

# Preship Acceptance Test

## Spartan IR Camera for the SOAR Telescope

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13 March 2008 draft

22 July 2008

29 September 2008 Added shipping list

### Abstract

This document describes the results of the preship acceptance test. The instrument passed the tests, except for the problems listed here that will be fixed prior to shipment. The instrument meets the requirements defined by the SOAR Scientific Advisory Committee (SAC), except for reading a region of interest at a high frame rate, and that may be added by writing software. In addition to the requirements, the instrument meets many of the SAC's goals, the most substantial of which is the extended field of view.

## 1 Instrument requirements and goals

The SOAR Scientific Advisory Committee wrote the requirements and goals for a near-infrared imager. The requirements were ranked A, B, or C in priority. In May 2001, E. Loh presented the Spartan IR Camera at a conceptual design review. The proposed instrument was to meet the requirements on the 'A' list. The two 'C' goals, a tunable filter and an extended spectral range, were not possible. The other 'B' and 'C' goals were to be implemented if funds and time allowed. In the fall of 2001, SOAR accepted the design.

The delivered instrument (Table 1) meets all of the requirements on the 'A' list except for reading a region of interest at a high frame rate. The controller electronics and data paths were designed to allow this feature. To add this feature requires writing software for the computer and for the field-programmable-gate-array. Writing and testing the software may be done after delivery of the instrument and does not require having the instrument.

The most substantial goal was the extended field of view. The optics were designed to allow for the extended field of view. Two detectors were added with funds from the National Council for Scientific and Technological Development of Brazil (CNPq), State of São Paulo Research Foundation (FAPESP), the National Science Foundation, and MSU. The instrument will have three science-grade detectors and one engineering-grade detector. The full complement of detectors is expected in late 2008.

The dark current is higher than the requirement and is close to the value that was proposed. The dark current is negligible compared with the sky background for the J filter in high-angular resolution (HR) configuration, where the sky rate is darkest, and it is comparable to the sky background for the 10-nm wide H $\alpha$  filter in the HR configuration. Furthermore, the dark current will likely be 2–3 times lower at the telescope since the ambient temperature is lower, which lowers the dark current from light leaks, and the pressure is lower, which lowers the boiling point of nitrogen and the true dark current.<sup>1</sup>

There are two filter wheels with 18 and 11 cells. Lyot stops occupy 4 cells in the little filter wheel. K-band filters may be put in any of the 18 cells in the big filter wheel, since the Lyot stops must be used. J and H-band filters may be put in any of 25 cells, since they do not require a Lyot stop.

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<sup>1</sup>Baker, D., & Loh, E., 2007, Cold test 3 run 3, Spartan IR Camera for the SOAR telescope. p. 11.

<i>Item</i>	<i>Required</i>	<i>Proposed</i>	<i>Delivered</i>	<i>Requirement met</i>
<b>A List (requirements)</b>				
Plate scale [mas/pix]	80 <sup>§</sup>	40 80	41 68 <u>Obs</u>	Yes
Field of view [arcsec]	80	82 × 164 164 × 328	170 280 <u>Obs</u>	Yes
Number of filter positions	8	24	18+11	Yes
Cold Lyot stop	Yes	Yes	Yes	Yes
Throughput of instrument [%]	30	23 (J), 28 (K)	51–61 (K) <u>CT3R4</u>	Yes
Spectral range [ $\mu\text{m}$ ]	1.0–2.5	1.0–2.4	0.85–2.5 <sup>1</sup>	Yes
Dark current [ $\text{e}^-/\text{s}$ ]	< 1	< 5	3–6 <u>CT3R6</u>	See discussion
Frame rate for 1.6" ROI [Hz]	100	250 100		No. Need software.
<b>B List (goals)</b>				
Number of filter positions	20	24	18+11	Yes
Extended field of view [arcsec]	200	164 + 328	170 280 <u>Obs</u>	Yes
Frame rate for 16" ROI [Hz]	20 <sup>ᵇ</sup>	2.5 10		No. Need software.
<b>C List (goals)</b>				
'Tunable' filter R=100–800	Yes	No	No	No
Grism and field mask $R < 2000$		$R = 380$	No	No. May be added.
Coronagraph	Yes	Yes	No	No. Need masks.
Extended spectral range [ $\mu\text{m}$ ]	1.0–4.0	No	No	No.
Extended field of view [arcsec]	> 200	164 + 328	170 280 <u>Obs</u>	Yes

Table 1: Requirements (A List), goals (B List), and low-priority goals (C List) for the instrument. References to documents are in the underlined links. Notes: <sup>1</sup>Rockwell Scientific, 2002, Data sheet. <sup>§</sup>Plate scale originally specified by the SAC. Later revised to 0.04"/pix to sample diffraction limited image core. <sup>+</sup>Was met by upgrade to 4x4 detector mosaic. <sup>ᵇ</sup>The requirement was intended to allow measurement of two stars separated by up to 16". With further software development, two 1.6"x1.6" ROIs separated by 16" could be read out at 6Hz @ 0.04"/pix and 24Hz @ 0.08"/pix

## 2 Test Results

The WBS and test results for the preship acceptance test are in Table 2. References to the test documents are in the links, which are underlined.

With concurrence from SOAR, a few tasks have been changed from the 2003 plan<sup>2</sup>.

- WBS 1.1.4.5, dark current, is new.
- We cannot think of a way to do WBS 1.1.4.5, sanity check of quantum efficiency, except in the K band.
- The measurements of the flexure of the instrument are done by illuminating a pin-hole on the mask wheel to produce a perfectly sharp image where the light is coherent over the pupil. Our measurements can reveal flexure that occurs between the mask and the detector, but it is insensitive to flexure between the mounting surface of the instrument and the mask wheel. Without a way to produce an image in the lab from the telescope or a telescope simulator, we cannot perform tasks WBS 1.1.7.3 and 1.1.7.4.
- Test mechanisms for 10% of lifetime, WBS 1.1.5.3, is new.

We discovered several problems during run 4 of cold test 3, the run concurrent with the acceptance test. These are the problems, and all of them have been fixed.

**Vacuum leak** Using a leak detector, we found a leak in the flange between the bathtub and lid prior to run 4. When cold, the pressure was 100  $\mu$ torr and increased by 50  $\mu$ torr/day.

Solution: There was some dust on the o-ring. Furthermore, the charcoal getter was contaminated. During run 6, after these problems were fixed, the pressure is 1  $\mu$ torr, and no measureable pressure increase was found over 11 days.

**Dark current** The dark current was 5–10 times higher (Cold test 3.4) than it had been during run 3.

Solution: We installed the baffle that was left off. For run 6, the dark current is the same as it was during run 3.

**Remote panels** Viewing front panels of subVIs of SpartanGUI using the web browser caused the subVI to lock up. This occurred when looking at LogTemperaturePressure from off campus.

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<sup>2</sup>Loh, E., 2003, Delivery of the Spartan IR Camera

Solution: When the browser opens a subVI directly, the problem does not occur. The software now prevents the browser from opening a subVI from the main VI.

**Motor software** The motor current did not shut off after an error occurred during the test of all of the mechanisms.

Solution: A software bug has been fixed.

**Mechanisms lose position** When moving the mechanisms for a significant fraction of the required life of the instrument, the wide-field camera mechanism lost position and hit the forward limit. The pressure rose rapidly to 2 mtorr and then fell gradually. The temperature of the several sensors also rose.

Solution: The motor board (inside the vacuum) overheated (Cold test 3.4). A new motor board was installed. To prevent the motor board from overheating, a restriction is placed on the motors: Over a half-hour period, the motors may run for less than 25% of the time.

Table 2: WBS for delivery with the preship acceptance test shown in detail. Some tests were witnessed, and the results of some are in linked documents.

WBS	Task	Witnessed	result	Documentation
1	<b>Acceptance tests</b>			
1.1	<b>Preship acceptance test</b>			
1.1.1	Demonstrate assembly			<a href="#">Assembly manual</a>
1.1.2	Demonstrate packing procedure			<a href="#">Maintenance manual</a>
1.1.3	Vacuum test			
1.1.3.1	Hold time for liquid nitrogen		17 hr	<a href="#">Cold test 3.6</a>
1.1.3.2	Time between pumping		>1 yr	<a href="#">Cold test 3.2</a>
1.1.4	Detector performance			
1.1.4.1	Read noise	yes	10–25 e <sup>−</sup>	<a href="#">Cold test 3.2</a>
1.1.4.2	Read noise, electronic contribution		6 e <sup>−</sup>	<a href="#">Cold test 3.2</a>
1.1.4.3	Saturation		80 ke <sup>−</sup>	<a href="#">Cold test 3.2</a>
1.1.4.4	Gain	yes	3.7–5.9 e <sup>−</sup> /ADU	<a href="#">Cold test 3.4</a>
1.1.4.5	Sanity check of K-band quantum efficiency	yes	51–61%	<a href="#">Cold test 3.4</a>
1.1.4.6	Dark current		3–6 e <sup>−</sup> /s	<a href="#">Cold test 3.6</a>
1.1.5	Mechanism performance			
1.1.5.1	Repeatability		At 21 C At 77 K	<a href="#">Recovery</a> <a href="#">Cold test 3.6</a>
1.1.5.2	Start from unknown position	yes	Routinely done	
1.1.5.3	Test mechanisms for 10% of lifetime		At 21 C At 77K	<a href="#">Recovery</a> <a href="#">Cold test 3.6</a> (0.3-3%)
1.1.6	Image quality			
1.1.6.1	Strehl ratio		0.7 @H	<a href="#">Cold test 3.6</a>
1.1.7	Flexure			
1.1.7.1	Flexure hysteresis within cryo-optical box		1 pixel	<a href="#">Cold test 3.2</a> , TBD
1.1.7.2	Flexure within cryo-optical box		1–2 pixel	<a href="#">Cold test 3.4</a>
1.1.7.3	Flexure hysteresis of entire instrument		Not done	
1.1.7.4	Flexure of entire instrument		Not done	
1.1.8	Software			
1.1.8.1	Demonstrate operating modes	yes		
1.1.8.2	Demonstrate communications with OPEX	yes		
1.1.8.3	Demonstrate diagnostic commands			<a href="#">Maintenance manual</a>
1.1.9	Documentation			
1.1.9.1	Software manual			<a href="#">Software manual</a>
1.1.9.2	Maintenance manual			<a href="#">Maintenance manual</a>
1.1.9.3	Alignment manual			<a href="#">Alignment of optics</a>
1.1.9.4	Operation manual			<a href="#">Observing manual</a>
1.1.9.5	Electronics drawings			<a href="#">Drawings of electronics</a>
1.1.9.6	Mechanical drawings			<a href="#">Mechanical drawings</a>
1.2	<b>Postship acceptance test</b>			
1.3	<b>Installation</b>			

### 3 Check list

The SOAR Scientific Advisory Committee wrote requirements for the Pre-ship Acceptance Test.<sup>3</sup> Here are items not included in other sections.

#### 3.1 Instrument weight and space envelope

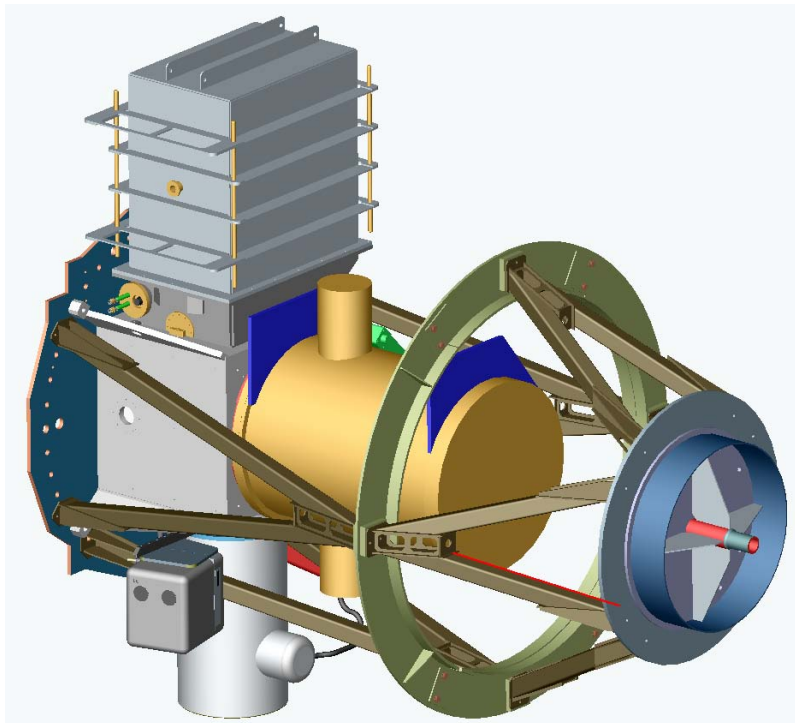


Figure 1: Spartan and other instruments on the instrument selector box

In May 2003, the SOAR project put the Spartan Solidworks model on the model of the instrument selector box and verified that Spartan does not interfere. See Figure 1.

In November 2002, SOAR used estimates of the mass and location of the center of mass of Spartan<sup>4</sup> to design mass simulators for the instrument selector box. The mass has not changed substantially.

<sup>3</sup>SOAR Scientific Advisory Committee, Acceptance Requirements for SOAR Facility Class Instrument, draft of 10 April 2008.

<sup>4</sup>Loh, E., 2002, Interface requirements, Spartan IR Camera

### 3.2 Instrument handling facilities/tools/procedures

SOAR built a fairly-clean room, which reduces dust, in which to disassemble the instrument. The room is modeled on the MSU fairly-clean room.<sup>5</sup> Workers must wear short-sleeved shirts without lint or a bunny suit.

Within the fairly-clean room is a small table with a metal top and grounding straps for working on assemblies. In particular, detectors may be removed or installed with the 4-eye detector assembly on the table.

The vacuum and nitrogen ports are described in the Maintenance Manual.<sup>6</sup> SOAR has an oil-free vacuum pump that mates to the QF40 port on the the instrument. The liquid-nitrogen autofill system will be shipped with the instrument, and SOAR has/will have fittings for it.

### 3.3 Spares of critical components

The operating model for repairing equipment<sup>7</sup> and the resulting list of spares (updated on 13 Nov 2007) is in Table 3.

There is no spare computer. There are two disks that are mirrors. Therefore failure of one disk should not disable the instrument, although this has not been tested. SOAR will back up the software on the Spartan computer as it does for all of the computers in the observatory.

### 3.4 Components installed at time of shipment

All available components are installed in the instrument. The narrow-band filters, which had arrived recently at SOAR, will be installed at the observatory. Although installing them will be done with the instrument completely open, installation of filters in the future may be done through the filter port without opening the instrument.

### 3.5 Instrument flexure

See WBS 1.1.7 in Table 2.

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<sup>5</sup>Loh, O., & Loh, E., The Fairly Clean Room.

<sup>6</sup>Loh, E., 2006, Maintenance & Operating Manual Spartan IR Camera for the SOAR Telescope, p. 15.

<sup>7</sup>Loh, E., 2003, Spares of the Spartan IR Camera



WBS	Task	Priority	U/S	Ship with instrument
1	<b>Spare Parts</b>			
1.1	<b>Mechanisms</b>			
1.1.1	Rotation stage (Phytron PRS110)	1	5/1	N Kept for maintaining software
1.1.2	Motor controller (NI7334)	0	2/1	N SOAR has spare
1.1.3	Motor driver (Prismatics MDM2200)	0	2/0	Y 3 spare channels on driver #2
1.1.4	Motor PCB	1	1/1	Y
1.2	<b>Gaskets</b>			
1.2.1	Filter access (Lesker GA-0600)	1	1/1	Y
1.2.2	Nitrogen plumbing (Swagelok CU-8-VCR-2-GR)	1	2/2	Y
1.2.3	Vacuum plumbing			
1.2.3.1	Motor & nitrogen port (Lesker GA-0600)	1	1/1	Y
1.2.3.2	Pump port (Lesker GA-0275)	1	6/1	Y
1.2.3.3	Valve (Lesker SA0150MVCF)	1	1/0	N
1.2.3.4	62-in custom o-ring	1	1/1	Y
1.3	<b>Electronics</b>			
1.3.1	Detector cable	1	2/1	Y
1.3.2	Detector PCB	1	4/1	Y
1.3.3	Detector controller PCB	1	4/1	Y
1.3.4	Umbilical PCB	1	1/1	Y
1.3.5	Misc			
1.3.5.1	Power supply (CUI DTM060200-P5-HF)	1	2/2	Y
1.3.5.2	Fiber-optic cable	1	4/1	Y
1.4	<b>Optics</b>			
1.4.1	Window	0	1/1	Y
1.5	<b>Computer</b>			
1.5.1	Windows computer	0	1/0	N
1.5.2	Data card (NI6533)	0	1/1	N SOAR has spare
1.6	<b>Vacuum sensor</b> (Inficon BPG400-SD-353-508)	0	1/0	N

Table 3: Spares. "U/S" is the number used and the minimum number of spares available.

### **3.6 Dewar vacuum hold verification**

See WBS 1.1.3 in Table 2.

### **3.7 Mechanisms function properly**

See WBS 1.1.5 in Table 2. We have run the mechanisms for many cycles but not for the number of cycles estimated for the lifetime of the instrument.

### **3.8 Telescope/instrument interfaces**

The bolts between the instrument and instrument selector box have not been checked physically, although they have been checked against the drawing.

The Spartan Graphical User Interface (SpartanGUI) controls the instrument, and it is a server using the SOAR Communications Library (SCLN) and SOAR command format. The Spartan Textual User Interface (SpartanTUI), which may be used to run scripts, is a client. Operation of SpartanTUI and SpartanGUI demonstrates that the Spartan software handles clients using the SCLN interface.

SpartanGUI queries the telescope using VIs supplied by SOAR, but of course SpartanGUI has not actually received any information from the telescope.

Since SpartanTUI will not move the telescope, it is not useful for observing. SpartanTUI was meant to run rudimentary scripts for testing the instrument and to demonstrate communication using SCLN. Since SOAR is writing a client for running more sophisticated scripts, we have not added code to SpartanTUI for moving the telescope.

### **3.9 Detector read noise and dark current**

See WBS 1.1.4 in Table 2

### **3.10 Dark current**

See WBS 1.1.4 in Table 2

### **3.11 Out-of-beam stray light and reflected light**

Tests to measure stray light and reflected light have not been done.

### **3.12 Detector stability**

The detector is stable at the level of the detector and photon noise except for this case: If the detector has collected a large amount of light, residual light appears after flushing. When time allows, the field-programmable-gate-array in the detector controller will be modified to flush the detector while it is idling to minimize the build up of charge. However, bright stars will still cause residuals in subsequent images.

### **3.13 Engineering and user software are demonstrated to allow commissioning**

See WBS 1.1.8.1 and 1.1.8.2 in Table 2

### **3.14 Software should enable remote operation**

The operating model<sup>8</sup> is to support a graphical user interface and a text-based user interface for scripting. Three computers are involved. The Spartan computer runs the instrument, the graphical user interface, and a command-line server. The gateway computer, which is on-site, runs the software on the Spartan computer through Remote Panels. The astronomer's computer, which may be at the astronomer's home, connects to the gateway computer via VNC. The astronomer may also run scripts. The software has been tested in these configurations: (1) The graphical user interface works when the Spartan computer is in the laboratory in East Lansing and the gateway computer is in a nearby town. (2) Scripts run successfully when the Spartan computer and the astronomer's computer are both in the laboratory. (3) Scripts run successfully when the Spartan computer and the astronomer's computer are a single computer (although one must stop the command-line client when stopping the Spartan software).

### **3.15 FITS images**

The software writes FITS images to a local disk. The observatory provides software for copying the images to the gateway computer, defined in the previous section. This software has not been installed. The FITS headers have not been checked for completeness.

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<sup>8</sup>Loh, E., 2007, Software Manual, Operating Model and Security, p. 41.

## 4 Packing list

<b>1</b>	<b>Spares</b>	
<b>1.1</b>	<b>Mechanisms</b>	
1.1.3	Motor driver channel (in motor driver)	3
1.1.4	Motor PCB	1
<b>1.2</b>	<b>Gaskets</b>	
1.2.1	Filter access (Lesker GA-0600)	6
1.2.2	Nitrogen plumbing (Swagelok CU-8-VCR-2-GR)	10
1.2.3	Pump port (Lesker GA-0275)	many
<b>1.3</b>	<b>Vacuum plumbing</b>	
1.3.1	Motor & nitrogen port (Lesker GA-0600)	1
1.3.2	Pump port (Lesker GA-0275)	1
1.3.4	62-in custom o-ring	1
<b>1.3</b>	<b>Electronics</b>	
1.3.1	Detector cable SN 1	1
1.3.2	Detector PCB #2	1
1.3.3	Detector controller PCB	1
1.3.4	Umbilical PCB (no serial number)	1
1.3.5	Misc.	
1.3.5.1	Power supply (CUI DTM060200-P5-HF)	3
1.3.5.2	Fiber-optic cable (in 2.6.1)	1
<b>1.4</b>	<b>Optics</b>	
1.4.1	Window	1

Table 4: Packing list, spare parts

<b>2</b>	<b>Spartan Camera</b>
<b>2.1</b>	<b>Vacuum enclosure and contents</b>
2.1.1	Optics
2.1.2	Mechanisms
2.1.3	Detectors
2.1.3.1	Detector SN 24 (outside of instrument)
2.1.3.2	Detector SN 92
2.1.3.3	Detector SN 97
2.1.3.4	Detector SN 66
2.1.3.5	Detector cable SN 2 in top
2.1.3.6	Detector cable SN 3 in bottom
2.1.4	Filters
2.1.4.1	J
2.1.4.2	H
2.1.4.3	K
2.1.4.4	Pupil-viewing lens
2.1.4.5	Blank filter cells (2)
2.1.5	For pupil
2.1.5.1	High-res, tight Lyot stop
2.1.5.2	High-res, loose Lyot stop
2.1.5.3	Wide-field, tight Lyot stop
2.1.5.4	Wide-field, loose Lyot stop
2.1.5.5	Dark slide
2.1.5.6	Neutral density 1/10 pupil
2.1.5.6	Neutral density 1/100 pupil
2.1.6	Masks
2.1.6.1	Focusing mask
2.1.6.2	Optimized focusing mask (not shipped)
<b>2.2</b>	<b>Computer</b>
<b>2.3</b>	<b>Tray</b>
2.3.1	Motor drivers (2) (Prismatics MDM2200D4-24VW1C4-D5-D5-D5-D5)
2.3.2	Umbilical controller (unknown serial number) in enclosure, EPROM ug4
2.3.3	Power supply (CUI DTM060200-P5-HF) for umbilical controller

Table 5: Packing list, part 1 of the instrument

- 2.4 Detector controller**
  - 2.4.1 Controllers #3 and #4 in enclosure, EPROM sch3
  - 2.4.2 Controllers #5 and #7 in enclosure, EPROM sch3
  - 2.4.3 Power supply (CUI DTM060200-P5-HF)
  - 2.4.4 Power splitter
  - 2.4.5 Mounting box (two rails, cover, back, screws)
  - 2.4.6 Isolation transformer
- 2.5 Filter cells**
  - 2.5.1 Cells (18)
  - 2.5.2 Springs (18) (not yet fabricated)
- 2.6 Cables**
  - 2.6.1 Umbilical bundle containing 5 fiber-optic cables
  - 2.6.2 Motor cable
  - 2.6.3 Motor cable for testing
  - 2.6.4 Heater cable
  - 2.6.5 Power cords (3)
  - 2.6.6 Pressure gauge cable and power supply (Inficon 353-511)
  - 2.6.7 Pressure gauge data RS-232 cable

Table 6: Packing list, part 2 of the instrument

- 3 Auto filler for liquid nitrogen**
  - 3.1 Electronics (NI 6522, relay, & power supply)
  - 3.2 Valve (Lesker LN2-SLV40) & fittings
- 4 Jigs**
  - 4.1 Lifting jig
    - T-bar
    - Four threaded rods
  - 4.2 Turning jig
    - Spreader bar & straps
    - Two offset plates
    - Handle

Table 7: Packing list, ancillary parts

**5 Installation kit**

- 5.1 Needle & quartz thread
- 5.2 1/4-in pins & pin puller
- 5.3 3/32-in cut-off allen wrench
- 5.4 5/64-in cut-off allen wrench
- 5.5 0.035-in allen wrench
- 5.6 Four 4-in bolts for guiding vacuum lid
- 5.7 Four feet for vacuum lid
- 5.8 6-32 nylon screws for lifting top of COB
- 5.9 Shims for mounting on ISB
  - 5.9.1 2-mil shims
  - 5.9.2 7-mil shims
  - 5.9.3 30-mil shims
- 5.10 Faux COB (for servicing 4-eye)
- 5.11 Tygon tube for vacuuming the vacuum flange on the bathtub (not shipped)

**6 Alignment kit**

- 6.1 Pins
  - 6.1.1 Undersized 3/16-in pins for mirrors
  - 6.1.2 Long 3/16-in pins for pyramidal mirror
  - 6.1.3 4-mm pins for rotation stages
- 6.2 Centering gizmo with precision shoulder bolt
- 6.3 Lathe tool for butt alignment
- 6.4 Assorted shims for feeler gauges

**7 Insulation kit**

- 7.1 Tape for blanket
- 7.2 Sheets of aluminized Polyimide

Table 8: Packing list, kits

**8 Software**

- 8.1 Spartan software
  - 8.1.1 Installed on computer
  - 8.1.2 Spartan software on web (password protected)
- 8.2 National Instruments
  - 8.2.1 LabView 7.1 installed on computer (Disk not available)
  - 8.2.2 Data acquisition package, NI-DAQ installed on computer (Disk not available)
  - 8.2.3 Motor package, NI-Motion installed on computer (Disk not available)
  - 8.2.4 Measurement and Automation installed on computer (Also in disk for 8.2.5)
  - 8.2.5 Data acquisition package, NI-DAQmx installed on computer (Disk included)
- 8.3 Disk for Prismatic motor driver

**9 Mechanical design**

- 9.1 Drawings in Solidworks eDrawings
- 9.2 Solidworks parts, assemblies, and drawings (password protected)

**10 Electronics design**

- 10.1 Drawings of electronics
- 10.2 Field-programmable gate array (FPGA)
  - 10.2.1 Detector controller (Xilinx Foundation 4.2.1) (password protected)
  - 10.2.2 Umbilical controller (Xilinx Foundation 4.2.1) (password protected)

Table 9: Packing list, software and designs