K1DM3 Design Note

Dampener Concept and Trade Discussion

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I. Overview

K1DM3 will be designed and constructed when *deployed* to feed light to the foci along the elevation axis and when *retracted* to allow the beam from M2 to travel unvignetted to the existing Cassegrain instrument focal planes. For the Preliminary Design, we studied a concept where a swing arm is deployed/retracted by a pair of linear actuators attached to the arm and the top of the K1DM3 module. Further analysis of this system indicates the retracted arm and actuators will likely interfere with the existing forward-baffle tracks at the top of the tertiary tower at some rotation angles.

Therefore, we have examined a modified design that uses the force of gravity to deploy/retract the swing arm, retarded by a set of dampeners and springs. This has the advantage of a slimmer profile such that the swing arm can be rotated to any angle once retracted. The obvious drawback to this approach is that one must retract K1DM3 by slewing the telescope to large elevation angles (> 60 deg from Zenith). This activity likely requires additional time to complete and it places additional operational constraints on WMKO.

In this design note, we detail this alternate concept and list the pros and cons of each approach.

II. Brief Summary of the Preliminary Design

The actuation concept developed for the Preliminary Design is summarized as follows. The swing arm is attached to a hinge fastened to the upper ring of the K1DM3 module. The swing arm may pivot on this hinge, directing the mirror assembly into the deployed or retracted position. The motion is powered by two linear actuators, each of which is also attached to the upper ring and one side of the swing arm (Figure 1). We have chosen actuators with a narrow profile that still provide more than sufficient force to deploy/retract, even under extreme gravity orientations.

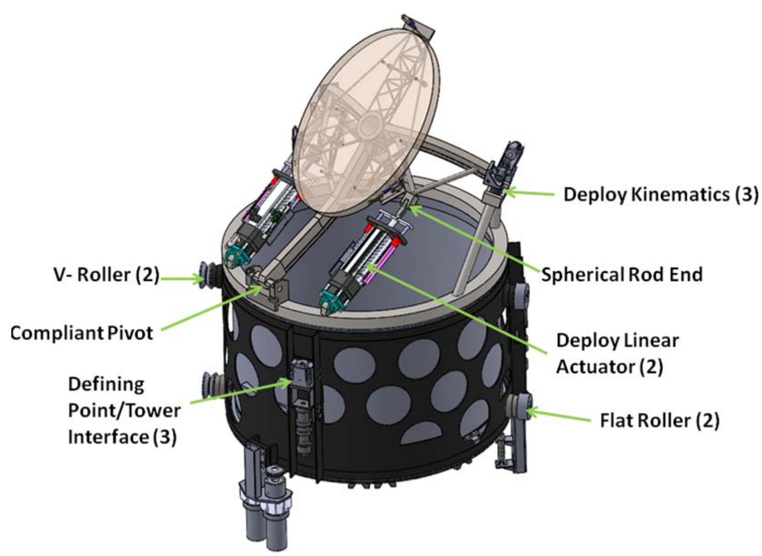

Fig. 1.— The K1DM3 module as envisioned in Preliminary Design. In this concept, the mirror assembly is deployed/retracted via mechanical articulation of a swing arm. The design uses two linear actuators to rotate the swing arm about a compliant pivot.

In refining this design for structural stability and after updating the positions of components at the top of the K1 tower, we have found that the linear actuators (and swing arm) interfere with the forward baffle tracks at a set of rotation angles for the K1DM3 module (Figure 2, left). Specifically, one cannot retract the swing arm towards the pair of baffle tracks, nor within approximately 30 degrees of a baffle edge. However, the swing arm and actuators can be retracted between the sets of baffle tracks (e.g. Figure 2, right). It may even be possible to retract towards the isolated baffle track. In this position, the retracted components avoid vignetting the LRIS and MOSFIRE fields-of-view (FOV) at any rotation of those instruments. We also would include a cover to protect the mirror in this upward-facing configuration.

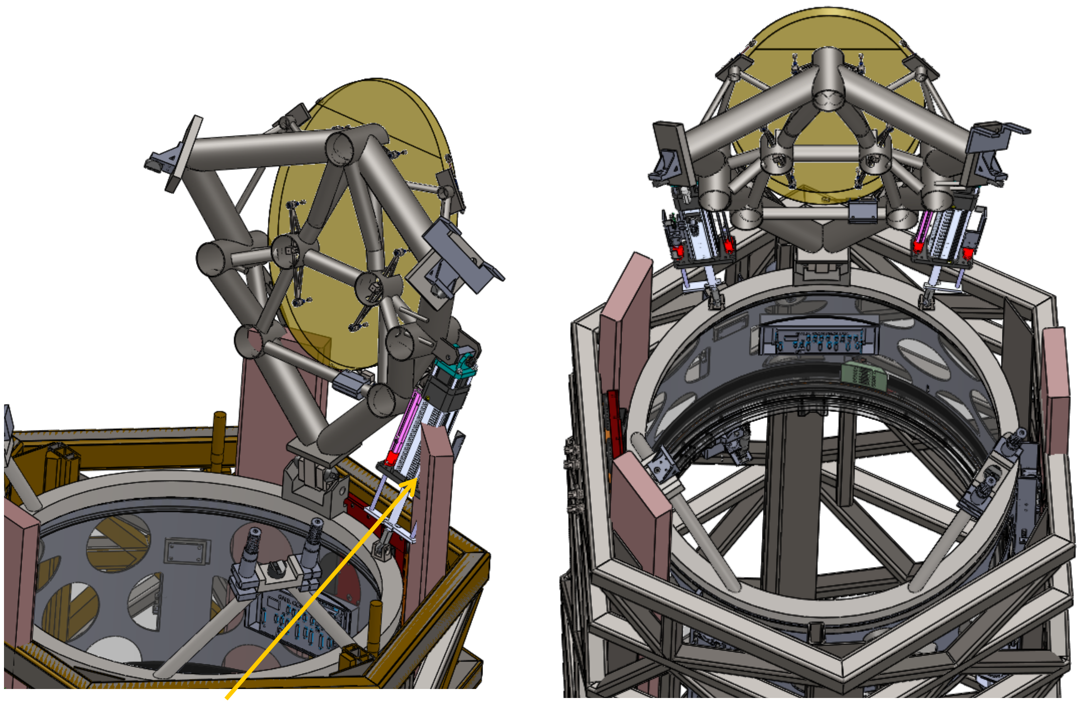

Fig. 2.— (*left*): Diagram showing the interference of the K1DM3 swing arm and actuators with the forward baffle tracks on the top of the K1 tertiary tower. While the outer pieces on the linear actuator may be removed to reduce the interference, there is still significant interference between the actuator and swing arm and the baffle tracks in this orientation. (*right*): View of the K1DM3 module with the swing arm retracted to a space between the baffle tracks. One could retract to a simliar position between the tracks on the other side of the tower. Current estimates also indicate we could retract toward the single baffle track.

Before closing this section, we note the following mitigations/considerations that could further improve this design as regards interference issues:

- One could remove the forward baffle tracks. Presently, WMKO has no intentions of implementing a forward baffle on K1.

- We may identify a thinner set of actuators that would reduce – but not eliminate – interference with the tracks.

- Retracting the swing arm to a position that stops just short of contacting the baffle tracks, we estimate that the K1DM3 system does not vignette MOSFIRE and only vignettes the corners of LRIS. Furthermore, we could rotate the system in this configuration to avoid vignetting LRIS.

III. A New Concept

Concerned by the interference between the swing arm and the baffle tracks, we have recently developed a conceptual design for an alternative approach to deploy/retract K1DM3. This design replaces the active mechanisms (the linear actuators) with a set of passive devices (dampeners and springs) to control the deceleration of the swing arm under gravity.

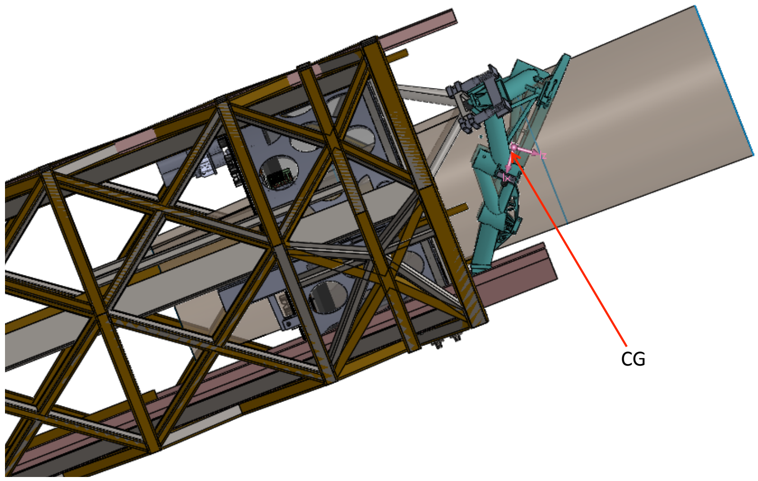

Fig. 3.— Diagram showing the telescope slewed to a low elevation angle (i.e. near horizon) such that the center of gravity of the swing arm and mirror assembly lies beyond the pivot point of the swing arm. In this orientation, gravity will retract the swing arm.

Retraction of the mirror assembly and swing arm would proceed as follows. The deployed K1DM3 module would be rotated so that the vector normal to the mirror is maximally aligned with the gravity vector. In parallel, the telescope is slewed away from Zenith to an elevation angle where the center of gravity of the swing arm extends beyond the compliant pivot of its hinge on the upper ring (Figure 3). When the swing arm is released, gravity will pull it towards the retracted position. The rotation of the swing arm would be controlled by a set of dampeners attached to the swing arm and the upper ring (Figure 4).

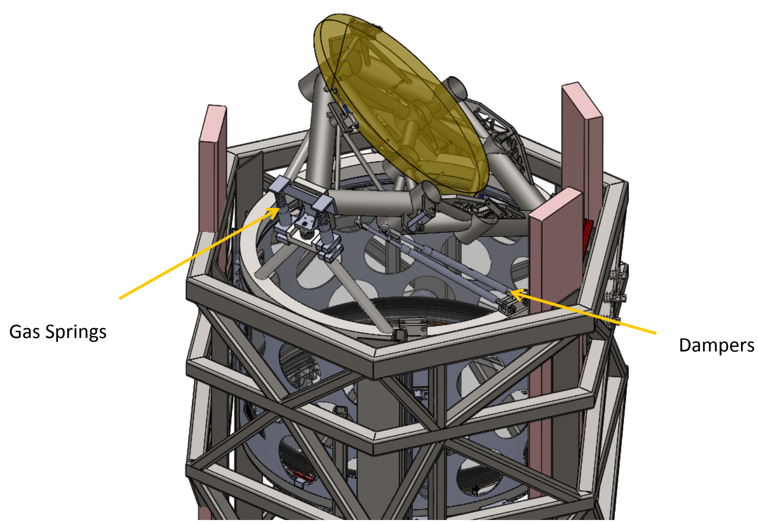

Fig. 4.— Diagram showing the K1DM3 system in deployed position with the retarding mechanisms (dampeners, springs) illustrated.

These liquid-filled dampeners behave similarly to shock-absorbers, restricting the velocity of the swing arm. By limiting its maximum speed, the accelerations on the mirror assembly would be small; we estimate less than $0.1g$. With this conceptual design, we achieve a configuration with dampeners that avoids interference with the forward baffle tracks (Figure 5).

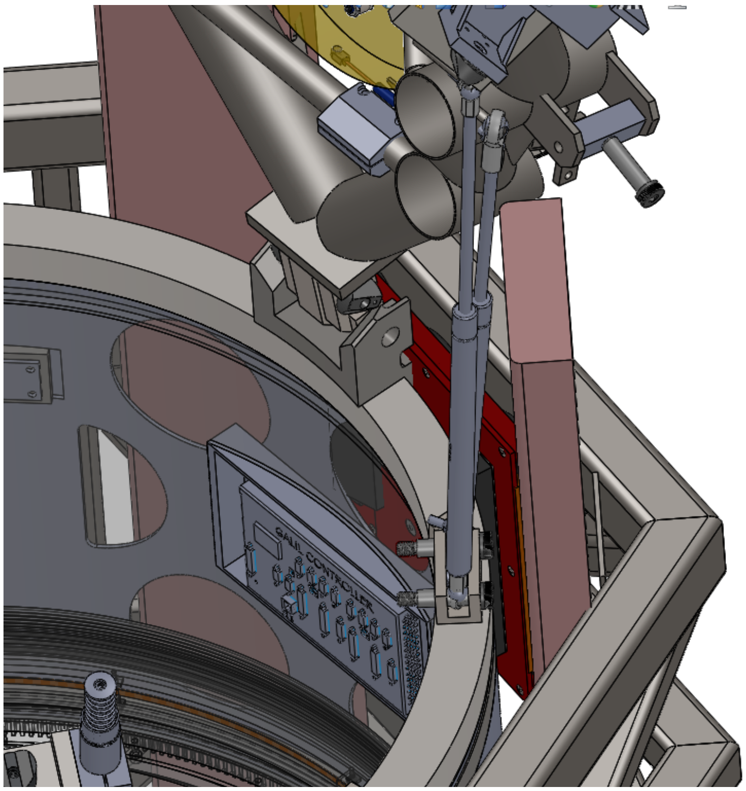

Fig. 5.— Diagram showing the swing arm and dampeners clear the forward baffle tracks on the tertiary tower.

Deployment would proceed in a similar fashion and could be achieved at any elevation angle less than approximately 5 deg. As with the Preliminary Design concept, however, we would deploy at the elevation angle which allows the kinematics to engage strictly under the force of gravity (i.e. without clamping). This is optimal for repeatable positioning. We may also include a set of springs on the ends of the bipod struts to further dampen the swing arm as it engages with the kinematics.

The key differences of this concept with respect to the preliminary design are:

- No linear actuators nor their associated electronics and software
- Two to four dampeners attached to the swing arm. These would need to be designed to restrict the velocity of the swing arm to approximately 0.05 m/s.
- Operationally, the retraction of K1DM3 would need to occur at a telescope elevation angle of less than approximately 25 deg and at a specific rotation angle for K1DM3.

Presently, the greatest negative impact of this concept that the Team has identified is a longer time on average to retract the mirror. We estimate its time as follows, where have assumed an elevation slew rate of $d\theta/dt = 1\,\mathrm{deg/s}$ and that the process begins with the telescope at an elevation angle of $\theta = 70\,\mathrm{deg}$ (20 deg from Zenith). For completeness, Table 1 lists all of the key actions noting that the majority of these can be accomplished in parallel. The estimated cumulative time to complete accounts for this fact. We have generated a similar table for deployment (Table 2).

Table 1: Time to Retract K1DM3 with Gravity Assist

Action	**Time**	**Cumulative**	**Comment**
Slew telescope to $\theta = 25\,\mathrm{deg}$	45 s	45 s	
Rotate K1DM3 to $\phi = 90\,\mathrm{deg}$	$< 20\,\mathrm{s}$	45 s	In parallel with slew
Unclamp kinematic preloads	2 s	45 s	In parallel with slew
Initiate retraction	10 s	55 s	Allow CG to move significantly
Slew telescope to $\theta = 70\,\mathrm{deg}$	45 s	100 s	To new observation
Complete retraction	10 s	100 s	In parallel with slew
Clamp swing arm	2 s	100 s	In parallel with slew

Table 2: Time to Deploy K1DM3 with Gravity Assist

Action	**Time**	**Cumulative**	**Comment**
Slew telescope to $\theta = 65\,\mathrm{deg}$	5 s	5 s	
Unclamp swing arm	2 s	7 s	In parallel with slew
Deploy	20 s	27 s	Swing arm 'falls' onto kinematics
Clamp kinematics	2 s	29 s	
Rotate to focus	$< 20\,\mathrm{s}$	49 s	
Slew telescope to $\theta = 70\,\mathrm{deg}$	5 s	49 s	New observation; in parallel

IV. Design Comparison

The two design concepts presented here are sufficiently different that it would likely be too expensive to develop each to a detailed design. Therefore, we wish to down-select to one of them in the next few weeks. Presently, Tables 3 and 4 contrasts the two concepts by listing the pros and cons of each.

Table 3: Pros/Cons of Linear Actuator Concept

Type	**Description**
Pro	Full, mechanical control of deployment/retraction
Pro	Retract in under 30 s
Pro	Substantial design work already complete
Pro	Testing under-way for one actuator
Pro	More stably fixed in place when retracted
Pro	In-house testing of retract/deploy may be easier
Con	Linear actuator and electronics subject to failure
Con	Can retract to 104.5 deg at only a few rotation angles
Con	Cannot rotate retracted K1DM3
Con	Hardware likely to be more expensive

Table 4: Pros/Cons of Gravity Assist

Type	**Description**
Pro	Simpler mechanism for deploy/retract
Pro	Likely cheaper
Pro	Could rotate retracted K1DM3 to any angle
Pro	Fewer parts to fail
Pro	Concept may be favored on K2
Con	Requires significant, new design work
Con	Would require substantial in-house testing
Con	Requires telescope movement for retraction
Con	Longer average time to retract
Con	Possible temperature dependence