LARGE SYNOPTIC SURVEY TELESCOPE

Large Synoptic Survey Telescope (LSST)
Systems Engineering

LVV-P68 M2 Hexapod Functional Re-Verification And Integration With Sal Test Plan and Report

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SCTR-21

Latest Revision: 2020-03-09

Abstract

This is the test plan and report for LVV-P68 (M2 Hexapod Functional Re-Verification And Integration With Sal), an LSST milestone pertaining to the System Engineering Subsystem.

Change Record

Version	Date	Description	Owner name
	2020-02-20	First Draft	Kevin Siruno
1.0	2020-03-09	LVV-P68 Approved SE-1372.	Kevin Siruno

Document curator: Kevin Siruno
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Version from source repository: a47f35e

Contents

LVV-P68 M2 Hexapod Functional Re-Verification And Integration With Sal Test Plan and Report

1 Introduction

1.1 Objectives

The objective of this test plan is to re-verify the hardware and software functional requirements of the M2 hexapod without SAL, as well as verify the software functional requirements of the M2 hexapod integrated with SAL 4.0. This test campaign will exercise the functionality of the hardware and software that was executed previously and meets the following criteria:

- Does **NOT** require the M2 hexapod to be loaded with an M2 simulated mass
- Only requires a laser tracker

The hardware and software requirements were previously verified during the test campaign by the vendor at the vendors facility and accepted by LSST during the Factory Acceptance Test review.

1.2 System Overview

The purpose of the M2 hexapod is to maintain proper orientation of the M2 Cell Assembly. It is attached to the spider spindle of the Top End Assembly of the TMA. Although the mass of the M2 mirror cell assembly is greater than the camera, the actuators of the M2 hexapod are identical to the Camera Hexapod's actuators. For this reason, the M2 Hexapod and Camera hexapod have the same operator's manual and similar test procedures.

1.3 Document Overview

This document was generated from Jira, obtaining the relevant information from the LVV-P68 Jira Test Plan and related Test Cycles (LVV-C147).

Section 1 provides an overview of the test campaign, the system under test (SIT-COM Integra-

tion), the applicable documentation, and explains how this document is organized. Section 2 describes the configuration used for this test. Section 3 describes the necessary roles and lists the individuals assigned to them.

Section 4 provides a summary of the test results, including an overview in Table 2, an overall assessment statement and suggestions for possible improvements. Section 5 provides detailed results for each step in each test case.

The current status of test plan LVV-P68 in Jira is **Approved** .

1.4 References

[1] **[LTS-206]**, Neill, D., Sebag, J., Gressler, W., 2017, *Hexapods and Rotator Specifications Document*, LTS-206, URL `https://ls.st/LTS-206`

[2] **[LTS-160]**, Schumacher, G., 2018, *TCS to Hexapods and Rotator Interface Control Document*, LTS-160, URL `ls.st/LTS-160`

2 Test Configuration

2.1 Data Collection

Observing is not required for this test campaign.

2.2 Verification Environment

The M2 Hexapod will be verified on the 3rd floor of the Summit Facility on the shipping/test plate.

2.3 Entry Criteria

In order to test the M2 Hexapod functionality, the following criteria must be met first:

- All the test setup for the Data Acquisition system must be completed and ready to record data for the laser tracker
- The Laser tracker and 4 SMR's are installed and setup
- All utilities and electrical connections are hooked up and allow the M2 Hexapod to be powered on and controlled
- The EFD must be set up to be able to store events and telemetry data
- The temperature measurement system is operational and the EFD is able to record temperature

2.4 Exit Criteria

In order for this event to be considered complete, the following criteria must be met:

- Raw test data, events, and telemetry have been saved for the M2 Hexapod in the EFD.
- All test data has been analyzed and post processed.
- All test steps have been statused in the Jira Test Cases within this Test Plan and actual results populated as required.
- A summary of the results of the test campaign has been captured in the Overall Assessment and Recommended Improvements fields of this Test Plan
- A link to the verification artifacts used to produce the summary of results has been populated in the Verification Artifacts field of this Test Plan
- For tests producing quantitative results reporting of the analysis shall include traceability to the raw data of the test and estimates for the statistical significance of the result(s).
- Any failures have been captured in the FRACAS project

3 Personnel

The personnel involved in the test campaign is shown in the following table.

	Test Plan (LVV-P68) owner:	**Kevin Siruno**	
	LVV-C147 owner:	**Undefined**	
Test Case	**Assigned to**	**Executed by**	**Additional Test Personnel**
LVV-T1804	Kevin Siruno		(1) Software Engineer (1) Hardware Engineer
LVV-T1800	Kevin Siruno		Eric Coughlin Roberto Tighe
LVV-T1802	Kevin Siruno		(1) Software Engineer (1) Hardware Engineer

4 Test Campaign Overview

4.1 Summary

Test Plan **LVV-P68: M2 Hexapod Functional Re-verification and Integration with SAL**				Approved
Test Cycle **LVV-C147: M2 Hexapod Re-verification and Integration Testing**				Not Executed
test case	**Ver.**	**status**	**comment**	**issues**
LVV-T1804	1	Not Executed		
LVV-T1800	1	Not Executed		
LVV-T1802	1	Not Executed		

Table 2: Test Campaign Summary

4.2 Overall Assessment

Not yet available.

4.3 Recommended Improvements

Not yet available.

5 Detailed Test Results

5.1 Test Cycle LVV-C147

Open test cycle *M2 Hexapod Re-verification and Integration Testing* in Jira.

M2 Hexapod Re-verification and Integration Testing
Status: Not Executed

Re-verify the hardware and software for the M2 Hexapod that was previously tested by MOOG and verify the integrated M2 hexapod with SAL 4.0.

5.1.1 Software Version/Baseline

1. M2 Hexapod Control Software with SAL v4.0
2. EFD with SAL v4.0

5.1.2 Configuration

No varying configuration between test cycles.

5.1.3 Test Cases in LVV-C147 Test Cycle

5.1.3.1 LVV-T1804 - M2 Hexapod Software Functional Re-verification

Version **1**. Open *LVV-T1804* test case in Jira.

The objective of this test case is to re-verify the functional requirements of the M2 hexapod's software, after shipment of the hardware from the vendor's facility to the Summit, as defined in LTS-206 and LTS-160. This test case will only exercise the functionality that was executed previously and meets the following criteria:

- Only requires the M2 hexapod to be operable

- Only requires testing of the synchronous mode
  - **Asynchronous mode is not a standard mode of operation**
- Only requires the vendors EUI software and hardware via local control
  - Does **NOT** require integration with SAL
- Does **NOT** require the M2 hexapod to be loaded with the camera simulated mass or actual camera hardware
- Does **NOT** require the M2 hexapod to be rotated to various elevation angles.

The software functional requirements were previously verified during the test campaign by the vendor at the vendor's facility and accepted by Rubin Observatory during the Factory Acceptance Test review. The test procedure used during the vendor's acceptance testing is the *LSST Hexapods-Rotator Software Acceptance Test Procedure* which is attached to this test case. The test steps of this test case are taken directly from that document on how to perform the test in a similar way as was performed previously and includes changes noted by the vendor.

See the attached *LSST Hexapod Operator's Manual* for more information on how to operate the hexapod.

Preconditions:
Prior to the execution of this test case to re-verify the M2 Hexapod hardware functional requirements, the following Summit tasks must be completed:

- The measurement equipment has been set-up for testing
  - `https://jira.lsstcorp.org/browse/SUMMIT-1943`

Execution status: **Not Executed**

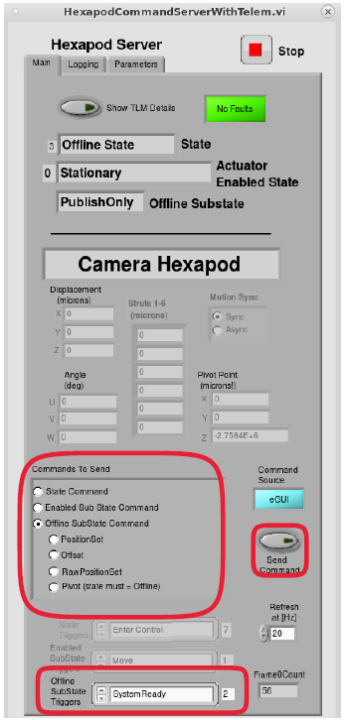
Final comment:

Detailed steps results:

Step	Step Details
1	Description **STARTING THE EUI** Double click the Hexapod GUI Viewer desktop icon on the computer. • This can be done on the Dell Management PC or another computer on the same network Expected Result A prompt to enter the password is shown. Actual Result Status: **Not Executed**
2	Description Enter the password “lsst-vnc” • If the EUI isn’t automatically up and running when the VNC opens, double click on the Hexapod-eGUI icon on the VNC viewer Expected Result The EUI is in the Offline State/PublishOnly substate and is able to publish through SAL but cannot receive commands. Actual Result Status: **Not Executed**
3	Description

OFFLINESTATE/AVAILABLESTATE

On the Main tab, select the "Offline SubState Cmd" field in the Commands to Send section, set the Offline SubState Triggers to "System Ready" and click on the Send Command button.



Expected Result

The system transitions from the OfflineState/PublishOnly substate to the OfflineState/AvailableState substate and the Command Source says eGUI.

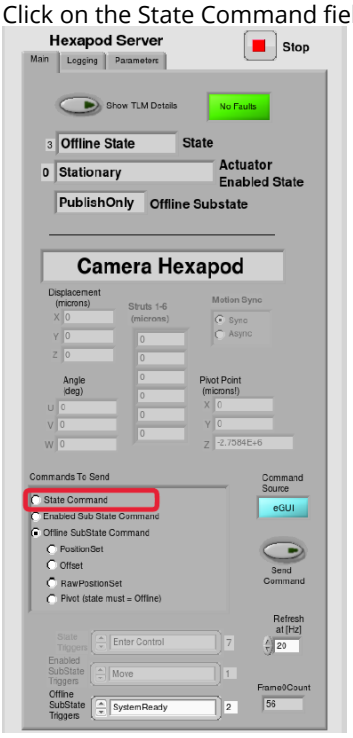
Actual Result

Status: **Not Executed**

4 Description

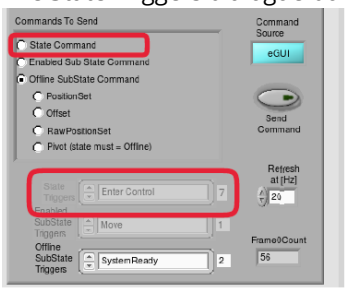
OFFLINESTATE -> STANDBYSTATE

Click on the State Command field in the Commands to Send section.



Expected Result

The State Triggers dialogue box shown below becomes visible.



Actual Result

Status: **Not Executed**

5 Description

Scroll through the available trigger options to select “Enter Control” and click the Send Command button.

Expected Result

The system transitions to the Standby state and the primary state display box at the top of the Main says Standby State.

Actual Result

Status: **Not Executed**

6	Description

STANDBYSTATE -> DISABLEDSTATE
From the StandbyState, send a Start State command.

Expected Result

The system transitions into DisabledState and the current configuration parameters are maintained from the default parameters or from the previous DDS start command.

Actual Result

Status: **Not Executed**

7	Description

DISABLEDSTATE -> ENABLEDSTATE
From the DisabledState, send an Enable State Command.

Expected Result

The system transitions into the EnabledState/Stationary substate, the motor drives are enabled and and motion can be commanded.

Actual Result

Status: **Not Executed**

8	Description

<conditional state>
FAULTSTATE
If a Fault occurs in any of the other states, the system will automatically transition to the Fault State. While in the Fault state, send a clearError.
Note: If the fault that occurs goes through the interlock system, reset the safety relay switch and send a clearError command.

Expected Result

The system transitions back to the OfflineState/PublishOnly substate. (Go back to Step 3)

Actual Result

Status: **Not Executed**

9	Description

Section 3.1.1 of the attached Software Acceptance Test Procedure
Test Sequence #1 - Synchronous PositionSet and Move Commands

With the synchronous button enabled and in enabled/stationary state, send a positionSet command of (0um, 0um, 200um, 0 deg, 0 deg, 0 deg) using the EUI.

Expected Result

The hexapod doesn't move.

Actual Result

Status: **Not Executed**

10 Description

With the synchronous button enabled and in enabled/stationary state, send a positionSet command of (2000um, -3500um, 200um, .01 deg, -.05deg, .002deg) using the EUI.

Expected Result

The hexapod doesn't move.

Actual Result

Status: **Not Executed**

11 Description

Send a move command using the EUI.

Expected Result

The hexapod moves to the last commanded position of (2000um, -3500um, 200um, .01 deg, -.05deg, .002deg) and the actuators complete the move at nearly the same time as seen on the motion complete lights on the telemetry screen.

Actual Result

Status: **Not Executed**

12 Description

Section 3.1.1 of the attached Software Acceptance Test Procedure
Test Sequence #2 - Pivot, PositionSet and Move Commands

In enabled/stationary state and at the last commanded position of (2000um, -3500um, 200um, .01 deg, -.05deg, .002deg), change the pivot point from the default location to (0,0,0) using the EUI.

Expected Result

The actuator positions do not change, but the hexapod position is (-407um, -3982um, 199um, 0.01deg, -0.05deg, 0.002deg)

Actual Result

Status: **Not Executed**

13 Description

In the enabled/stationary state, send a positionSet command of (2000um, -3500um, 200um, .01 deg, -.05deg, .002deg) using the EUI.

Expected Result

The hexapod doesn't move.

Actual Result

Status: **Not Executed**

14 Description

Send a move command using the EUI.

Expected Result

The hexapod moves to the commanded position of (2000um, -3500um, 200um, .01 deg, -.05deg, .002deg) and the actuators change position to account for the new pivot point.

Actual Result

Status: **Not Executed**

15 Description

Section 3.1.1 of the attached Software Acceptance Test Procedure
Test Sequence #4 - Synchronous Offset and Move Commands

With the synchronous button enabled and in enabled/stationary state, send a positionSet command of (500um, 800um, 200um, 0 deg, 0 deg, 0 deg).

Expected Result

The hexapod doesn't move.

Actual Result

Status: **Not Executed**

16 Description

With the synchronous button enabled and in enabled/stationary state, send an offset command of (0um, 0um, 2000um, 0 deg, 0 deg, 0 deg).

Expected Result

The hexapod doesn't move.

Actual Result

Status: **Not Executed**

17	Description

Send a move command.

Expected Result

The hexapod moves only 2000um in Z from the previous position and the actuators complete the move at nearly the same time as seen on the motion complete lights on the telemetry screen.

Actual Result

Status: **Not Executed**

18	Description

Instead of Asynchronous Test

With the synchronous button enabled and in enabled/stationary state, send a position set command of (0um, 0um, 0um, 0.1deg, 0deg, 0deg)

Expected Result

The hexapod doesn't move.

Actual Result

Status: **Not Executed**

19	Description

Send a move command.

Expected Result

The hexapod moves to the commanded position of (0um, 0um, 0um, 0.1deg, 0deg, 0deg)

Actual Result

Status: **Not Executed**

20	Description

With the synchronous button enabled and in enabled/stationary state, send a position set command of (0um, 0um, 0um, 0deg, 0.1deg, 0deg)

Expected Result

The hexapod doesn't move.

Actual Result

Status: **Not Executed**

21	Description Send a move command. Expected Result The hexapod moves to the commanded position of (0um, 0um, 0um, 0deg, 0.1deg, 0deg) Actual Result Status: **Not Executed**
22	Description With the synchronous button enabled and in enabled/stationary state, send a position set command of (0um, 0um, 0um, 0.1deg, 0.1deg, 0deg) Expected Result The hexapod doesn't move. Actual Result Status: **Not Executed**
23	Description Send a move command. Expected Result The hexapod moves to the commanded position of (0um, 0um, 0um, 0.1deg, 0.1deg, 0deg) Actual Result Status: **Not Executed**
24	Description **Section 3.1.1 of the attached Software Acceptance Test Procedure** **Test Sequence #5 - Stop Commands** In enabled/stationary state, send a position set command of (0um, 0um, 5000um, 0 deg, 0 deg, 0 deg). Expected Result The hexapod doesn't move. Actual Result Status: **Not Executed**

25	Description Send a move command. Expected Result The hexapod starts to move to the commanded position. Actual Result Status: **Not Executed**
26	Description While the hexapod is moving, send a stop command. Expected Result The hexapod quickly comes to a stop prior to reaching the commanded position. Actual Result Status: **Not Executed**
27	Description **Section 3.3.1 EUI Tests of the attached Software Acceptance Test Procedure** At startup, confirm that the system starts in the Offline/PublishOnly state. Expected Result The rotator starts in the Offline/PublishOnly state. Actual Result Status: **Not Executed**
28	Description Send an offline substate trigger of systemReady. Expected Result The system transitions into the Offline/Available substate. Actual Result Status: **Not Executed**
29	Description Send an EnterControl trigger. Expected Result The system transitions from Offline/Available to Standby state.

Actual Result

Status: **Not Executed**

30 Description

Send a Start trigger.

Expected Result

The system transitions from Standby to Disabled state.

Actual Result

Status: **Not Executed**

31 Description

Send an Enable trigger.

Expected Result

The system transitions from Disabled to Enabled state.

Actual Result

Status: **Not Executed**

32 Description

Send a Disable trigger.

Expected Result

The system transitions from Enabled to Disabled state.

Actual Result

Status: **Not Executed**

33 Description

Send a Standby trigger.

Expected Result

The system transitions from Disabled state to Standby state.

Actual Result

Status: **Not Executed**

34 Description

Send a exitControl trigger.

Expected Result

The system transitions from Standby state to Offline state.

Actual Result

Status: **Not Executed**

35 Description

Return to the Enabled state and trip the safety interlock switch.

Expected Result

The system transitions to Fault state.

Actual Result

Status: **Not Executed**

36 Description

Reset the safety interlock and send a ClearError trigger.

Expected Result

The system transitions from Fault state to Offline state

Actual Result

Status: **Not Executed**

37 Description

Section 4.1 Hexapod Events of the attached Software Acceptance Test Procedure

In the Enabled/Stationary state, unplug a motor encoder cable for one of the actuators.

Test Data

Deviation: Perform the following set of steps using the EUI instead of the DDS and verify the events are displayed on the EUI.

Expected Result

A Drive Fault error event is created and the system transitions to Fault state.

Actual Result

Status: **Not Executed**

38 Description

In the Enabled/Stationary state, unplug a linear encoder cable for one of the actuators.

Expected Result

A Drive Fault error event is created and the system transitions to Fault state.

Actual Result

Status: **Not Executed**

39	Description Unplug a motor power cable from one of the actuators and command a PositionSet/Move. Expected Result A Following Error event is created and the system transitions to Fault state. Actual Result Status: **Not Executed**
40	Description Activate an extension limit switch on one of the actuators by removing the limit switch cover and manually tripping. Expected Result An Extended Limit Switch error event is created and the system transitions into Fault state. Actual Result Status: **Not Executed**
41	Description Activate a retraction limit switch on one of the actuators by removing the limit switch cover and manually tripping. Expected Result A Retracted Limit Switch error event is created and the system transitions into Fault state. Actual Result Status: **Not Executed**
42	Description Unplug the Ethercat cable between the control PC and the first Copley XE2 drive. Expected Result An Ethercat Lost event is created and the system transitions to Fault state. Actual Result Status: **Not Executed**

5.1.3.2 LVV-T1800 - M2 Hexapod Hardware Functional Re-verification

Version **1**. Open *LVV-T1800* test case in Jira.

The objective of this test case is to re-verify the functional requirements of the M2 hexapod's hardware, after shipment from the vendor's facility to the Summit, as defined in LTS-206. This test case will only exercise the functionality that was executed previously and meets the following criteria:

- Only requires the M2 hexapod to be operable
- Only requires the EUI software and hardware via local control
- Only requires a laser tracker
- Does require the M2 hexapod temperature sensors be operating
- Does **NOT** require the M2 hexapod to be loaded with an M2 simulated mass or actual M2
- Does **NOT** require the M2 hexapod to be rotated to various elevation angles
- Does **NOT** require the M2 hexapod be in a climate controlled environment

The hardware functional requirements were previously verified during the test campaign by the vendor at the vendor's facility and accepted by Rubin Observatory during the Factory Acceptance Test review. The test procedure used during the vendor's acceptance testing is the *LSST Hexapods-Rotator Acceptance Test Procedure* which is attached to this test case. The test steps of this test case are taken directly from that document on how to perform the test in a similar way as was performed previously and includes changes noted by the vendor.

See the attached *LSST Hexapod Operator's Manual* for more information on how to operate the hexapod.

Preconditions:
Prior to the execution of this test case to re-verify the M2 Hexapod hardware functional requirements, the following Summit tasks must be completed:

- The measurement equipment has been set-up for testing

  - https://jira.lsstcorp.org/browse/SUMMIT-1943

- The laser tracker has been set up for measurements
  - https://jira.lsstcorp.org/browse/SUMMIT-3951

Execution status: **Not Executed**

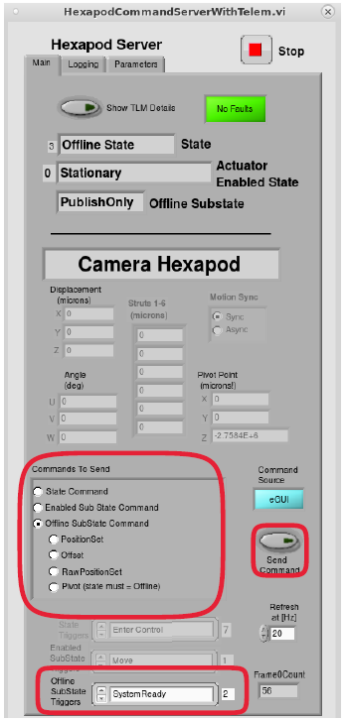
Final comment:

Detailed steps results:

Step	Step Details
1	Description **STARTING THE EUI** Double click the Hexapod GUI Viewer desktop icon on the computer. • This can be done on the Dell Management PC or another computer on the same network Expected Result A prompt to enter the password is shown. Actual Result Status: **Not Executed**
2	Description Enter the password “lsst-vnc” • If the EUI isn’t automatically up and running when the VNC opens, double click on the Hexapod-eGUI icon on the VNC viewer Expected Result The EUI is in the Offline State/PublishOnly substate and is able to publish through SAL but cannot receive commands. Actual Result Status: **Not Executed**
3	Description

OFFLINESTATE/AVAILABLESTATE

On the Main tab, select the "Offline SubState Cmd" field in the Commands to Send section, set the Offline SubState Triggers to "System Ready" and click on the Send Command button.



Expected Result

The system transitions from the OfflineState/PublishOnly substate to the OfflineState/AvailableState substate and the Command Source says eGUI.

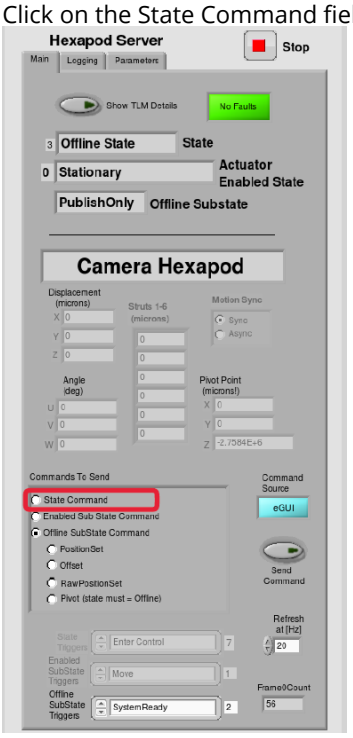
Actual Result

Status: **Not Executed**

4 Description

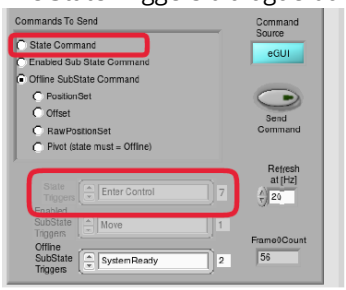
OFFLINESTATE -> STANDBYSTATE

Click on the State Command field in the Commands to Send section.



Expected Result

The State Triggers dialogue box shown below becomes visible.



Actual Result

Status: **Not Executed**

5 Description

Scroll through the available trigger options to select “Enter Control” and click the Send Command button.

Expected Result

The system transitions to the Standby state and the primary state display box at the top of the Main says Standby State.

Actual Result

Status: **Not Executed**

6	Description

STANDBYSTATE -> DISABLEDSTATE
From the StandbyState, send a Start State command.

Expected Result

The system transitions into DisabledState and the current configuration parameters are maintained from the default parameters or from the previous DDS start command.

Actual Result

Status: **Not Executed**

7	Description

DISABLEDSTATE -> ENABLEDSTATE
From the DisabledState, send an Enable State Command.

Expected Result

The system transitions into the EnabledState/Stationary substate, the motor drives are enabled and and motion can be commanded.

Actual Result

Status: **Not Executed**

8	Description

<conditional state>
FAULTSTATE
If a Fault occurs in any of the other states, the system will automatically transition to the Fault State. While in the Fault state, send a clearError.
Note: If the fault that occurs goes through the interlock system, reset the safety relay switch and send a clearError command.

Expected Result

The system transitions back to the OfflineState/PublishOnly substate. (Go back to Step 3)

Actual Result

Status: **Not Executed**

9	Description

Follow *3.5.12 Positioning* of the LSST Hexapods-Rotator Acceptance Test Procedure, Sheet 57-58.

Test Data

Deviation: Test at a single elevation angle and with no performance payload.

Expected Result

The position of the hexapod is able to reach the commanded positions within the absolute accuracy specifications of 25um in Z, 125um in XY, 83x10-5deg in RXRY, and 750x10-5deg in RZ.

Actual Result

Status: **Not Executed**

10 Description

Follow *3.5.13 Centers of Rotation* of the LSST Hexapods-Rotator Acceptance Test Procedure, Sheet 58-59.

Test Data

Deviation: Test at a single elevation angle and with no performance payload.

Expected Result

The center of rotation is able to be moved.

Actual Result

Status: **Not Executed**

11 Description

Follow *3.5.15 Radial (X and Y) Translation Range* of the LSST Hexapods-Rotator Acceptance Test Procedure, Sheet 59.

Test Data

Deviation: Test at a single elevation angle and with no performance payload.

Expected Result

The hexapod is capable of moving to the positions in the XY plane listed in the Acceptance Test Procedure.

Actual Result

Status: **Not Executed**

12 Description

Follow *3.5.17 Axial (Z) Translation Range* of the LSST Hexapods-Rotator Acceptance Test Procedure, Sheet 60.

Test Data

Deviation: Test at a single elevation angle and with no performance payload.

Expected Result

The hexapod is capable of moving to the positions in the Z plane listed in the Acceptance Test Procedure.

Actual Result

Status: **Not Executed**

13 Description

Follow *3.5.19 Rotational Range Around X-Axis (Tip) and Y-Axis (Tilt)* of the LSST Hexapods-Rotator Acceptance Test Procedure, Sheet 61.

Test Data

Deviation: Test at a single elevation angle and with no performance payload.

Expected Result

The hexapod is capable of moving to the positions in the RXRY plane listed in the Acceptance Test Procedure.

Actual Result

Status: **Not Executed**

14 Description

Follow *3.5.21 Rotation Range Around Z-Axis (Twist)* of the LSST Hexapods-Rotator Acceptance Test Procedure, Sheet 62.

Test Data

Deviation: Test at a single elevation angle and with no performance payload.

Expected Result

The hexapod is capable of moving to the positions in the RZ-axis listed in the Acceptance Test Procedure.

Actual Result

Status: **Not Executed**

15 Description

Follow *3.5.23 Hexapod Repeatability* of the LSST Hexapods-Rotator Acceptance Test Procedure, Sheet 63-70.

Test Data

Deviation: Allow a minimum of 30 seconds between moves.

Expected Result

The repeatability of the hexapod is likely better than can be determined by the test equipment. This test will likely falsely show a deficiency in the hexapod performance as a result of test equipment accuracy/ repeatability limitation.

Actual Result

Status: **Not Executed**

16 Description

Follow *3.5.24 Hexapod Absolute Accuracy* of the LSST Hexapods-Rotator Acceptance Test Procedure, Sheet 70-74.

Test Data

Deviation: Test at a single elevation angle and with no performance payload.

Expected Result

The accuracy of the hexapod is at least the following:

Axis	Required Accuracy (um, deg)
X	125
Y	125
Z	25
RX	0.00083
RY	0.00083
RZ	0.0075

NOTE: The accuracy of the hexapod may be better than can be determined by the test equipment. This may falsely show a deficiency in the hexapod performance as a result of test equipment accuracy/ repeatability limitation.

Actual Result

Status: **Not Executed**

17 Description

Follow *3.5.26 Hexapod Radial (X and Y) and Axial (Z) Velocity Range* and *3.5.27 Hexapod Rotational Velocity* of the LSST Hexapods-Rotator Acceptance Test Procedure, Sheet 75.

Test Data

Deviation: Only test this using synchronous mode.

Expected Result

The hexapod velocity exceeds the 106um/s in XY and 0.0062deg/s in RXYRY and RZ requirements.

Actual Result

Status: **Not Executed**

18 Description

Follow 3.5.28 *Hexapod Heat Dissipation* of the LSST Hexapods-Rotator Acceptance Test Procedure, Sheet 75-76.

Test Data

Deviation: Calculate the power by having an amp meter on the legs. This test can be done simultaneously with the other test steps.

Expected Result

The current measured by the inductive current probes is calculated to meet the heat dissipation requirement.

Actual Result

Status: **Not Executed**

19 Description

Follow *3.5.14 Cross Talk Motion* of the LSST Hexapods-Rotator Acceptance Test Procedure, Sheet 59.

Test Data

Deviation: Analyze data from 3.5.15, 3.5.17, and 3.5.19 test steps after testing to verify cross talk.

Expected Result

There is no cross-talk observed.

Actual Result

Status: **Not Executed**

5.1.3.3 LVV-T1802 - Integration of M2 Hexapod with SAL

Version **1**. Open *LVV-T1802* test case in Jira.

The objective of this test case is to re-verify the functional requirements of the M2 hexapod's software, after shipment of the hardware from the vendor's facility to the Summit, as defined in LTS-206 and LTS-160. This test case will only exercise the functionality that was executed previously and meets the following criteria:

- Only requires the use of Rubin Observatory code to replace MOOG's middleware code
- Only requires the M2 hexapod to be operable
- Only requires command through the CSC after the PXI real-time controller is switched

from GUI mode to DDS mode
- Only requires testing of the synchronous mode
  - **Asynchronous mode is not a standard mode of operation**
- Does require the M2 hexapod temperature sensors be operating
- Does **NOT** require the M2 hexapod to be loaded with the M2 simulated mass or actual M2
- Does **NOT** require the M2 hexapod to be rotated to various elevation angles.
- Does **NOT** require the M2 hexapod be in a climate controlled environment

The software functional requirements were previously verified during the test campaign by the vendor at the vendor's facility and accepted by Rubin Observatory during the Factory Acceptance Test review. The test procedure used during the vendor's acceptance testing is the *LSST Hexapods-Rotator Software Acceptance Test Procedure* which is attached to this test case. The test steps of this test case are the same steps from the procedure for the testing of the Camera Hexapod. The order of the steps were changed to reflect the *Proposal of Hexapod Test on Dec. 2019* Confluence page which can be found linked in the Traceability tab.

See the attached *LSST Hexapod Operator's Manual* for more information on how to operate the hexapod.

Preconditions:
Prior to the execution of this test case to re-verify the M2 Hexapod hardware functional requirements, the following Summit tasks must be completed:

- The measurement equipment has been set-up for testing
  - `https://jira.lsstcorp.org/browse/SUMMIT-1943`

Execution status: **Not Executed**

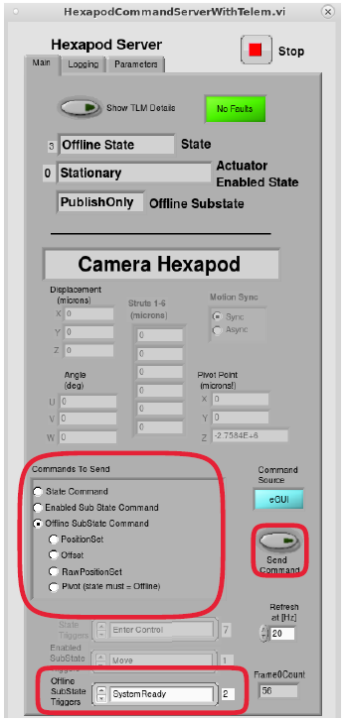
Final comment:

Detailed steps results:

Step	Step Details
1	Description **STARTING THE EUI** Double click the Hexapod GUI Viewer desktop icon on the computer. • This can be done on the Dell Management PC or another computer on the same network Expected Result A prompt to enter a password is shown. Actual Result Status: **Not Executed**
2	Description Enter the password “lsst-vnc” • If the EUI isn’t automatically up and running when the VNC opens, double click on the Hexapod-eGUI icon on the VNC viewer Expected Result The EUI is in the Offline State/PublishOnly substate and is able to publish through SAL but cannot receive commands. Actual Result Status: **Not Executed**
3	Description

OFFLINESTATE/PUBLISHONLY -> OFFLINESTATE/AVAILABLESTATE

On the Main tab, select the "Offline SubState Cmd" field in the Commands to Send section, set the Offline SubState Triggers to "System Ready" and click on the Send Command button.



Expected Result

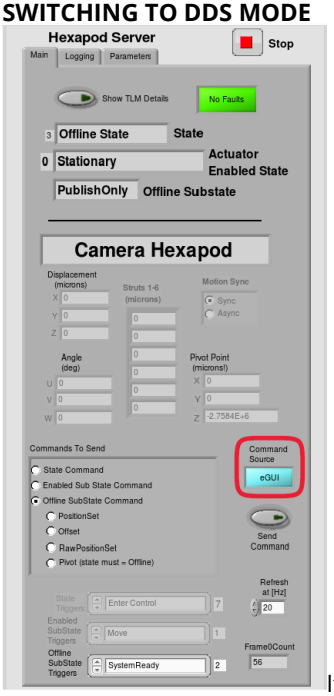
The system transitions from the OfflineState/PublishOnly substate to the OfflineState/AvailableState substate.

Actual Result

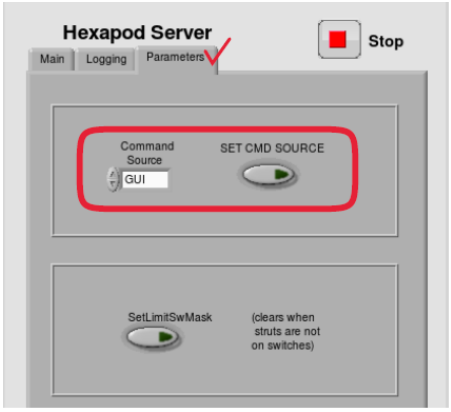
Status: **Not Executed**

4 Description

SWITCHING TO DDS MODE



If the Command Source does not show DDS, go to the Parameters tab, select DDS under the Command Source and click the Set Cmd Source button.



Note: If the GUI is used after being set to DDS mode, the system will switch back the Command Source to GUI and ignore any DDS commands. The Command Source must show DDS in order to receive DDS commands.

Expected Result

The system is capable of receiving/responding to DDS commands.

Actual Result

Status: **Not Executed**

5 Description

OFFLINESTATE -> STANDBYSTATE

The system receives an enterControl State Transition command through DDS.

Expected Result

The system transitions into the StandbyState and is capable of receiving/responding to DDS commands.

Actual Result

Status: **Not Executed**

6	Description

STANDBYSTATE -> DISABLEDSTATE

From the StandbyState, send a start command through the DDS.

Expected Result

The system transitions into DisabledState after receiving/responding to DDS command and the wrapper in the PXI real time controller looks for the configuration file.

If the configuration file is invalid or out of range, the system will transition into a Fault State

Actual Result

Status: **Not Executed**

7	Description

DISABLEDSTATE -> ENABLEDSTATE

From the DisabledState, send an enable state command through the DDS.

Expected Result

The system transitions into the EnabledState/Stationary substate, the motor drives are enabled, motor brakes are released and the system is capable of receiving/responding to DDS commands.

Actual Result

Status: **Not Executed**

8	Description

FAULTSTATE

If a Fault occurs in any of the other states, the system will automatically transition to the Fault State. While in the Fault state, send a clearError command through the DDS.
Note: If the fault that occurs goes through the interlock system, reset the safety relay switch and send a clearError command.

Expected Result

The system transitions back to the OfflineState/PublishOnly substate and is not capable of receiving/responding to DDS commands. (Go back to Step 3)

Actual Result

Status: **Not Executed**

9	Description

MOVE TEST
Section 3.1.2 of the attached Software Acceptance Test Procedure
Test Sequence #1 - Synchronous PositionSet and Move Commands
In enabled/stationary state, send a positionSet command of (0um, 0um, 200um, 0 deg, 0 deg, 0 deg, s).

Expected Result

The hexapod does not move.

Actual Result

Status: **Not Executed**

10	Description

With the synchronous button enabled and in enabled/stationary state, send a positionSet command of (2000um, -3500um, 200um, 0.01deg, -.05deg, 0.002deg).

Expected Result

The hexapod does not move

Actual Result

Status: **Not Executed**

11	Description

Send a move command.

Expected Result

- The hexapod moves to (2000um, -3500um, 200um, 0.01deg, -.05deg, 0.002deg)
- The actuators complete the move at nearly the same time.

Actual Result

Status: **Not Executed**

12	Description

Record the corresponding DDS events that were generated.

Expected Result

- The controllerState.enabledSubstate goes to MOVING_POINT_TO_POINT when the move begins and STATIONARY when the move ends.
- An inPosition event is generated when the move is complete

Actual Result

Status: **Not Executed**

13 Description

Section 3.1.2 of the attached Software Acceptance Test Procedure
Test Sequence #5 - Stop Commands
In the enabled/stationary state, send a position set command of (0um, 0um, 5000um, 0deg, 0deg, 0deg)

Expected Result

The hexapod doesn't move.

Actual Result

Status: **Not Executed**

14 Description

Send move command.

Expected Result

The hexapod begins to move.

Actual Result

Status: **Not Executed**

15 Description

Before the hexapod completes its movement, send a stop command.

Expected Result

- The hexapod stops before reaching the previously commanded position

Actual Result

Status: **Not Executed**

16 Description

Record the corresponding DDS events that were generated.

Expected Result

- The controllerState.enabledSubstate goes to CONTROLLED_STOPPING when the stop is requested, then STATIONARY when the hexapod has halted.
- No inPosition event is generated.

Actual Result

Status: **Not Executed**

17 Description

Section 3.1.2 of the attached Software Acceptance Test Procedure
Test Sequence #9 - positionSet and moveLUT
In enabled/stationary state, send a positionSet command of (0um, 0um, 200um, 0deg, 0deg, 0deg)

Expected Result

The hexapod doesn't move.

Actual Result

Status: **Not Executed**

18 Description

In enabled/stationary state, send a positionSet command of (0um, 0um, 800um, 0deg, 0deg, 0deg)

Expected Result

The hexapod doesn't move.

Actual Result

Status: **Not Executed**

19 Description

Send a moveLUT (180deg, 60deg, and 10deg) command

Expected Result

The hexapod moves to a different position than (0um, 0um, 800um, 0deg, 0deg, 0deg) and the actuators complete the move at nearly the same time.

Actual Result

Status: **Not Executed**

20 Description

OFFSET TEST
Section 3.1.2 of the attached Software Acceptance Test Procedure
Test Sequence #4 - Synchronous Offset and Move Commands
In enabled/stationary state, send a positionSet command of (500um, 800um, 200um, 0deg, 0deg, 0deg)

Test Data

Expected Result

The hexapod doesn't move.

Actual Result

Status: **Not Executed**

21	Description

In enabled/stationary state, send an offset command of (0um, 0um, 2000um, 0deg, 0deg, 0deg).

Expected Result

The hexapod doesn't move.

Actual Result

Status: **Not Executed**

22	Description

Send a move command.

Expected Result

- The hexapod moves only 2000um in Z from the previous position
- The actuators complete the move at nearly the same time.

Actual Result

Status: **Not Executed**

23	Description

Record the corresponding DDS events that were generated.

Expected Result

- The controllerState.enabledSubstate goes to MOVING_POINT_TO_POINT when the move begins and STATIONARY when the move ends
- The inPosition event is True when the move finishes
- The inPosition event is False when the enabledSubstate goes back to STATIONARY.

Actual Result

Status: **Not Executed**

24	Description

Section 3.1.2 of the attached Software Acceptance Test Procedure
Test Sequence #2 -Pivot, PositionSet and Move Commands
In enabled/stationary state, send a positionSet command of (2000um, -3500um, 200um, 0.01deg, -0.05deg, 0.002deg)

Test Data

Deviation: Record any offset commands necessary to test before sending the move command.

Expected Result

The hexapod doesn't move.

Actual Result

Status: **Not Executed**

25	Description

In the enabled/stationary state, send a pivot command of (0,0,0).

Expected Result

The actuator positions do not change but the hexapod position changes.

Actual Result

Status: **Not Executed**

26	Description

In the enabled/stationary state, send a positionSet command of (2000um, -3500um, 200um, 0.01deg, -0.05deg, 0.002deg)

Test Data

Deviation: Record any offset commands necessary to test before sending the move command.

Expected Result

The hexapod doesn't move.

Actual Result

Status: **Not Executed**

27	Description

Send a move command.

Expected Result

Confirm the hexapod moves to the commanded position and the actuators change position to account for the new pivot point.

Actual Result

Status: **Not Executed**

28 Description

CONFIGURE LIMITS TEST
Section 3.1.2 of the attached Software Acceptance Test Procedure
Test Sequence #6 - configureLimits Command
In enabled/stationary state, send a configureLimits command of (12000um, -1000um, 1000um, 0.1, -0.1, 0.05)

Expected Result

The command is rejected for being outside acceptable limits.

Actual Result

Status: **Not Executed**

29 Description

In enabled/stationary state, send a configureLimits command of (1000um, -1000um, 1000um, 0.1, -0.1, 0.05)

Expected Result

The command is accepted.

Actual Result

Status: **Not Executed**

30 Description

In enabled/stationary state, send a positionSet command of (850um, 0um, 500um, 0deg, 0deg, 0deg)

Test Data

Deviation: This command can be any valid positionSet command within the newly configured limits.

Expected Result

The command is accepted.

Actual Result

Status: **Not Executed**

31 Description

In enabled/stationary state, send a positionSet command of (1200um, 0um, 200um, 0deg, 0deg, 0deg)

Expected Result

The command is rejected for being outside of range limits

Actual Result

Status: **Not Executed**

32	Description Send a move command. Expected Result The Hexapod doesn't move. Actual Result Status: **Not Executed**
33	Description In enabled/stationary state, send a positionSet command of (990um, 990um, 200um, 0deg, 0deg, 0deg) Expected Result The command is rejected for being outside of range limits. Actual Result Status: **Not Executed**
34	Description In enabled/stationary state, send a positionSet command of (500um, 500um, 200um, 0deg, 0.1 deg, 0.01deg) Expected Result The command is accepted. Actual Result Status: **Not Executed**
35	Description Send a move command. Expected Result The previously accepted command is executed. Actual Result Status: **Not Executed**
36	Description Record the DDS events that were generated. Expected Result The change is reflected in the settingsApplied event and the EUI.

Actual Result

Status: **Not Executed**

37	Description **CONFIGURE ACCELERATION TEST** **Section 3.1.2 of the attached Software Acceptance Test Procedure** **Test Sequence #7 - configureAcceleration Command** In enabled/stationary state, at a position of (0, 0, 0, 0, 0, 0) with the velocity and acceleration values set to their nominal values, send a positionSet command of (0um, 0um, 4900um, 0 deg, 0 deg, 0 deg, s). Expected Result The hexapod doesn't move. Actual Result Status: **Not Executed**
38	Description Send a move command. Expected Result The move takes approximately 9 seconds to complete. Actual Result Status: **Not Executed**
39	Description Send a configureAcceleration command of 1000. Expected Result Confirm command is rejected for being outside of acceptable limits. Actual Result Status: **Not Executed**
40	Description Send a configureAcceleration command of 100. Expected Result The command is accepted. Actual Result Status: **Not Executed**

41	Description In enabled/stationary state, send a postionSet command of (0um, 0um, 0um, 0 deg, 0 deg, 0 deg, s). Expected Result The hexapod doesn't move. Actual Result Status: **Not Executed**
42	Description Send a move command. Expected Result It takes approximately 13 seconds to complete the commanded move with the reduced acceleration value. Actual Result Status: **Not Executed**
43	Description Send a configureAcceleration command of 500 to return the acceleration limit to its nominal value. Expected Result The command is accepted. Actual Result Status: **Not Executed**
44	Description Record the corresponding DDS events that were generated. Expected Result The change is reflected in the settingsApplied event and the EUI. Actual Result Status: **Not Executed**
45	Description **CONFIGURE VELOCITY TEST** **Section 3.1.2 of the attached Software Acceptance Test Procedure** **Test Sequence #8 - configureVelocity Command** In enabled/stationary state, at a position of (0, 0, 0, 0, 0, 0), send a configureVelocity command of (10000, .01, 100, .01).

Expected Result

This command is rejected for being outside of acceptable limits.

Actual Result

Status: **Not Executed**

46	Description

In enabled/stationary state, send a configureVelocity command of (100, .01, 200, .01).

Expected Result

This command is accepted.

Actual Result

Status: **Not Executed**

47	Description

In enabled/stationary state, send a positionSet command of (0, 0um, 2000um, 0 deg, 0 deg, 0 deg, s).

Expected Result

The command is accepted

Actual Result

Status: **Not Executed**

48	Description

Send a move command.

Expected Result

It takes approximately 20 seconds to complete the commanded move.

Actual Result

Status: **Not Executed**

49	Description

In enabled/stationary state, send a configureVelocity command of (100, .01, 100, .01).

Expected Result

This command is accepted.

Actual Result

Status: **Not Executed**

50	Description In enabled/stationary state, send an offset command of (0, 0um, 2000um, 0 deg, 0 deg, 0 deg). Expected Result This command is accepted Actual Result Status: **Not Executed**
51	Description Send a move command. Expected Result It takes approximately 40 seconds to complete the commanded move. Actual Result Status: **Not Executed**
52	Description Record the corresponding DDS events that were generated: Expected Result The change is reflected in the settingsApplied event and the EUI. Actual Result Status: **Not Executed**
53	Description **Section 3.3.2 of the attached Software Acceptance Test Procedure Hexapod Action on State Commands** In the Offline/PublishOnly state, send all commands Expected Result There is no change and command is rejected. Actual Result Status: **Not Executed**
54	Description In the Offline/Available state, send an enterControl command Expected Result The system enters the Standby state.

Actual Result

Status: **Not Executed**

55	Description In the Standby state, send any command except start or exitControl Expected Result There is no change and command is rejected. Actual Result Status: **Not Executed**
56	Description In the Standby state, send an exitControl command. Expected Result The system transitions into the Offline/Available state. Actual Result Status: **Not Executed**
57	Description In the Standby state, send a start command. Expected Result The system transitions into the Disabled state. Actual Result Status: **Not Executed**
58	Description In the Disabled state, send any command except for the enabled or standby command. Expected Result There is no change and the command is rejected. Actual Result Status: **Not Executed**
59	Description In the Disabled state, send the standby command.

Expected Result

The system transitions into the Standby state.

Actual Result

Status: **Not Executed**

60	Description In the Disabled state, send the enable command. Expected Result The system transitions into the Enabled/Stationary state. Actual Result Status: **Not Executed**
61	Description In the Enabled/Stationary state, send either the enterControl command, exitControl command, start command, clearError command, or enable command. Expected Result There is no change and command is rejected. Actual Result Status: **Not Executed**
62	Description In the Enabled/Stationary state, send a disable command. Expected Result The system transitions into Disabled state. Actual Result Status: **Not Executed**
63	Description In the Fault state, send any command except the clearError command. Expected Result There is no change and command is rejected. Actual Result Status: **Not Executed**

64 Description

In the Fault state, send the clearError command.

Expected Result

The system transitions into the Offline/PublishOnly state.

Actual Result

Status: **Not Executed**

65 Description

Section 4 of the attached Software Acceptance Test Procedure
In the Enabled/Stationary state, unplug a motor encoder cable for one of the actuators.

Expected Result

A Drive Fault error event is created and the system transitions to Fault state.

Actual Result

Status: **Not Executed**

66 Description

In the Enabled/Stationary state, unplug a linear encoder cable for one of the actuators.

Expected Result

A Drive Fault error event is created and the system transitions to Fault state.

Actual Result

Status: **Not Executed**

67 Description

Unplug a motor power cable from one of the actuators and command a PositionSet/Move.

Expected Result

A Following Error event is created and the system transitions to Fault state.

Actual Result

Status: **Not Executed**

68 Description

Activate an extension limit switch on one of the actuators by removing the limit switch cover and manually tripping.

Expected Result

An Extended Limit Switch error event is created and the system transitions into Fault state.

Actual Result

Status: **Not Executed**

69	Description Activate a retraction limit switch on one of the actuators by removing the limit switch cover and manually tripping. Expected Result A Retracted Limit Switch error event is created and the system transitions into Fault state. Actual Result Status: **Not Executed**
70	Description Unplug the Ethercat cable between the control PC and the first Copley XE2 drive. Expected Result An Ethercat Lost event is created and the system transitions to Fault state. Actual Result Status: **Not Executed**

A Acronyms used in this document

Acronym	Description
EFD	Engineering and Facility Database
FRACAS	Failure Reporting Analysis and Corrective Action System
GUI	Graphical User Interface
LSST	Legacy Survey of Space and Time (formerly Large Synoptic Survey Telescope)
M2	Secondary Mirror
SAL	Service Abstraction Layer
SMR	Spherically Mounted Retroreflector
TMA	Telescope Mount Assembly