SALT FOUNDATION (PTY) LTD



Southern African Large Telescope

Africa's Giant Eye on the Sky:
Inspiring society by exploring the Universe

SALT Strategic Plan Document (DRAFT)

The purpose of this document is to:

1. **Set out the vision and mission of SALT;**
2. **List the strategic objectives, on the path to fulfilling the mission;**
3. **Highlight the current and near-future capabilities and strengths of SALT;**
4. **Present a critical assessment of the current situation and astronomical landscape;**
5. **List SALT challenges, threats, and opportunities;**
6. **List the current near-future priorities of SALT;**
7. **List the key activities for a five-year strategic plan;**
8. **Discussion of a 10-20 year strategic plan.**

Table of Contents

1. SALT Mission statement
2. SALT Strategic Goals
3. SALT Current Capabilities
    - 3.1. SALT's Forté
    - 3.2. Telescope and site characteristics
    - 3.3. Instrument characteristics
    - 3.4. Near-future characteristics
4. The current astronomical landscape
5. SWOT analysis
6. SALT Priorities for 2016
7. SALT five year strategy
8. SALT long term strategy
9. Plans of action within each Strategic Goal

Annexure 1

SALT history and mode of operations, Astronomical projects in the 2020's, Instrument development options, etc.

SALT Vision

Africa's Giant Eye On The Sky:

Enhancing optical astronomy through research and innovation excellence
[if targeting the science community]

Inspiring society by exploring the Universe
[if targeting the public]

1. SALT Foundation Mission Statement

- **Provide a world-class large telescope research facility cost-effectively to astronomers in an international community.**
- **Lead the advancement and development of optical astronomy on the African continent.**
- **Inspire and educate new generations of scientists and engineers.**

The three-pronged SALT mission must be dynamic. While striving to satisfy the astronomers and astrophysicists in the diverse range of interests of the SALT consortium community, we must also continually search for the best ways to utilize the fields and areas, the approaches and operational models, where SALT is competitive. We must lead and set an example in development, to inspire and excel and make a positive difference. We owe this to the funders and the users and the public of the host country of South Africa.

SALT values:

Excellence, Collaboration, Innovation, Teamwork, Education, Development, Growth, Diversity.

2. Strategic Goals

The SALT Board formulated the following five long-term goals. Reaching the goals will fulfil the mission statement above. Specific details, challenges, and metrics are discussed later in the document.

1. **Enable world-class science:**
   To provide high quality data that result in highly cited published papers in front rank journals;

2. **Optimise science operations:**
   To maximise science efficiency and productivity while minimising technical downtime;

3. **Ensure sustainability:**
   To find and focus on science and operational areas of best performance; to maintain a creative staff; to secure financial support for operations and new developments;

4. **Instrumentation development:**
   To develop the skills and capacity needed for designing and building instrumentation and telescope functionality to keep SALT competitive in the future;

5. **Human Capital Development:**
   To use SALT for graduate student training, outreach to undergraduates, schools and general public; to have a special focus on developing professional astronomy on the African continent.

3. Current capabilities of SALT

3.1. SALT's Forté

- SALT is first and foremost a *spectroscopic telescope.* Due to its operating mode and design, it is at its most efficient when used as a survey telescope with a wide range of targets available in the queue.

- The large collecting power and dark skies mean that diffuse low surface brightness objects are ideal for very competitive results.

- Brighter targets where most of the light is above sky background regardless of seeing and image quality can be observed very efficiently.

- There are several modes of spectroscopy, including multi-object and Fabry-Perot capabilities, and polarimetric modes from 2016. Some of these observing modes are rare on large telescopes.

- SALT is capable of changing modes and instruments on-the-fly in less than a minute. Operationally SALT is able to respond to sudden events and requests, targets of opportunity during a night (though getting on-target is limited by the visibility).

3.2. Telescope and site characteristics

Sky Access:	• DEC range: +11 to -76 degrees • Fixed altitude, typically 1 hour tracks, up to 4h, with a moving prime focus
Field of View:	• 8 arcmin FoV for RSS and SCAM
Wavelength coverage:	• The instruments operate in wavelengths between ~3200A and ~9500A.
Image quality:	• Seeing limited with median effective FWHM of about 1.7 arcsec on the detectors • Currently the mirror alignment is in open loop control resulting in variable image quality.
Tracking accuracy:	• Closed-loop telescope position is stable and offsets can be done with rms 0.3 arcsec accuracy • Rotation is currently open-loop with drifts up to 0.05 deg per hour
Instrument availability:	• Rapid instrument selection makes for flexible operations and increase in science efficiency
Relative (spectro) photometry:	• Telescope pupil changes during an observation. • Relative photometry can be done down to a few percent accuracy over the whole field, limited by flat-fielding currently. • Higher accuracy can be achieved for individual sources using close-by reference stars, e.g. in high-time resolution observations. • Absolute fluxes can be obtained using supplementary calibration information of the target fields. • Spectral shapes are calibrated using nightly spectrophotometric standard stars.
Cost-effective:	• Building and operating costs at level of international 4-m class telescopes. • Science output as measured by refereed papers is on par with major international 10-m class observatories.
Sutherland site	• Night sky is very dark, ~22 mag/sq.arcsec in V-band. • Seeing is mediocre with intrinsic ~1.4 arcsec zenithal V-band median • Approximately 40% of annual night-time is lost to poor weather

3.3. Instrument characteristics

RSS:	• Low to medium resolution spectroscopy. • Observing modes: a. Long slit spectroscopy b. Multi-object spectroscopy c. High time resolution spectroscopy d. Fabry-Perot imaging spectroscopy e. Narrow-band imaging • Grating spectroscopy modes (a), (b), and (c) provide spectral resolving power (R=λ/δλ) from 250 to 5500 for 1.25 arc-second slits, over the spectral range 320-900 nm (R to 9000 for 0.6 arc-second slits). • Continuous time-resolved spectroscopy with temporal resolution of a few seconds is available via frame transfer for all grating modes, and long-slit slot mode spectroscopy gives time resolution of 0.05 sec. • Fabry-Perot mode provides spectroscopic imaging with R=300 to 8000 over the spectral range 430-860 nm using four different setups. • Narrow band imaging with R~50 is available over the spectral range 430-890 nm.
HRS:	• Dual-beam (370-555 nm and 555-890 nm) fibre-fed, white-pupil, échelle spectrograph, employing VPH gratings as cross dispersers. • HRS is a single-object spectrograph with simultaneous sky measurement, using pairs of optical fibres. • Three resolving power modes • R ~16,000 (unsliced 500 μm fibres), • R ~37,000 (sliced 500 μm fibres) • R ~67,000 (sliced 350 μm fibres). • High stability mode at R~67,000 employing fibre double-scrambling and optional iodine cell or simultaneous ThAr calibration injection.
Imaging:	• SALTICAM is the main imaging instrument, also used as the acquisition camera • Provides seeing and image quality-limited imaging over the spectral range 320-900 nm for the full 8-arcminute field of view of the telescope. • Filters include standard Johnson-Cousins, Sloan, and Strömgren sets and also Hα, 380 nm, and neutral density. • Operating modes: • Full field normal imaging • High speed frame tansfer • High speed slot mode provides high time resolution imaging at rates up to 10 Hz. BVIT • Photon-counting camera with a ~1.3-arcmin diameter FoV, capable of very high time resolution (millisec or microsec) photometry with a B, V, R or H-alpha filter. • Suitable for objects with magnitudes ranging from V~12-20. **Caveats:** • Currently cannot perform deep imaging in the conventional sense • Changing PSF makes the stacking of images difficult • Flat fielding is difficult • SCAM guidance is problematic due to size and location of guide probe.

	• No guidance available for BVIT, hence unable to monitor focus

3.4. SALT near-future capabilities

There are several on-going projects that will provide SALT with all of its planned initial capabilities.

System Throughput:	• RSS was removed from the telescope in October 2014 for refurbishment. This led to a roughly 45 per cent improvement in throughput. A new clean is scheduled for 2016. • Additional work involving replacement of the current RSS collimator doublet and triplet is planned, leading to almost full designed throughput. • Primary mirror and ADC throughput is monitored and kept optimal. • SAC clean is planned for 2016, perhaps re-coatings later. • All the above managed actively will keep SALT throughput at design spec level.
RSS FP modes:	• Dual-etalon mode is being commissioned in last quarter of 2015 to use for HR mode observations. • MR etalon coatings will have to be repaired for that mode to return.
RSS Polarimetry:	• All spectrographic modes of RSS allow spectropolarimetry. • The Wollaston beamsplitter mosaic has been fixed and polarimetric commissioning started in mid-2015. The mode is expected to be available for users by mid-2016.
Primary Mirror Alignment System:	• The original system for active alignment of the primary mirror segments failed, primarily due to the effects of site humidity. • The first portion of a new system has been delivered and tested during 2015. The full system is expected to be operational by mid-2016. • This will improve both the delivered image quality and the observing efficiency of the telescope. • Deeper imaging by stacking will become possible; flat fielding issues need to be solved separately.
NIR Spectroscopy:	• RSS was designed to accommodate a second near-infrared beam. It will extend the spectrograph wavelength range to 1.7 microns. • The current plan has the NIR arm delivered in 2017 and function as a fibre-fed instrument providing a ~20 arcsec size IFU system.

4. The current astronomical landscape

Before outlining the developments needed for keeping SALT competitive, it is necessary to establish the current environment where large observatories operate worldwide.

Due to its aperture size, SALT will inevitably be compared to the well established VLT, Gemini, Keck, and Subaru observatories. It is important to remember, however, that these facilities are run at far superior observing sites in Chile and Hawaii, typically with significantly larger budgets. SALT cannot compete with this group. It is crucial to place SALT in the correct landscape and realize its strengths, play on those, and have realistic benchmarks of achievement and future goals.

An obvious and fair comparison is the Hobby-Eberly Telescope, the older sibling of SALT in Texas. The Large Binocular Telescope (LBT) and the Gran Telescopio Canarias (GTC) may also provide useful comparisons: while they are fully steerable and have better seeing than SALT, their apertures are similar and in particular their first-light appeared around the same time as SALT's.

The likes of VLT and Gemini and Keck at excellent observing sites tend to put large effort on high-spatial resolution astronomy and near and mid-infrared science, while naturally also maintaining optical instruments.

TBD: briefly compare SALT to HET, LBT, GTC. For example, the mission of LBT is tied to high spatial resolution technology. What are the differences? What are the similarities? Where can we be unique?

5. SWOT analysis

In order to build a strategic plan it is necessary to objectively and critically consider all aspects of SALT and evaluate the fit between the organization's internal resources and external possibilities. This can be achieved by performing a SWOT (strengths, weakness, opportunities and threats) analysis.

	Helpful	**Harmful**
Internal factors	**Strengths:** • Skilled and motivated operations team • Scientifically productive partners • Support from NRF • Access to Southern Sky • Dark sky conditions • Variety of flexible instruments • Low operating costs	**Weaknesses:** • Lack of pro-active leadership and long-term direction • Not meeting expectations of many in the partnership • Some users/partners may not be deeply engaged • Low program completeness • Telescope and instruments not operating and performing to design specifications • Limited financial and human resources • Over-dependence on a few key staff, slow hiring processes • Weak relationship/communication between the operations team, board and TACs • Poor communication with user community • Lack of education of the user community of SALT strengths • Lack of marketing expertise • Inability to attract new partners
External factors	**Opportunities:** • Expand instrumentation skills and expertise • Investment interest from other institutes and countries • Local government is keen to invest in astronomy • Obtain funding and support from South African decadal plan • Scope to diversify operations • Weakening rand makes it cheaper to join SALT • Guaranteed time makes it attractive to join SALT • Scope to market SALT for countries with developing astronomy • Strong links with SAAO and OAD to draw expertise • Foster links to future large survey projects	**Threats:** • Partners defaulting on financial obligations • Partners withdrawing from SALT • Economic pressure on partner institutes • Degradation of observing site infrastructure • Light pollution due to windfarms and fracking • Fewer opportunities for specialist engineers once development phase is completed, leading to loss of institutional knowledge. • New technology may render the current telescope obsolete. • Competing against superior instruments • Unmanaged expectations among the user community • Unclear vision of SALT's future • Seen by some in the international astronomical community as not meeting expectations for 10-m class science • Low proposal pressure leading to the acceptance of weaker science projects and proposals • Rising operations costs

Key weaknesses and threats, which have limited the impact of SALT in the context of international astronomy, as well as responses, are identified below:

	Weaknesses and threats:	**PoA**	**Response:**
1.	Technological challenges to get the telescope up to its originally envisaged performance:	9.4a	
	• Lack of edge sensors		• SAMS to be completed over the next year
	• Inefficiency in the throughput of SALT		• RSS regained much of its throughput. But not being able to maintain the throughput of the full system at all times is still a challenge. Need to have RSS, the Primary Mirror, the SAC, all fold mirrors, ADC, and Payload optics clean *all* at the same time *all* the time.
	• Quality of photometry and large object spectroscopy		• The flat-fielding problems with a moving pupil affects many science applications using full field, and needs to be solved
	• Payload and guider		• Addressed as Priority Projects (Section 6).
2.	Unsatisfactory outputs - poor completion rate of programs:		
	• Time allocation not optimised - large diversity of fragmented observational programs in the queue	9.1a	• At operational level this is being addressed with much more statistics and analysis and simulations on what is happening, to advice scheduling. Needs higher-level decisions to implement time allocation changes however
	• Lack of focus amongst the users and TACs on what the strengths of the telescope are.		• SALT management to determine who should ultimately decide how SALT time is used – TACs or SALT Board. Should there be more binding guiding principles what to concentrate on to be more efficient in science? Importance of flagship projects?
	• Operational philosophies not formalised - lack of clear long term vision		• Clearer strategy for various time-scales is needed – it needs to get communicated clearly to the SALT users and TACs
	• Reputation loss due to unrealistic expectations, and being slow to re-market SALT when things have progressed.		• Aggressive publicity, marketing and communication strategy to address this. Target should be both the consortium partners and the astronomical community
3.	Limited financial and human resources:		
	• Operational funding insufficient to retain key staff due to	9.2b	• Aggressive fund-raising, advertising, marketing and publicity campaign by

	partners defaulting on financial obligations or withdrawing from partnership • Limited development on the telescope due to partners not contributing to the Development Fund		assisting existing partners to raise funds, and seeking new partners to buy shares or telescope time.
4.	Operational limitations of SALT: • At a mediocre seeing site objects fainter than sky brightness are inefficient to observe. • Observation of any specific target is restricted to about an hour. • Limited by the capabilities of the current suite of instruments.	9.3a	• These are as-designed limitations of SALT and the Sutherland observing site characteristics, need strategic decisions on development to perform on a new level of observations. See recommendations and options below. Fixing image quality still leaves us mediocre seeing limited.

Operational limitations of SALT - Development to perform on a new level of observations?

- *Poor or mediocre image quality* affects everything SALT does and SAMS will only partially correct this. Doing faint object spectroscopy of e.g. high-redshift sources with 1.7" arcsec effective images vs. the sub-arcsec conditions in Chile is hugely different, we need many times more observing time to rack up the same S/N. Thus, even when SAMS works routinely, SALT will still be very limited in faint point source spectroscopy and. Only very exceptional and rare conditions will allow true high-redshift 10-m class science to be done.

- Will we consciously decide to be a bright object and faint diffuse target telescope and attempt to capitalize on that? If so, SALT needs to make sure everyone understands the case and comes up with smart ways of doing such science.

- Will we eventually also want to do 10-metre class science of faint point sources? In this case developing at least ground-layer adaptive optics (AO) is the only solution and given the timescales of such development steps will need to taken very soon.

- Regarding *track times*, if it were possible to fill in at least some part of the sky in-accessible to the present tracker, it would significantly improve effectiveness by giving more flexibility to the queue observations. It is often a real impediment to productivity spend only 1 hour or so on any given target or to have to wait for e.g. a target-of-opportunity to get into the accessible zone. This is another strategic decision needed for the long term (longer than AO, and potentially meaning significant downtime of the telescope):

- Will we decide the limited visibility design is satisfactory and make it work for us, or investigate options of partially steerable or even fully steerable SALT designs?

- There are other similar critical decisions, which directly affect the long-term mission of SALT, questions, the answers to which depend on whether or not SALT wants to attempt to rise to the "next level" or consciously continue performing well in a more limited capacity.

Perhaps the most obvious of these ones would be questions regarding future instrumentation. In particular, SALT's current multi-object spectroscopy is limited to about 50 slitlets, which appears inadequate for a modern 10-m class telescope. Integral field units (IFU), hundreds or thousands of fibers, image slicers and lenslet arrays for focal plane slicing are the norm, which may well need larger field-of-views.

- Will we develop and/or buy large new instruments? In particular, for smart focal planes involving IFUs or larger numbers of fibres? If so, we need to start acquiring expertise and capability.

6. SALT Priorities for 2016

SALT Operations Team has prioritized several projects for the next 6 month to a year time scale, in an effort to better serve the SALT user community by fixing known issues on the telescope, and making sure already approved projects are efficiently carried out with the available resources.

These are mostly projects keeping the telescope going and functioning at the required level for the time being. These of course are not the *only* activities going on. All these projects are aimed at improving the operational efficiency of the telescope.

The highest priority P0 programs identified in September 2015 by SALT Operations:

- SAMS
- Tracker Upgrade
- New RSS Guider
- RSS Polarimetry Commissioning
- (HRS) Pipeline
- Laser Frequency Comb test
- HRS software fixes
- BMS (building, dome cooling, etc.) overhaul
- SALT Data Quality Monitoring
- SAC throughput
- Encouraging large science programs

The details of these projects are presented in a Priority Review Document by Vaisanen and Coetzee, from September 2015.

7. SALT five year strategy

In 3-5 years we see SALT as having found its feet, and embraced its strengths, concentrating most of operational effort and time allocation on productive and competitive programs and producing regularly 60 or more refereed papers a year. It will have a mix of PI-led science and larger dedicated experiments that are fed by well-calibrated data processed through a robust and effective pipeline. SALT would be one of the most efficient, in terms of instrument reconfiguration and setup time, OIR telescopes in the world. It has a suite of instruments (RSS-VIS+NIR, HRS, Salticam, and BVIT) in which all modes are fully functional and performing at design specification. A smaller fraction of effort would go to higher risk observational programs and modes. At that timescale SALT will also have a GLAO system under serious development in anticipation to deliver routinely sub-arcsec images through at least the middle of the optical range at a later stage.

In this time scale the major decisions about Development to perform on a new level of observations, referred to in Section 5 will need to have been made already. Will SALT go for AO? Will SALT start going to a (partially) steerable direction?

For SALT to remain competitive in the long-run development needs to happen, but given there are different options which path to go, depending on the science requirements of the partners and the community, and obvious resource constraints as well, weighing the options needs to be careful. By-ins for decisions from the stakeholders must happen.

In this time scale decisions on SALT instrument development should also be coordinated with what will be happening with the Sutherland 4-m telescope project. It is crucial for the success of both SALT and South African astronomy that the instrument choices of these projects complement each other intelligently.

8. SALT long term strategy

- What can SALT offer in the 2020s landscape? What kind of technological advances should be made to ensure SALT competitiveness?

A serious discussion about SALT long-term strategy must be started by the Board. The long-term strategy should take into account the landscape of astronomy in 2024 and beyond, the interests and desires of the partners, including any new ones, and ideas to fund any new developments.

Topics and development options to start this discussion include, but are not limited to:

- Retain SALT as a general purpose telescope with advanced instruments, wider field of view, and perhaps other modest improvements
- Retain SALT but focus its science mission on a specific goal (like HETDEX on HET)
- (in addition or separately) Modify SALT to be partially or fully steerable
- Build on SALT expertise to build a larger superSALT or a set of SALT clones, each with different state-of-the-art instruments
- Identify better imaging sites on the African continent and develop an observatory there

It is clear that SALT will work in a different scientific environment ten years from now with respect to new satellites, new ground based telescopes, and new scientific questions. The driving astronomy in the 2020s will be that of the Extremely Large Telescopes, the JWST, and LSST.

TBD: expand ideas here. See Annexure where lists of 2020's projects and instruments are given.

• Plans of action within each Strategic Goal

9.1 Achieving world class science: publishing highly cited papers in front rank journals

a) Effective telescope usage - Optimise time allocation and Enhance Science outputs

- Gather and analyse statistics on what is happening, conduct simulations of observations to advice scheduling.
- Review the effectiveness of telescope (science, engineering, operations and development) at each Board meeting.
- Monitor the equitable distribution of science observations amongst partners. Provide guidance to SALT Operations to correct cases where there is a problem. Solicit suggestions from and implement solutions offered by SALT operations when they identify issues at levels higher than purely operational issues, needing policy changes, etc.
- SALT management to determine who should ultimately decide how SALT time is used – TACs or SALT Board. Should there be more binding guiding principles what to concentrate on? Importance of flagship projects?
- Find practical ways to get multi-partner proposals going.
- SALT Board and SALT Ops to working with TACs and users to ensure high quality proposals and effective telescope usage. Implement communication program within consortium.
- Aggressive publicity, marketing and communication strategy to address the lack of focus amongst the users and TACs on what the strengths of the telescope are, and unrealistic expectations of the capabilities of the telescope. Promote successes.
- Provide pipeline reduced data. This would have the potential to decrease the time between receiving data and eventual publication, as well as increase the number of papers.

b) Responding to demands and changing trends in astronomy

- Finalize the Strategic Plan and compile the instrument development roadmap in close consultation with the Board. Estimate costs.

c) Shorten lead times to develop instruments

- Implement the Programme Management framework for core processes, including scope, time, cost, quality, communication, risks and performance management.

d) Prevent telescope failure

- Regular management review and reporting on preventative maintenance programme (daily, weekly, monthly and semester basis). Review the technical downtime (as well as other factors influencing science time) and sub-system faults. Take actions to rectify such faults on an on-going basis.

e) Protect the observing site

- Develop and promulgate AGA regulations. Implement monitoring of condition of Sutherland site.

f) Ensure proper corporate governance practices

- Review and update the governance and management structures for SALT.

9.2 Ensure sustainability: scientific, financial, development

a) Retention of key staff

- Establish an integrated observatory approach with SAAO, potentially getting younger SAAO staff to get involved in observing and more experienced SAs to move to larger research shares or to other expert knowledge positions within the organization – serving both SAAO and SALT.
- Develop and implement a succession planning strategy (support by an implementation plan). Identify key staff and determine appropriate succession plan for each key staff member.
- Secure new funding for critical projects that will improve data quality and improve performance and reliability. This is the most effective means to retain senior staff.

b) Annual subscriptions and development funding

- Follow-up on outstanding subscriptions for operations and development funding.
- Aggressive fund-raising, advertising, marketing and publicity campaign by assisting existing partners to raise funds, and seeking new partners to buy shares or telescope time.
- Manage the annual budget to stay within the financial means of the Board.
- Financial management (including reprioritisation of projects).

c) Return on investment

- Standing item on Board agenda to review the effectiveness of telescope (science, engineering, operations and development) and prospects for partner funding.
- Produce and publish an annual report (should report on the value-add and return on investment).

d) Document management

- Maintain proper company and engineering document management.

9.3 Instrumentation development: telescope capability, as well as better and more capable instruments

a) Responding to demands and changing trends in astronomy

- Finalize the Strategic Plan and compile the instrument development roadmap in close consultation with the Board. Estimate costs.
- Engage the current SALT community to find out which kinds of instruments would be most desirable.

b) Annual subscriptions and development funding

- Fund-raising, advertising, marketing and publicity campaign by assisting existing partners to raise funds, and seeking new partners to buy shares or telescope time.

e) Shorten lead times to develop instruments

- Implement the Programme Management framework for core processes, including scope, time, cost, quality, communication, risks and performance management.

9.4 Optimise Operations: science productivity maximized, downtime minimized

a) Monitor the performance of the telescope

- Review the effectiveness of telescope (science, engineering, operations and development) at each Board meeting.
- Determine priority projects to improve telescope efficiency.
- Monitor the equitable distribution of science observations amongst partners. Provide guidance to SALT Operations to correct cases where there is a problem. Solicit suggestions from and implement solutions offered by SALT operations when they identify issues at levels higher than purely operational issues, needing policy changes, etc.

b) Acceptance of science proposals with a high impact outcome and effective telescope usage

- SALT Board and SALT Ops to working with TACs and users to ensure high quality proposals and effective telescope usage.
- Implement communication program within consortium.
- Find practical ways to get multi-partner proposals going.

9.5 Use SALT for Human Capital Development (HCD): graduate student training, outreach to undergrads & schools, general public

- Develop plans for HCD for each interested partner.
- Development and implementation of a strategy for the optimal cross-utilisation of educational capacity of partners.
- Partner hosting Board meeting has standing invitation to hold an outreach day associated with each Board meeting.

Where we are	*Where we want to be*	*How we will do it*		*How are we doing*
Assessment	**Baseline**	**Components**	**Down to Specifics**	**Evaluate**
• *Environmental Scan*	• *Situation – Past, Present and Future*	• *Mission & Vision*	• *Performance Measurement*	• *Performance Management*
• *Background Information*	• *Significant Issues*	• *Values / Guiding Principles*	• *Targets / Standards of Performance*	• *Review Progress – Balanced Scorecard*
• *Situational Analysis*	• *Align / Fit with Capabilities*	• *Key Objectives*	• *Initiatives and Projects*	• *Take Corrective Actions*
• *SWOT – Strength's, Weaknesses, Opportunities, Threats*	• *Gaps*		• *Action Plans*	• *Feedback upstream – revise plans*

Annexure

SALT History and Operation mode

The Southern African Large Telescope (SALT) is the largest single optical telescope in the southern hemisphere and amongst the largest in the world. It has a hexagonal primary mirror array 11 metres across, comprising 91 individual 1m hexagonal mirrors. The light gathered by its huge mirror is fed into a suite of instruments (an imager and two spectrographs) from which astronomers infer the properties of planets, stars and galaxies, as well as the structure of the Universe itself. SALT is the nearly-identical twin of the Hobby-Eberly Telescope (HET) located at McDonald Observatory, Texas.

SALT is owned by the SALT Foundation, a private company registered in South Africa. The current shareholders of this company include universities and science funding agencies from South Africa, India, New Zealand, Europe and North America. The South African National Research Foundation is the major shareholder with an approxiately1/3 stake. Other large shareholders are Dartmouth College, the University of Wisconsin-Madison, Nicolaus Copernicus Astronomical Centre of the Polish Academy of Sciences and Rutgers University. Smaller shareholders (<10%) include the American Museum of Natural History, the Indian Inter-University Centre for Astronomy and Astrophysics, the University of Canterbury (in New Zealand), the 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 size of the shareholding of each partner determines the access to the telescope which they enjoy.

SALT is located at the observing site of the South African Astronomical Observatory, near the small town of Sutherland, about 400 km north-east of Cape Town in the Karoo. This site has been host to a number of other smaller telescopes since the early 1970s, and benefits from location in a semi-desert region with clear and very dark skies. The quality of this site for optical astronomy is preserved by South African legislation.

SALT is operated in “service mode”, it is a fully “queue scheduled” observatory without visiting astronomers. SAAO is tasked with operating SALT with a team of astronomers and engineers funded by the SALT Foundation. Observing time is allocated to astronomers through a competitive peer-reviewed proposal process, per partner, on a 6-month schedule. Accepted programs are submitted to the SALT Operations team who manages the scheduling and execution of the observations, as well as the data reduction and data delivery to all users. In this sense SALT is a normal general-purpose telescope for the user community. However, there are more and less efficient ways of using SALT, which derive from its characteristics.

Important telescopes (and their associated wavelength ranges) in 2024

Space-based
• 6.5m James Webb Space Telescope (optical/IR imaging and spectroscopy), launch 2018+
• Euclid (optical/NIR imaging and NIR spectroscopy), launch 2020
• eROSITA (German/Russian hard X-ray all sky survey), launch late 2016
• Athena X-ray observatory, launch 2028

Ground-based
• Giant Magellan Telescope (GMT) in Chile, optical/NIR, commissioning to begin 2021
• 35–40m E-ELT in Chile, optical/IR imaging and spectroscopy, ready for use by about 2022+
• Thirty-Meter Telescope (TMT) on Hawai, optical/IR imaging and spectroscopy, first light: 2022+
• 8.4m LSST (Large Synoptic Survey Telescope) in Chile, wide-field deep astronomical surveys, opt./NIR variability, first light: 2019?
• Square Kilometre Array radio telescope (SKA), South-Africa+, construction of phase 1 will take place from 2018 to 2023
• Cherenkov Telescope Array (CTA) for high-energy gamma ray observations, Namibia?+, 2020
• The Atacama Large Millimeter/submillimeter Array (ALMA), Chile, 2014
• ESO VLT, Keck, .. (existing telescopes)

Competitive Landscape

Looking into the future, it is important to imagine the landscape where a 10-m telescope at a mediocre observing site would still be a worthwhile undertaking in the 2020-s. For this purpose the list below indicates the likely players.

- The baseline JWST mission is for 5 years; thus there is a possibility that JWST will be done by 2024 and we could be in legacy follow-up mode. This is likely to enhance the emphasis on NIR and even thermal IR observations, which also are being driven by ALMA and the capabilities of adaptive optics and OIR interferometers.
- The role of high angular resolution astronomy merits a more thorough discussion when thinking about SALT. We can expect adaptive optics to be in routine operation, possibly into the visual bands, on 8-m class telescopes and in the NIR on 30-m class instruments. In both cases the angular resolution will be in the 0.01 arcsec regime. In addition ground layer AO is likely to be routine, yielding 1/3 arcsec images over wider fields of view. This would effectively double or triple the effective apertures of telescopes working on point sources in the sky background limited regime. These capabilities will complement those of the 30-m class telescopes and comfortably exceed what JWST can do.

- A UV/optical HST-2 is likely to be near launch or in space with renewable instruments.
- It seems likely that observational astronomy will continue its trend towards focusing more on quantitative measurements versus the current emphasis on semi-qualitative survey studies. Any surveys with SALT will have to exceed the quality of the ongoing or planned projects.
- Most of the facilities that are compared with SALT will be considerably more expensive than even a SALT on steroids. Thus SALT doesn't have to do everything but it must be able to do something well! The current cost per peer reviewed science paper, in US Dollar terms, is the lowest of any large telescope.

Dedicated scientific questions in 2024

- Search for planets with dedicated satellites (e.g. Plato)
- Spectroscopy of planets with JWST, E-ELT, TMT
- Spectroscopy of most distant objects with JWST, E-ELT, TMT
- High spatial imaging/spectroscopy of planets, stars, centers of galaxies, distant galaxies with JWST, E-ELT, TMT
- Studying structure formation and evolution of the universe (galaxies, clusters, black holes, cosmic web)
- dark matter, dark energy
- what is the origin and mode of acceleration of the highest-energy cosmic rays?
- What is the nature of space-time under the extreme conditions in the vicinity of black holes and neutron stars?
- How are the relativistic jets from compact objects launched, accelerated, and collimated?
- What are the progenitors of Type Ia supernovae?

Importance of SALT in 2024

Scientific questions/problems that can be tackled by SALT with its **present Instrumentation** (HRS spectrograph, direct imaging camera/high speed photometer, RSS/Prime Focus Imaging Spectrograph):

- Optical follow up spectroscopy and detailed investigation of radio sources (SKA), gamma ray sources (CTA), mm-sources (ALMA) with SALT
- Follow up spectroscopy of variable/faint LSST sources
- High speed photometry of planets, variable sources
- Dedicated spectroscopic/imaging projects of planets, stars, galaxies/AGN, large scale structures
- Dedicated surveys for bright and dark time: planets and extended faint objects

Importantce of SALT (**with new instrumentation**) in 2024:
- A wide field (at least 30 arcmin x 30 arcmin, with at least 300 fibers) low resolution spectrograph would enable SALT to take full advantage of LSST. The same is true for follow up discoveries by SKA. (For comparison: one VIRUS spectrograph at

HET has 230 fibers. Hardware costs for one VIRUS spectrograph : _ 20 000. US Dollar)

SALT in 2024

In 2024, LSST will have been operating for a couple of years. The next generation of ELTs (EELT, TMT, GMT) will have begun operating or be in commissioning. MeerKAT will have been subsumed into SKA1 which will also have begun operating. EUCLID will be imminent. SALT will, accordingly, be a 2nd rank facility much as the 4-m telescopes of today are.
Some of todays 4-m telescopes, lacking a dedicated mission, are being closed. Remarkably, others are being rejuvenated and put to use in dedicated surveys. It is likely that SALTs survival as a competitive facility on the world stage will depend on its ability to focus on specific research projects of the day.

To this end, we foresee SALT:
- Being fully-steerable, at least over a substantial fraction of the sky centred on the zenith
- Have a wide field of view of at least a degree and preferably two degrees
- Have spectroscopic capability of many tens of kilofibers
- Have a unique instrument or capability which will be unrivalled anywhere else in the world

These capabilities are entirely dependent on progress in astronomical technology. One of the great and unanticipated benefits of repairing and operating SALT is the development of a culture of astronomical technology associated with SALT. People with front rank skills are employed at SALT and provided adequate resources are provided, this infrastructure will be maintained into the future.

SALT II: Whether or not it is possible to realise the above ambitions in regard to the existing SALT is not clear. Another possible platform is the development of a SALT II. Such a facility should have a larger aperture than SALT I, probably at least 16-20 m. It should have all the capabilities outlined in the bulleted list above. Of course, considerable resources will be needed to turn such a telescope into reality.

As for scientific emphasis, there is no doubt that many large and/or focused surveys have been very effective and are important parts of the astronomical landscape. However, there are reasons to be cautious about converting SALT predominantly into a survey engine. First, this growing trend, at least in North America, will soon leave the community with very few publically available OIR options for general purpose flexible observing. A near total reliance on targeted experiments may lead to more groupthink and less innovative follow-up. Second, there is the practical limitation of organizing so many disparate partners and scientific interests into large-scale programs. The more successful approach likely will be moderate scale experiments that come with funding, either through the coordination of the observing time of one or two partners or through a dedicated funding stream through a national agency or a private foundation. LSST is heavily discussed everywhere by everyone.

In addition there are other exiting new surveys on the horizon. One example is LIGO-Virgo. The smallest positional errors for gravitational wave sources will occur in the southern Indian Ocean and over North America, making SALT well positioned for follow-up, particularly in collaboration with North American facilities.

A Wider Field of View

While the synergy with the wide field of view of MeerKAT (and, subsequently, the SKA) and, potentially, LSST, achieving a 30 arcmin field of view (FoV) on SALT will be difficult, if not impossible. The VIRUS instrument on HET required an entirely new spherical aberration corrector (SAC) design, and only achieved a 20 arcminute FoV. Even that has not yet been successfully manufactured. This system has pushed the FoV to as large as possible and stopped there due to the growing complexity and size of the required SAC mirrors. The total HETDEX project is $40M (which may include the 5-year survey too). Before considering such a costly upgrade for SALT, a study should be done on designing a fully steerable SALT II telescope. This may prove to be the most economic option for a wide field telescope that is not limited by short track times.

In general, the discussion of radically re-engineering the telescope and instruments at first thought seems somewhat challenging to Wisconsin. That will take the bulk of the 10-year period, during which we may have a large opportunity cost by not being able to use the existing instruments. The current & upcoming instrument suite has a lot of unusual, if not unique, capabilities for a telescope of this size. Rather than spend many tens of millions of dollars to radically alter the telescope (e.g, the VIRUS system), why not invest a small fraction of that into making the current system and instruments work really well?

New Instrument Development

SALT has established a fund to support the development of future instruments for the telescope. The consortium hopes to produce new major instruments on a 5-year cycle. No decisions have been taken yet for the next instrument to be developed, but preliminary investigations are underway in two areas.

[It is VERY important that the SALT user community is involved before making final decisions. We need a clear plan by which time the options (e.g. these two, or any other) have to make their case, and we then get an idea what people want and need for their science. No point in developing something that no one, or very few, will use.

Personally, I think AO is key (if it is found to be feasible), since that's the absolutely the only way either spectroscopy or imaging will ever be even close to what an 8-m telescope can do in Chile and Hawaii.

IFUs are great of as well.]

New Spectrograph Design

• D. O'Donoghue and collaborators have invented an innovative new spectrograph design that is currently in the lab breadboard design phase. This design promises to provide highly compact and cost efficient spectrographs with very high optical throughput. Thus these could be the basis for a massively multiplexed multi-object spectrograph that would allow thousands of simultaneous spectra to be obtained with a fibre-fed system on SALT. Such a spectrograph could possibly be deployed on the telescope by 2020 (who will develop it?).

Adaptive Optics System

• SAAO astronomers are investigating the characteristics of the atmosphere at Sutherland to assess the feasibility of image quality improvement with an adaptive optics system for SALT. It is clear from these observations that a substantial contribution to the seeing arises from a relatively thin layer of turbulent air near the ground level, and thus a significant improvement in image sharpness (and hence telescope efficiency) could be obtained by implementing a ground-layer adaptive optics system similar to those employed at other observatories. Investigation of possible designs for such a system at SALT will be pursued.

• Ground-layer adaptive optics (GLAO) system for reaching 0.6 arcsec images.

Ground-layer adaptive optics (GLAO) could make a huge improvement to SALT. A conventional high order AO system, indeed, is not feasible for SALT. However, SAAO site measurements over the past couple years have revealed that the majority of seeing occurs in the ground layer, which means it is correctable. GLAO systems do not try to correct down to the diffraction limit, but to something in the sub-arcsec range. A GLAO system would correct the limitations of the site, which have drastically degraded in recent years from 0.9 arcsec to 1.5 arcsec median seeing. The IR sees the greatest improvement, but these systems have demonstrated some improvement down into the optical as well. One limitation, however, is that one only gets correction over a few arcminute field of view. Steve Crawford is heading up a low level study on this with Matt Kenworthy. Devoting some extra resources to this effort should be a high priority for improving the efficiency of SALT. Remember that the goal is not to reach the diffraction limit. Rather, it is to compress the image quality histogram so that many nights are closer to or at the spec for the SALT optical system (0.6 arcsec). This would provide an enormous boon to spectroscopic observations and make imaging much more competitive.

Optimise operations

We still need to better understand SALT's technical limitations with the key question

being whether SALT can operate as a significantly more efficient observatory (e.g. much faster set ups, stable calibrations, etc.) that will compete with, say, 6.5-m and larger aperture telescopes. The near-term (3 year) strategic goal should be to understand what combination of instruments and observing modes will yield the most efficient operations. In other words, we should be looking at what SALT can do best and asking how to craft an effort to make use of this in the coming years, rather than building a general science case. We have a specialized telescope that seems to have potential to do some projects very well, not a general-purpose large aperture telescope. In thinking on these terms, it is good to consider where we can produce competitive quantitative results. We should be willing to rethink our plans for further instrumenting SALT in order to get out of our current state. For example, can we take advantage of fiber optics to overcome some of SALT's problems and to provide a more efficient operations? Are there ways to enhance our queue system that seems close to but not quite working? What have we missed?

The focus of the partnership must be on maximizing the performance and scientific output of SALT, perhaps through modest investments that would improve its operational efficiency and mitigate the marginal seeing of the Sutherland site. Achieving these twin goals would leave SALT in an excellent position to take advantage of some, but not all, of the scientific opportunities created by the suite of new and soon-to-be built facilities both on the ground and in space.

SALTs future is inexorably dependent upon the successful completion of five major initiatives: implementing SAMS; fixing the RSS throughput; upgrading the tracker; completing and commissioning the NIR spectrograph; and, perhaps most critically, completing a full pipeline for data calibration and analysis. Without these, SALTs future will be highly uncertain.

The primary aim is to improve the telescope efficiency, improve throughput and reduce downtime.

Payload

An integrated study and proposal was put together in 2013 to address most of the payload problems. It was found that some modifications could be done in situ and those have been done. Some were done during the RSS Throughput Repair during September and October 2014, but others need the payload to be taken down from the tracker.

The payload suffers from the following deficiencies:

DEFICIENCY	IMPACT OF SOLVING IT
1. Requirement to re-home fold mirrors / pellicle during operations	Improve on-sky efficiency and remove the requirement to do some of the rehoming at rho stage at zero degrees.
2. Slow movement of the fold mirrors /	Improve on-sky efficiency. Completed

pellicle reduces efficiency	
3. Reliability of mechanisms and the software control system. Failures at these levels include firmware lock-ups on the guidance camera, as well as sporadic communications failures with various internal subsystems	Minimise downtime.
4. Accessibility / Maintainability – difficulty performing maintenance and repair operations	Reduce downtime due to better access for fault finding and in-situ maintenance. Some current inaccessible devices can be reached (e.g. RSS autoguider)
5. Obsolescence – the need to pre-emptively replace parts that are no longer available	Reduce downtime and ensure continued operations. Receiving on-going attention.

The impact of these modifications will be more time on sky due to fewer problems with electromechanical glitches and breakdowns and more time for the software team to focus on improving and extending the control system.

Emphasis on Efficiency

The emphasis on efficiency is well placed. The short time span for most tracks puts a major premium on this, and it is currently one of SALTs weaknesses. Its worth pausing to remember that SALT already has a remarkable operational efficiency: the ability to switch so quickly between many different instruments and modes is envious. The target acquisition time is a real problem. Rather than re-engineer the telescope at great expense, how about much cheaper hardware and software solutions? For example, WIYN recently successfully implemented a Star Tracker-like system using off-the-shelf hardware and software (Rajagopal et al., Improving the WIYN Telescopes Pointing and Tracking Performance with a Star Tracker Camera, Proc. SPIE 9152, 91521Z, 18 July 2014) for low cost and modest effort. It saved a large, expensive, time consuming, and uncertain direct engineering solution to the pointing issues. With a similar system on SALT, along with predictive guide star acquisition, the guider could be pre-positioned along with instrument reconfiguration during slew. In fact, with a second Star Tracker camera with a narrower field of view and more precision once the primary pointing is known, it may be possible to perform final target acquisition for spectroscopy, including blind offsets, automatically and without a setup pre-image. This, combined with improved queue management software, should reduce overheads to near the minimum imposed by slew and settling times.

Calibration of the instruments and their various modes is fundamental. This deserves very strong support in terms of personnel and funding to take the necessary calibration data, perform the necessarily ~~modeling~~modelling (e.g., Ken Nordsieck), make hardware changes (e.g., the proposed scrambling fiber system) and incorporate these into an effective and relatively easy to use pipeline.

A list of possible projects has been given:

1. Humidity control will prevent mirror and instrument fogging. It may also lengthen shutter open time.
2. Payload improvements will improve science efficiency and reduce down time.
3. Enhancing Science output. This would have the potential to decrease the time between receiving data and eventual publication
4. Software and communication improvements will have far reaching positive impacts on almost all telescope systems.
5. SAC reflectivity restoration and maintenance would enhance the light throughput of the telescope.
6. Smart Focal Plane development would enable the scientific effectiveness of existing and future instruments to be greatly increased.
7. A revamp of the entire telescope involving removing the need for a tracker (and moving pupil) by installing an elevation drive of limited range, along with an enhanced azimuth drive, would give the telescope a step change in operational effectiveness.