Cold Test 3, Run 5
Spartan IR Camera for the SOAR Telescope

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Abstract

This note reports the results of Run 5 of Cold Test 3. The modification to the motor board (to reduce heating) was done incorrectly. Moving a mechanism caused four mechanisms to move. Therefore no useful tests were performed.

The hold time of a load of liquid nitrogen is 14 hr, which would require refilling during a night of observing. We suspect that the charcoal getter became contaminated when the window broke during Run 3.

An automatic system for filling liquid nitrogen was built and tested.

1 Introduction

This cold test began on 2 June 2008 and ended on 5 June. For the results of previous runs of cold test 3, see run 4 (19 Feb–3 April 2008),[1] run 3 (30 May–20 June 2007),[2] run 2 (22 Jan–10 Mar 2007),[3] and run 1 (22 Aug–15 Sept 2006)[4].

1.1 Tests

These were the outstanding problems at the end of run 4: (1) The focus was off. (2) The motor board overheated. (3) The rotation stage for the high-res collimator generated metal dust. (4) The rotation stages for the mask and little filter wheel lost positioning. (5) The dark current was high because a baffle was inadvertantly not installed.

[1]Baker, D., Thomas, B., Sanders, N., & Loh, E., 2007, Cold test 3, run 4, Spartan IR Camera for the SOAR telescope.

[2]Baker, D., & Loh, E., 2007, Cold test 3, run 3, Spartan IR Camera for the SOAR telescope.

[3]Baker, D., & Loh, E., 2007, Cold test 3, run 2, Spartan IR Camera for the SOAR telescope.

[4]Baker, D., & Loh, E., 2006, Cold test 3, run 1, Spartan IR Camera for the SOAR telescope.

One test was not completed during run 4, because a trace on the motor board melted. The flexure vs. orientation of the instrument needs to be repeated.

The tests listed below will complete the testing of the instrument prior to shipping.

Test positioning of all mechanisms The tests will be run at 25% duty cycle, which should prevent the motor board from overheating. The pressure will be monitored to verify that the motor board does not overheat. Run the mechanisms for 10% of the expected number of cycles over the lifetime of the instrument.[5]

Measure dark current Use the dark slide. Measure with detector 1, which glows, on and off.

Focus Find the focus for one detector for the wide-field and high-res channels. Use a lamp and an f/4 hole to define the beam. Use the K filter to lessen the effects of centering.

Image quality Measure the Strehl ratio, a measure of image quality, for all four detectors across the field. Use the K filter, the shortest band for which the image is sampled properly in the wide-field band.

Flexure repeatability Measure flexure for both the wide-field and high-res channels. Use a lamp. Take data in pairs separated by 5°. At the end, repeat the measurement at the starting orientation. Move the mechanisms and repeat the measurements to determine whether the flexure is repeatable enough to be corrected by the tip-tilt guider of the telescope.

Offset of mechanism positioning between room temperature and 77 K. At the end of the cold test, use "Test Home" to find the reverse limit for all mechanisms. After the instrument is warm, use Test Home again. The difference is the offset of mechanism positioning between room temperature and 77 K.

1.2 Installation

The bottom of the instrument is the side with the conflat vacuum opening for filter access. The window is on the front side.

[5]Baker, D., & Loh, E., 2007, Lifetime tests of the mechanisms, Spartan IR Camera for the SOAR telescope.

The detector locations are named A1, A2, B1, and B2, where the “B” detectors are closer to the exterior of the instrument and the “2” detectors are toward the top (Figure 1).

The detectors are installed according to Table 2, and Table 1 shows their connections to the vacuum bulkheads and detector controllers. The channel numbers refer to the inputs on the umbilical board.

		Bottom					*Top*		
Pins	*Posn.*	*Contr.*	*Pins*	*Contr.*	*Pins*	*posn.*	*Contr.*	*Pins*	*Contr.*
20	A1	3			30	A2	5		
30	A1	3			20	A2	5		
20	nc		10	nc	30	B2	7	10	5
30	B1	4			20	B2	7		
20	B1	4			30	nc			
30	nc				20	nc			

Table 1: Vacuum bulkhead for the detector cables. The bulkhead is oriented as viewed from the air side; the 10-pin cable is to the right of the 20 and 30-pin cables.

Chan.	*Cont. SN*	*Loc.*	*Det. SN*	*Grade*
0	3	A1	24	Science
1	6	B1	92	Engineering
2	7	B2	97	Engineering
3	5	A2	66	Science

Table 2: Detectors. The channel number determines rotation of the FITS file.

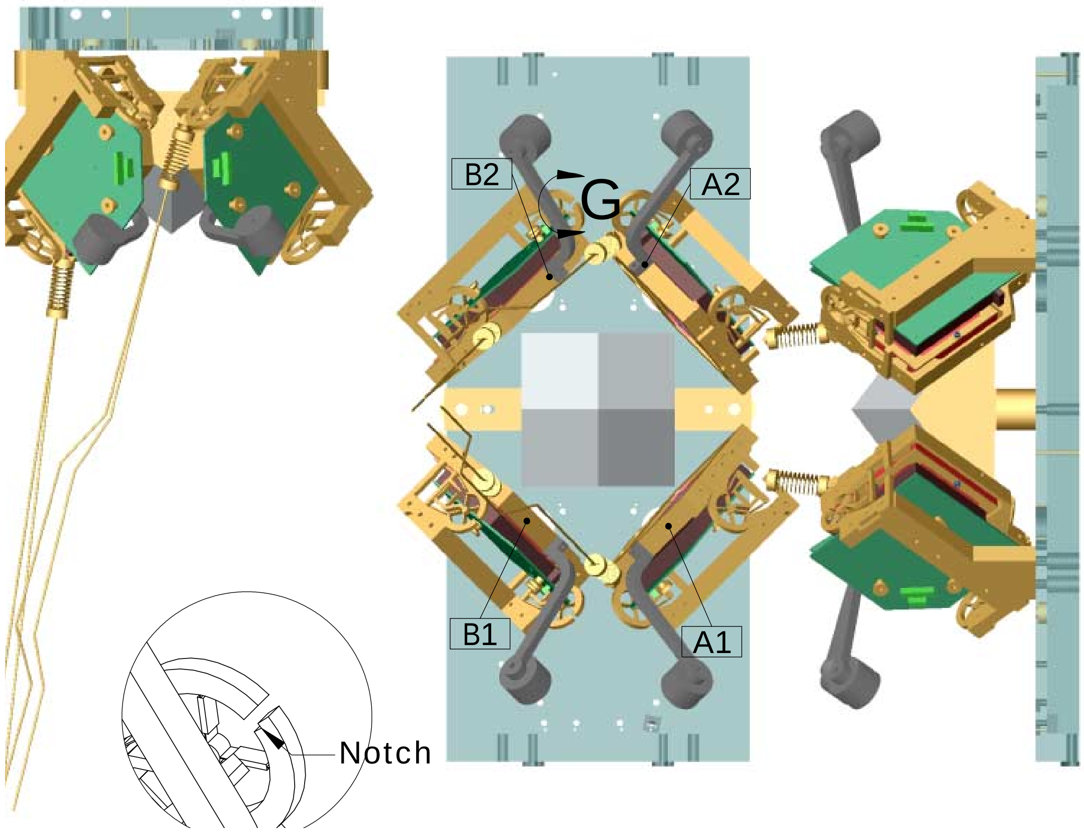

Figure 1: 4 eye shown for the wide field configuration. The top of the instrument is at the top for the center and right panels. The magnified detailed view shows the notch on the axles for the B detectors. The rotation axis, which points up before the mirror, points NW, NE, NE, and NW for the A2, B2, A1, and B1 detectors, respectively, after reflection. The rotation is right-handed for the wide-field configuration and left-handed for the high-res configuration.

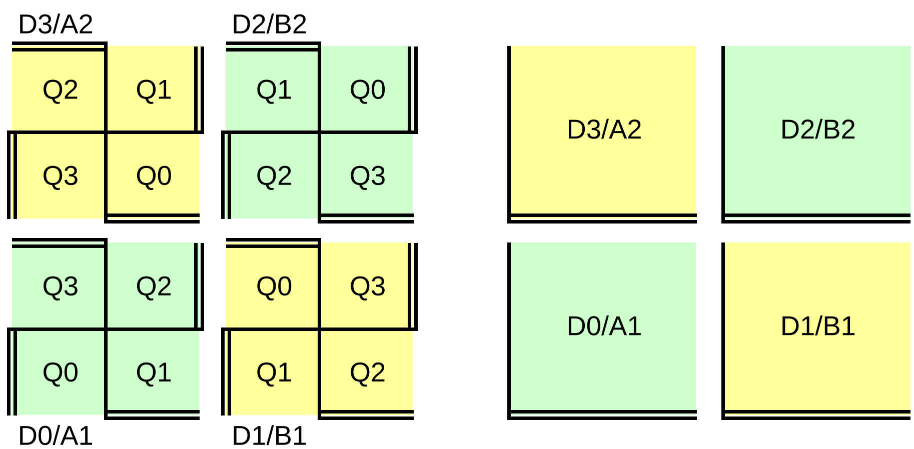

Figure 2: Detector arrangement. The x-axis, which changes more rapidly in the image file, is shown with double lines, and the single line is the y-axis. The right panels show the entire detector, and the left panels show the separate quadrants.

Pinholes on a mask plate are used to make artificial stars (Figure 3). There are three requirements. (1) Focus all four detectors over a range of (–1,+1) mm in order to see a substantial change in the image. Use wells that are 0.9 and 1.5 mm deeper to cover the negative range. Put pinholes on washers to cover the positive range. (2) Measure the tilt for all four detectors. For that, pinholes need to cover the full range of distances from the rotation axis of 4-eye. Pinholes at A5–A7 and B6–B8 are used to measure the tilt for two detectors. They need to be rotated slightly to measure tilt for the other two detectors. (3) Cover the corners and center of the field to evaluate the image over the field.

	x	y	z	$z - z_0$	ϕ
	mm	mm	mm	mm	μm
A1	45.72	45.72	2.18	–0.01	8
A3	25.40	25.40	0.66	0.01	8
A4	7.62	25.40	0.36	0.01	8
A5	16.51	16.51	0.36	–0.07	8
A6	45.72	7.62	1.12	0.00	8
A7	25.40	7.62	0.36	0.01	8
A9	7.62	35.56	1.60	–0.91	8
A10	16.51	30.48	1.52	–0.90	8
B1	–45.72	45.72	2.18	–0.01	8
B3	–25.40	25.4	0.66	0.01	8
B4	–7.62	25.4	0.36	0.01	8
B6	–45.72	7.62	1.12	0.00	8
B7	–25.40	7.62	0.36	0.01	8
B8	–7.62	7.62	0.10	–0.04	8
B9	–7.62	35.56	1.60	–0.91	8
B10	–16.51	30.48	2.11	–1.48	25
B11	–25.40	35.56	1.91	–0.91	8
C5	16.51	–16.51	–0.64	0.93	8
D4	–7.62	–25.40	–0.64	1.01	5

Table 3: Parameters of the pinholes, namely location x and y, axial position z, offset $z - z_0$ from the focal surface of the telescope, and diameter ϕ. The axial position includes the depth of the well and washers. A positive offset is toward the interior of the instrument.

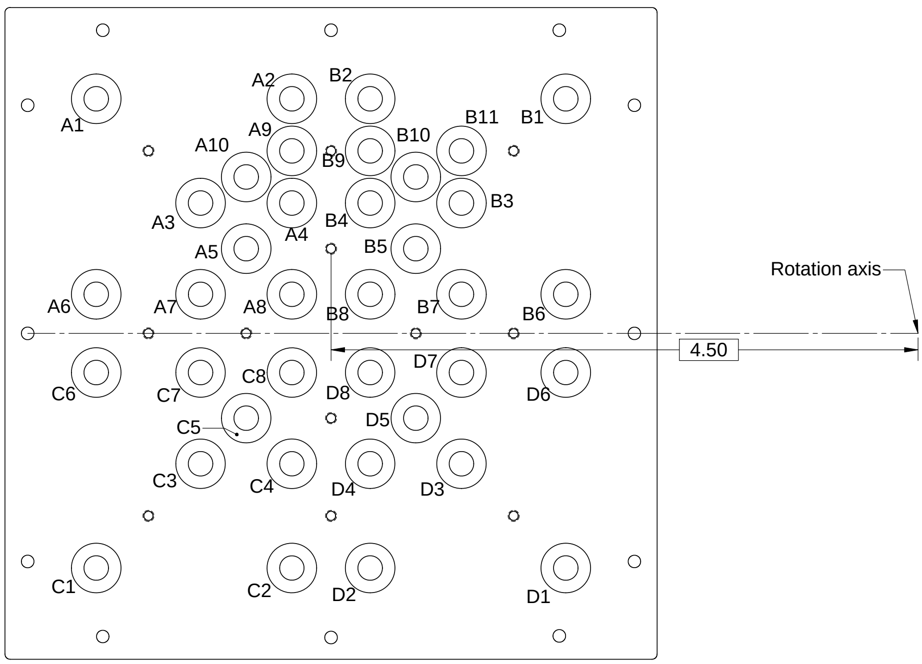

Figure 3: Pinholes as viewed from inside the instrument with the top up. If the mask is centered, the A, B, C, and D pinholes image onto the detectors 1, 0, 2, and 3, respectively.

2 Auto fill and heater control

We made an auto-fill system for liquid nitrogen, since cooling and keeping the nitrogen filled is a burden for a single person. The system consists of an NI USB-6525, which has relay drivers, a Crydom D1202 relay, and a power supply for the relay. The relay drives a liquid-nitrogen valve, which is part of a Lesker LN2-SL500 kit.

The software, LiquidNitrogenValve.vi, opens the valve if the temperature of the liquid nitrogen reservoir is above the trigger point. The valve remains open for a certain time. With the hand-operated valve open slightly, an open-time of 4 min is acceptable: The reservoir is not overfilled so that liquid comes out of the vent.

The trigger point must be higher at the beginning of cooling (Figure 4), since the nitrogen reservoir is several degrees warmer than the boiling point. Later, the trigger point may be lowered.

It is possible to sense the temperature of the vent and to shut off the valve when liquid comes out of the vent. However, we would need to make an appendix that fills with liquid independent of the orientation of the instrument. The temperature of the vent does not change significantly when liquid comes out of the vent, because liquid, exiting rapidly, does not cool the vent much more than gas.

When cooling, the valve opens every half hour initially, and then less often (Figure 4 and Table 4). It takes 25 hr before the time between fills lengthens to more than 8 hr. Without the autofiller, cooling requires three consecutive 8-hr shifts.

time	*open for*	*hold time*	*time*	*open for*	*hold time*
5.7 hr	9. min		14.	6.	2.7
6.3	4.	0.5 hr	19.	5.	4.8
6.8	5.	0.4	25.	5.	6.
7.6	6.	0.7	30.	7.2	
8.4	6.	0.7	44.	6.	14.
9.4	6.	0.9	46.	4.6	
11.	6.	1.8			

Table 4: Autofill history. Time 0 is the start of filling. Before time 5.7 and at 30 and 46, the valve was operated manually.

We made a heater control with the NI6522, relay, and the software, Heater.vi. Every minute, the software checks the temperature of the nitrogen reservoir and the temperature of the heater. The software turns on the heater for 5 min if the temperature of the nitrogen reservoir is below 21 C, and it turns off the heater if the temperature of the heater is above 30 C. See Figure 5 for the warm-up.

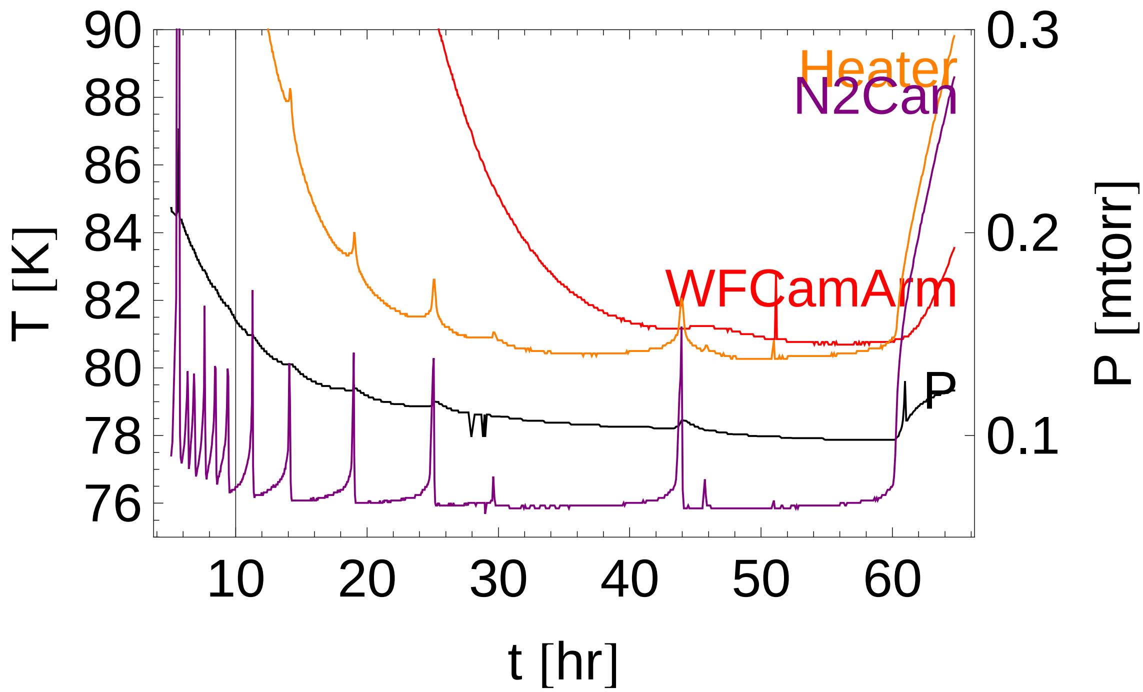

Figure 4: Temperatures and pressure during cooling. Nitrogen was first added at t=0. Filling was initiated by hand for the two cases where the temperature of the nitrogen can rose slightly at t=30 and 46. The instrument started to warm up at t=60. The fact that the temperature of the nitrogen reservoir is less than 77.35 K indicates the calibration of the temperature sensors is off.

3 Cooling and warming

Cooling the instrument requires 40 hr (Figure 4). The wide-field camera arm, for which heat conduction is through bearings with little contact area, requires the longest time to cool.

When cold, the pressure is 100 μtorr, whereas it was 2 μtorr at the start of run 2 and gradually increased to 8 μtorr.[6]

A load of liquid nitrogen lasts 14 hr (Table 4). The hold time used to be 20 hr.[7]

Warming the instrument above the dew point took 80 hr with the heater (Figure 5).

An hour after liquid nitrogen was exhausted, the pressure rose rapidly and then

[6]Baker, D., & Loh, E., 2007, Cold test 3, run 2, Spartan IR Camera for the SOAR telescope.
[7]*ibid.*

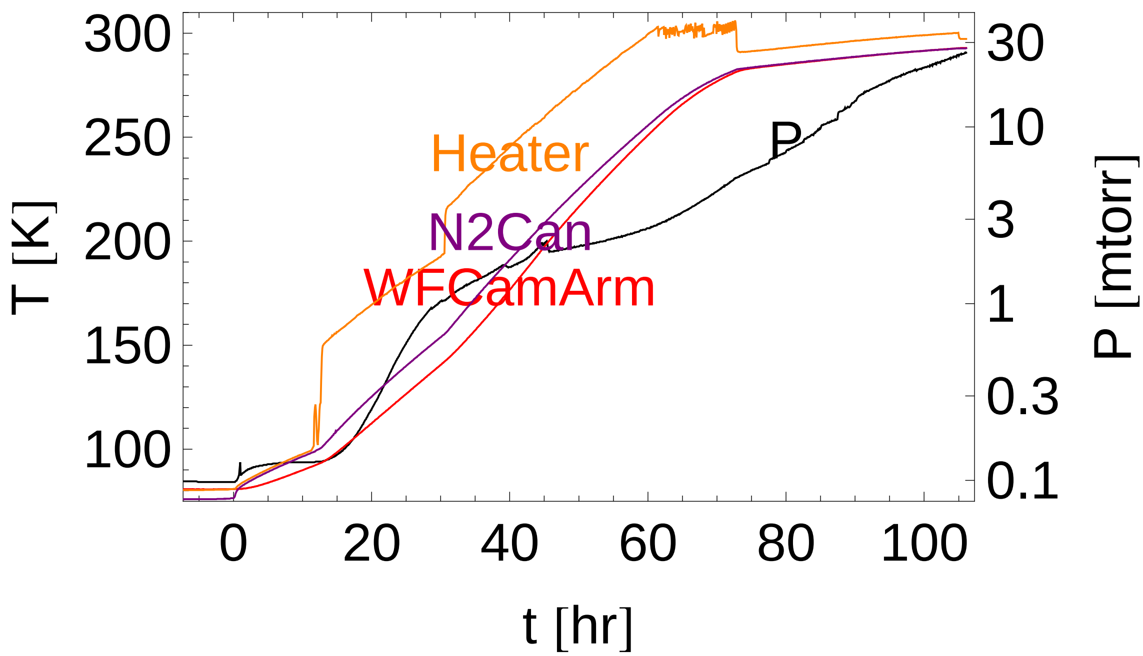

Figure 5: Temperatures and pressure during warming. Nitrogen was exhausted at t=0. Ten hours later, the heater was turned to 50 V. The voltage was increased to 80 V at 30 hr and decreased to 20 V at 70 hr.

dropped. A possible explanation is that the temperature of the charcoal closest to the nitrogen reservoir rose and released some gas. Over several minutes, some charcoal farther from the reservoir adsorbed the gas. (The charcoal is glued to the reservoir, but the thermal conductivity of charcoal is poor.)

The pressure rise occurs in three regimes. The pressure rose from 0.1 to 0.12 mtorr at T_{N2Can} = 84 K and flattened. The pressure rose again (to 2 mtorr) at T_{N2Can} = 130 K and flattened. The pressure rose (ultimately to 30 mtorr) at T_{N2Can} = 280 K. The specified temperatures are where the pressure is half of the rise.

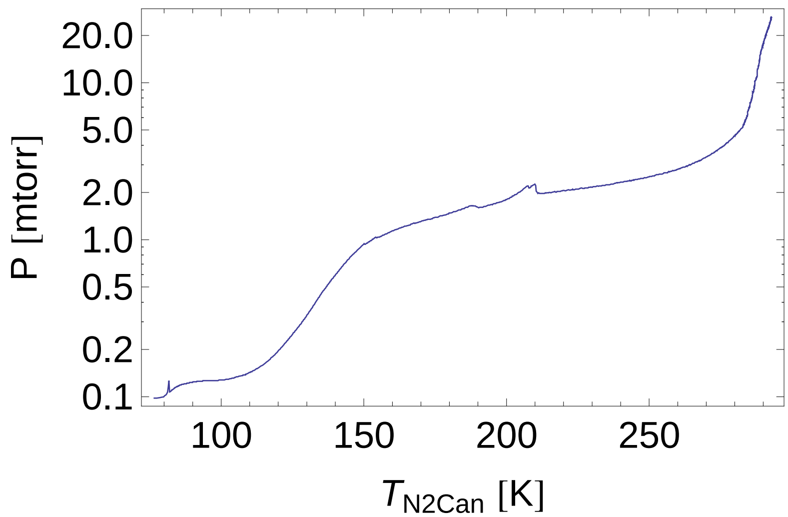

Figure 6: Pressure vs temperature during warm-up.

Possibly the three regimes are due to the release of three gasses, nitrogen, oxygen, and water. It is perhaps surprising that the pressure of the middle regime, identified as oxygen, is 16 times greater than the pressure of the coolest regime. However, the permeability through Viton of oxygen is 20 times that of nitrogen.[8]

4 Contaminated charcoal getter

The shorter hold time (14 hr) is a problem, since refilling would be required during a night of observing. The pressure (100 μtorr) is higher. A possible cause is helium left from testing for leaks. However, the instrument was pumped over a weekend. A more likely cause is that the charcoal getter became contaminated when the window broke during run 3 of cold test 3 (CT3R3). The pressure had been consistently less than 10 μtorr for all of the cold tests up until CT3R4.

Since the existing charcoal is glued on the nitrogen reservoir inside the cryo-optical box (COB), replacing it requires major work. We have built a charcoal well that attaches to the outside of the COB. It may be replaced without opening the

[8] O'Hanlon, John F., 1980, A User's Guide to Vacuum Technology, Wiley, New York, p. 390.

COB. Its location, though convenient, is not ideal for the operation of the getter. Its temperature is slightly higher. The surrounding radiation is warmer. It presents a less open face to gas, since the multilayer insulating blanket covers it.