Maunakea Spectroscopic Explorer after the National Strategic Planning Reviews

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ABSTRACT

The Maunakea Spectroscopic Explorer partners' national strategic planning reports were released in late 2021, including the US Astro2020 findings and recommendations. This paper is a two-part summary of the project's response to the reports' recommendations. The first part incorporates additional considerations due to the State of Hawai'i House Bill 2024 and its new Mauna Kea Stewardship and Oversight Authority, and their effects on the Maunakea Observatories and MSE, specifically. The second part summarizes the national strategic planning recommendations specific to MSE and states our plan to progress MSE as we prepare to enter the next project phase.

The stated plan in the second part of this paper describes our programmatic planning within the partnership for public outreach, technology development, and risk mitigation in response to the national strategic planning recommendations including community-based engagement related to the renewal of the Canada, France and Hawai'i Telescope (CFHT) site lease under the new authority. Since the Maunakea Master Lease renewal process is replaced by separate negotiations for individual observatory site leases, the paper also highlights our approach to secure continuous access to Maunakea for MSE.

Keywords: spectroscopic facility, Maunakea, authority, lease, wavelength splitter, pupil slicer, Pathfinder, Community Astronomy model

1. INTRODUCTION

Maunakea Spectroscopic Explorer (MSE) is the first planned project among the future generation of massively multiplexed spectroscopic facilities. MSE is designed to enable transformative science, being completely dedicated to large-scale multi-object spectroscopic surveys, each studying thousands to millions of astrophysical objects. At a minimum, MSE will use an 11.25 m aperture telescope to feed 4,332 fibers over a wide 1.52 square degree field of view. It will have the capabilities to observe at a range of spectral resolutions, from R~3,000 to R~40,000, with all spectral resolutions available at all times across the entire field. Alternate facility architectures are under evaluation with insight from participants' national strategic planning priorities along with technical feasibility. Engineering development is supported by a culturally and geographically diverse design team that is centrally coordinated and managed by the Project Office[1]. We are cognizant that the decisions we make today are intertwined with the future of Maunakea and its cherished summit. The MSE Project deeply respects its cultural importance and storied past.

In our 2020 paper[2], we described the challenges and opportunities for Maunakea Observatories (MKO) regarding the Master Lease renewal to recast the future astronomy in Hawai'i. As a long-standing member of the local community, CFHT/MSE led the efforts to promote astronomy interests and broaden education and economic opportunities in Hawai'i. However, the Master Lease renewal process is now replaced by individual observatory site lease negotiations with a new Mauna Kea Stewardship and Oversight Authority introduced by the State of Hawai'i House Bill 2024. We will discuss the implications on MKO and the opportunities for CFHT to implement the national strategic planning recommended community-based astronomy model for MSE alongside with MKO in this paper.

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After a long COVID delay, the funding priorities and timelines of our project participants are clarified in their national strategic planning reports. In response, we have re-planned and adopted an alternate development path that will allow us to explore and expand MSE's science capabilities, reduce spectrograph optical design challenges and fabrication risks, and fast track technology development for MSE with an end-to-end Pathfinder demonstrator as the next science instrument for CFHT with shared community access. We will describe our plan to continue MSE development programmatically in this paper. Moreover, scientific and technical progresses of MSE are reported in separate papers[3,4] of this SPIE conference.

2. CHANGES TO THE ASTRONOMY LANDSCAPE IN HAWAI'I

Professional astronomical research in Hawai'i began in 1968 when the University of Hawai'i (UH) obtained a 65-year lease to operate the Maunakea Science Reserve and establish Hawai'i astronomy as it is known worldwide today. The development of astronomical facilities began shortly after and continued through the early 2000s. Some community members, particularly in the Native Hawaiian community, felt the development ignored their expressed concerns. The issues came to a head in 1998 when an independent audit was critical of UH's management of Maunakea. In response, UH developed the Maunakea Master Plan and the Comprehensive Management Plan, created the Office of Maunakea Management (OMKM), Maunakea Rangers Program, and more to mitigate the community concerns.

Figure 1. Maunakea Acces Road on August 29, 2019

Protests related to the construction of the Thirty Meter Telescope (TMT) in 2015 and 2019 changed the landscape surrounding astronomy in Hawai'i. The 2019 protests ended in March 2020 when the start of the COVID-19 pandemic led to the majority of the remaining kia'i† departing the base of the Maunakea Access Road,

Figure 1. Towards the end of 2020, the Hawai'i State Department of Land and Natural Resources (DLNR) commissioned a local consulting firm, Ku'iwalu, to perform an independent evaluation of the University of Hawai'i's implementation of the Comprehensive Management Plan (CMP). The evaluation found the public assessment of UH management and implementation of the CMP varied sharply based on whether the respondents favored or opposed telescope development on Maunakea. Even so, the evaluation found OMKM made progress on implementing the CMP and Maunakea Science Reserve is among the best managed sites in the State. The evaluation also found OMKM did not effectively implement the CMP in three areas: timely adoption of the Administration Rules, lack of Native Hawaiian consultation on cultural and resources issues, and lack of engagement with the Native Hawaiian community on education and outreach efforts including decision making processes related to Maunakea Management.

† Hawaiian word for guardian or protector, the name adopted by the TMT protestors.

Building off the Ku'iwalu evaluation, the Hawai'i State House of Representatives passed House Resolution 33 in 2021. The resolution established the Mauna Kea Working Group[‡] (MKWG), convened to "develop recommendations, building on the findings of the independent evaluation of the implementation Maunakea Comprehensive Management Plan, for a new governance and management structure for Mauna Kea that collaboratively engages with all stakeholders, particularly the Native Hawaiian community".

MKWG was formed and began meeting in July 2021. Rich Matsuda, then the Chief of Operations at the W. M. Keck Observatory was nominated by the Maunakea Observatories to represent them on MKWG. The Working Group produced their final report entitled, "He Lā Hou Kēia ma Mauna a Wākea: A New Day on Mauna a Wākea," on January 25, 2022.

Drawing from the MKWG's report, the Hawai'i State House of Representatives submitted House Bill 2024 (HB2024) in the legislature during the 2022 session. It underwent one revision in the House, two revisions in the Senate, and then the differences in the house and senate versions were reconciled by a conference committee. The final version of the bill HB2024 HB1 SD2 CD1[5] was passed by the House and Senate on May 3, 2022 and was signed in to law by the Governor on July 7, 2022.

HB2024 removes UH from the role of Maunakea land manager establishing the Maunakea Stewardship and Oversight Authority (MKSOA) with the authority to grant leases. MKSOA's management principle is rooted in mutual stewardship – a concept placing the stewardship of Maunakea as the highest priority above any particular human use. Alongside the mutual stewardship principle, HB2024 also declares astronomy a policy of the state. MKSOA will be overseen by an eleven-voting member board appointed by the governor and approved by the legislature. The board members include:

- The chair of Hawai'i State Board of Land and Natural Resources
- Hawai'i County Mayor (or delegate)
- University of Hawai'i Board of Regents chair (or delegate)
- Land resources expert
- Education expert
- Business/finance expert
- Maunakea Observatories representative
- Lineal descendant of Maunakea cultural practitioner
- Recognized cultural practitioner
- House appointed member
- Senate appointed member
- University of Hawai'i at Hilo Chancellor (non-voting member)

In a statement regarding the passage of HB2024, the University of Hawai'i stated they are "committed to working collaboratively with the new authority, created by the legislation, to ensure a smooth transition of all stewardship responsibilities. An internal analysis is currently underway to determine how to best transfer UH's complex long-term obligations to the new management entity including leases, easements, subleases, permits, etc."

CFHT's interim director, Andy Sheinis issued this statement regarding the bill and its signing: "The Canada-France-Hawai'i Telescope thanks the Hawai'i State Legislature, the Mauna Kea Working Group, and the many passionate community members for their hard work and sincere effort to identify structure for the future of Maunakea governance where astronomy can thrive alongside the other interests of our local community here on Hawai'i Island. We are grateful to the University of Hawai'i for their long and continued partnership with our observatory, and for the tremendous work done every day by the men and women of the UH Center for Maunakea Stewardship." and "CFHT is encouraged that the final

[‡] The spelling of place names in 'ōlelo Hawai'i can vary island to island. Maunakea spelled as one word is the preferred spelling by the University of Hawai'i at Hilo Ka Haka 'Ula O Ke'elikōlani College of Hawaiian Language. Collectively the Maunakea Observatories use the one-word Hawai'i Island spelling unless Maunakea is spelled as two words in an official name such as "Mauna Kea Working Group".

version of House Bill 2024 codifies astronomy as a policy of the state of Hawai‘i. Our observatory shares the commitment by the University of Hawai‘i and the other Maunakea Observatories to support the new Mauna Kea Stewardship and Oversight Authority as it is established, and we look forward to working collaboratively with the authority into the future “

Management of Maunakea will transition from UH to the MKSOA over a five-year period beginning on July 1, 2023. HB2024 calls for a moratorium on new leases during the transition and the existing observatories’ leases will remain in effect until they expire in 2033.

3. IMPLICATIONS OF HOUSE BILL 2024 ON HAWAI'I ASTRONOMY

To understand the potential impacts of HB2024 on the Maunakea Observatories in general and the Canada-France-Hawai'i/Maunakea Spectroscopic Explorer (CFHT/MSE) specifically, it is critical to understand the existing lease situation. Under the current Master Lease, UH leases the Maunakea Science Reserve from the State of Hawai'i. The observatories sublease their parcel from UH. As leaseholder, UH operates the Center for Maunakea Stewardship to oversee the sustainable management and stewardship of Maunakea and provides the technology, operations, and auxiliary infrastructure such as internet, communication, weather center, rangers, astronomer residence, food services, mid-level office space, gas station, roadwork and road maintenance, etc. Determining by who and how those infrastructure issues are managed under the new MKSOA is a critical task during the transition.

Although HB2024 establishes MKSOA, it does not determine the details of the authority beyond the board's membership, transition timeline, and ability to hire staff. Therefore, details of the day-to-day management of Maunakea under MKSOA will be determined over the coming years. Over the ensuing months, a process to submit for consideration names for the board positions will be determined by Governor Ige and the Hawai'i State Legislature. The inaugural MKSOA board members are pivotal appointments for the success of the authority.

HB2024 provides both opportunities and challenges for us. As a state policy, HB2024 prioritizes the reuse of astronomy sites over new development as in the case of MSE reusing the existing CFHT site. We will work collaboratively with MKSOA to co-develop key aspects of a community *kuleana* package. *Kuleana* is the Hawaiian word describing a sense of responsibility. It is MSE's *kuleana* to care for the communities to which it belongs. Our goal is to establish MSE to be the model community-based site redevelopment project for Hawai'i and worldwide.

While HB2024 places a moratorium on new leases during the upcoming five-year transition period, the combined effort of community-guided facility design working in tandem with engineering development will optimize our potential on CFHT's site lease renewal for MSE and begin construction at the end of this decade. The success of MSE is critically linked to the success of MKSOA. Therefore, collaborative engagement with the new authority is our priority.

4. IMPLICATIONS OF NATIONAL STRATEGIC PLANNING RECOMMENDATIONS ON MSE

After an extended COVID disruption, finally we learned the findings and recommendations from our project participates' national long-term strategic planning processes. Their recommendations are summarized below. However, the Snowmass 2021[§] strategic planning process for the US particle physics community is still under review. Members of the Science Team have submitted letters of interest in the areas of dark matter and dark energy research, and facility development in support of MSE to the Snowmass panel.

Australia's *Mid Term Review of the 2016–2025 Decadal Plan*[6] declares multiplexed spectroscopic capability on a very large telescope is of national importance but the optimum path between MSE and similar future ESO facility is unclear.

- *"One of Australia's traditional strengths has been large-scale spectroscopic surveys. Australian engagement with a multiplexed spectroscopic capability on a very large telescope is important to build on this strength, but the optimum path remains unclear. For Australia to continue direct engagement with the Maunakea Spectroscopic Explorer (MSE), more funds would need to be sought."*

France's *Prospective Astronomie-Astrophysique 2020-2025*[7] states the MSE project and access to the CFHT site are long-term national priorities

- *"The MSE project, which is one of the priorities of the PNCG community, will allow medium and long term conduct of large spectroscopic surveys to the study of stellar populations and cosmology…"*

[§] Snowmass is a multi-year strategic planning process for setting priorities in US particle physics research for the coming decade.

- *"Access to a large telescope outside ESO on the best site in the Northern hemisphere is a major strategic priority, via an extension of the operation of the CFHT and its instruments or a potential evolution towards MSE."*

Canada's *Astronomy Long Range Plan*[8] (LRP2020) commits to MSE as the future of CFHT by stating "the development, design, and construction of the Maunakea Spectroscopic Explorer (MSE) at the current CFHT site on Maunakea" is key to playing "a leading and substantive role in a next-generation widefield spectroscopic survey facility."

- *Recommended 20% participation level at $110MM for construction and $7MM annually for operations.*

US *Decadal Survey on Astronomy and Astrophysics 2020*[9] (Astro2020) ranks a highly multiplexed spectroscopic facility with capability for time domain follow-up as one of NSF's top strategic priorities among the mid-scale programs.

- *"In the near term, investments that provide public access to some combination of SDSS-V, DESI, and the Subaru Prime Focus Spectrograph (PFS), or similar surveys, would help to advance science this decade with relatively modest funding, and later in the decade a major (MSRI-2 scale) investment could be made in a larger, dedicated facility."*
- *"In all cases, the United States could envision playing a significant role in these projects through a MSRI-2-level investment, which could provide up to about 20 percent of the cost of a project like MSE, SpecTel, or up to about 50 percent of MegaMapper, perhaps split with DOE."*

These recommendations confirm MSE is well aligned with the astronomy development priorities of France, Canada, and the US. We are working to realize MSE over the next decade, following the national strategic planning reports' recommendations.

Since modern astronomy facilities are located at remoted locations that are isolated from population centers, the Canadian and US recommendations[8,9] also require engagement with the local and indigenous communities to gain their support in a mutually beneficial partnership and consent through a respectful stewardship of their traditional territories.

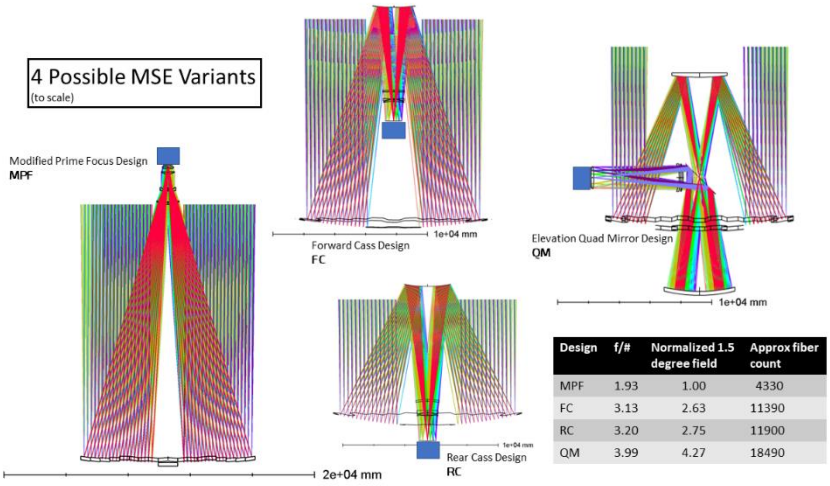
- *"Canadian astronomical community (e.g., ACURA, CASCA and NRC-HAA) work together with Indigenous representatives and other relevant communities to develop and adopt a set of comprehensive guiding principles for the locations of astronomy facilities and associated infrastructure in which Canada participates. These principles should be centred on consent from the Indigenous Peoples and traditional title holders who would be affected by any astronomy project."*
- *"The astronomy community should, through the American Astronomical Society in partnership with other major professional societies (e.g., American Physical Society, American Geophysical Union, International Astronomical Union), work with experts from other experienced disciplines (such as archaeology and social sciences) and representatives from local communities to define a Community Astronomy model of engagement that advances scientific research while respecting, empowering and benefiting local communities."*

This is the new paradigm of astronomy development in Hawai'i that ensures continuation of astronomy on Maunakea is grounded in community consent. Given MSE is the next major project under consideration for redevelopment, we are timed perfectly to enter a collaborative project planning process with the newly established Mauna Kea Stewardship and Oversight Authority (MKSOA). Since MKSOA incorporates extensive local and indigenous community representation and operates under the principle of mutual stewardship, this is the ideal alliance for we to establish the Community Astronomy model expected by the national strategic planning processes.

5. MAUNAKEA SPECTROSCOPIC EXPLORER DEVELOPMENT

A fundamental requirement set by our Management Group[**] for MSE to move forward to construction phase is renewing CFHT's land authorization with a new site lease. Transitioning to the new MKSOA management authority will naturally extend the originally project schedule intended. The expanded timeline provides opportunities to explore[††] broadening MSE's science capabilities, notably through examining alternate telescope concepts and spectrograph pre-optic designs, to enable potentially thousands of additional fibers thus boosting substantially the degree of multiplexing and survey speed.

A system-level trade study is planned to understand the viability of three alternate telescope concepts: two with a two-mirror telescope optical designs and one with a quad-mirror telescope optical design[10], Figure 2. Compared to the current single-mirror prime focus telescope baseline, the degree of multiplexing is increased by a factor of ~2.5 for the two-mirror telescopes and a factor of ~4 for the quad-mirror telescope. The trade study will assess the technical practicality on retrofitting the CFHT summit infrastructure to support the increase in telescope structural mass and the operational ability to install, access, service, and transport the telescope optics to the recoating facility safety and efficiently as affected by the increase in complexity of the telescope structure and in the quantity and size of telescope optics, including the wide field corrector and atmospheric dispersion corrector. In addition, the trade study will compare programmatic parameters such as overall cost, project schedule, and risks against increase in science return.



Design	f/#	Normalized 1.5 degree field	Approx fiber count
MPF	1.93	1.00	4330
FC	3.13	2.63	11390
RC	3.20	2.75	11900
QM	3.99	4.27	18490

Figure 2 Alternate telescope concepts – Modified Prime Focus (left) is the baseline design with modified wide field corrector that eliminates optical ghost, Forward and Rear Cass Designs (middle), FC and RC, respectively, are for the two-mirror telescope concepts, and Elevation Quad Mirror Design (right) is for the quad-mirror telescope concept.

Moreover, we believe an innovative pre-optics design will simplify the spectrograph inputs into a single wavelength band, such as blue, green, red, J, or H, individually[12], at reduced the pupil size representing smaller telescope aperture[13]. Narrower wavelength band and smaller entrance pupil will ease spectrograph optical design, decrease the technical risks of optics, and modularize the instrument configuration resulting in a spectrograph system that is geometrically compact, space efficient, and compatible with the high degree of multiplexing required cost effectively. We will develop a wavelength splitter and pupil slicer concept in-house and augment this effort with a National Science Foundation (NSF) Advanced Technologies and Instrumentation (ATI) proposal for prototype testing. If proven, wide field multi-object spectrographs of the next generation of large telescopes can benefit from our innovation.

[**] Under the current governance structure, representatives from project participants form the Management Group (MG). It is the MG responsibility to plan the construction and operations phase, define the corresponding partnership and funding models, and advocate for national resources to support MSE technical development.

[††] The exploration was motivated initially by ghosting mitigation of the wide field corrector optics of the single-mirror prime focus telescope baseline[11].

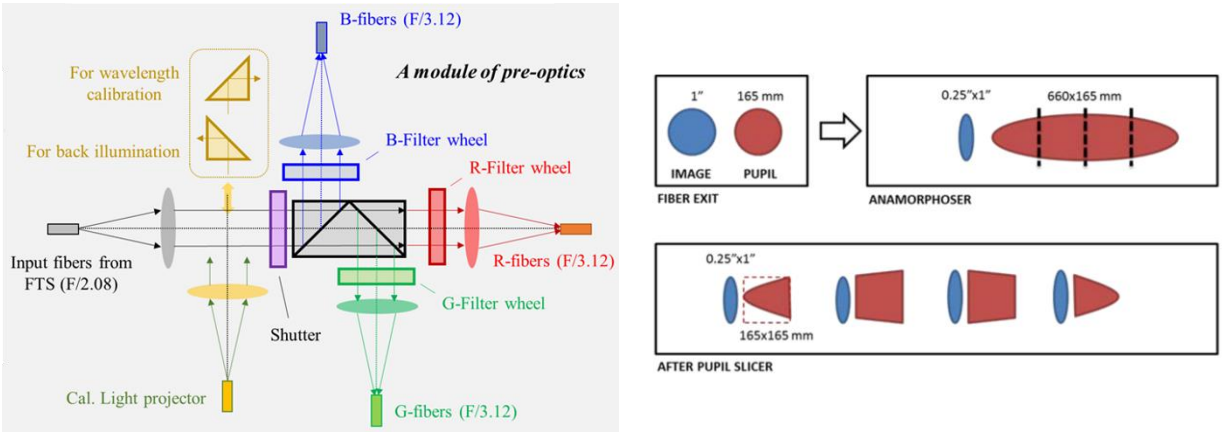


Figure 3 Left pane: Wavelength splitting concept proposed by the high resolution spectrograph design team where the pre-optics splits the visible band into three blue, green, and red bands and reformats the spectrograph input f-ratio. Right pane: Pupil slicing concept proposed by the ngCFHT feasibility study spectrograph design team where a deployable anamorphoser pre-optics works in concert with a fixed pupil slicer to enable "switchable" spectral resolutions of the spectrograph.

In addition, we will fast-track MSE technology development of selected subsystems with a Pathfinder prototype. Pathfinder[14] is an end-to-end science instrument representative of a proto-MSE for the 4m-class CFHT telescope. Pathfinder will demonstrate on-sky the science capabilities of MSE's primary subsystems and its principal software platform while producing shared science products for the US community. Utilizing the same MSE design and technology, Pathfinder will duplicate the fiber positioner system[15], fiber transmission system[16], spectrograph[17] with reduced multiplexing, from 4,000 targets to approximately 1,000 targets. In addition, Pathfinder will utilize MSE's Program Execution Software Architecture[18] platform and software modules to facilitate survey scheduling[19], targeting, data reduction[20] and analysis[21], database management, science products archive, and data-lab science platform.

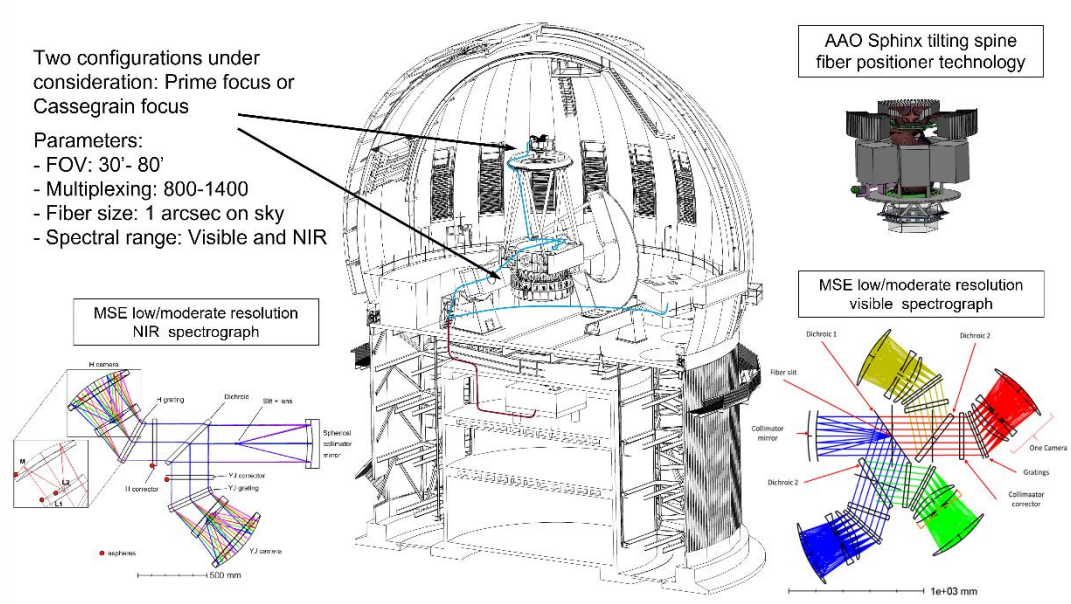


Figure 4 Pathfinder to fast track MSE subsystem development, including fiber positioner system, fiber transmission system, visible and NIR spectrographs, and Program Execution Software Architecture

The MSE Project Office (PO), CFHT Instrumentation Group, coinvestigators from US universities, and collaborators from NSF's NOIRLab are planning an NSF Mid-Scale Research Infrastructure (MSRI) proposal for the Pathfinder

development. The MSE Pathfinder science goals include time-domain spectroscopic follow-up of transient targets identified by the Vera C. Rubin Observatory and Zwicky Transient Factory Facility, galactic archeology, legacy-scale stellar abundance and evolution spectroscopy studies, etc.

6. SUMMARY AND CONCLUSION

The findings from the national strategic planning processes validate MSE's science capabilities making it the perfect follow-up facility and discovery tool for the 2030s and beyond. We are working to realize MSE over the next decade, with developmental and operational timelines consistent with the national strategic plans, the Mauna Kea Stewardship and Oversight Authority, and the MSE Management Group. In parallel, we plan to advance MSE's design at the system-level and for selected subsystems and begin construction toward the end of the decade.

We are preparing funding proposals for national scientific infrastructure programs in Canada, the UK, and the US and exploring new partnership as we move forward. We will innovate spectrograph pre-optics technology to facilitate compact, modular, and scalable spectrograph configuration to achieve a high degree of multiplexing cost effectively. We will fast-track MSE technology development of major subsystems with the Pathfinder prototype for risk mitigation.

CFHT is a pioneer of the Astro2020 recommended collaborative Community Astronomy model, which is the model for astronomy on Maunakea, having been invested in the life and work on the Hawai'i Island demonstratively for over 45 years. Building on CFHT's education[22] and public outreach legacy, we are looking forward to collaborating with the new MKSOA authority and co-create aspects of MSE's facility design and project development as integral part of our *kuleana* (responsibility) plan. We continue to embrace wholeheartedly the close collaboration that we share with our community and their educators to co-produce outreach and community engagement programs within the k*uleana* plan. It is MSE's *kuleana* to care, for our CFHT/MSE staff are the Hawai'i Island community.

ABOUT THE MAUNAKEA SPECTROSCOPIC EXPLORER PROJECT

The mission of the MSE Project is to realize a dedicated facility that enables a diverse suite of large-scale spectroscopic surveys of millions of astrophysical objects at a range of wavelengths, spectral resolutions, redshifts, and spatial scales.

The MSE Project is hosted by the Canada-France- Hawaii Telescope Corporation, and supported by contributing organizations in Canada, France, Hawaii, Australia, China, India, South Korea, Texas, the UK, and the US. The MSE collaboration recognizes the cultural importance of the Maunakea summit to a broad cross-section of the Native Hawaiian community, and is committed to equity, diversity and inclusion.

Statements of MSE's mission, cultural respect, and equity, diversity and inclusion are available on https://mse.cfht.hawaii.edu.

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