CBRF with high angular resolution and high sensitivity would give credible answers to such issues as the initial conditions for structure evolution, the origin of primordial fluctuations, the type of potential that drove inflation, the existence of topological defects, the nature and amount of dark matter, and the nature of dark energy. Planck will set constraints on theories of particle physics at energies greater than 10^{15} GeV, which cannot be reached by any conceivable experiment on Earth. Finally, the ability to measure to high accuracy the angular power spectrum of the CBRF fluctuations will allow the determination of fundamental cosmological parameters such as the density parameter Ω_0 and the Hubble constant H_0, with an uncertainty of the order of a few percent.

The mission's observational goal is to survey the whole sky with an angular resolution as high as 5 arcmin, a sensitivity approaching $\Delta T/T$~10^{-6}, and covering a frequency range that is wide enough to encompass and deconvolve all possible foreground sources of emission. The main scientific result will be an all-sky map of the fluctuations of the CBRF. In addition, the sky survey will be used to study in detail the very sources of emission that contaminate the cosmological signal, and will result in a wealth of information on the dust and gas in both our own Galaxy and extragalactic sources. One specific notable result will be the measurement of the Sunyaev-Zeldovich effect in many thousands of galaxy clusters.

Planck payload

The Planck payload consists of a 1.5 m-diameter offset telescope, with a focal plane shared by clusters of detectors in nine frequency bands covering the range 30–900 GHz. The three lowest frequency bands (up to ~70 GHz) consist of HEMT-based receivers actively cooled to ~20K by an H_2 sorption cooler. The higher frequency bands consist of arrays of bolometers cooled to ~100mK; the H_2 sorption cooler provides precooling for a Joule-Thomson 4K stage, to which a dilution refrigerator is coupled. The main elements of the Planck satellite are shown in Fig. 4.3.1, and the characteristics and goal performance of the instruments are given in Table 4.3.1.

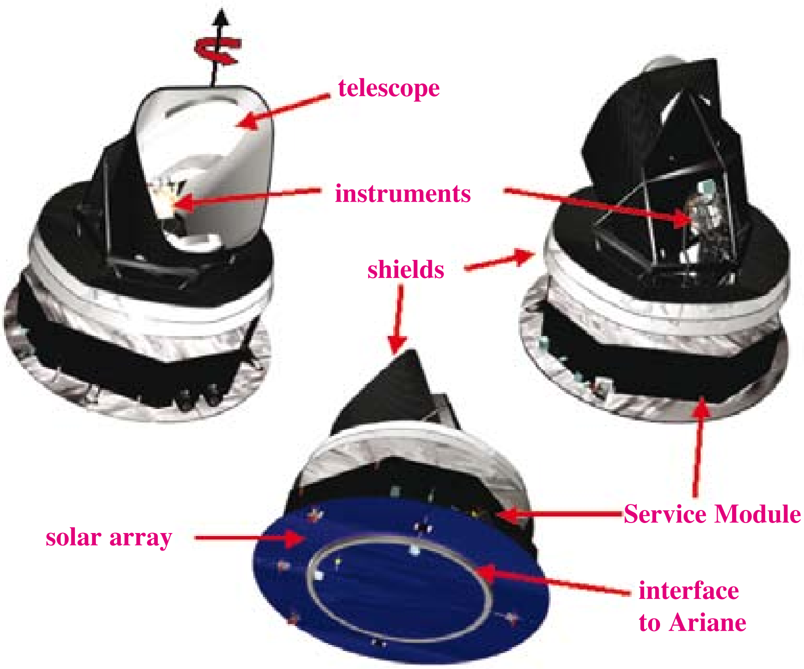
The satellite will be placed into a Lissajous orbit around the L2 point of the Earth–Sun system. At this location, the payload can point continuously in the anti-Sun direction, thus minimising potentially confusing signals due to thermal fluctuations and stray light entering the detectors through far side-lobes. From L2, Planck will carry out two complete surveys of the full sky, for which it requires about 14 months

For further information, see www.rssd.esa.int/Planck

Table 4.3.1. Planck instrument performance goals.

Telescope	1.5 m (projected aperture) offset; shared focal plane; system emissivity ~1% Viewing direction offset 85° from spin axis; field of view 8°								
Instrument	*LFI*			*HFI*					
Centre Frequency (GHz)	30	44	70	100	143	217	353	545	857
Detector Technology	HEMT LNA arrays			Bolometer arrays					
Detector Temperature	~20K			0.1K					
Cooling Requirements	H_2 sorption cooler			H_2 sorption + 4K J-T stage + Dilution cooler					
Number of Detectors	4	6	12	8	12	12	12	4	4
Bandwidth (GHz)	6	8.8	14	33	47	72	116	180	283
Angular Resolution (FWHM arcmin)	33	24	14	9.5	7.1	5	5	5	5
Average $\Delta T/T$ per pixel (14 months, 1σ, 10^{-6} units)	2.0	2.7	4.7	2.5	2.2	4.8	14.7	147	6700
Average $\Delta T/T$ (polarisation) per pixel (14 months, 1σ, 10^{-6} units)	2.8	3.9	6.7	4.0	4.2	9.8	29.8		

Figure 4.3.1 The main elements of the Planck satellite telescope reflectors.



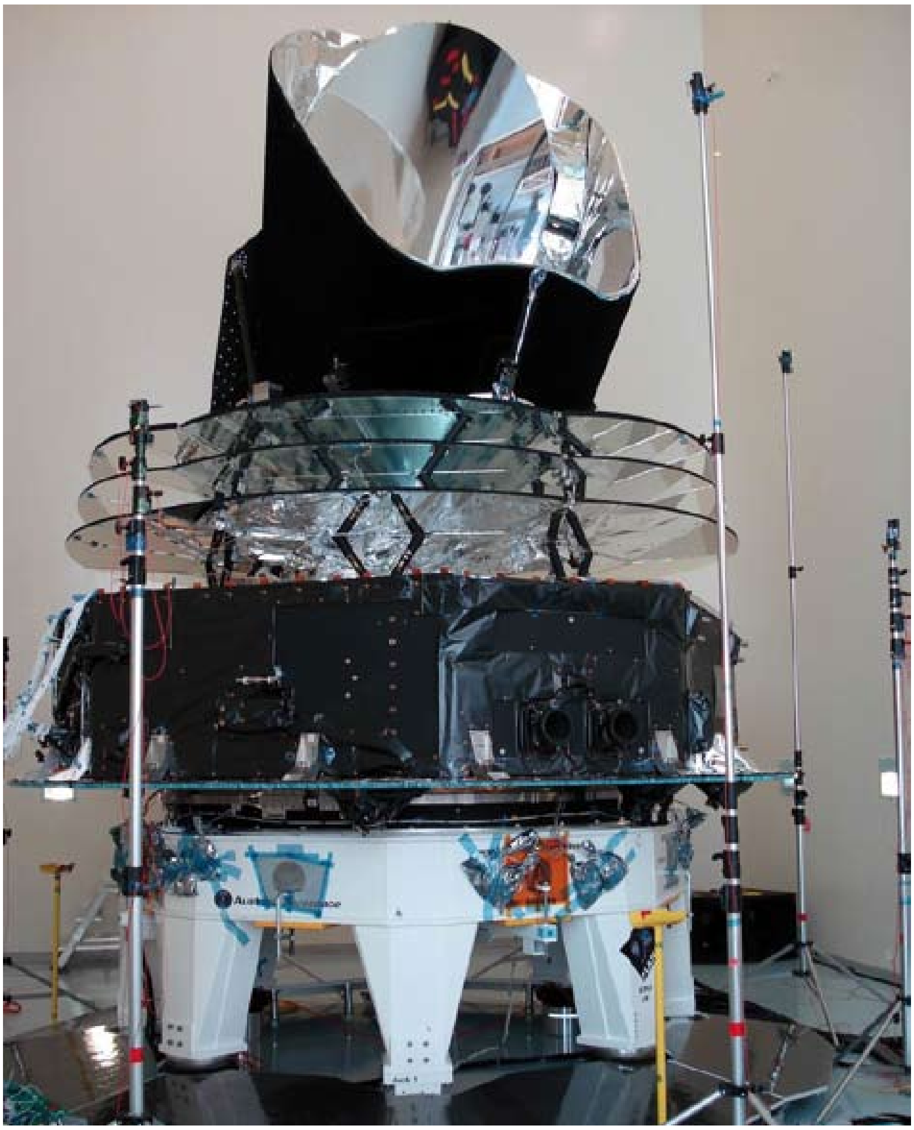


Figure 4.3.2. The fully-assembled Planck satellite being readied for acoustic tests.

of observing time. The spacecraft will be spin-stabilised at 1 rpm. The viewing direction of the telescope will be offset by 85° from the spin axis, so that the observed sky patch will trace a large circle on the sky.

Planck is a survey-type project, developed and operated as a PI mission. The payload will be provided by two PI teams, who will also man and operate two Data Processing Centres, which will process and monitor the data during operations and reduce the final data set into the science products of the mission. All-sky maps in the nine frequency bands will be made publicly available 1 year after completion of the mission, as well as a first-generation set of maps of the CBRF, Sunyaev-Zeldovich effect and dust, free-free and synchrotron emission. The time-series of observations (after calibration and position reconstruction) will also eventually be made available as an online archive.

Status

Planck was selected in late 1996 as the third Medium Mission (M3) of ESA's Horizon 2000 Scientific Programme, and is now part of its Cosmic Vision Programme. At the time of its selection, Planck was called COBRAS/SAMBA; after the mission was approved, it was renamed in honour of the German scientist Max Planck (1858–1947), winner of the Nobel Prize for Physics in 1918. Planck will be launched together with the Herschel far-IR and sub-mm observatory.

Starting in 1993, a number of technical studies laid the basis for the issue in September 2000 of an Invitation to Tender to European industry for the procurement of the Herschel and Planck spacecraft. From the submitted proposals, a single prime contractor, Alcatel Space (F) (now Thales Alenia Space), was selected in early 2001 to develop both spacecraft. Alcatel Space is supported by two major subcontractors: Alenia Spazio (Torino, I) (now Thales Alenia Spazio) for the Service Module, and Astrium GmbH (Friedrichshafen, D) for the Herschel Payload Module; and by many other industrial subcontractors from all ESA member states. The detailed definition work began in June 2001.

During 2003–2005, industry concentrated on qualifying the satellite design. This phase culminated in major environmental tests on purpose-built qualification models, including a full thermal-vacuum test in a specially-constructed chamber at the Centre Spatial de Liège (B). This successful test validated the passive thermal behaviour of the satellite and of most of the active cryogenic cooler chain. These two aspects were considered among the most critical in the satellite design.

In early 1999, ESA selected two consortia of scientific institutes to provide the two Planck instruments: the Low Frequency Instrument (LFI) by a consortium led by N. Mandolesi of the Istituto di Astrofisica Spaziale e Fisica Cosmica (CNR) in Bologna (I); and the High Frequency Instrument (HFI) by a consortium led by J.-L. Puget of the Institut d'Astrophysique Spatiale (CNRS) in Orsay (F). More than 40 European institutes, plus some from the US, are collaborating on the development, testing and operation of these instruments, as well as the ensuing data analysis and exploitation. The capabilities of the instruments are described in Table 4.3.1.

During 2006 and 2007, most of the flight hardware has been manufactured and assembled. The two instruments were calibrated and delivered to ESA in 2006. The Planck telescope reflectors were tested individually, and then assembled and aligned on the telescope structure. In parallel, a Qualification Model of the telescope went through an intensive RF measurement campaign in the Compact Antenna Test Range of Thales Alenia Space in Cannes. The flight model of the satellite is now completely integrated (see Figure 4.3.2) and has successfully undergone environmental testing (acoustic, vibration, EMC). It is now in the process of going through system-level functional testing. The complete flight satellite will undergo a flight-representative (cryogenic) end-to-end test in a specially-built chamber at the Centre Spatial de Liège, starting in April of 2008.

The development of the Planck ground segment is developing at a similar pace to the flight segment. The first series of Integration Tests took place in 2007, and the next milestones are the System Validation Tests in March and August 2008. In parallel, the scientific pipelines within each of the two Data Processing Centres are undergoing end-to-end testing, the first phase of which was finished in late 2007.

The launch date is currently expected to be in late 2008.

A detailed and updated version of the scientific case for Planck can be downloaded from the website.