Design choices for the Wide Field Optical Spectrograph on TMT

Feb 13, 2018 CASCA/ACURA TMT Advisory Committee (CATAC)

The Wide field optical Spectrograph (WFOS) represents a unique and critically important capability for the Thirty Meter Telescope (TMT). None of the other planned large telescopes will have an optical multi-object spectrograph (MOS) at first light, so there is an opportunity to have a huge impact despite the delays the project is facing. Multi-object spectroscopy in general is an important capability for Canadians, who broke much of the ground in this area with CFHT (e.g., the CFRS and CNOC surveys), and for whom GMOS remains the most subscribed instrument on Gemini. For these reasons, CATAC is paying close attention to the development of WFOS, in light of how it aligns with Canadian scientific interests.

As a first step, CATAC received a thorough presentation by the instrument Principal Investigator Kevin Bundy about the capabilities of the current WFOS designs, on Dec 19, 2017. We then reviewed the original Operational Concepts Definition Document (OCDD) for the HIA WFOS design (Sept 23, 2005) and for the subsequent MOBIE design (v1.7, Dec 5, 2008). These were considered together with the TMT Observatory Requirements Document (May 9, 2017). Some of the observations that came out of our subsequent discussions include:

- TMT has a top-level *goal* that WFOS be capable of benefiting from Ground Layer Adaptive Optics (GLAO). While GLAO did not feature prominently in the original HIA design, it moved to the forefront in the MOBIE design.
- The original field-of-view requirement was relaxed from >75 square arcminutes to 40 [REQ-1-ORD-3965], because of the technical challenges of MOBIE; this has since come down further to 25 square arcminutes in the latest MOBIE design.
- The decision not to proceed with a high resolution spectrometer (HROS) at first light drove MOBIE to try to recover some of that science by going to higher resolution than specified in the top-level requirements.
- Both designs are imaging spectrographs, as required [REQ-ORD-3905]. Both offered simultaneous wide wavelength coverage (a design goal), multiple resolutions [REQ-1-ORD-3980], and emphasized the need to reach Poisson-limited noise [REQ-1-ORD-3990, REQ-1-ORD-3992].

In general, the MOBIE requirements (section 2.3 in the OCDD) were not demonstrated to flow directly from the top-level requirements of the telescope. In particular, they included requirements that were either stated as goals (simultaneous wavelength coverage, integral field unit [IFU] and GLAO capability) or are not included at all (e.g., R=8000 resolution). While it is reasonable to expect top-level requirements to change over the extended development time of a big project like this, it is also important that the top-level requirements drive the instrument design, as described well in Simard & Crampton (2010).

Therefore, when considering the new designs before us (fiber-WFOS and slicer-WFOS), CATAC turned to the TMT Detailed Science Case 2015 (DSC). As points of comparison we also reviewed the Science Case for MOS on the European ELT (Jan 2015), as well as the capabilities of highly multiplexed spectrographs on 8-m class telescopes (Prime Focus Spectrograph on Subaru, and the proposed Maunakea Spectroscopic Explorer). We constructed an approximate mapping of science requirements to instrument capabilities, and drew the following conclusions:

- The TMT DSC does not, in general, contain enough detail to critically evaluate the feasibility under these two different instrument designs. In particular, the lack of source-density estimates and number of objects required to obtain sufficient statistics for the science goals were missing in many cases. This directly informs the field-of-view and multiplexing requirements that are relevant to the current downselect.
- A core strength of WFOS on TMT is very deep spectroscopy with little or no systematics. An excellent blue response down to the atmospheric cutoff would be a unique capability among planned facilities.
- Based on the available information, neither instrument design clearly stands out as superior to the other in terms of its ability to carry out the science in the DSC.
- A clear discriminator between design choices is the lack of imaging capability in fiber-WFOS. Imaging is a top-level requirement [REQ-ORD-3905]; however it is reasonable to ask whether or not this requirement is still valid. Some considerations include:
    - Will sufficiently deep imaging be available to the TMT partners from other telescopes to enable target selection?
    - Are there compelling science cases that rely on the optical imaging capability on its own that would not be otherwise feasible for the TMT partners?
    - Can target acquisition be sufficiently good without a pre-image? What are the corresponding requirements on the astrometry of input catalogues?
    - Does the absence of WFOS imaging affect other operational aspects of the TMT? For example, will WFOS imaging play a role in identifying guide asterisms for NFIRAOS, given that many of the guide stars will be faint dwarfs that may have significant proper motions?
- The IFU capability is also an important differentiator that features heavily in the DSC. More information is needed about how, or if, this could be done with slicer-WFOS.

In general, fiber-WFOS appears to be the more flexible instrument. It provides higher multiplexing, IFU capability, and a wider field of view. However, there are uncertainties about the following:

1. The lack of imaging, and its impact on target acquisition as well as imaging-only science cases.

2. The throughput in the blue. The top-level requirement [REQ-1-ORD-3985] is >30% throughput from 0.31 to 1.0 microns. Even though the mirror coatings currently only go down to 0.34 micron, it is easier to change the coating recipe than to change the instrument.
3. The precision of sky subtraction.
4. Relative flux calibration precision and accuracy.

To help inform the decision, it would be useful for several of the key science cases to develop quantitative specifications for the above. In particular, specific input addressing the capabilities of the two design choices as they relate to science cases in the DSC would be important input to the decision of which design is optimal. We also expect it would be instructive to populate a science flowdown matrix as described in Simard & Crampton (2010). CATAC stands ready to help with this effort.