K1DM3 Design Note

Coating Considerations for the K1DM3 Project

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INTRODUCTION

The Keck I Deployable Tertiary Mirror (K1DM3) is being designed to replace the current tertiary module (M3). The baseline plan is to coat it with aluminum using the coating chamber on Mauna Kea. This document examines issues related to coating K1DM3 including the trade-offs of using a protected (higher-performance) coating.

PROCEDURE FOR COATING K1DM3 AT WMKO

The following notes are intended to capture the primary steps of the procedure to coat K1DM3 at WMKO using their existing coating chamber. Here we pay particular attention to aspects of the procedure that may affect the K1DM3 design and also the handling of K1DM3 during the process.

The process is assumed to begin just after the K1DM3 module has been removed from the tertiary tower and placed in its handler on the Nasmyth deck.

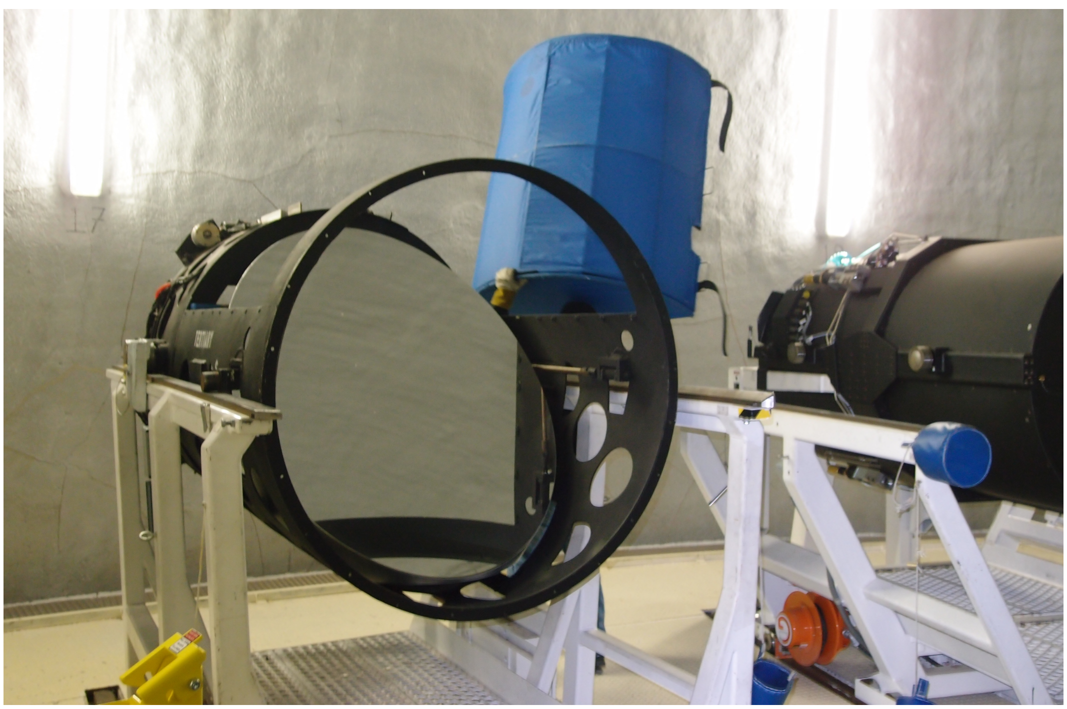

Figure 1. Existing tertiary module loaded onto the module handler.

1.0. REMOVE THE MIRROR ASSEMBLY OF K1DM3 FROM THE MODULE:

The following steps will configure the K1DM3 mirror assembly to a position so that it can be grasped by a lifting rig and lifted free from the swing arm assembly.

1.1. Lock K1DM3 module to the handling cart with a matching lock feature on the module.

1.2. Rotate K1DM3 to the nominal position (mirror facing up at a 45 degree angle) if not already there.
1.3. Unclamp deployed swing arm and retract.
   a. Remote power and control is to be used for this operation on the Nasmyth deck.
   b. Swing arm to be rotated so that the mirror surface is horizontal, pointing straight up. This is a different position than the fully retracted position.
   c. There will be a software requirement to move to this non-standard position.
   d. Swing arm to be held in this position by either the unpowered motors or by a mechanical locking mechanism.

Figure 2. Rendering of tertiary mirror held horizontal by swing arm.

1.4. Lower tertiary lifting rig into position above K1DM3 using the jib crane.
1.5. Attach tertiary lifting rig to mirror assembly.
   a. Four arms rotate down into position under the mirror assembly.
   b. The mirror assembly is to be lifted by the tips of the lifting arms contacting the glass directly.
   c. The contact points of the arms are to be padded with rubber.
   d. Lift points are to be located so that the mirror assembly is balanced when lifted.
   e. WMKO personnel to design the lifting rig.
   f. Handling risk – Shock from tertiary rig. Creep mode is to be used for this operation.
   g. A load cell is to be incorporated into the rigging to provide force feedback. This will help to prevent overloading the mirror assembly during handling.

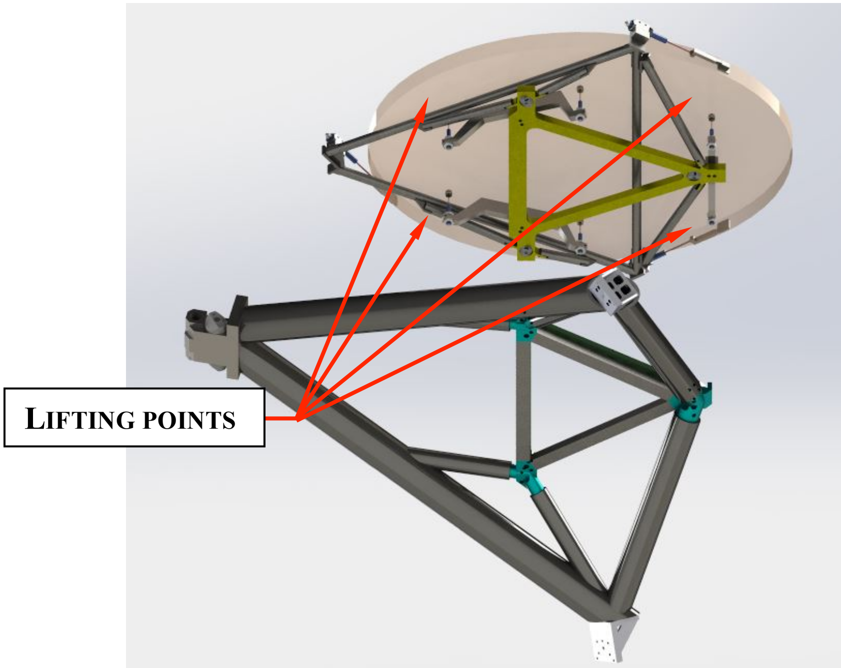

Figure 3. Possible mirror assembly lifting points.

1.6. Remove fasteners holding the mirror assembly to the swing arm assembly.
   a. Fasteners are to be captive screws so they don't fall or become misplaced.
   b. These bolts are to be easily accessible from under the mirror assembly.
   c. No lock washers or "threadlocker," just torque to hold bolts in place.
   d. Appropriate bolt heads are to be chosen for ease of operation using hand tools.
1.7. Slowly raise the crane to take the weight of the mirror assembly. Check for proper loading.
1.8. Slowly lift the mirror assembly off of the swing arm assembly.

Figure 4. Mirror assembly lifted off the swing arm.

1.9. The position that the swing arm is left in during the coating process, deployed or retracted, is to be determined once all hardware and tooling is in place.

2.0. SETTING THE MIRROR ASSEMBLY ON THE FLOOR CART:

The following steps describe the procedure to set the mirror onto a floor cart that may then transport the system to the coating chamber.

Figure 5. Setting a mirror segment onto a flip fixture and floor cart.

2.1. With the jib crane, lower the tertiary lifting rig and mirror assembly toward the dome floor.
   a. Handling risk – Permissible operation speeds and modes of the crane are to be determined beforehand by measuring the shock loads on an equivalent dead weight.

2.2. Position a standard handling fixture (this is what WMKO calls the floor carts) on the dome floor near the hallway door.
   a. Use an existing floor cart. No modifications necessary.
   b. Design and fab a new “flip fixture,” customized for use with the deployable tertiary, as shown in figure 6. The flip fixture is the beam that the mirror is attached to and sets on top of the floor cart. It can rotate to point the mirror up, down or sideways as needed.
   c. WMKO personnel to design this flip fixture.

2.3. Lower the mirror onto the flip fixture’s kinematic points.
   a. Handling risk – Avoid shock by moving in creep mode for this operation.
   b. Tertiary flip fixture is to attach to the mirror assembly in the same way as the swing arm does, through the kinematic mounts.
   c. The flip fixture is to be designed so that the CG of the mirror/flip fixture assembly is balanced about its rotational axis.
   d. Rotate and lock the flip fixture so that the mirror assembly can be lowered directly onto the kinematic mounts (mirror facing up).

Figure 6. A custom flip fixture will be designed for the tertiary mirror.

2.4. Attach the captive bolts to hold the mirror assembly securely to the flip fixture.
   a. Mimic design of swing arm attachment.
2.5. Swing the four lifting rig arms up out from under the mirror assembly and lock them in their upper position.
2.6. Rotate the flip fixture 90 degrees, so that the mirror is vertical, and lock it in place.
2.7. Stow the lifting rig and return the crane to its dock.

Figure 7. Segment on flip fixture and handler, ready to roll down the hallway.

3.0. TRANSPORT TO COATING LAB:

Once on the floor cart, K1DM3 will be rolled down the hallway and into the coating room. Care must to be taken to minimize shocks to the mirror (i.e. bumps) during this process. Consider adding felt isolator pads between the caster trucks and the floor cart to attenuate the higher shock peaks.

4.0. STRIPPING:

The aluminum stripping process will be substantially similar to the one used for regular segment recoating. Care will have to be used when masking around the perimeter of the mirror to accommodate the radial support hardware mounted to the perimeter of the glass.

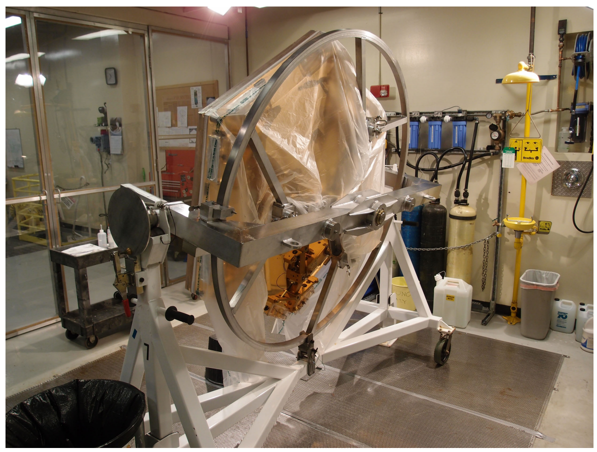

Figure 8. Segment in the stripping area with plastic masking sheets taped in place.

5.0. INSERTING K1DM3 INTO COATING CHAMBER:

5.1. Mask the radial support hardware for coating process (as required).
  a. Wrap aluminum foil around all hardware that extends outboard of the glass.
  b. Possibly use Kapton tape to hold foil in place if it is not secure enough on its own.

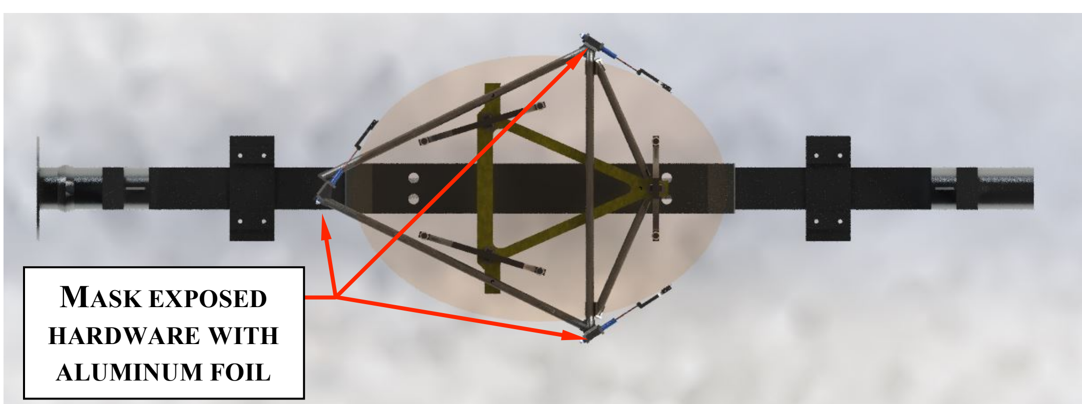

Figure 9. Plan view of mirror showing exposed hardware to be masked.

5.2. Rotate the flip fixture so that the mirror is facing down.
5.3. Roll the floor cart into the coating room and attach the hoist hook to the flip fixture.
    a. If a hook point is designed into the flip fixture, as shown in figure 10, then the spreader bar will not be needed. This would help simplify handling.
5.4. Lift flip fixture/mirror assembly up off of floor cart.
5.5. Lower mirror assembly into coating chamber and rest flip fixture on supports inside the chamber.
    a. No extra tooling or modifications will be needed if the flip fixture is designed with the same interface as all the others.

Figure 10. Bottom view of tertiary mirror ready to go into the coating chamber.

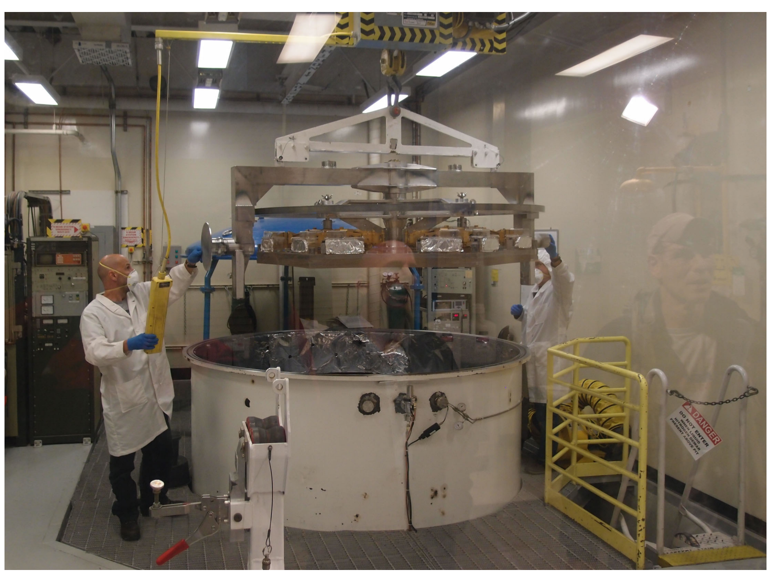

Figure 11. A primary mirror segment being lowered into the coating chamber.

List of New Tooling Needed:

1. Deployable Tertiary Mirror Lifting Rig
2. Deployable Tertiary Mirror Flip Fixture

ALTERNATIVE COATING

The nominal plan for coating K1DM3 is to use bare Al and apply it with the coating chamber at WMKO. This is the standard procedure for the current M3. We may consider, however, an alternate coating plan: contracting a vendor to coat K1DM3 with a protected, higher-performance coating. The obvious scientific advantage of the protected coating is higher reflectivity. This would benefit essentially every observation performed using K1DM3. The primary operations advantage of a protected coating would be a reduced rate for re-coating.

The competing factors to these benefits are cost and schedule. For a single application, the protected coating through an external vendor greatly exceeds the cost of recoating with bare Al at WMKO. Regarding operations schedule, the time to ship to an external vendor (and back) significantly exceeds the standard time to recoat at WMKO. In both of these cases, however, the extra single expense would be mitigated over the lifetime of WMKO if the cadence to reapply the protected coating were 2 to 3 times lower. The remainder of this section provides greater detail on these issues.

PERFORMANCE

Figure XX compares the reflectivity of bare Al to the so-called "Livermore recipe" of ZCOAT across the nominal observing window of Keck 1 (0.3 to 1 micron). The protected coating outperforms bare Al at all wavelengths except XX, by several to many %. This higher performance benefits any single observations with K1DM3 but the impact is more tangible for long-term projects. For example, a 20 night project to acquire radial velocity observations with HIRES would complete in XX fewer nights, a cost equivalent of $XXk.

The other advantage of the protected overcoating is longevity. The nominal time for recoating bare Al in an unprotected environment is 2 to 3 years, depending on the frequency with which the mirror is cleaned (CO snow and actual water washing). In contrast, the [predicted] lifetime of the protected coating is 5 to 10 years, again dependent on the frequency of cleaning and ??.

COST/SCHEDULE COMPARISON

We now compare the cost to coat K1DM3 with bare Al and a protected coating and also consider the additional time that K1DM3 would be out of service when one uses an external vendor for the coating process.

We have obtained a quote from ZCOAT for the coating of the K1DM3 mirror for $XX. This covers the tooling, labor, and materials of their process. This vendor has also estimated a time for coating of XX days. These quotes drive the cost/schedule comparison provided in the following Table. These are meant to capture the cost/schedule for a single recoating process.

Cost/Schedule for Protected Coating with Mainland Vendor

Activity	Details	Duration	Estimated Cost
Remove K1DM3	Attach tool, lift from module, lower to dome floor	3 hours	

Package K1DM3 for shipping		1 days	
Transport to Kona/Hilo		½ days	
Ship to mainland vendor		2 days?	
Unpackage at vendor	Whose staff?	½ day	
Coat at vendor		XX days	
Package for shipping		1 days	
Ship to Hawaii		2 days?	
Transport to WMKO		½ days	
Unpackage		½ days	
Return to module		5 hours	
TOTALS		XX days	$XX

Cost/Schedule for Bare Al Coating using WMKO Chamber

Activity	Details	Duration	Estimated Cost
Remove K1DM3	Attach tool, lift from module, lower to dome floor	3 hours	
Transport K1DM3	Insert on transport cart; roll K1DM3 from dome floor to chamber	2 hours	
Insert K1DM3 into chamber	Attach fixture, lift K1DM3, fix within chamber	2 hours	
Coat K1DM3		?? days	
Remove K1DM3 from chamber	Attach fixture, lower K1DM3 to cart	2 hours	
Transport to dome floor		1 hour	
Return to module		5 hours	
TOTALS		XX days	$XX

The above tables estimate the costs and time to recoat

Risk			
Shipping to mainland			
Handling by vendor			
True longevity of the protected coating			
Loss of vendor			

Schedule			
Degradation of bare Al			
More frequent handling (to recoat)			

Top Concerns/Risks/Queries

- The epoxy bonds must withstand the recoating process without any loss of strength (i.e. when they may be heated).
- Crane speeds and modes will have to be evaluated to ensure shock loads are within acceptable levels.

Other considerations

- Estimate cost to design/fabricate new fixtures for K1DM3 coating **at WMKO**.
    - Lifting Rig
    - Flip Fixture
- Estimate cost to design/fabricate new fixtures for K1DM3 coating **on mainland**.
    - Lifting rig
    - Shipping container with shock isolation features
    - Other handling equipment?
- Conduct cost trade-off with more frequent coating at WMKO to enhance its performance.
    - Recoating yearly?
    - Recoating can be scheduled for times when tertiary is not needed, no down time.
    - Unlike the primary mirror segments, the tertiary mirror can be safely removed from the telescope in the winter without regard to weather. Can schedule in winter when coating chamber is underutilized.