Functional and Performance Requirements

for the

Gemini Facility Calibration Unit

Version 2.0

This document represents the current understanding of the capabilities and performance of the Gemini Facility Calibration Units to be designed, fabricated, tested, and delivered by the Royal Observatory Edinburgh (PPARC) to AURA.

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PURPOSE OF THIS DOCUMENT

The purpose of the *Functional and Performance Requirements Document for the Gemini Facility Calibration Unit* ("GFCU FPRD") is to provide the Gemini scientific community with an understanding of what the GFCU will do and how quickly or how well it will do it, and engineers with the requirements to use in the design of the GFCU. This document answers the question "What?", but not the question "How?". The "How" is the design that is derived from, and traceable to, this document.

The design must serve the requirements in this document completely. This means every feature of the GFCU should be traceable to a requirement in this document, and there should be no features of the GFCU that are not required by this document. The GFCUs 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.

APPLICABLE DOCUMENTS

Reference Documents.

The following documents will be useful in the GFCU design:

1. Gemini Software Design Description, SPE-C-G0037, 7 March 95
2. Gemini Instrumentation Control Document, ICD-G-0009, [Very Rough Draft], 20 July 94
3. Gemini System Error Budget Plan, SPE-S-G0041, Version 2.1, 1 February 94
4. Gemini Electronic Design Specification, SPE-ASA-G0008, 23 February 94
5. Gemini ICD 07a, ICS Subsystem Interfaces, 22 February 95
6. RPT-0-G0047 Gemini Telescopes f/16 Design Summary, 6 July 1994.
7. Instrumentation Control Document, Section 2.2.
8. PG-I-G0010 Gemini instrument safety policy

RELEVENT INTERFACE CONTROL DOCUMENTS

ICD 1.5.3/1.7 Instrument support structure to Calibration unit

ICD 1.5.3 ISS Introductory ICD

ICD 1.9/3.8, Science Instruments to System Cables

ICD 1.5.2/1.9 describes cable wrap connector plates

ICD 1.9/3.6 covers the cooling water interface.

ICD 1.1.11/1.9 covers the Observatory Control System Interface

ICD 1.6/1.7 A&G system to calibration unit

ICD 1.5.3/1.6 Instruments support structure to A&G system

ACRONYM LIST

A&G	Acquisition and Guidance
CAD	Command Action Directive
CAR	Command Action Response
CICS	Core Instrument Control System
EPICS	Experimental Physics and Industrial Control System
GFCU	Gemini Facility Calibration Unit
ICS	Instrument Control System
IGPO	International Gemini Project Office (“Gemini” or “the Project”)
ISS	Instrument Support Structure (the “cube”)
OCS	Observatory Control System
PDR	Preliminary Design Review
SIR	Status Information Response
TCS	Telescope Control System
UPS	Uninterruptible Power Supply
USGP	United States Gemini Programmme
UKGP	United Kingdom Gemini Programme

1 Cassegrain Rotator Interfaces

1.1 Instrument Support Structure Interface

The GFCU shall interface mechanically to the Gemini Instrument Support Structure (ISS). (ref ICD 1.5.3/1.7 Instrument support structure to Calibration unit interface control document Dave Montgomery April 22 1997)

1.1.1 Ports

The GFCU shall be solely capable of being mounted on and used at the side-looking calibration unit port of the ISS.

1.1.2 Instrument Mounting Plate Flatness

The GFCU mounting interface shall be repeatable within the optical tolerances of the alignment between GFCU and ISS when removed and replaced.

1.1.3 Instrument Mounting Plate Material

The GFCU mounting interface shall take into account the material of which the ISS is made and shall hold differential temperature effects to a level that permits the GFCU to meet all optical alignment requirements over the entire operating temperature range.

1.1.4 Fasteners

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

1.1.5 Optical Feed

The GFCU shall use the Gemini A&G Science fold to simulate the telescope optical feed, which is approximately f/16 with a focal length of 128 meters. The telescope beam comes to a focus 300 mm from the ISS mounting surface inside the scientific instruments. The GFCU will produce a focus at 1900mm from the mounting face of the ISS.

Notes and Comments

1. The relevant ICD is ICD 1.5.3/1.7, ISS to GCFU . The ICD 1.5.3 ISS Introductory ICD 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.
3. Telescope focal length is given in Gemini Telescopes f/16 Design Summary, RPT-0-G0047, 6 July 1994.

1.2 Helium Interface

none required

1.3 Electric Power Interface

The GFCU shall derive its electric power through the connectors provided on the Cassegrain Rotator Utility Box appropriate to each instrument port. The power interface is part of ICD 1.9/3.8, Science Instruments to System Cables.

Gemini will provide an electric power supply as given in ICD 1.9/3.8.

1.3.1 Number of Electrical Connections

The GFCU shall have one electric power connection for the entire instrument, providing “clean” power for the electronics The GFCU shall have appropriate runs from a junction box to serve all instrument power needs. The ICD 1.5.2/1.9 describes cable wrap connector plates.

1.3.2 Length of Electrical Line Runs

Cable lengths between GFCU and A&G cabinets sufficient to allow adjustment.

1.3.3 Electric Power Line Flexibility

The electric power line to the Cassegrain Rotator Utility Box shall be flexible enough to permit easy routing, connection, disconnection, and dressing for operation.

1.3.4 Type of Electrical Connectors

AC power is provided via a 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.

1.4 Cooling Water Interface

If required, the GFCU shall 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.

1.4.1 Number of Plumbing Connections

The GFCU shall have one cooling water supply connection and one return line connection for the entire instrument. The GFCU shall have appropriate tees from these lines to serve all instrument cooling water needs.

1.4.2 Length of Cooling Water Runs

The cooling water lines to the Cassegrain Rotator Utility Box shall be of a length that permits the GFCU to meet Requirement 1.1.1. If good design practice dictates, a means of dressing the cooling water lines to a length appropriate for different ports, or lines of different lengths for different ports, shall be provided.

1.4.3 Cooling Water Line Flexibility

The supply and return lines to the Cassegrain Rotator Utility Box shall be flexible enough to permit easy routing, connection, disconnection, and dressing for operation.

1.4.4 Type of Plumbing Connectors

The cooling water lines shall connect to the Cassegrain Rotator Utility Box using a connector of type (TBD) and of gender (TBD), compatible with (TBD) vendor model number (TBD). The connector shall not permit more than a drop or two of coolant to escape the system when connecting or disconnecting the supply and return lines, and shall not leak during normal operation.

1.4.5 Resistance to Glycol

The cooling water lines and connectors shall not be damaged in any way when used with a cooling solution containing glycol.

Notes and Comments

1. It is expected that Gemini will provide a cooling water supply of (TBD) liters/minute at a pressure of (TBD) units and a temperature of (TBD)C. The low pressure return line is expected to carry (TBD) liters/minute at a pressure of (TBD) units and a temperature of (TBD)C.
2. Plumbing connection standards may already exist within the Gemini project.
3. Coolant mixture is expected to be 50/50 water/glycol.
4. ICD 1.9/3.6 covers the cooling water interface.

1.5 Signal, Control, and Data Interfaces

The GFCU shall receive and provide all signal, control, and data paths through the A&G VME crate. Connections providing the control of lamps and mechanisms in the GFCU will come from electronics located in the A&G cabinets

1.5.1 Number of Signal, Control, and Data Connections

1.5.1.1 2off DC motor control of filter wheel and lens diffuser wheel (2 core 16/0.2mm overall screen, screen terminated motor drive end only)

1.5.1.2 1off datum sense signal cable (12 core 7/0.2mm overall screen, terminated at calibration unit end only)

1.5.1.3 8off proprietary cables for illumination sources

1.5.1.4 A&G cabinet internal cabling for signal control of DC motors, and lamp switching control.

1.5.2 Length of Signal, Control, and Data Runs

The signal, control, and data lines to the Cassegrain Rotator Utility Box shall be of a length that permits the GFCU to meet Requirement 1.1.1. If good design practice dictates, a means of dressing these lines to a length appropriate for different ports, or lines of different lengths for different ports, shall be provided.

1.5.3 Signal, Control, and Data Line Flexibility

The signal, control, and data lines to the Cassegrain Rotator Utility Box shall be flexible enough to permit easy routing, connection, disconnection, and dressing for operation.

Notes and Comments

1. The ICD 1.9/3.8 contains references to all but the video LAN and Interlock System.
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.

1.6 Liquid Nitrogen Interface

none required

1.6.1 Vacuum Interfaces

none required

2 Control Systems Interfaces

2.1 Observatory Control System Interface

ICD 1.1.11/1.9 covers the Observatory Control System Interface.

2.2 Telescope Control System Interface

TBD (Control LAN?)

2.3 Engineering Interface

The GFCU shall provide a means for command and control of GFCU mechanisms and lamps without the need for having Gemini control systems (i.e., the Observatory Control System and the Telescope Control System) present or connected, but should be capable of exercising all functionality normally under TCS or OCS control

.It is required that the Engineering Interface use EPICS in its implementation.

2.3.1 Physical Interface

The Engineering Interface shall use the same model and configuration of workstation as that used for the Instrument Control System that runs with other Gemini control systems.

2.3.2 User Interface

To the extent practicable, the user interface in the Engineering Interface should appear to a user to be very similar to the user interface in the Instrument Control System.

2.3.3 Command and Control

The Engineering Interface shall be capable of commanding and controlling all GFCU mechanisms and reading status from all GFCU sensors.

2.4 Interlock System Interface

No GFCU interlocks require a complete stop of the telescope.

Some local interlocks should immediately notify the operator that the GFCU has shut down. For example: overheating of the electronics.

The physical interface is described in ICD 1.9/3.8.

2.5 Events Bus Interface

none required

The physical interface is included in ICD 1.9/3.8.

2.6 Synchro Bus Interface

none required

The physical interface is included in ICD 1.9/3.8.

The Synchro Bus In/Out Connector is dual SC fiber.

2.7 Time LAN Interface

Not required

2.8 General Control System Requirements

The GFCU shall meet all general control system requirements given below.

2.8.1 Operability

All filters, mechanisms, and other controllable features of the GFCU shall be controllable by computer through the standard EPICS control paths from the Telescope Control System.

2.8.2 Configuration Time

The goal for configuration of the GFCU for an observation from any previous observation configuration is 3 minutes or less.

3 Array and Array Controller Interfaces

none required

4 Environmental Requirements

4.1 Altitude Environment

The GFCU shall be capable of being transported, stored, and operated in a wide range of altitude environments.

4.1.1 Transportation Altitudes

The GFCU shall be capable of being transported at any altitude between -200 feet and 14,000 feet by any transportation mode. The GFCU shall be capable of being transported by commercial jet with pressurized cargo compartments at altitudes up to 50,000 feet.

4.1.2 Storage Altitudes

The GFCU shall be capable of being stored in or out of its shipping container at any altitude between -200 feet and 14,000 feet.

4.1.3 Operation Altitudes

The GFCU shall be capable of being operated at any altitude between -200 feet and 14,000 feet.

The GFCU must work at the Hilo Base Facility, at an altitude of approximately sea level, and at the telescope on Mauna Kea, at an altitude of approximately 13,900 feet.

The GFCU must work at the base facility at La Serena, at an altitude of a few hundred feet, and the telescope site on Cerro Pachon has an altitude of almost 9,000 feet.

4.2 Temperature Environment

4.2.1 Operational Environment

The GFCU operational environment shall be limited to -15 to +25^{o}C.

During operation any temperature below -7^{o}C may affect the operation of motors.

4.2.2 Survival Environment

The GFCU shall be capable of surviving a temperature range of -20 to +50^{o}C without damage.

4.2.3 Transport Environment

The GFCU shall be capable of withstanding without damage a temperature range of -20 to +50^{o}C during transport without damage.

Storage and shipping temperature environments should be limited to those given in MIL-STD-810E, (222 to 344 K, or -51 to 71^{o}C).

4.3 Humidity Environment

The GFCU shall be capable of being transported and stored, in a wide range of altitude environments in the range 0 to 100% relative humidity, with condensing moisture.

Operation of the GFCU at high relative humidity levels will cause condensation on optical surfaces. Using heaters on the window or a hot air system are incompatible with the thermal management of the telescope.

4.4 Vacuum Environment

none required

4.5 Mechanical Environment

The GFCU shall be capable of operating in the mechanical environment of the Gemini telescopes and their base facilities, and shall be capable of withstanding shipment among Edinburgh, Mauna Kea, and Cerro Pachon.

4.5.1 Telescope Slew Rates

The GFCU shall 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 shall meet their flexure and alignment specifications at these rates.

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

5 Optical Requirements

5.1 Science Requirements

The GFCU shall meet all science requirements listed below.

5.1.1 The calibration units will provide calibration frames (flat-field and wavelength calibration) for Gemini instruments covering a range of field sizes and wavelengths from the UV to the NIR

5.1.1.1 The southern GFCU will provide calibration sources for HROS and GMOS.

5.1.1.2 The northern GFCU will provide calibration sources for GMOS, GNIRS, and GNIRI.

5.1.1.3 The GFCUs will be capable of being upgraded to provide sources for all of GMOS, HROS, GNIRS and GNIRI.

5.1.2 The intrinsic assumption when flat-fielding a detector is that the flux falling in each pixel is the same. The calibration beam at the output of the GFCU must be smoothly varying and the 2D spatial profile well understood. This may be achieved by a combination of intrinsic 'flatness' of the beam at the output of the GFCU (output uniformity) and subsequent calibration of the 2D beam profile with reference to some flat external source such as the sky (output stability). Limits provided by the instrument groups are that the GFCU beam should be flat to 1% over the 7' science field, to 0.1% over scales of 20", and to better than 0.2% over 100". This reduces to the following functional requirement on output uniformity, plus a requirement on stability (FR3): The output beam covers 7 arcmin in radius and should be flat with a monotonic roll-off in intensity of <10% to the edge of the field. Variations over the 3' field should be 1%.

5.1.3 The two dimensional shape of the calibration beam should be stable during the course of a night. It should be stable to 0.3% over 12 hours. This limit is set in order that the flat-field can be rendered flat to 1% over the full field as required by GMOS. This translates to a limit on the alignment of the GFCU optics at any attitude of the telescope. The tolerance on the relative motion of the components is TBD.

5.1.4 The flux from the calibration unit should be sufficient to provide calibration frames with the specified signal/noise ratio within the following timescale

5.1.4.1 **HROS:** Wavelength calibration frames should have one line every 0. 3nm which can be measured with a signal/noise of 10 in 5s. Flat fields with signal/noise=300 in 5s and less than 60s at 310nm.

5.1.4.2 **GMOS:** The same exposure times are adopted as for HROS. With the array read-out time for calibration frames at 10s, a 5s exposure on the wavelength calibration or flat-field will not affect the observing efficiency.

5.1.4.3 **GNIRS:** There is no significant overhead in reading the IR arrays, therefore the guideline here is that that calibration frame should not take much longer than the time to move the science fold mirror into the beam (15s goal). A limit of 10s for an arc spectrum with signal/noise = 10 per pixel and 10 s for a flat-field with signal/noise=10^3 is adopted

5.1.4.4 **GNIRI:** As above. A flat-field with a signal/noise of 10^3 per pixel should be obtained in 10s.

5.1.5 For instrument/GFCU configurations where the flux output from the calibration unit will saturate the detector, provision for attenuating the flux should be made. For optical instruments, this can either be achieved using neutral density filters in the calibration unit or by some method of aperture control at the source. The exact method is TBD. For the NIR imager, the background thermal emission from a room temperature surfaces in the beam will saturate the detector longwards of ~3um. Cold ND filters must be supplied within the instrument if the instrument is to look at the calibration unit rather than the sky at thermal wavelengths.

5.1.6 The calibration unit should contain colour balance filters to flatten the output of lamps with steep spectra so that similar signal/noise at the blue and red ends of the spectra are obtained. The details of the filters are TBD. The requirement from GMOS is that the continuum strength should not vary by more than a factor of 4 over 100nm between 400nm and 1000nm.

5.1.7 Deployment timescales. The calibration unit must be configurable to suit the observing mode within the time taken to change the mode. This limit on changing instruments is set by the science requirements to TBD.

5.1.8 Control of lamps. The lamp sources, particularly the continuum sources, will require some length of time to stabilise before they are observed. The continuum sources should be permanently on during observing. When a lamp is requested, it should be deployed within 5s. The light sources should be baffled so that light from a source not in use is not scattered into the beam Control of the scattered light is not critical; a limit of 10% on the amount of light scattered into the beam is set. There should be on/off control.

5.1.9 The pupil must be centred to within 1% of its diameter. The change in this position with telescope attitude should be limited to 1%.

5.1.10 The intensity of the continuum sources should be stable to 5% (with a goal of 1%) during any 12hour period.

6 Mechanical Requirements

6.1 Rigidity

The GFCU shall be designed to be rigid, and to meet all the requirements listed below.

6.1.1 Alignment of the Instrument to the Telescope Optics

The alignment of the GFCU exit pupil with the secondary mirror shall be set and maintained to within 1% of the apparent secondary mirror diameter.

6.2 Mechanical and Thermal Tolerances

Mechanical Tolerances in Alignment

	Gravity Effects	Thermal Effects
Pupil imaging mirror 1	**(TBD)**	**(TBD)**
Pupil imaging mirror 2	**(TBD)**	**(TBD)**
Filter/ND wheel	**(TBD)**	**(TBD)**
Reflecting hemi-sphere	**(TBD)**	**(TBD)**
Lens diffuser wheel	**(TBD)**	**(TBD)**
Lamp mounting	**(TBD)**	**(TBD)**

6.3 Thermal Performance

Thermal effects due to temperature gradients (TBD)

6.4 Space Requirements

Space requirements are specified in ICD 1.6/1.7 A&G system to calibration unit and related documents ICD 1.5.3/1.6 Instruments support structure to A&G system, also the ICD for the ISS (1.5.3/1.7).

Space envelope is described in ROE drawing 00A01L5 “GFCU space envelope”.

6.4.1 Electronic Enclosures

All GFCU electronics will be housed within the A&G equipment cabinets. All GCFU VME control cards will be incorporated into a A&G VME card frame.

6.4.2 Access to Electronic Enclosures

The electronic enclosures shall be accessible without removing the GFCU from the ISS.

6.4.3 Mechanical Connections

All mechanical connections on the GFCU shall be accessible without removing the instrument from the ISS and while mounted with other instruments.

6.5 Mass and Center of Gravity Requirements

The GFCU shall meet all mass and center of gravity requirements listed below.

6.5.1 Total Mass

TBD

6.5.2 Center of Gravity

The GFCU shall have a center of gravity 200Kg at 600mm from the mechanical interface on the ISS.

6.5.3 Balance Tolerance

TBD

6.5.4 Ballast Weight

A ballast weight and its supporting structure are an A&G responsibility and shall be supplied as required to meet the above requirements.

6.5.5 Electronic Enclosures

None. All GFCU electronics housed in A&G cabinets.

6.6 Cooling System

Cooling for lamps (TBD)

6.7 Vacuum System

None required

6.8 Operational Requirements for Mechanisms

GFCU mechanisms shall meet the requirements listed below.

6.8.1 Safety

No mechanism shall be back-driveable in the event of loss of electrical power.

6.8.2 Time to Function

The goal for all individual mechanisms is to take no more than 60 seconds to operate from any position to any other position.

6.9 Instrument Handling

The GFCU shall be delivered with a simple pallet

6.10 Metric Dimensioning

Metric dimensions shall be used in the GFCU.

6.10.1 Metric Dimensions on Drawings

Metric dimensions in millimeters shall be used in all as-built drawings, with dimensions called out to 0.01 mm.

6.10.2 Metric Fasteners

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

7 Electrical and Electronic Requirements

7.1 Electronic Design Requirements

The GFCU shall be designed in accordance with modern electronics engineering practice for astronomical instruments.

7.1.1 Grounding and Shielding

The GFCU will have electrically isolated mechanical mounts and an easily identifiable single point ground connection to the ISS that can be disconnected for testing. All cables connecting to the GFCU will have screens (where appropriate) which are connected at one end only to avoid ground loops.

7.1.2 Electrostatic Discharge

The GFCU design shall protect sensitive components from electrostatic discharge.

7.2 Cassegrain Cable Wrap Interfaces

Cassegrain cable wrap interfaces are provided by the break out panels on the ISS, and should be defined by the ICD 1.5.2/1.9.

7.3 Temperature Monitoring

none required

8 Software Requirements

The Gemini Software Design Description contains guidelines for developing Gemini-compatible software.

Gemini will provide the GFCU team with a Core Instrument Controller Software Package to aid in the development of an ICS that conforms to Gemini requirements and standards.

8.1 Software Design Requirements

The GFCU shall be a "conforming" instrument, in that it shall use EPICS and conform to Gemini software and control system standards and the requirements listed below.

8.1.1 Use of EPICS

The GFCU shall use a standard Gemini configuration of a workstation for the operator interface, connected to an EPICS based system used for controlling motors, illumination sources and for receiving status information from sensors.

8.1.2 EPICS System

The EPICS system shall be a standard Gemini unit (VME crate, 68040 CPU, VxWorks operating system.

8.1.3 Use of the Core Instrument Controller Software Package

The GFCU software engineers shall use the Gemini-furnished Core Instrument Controller Software Package to develop the Instrument Control System (ICS).

8.2 EPICS Compatibility

The GFCU software shall be based on and use an EPICS system as required by 8.1.

8.2.1 Interfaces to the Gemini System

Interfaces to the Gemini system shall conform to the descriptions presented in the Core ICS documentation. In particular, all OCS commands to, and responses from, the GFCU shall be by CAD, CAR and SIR EPICS records as described in the Core ICS documentation. Interfaces to other Gemini subsystems shall conform to the relevant Interface Control Documents.

8.3 Gemini Furnished Software

Gemini shall furnish a complete and final set of all Interface Control Documents not later than the GFCU PDR.

Gemini shall furnish to the GFCU software engineers a functional CICS as soon as practical, and shall provide updates as they become available. The first release of the CICS should be by GFCU PDR with general information available before then.

9 Other Requirements

9.1 Documentation

The GFCU shall be delivered with adequate documentation to facilitate the operation, maintenance, and repair of the instrument.

9.1.1 User’s Manual

The User’s Manual shall be written to enable a new user of the GFCU to easily get acquainted with the operation of the instrument.

9.1.2 Service and Calibration Manual

9.1.3 Software Maintenance Manual

9.1.4 As-Built Drawings

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

9.1.5 Drawing Standards

(TBD)

9.1.6 Drawing Numbering System

(TBD)

9.1.7 Drawing Filing System

(TBD)

9.2 Training

The GFCU development team shall provide and a ½ day training / familiarisation to Gemini operations personnel on the operation, maintenance, and repair of the GFCU.

9.3 Reliability

The GFCU shall be designed and built to be reliable.

9.3.1 Downtime

The GFCU shall have a total downtime of 2%, with 1% as a goal. Where possible, component failure shall result in gradual performance degradation. Single point failures that may result in significant downtime shall be determined and, where necessary, critical spares shall be identified.

9.3.2 Continuous Duty

The GFCU shall be designed and built for continuous operation. Modules containing moving parts, e.g., cryocooler cold heads, shall be designed or selected to meet Requirement 9.3.1 assuming continuous operation.

9.4 Maintainability and Serviceability

The GFCU shall meet the requirements for maintainability in the Instrumentation Control Document, Section 2.2.

9.4.1 Standard Components

Wherever possible, the GFCU shall use unmodified commercially available standard components.

9.4.2 Modularity

To the extent possible, the GFCU shall be designed to be modular.

9.4.3 Access

Access to components and subassemblies shall be considered in the GFCU design, particularly for those elements that are accessed frequently. Tool and hand clearances shall 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).

9.4.4 Alignment

Alignment of optical components shall be achieved to the extent possible by accurate machining of locating fixtures.

Requirement 9.4.4 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.

9.4.5 Relative Equipment Arrangements

Equipment shall be located with due consideration of the sequence of operations involved in maintenance procedures. To the extent possible, the most accessible locations shall be reserved for the items requiring most frequent access.

9.4.6 Subassemblies

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

9.4.7 Handling

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

9.5 Lifetime

Components likely to affect the lifetime shall be identified.

9.6 Safety

(TBD) Will be determined with reference to PG-I-G0010 “Gemini instrument safety policy”