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Cheops, the CHaracterising ExOPlanet Satellite, is scheduled to launch on a Soyuz-Fregat rocket from Europe's Spaceport in Kourou, French Guiana at 09:54 CET on 17 December 2019.

Note: Cheops was launched on 18 December 2019.

Cheops is ESA's first mission dedicated to the study of extrasolar planets, or exoplanets. It will observe bright stars that are already known to host planets, measuring minuscule brightness changes due to the planet's transit across the star's disc.

Characterising exoplanets

The mission will target stars hosting planets in the Earth-to-Neptune-size range, yielding precise measurements of the planet sizes. This, together with independent information about the planet masses, will allow scientists to determine their density, enabling a first-step characterisation of these extrasolar worlds. A planet's density provides vital clues about its composition and structure, indicating for example if it is predominantly rocky or gassy, or perhaps harbours significant oceans.

Unlike previous exoplanet satellites, such as the CNES-led CoRoT (Convection, Rotation and planetary Transits) or NASA's Kepler and Tess missions, Cheops is not a 'discovery machine' but rather a follow-up mission, focusing on individual stars that are already known to host one or more planets. The exquisite precision with which Cheops is able to measure planetary transits, together with the stability of the telescope, will enable astronomers to determine planet sizes both accurately and precisely.

By knowing when and where to point in order to catch planetary transits, Cheops will maximise the time it spends monitoring actual transit events. It will point at stars over most of the sky, returning to the same stars to observe multiple transits over the course of the mission, thus building up the accuracy of measurement of planet sizes.

Cheops will not only follow up on previously discovered exoplanets, but it will also identify the best candidates for detailed study by future missions and observatories. For example, it will provide targets for the NASA/ESA/CSA James Webb Space Telescope, which will be used to search for the signatures of water and methane, important elements in our quest for habitable worlds.

Eighty percent of the science observing time on Cheops is dedicated to the Guaranteed Time Observing (GTO) programme, defined by the Cheops Science Team. The remaining twenty percent is made available to the astronomical community in the form of an ESA-run Guest Observers' (GO) programme, with proposals selected via a competitive peer-review selection process.

Cheops paves the way for the next generation of ESA's exoplanet satellites, with two further missions — Plato and Ariel — planned for the next decade to tackle different aspects of the evolving field of exoplanet science. Together, these missions will keep the European scientific community at the forefront of exoplanet research well beyond the next decade, and will build on answering the fundamental question: what are the conditions for planet formation and the emergence of life?

Launch

Cheops will lift off as a secondary passenger, hitching a ride on the Soyuz-Fregat that will deliver the first satellite of the Italian Space Agency's Cosmo-SkyMed Second Generation constellation into space. The launcher will also carry three ‘CubeSats’, small satellites based on standardised 10 cm cubic units, including ESA's OPS-SAT, the world's first free-for-use, in-orbit tested for new software, applications and techniques in satellite control.

Partners

• Cheops is a small, or S-class, mission in ESA's science programme. It is a partnership between ESA and Switzerland, with a dedicated consortium led by the University of Bern, and with important contributions from Austria, Belgium, France, Germany, Hungary, Italy, Portugal, Spain, Sweden and the UK.
• ESA is the Cheops mission architect, responsible for procurement and testing of the satellite, launch, the launch and early operations phase, in-orbit commissioning, as well as the Guest Observers' Programme. The consortium of 11 ESA Member States led by Switzerland provided essential elements of the mission.
• The prime contractor for the design and construction of the spacecraft is Airbus Defence and Space in Spain.
• The Cheops mission consortium runs the Mission Operations Centre located at INTA, in Torrejón de Ardoz, Spain, and the Science Operations Centre, located at the University of Geneva, Switzerland.
Provisional schedule at ESA’s astronomy centre (ESAC) near Madrid, Spain, 17 December (all times in local CET)

**08:30** Doors open

**09:15** Programme begins

Experts present the mission, with live transmissions from Kourou including the moment of lift-off at 09:54 CET. This will be followed by Q&A sessions and individual interview opportunities ahead of the Cheops separation, expected around 12:20, and announcement of acquisition of signal from the Mission Operations Centre located at INTA, in Torrejón de Ardoz, Spain.

**14:00** End of event – media invited to join lunch with representatives of ESA, industry and the scientific community.

How to get to ESAC
CHEOPS: KEY MESSAGES

First step characterisation of super Earth- to Neptune-sized planets

Piecing together the puzzle of what small planets are made of, and how they form and evolve

Measuring the size of known planets

A small, flexible and fast track science mission

Identifying the best targets for future in-depth observations

Tailor-made, with a high scientific return on a small investment
CHEOPS: SCIENCE THEMES

Using **ultra-high precision photometry**
to measure **accurate sizes** of a large sample of Earth- to Neptune-sized planets

Targeting primarily **bright stars** known to host exoplanets **smaller than Saturn**

Measuring light curves of **hot Jupiters** to see how energy is transported in **planetary atmospheres**

Identifying prime **targets** to search for the **fingerprints** of key molecules in the planets’ **atmospheres** using future observatories on Earth and in space

Combining the Cheops **size** measurements with existing planet masses to constrain their **compositions and internal structures**
**CHEOPS: AN EXOPLANET FOLLOW-UP MISSION**

**DISCOVERY MISSIONS**

- **Kepler/K2:**
  - Operations: 2009–2018
  - Planets discovered: 2345 (Kepler) + 385 (K2)

- **Tess:**
  - Operations: 2018–present
  - Planets discovered: 37 confirmed, 1516 candidates (as of 6/12/2019)

- **Corot:**
  - Operations: 2006–2013
  - Planets discovered: 33

**FOLLOW-UP MISSION**

Cheops will observe individual stars already known to host exoplanets rather than carry out sky surveys to find new ones.

The first discoveries of exoplanets were made with ground-based telescopes in the 1990s, opening the field of exoplanet research. Dedicated ground-based surveys to find exoplanets included the Wide Angle Search for Planets (WASP) and the Hungarian Automated Telescope Network (HAT) in the 2000s.

The 2019 Nobel Prize in Physics was awarded to Michel Mayor and Didier Queloz for the discovery of the first exoplanet around a Sun-like star in 1995. New innovations and discoveries continue to this day.
Transit photometry is one of the main techniques used to discover exoplanets. Cheops will use this technique to measure the sizes of known exoplanets and to start to characterise them.

By using the transit-timing variation technique, Cheops will be able to discover additional, previously unknown planets around some stars, and also determine the planet masses.

Other techniques used to discover new exoplanets (not employed by Cheops) are: radial velocity, microlensing, astrometry and direct imaging.
To date, **4143** planets have been discovered around stars other than the Sun.

These planets belong to **3077 planetary systems**, of which 674 host more than one planet.

**Radial velocity**
- 870

**Transit**
- 2970

**Direct imaging**
- 133

**Microlensing**
- 103

**Transit-timing variation**
- 11

**Astrometry**
- 10

**Other methods**
- 47

*Information based on exoplanet.eu (as of 5 December 2019)*
EXAMPLES OF PLANETARY SYSTEMS

Solar System

51 Pegasi

51 Pegasi b
Type: Hot Jupiter
Orbital period: 4.2 days
Discovery method: Radial velocity (1995)
First exoplanet discovered around a Sun-like star

55 Cancri

Double star system

55 Cancri b
Warm Jupiter
34 days
Radial velocity (1996)
First discovery of a super Earth exoplanet

55 Cancri c
Super Neptune
44 days
Radial velocity (2002)

55 Cancri d
Super Jupiter
4067 days
Radial velocity (2009)

COROT-7

COROT-7 b
Terrestrial planet
0.8 days
Transit (2009)

COROT-7 c
Super Earth
3.7 days
Radial velocity (2009)
First discovery of a terrestrial exoplanet

COROT-7 d
Candidate, to be confirmed
Radial velocity (2010)

TOI-270

TOI-270 c
Min Neptun 5.7 days
Transit (2019)

TOI-270 b
Super Earth
3.4 days
Transit (2019)

TOI-270 d
Mini Neptun 11.4 days
Transit (2019)

System with super Earth and mini Neptune exoplanets

Relative sizes and distances are not to scale
CHARACTERISING EXOPLANETS WITH CHEOPS

Transit photometry

Size (radius) of the planet and orbital parameters

Radial velocity

Minimum mass of the planet (depending on orbit inclination)

By combining radius (R) and mass (M) measurements, it is possible to estimate a planet’s bulk density (density = M / R^3)

Density enables scientists to distinguish between dense rocky worlds, gas planets, water-worlds and ice-rich planets

Cheops will also discover previously unknown planets by measuring transit-timing variations, and study planet atmospheres using the phase curve method (studying the reflected light as a planet orbits its parent star)
CHEOPS OBSERVING PROGRAMMES

GUEST OBSERVERS’ PROGRAMME, proposed by the scientific community worldwide

Ancillary science: non-time critical observations from other research areas such as stellar physics and planetary science

Searching for new planets around bright stars that are already known to host one or more planets

Searching for special features of particular planets (moons, rings, tidal stretching)

GUARANTEED TIME OBSERVING PROGRAMME, compiled by the Cheops science team

Improving the size measurements of planets for which transit and radial velocity measurements are already available, to provide better estimates of their density

Searching for transits of planets that were discovered via the radial velocity method

Characterising the atmosphere of planets using the phase curve method
**WHAT ARE EXOPLANETS MADE OF?**

How Cheops will investigate the composition and internal structure of planets

- Rocky super Earths
- Gas dwarfs (?)
- Ice giants
- Massive core subgiants (?)
- Mini Neptunes
- Ocean planets (?)
- Earths

**Hydrogen / helium envelope**
**Thin atmosphere**
**Ice mantle / volatile* envelope**
**Solid core (rocks, metals)**

* Planetary scientists call volatiles all chemical elements and compounds with low boiling points that are associated with a planet's or moon's crust or atmosphere. These include: nitrogen, water, carbon dioxide, ammonia, hydrogen, methane and sulphur dioxide.

**Super Earths**
1 M$_{\text{Earth}}$

**Neptunes**
10 M$_{\text{Earth}}$

**Jupiters**
1000 M$_{\text{Earth}}$

Cheops will measure the sizes of Earth- to Neptune-sized planets. Combining size and mass measurements, it is possible to determine the bulk density of the planets and constrain their composition.

Cheops will also measure the light curves of hot Jupiters to study how energy is transported in planetary atmospheres.
Some of the open questions Cheops will address

1. Which super Earths have volatile envelopes?
2. What is the minimum mass of a rocky/solid core needed to form a gas giant?
3. How massive can a solid core grow before accreting a hydrogen/helium or volatile envelope?
4. Which super Earths could bear habitable conditions?
5. Are there new families of yet undiscovered planets? What are they made of? Examples: giant ocean planets, dwarf gas planets
6. What is the role of planet migration on the formation and evolution of planets?
Some of the open questions Cheops will address

- What is the fate of planets that receive a lot of radiation from their parent star?
- Do all such irradiated planets lose their atmosphere?
- Are hot super Earths leftovers after the atmosphere has evaporated?
- Can rocky planets disintegrate?

Legend:
- Hydrogen / helium envelope
- Thin atmosphere
- Ice mantle / volatile envelope
- Solid core (rocks, metals)
HIGH PHOTOMETRIC STABILITY AND PRECISION

The *signal* of an exoplanet transit can be extremely tiny for the smallest planets, and *noise* from the instrument itself can potentially obscure the transit, so the instrument is designed to be as *stable* as possible.

- **Sunshield:** to keep the instrument shaded; it also carries the solar panels
- **Telescope tube:** housing the primary and secondary mirrors
- **Baffle cover:** to protect the optics from contamination up until and during launch; it will be opened once Cheops is in Earth orbit
- **Baffle:** to keep stray light (e.g. from the Earth and Moon) from entering the telescope
- **Radiators:** to provide cooling to the detector and electronics
- **Star tracker:** mounted directly onto the instrument to improve pointing stability and minimise misalignment effects
- **Spacecraft attitude and orbit control system:** to control the satellite pointing in order to minimise the pointing error; the instrument provides information on the actual position of the target star that is being measured to the platform attitude control system

One instrument: a high precision photometer
- 300 mm effective aperture telescope
- single charge-coupled device (CCD) detector
- covering wavelengths between 350 and 1100 nm
WHERE IS CHEOPS?

Riding on the day-night terminator in a **dawn/dusk orbit** at an altitude of **700 km**

Cheops will lift off on a **Soyuz-Fregat rocket** from Kourou, French Guiana

In contact with **ground stations** once or twice per day, downloading data at a rate of **1.2 Gbit/day**

**Science Operations Centre (SOC)**
Geneva, Switzerland
Planning of observations; processing, archiving and distribution of science data

**Mission Operations Centre (MOC)**
Torrejón, Spain
Spacecraft commanding sequences uplink; telemetry downlink

**Command uplink and data downlink via two ground station antennas** at Villafranca & Torrejón, Spain

The ESA ground station at Kiruna, Sweden will also be used during **early mission operations**
**LAUNCH DETAILS AND TIMELINE**

**Launch with Ariane 6 rocket**
- Launch date: 18 December 2019
- Time:
  - 05:54 GTF (French Guyana Time)
  - 08:54 GMT (Greenwich Mean Time)
  - 09:54 CET (Central European Time)

**Satellites Details**
- **Cosmo-SkyMed Second Generation**
- **OPS-SAT**
  - Height: 30 cm
  - The world's first free-for-use, in-orbit testbed for new software, applications and techniques in satellite control.
  - It carries a computer 10 times more powerful than on any preceding ESA mission, and enables innovative new software to be tested in orbit.
- **ANGELS**
- **EYE-SAT**
  - CubeSats are small satellites based on standardised 10 cm cubic units.
- **Cheops**

**Timeline**
- Lift-off (L) + 2 mins: First stage separation
- L + 3 mins: Fairing jettison
- L + 5 mins: Second stage separation
- L + 9 mins: Third stage separation
- L + 23 mins: Cosmo-SkyMed separation
- L + 145 mins: Cheops separation
- L + 174 mins: First acquisition of Cheops signal expected (L + 169–179 mins)
- L + 251 mins: OPS-SAT separation
- L + 257 mins: All CubeSats are separated
CHEOPS TEAM AND CONSORTIUM

CHEOPS TEAM

ESA Cheops project manager: Nicola Rando

ESA Cheops project scientist: Kate Isaak

Cheops consortium principal investigator: Willy Benz (University of Bern)

Cheops consortium project manager: Christopher Broeg (University of Bern)

CHEOPS CONSORTIUM MEMBERS

Cheops consortium webpage: cheops.unibe.ch

Austria
Institut für Weltraumforschung (IWF), Graz
University of Vienna

Belgium
University of Liège
Centre Spatial de Liege (CSL)

France
Laboratoire d’Astrophysique de Marseille (LAM)
Institut d’Astrophysique de Paris
Institut d’Astrophysique & de Planétologie de Grenoble
Institut de Physique du Globe
Observatoire de Paris

Germany
Deutsches Zentrum für Luft- und Raumfahrt (DLR) Institute of Planetary Research, Berlin
Technische Universität Berlin

Hungary
Admatis
Konkoly Observatory

Italy
Osservatorio Astrofisico di Catania – INAF
Osservatorio Astronomico di Padova – INAF
Università degli Studi di Padova
Università degli Studi di Torino

Portugal
Deimos
Centro de Astrofísica da Universidade do Porto

Spain
Institut de Ciències de l’Espai (ICE)
Instituto de Astrofísica de Canarias (IAC)
Centro de Astrobiología INTA-CSIC

Sweden
Chalmers University of Technology
Lund Observatory
Stockholm University

Switzerland
University of Bern
University of Geneva

UK
University of Cambridge
Keele University
University of St. Andrews
University of Warwick
ARTIST IMPRESSIONS

- CHEOPS OBSERVING EXOPLANETS
- THE CHEOPS SATELLITE
- CHEOPS IN SPACE (BAFFLE COVER CLEARED)
- CHEOPS IN SPACE (BAFFLE COVER OPEN)
- CHEOPS IN ORBIT
- EXOPLANET IMAGINARIUM
- TRANSITING EXOPLANETS
- EXOPLANET SYSTEM
- EXOPLANET SYSTEM
- EXOPLANET SYSTEM
- EXOPLANET SYSTEM
- TRANSMITTING EXOPLANET
- WHAT KIND OF PLANETS WILL CHEOPS STUDY?
Livestream
ESA will cover the launch of Cheops at esawebtv.esa.int on 17 December, TIME 09:30 CET. It will cover the liftoff at 09:54 CET, the Cheops separation approximately 2.5 hours later and the acquisition of signal approximately 3 hours later.

ESA TV productions
ESA TV productions are available at esa.int/esatv/Videos_for_Professionals.

Cheops online
Information for general public: esa.int/cheops
In-depth information: sci.esa.int/cheops

Cheops on social media
Twitter: @ESA_CHEOPS
Official hashtag: #cheops
Facebook: Facebook.com/EuropeanSpaceAgency
Youtube: Youtube.com/ESA
Instagram: Instagram.com/europeanspaceagency

Multimedia
A variety of photographs, illustrations, graphics and animations are available via:
ESA Space in Images
ESA Space in Videos
ESA’s Photo Library for Professionals
ESA’s Video Library for Professionals

See also pages 21-23 in this media kit for recommended multimedia products.