# IM(G): One time ComCam Image Ingestion and MTAOS Correction

This notebook is used to execute the LVV-T2228 (1.0) test script during System Spread Integration Tests on Level 3.
It is part of the plan LVV-P81 and of the test cycle LVV-C176.
Execution steps are separated by horizontal lines.
Upon completion, save the notebook and its output as a pdf file to be attached to the test execution in JIRA.

In summary, you slew to a target and start tracking. Then you find the Wavefront Error as Zernike Coefficients,
convert them to corrections to be applied to M1M3, M2, Camera Hexapod and M2 Hexapod.
Finally you stop tracking.

In [1]:
```
from lsst.ts import utils
import yaml


# Extract your name from the Jupyter Hub
__executed_by__ = os.environ["JUPYTERHUB_USER"]

# Extract execution date
__executed_on__ = utils.astropy_time_from_tai_unix(utils.current_tai())
__executed_on__.format = "isot"

# This is used later to define where Butler stores the images
summit = os.environ["LSST_DDS_PARTITION_PREFIX"] == "summit"

print(f"\nExecuted by {__executed_by__} on {__executed_on__}."
      f"\n  At the summit? {summit}")
```

```
lsst.ts.utils.tai INFO: Update leap second table
lsst.ts.utils.tai INFO: current_tai uses the system TAI clock
Executed by b1quint on 2022-05-18T19:20:16.687.
  At the summit? True
```

---

## Initial Setup

log onto the summit nublado
https://summit-lsp.lsst.codes/
git clone the ts_notebook repo

There will be a series of procedures to set up, "slew" and track the telescope before we get an image.
This is similar to test case LVV-T2189.

---

## Check ComCam Playback Mode

Verify that ComCam can be use the playback option and that the required images are stored in the right place **TBD**.

---

## Load all the needed libraries

Using the setup procedure, get the remotes and the components ready.

This includes simulators as well as real hardware when available (this will depend on when the test is conducted at NCSA or on level 3 or on the telescope):

- pointing
- mount ( with the CCW)
- rotator
- ready M1M3: raise mirror, turn on FB, clear forces. Note that if used at level 3, we need to have M1M3 LUT use mount telemetry
- ready M2: turn on FB, clear forces. Note that if used at level 3, we need to have M2 LUT use mount telemetry
- Get cam hex Ready: check config; make sure LUT is on and has valid inputs; make sure hex is at LUT position
- Get M2 hex (simulator) Ready: check config; make sure LUT is on and has valid inputs; make sure hex is at LUT position
- Finally, get the MTAOS CSC ready

In [2]:
```
%load_ext autoreload
%autoreload 2
```

In [3]:
```
import rubin_jupyter_utils.lab.notebook as nb
nb.utils.get_node()
```

```
/tmp/ipykernel_10440/1665379685.py:2: DeprecationWarning: Call to deprecated f
unction (or staticmethod) get_node. (Please use lsst.rsp.get_node())
  nb.utils.get_node()
```

Out[3]:
```
'yagan03'
```

In [4]:
```
import os
import sys
import asyncio
import logging

import pandas as pd
import numpy as np
```

```
from matplotlib import pyplot as plt

import lsst.daf.butler as dafButler

from lsst.ts import salobj
from lsst.ts.observatory.control.maintel import MTCS, ComCam
from lsst.ts.observatory.control import RotType
```

```
WARNING: version mismatch between CFITSIO header (v4.000999999999999) and link
ed library (v4.01).


WARNING: version mismatch between CFITSIO header (v4.000999999999999) and link
ed library (v4.01).


WARNING: version mismatch between CFITSIO header (v4.000999999999999) and link
ed library (v4.01).
```

In [5]:
```
logging.basicConfig(format="%(name)s:%(message)s", level=logging.DEBUG)
```

In [6]:
```
log = logging.getLogger("setup")
log.level = logging.DEBUG
```

In [7]:
```
domain = salobj.Domain()
```

In [8]:
```
mtcs = MTCS(domain=domain, log=log)
mtcs.set_rem_loglevel(40)
```

```
setup.MTCS DEBUG: mtmount: Adding all resources.
setup.MTCS DEBUG: mtptg: Adding all resources.
setup.MTCS DEBUG: mtaos: Adding all resources.
setup.MTCS DEBUG: mtm1m3: Adding all resources.
setup.MTCS DEBUG: mtm2: Adding all resources.
setup.MTCS DEBUG: mthexapod_1: Adding all resources.
setup.MTCS DEBUG: mthexapod_2: Adding all resources.
setup.MTCS DEBUG: mtrotator: Adding all resources.
setup.MTCS DEBUG: mtdome: Adding all resources.
setup.MTCS DEBUG: mtdometrajectory: Adding all resources.
```

In [9]:
```
await mtcs.start_task
```

```
MTHexapod INFO: Read historical data in 0.08 sec
MTHexapod INFO: Read historical data in 0.10 sec
```

Out[9]:
```
[None, None, None, None, None, None, None, None, None, None]
```

```
MTHexapod.electrical WARNING: tel_electrical DDS read queue is filling: 13
 of 100 elements
```

In [10]:
```
comcam = ComCam(domain=domain, log=log)
comcam.set_rem_loglevel(40)
```

```
setup.ComCam DEBUG: cccamera: Adding all resources.
setup.ComCam DEBUG: ccheaderservice: Adding all resources.
setup.ComCam DEBUG: ccoods: Adding all resources.
```

In [11]:
```
await comcam.start_task
```

```
MTHexapod.electrical WARNING: tel_electrical DDS read queue is filling: 13
 of 100 elements
MTHexapod.actuators WARNING: tel_actuators DDS read queue is filling: 12 of
100 elements
MTHexapod.application WARNING: tel_application DDS read queue is filling: 2
8 of 100 elements
MTHexapod.actuators WARNING: tel_actuators DDS read queue is filling: 28 of
100 elements
```

Out[11]:
```
[None, None, None]
```

In [12]:
```
await comcam.enable()
```

```
setup.ComCam INFO: Enabling all components
setup.ComCam DEBUG: Expand overrides None
setup.ComCam DEBUG: Complete overrides: {'cccamera': '', 'ccheaderservice':
'', 'ccoods': ''}
CCCamera.logevent_heartbeat ERROR: evt_heartbeat DDS read queue is full (10
0 elements); data may be lost
setup.ComCam ERROR: Unable to transition cccamera to <State.ENABLED: 2> Non
eType: None
.
Traceback (most recent call last):
  File "/opt/lsst/software/stack/conda/miniconda3-py38_4.9.2/envs/lsst-scip
ipe-3.0.0/lib/python3.8/site-packages/lsst/ts/salobj/csc_utils.py", line 15
7, in set_summary_state
    await cmd.start(timeout=timeout)
  File "/opt/lsst/software/stack/conda/miniconda3-py38_4.9.2/envs/lsst-scip
ipe-3.0.0/lib/python3.8/site-packages/lsst/ts/salobj/topics/remote_command.
py", line 485, in start
    return await cmd_info.next_ackcmd(timeout=timeout)
  File "/opt/lsst/software/stack/conda/miniconda3-py38_4.9.2/envs/lsst-scip
ipe-3.0.0/lib/python3.8/site-packages/lsst/ts/salobj/topics/remote_command.
py", line 195, in next_ackcmd
    raise base.AckError(msg="Command failed", ackcmd=ackcmd)
lsst.ts.salobj.base.AckError: msg='Command failed', ackcmd=(ackcmd private_
seqNum=484733883, ack=<SalRetCode.CMD_NOPERM: -300>, error=0, result='Ack :
NO Command not accepted in State{SummaryState = ENABLED}')

The above exception was the direct cause of the following exception:

Traceback (most recent call last):
  File "/opt/lsst/software/stack/conda/miniconda3-py38_4.9.2/envs/lsst-scip
ipe-3.0.0/lib/python3.8/site-packages/lsst/ts/salobj/csc_utils.py", line 15
9, in set_summary_state
    raise RuntimeError(
RuntimeError: Error on cmd=cmd_enable, initial_state=1: msg='Command faile
d', ackcmd=(ackcmd private_seqNum=484733883, ack=<SalRetCode.CMD_NOPERM: -3
00>, error=0, result='Ack : NO Command not accepted in State{SummaryState =
ENABLED}')
setup.ComCam DEBUG: [ccheaderservice]::[<State.ENABLED: 2>]
setup.ComCam DEBUG: [ccoods]::[<State.ENABLED: 2>]
```

```
---------------------------------------------------------------------------
RuntimeError                              Traceback (most recent call last)
Input In [12], in <cell line: 1>()
----> 1 await comcam.enable()

File ~/auto-op-env-packages/ts_observatory_control/python/lsst/ts/observatory/
control/remote_group.py:836, in RemoteGroup.enable(self, overrides)
    832 self.log.info("Enabling all components")
    834 complete_overrides = await self.expand_overrides(overrides)
--> 836 await self.set_state(salobj.State.ENABLED, overrides=complete_override
s)

File ~/auto-op-env-packages/ts_observatory_control/python/lsst/ts/observatory/
control/remote_group.py:732, in RemoteGroup.set_state(self, state, overrides,
 components)
    729         self.log.debug(f"[{comp}]::{ret_val[i]!r}")
    731 if error_flag:
--> 732     raise RuntimeError(
    733         f"Failed to transition {failed_components} to "
    734         f"{salobj.State(state)!r}."
    735     )
    736 else:
    737     self.log.info(f"All components in {salobj.State(state)!r}.")

RuntimeError: Failed to transition ['cccamera'] to <State.ENABLED: 2>.
```

In [13]:
```
await mtcs.enable()
```

```
setup.MTCS INFO: Enabling all components
setup.MTCS DEBUG: Expand overrides None
setup.MTCS DEBUG: Complete overrides: {'mtmount': '', 'mtptg': '', 'mtaos':
'', 'mtm1m3': '', 'mtm2': '', 'mthexapod_1': '', 'mthexapod_2': '', 'mtrota
tor': '', 'mtdome': '', 'mtdometrajectory': ''}
setup.MTCS DEBUG: [mtmount]::[<State.ENABLED: 2>]
setup.MTCS DEBUG: [mtptg]::[<State.ENABLED: 2>]
setup.MTCS DEBUG: [mtaos]::[<State.ENABLED: 2>]
setup.MTCS DEBUG: [mtm1m3]::[<State.ENABLED: 2>]
setup.MTCS DEBUG: [mtm2]::[<State.ENABLED: 2>]
setup.MTCS DEBUG: [mthexapod_1]::[<State.ENABLED: 2>]
setup.MTCS DEBUG: [mthexapod_2]::[<State.ENABLED: 2>]
setup.MTCS DEBUG: [mtrotator]::[<State.ENABLED: 2>]
setup.MTCS DEBUG: [mtdome]::[<State.ENABLED: 2>]
setup.MTCS DEBUG: [mtdometrajectory]::[<State.ENABLED: 2>]
setup.MTCS INFO: All components in <State.ENABLED: 2>.
```

---

## Slew and Track

Using the slew procedure, slew the systems to a specific elevation, azimuth and rotator angle. Verify that the telemetry is generated.

Slew to **RA 20:28:18.74** and **DEC -87:28:19.9** with **rot_type=RotType.Physical** and **Rotator Angle of 0º**. We use this field because it is the field that was simulated and that is a

field that is visible the whole year.

RotType Physical Ensures that the Rotator will not move. This is necessary because the CCW is not running (MTmount in simulation mode).

Slew to target:

In [14]:
```
await mtcs.slew_icrs(ra="20:28:18.74", dec="-87:28:19.9", rot_type=RotType.Sky,
```

```
setup.MTCS DEBUG: RotSky = 0.0 deg, RotPhys = -30.610835684886297 deg.
MTHexapod.electrical WARNING: tel_electrical DDS read queue is filling: 13
 of 100 elements
MTHexapod.application WARNING: tel_application DDS read queue is filling: 1
3 of 100 elements
MTHexapod.actuators WARNING: tel_actuators DDS read queue is filling: 12 of
100 elements
setup.MTCS DEBUG: Wait 5.0s for rotator to settle down.
setup.MTCS DEBUG: Workaround for rotator trajectory problem. Moving rotator
to its current position: 1.11
setup.MTCS DEBUG: Wait for MTRotator in position event.
setup.MTCS DEBUG: MTRotator in position: False.
setup.MTCS INFO: MTRotator in position: True.
setup.MTCS DEBUG: MTRotator in position True. Waiting settle time 5.0s
setup.MTCS DEBUG: Sending slew command.
setup.MTCS DEBUG: Scheduling check coroutines
setup.MTCS DEBUG: process as completed...
setup.MTCS DEBUG: Monitor position started.
setup.MTCS DEBUG: Waiting for Target event from mtmount.
setup.MTCS DEBUG: mtmount: <State.ENABLED: 2>
setup.MTCS DEBUG: mtptg: <State.ENABLED: 2>
setup.MTCS DEBUG: mtaos: <State.ENABLED: 2>
setup.MTCS DEBUG: mtm1m3: <State.ENABLED: 2>
setup.MTCS DEBUG: mtm2: <State.ENABLED: 2>
setup.MTCS DEBUG: mthexapod_1: <State.ENABLED: 2>
setup.MTCS DEBUG: mthexapod_2: <State.ENABLED: 2>
setup.MTCS DEBUG: mtrotator: <State.ENABLED: 2>
setup.MTCS DEBUG: mtdome: <State.ENABLED: 2>
setup.MTCS DEBUG: mtdometrajectory: <State.ENABLED: 2>
setup.MTCS DEBUG: Wait for mtmount in position events.
setup.MTCS DEBUG: Wait for dome in position event.
setup.MTCS DEBUG: Wait for MTRotator in position event.
setup.MTCS DEBUG: MTRotator in position: True.
setup.MTCS DEBUG: MTRotator already in position. Handling potential race co
ndition.
setup.MTCS DEBUG: Wait for MTMount elevation in position event.
setup.MTCS DEBUG: MTMount elevation in position: True.
setup.MTCS DEBUG: MTMount elevation already in position. Handling potential
race condition.
setup.MTCS DEBUG: Wait for MTMount azimuth in position event.
setup.MTCS DEBUG: MTMount azimuth in position: True.
```

```
setup.MTCS DEBUG: MTMount azimuth already in position. Handling potential r
ace condition.
setup.MTCS DEBUG: Mount target: private_revCode: bdcb00ba, private_sndStam
p: 1652901661.004253, private_rcvStamp: 1652901661.0044498, private_seqNum:
86750, private_identity: MTMount, private_origin: 35669, elevation: 28.0891
6709725511, elevationVelocity: -0.00010336337104704403, azimuth: 181.642504
10511298, azimuthVelocity: -0.00018075154970772142, taiTime: 1652901661.063
5624, trackId: 1, tracksys: SIDEREAL, radesys: ICRS, priority: 0
setup.MTCS INFO: MTMount elevation in position: False.
setup.MTCS INFO: MTMount azimuth in position: False.
setup.MTCS INFO: MTRotator in position: False.
setup.MTCS DEBUG: [Tel]: Az = +119.399[ +62.2]; El = +060.740[ -32.7] [Ro
t]: +001.113[  -0.0] [Dome] Az = +000.000; El = +000.000
setup.MTCS DEBUG: Dome azimuth in position.
setup.MTCS DEBUG: Dome elevation in position.
setup.MTCS DEBUG: [Tel]: Az = +162.756[ +18.9]; El = +039.066[ -11.0] [Ro
t]: +013.423[  -0.0] [Dome] Az = +000.000; El = +000.000
setup.MTCS INFO: MTMount azimuth in position: True.
setup.MTCS DEBUG: MTMount azimuth in position True. Waiting settle time 3.0
s
setup.MTCS INFO: MTMount elevation in position: True.
setup.MTCS DEBUG: MTMount elevation in position True. Waiting settle time
 3.0s
setup.MTCS WARNING: mtrotator not in <State.ENABLED: 2>: <State.FAULT: 3>
```

```
---------------------------------------------------------------------------
RuntimeError                              Traceback (most recent call last)
Input In [14], in <cell line: 1>()
----> 1 await mtcs.slew_icrs(ra="20:28:18.74", dec="-87:28:19.9", rot_type=Rot
Type.Sky, rot=0)

File ~/auto-op-env-packages/ts_observatory_control/python/lsst/ts/observatory/
control/base_tcs.py:590, in BaseTCS.slew_icrs(self, ra, dec, rot, rot_type, ta
rget_name, dra, ddec, offset_x, offset_y, az_wrap_strategy, time_on_target, sl
ew_timeout, stop_before_slew, wait_settle)
    585     valid_rottypes = ", ".join(repr(rt) for rt in RotType)
    586     raise RuntimeError(
    587         f"Unrecognized rottype {rot_type}. Should be one of {valid_rot
types}"
    588     )
--> 590 await self.slew(
    591     radec_icrs.ra.hour,
    592     radec_icrs.dec.deg,
    593     rotPA=rot_angle.deg,
    594     target_name=target_name,
    595     frame=self.CoordFrame.ICRS,
    596     epoch=2000,
    597     equinox=2000,
    598     parallax=0,
    599     pmRA=0,
    600     pmDec=0,
    601     rv=0,
    602     dRA=dra,
    603     dDec=ddec,
    604     rot_frame=rot_frame,
    605     rot_track_frame=rot_track_frame,
    606     az_wrap_strategy=az_wrap_strategy,
    607     time_on_target=time_on_target,
    608     rot_mode=self.RotMode.FIELD,
    609     slew_timeout=slew_timeout,
    610     stop_before_slew=stop_before_slew,
    611     wait_settle=wait_settle,
    612     offset_x=offset_x,
    613     offset_y=offset_y,
    614 )
    616 return radec_icrs, rot_angle

File ~/auto-op-env-packages/ts_observatory_control/python/lsst/ts/observatory/
control/base_tcs.py:762, in BaseTCS.slew(self, ra, dec, rotPA, target_name, fr
ame, epoch, equinox, parallax, pmRA, pmDec, rv, dRA, dDec, rot_frame, rot_trac
k_frame, rot_mode, az_wrap_strategy, time_on_target, slew_timeout, stop_before
_slew, wait_settle, offset_x, offset_y)
    755 getattr(self.rem, self.ptg_name).cmd_poriginOffset.set(
    756     dx=offset_x * self.plate_scale,
    757     dy=offset_y * self.plate_scale,
    758     num=0,
    759 )
    761 try:
--> 762     await self._slew_to(
    763         getattr(self.rem, self.ptg_name).cmd_raDecTarget,
    764         slew_timeout=slew_timeout,
    765         offset_cmd=getattr(self.rem, self.ptg_name).cmd_poriginOffset,
    766         stop_before_slew=stop_before_slew,
    767         wait_settle=wait_settle,
    768     )
```

```
    769 except salobj.AckError as ack_err:
    770     self.log.error(
    771         f"Command to track target {target_name} rejected: {ack_err.ack
cmd.result}"
    772     )

File ~/auto-op-env-packages/ts_observatory_control/python/lsst/ts/observatory/
control/maintel/mtcs.py:289, in MTCS._slew_to(self, slew_cmd, slew_timeout, of
fset_cmd, stop_before_slew, wait_settle, check)
    284         getattr(self.rem, comp).evt_summaryState.flush()
    285         self.scheduled_coro.append(
    286             asyncio.create_task(self.check_component_state(comp))
    287         )
--> 289 await self.process_as_completed(self.scheduled_coro)

File ~/auto-op-env-packages/ts_observatory_control/python/lsst/ts/observatory/
control/remote_group.py:1075, in RemoteGroup.process_as_completed(self, tasks)
   1073 except Exception as e:
   1074     await self.cancel_not_done(tasks)
-> 1075     raise e
   1076 else:
   1077     await self.cancel_not_done(tasks)

File ~/auto-op-env-packages/ts_observatory_control/python/lsst/ts/observatory/
control/remote_group.py:1072, in RemoteGroup.process_as_completed(self, tasks)
   1070 for res in asyncio.as_completed(tasks):
   1071     try:
-> 1072         ret_val = await res
   1073     except Exception as e:
   1074         await self.cancel_not_done(tasks)

File /opt/lsst/software/stack/conda/miniconda3-py38_4.9.2/envs/lsst-scipipe-3.
0.0/lib/python3.8/asyncio/tasks.py:619, in as_completed.<locals>._wait_for_one
()
    616 if f is None:
    617     # Dummy value from _on_timeout().
    618     raise exceptions.TimeoutError
--> 619 return f.result()

File ~/auto-op-env-packages/ts_observatory_control/python/lsst/ts/observatory/
control/remote_group.py:495, in RemoteGroup.check_component_state(self, compon
ent, desired_state)
    493 if state != desired_state:
    494     self.log.warning(f"{component} not in {desired_state!r}: {state!r}
")
--> 495     raise RuntimeError(
    496         f"{component} state is {state!r}, expected {desired_state!r}"
    497     )
    498 else:
    499     self.log.debug(f"{component}: {state!r}")

RuntimeError: mtrotator state is <State.FAULT: 3>, expected <State.ENABLED: 2>
```

In [15]:
```
await mtcs.set_state(salobj.State.ENABLED, components=["mtptg", "mtrotator"])
```

```
setup.MTCS DEBUG: [mtptg]::[<State.FAULT: 3>, <State.STANDBY: 5>, <State.DI
SABLED: 1>, <State.ENABLED: 2>]
setup.MTCS DEBUG: [mtrotator]::[<State.FAULT: 3>, <State.STANDBY: 5>, <Stat
e.DISABLED: 1>, <State.ENABLED: 2>]
```

```
setup.MTCS INFO: All components in <State.ENABLED: 2>.
```

In [17]:
```
await mtcs.slew_icrs(ra="20:28:18.74", dec="-87:28:19.9", rot_type=RotType.Sky,
```

```
setup.MTCS DEBUG: RotSky = 0.0 deg, RotPhys = -30.089954348323545 deg.
setup.MTCS DEBUG: Wait 5.0s for rotator to settle down.
setup.MTCS DEBUG: Workaround for rotator trajectory problem. Moving rotator
to its current position: 24.60
setup.MTCS DEBUG: Wait for MTRotator in position event.
setup.MTCS DEBUG: MTRotator in position: False.
setup.MTCS INFO: MTRotator in position: True.
setup.MTCS DEBUG: MTRotator in position True. Waiting settle time 5.0s
setup.MTCS DEBUG: Sending slew command.
setup.MTCS DEBUG: Scheduling check coroutines
setup.MTCS DEBUG: process as completed...
setup.MTCS DEBUG: Monitor position started.
setup.MTCS DEBUG: Waiting for Target event from mtmount.
setup.MTCS DEBUG: mtmount: <State.ENABLED: 2>
setup.MTCS DEBUG: mtptg: <State.ENABLED: 2>
setup.MTCS DEBUG: mtaos: <State.ENABLED: 2>
setup.MTCS DEBUG: mtm1m3: <State.ENABLED: 2>
setup.MTCS DEBUG: mtm2: <State.ENABLED: 2>
setup.MTCS DEBUG: mthexapod_1: <State.ENABLED: 2>
setup.MTCS DEBUG: mthexapod_2: <State.ENABLED: 2>
setup.MTCS DEBUG: mtrotator: <State.ENABLED: 2>
setup.MTCS DEBUG: mtdome: <State.ENABLED: 2>
setup.MTCS DEBUG: mtdometrajectory: <State.ENABLED: 2>
setup.MTCS DEBUG: Wait for mtmount in position events.
setup.MTCS DEBUG: Wait for dome in position event.
setup.MTCS DEBUG: Wait for MTRotator in position event.
setup.MTCS DEBUG: MTRotator in position: True.
setup.MTCS DEBUG: MTRotator already in position. Handling potential race co
ndition.
setup.MTCS DEBUG: Wait for MTMount elevation in position event.
setup.MTCS DEBUG: MTMount elevation in position: True.
setup.MTCS DEBUG: MTMount elevation already in position. Handling potential
race condition.
setup.MTCS DEBUG: Wait for MTMount azimuth in position event.
setup.MTCS DEBUG: MTMount azimuth in position: True.
setup.MTCS DEBUG: MTMount azimuth already in position. Handling potential r
ace condition.
setup.MTCS DEBUG: Mount target: private_revCode: bdcb00ba, private_sndStam
p: 1652901787.451883, private_rcvStamp: 1652901787.4521651, private_seqNum:
86992, private_identity: MTMount, private_origin: 35669, elevation: 28.0761
88202125646, elevationVelocity: -0.00010192134941317457, azimuth: 181.61958
353976385, azimuthVelocity: -0.00018178013611531684, taiTime: 1652901787.51
09541, trackId: 2, tracksys: SIDEREAL, radesys: ICRS, priority: 0
setup.MTCS INFO: MTMount elevation in position: False.
setup.MTCS INFO: MTMount azimuth in position: False.
setup.MTCS INFO: MTMount elevation in position: True.
```

```
setup.MTCS DEBUG: MTMount elevation in position True. Waiting settle time
 3.0s
setup.MTCS INFO: MTMount azimuth in position: True.
setup.MTCS DEBUG: MTMount azimuth in position True. Waiting settle time 3.0
s
setup.MTCS INFO: MTRotator in position: False.
setup.MTCS DEBUG: [Tel]: Az = +181.634[  -0.0]; El = +028.085[  -0.0] [Ro
t]: +024.597[  -0.0] [Dome] Az = +000.000; El = +000.000
setup.MTCS DEBUG: Dome azimuth in position.
setup.MTCS DEBUG: Dome elevation in position.
setup.MTCS DEBUG: [Tel]: Az = +181.618[  -0.0]; El = +028.075[  -0.0] [Ro
t]: +030.214[  +0.0] [Dome] Az = +000.000; El = +000.000
setup.MTCS INFO: MTRotator in position: True.
setup.MTCS DEBUG: MTRotator in position True. Waiting settle time 3.0s
```

Out[17]:
```
(<ICRS Coordinate: (ra, dec) in deg
    (307.07808333, -87.47219444)>,
 <Angle 0. deg>)
```

---

## Take in-focus image

Once the different components are ready (M1M3, M2, rotator and CCW, hexapods) and tracking, take an image using the take_image command in playback mode.
This second image should be the one that uses the correction calculated with the first slew.

In [16]:
```
# exp_focus = await comcam.take_object(15)
# print(f"Target exposure: {exp_focus}")
```

---

## Intra Focus Position

Using the Camera Hexapod, piston ComCam +1mm

In [18]:
```
await mtcs.move_camera_hexapod(x=0,y=0,z=1000,u=0,v=0, w=0)
```

```
setup.MTCS DEBUG: Wait for Camera Hexapod in position event.
setup.MTCS DEBUG: Camera Hexapod in position: True.
setup.MTCS DEBUG: Camera Hexapod already in position. Handling potential ra
ce condition.
setup.MTCS INFO: Camera Hexapod in position: False.
setup.MTCS INFO: Camera Hexapod in position: True.
setup.MTCS DEBUG: Camera Hexapod in position True. Waiting settle time 5.0s
```

---

## Intra Focus Image

While tracking, take an image with ComCam and check that the header is containing the right telemetry

In [19]:
```
exp_intra = await comcam.take_object(15)
print(f"Target 1 exposure: {exp_intra}")
```

```
setup.ComCam DEBUG: Generating group_id
setup.ComCam DEBUG: imagetype: OBJECT, TCS synchronization not configured.
Target 1 exposure: [2022051800006]
```

---

## Extra Focus Position

Using the Camera Hexapod, piston ComCam to -1mm

In [20]:
```
await mtcs.move_camera_hexapod(x=0,y=0,z=-1000,u=0,v=0, w=0)
```

```
setup.MTCS DEBUG: Wait for Camera Hexapod in position event.
setup.MTCS DEBUG: Camera Hexapod in position: True.
setup.MTCS DEBUG: Camera Hexapod already in position. Handling potential ra
ce condition.
setup.MTCS INFO: Camera Hexapod in position: False.
setup.MTCS INFO: Camera Hexapod in position: True.
setup.MTCS DEBUG: Camera Hexapod in position True. Waiting settle time 5.0s
```

---

## Extra Focus Image

While tracking, take an image with ComCam and check that the header is containing the right telemetry.

In [21]:
```
exp_extra = await comcam.take_object(15)
print(f"Target 1 exposure: {exp_extra}")
```

```
setup.ComCam DEBUG: Generating group_id
setup.ComCam DEBUG: imagetype: OBJECT, TCS synchronization not configured.
Target 1 exposure: [2022051800007]
```

---

## Go Back to Focus Position

Put the hexapod back to 0mm.

In [22]:
```
await mtcs.move_camera_hexapod(x=0,y=0,z=0,u=0,v=0, w=0)
```

```
setup.MTCS DEBUG: Wait for Camera Hexapod in position event.
setup.MTCS DEBUG: Camera Hexapod in position: True.
```

```
setup.MTCS DEBUG: Camera Hexapod already in position. Handling potential ra
ce condition.
setup.MTCS INFO: Camera Hexapod in position: False.
setup.MTCS INFO: Camera Hexapod in position: True.
setup.MTCS DEBUG: Camera Hexapod in position True. Waiting settle time 5.0s
```

---

## Stop Tracking

If using MTMount Simulator and CCW Following Mode Disabled, stop tracking to prevent the Rotator to hit the limit switches.

In [23]:
```
await mtcs.stop_tracking()
```

```
setup.MTCS DEBUG: Stop tracking.
```

---

## Get Zernike Coefficients

Use the MTAOS Wavefront Estimator Pipeline to calculate the required Zernike Coefficients that represent the Wavefront data.

In [24]:
```
wep_config = yaml.safe_dump(
    dict(
        tasks=dict(
            isr=dict(
                 config=dict(
                     doOverscan=False,
                     doApplyGains=False,
                 )
            ),
            generateDonutCatalogWcsTask=dict(
                config={
                    "filterName":"phot_g_mean",
                    "connections.refCatalogs": "gaia_dr2_20200414",
                    "donutSelector.sourceLimit": 10,
                    "donutSelector.fluxField": "phot_g_mean_flux"
                }
            )
        )
    )
)
```

Used the **Define Visits** notebook.

In [25]:
```
await mtcs.rem.mtaos.cmd_runWEP.set_start(visitId=exp_intra[0],
                                          extraId=exp_extra[0],
                                         config = wep_config)
```

Out[25]:
```
<ddsutil.MTAOS_ackcmd_fd03e870 at 0x7fba90934400>
```

---

## Get Corrections

Use the MTAOS Optical Feedback Controller to retrieve the corrections that should be applied to m1m3, m2, camera hexapod, and m2 hexapod.

In [26]:
```
await mtcs.rem.mtaos.cmd_runOFC.start(timeout=60.)
```

Out[26]:
```
<ddsutil.MTAOS_ackcmd_fd03e870 at 0x7fb9feb2d3d0>
```

---

## Issue the corrections

Issue the corrections found by the MTAOS OFC to m1m3, m2, camera hexapod, and m2 hexapod.

In [27]:
```
await mtcs.rem.mtaos.cmd_issueCorrection.start(timeout=60.)
```

Out[27]:
```
<ddsutil.MTAOS_ackcmd_fd03e870 at 0x7fba31304790>
```

---

## Verify ISR Data

Make sure that the Instrument Signature Removal ran on the intra- and extra-focus data and that this data is accessible via Butler.

In [28]:
```
if summit:
    butler = dafButler.Butler("/repo/LSSTComCam/")
else:
    butler = dafButler.Butler("/repo/main/")
```

In [29]:
```
registry = butler.registry

collections = [collection for collection in registry.queryCollections()
               if collection.startswith('mtaos_wep')]
```

```
MTHexapod.electrical WARNING: tel_electrical DDS read queue is filling: 28
 of 100 elements
MTHexapod.electrical WARNING: tel_electrical DDS read queue is filling: 14
 of 100 elements
MTHexapod.application WARNING: tel_application DDS read queue is filling: 1
4 of 100 elements
MTHexapod.application WARNING: tel_application DDS read queue is filling: 2
9 of 100 elements
MTHexapod.actuators WARNING: tel_actuators DDS read queue is filling: 13 of
100 elements
MTHexapod.actuators WARNING: tel_actuators DDS read queue is filling: 28 of
100 elements
```

In [30]:
```
exp_intra_id = {'instrument': 'LSSTComCam',
```

```
                'detector': 0,
                'exposure': exp_intra[0]}

raw_intra = butler.get('postISRCCD', dataId=exp_intra_id,
                       collections=collections)

print(raw_intra.getMetadata())
```

```
DATE = "2022-05-18T19:23:54.548"
// Creation Date and Time of File
MJD = 59717.808270231
// Modified Julian Date that the file was written
CCD_MANU = "ITL"
// CCD Manufacturer
CCD_TYPE = "3800C"
// CCD Model Number
TESTTYPE = "OBJECT"
// BIAS, DARK, FE55, FLAT, LAMBDA, PERSISTENCE, SP
IMGTYPE = "OBJECT"
// BIAS, DARK, FE55, FLAT, FLAT_<lam>, SPOT, PPUMP
FILENAME = "CC_O_20220518_000006_R22_S00.fits"
// Original name of the file
BINX = 1
// [pixels] binning along X axis
BINY = 1
// [pixels] binning along Y axis
CCDGAIN = 1.0000000000000
// Rough guess at overall system gain (e-/DNB)
CCDNOISE = 10.000000000000
// Rough guess at system noise (e- rms)
DATE-TRG = "2022-05-18T19:23:17.542"
// Date of the image trigger (readout), UTC f
MJD-TRG = 59717.807841921
// Modified Julian Date of image trigger
IMAGETAG = "3c9614921b167c35"
// DAQ Image id (Hex)
CCDSLOT = "S00"
// The CCD Slot
RAFTBAY = "R22"
// The RAFT Bay
FIRMWARE = "302c5003"
// DAQ firmware version (Hex)
PLATFORM = "comcam"
// DAQ platform version
CONTNUM = "0"
// REB serial # (Hex)
DAQVERS = "no_release 2021-11-18T18:42:53Z (dirty,b76790e)"
// DAQ version
DAQPART = "emu"
// DAQ partition
DAQFOLD = "raw"
// DAQ folder the image was initially created in
OBSANNOT = ""
// DAQ image annotation
OBSID = "CC_O_20220518_000006"
// The image name or obs-id
CAMCODE = "CC"
// The "code" for AuxTel | ComCam | Main Camera
CONTRLLR = "O"
// The controller (e.g. O for OCS, C for CCS)
DAYOBS = "20220518"
// The observation day as defined in the image nam
SEQNUM = 6
// The sequence number from the image name
HEADVER = 2
// Version number of header
INSTRUME = "COMCAM"
// Instrument
```

```
TELESCOP = "LSST"
// Telescope
TSTAND = "EOCCv2_SUM"
// Test Stand
SEQFILE = "FP_ITL_2s_ir2_v25.seq"
// Sequencer file name
SEQNAME = "FP_ITL_2s_ir2_v25.seq"
// Sequencer file name
SEQCKSUM = "2552520002"
// Checksum of Sequencer
LSST_NUM = "ITL-3800C-229"
// LSST Assigned CCD Number
CCD_SERN = "23166"
// Manufacturers? CCD Serial Number
REBNAME = "LCA-13574-061"
// LSST Assigned Name REB name
RAFTNAME = "LCA-11021_RTM-031"
// LSST Assigned Raft name
EMUIMAGE = "CC_H_20211231_006001"
// Image bring emulated (from 2-day store)
DATE-BEG = "2022-05-18T19:23:36.492"
// Time at the start of integration
MJD-BEG = 59717.808061250
// Modified Julian Date derived from DATE-BEG
DATE-END = "2022-05-18T19:23:54.544"
// End date of the observation
MJD-END = 59717.808270185
// Date derived from DATE-END
FPVERS = "1.1.3"
// The focal-plane version number
IHVERS = "1.0.29"
// The image-handling version number
OBSGEO-X = 1818938.9400000
// [m] X-axis Geocentric coordinate
OBSGEO-Y = -5208470.9500000
// [m] Y-axis Geocentric coordinate
OBSGEO-Z = -3195172.0800000
// [m] Z-axis Geocentric coordinate
RA = 307.07808333333
// RA commanded from pointing component
DEC = -87.472194444444
// DEC commanded from pointing component
RASTART = 307.07808557878
// RA of telescope from AZSTART and ELSTART
DECSTART = -87.472194448277
// DEC of telescope from AZSTART and ELSTART
RAEND = 307.07809697596
// RA of telescope from AZEND and ELEND
DECEND = -87.472194467738
// DEC of telescope from AZEND and ELEND
ROTPA = 8.4879831658374e-314
// Rotation angle relative to the sky (deg)
ROTCOORD = "sky"
// Telescope Rotation Coordinates
HASTART = -14.208136926663
// [HH:MM:SS] Telescope hour angle at start
ELSTART = 28.073239566731
// [deg] Telescope zenith distance at start
AZSTART = 181.61431261760
// [deg] Telescope azimuth angle at start
```

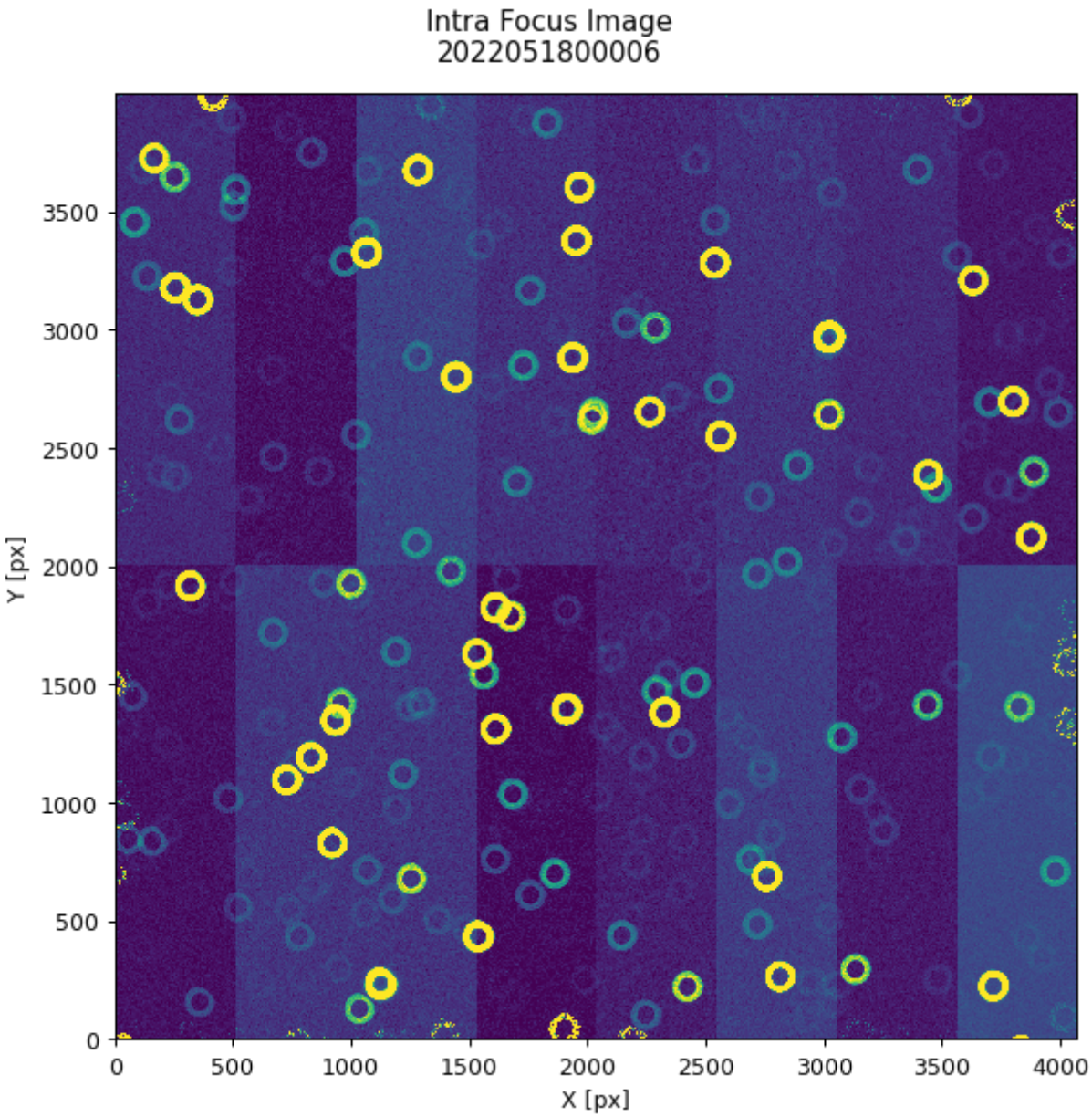
```
AMSTART = 2.1181142982103
// Airmass at start
HAEND = -14.202461244088
// [HH:MM:SS] Telescope hour angle at end
ELEND = 28.071176866315
// [deg] Telescope zenith distance at end
AZEND = 181.61061108360
// [deg] Telescope azimuth angle at end
AMEND = 2.1182564578895
// Airmass at end
TRACKSYS = "RADEC"
// Tracking system RADEC, AZEL, PLANET, EPHEM
RADESYS = "ICRS"
// Equatorial coordinate system FK5 or ICRS
FOCUSZ = 1000.0000000000
// Focus Z position
OBJECT = "slew_icrs"
// Name of the observed object
GROUPID = "2022-05-18T19:23:36.313"
BUNIT = "adu"
// Brightness units for pixel array
CURINDEX = 1
// Index number for exposure within the sequence
MAXINDEX = 1
// Number of requested images in sequence
PROGRAM = <Unknown>
// Name of the program
REASON = <Unknown>
// Reason for observation
FILTBAND = <Unknown>
// Name of the filter band
FILTER = "unknown"
// Name of the physical filter
FILTPOS = <Unknown>
// Filter measured position of slide
FILTSLOT = <Unknown>
// Filter home slot
SHUTTIME = 15.000000000000
// Shutter exposure time
SIMULATE MTMOUNT = 0
// MTMount Simulation Mode (False=0)
SIMULATE MTM1M3 = <Unknown>
// MTM1M3 Simulation Mode (False=0)
SIMULATE MTM2 = 0
// MTM2 Simulation Mode (False=0)
SIMULATE CAMHEXAPOD = 0
// CAMHexapod Simulation Mode (False=0)
SIMULATE M2HEXAPOD = 1
// M2Hexapod Simulation Mode (False=0)
SIMULATE MTROTATOR = 0
// MTRotator Simulation Mode (False=0)
SIMULATE MTDOME = 1
// MTDome Simulation Mode (False=0)
SIMULATE MTDOMETRAJECTORY = 0
// MTDomeTrajectory Simulation Mode (False
CHANNEL = 1
EXTNAME = "Segment10"
CCDSUM = "1 1"
DETSEC = "[509:1,1:2000]"
DETSIZE = "[1:4072,1:4000]"
```

```
DTV1 = 513
// detector transformation vector
DTV2 = 0
// detector transformation vector
DTM1_1 = -1.0000000000000
// detector transformation matrix
DTM2_2 = 1.0000000000000
// detector transformation matrix
DTM1_2 = 0.0000000000000
// detector transformation matrix
DTM2_1 = 0.0000000000000
// detector transformation matrix
WCSNAMEA = "AMPLIFIER"
// Name of coordinate system
CTYPE1A = "Seg_X"
// In the camera coordinate system
CTYPE2A = "Seg_Y"
// In the camera coordinate system
PC1_1A = 0.0000000000000
PC1_2A = -1.0000000000000
PC2_1A = -1.0000000000000
PC2_2A = 0.0000000000000
CDELT1A = 1.0000000000000
CDELT2A = 1.0000000000000
CRPIX1A = 0.0000000000000
CRPIX2A = 0.0000000000000
CRVAL1A = 2001.0000000000
CRVAL2A = 513.00000000000
WCSNAMEC = "CCD"
// Name of coordinate system
CTYPE1C = "CCD_X"
// In the camera coordinate system
CTYPE2C = "CCD_Y"
// In the camera coordinate system
PC1_1C = 0.0000000000000
PC1_2C = -1.0000000000000
PC2_1C = -1.0000000000000
PC2_2C = 0.0000000000000
CDELT1C = 1.0000000000000
CDELT2C = 1.0000000000000
CRPIX1C = 0.0000000000000
CRPIX2C = 0.0000000000000
CRVAL1C = 4001.0000000000
CRVAL2C = 513.00000000000
WCSNAMER = "RAFT"
// Name of coordinate system
CTYPE1R = "RAFT_X"
// In the camera coordinate system
CTYPE2R = "RAFT_Y"
// In the camera coordinate system
PC1_1R = 0.0000000000000
PC1_2R = -1.0000000000000
PC2_1R = -1.0000000000000
PC2_2R = 0.0000000000000
CDELT1R = 1.0000000000000
CDELT2R = 1.0000000000000
CRPIX1R = 0.0000000000000
CRPIX2R = 0.0000000000000
CRVAL1R = 4126.0000000000
CRVAL2R = 602.00000000000
```

```
WCSNAMEF = "FOCAL_PLANE"
// Name of coordinate system
CTYPE1F = "FP_X"
// In the camera coordinate system
CTYPE2F = "FP_Y"
// In the camera coordinate system
PC1_1F = 0.0000000000000
PC1_2F = -1.0000000000000
PC2_1F = -1.0000000000000
PC2_2F = 0.0000000000000
CDELT1F = 1.0000000000000
CDELT2F = 1.0000000000000
CRPIX1F = 0.0000000000000
CRPIX2F = 0.0000000000000
CRVAL1F = 29526.000000000
CRVAL2F = 26002.000000000
WCSNAMEE = "FP_SERPAR"
// Name of coordinate system
CTYPE1E = "FP_S"
// In the camera coordinate system
CTYPE2E = "FP_P"
// In the camera coordinate system
PC1_1E = -1.0000000000000
PC1_2E = 0.0000000000000
PC2_1E = 0.0000000000000
PC2_2E = -1.0000000000000
CDELT1E = 1.0000000000000
CDELT2E = 1.0000000000000
CRPIX1E = 0.0000000000000
CRPIX2E = 0.0000000000000
CRVAL1E = 26002.000000000
CRVAL2E = 29526.000000000
WCSNAMEB = "CCD_SERPAR"
// Name of coordinate system
CTYPE1B = "CCD_S"
// In the serial-parallel coordinate system
CTYPE2B = "CCD_P"
// In the serial-parallel coordinate system
PC1_1B = -1.0000000000000
PC1_2B = 0.0000000000000
PC2_1B = 0.0000000000000
PC2_2B = -1.0000000000000
CDELT1B = 1.0000000000000
CDELT2B = 1.0000000000000
CRPIX1B = 0.0000000000000
CRPIX2B = 0.0000000000000
CRVAL1B = 513.00000000000
CRVAL2B = 4001.0000000000
WCSNAMEQ = "RAFT_SERPAR"
// Name of coordinate system
CTYPE1Q = "RAFT_S"
// In the serial-parallel coordinate system
CTYPE2Q = "RAFT_P"
// In the serial-parallel coordinate system
PC1_1Q = -1.0000000000000
PC1_2Q = 0.0000000000000
PC2_1Q = 0.0000000000000
PC2_2Q = -1.0000000000000
CDELT1Q = 1.0000000000000
CDELT2Q = 1.0000000000000
```

```
CRPIX1Q = 0.0000000000000
CRPIX2Q = 0.0000000000000
CRVAL1Q = 602.00000000000
CRVAL2Q = 4126.0000000000
INHERIT = 1
// Extension inherits values from primary header
ASTRO METADATA FIX MODIFIED = 1
ASTRO METADATA FIX DATE = "2022-05-18T19:25:51.236232"
ASTRO METADATA FIX VERSION = "g4ae5eded10+a3e54b3923"
```

In [31]:
```
%matplotlib inline
fig, ax = plt.subplots(num="Intra Focus Image", figsize=(7,7), dpi=90)

vmin = np.percentile(raw_intra.image.array, 2)
vmax = np.percentile(raw_intra.image.array, 98)

ax.imshow(raw_intra.image.array,
          origin='lower',
          interpolation='nearest',
          vmin=vmin,
          vmax=vmax)
ax.set_xlabel("X [px]")
ax.set_ylabel("Y [px]")

fig.suptitle(f"Intra Focus Image\n{exp_intra_id['exposure']}")
fig.tight_layout()

plt.show()
```




```
MTHexapod.electrical WARNING: tel_electrical DDS read queue is filling: 10
 of 100 elements
MTHexapod.electrical WARNING: tel_electrical DDS read queue is filling: 21
 of 100 elements
MTHexapod.application WARNING: tel_application DDS read queue is filling: 1
7 of 100 elements
MTHexapod.application WARNING: tel_application DDS read queue is filling: 3
4 of 100 elements
MTHexapod.actuators WARNING: tel_actuators DDS read queue is filling: 16 of
100 elements
MTHexapod.actuators WARNING: tel_actuators DDS read queue is filling: 33 of
100 elements
```

In [32]:
```
exp_extra_id = {'instrument': 'LSSTComCam',
                'detector': 0,
                'exposure': exp_extra[0]}

exp_extra = butler.get('postISRCCD', dataId=exp_extra_id,
                       collections=collections)
```

```
print(exp_extra.getMetadata())
```

```
DATE = "2022-05-18T19:24:30.491"
// Creation Date and Time of File
MJD = 59717.808686238
// Modified Julian Date that the file was written
CCD_MANU = "ITL"
// CCD Manufacturer
CCD_TYPE = "3800C"
// CCD Model Number
TESTTYPE = "OBJECT"
// BIAS, DARK, FE55, FLAT, LAMBDA, PERSISTENCE, SP
IMGTYPE = "OBJECT"
// BIAS, DARK, FE55, FLAT, FLAT_<lam>, SPOT, PPUMP
FILENAME = "CC_O_20220518_000007_R22_S00.fits"
// Original name of the file
BINX = 1
// [pixels] binning along X axis
BINY = 1
// [pixels] binning along Y axis
CCDGAIN = 1.0000000000000
// Rough guess at overall system gain (e-/DNB)
CCDNOISE = 10.000000000000
// Rough guess at system noise (e- rms)
DATE-TRG = "2022-05-18T19:23:53.488"
// Date of the image trigger (readout), UTC f
MJD-TRG = 59717.808257963
// Modified Julian Date of image trigger
IMAGETAG = "e8dbecc0e54a99cc"
// DAQ Image id (Hex)
CCDSLOT = "S00"
// The CCD Slot
RAFTBAY = "R22"
// The RAFT Bay
FIRMWARE = "302c5003"
// DAQ firmware version (Hex)
PLATFORM = "comcam"
// DAQ platform version
CONTNUM = "0"
// REB serial # (Hex)
DAQVERS = "no_release 2021-11-18T18:42:53Z (dirty,b76790e)"
// DAQ version
DAQPART = "emu"
// DAQ partition
DAQFOLD = "raw"
// DAQ folder the image was initially created in
OBSANNOT = ""
// DAQ image annotation
OBSID = "CC_O_20220518_000007"
// The image name or obs-id
CAMCODE = "CC"
// The "code" for AuxTel | ComCam | Main Camera
CONTRLLR = "O"
// The controller (e.g. O for OCS, C for CCS)
DAYOBS = "20220518"
// The observation day as defined in the image nam
SEQNUM = 7
// The sequence number from the image name
HEADVER = 2
// Version number of header
INSTRUME = "COMCAM"
// Instrument
```

```
TELESCOP = "LSST"
// Telescope
TSTAND = "EOCCv2_SUM"
// Test Stand
SEQFILE = "FP_ITL_2s_ir2_v25.seq"
// Sequencer file name
SEQNAME = "FP_ITL_2s_ir2_v25.seq"
// Sequencer file name
SEQCKSUM = "2552520002"
// Checksum of Sequencer
LSST_NUM = "ITL-3800C-229"
// LSST Assigned CCD Number
CCD_SERN = "23166"
// Manufacturers? CCD Serial Number
REBNAME = "LCA-13574-061"
// LSST Assigned Name REB name
RAFTNAME = "LCA-11021_RTM-031"
// LSST Assigned Raft name
EMUIMAGE = "CC_H_20211231_006002"
// Image bring emulated (from 2-day store)
DATE-BEG = "2022-05-18T19:24:12.439"
// Time at the start of integration
MJD-BEG = 59717.808477303
// Modified Julian Date derived from DATE-BEG
DATE-END = "2022-05-18T19:24:30.491"
// End date of the observation
MJD-END = 59717.808686238
// Date derived from DATE-END
FPVERS = "1.1.3"
// The focal-plane version number
IHVERS = "1.0.29"
// The image-handling version number
OBSGEO-X = 1818938.9400000
// [m] X-axis Geocentric coordinate
OBSGEO-Y = -5208470.9500000
// [m] Y-axis Geocentric coordinate
OBSGEO-Z = -3195172.0800000
// [m] Z-axis Geocentric coordinate
RA = 307.07808333333
// RA commanded from pointing component
DEC = -87.472194444444
// DEC commanded from pointing component
RASTART = 307.07808775272
// RA of telescope from AZSTART and ELSTART
DECSTART = -87.472194451992
// DEC of telescope from AZSTART and ELSTART
RAEND = 307.07812551380
// RA of telescope from AZEND and ELEND
DECEND = -87.472194516467
// DEC of telescope from AZEND and ELEND
ROTPA = 8.4879831658374e-314
// Rotation angle relative to the sky (deg)
ROTCOORD = "sky"
// Telescope Rotation Coordinates
HASTART = -14.198110467581
// [HH:MM:SS] Telescope hour angle at start
ELSTART = 28.069598244904
// [deg] Telescope zenith distance at start
AZSTART = 181.60777022811
// [deg] Telescope azimuth angle at start
```

```
AMSTART = 2.1183652253820
// Airmass at start
HAEND = -14.192420815891
// [HH:MM:SS] Telescope hour angle at end
ELEND = 28.067541666832
// [deg] Telescope zenith distance at end
AZEND = 181.60405877260
// [deg] Telescope azimuth angle at end
AMEND = 2.1185071932334
// Airmass at end
TRACKSYS = "RADEC"
// Tracking system RADEC, AZEL, PLANET, EPHEM
RADESYS = "ICRS"
// Equatorial coordinate system FK5 or ICRS
FOCUSZ = -1000.0000000000
// Focus Z position
OBJECT = "slew_icrs"
// Name of the observed object
GROUPID = "2022-05-18T19:24:12.266"
BUNIT = "adu"
// Brightness units for pixel array
CURINDEX = 1
// Index number for exposure within the sequence
MAXINDEX = 1
// Number of requested images in sequence
PROGRAM = <Unknown>
// Name of the program
REASON = <Unknown>
// Reason for observation
FILTBAND = <Unknown>
// Name of the filter band
FILTER = "unknown"
// Name of the physical filter
FILTPOS = <Unknown>
// Filter measured position of slide
FILTSLOT = <Unknown>
// Filter home slot
SHUTTIME = 15.000000000000
// Shutter exposure time
SIMULATE MTMOUNT = 0
// MTMount Simulation Mode (False=0)
SIMULATE MTM1M3 = <Unknown>
// MTM1M3 Simulation Mode (False=0)
SIMULATE MTM2 = 0
// MTM2 Simulation Mode (False=0)
SIMULATE CAMHEXAPOD = 0
// CAMHexapod Simulation Mode (False=0)
SIMULATE M2HEXAPOD = 1
// M2Hexapod Simulation Mode (False=0)
SIMULATE MTROTATOR = 0
// MTRotator Simulation Mode (False=0)
SIMULATE MTDOME = 1
// MTDome Simulation Mode (False=0)
SIMULATE MTDOMETRAJECTORY = 0
// MTDomeTrajectory Simulation Mode (False
CHANNEL = 1
EXTNAME = "Segment10"
CCDSUM = "1 1"
DETSEC = "[509:1,1:2000]"
DETSIZE = "[1:4072,1:4000]"
```

```
DTV1 = 513
// detector transformation vector
DTV2 = 0
// detector transformation vector
DTM1_1 = -1.0000000000000
// detector transformation matrix
DTM2_2 = 1.0000000000000
// detector transformation matrix
DTM1_2 = 0.0000000000000
// detector transformation matrix
DTM2_1 = 0.0000000000000
// detector transformation matrix
WCSNAMEA = "AMPLIFIER"
// Name of coordinate system
CTYPE1A = "Seg_X"
// In the camera coordinate system
CTYPE2A = "Seg_Y"
// In the camera coordinate system
PC1_1A = 0.0000000000000
PC1_2A = -1.0000000000000
PC2_1A = -1.0000000000000
PC2_2A = 0.0000000000000
CDELT1A = 1.0000000000000
CDELT2A = 1.0000000000000
CRPIX1A = 0.0000000000000
CRPIX2A = 0.0000000000000
CRVAL1A = 2001.0000000000
CRVAL2A = 513.00000000000
WCSNAMEC = "CCD"
// Name of coordinate system
CTYPE1C = "CCD_X"
// In the camera coordinate system
CTYPE2C = "CCD_Y"
// In the camera coordinate system
PC1_1C = 0.0000000000000
PC1_2C = -1.0000000000000
PC2_1C = -1.0000000000000
PC2_2C = 0.0000000000000
CDELT1C = 1.0000000000000
CDELT2C = 1.0000000000000
CRPIX1C = 0.0000000000000
CRPIX2C = 0.0000000000000
CRVAL1C = 4001.0000000000
CRVAL2C = 513.00000000000
WCSNAMER = "RAFT"
// Name of coordinate system
CTYPE1R = "RAFT_X"
// In the camera coordinate system
CTYPE2R = "RAFT_Y"
// In the camera coordinate system
PC1_1R = 0.0000000000000
PC1_2R = -1.0000000000000
PC2_1R = -1.0000000000000
PC2_2R = 0.0000000000000
CDELT1R = 1.0000000000000
CDELT2R = 1.0000000000000
CRPIX1R = 0.0000000000000
CRPIX2R = 0.0000000000000
CRVAL1R = 4126.0000000000
CRVAL2R = 602.00000000000
```

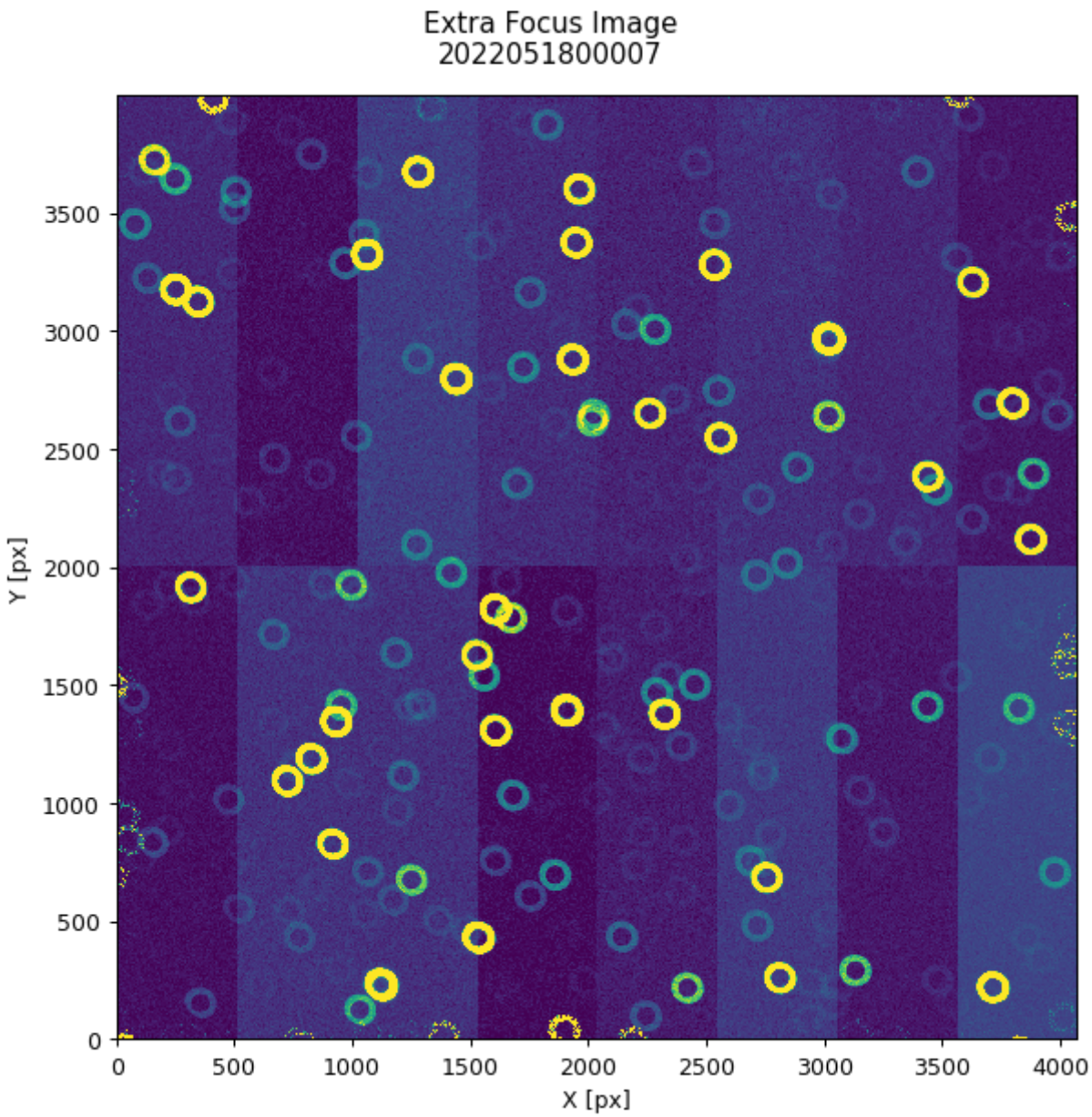
```
WCSNAMEF = "FOCAL_PLANE"
// Name of coordinate system
CTYPE1F = "FP_X"
// In the camera coordinate system
CTYPE2F = "FP_Y"
// In the camera coordinate system
PC1_1F = 0.0000000000000
PC1_2F = -1.0000000000000
PC2_1F = -1.0000000000000
PC2_2F = 0.0000000000000
CDELT1F = 1.0000000000000
CDELT2F = 1.0000000000000
CRPIX1F = 0.0000000000000
CRPIX2F = 0.0000000000000
CRVAL1F = 29526.000000000
CRVAL2F = 26002.000000000
WCSNAMEE = "FP_SERPAR"
// Name of coordinate system
CTYPE1E = "FP_S"
// In the camera coordinate system
CTYPE2E = "FP_P"
// In the camera coordinate system
PC1_1E = -1.0000000000000
PC1_2E = 0.0000000000000
PC2_1E = 0.0000000000000
PC2_2E = -1.0000000000000
CDELT1E = 1.0000000000000
CDELT2E = 1.0000000000000
CRPIX1E = 0.0000000000000
CRPIX2E = 0.0000000000000
CRVAL1E = 26002.000000000
CRVAL2E = 29526.000000000
WCSNAMEB = "CCD_SERPAR"
// Name of coordinate system
CTYPE1B = "CCD_S"
// In the serial-parallel coordinate system
CTYPE2B = "CCD_P"
// In the serial-parallel coordinate system
PC1_1B = -1.0000000000000
PC1_2B = 0.0000000000000
PC2_1B = 0.0000000000000
PC2_2B = -1.0000000000000
CDELT1B = 1.0000000000000
CDELT2B = 1.0000000000000
CRPIX1B = 0.0000000000000
CRPIX2B = 0.0000000000000
CRVAL1B = 513.00000000000
CRVAL2B = 4001.0000000000
WCSNAMEQ = "RAFT_SERPAR"
// Name of coordinate system
CTYPE1Q = "RAFT_S"
// In the serial-parallel coordinate system
CTYPE2Q = "RAFT_P"
// In the serial-parallel coordinate system
PC1_1Q = -1.0000000000000
PC1_2Q = 0.0000000000000
PC2_1Q = 0.0000000000000
PC2_2Q = -1.0000000000000
CDELT1Q = 1.0000000000000
CDELT2Q = 1.0000000000000
```

```
CRPIX1Q = 0.0000000000000
CRPIX2Q = 0.0000000000000
CRVAL1Q = 602.00000000000
CRVAL2Q = 4126.0000000000
INHERIT = 1
// Extension inherits values from primary header
ASTRO METADATA FIX MODIFIED = 1
ASTRO METADATA FIX DATE = "2022-05-18T19:25:56.644289"
ASTRO METADATA FIX VERSION = "g4ae5eded10+a3e54b3923"
```

```
MTHexapod.electrical WARNING: tel_electrical DDS read queue is filling: 13
 of 100 elements
MTHexapod.application WARNING: tel_application DDS read queue is filling: 1
3 of 100 elements
MTHexapod.actuators WARNING: tel_actuators DDS read queue is filling: 12 of
100 elements
MTM1M3.logevent_appliedForces ERROR: evt_appliedForces DDS read queue is fu
ll (100 elements); data may be lost
MTM1M3.logevent_appliedElevationForces ERROR: evt_appliedElevationForces DD
S read queue is full (100 elements); data may be lost
MTM1M3.logevent_appliedCylinderForces ERROR: evt_appliedCylinderForces DDS
 read queue is full (100 elements); data may be lost
MTM1M3.logevent_appliedBalanceForces ERROR: evt_appliedBalanceForces DDS re
ad queue is full (100 elements); data may be lost
MTM1M3.logevent_appliedAzimuthForces ERROR: evt_appliedAzimuthForces DDS re
ad queue is full (100 elements); data may be lost
MTM1M3.logevent_appliedActiveOpticForces ERROR: evt_appliedActiveOpticForce
s DDS read queue is full (100 elements); data may be lost
MTM1M3.logevent_appliedAberrationForces ERROR: evt_appliedAberrationForces
 DDS read queue is full (100 elements); data may be lost
```

In [33]:

```
%matplotlib inline
fig, ax = plt.subplots(num="Extra Focus Image", figsize=(7, 7), dpi=90)

vmin = np.percentile(exp_extra.image.array, 2)
vmax = np.percentile(exp_extra.image.array, 98)

ax.imshow(exp_extra.image.array,
          origin='lower',
          interpolation='nearest',
          vmin=vmin,
          vmax=vmax)

ax.set_xlabel("X [px]")
ax.set_ylabel("Y [px]")

fig.suptitle(f"Extra Focus Image\n{exp_extra_id['exposure']}")
fig.tight_layout()

plt.show()
```




```
MTHexapod.electrical WARNING: tel_electrical DDS read queue is filling: 11
 of 100 elements
MTHexapod.application WARNING: tel_application DDS read queue is filling: 1
2 of 100 elements
MTHexapod.actuators WARNING: tel_actuators DDS read queue is filling: 11 of
100 elements
```

---

## Wrap Up and Shut Down

This section is intended for shutting down the system and should not be run as part of the regular testing procedure. Only run the following cells if you are done with the system and don't plan on executing any further tests.

In [37]:
```
await mtcs.move_rotator(position=0)
```

```
setup.MTCS DEBUG: Wait for MTRotator in position event.
```

```
setup.MTCS DEBUG: MTRotator in position: True.
setup.MTCS DEBUG: MTRotator already in position. Handling potential race co
ndition.
setup.MTCS INFO: MTRotator in position: False.
setup.MTCS INFO: MTRotator in position: True.
setup.MTCS DEBUG: MTRotator in position True. Waiting settle time 5.0s
```

In [38]:
```
await mtcs.set_state(salobj.State.STANDBY, components=["mtaos"])
```

```
setup.MTCS DEBUG: [mtaos]::[<State.ENABLED: 2>, <State.DISABLED: 1>, <Stat
e.STANDBY: 5>]
setup.MTCS INFO: All components in <State.STANDBY: 5>.
```

In [39]:
```
await mtcs.lower_m1m3()
```

```
setup.MTCS DEBUG: M1M3 current detailed state {<DetailedState.ACTIVEENGINEE
RING: 11>, <DetailedState.ACTIVE: 7>}, executing command...
setup.MTCS DEBUG: process as completed...
setup.MTCS DEBUG: M1M3 detailed state 8
setup.MTCS DEBUG: mtm1m3: <State.ENABLED: 2>
setup.MTCS DEBUG: mtm1m3: <State.ENABLED: 2>
setup.MTCS DEBUG: M1M3 detailed state 5
```

In [40]:
```
await mtcs.set_state(salobj.State.STANDBY, components=["mtm1m3"])
```

```
setup.MTCS DEBUG: [mtm1m3]::[<State.ENABLED: 2>, <State.DISABLED: 1>, <Stat
e.STANDBY: 5>]
setup.MTCS INFO: All components in <State.STANDBY: 5>.
```

In [41]:
```
await mtcs.set_state(salobj.State.STANDBY, components=["mtm2"])
```

```
setup.MTCS ERROR: Unable to transition mtm2 to <State.STANDBY: 5> NoneType:
None
.
Traceback (most recent call last):
  File "/opt/lsst/software/stack/conda/miniconda3-py38_4.9.2/envs/lsst-scip
ipe-3.0.0/lib/python3.8/site-packages/lsst/ts/salobj/topics/remote_command.
py", line 193, in next_ackcmd
    ackcmd = await self._wait_task
  File "/opt/lsst/software/stack/conda/miniconda3-py38_4.9.2/envs/lsst-scip
ipe-3.0.0/lib/python3.8/site-packages/lsst/ts/salobj/topics/remote_command.
py", line 218, in _basic_next_ackcmd
    ackcmd = await asyncio.wait_for(
  File "/opt/lsst/software/stack/conda/miniconda3-py38_4.9.2/envs/lsst-scip
ipe-3.0.0/lib/python3.8/asyncio/tasks.py", line 501, in wait_for
    raise exceptions.TimeoutError()
asyncio.exceptions.TimeoutError

During handling of the above exception, another exception occurred:

Traceback (most recent call last):
  File "/opt/lsst/software/stack/conda/miniconda3-py38_4.9.2/envs/lsst-scip
ipe-3.0.0/lib/python3.8/site-packages/lsst/ts/salobj/csc_utils.py", line 15
7, in set_summary_state
    await cmd.start(timeout=timeout)
  File "/opt/lsst/software/stack/conda/miniconda3-py38_4.9.2/envs/lsst-scip
ipe-3.0.0/lib/python3.8/site-packages/lsst/ts/salobj/topics/remote_command.
py", line 485, in start
    return await cmd_info.next_ackcmd(timeout=timeout)
  File "/opt/lsst/software/stack/conda/miniconda3-py38_4.9.2/envs/lsst-scip
ipe-3.0.0/lib/python3.8/site-packages/lsst/ts/salobj/topics/remote_command.
py", line 209, in next_ackcmd
    raise base.AckTimeoutError(
lsst.ts.salobj.base.AckTimeoutError: msg='Timed out waiting for command ack
nowledgement', ackcmd=(ackcmd private_seqNum=1803175370, ack=<SalRetCode.CM
D_NOACK: -301>, error=0, result='No command acknowledgement seen')

The above exception was the direct cause of the following exception:

Traceback (most recent call last):
  File "/opt/lsst/software/stack/conda/miniconda3-py38_4.9.2/envs/lsst-scip
ipe-3.0.0/lib/python3.8/site-packages/lsst/ts/salobj/csc_utils.py", line 15
9, in set_summary_state
    raise RuntimeError(
RuntimeError: Error on cmd=cmd_standby, initial_state=2: msg='Timed out wai
ting for command acknowledgement', ackcmd=(ackcmd private_seqNum=180317537
0, ack=<SalRetCode.CMD_NOACK: -301>, error=0, result='No command acknowledg
ement seen')
```

```
---------------------------------------------------------------------------
RuntimeError                              Traceback (most recent call last)
Input In [41], in <cell line: 1>()
----> 1 await mtcs.set_state(salobj.State.STANDBY, components=["mtm2"])

File ~/auto-op-env-packages/ts_observatory_control/python/lsst/ts/observatory/
control/remote_group.py:732, in RemoteGroup.set_state(self, state, overrides,
 components)
    729         self.log.debug(f"[{comp}]::{ret_val[i]!r}")
    731 if error_flag:
--> 732     raise RuntimeError(
    733         f"Failed to transition {failed_components} to "
    734         f"{salobj.State(state)!r}."
    735     )
    736 else:
    737     self.log.info(f"All components in {salobj.State(state)!r}.")

RuntimeError: Failed to transition ['mtm2'] to <State.STANDBY: 5>.
```

In [45]:
```
await mtcs.set_state(salobj.State.STANDBY, components=["mtm2"])
```

```
setup.MTCS DEBUG: [mtm2]::[<State.DISABLED: 1>, <State.STANDBY: 5>]
setup.MTCS INFO: All components in <State.STANDBY: 5>.
```

In [46]:
```
await mtcs.set_state(salobj.State.STANDBY, components=["mthexapod_1"])
```

```
setup.MTCS DEBUG: [mthexapod_1]::[<State.ENABLED: 2>, <State.DISABLED: 1>,
 <State.STANDBY: 5>]
setup.MTCS INFO: All components in <State.STANDBY: 5>.
```

In [47]:
```
await mtcs.set_state(salobj.State.STANDBY, components=["mthexapod_2"])
```

```
setup.MTCS DEBUG: [mthexapod_2]::[<State.ENABLED: 2>, <State.DISABLED: 1>,
 <State.STANDBY: 5>]
setup.MTCS INFO: All components in <State.STANDBY: 5>.
```

In [48]:
```
await mtcs.standby()
```

```
setup.MTCS DEBUG: [mtmount]::[<State.ENABLED: 2>, <State.DISABLED: 1>, <Sta
te.STANDBY: 5>]
setup.MTCS DEBUG: [mtptg]::[<State.ENABLED: 2>, <State.DISABLED: 1>, <Stat
e.STANDBY: 5>]
setup.MTCS DEBUG: [mtaos]::[<State.STANDBY: 5>]
setup.MTCS DEBUG: [mtm1m3]::[<State.STANDBY: 5>]
setup.MTCS DEBUG: [mtm2]::[<State.STANDBY: 5>]
setup.MTCS DEBUG: [mthexapod_1]::[<State.STANDBY: 5>]
setup.MTCS DEBUG: [mthexapod_2]::[<State.STANDBY: 5>]
setup.MTCS DEBUG: [mtrotator]::[<State.ENABLED: 2>, <State.DISABLED: 1>, <S
tate.STANDBY: 5>]
setup.MTCS DEBUG: [mtdome]::[<State.ENABLED: 2>, <State.DISABLED: 1>, <Stat
e.STANDBY: 5>]
setup.MTCS DEBUG: [mtdometrajectory]::[<State.ENABLED: 2>, <State.DISABLED:
1>, <State.STANDBY: 5>]
setup.MTCS INFO: All components in <State.STANDBY: 5>.
```

In [ ]:
```
await comcam.standby()
```