ScyLight
OPERATIONS DEVELOPMENT SUPPORT FOR OPTICAL AND QUANTUM
GROUND INFRASTRUCTURE

SL-6C.031-P2

ESA Contract No. 4000140013/22/UK/AL

Telescope controller and PAT module

Operations Manual

Date: December 2025
DOCUMENT REFERENCE: S22SkinOperation_OperationsManual
Status: Draft

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Telescope controller

The SiTech Force One TCS controller is installed in a custom built case where all the other new boards and power supplies are installed. For backward compatibility with the previous TCS, the new case has the same connectors on the back as the old TCS. These include:

- Motor power
- Motor encoders
- Telescope encoders
- Mirror doors
- Telescope hard limits
- Telescope focus control

There is also a network interface for the Alpaca functionality of the new focuser and mirror doors boards. The SiTech controller is connected to the host computer via USB cable. The most accurate way to control and correct the telescope tracking via offsets is done via TCP/IP commands.

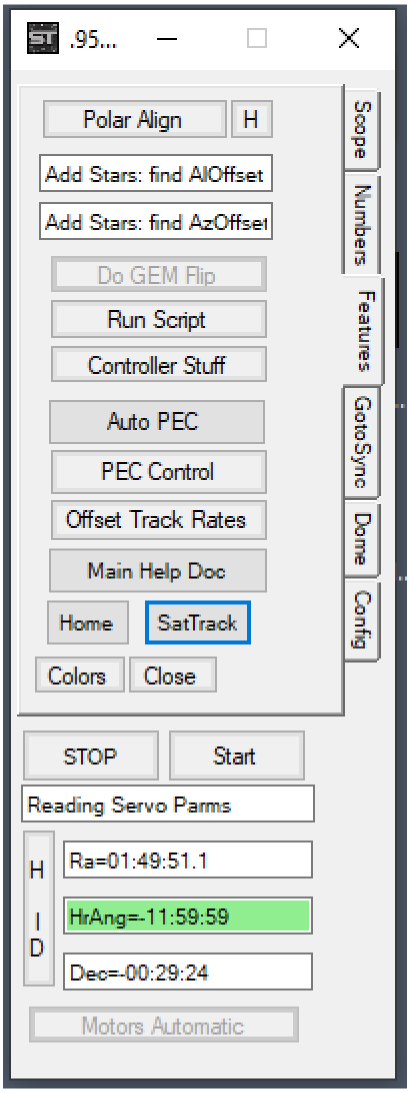
Force One Brushless SITECH controller user's manual

Available on:

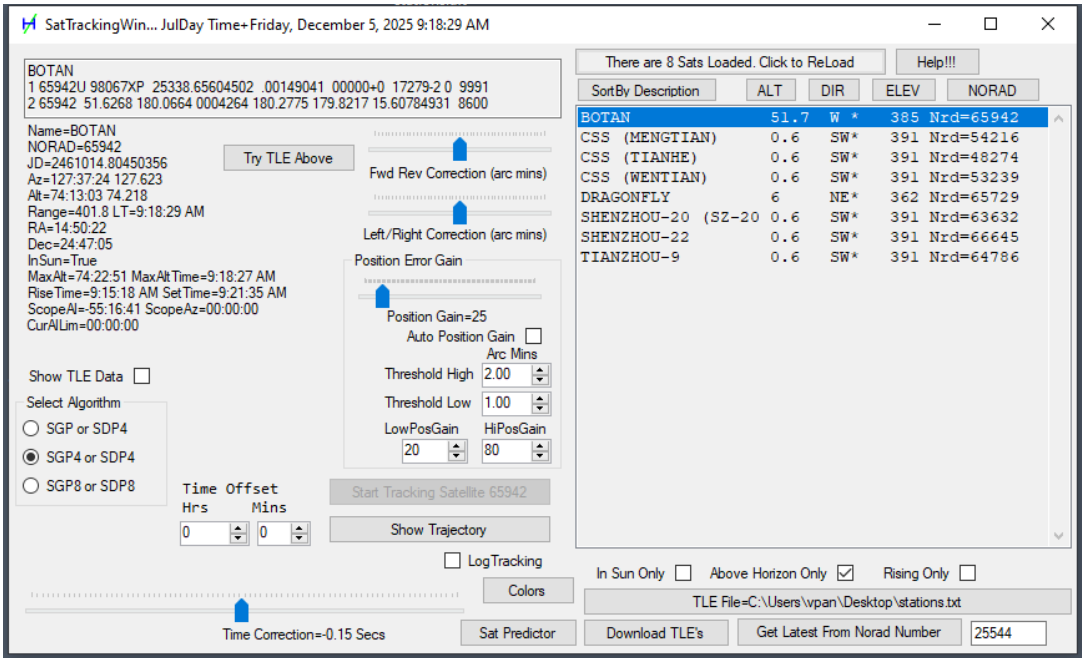
https://siderealtechnology.com/BrushlessManual_1_4.pdf

LEO operations with the New Controller

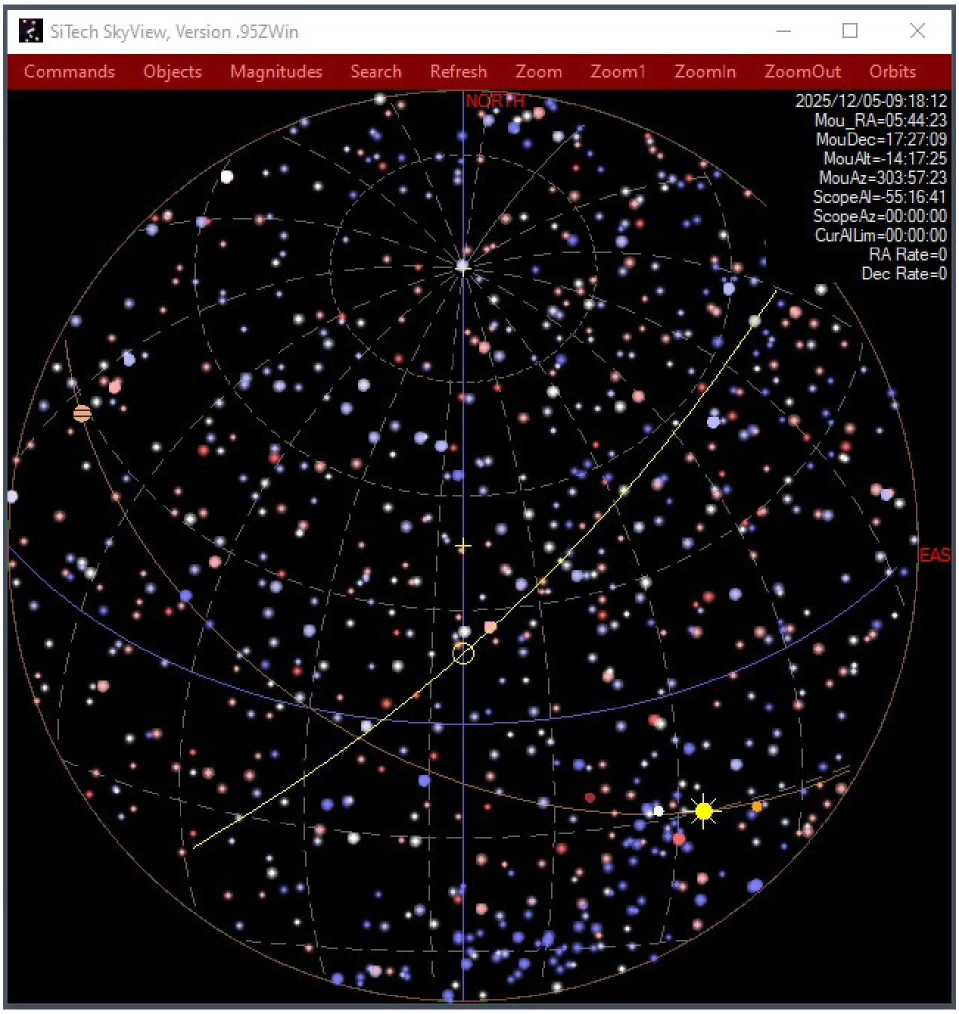
In the main SiTech telescope driver window, the user selects the Features tab and then clicks the SatTrack button:



This opens the Satellite window inside the SiTech telescope driver, where a TLEs text file can be loaded, or TLEs can be alternatively downloaded from the internet. The TLEs contained in the file are loaded in a list, and a satellite can be selected. Afterwards, the user can start tracking that satellite with the press of a button.



If the satellite is above the minimum telescope altitude limit, the tracking starts immediately. If it is lower, the telescope will move to the closest satellite path position and wait for the altitude to rise, thus automatically starting to track the satellite. The tracking stops automatically when the satellite reaches the lowest allowed telescope altitude. It is also possible to see the position of the telescope and the path of the satellite on the sky by opening the Sky window in the Scope tab of the SiTech driver:



The SiTech software provides an automatic satellite tracking interface with the capability for closed-loop feedback for corrections. There are two ways to initiate satellite tracking:

1) Via graphical user interface: The user can load a list of TLEs, select a Satellite and start tracking, but corrections in the path have to be done manually, which is not an easy task when performing LEO tracking.

2) Programmatically: Using the exposed TCP/IP API provided by SiTech. The client software connects to localhost:8086 and can send commands that will automate and fine-tune the case of LEO satellite tracking through closed-loop feedback. The most important commands are:

SateliteOpenWindow: This window must be opened for the rest of the commands to work.

SatelliteLoadTLE: Client sends the TLE to the controller software.

SatelliteStartTrack: This command initiates satellite tracking. If the satellite is below the telescope altitude limit, the telescope will move to the lowest point and wait for the satellite to climb higher in the sky to begin tracking.

SatelliteStopTrack: Stops tracking the current satellite.

SatelliteSetTrackingGain: Sets the tracking gain, a very important factor in satellite tracking precision. A balance between oscillating tight tracking and slower tracking movement is the key.

SatelliteNudgeFwdBack: Nudges the telescope a defined arcseconds offset along the path of the satellite.

SatelliteNudgeRightLeft: Nudges the telescope a defined arcseconds offset to the right or the left of the satellite path.

SatelliteTimeOffset: Adds defined seconds to the time calculation for the satellite being tracked.

The Nudge commands will be used when the closed-loop feedback system detects that the satellite being tracked exits a predefined radius from the center of the tip/tilt mirror optical axis, re-centering the satellite to its field of view.

“Dry test” for LEO tracking

A LEO pass dry run with the dome closed was performed. The telescope tracked the target effectively. A video demo is available and can be found in the project's SharePoint on

https://artes-sp-ext.esa.int/sites/TIA-T-ext/Projects/781

in the directory 40-Monthly Progress Reports under the name LEO_tracking_02_09_2024

Pointing, Acquisition, Tracking (PAT)

Installation

The following actions must be followed to mount the PAT on the telescope.

1. **Unpack the PAT**
   The PAT optical module is unpacked. All cables are carefully untangled and arranged, and the lid of the PAT unit is subsequently removed.

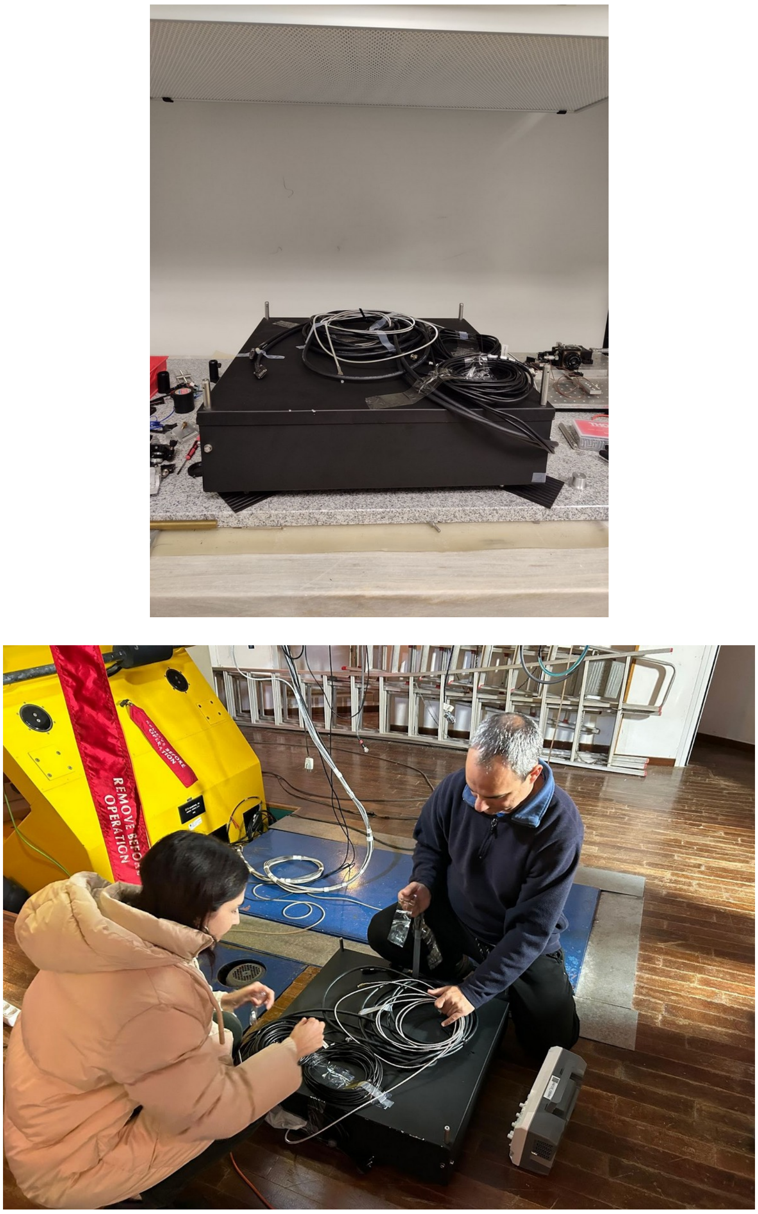


Figure 1: Unpacking the PAT module

Figure 2: PAT module without the covered lid.

2. Mount the flange (adapter) on the East side port of the GAM

The optical communication system designed and assembled by IESL-FORTH must be placed on the East GAM port of the 1.3m telescope.

The procedure is as follows:

With the telescope in zenith position, take out the lid that covers the port.

Attach the PAT breadboard to the telescope GAM. An adapter flange was designed for this specific purpose. The flange is used to connect the GAM flange to the breadboard entrance port. The flange is first attached to the GAM flange, and then, using specially arranged bore threaded holes from the flange side and matching holes from the PAT breadboard side, the breadboard can be attached.

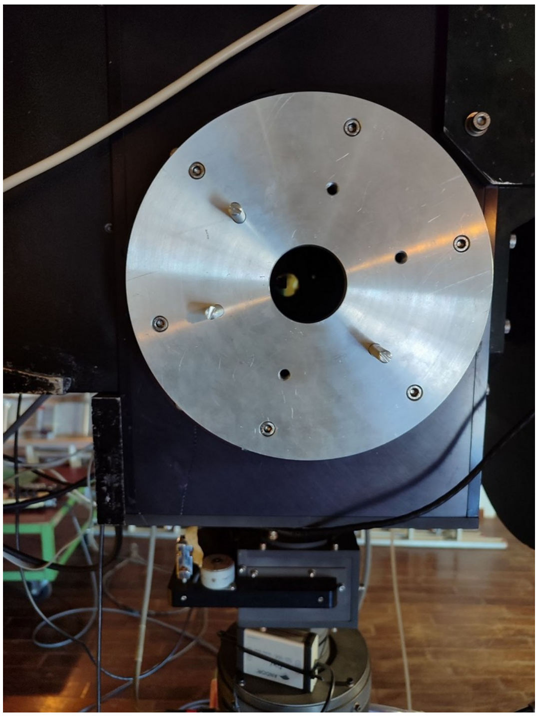


Figure 3: PAT external flange with the three guiding pillars for optical module installation.

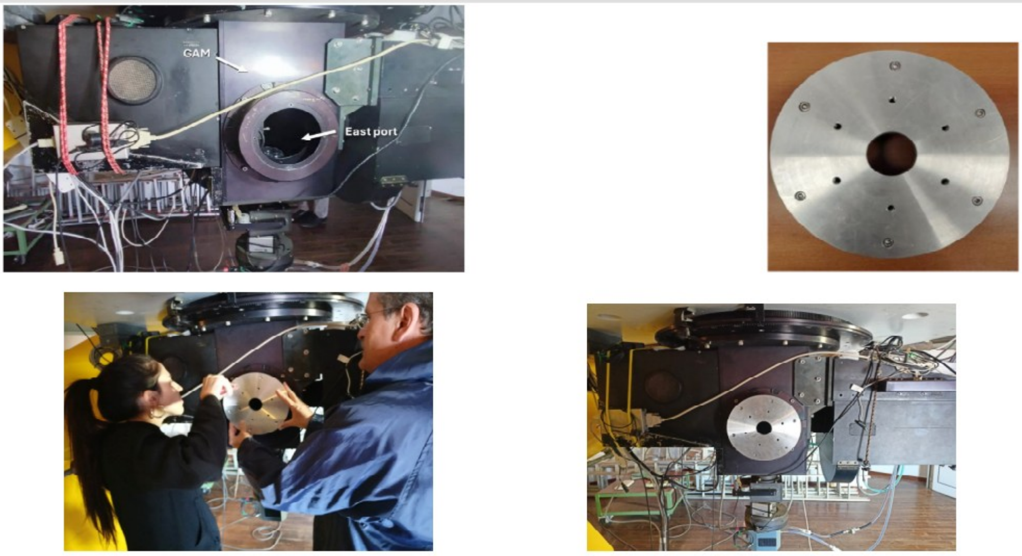


Figure 4: Mounting the PAT in the East port

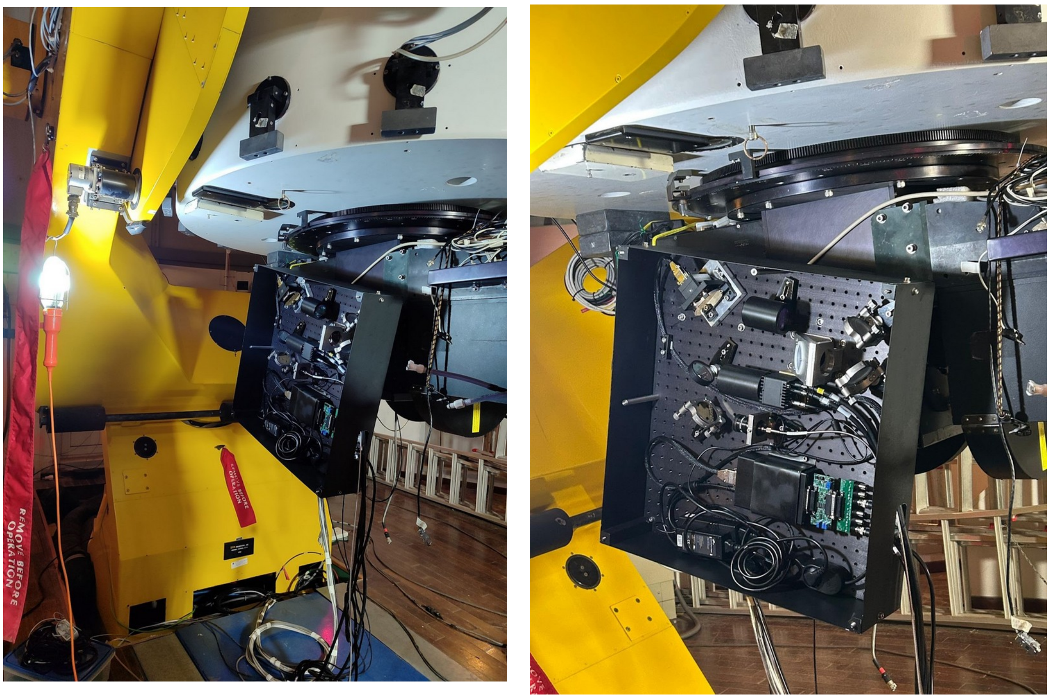


Figure 5: PAT mounted

3. **Connect the cables**

Four cables and one multimode fiber are routed from the PAT optical module. Two of the cables are Camera Link outputs from the SWIR camera and shall be connected to the rear panel of the desktop computer. The cable marked with the yellow tag and labeled “1” shall be connected to Desktop Input 0, while the cable labeled “2” shall be connected to Desktop Input 2. The remaining two cables carry the X and Y command signals from the fast-steering mirror controller and shall be connected to the AI0 and AI1 analog inputs of the card, respectively (see photos below).

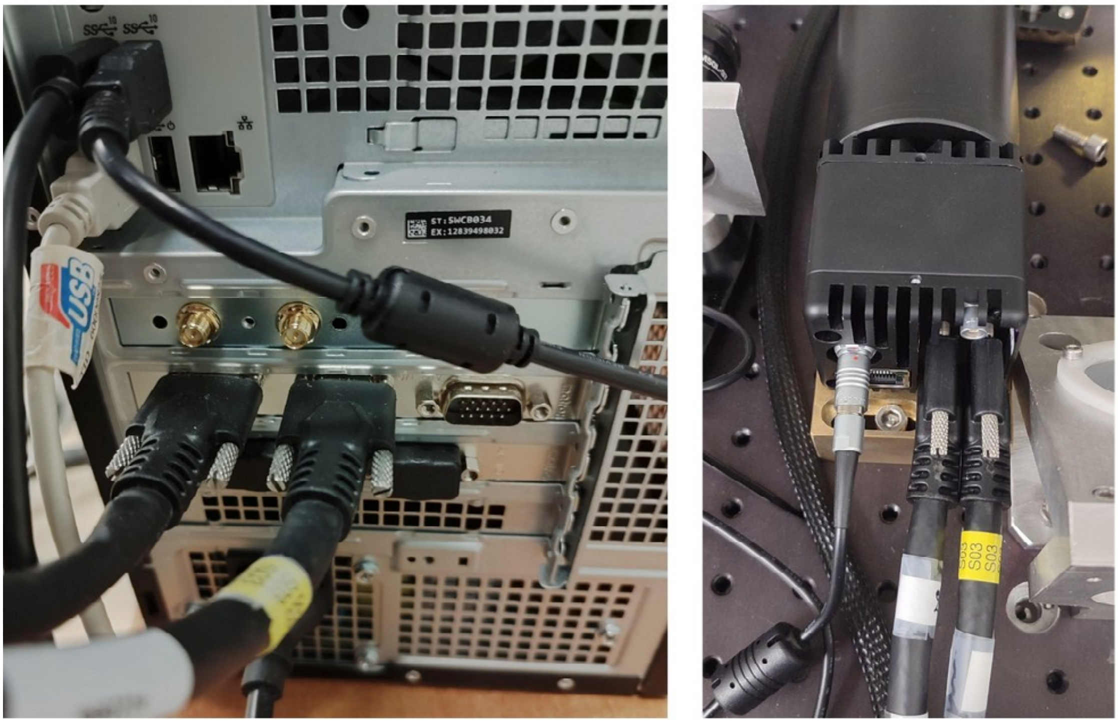


Figure 6: Camera Link inputs on the desktop (left) and outputs from the SWIR camera (right).

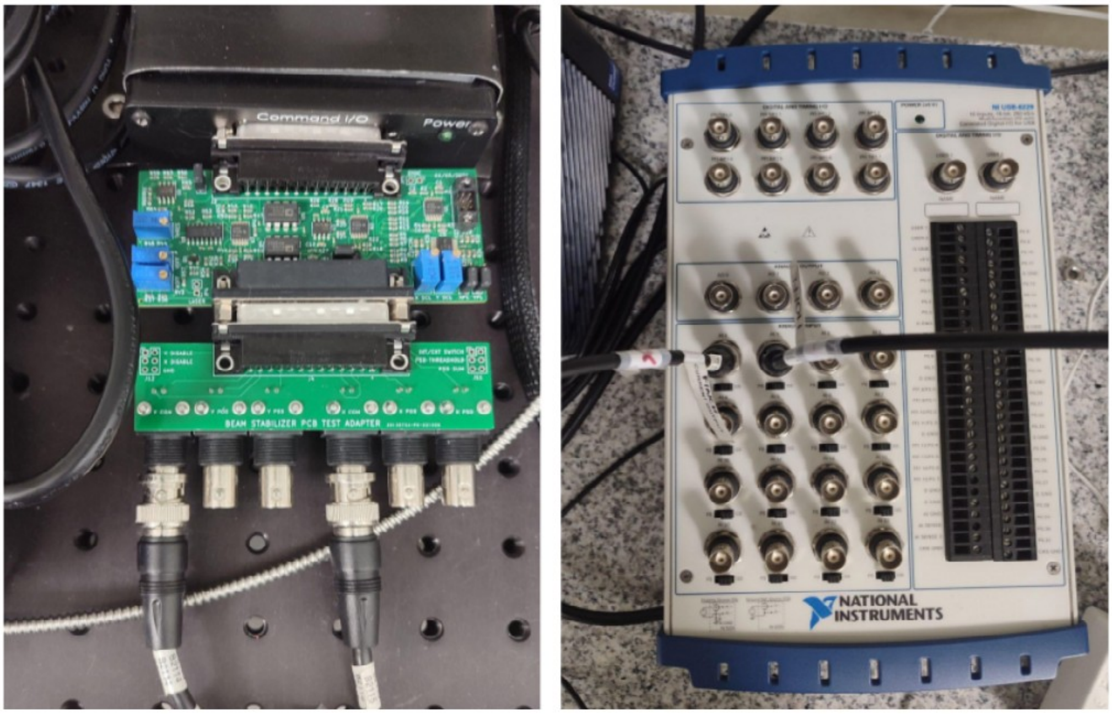
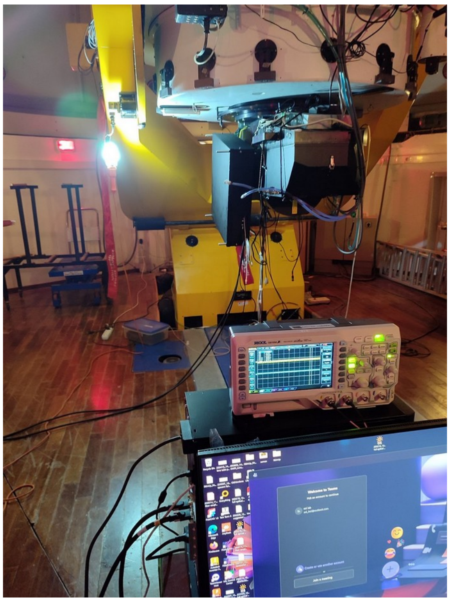


Figure 7: X and Y command outputs from the fast-steering mirror (left) and inputs at the analog card (right).

An additional power cable also extends from the PAT and shall be connected to the main power supply.

The desktop shall be placed on a separate desk, connected to the main power supply, and powered on after the Camera Link cables have been connected. The analog card shall also be placed there, connected to the power supply, and powered on. Note: the fast-steering mirror controller, which is located on the optical module, shall be powered on only after the analog card has been turned on.



Once the cables are connected, the operator must verify that their length is sufficient for the telescope's expected motion. Move the telescope in different directions and annotate its limits in terms of altitude and azimuth.

4. Telescope balance

LEO satellites are fast-moving targets. When the telescope tracks a LEO satellite, it covers a large portion of the sky in a short time. To achieve good tracking, the telescope must be properly balanced. The telescope balance is performed by adjusting counterweights on both the Declination (DEC) axis and the Right Ascension (RA) axis. The procedure is as follows:

1. The telescope is locked in vertical position (zenith position).To ensure proper locking, the safety pins are inserted in their corresponding the pins holes, in both the RA and DEC axes.

2. The DEC drive brake is released

3. The DEC locking pin is removed. By observing how the telescope moves, we can understand whether the imbalance comes from the top or the bottom. There are two types of counterweights: electro-mechanical and lead. The balance of the telescope in the DEC axis is performed by adjusting the two electromechanical counterweights to higher settings and moving the lead counterweights from the south side of the primary mirror housing to the north side. We keep adjusting the counterweights until the telescope is perfectly balanced along the DEC axis at all positions.

4. We set the DEC brake back into normal operation and the telescope in vertical position

5. The locking pin for the RA axis is removed. The telescope is moved only along the RA axis, positioning it 45° away from the Zenith, toward both East and West. By observing how the electrical current of the RA motor changed, we adjusted the counterweights—adding weight on the west side—until the motor drew the same current in all positions, with no imbalance toward either East or West.

PAT Alignment

The PAT design is shown in Figure 13. In this design, the breadboard has been lifted, using four pillars, so that Skinakas' operational conditions can be recreated in the laboratory. In this way, the entrance window is accessible, and after testing the breadboard can be transferred "as is" for installation at the OGS site.

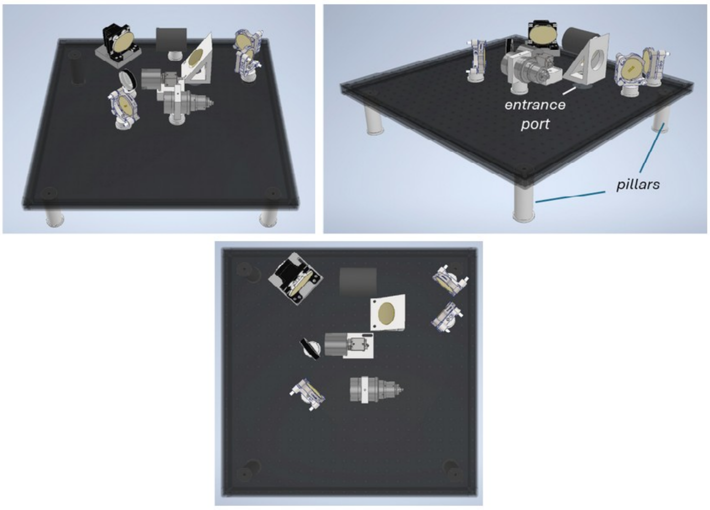


Figure 8: Optomechanical design of the PAT optical module

To align the PAT optical module, we first adjust all the protected-gold mirrors and the system's fast steering mirror to correctly redirect the light beam and ensure proper alignment throughout the entire optical path. Next, we collimate the incoming beam using the CL1 collimator system. The collimator (total length of 77mm) consists of three lenses: two plano-convex lenses with focal length f = 200 mm and one plano-concave lens with f = –100 mm. All optical components are coated with an IR anti-reflection coating. Once the beam is collimated, we install and align the SWIR camera module and the Rx module. After the fast-steering mirror, a 90:10 beam splitter is positioned to extract a small portion of the incoming beam and direct it toward the SWIR camera. In front of the camera, two lenses are placed: a positive meniscus lens with f = 200 mm and a plano-convex lens with f = 125 mm. Together, these lenses focus the beam onto the SWIR camera sensor. The rest of the incoming beam from the beam splitter is directed with the help of a protected gold mirror to the Rx module, which consists of a f=50mm fiber collimator and a multi-mode fiber (50 μm, 0.20 NA).

PAT operation

After the installation is completed:

1. **Power-on sequence:** Turn on the desktop computer, the analog card, and then the fast-steering mirror controller.

2. **System verification:**
   Open the Python software on the desktop and run it using the existing initial parameters. Verify that both the SWIR camera and the fast-steering mirror operate correctly, ensuring there are no unusual noises or warning indicators (e.g., red lights).

3. **Optical alignment and PAT integrity:**
   Using bright stars, perform a coarse alignment to identify the position of the SWIR camera's field-of-view (FOV) center relative to the telescope's central FOV.

4. **FSM calibration:**

   With the telescope's coarse tracking, track a bright star and manually introduce offsets within the SWIR camera's FOV. Activate the fast-steering mirror closed loop to recenter the star image.