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PLANCK Science Management Plan

Foreword

PLANCK (formerly known as COBRAS/SAMBA) was selected in December 1996 by ESA's Science Programme Committee to become the 3rd medium-sized mission (M3) in the Agency's Horizon 2000 Programme of scientific missions. A detailed description of the scientific objectives, the reference model payload, spacecraft and system design, science operations and management are published as ESA D/SCI(96)3 (the report on the Phase A Study).

The aim of this document (the PLANCK Science Management Plan) is to outline the management scheme which will be used to achieve the scientific objectives of PLANCK , up to and including the post-operations phase. This plan does not describe in detail the management of payload or instrument development, which will proceed in parallel.

Contents

1 Overview

PLANCK (formerly known as COBRAS/SAMBA) is the third medium-sized mission (M3) of ESA's long-term scientific plan Horizon 2000. As described in the Phase A Study Report ESA SCI(96)3, the main objective of the PLANCK mission is to image over the whole sky the temperature anisotropies of the cosmic microwave background radiation, with a sensitivity $\frac{\Delta T}{T}$ $\lesssim 2\times10^{-6}$ and an angular resolution of $\sim$10 arcminutes. To achieve this objective, the whole sky will be mapped in nine frequency channels ranging between 30 and 900 GHz, with a sensitivity and an angular resolution which allow the separation of the cosmological signal from all other sources of confusion. **Thus, PLANCK is essentially a survey project, and as such will be developed and operated as a Principal Investigator (PI) mission.**

There are three basic payload components: (1) a telescope and baffling system, providing the angular resolution and rejection of straylight; (2) a Low Frequency Instrument (or LFI) – an array of tuned radio receivers, based on HEMT amplifier technology, and covering the frequency range ~30 - 135 GHz; and (3) a High Frequency Instrument (or HFI) an array of bolometers covering the frequency range ~116 - 1000 GHz. The LFI and HFI are both placed in the focal plane of the telescope, and share the focal area equally.

The PLANCK telescope will be procured via a collaboration with a member state of ESA. Two Consortia, selected by ESA via a dedicated Announcement of Opportunity and funded by ESA member states, will provide the focal plane instruments, calibrate and operate them, process and archive the scientific data, and deliver the scientific products to the community.

ESA, via a Project Team, will have overall reponsibility for the mission. In particular, vis-à-vis the Consortia and the telescope provider, the Project Team will be responsible for the procurement of the spacecraft (excepting the telescope and focal plane instruments), instrument and telescope integration into the experiment module and its integration onto the spacecraft bus, system testing and execution of calibration plan(s), spacecraft launch and operations, and acquisition and transmission of the data to the science data centers. ESA will select a preferred spacecraft design and an industrial Prime Contractor for the procurement and delivery of the spacecraft, and for other tasks under ESA responsibility. ESA's Space Operations Center (ESOC) will implement the Mission Operations Center (MOC), operate the spacecraft, and deliver the raw scientific data to the Consortia. The ESA Project Scientist will act as the interface between the ESA Project Team, the telescope provider, and the instrument Consortia.

A Science Team composed of scientists representing the telescope provider and the instrument Consortia, with the ESA Project Scientist as its Chairman, will oversee the preparations and execution of scientific operations. An Observing Plan will be defined and constructed under the responsibility of the Science Team, and implemented by ESOC. Dedicated teams from within the two instrument Consortia will process the data from both instruments in parallel during all phases of the mission. The Consortia will ultimately be responsible for the creation, delivery, archival, and distribution of the scientific products of the mission.

2 Payload Selection Process

The two focal plane instruments will be provided by Consortia led by Principal Investigators (PIs), funded by ESA's member states, and selected via an Announcement of Opportunity (AO) which will be issued after approval of the Science Management Plan (see Table 1, and Appendix A for more details of the AO process).

In contrast, the provision of the telescope will not be open to competition. Rather, the main elements of the telescope system (the primary and secondary mirrors with their mounting brackets, and the baffle linking the focal plane and secondary) will be procured via a collaboration with a national institute or agency, referred to here as the "Telescope Provider" (TP). The TP is at present identified as a danish consortium led by the Danish Space Research Institute (DSRI).

It is useful here to emphasize that while the procurement of the telescope and instruments are considered independently, they really constitute a single experiment dedicated to a well focussed objective; as a consequence, their technical design must be carried out in a coherent fashion. For this reason, once the Consortia providing the instruments have been selected, close cooperation among themselves, the TP, and ESA will be required to finalize the design of the payload.

Similarly, during the operational phase, data processing activities will benefit from a high degree of connectivity between the scientists involved in both Consortia.

2.1 Announcement of Opportunity

2.1.1 Introduction and schedule

The principal aim of the AO will be the provision of two focal plane instruments which will together cover the frequency range ~30 to ~900 GHz; any proposed active cooling system is considered part of the instruments.

The AO will request proposals from Consortia of scientific institutes, which will provide both the instruments (one per Consortium) and the manpower and facilities needed for their development and testing, as well as for processing of the scientific and housekeeping data generated by the payload.

The schedule for the complete AO cycle and the PLANCK programme is given in Table 1. Details on the selection procedure, the proposal evaluation criteria, and the formal ESA/Consortia Agreements are given in Appendix A.

2.1.2 Programme Participation

The AO will be open to scientific groups within those European States which participate in the ESA Scientific Programme, and to scientific groups in the United States of America (via NASA) in accordance with the ESA/NASA agreement on the principle of reciprocity. After release of the AO, ESA will hold a briefing meeting for interested parties.

2.2 The Instrument Consortia

Two Instrument Consortia will be selected via the AO process; each will be expected to satisfy the following conditions:

- it will be led by a single Principal Investigator (PI), who will act as interface to ESA and will be a member of the Science Team (see Appendix B for a more detailed description of the formal reponsibilities of the PIs)
- it will include a senior scientist (here referred to as the Survey Scientist, or SS) who will provide scientific guidance to the Consortium and the ST, and in particular oversee the development and operation of the data processing structure proposed by the Consortium.

Request Letters of Intent	10 Jan 1997
Receive Letters of Intent	14 Feb 1997
Finalize definition of telescope provision	1 May 1997
Issue of AO	30 May 1997
Submission of questions for briefing	01 Jul 1997
General briefing meeting	15 Jul 1997
Proposals due	01 Oct 1997
Appoint evaluation committee	08 Oct 1997
Evaluation phase	08 Oct 1997 – 25 Nov 1997
Prelim. recommendation by eval. committee	08 Nov 1997
Clarification with potential PI's	08 Nov 1997 – 25 Nov 1997
Discussion with funding agencies	08 Nov 1997 – 25 Nov 1997
Final recommendation by eval. committee	28 Nov 1997
AWG/SSAC review	Dec 1997 – Jan 1998
SPC selection of payload	Feb 1998 (TBC)
Call for Core Programme proposals	Feb 1999 (TBC)
Call for External Programme proposals	Feb 2000 (TBC)
Review of Scientific Programme	Oct 2003 (TBC)
Issue ITT for Cooperative Definition (COD) Phase	May 1997
Cooperative Development (COD) Phase	Sep 1997 – Dec 1998
Issue ITT for Production (PROD) Phase	Jan 1999
PROD Phase	Sep 1999 – Dec 2004
Instrument model deliveries	Jul 2001→ Jun 2002
DPCs operational	Oct 2003
Flight acceptance review	Jan 2004
Launch	1 Oct 2004
End nominal mission	Apr 2006 (t_E)
Data reduction phase	$t_E \rightarrow t_E$+1 yr
Proprietary period	t_E+1 yr → t_E+2 yr
Data distribution to public	t_E+2 yr

Table 1: PLANCK AO cycle and programme schedule (TBC).

The SS is expected to be an active member of the Consortium, and to have a significant involvement in the scientific exploitation of the data. However, it is encouraged that the SS be institutionally independent from the PI. The SS will be a full member of the Science Team, and participate actively in its work.

- it will be committed to carry out the following tasks:
  - development, delivery and operation of an instrument (LFI or HFI)
  - daily and longer term processing of the payload data
  - reduction, distribution, and archiving of the scientific data
  - scientific exploitation of the data
- it will contain a well specified and identified management layer consisting at least of an experienced Technical Manager (responsible for instrument technical development) and a Data Processing Manager (responsible for development and operation of the data processing activities and facilities).
- it will provide a central location where the data will be delivered from the MOC. Data reduction activities may be carried out at this location or in a more distributed fashion. In either case, the assemblage of hardware, software, and manpower resources dedicated to data reduction activities will be referred to as the Data Processing Center (DPC).

The Consortia are encouraged to involve additional associates who could contribute actively to specific scientific and technical aspects of the mission throughout its development, operational, and exploitation phases.

3 The Project Team

ESA will maintain a PLANCK Project Team at ESTEC, directed by a Project Manager, until completion of the satellite in-orbit commissioning phase. ESA, via the Project Manager and his Project Team, will retain overall responsibility for the mission.

ESA will embark on a new procurement approach for PLANCK , known as the Pilot Project. The Pilot Project approach is being approved on the appropriate levels in parallel to this Science Management Plan.

Within this new procurement approach, the Project Team will delegate more tasks to industrial contractors than in previous ESA scientific missions. Notwithstanding this fact, the Project Team will control the process of definition of mission requirements and payload interfaces, and will finally select a Prime Contractor and a preferred spacecraft design.

Vis-à-vis the Consortia and the TP, the Project Team will be responsible for the procurement of the spacecraft (with the exception of the telescope and instruments), telescope and instrument integration into the experiment module and its integration onto the spacecraft bus, system testing and execution of calibration plans, spacecraft launch and operations, and acquisition and transmission of the data to the Data Processing Centers.

The Project Team will monitor and control the work of the PLANCK spacecraft industrial contractor(s), and determine suitable satellite launch dates. During the development phases of the mission, the Project Team will also monitor the development of the instruments, and ensure their timely readiness by monitoring the adherence of development plans to agreed-to

schedules. In addition, the Project Team will monitor and control all interface specifications; these include technical specifications between the telescope, the instruments, the spacecraft, and any ancillary equipment, as well as data and information exchange specifications among all parties involved (ESA, the TP, the Consortia, and industry). Within the scope of the Pilot Project procurement approach, the Project Team may decide to delegate the execution of all or some of the above tasks to industrial contractors.

The Space Science Department of ESA will assume responsibility for management of the PLANCK Project at a suitable time after launch, according to the guidelines set out in S/96/145/cb/205 ("Agreement on the Post Launch Management of a Science Project").

4 Scientific Operations

4.1 Introduction

As indicated in the Overview, PLANCK is a survey-type project which will be operated as a PI mission. As such, the total time available for observation will be used under the supervision of the Science Team to progressively build up the observational data required to generate the final scientific products which will be used by the whole community.

The main elements of scientific operations which are relevant for the formulation of a management approach are the following:

- PLANCK will be launched into GTO in late 2004 (TBC), from where it will cruise towards its final station in orbit around the L2 Lagrangian point of the Earth-Sun system.
- Routine operations begin 3-4 months after launch, once the period of payload commissioning has ended.
- Operations are commanded via a single ground station (presently assumed to be Kourou) with daily visibility period varying between 10-11 hrs.
- The observing plan is to survey the whole sky at least twice over. The spin axis will be pointed in the anti-Sun direction and will be kept aligned as the L2 point rotates around the Sun. Each sky coverage is achieved in $\sim$7.5 months of routine observations; thus the baseline mission allows for 15 months of routine scientific operations. However, in anticipation of a possible extension of the mission, spacecraft and instrument consumables are designed to allow a total lifetime of 5 years.
- Scientific operations consist of a pre-programmed sequence of manoeuvers to keep the spin axis in a (quasi-)antisolar direction. Manoeuvers have an amplitude $\sim 5'$, and are executed every 2 hours. The baseline sequence of manoeuvers is known far in advance (>weeks), and is executed autonomously by the on-board computer. Corrections to the sequence may be requested by the ST, normally with an implementation delay of $\sim$3 days.
- During routine operations, the instruments operate uninterruptedly in a unique instrumental mode. Other modes will be required only during the commissioning phase, or for technical characterization of the instruments.
- Data obtained in non-visibility periods is stored in on-board solid-state memory, and is telemetered to ground interleaved with data acquired in real time.

4.2 Architecture

Scientific operations will be supported by three main elements (see Figure 2):

- A Mission Operations Center (MOC), under the responsibility of ESOC.
- A Science Team (ST) - chosen after the AO process is completed.
- Two Instrument Consortia - proposed for in response to the AO.

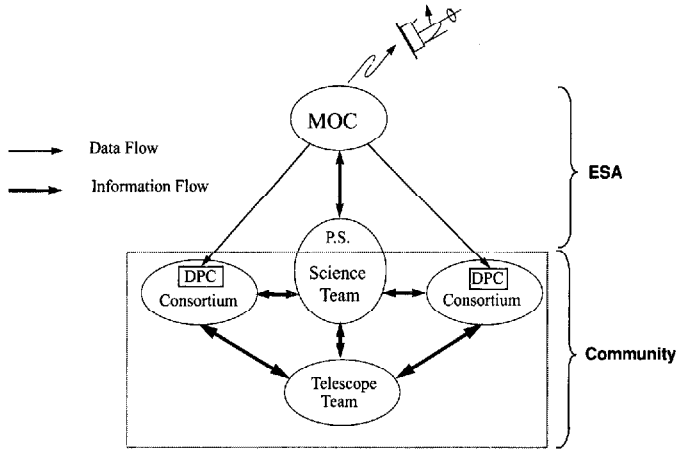

Figure 1: A schematic view of the various elements supporting PLANCK during its operational phase, and the flow of data and information among them. DPC stands for Data Processing Center (see Section 2.2).

The Science Team (ST) constitutes the center of the operations support structure. In particular, the ESA Project Scientist (PS), as Chairman of the ST, will act as interface between the MOC and the ST.

4.3 The Mission Operations Center

The satellite will be controlled from the ESA Mission Operations Center (MOC), via one ground station (presently assumed to be Kourou). The MOC will be designed, developed, and operated by ESA's Space Operations Center (ESOC). In addition to the usual tasks of preparing for and carrying out spacecraft operations and mission analysis, the MOC will be responsible for:

- supporting the ST on all aspects concerning spacecraft operations
- maintaining a database containing the long term spacecraft pointing plan, on the basis of ST inputs
- converting ST requests into spacecraft commands and uplinking them

- daily stripping of the payload data and housekeeping from the telemetry stream, ordering them by (spacecraft) time, and making all the data available to each of the two Data Processing Centers electronically (using dedicated lines paid for and maintained by ESOC)
- daily conversion of spacecraft housekeeping into the previous day's pointing history, prediction of pointing corrections for the next obscuration period, uplink of a corrected series of manoeuvers valid for the next 3 days, and provision of the pointing information to the DPCs
- checking the health and performance of the payload, by ensuring that payload housekeeping data remains within predetermined limits
- alerting the ST of all significant anomalies and/or deviations from the expected behavior of the spacecraft, and executing predetermined procedures to safeguard the spacecraft and payload
- archiving the raw payload telemetry data for a period of no less than 10 years

4.4 The Project Scientist

The ESA PLANCK Project Scientist (PS), located at ESTEC, will be the Agency's interface with the TP and the instrument Consortia for scientific matters. Within ESA, he will liaise with the PLANCK Project Manager until completion of the satellite in-orbit commissioning, and thereafter with the Mission Operations Manager at ESOC.

During all phases of the project, the PS will coordinate all scientific issues with the Project Team. In particular, the PS will advise the ESA Payload Manager on technical matters when they affect scientific performance. During the development and operational phases, the PS will monitor the state of implementation and readiness of the instrument operations and data processing infrastructure, and in particular will maintain the Data Processing and Delivery Document under formal configuration control. After the completion of the in-orbit operations the Project Scientist will coordinate the creation of the scientific products, their archival and distribution to the scientific community.

The ESA PS will act as the Chairman of the PLANCK Science Team (ST), and as such coordinate its activities (see 4.5).

4.5 The Science Team

The Science Team (ST) will be formed after selection of the Consortia through the AO process, and will remain in place until the scientific products are delivered to the community. It will include:

- the ESA Project Scientist (PS) as its Chairman;
- from the Telescope Provider: one scientific representative (equivalent to the Consortia PI), and one Technical Manager;
- from each of the two Consortia: the Principal Investigator (PI), the Survey Scientist (SS), the Technical Manager, and the Data Processing Manager.

The ST will not include any independent Mission Scientists. However, external scientific reviews of the programme will be carried out by a group reporting to ESA's Astronomy Working Group.

Ad-hoc experts will be invited to attend ST meetings as the need arises. The specific number and expertise of these experts will vary during the development of the mission to reflect the current needs of the ST.

The ST will mainly rely on the technical support of the Consortia and the TP for the fulfillment of its functions. However, if deemed necessary, the PS may request external scientific consultant(s) to conduct an independent review of any of the activities which normally fall under the responsibility of the ST, the Consortia, and the TP.

The ST will be responsible for:

- acting as a focus for the interest of the scientific community in PLANCK
- maximizing the scientific return of PLANCK within its boundary conditions, while at the same time insuring that the development of the mission remains compatible with the main scientific objectives
- reviewing the scientific goals of PLANCK at regular intervals in the light of recent results, while considering the technical requirements of the spacecraft
- advising on the scientific aspects of the development of the instruments
- formulating and optimizing the Observation Programme and the calibration strategy, both from the scientific and operational viewpoints
- recommending updates or changes to the observing plan during the operational phase, and requesting their implementation by the MOC
- defining data rights and publication policy following the established guidelines (Section 5.2)
- making every effort to promote public awareness and appreciation of the PLANCK mission, and supporting ESA in its public relations efforts
- preparing for and overseeing the analysis of the data
- creating and delivering the final scientific data products to the community
- overseeing the organization of the data archive(s)

In general, the members of the ST will be expected to monitor and advise on all aspects of PLANCK which affect its scientific performance. In particular, they will participate in major project reviews, and perform specific tasks as needed during the development and operation phases. The formal duties of the PIs are listed in Appendix B.

The members of the Science Team will have to provide their own funding to support their activities, and in particular will pay their travel expenses when attending meetings of the ST. This applies as well to any other members of the Consortia and TP team who contribute to the work of the ST.

4.6 Role of the Consortia in Operations and Data Processing

All of the data output from the payload will be piped daily from the MOC to each of the two DPCs. Independent data processing will be carried out by each of the Consortia, in order to maintain redundancy and a good level of cross-checking, as well as the expertise provided by the instrument development Teams. The HIPPARCOS experience demonstrates that this "double" data reduction approach is highly conducive to the production of a clean and well-understood set of final data; indeed, in the case of HIPPARCOS this approach was considered mandatory.

However, it is here recognized that duplication of certain parts of the data processing streams may not lead to improved scientific products, and may thus represent an unnecessarily heavy financial burden to the Consortia. Consequently, proposers may suggest ways and means to merge these parts, justifying them in terms of the quality of the final scientific products. Alternatively, proposals for different instruments may contain common data processing components. During the selection process, negotiations between ESA and the proposer(s) may be needed to ensure proper management of the interfaces between data processing streams.

The Consortia will be responsible for:

- on a daily basis, acquiring the (time-ordered) payload scientific and housekeeping data, and the past (reconstructed) pointing information from the MOC
- carrying out a daily analysis of instrument health and performance (for this function, each Consortium will be responsible for its associated instrument)
- carrying out a daily quick-look analysis of the current scientific data and providing the MOC with any information that may result in an optimization of operations
- continuous data processing during operations, which will include monitoring of the data quality, calibration, cleaning, etc
- regular reporting to the ST on the data processing activities, and in particular of any anomalies detected
- supporting the ST and the MOC in all areas regarding payload hardware and software, and interpretation of the data generated by it
- maintaining a capability to support the ST and the MOC during emergency or other situations which require non-standard work shifts
- maintaining an adequate level of information exchange with the other selected Consortium regarding data processing procedures and status, and data quality
- the final reduction of the data into the science products of the mission
- extracting and publishing scientific results (see Sections 6 and 7)
- archiving and distribution of the science products to the astronomical community at large and to ESA

It is expected that the daily activities will be carried out at the location of data delivery, whereas longer term data processing activities may be carried out in a more distributed manner.

5 Data Products

Three types of data products will be generated by the PLANCK project:

- **Scientific data products:** these are the deliverables resulting from the mission, which will be made available to the astronomical community at large, and which will form the basis for scientific research and publications. Their nature, and delivery schedule are described in more detail below (Section 5.1).
- **Scientific publications:** which are intended to appear in the scientific literature, having undergone scientific validation and peer review. Issues associated with such publications are discussed in Section 5.2 below.
- **Public Relations materials:** whose purpose is to maintain the public at large informed of the progress and scientific results of the mission, and which are normally distributed through the written and visual media (e.g. newspapers, magazines, TV). Public Relations issues are discussed in Section 5.3.

5.1 Scientific Data Products

In spite of the presence of two Consortia with two associated DPCs, the mission is conceived as an integrated one aimed at the fundamental cosmological and astrophysical measurements described in the Phase A Report, and thus there will only be one final set of data, derived optimally under ST supervision from all the products of the individual DPCs.

Final data processing consists mainly of two steps: generation of maps of the surveyed area from the raw data, and separation of the various signal components from the maps to obtain both the cosmological signal, and the foreground emissions. The Consortia will be responsible for both steps.

Three levels of scientific data products will be delivered by the Consortia:

1. Maps of the sky in nine frequency bands. This is the main product of the mission; the quantity of data (0.5-1.0 Gbyte) involved in these maps is relatively small.
2. Time series of the data acquired by each detector, after basic calibration, removal of systematic features, and attitude reconstruction. This product will be of interest to astronomers seeking refinements on the basic scientific products, or wanting to explore alternative data reduction schemes. It consists of a large amount of data (100-150 Gbyte of scientific data, to which should be added ancillary housekeeping information), but could (today) easily be maintained as an EXOSAT-type electronic data base[1].
3. Maps of the sky for each of the main underlying components (CMB, SZ, dust, free-free, synchrotron) and catalogue(s) of point sources. This product constitutes the main scientific result of the mission and will most likely require many iterations to achieve maturity. However a "first-generation" set of component maps will be distributed to the community simultaneously with the main product (the sky maps).

[1] A single workstation connected to an optical storage jukebox, accessible via public networks

5.1.1 Delivery Schedule of Scientific Data Products

In accordance with ESA policy (as laid down in ESA/C(89)95 Rev.1), the scientific data products should be available for distribution to the community 1 year after completion of the nominal mission. "Completion of the nominal mission" is here interpreted as the time when the calibration of the data has reached sufficient maturity to guarantee that the community receives a solid product, containing only well understood and documented anomalies and/or peculiarities.

The nature of the mission is such that the data products can only be generated from an analysis of the full set of data; i.e. distribution of partial sets of data before the complete set is processed is not useful and will be avoided. In particular, **all of the data acquired** over the duration of the mission **will be simultaneously used** to calibrate and remove systematic effects. Thus, the time at which the 1-year proprietary period begins can be appropriately defined as the time at which the 9 all-sky channel maps (the main product described above) have reached a level of maturity such that they could be delivered to the community. The exact time when this level is reached will be determined by the ST, but will not be later than 1 year after the spacecraft power has been switched off. Figure 3 sketches the main stages of data processing and delivery.

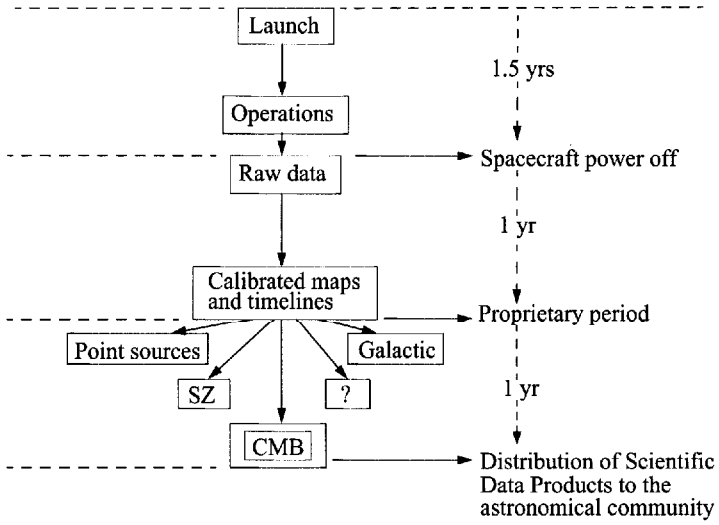

Figure 2: A simplified schematic view of the stages involved in scientific data product generation and the time allocated to each stage. In practice data reduction activities will start as soon as the payload is switched on. The data processing algorithms will be continuously refined during the course of the mission. Similarly, the scientific data products will already exist in an embryonic state soon after routine operations begin, and will be continuously refined in an iterative process as more data becomes available, and as systematic effects become gradually better understood. The box with an interrogation mark stands for serendipitous or unforeseen results.

In view of the characteristics of the data reduction process outlined above, no dissemination of the data products, either in partial or complete form, beyond the members of the Consortia

and TP team will be allowed before the end of the proprietary period, except in cases where urgency is justified (as decided upon by the ST), and then only with no guarantee of product quality [2].

It is worth noting here that the 1-year proprietary period will also be used to prepare the physical means of distribution of the scientific data products to the astronomical community, and the associated documentation (the "Explanatory Supplement"); given the large amounts of data involved (in particular in the time series) this operation will require a non-negligible amount of time.

If any significant extension of the mission is approved, funded and implemented, the schedule described above will be adhered to for delivery of the products resulting from the initial 1.5 years of operation. Delivery of further sets of products resulting from the extended period of operations will occur at a later time, with a schedule to be defined at the time when the extension of operations is approved.

5.2 Scientific Data Rights and Publication Policy

This section deals specifically with the scientific exploitation of the data generated by the PLANCK experiment (i.e. the second type of product enumerated in the introduction to Section 5), and not with materials to be used for purposes of Public Relations (see Section 5.3).

The policy set down here reflects the wish to:

- deliver to the astronomical community at large scientific results of the highest quality within the shortest delay possible;
- acknowledge the work and effort put into the PLANCK project by the members of the Consortia and the TP's team of collaborators, by giving them exclusive access to scientific interpretation of the PLANCK data for a limited period of time.

In the interest of the final quality of the products,

- regarding the main scientific goals of the mission (i.e. those connected with the CMB), publication of results based on PLANCK data will as a general rule not be sanctioned before the start of the proprietary period of one year. However, if results emerge which are of exceptional scientific interest and/or importance, and which are unlikely to be substantially affected by subsequent data processing, the ST may take the decision to allow publication of the results, always labelling them as preliminary.
- regarding "secondary" scientific goals of the mission (i.e. those connected to galactic and extragalactic foregrounds), the aim of the ST will be to publish results as early as possible during the course of the mission, always ensuring that such publications have undergone appropriate scientific validation (e.g. peer review)
- ad-hoc proposals contravening this baseline will be dealt with on a case-by-base basis by the ST.

Prior to the end of the proprietary period, any publication of scientific results based on PLANCK data must be approved by the ST. The ST will ensure that such publications do not infringe on the "data rights" of other investigators.

[2] A typical example where urgency would be justified could be that where another space platform (e.g. XMM) should be used to carry out complementary observations, in which case preliminary PLANCK data should be extracted to guide the complementary observing programme (e.g. a list of galaxy cluster positions).

5.2.1 Data Exploitation by PLANCK Scientists

Up to the end of the proprietary period of one year, only members of the Consortia, the TP team, and the PS will be able to access the mission data and products. Since it is anticipated that the scientific problems that will initially be attacked are of a global nature, it is not possible to partition the set of data among investigators in any reasonable way. However, it is anticipated that different subsets of investigators may wish to tackle different scientific aspects. Thus, the division of work among investigators will be done on a topical basis only.

The process of allocation of research topics will occur as follows. Approximately one year after the AO process is concluded, the PS will issue a call for research proposals limited to the members of the Consortia, the TP team, and the PS. The proposals will include:

- a title;
- the names of the proposal leader and his coinvestigators;
- the affiliation of the proposal to one of the Consortia or the TP team;
- a short description of the proposed use of PLANCK data.

The ST will evaluate the proposals, and prepare a final Core Programme of research topics and their corresponding investigators. In preparing this Programme, the ST will strive to make a fair partition of the work among all the investigators, taking into account the importance, complexity, and amount of resources required by each topic proposed. As a guideline, the number of research proposals affiliated to each of the Consortia/TP team, should be in proportion to the amount of resources invested by each of the Consortia/TP team in the PLANCK mission as agreed with ESA at the time of selection.

The ST will keep in mind that the main scientific goals of the mission (broadly characterized as the production and analysis of the CMB maps, and derivation of cosmological parameters) are of interest to the whole PLANCK collaboration, and will ensure that all partners are adequately represented in this particular "research topic". Regarding all other topics, if there should be a conflict between two proposals brought forward under the leadership of each of the two instrument Consortia, preference will be given to the proposal that has the closest instrumental link to that specific topic.

Finally, the Programme (Core plus External – see below) of research topics will be reviewed by the ST one year before launch, at which time it may be modified to take into account new scientific developments (e.g. results from MAP) or significant changes in the structure of the Consortia or TP team.

5.2.2 Data Exploitation by External Scientists

Once the Core Programme is established, the PS will issue a call for research proposals targeted to scientists external to the PLANCK collaboration. The Core Programme will be published together with this call. The research topics proposed for by external scientists must not overlap with those in the Core Programme. An independent committee will evaluate external proposals and recommend which should be accepted; successful proposers will receive the relevant data one year before the scheduled date for distribution of the scientific data products to the community (see Section 5.1.1). If the success of external proposals depends on receiving data and/or documentation in a state different from that available at the specified time of delivery, proposers

will have to consider ways and provide the means to achieve this state. Possible means may include association with other investigators within the PLANCK collaboration, or contributing enough resources to achieve their requirements.

From the time that the proprietary data period has expired, all data rights held by members of the Consortia and TP team cease, and any investigator will be given equal access to the PLANCK database.

5.3 Public Relations Plan

ESA will be responsible for planning and carrying out Public Relations (PR) activities related to PLANCK . A general outline of PR activities will be included in the AO in the form of a Public Relations Plan (PRP). This Plan must be formally agreed and adhered to by the PIs at the time of selection.

The active cooperation of all scientists involved in the PLANCK mission is essential for the success of the related PR activities. For this purpose, the Project Scientist will initiate and identify opportunities for publishing project-related progress reports and scientific results. PR materials suitable for release to the public will be provided by the members of the ST upon their own intitiative or upon request from the PS at any time during the development, operational and post-operational phases of the mission. Indeed, as noted in Appendix B.1, the PIs of the instrument Consortia have the obligation to supply ESA with such materials. The exact nature of these materials, if not specified in the PR Plan, is to be defined at the appropriate time.

Appendices

A Announcement of Opportunity

A.1 General requirements

The Announcement of Opportunity (AO) for PLANCK instruments will be issued in accordance with the schedule defined in Table 1. The issue will be composed of:

- the Announcement of Opportunity itself
- the Science Management Plan
- the Experiment Interface Document (EID) – part A
- the Data System Requirements Specification (ESOC interface)
- the Management Requirements Specification
- the Public Relations Plan

The specific components of the proposals will be detailed in the AO, but will in general include scientific aspects (including a description of the proposed core scientific programme), technical aspects (related to the instrument development and operation), data processing aspects (related to the development and operation of the data processing structure), and management aspects.

The proposals for the PLANCK instruments shall be made bearing in mind the scientific and operational objectives of the PLANCK programme and the current programme definition and constraints. The instrument complement will be optimized to accomplish the overall scientific aims of the mission. As a result, proposals may need to be amended after submission, in joint discussions between ESA and the proposer(s). The baseline proposed instruments must comply with the technical requirements contained in the AO documents. However, if proposers feel that a greatly improved scientific return together with a mature and proven instrument concept may be obtained by exceeding one or more of these constraints, they may identify this as an option in their proposal, justifying it in the scientific section and explaining it in the technical section.

Each instrument Consortium shall be headed by a single person, designated as the Principal Investigator (PI). The PI will be associated with a high level and experienced Technical/Engineering Manager, with specific expertise in the area of the proposed instrument, and similarly with a Data Processing Manager.

The PI shall establish an efficient management scheme especially in the case where many institutes are providing sub-assemblies, sub-systems, or tasks. Details of the management structure will be agreed after selection through the establishment of the Experiment Implementation Agreement (see Section A.4) and the Experiment Interface Documents (see below).

The proposal must demonstrate that the PI has adequate control over all aspects of the programme, including direct access to adequate financial resources, and to technical and human resources through his Technical and Data Processing Managers, so that the responsibilities of the PI can be met. Principal Investigators are at all times responsible for the funding arrangements of the instruments, their operation, the associated data processing structures, and the management thereof. A funding margin should be provided, not only to provide for

development evolution, but also to finance instrument interface changes resulting from the parallel development of instrument, spacecraft and ground segment. The PI's shall not assume any funding from ESA for any part of their programme. In this context, use of ESA facilities by investigators will be on a cost reimbursement basis, other than those facilities associated with spacecraft assembly, integration and verification. The PI and his Technical Manager shall represent the single point formal interface for the instrument programmes with the ESA Project Office.

After selection, an Experiment Interface Document (EID) will be established for each instrument. A draft EID will be contained in the AO package. This EID defines the PLANCK technical and programmatic requirements (including management and control procedures), specifies in detail the interface information applicable to each instrument and specifies the planning applicable to each instrument. The EID becomes the formal interface control document and formal reference for all progress reporting, and it shall be placed under formal configuration and change control once agreed and signed off by the parties involved.

A Data Processing and Delivery Document (DPDD), addressing specifically data processing and product delivery commitments, will also be established for each Consortium after selection on the basis of their respective proposals. The DPDD will be used as a reference and control document, and will be kept updated by the ESA Project Scientist (PS).

A.2 Selection Procedure

Proposals for instruments will be examined by an evaluation committee appointed by ESA's Director of Scientific Programmes on the advice of the Astronomy Working Group (AWG). The ESA PLANCK Project will assess the proposals against technical, managerial, programmatic and financial criteria, to assist the evaluation committee in the selection of proposals. Attention will be paid to establish an efficient and effective management scheme of the PI team and its contractors. The financial criteria will include both the assurance of adequate funding for the proposal and the impact upon ESA accepting that proposal. After taking into account all these aspects, the Project will put forward a preliminary payload, possibly with options, for consideration by the appointed evaluation committee. Both the scientific and technical assessment processes may include meetings with the proposers individually and/or collectively to clarify details and to discuss areas of overlap and complementarity. During and as a result of these meetings, the proposals may be modified in order to optimize the instrumentation to satisfy the global needs of the mission. In parallel, negotiations with funding agencies will be conducted and the management scheme will be reviewed.

At the end of the evaluation phase and after confirmation of the funding and endorsement by the relevant national authorities, the evaluation committee will recommend both a final payload complement and a data processing structure to the advisory bodies of the Agency. Based on the advice of the AWG and the Space Science Advisory Committe (SSAC), a recommendation will be presented by the Executive to the SPC for approval. The selected proposals will be announced following approval by the ESA SPC. Following selection, ESA will confirm participation of PI's and Co-I's. The schedule for proposal evaluation and selection is shown in Table 1.

A.3 Evaluation Criteria

The selection criteria for individual proposals will include the following (not in order of importance):

- Merit of specific scientific objectives of proposed instrument.
- Scientific compatibility with global mission objectives of PLANCK .
- Ability of proposed instrumentation to satisfy its scientific objectives.
- Technical feasibility of proposed instrumentation
- Reliability and space qualification of proposed instrumentation (especially previous space heritage of detectors and other sub-systems).
- Development status of proposed instrumentation.
- Technical compatibility with available spacecraft resources and mission constraints.
- Operational constraints and complexity
- Ability of proposed data processing concept to satisfy the operational and scientific objectives of the mission.
- Adequacy of proposed computational hardware configuration.
- Competence and experience of the team in all relevant areas (e.g. scientific, space technology, proposed techniques, software development and technology, numerical analysis etc.).
- Adequacy of proposed management scheme (including organigramme, project manager(s), roles of Co-I's etc.) to ensure a timely execution of instrument and data processing structure development, and associated tasks including post launch support.
- Adequacy of resources specifically assigned to interfacing to the telescope, the other selected instrument, and the spacecraft.
- Adequacy of human resources and institutional support to ensure a timely execution of instrument and data processing structure development, and associated tasks.
- Previous experience of key people (PI, SS, Technical and Data Processing Managers) in managing a space instrumentation programme, in scientific operations and large data processing programmes.
- Credibility and compliance of costing of proposed development programme.
- Compliance with all applicable management, reporting and product assurance requirements.
- Financial impact upon ESA of proposed instrumentation.
- Assurance of adequate funding for proposed instrumentation.

- Willingness to comply with ESA's policy in regard to Public Relations activities as defined in this Science Management Plan, and in particular acceptance of and adherence to the Public Relations Plan.

For the overall integrated complement of the payload for PLANCK , the selection criteria will include:

- Results of the evaluation of the individual proposals on the basis of the evaluation criteria listed above.
- Overall scientific merit of the complete payload with respect to meeting the PLANCK scientific objectives.
- Quality of the PI(s), SS(s), Technical Manager(s) and their teams.
- Technical compatibility with available spacecraft resources and mission constraints.
- Compatibility with programme constraints.
- Assurance of adequate funding.

A.4 Agreement between PI's and ESA

Following the selection of the instrument Consortia, an Experiment Implementation Agreement will be drawn up involving the PI, SS, Technical Manager, Data Processing Manager, Co-I's, their institutes, national funding agencies and ESA to cover all aspects of their relationship.

It is emphasized that the Experiment Implementation Agreement needs to be established before the final selection of the instrument Consortia can be confirmed.

A.5 Monitoring of Payload Development

ESA will monitor the progress of the design, development and verification of the scientific instruments and the implementation of the data processing scheme. The PI's (including the telescope PI) have to demonstrate to ESA in regular reports and during formal reviews compliance with the scientific mission goals, the spacecraft system constraints, the spacecraft interfaces and the programme schedule as defined in the mutually agreed Experiment Interface Document. The scientific performance will be monitored by the ESA Project Scientist who may draw on the support of the ST as a whole. The technical and programmatic compliance will be monitored by the ESA PLANCK Payload Manager.

B Responsibilities

B.1 Responsibilities of Principal Investigators (PIs)

In general, the PI, supported by his SS, and his Technical and Data Processing Managers, is responsible for ensuring that the complete instrument and data processing programmes are implemented and executed within the constraints of the approved PLANCK project. The responsibilities shall include, but are not necessarily limited to, the following:

Management

1. Take full responsibility for the instrument and data processing programmes at all times and retain full authority within the Consortium over all aspects related to procurement and execution of the programmes. In this context the PI shall be able to make commitments and make decisions on behalf of all other participants in the Consortium. The Technical and Data Processing Managers shall similarly be able to make commitments and decisions in their respective areas of responsibility.
2. Establish an efficient and effective managerial scheme which will be used for all aspects of the instrument and data processing programmes.
3. Define the role and responsibilities of each Co-Investigator (Co-I)
4. Identify (by name) key team members responsible for science management, technical management, technical interfacing, data processing management, and operational management.
5. Organise the effort, assign tasks and guide other members of the team of investigators.
6. Provide the formal managerial interface of the instrument to the ESA Project Office and support ESA management requirements (e.g. status reports, progress reviews, programme reviews, change procedures, product assurance etc.) as defined in the EID and DPDD.

Scientific

1. Attend meetings of the PLANCK ST and supporting groups as appropriate, to report on the development of the instrument and data processing programmes, and to take a full and active part in the work of the ST.
2. Ensure adequate calibration analysis of all parts of the instrument both on ground and also in orbit.
3. Support the MOC (ESOC) in the definition of the science operations.
4. Participate in the definition of the observing plan.
5. Exploit to full depth the scientific results of the mission.
6. Support ESA on Public Relations activities related to PLANCK , in particular by providing materials appropriate for release to the press or participation in ESA media events on request from the PS, in accordance with the Public Relations Plan.

Instrument Hardware

1. Define the functional requirements of the instrument and its ancillary equipment (e.g. ground support equipment).

2. Ensure the development, construction, testing and delivery of the instrument. This shall be in accordance with the standards, technical and programmatic requirements outlined in the AO including its Annexes and subsequently reflected in the approved Experiment Interface Document.

3. Ensure adequate test and calibration of all parts of the instrument both on ground and also in orbit.

4. Ensure that the design and construction of the instrumentation, and its development test and calibration programmes are appropriate to the objectives and lifetime of the mission, and reflect properly the environmental and interface constraints under which the instrumentation must operate. It is essential from technical, programmatic and cost viewpoints that a representative example of the flight instruments be developed, tested, and calibrated early in the programme to demonstrate their scientific performance, their flight worthiness from an engineering viewpoint and their ability to provide a valid scientific return for the lifetime of the mission. Only then will the commitment be taken to fly the instruments.

5. Ensure that all required hardware for the data processing activities is available within the scheduled times defined in the EID

6. Ensure that all procured hardware is compliant with ESA requirements as defined in the EID, through participation in technical working groups and control boards as requested (e.g. cleanliness control board) and to ensure that the hardware allows system level performance compatibility to be maintained.

7. Provide overall documentation during the project as defined in the EID.

Instrument Software

1. Ensure the development, testing and documentation of all instrument specific software (e.g. necessary for the control, monitoring, testing, simulation, operation, and data reduction/analysis etc.) in accord with procedures and schedules as defined in the EID.

2. Ensure the delivery of such instrument specific software and its documentation including user manuals to ESOC in accord with procedures and schedules as defined in the EID.

3. Support the instrument specific software integration and operation activities at the MOC, in particular during payload commissioning phases.

4. Ensure the development, testing, documentation and delivery of on-board software, and software required during instrument system level tests in the real-time or off-line mode including auxiliary software (instrument EGSE and interfaces) as defined in the EID.

5. Ensure the development, testing, and documentation of software required both for daily and long-term data processing activities, as defined in the DPDD.

6. Maintain and update all software for the duration of the mission including all data processing activities (described in the DPDD) and a post-operations (archiving) phase.

DPC Hardware

1. Define the functional requirements of the DPC [3] computers and its main and peripheral units (processing units, terminals, data storage devices and media, output devices etc.)
2. Ensure that all data processing and analysis devices including storage devices/media and output devices that are required for the full functionality of the DPC are available within the times scheduled in the DPDD.
3. Ensure that the functionality of the DPC is appropriate to the objectives and lifetime of the mission, and reflects properly the interface constraints under which the DPC must operate.
4. Provide overall documentation during the project as defined in the DPDD.

DPC Software

1. Ensure the development, testing and documentation of all DPC specific software (e.g. data access layer, user interfaces, simulation, database management, archiving etc.) in accord with procedures and schedules as defined in the DPDD.
2. Ensure that all software (including instrument specific software provided by instrument teams) is tested and integrated into the DPC data analysis system.
3. Ensure full operation of all software tasks including database management system at the DPC.
4. Ensure that all created software is maintained and updated.
5. Provide the community (either directly or through local science support centres) with the scientific data and archive in accord with procedures and schedules as defined in the DPDD.
6. Provide instrument teams (on their request) with off-line raw data to allow study and analysis of their instrument performance.

Product Assurance

1. Provide product assurance functions which are compliant with the requirements of the Product Assurance Requirements Document (PARD) and the DPDD.

Operations

[3] For the purpose of defining responsibilities, the term DPC (Data Processing Center) is taken to refer not only to hardware/software/resources located physically at the point of delivery of the payload data from the MOC, but also to hardware/software/resources at other locations, which within the terms of the proposal are an integral part of the data processing programme.

Operational phases include pre-launch activities (e.g. instrument software design and development, instrument calibrations), nominal operational phase and post-mission phases with a breakdown as follows: (a) pre-launch phase until launch minus two years; (b) full operational phase from launch minus two years until launch plus two years nominal or launch plus 5 years for extended mission if approved, and linear run-down phase until 2 years after end of mission (TBC). The PI will be responsible, to

1. Support all instrument operational phases by providing the necessary hardware, software, information (technical data), manpower and/or expertise (training) to the MOC. In particular, the PI must support pre-launch instrument operations (e.g. instrument calibration analysis and simulation, and the orbit operational phase (2 years nominal, extendable to 5 years if approved) by managing the necessary functionality, including resources and manpower of the DPC. The level of support shall be refined with the ESA Project Office.

2. Support operations through his expertise including resolution of anomalies and malfunctions of the instrument including recalibrations etc. as required.

3. Recognise during all operational phases the occurrence of transient and/or anomalous events and inform the Project Scientist and the ST.

4. Execute the archiving phase.

Financial

1. Ensure (through his SS and Co-I's, if necessary) that adequate funding is available at the required time(s) for all aspects of the instrument and its support, and for the DPC.

Relation with Scientific Users Community

1. Make the scientific data and archive available to the science community in accord with procedures and schedules as defined in the DPDD.

C Acronyms

AO	Announcement of Opportunity
AWG	ESA's Astronomy Working Group
CD-ROM	Compact Disc - Read Only Memory
CMB	Cosmic Microwave Background
COBRAS	Cosmic Background Anisotropy Satellite
COBRAS/SAMBA	Former name of the PLANCK project
Co-I	Co-Investigator
DPC	Data Processing Centre
DPDD	Data Processing and Delivery Document
DSRI	Danish Space Research Institute
EIA	Experiment Implementation Agreement
EID	Experiment Interface Document
EM	Electrical Model
ESA	European Space Agency
ESOC	European Space Operations Centre
EXOSAT	ESA's X-ray Observatory
FM	Flight Model
GTO	Geostationary Transfer Orbit
HEMT	High Electron Mobility Transistor
HFI	High Frequency Instrument
HIPPARCOS	ESA's Astrometry mission
ISO	ESA's Infrared Space Observatory
ITT	Invitation To Tender
L2	The L2 Lagrangian Point of the Earth-Sun System
LFI	Low Frequency Instrument
MCC	Mission Control Centre
MIRD	Mission Implementation Requirements Document
MMIC	Monolithic Microwave Integrated Circuit
MMS	Matra Marconi Space
MOC	Mission Operations Center
NASA	National Air and Space Administration (U.S.A.)
OP	Observing Programme
PARD	Product Assurance Requirements Document
PI	Principal Investigator
PS	Project Scientist
PR	Public Relations
PRP	Public Relations Plan
PV	Performance Test and Verification Phase
SAMBA	Satellite for the Measurement of Background Anisotropies
SPC	ESA's Science Programme Committee
SS	Survey Scientist
SSAC	Space Science Advisory Committee
ST	Science Team
STM	Structural and Thermal Model
SZ	Sunyaev-Zeldovich effect

TP	Telescope provider