GSAOI

GEMINI

AUSTRALIAN NATIONAL UNIVERSITY

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FUNCTIONAL AND PERFORMANCE REQUIREMENTS DOCUMENT

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Revision History

Revision No.	Author & Date	Approval & Date	Description
Revision 1	Peter J. McGregor 29 November 2001	John Hart 1 March 2002	Draft initial document.
Revision 2	Peter J. McGregor 23 April 2002	Jan van Harmelen 23 April 2003	Revised initial document.
Revision 3	Peter J. McGregor 23 July 2002	Jan van Harmelen 25 July 2003	Revised for CoDR
Revision 4	Jan van Harmelen 2 May 2003	Peter J. McGregor 8 May 2003	Revised after CoDR

Contents

1 Purpose

The Gemini South Adaptive Optics Imager (GSAOI) Operational Concept Definition Document (OCDD) defines the scientific requirements of the GSAOI instrument and describes operational scenarios. These are translated into technical requirements in the GSAOI Functional and Performance Requirements Document (FPRD). Other technical requirements for Gemini facility instruments derive from the GSAOI Design and Fabrication Contract Statement of Work (GEM00334A). The scientific and technical requirements are summarized in this FPRD, and their relationships are identified so that all functional and performance requirements can be traced from top-level science requirements.

The two purposes of the GSAOI FPRD are to provide the Gemini scientific community with an understanding of what GSAOI will do and how quickly or how well it will do it, and to provide engineers with the requirements on which to base the GSAOI design. The design is derived from this document. This document takes precedence over other design and fabrication documents. The design must serve the requirements in this document completely. Every feature of GSAOI should be traceable to a requirement in this document, and there should be no features of GSAOI that are not required by this document.

GSAOI will be designed in stages, with a review after each stage is complete. Comments from the review committee will be folded into the design, so the requirements will change as the design changes. Therefore, this document will be updated as needed after each major design review to maintain the correspondence between requirements and design. This current version reflects the status at the Conceptual Design Review.

2 Applicable Documents

Document ID	Source	Title
GEM00334A	IGPO	GSAOI Design and Fabrication Contract Statement of Work
SDN01.02	RSAA	GSAOI Operational Concept Definition Document
ICD 1.1.1/1.9	IGPO	Telescope Structure, Drives, and Brakes to Science Instruments ICD
ICD 1.1.11/1.9	IGPO	Telescope Control to Science Instruments ICD
ICD 1.1.13/1.9	IGPO	Interlock System to Science Instruments ICD
ICD 1.5.3	IGPO	Instrument Support Structure IDC
ICD 1.5.3/1.9	IGPO	Instrument Support Structure to Science Instruments ICD
ICD 1.6/1.10	IGPO	A&G System to On-Instrument WFS ICD
ICD 1.9/3.1	IGPO	Science Instruments to Observatory Control ICD
ICD 1.9/3.2	IGPO	Science Instruments to Data Handling ICD
ICD 1.9/3.6	IGPO	Science Instruments to System Services ICD
ICD 1.10	IGPO	On-Instrument Wave Front Sensor ICD
ICD 1.10.1	IGPO	OIWFS Feed Optics System ICD
ICD 1.10.2	IGPO	OIWFS Camera/Controller ICD
ICD 16	IGPO	The Parameter Definition Format
SPE-ASA-G0008	IGPO	Gemini Electronic Design Specification
SPE-C-G0037	IGPO	Gemini Software Design Description
SPE-S-G0041	IGPO	Gemini System Error Budget Plan
	AT&T Bell Laboratories, 1988	Ott, H. W., Noise Reduction Techniques in Electronic Systems, Second Edition

3 List of Acronyms

ASIC	Application Specific Integrated Circuit
CICS	Core Instrument Controller Software
DHS	Data Handling System
EPICS	Experimental Physics and Industrial Control System
FPRD	Functional and Performance Requirements Document
GIS	Gemini Interlock System
GSAOI	Gemini South Adaptive Optics Imager
ICD	Instrument Control Document
ICS	Instrument Control System
IGPO	International Gemini Project Office ("Gemini" or "the Project")
IOC	Input-Output Controller
ISS	Instrument Support Structure (the "cube")
LAN	Local Area Network
MCAO	Multi-Conjugate Adaptive Optics
NDR	Non-Destructive Read
NGS	Natural Guide Star
NIFS	Near-infrared Integral Field Spectrograph
NIRI	Near Infra-Red Imager
OCDD	Operational Concept Definition Document
OCS	Observatory Control System
OIWFS	On-Instrument Wave Front Sensor
SDSU	San Diego State University detector controller

4 Introduction

This document represents the current understanding of the capabilities and performance of the Gemini South Adaptive Optics Imager (GSAOI) to be designed, fabricated, tested, delivered, and commissioned by the Australian National University for use on the Gemini 8-m telescopes.

GSAOI will be the workhorse instrument used with Gemini's Multi-Conjugate Adaptive Optics (MCAO) system. GSAOI is a diffraction-limited imaging instrument. It will use a single imaging scale of 0.02"/pixel and have a square field of view 85" on a side. GSAOI will be equipped with broad band *Z*, *J*, *H*, *K'*, *Ks* and *K* filters and narrow band zero-redshift emission line filters. High sensitivity is essential to achieve the demanding science goals that have been set for the instrument. A pupil viewing system that will allow the internal cold stop to be accurately aligned with the telescope exit pupil will aid in realizing this sensitivity. An On Detector Guide Window (ODGW) will track flexure variations between MCAO and GSAOI at the same wavelength as the science observation, and act as a tip-tilt reference for MCAO when required.

5 Optical Requirements

5.1 System Functional Requirements

5.1.1 MCAO Compatibility

REQ-OCD-0001: GSAOI will accept the MCAO f/34 input beam with a pupil near the telescope secondary mirror.

5.1.2 Imager

REQ-OCD-0002: GSAOI will have an imager channel for science observations.

5.2 System Performance Requirements

5.2.1 Vacuum Environment

REQ-FPR-0001: All optical components and coatings will meet all performance requirements when operated in a vacuum of less than 10^{-5} Torr at operational temperatures down to 65 K.

5.2.2 Thermal Cycling

REQ-FPR-0002: The performance of all optical components and coatings will not be degraded by repeated thermal cycling at a maximum rate of temperature change of 0.25 K/minute over the operating, storage, and transportation temperature ranges.

5.3 Imager Functional Requirements

5.3.1 Imager Wavelength Coverage

REQ-OCD-0004: The imager will operate in the wavelength range from 0.9-2.4 μm.

5.3.2 Imager Spatial Sampling

REQ-OCD-0005: The imager will have a scale of ~ 0.02″/pixel.

5.3.3 Imager Field-of-View

REQ-OCD-0006: The imager will have a field-of-view of > 80″×80″.

5.3.4 Imager Cold Stop

REQ-OCD-0007: The imager will include a fixed cold stop at an image of the MCAO exit pupil. The cold stop will be sized so as not to vignette the imager beam while reducing background radiation to the greatest extent possible.

5.3.5 Imager Pupil Viewer

REQ-OCD-0008: The imager will have a facility for viewing an image of the MCAO exit pupil.

5.3.6 Imager Non-Common Path Phase Errors

REQ-OCD-0009: The imager will be capable of measuring low-order wave front errors through the entire optical path to the imager detector with a spatial resolution of ~ 200 mm referenced to the telescope primary mirror.

Notes and Comments:

1. Measurement of the wave front error at the imager detector will permit the removal of static aberrations due to the imager optics.
2. It is envisaged that this requirement will be met by recording pupil images on either side of focus, analyzing the images with the Roddier program, and inputting the result to the MCAO system as coefficients of low order Zernike polynomials. The ICD is **TBD**.

5.3.7 Imager Filters

5.3.7.1 Imager Filter Suite

REQ-OCD-0010: The imager will be able to interchange between any of the following filters and will have provision for at least 5 more filters:

Item	Filter	λ_c (μm)	$\Delta\lambda$ (μm)	50% cut on	50% cut off
1	*Z*	1.015	0.170	0.930	1.100
2	*J*	1.250	0.160	1.170	1.330
3	*H*	1.635	0.290	1.490	1.780
5	*K'*	2.120	0.340	1.950	2.290
6	*Ks*	2.150	0.320	1.990	2.310
7	*K*	2.200	0.340	2.030	2.370
7	*J* continuum	1.207	0.018	1.198	1.216
8	*H* continuum	1.570	0.024	1.558	1.582
9	CH_4 (short)	1.580	0.100	1.530	1.630
10	CH_4 (long)	1.690	0.100	1.640	1.740
11	*Ks* continuum	2.093	0.031	2.078	2.108
12	*Kl* continuum	2.270	0.034	2.253	2.287
13	He I 1.0830 μm	1.083	0.016	1.075	1.091
14	H I Pγ	1.094	0.011	1.089	1.100
15	H I Pβ	1.282	0.019	1.272	1.292
16	[Fe II] 1.644 μm	1.644	0.025	1.631	1.656
17	H_2O	2.000	0.080	1.960	2.040
18	He I (2p2s)	2.058	0.031	2.042	2.073
19	H_2 1-0 S(1)	2.122	0.032	2.106	2.138
20	H I Brγ	2.166	0.032	2.150	2.182
21	H_2 2-1 S(1)	2.248	0.034	2.231	2.265
22	CO Δv=2	2.360	0.080	2.320	2.400

5.3.7.2 Imager Filter Transmission

REQ-FPR-0003: The imager filters will have an on-band transmission greater than 70%, and an off-band transmission less than 10^{-4}.

5.3.7.3 Imager Filter Wedge

REQ-FPR-0004: The imager filters will have a wedge angle that produces an image deflection at the imager detector of < 0.1 pixels.

5.3.8 Imager Calibration

REQ-OCD-0011 The imager filter mechanism will contain one blocked position for recording bias frames.

5.3.9 Optical Baffling

REQ-FPR-0005: GSAOI will be baffled to suppress stray light, such that the baffling does not reduce the imager throughput.

5.3.10 Imager Pupil Viewer Resolution

REQ-OCD-0012 The imager pupil viewer will have a resolution of < 100 mm equivalent at the Gemini telescope primary mirror.

5.4 Imager Performance Requirements

5.4.1 Imager Strehl Ratio

REQ-OCD-0013: The total wave front error introduced by the imager optical system will be < 65 nm RMS over the wavelength range 0.9–2.4 μm. This corresponds to a Strehl ratio of > 0.94 at a wavelength of 1.6 μm.

Notes and Comments:

1. The optical image quality error budget is discussed in Gemini System Error Budget Plan, SPE-S-G0041.
2. The MCAO optical error budget places a tighter constraint on the science instrument. This is the origin of the above requirement.
3. The Marechal approximation, $S \sim \exp-(2\pi\sigma/\lambda)^2$, is used to convert RMS wave front error, σ, to Strehl ratio, *S*, at wavelength, λ.

5.4.2 PSF Uniformity

REQ-OCD-0013a: GSAOI shall have a uniform point spread function across its field-of-view such that the Strehl ratio does not vary by more than 0.01 at a wavelength of 2.2 microns.

5.4.3 Imager Distortion

REQ-OCD-0014: The imager will cause a geometrical distortion at the detector of < 0.1%.

5.4.4 Imager System Throughput

REQ-OCD-0015: The imager will have a throughput over its required wavelength range of ≥ 50% including the imager optics and filter, but not including the detector or throughput of the atmosphere, telescope, or MCAO science path.

5.4.5 Imager Instrumental Background

REQ-OCD-0016: The imager will have an internal instrument background less than either the natural background from the observed science field or the dark current of the detector whichever is greater.

5.4.6 Imager Ghost Images

REQ-OCD-0017: Ghost images generated in the imager optics must be at a level below 10^{-5} of the parent image.

5.4.7 Imager Sensitivity

REQ-OCD-0018: The imager will be capable of detecting point sources with K = 23.0 mag in 3600 s with a signal-to-noise ratio of 10 through a 0.08″×0.08″ aperture.

5.4.8 Imager On-Detector Guide Window Performance

The On-Detector Guide Window capability of the HAWAII-2RG imager detectors will be used for tip-tilt/flexure monitoring.

REQ-OCD-0041: The imager On-Detector Guide Window should be able to determine the centroid of a star with K < 19 mag to an RMS accuracy of 1/10 of the image full width at half maximum in a 30 s exposure and sense tip-tilt corrections in 0.01 s exposures on stars with K < 11 mag.

Notes and Comments:

1. There is a ~ 91% probability of having a guide star with $K \leq 19$ mag within a random 2′ diameter field at the Galactic pole, and probabilities of ~ 2.3% at the Galactic pole, ~ 2.8% at b =60º, and ~ 5.8% at b =30º for a $K \leq 11$ mag guide star.
2. MCAO fields are not random in that MCAO NGSs must be present for MCAO operation.

5.4.9 ODGW Tracking Performance

REQ-OCD-0041a: Tracking performance using the On-Detector Guide Window will result in < 0.1 pixel tracking error in the detector per 15 degree attitude change in the instrument.

5.4.10 Imager Pupil Viewer Sensitivity

REQ-OCD-0019: The imager pupil viewer will be capable of detecting the expected background emission in the *K* band with a signal-to-noise ratio of > 10 in a 1 min integration.

6 Mechanical Requirements

6.1 System Functional Requirements

6.1.1 Mechanical Duplication

REQ-FPR-0100: The mechanical design will duplicate NIRI/NIFS components to the greatest extent possible.

6.1.2 Instrument Alignment Provision

REQ-FPR-0101: A means will be provided for establishing alignment of the imager cold stop to within 1% of the projected size of the MCAO exit pupil.

Notes and Comments:

1. This requirement does not necessarily lead to the inclusion of interactive alignment aids in the design. Off-telescope alignment, together with a verification test could suffice.

6.1.3 Mechanical and Thermal Tolerances

REQ-FPR-0102: Where adequate mounting precision cannot be provided by dead reckoning, means will be provided to measure the misalignment of optical components of the imager under ambient conditions, and then adjust their alignment with a precision that allows the optical performance specification to be met. Where thermally induced misalignment is significant, theoretically derived compensation will be applied.

6.1.4 Temperature Gradients

REQ-FPR-0103: Thermal effects due to temperature gradients outside the cryostat, inside the cryostat, and near the detector will be considered in the design of GSAOI. Realistic limits will be set according to the NIRI performance. [**TBD**]

6.1.5 Thermal Transients

REQ-FPR-0104: Thermal transient effects during cool-down or warm-up will be considered in the design of GSAOI. Realistic limits will be set according to the NIRI performance. [**TBD**]

6.1.6 Instrument Volume

6.1.6.1 Space Requirement

REQ-FPR-0105: GSAOI will be designed to fulfill the space requirements for an instrument attached to the ISS.

Notes and Comments:
1. Space requirements are specified in ICD 1.1.1/1.9.

6.1.6.2 Thermal Enclosures

REQ-FPR-0106: All GSAOI thermal enclosures mounted on the ISS will be counted in the space requirements given above.

6.1.6.3 Access to Thermal Enclosures

REQ-FPR-0107: The thermal enclosures will be accessible without removing GSAOI from the ISS.

6.1.6.4 Access to Vacuum Ports

REQ-FPR-0108: Vacuum ports on GSAOI will be accessible without removing the instrument from the ISS.

6.1.6.5 Access to Cooling Water Ports

REQ-FPR-0109: Cooling water ports on GSAOI will be accessible without removing the instrument from the ISS.

6.1.6.6 Access to Dry Air Ports

REQ-FPR-0110: Dry air ports on GSAOI will be accessible without removing the instrument from the ISS.

6.1.6.7 Mechanical Connections

REQ-FPR-0111: All mechanical connections on GSAOI will be accessible without removing the instrument from the ISS and while mounted with other instruments.

6.1.7 Instrument Mass

6.1.7.1 Total Mass

REQ-FPR-0112: GSAOI, including its support frame, thermal enclosures, electronics, and all cabling and services connections, will have a mass of 2000 kg.

6.1.7.2 Center of Gravity

REQ-FPR-0113: GSAOI, including its support frame, thermal enclosures, electronics, and all cabling and services connections, will have a center of gravity on the port axis 1000 mm from the mechanical interface on the ISS.

6.1.7.3 Balance Tolerance

REQ-FPR-0114: In any orientation of the telescope and rotator, the out-of-balance caused by GSAOI must not exceed 400 Nm with respect to the telescope elevation axis. This will include static imbalance and any change in mass moment due to moving elements.

6.1.7.4 Ballast Weight

REQ-FPR-0115: A ballast weight and its supporting structure shall be supplied as required to meet the above requirements.

Notes and Comments:
1. Mass and center of gravity requirements are specified in ICD 1.5.3/1.9.

6.1.8 Cooling System

6.1.8.1 Closed-Cycle Coolers

REQ-FPR-0116: GSAOI will use a cryogenic closed-cycle cooling system.

6.1.8.2 Cooler Vibration

REQ-FPR-0117: Adequate measures will be taken to ensure that the use of cryogenic closed cycle coolers does not introduce sufficient vibrations into the mechanical structure to prevent meeting all rigidity, alignment, tracking, and other performance requirements.

6.1.9 Vacuum System

6.1.9.1 Vacuum System Facilities

REQ-FPR-0118: GSAOI will use a duplicate at Gemini South of the vacuum system facilities used by NIRI in the staging and holding areas at Gemini North.

6.1.9.2 Vacuum Pump Capacity and Selection

REQ-FPR-0119: GSAOI will use the same type of vacuum pump as NIRI.

6.1.9.3 Vacuum Operating Procedure and Set-Up

REQ-FPR-0120: GSAOI will use the same vacuum system operating procedures and set-up as NIRI.

6.1.9.4 Vacuum Test Set-Up

REQ-FPR-0121: GSAOI will use a duplicate at Gemini South of the vacuum system test set-up used for NIRI at Gemini North.

6.1.10 Mechanisms Operation

6.1.10.1 Mechanism Safety

REQ-FPR-0122: No mechanism will move in the event of loss of electrical power.

6.1.11 Environmental Cover

REQ-FPR-0123: GSAOI will be fitted with an environmental cover that can be operated either by the control system or manually in case of power failure.

6.1.12 Dust Removal System

REQ-FPR-0124: The GSAOI environmental cover will be fitted with a dry air blowing dust removal system that will also avoid condensation on the window.

6.1.13 Instrument Handling

REQ-FPR-0125: The GSAOI support frame shall have feet allowing the instrument to be stored freestanding, and attachment points for the Gemini instrument handling facilities.

6.1.14 Metric Dimensioning

REQ-FPR-0126: Metric dimensions will be used in GSAOI.

6.1.15 Metric Dimensions on Drawings

REQ-FPR-0127: Metric dimensions in millimeters will be used in all as-built drawings, with dimensions called out to 0.01 mm.

6.1.16 Metric Fasteners

REQ-FPR-0128: All screws, bolts, nuts, tapped holes, and fasteners will be of standard metric sizes, and called out as such on the as-built drawings.

6.2 System Performance Requirements

6.2.1 Instrument Alignment Maintenance

REQ-FPR-0129: The alignment of the GSAOI imager cold stop with the MCAO exit pupil will be maintained to the accuracy specified in REQ-FPR-0101 in any attitude of the telescope and rotator, and on any port of the Instrument Support Structure.

6.2.2 Cryogenic Cooling System

6.2.2.1 Cool Down Time

REQ-FPR-0131: GSAOI will have a cryogenic cooling system with the capability to cool the instrument from room temperature to operating conditions in **TBD** hours or less. Realistic limits will be set according to the NIRI performance.

6.2.2.2 Warm Up Time

REQ-FPR-0132: GSAOI will not require more than **TBD** hours to warm up the entire instrument from operating conditions to room temperature. Realistic limits will be set according to the NIRI performance.

6.2.2.3 Thermal Stability

REQ-FPR-0133: The surface on which the imager optical system is mounted will have an active temperature control system providing a variable temperature to be referenced to the center of the cold work surface between 65 K and 75 K with a stability of ±0.5 K.

6.2.3 Mechanisms Operation

6.2.3.1 Mechanism Set Time

REQ-OCD-0031: Individual GSAOI mechanisms should be set within 30 s.

6.2.3.2 Mechanism Configuration Time

REQ-OCD-0032: A complete reconfiguration of the GSAOI instrument should be achieved in < 1 min.

6.2.3.3 Repeatability of Configuration

REQ-FPR-0134: The total error at the detector resulting from reconfiguration of all mechanisms will be less than 0.5 pixels.

6.3 Imager Functional Requirements

6.3.1 Imager Filter Mechanism

REQ-FPR-0136: The imager will have two filter wheels with provision for up to 27 filters, as listed in Table 1 and Table 2.

Table 1: Upper Filter Wheel Contents

Position	Filter	λ_c (μm)	$\Delta\lambda$ (μm)	50% cut on	50% cut off
1	Clear	...	...	...	...
2	*Z*	1.015	0.170	0.930	1.100
3	*J*	1.250	0.160	1.170	1.330
4	*H*	1.635	0.290	1.490	1.780
5	*K'*	2.120	0.340	1.950	2.290
6	*Ks*	2.150	0.320	1.990	2.310
7	*K*	2.200	0.340	2.030	2.370
8	*J* continuum	1.207	0.018	1.198	1.216
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10	CH_4 (short)	1.580	0.100	1.530	1.630
11	CH_4 (long)	1.690	0.100	1.640	1.740
12	*Ks* continuum	2.093	0.031	2.078	2.108
13	*Kl* continuum	2.270	0.034	2.253	2.287
14	Spare	...	...	...	...
15	Spare	...	...	...	...

Table 2: Lower Filter Wheel Contents

Position	Filter	λ_c (μm)	$\Delta\lambda$ (μm)	50% cut on	50% cut off
1	Clear	...	...	...	...
2	He I 1.0830 μm	1.083	0.016	1.075	1.091
3	H I Pγ	1.094	0.011	1.089	1.100
4	H I Pβ	1.282	0.019	1.272	1.292
5	[Fe II] 1.644 μm	1.644	0.025	1.631	1.656
6	H_2O	2.000	0.080	1.960	2.040
7	He I (2p2s)	2.058	0.031	2.042	2.073
8	H_2 1-0 S(1)	2.122	0.032	2.106	2.138
9	H I Brγ	2.166	0.032	2.150	2.182
10	H_2 2-1 S(1)	2.248	0.034	2.231	2.265
11	CO Δv=2	2.360	0.080	2.320	2.400
12	Spare	…	…	…	…
13	Spare	…	…	…	…
14	Spare	…	…	…	…
15	Blocked	…	…	…	…

6.3.2 Imager Utility Wheel

REQ-OCD-0034: The imager will have a utility wheel for interchanging the following elements:

No.	Utility Wheel Contents
1	Clear
2	Pupil viewer
3	Convex defocus lens
4	Concave defocus lens

6.3.3 Imager Detector

6.3.3.1 Imager Detector Alignment

REQ-FPR-0137: The imager detector mosaic will be mounted such that the detector surface coincides with the imager focal plane over the full extent of the mosaic, with a precision that is finer than that corresponding to the spatial resolution of the imager. The spacing between individual detectors in the mosaic will be ≤ 2.5 mm, and the columns of the individual detectors will be parallel to < 1 pixel in 2048.

Notes and Comments:

1. The location of each detector within its chip carrier will have to be measured to < 18 μm accuracy to achieve this requirement.

6.3.3.2 Imager Detector Mechanical Interface

REQ-FPR-0138: The imager detector mosaic will be mounted such that, once adjusted, it can be removed and reinstalled without necessitating optical realignment.

6.3.3.3 Imager Detector Thermal Interface

REQ-FPR-0139: The imager detector mosaic will be thermally coupled to the cold head by high thermal conductivity material. The detector will be actively maintained at operating temperature by an electric heating element.

6.3.3.4 Imager Detector Optical Interface

REQ-FPR-0140: Means will be provided to measure the imager detector defocus error under operational conditions, and then adjust the position of the imager detector with a precision that is finer than that corresponding to the spatial resolution of the imager.

6.4 Imager Performance Requirements

6.4.1 Imager Filter Mechanism

6.4.1.1 Imager Filter Wheel(s) Orientation Stability

REQ-FPR-0144: The imager filter wheel(s) will maintain the orientation of the active element to < ±0.1 mm along the optical axis, < ±0.1 mm perpendicular to the optical axis, and with a tilt of < ±0.4 degrees, which is equivalent to a motion of ~ ±0.1 mm along the optical axis at a radius of 15 mm (i.e., half the beam diameter) from it.

6.4.1.2 Imager Filter Mechanism Setting Accuracy

REQ-FPR-0145: The imager filter mechanism will set to an accuracy of < ±0.1 mm at the optical axis.

6.4.1.3 Imager Filter Wheel(s) Setting Time

REQ-FPR-0146: The imager filter wheel(s) will complete a motion from one position to the diametrically opposite position and confirm completion within 30 s.

6.4.2 Imager Utility Wheel

6.4.2.1 Imager Utility Wheel Orientation Stability

REQ-FPR-0147: The imager utility wheel will maintain the orientation of the active element to < ±0.1 mm along the optical axis, < ±0.1 mm perpendicular to the optical axis, and with a tilt of < ±0.06 degrees, which is equivalent to a motion of ~ ±0.1 mm along the optical axis at a radius of 100 mm (i.e., the location of the first pupil viewer lens) from it.

6.4.2.2 Imager Utility Wheel Setting Accuracy

REQ-FPR-0148: The imager utility wheel will set to an accuracy of < ±0.1 mm at the optical axis.

6.4.2.3 Imager Utility Wheel Setting Time

REQ-FPR-0149: The imager utility wheel will complete a motion from one position to the diametrically opposite position and confirm completion within 30 s.

Detector Requirements

7.1 Imager Detector Functional Requirements

7.1.1 Imager Detector Device

REQ-FPR-0200: The imager detector will be a 4096×4096 mosaic of four Rockwell HAWAII-2RG HgCdTe/CdZnTe MBE devices with 2048×2048 18 μm pixels and separated by 2.5 mm.

7.1.2 Imager On-Detector Guide Window

REQ-OCD-0038: The imager will have a facility for defining and processing data from a rectangular guide window on the imager detector that will be used for monitoring tip-tilt motion due to flexure variations between MCAO and GSAOI, and for performing fast tip-tilt sensing when substituting for one of the MCAO NGS sensors.

7.1.3 Imager Detector Electrical Interface

REQ-FPR-0201: The electrical interface to the imager detector will be through suitable sockets.

7.1.4 Imager Detector Controller

7.1.4.1 Imager Detector Controller Type

REQ-FPR-0202: The imager detector will be controlled by an SDSU detector controller.

7.1.4.2 Imager Detector Controller Mechanical Interface

REQ-FPR-0203: The imager detector controller will be mounted on an external wall of the cryostat. The controller power supply will be mounted in one of the thermal enclosures.

7.1.4.3 Imager Detector Controller Thermal Interface

REQ-FPR-0204: The imager detector controller will be actively cooled with the coolant supplied via the Cassegrain Rotator Utilities Box.

7.1.4.4 Imager Detector Controller Readout Methods

REQ-FPR-0216: The imager detector controller will support double correlated sampling and Fowler sampling read out methods for the imager detector.

7.1.4.5 Imager Detector Controller Integration Times

REQ-FPR-0217: The imager detector controller will support integration times for the imager detector from 1 s to 10,000 s.

7.1.4.6 Imager Detector Controller Fowler Samples

REQ-FPR-0219: The imager detector controller will allow between 1 and 64 Fowler samples to be obtained before and after the integration in the Fowler sampling read out method.

7.1.4.7 Imager Detector Controller Number of Coadds

REQ-FPR-0220: The imager detector controller will support the coaddition of between 1 and 1000 imager detector data frames before the result is transferred to the DHS and archived.

7.1.4.8 Imager Detector Controller Regions of Interest

REQ-FPR-0229: The imager detector controller will support fixed-format regions of interest with pre-defined 64×64, 128x128, 256×256, 512×512, and 1024×1024 pixel windows at the centers of each HAWAII-2RG detector, and 512x512 and 1024x1024 pixel windows at the center of the mosaic.

7.1.4.9 Imager Detector Controller Guide Window Definition

REQ-FPR-0221: The imager detector controller will support the definition of a single On-Detector Guide Window in any position on any one of the four detectors of the mosaic. The window size is pre-defined to be 8x8, 12x12, 16x16, or 32x32 pixels.

7.1.4.10 Imager Detector Controller Guide Window Integration Time

REQ-FPR-0222: The imager detector controller will support integration times for the imager detector On-Detector Guide Window from 10 ms to 1000 s.

7.2 Imager Detector Performance Requirements

7.2.1 Imager Detector Read Noise

REQ-OCD-0039: The imager detector will employ read noise reduction techniques, such as Fowler sampling, to achieve an effective read noise of < 10 e.

7.2.2 Imager Detector Dark Current

REQ-OCD-0040: The imager detector will have a dark current < 0.1 e s^{-1} pix^{-1}.

7.2.3 Imager Detector Stability

7.2.3.1 Imager Detector Bias Variations

REQ-FPR-0205: Over a period equal to the longest anticipated integration time of 3600 s, bias variations will be < 50 electrons.

Notes and Comments:

1. The lowest background signal is expected to be ~ 0.82 e s^{-1} in the H I Pγ filter. This will produce an RMS noise of ~ 54 e in 3600 s. Bias drifts should be less than this background noise.

7.2.3.2 Imager Detector Gain Variations

REQ-FPR-0206: Over a period equal to the longest integration time of 3600 s, gain variations will be less than the photometric stability of the atmosphere, which is taken to be 1%.

7.2.4 Imager Detector Maximum Continuous Frame Rate

REQ-FPR-0223: The imager detector will be read out at a maximum continuous frame rate of at least 0.05 Hz.

Notes and Comments:

1. The 20 s minimum frame time comprises a 5 s read time prior to integration, a 5 s read time after integration, and 10 s in which to process the data and transfer it to the DHS (§10.2.3.1).

7.2.5 Imager On-Detector Guide Window Maximum Continuous Frame Rate

REQ-FPR-0224: The imager On-Detector Guide Window will be read out at a maximum continuous frame rate of ≥ 100 Hz using a 12×12 pixel guide window. Guide window reads need not continue while the imager detector is being read out.

Control System Requirements

8.1 Mechanism Control System Functional Requirements

8.1.1 Mechanism Control System Duplication

REQ-FPR-0300: The mechanism control system will duplicate the NIRI/NIFS mechanism control system to the greatest extent possible.

8.1.2 Mechanism Control System Operability

REQ-FPR-0301: All mechanisms and controlled features of GSAOI will be controllable by a Gemini-standard IOC computer.

8.1.3 Mechanisms

REQ-FPR-0302: The mechanism control system will control the following mechanisms:

Mechanism	Type	Positions
Environmental cover	Open/closed	2
Imager upper filter wheel	Rotary	15
Imager lower filter wheel	Rotary	15
Imager utility wheel	Rotary	4

8.2 Mechanism Control System Performance Requirements

8.2.1 Configuration Time

REQ-FPR-0303: The control system overhead on the mechanism configuration times will be such that the total GSAOI configuration time is within the limit set by REQ-OCD-0032.

8.2.2 Impact on Mechanism Accuracy

REQ-FPR-0304: The accuracy of the GSAOI controllable mechanisms will not be limited by the performance of the control system.

8.2.3 Impact on Scientific Performance

REQ-FPR-0305: The control system will not degrade the scientific performance of GSAOI. In particular, attention shall be given to the impact of the control actuators and sensors on the thermal regime of the instrument, including their thermal radiation.

8.3 Temperature Control System Functional Requirements

8.3.1 Temperature Control System Duplication

REQ-FPR-0306: The temperature control system will duplicate the NIRI/NIFS temperature control system to the greatest extent possible.

8.3.2 CWS Plate Temperature

REQ-FPR-0307: The GSAOI optical elements will be temperature stabilized by heat sinking to the cold work surface plate that is temperature controlled by the temperature control system.

8.3.3 Imager Detector Temperature Control

REQ-FPR-0308: The imager detector assembly will have an active temperature control system providing a variable temperature to be set at the optimum temperature for the detector between 60 K and 70 K.

8.3.4 Limiting Rate of Temperature Change

REQ-FPR-0310: If the thermal characteristics of GSAOI introduce extreme rates of temperature change on cooling down, the temperature control system will limit the rate of change at the detector to 0.25 K per minute.

8.3.5 Speeding the Warming Up

REQ-FPR-0311: If the thermal characteristics of GSAOI are such that warming up by turning off the cryo-coolers will not meet the requirement in REQ-FPR-0132, the temperature control system will actively heat the detector and the cold plate to speed the warming up, so that GSAOI meets this requirement, but the rate of change of temperature shall be limited to 0.25 K per minute.

8.3.6 Safety of Accelerated Warm-Up

REQ-FPR-0317: To safeguard the instrument against accidental activation of the accelerated warm-up system, it must only be activated manually for a preset period of time. Over-temperature switches on the cold work surface shall protect against overheating.

8.3.7 Temperature Monitoring

8.3.7.1 Temperature Sensors

REQ-FPR-0312: In addition to the sensors for temperature control, temperature sensors are required to monitor the cryogenic environment within the vacuum jacket at the locations listed below, and to monitor the air temperature in the thermal enclosures::

1. On the first stage of the cryocooler that cools the imager detector.
2. On the attachment of the cold strap from this cryocooler to the cold work surface plate.
3. On the edge of the cold work surface plate furthest removed from the cryocooler cold straps.
4. On the getter assembly that is connected to the second stage of the cryocooler which is not used to cool the imager detector.
5. Components Controller thermal enclosure.
6. Detector Controller thermal enclosure.

8.3.7.2 Temperature Sensor Interfaces

REQ-FPR-0313: The temperature sensor read-out interface will be part of the Engineering Interface as described in §10.1.3.

Notes and Comments:

1. The thermal enclosures contain over-temperature switches, which cut the power supply if the temperature exceeds 50°C.

8.4 Temperature Control System Performance Requirements

8.4.1 CWS Plate Temperature Stability

REQ-FPR-0314: The GSAOI cold work surface plate will be temperature stabilized to < 0.5 K as required by REQ-FPR-0133.

8.4.2 Imager Detector Temperature Stability

REQ-FPR-0315: The imager detector assembly will be temperature stabilized to < 1 mK, which will allow it to meet the bias stability requirements of REQ-FPR-0205.

9 Electrical and Electronic Requirements

9.1 Electrical and Electronic Requirements

9.1.1 Grounding and Shielding

REQ-FPR-0400: Separate ground returns will be provided for low-level signals, noisy components such as relays and motors, and hardware components such as mechanical enclosures, chassis, and racks.

Notes and Comments:

1. Good grounding practice is discussed in Ott, H. W., Noise Reduction Techniques in Electronic Systems, Second Edition, AT&T Bell Laboratories, 1988, Chapter 3.
2. Gemini electronic design guidelines are described in Gemini Electronic Design Specification, SPE-ASA-G0008.

9.1.2 Electrostatic Discharge

REQ-FPR-0401: The GSAOI design will ensure that sensitive components are protected from electrostatic discharge.

Notes and Comments:

1. Electrostatic discharge is discussed in Ott, H. W., Noise Reduction Techniques in Electronic Systems, Second Edition, AT&T Bell Laboratories, 1988, page 332.
2. Gemini electronic design guidelines are described in Gemini Electronic Design Specification, SPE-ASA-G0008.

9.1.3 Power Dissipation

REQ-FPR-0402: Individual elements exposed to the air volume will not attain a temperature 2°C above ambient.

9.1.4 Cassegrain Cable Wrap Interfaces

The requirements on the electrical and electronics interfaces with the Cassegrain cable wrap are included in §11.1.

Notes and Comments

1. Cassegrain cable wrap interfaces are provided by the break out panels on the ISS.

10 Software Requirements

10.1 Software Functional Requirements

10.1.1 Software Duplication

REQ-FPR-0500: The GSAOI software system will duplicate the NIRI/NIFS software system to the greatest extent possible.

10.1.2 Conforming Instrument

REQ-FPR-0501: GSAOI will be a "conforming" instrument, in that it will use EPICS and conform to Gemini software and control system standards and the requirements listed below.

10.1.2.1 Use of EPICS

REQ-FPR-0502: GSAOI will use a standard Gemini configuration of a workstation for the operator interface, connected to an EPICS-based system used for controlling motors, coolers, and heaters and for receiving status information from sensors.

10.1.2.2 EPICS System

REQ-FPR-0503: The EPICS system will be a standard Gemini unit (VME crate, Motorola PPC VME Architecture Single Board Computer, VxWorks operating system.).

10.1.2.3 Interfaces to the Gemini System

REQ-FPR-0505: Interfaces to the Gemini system will conform to the descriptions presented in the Core Instrument Control Software (CICS) documentation. In particular, all Observatory Control System (OCS) commands to, and responses from, GSAOI will be by CAD, CAR and SIR EPICS records as described in the CICS documentation. Interfaces to other Gemini subsystems will conform to the relevant Interface Control Documents.

Notes and Comments:

1. The Gemini Software Design Description (SPE-C-G0037) contains guidelines for developing Gemini-compatible software.
2. Low-level software in GSAOI will be a mixture of EPICS code and C/C++ coded tasks, both running directly on VxWorks.

10.1.3 Engineering Interface

10.1.3.1 Engineering Interface Function

REQ-FPR-0506: GSAOI will provide a means for command and control of GSAOI mechanisms and imager detector controller, and data capture from the imager detector without the need for having Gemini control systems (i.e., the Observatory Control System and the Telescope Control System) present or connected.

10.1.3.2 Engineering Interface Physical Interface

REQ-FPR-0507: The Engineering Interface will use a Sun/Solaris workstation of the same type as that used for the Instrument Control System that runs with other Gemini control systems.

10.1.3.3 Engineering Interface User Interface

REQ-FPR-0508: To the extent practicable, the user interface in the Engineering Interface should appear to a user to be similar to the NIRI Engineering Interface.

10.1.3.4 Engineering Interface Command and Control

REQ-FPR-0509: The Engineering Interface will be capable of commanding and controlling all GSAOI mechanisms and reading status from all GSAOI sensors.

10.1.3.5 Engineering Interface Data Capture

REQ-FPR-0510: The Engineering Interface will be capable of capturing data from GSAOI imager detector.

Notes and Comments:

1. It is expected (but not required) that the Engineering Interface would use at least DM, a part of EPICS, in its implementation.
2. Not all data readout modes need be supported. The data that is captured may require extensive processing normally done by the GSAOI Instrument Control System or the Gemini Data Handling System (DHS) to be intelligible. There is no requirement for the Engineering Interface to perform this data processing, which may be done off-line on another system to analyze results. The Engineering Interface may send unscrambled data to the DHS to be shown in a Quick Look Display.

10.1.4 Mechanisms Control

10.1.4.1 Mechanism Control Operability

REQ-FPR-0511: All mechanisms and controlled features of GSAOI will be controlled through the standard EPICS control paths from the Instrument Control System.

10.1.4.2 Mechanisms

REQ-FPR-0512: The software system will control the mechanisms listed in §8.1.3

10.1.4.3 Generic Filter Wheel

REQ-FPR-0513: The software system will maintain the concept of a single virtual filter wheel to the user such that any filter can be selected with a single filter command.

10.1.4.4 No Clear Optical Path

REQ-FPR-0514: The software system will prevent clear positions being simultaneously configured in the imager upper and lower filter wheels and will prevent this occurring during configuration by coordinating the motion of the filter wheels.

Notes and Comments:

1. The set time of the virtual filter wheel will be the set time of an individual filter wheel plus the overhead related to this requirement. This must be accomplished within the total GSAOI configuration time as defined in REQ-OCD-0032.

10.1.5 Temperature Control

10.1.5.1 CWS Plate Temperature

REQ-FPR-0515: The software system will configure the temperature controller stabilizing the temperature of the cold work surface plate.

10.1.5.2 Imager Detector Temperature Control

REQ-FPR-0516: The software system will configure the temperature controller stabilizing the temperature of the imager detector assembly.

10.1.5.3 Temperature Monitoring

REQ-FPR-0520: The software system will log and report temperatures from the temperature sensors monitoring the cryogenic environment within the vacuum jacket and at the detectors.

10.1.5.4 Imager Detector Temperature During Warm Up

REQ-FPR-0548: The software system will maintain the imager detector temperature between 5º and 20º higher than the Cold Work Surface plate temperature during warm up.

Notes and Comments:

1. The detector is maintained at a slightly elevated temperature to ensure that gases released during warm up do not condense on the detector.

10.1.6 Imager Detector

10.1.6.1 Imager Detector Controller DSP Code

REQ-FPR-0521: The software system will down load DSP code to the SDSU detector controllers controlling the imager detector.

10.1.6.2 Imager Detector Controller Configuration

REQ-FPR-0522: The software system will initialize the SDSU detector controllers controlling the imager detector by setting bias and clock voltages, selecting timing files, and clearing data buffers.

10.1.6.3 Imager Detector Read Out

REQ-FPR-0523: The software system will control all functions associated with defining and executing an exposure of the imager detector. This includes defining the read out method, integration time, and number of coadded data frames.

10.1.6.4 Imager Detector Read Out Methods

REQ-FPR-0524: The software system will support the read out methods of the imager detector as defined in detector functional requirement REQ-FPR-0216.

10.1.6.5 Imager Detector Integration Times

REQ-FPR-0525: The software system will support integration times for the imager detector as defined in detector functional requirement REQ-FPR-0217

10.1.6.6 Imager Detector Fowler Samples

REQ-FPR-0527: The software system will allow between a number Fowler samples to be obtained before and after the integration in the Fowler Sampling read out method as defined in detector functional requirement REQ-FPR-0219.

10.1.6.7 Imager Detector Number of Coadds

REQ-FPR-0530: The software system will support the coaddition of a number of imager detector data frames before the result is transferred to the DHS and archived as defined in detector functional requirement REQ-FPR-0220

10.1.6.8 Imager Detector Data Unscrambling

REQ-FPR-0531: The software system will unscramble data from the four imager detectors and transfer a single data frame with a consistent orientation to the DHS.

10.1.6.9 Imager Detector World Coordinate System

REQ-FPR-0550 The software system will obtain world coordinate information from calibration files and the Telescope Control System (TCS), compute standard FITS WCS parameters, then pass these to the Data Handling System (DHS) for inclusion in the FITS header.

10.1.6.10 Imager Detector Regions of Interest

REQ-FPR-0551: The software system will support fixed-format regions of interest on the imager detector with pre-defined as defined in detector functional requirement REQ-FPR-0229.

10.1.6.11 Imager On-Detector Guide Window Definition

REQ-FPR-0532: The software system will include a means for defining an On-Detector Guide Window as defined in detector functional requirement REQ-FPR-0221

10.1.6.12 Imager On-Detector Guide Window Data Acquisition

REQ-FPR-0533: The software system will control the read out of the On-Detector Guide Window defined for the imager detector and oversee the transfer of data to the A&G IOC for tip-tilt processing.

Notes and Comments:

1. The imager detector On-Detector Guide Window clocking must be performed by the imager detector controller. This means that the guide window must be defined via the GSAOI DC IOC software. This IOC may also have to initiate read outs.
2. The manner in which On-Detector Guide Window data is routed to the A&G IOC is **TBD**.

10.1.6.13 Imager On-Detector Guide Window Integration Times

REQ-FPR-0534: The software system will support integration times for the imager detector On-Detector Guide Window from 10 ms to 1000 s.

10.1.6.14 Observing Modes

REQ-OCD-0043: GSAOI will support a View mode for acquiring temporary imaging data and an Observe mode for acquiring archived imaging data.

10.2 Software Performance Requirements

10.2.1 Mechanisms Control

10.2.1.1 Configuration Time

REQ-FPR-0542: The software system overhead on the mechanism configuration times will be such that the total GSAOI configuration time is within the limit set by REQ-OCD-0032.

10.2.1.2 Impact on Mechanism Accuracy

REQ-FPR-0543: The accuracy of the GSAOI controllable mechanisms will not be limited by the performance of the software system.

10.2.2 Temperature Control

10.2.2.1 Impact on Temperature Control Accuracy

REQ-FPR-0544: The accuracy of the GSAOI temperature control will not be limited by the performance of the software system.

10.2.3 Imager Detector

10.2.3.1 Imager Detector Maximum Continuous Frame Rate

REQ-FPR-0545: The software system will read out a full imager detector frame, process the data, and transfer it to the DHS at a maximum continuous frame rate as defined in detector performance requirement REQ-FPR-0223

Notes and Comments:

1. The 20 s minimum frame time comprises a 5 s read time prior to integration, a 5 s read time after integration, and 10 s in which to process the data and transfer it to the DHS.
2. Current information is that the DHS can handle 2.8 MB/s. A full imager detector frame in Real*4 format contains 64 MB, so the minimum transfer time to the DHS is currently 22.9 s. **[TBD]** Actually, testing has shown that best achievable rate when the DHS server runs on SunBlade 1000 with 2x900MHz CPUs and 1GB RAM is 2.2MB/s.
3. Processing (summing, averaging, coadding and unraveling pixels) of a full imager detector frame is expected to take an additional ~ 2.3 s using a 400 MHz SVGM5 processor with the Altivec vector unit.
4. A speed increase for the DHS by a factor of ~ 3 would be required by upgrading existing Gemini hardware and software. Testing at RSAA has shown that this is currently not achievable.
5. Higher continuous frame rates may be achieved by pipelining the data read and data transfer functions. This will not reduce the time to record a single frame.

10.2.3.2 Imager On-Detector Guide Window Maximum Continuous Frame Rate

REQ-FPR-0546: If it is part of the guide window data path, the software system will be capable of reading out the guide window on the imager detector and transferring the data to the A&G IOC as defined in detector performance requirement REQ-FPR-0224

Notes and Comments:

1. The GSAOI DC IOC software may form part of the guide window data path.

11 External Interfaces

11.1 Cassegrain Rotator Interfaces

11.1.1 Instrument Support Structure Interface

REQ-FPR-0600: GSAOI will interface mechanically to the Gemini Instrument Support Structure (ISS).

11.1.1.1 ISS Ports

REQ-FPR-0601: GSAOI will be capable of being mounted on and used at any side-looking science instrument ISS port or the upward-looking port at the bottom of the ISS.

11.1.1.2 Instrument Mounting Plate Flatness

REQ-FPR-0602: The GSAOI mounting interface will be repeatable within the optical tolerances of the alignment between GSAOI and ISS when removed and replaced.

11.1.1.3 Instrument Mounting Plate Material

REQ-FPR-0603: The GSAOI mounting interface will take into account the material of which the ISS is made and will hold differential temperature effects to a level that permits GSAOI to meet all optical alignment and safety requirements over the entire operating temperature range.

11.1.1.4 Instrument Mounting Plate Fasteners

REQ-FPR-0604: The fasteners that are engaged for load transfer from the Cassegrain handling rig will be sized for a safe working load that includes a static and dynamic factor of safety to accommodate predicted loads on the Gemini telescope.

11.1.1.5 Optical Feed

REQ-FPR-0605: GSAOI will accept and use the MCAO optical feed, which is approximately f/34 with a focal length of 272 m. The beam comes to a focus 300 mm from the ISS mounting surface inside GSAOI.

Notes and Comments:

1. The ISS to Science Instrument ICD is 1.5.3/1.9. The ISS introductory ICD (ICD 1.5.3) is also relevant.
2. Fastener design must accommodate the changing direction of the gravity vector due to rotation of the ISS and positioning of the telescope.

11.1.2 Helium Interface

REQ-FPR-0606: GSAOI will obtain helium for its cryocoolers and return low pressure helium through the connectors provided in the Cassegrain Rotator Utility Box appropriate to each instrument port.

Notes and Comments:

1. The helium interface is described in ICD 1.9/3.6.

11.1.2.1 Number of Helium Connections

REQ-FPR-0607: GSAOI will have one high pressure connection for the entire instrument, and one low pressure return for the entire instrument. Each of these lines will have appropriate tees on the instrument to service the cryocooler heads.

11.1.2.2 Length of Helium Line Runs

REQ-FPR-0608: The high and low pressure lines to the Cassegrain Rotator Utility Box will be of a length that permits GSAOI to meet the requirement of REQ-FPR-0601.

11.1.2.3 Helium Line Flexibility

REQ-FPR-0609: The high and low pressure lines to the Cassegrain Rotator Utility Box will be flexible enough to permit easy routing, connection, disconnection, and dressing for operation.

11.1.2.4 Type of Helium Connectors

REQ-FPR-0610: The high-pressure line will connect to the Cassegrain Rotator Utility Box using a connector described in ICD 1.9/3.6.

Notes and Comments:

1. It is expected that Gemini will provide a helium supply of 3200 SLPM at a pressure of 300 psi. All helium delivered to GSAOI is expected to be 99.999% pure.
2. Details of the helium supply are in ICD 1.9/3.6.

11.1.3 Electric Power Interface

REQ-FPR-0611: GSAOI will derive its electric power through the connectors provided on the Cassegrain Rotator Utility Box appropriate to each instrument port.

Notes and Comments:

1. The power interface is part of ICD 1.9/3.6.

11.1.3.1 Number of Electric Power Connections

REQ-FPR-0612: GSAOI will have two pairs of electric power connections for the entire instrument. One pair will provide "clean" UPS power for the computer and electronics, while the other will provide "dirty" Mains power for motors, relays and fans. Each thermal enclosure connects to both the UPS and Mains power. The cryocoolers may require connection to the optional 220 V./3 phase power outlet.

11.1.3.2 Length of Electric Power Line Runs

REQ-FPR-0613: The power lines to the Cassegrain Rotator Utility Box will be of a length that permits GSAOI to meet the requirement of REQ-FPR-0601.

11.1.3.3 Electric Power Line Flexibility

REQ-FPR-0614: The electric power lines to the Cassegrain Rotator Utility Box will be flexible enough to permit easy routing, connection, disconnection, and dressing for operation.

11.1.3.4 Type of Electric Power Connectors

REQ-FPR-0615: AC power is provided to the science instrument via two, dual 3-prong, 120 VAC outlets (NEMA 5-15) mounted on the cable wrap interface plate. One outlet pair is UPS-conditioned power and the other is building mains power. The cable connector at the interface to the instrument is a circular MIL-style connector, MS3106R16-10S. The corresponding instrument connector must be an MS3100R16-10P. AC voltage at both observatories will be 120 VAC. Line frequency for Cerro Pachon is 50 Hz, while the Mauna Kea frequency is the US standard 60 Hz.

Notes and Comments:
1. Gemini will provide an electric power supply as described in ICD 1.9/3.6.

11.1.4 Cooling Water Interface

REQ-FPR-0616: GSAOI will derive cooling water supply (and return) for electronic enclosures and any other use through the connectors provided on the Cassegrain Rotator Utility Box appropriate to each instrument port.

11.1.4.1 Number of Cooling Water Connections

REQ-FPR-0617: GSAOI will have one cooling water supply connection and one return line connection for the entire instrument. GSAOI will have appropriate tees from these lines to serve all instrument cooling water needs.

11.1.4.2 Length of Cooling Water Runs

REQ-FPR-0618: The cooling water lines to the Cassegrain Rotator Utility Box will be of a length that permits GSAOI to meet the requirement of REQ-FPR-0601.

11.1.4.3 Cooling Water Line Flexibility

REQ-FPR-0619: The supply and return lines to the Cassegrain Rotator Utility Box will be flexible enough to permit easy routing, connection, disconnection, and dressing for operation.

11.1.4.4 Type of Cooling Water Connectors

REQ-FPR-0620: The cooling water lines will connect to the Cassegrain Rotator Utility Box using a connector of type Parker #FS-501-8FP Quick Disconnect and of female gender. The connector will not permit more than a drop or two of coolant to escape the system when connecting or disconnecting the supply and return lines, and will not leak during normal operation.

11.1.4.5 Resistance to Glycol

REQ-FPR-0621: The coolant lines and connectors will not be damaged in any way when used with a cooling solution containing glycol-ethylene.
Notes and Comments:
1. It is expected that Gemini will provide a cooling water supply of 12 liters/minute at a pressure of 15 psi and a temperature of 0°C. The low-pressure return line is expected to carry 12 liters/minute at a pressure of 10 psi and a temperature of 4°C.
2. Coolant mixture is Dowtherm SR-1, 40% by volume, and water.
3. The corrosion inhibitors in the coolant react with zinc to form a milky white paste that clogs the heat exchangers and piping system. Therefore, absolutely NO zinc or galvanized coated fittings, pipes or components are allowed to come into contact with the coolant
4. The cooling water interface is described in ICD 1.9/3.6.

11.1.5 Signal, Control, and Data Interfaces

REQ-FPR-0622: GSAOI will receive and provide all signal, control, and data paths through the connectors provided on the Cassegrain Rotator Utility Box appropriate to each instrument port.

11.1.5.1 Number of Signal, Control, and Data Connections

REQ-FPR-0623: GSAOI will have one connection for the entire instrument to the appropriate Cassegrain Rotator Utility Box for each of the following, if needed. GSAOI will have appropriate tees from these lines

to serve all instrument needs. In/out signals marked with * must be bridged at the cable wrap connector plate when not connected to instruments.

Circuit	Connector Type Cable Wrap	Instrument	Cable Connector
Control LAN in*	Fiber duplex SC	Fiber duplex SC	Fiber
Control LAN out*	Fiber duplex SC	Fiber duplex SC	Fiber
Time LAN in*	BNC Female	BNC Female	Coax RG58
Time LAN out*	BNC Female	BNC Female	Coax RG58
Terminal Server Console Port	Fiber duplex SC	Fiber duplex SC	Fiber
Data bus (star)	Fiber duplex SC	Fiber duplex SC	Fiber
Auxiliary Boot	KPSE00F18-11S	KPSE00F18-11P	Multi-connector
Interlock System	MS3120-F12-10S	MS3120-F12-10S	#22AWG, twisted pairs

Notes and Comments:
1. The event bus is used for chopping, which GSAOI will not require.
2. The Video LAN is non-existent.
3. GSAOI will not have to connect to the synchro bus.

11.1.5.2 Length of Signal, Control, and Data Runs

REQ-FPR-0624: The signal, control, and data lines to the Cassegrain Rotator Utility Box will be of a length that permits GSAOI to meet the requirement of REQ-FPR-0601.

11.1.5.3 Signal, Control, and Data Line Flexibility

REQ-FPR-0625: The signal, control, and data lines to the Cassegrain Rotator Utility Box will be flexible enough to permit easy routing, connection, disconnection, and dressing for operation.

Notes and Comments:
1. ICD 1.9/3.6 contains references to all but the non-existent video LAN and the Interlock System that is described in ICD 1.1.13/1.9.
2. There is also an auxiliary boot RS-232 to each instrument IOC control. Control, Time, Synchro, and Event LANs are in/out connector pairs.

11.1.6 Vacuum Interfaces

REQ-FPR-0626: GSAOI will be provided with interfaces for the connection of vacuum lines when the instrument is attached to the ISS at the telescope.

Notes and Comments:
1. It is not intended to provide vacuum lines in the ISS. This requirement is to provide for the ability to evacuate GSAOI when the instrument is attached to the ISS at the telescope.
2. Under normal conditions the instrument will be evacuated in the lab. If necessary, portable equipment will be used to evacuate GSAOI at the telescope.

11.1.7 Dry Air Interface

REQ-FPR-0627: GSAOI will derive dry air for flushing the cryostat window from the supply line on the Cassegrain Rotator Utility Box appropriate to each port.

11.1.7.1 Number of Dry Air Line Connections

REQ-FPR-0628: GSAOI will have one connection to the dry air supply for the entire instrument. GSAOI will have appropriate tees from this line to serve all instrument dry air supply needs.

11.1.7.2 Length of Dry Air Lines

REQ-FPR-0629: The dry air lines to the Cassegrain Rotator Utility Box will be of a length that permits GSAOI to meet the requirement of REQ-FPR-0601.

11.1.7.3 Dry Air Line Flexibility

REQ-FPR-0630: The dry air lines to the Cassegrain Rotator Utility Box will be flexible enough to permit easy routing, connection, disconnection, and dressing for operation.

11.1.7.4 Type of Dry Air Line Connector

REQ-FPR-0631: The dry air line will connect to the Cassegrain Rotator Utility Box using a connector of type Aeroquip #FD40-1014-06-06, Male half, non-valved, Male pipe end fitting.

Notes and Comments:
1. It is expected that Gemini will provide an air supply of 120 SLPM at a pressure of 80 -100 psi.
2. The dry air supply interface is covered in ICD 1.9/3.6.
3. The air supply from the ISS is compressed air. This can be used for flushing the entrance window if an in-line filter is used to trap any residual water that is in the line.

11.2 Control Systems Interfaces

11.2.1 Observatory Control System to GSAOI Instrument Sequencer

REQ-FPR-0632: A Parameter Definition Format document describing the CAD/CAR and SIR records used by the Instrument Sequencer will be presented.

Notes and Comments:
1. The Observatory Control System Interface is described in ICD 1.1.11/1.9.
2. The Parameter Definition Format document is defined in ICD 16.

11.2.2 Observatory Control System to GSAOI Components Controller

REQ-FPR-0633: A Parameter Definition Format document describing the CAD/CAR and SIR records used by the imager Components Controller will be presented.

Notes and Comments:
1. The Observatory Control System Interface is covered by ICD 1.9/3.1.
2. The Parameter Definition Format document is defined in ICD 16.

11.2.3 Observatory Control System to GSAOI Detector Controller

REQ-FPR-0634: A Parameter Definition Format document describing the CAD/CAR and SIR records used by the imager Detector Controller will be presented.

Notes and Comments:
1. The Observatory Control System Interface is covered by ICD 1.9/3.1.
2. The Parameter Definition Format document is defined in ICD 16.

11.2.4 Acquisition and Guidance Unit to GSAOI Detector Controller

REQ-FPR-0636: The GSAOI SDSU detector controller will interface to the Acquisition and Guide Unit for the transfer of on-detector guide window control and image data through **TBD**.

11.2.5 Data Handling System Interface

REQ-FPR-0637: GSAOI will use the DHS for permanent and temporary storage of GSAOI science data and GSAOI calibration frames, and transient storage of GSAOI data for display.

Notes and Comments:
1. The Data Handling System Interface is defined in ICD 1.9/3.2, and the physical interface is included in ICD 1.9/3.6.

11.2.6 Interlock System Interface

REQ-FPR-0638: GSAOI will interface with the Gemini Interlock System (GIS).

11.2.6.1 Interlock System Mechanical Interface

REQ-FPR-0639: GSAOI will provide a cable to connect to the GIS. The cable will use a connector of type MS3126F12-10S to connect to the Instrument Services connector plate (of type MS3120F12-F10P; supplied by Gemini), and a connector of type MS3126F12-10P to connect to the Instrument Thermal Enclosure connector plate (of type MS3120F12-10S).

11.2.6.2 Interlock System Electrical Interface

REQ-FPR-0640: Signals between GSAOI and GIS will be optically isolated by GSAOI. The signals from GSAOI will be a conjugate pair of open-collector outputs. The signals from the GIS will be a conjugate pair of open-collector outputs.

Notes and Comments:
1. Leaving a door open on a thermal enclosure requires a complete stop of the telescope.
2. Some local interlocks should immediately notify the operator that GSAOI has shut down. For example: a helium failure or overheating of the electronics.
3. The physical interface is described in ICD 1.9/3.6.
4. The electrical interface is described in ICD 1.1.13/1.9.

11.2.7 Events Bus Interface

REQ-FPR-0641: GSAOI does not use the Event Bus.

Notes and Comments:
1. The physical interface is described in ICD 1.9/3.6.

11.2.8 Synchro Bus Interface

REQ-FPR-0642: GSAOI does not use the Synchro Bus.

Notes and Comments:
1. The physical interface is described in ICD 1.9/3.6.
2. The Synchro Bus In/Out Connector is dual SC fiber.

11.2.9 Time LAN Interface

REQ-FPR-0643: GSAOI will interface with the Time LAN to time-stamp images.

Notes and Comments:
1. The physical interface is described in ICD 1.9/3.6.
2. The Time LAN to IOC thermal enclosure is BNC in and BNC out.

12 Environmental Requirements

12.1 Altitude Environment

12.1.1 Transportation Altitudes

REQ-FPR-0700: GSAOI will be capable of being transported at any altitude between -70 m and 4,200 m by any transportation mode. GSAOI will be capable of being transported by commercial jet with pressurized cargo compartments at altitudes up to 15 km.

12.1.2 Storage Altitudes

REQ-FPR-0701: GSAOI will be capable of being stored in or out of its shipping container at any altitude between -70 m and 4,200 m.

12.1.3 Operation Altitudes

REQ-FPR-0702: GSAOI will be capable of being operated at any altitude between -70 m and 4,200 m.

Notes and Comments:

1. GSAOI must work at the Base Facility, at an altitude of approximately sea level, and at the telescopes on Mauna Kea and Cerro Pachon.

12.2 Temperature Environment

12.2.1 Operational Environment

REQ-FPR-0703: GSAOI operational temperature environment will be limited to -15 to +25°C.

12.2.2 Survival Environment

REQ-FPR-0704: GSAOI will be capable of surviving a temperature range of -20 to +50°C without damage.

12.2.3 Transport Environment

REQ-FPR-0705: GSAOI will be capable of withstanding a temperature range of -20 to +50°C during transport without damage.

12.3 Humidity Environment

REQ-FPR-0706: GSAOI will be capable of being transported and stored, in a wide range of humidity environments in the range 0 to 100% relative humidity, with condensing moisture.

Notes and Comments:

1. Operation of GSAOI at high relative humidity levels will cause condensation on the cryostat window. Using heaters on the window or a hot air system are incompatible with the thermal management of the telescope. Dry, ambient temperature air will be provided in the ISS for window flushing.

12.4 Vacuum Environment

REQ-FPR-0707: GSAOI will maintain a vacuum of $< 10^{-5}$ torr inside the cryostat.

12.4.1 Creating the Vacuum

REQ-FPR-0708: GSAOI will provide a means to evacuate its cryostat while the instrument is on its handling rig in the instrument support area, and while it is attached to the ISS.

12.4.2 Vacuum Duration Cold

REQ-FPR-0709: GSAOI will be capable of being kept cold and operated without measurable degradation of scientific performance for 3 months.

12.4.3 Vacuum Duration Warm

REQ-FPR-0710: If needed, the instrument will be capable of being kept at room temperature without contamination of the detector or internal optics significantly affecting the scientific performance for at least 3 months without pumping.

Notes and Comments:

1. Instruments will be pumped down in the instrument support facility, and then transported to the telescope.
2. Operating vacuum may only be obtained with a cold instrument.

12.5 Mechanical Environment

REQ-FPR-0711: GSAOI will be capable of operating in the mechanical environment of the Gemini telescopes and their base facilities, and will be capable of withstanding shipment among Tucson, Hilo, Mauna Kea, and Cerro Pachon.

12.5.1 Telescope Slew Rates

REQ-FPR-0712: GSAOI will be capable of withstanding slew rates of 2° per second in azimuth and 0.75° per second in elevation, or any combination of these along with rotation of the Cassegrain rotator to maintain alignment with the parallactic angle as it changes at these slew rates. All optics and mechanisms will meet their flexure and alignment specifications at these rates.

Notes and Comments:

1. The rotator requires faster slew rates than specified for maintaining parallactic angle.

13 Other Requirements

13.1 Documentation

REQ-FPR-0800: GSAOI will be delivered with adequate documentation to facilitate the operation, maintenance, and repair of the instrument.

13.1.1 Users Manual

REQ-FPR-0801: The Users Manual will be written to enable a new user of GSAOI to easily get acquainted with the operation of the instrument.

Notes and Comments:

1. The GSAOI Statement of Work, 4.8.1(d) states: The User's Manual will contain all information necessary to enable a user who is familiar with the Gemini telescopes, but not necessarily familiar with the instrument, to understand the operation of the instrument. The User's Manual will include, but not be limited to, the following areas:

   (1) the instrument performance characteristics;
   (2) the instrument design and configuration;
   (3) modes of operation; and
   (4) calibration procedures.

13.1.2 Service and Calibration Manual

REQ-FPR-0802: A manual will be written to enable Gemini technical support personnel to maintain GSAOI. This manual shall include documentation to describe the observations required to allow calibration of GSAOI data.

Notes and Comments:

1. The GSAOI Statement of Work, 4.8.1(b) states: The Service and Calibration Manual will include assembly and disassembly procedures, wiring diagrams, inspection procedures, performance curves, and similar applicable information as necessary to guide service and maintenance of the instrument. Mechanisms requiring calibration or lookup tables will have standard calibration procedures included in the Service and Calibration Manual. Previous histories or results will be included in the Service and Calibration Manual as an indicator of normal operating parameters and as a diagnostic tool. The Service and Calibration Manual will include all test data pertaining to the system's optical components.

13.1.3 Software Maintenance Manual

REQ-FPR-0803: A Software Maintenance manual will be provided to enable Gemini software maintenance staff to maintain the GSAOI software.

Notes and Comments:

1. The GSAOI Statement of Work, 4.8.1(c) states: The Software Maintenance Manual shall describe the software at a level of detail that a programmer familiar with the Gemini software environment, but not initially familiar with the software, can maintain it properly. The manual will include detailed written descriptions of all software systems and subsystems at a high level, describing purpose, organization, and interaction with other software systems and subsystems. The manual will include any systems analyses, data flow diagrams, data dictionaries, structure charts, and specifications developed during the software design process, updated to reflect as-built condition. The manual will also include listings of all software delivered as part of the system, including firmware in Roms, and Proms, etc. All software source code modules will include a standard header documenting the module contents, and each module will contain a sufficient number and

quality of comments explaining the purpose and function of each few lines of code so that a programmer unfamiliar with the software can understand it. Any systems engineering analyses that led to the allocation of functions between hardware and software or the software design used will be included.

13.1.4 As-Built Drawings

REQ-FPR-0804: The as-built drawings will show all dimensions in millimeters, down to 0.01 mm. All fasteners specified in these drawings will be standard metric sizes. All drawings will otherwise be to RSAA standards used in instruments of similar size, function, and complexity.

13.1.5 Drawing Standards

REQ-FPR-0805: All drawings will comply with Australian Standard AS1100 or a Gemini approved standard.

13.1.6 Drawing Numbering System

REQ-FPR-0806: All drawings will be numbered 89-ANU-8000-xxxx in accordance with Gemini instructions.

13.1.7 Drawing Filing System

REQ-FPR-0807: Drawings will be maintained in electronic format. Final drawings will be provided in AutoCAD format and converted to PDF format on CDROM. Paper based printouts will be produced when necessary. A database of drawings will be maintained in Microsoft Access format.

Notes and Comments:

1. Final released drawings will be maintained by IGPO.
2. The software applications needed to access or read the electronic versions includes:
   AutoCAD R2000i
   Mechanical Desktop V5
   Protel 99SE

13.2 Training

REQ-FPR-0808: The GSAOI development team will provide training documentation and a training course to Gemini operations personnel on the operation, maintenance, and repair of GSAOI.

13.3 Reliability

13.3.1 Downtime

REQ-OCD-0042: GSAOI will have a downtime of < 2% scheduled time on the telescope and where possible, component failure shall result in gradual performance degradation.

13.3.2 Spares

REQ-FPR-0809: Single point failures that may result in significant downtime will be determined and, where necessary, critical spares will be identified.

Notes and Comments:

1. In accordance with the Statement of Work 4.3(a)(13), a list of recommended spares with sources and prices will be provided.

13.3.3 Continuous Duty

REQ-FPR-0810: GSAOI will be designed and built for continuous operation. Modules containing moving parts, e.g., cryocooler cold heads, will be designed or selected to meet the REQ-OCD-0042 (§13.3.1) assuming continuous operation.

13.4 Maintainability and Serviceability

13.4.1 Standard Components

REQ-FPR-0811: Wherever possible, GSAOI will use unmodified commercially available standard components.

13.4.2 Modularity

REQ-FPR-0812: To the extent possible, GSAOI will be designed to be modular.

13.4.3 Access

REQ-FPR-0813: Access to components and subassemblies will be considered in the GSAOI design, particularly for those elements that are accessed frequently. Tool and hand clearances will be considered, as well as space required to remove modules, visual access to components (or a means to feel their correct position and alignment, e.g., for electronic connectors).

13.4.4 Alignment

REQ-FPR-0814: Alignment of optical components will be achieved to the greatest extent possible by accurate machining of locating fixtures.

Notes and Comments:

1. This can be achieved by machining captive thick shims to achieve the assembled tolerances, but the intention is to avoid an involved re-alignment procedure on assembly or re-assembly.

13.4.5 Relative Equipment Arrangements

REQ-FPR-0815: Equipment will be located with due consideration of the sequence of operations involved in maintenance procedures. To the greatest extent possible, the most accessible locations will be reserved for the items requiring most frequent access.

13.4.6 Subassemblies

REQ-FPR-0816: Subassemblies of the equipment that require more frequent service (inspection, adjustment, repair, or replacement) will be configured as plug-in modules or, if in racks, as drawers that can be withdrawn easily.

13.4.7 Handling

REQ-FPR-0817: Modules greater than 20 kg in mass will have suitable handles for use in removing, replacing, and carrying them. Handles will be located such that the vector sum of resultant handling forces will pass close to the center of gravity of the unit.

13.4.8 Revisability

REQ-FPR-0818: Multilayer electronic boards will not be used unless they are replaceable as a module. Backplane interconnections between custom boards are discouraged.

13.5 Lifetime

REQ-FPR-0819: GSAOI will be designed for an operational lifetime of 10 yr without a major overhaul. Components likely to affect the lifetime requirement will be identified.

13.6 Materials

13.6.1 Toxic Products and Formulations

REQ-FPR-0820: No toxic products and formulations will be used for the development, construction, and maintenance of GSAOI.

13.7 Electromagnetic Radiation

13.7.1 Electromagnetic Radiation Generation

REQ-FPR-0821: GSAOI will not significantly add to the electromagnetic radiation of its operating environment.

13.7.2 Susceptibility to Electromagnetic Radiation

REQ-FPR-0822: GSAOI performance will not be compromised by the existing electromagnetic radiation of its operating environment.

13.8 Workmanship

REQ-FPR-0823: Standard RSAA workshop practices will apply to workmanship in development and construction.

13.9 Safety

REQ-FPR-0824: Normal considerations, including compliance with applicable regulations, will apply in the areas of mechanical, electrical, and electrostatic safety.

13.10 Human Engineering

REQ-FPR-0825: Human engineering considerations will apply especially with respect to handling of system items required in readying GSAOI for use on the telescope and its removal after use, and in the design of the user interfaces.

14 Appendices

14.1 Requirements Tabulation

The following table shows the progress towards meeting the requirements at each of several milestones.

Notes and Comments:

TBD	The requirement has not been (fully) defined yet.
Des	The requirement is met by the current state of the design.
RSAA	The requirement is met by RSAA design and manufacturing procedures.
TOC	A table of contents has been prepared for this manual.
Doc	A (draft) document has been prepared.
No	The current state of the design does not meet the requirement.

Requirement	Description	CoDR	PDR	CDR	Acceptance Test	
					RSAA	Tel.
REQ-OCD-0001	MCAO Compatibility					
REQ-OCD-0002	Imager					
REQ-OCD-0003	not used					
REQ-OCD-0004	Imager Wavelength Coverage					
REQ-OCD-0005	Imager Spatial Sampling					
REQ-OCD-0006	Imager Field-of-View					
REQ-OCD-0007	Imager Cold Stop					
REQ-OCD-0008	Imager Pupil Viewer					
REQ-OCD-0009	Imager Non-Common Path Phase Errors					
REQ-OCD-0010	Imager Filter Suite					
REQ-OCD-0011	Imager Calibration					
REQ-OCD-0012	Imager Pupil Viewer Resolution					
REQ-OCD-0013	Imager Strehl Ratio					
REQ-OCD-0013a	PSF Uniformity					
REQ-OCD-0014	Imager Distortion					
REQ-OCD-0015	Imager System Throughput					
REQ-OCD-0016	Imager Instrumental Background					
REQ-OCD-0017	Imager Ghost Images					
REQ-OCD-0018	Imager Sensitivity					
REQ-OCD-0019	Imager Pupil Viewer Sensitivity					
REQ-OCD-0020 to REQ-OCD-0030	Not used					
REQ-OCD-0031	Mechanism Set Time					
REQ-OCD-0032	Mechanism Configuration Time					
REQ-OCD-0033	Not used					
REQ-OCD-0034	Imager Utility Wheel					
REQ-OCD-0035	Not used					
REQ-OCD-0036	Not used					
REQ-OCD-0037	Not used					
REQ-OCD-0038	Imager Window					
REQ-OCD-0039	Imager Detector Read Noise					

Requirement	Description	CoDR	PDR	CDR	Acceptance Test	
					RSAA	Tel.
REQ-OCD-0040	Imager Detector Dark Current					
REQ-OCD-0041	Imager On-Detector Guide Window Performance					
REQ-OCD-0041a	ODGW Tracking Performance					
REQ-OCD-0042	Downtime					
REQ-OCD-0043	Observing Modes					
REQ-FPR-0001	Vacuum Environment					
REQ-FPR-0002	Thermal Cycling					
REQ-FPR-0003	Imager Filter Transmission					
REQ-FPR-0004	Imager Filter Wedge					
REQ-FPR-0005	Optical Baffling					
REQ-FPR-0006	Not used					
REQ-FPR-0007	Not used					
REQ-FPR-0008	Not used					
REQ-FPR-0100	Mechanical Duplication					
REQ-FPR-0101	Instrument Alignment Provision					
REQ-FPR-0102	Mechanical and Thermal Tolerances					
REQ-FPR-0103	Temperature Gradients	TBD				
REQ-FPR-0104	Thermal Transients	TBD				
REQ-FPR-0105	Space Requirement					
REQ-FPR-0106	Thermal Enclosures					
REQ-FPR-0107	Access to Thermal Enclosures					
REQ-FPR-0108	Access to Vacuum Ports					
REQ-FPR-0109	Access to Cooling Water Ports					
REQ-FPR-0110	Access to Dry Air Ports					
REQ-FPR-0111	Mechanical Connections					
REQ-FPR-0112	Total Mass					
REQ-FPR-0113	Center of Gravity					
REQ-FPR-0114	Balance Tolerance					
REQ-FPR-0115	Ballast Weight					
REQ-FPR-0116	Closed-Cycle Coolers					
REQ-FPR-0117	Cooler Vibration					
REQ-FPR-0118	Vacuum System Facilities					
REQ-FPR-0119	Vacuum Pump Capacity and Selection					
REQ-FPR-0120	Vacuum Operating Procedure and Set-Up					
REQ-FPR-0121	Vacuum Test Set-Up					
REQ-FPR-0122	Mechanism Safety					
REQ-FPR-0123	Environmental Cover					
REQ-FPR-0124	Dust Removal System					
REQ-FPR-0125	Instrument Handling					
REQ-FPR-0126	Metric Dimensioning					
REQ-FPR-0127	Metric Dimensions on Drawings					
REQ-FPR-0128	Metric Fasteners					

Requirement	Description	CoDR	PDR	CDR	Acceptance Test	
					RSAA	Tel.
REQ-FPR-0129	Instrument Alignment Maintenance					
REQ-FPR-0130	Not used					
REQ-FPR-0131	Cool Down Time	TBD				
REQ-FPR-0132	Warm Up Time	TBD				
REQ-FPR-0133	Thermal Stability					
REQ-FPR-0134	Repeatability of Configuration					
REQ-FPR-0135	Not used					
REQ-FPR-0136	Imager					
REQ-FPR-0137	Imager Detector Alignment					
REQ-FPR-0138	Imager Detector Mechanical Interface					
REQ-FPR-0139	Imager Detector Thermal Interface					
REQ-FPR-0140	Imager Detector Optical Interface					
REQ-FPR-0141	Not used					
REQ-FPR-0142	Not used					
REQ-FPR-0143	Not used					
REQ-FPR-0144	Imager Filter Wheel(s) Orientation Stability					
REQ-FPR-0145	Imager Filter Mechanism Setting Accuracy					
REQ-FPR-0146	Imager Filter Wheel(s) Setting Time					
REQ-FPR-0147	Imager Utility Wheel Orientation Stability					
REQ-FPR-0148	Imager Utility Wheel Setting Accuracy					
REQ-FPR-0149	Imager Utility Wheel Setting Time					
REQ-FPR-0150 to REQ-FPR-0162	Not used					
REQ-FPR-0200	Imager Detector Device					
REQ-FPR-0201	Imager Detector Electrical Interface					
REQ-FPR-0202	Imager Detector Controller Type					
REQ-FPR-0203	Imager Detector Controller Mechanical Interface					
REQ-FPR-0204	Imager Detector Controller Thermal Interface					
REQ-FPR-0205	Imager Detector Bias Variations					
REQ-FPR-0206	Imager Detector Gain Variations					
REQ-FPR-0207 to REQ-FPR-215	Not used					
REQ-FPR-0216	Imager Detector Controller Readout Methods					

Requirement	Description	CoDR	PDR	CDR	Acceptance Test	
					RSAA	Tel.
REQ-FPR-0217	Imager Detector Controller Integration Times					
REQ-FPR-0218	Not Used					
REQ-FPR-0219	Imager Detector Controller Fowler Samples					
REQ-FPR-0220	Imager Detector Controller Number of Coadds					
REQ-FPR-0221	Imager Detector Controller Guide Window Definition					
REQ-FPR-0222	Imager Detector Controller Guide Window Integration Time					
REQ-FPR-0223	Imager Detector Maximum Continuous Frame Rate					
REQ-FPR-0224	Imager On-Detector Guide Window Maximum Continuous Frame Rate					
REQ-FPR-0225 To REQ-FPR-0228	Not used					
REQ-FPR-0229	Imager Detector Controller Regions of Interest					
REQ-FPR-0300	Mechanism Control System Duplication					
REQ-FPR-0301	Mechanism Control System Operability					
REQ-FPR-0302	Mechanisms					
REQ-FPR-0303	Configuration Time					
REQ-FPR-0304	Impact on Mechanism Accuracy					
REQ-FPR-0305	Impact on Scientific Performance					
REQ-FPR-0306	Temperature Control System Duplication					
REQ-FPR-0307	CWS Plate Temperature					
REQ-FPR-0308	Imager Detector Temperature Control					
REQ-FPR-0309	Not used					
REQ-FPR-0310	Limiting Rate of Temperature Change					
REQ-FPR-0311	Speeding the Warming Up					
REQ-FPR-0312	Temperature Sensors					
REQ-FPR-0313	Temperature Sensor Interfaces					
REQ-FPR-0314	CWS Plate Temperature Stability					
REQ-FPR-0315	Imager Detector Temperature Stability					
REQ-FPR-0316	Not used					
REQ-FPR-0317	Safety of Accelerated Warm-Up					
REQ-FPR-0400	Grounding and Shielding					
REQ-FPR-0401	Electrostatic Discharge					

Requirement	Description	CoDR	PDR	CDR	Acceptance Test	
					RSAA	Tel.
REQ-FPR-0402	Power Dissipation					
REQ-FPR-0500	Software Duplication					
REQ-FPR-0501	Conforming Instrument					
REQ-FPR-0502	Use of EPICS					
REQ-FPR-0503	EPICS System					
REQ-FPR-0504	Not Used					
REQ-FPR-0505	Interfaces to the Gemini System					
REQ-FPR-0506	Engineering Interface Function					
REQ-FPR-0507	Engineering Interface Physical Interface					
REQ-FPR-0508	Engineering Interface User Interface					
REQ-FPR-0509	Engineering Interface Command and Control					
REQ-FPR-0510	Engineering Interface Data Capture					
REQ-FPR-0511	Mechanism Control Operability					
REQ-FPR-0512	Mechanisms					
REQ-FPR-0513	Generic Filter Wheel					
REQ-FPR-0514	No Clear Optical Path					
REQ-FPR-0515	CWS Plate Temperature					
REQ-FPR-0516	Imager Detector Temperature Control					
REQ-FPR-0517	Not used					
REQ-FPR-0518	Not Used					
REQ-FPR-0519	Not Used					
REQ-FPR-0520	Temperature Monitoring					
REQ-FPR-0521	Imager Detector Controller DSP Code					
REQ-FPR-0522	Imager Detector Controller Configuration					
REQ-FPR-0523	Imager Detector Read Out					
REQ-FPR-0524	Imager Detector Read Out Methods					
REQ-FPR-0525	Imager Detector Integration Times					
REQ-FPR-0526	Not Used					
REQ-FPR-0527	Imager Detector Fowler Samples					
REQ-FPR-0528	Not Used					
REQ-FPR-0529	Not Used					
REQ-FPR-0530	Imager Detector Number of Coadds					
REQ-FPR-0531	Imager Detector Data Unscrambling					
REQ-FPR-0532	Imager On-Detector Guide Window Definition					
REQ-FPR-0533	Imager On-Detector Guide Window Data Acquisition					
REQ-FPR-0534	Imager On-Detector Guide					

Requirement	Description	CoDR	PDR	CDR	Acceptance Test	
					RSAA	Tel.
	Window Integration Times					
REQ-FPR-0535 to REQ-FPR-0541	Not Used					
REQ-FPR-0542	Mechanisms Control					
REQ-FPR-0543	Impact on Mechanism Accuracy					
REQ-FPR-0544	Impact on Temperature Control Accuracy					
REQ-FPR-0545	Imager Detector Maximum Continuous Frame Rate					
REQ-FPR-0546	Imager On-Detector Guide Window Maximum Continuous Frame Rate					
REQ-FPR-0547	Not Used					
REQ-FPR-0548	Imager Detector Temperature During Warm Up					
REQ-FPR-0549	Not used					
REQ-FPR-0550	Imager Detector World Coordinate System					
REQ-FPR-0551	Imager Detector Regions of Interest					
REQ-FPR-0600	Instrument Support Structure Interface					
REQ-FPR-0601	ISS Ports					
REQ-FPR-0602	Instrument Mounting Plate Flatness					
REQ-FPR-0603	Instrument Mounting Plate Material					
REQ-FPR-0604	Instrument Mounting Plate Fasteners					
REQ-FPR-0605	Optical Feed					
REQ-FPR-0606	Helium Interface					
REQ-FPR-0607	Number of Helium Connections					
REQ-FPR-0608	Length of Helium Line Runs					
REQ-FPR-0609	Helium Line Flexibility					
REQ-FPR-0610	Type of Helium Connectors					
REQ-FPR-0611	Electric Power Interface					
REQ-FPR-0612	Number of Electric Power Connections					
REQ-FPR-0613	Length of Electric Power Line Runs					
REQ-FPR-0614	Electric Power Line Flexibility					
REQ-FPR-0615	Type of Electric Power Connectors					
REQ-FPR-0616	Cooling Water Interface					
REQ-FPR-0617	Number of Cooling Water Connections					
REQ-FPR-0618	Length of Cooling Water Runs					
REQ-FPR-0619	Cooling Water Line Flexibility					

Requirement	Description	CoDR	PDR	CDR	Acceptance Test	
					RSAA	Tel.
REQ-FPR-0620	Type of Cooling Water Connectors					
REQ-FPR-0621	Resistance to Glycol					
REQ-FPR-0622	Signal, Control, and Data Interfaces					
REQ-FPR-0623	Number of Signal, Control, and Data Connections					
REQ-FPR-0624	Length of Signal, Control, and Data Runs					
REQ-FPR-0625	Signal, Control, and Data Line Flexibility					
REQ-FPR-0626	Vacuum Interfaces					
REQ-FPR-0627	Dry Air Interface					
REQ-FPR-0628	Number of Dry Air Line Connections					
REQ-FPR-0629	Length of Dry Air Lines					
REQ-FPR-0630	Dry Air Line Flexibility					
REQ-FPR-0631	Type of Dry Air Line Connector					
REQ-FPR-0632	Observatory Control System to GSAOI Instrument Sequencer					
REQ-FPR-0633	Observatory Control System to GSAOI Components Controller					
REQ-FPR-0634	Observatory Control System to GSAOI Detector Controller					
REQ-FPR-0635	Not used					
REQ-FPR-0636	Acquisition and Guidance Unit to GSAOI Controller	TBD				
REQ-FPR-0637	Data Handling System Interface					
REQ-FPR-0638	Interlock System Interface					
REQ-FPR-0639	Interlock System Mechanical Interface					
REQ-FPR-0640	Interlock System Electrical Interface					
REQ-FPR-0641	Events Bus Interface					
REQ-FPR-0642	Synchro Bus Interface					
REQ-FPR-0643	Time LAN Interface					
REQ-FPR-0700	Transportation Altitudes					
REQ-FPR-0701	Storage Altitudes					
REQ-FPR-0702	Operation Altitudes					
REQ-FPR-0703	Operational Environment					
REQ-FPR-0704	Survival Environment					
REQ-FPR-0705	Transport Environment					
REQ-FPR-0706	Humidity Environment					
REQ-FPR-0707	Vacuum Environment					
REQ-FPR-0708	Creating the Vacuum					
REQ-FPR-0709	Vacuum Duration Cold					
REQ-FPR-0710	Vacuum Duration Warm					
REQ-FPR-0711	Mechanical Environment					
REQ-FPR-0712	Telescope Slew Rates					

Requirement	Description	CoDR	PDR	CDR	Acceptance Test	
					RSAA	Tel.
REQ-FPR-0800	Documentation					
REQ-FPR-0801	Users Manual					
REQ-FPR-0802	Service and Calibration Manual					
REQ-FPR-0803	Software Maintenance Manual					
REQ-FPR-0804	As-Built Drawings					
REQ-FPR-0805	Drawing Standards					
REQ-FPR-0806	Drawing Numbering System					
REQ-FPR-0807	Drawing Filing System					
REQ-FPR-0808	Training					
REQ-FPR-0809	Spares					
REQ-FPR-0810	Continuous Duty					
REQ-FPR-0811	Standard Components					
REQ-FPR-0812	Modularity					
REQ-FPR-0813	Access					
REQ-FPR-0814	Alignment					
REQ-FPR-0815	Relative Equipment Arrangements					
REQ-FPR-0816	Subassemblies					
REQ-FPR-0817	Handling					
REQ-FPR-0818	Revisability					
REQ-FPR-0819	Lifetime					
REQ-FPR-0820	Toxic Products and Formulations					
REQ-FPR-0821	Electromagnetic Radiation Generation					
REQ-FPR-0822	Susceptibility to Electromagnetic Radiation					
REQ-FPR-0823	Workmanship					
REQ-FPR-0824	Safety					
REQ-FPR-0825	Human Engineering					