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| Functional and Performance Requirements DocumentForIRMS |
| Version 1.4 |

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Figure 1 IRMS installed on the top port of NFIRAOS

# Introduction

## Introduction

This document describes the functional and performance requirements for the InfraRed MultiSlit Spectrometer (IRMS), a first-light cryogenic instrument on the Thirty Meter Telescope (TMT). These requirements flow down from the requirements in the IRMS Conceptual Design Study Work Package (AD4), and the Level 1 Requirements in the Observatory Architecture Document (OAD), the Observatory Requirements Document (ORD) and the Operational Concept Document (OCD). Requirements from the OAD and ORD which are specific to IRMS are included in this document, and given IRMS requirement numbers.

 IRMS is a copy of MOSFIRE, a W. M. Keck Observatory instrument, and replicates as much of MOSFIRE as possible in order to minimize cost and risk. Therefore, the majority of the functional and performance requirements replicate the requirements derived for MOSFIRE during its development.

## Purpose

The purpose of this functional and performance requirements document (FPRD) is to provide a comprehensive list of the IRMS functional and performance requirements. This document is to be used by the designer and fabricator of IRMS and any of its elements. As well it will be used as a checklist during acceptance and verification testing of IRMS.

The requirements documented in the IRMS FPRD are intended to fully describe the top level engineering requirements and functional concepts to satisfy the criteria of the IRMS Conceptual Design Study Work Package, ORD, OCD and OAD and by reference the Science Requirements Document, and the detailed Science Case for the Observatory.

The requirements in this document are at a draft level appropriate for the conceptual design phase of the instrument. However, many of the requirements are based on the as-built performance of MOSFIRE and will not change as the instrument design is developed. Further development of the requirements will take place in the next phase of the project (preliminary design). In particular, parametric performance requirements given at this stage are intended to indicate the scope and format of the requirements, but do not in all cases establish final values for the specified parameters. In some cases values for these parameters have yet to be established and are given as TBD.

## Scope

This document includes the Level 2 Requirements for IRMS.

Section 1 describes this document. Section 2 describes the overall IRMS System and Section 3 lists the requirements for IRMS. Paragraphs in Section 3 marked as “*Discussion*” are for information only and are not requirements.

This document does not include the external interfaces’ specific requirements. Instead compliance to each external ICD is an individual, numbered IRMS requirement.

## Applicable Documents

Applicable documents contain information that shall be applied in the context of current document.

**AD1 –** [Operations Concept Document (OCD)](http://project.tmt.org:8080/docushare/dsweb/Get/Document-7842), (TMT.OPS.MGT.07.002)

**AD2** – [Observatory Requirements Document](http://project.tmt.org:8080/docushare/dsweb/Get/Document-2688), (TMT.SEN.DRD.05.001)

**AD3** – [Observatory Architecture Document](http://project.tmt.org:8080/docushare/dsweb/Get/Document-2689), (TMT.SEN.DRD.05.002)

**AD4-** InfraRed MultiSlit Spectrometer (IRMS) Conceptual Design Study Work Package, (IRMS.CD.CIT.DRF02)

## Reference Documents

Reference documents contain information complementing, explaining, detailing, or otherwise supporting the information included in the current document.

**RD1** –Adkins, S. et al. “Requirements for MOSFIRE: Multi-Object Spectrometer for Infra-Red Exploration, Version 1.4”. April 15, 2007. W. M. Keck Observatory.

**RD2** – “Interface Control Document for MOSFIRE: Multi-Object Spectrometer for Infra-Red Exploration, Version 1.3”. April 12, 2007. W. M. Keck Observatory.

**RD3** – Narrow Field Infrared Adaptive Optics (NFIRAOS) To Infrared Multiple Object Spectrograph (IRMS), (TMT.SEN.ICD.08.001.DRF04)

**RD4** – NFIRAOS Design Requirement Document (TMT.AOS.DRD.07.002.REL07)

##  Referenced Standards

### Industry Consensus Standards

Table 1 lists the industry consensus standards referenced in this document in alphabetical order by standardizing organization. Unless otherwise noted all references to standards are included because compliance with some part of each standard may be required.

Table 1: Referenced Standards

|  |  |  |
| --- | --- | --- |
| **Source (Organization or Standardizing Body)** | **Number** | **Title** |
| ANSI | Y14.5M-1994 (R1999) | Dimensioning and Tolerancing |
| ANSI | Y14.1-1995 (R2002) | Decimal Inch Drawing Sheet Size And Format |
| ANSI | Y14.34-2003 | Parts Lists, Data Lists, And Index Lists: Associated Lists |
| ANSI | Y14.3M-1994 | Multi And Sectional View Drawings |
| ANSI / ASME | Y14.18M-1986 | Optical Parts (Engineering Drawings and Related Documentation Practices) |
| ASME | HPS‑2003 | High Pressure Systems  |
| ASME | Y14.100-2000 | Engineering Drawing Practices |
| ASME | Y32.10-1967 (R1994) | Graphic Symbols for Fluid Power Diagrams  |
| ASTM | E595-93 (2003)e1 | Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment |
| ATA | Spec 300‑2001.1 | Specification for Packaging of Airline Supplies |
| CENELEC | EN 50082-1:19971 | Electromagnetic compatibility – Generic immunity standard – Part 1: Residential, commercial and light industry |
| Council of the European Communities | EMC 89/336/EEC1 | Council Directive 89/336/EEC of 3 May 1989 on the approximation of the laws of the Member States relating to electromagnetic compatibility (EMC Directive) |
| County of Hawaii | 1995 edition | Hawaii County Code 1983 (1995 edition) |
| Department of Defense | MIL- STD-171E | Finishing of Metal and Wood Surfaces |
| Department of Defense | MIL-HDBK-217F-21 | Reliability Prediction of Electronic Equipment |

1. This reference for information only.

Table 1: Referenced Standards, continued

|  |  |  |
| --- | --- | --- |
| **Source (Organization or Standardizing Body)** | **Number** | **Title** |
| Department of Defense | MIL-STD-810F | Test Method Standard for Environmental Engineering Considerations and Laboratory Tests |
| EIA | EIA-310-D | Cabinets, Racks, Panels, and Associated Equipment |
| EIA | EIA-6491 | National Consensus Standard For Configuration Management |
| FCC | Title 47 CFR Part 151 | Radio Frequency Devices |
| IEEE | 802.3U revision 95 | Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method & Physical Layer Specifications: Mac Parameters, Physical Layer, Medium Attachment Units and Repeater for 100 Mb/S Operation (Version 5.0) |
| IEEE | 1012-2004 | Standard for Software Verification and Validation |
| International Code Council (ICC)  | IBC-2006 | 2006 International Building Code® |
| ISO/IEC | ISO / IEC 12207:1995 | Information Technology - Software life cycle processes |
| National Electric Manufacturers Association | 250-1997 | Enclosures for Electrical Equipment (1000 Volts Maximum) |
| National Fire Protection Association (NFPA) | NFPA 55, 2005 edition | Standard for the Storage, Use, and Handling of Compressed Gases and Cryogenic Fluids in Portable and Stationary Containers, Cylinders and Tanks |
| NFPA | NFPA 70, 2005 edition | National Electric Code |
| NFPA | NFPA 99C, 2005 edition  | Standard on Gas and Vacuum Systems |
| Naval Surface Warfare Center | NSWC 98/LE11 | Handbook of Reliability Prediction Procedures for Mechanical Equipment |
| OSHA | Title 29 CFR Part 1910 | Occupational Safety And Health Standards |
| Telcordia | GR-63-CORE | NEBS™ Requirements |

1. This reference for information only.

*Table 1: Referenced Standards, continued*

|  |  |  |
| --- | --- | --- |
| **Source (Organization or Standardizing Body)** | **Number** | **Title** |
| TIA/EIA | TIA/EIA-568-B | Commercial Building Telecommunications Cabling Standards |
| Underwriters Laboratories Inc. | Standard for Safety 508 | Industrial Control Equipment |

1. This reference for information only.

## Referenced Drawings

Table 2 lists the drawing numbers, revisions and date, source and title for all drawings referenced in this document.

Table 2: Referenced Drawings

|  |  |  |  |
| --- | --- | --- | --- |
| **Drawing #** | **Revision/Date** | **Source** | **Title** |
| TMT.SEN.DWG.10.004.REL02 | B/11-20-2010 | TMT | TMT Telescope – IRMS Instrument Space Envelope |

## Change Record

|  |  |  |  |
| --- | --- | --- | --- |
| Revision | Date | Section | Modifications |
| 1.0 | 6 August, 2012 | All | Initial draft B. Weber |
| 1.1 | 7 August, 2012 | All | Revisions by B. Weber (placeholder sections for electronics & software) |
| 1.2 | 10 January, 2013 | All | Revisions by B. Weber |
| 1.3 | 11 January, 2013 | All | Revisions by B. Weber |
| 1.4 | 29 January, 2013 | All | Converted to TMT format, B. Weber |

## Abbreviations & Acronyms

|  |  |
| --- | --- |
| **ANSI** | American National Standards Institute |
| **ASME** | American Society of Mechanical Engineers International |
| **ASTM** | ASTM International |
| **ATA** | Air Transport Association |
| **CCR** | Closed Cycle Refrigerator |
| **CENELEC** | European Committee for Electrotechnical Standardization |
| **CFR** | Code of Federal Regulations |
| **CIT** | California Institute of Technology |
| **COTS** | Commercial Off The Shelf |
| **CSU** | Configurable Slit Unit |
| **CVCM** | Collected Volatile Condensable Materials |
| **dBA** | Sound level in decibels, measured using the A contour frequency weighting network |
| **DCS** | Drive and Control System |
| **EIA** | Electronic Industries Alliance |
| **EMI** | Electro Magnetic Interference |
| **FOV** | Field Of View |
| **FPA** | Focal Plane Array |
| **FWHM** | Full Width at Half Maximum.  |
| **IBC** | International Building Code |
| **ICC** | International Code Council |
| **ICD** | Interface Control Document |
| **IEEE** | Institute of Electrical and Electronics Engineers |
| **IRMS** | Infrared Multiple Object Spectrograph |
| **MTBF** | Mean Time Between Failures |
| **NEBS** | Network Equipment Building System |
| **NEMA** | National Electric Manufacturers Association |
| **NFIRAOS** | Narrow Field Infrared Adaptive Optics |
| **NIR** | Near InfraRed |
| **OSHA** | Occupational Safety and Health Administration |
| **TBC** | To Be Completed |
| **TBD** | To Be Determined |
| **TIA** | Telecommunications Industry Association |
| **TML** | Total Mass Loss |
| **TMT** | Thirty Meter Telescope |
| **UCLA** | University of California, Los Angeles |
| **UCSC** | University of California, Santa Cruz |
| **UPS** | Uninterruptible Power Supply |
| **UL** | Underwriters Laboratories Inc. |
| **USGS** | United States Geological Survey |
| **WMKO** | W. M. Keck Observatory |
| **WRT** | With Respect To |

# Overall Description

## Perspective

The TMT SAC recognized that it is essential that TMT have a NIR multi-object spectroscopic capability available at first light. It was further recognized that a clone (as far as possible) of the Keck MOSFIRE instrument, fed by NFIRAOS, would fulfill that goal and be exceedingly powerful in its own right. IRMS is that instrument. IRMS will provide quasi diffraction-limited moderate spectral resolution (R~4000) multislit spectra and images over the full 2 arcmin diameter field of view of NFIRAOS.

IRMS will provide near‑IR (~0.95-2.4 μm) imaging and multi-object spectroscopy over a 2.04′ x 2.04′ field of view with a resolving power of R>3,270 for a three pixel slit width (R>4660 for a two pixel slit), or imaging over a field of view (FOV) of 2.04′ with 0.06″ per pixel sampling. Using a single state-of-the-art Rockwell Hawaii‑2RG HgCdTe detector with 2K x 2K pixels, IRMS will capture most or all of an atmospheric window in a *single* exposure for any slit placed within a 2.04′ x 0.97′ field, and the instrument will employ a single diffraction grating used in multiple orders (3, 4, 5, and 6) for dispersion in the K, H, J and Y (a.k.a. Z) bands, respectively. The grating is deployable at two discrete angles located by fixed stops providing a small position shift for spectra on the detector in order to maximize wavelength coverage for K and H at one position and J and Y at the other position.

A special feature of IRMS is that its multiplex advantage of up to 46 slits is achieved using a cryogenic configurable slit unit (CSU) that was developed for MOSFIRE in collaboration with the Swiss Centre for Microelectronics and Microtechnology (CSEM). The CSU is reconfigurable under remote control in ~5 minutes without any thermal cycling of the instrument.

##  System Overview

The scientific and technical requirements for IRMS result in the following basic system components:

1. An optical system to relay the required field of view onto the science detector and a dispersion system capable of achieving the required resolving power
2. A vacuum-cryogenic dewar to contain the opto-mechanical system
3. An opto-mechanical system consisting of:
	1. A support structure for the optical system
	2. A cryogenic cooling system capable of reaching operating temperature of 120 K
	3. A CSU with up to 46 slits
	4. Mechanisms for selection of filters and imaging or spectroscopic mode
	5. A cable wrap
4. An instrument rotator
5. An instrument support structure for interfacing IRMS’ rotator to the NFIRAOS top port support pads
6. A thermal baffle assembly to connect the IRMS entrance aperture to the NFIRAOS top port
7. A NGS OIWFS guider system located near the entrance window outside the instrument dewar
8. Electronics consisting of:
	1. An IR detector system
	2. Dewar temperature and pressure monitoring
	3. Motion control systems for all mechanisms
	4. An external NGS WFS guider system
9. Instrument control software
10. Interfaces to the telescope and observatory systems

### IRMS Instrument Layout and Constraints

A sectioned side view of the IRMS instrument in the conceptual design stage is shown in Figure 2. IRMS is designed for mounting at the top port position of NFIRAOS. This focal station imposes strict envelope and weight requirements. IRMS must provide an unpressurized, thermal interface with the NFIRAOS enclosure which controls the power input into the interface port. IRMS’ support structure must interface to NFIRAOS’ three top port mounting pads.



Thermal Interface & Guider Enclosure

Filter Wheel Mechanism

G-10 Support Tube

Electronics Cabinet

Cryogenic Slit Mask Unit (CSU)

Vacuum Window

Window Heater

Inner Window

Instrument Support Structure

Field Lens

Rotator Module

Cable Wrap

Instrument Envelope Limit

NGS OIWFS Guider

Cold Shield

Dewar Shell

Grating/Mirror Exchange Turret

Pupil Mechanism

Camera

Collimator

FCS Mirror

Figure 2: Section view of IRMS.

The thin black outline indicates the TMT NFIRAOS top port envelope limits.

### IRMS Operating Modes

IRMS provides both imaging and spectrometer modes of operation. The relative fields of view for the two operating modes are illustrated in Figure 3. The dashed circle shows the total field covered by the IRMS collimator. The square shows the field covered by the science detector. This corresponds to the imaging FOV. The center rectangle shows the FOV in the spectrometer mode.



Figure 3: IRMS field of view. Units are mm unless otherwise noted. The field lens cannot address the full field of view; instead, in imaging mode the four corners of the chip are vignetted as shown. The spectroscopic filed is defined as the intersection of the addressable field (circle) with the detector field of view. The IRMS spectroscopic field is roughly 1’ x 2’. Note that spectra are produced at the grating after the field lens and thus are not vignetted. The distance from the center of the field of view to the corner of the spectroscopic mode is ~155 mm.

## IRMS Glossary

In the descriptions that follow and in all other project documentation it is recommended that the following names and definitions for the components of IRMS be adopted:

**IRMS**: the complete system consisting of the IRMS Instrument and associated computers, private network, software and accessories.

**IRMS Instrument**: the telescope-mounted portion of MOSFIRE consisting of the dewar, cable wrap, electronics racks, thermal interface to NFIRAOS, NGS OIWFS guider, rotator, and instrument support assembly.

**Dewar**: a vacuum cryostat chamber containing the science optical path, configurable slit mask unit, science detector and associated components.

**Instrument Cable Wrap**: a structure attached to the top of the dewar to allow connections between the stationary telescope utility connection panels and the instrument mounted in the rotator.

**Instrument Electronics Racks**: s welded aluminum cabinet meeting the NEMA-4 specification that provides two bays equipped with EIA 19 inch rack mounting rails. Each bay has 25 U (43.75 inches) of rack panel space. The electronics cabinet is located on the top of the instrument cable wrap.

**Instrument Support Assembly**: the hexapod structure which supports the instrument on top of the NFIRAOS structure. It attaches to the instrument on the fixed portion of the rotator.

**Rotator**: the rotator is a structure in which the dewar, cable wrap and electronics racks are mounted and which rotates the dewar, cable wrap and electronics racks about the optical axis in order to compensate for the image rotation that occurs as the telescope follows the sidereal motion of the sky.

**IRMS NGS OIWFS Guider**: A natural guide star on-instrument wavefront sensor system is implemented to provide guide star position feedback. It is mounted outside the dewar at the bottom of the instrument near the dewar window. It resides inside an insulated, temperature controlled enclosure that has a thermal interface to the NFIRAOS enclosure.

# Specific Requirements

## Overall Requirements

### Purpose and Objectives

The purpose of the overall requirements section is to convey requirements that apply generally to the overall instrument and its accessories.

### Performance Requirements

#### Parametric Performance Requirements

##### Transportation and Shipping Environment

When packaged as required in §3.1.3.2.1 IRMS shall continue to meet all of the performance requirements without repair after a single shipment to the delivery location by any combination of air or surface transportation. For information, the expected conditions to be encountered during shipping are given in Table 3.

Table 3: Transportation and Shipping Environment

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Parameter** | **Min.** | **Typ.** | **Max.** | **Units** | **Notes** |
| [REQ-2-IRMS-0010] Altitude | 0 | - | 4,572 | m | 1 |
| [REQ-2-IRMS-0020] Temperature | -33 | - | 71 | ºC | 2, 3 |
| [REQ-2-IRMS-0030] Temperature shock | -54 | - | 70 | ºC | 4 |
| [REQ-2-IRMS-0040] Humidity | 0 | - | 100 | % | 5 |
| [REQ-2-IRMS-0050] Gravity orientation | - | - | - | NA | 6 |
| [REQ-2-IRMS-0060] Vibration | - | - | 0.015 | g2/Hz | 7, 8 |
| [REQ-2-IRMS-0070] Shock | - | - | 15 | g | 9 |
| Acceleration |
| [REQ-2-IRMS-0080] Due to transport | - | - | 4 | g | 10 |
| [REQ-2-IRMS-0090] Due to seismic activity | - | - | 3.2 | g | 11 |

Notes:

* + 1. See MIL-STD-810F Method 500 §2.3.1.
		2. Maximum is for induced conditions, see MIL-STD-810F Method 501 Table 501.4-I.
		3. Minimum is for induced conditions, see MIL-STD-810F Method 502 Table 502.4-II.
		4. See MIL‑STD‑810F Method 503.
		5. Relative, condensing.
		6. Packaged equipment may be subjected to all possible gravity orientations during transportation and shipping.
		7. 10 Hz to 40 Hz, -6dB/oct. drop-off to 500 Hz, all axes.
		8. See MIL-STD-810F Method 514.
		9. 0.015 second half-sine, all axes.
		10. All axes.
		11. 0.5 Hz to 100Hz, all axes.

##### Non-Operating Environment

IRMS shall meet all of the performance specifications without repair or realignment after being subjected to any number of cycles of any of the non-operating environment conditions defined in Table 4. These represent environments associated with normal non-operating telescope activities including but not limited to storage and handling within the facility and installation and removal from the telescope.

Table 4: Non-Operating Environment

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Parameter** | **Min.** | **Typ.** | **Max.** | **Units** | **Notes** |
| [REQ-2-IRMS-0100] Altitude | 0 | - | 4300 | m |  |
| Temperature |
| [REQ-2-IRMS-0110] Range | -10 | 0 | 30 | ºC | 1 |
| [REQ-2-IRMS-0120] Rate of change | -0.8 | - | 0.8 | ºC/h |  |
| [REQ-2-IRMS-0130] Humidity | 0 | - | 90 | % | 2 |
| [REQ-2-IRMS-0140] Gravity orientation | - | -1 | - | g | 3 |
| [REQ-2-IRMS-0150] Vibration | - | - | 8.0x10-4 | g2/Hz | 4 |
| [REQ-2-IRMS-0160] Shock | - | - | 15 | g | 5 |
| Acceleration |
| [REQ-2-IRMS-0170] Due to handling | - | - | - | g | 6 |
| [REQ-2-IRMS-0180] Due to seismic activity | - | - | 3.2 | g | 7 |

Notes:

1. Typical value is the average annual temperature.
2. Relative, non‑condensing.
3. Normal to the earth’s surface.
4. 20 Hz to 1000 Hz, 6db/oct drop- off to 2000 Hz.
5. 0.015 second half-sine, all axes.
6. 2 g vertical, 1 g fore/aft, 0.5 g lateral
7. 0.5 Hz to 100Hz, all axes.

##### Operating Environment

The operating environment is the ensemble of all conditions experienced under normal telescope operation when the IRMS Instrument is installed at the top port position of TMT’s NFIRAOS. All performance requirements shall be met while IRMS Instrument is subjected to the operating environment conditions given in Table 5.

Table 5: Operating Environment

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Parameter** | **Min.** | **Typ.** | **Max.** | **Units** | **Notes** |
| [REQ-2-IRMS-0190] Altitude | 0 | - | 4300 | m |  |
| Temperature |
| [REQ-2-IRMS-0200] Ambient Range | -10 | 0 | 20 | ºC | 1 |
| [REQ-2-IRMS-0210] Ambient Rate of change | -0.8 | - | 0.8 | ºC/h |  |
| [REQ-2-IRMS-0215] NFIRAOS Enclosure Range | -32 | -30 | -28 | ºC |  |
| [REQ-2-IRMS-0220] Ambient Humidity | 0 | - | 90 | % | 2 |
| [REQ-2-IRMS-0230] NFIRAOS Enclosure Humidity | 0 | TBD | TBD | % |  |
| [REQ-2-IRMS-0240] Gravity orientation | - | -1 | - | g | 3 |
| [REQ-2-IRMS-0250] Vibration | - | - | 1x10-5 | g2/Hz | 4 |
| [REQ-2-IRMS-0260] Acceleration | - | - | 3.2 | g | 5 |

Notes:

1. Typical value is the average annual temperature.
2. Relative, non‑condensing.
3. Normal to the earth’s surface.
4. 20 Hz to 1000 Hz, 6db/oct drop- off to 2000 Hz.
5. All axes, due to telescope drive system fault conditions.

#### Operational Performance Requirements

##### Air Borne Contaminants

[REQ-2-IRMS-0270] Instruments must be protected during installation and handling against the entry of air borne contaminants. In particular, care must be taken with optical surfaces, precision mechanisms and fine pitch or fiber optic connectors.

*Discussion: The weather conditions at the summit of Mauna Kea include frequent high winds resulting in some air borne contaminants, particularly dust and insects.*

##### Audible Noise

[REQ-2-IRMS-0270] Unless otherwise specified or accepted IRMS and any pumps, motors, outboard electronics or computers should not at any time produce audible noise in excess of 50 dBA at a distance of 1 meter. This includes intermittent noises from pumps and variable speed cooling fans. Audible warning signals for emergency or fault conditions are exempt from this requirement, but they must be provided with a silence after delay feature or a manual silencing switch.

*Discussion: This is a standard office operating environment maximum noise level.*

##### Telescope Reconfiguration

*Discussion: MOSFIRE was designed to facilitate telescope reconfigurations by allowing complete disconnection of all instrument services when the instrument is to be moved during telescope reconfigurations. This includes all power and control signals, glycol and closed cycle refrigerator (CCR) helium lines. For MOSFIRE, it was essential that the instrument be able to return to operation without requiring special procedures or maintenance provided that the total elapsed time of the disconnection did not exceed a specified duration. This specified duration was at least 30 minutes. The thermal design of MOSFIRE ensured that the shortest practical time was required to return to normal operating.*

*MOSFIRE’s instrument control system and software incorporate provisions for quick restart of temperature control and other essential housekeeping functions.*

*IRMS will retain the thermal performance and control of MOSFIRE and will, therefore, maintain the same ability for quick turnaround when powered down or disconnected for short durations. However, instruments mounted to the top port of NFIRAOS are not expected to be exchanged regularly. When they are, the mounting location on top of NFIRAOS requires installation/removal procedures which include utilizing an overhead crane and will take much longer to complete than the cassegrain instrument exchanges on the Keck I & II telescopes. Once IRMS has been installed on the top port of NFIRAOS, it is not expected to be removed from the top port until it is replaced with a follow-on instrument, unless there are unexpected problems requiring instrument removal to remedy.*

##### Power Failure Tolerance

[REQ-2-IRMS-0290] Because of the possibility of power failures, IRMS should be designed so that power failures of up to 1 hour in duration affecting the electronics, glycol cooling and CCR systems will not degrade the performance of the instrument or damage any components. It is highly desirable that the instrument tolerates the longest possible power failure duration. The limit of power failure duration is defined as the longest time that an instrument initially at operating temperature can go without power before maintenance procedures such as pumping are required to return to normal operation.

### Implementation Requirements

None.

#### Common Practice Implementation Requirements

None.

#### Standards Implementation Requirements

##### Shipping Containers

[REQ-2-IRMS-0300] All shipping containers must be designed to provide adequate protection for the equipment during transport. Unless otherwise specified single use containers suitable for the size, weight and shipment method to be employed are acceptable. For guidance in the design of suitable containers consult Air Transport Association (ATA) Spec 300, 2001.1 edition, “Specification for Packaging of Airline Supplies”.

#### Regulatory Implementation Requirements

IRMS shall comply in all respects with the applicable requirements of the Occupational Safety and Health Administration (OSHA) as established by Code of Federal Regulations (CFR) 29 Part 1910 “Occupational Safety And Health Standards”, particularly subpart O, section 1910.212 and subpart S sections 1910.302 through 1910.304.

[REQ-2-IRMS-0310] The requirements of Subpart O, section 1910.212 that are applicable to IRMS are summarized as follows:

1. *Machine guarding must be provided to protect the operator and other employees from hazards such as those created by ingoing nip points or rotating parts.*
2. *Guards shall be affixed to the machine.*
3. *Revolving barrels and drums shall be guarded by an enclosure that is interlocked with the drive mechanism so that the barrel or drum cannot revolve unless the guard is in place.*

[REQ-2-IRMS-0320] The requirements of Subpart S, sections 1910.302 through 1910.304 that are applicable to IRMS may be summarized as follows:

1. *Listed or labeled equipment shall be used or installed in accordance with any instructions included in the listing or labeling.*
2. *Conductors shall be spliced or joined with splicing devices suitable for the use or by brazing, welding, or soldering with a fusible metal or alloy. Soldered splices shall first be so spliced or joined as to be mechanically and electrically secure without solder and then soldered. All splices and joints and the free ends of conductors shall be covered with insulation equivalent to that of the conductors or with an insulating device suitable for the purpose.*
3. *Parts of electric equipment which in ordinary operation produce arcs, sparks, flames, or molten metal shall be enclosed or separated and isolated from all combustible material.*
4. *Electrical equipment may not be used unless the manufacturer’s name, trademark, or other descriptive marking by which the organization responsible for the product may be identified is placed on the equipment. Other markings shall be provided giving voltage, current, wattage, or other ratings as necessary. The marking shall be of sufficient durability to withstand the environment involved.*
5. *Each disconnecting means for motors and appliances shall be legibly marked to indicate its purpose, unless located and arranged so the purpose is evident.*
6. *Live parts of electric equipment operating at 50 volts or more shall be guarded against accidental contact by approved cabinets or other forms of approved enclosures.*
7. *A conductor used as a grounded conductor shall be identifiable and distinguishable from all other conductors. A conductor used as an equipment grounding conductor shall be identifiable and distinguishable from all other conductors.*
8. *No grounded conductor may be attached to any terminal or lead so as to reverse designated polarity.*
9. *A grounding terminal or grounding-type device on a receptacle, cord connector, or attachment plug may not be used for purposes other than grounding.*
10. *Conductors and equipment shall be protected from overcurrent in accordance with their ability to safely conduct current.*
11. *Overcurrent devices may not interrupt the continuity of the grounded conductor unless all conductors of the circuit are opened simultaneously.*
12. *Overcurrent devices shall be readily accessible to each employee or authorized building management personnel. These overcurrent devices may not be located where they will be exposed neither to physical damage nor in the vicinity of easily ignitable material.*
13. *Fuses and circuit breakers shall be so located or shielded that employees will not be burned or otherwise injured by their operation due to arcing or suddenly moving parts.*
14. *Circuit breakers shall clearly indicate whether they are in the open (off) or closed (on) position.*
15. *The path to ground from circuits, equipment, and enclosures shall be permanent and continuous.*
16. *Metal enclosures for conductors shall be grounded.*
17. *Exposed, non‑current‑carrying metal parts of fixed equipment, which may become energized, shall be grounded.*
18. *Exposed non‑current‑carrying metal parts of cord and plug connected equipment, which may become energized, shall be grounded.*
19. *Non-current-carrying metal parts of fixed equipment, if required to be grounded, shall be grounded by an equipment grounding conductor, which is contained within the same raceway, cable, or cord, or runs with or encloses the circuit conductors. For DC circuits only, the equipment grounding conductor may be run separately from the circuit conductors.*

*For the purposes of the foregoing approved means acceptable to the authority enforcing the applicable subpart. The authority enforcing the applicable subpart is the Assistant Secretary of Labor for Occupational Safety and Health. The definition of ‘‘acceptable’’ indicates what is acceptable to the Assistant Secretary of Labor, and therefore approved within the meaning of the applicable subpart. Approved for the purpose means approved a specific purpose, environment, or application described in a particular standard requirement. Suitability of equipment or materials for a specific purpose, environment or application may be determined by a nationally recognized testing laboratory, inspection agency or other organization concerned with product evaluation as part of its listing and labeling program.*

Note that the preceding text is reproduced verbatim from the referenced CFR and any grammatical errors or typographical errors are part of that text.

### Design Requirements

#### Technological Design Requirements

##### Materials Suitability and Safety

[REQ-2-IRMS-0330] Certain environmental conditions (low temperature and pressure) at the summit of Mauna Kea make certain materials unsuitable for use in instrument construction. Materials used in the construction, lubrication or packaging of instruments must not produce hazardous by-products such as gases or other contaminants under the conditions of operation and use at the summit of Mauna Kea. No mercury may be used in any component of IRMS.

Table 6 lists specific materials that should not be used. Note that this table applies to portions of the instrument normally open to the atmosphere. See §3.3.4.1.1 for materials considerations for vacuum cryostats and similar environments.

Table 6: Materials not Suitable for use in Equipment at the Summit of Mauna Kea

|  |  |  |
| --- | --- | --- |
| **Material Type**  | **Common Name**  | **Reason(s) for Unsuitability** |
| Adhesive, insulator | RTV silicone rubber1 | Outgases during curing |
| Adhesive | Cyanoacrylates | Outgases during curing, subject to hydrolytic degradation |
| Conductor | Mercury2 | Reactive, salts formed are toxic |
| Insulator | Acrylic4 | Outgases, hygroscopic, brittle at low temperatures |
| Plated finish | Cadmium2  | Outgases, reactive, hazardous  |
| Insulator | Cellulose Acetate Butyrate | Hygroscopic |
| Insulator | Glass-Reinforced Extruded Nylon  | Outgases, hygroscopic |
| Insulator | Kapton | Subject to hydrolytic degradation |
| Insulator | Neoprene | Outgases, subject to degradation by ozone and UV exposure |
| Insulator | Nylon5 | Outgases, subject to degradation by ozone and UV exposure |
| Insulator | Phenolic3 | Hygroscopic |
| Insulator | Polychlorinated Biphenyls2 | Combustion produces highly toxic gases |

Notes:

1. Neutral cure RTV silicones may be acceptable provided that the cured silicone and the surrounding area are cleaned after assembly.
2. Use is or soon will be highly regulated.
3. Electrical grade phenolic is not hygroscopic.
4. Cast acrylic resin
5. Cable ties of weather resistant Nylon 6/6 (carbon black additive) are acceptable.

#### Regulatory Design Requirements

None.

#### Standards Related Design Requirements

None.

#### Integration Related Design Requirements

None.

## Optical Requirements

### Purpose and Objectives

The purpose of this section is to describe requirements for the performance, implementation and design of the IRMS optical system. In many cases these requirements are derived directly from the preliminary optical design of the instrument.

Optical parametric performance requirements for IRMS are grouped into two categories, typical parameters and goal parameters. Requirements for typical parameters are given where enough is known to establish a range of values for the listed parameters. Requirements for goal parameters are given where scientific or technical uncertainty prevents a full definition of the achievable range of values for the listed parameters. Minimum and maximum values are provided for all goal parameters in order to indicate the acceptable bounds on worst-case performance.

### Performance Requirements

#### Parametric Performance Requirements

##### Typical Parameters

IRMS should provide the optical performance described in Table 7.

Table 7: IRMS Typical Optical Performance Requirements

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| ***Parameter*** | ***Min.*** | ***Typ.*** | ***Max.*** | ***Units*** | ***Notes*** |
|  |  |  |  |  |  |
| FOV |  |
| [REQ-2-IRMS-1010] Imaging | 2.04 x 2.04 | - | - | arcminutes |  |
| [REQ-2-IRMS-1020] Multi-object spectroscopy | 2.04 x 0.97 | - | - | arcminutes | 1 |
| Wavelength coverage |  |
| [REQ-2-IRMS-1030] Y-band | 0.95 | - | 1.05 | µm | 2 |
| [REQ-2-IRMS-1040] J‑band | 1.10 | - | 1.40 | µm | 2 |
| [REQ-2-IRMS-1050] H‑band | 1.48 | - | 1.83 | µm | 2 |
| [REQ-2-IRMS-1060] K‑band | 2.00 | - | 2.45 | µm | 2,4 |
| [REQ-2-IRMS-1070] Imaging plate scale | - | 0.06 | - | arcseconds/pixel |  |
| Spectral resolution |  |
| Multi-object spectroscopy |  |  |  |  |  |
| [REQ-2-IRMS-1090] 0.23” slit width | - | 3,270 | - | λ /Δλ |  |
| [REQ-2-IRMS-1100] 0.12” slit width | - | 4,660 | - | λ /Δλ |  |
| [REQ-2-IRMS-1110] Input focal ratio | - | f/15 | - | n/a |  |
| [REQ-2-IRMS-1120] Science detector | n/a | 2048 x 2048 | n/a | X by Y pixels |  |
| Guider |
| [REQ-2-IRMS-1130] FOV | 2.8 x 2.8 | - | - | arcminutes |  |
| [REQ-2-IRMS-1140] Sensitivity | 18 | - | - | V mag. | 3 |

Notes:

1. Slits can be placed anywhere within the imaging FOV. Maximum spectral coverage in each wavelength band is obtained for slits located in the spectral dispersion direction over the central 1’ of the imaging FOV.
2. Imaging and spectroscopy.
3. For a SNR of 10, assuming a CCD47-20BT CCD, RG780 filter and a total throughput (telescope + guider optics) of 35%.
4. The long wavelength value quoted here is beyond the end of the K-band, but is stated to reflect the values used in the optical design analysis. The exact cutoff will be determined by the filter choices.

##### Goal Parameters

The optical performance requirements shown in Table 8 are desired as design goals.

Table 8: IRMS Goal Optical Performance Requirements

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| *Parameter* | *Goal* | *Min.* | *Max.* | *Units* | *Notes* |
|  |  |  |  |  |  |
| Image quality |  |
| [REQ-2-IRMS-1150] Imaging | < 0.07 | - | 0.07 | arcseconds | 1,3 |
| [REQ-2-IRMS-1160] Spectroscopy | > 80 | 80 | - | % ensquared energy | 2,3 |
| [REQ-2-IRMS-1170] Guider | < 0.40 | - | - | arcseconds | 4 |
| Non-uniformity |  |
| [REQ-2-IRMS-1180] Imaging | < 10 | - | 30 | %, peak | 5 |
| [REQ-2-IRMS-1190] Spectroscopy | < 5 | - | 10 | %, peak | 6 |
| [REQ-2-IRMS-1200] Guider | < 1 | - | 2 |  | 5 |
| Distortion |  |
| [REQ-2-IRMS-1210] Guider | < 1 | - | 2 | %, peak to peak | 7 |
| Optical throughput |
| Imaging |  |
| [REQ-2-IRMS-1220] Y‑band | > 60 | 55 | - | % at 1.00 µm | 8 |
| [REQ-2-IRMS-1230] J‑band | > 60 | 55 | - | % at 1.25 µm | 8 |
| [REQ-2-IRMS-1240] H‑band | > 50 | 55 | - | % at 1.6 µm | 8 |
| [REQ-2-IRMS-1250] K‑band | > 40 | 40 | - | % at 2.2 µm | 8 |
| Spectroscopy |  |
| [REQ-2-IRMS-1260] Y‑band | > 40 | 35 | - | % at 1.00 µm | 8 |
| [REQ-2-IRMS-1270] J‑band | > 40 | 35 | - | % at 1.25 µm | 8 |
| [REQ-2-IRMS-1280] H‑band | > 40 | 40 | - | % at 1.6 µm | 8 |
| [REQ-2-IRMS-1290] K‑band | > 35 | 30 | - | % at 2.2µm | 8 |
| [REQ-2-IRMS-1300] Guider | > 65 | 60 | - | % at 850 nm | 9 |
| Instrument background |
| [REQ-2-IRMS-1310] Y‑band | < 0.001  | - | 0.02 | e-/sec/pixel | 10 |
| [REQ-2-IRMS-1320] J‑band | < 0.001  | - | 0.02 | e-/sec/pixel | 10 |
| [REQ-2-IRMS-1330] H‑band | < 0.001 | - | 0.02 | e-/sec/pixel | 10 |
| [REQ-2-IRMS-1340] K‑band | < 0.001 | - | 0.02 | e-/sec/pixel | 10 |
| [REQ-2-IRMS-1350] Slit mask light blocking | >10-7 | - | - | :1 | 11 |
| Ghosting |
| [REQ-2-IRMS-1360] Imaging | < 10-5 | - | < 10-4 | - | 12 |
| [REQ-2-IRMS-1370] Spectroscopy | < 10-5 | - | < 10-4 | - | 12 |

Notes:

* 1. Area weighted average rms diameter over the wavelength range of 0.95 to 2.45 µm.
	2. Ensquared energy in a 0.12” by 0.16” (2 pixel) box centered on the image centroid over the wavelength range of 0.95 to 2.45 µm.
	3. Achieved in all bands (Y, J, H and K) without refocusing the telescope.
	4. Area weighted average rms diameter over the wavelength range of 0.7 to 1.1 µm.
	5. This is the peak variation in rms diameter over the full FOV.
	6. This is the peak variation in ensquared energy over the full FOV.
	7. Total geometric distortion over the entire guider FOV.
	8. Instrument throughput, QE of the science detector is not included.
	9. Guider optical system throughput, QE of the guider detector is not included.
	10. This is the contribution of the instrument background to the total “dark counts”; the goal value is 10% of the goal for science detector dark current.
	11. At all wavelengths from 0.95 to 2.45 µm.
	12. Intensity of the ghost image compared to the parent image at all wavelengths from 0.95 to 2.45 µm.

#### Operational Performance Requirements

##### Observing modes

IRMS will provide two observing modes:

* [REQ-2-IRMS-1380] IRMS will provide direct imaging
* [REQ-2-IRMS-1390] IRMS will provide multi-object spectroscopy per the following requirements:
	+ [REQ-2-IRMS-1400] With a multiplex of up to 46 objects
	+ [REQ-2-IRMS-1410] Slits deployable on a nominal 2.7" pitch
	+ [REQ-2-IRMS-1420] Minimum slit length 2.4"
	+ [REQ-2-IRMS-1430] Adjacent slit bars can be combined to form longer slits in increments of 2.7".
	+ [REQ-2-IRMS-1440] The minimum slit width is 0.17", adjustable in increments of 0.03"

##### Filters

[REQ-2-IRMS-1450] IRMS will provide 10 filters in two six-position filter wheels (5 filters + open in each wheel). Although final specifications for the IRMS filter set are not finalized, some likely placeholder specifications based on the MOSFIRE set are shown in Table 9.

Table 9: IRMS Filters

|  |  |  |  |
| --- | --- | --- | --- |
| **Filter**  |  | **Filter Specifications** | **Description** |
| **(wheel-position)** | **CWL****(nm)** | **Min****(nm)** | **Max****(µm)** | **Min. T****%** | **Goal Passband T %** | **Passband Ripple %** |  |
| 2-0 | - | - | - | - | - | - | Open |
| 2-1 | 1048 | 972 | 1124 | >80 | >90 | <5 | Y Spectrometer |
| 2-2 | 1253 | 1153 | 1352 | >80 | >90 | <5 | J Spectrometer |
| 2-3 | 1637 | 1465 | 1808 | >80 | >90 | <5 | H Spectrometer |
| 2-4 | 2162 | 1921 | 2406 | >80 | >90 | <5 | K Spectrometer |
| 2-5 | 2147 | 1990 | 2304 | >80 | >90 | <5 | Ks |
| 1-0 | - | - | - | - |  | - | Open |
| 1-1 | 1181 | 1117 | 1246 | >70 | >90 | <5 | J2 (intermediate band) |
| 1-2 | 1288 | 1227 | 1349 | >70 | >90 | <5 | J3 (intermediate band) |
| 1-3 | 1556 | 1474 | 1639 | >70 | >90 | <5 | H1 (intermediate band) |
| 1-4 | 1709 | 1626 | 1793 | >70 | >90 | <5 | H2 (intermediate band) |
| 1-5 | - | - | - | - | - | - | Dark (Al plate) |

Note: (Min = short wavelength half power point, Max = long wavelength half power point)

##### Lyot stop

[REQ-2-IRMS-1460] A deployable rotating “hexagonal” cold Lyot stop matched to the telescope pupil will be provided. Under control of the IRMS host computer the stop will be deployed or retracted. When deployed the stop will be adjustable in rotation angle to match the hexagonal aperture to the telescope pupil at the current rotator angle. During guiding the stop will track the rotator angle so that the hexagonal aperture of the stop remains matched to the telescope pupil.

##### Spectrometer Grating

[REQ-2-IRMS-1470] The IRMS spectrometer will use a reflection grating that will be interchangeable with a plane mirror for imaging. Two grating angle stop positions will be provided for the reflection grating in order to optimize wavelength coverage across the near-IR wavelength bands.

##### Spectral Coverage

[REQ-2-IRMS-1480] The two grating positions in conjunction with order-sorting filters will maximize the single exposure spectral coverage in each wavelength band for slits located over at least the central 1’ of the spectrometer FOV in the spectral dispersion direction.

### Implementation Requirements

#### Feature Implementation Requirements

##### Dewar Window

The MOSFIRE dewar will have an entrance window approximately 370 mm in diameter.

[REQ-2-IRMS-1490] It is essential that condensation or frost does not form on this window. A means must be provided to ensure that this does not occur. The preferred method is heating the window in a manner that does not compromise window transmission over the operating wavelength, increase instrumental background, or obstruct the FOV.

[REQ-2-IRMS-1500] The temperature of the dewar window must be monitored to ensure that the condensation control is functioning.

[REQ-2-IRMS-1510] Stresses in the dewar window, such as those caused by differences in temperature or pressure, must not produce deformations of the window that affect the optical performance of the instrument.

##### Science Detector Focus Control

[REQ-2-IRMS-1520] In order to permit adjustment of final detector focus during initial testing of IRMS, and also to fine tune the focus for each wavelength range, a mechanism should be provided for a fine focus adjustment of the IRMS science detector. This mechanism should adjust focus by translating the detector along the optical axis with respect to the camera and should be capable of remote operation while the dewar is evacuated and cooled.

##### Guider

[REQ-2-IRMS-1530] The IRMS guider will be a NGS OIWFS system located outside the dewar near the entrance window. Any portion of the instrument FOV should be available to the guider. However, it is preferred that as much of the spectroscopic FOV remains available for science when the guider pick-off is deployed.

[REQ-2-IRMS-1540] The shadow of the guider pick-off window and mount on the science FOV shall be minimized.

*Discussion: The OIWFS guider components must be suitable for operations between -30 degrees C and ambient, as the guider will be located in an enclosure mated to the NFIRAOS enclosure.*

#### Common Practice Implementation Requirements

None.

#### Standards Implementation Requirements

None.

#### Regulatory Implementation Requirements

None.

### Design Requirements

#### Technological Design Requirements

##### Optical Component Mountings

[REQ-2-IRMS-1550] All optical components should be mounted so that alignment is maintained during cool down and warm up cycles.

[REQ-2-IRMS-1560] Mountings must ensure that excessive stress is not placed on the optical components due to thermal differentials between the optical component and the mount.

[REQ-2-IRMS-1570] Mountings must also ensure that alignment of optical components without excessive stress is maintained at all rotator angles and instrument elevation angles.

*Discussion: The instrument will be positioned at varying orientations with respect to gravity during assembly, test, and shipment to the observatory.*

[REQ-2-IRMS-1580] Materials used in optical component mountings, particularly elastomers and adhesives must be compatible with the coatings on the associated optical components.

[REQ-2-IRMS-1590] All materials used within the dewar must be compatible with vacuum and cryogenic environments, see §3.3.4.1.1.

##### Alignment Tolerancing

[REQ-2-IRMS-1600] Before assembly all optical components and systems must have a documented optical alignment tolerance budget. During assembly, measurements must be made as required to ensure that the stack-up of tolerances does not exceed the tolerance budget.

#### Regulatory Design Requirements

None.

#### Standards Related Design Requirements

[REQ-2-IRMS-1610] Drawings for optical components should conform to American National Standards Institute (ANSI) / American Society of Mechanical Engineers International (ASME) standard Y14.18M-1986 “Optical Parts (Engineering Drawings and Related Documentation Practices)”.

#### Integration Related Design Requirements

##### Focal Position

[REQ-2-IRMS-1620] IRMS will be compatible with the *f*/15 NFIRAOS focus of the TMT.

## Mechanical Requirements

### Purpose and Objectives

The purpose of this section is to describe requirements for the performance, implementation and design of the IRMS mechanical systems. As IRMS is based on MOSFIRE with a goal of changing as little of the design as possible, in many cases these requirements reflect the as-built mechanical design of the MOSFIRE instrument.

The mechanical requirements address issues of design, reliability and maintainability. The observatory is sensitive to certain aspects of performance, implementation and design that have proven to be important factors in the up time of its instruments. The mechanical requirements section has as a main objective the description of the expected performance, features and configuration of the instrument’s mechanical systems. A secondary objective is to identify specific areas where experience indicates particular attention is required with respect to performance, implementation or design.

### Performance Requirements

#### Parametric Performance Requirements

##### General

The general mechanical performance requirements for IRMS are given in Table 10.

Table 10: IRMS Mechanical Performance Requirements

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| ***Parameter*** | ***Min.*** | ***Typ.*** | ***Max.*** | ***Units*** | ***Notes*** |
|  |  |  |  |  |  |
| [REQ-2-IRMS-2010] Weight | - | - | 6500 | kg | 1 |
| [REQ-2-IRMS-2020] Overall dimensions |  | - | 2100 x 2100 x 3700 | mm | 2 |
| Temperature |  |
| [REQ-2-IRMS-2030] Operating Ambient | -15 | 0 | 20 | ºC |  |
| Internal – opto‑mechanics |   |   |   |   |  |
| [REQ-2-IRMS-2040] Operating Temperature | - | 120 | - | K |   |
| [REQ-2-IRMS-2050] Stability | -0.5 | - | 0.5 | K | 3 |
| Maximum Temperature Span |  |  |  |  |  |
| [REQ-2-IRMS-2060] Operating | - | - | <1 | K |  |
| [REQ-2-IRMS-2070] Transient (warm up or cool down) | - | - | 3 | K |  |
| Internal – science detector |  |  |  |  |  |
| [REQ-2-IRMS-2080] Operating Temperature | 63 | 70 | 77 | K | 4 |
| [REQ-2-IRMS-2090] Stability | -0.1 | - | 0.1 | K | 3,5 |
| [REQ-2-IRMS-2100] Science detector temperature variation (adequate zero point stability) | TBD | TBD | TBD | K |  |
| Guider Enclosure Internal |  |  |  |  |  |
| [REQ-2-IRMS-2110] Operating Temperature | - | -30 | - | ºC |  |
| [REQ-2-IRMS-2120] Stability | -2.0 | - | 2.0 | ºC | 3 |
| [REQ-2-IRMS-2130] Cool down time | - | 8 | 10 | Days | 6 |
| [REQ-2-IRMS-2140] Warm up time | - | 9 | 10 | Days | 6 |
| Vacuum |
| [REQ-2-IRMS-2150] Hold time | 12 | 25 | - | Weeks |  |
| [REQ-2-IRMS-2160] Pressure | - | - | 1 x 10-6 | Torr | 7 |
| Power Dissipation |
| [REQ-2-IRMS-2170] To ambient | - | - | 100 | Watts |  |
| [REQ-2-IRMS-2180] To glycol supply | - | - | 1200 | Watts |  |
| Glycol cooling |  |  |  |  |  |
| [REQ-2-IRMS-2190] Temperature rise | - | - | 3 | ºC | 8 |
| [REQ-2-IRMS-2200] Operating pressure | - | 80 | 100 | psig | 9 |
| [REQ-2-IRMS-2210] Pressure drop | - | - | 25 | psi |  |
| [REQ-2-IRMS-2220] Flow rate | - | - | 9.8 | l/min |  |
| [REQ-2-IRMS-2230] Flexure | < 0.1 | - | 0.3 | pixels | 10 |
| Alignment |
| [REQ-2-IRMS-2240] X, Y and Z axis | - | - | 1 | mm |  |
| [REQ-2-IRMS-2250] Rotation about X and Y axis | - | - | 0.1 | º |  |

Notes:

1. Total weight of instrument including rotator and instrument support assembly.
2. Height, width and length of instrument not including rotator and instrument support assembly. The portion of the envelope that protrudes into NFIRAOS is not included in the length. See the TMT NFIRAOS envelope drawing (Table 3) for details.
3. Variation with respect to the nominal operating temperature.
4. The FPA mosaic operating temperature is determined by the QE and dark current requirements.
5. Temperature variation must be controlled to ensure adequate zero point stability during exposures.
6. Minimum cool down or warm up time limited by acceptable maximum temperature gradients in internal components during transient conditions.
7. Instrument dewar pressure must be maintained at the level required to maintain the internal temperature.
8. Normal coolant supply temperature is 3 ºC below dome ambient.
9. All cooling system plumbing should be able to withstand a maximum pressure of 100 psig in the event of system pressure regulation failure.
10. Flexure is the amount of shift in the spectral footprint on the science detector during a two hour observation (a single exposure or multiple exposures); this applies to all rotator angles.

##### IRMS Instrument Mechanisms

Mechanisms internal to the IRMS dewar provide for selection of filters, a deployable rotating hexagonal Lyot stop, switching between imaging and spectrograph mode, configuration of the spectrograph multi-object slit mask, flexure correction (if necessary) and a focus adjustment for the science detector. External to the dewar mechanisms are provided for moving the guider optics in order to patrol the entire instrument FOV and to exchange filters for the guider.

The performance requirements for these mechanisms are given in Table 11. Where three values are given for a parameter they correspond to x, y, and z directions as described in the notes.

All of the requirements in Table 11 apply at the operating temperatures given in Table 5 for mechanisms external to the dewar, and Table 10 for mechanisms internal to the dewar.

The performance of the IRMS Instrument mechanisms is important to obtaining maximum on-sky productivity from the instrument. Mechanism cycle times should be consistent and as short as possible in order to reduce the set-up time for each observation. When multiple axis of motion control are used for reconfigurations it should be possible to simultaneously move all axes of motion that do not otherwise require sequencing because of mechanical design constraints.

Table 11: IRMS Instrument Mechanism Performance Requirements

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| ***Parameter*** | ***Min.******(x, y ,z)*** | ***Typ.******(x, y, z)*** | ***Max.******(x, y, z)*** | ***Units*** | ***Notes*** |
|  |  |  |  |  |  |
| Dewar Internal Mechanisms |
| Configurable Slit Unit |
| [REQ-2-IRMS-2260] Total slits (pairs of slit masking bars) | - | 46 | - | - | 1 |
| [REQ-2-IRMS-2270] Slit position accuracy | - | - | ±200, ±36, ±250 | µm | 1 |
| [REQ-2-IRMS-2280] Slit position repeatability | - | - | ±200, ±36, ±250 | µm | 1 |
| [REQ-2-IRMS-2290] Slit width error | - | - | ±36 | µm | 2 |
| [REQ-2-IRMS-2300] Slit width | 360 | - | - | µm | 3 |
| [REQ-2-IRMS-2310] Slit width resolution | 72 | - | - | µm | 4 |
| [REQ-2-IRMS-2320] Reconfiguration Time | - | 4.5 | 5 | min | 5 |
| Filter wheels |
| [REQ-2-IRMS-2330] In beam position repeatability | - | 0.1 | 1 | º |  |
| [REQ-2-IRMS-2340] In Beam position repeatability | - | 0.1 | 1 | º |  |
| [REQ-2-IRMS-2350] Cycle time | - | <30 | 50 | s | 6 |
| Rotating Lyot stop |
| Rotation speed |
| [REQ-2-IRMS-2360] Slew | 0.8 | 2 | - | º/s | 7 |
| [REQ-2-IRMS-2370] Tracking | - | - | 0.7 | º/s | 8 |
| [REQ-2-IRMS-2380] Rotation Range | 300 | - | - | º |  |
| [REQ-2-IRMS-2390] Tracking error | - | 0.02 | 0.5 | º |  |
| [REQ-2-IRMS-2400] Position repeatability | - | 0.02 | 0.5 | º |  |
| [REQ-2-IRMS-2410] Deploy/retract time | - | <30 | 55 | s |  |
| Grating/Mirror exchange turret |
| [REQ-2-IRMS-2420] Position accuracy | - | 0.21 | 15 | µrad |  |
| [REQ-2-IRMS-2430] In beam position repeatability | - | 0.21 | 15 | µrad |  |
| [REQ-2-IRMS-2440] Cycle time | - | 45 | 45 | s | 6 |
| Flexure correction (if implemented) |  |  |  |  |  |
| [REQ-2-IRMS-2450] Adjustment range | 0 | - | ±500 | µrad | 9 |
| [REQ-2-IRMS-2460] Position accuracy | 8 | 0.5 | - | µrad | 9 |
| [REQ-2-IRMS-2470] Position repeatability | 8 | ±1 | - | µrad | 9 |
| [REQ-2-IRMS-2480] Non-linearity | - | - | 0.1 | % | 10 |
| Science detector focus |  |  |  |  |  |
| [REQ-2-IRMS-2490] Adjustment range | - | ±275 | - | µm | 11 |
| [REQ-2-IRMS-2500] Position repeatability | - | ±3 | - | µm | 11 |
| [REQ-2-IRMS-2510] Position resolution | - | 0.12 | - | µm | 11 |
| [REQ-2-IRMS-2520] Non-linearity | - | 0.1 | 1 | % | 10 |
| [REQ-2-IRMS-2530] Tip/tilt | - | - | 30 | µrad | 9 |
| External Mechanisms |
| Guider Pick-off Positioning Mechanisms |  |  |  |  |  |
| [REQ-2-IRMS-2540] Radial Range | 2 | - | - | arc-min |  |
| [REQ-2-IRMS-2550] Angular Range | 360 | - | - | ° |  |
| [REQ-2-IRMS-2560] Position accuracy | - | TBD | - | µm |  |
| [REQ-2-IRMS-2570] Position repeatability | - | TBD | - | µm |  |
| [REQ-2-IRMS-2580] Reconfiguration Time | TBD | TBD | TBD | s |  |
| Guider Filter Wheel |  |  |  |  |  |
| [REQ-2-IRMS-2590] In beam position accuracy | - | 0.1 | 1 | º |  |
| [REQ-2-IRMS-2600] In beam position repeatability | - | 0.1 | 1 | º |  |
| [REQ-2-IRMS-2610] Cycle time | - | <30 | 50 | s | 6 |

Notes:

1. The slit mask X axis corresponds to the spectrometer dispersion direction. The slit mask Y axis corresponds to the spectrometer spatial direction. Z is the conventional optical axis direction.
2. Slit mask X axis.
3. Corresponds to 0.17" at the telescope focal plane.
4. Corresponds to 0.03" at the telescope focal plane.
5. Worst case reconfiguration (all slits from one extreme Y position to the other).
6. Cycle time is the time required for full travel from the first position to the last position.
7. The travel time for a full slew of the telescope from horizon to zenith is 72 seconds at a speed of 0.8°/s.
8. Tracking means that the rotator is moving at the variable rate required to compensate for the image rotation produced by the telescope as it follows the sidereal motion of the sky.
9. Tip/tilt about the instrument (Z) optical axis.
10. Non-linearity in closed loop over the full range of travel for each axis provided.
11. Translation along the camera optical (Z) axis.

Additional detail on the requirements for the CSU may be found in RD1.

##### Rotator

The rotator is a structure in which the IRMS dewar, cable wrap and electronics racks are mounted and which rotates this assembly about the instrument’s optical axis in order to compensate for the image rotation that occurs as the telescope follows the sidereal motion of the sky. The mechanical performance requirements for the rotator are given in Table 12.

Table 12: IRMS Rotator Performance Requirements

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| ***Parameter*** | ***Min.*** | ***Typ.*** | ***Max.*** | ***Units*** | ***Notes*** |
|  |  |  |  |  |  |
| Rotation speed |
|  [REQ-2-IRMS-2620] Slew | 0.8 | 2 | - | º/s | 1 |
|  [REQ-2-IRMS-2630] Tracking | - | - | 0.7 | º/s | 2 |
| [REQ-2-IRMS-2640] Rotation Range | - | 530 | - | º |  |
| [REQ-2-IRMS-2650] Tracking error | - | - | 0.5 | arcseconds, rms |  |
| [REQ-2-IRMS-2660] Skew | - | - | ±0.2 | arcseconds, peak | 3 |

Notes:

1. The travel time for a full slew of the telescope from horizon to zenith is 72 seconds at a speed of 0.8°/s.
2. Tracking means that the rotator is moving at the variable rate required to compensate for the image rotation produced by the telescope as it follows the sidereal motion of the sky.
3. Skew is defined as the amount by which the instrument optical axis deviates from telescope optical axis over a full 360º rotation by the rotator.

##### Vacuum Integrity

[REQ-2-IRMS-2670] The IRMS dewar should be capable of maintaining its internal vacuum under continuous cooling for more than 25 weeks without pumping.

##### Power Dissipation

[REQ-2-IRMS-2680] The IRMS instrument must not radiate more than 100 watts of heat into the telescope dome ambient environment. All heat generated by the IRMS instrument in excess of this amount must be carried away by a glycol based cooling system.

##### Guider Thermal Interface and Enclosure

[REQ-2-IRMS-2685] The guider enclosure must be designed such that it forms an unpressurized seal with the NFIRAOS enclosure.

[REQ-2-IRMS-2690] The enclosure design must also include a thermal seal that eliminates infiltration and thermal plumes into the NFIRAOS enclosure.

[REQ-2-IRMS-2700] The enclosure seals must allow rotation of the IRMS with respect to the NFIRAOS enclosure.

[REQ-2-IRMS-2710] All components within the guider enclosure must be maintained within +/- 2 C of the -30 C operating temperature of the NFIRAOS enclosure during operations.

####  Operational Performance Requirements

##### Operating Temperature Range

[REQ-2-IRMS-2720] IRMS should be designed for operation over the ambient temperature range given in §3.1.2.1.3.

##### Configurable Slit Unit

[REQ-2-IRMS-2730] The configurable slit unit (CSU) should meet the performance requirements given in Table 11 at all rotator positions. The CSU should meet the performance requirements given in Table 12 at the internal opto-mechanical operating temperature given in Table 10. See RD1 for additional details on the performance requirements for the CSU.

##### Flexure Correction

[REQ-2-IRMS-2740] Where piezoelectric actuators are used in these mechanisms they should be operated by a closed loop servo in order to eliminate hysteresis.

##### Vibration (TBD)

Vibration isolation should be employed as required to isolate sources of vibration within the IRMS instrument due to moving components such as fans, pumps and motors.

*Discussion: For MOSFIRE, the requirement was: “The instrument should meet all performance and operating requirements when installed in a vibration environment that conforms to the Generic Vibration Criteria[[1]](#footnote-1) Curve “C” as shown in*

*Figure 4. The instrument should not produce vibrations that result in rms velocities in excess of those given in curve “C” of*

*Figure 4.”*



Figure 4: Keck I Telescope Equipment Vibration Limits

### Implementation Requirements

#### Feature Implementation Requirements

##### IRMS Instrument Dewar

[REQ-2-IRMS-2750] Because the mechanisms internal to the IRMS instrument dewar are difficult to access for service, features should be provided that maximize the reliability of the mechanisms and provide as much information as possible about the status and performance of each mechanism.

[REQ-2-IRMS-2760] All IRMS instrument dewar mechanisms should provide a positive indication that the requested move(s) have been completed. The use of a relative position indicating means in conjunction with limit switches is preferred.

[REQ-2-IRMS-2770] Mechanisms should operate properly with reduced speed over the ambient temperature range given in §3.1.2.1.3.

*Discussion: This is essential to permit servicing and verification of proper operation prior to evacuation and cooling of the instrument dewar.*

##### Rotator

*Discussion: A rotator is required to rotate the IRMS instrument about the telescope’s optical axis in order to compensate for the image rotation that occurs as the telescope follows the sidereal motion of the sky*.

[REQ-2-IRMS-2790] The rotator should incorporate a manual mechanical lockout feature that locks the IRMS instrument in place so that it cannot rotate.

*Discussion: This feature will ensure that the instrument will not move due to an imbalance caused by removal of a component for service or during instrument integration activities which will be performed with the instrument oriented in differing gravity orientations.*

##### Instrument Support Assembly

[REQ-2-IRMS-2800] The instrument support structure must incorporate structural components that will maintain its integrity and ensure secure mounting during an earthquake with the IRMS instrument installed as required by seismic standards for a zone 4 earthquake zone (see §3.3.3.3.1 below).

*Discussion: MOSFIRE was designed per this requirement.*

##### Access and Covers

[REQ-2-IRMS-2810] Components requiring routine service or maintenance should be accessible by removing a single cover secured by no more than 8 fasteners. Covers that may be removed in a location where fasteners could fall into the interior of the enclosure shall be equipped with captive fasteners. Captive fasteners shall be of the threaded type and shall not be captivated by swaged sleeve fittings. Quarter turn fasteners engaging spring hooks are specifically discouraged for reasons of fit and reliability.

Whenever possible service access provisions should be provided that do not require disassembly of the entire instrument to access motors or switches for replacement.

All electronics systems of IRMS (not including the science detector and ASIC inside the instrument dewar) must be accessible for service without returning the instrument to atmospheric pressure.

##### Glycol Cooling

[REQ-2-IRMS-2820] All glycol cooling should be plumbed with braided stainless steel hose and stainless steel fittings.

[REQ-2-IRMS-2830] Custom manifolds should be used rather than arrangements of “T” fittings and hose.

[REQ-2-IRMS-2840] Permanent connections should be made with JIC 37º flare compression fittings or SAE straight thread O-ring fittings.

[REQ-2-IRMS-2850] Teflon tape should not be used to seal threaded connections.

[REQ-2-IRMS-2860] Removable connections should be made with ½” Parker Hannifin series FS quick disconnect fittings.

[REQ-2-IRMS-2870] The instrument supply coupler is male and the return coupler is female.

[REQ-2-IRMS-2880] Where required King Instrument Company flow meters and needle valves are preferred for flow metering and control applications. Where variable gravity orientations are encountered a spring loaded variable area flow meter, such as the in‑line flow meters manufactured by the Hedland Division of Racine Federated Inc. should be employed. The Hedland T303 stainless steel models are preferred.

[REQ-2-IRMS-2890] All glycol cooling systems should be provided with a flow switch, Proteus Industries Inc. type 100B110 is preferred, to generate a loss of coolant alarm. This flow switch should interrupt power to the affected system unless a separate over‑temperature detection system is provided to remove power from the affected system.

##### Vacuum Systems

[REQ-2-IRMS-2900] Vacuum system implementations must prevent contamination of the dewar from back streaming of oil or other contaminants. Oil free pumps are preferred.

[REQ-2-IRMS-2910] NW 40 size KF flanges are preferred. All vacuum system fittings, including valves and piping and flexible couplings should be stainless steel.

###### Pressure Control

*Discussion: Vacuum systems must be equipped with vacuum gauge facilities capable of accurately measuring the pressure in the dewar.*

[REQ-2-IRMS-2920] This should consist of at least one low vacuum gauge

[REQ-2-IRMS-2930] This should consist of at least one high vacuum gauge

[REQ-2-IRMS-2940] A back‑up high vacuum gauge is also required

[REQ-2-IRMS-2950] Dewars must be equipped with pressure relief valves to protect against over pressure due to the liberation of adsorbed gasses during the warm up process.

###### Gettering

[REQ-2-IRMS-2960] Vacuum systems must be equipped with passive gettering for the reduction of water and gasses adsorbed by the dewar walls and internal components.

*Discussion: The grain size of molecular sieve material should be selected to minimize the potential for migration of sieve material from the sieve holder.*

##### Cryogenic Systems

*Discussion: Cryogenic systems should provide adequate cryo-pumping capability to completely condense all residual gasses remaining at initial cool down.*

[REQ-2-IRMS-2970] CCR heads should be vibration isolated from the instrument dewar.

[REQ-2-IRMS-2980] Manifolds should be provided for the distribution of helium to the CCR heads according to the capacity of the associated compressors in order to minimize the number of instrument interconnections required.

#### Common Practices Implementation Requirements

##### Fit and Finish

[REQ-2-IRMS-2990] All steel or iron components should be plated or painted to prevent rust. This includes fasteners and rivets.

[REQ-2-IRMS-3000] Welds not ground to the surface or joint profile should be of dress quality.

[REQ-2-IRMS-3010] All welds and castings must be stress relieved prior to painting and assembly.

[REQ-2-IRMS-3020] Machined components should be free of tool marks, scratches and material flaws such as inclusions or voids.

[REQ-2-IRMS-3030] Unless otherwise specified all external enclosure and exposed structural elements should be finished in TBD epoxy paint applied in accord with the manufacturer’s instructions.

[REQ-2-IRMS-3040] All burrs and sharp edges shall be removed from all fabricated components unless the function of the component requires a sharp edge.

[REQ-2-IRMS-3050] Mild steel surfaces that cannot be painted for functional reasons (such as accurate interface surfaces) shall be protected by a non-tracking anti-corrosion dry film lubricant.

##### Continuity of Shielding and Grounding

[REQ-2-IRMS-3060] Dissimilar metals in contact under conditions where electrolytic corrosion may occur will be isolated by a dielectric finish or insulating spacers.

[REQ-2-IRMS-3070] Notwithstanding this requirement all components of enclosures that are required to provide protective grounding or EMI shielding must be electrically bonded at multiple points by threaded fasteners, finger stock, or a continuous conductive elastomeric gasket.

[REQ-2-IRMS-3080] Anodized aluminum parts must be free of anodizing at the points where electrical contact is required.

[REQ-2-IRMS-3090] Painted metal parts must be free of paint at the points where electrical contact is required.

##### Corrosion resistance

[REQ-2-IRMS-3100] All metal components should be finished to prevent corrosion in the operating environment (see Table 5) over a normal 10 year lifetime of operation including handling, maintenance and repair.

[REQ-2-IRMS-3110] All removable fasteners must be plated or treated to prevent corrosion.

[REQ-2-IRMS-3120] Internal components may be plated or paint finished. A contractor who can show conformance to the requirements of MIL-STD-171E “Finishing of Metal and Wood Surfaces” or equivalent should perform any required painting, plating or anodizing.

##### Fasteners

[REQ-2-IRMS-3130] Press fit studs or threaded inserts must be installed in the correct material (i.e. no aluminum inserts in steel) according to the manufacturer’s instructions.

[REQ-2-IRMS-3140] Self-tapping screws should not be used for removable covers or to secure components that will have to be removed for repair or replacement.

[REQ-2-IRMS-3150] Fasteners should have either Phillips or hex socket heads. Hex socket button head fasteners should not be used except where space or specific function requires them. Undercut machine screws should not be used except in special cases where there is no other appropriate design alternative.

[REQ-2-IRMS-3160] Prevailing torque locknuts or lock washers are preferred to thread locking compounds. Soft insert locknuts should have Kel-F or Vespel inserts, and should only be used where subsequent removal is not anticipated.

##### Lubricants

[REQ-2-IRMS-3170] Lubricants must be suited for the low temperature environment encountered at the summit. The base oil in a grease lubricant should have a high viscosity index, a low pour point temperature and a low viscosity at the average operating temperature (based on a 0 ˚C ambient).

##### Lubricated Components

[REQ-2-IRMS-3180] Exposed lubricated components such as gear trains or lead screws should be enclosed in a shroud or boot to prevent the collection of dust and dirt and also to prevent accidental contact that may result in the transfer of the lubricant to other surfaces.

#### Standards Implementation Requirements

##### Structural

[REQ-2-IRMS-3190] The structure of IRMS should meet the zone 4 earthquake survival requirements of Telcordia Standard GR-63-CORE, “NEBS™ Requirements”. (TBD)

##### Vacuum Systems

[REQ-2-IRMS-3200] Vacuum systems should be implemented in conformance with the requirements of ASME HPS‑2003, “High Pressure Systems”

[REQ-2-IRMS-3210] and NFPA 99C, “Standard on Gas and Vacuum Systems”, 2005 edition.

##### Cryogenic Systems

[REQ-2-IRMS-3220] Cryogenic systems should be implemented in conformance with the requirements of NFPA 55, “Standard for the Storage, Use, and Handling of Compressed Gases and Cryogenic Fluids in Portable and Stationary Containers, Cylinders and Tanks”, 2005 edition.

#### Regulatory Implementation Requirements

None.

### Design Requirements

#### Technological Design Requirements

##### Vacuum and Cryogenic Components

[REQ-2-IRMS-3230] Materials used in the construction of components for vacuum environments should have a total mass loss (TML) of ≤ 1%.

[REQ-2-IRMS-3240] Materials used in the construction of components for vacuum environments should have a collected volatile condensable materials (CVCM) value of ≤ 0.1%.

[REQ-2-IRMS-3250] Values for TML and CVCM should be determined in accord with the methods of ASTM standard E595-93 (2003)e1 “Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment”.

##### Opto-Mechanical Assemblies

[REQ-2-IRMS-3260] Optical and mechanical assemblies, modules or components that must be removed for service shall be provided with locating pins or other features as required to permit repeatable removal and replacement.

[REQ-2-IRMS-3270] Handling features shall be provided on all components unless they are inherently easy to handle without risk of damage.

[REQ-2-IRMS-3280] Components heavier than 25 kg and subassemblies shall be provided with lifting eyes or ‘A’ brackets.

##### Electrical/Electronic Assemblies and Enclosures

[REQ-2-IRMS-3290] Service access and regulatory compliance in electronic assemblies and enclosures requires attention to the dimensions of components and the space provided for terminal access, wire bending and component mounting.

[REQ-2-IRMS-3300]Sufficient space shall be provided for adequate terminal access.

[REQ-2-IRMS-3310] Sufficient space shall be provided to meet wire bend radii and electronic component spacing requirements.

*Discussion: The mechanical arrangement of the electronic assemblies within enclosures should be designed using techniques that document the proposed arrangement and permit the verification of accessibility, wire bend radii and electrical spacings. Computer aided design techniques including solid modeling may be of value in achieving these objectives.*

[REQ-2-IRMS-3320] Where possible electrical and electronic subsystems should consist of rack mounted modules conforming to the 19 inch (482.6 mm) width pattern of Electronic Industries Association (EIA) standard 310-D, “Cabinets, Racks, Panels, and Associated Equipment”, section 1.

[REQ-2-IRMS-3330] Where rack mounted modules are used each module should be installed using rack slides.

[REQ-2-IRMS-3340] Where rack mounted equipment can be accessed only from the front all rack slides must extend far enough to permit disconnection of any rear panel connections prior to removal of the rack module from the slides.

In systems that consist predominantly of rack mounted modules:

[REQ-2-IRMS-3350] All commercial off the shelf (COTS) modules, components and subsystems that are not available in rack mount configurations should be mounted in suitable rack module chassis or on rack mount shelves.

[REQ-2-IRMS-3360] All rack module chassis and shelves should be mounted on slides.

[REQ-2-IRMS-3370] Components or modules mounted on shelves must be fully enclosed as required to meet all other requirements for grounding, shielding and electrical safety.

[REQ-2-IRMS-3380] Components or modules weighing less than 0.5 kg may be mounted on hinged or screw mounted rack panels provided that all other requirements for grounding, shielding and electrical safety are met.

[REQ-2-IRMS-3390] Rails in 19 inch rack cabinets should be tapped or equipped with captive tapped inserts.

[REQ-2-IRMS-3400] Clip nuts should not be used.

[REQ-2-IRMS-3410] Enclosures for electrical and electronic components must provide a continuous shield to prevent the entry or emission of electromagnetic energy.

[REQ-2-IRMS-3420] No openings greater than 3 mm in diameter or 3 mm in width and 15 cm in length should be permitted on the exterior of any enclosure for electrical and electronic components. This includes gaps due to access covers, hinges or other enclosure components.

[REQ-2-IRMS-3430] Removable covers that do not make continuous contact with the enclosure must be provided with a fastener every 15 cm or with conductive gaskets or finger stock as described in §3.3.3.2.2.

*Discussion: Thermal analysis should be performed to ensure that all components operate within their temperature limits and to ensure that excess heat is not transmitted to other components or sub-systems of the instrument.*

##### Mechanisms

[REQ-2-IRMS-3440] Mechanisms in IRMS should be based on as few identical mechanical assemblies as possible.

[REQ-2-IRMS-3450] Mechanisms should be designed in modular assemblies.

[REQ-2-IRMS-3460] Mechanisms should be designed with a minimum of parts and with provisions for simple installation and removal during servicing and repair.

##### Drive Couplings

[REQ-2-IRMS-3470] Shaft couplings for motors, encoders and other drive components should be pinned or locked so that the shaft and coupling cannot slip.

[REQ-2-IRMS-3480] Separable couplings should be used whenever possible for motors to facilitate motor replacement.

##### Component Ratings

[REQ-2-IRMS-3490] Structural elements and fasteners whose failure could cause injury to personnel or equipment must be selected for a safety factor of 10 over ultimate strength of the material. All other structures and fasteners should be designed with a safety factor of at least 5.

[REQ-2-IRMS-3500] All mechanical moving parts should be selected for a 10 year operating lifetime in the operating environment specified in Table 5.

#### Regulatory Design Requirements

None.

#### Standards Related Design Requirements

[REQ-2-IRMS-3510] Enclosures for electrical/electronic components and wiring should conform to the requirements of the Underwriters Laboratories Inc. (UL) Standard for Safety 508 “Industrial Control Equipment”.

[REQ-2-IRMS-3520] All electrical and electronic components should be enclosed in a manner that meets the requirements for a NEMA type 4 or better enclosure. The requirements of a NEMA type 4 enclosure are given in the National Electric Manufacturers Association (NEMA) standards publication 250-1997, “Enclosures for Electrical Equipment (1000 Volts Maximum)”.

[REQ-2-IRMS-3530] Mechanical drawings should conform to ANSI standard Y14.5M-19994 (R1999) “Dimensioning and Tolerancing” and ASME standard Y14.100-2000 “Engineering Drawing Practices”.

#### Integration Related Design Requirements

##### Mounting Position

[REQ-2-IRMS-3540] IRMS should be designed for installation at the TMT NFIRAOS top focal station.

##### Handling

[REQ-2-IRMS-3550] IRMS must be provided with all fixtures and equipment needed to disassemble the instrument dewar for service. If required a crane will be provided by the observatory. The footprint of service fixtures or stands must be minimized because storage and working space on the summit is at a premium.

[REQ-2-IRMS-3560] The profile of all service fixtures or stands must be designed with as low of a center of gravity as possible to resist tipping.

[REQ-2-IRMS-3570] Seismic restraints may also be required.

*Discussion: Handling provisions, fixtures and stands must be designed for safe operation and with consideration for ergonomic factors such as range of motion and working posture.*

## Electronic/Electrical Requirements

[REQ-2-IRMS-4000] TBD

## Safety Requirements

### Purpose and Objectives

Safety is the paramount concern for all activities at the observatory. Specific regulations apply to health and safety as described in §3.1.3.3. The purpose of this section is to provide requirements related to specific safety concerns during the operation and handling of IRMS.

### Scope

Unless otherwise indicated all of the requirements of this section apply to all components of IRMS.

### Performance Requirements

#### Parametric Performance Requirements

None.

#### Operational Performance Requirements

[REQ-2-IRMS-5010] The normal operation of IRMS must not produce any safety hazard to personnel or equipment.

[REQ-2-IRMS-5020] Interlocks, labeling and procedures must be provided to ensure the safety of personnel and equipment during maintenance and repair.

[REQ-2-IRMS-5030] As part of the processes for the detailed design review and the pre-shipment review the safety of the system will be reviewed.

*Discussion: In general it is expected that conformance to the requirements of this document and the referenced regulatory standards will ensure a safe system.*

### Implementation Requirements

#### Feature Implementation Requirements

##### Local Control

[REQ-2-IRMS-5040] Mechanisms internal to the IRMS instrument dewar will not be accessible during normal operation. However, during servicing a means must be provided to ensure that all IRMS mechanisms are under local control and remote control is locked out.

[REQ-2-IRMS-5050] The rotator should be equipped with a local control switch to defeat remote control during service and maintenance operations.

[REQ-2-IRMS-5060] The rotator should be equipped with a motion stop switch to prevent motion of the mechanism during emergencies, service and maintenance.

[REQ-2-IRMS-5070] The rotator should also be connected to the Observatory’s emergency stop circuit to disable rotator motion when the emergency stop is activated.

##### Mechanical

[REQ-2-IRMS-5080] All areas of the rotator where exposed moving parts can create a pinch hazard should be clearly marked with a hazard warning label or equipped with shrouds to prevent accidental contact.

[REQ-2-IRMS-5090] The rotator should incorporate a mechanical lockout feature that locks the IRMS instrument in place so that it cannot rotate. This feature will ensure that the instrument will not move due to an imbalance caused by removal of a component for service.

#### Common Practice Implementation Requirements

None.

#### Standards Implementation Requirements

None.

#### Regulatory Implementation Requirements

[REQ-2-IRMS-5110] See §3.1.3.3.

### Design Requirements

#### Technological Design Requirements

##### IRMS Instrument Dewar

[REQ-2-IRMS-5120] No part of any IRMS mechanism should move when ac main power is applied to or removed from IRMS. The IRMS motion control hardware should inhibit all motion during a power on/reset.

[REQ-2-IRMS-5150] Limit switches should be closed when not actuated (N.C. contacts).

[REQ-2-IRMS-5160] Motion control software should be designed so that a disconnected limit switch will appear to be active, inhibiting further motion towards that limit.

[REQ-2-IRMS-5180] Position encoders should include a status loop through the connections to the encoder so that in the event of loss of the encoder connection (or intentional disconnection) all motion on the associated axis is inhibited.

##### Rotator

[REQ-2-IRMS-5190] No part of the rotator should move when ac mains power is applied to or removed from the rotator. The IRMS rotator motion control hardware should inhibit all motion during a power on/reset.

[REQ-2-IRMS-5200] The rotator motion control system should be designed so that loss of the encoder signal or disconnection of the motor cannot result in a “wind up” of the servo position command.

[REQ-2-IRMS-5210] Software features should be implemented to inhibit motion when the position error measured by the servo controller exceeds the smallest reasonable margin that reflects all of the expected operating conditions.

[REQ-2-IRMS-5220] Limit switches should be closed when not actuated (N.C. contacts).

[REQ-2-IRMS-5230] Motion control software should be designed so that a disconnected limit switch will appear to be active, inhibiting further motion towards that limit.

[REQ-2-IRMS-5240] Position encoders should include a status loop through the connections to the encoder so that in the event of loss of the encoder connection (or intentional disconnection) all motion on the associated axis is inhibited.

#### Regulatory Design Requirements

[REQ-2-IRMS-5250] As indicated in the sections for overall and mechanical requirements the design of IRMS must conform to all applicable regulatory requirements.

#### Standards Related Design Requirements

None.

#### Integration Related Design Requirements

None.

## Software requirements

[REQ-2-IRMS-6000] TBD

## Interface Requirements

### Purpose and Objectives

This section is reserved for interface requirements that are not addressed by other portions of the document.

### Performance Requirements

#### Parametric Performance Requirements

None.

#### Operational Performance Requirements

##### Handling

See §3.3.4.4.2.

### Implementation Requirements

#### Feature Implementation Requirements

##### Optical Requirements

See §3.2.3.1.

##### Mechanical

See §3.3.3.1.

#### Common Practice Implementation Requirements

##### Glycol Cooling

See §3.3.3.1.5.

##### Vacuum and Cryogenics

See §3.3.3.1.6 and §3.3.3.1.7.

##### Stray Light

TBD.

#### Standards Implementation Requirements

None.

#### Regulatory Implementation Requirements

None.

### Design Requirements

#### Technological Design Requirements

None.

#### Regulatory Design Requirements

None.

#### Standards Related Design Requirements

None.

#### Integration Related Design Requirements

##### Optical Interface

See §3.2.4.4.1.

##### Mechanical Interface

See §3.3.4.4.

##### Electrical/Electronic Interface

TBD.

## Reliability Requirements (TBD)

### Purpose

A process should take place to confirm that the IRMS instrument will provide a high level of reliability for a 10 year lifetime.

### Scope

Unless otherwise indicated all of the requirements of this section apply to all components of IRMS.

## Spares Requirements

[REQ-2-IRMS-7000] TBD.

## Service and Maintenance Requirements

[REQ-2-IRMS-8010] IRMS must incorporate provisions for disassembly for servicing of internal components.

[REQ-2-IRMS-8020] Handling fixtures and any specialized tools required for servicing must be provided with IRMS.

[REQ-2-IRMS-8030] A written procedure accompanied by illustrations must be provided for removal and replacement of all major sub-assemblies in IRMS.

## Documentation Requirements

### Documentation Package

The IRMS instrument should be provided with design, operating and maintenance documentation package including, but not limited to, the following:

1. [REQ-2-IRMS-9010] System overview and design description, including details of optical design, mechanical design (including thermal and vacuum design), electrical design and software design. All design documents shall be supplied in revised form as required to reflect the delivered as-built instrument.
2. [REQ-2-IRMS-9020] User’s manual, including but not limited to operating instructions.
3. [REQ-2-IRMS-9030] Revised fabrication/procurement drawings, specifications, and schematics that accurately depict the as-built condition of all of the components of the instrument. All such drawings should be detailed enough to allow fabrication of spare parts should the need arise.
4. [REQ-2-IRMS-9040] Bills of material including supplier information for all components of the instrument.
5. A maintenance manual, including all information and procedures needed to maintain and operate IRMS during its lifetime, including but not limited to the following:
	1. [REQ-2-IRMS-9050] Procedures for handling, assembly and disassembly of the instrument and all of its components accurately reflecting the as-built instrument. All assembly instructions shall be clear, and include a tools list, parts lists and check list.
	2. [REQ-2-IRMS-9060] Routine maintenance and inspection procedures, as well as a maintenance schedule.
	3. [REQ-2-IRMS-9070] Alignment procedures.
	4. [REQ-2-IRMS-9080] Troubleshooting guide.
	5. [REQ-2-IRMS-9090] Repair procedures.
6. [REQ-2-IRMS-9100] Acceptance Test Plan documents, test procedures and all performance data and results of acceptance testing.
7. [REQ-2-IRMS-9110] Descriptions of all recommend spare parts and procedures for removal and replacement including written procedures and assembly drawings and exploded view drawings.
8. [REQ-2-IRMS-9120] All manufacturer’s manuals and documentation for COTS components.
9. [REQ-2-IRMS-9130] All software design documents and related documents including, but not limited to software build and install procedures, source code, release description document, software design document(s), software acceptance testing plans and software user’s manual. All software design documents and related documents shall be supplied in revised form as required to reflect the delivered as-built instrument software.
10. [REQ-2-IRMS-9140] Safety plan and procedures.

### Drawings

#### Drawing Standards

[REQ-2-IRMS-9150] The primary units for all drawings are the international system of units (SI). All instrument drawings should be dimensioned in millimeters. Secondary dimensions may be provided in inches.

All instrument drawings should conform to the following:

1. [REQ-2-IRMS-9160] Drawings for optical components shall conform to ANSI/ASME standard Y14.18M-1986 “Optical Parts (Engineering Drawings and Related Documentation Practices)”.
2. [REQ-2-IRMS-9170] Mechanical drawings shall conform to ANSI Y14.5M-1994 (R1999) “Dimensioning and Tolerancing” and ASME standard Y14.100-2000 “Engineering Drawing Practices”.
3. [REQ-2-IRMS-9180] Each sheet shall conform to ANSI Y14.1-1995 (R2002), “Decimal Inch Drawing Sheet Size and Format”. Drawing size shall be determined on an individual basis.
4. [REQ-2-IRMS-9190] Each drawing shall have a title block with at least the following information:
* Development group
* Drawing number
* Title
* Designer
* Draftsman
* Scale
* Method for determining next higher assembly.
1. [REQ-2-IRMS-9200] All drawings shall include parts and materials lists in accordance with ANSI Y14.34‑2003, “Parts Lists, Data Lists, And Index Lists: Associated Lists”. All items shall be identified with an item number or other label (with reference to the drawing number if one exists) for each part or component with all information required for procurement.
2. [REQ-2-IRMS-9210] Assembly drawings shall include all relevant views required to clearly define the assembly including isometric and exploded views.
3. [REQ-2-IRMS-9220] All detail drawings shall include all views, geometry, dimensions and feature controls required to duplicate the part in accordance with ANSI Y14.5M-1994 (R1999) “Dimensioning and Tolerancing”.
4. [REQ-2-IRMS-9230] Multi and sectional view drawings shall be developed in accordance with ANSI Y14.3M-1994 “Multi and Sectional View Drawings”.
5. [REQ-2-IRMS-9240] Fluid power system schematics shall be drawn in accordance with ASME Y32.10-1967 (R1994) “Graphic Symbols for Fluid Power Diagrams”.
6. [REQ-2-IRMS-9250] Dimensions and tolerances shall be indicated in accordance with ANSI 14.5M-1994 (R1999).
7. [REQ-2-IRMS-9260] Surface finishes shall be described in accordance with ANSI 14.5M-1994 (R1999).
8. [REQ-2-IRMS-9270] The electronic drawing format shall be at least SolidWorks 2012 (or a more current release).
9. [REQ-2-IRMS-9280] The preferred CAD software for 3D drawings is SolidWorks.

#### Required Drawings

All drawings must be provided as specified in the formats listed above and in the native format if translated to one of the specified formats.

The following drawings should be provided:

1. [REQ-2-IRMS-9290] As‑built detailed mechanical drawings for all components not commercially available. Drawings shall provide sufficient detail to fabricate the components to original design intent.
2. [REQ-2-IRMS-9300] As‑built detailed drawings for all optical components not commercially available. Drawings shall provide sufficient detail to fabricate the components to original design intent.
3. [REQ-2-IRMS-9310] As‑built assembly drawings for all assemblies not commercially available along with appropriate detail drawings and assembly tolerances and procedures.

### Electrical/Electronic Documentation

TBD

### Software Documentation

TBD

1. Gordon, Colin G. *Generic Criteria for Vibration-Sensitive Equipment*. Proceedings of the SPIE Vol. 1619, pp. 71-85, Vibration Control in Microelectronics, Optics, and Metrology. Gordon, Colin G. editor. SPIE 1992. [↑](#footnote-ref-1)