estec

European Space Research
and Technology Centre
Keplerlaan 1
2201 AZ Noordwijk
The Netherlands
Tel. (31) 71 5656565
Fax (31) 71 5656040
www.esa.int

DOCUMENT

PLATO Experiment Interface Document - Part A

PLATO EID-A draft 01.doc

Prepared by	**ESA PLATO Study Team**
Reference	**SRE-PA/2010.046/EID-A**
Issue	**draft1**
Revision	**0**
Date of Issue	**05 July 2010**
Status	**N/A**
Document Type	**EID-A**
Distribution	

European Space Agency
Agence spatiale européenne

APPROVAL

Title	
Issue draft1	Revision 0
Author	Date 05 July 2010
Approved by	Date

CHANGE LOG

Reason for change	Issue	Revision	Date
New issue	1	0	05 July 2010

CHANGE RECORD

Issue	Revision		
Reason for change	Date	Pages	Paragraph(s)

Table of contents:

Table of Figures:

Table of Tables:

ACRONYMS AND DEFINITIONS

Definitions

For the purpose of this document, the following definitions are applicable:

- **Telescope:** unit which includes the barrel, optics, support structure, the dedicated baffle (if mounted) and the dedicated thermal hardware
- **Detection subsystem:** FPA + FEE + related interface harness
- **Camera:** sub-assembly which includes the telescope and detection subsystem
- **Data Processing System (DPS)**: DPU, fast DPU, ICU, and software
- **Instrument:** one full functional chain including a camera, and all the electronics and software associated to the camera (one DPU, ICU and the AEU) and internal harness up to the interface with the SVM.
- **Payload**: the full set of Instruments
- **Payload Module (PLM)**: the full set of Instruments, optical bench, supporting structures and the hardware thermal control. Note: the Sunshield is not part of the PLM

Therefore, the spacecraft shall be considered as constituted by the SVM, PLM and Sunshield.

For the purpose of this document the term "**Contractor'** refers to the system Prime Contractor responsible for all industrial activities mentioned in this Interface Document. The term "PLATO Mission Consortium", hereafter the **Consortium or PMC**, refers to the entity responsible for elements of the Payload that are provided as Customer Furnished Equipment (CFE) and the related activities.

Acronyms

ABCL	As Built Configuration List
AEU	Ancillary Electronics Unit
AIT	Assembly Integration Test
AIV	Assembly, Integration and Verification
AO	Announcement of Opportunity
AOCS	Attitude and Orbit Control System
ASW	Application Software
BB	Bread Board
CAD	Computer-Aided Design
CCD	Charge Coupled Device
CFE	Customer Furnished Equipment
CIDL	Configuration Item Data Lists
CLK	Clock
CNES	Centre National d'Études Spatiales
DP	Data Product
DPS	Data Processing System
DPU	Data Processing Unit
DS	Detection System
EEPROM	Electrically Erasable Programmable Read-Only Memory
EGSE	Electrical Ground Support Equipment
EID-A	Experiment Interface Document (Part A)
EID-B	Experiment Interface Document (Part B)

EM	Electromagnetic
ESA	European Space Agency
ESD	Electro Static Discharge
ESTEC	European Space Research & Technology Centre
FEE	Front End Electronics
FEM	Finite Element Model
FM	Flight Model
FITS	Flexible Image Transport System
FoV	Field of View
FPA	Focal Plane Assembly
GS	Ground Station
GSE	Ground Support Equipment
I/F	Interface
ICU	Instrument Control Unit
ITT	Invitation To Tender for Industry
LLI	Long Lead Item
LoS	Line of Sight
MEU	Main Electronics Unit
MGSE	Mechanical Ground Support Equipment
MLI	Multi Layer Insulation
MOC	Mission Operation Centre
MS	Microsoft
OB	Optical bench
OGSE	Optical Ground Support Equipment
PCL	PLATO Consortium Leader
P/L	Payload
PDAAS	Plato Data Acquisition and Analysis System
PDC	PLATO ground Data Centre
PFM	Proto Flight Models
PI	Principal Investigator
PID	Proportional–Integral–Derivative (controller)
PIPM	PLATO Instruments Program Manager
PLATO	PLAnetary Transits and Oscillations
PLM	Payload Module
PMC	PLATO Mission Consortium
PPLC	PLATO PayLoad Consortium
ppm	part per million
PSF	Point Spread Function
QM	Qualification Model
ROM	Rough Order of Magnitude
SGSE	Software Ground Support Equipment
SRE-PA	Advanced Studies and Technology Preparation Division
SOC	Science Operation Centre
SM	Spare Model
SMM	Structural Mathematical Model
STM	Structural Thermal Model
SVM	Service Module
SWT	Science Working Team
TBC	To Be Confirmed
TBD	To Be Determined/Defined
TC	Tele Command
TM	Telemetry
TMM	Thermal Mathematical Model
UFOV	Unobstructed Field Of View
w/o	without

1. INTRODUCTION

PLATO is a M-class mission candidate of the European Space Agency's Science programme Cosmic Vision 2015-2025 foreseen to be launched by end 2018. "PLAnetary Transits and Oscillations of stars" aims to characterise exoplanetary systems by detecting planetary transits and conducting asteroseismology of their parent stars. PLATO is currently in the Definition Phase. Two phase-A/B1, parallel industrial studies with 18-months durations are being conducted as described in the Statement of Work (see [RD01]). The objectives of these studies are to define a baseline spacecraft concept that accommodates the payload and satisfies the science requirements, while minimising complexity and risk and meeting the applicable programmatic constraints.

2. SCOPE OF THE DOCUMENT

The PLATO EID-A defines the formal requirements on engineering design, ground and flight operations and programmatic requirements between ESA, the PLATO Consortium..

The EID-A shall specify in particular:

- the detailed electrical, mechanical and thermal interfaces between the payload and the spacecraft.
- the design verification programme which shall be implemented to demonstrate the Payload's compliance with the mission environmental requirements.
- the resources allocated to the PLATO payload.
- the management and programmatic interface requirements the Consortium has to fulfil.
- the share of tasks between the Contractor and the Consortium w.r.t. the Payload Module (PLM).
- the deliveries from the Consortium to the Contractor via ESA.
- the elements of the PLM that shall be procured by the Contractor.
- the expected deliveries from the Contractor to the Consortium via ESA.

The EID-A will be released as part of the Payload Announcement of Opportunity (AO).
The purpose of the document is to ensure that:

- The Consortium designs the instrument within the technical constraints imposed by the PLATO spacecraft and compatible with the PLATO programme constraints.
- The Contractor designs the spacecraft such that the instrument can be successfully integrated into the system.
- The spacecraft can be successfully launched and operated to achieve the scientific objectives of the PLATO mission.

The EID-A contains the interface specifications that are applied to the design of the P/L. It has been release as an interim documents and reports the technical maturity of the PLATO Payload. It will be updated in the frame of the Definition Phase of PLATO.

The Consortium will respond with the EID-B in the frame of the AO..

The EID-A and the EID-B will be updated and completed during the Definition Phase as result of iterations and agreements on technical and programmatic aspects between ESA, the Consortium and the Contractor. ESA wll ensure technical and programmatic consistency between EID-A and EID-B, These documents will form the sole formal and binding document for all technical and programmatic agreements between ESA, the PLATO Consortium and related industrial partners.

3. KEY PERSONNEL AND DOCUMENT ARCHTITECTURE

The programme envisages three major organisations: ESA, the Consortium and the Contractor. The key people are identified here-after.

3.1 Personnel

3.1.1 ESA Personnel

Address

ESA/ESTEC
PO Box 299
2200 AG Noordwijk
The Netherlands

Generic Email: FirstName.FamilyName@esa.int

Name	Responsibility	Contact Information
Left blank intentionally		

For ESA personnel responsibilities see section 14.3.

3.1.2 Consortium Personnel

Name	Responsibility	Contact Information
Left blank intentionally		

For Consortium personnel responsibilities see section 14.2.

3.1.3 Contractor Personnel

Name	Responsibility	Contact Information
Left blank intentionally		

For Contractor personnel responsibilities see section 14.

3.2 Document Concept and Architecture

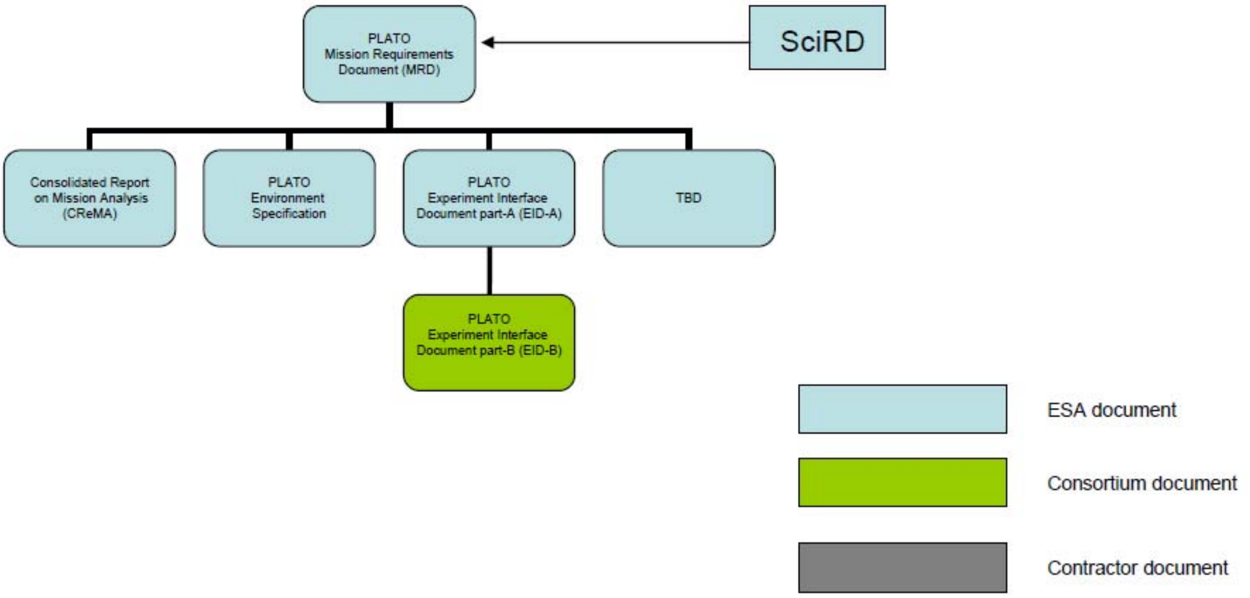

Figure 3-1: Preliminary PLATO Study document structure.

The Figure 3-1 can be updated when necessary. The documents from the Contractor will be inserted during the Definition Phase.

4. SCIENTIFIC REQUIREMENTS

The science objectives and requirements are formally listed in the PLATO Science Requirements Document (SciRD) [RD02], and are described below for information. In case of disagreement, the SciRD takes precedence.

4.1 Scientific objectives

PLATO is the next generation planetary transit experiment; its objective is to characterize exoplanets and their host stars in the solar neighbourhood. While it builds on the heritage from CoRoT and Kepler, the major breakthrough to be achieved by PLATO will come from its strong focus on bright targets, typically with $m_V \leq 11$. The PLATO targets will also include a large number of *very bright and nearby stars*, with $m_V \leq 8$ (see also [RD02]).

The prime science goals of PLATO are:

- the detection and characterization of exoplanetary systems of all kinds, including both the planets and their host stars, reaching down to small, terrestrial planets in the habitable zone;
- the identification of suitable targets for future, more detailed characterization, including a spectroscopic search for biomarkers in nearby habitable exoplanets;
- a full characterisation of the planet host stars, via asteroseismic analysis: this will provide us with the masses, radii and ages of the host stars, from which masses, radii and ages of the detected planets will be determined.

These ambitious goals will be reached by ultra-high precision, long (few years), uninterrupted photometric monitoring in the visible of very large samples of bright stars, which can only be done from space. The resulting high quality light curves will be used on the one hand to detect planetary transits, as well as to measure their characteristics, and on the other hand to provide a seismic analysis of the host stars of the detected planets, from which precise measurements of their radii, masses, and ages will be derived. For the brightest targets, planets are also expected to be detectable through the modulation of stellar light reflected on the planet surface, and/or through the astrometric wobble induced on the star by the planet orbital motion.

The PLATO space-based data will be complemented by ground-based follow-up observations, in particular very precise radial velocity monitoring, which will be used to confirm the planetary nature of the detected events and to measure the planet masses.

The full set of parameters of the systems with detected exoplanets will thus be measured, including all characteristics of the host stars and their orbits, radii, masses, and ages of the planets. Measurements of the radii and masses will be used to derive the planet mean densities and therefore will give insight on their internal structure and composition. The orbital parameters, together with the precise knowledge of all characteristics of the host star, will enable us to estimate the temperature and radiation environment of the planets. Finally, the knowledge of the age of the exoplanetary systems will allow us to put them in an evolutionary perspective.

4.2 Scientific Performance

4.2.1 Science product

The basic PLATO science product will be a very large sample of ultra-high precision stellar light curves in white light, obtained on very long time intervals (up to 3 years) and with very high duty cycle (≥90%, see section 4.2.5 for detailed duty cycle requirements).

In addition, part of the payload should provide photometric time series in at least two separate broad bands. This would be used in particular to constrain the identification of the detected oscillation modes in bright classical pulsators. The photometric bands must be separated in such a way that the photon flux integrated in the common wavelength range represents less than 10% of the total photon flux. Less than 50% of the photons are allowed to be lost due to this broadband photometry.

PLATO must also provide relative astrometric measurements of the targets of the bright samples P1, P2, P3 in all phases of the mission (see below for sample definition). These astrometric measurements will allow us to search for giant planets, through the detection of the associated star wobble, and will also be used to identify false positives, due for instance to background eclipsing binaries. Astrometric measurements may also be used to evaluate a posteriori instrument jitter properties.

4.2.2 Photometric precision and number of targets

The main requirement is to obtain a photometric precision better than 2.7×10^{-5} in one hour for more than 20,000 cool dwarfs and subgiants, later than approximately F5 (sample P1), to be monitored continuously for 2 to 3 years.

Additionally, PLATO will also have to monitor more than 1,000 cool dwarfs and subgiants brighter than m_V=8 continuously for 2 or 3 years (sample P2), and more than 3,000 such stars for more than a few months in the step&stare phase (sample P3), at a noise level better than 2.7×10^{-5} in one hour.

It is also required that monitoring at a noise level better than 8.0×10^{-5} in one hour of more than 250,000 cool dwarfs and subgiants down to approximately m_V=13 (sample P4) shall be performed.
In addition to these goals, the number of cool dwarfs and subgiants down to m_V=11 must be maximized, as these are the stars for which groundbased radial velocity follow-up will be most effective.

In order to reach these goals, PLATO will monitor two successive very wide fields, one for 2 or 3 years, the other one for 2 years. These two long monitoring sequences will be followed by a one- or two-year step&stare phase, during which a number of fields will be monitored for several months each. This step&stare phase will bring flexibility to the mission, allowing for instance to survey a very large fraction of the whole sky (up to 25% depending on the selected concept), as well as to re-visit particularly interesting targets identified during the long monitoring phases. Provision for a third 2-year monitoring phase must be planned, either at the end of the mission, or just before the step&stare phase.

4.2.3 Duration of the monitoring

The baseline duration of the nominal science operations is 6 years in the operational orbit, which consists of a long-duration observation phase (total 4 or 5 years) and a step&stare phase (1 or 2 years). The extended science operations would last an additional 2 years.

During the long-duration observation phase, monitoring duration of the first field is 2 (goal 3) years. The monitoring duration of the second field, is 2 years.

The step&stare phase must have a duration of 1 or 2 years, depending on the duration of the first long-duration pointing. During this phase, previously monitored fields, as well as additional fields, will be surveyed for at least 2 months and up to 5 months each. In addition, further visits of the previously surveyed fields will be organized in an optimized way to study long period exoplanets (several years), and will possibly occur at any time during the step&stare phase.

4.2.4 Sampling time

The sampling time for intensity measurements of stellar samples P1, P2 and P3 must be shorter than 50 sec. The sampling time for intensity measurements of stellar sample P4 must be shorter than 10 min, and shorter than 50 sec after a first transit detection, for a precise timing of further transits. The sampling time for relative astrometric measurements of stellar samples P1, P2 and P3, must be shorter than 10 min.

4.2.5 Duty cycle

Gaps longer than 10 minutes must represent less than 7% (goal 5%) of the total observing time per target, for the longest observation period (3 years).

Periodic gaps of any duration must represent less than 5% (goal 3%) of the total observing time, and less than 2% at any given frequency in Fourier space, over periods of 5 months.

The total amount of gaps, periodic or non periodic, of any duration, must represent less than 10% (goal 5%) of the total observing time over periods of 5 months.

4.2.6 Non-photonic noise

All sources of noise other than photon noise of the target must remain at least 3 times below photon noise of the target, at least for stars of sample P1, in the frequency range 0.02-10 mHz. Below 0.02 mHz, the non photonic noise level is allowed to rise gradually, to reach a maximum of 50 ppm per $(\mu Hz)^{1/2}$ in Fourier amplitude space at a frequency of 3 μHz, for stars with $m_V = 11$.

4.2.7 Colour information

Part of the payload should provide photometric time series in at least two separate broad bands. The photometric bands must be maximally separated, in such a way that the photon flux integrated in the common wavelength range represents less than 10% of the total photon flux. Less than 50% of the photons are allowed to be lost due to this broadband photometry. The number of targets from sample P2 for which this colour information is available must be larger than 300. The provisions for colour information, as well as the number of coloured targets, are goals rather than firm requirements.

5. MISSION DESCRIPTION

5.1 Mission Overview

The PLATO mission will start by the end of 2018. The spacecraft will be launched a Soyuz 2-1b launch vehicle with Fregat-MT upper stage on a direct transfer into a large-amplitude libration orbit around the Earth-Sun Lagrange Point 2 (L2 point).

Once in the operational orbit, the spacecraft will conduct at least two long-duration observations, each on a different sky field, for several years per field. Afterwards is an additional phase in which targets of specific interest will be observed for several months, for up to 2 years. The nominal mission duration in the operational orbit is six years, with a possibility to extend for two additional years.

During observations, the spacecraft must maintain the same line-of-sight (LoS) towards a field for up to several years. However, the spacecraft must be periodically repointed in order to ensure the solar arrays are pointed towards the Sun. This is achieved by rotating the spacecraft around the LoS 90° every 3 months. This strategy is illustrated in FIG.

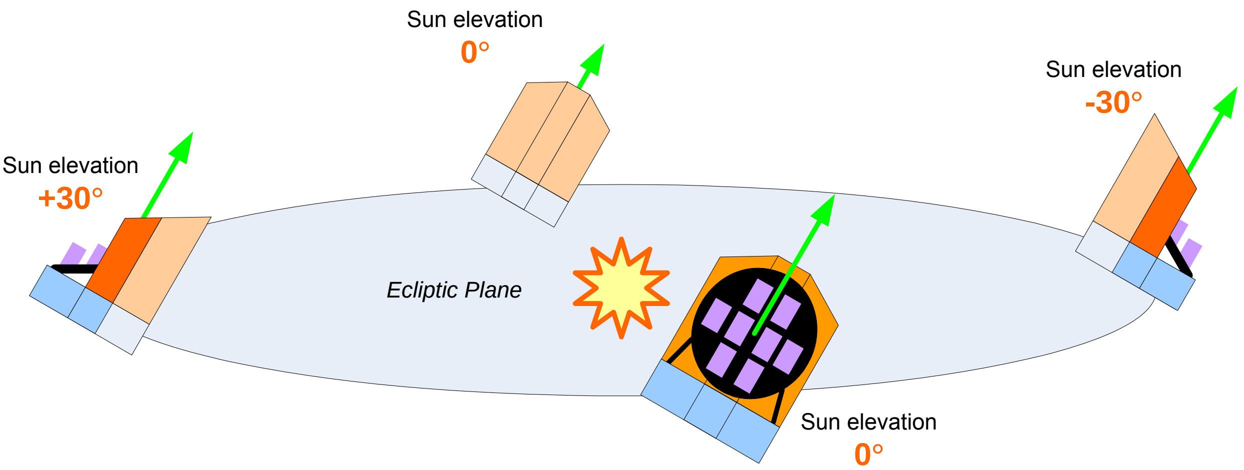

Figure 5-1: PLATO Observation and Rotation Strategy

Another major driver is the high pointing accuracy required during observations. The main requirement is that the relative pointing error (RPE) is at most 0.2 arcsec (1σ) over timescales of between 2.5 seconds and 14 hours.

The spacecraft can support maximum three days without ground contact while fulfilling the objectives.
The spacecraft can survive maximum seven days in Survival Mode.

5.2 Spacecraft Elements

The spacecraft is divided into three main elements, shown in Figure 5-2:

- **Payload Module** (PLM): contains the instruments on an optical bench, and generates/conditions the science data that is passed to the Service Module
- **Service Module** (SVM): supports the PLM by providing structural support, command and data management, attitude and orbit control, thermal control, communications, and power generation, conditioning and distribution.
- **Sunshield**: protects the instruments from the sun and other sources of straylight.

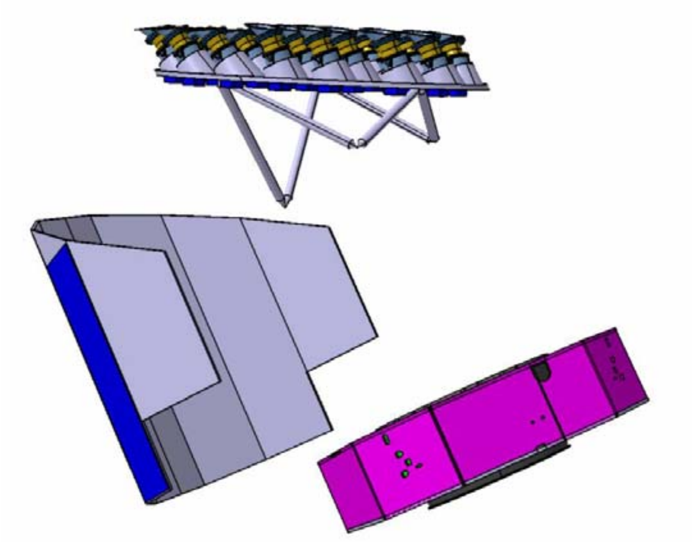

Figure 5-2: Exploded view of the three PLATO elements

5.3 Mission Phases

The PLATO mission has the following main phases, which are illustrated in Figure 5-3.

- LEOP
- Transfer Phase
- Commissioning Phase
- Nominal Science Operations Phase (6 years)
  - Long-Duration Observation Phases
  - Step-and-Stare Phase
- Extended Science Operations Phase (optional, 2 years)

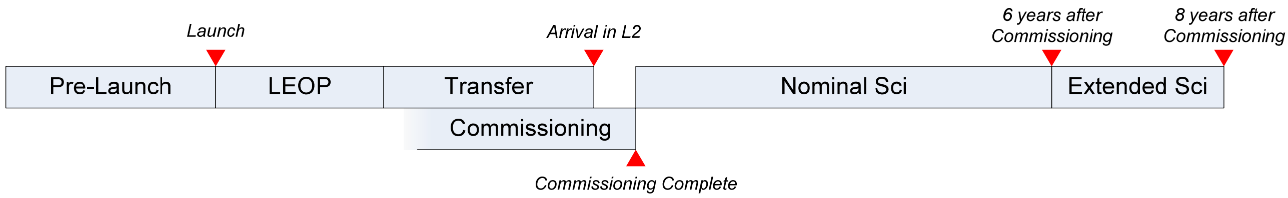

Figure 5-3: Mission Phase Timeline (phases not to scale)

5.3.1 Pre-launch Phase

This phase encompasses all pre-launch operations, starting several weeks before launch (the launch campaign). Activities include the final launch simulations, data flow tests, battery reconditioning (if necessary), filling of the propellant tanks, etc. The Pre-launch Phase ends with the lift-off event.

5.3.2 Launch and Early Orbit Phase (LEOP)

This phase follows the Pre-launch Phase and commences at launch (vehicle lift-off). It includes the ascent phase and injection into the transfer (cruise) trajectory into L2. The LEOP phase ends after the upper stage is separated.

5.3.3 Transfer & Commissioning Phases

The Transfer Phase starts immediately after the LEOP Phase is completed, and ends when the spacecraft reaches the operational orbit around L2. The Transfer Phase duration should be 30 days or less.

The Commissioning Phase starts during the Transfer Phase and runs in parallel. During this phase, the spacecraft functions are tested and verified, and the science instruments are calibrated and their performances are checked to ensure they can fulfil the scientific objectives of the mission. The spacecraft shall complete the Commissioning Phase less than two months after (goal: at the same time as) the end of the Transfer Phase and arrival in the operational orbit.

The Commissioning Phase ends only when:

- The spacecraft is in the operational orbit
- All spacecraft functions have been checked-out
- All science instrument functions have been checked-out and calibrated.

5.3.4 Science Operations

The Nominal Science Operations Phase starts after the completion of the Commissioning Phase and includes the spacecraft useful lifetime up to the end of scientific observations. The Nominal Science Operations Phase consists of two sub-phases:

- Long-Duration Observation Phase
- Step-and-Stare Observation Phase

In the Long-Duration Observation Phase, fields are observed for 2 years each (goal 3 for the first field). During this Phase, the spacecraft rotates 90° once every 3 months, in order to reorient the solar panels to the Sun. In the Step-and-Stare Observation Phase, fields are observed for between 2 and 5 months, while the Sun is in a favourable direction (defined as one that is compatible with a sunshield sized for the Long-Duration Observation Phase).

The Extended Science Operations Phase starts after the completion of the Nominal Science Operations Phase, and continues for up to 2 years.

5.4 SVM Description

This section describes the Service Module (SVM) as described in the CDF "PLATO DE" report. This represents the latest iteration of the spacecraft, taking into consideration the new payload and new/modified mission requirements. Further iterations to this design will be performed in the upcoming Definition Phase by industry.

5.4.1 Coordinate System

The spacecraft reference frame is defined by an origin point and three orthogonal axes (X_{SC}, Y_{SC} and Z_{SC},) with the following characteristics:

- Origin in the geometrical centre of the separation plane between the launch adapter and the spacecraft
- $+Z_{SC}$ coincident with the symmetry axis of the launcher
- $+X_{SC}$ is in the direction of the highest point of the sunshield.
- $+Y_{SC}$ is the remaining direction of the right hand orthogonal triad

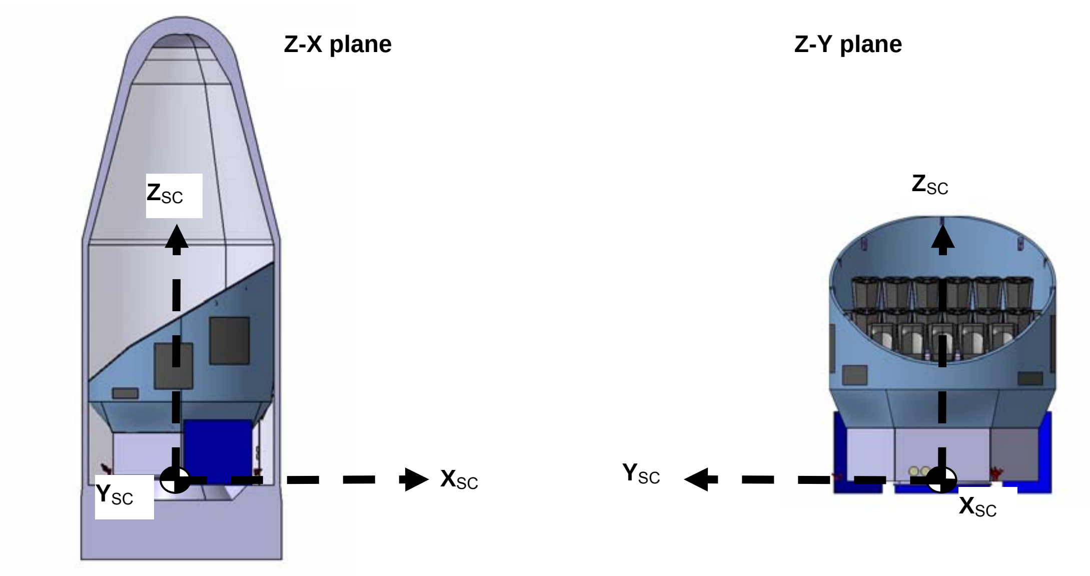

Figure 5-4: PLATO reference frame. The spacecraft shown is only to illustrate the coordinate reference frames and does not imply any specific design features.

5.4.2 Structures and Configuration

The SVM contains the supporting subsystems and provides structural interfaces to the Sunshield, PLM, and the launcher. The SVM design proposed by TAS in the Assessment Phase is shown Figure 5-5, and consists of a central thrust cone and eight shear panels. The components are mounted on the side panels, which also act as radiative surfaces to reject excess heat from these components.

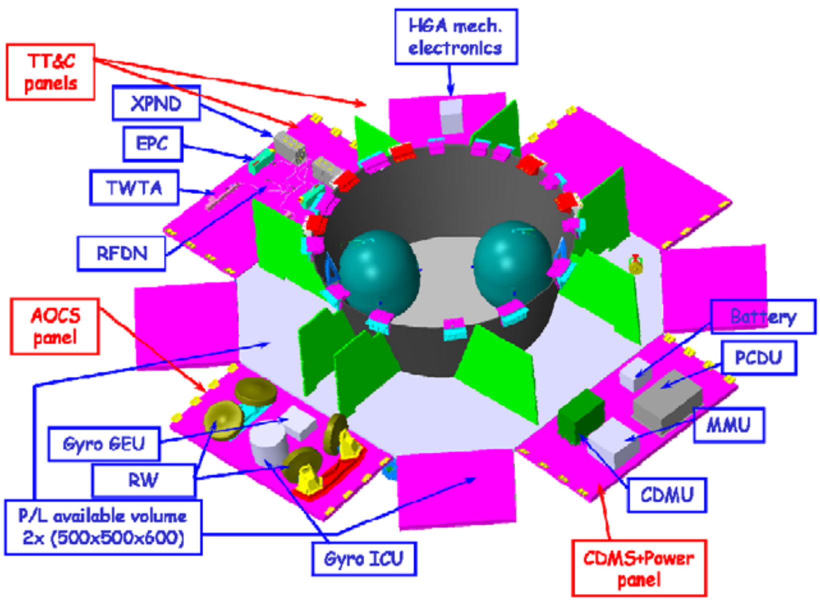

Figure 5-5: PLATO SVM

ESA UNCLASSIFIED – For Official Use

The Sunshield protects the instruments from sunlight and straylight. It consists of seven panels which form a quasi-semicircular shape around half of the spacecraft, from the +Y to –Y sides, with the highest point of the sunshield on the +X side. The sunshield panels extend to the bottom of the SVM, and the solar panels are mounted only on the sunshield. On the +Y and –Y sides, the sunshield is cut at the SVM top, so the SVM panel can be used as a radiative surface for installed components. Figure 5-6 illustrates the sunshield.

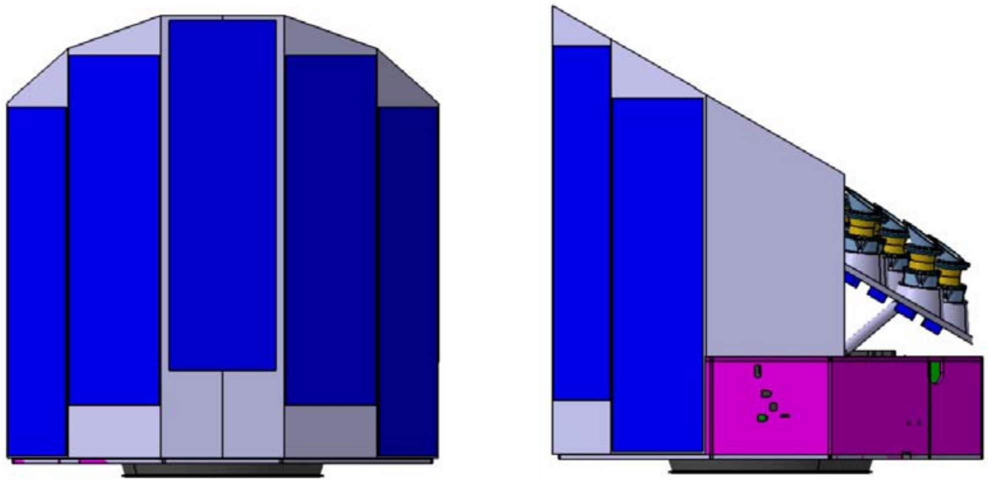

Figure 5-6: PLATO Sunshield: front view (left), side view (right)

The spacecraft is designed in a modular way so that the SVM, PLM and sunshield can be individually integrated and tested. There is an AIV requirement that states that the cameras and/or instruments can be mounted or dismounted individually throughout the integration process, without having to dismount other telescopes, the optical bench, or the sunshield.

Thermal Control of the SVM is achieved by covering the outer surfaces with MLI, while leaving some sections open to space to provide radiative surfaces to reject waste heat. In the cold case (particularly when the panel is not illuminated by the Sun), component temperatures are maintained by heaters. The SVM, PLM and Sunshield are thermally isolated from each other as much as possible.

5.4.3 AOCS

The AOCS ensures the strict pointing requirements are met during science operations. Primary fine guidance is provided by two “fast” cameras in the payload, and control actuation is performed by four reaction wheels. Other sensors supporting the AOCS include:

- 2 Star Trackers, used for reacquisition of pointing after science operations are suspended
- 2 Sun Acquisition Sensors, for initial deployment, cruise and safety monitoring
- 2 Coarse Rate Gyro, for safe mode and rate anomaly detection
- 1 Gyro package, for rate measurement during observation mode.

At all times, the AOCS prevents the spacecraft from reaching “unsafe” attitudes where either insufficient power is generated, spacecraft thermal control is compromised, or instruments are illuminated by the Sun.

5.4.4 Propulsion

The propulsion subsystem performs the following tasks:

- Provide attitude control during all mission phases after launcher separation
- Perform correction manoeuvres during the LEOP and Transfer Phase
- Perform orbital maintenance manoeuvres during the Nominal and Extended Science Operations Phases to maintain the quasi-stable orbit around L2
- Periodically desaturate the onboard reaction wheels

The baseline design uses monopropellant hydrazine for all manoeuvres. For large manoeuvres (launcher dispersion correction), a set of 2+2 20-N thrusters is used. In the operational orbit, a set of 6+6 1-N thrusters are used to desaturate reaction wheels, perform orbital maintenance, and perform other slew manoeuvres.

5.4.5 Electrical Power Subsystem

Electric power is generated by a series of five solar panels which are directly mounted on the sunshield, with a total area of 12.5 m^2. The solar panels are controlled by MPPT, which delivers regulated power to the spacecraft bus and the battery. The total power consumption of the spacecraft (SVM and PLM) is roughly 1700 W during science operations.

5.4.6 Communications

Primary communications are performed via a 0.3 m High Gain Antenna (HGA), operating in X-band for both up- and downlink. The HGA is steerable with two degrees of freedom. Contingencies and low data rates are handled by omnidirectional antennas, also in X-band.

During Nominal and Extended Science Operation Phases, the spacecraft communicates with Earth during a daily window of 4 hours (3.5 hours for up/downlink, 0.5 hrs for ranging). The maximum downlink data rate (science + housekeeping) is 8.72 Mbps.

5.4.7 Control and Data Management System

Central processing for the platform is performed by a single CDMU, with heritage from GOCE. It performs the following tasks:

- Telemetry acquisition, encoding, and formatting
- Telecommand acquisition, decoding validation, and distribution
- Data storage
- Time distribution and time tagging
- Autonomy supervision and management
- On Board Control Procedure Management (OBCP) functions

It does not perform any science data processing. The CDMU includes an internal memory of 2 Gb for housekeeping and other platform telemetry.

Science data is transferred from the Payload ICU to the Mass Memory Unit (MMU), based on that used in Herschel. The MMU has capacity for three days' worth of science data (approx. 330 Gb). It interfaces directly with the ICU to save science data without involvement of the CDMU, and then transfers the data to the communications system when ready for downlink.

5.5 Ground Segment

The ground segment consists of the following:

- Mission Operations Centre (MOC)
- Science Operation Centre (SOC)
- Ground Stations

The MOC is responsible for spacecraft operations after launch, including mission planning, spacecraft monitoring and control, and orbit and attitude determination and control. It controls all communications to and from the spacecraft.

The SOC receives all telemetry from the MOC, and is responsible for instrument characterisation and calibration. It is responsible for analysing science data, data reduction, and production of the final scientific products. It also prepares the Science Operation Plan and provides detailed operational requests to the MOC.

The ground stations used are part of the ESTRACK network. During science operations, the 35-m ESA station at New Norcia will be used for contact with the spacecraft. Other smaller antennas (15-m class) are used during LEOP, Transfer and Commissioning.

6. PLM TECHNICAL DESCRIPTION AND DESIGN

6.1 General Architecture

The Payload Module (PLM) shall include the full set of Instruments, optical bench, supporting structures and the hardware thermal control. Specifically the PLM shall include:

Set of Normal Instruments which consists of:
- 32 Telescopes
- 32 FPAs
- 32 FEEs
- 8 MEUs each containing 4 Normal DPUs
- 4 AEUs
- 2 ICUs
- Instrument-related interconnecting harness
- Instruments to SVM interconnecting harness

The Normal Instruments above are grouped into 4 sub-groups, each of which consists of:
- 8 Telescopes
- 8 FPAs
- 8 FEEs
- 2 MEUs each containing 4 Normal DPUs
- 1 AEU
- Instrument-related interconnecting harness

The four sub-groups interface with two (cold-redundant) ICUs, which then interfaces with the SVM.
Set of Fast Instruments which consists of:
- 2 Telescopes
- 2 Fast FPAs
- 2 Fast FEEs
- 2 Fast DPUs
- 1 Fast AEU
- 2 ICU shared with Normal Instruments
- Instrument-related interconnecting harness
- Instruments to SVM interconnecting harness

Optical Bench (OB)
The OB is a structure to (but not limited to):
- support a fully integrated sub-assemblies constituted by the Telescope and Detection System (DS) i.e. the cameras
- provide mechanical interface with the SVM
- provide PLM passive thermal control

The electrical architecture is shown in Figure 6-1 and Figure 6-2 and described in detail in section 6.2.4.

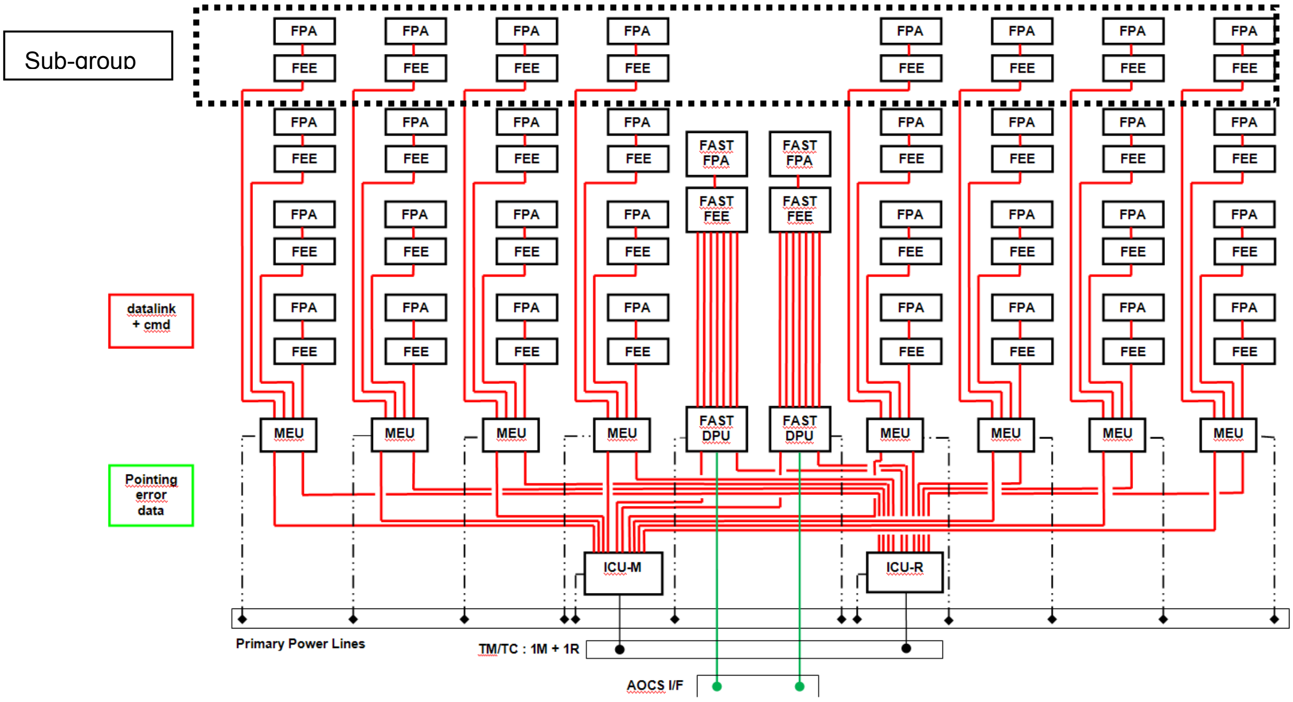

Figure 6-1: Electrical Architecture – Data & Command Interfaces.

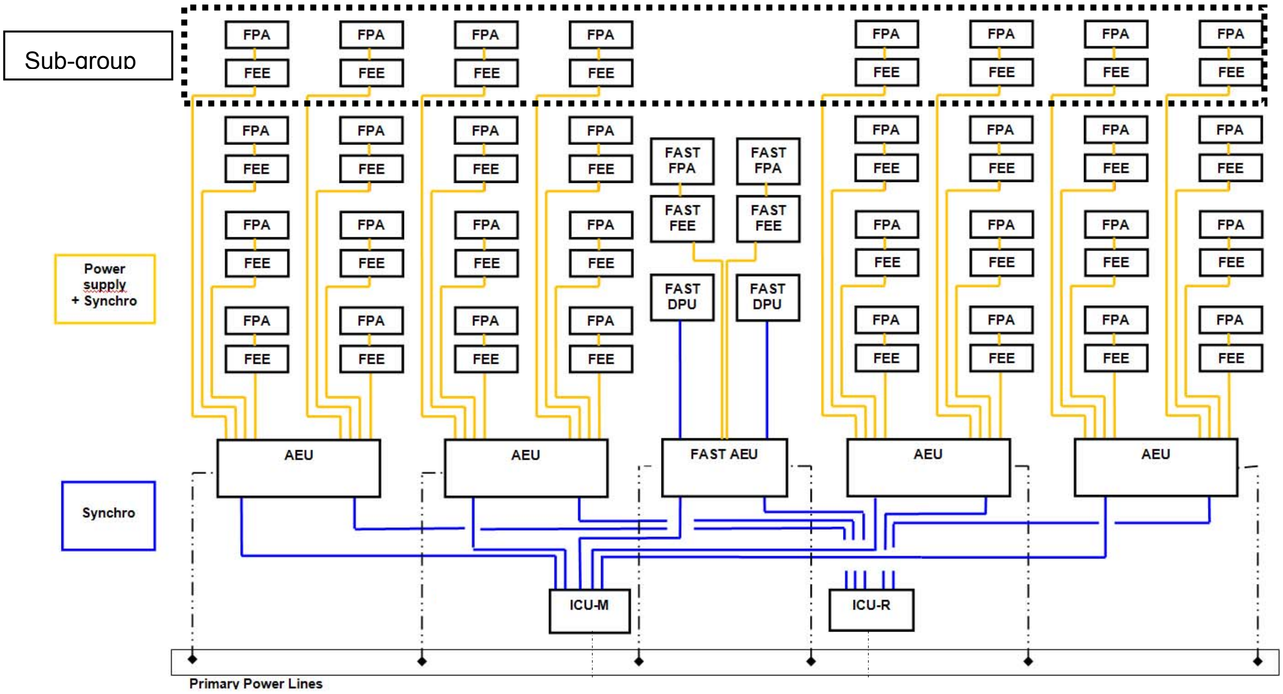

Figure 6-2: Electrical Architecture – Power & Synchronisation.

Figure 6-3 gives an indication of the cameras as mounted on the OB. Note: this is just for indication. As mentioned hereafter the OB shall be designed by the Contractor.

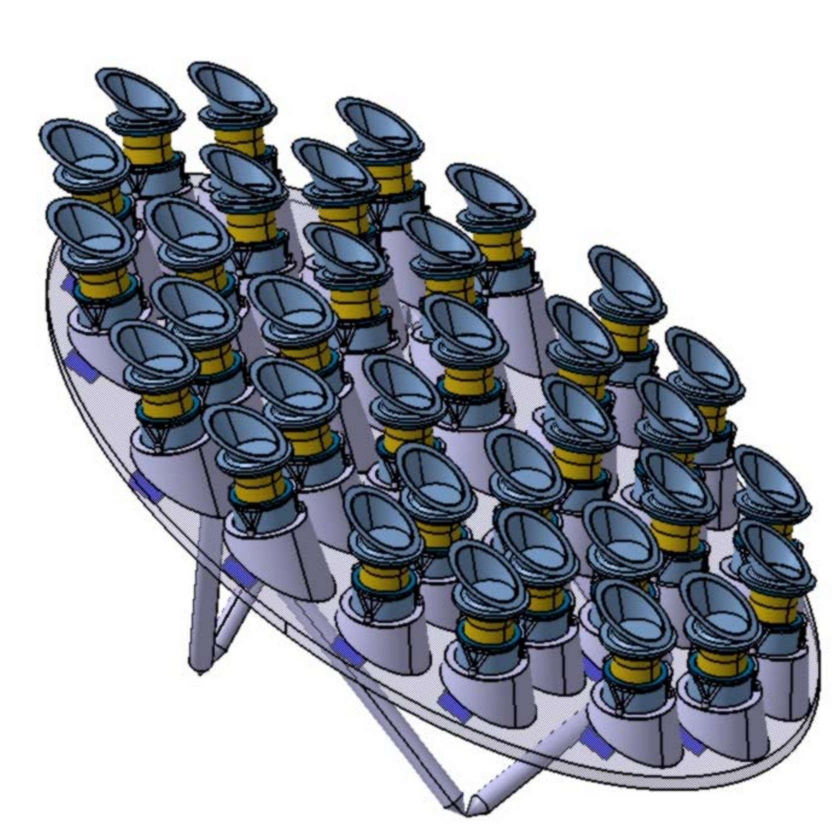

Figure 6-3: Cameras mounted on the OB. Only for reference.

6.2 Technical description

6.2.1 General

The instrumental concept proposed by the PLATO Payload Consortium is based on a multi-camera approach, involving a set of several normal instruments monitoring stars fainter than m_V=8, plus a low number of fast instruments observing extremely bright stars with magnitudes brighter than m_V=8.

The telescope is based on a fully dioptric design, working in an extended visible light range. It has been designed to reach a very large field, with respect to a sufficient pupil diameter.

The 32 normal cameras are arranged in four sub-groups of 8 cameras. All 8 cameras of each sub-group have exactly the same field of view, and the lines of sight of the four sub-groups are offset by 35% (~13°; see 7.8.1). This particular configuration allows surveying a very large field at each pointing, with various parts of the field monitored by 32, 16 or 8 normal cameras.

This strategy optimizes both the number of targets observed at a given noise level and their brightness. It is assumed that the satellite will be rotated around the mean line of sight by 90° every 3 months, resulting in a continuous survey of exactly the same region of the sky.

Each camera is equipped with its own CCD focal plane array, comprised of 4 CCDs, working in full frame mode for the normal cameras, and in frame transfer mode for the fast cameras (see Figure 6-4). The CCD working temperature is lower than -70°C.

Each FPA is associated to a Front End Electronics (FEE). The camera (after Instruments tests) is then delivered for PLM AIT with its FEE box attached to the rest of the camera by a temporary structure which shall be removed during the integration of the camera on the optical bench. The camera is delivered with FEE and FPA connected together by their flexi-cables. For safety reasons, these links shall never be disconnected after the delivery of the camera to PLM.

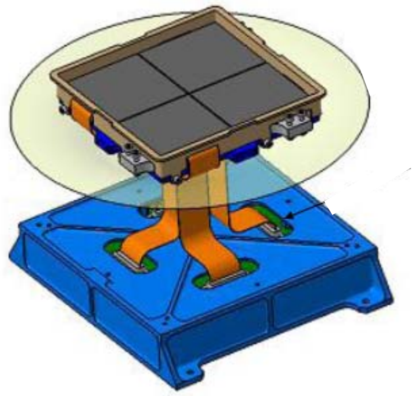

Figure 6-4: Schematic of the FPA.

There is one DPU per camera performing the basic photometric tasks and delivering a set of light curves, centroid curves and imagettes to a central Instrument Control Unit (ICU), which stacks and compresses the data, then transmits them to the SVM for downlink. Data from all individual telescopes are transmitted to the ground, where final instrumental corrections, such as jitter correction, are performed. The DPUs of the fast telescopes will also deliver a periodic pointing error signal to the AOCS. Several photometry algorithms (plain aperture photometry, weighted mask photometry, Line Spread Function fitting) are planned to run on board, each star being allocated one of them, depending on its brightness and level of confusion.

6.2.2 Optical architecture

The optical concept of the telescope is based on a design with 6 fully centred, spherical lenses, except the first one which features an aspheric face. The inner pupil, which limits the measured photometric flux, is well delimited by a circular diaphragm.

Glasses are selected in the rad-hard glasses catalogue, to limit transmission variations during the life in orbit.

Each telescope is fit out with a baffle around the front lens with the following functions:

- Limit the field of view of the instrument (straylight)
- Avoid the view of the sunshield edge by the front lens (straylight)

- Limit the field of view of the first lens (front lens temperature)
- Evacuate by radiation the power dissipated by the FPA (the baffle is used as a radiator)

The working temperature of the optics is close to -80°C, in view of cooling down the FPA. Special care is taken to reduce as much as possible the axial or radial temperature gradients inside the lenses.

6.2.3 Thermo-mechanical architecture

The mechanical design assumes two separate locations for the instruments parts:

- the cameras are installed on the optical bench, following such a way to comply with the constraints resulting from the overlapping field of view accommodation: orientation of the different sub-groups, optical constraints, mechanical and thermal stabilities…
- the four Ancillary Electronics Units (AEU) boxes, one per sub-group of cameras, shall be located close to their corresponding sub-group, in such a way to limit the power and synchronisation cable lengths. They have to be fixed "under" the optical bench, with the main constraint of the evacuation of power and the temperature control.
- the Fast AEU shall be located close to the Fast FEE (fast cameras), for the same reason of cable length as the normal ones, and with the same constraints of power evacuation.
- the digital electronics boxes needed in the Normal Instrument: to limit the number of boxes, the DPUs are grouped with their power converter in a box called "Main Electronics Unit" (MEU). The MEU regroups the DPU boards used for a sub-group of cameras, and their power converter. We then have 8 MEU, each with 4 DPUs inside, and 2 ICU boxes (digital electronics and power converter) in cold redundancy, for the baseline accommodation. These boxes, MEUs as well as ICUs, can be located "far" from the cameras, somewhere in the PLM or in the SVM. The main constraints for the location selection of these boxes are their thermal management, and especially, their power evacuation, and the cable lengths between cameras and the electronics boxes, with their impact on the total mass.

The main functions of the thermal system for the camera are:

- to cool down the FPA under the required temperature, and maintain its temperature stability,
- to maintain the telescopes in a specified working range temperature with a low level of spatial and temporal gradients,
- to evacuate the power of the front-end electronics.

The stability of the instrument is based both on use of very stable materials or components, and temperature stability. To reach the required temperature stability needed in the instrument, the overall thermal concept is based on:

- Thermal consumptions of the equipments and then thermal dissipation as constant as possible on time scales higher than 25.0 s,
- And evacuation of the heat by radiation in direction of very stable thermal wells.

The only remaining variation of temperature is therefore resulting from the rotation of the Sun around the satellite, and special care, especially on the thermal coupling between sunshield and instruments, shall be taken to reduce temperature variations induce by this effect.

The thermal design has frozen a solution based on a telescope and FPA cooled by radiation in the optical axis direction. To this end, the telescope and FPA are highly connected together and with the optical baffle around the front lens, which is used as a radiator looking the sky, to evacuate the power coming from FPA and telescope. To limit the size of the baffle, the telescope shall then be highly isolated from the rest: conductively, from its FEE and the optical bench, and radiatively, from its environment and especially from the sunshield inner surface and the optical bench. Finally, to control the focussing of the camera (best possible PSF on the detectors), each telescope is fit out with heaters and temperature sensors, and then temperature controlled by a thermal line which shall be managed by the SVM. The SVM shall then provide a TBD number of independent thermal lines to the instruments for this use.

The FEE is thermally isolated at the best from its FPA (low conductivity cables). Its power shall be evacuated by the way of the optical bench, and its temperature control in the different flight modes shall be ensured by the SVM.

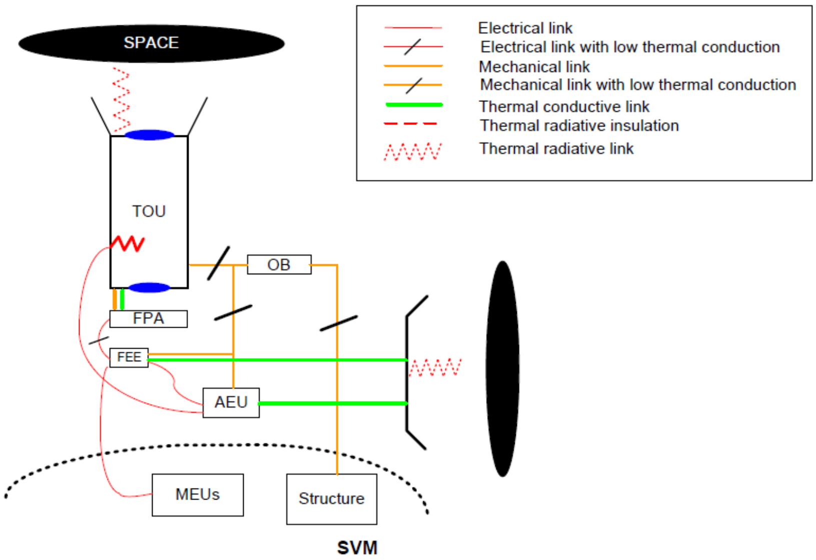

Figure 6-5: Thermo-mechanical architecture.

All the electronics boxes (MEUs, AEUs, Fast AEU, Fast-DPUs and ICUs) are temperature controlled by the SVM.

The description of these thermal interfaces and characteristics of the thermal lines are given further on in the thermal interface section.

6.2.4 Electrical architecture

The electrical system of the PLATO instrument is depicted in Figure 6-1 and Figure 6-2. These figures respectively focus on the data flow and command flow, on the clock/synchronization and power distribution.
The major electrical functions are included in the following subsets:

Table 6-1: Description of the electrical functions of the major sub-sets.

Equipment	Main function
Cameras (baseline 32+2)	Temperature control of the optics
Normal FPA (baseline 32)	4 full frame CCDs
Fast FPA (baseline 2)	4 frame transfer CCDs
Normal FEE (baseline 32)	Full frame CCD readout
Fast FEE (baseline 2)	Frame transfer CCD readout
Fast DPU (baseline 2)	Fast FPA data processing
AEU (baseline 4)	Power converter for normal camera, synchronisation signals distribution towards FEEs
Fast AEU (baseline 1) (including a cold redundancy)	Power converter for fast cameras, synchronisation signals distribution towards Fast FEEs

MEU (baseline 8)	Normal FPA data processing, power converter for its normal DPUs
ICU (2 in cold redundancy)	SVM data / command / housekeeping interface, synchronisation clock, power converter for itself.

6.2.4.1 Analogue electronics

The analogue functions are mostly dedicated to CCD readout. Due to high pixel rates these functions are located in the FEE units as close as possible to the FPA in order to avoid degradation of the detector performances caused for instance by distortion of the CCD phases and noise pick-up in the intermediate harnesses.

6.2.4.2 Digital electronics

Digital functions are implemented into several units: the image processing is firstly performed in the associated DPU (in MEU) and Fast-DPUs, and then, all processed images are transmitted to the active ICU for additional processing. Each MEU hosts also a SpaceWire router to merge the data from its DPUs. A second SpaceWire router is implemented in each ICU, this time to merge data from the MEUs and the Fast DPUs. When processed, the digital data are gathered by the ICU which is ultimately in charge of the generation of telemetry packets towards the SVM mass memory.

Note that one sub-group of 4 cameras are linked into one MEU and one sub-group of 8 cameras is linked into one AEU (see Figure 6-1 and Figure 6-2).

All command / data exchange between the units and with the SVM are then ensured thanks SpaceWire links except the AOCS link between Fast DPU and SVM (see Figure 6-1).

6.2.4.3 Clock and synchronization distribution

Due to the large number of detectors, it is mandatory to keep analogue electronics noise level compliant with instrument requirement, to avoid effect of electrical coupling either by conduction or by radiation. The best approach is to carefully synchronize the master clock using a SVM provided signal. Furthermore, internal synchronizations will be implemented (see Figure 6-2).

6.2.4.4 Power distribution

Power is provided with redundancies by the SVM to the AEUs, Fast AEU, MEUs, Fast DPUs and ICUs.

Power for the analogue electronics is distributed by the corresponding AEUs and Fast AEU. Each unit hosts a bench of independent DC/DC converters (one converter per camera).

Secondary power generation for other units (MEU, Fast DPU, ICU…) is performed locally in each unit.

6.2.5 Data treatment architecture

The PLATO payload data processing system is made up of several DPUs connected to two ICUs working in cold redundancy through a SpaceWire network. The ICUs are connected to the SVM through SpaceWire links.

Each camera is associated to its own DPU:

- There are 32 normal DPUs. Each normal DPU is responsible for processing the data of one normal camera. The processing cadence for normal DPUs is 25 sec.

- There are 2 fast DPUs. Each fast DPU is responsible for processing the data of one fast camera. The processing cadence for fast DPUs is 2.5 sec. For the fast cameras the fast DPUs are grouped in the fast AEUs.

The fast DPUs have a supplementary function: they are responsible for providing angle error measurements directly to the SVM AOCS.

The role of the ICU is to interface the communication between all DPUs and the SVM.

Figure 6-6 gives an overview of the PLATO data processing system architecture and of the data flow rates. This chart focuses on the sharing of the main functions and the data flows. It is a simplified view of the hardware architecture. The SpaceWire routers are not shown and the DPU assembly boxes (MEU) are not drawn.

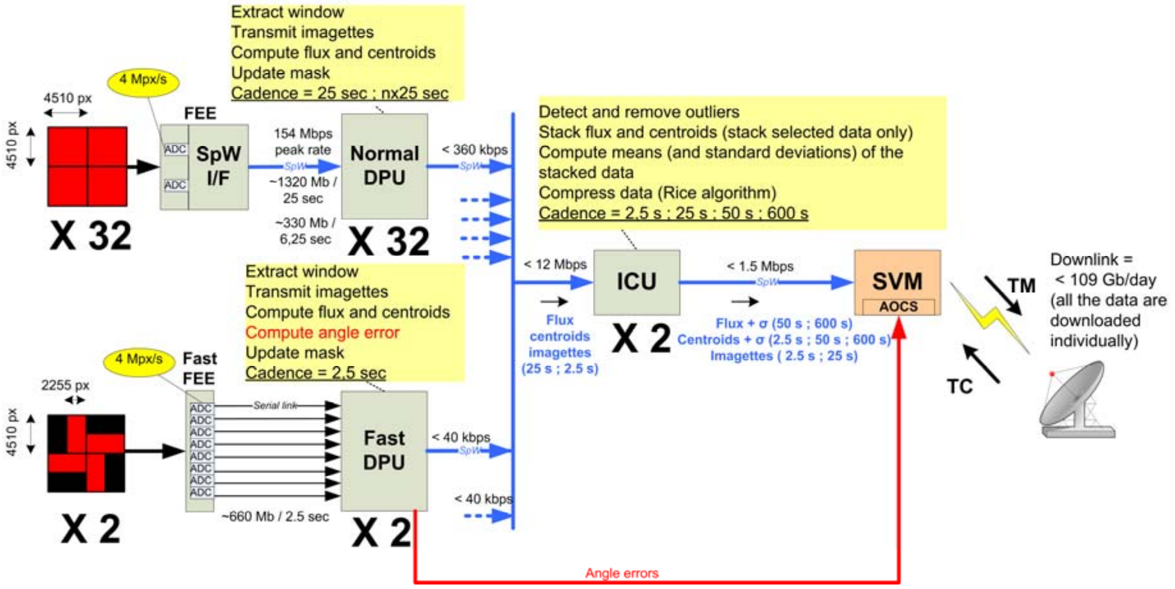

Figure 6-6: Data treatment architecture schematic.

6.2.5.1 INTERNAL Electrical INTERFACES

Internal interfaces are interfaces between units of the instrument. Depending on the location of the units the related interface harness may be either physically located entirely inside the PLM (e.g. between detector & analogue electronics) or split between PLM and SVM (e.g. between analogue electronics and digital electronics). The following table lists these interfaces:

Table 6-2: Internal interfaces from unit to unit

Interface Type	From	To	Interface Connectors	Comment
Image raw data	FPA	FEE	4	Flexi-cables
Image raw data	Fast FPA	Fast FEE	8	Flexi-cables
FEE raw data	FEE	MEU	2 (TBC)	SpaceWire link
MEU control / data transfer	ICU	MEU	2 (TBC)	SpaceWire link
Fast DPU control / data transfer	ICU	Fast DPU	2 (TBC)	SpaceWire link
Fast FEE raw data	Fast FEE	Fast DPU	8 (TBC)	High speed serial link

Power + synchronisation	AEU	FEE	2+1 (TBC)	
Power + synchronisation	Fast AEU	Fast FEE	2+1 (TBC)	
Synchronisation	Fast AEU	Fast DPU	1	
Synchronisation	ICU	AEU	1	
Synchronisation	ICU	Fast AEU	1	
Thermal monitoring	Camera	MEU	5 per Camera (TBC)	

6.2.5.2 EXTERNAL Electrical INTERFACES

External interface are interfaces between the instrument and the SVM equipments; it includes tele-command and telemetry interface as well as power supply interfaces. The following table lists these interfaces:

Table 6-3: External interfaces. Interface between Instruments and SVM from unit to unit

Interface Type	**From**	**To**	**Interface Connectors**	**Comment**
Power	SVM	MEU	2	
Power	SVM	Fast DPU	2	
Power	SVM	ICU	2	
Power	SVM	AEU	2	
Power	SVM	Fast AEU	2	
Instruments TM/TC	SVM	ICU	2	SpaceWire link
On Board Time	SVM	ICU	1	PPS I/F (**TBD**)
Pointing error data	Fast DPU	SVM (AOCS)	2	**TBD** serial I/F
Telescope thermal control	SVM	telescope	TBD connectors on SVM for 32 + 2 thermal lines	Thermal lines each including power to the heaters and feedback from temperature sensors.
TBD – Electronics boxes thermal control	SVM	electronics boxes	TBD	If needed for thermal reasons

7. INTERFACES DEFINITION

The Spacecraft will allocate resources to the payload related subassembly to be compliant with the interfaces requirements mentioned hereafter.

7.1 Definition of PLM Coordinate System

7.1.1 PLM reference frame

The coordinate reference frame for PLATO PLM is shown in Figure 7-1.

The origin is defined as the centre of the SVM/PLM interface plane.

+ Z_{PLM} is the longitudinal axis of the satellite, perpendicular to the SVM/PLM separation plane and oriented positively in the direction of pointing.

+X_{PLM} is in the direction of the highest point of the sunshield.

+Y_{PLM} is the remaining direction of the right hand orthogonal triad.

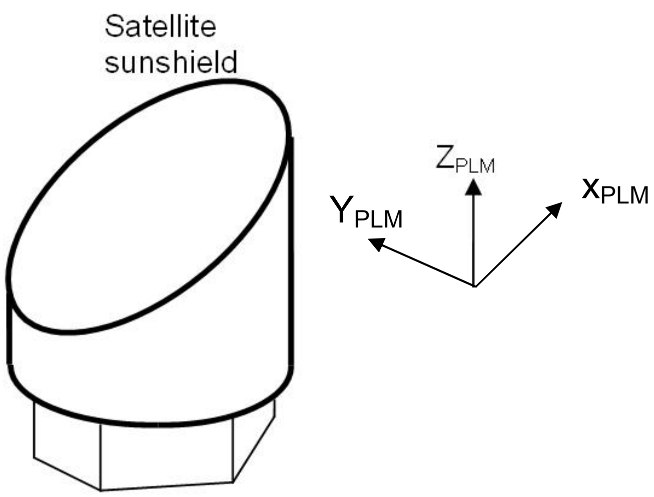

Figure 7-1: PLM Reference frame.

Note: The PLM reference frame is parallel to the spacecraft reference frame with origin moved to the point indicated above.

7.1.2 Camera reference frame

The camera reference frame is shown below (TBD). The origin is the centre of the camera/optical bench interface.

+Z_{CAM} is defined as optical axis of the camera, oriented positively in the direction of pointing.

$+X_{CAM}$ is oriented towards the orientation stud located at the middle of the reference foot
$+Y_{CAM}$ is the remaining direction of the right hand orthogonal triad
A Figure will be provided later.

Figure 7-2: Camera Reference Frame - TBD

N.B.: lines and columns of the CCDs are parallel or perpendicular to the transverse axes X_{CAM} and Y_{CAM}.

7.1.3 Electrical units reference frame

Each electrical unit shall have a reference frame attached to the box (see Figure 7-3):

The X axis is in the direction of the longest side of the box, in the fixation plane,

The Z axis is perpendicular to the fixation plate, oriented from the fixation plane to inside box,

The Y axis is the remaining direction of the right hand orthogonal triad (located in fact in the fixation plane).

The origin is at the intersection between the hole axis in the reference fixation foot, and the fixation plane

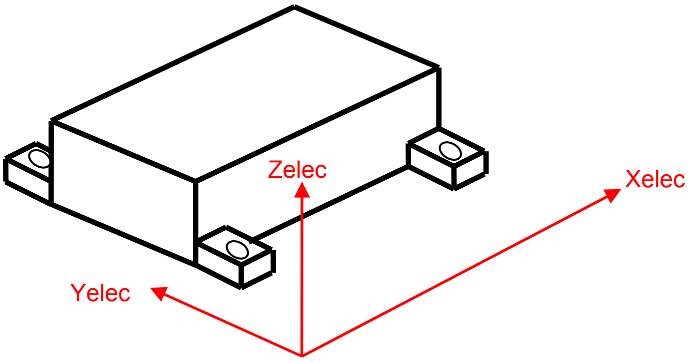

Figure 7-3: Electrical units reference frame.

7.2 Payload and Unit location

7.2.1 Overall PLM

The PLM shall be mounted on top of the SVM, in such a way that it remains in the shade of the sunshield at any time during the mission after lift-off. The PLM must be protected against Sun reflection on any appendix or surface.

7.2.2 Cameras

The locations of the cameras shall be such that the FoV of none of them is vignetted (considering the UFOV) by its neighbours or any part of the spacecraft (e.g. sunshield).

Cameras belonging to each sub-group of cameras will have to be accommodated close to each other (see Figure 6-1).

The useful FoV of a camera is a circle with diameter 37.0°, with nominal performances in the circular disk inscribed inside the square FoV, and lower optical performances in the FoV corners.

The unobstructed FoV (UFOV) of a camera is a cone centred on the optical axis, and with a half angle of 26°.

7.2.3 Electrical units

AEUs (one per sub-group) shall be located close to the cameras of the related sub-group (see Figure 6-2). The maximum allowed distance is TBD.

Fast AEU shall be located close to the Fast Cameras. The maximum allowed distance is TBD.

Fast DPUs shall be located close to the related Fast FEE (see Figure 6-2). The maximum allowed distance is TBD.

MEUs and ICUs can be located either in the PLM or the SVM

Note: The harness between the FPA and the FEE is a flexi-harness which is delivered with the camera. Its length is TBD.

7.3 Mechanical Interfaces

7.3.1 Dimensions and Mass

Table 7-1 provides the instrument nominal dimensions and maximum mass.

Table 7-1: Overall size and mass of the mechanical interfaces.

Unit	Dimensions L * W * H [mm3]	Max. mass per unit [kg]	Nb of identical units	Total Mass [kg]
Normal camera (w/o FEE)	See below	11.7	32	374.4
Fast camera (w/o fast FEE)	See below	11.9	2	23.8
FEE	TBD *TBD * TBD	0.8	32	25.6
FAST FEE	TBD *TBD * TBD	1.0	2	2.0
AEU	TBD *TBD * TBD	3.0	4	12.0
Fast AEU	TBD *TBD * TBD	1.0	1	1.0
DPS				28.2
MEU	TBD *TBD * TBD	2.7	8	
Fast DPU	TBD *TBD * TBD	1.5	2	
ICU	TBD *TBD * TBD	2.0	2	
TOTAL CAMERA (w/o FEE)				398.2
TOTAL ELECTRONICS				68.8
TOTAL				467.0
UNCERTAINTY (20%)				93.4
GRAND TOTAL				560.4

7.3.2 Camera mechanical interfaces

7.3.2.1 Camera mass properties

7.3.2.1.1 Mass

Normal Camera: see Table 7-1
Fast Camera: see Table 7-1

7.3.2.1.2 Centre of Gravity

To be provided later

7.3.2.1.3 Inertia

To be provided later

7.3.2.1.4 Eigen frequency

Eigen frequency (1^{st} mode) of all units in longitudinal direction when hard mounted (Z_{CAM} axis): > 140 Hz

Eigen frequency (1^{st} mode) of all units in transverse axes when hard mounted (X_{CAM} or Y_{CAM}): > 100 Hz

7.3.2.2 Camera overall dimensions

The camera fits into a cylindrical envelope with the following dimensions:

- Diameter (TBC): 340±10mm (incl. baffle/radiator)
- Overall length (TBC): 605±15mm (incl. baffle/radiator)

7.3.2.3 Interface schematic drawing

The fixation of each camera is ensured by a set of three bipods (feet) between the telescope tube itself and an interface plane on which it shall be fastened. This plane is considered as geometrically perpendicular to the optical axis of the camera (in fact, within the camera inner tolerances, whereby shims are foreseen to allow compensation).

Around the optical axis, the camera has reference pegs giving the orientation of the FPA, and then the CCDs and the field of view of the camera.

These interface data of the camera are given in the Figure 7-4

The mechanical interface of the camera is described in the following preliminary figure.

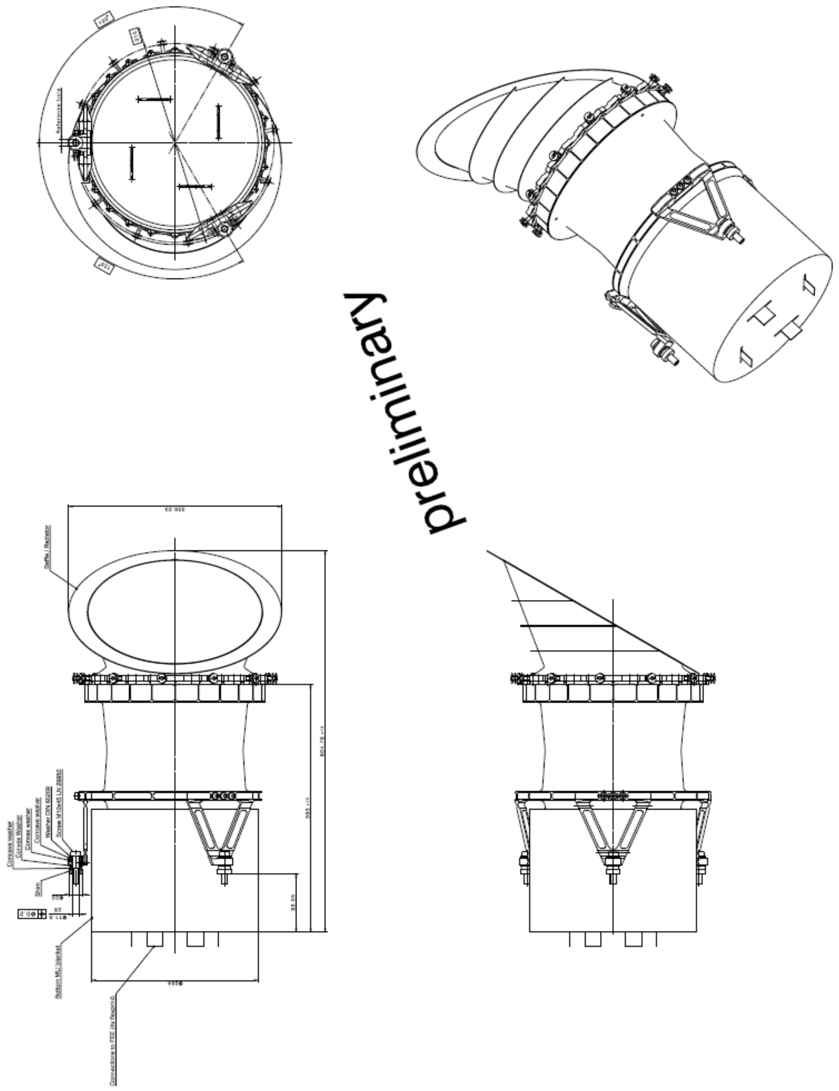

Figure 7-4: Camera Interfaces Drawings.

Note that the shape of the baffle and its orientation are fully linked to the sub-group to which the camera is belonging. In fact, the upper "cutting plane" of the baffle is a plane parallel to the sunshield plane (tilted by 60° wrt the LoS). The shape of the baffle then depends of the camera orientation (sub-group belonging), and there are therefore 4 different shapes of baffles for normal and 1 for fast cameras. The baffle shape and dimensions given in the figure above correspond to the baffle used in the fast camera.

The optical bench has to supply for each camera such a fixation plane, in accordance with the camera I/F, and with the following constraints:

- Flatness of the global surface: 0.02 mm (referred to the three insert/contact surfaces)
- Roughness Ra<0.8 (at the three insert/contact surfaces)

7.3.3 Electrical units mechanical interfaces

7.3.3.1 Electrical units mass properties

7.3.3.1.1 Mass

See Table 7-1

7.3.3.1.2 Centre of Gravity

To be provided later

7.3.3.1.3 Inertia

To be provided later

7.3.3.1.4 Eigen frequency

Eigen frequency (1st mode), all axes, when hard mounted: > 140 Hz

7.3.3.2 Electrical units overall dimensions

Will be provided later.

7.3.3.3 Interface schematic drawing

The mounting will include 4 screws of diameter M4 (**TBC**) for all units except MEU (6 points (**TBC**))

Minimum distance between 2 mounting points shall be higher than 45 mm.

Flatness of the interface plane: better than 0.1mm / 100mm

The contact surface shall be sufficient to ensure the thermal cooling by conduction.

7.4 Thermal Interfaces

7.4.1 Camera thermal interfaces

7.4.1.1 Temperature range

For the **camera** (except the FEE):

<u>Storage:</u>
15°C / +35°C (> dew point) in air. This range could be increased in other conditions

<u>Temperatures to be achieved during the mission:</u>
Non operational: -95°C / +35°C
Operational: -85°C / +35°C

Working temperature adjustable between -85°C / -75°C (**TBC**)

For the **FEE**:

Storage:
-40°C / +40°C

Temperatures to be achieved during the mission:
Non operational: -40°C / +40°C
Operational: -40°C / +30°C

During ground testing the Camera is compatible with normal clean room condition provided that the maximum temperature for the orbital case is not reached. The Camera will not reach nominal performance outside the operational conditions.

7.4.1.2 Temperature stabilities

Camera (except the FEE):

During the observation mode: +/- 0.1°C around the selected working temperature, over time scales shorter than 24 hours, with the possibility to increase this value to +/- 0.3 °C on longer time scales up to 3 months.

For the FEE:

During the observation mode: +/- 1°C around the selected working temperature, over time scales shorter than 24 hours, with the possibility to increase this value to +/- 3 °C on longer time scales up to 3 months.

7.4.1.3 Thermal insulation

To limit the thermal flux which coming from the optical bench heats the camera, the thermal resistance between the optical bench and the camera bipods interface shall be controlled.

The spacecraft shall provide a thermal insulation between the mounting surface of the bipods and the bipod interface of a maximum conductance of 0.015 W/K, e.g. by means of washers.

The spacecraft shall not introduce by radiative coupling a heat-load above TBD W onto each single camera.

The stability of the radiative load shall be better than TBD mW/day for time scales shorter than 24 hours and better than TBD mW/day on longer time scales up to three months.

7.4.2 Electrical units interface

7.4.2.1 Temperature range

These requirements are applicable to the Temperature Reference Point which will be defined for each unit.

Storage:
-30°C / +40°C

Temperatures to be achieved during the mission:

Non operational: -30°C / +40°C
Operational: -20°C / +30°C

7.4.2.2 Temperature stabilities

For the FEEs, during the observation mode: refer to section 7.4.1.2 above.

For the DPS, during the observation mode, the temperature shall be stable at +/- 5°C around the selected working temperature over time scales shorter than 24 hours.

7.4.3 Active thermal control

Note: The spacecraft shall, on top of the thermal control of the electrical units, provide the necessary thermal hardware to allow active temperature control of each single cameras around a selected average temperature within the "working" temperature range. The control shall be performed by the SVM and shall be defined in the EID-A. However, a possible implementation is described here-after.

A thermal line is defined as:
- the hardware needed to control independently the 2 heaters of the line,
- the hardware needed to acquire the 3 sensors of the line,
- the algorithm needed to fulfil the required performances of the temperature control. This algorithm is implemented in the SVM.

The SVM has to provide:
- the 34 thermal lines for the 34 cameras and related control.
- all the other lines required for the electrical units temperature control i.e. to keep the specified temperature range in all phases of the mission.

The camera thermal control is described hereafter.

7.4.3.1 Heaters and temperature sensors

Each point to control will be installed with two independent heaters and three temperature sensors for redundancy aspects.

Due to different temperature ranges and temperature precision, the active thermal control shall be able to acquire 3 kinds of sensor types.

Heaters and sensors wires of a thermal line (corresponding to a point to control) are re-grouped in a bundle departing from a location close to the point to control.

The PLM has to provide the corresponding cable, running from the SVM to the point to control.

7.4.3.2 Temperature control algorithms

The temperature control of each line shall have these characteristics:

- Acquire for each camera the reference temperature and controller coefficients from a database uploaded from ground and stored onboard. These values can be adjusted independently for each camera during flight by uploading new values from ground. The ranges of these values are TBD.
- acquire the values from the 3 sensors of a line and select from these the best value

- apply the thermal control algorithm to provide the correct power to the active heater

The thermal control strategy shall be tolerant to:

- Failure of up to two sensors
- Drift over time of one or more sensors
- Failure of one heater

The sampling and power correction frequency of the control shall be fixed and higher than 1/25 Hz.
The control shall be performed by the SVM.

7.4.4 Instruments thermal monitoring

Independently of the temperature control, the instruments require a temperature monitoring of several points located in the instrument or in its surroundings. This is used for calibration and post-processing of science data. Typically, 5 (**TBC**) measurement points per camera are requested. Three kinds of sensor types can be used and can be acquired by the thermal monitoring. This monitoring will be controlled by the Instruments.

7.5 Power Interfaces

7.5.1 Mean power needed by the instruments

The mean power consumption including uncertinties is given in Table 7-2. It includes an estimate for telescope thermal control (Not part of the Instruments power budget).

Table 7-2: Instruments power demand.

(in W)	Nominal per unit	Peak. per unit	Standby per unit	Quantity	Total nominal	Remarks
Telescope Thermal	2.0	Tbd	TBD	34	68.0	Not part of instrument budget but considered here.
FPA	0.5	TBD	TBD	32	16.0	
FEE	4.5	TBD	TBD	32	144.0	
FAST FPA	2.5	TBD	TBD	2	5.0	
FAST FEE	9.5	TBD	TBD	2	19.0	
AEU (incl. Fast PS)	14.0	TBD	TBD	4	56.0	
Fast AEU	12.0	TBD	TBD	1	12.0	
MEU	25.8	TBD	TBD	8	208.0	
FAST DPU	13.5	TBD	TBD	2	27.0	
ICU (including CLK) (1 active)	27.0	TBD	TBD	1	27.0	
Total					582.0	

7.5.2 Power peaks needed by the instruments

TBD, related to thermal control at switch on.

7.5.3 Power needed during transient phases

TBD

7.5.4 Electrical Interfaces

A nominal 28V regulated power bus interface, designed according to ECSS-E-ST-20C, will be made available to the Instruments units. The Instruments units shall be designed according to the following figures at units input.

Nominal Voltage	28 V
Operating Range	26 – 29 V
Survival Range	0 V – 32 V
Ripples and Spikes	300 mV pk-pk (in 50 MHz bandwidth)

7.6 Data Management Interfaces

7.6.1 FEE toward MEU

The input rate is ~1320 Mb per period of 25 sec, 330 Mb will be transferred every 6.25 sec from one FEE to one DPU inside MEU at a useful rate of 128 Mbps.

This rate implies that the FEE/DPU SpaceWire interface is configured to work at 200 Mbps (optionally, two SpaceWire interfaces can be used).

There will be 4 such links between 4 FEE and one MEU, repeated 8 times for the 8 MEU.

7.6.2 FAST FEE toward FAST DPU

The input rate is ~660 Mb every 2.5 sec. The data will be transferred from the fast FEE to the fast DPU over 8 serial links with a rate of 8 x 64 Mbps (2 channels per CCD).

7.6.3 FAST DPU toward ICU

The output rate (data flow toward the ICU) is 40 kbps per fast DPU.

7.6.4 FAST DPU toward SVM

This link is used for the transmission of the pointing error data to the SVM AOCS.

This link will be a low speed serial interface.

7.6.5 MEU toward ICU

The MEU output rate (data flow toward the ICU) is < 1.5 Mbps.

The ICU input rate is < 12 Mbps.

7.6.6 ICU toward SVM

The ICU output rate is < 1.5 Mbps.

7.7 Software Interfaces

The data exchanged between SVM and ICU will be compliant to the CCSDS and PUS standards.

The SVM shall offer the capability to manage time tag TC toward the ICU.

The SVM shall be sized to store 3 full days of produced science and housekeeping data, corresponding to a volume of ~330 Gb.

There is no long term storage at ICU level.

The ICU is responsible for storing in EEPROM the DPU application software and managing the maintenance of the DPU application Software (to change the content of the EEPROM, to add a new version of the application software in EEPROM…)

7.8 Alignment and Stability

7.8.1 Overlapping Field of View concept

The main driver for choosing the instrument basic configuration is related to the need to optimize simultaneously the number and the brightness of observed cool dwarfs and subgiants. The concept of overlapping field-of-view, offering a very wide field of view covered by a variable number of telescopes, was a natural consequence of this main idea.
In addition to this basic motivation, the overlapping field-of-view allows to re-observe, during the step&stare phase, some stars for which particularly interesting planets were detected in the long monitoring phases of the mission (in particular for instance telluric planets in the habitable zone), but only with a sub-set of telescopes, therefore without reaching the required photometric precision for seismic analysis during these phases. During the step&stare phase, these targets can be put in the part of field observed with all the 32 telescopes.

The 32 normal cameras are grouped in 4 sub-groups of 8 cameras, with LoS offset by 35% (13°) of their FoV with respect to one another. The co-alignment of the cameras of a sub-group shall be better than 1 arcmin. This value only includes the part of total tolerance affected to the optical bench and to the camera integration on it (the inner tolerances of the camera are not included).

The respective configuration of the FoVs of the various sub-groups is indicated in Figure 7-5.

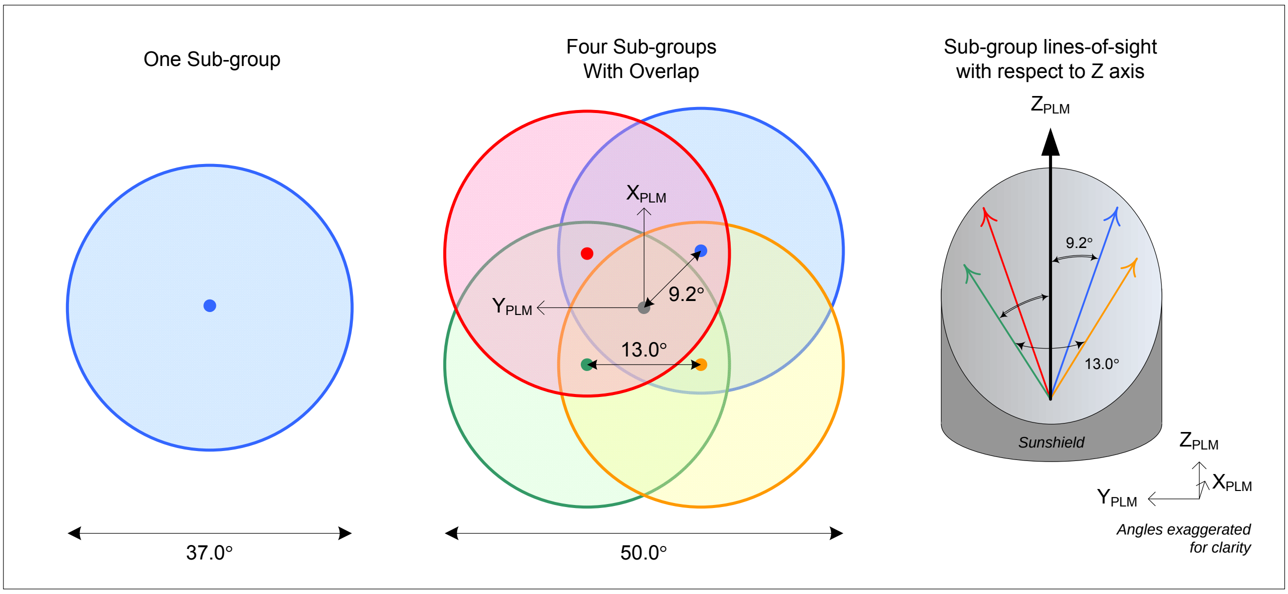

Figure 7-5: Configuration of the Field of View.

7.8.2 Alignment

The optical axes of each sub-group are tilted 9.2° +/- 1 arcmin (**TBC**) from the $+Z_{PLM}$ axis. In order to compensate for a field rotation implied by this axis offset, each camera will have to be rotated around its optical axis, by a **TBD** angle with a precision of +/-0.5 arcmin (**TBC**). The lines and columns of the CCDs are then aligned for all the cameras with the PLM axes.

The optical axis of the fast cameras shall be aligned with the Z_{PLM} axis, and the transverse axes of the fast cameras shall be aligned with the transverse axes of the payload, with a precision better than 1 arcmin (camera inner precision excluded). These alignments shall have a precision of +/-0.5 arcmin.

7.8.3 Stability

The full set of stability requirements is detailed in the Mission Requirements Document [AD01].

The optical axis of each camera shall remain stable within 0.2 arcsec on time scales between 2.5 seconds and 14 hours, with respect to an inertial reference frame. Between 14 and 90 hours, the maximum pointing stability increases linearly from 0.2 to 19 arcseconds.
N.B.: these requirements are applicable in observation conditions.

7.9 Lifetime Requirements

The nominal duration of the mission must allow for 6 years of net science observations, after satellite positioning and calibration phase. Two years extension may be required.

7.10 Maintainability and Fault Tolerance

The spacecraft shall support the capability to uploading the instruments software during the entire mission.

The spacecraft shall support the capability to patch the Instruments application software (partial modification of the software).

The spacecraft shall support the capability to uploading the instruments software during the entire mission, the upload of a new version of the Instruments application software and entirely replace the previous installed version.

The spacecraft shall support the capability to select one of several versions of the application software that are stored on-board (the choice of the version is done by a TC).

The Instrument design is such that no failure propagation from an instrument to another one is allowed.

No Instrument failure can trigger or request the spacecraft to enter Survival Mode.

7.11 Connectors Allocation

TBD

8. ENVIRONMENT REQUIREMENTS

The instruments shall be designed to withstand the environments they will encounter during their lifetime without degradation to their performances and without detrimental influence on the spacecraft or other instruments' performance. The mechanical loads produced by these environments shall include:

- Fabrication and assembly loads (e.g. welding, interference fitting)
- Handling and transportation loads
- Test loads (including thermal stresses)
- Loads from the launch vehicle (vibration, thermal and depressurisation)
- Operational loads (including thermal, attitude and orbit control induced loads)

The design of the instrument handling and transportation devices shall be such as to produce loads far lower than the predicted flight loads. Manufacturing and assembly induced loads shall also be minimised or properly relieved. Therefore if, for instance, a structure used for qualification is proposed to be reused as a flight spare, care should be exercised in determining well in advance that this is possible from a structural point of view. The design should therefore also consider the case of replacement of these critical parts.

8.1 Cleanliness

The particular contamination of the optics and especially the front lens shall be limited to 2000 ppm at the beginning of observation (after the launch phase which will be probably the major contributor to particular contamination).

The molecular contamination of the optics shall be limited to 10^{-6} g/cm² before launch.

A cleanliness plan with allocations at the different phases of the project during instrument and satellite activities shall be put in.

8.2 Radiation

The radiation environment will be mentioned in the EID-A. The Instruments design shall be consistent with [AD03].

8.3 Micrometeorite Environment

Not applicable.

8.4 EMC/RFC

Conducted emissions on power lines
The Instruments or the SVM shall not generate conducted emissions on the power bus higher than figure TBD (between 10 Hz and 50 MHz TBC). Verification will be done according to MIL-STD-XXXX.
The power bus will not be subjected to voltage variations higher than 50% TBC

Conducted emissions on interface signals
TBD

Radiated emissions
The Instruments or the SVM shall not generate radiated emissions higher than TBD.
Magnetic requirements
TBC
ESD protection
TBD
Grounding / shielding
TBD

8.5 Mechanical Environment

The mechanical environment are:

- Quasi-static load: Quasi-static load applicable at the Camera and electronic units I/F shall not be higher than **TBD**
- Sine vibration: Sine levels applicable at the Camera and electronic units I/F shall not be higher than **TBD**
- Random vibrations: Random levels applicable at the Camera and electronic units I/F shall not be higher than **TBD**
- Acoustic: Acoustic levels applicable at the Camera and electronic units I/F shall not be higher than **TBD**
- Pyrotechnic shock: Pyrotechnic shocks levels applicable at the Camera and electronic units I/F shall not be higher than **TBD**

8.6 Thermal Environment

The satellite shall accommodate the Payload in order to guaranty temperatures range and stability (see above) in all phases of Payload life (integration, transport, tests, launch, cruise, operations at L2).

8.7 Transportation and Handling

The MGSE (containers, handling devices, purges, environment control devices, etc), will be described and listed after an adequate analysis of the environmental requirements and the Integration & Test process.

Parts, equipments, cameras will be delivered with all the MGSE necessary to maintain a lower-than-flight level environment during all phases of handling and transportation. The concerned environments are cleanliness, temperature, humidity, stress, accelerations, and shocks. They will be described in Environmental Requirements.

Due to the number of cameras, they will be delivered in re-usable containers (2 or 3). Handling tools needed for the camera integration on the optical bench will not be delivered with the camera. The SVM contractor has to design and manufacture its own tool if needed.

The handling and transportation environment of the Instruments shall not exceed the flight one.

8.8 Stray-light

The contribution of the sunshield edge to stray-light budget is not yet fully evaluated, mainly because the mechanical concept is not defined. The light diffused by this edge shall be evaluated, and its value given to camera for stray-light inside the camera evaluation. In case of too high value (TBD), the edge of the sunshield should be modified to limit the diffused light to an admissible value.

9. OPERATIONAL REQUIREMENTS

9.1 Payload Operating Modes

At the payload data processing level, four main modes can be distinguished:

- The **off mode**: in this mode, the instrument is electrically off, nothing appends inside the instrument during launch and transfer, prior to instrument commissioning. The SVM shall then maintain the sub-systems and units in their storage temperature range. The instrument can go to the standby mode after power on, and after reaching its working temperature range.
- The **standby mode**: in this mode, some maintenance operations can be done (software upload, etc.).
- The **calibration mode:** in this mode, imagettes and full-frame images can be acquired for calibration and test purpose.
- The **observation mode:** this mode is the normal mode of operation, during which the data are acquired and transformed into light curves, to be downlinked to the ground. There are two distinct data flows: the one from the « normal » cameras and the one from the « fast » cameras. The observation mode can be started as soon as the windows and the photometric masks are attributed. The main tasks performed in observation mode consist in:
    - o Calculating intensities and centroids.
    - o Acquiring imagettes.
    - o Providing angle error measurements to SVM AOCS.
- The **configuration mode:** during this mode, field recognition and star position measurements are performed, background and PSF are measured and the photometric masks are computed. The configuration mode will be effective each time the line of sight will be temporarily lost.

The chart below gives an overview of the transition between modes:

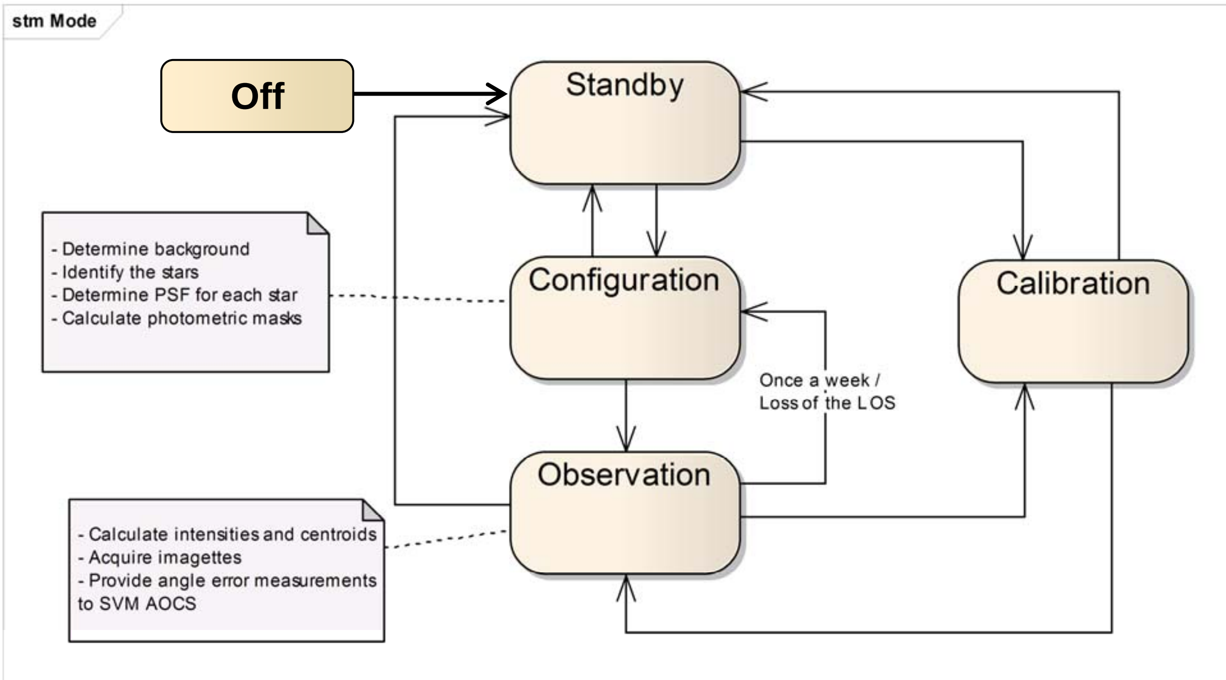

Figure 9-1: Transition between different Payload operating modes.

The software parameters can be uploaded in any mode except in OFF mode.
The software uploading shall be executed at the background task in any mode except in Off mode.
The non operational ICU can be activated for short periods of time for maintenance purpose.

9.2 Mission Operations

During the long-duration observation phase, the satellite shall be nominally rotated around the mean line of sight by 90° every 3 months, resulting in a continuous survey of exactly the same region of the sky.

During the step&stare phase, the satellite shall be nominally rotated around the mean line of sight by 90° every 3 months, or less if required.

Other aspects are TBD.

9.3 Science Ground segment

The major part of the data will become publicly available as soon as it is reduced. This is assured through the PLATO Data Acquisition and Analysis System (PDAAS). The PDAAS consists of a Ground Station (GS), a Mission Operations Centre (MOC), a Science Operations Centre (SOC) and a PLATO ground Data Centre (PDC). Of these, the latter (PDC) is community provided, while all the former are the task of ESA. PDAAS will provide support for the validation, calibration, and scientific analysis of the PLATO observations in order to deliver the PLATO Data products.

9.4 Mission products

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 data. The raw telemetry will be reformatted into a standard self-describing format in common use by the astronomical community (FITS). This restructuring may entail format expansion of the packed telemetry to be compatible with widely used file formats (e.g. from 24-bit to 32-bit integers), and/or duplication of some quantities which may in the raw telemetry be represented as a single value associated with a large ensemble of data points, but which must be duplicated across every object light curve if those light curves are to be fully self-describing (e.g. time-stamps). This reformatting may increase the data volume by approximately 50%.

The PLATO data products will be divided into three main categories, corresponding to three successive levels of treatment:

L0 (Level 0) data will correspond to the data delivered by the individual cameras. They will include individual light curves and centroid curves, as well as imagettes for a set of selected targets. L0 data will not include instrument corrections other than those already applied on board. Treatments at this level will also include 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 will include further instrumental corrections, such as those related to temperature sensitivity, some specific CCD corrections, and most importantly jitter a posteriori correction. L1 treatment will also include the calculation of suitable averages of individual light curves and centroid curves for each star.

L2 (Level 2) data will correspond to all further scientific treatment of the data, including transit detection and measurements, stellar oscillation mode parameters, as well as star and planet characteristics. The L2 data will have a high scientific added value, and will make use of the PLATO L1 data on one hand, and of all other 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 will also be used to assess the performance of onboard processing, and to check the optimization of the various parameters of this processing. The exploitation of the downlinked imagettes will play a major role in this performance assessment. The outcome of this assessment is a validation of the L0 and L1 data, as well as a possible feedback to the board for optimization of the onboard processing parameters (e.g. update of the size/shape of the processing windows, of the list of reference stars, of parameters defining the PSFs, etc.)
It is foreseen that all L0 and L1 data will be delivered under responsibility of the ESA-funded SOC, while the L2 data will be produced by the nationally-funded PDC.
More precisely, there will be seven PLATO Data Products (DP0-DP6) in all, distributed among the three levels of treatment described above:

DP0: The validated light curves and centroid curves for all individual cameras (L0). These are all the downloaded light curves (one from each star and from each camera) as well as the centroid curves, validated by assessing the quality and integrity of the data.

DP1: The calibrated light curves and centroid curves for each star (L1) 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 cameras 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.

DP2: The planetary transit candidates and their parameters (L2). This is a list of candidates with a ranking according to planetary likelihood and an assessment of false alarm probability. The list should contain (at least) the basic characteristics of the transits (depth, duration, period, ephemeris). The list of planetary candidates is discerned from both the light curves and the analysis of the centroid curves (astrometry).

DP3: The asteroseismic mode parameters

> *For solar-like pulsators:* frequencies, amplitudes, lifetimes, harmonic degrees, and azimuthal orders of individual modes of oscillation (and their associated errors). When individual modes are not resolved in frequency space, then average quantities will be provided, such as the large and small frequency separations and the average rotational splitting frequency (L2).

> *For classical pulsators:* frequencies, amplitudes, and phases of individual modes of oscillation and associated errors (L2).

DP4: The stellar rotation periods and stellar activity models inferred from activity-related periodicities in the light curves. Analysis and characterization of stellar variability on various time scales from micro-variability to activity cycles. In some cases, star spot models may be inferred from the light curves (L2).

DP5: The seismically-determined stellar masses, radii and ages of stars, (and their formal errors), obtained from stellar model fits to the frequencies of oscillations (L2).

DP6: 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 (L2).

DP6 represents the final and highest level PLATO deliverable and includes:
A list of confirmed planets, deduced from DP2 and follow-up observations.
The basic parameters of the confirmed planets: orbital parameters, planet size, mass, and age (from the seismology of central stars).

Any additional characterization of the properties of the planetary systems from the long duration PLATO light curves (e.g. secondary transits) and from specific ground-based observations (e.g. planetary atmospheres, imaging, etc).

10. PAYLOAD BUDGETS

10.1 Instruments power budget

The power budget is based on:
DC-DC converter efficiency of 0.7 for analogue voltages, and DC-DC converter efficiency of 0.8 for digital voltages.
This budget presents the effective dissipated power in each sub-system box.

Table 10-1: Instruments power budget.

(in W)	Nominal/unit	Peak/unit	Standby/unit	Quantity	Total	+20 % margin
Telescope Thermal	2.0	TBD	TBD	34	68.0	81.6
FPA	0.5	TBD	TBD	32	16.0	19.2
FEE	4.5	TBD	TBD	32	144.0	172.8
FAST FPA	2.5	TBD	TBD	2	5.0	6.0
FAST FEE	9.5	TBD	TBD	2	19.0	22.8
AEU (incl. Fast PS)	14.0	TBD	TBD	4	56.0	67.2
Fast AEU	12.0	TBD	TBD	1	12.0	14.4
MEU	25.8	TBD	TBD	8	208.0	249.6
FAST DPU	13.5	TBD	TBD	2	27.0	32.4
ICU (including CLK) (1 active)	27.0	TBD	TBD	1	27.0	32.4
TOTAL POWER					**582.0**	**698.4**

10.2 Instruments mass budget

Table 10-2: Instruments mass budget.

(in kg)		Per unit	Quantity	Total	+20% margin
Normal camera (w/o FEE)		11.7	32	374.4	
Fast camera (w/o fast FEE)		11.9	2	23.8	
FEE		0.8	32	25.6	
FAST FEE		1.0	2	2.0	
AEU		3.0	4	12.0	
Fast AEU		1.0	1	1.0	
DPS				28.2	
	MEU	2.7	8		
	Fast DPU	1.5	2		
	ICU	2.0	2		
TOTAL CAMERA (w/o FEE)				398.2	
TOTAL ELECTRONICS				68.8	
TOTAL MASS				**467.0**	**560.4**

Note: the harness, with exception for FPA to FEE harness, is excluded.

ESA UNCLASSIFIED – For Official Use

10.3 ICU telemetry budget

The telemetry volume is lower than 109 Gb/day.
Table 10-3 gives the TM budget for the normal cameras:

Table 10-3: TM budget for normal cameras.

Normal Cameras					
	Number per telescope	TM Cadence	TM volume per sec (per telescope)	TM volume per day (per telescope)	TM volume per day (all telescopes)
Sample P1	*10724*		*7.2 kbps*	*0.62 Gb*	19.9 Gb
Light	10724	50 s	5.6 kbps	0.48 Gb	15.4 Gb
Centroid	107	50 s	0.1 kbps	0.01 Gb	0.2 Gb
Centroid	10617	600 s	1.6 kbps	0.13 Gb	4.3 Gb
Sample P4	*114631*		13.5 kbps	1.16 Gb	37.3 Gb
Light (Oversampled)	1146	50 s	0.6 kbps	0.05 Gb	1.6 Gb
Light (Non oversampled)	113485	600 s	12 kbps	1.05 Gb	33.5 Gb
Centroid	1146	50 s	1 kbps	0.07 Gb	2.2 Gb
Background windows	400	25 s	0.4 kbps	0.03 Gb	1.1 Gb
Imagettes 6x6 pixels	1800	25 s	41 kbps	3.58 Gb	114.7 Gb
Prescan / Overscan windows	20	25 s	0.02 kbps	0.00 Gb	0.1 Gb
Total			63 kbps	5.41 Gb	173.0 Gb

Table 10-4 gives the TM budget for the fast cameras:

Table 10-4: TM budget for fast cameras.

Fast Cameras				
	Number per telescope	TM Cadence	TM volume per sec (per telescope)	TM volume per day (per telescope)
Sample Px	*374*		*1.5 kbps*	*0.13 Gb*
Light	374	50 s	0.4 kbps	0.04 Gb
Centroid (Non Oversampled)	334	50 s	0.6 kbps	0.05 Gb
Centroid (Oversampled)	40	2.5 s	0.5 kbps	0.04 Gb
Background windows	100	50 s	0.05 kbps	0.00 Gb
Imagettes 9x9 pixels	40	2.5 s	20.7 kbps	1.79 Gb
Prescan / Overscan windows	4	50 s	0.002 kbps	0.00 Gb
Total			22.3 kbps	1.93 Gb

Table 10-5 gives the overall TM budget:

Table 10-5: Overall TM budget.

Overall TM budget	
Normal telescope number	**32**
Fast telescope number	**2**
Compression factor	**2**
Daily volume for all normal telescopes	173,0 Gb
Daily volume for all fast telescopes	3,9 Gb
Margin	20,00%
Total daily volume without compression	**212 Gb**
Total daily volume with compression	**106 Gb**
Available daily rate (TBC)	**109 Gb**
Instantaneous rate ICU->SVM	**1,23 Mbps**

11. PAYLOAD VERIFICATION

11.1 General Approach

The Consortium shall, in a systematic manner, verify the instrument design and build against each requirement specified in the EID-A and EID-B.

The Consortium shall include in the Design Development and Verification Plan the tests and analyses that collectively demonstrate that hardware and software complies with the requirements.
The Plan shall show the overall approach to accomplish the instrument qualification and acceptance programme. The interaction of the test and analysis activity shall be described.

The verification will be reached by:

- Analysis, using mathematical models,
- Qualification and acceptance tests,
- Calibration.

Philosophy at Instrument level is Qualification on a dedicated QM and Acceptance on FMs.

11.2 Model Philosophy

11.2.1 Mathematical models

The following models will be delivered:

- the mechanical models (CAD drawings, FEM), of the camera and electrical units
- the thermal model of the camera,
- a thermo-elastic model of the camera (**TBC**).

11.2.2 Physical models

11.2.2.1 Camera

Definition of the different models:

- Structural Thermal Model (STM): 5 (TBC) cameras, conform to structural and thermal characteristics, without optics, detectors and FEE, replaced by dummies. The other cameras are entirely replaced by dummies, only conform in mass, centre of gravity position, mechanical and thermal I/F, first eigen frequency, thermal dissipation
- Engineering Model (EM): not delivered, expected conform to FM, used for characterisation, performance evaluations, functional optical tests and AIV processes validation.
- Qualification Model (QM): 2 models (1 normal and 1 fast), not delivered, fully conform to FM, used for environment qualification tests, performance measurements and calibration procedure validation.
- Flight Model (FM): 32 normal + 2 fast
- Spare Model (SM): 1 full flight model + sets of spare components for LLI

N.B.: the QM model can be used as Spare Model

11.2.2.2 Electronics boxes

Are considered here the electronics: AEU, and the digital electronics: MEU, fast DPU and ICU, with:

- Structural Thermal Model (STM): dummies, delivered to ESA;
- Breadboard Models (BB): not delivered to ESA, for software development;
- Engineering Models (EM1 & 2): not delivered to ESA, expected conform to FM, except for the electronics parts at a lower quality level, and a limited number of copies; for functional chain validation, software validation and expertise;
- Engineering Model (EM3): delivered to ESA, for satellite bench test purposes (TBC), limited to one ICU, expected conform to FM, except for the electronics parts at a lower quality level;
- Qualification Model (QM): not delivered to ESA, only 1 copy (TBC) of each type of unit;
- Flight Model (FM); delivered to ESA
- Spare Model (SM): 1 model of each type of unit, none for fast DPU and ICU;

N.B.: the QM model can be used as Spare Model, if needed.

Table 11-1: List of required models.

	STM	BB	EM1	EM2	EM3	QM	FM	Spare
AEU	4		1			1	4	1
Fast AEU	1		1			1	1	1
MEU	8	1 DPU	1	1		1	8	1
Fast DPU	2		1		1 (short term loan)	1	2	
ICU	2		1	1 (or BB)	1	1	2	
	Delivered to ESA		(functional chain validation)	(software validation)	Delivered to ESA		Delivered to ESA	

Additional models will be developed by partners for their own needs.
Additional models can be requested for delivery (e.g. to support the Avionic Model of the Spacecraft) subject to agreement during the Definition Phase.

11.2.3 Simulators

Simulators (and associated EGSE) will be developed, according to the needs of the various equipments, for their validation. To be detailed later.

The EM3 ICU model will be delivered to ESA with its own data input stimuli.
ESA shall deliver 2 simulators of SVM Data Handling Unit, for ICU and Instrument chain validation.

11.3 Unit Verification

Each unit will be verified / qualified by the supplier according to the ECSS standard.

11.3.1 Camera Verification

Performances will be measured on EM (prototype), QM, and FMs.

Qualification process will be obtained on QM model.

The FM models will be tested at Acceptance levels (vibration and thermal cycling). Performances at ambient will be measured. A few of them (one out of eight TBC) will be fully tested on thermal vacuum, in order to measure their performances.

11.4 Instruments level AIT

The Instrument chain will be validated, by coupling the Camera, AEU and DPS. Functionalities and a sub-set of performances will be verified. To be detailed during the Definition Phase.

11.5 Payload Module level AIT

The Instruments will be delivered to the Contractor via ESA. The Instrument will be delivered in a staggered way as soon they have completed Instrument level verification. The Contractor shall perform PLM level AIV by integrating the delivered Instruments and performing the related integration and functional tests. ESA requires that the PLM environmental tests are combined with the related spacecraft level environmental tests. An alternative approach can be elaborated during the Definition Phase.

11.6 Calibration

Each camera will be calibrated before delivery.

11.7 Ground Support Equipment (GSE) and facility

11.7.1 SGSE and EGSE

A Test Conductor System will be used, at Instrument level AIT.

Software for simulators shall be developed,
EGSE shall be developed,

11.7.2 Optical Ground Support Equipment

A specific Field-stars-stimulus will be developed for testing the cameras at ambient, and on thermal vacuum.

A collimator will be used, with adjustable focusing.

For S/L or PLM tests, specific OGSE will be developed under ESA responsibility (see section 12).

11.7.3 Mechanical Ground Support Equipment

MGSE for Cameras, and Instrument tests will be developed (tilting dolly usable under vacuum, handling device, supports, containers, etc....).

12. SATELLITE LEVEL AIT

A full Spacecraft Verification and AIT Plan including the models philosophy will be identified during the Definition Phase for implementation during the Implementation Phase.

For the time being, the Consortium shall assume that the system level AIT will be based on:

- Structural and Thermal Model (STM)
- Avionic Model (AVM)
- Proto-flight Model (PFM)

The STM shall support mechanical and thermal qualification tests of the satellite
The STM shall support as a minimum the following major tests:

- Static Test (Structure only)
- Fit check
- Mass Properties and alignment
- Leak test
- Modal survey
- Sine Vibration
- Acoustic Vibration
- Thermal Balance Test

The AVM shall support as a minimum the following tests:

- Electrical integration
- Functional tests
- Ground Segment preliminary compatibility tests
- Conducted EMC Tests

The PFM, actually the flight model, shall be used to complete the qualification and acceptance programme.

The PFM shall support as a minimum the following tests:

- Electrical Integration
- Functional and performance tests
- Integrated System Test
- Alignment, leakage and mass properties tests
- Sine survey, shock, acoustic
- Thermal tests
- Ground Segment compatibility tests
- EMC and RFC tests

In particular, a dedicated verification by test and analysis will be done to verify the co-alignment specification in the related environment.

The Consortium shall actively support PLM and the system level AIV activity by providing inputs for Instruments related tests, participation to testing, results analysis, support for non conformances processing, request for waiver and other support activity which may be required.

13. PRODUCT ASSURANCE PLAN

ECSS-Q standards shall be generally applied. During the course of Definition phase, the standards will be specifically customized to the PLATO needs.

14. PROJECT MANAGEMENT

The organization and management structure of the scientific team is an important element in assuring a timely success in the development and flight of a scientific payload. Clear roles must be defined and respected in order to ensure proper information flow between the many parties involved in the instrument development, the spacecraft contractors, the scientific community and the ESA Study Team. The requirements of this section will be the unique reference on the responsibilities and methods of resolving problems and disputes between the PLATO Consortium and any of the other stake holders in the instrument, spacecraft and mission development.

The implementation of the PLATO programme has to meet the various and multidisciplinary scientific objectives within the given financial envelope. The managerial complexity and the timely availability of payload will significantly contribute to the overall programmatic risk. It is therefore essential that the Consortium is conscious of the risks and contributes to their minimization by adhering to the programme requirements established in this section.

The following **ground rules** shall be followed:

- **Both the Contractor and Consortium report to ESA**
- **The Consortium shall work in parallel with the Contractor and support ESA during the Definition Phase**
- **Prototyping shall be done during the Definition Phase**

All formal communication and agreements concerning technical and programmatic aspects shall be made between the Consortium Lead and the ESA PLATO Study Manager. No other party shall have formal authority, without written delegation.

On a working level, for all technical aspects of the instruments, the ESA Payload Manager or his delegated shall represent the focal point for all communications between the Consortium and ESA

All communication between the Consortium and the spacecraft Industrial Contractors shall be conducted via the ESA PLATO Payload Manger with copy to the ESA PLATO Project Manager.

Prototyping and development activities of the Consortium shall include the following:

- Detectors prototyping (funded by ESA)
- Full telescope development
- FEE development
- FEE/detectors interface test and possibly camera testing
- Mathematical models shall be delivered early in the study

14.1 Consortium Organisation

14.1.1 Global Consortium organization

To be defined in the EID-B.

14.1.2 PLATO Payload Consortium organization

To be defined in the EID-B.

14.1.3 Consortium Council

To be defined in the EID-B.

14.1.4 PLATO Consortium organigram

To be defined in the EID-B.

14.2 Consortium Tasks and Responsibilities

A team shall be established to provide an effective and efficient managerial scheme and to ensure that all aspects of the instrument programme are covered by the appropriate expertise.
The Consortium shall establish a detailed organisation chart, identifying all the responsibilities involved and the associated links and reporting lines, with defined named responsibilities clearly showing that all aspects of the instrument are efficiently covered by the appropriate expertise. Key personnel, including technical instrument managers, shall be identified within the management scheme together with a short description of their tasks and functions and their time allocation to the project. Key personnel are defined as persons who because of their positions and individual qualifications perform an essential function required to achieve the objectives and requirements of the instrument development. CVs shall be provided for all the proposed key personnel. The appointment of key personnel and changes thereto shall always be agreed together with the Agency.

14.2.1 Consortium Responsibilities

The PLATO Mission Consortium is responsible for the provision of:

- The full set of instruments fully integrated, verified and calibrated for later integration into the PLATO spacecraft according to the interfaces outlined in this document.
- The resources (manpower and facilities) to support the post payload delivery integration and testing activities.
- The Consortium part of the SGS, manpower and facilities for the processing of the PLATO scientific and house-keeping data generated by the payload as specified in the SMP.

Specifically, the Consortium will be responsible for the following tasks:

- Telescope development
- Electronic units development
- Instrument application software (ASW) development, including on-board data processing
- Camera development
- Instrument Development and Performance verification
- Definition of the Telescope alignment and Instruments environmental constraints and pointing (jointly)
- Timely delivery of the Instruments and related items
- Support to System Level AIT which includes test inputs, active participation to testing and related assessment

The PLATO Mission Consortium shall be led by a single person, the PLATO Consortium Lead (PCL). The PCL is the single formal interface for the Consortium with the ESA Study team. He shall be supported by a PLATO Instrument Project Manager (PIPM) for the PLATO instruments and the Consortium contribution to the PLATO SGS shall be led by the PLATO Science Ground Segment Manager (PSGSM).

The PIPM is responsible for the overall management of the instruments development. The PSGSM is responsible for the overall management of the SGS development of the PLATO Mission Consortium contribution to the SGS. The PIPM and PSGSM will interact with their respective ESA counterparts for the day to day work, while the overall Consortium work coordination will be ensured by the PCL.

14.2.2 PCL and PIPM Responsibilities

It is overall responsibility of the PCL to ensure that the complete Payload is financed, developed and implemented within the mission and schedule constraints of the approved PLATO Programme.

The PCL shall take full responsibility for the instrument programme and retain at all times full authority within the Consortium Team over all aspects related to procurement and execution of the programme. In this context, the PCL shall be able to make commitments and make decisions on behalf of all other participants in the instrument programme. He shall organize all efforts, assign tasks and guide other members of the instrument consortium

More precisely, the PLATO Consortium Lead shall:

- Take full responsibility for the PLATO Mission Consortium provision,
- Act as the single and formal managerial interface of the PLATO Mission Consortium to the ESA Study team,
- Ensure the Consortium activities are timely and properly executed with deliveries to the ESA project according to schedule in line with the standards and technical requirements,
- Efficiently support ESA for the overall science performance evaluation and monitoring,
- Provide early warnings to ESA project in case of delay in the work execution and propose, on behalf of the Consortium, corrective actions to be discussed and agreed with the ESA project,
- Attend meetings of the PST and supporting groups as appropriate, to report on development of the instruments and SGS programmes,
- Establish and maintain an efficient and effective managerial scheme which will be valid for all aspects of instrument provision and participation to the SGS, both headed by dedicated Element Manager,
- Define role and responsibilities of the managerial leads of PLATO Mission Consortium provisions,
- Define and maintain the instrument specification and verify compliance with the science requirements,
- Ensure an adequate level of test and calibration of the instrument, both on ground and in orbit,
- Provide overall documentation during the project as defined in this EID-A,
- Ensure availability of adequate funding at the required time(s) for all aspects of the PLATO Mission Consortium work.

The payload development will be led by the PLATO Instruments Project Manager (PIPM). He is reporting to the PLATO Mission Consortium Lead. Within the PMC he is responsible for the delivery of the full set of instruments, the payload. In order to discharge his responsibilities the PIPM shall:

- Provide the necessary resources to develop, deliver and operate the PLATO payload in line with the scientific performance requirements and as defined in the Instruments Specification and this EID-A.
- Establish and maintain a well specified and identified management organization to handle the development and delivery of the payload.

The PIPM supports the PCL through regular reports and support during formal reviews to demonstrate compliance with the scientific mission requirements, the spacecraft system constraints, the spacecraft interfaces and the programme schedule as defined in the mutually agreed Experiment Interface Documents.
The PIPM participates in the PLATO~~PLATO~~ Science Team as a non-voting member.

14.3 ESA responsibilities

ESA has the overall responsibility for the PLATO mission design and implementation.

ESA has the responsibility for the procurement of the identified Payload elements (see section 15.1) from the Consortium and confirmation of their performances

Payload units and sub-assembly procured by ESA via the Consortium are delivered to the Contractor as Customer Furnished Equipment (CFE) for integration in the spacecraft

14.3.1 ESA PLATO Study Team

The management of the PLATO Study during the Definition Phase will be under the responsibility of the ESA Study Manager located at ESTEC, Noordwijk, The Netherlands. The ESA Study Manager has full responsibility for all aspects of the Definition Phase. If, in the interest of the overall programme, significant technical and/or programmatic changes to an experiment are necessary, then ESA shall be responsible for the definition of the required change to be implemented by the PCL.

The ESA Study Manager will be directly supported in the execution of the programme by the staff of the ESA Study Team located at ESTEC

The PLATO Payload is managed under the overall responsibility of the PLATO Payload Consortium (TBC). The ESA PLATO Study Team will follow up on the progress regularly to ensure that they meet the PLATO programme objectives.

The ESA PLATO Study Team will in particular:

- Coordinate with the Consortium the day to day Payload related matters;
- Control the technical interfaces defined in this EID-A, including the assessment, finalization and approval of change requests;
- Oversee acceptance tests of the Payload deliverable items as part of the delivery procedure to the Consortium;
- Supervise and coordinate with the Consortium the support and inputs required for the spacecraft system test activities and later the launch campaign and the operations in flight.
- After the Definition Phase: Coordinate with the PCL and the industrial Prime Contractor all deliverables needed by either the PCL or the Prime Contractor in relation to the accommodation of the instruments in the spacecraft.

The ESA Study Scientist is responsible for ensuring the scientific objectives of the mission are achieved, through the verification of instrument performance. As such he is the formal interface for all scientific matters. The ESA Study Scientist will organize regular Science Working Team (SWT) meetings in support of the above objectives.
The ESA Study Scientist will later on monitor the state of the implementation and readiness of the instrument operations and scientific data processing infrastructure.

14.4 Contractor responsibilities

The Contractor is responsible for the development, procurement, manufacturing, assembly, integration, test, verification and timely delivery of a fully integrated spacecraft capable of accommodating the defined payload elements, fulfilling the requirements of the applicable documents and achieving the mission objectives.

The Contractor is responsible for the development, procurement and verification of the PLM units and sub-assemblies as identified in paragraph 14.

During the Definition Phase, when there will be two competitive contractors engaged in studying instrument accommodation and technology developments all contacts will be made via the ESA Study Manager concerning questions of interface. This method of communication is to ensure that where confidentiality is needed that it will be maintained.

In the Definition phase ESA will retain the overall responsibility and supervision.

14.5 Planning, Meetings, and Reviews

14.5.1 Overall programme planning

All dates are to be confirmed and subject to approval of PLATO for the Implementation Phase.

In line with the Cosmic Visions M-class missions, the PLATO schedule is 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): end 2018
- L+ 0.25 years: start of nominal in-orbit science operation Phase
- L+6.25 years: end of nominal in-orbit operation Phase.

Note: The ESA technical and programmatic requirements will be updated in the course of the Definition study to reflect the full programmatic requirements for the implementation phase.

14.5.2 Meetings and Reviews

14.5.2.1 General

Meetings and Reviews of instrument development as well as reviews at system level are a normal part of the procurement process for space equipment.

a) The Consortium shall organize regular progress meetings with the ESA PLATO Study Team including instrument members at least quarterly or as required.

b) Ad-hoc meetings shall be supported when requested by the ESA PLATO Study Team to address critical subjects at the time

c) The Consortium shall provide the results of the instrument activities as input to the industrial definition phase studies with the major milestones being the Preliminary Configuration Definition Review (PCDR – mid October 2010), the Preliminary Requirements Review (PRR – mid May 2011) and Baseline Design Configuration Review (BDCR – end November 2011). Participation in and support to these reviews as well as limited participation in and support to the progress meetings of the industrial studies shall be considered.

d) Instruments Design Consolidation Review November 2011

e) (TBC:) The Consortium shall provide the resources to prepare review data packages as defined in TBD and support fully the review processes at payload level as defined hereafter:

i. Payload Preliminary Design Review (Implementation Phase)
ii. Payload Critical Design Review (Implementation Phase)
iii. Payload Qualification Review (Implementation Phase)
iv. Payload Acceptance Review (Implementation Phase)
v. Other TBD Reviews as required

These reviews will be managed by the ESA Study team. The instrument subassemblies shall follow a similar review plan. These reviews will be managed by the Instrument Project Office and supported by the ESA Study team. Ad hoc reviews shall be organised by the Instrument Project Office with support form the ESA Study team where deemed required.

f) The PCL shall participate and support the Science Working Team meetings called by the PLATO Study Scientist.

14.5.2.2 Payload progress meetings

These meetings will be conducted between the ESA PLATO Study Team, the Contractor and the Consortium with the objective of ensuring that the interfaces, the technical design integrity of the Instruments, its compatibility with the spacecraft system and programmatics are proceeding in a manner which will not jeopardize the overall programme.

a) Regular Payload Progress Meetings (bi-monthly starting in September 2010 TBC) shall be held on the premises of the Consortium during the design, development and verification programme of the instrument. The frequency may be changed on request of the ESA Study Manager depending on the severity of problems that may accumulate.

b) Detailed technical problems occurring on either side of the interface shall be flagged during these meetings and corrective actions, including their schedule impact, agreed and implemented.

c) The PCL shall maintain and publish minutes of meetings to all participants and stake holders in the payload.

14.5.2.3 Other meetings/Telecon

The Consortium and the Contractor are encouraged to organise regular teleconferences with the participation of the Agency, to ensure a smooth progress of the activities and to tackle technical problems occurring on either side of the interfaces to agree and implement corrective actions.

14.5.3 Reporting

The PCL shall submit to ESA a Monthly Progress Report in which the current status of each activity is described and problem areas or potential problem areas are highlighted together with identification of proposed remedial action. A summary of the latest working schedule shall also be included.

14.6 Configuration Management

14.6.1 General

An effective configuration management scheme shall be established within the Consortium in order to ensure all hardware, software and documentation is fully traceable with history and exact definition of the data or hardware at all times.

14.6.1.1 Objectives

The objectives of Configuration Management are to establish:

- a configuration identification baseline system which defines through approved specifications, interface documents and associated data the requirements for the payload,
- a configuration control system which controls all the changes to the identified configuration of the payload,
- a configuration accounting system which documents all changes to the baseline configurations, maintains an accurate record of configuration change incorporation, and ensures conformity between the end item As Built Configuration (ABCL) and its appropriate design and qualification identification (CIDL including waivers).

14.6.1.2 Responsibilities

1. The Consortium shall be responsible for managing the configuration of the payload and the lower level products of which it consists. For this purpose, he shall set up the necessary organization and means for satisfying the objectives and requirements of configuration management.
2. The Consortium shall also impose configuration management requirements on contractors and suppliers as appropriate for the items being provided to the payload.

14.6.2 Configuration requirements

14.6.2.1 Configuration Identification

1. Configuration baselines shall be established with respect to requirements, design and verification.
2. The Requirements Baseline shall include:
   a) Payload System Specification
   b) Payload System Support Specification
   c) Interface Control Documents

3. The Design Baseline shall include:
   a) Design Specification

b) Drawings
c) Manufacturing Procedures

4. The Verification Baseline shall include:
   a) Control and Inspection Procedures
   b) Operating and Handling Procedures
   c) Test Procedures

5. Configuration baselines shall be established and reviewed at each Payload Review (TBC). Baselines may also be established and reviewed as required at selected intermediate stages.
6. Verification documents including design analyses and test reports shall make reference to the configuration status of the design or the hardware or software being evaluated.

14.6.2.2 Configuration Control

1. As an integral part of the management structure, the Consortium shall set up a configuration control procedure for the payload in such a manner that the status of all aspects of his the payload such as the design and manufacturing of hardware and development of software can be unambiguously defined at any time.
2. The control procedure shall allow the ESA Study Manager to conduct a configuration audit at any point in the programme in order to obtain the up-to-date status of the instrument. The approval right for changes initiated by any party is exclusive right of the ESA Study Manager.

14.6.2.3 Configuration Status Accounting

1. The current status of all configured documents shall be sent to the ESA Study Manager as part of the reporting procedure.
2. Configuration Item Data Lists (CIDL) listing all the documents and their applicable issues and revisions which define the configuration baseline shall be prepared and submitted for each Payload Review.
3. The Consortium shall establish and maintain As Built Configuration Lists (ABCL) listing all the documents and their issues and revisions defining the as built configuration.
4. Differences between the as designed baseline and the as built configuration list shall be identified for all qualification and flight hardware and software. The validity of all design verifications, including analyses and tests, shall be assessed for all the differences and modifications from the as designed baseline.

14.7 Schedule

A detailed schedule down to component and sub-assembly level is an invaluable tool to coordinate all the members of the Consortium and to demonstrate the commitments for delivery to the spacecraft.

1. The PCL shall create and maintain a detailed payload development schedule deliverable to the ESA Study Manager quarterly or on demand in case of urgency.
2. The PCL shall agree and maintain deliverable dates with the Contractor and ESA PLATO Study Manager.
3. All ITAR related approval aspects shall be clearly identified and included in the planning (e.g. if lens material needs to be procured from Japan).
4. All schedule shall be in a MS Project or compatible format.

14.7.1 Overall project schedule

1. An overall project schedule will be issued and maintained by the Contractor and subject to ESA approval
2. All milestones specified by the ESA Study Manager shall be included in the schedule and be agreed by the Consortium.
3. The PCL shall identify additional milestones as required and agree them with the ESA Study Manager and the Contractor.
4. All interfaces, such as procurement items, ITAR permissions, hardware deliveries, reviews, etc. shall be clearly identified.
5. The schedule shall reflect the result of detailed task analysis and critical review of all the activities associated with the payload programme.
6. It shall contain all activity interdependencies durations and constraints.
7. Based on precedence type network, the schedule shall be so constructed that automatic analysis of time earliest and time latest for critical events can be performed and critical paths identified.

14.7.2 Baseline schedule of deliveries by the Consortium

The delivery dates of each item shall be consolidated during the Definition Phase. Preliminary dates are given hereafter:

- Delivery of Instrument Structural Thermal Model: Q1 2014 (TBC. See note below)
- Delivery of Instrument Engineering Model: Q3 2014 (TBC. See note below))
- Delivery of Instrument Flight Model: Q2 2015 (TBC. See note below)

Note: The ESA technical and programmatic requirements will be updated in the course of the Definition study to reflect the full programmatic requirements for the implementation phase.

14.7.3 Baseline schedule of deliveries by the Contractor to the Consortium

The delivery dates of each item shall be consolidated during the Definition Phase.

15. DELIVERABLE ITEMS AND SUPPORT

It shall be noted that an international partner may join the PLATO project as Junior Partner. Some instruments items e.g. telescopes baffles, AEU, might be delivered by this international partner to the Consortium. In this case the sections related to the deliveries shall be re-visited.

15.1 Product tree

The product tree for the PLATO study including the responsibilities of the individual items is shown in Figure 15-1.

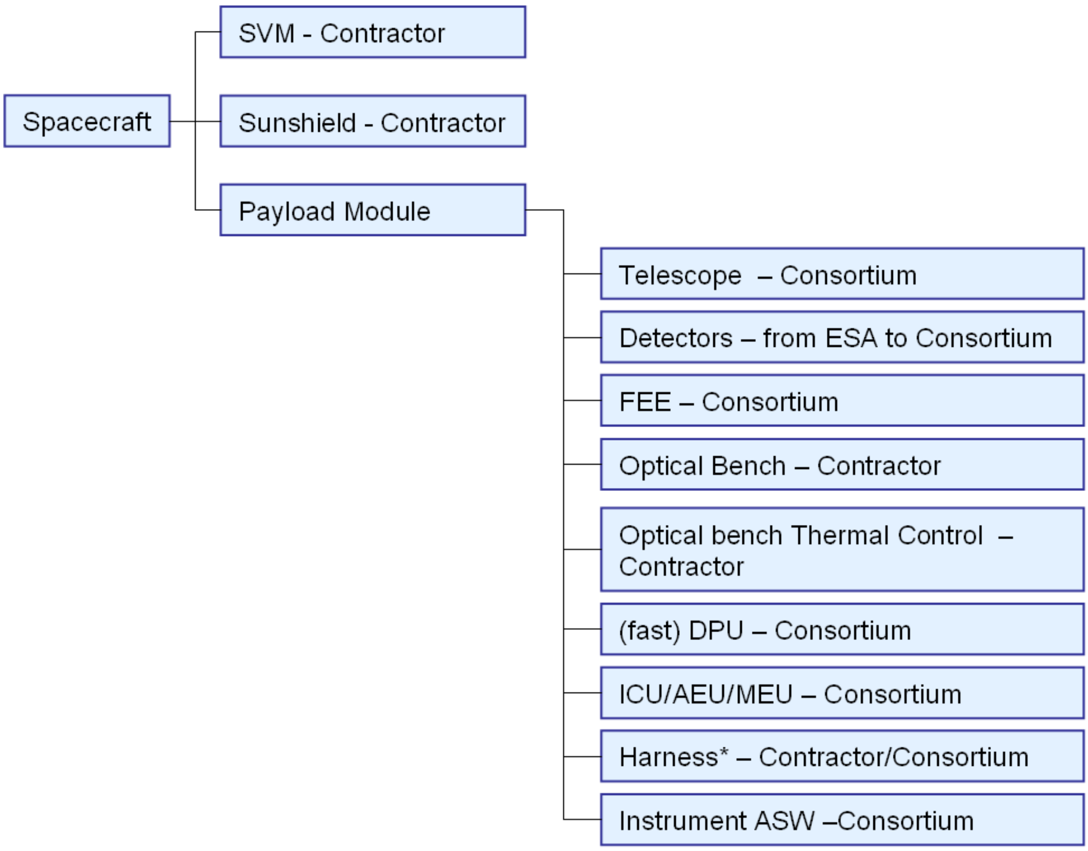

Figure 15-1: Product tree for the PLATO study.

The Harness between the FEE and FPA shall be provided by the Consortium. The other harness shall be designed and delivered by the Contractor who is also responsible for its accommodation and layout in the spacecraft.

Note that the definitions are listed in "Definitions", page 8.

15.2 Deliverables from the Consortium to ESA

The Consortium is responsible to ESA for the timely delivery of all following items:

- Usual documentation (e.g. User's Manual..)
- Mathematical Models (see section 15.2.1)
- Instrument models to support system level AIT including thermal models (see section 15.2.2)
- Software (see section 15.2.4)
- Full set of FM/PFM verified and calibrated Instruments
- Inputs for Instruments testing at satellite level
- Spare Items
- Instrument related Ground Support Equipment (GSE)
- Operational Data Base (TC/TM)

15.2.1 Mathematical Models

1. The Consortium shall deliver a Structural Mathematical Model (SMM) of his instrument, as defined in section 11.
2. The Consortium shall deliver a Thermal Mathematical Model (TMM) of his instrument, as defined in section 11.

These instrument mathematical models shall be updated as the design progresses. They will serve as input to the spacecraft mathematical models and may require revision at various points in the PLATO development programme.

15.2.2 Instrument Models

1. The Consortium shall deliver the following instrument models as defined in section 11
   - (Proto-) Flight Model (P)FM
   - Structural and Thermal Model (STM),
   - Electrical Model (EM),
2. Each delivery shall include, as appropriate, instrument hardware, on-board software and ground support equipment.
3. Each item delivered shall be accompanied by an End Item Data Package (content TBD).
4. Prior to delivery, each item shall undergo formal acceptance on the basis of mutually agreed acceptance programme.
5. Shipment of the instrument models and any other equipment required by either ESA or the Consortium shall be the financial responsibility of the Consortium. This responsibility shall extend to return for repair and return of all equipment following launch.
6. The points of delivery of all items will be determined later in the programme and be included in this document.
7. Any insurance deemed necessary by the Consortium Lead for his equipment during shipment or whilst on the premises of the Agency or its Contractors, shall be the financial responsibility of the Consortium.
8. If applicable, all ITAR papers necessary for shipment shall be obtained by the Consortium prior to the required shipment date and shall include all the delivery destinations for launch to orbit.
9. The build standard of each model shall be defined in this EID-A and agreed with the ESA Study Manager.
10. The Consortium shall support the system level integration and test activities by supplying the appropriate manpower and expertise.

15.2.3 Input for the stray-light analysis

The Consortium shall deliver the following items in support of the stray-light analysis of the Contractor:

a) Telescope structural model (sizes, materials, etc)

b) Optical model (lens sizes, distances, materials, coatings, etc)
c) Focal plane information (e.g. number of pixels on the CCDs, size of the pixels)

For more information see also section 8.8.

15.2.4 On-Board Software

1. The instrument on-board software shall be delivered together with the corresponding instrument model.
2. The on-board software shall either reside in the instrument in a non volatile memory or be delivered in a format such that it can be loaded through the spacecraft telecommand uplink.
3. In addition to the flight software, special test software for instrument diagnostics and failure investigation may be required.
4. The on-board software to be delivered shall comply with the ESA software standard ECSS TBD.
5. The Consortium remains responsible for the maintenance of the instrument software after delivery up to the end of mission.
6. The Consortium shall support the verification of updated instrument software at system level.

15.3 Deliverables from the Contractor to the Consortium via ESA

1. PLM related harness for test purpose
2. MGSE replicating the OB and allowing for PLM units accommodation in a representative way
3. EGSE to simulate the electrical interfaces of the SVM. Basically it shall be the same or similar to the EGSE used for PLM functional tests

15.4 Deliverables from ESA to the Consortium

1. The detector for the focal plane arrays for the telescopes shall be delivered to the Consortium.
2. ESA shall deliver and maintain all relevant **interface documentation** throughout the project lifetime.

15.5 Deliverables from ESA to the Contractor

ESA shall deliver and maintain (with support from the Consortium and the Contractor) all relevant **interface documentation** throughout the project lifetime.

Note: All items from the Consortium are delivered to the Contractor via ESA

15.6 Review Data Package

A data package shall be provided for each of the scheduled instrument review:

<u>Instruments Design Consolidation Review PRR above in November 2011</u>

- input to updates of the EID- part B
- updated Instrument functional requirements and performance specifications
- formal issue of unit level specifications and ICD
- Supporting tech notes and analyses reports demonstrating full compliance of the instrument with the applicable requirements

- Delivery of all the mathematical models
- Consolidated instrument operational concept document
- Final project plans.
- Updated financial plan
- Pre development status report

Payload Preliminary Design Review (Implementation Phase)
TBD

Payload Critical Design Review (Implementation Phase)
TBD

Payload Qualification Review (Implementation Phase)
TBD

Payload Acceptance Review (Implementation Phase)
TBD

16. DOCUMENTS

Documents relevant to the PLATO Study are classified as Applicable and Reference Documents. Applicable documents are referenced in the text of this EID-A as specific requirements which call up the section in the specified document. Reference documents are listed for information but are not formally requirement documents.

16.1 Applicable documents

[AD01] PLATO Mission Requirements Document – issue 3.0 – SCI-PA/2008-015/RL/PLATO/MRD – March 2010

[AD02] Consolidated Report on Mission Analysis (CReMA) – issue 1.1 – ref. MAS Working Paper No. 547 – March 2010

[AD03] PLATO Environment Specification – issue 2 – ref. JS-23-09 – 10 March 2010

16.2 Reference documents

The following documents as of the current issue, as indicated or most recent in the event of updates, are possible sources of clarification for the content of the PLATO EID-A.

[RD01] Statement of Work for Industrial Studies – issue 2 – ref. SRE-PA/2010.016

[RD02] PLATO Science Requirements Document – issue 4 – ref. SCI-PA/2008-020/PLATO/SciRD

16.3 ECSS Applicable Standards

ECSS standards are available for download at http://www.ecss.nl. The latest issue of all the ECSS documents listed below shall apply unless specified otherwise. Full tailoring of the ECSSS will be done as part of the Definition Phase.

ECSS number	Actual Title	Issue	Date of publication
ECSS-E-10-03A	Testing	First issue	15 February 2002
ECSS-E-70-41A	Telemetry and telecommand packet utilization	First issue	30 January 2003
ECSS-E-ST-10 C	System engineering general requirements	Third issue	06 March 2009
ECSS-E-ST-10-02C	Verification	Second issue	06 March 2009
ECSS-E-ST-10-04C	Space environment	Second issue	15 November 2008
ECSS-E-ST-10-06C	Technical requirements specification	Third issue	06 March 2009
ECSS-E-ST-10-09C	Reference coordinate system	First issue	31 July 2008
ECSS-E-ST-10-12C	Method for the calculation of radiation received and its effects, and a policy for design margins	First issue	15 November 2008
ECSS-E-ST-20 C	Electrical and electronic	Second issue	31 July 2008

ECSS number	Actual Title	Issue	Date of publication
ECSS-E-ST-20-06C	Spacecraft charging	First issue	31 July 2008
ECSS-E-ST-20-07C	Electromagnetic compatibility	First issue	31 July 2008
ECSS-E-ST-31 C	Thermal control general requirements	Second issue	15 November 2008
ECSS-E-ST-32 C Rev.1	Structural general requirements	Revision 1 of Second issue	15 November 2008
ECSS-E-ST-32-01C Rev.1	Fracture control	Revision 1 of Second issue	06 March 2009
ECSS-E-ST-32-03C	Structural finite element models	First issue	31 July 2008
ECSS-E-ST-32-08C	Materials	Second issue	31 July 2008
ECSS-E-ST-32-10C Rev.1	Structural factors of safety for spaceflight hardware	Revision 1 of First issue	06 March 2009
ECSS-E-ST-32-11C	Modal survey assessment	Second issue	31 July 2008
ECSS-E-ST-33-01C	Mechanisms	Second issue	06 March 2009
ECSS-E-ST-40 C	Software	Third issue	06 March 2009
ECSS-E-ST-50-12C	SpaceWire - Links, nodes, routers and networks	Second issue	31 July 2008
ECSS-E-ST-50-13C	Interface and communication protocol for MIL-STD-1553B data bus onboard spacecraft	First issue	15 November 2008
ECSS-E-ST-50-14C	Spacecraft discrete interfaces	Second issue	31 July 2008
ECSS-E-ST-50-51C	SpaceWire protocol identification	First issue	05 February 2010
ECSS-E-ST-50-52C	SpaceWire - Remote memory access protocol	First issue	05 February 2010
ECSS-E-ST-50-53C	SpaceWire - CCSDS packet transfer protocol	First issue	05 February 2010
ECSS-E-ST-70 C	Ground systems and operations	Second issue	31 July 2008
ECSS-E-ST-70-01C	On-board control procedures	First issue	16 April
ECSS-E-ST-70-11C	Space segment operability	Second issue	31 July 2008
ECSS-E-ST-70-31C	Ground systems and operations - Monitoring and control data definition	Second issue	31 July 2008
ECSS-E-ST-70-32C	Test and operations procedure language	Second issue	31 July 2008
ECSS-M-70A	Integrated logistic support	First issue	19 April 1996
ECSS-M-ST-10 C Rev.1	Project planning and implementation	Third issue revision 1	06 March 2009
ECSS-M-ST-10-01C	Organization and conduct of reviews	Second issue	15 November 2008
ECSS-M-ST-40 C Rev.1	Configuration and information management	Third issue revision 1	06 March 2009
ECSS-M-ST-60C	Cost and schedule management	Third issue	31 July 2008
ECSS-M-ST-80C	Risk management	Third issue	31 July 2008

ECSS number	Actual Title	Issue	Date of publication
ECSS-P-001B	Glossary of terms	Second issue	14 July 2004
ECSS-Q-20-07A	Quality assurance for test centres	First issue	31 July 2002
ECSS-Q-70-71A Rev.1	Data for selection of space materials and processes	Revision 1 of First issue	18 June 2004
ECSS-Q-ST-10 C	Product assurance management	First issue	15 November 2008
ECSS-Q-ST-10-04C	Critial-item control	Second issue	31 July 2008
ECSS-Q-ST-10-09C	Nonconformance control system	Third issue	15 November 2008
ECSS-Q-ST-20C	Quality assurance	Third issue	15 November 2008
ECSS-Q-ST-30 C	Dependability	Third issue	06 March 2009
ECSS-Q-ST-30-02C	Failure modes, effects (and criticality) analysis (FMEA/FMECA)	Second issue	06 March 2009
ECSS-Q-ST-30-09C	Availability analysis	Second issue	31 July 2008
ECSS-Q-ST-30-11C	Derating - EEE components	Third issue	31 July 2008
ECSS-Q-ST-40 C	Safety	Third issue	06 March 2009
ECSS-Q-ST-40-02C	Hazard analysis	Second issue	15 November 2008
ECSS-Q-ST-40-12C	Fault tree analysis - Adoption notice ECSS/IEC 61025	Second issue	31 July 2008
ECSS-Q-ST-70 C	Materials, mechanical parts and processes	Third issue	06 March 2009
ECSS-Q-ST-70-01C	Cleanliness and contamination control	Second issue	15 November 2008
ECSS-Q-ST-80C	Software product assurance	Third issue	06 March 2009
ECSS-S-ST-00C	Description, implementation and general requirements	First issue	31 July 2008