

Procedure to Install the 2.5m Secondary Mirror

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Cautionary Notes

- **This operation requires 5 people.**
 - **If the telescope runs away at any time, engage an e-stop button immediately.**
 - **Set up barriers to control personnel traffic.**
 - **Determine lead person and review procedure with crew before commencing.**
 - **The following weather conditions must be met:**
 - No threat of precipitation
 - Sustained wind speed < 35 MPH for 15 minutes
 - Wind gusts for instrument changes < 25 MPH
 - Dew point depression: $\geq 4^{\circ}\text{F}$ or 2°C
 - Dust count < 10,000 units
 - Check for condensation regularly when the dew point depression is less than 8°F or 6°C . Close the enclosure if condensation is found on rails, building skin, or the top of the doghouse.
 - Do not push the dust limit and the dew point limit at the same time. If the dust counts are near the stated limit, it is best to have a dew point depression of $> 18^{\circ}\text{F}$ or 20°C .
 - Safety wear (recommended): rubber-soled shoes, hard hat.
 - Only people trained by observatory staff may execute this procedure.
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Equipment Required

- M2, properly crated (the belly band must be attached to the mirror).
 - 500 lb. Force Gauge for crane, located in the 2.5m enclosure.
 - Hydraulic Damper for crane, located in the 2.5m storage cabinets.
 - Two 4' Step Ladders, located in the 2.5m enclosure.
 - Plastic Sheeting, 1/4" thick, located in the garage.
 - All three M2 whiffle assemblies, complete with axial actuator flexure and 3 blade flexures (which attach to the mirror).
 - Hardware to attach the whiffles to M2: 27 screws, 9 small washer plates for the mirror flexures, 2 suitable ball-end Allen wrenches, a grabber to retrieve screws dropped into the mirror and Kim-wipes to stuff into holes in the mirror.
 - M2 anti-rotation link.
 - Hardware to attach the M2 anti-rotation link: 2 screws, 2 washers and a suitable Allen wrench (probably 5/64", possibly 3/32").
 - Tools to tighten the axial actuator set screws onto the axial actuator flexures: two 1/8" ball-end Allen wrenches, at least one of them L-shaped.
 - Cotton gloves.
 - Spit mask.
 - All three Heidenhain axial encoders.
 - At least six spare flexures for the Heidenhain axial encoders.
 - M2 light baffle.
 - Hardware to attach the M2 light baffle: 8 screws and two suitable Allen wrenches.
 - M2 light baffle plates.
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Initial State of Telescope

- All instruments (excluding the spectrographs) removed and safely stowed.
 - Spectrograph corrector removed and safely stowed.
 - Telescope at horizon.
 - Wind baffle frame tied to eyebolt in floor.
 - Wind baffle frame supported on the front and back (east and west) by jackscrews.
 - Wind baffle frame turnbuckled to PSS.
 - [Primary mirror](#) and [secondary truss](#) installed.
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Procedure

1. Make sure the Mitutoyo linear gauges are taped fully retracted.

2. Rig the overhead crane with (in order from the hook): hydraulic damper, 500 lb. force gauge and M2 spreader bar.
3. Use the crane to raise the M2 spreader bar out of harm's way.
4. Prepare M2 for installation:
 - A. Bring the M2 crate (with M2 inside) to the front of the enclosure.
 - B. Holding the crate by the handles on the lid, not the body, lower the crate onto its lid, setting it flat on the 1/4" plastic sheeting.
 - C. Lift the body of the crate up off of the mirror and set aside. M2 should be lying face down and the trunnions of the lifting band should be exposed.
 - D. Rotate the crate so the belly band latches are approximately on the west side of the mirror (they'll be at a 45° angle, which is close enough).
 - E. Slide the M2 crate lid, with the mirror, under the M2 truss. Use the 1/4" plastic as a skid, to protect the mirror against bumps.
 - F. Stuff Kim-wipes into mirror holes near each mounting pad to keep screws from falling inside the mirror. Also have a grabber handy to catch screws that do fall in.
 - G. Carefully set each whiffle onto the correct set of mounting pads (each whiffle has an assigned position on the mirror).
 - H. Attach each of the 9 mirror whiffles to its mounting pad, using 3 screws and one small washer plate. The washer plate must be positioned with the tab up and the **radiused side of the tab against the mirror flexure**. (The order is screw, washer plate, flexure, mounting pad). **Do not over-tighten the screws; the mounting block material is soft.**
5. Install M2:
 - A. Lower the crane and attach the M2 lifting fixture to the trunnions on the belly band.
 - B. Position one person on each side (north and south) of the mirror, to guide the mirror and (when required, below) to keep it vertical. Position a third person behind the mirror to feed cables and make sure the actuator

flexures don't hang up on anything. Have a fourth person control the crane and a fifth observe the force gauge and watch for potential interference.

- C. Take up the weight of M2: approximately 255 lb. on the force gauge (195 lb. of mirror and 60 lb. of rigging).
- D. Use the crane to raise the mirror a few inches above the crate lid.
- E. Rotate the mirror about its vertical axis until the trunnions are on either side of the mirror (north and south). Make sure the latches for the belly band face are on the west side (so they will be on top when the mirror is vertical).
- F. Use the crane to raise the mirror approximately 3 feet above its crate lid (far enough so there is ample room to rotate it to vertical).
- G. Slide the crate lid out from under the M2 truss.
- H. Rotate the mirror 90° to vertical (facing the PSS.). The rivets on the belly band may hang up on the lifting fixture as you do this.
- I. Keeping the mirror vertical, use the crane to raise M2 until it is even with its mounting points.
- J. Lead the cables attached to the M2 flexures through the corresponding holes in the M2 cage. (If necessary, use the crane to move the mirror closer to the cage, but do not insert the axial flexures into the holes in the M2 frame).
- K. **Warning: the axial flexures are very vulnerable with the anti-rotation link removed. Do not allow the mirror to rotate or tip once the axial flexures have entered the M2 frame.**
- L. Using the crane, move the mirror east until the central linear bearing is on the central shaft and the axial flexures are seated in the ends of the axial actuators. **Do not try to force the central bearing onto the shaft.**
- M. Position one person on each side (north and south) of the mirror, to push the mirror against its mounting points. Position one person behind the mirror to attach the mirror and cabling. Have a fourth person ready to hand in parts and tools, as needed.

- N. Attach the anti-rotation link.
 - O. Attach the axial actuator flexures at the actuator end by tightening four set screws per actuator.
 - P. The people holding the mirror can now let go.
 - Q. Check all mounting screws.
 - R. Attach all cables that run to M2.
 - S. Attach the Heidenhain encoders and flexures. Use new flexures unless you are sure the old ones were not damaged. These flexures are very easy to deform, at which point they should not be used.
6. Lower the crane gently until you are sure M2 is being properly supported by the M2 truss.
 7. Lower the crane until you can detach the lifting fixture from the trunnions on the belly band.
 8. Get the crane out of the way and remove all rigging from the crane.
 9. Position one person on each side (north and south) of M2, with step ladders to handle the belly band.
 10. Carefully unlatch and remove the M2 belly band and set aside out of the way.
 11. Install the M2 light baffle:
 - A. Place the M2 light baffle on the floor below M2.
 - B. Station two people inside the M2 truss, one on either side of the mirror. These people are to guide the crane hook and light baffle and generally protect M2.
 - C. Lower the crane hook inside the M2 truss, keeping the hook and cable a safe distance away from M2. Have one person hold the crane hook to keep it from swinging into M2.
 - D. While one person continues to steady the hook, have a second person rig the M2 light baffle to the crane using 8 foot straps (400 lb. capacity, minimum).

- E. Use the crane to raise the M2 light baffle. Have two people guide the light baffle and prevent it from touching M2.
 - F. Attach the M2 light baffle to the M2 cage.
12. Attach all four M2 light baffle side plates; be careful of the delicate 1/4-turn quick-release screws.
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Document History

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