

# Lifetime Tests of the Mechanisms Spartan IR Camera for the SOAR Telescope

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## Abstract

The requirement is to test each mechanism for 10% of the number of cycles expected over the life of the instrument. We found wear on the antibacklash springs for the mask and filter wheels. We found fraying on the quartz strings that drive the 4-eye detector mechanism. We redesigned the antibacklash mechanism to use a torsional spring instead of a brake. We eliminated the sharp edges that cut the strings. These modifications having been made, the mechanisms for the mirror arms, 4-eye, and the big filter wheel ran successfully with the instrument cold for 10% of the expected life of the instrument.

## 1 Requirements

Over a 10-year lifetime operating for 25% of the time, the instrument runs for 9000 hr. The expected period between movements of each mechanism during observing and expected number of movements during the instrument life are in Table 1. We plan to test each mechanism for 10% of its expected number of movements. Testing the low-res collimator for the 450 movements takes 7 hr.<sup>1</sup>

Table 1: Required life of the mechanisms and test duration for 10% of the lifetime at 30% duty cycle.

<i>Mechanism</i>	<i>Period</i> <i>[hr]</i>	<i>Movements</i>	<i>Test</i> <i>[hr]</i>
Mask wheel	3	3,000 @90°	5
HR collimator	2	4,500 90	7
Wheel for Lyot stops	2	4,500 90	7
Filter wheel	0.1	90,000 20	32
LR camera/4 eye	2	4,500 90	7

<sup>1</sup>Moving 90 deg from the low-res to the high-res position takes 17 s. At room temperature, running at 100% duty cycle causes the motor to get very hot. Running at 30% duty cycle is acceptable.

## 2 4 eye mechanism

<i>Date</i>	<i>End at</i>	<i>Change</i>	<i>Result</i>
16 Nov 2006	7%		String broke at guide #3.
01 Dec 2006	10%	New smooth guides. New installation procedure for roller bearings.	See inspection report.
30 Mar 2007	10%	New split rings. Polished holes for #2 strings.	Success during Run 2 of Cold Test 3. Strings did not fray.

Table 2: Log of the lifetime test for 4-eye

The Henein flexible bearings, cut from a single piece of aluminum, did *not* fail. Although the thin flexible sections appear fragile, the stress is actually low: they are designed for millions of cycles.

The quartz strings have broken where they run against edges, defined to be where the radius of curvature changes abruptly. In the course of reducing friction, we eliminated several edges, but this test revealed another problem with an edge at guide #3 where the string turns 90°. A roller bearing provides most of the supporting force, but if the roller bearing is misaligned, the guide pushes on the string. (The guide has an edge.) After running for 7% of the instrument lifetime, the edge cut the string.

If the roller bearing is installed more than 20° from the proper angle, an edge on the roller bearing assembly can cut the string. We wrote new instructions for installing the roller bearings.

We made new guides with no edges that are accessible to the string.

The test of 1 December ran to completion. The position of the reverse limit remained true to a quantum, which is 0.1 step (Figure 3). After the test, we inspected the strings and these are the results:

**#1 strings** run from an eye through the spine, onto a Teflon tension equalizer, back through the spine, and to another eye. The string attaches to an eye with a wire ring. Although three of four strings show no problems, one string has a few cut strands where it runs through the wire ring. The wire ring is a McMaster #90990A120 split ring, which is made of two loops of a wire. The ends of the wire are sharp (Figure 1). Apparently one of the 8 ends of the #1 strings was installed on a sharp edge of a split ring. We will replace the split rings with custom rings made of #18 copper wire soldered to hide the ends of the wire.

**#2 strings** run from a tension equalizer of the #1 strings, through the spine, to a tension equalizer, back through the spine to a tension equalizer of another #1 string. There are a few broken strands where the strings go through the spine. We have no explanation. The force between these strings is the same as that for the #1 strings, which are fine. We will inspect the holes in the spine more carefully.

**#3 strings** run between two tension equalizers for #2 strings through a Teflon temperature compensator. These strings run through guide #1 to change direction. There is significant wear at guide #1. It is likely that the wear occurred when the old, sharp guides were installed.

**#4 strings** run from the string, through guides 2 and 3, and onto the anchor on the f/12 camera mechanism. They are fine; there is no sign of any wear.

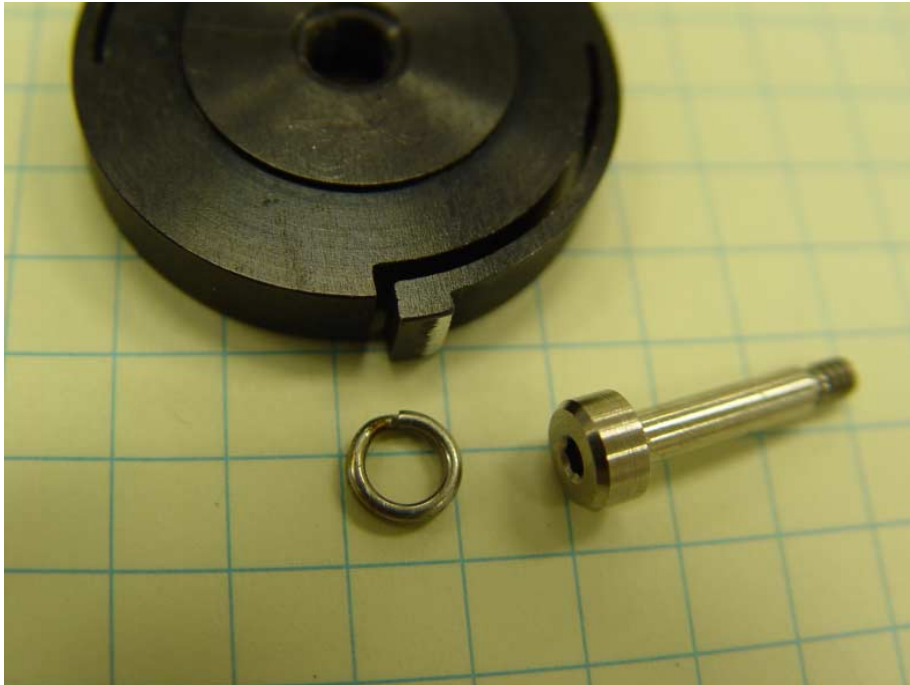


Figure 1: Antibacklash brake for the big filter wheel and a wire ring used in the 4-eye mechanism. Note the worn, shiny part of the brake shoe. The other shoe (diagonally opposite) is only very slightly worn. A string loops through the wire ring, and the shoulder bolt holds the ring on an eye. The wire ring has sharp ends at the ends of the wire.

We replaced the split rings with custom rings and polished the holes in the spine for the #2 strings. See §4 for the tests conducted during and after Run 2 of Cold Test 3.

### 3 Wheels

We tested the mask and filter wheels. For each cycle, the test is to find the location of the reverse limit switch, move 24 90-degree steps, and then find the reverse limit again. In alternate cycles, the motion is reverses direction.

The position of the reverse limit is true for the little filter wheel, but not for the mask and big filter wheels (Figure 2). In addition, the anti-backlash mechanism, which is a brake, shows wear.

**Little filter wheel** The position is true. The anodization of the brake is polished but not worn through.

**Mask wheel** The rotation stage lost position three times, at cycles 13, 15, and 16. The anodization on the brake wore through in three places.

**Big filter wheel** lost position in two large jumps and many small jumps. One of the brake shoes is worn (Figure 1).

The the rotation stages, which have no position sensors, lose position. The rotation stages use stepper motors without feedback.

Clearly the brake does not work. The brake is wearing, even though the computed stress is two orders of magnitude less than the strength of aluminum (the brake material). Apparently, the aluminum powder lubricates the brake and negates the friction needed for the antibacklash function.

We designed a new antibacklash mechanism that uses a torsional spring instead of a brake.

The torsional antibacklash spring works well. We tested it on the big filter wheel at room temperature, and the results are in Figure 3. The standard deviation of the position of the reverse limit is 0.2 step.

See §4 for the tests conducted during and after Run 2 of Cold Test 3.

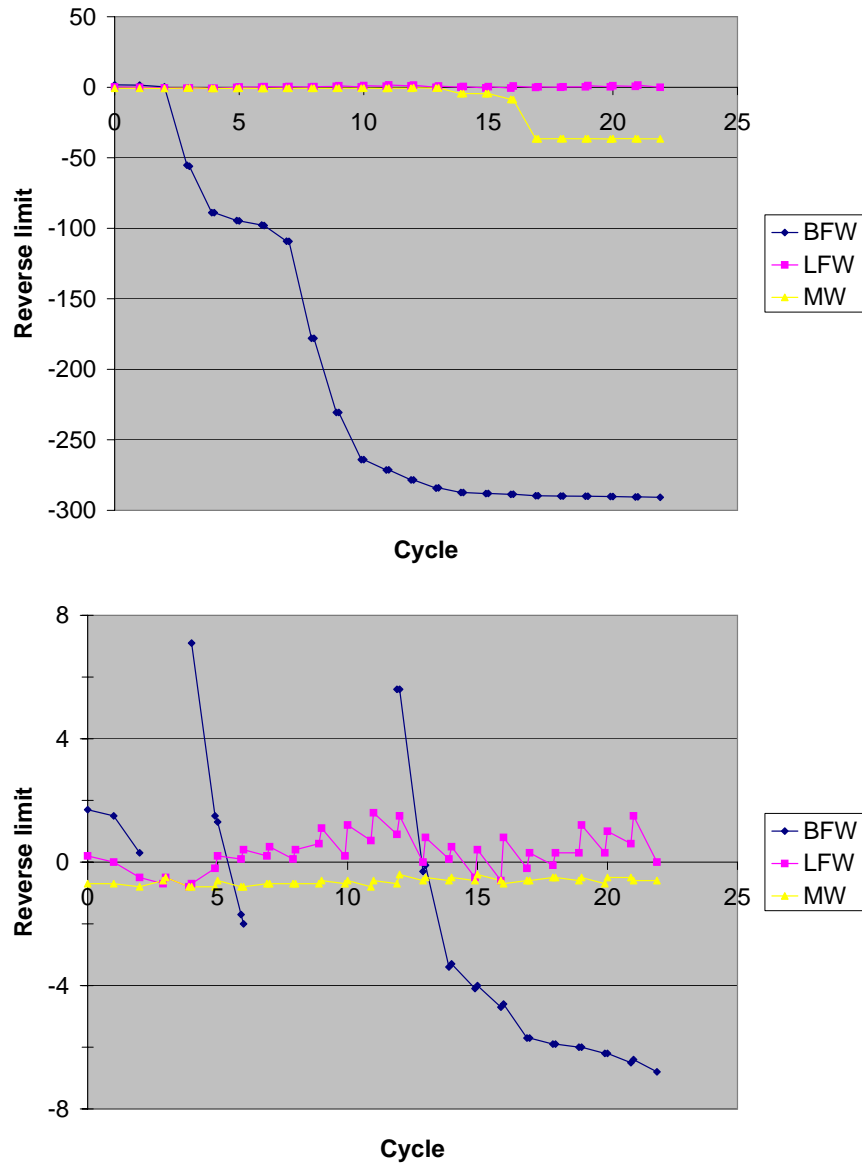


Figure 2: Top: Position of the reverse limit for the big filter wheel, little filter wheel and mask wheel vs. cycle of the test. In one cycle, the wheel makes 24 90-degree moves. The position is in full steps of the stepper motor. The current in the stepper motor repeats every 4 steps. Bottom plot: The position of the reverse limit of the mask is shifted by 1, 2, and 9 periods starting at the end of cycles 13, 15 and 16. For the big filter wheel, only cycles with small shifts are shown, and multiples of full periods are added to keep the position on the plot. The data for the little filter wheel are shown as is.

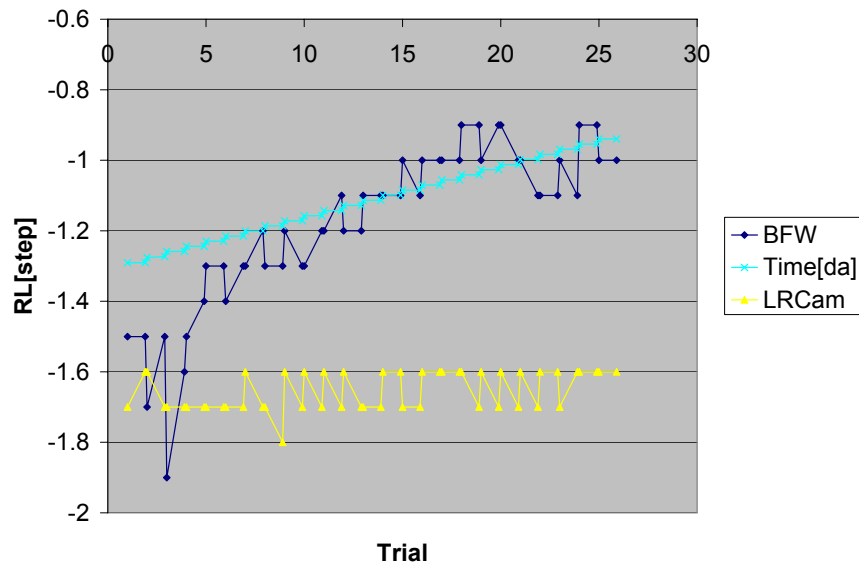


Figure 3: Lifetime test at room temperature with the torional antibacklash spring installed on the big filter wheel. Position of the reverse limit for the big filter wheel and wide-field camera vs. cycle of the test. The position is in full steps of the stepper motor. The time in days is also shown for the test of the big filter wheel.

## 4 Final test with the instrument cold

During Run 2 of Cold Test 3, we tested the mirror arms, 4-eye, and the big filter wheel, which has the new antibacklash spring. We ran 25 cycles of the script BFWf12f21LTTest. This script moves the big filter wheel  $80^\circ$  12 times and  $100^\circ$  6 times, the high-res collimator  $90^\circ$  18 times, and the low-res camera mirror  $90^\circ$  18 times. Since the mechanism for the low-res camera mirror drives 4-eye, 4-eye moves also. At the beginning and also at the end, this script finds the reverse limit switch of each mechanism to check whether positioning is true. With 25 cycles of the script, the big filter wheel moves  $20^\circ$  1,950 times, the high-res collimator moves  $90^\circ$  450 times, and the low-res camera mirror moves  $90^\circ$  450 times.

The position of the reverse limit for the three mechanisms (Figure 4) repeat within a full step of the stepper motor. The standard deviations are 0.18, 0.15, and 0.10 step for the big filter wheel, high-res collimator, and wide-field camera, respectively.

After the test, we verified that the pinholes on the mask wheel were in focus for the wide-field channel. Therefore 4-eye was functioning after the lifetime test.

We disassembled 4-eye and found none of the strings frayed.

Therefore the mechanisms for the mirror arms and 4-eye ran successfully with the instrument cold for 10% of the expected life of the instrument, and the mechanism for the big filter wheel ran successfully for 2.2% of the expected life of the instrument.

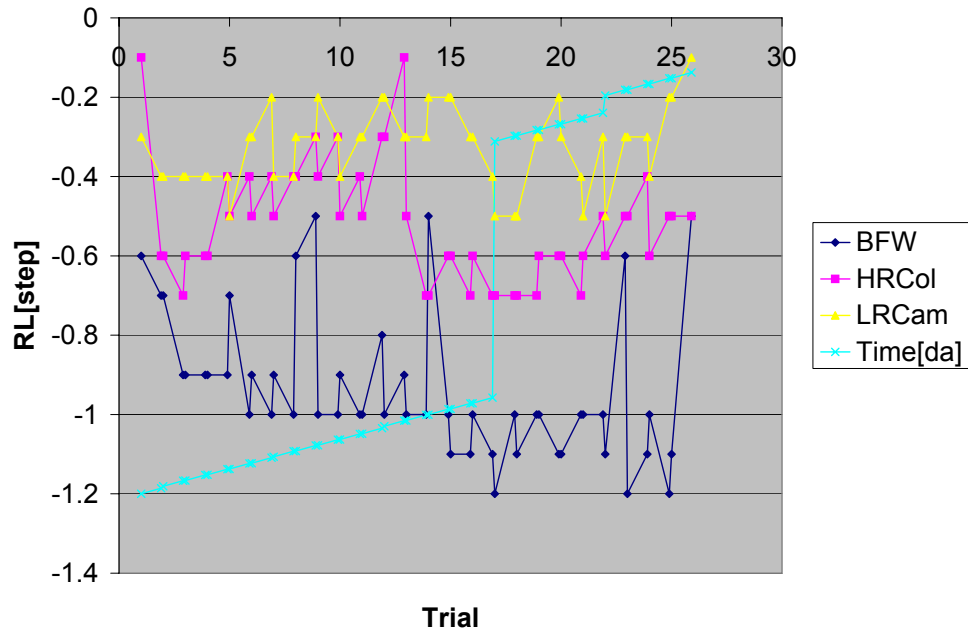


Figure 4: Lifetime test during run 2 of cold test 3. Position of the reverse limit for the big filter wheel, high-res collimator, and wide-field camera vs. cycle of the test. The position is in full steps of the stepper motor. The current in the stepper motor repeats every 4 steps. The time in days is also shown.