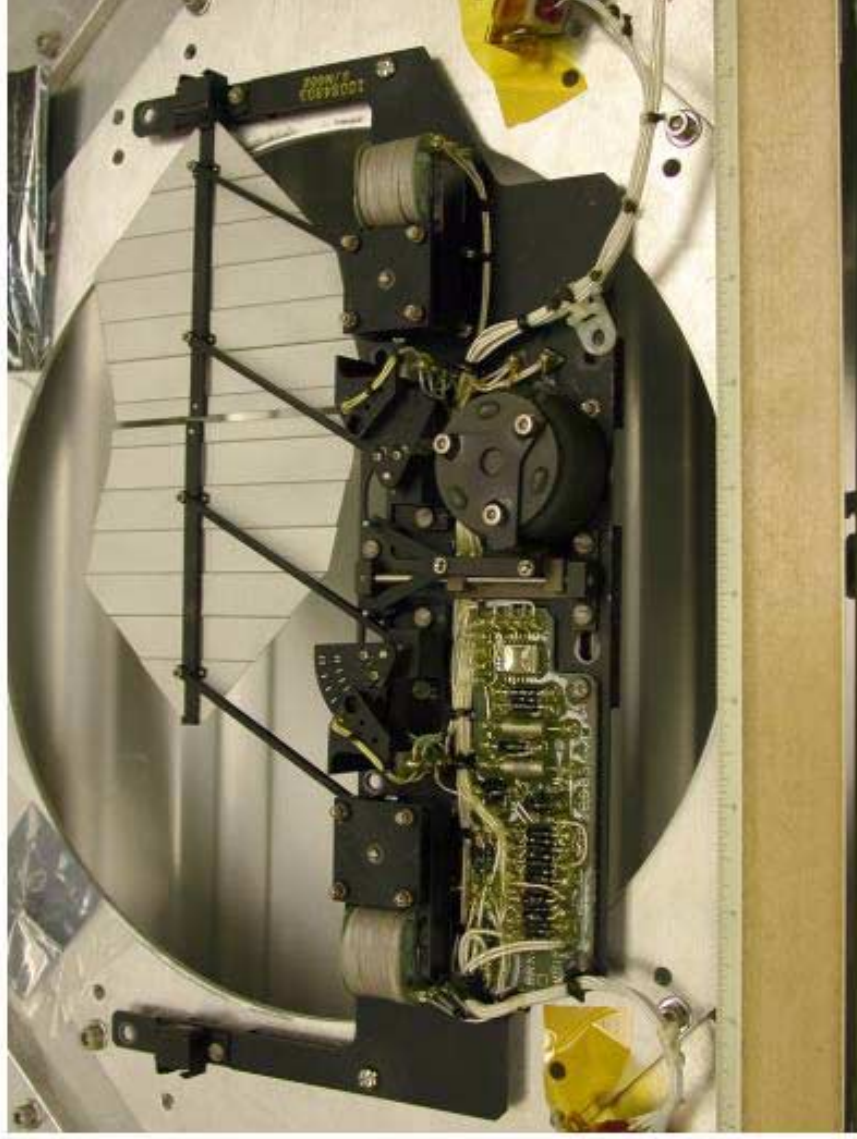


WFPC2 Shutter Anomaly History and Status

Chronology of events

- ◆ First detected event: shutter failed to open on August 31, 2000
- ◆ Reports both blades closed (physically impossible - Blade A open)
- ◆ Tiger Team review: Sensor malfunction, possibly single-event upset
- ◆ Second event detected on October 2: 13 consecutive failed exposures.
- ◆ Camera safed until October 6. More events found (August 21, 30). ARB formed.
- ◆ **Commanding analysis: multiple failures due to a single anomaly:**
 - Failed short exposures do not reset shutter, thus following exposures fail until first exposure > 180s. Camera restarted, normal with a few failures.
- ◆ **Secondary anomaly on October 26:**
 - Usual anomaly followed by shutter open at end of exposure.
 - Interpreted as shutter bounce. Camera safed November 1.
- ◆ **RAM patch developed to address the primary anomaly: extends LED on-time prior to sensor readout. Installed and verified November 8.**
- ◆ **Suite of WFPC2 test exposures to verify functioning and calibration of camera pre- and post-patch. All checks passed. Camera returned to science operations.**
- ◆ **About 1000 images taken since November 8; no anomaly detected.**

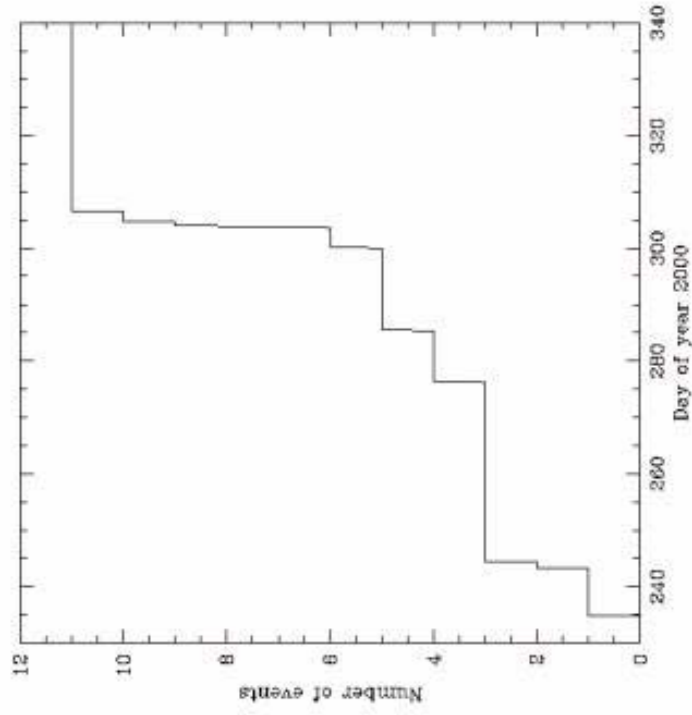
WF/PC shutter



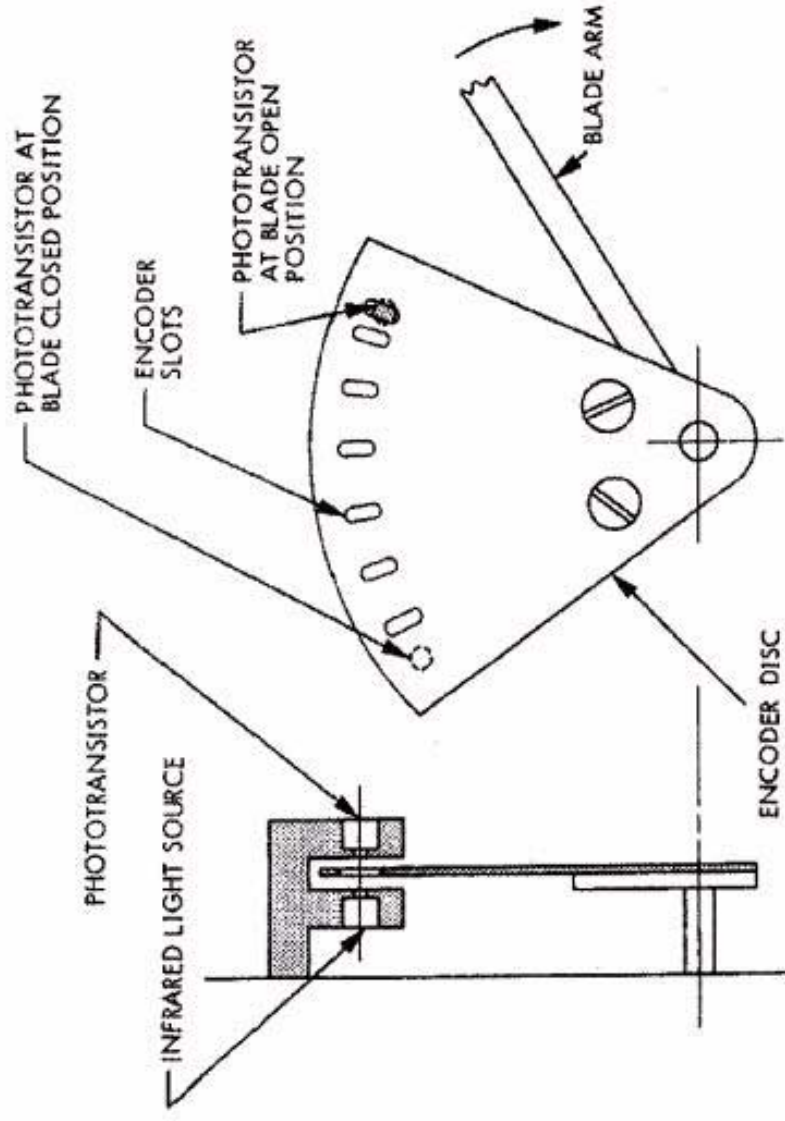
Current Status and Understanding

- ◆ 11 separate primary anomalies, August 21-November 1 (2417 exposures), of which 6 between October 26 and November 1 (79 exposures)
- ◆ 3 secondary anomalies: October 26, 29, November 1
- ◆ Primary anomaly most likely due to degradation in LED/sensor assembly combined with mechanical misalignment:
 - At start of exposure, microprocessor inquires about blade position
 - LED turned on, sensor polled after 30 μs (light = blade open, no light = blade closed). Blade A sensor incorrectly reports no light, implying both blades closed. Error condition occurs, shutter open operation aborted; Blade A remains open, B closed
 - Blade A sensor correctly reports light (blade open) after 200 μs , when the register value is stored in telemetry data - too late
 - If exposure < 180s (i.e., under microprocessor control), all shutter activity aborted. Shutter does not move, next exposure will also see anomaly
 - If exposure > 180s (i.e., under AP-17 control), shutter close operation commanded. Blade A closes, pushes Blade B open. Shutter timing confirms slower blade motion

Cumulative Number of Shutter Anomalies

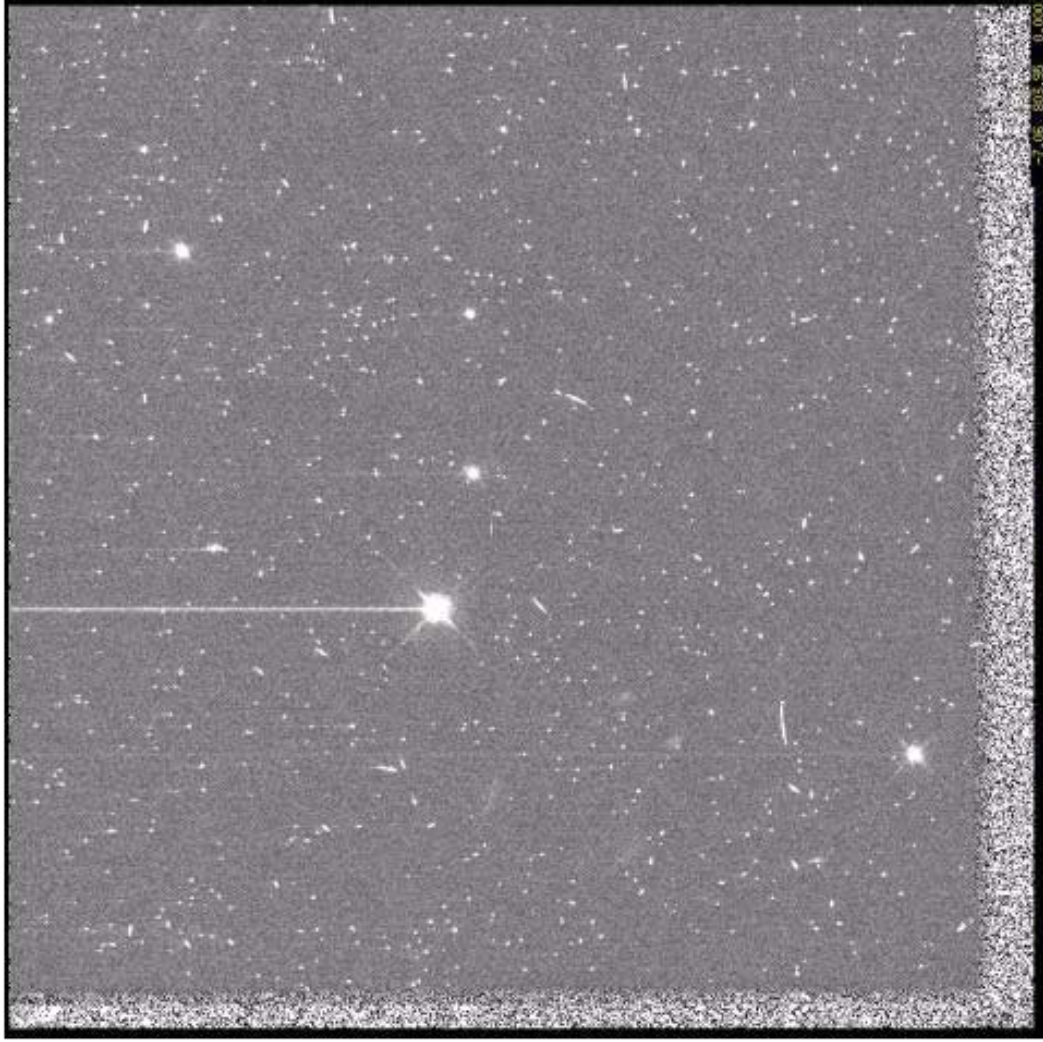


Encoder disc and follower arm



Current Status and Understanding (cont.)

- ◆ **Mechanical tests:**
 - 0.7 deg misalignment could produce observed behavior
- ◆ **Radiation degradation:**
 - Some LEDs known to be proton-sensitive
 - Spare parts available for radiation testing (January-February 2001)
- ◆ **Secondary anomaly:**
 - Failure of "blade push" to properly open Blade A
 - After push, Blade A "bounces" open; shutter stays open at end of exposure
 - Shutter may or may not be closed at readout; if not, next exposure will start with shutter open
 - Behavior reproduced in ground testing
- ◆ **RAM patch (current fix):**
 - Turn on LED 10 ms before sensor is polled (sensor gives correct answer after 200 μ s)
 - Patch developed by Michelle Troeltzsch and Bobbie Woo; involves 14 new instructions, can be turned on and off with changes to 3 instructions
 - No expected impact on camera performance or operations
 - Completely successful so far



Secondary anomaly

**Shutter open at
readout causes trail
above each star**

7 December 2000

WFPC2 Shutter Anomaly - Stefano Casertano

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Other possible workarounds:

- ◆ **Blade repositioning:**
 - All anomalies involve Blade A open, thus start all exposures with Blade B open.
 - More shutter motions, additional overhead.
- ◆ **Clocks-on operations:**
 - Clocks-on exposures do not use blade polling information.
 - Requires flight software changes; limits short exposures (only whole seconds).
- ◆ **Single-blade operation, likely with clocks on:**
 - May become necessary if mechanical degradation prevents Blade A from functioning at all (no evidence in that direction)
 - Large flight software changes, additional wear on Blade B, substantial shading correction, plus clocks-on drawbacks.

Future Prospects

- ◆ RAM patch fully successful so far; no immediate need to consider other workarounds
- ◆ Medium- and long-term prognosis uncertain:
 - mechanical degradation could progress quickly
 - radiation degradation likely slow
- ◆ Work continuing on diagnosis:
 - INTFLATS could provide evidence of mechanical degradation
 - Radiation testing could confirm potential part degradation
- ◆ Long-term prospects will be clearer after these studies