A REMOTELY OPERATED PLANETARY SCIENCE OBSERVATORY TO ENHANCE SPACE EDUCATION.

Charles A. Wood and Paul Abell, Department of Space Studies, University of North Dakota, Grand Forks, ND 58201

Planetaria and small observatories are traditional facilities for providing hands-on learning experiences for astronomy students. At the University of North Dakota we have established an observatory with a similar goal but with two significant differences. First, our Department of Space Studies, an interdisciplinary M.S. and undergraduate minor program combining space science and space policy, has a focus on planetary science, not traditional stellar and nebular astronomy. Second, the severity and duration of North Dakota winters limit the time that students can observe from inside the dome. Considering these two factors we have constructed an observing facility which may be of interest to other educators. In particular we have learned a number of lessons concerning observatory design, operations, and appropriate science projects.

Observatory Design and Instrumentation: Teaching at a small state university is reminiscent of living in a third world country. Only a small amount of money and little out of the ordinary technical advice are available. Because of the high cost of a commercial dome (~$35k plus $10k for concrete slab and pier), we chose to have the UND Plant Services group design and build our dome. This had the positive aspects that total cost would be lower ($25k), we could influence the design, and the builder would always be nearby for repairs and to correct any inevitable flaws. We now appreciate that the negative aspects of our decision are also substantial. Neither Plant Services nor we had ever designed or built a dome before and did not fully understand the potential complexities of a rotating building with a floor to ceiling slit in the wall. The dome is converted from a hemispherical silo top, 24' in diameter and 14' high, mounted on a 30' concrete slab. The 24" wide slit is raised and lowered by a garage door opener mechanism, and the dome rotates on 24 nylon wheels using a chain-drive mechanism.

We selected an 18" newtonian reflecting telescope (the NGT-18 made by JMI of Evergreen, Colorado) because of its modern design, integrated computer operation, and excellent value ($10k). A 24" wide pier supports the telescope and extends 4' below ground level. We use the telescope with a 375 x 242 pixel CCD camera with computer-controlled filter wheel (ST-6 camera from SBIG in Santa Barbara, California; $3.5k).

An critical part of our observatory complex is a heated trailer 50' to the west of the dome. An underground conduit brings electrical connections from the dome into an observatory control room in the trailer. Presently, from the control room we can rotate the dome, use electric slow motion controls to refine the pointing of the telescope, and acquire and display CCD images. But we must go into the observatory to open and close it, to initially set the telescope on an object of interest, and to repoint the telescope to another portion of the sky. These functions can not be remotely controlled with the present telescope and dome. An intercom facilitates aiming the telescope on the object of interest.

Science Goals: Although any small university observatory will be used for a variety of public and course-related observing sessions where little more than an eyepiece is necessary, our goal was to define significant research projects with publication potential. Our main research goal is the discovery and characterization of near Earth objects (NEOs - asteroids and comets). This is an important and active field of planetary research for a number of reasons. First, NEOs are small, relatively unmodified (compared to planets and moons) fragments of material left over from the formation of the solar system. Second, near Earth asteroids (NEAs) especially, may be immediate parent bodies of meteorites. Third, NEOS come closer to the Earth than any other celestial body (some pass inside the Moon's orbit!) and are very accessible objects for telescopic and radar investigations and future spacecraft missions. Fourth, NEOs are the projectiles that occasionally hit the Earth, forming impact craters and apparently sometimes dramatically affecting terrestrial life and geology.

In order to discover NEAs we have devised a search strategy that is similar to that pioneered by the Spacewatch project at the University of Arizona. We use a CCD camera at the prime focus of our 18" f/4.5 reflector to image strips of the sky near the opposition point (opposite the sun). A one minute exposure images objects as faint as 18th magnitude, and another minute is required to read the image from the CCD chip onto a computer hard drive. The telescope is then slewed to an adjacent part of the sky and the procedure is repeated continually for approximately one hour. Next, the telescope is slewed back to the original location in the sky and a second strip of images is acquired. At the completion of the night's observing run the stored images are transferred to floppy disks and brought to campus for analysis. The next day each pair of images is coregistered and subtracted (using Photoshop on a Macintosh computer). Stars and other objects which don't move disappear, but asteroids are betrayed by their movement between the two exposures. Based on the size of our telescope and CCD chip we

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expect to discover one NEA during each 300 hours of observing.

The second part of our program is the characterization of recently discovered NEAs. Most NEAs are so small that they can be easily observed only when near the Earth. Thus if measurements of physical properties are not made during the discovery apparition it may be another 5-10 years before the chance occurs again. Two measurements are important, and possible for a small observatory like ours. First, acquisition of a CCD image through each of the U, B, and V filters provides information on the object's brightness in three wavelengths, allowing classification of its spectral type. Second, a series of brightness measurements over a few hours on a few nights permits determination of the rotation period of the object.

Progress and lessons: The trials and tribulations of this project have been far greater than anticipated, but have increased solidarity between the faculty and students who have been involved. The dome and slit are underpowered and have required a succession of ever larger and more expensive motors. The slit is not weather proof when closed, and telescope and equipment must be protected from wind-blown snow which piles up inside the dome. Vandals have broken all the windows of the trailer and stolen computers and other equipment. Finally, our old trailer was invaded by deer mice during the summer, causing it to be placed off limits due to a hantavirus scare.

If starting over we would be tempted to pursue theoretical astronomy. But if an observing project is envisioned our recommendation would be to find adequate funds to buy a commercial dome that works from the first night. Secondly, we have found that our newtonian design telescope has considerable balance problems when the 4-5 pound CCD camera and filter wheel are attached to the eyepiece holder. A fork mounted schmidt-cassagrain telescope would be easier to add equipment to.

We are having some successes. Two students have completed independent study projects for their M.S. degrees using the telescope, and two others are underway. We are incorporating planet observing sessions into undergraduate and graduate space science courses that were previously classroom-bound. The observatory will also be used by classes in the geology and physics departments and has become the stimulation for the formation of an astronomy club. We have also used the observatory and a weather satellite receiving station as sources of digital data for image processing experiments and as the core for a successful NSF-funded equipment grant to integrate computer based projects in undergraduate teaching. And we still hope to discover an asteroid or two.

The observing facility has been built and outfitted with the support of the North Dakota Space Grant Program, to which we are very grateful.