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 hdrass on 2022-06-17T19:18:06.833.
  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_18086/1665379685.py:2: DeprecationWarning: Call to deprecate
d function (or staticmethod) get_node. (Please use lsst.rsp.get_node())
  nb.utils.get_node()
```
Out[3]:
```
'yagan07'
```

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 l
inked library (v4.01).


WARNING: version mismatch between CFITSIO header (v4.000999999999999) and l
inked library (v4.01).


WARNING: version mismatch between CFITSIO header (v4.000999999999999) and l
inked 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.
MTHexapod INFO: Read historical data in 0.62 sec
MTHexapod INFO: Read historical data in 0.64 sec
MTHexapod.electrical WARNING: tel_electrical DDS read queue is filling:
21 of 100 elements
MTHexapod.application WARNING: tel_application DDS read queue is fillin
g: 21 of 100 elements
MTHexapod.actuators WARNING: tel_actuators DDS read queue is filling: 22
of 100 elements
```

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

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

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.
MTHexapod.electrical WARNING: tel_electrical DDS read queue is filling:
11 of 100 elements
MTHexapod.application WARNING: tel_application DDS read queue is fillin
g: 12 of 100 elements
MTHexapod.actuators WARNING: tel_actuators DDS read queue is filling: 11
of 100 elements
```

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

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

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

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

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

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

In [ ]:
```
exp1 = await comcam.take_object(15)
print(f"Target 1 exposure: {exp1}")
```

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

```
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
```

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 0°**. 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 [17]:
```
await mtcs.slew_icrs(ra="20:28:18.74", dec="-87:28:19.9", rot_type=RotType.S
```

```
setup.MTCS DEBUG: RotSky = 0.0 deg, RotPhys = 4.495943666590193 deg.
setup.MTCS DEBUG: Wait 5.0s for rotator to settle down.
setup.MTCS DEBUG: Workaround for rotator trajectory problem. Moving rota
tor to its current position: 1.54
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
condition.
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
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
condition.
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 potent
ial 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 potentia
l race condition.
setup.MTCS DEBUG: Mount target: private_revCode: bdcb00ba, private_sndSt
amp: 1655495186.0796, private_rcvStamp: 1655495186.0799282, private_seqN
um: 207080, private_identity: MTMount, private_origin: 49119, elevation:
27.662373067448836, elevationVelocity: 6.8148741436526114e-06, azimuth:
179.89163046103943, azimuthVelocity: -0.0002143905325359057, taiTime: 16
55495186.138621, trackId: 5, tracksys: SIDEREAL, radesys: ICRS, priorit
y: 0
setup.MTCS INFO: MTMount elevation in position: False.
setup.MTCS INFO: MTMount azimuth in position: False.
setup.MTCS DEBUG: [Tel]: Az = +000.001[+179.9]; El = +080.000[ -52.3] [R
ot]: +001.543[  -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 INFO: MTRotator in position: False.
setup.MTCS INFO: MTRotator in position: True.
setup.MTCS DEBUG: MTRotator in position True. Waiting settle time 3.0s
setup.MTCS DEBUG: [Tel]: Az = +032.589[+147.3]; El = +063.734[ -36.1] [R
ot]: -003.845[  -0.0] [Dome] Az = +000.000; El = +000.000
setup.MTCS DEBUG: [Tel]: Az = +073.753[+106.1]; El = +043.139[ -15.5] [R
ot]: -004.379[  +0.0] [Dome] Az = +000.000; El = +000.000
setup.MTCS INFO: MTMount elevation in position: True.
setup.MTCS DEBUG: MTMount elevation in position True. Waiting settle tim
e 3.0s
setup.MTCS DEBUG: [Tel]: Az = +114.897[ +65.0]; El = +027.662[  +0.0] [R
ot]: -004.403[  +0.0] [Dome] Az = +000.000; El = +000.000
setup.MTCS DEBUG: [Tel]: Az = +156.010[ +23.9]; El = +027.663[  +0.0] [R
ot]: -004.430[  -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
3.0s
setup.MTCS DEBUG: [Tel]: Az = +179.885[  -0.0]; El = +027.663[  +0.0] [R
ot]: -004.447[  -0.0] [Dome] Az = +000.000; El = +000.000
```

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

In [13]:
```
await mtcs.slew_icrs(ra="20:28:18.74", dec="-87:28:19.9", rot_type=RotType.S
```

```
setup.MTCS DEBUG: RotSky = 0.0 deg, RotPhys = -1.721556789288229 deg.
setup.MTCS DEBUG: Wait 5.0s for rotator to settle down.
setup.MTCS DEBUG: Workaround for rotator trajectory problem. Moving rota
tor to its current position: 1.84
```

```
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 WARNING: mtm1m3 not in <State.ENABLED: 2>: <State.FAULT: 3>
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
condition.
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 potent
ial 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 potentia
l race condition.
```

```
---------------------------------------------------------------------------
RuntimeError                              Traceback (most recent call last)
Input In [13], in <cell line: 1>()
----> 1 await mtcs.slew_icrs(ra="20:28:18.74", dec="-87:28:19.9", rot_type=
RotType.Sky, rot=0)

File /opt/lsst/src/ts_observatory_control/python/lsst/ts/observatory/contro
l/base_tcs.py:589, in BaseTCS.slew_icrs(self, ra, dec, rot, rot_type, targe
t_name, dra, ddec, offset_x, offset_y, az_wrap_strategy, time_on_target, sl
ew_timeout, stop_before_slew, wait_settle)
    584     valid_rottypes = ", ".join(repr(rt) for rt in RotType)
    585     raise RuntimeError(
    586         f"Unrecognized rottype {rot_type}. Should be one of {valid_
rottypes}"
    587     )
--> 589 await self.slew(
    590     radec_icrs.ra.hour,
    591     radec_icrs.dec.deg,
    592     rotPA=rot_angle.deg,
    593     target_name=target_name,
    594     frame=self.CoordFrame.ICRS,
    595     epoch=2000,
    596     equinox=2000,
    597     parallax=0,
    598     pmRA=0,
    599     pmDec=0,
    600     rv=0,
    601     dRA=dra,
    602     dDec=ddec,
    603     rot_frame=rot_frame,
    604     rot_track_frame=rot_track_frame,
    605     az_wrap_strategy=az_wrap_strategy,
    606     time_on_target=time_on_target,
    607     rot_mode=self.RotMode.FIELD,
    608     slew_timeout=slew_timeout,
    609     stop_before_slew=stop_before_slew,
    610     wait_settle=wait_settle,
    611     offset_x=offset_x,
    612     offset_y=offset_y,
    613 )
    615 return radec_icrs, rot_angle

File /opt/lsst/src/ts_observatory_control/python/lsst/ts/observatory/contro
l/base_tcs.py:761, in BaseTCS.slew(self, ra, dec, rotPA, target_name, fram
e, epoch, equinox, parallax, pmRA, pmDec, rv, dRA, dDec, rot_frame, rot_tra
ck_frame, rot_mode, az_wrap_strategy, time_on_target, slew_timeout, stop_be
fore_slew, wait_settle, offset_x, offset_y)
    754 getattr(self.rem, self.ptg_name).cmd_poriginOffset.set(
    755     dx=offset_x * self.plate_scale,
    756     dy=offset_y * self.plate_scale,
    757     num=0,
    758 )
    760 try:
--> 761     await self._slew_to(
    762         getattr(self.rem, self.ptg_name).cmd_raDecTarget,
    763         slew_timeout=slew_timeout,
    764         offset_cmd=getattr(self.rem, self.ptg_name).cmd_poriginOffs
et,
```

```
    765         stop_before_slew=stop_before_slew,
    766         wait_settle=wait_settle,
    767     )
    768 except salobj.AckError as ack_err:
    769     self.log.error(
    770         f"Command to track target {target_name} rejected: {ack_err.
ackcmd.result}"
    771     )

File /opt/lsst/src/ts_observatory_control/python/lsst/ts/observatory/contro
l/maintel/mtcs.py:289, in MTCS._slew_to(self, slew_cmd, slew_timeout, offse
t_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 /opt/lsst/src/ts_observatory_control/python/lsst/ts/observatory/contro
l/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 /opt/lsst/src/ts_observatory_control/python/lsst/ts/observatory/contro
l/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_f
or_one()
    616 if f is None:
    617     # Dummy value from _on_timeout().
    618     raise exceptions.TimeoutError
--> 619 return f.result()

File /opt/lsst/src/ts_observatory_control/python/lsst/ts/observatory/contro
l/remote_group.py:495, in RemoteGroup.check_component_state(self, componen
t, desired_state)
    493 if state != desired_state:
    494     self.log.warning(f"{component} not in {desired_state!r}: {stat
e!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: mtm1m3 state is <State.FAULT: 3>, expected <State.ENABLED: 2>
```

```
setup.MTCS DEBUG: Mount target: private_revCode: bdcb00ba, private_sndSt
amp: 1655493656.0592363, private_rcvStamp: 1655493656.059522, private_se
qNum: 193265, private_identity: MTMount, private_origin: 49119, elevatio
n: 27.667743055112204, elevationVelocity: -1.3828330476511376e-05, azimu
th: 180.21964416714744, azimuthVelocity: -0.00021396961279421958, taiTim
e: 1655493656.1185932, trackId: 2, tracksys: SIDEREAL, radesys: ICRS, pr
iority: 0
setup.MTCS DEBUG: [Tel]: Az = +180.220[  -0.0]; El = +027.668[  -0.0] [R
ot]: +001.843[  +0.0] [Dome] Az = +000.000; El = +000.000
setup.MTCS DEBUG: [Tel]: Az = +180.218[  -0.0]; El = +027.668[  -0.0] [R
ot]: +001.843[  -0.0] [Dome] Az = +000.000; El = +000.000
setup.MTCS DEBUG: [Tel]: Az = +180.217[  -0.0]; El = +027.668[  -0.0] [R
ot]: +001.843[  +0.0] [Dome] Az = +000.000; El = +000.000
setup.MTCS DEBUG: [Tel]: Az = +180.216[  -0.0]; El = +027.667[  -0.0] [R
ot]: +001.843[  -0.0] [Dome] Az = +000.000; El = +000.000
setup.MTCS DEBUG: [Tel]: Az = +180.214[  -0.0]; El = +027.667[  -0.0] [R
ot]: +001.843[  +0.0] [Dome] Az = +000.000; El = +000.000
setup.MTCS DEBUG: [Tel]: Az = +180.213[  -0.0]; El = +027.667[  -0.0] [R
ot]: +001.843[  +0.0] [Dome] Az = +000.000; El = +000.000
setup.MTCS DEBUG: [Tel]: Az = +180.212[  -0.0]; El = +027.667[  -0.0] [R
ot]: +001.843[  +0.0] [Dome] Az = +000.000; El = +000.000
setup.MTCS DEBUG: [Tel]: Az = +180.211[  -0.0]; El = +027.667[  -0.0] [R
ot]: +001.843[  +0.0] [Dome] Az = +000.000; El = +000.000
setup.MTCS DEBUG: [Tel]: Az = +180.209[  -0.0]; El = +027.667[  -0.0] [R
ot]: +001.843[  +0.0] [Dome] Az = +000.000; El = +000.000
setup.MTCS DEBUG: [Tel]: Az = +180.208[  -0.0]; El = +027.667[  -0.0] [R
ot]: +001.843[  -0.0] [Dome] Az = +000.000; El = +000.000
setup.MTCS DEBUG: [Tel]: Az = +180.207[  -0.0]; El = +027.667[  -0.0] [R
ot]: +001.843[  +0.0] [Dome] Az = +000.000; El = +000.000
setup.MTCS DEBUG: [Tel]: Az = +180.205[  -0.0]; El = +027.667[  -0.0] [R
ot]: +001.843[  +0.0] [Dome] Az = +000.000; El = +000.000
setup.MTCS DEBUG: [Tel]: Az = +180.204[  -0.0]; El = +027.667[  -0.0] [R
ot]: +001.843[  +0.0] [Dome] Az = +000.000; El = +000.000
setup.MTCS DEBUG: [Tel]: Az = +180.203[  -0.0]; El = +027.667[  -0.0] [R
ot]: +001.843[  +0.0] [Dome] Az = +000.000; El = +000.000
setup.MTCS DEBUG: [Tel]: Az = +180.202[  -0.0]; El = +027.667[  -0.0] [R
ot]: +001.843[  +0.0] [Dome] Az = +000.000; El = +000.000
setup.MTCS DEBUG: [Tel]: Az = +180.200[  -0.0]; El = +027.667[  -0.0] [R
ot]: +001.843[  +0.0] [Dome] Az = +000.000; El = +000.000
setup.MTCS DEBUG: [Tel]: Az = +180.199[  -0.0]; El = +027.666[  -0.0] [R
ot]: +001.843[  +0.0] [Dome] Az = +000.000; El = +000.000
setup.MTCS DEBUG: [Tel]: Az = +180.198[  -0.0]; El = +027.666[  -0.0] [R
ot]: +001.843[  +0.0] [Dome] Az = +000.000; El = +000.000
setup.MTCS DEBUG: [Tel]: Az = +180.196[  -0.0]; El = +027.666[  -0.0] [R
ot]: +001.843[  +0.0] [Dome] Az = +000.000; El = +000.000
setup.MTCS DEBUG: [Tel]: Az = +180.195[  -0.0]; El = +027.666[  -0.0] [R
ot]: +001.843[  +0.0] [Dome] Az = +000.000; El = +000.000
setup.MTCS DEBUG: [Tel]: Az = +180.194[  -0.0]; El = +027.666[  -0.0] [R
ot]: +001.843[  +0.0] [Dome] Az = +000.000; El = +000.000
```

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

Intra Focus Position

Using the Camera Hexapod, piston ComCam +1mm

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

```
MTHexapod.electrical WARNING: tel_electrical DDS read queue is filling:
10 of 100 elements
MTHexapod.application WARNING: tel_application DDS read queue is fillin
g: 10 of 100 elements
MTHexapod.actuators WARNING: tel_actuators DDS read queue is filling: 10
of 100 elements
```

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 configure
d.
CCHeaderService.logevent_logMessage ERROR: evt_logMessage DDS read queue
is full (100 elements); data may be lost
Target 1 exposure: [2022061700011]
```

Extra Focus Position

Using the Camera Hexapod, piston ComCam to -1mm

In [38]:
```
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
race 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 configure
d.
Target 1 exposure: [2022061700012]
```

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
race 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"
                }
            )
        )
    )
)
```

In [ ]:
```
```

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 0x7f0c96da50d0>
```

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 0x7f0c8e22f040>
```

Issue the corrections

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

In [28]:
```
await mtcs.rem.mtaos.cmd_issueCorrection.start(timeout=60.)
```

Out[28]:
```
<ddsutil.MTAOS_ackcmd_fd03e870 at 0x7f0c9f63a9d0>
```

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 [29]:
```
if summit:
    butler = dafButler.Butler("/repo/LSSTComCam/")
else:
    butler = dafButler.Butler("/repo/main/")
```

```
MTHexapod.electrical WARNING: tel_electrical DDS read queue is filling:
33 of 100 elements
MTHexapod.electrical WARNING: tel_electrical DDS read queue is filling:
16 of 100 elements
MTHexapod.application WARNING: tel_application DDS read queue is fillin
g: 33 of 100 elements
MTHexapod.application WARNING: tel_application DDS read queue is fillin
g: 16 of 100 elements
MTHexapod.actuators WARNING: tel_actuators DDS read queue is filling: 32
of 100 elements
MTHexapod.actuators WARNING: tel_actuators DDS read queue is filling: 15
of 100 elements
MTM1M3.logevent_appliedAzimuthForces ERROR: evt_appliedAzimuthForces DDS
read queue is full (100 elements); data may be lost
```

```
MTM1M3.logevent_appliedActiveOpticForces ERROR: evt_appliedActiveOpticFo
rces DDS read queue is full (100 elements); data may be lost
```

In [30]:
```
registry = butler.registry

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

In [31]:
```
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 = "2022-06-17T19:48:09.738"
// Creation Date and Time of File
MJD = 59747.825112708
// 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_20220617_000011_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 = "2022-06-17T19:47:32.733"
// Date of the image trigger (readout), UTC f
MJD-TRG = 59747.824684410
// Modified Julian Date of image trigger
IMAGETAG = "c9d5887c77c0ee68"
// 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 = "R5-V3.2 2022-06-02T23:30:36Z (9a25b833)"
// DAQ version
DAQPART = "emu"
// DAQ partition
DAQFOLD = "raw"
// DAQ folder the image was initially created in
OBSANNOT = ""
// DAQ image annotation
OBSID = "CC_O_20220617_000011"
// 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 = "20220617"
// The observation day as defined in the image nam
SEQNUM = 11
// The sequence number from the image name
HEADVER = 2
// Version number of header
INSTRUME = "ComCam"
```

```
// Instrument
TELESCOP = "Simonyi Survey Telescope"
// 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_006011"
// Image bring emulated (from 2-day store)
DATE-BEG = "2022-06-17T19:47:51.679"
// Time at the start of integration
MJD-BEG = 59747.824903692
// Modified Julian Date derived from DATE-BEG
DATE-END = "2022-06-17T19:48:09.735"
// End date of the observation
MJD-END = 59747.825112673
// 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 = 307.07812081543
// RA of telescope from AZSTART and ELSTART
DECSTART = -87.472194510180
// DEC of telescope from AZSTART and ELSTART
RAEND = 307.07814764165
// RA of telescope from AZEND and ELEND
DECEND = -87.472194557224
// DEC of telescope from AZEND and ELEND
ROTPA = 4.9406564584125e-316
// Rotation angle relative to the sky (deg)
ROTCOORD = "sky"
// Telescope Rotation Coordinates
HASTART = -11.835587441880
// [HH:MM:SS] Telescope hour angle at start
ELSTART = 27.663005309924
// [deg] Telescope zenith distance at start
```

```
AZSTART = 179.87329589077
// [deg] Telescope azimuth angle at start
AMSTART = 2.1467514865521
// Airmass at start
HAEND = -11.829898144804
// [HH:MM:SS] Telescope hour angle at end
ELEND = 27.663170231573
// [deg] Telescope zenith distance at end
AZEND = 179.86893527684
// [deg] Telescope azimuth angle at end
AMEND = 2.1467397524062
// 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 = "2022-06-17T19:47:51.494"
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
```

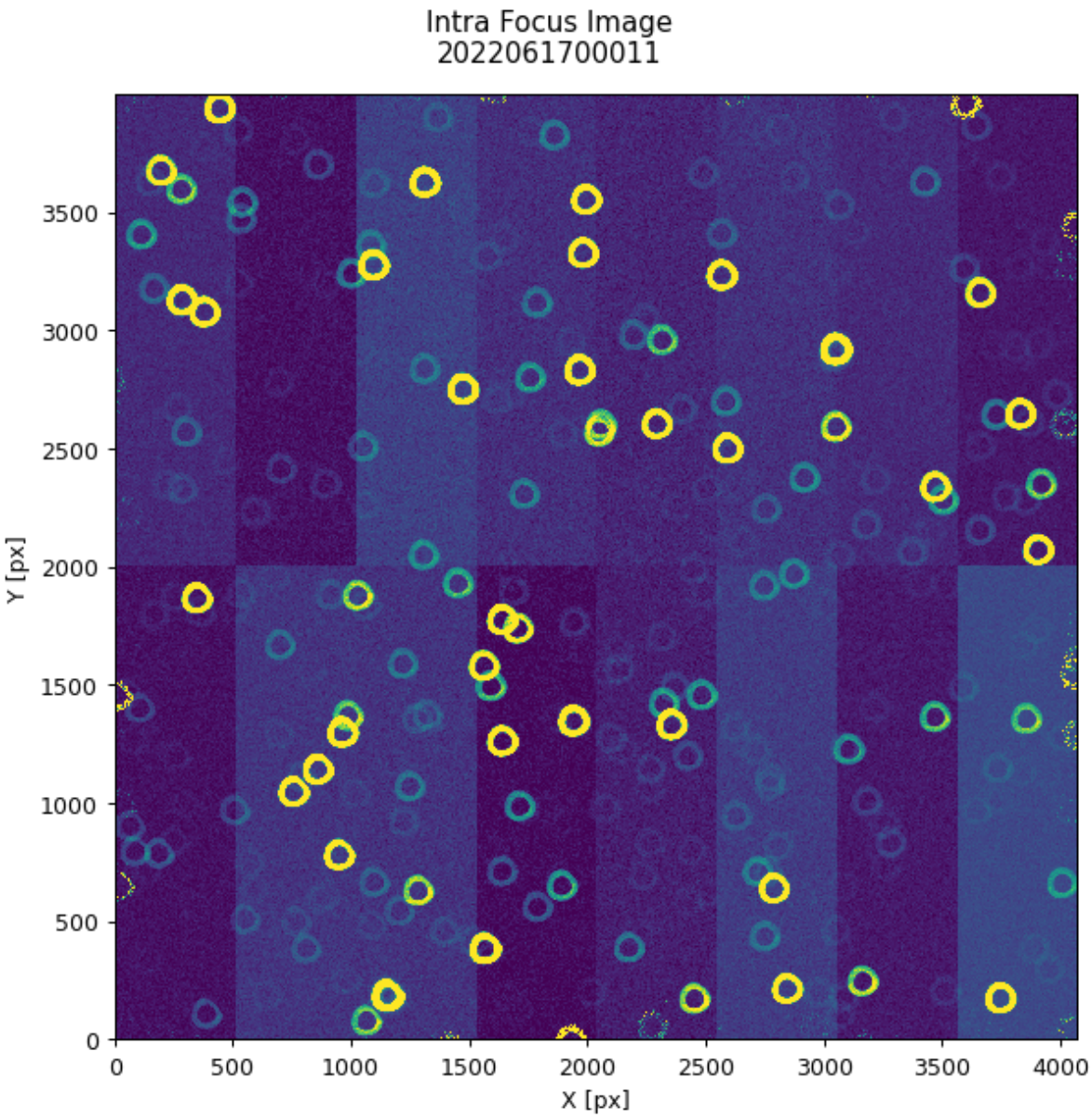
```
CRPIX1R = 0.0000000000000
CRPIX2R = 0.0000000000000
CRVAL1R = 4126.0000000000
CRVAL2R = 602.00000000000
WCSNAMEF = "FOCAL_PLANE"
// Name of coordinate system
CTYPE1F = "FP_X"
// In the camera coordinate system
CTYPE2F = "FP_Y"
// In the camera coordinate system
PC1_1F = 0.0000000000000
PC1_2F = -1.0000000000000
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 = "2022-06-17T19:52:07.346858"
ASTRO METADATA FIX VERSION = "g4ae5eded10+a3e54b3923"
```

```
MTHexapod.electrical WARNING: tel_electrical DDS read queue is filling:
11 of 100 elements
MTHexapod.electrical WARNING: tel_electrical DDS read queue is filling:
23 of 100 elements
MTHexapod.application WARNING: tel_application DDS read queue is fillin
g: 23 of 100 elements
MTHexapod.application WARNING: tel_application DDS read queue is fillin
g: 12 of 100 elements
MTHexapod.actuators WARNING: tel_actuators DDS read queue is filling: 22
of 100 elements
MTHexapod.actuators WARNING: tel_actuators DDS read queue is filling: 11
of 100 elements
```

In [32]:

```
%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:
30 of 100 elements
MTHexapod.electrical WARNING: tel_electrical DDS read queue is filling:
15 of 100 elements
MTHexapod.application WARNING: tel_application DDS read queue is fillin
g: 30 of 100 elements
MTHexapod.application WARNING: tel_application DDS read queue is fillin
g: 15 of 100 elements
MTHexapod.actuators WARNING: tel_actuators DDS read queue is filling: 14
of 100 elements
MTHexapod.actuators WARNING: tel_actuators DDS read queue is filling: 30
of 100 elements
MTM1M3.logevent_appliedThermalForces ERROR: evt_appliedThermalForces DDS
read queue is full (100 elements); data may be lost
MTM1M3.logevent_appliedStaticForces ERROR: evt_appliedStaticForces DDS r
ead queue is full (100 elements); data may be lost
MTM1M3.logevent_appliedForces ERROR: evt_appliedForces DDS read queue is
full (100 elements); data may be lost
```

```
MTM1M3.logevent_appliedElevationForces ERROR: evt_appliedElevationForces
DDS read queue is full (100 elements); data may be lost
MTM1M3.logevent_appliedCylinderForces ERROR: evt_appliedCylinderForces D
DS read queue is full (100 elements); data may be lost
MTM1M3.logevent_appliedAzimuthForces ERROR: evt_appliedAzimuthForces DDS
read queue is full (100 elements); data may be lost
MTM1M3.logevent_appliedActiveOpticForces ERROR: evt_appliedActiveOpticFo
rces DDS read queue is full (100 elements); data may be lost
```

In [33]:

```
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 = "2022-06-17T19:49:32.690"
// Creation Date and Time of File
MJD = 59747.826072801
// 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_20220617_000012_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 = "2022-06-17T19:48:55.687"
// Date of the image trigger (readout), UTC f
MJD-TRG = 59747.825644525
// Modified Julian Date of image trigger
IMAGETAG = "dcace81515b20253"
// 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 = "R5-V3.2 2022-06-02T23:30:36Z (9a25b833)"
// DAQ version
DAQPART = "emu"
// DAQ partition
DAQFOLD = "raw"
// DAQ folder the image was initially created in
OBSANNOT = ""
// DAQ image annotation
OBSID = "CC_O_20220617_000012"
// 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 = "20220617"
// The observation day as defined in the image nam
SEQNUM = 12
// The sequence number from the image name
HEADVER = 2
// Version number of header
INSTRUME = "ComCam"
```

```
// Instrument
TELESCOP = "Simonyi Survey Telescope"
// 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_006012"
// Image bring emulated (from 2-day store)
DATE-BEG = "2022-06-17T19:49:14.633"
// Time at the start of integration
MJD-BEG = 59747.825863808
// Modified Julian Date derived from DATE-BEG
DATE-END = "2022-06-17T19:49:32.690"
// End date of the observation
MJD-END = 59747.826072801
// 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 = 307.07811716686
// RA of telescope from AZSTART and ELSTART
DECSTART = -87.472194503780
// DEC of telescope from AZSTART and ELSTART
RAEND = 307.07809691086
// RA of telescope from AZEND and ELEND
DECEND = -87.472194468257
// DEC of telescope from AZEND and ELEND
ROTPA = 4.9406564584125e-316
// Rotation angle relative to the sky (deg)
ROTCOORD = "sky"
// Telescope Rotation Coordinates
HASTART = -11.812453651978
// [HH:MM:SS] Telescope hour angle at start
ELSTART = 27.663712826959
// [deg] Telescope zenith distance at start
```

```
AZSTART = 179.85551685002
// [deg] Telescope azimuth angle at start
AMSTART = 2.1467012875030
// Airmass at start
HAEND = -11.806778174149
// [HH:MM:SS] Telescope hour angle at end
ELEND = 27.663900621469
// [deg] Telescope zenith distance at end
AZEND = 179.85115487440
// [deg] Telescope azimuth angle at end
AMEND = 2.1466879652986
// 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 = "2022-06-17T19:49:14.456"
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 = "2022-06-17T19:52:06.893442"
ASTRO METADATA FIX VERSION = "g4ae5eded10+a3e54b3923"
```

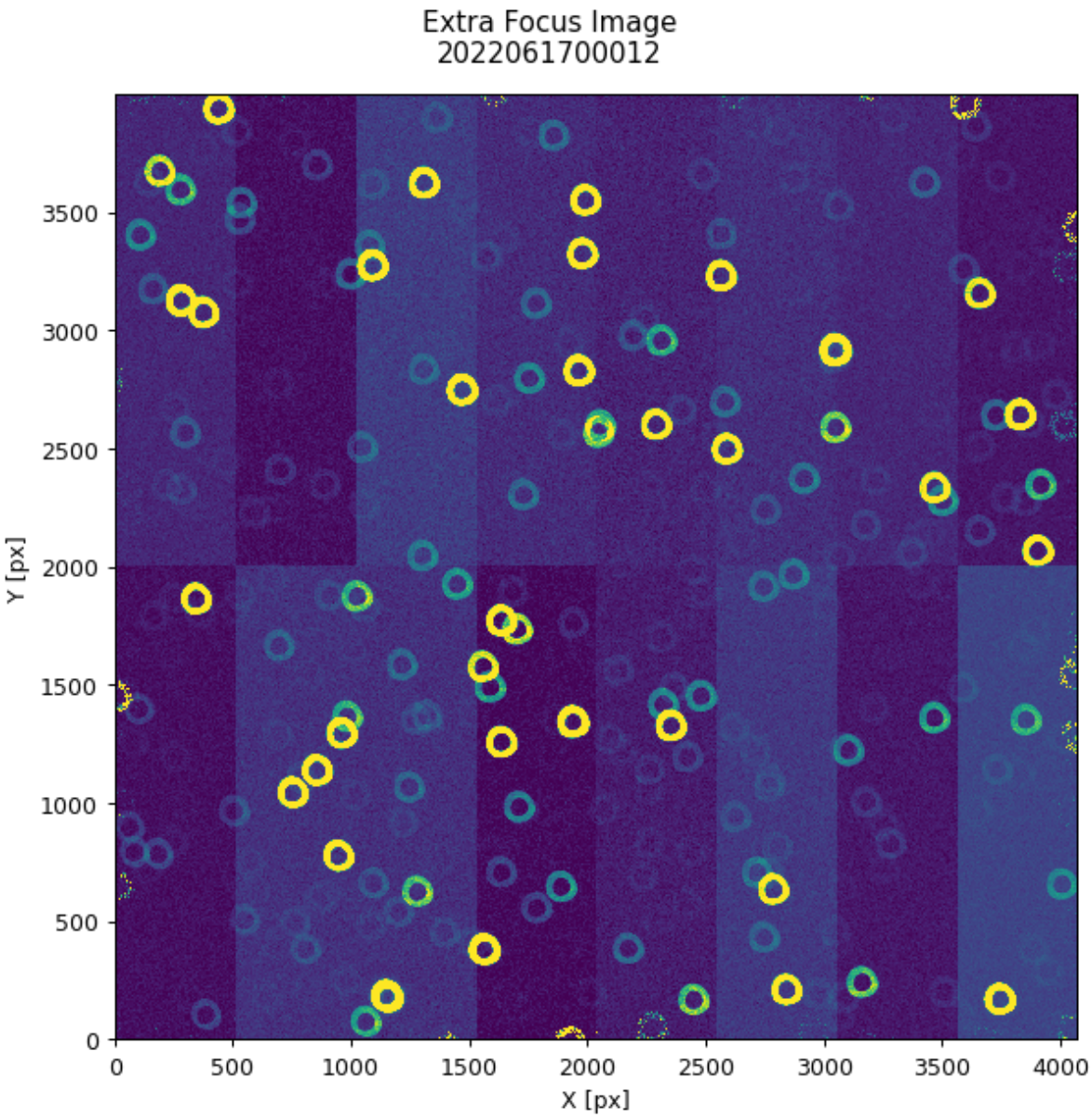
```
MTHexapod.electrical WARNING: tel_electrical DDS read queue is filling:
16 of 100 elements
```

```
MTHexapod.application WARNING: tel_application DDS read queue is fillin
g: 16 of 100 elements
```

```
MTHexapod.actuators WARNING: tel_actuators DDS read queue is filling: 15
of 100 elements
```

In [34]:

```
%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:
24 of 100 elements
MTHexapod.electrical WARNING: tel_electrical DDS read queue is filling:
11 of 100 elements
MTHexapod.application WARNING: tel_application DDS read queue is fillin
g: 24 of 100 elements
MTHexapod.actuators WARNING: tel_actuators DDS read queue is filling: 23
of 100 elements
MTHexapod.application WARNING: tel_application DDS read queue is fillin
g: 12 of 100 elements
MTHexapod.actuators WARNING: tel_actuators DDS read queue is filling: 11
of 100 elements
MTM1M3.logevent_appliedActiveOpticForces ERROR: evt_appliedActiveOpticFo
rces DDS read queue is full (100 elements); data may be lost
```

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

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

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

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

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

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

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

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