W. M. KECK OBSERVATORY

# Preliminary NGAO Technical Risk Evaluation

**KECK ADAPTIVE OPTICS NOTE 510**

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**ABSTRACT**

The following note contains a preliminary risk assessment for the NGAO made during the system design phase of the project. The note explains our methodology for risk evaluation. It also included a risk table with about 70 items. These are organized by system level risks, component risks, and architecture specific risks.

## 1. Introduction

At this date (August 2007) the NGAO system architecture down select process is still on going. Five possible architectures were identified during the team work shop at UC Santa Cruz in early July, see draft KAON 499. This risk table has been compiled to assist in the down selection process for NGAO system architecture and as a repository for risk evaluation for the final system design report.

## 2. Methodology

Risk areas in the project were identified. Each risk was evaluated for its impact and likelihood. Impact level was assigned in one of the following 4 categories:

- Major - Project objectives at risk (mandatory change to one or more of project scope, schedule, or resources)
- Moderate - Project objectives can still be met, but would require significant changes to plan
- Low - No major plan changes required; the risk is an inconvenience or it will be addressed through minor allocation of contingency resources
- Unknown - Impact is not quantifiable at this time

These categories are broad and include cost and schedule risk as inclusively. Each risk was also assigned a likelihood occurrence based on the following 3 categories.

- Likely - 50% or higher
- Unlikely - 10% to 50%
- Very unlikely - 10% or less

Using these criteria a risk table was developed, see Table 1.

**Table 1: Risk evaluation for NGAO**

| Ref. # | Description | Impact | Likelihood | Mitigation Plans | System Design Phase Mitigation |
|---|---|---|---|---|---|
| | **System Level Risks** | | | | |
| 1 | Achieving science requirements | | | | |
| a | Long exposure time performance | Moderate | Likely | On instrument metrology | |
| b | (add other parameters?) | | | | |
| 2 | Science requirements inadequately understood & changing | Major | Unlikely | Talk to the astronomers a lot | Science Core Requirements document and flowdown |
| 3 | Delivered PSF too variable (spatially and temporally) to satisfy astrometry and photometry requirements | Moderate | Likely | | CfAO funded PSF study (2008-2009) |
| 4 | Adequately meeting interferometer needs | Unknown | Likely | Review proposed performance with KI team | KI support trade study and KAON |
| 5 | Achieving contrast performance budget | Unknown | Unlikely | (Need to verify science requirements) | Contrast trade study & KAON |
| 6 | Achieving defined photometry budget | Unknown | Unlikely | (Need to verify science requirements) | Photometry trade study & KAON |
| 7 | Achieving defined astrometry budget | Unknown | Unlikely | (Need to verify science requirements) | Astrometry trade study & KAON |
| 8 | Achieving desired SNRs | Unknown | Unlikely | Managing throughput in optical design, making provisions for long exposure stability | Throughput and background trade study & KAON |
| 9 | Achieving polarimetry requirement | Unknown | Unlikely | Control effects that rotate or scramble polarization | Polarimetry trade study |
| 10 | Wavefront error budget assumptions & accuracy | | | | |
| a | Bandwidth error assumptions. Assumption that closed loop bandwidth is 1/15 of sample rate. The rate of ~1/20 has been demonstrated, but would significantly impact error budget. | Moderate | Unlikely | Investigate and simulate control loop impact. | |
| b | Sodium return expectations not met | Major | Likely | Refine and adjust assumptions based on data from current systems | See LAO web page for current info |
| c | low noise CCDs for WFS. | Major | Unlikely | Another design turn for CCID-56, more laser power | AODP CCD project |
| d | Impact of telescope vibration | Moderate | Likely | Reduce telescope vibrations | Vibration trade study & KAON |
| e | Tomography. No sky demonstration. | | | | MAD, MMT, LAO bench experiment |
| i | Codes contain assumptions that are untested in actual operating conditions | Major | Likely | Refine and adjust assumptions based on testing | |

| | | | | | |
|---|---|---|---|---|---|
| ii | Alignment and registration - beacons and WFS | Moderate | Unlikely | Design opto-mechanics for closed loop beacon positioning and stability. Implement test procedures during I&T to ensure proper alignment and registration. | |
| f | Tip/tilt tomography. No sky demonstration of benefits of multiple TT stars | Moderate | Unlikely | LAO laboratory experiments | |
| g | Rotating LGS constellation limits performance for long exposures | Moderate | Likely | De-rotate, configurable add beacons? | |
| h | MCAO mirrors are not at proper conjugates or correct "statistical position" for the actual Cn2 profile | Moderate | Unlikely | Get MASS/DIMM data for Mauna Kea before detailed design phase | Collate TMT and other Mauna Kea seeing measurements |
| 11 | Risk of not being able to find adequate tip/tilt stars for certain science cases | Low | Likely | System provides gradual degradation, TT stars AO corrected | |
| 12 | Rayleigh background on LGS WFS cannot calibrated out | Major | Likely | Issue for GS MCAO, will be tested by them. Use long period pulsed laser and electronic shutter on HOWFS CCD to gate out Rayleigh | Rayleigh Rejection trade study |
| | **Component Risks** | | | | |
| 13 | Availability of required lasers | Major | Likely | Continue to pursue laser development | |
| 14 | Fiber transport. Mitigation is conventional beam transport | Moderate | Likely | Testing programs underway for fibers | Keck I LGS experiment with Gemini Laser, Subaru Fiber; ESO & Subaru experience |
| 15 | Availability DM with small pitch and adequate stroke | Major | Unlikely | Use 48 x 48, 5 mm, add a second DM | |
| 16 | MEMs mirror window/no window | Moderate | Likely | Account for windows in budget or develop MEMs without windows | |
| 17 | MEMs mirror lifetime | Major | Likely | Work with MEMs vendors, other AO project | |
| 18 | DM on a tip/tilt stage | Major | Likely | | |
| a | DM incompatible with operation on TT stage | Major | Unlikely | Use a separate TT mirror | |
| b | Problems with DM interface cabling on TT stage | Major | Likely | Address in DM design | |
| c | Insufficient TT rejection | Moderate | Unlikely | Add a second TT mirror | |
| 19 | Switchyard approach: | | | | |
| a | Dichroics. Size and performance. | Major | Likely | (at report we will not have this level of risk). Test coating samples to confirm performance before completing design | |
| b | Performance and reliability of dichroic changers. | Moderate | Unlikely | | |
| 20 | K-mirror. Size, performance. | Moderate | Unlikely | Other architectures for derotation, better | |

| | | | | | |
|---|---|---|---|---|---|
| | | | | coatings | |
| 21 | Achieving real-time control performance requirements | Major | Unlikely | Benchmark tests, simulations anchored to RTC hardware performance, prototype testing | |
| 22 | Fitting system on telescope | Major | Unlikely | Design process will ensure compatible system | |
| 23 | Thermal/mechanical performance of AO system environmental enclosure | Moderate | Unlikely | Careful design, thermal performance modeling including FEA | |
| 24 | Design & cost of interfacing with existing instruments exceeds value of doing so | Unknown | Unlikely | Replace those instruments | |
| 25 | MOAO not demonstrated. | Moderate | Likely | MCAO gives reasonable sky coverage, VILLAGES testing planned. Other testing programs, perhaps on existing Keck AO system. | |
| 26 | Fast LOWFS IR based camera | | | | |
| a | Detector performance | Moderate | Unlikely | Some performance data on hand. Testing continues. | |
| b | Detector availability | Major | Unlikely | Two sources of supply | |
| 27 | Calibration unit with LGS simulators | | | | |
| a | Finding space for it | Major | Unlikely | Will be designed-in from the beginning as an essential capability | |
| b | Achieving required level of performance | Moderate | Unlikely | On-sky calibration can substitute at greater expense | |
| 28 | Rayleigh Laser | | | | |
| a | Complexity of pulse tracker or other range gate method | Unknown | Unlikely | | |
| b | Additional background light | Major | Unlikely | | |

**Table 2: Architecture specific risk for NGAO**

| Ref. # | Description | Impact | Likelihood | Mitigation Plans | System Design Phase Mitigation |
|---|---|---|---|---|---|
| | **candidate 1 split relay** | | | | |
| | Unclear that dNIRI can fit close enough to elevation journal | Major | Likely | | |
| | Unclear if there is enough space for dNIRI & narrow field at same time | Major | Likely | | |
| | Calibration: the non-common path accuracy between the TT location and narrow field science instruments (This is particularly true due to the adoption of rotators over a single k-mirror field de-rotator) | Major | Likely | | |
| | **candidate 2 AO secondary** | | | | |
| | Development of AM2 is costly and uncertain | Major | Likely | | |
| | Actual tip/tilt performance of the AM2 is Unknown | Major | Likely | | |
| | Fitting error for AM2 worse than expected | Major | Likely | | |
| | **candidate 3 large relay** | | | | |
| | Large instrument that needs to be cooled | Major | Likely | | |
| | Unclear if the instrument will fit on the platform | Moderate | Unlikely | | |
| | MCAO option only provides 60” field fully corrected (50% EE) | Moderate | Unlikely | | |
| | MCAO requires 2 DMs, one at ground and one at 5km | Moderate | Unlikely | | |
| | **candidate 4 Keck I upgrade** | | | | |
| | Higher background | Moderate | | | |
| | Parts not designed for Low Temp operation | Major | Likely | | |
| | dNIRI feed hard to fit in front of AO | Moderate | Likely | | |
| | Some of the hardware will be obsolete by the time of NGAO | Moderate | Likely | | |
| | **candidate 5 cascade relay** | | | | |
| | Cannot be packaged | Major | Likely | | |
| | Cannot support interferometer | Moderate | Unlikely | | |
| | High emissivity | Major | Unlikely | | |
| | Complication of woofer-tweeter control | Major | Likely | | |
| | Lower transmission for both the LGS path (loss of laser return) and instruments path (reduced sensitivity, but potentially offset by higher Strehl with less risky architectural approach) | Major | Likely | | |
| | LOWFS away from science instruments, though all are not rotating | Moderate | Likely | | |
| | Potentially more scintillation, static aberrations due to large number of surfaces that need to be controlled | Moderate | Likely | | |