

# Science and Facility Instruments

## Common Requirements Specification

### INST-REQ-0001

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# Version Control

REVISION CHART			
Version	Author(s)	Description of Version	Date Completed
A	Madeline Close	Initial Version Some content taken from the original GHOST requirements provided by Gemini. Other input solicited from Development, Science Operations and Engineering Operations.	20 April 2016  CR-16 2511
B	Andrew Serio	Updated any TBDs with more specific requirement wording. Updated Definitions section Updated some requirements wording for clarification. Made some updates with feedback from Manuel L. and Jeff R. Removed link to ICD 10 – EPICS Synchro Bus Driver as that is obsolete.	20 February 2017  CR-17 2686
C	Jeff Radwick Manuel Lazo	<ol style="list-style-type: none"> <li>1. Extensive requirement updates stemming from the course of the design of SCORPIO by the Gemini SCORPIO Team.</li> <li>2. Added rationale to each requirement not having a “Rationale” section and additional details to the “Rationale” section for each requirement requiring additional technical detail.</li> <li>3. Removed “by design” as an allowable verification method. Also, one “will” statement replaced with the correct “shall” statement.</li> <li>4. Increased emphasis placed on the timeliness and importance of the Concept of Operations document.</li> <li>5. Removed references to interface requirements as they are not found in this document (they are correctly found in the existing ICDs).</li> <li>6. Added a Visible/IR Instrument Common Functional Requirements section.</li> <li>7. Added a discussion of the interrelationships among the system design processes as these had not been rigorously followed in the past.</li> </ol>	20 August 2018

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## Acronyms

A&G	Acquisition and guiding
AO	Adaptive optics
bHROS	Bench-mounted high resolution optical spectrograph
CC	Cloud Cover
CoDr	Conceptual Design Review
CTE	Charge Transfer Efficiency
CONOPS	Concept of Operations
DPS	Differential Pressure Switch
EMI	Electromagnetic Interference
EPICS	Experimental Physics and Industrial Control System
FITS	Flexible Image Transport System
FMEA	Failure modes and effects analysis
FOV	Field of view
GCAL	Gemini calibration unit
GeMS	Gemini Multi-Conjugate Adaptive Optics System
GHOST	Gemini High-Resolution Optical Spectrograph
GIAPI	Gemini instrument application programmer interface
GIS	Gemini Interlock System
GN	Gemini North
GRACES	Gemini Remote Access to CFHT ESPaDOnS Spectrograph
GOA	Gemini Observatory Archive
GS	Gemini South
GUI	Graphical user interface
ICD	Interface control document
ISS	Instrument Support Structure
IR	Infrared
IQ	Image Quality
M1	8.1m primary mirror

M2	1m secondary mirror
MCAO	Multi-conjugate AO
MTBF	Mean time between failure
MTTR	Mean time to repair
OT	Observing tool
POC	Point of Contact
PSI	Pounds per square inch
PSV	Pressurized Safety Valve
PWFS	Peripheral wavefront sensor
PWM	Pulse width modulation
QE	Quantum Efficiency
RAM	Reliability, availability, maintainability factors
SB	Sky Background Level
SeqExec	Gemini observation Sequence Executor
SCAO	Single conjugate AO
TAI	International Atomic Time
TBD	To be determined
UPS	Uninterrupted power supply
UTC	Coordinated Universal Time
WV	Precipitable Water Vapor

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# Part 1: Overview

## 1 Description

In order to build a new instrument capable of successful sustained operations at Gemini Observatory, non-science as well as science requirements must be met. This document, the *Science and Facility Instrument Common Requirements Specification*, describes the Observatory's top level requirements related to instruments: in other words, non-interface requirements that apply to all scientific instruments brought to Gemini.

This document describes the top level Observatory requirements. Some top level requirements refer to detailed requirements contained within Interface Control Documents (ICDs), Gemini Instrument Application Interface (GIAPI) documents and Gemini Data Processing Software Group documents. See the References below for the complete list of documentations containing the set of Gemini provided requirements.

In addition, requirements for the instrument will be derived from the Science Cases and the instrument's Concept of Operations (CONOPS), documents developed before or during the Conceptual Design Stage. The CONOPS will contain additional requirements related to operations. As the CONOPS are a major source of requirements, this document needs to be completed by the Conceptual Design Review (CoDR) so that a complete requirements baseline is available for the System Requirements Review (SRR).

*Instrument Science Requirements* and *Instrument Data Reduction Requirements* are written specifically for each new instrument.

Figure 1 illustrates the recursive relationship among the system design processes. These processes start with a study team collecting and clarifying the stakeholder expectations, including the instrument objectives, constraints, design drivers, operational objectives, and criteria for defining mission success i.e. top level performance requirements. These three products must be consistent with each other and will require iterations and design decisions to achieve this consistency. Once consistency is achieved, analyses allow the project team to validate the design against the stakeholder expectations. A simplified validation asks the questions: Does the system work? Is the system achievable within budget and schedule constraints? If the answer to any of these questions is no, then changes to the design or stakeholder expectations will be required, and the process started again. This process continues until the system—architecture, CONOPS, and requirements—meets the stakeholder expectations.



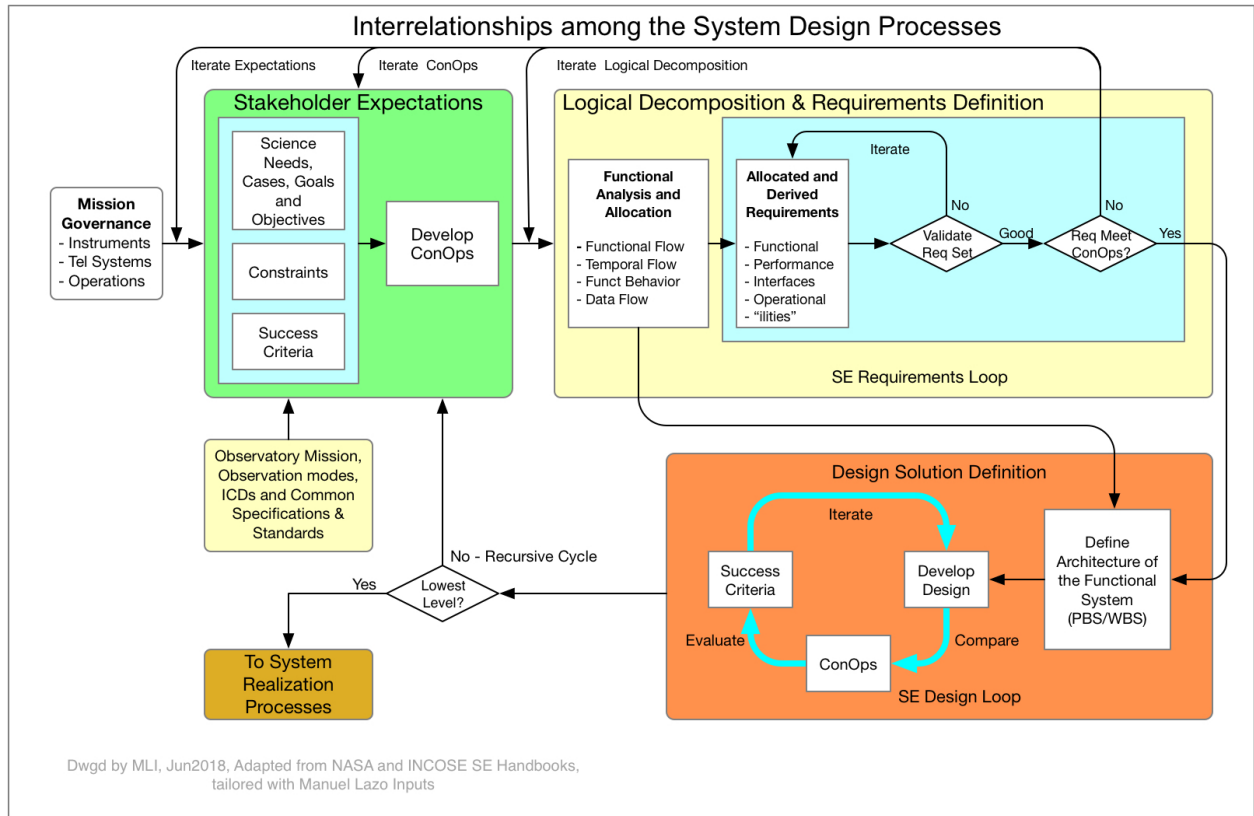


Figure 1: Interrelationships among the Instrument-System Design Processes

## 1.1 Contents of This Document

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

- Science operations
- Common functional requirements
- Engineering operations
- Safety standards
- Hazard and informational labeling standards
- Documentation standards

In addition, this document identifies the general set of interfaces between the Observatory and the instrument.

- Environment
- Telescope, telescope systems and telescope services
- Facility instruments for acquisition, guiding and calibration
- Software

**Science operations** is concerned with instrument performance when mounted on the telescope, including nighttime efficiency and long term reliability.

**Common functional requirements** are common functions facility instruments have to fulfill.

**Engineering operations** is concerned with instrument installation, removal and maintenance.

**Safety standards** describes engineering best practices that the instrument builder is required to comply with. Please note that these standards are not intended to be complete, and the inclusion of these standards does not mean that instrument builders should not follow industry standards and the best practices of their own organization.

**Hazard and informational labeling** is concerned with labeling for both safety and informational reasons.

**Documentation** is concerned with file types and formatting.

## 1.2 Definitions

The **Instrument** as it is referred to below, shall include the set of components and ancillary equipment necessary to mount and operate the instrument. This includes subsystems, enclosures, frames, weights, coolant, connectors, cabling, etc.

The **Instrument Builder** is defined as the non-Gemini team responsible for the design, development and commissioning of the **Instrument**.

A **Gemini requirement** is a requirement that is given by Gemini (as opposed to being developed or derived by the instrument builder).

All requirements written using a “**shall**” statement mean they are mandatory for the instrument builder to achieve for Gemini to accept the instrument. Anything written with wording such as “will”, “may” or “goal” means they are non-mandatory requirements for the instrument builder.

## 1.3 Structure of Each Requirement

Each requirement is presented as follows:

### .3.1.1. *Requirement Title*

**Requirement description in bold text**

Rationale: *The context behind this requirement and any specific values in the requirement.*

Verification Method: *Possible verification methods are IADT: Inspection, Analysis, Demonstration, and Test.*

## 1.4 Selecting Applicable Requirements

Gemini expects the vast majority of these requirements to be applicable to any new instrument. It is the responsibility of the instrument builder to read this document and recommend the set of applicable requirements.

In the event that requirements are not fully understood, it is the responsibility of the instrument builder to discuss them with Gemini for clarification.

In the event that there are requirements the instrument builder identifies as not being applicable to their instrument, it is the responsibility of the instrument builder to discuss this with Gemini to reach a formal agreement to waive said requirements.

## 1.5 Managing Requirements

It is the responsibility of the instrument builder to capture and manage all of the applicable requirements in a system engineering relational database tool of their choice. Appendix A presents a set of fields that

Gemini has found to be a useful minimum set for managing requirements throughout the project lifecycle from development through verification.

## 1.6 Changes to Gemini requirements

If Gemini identifies a Gemini requirement that they want to change and wishes for the change to be retroactive (to apply to instruments currently in development), Gemini **shall** follow the instrument project change request process.

## 1.7 Waivers to Gemini requirements

After establishing the Requirements Baseline if the instrument builder later identifies any additional Gemini requirements that they cannot meet, the instrument builder **shall** follow the instrument project waiver request process. In general, a deviation is requested prior to the start of the build phase and a waiver is requested thereafter.

# 2 References

## 2.1 Reference Documents Cited Herein

All of the references in table 1 below are directly downloadable from the Gemini web page at:

<http://www.gemini.edu/sciops/instruments/specifications/>

Reference	ID
Science and Facility Instruments to Transport, Observatory and Operations Environments ICD	ICD 1.9/5.0
ISS to Science Instruments ICD	ICD 1.5.3/1.9
Science and Facility Instruments to ISS System Services ICD	ICD 1.9/3.6
Science Instruments to Facility Handling Equipment ICD	ICD 1.9/2.7
Optomechanical Coordinate System	ICD-G0014
GIAPI Software Requirements for Instrument Builders	GIAPIBuilderReq-01302009
GIAPI C++ Language Glue API ICD	ICD 50
GIAPI Design and Use	GIAPIUse-08292006
Coding Standards and Guidelines for the Gemini Data Processing Software	DPSG-STD-102
Interlock System to Science Instruments ICD	1.1.13/1.9
Synchro Bus - Node/Page Specifications	ICD 20
DRAGONS	PIPE-USER-103

*Table 1: Gemini instrument contractual ICDs*

Instrument Builders who have worked with Gemini before, may have used other ICDs as well. For informational purposes, a list of deprecated ICDs is provided in Appendix B.

## 2.2 Reference Web Pages Cited Herein

Reference	URL
From Telescopes and Sites menu <ul style="list-style-type: none"><li>● Instrument Support Structure</li><li>● Optics</li><li>● Acquisition Hardware and Techniques</li><li>● Guiding and Wavefront Sensors</li><li>● Adaptive Optics</li><li>● Calibration (GCAL)</li><li>● Observing Condition Constraints</li></ul>	<a href="http://www.gemini.edu/sci-ops/telescopes-and-sites">http://www.gemini.edu/sci-ops/telescopes-and-sites</a>
From Future Instrumentation & Current Development menu <ul style="list-style-type: none"><li>● Specifications &amp; ICDs</li><li>● I&amp;T at Gemini</li></ul>	<a href="http://www.gemini.edu/sci-ops/future-instrumentation">http://www.gemini.edu/sci-ops/future-instrumentation</a>
From Observing with Gemini menu <ul style="list-style-type: none"><li>● Queue Mode Observations</li></ul>	<a href="http://www.gemini.edu/sci-ops/observing-gemini">http://www.gemini.edu/sci-ops/observing-gemini</a>

*Table 2: Gemini reference web pages*

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## 3 An Overview of Gemini Instrument Operations

### 3.1 Sites, Facilities and Services

The Gemini telescopes are located at two remote sites in Hawaii and Chile. There are differences between the sites in terms of environmental and observing conditions, and in terms of offered facilities and services.

Environmental conditions in terms of temperature, humidity, pressure and dust are described in the *Operations Environments ICD*.

Observing conditions in terms of image quality, cloud cover, water vapor and sky background are described in the *Observing Conditions Constraints web page*.

The *Systems Services ICD* describes offered air, coolant, power, communications and other services at each site.

### 3.2 Operating Model

#### 3.2.1 Telescope

Both Gemini telescopes are of identical Alt-Az mounted, 8.1 m Ritchey-Chretien optical design, optimized for infrared observations but with deployable baffles for optical work. Cassegrain and folded Cassegrain foci support observing with one of three instruments at any given time at each site. The 8.1 m primary mirror (“M1”) is only 20 cm thick, so its figure must be controlled via an active optics system consisting of both air bags and pneumatic/hydraulic actuators, governed by lookup tables as a function of elevation. The 1-m secondary mirror (“M2”) is actively controlled in tip-tilt and XYZ position to control tip-tilt, focus, and coma aberrations. M2 is surrounded by a deployable baffle which is fully retracted for infrared work and extended for optical. Both M1 and M2 are coated in overcoated silver which provides high reflectivity in the NIR and most of the optical (more uniform than Aluminum), and low emissivity in the thermal wavelengths beyond 2.4 microns. However, the coating reflectivity falls steeply shortward of ~400 nm. The shortest-wavelength filter in the current Gemini facility imager (GMOS) is the “u” filter (350 nm).

#### 3.2.2 Instrument Cluster

The instrument cluster and Acquisition/Guidance (A&G) unit are mounted on a Cassegrain Rotator which enables position angle selection and tracking of the sky’s rotation during exposures. The instrument support structure (ISS) has five ports, one upward looking (Cassegrain) port on the bottom and four side (folded Cassegrain) ports. Two of the side ports are “light weight” ports and do not support the full weight of a standard Gemini instrument. Science instruments are mounted either at the up-looking or side ports. On each telescope, one of the five ports is occupied by the facility Calibration unit (GCAL), and a second port by a facility AO system, leaving three ports for science instruments. The port and instrument are quickly (within minutes) selected via a deployable “Science Fold” tertiary mirror within the A&G unit. On a typical observing night, this switching is done numerous times. Optical fibers may be used to feed instrumentation on the observing floor, in the Pier laboratory below the telescope (as was done for bHROS and is planned for GHOST), or even at a site outside the building (e.g. GRACES at the time of writing).

### 3.2.3 *Queue Operations*

Gemini's standard mode of observation is queue mode. This means that on a daily basis, the nighttime observing plan is made taking into consideration what instruments are mounted on the telescope. This also means that the instrument will be operated not by the astronomer who designed the science program being observed. Using multiple instruments at night is routine; Gemini can send the light from one mounted instrument to another well within a typical telescope slew time via the Science Fold. Instruments are scheduled to be mounted on the ISS for blocks of time during a semester. The *Queue Mode web page* describes this in more detail.

When mounted on the telescope, instruments are normally available for use at any time. When dismounted, instruments are stored either on the dome floor or in the instrument lab and can still be attached to system services.

### 3.2.4 *Remote Operations*

Gemini operates both telescopes from their respective base facilities (in Hilo, and La Serena), meaning that there are no personnel physically at the telescope during nighttime operations. The ability to operate at the summit is still possible for engineering or instrument commissioning.

## 3.3 Telescope Optics

The telescope optical design, mirror coating, baffling, plate scale and instrument FOV are described on the *Optics web page*.

Zemax models of the telescope optical system and reflectivity data for the mirror coatings are available for download from this web page.

### 3.3.1 *Adaptive Optics (AO)*

Gemini provides a facility AO instrument at each site. At Gemini North (GN), AO is provided by Altair, an f/16 single conjugate AO (SCAO) system. At Gemini South (GS), AO is provided by Canopus/GeMS, an f/32.5 multi-conjugate AO (MCAO) system. In both systems, light below 589 nm is fed to the AO system and is thus not available to the instrument (note that this may be changing at GN). More information on Gemini AO is provided on the *Adaptive Optics web pages* and the *Guiding and Wavefront Sensors web page*.

## 3.4 Observing

### 3.4.1 *Acquisition*

Gemini uses a facility acquisition and guiding (A&G) system to adjust for telescope pointing offsets, for science target acquisition, and for closed loop guiding to keep the science target in position. Acquisition includes slewing to the target and then acquiring the target on the instrument. Further information is available via the *Acquisition Hardware and Techniques web page (2.2 above)*.

Slewing includes moving both the telescope and the dome to the position of the science target. A slew of 180 degrees azimuth (the maximum possible except when “unwrapping”<sup>1</sup>) can take up to approximately 3 minutes, depending on the speed setting of the dome. Telescope pointing is accurate on average to

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<sup>1</sup> “Unwrapping” refers to the process that occurs when the Cassegrain Rotator (CR) reaches its maximum rotation angle of 540°. The CR must be unwrapped which means it is rotated in the opposite direction until it reaches 0°. Since the ISS is attached to the CR, science operations do not occur while the CR unwraps and the process itself takes several minutes.

within 15 arcseconds of the science target's position. It is possible to configure the instrument while the telescope is slewing.

After slewing is complete, acquisition takes another ~2 minutes and typically includes several manual steps: offsetting the telescope to the guide star coordinates, sending the light to the acquisition camera, reading out the acquisition camera real-time, centering the guide star on the CR hotspot, absorbing any pointing offsets, then offsetting the telescope back to the science target coordinates and sending the light to the instrument for fine pointing adjustment.

Instruments may alternatively provide their own acquisition system and should refer to the *GIAPI reference documents* for information on interfacing to telescope systems.

#### **3.4.2 Guiding**

If the facility A&G system is used, guiding is provided by a peripheral wavefront sensor (PWFS). The *Guiding and Wavefront Sensors web page* provides details on use of the PWFS.

After acquisition is complete, the operator sets up guiding. This process includes reading out the PWFS to display the guidestar, selecting a guide frequency, making a sky background measurement (when needed), and starting the offloads to the telescope for position, focus and aberration corrections. This process is typically completed with stabilized offloads in 5-7 minutes.

Instruments may alternatively provide their own guiding system and should refer to the *GIAPI reference documents* for information on interfacing to telescope systems.

#### **3.4.3 Calibration**

At each telescope, the GCAL provides optical and near infrared wavelength and flat field calibrations. See the *GCAL web page* for detailed specifications.

### **3.5 Software**

#### **3.5.1 Observing Software**

Operators prepare instrument observations using the observing tool (OT) and execute observing sequences with the SeqExec. Gemini is responsible for integrating new instruments with these tools, and for making any necessary modifications to the tools.

#### **3.5.2 Control Software**

Starting with GPI, new instruments interact with the Observatory control software via the GIAPI, an application layer that abstracts the underlying EPICS system. See the *GIAPI reference documents* for more information.

#### **3.5.3 Data Reduction**

The Observatory makes reduced data available to users via the Gemini Observatory Archive (GOA). GOA requires a specific FITS file format in order to read and publish the data. See the *Data Reduction reference documents* for more information.

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## Part 2: Requirements and Standards

### 4 Science Operations Requirements

#### 4.1 Observing Efficiency

A general equation that characterizes Instrument Observing Efficiency is:

$$\text{Observing Efficiency} = (\text{Exposure time}) / (\text{Configuration time} + \text{Exposure time} + \text{Readout time})$$

This general equation must be adapted to the operational mode(s) for each individual instrument; the resulting Observing Efficiency equation will be unique for each instrument. The details of the derivation should appear in the instrument's CONOPS. Some factors that may play a role in the Instrument Observing Efficiency equation variables are:

1. Slew dome and telescope (both activities performed simultaneously)
2. Configure instrument (performed if slewing is set up)
3. Acquire guide star (performed through facility A&G or on-instrument system)
4. Set up guiding (performed through facility A&G or on-instrument system)
5. Acquire science target (performed through instrument, if instrument is configured)
6. Take Exposure (performed through Sequence Executor to the instrument)
7. Readout Exposure (performed by instrument, but full instrument dependent)
8. Assembling science data (performed through Sequence Executor and the instrument)
9. Transmit science data (performed by instrument)

**Telescope acquisition time** is defined as activities 1-4.

**Target acquisition time** is defined as the fifth activity.

**Science collection time** is defined as the sixth activity, gathering photons from science target.

**Data processing time** is defined as activities 7-9.

The Instrument Observing Efficiency for a specific instrument should be determined, documented, and formally agreed upon between Gemini and the instrument builder during or before the Conceptual Design Phase. The details should be recorded in the CONOPS document.

Instrument observing efficiency translates to observing overhead. Observing overhead and bad weather are generally the second and third largest users of available time after science. Decreasing observing overhead directly increases science time.

##### 4.1.1 Instrument Observing Efficiency

**The Instrument Observing Efficiency shall be at least XX% for a one-hour exposure, exclusive of telescope acquisition time and losses attributable to weather or other systems.**

**Rationale:** Instrument observing efficiency translates to observing overhead. Observing overhead and bad weather are generally the second and third largest users of available time, after science. Decreasing observing overhead directly increases science time.

**Verification Method:** Test

##### 4.1.2 Instrument Configuration Time

**The instrument shall perform a complete reconfiguration in 60 seconds or less.**



**Rationale:** Instrument reconfiguration time contributes to instrument observing efficiency. Time to slew the dome and telescope is 1 - 3 minutes on average, so a complete reconfiguration should finish within this timeframe.

This requirement drives the Configuration Time Error Budget and affects the Control System design as some processes have to be simultaneous and will imply synchronization to meet this requirement.

**Verification Method:** Test

## 4.2 Reliability

### 4.2.1 Instrument Lifetime

**The instrument lifetime shall be at least 12 years without a major overhaul due to failure or degradation, with annual usage time of 1200 hours.**

**Rationale:** Facility instruments are typically expected to be workhorse instruments. A workhorse instrument may be mounted on the ISS continuously and operated in queue mode where it can be used at any point in the night for any length of time. Total science time in one year is ~2400 hours and demand for a single instrument may be up to ~50% of available time<sup>2</sup>. Note that an MTBF analysis should take into consideration that an instrument may be required to be cold and operational for up to a year or more rather than the expected annual usage. Every day it is on it is expected to be available for science, calibrations etc.

**Verification Method:** Analysis such as mean time between failures (MTBF). The analysis may feed into the instrument maintenance plan and recommended spares.

### 4.2.2 Instrument Downtime

**The instrument downtime due to faults shall be 2% or less of scheduled time on the telescope.**

When the instrument is otherwise functioning normally, time spent in nominal preparations for instrument mounting or dismounting (e.g. pumping, cooling, warming) is not considered downtime.

**Rationale:** Although the Observatory operates in queue mode and can omit use of an instrument in the event of a serious fault, nominal procedure is to troubleshoot the issue and attempt to resolve it in real-time (as there is overhead associated with re-planning queue and switching instruments and targets). Time spent troubleshooting contributes to observing overhead. The Observatory has a goal of 1% time loss due to instrument and AO faults. The majority of current Observatory instruments have downtime of 0-2%<sup>3</sup>. With an annual usage time of 1200 hours, 2% translates to 24 hours of nighttime troubleshooting in the course of a year. Therefore, the instrument builder should think about possible failure, fault and error modes; how to prevent or reduce the possibility of these modes occurring; and how to facilitate/expedite recovery from an occurrence.

This requirement constrains the RAM (reliability, availability, maintainability) factors such as MTTR (mean time to repair) and MTBF (mean time between failures) that prevent the achievement of productive objectives.

**Verification Method:** Analysis such as failure modes and effects analysis (FMEA) during the design process and based on metrics collection during pre-delivery testing.

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<sup>2</sup> Gemini Operations Report for 2015A (internal)

<sup>3</sup> Gemini Current Instruments Report for 2015A (internal)

## 4.3 Ranges of Operational Conditions

**Performing to specification** is defined as meeting the instrument science and other performance requirements.

### 4.3.1 Performance on Different ISS Ports

**The instrument shall perform to specification on the side and bottom ports of the ISS.**

**Rationale:** The ISS has one bottom port and two side ports available to science instruments. For maximum flexibility when planning science operations, instruments should nominally be able to mount on any port, without impact to performance. Every instrument's needs are unique however, and a waiver may be requested in a situation where the bottom port has a compelling performance benefit. There are a few differences between the side and bottom ports:

(1) Reflectivity and polarization – side ports have an extra reflective surface from the science fold mirror; (2) Field of View (FOV) – side ports have a slightly smaller FOV owing from the science fold mirror; (3).

Note: the vibration environment for a side-port instrument has not yet been fully characterized.

**Verification Method:** Analysis, Test

*In the course of acceptance test planning, Gemini will identify the port that has priority for testing.*

### 4.3.2 Performance at Different Instrument Orientations

**The instrument shall perform to specification through the entire range of possible gravity vectors that it may experience.**

**Rationale:** For an instrument that may be mounted on both up-looking and side-looking ports, relative to the instrument coordinate frame (components vary continuously and in discrete steps):

X axis: +/-1g

Y axis: +/-1g

Z axis: -1g to 1g

For an instrument that will be mounted only on an up-looking port:

X axis: +/-1g

Y axis: +/-1g

Z axis: -1g to 0g (Assuming +Z axis is up with telescope pointing at zenith.)

During telescope operations, an instrument may be exposed to the full range of orientations and gravity vectors due to the combined motion of the telescope elevation and Cass Rotator, and the mounting on any instrument port. Instruments to be mounted only on the up-looking port will be subjected to a more restricted range of gravity vectors.

**Verification Method:** Test

### 4.3.3 Operation at Different Telescope Orientations

**Instruments shall operate at any orientation.**

**Rationale:** Instruments may be operated, especially for daytime testing and calibrations, at any combination of telescope elevation (0 to 90 deg), Cass Rotator angle, and ISS port position (side- or up-looking), which may rotate the instrument to any orientation.

**Verification Method:** Test

### 4.3.4 Performance in Different Observing Conditions

**The Instrument shall perform to specification in the average observing conditions.**

Note: The average observing conditions for a specific instrument shall be determined, documented, and formally agreed upon between Gemini and the Instrument Builder during or before the Conceptual Design Phase. Average observing conditions are defined as the quantitative values for the average Image Quality (%), average Cloud (%), average Precipitable Water Vapor (mm), and average Sky Background level (%).

**Rationale:** Gemini Observatory routinely executes science observations in less-than-ideal Observing Conditions. Observing Condition distributions are derived from statistics for Image Quality (IQ), Cloud Cover (CC), Precipitable Water Vapor (WV), and Sky Background Level (SB). IQ70, for example, indicates the 70th-percentile level in the image quality distribution. (See the Observing Condition Constraints web page, 2nd Table, values pre-2014B, which correspond to the image quality delivered by the telescope.). It is understood that at these limits the image quality will be limited by seeing, the sensitivity by both seeing and background level, etc., but there shall be no fundamental restriction inherent to the instrument that further reduces performance or prevents science operations.

**Verification Method:** Roll-Up

#### *4.3.5 Operation in Different Observing Conditions*

**Instruments shall operate in all Observing Conditions (IQ, CC, WV, SB) up to the limits for which the telescope enclosure is permitted to be Open.**

**Rationale:** Instrument calibration or testing may occur in poor Observing Conditions, even those too poor for science data collection. These conditions are defined on the Observing Condition Constraints web page.

Note that certain instrument characteristics can impact even internal calibrations. For example, a wavelength drift with ambient temperature or instrument orientation could require spectroscopic calibrations to contain additional steps for the data to match science data.

**Verification Method:** Roll-Up

#### *4.3.6 Performance at Different Sites*

**The instrument shall perform to specification at Gemini North and Gemini South.**

**Rationale:** The Gemini operational model includes four facility class instruments at each site. It may be necessary to rebalance the capabilities at each site, as new instruments are commissioned or old instruments are retired. The environmental conditions at the sites differ in terms of altitude, pressure, minimum and maximum temperatures, and atmospheric distortion at the sites differs due to the different altitudes. System services also have some key differences including AC power frequency.

This requirement may be relaxed if an instrument is specifically intended for just one site.

**Verification Method:** Roll-Up

## **4.4 Staff Operations**

### *4.4.1 Remote Science Operations*

**The instrument shall enable remote science operations by one trained Gemini staff member.**

**Rationale:** The Gemini operational model includes one instrument operator and one telescope operator located at the base facility. The instrument operator is responsible for operating each instrument as it comes up in the queue. Support is provided via the GI-API interface.

**Verification Method:** Test

#### 4.4.2 *Remote Recovery*

**The instrument shall be recoverable remotely in the event of a fault.**

**Rationale:** As the Observatory operates from the base facility, operators need the ability to troubleshoot and resolve issues remotely. Note that instruments are not required to be remotely commissioned - they can be commissioned by staff on the summit.<sup>4</sup>

**Verification Method:** Test

#### 4.4.3 *Restart After Power Failure*

**The instrument shall be able to power up from a quiescent state independent of how the power went down, with the exception of cryocoolers where there is a prolonged power failure and the cryostat begins to warm up.**

**Rationale:** Both Gemini sites suffer from occasional power outages.

**Verification Method:** Test

#### 4.4.4 *Internal Alignment*

**The instrument shall be able to detect misalignment by executing benchmark tests.**

**Rationale:** Instrument movement may impact alignment, whether it is movement during routine installation or due to an earthquake (experienced at both Gemini sites).

**Verification Method:** Test

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## 5 Instrument Visible/IR Common Functional Requirements

This section contains a set of Function Requirements common to Gemini facility instruments. In addition, contractors shall follow the ‘Logical Decomposition & Requirements Definition’ process, contained within figure 1, to derive additional function, performance, internal interface and operational requirements when creating the ConOps during the Conceptual Design stage of the instrument project.

### 5.1 Adapt to Telescope Optical Interface

**The instrument shall include any foreoptics required to adapt the telescope beam to the instrument’s internal optics.**

**Rationale:** The telescope provides an f/16 beam with a back focal length of 300 mm from the ISS mounting flange and a plate scale of 1.6 arcsec/mm. At Gemini South GeMS provides an f/32.5 AO corrected with a back focal length of 300 mm from the ISS mounting flange and a plate scale of 0.805 arcsec/mm.

Optics to adapt this beam to internal slits, optics, and detectors shall be provided as part of the instrument.

Note: Foreoptics are any opto-mechanical subsystem located pre-focal plane of the telescope in imager instruments, and pre-slit in spectrographs instruments.

**Verification Method:** Demonstration, Test

### 5.2 Internal Pupil Stop

**Instrument studies shall evaluate entrance pupil requirements and incorporate any required foreoptics, cold stops, etc. into their optical design.**

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<sup>4</sup> Base Facility Operations - Concept of Operations

**Rationale:** The telescope entrance pupil is at the secondary mirror, M2, which is undersized by about 2% relative to M1. Infrared instrument designs typically (but not always needed in order to satisfy science requirements) include a cold pupil stop conjugated to M2 to minimize thermal background. The requirement must be evaluated on case-by-case basis: most visible instruments omit internal pupil stops.  
**Verification Method:** Demonstration

### 5.3 Pupil Alignment

**Instruments with internal pupil stops shall provide a means of:**

- (1) aligning the internal pupil with the telescope entrance pupil at M2, and**
- (2) measuring the alignment, to the level of precision required by the science requirements and optical design.**

**Rationale:** For IR instruments, accurate pupil alignment, e.g. to < 1% of the M2 diameter, is critical. For visible instruments the alignment requirements may be more relaxed, but not completely negligible. Note that for ISS side-port mounted instruments the SF mirror facilitates pupil alignment, but up-looking port instrument require another method such as shimming.

**Verification Method:** Demonstration, Test

### 5.4 Baffling and Stray Light Strategy

**Instrument studies shall evaluate their baffling and stray light suppression strategies. One consideration for Gemini is the optimal setting of the M2 deployable baffle.**

**Rationale:** The telescope includes a Deployable Baffle around M2 that is typically extended to block stray light for instruments with no internal stops and retracted for IR instruments with internal cold pupil stops.

**Verification Method:** Demonstration

### 5.5 External Optics Protection

**Instruments shall provide a means removable by both manual and remote control for protecting exposed external optics from dust, moisture condensation, and accidental damage.**

**Rationale:** The observing floor is an exposed environment with dust and at times humidity up to 100%. Delicate optics require protection from long-term dust accumulation; large elements chilled by radiative cooling into cold cryostats often require a dry air purge to prevent condensation. Protection from accidental damage during transport and laboratory work periods is also required.

**Verification Method:** Demonstration, Test

### 5.6 Science Detectors

**Facility instruments shall contain science detectors of sufficient quality to meet long-term scientific and operational goals.**

**Rationale:** For optimal performance, facility instrument science detectors should be "science-grade," meeting industry-standard specifications for characteristics such as QE, bad pixels, dark current, read noise, and CTE. High reliability and stability over an instrument's lifetime also enhance its long-term scientific productivity. The exact science and detector-dependent requirements for each instrument shall be evaluated early in the design process.

**Verification Method:** Demonstration, Test

## 5.7 Guiding

**Instrument projects shall evaluate guiding requirements and choose between the telescope Peripheral Wavefront Sensor and/or an On-Instrument Wavefront Sensor.**

**Rationale:** All Gemini instruments require some form of guiding to correct tracking and wind-shake errors. The telescope Acquisition and Guiding unit (A&G) provides peripheral wavefront sensors which may be used with any instrument, but at the cost of significant field-of-view obscuration, sensitivity limitations, and flexure between the WFS and a science instrument. On-instrument wavefront sensors minimize obscuration and flexure, permitting long exposures without frequent interruptions to re-center on a slit.

**Verification Method:** Demonstration, Test

## 5.8 Vacuum Environment

**Cryogenic Instrument opto-mechanical components, coatings and detectors shall meet performance requirements when operated in vacuum at cryogenic operational temperatures.**

**Rationale:** Cryogenic instruments require a cryogen environment, typically a cryostat as packaging for all the internal components of the instrument. The cryogenic environment of IR instruments typically operates in vacuum of less than 10<sup>-5</sup> Torr and temperatures down to 60 K.

**Verification Method:** Demonstration, Test

Note: This requirement is key in assisting instrument builders to decompose it into vacuum environment performance requirements such as the those indicated in the list below. Instrument builders should consider the addition of any other requirements needed to assure that the instrument will perform to specifications.

1. Vacuum Duration Cold: The instrument shall be kept cold and operated without degradation of scientific performance for at least a 3-month period.
2. Vacuum Duration Warm: When needed, the instrument shall be kept warm at room temperature without contamination of the detector(s) and internal optics affecting the scientific performance for typically a 3-month period without pumping back down.
3. Thermal Cycling: The performance of all optical components and coatings shall be preserved during repeated thermal cycling at a maximum rate of temperature change of (0.25K/minute-TBD) over the operating, storage, and transportation ranges.
4. Instrument Background: The instrument shall have an internal instrument background less than either the natural background from the observed science field or the dark current of the detector(s), whichever is greater.
5. Thermal Gradients: Thermal effects due to temperature gradients outside or inside the cryostat and near the detector focal plane shall be considered in the design to achieve instrument thermal stability.
6. Thermal Transients: Thermal transient's effects during cooldown or warm up shall be considered in the design of the instrument to set safe limits to protect internal components.
7. Cool Down Time: The instrument cooling system shall be capable of cooling the instrument from room temperature to operating conditions in TBD hours (or days) or less.
8. Warm up Time: The instrument shall be safely naturally warmed up from operating conditions to room temperature in TBD hours (or days) or less.
9. Thermal Stability: The surface on which the instrument optical system is mounted shall have an active temperature control system providing a variable temperature to be referenced to the center (or critical surface) of the cold work surface between T<sub>a</sub> and T<sub>b</sub> K, with a stability of  $\pm$  TBD K.

## 5.9 Cryostat Vacuum Ports(s)

**The instrument cryostat shall be equipped with vacuum port(s) to permit evacuation of the internal volume to a pressure typically (at the lowest) of  $10^{-3}$  Torr to start the cooldown process.**

**Rationale:** The instrument cryostats require evacuation to permit cooling to cryogenic temperatures. The vent to ambient pressure of the cryostat is typically done using the cryostat vacuum port.

**Verification method:** Demonstration, Test

## 5.10 Cryostat Overpressure Protection.

**The instrument cryostat shall be equipped with a means to avoid overpressure.**

**Rationale:** This is a safety requirement aimed at preventing the occurrence of an overpressurized state of the cryostat that could damage the instrument or present risks to personnel. Gemini recommends adopting the GSAO or NIFS Vacuum Lock System; information on this device can be provided by request to Gemini.

**Verification method:** Demonstration, Test

## 5.11 Vacuum Pressure Monitoring

**The instrument cryostat vacuum pressure shall be monitored independent of the status of the instrument software, from ambient to maximum vacuum, typically  $10^{-7}$  Torr.**

**Rationale:** Vacuum pressure is monitored for several reasons; as an indication of the vacuum quality of a cryostat, performance of the cryostat to hold vacuum, in deciding when to start the cooldown (cryopumping), and in deciding when to warm up the cryostat during anomalies. Independent of the status of the software means that the instrument software should not limit the monitoring of the vacuum pressure, especially at startup.

**Verification method:** Demonstration, Test

## 5.12 Cryostats Cryocoolers

**The instrument shall use the Gemini facility GM Closed Cycle Cooler system to cool down cryogen cryostats.**

**Rationale:** Gemini provides a Helium 5 Closed Cycle system to service GM cryocoolers. If the instrument builder desires to employ a different technology the Gemini Instrument Department should be consulted to analyze the proposed technology.

**Verification Method:** Demonstration, Test

## 5.13 Cryostat Temperature Monitoring and Control

**Instrument cryostat temperatures of critical components shall be controlled and monitored independent of status of instrument software from ambient to working temperatures.**

**Rationale:** Cryostats temperatures of critical components such as detectors, internal cold work surface and optics are controlled to provide stable cryostat thermal environment and monitored to provide feedback of performance of the cryogenic environment. Independent of the status of the software means that the instrument software should not limit the control and monitoring of the temperature control system, especially at startup.

**Verification Method:** Demonstration, Test

## 5.14 Cooling System Control

**The instrument GM Cryocoolers shall be able to be powered on independent of the status of the software.**

**Rationale:** Before starting a cooling cycle and independent of the status of the instrument software the operator will need to verify that the vacuum pressure is at the nominal value to start the cryocoolers and be able to read and monitor the cryostat temperatures. The instrument software shall not limit these operations, especially at the startup.

**Verification Method:** Demonstration, Test

## 5.15 GM Cryocoolers Protection System

**GM cryocoolers motors shall have the means to be turned off automatically when GM helium loop differential pressure is below a threshold, typically 40 PSI.**

**Rationale:** The Gemini Helium Closed Cycle Cooler system is a distributed system. This means that the power supply (or driver) powering the motors of the cryocoolers is not provided by the compressor as is normally done in applications where the compressor and cryocooler are at short distance. At Gemini, in case of failure generated at the compressor or helium lines, the cryocoolers should be stopped to avoid damage. For this purpose, a Differential Pressure Switch (DPS) interlocked with the cryocooler power supply and/or driver will sense the lack of nominal differential pressure and respond by securing power to the cryocoolers.

**Verification Method:** Demonstration, Test

## 5.16 Instrument Mechanisms Engineering Software

**The instrument shall provide engineering software which allows the user to move cryogenic mechanisms to a predetermined set of positions prior to cool down.**

**Rationale:** Operationally prior to starting a thermal cycle cryogenic instruments must position mechanisms to specific positions. This requirement is aimed at having control of the mechanism of the instrument without requiring that the instrument software be running. This feature is especially needed when starting a cool down.

**Verification Method:** Demonstration, Test

## 5.17 Instrument Timestamp

**The instrument builder shall provide Gemini with the length of the timestamps (in milliseconds) used in FITS headers that enable reconstruction of the start and end times, in UTC and TAI, of the exposure of any pixel in the raw science data.**

**Rationale:** Well characterized timestamps may be needed to allow full science exploitation of data. All the instruments have different requirements in terms of timestamps and in all cases is internal to the instruments. Gemini needs to make builders aware that this requirement is needed, and Gemini has to be aware of timestamp performance and assess if Gemini infrastructure will support it.

**Verification Method:** Demonstration

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# 6 Engineering Operations Requirements

## 6.1 ISS Installation or Removal

**If ISS-mounted, the instrument shall be installed or removed in 3 hours or less.**



**Rationale:** The Gemini operational model is to perform instrument changes either from one instrument to another, or to remove and instrument and install a ballast weight in its place, then to check-out the instrument, and finally rebalance the telescope. All of these activities must be completed by a single Gemini engineer and 3 Gemini technicians within the course of one 6-hour summit work day.

**Verification Method:** Demonstration

## **6.2 Access to ISS-Mounted Instrument**

### *6.2.1 Access to Patch Panels while Mounted*

**When the instrument is mounted on the ISS, the instrument patch panels shall be accessible for connection or disconnection without removing more than one instrument access panel, without disassembling the instrument and without removing the instrument from the ISS.**

**Rationale:** In the course of installing, removing, or maintaining an instrument, it may be necessary to disconnect or connect the instrument from ISS services, and the instrument patch panel is the location on the instrument that connects to ISS services.

**Verification Method:** Test

### *6.2.2 Access to Enclosures while Mounted*

**When the instrument is mounted on the ISS, the instrument enclosures shall be accessible for maintenance without disconnecting it from services and without removing the instrument from the ISS.**

**Rationale:** Ease of maintenance.

**Verification Method:** Test

### *6.2.3 Access to Detector Controller Subsystems while Mounted*

**When the instrument is mounted on the ISS, the instrument detector controller subsystems shall be accessible for maintenance without removing the instrument from the ISS.**

**Rationale:** Ease of maintenance.

**Verification Method:** Test

### *6.2.4 Access to Frequently Maintained Subsystems while Mounted*

**When the instrument is mounted on the ISS, frequently maintained subsystems shall be accessible for maintenance without removing the instrument from the ISS.**

**Frequently maintained subsystems** are defined as subsystems or components of the instrument that may need to be accessed on a daily or weekly period. These could include items like masks, filters or gratings. The Frequently Maintained Subsystems for a specific instrument should be determined, documented, and formally agreed upon between Gemini and the instrument builder during or before the Conceptual Design Phase.

**Rationale:** Ease of maintenance.

**Verification Method:** Test

### *6.2.5 Access to Components Requiring Replacement*

**Instrument components that are likely to need replacement between major overhauls shall be accessible without having to fully disassemble the instrument.**

**Rationale:** Requirement needed to ensure that a major overhaul is not needed to replace certain components. A maintenance list with instructions will be created and will be part of the instrument service and maintenance manual.

**Verification Method:** Analysis

## 6.3 Safety During Access

### 6.3.1 *Local Disabling of Power*

**The instrument shall enable local disabling of power.**

**Rationale:** Personnel safety while working on the instrument, when it is still attached to services.

**Verification Method:** Test

### 6.3.2 *Local Disabling of Remote Operation*

**The instrument shall enable local disabling of remote operation.**

**Rationale:** Personnel safety while working on the instrument, when it is still attached to services.

**Verification Method:** Test

### 6.3.3 *Local Emergency Stop*

**The instrument shall enable local emergency stop of instrument mechanism operation.**

**Rationale:** Personnel safety while working on the instrument.

**Verification Method:** Test

### 6.3.4 *Automatic Disabling of Telescope Operation*

**The need to automatically disable telescope operation via the Gemini Interlock System shall be determined, documented, and formally agreed upon between Gemini and the instrument builder during or before the Conceptual Design Phase.**

**Rationale:** Instrument safety, such as in the circumstance where continued telescope motion would damage the instrument or telescope. Note that while possible, most current facility instruments do not use this interface.

**Verification Method:** Test

## 6.4 Ergonomics

### 6.4.1 *Ergonomic Lifting*

**Instrument modules that are handled directly by personnel shall not exceed a maximum lifting weight of 23 kilograms per person.**

**Rationale:** Personnel safety.

**Verification Method:** Analysis

### 6.4.2 *Ergonomic Access*

**When dismantled, the instrument shall not require ladders or steps for routine maintenance.**

**Rationale:** Personnel safety.

**Verification Method:** Inspection

### 6.4.3 *Full Access*

**The instrument access doors shall be able to open fully.**

**Rationale:** Ease of access.

## 7 Interface Requirements

### 7.1 Compliance with Environments Interface

The instrument shall comply with the environmental interface, as defined in the *Science and Facility Instruments to Transport, Observatory and Operational Environments ICD*.

**Rationale:** The instrument will experience all of the environments described in the ICD.

**Verification Method:** Roll-Up

### 7.2 Compliance with ISS Interface

The instrument shall comply with the ISS interface, as defined in the *ISS to Science Instruments ICD*.

**Rationale:** The instrument will be mounted on the ISS for science operations.

**Verification Method:** Roll-Up

### 7.3 Compliance with ISS System Services Interface

The instrument shall comply with the ISS System Services interface, as defined in the *Science and Facility Instruments to ISS System Services ICD*.

**Rationale:** The instrument will have access to only ISS System Services when it is mounted on the ISS and will have access to similar services when it is dismounted.

**Verification Method:** Roll-Up

### 7.4 Compliance with GIAPI Software Interface

The instrument shall comply with the GIAPI Software interface, as defined in the *GIAPI API and GIAPI Design and Use documents*.

**Rationale:** The instrument must communicate with Observatory control systems via GIAPI.

**Verification Method:** Roll-Up of the requirements contained in the GIAPI API and Design and Use documents.

### 7.5 Compliance with Data Processing and Data Reduction Software Interface

The instrument shall comply with the Data Processing Software interface, as defined in the *DPSG-STD-104 Coding Standards and Guidelines for Gemini Data Processing Software* and the *PIPE-USER-103 DRAGONS Gemini Recipe System* documents.

**Rationale:** The instrument data reduction software, and its outputs, must be compliant with Gemini standards.

**Verification Method:** Roll-Up

### 7.6 On-Instrument A&G Compliance with Observatory Systems

If the instrument performs on-instrument acquisition and/or guiding, then the instrument shall comply with relevant interface specifications, as defined in the *GIAPI, Synchro Bus ICDs* and *GIAPI Design and Use documents*.

**Rationale:** If the instrument is using an OIWFS, there are additional requirements for interfacing with Gemini systems.

**Verification Method:** Roll-Up.

## 7.7 Compliance with AO

**If the instrument uses Gemini AO, then the instrument shall not require modifications to the AO system with the exception of those approved by Gemini in the Design Phase.**

**Rationale:** If the instrument uses Gemini AO, then the instrument must be compatible with the optical interface of the AO system. Namely, the wavelengths of light available for science when using AO, and the focal ratio of the light beam output by the AO system. Current capabilities are described on the *Adaptive Optics web pages (2.2 above)*.

**Verification Method:** Roll-Up

## 7.8 Compliance with GCAL Unit

**If the instrument uses GCAL for calibrations, then the instrument shall not require modifications to GCAL with the exception of those approved by Gemini in the Design Phase.**

**Rationale:** If the instrument uses GCAL, then the instrument must be compatible with the GCAL lamps for all calibrations using GCAL. Current capabilities are described on the *GCAL web page (2.2 above)*.

**Verification Method:** Roll-Up

## 7.9 Compliance with the Gemini Interlock System (GIS)

**If the instrument uses the GIS, then the instrument shall comply with the GIS interface, as defined in the *GIS to Instrument ICD*.**

**Rationale:** GIS allows an instrument to generate a telescope interlock command which is essentially a command for the telescope to stop movement. Note that this feature is rarely used by instruments, but any instrument using it must comply with the interface.

**Verification Method:** Roll-Up

## 7.10 Compliance with Facility Handling Equipment

**The instrument shall comply with the Facility Handling Equipment interface, as defined in the *Facility Handling Equipment ICD*.**

**Rationale:** Facility handling equipment will be used to install, remove and service the instrument while it is mounted on the ISS.

**Verification Method:** Roll-Up

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# 8 Mechanical Safety Standards

The contents of this section are not intended as a comprehensive set of safety requirements, but rather emphasize aspects of safety commonly encountered at Gemini. Where stricter industry standards exist, instrument builders are expected to adhere to those.

## 8.1 Instrument Precautions

### 8.1.1 Optics Protection from Dust

**The instrument shall provide protection to its optics from dust and damage when the instrument is open.**

**Rationale:** Optics performance and safety. Even when the enclosure of the visible part of the instrument is fully sealed to avoid dust contamination, protection covers of optics components shall be provided to

protect them when instrument is opened for maintenance and/or service. The same is true for the IR cryostat optics components.

**Verification Method:** Analysis, Inspection

#### *8.1.2 Removal of Sharp Edges*

**The instrument shall not contain any exposed sharp edges.**

**Rationale:** Personnel safety. Note this includes optics as well as mechanical.

**Verification Method:** Analysis

#### *8.1.3 Safety Stops*

**All instrument mechanisms shall have both software limits and hard physical stops when there is the possibility of motion beyond the boundary of nominal movement.**

**Rationale:** Personnel and instrument safety. This is very important, especially for the IR Cryostat. Motion beyond the boundaries must be avoided, and if this happen it shall be able to recover the motion back to nominal ranges without opening the cryostat or opening the visible enclosure. Applies to internal and external mechanisms.

**Verification Method:** Inspection, Test

#### *8.1.4 Fasteners*

**For all locations where high grade/strength fasteners are an integral structural component, the instrument shall clearly indicate the use of the correct fastener through captive fasteners or labeling at the fastener hole.**

**Rationale:** Personnel and instrument safety.

**Verification Method:** Inspection

#### *8.1.5 Pressure Relief Valves*

**All vacuum dewars, and any containers that may be subject to a potential over-pressurization risk shall have automatic pressure release safety valves that must also be vacuum compatible.**

**Rationale:** Personnel and instrument safety.

**Verification Method:** Inspection

#### *8.1.6 Lockout of Pressure Relief Valves*

**Instrument pressure relief valves for subsystems at high vacuum conditions shall have lock-out wiring.**

**Rationale:** Personnel and instrument safety.

**Verification Method:** Inspection

#### *8.1.7 Glycol Fittings*

**All instrument glycol fittings shall be made of stainless steel.**

**Rationale:** Zinc or galvanized components that come in contact with Glycol coolant create a milky white viscous material that can plug components anywhere within the chilled water circulation system.

**Verification Method:** Inspection

#### *8.1.8 Self-Sealing Connectors*

**Instrument lines (helium, coolant, air) shall use self-sealing connectors.**

**Rationale:** Personnel and instrument safety.

**Verification Method:** Inspection

#### *8.1.9 Inset Cryostat Windows*

**All cryostat windows that are on the outside of the instrument shall be inset.**

**Rationale:** Cryostat window safety during installation onto the Gemini telescope.

**Verification Method:** Inspection

#### *8.1.10 Operating Line Pressure*

**Instrument lines (helium, coolant, air) shall operate safely and continuously at 110% of their nominal pressures.**

**Rationale:** Personnel and instrument safety. The recommended design margin for 0 through 507 PSI (0-35 bars) is 10% above the Pressurized Safety Valve (PSV) set point, and the PSV is 300 PSI (GN) or 320 PSI (GS).

**Verification Method:** Analysis

#### *8.1.11 Instantaneous Operating Line Pressure*

**Instrument lines (helium, coolant, air) shall be capable of experiencing 200% of their nominal pressures without damage.**

**Rationale:** When services are first turned on, it is possible to experience a surge in pressure up to this amount.

**Verification Method:** Analysis

#### *8.1.12 Audio Noise Levels*

**The instrument noise level shall never exceed 80dBA.**

**Rationale:** Personnel safety.

**Verification Method:** Test

## **8.2 Hazardous Material Avoidance**

### *8.2.1 Hazardous Materials*

**The instrument shall use only non-toxic, nonflammable materials for fabrication, assembly and maintenance, except where pre-approved by Gemini during the Design Phase.**

**Rationale:** Personnel safety.

**Verification Method:** Inspection

### *8.2.2 Liquids and Gases in Operations*

**The instrument shall not require flammable cryogenics, liquid nitrogen or liquid helium during operations.**

Note: use of liquid nitrogen or helium during pre-cooling is allowed where permission has been obtained from Gemini during the design phase.

**Rationale:** Personnel and facility safety.

**Verification Method:** Inspection

## **8.3 Other**

### *5.3.1 Use of standard metric sizes*

**Instrument screws, bolts, nuts, tapped holes and fasteners shall be of standard metric sizes. The only exception shall be internal components of commercially purchased mechanisms, or fixtures to attach these (e.g. pre-tapped holes).**

**Rationale:** Gemini uses the metric system.

**Verification Method:** Inspection

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## 9 Electrical Safety Standards

The contents of this section are not intended as a comprehensive set of safety requirements, but rather emphasize aspects of safety commonly encountered at Gemini. Where stricter industry standards exist, instrument builders are expected to adhere to those.

### 9.1 Instrument Precautions

#### 9.1.1 Enclosure Over-Temperature Power Down

**Over-Temperature** is defined as when a component of the instrument is above 45 degrees Celsius. **Upon detection of an over-temperature event in an enclosure, the instrument shall remove power from the enclosure and permit restart only after the temperature returns to nominal values.**

**Rationale:** Instrument safety. Note general monitoring of temperature and other environmental conditions is covered in the Environmental section. Nominal temperature internal to cabinets is 15-18C.

**Verification Method:** Test

#### 9.1.2 Over-Current Protection

**The instrument shall provide multiple levels of protection against over-current events, such as circuit breakers, power bar breakers and fuses.**

**Rationale:** Instrument safety.

**Verification Method:** Inspection, Test

#### 9.1.3 Power to Critical Systems

**Gemini provides uninterrupted power supplies (UPS) services for all facility instruments. It is for the instrument builder to determine if additional power redundancy is needed.**

#### 9.1.4 Removal of Shock Hazards

**The instrument shall not contain any electrical shock hazards.**

**Rationale:** Personnel safety. This is particularly important where high voltages are present.

**Verification Method:** Analysis

#### 9.1.5 Electrostatic Discharge

**The instrument shall protect sensitive components from static current build-up and electrostatic discharge.**

**Rationale:** Electrostatic discharge could result in failure of sensitive components and require costly downtime to repair.

**Verification Method:** Analysis

#### 9.1.6 Grounding

**The instrument components and chassis shall be grounded through normal power line supplies.**

**Rationale:** Safety considerations for personnel and equipment and use of available resources.

**Verification Method:** Inspection

#### *9.1.7 Ground Returns*

**The instrument shall have separate ground returns for electrically noisy components (such as fans, motors and pulse width modulation (PWM) drive systems).**

**Rationale:** Good design practice for best performance.

**Verification Method:** Inspection

#### *9.1.8 Shielding*

**The instrument shall employ shielded wires and cables as needed to suppress EMI.**

**Rationale:** EMI negatively affects instrument performance and needs to be minimized.

**Verification Method:** Analysis, Inspection

#### *9.1.9 High Voltages*

**The instrument shall not have exposed high voltages > 50V.**

**Rationale:** High voltages can harm personnel and the instrument when servicing the instrument.

**Verification Method:** Inspection

#### *9.1.10 High Voltages Wiring*

**High voltage wiring shall be double-insulated and contained within earth metal chassis.**

**Rationale:** High voltages can harm personnel and the instrument when servicing the instrument.

**Verification Method:** Inspection

#### *9.1.11 Connector Unique Keying or Pinning*

**Instrument connectors shall be uniquely keyed or pinned, and locked or otherwise secured. In cases where cross connecting is possible, and keying/pinning is not possible (generic cables), connectors shall be color coded and bundled to mitigate risk.**

**Rationale:** Prevents or mitigates risk of cross connection.

**Verification Method:** Inspection

#### *9.1.12 Cross-Cable Connecting*

**In cases where it is possible to cross-connect cables, the instrument shall ensure that no damage is possible due to cross-connecting.**

**Rationale:** Risk mitigation for equipment damage resulting from cross connection. Good design practice is to make cross-connection not possible.

**Verification Method:** Inspection

#### *9.1.13 Conductor and Cable Ampacity*

**The instrument conductor ampacity shall be de-rated to 75% of published values (for 30° C rise) for expected loads, and connectors and cables must be rated accordingly to avoid conductor heating.**

**Rationale:** Instrument safety. Derating is employed, independently of other design criteria, to achieve an increased level of reliability in equipment by limiting the electrical and thermal stresses placed on the components. The general rule employed by telescope staff on site is to derate all components by at least 25%.

**Verification Method:** Analysis



#### *9.1.14 Electrical Power Dissipation*

**Electrical power dissipation shall be de-rated to an equivalent 60°C environment.**

**Rationale:** This is due to the 40% reduced air density relative to sea level which reduces the effect of convective cooling by approximately 50%. High voltage systems should be rated for operation at an altitude of 4,500 meters (14,500 ft.).

**Verification Method:** Analysis

## **9.2 Operations**

### *9.2.1 Motor Voltage*

**Instrument motors shall be low voltage DC, where low voltage is  $\leq 24\text{V}$ .**

**Rationale:** Instrument safety. Instrument motors are any mechanisms such as shutters, filters and masks wheels, mirrors, linear stages, etc. It does not include cryocooler motor.

**Verification Method:** Inspection

### *9.2.2 Light indicators*

**Instrument component power supplies shall have controllable light indicators.**

**Rationale:** Light indicators when on can aid in engineering troubleshooting, but during nominal nighttime operations there should be no sources of light aside from the telescope light beam.

**Verification Method:** Demonstration

### *9.2.3 EMI*

**The instrument shall shield all sensitive components from EMI emitted from short wave radios.**

**Rationale:** Walkie talkies are used for summit facility communications at both sites.

**Verification Method:** Analysis

### *9.2.4 Cable and Service Line Routing Inside Enclosures*

**Cabling within the enclosures shall be routed along the sides, robustly strapped and strain relieved.**

**Rationale:** Instrument safety.

**Verification Method:** Inspection

### *9.2.5 Cable and Service Line Routing Between Enclosure and Instrument.*

**External cabling between the enclosures and the instrument hardware shall be run in wire-rack style cable trays such that cables may be individually replaced without significantly disturbing other cabling yet protected from mechanical damage.**

**Rationale:** Ease of maintenance

**Verification Method:** Inspection

### *9.2.6 Service Lines*

**Service lines shall be run in the same cable trays as other cables.**

**Rationale:** Efficient use of trays.

**Verification Method:** Design

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## 10 Hazard and Informational Labeling Standards

### 10.1 Labeling Standards

#### 10.1.1 *Bilingual Labeling*

**All labels and warnings shall be in English and Spanish.**

**Rationale:** Both languages are part of the working environment at Gemini.

**Verification Method:** Inspection

#### 10.1.2 *Use of International Color Coding*

**All labels and warnings shall use international signage color coding.**

**Rationale:** Staff at both sites are familiar with international standards.

**Verification Method:** Inspection

#### 10.1.3 *Use of International Pictograms*

**All labels and warnings that have an associated international pictogram shall include that pictogram as well.**

**Rationale:** Staff at both sites are familiar with international standards.

**Verification Method:** Inspection

### 10.2 Hazard Labeling

#### 10.2.1 *Pinch Point Labeling*

**All instrument pinch points shall be labeled.**

**Rationale:** Personnel and equipment safety.

**Verification Method:** Inspection

#### 10.2.2 *Sharp Edges and Points Labeling*

**All instrument sharp edges and points shall be labeled.**

**Rationale:** Personnel and equipment safety.

**Verification Method:** Inspection

#### 10.2.3 *Tipping Hazard Labeling*

**All instrument tipping hazards shall be labeled.**

**Rationale:** Personnel and equipment safety. To avoid tipping of the instrument the center of gravity should be properly labeled indicating a potential tipping condition during handling. The lifting points should be clearly marked and unstable lifting points (where lifting is not recommended) should be also labeled with warning signs.

**Verification Method:** Inspection

#### 10.2.4 *High Voltage Labeling*

**All instrument high voltage sources and locations shall be labeled, including wires and connectors to high voltage (> 50V).**

**Rationale:** Personnel and equipment safety.

**Verification Method:** Inspection

#### *10.2.5 High Current Labeling*

**All instrument high current locations shall be labeled.**

**Rationale:** Personnel and equipment safety.

**Verification Method:** Inspection

#### *10.2.6 Vacuum Valve Labeling*

**All instrument vacuum valves shall be labeled.**

**Rationale:** Personnel and equipment safety.

**Verification Method:** Inspection

#### *10.2.7 Hazardous Material Labeling*

**All instrument components containing hazardous materials (as pre-approved by Gemini) shall be labeled.**

**Rationale:** Personnel safety.

**Verification Method:** Inspection

#### *10.2.8 Other Hazards Labeling*

**All instrument components presenting other hazards shall be labeled.**

**Rationale:** Personnel and equipment safety.

**Verification Method:** Inspection

#### *10.2.9 Oxygen Deprivation Hazard Labeling*

**All instrument oxygen deprivation hazards, where personnel could be contained within, shall be labeled.**

**Rationale:** Personnel safety.

**Verification Method:** Inspection

### **10.3 Informational Labeling**

#### *10.3.1 Lift Point Labeling*

**All instrument lift points shall be labeled and shall specify the type of lifting method associated with it.**

**Rationale:** Personnel and instrument safety.

**Verification Method:** Inspection

#### *10.3.2 Weight Labeling*

**Major instrument subsystems shall be labeled with their weight in both imperial and metric units.**

**Rationale:** Staff use.

**Verification Method:** Inspection

#### *10.3.3 Center of Gravity Labeling*

**The instrument center of gravity location should be labeled.**

**Rationale:** Staff use, if possible to do so. The center of gravity (CG) should be indicated in the exact position where it is. A plate is usually attached to the instrument frame indicating the CG

**Verification Method:** Inspection

#### *10.3.4 Component Labeling*

**All instrument components shall be labeled with the following information:**

- unit/assembly/sub-assembly name
- serial number
- document or drawing number
- date of manufacture
- name of manufacture

**Rationale:** Staff use.

**Verification Method:** Inspection

#### *10.3.5 Cable Labeling*

**All instrument cables shall be uniquely labeled.**

**Rationale:** Staff use.

**Verification Method:** Inspection

#### *10.3.6 Connector Labeling*

**All connectors shall be uniquely labeled.**

**Rationale:** Staff use.

**Verification Method:** Inspection

#### *10.3.7 Service Line Labeling*

**All service lines and hoses shall be uniquely labeled and shall include whether it is a supply or return line.**

**Rationale:** Staff use.

**Verification Method:** Inspection

#### *10.3.8 Service Line Couplers Labeling*

**All service line couplers shall be uniquely labeled.**

**Rationale:** Staff use.

**Verification Method:** Inspection

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## **11 Documentation Standards**

### **11.1 Document Language**

**Instrument documentation shall be written in English.**

**Rationale:** All staff have working knowledge of English.

**Verification Method:** Inspection

### **11.2 Delivered Document Formats**

**Instrument documentation shall be delivered in both source file format and PDF files.**

**Rationale:** Source file format enables Gemini staff to maintain the documents after project close, and PDF format provides a historical record of the delivered document.

**Verification Method:** Inspection

### 11.3 Permitted Source File Formats

**Instrument documentation source files shall be delivered in the following formats:**

- **Mechanical Design file format shall be: Inventor.**
- **Optical Design file format shall be: Zemax**
- **Structural Analysis file format shall be: Ansys**
- **Thermal Analysis file format shall be: Ansys or Excel**
- **Electrical Design / Schematic file format shall be: Altium, Or, PADs or AutoCAD**
- **General document file format shall be: Microsoft Office Word, Excel or PowerPoint**

**Rationale:** Gemini staff are familiar with these file formats and have the necessary licenses to open documents delivered in these formats.

**Verification Method:** Inspection

### 11.4 Use of Metric Dimensions

**Instrument documentation shall express dimensions using the metric system, with the exception of angular dimensions which shall be expressed in degrees.**

**Rationale:** Gemini uses the metric system.

**Verification Method:** Inspection

### 11.5 Compliance with Observatory Opto-Mechanical Coordinate System

**The instrument shall comply with the opto-mechanical coordinate system, as defined in the *Opto-Mechanical Coordinate System ICD*.**

**Rationale:** The instrument orientation in all directions, for instance as represented in software, drawings, documentation, must adhere to the common coordinate system.

**Verification Method:** Inspection

## Appendix A: Requirements Fields

Field	Description
Unique ID	The project unique identifier for the requirement.
Category	The main category that the requirement falls under. Typical groupings may be based on architecture or function.
Title	Summary of the requirements key focus.
Description	The requirement itself.
Rationale	Additional context for the requirement to facilitate understanding.
Status	The requirement development status, useful for managing the requirement during the early part of the project lifecycle: Is the requirement still in work, finalized, or change controlled.
Source	The source of the requirement. Typical sources are parent requirements, budgets, project documents.
Child requirement(s)	Any following requirements that are derived or flowed down from this requirement.
Organizational Owner	Note: For instrument builders consisting of multiple organizations The organization responsible for implementing the requirement.
Point of Contact(s) (POC)	Typically, the person(s) responsible for authoring and reviewing change requests to the requirement.
Version History Log	Once change controlled, the record of approved changes made to the requirement.
Verification Method	The method of verification. See section 1.5 for explanation.
Verification Stage	The project stage when verification occurs.
Verification Status	The requirement verification status: Is the requirement verified, waived, failed.
Verification Reference	The document recording the verification status. Typical documents include test reports, inspection reports, and design documents for analysis.

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## Appendix B: Obsolete ICDs

### *1.1.1/1.9 Telescope Structure to Science Instruments*

Redundant with 1.5.3/1.9 because only content is Cassegrain Instrument Zone which is provided in 1.5.3/1.9 as the allowable space envelope.

### *1.1.11/1.9 TCS (Telescope Control System) to Science Instruments ICD*

Instrument now interfaces with GIAPI.

### *1.1.11/1.10 Telescope Control to On Instrument WFS ICD*

Written for specific OIWFS system. Not relevant for new instruments – a new ICD will need to be created.

### *1.4.4/1.9 SCS (M2 Control System) to Science Instruments ICD*

Instrument now interfaces with GIAPI.

### *1.6/1.9 A&G System to Science Instruments ICD*

Redundant with 1.6/1.10 because only content describes interface required with OIWFS.

### *1.6/1.10 A&G System to On Instrument WFS*

Written for specific OIWFS system. Not relevant for new instruments – a new ICD will need to be created.

### *1.7/1.9 Calibration System to Science Instruments ICD*

Deemed not necessary - the real need was for lamp specifications, and these are provided on the GCAL web page.

### *1.9 Science Instruments ICD*

Serves only to direct to specific interface ICDs, so not needed.

### *1.9/1.10 Science Instruments to On Instrument WFS ICD*

Written for specific OIWFS system. Not relevant for new instruments who may select their own OIWFS.

### *1.9/2.7 Science Instruments to Facility Handling Equipment ICD*

Never been finalized and redundant with ICD G0015

### *1.9/3.1 Science Instruments to Observatory Control System CD*

Instrument now interfaces with GIAPI.

### *1.9/3.2 Science Instruments to Data Handling System ICD*

Instrument now interfaces with GIAPI.

### *1.9/3.7 Science Instruments to Thermal Enclosure ICD*

No longer relevant as instrument builders are now required to provide their own enclosures.

### *1.9/3.21 Science Instruments to Environmental Monitoring System ICD*

Instrument now interfaces with GIAPI.

### *1.10 On Instrument WFS ICD*

Never been finalized and serves only to direct to specific interface ICDs, so not needed.