SAAO’s Mechanical Workshop and Optics Lab Upgrade

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The SAAO’s Mechanical Workshop in Cape Town recently took a huge leap forward with a R10 million infrastructure upgrade. All computer controlled, the workshop floor is now dominated by a huge 5-axis Milling Machine, surrounded by two Lathes, a Spark Eroder and Wire Cutter. The Optics Lab was also refurbished, enabling sophisticated optical work to be carried out in-house. The capabilities of these new machines have already been demonstrated with some technically challenging work produced for iThemba Labs and MeerKAT.

In late 2010, the National Research Foundation (NRF) notified the South African Astronomical Observatory (SAAO) of a generous grant from the Department of Science and Technology (DST). Approximately R10M had been made available and was to be committed (and, ideally, spent) before the end of the Financial Year! The only conditions were that the money be used exclusively for infrastructure and that items exceeding half a million Rand would be subject to a rigorous tender process.

Fortunately the Mechanical Workshop had a comprehensive wish-list on hand that could consume more than half the allocation, although tenders would have to be sought since the various machines exceeded the R500k limit.

Fast-forward through endless sequences of eye-wateringly painful meetings and flaming bureaucratic hoops, to where we are now – relishing a host of amazing new machines and other fantastic toys!

Machining in the computer era

The Workshop’s bold entry into the modern age actually came a few years ago with the acquisition of its first Computer Numerical Control (CNC) machines, in the form of a 4-axis CNC mill and a CNC lathe. While operating on much the same principles as conventional lathes (fixed...
The 5-axis CNC milling machine. The cutting tool comes down from the grey turret at the top while the part (a copper piece in this photo) gets clamped to an assembly that can translate in X and Y and rotate about two axes.

The steps that follow uploading a 3D Computer-Aided Design (CAD) file to a CNC machine are non-trivial, particularly as one has to simulate the entire tool-path to ensure that no collisions could occur during the machining process. However, once that has been done – any number of such parts can be produced without further investment, other than the operator having to physically set up each new block of material. This makes CNC machines ideal for mass-production environments, which, admittedly – the SAAO generally is not. The sorts of parts we need tend to be complex and are often unique. Even so, the remarkable “agility” of CNC machines calls for fewer setups for a given part and allows more ambitious designs to be manufactured. Furthermore, onboard metrology gear allows in situ measurements to be made during machining. This eliminates wasted effort in terms of removing the part to measure it with other devices and then having to meticulously set it up again before being able to continue.

The utility of the Workshop’s original two CNC machines prompted the selections made possible by this latest funding tranche. Top of the list was a 5-axis CNC mill (since the additional axis vastly increases the machine’s capabilities), followed by a substantially larger CNC lathe. The other two machines were chosen to provide an entirely new capability, namely Electrical Discharge Machining (EDM). The EDM machines are also of the CNC variety, but rather than relying on mechanical means to shape parts, the Spark Eroder and Wire Cutter do so using electrical energy. Both also have four axes and thus are extremely dexterous.

Electrical Discharge Machining principles
In the EDM game, the tool and the work-piece act as
electrodes and the two are immersed in a bath of dielectric fluid which provides insulation. A large voltage is applied to the system and the two electrodes are brought close to one another. At a given threshold separation, the electric field strength overwhelms the dielectric, causing electrical breakdown within the fluid and this allows a spark to jump across the gap. The spark erodes both the electrodes and so by using an appropriately shaped tool electrode, one can electrically “carve out” the desired shape in the work-piece electrode. This process is also known as die-sinking. In the case of the Wire Cutter, ~250 micron thick wire is continuously spooled from a large reel to serve as the tool electrode, rather than the shaped piece of copper that is typically employed in the Spark Eroder. In the latter case, it may be necessary to replace or reshape the tool electrode as it gets worn down, to ensure that it continues to spark out the appropriate shape.

EDM is a slow, repetitive process as the gap between the electrodes has to be opened again after each spark. This refreshes the dielectric and flushes away the fine particles liberated by the spark. Increasing the current can speed up the removal of material, but this produces a rougher finish. Also, one’s material selection is of course limited to substances that can conduct electricity. The advantages to this approach are significant though as the process allows for much more complex shapes to be machined — including sharp (e.g. 90°) corners and deep pockets that conventional cutting tools cannot produce. EDM is also safe to use on extremely delicate parts such as a platform that can move in the X and Y directions. The electrode can also be angled to allow side-sparking and the 4th axis is provided by the ability to rotate the tool electrode.

(left) The CNC Spark Eroder. The blue turret holds the tool electrode and moves it up and down (in the Z-direction). The blue door seals the work volume that gets filled with dielectric fluid and the part gets clamped to

(right) A variety of intricate copper parts (belonging to the detector system for one of the MeerKAT antennas) that were manufactured in the Workshop.
thin (sub-mm) flexures as there is no physical contact between the tool and the part. It works equally well on hardened materials that would require special heat treatment processes to allow conventional machining and then to relieve the mechanical stresses that this introduces.

**External work**

Until recently, the Mechanical Workshop only serviced the needs of the Observatory – for projects related to the small telescopes and to SALT. The introduction of this highly complementary set of machines will allow the production of extremely specialised parts, even in large numbers. This provides an exciting opportunity for the SAAO to participate in a broader range of scientific endeavours, both in astronomy and beyond. The completion of a number of technically challenging contracts for iThemba Labs over the past few months offered a steep learning curve for Craig Sass and his team and has resulted in a great symbiosis between two National Facilities. Interesting work has also been done to produce parts for the MeerKAT detector assemblies. This success bodes well for the SAAO’s future involvement in South Africa’s contribution to the Square Kilometre Array (SKA).

**Optics Lab Upgrade**

Although this may seem like a strange deviation from the SAAO Workshop’s traditional focus, taking on these sorts of jobs is an excellent way to hone the many skills required to use these machines to their full potential. This of course will be crucial if the Observatory is to grow its capacity to develop more ambitious astronomical instrumentation. In support of this vision, the old Optics Lab next door to the Mechanical Workshop was also given a thorough overhaul. Ian Glass kindly guided us through the daunting process of sorting through every item that had made its way into the lab over the past few decades. Having cleared out and then removed all of the less-than-ideal wooden storage spaces, a 1.6 ton overhead crane with an electric hoist was
installed in the Integration Room section. Fresh paint was applied throughout and then the old, damaged floor tiles were removed and replaced with a durable, easy-to-clean epoxy floor. The required grinding of the surface beneath the old tiles generated *epic* amounts of incredibly fine dust that perfectly coated every conceivable surface within the lab. This subsequently provided many hours of “team-building” for future lab users who spent a day washing and cleaning. Everything. At that point, the new furniture and equipment could at last be unpacked and installed in the completely transformed space.

**Projects lined up**
The new lab has been used for various small projects already, but we look forward to the year’s main challenge, namely aligning and integrating replacement optics for the collimator of SALT’s Robert Stobie Spectrograph (RSS). The RSS optics have caused their fair share of misery in the past and this time we are determined to deal with the issues ourselves, rather than sending the lenses back to California for further repairs. This affords the Observatory a great opportunity to develop capacity for handling large optical elements made of challenging materials like calcium fluoride and sodium chloride in our lab. Furthermore, all of the replacement opto-mechanics will be manufactured in the Mechanical Workshop using the CNC machines described above.

In the meantime, SALT’s new High Resolution Spectrograph (HRS) is due to be delivered around the middle of the year and so the Workshop is churning out parts for the Fibre Instrument Feed (FIF). The FIF, to be housed within the SALT payload, will provide the interface between the focal plane and the optical fibres that will feed the instrument (which will be situated in the spectrometer room below the telescope).

Second in priority to the Workshop’s current FIF work is the manufacturing of parts for a major upgrade to the SAAO 1.9-m telescope’s Cassegrain Spectrograph. This ancient workhorse instrument will receive new camera optics, a new detector and cryostat, various new mechanisms and the software will undergo a substantial overhaul to improve the efficiency of observing and data reduction. The upgraded lab facilities will be essential for the alignment and integration of the optics and the new hardware before the instrument can be returned to Sutherland for full on-sky commissioning.

Other than the need for more staff to take full advantage of the new equipment, the SAAO’s Instrumentation Division is superbly placed to tackle exciting challenges and grow from the experiences. We very much look forward to working with the SAAO’s new Director, Prof Ted Williams (a self-confessed instrumentation junkie!) to realize this potential.