SMARTS Revealed

John P. Subasavage[a], Charles D. Bailyn[b], R. Christopher Smith[a], Todd J. Henry[c], Frederick M. Walter[d], and Michelle M. Buxton[b]

[a]Cerro Tololo Inter-American Observatory, Casilla 603, La Serena, Chile;

[b]Yale University, Department of Astronomy, New Haven, CT, 06520-8101, USA;

[c]Georgia State University, Department of Physics and Astronomy, Atlanta, GA, 30302-4106, USA;

[d]Stony Brook University, Department of Physics and Astronomy, Stony Brook, NY, 11794-3800, USA

ABSTRACT

The Small and Moderate Aperture Research Telescope System (SMARTS)* consists of four telescopes atop Cerro Tololo Inter-American Observatory (CTIO): the 0.9m, 1.0m, 1.3m, and 1.5m. A consortium of twelve institutions and universities began funding operations in February 2003. Time allocation for these facilities is as follows: ∼65% to consortium members, ∼25% to the general community, and 10% to Chilean researchers. Thus, resources remain available to the community while providing a unique opportunity for consortium members; the possibility of high temporal cadence monitoring coupled with long time baseline monitoring. Indeed, a number of member programs have benefited from such a schema. Furthermore, two of the four telescopes are scheduled in a queue mode in which observations are collected by service observers. Queue mode investigators have access to spectroscopic observations (both RC and echelle) as well as direct imaging (both optical and near-IR simultaneously). Of the remaining two telescopes, the 1.0m is almost exclusively operated in user mode and contains a $20'$x$20'$ FOV optical imager, and the 0.9m is operated both in user and service mode in equal allotments and also has a dedicated optical imager. The latter facilities are frequently used for hands-on student training under the superb sky conditions afforded at CTIO.

Currently, three of the partner universities are responsible for managing telescope scheduling and data handling, while one additional university is responsible for some of the instruments. In return, these universities receive additional telescope time. Operations are largely run by a handful of people, with six personnel from the four support universities and seven dedicated personnel in Chile (five observers, one observer support engineer, and one postdoctoral appointee). Thus far, this model has proven to be both an efficient and an effective method for operating the small telescopes at CTIO.

Keywords: SMARTS, small telescopes, CTIO, observatory operations

1. INTRODUCTION

As astronomical observatories continue to push new optical telescope design boundaries, continually increasing primary mirror apertures (the latest designs measure in at 30-40 meter diameters), costs rise exponentially. Consequently, national funding sources (e.g., the National Science Foundation) must adjust funding allocations to meet the financial needs of the next generation of mega-telescopes. By and large, the smaller telescopes bear the brunt of the burden, forcing many to be decommissioned. However, given that operational costs of existing small telescopes are rather low, several must be shut down for a modest return of financial resources. Thus, we are moving to a situation where the bulk of resources (and astronomical capabilities) are funneled toward only a

Further author information: (Send correspondence to J.P.S.)
J.P.S.: E-mail: jsubasavage@ctio.noao.edu, Telephone: +56 51 205 284

*http://www.astro.yale.edu/smarts/

few large telescopes thereby increasing the difficulty for many facets of astronomical science to obtain necessary data.

One element of research that is not likely to be addressed with the next generation of telescopes relates to temporal data coverage. In this respect, both long-term (e.g., years, decades) coverage and high cadence (e.g., nightly, weekly, monthly) coverage provide unique datasets that are able to probe realms of astronomy beyond the reach of traditionally scheduled observations. Keeping in mind the reality that, as fewer collective observing nights become available to a growing population of astronomers, such research capabilities may become extinct.

Yet another element of observational astronomy that is likely to become increasingly more rare as we progress toward larger telescopes is that of researchers personally collecting their own data. Nearly all observational astronomers up to the current epoch have had the pleasure of sitting in a telescope control room (or a remote control facility), making decisions on-the-fly, to design observations that will best answer specific questions. Even with the current generation of new telescopes in the 8-10 meter class, "classical" observing mode is a distant second to the most widely used "queue" observing mode. While queue observing has its advantages, users obtaining hands-on experience is not one.

An obvious point that nonetheless warrants attention is the fact that bright objects are extremely difficult, if not impossible, to observe with large telescopes. There is no shortage of intriguing science being conducted on bright objects (e.g., see Section 3.2) that would not be possible without the use of small- and moderate-sized telescopes. Here we present an operational model that has been in place at CTIO since 2003 for small telescopes management that alleviates all of the aforementioned concerns.

2. SMARTS OPERATIONAL STRUCTURE

The SMARTS consortium has been operating the four small telescopes at CTIO (0.9m, 1.0m, 1.3m, and 1.5m) since February 2003. The novel operational structure of SMARTS, outlined in this section, allows it to operate small telescopes efficiently and still maintain access to the general astronomical community via National Optical Astronomy Observatory (NOAO).

2.1 Consortium Membership

SMARTS has two levels from which an institution/individual can choose, primary membership and secondary membership. The consortium is comprised of (currently) twelve universities/institutions that act as Primary Members. A Primary Member is defined as one who, in any semester, contributes $25,000 or the equivalent in any combination of cash, services, operations, telescopes, or instrumentation. At this level, members are entitled to a seat on the SMARTS Management Council and given voting privileges. There exists an option for institutions, as well as individuals, who contribute less than $25,000 to act as Secondary Members. In this case, the member is not entitled to a Management Council seat nor given voting privileges. Also, the member must be sponsored by a Primary Member and apply for time through the Primary Member. If the member chooses to join as an individual, then institutional signatures are not required.

2.2 Personnel

With regards to the personnel required to make SMARTS operations smooth and efficient, there is a modest collection of individuals, most of whom focus on specialized elements. The Principal Scientist (currently Charles Bailyn of Yale University) is responsible for the overall management of SMARTS. Key tasks include financial management, managing the membership (time allocations, and financial and in-kind contributions of the members), and scheduling. Once observing proposals from consortium members as well as successful proposals from the general community are collected, telescope schedules for each of the SMARTS telescopes are generated. Then, coordinators for each of the telescopes manage observations and data handling. Currently, three member universities employ individuals that act as coordinators: Yale University for the 1.0m and the 1.3m, Stony Brook University for the 1.5m, and Georgia State University for the 0.9m. In cases where service observing is available (0.9m, 1.3m, and 1.5m), the coordinator interfaces with the successful proposal PIs to obtain observing lists and relay specific instructions to the service observer. In general, the end-users (e.g., PIs) communicate directly with the coordinator. As such, day-to-day operations are largely handled by the coordinating institution, thus limiting the burden on any one set of managers.

When technical difficulties arise at the telescopes, engineering expertise employed by CTIO (and on-site already) provides support. SMARTS, in turn, contributes to the overall site maintenance by a standard aperture-based fee. We note that SMARTS (or a successful SMARTS-like operation) depends critically on being on a mountain where such services can be provided by a bigger operation. In addition, five full-time observers are employed by SMARTS to carry out the service observing. One additional full-time engineer provides observer support (e.g., visiting observer training, instrument setup, technical assistance) on the mountain. Beginning in 2009B, the first CTIO/SMARTS Postdoctoral Fellow (jointly funded by CTIO and SMARTS and based in La Serena, Chile) was hired to provide improved scientific support and on-site management of the SMARTS telescopes.

2.3 Time Allocation

Telescope time is allocated in the following manner: ∼65% to consortium members, ∼25% to the general community, and 10% to Chilean researchers. Since the onset of SMARTS, there has been fairly high demand from the general community, whose proposals are evaluated via the NOAO telescope allocation committee (TAC). In fact, the oversubscription rate for general users in 2010A for the 1.5m telescope was 3.0 (the highest since SMARTS began). Thus, while providing the consortium members with unique and valuable resources (see Section 3), the small telescopes (that otherwise would have been decommissioned) continue to provide capabilities that cover a much broader observational need.

Time on the SMARTS telescopes is assigned to institutions for several different kinds of contributions. Institutions that own and maintain the telescopes and the instruments receive time for that contribution (the general community time comes from this as NOAO owns most of the telescopes/instruments used by SMARTS). Time is also awarded for contributions of cash, currently at the rate of $1,100 per night. Those institutions who contribute to the management of the consortium and the day-to-day creation of the observing queues are also given time for this contribution. Programs that require service observing are charged at a rate of 1.5 times that of traditional user based observing

3. SMARTS CAPABILITIES

The resources available within SMARTS allow for a wide-range of observational capabilities. In addition, the somewhat unique structure of SMARTS provides capabilities that cover various time domains from short-range monitoring (e.g., nightly, weekly, monthly) to multi-year monitoring as well as a combination of the two for priority targets. Lastly, SMARTS facilities permit user observing (i.e., classical mode) for ∼1/3 of all of the time available through SMARTS. Thus, a significant fraction of time is available for hands-on training of our community's up-and-coming astronomers.

3.1 Telescopes

While operating only four telescopes, SMARTS has a wide range of observational and near-IR capabilities as well as both classical and queue scheduling modes. We outline each telescope's instrument(s) in Table 1 and available scheduling modes in this section.

3.1.1 0.9m

The 0.9m telescope is equipped with a dedicated Tektronics 2048 × 2046 pixel optical imager. This telescope/instrument combination has proven to be a stable astrometric device (see Section 3.2). Usable filters include any 3" × 3" or 4" × 4" filters available at CTIO (a complete list of filters can be found on the CTIO website[†]) with a standard Johnsons-Kron-Cousins UBVRI set as the default. Scheduling is a mix of classical and service modes assigned in alternating one-week increments. The service mode is similar to a standard queue mode in that the observations are taken by a service observer. The primary difference from a standard queue mode is that the schedule is set at the beginning of the semester and no adjustment to the schedule is made

[†]http://www.ctio.noao.edu/

Table 1. Overview of SMARTS Instruments

Telescope	0.9m	1.0m	1.3m		1.5m	
Instrument	CFCCD	Y4KCam	ANDICAM Optical	ANDICAM Near-IR	R-C Spectrograph	Echelle Spectrograph
FOV (′) / Slit (′)	13.6 × 13.6	20.0 × 20.0	6.0 × 6.0	2.4 × 2.4	single slit 1.5	one star
Plate Scale (″/px) / Resolving Power	0.401	0.289	0.369 (binned)	0.274 (binned)	300 – 4,000	20,000 – 43,000
Filters / λ Range (μm)	Multiple Filters	UBVRI SDSS ugriz	BVRI	YJHK	0.32–0.90	0.40–0.73

because of inclement weather conditions. During the service weeks, no more than two or three individual projects are scheduled on any one night. Thus, this mode is used by relatively large survey programs that need at least several hours per night. Data collected by service observers are transferred daily to the Georgia State University FTP server for delivery to the end-user.

3.1.2 1.0m

The 1.0m telescope is equipped with a dedicated STA 4064 × 4064 CCD that covers the largest FOV available within SMARTS. Scheduling is exclusively in classical mode and in increments as needed. Thus, it is not uncommon for individual projects to be scheduled for longer than one continuous week (when project requirements warrant a large number of nights).

3.1.3 1.3m

The 1.3m telescope is equipped with ANDICAM, a simultaneous optical and near-IR imager. The optical component is a Fairchild 447 2048 × 2048 CCD while the near-IR is a Rockwell 1024 × 1024 HgCdTe "Hawaii" array. Scheduling is exclusively in queue mode. As a general rule, no one program can occupy more than one hour per night to allow for a multitude of monitoring programs to be accommodated every night. In cases of high-priority programs (when important events are taking place, observations with other observatories, etc.), a three-hour limit is the absolute maximum. One rather convenient feature of this queue is that PIs can contact the queue manager by mid-afternoon and adjust their observing program for that night to allow for a wide variety of Targets of Opportunity (ToOs). The optical data (binned 2 × 2 on the CCD) are downloaded nightly to the Yale Repository where basic CCD reduction steps (bias and flat-field corrected) are performed prior to delivery to the end-user. To reduce the filesizes of the near-IR data, the frames are processed at the telescope to bin 2 × 2 in software (i.e., *after readout*) with reference to a bad pixel mask. No further processing is done to the near-IR data.

3.1.4 1.5m

The 1.5m telescope is equipped with two spectrographs, a Richey-Chrétien spectrograph mounted at the Cassegrain focus, and a fiber echelle spectrograph in a fixed configuration and connected by optical fiber. In this configuration, both instruments are available at all times so that switching between the two during the night is trivial with minimal overhead. The detector for the R-C spectrograph is a Loral 1200 × 800 CCD, while for the echelle, is a SITe 2048 × 2048 CCD. The R-C spectrograph currently has seven grating/tilt configurations that are the most widely used and can be found on the CTIO 1.5m scheduling website[‡]. Non-standard configurations are available at the expense of scheduling efficiency. The echelle is operated in one configuration with the option of increasing the slit width at the expense of resolution. The standard slit width setting produces a resolution of ∼43,000 while the lower resolution slit width setting produces a resolution of ∼26,000 though with a ∼30% transmission gain. An iodine cell positioned in the light path is available for high-precision radial velocity measurements. Scheduling is almost exclusively in queue mode. Rare exceptions allow for users to obtain their own data directly. Also, the Alpha Centauri project (see Section 3.2) is being conducted at the 1.5m with queue observing being scheduled around it.

[‡]http://www.astro.sunysb.edu/fwalter/SMARTS/smarts_15msched.html

3.2 Time-Domain Capabilities

Scheduling modes coupled with the quasi-permanent renewable basis on which SMARTS currently operates allows consortium members to have access to somewhat unique time-domain capabilities. As mentioned previously, both short-term (less than one year) and multi-year monitoring campaigns executed by SMARTS consortium members have produced vital results that would have been very difficult if not impossible by conventional time allocation processes. We illustrate this point with specific examples.

The 0.9m telescope has been host to the CTIO Parallax Investigation (CTIOPI[1–3]) since 1999, initially under the auspices of the NOAO Surveys Program and continues via SMARTS. While trigonometric parallax measurements to nearby stars are not new observational feats (parallaxes have been measured for nearly 200 years), the cadence demanded of the observations coupled with the need for multi-year observations often limit the breadth of such projects. SMARTS played no small role in allowing CTIOPI to grow from its initial expectations as a 3-year surveys project to one of the largest ground-based parallax surveys of this era (currently consisting of ∼600 systems for which parallax measurements are being collected or have been completed). Moreover, CTIOPI recently celebrated its 10th year anniversary. Few datasets in existence contain careful astrometric measurements taken every few months for a period of more than a decade for hundreds of nearby stars. These data are becoming sensitive to astrometric perturbations from unseen companions that have orbital periods of ∼20 years or longer thus probing uncharted parameter spaces for our nearest neighbors.

The 1.3m telescope has been host to two multi-wavelength monitoring programs aimed at mimicking the cadences with which high-energy space-based facilities observe. The first program targets X-ray emitting binary stars with observing cadences of a day or two, very similar to the Rossi X-ray Timing Explorer (RXTE), to construct long-term light curves, both in the optical and near-IR (e.g., Coriat et al. 2009[4]). These light curves can then be compared to the X-ray light curves to explore the underlying physics that drives the radiation seen over all wavelengths. The second monitoring program is very similar in observing strategy though with very different types of targets. In this case, the targets are gamma-ray bright blazars, types of galaxies with a very active nuclei that produce jets. The standard model states that our orientation with respect to the jets is directly in line with them. Thus, we are witnessing the relatively unimpeded radiation coming from the center of this very energetic radiation source. Again, long-term optical and near-IR monitoring with cadences of 1-3 days can then be compared to gamma-ray data taken with the space-based Fermi telescope to probe the sources of the radiation and better understand the inner workings of these highly energetic galactic cores (e.g., Bonning et al. 2009[5]). It is important to note that other members of the consortium, both private and public, are also carrying out their own programs of observations of both of these kinds of sources, in addition to the large long-term program described here.

The 1.5m telescope has been host to a radial velocity planet hunt known as "Mission to Alpha Centauri" using the echelle spectrograph. The Alpha Centauri system is the nearest to the Sun and is composed of two solar-type stars that orbit near one another and a third late-type red dwarf (Proxima Centauri) that orbits much more distant (∼ 10,000 AU). This program began in 2009 in which Alpha Centauri A and B (the two solar-type stars) are monitored nearly every night they are observable from CTIO for several hours per night. The strategy is to observe them repeatedly, obtaining hundreds of spectra per night, over five years. Simulations have shown that, with the radial velocity precision of the 1.5m + echelle system and the high observing cadence, earth-like planets would be detectable if they exist (Guedes et al. 2008[6]). If successful, this may be the first true detection of an earth-like planet outside of our solar system and it will have been done with a relatively small telescope. The vast amount of observing time needed for this program prohibits the use of large telescopes that are in very high demand. Also, as Alpha Centauri A is the third-brightest star in the night sky, large telescopes are poorly suited for these types of observations.

The 1.3m and 1.5m telescopes are being used for a long term photometric and spectroscopic study of galactic novae. Novae are unpredictable phenomena with short time-scales not amenable to the standard TAC/classical observing process. SMARTS affords the flexibility to begin obtaining data within 24 hours of the discovery of the nova, and the queue affords the luxury to observe the young, rapidly evolving nova on timescales of hours to days, and on longer timescales as they approach quiescence. One goal of this program is to look for optical diagnostics that correlate with the supersoft X-ray source (steady nuclear burning on the surface of the white dwarf). One discovery to date is that the line profiles of the recurrent novae resemble those of accretion disks, which implies that the disks may survive the initial nova explosion (Walter et al. 2010, in preparation). To date, 46 southern novae have been monitored, some with photometric baselines as long as 5.5 years[§].

3.3 Training Capabilities

Nearly every observational astronomer admits that one of the biggest joys of astronomy is traveling to remote places where skies are clear and city lights are largely absent to collect one's own data directly from the telescope. Also, having advanced undergraduates and beginning graduate students visit the mountain remains one of astronomy's best recruiting tools for new talent and thus maintains a high-quality influx to the astronomy career pipeline. One is also ensured that the data being collected are done in a manner necessary to target the underlying science. This scenario enables the observer to understand proper observing procedures and (perhaps more importantly) data reduction techniques. Given that astronomy is witnessing a push toward larger surveys where calibrated data ready for analysis are the end-products (e.g., Sloan Digital Sky Survey – SDSS), this is a non-trivial benefit gained. With SMARTS, nearly 1/3 of the total time available is scheduled in classical mode. As mentioned previously, the 1.0m is scheduled entirely in classical mode and the 0.9m is scheduled half of the time in classical mode. It is perhaps no surprise that these two telescopes are largely used to train undergraduate and graduate students in proper observing techniques. It is these students who may lead the next generation of large surveys and who must understand proper calibration techniques for the survey to be successful (after all, someone has to reduce the data for surveys).

4. CONCLUSIONS

Small telescopes continue to serve the astronomical community in myriad ways, many rather unique when compared to more modern (and in general, larger in size) facilities. We are currently witnessing a paradigm shift towards larger and larger telescopes and as a result, the smaller telescopes are paying the price. The end result is fewer resources for the continually growing astronomical community. Here, we have presented an operational model that has been very successful and beneficial for all parties (i.e., consortium members, general community, and hosting observatory). There seems no obvious reason such a schema would not work at other observatories where small telescopes have been decommissioned or are "clinging to life". The costs are relatively small to give these facilities new leases on life and in return they will produce quality data products that continue to push the envelope of astronomical research.

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