Modeling NGAO systems:

I have four tools that we are currently using at Keck:

- YAO: a full Monte Carlo simulation of narrow field adaptive optics includes physical optics wavefront sensor model (partially illuminated subapertures, centroids calculated from Hartmann images). Some advanced reconstructors, not as complete as Brent's codes see LAOS. Also included Keck pupil, Keck static segments errors, and vibrations.
- LAOS: a model from TMT project office, models NFAO, MOAO, GLAO. It includes only idealized model of Hartmann sensor and actuators. Noise model is idealized. Can include some effects of primary aberrations and laser elongation, more effects being added by Luc Gilles and Brent Ellerbroek for TMT, physical optics model of Hartmann sensor by Feb/March. Modeling of loop dynamics and reconstructor very advanced.
- Sky coverage tool from TMT. Estimates tracking error as a function of field of view, star model, outerscale, etc.
- Spread sheets to calculated exposure time, SNR. These need to be finalized. They assume a perfect PSF and high Strehl. I have given this lower priority assuming that astronomers have better tools, which could be a bad assumption.

Neither YAO nor LAOS support layer oriented AO, and neither supports pyramid sensors. YAO has some ability to use curvature sensors but not with multiple guide stars. At present I didn't see these missing architectures as important to the June proposal.

NGAO architecture options:

1. NFAO (KPAO)
   YAO: high fidelity ~ +/- 30nm in rms wavefront error
   LAOS: medium fidelity ~+/- 40 nm in rms wavefront error. +/- 40nm terms not included in model (vibration, segment error, physical optics wavefront sensing)
2. MCAO
   YAO: medium fidelity~ +/- 40nm in rms wavefront error
   LAOS: medium fidelity~ +/- 40 nm in rms wavefront error. +/- 40nm terms not included in model
3. MOAO
   YAO: doesn't have this capability at present.
   LAOS: medium fidelity~ +/- 50 nm in rms wavefront error. +/- 40nm terms not included in model. LAOS does not include temporal effect for MOAO, it only infinite bandwidth correction.
   Matt Britton and Don Gavel are both doing modeling for TMT IRMOS, will probably use them to sanity check results from LAOS.
4. GLAO
   YAO: low fidelity ~ +/- 50nm in rms wavefront error (GLAO error is very large typically 500-100 nm rms). The YAO GLAO reconstructor is just a simple averaging of LGS signals. Everybody thinks that more advanced estimators can work better.

LAOS: Haven't looked at LAOS models of GLAO in detail but it's included in options for the simulation

5. Adaptive secondary

   Neither YAO nor LAOS have the ability to model AO secondary influence functions and the complex control of the actuators. They can both model a conventional dm placed at the optical conjugate of an AO secondary. I have understood that this type of specialized modeling would be done by Microgate or perhaps someone at U. of Arizona.

6. Extreme AO

   We can add lots of actuators to KPAO and LAOS, better to leverage work by Bruce Macintosh for ExAO.

Science case support tasks:

Performance:

See comments on architectures, both LOAS and YAO can produce wavefront errors, PSF, FWHM over a wide field of regard. It is only a matter of computation time.

Science Instrument options/possibilities:

??? Don't know exactly what would be needed here. I can certainly provide PSF's as function of wavelength. Some connection to exposure calculator tool is missing.

Likely capabilities of competing systems:

See above: I think we could model anybody else's AO system. Exposure calculator tools could be used to estimate performance of space missions, example JWST, SIRTIF.

PSF (on-axis, off axis PSF, versus guide magnitude):

Possible, see comments under performance. Just takes lots of compute time to average out simulation noise in PSF halo

Simulated science fields:

I have assumed that we just have to provide PSF libraries. This could be a very involved activity if we have to produce lots of PSFs, for lots of types of AO systems, and also produce the final science images, or spectra.

SNR verses time for different science objects:

See comments above SNR spreadsheets

Photometric precision:

See PSF above, we have to average out the simulation noise in the PSF halos. YAO has methods for speeding up this process. LAOS would require lots of simulation runs and then averaging of the resulting PSFs.

Astrometric precision:

I'm not sure what's needed to simulate the distortions across a detector correctly. I believe that the dominant effect is tracking jitter plus focus, and astigmatism correction as such its going to be highly dependent on NGS distribution and magnitude in an individual field.