KOSMOS Design Review Report

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Executive summary:

The panel would like to thank the KOSMOS team for their efforts and presentations. In general we felt that the project is fundamentally sound and exhibits the good use of funding in following the theme of copying an appropriate instrument in order to upgrade an existing 4-meter facility. We felt that OSMOS was an appropriate instrument to start from and that the team has the necessary experience and skill to complete the modifications required to build an excellent instrument for the Mayall and Blanco telescopes. We felt that most of the systems presented were at a mature level of design, appropriately analyzed and ready for fabrication.

However, one major exception and several moderate to minor exceptions were noted: Specifically, we felt that the optical design for the camera, while promising, was not fully mature and did not meet all of the requirements as specified in the SRD and FPRD (which were not entirely consistent (e.g. requirement vs. goal for R~200-400 mode)). In addition several lesser issues are noted: 1) we felt that while the flexure as measured in OSMOS meets the letter of the requirement as specified in the KOSMOS SRD, it should be possible and well worth the effort of the design team to focus on reducing the flexure; 2) We note that the TORRENT controller, while demonstrated in the lab, is not yet a proven system operating at an observatory. We felt that a final review of this system with at least one qualified external reviewer should be a requirement prior to start of fabrication of the controller; 3) While the ADC issue was presented as "not our kuliana" we are very concerned that the science impact of the existing ADC is not fully understood and may be greater than the 10% quoted in the review (throughput, image quality, and FOV impacts); 4) We are concerned about the vacant Project Scientist position and that this may adversely impact the way in which user needs are communicated to the project.

Response to the specific questions for the review panel:

1. Do any of the design changes adversely affect the ability of KOSMOS to meet the scientific capabilities called for in the ReSTAR report?

Yes. Specifically, we find that the current optical design does not fully meet the requirements in the KOSMOS SRD/FPRD documents.

2. Are any of the design changes likely to lead to problems in fabrication, assembly or integration?

Yes. The optical design is not yet at a sufficiently mature level to support a bid process. Additionally, there are no current ROM estimates to support the current optical fabrication cost and schedule estimates.

3. Are the budget and schedule sufficient to allow the partners to complete the project successfully?

Not sure. We are concerned that the budget and schedule for the camera system (optics plus opto-mechanics) are under-scoped given the change in complexity and the addition of an asphere. We are also concerned that the preferred vendor may no longer be an option for this camera. (The panel suggests the following list of vendors you might want to explore.)

Lightworks (www.lightworks.com), SESO (France), KIWIstar optics, NZ,

Optical Solutions Inc (http://www.opticalsolutionsinc.com/),

Harold Johnson (just for figuring of sphere, no mechanics no aspheres),

ASML (formerly part of Tinsley),

L3-Tinsley (formerly the other part of Tinsley)

4. Are the plans for coordinating work between the partner institutions sufficient to ensure that the work can be completed successfully?

Not sure. The panel was concerned about the lack of project scientist. It appears that this role will primarily fall to Professor Martini, we have some concern about his workload, especially during the critical system integration phase.

5. Are the risks to the project well-understood, and are the plans for controlling or mitigating the risks sufficient to ensure success?

In general **yes**, with the exception of the camera as detailed below.

Findings:

A. Instrument performance analysis

We are concerned that the overall design of the instrument has not been optimized to obtain the most desirable performance on a 4m. For example, it is very likely that users will attempt to obtain higher resolution by using smaller slits; it would make a significantly more powerful instrument to have camera image quality that allows sharp imaging of a <0.5 arcsec slit. Evidence from WIYN suggests the native seeing at Kitt Peak site may be better than that currently delivered by the Mayall telescope. It would be useful to design the instrument to be capable of using the best native seeing as dome and telescope upgrades are implemented in the future. Moreover if the goal is to put a copy of the KOSMOS instrument on the Blanco telescope at CTIO (COSMOS), then the final optical design should not compromise the best seeing conditions at the best site (which we suspect may be CTIO, rather than KPNO).

B. Camera and Collimator Optical design

A fundamental concern is that the optical design does not meet the spectroscopic resolution or image quality requirements as specified in the FPRD. The final optical design should be described in a report and presentation, which provide sufficient explanation to convince the instrument team and reviewers that the full range of glass choices, surface shapes, and element groupings has been thoroughly considered.

Additional suggestions regarding finalizing the optical design:

- It will typically reduce the optical elements by a significant fraction in diameter, weight, and volume if the design vignettes the outer 5% of rays. This is generally a good compromise in terms of both optical and mechanical performance of the instrument. We recommend that some vignetting be allowed here.

- It would be useful to understand the system throughput based on material transmission, AR coatings, dispersion elements, and the ADC. A plot of such as a function of wavelength may provide important information for the final optimization in terms of dispersion choices and optical materials.

- Lens materials should be selected to minimize the curvature of the strongest elements, to reduce opto-mechanical risk, improve optical and mechanical performance, and the security/longevity of the bonded multiplets. (Glass choices in all elements, not just the specific element in question, will influence the strength of these curvatures.)

- We recommend consideration of modifications to the collimator optical design to improve overall optical performance.

- Please clarify the impacts and implications of the under-sized ADC for observing strategies.

- Only peak efficiencies were presented. Please clarify the system efficiency, including telescope and ADC, as a function of wavelength. Are there efficiency requirements from the FPRD, and are they clearly met by the design?

C. Detector Controller

This review committee does not include any electrical engineers, and so are we unable to fully judge the design maturity of the Torrent detector control system. During the review, it was stated that prototype systems are operating in the northern and southern observatories, but no Torrent system is currently operating on a working instrument. An NOAO internal review of the Torrent system was mentioned. We strongly recommend that the Torrent review include external members with sufficient detector controller experience to properly assess the controller design. Possible external reviewer candidates include Greg Bredthauer (greg.bredthauer@sta-inc.net) and Greg Burley (greg.burley@gmail.com)

E. Project Scientist

The committee is concerned that the project scientist position has been vacant for some time, and no plans for finding a replacement were mentioned. We are concerned that the current management structure may not be adequately considering users needs in the design choices that will significantly impact the operation and utility of the instrument.

F. Flexure

The panel was concerned that the flexure performance of OSMOS is less than optimal given the increased performance requirements associated with going to a larger telescope. We feel that this, coupled with the desire to build two systems, may be a larger issue than the efficiency of observation as stated in the review, in that reducing the flexure may obviate the need for additional nightly calibration, and the associated need to upgrade at least one calibration system to cover the full FOV.

We recommend that the team develop an optical model of instrument flexure of the key elements (slit, collimator, camera, and detector) and their relative motion based on the FEA model of the enclosure and stage/mechanism flexure to better understand the source of the image motion. This model can be utilized to drive the design towards a better performing system.

- We encourage the early procurement and testing of a stiffer precision grade stage for the camera.
- We recommend considering the removal of the collimator focus stage and replacement with a more direct and stiffer attachment to the optical bench.
- We recommend that the KOSMOS team seriously consider flexure testing at the NOAO facilities in Tucson, prior to shipping the instrument to Kitt Peak. Any flexure issues discovered in this process will be far easier to diagnose and repair in the lab, than on the telescope.

G: Requirements

The instrument does not appear to meet the basic spectrograph resolution requirements. As per SRD requirement:

***** START OF QUOTED SRD TEXT ******

· *Maximum resolution*. The maximum resolution with a 1 arcsec slit should be at least R=2300, with a goal of at least R=4000. Higher resolutions should be achievable with a 2-pixel slit (reqs. 1-2 need this). **This requirement, as well as the goal, is met by the current design.**

• *Low resolution mode*. A low-resolution mode (R~200-400) should be available, ideally one that covers the full wavelength range of the instrument (planetary science in req. 1). **The design solution in OSMOS (triple prism) probably will not meet this requirement if the camera is redesigned. Alternate approaches will need to be explored.**

******* END OF QUOTED SRD TEXT *******

We note that the SRD and FPRD are not consistent in that the SRD requires a low resolution mode and the FPRD lists it as a goal. We believe that the low resolution mode should be maintained as a requirement.

Slide 23, KOSMOS_Optical_Design.pdf:
The R=400 GRISM disperses light into the both the 1st and 2nd orders, requiring a cross-disperser and co-adding of the spectra. A design for the GRISM with cross-dispersion was not presented.

Slide 24, KOSMOS_Optical_Design.pdf:
States that R=2300 can be achieved with a 2 pixel slit. The requirement is that R=2300 be acheived with a 1 arcsec slit. A 2 pixel slit (0.6") should achieve higher resolutions (goal of R=4000). Does the camera image quality enable resolution of a 0.6" slit? We disagree with the statement in the SRD that the requirement and goal are met by the KOSMOS design as presented.

It would be useful to present actual achievable resolution plots as a function of wavelength for different slit widths. The plots should have the design image quality, with random fabrication and assembly errors (at the level prescribed by the assembly plan) convolved with a square slit function. Resolution can then be quoted at some reasonable criterion such as the Rayleigh limit.

H. Cost Estimating and Contingency

The overall contingency of ~15% may be appropriate for an exact copy of the OSMOS design. However, the uncertainty in the optical design and the changes in the camera, especially the larger lenses (the second triplet in the camera is 25 mm larger in diameter than the OSMOS camera) and aspheric surface lead us to conclude that additional contingency should be included in the estimate. We note that budgetary quotations have not been solicited for the updated camera design.

A possible cost savings may result from the procurement of both sets of KOSMOS and COSMOS optics at the same time. Since the COSMOS optics are not required until a later date there is an opportunity to use the second set of optics as a backup in case of damage to the first set.

We note that the cost and schedule assumptions were based on the vendor having a QED polishing machine and SSI (sub-aperture stitching interferometer) to fabricate the aspheric optical surface. We also note that the team wishes to procure complete tested lens barrel systems. We agree with this approach but note that it severely limits the potential vendors, which may increase the cost and cost uncertainty.

The mechanical components are low cost and schedule risk since they are either exact copies of OSMOS designs or minor modifications. The method of prioritizing the design and fabrication of mechanical parts is sound.

Similarly, the electronics design is nearly identical to OSMOS and is of low cost risk.

I. Requirements Documentation

We recommend a review of the SRD versus FPRD for consistency, and to specify which document takes precedence, and verify that the instrument design meets the key performance requirements.

We recommend development of a formal compliance matrix of expected system performance versus requirements.

Recommendations:

1. Revisit the current optical design, include the existing ADCs (north and south), and analyze the system performance implications with regard to a consistent SRD and FPRD for revising the collimator, disperser, and camera optical designs to balance cost and performance under the best seeing conditions at the best site (CTIO vs. KPNO). Formally review the final optical design prior to starting the purchasing process.

2. We endorse the existing plan to review the Torrent CCD controller system design, and recommend that the review panel include 2-3 external members with appropriate controller knowledge and background.

3. We recommend that a Project Scientist be added to the project team as soon as possible, and that the PS participate actively in the execution of (1) and (2) above.

4. Fully analyze the flexure requirements and the performance implications of the known OSMOS flexural image motion for both the northern and southern observatories. Review (and improve if necessary) the KOSMOS/COSMOS instrument flexure performance.

5. Solicit updated budgetary quotations for optical fabrication. Consider whether there is sufficient contingency allocated for optical fabrication.