THE MAUNAKEA SPECTROSCOPIC EXPLORER STATUS AND SYSTEM OVERVIEW

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Abstract. The Maunakea Spectroscopic Explorer (MSE) project explores the possibility of upgrading the existing CFHT telescope and collaboration to turn it into the most powerful spectroscopic facility available in the years 2020s. Its 10 meter aperture and its 1.5 hexagonal field of view will allow both large and deep surveys, as complements to current (Gaia, eRosita, LOFAR) and future imaging (Euclid, WFIRST, SKA, LSST) surveys, but also to provide tentative targets to the TMT or the E-ELT. In perfect agreement with INSU's 2015-2020 prospective, besides being well represented in MSE's science team (23/105 members), France is also a major contributor to the Conceptual Design studies with CRAL developing a concept for the low and moderate spectrographs, DT INSU for the prime focus environment and GEPI for systems engineering.

Keywords: astronomical observatories, maunakea, multiobject spectroscopy, survey, optical fibres, large telescope, CFHT

1 Introduction

Although always very competitive in terms of the number of scientific publications, the future of the 3.6 m Canada-France-Hawaii telescope, operational since 1979, has been discussed as early as 1996, when the Scientific Advisory Council of CFHT set up a working group to envisage possible evolution of the telescope and the observatory. This led to a proposal to replace the telescope by another with a 12-16 m aperture within the same dome (Grundmann 1997). More recently Canada set up a team for addressing the same subject as part of the LRP2010. Their convincing ngCFHT (new generation CFHT) design and case led the CFHT corporation to kick-off the MSE project in 2014.

MSE targets being the most efficient spectroscopic facility available in the years 2020s. Efficiency is to be understood as capable of conducting large scale surveys in terms of area on the sky, completeness down to magnitude 24 and resolution ranging from 3000 to 40000. As a comparison, MSE will produce 7 million spectra every year and yield as much science as the Sloan Digital Sky Survey every 4 months.

With the purpose of contributing spectroscopic observations to published imaging data from Gaia, eRosita and LOFAR, MSE aims at being on the sky by 2025. To this end, as well as for cost reasons, MSE is a risk-adverse, success-driven project aiming at building on existing technology and know-how. A clear example is the decision to make its primary mirror a segmented one, building on W. M. Keck's experience and available feedback thanks to geographic proximity, with segments whose dimensions would allow TMT partners to also fabricate or polish segments for MSE.

Figure 1 illustrates the transformation of the CFHT into MSE. The key element is to reuse the concrete pier on which the current telescope is anchored to support the new one. Comparison of their respective masses and the capabilities of the pier show that this is possible. Another key element is the dome, which expanded by 10% only will host the telescope and its prime focus instrument. The combination of these two facts mean that MSE will not need to go through the complex paper work required to obtain a building permit – the element which has been blocking the construction of TMT for the last 2 years.

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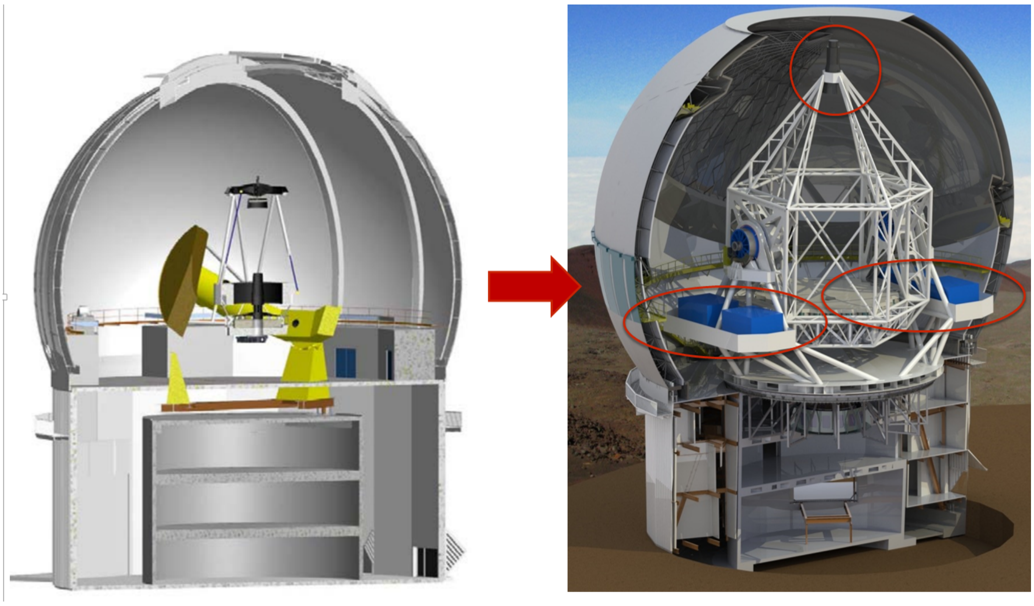

Fig. 1. Artist's conception of the transition between the existing CFHT (**Left**) and MSE (**Right**).

2 Partnership

It 10 meter aperture and its 1.5 hexagonal field of view will allow both large and deep surveys, as complements to current (Gaia, eRosita, LOFAR) and future imaging (Euclid, WFIRST, SKA, LSST) surveys, but also to provide tentative targets to the TMT or the E-ELT. In perfect agreement with INSU's 2015-2020 prospective, besides being well represented in MSE's science team (23/105 members), France is also a major contributor to the Conceptual Design studies with CRAL developing a concept for the low and moderate spectrographs, DT INSU for the prime focus environment and GEPI for systems engineering.

There are at least two reasons for expanding the existing partnership for MSE. One is to gather partners to benefit from their expertise in the design, another is to gather forces, either directly with in-kind contributions, or via funding for a project with a cost cap of $300,000 2018 US dollars. Technical collaboration (1) with Australia for the fiber positioners, (2) with China for the eventual polishing of MSE's mirror segments in Nanjing and the design of the high resolution spectrograph, (3) with Spain for a proposal on the fiber positioner technology, (4) and India's interest in mirror segment geometry has quite naturally resulted in putting them in the loop. "In the loop" refers to having them join the Manangement Group, which is the decision-making committee for MSE and which is expected to eventually turn into MSE's board of directors.

The composition of the Management Group (Tab. 1) reflects the amount of effort each partner invests in the project. Activities funded by the project lead to reduced representation in the Management Group as opposed to volunteered ones. Thanks to its investing significant work force in the project, France earns 2 votes.

Australia	Andrew Hopkins
Canada	Greg Fahlman & Pat Hall
China	Suijian Xue& Xuefei Gong
France	Guy Perrin & Jean Gabriel Cuby (chair)
India	G.C. Anupama
Spain	Eva Villaver
UHawaii	Bob McLaren & Len Cowie

Table 1. Composition of the Management Group in 2017 (in alphabetical order, members are appointed for two years).

Beyond the financial and technical activities, MSE is also working on making the project a success with the local community. For years the observatories have had outreach activities, but the group of inhabitants blocking the construction of the TMT has shown that it was not enough or that the community did not feel they owned the observatories or that they in turn served them well. Since 2015, considerable efforts have been devoted to change the way the observatories, grouped as the "MaunaKea Observatories", are perceived and work together to deliver more to the local community.

3 Baseline design

MSE has an alt-azimuthal mount which is very advantageous in terms of the overall mass compared the CFHT's equatorial mount and thereby makes the substitution possible. As represented in Fig. 1, the baseline telescope is of yoke type. It features a single focus located at the prime focus, similar to MegaPrime in intent, which is to offer a wide field of view and remain accessible. Being dedicated to spectroscopic surveys, MSE operates with low, medium and high resolution spectrographs, possibly simultaneously. These spectrographs are built in the project in the sense that MSE's requirements optimize the whole range of the observatory's constituents, from the building, the telescope all the way to the spectrographs' properties.

The French contribution in terms of design focuses on systems engineering, the Top End Assembly (TEA) and the Low and Moderate Resolution spectrographs (LMR) which are the subject of the following sections.

3.1 Systems engineering

All of MSE's WBS elements have or will soon be reviewed in order for the project to move from the concept design phase to the preliminary design phase. Internal modifications to the building, software and system design are to be found among the last.The system design review includes examining the requirement flow-down from the Science Requirements Document (SRD) to the Observatory Architecture Document (OAD), the Operations Concept Document (OCD) down to the Observatory Requirements Document (ORD). This organization is similar to the structure adopted by TMT. The intent is to rationalize the flow-down so that the OAD and OCD elaborate on the SRD and the ORD is built to serve as the unique reference for all subsystems. France is an active part of this requirement engineering process with Shan Mignot contributing to the systems budgets.

3.2 Top End Assembly

The DT INSU has been working on TEA since 2016[*]. They have been developing a mechanical environment supporting the prime focus: a barrel to maintain the relative alignment of the optics, a hexapod to align the optics as a whole versus the telescope, and a rotator in charge of compensating the field rotation[†].

They have chosen to subcontract the rotator and the hexapod which need not be specialized from MSE and have focused on the design of the wide-field corrector and atmospheric dispersion corrector barrel. They propose a modular approach with the use of spacers giving great flexibility on where to place the optics which is in line for the tolerance analysis for the optical system. An identified risk in this approach, however, is accumulating the position errors of modules resulting in failing to maintain the optics with the required absolute precision.

3.3 Low and Moderate Resolution spectrographs

Building on their experience with MUSE on the VLT and the low resolution spectrographs for 4MOST, CRAL is involved in the development of MSE's LMR. The LMR is summarized in Table 2. One of the very challenging aspects of the LMR design is the need to observe two wavelength ranges alternatively (either J or H). Indeed the cryogenics constraints resulting from the addition of the H band can prove critical as the mechanism used to operate the LMR in one mode or the other. This comes in addition to running the LMR in low or moderate resolution. A original optical design was proposed for the LMR CoDR. The panel recommended assessing the risks through a sensitivity analysis.

4 Conclusions

The French involvement in MSE, as part of the science or as part of the engineering teams is significant. The TEA and LMR teams are currently taking into account the recommendations made by the review panels in order to complete the Conceptual Design Phase. These activities are in perfect agreement with INSU's 2015-2020 prospective.

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[*]Together with a local optics engineer (David Horville from GEPI) to derive mechanical requirements from the optical design.
[†]Which is an unavoidable result of the alt-azimuthal mount.

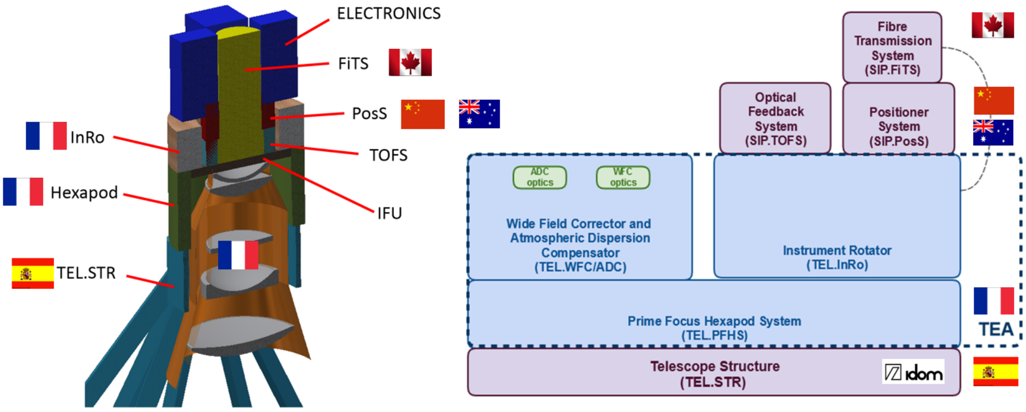

Fig. 2. Cut through TEA (**Left**) indicating its different components, compared to its functional block diagram (**Right**), with the indication of the ownership of the WBS elements to illustrate that TEA is at a critical location by both the number and the owners of its interfaces.

Modes	Low		Moderate
Wavelenth range	0.36 - 0.95 m	J, H bands	0.36 - 0.95 m
Spectral resolution $R = \lambda_c/d\lambda$	2500 (3000)	3000 (5000)	6000
Multiplexing		> 3200	
Spectral windows	Full		Half
Sensitivity	m=24@SNR=2		m=23.5 @ SNR=2
Velocity precision	20km/s@SNR=5		9 km/s @ SNR=5
Spectrophotometic		accuracy < 3 (relative)	

Table 2. Requirements on the LMR (from the SRD).

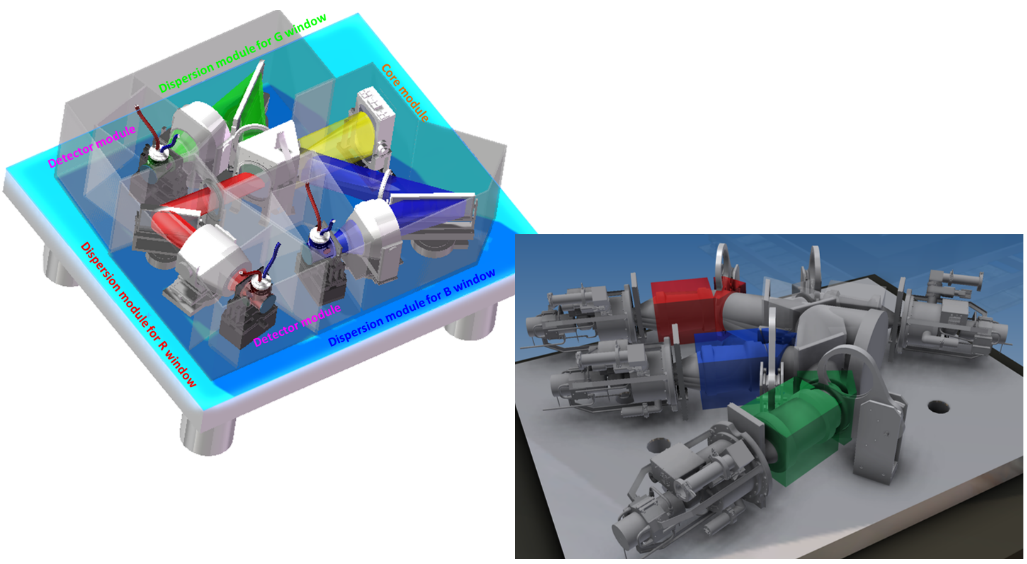

Fig. 3. Left Optical design of the LMR, **Right** corresponding mechanical design.

The French involvement in the next phase is pending on INSU's directives to pursue the effort or stop. In the long term such a decision implies having France leaving the CFHT corporation and losing access to a privileged observing site. INSU's decision partly depends on the cost of the project and its ability to make the funding effort minimum by accreting more partners and with averaging the expenses over the years

Whatever may INSU's decision be, MSE ,as it is, is an exciting project both scientifically and technically.

References