Science matrix

- PlaTO follow-up: host star characterisation
- Gaia follow-up: high resolution observations for all stars
- Dark matter: radial velocities of numerous faint targets
- Galaxy formation and evolution up to high z
- Transient follow-up over long durations
- Reverberation mapping
MSE Key Capabilities

- Survey speed: 11.25m primary, >4300 fibres, dedicated telescope
- Spectral performance:
  - simultaneous low & high resolution
  - switching low & moderate resolution, switching J & H band
  - dedicated to spectroscopic surveys: stability, homogeneous databases
### International WF-MOS

<table>
<thead>
<tr>
<th>Class</th>
<th>Facility / Instrument</th>
<th>First light (anticipated)</th>
<th>Aperture (M1 in m)</th>
<th>Field of View (sq. deg)</th>
<th>Etendue</th>
<th>Multiplexing</th>
<th>Wavelength coverage (μm)</th>
<th>Spectral resolution (approx)</th>
<th>IFU</th>
<th>Dedicated facility</th>
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*a* [http://www.ing.iac.es/Astronomy/telescopes/wht/weavepars.html#dlflow](http://www.ing.iac.es/Astronomy/telescopes/wht/weavepars.html#dlflow)

*b* [https://www.desi.lbl.gov](https://www.desi.lbl.gov)

*c* [https://www.eso.org/sci/facilities/develop/instruments/4MOST.html#status](https://www.eso.org/sci/facilities/develop/instruments/4MOST.html#status)

*d* [https://www.eso.org/sci/facilities/develop/instruments/MOONS.html#status](https://www.eso.org/sci/facilities/develop/instruments/MOONS.html#status)

*e* [http://pfs.ipmu.jp/schedule.html](http://pfs.ipmu.jp/schedule.html)

Also **ESO SpecTel** concept (Ellis et al. 2017); Working Group report; no detailed requirements or design available for comparison (WG recommends 10-12m class telescope, ~5 square degree field of view, ~5000 fibres, possible deployable IFUs)
Facility transformation

CFHT

MSE
**Enclosure**: Calotte style with vent modules for excellent airflow

**Fiber Transmission System**: 3,249 fibers leading to low/moderate resolution spectrographs; 1,083 fibers leading to high resolution spectrographs

**Fiber Positioner System**: 4,332 positioners providing simultaneous complete full field coverage for all spectroscopic modes, with upgrade path to multi-object IFU system

**Wide Field Corrector and Atmospheric Dispersion Corrector**: 1.5 square degree field of view

**Telescope Structure**: Prime focus configuration, high stiffen-to-mass ratio open-truss design to promote airflow

**M1 System**: 11.25m aperture with 60 1.44m hexagonal segments

**High resolution spectrographs**: located in Coude room for environmental stability

**Low/Moderate resolution spectrographs**: located on both instrument platforms

**Telescope and Enclosure Piers**: modified CFHT structures
The MSE Team

Canada
- Fibres
- Dome

France
- Low resolution spectrograph
- Prime focus mechanics

China
- High resolution spectrograph

Spain
- Telescope

India
- M1 design

Australia
- Positioner
- Wide-field corrector design

Hawaii
- Project Office
- Software Building
Telescope (IDOM Spain)

• Segmented primary mirror
  • 60 hexagonal segments
  • 1.44m corner-to-corner (similar to TMT and E-ELT to reuse existing facilities)
  • diameter 11.25m
• Fits inside the upgraded enclosure
  • focal length 18.845m
  • current observing floor removed
  • 10% size increase of the dome
• Prime focus for large field of view
• Instrument platforms due to alt-azimuthal mount
• Yoke concept rather than rocking chair due to stiffness/mass trade-off
Top end assembly (AAO & DT INSU)

- Includes
  - wide-field corrector optics
  - wide-field corrector positioning
  - fibre positioner and electronics
  - field derotator
- Novel approach to ADC to increase the throughput (reduce the number of optics)
  - shift L2
  - shift all other optics in the other direction
  - translate all the other optics
- Concept design
  - based on spacers to meet the wide range of positions to align optics
  - includes 2 hexapods
    - to move L2
    - to move the whole top end
Positioner (AAO)

- **Sphinx**
  - based on Echidna concept
  - longer spines (reduced geometric FRD)
  - reduced thermal emission (lower voltages)
  - 57 modules arranged in hexagonal shape

- **Fibre arrangement**
  - 2 HR / 5 LMR
  - patrol radius $1.2\times$pitch
  - coverage HR/LMR is:
    - 1 fibre 100%/100% (complete coverage)
    - 2 fibres 58%/100%
    - 3 fibres: 4%/97%
  - high allocation efficiency

- Works with metrology camera located in the centre of M1
  - residual error: 5µm achieved in 5 moves
Positioner (AAO)

- Electronics Cabinets
- Electronics Frame
- Mount for InRo Interface Frame
- Spines
Fibres (NRC & FiberTech Optica)

- Fibres
  - HR: 80µm (0.8”) core, LMR: 100µm (1.0”) core
  - high NA fibres to avoid f-ratio adaptation: 0.26-0.28 NA to inject at f/2
  - candidate manufacturers: Polymicro, Ceramoptec
- Fibre link geometries
  - no breaks/connectors
  - 57 identical cables (one per Sphinx module) to LR and LMR
  - lengths: 35m to LMR, 50m to HR
LMR (CRAL & AAO)

- Evolution of the design for Hector (AAO)
- 6 units, 4 arms (3 CCDs, 1 Hawaii4RG)
- Low/moderate switching by exchanging VPHs with grisms
- J/H band switching by exchanging gratings
- Cooled to -63°C
HR (NIAOT)

- Challenging due to resolution and étendue
- Resolution (3-arm design)
  - 40 000: 401-416nm & 472-490nm
  - 20 000: 626-675nm
- Multiplex: 542 (2 units)
- Optical design
  - driven by feasibility of dispersive elements
  - constrained by injection at f/2 in fibres
  - all channels optimised independently (corrector, disperser, camera)
  - 300mm beams
  - Off-axis f/2.05 collimator
  - f/1.55 transmissive cameras with 3 highly aspheric surfaces
  - 6.2-pixel sampling (10µm pixels)
HR (NIAOT)

- Dispersive element design
  - reduce line density with an immersed grating: grism (design driver) + prism
  - 5700 - 6500 l/mm
  - 300mm beam
  - grating technology: VPH or ion-beam etching

![Diagram showing the dispersing elements:](image)

Opening angle 67.5 degree

Interface to Camera

Grism

Prism

(a) Blue channel  
(b) Green channel  
(c) Red channel
2010: Launch of ngCFHT study
2014: Creation of MSE Project Office
2015 — 2017: Major subsystem conceptual design studies
2017: 10 subsystem conceptual design reviews
2018: System-level requirement and conceptual design review
      Transition to preliminary design phase
      • looking for a new project scientist (in Hawaii)
      • making the science team and consortium grow
      • collecting funds
      • open to new collaborators for:
        • LMR
        • M1 design
        • software
        • top-end assembly
ACKNOWLEDGEMENTS

The Maunakea Spectroscopic Explorer (MSE) conceptual design phase was conducted by the MSE Project Office, which is hosted by the Canada-France-Hawaii Telescope. MSE partner organizations in Canada, France, Hawaii, Australia, China, India, and Spain all contributed to the conceptual design. The authors and the MSE collaboration recognize the cultural importance of the summit of Maunakea to a broad cross section of the Native Hawaiian community.