NGAO Preliminary Design Phase Performance Budget Flowdown Reconciliation

Version 0.7

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Introduction

A number of high-level performance budget allocations and underlying assumptions, initially developed during the NGAO System Design phase, have been flowed down into a significant set of derivative subsystem performance and functional requirements. These flowdown budgets are captured in the MS Excel workbook:

NGAO_PD_Phase_Flowdown_Budgets_2003_Format_v0.95.xls

available at the NGAO TWiki page:

http://www.oir.caltech.edu/twiki_oir/bin/view/Keck/NGAO/FlowdownSummary

The flowdown process has in some cases resulted in inconsistent subsystem requirements, revision of original allocations, and identification of new requirements heretofore unidentified. The purpose of this memorandum is to describe the key flowdown issues and to propose feasible resolutions consistent with the NGAO science requirements.

Additional issues have been identified and will be tracked in subsequent revision to the version-controlled flowdown budgets .xls file.

Key issues

Surface Optical Transmission

The predicted reflectivity and transmissivity of all NGAO optical surfaces is captured in worksheets prefaced by "Trans", for various optical paths. To make these internally consistent, we propose the following be used consistently:

Adopted resolution	Unresolved issue for later
Keck 1 M1 reflectivity = $R_{M1}(\lambda) = R_{AL}(\lambda) * (1 – 5\%$ (degradation[1])) where R_{Al} is the reflectivity of Al Keck 1 M2 reflectivity = $R_{M2}(\lambda) = R_{AL}(\lambda) * (1 – 2\%$ (degradation)) where R_{Al} is the reflectivity of Al Keck 1 M3 reflectivity = $R_{M3}(\lambda) = R_{AL}(\lambda) * (1 – 4\%$ (degradation)) where R_{Al} is the reflectivity of Al 1st window transmission = $T_{W1}(\lambda) = T_{AR}(\lambda) * (1 – 2\%$ (degradation)) where T_{AR} is the anti-reflection coated transmission All 589 nm 'laser enhanced' reflections = R_{Na} = 99.4% All 589 nm 'laser enhanced' transmissions = T_{Na} = 98.9% Degradation loss on LGSF optical surfaces = (1 – 0.5% (dust loss)) Degradation loss[2] on all[3] AO system optical surfaces = (1 – 0.5% (dust loss)) Cold stop losses[4] = (1 – 2% (undersizing loss)) for all wavelengths in the science path Cold stop losses = (1 – 20% (inscribed circular[5] undersizing loss)) for all wavelengths in the LOWFS path	Gaussian beam losses arising from LGS uplink finite apertures Losses due to near-field propagation of initial optical surface phase errors scattering to vignette angles at later NGAO optical surfaces Laser system power division (depending upon # of lasers and ultimate power distribution into the 7 LGS beacons) Will there be requirements flowed down for optical ghost brightness, particularly from optical filters? The optimum size of the cold stop in the LOWFS should be obtained via SNR calculations that trade off background noise and loss of signal, for the range of circular pupil diameter between 9 and 10.949 meters.

Table 1

[1] In discussions, we agreed to include degradation losses estimated for performance 1 year into NGAO service (post first-lock). In other words, all our transmission numbers should be exceeded at first light, and degrade to our performance spec after one year. This agreement will generate one or more new functional requirements in the Contour database.

[2] The flowdown emissivity calculations should be made consistent with the same dust level assumptions established for optical transmission calculations.

[3] Excepting the NGAO first window (see above).

[4] Note, there is no cold stop in either the fixed-asterism HOWFS, the PnS HOWFS, the visible TWFS or the NGS HOWFS.

[5] To avoid complexity in the LOWFS that would arise if attempting to rotate a complete Keck pupil stop to follow pupil rotation, the NGAO design assumes an inscribed circular pupil of 9 meter diameter, for now.

System Optical Transmission

Based on coating data believed to be reliable, the system transmission requirements[6] are proposed to be modified as follows:

Optical path	**Old value**	**New value**
LGSF	0.75	0.60
Fixed Asterism LGS HOWFS	0.35	0.50
PnS Asterism LGS HOWFS	0.35	0.50
LOWFS	0.32	0.30[7]

Table 2

System Emissivity

Inclusion of coating data to the emissivity budget, updating of the surface counts to reflect the B2C design, and possible other changes to the emissivity calculation have resulted in a change optical surface temperature required to meet the requirement to not exceed the sky+telescope in K-band by more than 30%:

Term	**Old value**	**New value**
Internal enclosure temperature	-15C	-18C

Table 3

Servo Bandwidth Error

The flowdown for compute latency differs significantly between performance budgets:

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[6] For zenith pointing.

[7] We adopt this as an update to the functional requirements, but direct Velur to revisit the LOWFS architecture to attempt to improve LOWFS transmission.

Term	From WFE budget	From High-contrast budget	Adopted resolution
Allowable servo lag error	59 nm rms	30 nm rms	--
Min WFS readout time	Requirement was unclear	Enable 2,000 Hz steady-state operation	Enable 2,000 Hz steady-state operation
Compute latency (non-readout)	300 microsecond centroiding and pupil plane reconstruction 400 microsecond tomography <u>200 microsecond DM cmd calc</u> 950 microseconds total	300 microseconds total	TBD – Gavel and Reinig will rework compute latency for 2kHz update rate[8], but consistent with 59 nm rms WFE
½ DM hold latency	½ frame integration time included in servo latency calculation	½ frame integration time not included	½ frame integration time included in servo latency calculation

Table 4

Tomography Error

The B2C tomography error is unchanged by the flowdown process, but it remains one of our most difficult requirements (due to the large disconnect with proven, on-sky tomography error performance)

Term	Requirement
Residual tomography error from fixed 3+1 Na LGS beacon asterism	37 nm, rms

Table 5

[8] This update rate for the fixed-asterism HOWFS will most likely arise in conditions of high sodium abundance and good polarization return. The canonical 3e9 atoms/cm^2, median seeing and wind, fixed asterism HOWFS frame rate for the Gal/Gal lensing science case is closer to 900 Hz.

Tracking and Dither Errors

Term	Old value	New value
Dither precision	--	TBD; not yet flowed down
Non-common-path tracking error for T = 3600 second exposure	5 mas / hr	13.6 mas / hr implying optical bench temperature variation less than 1C per hr

Table 6

Calibration

Term	Previous value	Adopted value / comment
AO system optical surface figure quality[9]	λ /10 to λ /50	λ /20 for most surfaces with λ/10 allowed for cost drivers
LODM stroke allocated to correcting telescope, AO system, and instrument aberrations	0.7 microns peak-to-valley	Retain 0.7 microns peak-to-valley
Stale reconstructor error	15 nm, rms	Same, but flowdown implication for the NGAO high-level control and RTC software has not been performed.
Quasi-static WFE	--	50 nm rms before AO correction (all frequencies) 20 nm rms low-spatial-freq error after correction 10 nm rms mid-spatial freq error after correction
Dynamic WFS Zero-point Calibration Error	40 nm, rms	The implication of this requirement has not yet been flowed down to calibration and design requirements on the WFS. It is believe the current 4x4 pixel per subap design, with center projection, will enable this but it remains unproven.

Table 7

[9] Implied by the high-level requirement on non-correctable AO system aberrations.

TTFA Focus and Astigmatism Errors

The accuracy requirement for the measurement of focus and astigmatism terms in by the TTFA has not yet been flowed down:

Term	Requirement
TTFA focus and astigmatism measurement error	TBD

Table 8

Laser Beacon Spot Size

Term	Old value	New value
Laser beam FWHM due to inherent laser beam quality and BTO and LLT optics	900 mas due to laser, BTO, and LLT only	The flowdown based on BTO surface quality assumptions resulted in a much smaller value (600 mas, *including atmospheric errors*) We propose to leave this at 900 mas pending better understanding
LGS beacon FWHM measured on the HOWFS	1300 mas from all sources	

Table 9

Anti-aliasing

The implication to the high-contrast error budget of wavefront aliasing in the fixed asterism HOWFS is not well understood:

Term	Issue
Aliasing of high spatial frequency errors into mid-spatial frequency errors	Approximately 77 nm * 0.33 = 25 nm, rms of aliasing error is expected[10]

Table 10

WFE Budget Reorganization

To better reflect the design of the NGAO system, we propose renaming several of the high-level WFE budget terms:

[10] The efficacy of an anti-aliasing spatial filter for the fixed asterism HOWFS field stop is unclear. The LGS will generally not be sharpened strongly in the fixed asterism HOWFS.

Term	Former	Proposed / Comment
Leaky integrator zero-point calibration error	15 nm allocation	The relevance of this terms will depend on the details of the servo control implementation; for now retain as is but resolve before flowdown v2
HOWFS Pupil Misregistrations	DM-to-lenslet Misregistration and DM-to-lenslet Pupil Scale Error	Propose to replace two former errors allocated a total of 21 nm, rms with a single term at 21 nm, rms (further flowdown requiring detailed modeling)
PnS HOWFS Pupil Misregistrations	DM-to-lenslet Misregistration and DM-to-lenslet Pupil Scale Error in LOWFS sharpening budget	Propose to replace two former errors allocated a total of 21 nm, rms with a single term at 35 nm, rms
Non-common-path tracking errors	Science Instrument Mechanical Drift & Long-exposure Field Rotation Errors	Propose to replace two former errors with an allocation based on a more comprehensive NCP tracking budget

Table 11

Keyhole Proximity Budget

As part of our discussions at NGAO PD TM#8, we identified a need to consider all aspects of the NGAO system from the point of view of the minimum keyhole distance for NGAO operation. This will be assigned in the meeting action items.

Relative Astrometric Accuracy

An initial flowdown of relative astrometric accuracy has been developed for both spares and crowded (e.g. galactic center) fields. We continue to struggle with the construction of a clean flowdown that captures the various real-world observing issues (various observations at the GC, for example, require different calibrations, different observing cadences, etc.) The draft flowdowns should be reviewed for feedback at the Sept 2, 2009 team meeting.

System Uptime

No flowdown for system uptime has been developed. A prototype spreadsheet that may be useful in developing a flowdown of mean time between failure (MTBF) specifications has been developed.

Observing Efficiency

The time allocations for setting up both LGS AO observations and NGS AO observations have been flowed down, but the relatively challenge of meeting these allocations and the implied speed and latency requirements on software and mechanisms remains unknown.