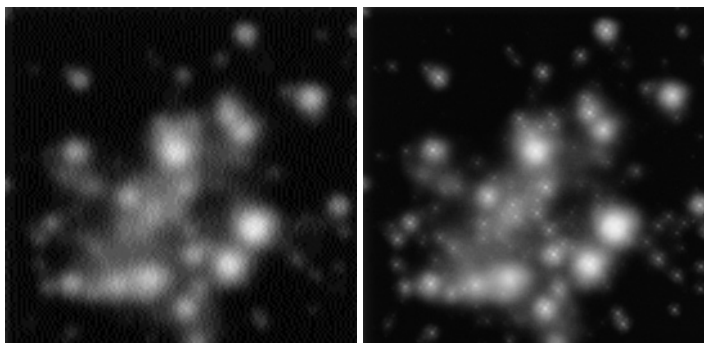




## Datacube's MaxVideo System is on the Frontier of Astronomy

The National Optical Astronomy Observatories (NOAO) organization is using Datacube equipment at its Kitt Peak observatory near Tucson, AZ, to capture and analyze extraterrestrial images. Using techniques such as contrast balancing and time averaging, their digital imaging system enables them to enhance images in real time, improving the visibility of features that may not have been evident in the original image. The imaging system can also correct for known system deficiencies and automatically detect changes in an image over time.

The NOAO design team simulated the application in order to define system requirements and performed a detailed trade study to determine the best image processing architecture for their application. After much consideration they went with the Datacube system, citing the proven performance of ImageFlow software, capabilities of the MaxVideo 200 ALU, and versatility of the VSIM memory architecture all as important factors in their decision. Datacube provided a wealth of support, including its week-long ImageFlow technical training class and monthly support visits by a Datacube regional application engineer.



Images captured at Kitt Peak before (left) and after (right) implementing the Datacube-based digital imaging system developed

The first steps included installing the MaxVideo 200 hardware and ImageFlow software on the observatory's Sun development system, then getting a basic video capture and display application up and running. Within a month of development they had implemented a simple tracking application and were feeling confident about success. With the system in working order, they shifted their attention to the part of their application that would make the most impact on their observations.

Using a technique called "real-time shift and add," the system collects thousands of independent frames of data from the telescope camera and sums them together using Datacube hardware and software. This summing process occurs at the camera's frame rate, corrects for atmospheric background, and produces images that are "diffraction limited," meaning they are as good as is theoretically possible given the size of the telescope.

Once the shift and add application was completed, the entire system was put into operation. The results were bet-

**What:** Extending Galactic Observations

**Who:** Kitt Peak National Observatory

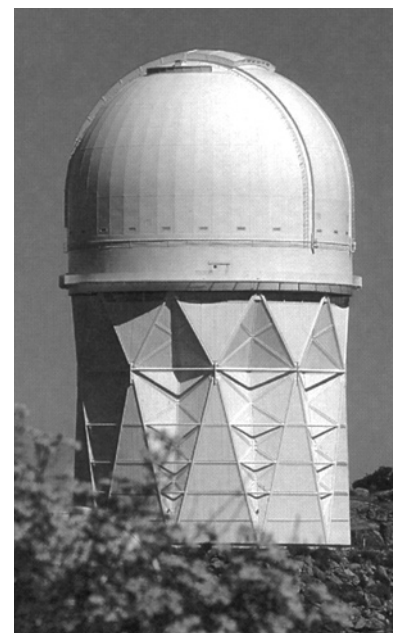
**How:** ImageFlow Software and the MaxVideo 200

**Technical Summary:** Astronomers at Kitt Peak National Observatory near Tucson, Arizona, are using Datacube technology to extend their vision into the very heart of the Milky Way Galaxy. Using an infrared imaging sensor mounted on the 4-meter Mayall telescope at Kitt Peak and a Datacube-based image processing system in the telescope's control room, they have produced the clearest photographs to date of the galactic center.

ter than NOAO expected. The system provides scientists with image analysis features such as a histogram capability beyond what they'd expected. NOAO scientists also list the system's ease of use and real-time display as major benefits. Before this system was put in place, images were processed after they were collected. Scientists had no way of knowing while they were observing whether or not their data would prove valuable. With the NOAO imaging system, scientists see the results of Datacube's powerful image processing features in real time, allowing them to immediately assess viewing conditions and make informed decisions about the potential usefulness of their observations. In the event of particularly poor observation conditions, the collection of data may be rescheduled, saving great time and expense.

After announcing the capability in the organization's newsletter, NOAO received proposals from scientists from around the world, to perform specific observations using the system. The proposals ranged from the discovery of new binary stars to detailed positional mapping, and are helping astronomers gain a better understanding of the forces at work within the universe.

Success on this project allowed the NOAO development team to propose a next-generation system for use on the Gemini project, twin 8-meter telescopes under construction in Hawaii and Chile. Development of that system, called the NOAO Advanced Array Controller, has now begun at the NOAO lab in Tucson.



The Mayall telescope at Kitt Peak National Observatory

Over for technical details



The architecture of the MaxVideo 200's AU device is designed for 8- or 16-bit image data. Because the camera used by NOAO provided 16-bit data, the accumulation of thousands of frames from this camera would result in 32-bit pixels, exceeding the basic architecture of the AU. The "shift and add" application engineered by the developers at NOAO broke new ground for the MaxVideo 200, creating a way for the AU to accommodate this massive amount of data in real time.

The basic solution splits the 32 bits of the accumulated image into the 16 most-significant bits (MSBits) and the 16 least-significant bits (LSBits). The addition of the accumulated image (Accum) to a 16-bit image (Input) to generate a 32-bit result image (Result) can be performed as the following 16-bit sums:

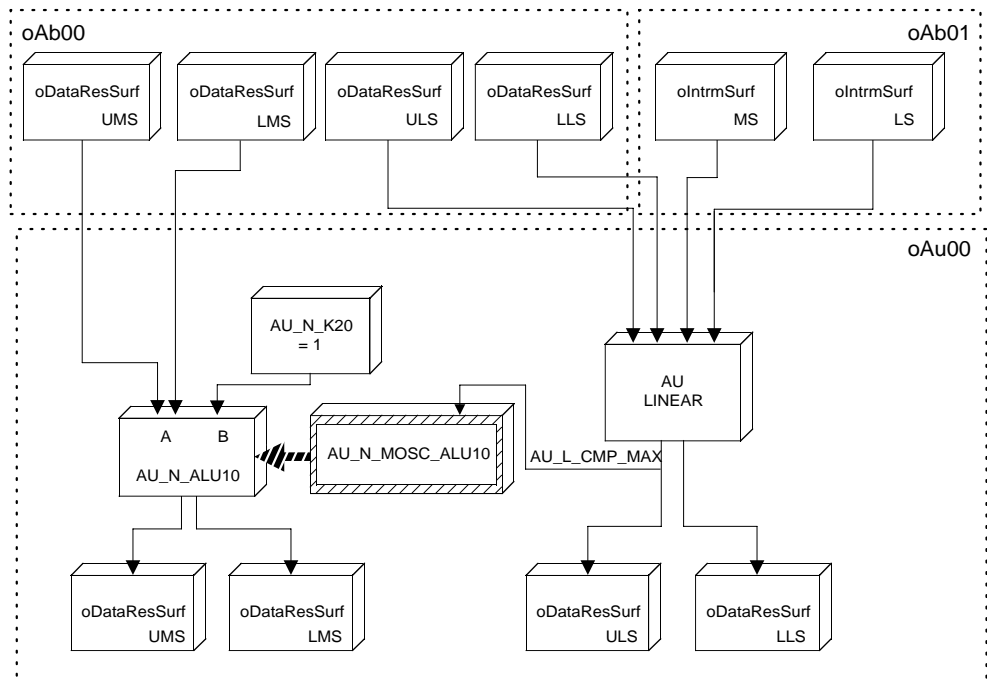
```
Accum(LSBits) + Input = Result(LSBits) + (Carry Bit << 16)
Accum(MSBits) + Carry Bit = Result(MSBits)
```

The mapping of these addition operations to the MaxVideo 200 is shown in the drawing above. The 16 bits of the input image (oIntrmSurf MS and LS) and the 16 LSBits of the accumulated image (oDataResSurf ULS and LLS) are added in the AU Linear section to form the 16 LSBits of the result image (oDataResSurf ULS and LLS). The carry bit is generated by the AU\_L\_LIMIT element. Programmed by the following line of ImageFlow code, this limiter element will set the AU\_L\_CMP\_MAX control signal to "1" when the carry bit should be set to "1", and otherwise to "0":

```
dqSpecLimits(oAu00, AU_L_LIMIT, 0, 65536);
```

The carry bit is added to the 16 MSBits of the accumulated image (oDataResSurf UMS and LMS) in the AU Non-Linear section with the following ImageFlow code:

```
dqConnect(oAu00, AU_N_ALU_LINK, AU_N_LINK); /*1*/
dqConnect(oAu00, AU_N_10_ATRUE, AU_N_10_AEXT);
/*2*/
dqConnect(oAu00, AU_N_10_AEXT, AU_N_ALU10_AOP);
/*3*/
dqSetKVal(oAu00, AU_N_K20, 1); /*3*/
dqConnect(oAu00, AU_N_K20, AU_N_ALU10_BOP); /*3*/
dqConnect(oAu00, AU_ZEROS, AU_B_OP8); /*4*/
dqConnect(oAu00, AU_L_CMP_MAX, AU_B_OP4); /*4*/
dqSetMoscState(oAu00, AU_N_MOSC_ALU10, 0); /*5*/
dqSetALUOp(oAu00, AU_N_ALU10, DQ_ALU_A); /*5*/
dqSetMoscState(oAu00, AU_N_MOSC_ALU10, 1); /*6*/
dqSetALUOp(oAu00, AU_N_ALU10, DQ_ALU_APB); /*6*/
```



Block diagram of NOAO real-time shift and add application.

Taking a closer look at this code sample one step at a time, the AU Non-Linear section is configured for 20-bit data paths (1). Next, the accumulated image is routed to the A input of AU\_N\_ALU10 (2), while the constant value "1" is routed to the B input of the same ALU (3). AU\_L\_CMP\_MAX is routed to AU\_N\_MOSC\_ALU10 (4), the MOSC that controls AU\_N\_ALU10, and this MOSC is programmed to add the constant to the accumulated image only when the carry bit (AU\_L\_CMP\_MAX) is set to '1' (6); otherwise, the accumulated image is passed through untouched (5).

This breakthrough allowed the developers at NOAO to collect and merge thousands of independent frames of data from their telescope camera accurately producing never-before seen images of our galactic core. The real-time nature of their Datacube-based vision system supports last-minute review of scheduling decisions, allowing them to reschedule costly data collection during periods of poor observability. The Kitt Peak observatory is now in great demand, receiving proposals from scientists around the world.

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