SELECTING, SCHEDULING AND CARRYING OUT OBSERVING PROGRAMMES AT SALT

DAVID A.H. BUCKLEY

Southern African Large Telescope
P.O. Box 9
Observatory 7935, South Africa
dibnob@saao.ac.za

Abstract. This paper describes the manner in which Southern African Large Telescope (SALT) observations are carried out, from the observation proposal process to the final distribution of data to the SALT users. As a background, the general operational model for SALT is also described. In addition I discuss the main top-level design and performance characteristics of both the telescope and instruments, which informs the nature of SALT observing programmes and leads to a natural selection of competitive science projects. Since SALT is a 100% queue-scheduled and service-observing telescope, there is a significant level of flexibility regarding how observations are undertaken. A single observation block can involve different instruments and modes, including calibrations. To support the often complex manner in which observations can be configured, a set of observation proposal and planning tools have been developed for both users and support staff, and these are described in this paper. SALT users can plan their observations using these tools and submit their proposals over the internet in two phases. The Phase 1 proposal contains the scientific and technical justification and target information, but only a basic description of the instrumental and observation configurations. Following approval of the proposals, the Phase 2 proposal is completed which contains all of the details of every observing block, including configurations, exposure times, signal-to-noise requirements, time windows (if applicable), total block observation time and calibration requirements. How SALT observations are undertaken, monitored and reduced is also described.

1. Introduction and History

The Southern African Large Telescope (SALT) is now one of five 10m-class segmented mirror telescopes, the only one in the southern hemisphere (Buckley 2006b). It is closely modeled on the pioneering design of the fixed-altitude Hobby Eberly Telescope (HET) at McDonald Observatory, Texas. HET and SALT represent a completely new design paradigm for optical telescopes (Ramsey *et al.* 1998, Buckley 2001), being analogues of the Arecibo radio telescope (although not zenith pointing). The SALT primary mirror consists of a 10m × 11m hexagonal array of 91 identical 1.2m × 1.0m hexagonal mirror segments with spherical surfaces with a radius of curvature of 23.2m, tilted 37° to the zenith. This array directs light to a 4-mirror spherical aberration corrector (SAC), mounted on a moving tracker at the prime focus. The telescope can only access an annular region of the sky, 12° wide, centred at the zenith, which represents ∼12% of the instantaneously visible sky at an airmass of <2.5 (see Fig. 1). This geometry implies that only objects in the Declination range +10° to -75° are observable, and the total uninterrupted observation times typically range from 1-2 hours, although they can be extended to 4-5 hours at the extreme Declinations if the telescope is re-pointed in azimuth. This design also implies that the entrance pupil of the telescope (11m in diameter) is not fixed on the primary mirror array, but rather moves over it during the course of an observation. This means that the effective aperture varies during an observation, at worst being equivalent to an un-obscured 7m diameter mirror, and at best (centred pupil) equivalent to a ∼8.5m diameter mirror. This changing pupil also poses additional complexities when it comes to calibrations, which require a calibration system which can mimic the pupil geometry of the on-sky observation.

SALT is owned by a private Foundation, set up to fund its construction and operation, which represents a collaboration of universities and institutes from Africa, India, Europe, New Zealand and North America. The South African National Research Foundation is a majority shareholder with ∼33% of the current observing shares. Other major shareholders are Dartmouth College (9%), University of Wisconsin-Madison (15%), Nicolaus Copernicus Astronomical Centre of the Polish Academy of Sciences (9%) and Rutgers University (10%). Other shareholders (at < 6% level) include the American Museum of Natural History, Carnegie Mellon University, the Indian Inter-University Centre for Astronomy and Astrophysics, University of Canterbury, University of North Carolina, Göttingen University and the UK SALT Consortium, the latter representing the Universities of Central Lancashire, Keele, Nottingham and Southampton, the Open University and the Armagh Observatory. The percentage shareholding as mentioned above
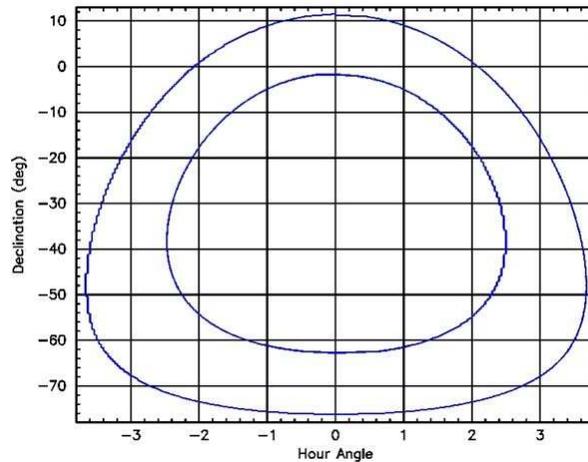
Figure 1.   The SALT visibility annulus. Only objects inside the annulus are visible to SALT.

(as at May 2011) do not quite reflect the percentage allocation of SALT observing time, since there are additional allocations over fixed periods for in-kind contributions to the project, one example being for the HET Consortium, for intellectual knowledge and assistance provided for the design of SALT.

Participation in SALT was attractive to its partners for a number of reasons, the most signifcant being:

• access to a 10-m class telescope, at an affordable cost, with versatile observational capabilities;

• access to the southern hemisphere;

• affordable ownership (∼$20M for telescope; ∼$8M for first-light instruments; ∼$3M per annum for operations);

• a good observatory site (50% photometric; 75% spectroscopic; 0.9 arcsec median seeing; dark; dry);

• synergies with other facilities accessible by SALT partners (*e.g.* HET, WIYN, SOAR);

• relatively inexpensive and flexible queue-scheduled service operations;

• assisting in the development of science & technology and educational opportunities in South Africa.

2. Completion and Commissioning

SALT was inaugurated in November 2005, when the construction phase was essentially completed (Buckley *et al.* 2006a). Two of the First Gen-

eration instruments, were mounted on the telescope and a third was still in its planning stages. Following this, SALT entered an intensive period of commissioning and performance verification, which included the initial science observations. "First Science" was announced in 2006, following the beginning of commissioning in mid-2005 of the UV-Visible imaging camera, SALTICAM (O'Donoghue *et al.* 2003), which culminated in the first SALT science paper (O'Donoghue *et al.* 2006). In parallel, the commissioning of the Robert Stobie Spectrograph (RSS; formerly known as PFIS; Burgh *et al.* 2003), began in October 2005 and continued through to November 2006 (Buckley *et al.* 2008). RSS is a versatile, but highly complex, imaging spectrograph, supporting multiple modes, namely:

- Longlsit and Multi-Object Spectroscopy from 320-900nm using a suite of fully tunable VPH diffraction gratings;
- Fabry-Perot imaging spectroscopy, including dual etalon and tunable filter modes;
- Polarimetry, both imaging and spectro polarimetry, in linear, circular or all-Stokes modes;
- High time resolution observations, by virtue of frame transfer CCDs.

It was during this commissioning period that problems with the telescope's image quality and the throughput of RSS were uncovered, which led to the eventual removal (in November 2006) of RSS for optical repairs (Nordsieck *et al.* 2010).

Despite the problems with image quality, SALT was scheduled regularly (∼50% of nights) for science observations from 2006-2009, although there was still significant continuing engineering work being carried out by the operations team, much related to various subsystems not fully completed before the Project Team left in late 2005/early 2006. Three major performance issues were uncovered during commissioning: the aforementioned problems with telescope image quality and low spectrograph throughput, and the failure of the capacitive mirror edge sensor system to meet its design specifications. The first problem culminated in a 15-month engineering downtime from April 2009 in order to effect opto-mechanical modifications to the SAC, in order to improve the telescope's image quality (O'Donoghue *et al.* 2010). This was completed by mid-2010 when the telescope became operational again. In the meantime the RSS optics were also removed and the throughput issues addressed (Buckley *et al.* 2008; Nordsieck *et al.* 2010). Modifications were also made to improve the performance of SALTICAM.

Both RSS and SALTICAM were re-installed on the telescope in early 2011 and science commissioning programs were initiated to characterise the performance of the telescope and instruments (Buckley 2012). This phase transitioned into the first science semester in September 2011, when 75% of the telescope time was set aside for charged science time for the SALT

partners. The remaining 25% of the time was retained to complete the commissioning of outstanding instrument modes. A total of 144 proposals were accepted for this first semester and as at the end of the semester, the average completion was just ∼55%. The reasons for such a low completion rate were due to several factors:

1. A 40% increase in the time lost to weather;
2. Unavailability of certain modes due to incomplete commissioning or subsequent instrument problems;
3. Difficulty with attempting some programs which were pushing the current limits of the telescopes and instruments;

The last points are currently being addressed and indeed some progress was made for Item 2, with the first successful MOS (Multi-Object Spectroscopy) commissioning observations beginning towards the end of the semester.

3. Designing to Science and Operations Requirements

For SALT much effort and thought went into correctly defining the top-level "science requirements" of the telescope as a whole and then the specifications for the SALT system, subsystems and their constituent components. In addition, the entire design process is one based upon systems engineering: an iterative process whereby the high level goals or requirements of the astronomers were converted or translated into a set of technical specifications (Swart & Buckley 2004). The engineers responsible for the latter needed to trade off such things as performance, cost and schedule to arrive at a suitable solution which, in the first instance, satisfied the top-level requirements. The outcome of this process was that the astronomers and engineers arrived at a revised set of overall specifications, which were broadly acceptable scientifically and conformed to the various budgetary, technical and schedule constraints imposed on the project. This iterative process of compromise continued until a satisfactory solution was found, ideally with enough margin for de-scope options, should they have been necessary, to alleviate potential future contingencies.

While a systems engineering approach was crucial for successful design, it also played a role in subsequent phases of the project, particularly in the integration and implementation stages. Here it is often necessary to revisit choices made during the design phase in order to address technical or schedule difficulties. The evolution from high-level goals, or requirements, through to the final development are many and varied, and typically involve a sequence of steps and feedback loops. These vary according to the design complexity, whether the technologies are established or novel, and issues relating to funding, legal, and partner/shareholder agreements, etc.

TABLE 1. Telescope efficiency comparisons.

Telescope	Bad weather	Faults	Engineering & Calibrations	Science time (incl. overheads)
SALT (by design)	25%	3%	7%	65%
SALT (May 2012)	35%	13%	12%	40%
HET (2001)	30%	6%	20%	44%
Keck*	16%	4%	11%	69%
Gemini*	20%	3%	10%	67%
VLT*	12%	3%	5%	80%

* circa ∼2004

In addition to the science driven requirements, which determined many of the design specifications at the system and subsystem level, operational considerations also had to be considered in defining these specifications. These included those relating to the scientific productivity and efficiency, like the telescope scheduling, remote observing, data handling, processing and archiving, creation of observing proposals and observing scripts, etc.

4. SALT Operational Criteria

In designing SALT, the basic overall operational criteria aimed at for the total system (*i.e.* telescope) can be condensed into several key efficiency parameters, as presented in Table 1. The figures in table apply to several telescopes at different times. The HET figures were for the initial operating science operations, before mirror edge sensors were installed. Thus the larger fraction for "Engineering & Calibrations" reflects the additional regular loss of observing time needed for mirror alignment, which can amount to 10-20% of a night, depending upon conditions.

A new mirror segment edge sensing system has been designed, based on inductive sensor technology, and is expected to be installed over the next two years. This will reduce the need for optical alignments (using the Shack-Hartmann wavefront camera at the mirror array centre of curvature) of the mirror array to several times a night, to once every ∼5 days. In principle the alignment can also be started during twilight and even in overcast (but not precipitating!) conditions, which will help in lessening the impact on science operations. SALT's design goals with an active mirror control system using edge sensors and actuators, reduced this loss – by design – to 0%, but the current lack of this on SALT reflects this larger fraction as at May 2011.

Calibration observations are somewhat of an unknown at present, al-

though it is clear that such observations will need to be done both during the night (*e.g.* spectral calibrations with arc lamps) and during the day (*e.g.* flat fields simulating the pupil motions of completed observation). SALT's instruments, particularly the main work-horse instrument, the Robert Stobie Spectrograph (RSS), will have various observing modes, and potentially many such modes will be used in a single night, all requiring relevant calibration observations.

In all aspects of both telescope and instrument design, the operational philosophies adopted have been purposely developed for a queue scheduled operation where getting to the target and observing it in whatever available instrument mode happens in the fastest and most efficient manner. In addition, instrument mode changes (*i.e.* from SALTICAM to RSS) can take place by simply inserting a fold mirror (< 60s).

5. Operating SALT

The South African Astronomical Observatory, the national facility for optical/IR astronomy in South Africa, has been contracted by the SALT Foundation to operate and maintain SALT, for an initial period of ten years (until 2015). The SAAO, which was founded in 1972, owns and operates its major observing station near Sutherland, in the arid central Karoo region of South Africa, $\sim$380km north east of its headquarters in Cape Town. Apart from SALT, nearly 20 telescopes, ranging from 0.042 to 1.9m in diameter are operated at the site. Many of the more recent additions (*e.g.* KELT South, MONET South, SuperWASP, SOLARIS) are robotic telescopes. Five telescopes, namely the SAAO 1.9, 1.0, 0.75 and 0.5m telescopes and the 1.4m Japanese IR Survey Facility telescope (IRSF), are scheduled and operated in the traditional manner, i.e. with weekly allocations to a specific astronomer.

The obvious departures, brought about by SALT, from previous experiences in operating the smaller SAAO telescopes includes the 100% queue scheduled 'service observing' mode in which SALT operates. In addition, the telescope is of such a different and complex design that the experience of SAAO's older and more conventional equatorially mounted telescopes provided little experience in knowing how to efficiently operate and maintain SALT. Indeed many of the SALT subsystems have used new technologies which had not previously been used at SAAO. Examples included:

- Active optics control (*i.e.* the primary mirror system of edge sensors and actuators);
- The primary mirror optical alignment system (*i.e.* the Shack-Hartmann wavefront sensor);

- Embedded control systems, precision actuators, sensors and associated control software;
- The LabVIEW graphical programming language, which is at the heart of the subsystem controllers and the Telescope Control System (TCS);
- Experience in web-based software (*e.g.* Java), queue scheduling software and database design and management;
- Operational experience with interferometers, optical alignment procedures, etc.

Many of the skills required for the above were subsequently acquired through a combination of appointing new experienced engineering and technical staff and training existing SAAO staff. This has resulted in the appointment of a core of 10 sufficiently qualified engineering staff within the SALT Technical Operations division (established in 2005), based at SALT, and supported by an additional logistics staff of five. The skills within the division cover all of the major disciplines required for supporting and developing a modern telescope, namely optical, electronic, mechanical and software engineering, mechatronics, information technology, etc. The SALT-based operations staff are also supported by six additional personnel, mostly based in Cape Town, who focus on software support (three), drive many of the current engineering developments (three), and also support technical operational activities at SALT as needed.

The scientific support staff for SALT reside within the SALT Astronomy Operations division of the SAAO, consisting of eight astronomers and a supporting software developer, plus three telescope operators. Most of the staff are based at the Cape Town headquarters of SAAO and astronomers are regularly scheduled (typically one week in six) for SALT support on a rotating roster arrangement. The operators, who are mostly based in Sutherland, are scheduled one week in three, but also have some daytime responsibilities during non-observing weeks. Each duty SALT Astronomer (SA) and SALT Operator (SO) spend seven full nights at the telescope, plus an additional half night during the weekly transition period. The SALT duty astronomer is supported by a Cape Town based support astronomer during their week, who checks on issues like data transfers from Sutherland to Cape Town, completion of the automatic data reduction pipeline, basic data quality checks and the distribution of data to the SALT users. Additional support duties undertaken by the SALT Astronomy Operations group includes:

- Assisting users in writing observing proposals, performing technical reviews of proposals, and liaising with the different partner Time Assignment Committees (TACs);
- Liaising with the Principal Investigators (PIs) of SALT proposals in formulating their observations, performing technical reviews of proposals, assisting with data reduction enquiries and general trouble shooting;

- Supporting the operational modes of the telescope and instruments by characterizing the current performance and assisting in the development of the data reduction pipeline for different instrument modes;
- Assisting in instrument and telescope commissioning, performing tests and updating information on the websites, wikis, etc.;
- Developing software tools for users (*e.g.* instrument simulators) and support astronomers to monitor program progress, schedule observations, update status and interact with the SALT Science Database;
- Undertake miscellaneous observatory duties, including such things as outreach activities (to users, students, the public), involvement in graduate student teaching and supervision, involvement in other SAAO activities (*e.g.* instrumentation projects);
- Monitoring and reporting of the general performance of the observatory in terms of key performance parameters (*e.g.* system throughput, image quality) and completion statistics for observing programs;
- In addition to the above duties, SALT Astronomers are given time (nominally 40%) to undertake research, focusing on the utilization of SALT.

The systems engineering approach used in constructing SALT has assisted in ensuring that the telescope, which is a complex machine involving many subsystems, is a well integrated system which can be operated easily and efficiently. One crucial area is the overall science efficiency of the telescope, which is affected by such things as how quickly the telescope can move from target to target. The design of the Telescope Control System (TCS) GUIs (Graphical User Interfaces), which both the SALT Operators and Astronomers use to control the telescope and its subsystems, are designed with ergonomics and efficiency in mind. The overall maxim is to be able to issue commands with the fewest number of mouse clicks or keyboard entries.

6. SALT Science Observations

Unlike all of the existing SAAO telescopes, the approved observational programs undertaken with SALT are not conducted by their respective proposers, but rather by SALT astronomy operations staff, namely the SALT Operator and SALT Astronomer. The manner in which a typical observation with SALT progresses, from the proposal phases to the relevant Time Allocation Committees (TACs; see Table 2), and then through to the eventual observation, quality assessment and data dissemination are summarized in the Tables 3 & 4. SALT users can apply for SALT observations twice a year, with observing semesters running from 1 May – 31 October and 1 November – 30 April.

TABLE 2. The full SALT proposal sequence.

Step #	Activity	Description
1	Complete Phase I web-based proposal form using a basic template	Write scientific justification and use web based tools to ascertain viability
2	Submit Phase I proposal	Send to SALT Astronomy Operations
3	Phase I technically reviewed and sent to respective partner TACs	Phase I proposals loaded into database. SALT Astronomy Operations perform tech feasibility & determine statistics
4	Phase I proposal reviewed and time allocated	PI alerted of allocation
5	Complete Phase II web-based proposal form	More detailed time-line and telescope and telescope and instrument configurations defined; SALT Astronomers (SAs) check viability, etc.

The observational efficiency of SALT is mostly determined by the time it takes various telescope and instrument subsystems to perform their respective tasks and the two basic timescales, as specified in the SALT Systems Specification, namely slew time to target (<180 s) and setup time to begin observations (<360 s). The telescope slewing involves the parallel execution of several TCS commands (*e.g.* dome rotate, structure rotate, tracker position, payload configuration). Most of these commands are transparent to the SALT Operator, who will simply issue a command to 'go to next target' via a single mouse click on a GUI, rather than issuing a sequence of subsystem commands. The observation set up time includes closed loop guidance and focus initiation and instrument set ups (*e.g.* alignment of targets on slit masks). SALT Astronomer and SALT Operator actions involving the observation itself occur in parallel, like the assessment of data quality (*e.g.* S/N ratio, spectral resolution, flux) and adjustment of the observing schedule as conditions or circumstances change.

An observation block (the smallest scheduled unit of a program) will more often than not consist of a set of repeat exposures, during which the data quality of the penultimate observation can be assessed in real time as the current observation is still in progress using the quick-look analysis tool (SALTFIRST; see Section 13 & Fig. 5). Adjustment of subsequent exposure times, as necessary, is then possible, provided the observation block time

TABLE 3. The full SALT observation process.

Step #	Activity	Description
1	Plan weekly observation priorities	look at viable programs for coming week; coordinate any engineering activities; define required filters/etalons for the week
2	Schedule observations, including calibrations	Review target availability (continuously during the night) and observing conditions; schedule suitable observing block(s)
3	Prepare to observe	Select specific observing block/target; send info to Observation Control System (OCS)
4	Acquire target; configure instrument; focus; acquire and setup guide/focus star	Point telescope and guide probes
5	Conduct observation	Take any requested calibration observations if requested (*e.g.* arcs); begin on-sky observations
6	Monitor observation	Check telescope guidance & focus; Run quick-look data reduction tool SALTFIRST; assess data quality (e.g. S/N)
7	Complete observation; store and transfer data; complete logs	Data copied to quick-look & quality control computer (QCPC); complete on-line logging logging as required
8	Primary mirror alignment	Assess delivered telescope image quality; monitor seeing; optically realign mirror
9	If observing conditions acceptable, go to step 3	Assess weather, seeing, transparency

is not exceeded. Many observations have observing blocks closely matching the maximum allowable track time (as determined by the target position and time), inclusive of any acquisition and setup overheads (typically 300-600s depending on complexity).

SALT observations are scheduled in real time by running the Observa-

TABLE 4. Daytime SALT astronomy operations

Step #	Activity	Description
1	End of night procedures	Do twilight calibrations (observe standards) if appropriate; park telescope & instruments and close down
2	Plan and schedule day calibrations	Mainly for accurate flat fielding using moving pupil baffle
3	Data delivery and problem solving	Check data was sent to Cape Town HQ & pipeline completed OK; look at night logs; contact PIs if needed; liaise with Tech Ops staff

tion Planning Tool (OPT), a LabVIEW program which interrogates the MySQL Science Database (SDB) which contains all observing program information. A search can be made of all active observing blocks currently accessible to SALT, and the resulting list can then be filtered to select appropriate programs (*e.g.* for the current Moon, seeing and transparency conditions). The start/end track times are displayed, as well as other information, and the SALT Astronomer (SA) can then select appropriate observing blocks and add them to a schedule. This schedule can then be sent to the SALT Operators control GUI from which the telescope can be pointed to a particular object with a single "point to target" command, which command the Telescope Control System. This sets in motion all of the various telescope subsystems to move the telescope to the target. In parallel, the SA can load the defined instrument configuration for the observing block into the Observation Control System, which configures the instrument (*e.g.* selects and inserts appropriate grating, filter, etalon, slit and rotates to the requested grating and camera angles, and position angle). The OCS is a sophisticated tool which allows for telescope – instrument communications, for example setting up dithering patterns, control nod & shuffle modes, etc.

A graphical display of the observing blocks is also now provided by a GUI, based on the SALT visibility plot (Fig. 1), which displays the instantaneous positions (at any given time) of all active targets, colour coded for project priority. This allows, at a glance, the SA to see which alternative programs are available, or will be available soon, or will be lost from the visibility annulus. Blocks can also be filtered on current observing conditions.

7. SALT Proposal Submission Tool

Observing with SALT involves three separate phases. In phase one the Principal Investigator (PI) uses the Principal Investigator Proposal Tool (PIPT) to submit a proposal containing a scientific justification and basic information about the planned observations. Submitted proposals are stored in the Science Database (SDB). The Time Allocation Committees of the partners included in the proposal use the Web Manager (see Section 11) to view the proposal and to allocate observing time to it. In phase two the PI downloads the accepted proposal (together with the information how much time has been allocated to it) into the PIPT, adds the detailed information required by SALT Astronomy Operations for performing the observations and resubmits the proposal. In the third and final phase the SALT Astronomers carry out the requested observations, and the observational data, and ancillary information (*e.g.* environmental and guide star data) are made available to the PI through a data download FTP site and eventually through a Web Manager interface, accessible through any internet browser.

Various tools are provided to aid the PI in planning the observations: instrument setups can be configured with the SALTICAM simulator and the RSS simulator. The availability of targets can be checked with the Visibility Tool. Slitmasks for multiple object spectroscopy (MOS) with RSS can be created with the RSS Slit Mask Tool. These tools are explained in detail in the following sections (Sections 8, 9 & 10). With the exception of the Web Manager, all the tools are Java applications and can be downloaded as a Windows executable, a Mac OS X application or a platform-independent jar file[1].

Observation proposals for SALT are submitted as XML documents. While these could in principle be written manually, due to the complexity this would be an extremely cumbersome task. The XML creation is therefore handled by the Principal Investigator Proposal Tool (PIPT), a Java application. This tool maps the XML of a proposal to a hierarchical tree structure, which can be used for navigating the proposal content. Each node of this navigation tree links to a form for entering proposal details. As mentioned in the introduction, the PIPT is used for both proposal phases, with the Phase 2 proposal tool requesting more details on observation blocks, instrument configurations, etc. At top level, the navigation structure includes four types of information.

Firstly, **general information**, such as the Principal Investigator and contact person, an abstract and a scientific justification need to be defined. The scientific justification is imported from a PDF and is displayed as a

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[1]`http://www.salt.ac.za/wm`

thumbnail image. Template proposal forms (*e.g.* in MS-Word and LaTeX) are available to PIs, who fill in sections (with word limits) covering the following:

1.) a *scientific rationale*,
2.) *immediate objectives*,
3.) *technical justification*,
4.) a *summary of previous SALT results*, and
5.) the *role of the PI* (only for South African proposers).

Secondly, the **contact details** of all the investigators must be supplied, although there is functionality to automatically insert these details from the Science Database if a given email address is contained in the database already. Third, each observed target has to be defined. In case of a target with a non-sidereal motion (such as an asteroid), a file containing a list of dates and times and corresponding positions must be supplied, which is submitted along with the rest of the proposal. Objects with high proper motions are also catered for. If a chosen target name already exists in the database, the PI is notified and can view the target information from the database. A name resolver which checks the SIMBAD database is used to automatically populate target information for an already catalogued object. A proposal with existing target names can only be submitted if the target information in the database is consistent with that in the proposal.

For Phase 1 proposals, only a table of target names and positions need to be completed in the Phase 1 form, including the Moon conditions required for each. Other conditions, like maximum seeing and degree of atmospheric transparency are also stipulated for the proposal as a whole. Both mandatory and optional targets are allowed, where the latter are a list of up to 50 targets (with potentially different priorities), from which a subset is expected to be observed, the choice of which is entirely up to the SALT Astronomers, for flexibility. The last information supplied in the Phase 1 proposal is a list of instrument modes and configurations.

Once a proposal is accepted by the TAC, PIs can then complete their Phase 2 proposal, starting by converting their existing Phase 1 proposal, thus avoiding the need to duplicate information already entered. The major additional information added in the Phase 2 proposal is:

1.) finding charts for all targets or fields, for which a tool is provided to generate these in a standard format (see Fig. 2),
2.) guide star information (optional),
3.) observation block definitions, including instrument and observation configurations, and
4.) calibration requirements (*e.g.* arcs, flat fields), whether done immediately prior to or after the observations (which are charged), or during twilight or daytime (which are free).
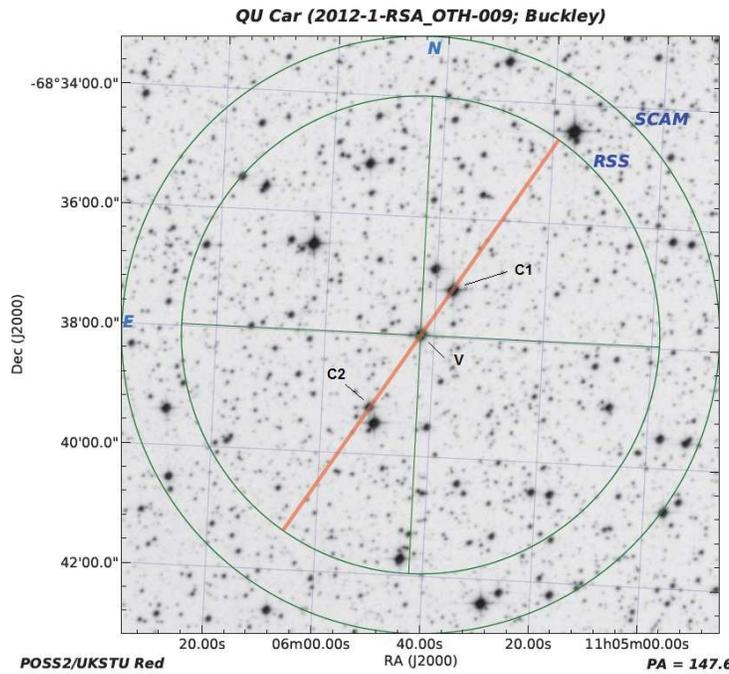
Figure 2.   An example of a finding chart generated by the SALT finding chart tool, showing the field of view of the two current instruments (SALTICAM imager and the RSS spectrograph), with the slit position for the latter indicated.

Observation blocks are the smallest schedulable unit, and contain one acquisition observation and a list of science observations, potentially with different instruments/modes and repeat exposure iterations or cycles of repeated configurations (*e.g.* filter cycles). Each observation in turn contains a list of instrument configurations. The software checks total observing time for a block doesn't exceed the maximum track length available for the observed target.

When proposal information is entered, the PIPT checks whether it is valid. If it isn't, the new value is rejected and the user is presented with a message dialog explaining the error. On a similar note, values which are technically correct but likely to be wrong are flagged as such. The PI is shown a list of warnings for these values before the proposal is submitted. Missing values are highlighted both in the input form and in the navigation tree. Most information entry boxes in the tool have a "help" text box which pops up when the cursor hovers over the box.

After finishing the proposal the PI can use the PIPT to submit it. During this submission process the proposal is validated, the PI is shown the list of any warnings in the proposal, it is checked whether there are any

inconsistencies between target information in the proposal and in the SDB, and a summary of the proposal structure is shown to the user. A submission is only possible if the proposal is found to be valid, but not all warnings necessarily invalidates submission. The submission itself consists of collecting the proposal XML, scientific justification, finding charts, target data files and slitmask files (see Section 10) in a single zip file and then sending that file to a server at the SAAO via an HTTP request. After unzipping the file, the server checks that the proposal is valid and that the submitting PI is allowed to submit. If that is the case, it maps the XML to the SDB by means of the Mapping Tool, an external Java application. Otherwise it sends back an error message to the PI.

While the schemas for describing a proposal and its instrument configurations and the structure of the SDB have been designed to be as similar as possible, there are still considerable differences. These are mainly due to the discrepancy between XML and SQL, but also due to their different operation purposes – the XML needs to work closely with the PIPT, whereas the SDB is the basis for operating the telescope. This makes parts of the Mapping Tool quite complex and a reverse mapping impossible, *i.e.* no XML file can be created from the SDB. Not all the data of a proposal is written into the SDB. Files like finding charts and scientific justifications are kept in the file system and are linked to from the SDB.

If the mapping is successful, an email notification is sent to all the investigators and a proposal code identifying the proposal is returned to the PIPT. The PIPT then inserts the proposal code into the proposal. On the other hand, if the mapping fails, an error message is sent back.

8. SALT Visibility Tool

As mentioned in Section 1, due to the fixed elevation angle of SALT's primary mirror ($37°$), target visibility is constrained to an annulus in the sky. The available "track length", *i.e.*, the amount of time SALT is able to follow continuously any given target, changes according to date, time and target position on sky. In order to check the visibility and available track length the PI may use the SALT Visibility Tool, a Java application which can be launched from the PIPT or run as a standalone tool. After the observation date and the target location has been entered, this tool displays a plot of the target visibility during the specified night. If the PI clicks in this plot, the track length available from the clicked time onwards is calculated (see Fig. 3).

The inverted parabolic curve shows the location of the target as a function of time. The target is visible if it is located in the horizontal shaded area, defined in the airmass range $\sim$1.16 (elevation = $59°$) to 1.37 (eleva-
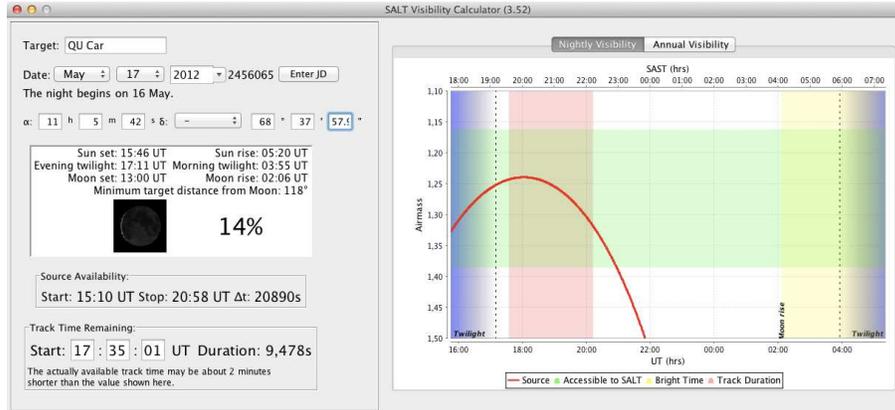
Figure 3.   The SALT Visibility Tool, used to see when and how long objects are visible to SALT on a given night.
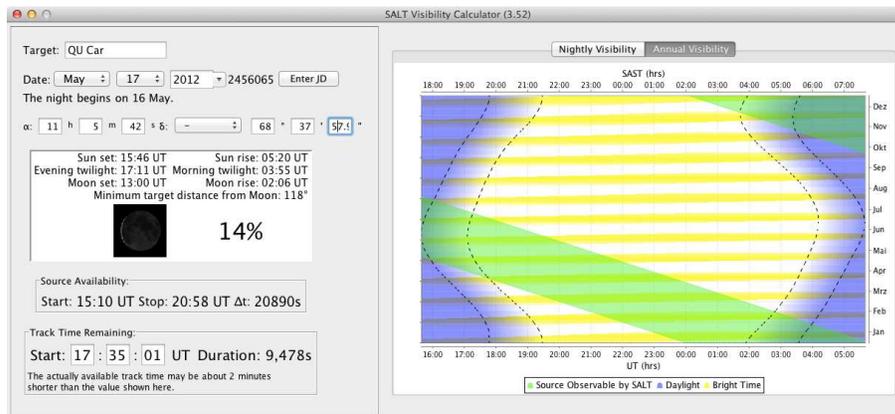

Figure 4.   SALT Visibility tool showing annual visibility of a target (green diagonal strips) and the periods when the Moon is above and below the horizon (yellow and white horizontal bands).

tion = 47°). The available track length is highlighted by a horizontal shaded area and is also given at the bottom left of the window. Other quantities shown in the tool for the given date are the sunrise and sunset times, the start and end times of the evening and morning twilight, the moonrise and moonset times, the lunar phase and the minimum angular distance between the target and Moon. Furthermore, the Visibility Tool contains a plot displaying the visibility over the course of the whole year (Fig. 4), including when new and full Moon occur.

9. Instrument Simulation Tools

In order to plan an observational setup with any of the SALT instrument, PIs can use the respective Java simulation tools. Currently they exist for the two First Light instrument, SALTICAM and RSS. These tools can be run as a standalone application, but it may also be launched from the PIPT. The simulation is a two step process, the first step being to define a target spectrum. The simulators offers the user a choice from a list of asteroid, blackbody, galaxy, stellar atmosphere (Kurucz models) and power law spectra, some of which may be further customized. In addition, spectra may be imported from an ASCII file. The user may superpose an arbitrary number of these spectra to model a more complex composite target spectrum. A redshift can also be applied to the target spectrum.

Along with the spectrum, the location of the Sun and Moon relative to the target, the lunar phase and the year of observation have to be specified, as these are required for the background calculation. The sky background used for the SNR calculation is made up of three components. First, the airglow, based on a high resolution moonless sky UVES spectrum (Hanuschik 2003) which has been corrected to the dark sky at Sutherland. Second, the zodiacal light contribution is obtained by normalizing the solar spectrum at 550nm, correcting for atmospheric extinction, and multiplying by a fit of zodiacal light photometry by Levasseur-Regourd & Dumont (1980). Thirdly, if the Moon is above the horizon, the simulated moonlight is based on a model for the V-band brightness of moonlight (Krisciunas & Schaefer 1991), extrapolated to other wavelengths.

Both the target and the sky spectrum are represented by arrays of flux values for an equidistant grid of wavelengths. The propagation through the telescope and instrument is simulated by applying the mirror efficiency, losses for the optical elements and the detector quantum efficiency to these flux values.

The second step is to provide the instrument setup details, for either SALTICAM or RSS. If the simulators are launched from the PIPT, updates made in the simulators are automatically reflected in the PIPT, and vice versa. After supplying all the information, the PI may calculate the expected photon count rates as well as the signal-to-noise ratios ("SNRs") for the given exposure times. The next step is to select the observation mode (*e.g.* various imaging modes for SALTICAM and imaging, spectroscopy or Fabry-Perot in the case of RSS) and provide the required setup information.

When launching the simulator from within the PIPT, the instrument configuration defined in the PIPT will automatically be used by the simulators. In case of spectroscopy the simulator displays the wavelength coverage of the CCD as well as the resolution for the selected grating, grating angle

and camera angle, and it also suggests an appropriate order-blocking filter to use for the setup.

The third and final step is to specify the exposure time and detector setup, including the pixel binning parameter, gain setting and readout speed. After all information has been supplied, the PI may calculate the expected photon count rate as well as the S/N ratio for a given exposure time. In case of a spectroscopic observation, the detection rate and the S/N are plotted as a function of the wavelength. Wavelengths for which more than 5% of the second order light is let through the order blocking filter are clearly marked in these plots.

Alternatively, the PI may calculate the required exposure time for a requested SNR. If the latter is done for spectroscopy, the PI may specify the wavelength for which the SNR is given. In this case the expected detection rate is plotted as a function of the wavelength, and the expected SNR is plotted as a function of the exposure time. As above, order contamination is indicated in the detection rate plot. Irrespective of whether the exposure time or the SNR is calculated, it is shown, either defined per bin or per resolution element. Here the size of the resolution element is calculated from the grating equation, taking anamorphic demagnification into account.

10. The SALT Slitmask Generation Tool

When requesting an RSS observation with multiple object spectroscopy (MOS), the PI has to design the slitmask to use. This is used to generate the required g-code used to laser-cut slitlets, typically up to ∼50, in a thin (200μ) carbon fibre mask. This can be created with the RSS Slit Mask Tool (RSMT), a standalone Java application based on JSky[2].

The Slitmask Tool lets the user add slits, boxes for reference and alignment stars, or arbitrary shaped slitlets, on top of a FITS image. Annotations in the form of text and simple graphics may be added. A created slitmask can be validated to ensure that all slits, slitlets and reference stars boxes are situated in the field of view, that all spectra fall on the CCD and, most importantly, that there are no overlapping spectra.

In order to support survey mode observations with many targets in a field, a recent Python-based version includes an optimizer. This assigns weights to the slitmask elements and varies the position and angle on sky of the slitmask to find the combination for which the sum of weights of the valid slitmask elements reaches its maximum. It can also be used to create a set of several slitmasks for the same field.

The slitmask can be exported to an XML file which is bundled with any annotations and (optionally) the file path of the FITS image or the FITS

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[2]http://jsky.sourceforge.net/index.html

image itself in a zip file. This file then has to be imported into the PIPT and is included with the proposal when a submission is made. The slitmask XML is later translated into the sequence of laser cutter commands to use for cutting the slitmask.

11. The SALT Web Manager

The Web Manager (WM) is a web application for accessing observing proposals, submitted to the SALT Database by the PIPT, which is written in PHP and JavaScript and uses the template engine Smarty[3] for generating its web pages. The purpose of the WM is to access information about observing programs and their status (*e.g.* completed observing blocks), both for users and SALT Astronomers. The only requirements for using it are internet access and a web browser.

Before using the Web Manager, the user has to create an account. Primarily this is used for authorization purposes, but the user management is also used for restricting access to submitted proposals in both the Web Manager and the PIPT. There are different access rights for the three groups of Web Manager users:

1. Normal users can access proposals that have been submitted with them as an investigator.
2. Time Allocation Committee members can access proposals that request time from the SALT partner they are responsible for. They can also assign time allocations directly into the WM.
3. The most comprehensive access is allowed for SALT Astronomy Operations, who can access all proposals.

The WM allows programs to be assigned a different status, for example completed, deactivated or unfinalized, the latter to allow PIs to make approved changes to some details of their programs, or to activate Target of Opportunity programs, or to put observations on hold.

After logging in, the Web Manager shows a page that is freely configurable by the user. Possible information on this page is weather data, proposal statistics, some news about the SALT software itself and one or more lists of proposals. The lists show the results of user-defined queries of the SDB. The default configuration is to show the list of proposals in which the currently logged-in user is included as an investigator.

For every proposal there is a page displaying all the proposal information in a human-friendly form. This information includes all the data that has been entered into the PIPT prior to the submission, as well as some additional information such as the proposal status. A copious amount of

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[3] http://www.smarty.net/

cross-links is provided throughout the page in order to facilitate navigating within a proposal. In a future version there will also be live status messages, e.g. about what has been observed when and where the observation data is available for download.

The WM consists of different sections which display the following information, all derived from the Science Database:

- Title, abstract, total time allocated in different priority and Moon classes
- Flags for ToO or time critical observations, name of Liaison SALT Astronomer, program status
- Status summary (dates and observing times of completed or attempted observing blocks)
- Instructions and critical aspects of programs (written by the PIs for the SALT Astronomers carrying out the observations)
- Feedback comments to the PIs from the SALT Astronomers attempting the observations
- Details on the investigators (names, institutions, contact details) and contact person
- Observations Block details (total observation time, number of visitis, frequency of visits)
- Observation Configuration details
- Target information (coordinates, type, brightness, proper motion, finding charts)
- Instrument Configurations (filters, gratings, angles, detector modes, individual exposure times, number of iterations, number of repeat cycles)

An additional task for which the Web Manager is used is the approval of proposals. When a proposal is first submitted, each investigator receives an email containing a link with a unique identifier. This link leads to a page where the investigator may accept (or reject) the proposal. As the user is identified by the identifier in the link, there is no need for the user to have a Web Manager account for accepting a proposal, although an account is required for viewing it. Finally, after observations are done, an email is sent to the investigators to inform them that there exists new observational data. The investigators can then use the Web Manager to request the download of their data.

12. Data Handling by the PIPT and Web Manager

The XML of a proposal contains eight levels of nesting. As most of this complexity usually isn't required, a custom tree model reducing the number of levels to three is used for the navigation tree. However, the PI can customize the PIPT so that the usually hidden levels are displayed as well.

The tree model also automatically replaces references to an element with the element itself.

As the PIPT uses an interface rather than concrete classes for handling instruments, new instruments can be added without making changes to the existing Java code. Hence the workflow for adding an instrument just involves creating a schema for the instrument, using the data model generator to obtain the instrument classes, creating a GUI for entering the instrument configuration, supplying a configuration file and collecting all these in a jar file. The jar file serves as a plugin, which can be put in a dedicated plugins directory, from where it will be picked up by the PIPT. Similarly, if a class for mapping the XML to the Science Database is included in the plugin, no changes are required in the mapping tool for it to handle the new instrument.

The Web Manager similarly wraps the SQL required for accessing the Science Database by getter and setter methods contained in dedicated classes, which are created directly from the database schema by means of a PHP script. Where a table contains a reference to a value in a lookup table, a getter method resolving this reference is provided. Similarly to the PIPT, the automatically created classes are extended by classes which may contain custom code. Both the PIPT data model generator and the Web Manager script for generating the database access classes are fairly generic. They therefore may also be of interest to projects which are completely unrelated to SALT.

An important functionality of the Web Manager is the ability to conduct sophisticated queries of the SDB, without resorting to complex SQL queries. A tab in the WM allows approved users to search for information about proposals in the SDB. All PIs can query their own proposal, or ones for which they are also a CoI, and vice versa. SALT Astronomy Operations staff can query all proposals, since they potentially will be observing all proposals. This also allows searches for statistical information on project completion, etc., towards the end of a semester.

A sophisticated database query can be constructed, whereby various keywords can be searched in an "and"/"or" manner. Examples of common proposal queries include searching for:

- Specific PIs or CoIs or SAs
- Specific objects (or coordinates, magnitudes)
- Object type
- Proposal title or sub-string
- Instrument modes (and filters, gratings, etalons, polarizers)
- Observing conditions (Moon, seeing, transparency)
- Coordinates
- Program priority class set by the TACs

- Year/Semester
- Proposal code or ID
- SALT Partner institution
- Proposal status (completed, active, rejected, being reviewed, on hold, accepted)

13. PYSALT: The SALT Data Reduction Pipeline

In order to add maximum value to the data which SALT users receive, SALT Astronomy Operations have been developing a SALT data reduction package based on PyRAF ("Pythonized IRAF"), which has been customized specifically for SALT instruments and has been named PySALT. This is a challenging task, given the complexity of instrument modes. However, since the start of the first semester of charged science (1 September 2011) all PIs have routinely been receiving both raw FITS data and pipeline reduced data, albeit only covering basic reductions at present. The same data reduction procedures that have been developed for the quick-look data analysis tool used at the telescope, SALTFIRST, is being expanded into the full PySALT versions.

The primary goal for the development of SALT science software is to increase the scientific productivity of the telescope. By providing fast access to high quality data, we can minimize the effort required to publish scientific results. Furthermore, by having a central resource provide the tools necessary for data reduction, the amount of redundant work done by the diverse SALT partnership is minimized. To achieve this goal, we have identified three critical areas of software development:

1. Provide science quality reductions for the major operational modes of SALT.
2. Create analysis tools for the unique modes of SALT.
3. Create a framework for the archiving and rapid distribution of SALT data.

Obviously providing science quality data reductions to users will have an immediate return by minimizing the amount of work required for the principal investigators to publish their results. As it is a large consortium with many members having similar data reduction needs, the existence of a common framework for data reduction minimizes the amount of redundant work that needs to be done.

Our choice of Python[4] and PyRAF[5] as a development environment for the SALT science data reduction pipeline software was due to several rea-

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[4]`http://www.python.org/`
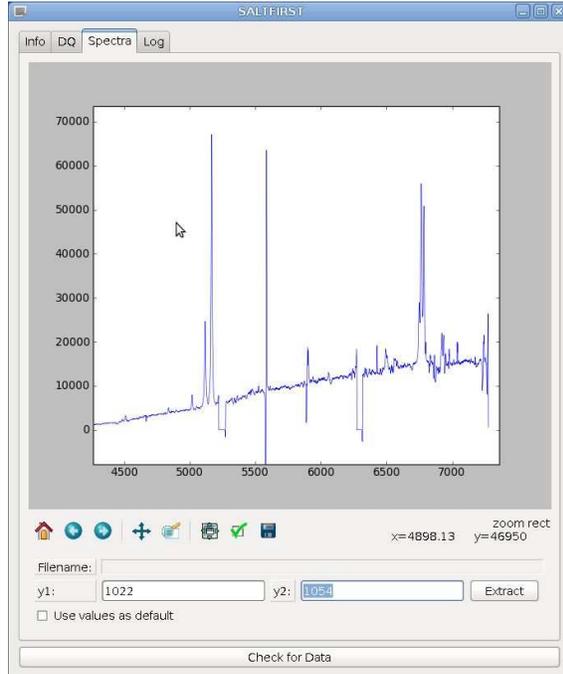[5]`http://www.stsci.edu/resources/software_hardware/pyraf`

Figure 5. An example of an automatic spectrum extraction plot from the SALT quick-
-look data reduction tool, SALTFIRST, which runs at the telescope continuously during
observations.

sons. First, Python is a well supported high-level language that has been
rapidly gaining support in the astronomical community. As a scripting lan-
guage, Python provides an easy environment for information manipulation,
interaction with databases, and different communication protocols. The
numpy[6], *scipy*[7] and *pyfits*[8] libraries provide access to very fast array han-
dling and manipulation software, and *matplotlib*[9] is a sophisticated software
library for data visualization.

The ease in wrapping other software with Python has provided low-level
access to a wide range of astronomical software such as ds9, Sextractor,
and IRAF. Further, PyRAF is the Python wrapper for IRAF developed by
Space Telescope Science Institute. The software provides access to existing
IRAF tasks that greatly enhances the ability of Python for reduction of
astronomy data. However, it also is an enhancement of the IRAF operating

[6]http://numpy.scipy.org/
[7]http://www.scipy.org/
[8]http;//www.stsci.edu/resources/software_hardware/pyfits
[9]http://matplotlib.sourceforge.net/

environment, so that Python libraries can be imported into a working environment that behaves in a very similar manner to the IRAF environment.

PyRAF tasks still have parameter and help files, but can interface both with IRAF and Python tools. The resulting combination of the extensive library of astronomy data reduction tools for IRAF along with the flexibility of Python is a powerful tool for data handling and analysis.

An important aspect of this development is the open-source nature of these tools. In the South African and many other African research communities, software with restrictive or expensive licenses are prohibited due to the lack of resources. Along with contributing to the cost-effective nature of SALT, open source software is far more accessible to these communities. As such, we have also adopted an open source license for all SALT science software and have avoided requiring any closed source or cost prohibitive software.

Basic CCD data reductions are implemented as part of the SALTRED package in PySALT. The full list of tasks that will be implemented as part of the SALTRED package are listed in Table 5. For imaging, it will provide tools for image reduction including gain and cross-talk correction, bias subtraction, flat-fielding and fringe correction, distortion correction, and astrometric solutions. For other modes, it will provide the same reductions through to distortion correction, at which point further reductions will be handled by packages specific to that mode. Further descriptions of each task are provided on the SALT website[10].

All of the tasks have been implemented with both speed and flexibility in mind. When available, the first implementation of each task utilized an IRAF task (or other existing software) and took advantage of existing tools for these corrections. To increase the speed and performance of the tasks, we have replaced the IRAF task with a Python implementation for certain modes of operation. In the end, we have leveraged the extensive history of selected IRAF tools to provide the user with reliable existing tools while enhancing the performance with new, more powerful code. In the current pipeline, reduction of SALT observations are handled by *saltclean*. The task identifies the images and required calibration data, and then applies each of the reduction steps. Currently, we only implement gain, crosstalk, overscan, and distortion corrections. Overscan subtractions are sufficient to correct for the bias levels for SALT data. Flat-fielding or fringe correction is not yet being routinely handled due to repeatability issues, probably a result of the varying pupil, some unexpected additional vignetting and possible scattered, which are being addressed. Along with cosmic ray cleaning and astrometric solutions, we expect all of these steps to be performed in the

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[10]http://pysalt.salt.ac.za/

TABLE 5. Tasks included in the SALTRED reduction package of PySALT*

Task Name	Description or Function
specprepare	Prepare FITS file for SALTSPEC reduction
specgain	Gain correct images
specxtalk	Correct images for amplifier cross talk
specbias	Create master bias frame and/or de-bias images
specflat*	Faltfield correct the images
saltfringe*	Fringe correct the images
saltcrclean	Clean cosmic rays
saltmosaic	Mosaic CCD amplifier images and apply distortion correction
saltastrom	Determine astrometric solution
salttimes	Convert to different time systems
saltslot	Reduce SALTICAM slotmode data
saltclean*	Fully reduce SALT data

* not all are yet implemented yet

near future. SALTICAM Slotmode (high-speed photometry) reductions are handled by the *saltslot* package.

To further enhance the performance of the data reductions, the files are only opened once and all of the reductions tasks are performed sequentially on the file. Only three corrections are applied currently as part of the pipeline process, which include gain, cross-talk, and overscan subtraction. Future development of the code is focused on increasing performance and usability of the functions. An important addition will be to implement variance and bad pixel frames. Furthermore, we hope to replace some of the IRAF tasks with faster algorithms for data reduction to further improve the performance of the pipeline.

Spectroscopic reductions are part of the SALTSPEC package and include all the steps necessary to produce wavelength calibrated 1-D spectra from long slit spectra. The tasks that form part of this package are listed in Table 6. The package was designed to provide automated reduction of SALT images aimed at producing high quality scientific reductions and are built for general use. They should be applicable to different observing modes and targets. However, different reductions tools may provide better results, but these should be applicable to most tasks.

The main task of the package is *specidentify*, which determines the wavelength solution for the arc lamps. Although the task includes an interactive mode, it is primarily designed to work without any human intervention and calculates the wavelength solution over the full frame. The *specidentify* task is built around the PySpectrograph package that produces a model

TABLE 6. Tasks included in the SALTSPEC reduction package
of PySALT

Task Name	Description or Function
specprepare	Prepare FITS file for SALTSPEC reduction
specidentify	Do wavelength calibration using arc lines
specrectify	Rectify the spectra
specsky	Sky subtract spectral data
specextract	Extract 1-D spectra for RSS image
specreduce	Fully reduce RSS spectroscopic data

of the spectrograph. Because the configuration of RSS is known very well, the model of the spectrograph provides a solution that is within a few percent of the actual solution. The model can be updated with calibration data to improve its performance further, but for many purposes, this model provides a sufficient solution for the images. However, *specidentify* only uses this model for a first guess for the wavelength solution. The actual wavelength solution is determined by cross-correlating the observed arc line observations with an artificial spectrum. The artificial spectrum is created from the line list that includes both wavelength information and line ratios. Having extensive and well maintained line lists will be critical for delivering automated data reductions. By having a very close approximation to the wavelength solution, we can produce an artificial spectrum with similar resolution as the observations, which minimizes the problem of line blending. The PySpectrograph model uses information about the system to model the spectrograph and is built upon the grating equation.

An example of this process is given in Fig. 6, which in the top frame provides an example of the spectra created using the PySpectrograph model for RSS. In the next frame, we provide an example of a Xe arc lamp image from SALT. Finally, we show the same spectra after wavelength calibration in the bottom frame, showing the removal of the distortion of the arc lines. The wavelength solution was generated automatically. Future development of the SALT spectroscopy software package will include providing support for multi-object and high speed modes. An important part of the spectrograph package will be integrating it into the data reduction pipeline to automatically produce wavelength calibrated data. The quicklook tool, SALTFIRST, currently does this using the PySpectrograph model (Fig. 5).
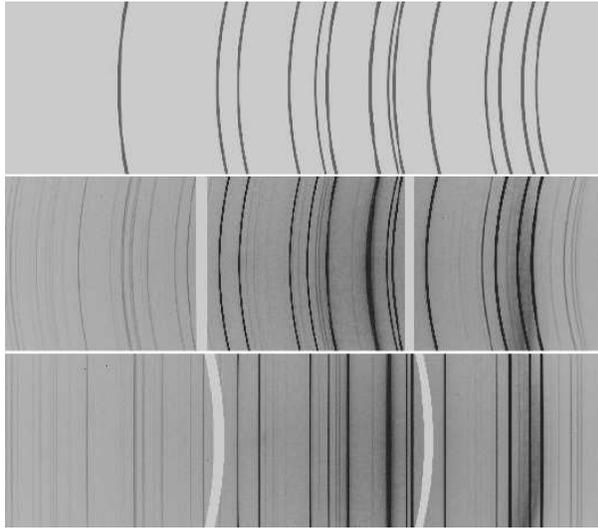
Figure 6.   An Example of an RSS long slit observation of an Xe arc lamp using the PG3000 grating. The top image is an artificial image created from the Xe line list, the middle image is an RSS observation of the lamp, and the bottom image is the image after applying the automatically-determined wavelength solution. The strong spatial curvature of the spectral lines in the upper two panels is a consequence of the nature of the off-axis behaviour of Volume Phase Holographic (VPH) diffraction gratings.

14. Concluding Remarks

SALT is now a fully operational telescope and has been routinely obtaining science observations for the SALT partners, delivering ∼650GB of data in the first semester (30 April 2012). Although SALT, by design, imposes restrictions on how observations can be conducted, the overall design of the telescope – from hardware to software – has been done with efficiency and ease of operation in mind. A variety of tools have been produced for SALT users to enable the writing and submitting of observing proposals, modifications of their observing programs, monitoring of progress, collection of data and pipeline data reductions.

SALT has some significant competitive advantages, mostly associated with the queued service observing mode, coupled with the flexible range of instrument capabilities, which can be switched quickly (within minutes) from one instrument or mode to the next. Data is routinely available to users within 24 hours of the observation blocks having been completed, allowing for a quick response by PIs to the results as they occur and allowing for reconfigurations of observations or instruments, if appropriate. This has a particular benefit for Target of Opportunity type observations. Likewise the queue-scheduled *modus operandii* is also well suited to time critical

observations and synoptic monitoring on a range of timescales (days, weeks, months, years).

At the time of writing, the first science semester with SALT is just behind us and we are embarking on the second. While there is still some commissioning to complete for some instrument modes (*e.g.* RSS polarimetry and MOS), these are expected to be mostly completed within the semester. Late in 2012 a new instrument, a stable high resolution (R $\sim$70,000) fibre-fed vacuum spectrograph (Bramall *et al.* 2010) will be installed on SALT, giving additional capabilities, and as with the exiting two instruments, able to be swopped between with minutes.

SALT users have keenly anticipated the potential for exciting new science afforded by SALT, and this was reflected in the first semester's over-subscription numbers for many partners (2-4). While current research papers highlighting SALT science is only just beginning to flow (only 35 refereed publication to date), this is anticipated to vastly accelerate over the next year or two. In addition, when a new near IR mode (currently under construction) is added to the RSS, probably in $\sim$2 year time, the range of capabilities will be greatly enhanced again.

Acknowledgments

References

1. Bramall, D.G., Sharples, R., Tyas, L., Schmoll, J., Clark, P., Luke, P., Looker, N., Dipper, N.A., Ryan, S., Buckley, D.A.H., Brink, J. & Barnes, S.I. 2010, The SALT HRS Spectrograph: Final Design, Instrument Capabilities, and Operational Modes, in *Ground-based and Airborne Instrumentation for Astronomy III*, Eds. I.S. McLean, S.K. Ramsay & H. Takami, *Proc. SPIE* **7735**, 77354F-77354F-10.
2. Buckley, D.A.H. 2001, The Southern African Large Telescope: An Alternative Paradigm for an 8m Class Telescope, *New Astron. Rev.* **45**, 13-16.
3. Buckley, D.A.H., Charles, P.A., Nordsieck, K.H., O'Donoghue, D. 2006a, The Southern African Large Telescope Project, in *The Scientific Requirements for Extremely Large Telescopes*, Eds P. Whitelock, M. Dennefeld & B. Leibundgut, *IAU Symp.* **232**, Cambridge Univ. Press, Cambridge UK, 1-12.
4. Buckley, D.A.H., Swart, G.P. & Meiring, J.G. 2006b, Completion and commissioning of the Southern African Large Telescope, in *Ground-based and Airborne Telescopes*,

Ed. L.M. Stepp, *Proc. SPIE* **6267**, 62670Z.

5. Buckley, D.A.H., Barnes, S.I., Burgh, E.B., Crawford, S., Cottrell, P.L., Kniazev, A., Nordsieck, K.H., O'Donoghue, D., Rangwala, N., Zánmar Sánchez, R., Sharples, R.M., Sheinis, A.I., Väisänen, P. & Williams, T.B. 2008, Commissioning of the Southern African Large Telescopes (SALT) First-Generation Instruments, in *Ground-based and Airborne Instrumentation for Astronomy II*, Eds. I.S. McLean & M.M. Casali, *Proc. SPIE* **7014**, 701407-15.

6. Buckley, D.A.H. 2012, The Good, the Bad and the Ugly: Commissioning the Southern African Large Telescope, in *Proc. Middle East and African Regional IUA Meeting (MEARIM) #2* (April 2011), *African Skies* **16**, 89.

7. Burgh, E,B., Nordsieck, K.H., Kobulnicky, H.A., Williams, T.B., O'Donoghue, D., Smith, M.P. & Percival, J.W. 2003, Prime Focus Imaging Spectrograph for the Southern African Large Telescope: Optical Design, in *Instrument Design and Performance for Optical/Infrared Ground-based Telescopes*, Eds. M. Iye, Masanori & A.F.M. Moorwood, *Proc. SPIE* **4841**, 1463-1471.

8. Hanuschik, R.W. 2003, A Flux-Calibrated, High-Resolution Atlas of Optical Sky Emission from UVES, *Astron. Astrophys.* **407**, 1157-1164.

9. Krisciunas, K. & Schaefer, B.E. 1991, A Model of the Brightness of Moonlight, *Publ. Astron. Soc. Pacific* **103**, 1033-1039.

10. Levasseur-Regourd, A.C. & Dumont, R. 1980, Absolute Photometry of Zodiacal Light, *Astron. Astrophys.* **84**, 277-279.

11. Nordsieck, K.H., Nosan, F. & Schier, J.A. 2010, Ultraviolet Compatibility Tests of Lens Coupling Fluids Used in Astronomical Instrumentation, in *Ground-based and Airborne Instrumentation for Astronomy III*, Eds. I.S. McLean, S.K. Ramsay & H. Takami, *Proc. SPIE* **7735**, 773582-1.

12. O'Donoghue, D., Bauermeister, E., Carter, D.B., Evans, G.P., Koorts, W.P., O'Connor, J., Osman, F., van der Merwe, S. & Bigelow, B.C. 2003, SALTICAM: $0.5M Acquisition Camera: Every Big Telescope Should Have One, in *Instrument Design and Performance for Optical/Infrared Ground-based Telescopes*, Eds. M. Iye & A.F.M. Moorwood, *Proc. SPIE* **4841**, 465-476.

13. O'Donoghue, D., Buckley, D.A.H., Balona, L.A., Bester, D., Botha, L., Brink, J., Carter, D.B., Charles, P.A., Christians, A., Ebrahim, F., Emmerich, R., Esterhuyse, W., Evans, G.P., Fourie, C., Fourie, P., Gajjar, H., Gordon, M., Gumede, C., de Kock, M., Koeslag, A., Koorts, W.P., Kriel, H., Marang, F., Meiring, J.G., Menzies, J.W., Menzies, P., Metcalfe, D., Meyer, B., Nel, L., O'Connor, J., Osman, F., Du Plessis, C., Rall, H., Riddick, A., Romero-Colmenero, E., Potter, S.B., Sass, C., Schalekamp, H., Sessions, N., Siyengo, S., Sopela, V., Steyn, H., Stoffels, J., Scholtz, J., Swart, G., Swat, A., Swiegers, J., Tiheli, T., Vaisanen, P., Whittaker, W. & van Wyk, F. 2006, First science with the Southern African Large Telescope: Peering at the Accreting Polar Caps of the Eclipsing Polar SDSS J015543.40+002807.2, *Monthly Not. Roy. Astron. Soc.* **372**, 151-162.

14. O'Donoghue, D.E., O'Connor, J., Crause, L.A., Strumpfer, F., Strydom, O.J., Brink, J.D., Sass, C., Wiid, E. & Atad-Ettedgui, E. 2010, Saving SALT: Repairs to the Spherical Aberration Corrector of the Southern African Large Telescope (SALT), in *Modern Technologies in Space- and Ground-based Telescopes and Instrumentation*, Ed. E. Atad-Ettedgui & D. Lemke, *Proc. SPIE* **7739**, 77390Q-1.

15. Ramsey, L.W., Adams, M.T., Barnes, T.G., Booth, J.A., Cornell, M.E., Fowler, J.R., Gaffney, N.I., Glaspey, J.W., Good, J.M., Hill, G.J., Kelton, P.W., Krabbendam, V.L., Long, L., MacQueen, P.J., Ray, F.B., Ricklefs, R.L., Sage, J., Sebring, T.A., Spiesman, W.J. & Steiner, M. 1998, Early Performance and Present Status of the Hobby-Eberly Telescope, in *Advanced Technology Optical/IR Telescopes VI*, Ed. L.M. Stepp, *Proc. SPIE* **3352**, 34-42.

16. Swart, G.P. & Buckley, D.A.H. 2004, Telescope Performance Verification, in *Modeling and Systems Engineering for Astronomy*, Eds. S.C. Craig & M.J. Cullum, *Proc. SPIE* **5497**, 62-72.