

**Instruments** **Common Requirements Specification**

**KITN 0039**



Version 1.4

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# Change record

|  |  |  |  |
| --- | --- | --- | --- |
| Version | Date | Changes | Author |
| 1.3 | June 30, 2022 |  | Sonia Karkar |
| 1.411.4 | January 13, 2023 | Update UNO related req. Add earthquake sectionAdd mechanical cooling section.Updated with community feedback. | Sonia Karkar, Marc Kassis |

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# Introduction

In order to build a new instrument capable of successful sustained operations at Keck Observatory, non-science as well as science requirements must be met. This document describes the Observatory requirements related to instrument operations and interfaces.

# Scope and Applicability

This document defines the non-science system-level requirements related to:

* **Engineering operations:** instrument installation, maintenance and removal.
* **Safety standards:** engineering best practices that the instrument builders are encouraged to comply with. The list of standards mentioned is not exhaustive, in particular, instrument’s builders should follow industry standards and the best practices of their own organization.
* **Hazard and informational labeling:** labeling for both safety and informational purposes.
* **Documentation standards:** guidance on the documentation requested to be delivered by the instrument's builders to the observatory.
* **Interfaces:** general set of interfaces between the Observatory and the instrument. It covers environmental, mechanical, electrical, optical, software and service interfaces. Detailed requirements for each interface are contained within the corresponding ICD, when one exists. Software interfaces may also be accompanied by design guides or style guides.

# References

## Related Documents

Table 1 Related documents

|  |  |
| --- | --- |
|  | Calabretta, M.R. and Greisen, E.W. (2002). Representations of celestial coordinates in FITS. 2002 *Astronomy and Astrophysics 395*, 1077. |
|  | Greisen, E.W. and Calabretta, M.R. (2002). Representations of world coordinates in FITS. *Astronomy and Astrophysics 395*, 1061 |
|  | Greisen, E.W., Calabretta, M.R., Valdes, F.G., and Allen, S.L. (2006). Representations of spectral coordinates in FITS *Astronomy and Astrophysics 446*, 747. |
|  | Gordon, Colin G. (1992). Generic Criteria for Vibration-Sensitive Equipment. *SPIE 1619*, pp. 71-85. |
|  | The Institute of Electrical and Electronic Engineers, Inc. [IEEE] (2009). IEEE Standards Style Manual. Retrieved from <http://www.ieee.org/portal/site/iportals>                   |
|  | Adkins, S. M., Cohen, J. G., Aycock, J., Bell, J., Cohen, R., Cooper, A., Goodrich, R., Johnson, J., Kwok, S. H., Lyke, J., McCann, K., Neyman, C., Nordin, T., Panteleev, S., Tolleth, G. & Tsubota, M. (2008). MAGIQ at the W. M. Keck Observatory: Initial deployment of a new acquisition, guiding, and image quality monitoring system. *Proc. SPIE 7014*, 70141U-70141U-12. |
|  | Adkins, S. & Matsuda, R. (2005). Multi-function Acquisition, Guiding and Image Quality monitoring system (MAGIQ) System Requirements Document, MAGIQ Technical Note MAGIQ-013. Waimea, HI: W. M. Keck Observatory. |
|  | Kwok, S., Johnson, J., Adkins, S., McCann, K. (2008). The Software for MAGIQ: a new acquisition, guiding and image quality monitoring systems at the W. M. Keck Observatory. *Proc. SPIE 7019 (KOR 285)* |

## Referenced Standards

### Industry Consensus Standards

Table 2 lists the industry consensus standards referenced in this document. Instrument’s documentation is required to comply with some part of each standard as detailed in chapter 15.

Table 2 Referenced standards

|  |  |  |  |
| --- | --- | --- | --- |
| **Ref** | **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 | Y14.100-2000 | Engineering Drawing Practices |
|  | ASME | Y32.10-1967 (R1994) | Graphic Symbols for Fluid Power Diagrams  |
| 1.
 | National Electric Manufacturers Association | 250-1997 | Enclosures for Electrical Equipment (1000 Volts Maximum) |
| 1.
 | Underwriters Laboratories Inc. | Standard for Safety 508 | Industrial Control Equipment |

### WMKO Software Standards

WMKO software standards are also referenced in this document.  References to these standards are included because compliance with some part of each standard is required.

Table 3 WMKO software standards

|  |  |  |
| --- | --- | --- |
| **Source (Organization or Standardizing Body)** | **Number** | **Title** |
| WMKO | KSD 8 | KTL: the Keck Task Library |
| WMKO | KSD 28 | KTL Programming Manual |
| WMKO | [KSD 243](https://keckhawaii.sharepoint.com/%3Ab%3A/r/sites/Sonia%27sTasks/intruments/Shared%20Documents/Software/KTL%20reference%20docs/KTL%20keyword%20design%20and%20best%20practices.pdf?csf=1&web=1&e=xGPgfo) | KTL Keyword Design and Best Practices |
| WMKO | [KSD 245](https://keckhawaii.sharepoint.com/%3Ab%3A/r/sites/Sonia%27sTasks/intruments/Shared%20Documents/Software/KTL%20reference%20docs/KSD%20245%20WMKO%20instrument%20computers%2C%20accounts%2C%20and%20procedures.pdf?csf=1&web=1&e=AFYj5a) | Server and Code Layout for WMKO Instruments (partial) |
| WMKO | [DesignDoc](https://keckhawaii.sharepoint.com/%3Ab%3A/r/sites/Sonia%27sTasks/intruments/Shared%20Documents/Software/DSI-KOA-RTIDesignDocument-270123-1537.pdf?csf=1&web=1&e=gra4jc) | DSI-KOA-RTI Design Document v1 March 2021 |

## Observatory Reference Drawings

Table 3 lists the drawing numbers, revisions and date, source and title for drawings that may be of use to the instrument designer.

Table 4 Observatory Reference Drawings

|  |  |  |  |
| --- | --- | --- | --- |
| **Drawing #** | **Revision--Date** | **Source** | **Title** |
| [640-C0011](https://keckhawaii.sharepoint.com/%3Ab%3A/r/sites/Sonia%27sTasks/intruments/Shared%20Documents/Instruments%20interface%20control%20drawings/640-C0011.pdf?csf=1&web=1&e=KZ8vGr)  | K-- -06/17/2020  | WMKO | Keck I Instrument Stowage Layout |
| [640-C0012](https://keckhawaii.sharepoint.com/%3Ab%3A/r/sites/Sonia%27sTasks/intruments/Shared%20Documents/Instruments%20interface%20control%20drawings/640-C0012.pdf?csf=1&web=1&e=pMlNJV)  | L--06/17/2020 | WMKO | Keck II Instrument Stowage Layout |
| [740-C0058](https://keckhawaii.sharepoint.com/%3Ab%3A/r/sites/Sonia%27sTasks/intruments/Shared%20Documents/Instruments%20interface%20control%20drawings/740-C0058%20K1%20nas%20platform%20instrument%20ICD%20center%20position.pdf?csf=1&web=1&e=Srz3LX) | A--5/17/2012 | WMKO | K1 Left Nasmyth Platform Instrument Interface Control - Center Position |
| [740-C0056](https://keckhawaii.sharepoint.com/%3Ab%3A/r/sites/Sonia%27sTasks/intruments/Shared%20Documents/Instruments%20interface%20control%20drawings/740-C0056.pdf?csf=1&web=1&e=HijkX8) | B--1/4/2012 | WMKO | K1 Left Nasmyth Platform Instrument Interface Control - Off Axis (Kcam) Position |
| [740-C1002](https://keckhawaii.sharepoint.com/%3Ab%3A/r/sites/Sonia%27sTasks/intruments/Shared%20Documents/Instruments%20interface%20control%20drawings/740-C1002.pdf?csf=1&web=1&e=QuggFJ)  | B--3/30/2016 | WMKO | Keck 2 Right Nasmyth Platform Instrument Interface Control Drawing. Instrument Addendum |
| [740-C0055](https://keckhawaii.sharepoint.com/%3Ab%3A/r/sites/Sonia%27sTasks/intruments/Shared%20Documents/Instruments%20interface%20control%20drawings/740-C0055_01-5%20K2%20left%20nas%20platform%20instrument%20ICD%20center%20position.pdf?csf=1&web=1&e=qTCc0V) | F--4/27/2007 | WMKO | K2 Left Nasmyth Platform Instrument Interface Control - Center Position |
| [1300-C0860](https://keckhawaii.sharepoint.com/%3Ab%3A/r/sites/Sonia%27sTasks/intruments/Shared%20Documents/AO/Mechanical%20drawing%20and%20CAD%20files/1300-C0860.pdf?csf=1&web=1&e=IEoL4q) [1300-C0861](https://keckhawaii.sharepoint.com/%3Ab%3A/r/sites/Sonia%27sTasks/intruments/Shared%20Documents/AO/Mechanical%20drawing%20and%20CAD%20files/1300-C0861.pdf?csf=1&web=1&e=fPfTxZ) | NC--03/06/2014A--03/06/2014 | WMKO | K1 AO bench assembly |
| [1300-C0871](https://keckhawaii.sharepoint.com/%3Ab%3A/r/sites/Sonia%27sTasks/intruments/Shared%20Documents/AO/Mechanical%20drawing%20and%20CAD%20files/1300-C0871.pdf?csf=1&web=1&e=pMqTdj) | NC--03/21/2011 | WMKO | K2 AO bench assembly |

## Verification Method Definitions

These definitions were obtained from:

<https://spacese.spacegrant.org/index.php?page=verification-module>

More information can also be found here:

<https://reqexperts.com/2012/10/17/use-of-multiple-verification-methods/>

**Inspection Method**

Inspections determine conformance to requirements by the visual examination of drawings, data, or the item itself using standard quality control methods, without the use of special laboratory procedures or equipment.

Inspections include a visual check or review of project documentation such as, drawings, vendor specifications, software version descriptions, computer program code, etc.

Inspection includes examining a direct physical attribute such as dimensions, weight, physical characteristics, color or markings, etc.

**Analysis Method**

Analysis is the evaluation of data by generally accepted analytical techniques to determine that the item will meet specified requirements.

Analysis techniques: systems engineering analysis, statistics, and qualitative analysis, analog modeling, similarity, and computer and hardware simulation.

Analysis is selected as the verification activity when test or demonstration techniques cannot adequately or cost-effectively address all the conditions under which the system must perform or the system cannot be shown to meet the requirement without analysis.

**Demonstration Method**

Demonstration determines conformance to system/item requirements through the operation, adjustment, or reconfiguration of a test article.

Demonstration generally verifies system characteristics such as human engineering features, services, access features, and transportability.

Demonstration relies on observing and recording functional operation not requiring the use of elaborate instrumentation, special test equipment, or quantitative evaluation of data.

**Test Method**

Test is a verification method in which technical means, such as the use of special equipment, instrumentation, simulation techniques, or the application of established principles and procedures, are used for the evaluation of the system or system components to determine compliance with requirements.

Test consists of operation of all or part of the system under a limited set of controlled conditions to determine that quantitative design or performance requirements have been met.

Tests may rely on the use of elaborate instrumentation and special test equipment to measure the parameter(s) that characterize the requirement.

## Requirements terminology

* **Shall – Requirement**:  *Shall* is used to indicate a requirement that is contractually binding, meaning it must be implemented, and its implementation verified.
* **Will -- Facts or Declaration of Purpose**. *Will* is used to indicate a statement of fact.  *Will statements* are not subject to verification.
* **Should – Goals, non-mandatory provisions.** *Should* is used to indicate a goal which must be addressed by the design team but is not formally verified.

# Overview of Keck Operations

## Site, Facilities and Services

The W. M. Keck Observatory operates two 10-meter telescopes at the summit of Maunakea on the Big Island of Hawaii. The summit is at an altitude of 13,800 ft (4206 meters). Environmental conditions are described in Section 5.1.3

Each telescope has several focal stations available. These include the two Nasmyth locations, Cassegrain, and bent Cassegrain locations that all receive an f/15 focus from the Keck telescopes. Secondary slots are available for Prime Focus instrumentation. Instruments may also be installed in the basement with multiple locations under and between the two telescopes available. Occupied locations may be repurposed with justification, and other locations may be considered.

WMKO will help assess the feasibility for any location by providing the mechanical configurations for existing locations, and when appropriate, instrumentation specifics that interface with these locations. For any location shared by multiple instruments, new instrumentation shall be compatible with existing instrumentation at those locations.

The Keck facility can supply power, instrument cooling, and communications. Specifications for these services are provided in the relevant sections. Keck also provides Adaptive Optics facilities on each telescope. Modifications to these systems may be considered.

Observing is conducted from the headquarters facility in Waimea. All operational functions of the instrument must be capable of remote command, control and feedback.

|  |  |  |
| --- | --- | --- |
| **ID** | **Contents** | **Verification Method** |
| 7 | Environment |  |
|  | Environment Information |  |
|  | Telescope Operating Environment |  |
| info | Conditions that may be experienced under normal telescope operations inside the dome are listed in table 5 |  |
|  | **Table 5: Telescope operating environment** |  |
| info |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Parameter** | **Min.** | **Typ.** | **Max.** | **Units** | **Notes** |
| Altitude | 0 |  - | 4300 | m |   |
| Atmospheric pressure | 607.43 | 620.71 | 627.38 | mbar |   |
| Temperature | -10 | 1.8 | 30 | ºC |   |
| Temperature variation rate | 0 | 0.024 | 0.5 | ºC/min |   |
| Humidity | 0 | 34 | 100 | % |  A non-condensing condition is normal when the dome is closed because the dome is air conditioned to control humidity. The dome is not opened unless the dome and outdoor temperatures are above the dew point. Transient conditions can occur that result in condensation. |
| Gravity orientation | - | -1 | - | g | Normal to the earth’s surface. Cassegrain instruments experience a variable gravity vector. |
| Vibration | - | - | 0.25x10-9 | g2/Hz | 8 Hz to 80 Hz |
| Acceleration | - | - | 2 | g |  All axes, due to telescope drive system fault conditions (1g), and seismic activity (2g) |

 |  |
|  | Keck Observatory Basement Operating Environment |  |
| info | Conditions that may be experienced by equipment installed in the Keck observatory basement are given in Table 6. |  |
|  | **Table 6: Keck observatory basement operating environment** |  |
| info |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Parameter** | **Min.** | **Typ.** | **Max.** | **Units** | **Notes** |
| Altitude | 0 | - | 4300 | m |   |
| Atmospheric pressure | 607.43 | 620.71 | 627.38 | mbar |   |
| Temperature | 0 | 15 | 25 | ºC |  Typical basement temperature is 15 °C.  Laboratory operation requires a maximum of at least 20 ºC.Based on KPF project measurements of the basement environment. |
| Temperature variation rate | 0 | - | 1 | ºC/hr |   |
| Humidity | 0 | 15 | 100 | % |  Relative humidity. Based on reference 1, typical is the average annual humidity. A non-condensing condition is normal when the dome is closed because the dome is air conditioned to control humidity. The dome is not opened unless the dome and outdoor temperatures are above the dew point. Transient conditions can occur that result in condensation. |
| Gravity orientation | - | -1 | - | g |   |
| Vibration | - | - | 0.25x10-9 | g2/Hz | 8 Hz to 80 Hz |
| Acceleration | - | - | 2 | g | seismic accelerations |

 |  |
|  |  |  |
|  |  |  |
|  | Air Borne Contaminants |  |
| info | The weather conditions at the summit of Mauna Kea include frequent high winds resulting in some air borne contaminants, particularly dust and insects.  |  |
|  | Vibration Environment |  |
| info | The vibration environment that instruments may experience at Keck is shown in Figure1 below:**Figure 1: Keck I & II telescope equipment vibration environment1** |  |
|  | 1Gordon, 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. |  |
|  | Transport Requirements |  |
| info |

|  |
| --- |
| Transportation and Shipping Environment  |
| Conditions that may be encountered during shipping are given in Table 4. |
| **Table 4: Transportation and shipping environment** |
|

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Parameter** | **Min.** | **Typ.** | **Max.** | **Units** | **Notes** |
| Altitude | 0 | - | 4572 | m |   |
| Temperature | -33 | - | 71 | ºC | Min and Max for induced conditions. "Induced Conditions" are air temperature levels to which materiel may be exposed during storage or transit situations that are aggravated by solar loading. |
| Temperature shock | -54 | - | 70 | ºC |  Temperature changes of 10°C per minute. |
| Humidity | 0 | - | 100 | % |  Relative, condensing. |
| Gravity orientation | - | - | - | NA | Packaged equipment may be subjected to all possible gravity orientations during transportation and shipping. |
| Vibration | - | - | 0.015 | g2/Hz | 10 Hz to 40 Hz, -6dB/oct. drop-off to 500 Hz, all axes |
| Shock | - | - | 15 | g | 0.015 second half-sine, all axes  |
| Acceleration | - | - | 4 | g |  All axes. |

 |

 |  |
| 7.2.1.1 | The instrument and related subsystems shall be packaged in a manner that protects it from shock and other reasonably anticipated environmental conditions. Typical shipping conditions are specified in Table 4. | Inspection |
| 7.2.1.2 | The instrument shall be packaged for transport in a way that allows inspections by the Department of Homeland Security and the US Department of Agriculture to be conducted without damage to the instrument. This is normally achieved by using a port/window in the container. | Inspection |
| 7.2.1.3 | The following are descriptions of the inspections, as provided by Pasha Hawaii:Inspections:1. All cargo will be inspected by the Department of Homeland Security. All cargo must be accessible and any compartments unlocked.2. All cargo is subject to inspection by U. S. Department of Agriculture (USDA) upon arrival at both the origin and destination terminals. |  |
| 7.2.1.4 | The packaging material shall comply with the Maunakea Invasive Species Management Plan available at <http://keckobservatory.org/wp-content/uploads/2018/10/MK-Invasive-Species-Plan_2018.pdf> specifically, Page 8, Section 2. Preparation (using bark-free wood for crate). | Inspection |
| 7.2.1.5 | Shock sensor/trigger devices shall be installed on the shipping containers. | Inspection |
|  | Transport Best Practices |  |
| 7.2.2.1 | All shipping containers need 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”. |  |
|  | Observing, Functional, and Survival environment Requirements |  |
| Info | Observing conditions*The intent of the Observing Performance Conditions is to describe the range of ambient conditions over which all requirements (unless they specify their own specific range) are met. The instrument shall be designed to produce science over this range and requirements are verified with respect to this range (again unless specifically stated otherwise). This does not necessarily mean that science observations are not possible beyond this range nor does it mean that the instrument must be shut down beyond this range.* |  |
| 7.3.1.1 | Instruments or subsystems located within the dome shall be operational and meet their performance requirements under the conditions specified in Table 5. | Demonstration |
| 7.3.1.2 | Instruments or subsystems located within the observatory basement shall be operational and meet their performance requirements under the conditions specified in Table 6. | Demonstration |
| 7.3.1.3 | Instruments or subsystems located within the AO enclosure shall be operational and meet their performance requirements under the conditions specified in Table 5 |  |
| 7.3.1.4 | Instruments or subsystems located within the computer room shall be operational and meet their performance requirements under the conditions specified in Table 5, but will have an operating temperature range that is between 10-25C. |  |
| Info | Functional conditions*The intent of the Functional Conditions is to describe the range of conditions over which any subcomponent of the instrument is expected to function. For example, motors, pumps, mechanisms, computers, valves, actuators, hydraulics and electronics all must function over this range. In principle any removed subcomponent should function over this range. This requirement does not imply that any* ***system*** *requirements () are met over this range*. |  |
| 7.3.2.1 | The instrument shall be functional under the environmental conditions listed in table xxx,  |  |
|  |  |  |
| Info | Survival conditions*The intent of the Survival Conditions is to describe the range of conditions over which any subcomponent of the instrument is expected to survive.* *No prior warning is available for this condition and subsystems cannot assume that their equipment is manually switched to an off or standby state prior to arrival of these conditions. No system shall be damaged by onset of the survival conditions in any operating state. Survival conditions apply at the observatory. Consumable or one-time safety measures are not permitted.* |  |
| 7.3.3.1 | The instrument shall survive under the environmental conditions in table 5 and those found in section 7.4 regarding seismic events. |  |
|  |  |  |
|  | Seismic events |  |
|  | Definitions of categories of seismic eventsBased on historical data, WMKO defines four categories of seismic events: **normal seismic activity, minor event, significant event, major event** |  |
| info | Normal seismic activity definition:Below 3milli-g on facility accelerometers.  |  |
| info | Minor seismic event definition:A minor seismic event is intended to be **immediately** recoverable; operations may be resumed after a basic inspection of the facility and instrument. A minor seismic event is one that meets one of the following cases: * has triggered any of the facility accelerometers with less than 10 seconds between 3milli-g and 10milli-g on facility accelerometers
* has created a notable effect in the facility (rattling objects or perceptible shaking) or affected observing (lost guide star, large tracking errors, etc.)
 |  |
| info | Significant seismic event definition:A significant seismic event is intended to be **recoverable in a short time**; operation of the instrument may be resumed after some inspection and light intervention if necessary.A significant seismic event is one that meets one of the following cases: * has triggered any of the facility accelerometers with more than 10 seconds between 10 milli-g and 1 g facility accelerometers
* has created a notable effect in the facility (rattling objects or perceptible shaking) or affected observing (lost guide star, large tracking errors, etc.)
 |  |
| info | Major seismic event definitionA significant seismic event is NOT intended to be recoverable. This is classified as greater than 1g.  |  |
|  | Requirement for the different categories of seismic events Based on the 4 categories of seismic events, the instruments operating at WMKO are subjected to the following requirements:  |  |
| 7.4.2.1 | Normal seismic activity requirements:The instrument shall endure normal seismic activity without disruption of its operation and with its required performances.  |  |
| 7.4.2.2 | Minor seismic events requirements: The instrument shall endure minor seismic events with sufficient structural integrity to protect personnel and nearby hardware.After a minor seismic event, the instrument shall be back to its operational state with its required performances without intervention. |  |
| 7.4.2.3 | Significant seismic events requirements: The instrument shall endure significant seismic events with sufficient structural integrity to protect personnel and nearby hardware.After a significant seismic event, the instrument shall be back to its operational state with its required performances with a minimal intervention: |  |
| 7.4.2.4 | Major seismic event requirements: The instrument shall endure a major seismic event with sufficient structural integrity to protect personnel and nearby hardware but is not required to survive and be restored to service. |  |
|  | Component Ratings Best Practices |  |
| 7.5.1 | All power dissipating components to be cooled by free air convection should be de-rated to 80% of their sea level absolute maximum average power dissipation ratings. |  |
| 7.5.2 | The voltage ratings of relays, switches and insulated cables should be reduced to 80% of their rated value due to the altitude at the summit of Mauna Kea. |  |
| 7.5.3 | All mechanical moving parts should be selected for a 15-year operating lifetime in the operating environment specified in Table 6. |  |
| 7.5.4 | Due to the summit environment, the materials listed in Table 7 shall be avoided unless a specific exception has been granted. | Inspection |
|  | **Table 7: Materials not Suitable for use in Equipment at the Summit of Mauna Kea** |  |
| 7.5.5 |

|  |  |  |
| --- | --- | --- |
| **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 | Acrylic3 | 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 | Kapton4 | Subject to hydrolytic degradation |
| Insulator | Neoprene | Outgases, subject to degradation by ozone and UV exposure |
| Insulator | Nylon6 | Outgases, subject to degradation by ozone and UV exposure |
| Insulator | Phenolic5 | 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. Silicones are prevalent in many common items such as RTV, soap, skin and hair products, and adhesive release agents. They migrate easily, are difficult to remove, and interfere with many types of adhesive bonding. Care should be taken when adhesive bonding or coating to prevent silicone contamination, and should not be used where bonding/coating is performed. This includes the segment aluminizing room.
2. Use is or soon will be highly regulated.
3. Cast acrylic resin
4. Kapton tensile strength and electrical resistance does degrade somewhat in high moisture environments but maintains its properties in relatively dry environments. Suitability for a particular application depends on the environment.
5. Electrical grade phenolic is not hygroscopic.
6. Cable ties of weather resistant Nylon 6/6 (carbon black additive) are acceptable.
 |  |
| 7.5.6 | Due to the summit environment, the materials listed in Table 8 shall be used unless a specific exception has been granted. | Inspection |
|  | **Table 8: Required Parts Selection for Equipment at the Summit of Mauna Kea** |  |
| 7.5.7 |

|  |  |  |
| --- | --- | --- |
| **Parts** | **Materials** | **Reason(s) for Use** |
| Quick Disconnects for fluids | Stainless Steel | Enables quick disconnect of plumbing circuits as a manual means of mitigating a leak. Also allows for easily troubleshooting equipment and moving equipment. |

 |  |
|  | Air Borne Contaminants Requirements |  |
| 7.6.1 | During installation, handling, and when not in use, instruments shall be protected against the entry of air borne contaminants; in particular, care shall be taken with optical surfaces, precision mechanisms, fine pitch connectors and fiber optic connectors. | Inspection |
|  | Vibration Requirements |  |
| 7.7.1 | The instrument shall not produce vibrations that result in rms velocities in excess of those given in curve “D” of Figure 1. | Test |
| 7.7.2 | *Vibration isolation can be employed to isolate sources of vibration within the instrument due to moving components such as fans, pumps and motors.* |  |
|  | Stray Light Requirements |  |
| info | Stray light requirements in this section pertain to the telescope and dome environment with the goal of preventing light from being detected by any operational instrument. This may include the instrument under development as any external light source could be detected by the instrument. These requirements may also be considered best practices for light sources inside the instrument.  |  |
| 7.8.1 | The instrument shall not produce any stray light. *Special attention shall be given to video cameras used to monitor instrument subsystems, LEDs, lamp indicators, optical switches, internal calibration sources, or optical shaft encoders.* | Inspection |
|  | Safety |  |
|  | Safety Information |  |
| 8.1 | Safety is the paramount concern for all activities at the observatory. The purpose of this section is to provide requirements related to specific safety concerns during the operation and handling of the instrument.The safety of the system shall be reviewed at the detailed design review and the pre-shipment review. In general, it is expected that conformance to the requirements of this document and industry standards will ensure a safe system. |  |
|  | Mechanical Safety Requirements |  |
| 8.2 | Machine guarding shall be provided to protect the operator and other employees from hazards such as those created by nip points or rotating parts, if external to the instrument enclosure. | Inspection |
| 8.3 | Instrument fluid lines (helium, coolant, air) shall use self-sealing connectors. | Inspection |
| 8.4 | A means shall be provided to ensure that all instrument mechanisms are under local control and remote control is locked out during servicing.*This can be done by software interlock, powering down the motor crate, disconnecting communications, or other methods.* | Inspection |
| 8.5 | No part of any instrument mechanism shall move when power is applied to or removed from the instrument. | Test |
|  | Software Safety Requirements |  |
| 8.6 | Software coming up from the boot state shall not command motion of any attached hardware.*All motion should be explicitly commanded by the user.* | Test |
| 8.7 | All software outputs shall be initialized to safe default values. | Test |
| 8.8 | If closed loop or servo systems are used in the instrument motion control systems, these servo loops shall 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. | Analysis |
| 8.9 | Software features shall 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. | Analysis |
| 8.10 | Software limits shall be implemented which inhibit motion prior to the activation of physical limit switches. | Test |
| 8.11 | For device relying on encoders to determine their position, the loss of the encoder connection (or intentional disconnection) shall inhibit all motion on the associated axis.*This can be achieved by including a status loop through the connections to the encoder.*  | Test |
|  | Electrical Safety Requirements |  |
| 8.4.1 | All electrical enclosures shall be grounded. | Inspection |
| 8.4.2 | Limit switches shall be wired so that a disconnected switch shall appear to be active, inhibiting further motion towards that limit. |  |
| 8.4.3 | The instrument shall enable local disabling of power.*This ensures personnel safety while working on the instrument, when it is still attached to services.* | Test |
| 8.4.4 | Lock out tag out provisions shall be provided for instruments using voltage in excess of 50V. | Inspection |
|  | Emergency Stop Requirement |  |
| 8.5.1 | If the external motion of the instrument could cause harm to personnel, the instrument shall be provided with an emergency stop input that removes all power to the motors providing the motion and stops all instrument motion when the observatory emergency stop signal is activated.  | Test |
|  | Emergency Stop Best Practice |  |
| 8.6.1 | If the external motion of the instrument could cause harm to personnel, the instrument should be provided with a local emergency stop input that removes all power to the motors providing the motion and stops all instrument motion.  | Test |
|  | Instrument Cooling |  |
|  | Glycol Cooling |  |
|  | Glycol Cooling Information |  |
| info | Maximum flow per circuit from the facility is ~6 gallons/minute. Typical flow provided for instrument cooling is 3 gallons/minute. Instrument glycol temperature is normally about 3°C cooler than the dome temperature. |  |
|  | Glycol Cooling Requirements |  |
| 9.1.2.1 | All glycol cooling circuits shall be compatible with a 50/50 mix of Dowtherm SR-1 and water. | Analysis |
| 9.1.2.2 | All glycol cooling circuits shall be plumbed with braided stainless steel hose with Teflon jackets and stainless steel fittings. | Inspection |
| 9.1.2.3 | Removable connections to the facility shall be made with ½” Parker Hannifin series FS quick disconnect fittings. Exceptions to this requirement may be possible with prior approval of WMKO.Quick Disconnects made of Acetal or brass have been known to fail under summit conditions. | Inspection |
| 9.1.2.4 | Removable connections on board the instrument shall be quick connectors with the instrument supply coupler is male and the return coupler is female.  | Inspection |
| 9.1.2.5 | Observatory approved flow meters shall be provided on both the supply and return lines on the facility side of the instrument interface panel. | Inspection |
| 9.1.2.6 |  Flow meters shall be available for any reasonable parallel circuit (e.g. multiple electronics cabinets) and those meters shall be available for external inspection. | Test |
| 9.1.2.7 | Manual shut-off valves shall be installed on both the supply and return on the facility side of the instrument interface panel as a means of isolating the instrument from the main glycol distribution. | Test |
| 9.1.2.8 | The design of the glycol interface panel shall reserve a volume for the addition of an automatic shutoff valve the observatory identifies in the future. | Inspection |
|  |  |  |
| 9.1.2.9 | Instruments shall have a means of measuring and reporting internal temperatures for hardware via KTL keyword but not specifically the glycol temperature. | Test |
| 9.1.2.10 | Hoses shall have a minimum 1000 psi burst pressure | Inspection |
|  | Glycol Cooling Best Practices |  |
| 9.1.3.1 | If parallel circuits on the instrument are needed, best practice at the observatory is to create a custom manifold to enable parallel circuits.   |  |
|  | Dewar and Cryostat |  |
|  | Dewar and Cryostat Information |  |
| info | Dewars and Cryostats refer to an enclosed volume inside which components are held to cryogenic temperatures. Traditionally, optical instruments have been cooled with LN2 while IR instruments are cooled with CCRs that have compressors in the mechanical room to keep vibrations off the telescope. |  |
|  | Mechanical cooling |  |
| 9.2.2.1 | Instruments requiring operation at cryogenic temperatures shall use mechanical cooling, such as CCRs |  |
| 9.2.2.2 | Compressors for the mechanical cooling shall be located on vibration isolation hardware in the basement or in the K1 or K2 mechanical room. |  |
| 9.2.2.3 | All mechanical cooling heads shall be serviceable so that they may be easily replaced.  |  |
| 9.2.2.4 | All CCRs shall have speed controls to adjust to the cooling environment at the summit and so that the CCR heads have longer lifetimes. Speed controllers are available in-house or from vendors. |  |
| 9.2.2.5 | CCR Speed controllers hardware shall be controlled via KTL keywords. |  |
| 9.2.2.6 | CCRs and speed controllers shall be remotely power cycled via KTL Keyword. Remote power cycling capabilities is supplied by the Observatory. |  |
|  | Dewar and Cryostat Cooling Best Practices |  |
| 9.2.3.1 | Use compressors and heads that are already in use at the observatory for common sparing.  |  |
|  | Power |  |
|  | Power Information |  |
| Info | The observatory summit facilities provide clean and backup power to the instrument electronics. By default, all power plugs provide 120V. 380V can be found at the observatory and shall be specifically required.The first level of backup is the K1 or K2 instrument UPS, an industrial uninterruptible power supply (UPS) shared with the other instruments at the observatory. This UPS has a hold up time of approximately 20 minutes. A separate UPS is provided for each computer room, and these UPS provide backup power for the instrument computers. The computer room UPS also has a hold up time of 20 minutes.In the event of a commercial power outage, the UPS is supported by a backup generator. However, the generator does not supply power to the A/Cs, so electronics may need to be powered off to prevent overheating. |  |
| Info | A similar UPS capability is available in the Keck observatory basement (same UPs units but wired down to the basement). |  |
| Info | During a power failure, the glycol cooling system pumps and chiller will be inoperative, so instrument electronics dependent on glycol cooling require either flow switches or temperature sensors to ensure that the electronics are shut down even though the electronics will be powered from the facility UPS and the Observatory summit standby generator. |  |
|  | Power Failure Tolerance Requirements |  |
| 10.2.1 | The instrument shall be able to endure power failures of up to 2 hours in duration without damage to any component, and without degradation of performance upon power restoration.Special attention should be given to electronics, glycol cooling and detector systems. Rationale: Possibility of power failures, and necessity of disconnecting instruments from services during telescope reconfiguration. | Analysis |
| 10.2.2 | *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 vacuum vessel pumping are required to return to normal operation.* |  |
| 10.2.3 | The instrument shall have the capability to remotely recover from a power outage. | Test |
|  | Power Dissipation Requirements |  |
| 10.3.1 | An Instrument shall not radiate more than 50 Watts of heat into the telescope dome environment.*This requirement applies only to equipment used during normal operations.* | Test |
| 10.3.2 | All heat radiated into the telescope dome environment in excess of 50 Watts shall be carried away via instrument cooling in the form of glycol or CCRs. | Analysis |
| 10.3.3 | An instrument shall not dissipate more than 50 Watts of heat into the telescope basement environment. *This requirement applies only to equipment used during normal operations.* | Test |
| 10.3.4 | All heat radiated into the telescope basement environment in excess of 50 Watts shall be carried away by a via instrument cooling in the form of glycol or CCRs.  | Analysis |
| 10.3.5 | *Methods used to measure radiated heat have included:** *Glycol temperature measurements compared to power consumption.*
* *FLIR camera testing*
* *Analysis of glycol capacity vs theoretical total power in instrument.*
 |  |
|  | Electrical Power Requirements |  |
| 10.4.1 | Instruments using both clean and commercial power shall have separate power circuits for each type of power. | Inspection |
| 10.4.2 | The instrument shall provide the capability to individually remotely cycle power from any facility power source. | Test |
| 10.4.3 | The instrument shall provide the capability to remotely monitor power usage from each power source via KTL keyword. | Test |
|  | Electrical Power Best Practices |  |
| 10.5.1 | All electrical/electronic components and wiring should conform to the requirements of [RS9] Underwriters Laboratories Inc. (UL) Standard for Safety 508 “Industrial Control Equipment”. |  |
| 10.5.2 | Instruments using multiple levels of voltage should include a means of separating voltages. Voltages greater than 50V should have barriers.  |  |
| 10.5.3 | The capability to remotely power cycle each individual powered component should be provided. |  |
| 10.5.4 | The capability to remotely monitor power usage for each individual component should be provided. |  |
|  | Motors and other noisy components should not be powered by the UPS power lines  |  |
|  | Mechanical |  |
|  | Mechanical Information |  |
| info | The mechanical requirements address issues of design, reliability and maintainability. Based on experience with previous instruments 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. |  |
|  | Focal Station Requirements |  |
| 11.2.1 | For any location shared by multiple instruments, new instrumentation shall be compatible with existing mechanical interfaces of current instrumentation at those locations. | Demonstration |
|  | Maximum Weight Requirements |  |
| 11.3.1 | If the instrument will need to be lifted to or from the Nasmyth deck, the total instrument weight shall be < 5000kg.*5000 kg. is the maximum lifting capacity of the dome crane.* | Test |
| 11.3.2 | Additionally, there are mass limits at each of the instrument locations on the telescope.* KII Right Nasmyth NRT2 supports DEIMOS, KCWI, and NIRSPEC.
* KII Right Nasmyth NRT3 supports NIRSPEC.
* KII Right Nasmyth NRT1 supports DEIMOS.
* KII Left Nasmyth: KII AO with NIRC2 at the direct port. Previously OSIRIS was at the folded port.
* KI Right Nasmyth: Support HIRES.
* KI Left Nasmyth: Supports KI AO with OSIRIS at direct port.
* KI and KII Bent Cassegrain: NIRES weight is the bench mark.
* KI and KII Prime Focus: N/A no previous instrument was supported at this location.

Below are the weights at locations on KII from 640-C0012 sheet 2. A similar list does not yet exist for KI. The Prime Focus has never had instruments installed at that location and testing is in progress to define the weight that may be supported. Prime focus for the moment has a weight limit that is set by the secondary at SSRT1&2.   |  |
|  |  |  |
|  | Instrument Transition Requirements |  |
| 11.4.1 | The instrument shall have provisions to be safely moved between stowed and operational locations if required for operations.*This provision should address cabling storage and access.* | Inspection |
|  | Access, Covers and Enclosures Requirements |  |
| 11.5.1 | The instrument exterior shall include covers and provisions to prevent damage from incidental contact, such as someone passing by. | Inspection |
| 11.5.2 | Components requiring routine service or maintenance shall be accessible by removing a single cover secured by accessible fasteners. | Inspection |
| 11.5.3 | Covers that may be removed in a location where fasteners could fall into the interior of the enclosure shall be equipped with captive fasteners.  | Inspection |
|  | Access, Covers and Enclosures Best Practices |  |
| 11.6.1 | 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)”.* |  |
|  | Connection Panels Requirements |  |
| 11.7.1 | The instrument shall provide a cable interconnect panel on a stationary location (non-removable). | Inspection |
| 11.7.2 | Sub-systems with enclosures separate from the primary instrument enclosure shall be provided with corresponding connection panels. | Inspection |
| 11.7.3 | All external, interconnecting cables and any corresponding panel mounted connectors shall be uniquely identified and labeled. | Inspection |
| 11.7.4 | Where multiple connector pairs of identical type are used on an external connector panel, each connector pair shall be uniquely keyed to prevent accidental interchange of the connections. | Inspection |
|  | Vacuum Systems Requirements |  |
| 11.8.1 | If a vacuum is required for the instrument, a common vacuum port shall be provided for connection to observatory pumping stations.  | Inspection |
| 11.8.2 | Vacuum ports shall provide a port interface that is accessible given the instrument volume constraints and locations. | Demonstration |
|  | Vacuum Systems Best Practices  |  |
| 11.9.1 | NW 25 size KF flanges or larger should be used for all removable vacuum connections. |  |
| 11.9.2 | All vacuum system fittings, including valves and piping and flexible couplings should be stainless steel. |  |
|  |  Pressure Control Requirements |  |
| 11.10.1 | Vacuum vessels shall be equipped with vacuum gauge facilities capable of accurately measuring the pressure in the vessel, consisting of at least one low vacuum gauge and one high vacuum gauge.   | Inspection |
| 11.10.2 | Cryogenically cooled vessels shall be equipped with pressure relief valves to protect against over pressure due to the liberation of adsorbed gases during the warmup process. | Inspection |
|  |  Corrosion Resistance Requirements |  |
| 11.11.1 | All metal components shall be finished to prevent corrosion in the operating environment (see Table 6) over a normal 15 year lifetime of operation including handling, maintenance and repair. | Inspection |
|  |  Lubricants Requirements |  |
| 11.12.1 | Lubricants shall be suited for the low temperature environment encountered at the summit. | Inspection |
|  |  Service and Maintenance Requirements |  |
| 11.13.1 | Optical and mechanical assemblies, modules or components that will need to be removed for service shall be provided with locating pins or other features as required to permit repeatable removal and replacement. | Inspection |
| 11.13.2 | Components and subassemblies with weights greater than 25 kg shall be provided with lifting eyes or ‘A’ brackets, or other means of secure lifting | Inspection |
| 11.13.3 | Large subassemblies (>25 kg mass) shall be provided with handling fixtures and service access provisions that do not require use of a crane for removal or access. | Not Set |
| 11.13.4 | The instrument shall be provided with all handling fixtures and equipment needed to disassemble the instrument for service. | Inspection |
| 11.13.5 | For sub-systems that require video confirmation of status or operation to assess maintenance needs or troubleshooting, the video camera used to monitor the instrument on the summit shall be approved for use by summit personnel  |  |
|  |  Service and Maintenance Best Practices |  |
| 11.14.1 | Handling provisions, fixtures and stands should be designed for safe operation and with consideration for ergonomic factors such as range of motion and working posture. |  |
| 11.14.2 | The footprint of service fixtures or stands should be minimized because storage and working space on the summit is at a premium. |  |
| 11.14.3 | The profile of all service fixtures or stands should be designed with as low of a center of gravity as possible to resist tipping. |  |
| 11.14.4 | Seismic restraints for service fixtures or stands may also be required.  |  |
|  |  Spares |  |
|  | Spares Requirement |  |
| 12.1.1 | Spares shall be provided for all components that are considered “consumable”.Spares shall be provided for all components designed with a service life of less than 15 years. (This service life shall include possible minor earthquake damage.)*For these components, the required spares quantity is 20% (or at least 1 unit) of the in-service quantity.* | Inspection |
|  |  Spares Goals |  |
| 12.2.1 | Spares shall be provided for all components that have an EndOfLife (end of vendor support) closer than 15 years after commissioning. |  |
|  |  Computing |  |
|  | Network Communication Requirements |  |
| 13.1.1 | Control communications between the instrument components and the target and/or host computers shall employ standard network protocols (TCP/IP, UDP/IP. or equivalent as the transport layer) over a private network. | Test |
| 13.1.2 | Network devices that are physically part of the instrument shall be routed to the remotely located devices in the computer room (host or target computers) via switches located on the instrument and in the instrument computer rack. | Test |
| 13.1.3 | Switches on the private network shall be managed switches. | Test |
| 13.1.4 | Switches on the private network shall be capable of connecting at gigabit speeds over multimode fiber uplink. Fibers shall be OM-4 multimode 15um core, with military jacket. | Test |
| 13.1.5 | Switches on the private network shall be capable of connecting at gigabit speeds on multiple copper Ethernet ports simultaneously. | Test |
|  | Computer Requirements |  |
| 13.2.1 | The host computer for the instrument shall be an industry-standard server using a WMKO approved operating system. As of January 2023, WMKO is deploying Rocky Linux and Ubuntu on the x86\_64 platform. | Inspection |
| 13.2.2 | Ethernet network interfaces are required.  |  |
| 13.2.3 | Connections to the observatory operations network and the instrument private network shall be made from two separate Ethernet network interfaces in the host computer.* Public observatory network
* Private instrument network

*This will isolate the time critical instrument control and data communications from the observatory operations network traffic. Galil devices require an independent instrument private network.* | Demonstration |
| 13.2.4 | A dedicated network management Ethernet port providing the capability for remote reset (such as Intelligent Platform Management Interface (IPMI) / Lights Out Management (LOM)) shall be provided by the host computer.* IPMI connection for remote reset
 | Not Set |
| 13.2.5 | The host computer shall be configured to ensure that there are no routes or bridges between the observatory operations network and the instrument private network.  | Inspection |
| 13.2.6 | The computer shall be equipped with provisions for testing and diagnostics, such as local monitor, mouse and keyboard connections. | Test |
|  | Data Storage Requirements |  |
| 13.3.1 | The capacity of the internal storage shall be sufficient to contain data from at least 14 typical observing nights. | Test |
|  | Science Detector Readout System Requirements |  |
| 13.4.1 | The instrument science detector readout system shall be a controller that is a system approved by the observatory. | Inspection |
|  | Digital Control and Status Communication Requirements |  |
| 13.5.1 | Digital communications for control and telemetry shall be implemented using standard Ethernet wiring and standard protocols for their data link layer. | Test |
| 13.5.2 | Digital communications for control and telemetry shall be implemented using standard protocols for their application layer that includes EPICS, KTL, Google RPC, ZeroMQ, and HTTP/HTTPS |  |
| 13.5.3 | Where legacy or COTS hardware is used, and only serial communications is available, all serial communication shall be handled using a serial to Ethernet converter. | Test |
|  | Digital Control and Status Communication Best Practices |  |
| 13.6.1 | Control, science data and guider image data communications between the remotely-located host computers and the instrument controllers should be via a multi-strand fiber optic bundle. |  |
| 13.6.2 | Fiber optic bundle connections should be via panel mounted connectors equivalent in performance to connectors that conform to military specification MIL-C-38999 series IV. Commercial equivalents are acceptable. |  |
| 13.6.3 | Connectors used for low voltage ac and dc circuits should be types equivalent in performance to connectors that conform to military specification MIL-DTL-26482 style connectors. Military specification MIL-C-38999 series IV style connectors are also supported. Commercial equivalents are acceptable. |  |
|  | Software |  |
|  | Software Information |  |
| info | The software requirements section describes requirements for performance, implementation and design. Based on experience with previous instruments 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 software requirements section has as a main objective ensuring compatibility of the instrument software with existing observatory software systems. A secondary objective is guiding the selection of software architecture and implementation decisions towards reuse of prior successful instrument software and towards implementations that fit within the software skill sets at the observatory in order to maximize the ability of the observatory to support and maintain an instrument’s software. |  |
| info | WMKO has established a number of standards for software and these standards form an integral part of the software requirements for new instruments. |  |
| info | Specific requirements are given in areas where repeated problems have affected the availability of instruments. Among these are issues of network reliability, reliability of fiber optic data connections to detector controllers, and problems with handling errors in a manner that minimizes the loss of observing time by providing useful error messages and avoids total system resets or power cycling to restore proper operation. |  |
|  | Software Performance Requirements |  |
| 14.2.1 | All software shall operate without failure for a week of continuous use.*Systemic failures (bugs) in software will occur but should not be accepted as inevitable. Scheduled software restarts and/or host reboots are not an acceptable workaround for systemic failure. “Continuous use” depends on the duty cycle of any equipment controlled by the software; when such systems are tested the software duty cycle should be at least twice the expected hardware duty cycle. For example, if a filter wheel is expected to change positions once an hour it should be tested at a rate of once per half hour.* |  |
| 14.2.2 | All controlled mechanisms shall be capable of independent, simultaneous operation via KTL keywords.*All mechanisms shall be capable of simultaneous motion except where this would violate safety constraints.* | Not Set |
| 14.2.3 | All persistent software shall start automatically at boot time, whether or not hardware is accessible. | Test |
|  | Software Error Recovery Requirement |  |
| 14.3.1 | If the connection to the hardware is interrupted for any reason, the software shall reconnect and restore nominal operations. *Automated recovery from such failures is not strictly necessary (stages may need to be re-homed if a controller resets), but it should not be necessary to restart the software strictly because the hardware was briefly offline. Auto initialization  is not required.* | Test |
|  | Software Implementation Requirements |  |
| 14.4.1 | All software shall be compatible with current Observatory supported operating systems.*RedHat Enterprise Linux (RHEL) and the functionally identical Rocky Linux and Ubuntu distribution are the standard Linux distributions used at W. M. Keck Observatory (WMKO), as of 2023. The Extra Packages for Enterprise Linux (EPEL) repository will be available for use on production systems.* | Test |
| 14.4.2 | All software shall be developed in and committed to the WMKO Subversion repository.*WMKO uses Subversion as its primary version control system for source code. All users interacting with the repository will need an account; all users working remotely will need to authenticate with the WMKO firewall to gain access to the repository. Code should be committed frequently when development is taking place.* |  |
| 14.4.3 | All software shall build and install from kroot.*kroot is a build environment for nearly all observing software at WMKO. Specifics are identified in KSD 245. All instruments will have instrument-specific code in the kroot/kss/[instrument] subdirectory and may provide tools for general use in other directories, such as kroot/kui and kroot/util. The instrument code base should build and install directly after a source code check-out. This implies that all operational software must be checked into the WMKO svn repository. Dependencies on binary distribution of any software is strongly discouraged.* | Demonstration |
|  | Keywords Requirement |  |
| 14.5.1 | All inter-process communication and control shall occur via KTL keywords defined at the keyword server level. These communications include but is not limited to detector systems, motion stages, calibration lamps, power, video cameras for monitoring subsystems, alarm handling, and real time data reduction.*KTL is a WMKO-standard API (Conrad and Lupton (1993); Lupton and Conrad (1993)) for keyword/value representation of individual data points, typically Booleans, integers, strings, and enumerated values. There will be circumstances where KTL keywords are not a practical fit for the problem at hand; those situations are few and far between and waiver requests for this requirement should be rare.**KTL is very flexible and affords a lot of design space to the software engineer. Keywords should strive to be consistent in their behavior, and that behavior should be consistent with best practices. A document enumerating the best practices (KSD 243) will be distributed separately.* | Test |
|  | Telemetry Requirements |  |
| 14.6.1 | All derived telemetry shall be generated in persistent daemons with critical parameters available via keywords.*Client software (GUIs, etc.) should not be used to calculate state derived from other KTL keywords. The calculations should instead be performed in a persistent KTL dispatcher and exposed as yet another KTL keyword.* | Test |
| 14.6.2 | All software shall respond to telemetry requests within five milliseconds and commands within fifty milliseconds.*A timing budget will be created for an individual operation. Latency must be “in the noise” for all telemetry requests or operations. This typically means no more than five milliseconds of overhead to initiate a command or retrieve telemetry. Most dispatchers can also complete simple commands within fifty milliseconds, which is much easier to measure than the round-trip time for a first-stage notification of a write request.* | Test |
|  | Science Data File Format Requirements |  |
| 14.7.1 | Science detector data shall be written as a FITS formatted file.*The comments and header keywords are to conform to FITS keyword standards agreed upon by the International Astronomical Union FITS Working Group (see related documents 3, 4 and 5).* | Test |
| 14.7.2 | FITS header data for the science data files shall incorporate keywords that fully describe the conditions under which the data in the file was taken. | Test |
| 14.7.3 | The instrument shall provide timestamps in FITS headers corresponding to the start and stop of the exposure to an absolute accuracy of 1 millisecond or better. | Test |
|  | Data Reduction Pipeline Requirements |  |
| 14.8.1 | A data reduction pipeline (DRP) shall be provided for use with the instrument’s science data. | Test |
| 14.8.2 | The development of data reduction products (DRP) shall adhere to the requirements of the WMKO DRP working group.*The data reduction tools for modern instruments are maintained primarily by WMKO with collaboration from interested parties at partner institutions. A working group has been tasked with establishing requirements and plans for DRP development and maintenance.* | Test |
|  | User Interface Requirements |  |
| 14.9.1 | The instrument shall enable remote science operations by one person. | Test |
| 14.9.2 | Instrument host software shall include user interfaces for instrument control and image display. | Demonstration |
| 14.9.3 | The design of all graphical interfaces used for observing shall be directly approved by the observing support team.*The interfaces used by observers should be designed to directly meet their needs. In contrast to observer interfaces, engineering interfaces may be created as needed during instrument development and do not require any formal approval process.* | Inspection |
| 14.9.4 | All graphical interfaces shall function within a VNC session, which is the standard operating mode at WMKO.*All observer interfaces are run inside a VNC session, typically running an older window manager such as fvwm. Interfaces with rapid refresh rates or smooth/blending visual effects will perform poorly, especially when the instrument is operated remotely from a mainland site. The negative effects are more severe if the mainland site has failed over to a less capable network connection.* | Test |
| 14.9.5 | The instrument user interfaces shall be written in a language that is approved by the observatory.*Python 3.x is in current use. IDL should be avoided. C/C++ is also used.* | Inspection |
| 14.9.6 | Access to video cameras shall be available via engineering gui interfaces and available for troubleshooting purposes only.  | Test |
|  | Documentation |  |
|  | Documentation Package Requirements |  |
| 15.1.1 | All delivered documentation shall include page #s, author name(s), date and revision information. | Inspection |
| 15.1.2 | The instrument shall be provided with design, operating and maintenance documentation package including, but not limited to, the following:1. 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. User’s manual, including but not limited to operating instructions.
3. 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 shall be detailed enough to allow fabrication of spare parts shall the need arise.
4. All agreed to ICDs.
5. Bills of material including supplier information for all components of the instrument.
6. A maintenance manual, including all information and procedures needed to maintain and operate the instrument during its lifetime, including but not limited to the following:
	1. 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. Routine maintenance and inspection procedures, as well as a maintenance schedule.
	3. Alignment procedures.
	4. Troubleshooting guide.
	5. Repair procedures.
	6. Written procedure accompanied by illustrations for removal and replacement of all major sub-assemblies in the instrument.
7. Acceptance Test Plan documents, including requirements, test procedures and all performance data and results of acceptance testing.
8. Descriptions of all recommend spare parts and procedures for removal and replacement including written procedures and assembly drawings and exploded view drawings.
9. All manufacturer’s manuals and documentation for COTS components.
10. 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.
11. Safety plan and procedures.
 | Inspection |
|  | Drawing Requirements |  |
| 15.2.1 | The following drawings shall be provided:1. 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. 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. As-built assembly drawings for all assemblies not commercially available along with appropriate detail drawings and assembly tolerances and procedures.
 | Inspection |
| 15.2.2 | All instrument drawings shall conform to the following:1. Drawings for optical components shall conform to ANSI/ASME standard Y14.18M-1986 “Optical Parts (Engineering Drawings and Related Documentation Practices)”.
2. Mechanical drawings shall conform to ANSI Y14.5M-1994 (R1999) “Dimensioning and Tolerancing” and ASME standard Y14.100-2000 “Engineering Drawing Practices”.
3. 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. 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. 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. Assembly drawings shall include all relevant views required to clearly define the assembly including isometric and exploded views.
3. 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. Multi and sectional view drawings shall be developed in accordance with ANSI Y14.3M-1994 “Multi and Sectional View Drawings”.
5. Fluid power system schematics shall be drawn in accordance with ASME Y32.10-1967 (R1994) “Graphic Symbols for Fluid Power Diagrams”.
6. Dimensions and tolerances shall be indicated in accordance with ANSI 14.5M-1994 (R1999).
7. Surface finishes shall be described in accordance with ANSI 14.5M-1994 (R1999).
8. The electronic drawing format for optical and mechanical drawings shall be provided in a standard format using software for mechanical drawings and CAD. A standard package is the Dassault Systèmes SolidWorks Corporation SolidWorks 3D computer aided drafting (CAD) SWX format or another industry standard format suitable for fully functional import into SolidWorks. A pack-and-go has been used to transfer designs as well as direct access to drawing vaults. Both 3D models and 2D part and assembly drawings shall be supplied. Naming conventions, CAD drawing conventions, and hierarchical file structures shall be per the current WMKO CAD drawing standards. All part and assembly drawings shall also be supplied in PDF form.
9. The electronic drawing format for electrical/electronic schematics and printed circuit board layouts and assembly drawings shall be provided in a standard format and software for electrical DWGs. Such software packages include but are not limited to Visio or OrCAD. A less desirable alternative is to provide drawings for electrical/electronic schematics and printed circuit board layouts and assembly drawings as PDF files. In any case PDF files shall be provided for all schematics, assembly drawings and bills of material.
 | Inspection |
|  | Electrical/Electronic Documentation Requirements |  |
| 15.3.1 |  The following documentation for all electrical and electronic assemblies and modules in the instrument shall be provided:1. A top-level system block diagram.
2. An interconnection diagram showing all interconnecting cables and connected assemblies and modules in the instrument.
3. An interconnection diagram showing the external connections to the instrument.
4. Pinouts and wire color codes for all internal and external connectors and cables.
5. Schematics, assembly drawings, bills of material, printed circuit board designs and printed circuit board artwork for all custom printed circuit boards in the instrument.
6. Programmable logic device source code for all programmable logic devices used on custom printed circuit boards in the instrument.
7. Programmable logic device source code for all programmable logic devices used in COTS components where the programmable logic device source code has been modified or customized for the instrument.
8. Configuration, set up and/or switch/jumper setting information for all COTS components.
 | Inspection |
|  | Software Documentation Information |  |
| 15.4.1 | The instrument software is defined as all host, target, embedded controller software (including detector controller code) and data reduction software for the instrument including the code for servo controls such as DSP code, Galil code or other motion control code and the like.WMKO will not accept the computer server built and tested at the remote site. The instrument computer server will be rebuilt from scratch after delivery to WMKO. |  |
|  | Software Documentation Requirements |  |
| 15.4.2 | The following software data files and documentation shall be provided:1. Source code for all instrument software.
2. Executables for all instrument software.
3. One copy of any and all software libraries required to build the instrument software executables.
4. A list of any and all code compilers required to build the instrument software.
5. All makefiles required for building the instrument software.
6. All configuration files and all data files read by the instrument software executables at start-up time.
7. Any scripts required to run the instrument or the data reduction package.
8. Any aliases, environment variable definitions, etc. required to correctly set up the environment to build or run the instrument software.
9. For any models developed for simulation of the instrument including optical designs and control loops the model code and data shall be supplied.  The preferred software for optical design is Zemax.  For all software control loops full design documentation shall be provided including block-diagrams, transfer-function models of the system, performance criteria and analyses to show how the control loop design satisfies the requirements. Models and simulations of the control loops shall also be provided.
10. Documentation for the instrument software, consisting of:
	1. User’s Manual: a detailed tutorial describing how to use this version of the software.
	2. List of Source Code: A hierarchical list of all directories, source files, include files, libraries, etc. that can be used as a checklist for new releases.
	3. Functional Descriptions: a software architecture diagram, as well as a description of each routine or module describing its function.
	4. Startup/Shutdown procedures: descriptions of the steps necessary to cold start the system and the steps necessary to safely shut down a running system.  This document shall include descriptions of any configuration files required at start-up time.
	5. Installation Manual: a detailed description of the steps necessary to rebuild and install the system from sources.
	6. Troubleshooting Guide: A description of the techniques for tracking down failures, checking system health, killing and re-starting portions of the system without a full reboot.
	7. Software Test Procedures:  a detailed description of how to run the software acceptance tests.
	8. Programmer’s Manual: This document shall include a description of the theory of operations; data and control flow and how standard functionality can be extended (e.g. add a new command to the API).
 | Demonstration |