# CHEOPS Science Management Plan

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European Space Agency
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| **Key Science Goals** | **What are the conditions for planet formation and the emergence of life?**<br><br>Study the structure of exoplanets smaller than Saturn orbiting bright stars, by determining accurate radii, for which the mass has already been estimated from ground-based spectroscopic surveys. |
| **Observational concept** | Observations of planetary transits through precision photometry of at least 20 ppm (goal: 10 ppm) in 6 hours of integration time. |
| **Targets** | Known exoplanet host stars with a V-magnitude < 12, with planets mainly in the super-Earth to Neptune mass range. |
| **Payload** | • Photometer with single, frame-transfer, back-illuminated CCD detector<br><br>• On-axis Ritchey-Chrétien telescope of 33 cm diameter |
| **Spacecraft** | • 3-axis stabilized<br><br>• Pointing accuracy: 8 arcsec rms over a 48 hour observation<br><br>• Mass: ~250 kg<br><br>• TM rate: 1 Gbit/day downlink |
| **Mission profile** | • Baseline orbit: 6-am/6-pm sun-synchronous with an altitude in the range between 620 and 800 km<br><br>• Launch: 2017<br><br>• Launcher: As auxiliary payload or co-passenger in Vega or Soyuz (baseline scenarios), or in other small launch vehicles.<br><br>• Nominal mission duration: 3.5 years |

# 1 SUMMARY AND SCOPE

The CHaracterising ExOPlanet Satellite (CHEOPS) is a Small mission in the ESA Science Programme to be implemented in partnership with Switzerland, and with a number of Member States delivering significant contributions. These Member States are Austria, Belgium, France, Germany, Hungary, Italy, Portugal, Sweden, and UK, and will cooperate under a Swiss led CHEOPS Mission Consortium (CMC).

On 19 October 2012, CHEOPS was selected by the Science Programme Committee for a definition phase study as the first Small mission in Cosmic Vision 2015-2025. The two main conditions for the selected mission specified in the "2012 Call for a Small mission opportunity in ESA's Science Programme for a launch in 2017" (9 March 2012) were: i) a development time not exceeding 3.5-4 years, leading to a launch in 2017, and ii) a total cost to be covered by the ESA Science Programme limited to 50 M€ at 2012 economic conditions. The adoption of CHEOPS will be decided in early 2014.

The Science Management Plan (SMP) defines the top-level science management principles and organisation of the mission. It identifies roles and duties of ESA, the CMC, and the scientific community at large. The document provides an overview of the mission science objectives and a high-level description of the operations and processes that will be established to generate the outlined scientific data products. The SMP addresses the data rights policy, and the distribution of responsibilities for public outreach and communication.

Based on the principles presented in this document, a Multi-Lateral Agreement (MLA) will be established between ESA and the CMC lead funding agencies to formalise the commitments and deliverables of all parties. If and when applicable, the MLA will take precedence over the SMP.

Upon adoption of the mission by SPC, ESA will issue an Announcement of Opportunity (AO) for membership in the CHEOPS Science Team.

# 2 MISSION OVERVIEW

The scientific objectives and the mission description contained in this section are provided exclusively for reference.

## 2.1 Scientific Objectives

CHEOPS will be the first mission dedicated to search for exo-planetary transits by means of ultrahigh precision photometry on bright stars already known to host planets. By being able to point at nearly any location on the sky, it will provide the unique capability of determining accurate radii for a subset of those planets in the super-Earth to Neptune mass range, for which the mass has already been estimated from ground-based spectroscopic surveys. It will also provide precision radii for new planets (Super-Earth- and

Neptune-size) discovered by the next generation of ground-based transits surveys (e.g., NGTS, HAT-S).

The main science objective of the CHEOPS mission will be to study the structure of exoplanets smaller than Saturn orbiting bright stars. In particular, CHEOPS will: 1) determine the mass-radius relation in a planetary mass range for which only a handful of data exist and to a precision not achieved before; 2) identify planets with significant atmospheres in a range of masses, distances from the host star, and stellar parameters; 3) place constraints on possible planet migration paths followed during the formation and evolution of planets; 4) bring new constraints on the atmospheric properties of known hot Jupiters via phase curves; 5) provide unique targets for detailed atmospheric characterisation by future ground- (e.g., E-ELT) and space-based (e.g., JWST) facilities with spectroscopic capabilities. In addition, 20% of the CHEOPS observing time will be made available to the community through a selection process carried out by ESA, in which a wide range of science topics may be addressed.

## 2.2 Mission Description

To reach its science objectives, CHEOPS will measure photometric signals with a precision (limited by stellar photon shot noise) of 20 ppm (goal: 10 ppm) in 6 hours of integration time. This corresponds to the transit of an Earth-sized planet orbiting a star of 0.9 $R_{sun}$ in 50 days detected with an $S/N_{transit} > 5$ (100 ppm transit depth). This precision will be achieved by using a single, frame-transfer, back-illuminated CCD detector at the focal plane assembly of a 33 cm diameter, on-axis Ritchey-Chrétien telescope. The spacecraft will be 3-axis stabilized, with a pointing accuracy of 8 arcsec rms over a 48 hour observation, and will allow for at least 1 Gbit/day downlink. The baseline orbit satisfying the science requirements is a 6-am/6-pm sun-synchronous orbit with an altitude in the range between 620 and 800 km, enabling to have the Sun permanently on the backside of the spacecraft and minimising Earth straylight. The mass of the spacecraft (< 250 kg) is compatible with a launch as auxiliary payload or co-passenger on Vega or Soyuz (baseline scenarios), as well as with other small launch vehicles. A mission duration of 3.5 years in orbit is the baseline to enable the execution of the proposed science observation programme.

The CHEOPS satellite includes two elements:

- The Instrument assembly, which includes the complete CHEOPS instrument, composed by the telescope with its baffle, the optical bench, the focal plane assembly, the thermal control hardware and the instrument electronics, including the mechanical interface structure and harness connecting to the platform.
- The Platform, which provides all S/C subsystems and resources supporting the payload operations as well as the structural interface to the Instrument assembly and the launch vehicle. The platform provider is hereafter indicated as spacecraft contractor.

## 2.3 Mission phases and milestones

The nominal schedule of CHEOPS as an S-class mission in Cosmic Vision is as follows:

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|---|---|
| June 2013 | Start of the industrial Definition phase |
| November 2013 | Preliminary Requirements Review |
| February 2014 | End of the Definition phase with System Requirements Review |
| February 2014 | Mission adoption for the Implementation phase (B2/C/D/E1) |
| March 2014 | Spacecraft contractor selection |
| April 2014 | Start of the Implementation phase |
| July 2014 | Preliminary Design Review |
| June 2015 | Critical Design Review |
| September 2016 | Start of System level AIT |
| April 2017 | Flight Acceptance Review |
| December 2017 | Launch (L, including schedule contingency) |
| L+~days | Start of the in-orbit commissioning phase |
| L + 2 months | Start of the routine phase |
| L + 3.5 years | End of nominal mission |
| >L + 3.5 years | Spacecraft disposal |

# 3 SCIENCE AND PROJECT MANAGEMENT

This section describes the high level organisation of the mission and the provisions by ESA and the CMC. Figure 1 shows the main organisational units that are described in the following sections, and their primary interfaces until the end of the in-orbit commissioning phase.

## 3.1 ESA provisions

ESA will be in charge of the overall mission architecture with the support of the CMC. As such, ESA will manage the overall CHEOPS spacecraft development. In particular, ESA will provide, within the remit of the MLA:

- The design, implementation and management of the CHEOPS Platform that will accommodate the Instrument assembly.
- The CCD procurement for the Instrument assembly.
- The satellite integration and tests, including the Instrument assembly integration on the Platform.
- Satellite qualification, acceptance and testing.
- The procurement of the mission control system, the spacecraft simulator and the flight dynamics system.
- The launch vehicle procurement and launch operations.
- In-orbit commissioning.

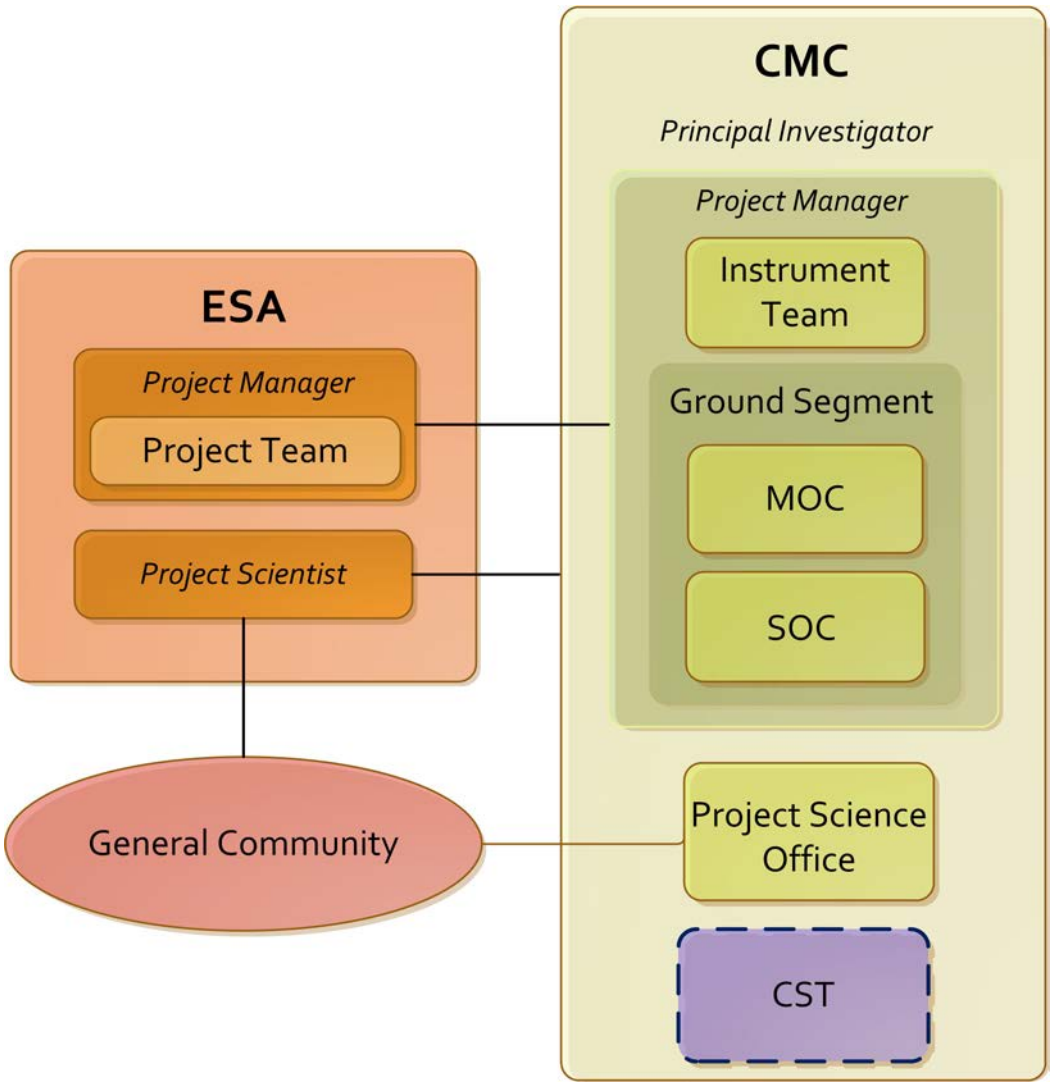


**Figure 1: Scheme showing the main organisational elements in the CHEOPS mission and their primary interfaces. Main contact persons at ESA and the CMC are specified in italics. A dashed contour indicates advisory role.**

During the development and commissioning phases, an ESA-appointed Project Manager will be responsible for implementing and managing the ESA's activities listed above. The ESA Project Manager will be the routine interface to the CMC Project Manager.

ESA will nominate a Project Scientist (PS) for CHEOPS, who will:

- In close collaboration with the PI and the CMC Project Science Office (see Sections 3.2 and 3.2.2), provide support to ensure that the maximum scientific return is achieved within programmatic constraints, during all mission phases.
- Act as the interface with the ESA Project Manager for scientific matters.

- Act as ESA's interface to the CMC for scientific matters, and coordinate with the PI the scientific support from the CMC to ESA's activities.
- Act as ESA's interface with the general community for scientific matters, public outreach, communication and education activities, during all mission phases.
- Represent the interests of the general scientific community during all mission phases, and organise the activities related to their participation in the mission (e.g., announcements of opportunity, time allocation committee).

## 3.2 CMC provisions

The CMC will provide :

- Instrument assembly, calibration, system AIV contributions, ground segment and operations.
- Science preparation and exploitation.

The CMC will be led by the CHEOPS Principal Investigator (PI), appointed by the Swiss Space Office in consultation with D/SRE. The PI will:

- Organise the efforts and assign tasks in the CMC.
- Establish and maintain a managerial scheme, which will be used for all aspects and through all phases of the provision of the Instrument assembly, ground segment and operations.
- Ensure that the CMC activities are timely and properly executed with deliveries to ESA according to the agreed schedule, and in line with the standards and technical requirements.

### *3.2.1 Instrument, system AIV contributions, ground segment and operations*

Within the remit of the MLA, the CMC will provide the following mission elements:

- Development, procurement, integration, qualification, verification and calibration of the Instrument assembly. This will also include:
    - Definition and maintenance of the Instrument assembly specification and verification of compliance with the science requirements.
    - Contribute and support the definition (and maintenance) of the interfaces between Instrument assembly and platform.
    - Ensuring an adequate level of test and calibration of the instrument, both on ground and in orbit.
    - Supporting as required system level integration and verification activities.
    - Supporting as required instrument operations in orbit.

- The System Level AIV services and facilities to the spacecraft contractor as defined in the related System AIV Interface Control Document.

- Monitoring and evaluation of the overall science performance.
- The CHEOPS ground segment, including:

    - The Ground station(s).
    - The Mission Operations Centre (MOC) as described in section 5.2.
    - The Science Operations Centre (SOC), as described in section 5.3.

- Mission and science operations following completion of the in-orbit commissioning phase.

During the development and commissioning phases, the PI will appoint a CMC Project Manager, who will be responsible for managing and implementing the CMC provided elements listed above. The CMC Project Manager will be the routine interface to the ESA Project Manager.

After in-orbit commissioning phase, the PI will appoint a Mission Manager, who will assume responsibility for operations of the S/C, its payload, and the ground segment.

During the routine and post-operations phases, the PI and the Project Science Office (see next section) will interact with the ESA PS.

### *3.2.2 Scientific activities*

The CMC will be responsible for the scientific outcome of the mission and for maximising its scientific return. For this purpose, the PI will set up a Project Science Office, which will:

- Coordinate the scientific aspects of the Instrument assembly and operations provision.
- In coordination with the ESA PS, provide documentation and technical support for the open time AO.

The CMC will exploit the scientific results of the mission and assure their diffusion as widely as possible.

The CMC will establish a core observing programme, which will define the distribution of observing time among the science objectives described in the Definition study report. On this basis, the CMC will produce six months before launch a first prioritised core observing programme target list that will cover up to 80% of the nominal duration of the mission. The core programme target list will periodically be revised during routine operations to allow for updates that will maximise the scientific return.

A CHEOPS Science Team (CST) will be constituted in the CMC, which will advise the PI on scientific matters, in particular:

- Science requirements
- The core observing programme that will fulfil the core scientific objectives

- Observation and calibration strategies
- Processing and analysis of the data
- Definition of data products
- Quality of the data products to be released to the general community
- Scientific exploitation of the data
- Publication rules inside the CMC
- Public outreach, communication, and education activities

Other tasks of the CST will be:

- Monitor the mission's development and operations in order to ensure the achievement of the scientific objectives.
- Support the activities of the ESA PS (e.g., by providing input to ESA reviews, production of documentation, public outreach and communication).

The CST will consist of:

- CMC scientists appointed by the PI. Some of them will be ex-officio members with key positions in the project.
- Scientists appointed by ESA following an AO (see section 4.1).

The PI will appoint the CST chair.

CST members will be authors of the core observing programme resulting papers during the proprietary period. The PI will decide, with the advice of the CST, on the inclusion of collaborators of CST members as co-authors of these papers. This decision will be made on individual paper basis, after assessing the actual contribution of the collaborator(s) to the scientific investigation.

The ESA PS will closely follow the CST activities. The ESA PS and the ESA Project Manager have a standing invitation to attend CST meetings as observers.

## 3.3 Joint Management Team

A joint ESA-CMC management team will be constituted to coordinate, monitor and discuss issues with major programmatic and financial implications, like design options, work distribution and reinforcement, schedule execution, and launcher. This team is a consultative body, and will consist of the PI, a representative of the Swiss Space Office, the Head of the Future Missions Office, the ESA Project Manager, the CMC Project Manager, the ESA PS, and a representative of the Project Science Office.

## 3.4 Steering Committee

A Multi-Lateral Agreement (MLA) will be established between ESA and the CMC lead funding agencies to formalise the commitments and deliverables of all parties. A CHEOPS Steering Committee with representatives from the national funding agencies and ESA will

be then set up to oversee the deliveries of the CMC and the timely fulfilment of the obligations of all parties as established in the MLA. The PI will represent the CMC in the Steering Committee.

# 4 PROGRAMME PARTICIPATION

## 4.1 ESA-appointed scientists in the CST

To ensure a commensurate involvement of scientists from ESA Member States in the CHEOPS mission, five CST members, corresponding to a fraction of 20% of the non-ex-officio CST members, will be appointed by ESA through an AO.

The ESA-appointed scientists in the CST will be full members of the CST with the same rights and responsibilities as the CMC appointed members.

The AO for membership in the CST will be open to scientists in the ESA Member States. Scientists whose institutional affiliation would allow access to the CHEOPS core observing proprietary data through other channels are not eligible for the participation in the AO. The submitted proposals should show the candidate's expertise in the CHEOPS core science field described in the science objectives chapter of the Definition study report. The candidates should state their time commitment to the CST activities and their willingness to take up specific and time-limited tasks as assigned by the CST. The proposals should also include the explicit endorsement and support from their Institutes to their application.

The proposals will be evaluated by ESA. Based on the resulting recommendations, and in consultation with the PI, D/SRE will appoint the ESA selected members to the CST for an initial period of four years, renewable throughout the duration of the mission. With the exception of expenses incurred while travelling to CST meetings, ESA will not fund any of the member's CHEOPS activities. Each ESA-selected CST member must submit an annual report of his/her CHEOPS related activities to ESA. At the end of each four-year period, D/SRE, in consultation with the PI, will decide on each appointment extension. Should an ESA-appointed CST member position become vacant, it will be filled by competitive selection via the usual AO process.

## 4.2 Guest observers

Twenty per cent of the observing time will be open to guest observers to conduct scientific investigations. Proposals will be requested yearly through an open ESA AO to the general scientific community. An AO will be issued six months before launch. Proposals will not be allowed to include targets that are in the core observing programme target list defined and announced by the CMC prior to each AO. Proposals will be selected on scientific merit by a CHEOPS Time Allocation Committee (TAC) appointed by ESA in consultation with the PI. The TAC will work independently. The TAC will receive technical support from the Project Science Office through the ESA PS.

In order to allow important new targets to be included in the open time programme at any time during the mission, up to 25% of the open time will be allocated to a discretionary programme. The discretionary programme will be overseen by ESA, in consultation with the chair of the TAC and the PI.

# 5 OPERATIONS

ESA will be responsible for the launch and the in-orbit commissioning of the spacecraft. Following a successful completion of the in-orbit commissioning phase, the CMC will take over the responsibility for CHEOPS operations.

The CMC will provide the ground segment, which will consist of the ground station(s), the MOC and the SOC. In the current baseline, the ground station(s) and the MOC are under the responsibility of SACC/Catapult and located at Harwell (UK), and the SOC is distributed across Europe with its main centre at the University of Geneva (Switzerland).

## 5.1 Ground stations(s)

The ground station(s) will support the telemetry and telecommand communications with the spacecraft. The baseline scenario is to use the STFC's RAL 12m S-band antenna at Harwell. Other solutions will be assessed during the MOC Phase A/B1 as a back-up plan.

## 5.2 MOC

The Mission Operations Centre (MOC) will be responsible for:

- Operation of the ground stations and MOC infrastructure
- Reception of tracking data from the Ground Station(s)
- Telecommanding
- Reception and archiving of telemetry
- Spacecraft orbit determination and maintenance
- On-board S/W maintenance
- Monitoring of the spacecraft health and safety
- Execution of predetermined nominal and contingency procedures to safeguard the spacecraft
- The mission planning system
- The low level data processing system and first level validation of the observation execution
- Data and operations information dissemination to the SOC

## 5.3 SOC

The SOC will be in charge of the following tasks:

- Science operations system requirements, design, implementation and management
- Scientific mission planning

- Science Instrument operations and calibration
- Data processing from level 0 to level 2
- Data archiving and access to the CHEOPS data products and documentation
- Supporting ESA in the preparation of the open time AOs by providing documentation and technical support
- Mission management after in-orbit commissioning

To fulfil these responsibilities, the SOC will closely collaborate with the CMC Instrument Team, the MOC and ESA.

The SOC will store the data and maintain the public access to the archive for 10 years after the end of the mission operations.

## 5.4 Operations concept

The CMC will define the science targets for the core observing program. The general scientific community, via the AO, will define the targets for the open time programme. These core and open time targets will form the mission prioritised target list, which will be converted by the SOC into a sequence of observations based on the platform boundary conditions provided by the MOC. After a feedback loop with the MOC, the observation sequence will be passed to the MOC for conversion into telecommands and uplink to the spacecraft.

The SOC will receive the Instrument assembly and Platform data from the MOC after the execution of the observations. Science and housekeeping data will then be processed together with auxiliary information like orbit and attitude data. The CST will ensure the quality of the observational data and request follow-up observations when necessary. The data will finally be archived and made accessible to the CMC and to the guest observers for scientific analysis during the proprietary period as specified in section 7, and to the general community after the proprietary period has expired.

# 6 DATA PRODUCTS

The CHEOPS data products are defined in three levels as follows:

- L0 data, which result from the unpacking of data packets received at the MOC from the ground station. They contain the science data and meta-data, as well as the housekeeping and auxiliary data. The housekeeping data (e.g., Platform and Instrument assembly status) are used at the level of the MOC for spacecraft monitoring. All the L0 data are sent to the SOC, where they are directly archived and used as inputs for the data processing pipeline.

- L1 data, which result from the processing of L0 data at the SOC. The processing produces calibrated science, error, and data quality 2D images as well as the science and engineering meta-data. These data are used as input to the quick look (in view

of producing the payload monitoring and the L2 science data processing described below).

- L2 data, which result from the processing of L1 2D images. They consist of photometric time series (light curves) and associated auxiliary and meta- data. These are the CHEOPS final science products, which are expected to be used as input to the science analysis by scientists in the CST and the general community (who could anyway access all data levels). These data will be used for the light curve quality monitoring allowing a precise assessment of the instrument photometric precision.

The CMC will provide to the general community detailed descriptions of the data products and the data processing steps from level 0 to level 2, including calibration. The format of the data products will be such (e.g., FITS) that they can be visualised and analysed using commonly available tools in astronomy. The data products will be reprocessed at the SOC with the latest versions of the data processing pipeline and calibration files, and made available to the mission users through the science archive.

# 7 DATA RIGHTS

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

The data rights policy set down here reflects the wish to:

- Reward the contributions of the scientists involved in the development of CHEOPS by giving them exclusive access to CHEOPS data for a limited period of time, hereafter the proprietary period.
- Deliver to the general scientific community scientific data and results of the highest possible quality as soon as possible.

The members of the CST will have access to all data of the core observing programme as soon as they are available. Co-Is, in collaboration with CST members, will have access to these data following the approval by the PI. They will comply with the publication rules described in section 3.2.2.

The data from a particular target of the core observing programme and the open time programme will have associated a 1-year proprietary period, after which the L0, L1 and L2 data will be publicly available through the CHEOPS science archive. The 1-year proprietary time will begin just after the last measurement on that particular target has been received, and the planetary transit observation declared complete by the CST after the corresponding

quality-check. In order to ensure a timely publication of scientific results, the proprietary time will not exceed 1.5 years counting from the first measurement of the corresponding target. This is in the context that most planetary transits will need few measurements (from 1 to ~3) before the required precision has been reached. Since the vast majority of targets will have short period planets, the time to complete the required set of measurements will generally be of a few months.

During the proprietary time, the open time observers will have access to data products of the same type and quality as the CMC. This will also apply to the general community once the proprietary period has expired.

# 8 PUBLIC OUTREACH, COMMUNICATION AND EDUCATION

ESA and the CMC will be jointly responsible for planning and coordinating public outreach, communication, and education activities related to the mission. The following guidelines will be applicable:

- All public outreach, communication and education activities related to CHEOPS shall be coordinated between ESA and the CMC.
- For the purpose of public outreach and communication activities, the CMC will provide to ESA unlimited access to all processed and analysed data, even during their proprietary period (if applicable); this material will not be used for scientific publication, or its dissemination jeopardise the scientific publication of proprietary data.
- Both the members of the CST and ESA will have a duty to support each other with regards to public outreach, communication and education.
- ESA gives credit to members of the CST and the CMC regarding scientific and technical results when applicable. Similarly, the CST and the CMC give credit to ESA whenever applicable.

# ACRONYMS

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|---|---|
| AIT | Assembly, Integration and Test |
| AIV | Assembly, Integration and Verification |
| AO | Announcement of Opportunity |
| CCD | Charge Coupled Device |
| CHEOPS | CHaracterising ExOPlanet Satellite |
| CMC | CHEOPS Mission Consortium |
| CST | CHEOPS Science Team |
| D/SRE | Director of Science and Robotic Exploration |
| E-ELT | European Extremely Large Telescope |
| ESA | European Space Agency |
| FITS | Flexible Image Transport System |
| HAT-S | Hungarian-made Automated Telescope South |
| JWST | James Webb Space Telescope |
| MLA | MultiLateral Agreement |
| MOC | Mission Operations Centre |
| NGTS | Next-Generation Transit Survey |
| PI | Principal Investigator |
| PS | Project Scientist |
| RAL | Rutherford Appleton Laboratory |
| S/C | Spacecraft |
| SACC | Satellite Applications Catapult Centre |
| SMP | Science Management Plan |
| SOC | Science Operations Centre |
| SPC | Science Programme Committee |
| SRE | Science and Robotic Exploration Directorate |
| STFC | Science and Technology Facilities Council |
| TAC | Time Allocation Committee |
| TM | Telemetry |