PLANCK
Looking back to the dawn of time
Measurements of the CMB by the PLANCK satellite

M.C. Falvella

Italian Space Agency (ASI)

on behalf of Planck collaboration
In 1992 two space-based CMB experiments (COBRAS and SAMBA) were proposed to ESA.
In 1996 ESA selected a combined mission called COBRAS/SAMBA as the third Medium-Sized Mission (M3) of the Horizon 2000 Scientific Programme COBRAS/SAMBA, renamed in honor of Max Planck.

In 1997 ESA released an Announcement of Opportunity for *Planck* instruments.

Two proposals were received and accepted (1999):

- **the Low Frequency Instrument** (LFI, an array of receivers based on HEMT amplifiers, covering the frequency range 30–100 GHz, and operated at a temperature of 20 K), led by N. Mandolesi (INAF, Bo).

- **the High Frequency Instrument** (HFI, an array of receivers based on bolometers covering the frequency range 100–857 GHz, and operated at a temperature of 0.1 K), led by J.L. Puget (IAS, Orsay).

**Today PLANCK forms part of ESA “Cosmic Vision 2020” programme.**
1992 – COBE team announced the detection of intrinsic temperature fluctuations in the CMB on angular scales larger than about $7^\circ$, at a level $\Delta T/T$ of $10^{-5}$.

Since this detection the main objective is to measure the fluctuations of the CMB with an accuracy set by fundamental astrophysical limits.

2003 – WMAP team announced results on scales of about 15’ with similar sensitivity

>>> strongly support inflationary Big Bang models and confirms Standard Model but CMB measurements with high angular resolution and sensitivity are required to determine the initial conditions for structure evolution, the origin of primordial fluctuations, the existence of topological defects, and the nature and amount of dark matter.
Planck, the third space CMB mission after COBE and WMAP, is designed to extract essentially all of the information in the CMB temperature anisotropies.

*Planck* will image the whole sky with an unprecedented combination of sensitivity ($\Delta T/T \sim 2 \times 10^{-6}$), angular resolution (to 5’), and frequency coverage (30–857 GHz).
The collaboration

*Planck* is being developed in a partnership with the European scientific community:

- Two Consortia of scientific institutes, each led by a PI, supported by national agencies, have delivered to ESA Instruments.

- The instruments sit at the focus of a telescope whose mirrors are being developed in a collaborative effort between ESA and a Danish Consortium of Institutes led by H. U. Norgaard Nielsen (DSRI, Copenhagen).

- ESA manages the project, develops and procures the spacecraft, integrates the instruments into the spacecraft, and will launch and operate it.

- Each of the two instrument Consortia will operate their respective Instrument and process all the data into usable scientific products.

At the end of the mission (approximately in December of 2012), the Consortia will deliver the final products to ESA, who will archive them and distribute them to the wide community. **Up to that time, the three scientific institutes will have exclusive access to the data for scientific exploitation.**
The LFI team, a great international collaboration: **about 300 people** contributing to the instrument and the data processing development
It is currently planned to launch Planck on An Ariane 5 rocket at the end of 2008, together with the Herschel Space Observatory.

After launch, they will both be placed into orbits around a point located at 1.5 million km from the Earth (L2).
It is crucial to limit at µK level the residual instrumental systematic errors specially those that are synchronous with spacecraft spin period. Spin-synchronous signals are virtually indistinguishable from any true sky signal and can affect permanently the final maps.

>>> Need of a stable environment to minimize thermal and radioactive systematics effects:
- L2 orbit
- Scanning strategy

spin axis in anti-solar dir., field of view scan circles in the sky at 85° from the spin axis
Not sufficiently “cross-linked” to suppress the effects of correlated (e.g., 1/f) noise
Polarization angle coverage is not uniform enough
Launch and orbit

Planck orbit at the 2nd Lagrangian point of the Earth-Sun system (L2). The spin axis is pointed near the Sun, with the solar panel shading the payload, and the telescope sweeps the sky in large circles at 1 rpm.
LIFETIME

- Planck will operate for 14 months
- Its lifetime strongly depends on cryogenic system
- From L2 *Planck* will sweep the sky in large swaths, and cover it fully at least twice (hopefully 4!!!!!!).
The main components of Planck

- an off-axis telescope with a projected diameter of 1.5 m;
- a telescope baffle that simultaneously provides straylight shielding and radiative cooling;
- two state-of-the-art cryogenic instruments, operating at 20K and 0.1 K;
- three conical "V-groove" baffles that provide thermal isolation between the warm spacecraft and the cold telescope and instruments;
- the service module;
- the solar panel.

In flight, the solar panel faces the Sun; everything else is always in shadow. The cryogenic temperatures required by the instruments are achieved through a combination of passive radiative cooling and three active refrigerators. The cooling provided by the passive system leads to a temperature of ~50K for the telescope and baffle. The active cryocoolers further reduce the temperature to 20K and 0.1K for the instruments.

M.C. Falvella, Italian Space Agency
7 May 2008
All information about Planck performance are from the Planck “Bluebook”

A performance update will be issued following the system level cryo test in late spring
## PLANCK INSTRUMENT CHARACTERISTICS

<table>
<thead>
<tr>
<th>Detector Technology</th>
<th>LFI</th>
<th>HFI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center Frequency [GHz]</td>
<td>30 44 70</td>
<td>100 143 217 353 545 857</td>
</tr>
<tr>
<td>Bandwidth (Δν/ν)</td>
<td>0.2 0.2 0.2</td>
<td>0.33 0.33 0.33 0.33 0.33 0.33</td>
</tr>
<tr>
<td>Angular Resolution (arcmin)</td>
<td>33 24 14</td>
<td>10 7.1 5.0 5.0 5.0 5.0</td>
</tr>
<tr>
<td>ΔT/T p.p. (Stokes I)*</td>
<td>2.0 2.7 4.7</td>
<td>2.5 2.2 4.8 14.7 147 6700</td>
</tr>
<tr>
<td>ΔT/T p.p. (Stokes Q &amp; U)*</td>
<td>2.8 3.9 6.7</td>
<td>4.0 4.2 9.8 29.8 . . . . .</td>
</tr>
</tbody>
</table>

* Goal (in μK/K) for 14 months integration, 1σ, for square pixels whose sides are given in the row “Angular Resolution”.
The HFI is inserted into the ring formed by the LFI horns, and includes thermal stages at 18 K, 4K, 2K and 0.1 K. The cold LFI unit (20 K) is attached by bipods to the telescope structure.
HFI and LFI FPU on spacecraft
HFI and LFI detectors systems
The Planck LFI Instrument
The LFI radiometer array assembly.

The front-ends are based on wide-band low-noise amplifiers, fed by corrugated feedhorns which collect the radiation from the telescope. The waveguides transport the amplified signals from the front-end (at 20 K) to the back-end (at 300 K). They are designed to meet simultaneously radiometric, thermal, and mechanical requirements, and are thermally linked to the three V-groove thermal shields of the Planck payload module. The back-end unit, located on top of the Planck service module, contains additional amplification as well as the detectors, and is interfaced to the data acquisition electronics. The HFI is inserted into and attached to the frame of the LFI focal-plane unit.
LFI take advantage of transistor amplifier technology particularly for low noise performance and reliability of criogenically cooled indium phosphide (InP) high-electron-mobility transistors (HEMTs).

HEMTs exhibit the best noise performance in the LFI frequency range.
The front-end unit is located at the focus of the *Planck* telescope, and comprises: dual profiled corrugated feed horns (Villa et al. 2002); low-loss (~0.2 dB), wideband (> 20%) orthomode transducers; and radiometer front-end modules with hybrids, cryogenic low noise amplifiers, and phase switches. (Bottom) Measured radiometer output of the Elegant Breadboard model at 30 GHz. Shown are the signals from the two detector diodes (“odd” and “even” samples), which correspond to the sky and reference load, in which the noise is dominated by a non-white 1/f-type component. The radiometer design, however, is such that the 1/f component is highly correlated in the two diodes, so that the difference signal is extremely stable and insensitive to 1/f fluctuations.
LFI contains 11 feed horns and 22 radiometers

30 GHz Radiometer chain
Systematics effects

- Main Beam distortion
- Instrument Intrinsic
- External Straylight (dominates at high galactic latitude, crucial for polarization measurements)
- Thermal effects (due to ext. & int. source, crucial out of 1’- 60’ range)
- Pointing (affects recovery of beam resolution & angular resolution >>> accuracy 1’ at 2σ level)
4K Load

M.C. Falvella, Italian Space Agency
7 May 2008
4K Load

- It a critical part of LFI
- The 54 receivers of LFI follow a correlation scheme observing continuously the sky and the stable reference load at a T~4K
- 4K Load is made of 54 absorbing targets mechanically and thermally connected to HFI cryostat.
## LFI PERFORMANCE GOALS

<table>
<thead>
<tr>
<th>CENTER FREQUENCY [GHz]</th>
<th>30</th>
<th>44</th>
<th>70</th>
</tr>
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<tbody>
<tr>
<td>INSTRUMENT CHARACTERISTIC</td>
<td>MIC</td>
<td>MMIC</td>
<td></td>
</tr>
<tr>
<td>InP HEMT Detector technology</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detector temperature</td>
<td>20K</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooling system</td>
<td>H2 Sorption Cooler</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of feeds</td>
<td>2</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Angular resolution [arcminutes FWHM]</td>
<td>33</td>
<td>24</td>
<td>14</td>
</tr>
<tr>
<td>Effective bandwidth [GHz]</td>
<td>6</td>
<td>8.8</td>
<td>14</td>
</tr>
<tr>
<td>Sensitivity [mK Hz−1/2]</td>
<td>0.17</td>
<td>0.20</td>
<td>0.27</td>
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<tr>
<td>System temperature [K]</td>
<td>7.5</td>
<td>12</td>
<td>21.5</td>
</tr>
<tr>
<td>Noise per 30 reference pixel [μK]</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>$\Delta T/T$ Intensity b [10−6 μK/K]</td>
<td>2.0</td>
<td>2.7</td>
<td>4.7</td>
</tr>
<tr>
<td>(ΔT/T) Polarisation (Q and U) b [μK/K]</td>
<td>2.8</td>
<td>3.9</td>
<td>6.7</td>
</tr>
<tr>
<td>Maximum systematic error per pixel [μK]</td>
<td>&lt; 3</td>
<td>&lt; 3</td>
<td>&lt; 3</td>
</tr>
</tbody>
</table>

All subsystems are designed to reach or exceed the performances of this table.

Average 1σ sensitivity per pixel (a square whose side is the FWHM extent of the beam), in thermodynamic temperature units, achievable after 2 full sky surveys (14 months).
Complete LFI in AAS-I (summer 2006)
The Planck HFI Instrument

- Back-to-back horns (4 K)
- Spider-web bolometer
- Filters
- 100 mK horn
- Bolometer Holder
- Polarization-sensitive bolometer
HFI performances

-HFI covers the frequency range between 100 and 1000GHz at 5′ in 6 spectral bands.

-The detectors are bolometer cooled down to 100mK

-Its sensitivity will be limited, in CMB channels, by the statistical fluctuations of the CMB itself
The heart of the HFI is the bolometer detectors.

These detectors give extremely high performance and are insensitive to ionizing radiation and microphonic effects:

- 52 bolometers are split into six channels at frequencies optimised for removal of foregrounds (mainly dust emission) and for the detection of the Sunyaev-Zeldovich effect
- 20 bolometers are unpolarized, absorbing radiation in a grid that resembles a spiderweb
- 32 bolometers are sensitive to linear polarization (Jones et al. 2002), absorbing radiation in two orthogonal grids of parallel resistive wires, each of which absorbs only the polarized component with electrical field parallel to the wire
The HFI focal plane unit. The telescope focuses radiation at the entrance of the corrugated horns. This flux is then filtered and detected by the low temperature (0.1 K) bolometers. The attachment points for the 20 K, 4K, and 0.1K coolers are shown, as well as the entrance point of the harness. The harness is shielded by a flexible bellows, and leads the bolometer signals to JFET-based circuits mounted in a box on the frame of the telescope. A second harness leads the signals to room-temperature electronics in the service module.
The Cryostat

4 K 4He JT cooler:
- Cools overall HFI structure to ~ 4 K; precools gas for dilution cooler;
- Cools LFI cold loads 0.1 K 3He–4He dilution cooler
- Cools bolometers to 100 mK; JT expansion cools feeds, etc., to 1.6 K

Cooling system

V-groove radiators (to 60 K)

20 K H₂ sorption coolers (JPL)

4 K Stirling cooler (RAL/MMS)

0.1 K³He/⁴He dilution cooler (CRTBT)
### HFI PERFORMANCE GOALS

<table>
<thead>
<tr>
<th>CENTER FREQUENCY [GHz]</th>
<th>100</th>
<th>143</th>
<th>217</th>
<th>353</th>
<th>545</th>
<th>857</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INSTRUMENT CHARACTERISTIC</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spectral resolution $v/\Delta v$</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
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<tr>
<td>Detector technology</td>
<td>Spider-web and polarisation-sensitive bolometers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detector temperature</td>
<td>0.1K</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooling system</td>
<td>20K Sorption Cooler + 4K J-T + 0.1K Dilution</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of spider-web bolometers</td>
<td>0</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Number of polarisation-sensitive bolometers</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Angular resolution [FWHM arcminutes]</td>
<td>9.5</td>
<td>7.1</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Detector Noise-Equivalent Temperature $[\mu Ks0.5]$</td>
<td>50</td>
<td>62</td>
<td>91</td>
<td>277</td>
<td>1998</td>
<td>91000</td>
</tr>
<tr>
<td>$\Delta T/T$ Intensity $b$ $[10^{-6} \mu K/K]$</td>
<td>2.5</td>
<td>2.2</td>
<td>4.8</td>
<td>14.7</td>
<td>147</td>
<td>6700</td>
</tr>
<tr>
<td>$\Delta T/T$ Polarisation (U and Q)$b$ $[10^{-6} \mu K/K]$</td>
<td>4.0</td>
<td>4.2</td>
<td>9.8</td>
<td>29.8</td>
<td>615</td>
<td>6.5</td>
</tr>
<tr>
<td>Sensitivity to unresolved sources [mJy]</td>
<td>12.0</td>
<td>10.2</td>
<td>14.3</td>
<td>27</td>
<td>43</td>
<td>49</td>
</tr>
<tr>
<td>$\nu$SZ per FOV $[10^{-6}]$</td>
<td>1.6</td>
<td>2.1</td>
<td>615</td>
<td>6.5</td>
<td>26</td>
<td>605</td>
</tr>
</tbody>
</table>

All subsystems have been designed to reach or exceed the performances of this table, which are expected to be achieved in orbit. Sensitivity requirements are a factor of two worse, and would still achieve the core scientific objectives of the mission.

Average 1$\sigma$ sensitivity per pixel (a square whose side is the FWHM extent of the beam), in Thermodynamic temperature units, achievable after 2 full sky surveys (14 months).
Planck Sorption Coolers on SVM Radiator Panels

Using metal hydrides to provide 1 Watt of vibration free cooling at 19K

M.C. Falvella, Italian Space Agency
7 May 2008
Sorption Cooler

Planck principal cryogenic cooler system, a very new development of JPL (NASA) offering a new baseline for active high cooling power in cryogenic space missions

20 K hydrogen sorption cooler (fully redundant)
- Cools LFI to ≤20 K
- Provides precooling to HFI at ~18 K
The telescope
The telescope

- It represents a challenge both for telescope technology and optical design.
- It will operate at ~50 K (passively cooled).
- Electromagnetic models, verified in clean room, still need an in-flight validation.
- **Design**: Aplanatic optimized Gregorian
- **Frequency**: 25 – 1000 GHz
- **Temperature**: 50 K
- **Totale mass**: < 120 Kg
- **Lifetime**: 6 years on the ground + 2 years in space
Planck Spacecraft ready for Cryogenic Test (at CSL)
Scientific data will be sent daily from the MOC to Data Processing Centres (DPCs) Developed and operated by the Instrument Consortia. The DPCs are responsible for all levels of processing of the Planck data, from raw telemetry to deliverable scientific products.

- The success of the mission depends on the combination of measurements from both instruments.
Data Processing

The Data Processing Centre will transform the telemetry received from the satellite into the scientific results of the mission, using massive parallel computation. The LFI and HFI DPCs share data and resources to achieve these ambitious goals.
Level 1: telemetry processing and instrument control (no scientific processing of the data)

direct interface with the ESA Mission Operations Centre (MOC) in Darmstadt;

- Level 2: data reduction and calibration (requires detailed instrument knowledge);
- Level 3: component separation and optimization (requires joint analysis of HFI and LFI data);
- Level 4: generation of final products (reception, archiving, preparation of public release material, operated by MPA, Garching);
- Level S: simulation of data acquired from the Planck mission on the basis of a software system agreed upon across Consortia, operated by MPA, Garching
LFI operations are centralized in Trieste, where they are run jointly by the OAT and SISSA. The HFI DPC is a more distributed system, with Levels 1 and 2 distributed among several institutes, mostly located in the Paris area, but with some contributions from the UK. HFI Level 3 processing is concentrated in the UK at Cambridge University. Levels 4 and S are shared with the LFI.
The goals of *Planck* data simulation are:

- to provide simulated data for testing *Planck* data analysis
- to prototype the *Planck* data archive, handling of and access to *Planck*
- to produce software environment for data analysis

The simulation pipeline is thus a testing ground for the DPC infrastructure and operations.
Simulated Planck Temperature maps

- 30 GHz
- 44 GHz
- 70 GHz
- 100 GHz
- 143 GHz
- 217 GHz
- 353 GHz
- 545 GHz
- 857 GHz

M.C. Falvella, Italian Space Agency
7 May 2008
Simulated maps of the CMB sky in inflationary CDM models. The top two pictures show temperature anisotropies over the whole sky at COBE and Planck resolutions. Such small pictures cannot show the difference in resolution between WMAP and Planck. Accordingly, the middle three pictures show an expanded view of a 5° × 5° patch of sky at WMAP (94 GHz, 15 FWHM) and Planck (217 GHz, 5 FWHM) resolutions, with noise calculated for 2 and 8 years for WMAP and 1 year for Planck.
The significant differences between WMAP and Planck in resolution and noise (even for an 8-year WMAP mission) shown in a different way.
Although the primary goal of Planck is cosmology, it will provide data valuable for a broad range of astrophysics.
Main scientific goals

• Highly precise determination of fundamental cosmological parameters: age of the Universe, balance of different cosmological components (baryons, Dark Matter, Dark Energy), ‘re-ionization’ epoch, cosmological constant

• Understanding of the origin of the Universe: inflationary parameters, origin of primordial perturbations, detection of potential ‘non-gaussian’ features...

• Studing of gravitational lensing, reionization, galaxy clusters, clustering of dark energy, massive neutrinos, etc.

• Non CMB science: Galactic properties, extragalactic sources
Spectrum of the CMB, and the frequency coverage of the Planck channels. Also indicated are the spectra of other sources of fluctuations in the microwave sky. Dust, synchrotron, and free-free temperature fluctuation (i.e., unpolarized) levels correspond to the WMAP Kp2 levels (85% of the sky; Bennett et al. 2003). The CMB and Galactic fluctuation levels depend on angular scale, and are shown for ~1°. On small angular scales, extragalactic sources dominate. The minimum in diffuse foregrounds and the clearest window on CMB fluctuations occurs near 70 GHz. The highest HFI frequencies are primarily sensitive to dust.
Polarization measurements

Planck will also measure to high accuracy the polarization of CMB anisotropies:
- Wealth of cosmological information
- Probe of the thermal history of the Universe during the time when the first stars and galaxies formed.
- Signature of a stochastic background of gravitational waves generated during inflation, $10^{-35}$ s after the Big Bang.

Planck will measure polarization about as well as WMAP measures temperature.

All of the LFI channels, and four of the HFI channels, can measure Linear Polarization as well as intensity.

By combining the signals measured by several detectors, whose planes of Polarisation are rotated with respect to each other in multiples of $45^\circ$, the linear polarization of the incoming radiation can be determined fully. The horn location and orientation are chosen to optimise these measurements. Circular polarisation is not detectable by *Planck*. 

M.C. Falvella, Italian Space Agency
7 May 2008
Forecast on E-mode polarization spectrum

In plots above (WMAP 4 years; Planck 1 year), WMAP is averaged over $\Delta \ell = 100$. Planck is averaged over $\Delta \ell = 20$ in main plot, over $\Delta \ell = 2$ in inset.
Fig 2.11.—The solid lines in the upper panels of these figures show the power spectrum of the concordance ΛCDM model with an exactly scale invariant power spectrum, $n_s = 1$. The points, on the other hand, have been generated from a model with $n_s = 0.96$ but otherwise identical parameters. The lower panels show the residuals between the points and the $n_s = 1$ model, and the solid lines show the theoretical expectation for these residuals. The left and right plots show simulations for WMAP and Planck, respectively.
Forecasts of 1 and 2σ contour regions for various cosmological parameters when the spectral index is allowed to run. Blue contours show forecasts for WMAP after 4 years of observation and red contours show results for Planck after 1 year of observations. The curves show marginalized posterior distributions for each parameter.
The scientific management

The three Planck Consortia currently include about 450 scientists representing some 25 scientific institutes from all over Europe and the USA.

Many of these scientists are actively participating in either the development of the payload hardware or that of the DPCs. After launch, they will be deeply involved in the instrument and DPC operations, and in the analysis of the data.

*The Planck* Science Team, chaired by the ESA Project Scientist, is in charge of distributing scientific work, as well as of establishing and managing data rights and publication policy up to the end of the proprietary period.

The Science Team has established the Baseline Scientific Programme (TBR) of *Planck*, which describes the scientific exploitation activities which will be undertaken by the *Planck* Consortia during the proprietary period.
Deliverables

Deliverables will be produced by the two DPCs jointly, and will be made publicly available two years after completion of mission operations:
- 1 year to reduce the survey data into scientifically usable products
- 1 year of proprietary exploitation by the Planck Consortia.

Two years after termination of survey operations, the Planck data will be put into the public domain.
The major deliverables of the *Planck* mission

- Calibrated time-ordered data
- All-sky maps at each frequency
- All-sky component maps, including the CMB itself, plus Galactic synchrotron, free-free, and dust emission, etc.
- A final compact-source catalog, including galactic and extra galactic objects. This catalog will also include galactic clusters detected through the Sunyaev-Zeldovich effect.
Data Exploitation

The principal objective of Planck is to produce an all-sky map of the CMB.

As a byproduct of the extraction of the CMB, Planck will also yield all-sky maps of all the major sources of microwave to far-infrared emission:

- the physics of dust at long wavelengths and the relative distribution of interstellar matter (neutral and ionized) and magnetic fields will be investigated using dust, free-free, and synchrotron maps
- a systematic search of the sky for dense, cold condensations which are the first stage in the star formation process (i.e. SZ effect).

The Planck all-sky surveys of foreground emission will constitute a rich astrophysical resource comparable to the IRAS and COBE-DIRBE maps at shorter wavelengths.

The goal of Planck is to obtain a photometric calibration of better than 1% across all frequency channels where the CMB is strong.
The first data release

Based on two sky surveys (~100 paper):

- Calibrated data
- Frequency maps
- Component maps (CMB, synchrotron, dust, etc.)
- Source catalog
- Likelihood function

The Early Release Compact Source Catalog will be released 9 months after completion of the first all sky survey, i.e., approximately 16 months after the start of routine operations.
The current status

- Planck has been fully integrated and functional tests confirmed nominal functionality
- Mass properties has been fixed
- Planck fully passed:
  - vibration campaign (including acustic test)
  - EMC tests
  - balancing test
# SCHEDULE

<table>
<thead>
<tr>
<th>Event</th>
<th>Timeline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cryo-calibration Campaign</td>
<td>May-Sept. 2008</td>
</tr>
<tr>
<td>FAR</td>
<td>Sept. 2008</td>
</tr>
<tr>
<td>Launch</td>
<td>end 2008</td>
</tr>
<tr>
<td>Cruise, cooldown, checkout</td>
<td>3m up to 3/2009</td>
</tr>
<tr>
<td>First sky survey</td>
<td>6m up to 9/2009</td>
</tr>
<tr>
<td>Second sky survey</td>
<td>6m up to 3/2010</td>
</tr>
<tr>
<td>ERCSC (based on first sky survey)</td>
<td>6/2010</td>
</tr>
<tr>
<td>Analyze first year data</td>
<td>24 m</td>
</tr>
<tr>
<td>Release results based on first year</td>
<td>3/2012</td>
</tr>
<tr>
<td>Extended mission</td>
<td>TBC</td>
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</table>
Conclusions

- **Planck can be considered a kind of ultimate experiment in CMB**

- **Planck will also open to a new survey era**: with such a great increase in capability over previous CMB missions we can also anticipate completely new Science. As well as several thousands of galaxies, of young stellar objects, of clustes of galaxies will be observed in a new way.
• After Planck our knowledge of physical conditions and large-scale structure at \( z \sim 1000 \) will be better than our knowledge of such quantities at \( z \sim 0 \)

• The scientific return from Planck is indeed spectacular

• The scientific case for Planck is even stronger now than it was when the mission was proposed a decade ago.