Topic	Worksheet Name	Inputs	Outputs	To Do	Comments
Summary	Sum	None	Overview of Error Budget	Add MCAO blind mode error terms to spreadsheet	
Optimization	Optim	Results wavelengths WFS integration times TT guide star search radius LGS asterism radius	RMS WFS Strehl ratio TT errors Sky coverage Assumptions and parameters Publishable summary table		
Telescope	Tel	Telescope name (some values are picked up from this) Telescope diameter Obscuration diameter (equivalent circular obscuration) Static aberration information Dynamic aberration information	Uncorrectable static errors Uncorrectable dynamic errors	Check Keck equivalent circular obscuration value	
Atmosphere	Atm	Cn^2(h) model Wind model r0 Turbulence-weighted wind Outer scale Atmospheric pressure model Atmospheric extinction model Zenith angle of observation	Theta0 Theta0 (finite aperture) Greenwood frequency tau0 Tilt isoplanatic angle Tilt tracking frequency d0 (Hardy) d0 (KAON 208) Scintillation index Effective turbulence height Global one-axis tilt Peak tilt		
High order WFS Flux	HO Flux	Guide star type (NGS/LGS) Subaperture geometry (square/ circ) Subaperture width Integration time Apparent mag of GS (mV) Choice of spectral bands Transmission model QE model	Subaperture area Photodetections per subap per exposure Shot noise		
LGS Return Flux	LGS Flux	Laser power Laser pulse format Transmission model Slope efficiencies Na density	Transmitted power Na layer distance Delivered power Na return flux per subap per exposure time		
High order Centroiding Error	HO Cent	Sensing wavelength Pixel sampling per subap Intrinsic GS diameter LGS beam aberrations Uplink correction? Rayleigh gating? Off-axis launch distance Sensor type (SH/Pyr) Downlink residual aberrations Charge diffusion CCD read noise model Sky background flux Dark current model Rayleigh scatter model	Total number of pixels per measurement Max LGS elongation Mean LGS elongation Delivered Na spot size WFS optical spot size Subap diffraction Spot size for centroiding SNR of detection RMS centroid error	Verify values in Rayleigh scatter model	
High order Measurement Error	HO Meas		Estimate of measurement error		
Focal Anisoplanatism / Tomography Error	FA Tomog			Update using Ralf's latest values	
Asterism Deformation Error	Ast Def		Estimate of error due to asterism deformation		
Sodium layer height focus error	Na H		Estimate of error due to unpredictable Na layer height		
Fitting Error	Fit		Estimate of fitting error		
Aliasing Error	Alias		Estimate of aliasing error		

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Fintie Stroke Error	Stroke	DM woofer stroke DM tweeter stroke Allocation made for fas tip/tilt correction	Number of saturating actuators Estimate of impact on delivered science Strehl		
Hysteresis Error	Hyst	DM actuator hysteresis	Estimate of error due to hysteresis		
Go-to Error	Go-to	DM positioning error model	Estimate of error due to go-to control		
Digitization Error	Dig	Number of control bits	Estimate of error due to finite digitization		
Tip/tilt WFS Flux	TT Flux	Subaperture geometry (square/ circ) Sensor type (TT, TTFA, 3x3, HOWFS) Integration time Apparent mag of GS (mV) Choice of spectral bands Transmission model QE model Number of tip/tilt guide stars Model of flux gain with multiple GS Model of tilt anisoplanatism reduction with multiple GS AO correction mode (SCAO, MOAO, or MCAO) Special spectral color for GC guide star IRS7	Total transmission TT GS Strehl, as delivered by SCAO, MOAO, or MCAO system models Total photodetections in the tip/ tilt measurement per exposure time Shot noise	Update model of TT GS Strehl due to MCAO correction; once MCAO better handled among HO error terms	
Tip/tilt Measurement Error	TT Meas	Number of pixels per subaperture Read noise models for IR and visible detectors Dark current models for IR and visible detectors Sky brightness in various wavebands Total field of view for tip/tilt measurement (determines sky background contribution) Intrinsic object diameter Is there sharpening of the TT GS by the AO system? (Yes/No) Is there atmospheric dispersion correction in the LOWFS? (Yes/ No) LOWFS detector choice (CCD, SNAP, 2.5u cuttoff HgCdTE)	Total photocounts per spectral band DL core photocounts per spectral band Shot noise contribution Sky flux per measurement Shot noise due to sky flux Linear atmospheric dispersion Image width used for TT measurement per spectral band SNR of TT measurement per spectral band TT measurement error (one-axis) per spectral band Total TT measurement error for chosen detector (e.g. multiple spectral bands)	Add an independent CCD noise model for LOWFS (currently using same noise as HOWFS CCD model) Add a noise model for each IR detector choice (currently IR read noise is one value for all rates and detector types).	
Bandwidth Error	Bandw	Servo coefficient, Kappa Decimation factor relating frame rate and -3db rejection bandwidth Telescope jitter model	Estimate of bandwidth error Estimate of TT bandwidth error Estimate of residual telescope pointing jitter	Could move the telescope jitter model to 'Tel' worksheet	
Scintillation	Scint		Scintillation index as function of wavelength Estimate of scintillation error in science beam (Strehl impact converted into equivalent rms wavefront error thru Marchel approximation) Estimate of rms wavefront error due to scintillation in HOWFS (from simulation)		
Anisoplanatism	Aniso	Distance from HO GS to science target Distance from (brightest) TT GS to science target	Estimate of angular anisoplanatism error at the science target Estimate of angular anisoplanatism error at the TT guide star Estimate of TT anisoplanatism error at the science target (assumes science target at center of corrected field) Effective off-axis distance for TT anisoplanatism, assuming a simple model of TT tomography		

Topic	Worksheet Name	Inputs	Outputs	To Do	Comments
Centroid Anisoplanatism	CA	Documentation of several approaches to mitigating centroid anisoplanatism (Sandler, Sasiela, Dekens)	Estimate of residual centroid anisoplanatism error		
Chromatic Errors	Chrom	45 and 60 degree zenith angle models taken from Hardy	Estimate of Dispersion Displacement Error Estimate of Multispectral Error Combined estimate of Chromatic Errors	Need model of dispersion displacement error across the IR - currently broken	
Atmospheric Dispersion	Atm Dispersion	Is there a dispersion corrector? (Yes/No) Air temperature Partial pressue of water Dispersion models from Elden, Barrell and Sears, and Lacasse	Refractivity Atmospheric dispersion across many spectral bands	Could move temp and H20 vapor inputs to 'Atm' worksheet	The dispersion model from Lacasse doesn't agree with the others; haven't bothered to track this down
Calibration Errors	Cal	Observed best K-band Strehl obtained with an internal pointlike source Allocation for Static Zero-Point calibration Allocation for Dynamic Zero-Point calibration Allocation for DM-to-lenslet misregistration Allocation for uncorrectable AO system aberrations Allocation for uncorrectable instrument aberrations		Incorporate better model of how lack of proper calibration / WFS PSF model affects performance. This is an important issue for Keck LGS, perhaps slightly less so for NGAO, but still needed	
Notes	Notes	Documentation / capture of developer thoughts and to-do lists (very informal)			
Sky Coverage	Sky Coverage	Star density model (Spagna, Bahcall, Parenti, Allen)	Areal densities of stars of the GS brightness and somewhat fainter Probabilities of finding one or more GS within the TT star search radius (taken from 'Optim' worksheet Sky Coverage defined as P(at least 1 star brighter than a given mag nearer than the search radius, providing a certain performance); For example P(1, mJ=19, 60 arcsec, 180 nm) = 20% (not actual value).		
Spagna Model	Spagna	Spagna model of star density as function of galactic latitude	Areal densities of stars brighter than a given mJ or mK vs. galactic latitude, b; some information vs. galatic longitude (we only use longitude = 90 for now)		Is there value in incorporating other longitudes?
Bahcall-Soniera Model	Bahcall	Soniera model of star density as function of galactic latitude	Areal density of stars brighter than a given mV vs. b		
Parenti Model	Parenti	Parenti model of star density as function of galactic latitude	Areal density of stars brighter than a given mV at the b=0, b=90, and all-sky average		
Allen Model	Allen	Allen model of star density as function of galactic latitude	Areal density of stars brighter than a given mV vs.galatic latitude b; both Allen 3rd ed. and 4th ed. models included		
Specific Fields	Specific Fields	Ad hoc models of star density for specific target fields, such as GOODS-N or COSMOS			Analysis tools using actuator star catalogues have been developed independently by Bouchez and by Gavel - turn to these when specific field detail is needed.