Status, Flight Preparation, and Future Instrument Opportunities of the STUDIO Balloon-Borne Telescope Platform

Sarah Bougueroua *[1], Philipp Maier [1], Mahsa Taheran [1], Andreas Pahler [1],, Maria Ångermann, Jürgen Barnstedt [3], Angel Colin[4], Lauro Conti [3], Sebastian Diebold[3], Rene Duffard [4], Christoph Kalkuhl [3], Norbert Kappelmann [3], Thomas Keilig [1], Sabine Klinkner [1], Alfred Krabbe [1], Michael Lengowski [1], Christian Lockowandt [2], Thomas Müller [5], Thomas Rauch [3], Thomas Schanz [3], Beate Stelzer [3], Alf Vaerneus[2], Klaus Werner [3], Jürgen Wolf [1]

* sbougueroua@irs.uni-stuttgart.de,

[1] Institute of Space Systems, Stuttgart, Germany; [2] Swedish Space Corporation, Solna, Sweden; [3] Institute for Astronomy and Astrophysics Tübingen (IAAT), Tübingen, Germany; [4] Instituto de Astrofísica de Andalucía (CSIC), Granada, Spain; [5] Max-Planck-Institut für extraterrestrische Physik, Garching, Germany

The European Stratospheric Balloon Observatory *Design Study* (ESBO *DS*)

The **E**uropean **S**tratospheric **B**alloon **O**bservatory *Design Study* (ESBO *DS*) project aims to establish a balloon-based observatory that offers the scientific community access to astronomical observations in the stratosphere (30 to 40km).

The observatory will offer regular flights with reusable hardware. Safe recovery of the payload allows for update, exchange, and refill of the systems before subsequent flights. The modular and flexible design of the gondola and payload increase the efficiency of the infrastructure while keeping the cost of flights reasonably low.

STratospheric UV Demonstrator of a Imaging Observatory (STUDIO)

The first prototype mission of ESBO is the **St**ratospheric **U**V **D**emonstrator of an **I**maging **O**bservatory (STUDIO).

Two main scientific cases motivate the UV scientific part of Studio; **a-** the search for hot and compact stars, and **b-** the detection of cool dwarf stars. Other secondary planetary and asteroid cases are being discussed.

STUDIO's optical payload is composed of a 50cm aperture closed-tube telescope, onto which is mounted the **T**elescope **I**nstruments **P**late (TIP). It is a modified Dall Kirkham in an F/13 configuration. The telescope secondary mirror is moveable via three remotely operable actuators. These are used to move the telescope's M2 with a resolution of ~3 µm, while the telescope's depth of focus is ±30 µm at 180 nm.

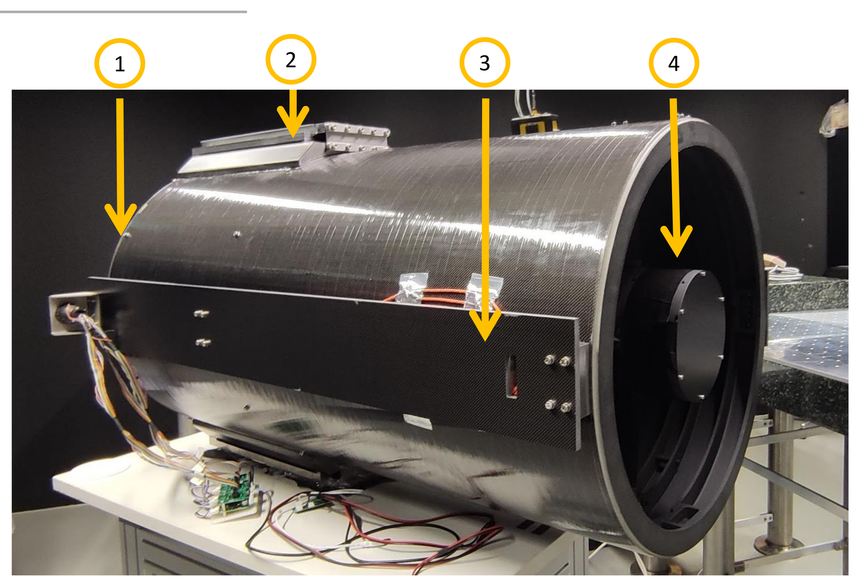

Figure 1 : STUDIO 50 cm telescope in the clean room of the IRS, Uni. Stuttgart

1- Back-plate pf the telescope and mechanical interface to the TIP
2- Mechanical interface to the gondola
3- Mechanical interface to the star tracker
4- Telescope secondary mirror mechanism

The main scientific instruments on the TIP are:

1. **An advanced photon-counting, imaging**
2. **microchannel plate (MCP) detector** that measures photons in the UV band from 180 nm to 300 nm. The detector will be capable of processing about 300 000 detected photons per second. The detector is currently being developed at the Institute Institute for Astronomy and Astrophysics Tübingen (IAAT), Germany. [1]
3. **A visible light imaging instrument** that will mainly serve as the tracking sensor in a closed-loop fine image stabilization system, but that will also be used as an auxiliary science instrument. The PCO.edge 4.2[2] camera was selected.

Additionally, the TIP will house one filter wheel for each instrument carrying Sloan u & GALEX NUV filters as well as an open position, a beam splitter and a Tip/Tilt mirror and a S-340 Piezo Tip/Tilt Platform [3] used for the image stabilization systems.

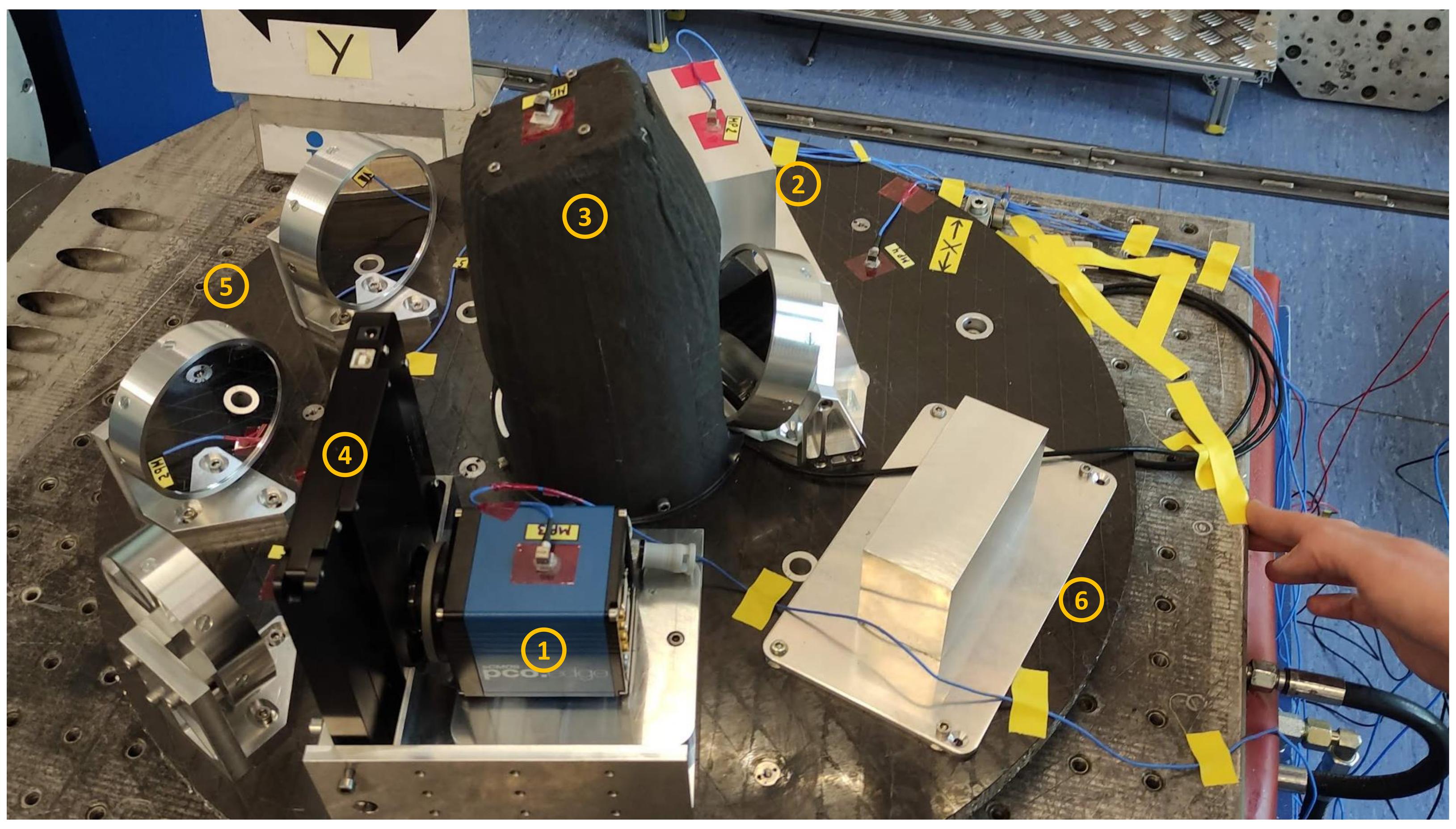

Figure 2 : Picture of the TIP duirng the vibration tests

1- PCO.edge 4.2 camera 2- mass dummy of the UV detector 3- CFRP tower holding the tip/tilt platform 4- Filter wheel 5- Fold mirrors 6- Mass dummy of the UV detecor proximity electronics

STUDIO Balloon Gondola

The balloon gondola that houses the STUDIO payload has been custom built for the prototype mission. Its structure is designed from COTS aluminum trusses in combination with custom-made tubing structures and holds the payload and all the subsystems.

The modular design of each part allows for fast and easy assembly and disassembly, with the possibility to house different, also larger, payloads (telescopes). The telescope and star tracker are installed on a central stiff gimbal of the gondola, whereas all the electronics, service systems and potential add-on instruments are mounted on the gondola floor. The floor uses fastener rails that offer multiple mounting points for more flexibility of positioning of the said systems.

The gondola offers a coarse stabilization system of ~40 arcsec. A fine image stabilization system placed on the TIP compensates for the Remaining jitter and achieves the 1 arcsec pointing stability.

Figure 3 : CAD of the Gondola Structure [4]

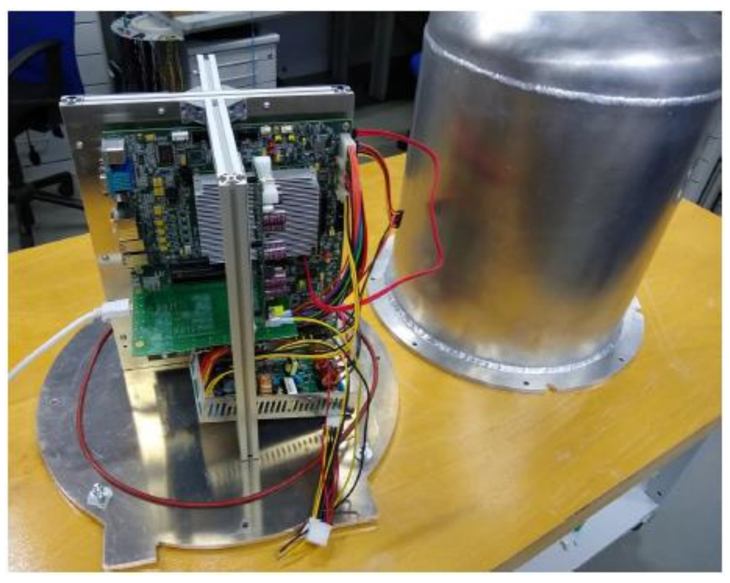

Figure 4 : Pressure housing including the STUDIO onboard computer and peripheral components

Figure 5 : Mechanical Gondola Structure and telescope mass dummy [4]

Flight preparation and tests

In preparation of STUDIO's maiden flight, in season 2023 or 2024, the prototype is undergoing various functional (on-sky, software, image stabilization system, attitude control system) and environmental (thermal-vacuum, vibration) tests.
Details and results of which can be found in the "Status, Flight Preparation, and Future Instrument Opportunities of the STUDIO balloon-borne telescope platform" SPIE 2022 published manuscript.

The integration of the gondola and payload will take place in the next months and will be followed by full-system tests.

Flight opportunities

ESBO aims to establish a balloon-based observatory to offer a wide scientific community the possibility to fly their instruments and make astronomical observations in the high stratosphere. This is possible due to the already implemented features:

1- The TIP's modular design allows to easily access the scientific instruments. These can easily be updated before next flights, or exchanged with more advanced ones without having to modify the TIP configuration.
2- The needs of a new mission might require different TIP layout. The long focal length (ca. 905mm out of the telescope) offers a flexibility and space to design a completely new TIP. The mechanical interface on the telescope back-plate can be used to attach a total weight of the new TIP up to 50 Kg.
3- The modular and scalable gondola offers the possibility to replace the complete payload. Allowing the installation of larger telescopes (goal of 5 m aperture in the long term). This enables observations in the visible, near infrared, and far infrared.

A safe landing technology is currently being investigated. It uses steerable parafoil which allows a considerable reduction of structural landing loads. This ensures that a maximum of flight hardware is re-used and that the flight costs remain reasonably low.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 777516.

ESBO DS Stratospheric Observatory

University of Stuttgart Germany

SSC

MPE

EBERHARD KARLS UNIVERSITÄT TÜBINGEN

References

[1] Conti, L., Barnstedt, J., Hanke, L., Kalkuhl,C., Kappelmann, N., Rauch, T., Stelzer, B., Werner, K., Elsener, H.-R. and Schaadt, D.M., "MCP detector development for UV space missions," Astrophys Space Sci 2018
[2] PCO AG, "pco.edge 4.2 scientific CMOS camera | v1.03A," Germany.
[3] PI, "Piezo Tip/Tilt Platform, High Dynamics for Mirrors and Optics to Ø 75 mm (3")" 2022.
[4] Christian Lockowandt, "Gondola and pointing system", Swedish Space Corporation, 2018.