THIRTY METER TELESCOPE

MOBIE FUNCTIONAL AND PERFORMANCE REQUIREMENTS DOCUMENT

TMT.INS.DRD.08.002.DRF01

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1. INTRODUCTION

1.1 INTRODUCTION

This document contains the functional and performance requirements for the Multi-Object Broadband Imaging Echellette (MOBIE), an instrument design for the wide-field optical spectrograph (WFOS) for the TMT.

1.2 PURPOSE

The purposes of this document are to inform the greater TMT scientific, technical, and administrative communities about the features and capabilities of MOBIE, and to provide the instrument development team (engineers, technicians, consultants, vendors, and sub-contractors) with the specific requirements for the instrument design. The FPRD provides the "necessary and sufficient" requirements for the design.

The functional and performance characteristics of the MOBIE system design should be traceable to requirements in this document. The scientific requirements are defined in the TMT Science Requirements Document (SRD), the TMT Observatory Requirements Document (ORD), and the MOBIE Operational Concepts Definition Document (OCDD). The TMT-ORD requirements are summarized here for convenience. The requirements described here are extracted or derived from the TMT SRD, ORD, OCD, OAD, and the MOBIE OCDD.

We expect this document to evolve significantly as the design of the instrument progresses over time.

1.3 SCOPE

There are three first-light instruments planned for TMT: an infrared multi-object spectrograph (IRMS), an infrared integral field spectrograph (IRIS), and a wide field optical spectrograph (WFOS). This document describes the requirements for the Multi-Object Broadband Imaging Echellette (MOBIE), the most recent of several wide-field imaging spectrograph concepts for the TMT. The MOBIE design is independent of the previous designs (CIT-MILES, UC-ELVIS, and HIA-WFOS), and unique in providing both low and medium resolution spectroscopy via a cross-dispersed echellette spectroscopic mode.

This document uses the TMT standard subsystem requirements document template. Section 1 provides an introductory overview. Section 2 defines the boundaries of the MOBIE design with respect to the telescope, summarizes the instrument functions and user characteristics, and lists the external interfaces and design constraints. Section 3 provides the detailed functional and performance requirements for the MOBIE instrument design and all of its subsystems.

1.4 APPLICABLE DOCUMENTS

AD01 – TMT Science Requirements Document (SRD) v17.0, (TMT.PSC.DRD.07.001.DRF01)

AD02 – TMT Operations Concept Document (OCD), (TMT.OPS.MGT.07.002)

AD03 – TMT Observatory Requirements Document (ORD), (TMT.SEN.DRD.05.001)

AD04 – TMT Observatory Architecture Document (OAD), (TMT.SEN.DRD.05.002)

AD05 – Observation Workflow for the TMT (TMT.AOS.TEC.07.013.DRF06)

AD06 – TMT Acronym List (TMT.SEN.COR.06.018.REL01)

AD07 – Nasmyth Instrument Support Requirements Document (TMT.SEN.DRD.06.003.DRF02)

AD08 – MOBIE Feasibility Study Report, (TMT.INS.TEC.08.003.DRF01)

AD09 – MOBIE Interface Control Document, (TMT.INS.ICD.08.006.DRF01)

AD10 – MOBIE Operational Concepts Def. Document, (TMT.INS.DRD.08.003.DRF01)

1.5 REFERENCE DOCUMENTS

RD01 – HIA WFOS Feasibility Study Report (FSR), (TMT.INS.FDD.06.003.REL01)

RD02 – Errata for WFOS Feasibility Study Report, (TMT.INS.ECR.06.007.REL01)

RD03 – Review Committee Report on the WFOS Design for TMT (TMT.INS.COR.06.008.REL01)

RD04 – WFOS Operations Conc. Def. Doc. (OCDD), (TMT.INS.DRD.05.002.DRF01)

RD05 – WFOS Operations Conc. Def. Doc. (OCDD) Appendix 1, (TMT.INS.TEC.06.004.REL01)

RD06 – WFOS Functional Performance Def. Document (FPRD), (TMT.INS.DRD.05.001.DRF06)

RD07 – TMT Nasmyth Instrument Mass Budget, (TMT.INS.TEC.07.004.DRF01)

RD08 – Notes on TMT Instrument Cooling, (TMT.INS.TEC.08.001.DRF01)

RD09 – TMT EAP Final Report, 27 June 2007, (TMT.PMO.COR.07.029.REL01)

RD10 – Appendix to EAP Final Report, 27 June 2007, (TMT.PMO.COR.07.030.REL01)

RD11 – Glazebrook, K. and Bland-Hawthorn J., “Microslit Nod-Shuffle Spectroscopy – a technique for achieving very high densities of spectra”, Astro-Ph/0011104 v1 4 Nov 2000

1.6 CHANGE RECORD

Revision	Date	Section	Modifications
DRF01	June 12, 2008	All	Feasibility-phase Initial draft

1.7 ABBREVIATIONS AND ACRONYMS

ADC – Atmospheric Dispersion Corrector
AO- Adaptive Optics
APS – Alignment and Phasing System (for TMT)
AR – Anti-reflection (coatings)
ASIC – Application-Specific Integrated Circuit
CaF2 – Calcium fluoride
CIT – California Institute of Technology
DMS – Data Management System (for TMT)
EAP – External Advisory Panel (for TMT)
EMI – Electro-Magnetic Interference
FOV – Field of View
FSR – Feasibility Study Report
FPRD – Functional and Performance Requirements Document
HIA – Hertzberg Institute for Astrophysics
HROS – High Resolution Optical Spectrograph (for TMT)
GMS – Global Metrology System (for TMT)
ICD – Interface Control Document
ICS – Instrument Control System
IDMS – Instrument Data Management System
MOBIE – Multi-Object Broadband Imaging Echellette (spectrograph)
MRF – Magneto-Rheological Finishing
OAD – Observatory Architecture Document (for TMT)
OCS – Observatory Control System (for TMT)
OCD – Operation Concepts Document (for TMT)
OCDD – Operational Concepts Definition Document
ORD – Observatory Requirements Document (for TMT)
RFI – Radio Frequency Interference
SAC – Science Advisory Committee
SOW – Statement of Work
SRD – Science Requirements Document (for TMT)
ST – Science Team (for MOBIE-WFOS)
TCS – Telescope Control System
UCSC – University of California, Santa Cruz
UCO – University of California Observatories
UPS – Uninterruptible Power Supply
WBS – Work Breakdown Structure
WFOS – Wide Field Optical Spectrograph (for TMT)

1.8 DEFINITIONS

Nod & Shuffle	An observing mode where the observation is made up of a number of sub-integrations between which the detector charge is 'shuffled' between the object exposure and the sky background exposure. The telescope executes a small pointing change, 'nod', with a significant vector component parallel to the detector direction, to point sequentially at the object and sky background [RD2]. The 'nod vector' is the distance and direction on the sky that the telescope pointing is changed, defined in arcseconds on the sky. The 'shuffle distance' is the distance in the detector parallel direction in which the charge is shuffled, defined in arcseconds referred to the slitmask plane. The 'nod-shuffle period' is the time from the beginning of an object or sky exposure until the beginning of the next object or sky exposure within the same observation. The 'sub-integration exposure time' is the time spent on one object or sky sub-integration. The 'nod-shuffle transition time' is the time from closing one sub-integration and opening for the next sub-integration.

2. OVERALL DESCRIPTION

2.1 PERSPECTIVE

MOBIE, the Multi-Object Broadband Imaging Echellette, is a seeing-limited, wide-field imaging multi-object echellette spectrograph. MOBIE can directly image or create low (R = ~1000) to medium-resolution (R = ~8,000) spectra in two color channels simultaneously, spanning 310-550nm and 500-1000nm passbands respectively. The single-field version of MOBIE views a rectangular field of approximately 4.2 arcmin x 9.6 arcmin (see Figure 1 and Figure 2), resulting in a field area of ~40 square arcminutes, and a maximum slit length of 576 arcsec (single stack of slits).

The MOBIE instrument mounts at the TMT +X Nasmyth focus, coaxial with the telescope elevation axis (see Figure 3 and Figure 4). As the only visible-light instrument planned for early science operations at TMT, the MOBIE design will strive to provide a wide range of highly efficient visible-passband imaging and spectroscopic capability, while striking the challenging balance between cost and complexity

MOBIE operates as a nearly self-sufficient subsystem to the telescope. The instrument is physically supported by the telescope, and exchanges science and engineering data with the telescope through various observatory control systems (TCS, OCS, DMS, and TSS). The instrument is mechanically and kinematically isolated at its mechanical interface to the telescope (at the Nasmyth platform structure), to minimize vibration exchange and gravity-induced distortions that could cause optical performance degradation in either the telescope or the instrument. The instrument is supplied with liquid cooling, electrical power, compressed air, data lines (optical fiber) through a utility/service interface to the telescope. MOBIE will provide internal calibration systems for wavelength calibration and flat fielding, but will also depend on additional external calibration systems (e.g. a flat fielding screen inside the dome).

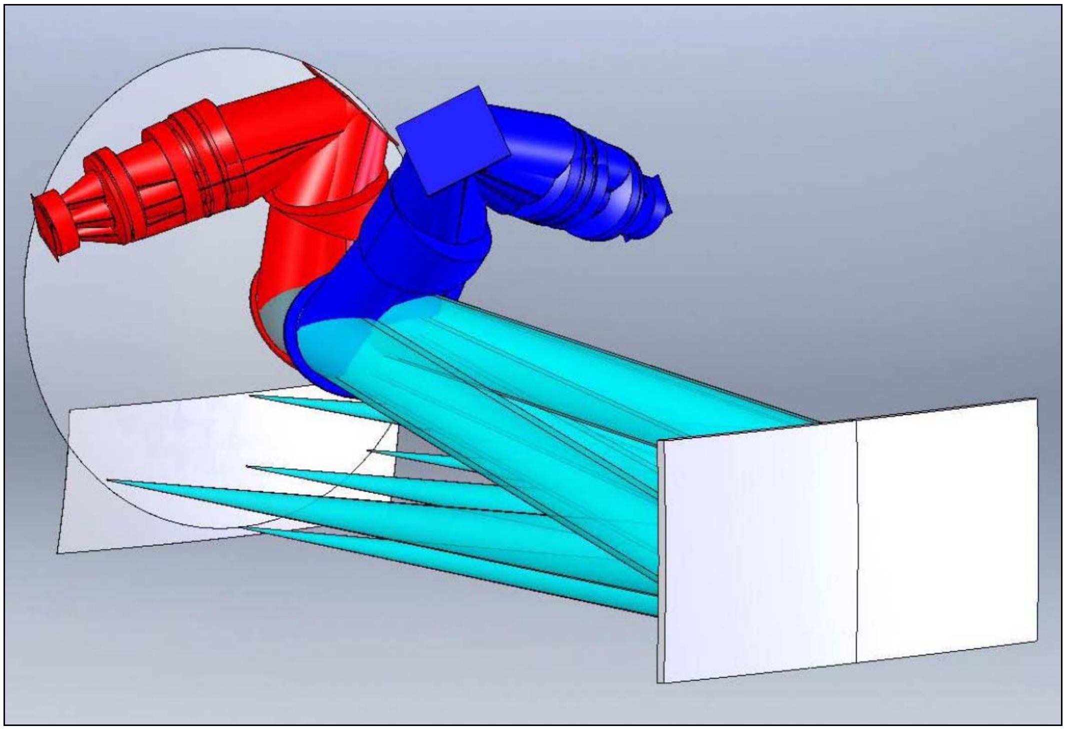

Figure 1. The reflecting collimator version of MOBIE.

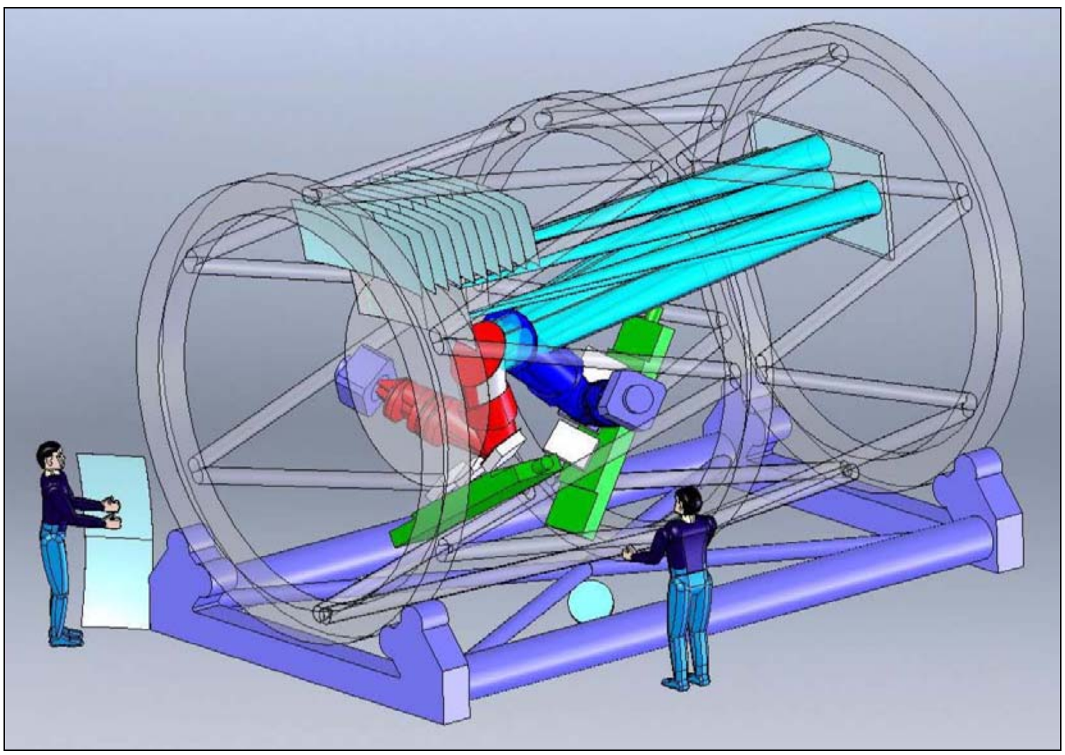

Figure 2. Schematic layout of the MOBIE instrument.

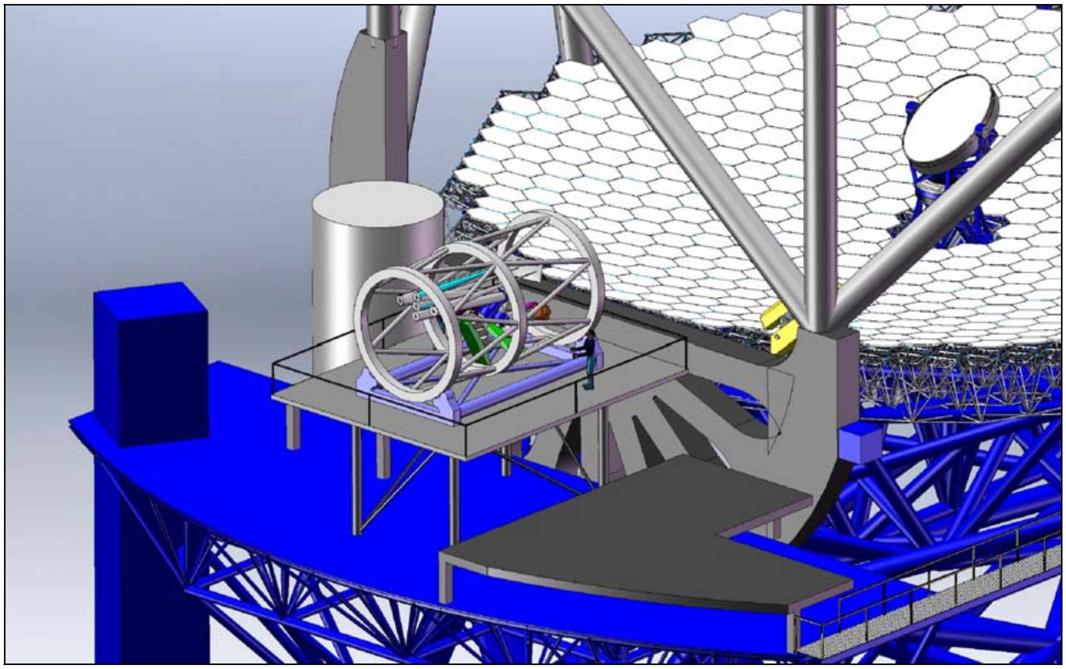

Figure 3. MOBIE shown on the TMT +X Nasmyth platform.

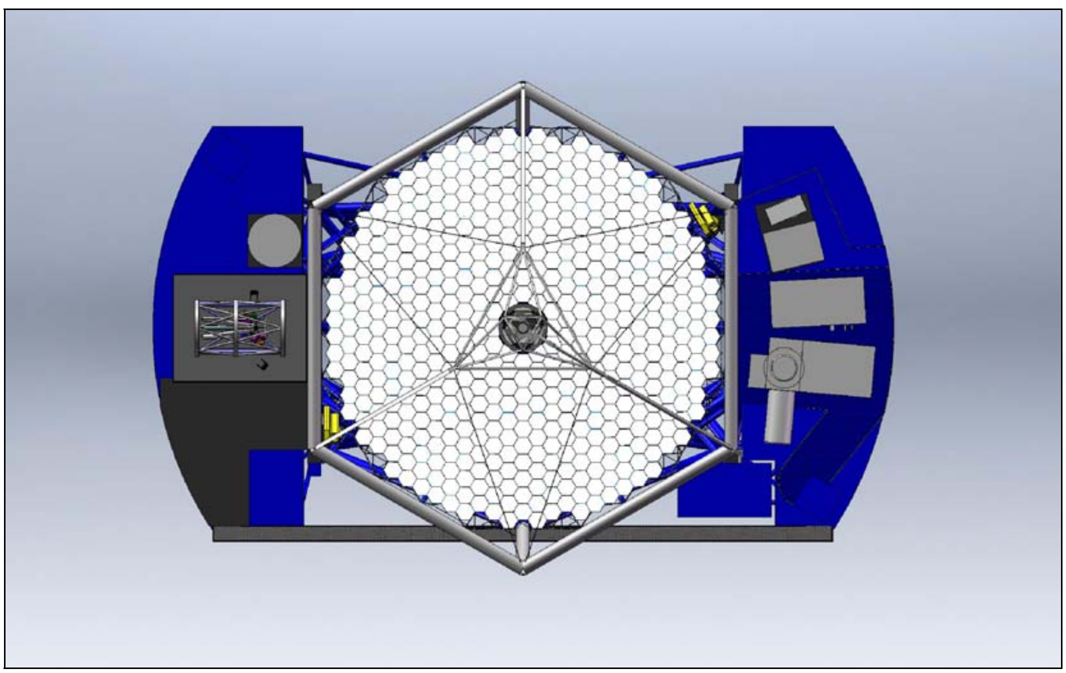

Figure 4. MOBIE on TMT, top view.

2.2 SYSTEM FUNCTIONS

The primary functions of MOBIE are common to existing imaging multi-object spectrographs. These include single and multi-slit spectroscopy, low and medium resolution spectroscopy, and direct imaging (both wide and narrow band). Other common spectroscopic capabilities (e.g. integral field spectroscopy, image slicing spectroscopy, and tunable filter spectroscopy) are not included in the core instrument design, but are considered in the design to the extent that the design does not preclude their addition to the instrument in the future.

The MOBIE instrument will provide the normal range of utility and configurability for a modern astronomical spectrograph and imager, including the following functions:

1. Automated field de-rotation of the instrument with respect to the Nasmyth platform
2. Automated atmospheric dispersion correction
3. Automated control of the enclosure optical entrance hatch
4. Automated control of internal and external calibration systems
5. Automated control of field/object acquisition, direct, and offset telescope guiding
6. Automated guide camera patrol of the telescope field
7. Automated guide camera position control (e.g. for slit-scanning)
8. Automated wavefront sensing camera (WFS) for feedback to telescope alignment and phasing system (APS)
9. Automated WFS patrol of the telescope field
10. Automated insertion of a long slit viewing (LSV) guide camera
11. Automated control of the LSV slit , both width and length
12. Automated selection of light sources for wavelength calibration and detector flat-field calibration
13. Automated selection of multi-slit masks and imaging field stop
14. Automated selection of diffraction gratings, prisms, and fold mirrors for low and medium resolution spectroscopy and direct imaging.
15. Automated selection of spectroscopic and imaging filters
16. Automated control of shutters for precisely timed science detector exposures
17. Automated coordination of telescope and instrument motion during exposures (e.g. to facilitate a “Nod and Shuffle” mode)
18. Automated control of image stability (“flexure control”)
19. Automated control of instrument focus (red and blue channels)
20. Automated configuration and control of the detector systems

2.3 USER AND OPERATOR CHARACTERISTICS

Due to the variety of operating modes offered by the MOBIE design, experienced users of the instrument will have a broad range of choices to make, prior to the observing run, and during set-up and operation of the instrument. For example, multi-slitmasks will be designed by the observer(s), fabricated by the observatory, and then loaded into the instrument prior to the start of a night's observations. Observers will generate the list of fields and objects that will be observed, and will select slitmasks, guiding objects, wavefront sensing objects, calibration sources, filters, resolution modes, and exposure times according to observing plans, and in reaction to weather and other variables.

It is anticipated that observers will work closely with a telescope night assistant, who has responsibility for operation of the telescope, acquisition of the pre-selected target field list, and control of the instrument on-board wavefront sensor and guide cameras.

A key feature of the instrument will be the primary (observer's) graphical user interface, which provides remote control and feedback (visual and audio) for all the user-configurable features of the instrument. A secondary user interface will provide access to instrument subsystem status and telemetry, engineering, trouble-shooting, and maintenance diagnostics. The design of the MOBIE user interfaces will be based on standard TMT user interface standards (TBD), in order to maximize commonality with other instrument and telescope subsystems.

2.4 EXTERNAL INTERFACES

2.4.1 Mechanical Interfaces:

1. Structural interface to the telescope Nasmyth platform
2. Plumbing interface to the telescope liquid cooling system
3. Plumbing interface to the telescope compressed air system
4. Plumbing interface to the telescope dry nitrogen system
5. Plumbing interface to the telescope cryogenic cooling system

2.4.2 Electrical Interfaces:

1. Electrical power interface to the telescope electrical system
2. Service lighting interface to the telescope / observatory control systems
3. Back-up power interface to the telescope UPS electrical system
4. Data interface to the telescope / observatory control systems
5. Wavefront sensor interface to the telescope APS
6. Guide camera interface to the telescope / observatory control systems
7. Long slit viewer camera interface to the telescope / observatory control systems
8. Data (e.g. RS 232) interface to the telescope / observatory control systems
9. Emergency-stop interface to the telescope / observatory safety control systems

10. Audio interface (wired or wireless) to the observatory control room
11. Closed-circuit television interface(s) to the observatory control room

2.4.3 Optical Interfaces:

1. Unbaffled optical interface to the telescope optical system (via the tertiary mirror), accepting direct and stray light.
2. Wavefront sensor interface to the telescope alignment and phasing system (APS)
3. Guide camera interface to the telescope control system (TCS)

2.4.4 Data Interfaces:

1. Instrument configuration database to the observatory control system (OCS)
2. Instrument configuration database to the telescope data management system (DMS)
3. Telescope configuration database to the instrument control system (ICS)
4. WFS images to the alignment and phasing system (APS)
5. Guide camera images to the telescope control system (TCS)
6. Long slit viewer camera images to the telescope control system (TCS)

2.4.5 Interface Control Documents

The initial set of Interface Control Documents (ICDs) expected for the MOBIE-WFOS instrument are listed below.

[INT-STR-WFOS-00010] Telescope structure to MOBIE-WFOS (Nasmyth structure to instrument support structure).

[INT-APS-WFOS-00020] Alignment and Phasing System to MOBIE-WFOS (instrument wavefront sensor data to the APS).

[INT-TCS-WFOS-00030] Telescope Control System to MOBIE-WFOS (reporting of telescope status (pointing, dome location) to the instrument control system).

[INT-TSS-WFOS-00040] Telescope Safety System to MOBIE-WFOS (e.g. bi-directional emergency shutdown signals between the telescope and instruments).

[INT-WFOS-DMS-00050] MOBIE-WFOS to the telescope Data Management System (instrument telemetry and image data to the telescope DMS).

[INT-WFOS-ESW-00060] MOBIE-WFOS to the telescope Executive Software (e.g. coordinated telescope-instrument operation for Nod-and-shuffle exposures).

[INT-WFOS-SOSS-00070] MOBIE-WFOS to the telescope Science Operations Support System (e.g. tracking of instrument slitmask and filter identification numbers, both on-instrument and in storage).

[INT-WFOS-DPS-00080] MOBIE-WFOS to the telescope Data Processing System (e.g. archiving of the instrument image data).

[INT-WFOS-SCMS-00090] MOBIE-WFOS to the telescope Site Conditions Monitoring System (e.g. site conditions stored to instrument science image file headers).

2.5 CONSTRAINTS

The following constraints are expected to apply to the instrument design:

1. Allowed heat load delivered to the telescope enclosure **(TBD)**
2. Allowed heat load delivered to the telescope liquid cooling system **(TBD)**
3. Allowed mass (total) on the +X Nasmyth platform
4. Allowed mass (per mounting point) on the +X Nasmyth platform
5. Allowed volume on the +X Nasmyth platform
6. Allowed location on the +X Nasmyth platform
7. Allowed mass and volume of exchangeable components (e.g. slitmasks, filters)
8. Observatory standard environmental conditions
9. Observatory standard safety regulations
10. Observatory software standards, systems, and design conventions
11. Observatory hardware standards, systems, and design conventions
12. Observatory standards for serviceability and maintainability
13. Observatory standards for electro-magnetic interference (RFI and EMI)

2.6 ASSUMPTIONS AND DEPENDENCIES

The top-level design requirements for the MOBIE design of the TMT WFOS are dependent on the following TMT documents:

- Science Requirements Document (SRD), [AD1]
- Operations Concept Document (OCD), [AD2]
- Observatory Requirements Document (ORD), [AD3]
- Observatory Architecture Document (OAD), [AD4]
- Observation Workflow for the TMT (OWF), [AD5]

One step below the top-level observatory requirements are the derived and instrument-specific requirements in the following documents:

- MOBIE Operational Concepts Definition Document (OCDD), [AD10]
- TMT Nasmyth Instrument Mass Budget, [RD7]

The operational environmental conditions will be dependent on the final site (as yet undetermined) for the TMT observatory. The current operational, non-operational and basis survival conditions are specified in the ORD.

The instrument will be designed, constructed, and partially assembled at a variety of sites, potentially both national and international. Final integration of the instrument will occur at UCSC, Santa Cruz, California. All parts and sub-assemblies will be designed to survive multiple occurrences of shipping and handling, including extended exposure to the elements (e.g. airport gate aprons) prior to final integration and installation at the observatory site. In general, it is assumed that all parts and subsystems will be designed, fabricated, and packed to survive the transportation loads (shock and vibration), and atmospheric environments (pressure, temperature, humidity).

3. SPECIFIC REQUIREMENTS

3.1 GENERAL CONSTRAINTS

3.1.1 Mass

[REQ-2-WFOS-01010] The total mass of the instrument shall not exceed 32 metric tons (32,000 Kg = 70,400 lbs).

Discussion: The mass allowances for the Nasmyth platform instruments are defined in TMT.INS.TEC.07.004.DRF01, "TMT Nasmyth Instrument Mass Budget". This mass limit applies to all parts of the instrument that are supported by the Nasmyth platform, with the exception of separate cabinets for the instrument electronics and servicing tools.

[REQ-2-WFOS-01020] The total mass of the instrument supporting cabinets (electronics and servicing tools) shall not exceed 1000 Kg.

Discussion: The mass allowance for the Nasmyth platform instruments is defined in TMT.INS.TEC.07.004.DRF01, "TMT Nasmyth Instrument Mass Budget". This mass limit applies to the separate cabinets for the instrument electronics and servicing tools.

3.1.2 Volume

[REQ-2-WFOS-01030] The volume of the instrument shall not exceed the boundaries of a horizontal cylinder 7m in diameter, and 11.7m long.

Discussion: The telescope f/15 focal surface vertex lies on the elevation axis, 3.2m inside the cylindrical volume. The volume allowances for the Nasmyth platform instruments are defined in Table 9 of the OAD.

[REQ-2-WFOS-01040] The volumes for the electronics and tool cabinets shall not exceed (each) the boundaries of 1.2m wide x 2.5m high x 0.5m deep.

Discussion: The volume allowances for the Nasmyth platform instrument electronics and tool cabinets are defined in TMT.INS.TEC.07.004.DRF01, "TMT Nasmyth Instrument Mass Budget".

3.1.3 Power Consumption

[REQ-2-WFOS-01050] Power consumption from the telescope clean power system shall not exceed 3000W (**TBD).**

Discussion: "Clean" power refers to 60Hz, voltage-regulated power, free from spikes, noise, etc.

[REQ-2-WFOS-01060] Power consumption from the telescope "dirty" power system shall not exceed 3000W (**TBD).**

Discussion: "Dirty" power refers to unregulated "utility line" power that may fluctuate in voltage and frequency.

[REQ-2-WFOS-01070] Power consumption from the telescope uninterruptable power system (UPS) shall not exceed 3000W (**TBD).**

Discussion: "UPS" power refers to locally provided emergency power, free from spikes, noise, etc.

3.1.4 Heat Dissipation

[REQ-2-WFOS-01080] Heat rejection from the instrument into the dome free air shall not exceed 300 W **(TBD).**

[REQ-2-WFOS-01090] Heat rejection from the instrument into the Nasmyth platform (via conduction) shall not exceed 100 W (**TBD).**

[REQ-2-WFOS-01100] Heat rejection from the instrument into the telescope liquid cooling system shall not exceed 8000W (**TBD).**

Discussion: As of the date of the writing of this document, the TMT project has yet to develop a heat dissipation budget for the observatory. These requirements will be revised to reflect the observatory heat budget when it becomes available.

3.2 ENVIRONMENTAL CONSTRAINTS

3.2.1 Operational Environment

[REQ-2-WFOS-02010] The instrument shall meet all of its performance requirements while operating within the range of TMT operational performance conditions specified in the ORD.

[REQ-2-WFOS-02020] The instrument shall meet all requirements while operating within the range of TMT observing conditions specified in the ORD.

Discussion: The ORD specifies the temperature range, humidity, and wind velocity during operation and astronomical observations at TMT, as well as survival conditions for weather and earthquakes.

[REQ-2-WFOS-02030] The instrument shall meet all requirements while operating at the final integration site (UCSC).

Discussion: The final integration site is assumed to be in Santa Cruz, California, within 200m of sea level. This requirement implies that the instrument, and especially the optical systems, should operate at sea-level atmospheric pressure and room temperatures (e.g. 15C – 25C).

3.2.2 Non-Operational Environment

[REQ-2-WFOS-02040] The instrument shall meet the appropriate sub-set of its performance requirements while operating within the range of TMT non-operational conditions specified in the ORD.

Discussion: The non-observing facility-operating conditions are those when the aperture and vents are closed, but when servicing and maintenance are undertaken. These conditions include the range of temperature, humidity, rainfall, and possible lightning strikes outside the dome while servicing is underway. The instrument should perform the appropriate range of pre-observing functions during this time (calibration, slitmask set-up, etc).

3.2.3 Operational Basis Survival Conditions

[REQ-2-WFOS-02050] The instrument shall be designed to survive repeated operational basis survival conditions without damage.

Discussion: The operational basis survival conditions are specified in the ORD.

3.2.4 Shipping and Transport Survival Conditions

[REQ-2-WFOS-02060] The instrument shall be transportable in a partially disassembled state.

[REQ-2-WFOS-02070] The instrument subsystems shall be transported in partially disassembled states, based on the environmental sensitivity of the individual subsystem to thermal and dynamic loads.

[REQ-2-WFOS-02080] Optical components will be shipped in shock-mounted, thermally insulated containers.

[REQ-2-WFOS-02080] Thermally-sensitive sub-assemblies (e.g. optical subsystems) shall be allowed to equilibrate to local ambient temperatures for at least 24 hours (or as specified) prior to opening.

3.3 FUNCTIONAL REQUIREMENTS

3.3.1 Instrument Rotator

The instrument rotator system (IRS) supports the rotating mass of the instrument, and drives the instrument structure to follow the rotation of the telescope's field of view. The requirements here address:

- Control of instrument rotation
- Alignment features
- Mounting features
- Servicing features
- Utility interfaces and routing
- Heat transfer between the telescope and instrument structures
- Initial assembly, testing, and integration

[REQ-2-WFOS-03010] The instrument design shall include an IRS that carries the rotating portion of the instrument.

Discussion: This requirement flows from REQ-1-ORD-2705, and MOBIE OCDD sections 2.2 and 2.3.20.

[REQ-2-WFOS-03020] The IRS shall provide remote-control of the rotation angle and velocity of the instrument structure (to follow field rotation at the telescope Nasmyth focus).

Discussion: This requirement flows from REQ-1-ORD-2705, and MOBIE OCDD sections 2.2 and 2.3.20.

[REQ-2-WFOS-03030] The IRS shall include metrology features (e.g. interfaces for corner cubes) for alignment of the IRS to the telescope with the Global Metrology System (GMS).

[REQ-2-WFOS-03040] The IRS shall provide a kinematic mounting interface between the telescope and the instrument.

[REQ-2-WFOS-03050] The IRS mounting points shall attach to the Nasmyth platform's instrument mounting points.

[REQ-2-WFOS-03060] The IRS shall provide means for carrying telescope utilities (electric power, ethernet, etc) from the junction point on the Nasmyth platform to the instrument utility wrap.

Discussion: This may include conduit or other specialized cabling and plumbing management systems.

[REQ-2-WFOS-03070] The IRS shall provide a means for controlling conductive heat transfer between the instrument and the Nasmyth platform.

[REQ-2-WFOS-03080] The IRS shall provide features (e.g. platforms, hand-holds, steps) to facilitate routine service operations on the IRS and inside the instrument (e.g. slitmask exchange).

[REQ-2-WFOS-03090] The IRS shall provide a means for transferring utilities (power, ethernet, compressed air, etc) from the stationary IRS to the rotating IS (i.e. a utility wrap).

[REQ-2-WFOS-03100] The IRS system shall be operable in a stand-alone fashion (independent of the telescope), to facilitate alignment, testing and integration of the instrument prior to delivery.

3.3.2 Instrument Structure

The instrument structure (IS) supports all of the on-board instrument subsystems, including the optical systems, motion stages, etc. The requirements here address:

- Mounting interfaces
- Alignment features
- Metrology features
- Servicing features
- Utility interfaces and routing
- Internal stray light controls
- Initial assembly, testing, and integration

[REQ-2-WFOS-04010] The instrument design shall include an instrument structure (IS) that provides the framework for supporting all of the rotating instrument subsystems.

Discussion: This requirement flows directly from MOBIE OCDD sections 2.2.

[REQ-2-WFOS-04020] The IS shall provide mounting interfaces (kinematic or other) for all the instrument subsystems which rotate with the IS.

[REQ-2-WFOS-04030] The IS shall include metrology features (e.g. interfaces for corner cubes) for alignment of the IS to the telescope with the Global Metrology System (GMS).

[REQ-2-WFOS-04040] The IS shall include metrology features (e.g. interfaces for corner cubes) to facilitate installation and alignment of the instrument subsystems on the IS.

[REQ-2-WFOS-04050] The IS shall provide features (e.g. platforms, hand-holds, steps) to facilitate routine service operations on and inside the instrument (e.g. filter exchanges).

[REQ-2-WFOS-04060] The IS shall provide means for routing utilities from the utility wrap to each of the instrument subsystem as required (e.g. electrical harnesses, compressed air plumbing, liquid cooling plumbing, etc).

Discussion: This may include conduit or other specialized cabling and plumbing management systems.

[REQ-2-WFOS-04070] The IS shall provide internal stray light controls (e.g. baffles, aperture stops) between the instrument optical subsystems.

[REQ-2-WFOS-04080] The IS and IRS systems shall be operable together, in a stand-alone fashion (independent of the telescope), to facilitate alignment, testing and integration of the instrument prior to delivery.

3.3.3 Atmospheric Dispersion Corrector

An atmospheric dispersion corrector (ADC) compensates for variable dispersion caused by the atmosphere, as a function of the telescope's elevation angle. The requirements here address:

- Vignetting
- Alignment features
- Metrology features
- Servicing features
- Initial assembly, testing, and integration

[REQ-2-WFOS-05010] The instrument shall provide atmospheric dispersion correctors (ADC) for all instrument fields of view.

Discussion: This requirement flows directly from REQ-1-ORD-2950, REQ-1-ORD-3910, and MOBIE OCDD sections 2.2 and 2.3.14.

[REQ-2-WFOS-05020] The ADC shall be permanently mounted in the optical path.

Discussion: The requirement flows from the SRD V17.5, section 2.5.3.5 (the ADC may be permanently mounted in place (i.e. not removable from the beam) as long as its optical throughput is 95% or greater).

[REQ-2-WFOS-05030] The ADC system(s) shall operate over the full range of telescope observing elevation angles.

[REQ-2-WFOS-05040] The ADC system(s) shall not vignette any part of the optically active fields of the instrument.

[REQ-2-WFOS-05050] The ADC shall be functionally operable (motion control, etc) in a stand-alone fashion, to facilitate testing and integration with the instrument.

[REQ-2-WFOS-05060] The ADC systems shall include metrology features (e.g. interfaces for corner cubes) to facilitate initial alignment of the instrument.

[REQ-2-WFOS-05070] The ADC systems shall include indexed mounting features, to facilitate repeatable removal and re-installation of the ADC assembly from the instrument, without requiring re-alignment of the instrument optical system.

[REQ-2-WFOS-05080] The ADC system(s) shall include features to enable in situ cleaning of exposed optical surfaces.

[REQ-2-WFOS-05090] The ADC system(s) design shall include stray-light controls for baffling the entrance to the instrument.

Discussion: This requirement flows from REQ-1-ORD-2940. The telescope will not be baffled; the instruments are required to provide their own internal baffling.

3.3.4 Telescope Field Corrector

The telescope field corrector (FC) corrects the field-radius-dependent residual aberrations from the telescope optical system. The field correcting functions may be merged into the ADC optics (see below) at a later date. The requirements here address:

- Alignment features
- Metrology features
- Servicing features
- Initial assembly, testing, and integration

[REQ-2-WFOS-06010] The instrument shall provide optical correction of the field for all instrument fields of view.

[REQ-2-WFOS-06020] The FC system(s) shall not vignette any part of the optically active fields of the instrument.

[REQ-2-WFOS-06030] The FC system(s) shall be functionally operable in a stand-alone fashion, to facilitate testing and integration with the instrument.

[REQ-2-WFOS-06040] The FC system(s) shall include metrology features (e.g. interfaces for corner cubes) to facilitate initial alignment of the instrument.

[REQ-2-WFOS-06050] The FC systems shall include indexed mounting features, to facilitate repeatable removal and re-installation of the ADC assembly from the instrument, without requiring re-alignment of the instrument optical system.

[REQ-2-WFOS-06060] The FC system(s) shall include features to enable in situ cleaning of exposed optical surfaces.

3.3.5 Calibration Systems

The calibration system (CAL) provides a means for wavelength calibration for spectroscopic modes, and a means for flat-field calibration of the science detectors. The calibration system may include internal (within the instrument) and external (observatory) subsystems. The requirements here address:

- Optical systems
- Light sources for wavelength calibrations
- Light sources for flat-field calibrations
- Alignment features
- Metrology features
- Servicing features

- Initial assembly, testing, and integration

[REQ-2-WFOS-07010] The instrument shall provide an internal wavelength calibration system (CAL) for spectroscopic operating modes, and internal incandescent lamps for flat fielding in imaging mode. These light sources may be used in conjunction with a diffuser slide in the filter server systems (FSS).

Discussion: This requirement for the generation of internal calibration data flows from REQ-1-ORD-2545 and MOBIE OCDD sections 2.2 and 4.4.

[REQ-2-WFOS-07020] The CAL shall include an optical system for internally illuminating the instrument focal planes.

[REQ-2-WFOS-07030] The CAL shall include light sources for flat-field illumination of the instrument focal planes.

[REQ-2-WFOS-07040] The CAL shall include light sources for wavelength calibration of the instrument focal planes.

[REQ-2-WFOS-07050] The CAL light sources shall generate calibration light across the full operating wavelength range of the instrument.

[REQ-2-WFOS-07060] The CAL optics shall provide features to enable in situ cleaning of exposed optical surfaces.

[REQ-2-WFOS-07070] The CAL shall include indexed mounting features, to facilitate repeatable removal and re-installation of the system on the instrument.

[REQ-2-WFOS-07080] The CAL shall be operable in a stand-alone fashion, to facilitate testing and integration with the instrument.

3.3.6 Wavefront Sensors

Wavefront sensors (WFS) are mounted on the instrument, to provide feedback to the telescope alignment and phasing system (APS). The WFS systems will be operationally identical to the guide camera(s) (GCM, see below), in order to maximize the available field size for acquiring reference objects (for wavefront sensing) and guide stars (for guiding the telescope). The requirements here address:

- Interoperability with guide cameras
- Patrol of the telescope focal plane
- Pupil sampling with lenslet arrays
- Optical filters
- Control and display of WFS/GCM images
- Alignment features
- Metrology features
- Servicing features
- Initial assembly, testing, and integration

[REQ-2-WFOS-08010] The instrument shall provide one active optics wavefront sensor (WFS), including optical and detector systems, for each observational field channel.

Discussion: This requirement flows directly from REQ-1-ORD-2670 and REQ-1-ORD-3912.

[REQ-2-WFOS-08020] The design of the WFS system shall provide identical functionality with the GCM, such that WFS and guide camera systems can be operated interchangeably.

Discussion: This requirement flows from MOBIE OCDD section 2.3.19, and maximizes the available field of view for wavefront sensing sources and telescope guiding objects.

[REQ-2-WFOS-08030] The location of the WFS with respect to the observing field shall be remotely controllable over a continuous range of travel (a continuous patrol area).

Discussion: This requirement assumes that the WFS field of view will not be large enough for find a suitable guiding object over the full field of view accessible by the telescope.

[REQ-2-WFOS-08040] The WFS shall provide a 6x6 (**TBC**) array of pupil sub-apertures to provide feedback to the telescope APS.

Discussion: this requirement flows directly from REQ-1-ORD-3913.

[REQ-2-WFOS-08050] The WFS shall provide a high-density (density **TBD**) array of pupil sub-apertures to provide independent confirmation of the alignment of the telescope for analysis of MOBIE performance.

[REQ-2-WFOS-08060] The WFS pupil-sampling lenslet arrays shall be remotely selectable.

[REQ-2-WFOS-08070] The WFS filters shall remotely selectable.

Discussion: this requirement follows from the need to enable WFS or guiding over a wide range of object brightness (magnitude).

[REQ-2-WFOS-08080] The WFS shall be operable in a direct-imaging mode.

[REQ-2-WFOS-08090] The WFS control system shall provide means for capturing, displaying, transferring, logging, and saving images via the instrument control system.

[REQ-2-WFOS-08100] The WFS systems shall be operable in a stand-alone fashion, to facilitate testing and integration with the instrument.

[REQ-2-WFOS-08110] The WFS systems shall include metrology features (e.g. interfaces for corner cubes) to facilitate initial alignment of the instrument.

[REQ-2-WFOS-08120] The WFS systems shall include indexed mounting features, to facilitate repeatable removal and re-installation of the WFS assembly from the instrument, without requiring re-alignment of the optical system.

[REQ-2-WFOS-08130] The WFS, GCM, and LSV shall use a common detector system.

[REQ-2-WFOS-00140] The WFS detector system shall include indexed mounting features, to facilitate repeatable removal and installation of the detector system from the WFS system.

3.3.7 Guide Camera Systems

Guide cameras (GCM) are mounted on the instrument, to provide feedback to the telescope control system. The GCM systems will be operationally identical to the WFS (see above), in order to maximize the available field size for acquiring reference objects (for wavefront sensing) and guide stars (for guiding the telescope). The requirements here address:

- Interoperability with the WFS
- Patrol of the telescope focal plane
- Pupil sampling with lenslet arrays
- Optical filters
- Control and display of WFS/GCM images
- Alignment features
- Metrology features
- Servicing features
- Initial assembly, testing, and integration

[REQ-2-WFOS-09010] The instrument shall provide a guide camera (GCM) system, including detector system, for each field channel.

Discussion: This requirement flows directly from REQ-1-ORD-2670 and REQ-1-ORD-3912.

[REQ-2-WFOS-09020] The design of the WFS system shall provide identical functionality with the GCM, such that WFS and guide camera systems can be operated interchangeably.

Discussion: This requirement flows from MOBIE OCDD section 2.3.19, and maximizes the available field of view for wavefront sensing sources and telescope guiding objects.

[REQ-2-WFOS-09030] The location of the GCM system with respect to the observing field shall be remotely controllable over a continuous range of travel (a continuous patrol area).

Discussion: This requirement assumes that the guider field of view will not be large enough for find a suitable guiding object over the full field of view accessible by the telescope.

[REQ-2-WFOS-09040] The GCM systems shall provide a remotely selectable filter.

[REQ-2-WFOS-09050] The GCM shall be operable in a direct-imaging mode.

[REQ-2-WFOS-09060] The GCM control system shall provide a means for capturing, transferring and saving images via the instrument control system.

[REQ-2-WFOS-09070] The GCM systems shall be operable in a stand-alone fashion, to facilitate testing and integration with the instrument.

[REQ-2-WFOS-09080] The GCM systems shall include metrology features (e.g. interfaces for corner cubes) to facilitate initial alignment of the instrument.

[REQ-2-WFOS-09090] The GCM systems shall include indexed mounting features, to facilitate repeatable removal and re-installation of the GCM assembly from the instrument, without requiring re-alignment of the optical system.

[REQ-2-WFOS-09100] The GCM, WFS, and LSV shall use a common detector system.

[REQ-2-WFOS-09110] The GCM detector system shall include indexed mounting features, to facilitate repeatable removal and installation of the detector system from the GC system.

3.3.8 Long Slit Viewer

The Long Slit Viewer (LSV) provides a means for rapid acquisition, guiding, wavefront sensing, and viewing of a long slit for single-object spectroscopy. The LSV is normally parked outside of the instrument field of view. When in use, the LSV inserts into the optical path, and presents a tilted slit on the telescope focal surface. The tilt angle allows the beam reflected from the slit to enter the LSV camera, such that the target object and slit can be viewed simultaneously.

The requirements here address:

- Wavefront sensing function
- Guiding function
- Slit viewing function
- Pupil sampling with lenslet arrays
- Selection of long slits
- Optical filters
- Control and display of LSV images
- Alignment features
- Metrology features
- Servicing features
- Initial assembly, testing, and integration

[REQ-2-WFOS-10010] The instrument shall provide a single long slit viewer (LSV) system, regardless of the number of fields of view.

Discussion: This requirement flows from section 2.5.3.10 of the SRD, for rapid acquisition of transient objects, and from MOBIE OCDD section 2.3.5.

[REQ-2-WFOS-10020] The design of the LSV system shall provide a wavefront sensing optical channel, common with the WFS, such that the LSV can provide wavefront sensing.

[REQ-2-WFOS-10030] The LSV shall provide a 6x6 (**TBC**) array of pupil sub-apertures to provide feedback to the telescope APS.

Discussion: this requirement flows directly from REQ-1-ORD-3913.

[REQ-2-WFOS-10040] The LSV shall provide a high-density (density **TBD**) array of pupil sub-apertures to provide independent confirmation of the alignment of the telescope for analysis of MOBIE performance.

[REQ-2-WFOS-10050] The design of the LSV system shall provide a direct imaging optical channel, common with the GCM, such that the LSV can provide both guiding and slit viewing functions.

[REQ-2-WFOS-10060] The design of the LSV shall provide a means for selecting from a set of slit-length and slit-width combinations.

Discussion: This requirement flow from MOBIE OCDD section 2.3.5, for rapid target acquisition and single-object spectroscopy.

[REQ-2-WFOS-10070] The LSV optical systems shall provide remotely selectable filters.

[REQ-2-WFOS-10080] The LSV shall be operable in a direct-imaging mode.

[REQ-2-WFOS-10090] The LSV control system shall provide a means for capturing, transferring and saving images via the instrument control system.

[REQ-2-WFOS-10100] The LSV system shall be operable in a stand-alone fashion, to facilitate testing and integration with the instrument.

[REQ-2-WFOS-10110] The LSV system shall include metrology features (e.g. interfaces for corner cubes) to facilitate initial alignment of the instrument.

[REQ-2-WFOS-10120] The LSV system shall include indexed mounting features, to facilitate repeatable removal and re-installation of the LSV assembly from the instrument, without requiring re-alignment of the optical system.

[REQ-2-WFOS-10130] The LSV, WFS, and GCM systems shall use a common detector system.

[REQ-2-WFOS-10140] The LSV detector system shall include indexed mounting features, to facilitate repeatable removal and installation of the detector system from the GC system.

3.3.9 Focal Plane Server

The focal plane server (FPS) enables remote-controlled selection of slit masks (or other focal plane accessories) from an exchangeable selection carried on the instrument. The requirements here address:

- Selection of slitmasks
- Accessory masks
- Slitmask material
- Slitmask sensing
- Flexure control
- Alignment features
- Metrology features
- Servicing features
- Initial assembly, testing, and integration

[REQ-2-WFOS-11010] The instrument shall provide means for taking spectra of multiple objects in each field of view.

Discussion: This requirement flows directly from REQ-1-ORD-3900 (seeing-limited multi-object optical spectrometer and imager), and from MOBIE OCDD section 2.3.2 and 2.3.3.

[REQ-2-WFOS-11020] The instrument shall provide a focal plane server (FPS) system for each field of view.

Discussion: This requirement flows directly from REQ-1-ORD-3900 (seeing-limited multi-object optical spectrometer and imager), and from MOBIE OCDD section 2.3.2 and 2.3.3.

[REQ-2-WFOS-11030] The FPS system(s) shall provide remote-controlled selection from a set of focal plane accessories (including, but not limited to slitmasks).

Discussion: This requirement flows from MOBIE OCDD section 2.3.6. Other "accessories" (e.g. integral field units, image slicers) are not at planed at this time, but could be added in the future, in modules which the FPS system sees as identical to the slit masks.

[REQ-2-WFOS-11040] The instrument shall provide a focal plane mapping mask, for calibrating distortion of the telescope focal surface.

Discussion: This requirement flows from MOBIE OCDD sections 2.3.3, 2.3.16, and 4.2. Calibration of focal plane distortion can be mapped with an array of regularly spaced pin-holes on a standard slitmask. This is often called a pin-hole grid mask.

[REQ-2-WFOS-11050] The slitmask blank coefficient of thermal expansion shall be matched to the change in the plate scale of the telescope focal plane with temperature.

Discussion: Although the telescope optics may be made from low or zero-expansion materials, the telescope structure will not. This may result in a temperature dependent focal plane scale. The slitmask material should match this temperature dependency in order to maximize the usable temperature range for the mask

[REQ-2-WFOS-11060] The focal plane accessories shall have standardized dimensions (length, width, height, mass, interface).

[REQ-2-WFOS-11070] The FPS system shall be able to store, select, and transfer any single accessory item the height of which does not exceed a total height of 1-4 times [**TBD**] the standard accessory height.

Discussion: Focal plane accessories, such as integral field units, may require greater height (length along the optical axis) than a standard slitmask unit.

[REQ-2-WFOS-11080] The FPS system shall be able to select and transfer a single accessory item of a mass no greater than TBD times the standard accessory unit mass.

Discussion: Focal plane accessories, such as integral field units, are likely to be more massive than a standard slitmask.

[REQ-2-WFOS-11090] The FPS system shall provide a field stop mask unit, to control the shape of the entrance aperture(s) for the direct imaging mode.

[REQ-2-WFOS-11100] The FPS system(s) shall provide a system to sense and identify the loaded focal plane accessories carried in the FPS system, and to identify the item currently installed at the telescope focal position.

[REQ-2-WFOS-11110] The FPS system(s) shall provide a means for supplying flexure sensing light for measurement at the instrument focal plane (DET).

Discussion: Flexure control may be active (closed-loop control) or passive (open-loop control). Flexure sensing may be accomplished with sky sources (sky lines or objects) transmitted through holes in the slit masks defined for this purpose, or with fixed light sources located at the slit mask focal surface.

[REQ-2-WFOS-11120] In the event of two or more fields of view on the instrument, at least one FPS shall provide a means for alignment (XY position, and rotation about the optical axis) of the focal plane accessory (e.g. slitmask), with respect to the telescope focal surface.

[REQ-2-WFOS-11130] The FPS system(s) shall provide a user-friendly means for manual loading and unloading of focal plane accessories from the selection mechanism.

Discussion: A set of focal plane accessories will usually be loaded into the FPS prior to each observing night. The process of removing items from the previous night, and loading new items, should be made as simple as possible.

[REQ-2-WFOS-11140] The FPS system(s) shall provide continuous mechanical support and mechanical guidance for a focal plane accessory as it is transferred from the selection system to the active position at the focal surface.

Discussion: Mechanisms which transfer items from one subsystem to another (e.g. jukebox mechanisms) are prone to misalignment and jamming. The position and velocity of the transferring item should be controlled throughout the transfer.

[REQ-2-WFOS-11150] The FPS systems shall be operable in a stand-alone fashion, to facilitate alignment, testing and integration with the instrument.

[REQ-2-WFOS-11160] The FPS systems shall include metrology features (e.g. interfaces for corner cubes) to facilitate initial alignment of the instrument.

[REQ-2-WFOS-11170] The FPS systems shall include indexed mounting features, to facilitate repeatable removal and re-installation of the FPS assembly from the instrument, without re-alignment of the optical system.

3.3.10 Collimator

The collimator optical system (COL) creates a pupil at which the dispersing optics will operate. It is assumed here that the collimator is a reflecting optic, although refracting designs also exist. The requirements here address:

- Focus and flexure control
- Alignment features
- Metrology features
- Servicing features
- Initial assembly, testing, and integration

[REQ-2-WFOS-12010] The instrument optical design shall include a COL system for each field of view, to generate sharp and controlled (i.e. baffled) image of the telescope pupil.

Discussion: this requirement flows directly from REQ-1-ORD-3915 (goal for full wavelength coverage in each science exposure) and REQ-1-ORD-3940 (internal baffling). The most critical location for the internal baffling is at the image of the telescope exit pupil, which is formed by the collimator systems.

[REQ-2-WFOS-12020] The COL support assembly shall be actuated to provide for focus control of the collimator with respect to the slit focal surface.

Discussion: Thermal expansion of the instrument structure is expected to alter the collimator focal distance, which will be compensated by remote control of the collimator vertex position (focus).

[REQ-2-WFOS-12030] The COL support assembly shall be actuated to provide tip/tilts motion for compensating instrument flexure.

Discussion: This requirement flows from REQ-1-ORD-3995 (flexure-induced image motion of less than 0.15 arcsec at the detector). With two color channels, flexure control motions of the collimator mirror will only be able to correct common path flexure errors in the red and blue channels. The red and blue focal planes will also be actuated to correct non-common path flexure.

[REQ-2-WFOS-12040] The COL system shall include metrology features (e.g. interfaces for corner cubes) to facilitate the testing and initial alignment of the instrument optical system.

[REQ-2-WFOS-12050] The COL system shall be operable in a stand-alone fashion, to facilitate alignment, testing and integration with the instrument.

[REQ-2-WFOS-12060] The COL system shall include indexed mounting features, to facilitate removal and re-installation from/to the instrument, without requiring re-alignment of the optical system.

[REQ-2-WFOS-12070] The COL optic(s) mount shall provide features to enable in situ cleaning of exposed optical surfaces.

3.3.11 Dichroics

The fixed dichroic system (DCR) includes the dichroic beam-splitting optic and the supporting opto-mechanics, which split the optical system into red and blue channels, following the collimator. The requirements here address:

- Alignment features
- Metrology features
- Servicing features
- Initial assembly, testing, and integration

[REQ-2-WFOS-13010] The instrument optical design shall contain means for separating the instrument optical path into two color channels.

Discussion: This requirement flows directly from REQ-1-ORD-3915. Color beam-splitting is typically accomplished with a dichroic. Separation of the beam into red and blue color channels enables the selection of channel-specific high transmission optical materials, AR coatings, and detectors for highest efficiency.

[REQ-2-WFOS-13020] The dichroic shall be mounted in a frame that can be (manually) repeatably removed and exchanged from the DCR system for maintenance or replacement.

Discussion: This requirement flows directly from MOBIE OCDD section 2.3.8.

[REQ-2-WFOS-13030] The DCR system shall include indexed mounting features, to facilitate repeatable removal and re-installation of the DCR system from the instrument without requiring re-alignment of the optical system.

[REQ-2-WFOS-13040] The DCR system shall include metrology features (e.g. interfaces for corner cubes) to facilitate the testing and initial alignment of the instrument optical system.

[REQ-2-WFOS-13050] The DCR system shall provide features to enable in situ cleaning of exposed optical surfaces.

3.3.12 Echellette Prisms

The echellette servers (ECH) enable the echellette spectroscopic mode, in each color channel, by inserting a cross-dispersing prism into the optical path. The requirements here address:

- Motion control
- Alignment features
- Metrology features
- Servicing features
- Initial assembly, testing, and integration

[REQ-2-WFOS-14010] The instrument shall provide a remote-controlled prism server that can insert and retract a single prism (cross-dispersing optic) in each color channel.

Discussion: The prism server enables the cross-dispersed spectroscopic (echellette) mode, which flows from a goal in REQ-1-ORD-3930, and from the MOBIE OCDD, section 2.3.1.

[REQ-2-WFOS-14020] The ECH optics shall be mounted in frames that can be (manually) repeatably removed and exchanged from the prism server.

[REQ-2-WFOS-14030] The ECH systems shall include indexed mounting features, to facilitate repeatable removal and re-installation of the ECH system from the instrument without requiring re-alignment of the optical system.

[REQ-2-WFOS-14040] The ECH systems shall include metrology features (e.g. interfaces for corner cubes) to facilitate the testing and initial alignment of the instrument optical system.

[REQ-2-WFOS-14050] The ECH systems shall be operable in a stand-alone fashion, to facilitate alignment, testing and integration with the instrument.

[REQ-2-WFOS-14060] The ECH systems shall provide features to enable in situ cleaning of exposed optical surfaces.

3.3.13 Disperser Servers

The disperser server systems (DSS), one per color channel, enable the exchange of optics to switch between imaging or spectroscopic modes. The requirements here address:

- Motion control
- Optics exchangeable units
- Alignment features
- Metrology features
- Servicing features
- Initial assembly, testing, and integration

[REQ-2-WFOS-15010] The instrument design shall provide a means for remote-control selection of gratings and mirrors, at the location of the collimator exit pupil, in each color channel.

Discussion: This requirement flows directly from REQ-1-ORD-3905 (imaging and spectroscopy of the same fields). The primary dispersion elements (gratings) are located at the exit pupil of the collimator, and must be exchangeable (or replaced by a mirror) to enable multiple spectroscopic/imaging modes for the instrument. This requirement also flows from MOBIE OCDD section 2.3.1 and 2.3.2.

[REQ-2-WFOS-15020] A Disperser Server System (DSS) shall be provided for each field of view of the instrument.

Discussion: This requirement flows from MOBIE OCDD section 2.3.1 and 2.3.2.

[REQ-2-WFOS-15030] The DSS shall provide mounting locations for up to **TBD** dispersing elements.

[REQ-2-WFOS-15040] The DSS shall provide a means for enabling the direct imaging mode (e.g. via a mirror).

Discussion: This requirement flows from MOBIE OCDD sections 2.3.1 and 2.3.2.

[REQ-2-WFOS-15050] The optical components carried by the DSS systems will be mounted in frames with indexed attachment features to facilitate repeatable removal and exchange from the DSS system.

[REQ-2-WFOS-15060] The gratings will be mounted in exchangeable units which allow one-time tip/tilt alignment of the grating within the cell.

Discussion: The grating angle is fixed within the exchangeable unit, and remote-control of grating angle is not provided.

[REQ-2-WFOS-15070] The DSS system exchangeable units will include metrology features (e.g. interfaces for corner cubes) to facilitate testing and initial alignment of the instrument optical system.

[REQ-2-WFOS-15080] The DSS systems shall include indexed mounting features, to facilitate repeatable removal and re-installation of the DSS system from the instrument, without requiring re-alignment of the optical system.

[REQ-2-WFOS-15090] The DSS systems shall include metrology features (e.g. interfaces for corner cubes) to facilitate the testing and initial alignment of the instrument optical system.

[REQ-2-WFOS-15100] The DSS systems shall provide features to enable in situ cleaning of the exposed PS optical surfaces.

[REQ-2-WFOS-15110] The PSS systems shall be operable in a stand-alone fashion, to facilitate alignment, testing and integration with the instrument.

3.3.14 Camera Assemblies

There are focusing optical systems (cameras) for each color channel. The requirements here address:

- Alignment features
- Metrology features
- Servicing features
- Initial assembly, testing, and integration

[REQ-2-WFOS-16010] The instrument design shall include a camera assembly for each color channel (blue camera – BCM, red camera, RCM).

Discussion: This requirement flows from REQ-1-ORD-3905, which requires the capability to take images or spectra over the instrument field of view.

[REQ-2-WFOS-16020] The camera assemblies shall include indexed mounting features, to facilitate repeatable removal and re-installation of the camera system from the instrument, without requiring re-alignment of the optical system.

[REQ-2-WFOS-16030] The camera assemblies shall include metrology features (e.g. interfaces for corner cubes) to facilitate the testing and initial alignment of the instrument optical system.

[REQ-2-WFOS-16040] The camera systems shall provide features to enable in situ cleaning of exposed optical surfaces.

[REQ-2-WFOS-16050] The camera assemblies shall provide a mounting interface to the shutter systems, for mounting and support of the shutters.

[REQ-2-WFOS-16060] The camera assemblies shall provide a mounting interface to the science detector systems (DET).

[REQ-2-WFOS-16070] The camera assemblies shall provide filtered venting for any air cavities created between optics and the supporting opto-mechanics.

[REQ-2-WFOS-16080] The camera assemblies shall be operable in a stand-alone fashion, to facilitate alignment, testing and integration with the instrument.

3.3.15 Filter Servers

The filter server systems (FSS) provide a means for remote-controlled selection of optical filters. The requirements here address:

- Motion Control
- Filter exchangeable units
- Alignment features
- Diffuser optic for calibrations
- Metrology features
- Servicing features

- Initial assembly, testing, and integration

[REQ-2-WFOS-17010] The instrument design shall provide a means for remote-controlled selection of order-sorting and passband-limiting filters.

Discussion: The requirement flows from REQ-1-ORD-3925 (goal to provide imaging through narrow band filters) and REQ-1-ORD-3930 (goal to provide higher spectral resolution).

[REQ-2-WFOS-17020] The instrument design shall provide a filter server system (FSS) for each color channel.

Discussion: This requirement flows from MOBIE OCDD sections 2.3.2 and 2.3.9.

[REQ-2-WFOS-17030] The filters carried by the FSS will be mounted in frames with indexed attachment features, to facilitate repeatable removal and exchange from the FSS (a filter mounted in its frame is called a filter unit).

[REQ-2-WFOS-17040] The FSS systems shall provide carrying locations for up to **10** filter units.

Discussion: This requirement flows from MOBIE OCDD section 2.3.9.

[REQ-2-WFOS-17050] The delivered instrument shall provide **TBD** order-sorting filters for each color channel.

Discussion: Order sorting filters are also assumed to be used as color filters in the imaging modes.

[REQ-2-WFOS-17060] The delivered instrument shall provide **TBD** narrow-band filters for each color channel, for direct imaging.

[REQ-2-WFOS-17080] The delivered instrument shall provide a diffuser, for flat field calibrations, for each color channel.

Discussion: The diffuser slide is part of the calibration system that resides in the filter server. This requirement may change as the calibration strategy develops.

[REQ-2-WFOS-17090] The FSS shall include indexed mounting features, to facilitate repeatable removal and re-installation of the FSS from the instrument, without requiring re-alignment of the optical system.

[REQ-2-WFOS-17100] The FSS shall include metrology features (e.g. interfaces for corner cubes) to facilitate the testing and initial alignment of the instrument optical system.

[REQ-2-WFOS-17110] The FSS shall include features to enable in situ cleaning of the exposed optical surfaces.

[REQ-2-WFOS-17120] The FSS shall be operable in a stand-alone fashion, to facilitate alignment, testing and integration with the instrument.

3.3.16 Shutters

Shutters provide a means for precise remote-control timing of imaging and spectroscopic exposures. One shutter is required for each color channel. The requirements here address:

- Alignment features
- Metrology features
- Servicing features
- Initial assembly, testing, and integration

[REQ-2-WFOS-18010] The instrument shall include a means for remote-controlled exposure-control shuttering (SHT) for each color channel.

Discussion: This requirement flows from REQ-1-ORD-3905 (shall be able to take images of the sky over the same field as it collects spectra). The shutter enables the collection of images over a specified period of time. This requirement also flows from MOBIE OCDD section 2.3.2 and 2.3.25.

[REQ-2-WFOS-18020] The SHT systems shall include indexed mounting features, to facilitate repeatable removal and re-installation of the SHT system from the instrument, without requiring re-alignment of the instrument optical system.

[REQ-2-WFOS-18030] The SHT systems shall include metrology features (e.g. interfaces for corner cubes) to facilitate the testing and initial alignment of the instrument optical system.

[REQ-2-WFOS-18040] The SHT systems shall be operable in a stand-alone fashion, to facilitate alignment, testing and integration with the instrument.

3.3.17 Science Detectors

There are science detector systems (DET) for each color channel. The DET systems include a vacuum vessel for housing the detectors, the detector focal plane mosaic, and the cryogenic cooling systems for maintaining the detectors at the (low) operating temperature. The requirements here address:

- Vacuum vessel
- Remote sensing of dewar internals
- Test optics
- Focal plane mosaic
- Detector control
- Getters
- Ion pumps
- Focus control actuation
- Flexure control
- Alignment features
- Metrology features
- Servicing features
- Initial assembly, testing, and integration

[REQ-2-WFOS-19010] The instrument design shall include a science detector system (DET) for each color channel.

Discussion: This requirement flows from REQ-1-ORD-3905 (shall be able to take images of the sky over the same field as it collects spectra). The detector systems receive the images created by the instrument optical systems, and convert them into electronic image data.

3.3.17.1 Vacuum Vessel

[REQ-2-WFOS-19020] The DET systems shall be housed in a vacuum vessel, to maintain a clean, cryogenic environment for the science detectors.

[REQ-2-WFOS-19030] The last lens (field flattener) in each science camera optical system shall serve as the window to the DET vacuum vessel.

[REQ-2-WFOS-19040] The DET system shall provide a separate, plano-plano vacuum window for testing and development use.

[REQ-2-WFOS-19050] The DET system shall provide means for remote sensing of the vacuum level inside the vacuum vessel.

[REQ-2-WFOS-19060] The DET system shall provide a means for remote sensing of the temperature of each science detector.

[REQ-2-WFOS-19070] The DET systems shall provide local ion pumps for maintaining vacuum pressure.

[REQ-2-WFOS-19080] The DET system (not including the focal plane mosaic or the motion control stages) shall be capable of glow-discharge cleaning.

3.3.17.2 Focal Plane Assembly

[REQ-2-WFOS-19100] The science detectors in the DET system shall be mounted to a single focal plane assembly (FPA), carried inside the DET system.

[REQ-2-WFOS-19110] The FPA shall be thermally isolated from the vacuum vessel.

[REQ-2-WFOS-19120] The FPA shall be mounted in the DET system with indexing features to allow repeatable (manual) removal and installation of the FPA.

[REQ-2-WFOS-19130] The science detectors shall be mounted to the FPA with indexing features to allow any science detector to be repeatably installed in any position on the FPA.

[REQ-2-WFOS-19140] The DET system shall provide a means for remote sensing of the FPA temperature at several locations distributed across the FPA.

[REQ-2-WFOS-19150] The DET system, with a flat window installed, shall enable external measurement of the flatness and tilts of the active surface of the FPA.

[REQ-2-WFOS-19160] The DET system shall orient the science detectors on the FPA so as to enable nod and shuffle observations.

Discussion: This requirement flows from REQ-1-ORD-3990 (photon-noise limited sensitivity for exposures greater than 60 seconds).

[REQ-2-WFOS-19170] The temperature of each detector shall be independently sensed and logged.

[REQ-2-WFOS-19180] The temperature of the cryo-cooler cold end(s) shall be sensed and logged.

3.3.17.3 Detector Control Systems

[REQ-2-WFOS-19200] The DET control system shall provide means for remote configuration of readout modes.

Discussion: This requirement flows from the MOBIE OCDD, section 2.3.2.

[REQ-2-WFOS-19210] The DET control system shall provide remote configuration of pixel binning.

Discussion: This requirement flows from the MOBIE OCDD, section 2.3.2.

[REQ-2-WFOS-19220] The DET control system shall provide remote configuration of sub-frame windowing.

Discussion: This requirement flows from the MOBIE OCDD, section 2.3.2.

[REQ-2-WFOS-19230] The DET control system shall provide remote configuration of readout speed.

Discussion: This requirement flows from the MOBIE OCDD, section 2.3.2.

3.3.17.4 Cryogenic Cooling System

[REQ-2-WFOS-19300] The DET system shall include a cryogenic cooling system (CCS) to maintain the FPA at its operating temperature.

Discussion: This requirement flows from MOBIE OCDD, sections 2.3.22, 2.3.24, and 2.3.25. Cooled detectors are required to achieve acceptable levels of sensitivity and detector dark current.

[REQ-2-WFOS-19310] The DET system shall provide a means for remote sensing of the temperature of the active elements in the cryo-coolers.

{REQ-2-WFOS-19320] The DET system cryogenic cooling system design shall enable efficient removal and replacement of the cold end from the detector vessel, without disturbing the FPA.

[REQ-2-WFOS-19330] The DET systems shall provide a getter system to protect the detectors from collecting condensates.

3.3.17.5 Focus Control

[REQ-2-WFOS-19400] The DET systems shall provide a means for remote-control of the location of the active detector surface along the camera optical axis (focus control).

[REQ-2-WFOS-19410] The DET focus control systems shall provide optical or electronic encoding of the focus travel stroke.

3.3.17.6 Flexure Control

[REQ-2-WFOS-19500] The DET systems shall provide a means for remote-control of XY translations of the active detector surface normal to the camera optical axis (flexure control).

Discussion: This requirement flows from REQ-1-ORD-3995 (flexure-induced image motion to be less than 0.15 arcsec at the detector). It is anticipated that active control of flexure will be needed to meet this requirement.

[REQ-2-WFOS-19510] The DET systems shall provide a means for active sensing of image motion on the science focal plane during an exposure (flexure sensing).

3.3.17.7 Assembly, Test, and Integration

[REQ-2-WFOS-19600] The DET systems shall include indexed mounting features, to facilitate repeatable removal and re-installation of the system from the instrument, without requiring re-alignment of the instrument optical system.

[REQ-2-WFOS-19610] The DET systems shall include metrology features (e.g. interfaces for corner cubes) to facilitate the testing and initial alignment of the instrument optical system.

[REQ-2-WFOS-19620] The DET systems shall be operable in a stand-alone fashion, to facilitate alignment, testing and integration with the instrument.

[REQ-2-WFOS-19630] The DET systems shall include features to enable in situ cleaning of exposed optical surfaces.

[REQ-2-WFOS-19640] The DET system shall include a handling cart, for facilitating assembly, routine maintenance, and servicing.

[REQ-2-WFOS-19650] The DET system shall provide a means for preventing condensation on the exposed surface of the dewar window.

Discussion: Large dewar windows are prone to radiative cooling below the dew point, and hence condensation on the optical surface. This effect can be eliminated by heating the window, flushing the window area with dry air or nitrogen, or other methods.

3.3.18 Stray Light Controls

Stray light controls and features (aperture stops, vanes, baffles, absorbing coatings, etc) are distributed throughout the instrument. The requirements here address:

- Stray light analysis
- Stray light controls

[REQ-2-WFOS-20010] The instrument design shall include a comprehensive stray light analysis.

Discussion: This requirement flows directly from REQ-1-ORD-3940 (the instrument shall provide internal baffling). The type, locations, and quantities of internal baffles are determined via the stray light analysis.

[REQ-2-WFOS-20020] The instrument subsystems shall incorporate and provide the stray light controls (e.g. baffles, stops) as determined by the stray light analysis.

Discussion: This requirement flows from MOBIE OCDD section 2.3.23. The provision of stray light controls will be added to the requirements for each subsystem requiring stray light control features (e.g. aperture stops, field stops, vanes, etc.), following the results of the stray light analysis.

3.3.19 Instrument Enclosures

The instrument enclosure system (ENC) provides a means for making the rotating portion of the instrument light-tight, dust-tight, thermally isolated, and protected from foreign object damage (e.g. falling objects, moving items on the Nasmyth platform). The requirements here address:

- Thermal isolation
- Light-tight sealing
- Dust-tight sealing
- Enclosure pressurization
- Access hatches
- Entrance hatch
- Calibration screen
- Alignment features
- Metrology features
- Servicing features
- Initial assembly, testing, and integration

[REQ-2-WFOS-21010] The instrument design shall include an enclosure system (ENC) that fully surrounds the rotating portion of the instrument.

Discussion: This requirement flows from MOBIE OCDD, sections 2.2 and 2.3.23. The enclosure protects the instrument optics from damage, and provides a light-tight environment for the instrument optical and detector systems.

[REQ-2-WFOS-21020] The ENC system shall be composed of multiple sub-units (parts or panels), such that individual parts of the enclosure may be removed from the instrument for service and repair operations.

[REQ-2-WFOS-21030] The ENC sub-units shall be removable with simple hand tools,

[REQ-2-WFOS-21040] The ENC sub-units shall be removable by two technicians, working without lifting equipment.

[REQ-2-WFOS-21050] The ENC sub-units shall be provided with hand-holds or other means to enable manual lifting, attachment, and removal.

[REQ-2-WFOS-21060] The ENC system shall provide a thermally isolated and controlled environment for the rotating portion of the instrument.

[REQ-2-WFOS-21070] The ENC shall provide a light-tight seal between the internal instrument subsystems and the dome environment.

[REQ-2-WFOS-21080] The ENC shall provide a leakage-controlled air seal between the internal instrument air volume and the dome environment.

[REQ-2-WFOS-21090] The ENC shall provide a means for maintaining a small over-pressure of air inside the instrument with respect to the dome environment (for dust rejection).

[REQ-2-WFOS-21100] The ENC shall be sufficiently robust to protect the internal instrument subsystems from falling objects within the dome environment (e.g. ice, hand tools, etc.).

[REQ-2-WFOS-21110] The ENC shall provide a means for meeting the observatory requirements on allowable radiative and convective heat dissipation into the dome environment.

[REQ-2-WFOS-21120] The ENC shall provide manual access hatches for all areas of the instrument that require regular servicing or configuration of the instrument (e.g. access for exchange of slitmasks).

[REQ-2-WFOS-21130] The ENC access hatch doors shall be interlocked with the instrument control system, to prevent operation or rotation of the instrument with any hatch open.

[REQ-2-WFOS-21140] The ENC shall attach to the instrument structure such that any subsystem inside the ES can be removed and replaced without removing the instrument from the telescope.

[REQ-2-WFOS-21150] The ENC shall include a remote-controlled hatch (door) at the optical entrance aperture.

Discussion: The entrance hatch is normally open during operation, and closed at all other times.

[REQ-2-WFOS-21160] In the closed position, the ENC entrance hatch shall provide a light-tight seal between the instrument and the dome environment, sufficient to enable internal calibration at all times.

Discussion: In particular, the enclosure and hatch must enable internal calibrations during the day, under full daylight conditions.

[REQ-2-WFOS-21170] In the closed position, the ENC entrance hatch shall provide a controlled-leakage air seal between the instrument and the dome environment.

[REQ-2-WFOS-21180] The internal surface of the ENC entrance hatch shall provide a diffuse reflecting surface to act as a screen for instrument internal calibration sources.

Discussion: The need for an internal screen is still under investigation, and this requirement may change in later versions of this document.

[REQ-2-WFOS-21190] The ENC entrance hatch shall be operable in a stand-alone fashion, to facilitate testing and integration with the instrument.

[REQ-2-WFOS-21200] The ENC entrance hatch shall include metrology features (e.g. interfaces for corner cubes) to facilitate initial alignment of the instrument.

[REQ-2-WFOS-21210] The ENC entrance hatch shall include indexed mounting features, to facilitate repeatable removal and re-installation of the system on the instrument.

[REQ-2-WFOS-21220] The ENC shall provide the active means for controlling temperature inside the (enclosed) rotating portion of the instrument.

Discussion: Environmental control of the instrument volume is provided by the enclosure. This may include recirculating fans, ducting, heat exchangers, filters, sensors, etc.

3.3.20 Instrument Electronics

The instrument electronics include all electrical and electronic subsystems required for instrument motion control, exposure control, data collection and management, environmental sensing, safety sensing, and all cabling, harnessing, connectors, racks and rack mounts. The electronics subsystems will be carried on both the rotating portion of the instrument, the instrument rotator, and electronics cabinets installed on the Nasmyth platform. The requirements here address:

- Instrument-mounted electronics
- Rotator-mounted electronics
- Nasmyth-mounted electronics
- Control electronics and computers
- Cabling and harnessing
- Utility wraps
- UPS power
- Audio and video feedback to users
- Servicing features
- Initial assembly, testing, and integration

[REQ-2-WFOS-22010] The instrument design shall include all instrument electronics systems (ELE) required to provide instrument control, motion control, detector control, environmental sensing, environmental control, safety monitoring, and status reporting.

Discussion: This requirement flows from MOBIE OCDD section 2.3.2, for remote control of all instrument functions.

[REQ-2-WFOS-22020] The ELE system shall provide all the necessary electrical functions and components required on the rotating portion of the instrument.

[REQ-2-WFOS-22030] The ELE system shall provide all the necessary electrical functions and components required on the fixed (instrument rotator) portion of the instrument.

[REQ-2-WFOS-22040] The ELE system shall include all computer systems required for controlling and operating the instrument.

[REQ-2-WFOS-22050] The ELE system shall include all the sensors and related electronics required for monitoring the state of each instrument subsystem (e.g. air and coolant temperatures, air and coolant pressures, coolant flow rates, etc).

[REQ-2-WFOS-22060] The ELE design shall include separate electronics enclosures mounted external to the instrument (e.g. on the instrument rotator or the Nasmyth platform).

[REQ-2-WFOS-22070] The ELE design shall include cooling and thermal control of the remote electronics enclosures, such that the observatory requirements on allowable radiative and convective heat dissipation into the dome environment are met.

[REQ-2-WFOS-22080] The ELE design shall include all electrical harnessing between the electronics enclosures and the instrument rotator.

[REQ-2-WFOS-22090] The ELE design shall include all electrical harnessing between the IRS and the IS (via the utility wrap).

[REQ-2-WFOS-22100] The ELE design shall include all electrical harnessing between the utility wrap and the instrument subsystems mounted on the instrument structure.

[REQ-2-WFOS-22110] The ELE design shall include all electrical harnessing internal to each instrument subsystem.

[REQ-2-WFOS-22120] The ELE design shall include all connectors required between the telescope utility interface and each instrument electrical subsystem.

[REQ-2-WFOS-22130] The ELE design shall provide sufficient segmentation (via connectors) of cables to allow the replacement of electrical subsystems with simple disconnection via electrical connectors.

[REQ-2-WFOS-22140] The ELE design shall include provision of a local UPS, to maintain the instrument status in the event of short loss of power events.

[REQ-2-WFOS-22150] The ELE design shall include provision of multiple channels of audio and video feedback from within the instrument enclosure to the telescope control room.

Discussion: Audio and video feedback from the instrument are extremely useful for maintaining awareness of instrument functionality, and for preliminary diagnosis of mechanism malfunction.

[REQ-2-WFOS-22160] The ELE design shall include remote and locally controlled lighting of the internal instrument areas, on the instrument rotator, and at the Nasmyth electronics cabinets, for servicing and video feedback when necessary.

3.3.21 Instrument Control Systems

The TMT project does not yet have a comprehensive software development program in place for the telescope or the instruments. Consequently, an instrument software requirements document will be developed in a later phase of the instrument project. Nevertheless, preliminary top-level functional requirements for instrument control software are presented here, addressing:

- Control system interfaces
- User interfaces
- Operating modes
- Fault tolerance and error recovery
- Data logging
- Engineering interface
-

[REQ-2-WFOS-23010] The instrument design shall include an instrument control system (ICS) that enables remote sensing and control of all instrument functions, sensors, and detector systems.

Discussion: This requirement flows from MOBIE OCDD section 2.3.2, for remote control of all instrument functions.

[REQ-2-WFOS-23010] The instrument control system (ICS) shall interface with the observatory control system (OCS) for overall control and sequencing of observations.

[REQ-2-WFOS-23020] The ICS shall interface with the observatory data management system for the coordination of telemetry regarding observing conditions (pointing, environmental conditions, telescope and instrument configuration and status).

[REQ-2-WFOS-23030] The ICS shall provide graphical user interfaces for all controlled functions, consistent with TMT standards for observer and engineering user interfaces.

[REQ-2-WFOS-23040] The ICS shall include provisions for scripted operation of the instrument (e.g. set-up scripts, observing scripts).

Discussion: This requirement flows from MOBIE OCDD section 2.3.2, for scripted operation of all instrument configuration and operational functions.

[REQ-2-WFOS-23050] The ICS shall include provisions for scripted interaction between the instrument and the telescope (e.g. nod-and-shuffle observing mode).

[REQ-2-WFOS-23060] The ICS shall provide a “start-up mode” for initialization of all instrument motion control systems.

[REQ-2-WFOS-23070] The ICS shall be capable of initializing all of the controlled subsystems in parallel.

Discussion: This requirement flows from MOBIE OCDD section 2.3.18, regarding observing efficiency. The design of the control system must support parallel initialization and operation of the controlled subsystems. It is expected that initialization is not entirely simultaneous, but rather that initialization signals are generated with an intentional delay between them.

[REQ-2-WFOS-23080] The ICS shall be designed such that all controlled subsystems can still be normally operated in the event of single or multiple unrelated subsystem failures.

[REQ-2-WFOS-23090] The ICS shall provide a fail-safe “recovery mode” for each of the instrument subsystems, for recovery from unknown states that may occur (e.g. following an extended power failure).

[REQ-2-WFOS-23100] The ICS “recovery mode” shall provide safe recovery and re-initialization of instrument subsystems, and especially for motion control systems that can generate collisions.

[REQ-2-WFOS-23110] The ICS shall provide a “shut-down mode” for controlled and safe parking of all the subsystem motion control systems.

[REQ-2-WFOS-23120] The ICS shall provide “set-up modes” for rapid servicing of regularly exchanged components (e.g. slitmasks and filters).

[REQ-2-WFOS-23130] The ICS shall provide a means for capturing, viewing, and storing image frames from the WFS, GCM, and LSV cameras.

[REQ-2-WFOS-23140] The ICS shall provide a means for “quick look” viewing of science detector images.

[REQ-2-WFOS-23150] The ICS shall maintain a log of all instrument actions, states, telemetry, loaded components, etc., in order to aid fault analysis and fault recovery.

[REQ-2-WFOS-23160] The ICS shall provide features for self-testing and self-diagnosis of the condition of all controlled functions and subsystems.

[REQ-2-WFOS-23170] The ICS shall provide an engineering interface, with access to the status and recent performance of all subsystems and components controlled by the ICS.

3.3.22 Mask Fabrication System

The slit mask fabrication system (MFS) includes all the subsystems, hardware, and software required to define the size and location of the slits on the mask, apertures for mask alignment, and apertures for flexure sensing objects. The MFS includes simulation software for viewing mask designs and the format of spectra on the focal plane, based on the mask design. The MFS includes the cutting system that produces the finished slit masks, a transportation system for moving the masks from the cutter to the instrument, and a system for storing finished and used masks. The requirements here address:

- Marking of ID codes on masks
- Sensing of ID codes on masks
- Environmental operating conditions
- Mask geometry
- Mask indexing (with respect to the telescope focal surface)
- Mask cutting
- Mask transfer from MFS to instrument
- Mask installation on the instrument

[REQ-2-WFOS-24010] The instrument project shall provide a complete, turn-key system to the observatory, for the fabrication of slitmasks.

Discussion: This requirement flows from MOBIE OCDD section 2.3.3, regarding provision of a local mask fabrication system.

[REQ-2-WFOS-24020] The mask fabrication system (MFS) shall include a marking and sensing system, which will facilitate identification and tracking of slitmasks.

Discussion: This requirement flows from MOBIE OCDD section 2.3.3, regarding mask tracking. The focal plane server (FPS) will read the ID marking on the mask, for all masks installed on the instrument.

[REQ-2-WFOS-24030] The MFS system shall perform under the same environmental conditions applicable for the instrument, as specified in the ORD.

[REQ-2-WFOS-24040] The MFS system shall be capable of generating slitmasks that are flat, or curved (in two dimensions), as required to match the telescope focal surface.

[REQ-2-WFOS-24050] The MFS shall include an automated means (auto-focus) for sensing the curvature of a non-flat slitmask, and maintaining slit edge finish quality over the entire mask surface.

[REQ-2-WFOS-24060] The MFS system shall provide a means for indexing slitmasks with respect to a slitmask unit.

Discussion: It is assumed that slitmasks will be mounted in frames, which together form an assembly, called a mask unit. The focal plane server system will be designed to select and load these units. The MFS system may generate masks as stand-alone parts, or as pre-assembled mask-frame units.

[REQ-2-WFOS-24070] The MFS system shall be able of generating slits of any rotation with respect to the normal to the mask surface.

Discussion: The MFS should be able to rotate the field of slits at any angle with respect to the mask frame.

[REQ-2-WFOS-24080] The MFS system shall include a (manual) mask transfer system (MTS) for transporting finished mask units between the MFS and the instrument. The MTS will also provide the means for transporting used mask units to the storage and archiving area.

[REQ-2-WFOS-24090] The MFS shall provide a means for a single technician to safely transport and install slitmask units in the instrument focal plane server system(s).

[REQ-2-WFOS-24100] The MFS design software shall be able to accept astrometry data from external sources, for the design and definition of slit masks.

Discussion: This requirement flows from the MOBIE OCDD, section 2.2.3.

3.4 SCIENCE PERFORMANCE REQUIREMENTS

3.4.1 ORD Top Level Science Requirements

For convenience, the following performance requirements are extracted directly from the TMT ORD. **However, the latest version of the ORD shall be considered the final reference for these requirements.**

[REQ-1-ORD-3900] WFOS is a wide field, seeing limited multi-object optical spectrometer and imager.

[REQ-1-ORD-3905] WFOS shall be able to take images of the sky over the same field as it collects spectra.

[REQ-1-ORD-3910] WFOS shall provide atmospheric dispersion correction.

[REQ-1-ORD-3912] WFOS shall provide a tip-tilt-focus WFS/guider for each sub-field of the instrument.

Discussion: It is anticipated that the WFOS field will not be contiguous. A guider is required in each field to ensure slit transmission in each sub-field.

[REQ-1-ORD-3913] WFOS shall provide a 6 x 6 (**TBC**) WFS to supply active optics feedback signals.

Discussion: It is expected that this higher order WFS can serve as a guider for one of the fields.

[REQ-1-ORD-3915] A goal is to record the entire wavelength range in a single exposure. However, this wavelength range can be covered through multiple optimized arms covering suitable wavelength ranges.

[REQ-1-ORD-3920] A goal is to provide enhanced image quality using Ground Layer Adaptive Optics, over the full wavelength range, and the full field of the spectrograph.

[REQ-1-ORD-3925] A goal is to provide imaging through narrow band filters.

[REQ-1-ORD-3930] A goal is to provide a cross-dispersed mode for smaller sampling density and higher spectral resolution.

[REQ-1-ORD-3935] A goal is to provide an integral field unit (IFU) mode.

[REQ-1-ORD-3940] WFOS shall provide internal baffling.

Requirement #	Description	Requirement
[REQ-1-ORD-3950]	Wavelength Range	0.31 – 1.0μm
[REQ-1-ORD-3955]	Image quality: Imaging	≤ 0.2 arcsec FWHM over any 0.1μm wavelength interval (including contributions from the telescope and the ADC at z=60°)
[REQ-1-ORD-3960]	Image quality: Spectroscopy	≤ 0.2 arcsec FWHM at every wavelength
[REQ-1-ORD-3965]	Field of View	40.5 $arcmin^2$. The field need not be contiguous.
[REQ-1-ORD-3970]	Total Slit Length	≥ 500 arc-seconds
[REQ-1-ORD-3975]	Spatial Sampling	< 0.15 arc-sec per pixel, goal < 0.1 arc-sec
[REQ-1-ORD-3980]	Spectral Resolution	R = 500-5000 for a 0.75 arc-sec slit, 150-7500 (goal)
[REQ-1-ORD-3985]	Throughput	≥ 30% from 0.31 – 1.0μm, or at least as good as that of the best existing spectrometers
[REQ-1-ORD-3990]	Sensitivity	Spectra should be photon noise limited for all exposure times >60 sec. Background subtraction systematics must be negligible compared to photon noise for total exposure times as long as 100 Ksec. Nod and shuffle capability in the detectors may be desirable
[REQ-1-ORD-3995]	Wavelength Stability	Flexure at a level of less than 0.15 arc-sec at the detector is required.

Table 1. Summary of Science Requirements from the ORD

3.4.2 OCDD Level Science Requirements

The requirements in this section are repeated from the ORD as applied to the MOBIE instrument design, or are extracted from the MOBIE OCDD.

[REQ-2-WFOS-25000] The instrument operational wavelength range shall extend from 0.31 – 1.0 µm.

Discussion: This requirement repeats REQ-1-ORD-3950, and flows also from the MOBIE OCDD, section 2.3.13.

[REQ-2-WFOS-25010] The final image quality in the direct imaging modes shall be ≤0.2 arcsec FWHM over any 0.1µm wavelength interval (including contributions from the telescope and the ADC at z=60°).

Discussion: This requirement repeats REQ-1-ORD-3955, and flows also from the MOBIE OCDD, section 2.3.13.

[REQ-2-WFOS-25020] The final image quality in the spectroscopic modes shall be ≤0.2 arcsec FWHM at every wavelength

Discussion: This requirement repeats REQ-1-ORD-3960, and flows also from the MOBIE OCDD, section 2.3.13.

[REQ-2-WFOS-25030] The instrument field of view shall be ≥ 40.5 $arcmin^2$.

Discussion: This requirement repeats REQ-1-ORD-3965, and flows also from the MOBIE OCDD, section 2.3.10.

[REQ-2-WFOS-25040] The instrument total slit length shall be ≥ 500 arcsec.

Discussion: This requirement repeats REQ-1-ORD-3970, and flows also from the MOBIE OCDD, section 2.3.10.

[REQ-2-WFOS-25050] The instrument focal plane spatial sampling shall be < 0.15 arcsec per pixel, with a goal of < 0.1 arc-sec.

Discussion: This requirement repeats REQ-1-ORD-3975, and flows also from the MOBIE OCDD, section 2.3.24.

[REQ-2-WFOS-25060] The instrument range of spectral resolutions shall include R = 500-5000 for a 0.75 arc-sec slit, with R = 150-7500 as a goal.

Discussion: This requirement repeats REQ-1-ORD-3980.

[REQ-2-WFOS-25070] The instrument range of spectral resolutions shall include R = 1000-8000 for a 0.75 arc-sec slit.

Discussion: This requirement flows from the MOBIE OCDD, section 2.3.11.

[REQ-2-WFOS-25080] The end to end transmission efficiency of the instrument (not including telescope, slit losses) shall be ≥ 30%, over the full wavelength range of the instrument.

Discussion: This requirement repeats REQ-1-ORD-3985, and flows also from the MOBIE OCDD, section 2.3.17.

[REQ-2-WFOS-25090] The instrument sensitivity shall be photon noise limited for all exposure times > 60 sec.

Discussion: This requirement repeats REQ-1-ORD-3990, and flows also from the MOBIE OCDD, section 2.3.22.

[REQ-2-WFOS-25100] The instrument image stability due to flexure shall be at a level < 0.15 arcsec at the detector.

Discussion: This requirement repeats REQ-1-ORD-3995.

[REQ-2-WFOS-25110] The instrument image stability due to flexure shall be at a level < 0.1 arcsec at the detector.

Discussion: This requirement flows from the MOBIE OCDD, section 2.3.21.

3.5 INSTRUMENT PERFORMANCE REQUIREMENTS

3.5.1 Instrument Rotator

The IR performance requirements address:

- Mass
- Initialization time
- Configuration time
- Slew rate
- Tracking rate
- Tracking jitter
- Tracking open-loop accuracy
- Heat transfer to the instrument cooling system
- Heat transfer to the dome environment

[REQ-2-WFOS-30010] The IR mass shall not exceed **TBD** Kg (mass allocation budget).

[REQ-2-WFOS-30020] The IR shall be able to start and fully initialize itself in no more than TBD seconds (configuration time budget).

[REQ-2-WFOS-30025] The IR shall be able to rotate the instrument to any position angle (0-360 degrees) in less than **30** seconds.

Discussion: This requirement flows from the MOBIE OCDD, section 2.3.18.

[REQ-2-WFOS-30030] The IR shall be able to slew (rapid rotation of the instrument about the Nasmyth axis) at a speed of at least **TBD** degrees per second.

Discussion: The IR should be able to slew from one pointing to another at least as rapidly as the telescope can accomplish the same move.

[REQ-2-WFOS-30040] The IR shall be able to track (tracking rotation of the instrument about the Nasmyth axis) at a speed of at least **TBD** degrees per second.

Discussion: The worst case for tracking speed will be for non-sidereal tracking near the zenith. This requirement should be met for all operating zenith angles of the telescope.

[REQ-2-WFOS-30050] Tracking velocity jitter shall be no more than **TBD** degrees per second RMS.

Discussion: This requirement may be better cast in terms of its contribution to image quality. The jitter will be a small fraction of the minimum tracking velocity. Tracking RMS image motion is limited to 0.05 arcsec by REQ-1-ORD-2720.

[REQ-2-WFOS-30060] The instrument rotator shall be able to position within 0.1 degrees absolute under open-loop (not tracking or slewing) control.

Discussion: This requirement flows from the MOBIE OCDD, section 2.3.20.

[REQ-2-WFOS-30070] The instrument rotator shall be able to make fine angular position corrections, at the level of 0.01 degrees, for the alignment of slit masks.

Discussion: This requirement flows from the MOBIE OCDD, section 2.3.20, and corresponds to 0.1 arcsec of rotation at the edge of the MOBIE field of view.

[REQ-2-WFOS-30080] Heat sources for control of the IR shall dissipate no more than **TBD** W into the instrument cooling system (cooling budget).

[REQ-2-WFOS-30090] Heat sources for the control of the IR shall dissipate no more than **TBD** W into the telescope enclosure (waste heat budget).

3.5.2 Instrument Structure

The instrument structure performance requirements address:

- Mass
- Flexure

[REQ-2-WFOS-31010] The instrument structure mass shall not exceed **TBD** Kg (mass allocation budget).

[REQ-2-WFOS-31020] Flexure of the instrument structure itself shall contribute no more than **TBD** arcseconds of image motion (blur) for a 180 degree rotation of the instrument (image motion error budget).

3.5.3 Atmospheric Dispersion Corrector

The atmospheric dispersion corrector (ADC) compensates for variable dispersion, as a function of the telescope's elevation angle, caused by the atmosphere,. The requirements here address:

- Transmission
- Mass
- Static image quality
- Image motion due to flexure
- Initialization time
- Configuration time
- Heat transfer to the instrument cooling system
- Heat transfer to the dome environment

[REQ-2-WFOS-32010] The ADC optical throughput shall be greater than 95% transmission over the full instrument wavelength range.

Discussion: This requirement flows from the SRD V17.5, section 2.5.3.5., throughput for a fixed (non removable) ADC.

[REQ-2-WFOS-32020] The ADC subsystem mass shall not exceed **TBD** Kg (mass allocation budget).

[REQ-2-WFOS-32030] The ADC optics shall contribute no more than **TBD** microns RMS to the final image quality (image quality error budget).

[REQ-2-WFOS-32040] The ADC total static figure error shall be no more than **TBD** nm PV (image quality error budget).

[REQ-2-WFOS-32050] The ADC system shall contribute no more than **0.05** arcsec of image motion over any TBD degree rotation of the instrument about the Nasmyth axis (image motion error budget).

Discussion: This requirement flows from the MOBIE OCDD, section 2.3.14.

[REQ-2-WFOS-32060] The ADC motion control system shall be able to start and initialize itself in no more than **TBD** seconds (configuration time budget).

[REQ-2-WFOS-32070] The ADC motion control system shall be able position the ADC for operation at any elevation angle, and at any rotator position angle, in less than **30** seconds.

Discussion: This requirement flows from the MOBIE OCDD, section 2.3.18.

[REQ-2-WFOS-32080] Heat sources for control of the ADC shall dissipate no more than **TBD** W into the instrument cooling system (cooling budget).

[REQ-2-WFOS-32090] Heat sources for the control of the ADC shall dissipate no more than **TBD** W into the instrument enclosure (cooling budget).

3.5.4 Telescope Field Corrector

The telescope field corrector (FC) corrects the field-radius-dependent residual aberrations from the telescope optical system. The field correcting functions may be merged into the ADC optics (see above) at a later date. The requirements here address:

- Mass
- Image quality
- Image blur due to flexure
- Image motion due to flexure

[REQ-2-WFOS-33010] The mass of the FC system shall not exceed **TBD** Kg (mass allocation budget).

[REQ-2-WFOS-33020] The FC static figure error shall be no more than **TBD** nm RMS (image quality error budget).

[REQ-2-WFOS-33030] The FC lens static figure error shall be no more than **TBD** nm PV (image quality error budget).

[REQ-2-WFOS-33040] The FC optics shall contribute no more than **TBD** arcsec of image motion over any TBD degree rotation of the instrument about the Nasmyth axis (image motion error budget).

3.5.5 Calibration Systems

The calibration system performance requirements address:

- Mass
- Light sources
- Light source flux
- Initialization time
- Configuration time
- Heat transfer to the instrument cooling system
- Heat transfer to the dome environment

[REQ-2-WFOS-34010] The calibration system mass shall not exceed **TBD** Kg (mass allocation budget).

[REQ-2-WFOS-34020] The calibration system shall provide the following light sources:

- Continuum Lamps **TBD**
- Emission Line Lamps; Ne, Ar, Hg, others **TBC**
- Hollow Cathode Lamps; FeAr, CuAr, others **TBC**

[REQ-2-WFOS-34030] The calibration sources shall be sized or used in groups to provide at least **TBD** photons/sec/nm/pixel.

Discussion: Flux requirements will vary with spectroscopic mode and system sensitivity as a function of wavelength.

[REQ-2-WFOS-34040] The calibration system shall be able to start and initialize itself in no more than **TBD** seconds (initialization time budget).

[REQ-2-WFOS-34050] The calibration system shall be able to configure itself in no more than **30** seconds (configuration time budget).

Discussion: This requirement flows from the MOBIE OCDD, section 2.3.18.

[REQ-2-WFOS-34060] Heat sources in the calibration system shall dissipate no more than **TBD** W into the instrument cooling system (cooling budget).

[REQ-2-WFOS-34070] Heat sources in the calibration system shall dissipate no more than **TBD** W into the instrument enclosure (waste heat budget).

3.5.6 Wavefront Sensors and Guide Cameras

Although a distinction is made between the names of the WFS and GCM systems, both are intended to operate interchangeably, to maximize the field of view for guiding and wavefront sensing objects. The performance requirements on the WFS / GCM address:

- Acquisition time
- Mass
- Field of view area
- Field of view width
- Field of view patrol area
- Flexure
- Pupil sampling
- Sub-aperture sampling
- Detector performance
- Initialization time
- Configuration time
- Hold position stability
- Thermal stability
- Filters
- Heat transfer to the instrument cooling system
- Heat transfer to the dome environment

[REQ-2-WFOS-35010] The WFS / GCM subsystem must enable field acquisition for multi-slit masks in less than 3 minutes.

This requirement flows from SRD V17.5, section 2.5.3.10, "Field acquisition for multi-slit masks must be short (<3 minutes) once the telescope is in position".

[REQ-2-WFOS-35020] The WFS / GCM subsystem mass shall not exceed **TBD** Kg (mass allocation budget).

[REQ-2-WFOS-35030] The WFS / GCM field of view shall enclose an area of at least **1.2** square arcminutes.

Discussion: This requirement flows directly from the MOBIE OCDD, section 2.3.19.

[REQ-2-WFOS-35040] The WFS / GCM camera field of view shall provide a minimum field of view width of at least **TBD** arcminutes.

Discussion: This requirement will depend on the optical design for the WFS /GCM, and flows from MOBIE OCDD section 2.3.19.

[REQ-2-WFOS-35050] The WFS / GCM shall patrol an area of **TBD** square arcmin (based on the field of view multiplied by the patrol area dimensions).

Discussion: This requirement will depend on the optical design for the WFS /GCM, and flows from MOBIE OCDD section 2.3.19. If a fixed WFS/GCM system can provide sufficient field area, no patrolling will be necessary.

[REQ-2-WFOS-35060] The WFS / GCM optical system shall be confocal with the slit mask surface (i.e. the surface on the optical axis which the instrument requires the telescope to focus).

[REQ-2-WFOS-35070] Flexure of the WFS / GCM optical system shall not exceed **TBD** arcsec (microns) at the WFS / GCM focal plane.

[REQ-2-WFOS-35080] The WFS / GCM shall sample the telescope pupil with a coarse **TBD1 x TBD2** sub-aperture lenslet array.

[REQ-2-WFOS-35090] The WFS / GCM shall sample the telescope pupil with a fine **TBD3 x TBD4** sub-aperture lenslet array.

[REQ-2-WFOS-35100] The WFS / GCM detector shall sample each sub-aperture with at least **TBD** pixels per sub-aperture.

3.5.6.1 Detector Performance

The WFS / GCM detectors shall meet the following performance requirements under the normal operating conditions:

[REQ-2-WFOS-35120]	Dark current:	**TBD** e-/sec
[REQ-2-WFOS-35130]	Read noise:	**TBD** e- at TBD pixels/sec
[REQ-2-WFOS-35140]	Frame rate:	**TBD** frames per second
[REQ-2-WFOS-35150]	Quantum efficiency:	**TBD** % at 320 nm
		TBD % at 600 nm
		TBD % at 900 nm
		TBD % average across wavelength range
[REQ-2-WFOS-35160]	Readout time:	**TBD** milliseconds
[REQ-2-WFOS-35170]	Pixel size:	**TBD** microns
[REQ-2-WFOS-35180]	Pixel format:	**TBD** x **TBD** pixels
[REQ-2-WFOS-35190]	Operating temp:	**TBD** K

[REQ-2-WFOS-35300] The WFS / GCM subsystems shall be able to start and initialize in no more than **TBD** seconds (initialization time budget).

[REQ-2-WFOS-35310] The WFS / GCM subsystems shall be able to configure itself in no more than **30** seconds (configuration time budget).

Discussion: This requirement flows from the MOBIE OCDD, section 2.3.18.

[REQ-2-WFOS-35310] The WFS / GCM, once parked at the guiding field position, and under the effects of gravity flexure and thermal changes, shall not move in X, Y, Z (instrument coordinates) by more than **TBD** microns and **TBD** arcsec in Rx, Ry, Rz.

[REQ-2-WFOS-35320] The position of the WFS / GCM within the patrol area shall be encoded, stable, and repeatable to **TBD** arcsec (microns).

[REQ-2-WFOS-35330] The WFS / GCM optical system shall remain in focus with respect to the nominal telescope surface over the operating temperature range (no automated focus) of **TBD** degrees C.

[REQ-2-WFOS-35340] The WFS / GCM filter changer shall exchange filters in no more than **TBD** seconds (configuration time budget)

[REQ-2-WFOS-35350] The WFS / GCM filter changer shall position filters in the WFS / GCM optical path repeatably to better than **TBD** microns RMS.

[REQ-2-WFOS-35360] The WFS / GCM filters shall have passbands from **TBD** to **TBD** nm, and **TBD** to **TBD** nm.

[REQ-2-WFOS-35370] WFS / GCM filters shall be able to be exchanged within **TBD** seconds.

[REQ-2-WFOS-35380] WFS / GCM filters shall position repeatably to **TBD** X, Y, Z microns, and **TBD** Rx, Ry, Rz arcsec.

[REQ-2-WFOS-35390] Heat sources for control of the WFS / GCM shall dissipate no more than **TBD** W into the instrument cooling system (cooling budget).

[REQ-2-WFOS-35400] Heat sources for the control of the WFS / GCM shall dissipate no more than **TBD** W into the instrument enclosure (waste heat budget).

3.5.7 Long Slit Viewer

The long slit viewer (LSV) enables rapid acquisition of single objects, and provides a long slit for isolating spectra of single objects. The LSV includes two optical systems, one which provides both guiding and slit viewing, and another which provides wavefront sensing. The performance requirements on the LSV address:

- Acquisition time
- Mass
- Field of view area
- Field of view width
- Flexure
- Long slit selection
- Pupil sampling
- Sub-aperture sampling
- Detector performance
- Initialization time
- Configuration time
- Hold position stability
- Thermal stability
- Filters

- Heat transfer to the instrument cooling system
- Heat transfer to the dome environment

[REQ-2-WFOS-36010] The LSV shall be able to activate and begin slit viewing in less than 1 minute.

This requirement flows from the SRD V17.5, section 2.5.3.10, "fast acquisition (<1 minute) of single targets onto a long slit must be supported". This requirement also flows from MOBIE OCDD section 2.3.5.

[REQ-2-WFOS-36020] The LSV subsystem mass shall not exceed **TBD** Kg (mass allocation budget).

[REQ-2-WFOS-36030] The LSV field of view shall image an area of at least **1.2** square arcminutes.

This requirement also flows from MOBIE OCDD sections 2.3.5 and 2.3.19.

[REQ-2-WFOS-36040] The LSV camera field of view shall provide a minimum field of view width of at least **TBD** arcminutes.

Discussion: The LSV field of view may not be round, and there may be advantages to a non-square rectangular field of view.

[REQ-2-WFOS-36050] The LSV optical systems shall be confocal with the slit mask surface (i.e. the surface on the optical axis which the instrument requires the telescope to focus).

[REQ-2-WFOS-36060] Flexure of the LSV optical system shall not exceed **TBD** arcsec (microns) at the LSV focal plane.

[REQ-2-WFOS-36070] The LSV shall sample the telescope pupil with a coarse **TBD x TBD** sub-aperture lenslet array.

[REQ-2-WFOS-36080] The LSV shall sample the telescope pupil with a fine **TBD x TBD** sub-aperture lenslet array.

[REQ-2-WFOS-36090] The LSV detector shall sample each sub-aperture with at least **TBD** pixels per sub-aperture.

The LSV detector shall meet the following performance requirements under the normal operating conditions:

[REQ-2-WFOS-36200]	Dark current:	**TBD** e-/sec
[REQ-2-WFOS-36210]	Read noise:	**TBD** e- at TBD pixels/sec
[REQ-2-WFOS-36220]	Frame rate:	**TBD** frames per second
[REQ-2-WFOS-36230]	Quantum efficiency:	**TBD** % at 320 nm
		TBD % at 600 nm
		TBD % at 900 nm
		TBD % average across wavelength range
[REQ-2-WFOS-36240]	Readout time:	**TBD** milliseconds
[REQ-2-WFOS-36250]	Pixel size:	**TBD** microns
[REQ-2-WFOS-36260]	Pixel format:	**TBD** x **TBD** pixels
[REQ-2-WFOS-36270]	Operating temp:	**TBD** K

[REQ-2-WFOS-36300] The LSV subsystems shall be able to start and initialize in no more than **TBD** seconds (initialization time budget).

[REQ-2-WFOS-36310] The LSV subsystems shall be able to configure itself in no more than **30** seconds (configuration time budget).

Discussion: This requirement flows from the MOBIE OCDD, section 2.3.18.

[REQ-2-WFOS-36320] The LSV subsystem shall provide a selection of slit length x slit width combinations that are **TBD**.

Discussion: This requirement flows from the MOBIE OCDD, section 2.3.5.

[REQ-2-WFOS-36330] The LSV, once parked at the active position, and under the effects of gravity flexure and thermal changes, shall not move in X, Y, Z (instrument coordinates) by more than **TBD** microns and TBD arcsec in Rx, Ry, Rz.

[REQ-2-WFOS-36340] The LSV optical system shall remain in focus with respect to the nominal telescope surface over the operating temperature range (no automated focus) of **TBD** degrees C.

[REQ-2-WFOS-36350] The LSV filter changer shall exchange filters in no more than **TBD** seconds (configuration time budget)

[REQ-2-WFOS-36360] The LSV filter changer shall position filters in the LSV optical path repeatably to better than **TBD** microns RMS.

[REQ-2-WFOS-36370] The LSV filters shall have passbands from **TBD1** to **TBD2** nm, and **TBD3** to **TBD4** nm.

[REQ-2-WFOS-36380] LSV filters shall be able to be exchanged within **TBD** seconds (configuration time budget).

[REQ-2-WFOS-36390] LSV filters shall position repeatably to **TBD** X, Y, Z microns, and **TBD** Rx, Ry, Rz arcsec.

[REQ-2-WFOS-36400] Heat sources for control of the LSV shall dissipate no more than **TBD** W into the instrument cooling system (cooling budget).

[REQ-2-WFOS-36410] Heat sources for the control of the LSV shall dissipate no more than **TBD** W into the instrument enclosure (waste heat budget).

3.5.8 Focal Plane Server

The focal plane server (FPS) carries and inserts slit masks (and similar accessories) into the telescope focal plane. The performance requirements on the FPS address:

- Slit mask characteristics
- Mass
- Acquisition time
- Initialization time
- Configuration time
- Motion control
- Hold position stability (flexure)
- Thermal stability
- Heat transfer to the instrument cooling system
- Heat transfer to the dome environment

3.5.8.1 Slitmasks

[REQ-2-WFOS-37010] The mask material CTE shall match the thermal plate scale change of the telescope within **TBD** PPM/C. Alternately, the scale solution for a mask shall be within **TBD** arcsec within TBD degrees of the design temperature.

Discussion: This requirement flows directly from REQ-1-ORD-2850, which limits telescope plate scale variation to 0.06 arcsec, with a goal of 0.02 arcsec.

[REQ-2-WFOS-37020] Masks shall have slits cut such that no slit is more than TBD microns from its nominal position, over a temperature range of **TBD** C.

[REQ-2-WFOS-37030] Masks mounted in frames shall match the telescope focal surface radius of curvature within **TBD** microns RMS.

[REQ-2-WFOS-37040] Masks mounted in frames shall match the telescope focal surface radius of curvature such that the worst location on the mask is within **TBD** microns of the focal surface.

[REQ-2-WFOS-37050] Slitmasks shall be completely opaque from **TBD1** nm to **TBD2** nm.

[REQ-2-WFOS-37060] Slitmask unit mass shall not exceed **TBD** Kg.

3.5.8.2 Focal Plane Server

[REQ-2-WFOS-37070] The mass of the FPS system shall not exceed **TBD** Kg (mass allocation budget).

[REQ-2-WFOS-37080] The FPS system shall provide the capacity to hold **10** slitmasks.

Discussion: This requirement flows directly from MOBIE OCDD section 2.3.3.

[REQ-2-WFOS-37090] The instrument shall be delivered with **TBD** slitmask blanks (un-cut slitmasks).

[REQ-2-WFOS-37100] The instrument shall be delivered with **TBD** slitmask frames.

[REQ-2-WFOS-37110] The FPS shall provide a field stop mask for use during direct imaging.

[REQ-2-WFOS-37120] The FPS shall carry a maximum of **TBD** masks at any time.

[REQ-2-WFOS-37130] The FPS shall provide features to facilitate the installation of a full complement of masks within **TBD** minutes, by a single technician.

[REQ-2-WFOS-37140] The FPS shall enable field acquisition in less than 3 minutes.

This requirement flows from the SRD V17.5, section 2.5.3.10, "field acquisition for multi-slit masks must be short (<3 minutes once the telescope is in position)". This implies that the FPS must remove one mask, select, and insert a new mask, all in less than 3 minutes.

[REQ-2-WFOS-37150] The FPS shall be able to start and initialize itself in no more than **TBD** seconds (initialization time budget).

[REQ-2-WFOS-37160] The FPS shall be able to configure itself in no more than **30** seconds (configuration time budget).

Discussion: This requirement flows from the MOBIE OCDD, section 2.3.18.

[REQ-2-WFOS-37170] The FPS shall be able to select any mask from the selection, and place it at the insertion position, within **TBD** seconds (configuration time budget).

[REQ-2-WFOS-37180] The FPS shall be able to transport a selected mask from the changer to the operating position within **TBD** seconds (configuration time budget).

[REQ-2-WFOS-37190] The FPS shall place a mask at the operating position repeatably to **TBD** microns in X, Y, and Z.

[REQ-2-WFOS-37200] The FPS shall place a mask at the operating position repeatably to **TBD** arcsec in Rx, Ry, and Rz.

[REQ-2-WFOS-37210] The FPS shall hold a mask rigidly at the operating position, such that flexure or other effects move the mask by less than **TBD** microns in X, Y, Z, and less than **TBD** arcsec in Rx, Ry, Rz over a **TBD** rotation of the instrument about the Nasmyth axis.

[REQ-2-WFOS-37220] The FPS and associated stray light controls shall limit stray light to **TBD** orders of magnitude less than the incident illumination. (light leaks)

[REQ-2-WFOS-37230] Heat sources in the FPS shall dissipate no more than **TBD** W into the instrument cooling system (cooling budget).

[REQ-2-WFOS-37240] Heat sources in the FPS shall dissipate no more than **TBD** W into the instrument enclosure (waste heat budget).

3.5.9 Collimator

The collimator optical system (COL) creates a pupil at which the dispersing optics will operate. It is assumed here that the collimator is a reflecting optic, although refracting designs also exist. The requirements here address:

- Mass
- Image quality
- Image motion due to flexure
- Initialization time
- Configuration time
- Positioning resolution
- Positioning repeatability
- Focus travel range
- Tilt angle range
- Heat transfer to the instrument cooling system
- Heat transfer to the dome environment

[REQ-2-WFOS-38010] The mass of the COL system shall not exceed **TBD** Kg (mass allocation budget).

[REQ-2-WFOS-38020] The collimator mirror static figure error shall contribute no more than **TBD** nm RMS to the final image size (image quality error budget).

[REQ-2-WFOS-38030] The collimator mirror static figure error shall contribute no more than **TBD** nm RMS to the final image size (image quality error budget).

[REQ-2-WFOS-38040] The collimator mirror static figure error shall contribute no more than **TBD** nm Peak-to-Valley to the final image size (image quality error budget).

[REQ-2-WFOS-38050] The collimator optical system shall contribute no more than **TBD** arcsec of image motion (blur) over any **TBD** degree rotation (**TBD** minute exposure within **TBD** of zenith) of the instrument about the Nasmyth axis (image motion error budget).

[REQ-2-WFOS-38060] The COL motion control system shall be able to start and initialize itself in no more than **TBD** seconds (configuration time budget).

[REQ-2-WFOS-38070] The collimator mirror shall be able to configure itself in less that **TBD** seconds (configuration time budget).

Discussion: This requirement flows from the MOBIE OCDD, section 2.3.18.

[REQ-2-WFOS-38080] The COL opto-mechanics shall provide **TBD** mm of focus stroke for the mirror.

[REQ-2-WFOS-38090] Focus motion of the collimator mirror shall be encoded and the position of the mirror shall be repeatable to **TBD** microns.

[REQ-2-WFOS-38100] The COL opto-mechanics shall provide **TBD** arcsec of tilt motion for flexure control.

Discussion: The red and blue science cameras may be located at different distances from the collimator mirror, and the focal lengths of the two cameras may be different. The effectiveness of flexure correction with the collimator remains to be determined, and these requirements will change accordingly.

[REQ-2-WFOS-38110] Tilt motion of the collimator mirror shall be encoded and tilt angles of the mirror shall be repeatable to **TBD** arcsec.

[REQ-2-WFOS-38120] Heat sources for control of the collimator mirror shall dissipate no more than **TBD** W into the instrument cooling system (cooling budget).

[REQ-2-WFOS-38130] Heat sources for the control of the collimator mirror shall dissipate no more than **TBD** W into the instrument enclosure (waste heat budget).

3.5.10 Dichroics

The fixed dichroic system (DCR) includes the dichroic beam-splitting optic and the supporting opto-mechanics, which split the optical system into red and blue channels, following the collimator. The requirements here address:

- Mass
- Image quality
- Image degradation due to flexure
- Image motion due to flexure

[REQ-2-WFOS-39010] The dichroic cross-over wavelength shall be **TBD** nm.

Discussion: The nominal cross-over wavelength will be determined later in the MOBIE development process.

[REQ-2-WFOS-39020] The mass of the dichroic subsystem shall not exceed **TBD** Kg (mass allocation budget).

[REQ-2-WFOS-39030] The dichroic static reflected wavefront error shall be no more than **TBD** nm RMS (image quality error budget).

[REQ-2-WFOS-39040] The dichroic static transmitted wavefront error shall be no more than **TBD** nm RMS (image quality error budget).

[REQ-2-WFOS-39050] The dichroic static reflected wavefront error shall be no more than **TBD** nm peak-to-valley (image quality error budget).

[REQ-2-WFOS-39060] The dichroic static transmitted wavefront error shall be no more than **TBD** nm peak-to-valley (image quality error budget).

[REQ-2-WFOS-39070] The dichroic shall contribute no more than **TBD** microns of image degradation, to the reflected and transmitted beams, over any **TBD** rotation of the instrument about the Nasmyth axis (image quality error budget).

[REQ-2-WFOS-39080] The dichroic shall contribute no more than **TBD** arcsec of image motion (blur) in the reflected beam, over any **TBD** degree rotation of the instrument about the Nasmyth axis (image motion error budget).

[REQ-2-WFOS-39090] The dichroic shall contribute no more than **TBD** arcsec of image motion (blur) in the transmitted beam, over any **TBD** degree rotation of the instrument about the Nasmyth axis (image motion error budget).

3.5.11 Echellette Prisms

The echellette server (ECH) enables the echellette mode by inserting a cross-dispersing prism into the optical path. The requirements here address:

- Mass
- Image quality
- Initialization time
- Configuration time
- Motion control
- Image degradation due to flexure
- Image motion due to flexure
- Heat transfer to the instrument cooling system
- Heat transfer to the dome environment

[REQ-2-WFOS-40010] The mass of the prism server subsystem shall not exceed **TBD** Kg (mass allocation budget).

[REQ-2-WFOS-40020] The prism server shall contribute no more than **TBD** microns RMS to the final image quality (image quality error budget).

[REQ-2-WFOS-40030] The prism server shall contribute no more than **TBD** microns of image degradation over any **TBD** rotation of the instrument about the Nasmyth axis (image quality error budget).

[REQ-2-WFOS-40040] The prism server shall contribute no more than **TBD** arcsec of image motion (blur) over any **TBD** degree rotation of the instrument about the Nasmyth axis (image motion error budget).

[REQ-2-WFOS-40050] The prism server shall be able to start and initialize itself in no more than **TBD** seconds (initialization time budget).

[REQ-2-WFOS-40060] The prism server shall be able to traverse the full insertion/retraction stroke in less that **TBD** seconds (configuration time budget).

Discussion: This requirement flows from the MOBIE OCDD, section 2.3.18.

[REQ-2-WFOS-40060] The prism server shall position the prism in the optical path repeatably with positional accuracy of better than **TBD** microns in X, Y, Z (instrument coordinates).

[REQ-2-WFOS-40070] The prism server shall position the prism in the optical path repeatably with rotational accuracy of better than **TBD** arcsec in Rx, Ry, Rz (instrument coordinates).

[REQ-2-WFOS-40080] Heat sources for control of the prism server shall dissipate no more than **TBD** W into the instrument cooling system (cooling budget).

[REQ-2-WFOS-40090] Heat sources for the control of the prism server shall dissipate no more than **TBD** W into the instrument enclosure (cooling budget).

3.5.12 Disperser Servers

The disperser server systems (DSS), one per color channel, enable the exchange of optics to switch between imaging or grating-dispersed spectroscopic modes. The requirements here address:

- Optics capacity
- Mass
- Image quality
- Initialization time
- Motion control
- Image degradation due to flexure
- Image motion due to flexure
- Heat transfer to the instrument cooling system
- Heat transfer to the dome environment

[REQ-2-WFOS-41000] The DSS shall carry a minimum of 3 dispersing optics, and at least one mirror for the imaging modes.

Discussion: This requirement flows from the MOBIE OCDD, section 2.3.1.

[REQ-2-WFOS-41010] The mass of the DSS shall not exceed **TBD** Kg (mass allocation budget).

[REQ-2-WFOS-41020] Grating(s) shall contribute no more than **TBD** microns RMS to the final image quality (image quality error budget).

[REQ-2-WFOS-41030] Grating(s) shall contribute no more than **TBD** microns RMS of image degradation over any **TBD** rotation of the instrument about the Nasmyth axis (image quality error budget).

[REQ-2-WFOS-41040] Grating(s) shall contribute no more than **TBD** arcsec of image motion (blur), over any **TBD** degree rotation of the instrument about the Nasmyth axis (image motion error budget).

[REQ-2-WFOS-41050] The disperser server shall be able to start and initialize itself in no more than **TBD** seconds (initialization time budget).

[REQ-2-WFOS-41060] The disperser server shall be able to configure itself in no more than **20** seconds (configuration time budget).

Discussion: This requirement flows from the MOBIE OCDD, section 2.3.1.

[REQ-2-WFOS-41070] The disperser server shall be able to switch between selected optics in less than **TBD** seconds (configuration time budget).

[REQ-2-WFOS-41080] The disperser server shall position the selected optic in the optical path repeatably, to better than **TBD** microns in X, Y, Z (instrument coordinates).

[REQ-2-WFOS-41090] The disperser server shall position the selected optic in the optical path repeatably, to better than **TBD** arcsec in Rx, Ry, Rz (instrument coordinates).

[REQ-2-WFOS-41100] Heat sources for control of the disperser server shall dissipate no more than **TBD** W into the instrument cooling system (cooling budget).

[REQ-2-WFOS-41110] Heat sources for the control of the disperser server shall dissipate no more than TBD W into the instrument enclosure (cooling budget).

3.5.13 Blue Camera

There is a blue-channel optical camera (BCAM). The requirements here address:

- Mass
- Image quality
- Image degradation due to flexure
- Image motion due to flexure

[REQ-2-WFOS-42010] The mass of the BCAM system shall not exceed **TBD** Kg (mass allocation budget).

[REQ-2-WFOS-42020] The BCAM optics shall contribute no more than **TBD** microns RMS to the final image quality (image quality error budget).

[REQ-2-WFOS-42030] The BCAM optics shall contribute no more than **TBD** microns RMS of image degradation over any TBD rotation of the instrument about the Nasmyth axis (image quality error budget).

[REQ-2-WFOS-42040] The BCAM optics shall contribute no more than **TBD** arcsec of image motion (blur), over any TBD degree rotation of the instrument about the Nasmyth axis (image motion error budget).

[REQ-2-WFOS-42050] Thermal defocus of the BCAM shall not exceed **TBD** microns RMS over the operating temperature range (range of focus control).

[REQ-2-WFOS-42060] Thermal defocus of the BCAM shall not exceed **TBD** microns RMS over any **TBD** degree temperature change (range of focus control).

3.5.14 Red Camera

There is a red-channel optical camera (RCAM). The requirements here address:

- Mass
- Image quality
- Image degradation due to flexure
- Image motion due to flexure

[REQ-2-WFOS-43010] The mass of the BCAM system shall not exceed **TBD** Kg (mass allocation budget).

[REQ-2-WFOS-43020] The RCAM optics shall contribute no more than **TBD** microns RMS to the final image quality (image quality error budget).

[REQ-2-WFOS-43030] The RCAM optics shall contribute no more than **TBD** microns RMS of image degradation over any **TBD** rotation of the instrument about the Nasmyth axis (image quality error budget).

[REQ-2-WFOS-43040] The RCAM optics shall contribute no more than **TBD** arcsec of image motion (blur), over any **TBD** degree rotation of the instrument about the Nasmyth axis (image motion error budget).

[REQ-2-WFOS-43050] Thermal defocus of the RCAM shall not exceed **TBD** microns RMS over the operating temperature range (range of focus control).

[REQ-2-WFOS-43060] Thermal defocus of the RCAM shall not exceed **TBD** microns RMS over any TBD degree temperature change (range of focus control).

3.5.15 Filter Servers

The filter server systems (FSS) provide a means for remote-controlled selection of optical filters. The requirements here address:

- Filter capacity
- Mass
- Image quality
- Initialization time
- Configuration time
- Motion control
- Image degradation due to flexure
- Image motion due to flexure
- Heat transfer to the instrument cooling system
- Heat transfer to the dome environment

[REQ-2-WFOS-44000] The filter servers shall carry a minimum of **6** filter units.

Discussion: This requirement flows from the MOBIE OCDD, section 2.3.9.

[REQ-2-WFOS-44010] The mass of the FSS shall not exceed **TBD** Kg (mass allocation budget).

[REQ-2-WFOS-44020] The filters shall contribute no more than TBD microns RMS to the final image quality (image quality error budget).

[REQ-2-WFOS-44030] The filters shall contribute no more than **TBD** microns RMS of image degradation over any **TBD** rotation of the instrument about the Nasmyth axis (image quality error budget).

[REQ-2-WFOS-44040] The filters shall contribute no more than **TBD** arcsec of image motion (blur), over any **TBD** degree rotation of the instrument about the Nasmyth axis (image motion error budget).

[REQ-2-WFOS-44050] The FS shall be able to start and initialize itself in no more than **TBD** seconds (initialization time budget).

[REQ-2-WFOS-44070] The FS shall be able to insert or retract any optic to/from the optical path in less than **30** seconds (configuration time budget).

Discussion: This requirement flows from the MOBIE OCDD, section 2.3.18.

[REQ-2-WFOS-44080] The FS shall position the filters in the optical path repeatably, to no more than **TBD** microns in X, Y, Z (instrument coordinates).

[REQ-2-WFOS-44080] The FS shall position the filters in the optical path repeatably, to no more than **TBD** arcsec in Rx, Ry, Rz (instrument coordinates).

[REQ-2-WFOS-44090] Heat sources for control of the FS shall dissipate no more than **TBD** W into the instrument cooling system (cooling budget).

[REQ-2-WFOS-44100] Heat sources for the control of the FS shall dissipate no more than **TBD** W into the instrument enclosure (cooling budget).

3.5.16 Shutters

Shutters provide a means for precise remote-control timing of imaging and spectroscopic exposures. One shutter is required for each color channel. The requirements here address:

- Mass
- Initialization time
- Configuration time
- Linearity
- Reset time
- Heat transfer to the instrument cooling system
- Heat transfer to the dome environment

[REQ-2-WFOS-45010] The mass of the shutter system shall not exceed **TBD** Kg (mass allocation budget).

[REQ-2-WFOS-45020] The shutter shall be able to start and initialize itself in no more than **TBD** seconds (initialization time budget).

[REQ-2-WFOS-45030] The shutter shall be able to configure itself in no more than **TBD** seconds (configuration time budget).

Discussion: This requirement flows from the MOBIE OCDD, section 2.3.18.

[REQ-2-WFOS-45040] The minimum exposure time shall be **TBD** milliseconds, at **TBD** linearity.

[REQ-2-WFOS-45050] The linearity of timing for any exposure shall be better than **TBD** % of the total exposure time.

[REQ-2-WFOS-45060] The shutter shall be able to reset, and become ready for a new exposure, in no more than **TBD** seconds (configuration time budget).

[REQ-2-WFOS-45070] Heat sources for control of the shutters shall dissipate no more than **TBD** W (each) into the instrument cooling system (cooling budget).

[REQ-2-WFOS-45080] Heat sources for the control of the shutters shall dissipate no more than **TBD** W (each) into the instrument enclosure (waste heat budget).

3.5.17 Science Detectors

There are science detector systems (DET) for each color channel. The DET systems include a vacuum vessel for housing the detectors, the detector focal plane assembly (FPA), and the cryogenic cooling systems (CCS) for maintaining the detectors at cryogenic operating temperatures. The requirements here address:

- Mass
- Dewar windows
- FPA motion control (flexure and focus)
- Initialization time
- Configuration time
- Detector performance
- Vacuum controls
- Thermal performance
- Detector controllers
- Heat transfer to the instrument cooling system
- Heat transfer to the dome environment

[REQ-2-WFOS-46010] The mass of the DET system shall not exceed **TBD** Kg (mass allocation budget).

Discussion: The mass of the DET system includes all parts of the system that mount on the rotating portion of the instrument. It is anticipated that additional mass, in the form of cryogenic refrigerator compressors and associated gas hoses, will be supported by the telescope.

3.5.17.1 Window

The DET windows are specified optically as the last element in both of the optical cameras. Non-optical issues are addressed here.

[REQ-2-WFOS-46020] Stresses due to the pressure drop (atmospheric pressure to vacuum) in the window shall not exceed **TBD** MPa.

Discussion: High stresses in the window could lead to failure, and destruction of expensive detectors. The design of the window must insure that the sum of all stresses acting on the window is well under the yield stress of the window material.

[REQ-2-WFOS-46030] Stresses due to thermal gradients in the window shall not exceed **TBD** MPa.

Discussion: Radial thermal gradients will occur in the window, due to the thermal loading and mechanical constraints on the window.

[REQ-2-WFOS-46040] Non-optical edges and surfaces shall be polished to **TBD** surface roughness to eliminate fracture propagation sites in the window.

Discussion: Brittle materials are subject to failure at low stress over extended time periods. Stresses in the window should be low enough that the expected lifetime of the window is effectively infinite.

3.5.17.2 FPA Motion Control

Motion control of the in-plane and out-of-plane translations of the FPA is used to provide flexure compensation (removal of image motion) and focus control.

[REQ-2-WFOS-46050] The DET system shall provide **TBD** microns of X motion of the focal plane mosaic (for flexure control).

[REQ-2-WFOS-46060] The DET system shall provide **TBD** microns of Y motion of the focal plane mosaic (for flexure control).

[REQ-2-WFOS-46070] The DET system shall provide **TBD** microns of Z motion of the focal plane mosaic (for focus control).

Discussion: Translations of the FPA are intended to provide flexure and focus control. No tilt correction or control of the FPA is planned.

[REQ-2-WFOS-46080] The DET motion control systems shall be able to start and initiate themselves in no more than **TBD** seconds (initialization time budget).

[REQ-2-WFOS-46090] The DET motion control systems shall be able to configure themselves in no more than **30** seconds (configuration time budget).

Discussion: This requirement flows from the MOBIE OCDD, section 2.3.18.

[REQ-2-WFOS-46100] The position of the focal plane in X and Y shall be encoded, stable, and repeatable to **TBD** micron RMS.

[REQ-2-WFOS-46110] Focus (Z) translation shall be encoded, stable, and repeatable to **TBD** microns.

[REQ-2-WFOS-46120] The motion control system shall add no more than **TBD** microns of image motion itself (static stiffness).

[REQ-2-WFOS-46130] Tip/tilt of the focal plane (unintentionally) due to X, Y, and Z translations shall not exceed **TBD** microns over the shortest baseline across the focal plane.

[REQ-2-WFOS-46140] The FPA motion control systems shall dissipate no more than **TBD** W into the instrument cooling system (cooling budget).

[REQ-2-WFOS-46150] The FPA motion control systems shall dissipate no more than **TBD** W into the instrument enclosure (waste heat budget).

3.5.17.3 Detectors

The blue camera detectors shall meet the following performance requirements under the normal operating conditions:

[REQ-2-WFOS-46300]	Dark current:	**TBD** e-/sec
[REQ-2-WFOS-46310]	Read noise:	**TBD** e- at TBD pixels/sec
[REQ-2-WFOS-46320]	Frame rate:	**TBD** frames per second
[REQ-2-WFOS-46330]	Quantum efficiency:	**TBD** % at 320 nm
		TBD % at 600 nm
		TBD % at 900 nm
		TBD % average across wavelength range
[REQ-2-WFOS-46340]	Readout time:	**TBD** milliseconds
[REQ-2-WFOS-46350]	Pixel size:	**TBD** microns
[REQ-2-WFOS-46360]	Pixel format:	**TBD** x **TBD** pixels
[REQ-2-WFOS-46370]	Operating temp:	**TBD** K

The blue camera detectors shall meet the following performance requirements under the normal operating conditions:

[REQ-2-WFOS-46400]	Dark current:	**TBD** e-/sec
[REQ-2-WFOS-46410]	Read noise:	**TBD** e- at TBD pixels/sec
[REQ-2-WFOS-46420]	Frame rate:	**TBD** frames per second
[REQ-2-WFOS-46430]	Quantum efficiency:	**TBD** % at 320 nm
		TBD % at 600 nm
		TBD % at 900 nm
		TBD % average across wavelength range
[REQ-2-WFOS-46440]	Readout time:	**TBD** milliseconds
[REQ-2-WFOS-46450]	Pixel size:	**TBD** microns
[REQ-2-WFOS-46460]	Pixel format:	**TBD** x **TBD** pixels
[REQ-2-WFOS-46470]	Operating temp:	**TBD** K

3.5.17.4 Vacuum Controls

[REQ-2-WFOS-46500] The DET system nominal operating pressure shall be **TBD** Torr.

[REQ-2-WFOS-46510] The DET system shall be capable of being pumped down to the nominal operating pressure in less than **TBD** hours.

[REQ-2-WFOS-46520] The DET system shall maintain the operating pressure for at least **TBD** days (weeks) between pumping cycles.

[REQ-2-WFOS-46530] The DET system internal pressure shall be remotely sensed, displayed, and logged with a resolution of **TBD** e-6 Torr.

3.5.17.5 Thermal

[REQ-2-WFOS-46550] The DET detector controllers shall dissipate no more than **TBD** W (each) into the instrument cooling system (cooling budget).

[REQ-2-WFOS-46560] The DET detector controllers shall dissipate no more than **TBD** W (each) into the instrument enclosure (waste heat budget).

[REQ-2-WFOS-46570] The focal plane mosaic shall be capable of safely cooling from room temperature to operating temperature within **TBD** hours.

[REQ-2-WFOS-46580] The focal plane mosaic shall be capable of safely warming from operating temperature to room temperature within **TBD** hours.

[REQ-2-WFOS-46590] The dewars shall be capable of accelerating warm-up of the focal plane by the introduction of dry nitrogen into the vacuum vessel.

[REQ-2-WFOS-46600] The temperature of the focal plane mosaic shall be actively (closed-loop) controlled to the nominal operating temperature of **TBD** degrees K.

Discussion: The nominal operating temperature for the blue and red detector systems may differ based on the performance of the blue and red channel detectors.

[REQ-2-WFOS-46610] Gradients in the focal plane mosaic temperature with position shall be less than **TBD** degrees K.

[REQ-2-WFOS-46620] The detectors on the focal plane mosaics shall operate within **TBD** degrees K of each other.

[REQ-2-WFOS-46650] The temperature of the FPA base plate shall be sensed at **TBD** locations, at equally spaced over the focal plane area.

3.5.17.6 Detector Controllers

[REQ-2-WFOS-46700] The detector controllers shall be able to start and initialize in less than **TBD** seconds (initialization time budget).

[REQ-2-WFOS-46800] The detector controllers shall be able to configure themselves in less than **30** seconds (configuration time budget).

Discussion: This requirement flows from the MOBIE OCDD, section 2.3.18.

[REQ-2-WFOS-46710] The detector controllers shall dissipate no more than **TBD** W into the instrument cooling system (cooling budget).

[REQ-2-WFOS-46720] The detector controllers shall dissipate no more than **TBD** W into the instrument enclosure (waste heat budget).

The detector controllers shall meet the following requirements:

[REQ-2-WFOS-46730]	Readout channels/device:	**TBD** (2?)
[REQ-2-WFOS-46740]	Bits/pixel:	**TBD** (16?)
[REQ-2-WFOS-46750]	Read noise:	**TBD** minimum**, TBD** maximum
[REQ-2-WFOS-46760]	Crosstalk:	**TBD** e-, between channels
[REQ-2-WFOS-46770]	Crosstalk:	**TBD** e-, between devices
[REQ-2-WFOS-46780]	Readout time:	**TBD** seconds, fastest readout mode, at **TBD** e-
		TBD seconds, lowest noise mode, at **TBD** e-
		TBD second, normal operating mode, at **TBD** e-
[REQ-2-WFOS-46790]	Uniformity:	**TBD** %
[REQ-2-WFOS-46800]	Non-linearity:	**TBD** %
[REQ-2-WFOS-46810]	Pixel readout rate:	**TBD** MHz, continuously variable

3.5.18 Stray Light Controls

Stray light controls and features (aperture stops, vanes, baffles, absorbing coatings, etc) are distributed throughout the instrument. The requirements here address:

- Stray light levels at the focal planes

[REQ-2-WFOS-47010] The instrument stray light controls shall maintain the level of scattered and stray light, at the science detectors, to less than **3%** of the night-sky background level, across the full operating wavelength range for each color channel.

Discussion: This requirement flows from the MOBIE OCDD, section 2.3.23.

3.5.19 Instrument Enclosures

The instrument enclosure system (ENC) provides a means for making the rotating portion of the instrument light-tight, dust-tight, thermally isolated, and protected from foreign object damage (e.g. falling objects, moving items on the Nasmyth platform). The requirements here address:

- Thermal performance
- Heat transfer to the instrument cooling system
- Heat transfer to the dome environment
- Air pressurization

[REQ-2-WFOS-48010] Heat sources (e.g. circulation fans, sensors, switches, control electronics) associated with the instrument enclosure system shall dissipate no more than **TBD** W into the instrument cooling system (cooling budget).

[REQ-2-WFOS-48020] Heat sources associated with the instrument enclosure system shall dissipate no more than **TBD** W into the instrument enclosure (waste heat budget).

[REQ-2-WFOS-48030] The enclosure shall maintain the internal temperature of instrument volume to within TBD degrees C over any **TBD** hour period.

[REQ-2-WFOS-48040] The enclosure shall provide filtered-air at **TBD** Pa above ambient pressure into the enclosure for dust-rejection from the instrument.

3.5.20 Instrument Electronics

The instrument electronics include all electrical and electronic subsystems required for instrument motion control, exposure control, data collection and management, environmental sensing, safety sensing, and all cabling, harnessing, connectors, racks and rack mounts. The electronics subsystems will be carried on both the rotating portion of the instrument, the instrument rotator, and electronics cabinets installed on the Nasmyth platform. The requirements here address:

- Mass
- Power consumption
- Initialization time
- Heat transfer to the instrument cooling system
- Heat transfer to the dome environment

[REQ-2-WFOS-49010] The mass of the Nasmyth-mounted instrument electronics systems shall not exceed **TBD** Kg (mass allocation budget).

[REQ-2-WFOS-49020] The power consumption of the Nasmyth-mounted electronics systems shall not exceed **TBD** KVA.

[REQ-2-WFOS-49030] The instrument electronics systems shall be able to start and initialize in less than **TBD** seconds (initialization time budget).

[REQ-2-WFOS-49040] Heat sources associated with the Nasmyth-mounted electronics systems shall dissipate no more than **TBD** W into the instrument cooling system (cooling budget).

[REQ-2-WFOS-49050] Heat sources associated with the Nasmyth-mounted electronics systems shall dissipate no more than **TBD** W into the instrument enclosure (waste heat budget).

3.5.21 Instrument Control System

The TMT project does not yet have a comprehensive software development program in place for the telescope or the instruments. Consequently, an instrument software requirements document will be developed in a later phase of the instrument project. Nevertheless, preliminary top-level performance requirements for instrument control software are presented here, addressing:

- Initialization time
- Configuration time
- Heat transfer to the instrument cooling system
- Heat transfer to the dome environment

[REQ-2-WFOS-50010] The instrument control system shall be able to restart and initiate itself in no more than **TBD** seconds (configuration time budget).

[REQ-2-WFOS-50020] The instrument control system shall be able to restart and initiate all of its dependent subsystems in no more than **30** seconds (configuration time budget).

Discussion: This requirement flows from the MOBIE OCDD, section 2.3.18.

[REQ-2-WFOS-50030] The instrument control systems shall dissipate no more than **TBD** W into the instrument cooling system (cooling budget).

[REQ-2-WFOS-50040] The instrument control systems shall dissipate no more than **TBD** W into the dome environment (waste heat budget).

3.5.22 Mask Fabrication System

The slitmask fabrication system (MFS) includes all the subsystems, hardware, and software required to define the size and location of the slits on the mask, apertures for mask alignment, and apertures for flexure sensing objects. The MFS includes simulation software for viewing mask designs and the format of spectra on the focal plane, based on the mask design. The MFS includes the cutting system that produces the finished slit masks, a transportation system for moving the masks from the cutter to the instrument, and a system for storing finished and used masks. The requirements here address:

- Minimum feature sizes
- Feature locations on the slit masks
- Feature orientation on the slit masks
- Feature shapes
- Slit edge roughness
- Slit parallelism
- Slit corner radii
- Maximum number of slits per mask
- Slit cutting speed

3.5.22.1 Slit Cutting

[REQ-2-WFOS-51010] The minimum slit size shall be TBD1 arcsec wide by TBD2 long.

[REQ-2-WFOS-51020] The minimum slit size (round or square) shall be **TBD** microns (or **TBD** arcseconds) across.

[REQ-2-WFOS-51030] Slits shall be able to be placed at arbitrary angles with respect to the instrument spatial and dispersion directions.

[REQ-2-WFOS-51040] Slits of arbitrary shapes shall be allowed.

[REQ-2-WFOS-51050] Slit edges shall be cut to **TBD** RMS surface roughness without additional post-cutting treatment.

[REQ-2-WFOS-51060] Slit edges shall be parallel to each other within **TBD** % of the slit width.

[REQ-2-WFOS-51070] Slit corners shall have a radius of no more than **TBD** microns.

3.5.22.2 Mask Fabrication System

[REQ-2-WFOS-51100] The slitmask fabrication system shall be capable of producing masks on short notice (less than **TBD** hours).

This requirement flows from the MOBIE OCDD, section 2.3.3, and is intended to allow rapid production of slit masks when justified by scientific need.

[REQ-2-WFOS-51110] The slitmask fabrication system shall be capable of cutting at least **TBD** slits on a single mask.

[REQ-2-WFOS-51120] The MFS shall be capable of cutting the maximum number of slits in less than **TBD** minutes.

[REQ-2-WFOS-51130] The MFS shall be capable of cutting slits on a curved surface that matches the nominal focal surface of the telescope.

[REQ-2-WFOS-51140] The MFS shall be capable of cutting a single night's complement of **TBD** masks in a single 8 hour (daytime) shift.

[REQ-2-WFOS-51150] The MFS shall be capable of stand-alone operation during the period required to cut all the slits on a single mask.

3.6 SYSTEM ATTRIBUTES

3.6.1 Design Attributes

[REQ-2-WFOS-52010] The instrument shall be designed, analyzed, and documented in SI (MKS) units.

*Discussion: SI units are the standard units for the design of TMT and its subsystems, as specified in the TMT Document Control Plan (**TMT.SEN.SPE.05.004).***

[REQ-2-WFOS-52020] The instrument shall be designed using "Design for Manufacturability" methodologies.

Discussion: "Design for Manufacturability" refers to designing parts and assemblies for ease of economical fabrication and assembly. See "Design for Manufacturability", D. M. Anderson, CIM Press, Cambria, CA, 2001, ISBN 1-878072-21-8.

[REQ-2-WFOS-52020] The instrument shall be designed using "Design for Metrology" methodologies.

Discussion: TMT will be assembled and aligned using the GMS (Global Metrology System), an optical metrology system (assumed here to be an array of laser trackers). The instrument subsystems shall incorporate metrology features (e.g. interfaces for corner cubes) to facilitate internal alignment. The instrument structure shall include metrology features (e.g. interfaces for corner cubes) to facilitate alignment of the instrument with the telescope.

3.6.1.1 Cabling and Plumbing

[REQ-2-WFOS-52030] All wiring, cabling, and plumbing shall carry numbering for uniquely identifying individual conductors or hoses.

Discussion: Marking or numbering of wiring, cabling, and plumbing can be accomplished with permanently attached labels or tags.

[REQ-2-WFOS-52040] Wire, cable, and hose numbering shall be visible at all junction points, connectors, and interface panels.

[REQ-2-WFOS-52050] All wiring, cabling, and plumbing shall be routed in conduit or other engineered wiring management systems.

Discussion: Self-adhesive anchors, "zip-ties", tape, and other temporary means for securing wiring, cabling, or plumbing should be avoided.

[REQ-2-WFOS-52060] Means for routing and securing of wiring and cabling shall be designed into all subsystems which utilize wiring or cabling.

[REQ-2-WFOS-52070] Means for routing and securing of plumbing lines (compressed air, coolant, etc.) shall be designed into all subsystem utilizing plumbing.

[REQ-2-WFOS-52080] Subsystems with motion control components shall provide a control interface to allow operating and fault diagnosis with a portable (laptop) computer.

3.6.1.2 Other

[REQ-2-WFOS-52090] All subsystems shall provide three lifting points (e.g. lifting eyes, swivel hoist rings), located on the subsystem so as to facilitate lifting, handling, and installation on the instrument.

Discussion: If the lifting features are not obvious, labels identifying lifting points shall be provided.

[REQ-2-WFOS-52100] All subsystems shall provide design features for interfacing with shipping containers.

Discussion: Most subsystems will be shipped as assembled units, and the subsystem mechanical designs should include support points or surfaces to facilitate safe and secure mounting and attachment of the subsystem into its shipping container.

3.6.2 Reliability

[REQ-2-WFOS-53010] The instrument shall have no more than 1.5% (**TBD**) unscheduled technical downtime between the end of nautical twilight and the start of morning nautical twilight, during hours scheduled for science operations.

Discussion: This requirement is a restatement of REQ-1-OCD-3085], as applied to the MOBIE instrument. The total unscheduled downtime for the observatory is 3%. Given that there nominally four instruments mounted at any time, and that any instrument shall be available within 10 minutes (see REQ-1-OCD-3125), we have divided the 3% allocation by 4, added in quadrature.

[REQ-2-WFOS-53020] To meet the unscheduled technical downtime requirement, the MOBIE instrument design shall include measures during the design and implementation phase to minimize the number of such failures, as well as minimize the cost and time necessary to recover from such failures.

Discussion: This requirement is a restatement of REQ-1-OCD-3090, applied to the MOBIE instrument. Such measures shall include:

• Identify all potential single-point failures. Whenever technically and fiscally possible, build in redundancy to minimize the number of potential single-point failures.

• Enable subsystem condition monitoring through implementation of mechanical and/or electronic wear and performance indicators. As much as possible, such condition information shall be captured and stored electronically for monitoring and analysis purposes.

*• Identify all parts likely to become obsolete during the first **TBD** years of operation and, as a goal, procure enough spare parts (consistent with their expected Mean Time Between Failure - MTBF) to cover all expected failures in that period.*

• Use common mechanical and electronic parts and solutions for common tasks and requirements.

• Design assemblies so that components can be replaced quickly in the event of a failure.

[REQ-2-WFOS-53030] In the design phase, and before Critical Design Review, the instrument design team shall perform a subsystem reliability analysis, and component tests as appropriate, to show that the instrument will meet the required level-1 reliability and maintainability budgets.

Discussion: This requirement is a restatement of REQ-1-ORD-6315, applied to the MOBIE instrument.

3.6.3 Availability

These are the 54000s.

This section is **TBD.**

3.6.4 Safety

[REQ-2_WFOS-55010] The instrument design shall comply with all applicable local and national safety regulations and standards.

Discussion: This requirement is a restatement of REQ-1-ORD-7000, applied to the MOBIE instrument design.

[REQ-2-WFOS-55020] Hazard analysis and safety practices developed for the MOBIE instrument shall be governed by an order of precedence as follows:

1. Design for Minimum Risk: The primary means for mitigation of risk shall be to eliminate the hazard through design.
2. Incorporate Safety Devices: Fixed, automatic or other protective devices shall be used in conjunction with the design features to attain an acceptable level of risk. Provisions shall be made for periodic functional checks as applicable.
3. Provide Warning Devices: When neither design nor safety items can effectively eliminate or reduce hazards, devices shall be used to detect the condition, and to produce an adequate warning to alert personnel of a hazard. Devices may include audible or visual alarms, permanent signs or movable placards.
4. Procedures and Training: Where it is impractical to substantially eliminate or reduce the hazard or where the condition of the hazard indicates additional emphasis, special operating procedures and training shall be used.

Discussion: This is a restatement of REQ-1-ORD-7005, applied to the design of the MOBIE instrument.

3.6.5 Maintainability

[REQ-2-WFOS-56010] A complete maintenance plan for the MOBIE instrument shall be delivered with the instrument.

Discussion: The above requirement is a restatement of REQ-1-ORD-6105, as applied to the MOBIE instrument.

[REQ-2-WFOS-56020] According to a written agreement (**TBD**) between the TMT and MOBIE projects, a set of MOBIE-specific servicing and spare parts shall be delivered with the instrument.

Discussion: The above requirement follows from REQ-1-ORD-6110, as applied to the MOBIE instrument.

[REQ-2-WFOS-56030] The MOBIE instrument subsystems shall be designed for maintainability, including the use of standard commercial components were possible, standardization on metric fasteners, etc.

Discussion: The above requirement follows from REQ-1-OCD-3000, as applied to the MOBIE instrument.

[REQ-2-WFOS-56040] The MOBIE instrument subsystems shall be delivered with maintenance manuals, as-built drawings, and comprehensive component parts lists.

Discussion: The above requirement follows from REQ-1-OCD-3005, as applied to the MOBIE instrument.

[REQ-2-WFOS-56050] For the purposes of monitoring technical performance, a **TBD** set of automatic reports based on engineering telemetry shall be generated on a daily basis. More detailed requirements are **TBD.**

Discussion: The above requirement follows from REQ-1-OCD-3020, as applied to the MOBIE instrument.

[REQ-2-WFOS-56060] Instrument subsystems shall be designed in a modular fashion, to facilitate stand-alone testing, integration, and removal/installation from the instrument.

[REQ-2-WFOS-56070] Instrument subsystems with electronic components shall be fitted with a centralized set of commercially standard electrical connectors, to facilitate installation and removal of the subsystem for servicing and maintenance.

[REQ-2-WFOS-56080] The instrument shall provide service features (e.g. hand-holds, steps, platforms, etc.) adjacent to all configurable subsystems (e.g. focal plane server with slitmasks, and filter servers with filters), to facilitate servicing and maintenance.

3.7 ACCESS AND HANDLING

The requirements in this section will be numbered as the 57000s. Access and handling requirements will be defined later in the MOBIE project development process.

3.8 OTHER REQUIREMENTS

[REQ-2-WFOS-58010] The IS design shall carry and transfer loads in tension-compression members, or in plate structures under shear loading.

Discussion: The use of structural members in bending, other than in the design of flexures, is inefficient in terms of mass and flexibility, both of which should be minimized in the structure design.

[REQ-2-WFOS-58020] Subsystems shall be permanently labeled with assembly drawing number and references to relevant service and repair documentation.

[REQ-2-WFOS-58030] The instrument guide, wavefront sensing, and slit viewing cameras shall utilize a common detector system, common readout electronics, and common control software.

[REQ-2-WFOS-58040] The GCM, WFS, and LSV cameras shall be electrically, optically, and mechanically interchangeable, such that any one of the camera/detector systems may be swapped between the GCM, WFS, and LSV systems.

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