

SALT Board Meeting #38

South Africa

SALT Edge Sensor (SAMS) Project

Chris Coetzee - Project Manager

Supported by the SAMS Project Team:

Hitesh Gajjar (HG), Project Engineer; John Menzies (JWM), Analyst; Ockert Strydom, System Engineer; Keith Brown, Electronics Engineer; Deon Bester, Software Engineer; Jonathan Love, Mechanical Technician; Vic Moore, Project Procurement Officer

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1. Summary

A contract which merged the original Phases 2 and 3 was placed with Fogale shortly after the decision was made to do so at Board Meeting #36. All the hardware including sensors, electronics and supporting components is in the process of being manufactured by Fogale. The manufacture of the sensor pieces which are to be bonded to L-brackets by SALT has already been completed ahead of schedule.

After significant optimisation efforts of the control software including MARS and SAMS, significant progress was made and the system has demonstrated the maintenance of the 7 segment array over a 24 nights and a temperature span in excess of 20 °C.

The primary focus is now to prepare all the necessary hardware and software for the full production, installation and commissioning of the full array. This involves the further optimisation of the bonding tooling, bonding the sensors to L-brackets, bonding bushes to segments, and the test and characterisation of these sensors in an environmental chamber before installation on the telescope.

Despite the additional time and resources required to optimise the bonding tools originally developed by Fogale, every effort is being made to maintain the original schedule. The optimised tools and bonding process will enable us to bond sensors at double the rate, control the quality over a production run of ~1000 and deskill the job

Phase 1 Test Results

A single continuous closed loop test run with a 24 day duration has been achieved over a temperature span exceeding 20 ˚C including sub-zero temperatures.

The figure 1 below summarises the results of the test, which was highly successful.

The top panel shows the rms tip/tilt as recorded at intervals through the night from 5 August to 27 August. The blue points at the beginning show the initial alignment at twilight on 5 August, where rms tip/tilt was 0.07 arcsec. The temperature experienced by the mirror array during night-time tests was from 0 ^{o}C to about 16 ^{o}C. On some days the temperature was higher or lower than these end-points, and the total range experienced in the test period was from about -2 ^{o}C to about 20 ^{o}C.

The scatter in the plot is related entirely to CCAS measurement errors.

The second panel shows the rms tip/tilt as a function of temperature. There is a clear linear relation. There are several possible reasons, but a simple fix would be to apply a scale factor to the GroC corrections applied by SAMS, which are based on temperature. If SAMS were not in control, the rms tip/tilt would have changed by about 1.4 arcsec over the temperature range shown.

The third panel shows the rms tip/tilt after correction for the temperature effect.

SAMS has clearly maintained control of the central 7 segments for the entire period.

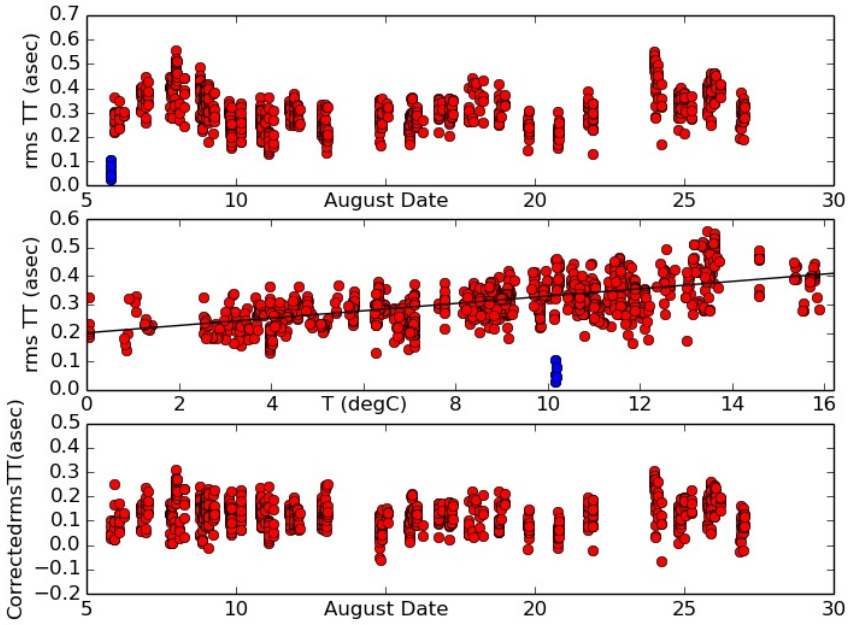


Figure 1. 24 day test results measured with the CCAS instrument

2. Sensor Production

Following the sensor bonding training that Jonathan Love received at Fogale, the following points became evident. The sensor bonding process requires highly skilled operators to ensure consistent quality. The bonding process took approximately 90 minutes which is unreasonable given the quantity of sensors required for the SALT array.

The tooling developed by Fogale had several shortcomings which made the bonding process more complex than necessary.

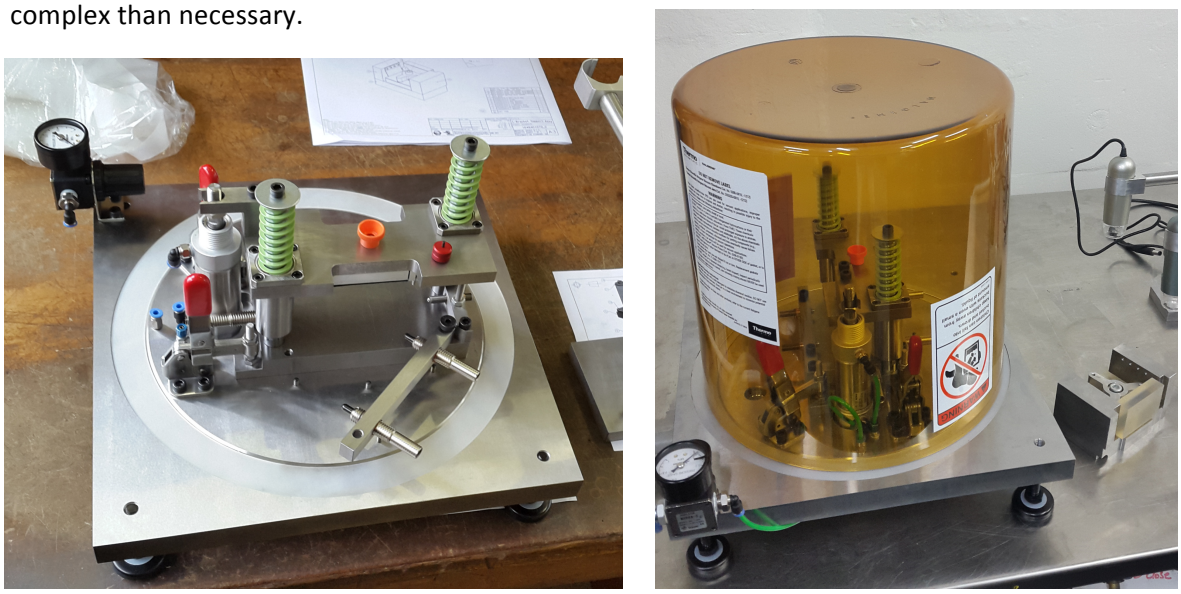


Figure 2. SALT developed sensor bonding equipment

The project team decided that it was essential to redesign the tooling and update the bonding procedure in order to improve the quality of the bond, reduce the cycle time and de-skill the operator requirement. The redesign of the tooling and the process took approximately 3 months.

With the new tooling and process we are now able to produce bonded sensors of consistent quality at a rate of 50 per week per station which is double the rate previously attainable. We are now in the process of manufacturing three bonding stations which will bring our capacity to 150 L-brackets per week.

The development of the first prototype tool concluded with the 2 bonded sensor pairs. These pairs were tested in our environmental chambers to validate the quality of the bond and the process.

Environmental tests conducted on the 2 test sensors show excellent agreement in the behaviour of the 2 sensors with respect to each other, demonstrating good consistency in the bonding process. The response of the two sensors to temperature and RH is also within specification with regards to temperature sensitivity, RH sensitivity and hysteresis. The manufacture of the additional bonding jigs is underway to meet the required production rate of 150 sensors/week (to overcome the time lost to delays in development).

3. Bush Bonding

The bush which attaches the L-bracket to the underside of the segment requires bonding with epoxy to the segment. This task is currently being carried out progressively throughout the array.

This task is progressing at the required rate of approximately 4 segments per a week; a total of 35 segments have now been bonded. A second bonding tool is being completed which will double the rate so as to meet the schedule.

4. Risks

The Risk Register is still a work in progress and will be refined, as we understand the production jobs better. The RESIDUAL RISKS must be understood to be the risk remaining after the mitigation actions have been successfully implemented. It does not mean that the risks are currently mitigated. The CURRENT STATUS is as defined in the RISK NUMBER column.

TABLE 1: RISKS

CURRENT STATUS					MITIGATED STATUS AT END OF THE PROJECT (RISK NUMBER INDICATES LATENT DEFECTS THAT MAY AFFECT OPERATIONS IN THE FUTURE)			
RISK	EFFECTS	IM-PACT	PROBABILITY	RISK NUMBER	MITIGATION IN PROCESS AND BEING PLANNED	IMPACT	PROBABILITY	RISK NUMBER
PMAS does not meet 5 day >10C specification	• Specification - alignments must be done daily to every 3 days until that test is completed and passed successfully. • Project – Schedule delay in commissioning because weather is not under our control	M	L	ML	• Keep on testing the 7 segment installation and achieve the 5 day, >10 C target as soon as operating and weather condition allow • Test production system in an incremental fashion as the installation becomes more mature • Do not only a SAMS acceptance test but also a PMAS acceptance test	L	L	Low
Sensor system does not meet specification	• Specification - Incorrect measurements	0	0	0	• Completed • Report in progress	0	0	0
Residual software bugs in PMAS	• Project - schedule delay to find and debug • Operations – sporadic uncovering of bugs as the system is thoroughly tested during very large temp swings and full operations	L	M	LM	• Currently known bugs, as defined above, can be mitigated by an experimental setup using virtual machines currently being tested in an effort to resolve these issues • Software work is never completely done since the requirements for new functionality always comes to the fore but new software can be vetted and tested thoroughly before implementation • Unknown bugs may be uncovered as the array develops from 7 segments to the full 91 segments. They have to be found and fixed in a systematic way as is currently done with the 7 segment installation	L	L	Low and fit for purpose Requirements for new or modified function will continue during full scale operations as is the case with all s/w based systems
Bonding of buttons takes longer than estimated	• Project -schedule delay	M	M	MM	• Experiments are being done to establish a realistic production process and effort • The correct curing equipment has been supplied and tested • Hitesh has successfully bonded prototype buttons during the 7 segment installation. That time is available and is being used in the current calculations. • Anothare bonding tool is being manufactured to double the bonding rate and will ensure schedule compliance	L	L	Low
Button bonding delivers inconsistent quality	• Project - schedule delay • Operations – repairs required	M	L	LM	• Process proven on small scale • Implement prescribed process • Use FOGALE supplied bonding jigs and equipment • Train staff • Supervision • Regular quality inspections, audits, reports and reviews • Spares available – buttons can be removed and re-bonded during project phase and operations	L	L	Low
Flexure bonding takes longer than estimated	• Project - schedule delay	M	M	MM	• Training of team leader in June. • A greatly improved production jig to be made to deliver at the required rate.	L	L	Low

					• **Extra short-term staff may be needed to produce at the required rate. They will have low labour rates. A firm request will be made once more detail is available but a first-order estimate is R75-R120k** • **This task is still on the critical path and the final schedule risk can only be assessed when the production is at full capacity, estimated to be around the end of November**			
Flexure bonding delivers inconsistent quality	• Specification - PMAS system performance will be compromised • Project – schedule delay as more flexures have to be bonded	M	L	ML	• Process proven on small scale • Process to be followed • Set-up production line to conform with requirements • Team leader to be trained • Team leader trains and supervises staff • New improved production jigs have been developed and tested. They will double the rate and ensure consistent quality • Test and calibration equipment is being obtained from FOGALE • Regular quality inspections, audits, reports and reviews • Spares of flexures and L-brackets and connectors are available to replace faulty ones during project phase and operations	L	L	Low Latent defects may become apparent during full scale opera-tions.
Cable installation faulty	• Project - PMAS system performance can be erratic and cause schedule delays to debug • Operations – connectors and small cables disturbed during mirror segment swapping	L	L	LL	• We have sufficient manpower to fix it if necessary • Spare cables and connectors available • Will probably have to develop support equipment to minimise inadvertent damage during mirror swapping	L	L	Low Inadvert ent damage to small cables and connecto rs during mirror segment swappin g
FOGALE delivers late	• Project - schedule delay	L	L	LL	• Production readiness review found that FOGALE and sub-contractors have the capacity to deliver the required volumes and required rate. • 20% Final payment at end of ATP will act as a motivator to deliver on time	0	0	0 Deliverie s have been ahead of schedule
FOGALE delivers non conforming products	• Specification - PMAS system performance can be compromised • Project -schedule delay	H	L	HL	• Production readiness review of FOGALE and sub-contractors completed. No show stoppers found as far as quality issues are concerned. • Quality problems with button manufacturing at SAAO attended to before full-scale production starts.	L	L	Low Very minor latent defects may be discover-ed during opera-tions and repairs should be possible
Telescope operations are affected by constant work on the PMAS and SAMS and primary mirror array. This means more Engineering downtime than budgeted for - as we have seen with the installation and testing of the first 7 segments	• Project - PMAS test schedule delay since operations will get priority. • Project - Acceptance testing of the system may take longer than foreseen • Operations – newly swapped segments out of capture range	M	M	MM	• Refine current installation and operational procedures to take into account the challenges of much larger scale operations • Train operators (they are being trained and gaining valuable experience on the 7 segments system) • Co-ordination of installation and testing between project and operational teams. This is much easier now that both functions reside under one management team. • System is designed to allow for mirror swapping but more thought has to go into the operational process and then implementation in the software.	L	L	Low
Retention of key contractors as defined in SALT Operations report Chapter 3	• Project – some functions cannot be executed without them and the project will fail or be delayed for an unknown time until others can take over and become proficient in the job. This will also be the case even if current staff have to take over although the	H	M	HM	• Retain John Menzies (mathematician and analyst) • Retain Deon Bester (PMAS and SAMS software engineer). Deon Bester has other options abroad so his contract needs **immediate** attention. This risk has materialised since Deon is no longer interested to work for SALT. The PMAS and MARS software are being transferred to Paul Rabe, but he has to go through a learning curve to get to know the software • The risks (technical and schedule) have increased due to Deon Bester no longer being available	M	M	MM Some latent defects and bugs may still be uncover-ed during

	learning curve might be shorter.							full scale operations

Legend:

IMPACT	DEFINITION	PROBABILITY	DEFINITION
Low	Will not affect the performance of the mirror alignment and or minimally (1 w) affect the schedule	Low	May happened sporadically during operations and/or project phase. Multiple failures will have to happen before this failure will occur
Medium	Will affect the mirror alignment from time to time but the system regains control after an anomaly has occurred and/or somewhat (1w-1m)affect the project schedule	Medium	May happen from time to time during operations and/or project phase. More than one smaller failures will have to occur before this particular probability will manifest itself
High	The alignment is affected to the extent that alignment must be done on a daily basis and/ or materially affect the project schedule (1m-6m)	High	May happen on a daily basis during operations and or project phase . Single point failure

6. Schedule

The development of the sensor bonding tooling has taken 3 months not originally accounted for in the schedule. The tooling does however halve the time (compared with the original Fogale developed system) required to bond a sensor. It also ensures that the bonded sensor is of a sufficiently high quality with reduced technical operator demand. The overall schedule and the expected completion date of end March 2016, with April 2016 as the buffer, remain unchanged.

The manufacture of sensors, cabling and electronics by Fogale is tracking slightly ahead of schedule. All 480 flex sensor pairs required for the complete array have been delivered to SALT, several weeks ahead of schedule.

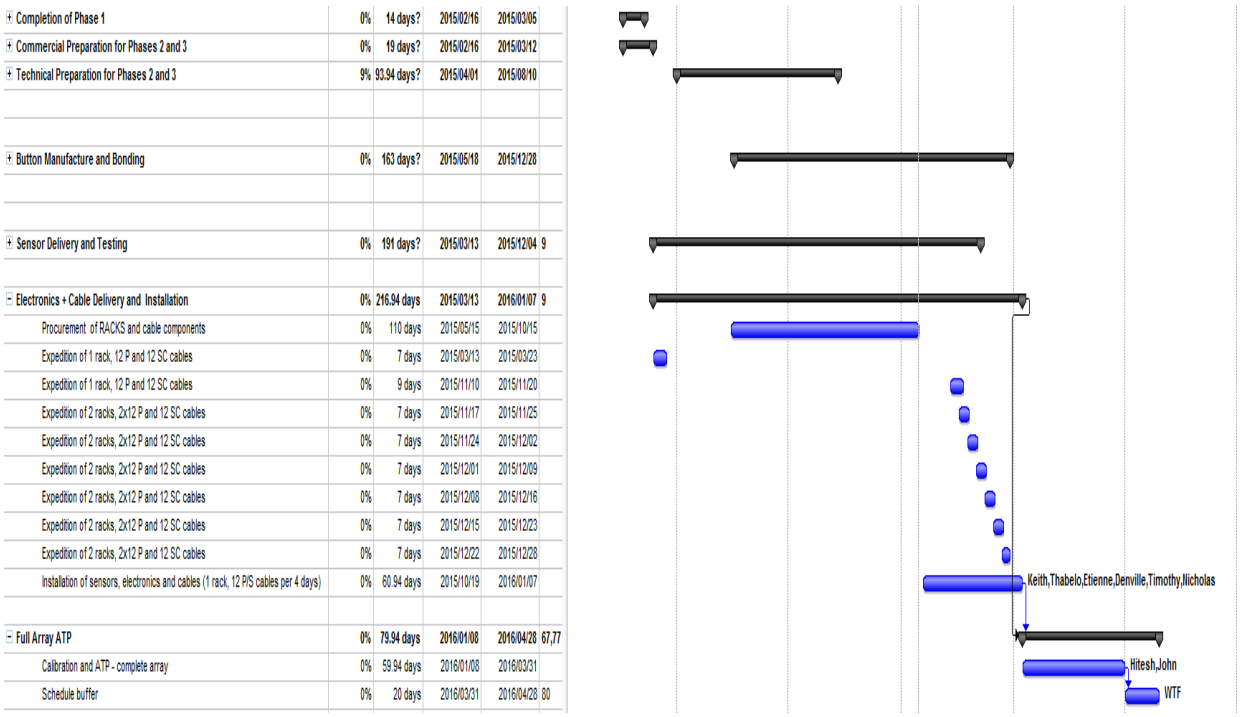


Figure 3. Project schedule

7. Budget

The cost versus budget and year-end projections are reported in the separate Development Fund Projects report.

8. Conclusion

The recent test demonstrating the system's ability to maintain control over a 24 day period with a temperature span exceeding 20 degrees is an important technical achievement. Tremendous effort has gone into improving the bonding equipment and preparing for the production and installation of the system maintaining quality, ensuring system performance and adhering to the original schedule.

All high risk technical issues have been addressed and, with tremendous effort and emphasis on the installation underway, the project is on track towards delivering the full array within schedule.

The schedule does however remain the highest risk item. Although the known technical risks have been satisfactorily mitigated on the 7-segment installation, typically with the integration of such complex systems unforeseen and unknown problems may surface during the acceptance of the fully instrumented array. The significantly higher planned production and installation rates will have to be proven in practice in order to stay on schedule. Should some of these risks materialise, the buffer month of April may be required to complete the project.