MSE Science Requirements Document

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Change Record

Version	Date	Affected Section(s)	Reason/Initiation/Remarks
A	2015-10-23	All	First Release
B	2015-11-04	All	Format requirements for DOORS import (Kei Szeto/Laurie Dale)
C	2017-05-08	All	Updated document number; Minor text edits; Updated Table 1; Inserted Table 3; Added Abbreviations and Acronyms as Section 3 Improved justification and notes for multiple requirements, including cross-referencing requirements to DSC REQ-SRD-013: changed to reflect new high resolution capabilities; REQ-SRD-021: changed to Science Field of View instead of Etendue; REQ-SRD-033: modified to reflect new high resolution capabilities, including moving red cutoff to 900nm from 950nm; REQ-SRD-034/35/36: better defined IQ condition (defined in r band for 034/35 and in g band for 036) REQ-SRD-42: corrected to 10km/s precision from 9km/s (previously, a typo); REQ-SRD-046: value added (changed from NN.n) REQ-SRD-051,/052: updated --- (Alan McConnachie)

1 Purpose

This is the MSE Science Requirements Document (SRD). It represents the highest level of requirements that the MSE facility must meet, and every requirement described herein is traced directly to a key science driver for the facility. The key science drivers are described in the *Detailed Science Case (DSC) for the Maunakea Spectroscopic Explorer: The Composition and Dynamics of the Faint Universe* [RD-01], which provides a narrative describing the scientific importance of MSE to address fundamental questions regarding the nature of stars, galaxies and the Universe.

It is fully expected that the scientific scope and impact of MSE that is currently envisioned and described in the DSC is incomplete; the key science questions naturally and continually evolve or change dramatically as our understanding advances and new discoveries are made. To ensure that the design of MSE will be best optimized to address a broad range of transformational science during its lifetime, the DSC additionally describes a suite of “Science Reference Observations” (SROs) that together constitute the equivalent of a “Design Reference Mission” for the facility. The SROs have been identified by the international science team as specific science goals that are high impact, transformational – i.e., will provide a highly important and significant increase in our understanding of the field – and which are *uniquely possible with MSE.* They have been developed in considerable detail, with particular focus on implementation issues such as the origin of pre-imaging, the luminosity distribution of targets, their space density and the survey region required, the specific spectral features that must be observed, the quality of the measurement that is required, the observing cadence, any special calibration measurements, and related issues.

Science requirements are then defined as the capabilities that the MSE system must have in order to make the measurements necessary to successfully carry out the programs described by the SROs.

At science commissioning for MSE, and during its first decade of operations, many of the observing programs that MSE will undertake may address directly the science described by the SROs. Quite possibly, a more contemporary set of observations will be conducted. Nevertheless, it is expected that the capabilities that are captured by the science requirements will ensure that MSE becomes the premier international facility for multiplexed spectroscopy, enabling a vast range of high-impact science programs.

MSE is envisioned as a ground based, dedicated, wide field, highly multiplexed spectroscopic facility. All science cases, SROs and facility synergies described in the DSC assume this basic architecture. Within this context, the science requirements listed in this present document describe, whenever possible, system-level performance at the end-user level. This point is important and worth expounding. At the level of the science requirements, distinctions between major sub-systems such as the telescope, fiber-system, and spectrographs, are generally unnecessary and may impede the design of the optimal system. We therefore try to make explicit the distinction between a *science requirement*, and a *design solution that meets the science requirement*. A good example is "sensitivity". At the level of the science requirements, what is important is the observed signal to noise ratio per resolution element for a given spectral resolution as a function of wavelength. This might be achieved with a relatively small aperture and high throughput optics, or it might be achieved with a design that has a larger aperture to allow for more leeway in other aspects of the optical design. Both are satisfactory solutions. Wherever possible, care has been taken to ensure the science requirements are generally described in a way that does not explicitly assume a design solution.

2 Related Documents and Drawings

2.1 Reference Documents

Reference	Document title	Date	Document ID
[RD-01]	The Detailed Science Case for the Maunakea Spectroscopic Explorer: the Composition and Dynamics of the Faint Universe	2017-02-08	MSE.PO.SCI.DOC-RPT-001
[RD-02]	MSE Operations Concept Document	2016-12-16	MSE.PO.ENG.DOC-REQ-002
[RD-03]	MSE Observatory: Technical Note – Sky Subtraction Accuracy	2016-02-11	MSE TN005

2.2 Applicable Documents

Reference	Document title	Date	Document ID

3 Abbreviations and Acronyms

AGN Active Galactic Nuclei
CFHT Canada-France-Hawaii Telescope
DSC Detailed Science Case
IFU Integral Field Unit
IGM Inter-galactic medium
IQ Image Quality
LSST Large Synoptic Survey Telescope

M31 Messier 31 (the Andromeda Galaxy)
MSE Maunakea Spectroscopic Explorer
NIR Near infra-red
rms root mean square
SKA Square Kilometer Array
SNR Signal to Noise Ratio
SRD Science Requirements Document
SRO Science Reference Observation
TBC To be confirmed
TBD To be determined

4 Science Requirements

The science requirements are summarized at various points throughout this document. In case of any inconsistencies in the text, the requirements and descriptions given in Section 4.2 take precedence.

4.1 Summary of MSE Science Capabilities

Table 1 is a copy of Table 2 from the DSC, and provides a summary of the major, high level, science-enabling characteristics for MSE as defined directly by the science requirements. MSE will conduct multi-object spectroscopy for astrophysical objects located anywhere in at least three-quarters of the entire sky. It will operate at three different spectral resolutions spanning from R ~ 2500 to ~ 40000, and will obtain spectra stretching from blue-optical wavelengths to the near-infrared. With a 1.5 square degree science field of view, MSE will obtain at least 3200 spectra per exposure at low and moderate resolutions, and ~1000 spectra per exposure at high resolution. It will conduct surveys that include millions of targets spread over potentially several tens of thousands of square degrees. During its lifetime it will be able to support a multi-object IFU capability to allow for spatially resolved studies of extended sources. The data that MSE will produce over its > 20 year lifetime will be calibrated to a high level of accuracy and repeatability. Overall, these science-enabling capabilities will provide for transformational scientific discoveries spanning a very broad range of astronomical topics.

Table 1: Summary of the scientific capabilities of MSE (updated copy of Table 2 from the DSC)

Accessible sky	30000 square degrees (airmass < 1.55)						
Aperture (M1 in m)	11.25m						
Field of view (square degrees)	1.5						
Etendue = FoV x π (M1 / 2)²	149						
Modes	**Low**		**Moderate**	**High**			**IFU**
Wavelength range	0.36 - 1.8 µm		0.36 - 0.95 µm	0.36 - 0.90 µm ♯			IFU capable; anticipated second generation capability
	0.36 - 0.95 µm	J, H bands		0.36 - 0.45 µm	0.45 - 0.60 µm	0.60 - 0.90 µm	
Spectral resolution, R = $\lambda_c/d\lambda$	2500 *(3000)*	3000 *(5000)*	6000	40000	40000	20000	
Multiplexing	>3200		>3200	>1000			
Spectral windows	Full		≈Half	$\lambda_c/30$	$\lambda_c/30$	$\lambda_c/15$	
Sensitivity ★	m=24 @ SNR=2		m=23.5 @ SNR=2	m=20.0 @ SNR=10			
Velocity precision ★	20 km/s @ SNR=5		9 km/s @ SNR=5	< 100 m/s @ SNR=30			
Spectrophotometic accuracy	< 3 % relative		< 3 % relative	N/A			

♯ Dichroic positions are approximate

★ Signal-to-noise ratios are measured per resolution element

The basic architecture that is assumed for MSE is as a dedicated, ground-based, wide-field spectroscopic facility, and within this context all science requirements are traceable to the DSC. Each requirement emerges either from consideration of specific or multiple SROs described in that document. The science requirements are summarized in Table 2, divided into major sub-groupings. The flowdown from the SROs to the science requirements is summarized by the Science Traceability Matrix, shown in Table 3 (a copy of Table 1 from the DSC).

Table 2: Summary of MSE science requirements

Requirements relating to Spectral Resolution:	
REQ-SRD-011	Low spectral resolution
REQ-SRD-012	Moderate spectral resolution
REQ-SRD-013	High spectral resolution
Requirements relating to the Focal Plane Input:	
REQ-SRD-021	Science field of view
REQ-SRD-022	Multiplexing at low resolution
REQ-SRD-023	Multiplexing at moderate resolution
REQ-SRD-024	Multiplexing at high resolution
REQ-SRD-025	Spatially resolved spectra
Requirements relating to Sensitivity	
REQ-SRD-031	Spectral coverage at low resolution
REQ-SRD-032	Spectral coverage at moderate resolution
REQ-SRD-033	Spectral coverage at high resolution
REQ-SRD-034	Sensitivity at low resolution
REQ-SRD-035	Sensitivity at moderate resolution
REQ-SRD-036	Sensitivity at high resolution

Requirements relating to Calibration	
REQ-SRD-041	Velocities at low resolution
REQ-SRD-042	Velocities at moderate resolution
REQ-SRD-043	Velocities at high resolution
REQ-SRD-044	Relative spectrophotometry
REQ-SRD-045	Sky subtraction, continuum
REQ-SRD-046	Sky subtraction, emission lines
Requirements relating to Lifetime Operations	
REQ-SRD-051	Accessible sky
REQ-SRD-052	Observing efficiency
REQ-SRD-053	Observatory lifetime
Requirements relating to Data Management and Processing	
REQ-SRD-061 ++	

Table 3: Science Reference Observations cross-referenced to Science Requirements. Boxes with red borders indicate that the SRO is used in the derivation of the requirement; dark green boxes indicate the requirement is highly relevant to the SRO; light green indicates that the requirement has some relevance to the SRO; grey indicates minimal or no impact of the SRO on the requirement. Updated copy of Table 1 from the DSC.

			Resolved stellar sources					Extragalactic sources						
			DSC-SRO-01 *Exoplanet hosts*	DSC-SRO-02 *Time domain stellar astrophysics*	DSC-SRO-03 *Chemical tagging in the outer Galaxy*	DSC-SRO-04 *CDM subhalos and stellar streams*	DSC-SRO-05 *Local Group galaxies*	DSC-SRO-06 *Nearby galaxies*	DSC-SRO-07 *Virgo and Coma*	DSC-SRO-08 *Halo occupation*	DSC-SRO-09 *Galaxies and AGN*	DSC-SRO-10 *The InterGalactic Medium*	DSC-SRO-11 *Reverberation mapping*	DSC-SRO-12 *Peculiar velocities*
Spectral resolution	REQ-SRD-011	*Low spectral resolution*		R~2000 (white dwarfs)				R~3000	R~3000	R~2000-3000	R~3000		R~3000	R~1000-2000
	REQ-SRD-012	*Intermediate spectral resolution*		Any repeat observatio-ns	Essential, R~6500	Essential, R~6500	Essential, R~6500	Velocities of low mass galaxies	Velocities of low mass galaxies			R~5000		
	REQ-SRD-013	*High spectral resolution*	R>=40000	R>=20000	Essential, R~20-40K	Essential	Young stars		Bright globular clusters					
Focal plane input	REQ-SRD-021	*Science field of view*	~2000 sq. deg	all-sky	1000s sq. deg	1000s sq.deg	100s sq. deg	3200 (100) sq.deg	~100sq.deg	~1000sq.deg	~300 sq.deg	40 sq.deg	7 sq. deg	all-sky
	REQ-SRD-022	*Multiplexing at lower resolution*						~5000 galaxies/sq. deg	100s targets (galaxies/GCs) / sq.deg	>5000 galaxies/sq. deg	770 galaxies/sq. deg		600AGN/deg	1000s galaxies/sq. deg
	REQ-SRD-023	*Multiplexing at moderate resolution*			1000s stars/sq.deg to g~23	1000s stars/sq.deg to g~23	few - thousands stars/sq. deg	~5000 galaxies/sq. deg				500 galaxies/sq. deg		
	REQ-SRD-024	*Multiplexing at high resolution*	~100 stars/sq.deg @ g = 16	~1000 stars/sq.deg to g=20.5	~1000 stars/sq.deg to g=20.5	1000s stars/sq.deg to g~23								
	REQ-SRD-025	*Spatially resolved spectra*						Goal	Goal					Yes
Sensitivity	REQ-SRD-031	*Spectral coverage at low resolution*						0.37 - 1.5um	0.37 - 1.5um	0.36 - 1.8um	0.36 - 1.8um	0.36 - 1.8um (0.36 -	0.36 - 1.8um	Optical emission lines
	REQ-SRD-032	*Spectral coverage at moderate resolution*			Strong line diagnostics in optical	CaT essential	CaT essential	Goal: complete	Goal: complete			Goal: complete		
	REQ-SRD-033	*Spectral coverage at high resolution*	Strong lines for velocities; tagging	Strong lines for velocities	Chemical tagging	Strong lines for velocities								
	REQ-SRD-034	*Sensitivity at low resolution*						i=24.5	i=24.5	i=25.3	i=25 / H=24		i=23.25	i=24.5
	REQ-SRD-035	*Sensitivity at moderate resolution*			g>20.5	g~23	i=24	i=24.5	i=24.5			r~24		
	REQ-SRD-036	*Sensitivity at high resolution*	g=16 @high SNR	g=20.5	g=20.5	g~22								
Calibration	REQ-SRD-041	*Velocities at low resolution*						v~20km/s	v~20km/s	v~100km/s	v~20km/s		v~20km/s	v~20km/s
	REQ-SRD-042	*Velocities at moderate resolution*			v~1km/s	v~1km/s	v~5km/s	v~9km/s	v~9km/s			v~20km/s (10km/s goal)		
	REQ-SRD-043	*Velocities at high resolution*	v<100m/s	v~100m/s	v~100m/s	v<1km/s								
	REQ-SRD-044	*Relative spectrophotometry*						~4%					Critical:3%	
	REQ-SRD-045	*Sky subtraction, continuum*	few %	few %	few %	few %	<1%	<1%	<1%	<0.5%	<0.5%	<1%	<1%	<1%
	REQ-SRD-046	*Sky subtraction, emission lines*				important (CaT region)	important (CaT region)	critical	critical	critical	critical	critical	critical	
Operations	REQ-SRD-051	*Accessible sky*	Plato footprint (ecliptic)	Gaia footprint (all sky)	Gaia footprint (all sky)	Gaia, PS1, HSC footprint	Northern hemisphere (M31, M33, dec~+40)	LSST overlap useful (10000 sq.deg)	NGVS footprint; dec +12	LSST overlap useful (10000 sq.deg); Euclid (all sky)	LSST overlap useful (10000 sq.deg); Euclid (all sky)	LSST overlap useful (10000 sq.deg); Euclid (all sky)	all sky target distribution	all sky target distribution
	REQ-SRD-052	*Observing efficiency*	maximise	maximise	maximise	maximise	maximise	maximise	maximise	maximise	maximise	maximise	maximise	maximise
	REQ-SRD-053	*Observatory lifetime*	Monitoring >=years	Monitoring >=years	Survey >=5 years	Survey >=5 years	Survey ~100s nights	Survey ~ few years	Survey ~100s nights	Survey ~7 years	Survey ~100s nights	Survey ~100s nights	Monitoring ~5 years	Survey ~years

4.2 Individual Requirements

Each science requirement is described in detail in this section. Each requirement contains the following information:

- the ID for the requirement identification number
- the name of the requirement
- the details for the requirement
- the justification of the requirement with explicit description of its scientific origin, including cross-reference to the relevant SRO(s) and the appropriate sections of the DSC
- notes on any other relevant information pertaining to the requirement in order to provide a complete understanding of its intent.

4.2.1 REQ-SRD-011 Low spectral resolution

[REQ-SRD-011] MSE shall provide a mode with an average spectral resolution of $2500 \leq R \leq 3000$ at optical wavelengths ($\lambda < 950$nm, **TBC**), with a minimum resolution of $R > 2000$ at optical wavelengths, and a minimum spectral resolution of at least R = 3000 (Goal: R = 5000) at near infrared wavelengths ($\lambda > 950$nm, **TBC**).

Justification: Spectral resolution is set by measurement of extragalactic redshifts [DSC-SRO-06, DSC-SRO-07, DSC-SRO-08, DSC-SRO-09] and by AGN reverberation mapping [DSC-SRO-11] requiring nominal velocity resolution of 100km/s. Resolution of at least R = 3000 needed in the NIR to observe between the bright sky lines [DSC-SRO-08, DSC-SRO-09; DSC-SRO-11].

Notes: (i) Spectral resolution is defined as $\lambda/d\lambda$. $d\lambda$ is the full width at half maximum of a Gaussian fitted to an unresolved spectral line on the extracted spectrum that has a wavelength of λ. For a real instrument, the delivered instrument profile may differ significantly from Gaussian, and interactions with the science team will be necessary to ensure that the delivered resolution meets expectations in terms of science performance (ii) At optical wavelengths, this spectral resolution refers to an average value. At NIR wavelengths ($\lambda \gtrsim 950$nm), this spectral resolution refers to a minimum value (R > 3000 needed to observe between bright sky lines in the NIR). (iii) This mode will hereafter be referred to as "low". It is a key mode of operation that will account for most of the dark time science. (iv) Refer to REQ-SRD-031 for the precise wavelength coverage of MSE in this mode.

4.2.2 REQ-SRD-012 Moderate spectral resolution

[REQ-SRD-012] MSE shall provide a mode with an average spectral resolution of $5000 \leq R \leq 7000$ in each wavelength window, with a minimum spectral resolution within each window of R > 4500.

Justification: Spectral resolution is set by the need to get velocities of the brightest stars in the Local Group with a precision of 1 – 2 km/s in a reasonable integration time (hours) [DSC-SRO-04, DSC-SRO-05], analysis of strong stellar lines in the Galaxy [DSC-SRO-03], the stellar population analysis of nearby galaxies [DSC-SRO-06, DSC-SRO-07], and by the study of the IGM [DSC-SRO-10].

Notes: (i) Spectral resolution is defined as $\lambda/d\lambda$. $d\lambda$ is the full width at half maximum of a Gaussian fitted to an unresolved spectral line on the extracted spectrum that has a wavelength of λ. For a real instrument, the delivered instrument profile may differ significantly from Gaussian, and interactions with the science team will be necessary to ensure that the delivered resolution meets expectations in terms of science performance (ii) It is expected that this mode will be used during both bright time and dark time depending on the science. (iii) This mode will hereafter be referred to as "moderate". (iv) Refer to REQ-SRD-032 for the precise wavelength coverage of MSE in this mode.

4.2.3 REQ-SRD-013 High spectral resolution

[REQ-SRD-013] MSE shall provide a mode with an average spectral resolution of $38000 \leq R \leq 42000$ in wavelength windows at $\lambda \lesssim 500$nm, with a minimum spectral resolution within these windows of R > 35000 (ii) an average spectral resolution of $18000 \leq R \leq 22000$ in any wavelength windows at $\lambda \gtrsim 500$nm, with a minimum spectral resolution within these windows of R > 15000 (**TBC**) .

Justification: Spectral resolution is set by stellar chemistry science cases, in particular the ability to measure abundances from weak lines and to resolve lines in the blue (where blending is significant) [DSC-SRO-03]. At redder wavelengths, blending is less significant and thus a lower spectral resolution is sufficient. High velocity precision is also required by stellar astronomy programs [DSC-SRO-02, DSC-SRO-03, DSC-SRO-04] and by exoplanetary host studies [DSC-SRO-01].

Notes: (i) Spectral resolution is defined as $\lambda/d\lambda$. $d\lambda$ is the full width at half maximum of a Gaussian fitted to an unresolved spectral line on the extracted spectrum that has a wavelength of λ. For a real instrument, the delivered instrument profile may differ significantly from Gaussian, and interactions with the science team will be necessary to ensure that the delivered resolution meets expectations in terms of science performance (ii) The transition between “blue” and “red” wavelengths at $\lambda \sim 500$nm is gradual and should not be interpreted during the Design Phase as a hard number. (iii) This mode will hereafter be referred to as "High". It is a key mode of operation that will account for a large fraction of the bright time science. (iv) Refer to REQ-SRD-033 for the precise wavelength coverage of MSE in this mode.

4.2.4 REQ-SRD-021 Science field of view

[REQ-SRD-021] MSE shall have a science field of view from which targets can be selected that has a shape that can be tiled in a regular pattern and which has an area not less than 1.5 square degrees.

Justification: MSE must conduct surveys spanning areas of up to many thousands of square degrees, thus a large field of view that can be tiled is essential for efficient completion of these surveys. The S1-W component of DSC-SRO-06 has detailed plans for what is envisioned as a typical, extensive, legacy survey requiring covering 3200 square degrees. We assume that this takes the form of a single-pass survey, with an exposure time of 1 hour per pointing, sufficient to obtain good SNR on the faint targets. An efficient completion time for this survey component is estimated to be 1 year of dark time. We assume an average of 9.9 hours per night, and a historical weather impact of 2.7 hours per night (these numbers are based on Section 1.2 of http://www.cfht.hawaii.edu/Instruments/Imaging/MegaPrime/observingstats.html). Adopting a science observing efficiency (open shutter time on science targets) of 80% (see REQ-SRD-052) implies ~2100 hours of science observing per year. Completion of S1-W in 1 year of Dark Time therefore requires a science field of view from which targets are selected of 1.5 square degrees.

Notes: (i) There is more flexibility in the acceptable field of view compared to other science requirements (with an appropriate modification in the multiplexing consistent with REQ-SRD-022, REQ-SRD-023 and REQ-SRD-024); the field must be sufficiently large to allow a large area to be covered efficiently (ii) A regular shaped field of view is required in order to facilitate survey planning/tiling. (iii) The phrase "from which targets can be selected" implies that any target at any position in the science field of view is potentially accessible for observing (i.e., if a region of the field of view cannot be accessed for any reason, then that area does not count towards the science field of view) (iv) Field of view is coupled to multiplexing (REQ-SRD-022, REQ-SRD-023, REQ-SRD-024), sensitivity requirements (REQ-SRD-034, REQ-SRD-035, REQ-SRD-036), and science observing efficiency (REQ-SRD-052) since the product of all of these components defines the “survey speed” of MSE.

4.2.5 REQ-SRD-022 Multiplexing at low resolution

[REQ-SRD-022] In low resolution mode, MSE shall be able to obtain the greater of (a) 3200 spectra, or (b) the equivalent of at least 0.593 spectra/sq.arcmin, averaged over the field of view from which targets can be selected, per exposure.

Justification: Low resolution mode will be primarily used in dark time to study galaxies. The source density of galaxies at z < 0.2 brighter than i = 23 is 2100/sq.degree (with a variance of ~30%), or ~3200 per 1.5 square degrees [DSC-SRO-06; see also REQ-SRD-021]. This sets the minimum fiber density for extragalactic studies. The space density of fainter targets is even higher [DSC-SRO-08] and drives us to as high a space density as possible (as close to 1 per sq. arcmin as possible).

Notes: (i) 0.593 spectra/sq.arcmin corresponds to 3200 spectra in a 1.5 square degree field of view (thus, if the field of view increases beyond 1.5 square degrees, the multiplexing should increase proportionally). (ii) In reality, sources are not smoothly distributed. Some potential targets will be close to each other, and the ability to observe targets close together in the same exposure will increase efficiency. (iii) Without any pre-selection, the galaxy source density at i < 23 is high, and this drives us to as high a degree of multiplexing as possible. Therefore the stated multiplexing is a minimum value and higher values are preferable (as close to 1 per sq. arcmin as possible; [DSC-SRO-08]). (iv) Sky fibers (and other calibration fibers) are not explicitly included in the multiplexing requirement. It is envisioned, however, that for almost all viable multiplexing solutions, 100% of fibers will not be able to be assigned to science targets. Thus, these fibers will be allocated to sky and other calibration targets. (v) Multiplexing is coupled to field of view (REQ-SRD-021), sensitivity requirements (REQ-SRD-034, REQ-SRD-035, REQ-SRD-036), and science observing efficiency (REQ-SRD-052) since the product of all of these components defines the “survey speed” of MSE.

4.2.6 REQ-SRD-023 Multiplexing at moderate resolution

[REQ-SRD-023] At moderate resolution, MSE shall be able to obtain the greater of (a) 3200 spectra, or (b) the equivalent of at least 0.593 spectra/sq.arcmin, averaged over the field of view from which targets can be selected, per exposure.

Justification: The source density of galaxies at z < 0.2 brighter than i = 23 is ~2100/sq.degree (with a variance of ~30%), or ~3200 per 1.5 square degrees [DSC-SRO-06; see also REQ-SRD-021]. This sets the minimum fiber density for extragalactic studies.

Notes: (i) Moderate resolution will be used for both galaxy stellar populations [DSC-SRO-06] and resolved stars in the nearby Universe [DSC-SRO-03, DSC-SRO-04, DSC-SRO-05]. Galaxies set the higher multiplexing constraint. (ii) 0.593 spectra/sq.arcmin corresponds to 3200 spectra in a 1.5 square degree field of view (thus, if the field of view increases beyond 1.5 square degrees, the multiplexing should increase proportionally). (iii) In reality, sources are not smoothly distributed. Some potential targets will be close to each other, and the ability to observe targets close together in the same exposure will increase efficiency. (iv) Without any pre-selection, the galaxy source density at i < 23 is high, and this drives us to as high a degree of multiplexing as possible. Therefore the stated multiplexing is a minimum value and higher values are preferable. Note, however, that the gains of higher multiplexing are less than for the low resolution mode since the moderate resolution mode will generally not be used on very faint targets (iv) Sky fibers (and other calibration fibers) are not explicitly included in the multiplexing requirement. It is envisioned, however, that for almost all viable multiplexing solutions, 100% of fibers will not be able to be assigned to science targets. Thus, these fibers will be allocated to sky and other calibration targets. (v) Multiplexing is coupled to field of view (REQ-SRD-021), sensitivity requirements (REQ-SRD-034, REQ-SRD-035, REQ-SRD-036), and science observing efficiency (REQ-SRD-052) since the product of all of these components defines the "survey speed" of MSE.

4.2.7 REQ-SRD-024 Multiplexing at high resolution

[REQ-SRD-024] At high resolution, MSE shall be able to obtain the greater of (a) 1000 spectra, or (b) the equivalent of at least 0.185 spectra/sq.arcmin, averaged over the field of view from which targets can be selected, per exposure.

Justification: High resolution mode will be used primarily in bright time to study the chemodynamics of stars in the Galaxy. The source density of thick disk and halo stars at high Galactic latitude in the critical magnitude range 17 < g < 21 is ~700 per square degree, or ~1000 per 1.5 square degree (Besançon model; Robin et al. 2003, A&A, 409, 523); [DSC-SRO-03]; see also REQ-SRD-021).

Notes: (i) The bright magnitude limit of 17 used in the Justification ensures that all targets for MSE chemical abundance studies are too faint to be studied using 4m-class facilities. (ii) MSE focuses on studies of the thick disk and halo since excellent studies of the thin disk can be accomplished using 4m-class facilities. (iii) In reality, sources are not smoothly distributed. Some potential targets will be close to each other, and the ability to observe targets close together in the same exposure will increase efficiency. (iv) 0.185 spectra/sq.arcmin corresponds to 1000 spectra over a 1.5 sq.degree field of view (thus, if the field of view increases beyond 1.5 square degrees, the multiplexing should increase proportionally). (v) Sky fibers (and other calibration fibers) are not explicitly included in the multiplexing requirement. It is envisioned, however, that for almost all viable multiplexing solutions, 100% of fibers will not be able to be assigned to science targets. Thus, these fibers will be allocated to sky and other calibration targets. (vi)

Multiplexing is coupled to field of view (REQ-SRD-021), sensitivity requirements (REQ-SRD-034, REQ-SRD-035, REQ-SRD-036), and science observing efficiency (REQ-SRD-052) since the product of all of these components defines the "survey speed" of MSE.

4.2.8 REQ-SRD-025 Spatially resolved spectra

[REQ-SRD-025] During the lifetime of MSE, MSE shall be able to provide a multi-object integral field capability, to obtain spatially resolved spectral data on targets that subtend many arcseconds on the sky, with parameters **TBD**.

Justification: MSE will have the capability to provide multi-object Integral Field Units to address key science cases for spatially resolved targets ([DSC-SRO-12], DSC – Sections 3.3.3.; 4.4.2 – 4.4.5).

Notes: (i) The IFU mode requires detailed analysis to decide upon the optimal arrangement (especially, number of spectra per target versus number of targets). (ii) The IFU mode is not anticipated as a first light capability. At first light, allowance must have been made for the ability to include this capability during the lifetime of MSE (at the very least).

4.2.9 REQ-SRD-031 Spectral coverage at low resolution

[REQ-SRD-031] In the low resolution mode, MSE shall provide the following two, critically-sampled, spectral coverage options: (a) continuous spectral coverage from 360nm to 1300nm, in a single exposure (the "J-band" mode), and (b) continuous coverage from 360nm to 950nm (**TBC**) and from 1500 to 1800nm in a single exposure (the "H-band" mode).
(Goal and lifetime requirement: optical + J-band + H-band simultaneously)

Justification: (i) MSE must have good sensitivity to OII3727Å [DSC-SRO-06, DSC-SRO-07, DSC-SRO-10]. (ii) A large number of chemical species have lines shortward of 400nm, and sensitivity to these features is important for estimates of the metallicity [DSC-SRO-06, DSC-SRO-07]. (iii) In the low resolution mode, MSE must be able to derive redshifts and identify the same features in galaxies at a range of redshifts [DSC-SRO-08]. The NIR cut-off is therefore set by the redshift out to which certain features can be identified. In practice, the cut-off is set by technical and financial limitations, not by clear science thresholds. (iv) J and H are required for the high redshift objects [DSC-SRO-08, DSC-SRO-09, DSC-SRO-10, DSC-SRO-11]. Ideally, both bands will be observed simultaneously, although at first light it is acceptable if only a single band is observable at once.

Notes: (i) Due to the difficulties of optimization of optics to 360nm, and the inevitable compromises this will entail for performance at other wavelengths, MSE will be sensitive to 360nm but its performance will be optimized for wavelengths longer than 370nm. MSE will conduct its primary scientific analysis on wavelengths longer than 370nm, with some limited science analysis occurring for wavelengths between 360 – 370nm. (ii) The wavelength cut-offs in the NIR (end of J-band, 1300nm; H band, 1500 – 1800nm) are approximate values only, and some small variation around these numbers is potentially acceptable after consultation with the Science Team, if such a change leads to an optimal technical solution.

[Comments: During the Conceptual Design the feasibility of including the H-band (or some fraction thereof) will be examined. Once the cost and risk of this capability are known, changes in this requirement may be sought, if necessary]

4.2.10 REQ-SRD-032 Spectral coverage at moderate resolution

[REQ-SRD-032] In the moderate resolution mode, MSE shall provide coverage in one or more spectral windows selected from the range 360 – 950 nm (**TBC**) that together provide a total bandwidth of at least 250nm and that contain the wavelength interval 845 – 885nm.

Justification: (i) Moderate spectral resolution is required for stellar population analyses of unresolved (brighter) galaxies [DSC-SRO-06] and for chemical abundance [DSC-SRO-03] and radial velocity studies [DSC-SRO-04, DSC-SRO-05] of faint stars, in which it may be used in conjunction with the high resolution mode. (ii) Broad wavelength coverage is required in order to access as many spectral features as possible to support these analyses. (ii) The region from 845 – 885 nm is required to access the CaII Triplet region [8498, 8542, 8662Å], MgI 8806Å (gravity-sensitive), and a large number of Fe lines and α-elements, necessary for nearby resolved stellar population analysis [DSC-SRO-05].

Notes: (i) Due to the difficulties of optimization of optics to 360nm, and the inevitable compromises this will entail for performance at other wavelengths, MSE will be sensitive to 360nm but its performance will be optimized for wavelengths longer than 370nm. (ii) The wavelength coverage need not be continuous.

4.2.11 REQ-SRD-033 Spectral coverage at high resolution

[REQ-SRD-033] In the high resolution mode, MSE shall provide critically sampled spectral coverage in at least three, non-overlapping, wavelength windows selected from the range 360 – 900nm **(TBD)** that can be adjusted over the lifetime of MSE. The wavelength coverage in each window will be at least $\frac{\lambda_c}{30} \times \frac{40000}{R}$, where λ_c is the central wavelength of the window and R is the spectral resolution of the window at λ_c , and at least half of these windows will be situated at $\lambda_c \lesssim 500$ nm.

Justification: In the high resolution mode, MSE must be able to measure the abundances of a large number of chemical species that are distributed across the optical region with a concentration towards bluer wavelengths [DSC-SRO-03]. Multiple wavelength windows are therefore required in order to access a range of chemical species.

Notes: (i) In the high resolution mode, all major scientifically interesting features at high resolution are at wavelengths shorter than 900nm. (ii) It is expected that the spectral coverage of the windows will be as large as is possible given large format detectors. (iii) Due to the difficulties of optimization of optics to 360nm, and the inevitable compromises this will entail for performance at other wavelengths, MSE will be sensitive to 360nm but its performance will be optimized for wavelengths longer than 370nm. (iv) Ongoing interactions between the spectrograph design team and the science team is critical to ensure that the final wavelength windows best sample the range of chemical species of most relevance to the science programs. The diversity of species accessible, the diversity of science cases addressed within DSC-SRO-03, and the rate of progress in this field, means that a more exact definition of the position and wavelength coverage of the high resolution capability is premature.

[Comments: During the Conceptual Design Phase, the spectral coverage per arm and the cost per arm will be investigated. Once known, the Science Team will advise on the number of arms that are required for that design and the Project Office will decide if this requirement should be modified.]

4.2.12 REQ-SRD-034 Sensitivity at low resolution

[REQ-SRD-034] In the low resolution mode, an extracted spectrum from MSE taken in the observing conditions described below shall have a signal to noise ratio per resolution element at a given wavelength that is greater than or equal to two for a 1 hour observation of a point source with a flux density of 9.1×10^{-30} ergs/sec/cm^2/Hz at that wavelength, for all wavelengths longer than 400nm. Between 370 – 400nm, the SNR shall not be less than one at any wavelength. The observing conditions in which this requirement shall be met correspond to a sky brightness of 20.7mags/sq.arcsec in the V-band at an airmass of 1.2, and a delivered image quality at that airmass of 0.6 arcseconds full width at half maximum in the r band.

Justification: Various proposed redshift surveys for MSE all require signal to noise ratios of a few to derive sufficiently accurate redshifts for intrinsically faint targets. The LSST single visit depth is i = 24, and MSE should aim to efficiently measure redshifts for these targets [DSC-SRO-06]. This magnitude limit also corresponds to the limiting magnitude for a volume at moderate redshift in DSC-SRO-08; closer volumes in DSC-SRO-08 can be probed more efficiently, and more distant volumes will still be able to be probed moderately efficiently through the use of longer exposures.

Notes: (i) This requirement corresponds to an observation of an astrophysical source with a monochromatic AB magnitude of m = 24 in typical observing conditions. (ii) A "delivered image quality of 0.6 arcseconds" corresponds to the IQ as seen on the telescope's optical focal surface (i.e., including atmospheric components as well as dome seeing effects and telescope optics). (iii) Relevant data files relating to the emission and transmission of the atmosphere can be accessed at http://mse.cfht.hawaii.edu/docs/mse-science-docs/SRD/ (iv) Sensitivity is coupled to the field of view (REQ-SRD-021), multiplexing (REQ-SRD-022, REQ-SRD-023, REQ-SRD-024) and science observing efficiency (REQ-SRD-052), since the product of all of these components defines the "survey speed" of MSE.

4.2.13 REQ-SRD-035 Sensitivity at moderate resolution

[REQ-SRD-035] In the moderate resolution mode, an extracted spectrum from MSE taken in the observing conditions described below shall have a signal to noise ratio per resolution element at a given wavelength that is greater than or equal to two for a 1 hour observation of a point source with a flux density of 1.4 x 10^{-29} ergs/sec/cm^2/Hz at that wavelength, for all wavelengths longer than 400nm. Between 370 – 400nm, the SNR shall not be less than one at any wavelength in the relevant window. The observing conditions in which this requirement shall be met correspond to a sky brightness of 20.7mags/sq.arcsec in the V-band at an airmass of 1.2, and a delivered image quality at that airmass of 0.6 arcseconds full width at half maximum in the r band.

Justification: Various proposed galaxy and stellar surveys for MSE all require signal to noise ratios of a few to derive sufficiently accurate velocities for intrinsically faint targets. Specifically, DSC-SRO-06 (S1-D component) and DSC-SRO-07 require the efficient observation of i = 23.5 targets for the derivation of velocities accurate to a few tens of km/s for galaxy groups and clusters. Further, DSC-SRO-05 requires being able to efficiently measure velocities for stars at least one magnitude below the tip of the red giant branch at the approximate distance of M31 (corresponding to i ~ 23.5).

Notes: (i) This requirement corresponds to an observation of an astrophysical source with a monochromatic AB magnitude of m = 23.5 in typical observing conditions. (ii) A "delivered image quality of 0.6 arcseconds" corresponds to the IQ as seen on the telescope's optical focal surface (i.e., including atmospheric components as well as dome seeing effects and telescope optics). (iii) Relevant data files relating to the emission and transmission of the atmosphere can be accessed at http://mse.cfht.hawaii.edu/docs/mse-science-docs/SRD/ (iv) Sensitivity is coupled to the field of view (REQ-SRD-021), multiplexing (REQ-SRD-022, REQ-SRD-023, REQ-SRD-024) and science observing efficiency (REQ-SRD-052), since the product of all of these components defines the "survey speed" of MSE.

4.2.14 REQ-SRD-036 Sensitivity at high resolution

[REQ-SRD-014] In the high resolution mode in any wavelength window observed over the lifetime of MSE, an extracted spectrum from MSE taken in the observing conditions described below shall have a signal to noise ratio per resolution element at a given wavelength that is greater than or equal to ten for a 1 hour observation of a point source with a flux density of 3.6 x 10^{-28} ergs/sec/cm^2/Hz at that wavelength, for all wavelengths in the relevant window longer than 400nm. Between 370 – 400nm, the SNR shall not be less than five at any wavelength in the relevant window. The observing conditions in which this requirement shall be met correspond to a sky brightness of 19.5mags/sq.arcsec in the V-band at an airmass of 1.2, and a delivered image quality at that airmass of 0.6 arcseconds full width at half maximum in the g band.

Justification: High SNR observations of moderately faint targets are required for the efficient measurement of velocities (especially DSC-SRO-04) and chemical composition of stars in the Milky Way [DSC-SRO-02, DSC-SRO-03) faint targets in order to robustly derive chemical abundance information. G = 20 is the nominal magnitude limit of Gaia sources, for which MSE must be able to conduct efficient observations.

Notes: (i) This requirement corresponds to an observation of an astrophysical source with a monochromatic AB magnitude of m = 20 in typical observing conditions. (ii) A "delivered image quality of 0.6 arcseconds" corresponds to the IQ as seen on the telescope's optical focal surface (i.e., including atmospheric components as well as dome seeing effects and telescope optics). The IQ is defined in the g band (in contrast to REQ-SRD-034 and REQ-SRD-035) since the majority of the key science measurements in the high resolution mode will be made shortward of 500nm (iii) Relevant data files relating to the emission and transmission of the atmosphere can be accessed at http://mse.cfht.hawaii.edu/docs/mse-science-docs/SRD/ (iv) Sensitivity is coupled to the field of view (REQ-SRD-021), multiplexing (REQ-SRD-022, REQ-SRD-023, REQ-SRD-024) and science observing efficiency (REQ-SRD-052), since the product of all of these components defines the "survey speed" of MSE.

4.2.15 REQ-SRD-041 Velocities at low resolution

[REQ-SRD-041] For any object with a known velocity, observed at multiple epochs by MSE with up to a 5 year cadence with a signal to noise ratio per resolution element of 5 at low spectral resolution, the contribution from MSE to the rms difference between the known velocity of the object and the measured velocity of the object shall be less than or equal to 20 km/s, and shall have no systematic dependence on the wavelength region of the spectrum that is used to the level of 5km/s (**TBC**) (provided suitable features exist, i.e., any strong absorption or emission lines).

Justification: MSE must be able to measure accurate redshifts of moderately faint galaxies, especially (but not only) for clustering studies [DSC-SRO-06, DSC-SRO-07, DSC-SRO-09, DSC-SRO-11).

Notes: This velocity accuracy is the intrinsic velocity of this mode at this SNR ($dv = \frac{\left[\frac{c}{R}\right]}{SNR} \sim (3\times10^5/3000)/5 \; = \; 20$ km/s) and requires that there are no systematic errors in the wavelength calibration across the wavelength range. Note also that the velocity precision scales inversely as SNR, and the chosen [velocity – SNR] combination used to define the requirement does not necessarily represent the expected values for all observations .

4.2.16 REQ-SRD-042 Velocities at moderate resolution

[REQ-SRD-042] For any object with a known velocity, observed at multiple epochs by MSE with up to a 5 year cadence with a signal to noise ratio per resolution element of 5 at moderate spectral resolution, the contribution from MSE to the rms difference between the known velocity of the object and the measured velocity of the object shall be less than or equal to 10km/s, and shall have no systematic dependence on the wavelength region of the spectrum that is used to a level of 1km/s (**TBC**) (providing suitable features exist, i.e., any strong absorption or emission line).

Justification: MSE must be able to measure accurate velocities for moderately faint stars in the Local Group, especially in dwarf galaxies and stellar streams, which have typical velocitiy dispersions of order 10km/s [DSC-SRO-04, DSC-SRO-05].

Notes: This velocity accuracy is the intrinsic velocity of this mode at this SNR ($dv = \frac{\left[\frac{c}{R}\right]}{SNR} \sim (3\times10^5/6000)/5 = 10$ km/s) and requires that there are no systematic errors in the wavelength calibration across the wavelength range. Note also that the velocity precision scales inversely as SNR, and the chosen [velocity – SNR] combination used to define the requirement does not necessarily represent the expected values for all observations.

4.2.17 REQ-SRD-043 Velocities at high resolution

[REQ-SRD-043] For a radial velocity standard star, observed at multiple epochs by MSE with up to a 5 year cadence with a signal to noise ratio per resolution element of 30 at high spectral resolution, the contribution from MSE to the rms difference between the known velocity of the object and the measured velocity of the object shall be less than or equal to 0.1 km/s.

Justification: MSE must be able to measure precision velocities for stellar monitoring programs including planet-hosting systems [DSC-SRO-01, DSC-SRO-02, DSC – Section 2.2.1].

Notes: (i) The high resolution mode of MSE has different spectral resolution long-ward (R = 20K) and short-ward (R = 40K) of 500nm. It is probable, therefore, that this velocity accuracy will be achieved most easily short-ward of 500nm. It is expected that in meeting this requirement, a comparable velocity accuracy (adjusted for spectral resolution) will also be achievable long-ward of 500nm. (ii) This velocity accuracy is higher than the "intrinsic" accuracy of this mode ($dv = \frac{\left[\frac{c}{R}\right]}{SNR} \sim (3\times10^5/40000)/30 = 250$ m/s) and will rely on the use of multiple lines simultaneously to derive velocities.

4.2.18 REQ-SRD-044 Relative spectrophotometry

[REQ-SRD-044] For a spectrophotometric standard star, observed in the low resolution mode at multiple epochs by MSE with up to a 5 year cadence with a signal to noise ratio per resolution element of 30, the rms variation in the ratio of fluxes measured in any two wavelength intervals shall be less than 3% of the mean measured value.

Justification: This requirement is specifically necessary for AGN reverberation mapping studies [DSC-SRO-11]; spectrophotometry is also required for stellar population studies of nearby galaxies at low and moderate spectral resolution [DSC-SRO-06, DSC-SRO-07]. It is anticipated that meeting this specific requirement for DSC-SRO-11 will also allow MSE to satisfy the spectrophotometric needs of DSC-SRO-06 and DSC-SRO-07.

Notes: (i) Relative spectrophotometry is defined as the ratio between two fluxes. (ii) We anticipate testing this requirement by observing many spectrophotometric standards in many fields over multiple epochs. After a relative flux correction, the rms variation of the difference between the actual relative flux of the target and the measured relative flux values should be less than or equal to 3%. (iii) Since this requirement is quite complex in definition, an alternative drafting of REQ-SRD-044, expressed mathematically, is the following:

For a single observation, n, of a spectrophotometric star (with R=3000 and SNR/resolution element > 30), we can define a quantity F_n such that

$$F_n = \frac{\int_{\lambda_1}^{\lambda_2} f(\lambda)d\lambda}{\int_{\lambda_3}^{\lambda_4} f(\lambda)d\lambda}$$

Here, $f(\lambda)$ is the spectrum as a function of wavelength (λ), and (λ_1, λ_2) and (λ_3, λ_4) define two wavelength intervals.

For a set of N observations of this same star and with the same wavelength intervals, we can define the mean quantity $\bar{F}$ and the standard deviation σ_F such that

$$\bar{F} = \frac{\sum_{n=1}^{N} F_n}{N}$$

$$\sigma_F = \sqrt{\frac{\sum_{n=1}^{N}(F_n - \bar{F})^2}{N-1}}$$

Our spectrophotometric requirement requires that:

$$\frac{\sigma_F}{\bar{F}} \leq 0.03$$

4.2.19 REQ-SRD-045 Sky subtraction, continuum

[REQ-SRD-045] In wavelength intervals free from airglow emission-line contamination and strong telluric absorption, MSE shall allow for removal of the sky flux with a root-mean-square error of less than 0.5% of the sky flux, at all wavelengths **(TBC).**

Justification: MSE must routinely obtain spectra of very faint targets, especially (but not only) in the low resolution mode (especially, DSC-SRO-08). Systematic errrors in the sky subtraction lead to an effective “limiting magnitude”, below which data will be unreliable. This is summarized in DSC-SRO-08, which aims to target some of the faintest systems. In order to make reliable measurements of sources that are typically 25th magnitude in any band (24th magnitude in H band) (see DSC-SRO-08) requires 0.5% accuracy in sky subtraction given typical dark time sky values to reach a noise equivalent error of at least 1 (that is, the measured flux in a pixel will have equal contributions from the science source as from the sky).

Notes: (i) This is pushing the limits of the best sky subtraction using fibers that can currently be achieved. (ii) Requires advanced analysis (e.g. Principal Component Analysis); See Sharp & Parkinson 2010, MNRAS, 408, 2495. (iii) See also the *MSE Operational Concept Document [RD-02]* and the *MSE Observatory Technical Note on Sky Subtraction Accuracy TN005 [RD-03].* (iv) Higher sky subtraction accuracy (pushing to 0.1%) is highly desireable.

4.2.20 REQ-SRD-046 Sky subtraction, emission lines

[REQ-SRD-046] MSE shall achieve a sky subtraction accuracy for atmospheric airglow emission-lines such that the mean residual error for spectral pixels, within 1 resolution element of known atmospheric emission-lines, is <1.5 times **(TBC)** the Poisson limit indicated by the propagated variance spectrum for each resolution element.

Justification: This follows from the same justification for REQ-SRD-045, but is appropriate for regions with bright sky lines.

Notes: (i) This is pushing the limits of the best sky subtraction using fibers that can currently be achieved. (ii) Requires advanced analysis (e.g. Principal Component Analysis); See Sharp & Parkinson 2010, MNRAS, 408, 2495 (iii) the definition of sky subtraction in areas of bright sky lines can be a source of confusion in the literature, and we follow the definitions given by Sharp & Parkinson 2010, MNRAS, 408, 2495.

4.2.21 REQ-SRD-051 Accessible sky

[REQ-SRD-051] MSE shall conduct its primary science objectives on astrophysical targets located at declinations greater than -30 degrees, and will therefore meet the Science Requirements in this declination range.

Justification: In addition to northern targets, MSE must be able to access a large fraction of the southern hemisphere to follow up survey facilities based in the south, especially LSST and SKA (see discussion in DSC – Section 1.6). A declination of -30 degrees as the primary limit corresponds to accessing fully 50% of the southern hemisphere. This corresponds to accessing half of the main LSST footprint and two-thirds of the SKA footprint. Access to the LSST area is required for some SROs due to the quality, extent and homogeneity of photometric data available, especially for DSC-SRO-06, DSC-SRO-08, DSC-SRO-09 and DSC-SRO-11.

Notes: (i) A limited number of science observations will occur for astrophysical targets located at declinations between -30 and -40 degrees, but MSE is not required to meet the science requirements in this range (ii) This requirement does not supersede requirements that explicitly specify an airmass or zenith distance (e.g., the sensitivity requirements, REQ-SRD-034/035/036, are only expected to be met at an airmass of 1.2 as described in those requirements) (iii) A declination of -40 degrees corresponds to an airmass of 2, and a declination of -30 degrees corresponds to an airmass of ~1.55

4.2.22 REQ-SRD-052 Science observing efficiency

[REQ-SRD-052] MSE shall have an average science observing efficiency of at least 80%. Science observing efficiency is defined as the ratio of time spent during the night observing science targets (open shutter time), compared to the time spend during the night conducting all other activities in which the telescope is not collecting photons from a science target. All other night-time activities include time spent configuring the telescope or instrument, reading-out, observing calibration exposures, other overheads, scheduled or unscheduled engineering time, etc. Loses due to weather are excluded from the calculation of science observing efficiency.

Justification: The average length of a night at Maunakea is 9.9 hours, and the historical average of the impact of adverse weather is 2.7 hours per night (using the numbers from CFHT that can be found in Section 1.2 of http://www.cfht.hawaii.edu/Instruments/Imaging/MegaPrime/observingstats.html). This implies there are 2628 hours of potential science observing time per year. In order to complete the multiple Science Reference Observations in a reasonable time, a high science observing efficiency is critical. For example, the completion of the S1-W component of DSC-SRO-06 (which is envisioned as a typical, extensive, legacy survey requiring covering 3200 square degrees) within 1 year of Dark Time requires an 80% science observing efficiency (see also REQ-SRD-021).

Notes: (i) A high value of science observing efficiency is critical to the overall success of MSE. Any increases in the value of this quantity over and above the requirement will produce significant financial savings and increased science impact for the Observatory. (ii) Science calibration exposures are critical to the scientific success of MSE. However, for the purpose of defining this requirement, they are considered as overheads, although this does not reflect on their overall importance to the success of the Observatory (iii) Science observing efficiency is coupled to the field of view (REQ-SRD-021), multiplexing (REQ-SRD-022, REQ-SRD-023, REQ-SRD-024) and sensitivity requirements (REQ-SRD-034, REQ-SRD-035, REQ-SRD-036), since the product of all of these components defines the “survey speed” of MSE. The current justification of Science observing efficiency is coupled directly to REQ-SRD-021.

4.2.23 REQ-SRD-053 Observatory lifetime

[REQ-SRD-053] MSE shall be able to operate for at least 20 years.

Justification: Excluding monitoring surveys, the longest duration SROs that are able to be conducted at first light (Bright time – DSC-SRO-03, DSC-SRO-04; Dark time – DSC-SRO-06, DSC-SRO-08) have an estimated total completion time of ~10 years accounting for the bright/dark time splits. The role of the SROs is to identify high impact programs that are expected to be typical of the scope of MSE science, but which clearly do not describe the totality of MSE science given the diversity and range of science in the DSC (much of which is not addressed by any specific SRO), as well as the clear difficulty in designing programs contemporary to the science landscape of ~2025. Therefore, we estimate the minimum Observatory lifetime to be the time required to complete an overall science program that is at least double in scope from what is currently described by the SROs.

Notes: –

4.2.24 REQ-SRD-061++ Data processing and management