Southern African Large Telescope Five-Year Review 2016

10-14 October, 2016

Committee:

Chair: Catherine Cesarsky (French Alternative Energies and Atomic Energy Commission, France)
Megan Donahue (Michigan State University, USA)
Laura Ferrarese (National Research Council (NRC), Canada)
Azwinndini Muronga (Nelson Mandela Metropolitan University, South Africa)
Chris Smith (Association for Universities in Research in Astronomy (AURA), Chile)
Patrick Woudt (University of Cape Town, South Africa)

Final report delivered to:

Michael Shara (American Museum of Natural History), Chair of the SALT Board, Finance and Audit Committee member
Brian Chaboyer (Dartmouth College), Board Executive Committee Member

Executive Summary

The time of this report is a special time in the history of the Southern African Large Telescope (SALT). Only last April, improvements were put in place that now allow the mirror to maintain its optimal configuration for many nights rather than only a few hours. SALT now regularly achieves image quality that matches the best quality possible, given site atmospheric conditions. With the completion of significant improvements to the telescope, SALT, together with its dedicated and highly motivated staff, is emerging as a truly world class observatory, fulfilling the promise of its large 10-meter class aperture and the dark skies of its site. The astronomers who use and publish SALT data report that the most recent data are the best the telescope has ever produced, and they are excited at the prospect of using SALT to make significant discoveries.

Astronomy is inherently multi-wavelength, since the universe generously produces light at every energy, from radio through gamma-ray energies. To answer our most pressing questions, we need the full spectrum to interpret the information that this light brings to us. South Africa and the SALT community have a unique opportunity with SALT now at full strength. The radio observatory of MeerKAT/SKA together with visible and near-infrared observatories of SALT and SAAO combine to create a truly world-leading astronomy system of synergistic telescope facilities.

However, there are dark clouds on the horizon. SALT will not achieve its goals, and indeed may not survive, with its current allocation of resources. Even excellent instruments and telescopes inevitably age, and the scientific environment also changes: other telescopes are built or enhanced and new scientific questions emerge. SALT's role in the world-wide observatory system will change. If there are no new instruments or significant upgrades to current instrumentation (or adaptations of the telescope itself), the capacity of the telescope to contribute to scientific progress will decrease. Furthermore, even in a flat funding scenario, there is little to no room in the current budget for contingency management, for emergency repairs, major maintenance, or currency fluctuations.

A summary list of the recommendations can be found in Appendix 1. A full list of defined acronyms used in this document is in Appendix 2. A summary of the review committee terms of reference is provided in Appendix 3.

1.0 Introduction and Review of Charge

This report contains the first external review of the Southern African Large Telescope (SALT) operations, including management, scientific productivity, and planning for the future. The SALT Shareholders Agreement, Section 49, requires such reviews to be conducted at 5 year intervals. Due to the delays in bringing the telescope and first generation science instruments to maturity, this report is the first such report. The report was commissioned by the SALT Board, and will be submitted to the chair of the SALT Board. By requirement, the review committee is composed of senior astronomers from institutions other than the SALT partners, including SAAO. The Review Committee Terms of Reference are reproduced in Appendix 3.

The committee was provided documents on an on-line repository about two weeks prior to the meeting. The meeting in Cape Town was held on 10-14 October 2016. The entire committee of six individuals attended the meeting. On Monday October 10, the committee chose Catherine Cesarsky as its chair. After meeting with the SAAO Director and *de facto* director of SALT, Ted Williams, and then the Chief Financial Officer and business manager, Lizette Labuschagne, the committee conducted interviews of local staff at SAAO and visited the machine shop. Interviews by video conference with SALT users as well as the Chair of the SALT Board, Mike Shara, were also conducted. The committee members were driven to Sutherland and visited the SALT structure and observing room on Tuesday, and continued meeting with the staff in Sutherland on Wednesday. It also conducted several video conference interviews, including a group meeting with the SALT stakeholders. On Thursday, the committee returned to Cape Town and met with graduate students and the SAAO Director, Ted Williams. Nearly every interview was followed by executive session when the committee discussed its impressions. The final day was spent primarily in executive session, summarizing the recommendations and drafting the report. The committee used a Google Drive folder, shared by all of the members, and kept notes and a report draft throughout the week.

2.0 Strategic Vision for the Observatory and Development Program

Now is a very special time for SALT. With the last of the major hurdles -- achieving a stable alignment of SALT's 91 mirror segments -- now overcome, SALT is meeting its original specifications and demonstrating its potential to be a world-class facility. The three first light instruments, SALTICAM, RSS, and the HRS, are stable. Maintenance has entered a "routine" phase. Queue operations are efficient. The downtime due to faults is well within accepted standards. In this framework, SALT's partner institutions are finally in a position, 11 years after the dedication of the telescope, to reap the scientific benefits of their investment.

Because of the specific time at which this review is written -- only a few months after SALT has realized its full potential -- the majority of the programs now being carried out at the Observatory

are very targeted and of relatively limited scope, with the notable exception of the large observing campaigns ("Key Projects", using hundreds of hours spread across several semesters) initiated by the South African astronomical community in collaboration with several of the SALT partners. The SALT partnership still functions primarily as a collection of users of the telescope, whose focus is driven by the scientific needs and budgetary constraints of each partner. However, if SALT is to remain viable as a world class observatory, this focus must soon shift towards a collective vision for the future of the telescope, guided by clear and long term scientific goals that capitalize and enhance the strengths of the Observatory and the Karoo site.

In the views of this Review Committee, one of the major risks to the goal of achieving such a vision is whether the current partners will be able to shift from the current mindset of being "users" of the telescope, to seeing themselves as "owners" of an Observatory with still undeveloped potentials. From a practical side, the large number of partners might make it difficult to reach a consensus vision, especially given that partners with significantly different shares (by over a factor of 2) carry equal weight within the SALT Board:

Recommendation 1: the SALT Board should explore ways to consolidate the partnership. Possible ways towards this goal include 1) explore whether existing partners are willing to increase their share, ideally at the 10% level or more; and 2) encourage the smaller partners to participate as a consortium with a predefined minimum share (10% or more).

1.1 SALT's Strategic Plan

The Strategic Plan developed by the Observatory Staff and discussed by the Board of Directors is an excellent first step towards ensuring a long term future for the Observatory, and the SALT staff needs to be congratulated for undertaking this important initiative. The Strategic plan document outlines several areas where SALT could make significant contributions and be competitive with the world's premier 10m class facilities in the 2020-2030 timeframe. Amongst the various options, the follow up observations of even faint transient sources discovered by MeerKAT, LSST, and Plato, amongst others, appears particularly attractive. These follow up observations are a specific strength of SALT because of the flexibility enabled by the rapid instrument selection, combined with the darkness of the Karoo site.

This Review Committee is strongly supportive of the roles played by the recently formed SALT User Group (SUG) in exploring the various technical options that are open to SALT, as well as prioritizing and costing the feasibility studies that need to be carried out. In doing so, the SUG should consult extensively within the SALT partnership communities. However, a more developed strategy is needed to move forward.

Recommendation 2: The SALT Strategic plan must be a priority for the observatory and a main focus for the current and future SAAO Director. The Review Committee recommends that the SUG and the Board, in consultation with the SAAO Director and the Observatory staff, draft a detailed schedule that will lead to a selection of one of the available options and begin implementation no later than Nov. 2018 to maximize synergy

with current and future facilities. The first step in this schedule is the delivery, in Nov. 2016, of the SUG report on feasibility studies priorities.

Regardless of the precise choices, keeping SALT competitive in the 2020-2030 timeframe will require a fundamental change in the way the Observatory is currently operated. The current budget needs a substantial boost. This augmentation can be achieved in two ways: 1) by the current partners injecting significant funds into a Development Fund designed to implement new telescope capabilities, including new instrumentation; and 2) by expanding the partnership.

In the context of future facilities, the committee heard about the tentative plans of the South African community to construct a 4m-class telescope at SAAO as part of their Decadal plan. While recognizing that this topic is part of an ongoing discussion of potential opportunities, it is immediately apparent that the resources needed to execute such a project could adversely impact further investment in SALT, both through limitations on the Development Fund and through operational funding issues at SAAO.

1.2 Development Fund

In 2012, the SALT Board established a one-time contribution to a Development Fund to support capital projects and future instrumentation. However, contributions to the Fund have been uneven, with some partners being unable to meet their obligations by the initially specified deadline (May 2016). At the time this report is written, it is anticipated that close to 10% of the fund will remain unpaid even by the extended deadline, June 2017. Additionally, 60% of the 76 million ZAR originally to be allocated to the fund has already been spent to support major capital projects, including the UW near-IR extension and other critical telescope upgrades.

While the Fund has been critical to ensure necessary upgrades to the Observatory, it is clearly insufficient to allow for the development of new instruments, or a major upgrade of the Observatory.

Recommendation 3: the SALT Board must explore ways to replenish the Development Fund with regular contributions. The fund should be used to realize SALT's Strategic Vision and augment the telescope capabilities, including, but not limited to, procuring a new instrument. The Fund could be sustained through contributions (including in-kind contributions) from the existing partners, increasing the share of existing partners, and recruiting new partners.

1.3 Expanding the Partnership.

Exploring whether existing partners are willing to increase their share is an obvious, but not sufficient, step. Enlarging the partnership is critical and new partners should be aggressively pursued. The search for new partners is intimately linked to SALT's vision for the future: having a solid strategic plan in place, and a clear understanding of the cost needed to implement it, is essential in attracting new partners:

Recommendation 4: SALT's strategic vision must be leveraged in attracting new partners. As one of many possible examples, institutions in the LSST consortium would certainly be far more interested in a SALT partnership if their contribution were used to enable SALT to follow-up LSST transients. Conversely, SALT could be leveraged to gain LSST access to the communities (the South African community in particular) that are not currently part of the LSST consortium.

2.0 Management Structure

SALT is a small operation. The current management structure is extremely lean, comprising the SAAO Director, a Chief Financial and Business Officer (who reports directly to the SALT Board), a SALT Operations Manager, and a Head of Astronomy Operations. This structure serves the Observatory well, and a common thread emerging in discussions with the staff is clear and undivided support and appreciation for the leadership provided by the management. Building on the groundwork laid during the past 10 years, the current leadership has been able to deliver a cost-effective, productive Observatory that is now consistently delivering on its promised performance: a significant achievement for which the leadership, as well as the entire SALT staff, needs to be congratulated. Throughout this review, good managerial practices were found to be followed.

In 2006, an agreement was signed between the SALT foundation and SAAO, entrusting the direction of the telescope operations to SAAO. The renewal agreement of 2015 defines an Operations technical manager who is responsible for the operations, assisted by a Science operations manager, all under the responsibility of the SAAO Director.

This agreement is very advantageous to the SALT Observatory, which can in many instances obtain help and even direct participation of SAAO forces to fulfill its goals and duties. In many ways, we find that SAAO is generous towards the SALT consortium. For example: to take optimum advantage of the telescope and its instruments, it is necessary to utilize a group of competent scientists, who continue, in parallel, with their own research. SALT has an excellent team of astronomers, but most of their "science time" is paid by SAAO. In addition, the SAAO Director's management of SALT is completely funded by SAAO. For outreach also, SALT piggybacks on the extensive SAAO Education and Public Outreach (EPO) program. For instrument needs or repairs, SALT has access to the SAAO engineers and technicians, as well as well-equipped technical facilities.

Of particular note is the fact that the current leadership structure -- under which the SAAO Director is also the *de facto* SALT Director -- serves both SAAO and SALT very well. In particular, it allows for better integration of the various facilities, promotes sharing resources and expertise amongst the telescopes, opens the possibility to transfer knowledge and build a stronger succession plan. All of the SALT staff that had an opportunity to comment on this issue strongly supported a joint SAAO/SALT leadership.

Recommendation 5: As the search for a new SAAO director is carried out, it is highly desirable to select candidates with the expertise, knowledge and desire to take on a strong leadership for SALT as an international scientific organization. A deputy director with extensive SALT knowledge could be selected to assist the new Director if necessary. However, in the view of this committee, it would not be advisable to entirely separate the SALT and SAAO leaderships.

One of the strengths of SALT is its people. The dedication, pride and excitement of the staff is palpable. The staff is extremely collegial and feels involved: they work as a team whose goal is to deliver an Observatory that enables excellent science. To maintain this unique atmosphere, it is extremely important for the staff to be informed and, when feasible, consulted about the decisions taken by the SALT leadership and Board. As an immediate example, transparency and open communications (compatible with confidentiality and other constraints) between the SALT Board and the Observatory staff in the search for a new Director are very highly encouraged.

The most significant risk to internal communications is the physical separation of the Sutherland and Cape Town sites. Although it is important to continue to monitor the situation, there are currently no indications that this separation poses a problem. Communications have improved during the present leadership, and the staff at Sutherland feels involved in the operations at Cape Town. Knowledge transfer between the two sites is common and encouraged.

3.0 Corporate governance of the SALT Foundation

The SALT Foundation is regulated by the Shareholder's Agreement. The South African National Research Foundation (NRF) is the major shareholder with 34.77% shareholding. Four other shareholders hold close to 10% shares or above, and 5 others are well below this percentage. The observing time is allocated proportionally to the shares. The decisions are taken by a Board of Directors, which comprises two members from the NRF and one member from all the remaining partner institutions, and which is the main decision making body. Other officers of the Company include the Chief Financial Officer and the Corporate Secretary (same person), where the Secretary has various functions, e.g. treating legal aspects and organizing and writing minutes of Board meetings. The Board meets twice a year.

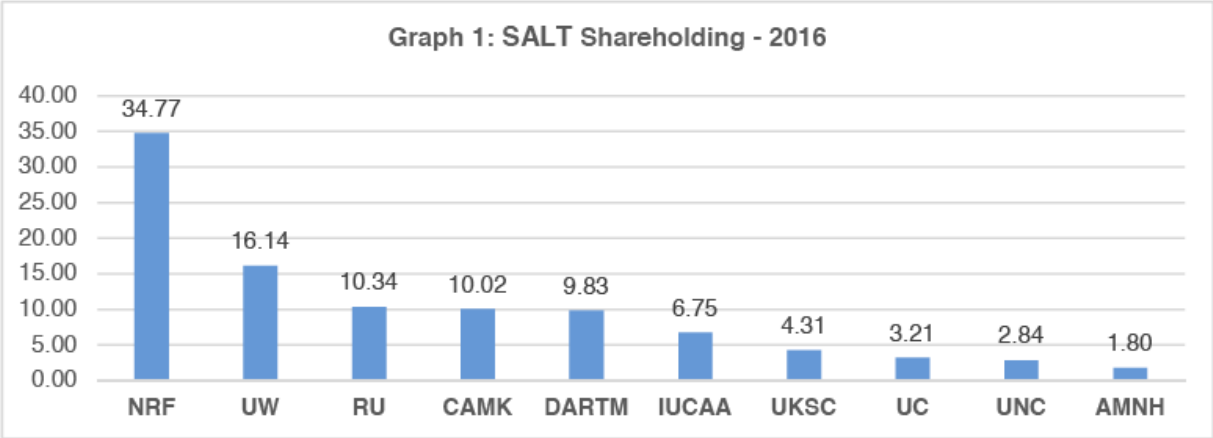

***Figure 1**. "Graph 1" is taken from the SALT Business Report 2016. The vertical axis is the percentage share allocated to each institution or consortium. The labels identify the SALT partners by acronym, which are defined in Appendix 2 of this document.*

This committee has a number of suggestions that could be implemented at the corporate level to potentially increase the visibility and productivity of the observatory. First, in the Shareholder's Agreement, there is no provision for outreach or for education activities, neither in the Host country, South Africa, nor in the rest of Southern Africa. Any activity in this direction is left to the goodwill of the partners. A more organized and coordinated outreach program would be beneficial.

There are no provisions for observing time open to astronomers who are not in partner institutions, except for the South Africans who provide for open access on their time. Now that it has become a world-class observatory, SALT could consider offering some percentage of the total time as open time. This opportunity for access may raise visibility, encourage collaborations, and attract new partners, and it may also bring new science ideas or fields to the partners.

In the current corporate agreement, there is no joint Time Allocation Committee and no Science User group. A statutory Science and Technical Committee, such as the SUG in action at present, that also plays the role of a User Group, would be an advantage. As is, it has existed in prior incarnations and exists now, but without enough stability. It should be instated in a permanent way, with clear terms of reference. In addition, the quality of the science output would probably rise if there were a common Time Allocation Committee, which would distribute the time to the partners according to their share. We however realize that this would be difficult to set up.

Recommendation 6: The Board should establish a permanent Science and Technical Committee, or evolve the SUG, with clear terms of reference covering assessment of

present facilities and of possible future developments, and of topics relevant for operations and data reduction.

Recommendation 7: The Board should consider the possibility of having some open time for the international community, and Key projects decided at the level of the Corporation as a whole. To facilitate time allocation, the Board could discuss handling the open time as well as Key Programs through a common TAC. In the future, such a TAC could evolve to review all proposals.

4.0 Business and Financial Management

The processes of accounting and auditing, and finance discussions in the Finance and Audit Committee, appear to all be well under control. However, the business office is under-resourced for an observatory of this level. A single person is doing multiple major jobs: CFO, business manager, and corporate secretary. At present, this role is played by a highly motivated and qualified employee (the only person directly employed by SALT), and she is an asset to the Observatory.

While the processes are right, the budgets are not. The Observatory appears to be severely underfunded. At the end of the 2016 financial year, the company had capital reserves that could cover only 2 months of operating expenses. There is a major risk of financial breakdown, especially if some partners are late in paying their dues.

In the last few years, the ZAR has suffered strong devaluation with respect to other currencies, leading to substantial savings for the international partners. The SALT Corporation would be in a much healthier financial situation had contributions be made in dollars or euros, or had a "floor" been established for international contributions in those currencies. Instead, the Board has agreed to keep the operations budget flat in ZARs from 2015 to 2020, only re-evaluated for SA inflation. This situation represents a huge missed opportunity of restoring the finances and firming up the future of the telescope.

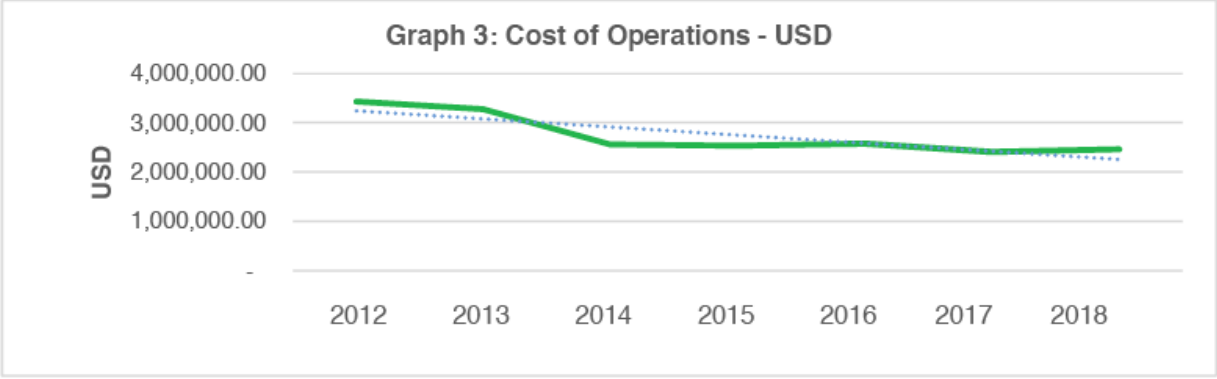

Figure 2. *"Graph 3" is taken from the SALT Business Report 2016. It shows a decrease in cost to the partners over time, a decrease largely driven by the devaluation of the ZAR compared to*

the USD, despite the inflation of costs in South Africa. Therefore for the time under consideration for this review, SALT has become an increasingly good investment for its non-South African shareholders.

The annual funding for the Asset Renewal fund, an important feature in the budget for a telescope in its tenth year of operations, was halved in the past year. Given the lack of budget, the instrumentation division was not active for SALT in the 2016/17 year.

An excellent initiative of the SALT Board was to establish, in 2012, a Development Fund at 75 million ZAR to support projects and future instrumentation for the telescope, as discussed previously. In the near future, as discussed elsewhere in this review report, a plan of new investments should be established, with items prioritized. To be able to carry out this plan, new resources will have to be found, from additional funds released by the partners following the Development Fund model, to the inclusion of new partners, who will also pay an entrance fee covering their share of the construction cost (capital costs).

5.0 SALT-SAAO operations contract (site services, housing, human resources, health, safety, and security support)

The SALT-SAAO operations contract provides a firm general foundation upon which SALT operations are based. The fundamental element of the agreement, that in which the SAAO Director is given the responsibility for management and operation of SALT, appears to be working quite well. This joint management from the position of Director's office has led to an overall healthy and strong relationship between SALT and SAAO operations.

The SAAO Director has indicated that SALT is recognized as the highest priority facility for SAAO. Although it was not the purview of this committee to review other SAAO operations and initiatives, from our view of both national (South African) and international perspectives, this priority seems entirely appropriate. While the SAAO Director must certainly balance the needs of the broader operations of the Observatory, the priority of SALT for SAAO as an institution provides confidence for the ongoing implementation and success of the SALT-SAAO agreement.

Through the joint management by the SAAO Director, SALT appears to be extremely well integrated into SAAO operations and management. The shared site infrastructure services SAAO provides seems to be meeting the needs of SALT without any significant issues. The recent upgrade of electric systems on the mountain stands as an example of the continued investments SAAO (and NRF) are making to maintain and improve the site, investments from which SALT directly benefits. Another notable example is the housing on the Observatory grounds in Cape Town and in Sutherland, both in town and on the Observatory site. We recognize that such housing can be a significant element for the attraction of staff, and it was noted by existing SALT staff that this benefit is greatly appreciated.

The costs for these services, including more general “overhead” elements such as human resources and utilities, appear to be reasonable and well managed. The agreement specifies an “Activity Based Costing” (ABC) basis for these expenses, and it seems that while the ABC analysis provides a good fundamental foundation, the annual costing is done with a more informal and consensus-based approach. Befitting the previously mentioned status that SAAO gives to SALT in its operational prioritization, SAAO is quite generous in its support of SALT in the provision of general site services. It is clear that the equivalent costs for operations of a standalone facility would be significantly higher.

Although safety is listed in the charge as a topic under the operations contract, its importance at any operational facility merits separate mention. Indeed, to its credit, SALT management (in this case led by the Operations Manager) has not left safety and risk management as a service, but have developed a multifaceted safety program within the facility and has designated a part-time safety coordinator (one of the on-site technical staff). The internal safety program appears to be good, with appropriate safety equipment and procedures in place (e.g., lock-out systems are easily accessible and prominently located). The last internal audit was in August of 2015, with reasonable results. Although safety conditions appear to be good within the facility, it is recommendable to consider augmenting them by regular consultation (at least two times each year) with professional safety personnel, perhaps through collaboration with another NRF facility.

Recommendation 8: SALT, through the Operations Manager and the designated Safety coordinator, should strengthen its safety program by getting advice and guidance from a professional safety engineer, possibly by establishing a relationship with another NRF facility (such as iThemba LABS).

That said, it should be noted that the SALT safety program exists within the context of the SAAO safety environment. The SALT safety lead participates in the SAAO site safety committee, and relies upon the broader safety support of the site. The joint SAAO-SALT purchase of a new ambulance and the global training of personnel across the site at various levels of emergency response and paramedic services is an example of the continued concern and emphasis on safety at the mountaintop facilities. Further coordination in development and execution of a strong safety program is essential for ongoing operations of both SALT and the rest of the SAAO facilities.

Recommendation 9: SALT and SAAO should further strengthen coordination of safety programs, including joint safety exercises and external audits.

6.0 Observatory infrastructure and staff

The SALT observatory infrastructure is in good shape, but is certainly aging. Although the telescope is only recently reaching its productive potential, one has to remember that construction ended in 2006, and therefore much of the infrastructure is over ten years old. Not only are some components wearing out, others are becoming obsolete and it has quickly

become difficult to find replacements. The partners should anticipate a growing necessary investment in asset renewal going forward. Beyond purchasing spares and renewing existing systems under an asset renewal scheme, obsolete components will require more than "renewal". Upgrade projects will be needed to design, implement, and integrate solutions into existing systems with up-to-date hardware and software. The risk of letting the observatory infrastructure decay is significant, given current budgetary restrictions and the desire to look forward to new initiatives. The fact that the asset renewal budget was cut in half in 2016 only reinforces this concern. Given that the current maintenance budget has been marginally sustainable, investment in this sort of activity will be an ongoing additional expense in the mix of operations, asset renewal, and development funding. The continuing investment in upgrade projects will maintain the observatory infrastructure in a healthy and reliable state.

Recommendation 10: The asset renewal fund should not only be restored, but plans to continue to grow this critical fund should be developed, alongside the ongoing operations levy and the development fund, in order to address obsolescence and prevent eventual failures and loss of reliability.

The shared infrastructure in Cape Town appear to be solid. In particular, the SAAO laboratory shops are well-instrumented, representing an excellent resource for SALT instrument upgrades as well as a good foundation for participation in new instrumentation projects (if development funding is made available). As mentioned above, the SAAO-SALT agreement, providing for sharing of these and other facilities, provides a solid foundation upon which SALT can build a strong and successful future.

The SALT staff are an extremely highly motivated, cohesive team reasonably well-integrated into the overall SAAO pool. That said, they act as a distinct group, and are managed completely independently of the rest of the SAAO staff (i.e., effectively no true matrix management) by the SALT Operations manager and the Head of Astronomy Operations. These two key SALT managers have together done an excellent job in creating close to optimal environments in both the technical and astronomy operations areas. There is a modest level of group distinction, both between technical and scientific operations staff and between Sutherland and Cape Town staff. This distinction is normal, but it will require continued vigilance and effort to keep any such divisions from growing to levels that would be unhealthy for the organization. A good example of ongoing efforts is the current participation of the mountain technical staff in project work being done in Cape Town via videoconferencing. While the status quo seems healthy, it will be important to implement full participation of mountain technical staff in new development projects, whether upgrades or new instrumentation, both to reinforce the motivation of those staff members as well as to ensure the instrumentation is well designed for the realities of on-site operations and maintenance.

Although the SALT staff demonstrate a culture of outstanding dedication, it is clear that they are working in “hero” mode, with far more to do on all fronts (technical and scientific) than time and resources allow. This situation is borne out not only through comments from staff, but also in the overtime excess of more than a human year in the technical staff time reporting. On the

scientific side, the recent addition of 1.5 FTEs to the SALT Astronomer group should help significantly in managing the workload and meeting expectations, especially in pipeline development and general data reduction support. However, there is a discernible need for additional software support, perhaps in the form of a software engineer to support the pipeline efforts and broad scientific software and data management efforts. Beyond this position, it is clear that additional investment in both technical and scientific staffing would have a positive impact on the productivity of SALT.

7.0 Effectiveness of end-to-end operations from proposal to data products

The SALT telescope is operated in “queue-mode”. Astronomers submit proposals to their host partner or consortium. Proposals are evaluated, selected, and ranked in different ways at different partners. Principal investigators of successful proposals submit their observation plans and supporting information, known as “blocks”, through a Phase 2 process. The blocks eligible for observation at a given night and time are then prioritized and presented to the SALT observers for selection in real-time, at the telescope.

The science operations from the vantage point of the SALT observers and the SALT proposers seems to be satisfactory over most of the observing cycle from proposals to implementation of the planned observations. Specifically, proposal preparation, including detailed observation block preparation (Phase 2), appears to be in excellent shape. The software used by SALT observer software (used to select observation blocks, instrument control, feedback about the night conditions) also appears to work well, although the final prioritization and optimization of the program are in the hands of the SALT observer. Additional improvements to the sophistication of the algorithm that assigns real-time priorities are in progress.

A very basic data reduction pipeline exists for the data that are read out from the instrument detectors. This pipeline removes bias, corrects for charge transfer, and mosaics the data. The product of this pipeline can, in principle, be analyzed with standard astronomical analysis software such as IRAF. RSS data are the only data products that seem to be commonly analyzed and published using standard IRAF routines after being processed by the basic SALT pipeline. While this next step in data processing appears to be routinely carried out for RSS data, the advanced reduction of HRS data remains problematic.

This lack of established pipelines from acquisition to science product has slowed, and in some cases, prevented scientific paper production. Real-time/"quick look" pipelines now exist for the RSS and HRS, and the SALT astronomers reported that these quick look results are delivered with the data. The team uses github (https://github.com/saltastro) to share and exchange data reduction scripts, mostly written in Python. The github site includes a sandbox for software and scripts in development. This site is curated and supported by an SAAO astronomer. It is good that SALT data reduction software is developed primarily in python instead of IRAF. The reliance on IRAF (or pyRAF in some cases) for post-pipeline analysis depends on the future of

external resources that maintain and develop these software packages. Those IRAF resources are not under control of any of the SALT shareholders.

Recommendation 11: The lack of a broadly available HRS pipeline is limiting the productivity of that instrument. Release of a fully functional HRS pipeline for general use (perhaps starting with local SAAO and SALT partners) should be a high priority.

Archive data products – currently, simply the raw files representing the data as they are read out of the detectors -- are now visible through the VO interface (https://vodasdata.salt.ac.za). During the review week, the committee experimented with and tested the archive to understand its functionality. They found that observations can be searched for using a standard astronomical name-resolver or sky coordinates, but found no search capability for lists of objects or lists of sky coordinates. There is an extended-capability search interface offering more search options (search by instrument, PI, etc.), but the search-by-observation-date feature does not work (it does not accept a date, at least in the Firefox browser.) To download data, a user needs a credentialed account available through a contact (presumably at a SALT shareholder) who can set up accounts through the SALT web manager. This account appears to give full access to SALT partner astronomers. There is no access yet available for a hypothetical user from the non-SALT scientific community. It is not clear whether recent (2014-2016) non-South African PI data is (yet) visible through this interface, but one of the committee members with SALT access discovered and downloaded a Dartmouth observation from 2012. There is no direct association between object observations and the associated calibration files such as arcs or flats beyond the sequential (time-) and target position-based proximity of these files. It is likely that calibrations taken early or late in the night, such as twilight flats or other items are not listed when the files are found as a result of a position-based query. This VO-based archive is not yet a truly public data archive with anonymous or registered public user access, but it has potential.

A working archive with access to all of the data would be of use to all partners, including current proposers and principal investigators. Furthermore, public access to observations after a short proprietary period has yielded dramatic increases in the science output of other observatories, and will increase the visibility of SALT worldwide.

Recommendation 12: We recommend the SALT project consider a default proprietary period of a maximum of 1.5-2 years. Key projects could have significantly shorter proprietary times. A recommended statement of acknowledgement of the use of SALT archival data should be prominently featured on the SALT data access website.

Recommendation 13: We suggest the following enhancements to the VO data archive: provide data quality information to allow users to filter out poor quality observations, provide quick-look products (images of provisionally calibrated data) that can be inspected by the archive user in the browser, explicitly associate observations and the calibration files necessary to create science-ready products so any further reductions required can be made by the user, making provisionally science-ready products

available. (The latter step will minimize the necessity of providing a full suite of associated calibration files.)

8.0 Observational and scientific productivity of the observatory

The SALT operations team is to be commended for their continuous efforts to increase the observational and scientific productivity of the observatory. A significant milestone in 2016 has been the successful completion and integration of the edge sensor technology of the SALT Array Management System (SAMS). This integration greatly benefits the scientific productivity both in terms of achieving the best possible image quality at the Sutherland site (see Figure 3), and removing the need for multiple mirror alignments per night. The latter has led to a major increase in time for science observations.

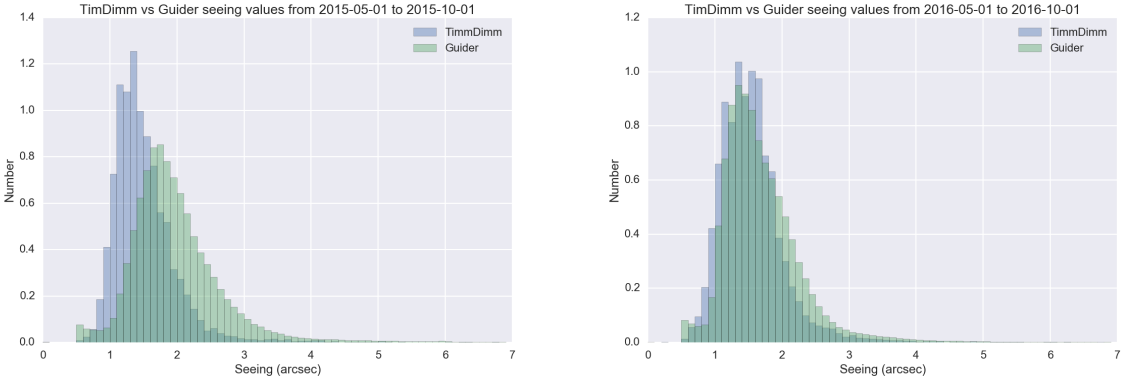

Figure 3*: Seeing values derived from the SALT guider (green histogram) compared to the seeing measurements from the Differential Image Motion Monitor - DIMM - (blue histogram) before (left panel) and after (right panel) the successful integration of the edge sensors (SAMS). The comparison is made over the same period of the year (2015 vs. 2016). Figure provided by SALT astro-operations (Petri Vaisanen).*

We witnessed the SALT science operations first-hand during a two-day visit to the Observatory. The operational efficiency was evident, as was the improvement of the mirror alignment process. Figure 4 shows a SALTICAM acquisition image obtained on 2016 October 13 under good seeing conditions (1.2 arcseconds), where SALT achieved the same image quality as the site seeing monitor (a situation described by the right panel of Figure 3), over the entire field of view.

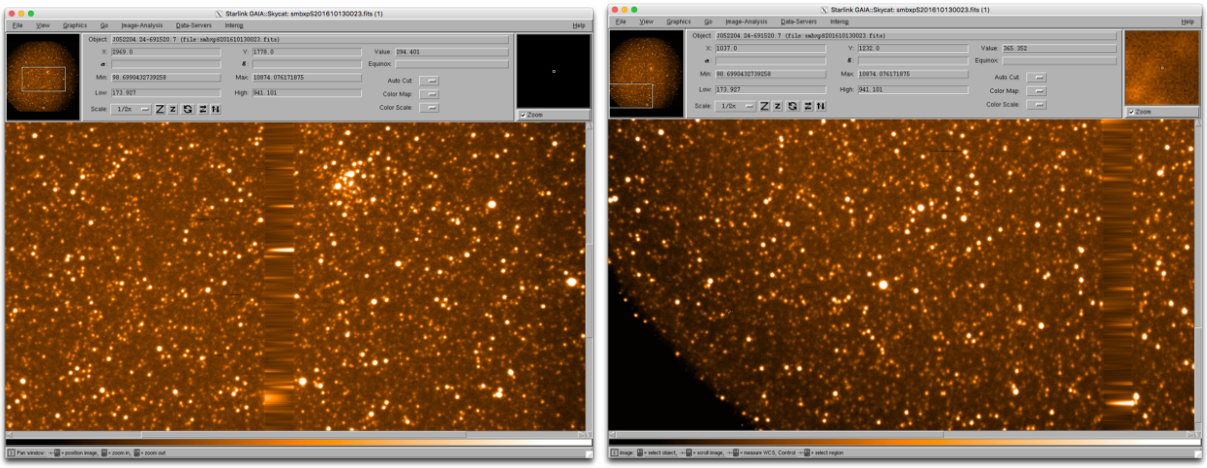

Figure 4: *SALTICAM acquisition image obtained on 2016 October 13 during the visit of the review committee to the observatory. The image quality obtained by SALTICAM matches the measured DIMM value (seeing 1.2 arcseconds), over the entire field of view. The left panel shows the central part of the field, the right panel shows the lower-left corner of the same image. Figure provided by SALT astro-ops (Petri Vaisanen).*

The effectiveness and collegiality of the technical and astronomy operations staff are impressive; a clear team effort is visible, and staff work together to increase the productivity of the observatory. Intelligent program-scheduling software has allowed for optimising the completion of observing programs throughout a semester, and for adapting efficiently to changes in observing conditions throughout a typical observing night. Good communication and interaction with principal investigators of science programs has furthermore allowed the observatory to take full advantage of one of SALT's strengths - the rapid response to target-of-opportunity requests.

Weather remains one of the most significant sources of downtime on SALT; around 40% of the available time is lost due to weather. Currently, the relative humidity limits are set conservatively at around 83-84%, defined by a difference in the ambient and dew point temperature of 2.5 degrees Celsius. Significant gains could possibly be made in terms of on-sky time by relaxing the relative humidity limits (e.g. set the limit to 1.5 degrees Celsius relative to the dew point, relative humidity of 90%).

Recommendation 14: We recommend that the SALT operations team investigates the feasibility of relaxing the humidity limits of SALT science operations and thus identify the gains that can be made to reduce weather down time.

A critical factor limiting the scientific productivity of the HRS is the availability of a science pipeline. Two years worth of HRS observations have been slow to be published due to the difficulty in extracting the scientific information. We have already identified the production of an HRS pipeline for the SALT community as a priority development item. Further, easy access to archival data, and in particular, to science-ready archival data, would enhance the scientific productivity of SALT and its community.

In further developing the community of SALT users and making efficient use of the observatory, we emphasize the importance of science ‘Key Projects’ which speak to the strengths of the observatory. The first such key science project started in 2016. The 'Transient’ key science project is a collaboration that includes four of the SALT partners and 40 astronomers, including 3 MSc and 5 PhD students.

In terms of the SALT science community development we stress the importance of detailed and constructive feedback regarding the assessment of proposals to South African SALT users after the deliberations of the South African SALT TAC process, particularly for new users of SALT.

9.0 Productivity of the scientific staff

The SALT scientific staff forms an excellent, collegial team. The flexible ratio of research to functional duties from individual to individual allows the team to perform at maximum efficiency, and to benefit from the individual’s strengths in either research or observatory support functions.

The overall scientific productivity of the team is very good. The SALT astronomers have well-established international research profiles, they publish in high-impact astronomical journals, and they make excellent use of SALT and related facilities for their own research. This team of SALT astronomers also provides a good environment for supporting young (PhD in last 5 years) emerging researchers in their efforts to become internationally established.

The three recent hires on the scientific staff are South African astronomers who have all been trained through the National Astrophysics and Space Science Program. We commend SALT for engaging with the emerging astronomical community in southern Africa, both in terms of hiring new staff, as well as contribution to capacity development in terms of teaching and postgraduate supervision.

It is important to create dedicated time for research for the SALT scientific staff, e.g. through extended periods of research time (including sabbatical leave at other research institutes or universities), or through the flexible allocation of tasks to team members. This is happening already within SALT astronomy operations, and we encourage a dedicated effort to preserve time for research.

Recommendation 15: Given the importance of scientific software for the scientific productivity of SALT, we identify the need for a dedicated software engineering expert for SALT science pipelines and science support software.

10.0 Human Capital Development

SALT is contributing to human capital development and transformation in SA astronomy.

This contribution is seen in the demographics of throughput of students who graduated since 2008 and also through an employment policy that takes into account transformation and skills development.

The students we interviewed were very enthusiastic about working in the SALT environment. The enabling environment of teamwork and collegiality at senior level should be used to attract and retain future SALT personnel. However, most of the students had had little or no chance to spend time in Sutherland and get acquainted with the detailed operations of the SALT telescope. This is a missed opportunity.

Recommendation 16: We recommend that students should be provided with opportunities to acquire hands-on experience at the SALT telescope.

We have noted that there is no clear plan on Human Capital Development and Transformation. A clear plan is needed with targets and timelines. The plan should be informed by the Strategic Goal #5 in the current Strategic Plan document. Beyond the societal benefits, such a plan would provide a clear roadmap for the development of human capital at the level of students and junior staff to be used in succession planning for the observatory itself.

Recommendation 17: We recommend that a strategic plan for Human Capital Development (HCD) and Transformation be developed.

When it comes to counting the number of SA-SALT students, a clear definition of a SALT student is necessary. Sixty three (63) students trained at SAAO and SALT have graduated. The majority of these have worked in whole or in part with SALT, according to the NRF reports and the Director reports (it would be useful in future reviews to know the exact percentage). Also a significantly larger number (probably about 3 times more) of students have used SALT and SAAO data in their studies but did not work under the supervision of SALT or SAAO mentors. These students are not represented in current statistical reports and probably should be. It would also be useful to have statistics about the number of students using SALT to acquire their Masters or PhD degrees throughout the world. All these students could create a network and interact regularly through modern online collaboration tools to share ideas and address common challenges in data reduction.

Recommendation 18: We recommend that SALT improves tracking and accounting of students from SALT partner institutions and the SA community; possibly creating a network of SALT students to encourage cross-institutional collaboration.

The Stobie-SALT scholarship program which sponsored South African students to attend SALT partner universities for PhD studies has been a success; nine students have worked at institutions in the USA and the UK, six of whom have completed their degrees and returned to positions within South Africa. We understand that this program had been stopped.

Recommendation 19: We recommend that the concept of a student exchange programme be revisited and discussed, building on Stobie-SALT experience.

The South African National Astrophysics and Space Program (NASSP) program is ideal for HCD in astronomy. SALT staff should continue to participate in NASSP activities to attract students to SALT science. In addition SALT should think of where to draw in artisans, technicians and engineers since NASSP does not address the shortage of these skills.

11.0 Education and Public Outreach

SAAO has a science education and outreach arm known as the SALT Collateral Benefits Program (SCBP). The program focuses on astronomy and science education programs for school learners and on teacher-training workshops in the Western Cape and Northern Cape Provinces. SCBP also participates in national programs. Public open nights are held bi-weekly at SAAO in Cape Town and a visitors centre offers day and night tours at the observing site in Sutherland, highlighting SALT. The numbers reached by these programs for 2015/2016 are impressive.

The presence of SALT in Sutherland has brought enormous benefits to the community. SALT is supporting a Community Outreach Centre in Sutherland, which is used by primary and secondary school pupils (learners) and the members of the community to enhance the life of the community. Some of the societal benefits include technical services, basic health needs and the booming of tourism industry

Education and Outreach activities within SALT have been carried out by different partners without collective coordination. Currently, each partner contributes to the education and public awareness independently. We commend the partners for seeking funds at home within different programmes out of the SALT agreement to contribute to such activities.

In the current astronomy arena where there are other new telescopes/developments there is a risk for SALT to be forgotten, both in the public eye as well as by government authorities. For this reason there should be a stronger education and public awareness drive nationally as a component of the SAAO EPO Program, in the SADC region and the continent. Other partners should assist in raising the profile of SALT globally.

Recommendation 20: We recommend that the visibility of SALT be reinforced worldwide, particularly in Southern Africa, through a stronger EPO programme, in close coordination with SAAO. Each partner should contribute to such an active EPO program through the overhead costs and/or through in-kind contributions (outside SALT budget). Additionally, SALT should partner with other organizations, such as MeerKAT/SKA and the South African Institute of Physics, with established EPO programs. All activities and contributions should be recorded. The resources invested in this effort should possibly be overseen by the CFO.

Activities such as Education and Outreach are best carried out when there are partnerships with organizations that are doing Education and Outreach.

APPENDIX 1: List of Recommendations

We note that these recommendations are listed in the order they appear in text. The numbering represents that order, and not the relative priority of the recommendation.

Recommendation 1: the SALT Board should explore ways to consolidate the partnership. Possible ways towards this goal include 1) explore whether existing partners are willing to increase their share, ideally at the 10% level or more; and 2) encourage the smaller partners to participate as a consortium with a predefined minimum share (10% or more).

Recommendation 2: The SALT Strategic plan must be a priority for the observatory and a main focus for the current and future SAAO Director. The Review Committee recommends that the SUG and the Board, in consultation with the SAAO Director and the Observatory staff, draft a detailed schedule that will lead to a selection of one of the available options and begin implementation no later than Nov. 2018 to maximize synergy with current and future facilities. The first step in this schedule is the delivery, in Nov. 2016, of the SUG report on feasibility studies priorities.

Recommendation 3: the SALT Board must explore ways to replenish the Development Fund with regular contributions. The fund should be used to realize SALT's Strategic Vision and augment the telescope capabilities, including, but not limited to, procuring a new instrument. The Fund could be sustained through contributions (including in-kind contributions) from the existing partners, increasing the share of existing partners, and recruiting new partners.

Recommendation 4: SALT's strategic vision must be leveraged in attracting new partners. As one of many possible examples, institutions in the LSST consortium would certainly be far more interested in a SALT partnership if their contribution were used to enable SALT to follow-up LSST transients. Conversely, SALT could be leveraged to gain LSST access to the communities (the South African community in particular) that are not currently part of the LSST consortium.

Recommendation 5: As the search for a new SAAO director is carried out, it is highly desirable to select candidates with the expertise, knowledge and desire to take on a strong leadership for SALT as an international scientific organization. A deputy director

with extensive SALT knowledge could be selected to assist the new Director if necessary. However, in the view of this committee, it would not be advisable to entirely separate the SALT and SAAO leaderships.

Recommendation 6: The Board should establish a permanent Science and Technical Committee, or evolve the SUG, with clear terms of reference covering assessment of present facilities and of possible future developments, and of topics relevant for operations and data reduction.

Recommendation 7: The Board should consider the possibility of having some open time for the international community, and Key projects decided at the level of the Corporation as a whole. To facilitate time allocation, the Board could discuss handling the open time as well as Key Programs through a common TAC. In the future, such a TAC could evolve to review all proposals.

Recommendation 8: SALT, through the Operations Manager and the designated Safety coordinator, should strengthen its safety program by getting advice and guidance from a professional safety engineer, possibly by establishing a relationship with another NRF facility (such as iThemba LABS).

Recommendation 9: SALT and SAAO should further strengthen coordination of safety programs, including joint safety exercises and external audits.

Recommendation 10: The asset renewal fund should not only be restored, but plans to continue to grow this critical fund should be developed, alongside the ongoing operations levy and the development fund, in order to address obsolescence and prevent eventual failures and loss of reliability.

Recommendation 11: The lack of a broadly available HRS pipeline is limiting the productivity of that instrument. Release of a fully functional HRS pipeline for general use (perhaps starting with local SAAO and SALT partners) should be a high priority.

Recommendation 12: We recommend the SALT project consider a default proprietary period of a maximum of 1.5-2 years. Key projects could have significantly shorter proprietary times. A recommended statement of acknowledgement of the use of SALT archival data should be prominently featured on the SALT data access website.

Recommendation 13: We suggest the following enhancements to the VO data archive: provide data quality information to allow users to filter out poor quality observations, provide quick-look products (images of provisionally calibrated data) that can be inspected by the archive user in the browser, explicitly associate observations and the calibration files necessary to create science-ready products so any further reductions required can be made by the user, making provisionally science-ready products

available. (The latter step will minimize the necessity of providing a full suite of associated calibration files.)

Recommendation 14: We recommend that the SALT operations team investigates the feasibility of relaxing the humidity limits of SALT science operations and thus identify the gains that can be made to reduce weather down time.

Recommendation 15: Given the importance of scientific software for the scientific productivity of SALT, we identify the need for a dedicated software engineering expert for SALT science pipelines and science support software.

Recommendation 16: We recommend that students should be provided with opportunities to acquire hands-on experience at the SALT telescope.

Recommendation 17: We recommend that a strategic plan for Human Capital Development (HCD) and Transformation be developed.

Recommendation 18: We recommend that SALT improves tracking and accounting of students from SALT partner institutions and the SA community; possibly creating a network of SALT students to encourage cross-institutional collaboration.

Recommendation 19: We recommend that the concept of a student exchange programme be revisited and discussed, building on Stobie-SALT experience.

Recommendation 20: We recommend that the visibility of SALT be reinforced worldwide, particularly in Southern Africa, through a stronger EPO programme, in close coordination with SAAO. Each partner should contribute to such an active EPO program through the overhead costs and/or through in-kind contributions (outside SALT budget). Additionally, SALT should partner with other organizations, such as MeerKAT/SKA and the South African Institute of Physics, with established EPO programs. All activities and contributions should be recorded. The resources invested in this effort should possibly be overseen by the CFO.

APPENDIX 2: List of Acronyms

ABC Activities Based Costing
AMNH American Museum of National History
CAMK Centrum Astronomiczne im. M. Kopernika (Poland)
CFO Chief Financial Officer
DARTM Dartmouth College (USA)
DIMM Differential Image Motion Monitor
DST (South Africa) Department of Science and Technology
EPO Education and Public Outreach
FTE Full-Time Equivalent
HCD Human Capital Development
HRS High Resolution Spectrograph
IRAF Image Reduction and Analysis Facility (astronomical data analysis software)
IR Infrared, light wavelengths from 800-million nm ("near-IR" is approximately 800-3500 nm)
IUCAA Inter-University Centre for Astronomy and Astrophysics
MSc Masters of Science (a degree that usually requires 1-2 years post-undergraduate degree work)
MeerKAT a precursor radio telescope of SKA (originally Karoo Array Telescope, renamed MeerKat "more of KAT" after the number of telescopes increased.)
NASSP (South Africa) National Astrophysics and Space Science Programme
NRF (South Africa) National Research Foundation
PhD Doctor of Philosophy (a degree which usually requires 5 or more years work post-undergraduate degree and the production of a research dissertation)
RSS Robert Stobie Spectrograph, formerly the Prime Focus Imaging Spectrograph, named in honor of the late director of the SAAO.
SA South Africa
SAAO South African Astronomical Observatory
SADC Southern African Development Community
SALT Southern African Large Telescope
SALTICAM SALT Imaging and Acquisition Camera
SAMS SALT Array Management System
SCBP SALT Collateral Benefits Program
SUG SALT User Group
SKA Square Kilometer Array
UC University of Canterbury (New Zealand)
UKSC United Kingdom SALT Consortium (Keele University, the University of Central Lancashire, the University of Southampton, the Open University, and Armagh Observatory)
UNC University of North Carolina (USA)
USA United States of America
USD United States Dollar
ZAR South African Rand

APPENDIX 3: SALT REVIEW TERMS OF REFERENCE

SALT External Review Committee Draft Terms of Reference

The external review committee should consist of 4-6 senior astronomers, who are not employed by any of the SALT partner institutions. Committee members will receive written reports at least two weeks in advance of their visit to SALT. The committee will visit Cape Town and Sutherland, and will be briefed in person by SALT and SAAO staff including the SAAO Director, the SALT Operations Manager, the Head of Astronomy Operations, and the SALT Chief Financial Officer. The committee will have the authority to interview any relevant SALT staff that they deem necessary. Electronic meetings with SALT Board members, or users of SALT may also be arranged. Four weeks after their visit is complete, the committee will deliver a written report to the SALT board summarizing their findings. The committee shall be charged with examining all aspects of observatory functions, including:

- management structure
- strategic vision for the observatory
- observatory infrastructure and staff
- effectiveness of end-to-end operations: from proposal to data products
- observational and scientific productivity of the observatory
- productivity of the scientific staff
- human capital development, education and public outreach
- development program
- effectiveness of the SALT-SAAO operations contract, including such items as site services, housing, HR, health, safety and security support
- business and financial management
- corporate governance of the SALT foundation

The committee shall receive the following documents prior to their visit:

- strategic vision from the SALT board
- report from the SALT board chair
- report from the SAAO director
- report from the SALT Operations manager
- report from the head of SALT Astronomy operations
- financial and business report from the Chief Financial Officer
- recent annual reports
- list of SALT publications
- curriculum vitae of SALT scientific staff, and principal technical staff