Design and Operation of a Harsh-Climate Observatory for Amateur Astrophotography

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***Abstract*—Increasingly complex equipment for amateur astronomers is becoming available at the retail level and at affordable prices. A significant stumbling block for those wishing to participate in this scientific endeavor is convenient equipment access (mobilization, operation, and demobilization) in less than ideal regions. This work describes the systematic design, construction and operation of a facility that meets these requirements. Though some work remains in finalizing the operational protocols for digital image processing, early experimentation with the built facility suggests that the structural, mechanical and computer design is fit for purpose and with an improved understanding of software capabilities the operation of the observatory may yield scientifically valuable results worthy of publication.**

***Index Terms*: Observatory, Astronomy, Harsh Climate**

I. INTRODUCTION AND CONTEXT

REMOTE high-elevation, arid locations in stable climatic zones are the preferred sites for leading observatories.

For amateurs living elsewhere, night viewing may be facilitated by clear skies, low wind, favorable temperatures, low light pollution and atmospheric clarity. In Newfoundland these conditions rarely exist concurrently (apparently, the worst in North America, [1]), and so hobbyists must be patient and opportunistic for success. Success does not, however, depend entirely on external factors and one's chances can be considerably improved though activity planning and through careful design of facilities, resources, and protocols. A wide range of approaches to solving the problem of convenient access is documented in the literature and described on various internet resources [2].

Observatories: The most simplistic approach to astrophotography involves using light duty instruments and a portable system of mounting – allowing for all components to be brought in and out when use is desired. Sometimes a shed or porch is used to store equipment in a state of semi-readiness somewhat decreasing the set up time. Increased levels of sophistication involve a shed or canopy structure that can be rolled away or removed so that the instruments need not be moved for use. Often with this arrangement the hobbyist will construct a rigid base or pedestal that facilitates clearer viewing through vibrational isolation. Typically a permanently founded pedestal for this purpose is constructed first and the shelter, after, without structural contact.

Today there is a wide range of commercially available astro-hobby shelters. Roll away sheds and fiberglass domes equipped with various types of motorized controls can be purchased retail. One variation is the skyshedPOD a high density polyethylene dome and support structure. This unit is approximately 8ft in height and diameter, floorless and manually operated insofar as dome retraction and rotation are concerned.

There are hobbyists with remotely operated observatories that easily rival professional/research facilities used by academic institutions. Fully automated observatories are typically constructed by serious/wealthy enthusiasts who may not live in an ideal viewing location but would like to access the sky from such a place without having to travel there. Direct computer control of all systems is achieved remotely though various kinds of secure internet communication.

Telescopes: Telescopes permit viewing of distant objects at high degrees of magnification through the clever use of curved mirrors and lenses. Light entering the scope is reflected and refracted in various ways to produce an in-focus enlarged image of the target through an eyepiece. For astronomy, computer controls are available on even the most basic retail units today allowing for compensatory rotation for steady viewing of non-terrestrial targets. Most serious amateur telescopes are also equipped with GPS and auto orienting technology so that declination, elevation and bearing are electronically detected so that scopes self-align with the heavens and automatically commence tracking with little user input. Advances in computing and access to significant memory have further resulted in the commonplace offering of a sophisticated built-in library and atlas of astronomical bodies and phenomena. On any day from present into the distant future, most telescopes on the market today are programmed to know precisely where all planets, moons and heavenly bodies will appear in the night sky at any instant of time – and will take you there if prompted. A typical feature offered by most is a nightly tour of planets and objects that may be in particularly good viewing position according to the location of the viewer.

Cameras: Astrophotography has typically been carried out by attaching an SLR camera body to the viewing mount of a telescope where the eyepiece would normally be. An assortment of filters may also be employed and exposure time and film/sensor sensitivity is adjusted to capture an image. Often images are layered to heighten the appearance of dim objects and features, while eliminating noise. Today, digital

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cameras have replaced film, and computer screens have replaced prints, but there remain many options and challenges in the pursuit of good quality images. In the mid-range hobbyist genre it appears that purpose-built digital astro-cameras equipped with built-in preferred sensors and a simplistic compact design with a USB-only connection are edging out SLR cameras. The sophisticated software accompanying these units permits a wide range of multi-layering, noise cancellation, coloration options etc. – complete control of the photographic process can be exercised from the computer screen in the comfort of a heated room. In addition to the image taking and processing it is not uncommon to employ a micro-focuser to allow subtle focus control from the computer – something that must otherwise be done by making contact with the telescope body dials risking shake, alignment aberrations or other detrimental outcomes.

II. Design Summary

As a classical engineering design challenge the problem may be stated as follows: Create a convenient and secure means of using sensitive optical instruments at night for capturing distant nebulae, planetary features and other dim phenomena in a less-than-ideal geo-climatic zone at "reasonable" cost.

General Criteria and Desired Characteristics:

- A secure mounting for steady viewing.
- Convenience of use and optimal mob/demob time
- A facility that allows for storage and safekeeping of equipment, year-round.
- Selection of equipment to maximize utility within spatial, cost and weather constraints.
- A location where evening light pollution is minimized yet easy access is maintained & shelter from wind is obtained.
- Security is required so access and visibility are important considerations.
- The comfort of users considered throughout design.
- Cost efficiency and moderation.
- Quality of materials and build practices.
- Low maintenance requirements as it is intended to be a hobby with minimal obligation.
- Flexibility for upgrades, add-ons alternative uses and future equipment changes.
- Constraint: The facility is to be designed, constructed owned and operated by the amateur users.

Facility Concepts out of which No. 4 was selected:*

1. **Pedestal mount only** requiring placement of the equipment for each use. It was proposed to be built in a wooded spot on user-owned property in Portugal Cove - St. Philips. The shelter of the woods from adjacent lighting and wind, plus the slight distancing from city lights were assets, however, the inconvenience of setup time, exposure to cold, wind, rain, flies etc. dampened enthusiasm for this option.
2. **Coupled observatory/greenhouse** concept so that a modest glazed structure with a roll-back gabled end was visualized. Humidity and other concerns for security led to the abandonment of this idea.
3. **Wooden shed with retractable roof**, enabling many of the security and convenience factors desired. As drawn, the concept had limited sky-range if the desired location (country setting wooded lot) were to be used.
4. ***Shed with top-mounted pre-fab dome**. Thus it was determined that the preferred structure option would be one that had some form of roof retractability, secure storage, shelter from wind/elements and light pollution, a permanent rigid scope mount, and a wide open sky view.

Design Features of Facility

The shed-with-dome option (Figure 1) has a 10'x10'x10' office/storage room, through which a massive sand-filled, vibrationally isolated steel pedestal passes to an elevated viewing chamber. The operating dome was purchased from SKYSHEDPOD for simplicity, resilience (HDPE) and to expedite construction. The facility has a grid-based electrical service with surge protection and battery back-up for scopes, computers and lighting, and is situated in a wooded setting for low public visibility, high sky visibility, and weather shielding. Exposed surfaces are cedar, pressure treated lumber and commercial torch-on membrane for the near-level roof. The office is fully serviced; heated and insulated with a high degree of lighting control inside and out for convenience of nighttime access and darkening requirements for sensitive viewing. Tree trimming for view maintenance and building health is planned.

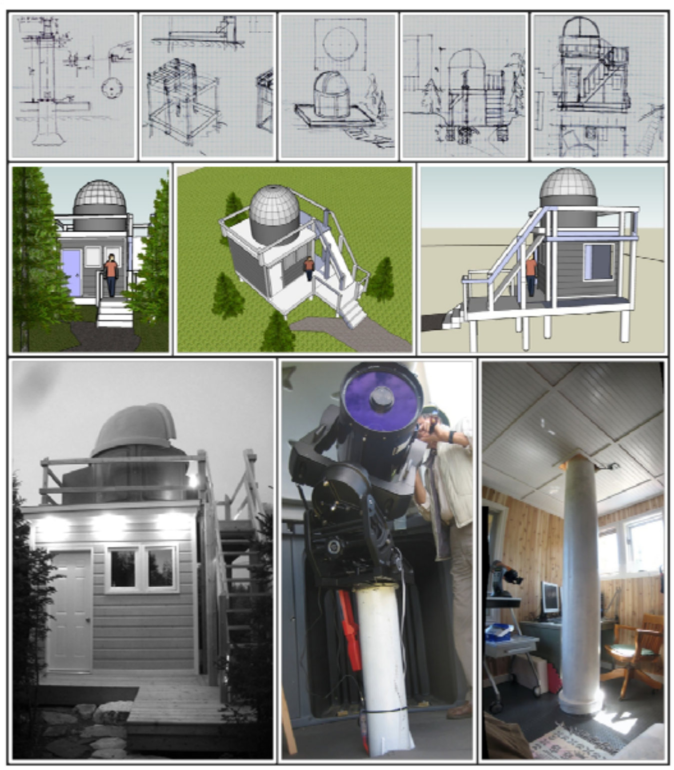

Figure 1 – Evolution of concepts through to completion.

Equipment Selection

The table below lists the equipment purchased or owned – that were deemed to be of optimal value for the purposes of astro-photography. An explanation of key choices follows.

Telescopes	*Stationary*	*Primary*	12" Meade LX200-A.C.F. (Advanced Coma Free optics), GPS, Autostar Guidance Systems
		Photo	4" Meade ED APO Triplet Refractor - exceptional quality optics/clarity
		Guide	2" Rear focus viewfinder
	Portable		4" - Meade, S.C. Fully Manual operated
			5" - Celestron, S.C. w/ Nexstar Computerized Guidance System
			6", Celestron Ref Manual, High quality optics
	Eyepieces		various: 40 mm - 25mm - 9mm
	Focuser		Zero Image Shift-Electronic Micro Focuser, Meade
	Diagonal		Series 5000 enhanced diagonal, Meade
	Accessories		Piggyback Brackets, mounting rings, Dew Shield, various tripods
Cameras	*Astro*		Meade Deep Sky Imager II Color Camera w/ 1/2" color genuine Sony® xview HAD™ CCD Sensor
	SLR		Canon D20 w/filter adj. capable & 30 sec. noise subtraction
Binoculars	*Sky*		Orion mini-giant 15x63
	Sky		Celestron skymaster 15x50
	Multi-purpose		Canon IS 10x42 L IS Water proof
Pedestals	*Primary*	*Base*	2250 kg concrete base w tapered 14" dia. 1/4" thickwall 8' primary steel pedestal - sand-filled.
		Secondary	Steel 6" dia. w/gussets 3/16 wall, 3' secondary pedestal for top mount onto primary
		Mount	Meade Ultrawedge heavy duty
	Auxiliary		Steel 4" dia, w/gussets bolt-down 40" pedestal
Computer	*Hardware*		HP desktop w/ Windows XP (preferred over newer O.S. due to custom software compatability)
	Software		Various Freeware and hobbyist packages, Autostar suite Meade, Nexstar Suite Celestron

Chosen for the primary stationary scope was the Meade LX200. It utilizes an Advanced Coma-Free (ACF) optical design by combining a hyperbolic secondary mirror with a corrector-lens and spherical primary mirror combination that performs as one hyperbolic element. This ACF design produces a coma-free, flat field of view that rivals traditional Ritchey-Chretien reflector telescopes used in most scientific observatories (and considerably outperforms Schmidt-Cassegrain reflectors [3]). The scope also has ultrahigh light transmission coatings on lenses and a primary mirror lock to prevent movement during long-exposure photo shoots. The smart motor drive has a very low error and correction requirement with either polar-aligned or level installations. A massive wedge for polar oriented – single axis rotation was purchased and installed. The GPS unit built in to the scope provides precise time, date and location for error-free alignment and the software contains autoalignment and access to over 145,000 celestial objects.

In addition to the scope, a heated dew shield for moisture abatement and a zero image-shift micro-focuser for better photographic results – were purchased. The cameras selected were the older model Canon D-20 digital SLR – a model that is particularly well suited for filter replacement and background scatter and noise cancellation. Research indicated that Meade Deep Sky Imager II Color Camera w/AutoStar Suite is the fastest and easiest way to take outstanding, high resolution full color images. The Deep Sky Imager II is easy to use and has a 1/2" color Sony® xview HAD™ CCD Sensor. The Meade camera/imager also uses a USB 2.0 high speed connection for communication and power requirements, and also has a temperature sensor, low pixel noise for more data, drizzle software technology, and AutoStar Suite Software Camera Control and Image Processing Software. Chip specifications are 752 x 582 Pixels (437,664 pixels, [3]). Pixel size is near square, resulting in better image processing results, measuring 8.3 microns wide by 8.6 microns high. Full 16-bit A/D conversion allows for signal integrity maintenance through capture and processing. A minimum exposure time of 1/10,000 of a second and maximum exposure time of one hour allows one to capture anything ranging from a day lit scene to the dimmest of objects in the night sky.

Optionally, for crisp wide-field observing and imaging, the best scope type is a true triple-element apochromatic refractor (APO). This is especially true for astrophotography, and so another Meade product was chosen – one that virtually eliminates color aberration/fringing. The 4 inch Meade E.D. APO Triplet optical design guarantees textbook color correction, and has ultra high light trasmissivity and extremely low dispersion. Mount rings on the 12 inch Meade permit piggybacking of this scope so that auto-controllers are not duplicated and simultaneous imaging/viewing can be realized.

Construction, Operation Lessons

The observatory was built in the summer/fall of 2009 and spring of 2010 on user-owned land outside the city of St. John's. Equipment was installed in early summer 2010 and calibrations and protocols are ongoing. For unrelated reasons the full operation of the observatory facility has not yet been realized, however, it is expected that continued efforts this fall will complete the set-ups and adjustments so that routine and convenient use will be achieved. It has been noted that the extreme wind conditions have not adversely affected the structure, dome or equipment - there have been no leaks except that water incursion occurs under the lip of the plastic dome during high winds. The space in the dome is also restrictive for night-time use with more than two people present. A larger and tighter dome would be beneficial though separation from the working office is still preferred for comfort and security. There have been no security breaches or damage from natural events. The original pedestal foundation was deemed to be insufficiently stiff requiring the retro-placement of an additional cubic-meter concrete footing – solving the problem. The cost of the facility was approximately $25k exclusive of land, and new equipment purchases were around $12k.

III. Conclusion

The construction of a Harsh Climate observatory was accomplished and has recently begun operation. Indications are that the facility will perform as planned though some weaknesses have been identified and improvements considered. Insufficient operational experience with the CCD camera on the primary ACF scope via AUTOSTAR software prevents further comment on functional output at this time.

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