Packaging constraints for d-NIRI and LGS WFS's with a note on tip-tilt stability in Split Relay architecture KAON # 506

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1 Introduction

The NGAO systems engineering team came up with five architectures during the course of meeting #8. The team had doubts about being able to package Split Relay Architecture within the geometric constraints of the Keck telescopic structure.It is expected that the IWG will use this document as a reference for designing d-NIRI if Split Relay Architecture was chosen. Due to the limited scope and time alloted for this work package, a fully reflective OAP relay was not incorporated in the mechanical model or allocate envelopes for the other science instrument.

The packaging constraint for the Stimulus/ Telescope Simulator, Vibration sensors, and the space available for d-NIRI and LGS WFS's. The system arch. team did cast their doubts on the front end of the relay and this issue is addressed here. The packaging issue is dealt in this note by allocating volume envelopes to the critical components.

A e-drawing of the d-NIRI envelope and partial structural description of the telescope can be found at : `http://www.oir.caltech.edu/twiki_oir/pub/Keck/NGAO/SystemArchitecture/NGAO_split_relay.EASM`.

Figures 1 and 2 shows the zoomed in view from the aforementioned e-drawing and a schematic with some dimensions. The constraint on d-NIRI is quite rigid, it will need to be mounted on a load bearing structure that has bearings as shown in the figure and a worm drive will need to be designed to drive the unit to track objects on the sky. The LGS WFSs are indicated in gold and can be longer, it also needs to rotate and can be mounted on an arch like structure.

2 Conclusions on packaging

Packaging split relay is possible with sufficient engineering subject to the following conditions.

1. First order look at d-NIRI's layout suggests that the instrument needs about 200 mm of clearance from the Nasmyth axis to the focal plane. The LGS WFS's will need to be after d-NIRI to minimize the number of surfaces that d-NIRI looks through. Secondly, the LGS WFS's are at least 0.5 m is length and need a two stage translation mechanism to working with changing in DEC angle and change in WFS sampling (# of sub-aps). There is not enough space to get all this in the elevation bearing with appropriate rigidity to mitigate flexure effects.
2. The focal plane is 210 mm from the Nasmyth axis (useful # for IWG to see if d-NIRI can cope with this). The envelope of the instrument is 175 mm from the Nasmyth axis to make room for the pick-off mechanism.
3. d-NIRI must fit into a cylindrical volume of 1050 mm diameter and 575 mm length. The instrument support structure will need to rest on the Nasmyth platform. A

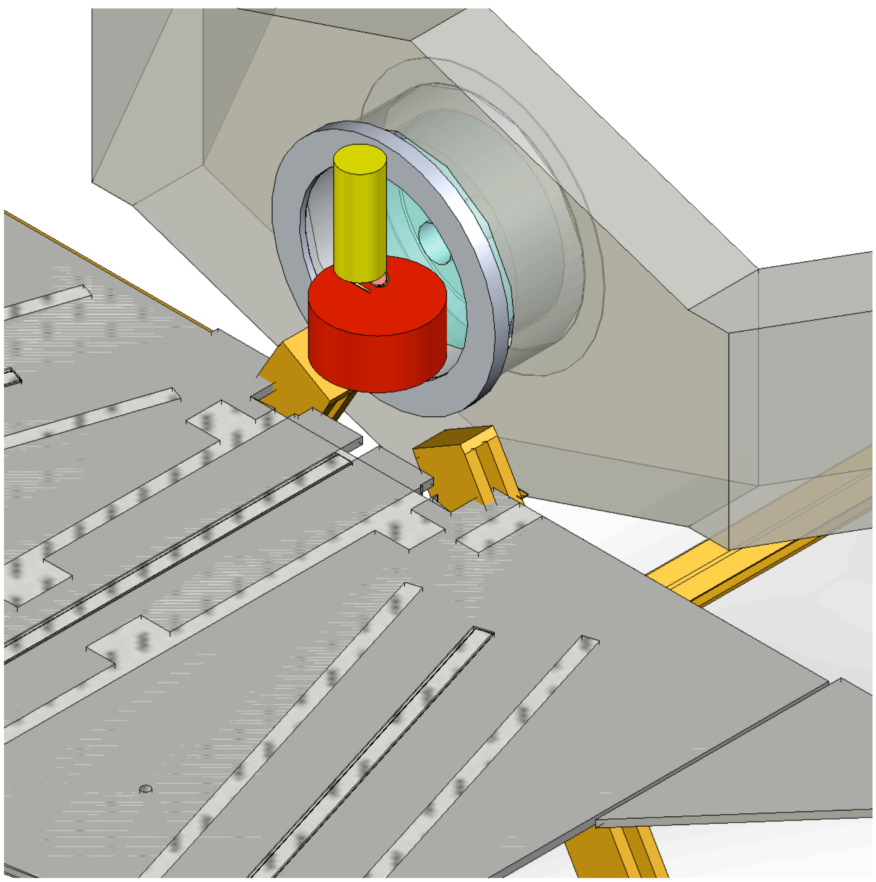

Figure 1: Zoomed in perspective view of envelopes - Red envelope is the d-NIRI volume, bright yellow indicates the LGS WFS's volume and the transparent cyan disk with a central hole shows the volume where the calibration unit, telescope simulation and vibration measurement units need to reside.

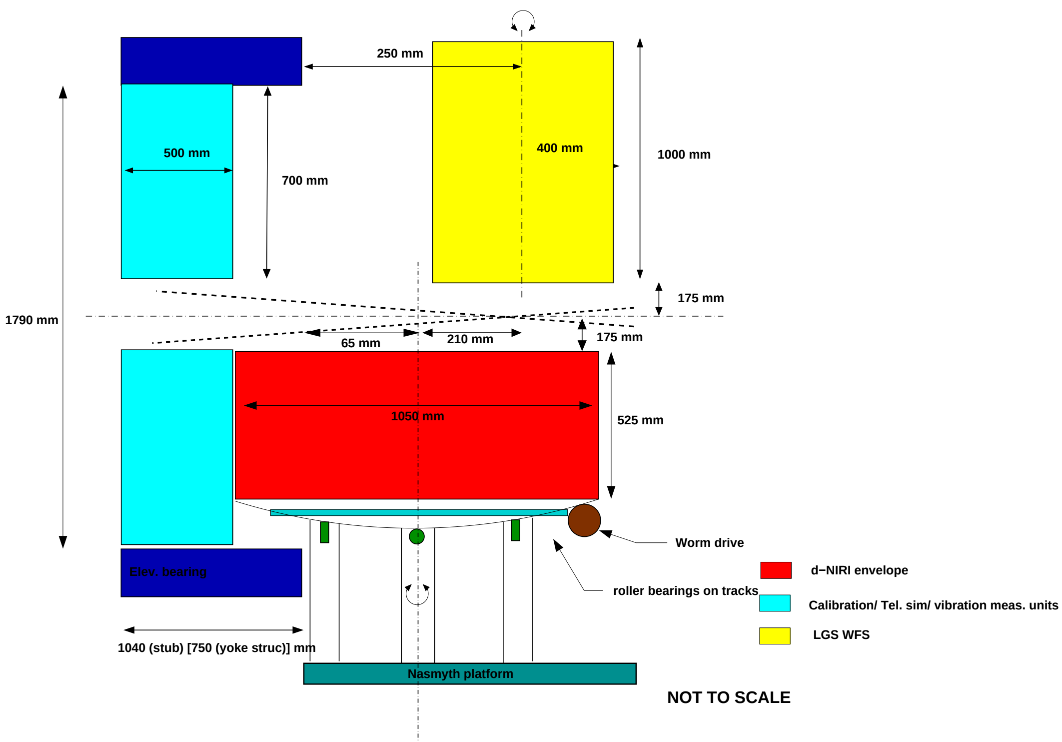

Figure 2: A schematic of the perspective view shown in fig. 1 with call outs and dimensions

worm drive with a appropriate gear ratio to and range of operating speed will need to be designed.

4. LGS WFS's envelope can be above Nasmyth axis by about 175 mm.
5. Vibration measuring/ compensating, misc. calibration and telescope simulator units need to fit within a cylinder of 200 mm length by 1.79 m dia. This cylindrical portion is located on the far side of the AO bench (closer to the Tertiary mirror) the elev. bearing. The units will need to be mounted to the yoke structure without having any rigid contact with the elev. bearing if the units need to work while tracking (for e.g. vibration measurement units). The telescope simulator may have the option of being rigidly attached to the elevation bearing (if the bearing can take the additional load). There is sufficient space for brackets to be built to attach the cyan envelope to the yoke.

In essence, the Split Relay Architecture can be made to work with *enough engineering effort*. The IWG has to confirm that d-NIRI can fit into the envelope suggested in this document, this is a hard bound constraint with little leeway. The cost of d-NIRI may be higher because of the increased volume and drive mechanism constraints. More structural analysis may be needed to work out the details of mounting the different bits. The AO system optical relay can be easily incorporated in the above scheme when an folded OAP relay design is completed.

3 Split Relay Tip/Tilt Stability

This section summarizes a mini-study of the pointing stability issues that arise due to the non-common path error in the split relay architecture. This architecture separates the tip/tilt sensors, which would be located on the turret of the d-NIRI instrument, from the focal plane of the narrow field science instrument. The non-common path consists of the tip/tilt splitter, ADC, K-mirror derotator, and narrow field relay optics. Stability is only an issue in narrow field science mode, but this is when the tip/tilt requirements are the strictest, with a science case driven error budget of 15 milli-arcseconds.

There is no inherent difficulty with positioning or pointing along beam lines, or with nutation. The tolerances are rather lax (a few microns in positioning) and any decenter, nutation, or rotation error can be calibrated out. There is a very difficult problem with the 3 mirrors in the K-mirror scheme as shown however. The 15 mas tolerance on tip/tilt can easily be destroyed by the smallest of wobble or vibration of the 2nd mirror in the derotator (the MEMS in this picture) which is located at a pupil. In spite of the pupil demagnification of 400:1 working in our favor, this is still a very tight mechanical tolerance. It allows only 0.015 x 400 = 6 arcseconds of physical motion of M2 with respect to M1 or M3 in the K-mirror. There are probably similar tolerances on the tilt of either of the other two mirrors with respect to each other or with respect to the beam line, since they

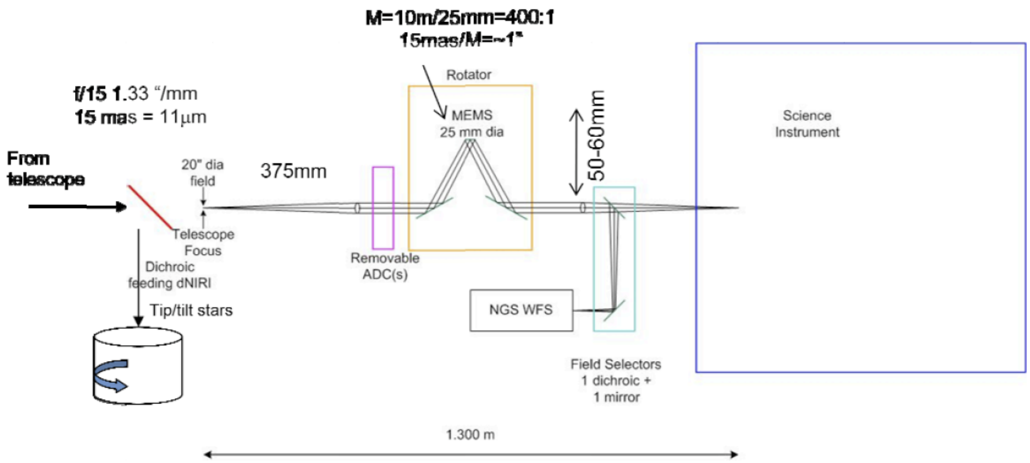

Figure 3: A annotated schematic showing the considerations for TT stability and K-mirror wobble

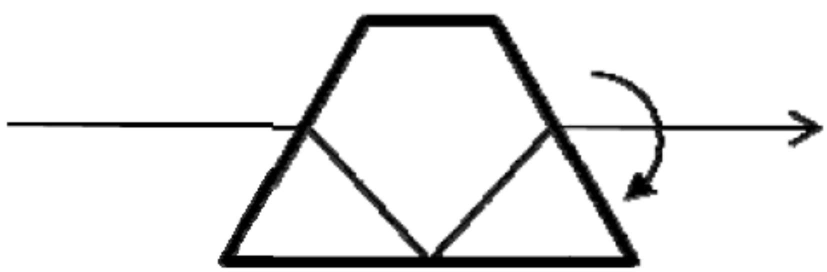

Figure 4: A dove prism based K mirror

are also both near the pupil. For perspective, assuming a 1 inch M2, this allows one edge of the mirror to move only 0.375 ?m with respect to the center, a motion that might easily be induced by bench vibrations or air in the path. This motion is of course present in all the architectures, and M2 could in fact be on a fast tip/tilt correction stage, but this is the only architecture where the tip/tilt sensing is upstream and hence blind to the disturbance.

There are three solutions to the above difficulty which all seem feasible (aside from being very careful not to induce vibration and move these mirrors with extremely repeatable action):

1. Use a metrology system. Propagate an artificial tip/tilt guide star starting at the center of the d-NIRI field, and using a retro mirror behind the dichroic, send it down the center of the AO relay into the sensor labeled here NGS WFS. Use a wavelength that would be blocked by every science filter. This would essentially give the same advantage enjoyed by the other architectures, i.e. the tip/tilt star (in this case artificial) probes the non-common path, particularly the troublesome K-mirror.
2. Put the K-mirror ahead of the d-NIRI split. This would but its problems in the common path, and would have a side benefit of eliminating the need to rotate d-NIRI. Disadvantages are the K-mirror would now have to pass the full 150 (180?) arcsecond field of view, and it would also need to be ahead of focus, well inside the elevation bearing.
3. Brian Bauman has suggested the use of a dove-prism in place of a 3-mirror K design. This is a single piece of fused silica glass (illustrated in concept in Figure 2 below) that would use total internal reflection for M2 and refractive bending to substitute for M1 and M3. The dove-prism can be made rather small given the small science field, and located at the same position as the K-mirror in the split relay. The induced pointing wander is insensitive to the prisms centering and tilt with respect to the nominal beam line. For example, if we imagine 1/10 of a subaperture being the allowable tolerance of beam wander at the pupil, then beam wander can be as much as 25mm/640 = 40 microns, rather easy to achieve mechanically. Optically, there is an issue with lateral color shear of the pupil with this refractive solution, but the amount of shear, calculated by Brian, is less than 10 μm across H band and 13μm across the K band. One issue with the dove prism is the DM (and hence the pupil) cannot be part of the K mirror and it adds a extra surface as compared to the schematic in figure 3.

3.1 Summary

The split relay architecture can still be feasible for precise tip/tilt tolerance, but will need either metrology or a different derotator solution than originally envisioned.