

Spartan IR Camera

Report of the Preliminary Design Review Panel
to the SOAR Consortium and the Spartan Instrument Team

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Executive Summary: *This report summarizes the results of the PDR for the Spartan IR Camera. The review panel was firmly in favor of constructing Spartan. To ensure success in this endeavor they recommended (a) expansion of the project team through the addition of a full time mechanical engineer; and (b) restriction of the project scope by initially building and deploying the scaled back version of the instrument, while preserving the option of restoring the deferred capabilities through a future upgrade. The panel was concerned that the program plan lacked the level of detail necessary to support accurate estimation of project costs and believed that the level of effort had been underestimated at least in the area of mechanical design and fabrication. It was suggested that the PI should work with N. Gaughan to develop the preliminary program plan to a sufficient level of detail to permit more reliable cost estimation. The panel also made specific recommendations with regard to various details of the design.*

1 Introduction

The preliminary Design Review for the Spartan IR Camera took place at Michigan State University on 22nd and 23rd May 2001. The review was based on detailed written materials distributed in advance of the meeting, a summary presentation made by the PI, Dr. Ed Loh, and discussion with Dr. Loh and other members of the project team and MSU faculty. The various review materials are available in electronic form at the URL <http://www.soartelescope.org/sac/IRImagerDesignReview>.

In light of uncertainties regarding the funding for Spartan, the review panel was also asked to evaluate a “proof of concept study” for an alternate fall back instrument, INPI. This was derived by modifying the optical design for ISPI, an instrument under construction at CTIO, in such a way as to meet SOAR’s core requirements while minimizing changes to the mechanical design. Again the review was based on written material circulated in advance and a presentation made by Dr. Ron Probst, PI for ISPI. These various documents are available from the above URL.

This report summarizes the findings and recommendations of the review panel for reference by the instrument team and SOAR consortium.

2 Should Build Spartan

Overall the review panel was favorably impressed by Spartan and had no hesitation in declaring it to be the correct instrument for SOAR. The instrument concept was felt to be very good and considerable thought and effort had evidently gone into its development. The full up version of the instrument meets or exceeds all the science requirements

specified by the SOAR SAC, and even in descoped form the instrument satisfies all the key A-level specifications. The ability to install a mosaic of four detectors as a future upgrade was viewed as a powerful selling point since it would allow the instrument to remain competitive for several years. The possibility that the engineering array was good enough to contemplate initial deployment with two detectors was seen as a very big plus.

Conversely the panel was not at all enthusiastic about INPI. This is in no way a criticism of ISPI, the instrument on which it is based, nor is it a reflection on the thought and effort that went into preparing the INPI concept sketch. Rather it demonstrates the impossibility of fitting a quart into a pint pot. The design of INPI was driven by two conflicting requirements: (a) to increase the focal length of the camera in order to achieve the correct scale; while (b) keeping the physical length short enough to allow re-use of the same basic mechanical design. This resulted in an optical system that gave images poorer than those of Spartan on axis and which degraded rapidly toward the edge of the field. Even increasing the length to the maximum allowed by the SOAR space envelope, which would at a minimum require a new structural analysis, still resulted in poorer image quality, over a smaller field, compared to Spartan. Together with the poorer transmission of the refractive optics this translates directly into a significant loss of observing efficiency. Thus INPI would be a greatly inferior instrument, without any scope for future upgrades, and with an only marginally lower (although more accurately known) price tag. An important additional consideration was the absence of a strong advocate for INPI; instruments are rarely successful lacking a passionate personal and scientific commitment on the part of their builder.

Panel Recommendation: The panel recommends that a decision on whether to proceed with Spartan, backed by a solid funding commitment, should be taken immediately. The panel firmly believes that this decision should be affirmative. Further delay in funding the project will directly impact the delivery schedule, while the continuing uncertainty is clearly having an adverse effect on the morale of the instrument team.

3 Should Build Descoped Instrument

The instrument team presented a descope option as a means to reduce the cost of the instrument in case of a funding shortfall and/or increase the contingency in case of a cost overrun. The measures envisaged were (a) implementation of only a single plate scale; (b) omission of the capability for grism spectroscopy; and (c) the purchase of a more limited set of filters. The first of these steps constitutes a substantial simplification of the instrument, reducing the number of mechanisms that must be designed and built from seven (two of which are very challenging) to only one (a straight forward filter wheel). The second two steps merely postpone capital outlay. Any or all of the items eliminated could be restored at a later date.

For several reasons the review panel felt that, rather than regarding the descope as a fallback position, the wisest course would be to take an incremental approach. First build the descoped instrument and deploy it at the telescope, and only then proceed to add the omitted capabilities through a series of upgrades. The full-up instrument was thought to be too ambitious given the resources available and the relative inexperience of the

instrument team. A phased development approach would minimize risk and allow the instrument team to hone its skills on a more modest problem before tackling the more challenging mechanisms. It also best addresses the scientific imperative of getting an IR imager, optimized to exploit SOAR's capabilities, installed and operational as soon as possible after first light. The demonstrated success of the descoped instrument would surely make it much easier to obtain the additional funding needed to add capability in the future. Even experienced instrument groups, such as that at OSU, prefer to build instruments in such an incremental fashion, using success of a basic, but adaptable, initial product to leverage funding for subsequent upgrades.

As discussed below the panel was concerned that the project team is under staffed and that the mechanical engineering and design effort required to build Spartan have been significantly underestimated. They were thus of the opinion that any savings realized by taking the descope option should be directed toward expansion of the mechanical engineering capability of the team in order to ensure the success of the project.

That said, the panel firmly believed that the additional capabilities provided by the full-up instrument do add enormous scientific value. Therefore every effort should be taken during the design process to retain the option to carry out the upgrade in the future. This is primarily an issue with regard to the second scale. It is imperative that installation of the additional optics and associated mechanisms should be possible without the need to re-machine the cryogenic optical bench or enclosure. This requires that the preliminary design for the full up configuration be completed to the level of detail needed to fully define the mounting interfaces and establish the space envelopes for all of the additional components. The cryogenic optics box should then be fabricated with all the features needed to mount the additional hardware.

Panel recommendation: Spartan should be built incrementally. The descoped version of Spartan (only one scale, no gratings or slit masks, restricted filter compliment) should be built and deployed at the telescope. The deferred capabilities should then be added as upgrades once success of the basic instrument has been demonstrated. However, this phased approach requires that the optics box should be designed and built to include all the necessary mounting fixtures required for installation of the additional hardware.

4 Instrument Team is critically understaffed

The Spartan team consists of: Dr. Ed Loh (PI); a full time technician, Jason Biel (electronics design and testing); a graduate student, Mike Davis, working about half time (Optical design); a high school student, Owen Loh (FEA analysis and drafting), who works 5-10 hours a week on a volunteer basis; and Tom Palazzolo head of the departmental machine shop.

The review panel was extremely impressed by how much this small team has been able to achieve, as evidenced by the effort that had clearly gone into many aspects of the design. However, the panel felt very strongly that the instrument team was critically understaffed.

For comparison other university instrument groups (e.g. OSU, U. Florida, IFA, Boston U., and UCLA) employ teams with two to four dedicated engineers to build instruments of this scale. Certainly if MSU is serious about playing a future role in the development of astronomical instrumentation they need to substantially expand the professional engineering staff dedicated to this effort.

The situation is especially critical in the case of Dr. Loh who is heavily oversubscribed. He is acting as PI, project manager, systems engineer, mechanical engineer and electronics engineer. Yet he still has a normal teaching load. No single individual, however talented and conscientious, can successfully keep so many balls in the air at the same time. The panel therefore felt that it was essential to reduce the scope of Dr Loh's job offloading several of these tasks onto an expanded instrument team.

The panel understood and fully endorsed the educational motivation for having graduate students play a significant role in instrumentation projects such as Spartan. They were also impressed by the important contribution to the project that had been made by Davis. However, they felt that the project currently relied too heavily on graduate student manpower.

The need to strengthen the instrument team is most pressing in the area of mechanical engineering. This is both the area where, on its own admission, the team now has the least experience, and where the design is least well developed.

Panel Recommendation: The panel categorically recommends that a full time mechanical engineer, with several years of experience in the design and fabrication of cryogenic opto-mechanical systems be added to the project team as soon as possible. The ideal candidate would also be familiar with the use of formal project management techniques. Adding a full time designer/draftsman to the team is also highly desirable.

5 Need for a detailed Program Plan and Costing

The panel was very concerned that, based on the documents presented, the program plan had not been developed to the level of detail required. The panel was thus unable to assess the accuracy or care with which the work estimates had been made. However in some cases noted below the panel felt the resource requirements were clearly underestimated based on experience with projects of similar size and complexity. The panel were thus of the view that the scope of the work was only mapped at a preliminary level, and that the cost estimate was therefore prone to significant error.

Panel Recommendation: The panel recommended that a detailed program plan and costing for the descoped instrument should be developed as a matter of urgency. As a first step in this process it was suggested that Dr Loh visit Neil Gaughan in Tucson for several days to a week. This would permit the preparation of a preliminary program plan based on the current instrument concept at a level of detail sufficient to make a good first

estimate of the level of effort and cost. This would also serve as the basis for the development of a full program plan once the preliminary design is complete.

6 Mechanical Design

The panel judged the mechanical design to be in a much more preliminary state than the rest of the project. This is in no sense a reflection on the effort put in by the project team, but rather is a symptom of the lack of a full time mechanical engineer. Developing the mechanical concept to preliminary design level should be a priority for the new mechanical engineer.

The panel felt that the scale of the effort for both mechanical design and fabrication had been significantly underestimated. Based on experience with projects of similar size and complexity the panel estimated that the mechanical project would require 3 man years of design and drafting and that 50-100 detailed fabrication drawings would be needed to fully define the instrument.

7 Use of warm mechanisms

A specific weakness of the mechanical concept was the proposed use of warm mechanisms. The unanimous opinion of the panel was that these would cause severe problems of emission inside the dewar. It was felt that solving these problems would likely prove harder than designing appropriate cryogenic mechanisms. The panel cautioned that proper control of emission and stray light is often one of the most challenging aspects in the design of IR instrumentation. For the simpler, commonplace mechanisms, such as the filter wheels, existing designs from other groups could be adapted, or suitable commercial mechanisms were available. It was suggested that visits by Dr Loh and or the new engineer to established IR instrumentation groups would be a very cost effective way of obtaining valuable advice and learning about existing designs that could be copied or adapted.

Panel recommendation: The panel felt that the use of cryogenic mechanisms was mandatory. It was suggested that during his visit to Tucson Dr. Loh should visit IR labs both a source of commercial filter wheels, and a possible contractor for cost effective custom design of cryogenic mechanisms.

8 Optical Design

The panel judged the optical design to be sound, and elegant in its simplicity and to have been carried out to an appropriate level of detail. They felt that it should deliver the expected diffraction limited imaging performance.

Panel Recommendations:

- As a matter of prudence and good engineering practice it was recommended that an independent optical designer be asked to check the optical design before proceeding to procurement.
- New bids should be obtained for the optical fabrication. It was thought that the present bids were too high, possibly because an overly stringent requirement had been set on surface roughness. A global criterion for the entire surface was used, whereas it is the local roughness on scales comparable to the point source beam that needs to be controlled. Discussion with prospective manufacturers would establish how the specification should be set and might well result in a substantial reduction in the cost of the optics without loss of performance.
- The proposed warm alignment procedure should be re-examined. This procedure relies on the measurement of small changes in the brightness of a grid of calibration spots made at successive alignment steps. Although the procedure had been simulated, the panel was concerned that measurement errors and other real world effects had not been adequately allowed for and that these might seriously compromise the accuracy of the procedure. It was suggested that an alternative more conventional method employing a combination of mechanical measurement and bore sighting should be evaluated.

9 Electronic Design

Barry Starr was unable to attend the review meeting, but reviewed the written material on the electronic design. His detailed comments sent directly to Dr Loh are appended to this report. In general the design was found to be sound and well thought out with careful attention paid to a number of key parameters.

One specific area of concern involved the use of flex cables for the interconnection between the electronics in the dewar and the camera card. Starr himself has had considerable success with the use of single layer flex cables for similar applications and unreservedly supports this approach. However, the Spartan design calls for a three layer flex cable to improve shielding and reduce cross talk. Other groups who have used multi-layer flex cables have experienced problems with delamination of the cable on repeated thermal cycling with consequent issues of long term unreliability.

Recommendation: In the interests of ruggedness and reliability a single layer flex cable design should be evaluated to see whether adequate shielding and sufficiently low cross talk could be achieved.

10 Software Design

The instrument team plans to adapt the ArcView software being developed by SOAR for control of Spartan. ArcView is being successfully used at CTIO to control IR arrays as well as optical CCD's but using the SDSU-II detector controller. The ability to easily adapt ArcView to work with different controllers was a major design driver for that software and Commercial LabView drivers exist for the computer interface board specified for Spartan. Similarly every effort would be made to obtain mechanism controllers for which LabView drivers existed. Thus, in principle, this should be a

straightforward task. However, due to late delivery of the ArcView software by the contractor, the Spartan team had only just received the beta release of the code for evaluation. It was consequently too early to accurately assess the level of effort that would really be required.

In general the panel regarded this as a very sound approach that will lead to a considerable reduction in the software development effort by maximizing the use of existing commercial code. Achieving commonality with the rest of the SOAR software system was, in any case, a very laudable goal since it would greatly simplify use of the instrument by observers and operation and maintenance by the observatory staff. The panel was encouraged to learn that it might be possible to add a university staff member with considerable LabView experience to the project team. Nonetheless, considering the over subscription of the team in other areas it was felt prudent to out contract as much of the software effort as possible.

Panel Recommendation: The panel strongly recommends contracting with Mike Ashe of Imagenatics, the developer of the ArcView code to adapt and extend that software for use with Spartan. This was likely to be highly cost effective, would minimize risk, and would ensure a seamless integration of Spartan into the SOAR software system. Conversely it was thought that the motor control software could be written by any good LabView programmer and hence could be done in house or contracted out as convenient.

11 Assembly & Integration

The panel felt that the level of effort and time that would be needed for assembly and integration of the instrument had been very significantly underestimated. This should be re-examined during the process of developing the detailed project plan. Some specific items requiring attention were:

- A detailed test plan should be developed covering both integration of the instrument at MSU prior to shipping to SOAR and commissioning activities to be carried out at the telescope.
- As already noted the warm alignment strategy for the optics should be re-evaluated.
- Extensive flexure tests should be carried out both to detect potential problems prior to delivery, and to serve as a starting point for the pointing model to be used with the instrument.