All photos courtesy of Palomar Observatory

The world's largest CCD camera

CCD cameras are used not only in surveillance and consumer cameras, but also in astronomy. The world's largest astronomical camera has been installed on Palomar Observatory's 48-inch Oschin Telescope in California. This telescope has been working to improve our understanding of the universe for nearly 55 years. The new upgrade will help it to push the limits of the unknown for years to come.

The new camera is known as QUEST (Quasar Equatorial Survey Team). Designed and built by astrophysicists at Indiana and Yale universities, QUEST recently "saw" its first starlight and is now scanning the sky.

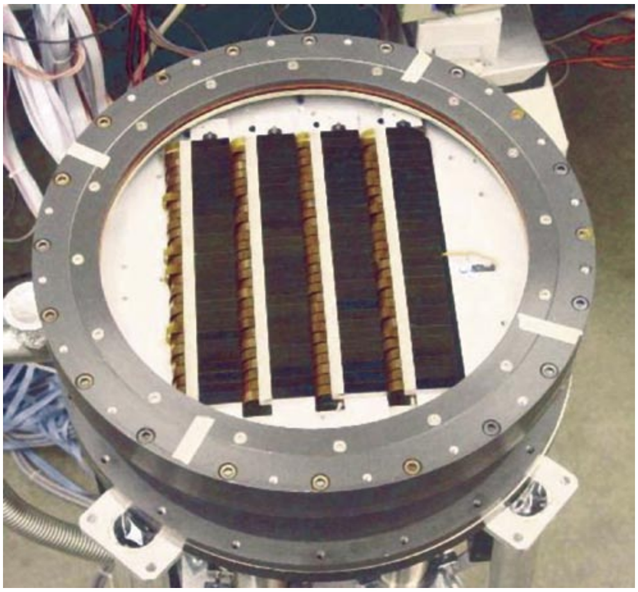
In 2001, an electronic camera known as the Near-Earth Asteroid Tracker was installed in the Oschin Telescope. The camera, which employed a charge-coupled device (CCD) to detect light, was very successful. During its tenure on Palomar, the NEAT team discovered 189 near-Earth asteroids and 20 comets.

The Oschin Telescope at the Palomar Observatory, where this camera is installed, had to undergo some major changes to accommodate the QUEST camera. Under the oversight of Richard Ellis, director of Palomar Observatory, this process was guided by Robert Thicksten and Hal Petrie of the California Institute of Technology. The delicate installation of the camera and its electronics inside the telescope was handled by Mark Gebhard (Indiana University), William Emmet (Yale University) and David Rabinowitz (Yale University). The camera's readout electronics were constructed in the Physics and Astronomy departments at Indiana University by Gebhard and Brice Adams, under the direction of James Musser, Kent Honeycutt and Stuart Mufson. The hardware for the QUEST camera was constructed by the Yale University Physics Department under the direction of Charles Baltay.

The Quest camera design

The QUEST camera has an array of 4X28 CCDs (112 CCDs in total), each with 2400X600 pixels, thus making a total imaging area of 16800X9600 pixels. It covers the full field of view of the telescope (3.6^{o} x 4.6^{o}).

The CCDs are thinned, back illuminate 600 x 2400 13µ x 13µ pixel devices fabricated at the Sarnoff Laboratories. The camera is designed to operate either in the Drift Scan or a Point and Stare mode. Each of the four rows of CCDs has a color filter in front of it with different Johnson or Gunn bands. Thus in the Drift Scan mode data in four different colors can be obtained essentially simultaneously.



The CCDs are mounted on four separate fingers, 28 CCDs each. Under steppor-motor control, the angles between the fingers can be altered to align the parallel readout direction of the CCDs with the paths of drifting stars. The motor controller is attached to the outside of the telescope.

The window of the camera dewar is an AR-coated, fused-silica lens that flattens the otherwise curved focal plane of the Schmidt optics. A filter tray is located immediately in front of the camera window. Dry nitrogen gas is passed between the camera window and the filters to prevent moisture condensation. The camera shutter is pneumatically powered with pressurized air.

CCD cooling

The CCDs are housed in an evacuated dewar, and cooled with liquid Nitrogen (LN2). A large, pressurized LN2 dewar on the floor of the dome feeds LN2 through a vacuum-insulated transfer line to a smaller LN2 dewar inside the telescope. The smaller LN2 dewar provides direct cooling to the CCDs through cold-fingers running through the back of the camera dewar. An automated feed system allows unmonitored continuous recharging of the internal LN2 dewar.

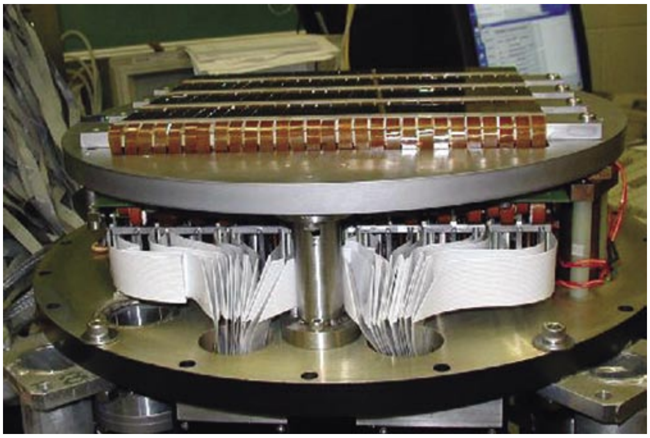
The CCD temperatures are held constant with heaters inside the camera dewar. A temperature controller in a control room below the dome floor monitors the CCD temperature through lines to RTDs inside the camera dewar, and provides current to the CCD heaters.

CCD electronics

CCD readout and switching electronics are located inside the camera dewar. Custom-built feedthroughs pass the analog video signals through ribbon cables to ADCs and digital logic mounted on the outside of the telescope. A single-board computer also controls camera readout rates and the camera shutter. An EDT fiber interface passes digitized images data from

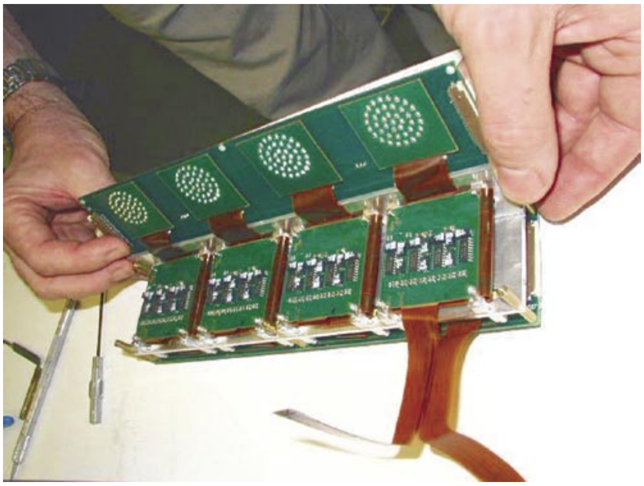
the camera electronics to a controlling computer (quest7). The camera electronics are cooled with chilled water.

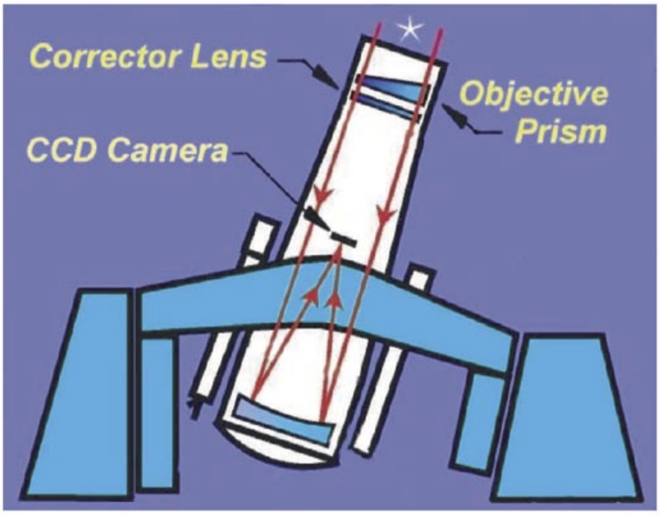
A National Instruments timer/IO card in quest7 allows control of the camera electronics through an optically-isolated ribbon cable. An optically-isolated serial link to the single-board computer on the telescope passes shutter commands and programs readout timing. Another optically-isolated serial link to the camera temperature controller allows setting and monitoring of the CCD temperatures. A third serial link allows control and programming of the steppor motor controller.



Networking

The digitized camera data are passed through an optical fiber to computers in the telescope control room below the observing floor. One computer (quest7) is dedicated to receiving and buffering the data. Another computer (quest16) is dedicated to storage, display and on-line control of the camera. Data received by quest7 is passed to quest16 through a gigabit fiber link. Quest16 is networked through another internet fiber link to a JPL computer ("Asok") and also through a 100-Mbit link to the Palomar Mountain network. There is also a high-speed radio network connected to a UC Berkeley machine ("Berlioz"). In addition to the usual point-and-shoot mode, the new camera is designed to work in the drift scan mode. The telescope is pointed at the sky but does not move to counteract the rotation of the Earth. Instead, various objects in the sky gradually drift across the field of view at the same rate as the computer records data from the CCDs, producing photographs that are long strips of the sky. Astronomers will use these photographic slices of the sky to look for quasars, supernovae, asteroids and more.





What can be seen with the Quest camera

Last year, Caltech astronomers Chad Trujillo and Mike Brown used the NEAT camera on the Oschin Telescope to find the distant world known as Quaoar. Quaoar is about half the size of Pluto, making it the biggest object to be found in our solar system since Pluto was discovered in 1930. Quaoar is the largest known member of the Kuiper Belt, a swarm of thousands of icy objects that orbit beyond Neptune. Brown is convinced there are more big Kuiper Belt objects, possibly as big as the planet Mars, and he will use QUEST to look for them.

Other scientists plan to use the camera to find objects that might be quasars. Quasars are the very bright cores of distant galaxies that are thought to contain supermassive black holes. They are among the most luminous objects in the universe. Any quasar candidates that are found with the Oschin Telescope will be looked at again with Palomar's 200-inch Hale Telescope. Those objects that the Hale Telescope confirms to be quasars will be the targets of more detailed study with one of the 10-meter Keck Telescopes in Hawaii.

A similar approach will be used as distant galaxies are probed in a search for exploding stars known as supernovae. The QUEST camera will do the survey work, suspected supernovae will be looked at with the Hale Telescope, and supernovae of the right type will be scrutinized at one of the Keck Telescopes. Astronomers will use data from these exploding stars to try to confirm that the universe is accelerating as it expands.

The image below is of the famous Andromeda Galaxy as photographed by the Palomar Observatory's 48-inch Samuel Oschin Schmidt Telescope with the QUEST camera.

The Andromeda Galaxy is the closest spiral galaxy to our own Milky Way Galaxy. It is located some 2.9 million light-years away. From dark light pollution free skies it is one of the most distant objects visible to unaided eyes. In 1764 Charles Messier made it the thirty first object, M 31, of his famous catalog.

Also visible in the image are two of Andromeda's companion galaxies. M 32 is visible to the right of the bright nucleus of the Andromeda Galaxy and M 110 is visible near the lower left part of the image.

The image was taken with the QUEST camera operating in driftscan mode. During driftscan mode the telescope is stationary. Because the telescope does not correct for Earth's rotation objects drift across the field of view. The QUEST camera records the data as objects drift past. The image was taken 2003 Oct 6 UT through a Gunn i filter. The image has been dark subtracted and flattened. The dark lines and bright streaks are not real, but rather artifacts of the imaging process. [•]

Sources: Sarnoff Corporation; NASA, Yale University; Caltech; Science daily; Palomar Observatory.