From Rich Dekany

1) Getting and keeping things straight: The TWiki site for AO System Design PD phase has some 7 version of the design, but v5 says "current". Is this true? I've lost track of which is official and find this confusing.

> Response: the zemax version number is not the same as the design document number. The “official” design document is KAON 685. The latest posted zemax file is version 7 on the AO System Design PD phase page.

2) Similar: the file on the AO System Design PD phase page doesn't match the pics in the document

> The latest CAD drawing is on the Design Review page, and should closely match the drawings in KAON 685.

3) The pupil size for all field points and configurations exceeds 106 mm (slightly). Is the LODM a 100 mm mirror or a 106 mm active actuator area mirror?

> The LODM map is shown in Figure 16. The flat-edge to flat-edge primary is 100 mm on the DM. The DM is 105 mm. This gives room for the pupil to rotate

4) We see the pupil footprint wander on both the DM and a pupil Viswa created using a paraxial lens for different field points after the LGS focal plane. What is the pupil shear across the field (related to 5) below, perhaps?)

> The wander is restricted to < 10% of the actuator pitch.

5) We have the EXPP at -4000-odd mm, not at infinity, so the 1st relay isn't strictly telecentric. Do we have this right? If so, -4 meters is far from telecentric.

> EXPP cannot be used to determine telecentricity in an off-axis system. We added in section 4.4, Figures 20, 21, and 22 to show telecentricity.

6) Your requirements in Section 2 include:

6a) "The optical relay will have a K-mirror upstream of the science instruments, wavefront sensors, and tip-tilt sensors" - should this also include the interferometer feed? Should it read "... science instruments, LGS WFS, and NGS WFS's." (?)

6b) I don't recall the "science relay with a ... FoV of between 20 and 40 arcsecconds.

6c) Next bullet "120 FoV" should probably be "120 FoR"

6d) Under 'Pupil Diameter', the report should be more clear whether this is mirror diameter, circumscribed pupil diameter, active mirror area, active area - 5% (ala Peter), or other.

6e) Output focal ratio matching "f/15" Nasmyth focus should be more explicit, probably for the 10.979m circumscribed pupil

6f) Sodium layer is listed as 90 - 180km above the telescope. I think we want 85km ASL, or as low as 80.8 km above the telescope (TBC)

> These sections have been updated.

7) Section 3.1 - are the K-mirror diameters cited the 90% clear aperture numbers, the physical diameter, or the beam footprint? What thickness need these individual mirrors be?

> 90% or less clear aperture. Thicknesses of several elements still need to be determined based on mechanical considerations.

8) Section 3.2 - the 1st OAP doesn't really produce a plane conjugate to the primary mirror, but an aberrated pupil surface. How bad is the curvature and tilt for the LODM pupil? Will it affect our conjugation of correction, and is this an anisoplanatism effect for the error budgets that is falling through the cracks?

> The PSF is shown in viewgraph 8 of Reni's presentation, and described in Table 6 of the design document.

9) Section 3.2 - 2nd paragraph. I think the history of the 1 vs 2-tier designs may be irrelevant for this document. Rewording to just state the conjugate height of each mirror might be enough (in fact, I like to see tables with the conjugate height of *every* optic in a design, though time might be short to prepare this.)

> The history records some of the motivation, although this was probably captured in other documents we should just refer to. We'll add the conjugate heights of every optic in the final version design document - this is a good suggestion.

10) Section 3.2 - 6th paragraph. The 10 degree incidence angle generates 1.5% foreshortening, which is 1.5% * 63/2 ~ 1/2 the outer most pupil spacing. Is this a problem? Does Peter's 5% 'underfilled' pupil concept affect this?

> See Figures 16 and 17 in the design document, which includes the foreshortening on both DMs. (sorry about the figure numbering goof - this is the first Figs 16 & 17 starting on page 24)

11) What is the thickness of the sodium dichroic beamsplitter? It's 11 inches in diameter (pretty big) so does it require any special mounting design?

> This is an 8 inch optic (note the new position and angle from an earler design, which shrinks this optic and makes more room for the DSM feed). Nominal thickness is 20 mm.

12) Section 3.3 - I sort of got lost here in the discussion of the 140mm diameter DM. I think the point of this section is that the performance of the fast LODM tip-tilt stage set the LODM diameter to 100mm (or is it 106mm? or 106mm - 5%), and this set the scale of the entire relay. There may be a 2nd purpose for this section, to convey whether or not an appropriate tip-tilt stage can be procured, but I couldn't clearly find the conclusion to this question.

> The mirror mass / tt bandwidth / cost trade-off led us to the 100 mm design over the 140 mm design. We have been in discussion with Cilas about this. Specifying the tt stage is part of our charge (WBS 1.3.4.4.2)

13) Section 3.4 - Can you specify the details of the notch filter? What transmission in band, what leakage out of band, and what width (e.g.)?

> We have not specified the notch filter yet. Thanks for the reminder. These are important: to maximize SNR on the HOWFS, but to allow some leakage for the acquisition camera. There is some latitude in width as the science band doesn't start until 600 nm.

14) Figure 2 caption - this is the first example of file names that are confusing. I think this one says "...v3..." in it.

> Don't understand this question. There is no v3 in the caption of Fig 2.

15) Section 3.4 - When you say the 'lens is located one focal length away from the woofer', is this the front principal plane of the lens, the vertex of the lens, it's center, or other? (See 5) as we have some confusion over the telecentricity of the LGS output beam)

> This is a rough statement. Use the zemax prescription for the exact placement.

16) We should detail a baseline location for the '90 degree' removable mirror for visible laser ACQ. Is there an optical design for said ACQ camera missing?

> Design of the ACQ camera and optics is outside our scope (WBS 1.3.4.2.9)

17) Figure 4 - Does the pictured interferometer feed fit onto the Nasmyth platform? Does it interfere with access and/or service? Does Chris have more mounting detail?

> 1st q: yes, see the EASM drawing for detail. 2nd q: we don't think so. 3th q: again, see Jim Bell's EASM drawing which has details of the Nasmyth platform. If this doesn't show it well, the latest CADs are in the drawings database. Jim is in charge of space allocation on the Nasmyth platform.

18) Section 3.6 – Is there a missing PD for the ACQ camera? Is the scale appropriate for just inserting a MAGIQ? What about chromatic aberrations in the ACQ?

We are using MAGIQ as a placeholder. Design of this camera is outside our scope.

19) Section 3.7 – For the 40 x 60 arcsec FoV, is the 40" in or out of the AO bench plane?

The 60" is out of plane, 40" in plane.

20) Section 3.7 – There is no longer a dIFS in NGAO

Changed to read IFS.

21) Section 3.7 – Same comments for the HODM as above for the LODM. Does the curved conjugate surface produced by the optical relays have any impact on AO performance?

See Table 6 for design parameters. We couldn't find specifications for these, but we believe they represent tolerable pupil blur (less than 10% of a tweeter subap). We recommend a LAOS simulation be done to determine the impact of slight amounts pupil image blur on AO performance to see if it is significant.

22) Section 3.7 – If OAP4 is to be used to direct light to alternative instruments, what space envelope would need to be kept clear? Is this consistent with the LGS WFS, LOWFS and all the other subsystems as conceived for PDR?

OAP4 is not used to direct light to alternative instruments. A flat fold mirror is used for this. Unfortunately this scheme precludes the use of the LGSWFS on the second instrument. There are no requirements on the feed for the second instrument to guide us.

23) Figure 6 caption – is the science FoV 40 arcsec circular, or 40 x 60" (as mentioned in p1 of S3.7)?

There are no field stops in the second relay to put a hard limit on the field. Some optics (i.e. the first fold mirror) set the limit before vignetting. The map of fields on to a representative wide field imaging detector is shown in Figure 7.

24) Section 3.8 – There is some confusion here, I think. Does Viswa also believe the NGS WFS will use an OSM for pick-off? I had thought the NGS WFS was to use a dichroic as the first element of an FSM pair for (periscopic) acquisition...?

This is still under discussion, and up to the WFS team to decide what is best.

25) Section 3.8 – I think Fig 6 reference herein is actually Fig 7

Text is fixed.

26) Figure 7 - what is the orientation of this field w.r.t. the optical bench?

Bench is horizontal in this view.

27) Section 3.8 p2 - I think we have accepted operation down to 0.6 microns as a goal, so the design needs to attempt to satisfy this.

We are attempting to satisfy this.

28) Section 3.8 p3 - The idea of using the NGS WFS as a LOWFS presumably has some optical design related questions. For example, is there a color-dependent tilt in the optical relay that would need to be accounted for (presumably in software or through a calibration procedure) in order to use the NGS WFS as a LOWFS?

Yes, calibration will be needed.

29) Section 3.9 - is it clear that 'the shift in focal plane' here can be compensated by a telescope focus shift? What does this do to all the other foci?

Nominal solutions: for the NGSWFS dichroic, refocus the science instrument (the only focus affected); for the interferometer dichroic, adjust the telescope to put the LOWFS focus in place, then refocus the LGS HOWFS on its focus stage as needed. The interferometer feed will need to be nominally configured to accept the resulting focal position. The possible shift of pupil on the LOWFS in this configuration still needs to be examined.

30) Section 3.9 - "in the beam between OAP4 and and instrument is one removable dichroic" may be misleading. There is also a flat mirror in the design. And the 'removal dichroic' should be specified to be the NGS dichroic, as it could sound like there is something here different than described previously for the NGS WFS.

Text is modified.

31) Section 3.10 - I think we do need to go to 0.6u, so is it right that 2 switchable ADC's are needed? Will they fit?

The BTC has descoped to one ADC.

32) Section 4 - this section sounds like you assume static correction of relay aberrations using DM stroke. Is this the case, and if so, how much stroke?

Less than 50 nm of stroke will be needed for correcting relay aberrations. These are low order so can be put on the woofer.

33) Section 4 p2 - All paths originating on sky will see the entrance window, so there's no 'purely reflective' path.

Correct. We’ll fix this text.

34) Section 4.1 p1 – Same issue with there being a window in the LOWFS path

Agreed.

35) Section 4.1 p2 – How much of the PnS MEMS DM stroke is needed to compensate for the described astigmatism compensation?

Less than 50 nm, placed on the PnS MEMS DM.

36) Table 3 – Is the 91 micron focal shift w/ interferometer dichroic in a problem for the LOWFS? If the +– lambda/4 DoF = 900 microns, then lambda/4 = 450um, so a 91um shift is some lambda/5 (where I think you used lambda = 1u), so is this a 200 nm error in the LOWFS? I don't think so, because the chromatic shift is I think meant to describe the entire bandpass. But what is the impact on LOWFS performance?

Agreed, the interferometer dichroic may introduce undesirable chromatic focus shift. This still needs to be evaluated.

37) Table 3 – I think there's an unassigned asterisk here.

Fixed.

38) Section 4.2 p1 – I think the S3.6 reference is really S3.7

Fixed.

39) Section 4.2 p3 – how much tilted-dichroic astigmatism will need to be corrected by the HODM?

<50 nm P-V

40) Table 4 – Is the 300 mm field curvature to the Sci Instrument a problem?

This is presented as a candidate interface to the instrument team. The requirements need to be written.

41) Section 4.2 – refs to Figs 7 and 8 are really 8 and 9

Fixed.

42) Section 3.10 p3 – ref to Fig 10 is really Fig 11 (and subsequent refs seem off, as well)

We're trying to fix these figure numbers. The latest version still has some problems – sorry, please bear with us.

43) Section 3.10 p3 – the comparison to 1.47" includes charge diffusion. The optical comparison should be more to something like 1.21" FWHM. Your spot size of 250 mas is, I think, equivalent to 250 * 2.355 = 589 mas FWHM, which isn't necessarily objectionable. We should check these numbers.

The documented spot size is as set by the optics and presented at the instrument interface, without consideration for detector charge diffusion or optics in the instrument.

44) Section 3.10 – use of 'the WFS focal plane' should probably be clarified as the input focal plane to the LGS WFS.

Section 3.10 is in “Science Instrument ADC”. Please clarify.

45) Figure 14 – does this also show the degradation in image quality within each subaperture due to the steep astigmatism (or just the 6% of subap max spot shift?)

Image degradation of each spot is very small. Figure 14 is the result of a full wave-optic simulation, so it should show the true spot PSF.

46) Figure 12 and associated – Zemax can handle larger than 18x18 lenslet arrays, geometrically. I think the PDR material should not stop with the 18 x 18 examples herein.

Figure 14 shows the full 64x64 wave-optic simulation.

47) Section 4.3 – there is also nutation of the telescope pupil as a function of alt/az position

Agreed. Do we have any starting-point numbers for this?

48) Section 4.3 – a summary statement of whether these grid distortions are acceptable or problematic would be helpful

Grid distortion is within specification of < 10% of a HOWFS subap. We’ll add this text.

49) Section 5 – General – are you sure Zemax handles tolerances of tilted and decentered optical systems correctly?

We will double check using the methods of KAON 107.

50) Section 5.2 p5 – Which 'pixel' are you referring to here?

Nominal science imaging detector pixel. We’ll rewrite this to state it in physical units (arcsec on sky).

51) Section 5 – I find the discussion of compensators difficult to follow. I think it's that I basically worry about the impact to other subsystems (e.g. interferometer or WFS's) is one uses the indicated compensators. I think the context of an overall alignment plan would help make this section clearer, particularly regarding what can and cannot be left variable to the I&T phase.

Compensators are those used in Zemax during tolerancing. We’ll need to work with the SYSENG team to establish an alignment procedure (this effort was outside the scope of this WBS).

52) Section 6 – mini-review moved to Nov 17, 2009

53) General - the document has several occurrences of 'miliradian' instead of 'milliradian'.

Fixed text.

54) The working f/# for the LGS focal plane is 13.52 (instead of 13.66), so is this a 1:1 relay? Is there a paraxial v. real ray issue here?

It is probably better to state a plate scale rather than an f/# throughout, as the f/# used by zemax is from the output pupil. Also there is a bit of ambiguity because of the hex shaped Keck pupil.

55) Looking at figure 17, it seems like there is 300 um of image motion at different field points ... which is about 1/6th of a 32x32 LGS sensor sub-ap. (greater than 10% on the worst case sub-aperture). this is worse than the estimate in the LGS WFS section. The file on the website shows 9 waves of astigmatism and 14 waves of total error.

See Figure 16 for the grid distortion (second “Figure 16”, sorry). Grid distortion is a different concept from pupil image blur, which is show in (second) Figure 17 (see Figures 18 and 19 respectively for the tweeter versions). Grid distortion meets the 10% of tweeter subap requirement. Image blur is about 15%. This needs to be evaluated for system impact, and may be a push-back point if it is indeed set to a 10% requirement.

For Chris' slides (which I just found today), the following questions have also arisen:

56) Can the CILAS LODM tip-tilt stage really fit onto this crowded bench?

We’re working on it. This needs close collaboration between the AO relay team and the WFS team, as well as with Cilas.

57) Slide 5 - "CILAS" and "MAGIQ", I believe

Fixed

58) A view showing the swept-out volume of the K-mirror rotator would be helpful to understand the feasibility of packaging everything.

Ok. This now sweeps 360 degrees.

59) Is beam height off the NGAO bench consistently 300mm everywhere?

Yes.

60) If we are to run the HODM without it's front window, are there cleanliness issues within the bench of concern (e.g. outgassing from mount lubricants, etc.) I presume the HODM can never be cleaned. Is this true?

No concerns have been determined other than the need for low humidity during high voltage operation. The HODM cannot be cleaned. It is recommended to have one spare on hand and be ready to swap it out possibly yearly.

61) Slide 8 – This terrible packaging problem may require reconsideration of the folding of the 2nd relay. We should discuss, as now the 2nd relay and LOWFS structural work will be done together.

We disagree with the word “terrible”. I would say non-trivial. We should work closely with the WFS team to open up this structure, possibly with a space frame approach, that allows easier access.

62) Slide 9 – What sets the proposed depth of the honeycomb table?

Vibration and flexure issues, as well as the need to cool it to the “cold” temperature (~ -15 c). It is nominally 18 inches. More information about the mass and CG of other subsystems on this bench is needed to move forward with this decision.

63) Slide 9 – What are all the clrnc issues that drive this bench to just a Byzantine shape? What are the implications of all these same things on NGAO human access, instrument volume, etc.?

The shape accommodates the layout and, as much as possible, is trimmed to allow human access. Full access with all the instruments and sensors in place is beyond our scope at this point. Jim Bell is the Nasmyth “space Czar”.

64) Slide 10 – Not all the Decenter tolerances are ~ 100 um (such as the 400 um pitch HODM).

Correct. Thank you for pointing this out. The HODM needs a tolerance closer to 10 microns.

65) Slide 11 – Vibrations – should you include potential vibrations from LOWFS dewar cryo-system? The LOWFS OSM's also move in some non-sidereal tracking modes, but this is very slow and a relatively small mass.

Yes. Thank you.

66) Slide 12 – I think the ACQ dichroic(s) and ADC(s) belong on this list, as well.

Yes, it will be added.