\* Sect. 5.1.2.  "Capture need, say is, 0.5 arcsec"  I would like to see more justification for the capture need.  Perhaps Chris could dig up numbers from our K2 LGS experience.  The selected mirror does seem to have adequate range however (10 mrad = +/-1.18" on the sky).

*Fixed in doc. Version 1.3 - we can position the laser beacons with slow moving mirrors to 2 arcsec precision on sky*

\* Sect. 5.1.2.  What is the LGS beam diameter at TT mirror?  Is the 1" diameter optic adequate?  Could you get away with a 0.5" diameter optic?

*0.5” would be cutting it close for the patrolling WFS.*

\* Sect. 5.1.3.  Table 2.  Should make it clear that this table is just for the central fixed asterism and that the "focal plane size" column is the "focal plane radius".

\* Sect. 5.1.3.  The equations starting with "alpha = 1.22 radians" need some introduction.

+ I don't think that b is drawn correctly in Fig 12 to produce x = b tan(alpha).

+ By the way here is an alternate derivation: Let s1 be the distance to the nearer beacon and s2 be the distance to the furthest beacon.  Then s2-s1 =

h[1/cos(alpha+beta/2)-1/cos(alpha-beta/2)] = h{[cos(alpha-beta/2)-cos(alpha+beta/2)]/[cos(alpha+beta/2)cos(alpha-beta/2)]} =

h{[2sin(alpha)sin(beta/2)]/[cos^2(alpha)]} = h sin(alpha) beta / cos^2(alpha)

+ You should explain how you get from "x" to the defocus error values in table 3.  You should also show in the table caption what zenith angle this is for.  As a check here is how I would do it using the lens equation 1/s' = 1/s + 1/f: Assuming f1=150m, for the innermost LGS, s1 = -h/cos(alpha-beta/2)

and for the outermost, s2 = -h/cos(alpha+beta/2). Then for alpha = 70 deg and beta = 20" you get s2'-s1' = 150.08554 - 150.08557 = 22.8 microns.

+ In the table 3 caption could you change the last bit "F/#2" to show that this is a square.

\* Sect. 5.1.4. If the fixed asterism plate scale is 1.41/2 arcsec/pixel then the rms spot size is ~ 3.2 um which is not consistent with the closing sentence:

"the spec would be only a few percent tighter".

*Fixed in doc. Version 1.3*

\* Sect. 5.1.5.  "The FoV of the Fixed and Patrolling WFS sub-apertures are 5.96 and 5.64 arcsecs respectively."  Correcting for the "p" factor and some English I think that this sentence should read: "The FoV of the Fixed and Patrolling WFS sub-apertures are 2.82 and 5.96 arcsec, respectively."  It is not clear to me that we need a field stop as large as 5.96".  I believe that our current K2 system has a max field stop diameter of 4.8" and this is for a side launched laser.  The disadvantage of having a large field stop is potentially Rayleigh contamination from both the LGS transmitting through this field stop and from the other LGS.  We need an analysis of optimal field stop size that addresses the Rayleigh issue.  On the other hand is the 2.82" diameter field stop big enough not to throw away some of the LGS light?

*Fixed in doc. Version 1.3. Will ask Systems Engineering Team (and Don) if a 2.8 arcsec field stop is OK, or we have to make the Fixed LGS asterism plate scale coarser.*

\* Sect. 5.2.1.1.

+ 2nd sentence.  Does the "NGAO optical design" really give "720 um" for "1" on-sky"?  Are you sure that this isn't the same as the input f/# of 727um/arcsec?

*Yes, the output isn’t 727 um/sec and the f/# isn’t 13.66 at the LGS output in Version 7 of the Keck NGAO optical design.*

+ 2nd set of eqns.  Should use f/13.66 for the telescope (not 13.56).  From the agreed upon drawings of the telescope pupil on the MEMS actuators should use 60 subapertures (not 63).  Using these two numbers you get a lenslet pitch of 97.6 um.

***Don and I talked at a meeting at UCSC and agreed on 31 and 63 sub-apertures based on a Fried geometry for the 32x32 and 64x64 mirror. This supposed change is not reflected on in the requirements.***

+ Is there any chance of having the detector directly at the lenslet focal plane, without the need for reimaging optics?  Then the lenslet pitch would need to be 84 um, which would require a collimator focal length of 72.3 mm and the lenslet focal length would be 3 mm.  I see that you discuss this later in sect. 5.2.1.3.

\* Sect. 5.2.1.2.

+ The required FoV is only 4 pixels or 2.82".  This design is delivering 5" FoV.  Can you make the design easier by backing off on this FoV?  At minimum you only need to show the spot size at this 1.4" radius instead of 2.5".  Can't you reduce this spot size by refocusing?

*Good point, the change in the FoV will make a big improvement on the spot size. But, as indicated in the, initial part of the LGSWFS KAON, these errors are small after the wavefront is split up into 30+ sub-apertures.*

+ 2nd last sent. "that the AO relay generated from the AO relay" should be "that the AO relay generated".

*Fixed in Version 1.3.*

\* Sect. 5.2.2.1.

+ 2nd sentence.  Does the "NGAO optical design" really give "720 um" for "1" on-sky"?  Are you sure that this isn't the same as the input f/# of 727um/arcsec?

*Yes, the output isn’t 727 um/sec and the f/# isn’t 13.66 at the LGS output in Version 7 of the Keck NGAO optical design.*

+ Should use f/13.66 for the telescope (not 13.56).  From the agreed upon drawings of the telescope pupil on the MEMS actuators should use 30 subapertures (not 31).

***Don and I talked at a meeting at UCSC and agreed on 31 and 63 sub-apertures based on a Fried geometry for the 32x32 and 64x64 mirror. Requirements say the same thing as our meeting. And to my best knowledge, the EBS has the 63 and 31 subapertures for the Fixed and Patrolling sensors. Wonder how the Systems Engg. Group didn’t realize the change in architecture when the pupil mapping definition was changed! It certainly didn’t make it into the requirements.***

+ Is it possible to make the Patrolling WFS more like the Fixed WFS?  For example, if you had a 1:1 relay and a f=40mm collimator for the patrolling LGS then you would have the same lenslet pitch as the fixed asterism; if you selected the same lenslets then you would get your desired 2x arcsec/pixel for the patrol WFS, but you would need different reducer optics.  Example 2, if you instead doubled the lenslet pitch (vs the fixed WFS) then you could select their focal length for the desired plate scale and use the same reducer optics.

\* Fig. 25.  "130 um rms spots delivered by the AO relay" doesn't seem consistent with the last "40 um RMS that the AO relay generated" in the 2nd last sent. of 5.2.1.2.  Also "for reference 101 um is ¼ arcsec"; shouldn't this be "181 um"?

*40 um RMS is for the Fixed LGS asterism. The spot size is 130 um rms for the Patrolling LGS spots delivered by the AO system (see Figure 8 of Version 1.3 of the LGSWFS PDR KAON).*

\* Fig. 33.  Could you put in the caption what the extreme field points are in arcsec?

*Updated in Version 1.3.*

\* Sect. 5.3.  End of 1st para.  "Figure 1" should be deleted.

*Updated in Version 1.3.*

+ Was it ever considered to put a mirror at the input LGS focal plane that either reflected the fixed asterism or the patrolling field, in order to separate the fixed and patrolling LGS?  This could potentially help alleviate the packaging tightness and more importantly potentially allow us to get rid of some of the relays.

***Yes, we considered a tetrahedron shaped structure with a central hole. The current design provided more flexibility in terms of holding optics and there is some commonality in mounting the pick off mirror in all the pick-offs.***

\* Sect. 5.3.1.  Formatting is strange at the bottom of p. 40.

+ Is the use of different TT mirrors for the fixed and patrolling WFS really justified?  Commonality is a very good thing.

*Both the Fixed and the Patrolling WFS use the same fast TT mirror.*

+ Last para.  A price of using a theta-phi stage is apparently the need to rotate the lenslet/detector by up to 40 deg.  The benefit is that we don't have to refocus.  I would suggest that we might be better off refocusing each patrolling arm rather than messing with the lenslet-to-DM registration (note that this would also allow us to deal with the focus issues discussed in section 5.1.3).

*There is no rotation required as the pupil doesn’t rotate. Please see* [*http://www.oir.caltech.edu/twiki\_oir/pub/Keck/NGAO/WFS/OSM\_De-rotation.ppt*](http://www.oir.caltech.edu/twiki_oir/pub/Keck/NGAO/WFS/OSM_De-rotation.ppt) *to understand why we don’t need a derotation.*

\* Sect. 5.3.2.

+ 1st sent.  You mention a 3.6" field-stop.  This is the first time this particular number is mentioned.  In section 5.1.5 you never mentioned this number.  Is this just a mistake?

*It was a mistake, it has been fixed.*

+ 2nd sent.  "An enclosure made of sheet metal".  I can imagine large pieces of sheet metal picking up acoustic noise and vibrating.  Have you thought about this risk?

*This is now obsolete as a structure as been designed.*

+ 3rd sent.  "a 205 mm travel linear stage".  Could you show the justification for this travel range somewhere in this document?  Should explain the range of sodium altitude and zenith angle you are assuming.

*Updated in Version 1.3.*

+ 4th & 5th sent.  Really should state somewhere the development of the requirements for this stage and how this stage meets these requirements (e.g., linearity, smoothness, positioning accuracy, etc.).

*Alex will deal with this.*

\* Sect. 5.3.3.

+ 2nd sent.  "we have a slow TT mirror near the pick-off focus to register the LODM actuators to the lenslet".  I would like to see the need for this mirror justified somewhere by how much the pupil registration changes as you move around the field (I think it probably is justifiable).  Should point out that this is just for the patrolling WFS.

*This is an outstanding item ☹.*

+ Last sent.  "Each LGS arm has a downlink TT mirror to correct the differential motion of LGS light WRT the science light at the pupil formed in the pick-off mechanism."  Suggested re-write for clarity "Each LGS arm has a downlink TT mirror, located at the pupil formed in the pick-off mechanism, to correct the differential motion LGS light with respect to the desired centroid location."

\* Sect. 5.6.

+ Is there a summary of the required motion control somewhere?