Keck Adaptive Optics Note 720

NGAO Preliminary Design Phase
Risk Evaluation

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Introduction

This note is intended to summarize the significant programmatic and technical risks associated with the NGAO program at the end of the preliminary design phase. This KAON is an update to the system design phase programmatic risk evaluation discussed in KAON 566 and the technical risk evaluation discussed in KAON 510.

1. Methodology

The JPL risk evaluation matrix approach used for the Keck Interferometer was selected to track the significant programmatic and technical risks. This matrix ranks each risk by the consequences and likelihood of the risk occurring. A scale of 1 to 5 is used with higher numbers representing higher risk.

Likelihood of Occurrence:

Level	Definition
5	Very High > 70%, almost certain
4	High >50%, more likely than not
3	Moderate >30%, significant likelihood
2	Low > 1%, unlikely
1	Very Low <1%, very unlikely

Consequence of Occurrence – Programmatic Risks
(replaced JPL's usage of "launch" with "schedule")

Level	Implementation Risk Definition
5	Overrun budget & contingency. Cannot deliver.
4	Consume all contingency, budget or schedule
3	Significant reduction in contingency or schedule slack
2	Small reduction in budget or schedule slack
1	Minimal reduction in budget or schedule slack

Consequence of Occurrence – Technical Risks
(replaced JPL's usage of "mission return" with "science return")**:**

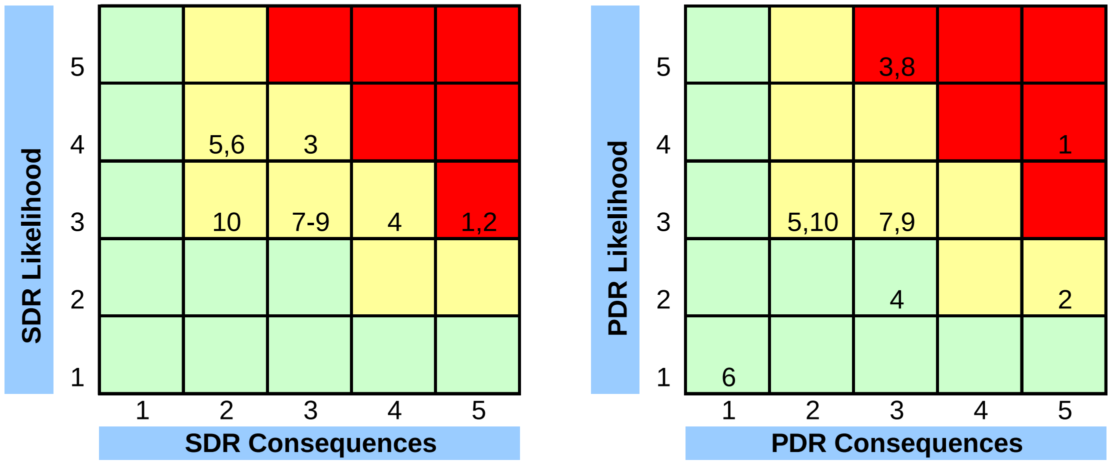
Level	Performance Risk Definition
5	Project Failure
4	Significant reduction in science return
3	Moderate reduction in science return
2	Small reduction in science return
1	Minimal or no impact to science return

The JPL-format risk matrices using these definitions are shown in the next section. In this risk matrix red represents high risks that require implementation of new processes or a change in the baseline plan, yellow represents medium risks that need to be aggressively managed including considering alternative approaches, and green represents relatively low risks that should at least be monitored.

2. Programmatic Risks Identification and Ranking

2.1 Programmatic Risk Matrix

The programmatic risk matrix before and after the PDR are shown in the following Figure. At left is the risk matrix presented at the SDR and the current risk matrix is shown at right.



Overall the three risks associated with funding have increased in likelihood (all are in the red), two risks have decreased in both likelihood and consequence (moving them into the green), two other risks have decreased in likelihood and two risks remain unchanged.

2.2 Significant Programmatic Risks

The following table lists the significant programmatic risks that were identified during the system design in the same order as in KAON 566. No new risks have been identified. Each risk has a unique number, a trend column which has been used for tracking which way the risks are moving, a consequence ranking, a likelihood ranking, a description, the status of the risk and plans for mitigation.

#	Trend	Conse-quence	Like-lihood	Description	PDR Status	PDR Planned Mitigation
1	up	5	4	Significant NGAO funding needed.	No funding currently available for detailed design. Economy in worse shape than at end of SD phase. Seeking advancement funding is a high priority for WMKO. Launch telescope proposal funded. IR tip-tilt sensor & laser proposals submitted.	1) Good project performance, especially in the system and preliminary design phases, will aid the funding search. 2) Support WMKO Advancement Office fundraising efforts. 3) Produce funding proposals.
2	down	5	2	Required lasers unavailable &/or costs too high	Preliminary designs successfully produced by two vendors. ESO has placed contract for 4 lasers. Build-to-cost design requires less laser power.	1) Participate with ESO in laser final design & prototype phases.
3	up	3	5	Challenge of a rapid project ramp-up	Current plans require a rapid ramp up of personnel between the design phase and the full scale development phase.	1) Produce of a viable plan, during the PD phase, for rapid personnel ramp up. 2) Find additional funds early to allow more people to be involved sooner.

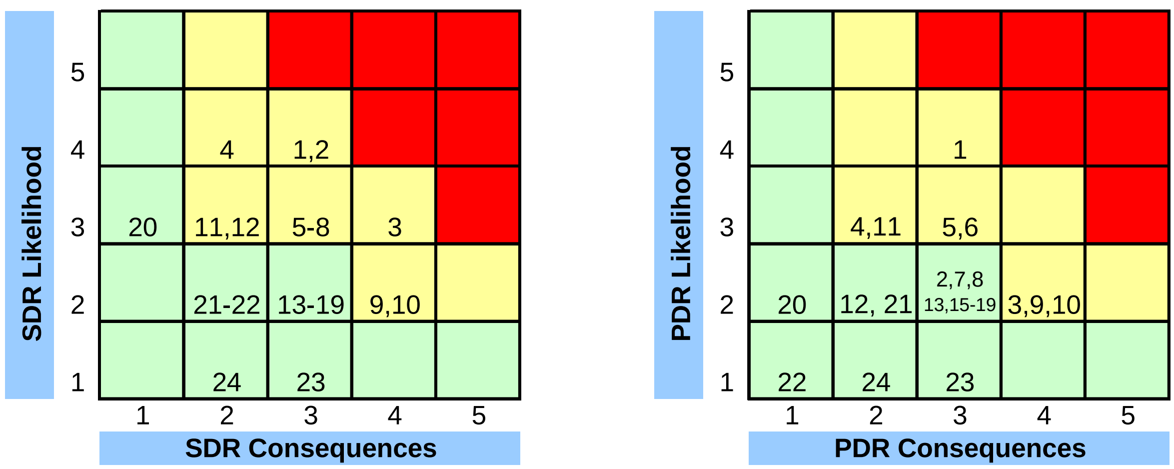
#	Trend	Conse-quence	Like-lihood	Description	PDR Status	PDR Planned Mitigation
4	left & down	3	2	Growth in cost estimate	A preliminary design level cost estimate has been prepared. Build-to-cost exercise reduced system complexity & cost. The costs could potentially grow as the design and costs are further developed during the detailed design phases.	1) Careful monitoring & management of potential cost increases. 2) Employ a design to cost approach during DD.
5	down	2	3	Lack of full-time personnel	During the SD phase only one to two people were working essentially full time on NGAO, with the rest working part-time. This obviously leads to inefficiencies and the overhead associated with keeping more people involved. This improved over the course of the PD phase.	1) Identify further full-time personnel and get them on board as early as possible. 2) Work with existing personnel to transition from other responsibilities in order to focus on NGAO.
6	Left & down	1	1	Committee management structure (Executive Committee)	Committee management structure changed to project manager structure for the PD phase. There is still a senior management committee, which is needed to manage the multi-institutional nature of NGAO.	
7	No change	3	3	Development schedule for Science Instruments is delayed with respect to NGAO	The science instruments for NGAO were to have been under separate management from the NGAO system. The build-to-cost guidelines moved the instrument design under NGAO project management. The instrument design started late during the NGAO PD. The instrument suite has been reduced to a single imager/IFU instrument; the deployable IFS was removed. It will be critical to have at least the NIR camera available for NGAO lab I&T.	1) Observatory needs to obtain funding for the science instruments. 2) Get active engagement of UCLA instrument team during DD.
8	Up	3	5	Schedule impact of funding uncertainty	Funding uncertainty makes it more difficult to attract new people. During the PD phase we were unable to replace some people who left.	1) Identify more funding. 2) Make commitments to a few key people.

9	No change	3	3	External contract schedule slips	Gemini experienced significant slips in their external contracts for MCAO (laser ~ 40 months instead of 16 months; RTC ~ 43 months instead of 22 months). We currently only have scheduled 18 months between completion of the detailed design and the start of lab I&T.	1) Release long lead external contracts during DD phase. This requires planning to have these items reach the appropriate design level early. 2) Plan in contingency time for late contract delivery. 3) Carefully monitor contract progress and respond to schedule issues.
10	No change	2	3	Schedule slip due to personnel availability	Conflicts were encountered during the SD & PD phases (better in PD) with timely access to part-time personnel due to the press of other competing activities.	1) Switch to full time personnel where possible and get them on board. 2) Clearly identify part-time needs and get commitments from the relevant staff and their supervisors.

3. Technical Risks Identification and Ranking

3.1 Technical Risk Matrix

The technical risk matrix before and after the PDR are shown in the following Figure. At left is the risk matrix presented at the SDR and the current risk matrix is shown at right.



Overall there are no risks in the red and the risks in the yellow have decreased from 12 to 8 with two of the remaining yellow risks dropping in likelihood. The simplifications introduced by the build-to-cost redesign and the completion of the preliminary design have both resulted in lowering the technical risks.

3.2 Significant Technical Risks

The following table lists the significant programmatic risks that were identified during the system design in the same order as in KAON 510. No new risks have been identified. Each risk has a unique number, a trend column which has been used for tracking which way the risks are moving, a consequence ranking, a likelihood ranking, a description, the status of the risk and plans for mitigation.

#	Trend	Conse-quence	Like-lihood	Description	PDR Status	DD Planned Mitigation

1	No change	3	4	Inadequate PSF calibration to support precision astrometry, photometry and companion sensitivity science.	Only 1st year of the CfAO funded PSF reconstruction effort occurred; unable to re-hire after Flicker departure. Currently working with Gemini & Groningen to fund Jolissaint to implement PSF reconstruction at Gemini. WMKO obtained a TMT MASS/DIMM & this was successfully implemented using Mauna Kea resources under the leadership of CFHT.	1) Participate in and monitor Jolissaint's effort, including support for PSF reconstruction tests & demonstrations with the existing Keck AO systems. 2) Develop a PSF calibration system-level design and design of the PSF calibration sequences and pipeline.
2	Down	3	2	Inadequate sky coverage to support the wavefront error budget and hence science cases.	HxRG tests at CIT indicate that these detectors should meet our needs. Sky coverage calculations checked by Troy. Risk is a modest reduction in sky coverage.	1) Prototype a near-IR tip/tilt sensor to demonstrate that adequate detectors are available and that the AO correction is adequate (ATI proposal submitted for a K1 tip/tilt sensor) 2) Demonstrate the technique in the lab and/or on-sky.
3	Down	4	2	Required lasers unavailable	PDR-level designs produced by two laser vendors that meet or exceed our requirements.	1) Participate in the laser final design & prototype phases.
4	Down	2	3	Wavefront error budget not achieved due to inadequate assumptions and calculations	Several existing terms of the wavefront error budget have been further developed (e.g. bandwidth error) & new terms have been developed (e.g., TWFS budget, flowdown budgets). We adopted more conservative assumptions (i.e., Na return).	1) Monitor impact of changes during the detailed design phase.
5	No change	3	3	Inadequate tomographic reconstruction accuracy to support the wavefront error budget and hence specific science cases.	Laser tomography of the atmosphere has not yet been demonstrated or used for AO science. Tomography approach in build-to-cost redesign is considerably simpler, but tomographic errors assumed to be smaller. Wind knowledge demonstrated to reduce error at LAO (backup improvement). NGAO will a pathfinder at our required tomography precision.	1) Closely monitor the results of tomography experiments being performed by other groups (Gemini, MMT). 2) Continue to perform lab experiments at the LAO directly in support of NGAO tomography issues.

6	No change	3	3	Astrometry performance requirement not achieved	Astrometry error budget not yet adequately understood. Current understanding summarized in flowdown budget.	1) We will continue to work with the UCLA Galactic Center team and with the CIT proper motions team to understand the limitations imposed by the existing Keck AO system and science instrument. 2) A full error budget will be developed during the detailed design phase.
7	Down	3	2	Tomographic reconstruction computer architecture not yet tested in hardware	Good progress on the preliminary design but hardware not yet tested & complexity reduced by build-to-cost redesign.	1) Monitor the progress of other projects (i.e., P3K). 2) Benchmark on a software simulator. 3) Benchmark on a scaled subset of hardware.
8	Down	3	2	Keck Interferometer needs not met.	Needs & options documented in KAONs 428 and 483. Conceptual design for implementation partially addressed in the optical relay system design report (KAON 549). A complete layout of the interferometer feed and an analysis of the polarization impact needs to be developed next.	1) Complete the detailed design with the interferometer requirements in mind.
9	No change	4	2	Complexity and instability of interactions in the overall software control system	NGAO complexity has been reduced by the build-to-cost redesign. NGAO will still be significantly more complex than the existing Keck AO system with many more potentially interacting control loops and significantly more motion control. We are addressing this issue with significant attention to the final science operations product and utilization of significant operational "lessons learned" experience from the current LGS AO system.	1) Good system-level design with attention to science observing sequences and operations. 2) Employ a hierarchical control structure and test each level comprehensively before integration.
10	No change	4	2	Adequate wavefront sensor CCDs not available	The AODP funded CCDs have made progress, however a CCD and a camera meeting our requirements have not yet been produced.	1) Monitor the progress of the AODP-funded CCID-56 project. 2) Evaluate alternative options (e.g., 240x240 PN-CCD or ESO OCAM approach).

11	No change	2	3	Photometry performance requirement not achieved	Error budget not adequately understood. Current understanding and recommendations summarized in KAON 474.	1) Develop a more complete understanding of this performance budget, which will be closely tied to the quality of PSF determination (listed as a separate risk item).
12	Down	2	2	Inadequate tip/tilt performance for 1st relay DM mounted on a tip/tilt stage	TMT tests by Cilas indicate that the required performance can be met: achieved 500 urad PV with 40 nrad rms noise & > 100Hz bandwidth (at -3dB in closed loop) while supporting 32 kg DM.	1) Monitor GPI woofer on tip-tilt stage performance. 2) Better modeling of the tip/tilt performance during detailed design.
13	No change	3	2	Inadequate performance (measurement error, reliability & observing efficiency) of multiple LGS projection and sensing system.	Systems have been significantly simplified by build-to-cost & preliminary design. Preliminary design of projection & sensing system completed.	1) Consider prototyping one LGS WFS during DD phase.
14	left & down	0	0	No workable design for deployable near-IR integral field spectrograph (d-IFS).	As a result of the build-to-cost re-design there is not d-IFS	
15	No change	3	2	Rayleigh-scattered background on LGS WFS cannot be calibrated out.	A first-order Rayleigh rejection trade study has been performed (KAON 490)	1) Learn from Gemini MCAO experience. 2) Perform additional modeling during detailed design phase.
16	No change	3	2	K-band background requirement not achieved.	Re-evaluated K-band background based on preliminary design --> Now -12.5C seems adequate but continuing to plan for -15C to provide thermal contingency. Enclosure design developed.	1) Develop enclosure detailed design.

17	No change	3	2	Inadequate MEMS performance	Good lab experience, but little on-sky performance data and no on-sky lifetime data yet. GPI MEMS delivered in Feb/10; engineering grade version would be suitable for NGAO. Planning not to use MEMS windows assuming a clean dry environment control during operation, as it eliminates 4 surfaces. Degradation of actuators and coatings a potential issue.	1) Monitor VILLAGES on-sky experiments and LAO lab experience. 2) Determine how to protect MEMS during development (use windows) & during operations without windows.
18	No change	3	2	High and low order DM performance inadequate.	High (tweeter) and low (woofer) order DMs are used for the science instruments & the low order wavefront sensors. The high order DMs are used open loop. Such systems have not yet been demonstrated on-sky. UVic successfully demonstrated closed loop operation in the lab (results published).	1) Need to design servo control. 2) Monitor lab & sky demonstrations. UVic performing slower tip-tilt woofer, faster tweeter experiments. UVic planning closed-loop woofer/open loop tweeter investigations for Raven. GPI woofer/tweeter/RTC integration at LLNL is happening in early/mid-2010. PALM-300 will test a woofer-tweeter servo on sky in ~ Feb 2011. Need to quantify the performance results.
19	No change	3	2	Space command shutdowns	No concrete change in US Space Command requirements. NSF level discussions are happening (an NSF group visited Keck in Feb 2010 to learn about impact). Keck has tools in place for submitting target lists & incorporating blackout periods during observing.	1) Monitor progress of discussions with Space Command.
20	down	1	2	Low mass star companions sensitivity science requirement not achieved.	Requirements relaxed as part of the build-to-cost exercise.	
21	No change	2	2	Science requirements inadequately understood and/or defined.	Some more progress in understanding the requirements. Flowdown of requirements better documented. Observing Operations Concept Document produced.	

22	Down	2	1	Required dichroic performance not achieved	The number of dichroics was significantly reduced during the build-to-cost redesign.	1) Discuss with vendors. 2) Evaluate whether coating tests are valuable.
23	No change	3	1	Impact of telescope vibrations on wavefront error budget higher than predicted.	Parametric oscillator will be part of the vibration mitigation design.	1) Demonstrate parametric oscillator with existing Keck AO. 2) Improve tip/tilt vibration model in the wavefront budget during the detailed design. 3) Reduce tip/tilt vibrations.
24	No change	2	1	LOWFS-based tip/tilt correction for narrow field science instruments inadequate	Tip/tilt errors from the 2nd AO relay or opto-mechanical drifts will not be sensed by the low order wavefront sensors.	1) Evaluate the error budget impact. 2) Measure non-common path tip/tilt on current Keck AO. 3) Design a stable system. 4) Design a metrology system if needed

4. Risk Mitigation Plan

The risk mitigation plan addresses risks that were shown as “red” or “yellow” in the risk matrices. For “green” items is to simply track these risks and look for opportunities to reduce these risks.

4.1 Programmatic Risk Mitigation Plan

There are three “red” programmatic risks all associated with funding uncertainty:
- Significant NGAO funding needed.
- Challenge of a rapid project ramp-up.
- Schedule impact of funding uncertainty.

The “yellow” risks include:
- Required lasers unavailable &/or costs too high.
- Lack of full-time personnel.
- Development schedule for Science Instruments is delayed with respect to NGAO.
- External contract schedule slips.
- Schedule slip due to personnel availability.

4.2 Technical Risk Mitigation Plan

There are no “red” technical risks. The “yellow” risks include:
- Inadequate PSF calibration to support precision astrometry, photometry and companion sensitivity science.
- Required lasers unavailable.
- Wavefront error budget not achieved due to inadequate assumptions and calculations.
- Inadequate tomographic reconstruction accuracy to support the wavefront error budget and hence specific science cases.
- Astrometry performance requirement not achieved.
- Complexity and instability of interactions in the overall software control system.
- Adequate wavefront sensor CCDs not available.
- Photometry performance requirement not achieved.