Reflections on Chandra

In July 1999, NASA launched Chandra, the world's most powerful x-ray telescope—packed with the strength and accuracy to read a newspaper from one-half a mile away or see the letters of a stop sign from 12 miles.

A month later Chandra, a member of NASA's family of Great Observatories, released its spectacular first celestial images. Unlike other telescopes in NASA's "Great Observatories" series, Chandra was designed to study X-rays rather than visible light or gamma rays. Since X-rays are absorbed by the Earth's atmosphere, space –based observatories are necessary to study these phenomena. By capturing images created by these invisible rays, the observatory has allowed scientists to analyze some of the greatest mysteries of the universe.

The journey from Chandra's program inception to initial image was a challenging one. The Marshall Space Flight Center in Huntsville, Alabama, managed program . Marshall focused on precision engineering and attention to detail. "It has been a long hard road, said Marshall's Fred Wojtalik following the launch. Wojtalik served as manager of NASA's Chandra X-ray Observatory Program and manager of the Observatory Projects Office at Marshall.

With its combination of large mirror area, accurate alignment, and efficient x-ray detectors, Chandra has10 times greater resolution and is 50 to 100 times more sensitive than any previous x-ray telescope. Chandra's mirrors are the smoothest ever created. If the surface of the state of Colorado were as relatively smooth, Pike's Peak would be less than 1-inch tall. The Chandra team not only produced and polished the mirrors, but also created the systems to put them together.

The team also had to align all the components to within miniscule tolerances, assemble them into a spacecraft that could survive the rigors of launch and space, then test them and validate their performance. In many instances, the Chandra team had to come up with new processes for things that had never been done before. They developed, built and validated a measurement system that was used to make sure the cylindrical mirrors were ground correctly and polished to the right shape.

The eight mirrors are the largest of their kind—the biggest is 4 feet in diameter and 3 feet long. The mirror group weighs more than 1 ton. The team created and executed a system to carefully assemble the mirrors into a total package that could survive the rigors of a rocket ride, weightlessness, and the temperature extremes of space.

The spacecraft is made of graphite epoxy to meet stringent weight requirements, and yet Chandra is the largest and heaviest payload ever deployed from the Space Shuttle. Fully fueled, Chandra weighed 12,930 pounds. With the Inertial Upper Stage set of boosters added to the craft, the assembly totaled 50,162 pounds and measured 45.3 feet long by 64 feet wide with its solar arrays deployed.

On the other end of the size spectrum, microtechnology was used in manufacturing processes to make components for Chandra's imaging systems. Spectrographic transmission gratings, used to precisely determine the energies of incoming x-rays, had never been built before. The gratings include tiny gold bars that are closer together than a wavelength of visible light. It would take hundreds of the bars to equal the thickness of a sheet of paper. Plastic membranes, thin as a soap bubble, support the bars. While all of these incredibly small and large items were being designed and built, the team also had to make sure that they all came together to form the very best overall system.

The spacecraft had to be precise and reliable. Also, the ground control system and its operating staff had to be able to efficiently and safely operate Chandra for years to come.The team tested, tested and re-tested the spacecraft and ground system together to make sure they were compatible. On the optics system testing they made sure that they had at least two ways to crosscheck all results. In some instances the team had even more checks.

Calibrating and validating the telescope's scientific operation proved to be another challenge. Unlike optical astronomy, where there are established, well known targets in the universe that can be used for calibration purposes, there aren't any for x-ray images.

A new world-class X-Ray Calibration Facility was built at the Marshall Center to precisely calibrate Chandra's x-ray optics. The facility also provided opportunities for additional crosschecks of the total optical system and for an independent check of Chandra's optical

performance. From x-rays entering the optics to the quality of the images produced by the science instruments, the testing verified the exceptional accuracy of Chandra's optics. Chandra is so finely tuned it can detect objects separated by one-half arc second. That is like identifying two dimes side-by-side from 2 miles away.

NASA launched Chandra on July 23 at 12:31 EDT as the primary payload on Space Shuttle mission STS-93. Its onboard computers activated flawlessly July 23 at 3:25 a.m. EDT. On August 4, 1999, at 12:36 p.m. EDT controllers at the Chandra Operations Control Center in Cambridge, Mass., commanded the observatory's engines to ignite. The 45-foot-long TRW-built Chandra used five engine firings of its Integral Propulsion System to propel itself from a temporary transfer orbit, where it was placed by an Inertial Upper Stage, to a highly elliptical Earth orbit that extends more than one-third the distance to the Moon.

On August 8, 1999, following a pre-planned series of commands from the flight operations team, Chandra's Advanced Charge-Coupled-Device Imaging Spectrometer door opened clearing the way for additional activation and testing of the instrument used to take Chandra's first images. Meanwhile, controllers continued activation and checkout of the observatory's science instruments and began the process of replacing the early mission flight software in Chandra's onboard computers with software for the operational phase of the mission.

Wojtalik expressed pride in the observatory team. "A great number of people from NASA and industry, here and around the country, have put in a tremendous effort to get where we are." Jean R. Olivier, who served as Marshall's deputy manager of the program, said the most significant progress related to the Chandra mission came with the "first firing of the Integral Propulsion System." He said the spacecraft system "worked even better than expected."

Marshall's Dr. Martin C. Weisskopf who served as project scientist for Chandra, also expressed his excitement over the scientific discoveries expected from the observatory. He spent 22 years helping make Chandra possible. Responsible for the scientific integrity of the program, he spent two decades of his life "breathing it." On joining the project in 1977, Weisskopf took out a piece of paper and wrote his estimate when the telescope would launch: the year 2000.

“I did not expect it to go fast,” he said... “We’ve actually exceeded my expectations.” After committing his prediction to paper, Weisskopf saw his children grow up, watched them have children, and held on to that piece of paper.