SPARTAN IR CAMERA FOR THE SOAR TELESCOPE

Response to the Preliminary Design Review

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This document describes our response to the recommendations of the preliminary design review. The panel, Don Figer, Neil Gaughan, Steve Heathcote, Tom O'Brien, and Barry Starr, met 22–23 May 2001, and the submitted "Spartan IR Camera, Report of the Preliminary Design Review Panel to the SOAR Consortium and the Spartan Instrument Team" on 13 August 2001.

The instrument team has developed a program plan and modified several designs as suggested by the review. These are described here.

1 Should Build Spartan (§2 of Panel Report)

We *are* building Spartan.

2 Need for Detailed Program Plan and Costing (§5 of Panel Report)

Neil Gaughan and I developed a program plan during the period 6–10 August in Tucson. The program plan runs from 1 September 2001 to delivery of the instrument in June 2003.

A preliminary WBS is shown in Table 1. This is a first pass; it will certainly change. Project management (WBS 1.1) includes management, meetings, reviews, reports, and fixed labor costs for Loh, Biel, and Davis. System engineering (WBS 1.2) includes analysis, writing plans, writing requirements, concept designs, and writing software requirements. Mechanical (WBS 1.3) includes the cryogenic optical box, vacuum enclosure, filter wheels, mirrors and mounts, mirrors and mounts for the second channel, and a mask wheel. Electronics (WBS 1.4) includes the detector assembly and electronics. Software (WBS 1.5) is to modify ArcView and to write scripts. The cost estimate is that of producing ArcView and is therefore probably an overestimate. Integration (WBS 1.6) includes the telescope simulator and integration. Deliverables (WBS 1.7) includes manuals, the acceptance tests, packing & shipping, and documentation. Procurements (WBS 1.8) includes an instrument computer, software licenses, and a dust-free hood. Preplan spending (WBS 1.9) is money spent before 1 September 2001; the major item here is the detector for $250k.

The category "hourly labor" is that which is charged by the hour and includes mechanical design, drafting, and the mechanical shop. "All labor" means the expenditure of hourly labor, fixed-cost labor, and labor that is cost-free.

The budget for the remainder of the descoped instrument is $513k. To restore the second focal ratio, grism spectroscopy, and coronagraphy requires $166k. With $416k already spent, the total budget is $1,095k.

Table 1 Preliminary WBS

WBS	**Item**	**All Labor hrs**	**Hourly Labor k$**	**Purchased Parts k$**	**Total k$**
1	Total	8720	115.2	437.1	1095.0
1.1	Project management	1560	0.0	0.0	126.7
1.2	System engineering	556	0.0	0.0	0.0
1.3	Mechanical & optics	4152	101.0	363.7	464.7
1.4	Electronics	920	6.6	25.9	32.5
1.5	Software	104	0.0	25.0	25.0
1.6	Integration	904	4.8	0.5	5.3
1.7	Deliverables	424	2.8	1.0	3.8
1.8	Procurement	100	0.0	21.0	21.0
1.9	Preplan spending				416.0

Notes

1 Fixed-cost labor is included in project management

There is a 3-month contingency during which problems may be fixed. The labor estimates are conservative and therefore include contingency. The contingency for purchased parts without a vendor quote is 17% ($45k contingency for $267k).

3 Should Build Descoped Instrument (§3 of Panel Report)

As the panel points out, designing the full instrument is necessary to avoid machining the cryogenic optical box during installation of the upgrades. The descope is to stop after design and before fabrication and purchase of parts.

The program plan and budget show both the full and descoped instrument. The descoped items can be fabricated and purchased within the schedule if a decision is made by February 2002.

4 Instrument Team is Critically Understaffed (§4 of Panel Report)

4.1 Mechanical Design

The most critical need is for mechanical designers, and we have several options.

We have hired Dave Keesaer, the mold design supervisor at M C Molds in Williamston, MI as a part-time 3-dimensional designer. Dave designs blow molds with the software SolidWorks. (NOAO uses SolidWorks and recommends it highly.) As a test project, Dave designed the nitrogen can. That was done well and in a very short time.

We can hire Bill Palazzolo, Dave's assistant at M C Molds, to do 2-dimensional drawings.

We have advertised for a mechanical engineer. The engineer must be able to produce work without a customary 3-month learning period, because the schedule is tight. There is about a year of work for mechanical design. We must find a job within the department or university after about a year for the engineer.

NOAO is beginning to wind down the GNIRS project. We may be able to hire or contract for a designer from the GNIRS staff.

4.2 Loh's Workload

In the project plan, the 8-month period starting September 2001 is critical, and there are heavy demands on Loh's time. During the 14-week Fall semester, Loh has 9 weeks of work. In addition, he planned to teach two courses. Gene Capriotti has generously agreed to teach one of the courses.

5 Mechanical Design (§6 of Panel Report)

Constructing the project plan with Neil Gaughan has sharpened the estimate for mechanical design. About 8 months of design and drafting are needed. The estimate is a factor of 3 lower than the panel's because the design concept is simple and Loh failed to communicate that to the panel.

Table 2 Estimates for mechanical design.

WBS	Item	Designer (hr)	Drafting (hr)	Drawings
1	Total	552	736	83
1.3.1	Cryo optical box	144	184	23
1.3.2	Vacuum enclosure	40	100	12
1.3.3	Filter wheels	80	200	16
1.3.4	Mirrors & mounts	24	8	2
1.3.5	Mirrors & mounts for 2nd channel	120	80	8
1.3.6	Mask wheel	60	40	4
1.4.1	Detector assembly	44	44	6
1.6.1	Telescope simulator	40	80	12

6 Use of Warm Mechanisms (§7 of Panel Report)

We will use a single type of cryogenic rotational stages for all mechanisms.

We revisited the idea of purchasing cryogenic rotation stages from Phytron of Waltham, MA. We had rejected their cryogenic stages and instead used their stages at room temperature, because they will guarantee operation but not specifications at 77K.

The tightest specification, the spring constant k_θ for tilt in response to a torque, is needed to maintain boresight alignment with the tip-tilt sensor. The revised requirement for boresight is 0.5μrad in the sky to match the requirement of the Instrument Support Box (ISB). The requirement is a factor of 100 times looser than the specification for Phytron DT–90 rotational stages at room temperature, which is k_θ=2μrad/(N-m).

We investigated the spring constant for contact bearings using the reference Brändlein, J., Eschmann, P., Hasbargen, L., & Weigand, K., 1999, *Ball and Roller Bearings*, 3rd ed., Wiley, New York. We are convinced that a spring constant of 2μrad/(N-m) is possible with proper design to hold the bearing at cryogenic temperature. Without detailed information from the bearing vendor, we are not able to insure that the design will achieve it. We are convinced that a specification looser by a factor of 100 is easy to achieve.

The plan is to purchase one rotational stage (for $15.5k plus $6k of nonrecurring engineering) and to measure the spring constant. The stage will surely work for the filter wheel, since the requirements are looser. If the spring constant is sufficient for the mirror insertion mechanisms, we will use these stages for all of the mechanisms.

7 Optical Design (§8 of Panel Report)

7.1 That an independent optical designer check the design

We will do that.

7.2 New bids for optical fabrication

We have contacted Hampton Controls of Pittsburgh and REOSC of Paris.

We discussed with SORL of Waltham, MA whether specifying the surface roughness over 1/3–1/2 of the diameter (rather than the entire surface) would reduce cost. The cost would be the same.

7.3 Warm alignment procedure should be re-examined

The required photometric accuracy, ½%, of the warm alignment procedure can be achieved with 40,000 photoelectrons (A single picture suffices.), but systematic errors are the concern.

A concern was expressed about the stability requirements. The alignment procedure is equivalent to measuring the Strehl ratio across the field of the instrument, and this means comparing the amount of light in the diffraction spike of a point source with the total. Therefore information is contained in a single picture: no comparisons across pictures are needed, and the light source does not need to be stable. A defocused picture will be needed to calibrate detector nonuniformities

The revised plan is to use two multiplexers, which sense visible light, rather than a small CCD. A CCD has to be moved to cover the field, and it requires construction of a special jig. (This is Don Figer’s idea.) Two multiplexers cover half of the full field, and we demonstrated that that is sufficient for alignment.

We are also exploring the use of a measuring machine to position the optics precisely. The telescope simulator would then be used to test the image quality, pupil location, and flexure and not used for alignment. We have found that this is possible but expensive ($60k).

8 Electronic Design (§9 of Panel Report)

The flex cable has been changed to two layers from 3 layers to avoid possible separation of the lamination. The polyamide material is manufactured with copper on both sides or on one side. A three-layer flex board requires gluing a two-layer board to a one-layer board. The glue is the point of failure. Without shielding on both sides, there is a risk that the shielding will be insufficient, but we judge the risk of loss of vacuum with delamination to be more serious. We can shield the electronics in a Faraday cage, if necessary.

9 Software Design (§10 of Panel Report)

We plan to contract software either to Imaginatics or to an MSU in-house Labview expert in the Chemistry Department.

10 Assemble and Integration (§11 of Panel Report)

The program plan includes time for assembly, test and integration. (See Table 3.) Each assembly is tested by itself. Integration takes 6 months.

We will write test plans for each assembly.

We will write an acceptance test and commissioning plan and submit these to the SOAR Director.

Flexure tests will be performed with the telescope simulator.

Table 3 Labor for assembly, test, & integration.

WBS	**Item**		**Labor (hr)**
1.0	Total		1634
1.3.1	Cryogenic optical box		120
	Assemble box	40	
	Thermal test	80	
1.3.2	Vacuum enclosure		40
	Test vacuum	40	
1.3.3	Filter wheels		166
	Assembly	80	
	Warm test	16	
	Cold test	40	
	Final test	30	
1.3.4	Mirrors & mounts		72
	Installation	32	
	Measure & set angles	40	
1.3.5	Mirrors & mounts for 2nd channel		120
	Assembly	60	
	Test	60	
1.3.6	Mask wheel		100
	Assembly	40	
	Warm & cold tests	60	
1.4.1	Detector assembly		432
	Assemble prototype in test dewar	24	
	Thermal test in test dewar	40	
	Test multiplexer, warm	40	
	Test multiplexer, cold	20	
	Install engineering-grade detector	40	
	Optical test of engineering grade detector	100	
	Test J-band detection of stars	40	
	Rework	120	
	Assemble final detector assembly	8	
1.6.1	Telescope simulator		64
	Assembly	24	
	Test & characterize	40	
1.6.2	Integration		520
	Install assemblies into optical box	40	
	Align optics	160	
	Test flexure with multiplexer	40	
	Install detector	40	
	Test focus & image quality, cold	40	
	Warmup & adjust focus	120	
	Retest focus & image quality, cold	40	
	Test background with sky	40	