COATLI Technical Manual

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Chapter 1

Introduction

This is the technical manual for the COATLI[1] installation, telescope, and instrument. It has two aims. The first is to provide clear instructions to the OAN/SPM technical staff supporting routine operations. The second is to aid COATLI and OAN/SPM technical staff perform preventative and corrective maintenance of the equipment.

For an overview of the COATLI project, we recommend our 2016 SPIE paper:

- "COATLI: an all-sky robotic optical imager with 0.3 arcsec image quality", Watson et al. 2016, Proc. SPIE, 9908, 99085O-2

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[1] http://coatli.astroscu.unam.mx

Part I

Operations

Chapter 2

Safety

In this manual, safety instructions and observations are highlighted by boxes.

2.1 Feedback

If you encounter a dangerous situation that is specific to COATLI and is not covered by the rules below or if you have comments or suggestions on the existing rules, please inform the PIs of COATLI (Alan Watson and William Lee) and the Secretario Técnico of the OAN.

2.2 Priorities

The safety priorities at the COATLI installation, from highest to lowest, are:

1. *Personnel safety: avoiding injury and death to personnel.*
2. *Equipment safety: avoiding damage or loss of equipment.*
3. *Observing and data preservation.*

2.3 Personnel Safety

The COATLI installation is potentially one of the most dangerous installations at the OAN/SPM. Personnel safety is more important than equipment safety or observations. The following rules are designed to maintain personnel safety and must be followed at all times.

You must not work alone on the open platform or on the balconies.

At least one other person must be present either on the platform or at ground level.

> *You may work alone on the closed platform. However, someone else must be present when you ascend or descend.*

You should have someone to close the enclosure manually after you have entered and open it manually for you to leave. Remember that you must have a radio on hand.

> *You must use a safety harness, line, and helmet whenever you are on the platform or balconies or to ascend the tower. When you are working on the balcony or another position from which you might fall, attach your line to one of the eyes, to the balcony rail, or to something equivalently strong. In cold weather, we strongly recommend using gloves.*

The main platform is about 5 meters above the walkways. A fall from this height can easily kill.

Safety harnesses, lines, and helmets are stored in the shed.

The line can be attached to various points: the eyes in the platform floor and balconies installed specifically for this purpose, the balcony safety rails, and other parts of the platform or tower structure.

The helmet will protect you from collisions with the telescopes, if you fall, and from falling objects.

> *You must use a safety helmet if you are working under the platform or balconies.*

The main platform is about 5 meters above the walkways. An impact from an object falling from this height can easily kill.

Safety helmets are stored on the shed.

> *Transport equipment and tools to and from the platform using the appropriate equipment provided: ropes, locking carabiners, locking hooks, straps, a tool carrier, and an equipment bag.*

Using this equipment in an appropriate manner will significantly reduce the risk of something falling. This equipment is stored in the project cabinet in the ground-floor of the 84-cm telescope. When you use the rope, you can fasten the upper end to one of the eyes in the platform using a locking carabiner. See Figure 2.1. When lifting heavy equipment to the platform, consider using the locking hook.

MAGUI: This equipment, shown in Figure 2.1, is stored in the project cabinet in the ground-floor of the 84-cm telescope. Using this equipment in an appropriate manner will significantly reduce the risk of something falling. When you use the rope, you can fasten the upper end to one of the eyes in the platform using a locking carabiners. When lifting heavy equipment to the platform, consider using the locking hook.

> *Return equipment and tools to their usual storage location when you have finished using them.*

Figure 2.1: Equipment to safely transport equipment to and from the platform: ropes, locking carabiners, straps, a tool carrier, and an equipment bag.

This ensures that equipment can be found when it is next needed. This is especially important for safety equipment.

> *If you wish to ascend to the platform or balconies, you must put the enclosure in local mode.*

In remote mode the enclosure can close without warning.

> *You may only be on the platform or balconies if it is strictly necessary.*

The platform and balconies are not a vantage points. You must only be on them to work on equipment.

> *You may only be on the platform or balconies at night if you need to close the enclosure manually or are testing or commissioning equipment on the sky.*

You must not perform maintenance at night.

If there is a failure at night, you must not ascend to the platform to fix it. Instead, you must abandon the night's observations and attempt to close the enclosure from the shed.

You may only ascend to the platform at night if you need to close the enclosure manually.

> *You may only be on the platform or balconies in poor conditions if you need to close the enclosure manually.*

Poor conditions include high wind, snow, and rain.

You must not perform maintenance in poor conditions.

You may only climb the platform in poor conditions if you need to close the enclosure manually.

> *Do not walk on the elevated areas at the ends of the platform.*

These areas are not load-bearing. If you walk on them, it is likely that they will collapse and you will fall.

> *If you need to summon help and do not have a portable radio, you can use the static emergency radio located between the 84-cm building and DDOTI.*

> *You must physically disconnect mains power before working on an electronics boxes C–F.*

Note that box C has two mains connectors, one for regulated power and one for unregulated power. Boxes D–F have only one mains connector, for regulated power.

Using the switch is not enough; it is present to allow the equipment to be rebooted. Besides, the unregulated power to box C is not switched.

> *Be extremely careful when working inside the enclosure, covers, and secondary cabinets as they use 220 VAC.*

2.4 Equipment Safety

Only open the enclosure explicitly when conditions are benign. Conditions are not benign if:

1. *It is raining or snowing.*
2. *The humidity is 85% or higher and rising or previously reached 90% and has not yet fallen below 80%.*
3. *The wind average speed has been 20 km/h or greater at any moment in the previous 30 minutes.*
4. *There are other circumstance which, in the judgement of observatory technical staff, dictate that it is not safe to open.*

These rules are implemented in the COATLI weather server. If you check the COATLI web interface (see §3), there is a summary line for the weather that says "may be open", conditions are benign and you may open. If it does not, conditions are not benign and you must not open.

Note that the rules for opening the other telescopes specify a wind limit of 45 km/h. The limit for COATLI is currently lower until we have greater confidence in its reliability and performance in high winds.

Before opening the enclosure, check on the webcams in the interface (see §3) that the telescope is not pointed to towards the sun.

In the home position, the telescope is pointed to the northern horizon and on the western side of the mount. This is to protect the telescope mirrors from falling debris or water drops.

The enclosure controller (see §11) should normally be switched on at all times in order to keep the electromagnetic lock activated.

If the lock is not activated, the wind can open the roof a few centimeters and allow the ingress of rain or snow.

In case of fire, there is an extinguisher in the shed.

If you do fight a fire, remember that personnel safety is more important than equipment safety.

Chapter 3

Interface

This chapter describes the interface used by the observatory staff to interact with the COATLI control system.

3.1 Access

The address of the COATLI web site is:

> `http://coatli.astrossp.unam.mx/`

The web site contains the interface and documentation. They are only directly available to computers on the mountain-top network, although ssh port-forwarding can make it indirectly available elsewhere.

The interface is protected by passwords. The `operator15` and `operator21` accounts are configured with the same passwords as the RATIR interface. If in doubt, ask on the Skype chat.

3.2 Main Page

Figure 3.1 shows an example of the main page of the interface. The major elements of the interface are:

- Thumbnail images from the webcams. Clicking on the thumbnail images brings up larger images, examples of which are shown in Figures 3.2, 3.3, 3.4, and 3.5. These images are useful for checking the status of the enclosure and telescope. At night, one needs to switch on the enclosure lights (see §3.2) to see anything in the webcams.
- A thumbnail image from the all-sky camera. Clicking on the thumbnail image brings up a larger image. This is useful for checking for clouds.

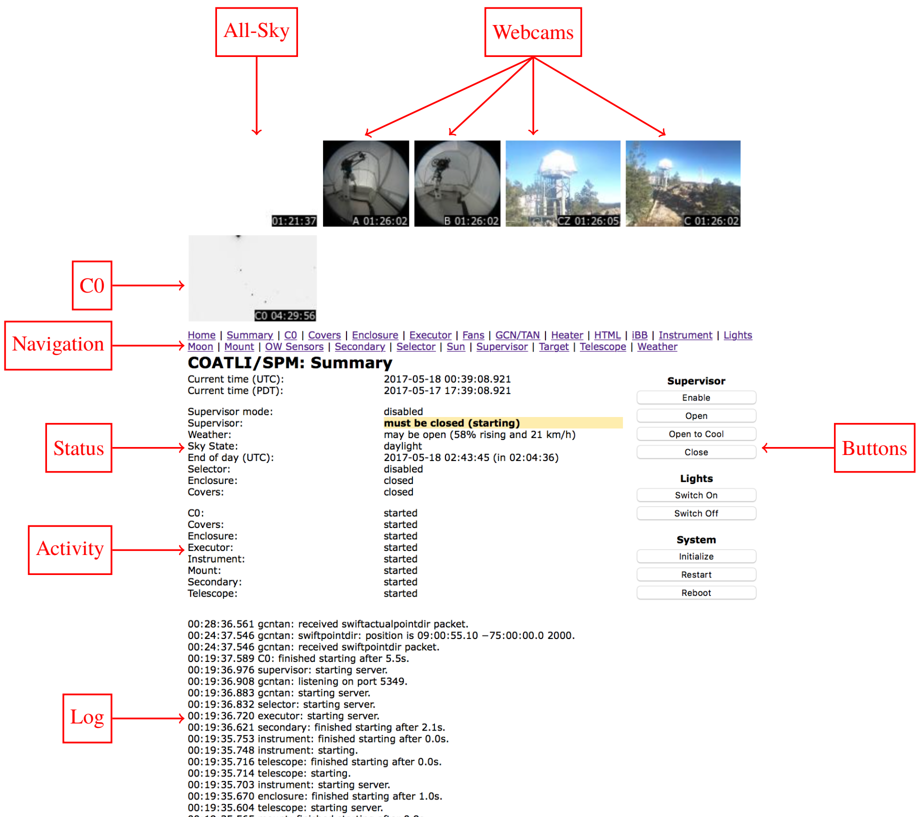

Figure 3.1: An example of the main page of the interface. The major elements are labelled and described in the text.

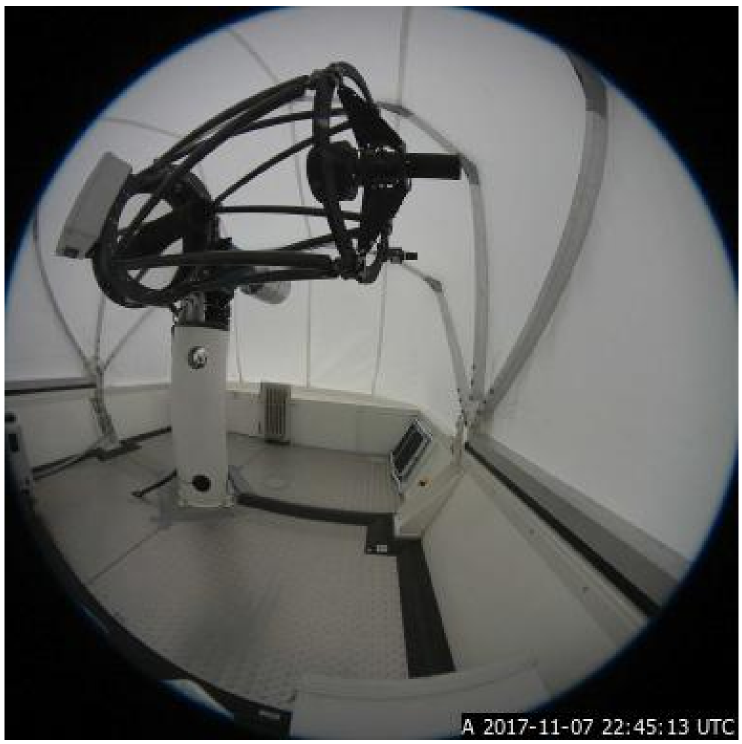

Figure 3.2: An example view from webcam A (in N corner of the enclosure looking to the SW).

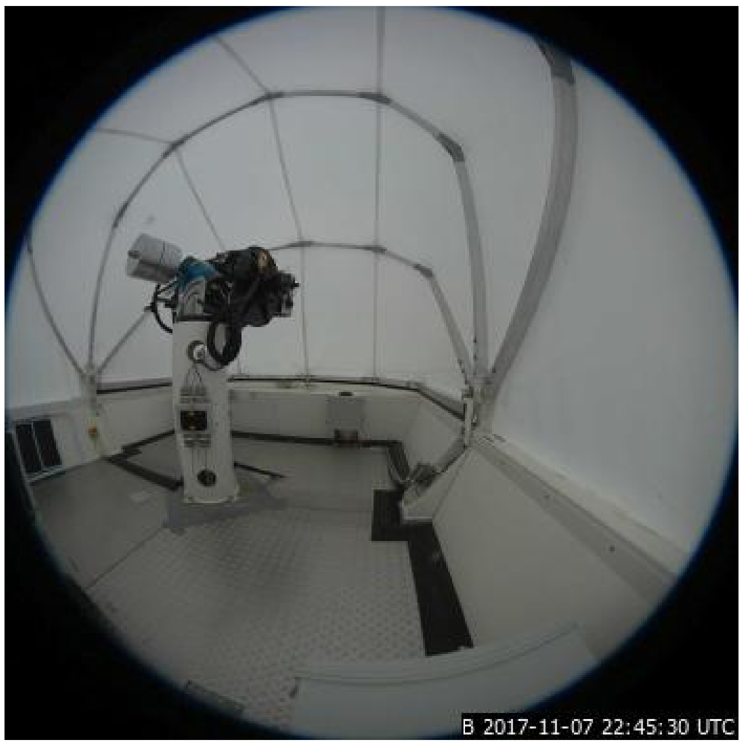

Figure 3.3: An example view from webcam B (in S corner of the enclosure looking to the NE).

Figure 3.4: An example view from webcam CZ (on the 84-cm telescope building looking towards COATLI). Webcam CZ is actually just a fixed zoom of webcam C.

Figure 3.5: An example view from webcam C (on the 84-cm telescope building looking towards COATLI).

- A thumbnail image of the latest image taken by the C0 detector. Clicking on the thumbnail image brings up a larger image. This is useful for checking focus.
- A navigation section. Clicking on these links will bring up the detailed page for the corresponding control system server. These pages are typically used by the team members to diagnose problems.
- A status section. In the main page this gives:
  - The UTC time.
  - The civil time at the observatory (PST or PDT).
  - The supervisor mode ("enabled", "disabled", "open", "opentocool", or "closed").
  - A description of whether the supervisor mode permits the enclosure to be open and why.
  - A description of whether the current weather conditions permit the enclosure to be open and why (wind, rain, and humidity).
  - A description of the current sky state (daylight, twilight, and night).
  - The time of the next day/twilight/night transition in UTC.
  - The enclosure state (open or closed).
- The activity section. If a control system server activity is not "idle" (for example, if it is "started", "initializing", "moving", "tracking", "opening", or "closing"), this is shown here. If a server activity is "idle", it is not shown here. Thus, if all of the servers are "idle", this section is empty.

  Errors and warnings are shown here in red and yellow respectively.
- The log section. This section shows the latest log messages from the control system in reverse order.
- The buttons. These are used to interact with the control system.
  - Enable. Enabled the supervisor. This permits the supervisor to open and close according to the weather and sky state. Note that the supervisor only takes decisions to open, open to cool, or close if it is enabled.
  - Open. Force the supervisor to open and to stay open until explicitly instructed otherwise.
  - Open to Cool. Force the supervisor to open to cool and to stay open to cool until explicitly instructed otherwise. Opening to cool opens the enclosure partially, and starts to cool the CCD. It is typically used at the end of the day to cool the enclosure, telescope, and CCD ready for observations after sunset.
  - Close. Force the supervisor to close and to stay closed until explicitly instructed otherwise.

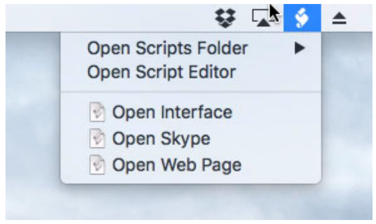

Figure 3.6: The script menu, in the upper right, can open the interface and Skype on the Access Mac.

- Switch On. Switch on the enclosure lights. This is useful when you want to use the webcams to check the status of the telescope or enclosure. Of course, one does not want to turn the lights on if the telescope is observing.
- Switch Off. Switch off the enclosure lights.
- Restart. Schedule a restart of the control system servers for the top of the next minute. This can be used to recover from software problems.

3.3 Running the Interface on the Access Mac in the Shed

The interface can be run locally on the Access Mac in the Shed.

If you need to log into the Mac, use the "coatli" account with password "coatli".

If the interface and Skype are not running, you can select "Open Interface" or "Open Skype" from the script menu in the upper right, as shown in Figure 3.6.

Chapter 4

Operations

COATLI is in regular robotic operation under the responsibility of the observatory staff. Weather permitting, COATLI will operate from 30 minutes before sunset to the end of morning astronomical twilight.

4.1 Participants

By "observatory staff" we refer to the telescope operators, resident astronomers, and maintenance technicians. The actually division of responsibilities will be decided by the Secretario Técnico of the observatory.

By "team members" we refer to members of the COATLI technical teams.

4.2 Communications

Communication between the observatory staff and the team will take place primarily through the RATIR/COATLI/DDOTI operations Skype chat.

4.3 Daily Operations

The daily operating procedure is:

1. At the latest one hour before sunset, the observatory staff will carry out a review of the COATLI installation.

   This revision has three elements. The observatory staff will:

   (a) Check that all of the control system servers are not showing errors in the web interface (see §3.1). If there are problems, attempt to solve them by pressing the “Restart” button in the web interface and giving the system a couple of minutes to restart. If that doesn’t work, seek the help of a team member.

   (b) Check that the webcams in the web interface are not showing an unusual situation.
   (c) If necessary, carry out an on-site inspection of COATLI. For example, after a snowfall, it might not be obvious from the webcams whether snow remains on the roof of the enclosure.

   MAGUI: To interact with the COATLI/OAN control system, in regular robotic operation, the observatory staff will use the web interface described in section 3.

   If the observatory staff consider that decisions to open and close the installation can be safely taken by the control system, they will enable the supervisor by pressing the “Enable” button in web interface (see §3.1).

   If the observatory staff considers that decisions to open and close the installation cannot be safely taken by the control system, they should explicitly force the supervisor to maintain the telescope closed by pressing the “Close” button in the web interface (see §3.1)..

   The observatory staff will report the result of their inspection in the Skype chat and will indicate whether they are enabling the supervisor or forcing it to close.

2. If the supervisor is enabled and weather conditions are benign, the control system will:
   (a) Open partially to cool about half an hour before sunset;
   (b) Open completely to observe at sunset; and
   (c) Close at the end of morning astronomical twilight.

   If the supervisor is enabled and weather conditions are not benign, the control system will not open (if closed) or will close (if open).

   If the supervisor is enabled and weather conditions change from not benign to benign, the control system will open partially to cool (between half and hour before sunset and sunset) or open completely to observe (between sunset and the end of morning astronomical twilight).

3. The supervisor considers weather conditions to be *not benign* if:
   (a) It is raining or snowing.
   (b) The humidity is 85% or higher and rising or previously reached 90% and has not yet fallen below 80%.
   (c) The wind average speed has been 30 km/h or greater at any moment in the previous 30 minutes.

   Note that the rules for opening the other telescopes specify a wind limit of 45 km/h. The limit for COATLI is currently lower until we have greater confidence in its reliability and performance in high winds.

4. The observatory staff will monitor COATLI during the night. Their primary responsibilities are:

   (a) If the observatory staff consider that decisions to open and close the installation can be safely taken by the control system, they should enable the supervisor by pressing the "Enable" button in the web interface (see §3.1) and report this in the Skype chat.

   (b) If the observatory staff consider that decisions to open and close the installation cannot be safely taken by the control system, they must explicitly force the supervisor to maintain the telescope closed by pressing the "Close" button in the web interface (see §3.1) and report this in the Skype chat.

   (c) The observatory staff should verify that the control system opens and closes as expected according to the weather conditions and the state of the supervisor. If it does not close, they should intervene as described in §4.4.

   (d) When the control system closes (at the end of the night, in response to weather conditions, or if the supervisor is forced to close), it switches the lights on for safety. At the end of the process, if the control system can determine that the enclosure closed correctly, it will switch the lights off. If it cannot, it will leave the lights switched on. Thus, if the lights are left on, this indicates that there was a problem during closing and the observatory staff should intervene as described in §4.4.

   (e) The observatory staff should report explicit changes to the supervisor state (e.g., use of the "Enable" and "Close" buttons) and any other relevant information in the Skype chat.

   As their other duties permit, the observatory staff are encouraged to report other conditions or occurrences that might degrade the ability of the telescope to observe (e.g., failures of the control system or failures to focus) in the Skype chat.

5. During the evening and night, interventions by the observatory staff are limited to whatever is necessary to close COATLI and return it to a safe state. Once the observatory staff have intervened, COATLI must be closed and may not open again until the next day.

6. Requests by team members for interventions beyond those needed to close COATLI correctly will be directed to the Secretario Técnico of the observatory.

4.4 Interventions to Close

The control system should normally operate without problems and with minimal action on the part of the observatory staff beyond setting the supervisor mode. However, in the event of a failure, the observatory staff may need to intervene to close.

If the control system does not close when expected or does not close correctly, the observatory staff should:

1. First attempt to close normally:
    (a) Press the “Close” button in web interface (see §3.1). This should turn on the enclosure lights and close.
    (b) Check the web interface and webcams for success or failure.
2. If that fails, attempt an emergency close:
    (a) Press the “Emergency Close” button in the web interface (see §3.2). This should turn on the enclosure lights and close.
    (b) Check the web interface and webcams for success or failure.
3. If that fails, close the enclosure locally according to the procedure in §11.2.2.
4. If that fails, close the enclosure manually according to the procedures in §11.2.6.

4.5 Weekly Inspection

The observatory staff should carry out a physical inspection of the installations during daytime at least once per week (if weather conditions permit). The Secretario Técnico will determine the schedule for this inspection.

Safety Considerations

You must use a safety harness, line, and helmet whenever you are on the platform or balconies or to ascend the tower. Attach your line to one of the fasteners, to the balcony rail, or to something equivalently strong.

You must use a safety helmet if you are working under the platform or balconies.

Requirements

You will need:

- At least two persons.
- The key to the shed (see §5.3).
- Weather conditions adequate for opening the enclosure and ascending to the platform.

Procedure

1. Verify that there is a fire extinguisher in the shed.
2. Verify that the web interface and the Skype chat are open on the control Mac in the shed. If they are not, open them by following the procedures in §3.3.
3. Inspect the inside of the shed.
4. Inspect the columns and underside of the platform.
5. Open the enclosure locally to 30 degrees using the procedure in §11.2.2.
6. One person should ascend to the platform to inspect: the electronics boxes, the instrument, the telescope, the mount, and the platform.
7. Close the enclosure locally using the procedure in §11.2.2, but leave the enclosure controller in local mode.
8. The person on the platform should inspect the enclosure roof from the inside.
9. Open the enclosure locally using the procedure in §11.2.2.
10. The person on the platform should descend.
11. Leave the enclosure controller in remote mode.
12. Report that the revision has been carried out in the Skype chat. Additionally, report any anomalies in the Skype chat.

4.6 Soft Shut-Down and Start-Up

A "soft" shut-down is appropriate for circumstances in which electrical power will continue to be supplied to COATLI. This is the normal situation over the winter break. In this case, we can leave the computers on and rely on the electromagnet to maintain the enclosure closed.

4.6.1 Soft Shut-Down

Safety Considerations

You must use a safety harness, line, and helmet whenever you are on the platform or balconies or to ascend the tower. Attach your line to one of the fasteners, to the balcony rail, or to something equivalently strong.

You must use a safety helmet if you are working under the platform or balconies.

The enclosure controller cabinet uses 220 VAC. Switch off the power using the main power switch on the door before working inside the cabinet (see Figure §11.9) .

Requirements

You will need:

- At least two persons.
- The key to the shed (see §5.3).
- Weather conditions adequate for opening the enclosure and ascending to the platform.
- A clean tarpaulin and one short red cord. You can find clean tarpaulins in the shelves next to the cabinet in the 84-cm and rope in the tool-drawer of the cabinet.

Procedure

1. Place the enclosure in local mode.

   Move the enclosure controller mode selector switch to "LOCAL" (see Figure §11.9).

2. If the weather permits, open the enclosure to 60 deg.

   Set the angle selector switch to 60 deg and then press and hold the open button until the green light goes out.

3. Both persons should ascend to the platform.
4. Verify that the telescope is in the parked position, pointed at the north pole and with the telescope above the mount. If not, release the break on the mount by pressing the "BRAKE" button and move it to this position.
5. Press the mount emergency stop button.
6. Cover the telescope with a tarpaulin. Gather the loose ends of the tarpaulin below and fasten them with a short red cord. See Figure 4.1.
7. Descend from the platform.
8. Close the enclosure.

   Press and hold the close button until the green light goes out.

9. Switch off the enclosure controller.

   Move the main power switch on the controller door from ON to OFF. (see Figure §11.9).

Figure 4.1: The telescope covered by a tarpaulin.

10. Open the enclosure controller cabinet.
11. Engage the manual lock. This switches on the enclosure electromagnet and actuates the enclosure emergency stop buttons. This ensures that the electromagnet stays energized even if the PLC fails and that the PLC cannot attempt to open the enclosure.

    Move the manual lock switch inside the enclosure controller cabinet from OFF to ON. See Figure 11.5.
12. Close the enclosure controller cabinet.
13. Switch on the enclosure controller.

    Move the main power switch on the controller door from OFF to ON.
14. Place the enclosure in remote mode.

    Move the enclosure controller mode selector switch to "REMOTE".
15. Make sure the "PROHIBIDO EL PASO" sign is left in position at the bottom of the access stairs.
16. Leave the shed locked. Return the shed keys to the tool box (see §5.3).

4.6.2 Soft Start-Up

Safety Considerations

> *You must use a safety harness, line, and helmet whenever you are on the platform or balconies or to ascend the tower. Attach your line to one of the fasteners, to the balcony rail, or to something equivalently strong.*

> *You must use a safety helmet if you are working under the platform or balconies.*

> *The enclosure controller cabinet uses 220 VAC. Switch off the power using the switch on the door before working inside the cabinet.*

Requirements

You will need:

- At least two persons.
- The key to the shed (see §5.3).
- Weather conditions adequate for opening the enclosure and ascending to the platform.

Procedure

1. In the shed, switch off the enclosure controller.

   Move the main power switch on the controller door from ON to OFF (see Figure §11.9).

2. Open the enclosure controller.

3. Disengage the manual lock.

   Move the manual lock switch inside the enclosure controller from ON to OFF. See Figure 11.5.

4. Close the enclosure controller.

5. Switch on the enclosure controller.

   Move the main power switch on the controller door from OFF to ON.

6. Place the enclosure in local mode.

   Move the enclosure controller mode selector switch to “LOCAL”.

7. If the weather permits, open the enclosure to 60 deg.

   Set the angle selector switch to 60 deg and then press and hold the open button until the green light goes out.

8. Both persons should ascend to the platform.

9. Remove the tarpaulin from the telescope.

10. Disengage the mount emergency stop button on the platform.

11. Verify that the telescope is in the parked position, pointed at the northern horizon with the telescope on the west side of the pillar. If not, release the break on the mount by pressing the “BRAKE” button and move it to this position.

12. Descent from the platform.

13. Close the enclosure.

    Press and hold the close button until the green light goes out.

14. Place the enclosure in remote mode.

    Move the enclosure controller mode selector switch to “REMOTE”.

15. Make sure the “PROHIBIDO EL PASO” sign is left in position at the bottom of the access stairs.

16. Leave the shed locked. Return the shed keys to the tool box (see §5.3).

17. Store the tarpaulin in the shelves next to the cabinet in the 84-cm and the rope in the tool-drawer of the cabinet.

4.7 Hard Shut-Down and Start-Up

A "hard" shut-down is appropriate for circumstances in which electrical power will not continue to be supplied to COATLI. This occurred, for example, in the evacuations for COVID-19. In this case, we must shut down the computers and cannot rely on the electromagnet to maintain the enclosure closed.

4.7.1 Hard Shut-Down

Requirements

You will need:

- Two people plus the participation of a remote team member.
- The key to the shed (see §5.3).
- Weather conditions adequate for opening the enclosure and ascending to the platform.
- The tarpaulin and ropes required for the soft shut-down (see §4.6.1).
- The two riveted plates, a riveter, and rivets.

Procedure

1. Perform a soft shut-down (see §4.6.1).
2. Communicate with the remote team member. They will:
   (a) Log into a computer on the CU, Ensenada, or OAN networks of the Instituto de Astronomía (in order to gain ssh access to the firewall):
   ```
   $ ssh user@somewhere.astrosxx.unam.mx -p 2222 -A -L 8080:localhost:8080
   ```
   (b) Log into the firewall:
   ```
   somewhere$ ssh user@ddoti.astrossp.unam.mx -p 2222 -A -L 8080:localhost:80
   ```
   (c) Halt the computer `access`:
   ```
   firewall$ ssh user@10.0.1.2
   access$ sudo shutdown -h -u now
   ```
   (d) Switch off `access` from `ibb-127`.
   ```
   firewall$ telnet 10.0.1.5
   > get device #1
   > set device #1 outlet <n> off
   ...
   ```
   To log out of the iBootBar, use CTRL-] and then `quit`.

   (e) Halt the computers `services`, `control`, `c0`, `d0`, `d1`, `d2`, `d3`, `e0`, `e1`, `e2`, `e3`:

```
firewall$ ssh ddoti@10.0.1.3
services$ sudo haltsoon
```

(f) Switch off `instrument`, `platform`, `services`, `control`, and `mount` from `ibb-127`.

```
$ ssh user@ddoti.astrossp.unam.mx -p 2222
firewall$ telnet 10.0.1.5
> get device #1
> set device #1 outlet <n> off
...
```

To log out of the iBootBar, use CTRL-] and then `quit`.

(g) Halt the computer `firewall`.

```
$ ssh user@ddoti.astrossp.unam.mx -p 2222 -L8080:localhost:80
```

Open a browser to `http://localhost:8080/` and halt the firewall from the web interface (select "Halt System" on the "Diagnostics" menu).

3. Switch off the two UPSes, the 127 V UPS and the 220 V UPS.

   On both UPSes, press the power button on the front panel for three seconds. The UPS will start to beep and will then switch off.

4. Switch off the power supply to the two UPSes.

   Open the breaker panel on the wall next to the door. Switch off circuits A and B.

5. Install the two riveted two plates, one on each side of the enclosure, that hold it closed. See Figure 4.2.

4.7.2 Hard Start-Up

Requirements

You will need:

- At least two persons.
- The key to the shed (see §5.3).
- Weather conditions adequate for opening the enclosure and ascending to the platform.
- A drill (to remove the riveted plates).

Procedure

1. Remove the two riveted two plates, one on each side of the enclosure, that hold it closed. See Figure 4.2.

2. Switch on the power supply to the two UPSes.

   Open the breaker panel on the wall next to the door. Switch on circuits A and B.

Figure 4.2: One of the riveted plates that hold the enclosure closed when power is switched off.

3. Switch on the two UPSes, the 127 V UPS and the 220 V UPS.

   On both UPSes, press the power button on the front panel for at least one second.

4. Switch on the computer `access`.

   Press the button on the rear right of the computer.

5. Communicate with the remote team member. They will:

   (a) Switch on the computers `instrument`, `platform`, `services`, `control`, and `access` from `ibb-127`.

   (b) Verify that all of the computers boot.

6. Perform a soft start-up (see §4.6.2).

Part II

Installations

Chapter 5

Buildings and Structures

The COATLI installation is spread through four buildings or structures: the ground-floor of the 84-cm telescope building; the shed; the access staircase and walkways; and the tower, platform, and enclosure. See Figure 5.1.

5.1 Civil Works

The shed, access, and tower are constructed on a rock outcrop to the south-east of the 84-cm building. The outcrop rises to about 5 meters above the ground level at the 84-cm telescope. The buildings and structures were constructed in 2015–2016, the enclosure was installed in 2016, the enclosure was replaced in 2017, and the telescope column was significantly modified in 2018.

Figures **??** to **??** show the 2015 design drawings for the shed, access staircase and walkways, and the concrete columns that support the platform and telescope. Figure 5.5 shows the ASTELCO ARTS platform and the ASTELCO steel pillar mounted on the concrete columns. The center of rotation of the mount axes is 6.5 meters above the rock outcrop and about 11.5 meters above the ground at the 84-cm telescope. The long axis of the enclosure is oriented roughly ENE-WSW to match the shape of the rock outcrop.

The telescope concrete column originally had three parts, each square in cross section and tapering from 1.8, 1.2, and 0.6 meters to a side (see Figure **??**). In 2018, in response to concerns about stiffness, the column was modified and the upper two parts were reinforced to 1.4 meters to a side (see Figure **??**). The steel pillar was also filled with concrete to the bottom of the upper holes. The platform floor was modified to accommodate the enlarged column and new support beams for the floor were designed, manufactured, and installed (see Figures **??** and **??**).

Figure 5.1: The COATLI/OAN and DDOTI/OAN installations seen looking west. On the left is the COATLI/OAN shed, access staircase and walkways, tower, platform, and enclosure. In the middle is is 84-cm telescope building. On the right is the DDOTI/OAN tower, platform, enclosure, and shed. Photographer: Fernando Angeles.

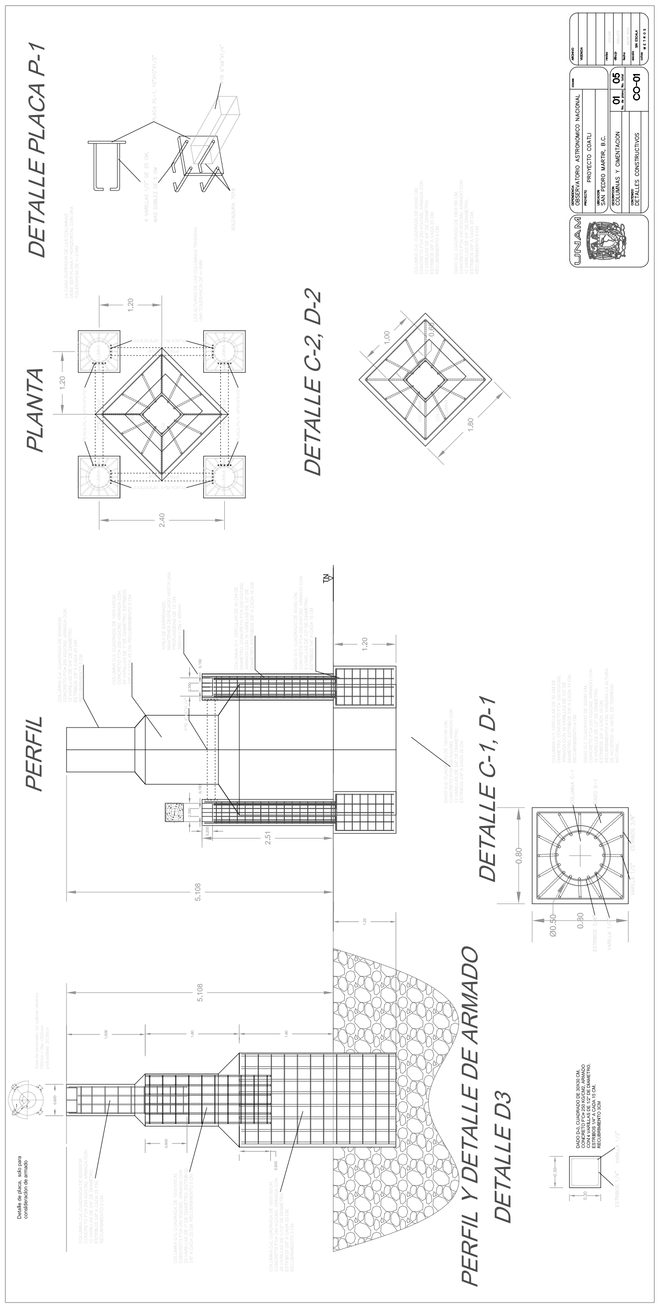

Figure 5.2: COATLI original 2015 design drawing (1 of 5).

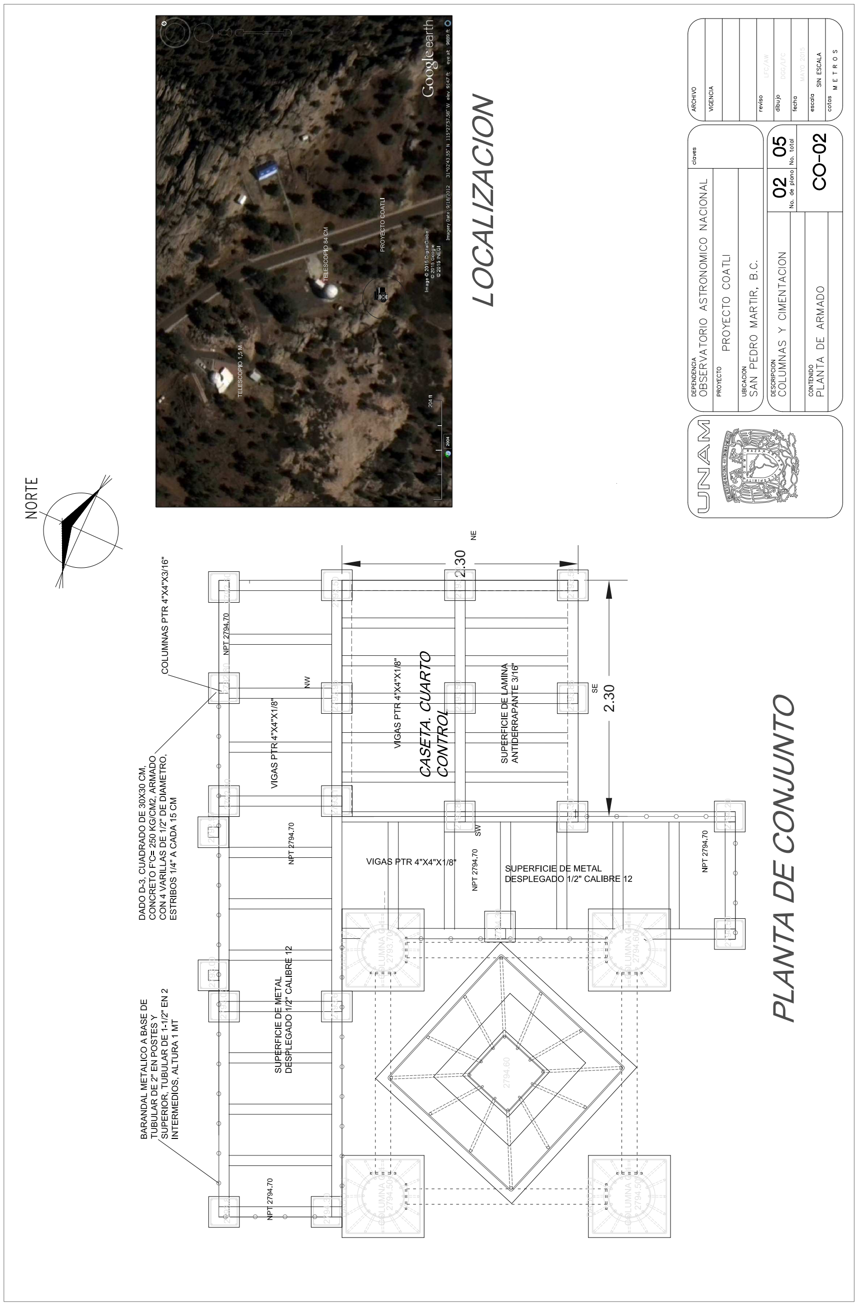

Figure 5.3: COATLI original 2015 design drawing (2 of 5). The actual stairs turn by 90 degrees to descend towards the 84-cm building. See Figure **??**.

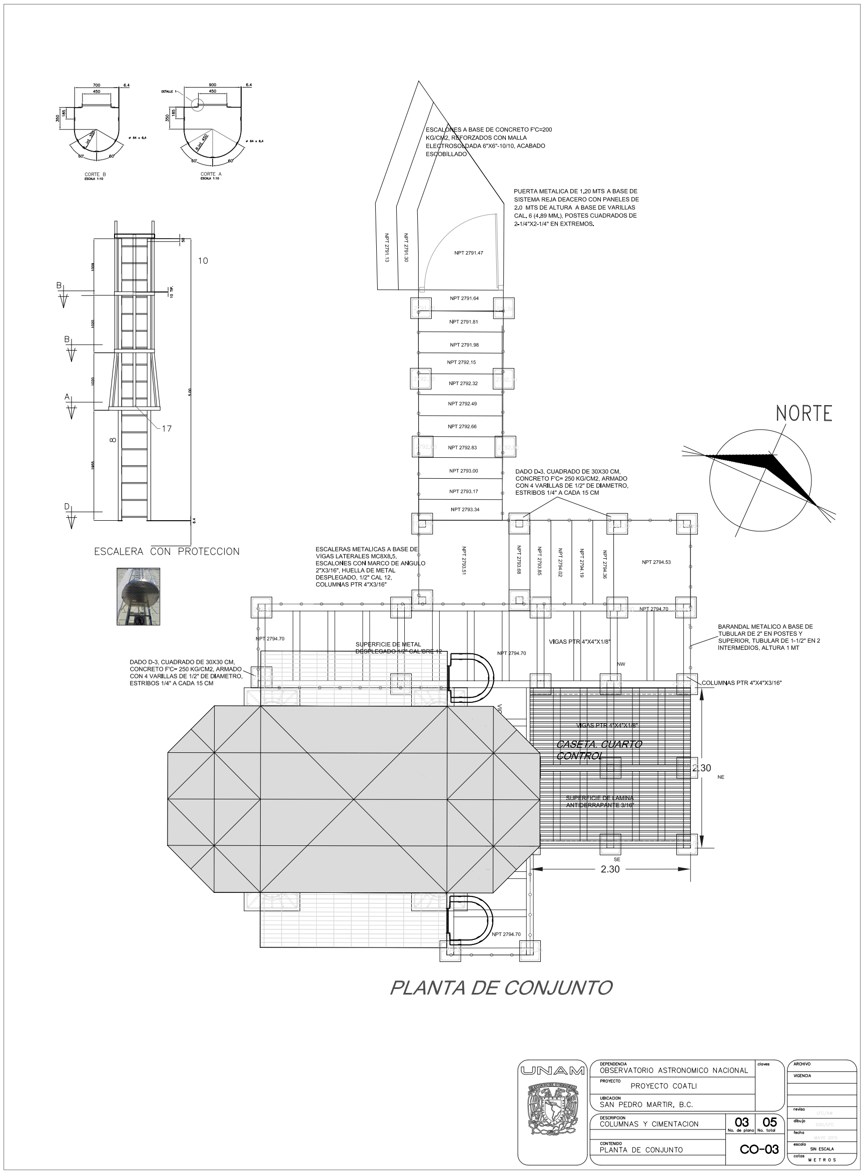

Figure 5.4: COATLI original 2015 design drawing (3 of 5).

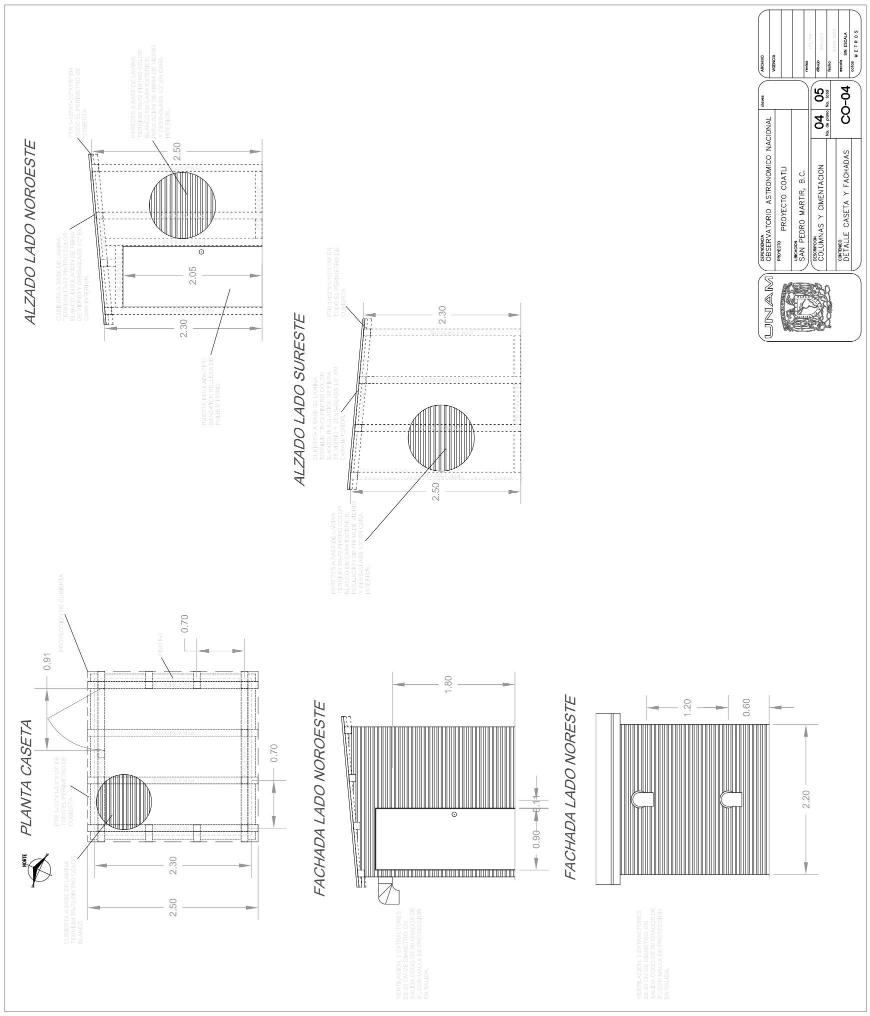

Figure 5.5: COATLI original 2015 design drawing (4 of 5).

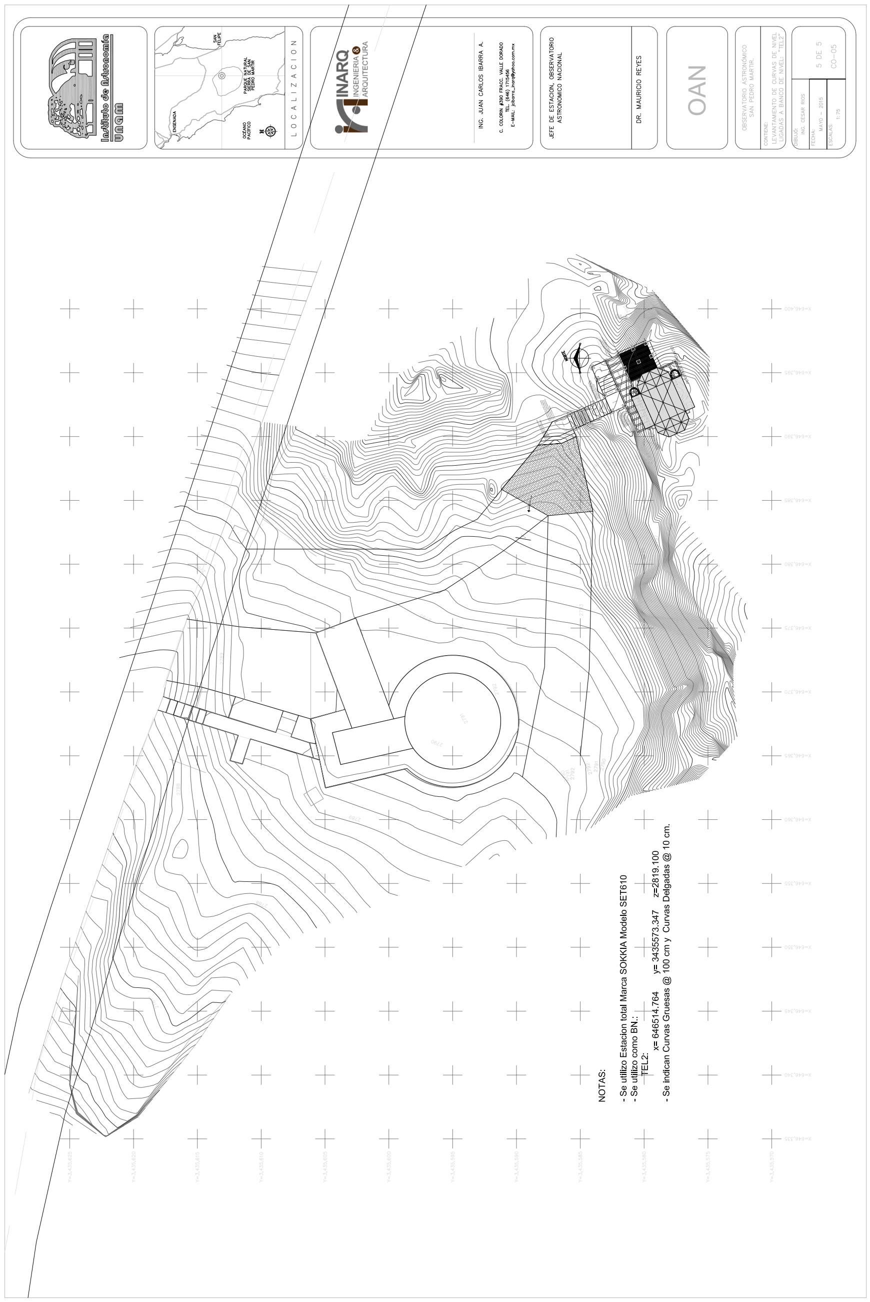

Figure 5.6: COATLI original 2018 design drawing (5 of 5).

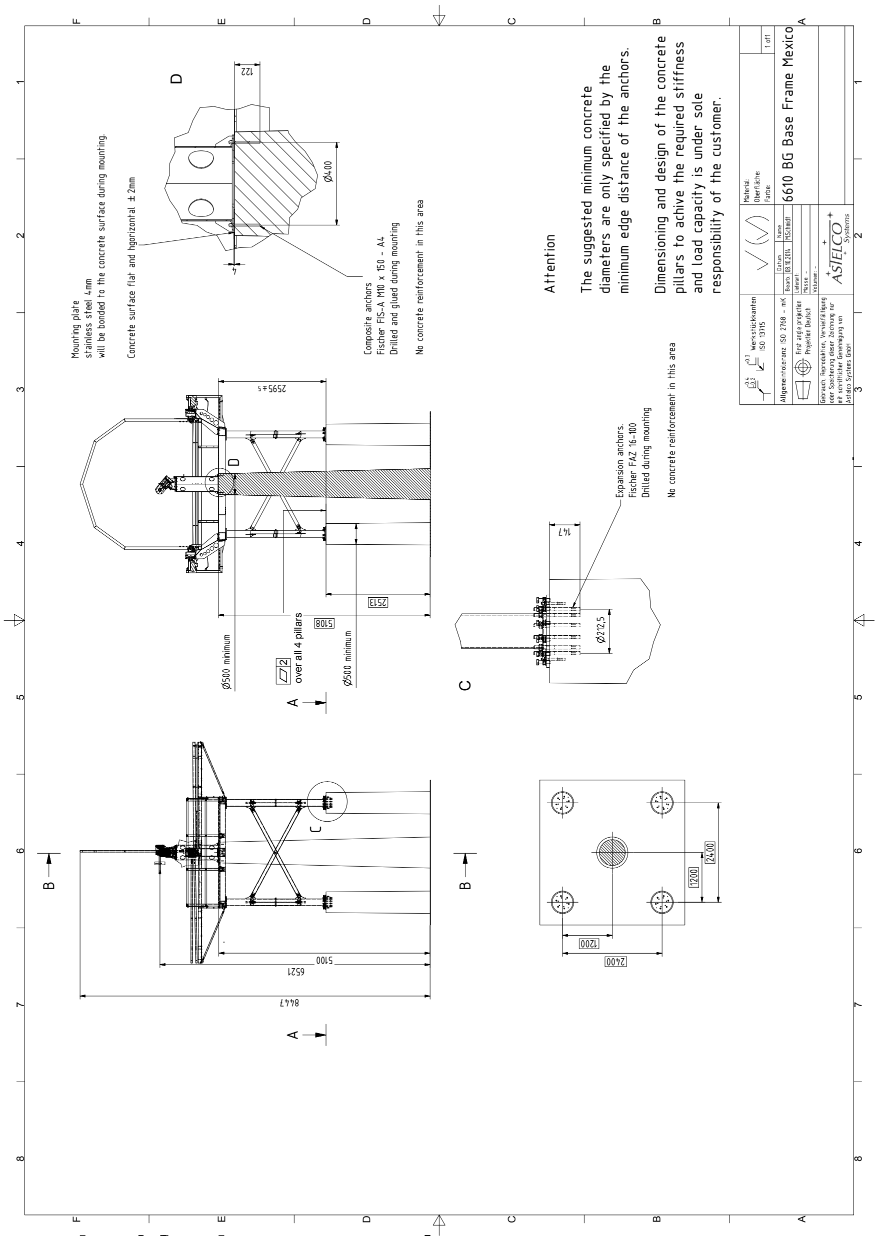

Figure 5.7: COATLI ASTELCO Platform and Telescope Pillar.

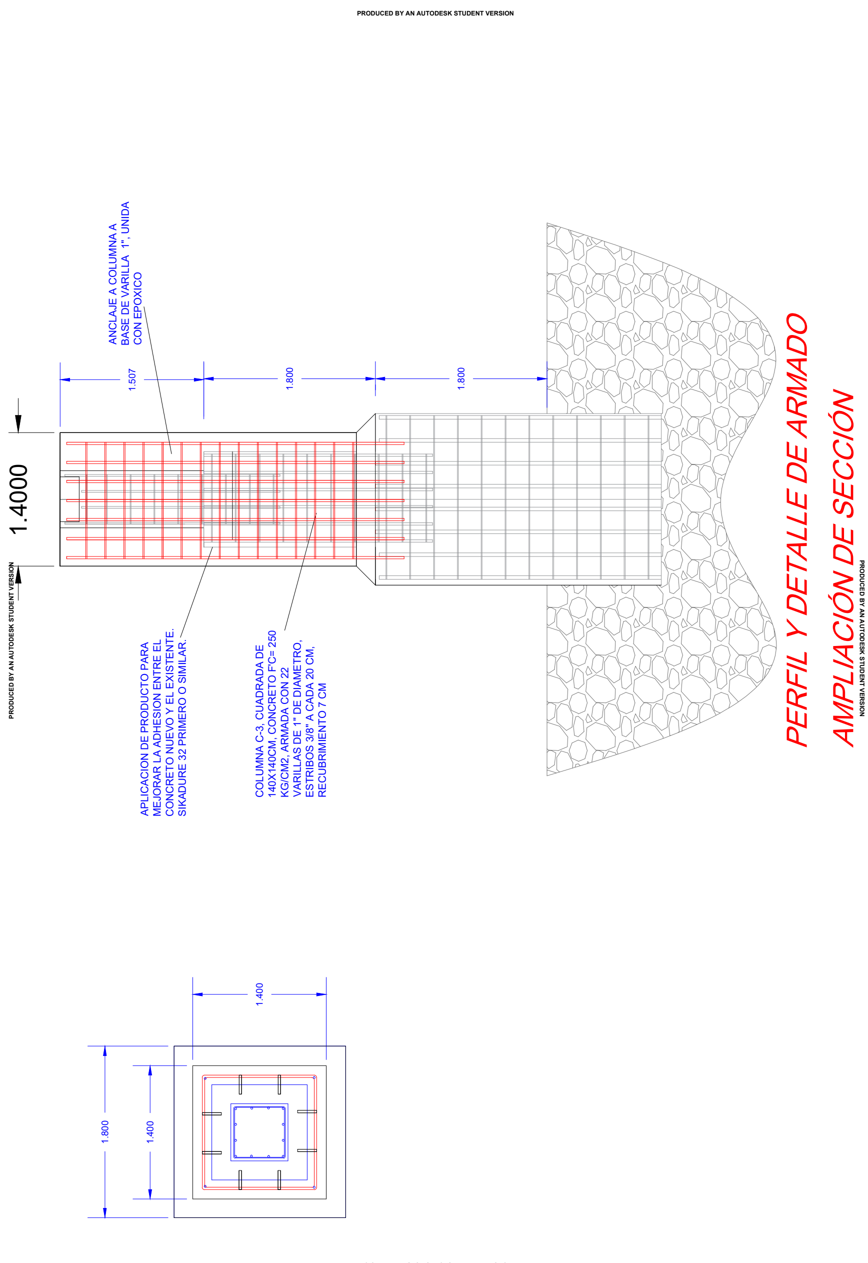

Figure 5.8: COATLI Modified 2018 design drawing (1 of 3).

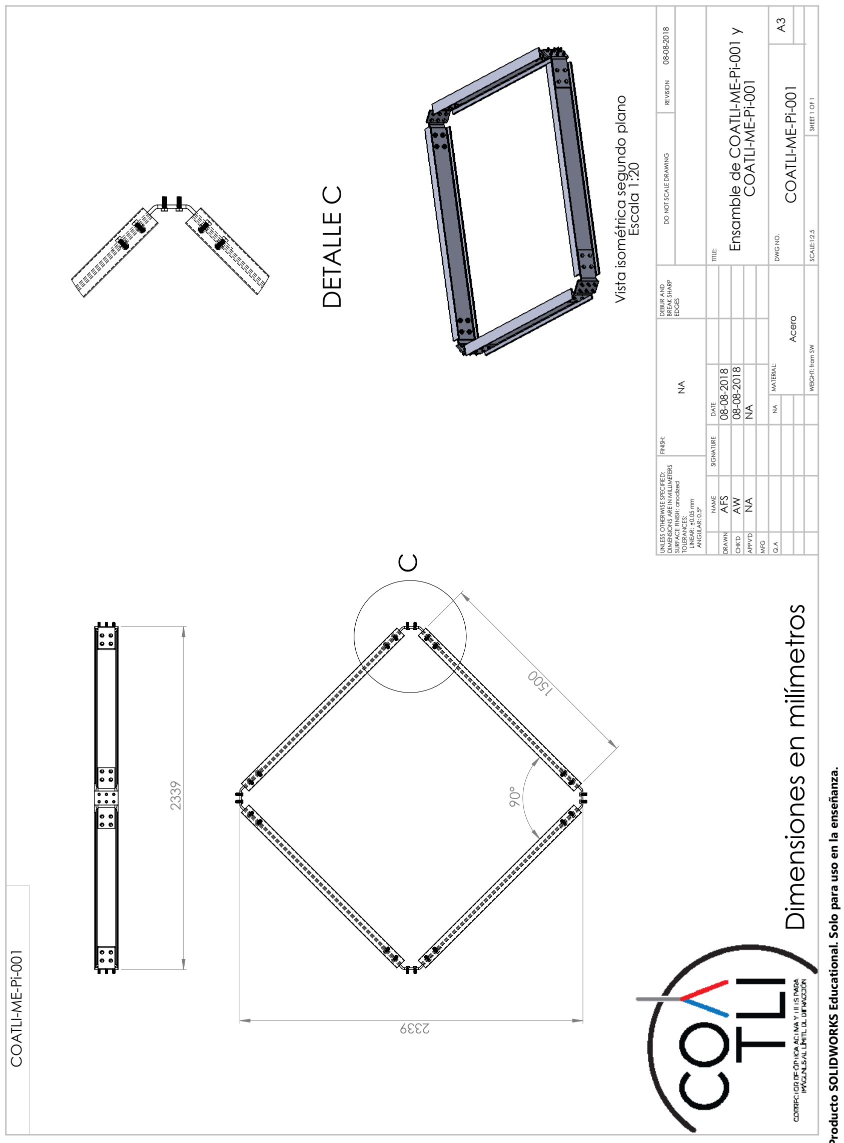

Figure 5.9: COATLI Modified 2018 design drawing (2 of 3).

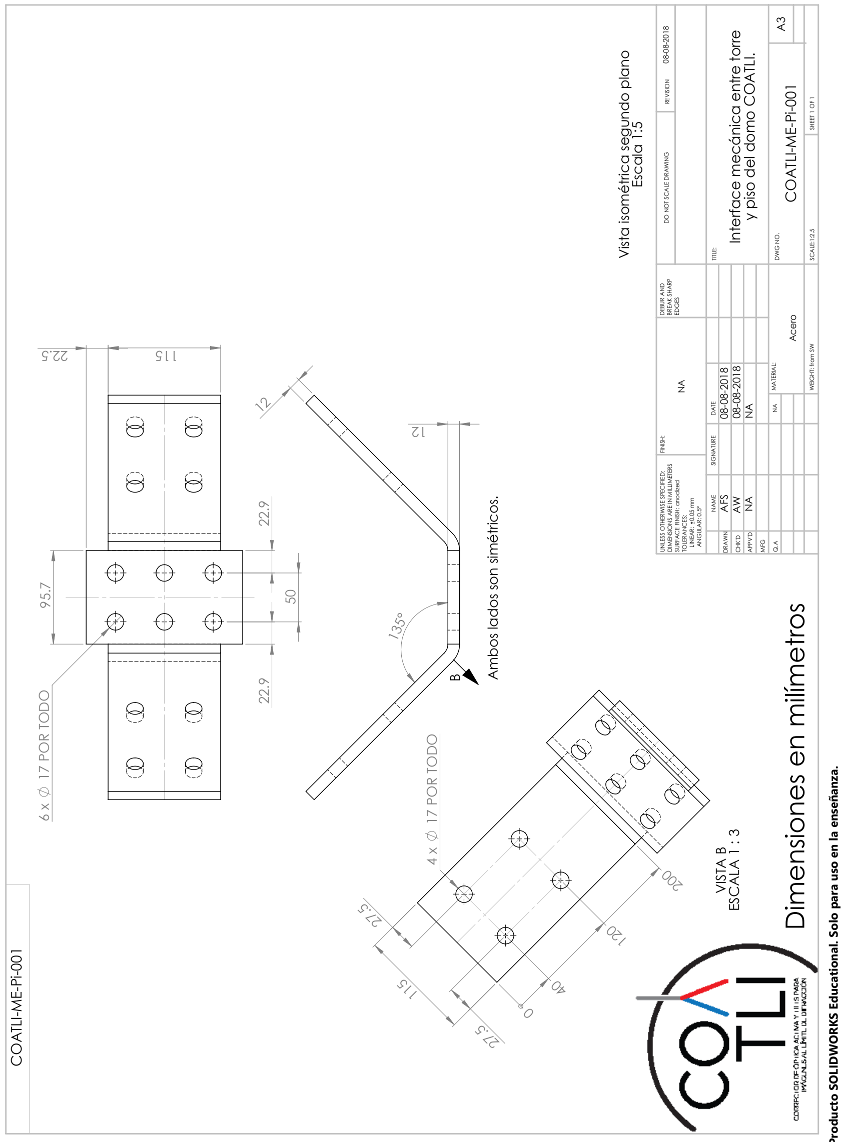

Figure 5.10: COATLI Modified 2018 design drawing (3 of 3).

5.2 Ground-Floor of the 84-cm Telescope Building

We use the ground-floor of the 84-cm telescope building for storage of equipment and as a temporary work space.

COATLI tools and equipment are stored mainly in the equipment cabinet. They are to be used only for maintenance of COATLI and DDOTI and must be returned to the cabinet at the end of the maintenance procedure.

ASTELCO tools and equipment are stored in a locked metal box and are only to be used under the supervision of project or ASTELCO personnel.

5.3 Shed

The shed contains infrastructure and control electronics.

The door to the shed should be left locked.

The key should be hung on the shelves next to the cabinet in the ground-floor of the 84-cm telescope building (see Figure 5.7).

The temperature in the shed it controlled by a heater and a pair of fans (one inlet and one exhaust). The fans are controlled by a Lux WIN100 thermostat and are set to turn on at 10 C. The internal thermostat of the heater is set to its minimum level.

5.4 Bibliography

- "Building 2015 Drawing 1 - Columns", UNAM.
- "Building 2015 Drawing 2 - Plan", UNAM.
- "Building 2015 Drawing 3 - Stairways", UNAM.
- "Building 2015 Drawing 4 - Shed", UNAM.
- "Building 2015 Drawing 5 - Location", UNAM.
- "ASTELCO Drawing 0500 – Platform", ASTELCO.
- "ASTELCO Drawing 5572 – Tower Mounting Plate", ASTELCO.
- "ASTELCO Drawing 5798 – Tower", ASTELCO.
- "ASTELCO Drawing 6610 – Tower, Platform, and Enclosure", ASTELCO.
- "ASTELCO Drawing 6658 – Tower, Platform, and Enclosuure", ASTELCO.
- "ASTELCO Drawing 6662 – Interface", ASTELCO.
- "Building 2018 Drawing 1 - Column", UNAM.
- "Building 2018 Drawing 2 - Floor Support Beams", UNAM.

Figure 5.11: The shed key is hung on the shelves next to the cabinet in the ground floor of the 84-cm telescope building.

- "Building 2018 Drawing 3 - Floor Support Beams", UNAM.
- "Lux WIN100 Manual", Lux.

Chapter 6

Electrical Power

This chapter describes the electrical power system in the COATLI installation. The electrical grounding system is described in Chapter 7.

Figure 6.1 shows a schematic of the electrical power system. The sections below describe each part in detail.

TODO: Don't know which DDOTI circuits are L1-N, L2-N, or L3-N.

6.1 External Mains Supply

The OAN electricity supply is 220 V 60 Hz three-phase.

The COATLI installation is connected to the OAN electricity supply via a spur to the circuit box in the 84-cm telescope building. This spur carries two phases (L1 and L2) and neutral (N). The phases are protected by an 80 A breaker. The circuit box and the breaker are shown in Figure 6.2.

6.2 Circuits

Figure 6.3 shows the circuit box in the shed. The master breaker is 80 A. The electricity supply is divided between the circuits listed in Table 6.1, each with their own breaker.

The 220 V circuits are generated between the two phases (L1 and L2). As a consequence, the 220 V circuits are live-live-ground, with 220 V between the two lives but each live 127 V above ground. (This is in contrast to a European-style live-neutral-ground 220 V circuit, with 220 V between live and neutral and with neutral nominally at the ground level.)

The 127 V circuits are generated between one of the two phases (L1 or L2) and the neutral (N). As a consequence, the 127 V circuits are live-neutral-ground, with 127 V between live and neutral and with neutral nominally at the ground level.

The wall sockets in the shed are labelled with their circuit.

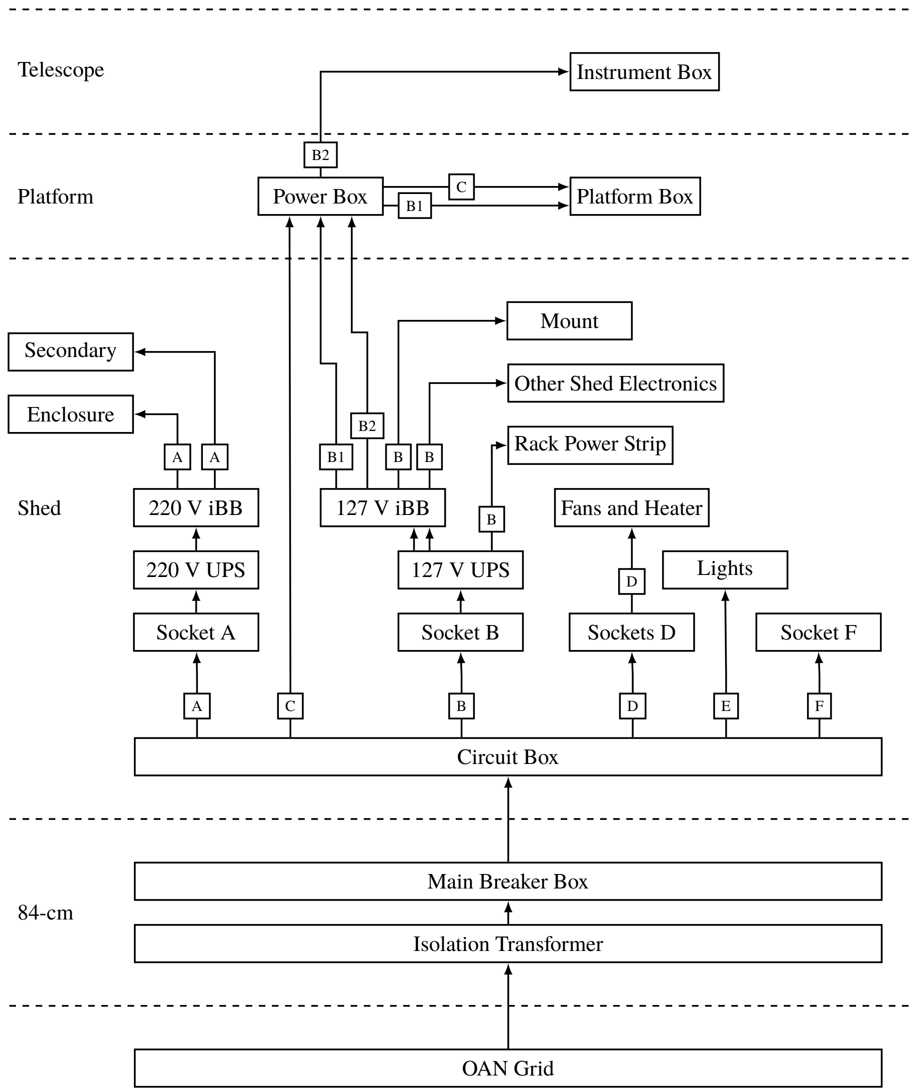

Figure 6.1: Schematic of the Distribution of Electrical Power. The letters A to F refer to circuits.

Figure 6.2: The main breaker box in the 84-cm telescope building. The main breaker for the COATLI spur are at the lower left.

Circuits A and B are regulated after the wall sockets by the two UPS units. The other circuits are unregulated.

6.3 UPS Units

There are two UPS units in the rack in the shed. Both are Eaton 9310 models with nominal capacities of 3000 VA or 2700 W. Each is equipped with an external battery module, which extends the capacity to about 20 minutes of supply at full load.

6.3.1 220 V UPS

The 220 V UPS is an Eaton PW9130G3000R-XL2U with PW9130N3000R-EBM2U external battery module. It is configured for 220 V 60 Hz input and output. Both the input and output are 220 V live-live-ground, with 220 V between the two lives and 127 V between each live and the ground.

Figure 6.3: The circuit box the COATLI shed. The master breaker is at the top. The breakers for circuits A–F are at the bottom.

Figure 6.4 shows a schematic of the electrical power connections.

The UPS is supplied via a NEMA L6-20P to C19 coupler connected to the NEMA L6-20R wall socket of circuit A and the C20 input socket of the UPS.

One of the NEMA L6-20R output sockets is connected to the 220 V iBootBar. No other output sockets are used.

If the UPS fails, it can be bypassed manually by connecting the NEMA L6-20P plug of the 220 V iBootBar to directly to the wall socket of circuit A.

6.3.2 127 V UPS

The 127 V UPS is an Eaton PW9130L3000R-XL2U with PW9130N3000R-EBM2U external battery module. It is configured for 127 V 60 Hz input and output.

Table 6.1: Circuits

Circuit	Connection	Voltage	Breaker	Use
Master	L1-L2	220 V	80 A	Master for all circuits
A	L1-L2	220 V	30 A	Wall socket in shed for 220 V UPS (T5 1× NEMA L6-20R)
B	L2-N	127 V	30 A	Wall socket in shed for 127 V UPS (T4 1× NEMA L5-30R)
C	L1-N	127 V	20 A	Platform
D	L2-N	127 V	20 A	Wall sockets in shed (T0/T1/T2/T3 2× NEMA 5-15R)
E	L2-N	127 V	20 A	Lights in shed
F	L1-L2	220 V	30 A	Wall socket in shed (T6 1× NEMA L6-20R)

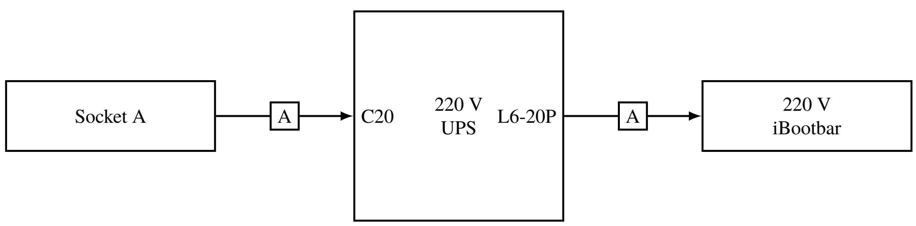

Figure 6.4: Schematic of the Electrical Power Connections To and From the 220 V UPS

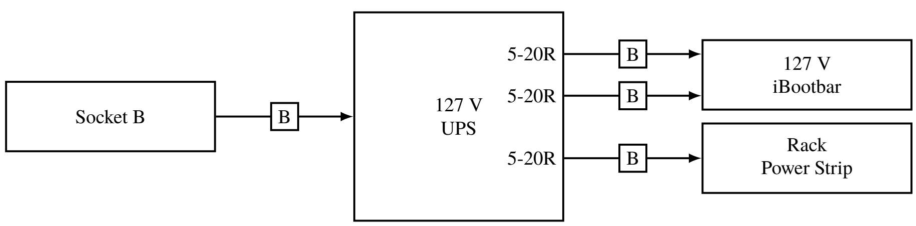

Figure 6.5: Schematic of the Electrical Power Connections To and From the 127 V UPS

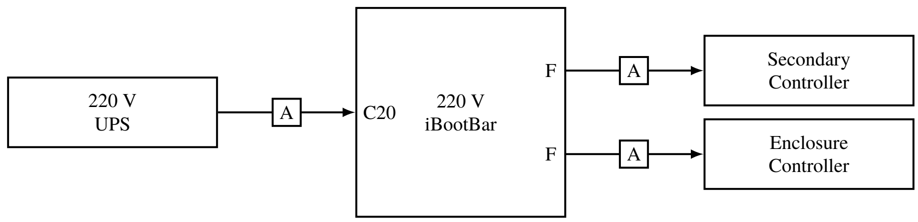

Figure 6.6: Schematic of the Electrical Power Connections To and From the 220 V iBootBar

Figure 6.5 shows a schematic of the electrical power connections.

The UPS is supplied via a NEMA L5-30P plug connected to the NEMA L5-30R wall socket of circuit B.

Two of the NEMA 5-20R output sockets are connected to the NEMA 5-15P plugs of the 127 V iBootBar. Another NEMA 5-20R output socket is connected to the rack power strip.

If the UPS fails, it can be bypassed manually by connecting the two NEMA 5-15P plugs of the 127 V iBootBar directly to the wall sockets of circuit D.

6.4 iBootBars

There are two iBootBars in the rack in the shed, one 127 V and one 220 V. Both are the connected to the corresponding 127 V and 220 V UPS units. They are physically located in the rear of the rack towards the top.

6.4.1 220 V iBootBar

This is a DataProbe iBootBar iBB-C20. Figure 6.6 shows a schematic of the electrical power connections.

The C20 input socket is connected to the 220 V UPS unit with a cable with C19 and NEMA L6-20P plugs.

The connections to the type F output sockets ("C13 female") are given in Table 6.2. The iBootBar can supply up to 20 A.

The iBootBar is connected to the LAN at the address given in Table 8.1. The HTTP and telnet account names and passwords are "coatli" and "coatli". The HTTP interface is available from the COATLI web interface home page.

6.4.2 127 V iBootBar

This is a DataProbe iBootBar iBB-2N15-M. Figure 6.7 shows a schematic of the electrical power connections.

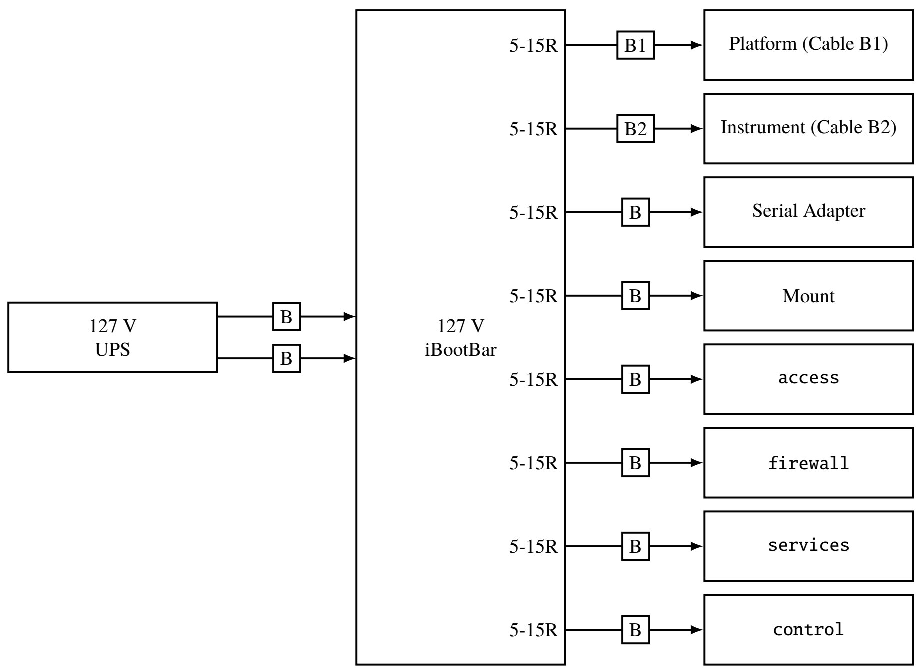

Figure 6.7: Schematic of the Electrical Power Connections To and From the 127 V iBootBar

Table 6.2: iBootBar Output Sockets

Socket	220 V iBootBar	127 V iBootBar
1	Enclosure	Platform (Cable B1)
2	Secondary	`access`
3	-	Instrument (Cable B2)
5	-	Mount
5	-	`firewall`
6	-	`services`
7	-	`control`
8	-	`serial`

Table 6.3: Fuzes

Location	Circuit	Fuze
Power Box	B1	3 A
Power Box	B2	3 A
Power Box	C	15 A
Platform Box	B1	3 A
Instrument Box	B2	3 A

The two NEMA 5-15P input plugs are connected to the 127 V UPS unit.

The connections to the NEMA 5-15R output sockets are given in Table 6.2. The iBootBar can supply up to 15 A to each bank of four output sockets.

The iBootBar is connected to the LAN at the address given in Table 8.1. The HTTP and telnet account names and passwords are "coatli" and "coatli". The HTTP interface is available from the COATLI web interface home page.

The modem facility is not used.

TODO: Configure watchdog.

6.5 Rack Power Strip

At the rear of the rack, adjacent to the 127 V iBootBar, is a 8-way NEMA 5-15R power strip. The power strip powers the computers and network equipment in the rack. The entire power strip, and hence all of the connected equipment, is directly supplied by the 127 V UPS.

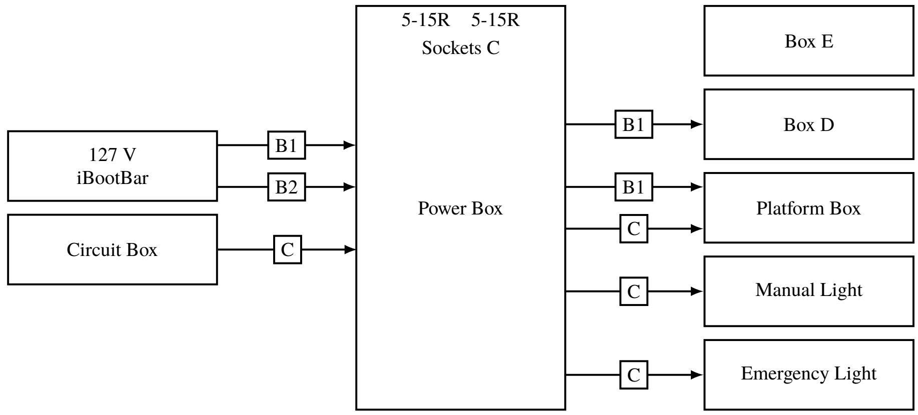

Figure 6.8: Schematic of the Electrical Power Connections To and From the Power Box

6.6 Power Box

The power box is a dumb electrical distribution box located on the platform. Figure 6.8 shows a schematic of the electrical power connections to Power Box.

The power box is connected to circuits B1, B2, and C. Circuits B1 and B2 are subcircuits of circuit B. Circuit B1 is used to power electronics, internal heaters, and internal fans in Boxes C and D, the two other boxes on the platform. Circuit B2 is used for power the electronics, internal heaters, and internal fans in Box E on the telescope. Circuit C is used to power the two NEMA 5-15R plugs on the power box (for general use), the three lights on the platform (one with manual control, one with manual/electronic control, and one emergency), and the external heater on the platform.

The connection to circuits B1 and B2 are via cables with NEMA 5-15P plugs connected to the 127 V iBootBar.

The connection to circuit C is hardwired to the circuit box in the shed. The connections are hardwired at the power box.

The three circuits are switched and fuzed (see Table 6.3) at the entrance to the power box.

The manually-controlled light is hardwired to the platform box and has a manual switch on the power box.

6.7 Platform Box

The platform box is a smart control box located on the platform. Figure 6.9 shows a schematic of the electrical power connections to the platform box.

The platform box is connected to circuits B1 and C. Circuit B1 is a subcircuit of circuit B. Circuit B1 is used to power the electronics, the internal heater, and the internal fans.

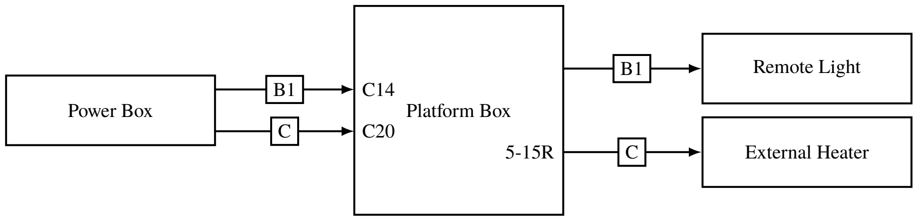

Figure 6.9: Schematic of the Electrical Power Connections To and From the Platform Box

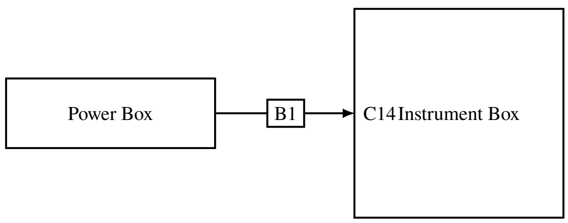

Figure 6.10: Schematic of the Electrical Power Connections To Instrument Box

Circuit C is used to power an external light and the external heater on the platform.

The connection to circuit B1 is via a cable with a C13 plug that connects to the C14 input socket on the platform box. The cable is hardwired to the power box.

The connection to circuit C is via a cable with a C19 plug that connects to the C20 input socket on the platform box. The cable is hardwired to the power box.

The connections to the manually/electronically-controlled light and heater are via the two NEMA 5-15R sockets on the platform box. The light is controlled both by a relay and by a manual switch on the platform box (with the light being on if either the relay or manual switch are on). The heater is controlled by a relay.

Circuit B1 is switched and fuzed (see Table 6.3) at the entrance to the platform box.

6.8 Instrument Box

The instrument box is a smart control box located on the platform. Figure **??** shows a schematic of the electrical power connections to Box D.

The instrument nox is connected to circuit B1. Circuit B1 is a subcircuit of circuit B. Circuit B1 is used to power the electronics, the internal heater, and the internal fans.

The connection to circuit B1 is via a cable with a C13 plug that connects to the C14 input socket on the platform box. The cable is hardwired to the power box.

Circuit B1 is switched and fuzed (see Table 6.3) at the entrance to the instrument box.

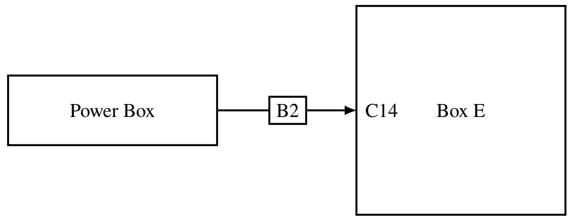

Figure 6.11: Schematic of the Electrical Power Connections To Box E

6.9 Box E

Box E is a smart control box located on the pillar of the COATLI telescope. Figure 6.11 shows a schematic of the electrical power connections to Box E.

Box E is connected to circuit B2. Circuit B2 is a subcircuit of circuit B. Circuit B2 is used to power the electronics, the internal heater, and the internal fans.

The connection to circuit B2 is via a cable with a C13 plug that connects to the C14 input socket on Box E. The cable is hardwired to the power box.

Circuit B2 is switched and fuzed (see Table 6.3) at the entrance to Box E.

6.10 Trouble-Shooting

- Check cables. Has one been disconnected or worked itself lose?
- Check switches. Is the equipment switched on? The smart boxes have switch for their regulated input (circuits B, B1, or B2). The power box has switches for circuits B1, B2, and C. The Macs and the PC have power switches. The ASTELCO equipment has power switches.
- Check fuzes. Has one blown? See Table 6.3.
- For circuits connected via an iBootBar (A, B, B1, and B2), check that the corresponding output socket is on. The state of the output sockets is given by the row of 8 green LEDs on the front of each iBootBar.
- The emergency lights come on if the corresponding circuit (C for the platform and E for the shed) has no power. This can happen because a breaker trips or because the OAN mains supply has failed.
- For circuits not connected via a UPS unit (C, D, E, and F), check that the OAN mains supply is working.
- For circuits connected via a UPS unit (A, B, B1, and B2), check that the corresponding UPS is working.

- Check the breakers in the circuit box in the shed. Has one tripped?
- Check the breaker in the main breaker box in the 84-cm. Has it tripped?
- Check the equipment has not failed.

6.11 Bibliography

- "Eaton 9300 UPS 700/3000 VA User's Guide" (Revision 8)
- "iBootBar Installations and Operations" (Version 1.5)

Chapter 7

Electrical Grounding

This chapter describes the electrical grounding system in the COATLI installation. The electrical power system is described in Chapter 6.

TODO: Measure DDOTI ground resistance.

7.1 Grounding Rods

We have installed a network of ground rods to the east of the 84-cm telescope building. There is one main rod and two delta or triad rod systems. The three systems are connected through a ground bar in a box on the eastern wall of the 84-cm telescope.

The 84-cm telescope building is grounded through an independent network of grounding rods just to the south of the building.

TODO: Photo.

7.2 Grounding System

Figure 7.1 shows a schematic of the electrical grounding system. These grounding cable from the grounding rods runs through the conduit from the 84-cm to the COATLI installation. It is terminated at a protected grounding bar underneath the metal walkway. This is the "tau-point" of the grounding system. From here, spurs are used to ground the electrical system in the shed, the walkways, the tower, and the platform.

TODO: Photo of the tau-point.

TODO: Cable calibres.

The ground bar in the shed is used to provide ground to circuit box and hence to the circuits and the sockets in the shed. It is also used to ground the rack.

Circuits B1, B2, and C run from the shed to Box B on the platform. However, their ground is not connected in Box B. Instead, the ground bar on the platform is used to

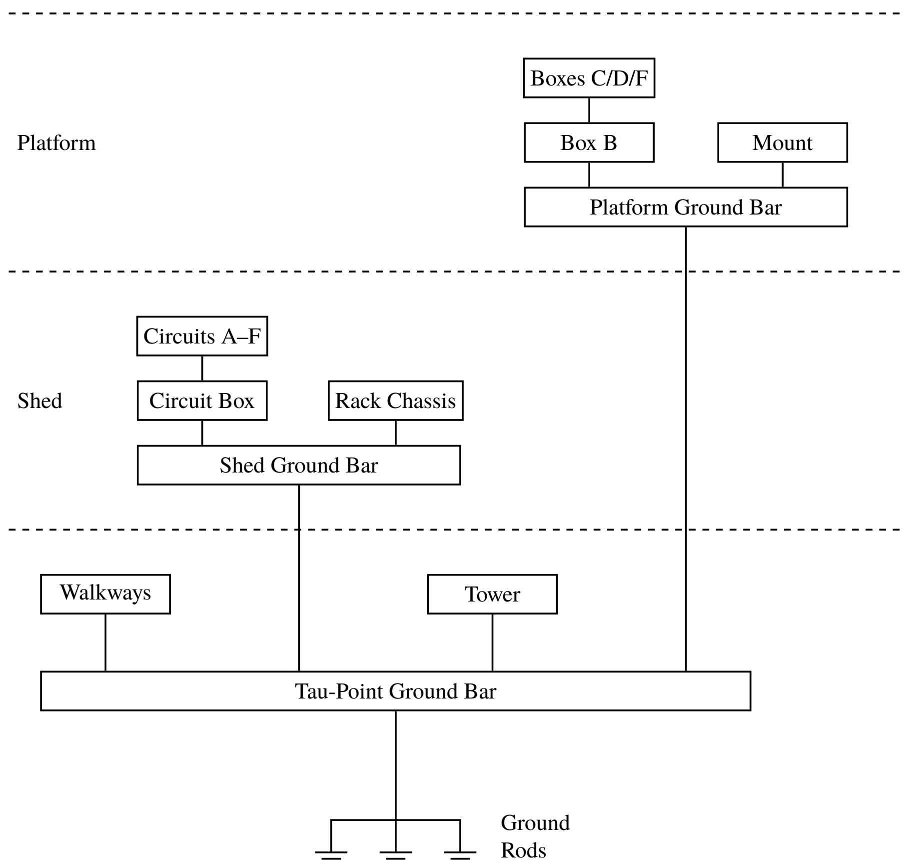

Figure 7.1: Schematic of the Electrical Grounding System

provide ground for Box B and subsequently for the sockets on the platform (in boxes B and C), the cables to boxes C, D, E, and F, and the mount.

TODO: Make sure the ground is connected to the cables between the boxes.

The Astelco controllers in the shed are connected to the platform and mount. There are undoubtedly ground loops through these connections. However, the connections from the platform to the tau-point is through a heavy-gauge cable, and this is likely to mitigate these ground loops.

7.3 Ground Resistance

In October 2016 we measured a ground resistance of about 5.5 Ω at all three of the ground bars (the tau-point, shed ground bar, and platform ground bar) using the three-point method. We further measured a resistance of about 0.8 Ω between the grounding point of the NTM-500 mount and the platform grounding bar and between the ground contacts of the outlets of the iBootBars and the shed grounding bar. This suggests that the grounding system is working well.

Chapter 8

Network

TODO: haltsoon and rebootsoon

8.1 WAN and LAN Addresses

The observatory uses 132.248.4/24 as a WAN. COATLI uses 10.0.1/24 as a LAN. The firewall computer in the rack in the shed serves as a firewall and router between the WAN and the LAN. The addresses of the equipment are given in Table 8.1.

8.2 Port Filtering and Forwarding

The observatory firewall filters access to `coatli.astrossp.unam.mx` (132.248.4.23) from outside the observatory WAN except for ports TCP/22 (SSH), TCP/80 (HTTP), and TCP/5349 (GCN/TAN).

The firewall forwards certain TCP ports from its WAN address to hosts on the LAN. These are listed in Table 8.2. The firewall restricts access on most of these port, with only the main ssh port being open to all hosts.

8.3 Access

All of the hosts have an account coatli with password coatli. Local and ssh access is permitted on the Linux machines, but only local access is permitted on the `access`.

SSH access to `access` is limited to the accounts of project staff and the OAN/SPM network maintenance staff. Thus, remote access is accomplished by first logging into `access` using a non-coatli account and then logging into a local machine using the coatli account.

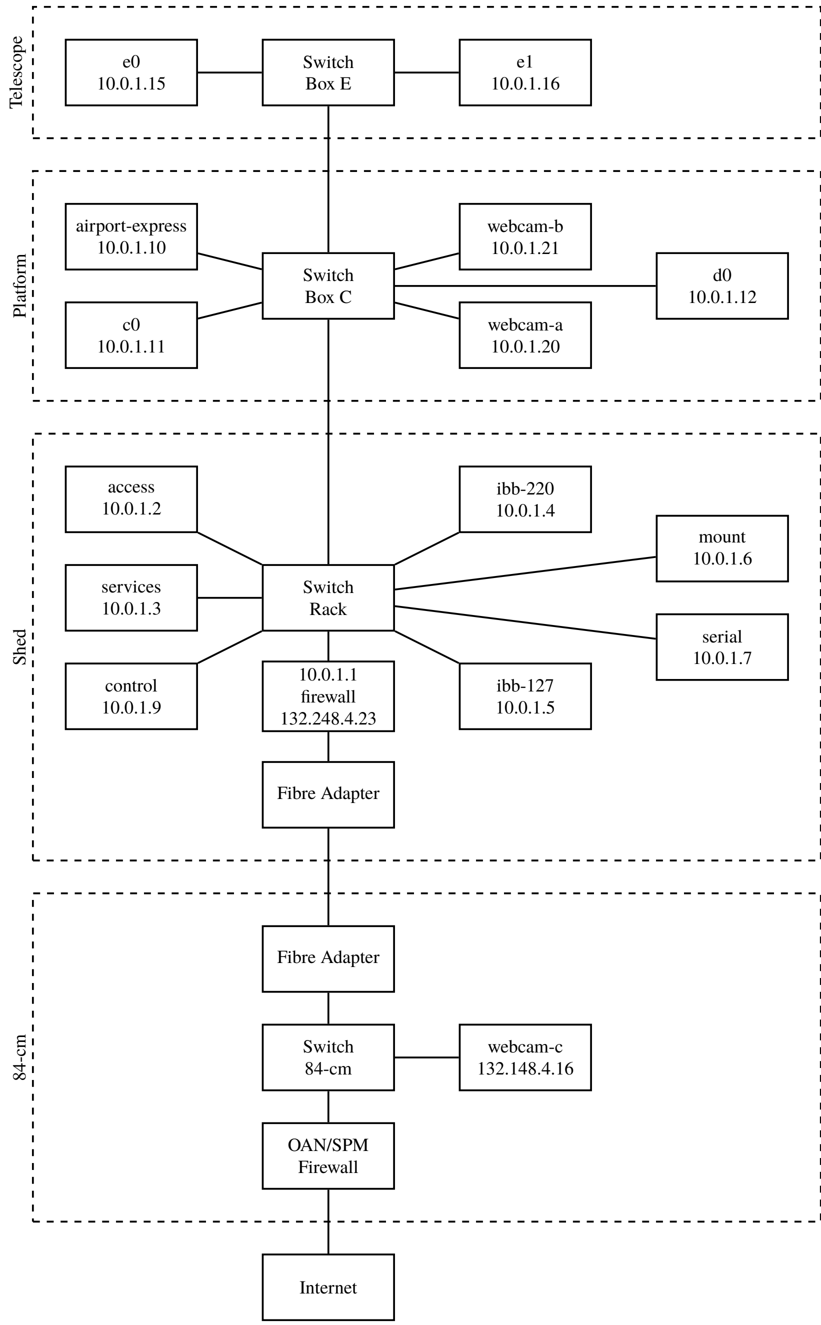

Figure 8.1: Network Physical Topology

Table 8.1: Addresses

Address	Name	Equipment	Location
132.248.4.23	`firewall`	HP Server	Rack
10.0.1.1	`firewall`	HP Server	Rack
10.0.1.2	`access`	Mac mini	Rack
10.0.1.3	`services`	HP Server	Rack
10.0.1.4	`ibb-220`	iBootBar 220 V	Rack
10.0.1.5	`ibb-127`	iBootBar 127 V	Rack
10.0.1.6	`mount`	Mount Controller	Rack
10.0.1.7	`serial`	HP Adapter	Shed Wall
10.0.1.8	`pc`	PC	Not currently installed
10.0.1.9	`control`	Linux Server	Rack
10.0.1.10	`airport-express`	Airport Express	Box C
10.0.1.11	`c0`	Minnowboard Max	Box C
10.0.1.12	`d0`	Minnowboard Max	Box D
10.0.1.15	`e0`	Minnowboard Max	Box E
10.0.1.16	`e1`	Minnowboard Max	Box E
10.0.1.20	`webcam-a`	Webcam	Platform (above Box B)
10.0.1.21	`webcam-b`	Webcam	Platform (above Box C)
132.248.4.16	`webcam-c`	Webcam	84-cm (SE side)

Table 8.2: Ports Forwarded from the WAN to the LAN

Port on WAN	Host on LAN	Port on LAN	Notes
22	`access`	22	Main ssh access.
80	`services`	80	Web page and interface.
873	`services`	5349	rsync.
2222	`firewall`	22	Backup ssh access.
5349	`services`	5349	GCN/TAN notices.

We recommend using an SSH public key to avoid needing to type passwords repeatedly. If you do not have a key, you can generate one by running these commands on your computer:

```
mkdir ~/.ssh
chmod 700 ~/.ssh
ssh-keygen -t rsa
```

Once you have generated a key, you can copy it to `access` using:

```
ssh-copy-id user@coatli.astrossp.unam.mx
```

You should then by able to ssh to `access` without having to type your password.

Having copied the key to access, you can copy it to the coatli accounts on the other computers on the LAN by running this command on `access`:

```
ssh-copy-id-to-lan
```

To use your key this, you should make sure that the key is forwarded by using the `-A` option to ssh when you connect to `access` or by adding the `ForwardAgent yes` option to your `.ssh/config` file.

8.4 Wireless Networks

There are two wireless networks for general use. The access Mac in the shed implements `apcoatli0` and the Airport Extreme in Box C on the platform implements `apcoatli1`. The password is “keplerxv”.

8.5 DHCP

The firewall runs a DHCP server that allocates addresses in the range 10.0.1.100 to 10.0.1.200.

Chapter 9

Lights

This chapter describes the lighting in the COATLI installation.

9.1 Shed Lights

The shed has standard manual lights controlled by a switch just inside the door.

The shed lights are on circuit E and are backed up by emergency lighting that switches on if the power fails.

9.2 Platform Manual Lights

The platform manual lights controlled by a switch on Box B by the usual entrance to the platform. The lights are a small LED panel supplied by a 12 VDC power supply in Box B.

The platform manual lights are on circuit C and are backed up by emergency lighting that switches on if the power fails.

9.3 Platform Remote-Controlled Lights

9.3.1 Hardware

The platform remote-controlled lights controlled by Box C. The lights are a small LED panel supplied by a 12 VDC power supply in Box C. Electrically, the supply is switched by a H-bridge controlled by GPIO pin 481 on `c0`.

The platform remote-controlled lights are on circuit B1.

9.3.2 Control

The `lights` server for the remote-controlled lights runs on `c0`.

The server starts automatically after `c0` boots, but if necessary it can be stopped, started, or restarted explicitly by issing the following shell commands on `c0`:

- sudo stopserver lights
- sudo startserver lights
- sudo restartserver lights

Server requests can be issued from any of the Mac or Linux machines on the LAN. The following requests are supported:

- `request lights status`

  Show the status of the server.

  Obtain the values of the status data from the server and print them to stdout.

- `request lights initialize`

  Initialize the server and hardware. As part of the process of initializing, the lights will switch off.

- `request lights reset`

  Attempt to recover from an error.

- `request lights stop`

  Attempt to stop the current activity.

- `request lights switchon`

  Switch the lights on.

- `request lights switchoff`

  Switch the lights off.

There are buttons to control the lights on the web interface. These are useful for illuminating the platform to allow inspection by the webcams.

Chapter 10

Webcams

TODO: Photos of the webcams.

TODO: Photos with the webcams.

COATLI uses webcams to monitor the platform and enclosure from inside and out.

10.1 Platform Webcams

There are two webcams installed on short posts on the platform. Webcam A is installed above Box B and webcam B is installed above Box C. Figures 10.1 and 10.2 show typical daytime views from webcams A and B. Between them, they can see all of the platform. The platform remote light allow the webcams to monitor the platform even at night. The webcams are Vivotek FE8174V with a 180 degree field of view. This model has an IP66-rated weatherproof housing and can operate down to −40 C.

The platform webcams are on the LAN at the addresses given in Table 8.1. The web interfaces can be accessed with the "coatli" account with password "coatli".

10.2 External

Webcam C is installed on the outside wall of the 84-cm, above the balcony, giving a view of the COATLI enclosure. An electronic zoom of webcam C, that shows the enclosure in more detail, is known as webcam CZ. Figures 10.3 and 10.4 show typical daytime views from webcams C and CZ. The webcam is a Vivotek MD7560D with a 98×73 degree field of view lens. This model has an IP67-rated weatherproof housing and can operate down to −25 C.

The external webcam in on the observatory public network at the address given in Table 8.1. The web interfaces can be accessed with the "coatli" account with password "coatli".

10.3 Bibliography

- "FE8174/74V Data Sheet", Vivotek.
- "FE8174V User's Manual", Vivotek.
- "MD7530/60 MD8562/62D Alignment", Vivotek.
- "MD7560/60D Data Sheet", Vivotek.
- "MD7530/7530D MD7560/7560D User's Manual", Vivotek.
- "MD7530/7530D MD7560/7560D Quick Installation Guide", Vivotek.

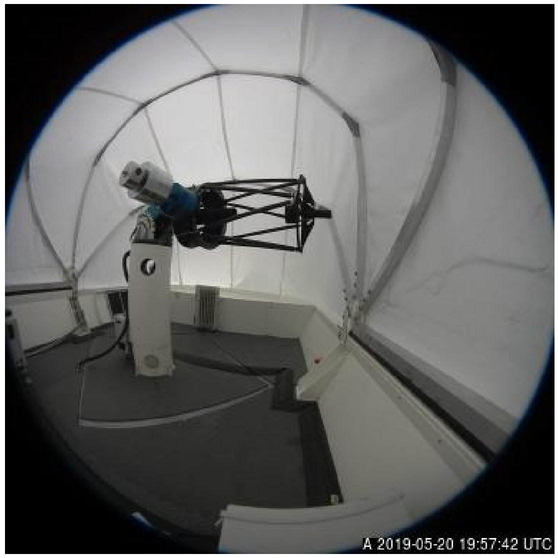

Figure 10.1: Typical daytime view from COATLI webcam A.

Figure 10.2: Typical daytime view from COATLI webcam B.

Figure 10.3: Typical daytime view from COATLI webcam C.

Figure 10.4: Typical daytime view from COATLI webcam CZ (en electronic zoom of webcam C).

Chapter 11

Enclosure

11.1 Description

COATLI is protected by an ASTELCO ARTS enclosure, shown in Figure 11.1. The ARTS enclosure consists of a tower, a platform with balconies, and set of folding arches that support a flexible waterproof fabric roof.

> *Under no circumstances ascend to the platform or balconies if the enclosure is in remote mode as the enclosure can close without warning.*

The enclosure can open to 60, 120, and 180 deg and can be controlled locally or remotely. The enclosure is oriented ENE to WSW and opens from the ENE towards the WSW.

The enclosure can open and close in wind speeds of up to 90 km/h and has a survival windspeed of 180 km/h.

The controller for the enclosure, shown in Figure 11.2 is located in a cabinet in the shed. The enclosure is opened and closed by two geared motors, one on each balcony. The position is sensed by proximity sensors on the bearings (fully open and partially open positions) and at the point that the last arch closes (closed position). The controller and the motors are powered by 220 V 60 Hz from the Circuit A via the 220 V UPS and 220 V iBootBar.

The enclosure has an electromagnetic lock, shown in Figure 11.4, that holds it firmly closed. If the lock is not activated, the wind can open the roof a few centimeters and allow the ingress of rain or snow.

> *The enclosure controller should normally be switched on at all times in order to keep the electromagnetic lock activated.*

The electromagnet that holds the enclosure closed is normally activated by the PLC. However, we have modified the controller to add a switch inside the controller that switches on the enclosure electromagnet and actuates the enclosure emergency stop

Figure 11.1: The COATLI enclosure.

Figure 11.2: The enclosure controller in the shed.

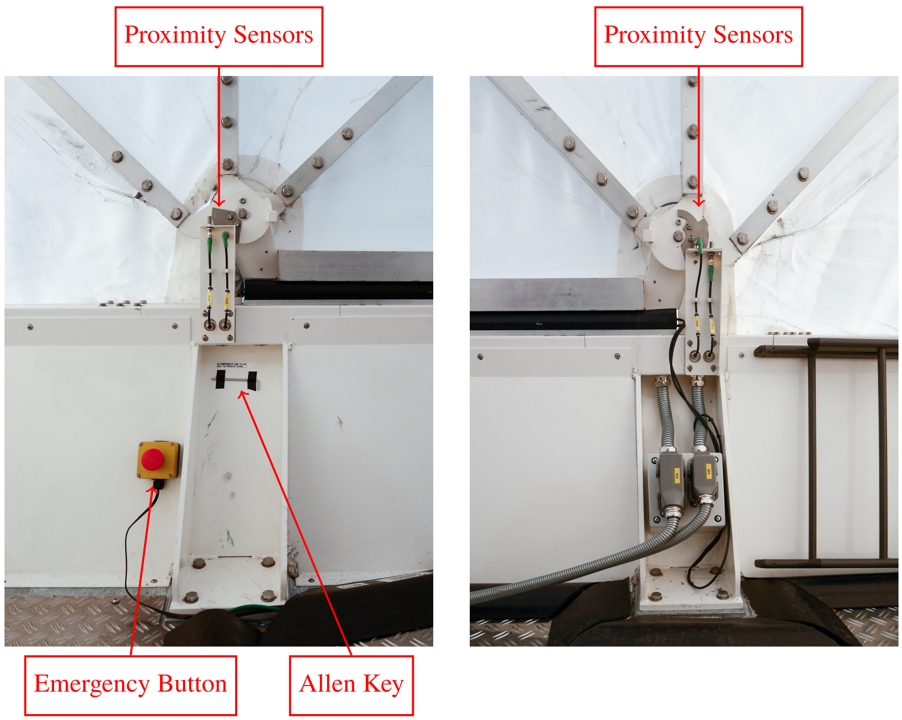

Figure 11.3: The north (left) and south (right) bearings for the folding roof. Notice the proximity sensors, the emergency stop button for the mount, and the Allen key to escape in an emergency.

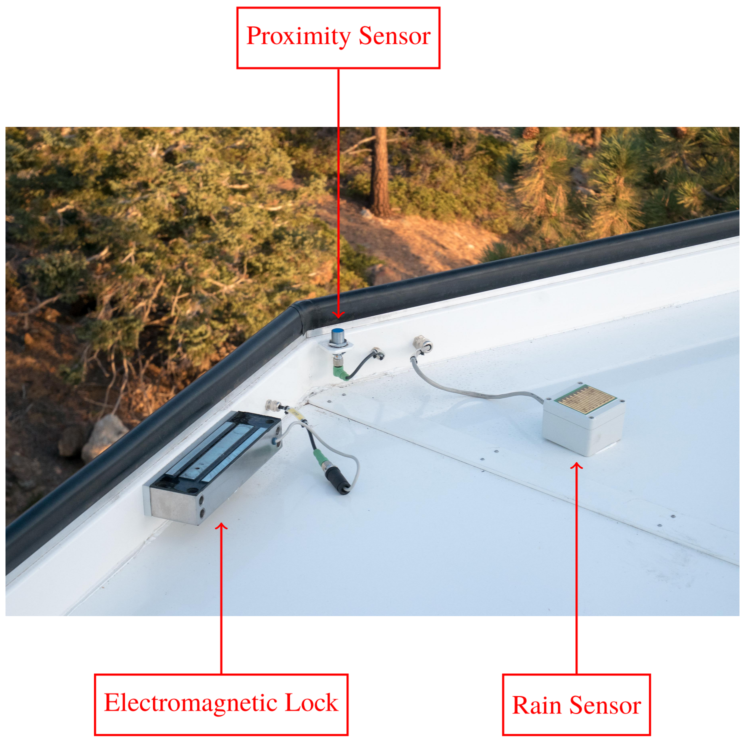

Figure 11.4: The enclosure electromagnetic lock (left), 0 deg proximity sensor (the cylinder with the blue top in the center), and rain sensor (the white box with the copper contacts on the right).

buttons. This ensures that the electromagnet stays energized even if the PLC fails and that the PLC cannot attempt to open the enclosure. This switch is shown in Figure 11.5.

The enclosure has a rain sensor, also shown in Figure 11.4. In automatic mode, it will automatically close if the rain sensor gets wet.

The enclosure has a safety seal along the lower edge of the opening. The motors will stop if this is pressed. This avoids the enclosure closing on someone or something. However, it is easy to activate the safety rail when entering or leaving the enclosure.

The enclosure also has two emergency stop buttons, one at the bottom of the main access ladder and the other on the northern motor cowling. These are shown in Figure 11.7. Again, the motors will stop if either of these are pressed.

The two semi-circular elevated areas at the ends of the platform, shown in Figure 11.8, are not load bearing and are marked with "no step" signs. If you attempt to walk on these, you will likely fall.

Do not walk on the elevated areas at the ends of the platform!

If you are trapped in the enclosure and cannot summon help, you can escape by using the Allen key taped below the northern bearing to remove one of the sloping side panels to gain access to the balcony. See Figure 11.3.

The enclosure controller can be in remote or local mode. The mode is selected by the switch on the door of the enclosure controller in the shed (see Figure 11.9). In remote mode:

- The switches on the enclosure controller to open and close the enclosure and to reset errors are deactivated.
- The robotic control system can open and close.
- The enclosure will close automatically if the rain sensor gets wet.

In local mode:

- The switches on the enclosure controller to open and close the enclosure and to reset errors are active.
- The robotic control system cannot open or close.
- The enclosure will not close if the rain sensor gets wet.

If there is an error, the red error button on the enclosure controller will flash or be constantly lit. The interpretation depends on whether the controller is in local mode or remote more.

In remote mode, the red button will be constantly illuminated for all detected errors. The specific error can be diagnosed either by software (via the inputs to the ADAM module) or by switching to local mode.

In local mode, the following error states are distinguished:

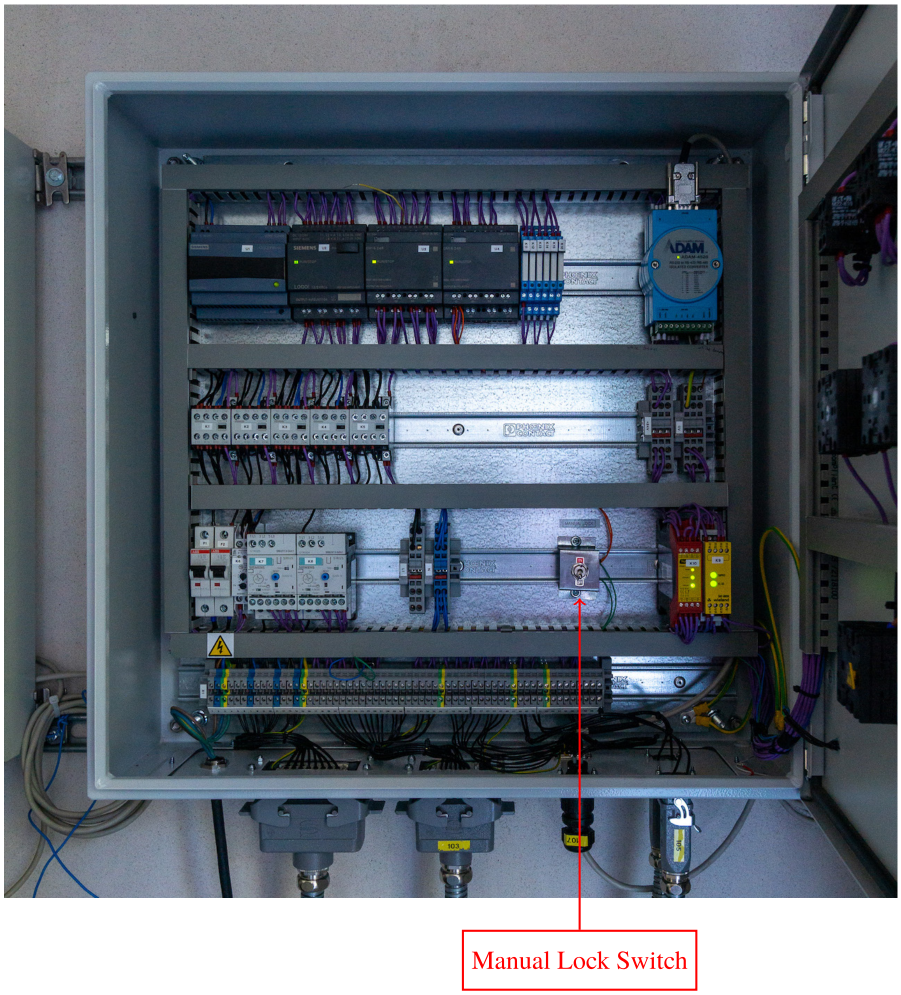

Figure 11.5: The inside of the enclosure controller cabinet showing the manual switch for the electromagnet.

Figure 11.6: The enclosure safety seal, the black rubber seal on the lower edge of the enclosure opening. If this is pressed, the motors will stop and an error is set in the controller.

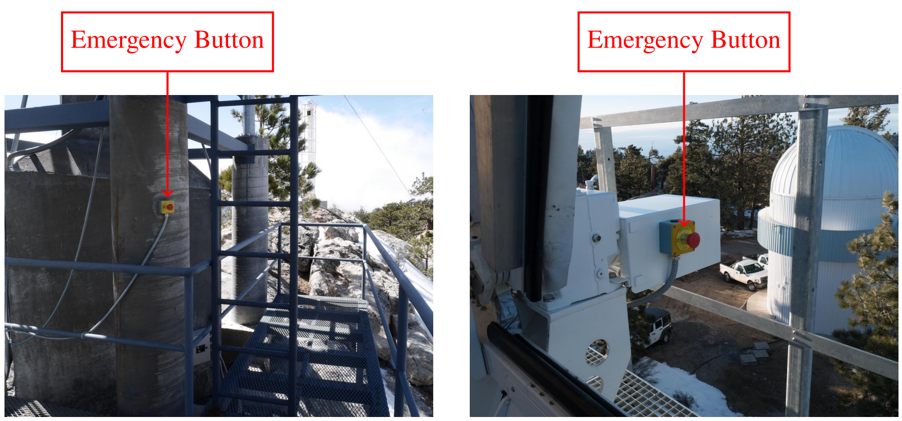

Figure 11.7: The enclosure emergency stop buttons, next to the main access ladder (left) and on the northern motor cowling (right).

Figure 11.8: Do not walk on the elevated areas at the ends of the platform as they are not load bearing. Note the “no step” signs.

- Constant: One or both of the emergency stop buttons have been pressed. There is one emergency stop button at the bottom of the north ladder and another on the cowling around the north motor. Follow the procedure in §11.2.5 to clear the error.
- Slow flashing (1 Hz): The motor under-current relay (K6) has been activated.
- Medium flashing (2 Hz): One or both of the motor over-current relays (K7 and K8) have been activated. This can happen if the enclosure is opened and closed continously for several minutes. Follow the procedure in §11.2.4 to clear the error.
- Fast flashing (4 Hz): The safety seal around the enclosure cover has been activated. Follow the procedure in §11.2.3 to clear the error.

11.2 Maintenance Procedures

11.2.1 Enabling Remote Mode

Safety Considerations

Under no circumstances ascend to the platform or balconies if the enclosure is in remote mode as the enclosure can close without warning.

Requirements

You will need:

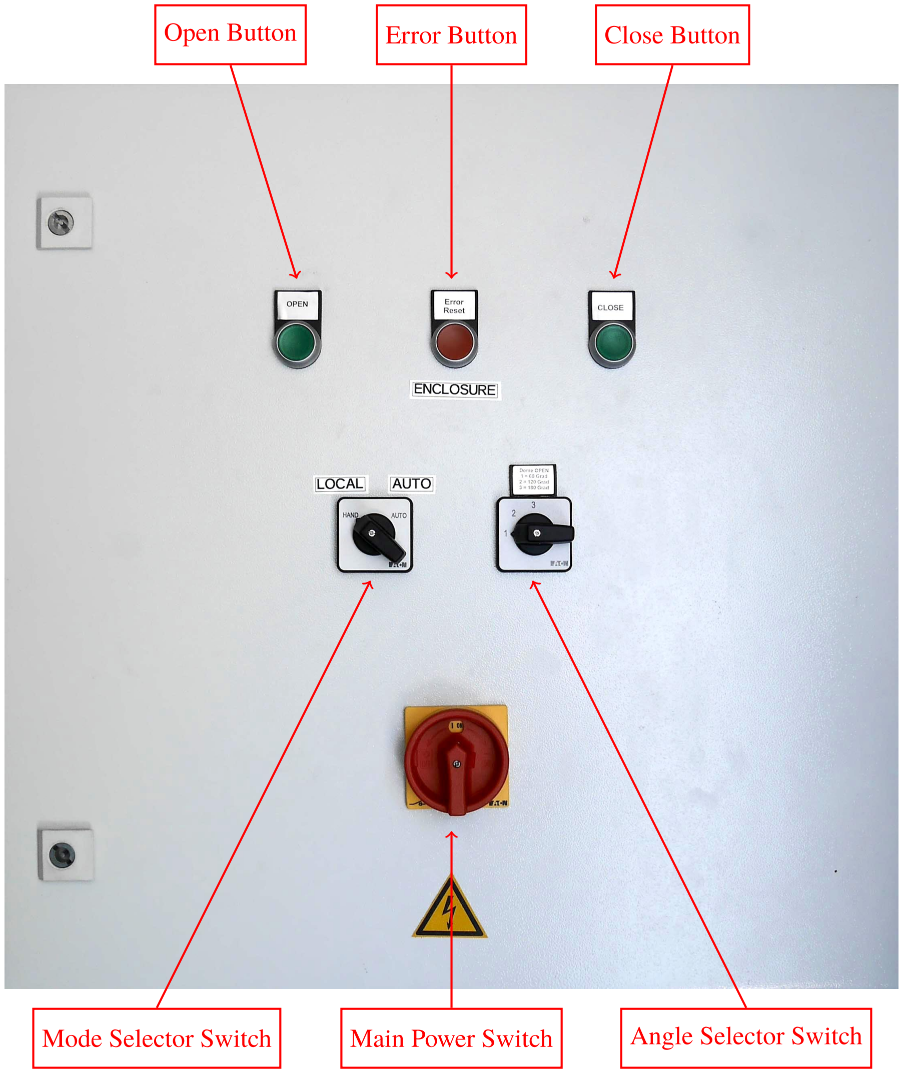

Figure 11.9: The enclosure controller door and control panel. Bottom: the main power switch. Middle row, left to right: the mode selector switch (“LOCAL” and “REMOTE”) and the angle selector switch (180 deg is fully open). Top row, left to right: the open button, the error button, and the close button.

- One person.
- The key to the shed (see §5.3).

Procedure

1. Go to the shed.
2. Move the main power switch on the enclosure controller door to “ON”.
3. Move the mode selector switch on the enclosure controller door to “REMOTE”.

11.2.2 Opening or Closing in Local Mode

Safety Considerations

In local mode, the control system cannot open or close enclosure.

In local mode, the rain sensor cannot close enclosure.

Before opening the enclosure, check on the webcams that the telescope is not pointed to towards the sun. In the home position, the telescope is pointed to the north pole.

Requirements

You will need:

- One person (to open or close only) or two or more persons (if you wish to ascend to the platform).
- The key to the shed (see §5.3).

Procedure

1. Go to the shed.
2. Move the enclosure controller main power switch on the enclosure controller to “ON”.
3. Move the enclosure controller mode selector switch to “LOCAL”.
4. If there is an error, the red error button will flash or be constantly lit. Investigate the error, and clear it before proceeding:

   In local mode, the following error states are distinguished:

- Constant: One or both of the emergency stop buttons have been pressed. There is one emergency stop button at the bottom of the north ladder and another on the cowling around the north motor. Follow the procedure in §11.2.5 to clear the error.
- Slow flashing (1 Hz): The motor under-current relay (K6) has been activated.
- Medium flashing (2 Hz): One or both of the motor over-current relays (K7 and K8) have been activated. This can happen if the enclosure is opened and closed continously for several minutes. Follow the procedure in §11.2.4 to clear the error.
- Fast flashing (4 Hz): The safety seal around the enclosure cover has been activated. Follow the procedure in §11.2.3 to clear the error.

5. To open, set the angle selector switch to the desired angle (60, 120, and 180 deg) and then press and hold the open button until the green light goes out. The 60 deg position gives access to the dome while continuing the shade the telescope from the elements.
6. To close, press and hold the green close button until the light goes out.
7. If you wish to subsequently operate the enclosure remotely, move the mode selector switch to "REMOTE".

11.2.3 Resetting a Safety Seal Error

If the safety seal is pressed the error button on the enclosure controller door flashes at 4 Hz in local mode and the enclosure will not operate. This procedure describes how to reset the error.

Safety Considerations

Use a harness, line, and helmet when you work on the platform or balconies.

Requirements

You will need:

- At least two persons.
- The key to the shed (see §5.3).

Procedure

1. Go to the shed.
2. Move the enclosure controller main power switch on the enclosure controller to "ON".
3. Move the enclosure controller mode selector switch to "LOCAL".
4. One person should use a safety harness, safety line, and safety helmet and ascend to the platform. They should remove whatever is pressing the safety seal. They should then descend from the platform.
5. Press the error button to clear the error.
6. Attempt to move the enclosure slightly using the open or close buttons.
7. Verify that the error button no longer signals an error. That is, that is no longer flashes. If not, continue to investigate the error.
8. Close the enclosure.
9. If you wish to subsequently operate the enclosure remotely, move the mode selector switch to "REMOTE".

11.2.4 Resetting a Motor Over-Current Error

The motors are protected by over-current relays. In normal operation, these should not activate. However, if they do the error button on the enclosure controller door flashes at 2 Hz in local mode and the enclosure will not operate. This procedure describes how to reset the error.

Safety Considerations

Be extremely careful when working inside the controller cabinet as it uses 220 VAC.

Requirements

You will need:

- One person.
- The key to the shed (see §5.3).

Procedure

1. Go to the shed.
2. Move the mode selector switch to “LOCAL”.
3. Move the enclosure controller main power switch on the enclosure controller to “OFF”.
4. Open the enclosure controller door.
5. Locate the motor over-current relays K7 and K8 (see Figure 11.11). Press the blue buttons on K7 and K8 to reset them.
6. Close the enclosure controller door.
7. Move the enclosure controller main power switch on the enclosure controller to “ON”.
8. Attempt to move the enclosure slightly using the open or close buttons.
9. Verify that the error button no longer signals an error. That is, that is no longer flashes. If not, continue to investigate the error.
10. Close the enclosure.
11. If you wish to subsequently operate the enclosure remotely, move the mode selector switch to “REMOTE”.

11.2.5 Resetting an Emergency Button Error

If one of the emergency buttons is pressed the error button on the enclosure controller door will be constantly lit in local mode and the enclosure will not operate. This procedure describes how to reset the error.

Safety Considerations

Use a harness, line, and helmet when you work on the platform or balconies.

Requirements

You will need:

- At least two people.
- The key to the shed (see §5.3).

Procedure

1. Check the emergency button at the bottom of the ladder. If it is activated, twist it clockwise to release it.
2. One person should use a safety harness, safety line, and safety helmet and ascend to the platform. They should check the emergency button at on the north motor casing. If it is activated, they should twist it clockwise to release it. They should then descend from the platform.
3. Move the mode selector switch to “LOCAL”.
4. Press the error button to clear the error.
5. Attempt to move the enclosure slightly using the open or close buttons.
6. Verify that the error button no longer signals an error. That is, that is no longer flashes. If not, continue to investigate the error.
7. Close the enclosure.
8. If you wish to subsequently operate the enclosure remotely, move the mode selector switch to “REMOTE”.

11.2.6 Manual Opening or Closing without Power

If the enclosure cannot be operated normally using remote mode or local mode, you can bypass the control system and operate it manually by driving the motor axles manually with portable electric drills. This procedure requires two people.

This is not to be undertaken lightly, as it involves working on the balcony. However, when carried out with appropriate safety precautions and with calm, it is quite safe.

Safety Considerations

Be extremely careful when working inside the controller cabinet as it uses 220 VAC.

Use a harness, line, and helmet when you work on the platform or balconies.

Requirements

You will need:

- Two people.
- Two portable electrical drills with 6 mm hex drives.

Figure 11.10: Opening or closing the enclosure with portable electric drills. The motor brake is disengaged by pushing the lever under the motor away from the platform.

- The key to the shed (see §5.3).

Two suitable drills with drives are stored in the COATLI equipment cabinet in the ground floor of the 84-cm telescope building. The batteries are normally connected to wall socket.

Procedure for Closing the Enclosure

To close the enclosure:

1. Switch off the enclosure controller.

   Move the main power switch on the controller door from ON to OFF.

2. Use appropriate safety equipment: harnesses, lines, and helmets. These are found in the shed.

3. One person should ascend to one balcony with one drill and the other person to the other balcony with the other drill.

4. Use your safety line to secure yourself to the balcony rail. Loop the line over the rail and then fasten the clasp on the line itself.

5. Set the direction of the drill appropriately to close the enclosure.

6. Insert the drill into the motor axle. See Figure 11.10.

7. Push the lever underneath the motor away from the platform to release the brake. Keep the brake released and run the electric drill to turn the motor axle. The two people should do this relatively slowly and coordinate; if one gets too far ahead of or behind the other, you can damage the arch or bearing.

8. Once the enclosure is closed, release the brake lever, remove the drills, and descend from the platform.

9. Open the enclosure controller.

10. Engage the manual lock. This switches on the enclosure electromagnet and actuates the enclosure emergency stop buttons. This ensures that the electromagnet stays energized even if the PLC fails and that the PLC cannot attempt to open the enclosure.

    Move the manual lock switch inside the enclosure controller from OFF to ON. See Figure 11.5.

11. Close the enclosure controller.

12. Switch on the enclosure controller.

    Move the main power switch on the controller door from OFF to ON.

13. Place the enclosure in remote mode.

    Move the enclosure controller mode selector switch to “REMOTE”.

Procedure for Opening the Enclosure

To open the enclosure:

1. Switch off the enclosure controller.

   Move the main power switch on the controller door from ON to OFF.

2. Open the enclosure controller.

3. Disengage the manual lock.

   Move the manual lock switch inside the enclosure controller from ON to OFF. See Figure 11.5.

4. Close the enclosure controller.

5. Use appropriate safety equipment: harnesses, lines, and helmets. These are found in the shed.

6. One person should ascend to the northern balcony with one drill and one to the southern balcony with the other drill.

7. Use your safety line to secure yourself to the balcony rail. Loop the line over the rail and then fasten the clasp on the line itself.

8. Set the direction of the drill appropriately to open the enclosure.
9. Insert the drill into the motor axle. See Figure 11.10.
10. Push the lever underneath the motor away from the platform to release the brake. Keep the brake released and run the electric drill to turn the motor axle. The two people should do this relatively slowly and coordinate; if one gets too far ahead of or behind the other, you can damage the arch or bearing.
11. Once the enclosure is open, release the brake lever, remove the drills, and descend from the platform.
12. Switch on the enclosure controller.

    Move the main power switch on the controller door from OFF to ON.

11.2.7 Shutting-Down Before and Starting-Up After the Winter Break

The observatory and COATLI cease operations during a winter break of about three weeks. During the winter break the enclosure should be left closed and powered on but with a hardware override on the electromagnetic lock.

Safety Considerations

Be extremely careful when working inside the controller cabinet as it uses 220 VAC.

Requirements

You will need:

- At least one person.
- The key to the shed (see §5.3).

All of these can be found in the tool box in the COATLI equipment cabinet in the ground floor of the 84-cm telescope building.

Procedure for Shutting-Down Before the Winter Break

To prepare the enclosure before the winter break:

1. Go to the shed.
2. Move the enclosure controller mode selector switch to “LOCAL”.

3. If the weather permits, open the enclosure to 60 deg.

   Set the angle selector switch to the 60 deg and then press and hold the open button until the green light goes out.

4. Close the dome.

   Press and hold the close button until the green light goes out.

5. Switch off the enclosure controller.

   Move the main power switch on the controller door from ON to OFF.

6. Open the enclosure controller.

7. Engage the manual lock. This switches on the enclosure electromagnet and actuates the enclosure emergency stop buttons. This ensures that the electromagnet stays energized even if the PLC fails and that the PLC cannot attempt to open the enclosure.

   Move the manual lock switch inside the enclosure controller from OFF to ON. See Figure 11.5.

8. Close the enclosure controller.

9. Leave the enclosure controller mode selector switch to "LOCAL".

Procedure for Starting-Up After the Winter Break

To prepare the enclosure after the winter break:

1. Go to the shed.

2. Switch off the enclosure controller.

   Move the main power switch on the controller door from ON to OFF.

3. Open the enclosure controller.

4. Disengage the manual lock.

   Move the manual lock switch inside the enclosure controller from ON to OFF. See Figure 11.5.

5. Close the enclosure controller.

6. Switch on the enclosure controller.

   Move the main power switch on the controller door from OFF to ON.

7. Move the enclosure controller mode selector switch to "REMOTE".

11.3 Remote Interface

11.3.1 Lantronix EDS

The RS-232 interface to the enclosure controller is made available via the Lantronix EDS 4100 ethernet-to-serial converter. Specifically, it is connected to line 3 and configured as 9600/8-N-1 with a tunnel on TCP port 10003.

The Lantronix EDS is on the LAN at `serial`.

11.3.2 ADAM Modules

Remote control of the enclosure is through an ADAM-4055 digital input/output module. The input and output channels of the ADAM-4055 module are connected to the enclosure controller PLC.

The RS-485 serial interface of the ADAM-4055 is exposed via an ADAM-4520 RS-232 to RS-485 converter and isolator as RS-232 at 9600/8-N-1.

The state of the input and output channels can be determined either from the web interface (the “Input Channels” and “Output Channels” variables in the “Enclosure” tab) or by unscrewing the ADAM-4520 RS-232 to RS-485 converter on top of the ADAM-4055 to reveal LEDs which show the state of the channels.

The input channels are:

DI0 Open. 0 = not open and 1 = open. This channel is connected to terminal U3/Q5 (“Kuppel AUF”) on the PLC. Its value is determined by the PLC from the proximity switches on the platform.

DI1 Closed. 0 = not closed and 1 = closed. This channel is connected to terminal U3/Q6 (“Kuppel ZU”) on the PLC. Its value is determined by the PLC from the proximity switches on the platform.

DI2 Error. In remote mode, 1 = error and 0 = no error. In local mode, this follows the state of the red error button (constant 0 = not error, constant 1 = emergency stop button pressed, and intermittent at 1, 2, or 4 Hz for under-current, over-current, and safety rail errors). This channel is connected to U3/Q4 (“Störung”) on the PLC, which also control the red error button. Its value is determined by the PLC. Note that the behavior of this channel in local mode makes it only useful in remote mode.

DI3 Mode. 0 = local and 1 = remote. This channel is connected to terminal U4/I2 (“Hand/Auto”) of the PLC. Its value is directly determined by the mode switch.

DI4 Motor over-current error. 0 = no error and 1 = error. This channel is connected to terminal U3/I7 (“Motorschutz”) of the PLC. Its value is directly determined by the motor over-current relays K7 and K8.

DI5 Rain sensor. 0 = dry and 1 = wet. This channel is connected to terminal U3/Q8 ("Regensensor") on the PLC. Its value is determined by the PLC from the rain sensor switch on the platform.

DI6 Safety strip. 0 = not pressed and 1 = pressed. This channel is connected to terminal U4/I1 ("Dichtlippe") on the PLC. Its value is directly determined by the safety rail switch.

DI7 Emergency stop. 0 = not pressed and 1 = pressed. This channel is not connected to the PLC but rather to the emergency stop button circuit. Its value is determined directly by the emergency stop buttons.

The output channels are:

DO0 Open. In remote mode, set to 1 to open to the position specified by DO3, DO4, and DO5. This channel is connected to terminal U2/I3 ("AUF") of the PLC via relay K11.

DO1 Close. In remote mode, set to 1 to close. This channel is connected to terminal U2/I4 ("ZU") of the PLC via relay K12.

DO2 Reset. In remote mode, set to 1 to reset an error. This channel is connected to terminal U2/I8 ("Reset") of the PLC via relay K13.

DO3 60 deg. Set to 1 to select 60 degrees. This channel is connected to terminal U4/I5 ("Auto 60-Grad") of the PLC via relay K14.

DO4 90 deg. Set to 1 to select 90 degrees. This channel is connected to terminal U4/I6 ("Auto 90-Grad") of the PLC via relay K15. (The COATLI enclosure does not have hardware to open to 90 degrees.)

DO5 120 deg. Set to 1 to select 120 degrees. This channel is connected to terminal U4/I7 ("Auto 120-Grad") of the PLC via relay K16.

DO6 Not used.

DO7 Not used.

If D03, D04, and D05 are all set to 0, opening will open to 180 degrees. The COATLI enclosure has hardware to support opening to 60, 120, and 180 degrees; it does not have hardware to support opening to 90 degrees.

11.3.3 Diagnostics

To check communication with the Lantronix EDS, from a terminal run:

```
ping serial
```

Table 11.1: Enclosure Controller Components

Code	Component
K6	Dold IK9217
K7/K8	Siemens 3RB2016-1PB0
	Siemens 3RB2913-0AA1

To check communication with the ADAM modules, from a terminal on `control`, first stop the enclosure server so that it releases the enclosure TCP port on the Lantronix EDS:

```
sudo stopserver enclosure
```

Then connect to the enclosure TCP port on the Lantronix EDS using telnet:

```
telnet serial 10003
```

You can then send commands to the ADAM-4055. Some useful commands (which should be followed by ENTER) are:

- Command: `$01M`

  Response: `!014055`

  Read Module Name. The response shown above confirms that you are talking to an ADAM-4055.

- Command: `$016`

  Response: `!`$XXYY$`00`

  Digital Data In. The values of the output channels (in upper-case hexadecimal) are given by XX and the values of the input channels (in upper-case hexadecimal) are given by YY.

- Command: `#0100`XX

  Response: >

  Digital Data Out. The output channels are set to XX (in upper-case hexadecimal).

For more details of the commands, see the ADAM-4000 Manual.

You can exit from telnet by typing CTRL-`]` and then `quit`. Once you have done so, you should probably restart the enclosure server on `control` with:

```
sudo startserver enclosure
```

Figure 11.11: The Enclosure Controller. Top rail, left to right: U1 is the power supply for the PLC; U2 is the PLC; U3 and U4 are extension units for the PLC; K11 to K16 are relays to convert between ADAM and PLC signal levels; finally two stacked ADAM modules. Middle rail, left to right: K1 to K4 are relays for the motors; K5 is the relay for the motor brakes; and +24 VDC and 0 VDC distribution blocks. Bottom rail, left to right: F1 and F2 are breakers for the motors; K6 is the delay relay to run the motors for a few seconds one the enclosure is open in order to synchronize the motors; K7 and K8 are motor over-current relays; 220 VAC live and neutral distribution blocks; K10 is XXX; and K9 is XXX.

11.4 Control

The server for the enclosure runs on `control`.

The server starts automatically after `control` is boots, but if necessary can be stopped, started, or restarted explicitly by issuing the following shell commands on `control`:

- `sudo stopserver enclosure`
- `sudo startserver enclosure`
- `sudo restartserver enclosure`

Server requests can be issued from any of the Mac or Linux machines on the LAN. The following requests are supported:

- `request enclosure initialize`

  Initialize the server and enclosure hardware. As part of the process of initializing, the enclosure will close.

  For this request to be accepted, the server activity must not be `starting` or `error`.

  If the request is accepted, the server activity changes to `initializing` and then, once it has initialized, to `idle`.

- `request enclosure open` ⟨angle⟩

  Open the enclosure to the specified ⟨angle⟩. If ⟨angle⟩ is omitted, a default value of `180` is assumed.

  Valid values of ⟨angle⟩ are `60`, `120`, and `180`.

  For this request to be accepted, the server activity must not be `starting`, `started`, `initializing`, or `error`.

  If the request is accepted, the server activity changes to `opening` and then, once it has opened to the specified angle, to `idle`.

- `request enclosure close`

  Close the enclosure.

  For this request to be accepted, the server activity must not be `starting`, `started`, `initializing`, or `error`.

  If the request is accepted, the server activity changes to `closing` and then, once it has closed, to `idle`.

- `request enclosure stop`

  Stop the enclosure.

  For this request to be accepted, the server activity must not be `starting` or `error`.

If the request is accepted, the server activity changes to `stopping` and then, once it has stopped, to `started` (if the server has not been initialized) or to the activity after the previous completed request.

- `request enclosure reset`

  Reset an error in the enclosure.

- `request enclosure status`

  Show the status of the server.

  Obtain the values of the status data from the server and print them to stdout.

11.5 Bibliography

- "Technical Specifications: ASTELCO Remote Telescope Station (ARTS)", ASTELCO, Version V-1304-21.
- "Foldable Enclosure ENCL-ALTS-01 Technical Reference Manual", ASTELCO, Revision V-1.4.
  - The statement that the enclosure used 230 V 50 Hz is not applicable. The COATLI and DDOTI/OAN enclosures use 220 V 60 Hz phase-phase.
  - The description of the ADAM input and output channels on page 19 is not applicable. The correct description is given in §11.3.2.
  - The COATLI enclosure has hardware to support opening to 60, 120, and 180 degrees; it does not have hardware to support opening to 90 degrees.
- Electronic Schematics, ASTELCO, Revision A (in German).
- Drawing 0500 – Enclosure Platform, ASTELCO.
- Drawing 5772 – Enclosure Tower Base Plates, ASTELCO.
- Drawing 5798 – Enclosure Tower, ASTELCO.
- Drawing 6610 – Enclosure Tower on Columns, ASTELCO.
- Drawing 6658 – Enclosure Tower on Columns, ASTELCO.
- Drawing 6662 – Interface with Columns, ASTELCO.
- "Lantronix EDS Device Servers/Terminal Servers User Guide", Lantronix, Revision 1 April 2011.
- "ADAM-4000 Data Adquisition Modules User's Guide]", Advantech, Edition 10.5, 2007.

Part III

Telescope and Instrument

Chapter 12

Mount

12.1 Description

The mount is an ASTELCO NTM-500 German equatorial mount. For details, see the ASTELCO manual.

12.1.1 Mount

The mount itself is obviously located at the top of the telescope pier. Figure 12.1 shows the mount panel.

At COATLI we not not pass any electrical connections through the mount. All electrical connections to the instrument and telescope pass through the flexible cable chain.

12.1.2 Mount Controller

The mount controller is a cream 4U box located in the rack in the shed. Figure 12.2 shows the controller front panel, with the connectors and the power, fan alarm reset, and factory reset buttons.

The mount controller is connected to the mount by two cables (one for the motors and another for the encoders) and a compressed air hose (for the brakes). It is also connected to a GPS receiver which is located on the south-west side of the shed.

The mount controller is connected to circuit B, through the 127 V UPS and iBootBar. (The mount controller should not be connected to 220 VAC.)

Figure 12.1: The mount panel showing the break release button.

Figure 12.2: The mount controller front panel showing the connectors and the power, fan alarm reset, and factory reset buttons.

12.2 Maintenance Procedures

12.2.1 Manually Moving the Mount

Press the BRAKE button on the panel on the south side of the mount. While this button is pressed, the brakes on both axes will be released and you can move the telescope by hand.

Sometimes, especially after an error, the mount takes a while to recover and you need to press and hold the button for up to a minute before the brakes are released.

12.2.2 Manually Switching Off

Press the power button on the front panel (shown in Figure 12.2). Do not confuse the power button with the factory reset button! The power button is in the lower right and the factory reset in the upper right.

12.2.3 Manually Switching On

Press the power button on the front panel (shown in Figure 12.2). Do not confuse the power button with the factory reset button! The power button is in the lower right and the factory reset in the upper right.

12.3 Bibliography

- “NTM Technical Reference Manual”, ASTELCO, Version 3.7.
- “NTM Technical Description”, ASTELCO, Version 3.7.
- “OpenTCI”, ASTELCO, Version 2.5.
- “TPL2”, ASTELCO, Version 2.0.
- “Drawing 5824 – Mount column interface”, ASTELCO.
- “Drawing – NTM Base Plate”, ASTELCO.
- “Drawing – NTM Dimensions”, ASTELCO.
- “TCLM/TPL2 ASCOM Driver User Manual”, Tau-tec, 2010

Chapter 13

Telescope

13.1 Optics

The COATLI telescope is a 50-cm $f/8$ Ritchey-Crétien supplied by ASTELCO.

The optics originally supplied in 2016 performed poorly and never gave images better than about 1.4 arcsec FWHM. We received new optics in 2020, tested them extensively in CU, and installed them in November 2021. The adopted parameters of the 2020 optics are given in Table 13.1.

The mirrors are fabricated in an unspecified low-expansion glass and coated with aluminium protected with a layer of MgF_2.

13.2 Mechanics

The primary mirror cell is mainly carbon fiber, with an aluminum dovetail and instrument flange. The telescope nominal focal plane is 136 mm below the instrument flange.

Carbon fiber Serrutier struts support the aluminum secondary ring. The structs have ball-and-socket joints at both ends, which help maintain collimation at different pointings.

The telescope is equipped with a motorized focuser for the secondary.

The primary mirror can be adjusted in tilt, the secondary mirror in center and tilt, and the primary baffle in tilt with respect to the primary.

Figures 13.1 to 13.4 show plans of the telescope.

13.3 Resumen

Se presentan los métodos a seguir para retirar o instalar los espejos del telescopio COATLI para su aluninización o servicio de sus componentes.

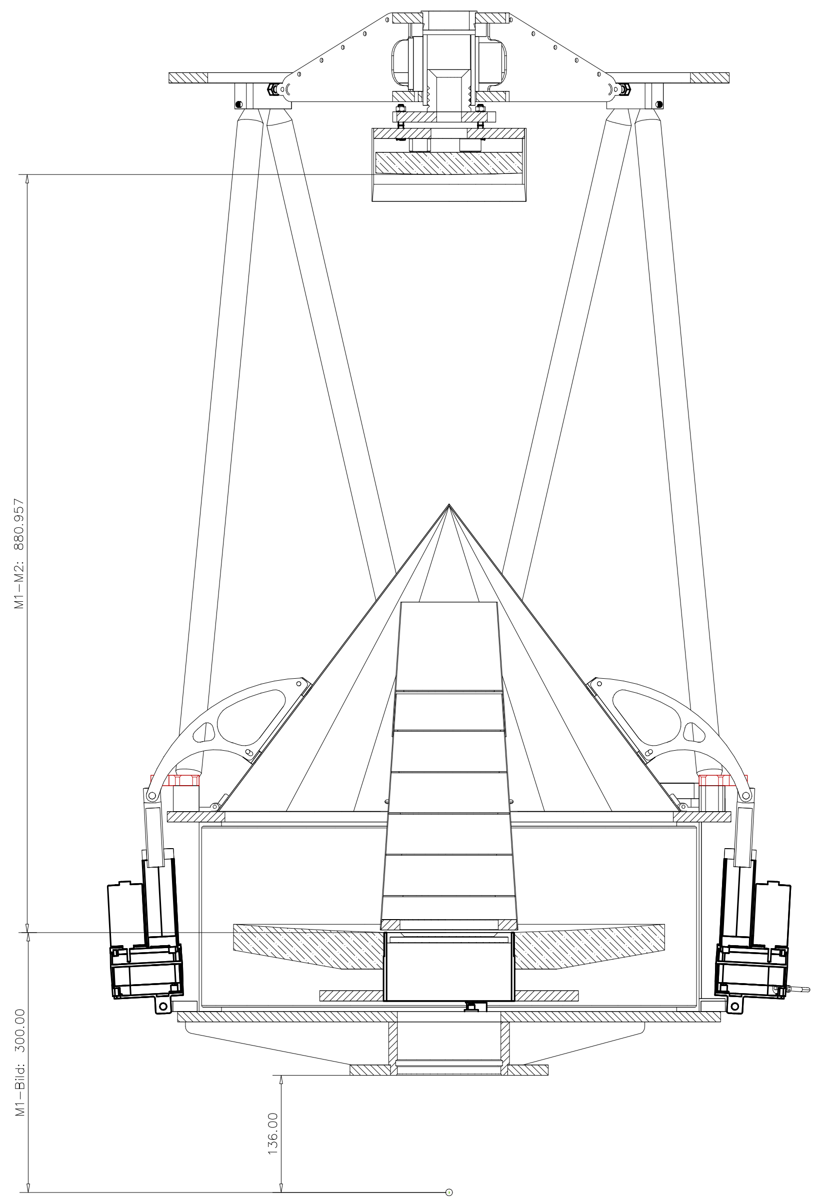

Figure 13.1: Lateral section of the telescope. Note that our telescope has a focuser with a different design and that the covers have been removed. The M1 to M2 distance is also different with the 2020 optics.

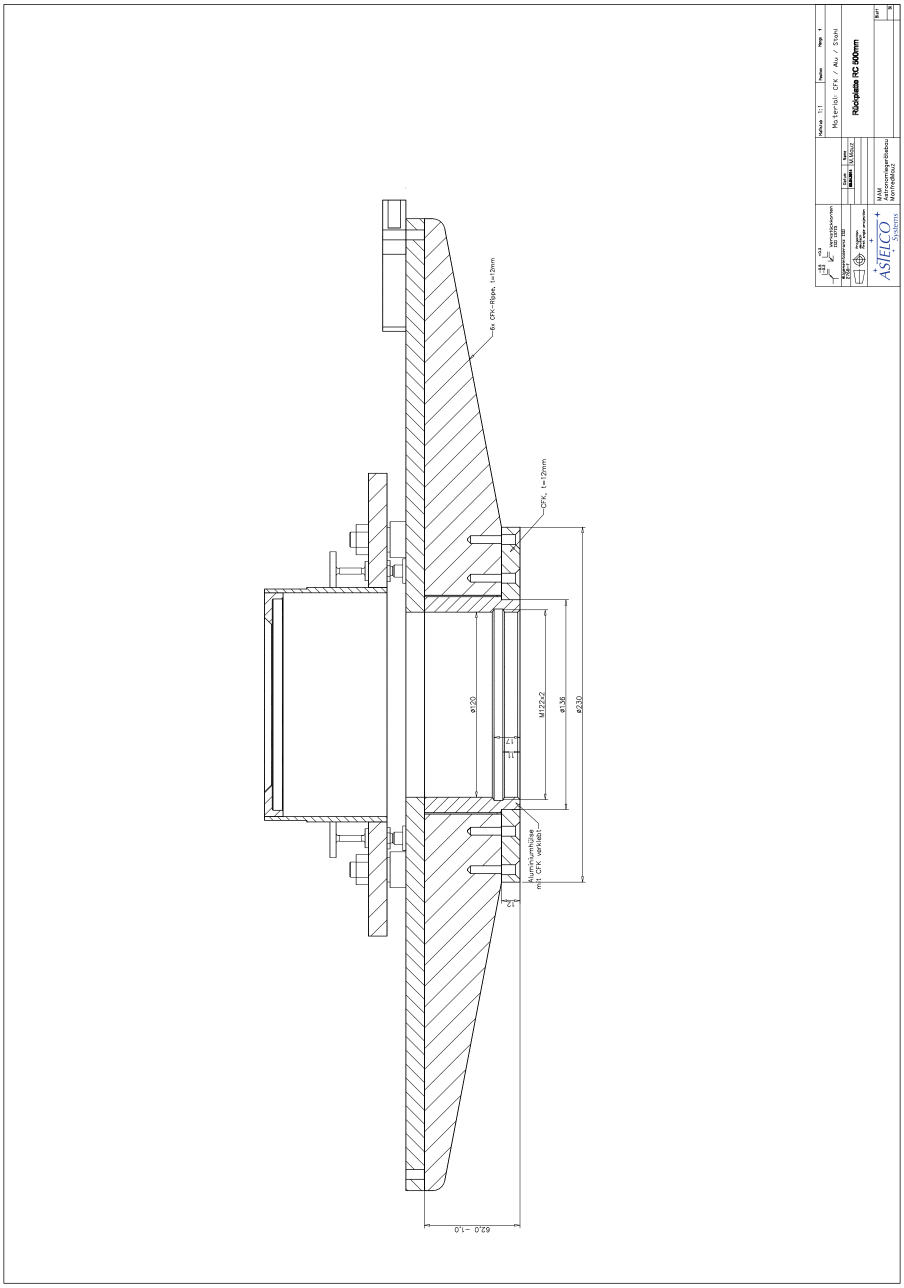

Figure 13.2: Lateral section of the backplane of the primary mirror cell.

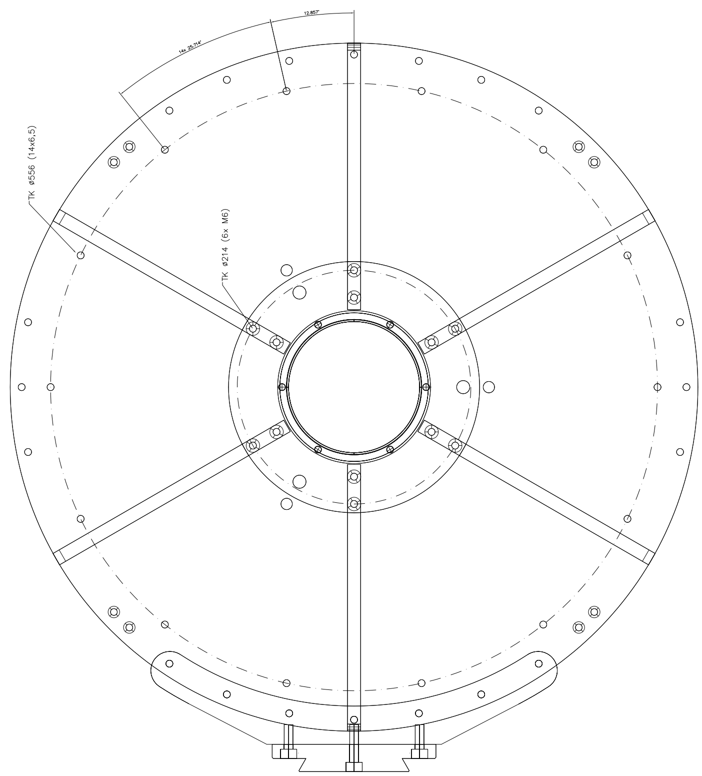

Figure 13.3: Lateral section of the telescope.

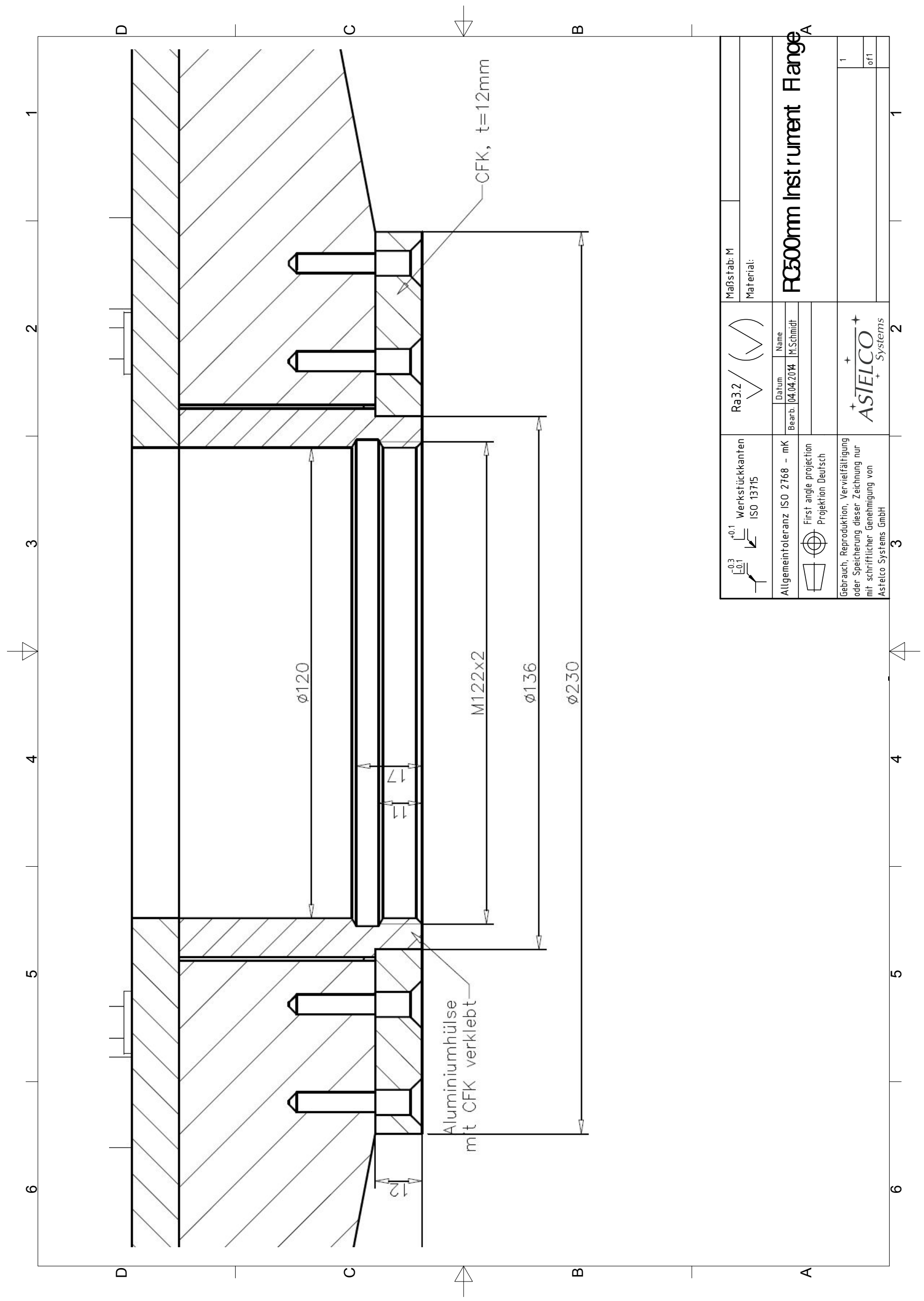

Figure 13.4: Lateral section of the instrument flange.

Table 13.1: Telescope Optical Parameters

Component	Parameter	Value
M1	Clear Aperture Diameter (mm)	500
	Radius of Curvature (mm)	-2554.7
	Focal Length (mm)	-1277
	Focal Ratio	$f/2.555$
	Conic Constant	-1.05
	Central Hole Diameter (mm)	120
M2	Clear Aperture Diameter (mm)	160
	Radius of Curvature (mm)	-1137.2
	Focal length (mm)	-569
	Focal Ratio	$f/3.554$
	Conic Constant	-4.346
	Baffle Diameter (mm)	180
M1+M2	Focal Length (mm)	-3967
	Focal Ratio	$f/7.933$
	Vertex of M1 to Vertex of M2 (mm)	-891.85
	Vertex of M1 to Focal Plane (mm)	300
	Flange to Focal Plane (mm)	136

13.4 Descripción general

COATLI es un telescopio de tipo Ritchey-Chretien de 500 mm de diámetro trabajando en F/8 en una montura ecuatorial de tipo alemán.

El tubo del telescopio, mayormente construido de fibras de carbono tejidas y prensadas, tiene una estructura básica montada sobre el eje de declinación, a la que en adelante se llamará cubo del telescopio o simplemente cubo. En su parte inferior presenta la platina de montaje de instrumentos, en el interior contiene a la celda del primario, que consiste de una placa de soporte y Tip-Tilt.

En la parte superior del cubo se encuentran las bases de los tubos que forman la estructura Serrurier. Dicha estructura, se completa con el anillo superior, que porta la araña, la araña al sistema de enfoque y éste a la celda del secundario.

En la base del cubo se encuentran tres tornillos de alineación con tuercas M17 provenientes de la placa de soporte del primario. Entre la placa de soporte y el cubo llevan estos tornillos cada uno un muelle formado por rondanas con forma de menisco. Al lado de éstos tornillos se encuentran tres prisioneros Allen M4 que una vez conseguida la alineación, fijan la placa de soporte del primario.

El bafle del primario pasa a través del boquete central del espejo y se fija en el cubo con tres pares de tornillos similares a los anteriores, tuercas MXX y prisioneros MXX, de manera que su inclinación es independiente de la del espejo primario. Estos tornillos se acceden desde el exterior del cubo, por su agujero central.

La araña se fija en su posición por medio de cuatro tornillos insertados en sendos cilindros, cada uno con una tuerca exterior y otra interior con lo que se puede obtener un descentrado de hasta Nmm del secundario.

La celda del secundario, consiste de una placa sobre la que el espejo va pegado y a la que se fija el bafle mediante tres tornillos radiales. En el bafle, además van montadas tres pestañas de seguridad para el caso de que el secundario se despegase. La alineación se obtiene en forma idéntica a las anteriores, En este caso las tuercas son M10 y los prisioneros MXX

Finalmente, nótese que en la cara sur del estator del eje de AR se encuentra un botón metálico que, al mantenerse presionado, libera los frenos de ambos ejes y es entonces posible mover manualmente el telescopio a las posiciones adecuadas para las operaciones que a continuación se detallarán.

13.5 Consideraciones y precauciones generales

- Los siguientes procedimientos causarán o bien se iniciarán con un desbalanceo del telescopio en ambos ejes.
- Recuerde siempre que la única posición relativamente segura en caso de desbalanceo del telescopio, es la de reposo, en la que el eje de AR se encuentra en equilibrio estable y en el eje de Dec. la torca residual es en todo caso muy pequeña.
- No confie nunca en que los frenos serán capaces de contrarrestar la torca de una posición desbalanceada, se recomienda contar en estos casos , con una tercera persona cuya única función sea la de prevenir una falla de los frenos.

13.6 Desensamble de la celda del secundario

13.6.1 Requerimientos

- Dos personas
- Llave española M10

13.6.2 Procedimiento

- Presione el botón de liberación de los frenos ubicada en la parte posterior de la montura del telescopio, oriente horizontalmente el tubo del telescopio y libere el botón.
- La persona 2 colocará la funda de protección del secundario.
- La persona 1 extraerá las tuercas M10 y sus rondanas del soporte de la celda, mientras la persona 2 sostiene la celda.
- La persona 2 extraerá la celda mientras la persona 1 toma las rondanas que forman el muelle.

- La persona 2 pondrá la celda con el secundario en lugar seguro.
- Sujetando el tubo y las pesas, presione el botón de liberación de los frenos y regrese el telescopio a la posición de descanso.

13.7 Ensamble de la celda del secundario

13.7.1 Requerimientos

- Dos personas
- Llave Allen M5

13.7.2 Procedimiento

- Presione el botón de liberación de los frenos, oriente horizontalmente el tubo del telescopio y libere el botón.
- La persona 2 presentará los tornillos de la celda en las cercanías de sus correspondientes boquetes de la placa de montaje.
- La persona 1 instalará en los tres tornillos, las rondanas que forman los muelles.
- La persona 1 elegirá la rotación correcta de los tornillos, ya que los prisioneros Allen se accionarán a través de los boquetes que al efecto existen en la placa de montaje.
- Introdúzcanse los tornillos M10 en sus correspondientes boquetes
- La persona 1 se asegurará de que los prisioneros han quedado accesibles y los desenroscará de manera que no entorpezcan el ajuste siguiente.
- La persona 2 empujará la celda suavemente, hasta que las rondanas de los muelles entren en contacto con la celda y la placa.
- La persona 1 instalará las tuercas M10 y sus rondanas de soporte de la celda, apretándolas a mano.
- La persona 1 aplicará una precarga mediante dos vueltas de las tuercas usando la llave española M10
- La persona 1 ajustará los prisioneros Allen para fijar la celda en esa posición.
- Presione el botón de liberación de los frenos y lleve el telescopio a la posición de reposo.

13.8 Desensamble del Bafle del primario

13.8.1 Requerimientos

- Dos personas
- Llave española Mxx
- Llave Allen MXX

13.8.2 Procedimiento

- Abra las tapas de protección del primario.
- Presione el botón de liberación de los frenos, oriente horizontalmente el tubo del telescopio y libere el botón.
- La persona 2 sujetará el bafle usando guantes de látex, permitiendo las oscilaciones que se producirán, pero manteniendo una ligera presión hacia la celda
- La persona 1 localizará las tuercas MXX de soporte y alineación del bafle dentro del boquete del Cubo y procederá a extraerlas con sus rondanas de forma pareja, para limitar las oscilaciones del bafle.
- La persona 2 extraerá el bafle mientras la persona 1 vigila las rondanas que forman el muelle, mismas que no deberían salirse de los tornillos gracias a un arosello que debe impedirlo.
- La persona 2 colocará el bafle en lugar seguro y protegido.
- Cierre las tapas de protección del primario.
- Presione el botón de liberación de los frenos y regrese a la posición de reposo.

13.9 Ensamble del Bafle del primario

13.9.1 Requerimientos

- Dos personas
- Llave española Mxx
- Llave Allen MXX

13.9.2 Procedimiento

- Abra las tapas de protección del primario.
- Presione el botón de liberación de los frenos, oriente horizontalmente el tubo del telescopio y libere el botón.
- La persona 2 usando guantes de látex, introducirá el bafle por el boquete del primario, girándolo según las instrucciones que le dará la persona 1 para hacer coincidir los tornillos con las perforaciones correspondientes.
- La persona 1 insertará las tuercas MXX de soporte y alineación del bafle dentro del boquete del Cubo y procederá a atornillarlas a mano.
- La persona 1 aplicará una precarga a las tuercas girándolas dos vueltas
- Cierre las tapas de protección del primario.

13.10 Desensamble de la celda del primario

Si se encuentra instalado algún instrumento en la celda del primario, desinstálelo siguiendo el procedimiento recomendado para dicho instrumento. Si el Bafle del primario está instalado, siga el correspondiente procedimiento de desinstalación.

13.10.1 Requerimientos

- Dos personas
- Llave española M17
- Llave Allen MXX
- Guantes de látex

13.10.2 Procedimiento

- Abra las tapas de protección del primario. Puede ser necesario retirar alguno?
- Presione el botón de liberación de los frenos, oriente el tubo del telescopio hacia el cenit y libere el botón.
- La persona 1 localizará las tuercas M17 de soporte y alineación del primario en la parte inferior del Cubo y procederá a extraerlas con sus rondanas de forma pareja, para limitar las oscilaciones del primario.
- La persona 2, con guantes de látex extraerá el primario con su celda sujetándolo a través del boquete del primario.

- Mientras tanto, la persona 1 vigilará las rondanas que forman el muelle, mismas que no deberían salirse de los tornillos gracias a un arosello que debe impedirlo.
- La persona 2 colocará el primario con su celda en lugar seguro y protegido. Esto puede requerir mas aclaraciones
- Presione el botón de liberación de los frenos y regrese a la posición de reposo.

13.11 Ensamble de la celda del primario

13.11.1 Requerimientos

- Dos personas
- Llave española M17
- Llave Allen MXX
- Guantes de látex

13.11.2 Procedimiento

- Abra las tapas de protección del primario. Puede ser necesario retirar alguno?
- Presione el botón de liberación de los frenos, oriente el tubo del telescopio hacia el cenit y libere el botón.
- La persona 2, con guantes de látex sujetando la celda a través del boquete del primario presentará, los tornillos de la celda en las cercanías de sus correspondientes boquetes en el Cubo.
- La persona 1 indicará a la 2 la rotación correcta de la celda para los siguientes pasos
- La persona 1 vigilará las rondanas que forman el muelle, mismas que no deberían salirse de los tornillos gracias a un arosello que debe impedirlo.
- Introdúzcanse los tornillos Mxx en sus correspondientes boquetes
- La persona 1 desatornillará los prisioneros de fijación de la celda, de manera que no entorpezcan el ajuste siguiente.
- La persona 1 atornillará las tuercas M17 de soporte y alineación del primario en la parte inferior del Cubo apretándolas a mano.
- La persona 1 aplicara una precarga a las tuercas usando la llave española M17, dándole dos vueltas a cada una.
- La persona 1 ajustará los prisioneros Mxx
- Presione el botón de liberación de los frenos y regrese a la posición de reposo.

13.12 Notas

- Ya que la inclinación del bafle del primario es independiente de la alineación del espejo, es necesario contar con un método para alinearlo. Se sugiere usar hilos cruzados desde los tubos Serrurier, formando una cruz a la altura de la entrada del bafle y ya que la exactitud de la posición de dicha retícula puede ser engañosa por causa de la inclinación de los tubos, incertidumbres en la alineación del láser y posibles asimetrías, se puede verificar su centrado observando el paso del láser, una vez alineado con el secundario, usando un papel sobre la misma retícula. Si fuese necesario, se pueden modificar los hilos para señalar el nuevo punto de referencia para realinear el bafle con ese punto, para lo que sería necesario abrir el acceso a los tornillos en la base del bafle.
- Es conveniente fabricar una cubierta para el primario para protegerlo durante las manipulaciones.
- La funda del bafle del secundario ajusta demasiado, se recomienda aumentar su diámetro y añadirle un resorte para facilitar su instalación.

13.13 Recoating

ASTELCO recommend removing the aluminum and MgF_2 coatings by soaking in a 10% solution of NaOH for several hours.

13.14 Preguntas

¿Cuáles son las constantes cónicas medidas de los espejos?

¿En qué material están construidos?

¿Las películas de Al tienen capas protectoras? Y de ser así, ¿Qué procedimiento debe seguirse para retirarlas?

Una vez retirado el bafle y las tuercas de los tornillos de jalar del primario, para retirarlo del telescopio:

¿El espejo y su base caben entre las barras del serrurier o es necesario desmontar antes algo más?

¿Es necesario para aluminizar, despegar el primario y/o el secundario de las placas de carbón que los portan?, de ser así, ¿Cuáles son los procedimientos necesarios para hacerlo y posteriormente para pegarlo?

¿Cuál es el cemento con el que está pegado? ¿Cuál es su expectativa de vida?

En ambas celdas, ¿Qué es lo que evita que los tornillos de jalar giren? Y ¿Sobre qué apoyan los tornillos de empujar?

Figure 13.5: The Hartmann mask mounted on the telescope..

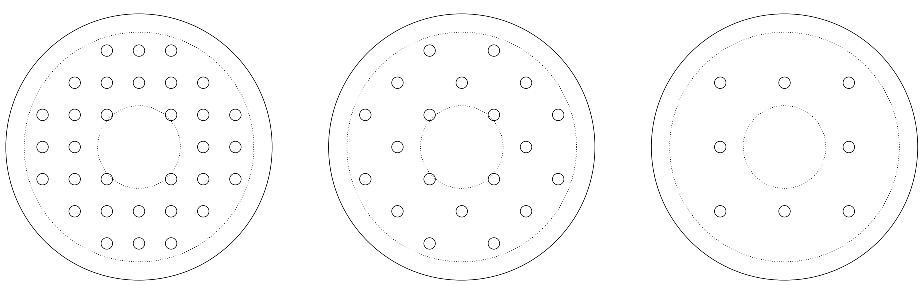

Figure 13.6: The geometry of the Hartmann mask. The raw grid spacing is 70 mm (left). By covering holds with tape, this can be used to create less dense grids with spacings of 100 mm (center) and 140 mm (right).

13.15 Hartmann Test

We have constructed a Hartmann mask for the telescope. The mask has an array of 25 mm diameter holes on a Cartesian grid with a spacing of 70 mm between hole centers. By blocking holes with tape, one can create grids with spacings of 70, 100, and 140 mm (see Figure 13.6).

The mask is split into two to facilitate mounting. It should be secured to the secondary ring with cable ties and the joints between the two sections should be covered with tape. The telescope needs rebalancing in both axes after mounting the mask.

13.15.1 Spherical Aberration

In a conventional Hartmann test, one moves the detector and leaves the optical system fixed. However, this is not convenient here and we instead will move the secondary and leave the detector fixed. This will introduce spherical aberration. We have quantified this in ZEMAX using the nominal telescope design.

We placed a grid of rays on the pupil and then measured the radii R_{outer} and R_{inner} of the innermost and outermost points in the intrafocal and extrafocal images as function of the distance between M1 and M2. We interpolate the outer radii to zero to define the position of best focus. We then interpolate the inner radii to the same position determine the radius $R_{\text{inner}}^{\text{best}}$ of the image formed by the inner part of the pupil. We see that for images taken with the secondary moved ± 1.0, the spherical aberration amounts to 0.4 μm or 0.02 arcsec radius in the interpolated best image plane. For images taken with the secondary moved ± 1.5, this rises to 2.0 μm or 0.10 arcsec radius.

The diffraction-limited image radius for the telescope in B is $\lambda f/2D$ or about 1.8 μm or 0.09 arcsec. Thus, for ± 1.5 mm displacement of the secondary, the spurious spherical aberration is small compared to the seeing but comparable to the diffraction limit and for ± 1.0 mm displacement of the secondary, the spurious spherical aberration is small even compared to the diffraction limit. These should be borne in mind when determining the appropriate secondary displacement to use for a given application of the Hartmann test.

13.16 Bibliography

- "Telescope Technical Description", ASTELCO.
- "Drawing – Optics Section", ASTELCO.
- "Drawing – Instrument Flange Section", ASTELCO.
- "Drawing – Instrument Flange Plan", ASTELCO.

Table 13.2: Spherical Aberration in the Hartmann Test

$M1 - M2$ (mm)	$\Delta(M1 - M2)$ (mm)	R_{outer} (μm)	R_{inner} (μm)	$R_{\text{inner}}^{\text{best}}$ (μm)
880.457	−0.5	343.3720	116.5	
881.457	+0.5	343.372	117.2	
				0.7
879.957	−1.0	689.912	233.2	
881.957	+1.0	688.212	234.1	
				0.7
882.457	+1.5	1033.26	351.9	
879.457	−1.5	1033.93	350.1	
				2.0

Chapter 14

Secondary Focus Mechanism

14.1 Description

The secondary mirror cell is mounted on a mechanism that allows it to move axially to focus the telescope.

The mechanism, shown in Figure 14.1, appears to be an adaptation of an Optec TCF-S focuser.

The controller for the secondary focus mechanism is located in the cabinet of the covers controller in the shed, and is shown in Figure 14.2. Communication is via the Lantronix ethernet-to-serial server.

The mechanism does not appear to have an encoder, but rather appears to use a stepper motor and then count steps. The range of 0 to 7000 steps corresponds to 5.6 mm of motion (0.8 μm per step), with 0 corresponding to the secondary at its lowest position (closest to the primary). The absolute calibration appears to be achieved by a combination of moving the secondary down towards the primary when it is powered on until it the movement is stopped by a hard stop. This defines the 0 position. The motor then moves to 3400 steps. Adjusting the position of the hard stop allows the range of physical motion of the secondary to be changed.

The secondary moves at about 30 steps per second. To compensate for backlash, when moving to lower step numbers the control system initially overshoots by 25 steps then approaches the final position from below. This adds about 3.5 seconds to the process.

TODO: Block diagram of hardware.

TODO: Control protocol.

Figure 14.1: The secondary focus mechanism with its cover removed.

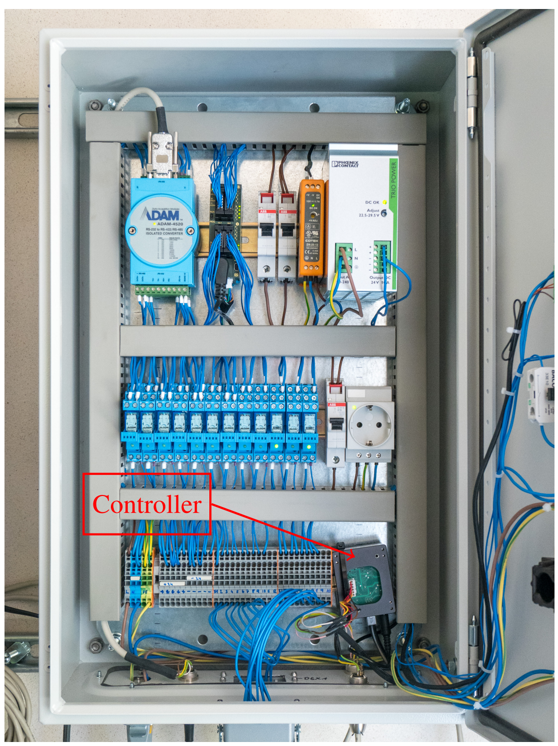

Figure 14.2: The secondary focus mechanism controller in the covers cabinet.

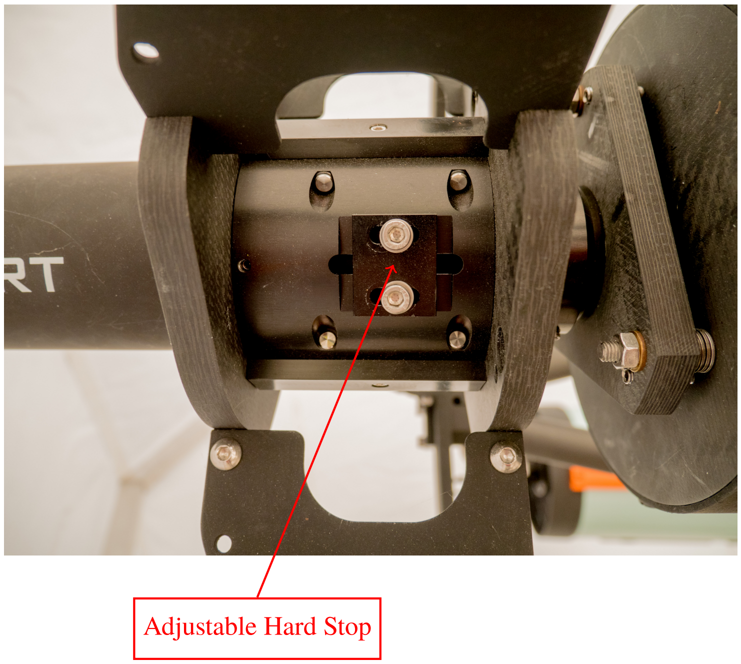

Figure 14.3: The secondary focus mechanism adjustment. When the secondary focus mechanism is switched on, the mechanism moves down until the mechanism comes into contact with the hard stop. This defines position 0. The mechanism then moves back to 3400.

14.2 Maintenance Procedures

14.2.1 Static Adjustment of the Focus Range

This procedure describes how to statically adjust the range over which the secondary can be moved.

Safety Considerations

Use a harness, line, and helmet when you work on the platform or balconies.

Requirements

You will need:

- At least two persons.

- The key to the shed (see §5.3).
- Metric hex keys. TODO: Size

Procedure

TODO: Photo.

1. Turn off power to the secondary controller, either by switching off power to the covers cabinet manually or by running

   ```
   tcs request power switchoff secondary
   ```

2. Adjust the position of the block. When the secondary focus mechanism is switched on, the mechanism moves downwards until the block comes into contact with the hard stop. This defines position 0. The mechanism then moves back to 3400. See Figure 14.3.

3. Turn on the power to the secondary controller, either by switching on the covers cabinet manually or by running

   ```
   tcs request power switchon secondary
   ```

14.3 Remote Interface

14.3.1 Lantronix EDS

The RS-232 interface to the secondary controller is made available via the Lantronix EDS 4100 ethernet-to-serial converter. Specifically, it is connected to line 2 and configured as 19200/8-N-1 with a tunnel on TCP port 10002.

The Lantronix EDS is on the LAN at `serial`.

14.4 Control

The server for the secondary runs on `control`.

The server starts automatically after `control` is boots, but if necessary can be stopped, started, or restarted explicitly by issuing the following shell commands on `control`:

- `sudo stopserver secondary`
- `sudo startserver secondary`
- `sudo restartserver secondary`

Server requests can be issued from any of the Mac or Linux machines on the LAN. The following requests are supported:

- `request secondary initialize`

  Initialize the server and secondary hardware. As part of the process of initializing, the secondary will more to its initial position.

  For this request to be accepted, the server activity must not be `starting` or `error`.

  If the request is accepted, the server activity changes to `initializing` and then, once it has initialized, to `idle`.

- `request secondary move` ⟨z0⟩

  Move the secondary to position ⟨z0⟩.

  For this request to be accepted, the server activity must not be `starting`, `started`, `initializing`, or `error`.

  If the request is accepted, the server activity changes to `moving` and then, once it has opened to the specified angle, to `idle`.

  The nominal position ⟨z0⟩ is converted to a raw position by applying corrections for the filter, position, and temperature.

- `request secondary stop`

  Stop the secondary.

  For this request to be accepted, the server activity must not be `starting` or `error`.

  If the request is accepted, the server activity changes to `stopping` and then, once it has stopped, to `started` (if the server has not been initialized) or to the activity after the previous completed request.

- `request secondary reset`

  Reset an error in the secondary.

- `request secondary status`

  Show the status of the server.

  Obtain the values of the status data from the server and print them to stdout.

14.5 Bibliography

- "TCS-F Technical Manual", Optec Inc, Revision 11, August 2010.

Chapter 15

The Huitzi $f/20$ Imager

The Huitzi $f/20$ imager was installed on the COATLI telescope in December 2022. The imager is named for the mexica god Huītzilōpōchtli, the son of the goddess Coatlicue.

Earlier, the "Interim Imager" and "Huitzi $f/8$ Imager" were installed on the telescope. For historical reference, these are described in Appendices B and **??**.

15.1 Overview

Figure 15.1 shows the Huitzi $f/20$ imager on the telescope.

The imager uses a 150 mm diverging lens to convert the $f/8$ beam of the telescope into an $f/20$ beam. This beam is then imaged an Andor iXon electron-multiplying CCD detector with 1024×1024 pixels with a pixel scale of 0.27 arcsec and a field of 4.6 arcmin. The detector can be read through either a conventional amplifier or the electron-multiplying amplifier at a variety of speeds.

The imager has three Finger Lakes Instruments filter wheels. Currently, the following filters can be provided:

- open: Completely open.
- dark: Completely blocked.
- $grizy$: Filters similar to the Pan-STARRS equivalents. Note, however, that while the filters are similar, the CCD is not deep-depleted and so the bandpasses are somewhat different.
- w: A filter that combines the r and i bands. Note that this is different to Pan-STARRS w which includes the g band too. It is mainly intended for sensitive imaging of GRBs.
- $BVRI$: Johnson-Cousins filters according to the Bessell formulation.

Figure 15.1: The Huitzi $f/20$ imager on the COATLI telescope.

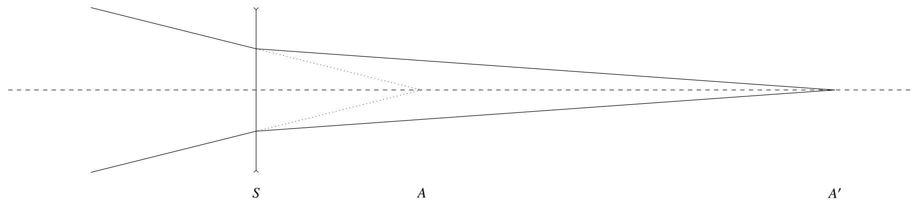

Figure 15.2: Schematic of the Optical Design

- I_s: The I filter with a sharp red cutoff at 900 nm. This is intended to better match the bandpass of the original Cousins (1978) I photomety. The blue edge is the same as the Bessell formulation, but the red edge is defined by a 900 nm short-pass filter to simulate the red edge of a GaAs tube. The Bessell (1990) and Bessell & Murphy (2012) bandpasses fall at about 900 nm.
- 470/10, 515/10, and 640/10: Nebular continuum filters.
- 501/8, 656/3, 656/8: Nebular line filters.

Some of these filters are constructed from combinations of filters in different wheels, as described in more detail below.

The detector is mounted on Optec Gemini focuser and rotator, which allows up to 12.7 mm of motion of the detector with respect to the lens.

15.2 Optics

The effect of the negative lens is shown schematically in Figure 15.2. A is the position of the telescope focus without the lens. S is the position of the lens. A' is the position of the telescope focus with the lens. The magnification m is given by

$$m = SA'/SA,$$

in which SA' and SA are optical distances. If the focal length of the lens is F, then Gauss' equation gives the relation between SA and SA' as:

$$1/F = 1/SA' - 1/SA.$$

We then solve to find:

$$m = 1 - SA'/F$$

and

$$SA' = -(m - 1)F.$$

We can see the approximate dimensions of the system by ignoring chromatic aberration and taking $F = -150$ mm. Then, if we choose $SA = 90$ mm we have $SA' = 225$ mm

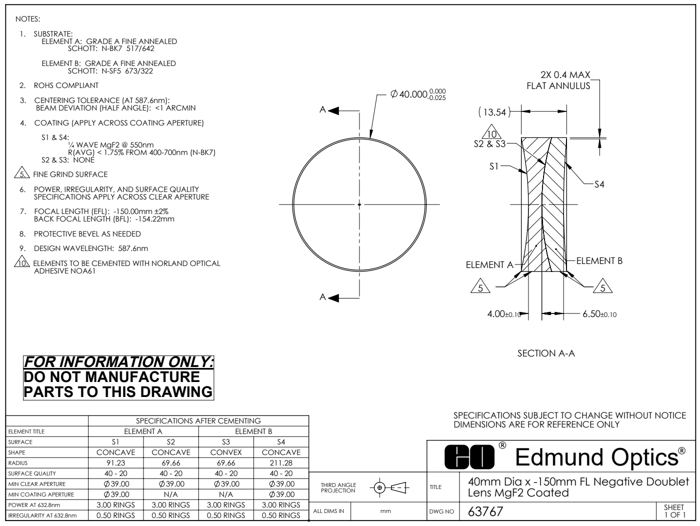

Figure 15.3: The lens design.

and $m = 2.5$. Since the focal ratio of the telescope is $f/8$, this magnification gives a focal ratio of $f/20$.

The actual lens is Edmund Optics part #63-767, whose design is shown in Figure 15.3. It has a design effective focal length of -150 mm at 587.6 nm. It is nominally 40 mm in diameter and 13.54 mm thick at the edge. The precise optical and mechanical prescriptions of are given in the files "`zmax_63767.ZMX`"and "`step_63767.STP`" supplied by Edmund Optics. The lens is used with the convergent element B uppermost (towards the secondary) and the divergent element A lowermost (towards the detector). That is, surface S4 is uppermost (towards the secondary) and surface S1 is lowermost (towards the detector). If the lens is inverted, the system will suffer significant spherical aberration.

The lens is an achromatic doublet, so its focal length varies with wavelength. This has two effects. First, the different focal length between bands requires us to refocus for each filter. In theory, we could adjust both the secondary and the focuser to achieve focus while holding the magnification constant. In practice, we simply adjust the focuser to maintain focus and let the magnification vary slightly. (The focuser is also used to compensate for the different optical thicknesses of the filters.) Second, chromatic aberration within the g and B bands limits their image quality.

The lens has a $\lambda/4$ MgF_2 coating on both surfaces.

The lens also serves as a window to prevent ingress of dust and insects.

Table 15.1: Filter Wheel Loading

Slot	A	B	C
0	open	P0	open
1	B	656/3	g
2	V	470/10	r
3	R	z	i
4	825SP	I	550LP
5		925LP	900SP
6		515/10	656/8
7		640/10	501/8

15.3 Filters

The upper filter wheel ("A") is an FLI CFW-1-5 wheel for five 50 mm diameter filters. The two lower filter wheels ("B" and "C") are FLI CFW-1-8 wheels for eight 25 mm diameter filters. The elements installed in each wheel are shown in Table 15.1.

The filter elements are:

- $griz$: These are similar to the Pan STARRS filters. They were acquired from Custom Scientific and fabricated to our specifications. They are 25 mm in diameter and 5 mm thick. They have dielectric coatings on fuzed silica substrates.
- $BVRI$: These are Johnson-Cousins filters adapted from the Bessell (1990) recipe. They are off-the-shelf filters acquired from Custom Scientific. They are 50 mm (BVR) or 25 mm (I) diameter and 5 mm thick. From modeling the transmission curves, we believe the recipes are:
  - B: 2 mm Hoya L38 + 1 mm Schott BG25 + 2 mm Schott BG39
  - V: 1 mm Schott GG495 + 3 mm Schott BG39 + 1 mm filler
  - R: 2 mm Schott OG570 + 3 mm Schott KG3
  - I: 3 mm Schott RG9 + 2 mm filler
- 825SP: This is an 825 nm OD4 short-pass filter. It is Edmund Optics part #86-113. It is 50 mm in diameter and 5 mm thick. It has dielectric coatings on a fuzed silica substrate.
- 925LP: This is an 925 nm OD4 long-pass filter. It is Edmund Optics part #86-072. It is 25 mm in diameter and 3 mm thick. It has dielectric coatings on a fuzed silica substrate.
- 900SP: This is an 900 nm OD4 short-pass filter. It is Edmund Optics part #64-335. It is 25 mm in diameter and 3 mm thick. It has dielectric coatings on a fuzed silica substrate.

Table 15.2: Filter Combinations

Filter	A	B	C	Thickness (mm)
dark	B	z	656/8	13
open	open	P0	open	3
g	open	P0	g	8
r	open	P0	r	8
i	open	P0	i	8
z	open	z	open	5
y	open	925LP	550LP	6
w	825SP	P0	550LP	11
B	B	P0	open	8
V	V	P0	open	8
R	R	P0	open	8
I	open	I	open	5
I_s	open	I	900SP	8
470/10	open	470/10	open	3
501/8	open	P0	501/8	6
515/10	open	515/10	open	3
640/10	open	640/10	open	3
656/3	open	656/3	open	3
656/8	open	P0	656/8	6

- 550LP: This is an 550 nm OD4 long-pass filter. It is Edmund Optics part #62-984. It is 25 mm in diameter and 3 mm thick. It has dielectric coatings on a fuzed silica substrate.
- P0: This is a window. It is Edmund Optics part #48-066. It is 25 mm in diameter and 3 mm thick. It has Edmund UV-VIS coatings on a fused silica substrate.
- 470/10, 501/8, 515/10, 640/10, 656/3, and 656/8: These are narrow-band filters, named for their approximate central wavelength and width in nm. They are off-the-shelf filters acquired from Custom Scientific. They are 25 mm in diameter and 3 mm thick. They have dielectric coatings on a fuzed silica substrate.

  In addition to these, we have 486/8 and 501/3 filters that could be installed by special request. Furthermore, Custom Scientific have 672/3, 672/8, and 889/18 filters that could be purchased for about US$500 each.

The filter bandpasses are created by combinations of conventional bandpass filters, long-pass, and short-pass filters. The combinations used are given in Table 15.2. Most of the combinations are straightforward, but we comment on three aspects in particular:

- I_s: The system responses in both I and I_s have their blue edge defined by RG9 glass. However, in I the red edge is defined by the CCD but in I_s (“I short”) it is defined by the 900SP filter. This gives I_s a system response that is a better match that of Cousins (1978), whose I has its the red edge defined by the cutoff of a GaAs photocathode around 900 nm. Compare Figure 15.7 here with Figure 9 of Bessell & Murphy (2012).

- w: The w filter essentially encompasses the bandpasses of r and i (although the exact edges are slightly different). Note that this is different to Pan-STARRS w which includes the g band too. It is mainly intended for sensitive imaging of GRBs.

- P0: The role of the P0 ("prism 0") element might seem to be a puzzle. However, we are considering converting the telescope to an altitude-azimuth configuration at some point in the future and installing wedged windows P1 and P2, similar to P0, in wheel B in place of two of the narrow-band filters. This will allow us to implement an atmospheric dispersion corrector for the BVR and $griw$ filters using P0, P1, and P2. However, while the telescope is in an equatorial configuration, there is no point in installing P1 and P2. We could have left the position occupied by P0 as open, but we decided to install it to give consistent bandpasses in these filters in both the equatorial and altitude-azimuth configurations.

Model system efficiency curves at the zenith (including the atmosphere, telescope mirrors, lens, filters, detector window, and detector, but excluding the obscuration of the secondary) are shown in Figures 15.4 to 15.23.

Table 15.3 gives the model properties of the filter. The filter pivot wavelength λ_{pivot} is defined by

$$\lambda_{\text{pivot}} \equiv \sqrt{\frac{\int \lambda S \, d\lambda}{\int S/\lambda \, d\lambda}}.$$

For a discussion of the interpretation of the pivot wavelength, see §A2.1 of Bessell & Murphy (2012). The filter FWHM is defines as the width over which S is at least half its maximum. The filter ZP is the expected electron count rate for a star with AB = 0,

$$ZP \equiv A \int SF_\lambda/(hc/\lambda) \, d\lambda,$$

in which A is the geometric area of the telescope (the area of the primary mirror not occulted by the secondary obscuration) and F_λ is the flux density of a source with $F_\nu = 3631$ Jy.

We are monitoring photometric standards from Oke & Gunn (1983) to verify the theoretical zero-points and sensitivity curves presented above. Initial results suggest that the zero points in the blue are approximately correct, but beyond about 600 nm the observed sensitivity is only about 75% of the theoretical sensitivity.

15.4 Focuser and Rotator

The instrument incorporates an Optec Gemini focuser and rotator between the last filter wheel and the detector.

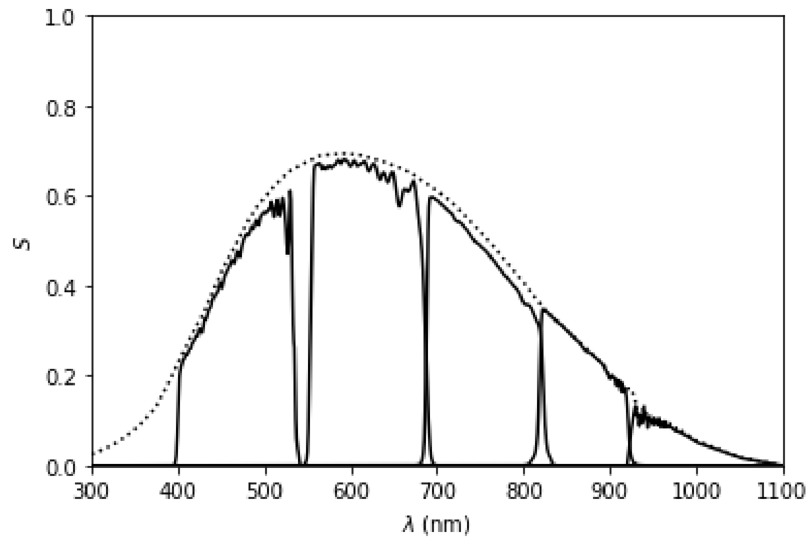

Figure 15.4: The model system efficiency S at the zenith in the $grizy$ filters. The dotted line is the model unfiltered efficiency.

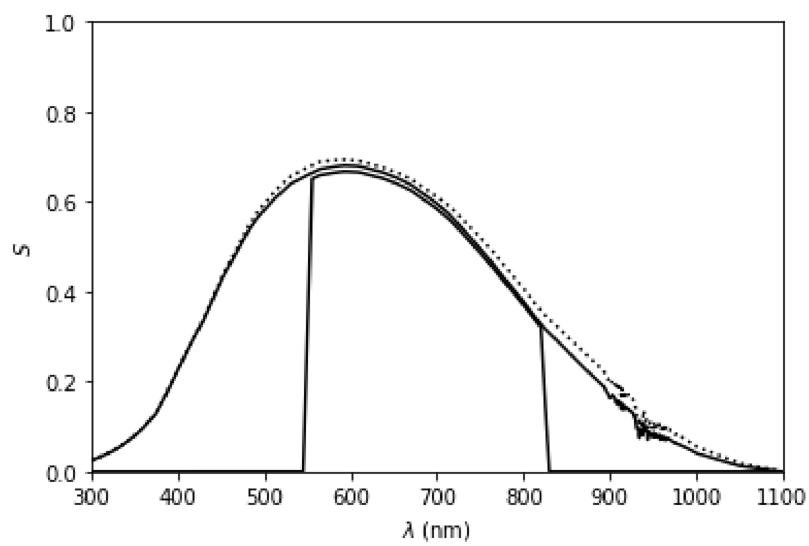

Figure 15.5: The model system efficiency S at the zenith in the w and open filters. The dotted line is the model unfiltered efficiency.

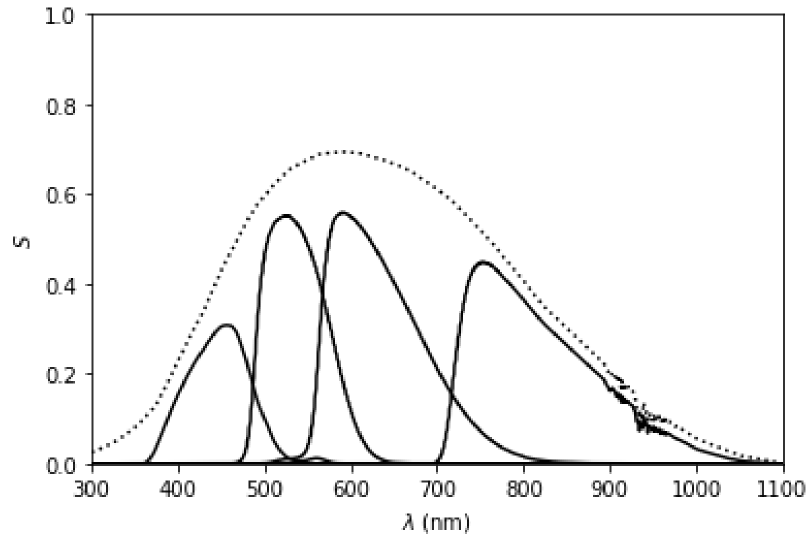

Figure 15.6: The model system efficiency S at the zenith in the $BVRI$ filters. The dotted line is the model unfiltered efficiency.

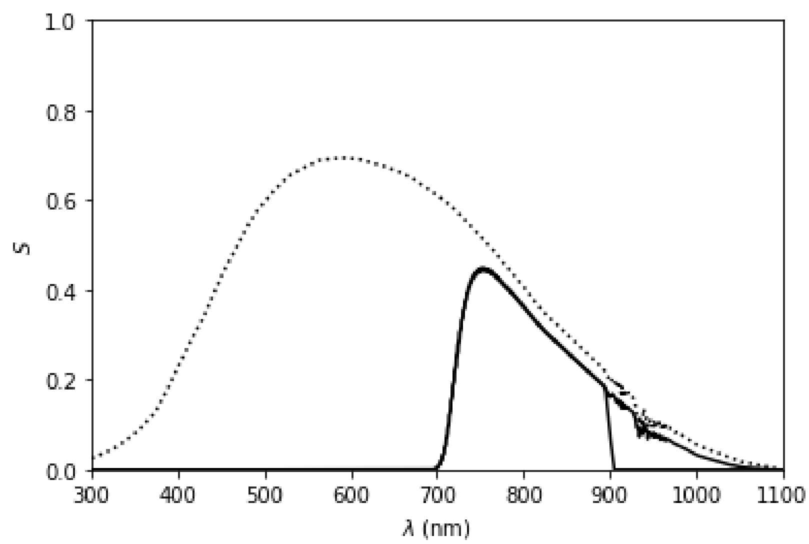

Figure 15.7: The model system efficiency S at the zenith in the I and I_s filters. The I_s filter has a red cutoff defined by the 900SP filter whereas the I filter has the red cutoff defined by the CCD. The dotted line is the model unfiltered efficiency.

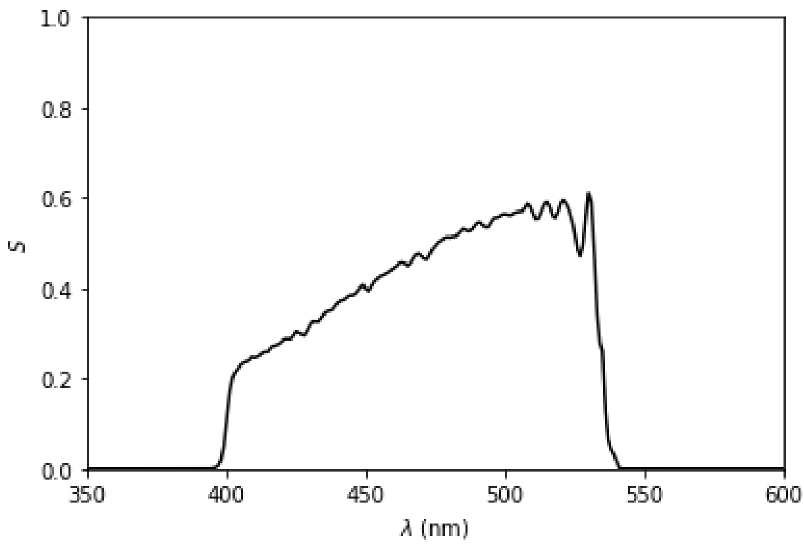

Figure 15.8: The model system efficiency S at the zenith in the g filter.

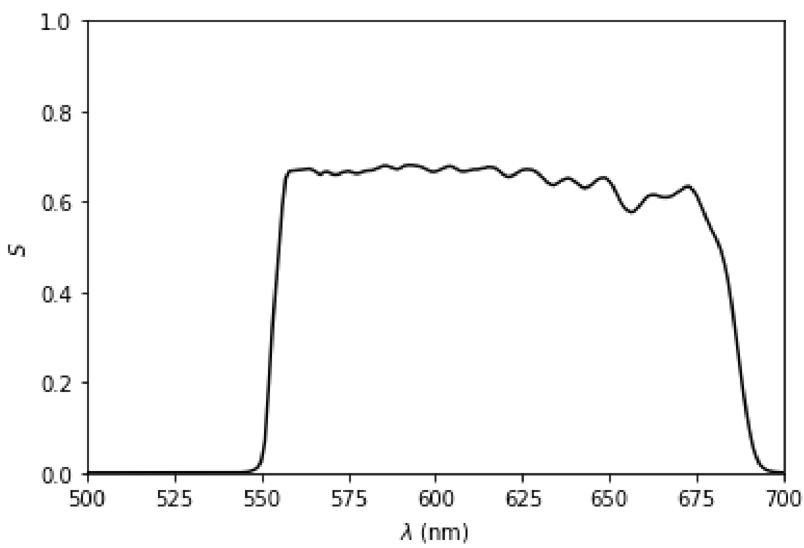

Figure 15.9: The model system efficiency S at the zenith in the r filter.

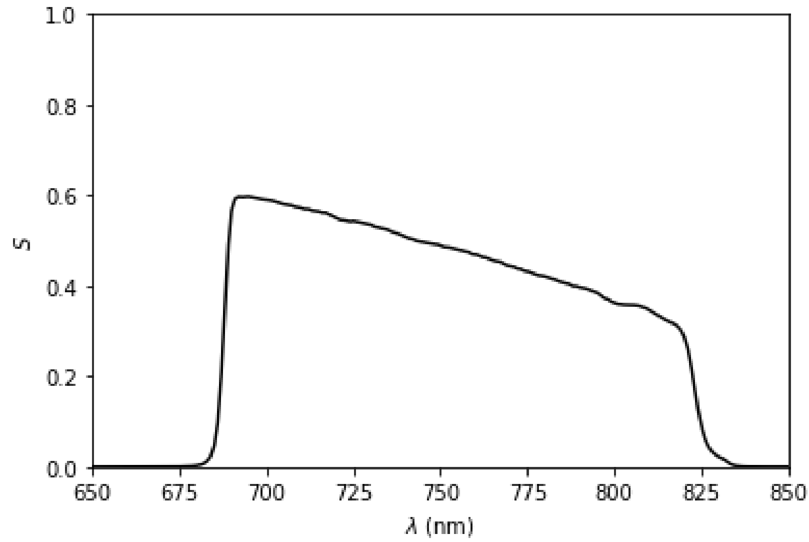

Figure 15.10: The model system efficiency S at the zenith in the i filter.

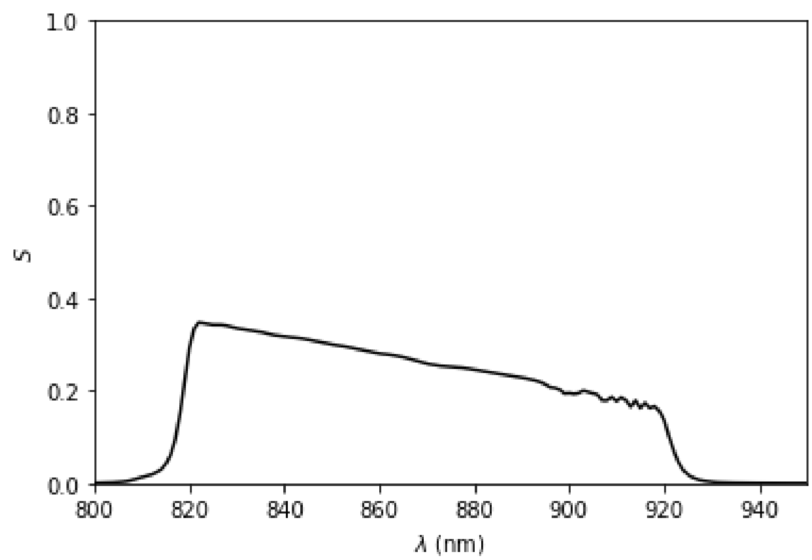

Figure 15.11: The model system efficiency S at the zenith in the z filter.

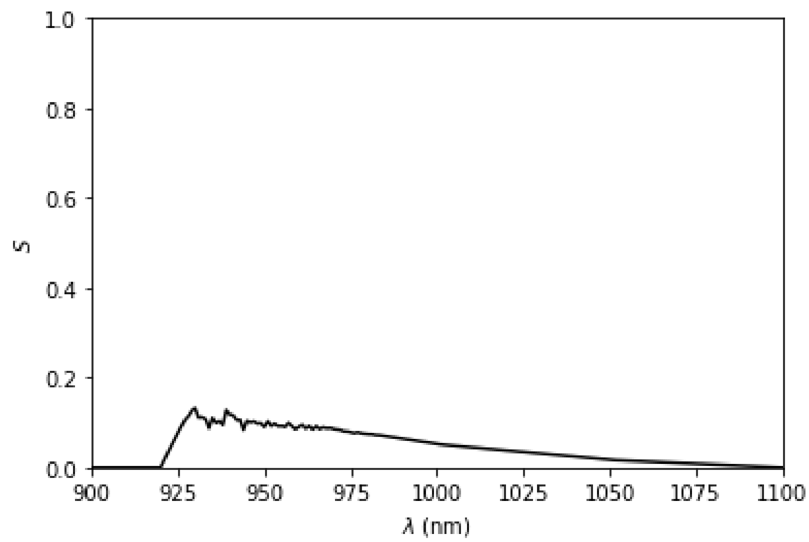

Figure 15.12: The model system efficiency S at the zenith in the y filter.

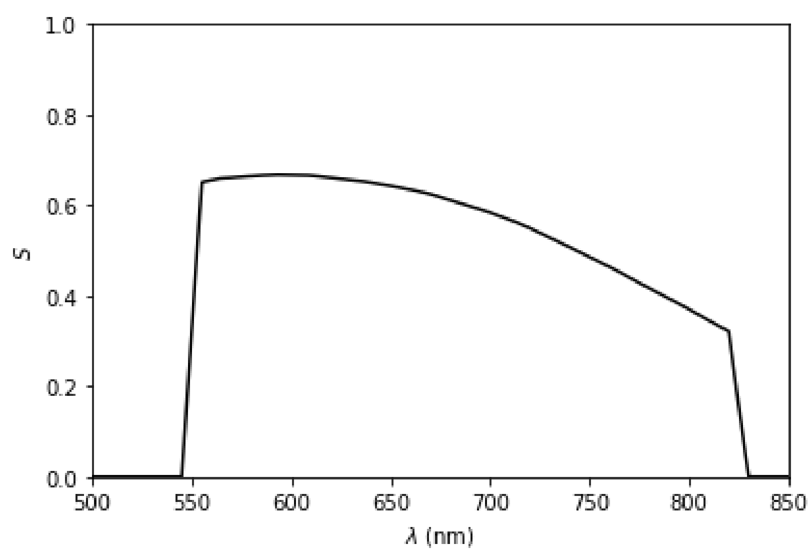

Figure 15.13: The model system efficiency S at the zenith in the w filter.

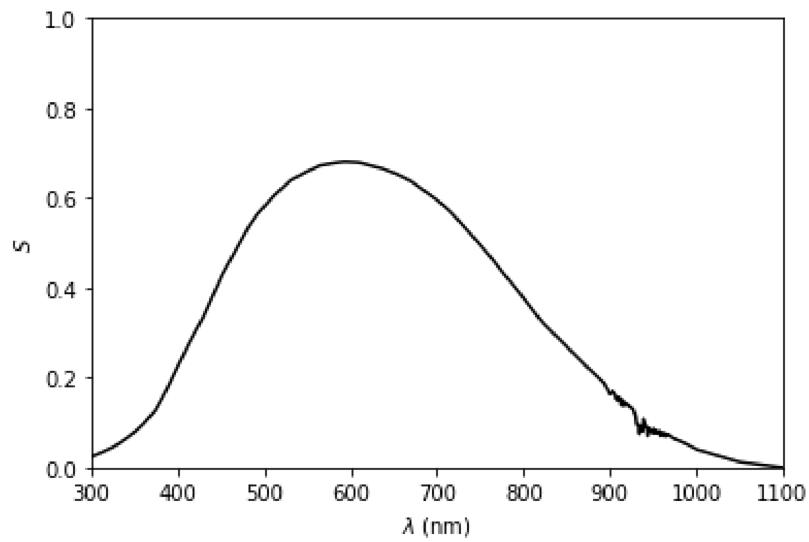

Figure 15.14: The model system efficiency S at the zenith in the open filter.

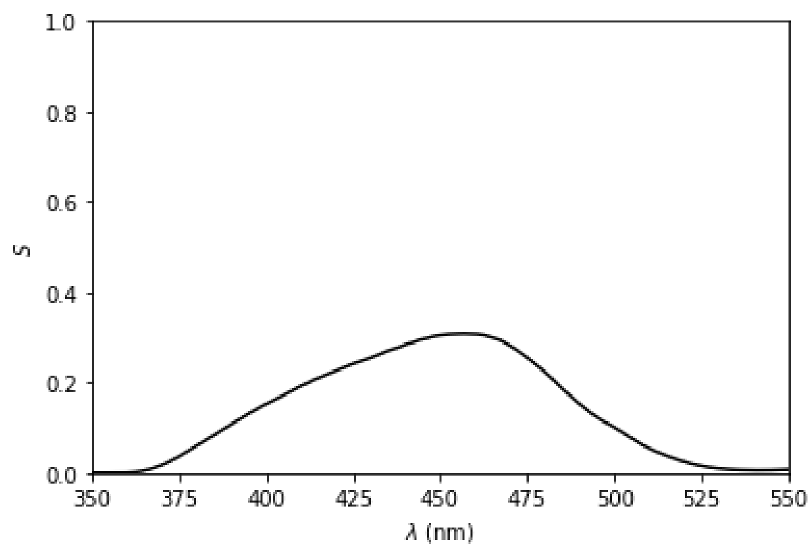

Figure 15.15: The model system efficiency S at the zenith in the B filter.

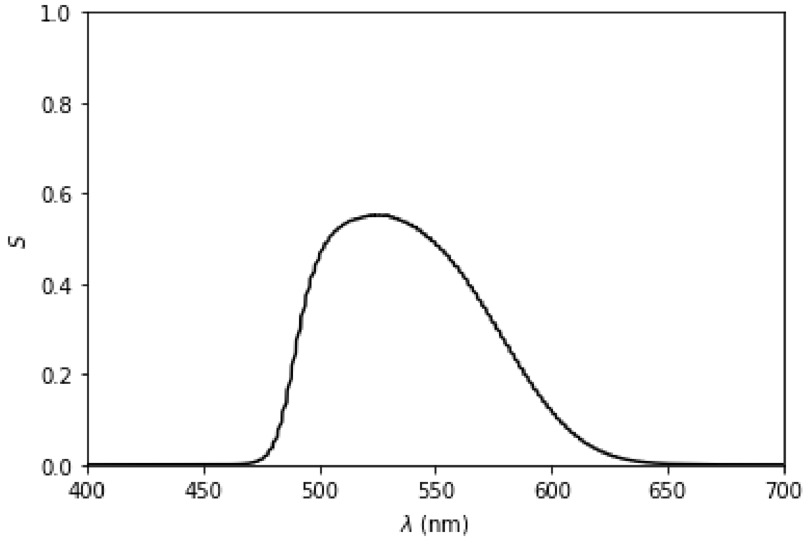

Figure 15.16: The model system efficiency S at the zenith in the V filter.

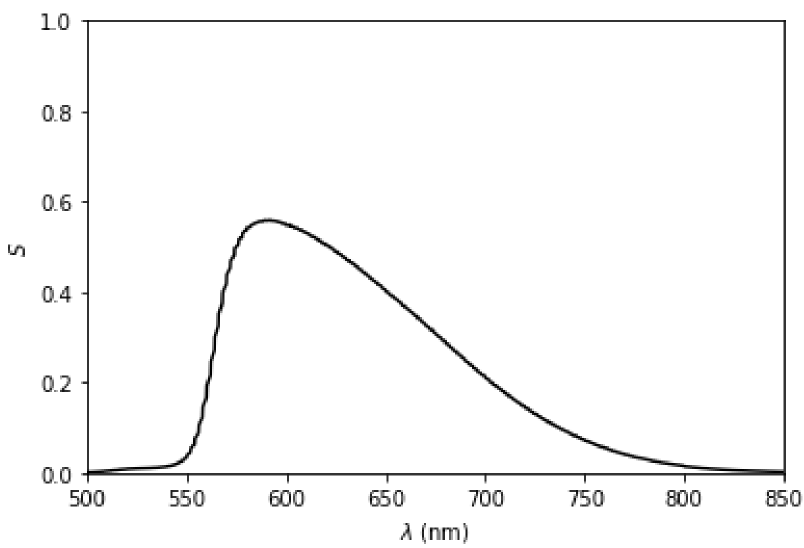

Figure 15.17: The model system efficiency S at the zenith in the R filter.

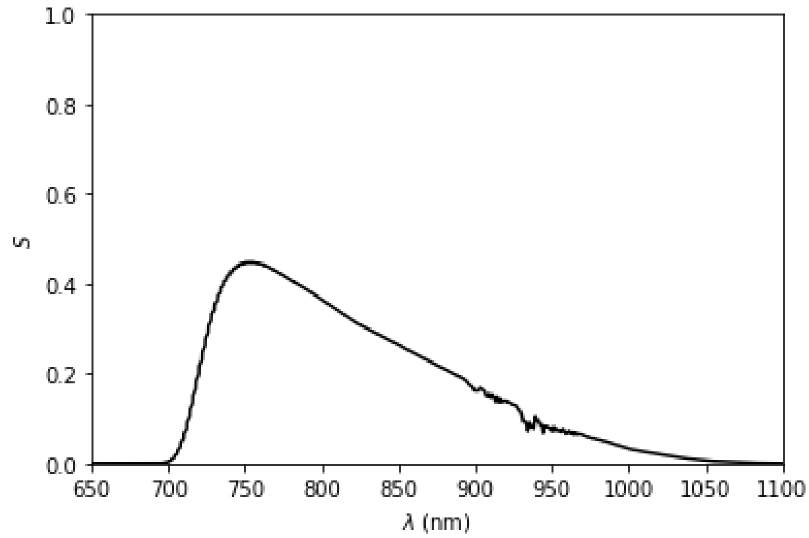

Figure 15.18: The model system efficiency S at the zenith in the I filter.

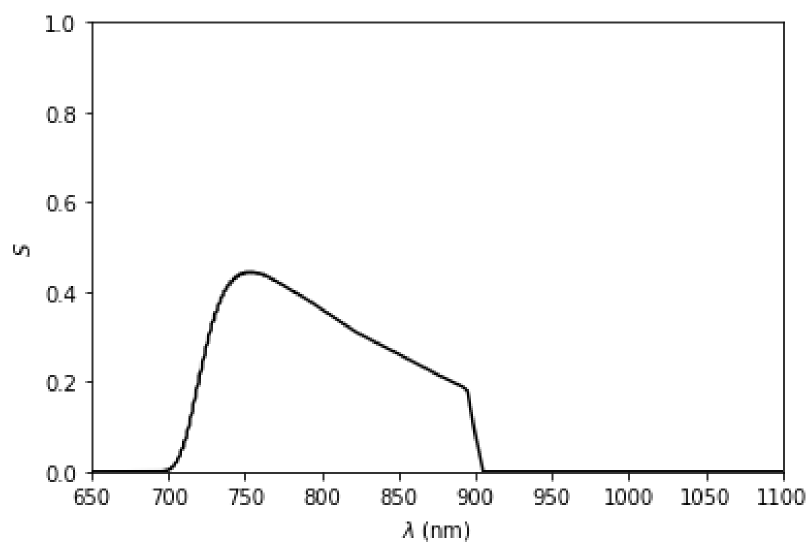

Figure 15.19: The model system efficiency S at the zenith in the I_s filter.

Table 15.3: Model Filter Properties

Filter	λ_{pivot} (nm)	$\Delta\lambda$ (nm)	ZP (s^{-1})
open	618.7	384.1	4.2×10^9
g	475.9	104.6	1.2×10^9
r	617.2	132.4	1.3×10^9
i	747.4	131.5	8.0×10^8
z	862.8	94.8	3.0×10^8
y	973.3	64.2	8.6×10^7
w	668.4	264.6	2.2×10^9
B	446.5	89.4	5.9×10^8
V	537.9	89.8	8.5×10^8
R	633.9	118.0	1.0×10^9
I	814.8	150.7	8.0×10^8
I_s	795.0	150.7	7.0×10^8
470/10	469.7	10.1	9.9×10^7
486/8	485.5	9.3	1.0×10^8
501/3	500.7	3.2	3.5×10^7
501/8	500.5	7.0	8.2×10^7
515/10	514.2	10.0	1.1×10^8
640/10	638.9	9.9	9.8×10^7
656/3	656.5	2.9	2.8×10^7
656/8	655.9	7.7	8.4×10^7
672/3	672.3	2.9	2.7×10^7
672/8	672.2	7.6	6.8×10^7
889/18	887.3	17.5	4.3×10^7

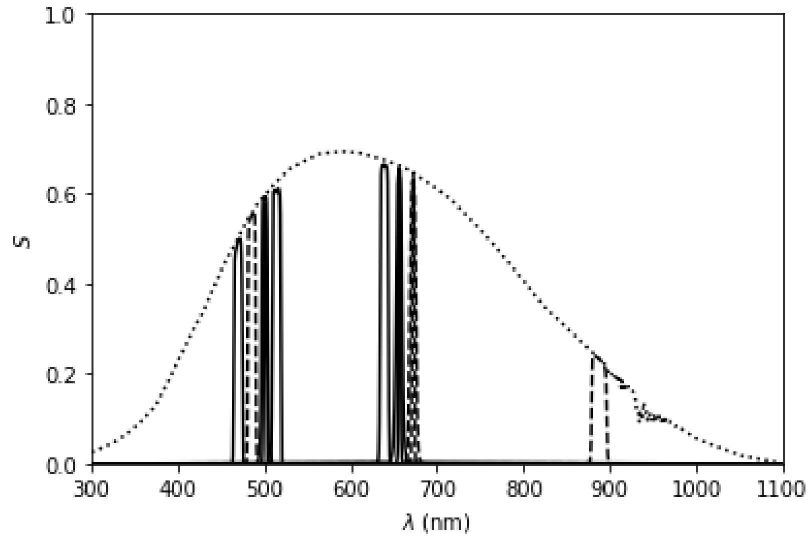

Figure 15.20: The model system efficiency S at the zenith in the narrow-band and medium-band filters. The dotted line is the model unfiltered efficiency.

The focuser moves from 0 to 115200 steps over 12.7 mm which corresponds to 9.07 steps per micron. The 0 position is above and the 115200 position is below. The focuser moves at about 900 steps or 0.1 mm per second.

15.5 Focus Compensation

The lens has chromatic aberration and the filters have different thicknesses. Both of these require us to use a compensator to maintain focus. Our options are the focuser, the secondary, or both. If we use only one compensator, then the magnification necessarily changes slightly was we adjust for focus. If we use both, we can maintain the magnification.

However, it is fairly easy to show that if we use the focuser, either on its own or in combination with the secondary to maintain the magnification, in the worst case we need to move it about 3 mm. Since the focuser moves at about 0.1 mm per second, this means the worse case time is about 30 seconds. This is long compared to slew speed (without a meridian flip) and cannot be overlapped with changing the filter. On the other hand, if we use only the secondary, in the worst case we need to move about 60 steps. Even with backlash compensation, this takes about 5.5 seconds. Furthermore, this can be overlapped with changing the filter. Therefore, in the interests of preserving the rapid response of COATLI, we have chosen to compensate the focus using only the secondary. This compensation is handled automatically by the control system.

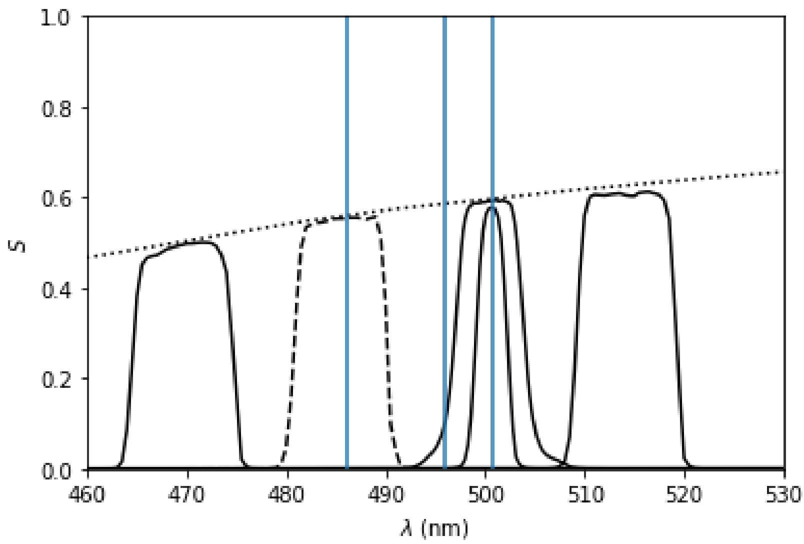

Figure 15.21: The model system efficiency S at the zenith in the narrow-band and medium-band filters in g: 470/10, 486/8, 501/3, 501/8, and 515/10. The filters shown with dashed lines have not yet been acquired. The dotted line is the model unfiltered efficiency. The blue vertical lines are at 486.1, 495.9, and 500.7 nm.

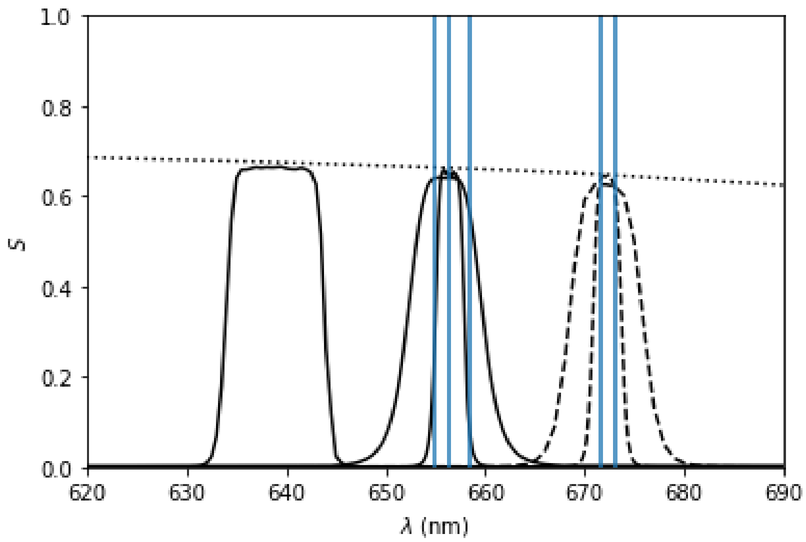

Figure 15.22: The model system efficiency S at the zenith in the narrow-band and medium-band filters in r: 640/10, 656/3, 656/8, 672/3, and 672/8, 501/8, and 515/10. The filters shown with dashed lines have not yet been acquired. The dotted line is the model unfiltered efficiency. The blue vertical lines are at 656.3, 654.8, 658.4, 671.6, and 673.1 nm.

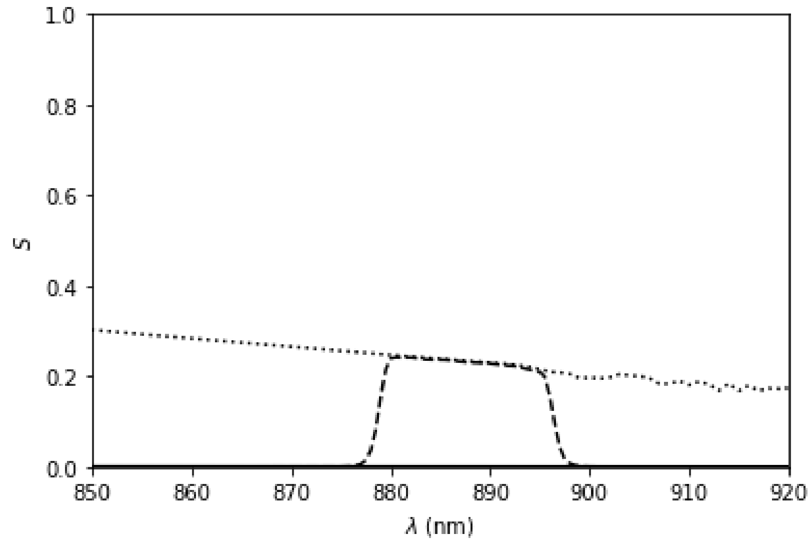

Figure 15.23: The model system efficiency S at the zenith in the medium-band filter in z: 889/18. The filters shown with dashed lines have not yet been acquired. The dotted line is the model unfiltered efficiency.

Our model is as follows. We define L to be the (fixed) physical distance from the lens to the detector and T to be the total physical thickness of filter glass between the lens and the detector. We then have

$$SA' = L - [(n-1)/n]T \approx L - 0.32T,$$

where we have assumed $n = 1.48$ for fused silica. We then solve for SA using

$$1/F = 1/SA' - 1/SA,$$

taking into account the dependence of F on wavelength. We determine ΔSA relative to the i filter. We then determine the corresponding change in the secondary taking into account the amplification of 10.64 between the movement of the secondary and the movement of the telescope focal plane.

Table 15.4 shows the results. Note that for the medium band filters, there are two values depending on whether the filter is in wheel B (T = 3 mm) or wheel C (T = 6 mm). The offsets of the narrowband filters are the same as for the corresponding medium band filters.

Table 15.4: Filter Secondary Offsets

Filter	F (mm)	Thickness (mm)	Offset (steps)
open	-150.22	3	-24
g	-150.20	8	$+7$
r	-150.07	8	$+13$
i	-150.37	8	0
z	-150.66	5	-30
y	-150.96	6	-37
w	-150.25	11	$+24$
B	-150.43	8	-2
V	-150.97	8	$+17$
R	-150.14	8	$+10$
I	-150.27	5	-30
I_s	-150.50	8	-5
470/10	-149.99	3/6	$-14/+4$
515/10	-149.93	3/6	$-12/+6$
640/10	-150.07	3/6	$-16/+1$

15.6 Detector

The detector unit is an Andor iXon Ultra 888 with an e2v CCD201-20 electron-multiplying CCD detector. The detector was acquired in 2014 and originally intended to be the tilt sensor for the planned two-channel imager.

15.6.1 Format, Scale, and Field

The detector has 1024×1024 pixels each 13×13 μm square.

The detector gives a pixel scale of 0.269 arcsec and a field of 4.59 arcmin.

The orientation of the field on the sky depends on the mount rotation (given by the values of the `SMTMRO` and `EMTMRO` keywords in the header), and is shown in Figure C.2. However, the pipeline reduction rotates all images to the conventional orientation with north up and east left.

15.6.2 Quantum Efficiency

The detector has standard silicon and the e2v midband coating (which in Andor's terminology makes it a "BV" device). The nominal quantum efficiency is shown in Figure C.3. The detector has excellent efficiency from 500 to 800 nm.

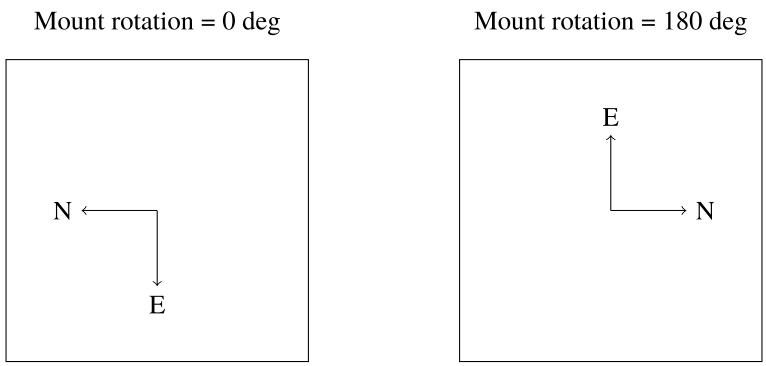

Figure 15.24: The orientation of the detector on the sky according to the mount rotation. The pixel origin is in the lower left.

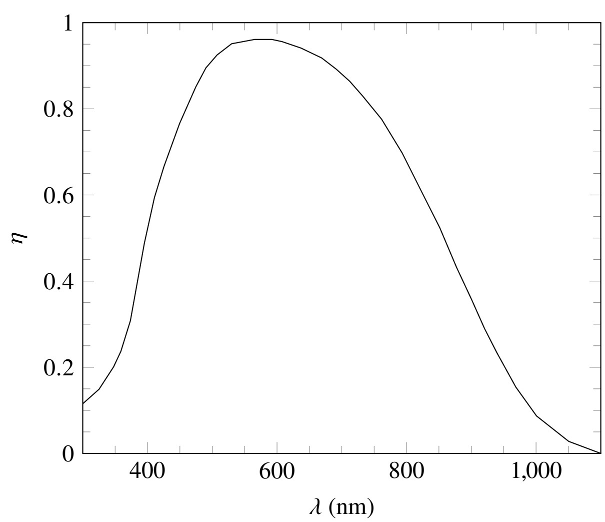

Figure 15.25: The nominal quantum efficiency η of the Huitzi detector.

15.6.3 Readout Architecture

The detector can be read using either a conventional signal chain (at 100 kHz or 1 MHz) or an EM signal chain (at 1, 10, 20, or 30 MHz). Both chains have two gains and the EM gain can be set to up to 1000.

Although the conventional and EM amplifiers clock the serial register in different directions, the control software flips each row in conventional data so that physical pixels have the same logical position in the FITS files.

The detector is used in frame-transfer mode without a mechanical shutter (see §C.2.4). At the end of an exposure, the charge is rapidly clocked into from the light-sensitive image section to the shielded store section. The change can then be read. In EM mode, the next exposure can then start immediately.

With the normal vertical-shift frequency of 4.33 MHz, the frame transfer takes about 4.5 ms. This leads to some trailing above and below bright stars.

The read-out architecture has several parameters, which are encoded in the value of the `READMODE` header keyword. The value is a string of the form A-B-C-D-E-F-G in which A to G are non-negative integers with the following meanings:

- *A* The ADC channel index. This is always 0 since the detector only has one ADC channel.
- *B* The amplifier index. This is 0 for the EM amplifier and 1 for the conventional amplifier.
- *C* The vertical shift speed index. For both amplifiers, 0 is 0.60 MHz, 1 is 1.13 MHz, 2 is 2.20 MHz, and 3 is 4.33 MHz.
- *D* The horizontal shift speed index. For the EM amplifier, 0 is 30 MHz, 1 is 20 MHz, 2 is 10 MHz, and 3 is 1 MHz. For the conventional amplifier, 0 is 1 MHz and 1 is 100 kHz.
- *E* The gain index. For both amplifiers, 0 is low gain (more electrons per ADU) and 1 is high gain (fewer electrons per ADU).
- *F* The nominal EM gain. This is ignored when the conventional amplifier is used. For the EM amplifier, it can be between 1 and 1000.
- *G* The software gain. After the data are read, each ADU signal is divided by the software gain to reduce white noise in the low-order bits (see Watson 2002, RMAA, 38, 233).

Fortunately, there is little need to use these values directly, since aliases are defined for common modes. They are shown in Table C.1.

Table 15.5: Read-Mode Aliases

Alias	Mode
initial	default
default	em-30MHz
conventionaldefault	1MHz
fastguidingdefault	em-30MHz
1MHz	1MHz-low
em-10MHz	em-10MHz-low
em-20MHz	em-20MHz-low
em-30MHz	em-30MHz-low
1MHz-low	0-1-3-0-0-1-1
1MHz-high	0-1-3-0-1-1-2
em-10MHz-low	0-0-3-2-0-250-2
em-10MHz-high	0-0-3-2-1-160-4
em-20MHz-low	0-0-3-1-0-500-4
em-20MHz-high	0-0-3-1-1-320-8
em-30MHz-low	0-0-3-0-0-1000-8
em-30MHz-high	0-0-3-0-1-640-16

15.6.4 Shutter and Dark Filter

We originally attempted to use the mechanical shutter for conventional CCD modes and the frame-transfer capability for EM modes. However, we found that the shutter sometimes failed to open or failed to open completely. We suspect that at the colder temperatures at night, the power supply does not provide sufficient voltage to open the shutter. Therefore, we now leave the shutter open permanently and use the frame-transfer capability in both conventional and EM modes. As noted above, with the normal vertical-shift frequency, the frame transfer takes about 4.5 ms.

To take bias and dark images, we have use a "dark" filter that consists of the B, z, and 656/8 filters in series. Despite this, light leaks in the filter wheel mean that we need to take biases and darks at night.

15.7 Bibliography

- "Andor iXon Ultra 888 Data Sheet", Andor, May 2014.
- "Andor iXon Ultra & Life 888 Hardware Guide", Andor, Version 1.8 of 30 September 2019.
- Bessell, M.S., 1990, PASP, 102, 1181: "$UBVRI$ Passbands".
- Bessell, M., & Murphy, S., 2012, PASP, 124, 140: "Spectrophotometric Libraries, Revised Photonic Passbands, and Zero Points for UBVRI, Hipparcos,

Mode Name	1MHz-0	em-10MHz-0	em-20MHz-0	em-30MHz-0
Amplifier	Conventional	EM	EM	EM
Horizontal Speed	1 MHz	10 MHz	20 MHz	30 MHz
Software Gain	1	2	4	8
ADC Range (DN)	64k	32k	16k	8k
Gain (e^-/DN)	3.3	41	78	117
Read Noise (DN)	2.1	2.6	1.9	1.7
Read Noise (e^-)	7	105	145	204
Bias Level (DN)	500	242	123	62
Linear Limit (e^-)		400k	400k	400k
Saturation (DN)	58k	32k	16k	8k
Saturation (e^-)	190k	1300k	1250k	940k
Linearity (e^-)		400k	400k	400k
Linearity (DN)		9700	5100	3400
Dynamic Range (bits)		11.9	11.4	10.9

Table 15.6: Detector Characteristics with the Low Preamplifier Gain

Mode Name	1MHz-1	em-10MHz-1	em-20MHz-1	em-30MHz-1
Amplifier	Conventional	EM	EM	EM
Horizontal Speed	1 MHz	10 MHz	20 MHz	30 MHz
Software Gain	2	4	8	16
ADC Range (DN)	32k	16k	8k	4k
Gain (e^-/DN)	1.6	21	45	70
Read Noise (DN)	2.9	2.7	2.4	1.6
Read Noise (e^-)	5	56	108	115
Bias Level (DN)	250	119	62	31
Saturation (DN)	22k			
Saturation (e^-)	35k			
Linearity (e^-)		400k	400k	400k
Linearity (DN)		19000	8900	5700
Dynamic Range (bits)		12.8	11.9	11.8

Table 15.7: Detector Characteristics with the High Preamplifier Gain

and Tycho Photometry".

- "CCD201-20 Datasheet", Teledyne e2v, Version 7 of August 2019.
- Cousins, A.W.J., 1976, MNRAS, 81, 25: "VRI standards in the E regions".
- Oke, J.B, & Gunn, J.E., 1983, ApJ, 266, 713: "Secondary Standard Stars for Absolute Spectrophotometry"

Chapter 16

Calibrations

This chapter describes the routine calibrations procedures for COATLI.

16.1 Twilight Flats

The control system takes twilight flats each evening that conditions permit.

The flats are taken with the telescope pointed to -3 hours of HA and +45 degrees of declination and with the tracking turned off. The detector uses a read mode of `conventionaldefault` (which is `1MHz-low`). The control system monitors the level in the flats, considers a flat to be good it its level is between 3500 and 16000 DN, and moves to the next filter either after acquiring a certain number of good flats (typically 7) or when the level is too low for the flat to be considered good.

HUITZI has many filters and the flats for each filter is associated with a different visit identifier, according to Table **??**.

In HUITZI it is not possible to take flats in all filters each night, so there are several block files for different sets of filters that are run in turn.

Table 16.1: Visit Identifiers for Twilight Flats

Filter	Visit Identifier
g	0
r	1
i	2
z	3
y	4
w	5
B	10
V	11
R	12
I	13
I_{s}	14

Part IV

Control System

Chapter 17

Control System

TODO: What runs where.

TODO: Structure.

TODO: stopserver/startserver/restartserver

TODO: restartsoon (haltsoon and rebootsoon in network)

TODO: state and activity

TODO: basic requests: initialize, status, reset, stop

TODO: supervisor
request supervisor enable/disable/open/close/emergencyclose

TODO: Detectors:
expose <time> object/dark/bias/flat
setcooler on/off
movefilterwheel position/filter
movefocuser position
setfocuser position setwindow 1kx1k/2kx2k/6kx6k/default/full
setbinning 1/2/4
setreadmode mode
setsoftwaregain
focus TBD
analyze fwhm/levels

TODO: selector
request selector enable/disable
request select setunfocused

TODO: instrument
open/close

TODO: telescope
park
unpark
move HA dec

newtrack RA dec equinox
newtracktopocentric HA dec
01:23:45.67 +3h 60d
open/close

TODO: executor
open/close

TODO:
request telescope emergencyclose
sudo restartsoon
request supervisor enable

Chapter 18

JSON

JSON is used widely in TCS to represent data structures in configuration files, alert files, block files, and in inter-process communication. JSON has a simple and regular syntax that is fairly easy for humans to write, easy for computers to parse, and should be quite familiar to C, C++, and JavaScript programmers.

18.1 Dialect

The dialect of JSON used in TCS is both extended and restricted compared to standard JSON.

It is extended by the addition of comment lines that can appear wherever white-space can appear in standard JSON. A comment line is a line that begins with zero or more space and horizontal tab characters followed by two slash characters ("//"). Formally, the slash character is U+002F SOLIDUS. Other types of comments (e.g., block comments introduced by "/*" and terminated by "*/") are not allowed. Comment lines are treated as if they were empty lines. Our dialect of JSON can be converted to standard JSON by using a regular expression substitution to replace comment lines with empty lines.

It is restricted with respect to standard JSON in that it only uses array, object, and string values and does not use number, true, false, or null values. If a value represents a number, then the string representation should be used. This restriction ensures that value can be read and written without being changed.

The dialect of JSON is formally a very limited subset of JavaScript. Therefore, if you are editing data files manually, it might be useful to select an editing mode suitable for JavaScript.

18.2 Encoding

Data files should be encoded in UTF-8. ASCII is a subset of UTF-8, but ISO-8859-1 "Latin-1" is not.

18.3 Values

18.3.1 Value Types

Only array, object, and string values are used. Number and boolean values are represented by their string representation. For example, we do not write

```
0
true
false
```

but rather

```
"0"
"true"
"false"
```

Null values are not used.

18.3.2 Dates and Times

Dates and time values are written as strings containing an IS0-8601 basic date or basic combined date and time. The time zone is understood to be UTC; an explicit time zone must not be specified. The precision must not be specified more finely than seconds.

Examples of valid dates are:

`"20101117T223815"`	:	2010 Nov 17 22:38:15 UTC
`"20101117T2238"`	:	2010 Nov 17 22:38:00 UTC
`"20101117T22"`	:	2010 Nov 17 22:00:00 UTC
`"20101117"`	:	2010 Nov 17 00:00:00 UTC

18.3.3 Angles

A value representing an angle may be written as:

1. a string containing a decimal number (and interpreted as *radians* not *degrees*);
2. a string containing sexagesimal notation with colons as separators and no white space;
3. a strings containing a decimal number with a unit suffix (with no intermediate white space):
   (a) "r" for radians;

   (b) “h” for hours;
   (c) “m” for minutes;
   (d) “s” for seconds;
   (e) "ad" or “d” for degrees;
   (f) “am” for arcminutes; and
   (g) “as” for arcseconds.

For hour angles and right ascensions, sexagesimal notation indicates hours, minutes, and seconds. For all other angles, including offsets, it indicates degrees, arcminutes, and arcseconds.

Examples of valid angles are:

`"-22.5"`	: -22.5 *radians*
`"-22.5d"`	: -22.5 *degrees*
`"-01:30:00"`	: -1.5 hours or -1.5 degrees, depending on the context
`"0.5r"`	: 0.5 radians
`"-1.5h"`	: -1.5 hours
`"5am"`	: 5 arcminutes
`"+20as"`	: 20 arcseconds

18.3.4 Durations

A value representing a duration may be written as:

1. a string containing a decimal number (and interpreted as decimal seconds);
2. a string containing sexagesimal notation with colons as separators and no white space;
3. a string containing a decimal number with a unit suffix (with no intermediate white space):
   (a) “h” for hours;
   (b) “m” for minutes; and
   (c) “s” for seconds.

Sexagesimal notation indicates hours, minutes, and seconds.

Examples of valid durations are:

`"60"`	: 60 seconds
`"00:30:10”`	: 30 minutes and 10 second
`"60s"`	: 60 seconds
`"10m"`	: 10 minutes
`"1h"`	: 1 hour

18.3.5 Validation

JSON written by hand is prone to errors such as missing commas. For this reason, it is often worthwhile checking JSON with one of the many on-line validators. The following validator is especially useful, as it tolerates comments:

`https://jsonformatter.curiousconcept.com/#`

18.4 Bibliography

- "Introducting JSON", `https://www.json.org/json-en.html`

Chapter 19

Observing Blocks

19.1 Introduction

Observations are organized as *project*, *blocks*, and *visits*.

A project is associated with a successful observing proposal. It has a PI, a name, and an identifier. It consists of one or more blocks.

A block consists of a ordered set of visits associated with a set of constraints and a program. The selector and executor deal with blocks: the selector selects a block and the executor executes it. A block is only selectable if all of its visits satisfy all of the constraints. When a block is executed, its visits are carried out in order.

A visit is typically a logical operation with the telescope such as focusing, correcting the pointing, or observing an objects.

19.2 Block Files

A block file contains a JSON representation of a block.

It consists of a single JSON object with the following structure:

```
{
  "project": {
    "identifier": <project-identifier>,
    "name": <project-name>
  },
  "identifier": <block-identifier>,
  "name": <block-name>,
  "visits": <visits>,
  "constraints": <constraints>,
  "persistent": <persistent>
}
```

As for any JSON object, the order of the members is irrelevant.

The members and values are interpreted as follows:

- <project-identifier>: The project identifier.

  This is a four-digit non-negative integer represented as a string.

  By convention, calibration programs have identifiers from 0000 to 0999, alert science programs from 1000 to 1999, and non-alert science programs from 2000 to 2999. (The pipeline uses this convention to reduce alert observations immediately but delay reducing non-alert observations until the morning.)

  This member cannot be omitted.

- <project-name>: The project name.

  By convention, we use the surname of the PI followed by a brief description of the objects (e.g., `"Watson YSOs"`).

  If omitted, the default is `""`.

- <block-identifier>: The block identifier.

  This is a non-negative integer represented as a string.

  This member cannot be omitted.

- <block-name>: The block name.

  By convention, we briefly describe the main science target (e.g., `"HL Tau"`).

  If omitted, the default is `""`.

- <visits>: An array representing the visits. See below.

  If omitted, the default is an empty array.

- <constraints>: An object representing the constraints. See below.

  If omitted, the default is an empty object.

- <persistent>: Whether the block is persistent.

  Either `"true"` or `"false"`.

  If `"true"`, the block is persistent. Persistent blocks remain in the queue after they have been executed. Non-persistent blocks are removed after they have been executed.

  If omitted, the default is `"false"`.

19.3 Constraints

The <constraints> value specifies constraints which shall be satisfied by all of the visits in a block in order for the block to be selectable. If any constraint is not satisfied by any visit, the block will not be selectable.

For a block to be selectable:

- All time-based constraints (`mindate`, `maxdate`, `minfocusdelay`, and `maxfocusdelay`) must be satisfied at the start of the first visit.
- All condition-based constraints (e.g., on transparency) must be satisfied at the start of the first visit. (In the present version of the selector, there are no constraints on unpredictable properties, but this may change in future versions.)
- All other constraints must be satisfied at the start and end of *each* visit.

Syntactically, the <constraints> value is a JSON object with the following structure:

```
{
  "mindate": <date>,
  "maxdate": <date>,
  "minsunha": <ha>,
  "maxsunha": <ha>,
  "minsunzenithdistance": <distance>,
  "maxsunzenithdistance": <distance>,
  "minmoondistance": <distance>,
  "maxmoondistance": <distance>,
  "minha": <ha>,
  "maxha": <ha>,
  "mindelta": <delta>,
  "maxdelta": <delta>,
  "minairmass": <airmass>,
  "maxairmass": <airmass>,
  "minzenithdistance": <distance>,
  "maxzenithdistance": <distance>,
  "minskybrightness": <skybrightness>,
  "maxskybrightness": <skybrightness>,
  "minfocusdelay": <delay>,
  "maxfocusdelay": <delay>,
}
```

As for any JSON object, the order of the members is irrelevant.

The members and values are interpreted as follows:

- The <mindate> and <maxdate> values specify the earliest and latest date and time on which to the visit shall be executed.

  Valid values are dates.

- The <minsunha> and <maxsunha> values specify the minimum and maximum values of the HA of the Sun.

  Valid values are angles.

  These are of most interest to calibration blocks, where these can be used to determine whether it is morning or evening.

- The <minsunzenithdistance> and <maxsunzenithdistance> values specify the minimum and maximum values of the zenith distance of the Sun.

  Valid values are angles.

  These are of most interest to calibration blocks.

- The <minmoondistance> and <maxmoondistance> members specify the minimum and maximum values of the distance of the Moon from the visit targets.

  Valid values are angles.

- The <minha> and <maxha> values specify the minimum and maximum values of the HA of the visit targets.

  Valid values are angles.

  These can be used to program several blocks on the same target in the a given night by giving each a HA range disjoint from the others.

- The <mindelta> and <maxdelta> values specify the minimum and maximum values of the declination of the visit targets.

  Valid values are angles.

- The <minairmass> and <maxairmass> members specify the minimum and maximum values of the zenith distance of the visit targets.

  Valid values are numbers.

- The <minzenithdistance> and <maxzenithdistance> values specify the minimum and maximum values of the zenith distance of the visit targets.

  Valid values are angles.

- The <minskybrightness> and <maxskybrightness> values specify the minimum (faintest) and maximum (brightest) sky brightness in which the visit shall be executed.

  Valid values are: `"daylight"`, `"civiltwilight"`, `"nauticaltwilight"`, `"astronomicaltwilight"`, `"bright"`, `"grey"`, and `"dark"`.

  Daylight and the twilights are defined conventionally by the altitude of the Sun. Bright time is any time between twilights when the moon is above the horizon and is 50% illuminated or more. Grey time is s any time between twilights when the moon is above the horizon and is 50% illuminated or less. Dark time is any time between twilights when the moon is below the horizon.

- The <minfocusdelay> and <maxfocusdelay> values specify the minimum and maximum time since the telescope was last focused. So, for example specifying a <minfocusdelay> of `"1h"` will constrain the block to be run no sooner than 1 hour after focusing and specifying a maxfocusdelay of `"1h"` will constrain the block to be run no later than 1 hour after focusing.

  Valid values are durations.

  These are of most interest to focus blocks.

In addition to any explicit constraints, the scheduler requires that all visit targets are within the telescope pointing limits at the expected start and of the visit.

If no explicit constraints are given, the implicit telescope pointing limits are the only constraint and, for example, a block may be executed at very high airmass, close to the mount, or during twilight. Therefore, it is advisable to include at least minimal constraints, for example:

```
{
  "maxskybrightness": "astronomicaltwilight",
  "maxairmass": "2.0",
  "minmoondistance": "15d"
}
```

19.4 Visits

Syntactically, the <visits> value is a JSON array containing zero or more <visit> objects:

```
[
  <visit>,
  <visit>,
  <visit>,
  ...
  <visit>
]
```

Each <visit> value is a JSON object with the following structure:

```
{
  "identifier": <visit-identifier>,
  "name": <visit-name>,
  "targetcoordinates": <target-coordinates>,
  "estimatedduration": <estimated-duration>,
  "command": <command>
}
```

As for any JSON object, the order of the members is irrelevant.

The members and values are interpreted as follows:

- <visit-identifier>: The visit identifier.

  This is a non-negative integer represented as a string.

  By convention, science visits have identifiers from 0 to 999 and focusing, pointing correction, and other non-science visits from 1000 onward. (The pipeline uses this convention to avoid reducing non-science visits.)

- <visit-name>: The visit name.

  By convention, we used names that describe the activity generically, such as `"focussing"`, `"pointingcorrection"`, `"science"`.

  If omitted, the default is `""`.

- <target-coordinates>: The target coordinates. See below.

- <estimated-duration>: The estimated duration of the visit.

  Valid values are durations (e.g., `"10m"` for 10 minutes).

  This is used to by the selector to check the constraints at the estimated end of the visit.

- <command>: The command to execute the visit. See below.

19.5 Target Coordinates

The <target-coordinates> value is a JSON object with one of the following structures.

For equatorial coordinates, the structure is:

```
{
  "type": "equatorial",
  "alpha": <alpha>,
  "delta": <delta>,
  "equinox": <equinox>
}
```

The <alpha> and <delta> values are angles. The <equinox> value is a number.

For fixed topocentric coordinates, the structure is:

```
{
  "type": "fixed",
  "ha": <ha>,
  "delta": <delta>
}
```

The <ha> and <delta> values are angles.

For the zenith, the structure is:

```
{
  "type": "zenith"
}
```

For the idle position, the structure is:

```
{
  "type": "idle"
}
```

For a solar system body, the structure is:

```
{
  "type": "solarsystembody",
  "number": <number>
}
```

The <number> is a number and refers to the number part of the minor-planet designation. For example, for (388188) 2006 DP_{14}, it would be `388188`.

19.6 Commands

The <command> value is a string representing the Tcl command that will be run to execute the visit. Here we describe the three main commands of interest to science blocks and omit the other commands that are used in calibration blocks.

Many parameters of commands have default values.

19.6.1 Focus

The `focusvisit` command focuses the secondary on C0.

The parameters are:

- `filter`: the filter in which to focus. The default is `i`.
- `exposuretime`: the exposure time in seconds. The default is `5`.

Examples:

```
"focusvisit"
"focusvisit z"
"focusvisit r 10"
```

19.6.2 Pointing Correction

The `pointingcorrectionvisit` command attempts to correct the pointing.

The parameters are:

- `filter`: the filter in which to expose. The default is `i`.
- `exposuretime`: the exposure time in seconds. The default is `15`.

Examples:

```
"pointingcorrectionvisit"
"pointingcorrectionvisit z"
"pointingcorrectionvisit z 5"
```

19.6.3 Grid

The `gridvisit` command takes exposures in possibly multiple filters over grid of dithers.

The parameters are:

- `gridrepeats`: The number of times the whole grid is repeated.
- `gridpoints`: The number of points in the grid.

  Valid values are 1 to 9.

  The grid points are distributed in a square that is 1 arcmin to a side. The grid points, in order, are the center, the four corners, and the four midpoints of the sides. So, for example, if a value of 5 is given, the grid will consist of the center and the four corners.
- `exposurerepeats`: The number of exposures taken in each grid repetition for each filter/dither combination.
- `exposuretime`: The exposure time of each exposure.
- `filters`: The filters.

  A list of filters in which to observe.

  Remember that lists in Tcl are surrounded by curly brackets. For example, `{g r i z}`.

  Filters can be repeated. So, for example, to do an ABBA sequence in *g* and *r*, you might use `{g r r g}`.
- `offsetfastest`: Whether to offset fastest (`true`) or change filters fastest (`false`).

  The default is `true`.

  If `offsetfastest` is `true`, the code will observe a whole grid in the first filter, then the observe a whole grid in the second filter, and so on.

  If `offsetfastest` is `false`, the code will observe in each filter at the first grid point, then observe in each filter at the second grid point, and so on.
- `readmode`: The read-mode.

  The default is `fastguidingmode`.

The total number of exposure is the value of `gridrepeats` multiplied by the value of `gridpoints` multiplied by the value of `exposurerepeats` multiplied by the number of `filters`. The total exposure time is this multiplied by the value of `exposuretime`.

Examples:

```
"gridvisit 4 9 1 30 {r}"
"gridvisit 1 5 1 60 {g r i z}"
"gridvisit 1 5 1 60 {640/10 656/3} false"
```

19.7 Managing the Block Queue

The telescope maintains an alert queue and a block queue. We will not discuss the alert queue here, except to note that observations are selected at a higher priority from the alert queue than from the block queue.

The block queue is maintained in a repository in GitHub:

https://github.com/alanwatsonforster/coatli-blocks

This repository contains block files, shell scripts to generate block files, and a BLOCKS file to specify which block files are loaded, when, and with which priority.

At 00:00 UTC each day (16:00 PDT or 17:00 PST), the telescope control system fetches a copy of the repository from GitHub. At 00:01 UTC each day, it loads blocks from the copy of the repository into the queue. These actions are separate, so that even if the telescope is not able to fetch the latest version of the repository, it will still load the queue using a previous version of the repository.

The blocks that are loaded are specified in the BLOCKS file in the repository.

In the BLOCKS file, empty lines and lines beginning with `#` are ignored.

The remaining lines shall have four obligatory fields possibly followed by additional fields that give a time specification. Fields are separated by tabs or spaces.

The fields are:

1. Action. Either the the word `load` or the word `unload`. This specifies whether the block will be loaded or unloaded.
2. Priority. A letter, with a being highest priority and z being lowest priority.
3. Duplicates. The number of copies of the block file that are loaded or unloaded. This is useful when breaking long observations into shorter blocks; simply set this field to the number times you want to run the shorter block.
4. Block file. This can be a file name or a shell glob pattern to match a set of file names. Omit the trailing `.json`.

After the first four columns, additional optional fields can give a time specification. If no time specification is given, the block files are loaded or unloaded every day. Valid time specifications are:

- Load or unload the blocks on a fixed UTC date.

  In this case, the 5th field is the word `date` and the 6th field specifies the date as YYYYMMDD.

  This is useful when you only want to add blocks to the queue once.

- Load or unload the blocks every N days.

  In the case, the 5th field is the word `day`, the 6th field is a number M, and the 7th field is another number N. The blocks are loaded into the queue when the day of year D (1 to 366) satisfies $M = D \bmod N$.

  Note that by choosing different values of M you can cycle through a set of blocks.

Example BLOCKS file:

```
load   a 1 0004-initial-focus-*
load   b 1 0004-focus-*
load   f 1 2001-smith-*
load   g 1 2000-jones-0      day 0 2
load   g 1 2000-jones-1      day 1 2
load   h 3 2003-harris-0     date 20220218
unload h 3 2003-harris-0     date 20220318
load   i 1 2002-bloggs-0
load   x 1 0001-twilight-flats-evening-0
```

Chapter 20

Archive

20.1 Introduction

The control system generates many data files during operations.

Most of the data files are organized by first date and then component. For example, all files for the UTC date YYYYMMDD generated by the sensors component are located in

```
/usr/local/var/tcs/YYYYMMDD/sensors/
```

Some components have subdirectories at the top level for data files that are applicable to more than one night. For example, the selector maintains the alert files in

```
/usr/local/var/tcs/selector/alerts/
```

These files are copied from the control system computers at the telescope to the archive. This is a central NAS on the private transients subnetwork at the OAN. Public access is via SSH, RSYNC, HTTP access to `transients.astrossp.unam.mx`. The NAS is shared by the control system computers and the data pipelines for RATIR, COATLI, DDOTI.

The archive volume on the NAS is mounted on other computers on the transients network at:

```
/nas/archive-coatli/
```

The data files on the control system computers are copied by rsync to the subdirectory `raw` in the archive volume. The log files are copied every minute, the FITS data and header files every five minutes, and the other files every hour.

20.2 Logs

The log files are created under

```
/usr/local/var/tcs/YYYYMMDD/log/
```

They are mainly of interest to the engineering and operations team.

20.3 Image Files

The image files are created under

```
/usr/local/var/tcs/YYYYMMDD/executor/images/
```

The files are created below this directory in subdirectories whose names are the program, block, and visit identifiers. For example, the files for program 2022A-2001, block 10, visit 0 are created in

```
/usr/local/var/tcs/YYYYMMDD/executor/images/2022A-2001/10/0/
```

The base name of each image created by the executor is the UTC time in ISO 8601 basic combined format followed by the channel name (e.g., `C0`, `C1`, `C2`, . . .), followed by a letter indicating the type of exposure (`o` for object, `f` for flat, `b` for bias, and `d` for dark). If the image is a data cube, a further letter `c` follows. In this case, both a normal image and a data cube may be present with identical names except for the letter `c`. The normal image typically representing a quickly flattened version of the data cube. For example,

```
20220405T072311C0o
20220405T072311C0oc
20220405T072341C0b
20220405T072351C0f
20220405T072411C0d
```

For each image there are two files (or four for cubes): the full FITS image compressed losslessly with fpack (with suffix `.fz`) and a text version of the header (with suffix `.fits.txt`). In the text version, each record is separated with a newline character.

20.4 FITS Header Records

The FITS header records are largely self-documented by comments. However, these are the most relevant header records for searching for particular data:

- `DATE-OBS`: The UTC date of the start of the exposure.

- `CCD_NAME`: The channel (e.g., `C0`, `C1`, `C2`, . . .).
- `EXPTIME`: The exposure time (seconds).
- `EXPTYPE`: The exposure type (e.g., `object`, `flat`, `bias`, `dark`).
- `FILTER`: The selected filter name.
- `BINNING`: The detected binning (pixels).
- `READMODE`: The detector read mode.
- `PRPID`: The proposal identifier (integer).
- `BLKID`: The block identifier (integer).
- `VSTID`: The visit identifier (integer).
- `STRSTRA`: The J2000 RA of the target at the start of the exposure (degrees).
- `STRSTDE`: The J2000 declination of the target at the start of the exposure (degrees).
- `STROBHA`: The observed HA of the target at the start of the exposure (degrees).
- `STROBDE`: The observed declination of the target at the start of the exposure (degrees).
- `STROBAZ`: The observed azimuth of the target at the start of the exposure (degrees).
- `STROBZ`: The observed zenith distance of the target at the start of the exposure (degrees).
- `STROBAM`: The observed airmass of the target at the start of the exposure.
- `SMNZD`: The observed zenith distance of the Moon at the start of the exposure (degrees).
- `SMNIL`: The illuminated fraction of the Moon at the start of the exposure.
- `SMNTD`: The distance between the target and the Moon at the start of the exposure (degrees).
- `SSNZD`: The observed zenith distance of the Sun at the start of the exposure (degrees).

For all of the records that begin with `S` and refer to the start of the exposure, there is another record that begins with `E` and refers to the end of the exposure. So, for example, `STROBAM` gives the airmass at the start of the exposure and `ETROBAM` gives the airmass at the end of the exposure.

Part V

Obsolete Components

Appendix A

Covers

The COATLI telescope was originally equipped with M1 covers supplied by ASTELCO and controller by a PLC in a cabinet in the shed. These were removed in October 2017 to reduce wind shake. The cabinet is still installed (as it also contains the secondary controller) and the covers are stored in the COATLI/DDOTI warehouse. This appendix remains as a historic reference.

A.1 Description

The COATLI telescope is protected by covers, supplied by ASTELCO, which close to seal the space over the primary mirror and the primary baffle. These are shown in Figure A.1. The covers are divided into four petals, which open and close in oposite pairs. The covers are opened by Transmotec DLA-24-40-A-50-IP65-NC linear actuators.

The covers can be controller locally or remotely.

The controller for the covers, shown in Figure A.2 is located in a cabinet in the shed. The controller is powered by 220 V 60 Hz from Circuit A via the 220 V UPS and 220 V iBootBar. The covers controller cabinet also houses the focuser controller for the secondary.

The covers should normally be closed while opening or closing the covers, to protect the telescope and instrument.

The covers controller can be in local or remote mode. The mode is selected by the switch on the door of the covers controller in the shed (see Figure A.3). In remote mode

1. The switches on the covers controller to open and close the covers are deactivated.
2. The robotic control system can open and close.

In local mode:

Figure A.1: The covers that protect the telescope and instrument, here shown open.

Figure A.2: The covers controller in the shed, between Box A (left) and the covers controller (right).

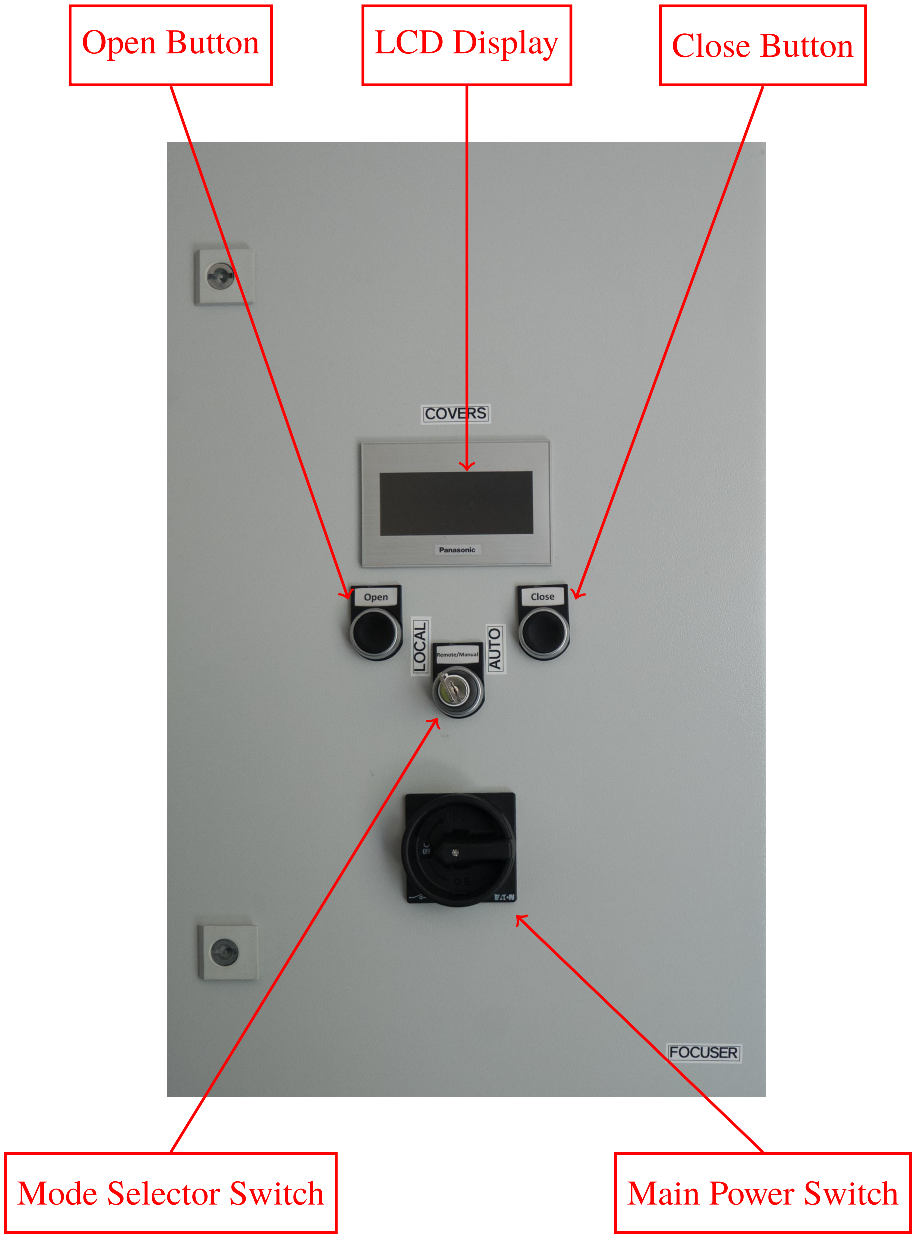

Figure A.3: The covers controller door and control panel. Bottom: the main power switch. Middle, left to right: the open button, the mode selector switch ("LOCAL" and "REMOTE"), and the close button. Top: the LCD display.

1. The switches on the covers controller to open and close the covers are active.
2. The robotic control system cannot open and close.

A.2 Maintenance Procedures

A.2.1 Enabling Remote Mode

Safety Considerations

> *In local mode, the control system can open or close the covers.*

Requirements

You will need:

- One person.
- The key to the shed (see §5.3).

Procedure

1. Go to the shed.
2. Move the main power switch on the covers controller to "ON".
3. Move the mode selector switch on the covers controller door to "REMOTE".

A.2.2 Opening or Closing in Local Mode

Safety Considerations

> *In local mode, the control system cannot open or close the covers.*

> *Before opening the covers, check on the webcams that the covers is not open and the telescope is not pointed to towards the sun. In the home position, the telescope is pointed to the north pole.*

Requirements

You will need:

- One person.
- The key to the shed (see §5.3).

Procedure

1. Go to the shed.
2. Move the main power switch on the covers controller door to “ON”.
3. Move the mode selector switch on the covers controller door to “LOCAL”.
4. To open, press and hold the open button until the LCD display indicates that the covers are open.
5. To close, press and hold the close button until the LCD display indicates that the covers are closed.
6. If you wish to subsequently operate the covers remotely, move the mode selector switch to “REMOTE”.

A.3 Remote Interface

A.3.1 Lantronix EDS

The RS-232 interface to the covers controller is made available via the Lantronix EDS 4100 ethernet-to-serial converter. Specifically, it is connected to line 1 and configured 9600/8-N-1 with a tunnel on TCP port 10001.

The Lantronix EDS is on the LAN at `serial`.

A.3.2 ADAM Modules

Remote control of the covers is through an ADAM-4055 digital input/output module. The input and output channels of the ADAM-4055 module are connected to the covers controller PLC.

The RS-485 serial interface of the ADAM-4055 is exposed via an ADAM-4520 RS-232 to RS-485 converter and isolator as RS-232 at 9600/8-N-1.

The state of the input and output channels can be determined either from the web interface (the “Input Channels” and “Output Channels” variables in the “covers” tab) or by unscrewing the ADAM-4520 RS-232 to RS-485 converter on top of the ADAM-4055 to reveal LEDs which show the state of the channels.

The input channels are:

DI0 Open. 0 = not open and 1 = open. This channel is connected to terminal Y8 on the PLC via relay 8K1.

DI1 Closed. 0 = not closed and 1 = closed. This channel is connected to terminal Y9 on the PLC via relay 8K2.

DI2 Reserved. This channel is connected to terminal YA on the PLC via relay 8K3.

DI3 Mode. 0 = local and 1 = remote. This channel is connected to terminal Yb on the PLC via relay 8K4.

DI4 Not used.

DI5 Not used.

DI6 Not used.

DI7 Not used.

The output channels are:

DO0 Open or close selector. Set to 0 to select open and 1 to select close. Setting this bit does not initiate the movement. This channel is connected to terminal X4 of the PLC.

DO1 Move. Set to 1 to carry out the movement specified by DO0. This channel is connected to terminal X5 of the PLC.

DO2 Reserved. This channel is connected to terminal X6 on the PLC.

DO3 Reserved. This channel is connected to terminal X7 on the PLC.

DO4 Not used.

DO5 Not used.

DO6 Not used.

DO7 Not used.

A.3.3 Diagnostics

To check communication with the Lantronix EDS, from a terminal run:

```
ping serial
```

To check communication with the ADAM modules, from a terminal on `control`, first stop the covers server so that it releases the covers TCP port on the Lantronix EDS:

```
sudo stopserver covers
```

Then connect to the covers TCP port on the Lantronix EDS using telnet:

```
telnet serial 10001
```

You can then send commands to the ADAM-4055. Some useful commands (which should be followed by ENTER) are:

- Command: `$01M`

  Response: `!014055`

  Read Module Name. The response shown above confirms that you are talking to an ADAM-4055.

- Command: `$016`

  Response: `!`$XXYY$`00`

  Digital Data In. The values of the output channels (in upper-case hexadecimal) are given by XX and the values of the input channels (in upper-case hexadecimal) are given by YY.

- Command: `#0100`XX

  Response: >

  Digital Data Out. The output channels are set to XX (in upper-case hexadecimal).

For more details of the commands, see the ADAM-4000 Manual.

You can exit from telnet by typing CTRL-`]` and then `quit`. Once you have done so, you should probably restart the covers server on `control` with:

```
sudo startserver covers
```

A.4 Control

The server for the covers runs on `control`.

The server starts automatically when `control` is rebooted, but if necessary can be stopped, started, or restarted explicitly by issuing the following commands on `control`:

- `sudo stopserver covers`
- `sudo startserver covers`
- `sudo restartserver covers`

Server requests can be issued from any of the Mac or Linux machines on the COATLI LAN. The following requests are supported:

- `request covers initialize`

  Initialize the server and covers hardware. As part of the process of initializing, the covers will close.

  For this request to be accepted, the server activity must not be `starting` or `error`.

  If the request is accepted, the server activity changes to `initializing` and then, once it has initialized, to `idle`.

- `request covers open`

  Open the covers.

  For this request to be accepted, the server activity must not be `starting`, `started`, `initializing`, or `error`.

  If the request is accepted, the server activity changes to `opening` and then, once it has opened, to `idle`.

- `request covers close`

  Close the covers.

  For this request to be accepted, the server activity must not be `starting`, `started`, `initializing`, or `error`.

  If the request is accepted, the server activity changes to `closing` and then, once it has closed, to `idle`.

- `request covers stop`

  Stop the covers.

  For this request to be accepted, the server activity must not be `starting` or `error`.

  If the request is accepted, the server activity changes to `stopping` and then, once it has stopped, to `started` (if the server has not been initialized) or to the activity after the previous completed request.

- `request covers reset`

  Reset an error in the covers.

- `request covers status`

  Show the status of the server.

  Obtain the values of the status data from the server and print them to stdout.

A.5 Bibliography

- Electronic Schematics, ASTELCO, Version 1.1.
- "Lantronix EDS Device Servers/Terminal Servers User Guide", Lantronix, Revision 1 April 2011.
- "ADAM-4000 Data Adquisition Modules User's Guide]", Advantech, Edition 10.5, 2007.
- "Transmotec DLA Series Linear Actuators (2017).

Appendix B

Interim Imager

The COATLI telescope was originally equipped with an interim imager. The imager was removed in January 2020. This appendix remains as a historic reference.

B.1 Introduction

The interim imager is a simple direct imager that will be used for commissioning the telescope and early science pending the delivery of the definitive high-resolution imager. It is based on an air-cooled Finger Lakes Instruments Microline ML3200 detector and a Finger Lakes Instruments CFW-1-5 filter wheel. The wheel accepts five 50 mm diameter filters. We have installed $BVRI$ and clear filters.

B.2 Detector

The interim imager uses a Finger Lakes Instruments Microline ML3200 detector with an Kodak KAF-3200ME CCD. The detector has a thermoelectric cooler and can nominally reach 60 C below ambient. Heat is vented to air via heat exchanger and fan. The detector serial number is ML0053812.

The CCD has 2184×1472 active pixels each 6.8 μm square. It is front-illuminated, but employs a microlens array to boost the fill-factor and quantum efficiency. The detector has two read modes, 1 MHz and 6 MHz. Table B.1 shows detector read performance in each read mode and for binning 1×1 and 2×2.

The full data image from the CCD is 2267×1510. The vertical structure is:

- 34 dark lines
- 1472 photoactive lines
- 4 dark lines

Table B.1: Detector Read Performance

Read Mode (MHz)	Binning Pixels	Gain e^-/DN	Read Noise e^-	Overhead s
1	1×1	6.3	9.4	4.0
1	2×2	6.2	10.7	3.9
6	1×1	6.4	19.5	1.2
6	2×2	6.4	25.8	1.0

Each photoactive line has the following horizontal structure:

- 8 inactive pixels
- 1 photoactive pixel
- 3 inactive pixels
- 34 dark reference pixels
- 2184 photoactive pixels
- 34 dark reference pixels
- 1 photoactive pixel
- 2 inactive pixels

The inactive pixels do not accumulate charge and read only the bias level. The dark reference pixels accumulate only dark current and read the bias level plus the dark level. The photoactive pixels accumulate both dark current and photoelectric current and read the bias level plus the dark level plus the photon signal. The single columns of photoactive pixels close to the start and end of each line are for monitoring horizontal CTE.

The dark lines have a similar structure, with dark reference pixels replacing the photoactive pixels.

The maximum field diameter is 18 mm, which is well within the nominal diffraction-limited field of the telescope of 26 mm. The measured pixel scale is 0.351 arcsec (binned 1×1) and the field is 12.8×8.7 arcmin.

B.3 Filters

We plan to install 5-mm thick BVRI and clear filters. The BVRI filters will be supplied by Custom Scientific. The clear filter will be a window supplied by Edmund Optics.

The detector is a

B.4 Mechanical Design

Figure 1 shows a CAD model of the telescope and the interim instrument. The CAD model of the Astelco RC500 telescope was supplied by Astelco. The CAD model of the instrument was developed in the Instituto de Astronomía of the UNAM.

Figure 1. CAD model of the Astelco RC500 telescope, the interim instrument, the finder, and the electronics cabinet.

Figure 2 shows an exploded view of the components of the interim instrument. Table 1 lists the mechanical components. The total weight of the instrument excluding the filter wheel, filters, and detector is 6.8 kg. When the filter wheel (0.77 kg) and the camera (1.36 kg) are included, the weight rises to 8.93 kg.

Figure 2. Exploded view of the interim instrument.

Table 1. List of mechanical components of the interim instrument.

1.2 Description of the Components. The following is a brief description of each component: 1.- Instrument flange: This is the mechanical interface with the telescope, and permits the interim instrument (and eventually the definitive instrument) to be mounted. The instrument flange will be attached to the telescope flange by six M10x1.5 bolts (part 13) and nuts (part 14). The bolts pass through six smooth, 11 mm diameter holes in the instrument flange. These holes will also serve as templates for the six simular holes that will be drilled in the telescope flange in situ; these holes are not part of the standard telescope design. These holes are shown in Figure 3.

Figure 3. The six holes to be drilled in the telescope flange. .

2.- Extension barrel: The function of this component is simply to serve as an interface between the instrument flange and the filter wheel. The length is chose to place the detector in the nominal focal plane of the telescope, as shown in Figure 4. (See also the diagram "T0500-20 focal plane without corrector 2014-06-06" supplied by Astelco.)

Figure 4. Position of the focal plane of the camera and telescope.

3, 4 y 5: Interface EB/CFW1-5, Interface CFW1-5/Camera and Adapter for centering: These interfaces serve to attach the filter wheel and the camera to the telescope, via the extension barrel. They will be fabricated by a CNC machine. They have a series of through bolts that will act to avoid rotation of the wheel and camera. These bolts are shown in Figure 5. The filter wheel will be modified with six through holes through the outer rim to accomodate these bolts. This modification will not significantly affect the operation or rigidity of the wheel.

Figure 5. The filter wheel between the two interfaces. The Interface CFW1-5/Camera also supports the detector using four bolts with lock washers. These will keep the bolts tight even in the presense of rapid movements by the telescope.

Figure 6. The detector and its interface plate. N.B.: The design uses SS thread-locking inserts. N.B.: The design uses and lock washers, to guard against bolts or nuts coming loose because of vibrations or motion.

2. Finder and Support: 2.1 Overview. The finder is a IDS UI-1540RE-M-GL detector head with a Fujinon HF35HA-1B 35 mm f/1.6 C-mount lens. The detector is an Aptina MT9M001STM CMOS device with a format of 1280 by 1024 and 5.4 micron pixels.

The field is about 9 by 11 degrees and the pixel scale is about 30 arcsec. Figure 7 and Table 2 show the components of the finder and its support.

Figure 7. Exploded view of the finder and its support

Table 2. List of mechanical components of the finder .

2.2 Functional Description. 1.- Holder grip top: This component acts to couple the finder support to the the upper ring of the telescope. The shape of the cut-out follows that of the ring. As shown in Figure 8, in theory the finder can be located at any azimuth, but locating it close to the polar axis is probably beneficial for reasons of torque and balance.

Figure 8. Left: although the finder can be mounted at any azimuth, we plan to mount it closes to the polar axis. Right: the assembly of the holder is straightfoward.

2.- Holder grip bottom: These two identical components are used to firmly attach the Holder grip top to the upper ring. We will use four lock washers (5) between components 1 and 2, as shown in Figure 7.

3.- Camera interface with holder grip: This is a 90 degree bracket, with holes to make it lighter, and two sets of four through holes for bolts. These bolts attach the interface to the holder grip top and to the detector (see Figure 9). Lock washers will be used with the bolts.

Figure 9. The finder detector head and the support.

3. The electronics cabinet support The interim instrument will use one electronics cabinet mounted opposite the dovetail. (The definitive instrument will use two cabinets mounted at 90 and 270 degrees of azimuth from the dovetail.) The electronics cabinet will be bolted to two L brackets, as shown in Figures 10 and 11. The two brackets are similar, with the exception that the lower bracket attaches to two holes on the telescope whereas the upper bracket attaches to three. These holes in the telescope appear in the model supplied by Astelco. We will use five M6x1.0 bolts, nuts, and lock washers. The total weight of the two brackets, bolts, nuts, and washers is 290 g.

Figure 10. Exploded diagram of the electronics cabinet.

Figure 11. The electronics cabinent mounted on the telescope.

The upper bracket has slots which will permit minor adjustments of its position with respect to the cabinet and and the telescope (see Figure 12). They will be attached to the telescope with four M5 bolts.

Figure 12. Slots in the upper bracket will permit fine adjustment.

B.5 Control

The server for C0 runs on `f1`.

It starts automatically when `f1` is rebooted, but if necessary can be stopped, started, or restarted expliciatly by issuing the following commands on `f1`:

- `sudo stopserver C0`

- `sudo startserver C0`
- `sudo restartserver C0`

Server requests can be issued from any of the Mac or Linux machines on the COATLI LAN. The following requests are supported:

- `request C0 movefilterwheel` ⟨filter⟩

  Move the filter wheel to the specified ⟨filter⟩.

  The server activity must be `idle` for this request to be accepted. The server activity changes to `moving` and then, once the filter wheel has finished moving, to `idle`.

  The ⟨state⟩ argument can be:

  - The filter name: `C`, `BB`, `BV`, `BR`, or `BI`.
  - An integer from 0 to 4 specifying the slot number.

- `request C0 setcooler` ⟨state⟩

  Set the cooler to the specified ⟨state⟩.

  The server activity must be `idle` for this request to be accepted. The server activity does not change.

  The ⟨filter⟩ argument can be:

  - a decimal fraction

    Turn on the cooler. Set the cooler set temperature to the value given.

    The initial set temperature is `-30`.
  - `on`

    Turn on the cooler. Do not change the current cooler set temperature.
  - `off`

    Turn off the cooler. Do not change the current cooler set temperature.
  - `following`

    Turn on the cooler. Periodically adjust the cooler set temperature to the value of the detector housing temperature. This setting is intended to extract the heat generated by the CCD electronics without generating excessive waste heat.
  - `open`

    This is an alias currently defined to be for `on`. When the executor server opens the telescope, it requests C0 to use this cooler state.
  - `closed`

    This is an alias currently defined to be `following`. When the executor server closed the telescope, it requests C0 to use this cooler state.

Bibliography

- “FLI MicroLine Drawings for 25-mm Shutter”, 2015.
- “FLI MicroLine Imaging System User’s Guide”, 2009.
- “FLI MicroLine ML3200 Data Sheet”, 2015.
- “Kodak KAF-3200ME Image Sensor”, 2008, Revision 3.0.

Appendix C

The Huitzi $f/8$ Imager

The Huitzi imager was installed on the COATLI telescope in October 2021. The imager is named for the mexica god Huītzilōpōchtli, the son of the goddess Coatlicue.

C.1 Introduction

The Huitzi imager has an Andor iXon electron-multiplying CCD detector with 1024×1024 pixels with a pixel scale of 0.68 arcsec and a field of 11.6 arcmin. The detector can be read through either a conventional amplifier or the electron-multiplying amplifier at a variety of speeds.

The image also has Finger Lakes Instruments CFW-1-8 filter wheel for eight 25 mm diameter filters. At the time of writing, the following filters are installed:

- Pan-STARRS $griz$;
- 470/10, 640/10 continuum;
- 656/3 Hα; and
- a dark filter.

The hardware of the Huitzi instrument is shown in Figure C.1. On the telescope the principal components are the Andor iXon detector and FLI filter wheel. The control electronics are located in the box mounted on the south side of the pillar. The cables pass up onto the telescope through an Igus Triflex chain. The mechanical hardware is adapted from the previous interim imager (see Appendix B).

C.2 Detector

The detector unit is an Andor iXon Ultra 888 with an e2v CCD201-20 electron-multiplying CCD detector. The detector was acquired in 2014 and originally intended to be the tilt sensor for the planned two-channel imager.

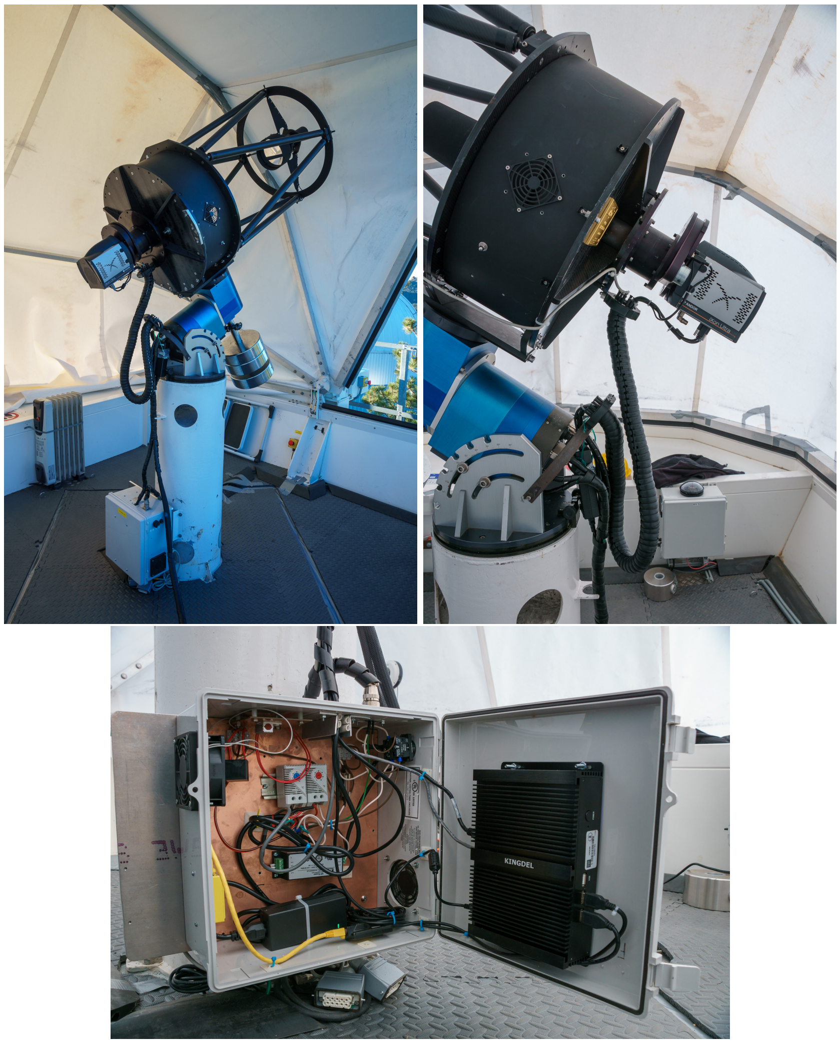

Figure C.1: The Huitzi hardware. On the telescope the principal components are the Andor iXon detector and FLI filter wheel. The control electronics are located in the box mounted on the south side of the pillar. The cables pass up onto the telescope through an Igus Triflex chain.

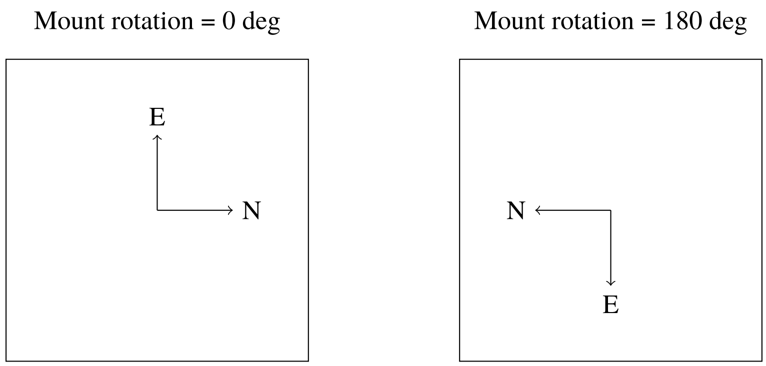

Figure C.2: The orientation of the detector on the sky according to the mount rotation. The pixel origin is in the lower left.

C.2.1 Format, Scale, and Field

The detector has 1024×1024 pixels each 13×13 μm square.

The detector gives a pixel scale of 0.68 arcsec and a field of 11.6 arcmin.

The orientation of the field on the sky depends on the mount rotation (given by the values of the `SMTMRO` and `EMTMRO` keywords in the header), and is shown in Figure C.2. However, the pipeline reduction rotates all images to the conventional orientation with north up and east left.

C.2.2 Quantum Efficiency

The detector has standard silicon and the e2v midband coating (which in Andor's terminology makes it a "BV" device). The nominal quantum efficiency is shown in Figure C.3. The detector has excellent efficiency from 500 to 800 nm.

C.2.3 Readout Architecture

The detector can be read using either a conventional signal chain (at 100 kHz or 1 MHz) or an EM signal chain (at 1, 10, 20, or 30 MHz). Both chains have two gains and the EM gain can be set to up to 1000.

Although the conventional and EM amplifiers clock the serial register in different directions, the control software flips each row in conventional data so that physical pixels have the same logical position in the FITS files.

The detector is used in frame-transfer mode without a mechanical shutter (see §C.2.4). At the end of an exposure, the charge is rapidly clocked into from the light-sensitive image section to the shielded store section. The change can then be read. In EM mode, the next exposure can then start immediately.

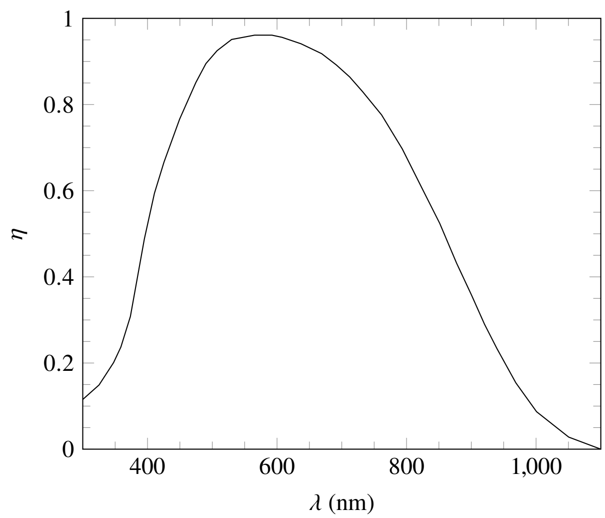

Figure C.3: The nominal quantum efficiency η of the Huitzi detector.

With the normal vertical-shift frequency of 4.33 MHz, the frame transfer takes about 4.5 ms. This leads to some trailing above and below bright stars.

The read-out architecture has several parameters, which are encoded in the value of the `READMODE` header keyword. The value is a string of the form A-B-C-D-E-F-G in which A to G are non-negative integers with the following meanings:

A The ADC channel index. This is always 0 since the detector only has one ADC channel.

B The amplifier index. This is 0 for the EM amplifier and 1 for the conventional amplifier.

C The vertical shift speed index. For both amplifiers, 0 is 0.60 MHz, 1 is 1.13 MHz, 2 is 2.20 MHz, and 3 is 4.33 MHz.

D The horizontal shift speed index. For the EM amplifier, 0 is 30 MHz, 1 is 20 MHz, 2 is 10 MHz, and 3 is 1 MHz. For the conventional amplifier, 0 is 1 MHz and 1 is 100 kHz.

E The gain index. For both amplifiers, 0 is low gain (more electrons per ADU) and 1 is high gain (fewer electrons per ADU).

F The nominal EM gain. This is ignored when the conventional amplifier is used. For the EM amplifier, it can be between 1 and 1000.

G The software gain. After the data are read, each ADU signal is divided by the software gain to reduce white noise in the low-order bits (see Watson 2002, RMAA, 38, 233).

Table C.1: Read-Mode Aliases

Alias	Mode
initial	default
default	em-30MHz
conventionaldefault	1MHz
fastguidingdefault	em-30MHz
1MHz	1MHz-low
em-10MHz	em-10MHz-low
em-20MHz	em-20MHz-low
em-30MHz	em-30MHz-low
1MHz-low	0-1-3-0-0-1-1
1MHz-high	0-1-3-0-1-1-2
em-10MHz-low	0-0-3-2-0-250-2
em-10MHz-high	0-0-3-2-1-160-4
em-20MHz-low	0-0-3-1-0-500-4
em-20MHz-high	0-0-3-1-1-320-8
em-30MHz-low	0-0-3-0-0-1000-8
em-30MHz-high	0-0-3-0-1-640-16

Fortunately, there is little need to use these values directly, since aliases are defined for common modes. They are shown in Table C.1.

C.2.4 Shutter and Dark Filter

The detector has a conventional mechanical iris shutter, but we do not use it as it does not open at low temperature.

We originally attempted to use the mechanical shutter for conventional CCD modes and the frame-transfer capability for EM modes. However, we found that the shutter sometimes failed to open or failed to open completely. We suspect that at the colder temperatures at night, the power supply does not provide sufficient voltage to open the shutter.

Therefore, we now leave the shutter open permanently and use the frame-transfer capability in both conventional and EM modes. As noted above, with the normal vertical-shift frequency, the frame transfer takes about 4.5 ms.

To take bias and dark images, we have installed a “dark” filter (an opaque cylinder of black Delrin 25 mm in diameter and 5 mm thick) in the filter wheel. Despite this, light leaks in the filter wheel mean that we need to take biases and darks at night.

C.3 Filter Wheel

The slots are filled as follows:

Mode Name	1MHz-0	em-10MHz-0	em-20MHz-0	em-30MHz-0
Amplifier	Conventional	EM	EM	EM
Horizontal Speed	1 MHz	10 MHz	20 MHz	30 MHz
Software Gain	1	2	4	8
ADC Range (DN)	64k	32k	16k	8k
Gain (e^-/DN)	3.3	41	78	117
Read Noise (DN)	2.1	2.6	1.9	1.7
Read Noise (e^-)	7	105	145	204
Bias Level (DN)	500	242	123	62
Linear Limit (e^-)		400k	400k	400k
Saturation (DN)	58k	32k	16k	8k
Saturation (e^-)	190k	1300k	1250k	940k
Linearity (e^-)		400k	400k	400k
Linearity (DN)		9700	5100	3400
Dynamic Range (bits)		11.9	11.4	10.9

Table C.2: Detector Characteristics with the Low Preamplifier Gain

Mode Name	1MHz-1	em-10MHz-1	em-20MHz-1	em-30MHz-1
Amplifier	Conventional	EM	EM	EM
Horizontal Speed	1 MHz	10 MHz	20 MHz	30 MHz
Software Gain	2	4	8	16
ADC Range (DN)	32k	16k	8k	4k
Gain (e^-/DN)	1.6	21	45	70
Read Noise (DN)	2.9	2.7	2.4	1.6
Read Noise (e^-)	5	56	108	115
Bias Level (DN)	250	119	62	31
Saturation (DN)	22k			
Saturation (e^-)	35k			
Linearity (e^-)		400k	400k	400k
Linearity (DN)		19000	8900	5700
Dynamic Range (bits)		12.8	11.9	11.8

Table C.3: Detector Characteristics with the High Preamplifier Gain

0: *g*

1: *r*

2: *i*

3: *z*

4: 470/10

5: dark

6: 640/10

7: 656/3

C.4 Filters

C.5 Mounting Hardware

C.6 Control Hardware

C.7 Control Software

C.8 Calibration Data

C.8.1 Biases and Darks

C.8.2 Flats

C.8.3 Gain and Read Noise

The control system does not automatically take data for calibrating the gain and read-noise, but there are blocks that can be executed manually either in evening or morning twilight.

For best results, do this procedure either at the start of evening civil twilight or the start of morning nautical twilight.

The procedure is:

- Make sure the telescope is closed:

  ```
  tcs request supervisor close
  ```

- Unpark the telescope and cool the instrument:

```
tcs request telescope unpark
tcs request instrument open
```

- Wait for the detector to cool to the operating temperature. Then run the morning or evening block, as appropriate:

  ```
  tcs request executor execute block \
    /usr/local/var/tcs/blocks/0013-signal-chain-morning.json
  tcs request executor execute block \
    /usr/local/var/tcs/blocks/0013-signal-chain-evening.json
  ```

  The difference between the blocks is that in the morning the block takes biases and then flats, whereas in the evening it takes flats and then biases.

- One the block has finished, close the telescope again by running:

  ```
  tcs request executor close
  ```

For these data:

- The program identifier is 0013.
- The block identifier is 0 for the morning and 1 for the evening.
- Visit 0 is for readmode "1MHz-low" and visit 1 is for readmode "1MHz-high".

In each readmode, the block takes 10 biases and attempts to obtain 10 flats with levels suitable for determining the gain. These flats will normally be the last 10 flats, as the block waits for the signal in the flat to be in a suitable range.

The dome lights should not be switched on during this process. If they are, then the biases will be contaminated with light, since the dark filter has light leaks, and the flats will be saturated. Note that sometimes the technical staff switch the lights on in the morning to check that the enclosures have closed, so you should warn them in the chat that you are taking calibration data and that they should not do this.

C.9 Maintenance Procedures

C.9.1 Dismounting and Mounting the Instrument

Requirements

You will need:

- Two persons.
- The key to the shed (see §5.7).
- 4 mm and 2 mm hex keys
- 5/16 inch hex key.

Figure C.4: The detector power button.

Dismounting the Imager

1. Go to the shed. Put on harnesses and helmets. Move the enclosure switch to LOCAL. Open the enclosure to 60 degrees. Ascend to the platform.

2. Move the telescope to the home position (above the mount and pointed at the north pole). To do this, press the brake button and move the telescope by hand. This is important, as after the instrument is removed the telescope will not be balanced.

3. Turn off the detector by pressing the power button on its underside. See Figure C.4.

4. Disconnect the four cables: detector USB and power and filter wheel USB and power (see Figure C.5).

5. Dismount the filter wheel and detector by removing the six screws that hold them to the separator barrel. See Figure C.6. Use a 4 mm hex key. One person should support the filter wheel and detector while the other removes the screws.

6. Place the filter wheel and detector in a safe place resting on the rear surface of the detector. The covered end of the enclosure is ideal. See Figure C.7.

7. If you do not need to operate the instrument when dismounted, skip this step.

   If you do need to operate the instrument when dismounted, the easiest approach is place the instrument on the steps just to the south of the columm. Be careful that the steps do not penetrate the duct-taped gap between the column and the platform. Then, disconnect the Igus Triflex chain from the telescope and remove

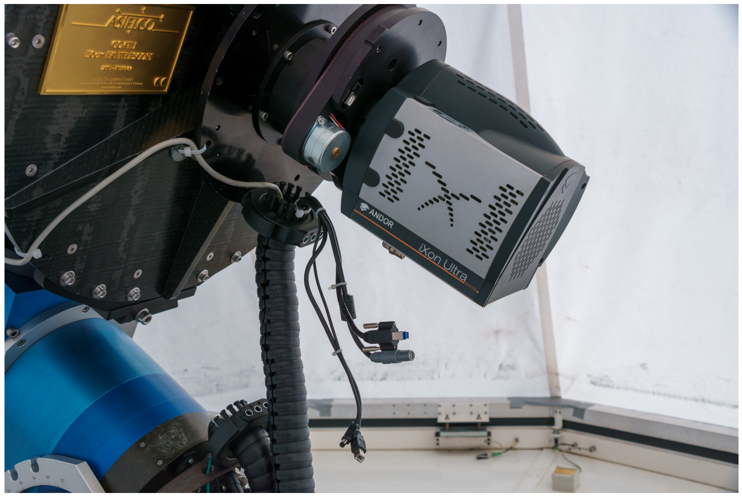

Figure C.5: The disconnected detector and filter wheel USB and power cables.

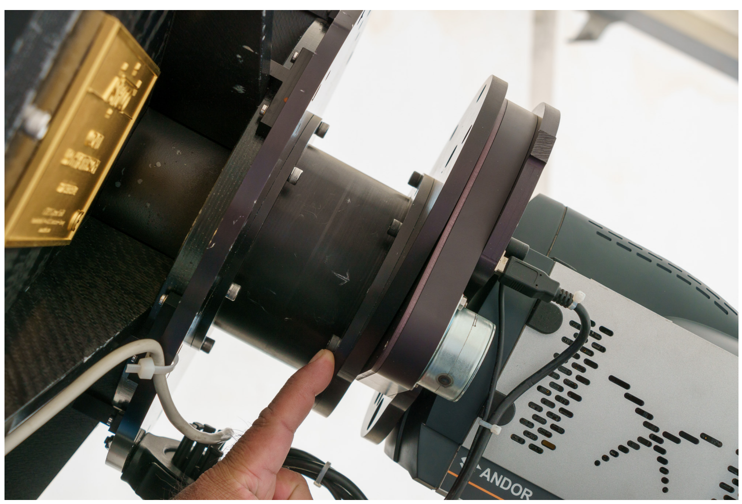

Figure C.6: The six screws that hold the filter wheel and detector to the separator barrel. Note the arrow scratched on the separator barrel that aligns with a similar barrel on the front filter wheel plate.

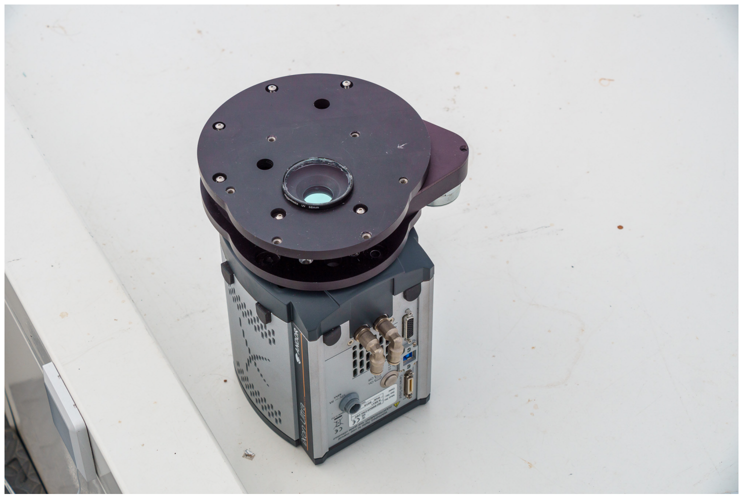

Figure C.7: The dismounted detector and filter wheel resting on the rear surface of the detector. The six screws that hold the filter wheel between the front and rear plates can be seen here.

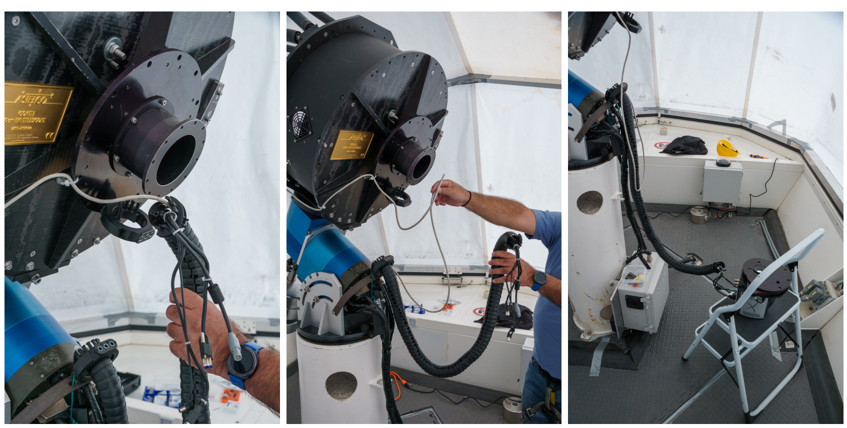

Figure C.8: Operating the instrument off the telescope. Disconnect the Igus Triflex chain, remove the white secondary cable, connect the instrument, and press the power button on the detector..

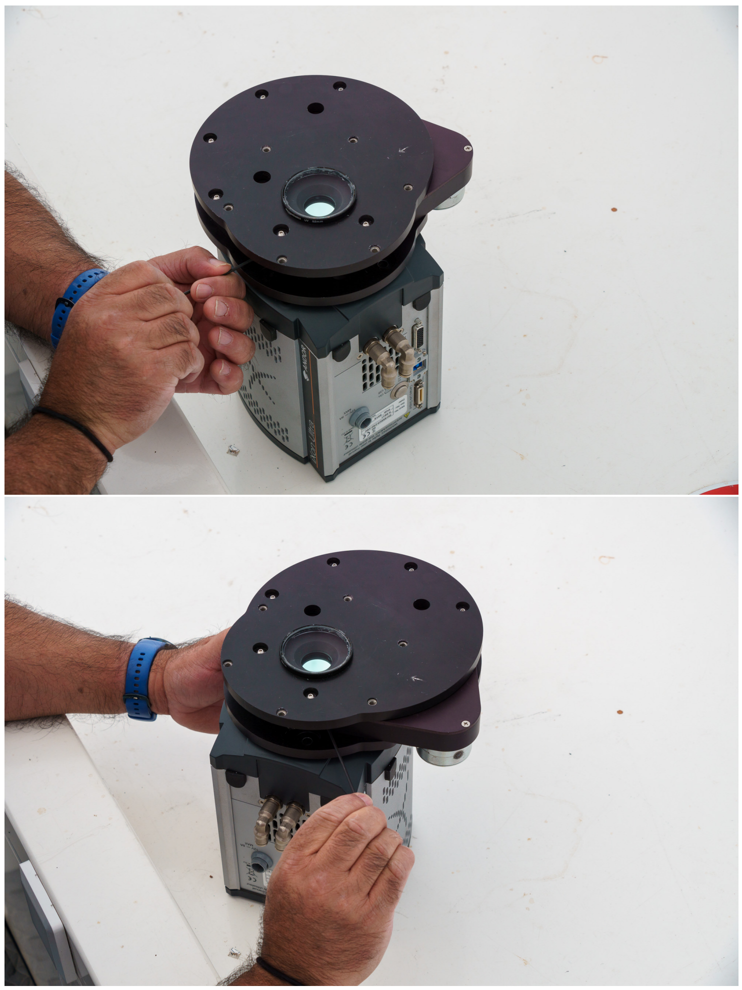

Figure C.9: The two set screws in the filter wheel.

Figure C.10: The detector and filter wheel without the front plate.

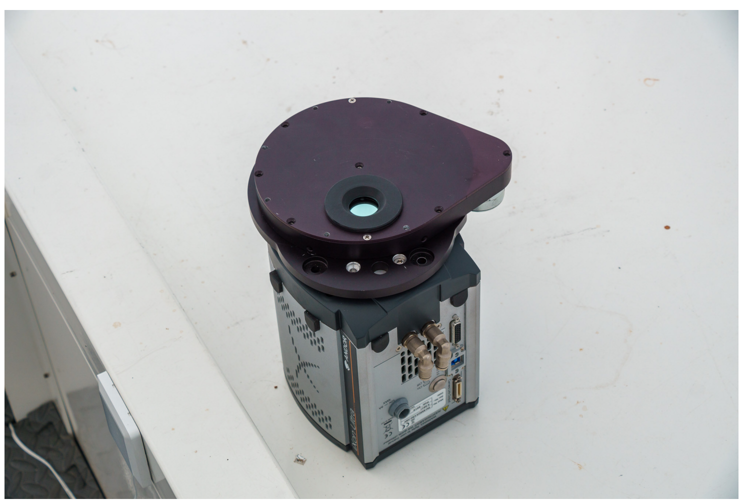

Figure C.11: The detector and filter wheel without the spacer.

Figure C.12: The detector without the filter wheel, revealing the rear plate and the rear light baffle cone.

Figure C.13: The detector without the rear light baffle cone. The four screws that hold the rear plate to the detector can be seen here. Note that the holes for the screws are indicated with scratched lines.

the white secondary cable. Finally, connect the detector and filter wheel cables to the instrument and press the power button on the detector. See Figure C.8.

8. If you do not need access to the filter wheel and/or detector, stop here. If you do, continue.

9. Remove the two set screws between the filter wheel and the detector. Use a 5/16 inch hex key. See Figure C.9.

10. Remove the the six screws that pass from the front plate, through the wheel, and into the rear plate. Use a 2 mm hex key. See Figure C.7.

11. Remove the front plate to expose the filter wheel and spacer. See Figure C.10.

12. Remove the spacer to expose the filter wheel. See Figure C.11.

13. Remove the filter wheel. See Figure C.12.

14. If you do not need access to the detector, stop here. If you do, continue.

15. Remove the rear light baffle cone from the rear plate. It is held in place by friction. See Figure C.12.

16. Remove the four screws that hold the rear plate to the detector flange. Use a 4 mm hex key. See Figure C.13.

Mounting the Imager

1. Go to the shed. Put on harnesses and helmets. Move the enclosure switch to LOCAL. Open the enclosure to 60 degrees. Ascend to the platform.

2. Replace the four screws that hold the rear plate to the detector flange. Use a 4 mm hex key. The correct holes for the screws are indicated with scratches on the rear plate. Note the orientation of the plate. See Figure C.13.

3. Replace the rear light baffle cone from the rear plate.See Figure C.12.

4. Replace the filter wheel. See Figure C.12.

5. Replace the spacer. See Figure C.10.

6. Replace the front plate. See Figure C.7.

7. Replace the the six screws that pass from the front plate, through the wheel, and into the rear plate. Use a 2 mm hex key. See Figure C.7.

8. Replace the two set screws between the filter wheel and the detector. Use a 5/16 inch hex key. See Figure C.9.

9. Mount the filter wheel and detector by replacing the six screws that hold them to the separator barrel. See Figure C.6. Use a 4 mm hex key. One person should support the filter wheel and detector while the other replaced the screws. Note the orientation of the filter wheel and detector. The arrows scratched on the separator barrel and front plate should be aligned.

10. Connect the four cables: detector USB and power and filter wheel USB and power (see Figure C.5).

11. Turn on the detector by pressing the power button on its underside. See Figure C.4.

C.9.2 Changing a Filter

Requirements

You will need:

- Two persons.
- The key to the shed.
- 4 mm and 2 mm hex keys (to dismount and mount the instrument).
- 5/16 inch hex key (to dismount and mount the instrument).
- A clean plastic bag to transport the filter wheel. There are bags in the COATLI/DDOTI tool cabinet.
- PH1 screwdriver.
- Tweezers
- Nitrile gloves
- If replacing a 5 mm filter with a 3 mm filter, one of the 25 mm O-rings supplied with the filter wheel.

Procedure

> *Filters are delicate optical components. Work in the laminar-flow cabinet at the 2.1 meter. Handle them by their edges. They should only be cleaned by optical engineers.*

> *Do not remove dust from filters by blowing them with compressed air from a compressor, cylinder, or can, as these sources can contain oil. Only use a hand blower (perilla).*

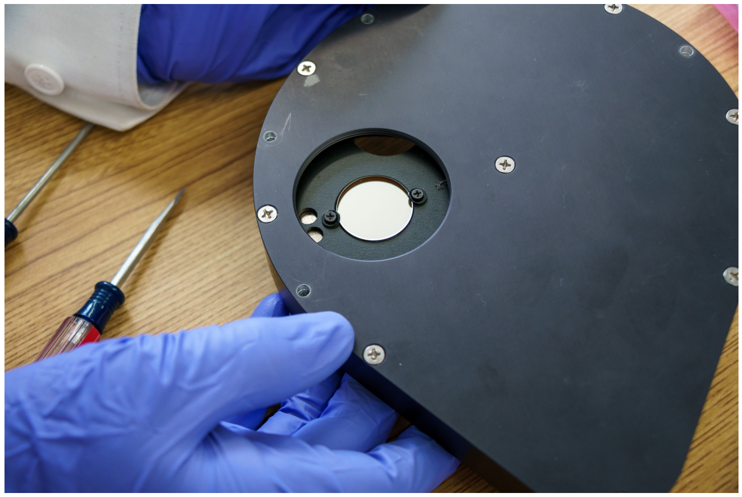

Figure C.14: The filter wheel. There are 8 filter slots, labelled 0 to 7. The filter wheel can be moved by hand.

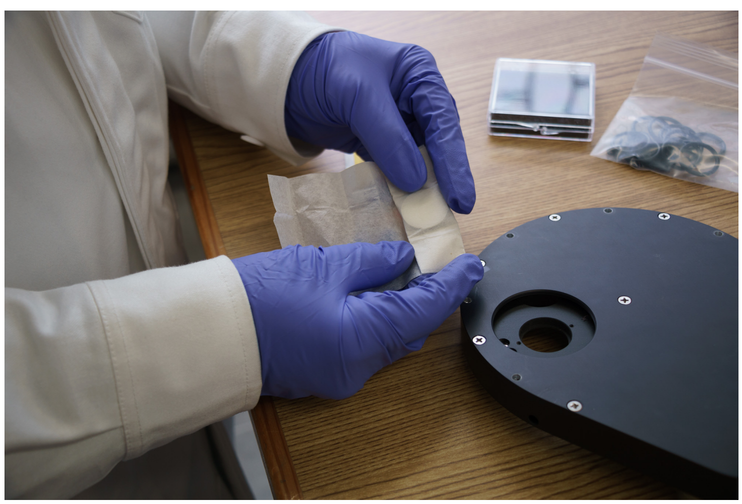

Figure C.15: The filters are wrapped in optical paper.

Figure C.16: The filters are protected by cases like this one.

Figure C.17: The difference in thickness between the 3 mm and 5 mm thick filters is compensated by an O-ring.

1. Remove the filter wheel from the instrument. See §C.9.1.
2. Place the filter wheel in the clean plastic bag. Take the filter wheel to the optical workshop at the 2.1 meter. Replace the filters in the laminar-flow cabinet to avoid dust.
3. Use nitrile gloves.
4. Move the filter wheel by hand to expose the correct filter. See Figure C.14. The 8 filter slots are labelled from 0 to 7.
5. Remove the two screws and washers that hold the filter in place. See Figure C.14. Use the PH1 screwdriver and the tweezers.
6. Use one finger to push the filter from below and the other hand to remove the filter.
7. Wrap the filter in optical paper (which should be in its box). See Figure C.15.
8. Replace the filter in its case. See Figure C.16.
9. If you are replacing a 5 mm thick filter ($griz$ and $BVRI$) with a 3 mm thick filter (the medium-band XXX/10 and narrow-band XXX/3 filters), place a 25 mm O-ring in the filter slot. See Figure C.17.

   If you are replacing a 3 mm thick filter with a 5 mm filter, remove the 25 mm O-ring from the slot and store it the ziploc bag that contains the others.
10. Place the filter in the slot. For interference filters (all but $BVRI$), the bandpass coating (which will often appear to be reflective) should be on the side towards the filter wheel motor. This is down in the orientation shown in C.14 but up once the filter wheel is installed on the telescope.
11. Replace the two screws and washers that hold the filter in place. See Figure C.14. Use the PH1 screwdriver and the tweezers. The washers should make contact with the filter. We find it is easiest to insert both screws first without tightening either and then tighten each in turn. You can use tweezers to make sure the washers are positioned correctly.
12. If necessary, use a hand blower (perilla) to remove dust from the filter surfaces.
13. Make sure the filter wheel can turn without the screws interfering with the casing. Do this by turning the filter wheel by hand.
14. Place the filter wheel in the clean plastic bag. Return it to the platform.
15. Replace the filter wheel in the instrument. See §C.9.1.

C.10 Bibliography

- "Andor iXon Ultra 888 Data Sheet", Andor, May 2014.
- "Andor iXon Ultra & Life 888 Hardware Guide", Andor, Version 1.8 of 30 September 2019.
- "CCD201-20 Datasheet", Teledyne e2v, Version 7 of August 2019.