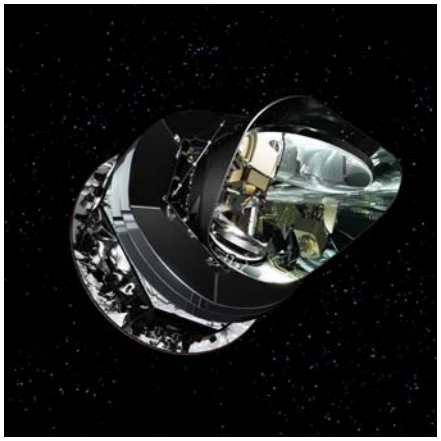
Science & Technology Facilities Council

Planck

Planck is Europe's first mission to study the relic radiation from the Big Bang. Ever since the detection of small fluctuations in the temperature of this radiation, announced in late 1992, astronomers have used the fluctuations to understand both the origin of the Universe and the formation of galaxies.



The mission is named after the German physicist Max Planck, whose work on the behaviour of radiation won the Nobel Prize in 1918.

Planck will map the structure of the Cosmic Microwave Background radiation and the detail and sensitivity of the measurements will help determine fundamental parameters relating to the origin and evolution of the universe.

UK groups are involved in building the two focal plane instruments for Planck and UK astronomers are also posed to work on the scientific observations that Planck will make.

The focal plane instruments are LFI and HFI:

Low Frequency Instrument (LFI)

LFI is an array of 22 tuned radio receivers that is located in the focal plane of the Planck telescope. LFI will image the sky at three frequencies between 30 GHz and 70 GHz.

LFI was designed and built by a consortium of scientists and institutes from Italy, Finland, the United Kingdom, Spain, the United States, Germany, the Netherlands, Switzerland, Norway, Sweden and Denmark.

High Frequency Instrument (HFI)

HFI is an array of 52 bolometric detectors that is also placed in the focal plane of the Planck telescope. HFI will image the sky at six frequencies between 100 GHz and 857 GHz.

HFI was designed and built by a consortium of scientists and institutes from France, the United States, the United Kingdom, Canada, Italy, Spain, Ireland, Germany, the Netherlands, Denmark and Switzerland.

UK involvement

Cardiff University: The Astronomy Instrumentation Group (AIG) at Cardiff University has been involved with the High Frequency Instrument (HFI) since its inception. The group developed,

manufactured and tested the unique cold optics, including the triple horns configuration and band defining filters.

The team integrated the optics with bolometers provided by JPL-Caltech, and assembled and calibrated all the detection channels. They then assembled the focal plane units for integration with the rest of the instrument and participated in full instrument calibration in France and Belgium.

The detailed component measurements of the spatial and spectral behaviour of the Planck-HFI have been crucial to development of the data processing algorithms. Members of the group are therefore involved in Post-Launch Support and will perform continual health checks on the instrument to ensure data quality. The team's knowledge will also prove vital for the extraction of the key CMB science products.

STFC: STFC Rutherford Appleton Laboratory provided thermal analysis for the HFI instrument as well as developing, testing and supplying the 4K cooling sub-system. This takes the temperature of the HFI instrument from 18K down to 4K using a closed cycle Joule-Thomson system based on reciprocating compressor technology.

SEA: Under STFC contract the Bristol-based Aero-Space Division of SEA Group Ltd has provided the Cooler Drive Electronics for the 4K Cooler subsystem which provides a key stage of the detector cooling chain for the Planck HFI instrument. The 4K cooler subsystem is led by Rutherford Appleton Laboratory and SEA has worked very closely with RAL. A balanced pair of compressors are driven in antiphase to minimise exported disturbances. Because the gas dynamics in the two compressors are not identical and there are large nonlinear effects such as the operation of non-return valves the motion is far from sinusoidal; the exported forces are measured with piezoelectric washers and the drive current waveforms autonomously modified to eliminate disturbances at all harmonics up to 8 times the fundamental frequency. The nonlinearities make design of the control loop very challenging, and so SEA used its simulation expertise to develop a high fidelity simulation of the coupled thermodynamic and electronic system. The residual exported disturbances are less than 20mN.

University of Cambridge: The University of Cambridge has been involved in Planck since its conception in 1992. They were part of the team that developed the scientific case which led to the mission being selected by ESA in1996. They will be heavily involved in analysing data from Planck with colleagues in the UK, France and Italy and will be responsible for producing several of the key mission products which will be released at the end of the mission. Their main scientific interests are in cosmology, in particular understanding physical conditions in early universe, and finding and analysing galaxies from radio to infrared wavelengths.

Jodrell Bank / University of Manchester: Jodrell Bank Centre for Astrophysics, University of Manchester, have been responsible for constructing the Planck Low Frequency Instrument (LFI) Front End Modules (FEMs) at 30 and 44 GHz .

The FEM design is that of a differential pseudo-correlation radiometer in which the signal from the sky is compared with a 4-K blackbody load. The Low Noise Amplifier (LNA) at the heart of the FEM is based on indium phosphide High Electron Mobility Transistors (HEMTs). The radiometer incorporates a novel phase-switch design which gives excellent amplitude and phase match across the band. The 30 and 44 GHz FEMs have met or bettered the mission requirements in all critical aspects. The most sensitive LNAs have reached new limits of noise temperature for HEMTs at their band centres. The FEMs have well-defined linear polarization characteristics.

Jodrell Bank will continue to be intimately involved with the day to day performance of the radiometers during flight. They will also be concerned with identifying and removing systematics which will be crucial to the science requirements.

Imperial College London: Imperial College has been involved in Planck for over a decade. They are responsible for the crucial task of determining and calibrating the attitude of the Planck spacecraft and for measuring its response to signals on the sky. The Imperial team is especially interested in determining the underlying cosmological model, and in using Planck as part of a campaign to observe distant galaxies over a wide range of wavelengths, especially in combination with data from Planck's sister satellite, Herschel.

Thomas Keating Ltd, **Cardiff University**: Thomas Keating Ltd was involved in the design and manufactured the space qualified Back-to-Back Corrugated horns for the HFI Instrument on Planck. They also supplied an "illuminator" to the ESTEC/Alcatel team responsible for aligning the focal plane array with respect to the pimary dish of Planck.

Additional information from ESA press kit

Objectives
Planck will make the most accurate maps yet of the microwave background radiation that fills space. It will be sensitive to temperature variations of a few millionths of a degree and will map the full sky over nine wavelength bands. It will measure the fluctuations of the CMB with an accuracy set by fundamental astrophysical limits.

The mission will address a number of fundamental questions, such as the initial conditions for the evolution in the Universe's structure, the nature and amount of dark matter (matter that does not emit or reflect electromagnetic radiation, but whose presence can be inferred from its effects on detectable matter), and the nature of dark energy (a hypothetical form of energy that may account for the Universe's expansion at an accelerating rate).

Planck's maps will allow a number of specific investigations to take place:

- The determination of the Universe's fundamental characteristics, such as the overall geometry of space, the density of normal matter and the rate at which the Universe is expanding.
- A test of whether the Universe passed through a period of rapidly-accelerated expansion just after the Big Bang. This period is known as inflation.
- The search for 'defects' in space, for example cosmic strings, which could indicate that the Universe fundamentally changed state early in its existence.
- Accurate measurement of the variations in the microwave background that grew into the largest structures today: filaments of galaxies and voids.
- A survey of the distorting effects of modern galaxy clusters on the microwave background radiation, giving the internal conditions of the gas in the galaxy clusters.

Cost

The total cost of the Planck mission is about €600 million. This includes the spacecraft and its scientific payload, the launch and the operations.

Launch

Planck is scheduled for launch on an Ariane 5 from Europe's Spaceport in Kourou, French Guiana, on 14th May 2009. It will be launched together with ESA's Herschel spacecraft, in a dual launch configuration.

Mission timeline

Launch:	14 May 2009
About 0.5 hours after launch:	Planck separates from the upper stage, a couple of minutes after Herschel, and starts the cruise to its final orbit around L2 (the second Lagrangian point).
In about 2 months:	Planck enters its operational orbit, a Lissajous orbit on average 400 000 km from L2.
One month later:	Planck starts its nominal scientific observations.

Planned mission lifetime

Planck's routine science observations at L2 will last 15 months, allowing two sky surveys. The mission could in principle be further extended by one year, depending on the resources still available for cooling the instruments.

Spacecraft

Design

The Planck telescope and instruments are mounted on top of an octagonal service module. A baffle surrounds the telescope and instruments to prevent straylight from the Sun and Moon from spoiling the detection of microwave radiation. The baffle is also used to radiate to cold space the heat generated by the focal plane units of the scientific payload, and to provide to the instrument coolers a cold and stable background environment of about –223ºC (or 50K).

Inside the service module are the computers and subsystems that allow the spacecraft to function and to compress the raw data signals from the instrument detectors. At the base of the service module is a flat, circular solar panel to generate electricity from sunlight to power the spacecraft, and to protect the whole spacecraft from direct solar radiation.

In order to achieve its scientific objectives, Planck's detectors have to operate at very low and stable temperatures. The spacecraft is therefore equipped with the means of cooling the detectors to levels close to absolute zero (–273.15ºC), ranging from about –253ºC to only a few tenths of a degree above absolute zero.

Mass

Approximately 1950 kg at launch.

Dimensions

Planck is 4.2 m high and has a maximum diameter that is also 4.2 m.

Industrial involvement

The prime contractor is Thales Alenia Space (Cannes, France). It leads a consortium of industrial partners with Thales Alenia Space (Turin, Italy), who are responsible for the Service Module. There is also a host of subcontractors spread throughout Europe, with a few more in the USA. ESA and the Danish National Space Centre (Copenhagen, Denmark, funded by the Danish Natural Science Research Council) are responsible for the provision of Planck's telescope mirrors, manufactured by EADS Astrium (Friedrichshafen, Germany).

Operations

Primary Ground Station: ESA's deep space antenna in New Norcia (Australia).

Mission Operations Centre (MOC): provided by ESA at the European Space Operations Centre (ESOC), Darmstadt, Germany.
Planck Science Office (PSO): provided by ESA at the European Space Astronomy Centre (ESAC) in Villafranca (Spain).
Data Processing Centres (DPCs): HFI DPC, led by the Institut d'Astrophysique Spatiale, is located at the Institut d'Astrophysique de Paris, France; LFI DPC, led by the Istituto di Astrofisica Spaziale e Fisica Cosmica (IASF) is located at the Osservatorio Astronomico di Trieste, Italy.

Herschel & Planck Programme Manager: Thomas Passvogel
Planck Project Scientist: Jan Tauber

General information about this and other ESA Science missions can be found at:
http://www.esa.int/science

Images

Images of Planck: http://www.scitech.ac.uk/planckimages