DOCUMENT

PLATO Science Management Plan

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1 INTRODUCTION, PURPOSE & SCOPE

1.1 Introduction

PLATO (PLAnetary Transits and Oscillations of stars) is an ESA mission with a possible contribution of NASA and the participation of ESA member states for the provision of the payload and part of the ground segment. PLATO was proposed as an M-class mission in the Cosmic Vision 2015-2025 programme to detect and characterise a large sample of exoplanets down to earth-size and below.

Upon completion of a one-year assessment study in late 2009, PLATO was selected by the SPC for a definition study in February 2010. The definition study is expected to last until June 2011.

1.2 Purpose and Scope

The Science Management Plan defined in this document presents the top-level science management principles of the mission and its main organisational units. It identifies the rights and responsibilities of ESA, International Partners, the PLATO Mission Consortium funded by ESA Member States, and the scientific community at large. The document provides an overview of the mission science objectives and a description of the scientific operations and data processing centres that will be established to generate the outlined scientific data products. Only a brief description of PLATO is provided in so far as it is relevant to a correct understanding of the mission management.

Contingent upon SPC approval of the Science Management Plan, ESA will issue an Announcement of Opportunity for the PLATO Mission Consortium, which will include contributions to the payload and to the scientific ground segment, and an Announcement of Opportunity for Independent Legacy Scientists.

The Science Management Plan (SMP) is the highest level document in the project documentation tree and will remain applicable to all subsequent phases of the mission.

The Science Management Plan will be revised at the end of the Definition phase. The purpose is to ensure that the evolution of the mission's configuration's, including (but not limited to) the international cooperation, the provision of nationally-funded elements, and the time necessary to the processing of the data prior to their being released to the public, can be properly taken into account prior to the implementation phase, and thus provide a solid basis for the mission's science management in the subsequent phases. The revised version will be subject to the same approval cycle as the present version.

2 MISSION OVERVIEW

2.1 Science Objectives

The objective of PLATO is to detect and characterise a sample of exoplanets sufficiently large and with a photometric accuracy high enough that the data can be used to:

- Build a statistically significant sample of Earth-size planets orbiting main sequence F-, G-, K-type (Solar Type) and M-stars in their habitable zone.
- Determine, through asteroseismology, the radius and mass of both the parent star and the planet(s) orbiting it with an accuracy of ~1%, and derive the age of the systems to an accuracy better than 10%
- Derive a planetary mass function extending from Brown Dwarfs down to planets smaller than the Earth.
- Allow the selection of a sample of bright and nearby systems for further studies with ambitious facilities such as JWST, the ELT or a future spectroscopy mission and provide reliable statistics for the occurrences of earth-like planets in the solar neighbourhood.

The above objectives are achieved by collecting long, uninterrupted, ultra-high precision photometric light-curves of a sample of 20,000 relatively bright stars. The same light-curves will be used for detecting exoplanets via the occultation techniques and characterising their host star by asteroseismology.

In addition to the seismic analysis of planet hosting stars, which is a key tool to reach the mission objectives, asteroseismology of the many other stars present in the field of view will be used to study stellar evolution. Light curves of stars of all masses and ages across the HR diagram, including members of several open clusters and old population II stars, will be collected for this purpose.

2.2 Additional science programmes

Besides the core programme, PLATO will allow a broad range of studies involving photometric variability. Its high signal to noise, long time coverage and the very large field of view, will enable the study of variability on several time scales – between 1 minute and several years – on statistically significant stellar samples. These properties will be used to address many different questions, mainly (but not exclusively) in the area of stellar physics.

2.3 Mission description

The PLATO reference payload consists of 34 refractive cameras (i.e. telescope & detectors) each with a 120 mm entrance pupil and 6 lenses (including one aspheric lens). Cameras are

grouped in 4 subsets with slightly different Lines-of-Sight (LoS) but with significant overlap of their Field-of-Views (FoV). Each camera has a FoV with a diameter of 37^{o}.

PLATO will be launched by a Soyuz Fregat into a large-amplitude libration orbit around the Sun-Earth second Lagrange point, L2. Commissioning of the spacecraft as well as calibration and performance verification of the payload will be performed during the cruise phase to L2. The 6-years nominal duration of the scientific exploitation phase consists of three parts: two long-duration observations (of 3 & 2 years respectively), each focusing on a particular part of the sky with a high density of F, G and K dwarf stars, plus a one year long step-and-stare phase where a small number of selected fields will be monitored for a few months each. A mission extension of one (or more) years is possible.

Each of the long-duration observations will monitor a separate field in the sky that together will be encompassing a minimum of 20 000 dwarf stars of spectral type later than F5, each sufficiently bright to reach a photometric accuracy ≤ $2.7 * 10^{-5}$ in one hour. The photometric precision required by the mission puts stringent requirements on the pointing stability and accuracy of the s/c which must reach 0.2 arcsec (Relative Pointing Error) over time scales of 2.5 seconds to 14 hours. The step-and-stare phase will consist of a series of separate observations each lasting up to 5 months. The rationale is to extend the surveyed area of the sky and to further characterise planetary candidates that were found to have two or more transits during the long observations.

The Ground Segment consists of three main elements:

- An ESA provided Mission Operations Centre (MOC) in charge of satellite operations. This includes the Ground Stations and antenna required for telemetry receptions, telecommand uplink and ranging.
- An ESA provided Science Operations Centre (SOC) in charge of the scientific mission planning and the generation, validation, archival and distribution of the Level 1 mission products (calibrated light curves and centroid curves) to the PDC. The SOC will also develop and operate the archives that will be used to store and distribute all PLATO mission products.
- A PLATO Data Centre (PDC), provided by the Member States with a possible participation from US, in charge of processing level 1 data so as to generate the scientifically added-value Level 2 mission products for archival and distribution by the SOC. The PDC is also responsible for the calibration of the payload as well as the design, development, operations and maintenance of the ancillary data base and the generation of the final science data products and catalogues. It is foreseen that the PDC will be distributed among a few physical institutes in Europe and the US. The PDC will remain operational for at least three years after the end of PLATO operations to enable confirmation of planetary candidates with orbital periods of up to three years.

The spacecraft operates autonomously for most of the time except for a period of 4 hours per day when data are downloaded to the Ground Station and telecommand sequences uploaded as required to activate the following 24 hours of observations. Data obtained outside the 4 hours visibility period are stored in an on-board mass-memory. The X-band facility allows science data rates of up to 109 Gbit per day.

2.4 Mission phases and milestones

PLATO is currently foreseen to be launched in 2018. The main milestones of the mission are as follows:

- Start of Definition Phase with two parallel industrial contracts: July 2010
- Down-selection for CV M1/M2 missions: June 2011
- Completion of the Definition Phase (A/B1): December 2011
- Final adoption for the Implementation Phase (B2/C/D/E1): Feb 2012
- Start of the Implementation Phase: July 2012
- Launch (L): 2018
- L+: launch and early operations phase (LEOP)
- End of commissioning, Performance Verification & cruise to L2: L + 3 months
- End of first long observations: L + 3.25 years
- End of second long observations: L + 5.25 years
- End of step & stare phase: L + 6.25 years
- End of archival phase: L + 9 years

2.5 Member States funded elements: The PLATO Mission Consortium

The responsibility of the PLATO Mission Consortium (PMC) is to provide:

- The full set of Instruments (cameras and warm electronic units) fully verified and calibrated for later integration into the PLATO spacecraft by ESA
- The PLATO Data Centre (PDC) in charge of processing all data from Level 1 upward and transferring them to the ESA SOC for archival and distribution
- The organisation and leadership of associated ground based observations required by the mission
- Members of the Plato Science Team

The PMC is funded by ESA's member states, and selected via an Announcement of Opportunity (AO) to be issued after approval of this Science Management Plan. The Proposals received in response to the AO will be evaluated under the responsibility of the Advisory Structure and submitted for approval to the SPC. At the start of the implementation phase,

the exact responsibility of each party in the PLATO Mission Consortium will be formalised through a Multilateral Agreement (MLA) between ESA and the relevant national funding authorities. After SPC endorsement, the MLA will be approved by the ESA Council. A timeline for the selection of the PLATO Mission Consortium is provided in Table 1.

Table 1: Indicative PLATO AO Cycle

Date	Event
July 2010	Release of AOs for a PLATO Consortium and Independent Legacy Scientists
October 29, 2010	Proposals Due
November 2010	Meetings with national funding agencies for the Definition Phase
November 2010-January 2011	Internal evaluation
January 25-26, 2011	AWG recommendation
February 1-2, 2011	SSAC recommendation
February 10-11, 2011	SPC decision
June 21-22, 2011	M-class mission selection
July-October 2011	MLA negotiations with national funding agencies
November 16-17, 2011	MLA SPC Decision

ESA will procure the focal plane CCDs and deliver them to the PLATO Mission Consortium. The PMC will be responsible for their integration into the cameras as well as for the procurement, integration and verification of the refractive cameras and their delivery to ESA as part of the Instruments. The PMC leads the Instrument Level Tests and plays a major role in the Integrated System tests.

While the procurement of the Instruments and spacecraft are managed independently, they constitute a single high precision experiment dedicated to a well focussed objective. As a consequence, their technical design must be carried-out and optimised in a coherent fashion. For this reason, once the PMC has been selected, close cooperation with ESA will be required to finalise the design of the payload.

Similarly and intimately connected to the payload development, data processing activities will benefit from a high degree of connectivity between the scientists involved; this is achieved through a single consortium, the PMC. Furthermore, through their payload procurement activities, the PMC will acquire expertise in:

- Instruments calibration
- Instruments operations
- Scientific performance of the Instruments

The PMC will have a major stake in the PLATO data processing activities. More specifically, the PLATO Mission Consortium will be responsible for:

- The development, integration, validation, maintenance and operations of the Data Processing system (hardware and software) that will be used by the PDC to process

and validate all PLATO data from Level 1 upward. This includes any simulations and modelling tools required to achieve that goal.

- Detailed study and characterisation of the stellar fields that will be observed by PLATO. This may entail dedicated wide-field observations with other ground or space based facilities, as needed.
- The delivery of validated payload operations procedures (nominal and contingency) to ESA for their integration into the MOC and SOC. This includes the procedures required to monitor the performance of the payload, identify possible malfunctions and take corrective actions as appropriate.
- The pre-launch and in orbit calibration and characterisation of the PLATO payload
- The maintenance of the payload during operations. This includes maintenance of the observing modes and operations of the Instruments as well as their on-board software.
- The organization and execution of follow-up activities required to further characterise planetary candidates found with PLATO, such as radial velocity monitoring and additional ground based photometric, spectroscopic, and imaging.
- The production of all level-2 data products (section 5.2) as well as higher level scientific products of the mission such as catalogues, and their delivery to ESA for archival and distribution.

2.6 The general scientific community

The scientific community at large will be invited to get involved in the scientific preparation of the mission in close interaction with the PLATO Mission Consortium. Especially in the area of preparatory observations, characterisation of the field and ground based follow-up, the community is expected to play a significant role. Further, beside the core programme, PLATO will allow a broad range of studies involving photometric variability. The high signal to noise, long time coverage and very large field of view, will enable the study of variability on several time scales – between one minute and several years – on statistically significant samples. These properties will be used to address many different questions, mainly (but not exclusively) in the area of stellar physics.

To acknowledge the role and importance of the broad scientific community, two Independent Legacy Scientists will be appointed through an AO open to the general community. The Independent Legacy Scientists are closely involved in the PLATO mission through membership of the PLATO Science Team (PST). Their main responsibility will be to give advice on the support to the general scientific community concerning the usage and availability of the PLATO data, and to represent the scientific community that is involved in the PLATO additional science programmes.

As part of the response to the AO, each Independent Legacy Scientist shall make a proposal for a legacy data analysis project unique to PLATO. The proposed legacy project shall not

address the main scientific objectives of the mission, but cover additional areas as described in section 2.2. The Independent Legacy Scientists may include in their respective proposals a team of collaborators to aid them in the analysis of the data. Proposals shall have a concrete and delimited scope and include a credible data analysis scheme. Research activities in relation with the proposal will not be funded by ESA and will be expected to rely on institutional and national sources for support.

The Independent Legacy Scientists projects shall not impose additional requirements on the mission. However the PST, after proper analysis and evaluation, may recommend changes to the configuration or to the satellite operations that would have a positive impact on the execution of additional science programmes.

The Independent Legacy Scientists and their teams have proprietary access to the PLATO data for the purpose of their respective scientific projects, and follow the rules defined by the PST regarding publications.

Based on a recommendation by the Advisory Structure, the Independent Legacy Scientists will be appointed by ESA for an initial period of three years, renewable through the duration of the mission.

2.7 Participation of NASA on PLATO

Discussions between ESA and NASA have resulted in a framework for both near-term studies and a potential long-term collaboration on the PLATO mission itself. The top-level conditions for the collaborative framework are currently the following:

- The total US contribution to the PLATO mission will not exceed ~20% of total mission costs from all contributors (estimated assuming the ESA procurement approach), but excluding scientific preparation and exploitation.
- NASA will participate in the definition phase studies in order to identify together with ESA potential contributions to the PLATO scientific payload. Additional contributions to the PLATO mission such as hardware for the spacecraft, ground segment contributions, launch segment contributions, etc. will also be investigated jointly with ESA
- Data processing and calibration activities to provide “level 1” data products (calibrated data with instrumental artefacts and cosmic rays removed) will also count towards the U.S. contribution (~ 20% mentioned above). U.S. funding to the selected scientific participants for data exploitation (i.e. data analysis and scientific interpretation) will not be counted against the U.S. contribution to the mission.
- Scientist participants will have access to the scientific data required to carry out their selected and agreed to scientific investigations.

- Possible U.S. participation in, and contributions to, European-led payload elements, provided in response to the ESA Announcement of Opportunity (see below) will count towards the total US contribution of ~ 20%.
- NASA will appoint proportional representation to the PLATO Science Team (see below) up to ~ 20% of the membership
- Selected US scientists will have the right of first-authorship on a pro-rata fraction of papers (again up to ~ 20%) published during the relevant proprietary phases. Agreement of authorship of individual papers will be left to the PLATO Science Team with the agencies only intervening in the case of major disagreements. If the PLATO Science Team agrees on a different metric to measure the scientific return to NASA scientists, the 20% limit will apply to that metric.
- All data from the PLATO mission will eventually be archived and made accessible at the appropriate time for further exploitation by the general scientific community.. The maximum proprietary time is 1 year.

The percentages quoted above, refer to the ESA-estimated total mission costs from all contributors excluding scientific preparation and exploitation.

This ESA-NASA framework agreement is contingent upon the outcome of the US National Research Council's Astronomy and Astrophysics Decadal Survey, which will be released during the 3rd quarter of 2010.

3 SCIENCE MANAGEMENT

3.1 Overview and overall responsibilities

The overarching responsibility for all aspects of the PLATO mission rests with ESA's Directorate of Science and Robotic Exploration and its director (D/SRE). During the development phase, D-SRE delegates his responsibility to the ESA Project Manager and his Project Team. In particular, the Project Team is responsible for the development, procurement, manufacturing, assembly, integration, test, verification and timely delivery of a fully integrated spacecraft capable of accommodating the Payload, fulfilling the mission requirements and achieving the mission objectives. After the completion of the satellite in-orbit Commissioning Phase, the responsibility of the mission is transferred to the ESA Mission Manager.

While ESA has the responsibility of the overall PLATO mission definition and space segment development, the Payload module hardware breakdown and the responsibilities are foreseen as following:

- ESA is responsible for the Payload module optical bench and Payload module system integration and tests,

- The PMC provides the camera assemblies, including the optics, the Focal Plane Assembly, and camera related mechanical and thermal hardware,
- The PMC provides the Instrument electronics control units and the on board data processing units,
- The PMC shall verify the Instruments and contribute to the integration and tests of the Instruments at Payload module level, under the control of the spacecraft industrial Prime contractor,
- The VIS CCD detectors will be procured by ESA and formally delivered to the PMC through ESA. The PMC is responsible of the overall Instrument performance. Therefore, the PMC shall provide the necessary support to ESA in the CCD detector procurement for ensuring the science mission performance is effectively met.

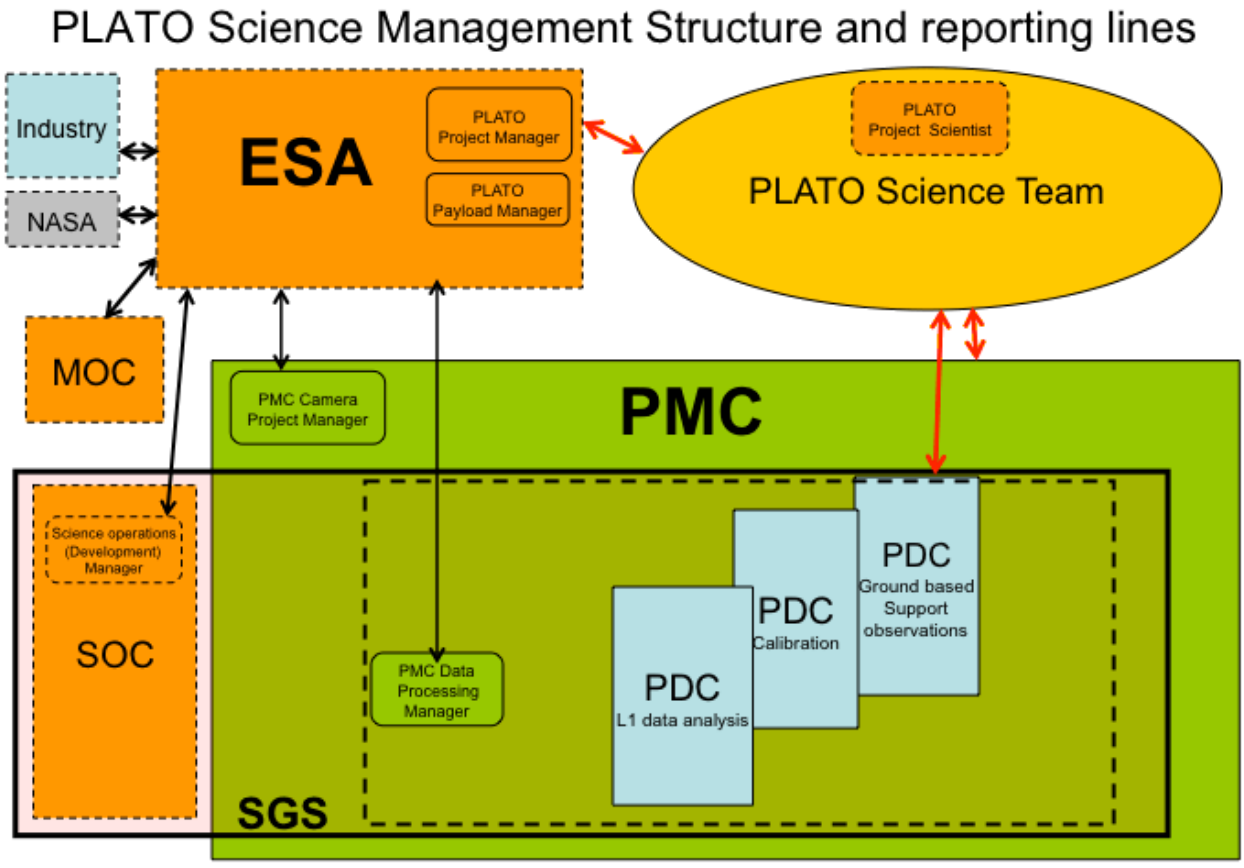

Figure 1: *Parties involved for the Science management. Arrows indicate main reporting (black) or coordination (red) lines. Note that responsibility for the mission is transferred*

from the Project manager to the Mission Manager after the completion of the satellite in-orbit Commissioning Phase. The PLATO Project Scientist chairs the PLATO Science Team. The PLATO Ground Segment includes the Science Operations Centre (SOC), the Missions Operations Center (MOC), both ESA provided, and the PLATO Data Centre (PDC) provided by the PLATO Mission Consortium (PMC). This baseline organisation structure will be reviewed throughout the Definition phase and may be modified as part of the SMP revision at the end of the Definition Phase.

The PMC, selected by ESA via the Announcement of Opportunity and funded by ESA member states, is responsible for the design and development of the above mentioned Payload Module Components along with the camera specifications and preliminary resources allocation. In addition, the PMC provides:

- The PLATO Data Centre in charge of the data processing and the derivation of higher level science data products and catalogues (see Section 4)
- Instrument maintenance and operations support
- Quality-controlled data products to the PLATO Archives

The PMC Camera Project Manager is responsible for the overall management of the payload development. The PLATO Data Processing Manager is responsible for the overall management of the PLATO Data Centre development. Both managers act as interfaces to ESA. This baseline organisation structure will be reviewed throughout the Definition phase and may be modified as part of the SMP revision at the end of the Definition Phase.

The European Space Operations Centre (ESOC) implements the Mission Operations Centre (MOC), operates the spacecraft, and delivers telemetry and attitude data to the Science Operations Centre (SOC). The European Space Astronomy Centre (ESAC) implements the SOC, which acts as the central node for the mission planning and distributes the first level data products to the PDC after a first quick quality check. The SOC is also responsible for the development and operations of the PLATO Archives. The SOC populates and maintains the PLATO Archives and delivers the data products to the general scientific community.

The PLATO Science Team (PST) oversees the preparations and execution of scientific operations, and endorses the distribution of the data products to the community via the Archives.

The Project Scientist defines the PLATO specific observing requirements based on the scientific guidelines provided by the PST. The PS approves the resulting observing plan produced by the SOC. The approved observing plan is sent to MOC for execution.

The PMC is ultimately responsible for the creation and delivery to ESA of the second and higher level data products.

3.2 Project Scientist

The PLATO Project Scientist (PS) is the Agency's interface with the PLATO Mission Consortium and general scientific community for scientific matters. Within ESA, the PS liaises with the PLATO Project Manager until completion of the satellite in-orbit commissioning, and thereafter with the PLATO Mission Manager during routine operations.

During all phases of the project, the PS is responsible for coordinating all scientific issues with the ESA Project Team. In particular, the PS will advise the ESA Project and Payload Managers on technical matters when they affect scientific performance. During the development and operational phases, the PS monitors the state of implementation and readiness of the payload operations and data processing infrastructure. During and after routine operations the PS is responsible for the scientific coordination of the creation of the scientific products, their archival and distribution to the scientific community.

The PS chairs the PLATO Science Team and coordinates its activities.

3.3 PLATO Science Team (PST)

The PLATO Science Team supports the PS in monitoring the correct implementation of the scientific objectives of the mission and maximising its scientific return. The PLATO Science Team will be formed with the selection of the PLATO Mission Consortium, and will remain in place until the scientific products are delivered to the community. In addition to the ESA Project Scientist who chairs it, the PST is composed of 10 members as follows:

- Two Programme Scientists, who are closely involved in the definition and monitoring of the progress of the PLATO observing programme. They will also define, organise and oversee the procurement of external ground based data which will be required to confirm and characterise planetary candidates discovered by PLATO. The European Programme Scientist will be specifically responsible for the choice of target fields and the stars within these fields.
- Two Calibration Scientists with specific expertise in the PLATO Instruments, their calibrations, and data processing.
- A Follow-up Scientist with specific expertise relating to ground based activities (preparation and follow-up).
- Three Data Processing Scientists, who closely monitor
    - data processing infrastructure and interfaces
    - product generation,
    - simulation and modelling infrastructure,
- Two Independent Legacy Scientists who will give advice on support to the community in the usage and availability of the PLATO data (e.g. documentation,

information on data quality, data products definition etc.) and with more specific responsibilities for advising on:

- additional science catalogues,
- preparatory and follow-up activities

In addition, the Independent Legacy Scientists will represent the needs of the broad astronomical community in relation with the PLATO additional science programmes described in section 5.3.

Six PST members (a Programme Scientist, the two Calibration Scientists, the Follow-up Scientist, and two Data Processing Scientists) will be leading scientists in the PLATO Mission Consortium and their names and designated functions within the PST will be identified in the proposal submitted in response to the AO.

Two members, a Programme Scientist and a Data Processing Scientist, may be affiliated to a US institution and are appointed by NASA. The two Independent Legacy Scientists are selected through a separate AO issued by ESA.

The PST members will be appointed by the ESA Director of Science and Robotic Exploration. In case a member of the PST needs replacing, the ESA Director of Science and Robotic Exploration will appoint his successor, upon proposal from the PMC or NASA, depending on the member's appointment. The replacement of an Independent Legacy Scientist will be recruited through an AO issued by ESA at the appropriate time.

The ESA Project Manager, ESA Mission Manager (after launch), ESA Payload Manager, ESA Science Operations (Development) Manager, PMC Camera Project Manager, NASA Project Manager, and PLATO Data Processing Manager have standing invitations to attend all meetings and participate in all activities of the PST as non-voting members.

To discharge its responsibilities, the PST mainly relies on the technical information provided by the PMC and ESA Project. 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 PST and PMC.

The PST acts as a focus for the interest of the scientific community in PLATO. The PST advises the PS on:

- maximising the scientific return of PLATO within its programmatic constraints, while at the same time ensuring that the development of the mission remains compatible with the main scientific objectives
- the scientific aspects of the development of the payload and spacecraft
- the formulation, optimisation, and maintenance of the observing plan and the calibration strategy

- the definition of data rights and publication policy within the guidelines established in this document
- the promotion of public awareness and appreciation of the PLATO mission and supporting ESA in its outreach efforts
- overseeing the analysis of the data
- the supervision and authorisation of the release of the final scientific data products to the community
- the organisation of the data archive(s)

In general, the members of the PST are expected to monitor and give advice on all aspects of PLATO which affect its scientific performance. In particular, they participate in major project reviews, and perform specific tasks as needed during the development and operation phases.

The PST is responsible for the definition of the external data required by the PLATO mission to achieve its scientific goals. They will organise and coordinate the procurement of the data both prior to launch as well as during and after the operations phase.

3.4 Steering Committee

A Multi-Lateral Agreement (MLA) will be established between ESA and the PMC funding agencies to formalise the commitments and deliverables of all parties. A PLATO Steering Committee with representatives from the national funding agencies and ESA will be set-up to oversee the activities of the PMC and the timely fulfilment of the obligations of all parties to the MLA.

The PLATO Steering Committee will participate to the periodic milestone reviews of the PMC to monitor the status and progress of the Consortium.

4 THE PLATO GROUND SEGMENT

4.1 Overview

The ultimate science goal of PLATO is the detection and the full characterisation of a large number of exoplanets, including telluric planets in the habitable zone of sun-like stars. The characterisation of many exoplanetary systems will be achieved thanks to a combination of factors specific to PLATO: the high-precision photometry of a large sample of stars to search for planetary transits, the observation of bright stars that are amenable to high-precision follow-up observations (radial velocities, spectroscopy, Gaia astrometry), and high-cadence long-duration observations for the asteroseismology of planet-host stars (mass, radius, age, rotation, chemical composition).

The PLATO Ground Segment consists of the Ground Station, the Mission Operations Centre (MOC), the Science Operations Centre (SOC) and the PLATO Data Centre (PDC). The SOC and the PDC are the two elements of the PLATO Science Ground Segment.

The data analysis system for PLATO is jointly developed by the SOC and the PDC to provide support for the validation, calibration, and scientific analysis of PLATO observations. In particular, this system provides tools to monitor and validate the quality of the light curves and generate the PLATO scientific products.

The data analysis consists of three data processing levels:

- L0 (Level 0) data, which corresponds to the data delivered by the individual telescopes. They include individual light curves and centroid curves, as well as imagettes for a set of selected targets (an imagette is a ”postage-stamp” image around a target star). L0 data does not include instrument corrections other than those already applied on board. Treatments at this level also includes a processing of the available imagettes, in order to validate the performances of the on board treatment and provide elements to optimize it.
- L1 (Level 1) data, which includes further instrumental corrections, such as those related to temperature sensitivity, some specific CCD corrections, and most importantly jitter a posteriori correction. L1 treatment also includes the calculation of suitable averages of individual light curves and centroid curves for each star.
- L2 (Level 2) data, which includes transit detection and measurements, stellar oscillation mode parameters, as well as star and planet characteristics. The L2 data has a high scientific added value, and makes use of the PLATO L1 data on one hand, and of information gathered on the PLATO targets on the other hand (e.g. high spectral resolution observations and radial velocity monitoring), assembled in an ancillary database.

L0 and L1 data are produced under the responsibility of the SOC. The SOC makes available the L1 data to the PDC, which is responsible for the production of the L2 data. The PDC delivers the L2 data to the SOC for archiving.

When data products have passed quality control and after the established proprietary period (when applicable), the data are accessible to the wide astronomical community through an archive which is developed, managed and maintained by ESA/SOC. The long-term responsibility of this archive will remain with ESA for as long as the archive is scientifically usable. In this respect ESA will be advised by the normal scientific advisory groups. The mission delivers not only the complete set of data products but also software tools, and the applications to interface to the data obtained during the mission. Results in the form of proper identification of targets, catalogues and relevant associated supporting follow-up observations are made available.

Software developed specifically for PLATO jointly by ESA and its partners will be put under a worldwide license such as LGPL. In accordance with SPC(2009)6 approval for this action will be sought from the ATB (Agency Technology Transfer Board).

4.2 The PLATO Data Centre

The PLATO Data Centre is under the responsibility of the PLATO Mission Consortium. The PDC supports the SOC in the production of the L1 data by carrying out the following tasks:

- Calibration of the scientific data. This includes the definition of a calibration plan, the specification of observations or payload configurations required to gather calibration data, the derivation of the calibration parameters and their delivery to the SOC for implementation into the L1 processing pipeline.
- Definition of algorithms and support to the implementation of modules in the data analysis system for the generation of L1 data.
- Provision of input to the scientific quality control software and procedures.

The PDC designs, implements, tests and maintains the data analysis tools needed to generate the level 2 data and higher level scientific products, which include catalogues, list of planets, their parameters and additional characterisation information.

The PDC supports the spacecraft operations by providing input to the procedures needed for payload operation and for scientific mission planning. The PLATO Mission Consortium organizes the field analysis and selection prior to the mission. The PDC provides the field selection information to the SOC for the scientific mission planning.

The PLATO Mission Consortium is responsible for the organisation of the ground-based follow-up activities. The PDC manages the database that assembles all follow-up data on PLATO targets, plus ancillary data extracted from various existing catalogues and databases, and places them at the disposal of the PLATO Mission Consortium scientists during the proprietary period of the PLATO L1 products, and at the disposal of the world-wide community after this period.

4.3 ESA responsibilities

4.3.1 Ground Station (GS)

This is provided by ESA and will support the daily telemetry communications period every 24 hours for 4 hours during nominal operations and longer during commissioning, performance verification and interface periods between operation pointings (slewing, acquisition, verification, data set up).

4.3.2 Science Operations Centre (SOC)

The Science Operations Centre (SOC) is located at ESAC (Spain) and is responsible for:

- Acquisition and distribution of spacecraft telemetry from MOC
- Acting as the interface between the PDC and the MOC for payload operations and for all files and procedures required for optimizing the quality of the data and safeguarding of the payload
- Scientific mission planning based on input from the PDC after endorsement by the PST. The observing plan and strategy from the PDC has also to be authorised by the PST.
- Quality control: Monitoring of data integrity and quality
- Fine tuning of on-board software, parameters and payload configuration, based on quick look data
- Ground support for onboard processing. The SOC issues payload configuration change requests to the MOC as appropriate to optimize the quality of the PLATO data.
- Design, development, testing and maintenance of the modules in the data analysis system required for the quick-look assessment and the validation of L0 data
- Design, development, testing and maintenance of the data analysis modules required for the generation of the L1 data
- Archiving of all PLATO data products, HK data, and ancillary data
- Distribution of the data products to the scientific community
- Post-operations activities

4.3.3 Mission Operations Centre (MOC)

The MOC is located at ESOC (Germany). It is responsible for the operation of the satellite, in particular the MOC is in charge of the following tasks:

- Monitoring spacecraft health and safety
- Monitoring the payload safety and reacting to contingencies and anomalies according to procedures provided by the PLATO Mission Consortium.
- Alerting the SGS of all significant anomalies or deviations from nominal behaviour of the satellite
- Executing predetermined procedures to safeguard the spacecraft and payload, and preserve data integrity

- The uplink of the satellite and payload telecommands
- The maintenance of the satellite's on-board software
- The uplink of payload on-board SW executables as generated, validated and delivered by the PDC via the SOC.
- The flight dynamics support including determination and control of the satellite's orbit and attitude
- Handling and provision of the telemetry to the SOC
- Production and provision of ancillary data to the SOC (e.g. orbit files, pointing information)
- Archiving the full telemetry data for a period of no less than 10 years

The ESA/ESOC (GS/MOC) ground segment consists of:

- The Ground Stations and the Communications Network
- The Mission Control Centre (infrastructure and computer hardware)
- The Flight Control software System (data processing and Flight Dynamics Software)
- Computer Infrastructure (Mission Control System, Simulator, etc).

The readiness of the ground segment is tested and validated by a series of test campaigns, e.g. Radio Frequency Compatibility Test (RFCT), Data Flow Test, Mission Sequence Test, and System Validation Tests.

5 SCIENCE DATA PRODUCTS

5.1 Telemetry data

The baseline science telemetry budget yields a daily uncompressed data volume of 109 Gb. Over a nominal 6 year mission the total science telemetry down-linked will therefore be around 30 TB uncompressed for L0 data. For efficiency of access by down-stream pipeline and high-level science tools, it is likely necessary to reformat the raw telemetry which may increase the data volume by 50%.

Telemetry (TM) is the packetized stream of raw data, including science and house-keeping (HK) data. The telemetry rate makes it possible to downlink all the individual light curves of the telescopes, all the centroid curves, and a large number of imagettes. The exact number of imagettes is currently being scoped but will include (at least) imagettes of 1000 brighter stars (for image control) as well as imagettes of target stars brighter than m_V = 10.9. The ground segment implements the required corrections to produce the science-ready light curves and to then extract the science data products from these light curves.

5.2 Data products

The PLATO data products are divided into three main categories, corresponding to the three successive levels of processing described in the previous section. A preliminary list of deliverables includes:

Level 0:

- The validated light curves and centroid curves for all individual telescopes. These are all the downloaded light curves (one each from each star and from each telescope) as well as the centroid curves and validated by assessing the quality and integrity of the data.
- Housekeeping data
- Ancillary data, e.g. pointing

Level 1:

- The calibrated light curves and centroid curves for each star and corrected for instrumental effects e.g. jitter. For all stars, the L1 calibrated data is the basic science-ready PLATO data. For the normal telescopes and for each star, the L1 light curves and centroid curves are (suitably) averaged, and an associated error is provided. The stars for which imagettes are available undergo a specific treatment.
- Ancillary data, e.g. pointing
- Associated calibration data

Level 2:

- The planetary transit candidates and their parameters with formal uncertainties.
- The asteroseismic mode parameters with formal uncertainties.
- The stellar rotation periods and stellar activity models inferred from activity-related periodicities in the light curves, with formal uncertainties.
- The seismically-determined stellar masses and ages of stars, (and their formal errors), obtained from stellar model fits to the frequencies of oscillations
- The list of confirmed planetary systems, which will be fully characterized by combining information from the planetary transits, the seismology of the planet-host stars, and the follow-up observations. This represents the most important PLATO (the final and highest level PLATO science) deliverable.

5.3 Data Rights

The ownership, access, use, and dissemination of PLATO raw and calibrated data and of information, data and intellectual property produced by the analysis of data shall be governed by Chapter III, Sections II and III of the Rules on Information, Data and Intellectual Property, ESA/C/CLV/Rules 5 (Final), as adopted by the ESA Council Resolution on the Rules concerning Information, Data and Intellectual Property, ESA/C/CLV/Res. 4 (Final).

The general data policy is to make the PLATO L1 data publicly available as soon as they are validated by the SOC, following a procedure defined by the PST (based on current best knowledge this time ranges ~ a few months in the early phases of the mission to days later on).

The L2 data, which depend also on additional (ground based) supportive observations, will be made publicly available in a timely manner, and no later than the acceptance for publication of the first refereed papers based on them.

However, among the several hundreds of thousand targets, the data from a certain number not exceeding 2000 in total (the exact number will be defined and agreed by the PST), remains the property of the PLATO involved scientists for a period of one year after the corresponding L1 data have become validated and made available to them by the SOC. In this context PLATO involved scientists comprises members of the PLATO Mission Consortium, US scientists in the SGS (subject to the conditions as given in section 2.7), members of the PLATO Science Team (PST) as well as staff of the ESA provided SOC. The distribution of reserved targets is such that 20% is assigned to US participants and 5% to the SOC, which leaves a total of 75% to the PLATO Mission Consortium. The PST shall encourage the collaboration on the proprietary targets between the PLATO Mission Consortium and the Independent Legacy scientists.

The list of proprietary targets is established at least 6 months prior to each phase of the mission (one phase being defined as one long run or the step & stare phase), as the outcome of a call for proposals aimed at the PLATO involved scientists. The call for proposal will be issued at least two years before the beginning of each phase. In response to this call, the PLATO involved scientists will submit proposals for a limited number of identified targets, specifying the scientific use they propose to make of these proprietary data, as well as the preparation work that they have performed or intend to perform, detailing the organization of their teams toward these goals. The PST will review the proposals and come up with a final selection of proprietary targets that will then be distributed among the PLATO involved scientists according to the initial proposals. All L1 data distributed under this procedure will become public after one year of proprietary period.

A call for proposals, directed at the general scientific community, will be issued before launch and after the outcome of the call for proprietary data. More open calls may be issued during the mission to the discretion of the PST. The open calls will ask for additional science programmes not covered by the PLATO core science objectives listed in section 2.1. Additional science programmes will focus on additional objects found within the field of view of each core programme pointing. They will not require repointing of the spacecraft or exclusively dedicated observing time. Proposers will be requested to describe the science objectives, specify the requirements on PLATO data acquisition and calibration to achieve the science goals, and provide a plan for the associated data processing. The proposals will be selected by a committee of experts formed under the supervision of the AWG. The SOC will provide dedicated support to the successful proposers.

When an open call programme contains targets that are part of the proprietary target list, access to the associated data will be granted also to this programme, with the condition that the observations are exclusively used in relation with the science objectives of the proposal, and the same proprietary period will apply. For the remaining targets in the programme, no proprietary period will be assigned and the L1 data will be publicly available as soon as they are validated by the SOC.

5.4 Public relations, Education and Outreach

PLATO has a strong outreach potential. It will provide a list of Earth-size planets and their associated evolutionary status (ages). ESA and its partners in the mission should address the many scientific questions which can be addressed by PLATO from both an outreach and an educational aspect. This requires both the necessary skills and resources to provide a continuous production of the required materials which consist of a high quality website, text at many levels (children booklets, secondary school material, press-releases, popular science-level material), simulations, audio-visual aids, etc. These skills and resources will be developed both within ESA as well as within the PMC and PST.

ESA will be responsible for planning and carrying out education and outreach activities related to PLATO. In addition, a general outline will be requested in the AO in the form of a public relations plan. This plan must be formally agreed and adhered to by the PST. The plan will take into account that:

- ESA has the lead on applications of education and outreach within the data rights framework described in section 5.3,
- The members of the PST and the PMC have a duty to support ESA with regards education and outreach,
- ESA will give credit to members of the PST and the PMC regarding scientific and technical results when applicable.

6 ACRONYMS

AO	Announcement of Opportunity
AOCS	Attitude and Orbit Control System
ATB	Agency Technology Transfer Board
AWG	Astronomy Working Group
CV	Cosmic Vision
DP	Data Product
ELT	Extremely Large Telescope
ESA	European Space Agency
ESAC	European Space Astronomy Centre
ESOC	European Space Operations Centre
FoV	Field of View
FPA	Focal Plane Assembly
GS	Ground Station
HK	House Keeping data
JWST	James Webb Space Telescope
LEOP	Launch and Early Orbit Phase
LoS	Line of Sight
MLA	Multi-Lateral Agreement
MM	Mission Manager
MOC	Mission Operations Centre
NASA	National Aeronautics and Space Administration
PMC	PLATO Mission Consortium
PDC	PLATO Data Centre
PLATO	PLAnetary Transits and Oscillations of stars
PM	Project Manager
PSGS	PLATO Science Ground Segment
PS	Project Scientist
PST	PLATO Science Team
PSST	PLATO Science Study Team
POAT	PLATO Optimisation and Advisory Team
SMP	Science Management Plan
SOC	Science Operations Centre
SPC	Science Programme Committee
SSAC `	Space Science Advisory Committee
TBC	To Be Confirmed
TBD	To Be Defined
TM	Telemetry
WP	Work Package