STARGAZER TELESCOPE

SYSTEMS ENGINEERING REPORT N.1

Introduction

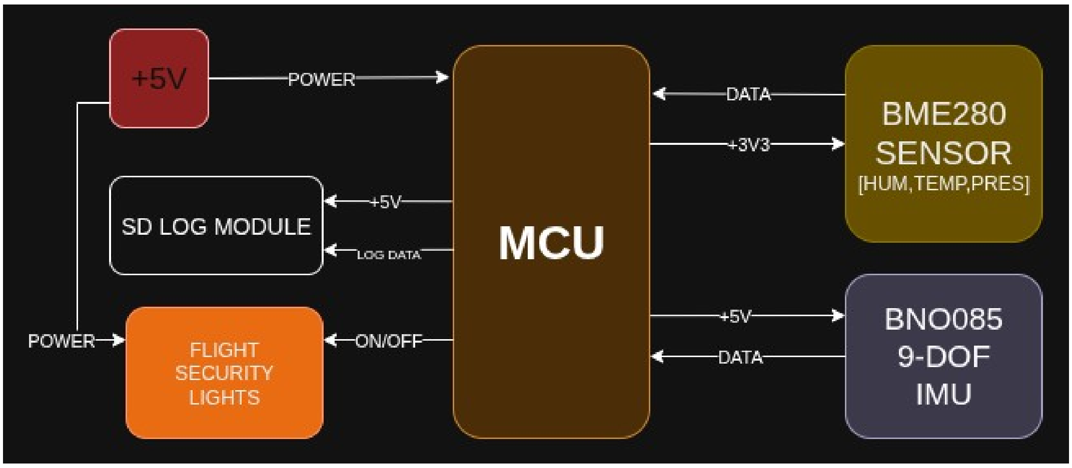
This Engineering & Design Report n.1 summarizes the current state of development of the first Stargazer Telescope platform. It describes how the system is designed, how its subsystems work individually, and how they interact to perform the mission.
The goal of this document is to give anyone interested — whether engineers, students, or curious readers — a clear and structured view of how the project was built and how it works at this stage. Future reports will expand on improvements, test results, and new iterations of the system.

SUBSYSTEMS OVERVIEW

Environmental Monitoring Unit (EMU)

The Environmental Monitoring Unit (EMU) is an electronic board responsible for monitoring and logging flight conditions. This includes measuring temperature, humidity, and atmospheric pressure, as well as tracking the movement of the payload during flight through its dedicated 9-DOF inertial measurement unit (IMU).

Thanks to its onboard sensors, the EMU also manages the ALTITUDE TRIGGER — a digital signal that indicates when the observation altitude has been reached.



EMU Diagram

Moon Camera Unit

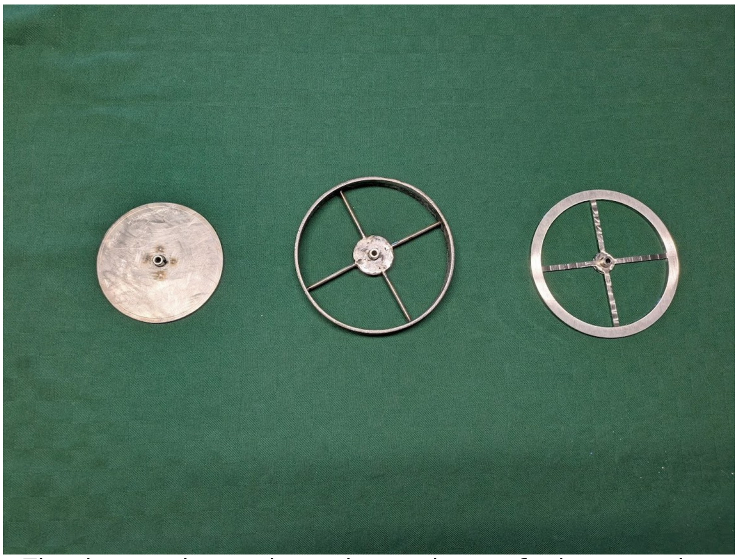
The Moon Camera is a critical subsystem for determining the absolute orientation of the payload with respect to the night sky. It consists of a wide-angle camera and dedicated processing electronics that periodically capture images of the sky. Through onboard algorithms and filtering techniques, the system identifies the position of the Moon relative to the payload’s current attitude.
By knowing the Moon's position in the sky, the Moon Camera provides the rest of the system with an absolute celestial reference. This is essential for accurately aiming the payload camera toward the desired observation target.

Reaction Wheel Unit

The Reaction Wheel Unit is a subsystem composed of a BLDC motor, a precision steel wheel with a diameter of 15 cm, and the supporting motor electronics, including a VESC controller, a magnetic encoder, and a 9-DOF IMU.

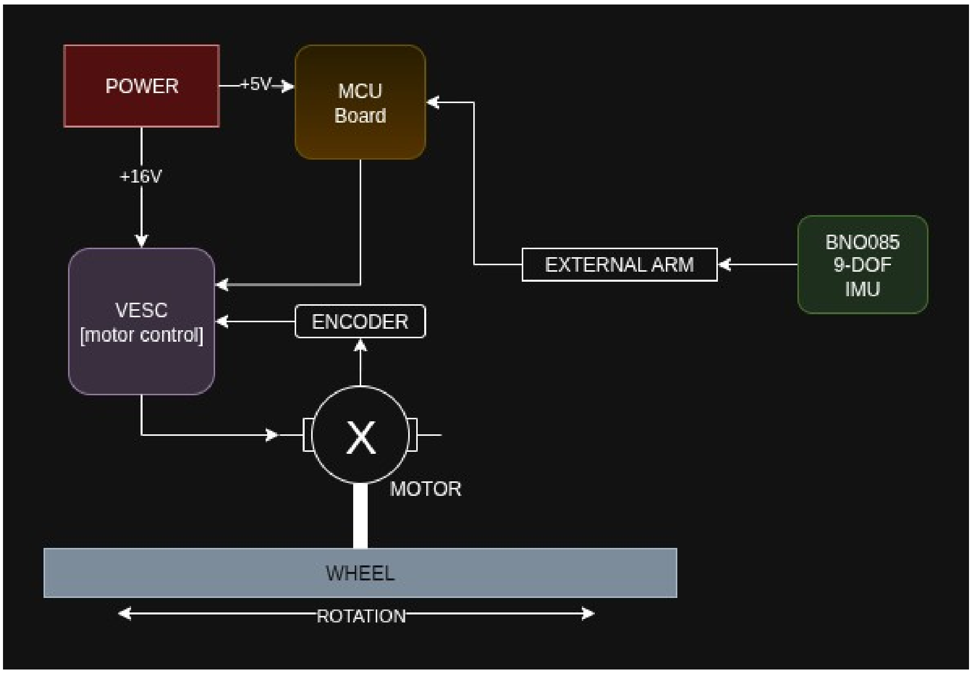
This unit is responsible for the azimuthal attitude control of the payload, allowing it to rotate toward the target direction once at the observation altitude and maintain stable pointing throughout the mission.

The operating principle is relatively simple: the wheel spins in the opposite direction of the payload’s motion to either stabilize it or actively steer it toward a specific heading. The VESC controls the brushless motor, while the encoder provides precise feedback on the motor shaft position, enabling smooth and accurate rotation even at low speeds.



The image shows three iterations of the reaction wheel design. The first two versions were used for early testing, while the final version on the right was CNC-machined and selected for integration into the flight unit.

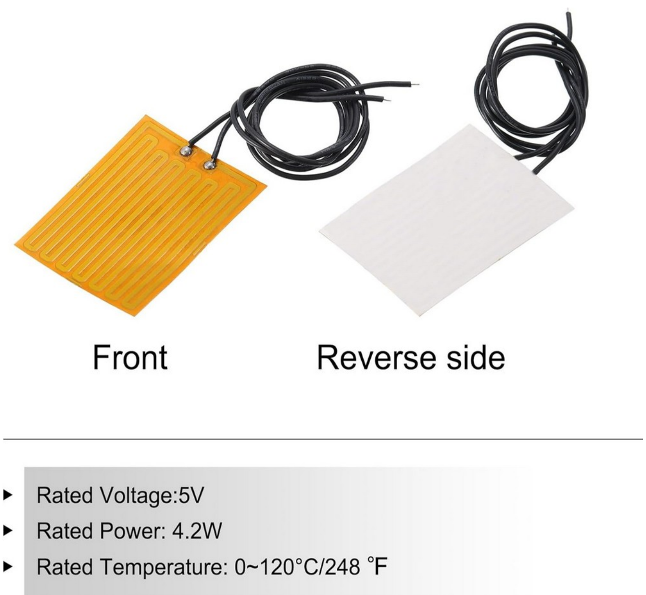
The 9-DOF IMU is mounted externally on a dedicated arm to reduce interference and improve measurement accuracy. It estimates the payload’s orientation in space and provides input to a PID control loop running on the wheel's control board, enabling precise pointing and active stabilization.



Reaction Wheel Unit Diagram

Finally, once the system detects that it has maintained correct pointing for a certain duration, it activates a digital signal (READY TO STARGAZE) to notify the rest of the payload that the target orientation has been successfully reached.

Temperature Control Unit



The Temperature Control Unit is a straightforward yet essential subsystem that enables the payload to operate in extreme thermal environments, such as the -50 °C conditions commonly found in the stratosphere. It consists of an electronic board that reads multiple thermistors placed throughout critical areas of the system. Based on the temperature readings, it selectively activates corresponding resistive heaters to maintain safe operating conditions for the onboard electronics and mechanical components.

Payload Camera Control Unit

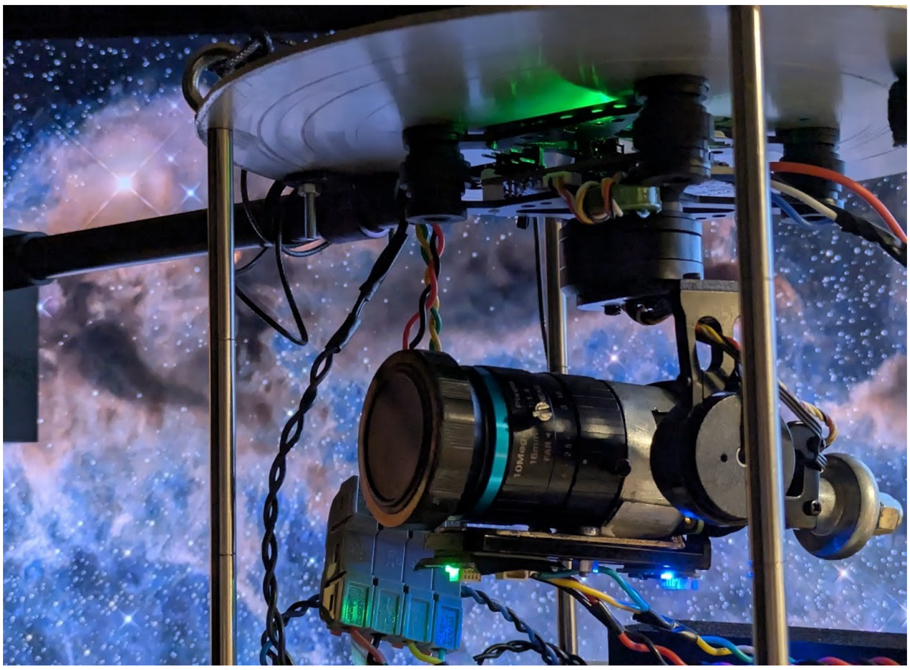
The Payload Camera Control Unit is at the core of the mission. It consists of the electronics responsible for managing the payload camera, including capturing image frames and storing them locally for post-mission image processing and data analysis.

In addition to image acquisition, the unit handles the high-level control of the camera stabilization system (gimbal). Rather than performing real-time stabilization itself, it sends commands to the gimbal defining the desired pointing direction and selecting the appropriate stabilization mode. This allows the system to maintain flexibility and modularity while keeping the control logic centralized.

Gimbal Stabilization Module

The Gimbal Stabilization Module is based on the SimpleBGC platform, a widely used and reliable solution for stabilizing camera systems in professional and hobbyist applications. Although it is a closed-source system, it offers extensive configurability and high performance, making it well-suited for integration into the telescope platform. Through careful tuning of its PID parameters and motor settings, the system achieves precise and responsive stabilization, essential for capturing sharp and stable images during operation.

This is a three-axis gimbal – a mechanical platform that isolates a mounted camera from rotational motion along the pitch, roll, and yaw axes. The unit keeps the camera steady during image capture and, in combination with other subsystems, enables the collection of multiple frames from the same region of the sky.



This consistency is essential for post-processing techniques such as frame stacking.

Stratospheric balloon flights are inherently turbulent, and this unit plays a key role in filtering out that motion, resulting in sharp and usable images.

Power Unit

The Power Unit consists of the battery pack and voltage regulation circuitry that supply electrical power to the entire payload. It provides multiple voltage rails required by the different subsystems and ensures stable and continuous operation throughout the duration of the mission.

INTEGRATED SYSTEM BEHAVIOR