The Remote Observatory for Variable Object Research (ROVOR)

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ABSTRACT
The Remote Observatory for Variable Object Research (ROVOR) is an 0.4m RC Optical telescope on a Paramount ME pier located in Central Utah 100 miles south of the BYU campus. It has been in remote operation since the summer of 2008. Principle research has been monitoring blazars, x-ray binaries, AGN, and an occasional gamma ray burst. Originally conceived as a prototype to use in teaching remote observing to undergraduate astronomy majors, ROVOR has become a useful scientific tool for monitoring brighter sources. We present the basics of the observatory with an emphasis on 1) its economics, 2) the control system, 3) its unique dome, and 4) lessons learned.

Keywords: Remote observing, blazars, AGN

1. INTRODUCTION

A constant challenge to university and college astronomy educators and students is the schizophrenic nature of our duties. We teach and study at day about objects only visible at night. While there are many stories of intrepid souls who have maintained a sleep-deprived regimen to successfully practice the trade, it is impractical to add a regular full-time observing schedule to a 40 hour work week and expect this to be an efficient, sustainable way to advance astronomy. Something has to give. Always it is the night-time observing that suffers more than the day-time instruction. This is regrettable; taking data is part of any complete astronomical education even if sitting in a cold dome all night is not.

Remote observing of course solves the problem. A remote system can be set up in the afternoon or evening then run by itself all night furnishing data in the morning. For our purposes this system must meet the following requirements:

* Be inexpensive to build
* Be easy to maintain
* Be robust with little down time
* Be operable with unskilled labor
* Provide significant data

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Figure 1. A schematic showing the Lifferth dome and how it pivots off to the west.

The system must be inexpensive and robust since both money and time are always limited. There are many impressive remote telescopes that work well but are costly, well out of range of most institutions. In the past decade private companies have developed and marketed smaller but excellent systems for reasonable costs, largely solving the first three problems. It is fortunate that the general public loves and supports astronomical imaging! The last two points are more an obligation of higher education than industry and we have addressed them ourselves.

We present the details of an observatory designed to meet the listed requirements named the Remote Observatory for Variable Object Research or ROVOR. This observatory was built by undergraduate students specifically to monitor varying sources of general interest. ROVOR was conceived as a prototype to springboard to a larger system and we hope that will be the case. But it has been productive by itself, providing data for two published blazar campaigns$^{12}$ and several more AGN and x-ray binary monitoring projects that that are underway. In Sec. 2 we present the basic data on the ROVOR facility including the telescope, detector and building. In Sec. 3 we talk about the control of the facility and in Sec. 4 we discuss what we have learned and where we intend to go.

2. THE FACILITY

The ROVOR project began in 2001 when an unfinished 0.6m Autoscope telescope was donated to the BYU physics and astronomy department. An undergraduate project was organized to make it functional. Unfortunately the secondary support truss was damaged in shipment making it impossible to collimate the mirrors. After unsuccessfully attempting to repair it, the entire telescope was replaced with an RC Optical 0.4m tube and a Paramount ME pier, similar to the telescopes of the PROMPT$^3$ and MEarth$^4$ arrays. The tube is an open truss f/9 with optics milled to 1/30 wave rms. Details can be found at http://www.ropticalsystems.com/telescopes/16truss.html. Details on the mount can be found at http://www.bisque.com/sc/pages/Paramount-ME.aspx.

The telescope is equipped with a CCD and filter wheel that are essentially permanently mounted. The filter wheel is an FLI CFW-6-6 equipped with parafocal Johnson BVRIClear filters. The camera is a 1024x1024 Apogee AP8 remanufactured by FLI to improve the cooling. The FOV is 23' on a side with a resolution of 1.35 /pixel. There is no guiding and individual exposures are typically limited to less than 2 minutes to minimize or eliminate trailing. Within a 45° circle centered on the zenith, the images are rarely trailed.

The ROVOR site is located 12 miles west of Delta Utah at the end of the local power grid and on a valley floor for ease of access. The exact coordinates are $+39^\circ 27^\prime 17.1^\prime$ latitude, $112^\circ 43^\prime 1.0^\prime$ longitude, 4579 feet elevation. Local seeing is fairly constant at approximately 2.5′. While superior sites are available, this site was
chosen both for logistical reasons and to prove the science that can be done in the less-than-ideal conditions typically available for smaller projects. The ROVOR project is designed to explore what is possible more than what is ideal.

ROVOR is housed in a simple 10 foot x 10 foot shed dubbed the “doghouse”. The roof pivots off in a manner similar to the lids of the HATNet\textsuperscript{5} telescopes (See figure 1). Called a “Lifferth” dome after its designer Wes Lifferth, the roof pivots to below the horizon of the telescope which sits just above the top of the building walls. We favored this design over a traditional dome to make slit tracking unnecessary. Dome control is of course an easily solved problem but the simpler the system the more robust it can be made and a non-tracking pull-off roof seemed simpler even if it limited the winds speeds in which we can work.

The pivot-off design works better than a traditional roll off roof for remote observing because there is no track to keep clean. The roof is moved by a low-power electric motor twisting a 6 foot 1.5 inch steel threaded rod pushing on a gimballed threaded brass sleeve attached to a rigid steel framework at the back of the roof (see figures 1 and 2). It pulls off to the west side to provide shelter against the local winds when opened. When observing in the east the roof can be positioned to be a wind barrier. When fully open it protects the side of the building against wind vibrations. A mercury gravity switch attached to the telescope prevents the roof from moving whenever the telescope is not stowed out of the way.

The paint scheme is a non-standard brown for the sides and blue for the roof. Traditional white is not as critical for a removable roof. We open up an hour before observing and the temperature equalizes in that time. The brown sides and blue roof are for camouflage against the horizon. At the remote location there is a concern for vandalism. The paint scheme significantly reduces the visibility of the building.

Control computers are housed in the small shed to the side called the “outhouse”. This structure also holds an all-sky camera and the communications dish. The outhouse serves for temperature control and prevents critical equipment from being exposed to the weather when the roof is off. A weather station is on the property perimeter.

3. COMMUNICATION AND CONTROL

The site is controlled by two computers communicating through a LAN router. One computer manages the telescope, roof, and detector while the other manages the weather station, data storage, security cameras, and communication. Little \textit{et al.}\textsuperscript{6} describe the control system in greater detail.
The data connection is a DirecWay satellite link. We chose a satellite link over a land line for convenience and to force us to learn to use its slower speed. Satellite links are available world-wide and are easier to set up while a telephone link may not always be possible. So we felt it wise to learn now how to live with the more readily available option.

There are two ways to control the site. First is by remote terminal with the computers themselves. We use the software suite from Software Bisque of Orchestrate, CCDSoft, and The Sky to control the telescope and detector. We use our own software written in LabView to open and close the roof. Accessing these programs through a remote terminal is quite slow but adequate for setting up a single night’s observation. It allows us to also examine the general health of our systems as if we were sitting at the telescope itself. But there is a learning curve to understanding how to operate all three programs and when mentoring students, it is wise to minimize the curve as much as possible so their instruction can be more on astronomy and less on technology.

To make operations simpler we wrote an interface called CelestialGrid to talk to the above programs. It allows untutored students to create an observing program from a directory of objects, guiding them on when the objects are most visible. Once a program is created and queued CelestialGrid runs the system in a nearly robotic mode; starting the night’s observations at twilight, taking calibration and flat frames, conducting the observations, and parking the telescope when finished. It also has a feed from the Gamma-ray burst Coordinates Network (GCN), and will automatically interrupt the program to image any bursts above the horizon. We usually operate with CelestialGrid and have had few problems with it. We revert to remote terminal to trouble-shoot or to run more complicated special observing programs.

4. DISCUSSION

The successes of the ROVOR project are many. The total cost to build it was less than $100K, excluding labor. Ongoing costs are about $5K per year in parts, communication, and transportation and another $10K in student labor.

We routinely obtain 0.01 mag accurate data and have found it to be applicable to a variety of AGN monitoring projects. The focus is stable and the pointing is quite adequate. We are pleased but not surprised with the depth with which we can probe for gamma-ray bursts. Even in the LSST era we envision ROVOR-like telescopes constantly monitoring at a high cadence the brighter, prototypical objects that are saturated in larger aperture surveys or that are not observed with as high a cadence as in the smaller aperture all-sky surveys.
We have had very little hardware problems with the telescope and none with the CCD. The roof has functioned flawlessly for three years with the only glitches being a bolt that worked loose, dropping the north pivot arm to the ground and a relay that welded open dumping the roof onto the ground. Both were easily repaired. And so far there have been no bullet holes in the walls although an enraged bull did bend the threaded rod on the roof pull-off mechanism. We have yet to invoke our ultimate backup; a large tarp and a cell-phone call to a kind local farmer.

The biggest problem has been the communication link which has failed in many novel ways including a fried satellite modem, a failed LAN router, a computer virus, and a wasp nest in the satellite feed horn. We accept much of this as the ongoing price to be paid but are still looking at how we might simplify the system further. We have learned the wisdom of paying a regular monthly visit to check on the hardware, swapping out parts before they fail, and regularly updating the virus data base.

Disappointments include a long time to get the system working when relying on undergraduate labor. Over 20 astronomy majors have worked on it. As soon as they become proficient, they leave and we start training again. This is a great model for education but a poor model for progress. The tracking can be improved and we are learning how to do this. The smaller aperture is also frustrating. We aspire to a much larger telescope and are bending effort in that direction. Ideally, we would like the next ROVOR installation to have a meter class imager and a two meter spectroscopic telescope.

Future effort will be concentrated on the data analysis pipeline. Currently data are uploaded automatically the morning after observing (when satellite bandwidth is cheapest) for analysis at BYU. We are working toward having all analysis take place on site so that only calibrated magnitudes need be transmitted.

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