Minutes of the 3rd SALT Science Working Group meeting

24 May, 2000

SAAO, Cape Town, South Africa

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10 August 2000

The third meeting of the SSWG took place on Wednesday, 24th May 2000, in the SALT Meeting Room of the South African Astronomical Observatory, Cape Town, South Africa.

1. Agenda

The following was the pre-meeting agenda.

1. Minutes of the previous SSWG meeting.
2. Reports from SALT partners (e.g. UK group, Gordon Bromage)
3. Report on optical design studies of the SALT Spherical Aberration Corrector (Darragh O'Donoghue).
4. Discussion of pupil size and presentation of Leon Nel's analysis of pupil characteristics (David Buckley).
5. Final draft of SALT Science Requirements.
6. Discussion of Operations Requirements.
7. SALT instrument Concept Proposals
   - PFIS (Ken Nordsieck)
   - University of Canterbury HRS (Peter Cottrell)
   - Acquisition/guide CCD (Darragh O'Donoghue)
   - Fibre Instrument Feed (David Buckley)
8. Other instrumentation issues.
9. Presentation on SAAO's instrumentation capabilities
   - CCD program (SAAO Electronics).
   - Mechanical & design
   - Tour of SAAO workshops
10. Any other business.

Because of time constraints, item 6 (operations), 8 (other instrumentation) and the fibre instrument feed were not discussed. The tour of the SAAO workshops was also abandoned.

2. Participants

Those in attendance were:

Matthew Bershady	Wisconsin SSWG representative	MAB
Gordon Bromage	UK Consortium representative	GEB
David Buckley	SSWG Chairperson	DAHB
Peter Cottrell	NZ SALT Board member (proxy)	PLC
Klaus Fricke	Göttingen representative	KF
Richard Griffiths	Carnegie Mellon SSWG representative	REG
Kobus Meiring	SALT Project Manager (ex officio)	KM
Ken Nordsieck	Wisconsin SSWG representative	KHN
Darragh O'Donoghue	South Africa SSWG representative	DOD
Bob Stobie	SALT Board Chairperson (ex officio)	RSS
Gerhard Swart	SALT System Engineer (ex officio)	GS
Ted Williams	Rutgers SSWG representative	TW

3. Minutes of previous meeting

David Buckley presented minutes of the 7th February SSWG meeting held in Christchurch, New Zealand. Items for further discussion included the changes to the Science Requirements, which were under item 6.

4. Reports from Partners

4.1 UK group (Gordon Bromage, University of Central Lancashire)

Gordon discussed the formation of a UK consortium (UKSC; UK SALT Consortium, for want of a better name) of university astronomy groups, initiated by Phil Charles (Oxford/Southampton), who are interested in joining SALT. These include the following:

a.) UCLAN (University of Central Lancashire, Preston)
b.) Armagh Observatory, Northern Ireland
c.) Nottingham University
d.) Southampton University

The consortium has interests in most of the science areas, predominantly in stellar and ISM and some interest in high time resolution studies. There is also a significant interest in galaxies, kinematics and imaging spectroscopy. The predominant wavelengths of interest are 350-1000 nm, and lesser interest in the NIR. Nottingham has a particular interest in Integral Field spectroscopy.

There is currently a good likelihood of the first 3 groups mentioned raising the necessary $1M amongst themselves. There was some discussion of the recent UK proposal to join ESO, but it was clear that the VISTA telescope could not be considered as an ‘in kind’ contribution on the part of the UK.

Gordon also mentioned the collateral benefits aspect of SALT, which is of interest to UCLAN, due to their strong interest and involvement in distance-learning. They also have a relationship to some SA tertiary institutions (e.g. University of the Western Cape and the Cape Technicon), which might benefit from their SALT involvement.

4.2 University of Göttingen (Klaus Fricke)

This was the first SSWG meeting attended by Klaus, so he summarized the current situation at Göttingen. There are two main astrophysics groups:

Stellar	(Department I)	Director: Klaus Beuermann
Galactic & Extragalactic	(Department II)	Director: Klaus Fricke

In addition there is a Solar Physics group, which was originally responsible for having the workshop built. The latter comprise 4 permanent staff, and typically 6 temporary positions funded by grants. The FORS 1 & 2 spectrographs, for the VLT, were built in the workshops. Current instrument projects include a wide field camera (MegaCam).

Although Department II was solely responsible for raising the contribution to join SALT, it is likely that the other Göttingen groups will also have some access to SALT.

A discussion later looked at the possibility of Göttingen’s involvement in a SALT instrument. This would need to be negotiated with the instrument PIs, and some discussion followed outside of the meeting, between DAHB, MAB & KF, regarding Göttingen being involved in some aspect of the SALT Fibre Feed.

[Action: KF to look into this.]

4.3 Rutgers University (Ted Williams)

Recent developments at Rutgers include the hiring of 3 new faculty, bringing the total faculty to 12.

4.4 University of Wisconsin

One new faculty member has been appointed.

5. Report on the Spherical Aberration Corrector design

5.1 Optical Design Studies

Darragh O'Donoghue discussed the design work he has been doing for the SALT Spherical Aberration Corrector (SAC) and particularly a study of the image quality for different optical design.

The results are summarized in his report “Optical Design Studies for the SALT Spherical Aberration Corrector”. This includes details of the 9.2-m pupil design (same size as HET) optical tests. Modifications on the design were presented, with larger pupils and/or larger diameter mirrors.

Darragh presented a grid of such models, with pupils from 9.2-m to 13m and maximum mirror diameters of 500 mm to 750 mm. Focal ratios were kept at f/4.6 except for one of the 11-m pupil designs. Figures and Tables summarizing the performance parameters of these designs were presented and discussed. The former included vignetting functions, spot diagrams and pupil illumination figures. Parameters listed in the Tables included geometric spot radii and fractional vignetting (both on-axis and at the edge of the FoV).

The results indicate that the image quality remains very good (EE(50) < 0.1 arcsec) for pupils up to 11-m, but then begins to degrade significantly (e.g. spot radii of 0.21 and 0.47 arcsec, respectively for on-axis and 4 arcmin field angles. The amount of degradation is lessened if the M2 mirror diameter is allowed to increase.

The main concerns were ones of image quality, cost and implications regarding the PFIP (e.g. increased weight of larger diameter SAC). Other issues were concerned with the focal ratio and plate scale at the focus. For constant primary focal length, the size of the focal plane (for given field angle) grows as the pupil radius. This might affect the prime focus instrument (e.g. larger and potentially more expensive) and choice of fibre size. Darragh found that somewhat faster f/ratios than assumed (f/4) would make things easier (focal ratio conversion to an f/ratio < 4.6 is easier with the fast (f/1.2) primary).

5.2 Pupil size optimization

David Buckley showed some results from Leon Nel’s (Tracker & Payload Manager) analysis of the effective collecting area of SALT as a function of pupil size and field angle, taking into account the effects of track trajectory, in position and time. (Detailed results of this analysis were subsequently presented by Leon during the concept design presentations to the Board the following day.)

This work used an engineering CAD model to account for pupil ‘migration’ over the mirror array, central obstruction (fixed at a diameter of 40% the pupil diameter) and shadowing of the top hexagon.

Effective area is maximized (for a centered tracker) for a pupil of 11.5-m, ~25% larger than the HET's. The effective collecting area has a maximum of 63-65 square metres (for pupil diameters 11-12 m), which is >12.5% larger than the HET's effective area (~52 m^2). For pupils above 12-m, the effective area decreases again because the SAC central obstruction vignettes more of the primary while the outer regions of the pupil overfill the primary.

The time-averaged collecting area for centered track trajectories is ~58 m^2, equivalent to a mirror diameter of 8.6-m (inclusive of the 40% central obstruction).

5.3 SAC trade study

It was agreed to undertake a trade-off study of SAC designs to establish the optimal values for key parameters like pupil size, SAC mirror diameters, and effective f/ratio, with focal length kept constant. This has some implications on the prime focus instrumentation (e.g. slit and fibre sizes). Issues regarding resolution and throughput also need to be addressed. These criteria need to be added to the rest when it comes to deciding on the final adopted SAC design.

N.B. Further work by DOD on optimizing pupil size was done in a subsequent draft of the SAC design study, completed after the meeting (Version 2.0, 31 May 2000).

[*Action:* *KHN, Leon Nel*]

6. SALT Science Requirements

Discussion took place on the latest draft (#6.2) of *the SALT Observatory Science Requirements* document, the top-level user specifications for SALT. This draft incorporated all changes suggested at the last SSWG meeting as well as incorporating some suggested re-wording by the SALT Team (emphasising requirements rather than technical solutions).

The following additional changes were made in these sections:

a.) Section 2, page 2: specify low IR emissivity for H-band imaging.
b.) Section 2.1: minimum field size was set to 8 arcmin.
c.) Section 3.1.1: specify prevailing wind direction (W-NW)
d.) Section 3.2.1 & 3.2.2: A single image quality figure given for EE(50) and EE(80) for the whole FoV. (This because the SAC is the only contributor and DOD's designs show off-axis performance not seriously degraded).
e.) Section 3.2.1: Include wording that the SSWG will be consulted regarding the formal adoption of the system image error budget.
f.) Section 3.2: Time to align mirror segments specified in hours (< 2 hours). Remove sentence of 3.2.1 relating to IQ maintenance for minimum 60 minutes, etc. (this was original spec. for a system with no edge sensors).
g.) Section 3.2.2: f/ratio TBD (results from trade-off study).
h.) Section 3.2.3: Have goal of 320 nm. Recoating primary mirror specified.
i.) Section 3.2.3: Spec pupil to be > 10.2-m diameter (exact value TBD from trade-off studies).

j.) *Section 3.2.4: Remove 'flat'. (exit pupil has a max sag of 15mm). Include the specs for HET's moving baffle (speed of motion, following and positioning accuracies).*
k.) *Section 3.2.6: Mention desire to minimize Lunar illumination effects on CCAS tower.*
l.) *Section 3.4: Minimize transmitting compressive forces or tension on optical fibres.*
m.) *Section 3.4.3: Change offset angles for objects within an 8 arcmin diameter.*
n.) *Section 3.4.10.4: Include designing to allow for easy upgrading or replacement of cables.*
o.) *Section 3.6.2.: Specify overlay GUIs for slits, fibres, etc.*
p.) *Section 3.8.2: ADC to correct dispersion (secondary dispersion <0.15"), with a transmission >95%, from 340-850nm, with a goal of correcting dispersion over 320-1800 nm.*

[A revised version of the Science Requirements (#7.0) was subsequently tabled at the SALT Board meeting and ratified with minor changes. The final adopted version (#7.1, dated 31 May 2000) was subsequently passed on to the SALT Project Team to be used in defining the SALT system specifications.]

7. Instrument Concept Proposals

Following from the decisions made at the last SSWG meeting, specific concepts for SALT instruments were tabled. There was no time to present anything on the Fibre Instrument Feed (FIF), which anyway is partly dependent on the parameters of the fibre-fed spectrograph, UCHRS (see 7.3 below). It was recognized that the FIF would be 'fed' by a 45º mirror, and that that suitable space/mass has to be set aside for it in the design of the PFIP.

David Buckley briefly mentioned that he was supervising an engineering student, Nicholas Sessions, who was investigating fibre issues for SALT as part of his MSc thesis. He was currently working with Larry Ramsey at Penn State on moving pupil effects in fibres. It was hoped that Nick would use this experience on returning to SAAO, and be involved in designing and building the FIF, if indeed SAAO became the PI institution for this instrument.

7.1 Prime Focus Imaging Spectrograph (PFIS)

Ken Nordsieck tabled the University of Wisconsin – Madison's proposal to build an imaging spectrograph to be mounted at SALT's prime focus. The document *"Prime Focus Imaging Spectrograph (PFIS): a concept proposal for the Southern African Large Telescope"* had been circulated to the SSWG.

The proposal covered the scientific 'niches' that such an instrument would exploit, including:

- UV spectroscopy (310-400 nm)
- High throughput, multi-object medium resolution (R ~ 10,000) spectroscopy.
- Fabry-Perot imaging spectroscopy.
- Spectropolarimetry.

The instrument would take advantage of recent technological developments, including Volume Phase Holographic transmission gratings and Sol-Gel anti-reflection coatings.

An optical design of the instrument was presented, which assumed an 11-m diameter pupil and the same platescale as the HET (i.e. a 100mm diameter focal plane). Design goals were high throughput in the blue, and capability over the region 320-850 nm, but with the possibility of an upgrade to a near-IR beam extending to 1.7 microns (this beam would share the collimator).

The UV performance requires using the very hygroscopic UV crystal NaCl, which is restricted to be the center member of sealed triplets. The resolutions were determined assuming median seeing of 0.9 arcsec (FWHM). These could reach R ~ 13,000 with narrower slits (0.5 arcsec), or even higher if VPH échellettes become a reality. Lateral colour aberrations will limit the imaging performance, but it expected to produce ~1 arcsec imaging in the B-band filter. The waveplates would consist of a 100 mm mosaic, expected to be expensive ($60K each).

The detector would need to be ~60mm in the spectral direction, and is currently planned to consist of 3 butted 2048 × 4096 *EEV-Marconi* CCDs (13.5µm = 0.13" pixels). Binning by 2 × 2 would give 0.25" pixels. Readout rates would be 26 seconds for full-frame at the standard rate, and ~1 sec for rapid readout.

A crude weight estimate for PFIS is 193 kg, with a suggested budget of 250 kg. The total rough estimated cost for PFIS is $3.2M. Potential partners in the project include SAAO (CCD detectors) and Rutgers (F-P etalons and maybe the disperser unit). A delivery date to the telescope of mid-2004 follows from the preliminary schedule.

Trade-off study

Several design parameters need to be decided upon based on the final design adopted for the SAC. These issues include:

- Field of view (SAC will give 8 arcmin)
- Imaging quality (0.25 arcsec resolution currently)
- Detector size (~900 spectral resolution elements)
- Near IR capability
- Near IR beam upgrade path possibility
- Slit geometry (30 slitlets ? slit masks ? See Section below)
- First-light etalon availability (R ~2500 or 10,000 ?)

Some of these issues should be decided following input from potential users. A suggestion of a questionnaire to canvas opinion was raised.

Further action items required include:

a.) complete a SOW (statement of work) and preliminary budget
b.) liaise with SAAO detector group on CCD camera for instrument
c.) liaise with Leon Nel over interface and mass/volume specs

d.) development of mechanical structure and electronics
e.) power requirements and cabling issues
f.) derive a more accurate cost estimate

The latter will be required in order for the instrument budget to be managed and for any in-kind contribution assessed. A maximum cost for the instrument will need to be ratified by the SALT Board.

[Action: KHN]

7.2 PFIS slit options

Matt Bershady presented a report on the MOS (Multiple Object Spectroscopy) focal plane for PFIS, which looked into the various options regarding multiple slit over the FoV. He considered 6 possible methods:

- Monolithic aluminized quartz strips with etched slitlets (e.g. LRS on HET)
- Custom machined masks in serviceable juke-box
- Metal rolls with punched slitlets
- Independently adjustable mechanical slitlet jaws
- Micro-aperture arrays

The first 2 options were considered to be the most feasible for PFIS, while the last option is a possible future up-grade path, once the technology is proven.

Anything between 30 and 90 slits could be possible.

7.3 UC High Resolution Spectrograph proposal

Peter Cottrell tabled a concept proposal from the Department of Physics and Astronomy of the University of Canterbury to build a High Resolution Spectrograph for SALT (hereafter referred to in this report as the UCHRS). The proposal is based on a fibre-fed échelle spectrograph (*HERCULES*), currently being built at Canterbury for their 1-m telescope. This instrument has a resolution of 35,000 or 70,000 (dependent on fibre size), and is designed to be extremely stable, being housed in a tank under soft vacuum (2-3 Torr) to avoid index of refraction variations leading to radial velocity errors.

The proposal was discussed and it was felt that an instrument, along the lines of that proposed, would address some of SALT's requirements in the area of high dispersion spectroscopy (R > 30,000). [The principle of an instrument, along the lines of UCHRS, as an in-kind contribution by New Zealand was subsequently ratified by the interim SALT Board.]

Issues raised by the SSWG basically involve a better matching of the UCHRS design (currently based on a 1-m telescope class instrument) to a 10-m class telescope. Specific issues and concerns include the following:

a.) Some science goals, at least for the NZ community, have been identified. The science case needs to be extended, involving the

SALT partners. The particular niches where the UCHRS will excel needs to be discussed, and a comparison made to existing or planned instrumentation. How competitive will the instrument be on similarly sized telescopes (e.g. UVES on VLT)?

b.) Matching image scale to fibre size. Typical images will have a FWHM of ~1 arcsec, and the platescale of SALT is in the region of 200 mm arcsec-1. This means that fibres will ideally have core diameters of 200-400 mm, four times larger than the 50-100 mm fibres used in *HERCULES*. A significant redesign of *HERCULES* would be required to match the resolution (R ~35,000 to 70,000) to these fibre sizes.

c.) No multi-fibre capacity, except for the mention of fibre bundle to increase R, while preserving throughput. Many science drivers call for some multi-fibre capacity, either for spatial sampling (e.g. an Integral Field Unit), image slicing (fibre bundle) or modest multi-object (several) capability (the latter would be a unique capability for this resolution over an 8 arcmin field). Sufficient inter-order spacing would then require significantly more cross dispersion than is currently possible with the *HERCULES* design.

d.) The above requirement, plus the desire to increase wavelength coverage, might demand a larger detector (4K × 4K CCD, or larger) and different camera design. Thus the comment in the proposal (Section 3e) needs addressing (i.e. we need to see what alternatives exist to achieve the capabilities listed in c.) above).

These issues were clearly recognized by the proposal authors (e.g. in their discussion of Risks and Mitigation, section 9) and would no doubt be addressed in the next phase of a design study. Their current proposal is for such a study to be completed January to June 2001. In the meantime it was felt that it is important that these issues are discussed amongst the SALT community.

[Action: All SSWG representatives.]

The response of the SSWG to the proposal would be relayed back to the New Zealand SSWG representative, Glen Mackie and the PI for UCHRS, John Hearnshaw.

[Action: DAHB, PLC]

7.4 SALT acquisition and imaging camera (SALTICAM)

Darragh O'Donoghue presented current ideas on an acquisition camera for SALT (SALTICAM), which would also double as a science-grade imager and commissioning instrument. The proposal is for SAAO to take the lead with this instrument, partly because of the requirement of close liason with the SALT team, who will be responsible for its integration into the Prime Focus Instrument Package.

SALTICAM will intercept the beam after the exit pupil with a 45º pick-off mirror. Re-imaging optics will convert to ~f/2, more suited to CCD sizes (no CCDs larger than 60 mm are easily obtainable). The instrument in the presented configuration would use an EEV-Marconi 2048 × 4600 frame transfer CCD, capable of imaging a 4 × 8 arcmin field. Some discussion ensued as to whether it would be better to mosaic two CCDs to allow the entire FoV to be accessed. This would have significant cost implications, with the present estimate being $285K for the smaller FoV, and ~$500K for the full field.

The science niche of SALTICAM would be high-speed photometry, with sensitivity in the UV, and, notwithstanding the roving pupil and gaps in the mirror array, useful photometry (certainly differential) with SALTICAM will be possible. This is of wide interest amongst the SALT consortium.

8. SAAO's instrumentation experience

Darragh O'Donoghue (Head of SAAO Instrumentation division) introduced Geoff Evans (Head of Electronics), James O'Connor (recently appointed Head of Mechanical Workshop & Design Office) and Dave Carter (CCD development).

8.1 CCD development

Geoff described the CCD projects undertaken at SAAO over the last few years. These were based on RAL (Rutherford Appleton Lab in UK)-designed transputer controllers, and have been used in:

- Several *Tektronics* CCD (512^2 and 1024^2) based cameras (mainly for photometry).
- Several *SITE* CCD cameras (similar dimensions).
- A SITE 1788 × 266 frame transfer CCD (for spectroscopy)
- Thermoelectrically cooled acquisition/guiding camera based on small frame-transfer CCDs (not science grade).

In addition some work has also been done on IR arrays for Ian Glass (SAAO IR instrumental astronomer). Recent activities have centred around using SDSU (Leach) controllers (2 have been purchased). A clean room for CCD preparation has also recently been built.

The possibility of involvement in detectors for SALT (e.g. *EEV-Marconi* arrays) will require developing skills to mosaic CCDs, which has yet to be attempted at SAAO.

8.2 SAAO instrumentation experience

DOD summarized the various instrumentation projects carried out at SAAO in order to give some idea of the experience of SAAO technical staff. DAHB briefly mentioned the fibre-fed spectrograph, *GIRAFFE*. His opinion was that similar mechanical components for a SALT bench-mounted spectrograph could be undertaken at SAAO, given this experience.

Although time constraints precluded a tour of the SAAO instrument workshops, some members of the SSWG did have an opportunity for a quick look later in the week. KHN and MAB also discussed CCD issues with the some SAAO staff later.