Keck Near-Infrared Tip-Tilt Sensor System Design Review

Review Committee Report

December 14, 2010 – v3

Prepared by:

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1. INTRODUCTION

1.1 Scope

This document is the report of the review committee established by the Keck Observatory to evaluate the system design of the Near-Infrared Tip-Tilt Sensor to be implemented with the Keck I LGS AO system. The report is based on documentation provided to the panel before the review, and on presentations and discussions given during the review December 7, 2010.

The review panel members were:

- Antonin Bouchez (GMT), abouchez@gmto.org
- Corinne Boyer (TMT), cboyer@tmt.org (Chair)
- Randy Campbell (Keck), randyc@keck.hawaii.edu

1.2 Review documentation

The Near-Infrared Tip-Tilt Sensor System Design Review documentation is available at: http://www.oir.caltech.edu/twiki_oir/bin/view/Keck/NGAO/SystemDesignReviewNIRTTS

The review documentation was made available to the review panel on November 24th, apart from the Systems Engineering Management Plan document, which was provided on November 29, 2010.

The review members provided a list of discrepancies, questions and comments (RIXes) to the Near-Infrared Tip-Tilt Sensor System team by December 2, 2010 using the "SDR Reviewer Question Form". The RIXes were answered by the Near-Infrared Tip-Tilt Sensor System team on December 4, 2010. RIXes and associated answers are also available on the twiki web site linked above.

2. CHARGE TO THE REVIEW PANEL

The panel is asked to determine whether the project meets the success criteria and to make one of the following recommendations:

- The success criteria were completely met and the project is recommended to proceed as planned.
- The success criteria were partially met. The committee recommends that the project complete specific actions identified by the panel before proceeding.
- The success criteria were not adequately met. The committee recommends that the project should undergo a delta review to address the specific areas identified by the panel.

The success of the design is judged by whether the following have been accomplished:

1. The science cases developed for the system are compelling and competitive *(This does not apply to this project and will not be addressed in this report)*,
2. The scientific and technical requirements established for the system are sufficiently complete and consistent, to guide the development of the system,
3. A reasonable design that meets the scientific and technical requirements has been developed,
4. The risks associated with the design concept have been adequately assessed and the mitigation strategies are satisfactory,
5. The management plan, including cost and schedule, to complete the project, with emphasis on the next project phase, is viable and appropriate.

The review panel is requested to provide comments at the conclusion of the review, and a final written report of findings, comments, and recommendations by December 17, 2010.

3. EXECUTIVE SUMMARY

The review panel congratulates the Near-Infrared Tip-Tilt Sensor design team for its excellent work to date in the System Design phase of the Near-Infrared Tip-Tilt Sensor system, for the high quality of the documentation, the answers to comments, questions and concerns posed by the panel and for the excellent presentations during the review.

The team has successfully leveraged the work done for the NGAO Low Order Wavefront Sensor sub-system to develop a Near-Infrared Tip-Tilt Sensor which will be implemented on the Keck I LGS AO system and will provide a dramatic improvement in AO performance, increasing directly the existing Keck I system's scientific return in the near term. This new capability will also directly support the development of the NGAO Low Order Wavefront Sensor sub-system in the longer term.

The review panel believes that the success criteria were completely met and the project is recommended to proceed with the preliminary design. In fact in some areas, we believe that the design is near preliminary design level.

There are some aspects of the design and of the project plan that should be further developed and consolidated during the next phase of the design (preliminary design). These areas are summarized here:

- Expected system performance under the full range of operational conditions including the continued need for visible guide stars
- Component requirements flow down and interfaces
- More reasonable contingency by Preliminary Design Review

The review panel detailed comments are summarized in the following sections organized according to the review panel charge.

3.1 Scientific and Technical Requirements Status

The scientific and technical requirements established for the Near-Infrared Tip-Tilt Sensor system are sufficiently complete and consistent, to guide the development of the system.

There are a few specific areas that the team should further investigate during the preliminary design phase to either help formulate the specification, reduce the risk, or descope to help offset schedule and budget concerns:

- Develop requirement 4: It would be useful to add words to define the measurement precision and accuracy needed for the Tip-Tilt guide star position under various operational conditions.
- The motivations to use simultaneously the Near-Infrared Tip-Tilt Sensor and the existing STRAP system are not convincing. There are still some concerns about additional complexity. We recommend considering descoping this capability.
- Consider descoping requirement 9 (only one Tip-Tilt Guide Star)
- Develop the operation concept document to better define the calibration, acquisition and dithering requirements including the software requirements.

A requirement should be added that the Near-Infrared Tip-Tilt Sensor unit, cryogenics, CCR, coolant, mechanisms, electronics, etc, is serviceable while in position, or that the unit can be removed for service and re-installed without realignment.

The wavefront error budget requirements should flow down into subsystems requirements.

3.2 System Design Status

We are concerned that the Low Bandwidth WFS performance on faint stars might limit the system performance. While the team did consider this issue, models used of the Low Bandwidth WFS performance appear optimistic. We recommend that the Low Bandwidth WFS performance model be validated against Keck's operation experience.

The opto-mechanical design looks sufficiently developed for this stage of the design. The location of the Near-Infrared Tip-Tilt Sensor System has been extensively studied and the proposed solution looks like the best compromise. The proposed design fits the envelope and should not require modifications of other AO elements such as the pupil simulator except for some extension off the AO bench. Particular care should be given to access during the next phase of the design, as well as thermal dissipation and vibration. Furthermore, the team is proposing to study some alternative options to the current optical design to reduce the number of elements, to simplify alignment and hopefully to reduce the cost. Finally, thoughts have been developed on how to align and calibrate the system.

We support the team's effort to make the design consistent with the future addition of a Tip-Tilt mirror. Such an option will reduce the risks associated with operating with under-sampled images.

The requirements for the RTC modifications have been extensively developed and iterated with Microgate. Keck has a very good past experience working with Microgate and the Near Infrared Tip-Tilt Sensor team is very confident that these modifications will be implemented within the required schedule for a fixed priced contract.

The operation of the Near-Infrared Tip-Tilt Sensor in it's various modes, that is acquisition, zoom-in/out-capture, and tip/tilt lock, while synchronized with other units that include the science instrument, the laser, the DM loop, the Low Bandwidth WFS, offloading, etc. needs to be developed during Preliminary Design.

Although the interfaces between the Near-Infrared Tip-Tilt Sensor and the other systems that were listed in the ICD, KAON 836, are developed to an adequate level for a System Design Review, there were a few mistakes in this document that need cleaned up. Also, the interface issues of course will need significant development during Preliminary Design, particularly the cooling issues, high-pressure gas lines, and the possible need for an interface panel installed in K1 AO.

3.3 Risks and Mitigation Strategies

A list of technical and programmatic risks along with some proposed mitigation strategies has been proposed and looks appropriate at this stage of the design. In particular, we endorse the plan to perform laboratory tests of the detector ROI (self heating) and of the RTC interface during the preliminary design phase.

The greatest risk for the committee is the lack of adequate contingency. We understand that the NSF funding fell short of the requested amount by $250k and that some reductions in planned labor and additional contributions by the observatory were made as a result. However, proceeding with an ambitious development project with just 3% contingency does not appear to the committee to be a realistic strategy. We strongly recommend that project management implements in the Preliminary Design phase significant reductions in scope, or seek assurance that the observatory or partners will cover the potential overrun.

The second area of concern is that with the many AO-related development projects currently underway at Keck Observatory, we see a potential for lack of availability of key personnel. This will be particularly acute if the NGAO project is funded.

Finally on the technical side, the use of a low vibration "Cryo-Tiger" cryogenic system to cool the dewar may have implications related to the placement of the compressor. If the gas lines cannot run long enough to get through the telescope wrap, placing the compressor on the telescope structure could prove quite difficult in order to avoid any negative consequences. The risk of this issue should be fully retired during Preliminary Design.

3.4 Management Plan

The proposed development plan and cost estimates for the overall project were found to be reasonable considering Keck and Caltech's experience and the stage of the design.

A Product Breakdown Structure and a Work Breakdown Structure have been defined at a sufficient level of details at this stage of the design.

A detailed resource level schedule has been developed for the preliminary design phase and a detailed schedule has been developed for the remainder of the design, fabrication, assembly and test activities and the telescope Integration and Test phase (except for the activities taking place at Caltech). We note that the preliminary design schedule is tight. (3.5 months). This is particularly a concern considering the potential risk of personnel non-availability as mentioned above. We recommend building some schedule contingency directly in the preliminary design schedule.

Non-labor estimates are well defined for this stage of the design.

As mentioned above, the 3% level contingency is very low and not acceptable. The proposed plan to increase back the contingency to a more acceptable level should be more aggressive and descopes of requirements and or goals should be made.

The organization chart for the project has been revised to deal with key personnel non-availability during the next phase of the project. The PI will also act as the project manager and additional key AO staff will be added to the team for the preliminary design phase. We recommend making sure that the team members are not overcommitted.

Change Control Board Review and other mechanisms to review the proposed changes will be used to upgrade the Keck I AO system and the Keck II RTC system so as not to impact the operations. The AO team has already successfully upgraded the Keck I and Keck II AO systems, so this is not seen as a major risk.

Finally, it was noted during the review that the image quality, sensitivity, field of view, and other qualities of the camera would have significant capability for use as a science instrument. Since it's possible to readout ROI's on a H2RG at a high bandwidth for use in sensing tip/tilt correction while integrating on the rest of the chip (for example WIRCam on CFHT) this option should be considered for a possible upgrade project.

4. APPENDIX: LIST OF REVIEWER TOPICS DISCUSSED DURING THE REVIEW

This section contains the list of topics submitted to the Near-Infrared Tip-Tilt Sensor team on December 6, 2010 by the reviewers. These topics were discussed during the review in great details, thanks to the team.

- Wavefront error budget (Table 1 of KAON 823):
    - Clarify the range of conditions over which the NIR TT Sensor System will fully meet the requirements defined in table 1
    - Derive the sub-systems requirements from table 1
- The motivations to use simultaneously the NIR TT Sensor and the STRAP are not convincing (still concerns about additional complexity) - Recommend considering this option as a possible de-scope.
- Detector plate scale and algorithm
    - Additional simulations to confirm the choice of plate scale and algorithm during next phase
        - *Simulate under a wide range of conditions*
    - How to estimate centroids gain when using multiple guide stars?
        - *Measure the Strehl and have a model*
    - How correlation algorithm works with changing ROIs?
        - *Not a concern, will require to re-calculate the template*
    - *Self heating is another area which is risky but they are trying to address this now in the lab*
- Reconsider the design to better use the NIR TT Sensor system as a pathfinder for NGAO:
    - In particular review the possibility to include a TT mirror and/or a MEMS deformable

mirror

- Review alternatives of the NIR TT Sensor location on the AO bench:
    - Proposed location is small and difficult to access,
    - Not demonstrated that the proposed design fits the envelope,
    - Not clear if alternatives have been considered, for example can the pupil simulator be moved or redesigned to provide more room to the NIR TT Sensor System?
- Low Bandwidth WFS
    - The proposed system does not solve the sky coverage limitations with the LBWFS - Consider solutions to increase sky coverage for this system such as sending all the light to the LBWFS (requires an additional mechanism) - May still be an issue in dust obscure region.
- Acquisition and dithering
    - Not well defined at the moment - Will need to be better defined early in PD phase.
        - *Writing the Operation Concept Document should be one of the first activities of the Preliminary Design Phase*
- Detector performance
    - Concern that the H2RG detector recently procured is not as good as expected: what are the impacts on the system performance?
        - *It would be the best detector at Keck*
- Current contingency of 3% is a concern: Recommend to propose some descope (requirements and/or goals) to save up to 20 - 25% of contingency or be ready to come up with this amount if necessary.
    - Possible descope to be considered: 1 guide star instead of 3 guide stars
- Availability of key people is a concern: People may not be available when needed - Recommend to develop a backup plan
- Project management now performed by Peter W. to solve Observatory staff availability issue. How the effort on NGAO will impact Peter's availability to this project?
- Upgrade of the 3 RTC (K1, K2 and spare) will have to be well coordinated as to not impact observatory operations (in particular K2 system).