Maintenance & Operating Manual
Spartan IR Camera for the SOAR Telescope

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	new instructions for setting digital pots

Abstract

This manual describes the installation, maintenance, and operation of the Spartan Infrared Camera. It is intended for technicians who work on the camera. It is not intended for astronomers.

1 Safety of the instrument and personnel

1.1 Instrument as a bomb—keep the poppet free

When the instrument warms, the cryogenic charcoal getter may release a large quantity of gas, which vents through a poppet valve (Figure 9) if the internal pressure becomes high. Without the poppet, the instrument may become a bomb.

1.2 Don't open the instrument when cold

When venting the instrument to air, the instrument must be at ambient temperature. Venting when the temperature of the instrument is below the dew point will cause condensation and damage the rotation stages.

1.3 Recovery from lost vacuum

If vacuum is lost when the instrument is cold, the following procedure will prevent damage to the rotation stages. You must pump so that ice sublimates and does not liquefy. Liquid water will damage the lubricant on the rotation stages.

Close the leak. You have time: If the instrument is at 77 K, it will take days to warm up.

Attach a dry (oil-free) pump to the pumping port. Turn on the pump. After a minute, open the valve.

Pump until the instrument is a few degrees above ambient. You may want to turn on the heater to speed this up. See the section, “Warming up the instrument” in the Assembly Manual.

1.4 Fill liquid nitrogen in an open area

Cooling the instrument from ambient must be done in an open area to avoid asphyxiation, since the nitrogen displaces the air in a large (8m$\times$8m) room. Operating in a closed laboratory is acceptable, since the nitrogen in the cryostat, if it were to escape suddenly, would merely fill a (3m$\times$1m) closet.

1.5 Electrical—ground yourself

A detector can be damaged with electrical discharge from the body. The parts that have a direct connection with the detector are the detector card, the controller card, and the flexible cable. When working with these, use a wrist strap that is connected to ground. There is a copper wire on the instrument near the detector controller for grounding yourself.

1.6 Cleanliness

Keep oil from getting inside the vacuum enclosure. Use an oil-free pump. Wear gloves when handing the parts that go inside the instrument.

Keep dust from getting in the instrument. Work in a clean room.

1.7 Save your back—use a hoist

The instrument is heavy. Use the lifting jig or rotating jig to move or rotate the cryo-optical box. Use a hoist attached to the lifting bars (Figure 9) to move the instrument.

2 Routine maintenance

See Table 1 for the schedule for routine maintenance. Although most tasks are indeed routine, changing filters takes at least a week because of the time to warm up and cool back down.

Table 1: Maintenance schedule

Task	*Trigger*
Add liquid nitrogen	Daily
Check pressure	Monthly
Renew vacuum	$P > 30\,\mu\mathrm{Torr}$
Change filters	When needed

2.1 Adding liquid nitrogen

Add liquid nitrogen at least once every 18 hours. A few pixels fail every time the detectors warms to room temperature. You have 18 hours after nitrogen is exhausted before the detector warms by 20 C, which is still safe.

The fill port is 1/2-in VCR (face seal with a metal gasket). The parts are a Swagelok male nut SS-8-VCR-4, a socket weld gland SS-8-VCR-3, and a copper gasket retainer assembly CU-8-VCR-2-GR. An adaptor converts VCR to JIC Swivel, also called 1/2-in flare nut, which is common for liquid nitrogen plumbing.

To fill, attach the line from the nitrogen dewar to the fill port. (Either port may be used as the fill port.) Fill until liquid comes out of the vent port. The capacity of the nitrogen container is 7 L.

2.2 Checking the pressure log

Check the log of pressure, `\instLog\TPyyyy-mm-dd.txt` to estimate the duration before the vacuum must be renewed. For example, the log that was started on 31 January 2006 is named `\instLog\TP2006-01-31.txt`. The format of the file is tab-separated-variables, which means Excel can read it. The units of pressure is mtorr, and the units of temperature is K.

2.3 Renewing the getter

The vacuum degrades over time because of permeation through the o-rings. When cold, the vacuum must be below 30 μTorr (0.03 μmHg, 40×10^{-6} mbar) for heat loss by gas conduction to be less than that by radiation. The prediction is that the lifetime of the vacuum is well over a year. We do not have sufficient time to test that prediction.

This procedure may be done with the instrument on the telescope.

The temperature of the charcoal getter must rise above 95 K to release oxygen, which is the most abundant gas that permeates through the o-rings. If the temperature does not rise much higher, there is little risk that pixels on the detector become damaged.

Preparation You must record all work on the vacuum in the Spartan Vacuum Notebook. You need an oil-free mechanical pump.

Let the temperature rise to at least 95 K. Allow the liquid nitrogen to run out. After about a day, the temperature should warm to 100 K. If a lot of gas is released, warming takes less time.

Attach an oil-free mechanical pump to the pumping port. Turn on the pump, and wait a few minutes for the plumbing to evacuate.

Open the valve. Pump until the pressure is below 10 mTorr. Do not leave the valve open any longer, since the getter will then be cleaning the pump and plumbing.

Fill instrument with liquid nitrogen.

Check that the pressure is below 30 μTorr . If the pressure is still high after renewing the getter, there may be a leak or the predominant species are hydrogen, helium, or neon, gases that the charcoal getter does not pump effectively (and somehow the mechanical pump did not remove these gases).

2.4 Changing filters

Changing filters should be done very infrequently, since it requires warming the instrument and breaking vacuum. A few pixels are lost each time the detector is cooled and warmed. Furthermore, the procedure takes a week.

2.4.1 Preparation for changing filters

A spacer, which holds the filter in the filter cell (Figure 1) and compensates for differences in thermal contraction when cold, must be machined to match the thickness of the filter. The thickness of the spacer must be $14.40 - t \pm 0.05$ mm [$0.567 - t \pm 0.002$ in], where t is the thickness of the filter. For

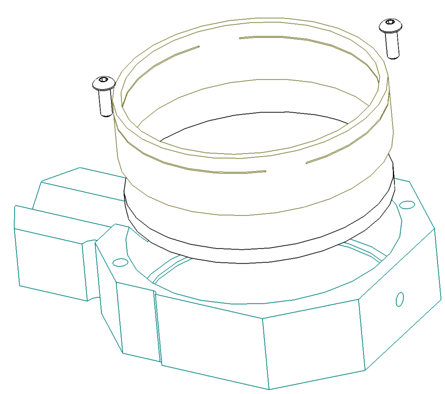

Figure 1: Filter, spacer, and filter cell. The screws press on the slit sections of the spacer, which acts as springs.

the nominal thickness of 3 mm, the thickness of the spacer is 11.40 mm. If the spacer is too thick, the filter will be crushed. An undersized spacer will not hold the filter.

The filter wheels must be balanced in order not to overcome the antibacklash springs. The little filter wheel must be balanced so that the gravitational torque is less than 0.07 N-m. The little filter wheel holds Lyot stops, which must be placed accurately, and the anti-backlash spring cannot resist larger torques. The balance of the big filter wheel is not as critical, since the filters are oversized. However, it must be approximately balanced to reduce the load on the rotation stage.

The torque for one cell with a 3-mm thick silica filter is 0.10 N-m on the big filter wheel and 0.07 N-m on the little filter wheel. Enter the filter masses and locations in the spreadsheet `\homeSpartan\Configuration\filterBalance.xls` to check the balance.

Modify the VI `\homeSpartan\Configuration\SpartanToWheelNames.vi`, which allows the software to know the locations of the filters. After you restart the software, the new locations will be in effect.

Besides the filter, you will also need (1) the spring for retaining the filter, (2) the filter insertion tool, and (3) a 6-in, copper, Conflat o-ring.

2.4.2 Procedure for changing filters

Try to minimize the time when the instrument is open. Water condenses on the internal surfaces, and pumping the water out takes a long time. Cover the filter port when you are not actually accessing the filters.

Warm up the instrument. See "Warming up the instrument" in the Assembly Manual.

Remove the Conflat cover on the filter access port, and open the door on the cryo-optical box (COB).

Insert the new filters and remove the old ones. Use the computer to move the wheel.

Verify positioning. When all of the filters are in place, move the wheels to position 0. Check that the cell 4 on the big filter wheel and cells 9 and 10 on the little filter wheel are visible through the filter access port. If those cells are not visible, the wheel position is lost, and you must reinitialize it. See §5.6.

Close the door on the COB and replace the aluminized Kapton thermal reflector.

Replace the Conflat cover on the filter access port. Use a new copper o-ring.

Pump the instrument and cool. See See §3.1 and §3.2.

2.5 Window inspection & cleaning

This section is taken with slight changes in wording from the *GNIRS Service and Calibration Manual*.

2.5.1 Inspecting the window

The entrance window should always be inspected prior to preparing the instrument for use, and after any prolonged use on the telescope.

Use a bright light to look for dust, stains, and other contamination, as well as cracks or chips. Contamination will almost always be on the outside, but be aware that it might be on the inside of the window. The most common contaminants will be small particles (dust, hairs, etc.). If the window is chipped or cracked, it must be replaced, since the fractures will tend to propagate with time, and may lead to catastrophic loss of vacuum.

Do not touch the window surface. Use of a facemask is recommended. . .

2.5.2 Cleaning the window

The procedure to be followed depends on the level of contamination. If only loose particles are present, follow step 1, which may be carried out with the window still mounted in the instrument. Otherwise, proceed to step 2.

1. Mild Cleaning for Light Contamination (dust, lint particles). Use an air bulb to blow off any loose contamination from the surface of the optic before proceeding to the cleaning steps. If this step does not remove the contamination, continue to Step 2.

   Do not use shop air lines because they usually contain significant amounts of oil and water, which will contaminate the optical surface. Air lines with filtering suitable for optics cleaning can be used.

   Do not use of portable compressed cleaners such as (Effadusters). The propellant evaporates quickly and can produce a localized region of very cold air, which can crack the entrance window.

2. Mild Cleaning for Light Contamination (smudges, fingerprints) It is strongly recommended that this procedure be carried out with the window removed from the instrument. If it is not possible to do this, localized cleaning with the window installed may be successful, if carried out with caution.

   (a) Saturate an unused cotton swab or a cotton ball with methanol or propanol. Gently wipe the surface with the saturated cotton. Do not rub hard. Use only the weight of the saturated cotton ball.

(b) Drag the cotton across the surface just fast enough so that the liquid evaporates right behind the cotton. This should leave no streaks. If this step does not remove the contamination, stop and seek advice from a professional optician.

3 Pumping and cooling

3.1 Evacuating the instrument

You must record all work on the vacuum in the Spartan Vacuum Notebook.

Use this procedure if the instrument has been opened for a long time, in which case water will have adsorbed on the surfaces.

1. Preparation: You will need an oil-free mechanical pump.
2. Turn on the pump and keep the instrument value closed to evacuate the hose.
3. Open the value a small amount, and pump for a few minutes to evacuate the interior of the multi-layer insulating (MLI) blanket. If you open the value completely, the rush of air may break the taping on the blanket.
4. Open the valve completely, and pump the instrument for an hour. The pressure reached 200 mTorr when the instrument was first assembled. When the instrument was clean (fairly free of water), the pressure reached 50 mTorr.
5. If the pressure is high after an hour, pump overnight.

3.2 Cooling the instrument

Cooling the instrument from ambient must be done in an open area to avoid asphyxiation, since the nitrogen displaces the air in a large (6m$\times$6m) room.

Note that after the cryostat is first filled with liquid nitrogen, the instrument continues to cool. The parts that are on the rotation stages take 43 hr to cool to within 2 C of the equilibrium.

1. Open the window of PressureTemperatureLog in order to look at the temperature sensors and the pressure. Set the time step for the log. If you want to monitor the pressure open the window of PressureSensor.

2. Attach the hose that supplies liquid nitrogen to the fill port (Figure 9). Fill until liquid comes out of the vent. The filling history (Figure 2) shows that filling every 20 min is required initially (The pressure rises when nitrogen is exhausted.), that the fill time lengthens to 12 hr after 18 hr. About 150 L of liquid nitrogen is required.

3. When the temperatures of the wide-field camera arm and the wide-field camera post are within 2 C, the temperature of the optics and cryo-optical box have reached equilibrium, and the focus is stable.

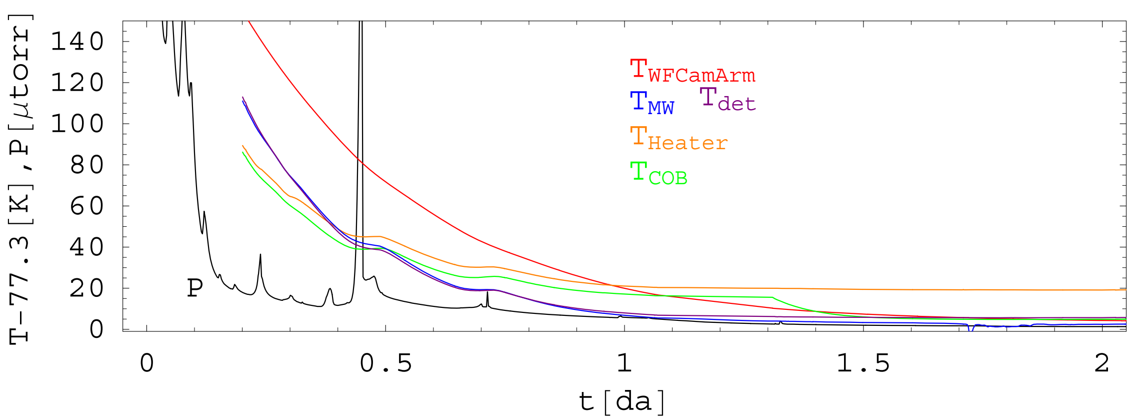

Figure 2: Pressure and temperatures of the arm for the wide-field camera mirror, detector, mask wheel, heater, and cryo-optical box (COB) during cooldown for Run 3 of Cold Test 3. The first filling with liquid nitrogen occurred at t=0. The pressure rises whenever nitrogen is exhausted or when warm gas is introduced at the start of a fill. Since the heater was not attached to the COB securely, its equilibrium temperature is higher. The sensor on the COB is near the high-res collimator. The temperature of the arm for the wide-field camera mirror has a 9-hr e-fold time. At t=2da, the temperature of the mirror is within 1C of the equilibrium temperature. In the legend, the sensors are ordered by the temperature at the first point. The temperatures of the mask wheel and detector are very close.

4 Troubleshooting

This section describes tests for isolating problems in the mechanisms and in the detector electronics.

4.1 Software installation

LabView pops up a message "Please find the VI named xxx.vi" LabView cannot find a VI in folders that it searches. If you can find the VI, respond with the location of the VI. If you cannot find it, the file tree was not copied correctly. Since LabView saves a list of folders that it needs to search, you will not have to fix this problem more than once.

Message "Detector controller disconnected" appears in the instrument log. The NI6533 card is not installed in the computer.

Message "Motor controller(s) disconnected" appears in the instrument log. The NI7334 motor controller(s) are not installed in the computer.

4.2 Mechanisms

Proper function of the rotation stages requires the motor controller, motor driver, cabling, and indexing switches. (See Table 7 for a block diagram.) Each motor controller (NI 7334), which is inside the computer, controls a motor driver (Prismatics MDM2200), and each motor driver can handle 4 mechanisms, which are called axes. See Table 2 for the assignment of the axes. The cabling for the motors in in Table 3. This section describes ways to isolate problems.

The motor drivers (Prismatics MDM2200) have one fuse next to the power cord and several fuses on the inside.

Table 2: Assignment of controller & axis for each mechanism.

Mechanism	*Cont.*	*Axis*
Big Filter Wheel	1	1
Little Filter Wheel	1	2
f/21 Collimator	1	3
f/12Cam	1	4
Mask Wheel	2	3

Three diagnostics, `forMechanismEngineer` in the VI `SpartanGUI`, the VI `MechanismHoming`, and the VI `MechanismMoving`, are helpful if the mechanism is working partially. They show the inferred motion of the mechanism; they do not show the actual motion, since the only feedback from the mechanism is the limit switches. Keep this in mind when you read the graphs of the motion. If the motion causes a limit switch to engage, then the mechanism is truly moving. If the motion does not produce a change in the state of a limit switch, then there is no guarantee that the mechanism actually moved.

The Spartan software shows the state of the limit switches at initialization and updates when a mechanism is moved. If you suspect a limit switch changed state, you may initialize the mechanisms to see the state of the switches. If you want to monitor a limit switch continuously, use NI Measurement and Automation Explorer (NI-MAX).[1]

If the mechanism position is incorrect, either the mechanism is not working or the position is lost.

When the software moves the motors, you do not hear a soft whine. The motors are not moving. Either the motor drivers are not turned on, they are not enabled, or the motor cable is disconnected.

When the software moves the motors, you hear a grinding noise. One of the two phases of the motor is broken. If this occurs for only one motor, the wire for it is broken. If this occurs for all of the motors on a drive, then the common wire for the phase is broken.

Does the mechanism find home? Press the button `test home` on the panel `forMechanismEngineer` to test the location of the reverse limit switch. If the position repeats, then the mechanism is fine. Press the button `store home` to save the new home position.

Does the mechanism make a grinding noise? If the mechanism is jammed or one of the two motor phases is disconnected, then moving the motor causes a grinding noise.

Motor Controller & Motor Driver Each motor controller handles one motor driver, and each motor driver handles 4 motors (Table 2). If not all of the motors on a controller and driver are failing, then the controller is working. If one motor is failing, swap the plug on the back of the motor driver to decide whether the problem is in the motor driver. If the problem is in the motor driver, check the fuses inside the motor driver.

Cabling 1 There are two identical cables between the motor controller and the motor driver. Swap the two cables to test them.

Cabling 2 Swap the connections (P18 and P19) where the long motor cable plugs into the panel behind the motor controller. Then test the mechanism that was not working. (Remember that after you swap the cable, you must mentally swap the name so that the software moves the same mechanism.) If the mechanism is still broken,

[1] Go to Start>All Programs>National Instruments>Measurement and Automation.

then the problem is somewhere between the plugs P18 or P19 and the mechanism. If the mechanism works, then some cable between J18 or J19 and the motor driver is broken. The wiring from the motor driver to the connector can be tested, since it is open.

Cabling 3 The connection between the motor driver assembly and the motor can be checked without opening the instrument. The cable can be removed. The connections inside the vacuum enclosure should show this: (1) The wires that include a motor coil should have a resistance of about 5Ω. (The resistance changes slightly when the motor is cold.) (2) The switches are normally closed; they open when the limit is engaged.

4.3 Detector electronics

Proper function of the detector electronics requires the detector, detector card, flexible cables, detector controller, umbilical, umbilical card, data cable, the data card in the computer, and three power supplies. (See Table 7 for a block diagram.) This section describes ways to isolate problems.

Heartbeat On the Spartan GUI, the light, “Heart” blinks about once a second to indicate that the detector controller is communicating with the computer. The light changes state each time the detector controller sends status to the computer, which occurs at 2.5 Hz. If the light changes state once every 5 s, then the computer is not receiving status. If the light blinks at 1.25 Hz, the umbilical, umbilical card, data cable, the data card in the computer, two power supplies, and the digital section of the detector controller are all fine.

Umbilical Board & NI 6533 Data Card On the CameraControl GUI, press the button, “send command,” which tests only the communication between the umbilical card and the computer. If that fails, communication is lost. Check that the umbilical cable is seated. Check that power to the card is OK by swapping power supplies. If the cable and power are OK, then the umbilical board or the NI-6533 data card (inside the computer is not functioning.

Detector Controller If the temperatures are OK (Use the CameraControl GUI.), most of the detector controller is functioning, since reading the temperature requires digital and analog parts to function. Proceed to check power rails if reading temperature fails.

Table 3: Motor and heater wiring. M3: mask wheel; M5: big filter wheel; M6: little filter wheel; M7: f/21 collimator; M7: f/12 camera

	Motor driver & cable panel		Cable panel & vacuum bulkhead				Bulkhead & motor PCB		Motor PCB & motors		
Name	On motor driver	19-pin Female Circular	19-pin Male Circular			41-pin Female Circular	41-pin Male Circular	40-pin Rect.	10-pin Rect.	Motor	
	Cont 2	Q18	P18	Wire		P20	Q20	P22			
M1AP	~~P12-1~~	A	A	Yellow	10 Conductor Cable A	K	K	6	B1-1	Heater	M3=MaskWheel
M1BP	~~P12-4~~	B	B	Purple		L	L	7	B1-3		
M2AP	~~P13-1~~	C	C	Grey		M	M	9	B2-1		
M2BP	~~P13-4~~	D	D	White		N	N	11	B2-3		
M3AP	P37-A	E	E	Green		P	P	2	B3-1	M3AP	
M3BP	P37-B	F	F	Orange		f	f	1	B3-3	M3BP	
M4AP	~~P15-1~~	S	S	Blue		t	t	3	B4-1		
M4BP	~~P15-4~~	R	R	Brown		d	d	5	B4-3		
AN	P37-T	P	P	Red		e	e	8	B3-2	M3AN	
BN	P37-C	V	V	Black		q	q	10	B3-4	M3BN	
M1Rev	~~P8-3~~	G	G	Yellow	10 Conductor Cable B	R	R	34	B1-5	Heater	
M1Fwd	~~P8-1~~	H	H	Purple		S	S	35	B1-6		
M2Rev	~~P9-3~~	J	J	Grey		T	T	25	B2-5		
M2Fwd	~~P9-1~~	K	K	White		U	U	26	B2-6		
M3Rev	P37-Z	L	L	Green		j	j	31	B3-5	M3Rev	
M3Fwd	P37-Y	M	M	Orange		s	s	32	B3-6	M3Fwd	
M4Rev	~~P11-3~~	N	N	Blue		r	r	23	B4-5		
M4Fwd	~~P11-1~~	U	U	Brown		h	h	24	B4-6		
Common	P37-c	T	T	Red		I	I	33	B3-7	M3Com	
SafetyGnd	P37-a	Shell		A+Bshield		a+Shell	a	20	B3-8	SafetyGnd	
	Cont 1	Q19	P19								
M5AP	P31-A	A	A	Yellow	10 Conductor Cable C	A	A	16	A1-1	M5AP	M5=BFW; M6=LFW; M7=f/21Col; M8=f/12Cam
M5BP	P31-B	B	B	Purple		B	B	17	A1-3	M5BP	
M6AP	P32-A	C	C	Grey		C	C	19	A2-1	M6AP	
M6BP	P32-B	D	D	White		D	D	21	A2-3	M6BP	
M7AP	P33-A	E	E	Green		Z	Z	12	A3-1	M7AP	
M7BP	P33-B	F	F	Orange		m	m	13	A3-3	M7BP	
M8AP	P34-A	S	S	Blue		k	k	14	A4-1	M8AP	
M8BP	P34-B	R	R	Brown		W	W	15	A4-3	M8BP	
AN	P31:34-T	P	P	Red		Y	Y	18	A1:4-2	M6:8AN	
BN	P31:34-C	V	V	Black		X	X	22	A1:4-4	M6:8BN	
M5Rev	P31-Z	G	G	Yellow	10 Conductor Cable D	E	E	39	A1-5	M5Rev	
M5Fwd	P31-Y	H	H	Purple		F	F	40	A1-6	M5Fwd	
M6Rev	P32-Z	J	J	Grey		G	G	30	A2-5	M6Rev	
M6Fwd	P32-Y	K	K	White		H	H	29	A2-6	M6Fwd	
M7Rev	P33-Z	L	L	Green		J	J	36	A3-5	M7Rev	
M7Fwd	P33-Y	M	M	Orange		c	c	37	A3-6	M7Fwd	
M8Rev	P34-Z	N	N	Blue		p	p	27	A4-5	M8Rev	
M8Fwd	P34-Y	U	U	Brown		n	n	28	A4-6	M8Fwd	
Common	P31:34-c	T	T	Red		b	b	38	A1:4-7	M5:8Com	
SafetyGnd	P31:34-a	Shell		C+Dshield		g+Shell	g	4	A1:4-8	SafetyGnd	

Power Check the power rails by looking at the indicator light emitting diodes (LED) (Figure 3). To enable the indicating LEDs on the controller card, you must push the button below the LEDs. Regulators make each of the power rails (+3.3V and +1.8V on both cards and +5V on the controller) from the 6-V power supply. If all of the power rails are down, swap the 6-V power supply.

If you cannot read a picture, there is a problem in the digital circuits. If you can read a picture but the picture does not look right, there is a problem in the analog circuits. Examine the four quadrants of the picture. If one quadrant is bad, an analog signal chain, the flexible cable, or a clock driver for that quadrant is bad. If all quadrants are bad, the power to the detector or the flexible cable is bad.

Swap detector controllers to determine whether the problem lies with the detector controller or something inside the vacuum enclosure.

Noise If the image shows noise that is not synchronous with rows or columns, then grounding may be improper. See §5.3.1.

Check that the power supply for the detector controller uses the same AC circuit as the computer and motor driver. We have found that the safety grounds of two circuits in the lab have large RF noise between them.

Each detector controller is grounded to its box though the screws to the box. Check that the controller is screwed into the box. Check that the screws on the detector controller are attached to pads that have a jumper to ground.

It is impractical to look for noise on the detector controller, since the noises of interest are not synchronous with the signal and they are of order $10\,\mu$V whereas the signal changes by of order a volt over the period of a pixel.

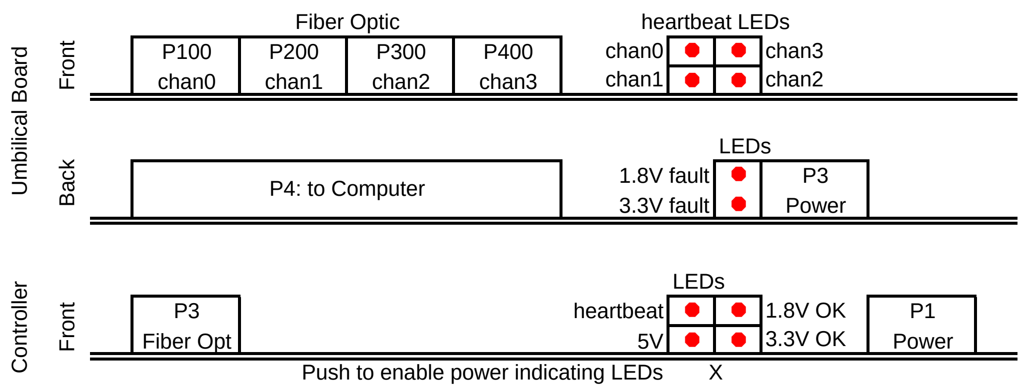

Figure 3: Indicator lights on the umbilical board and detector controller.

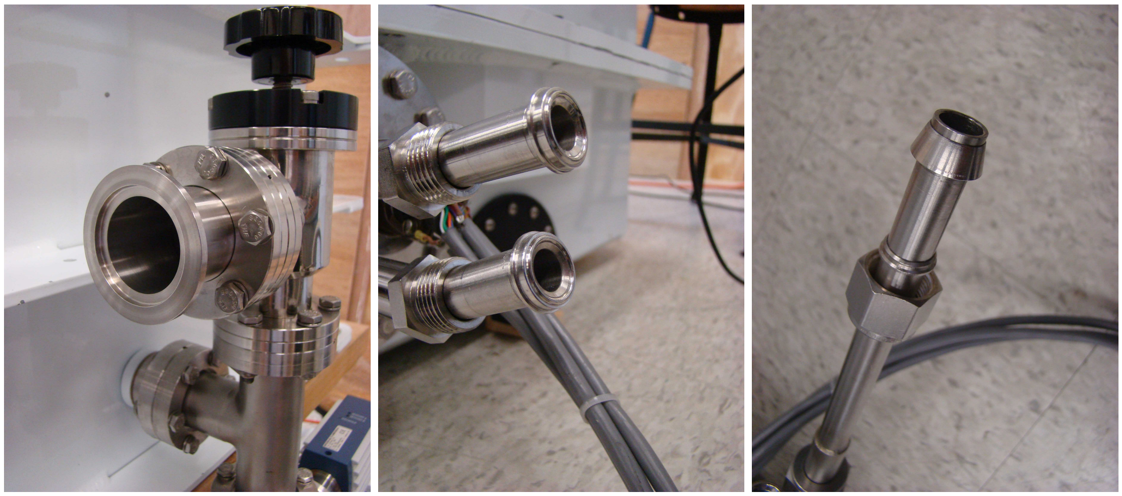

Figure 4: Vacuum port (left), nitrogen ports (center), and VCR to Swagelok adaptor for the nitrogen port (right)

5 Installation

5.1 Vacuum and nitrogen interface

The pumping port (left panel of Figure 4) is QF40. The end part in the figure is a 2 3/4” ConFlat to QF40 adapter, Lesker F0275XQF40. The QF end is exposed.

The nitrogen fill and vent ports, which are identical, use Cajon 1/2” VCR metal gasket face seal fittings (center panel of Figure 4). The end part is made of a socket weld gland, Lesker 8FVCR-GL, and a male nut, Lesker 8FVCR-N. A gasket retainer assembly, Lesker 8XVCR-GACR, and copper gasket, Lesker 8XVCR-GAC, are needed.

A VCR to 1/2” Swagelok adapter is provided (right panel of Figure 4). The end part is a Swagelok nut and ferrules, taken from a female connector for 1/2” NPT and 1/2” tube, Swagelok SS-810-7-8. However, the Swagelok nut and ferrules on the adapter can attach to any 1/2” Swagelok part.

5.2 Installation on the telescope

5.2.1 Lifting the instrument

Use a crane. Loop lifting straps on the lifting bar (Figure 9). Insert the straps on the hook of the crane.

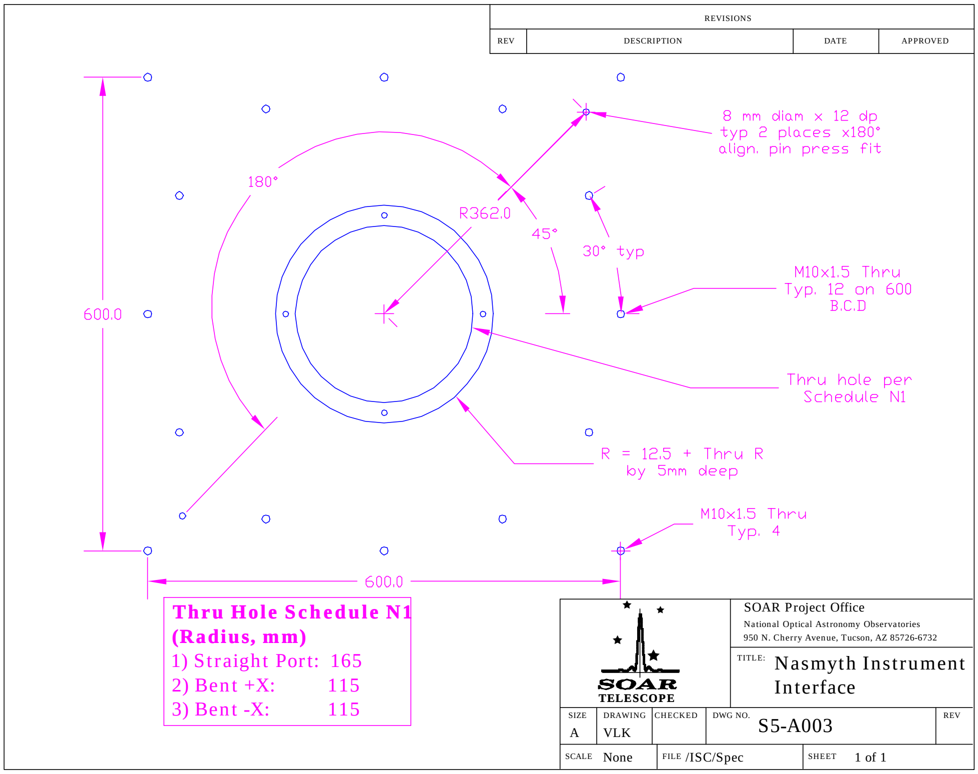

Figure 5: Bolts and pins on the ISB. The instrument uses three of the four bolts at the north, south, east, and west positions in the picture.

5.2.2 Attaching to the instrument support box (ISB)

Turn the ISB so that the face that is to receive the instrument is up. Insert the ϕ8-mm pins into the ISB (Figure 5). Lower the instrument onto the ISB. Orient the instrument so that the filter access port is accessible. Bolt the instrument on with three M10-1.5 bolts.

You will have to insert shims to align the primary mirror with the Lyot stop. This will be done by looking at a bright star that is far out of focus. See §5.7.

5.3 Installing the computer & electronics

Install the computer, motor drivers, and power supplies in the electronics rack. Connect the cabling per Figure 13 and Table 4.

5.3.1 Connecting AC power

Proper connection of AC power is a mystery that may depend on the radio-frequency (RF) noise and wiring of the locale. The following works in the laboratory: Use the same AC circuit for the computer and motor driver, vacuum gauge, and power supply for the detector controllers. Connect the vacuum enclosure to safety ground (the green wire or round connector on the AC power plug).

With the following scheme, noise does appear in the image: Use two different AC circuits for the power supply for the detector controllers and the computer and motor driver. We have found that the safety grounds of two AC circuits in the lab have a large RF noise between them.

The detector wires may pick up radiation from the motor wires, even though the detector circuit board is inside the aluminum vacuum enclosure, a Faraday cage, and the flexible cable to the detector controller is a microstrip (traces over ground plane, 0.025 mm away). The bandwidth is in the MHz range, and the impedance of the video line is in the KΩ range.

The most likely path for radiation is from the motor wires to the detector circuit board, since the detector circuit board and detector have the largest antenna areas. Wires that originate in the computer and motor drivers go inside the Faraday cage of the vacuum enclosure. If the ground of the computer and motor drivers are different from the ground of the detector controller, then the motor wires may have tens of volts of RF noise. We have found that using a single AC circuit and connecting the safety ground of the AC power to the vacuum enclosure is sufficient to reduce the RF noise to a level that is barely detectable in the Fourier transform of a dark image.

5.4 Installing hardware

You must have already installed LabView (The software uses LabView version 7.1.) and the components Traditional NI-DAQ, NI-Motion, and NI-VISA. If you are uncertain whether the components are installed, open NI Measurement and Automation Explorer (NI-MAX)[2] and look at the Software tab.

Install two NI-7334 motion controllers and one NI-6533 data acquisition card in the computer.

Configure the NI-6533 data acquisition card to use device 1. You will use the NI Measurement and Automation Explorer (NI-MAX). See Figure 6. Right click on the device to access properties. Change the device number to 1. This needs to be done only once, since the configuration is saved.

[2] To start NI-MAX, go to Start > All Programs > National Instruments > Measurement and Automation.

Cable	Terminus	Loc.	Terminus	Loc.	Cable
A1	Motor controller 1 (Motion I/O)	Computer	Motor driver	Tray 1	NI SH68-C68-S
A2	Motor controller 2 (Motion I/O)	Computer	Motor driver	Tray 1	NI SH68-C68-S
B	2 Motor receptacles	Tray 1	Motor receptacle	Vac 1	Custom cable with two 19-pin and one 41-pin MS3116 plugs.
C	NI 6533 I/O card	Computer	Umbilical card	Tray 1	NI SHC68-68-D1
D1	Umbilical card port 0	Tray 1	Detector controller 0	Tray 2	Fiber optic
D2	Umbilical card port 1	Tray 1	Detector controller 1	Tray 2	Fiber optic
D3	Umbilical card port 2	Tray 1	Detector controller 2	Tray 2	Fiber optic
D4	Umbilical card port 3	Tray 1	Detector controller 3	Tray 2	Fiber optic
E1	6-V power supply	Tray 1	Umbilical controller	Tray 1	On power supply.
E2	6-V power supply	Tray 2	Power fanout	Tray 2	On power supply.
F1-F4	Power fanout	Tray 2	4 detector controllers	Tray 2	custom. Use 4 Switchcraft female RAPC722 connector.
G1	Detector controller 0	Tray2	Det conn. 1	Vac 2	Custom. Use W1, N1, & TS.
G1	Detector controller 1	Tray2	Det conn. 1	Vac 2	Custom. Use W2 & N2.
G2	Detector controller 2	Tray2	Det conn. 2	Vac 2	Custom. Use W1 & N1.
G2	Detector controller 3	Tray2	Det conn. 2	Vac 2	Custom. Use W2 & N2.
H	RS232 port	computer	Pressure sensor	Vac 3	Inficon cable with RS232 extender.

Table 4: Cabling. Location "Vac 1" is on the motor-nitrogen header on one side of the vacuum bathtub. Location "Vac 2" is on the other side of the bathtub. Location "Vac 3" is on the vacuum lid. The flexible cables on the detector connectors are labeled W1, N1, W2, N2, W3, N3, (in order on the plug) and TS. "W" stands for a wide, 30-pin cable, "N" stands for a narrow, 20-pin cable, and "TS" is the 10-pin very narrow cable. Plug the 6-V power supplies and the Inficon cable into 110-V line power.

Configure the NI-7334 motion controller. Start NI-MAX. Configure the Trajectory Setting according to Figure 6. You must do this for both motion controllers; the settings are the same for both. Since the software overrides settings in the panels Axis Configuration, Axis Setting, Trajectory Settings>Move Complete Criteria, and Find Reference; you need not do anything with these panels. The other panels Digital I/O Settings, ADC Settings, Encoder Settings, PWM Settings, and Synchronization Settings are not applicable.

Configure the serial port (COM1) to use these settings: 9600 baud, 8 data bits, no parity, 1 stop bit, and no flow control. (The pressure sensor uses the serial port.)

5.5 Installing software

See *Installing software, Spartan IR Camera*.

5.6 Initialization after servicing

Since the stepper motors have no encoders, the computer keeps track of the positions of the mechanisms. If the motors moved without the computer's knowledge, you must find home, which is the reverse limit switch.

1. Go to the tab **forMechanismEngineer** in SpartanGUI.vi.
2. Select a mechanism and press the button **Test Home** to check the location of the reverse-limit switch. If the reverse limit is far from zero (much more than 40 musteps), the mechanism has probably moved. A shift of the location of the limit switch is reason for concern. Submit this as a problem.
3. Press the button **Store Home** to reset the location of the reverse-limit switch.
4. Press the button **Test Home** several more times to verify that the location of the reverse limit is repeatable.
5. Repeat for each mechanism.

5.7 Alignment

In principle, aligning the instrument on the Instrument Support Box (ISB) requires fixing six degrees of freedom (Table 5), but the only two degrees of freedom for which

Table 5: Alignment of the instrument on the Instrument Support Box

Parameter	*Adjustment*	*Tolerance*
x&y-tilt	Shim	0.5 mrad
		at shim: 0.15 mm
z-rotation	No, pinned	
x&y-translation	No, pinned	
z-translation	Shim	3 mm

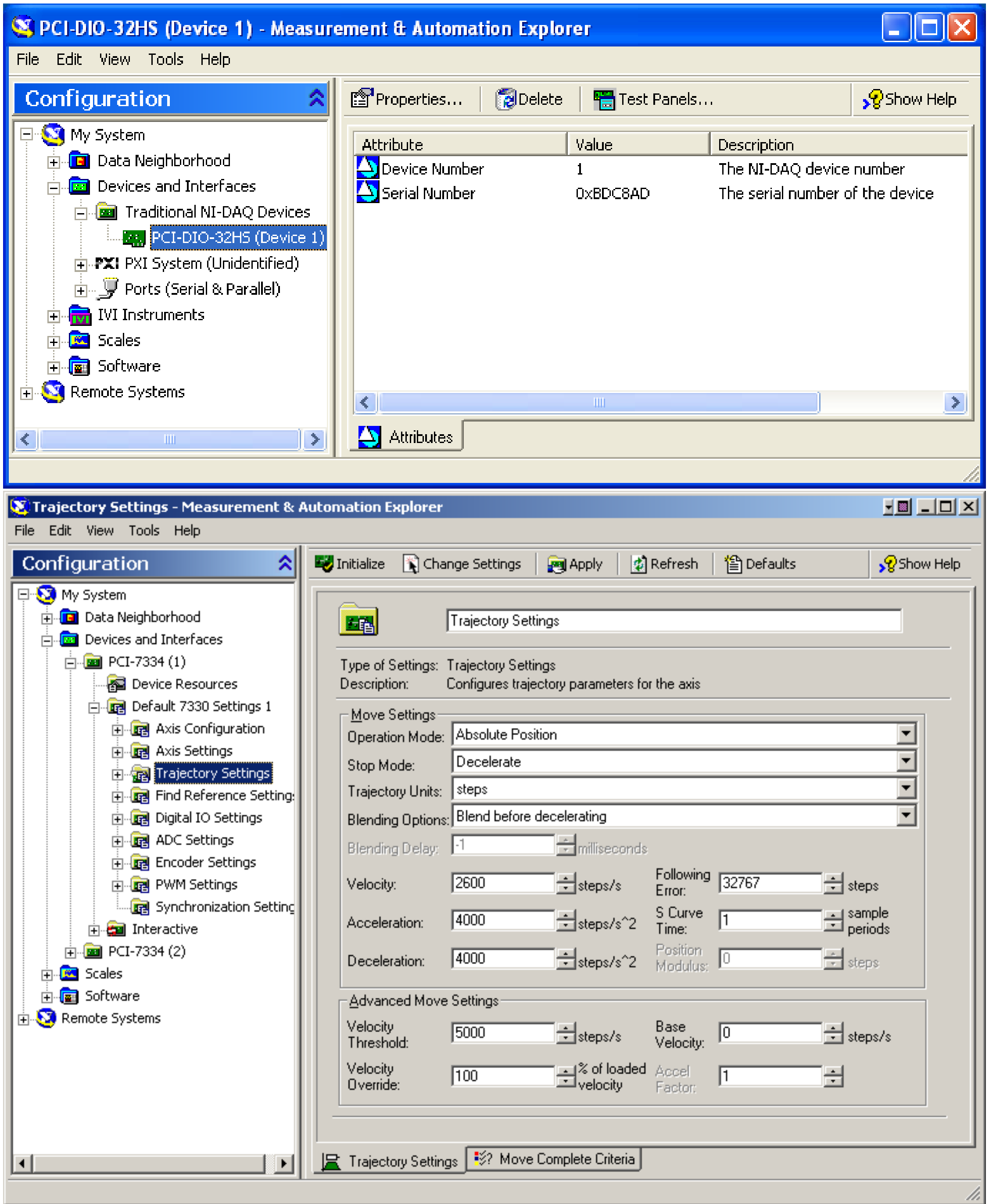

Figure 6: The panels in NI Measurement and Automation Explorer (NI-MAX) for setting up the NI-6533 data acquisition card (top) and the NI7334 motion controller (bottom).

the tolerance is tight are the x-tilt and y-tilt of the mounting surface. Tilt moves the image of the primary mirror on the Lyot stop. Shims on the Flamant transitions (Figure 7) allow adjustment of the these two degrees as well as focus. The tolerance for focus is loose: focus must be within the focus range of the telescope. Two pins fix the other three degrees of freedom.

The goal is to center the image of the telescope primary mirror on the Lyot stop so that the loss in the amount of light is less than 1%. If the pupil is shifted by δ, then the loss is $2R\delta/(\pi R^2)$, where R is the radius of the pupil. Therefore the requirement at the Lyot stop is $\delta/R <= 0.01\pi/2$.

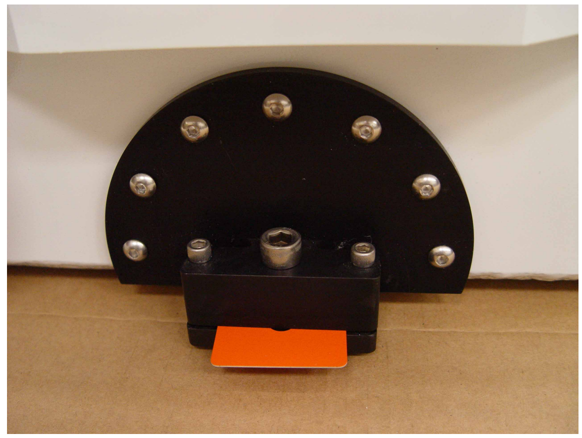

Figure 7: Flamant transition and orange shim

The pupil can be visualized by looking at an out-of-focus image of a star. The telescope is adjusted to put a stellar image out of focus (using the telescope secondary) on the Spartan detector. If the focal plane of the telescope is shifted (defocussed) by an amount z, the diameter of the stellar image on the detector will be $D = z16/f$ where f is the focal ratio at the image. For $z = 2$ mm with the f/12 channel, $D = 2.7$ mm $= 150$ pixels. The edges of the out-of-focus image should be determined in pixels in the x and y directions, respectively (4 numbers). A precision of 2.2 pixels is required.

xxx This will not likely work, since moving the secondary probably moves the image.

1. Install the tight Lyot stop for the wide-field channel. Point at a bright star. Move the telescope focus 2 mm from the true focus. Find the edges of the image.

2. Install the loose Lyot stop for the wide-field channel. Find the edges of the image. (The image should be slightly larger.)

3. If the two images are concentric to $\delta/R < 0.015$, then the alignment is finished.

4. If not, change the shim. For the direction with two bolts, add to one side and remove from the other side an amount $(\delta/R)(R/f_{\text{coll}})d_{\text{bolt}}$=$8\delta/R$ mm. (For the wide-field channel, $R = 20$ and $f_{\text{coll}} = 750$. $d_{\text{bolt}} = 300$.) For the direction with a single bolt, add or remove $8\delta/R$ mm from the single shim. Then repeat.

5.8 Setting detector parameters

The detector requires two adjustable voltages, vReset and biasGate, and the controller requires a DC offset for each quadrant, vOffset0–vOffset3. These must be adjusted for each detector. To clear the photoelectrons, the charge-storing capacitor is connected to vReset. The potential biasGate affects the speed of the amplifier on the detector.

The detector controller has digital potentiometers for adjusting the voltages. For vReset, the conversion between the setting i and voltage is

$$V_{\text{reset}} = 2.500\,\text{V}\; i/256,$$

and for the others, the conversion is

$$V_{\text{other}} = 5.000\,\text{V}\; i/256.$$

For vReset and biasGate, we have found that the manufacturer's setting is fine.

To set vOffset, the signal level for the picture with no light and the signal level for the reference pixel must be low but not off scale (near zero).

The information on the images is in two places. In the instrument log, the entry "MRefShort" is the average signal level of the reference pixels (the 1025th column of each quadrant) for the short image. "MRefShortDrift" is the change in the MRefShort since the last time the digital pots were loaded. "MShort" is the median of the light-sensing pixels for the short image. "MShortDrift" is the change in the MShort since the last time the digital pots were loaded. "MLong" is the median of the light-sensing pixels for the image long-short. More detailed information is in StashImageStats.vi. To open its front panel, in the Window menu on SpartanGUI, select the item Image Statistics.

Nominally, the signal level changes +1536 ADU for a change of +1 in vOffset (with the gain of the signal chain set to 3). Since the steps of the Analog Devices AD8400 digital pot are accurate to 1/4 step, expect wide variations.

This is the procedure:

1. In SpartanGUI, press the buttom forEngineering. Select the Setup tab. The offsets, vReset, and biasGate settings are on this tab.
2. Adjust vOffset so that the intensity of the light-sensing pixels at low light level and the intensity of the reference pixel are both at least 5000 counts.

5.9 Programming EPROMs

The detector controller and umbilical card each use one Atmel AT17LV010-10JI EPROM (20-pin PLCC package, 1 Mbit size).

The programmer is Atmel's ATDH2200 FPGA Serial Configuration EEPROM Programming Board, which connects to a parallel port. The software is Atmel CPS Version 8.02. The input to the programmer is a file with an extension .mcs, sch.mcs for the detector controller and ug.mcs for the umbilical board. The command is to convert a Xilinx file, program, and verify. These are the programming parameters. Option: AT6K/Other. Device: AT17LV010(A). Reset polarity: low. Com port: LPT1. Data rate: medium. A2 bit level: low.

Version	*Date*	*Change*
Detector controller		
SCH4	23 Oct 2008	Flush charge while idle.
		Turn off indicator light after 24s
SCH3	26 June 2008	Default gain is 3.
		Ramp and test pods are now disabled by default.
SCH2	29 May 2007	Default gain is 5.
		Temperature data changed from 10 to 11 bits.
Umbilical controller		
UG4	17 Jul 2006	

Table 6: EPROM versions

6 Shipping

This section describes the procedure for removing the instrument from the shipping container. The container is designed to protect the instrument for a 30-cm drop and to insulate it from vibration.[3]

With the sides of the shipping container removed and rollers installed, the container becomes a fixture for transporting the instrument inside the observatory. See Figure 8.

6.1 Unpacking

1. Remove the top and side panels, which are held by screws.
2. Remove the boxes, which contain ancillary equipment and fixtures.
3. Remove the top plate, which has the horizontal safety bumpers.
4. Remove the parts that are screwed onto the base of the shipping container or the top plate.
5. Install the wheels, if you want to move the instrument.

6.2 Removing the instrument from the fixture

You will need a hoist.

1. Remove the three bolts that hold the instrument on the base.
2. Attach straps to the lifting rods. Lift the instrument.

[3]Loh, M., Loh, O., & Loh, E., 2006, Test of the Shipping Container, Spartan IR Camera for the SOAR Telescope.

Figure 8: Top left: instrument leaving the lab. Top right: side and top removed. Bottom: Instrument packed with the sides and top of the shipping container removed.

7 Acknowledgement

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[4]This material is based upon work supported by the National Science Foundation under Grant No. 0242794. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

A Instrument description

The Spartan Infrared Camera (Figure 9) operates in the 1–2.4 μ spectral band. It has two focal ratios, wide-field with 68 mas/pixel for a wide field and high-res with 41 mas/pixel for high angular resolution. In the high-res configuration, the detectors resolve the diffraction limit. The detectors are HAWAII-2 arrays, (**H**gCdTe **A**stronomical **W**ide **A**rea **I**nfrared **I**magers with **2**048x2048 pixels). The instrument is cooled with liquid nitrogen.

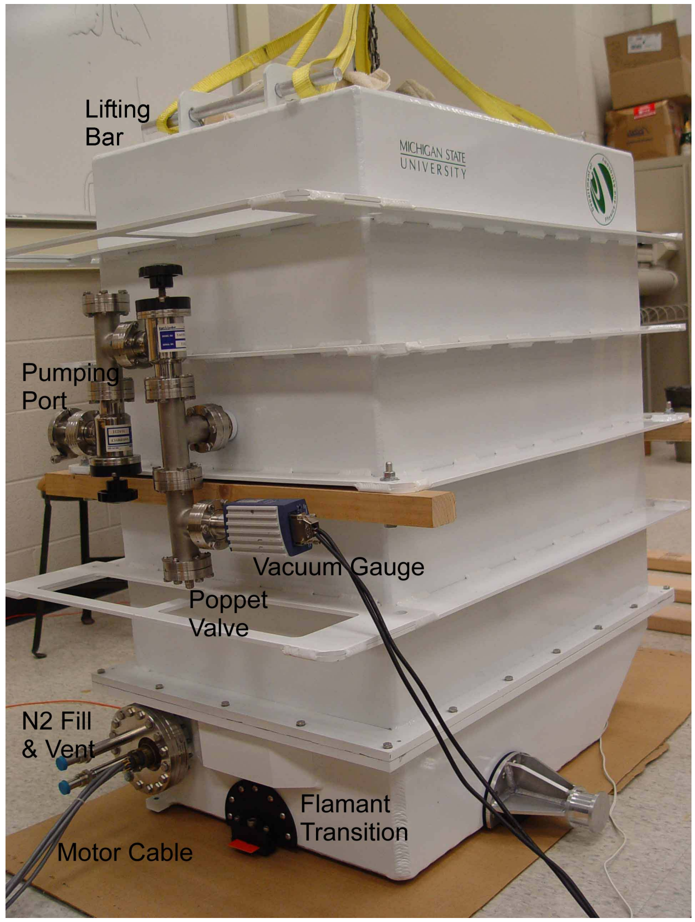

Figure 9: Spartan Camera. The bathtub (lower part) and the vacuum lid (upper part) bolt together at the flange. The inside of the instrument attaches mechanically, electrically, and plumbingly to the bathtub only; the lid lifts off freely.

The symmetrical design minimizes flexure. The optics and cryostat for nitrogen (Figure 10) bolt on the top and bottom plates of the cryo-optical box (COB) (Figure 11). As the Nasmyth port turns to compensate for the rotation of the field, the instrument turns along an axis perpendicular to those plates. Since the optics are midway between the top and bottom plates and gravity is parallel to these plates, flexure cannot move the image toward or away from these plates.

The connections to the inside of the instrument are all with the bathtub of the vacuum enclosure (Figure 9). The vacuum lid mates to the bathtub at a flange to complete the vacuum enclosure. The COB attaches to the bathtub through four A-struts (Figure 11), which are made of G-10 fiberglass, a stiff, insulating material. The electrical connections and nitrogen plumbing also attach to the bathtub. Therefore the vacuum lid lifts off freely during disassembly.

The instrument attaches to the instrument selection box (ISB) on the telescope through three Flamant transitions. The Flamant transition is a semicircular plate that allows movement to compensate for the difference in thermal expansion of the aluminum instrument and steel ISB.

A.1 Optics

The optics image the curved, focal surface of the telescope onto the detector. A collimating mirror collimates the light and images the primary onto a stop. A focusing mirror focuses the light onto the detector. A plano-convex lens near each detector flattens the field. The mirrors are off-axis to avoid blocking the beam. There are two focal ratios. To switch between the two focal ratios, rotation stages move the high-res collimator and the wide-field focusing mirror move in or out of the beam. Two fold mirrors make the system more compact.

Two filter wheels allow a large number of filters. The little filter wheel is at the image of the primary mirror of the telescope. For the K band, where the Lyot stop must be accurate to block thermal radiation, the Lyot stop must be in the little wheel and filters must be in the big wheel. For other bands, the filters may be placed on the little filter wheel.

A mask wheel at the telescope focus holds the field stops and masks for coronagraphy or slits for spectroscopy.

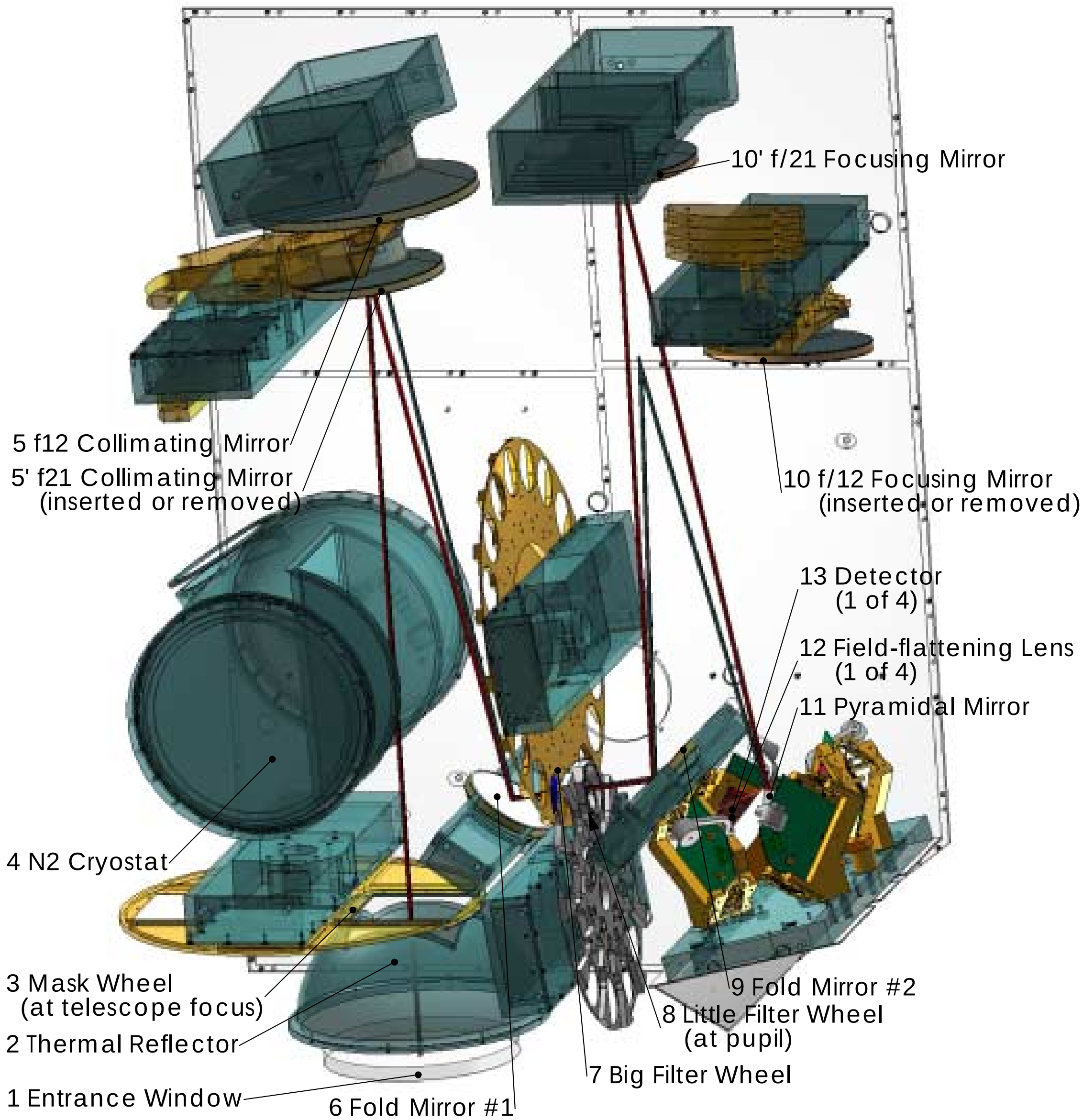

Figure 10: Optical schematic oriented with the front of the instrument down and the top toward the viewer

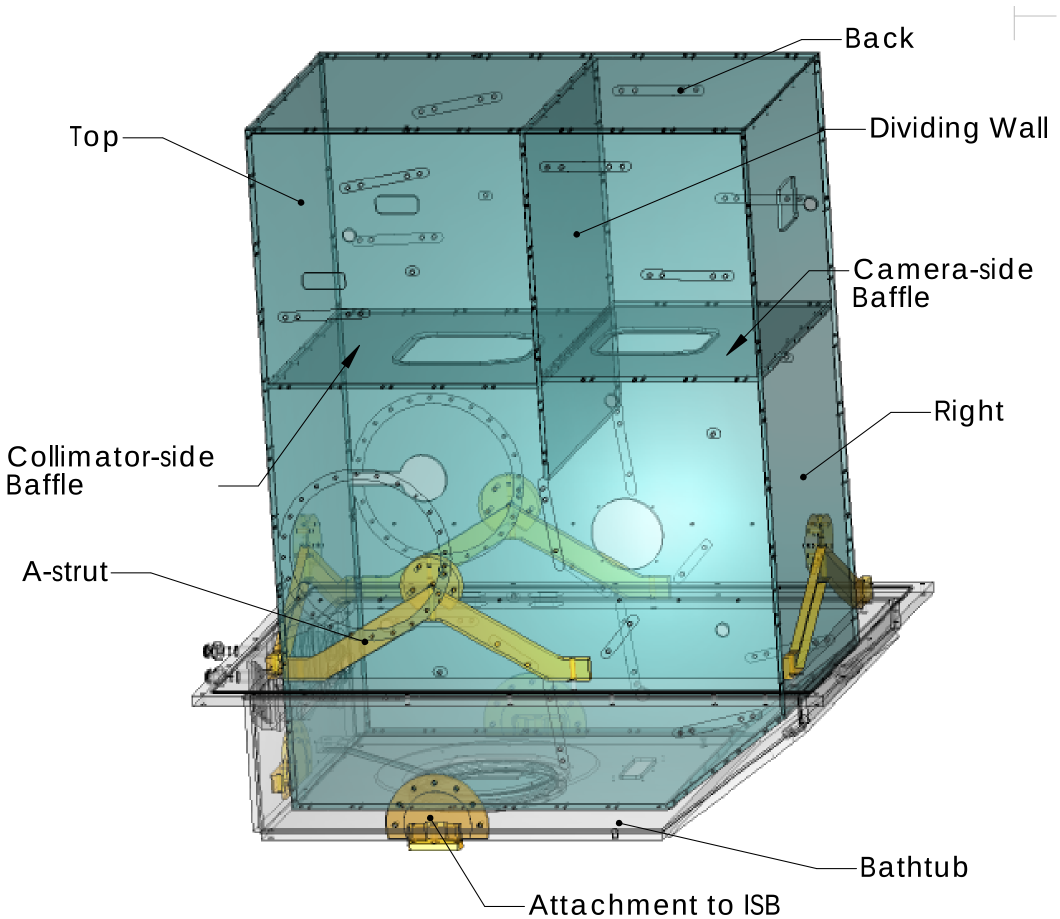

Figure 11: Cryo-optical box inside the bathtub of the vacuum enclosure

A.2 Vacuum & cooling

The vacuum enclosure consists of a bathtub and lid, which mate at a flange visible in Figure 9 & Figure 11.

The vacuum plumbing (Figure 12) has a pumping port, which is Conflat with a quik-connect adapter.

The poppet valve is a safety relief. It opens if the internal pressure becomes high, as would be the case if the charcoal getter warms and releases the nitrogen and oxygen adsorbed from a large leak.

The vacuum gauge is an Inficon BP400 Bayard-Alpert Pirani. According to the manual,[5] "The gauge functions with a Bayard-Alpert hot cathode ionization measurement system (for $P < 2.0 \times 10^{-2}$ mbar) and a Pirani measurement system (for $P > 5.5 \times 10^{-3}$ mbar). In the overlapping pressure range ..., a mixed signal of the two measurement systems is output. The hot cathode is switched on by the Pirani measurement system only below the switching threshold of 2.4×10^{-2} mbar (to prevent filament burn-out). It is switched off when the pressure exceeds 3.2×10^{-2} mbar."

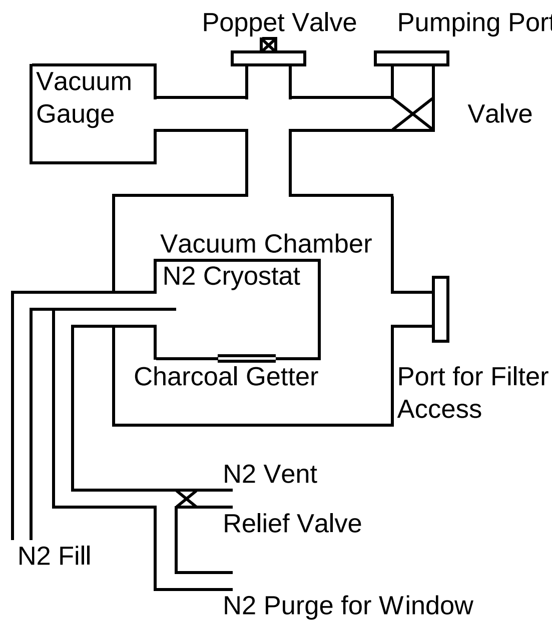

Figure 12: Schematic of vacuum plumbing and nitrogen plumbing

The actual pressure P and pressure reading P_R are related by $P = CP_R$. For N_2 and O_2, $C = 1$. $C = 2.4$, 5.9, and 4.1 for H_2, He, and Ne, respectively. The conversion is nonlinear for $P > 1$ Torr. See the manual for more information.

A cryogenic charcoal getter pumps oxygen, nitrogen, and argon, which permeate through the Viton o-rings. The coconut charcoal is glued on the nitrogen cryostat. The charcoal getter should keep the pressure low for more than a year. Charcoal releases adsorbed gases when warm. It does not need to be baked: unlike zeolite, charcoal does not bond to water.

Liquid nitrogen cools the instrument. The cryostat holds 7 L of nitrogen independent of rotation along an axis perpendicular to the top, which is the rotation axis of the instrument on the telescope. The nitrogen can be forced out if the instrument is oriented with the filter port facing down.

Several design features control the heat load. A multilayer insulating (MLI) blanket reduces the thermal radiation by a factor of about 100. The MLI consists of 10 layers of single-sided aluminized polyimide. A thermal reflector reduces the solid angle of thermal

[5] Inficon, 2002, Operating Manual, BPG400 Bayard-Alpert Pirani Gauge

radiation from the window. The G-10 struts have low conduction. The flexible cables that connect the cold detector and warm electronics have very low cross section and therefore low conduction. The motor wires run on a board with thin traces, which reduce conduction.

Because the window radiates into about 0.9 steradian of cold, it may cool below the dew point on very humid days. Some nitrogen boil-off, after warmed in a length of pipe, blows on the window to purge the surrounding air of water.

A.3 Electronics and cabling

The electronics are in several places. The block diagram and cables are in Figure 13 and Table 7.

- Inside the vacuum are detector printed circuit boards (PCB) and a motor PCB. The motor PCB is a thermal insulator and a fan-out.
- On the instrument outside the vacuum is an electronics box, which contains the detector controller PCBs.
- In the cooled electronics rack (up to 7 m from the instrument) are two motor drivers (NI MID-7604), the umbilical PCB, and the computer.
- Inside the computer are two motor controllers (NI PCI-7344) and a data card (NI PCI-DIO-32HS) for communicating with the umbilical card.

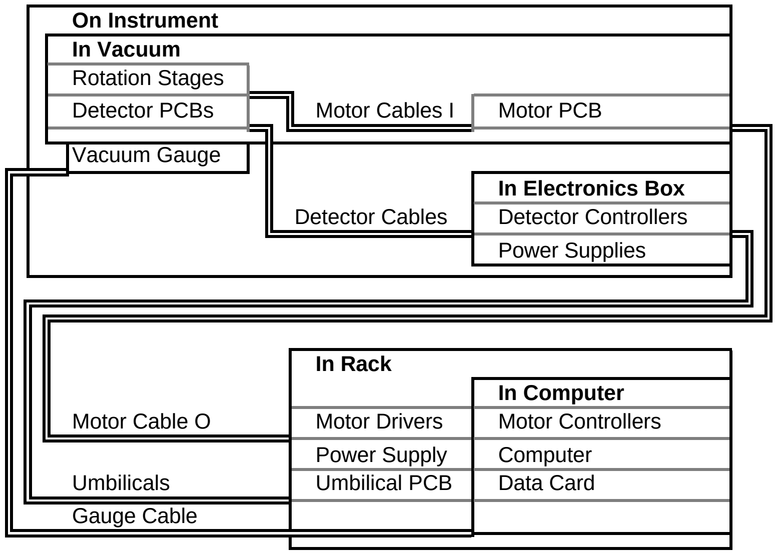

Figure 13: Cabling schematic

	Power	Ethernet	Computer	Motor Driver #1	Motor Driver #2	Motor Driver Assembly	Umbilical Box	Power Supply #1	Power Supply #2	Power Supply #3	Motor Bulkhead	Detector Controller #1	Detector Controller #2	Vacuum Gauge
Computer	1	2		3	3		4							8
Motor Driver #1	1		3											
Motor Driver #2	1		3											
Motor Driver Assembly											5			
Umbilical Box			4					7				6	6	
Power Supply #1	1						7							
Power Supply #2	1											7		
Power Supply #3	1												7	
Motor Bulkhead						5								
Detector Controller #1							6		7					
Detector Controller #2							6			7				
Vacuum Gauge	1		8											

ID	Name & Number	Part Number, Description
1	Power Cord (7)	NA
2	Ethernet Cable (1)	100Base-TX
3	Motor Control Cable (2)	NatInst SCH68C
4	Data Cable (1)	NatInst 183432A-01
5	Motor Cable (1)	NA
6	Umbilical (2)	Black Box EFP080-010M, MT-RJ, Multimode, Duplex, 62.5-µm/125-µm Fiber Optic Cable
7	Cable on Power Supply (3)	CUI DTM060200UDC-P5-HF
8	Gauge Cable & PS (1)	Inficon 353-511

Table 7: Cabling

A.4 Software

To start the software, run `\homeSpartan\SpartanGUI`, and the window in Figure 14 should appear. The software has several components, which are described briefly here.

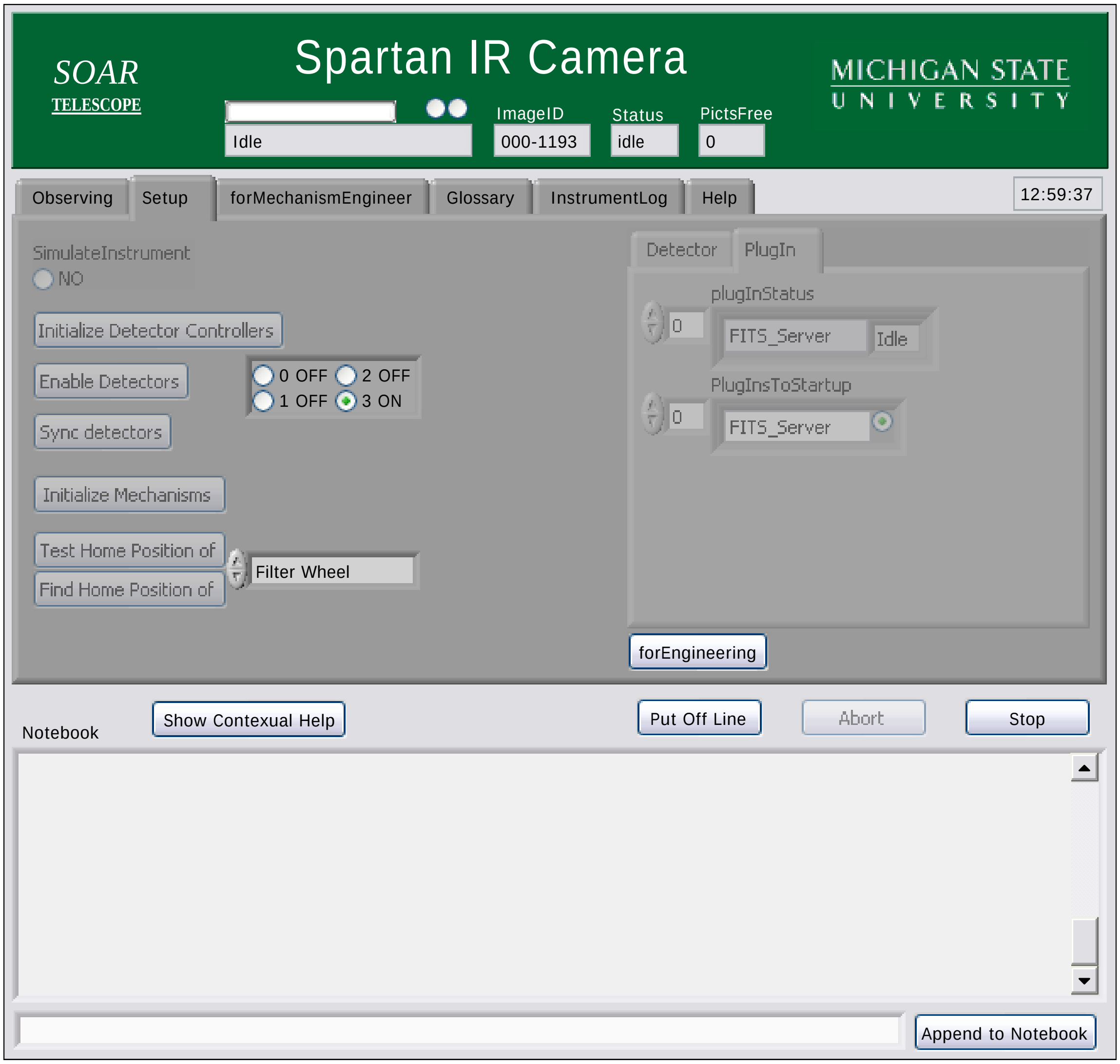

Figure 14: SpartanGUI, which is the main window of the software

For a more complete description, see Spartan software manual.

SpartanGUI is the user's control panel. In normal operation, the observer need only look at this window. Status information is in the top section. The observing functions are in the observing panel. The notebook maintains a record of the observations; the observer can log comments in the notebook.

SpartanGUI has several panels:

Observing is for the observer. The observer presses buttons on SpartanGUI to set exposure time, take pictures, change filters, switch between wide-field and high-res modes.

Setup is to setup the detector and the mechanisms. The operations are (1) choose the detectors, (2) load the operating voltages for each detector, (3) initialize the mechanisms, (4) test the home positions of the mechanisms, and (5) find and store new home positions. The parameters that are unlikely to need changing are in a tab control, the two tabs of which are named Detector and PlugIn. Select the button SimulateInstrument to run without any hardware.

forMechanismEngineer is for monitoring the mechanisms and more detailed control of the them. Normally, the mechanisms move by the amount needed to change the optics, an example of which is the 20° to move between filters. This panel allows movement by steps of 0.002°.

Glossary contains definitions of terms, an optical schematic, and a map of the detector layout.

InstLog maintains a record of mechanism movement and unexpected problems. The observer may add comments that will help diagnose problems.

Help

CameraControl controls the detector. It sends commands to the detector controller cards and receives status and images from them.

MechanismInitiation initializes the mechanisms by initializing the motor controllers and reading the locations of each mechanism from files on the disk.

MechanismHoming locates the reverse limit of a mechanism in order to test or set its home position.

MechanismMoving moves the mechanisms.

PGauge reads the Inficon pressure gauge.

LogTempPressure maintains a log of the temperatures at several points in the instrument and the pressure inside the instrument.

Telescope Link communicates with the observatory control system (OPEX). SpartanServer receives commands from OPEX and passes them on to StartanGUI. In addition, it send status to OPEX.

TUI Link communicates with the text-based user interface.

StartanTUI is a text-based user interface. It may run on a remote computer.

In order to reduce clutter, most of the VIs run without a visible window. To make a VI visible, use the Window menu of SpartanGUI.

A.4.1 Volatile data

Volatile data are the mechanism positions and the current image ID. The data are stored in these files, whose path is in the entry `volatileDataPath` in the configuration file `spartan.txt`.

mech0.txt-mech5.txt Before moving mechanism 0, the flag "moving" is written to the file `mech0.txt` to indicate that the mechanism position is changing. After finishing a motion, the flag is erased and the new position is written to the file. Thus the position of the mechanism and whether the position is accurate are both stored on disk to ensure safe recovery from a crash. Each mechanism has its own file.

image ID.txt contains the serial number of the last image. The image ID is used as part of the name of the image, and it must be unique.

A.4.2 Software configuration

These files, which are in `\homeSpartan\Configuration`, contain configuration information.

spartan.txt has computer-specific paths. An example is in Table 8. The format is that of Windows configuration files. The line in brackets specifies the IP number of the computer to which the following information applies.

defaultOptic.vi (Figure 15) contains the default mechanism positions for the high-res and wide-field observing channels.

mechanismParameter.vi (Figure 15) contains the operating information for the mechanism, which are the controller and axis number to address the mechanism, the maximum position (counting from 0), the number of steps per position, whether to

Table 8: Example configuration. Note: the first slash is translated to a colon; *e. g.*, the entry `C/home Spartan/instLog` translates to the path `C:home Spartan/instLog`.

```
[default]
computerName="unknown"
imagePath="/C/images"
volatileDataPath="/C/data"
observingLogPath="/C/obsLog"
instrumentLogPath="/C/instLog"
[35.10.222.84]
computerName="horolog4"
imagePath="/C/images"
volatileDataPath="/C/home Spartan/data"
observingLogPath="/C/home Spartan/ObsLog"
instrumentLogPath="/C/home Spartan/InstLog"
[35.9.70.129]
computerName="sextans"
imagePath="/E/images"
volatileDataPath="/C/data"
observingLogPath="/C/obsLog"
instrumentLogPath="/C/instLog"
```

compensate for backlash, the offset from the index to the 0-th position, whether the mechanism is a wheel (and therefore the last position is adjacent to the first), and the serial number of the rotation stage. You must access the block diagram to make changes.

filterBalance.xls is a spreadsheet for figuring out where to put filters to balance the wheels.

SpartanToWheelNames.vi (Figure 15) contains the correspondence between the mechanism positions and names of the optics.

detectorSetPoint.vi contains information about the detectors, namely the serial number, location, and operating voltages.

initDatabase.vi contains information on the observatory, time system, equinox, and versions of the hardware and software.

hdr-obs.txt contains the FITS key words that are implemented.

soar_commsXXX.txt contains IP addresses of TUI Link, the text-based server, Spartan TUI, the text-based client, and Telescope Link, the server that provides information about the state of the telescope. (The observer types commands on the client which are sent to the server for execution.) XXX is the name of the computer. This is an example:

```
[Spartan]
IP_Server=35.10.222.145
IP_Client=35.9.2.14
IP_Port=30040

[AOS]
IP_Server=139.229.3.100
IP_Client=139.229.3.217
IP_Port=5679
```

TUI Link must run on the same computer as SpartanGUI. StartanTUI may be on a remote computer.

The server enforces security using the IP address of the client. The IP address of the client must be in the configuration file when the server starts; otherwise the server will not open a communications link with the client.

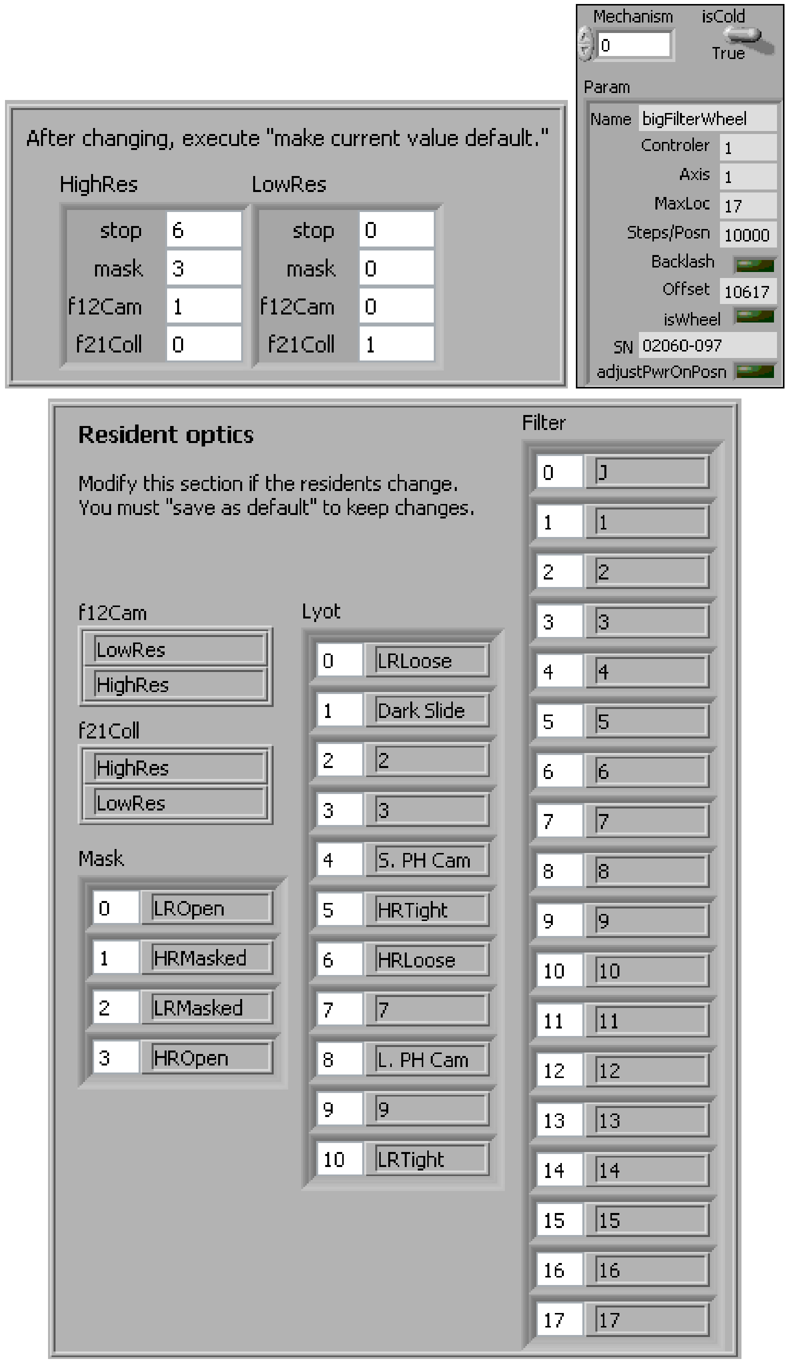

Figure 15: VIs, defaultOptic (top left), mechanismParameter (top right), and SpartanToWheelNames (bottom), for configuring the instrument.

B Other Documentation

Spartan documentation

- **Spartan assembly manual** Loh, E., 2007.
- **Spartan observing manual** Loh, E., 2006.
- **Spartan software manual** Loh, E., 2006.

Vendor documentation

- **Inficon pressure gauge** Inficon, 2002, Operating Manual, BPG400 Bayard-Alpert Pirani Gauge, www.inficon.com.
- **NI digital input/output card** National Instruments, 2001, 653X User Manual, www.ni.com.
- **NI motor controller** National Instruments, 2001, 7344/7334 Hardware User Manual, www.ni.com.
- **Prismatics motor driver** Prismatics, 2005, MDM2200 Reference & Maintenance Manual, www.prismatics.com