SOAR Forward Look Instrument Plan

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SOAR Science Advisory Committee[1]

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Current Status

First Generation SOAR: The first generation instruments are being delivered now with the hope that the initial suite will be delivered and commissioned within two years. These are described briefly below.

■SOAR Optical Imager: Delivered. Commissioned. Basic optical imaging, 5 arcminute FOV, broad filters and some narrow filters.
■OSIRIS NIR imager and Spectrometer: Delivered. Commissioned. *JHK*, NB imaging, *R*=1200, 3000 spectra , 1.5' or 3 ' FOV. OSIRIS was transfered as is from the Blanco 4m and is previous generation instrument.
■Goodman Optical Multi Object Spectrograph: Delivered. Partially commissioned. Imaging and Long slit modes commissioned. MOS mode not commissioned (2009B?)
■Spartan: NIR imager. Delivered. To be commissioned in late 2008, early 2009. *JHK* imaging over 3' to 5' FOV with better sampling than OSIRIS (0.043"/0.073" v 0.14"/0.3"). A modern instrument with 4096 x 4096 pixel format (four detectors).
■SIFS: Optical IFU spectrometer. In development. To be used with SAM. R=1000-3000, 4"-8" & 8"-15" FOV, 0.15" & 0.3" scales. Delivered mid 2009 (SAC feels this is optimistic).

Approved Second Generation: These instruments should also be delivered within two years.

■SAM, SOAR Adaptive Optics Module: In development. Ground Layer AO imaging over 3 arcminute FOV. CCD camera and SIFS. First light mid 2009. First Laser Light mid 2010. Not initially considered a first generation instrument.
■STELES: High dispersion optical spectrometer. In development. Long Slit, optical relay feed to bench spectrometer. Delivered 2010? SIFS comes first.

Other: These instruments are available or in development, but not facility intruments.

[1] The SAC thanks Director Steve Heathcote for his participation in the discussion and input to the resulting report.

■Phoenix Working. Currently deployed at Gemini. Good fit to SOAR? Would conflict with BTFI in seeing limited (IR ISB) mode.
■BTFI. In development. Tunable filter + Fabry Perot. Delivered as RUI in 2009? Currently envisioned as a restricted use instrument that could develop into a facility instrument.

Competition: A brief survey of competing facilities and instruments was done to help better inform the SOAR instrument development goals. This survey is incomplete, but should serve to provide context. Capabilities which have substantial overlap with SOAR are highlighted in red.

■CFHT, wide field optical and NIR imaging with excellent DIQ site. CFHT Legacy survey is major campaign (MegaCAM). Emphasis on data products, pipeline, reduced data to users. Dedicated, compact instrument suite (imaging). Some optical echelle polarimetry.
■WHT, Wide field optical MOS, *GLAO for optical IFU, up to 17" FOV*, GLAO with NIR imaging. *NIR spectroscopy* (OSIRIS like but wider field, coarser scale, more modern), *Optical FP GHaFaS (visitor inst)*, 4' FOV, no tunable filter, SL mode.
■AAT, Wide Field optical MOS is world class (AAOmega), *IRIS2 NIR spectrograph, Echelle spetrograph*. AAOmega is most used in 2008A.
■WIYN, Optical imaging, wide field optical MOS. ODI will be state of the art wide field imager with image motion correction over 1 degree field. ODI should be heavily subscribed. *Seeing limited NIR imaging*.
■NOAO Blanco/Mayall 4m's, Many capabilities. Wide field optical and NIR imaging. Blanco has fixed complement of NIR imager, wide field optical imaging and MOS. When DECam arrives it will be heavily used in campaign mode.
■IRTF/UKIRT, Many NIR imaging and spectroscopic capabilities. UKIRT in major campaign mode (UKIDS). UKIRT may close within several years or be privatized. IRTF serves NASA planet community for 1/2 its time. Mostly NIR imaging, MIR imaging (visitor instruments), and *NIR spectroscopy*. Some AO work at NIR.
■ESO, Vista (wide field NIR imaging), 3.6m dedicated planet RV survey, NTT, *NIR imager/spectrograph*, optical spectroscopy, *3D-NTT* (visitor, similar to BTFI in SL mode)
■ARC, *Optical Echelle* (point source), NIR imager/FP (not yet operational?) , optical spectrograph, optical imager, *NIR spectrograph (TRIPLESPEC)*
■Lick 3m, *Optical echelle, NIR imaging including AO*, Optical LS spectrograph
■Calar Alto 3m, Optical spectrograph, *NIR imaging/spectrograph*, *Optical tunable filter* and MOS spectrograph, Optical imaging, *Optical SL IFU*
■Palomar 5m, *NIR spectrograph (TRIPLESPEC), NIR AO imaging*, Optical imaging/spectroscopy, limited optical MOS

There are some clear trends in the above information. Work horse NIR spectrographs are common as are moderate resolution LS optical spectrometers and basic seeing limited Optical imagers. Optical echelles are relatively common as well. Much of the work being done on our competitor facilities involves wide field imaging and optical spectroscopy and large dedicated

surveys.

Two facilities which are similar to SOAR in that they are consortia operated are WIYN and ARC. ARC has some similar capabilities, but its site may not be as good as SOAR for high angular resolution. WIYN is betting heavily on wide field optical imaging with ODI (orthogonal transfer 1 degree imager). This suggests (again) SOAR should focus on narrow fields and high angular resolution.

The WHT appears the most similar in offered capabilities to SOAR. Their GLAO system feeds both an optical IFU with capabilities similar to SIFS and a NIR imager. The latter will have excellent DIQ, but is smaller format than Spartan. Indeed Spartan could be a unique facility in that it has a large format and fine pixel scale. Its success would seem to depend on the SOAR site image quality and facility delivered image quality.

A recent paper by Trimble and Ceja (2007, AN **328**, 983) reviewed publications and citations for ground based optical/IR telescopes (among others). ***This is just a snapshot for the years 2001-2002 and citations following the next three years.*** But it is clear 4m class telescopes made their biggest impact in large surveys related to cosmology and planet searches. The AAT particularly stands out in this snapshot (2DF and large scale structure). Other hot topics which have a time critical component (e.g. GRBs) can produce widely cited papers. The RV work at Lick for planet discovery was another high impact project during this time frame.

The same paper tracked total citations and publications, and among SOAR's competitors (SOAR was not included because the time period was before operations began) AAT, WHT, CFHT, UKIRT, and NTT did the best (about 1000-2000 citations). The NOAO 4m's, the Lick 3m, IRTF, and ESO 3.6m were a bit less productive, but still very good (about 700 citations). WIYN, Calar Alto and Palomar were further down (300), followed by ARC (100).

For reference, WIYN and Palomar produced roughly 30 papers and 300 citations each in this time frame (i.e. papers published in a two year span and associated citations in the following three years).

New instrumentation can affect these numbers in any given period. The Lick planet searches and 2DF at AAT are good examples. The NOAO 4m instruments had been pretty stable across this period, while new very wide field imagers should produce increases in current rates (DECam and NEWFIRM). WIYN is putting a huge effort into a single instrument , ODI which is unique in its ability to deliver a 1 degree field with excellent image quality. WHT and NTT/3.6m have large user bases.

SOAR appears at first glance to have a large planned instrument suite and a somewhat smaller user base.

Science Strategy

How should SOAR look in two years time (near term vision) with respect to its instrument suite? The SAC believes that SOAR is on track to providing its community with an excellent

suite of capabilities in the next few years and offers the following specific recommendations:

- Goodman, Spartan, and SAM should be fully commissioned as soon as possible in all their modes. Full operations with these three instruments should be SOAR's top instrument priority right now.

- Plans to adapt the high resolution NIR spectrometer Phoenix, should be dropped. The SAC believes the instrument suite needs to more realistically reflect the level of support available. While Phoenix could do good science at SOAR, it is not a good match to the smaller aperture (compared to Gemini) and capabilities with a broader science appeal should be given priority.

- The Goodman imaging capability should eventually take over for SOI and SOI should be retired. Specific issues to be addressed are narrow band imaging capability and I-band imaging. The latter is difficult with the current detectors in Goodman due to fringing. A detector upgrade should be considered in order to add this capability to Goodman. The narrow filter science might be done as well with SAM and BTFI. SOAR is encouraged to investigate this possibility soon so that by the time SIFS and STELES are commissioned, SOI could be ready for retirement, leaving a complement of six instruments.

- SOAR should ensure that the telescope facility delivers the required performance for these instruments. The SAC recommends that SOAR complete or initiate three facility improvements as soon as possible. An ADC as proposed by UNC to be used for the Goodman and other instruments on the optical ISB should be built and deployed. Real time low order wavefront/aberration sensing should be implemented (astigmatism and auto focus). The tip-tilt capability on M3 should be enhanced. The current closed loop bandwidth is marginal and it is expected that Spartan and SAM will need improved performance from M3 in order to reach their full potential.

The SAC did not reach a specific consensus on how many instruments the observatory can and should operate at one time. The SAC was unanimous, however, in believing that eight (see above) was too many. Concentrating only on high angular resolution imaging and various modes of optical spectroscopy might lead to as few as four instruments. Satisfying broad community aspirations requires more, and the SAC currently foresees six facility instruments within two or three years (Spartan, SAM, Goodman, OSIRIS, SIFS, STELES).

The SAC discussed concentrating the instrument suite with a view to accessing certain capabilities through time trades with other facilities. The NOAO community has spoken recently through its ReSTAR process (http://www.noao.edu/system/restar) for a renewed emphasis on basic capabilities like optical moderate resolution spectroscopy. In the absence of new facilities, NOAO would be interested in trading time on other facilities to gain more access to the Goodman (for example through time trades for wide field imaging on the Mayall or Blanco 4m's). The survey above shows ample possibilities to gain access to NIR spectroscopy. In addition, NOAO plans, through ReSTAR to implement a basic NIR spectrometer on the Blanco 4m within a few years. This might provide a means to retire OSIRIS (or “replace” it if it

fails) and simplify operations. While there are multiple NIR spectroscopic capabilities on US 4m's (see above), OSIRIS is currently the only capability offered in the south. The US community will soon have access to Flamingos 2 on Gemini South. The SAC recognizes that this is not an ideal replacement since Gemini time will be highly competitive and it is not at all suitable for Brazil since their fraction of time on Gemini is much smaller than on SOAR.

Furthermore, the Brazilian community sees a NIR spectrograph (the role of which is currently played by OSIRIS) as part of a base or core set of instrument capabilities which they would like to have on SOAR. The SAC thus recommends only that time trades be pursued when appropriate and/or needed. The SAC recognizes that the partnership needs to work together to satisfy the desires of its diverse user communities which have differing sets of astronomical capabilities available to them.

The SAC sees the development of SAM and attendant capabilities as a a fruitful area to distinguish itself from other 4m's as well as a strategic investment in the future for the observatory (see below). As mentioned above, the SAC places a high priority on getting SAM running routinely, first with its dedicated imager, and then with SIFS and BTFI (as an RUI with potential to be a facility instrument).

Building and Operating Instruments

Within five years, SOAR's instrument suite should be mature and functioning very well. The observatory should be well versed in laser guide star operations and have reliable data flowing off all its instruments. Users should be comfortable reducing data from all the instruments due to well documented software and well calibrated instruments.

The SAC believes a combined approach (Elias model) to next generation instrument development might serve the observatory better than the individual approach where each partner attempts to develop new capabilities independently. Cost and schedule risks could be better managed by spreading work over the partnership. Such an approach would require accurate costing and schedules up front and would incur some added overhead due to the requirement of robust management and communication between instrument teams in widely separated locations.

Whichever model is used, the SAC believes that new instruments should be spaced in time appropriately to avoid over burdening the observatory with commissioning and support while providing new capabilities on a time scale rapid enough to keep the observatory relevant and at the forefront of astronomy. A several year gap (at a minimum) between introducing new instruments would allow users to fully embrace the current instruments and provide the stability needed to envision and carry out significant research programs. Restricted use instruments, allow for rapid response to new opportunities while minimizing the impact on operations.

The next generation of instruments/capability should be conceptually ready by about the time the last of the current suite (STELES?) is fully operational. The SAC has identified two candidate capabilities for consideration:

- A modern work horse NIR spectrograph which would replace OSIRIS. OSIRIS is an aging facility and will eventually need to be replaced. OSIRIS was down for maintenance and repairs for a significant time in semester 08A.

- Building on our GLAO experience from SAM, develop similar capabilities which would serve a broad range of instruments or capabilities.