Maunakea Spectroscopic Explorer

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The Maunakea Spectroscopic Explorer (MSE) is envisioned to be a dedicated wide field 11.25m aperture spectroscopic facility that will lead the world in multi-object spectroscopy, with its unique capability to study 4,000+ astronomical objects simultaneously across a 1.5 square-degree focal plane. It is planned to have optical to near-infrared (NIR) spectrographs covering resolutions R2,500 - R20,000+. The current Design Reference (DR) implementation of the telescope will see it replace the operational 4m Canada France Hawaii Telescope (CFHT) on the premier observational site in the world: the peak of Maunakea (~4,200m) in Hawaii. This complement of collecting area, field-of-view, multiplexing and site will mean MSE is capable of producing orders-of-magnitude more high-quality optical-NIR spectra (vital for a huge range of scientific interests) per unit time than currently operating facilities. This will allow massive scale survey science covering galactic archaeology, local and distant Universe, exoplanets and cosmology.

MSE started life as a grassroots initiative in the Canadian community during a national planning process in 2011. It rapidly gained attention as a true next-generation survey facility that will build on the type of science already conducted on the Anglo Australian Telescope (AAT, with 2dF and AAOmega/Hermes) and the Dark Energy Spectroscopic Instrument (DESI on Mayall), and soon to start on the 4m Multi-Object Spectroscopic Telescope (4MOST) and the Prime Focus Spectrograph (PFS on Subaru). A facility such as MSE has been highlighted as the highest priority for the next generation of major European Southern Observatory facilities (a recent three-year design white paper regarding such a facility was recently submitted by Richard Ellis), and the project has seen significant international effort and engagement to date. The major partners currently are Australia, Canada, France, Hawaii, China, India, and various USA institutions (Texas A&M, NOAO). Most recently, a consortium of UK institutes joined the project as observers. Given the present phase of the MSE project (it just concluded the Concept Design Phase and is moving into the Preliminary Design Phase) there are notable efforts across the world to ensure MSE is being highly ranked in respective long term planning processes. The Australian Mid-Term Review is seen as critical to the MSE project, and the MSE project office has been assisting and supporting where possible.

MSE has been planned in various guises (previously ngCFHT) for eight years already, and Australian scientists have been leading major components of this planning process for seven of those years. Australia was also recently selected to provide the echidna style 4,000 fibre positioner *Sphinx* (AAO) for MSE. During this time hundreds of scientists (and dozens of Australians) have submitted hundreds of expressions-of-interest and white papers outlining a huge diversity of science possible with such a paradigm shifting survey facility. The most recent iteration of this process occurred in the early part of 2019, where fresh ideas and engagement were sought. Australia provided four chapter leads in the updated version of the Detailed Science Case (DSC), and currently plays a leading role in three scientific working groups. This white paper process led to major benchmark surveys being outlined, many of which already align with the science priorities of the last Australian decadal plan. This includes surveys to uncover the nature of dark matter and exotic aspects of the expansion history of the Universe (priority 2) and major extra-galactic surveys probing cosmic noon in the star formation history of the Universe (priority 3).

MSE in its current form aligns excellently with all wide area next-generation survey facilities, including in particular the Large Synoptic Survey Telescope (LSST, considered a high priority for Australia in this mid-term review), the Square Kilometre Array (SKA), Euclid and WFIRST. MSE, whilst a “Northern” facility is located very close to the equator at a latitude of +19 degrees. From this equatorial location, it can see over half of the southern sky, ensuring good access to LSST and SKA footprints. As such, there are major suggested ancillary and complementary MSE surveys that will lever much additional science from planned LSST and SKA surveys, and these links are being strengthened as the project matures and MSE moves towards producing its Design Reference Surveys (DRS).

In broad terms, MSE will cost US$424m to build (2018 economics, base cost US$328m and risk cost of US$86m). Operational costs per year are anticipated to be ~6% of construction costs, although there could be some additional saving caused by the dedicated instrument suite and robotic observations. The methods of engagement with MSE are

still under active discussion and costs vary by the period of expected commitment given the ~$60m a year running costs expected. They will range from:

(a) ~1% share current/minimal/in-kind: LIEF-style/scope ~$0.6m/year level maximum contribution, maintaining a foot in the door but leading to decreasing role in leadership/governance as project costs ramp up;

(b) ~3% modest contribution: of order a $9m contribution over five years, fully funding the Sphinx positioner (for example), allowing us to position for a greater governance/leadership role as the project transitions from Preliminary Design Phase to Final Design (NCRIS scale contribution);

(c) ~5% significant contribution share ~$45m, which could be spread over the coming ten years, leading to a roughly $4-5m contribution per year, some of which would be spent onshore, more offshore.

The options above are increasingly ambitious from an Australian perspective, but the scientific (through survey leadership) and industry (through construction of Sphinx and other hardware) rewards are increasingly significant. In the current partner model there will be restrictions on the types of surveys that can be executed within different tiers of the partner model, so the current extragalactic survey (largely planned in Australia) would require much more than a subsistence level of minimal engagement for continued Australian leadership. It is clear that a high level of engagement with MSE will require highly significant sums of money- on a par with Australian funding of the Giant Magellan Telescope (GMT), the SKA, and the European Southern Observatory (ESO). For context, Australia currently makes up 10% of the MSE science team and 25% of the working group leads. Whilst this level of involvement is currently encouraged by the MSE project, it will clearly require commensurate financial support longer term.

Given the strong desire for ESO to operate something close to an MSE-like facility post its Extremely Large Telescope (ELT) construction commitments, there might be a natural synergy to be made between the interested non-ESO partner countries (Australia, Canada, China, India and the USA are not full ESO members) and ESO, where various loose and tight partnership models are plausible. Given the scale of money involved, there is some assumption that there will at most be two such facilities built in the next generation (one in each hemisphere), but the ESO design (a very similar 11m optical wide-field facility for the Southern hemisphere) is currently mothballed. Given the timescales involved and the momentum behind MSE, it is likely to be the first, and possibly only, such facility in the world. Australia cannot assume such a facility will certainly be built by ESO, so for the time being it is prudent to stay engaged with the MSE project in parallel with any commitment to ESO. Longer term, it is also plausible that our engagement in MSE could play a role in longer term Australian engagement in ESO (assuming all parties remain suitably motivated).

The key risk, beyond the usual political and funding uncertainties, is the long-term future of the Maunakea observatories. There ongoing protests against the construction of the Thirty Metre Telescope (TMT) at a new site on Maunakea, and these protests have affected the operations of all telescopes on the mountain. There is also some uncertainty over the new Master Lease for the site, since the current one expires in 2033, and in principle all telescopes would need to be removed by this date if a new agreement is not signed by then. Certainly no project on the scale of MSE could occur on Maunakea without a new Master Lease, and CFHT/MSE have made clear no construction will begin until after a new Master Lease is signed. The renewal process is ongoing; it was originally expected to be complete by around 2021-2022, but the current situation in Hawaii could reasonably be expected to shift this completion date. CFHT have much better historic relationships with the Big Island community, and are at the forefront of engagement activities with the whole community. The CFHT consortium have a 40 year legacy on Hawaii Island, and the design of MSE has deliberately not exceeded the current footprint of CFHT, i.e. it is discussed more in terms of being a major upgrade to an operating facility, not a new facility breaking new ground (like TMT).

In summary MSE is an exciting international project that Australia is already deeply embedded in over a significant period of time. Scientifically, Australia is leading three of the main scientific threads and will likely lead one of the two Design Reference Surveys (covering surveys for the first two years of MSE operations). There are many routes to longer term engagement that will require different scales of commitment, and it is important that MSE is appropriately prioritised to ensure we achieve a significant return on our community's collective investment to date.