The Maunakea Spectroscopic Explorer:
Science and Status

Andrew Hopkins

on behalf of Alan McConnachie
MSE Project Scientist

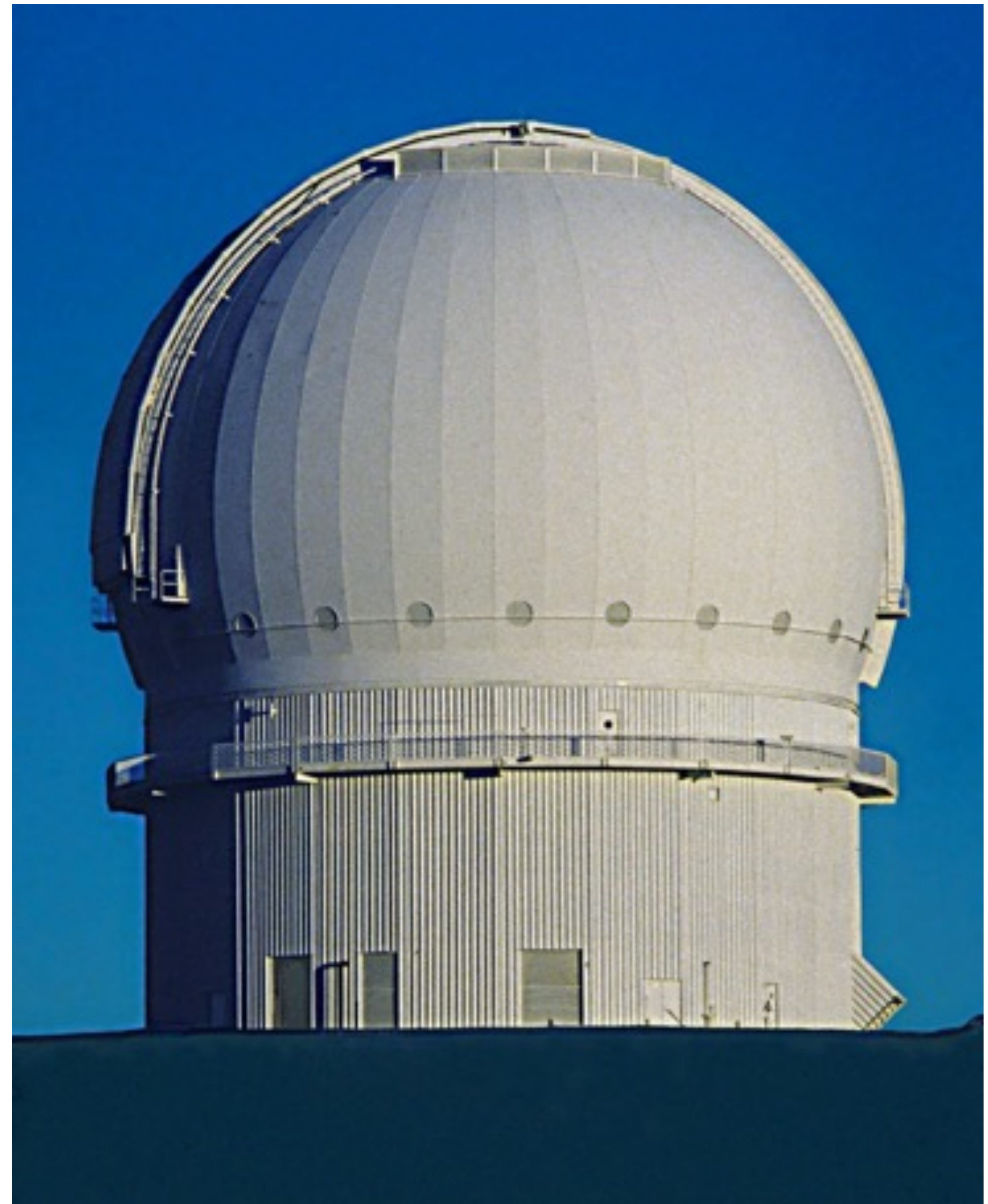
MOS in the Next Decade, La Palma, 2 - 6 March 2015

http://mse.cfht.hawaii.edu

The Big Idea: CFHT redevelopment

Mauna Kea Master Plan

- Allowed to redevelop the CFHT site
- Keep within the same 3-D footprint
- must not harm the ground beyond what has already been done
- the next generation of the CFHT will stay within the same envelope
- the less work done at the summit, the better (e.g., keep the building and pier if possible)
- MSE is the first project to recycle a telescope on Maunakea



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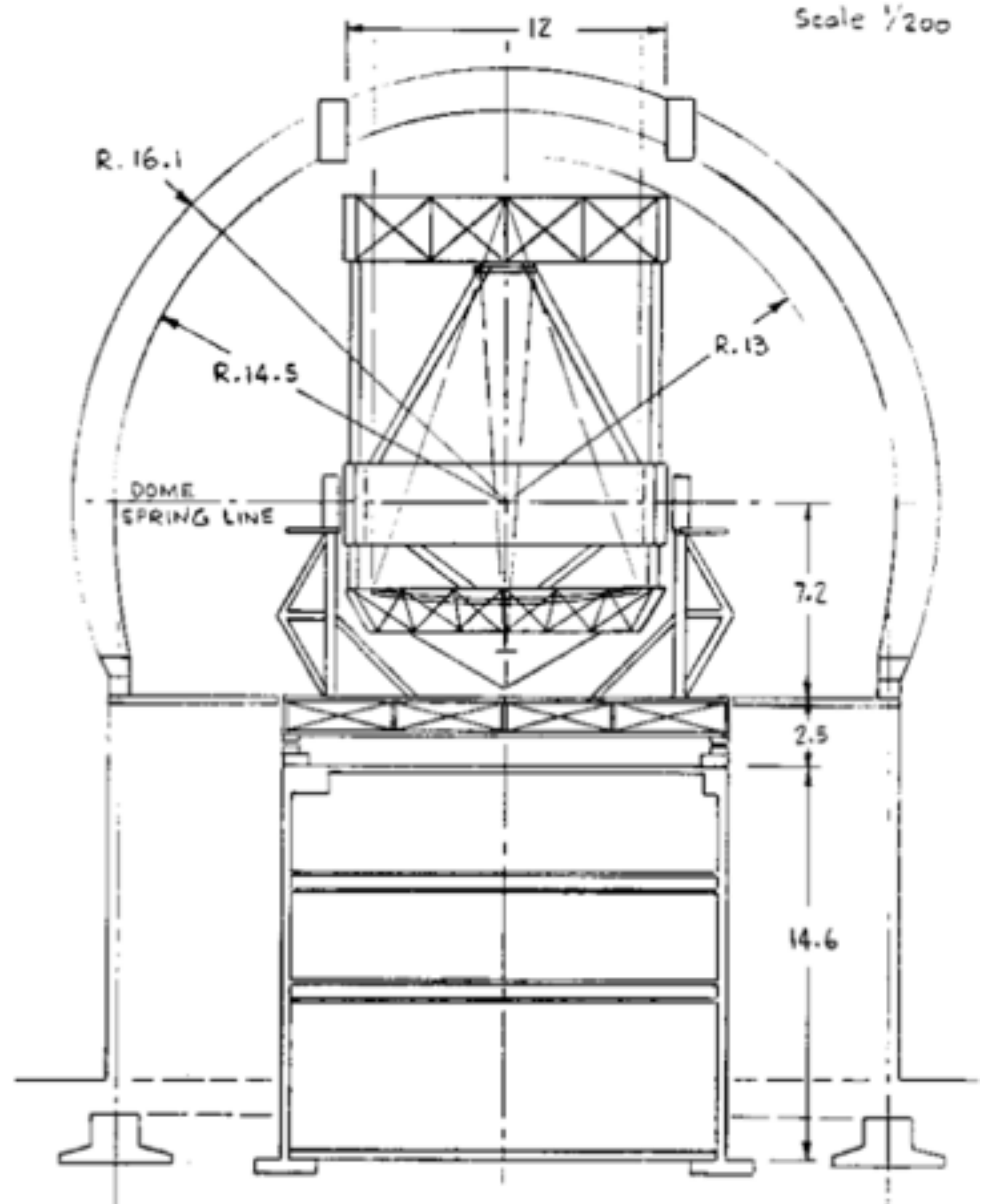
Redevelopment of CFHT is not a new idea

- e.g. SAC Working Group on the Future of CFHT (1996)
- Resulted in “CFH 12 - 16m Telescope Study”, Grundmann (1997) [right]

- CFHT 3.6m weighs 266 tonnes
- Keck is 270 tonnes



[Original] Defining Concept

MSE will:

- obtain efficiently very large numbers (>10^6) of low- (R ~ 2 000), moderate- (R ~ 6 500) and high-resolution (R > 20 000) spectra
- for faint (20 < g < 24) science targets
- over large areas of the sky (10^3 – 10^4 sq.deg)
- spanning blue/optical to near-IR wavelengths, 0.37 –> NIR (J or H band)
- At the highest resolutions, it should have a velocity accuracy of <<1 km/s
- At low resolution, complete wavelength coverage should be possible in a single observation

- **Unique science cases of MSE stemming from:**
  - **10 m class aperture**
  - **Operation at a range of spectral resolutions**
  - **Dedicated Operations, producing stable, well-calibrated and characterised data**
  - **Long lifetime**
- Each element is essential and sets MSE apart from other efforts in wide-field MOS
- *Natural path from 4m-class facilities (DESI, WEAVE, 4MOST, HERMES...) and 8m class instruments (Subaru/PFS, VLT/MOONS) to MSE*

The MSE Project Office

- MSE started life as ngCFHT in 2010. Grassroots team prepared Feasibility Study (on a shoestring) and led effort to promote concept internationally. MSE is a distinct project that builds on CFHT infrastructure that requires a new international collaboration
- Board approved establishment of Project Office, February 2014 (ngCFHT—> MSE)

Announcing the Launch of the Maunakea Spectroscopic Explorer (MSE) Project Office

Throughout its 35 year history, CFHT has provided forefront research capabilities from its exceptional site on Maunakea. However, to maintain its potential to shed light upon the biggest questions confronting 21st century astrophysics, CFHT is launching a project to explore its renewal. A cornerstone of our renaissance will be the expansion of the current partnership, making Maunakea accessible to an even broader international research community.

Project Manager: **Rick Murowinski;** Project Scientist: **Alan McConnachie; (**Interim) Project Engineer: **Derrick Salmon —> Kei Szeto (April 2015 onwards)**

- Produce a **Construction Proposal**, 2014 - 2017, to inform decision to proceed
- Lead/coordinate technical, scientific and partnership development
- *2014: Further building of partnership; laying foundation and infrastructure for PO; ramping up effort in Waimea and internationally*

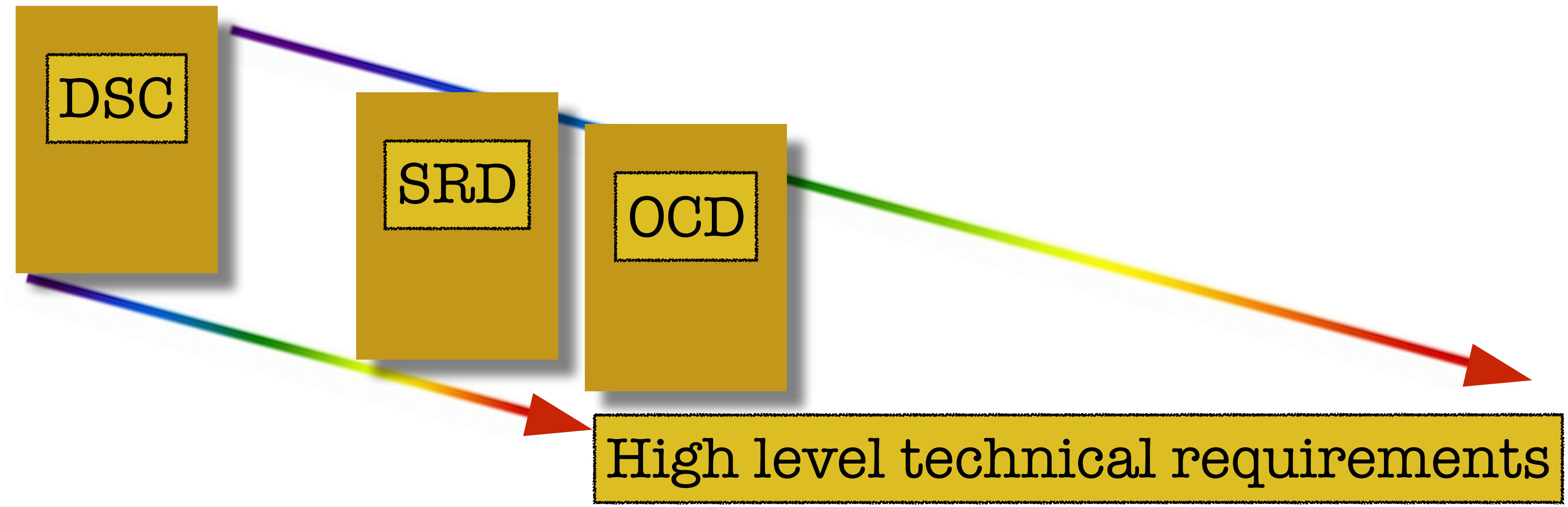
2014 main events

- Formation of the **Science Team** (80+ members from 12 countries) and engagement of key scientists to lead the scientific development; establishment of the **Advisory Group** to provide strategic advice on all aspects of MSE activities
- Expanding the partnership; now a **Canada - China - France - Hawaii - India** project
- **China** *(Contact Scientist: Eric Peng; AG representative: Xiangqun Cui)*
  - Recently signed MOU with CFHT has China contributing FTEs to MSE PO for duration of design phase

- **India** *(Contact Scientist: Gajendra Pandey; AG representative: TBD)*
  - IIA in process of formally negotiating MOU with CFHT following receipt of formal letter of interest in collaborating in MSE project; already contributing FTEs

Science Development

- **Current Science Requirement Development activities started in August 2014** to feed technical development, specifically:
  - Detailed Science Case (DSC)
  - Science Requirements Document (SRD)
  - Operational Concept Document (OCD)



- **Science Team submitted first Science Reports in January 2015; first draft of SRD in preparation for internal release to Science Team in March 2015; some changes to baseline concept (marked in red)**

Defining elements I

MSE

10m class

- Large number of excellent 4-m class efforts underway to provide extreme MOS over wide field of view, for which a 10-m is by design complementary
- On 4-m, the faint Universe is not accessible. *New science development activities make clear that sensitivity is key for MSE:*
- New baseline aperture 10 - 12m effective diameter

Range of Spectral Resolutions

- Original baseline, low (R~3000), moderate (R~6500) and high (R~20000).
- Enables a broad range of science to be addressed, with efficient operations throughout lunar cycle
- New science development activities make compelling case for even higher resolution (R~40K, cf ESO-Gaia, AAT/HERMES)

Defining elements II

Dedicated operations

- For instruments that move on and off the telescope at regular intervals, issues such as calibration, stability, reproducibility can be problematic
- For the MSE, *basic operational philosophy* enables production of homogeneous, high quality and well characterised datasets (cf. SDSS)
- Science enabling capability (e.g., time domain stellar spectroscopy, AGN reverberation mapping, etc)

Long lifetime

- MSE has a baseline operational lifetime of >20 years; upgrades will naturally occur, although it is envisioned MSE will remain a spectroscopic telescope
- Science Requirements being drafted refer to both “First light” capabilities and “Lifetime capabilities” (e.g., the facility will be IFU-capable, and will be able to support spectrographs working out to 2.5um)

Driving science

The composition and dynamics of the faint Universe

I. Stars, resolved stellar populations and the Milky Way

Lead Scientist: Carine Babusiaux (Observatoire de Paris)

Science Reference Observations in development include:

- Tomographic mapping of the interstellar medium (lead, Rosine Lallement)
- In search of the most metal poor stars (lead, Martin Asplund)
- Substructure and dark matter halos in the Milky Way (lead, Rodrigo Ibata)

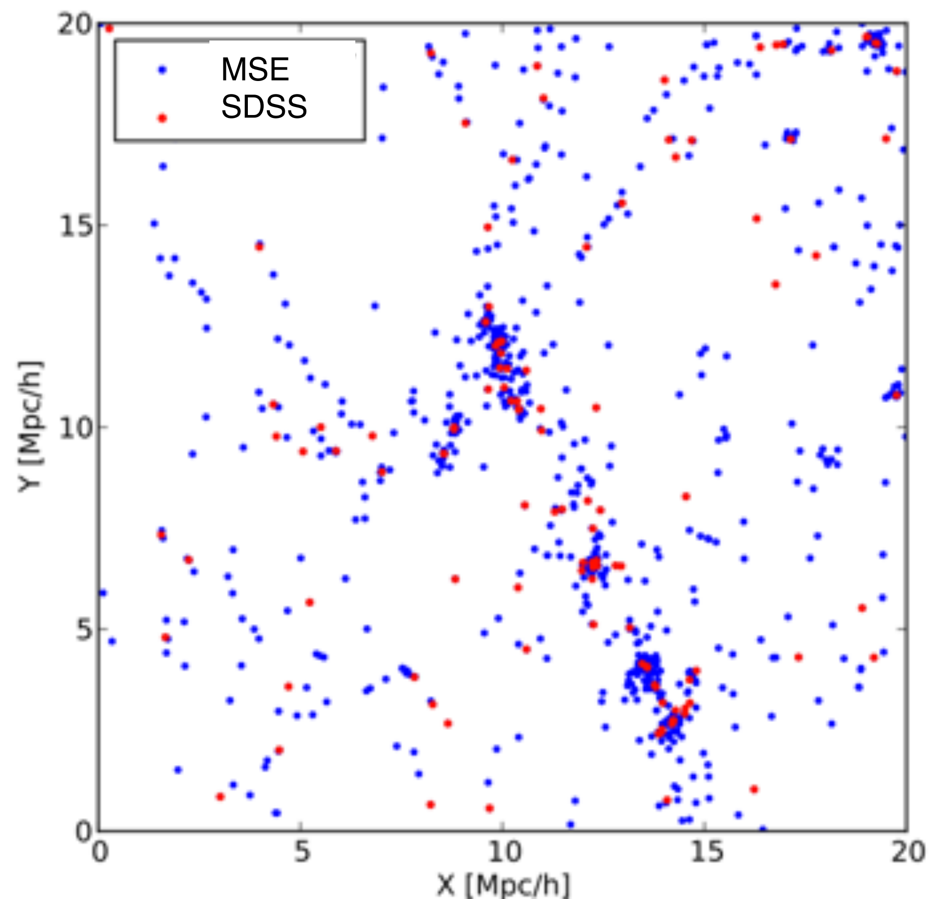
Driving science
The composition and dynamics of the faint Universe

II. Nearby galaxies and the low redshift Universe

Lead Scientist: Michael Balogh (University of Waterloo)

Science Reference Observations in development include:

- Rich galaxy clusters (lead, Allesandro Boselli)
- Population and dynamics of galaxy groups (lead, Iraklis Konstantopoulos)
- Physical properties of dwarf galaxies (lead, Sara Ellison)

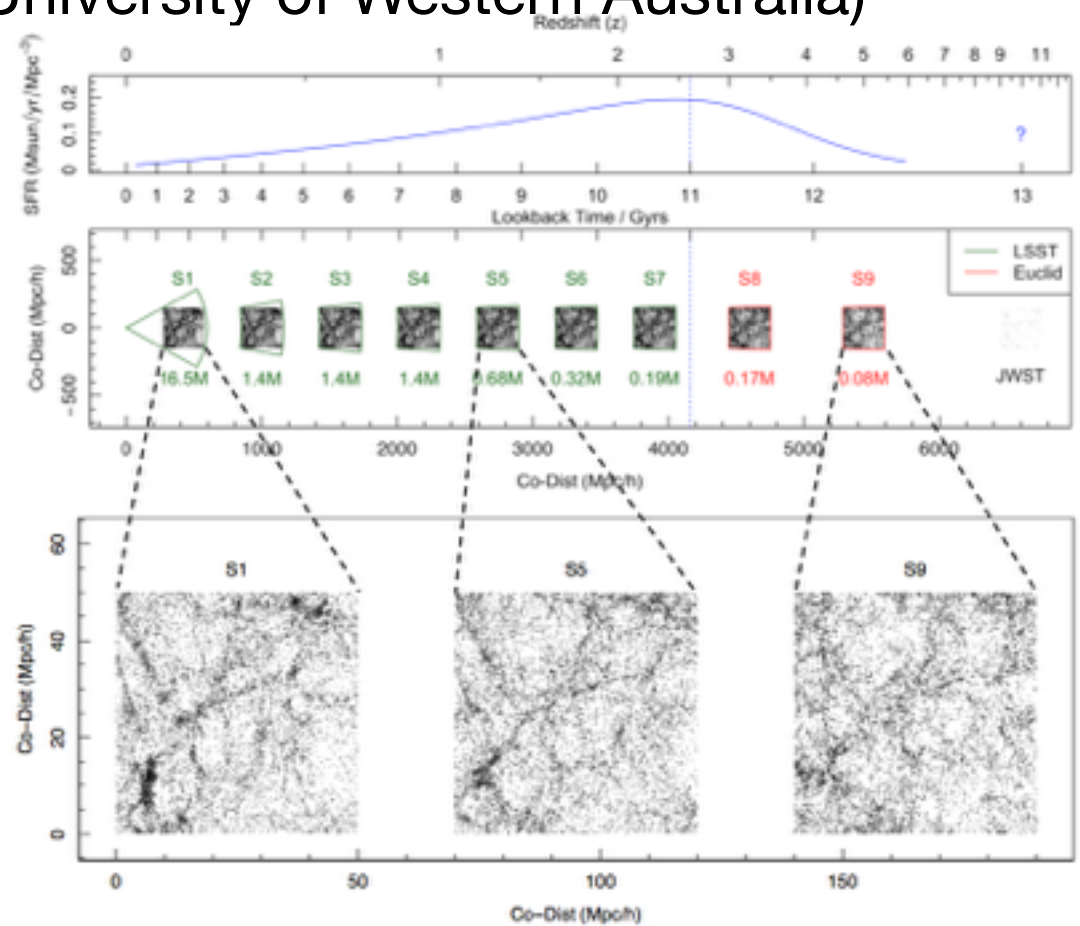


Driving science

The composition and dynamics of the faint Universe

III. The high redshift universe

Lead Scientist: Simon Driver (University of Western Australia)



Science Reference Observations in development include:

- AGN Reverberation Mapping (lead, Sarah Gallagher, Yue Shen, et al.)
- Big facility synergy and transients (lead, Simon Driver)
- The halo mass function (lead, Aaron Robotham)

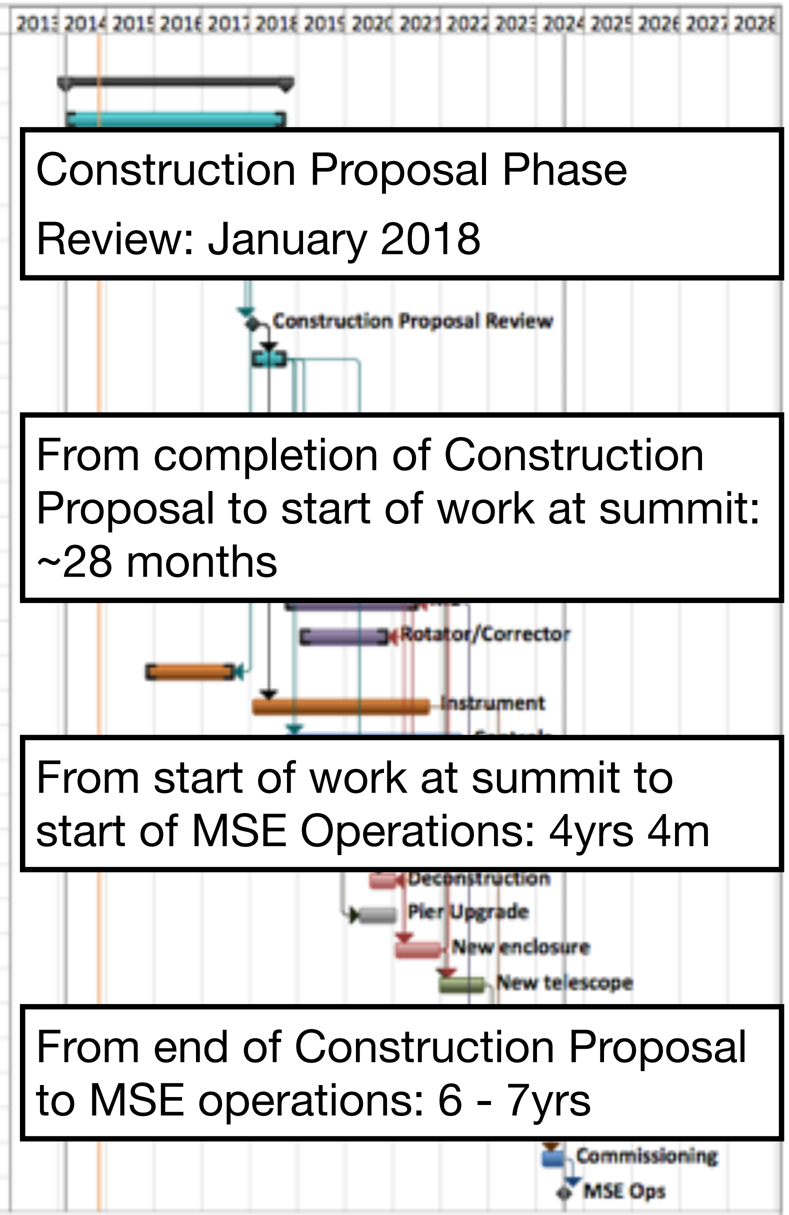
Plan for 2015+

In addition to contributed effort by Canada, China, France, Hawaii and India, PO has 2015 budget of **USD1.085M** (anticipated average budget of USD1.2M for 2015 -17)

1. Science
   - Development of DSC and SRD; baseline observing program; independent review of DSC and SRD by blue-ribbon panel
2. Establishing baseline design
   - Key milestone of having first draft of the SRD, Architectural Design Document, System Technical Requirements (February 2015); first draft OCD, second draft SRD, STR (Summer 2015)
3. Design development
   - Following release of ADD and STD, major expansion in engineering effort
   - Focus on Level 1 systems and subsystems: Instrument (fibre pickoff through to science detectors), Observatory Control Systems, Observing Preparation and Data Reduction, Corrector and ADC optics, M1 Optics, Segment Support and Alignment, Telescope Mount, Enclosure, Piers
4. Permitting process
   - Partially linked to design milestones to provide information to guide process
   - Involves close interactions OMKM and other stakeholders on the islands

Baseline Schedule

ID	Task Name	Start	Finish
1	**MSE Overview**		
2	**Development Phase**	**03 Mar '14**	**08 Oct '18**
3	Outreach and Site Permitting	03 Mar '14	05 Oct '18
4	Establish project office and initial	03 Mar '14	17 Jul '15
28	**Integration, Test, Commissioning**	**09 Aug '22**	**05 Aug '24**
29	M1 Integration	09 Aug '22	10 Jul '23
30	Instrument Integration	21 Mar '23	19 Feb '24
31	Commissioning	20 Feb '24	05 Aug '24
32	**Start of MSE Operations**	05 Aug '24	05 Aug '24



Later this year (once a revised cost estimate is available). **MSE will adopt a cost and schedule cap** to allow for planning in partner communities

Meanwhile, a reasonable estimate of the cost of construction of MSE is USD250M (amortized over ~7 years of construction)

Construction Proposal Phase

Review: January 2018

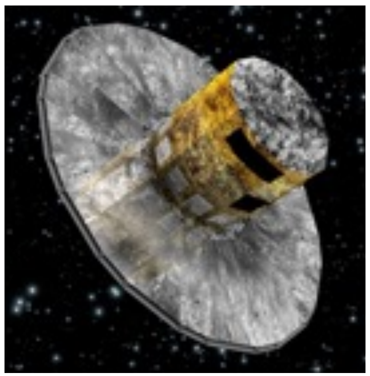
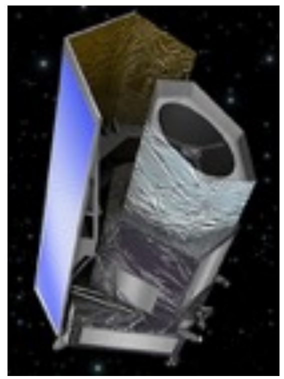
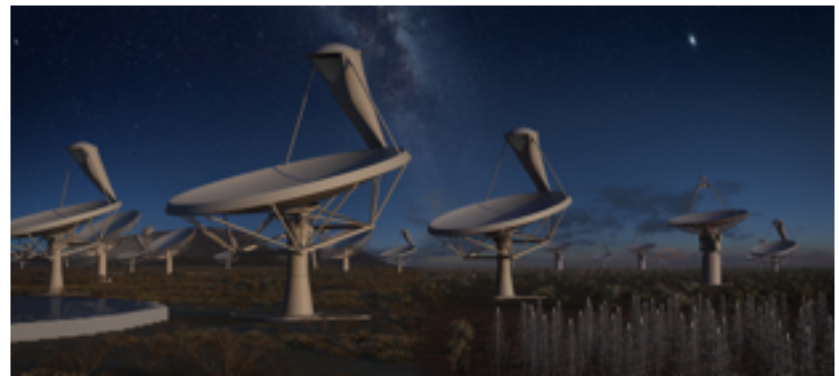
From completion of Construction Proposal to start of work at summit: ~28 months

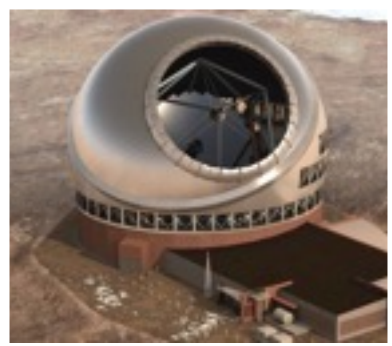
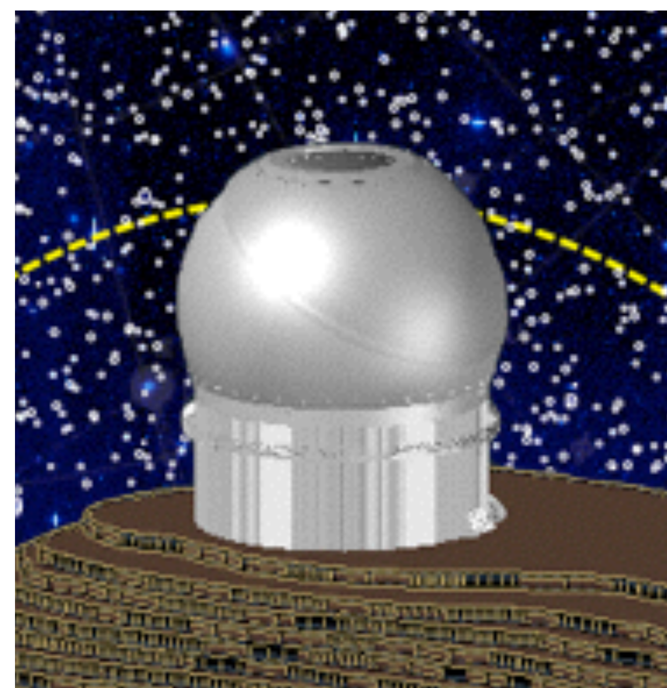
From start of work at summit to start of MSE Operations: 4yrs 4m

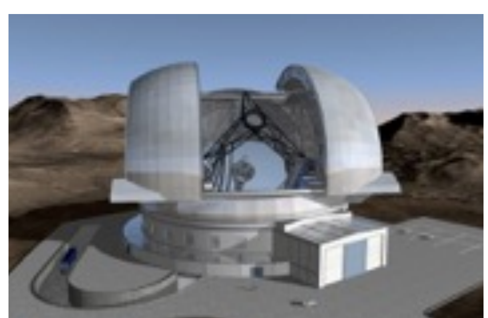
From end of Construction Proposal to MSE operations: 6 - 7yrs

Thank you

URL: http://mse.cfht.hawaii.edu   Email: mcconnachie@mse.cfht.hawaii.edu



The International Context

Telescope/Instrument	D_{M1} (m)	Status	Available	λ (μm)	Ω (deg^2)	$A\Omega$ (m^2 deg^2)	N_{mos}	$\mathcal{R}$	f	IQ	$\log\eta$
Ground-Based											
AAT/AAOmega	3.9	Existing	1996	0.37–1.00	3.14	37.5	392	1000–17000	0.5	1.5	3.5
SDSS	2.5	Existing	2000	0.38–0.92	1.54	7.6	640	1800	1.0	1.4	3.6
Keck/DEIMOS	10.0	Existing	2002	0.41–1.10	0.023	1.8	150	2500–5500	0.4	0.7	2.1
VLT/VIMOS	8.2	Existing	2002	0.37–1.00	0.062	3.3	600	180–2500	0.2	0.8	2.9
VLT/FLAMES	8.2	Existing	2003	0.37–0.95	0.136	7.2	8–130	5600–25000	0.2	0.8	1.3–2.6
MMT/Hectospec	6.5	Existing	2004	0.36–0.92	0.79	26.1	240–300	1000–40000	0.2	1.0	2.6–2.7
WIYN/Hydra	3.5	Existing	2005	0.37–1.00	0.79	7.5	90	800–40000	0.2	0.8	2.4
Magellan/IMACS	6.5	Existing	2008	0.36–1.00	0.16	5.3	400	1100–16000	0.2	0.6	3.3
SDSS/APOGEE	2.5	Existing	2011	1.51–1.70	1.54	7.6	300	27000–31000	0.5	1.4	2.8
Subaru/FMOS	8.2	Existing	2012	0.8–1.8	0.20	10.4	400	600-2200	0.2	0.7	3.3
LAMOST†	4.0	Existing	2012	0.37-0.90	19.6	247	4000	1000–10000	1.0	3.0	5.1
AAT/HERMES	3.9	Existing	2013	4 windows	3.14	37.5	392	28000	0.5	1.5	3.6
Subaru/PFS	8.2	Planned	2017	0.38–1.30	1.1	70	2400	1900-4500	0.3	0.7	5.0
WHT/WEAVE	4.2	Planned	2018	0.37–1.00	3.14	41	~1000	5000–20000	0.7	0.8	4.8
Mayall/DESI	4.0	Planned	2018	0.36–1.05	7.1	89	5000	3000–4800	0.5	1.5	5.1
VLT/MOONS	8.2	Planned	2018	0.8–1.8	0.14	7.3	1000	4000-20000	0.3	0.8	3.3
VLT/4MOST	4.1	Planned	2019	4 windows	3.0	40	1500	3000-20000	1.0	0.8	5.1
MSE	10.0	Planned	2021	0.37–1.30	1.5	118	3200	2000	1.0	0.7	6.0
				0.37–1.00			3200,800	6500,20000	1.0	0.7	5.4
Space-Based											
Gaia	2×(1.4×0.5)	Existing	2014	0.85–0.87	all sky survey (V < 17)			11500			
Euclid	1.2	Planned	2020	1.10–2.00	0.55	0.62		250			
WFIRST	1.5	Planned	2025:	1.10–2.00	0.5	0.89		75–320			

† – *Also known as the Guo Shou Jing Telescope (GSJT).*

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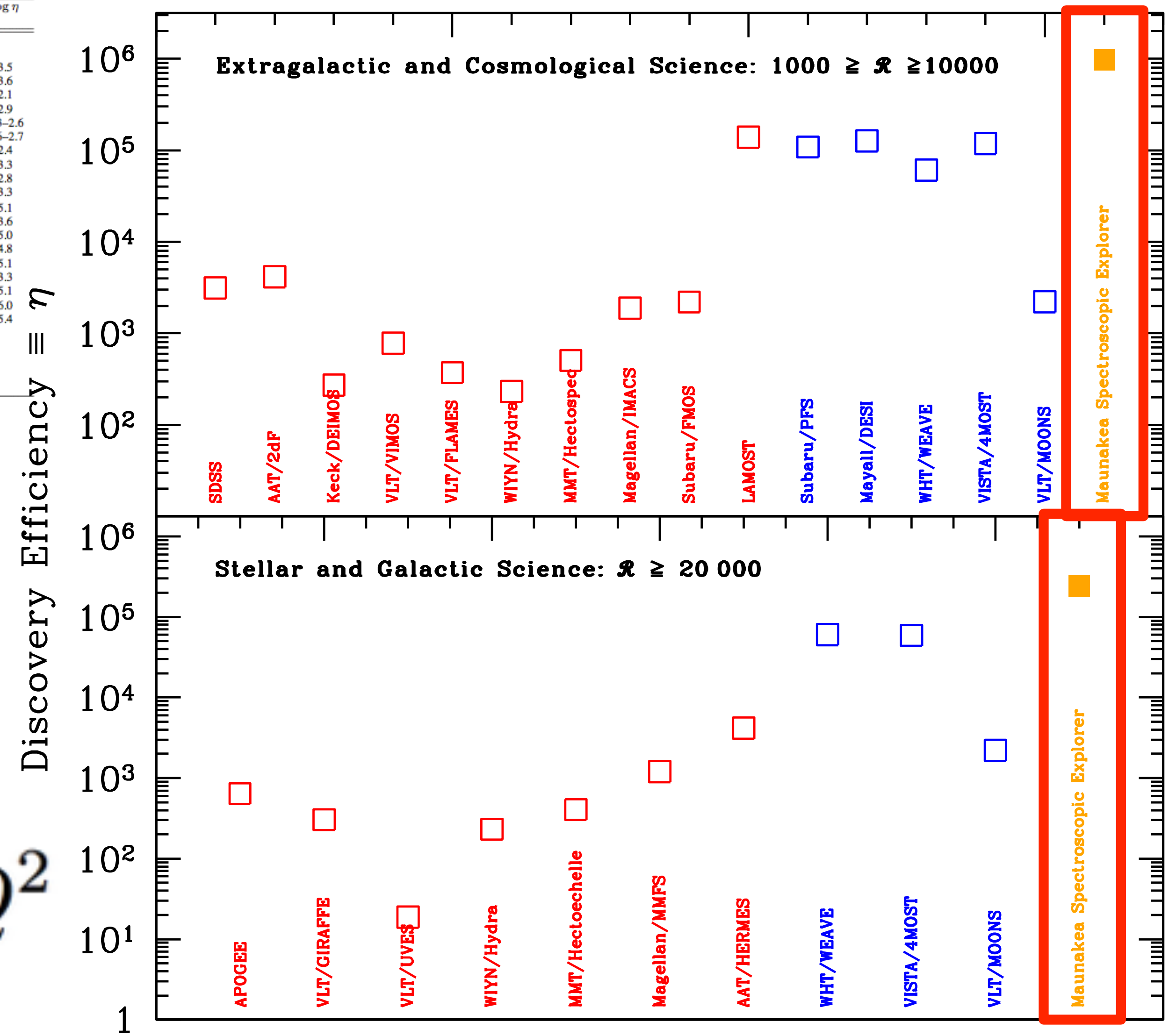
$$\eta \equiv D_{M1}^2 \Omega N_{mos} f / IQ^2$$



High impact science: example surveys*

(*from the Feasibility Study)

- Stars: **one "SDSS" every 3.7 months** [plus factors of 3.6-11 gains in spectral resolution, and 2-4 mags in depth]
- Galaxies: **one "SDSS" every 4.6 months** [with 5-8 mag gains in depth, plus NIR coverage]
- **with a flexible operational model** to ensure small, medium, large and legacy observational programs, responsive to rapidly evolving scientific landscape

Andromeda	Grey/Dark	350	6500	436 - 504 ; 770 - 889	23.0	50

A suite of dark-time surveys covering many thousands of square degrees would yield spectra for **10^7 galaxies**, allowing a study of galaxy evolution at **seven distinct epochs between 0.5 < z < 1.5, each with the same statistical power as the SDSS**

Dark-Wide	Dark	4300	2000	370 - 1300	$i = 23.5$	520
Dark-Medium	Dark	100	2000	370 - 1300	$i = 24.25$	480
Dark-Deep	Dark	1.5	2000	370 - 1300	$i = 26$	105
Quasar Reverb. Mapping	Dark	1.5	2000	370 - 1300	$i = 22.7$	105
Cosmological Clusters	Dark	750	2000	370 - 1300	$i = 23.5$	195
BAO/Cosmology	Dark/Grey	10000	2000	370 - 1300	$r = 23.7$	600


Space-based complement
Wide-field follow-up
ELT-feeder

MSE pre-history ("ngCFHT")

Feasibility Study Working groups (2011-2012)

1. Exoplanets
Magali Deleuil (Lab. d'Astrophysique de Marseille, France)
Francois Bouchy (IAP, France)
Ernst de Mooij (Toronto, Canada)
Norio Narita (NAOJ, Japan)

2. The Interstellar Medium
Rosine Lallement (GEPI/Observatoire de Paris, France)
Patrick Boissé (Institut d'Astrophysique de Paris, France)
Ryan Ransom (Okanagan College, DRA, Canada)

3. Stars and Stellar Astrophysics
Kim Venn (University of Victoria, Canada)
Katia Cuhna (NOAO, USA)
Patrick Dufour (Montreal, Canada)
Zhanwen Han (Yunnan Observatory, China)
Chiaki Kobayashi (ANU, Australia)
Rolf-Peter Kudritzki (IfA, Hawaii, USA)
Else Starkenburg (Victoria, Canada)

4. Milky Way Structure and Stellar Populations
Piercarlo Bonifacio (GEPI, France)
Nobou Arimoto(NOAJ, Japan)
Ken Freeman (ANU, Australia)
Bacham Eswar Reddy (IIA, India)
Sivarani Thirupathi (IIA, India)

5. The Local Group
Alan McConnachie (HIA, Canada)
Andrew Cole (Tasmania, Australia)
Rodrigo Ibata (Strasbourg, France)
Pascale Jablonka (Observatoire de Paris, France)
Yang-Shyang Li (KIAA, China)
Nicolas Martin (Strasbourg, France)

6. Nearby Galaxies and Clusters
Mich
Cana
Rich
Simo
Eric
Yen-

7. G
Mich
Cana
Seba
Dam
Karl
Lihw
Cha
Swa
Mar
Luc

8. The Intergalactic Medium
Céline Péroux (Lab. d'Astrophysique de Marseille, France)
James Bolton (Melbourne, Australia)
Sara Ellison (Victoria, Canada)
Raghunanathan Srianand (IUCAA, India)

9. QSOs and AGNs
Pat Hall (York University, Canada)
Len Cowie (IfA, Hawaii)
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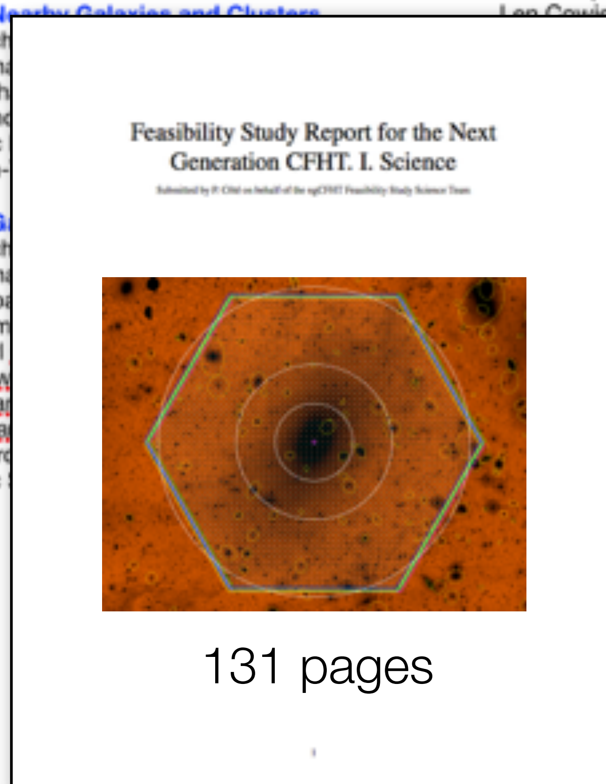
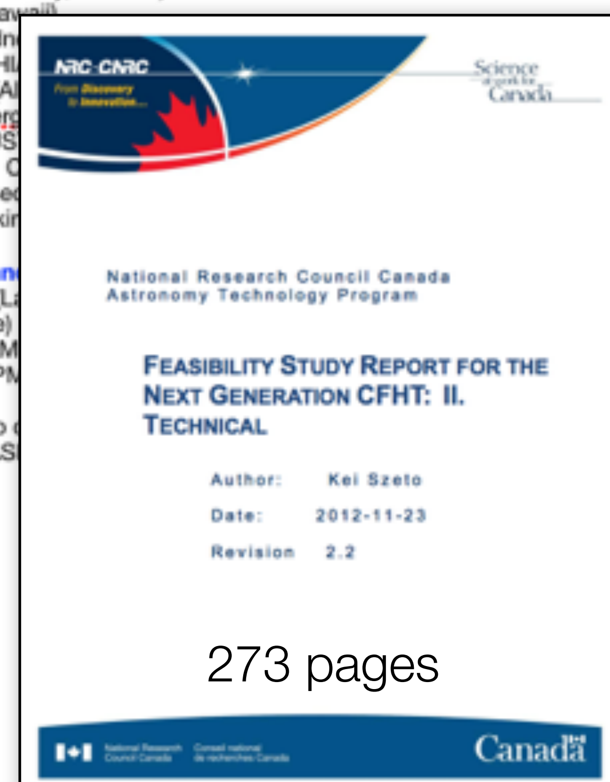

Feasibility Study Report for the Next Generation CFHT. I. Science

131 pages


NRC·CNRC
National Research Council Canada
Astronomy Technology Program

FEASIBILITY STUDY REPORT FOR THE NEXT GENERATION CFHT: II. TECHNICAL

Author: Kei Szeto
Date: 2012-11-23
Revision 2.2

Canada

273 pages

Completed Feasibility Studies available at http://mse.cfht.hawaii.edu

Science Executive

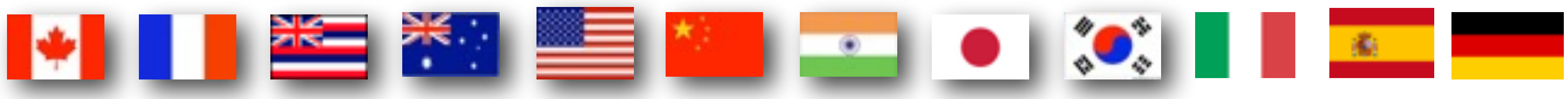
- Governing body of the Science Team, responsible for setting science direction and coordinating science activities. Meets at monthly telecons and frequent email.

- **Project Scientist** (Project Office): Alan McConnachie

- **Contact scientists** (MSE partner community):
  - *Australia (Andrew Hopkins)*
  - Canada (Michael Balogh)
  - China (Eric Peng)
  - France (Nicolas Martin)
  - Hawaii (Brent Tully)
  - India (Gajendra Pandey)

- **Lead scientists** (Science Team):
  - The Milky Way and Resolved Stellar Populations: Carine Babusiaux (France)
  - Nearby and low redshift galaxies: Michael Balogh (Canada)
  - High redshift galaxies and cosmology: Lisa Kewley —> Simon Driver (Australia)

Science Team Membership



- During the Design Phase, science team membership is open to any PhD astronomer in the international community with science interests overlapping with MSE
- Currently **80 members**, including participants from Australia (12), Canada (11), China (8), France (21), Germany (2), Republic of Korea (1), Hawaii (2), Italy (1), India (10), Japan (1), Spain (1), Taiwan (1), United Kingdom (2), United States (7)

Nobuo Arimoto, Subaru/NAOJ, Japan

Martin Asplund, Australian National University, Australia

Herve Aussel, CEA Saclay, France

Carine Babusiaux, Observatoire de Paris, France

Michael Balogh, Waterloo, Canada

Giuseppina Battaglia, IAC, Spain

Harish Bhatt, Indian Institute of Astrophysics, India

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