MMT Elevation Axis Controller Commissioning Checkout
Version 1.2
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First, set the telescope elevation angle at ~ 45° and adjust balance if necessary. To set up the new controller system, the hardware shall be configured the same as during open-loop and closed loop testing:

Item	Location	Action	X
Amplifier AC power	PWM amplifier power supply rear panel	Remove from existing Copley PWM amplifier supply and connect to splitter box to power temporary linear amplifiers.	
Elevation Motor Cables	PWM amplifier chassis rear panel	Remove from PWM amplifier and connect to adapter cables in place at linear amplifier outputs.	
Elevation Drive Command Signal	Mount interface chassis connector P3	Remove existing MS connector and replace with BNC adapter connector with BNC marked “Channel 1” routed to linear amplifiers.	
Elevation Tape Head Interpolator cables	Mount interface chassis connectors P7 and P8	Remove EXE702 output cables from the rear of the mount interface and replace with EXE650B types.	
Elevation Tape Head Interpolator boxes	Shelf below mount interface in drive rack	Disconnect the two elevation tape input cables and connect each to EXE650B units.	
Elevation Tape Head Interpolator box cables	Shelf below mount interface in drive rack to P7 and P8	Connect EXE650B units with East interpolator output to P7, and the West output to P8.	
IP-Servo Interface board	Mount interface chassis, slot #1	Remove the in-use unit and replace with “hot spare” from lower chassis.	
IP-Servo ribbon cable	IP-Servo Interface i/o connector	Remove and connect to the rear ribbon connector on servo bridge panel marked “IP-Servo Counter #1”.	
Servo Bridge DAC input	Servo Bridge panel rear side	Ensure that the MCC DAC-6703 cable for pins 1-50 is connected to the center rear connector marked “MCC DAC-6703”	
IP-Servo Interface board	Servo Bridge panel front side	Connect a ribbon cable to the IP-Servo board from the front servo bridge connector marked “IP-Servo Channel #1”.	
Linear Amplifier power	Amplifier front panels	Turn on AC input breakers on the front panels, and ensure that the bias switches are set to the center-off position.	

Once the hardware is connected and ready, the next step is to check out the system startup behavior:

Test	Procedure	Expected Result	X
Mount PC controller code installation	Boot the mount PC.	New mount controller code shall be automatically loaded at boot time without any operator intervention or special setup required.	
Mount PC controller code startup	Start the mount control GUIs.	The mount control GUIs shall start normally and be running the new controller code.	
Mount PC and Interlock system	Boot the Interlock VME crate.	The interlock system shall properly communicate with the mount PC and safely interrupt operation if communication is lost.	
Mount PC and other telescope computers	Start all other telescope computers (i.e. hexapod, cell, instrument).	Mount PC network communications and GUI operations shall continue to run normally.	
Mount PC and other system GUIs	Start all system GUIs (i.e. cell, hexapod, thermal, etc.)	All GUIs and controls shall continue to work normally.	
Emergency stops	Press any emergency stop button.	The interlock system shall shut down the system and this condition properly reported and handled by the interlock and mount control computers.	
Safety interlocks	Test the interlock ready chain.	Interruptions in the axis ready chain shall result in axis shutdown and corresponding handling by the computers.	
Hardware controls	Release brakes, turn on amplifiers.	The system controls from the GUI buttons shall respond properly.	
Axis startup	Turn on drives, release brakes.	Telescope shall safely start up without a torque transient or un-commanded motion.	
Axis running	Hold position with drives on	Telescope shall safely hold position without oscillations in the servo loop.	
Axis disturbance	Holding position, apply disturbance force to the telescope.	Telescope shall safely hold position without oscillations in the servo loop, nor should it react with motions away from the initial position.	

Axis brake windup	Turn on motor amplifiers without releasing cell brakes.	Amplifier outputs do not wind up excessively against cell brakes.	
Axis unbalance on startup	Unbalance axial counterweights by 20% and start drives. Check both positive and negative unbalances.	Axis shall start up and not move off initial position with unbalance torque present.	
Axis unbalance while running.	Start drives with counterweights in balance, and move them off by ±20% while drives are running and holding position	Telescope shall safely hold position while unbalance torque is changing.	
Alternate axis startup	With drives off, start other drives, then start elevation axis.	Elevation axis should safely start and all running axes should safely hold position.	
Axis startup while elevation is running	With the elevation axis running and holding position, start the other axes.	The other axes of the telescope should startup safely with disturbing the elevation axis controller.	
Cell startup while axis is running	With the elevation axis running and holding position, start the cell system and raise the primary mirror.	The primary mirror raise should complete safely and the elevation axis should remain undisturbed.	
Thermal system startup while axis is running	With the elevation axis running and holding position, start the thermal system and blower.	The elevation axis should remain undisturbed by any inputs from the moving air in the thermal control system.	
Secondary system startup	With the elevation axis running and holding position, power the hexapod and secondary mirror support system.	The elevation axis should remain unperturbed by any activity of the hexapod and secondary mirror support.	
Secondary hexapod motions	With the elevation axis running and holding position, command motions of the secondary hexapod.	The elevation axis should remain undisturbed by any hexapod motions.	

Now we are ready to test actual motions with the new controller, starting with a balanced telescope:

Test	Procedure	Expected Result	X
Small motions in both directions from the initial position.	Move elevation in small (less than 1°) motions.	The motion should safely complete to within 0.1 arcseconds of the commanded positions, and return to the starting position to the same precision, without exceeding the velocity and acceleration limits.	
Large motions in both directions	Move elevation in a range of 1 to 20° motions.	The motion should safely complete to within 0.1 arcseconds of the commanded positions, and return to the starting position to the same precision, without exceeding the velocity and acceleration limits.	
Measure encoder deltas	While moving elevation over nearly the full range (89 to 10 degrees for example), log the difference between the absolute encoder position and the absolute position using the combination of the starting position and the tape encoder.	Gain information about the difference in telescope pointing with tape encoder position feedback to have a metric for evaluation of overall pointing accuracy and/or pointing changes for comparison to the absolute encoder values.	
Repeat the small and large motions with 25% unbalance torque.	Move the axial counterweights to achieve 25% of the available current limit (5.0A) while holding position in the starting position.	The starting position should not vary while adjusting the counterweights, and motions should safely complete as in the previous tests.	
Motion cancellation	After commanding a motion, cancel it with the operator GUI.	The motion should gracefully end and the position at the end should be safely held.	
Motions to stow positions.	Command telescope to each standard stow position. Approach the zenith and service stow positions with caution to ensure no over-speed contact with the shock absorber and final stop assemblies.	The telescope should approach the stow positions and complete the motions while maintaining safe velocities when near the shock absorbers and final stop assemblies.	
Service position disturbances	Command telescope to service and allow personnel to walk on the truss arms and otherwise	The telescope should tolerate the disturbance without moving out of position or exhibiting	

	disturb the telescope.	instability.	
Acquire and track observing target	Command a specific observing target.	The telescope should safely slew to the object position and begin tracking the object without excessive overshoot or unsafe velocities during the slew.	
Change observing target	While tracking an object, command a new target.	The telescope should safely slew to the object position and begin tracking the object without excessive overshoot or unsafe velocities during the slew.	
Position offset inputs	While tracking an object, apply position offsets.	Offsets should be properly processed and applied to the controller command pre-processor, with the controller achieving the desired offset to within 0.1 arcseconds.	
Paddling offset inputs.	While tracking an object, apply paddling offsets.	Offsets should be properly processed and applied to the controller command pre-processor, with the controller achieving the desired offset to within 0.1 arcseconds.	
Network offsets	While tracking an object, apply guider or pointing offsets over the network interfaces.	Network offsets should be properly handled, with the controller achieving the desired offset to within 0.1 arcseconds.	
Logging system and telemetry	While drives are on and in all modes of operation (track, slew, idle), ensure that all data logging and telemetry channels are working.	Logging and telemetry data are available during all phases of operation.	

Assuming all the above tests are completed successfully, we are then ready to release the controller for use during science observing. Provided the hardware is set up, the telescope is balanced and all systems are in working order, the following series of tests should be performed:

Test	Procedure	Expected Result	X
Acquire Polaris	Using the normal startup procedures, acquire and track Polaris.	The telescope should point and acquire Polaris to within 0.1? arcseconds.	
Track Polaris	While tracking Polaris, measure the RMS tracking	Tracking data should be collected during the track, and the position error should	

	error with wind disturbance preferably present.	remain within the tracking error specification (0.1? arcseconds over a 10-minute? period).	
Acquire stars	Acquire stars on the MMT's meridian and latitude.	Gather pointing data and acquire more tracking error information.	
Acquire non-stellar objects	Acquire non-stellar objects, such as planets, asteroids, and satellites	Gather pointing and tracking data on non-sidereal objects.	
MMT open-loop pointing	Perform a pointing test run with a selected group of pointing objects in each sky quadrant.	Gather pointing data and acquire tracking performance information.	
Apply pointing offsets	Acquire objects and apply the various methods of injecting pointing offsets into the current coordinates	Ensure that pointing offsets are correctly handled under operating conditions.	
Wind buffeting rejection	If conditions permit, perform pointing and tracking into and out of the wind.	Gather tracking disturbance rejection data and quantify high-frequency modal response of the telescope (i.e. 6Hz, 20Hz, or other eigenfrequencies of interest).	
Operator testing	Allow the T.O. to run the telescope under normal science observing conditions.	Gain user information on any problems, strange or unexpected behavior, or favorable comments on the new controller's performance.	