

# LRIS Blue Channel Shutter History

Updates	Author
2006 September 27 Original Version	Marc Kassis
2010 June – Following Failure	Marc Kassis
2012 September	Luca Rizzi
2013 September	Luca Rizzi

## Introduction:

This document is a status report for the suite of blue side shutters in use at the Keck Observatory. This is to provide a history of service and track when the shutters have been replaced inside LRIS.

Below, the shutter operation is briefly described. A list of shutters that have been or are in use with the blue channel is presented along with history of the failures and repair work that was completed on each shutter. Following the description and history are suggested options for the future and notes concerning the failures.

## Shutter Description and Operation:

There are four Prontor E/100 iris type shutters that could be used in the LRIS blue channel. The packaging of the shutter is relatively thin so as to fit inside the gimbal mount just in front of the dewar window and behind the camera optics. The measured force required to open and close a freely moving shutter is roughly  $\frac{1}{4}$  lbs. Two thin rods screw into a custom pivot pin that attaches to the pivot arm on the shutter. The pivot arm is moved back and forth to open and close the shutter. Two armatures or plungers attach to the thin rods and slide in and out of two 12 V, magnetically latching solenoids. The thin rods are designed to pass through holes in the gimbal support housing. The shutter is only accessible after removing the dewar and gimbal. See figures one and two below for views of the shutter, pivot arm, pivot lever, thin rod, and armature.

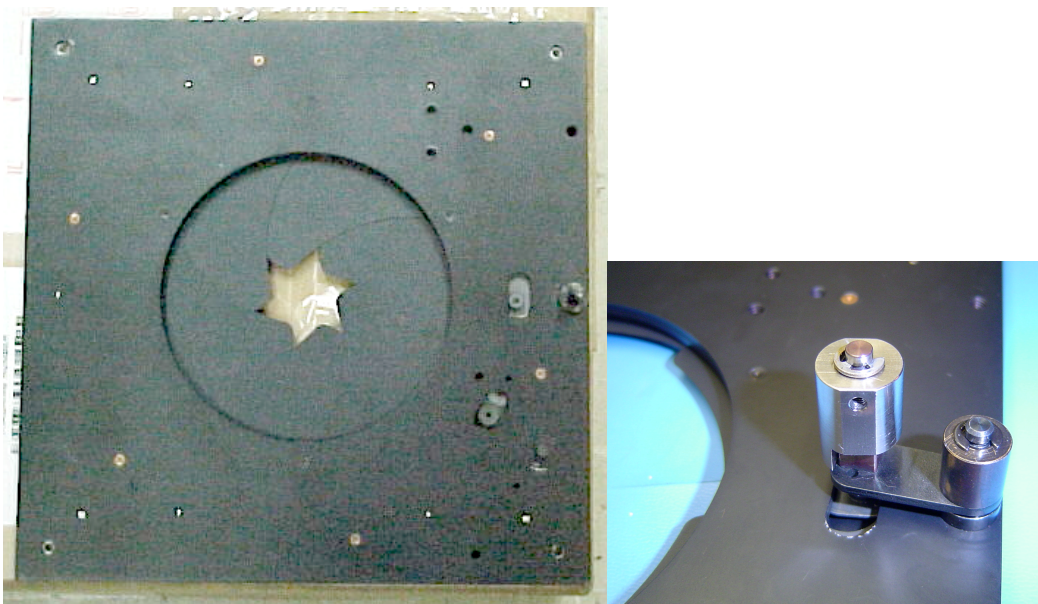
To open or close the shutter under normal operation, the solenoids are pulsed with a 48 V pulse approximately 50 milliseconds long. The current to one solenoid is reversed, to oppose the magnetic field of the latching magnet, while the other adds to the latching magnet field. The result is a very fast transition from open to close or vice versa. After the pulse is gone, there is no current through the solenoids, so the magnet in the one with the armature seated maintains (latches) the shutter open or closed, while the other armature is extended and thus the magnet does not have enough force to pull the shutter back. In order to reduce the gradient effect on the image caused by the opening and closing transition of the iris type shutter, the transit time had to be on the order of one tenth the exposure time (less than 0.1 s).

Lifetime tests of the Prontor E/100 shutter included placing the shutter in a freezer and cycling the shutter open and closed 275,000 times without a failure. The conclusion of the test was that the shutter would have lasted more than 10 years during normal

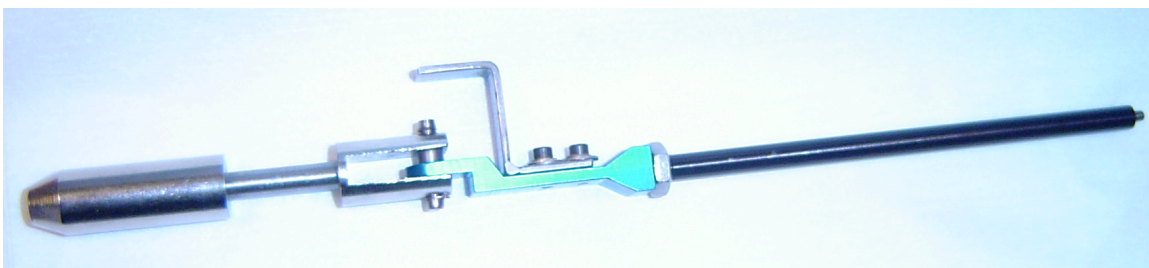
operation. The tests also indicated that the dri-lube was worn and cracks formed in some of the shutter blades near the pivot points. The recommendation was to replace shutters every five years as a precaution against failure due to the blade pivot cracking.

There is no feedback that indicates that a shutter is open or closed. Thus, the only indication that a shutter has failed is when an observer notices oddities in an image or a skilled technician notices audible differences in the shutter mechanics.

Before May 2006, shutter failures have resulted in a significant loss of data. Since 2006, software and hardware modifications enable observers to use the trapdoor as a shutter when the blue shutter fails.



*Figure 1: Face on view of a Pronto E/100 shutter used on the LRIS blue channel (left). The shutter is slightly open. The pivot arm has been removed in this view. At right, the pivot arm and custom pin are shown. The thin rods thread in the tapped hole seen in this view of the custom pivot pin.*



*Figure 2: Assembly of the armature and the thin threaded rod. The armature at the left of the image fits inside a solenoid.*

## Descriptions of the shutters available for use with LRIS

The shutters nomenclature is adopted from a recent LRIS Blue Shutter ‘B’ examination report. In this document, Shutters C and D are identified. Four shutters have been used with the LRIS blue channel. Two modifications were made to these shutters by Caltech. The first was to replace the spring-loaded solenoid operator. This was done to allow Caltech to decrease the opening and closing time and to fit the shutter into the camera. Second, Caltech fabricated pivot arms using new materials to increase reliability.

- 1) Shutter A – This shutter belongs to Caltech.
  - a. a.k.a. Original Shutter
  - b. Identifying marks: “Shutter A”
  - c. Location: Keck
  - d. Status: May be usable, but is a spare for Palomar
- 2) Shutter B
  - a. a.k.a. NBC spare
  - b. Identifying marks: “Shutter B” and dated with a paint pen.
  - c. Location: Keck
  - d. Status: needs repair
- 3) Shutter C
  - a. a.k.a. lifetime test shutter
  - b. Identifying marks: “Shutter #3 Repaired April 2004” written with white paint pen. Also labeled “C” in 2010.
  - c. Location: Keck
  - d. Status: needs repair
  - e. Repaired in Sept 2012, ready for use.
- 4) Shutter D
  - a. a.k.a. the missing shutter
  - b. Identifying marks: Machine stamped as B89, “Shutter #4” written with white paint marker.
  - c. Location: Keck
  - d. Status: Installed in the LRIS blue channel

## Operational History:

The history is compiled from e-mail communication with Caltech, Keck 1 night and day log tickets, and a Microsoft Outlook forum for tracking instrument tasks. The night and day log ticket numbers are provided so that further details of the failure may be reviewed.

Date	Shutter	Description
May 1999	C	Life time tests resulted in cracks at the blade pivot points.
May 2000	A & D	LRIS commissioned at the Keck Observatory. Shutter A is in use. Shutter D is provided as a spare.
Dec. 2001	A	Oil contamination leads to increased friction

		preventing the shutter from opening and closing. Shutter D was is misplaced. K1-10685
Feb. 2002	A	Oil contamination leads to increased friction preventing the shutter from opening and closing. K1-10796
Jan. 2003	A	Failed due to a defective lever part which clearly had disintegrated into two pieces.
?????	B	linkage mal-adjustment. An internal stop button pressed into one of the blades and was sheered off. The piece jammed inside the shutter housing. A failure described by Caltech staff that could not be found in our records.
30 Aug 2003	C	The shutter only opens about 80% and closes 90%. One of the leaves is bent and it is also possible that two of the leaves have dings on them. One of the blades was cut. K1-07638
2 June 2004:	B	One of the blades did not properly close and started hitting a second blade. The second blade was cut through. K1-12950
May 2006:	C	Shutter was stuck wide open. When it was removed, the shutter was noticeably binding. After 50 cycles, the shutter began operating but with noticeable friction. K1-09452, K1-09448, K1-09406
Aug 2006:	B	The pivot pin and pivot arm were responsible for binding the shutter. The force required to open and close the shutter was 3 lbs vs. ¼ lbs for the spare. K1-09780
April 2007	D	Cleaned pivot pin and bushing. Applied dry moly to pin and reassembled. Measured ~1oz open and close after reassembly. K1-10591, K1-16099, K1-16103, K1-161114
June 2010	D	K1-19120
July 2010	B	Taken off on Sept. 2012. Shows small signs of grease contamination and it's somewhat hard to move, but was not about to fail.
September 2012	C	Currently installed. Cleaned and inspected by Dwight and Gary.
September 2013	C	Removed Blue side dewar and camera assembly today. Removed gimbal off of camera and test shutter. Shutter tested okay with approximately 3 oz. pull force to open and close shutter. We did not replace the shutter. Shutter C is installed on the camera assembly. We tested the shutter in the lab with the controller with no problems. We tightened the solenoid bracket that was loose and added some loctite to both the open and close sides.

June 2014	Removed C, installed B	Replaced blue shutter on camera assembly. Installed shutter "B", removed shutter "C". Pull test on shutter "B" 2.4 oz. We then installed the camera assembly on to LRIS. We will install the dewar sometime next week.
March 14, 2016	Removed B, installed D	A number of problems started surfacing after about a month. Mostly shutter not closing completely. We scheduled a new mission for as soon as possible.
May 17 2016	Removed D installed C	Shutter labeled #4 has a loose leaf. This is the one that was removed

### **Summary of damage and repair work:**

#### Shutter A

- Cleaned of oil contamination twice
- Bearings replaced and lever pin replaced with custom delrin bearings after the lever pin disintegrated.
  - A does not have a hard stop -
  - Circle on a pin on one side and an arrow on the other with an indication that it may be stripped.
- MK – Checked with Lick about hard stop missing

#### Shutter C

- Shutter leaves were replaced.
- Shutter pivot pin and lever arm were worn and binding.
- Work required to make it a serviceable spare: reverse engineering to fabricate a new shutter pivot pin and lever arm
- 2010 June – MW/DC assessed shutter and determined that it is a usable spare.
- 2012 September: repaired and installed
- 2013 September: shutter solenoids failed. Shutter was unable to close completely. Repaired and re-installed. See K1-18276

#### Shutter B

- Blade pivot lever parts and blades replaced after worn and cracking during lift time tests.
- Blades replaced in Aug. 2003
- Contaminated by oil in May 2006

- There is also a probable crack in two blades, both at the pivot point in May 2006
- Work required to make it a serviceable spare:
  - Blades need to be replaced
  - recoat some parts where the dry lube has worn off
- Oct 2008- Shutter repaired by Lick (Cowley) & June 2010 MW/DC reassessed shutter and determined it is a serviceable spare.

#### Shutter D –

- Although the history of this shutter prior to April 2006 is unknown, it is likely that this shutter had not been used.
- Cleaned pivot pin and bushing. Applied dry moly to pin and reassembled. Measured ~1oz open and close after reassembly.
- 23 July 2010 – under refurbishing – M Wagner leading effort. Bad bushing identified to be a probable cause for failure. Leaf where bushing failed does not always open or close completely.
- May 17 2016 – removed from instrument. Found it had a loose leaf.

#### **Oil Contamination:**

Caltech assessment is that the oil in combination of the severe weather that was encountered during the 2005-2006 winter led to increased friction between the parts that resulted in the failure in May 2006. The increased friction delayed the operation enough that the 0.05 second pulse ended before the shutter was completely open or closed. This assessment could also be applicable to the failures in December 2001 and February 2002.

The oil mentioned above is identified as the coupling fluid that leaks from the lens cell. When the fluid coats the shutter blades and linkages, they tend to stick together. This increases the operating loads on the components and sometimes prevents the shutter actuation from completing.

Because of the increased friction, we can expect these shutters to reach a mechanical failure sooner than lifetime tests indicate. Based on the failures of shutter C, the oil contamination places additional loads on the blade pivot points which accelerate the blade pivot point cracking. This means that shutters need to be replaced more frequently than was originally recommended (5 years). Shutter C lasted 2.5 years before being rebuilt.

#### **Status of spare parts:**

There appear to be two parts that suffer significant wear in the Prontor shutter. One is the blade, and the other is the pivot lever for the shutter. Both wear at the pivot pin-shutter blade interface, because of the high speeds at which the shutter must operate. The Prontor shutters are being pushed faster than how they were designed to operate, but the life time test results convinced everyone that the shutter parts would have an adequate life.

Prontor neither makes the shutters nor supplies parts. The remaining Prontor shutter stock was reviewed by Josh Sioringas, a customer service representative with Schneider Optics who represents Prontor in the US. No blades were found for the Prontor shutter.

At Caltech, there are both shutter blades and levers available, but they are all used and have to be checked carefully for wear and cracks. Some parts may only need to be recoated while others are unusable.