National Aeronautics and Space Administration

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Closed and Not Closed: Mitigating a Mystery on Chandra's Door

The Chandra X-ray Observatory is part of NASA's fleet of "Great Observatories" along with the Hubble Space Telescope, the Spitzer Space Telescope, and the now deorbited Compton Gamma Ray Observatory. The observatory was designed to detect x-ray emissions from some of the hottest regions of the galaxy including exploded stars, clusters of galaxies, and matter around black holes.

One of the observatory's key scientific instruments is the Advanced CCD Imaging Spectrometer (ACIS), which is one of four primary and two focal plane instruments. Due to the sensitivity of the charged coupled devices (CCD's), an aperture door was designed and built by Lockheed-Martin that protected the instrument during testing and the time leading up to launch.

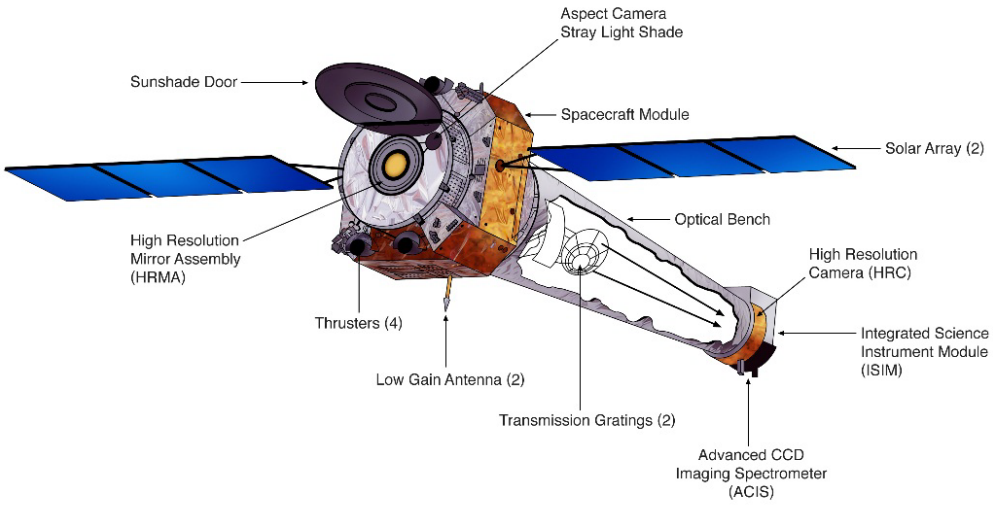

Figure 1 Chandra Spacecraft (NASA/CXC Program)

The design called for a system of wax actuators (manufactured by STARSYS Corp) to be used as components in a rotary actuator that would open and close the door during ground testing and on-orbit operations. Another feature of the design was an internal shear disc located in each actuator to prevent excessive internal pressure and to shield other components from damage.

Because the actuators had a significant flight heritage of flawless performance, it was determined that a single paraffin actuator with redundant heaters would be adequate for a one-time on orbit activation requirement. This meant a failure of the actuator on-orbit would mean loss of mission.

While at Lockheed, an engineering model was fully qualified and life tested with the flight unit actuated at least 23 times during component testing and during system assembly and test operations. Additional testing of the flight hardware took place during system level Thermal Vacuum test at Lincoln Labs at MIT and in the MSFC X-Ray Calibration Facility where additional door operation cycles were performed under flight-like operating conditions. Both rounds of testing were completed with nominal performance. The door was opened again at Ball Aerospace on November 14, 1997 during a check of filter integrity.

In April of 1997, a failure had occurred during the testing of a separate, but similarly designed rotary actuator at Lincoln Labs. It was determined that this failure was the result of an "operator error" which caused both the open and close actuators to be powered simultaneously, causing one of the shear disks to rupture. A spare actuator was installed which underwent hundreds of additional cycles without any additional failure.

Integration at TRW

The observatory was delivered to Chandra prime contractor TRW facilities at Redondo Beach, California where it was to be fully integrated and subjected to over one month of thermal vacuum testing. The launch date was scheduled for January of 1999.

While in the vacuum chamber on June 18, 1998, a final test was planned in which the ACIS door would be opened so that the instrument could evaluate light leakage in the spacecraft by a set of lights designed to simulate solar illumination. When the opening procedure was run, the door failed to open. This failure caused a serious concern with the team leadership. As stated before, if the door failed to open on orbit the mission would be lost. The leadership team, including Dr. Claude Canizares and Dr. Mark Bautz, debated how to proceed on the project.

The only information available to the investigation team at the time was that the "door open" actuator had exceeded its power shut-off temperature at 133ºC and that little to no motion of the door had occurred. Further investigation revealed that the open actuator shear disc had ruptured due to excessive pressure. While investigators would have preferred for the instrument to be examined in an "undisturbed" state, it was determined that the risk of contamination to the focal plane was too great and the door had to be resealed.

Dr. Claude Canizares expressed his trepidation at proceeding with using the door design, saying, "there was this, you know, this mechanism and one thermal vac. In one thermal vac test it didn't function properly and that caused us a huge problem. Again a tiger team tried to look in all the reasons [but] can't ever find the root cause and brought in outside experts…you could

never a hundred percent say we understood the root cause." He was concerned, "..because if the door doesn't open, you know, you're dead. That's thick aluminum."

Dr. Mark Bautz stated his feelings this way, "I was perfectly happy about how things went at TRW until the door failed to open. And to be honest with you, I know a report has been written on why the door failed to open, but I've never been convinced that we understand exactly what happened there."

Make the Call:

How confident are you that the door will open as expected on-orbit?

How should the project proceed?

Part II: Proceeding On and Mitigating Risk

The ACIS instrument was then removed from the observatory and sent back to Lockheed. Further investigation determined the failure could have been a result of a number of issues including a frozen O-ring preventing the door from opening. No flaw in the design or operation of the door was discovered.

There was never any conclusive reason why the door failed to open.

To decrease the risk of failure on orbit, a potentiometer was added to the drive shaft that operates the door to track opening and a procedure was developed that could cut power to the actuator before the disc ruptured. If a failure were to occur, a series of temperature cycles could be initiated to break any O-ring adhesion that might prevent the door from opening.

The new door procedure was tested on September 27, 1998 with the Chandra Operations Center in Cambridge, Massachusetts remotely controlling the observatory back at TRW. The door opened nominally in five heating cycles. The final test of the aperture door took place on May 10, 1999 just before Chandra was loaded into the Columbia orbiter's payload bay. Again, the door opened as expected.

Chandra launched on July 23, 1999. The door opened as expected on orbit.

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