UK Astronomy Technology Centre	University of Hertfordshire	Institute for Astronomy, University of Hawai'i	PennState 1855

PRECISION RADIAL VELOCITY SPECTROMETER

Document Title	Initial Functional Performance and Requirement Document
Document Number	PRVS-SPEC-00003-0001
Issue	1.0
Date	18th September 2006

Document Prepared By:	Phil Rees	Signature and Date	Phil Rees 18th September 2006
Document Approved By:	Hermine Schnetler	Signature and Date	Hermine Schnetler
Document Released By:	David Lunney	Signature and Date	David Lunney 18th September 2006

CHANGE RECORD

Issue	Date	Section affected	Change Description
0.1	10th May 2006	All	First Draft by Phil Rees with comments supplied by team incorporated by David Lunney
0.2	25th May 2006	All	Section numbers rearranged for more logical flow Updated due to comments by Gemini Removed reference to Gemini North Radial velocity requirement removed. This is implicit in the spectral performance. Dark Current added at 0.02 e/s/pix Training requirements added
0.3	27th July 2006		Sub-system specs added
0.4	15th August 2006		Need to import list from e-mail.
0.5	28th August 2006		3.1 Instrument layout and PBS added 3.1.2 Mode transition diagram added 3.1.2.2.1 Added 3.1.3 Part numbers added 3.3.5.2, 3.3.5.3 added 3.7.X functional descriptions added to each major component Appendix 1 Verification method definitions added
0.6	30th August 2006		3.2.2.8 Deleted Instrument Profile Spec
0.7	12th September 2006	3	Changes to Section 3 and Table 3 added
1.0	18th September 2006		Final review before release to Gemini by DWL, HS & PR

Table of Contents

List of Figures

List of Tables

List of Abbreviations

AURA	Association of Universities for Research in Astronomy
COG	Centre of Gravity
DHS	Data Handling system
EED	Encircled Energy Diameter
FDAS	Fibre Deployment and Acquisition Unit
EMC	Electromagnetic Compatibility
FITS	Flexible Image Transport System
FPRD	Functional Performance Requirements Document
GCAL	Gemini Facility Calibration Unit
PRVS	Precision Radial Velocity Spectrograph
ICD	Interface Control Document
ICP	Instrument Connection Point
IfA	Institute for Astronomy, University of Hawaii
IEC	International Electro-technical Commission
IRAF	Image Reduction and Analysis Facility
ISO	International Standards Organisation
ISS	Instrument Support Structure
IVCS	Instrument Vertical Control System
MTBF	Mean Time Between Failures
OCDD	Operational Concepts Definition Document
OLDP	Off Line Data Processing
OCS	Observation Control Software
PCB	Printed Circuit Board
PRVS	Precision Radial Velocity Spectrometer
PSF	Point Spread Function
PWFS	Peripheral Wavefront Sensor
SRF	Spectral Response Function
RMS	Root mean square
SOW	Statement of Work
SPIE	Society of Photonic Industry Engineers
TCS	Telescope Control Software
WFS	Wave Front Sensor
UK ATC	United Kingdom Astronomy Technology Centre

List of Definitions

TBD	To Be Defined : a requirement to be developed during the preliminary design stage of the instrument.
TBC	To Be Confirmed : a requirement that is correct with the current design information but requires confirmation during the preliminary design stage of the instrument.
TBR	To Be Reviewed : a requirement specified to meet the PRVS top-level requirements, but which might over-constrain the design.

1 INTRODUCTION

1.1 CONTRACTUAL STATUS

This document is an initial draft, prepared as part of the design study, and will form the basis of the contractual version of the document.

Should the proposal be accepted the top level system performance specification will be specifically referenced and frozen in the contractual version of this document. The derived engineering budgets and therefore the individual sub-system specifications will however be subject to changes made at the consortium management level as the design matures. It is envisaged that all final sub systems specifications will have been derived and approved by the time of the Preliminary Design Review.

1.2 PURPOSE AND SCOPE

Precision Radial Velocity Spectrometer (PRVS) is a high resolution spectrometer which shall be developed for use on either of the Gemini 8 meter telescopes. Gemini North, located at Mauna Kea or Gemini South, located at Cerro Pachon. The instrument shall primarily be used to measure the radial velocity of M class stars and the instrument shall be compatible with either location. By measuring the radial velocity of M class stars very accurately the science community intend to detect the presence of orbiting planets. In the science case it is recommended that Gemini North should be used as that location will have slightly improved atmospheric conditions.

The science requirements have been derived in the PRVS Science case and are detailed in the PRVS Science Requirements Document. Observatory requirements are mainly derived from the Gemini Interface Control Documents listed in Section 2.2.

This document establishes the functional performance, design, build, verification and validation requirements of the instrument that flow down from these. The general functions of PRVS are defined and the broad requirements that these place on instrument characteristics are described. An overview of the PRVS major components and the system requirements that flow down to them is given. The final section contains a requirements verification matrix which identifies the origin of all of the functional and performance requirements detailed as well as the means by which each requirement will be verified.

1.3 PRODUCT IDENTIFICATION

The instrument described in this FPRD shall be identified as the Precision Radial Velocity Spectrometer (PRVS). The configuration identification number at instrument level is 89-ATC-8001-3000.

1.4 ASSUMPTIONS

The following are the assumptions regarding the characteristics or performance capabilities of the Gemini system and infrastructure.

1.4.1 INTERFACES

The Gemini interface documents listed in section 2 of this document completely and accurately define the observatory interfaces. All document and drawing updates shall be provided to the design team as they become available to Gemini.

1.4.2 DELIVERED IMAGE QUALITY

The image quality delivered by the telescope to the focal plane is assumed to be TBD.

1.4.3 UN-TOLERANCED VALUES

For parameters in Gemini documents which have no tolerances, tolerances shall be supplied to UK ATC by GEMINI on request.

1.4.4 VIBRATION

It is assumed that in the pier lab PRVS shall not be subject to ≥ TBC g2/Hz from TBD Hz to TBD Hz during normal operation.

1.4.5 ENVIRONMENT

The temperature in the Pier Lab is assumed to vary by less than 5 °C over the course of the year and by less than 1°C in any 24 hour period.

1.4.6 ACQUISITION AND GUIDING

The observational efficiency requirement assumes that the telescope PWFS will acquire a guide star within 2 minutes and that the instrument acquisition camera does not require the control loops to have settled before starting to acquire the target. We also assume that the telescope is able to accept additional slow guiding offsets at the order of 1 Hz via a software socket.

1.4.7 OBSERVATION PREPARATION

Gemini standard observation preparation tools shall be used. Modifications to this are not within the scope of the contract.

2 DOCUMENTS AND DRAWINGS

Where there is a conflict between the information in the applicable documents and that contained in this document, this document takes precedence.

2.1 APPLICABLE AND REFERENCE DOCUMENTS

Reference	Document Title	Document Number	Issue / Date
AD01	Design Study for PRVS : Exhibit A, Work Scope	Contract No.0084699-GEM01056	6 January 2006
AD02	PRVS Science Requirements	PRVS-SPEC-00005-0001	1.0 September 2006
AD03	Guidelines for Designing Gemini Aspen Instrument Software	AspenSoft-03072004-6	13 May 2004
AD04	Gemini Environmental Requirements	ICD-G0013	Rev B, October 8 1996
AD05	Gemini Observatory Opto-mechanical Coordinate System	ICD-G0014	Version 1, January 7, 1997
AD06	Gemini Facility Handling Equipment and Procedures for Instrumentation	ICD-G0015	Version C, March 8, 2000
AD10	UK ATC Programme Delivery and Engineering Handbook	TBD	1, August 2006
AD10	UKATC Mechanical Group Procedures		D. Montgomery, Date: 18 March 2005

2.2 GEMINI INTERFACE DOCUMENTS

2.2.1 SCIENCE INSTRUMENT ICDs

Reference	**Document Title**	**Document Number**	**Issue & Date**
As Doc. No.	Telescope Structure, Drives, and Brakes to Science Instruments ICD	1.1.1/1.9	Version 1, June 5, 1995
As Doc. No.	Science Instrument to Telescope Control System ICD (Also known as 'ICS/TCS Direct Control Interface')	1.1.11/1.9 (ICD-06)	Version A, August 18, 1997
As Doc. No.	Interlock System to Science Instruments ICD	1.1.13/1.9	Version A, June 16, 1997
As Doc. No.	SCS to Science Instruments Interface	1.4.4/1.9	Version 1, October 22, 1996
As Doc.	Instrument Support Structure to Science	1.5.3/1.9	Version B, April

Reference	Document Title	Document Number	Issue & Date
No.	Instruments ICD		22, 1997
As Doc. No.	A&G System to Science Instruments (ICD)	1.6/1.9	Version 1, September 23, 1996
As Doc. No.	Calibration Unit to Science Instruments ICD	1.7/1.9	Not issued
AD07	*Optical interface information for GCAL is contained in :* Functional and Performance Requirements for the Gemini Facility Calibration Unit		Version 2.0, Oct 17 2000
AD08	*Optical interface information for GCAL is contained in :* Gemini Calibration Unit Operation Concepts Definition Document		V2.7, Oct 28 1999
As Doc. No.	Science Instruments Interface Control Documents Overview and Guide	1.9	Version B, September 4, 1997
As Doc. No.	Science and Facility Instruments to Facility Handling Equipment ICD	1.9/2.7	Version C, August 30, 1999
As Doc. No.	Science Instrument to Observatory Control System (ICD)	1.9/3.1	Version B, August 29, 1997
As Doc. No.	Science Instrument to Data Handling System (ICD)	1.9/3.2	Version B, August 14, 1997
As Doc. No.	Science and Facility Instruments to System Services ICD	1.9/3.6	Version C, May 2001
As Doc. No.	Science Instruments to Facility Thermal Electronics Enclosures (ICD)	1.9/3.7	Version C, October 28, 2002
AD09	Pier Lab Space Constraints	TBD	
AD010	GCAL Interface drawing	TBD	

2.2.2 SOFTWARE ICDs

Reference	Document Title	Document Number	Issue & Date
As Doc. No.	The System Command Interface	ICD-01a	December 12, 1996
As Doc. No.	The Baseline Attribute/Value Interface	ICD-01b	December 13, 1996
As Doc. No.	Baseline DHS interface	ICD-01c	March 6, 2000
As Doc.	System Status and Alarm Interfaces	ICD-02	December 13,

No.			1996
As Doc. No.	Bulk Data Transfer	ICD-03	October 25, 2000
As Doc. No.	Wavefront Sensing Information Interface	ICD-05	February 17, 1995
As Doc. No.	ICS Subsystem Interfaces	ICD-07a	August 14, 1997
As Doc. No.	EPICS Time Bus Driver	ICD-09	September 5, 1996
As Doc. No.	EPICS Synchro Bus Driver	ICD-10	November 12, 1997
As Doc. No.	Interlock System	ICD-12	February 17, 1995
As Doc. No.	The Parameter Definition Format	ICD-16	December 18, 1996

2.3 REFERENCE DOCUMENTS

Reference	Document Title	Document Number	Issue & Date
RD01	Gemini Electronic Design Specification	SPE-ASA-G0008	Issue 0, Jun 21, 1994
RD02	Adaptive Optics Program – Altair/ISS Vibration Measurements	AO 00100 Report	REV-AO-00100
RD03	PRVS Instrument simulation model	TBD	
RD04	OLDP SPIE Paper	TBD	

3 REQUIREMENTS

The following functional and performance design requirements are derived from the science requirements and from the Gemini Interface Control Documents.

3.1 ITEM DEFINITION

PRVS is a precision radial velocity spectrometer operating in the near infra-red. It shall be located in the pier laboratory of either the Gemini North or Gemini South observatories and connected to the Gemini telescope via an optical fibre that passes through the telescope yoke and connects to an interface unit fitted close to GCAL. The fibre is illuminated by the science object by moving a pick-off mirror into the centre of the field at the GCAL focus.

Science instruments normally connect to the telescope via an instrument support structure (ISS) which is located at the Cassegrain focus of the telescope. GCAL has its own instrument port and the fibre deployment and acquisition unit of PRVS will be attached directly to the structure of the ISS at the GCAL port with GCAL still mounted as normal.

PRVS shall consist of the following major sub-systems

- Fibre Deployment and Acquisition System
- Calibration Unit
- Fibre Fore-Optics
- Infrastructure
- Instrument Control Electronics
- Spectrograph
- Data Pipeline

3.1.1 ITEM DIAGRAMS

A schematic diagram of the PRVS opto-mechanical concept is shown in Figure 1. The instrument block diagram and instrument level product breakdown structure are shown in Figure 2 and Figure 3 respectively.

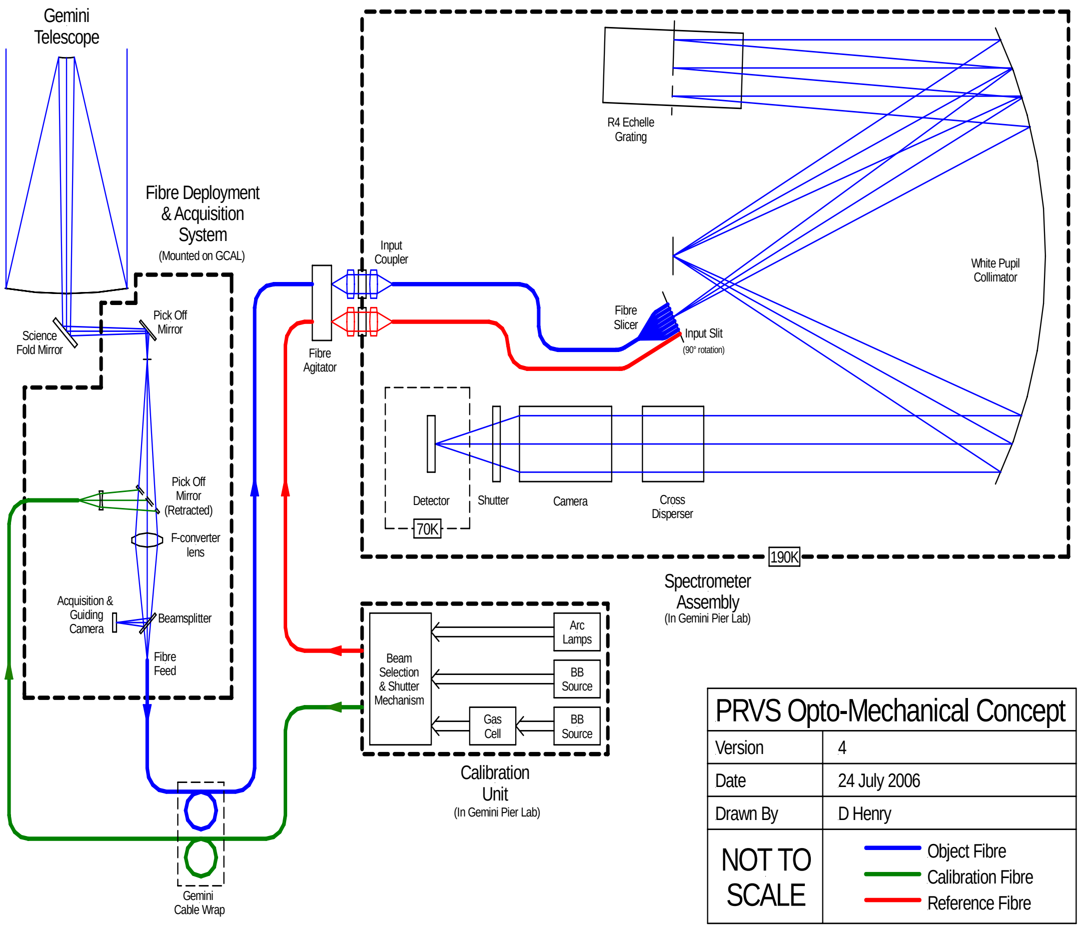

Figure 1 PRVS Opto-mechanical concept

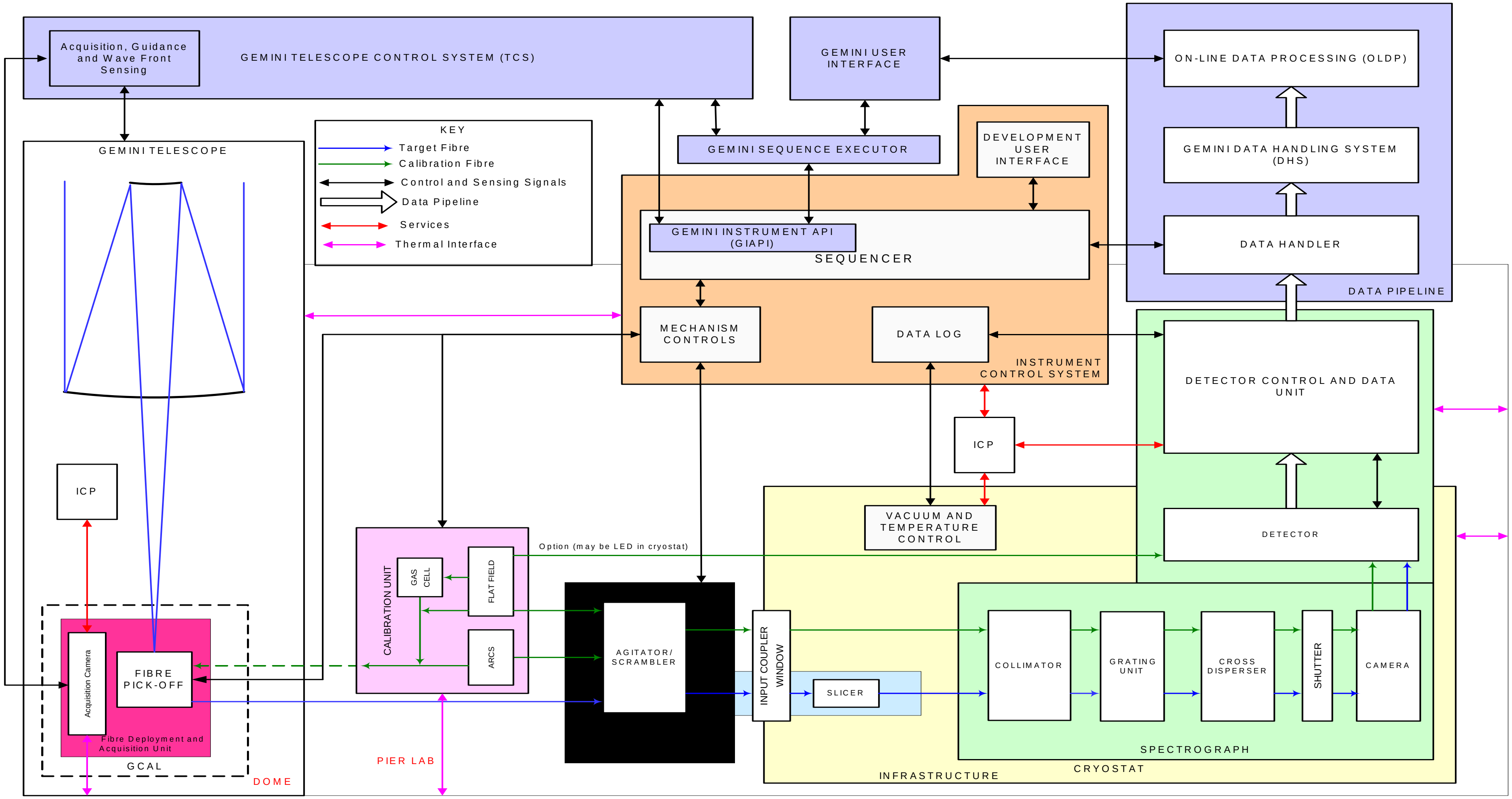

Figure 2 PRVS Instrument block diagram

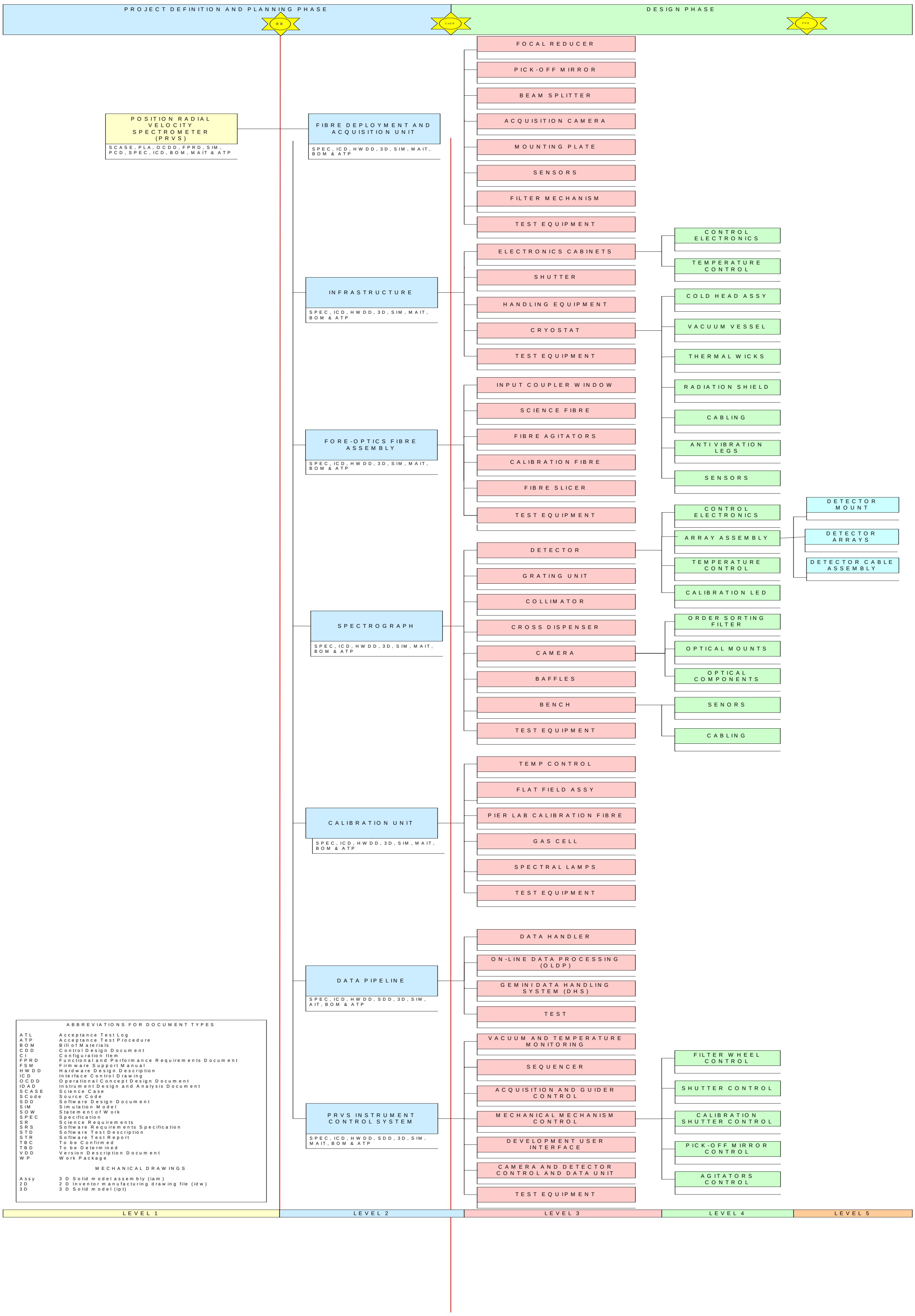

Figure 3 Instrument level product breakdown structure

3.1.2 EXTERNAL INTERFACES

3.1.2.1 Functional Interfaces

3.1.2.1.1 Engineering Interface

An Engineering Interface System shall provide control of the PRVS instrument and basic detector data capture without the use of the Gemini OCS and TCS.

3.1.2.2 Modes of Operation

PRVS shall operate in the following modes

Off – The instrument is off

Maintenance – The instrument interfaces with the engineering user interface only

Radial Velocity – The instrument performs high resolution spectroscopy with simultaneous calibration lines input at the fore optics fibre.

Calibrate – The calibration light is input at the fibre deployment system

High Resolution Spectroscopy – The calibration lines are not present

3.1.2.3 Physical Interfaces

The Fibre Deployment and Acquisition System (FDAS) shall interface with the GCAL instrument port and shall not affect the operation of GCAL. It shall be the only sub-system which mounts directly onto the telescope.

Coolant, Helium and compressed air shall be connected to the instrument where necessary in accordance with the Science and Facility Instruments to System Services ICD 1.9/3.6.

3.1.2.3.1 Fibre Routing

a. The fibre shall route between the FDAS and the pier lab in such a way that it is not liable to damage during telescope daytime operations and mirror maintenance.

b. The fibre cable shall be removable from the ISS with a safe stowing position to protect the cable during telescope maintenance activities.

c. The Fibre shall be routed through the telescope cable wraps in accordance with the Cass Cable wrap to Science Instruments ICD 1.52/1.9 and shall pass into the Pier lab through the hole in the telescope structure. The hole shall be light tight when the fibre is in place.

3.1.2.4 Optical Interfaces

The optical interfaces are defined in TBD

3.1.2.5 Signal Interfaces

3.1.2.5.1 Power Sources

a. The instrument shall operate from the electrical supplies provided by the Gemini telescope, as defined in Science and Facility Instruments to System Services ICD 1.9/3.6.

b. The maximum power consumed by the instrument on each supply shall be as shown in the table 1. The compressed helium shall be provided by the telescope services and does not form part of this budget

Table 1 Maximum power consumed by instrument on each supply

Supply	**Power**	**Notes**
120 VAC	TBD	
208 VAC	TBD	

3.1.2.5.2 Digital Communication

a. There shall be only one machine interface between the instrument and the telescope (TBC).

b. The communications shown in table 2 shall exist between the instrument and the telescope system.

Table 2 Digital Interfaces

Description	Data Type	Comments
System Health Data		
Alarms		
FITS data		

3.1.2.5.3 Video Interfaces

There are no video interfaces with the telescope system.

3.1.2.5.4 Analogue Signals

There are no analogue signals between the instrument and the telescope (TBC)

3.1.2.5.5 Synchronisation Signals

TBD.

3.1.2.6 Service Interfaces

All instrument services shall be provided by the telescope according to the Science and Facility Instruments to System Services ICD 1.9/3.6

The instrument shall operate on the services shown in table 3 .

Table 3 Services Consumed by PRVS

Description	Volume	Flow Rate
Glycol	TBD	TBD
Compressed Air	TBD	TBD
Helium	TBD	TBD

3.1.3 MAJOR COMPONENT LIST

The inter-relationship between the major components is illustrated in Figure 2. The major components are listed in Table 4.

Table 4 Major Component List

Name	Acronym	Part Number	Level	Responsible Institute
Fibre Deployment and Acquisition System	FDAS	89-ATC-8001-3050	1	UKATC/IfA
Infrastructure	INF	89-ATC-8001-3150	1	UKATC
Fore-Optics Fibre	FFO	89-ATC-8001-3300	1	PSU
Spectrograph	SPEC	89-ATC-8001-3500	1	UKATC
Calibration Unit	Cal	89-ATC-8001-3750	1	UKATC/PSU
Instrument Control system	ICS	89-ATC-8001-3900	1	IfA
Data Pipeline	DRS	89-ATC-8001-3950	1	UKATC/PSU

3.1.4 GEMINI FURNISHED EQUIPMENT

The Gemini equipment listed below shall be made available as required by the PRVS design team.

a. Bancomm bc635VME time-bus module
b. Cisco 2950C-24 switch
c. Perle Terminal Server
d. Documentation delivered with the above components when purchased by AURA.
e. Copy of OLDP to run independently from the Gemini system (TBD).

3.2 CHARACTERISTICS

3.2.1 FUNCTIONAL REQUIREMENTS

In this section the overall functionality, rather than the quantified performance requirements, of the PRVS conceptual design is described. Quantified performance parameters are contained in section 3.2.2

3.2.1.1 Spectral Dispersion

The radiation incident from the science object shall be spectrally dispersed and the wavelength of the dispersed radiation measured.

3.2.1.2 Calibration

a. PRVS shall include all necessary calibrations to allow accurate measurements of the spectrum.
b. Calibration products required to perform data reduction shall be collected.
c. In radial velocity mode, calibration lines shall and science beam shall illuminate the detector simultaneously.

3.2.1.3 Acquisition and guiding

In conjunction with the telescope guiding functions, the instrument shall acquire a target onto the fibre and maintain it centred throughout an observation.

3.2.1.4 Data Reduction

PRVS shall produce data sets with instrument, telescope and atmospheric artefacts removed to a sufficient degree that the radial velocity may be calculated to <3 m/s. These data sets shall be stored for retrieval off-line

3.2.1.5 Self-Test

The instrument shall monitor its own health and the quality of the science data produced and report faults to the telescope operating system.

3.2.1.6 Alarms

The instrument shall provide automated instrument safety response to faults, inform operators of failure and supply procedures for investigation and recovery.

3.2.2 PERFORMANCE REQUIREMENTS

The following lists the performance requirements. Unless otherwise stated, these requirements apply across the full range of environmental conditions detailed in section 3.2.6.

3.2.2.1 Acquisition and guiding

Once the telescope has slewed to the nominal position and acquired the guide star, the instrument shall acquire the science target in less than 2 minutes and maintain it on the fibre to better than 0.1 arc seconds on the sky for a one hour observation (AD02, SR_11).

3.2.2.2 Observational Efficiency

Observational Efficiency shall be

a) ≥ 70% for a one hour observation

b) ≥ 50% for a 10 minute observation

This does not include the time taken to perform flat fielding (AD02, SR_3).

3.2.2.3 Vibration

Internal Instrument Vibration from (e.g. closed-cycle coolers) shall not cause the image quality at the detector to increase by greater than 0.1 pixels.

3.2.2.4 Structural Stability

The mechanical alignment between the Science Detector focal plane, the intermediate optical elements and the instrument interface shall be stable enough over all operating conditions so that the centroid of the spectral lines on the detector does not move by more than 0.1 pixels within a one hour observation (AD02, SR_7).

3.2.2.5 Surface Temperature

a. The external surface temperature of any part of the instrument within the telescope enclosure shall be less than 2 degrees maximum above ambient during operation. (ICD 1.5.3/1.9).
b. The local difference in temperature between the instrument and the telescope mounting face used shall be ≤ 1.0 deg C during operation (ICD 1.9)..

3.2.2.6 Power Dissipation

a. The total power dissipation of the on-telescope instrument shall be such that it complies with the thermal transfer requirements given in ICD 1.5.3/1.9 and the guidelines in Science Instruments Overview and Guide ICD 1.9 section 4.
b. The total heat released into the telescope enclosure by the instrument shall not exceed 50W.
c. The total heat released into the pier lab by the instrument shall not exceed 60W

3.2.2.7 General Mechanism Requirements

3.2.2.7.1 Independent Operation

All instrument mechanisms shall be capable of operating independently of the other mechanisms in terms of mechanical and control aspects, not including the loading capabilities of the position control processing electronics and any data transfers.

3.2.2.7.2 Temperature

All mechanisms external to the cryostat shall operate to specification over the temperature range specified in section 3.2.5

Cryogenic mechanisms shall operate at temperatures between 180K and 300 K with full specified performance achieved between 180 K and 230 K. If operation at room temperature is not advised, operating and handling procedures shall be clearly defined.

3.2.2.7.3 Position Control

All multi-position mechanisms shall have either absolute position sensing devices at each position or a switch-on datum gathering procedure to ensure a known mechanical state at switch on.

3.2.2.8 Spectral Range

The instrument shall meet all of the specifications across greater than 80% of the atmospherically clear regions of the spectral range of 0.99 μm – 1.75 μm (AD02, SR_6).

3.2.2.9 Spectral Resolving Power

3.2.2.9.1 Spectral Sampling

The instrument shall sample the spectrum with at least 2.5 pixels per resolution element (AD02, SR_5).

3.2.2.9.2 Resolving Power

The spectral resolving power shall be greater than R=50000 (essential, AD02, SR_4(1))

The goal for spectral resolving power is R= 70000 (optimal, AD02, SR_4(2))

3.2.2.9.3 Spectral Stability

a) The instrument shall be capable of measuring the centroid of spectral lines to better than 0.001 pixels (AD02, SR_7).

b) In the course of a 1 hour observation the centroid of the spectral lines shall remain stable to 0.1 pixels without calibration (AD02, SR_7).

c) The 3rd moment of the spectral image shall remain stable to ≤1 part in 1000 over a period of 1 month

3.2.2.10 Stray Light and Ghosting

3.2.2.10.1 Scattered Light

Scattered light is defined as the diffuse light which illuminates the detector at pixels other than those intended due to scattering in the optical elements. The scattered light seen at the detector shall be less than 1 part in 10^5 of the input signal..

3.2.2.10.2 Ghost Images

No ghost image shall be formed which is greater than 1 part in 10^5 of the intensity of the source of the ghost

3.2.2.10.3 Wide Angle Radiation

The illumination at angles greater than 2.5 pixels from the optical PSF shall be less than TBD at any point on the slit.

3.2.2.11 Thermal Radiation

The average thermal radiation reaching the detector, across the sensitive waveband of the detector, from the instrument shall be less than 0.01 photons/second/pixel.

3.2.2.12 Flat Field Quality

The flat field calibration of the instrument shall be performed to better than 0.2% deviation from the mean value.

3.2.2.13 Acquisition Accuracy

Science targets shall be acquired onto the fibre with an accuracy of better than 0.1 arc seconds (AD02, SR_11).

3.2.2.14 Field Of View

The instrument shall have a field of view on the sky of ≥1.2 arc seconds (AD02, SR_9).

3.2.2.15 Detector Quantum Efficiency

The detector quantum efficiency shall be ≥0.6 across the waveband of the instrument .

3.2.2.16 Throughput

The instrument throughput shall be ≥0.05 at all wavelengths between 0.99 and 1.75 μm with a goal of ≥0.1 (AD02, SR_8(1)).

3.2.2.17 Image Quality

3.2.2.17.1 At the Detector

The image quality at the detector shall be such that:

a. 50% Encircled Energy Diameter ≤ 0.8 pixel (AD02, SR_14(a)).

b. 80% Encircled Energy Diameter ≤ 1.6 pixels (AD02, SR_14(b)).

3.2.2.17.2 At the Object Fibre

The image quality at the object fibre shall be such that:

50% Encircled Energy Diameter ≤ 0.10 arcsec (AD02, SR_13).

3.2.2.18 Handling

a. The instrument shall be handled using the Gemini facility handling equipment as specified in the Science and Facility Instruments to Facility Handling Equipment ICD (1.9/2.7).

b. All necessary handling points shall be provided.

3.2.2.19 Electrical Interlocks

Safety interlocks shall be provided which shall comply with Interlock System to Science Instruments ICD and Interlock System (ICD 1.1.13/1.9 and ICD-12 respectively).

3.2.2.20 Standards

a. The instrument software shall comply with the design requirements of Guidelines for Designing Gemini Aspen Instrument Software, AspenSoft-03072004-6 (AD3). Where this contradicts other software standards, this shall be deemed to take precedence over all other information.

b. Mechanical Drawings shall be prepared to TBD

c. Electrical design shall comply with TBD

3.2.3 PHYSICAL CHARACTERISTICS

3.2.3.1 Mass

a. The mass of PRVS sub-systems mounted on the ISS port shall be such that the total mass is 20 Kg ± TBD.

b. The mass of the parts of the instrument in the Pier lab shall be no more than 3000 Kg.

c. No single assembly shall exceed the safe working limit of the Pier lab hoist which is TBD

3.2.3.2 Centre of Gravity

a. The COG of the parts of the instrument on the ISS shall be trimmed to be TBD mm out from the ISS mechanical interface.

b. The allowable out of balance in any orientation shall not exceed TBD Nm with respect to the telescope elevation axis.

3.2.3.2.1 Dynamic Mass Moment

Changes in COG due to mechanism operation shall not cause the mass moment on the ISS to exceed TBD Nm with respect to the telescope elevation axis.

3.2.3.3 Space Envelope

a) The parts of the instrument within the pier lab shall fit entirely within the pier lab and allow safe access.

b) The space envelope of the ISS mounted parts shall be TBD

3.2.4 RELIABILITY

a. PRVS shall have a total downtime of ≤2% of scheduled time on the telescope, with 1% as a goal.

b. With PRVS otherwise functioning normally, time spent pumping, cooling, or warming the instrument prior to mounting or dismounting PRVS on the telescope is not considered down time.

c. A combination of careful component and materials selection based on proven equipment designs and prototype testing, supplemented by a failure effects analysis will be used to reduce both the probability of critical component failure and the effects of such a failure on the instrument performance. No formal MTBF calculations will be performed as this is beyond the scope of the project.

d. During the instrument detailed design, single point failures that would result in significant downtime shall be determined and critical spares shall be identified.

3.2.5 MAINTAINABILITY

3.2.5.1 Re-alignment

No instrument mechanical re-alignment shall be required subject to the instrument experiencing normal handling and operating forces.

3.2.5.2 Handling

Disassembly of the instrument shall be possible within the Pier lab for maintenance of all moving parts.

3.2.5.3 Access

a. All major assemblies shall be removable within the Pier lab.

b. The cold head displacer shall be replaceable without the need to open the vacuum vessel.

3.2.6 ENVIRONMENTAL CONDITIONS

The parts of PRVS wholly or partly within the dome shall meet all requirements contained in this specification under the environmental conditions specified below. Conditions within the pier lab are less severe and those parts of the instrument wholly within the pier lab shall meet the relevant specification.

3.2.6.1 Ambient Air Temperature

a. -5 °C to 20 °C in the dome

b. 0 °C to 10 °C in the pier lab

3.2.6.2 Ambient air temperature rate of change

a. The maximum rate of change of ambient air temperature shall be ±8 °C per hour in the dome

b. The pier lab may be subject to step changes of ±5 °C

3.2.6.3 Altitude

0 m to 4300 m above mean sea level.

3.2.6.4 Relative Humidity

0% to 90% at all points

3.2.6.5 Wind Speed

a. 0 to 5 m/s in the dome.

b. No wind in the pier lab.

3.2.6.6 Vibration

PSD $1x10^{-5}$ g^2/Hz, 20-1000Hz, 6dB/oct drop-off to 2000Hz at all points.

3.2.6.7 Gravity Component

The parts of the instrument attached to the ISS shall operate under a gravity component changing continuously or in discrete steps between ±1g X axis, ±1g Y axis and -1g to 0g in the Z axis according to the optical support structure coordinate system specified in the Gemini Observatory Opto-mechanical Coordinate System ICD-G0014.

3.2.7 TRANSPORTABILITY

PRVS shall remain undamaged after repeated cycles of the following conditions. This specification applies to the instrument in its packaging and at the state of assembly specified in the assembly integration and test plan.

3.2.7.1 Ambient Air Temperature

-25 °C to 71 °C

3.2.7.2 Temperature Shock

Temperature shocks of ±35 °C anywhere within the ambient temperature range.

3.2.7.3 Altitude

0 m to 15000 m above mean sea level.

3.2.7.4 Relative Humidity

0% to 100% with condensation

3.2.7.5 Wind Speed

0 to 67m/s

3.2.7.6 Vibration

a. PSD 0.015 g^2/Hz, 10-40Hz

b. 0.00015 g^2/Hz, at 500Hz

3.2.7.7 Gravity Component

±1 g in all orientations

3.2.7.8 Shock

Peak acceleration 15g in all axes

3.3 DESIGN AND CONSTRUCTION

3.3.1.1 Processes and Parts

a. The UK ATC Programme Delivery and Engineering Process, Procedures and Policy Handbook [AD tbc] shall be used for the design, development, build, integration and verification of the PRVS instrument.

b. UKATC mechanical group procedures shall be followed [AD08].

c. Metric design standards shall be utilised.

d. Outline drawings shall be dimensioned using metric units in accordance with BS308.

e. The quantity and types of parts within the instrument should be minimised to maximise standardisation.

f. Single source materials, processes and components shall be avoided.

g. EMC design standards shall be in accordance with REF APPLICABLE SPEC

h. Design standards for reliability and maintainability shall be in accordance with TBD

i. All software supplied shall meet software standards as specified in TBD.

3.3.1.2 Materials

a. All materials used in the construction of the equipment shall be suitable for their intended use and shall have been treated to withstand the environmental conditions to which they will be subjected.

b. No magnesium or magnesium rich alloys shall be used in the construction of the equipment.

c. Special attention to the choice of materials shall preclude the use of strategic or critical materials.

d. The equipment shall not utilise devices containing liquid mercury, mercury salts or mercury vapour.

e. The equipment shall not utilise toxic substances.

f. The following materials shall not be used:

   i. Asbestos

   ii. Polycarbonate Bi-phenols (PCBs)

   iii. Radioactive Thorium

   iv. Magnesium Thorium

   v. Beryllium

   vi. Radioactive optical coating

g. The equipment shall not constitute a fire hazard, it shall have low flammability.

h. The materials and their manner of enclosure shall be such that under any conditions of overheating or malfunction, no harmful concentrations of toxic products will result.

3.3.1.3 Thermal design

TBD

3.3.1.4 Cleanliness

All optical components shall be handled and delivered according to TBD

3.3.1.5 Packaging

TBD

3.3.2 ELECTROMAGNETIC ENVIRONMENTAL EFFECTS

3.3.2.1 Electromagnetic interface and compatibility

Good engineering practice (such as the advice given in RD01) shall be followed in the electrical design process to reduce electromagnetic interference effects to a level where they do not significantly impact either instrument performance or operation of Gemini systems.

3.3.2.2 Electromagnetic vulnerability

TBD

3.3.2.3 Screening, bonding and earthing

3.3.2.4 Electrical systems grounding

(Excluding safety)

Good engineering practice (such as the advice given in RD01) shall be followed when designing the electronics and internal power supplies to reduce ground loop effects to a level where they do not significantly impact either instrument performance or operation of Gemini systems.

3.3.3 IDENTIFICATION AND WORKMANSHIP

a. Level 2 and 3 configuration items as identified in Figure 3, shall be marked in a prominent position with identification and modification labels.

b. The following information shall be supplied:

i. Manufacturing Institution's name.
ii. Item name.
iii. Part number.
iv. Serial number (if applicable).
v. Modification.
vi. Date of manufacture.

3.3.4 INTERCHANGEABILITY

All assemblies shall be interchangeable with other assemblies of the same part number following all necessary alignments and calibrations.

3.3.5 SAFETY

3.3.5.1 Mechanical Safety

A safety margin of 1.5 with respect to sigma yield (sigma 0.2%) shall be used in the design of all those mechanical components which, in case of failure, would lead to an unacceptable or undesirable hazard risk.

Interlocks will be provided where necessary to prevent movement of the telescope during maintenance activities where this would be hazardous.

3.3.5.2 Electrical Safety

The instrument, considered as electrical equipment, shall comply with IEC 644 & 644 A, and IEC 950.

3.3.5.3 Operational Safety

None of the following failures shall lead to an unacceptable hazard.

a. Astronomer error

b. One or two independent operator errors (maintenance staff, operations staff)

c. One instrument operator error plus one hardware failure

d. One or two hardware failures

e. Any software failure

f. One hardware plus one software failure

3.3.6 HUMAN PERFORMANCE/HUMAN ENGINEERING

The PRVS design shall optimise the ability of the scientists, telescope operators and engineering personnel to satisfactorily perform operational and maintenance tasks.

3.3.6.1 Operational

TBD

3.3.6.2 Maintenance

PRVS shall be designed to minimise the workload of observatory personnel. Design shall include the following:

a. Adequate self-test and test equipment.

b. Tooling and simplified mechanical interfaces facilitating the removal and installation of configuration items.

c. Keying of mating surfaces and components.

d. Special lifting interfaces to ensure easy and safe handling when observatory lifting equipment is required for installation and removal of heavy equipment.

e. Equipment shall be design to minimise the need for scheduled preventative maintenance tasks.

f. The use of consumables to ensure the correct operation of the instrument shall be kept to a minimum.

g. If the instrument requires the use of consumables, it shall be designed for easy access and replacement.

3.4 DOCUMENTATION

The following documentation shall be provide

a. User manual

b. Maintenance Manual

c. Handling Procedure Document

d. Software Design & Maintenance Manual

The PRVS Handling Procedure Document shall describe how the instrument is mounted, moved, oriented and dismounted from the telescope and handling jig in a safe and easily controllable manner.

The handling operations shall comply with the instructions and advice given in ICD-G0015 and ICD 1.9/2.7.

3.5 LOGISTICS

a) The instrument shall be delivered to the observatory by means of TBD

b) A list of necessary spare parts shall be provided

3.6 PERSONNEL AND TRAINING

Gemini personnel shall be trained in the operation and maintenance of the instrument.

3.7 MAJOR COMPONENT CHARACTERISTICS

3.7.1 FIBRE DEPLOYMENT AND ACQUISITION SYSTEM

This sub-system will deploy a pick-off mirror into the Gemini field to illuminate the fibre with the science object. The numerical aperture of the fibre will be different to the uncorrected focal ratio of the telescope so there will be optics in this unit to convert between the two in order to maximise throughput. The unit will be bolted to the ISS next to GCAL which will be modified to ensure that it remains light tight.

The fibre optic cables will be part of this sub-system as well as the cable routing and fixings such as the light tight connection through the floor to the pier lab. The cable will be routed through the Cassegrain rotator so that it is out of the way during maintenance activities. The cable will be removable and easily stowed during telescope mirror maintenance in order to reduce the chance of damage.

The unit will also allow the calibration unit to selectably illuminate the science fibre at the input.

An acquisition camera will be part of this sub-system. This will be peltier cooled with further water/glycol cooling required. The output from the camera will be fed to a control computer where it will be converted to telescope offsets. The acquisition camera will have a neutral density filter optionally placed in front of it to allow for greater contrast in the acquisition objects.

The conceptual deign of the sub-system layout is illustrated in Figure 4.

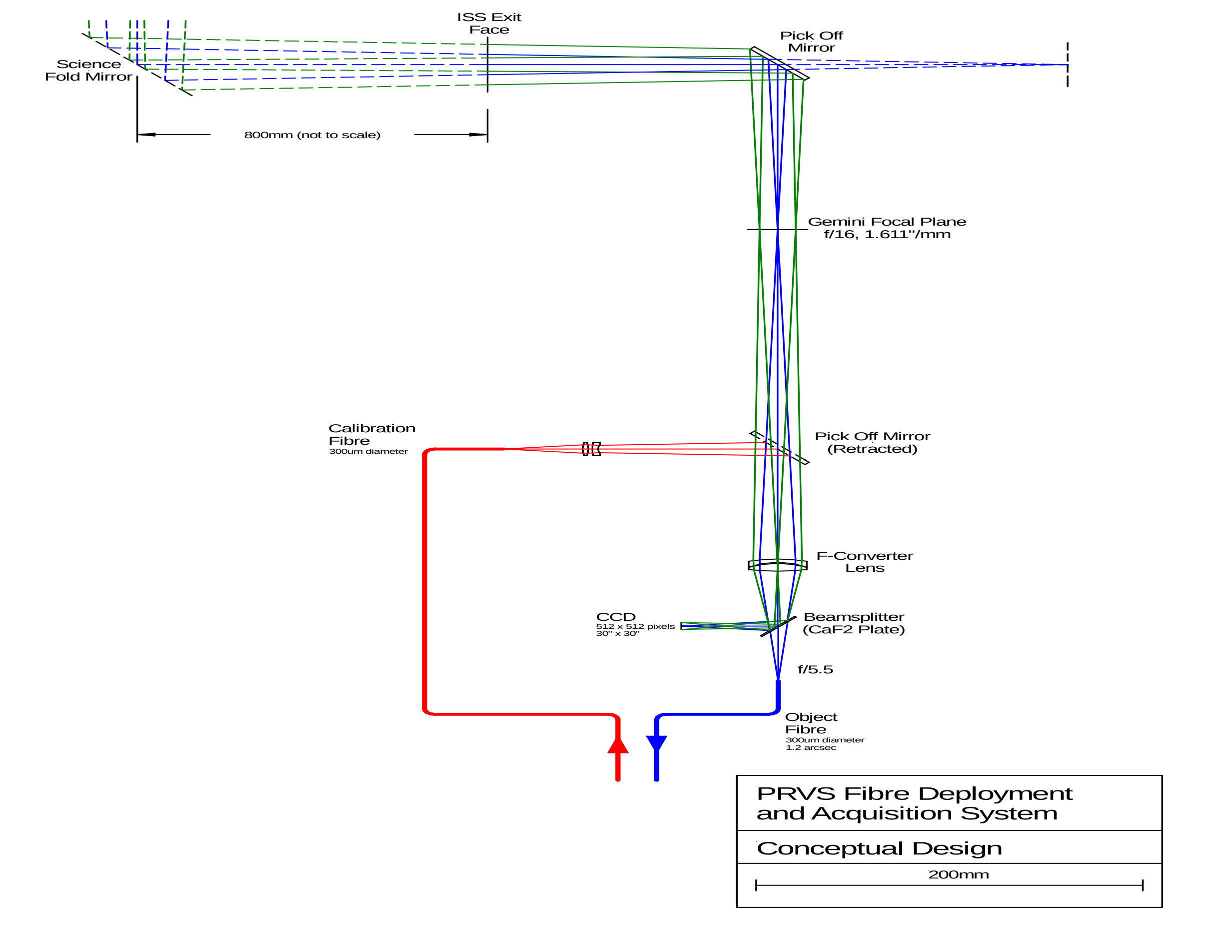

Figure 4 Fibre Deployment and Acquisition Unit layout

This sub-system will form the interface between the instrument and the GCAL Unit.

3.7.1.1 Interface Definition

The sub-system interfaces are defined in Table 5.

Table 5 Fibre Deployment and Acquisition Unit interface definition

Description	Interface with	Type
ISS mount	Gemini ISS (TBD)	Mechanical
Pick-off	Gemini Science field (AD07, AD08)	Optical
Coolant	Gemini services (ICD 1.9/3.6)	Glycol
Power	Instrument control	24 V D.C.
Acquisition images	Instrument control	Ethernet
Filter Wheel	Instrument Control	Analogue
Fibre connection	Fore-optics Fibre	Ferrule connector
Fibre Connection	Calibration Unit	Ferrule connector

3.7.1.2 Object Fibre

3.7.1.2.1 Image Quality

The image quality delivered by the re-imaging optics onto the fibre shall be such that 50% EED ≤ 0.10 arcsec.

3.7.1.2.2 Field of View

The fibre shall cover an area equivalent to ≥1.2 arc seconds diameter on the sky (AD02, SR_9).

3.7.1.2.3 Repeatability

The mounting system shall have alignment repeatability less than 0.05 arc seconds on the sky.

3.7.1.2.4 Stability

The image shall remain stable on the fibre to better than 0.1 arc seconds over a period of 1 hour..

3.7.1.2.5 Numerical Aperture

The numerical aperture of the fibre shall be 0.22 ±0.02

3.7.1.2.6 Throughput

The throughput of the Science beam shall be ≥0.8 (see AD02, SR_8).

3.7.1.3 Fibre Viewer

3.7.1.3.1 Field of View

The fibre viewer camera shall have a field of view of ≥30 arc seconds square (essential) and a goal of ≥60 arc seconds square

3.7.1.3.2 Image Quality

The image quality delivered by the re-imaging optics onto the fibre viewer camera shall be such that:

a. 50% EED ≤ 0.10 arcsec, within central 5 arcsec FOV

b. 50% EED ≤ 0.05 arcsec, within 30 x 30 arcsec FOV

3.7.1.3.3 Sensitivity

The fibre viewer camera shall have a sensitivity of 14.8 in the Z band (20 sigma in 1 second). (AD02, SR_14)

This assumes that the telescope throughput is 0.96 (including science fold mirror)

3.7.1.3.4 Throughput

The throughput of the fibre viewer system shall be ≥0.01 (in Z band)

3.7.1.3.5 Readout Speed

a. The camera shall read out a full frame in less than 10 seconds.

b. The camera shall read out a sub-array of 20x20 pixels in less than 1 second.

3.7.1.3.6 Exposure time

The exposure time of the camera shall be selectable between 0.1 seconds and 20 seconds

3.7.1.3.7 Readout Mode

The fibre viewer camera shall be capable bin and window readout

3.7.1.3.8 Co-addition

The camera shall be capable of co-adding at least 500 integrations

3.7.1.3.9 Output

The camera controller shall have an Ethernet connection

3.7.1.3.10 Pixel Size

The pixel size of the camera shall be ≤0.05 arc seconds on the sky

3.7.1.3.11 Filter

The fibre viewer shall have a deployable neutral density filter of density = 2 ± 0.1 for acquisition of the brightest objects.

3.7.2 CALIBRATION UNIT

a. The calibration unit will provide flat field illumination and spectral lines to the spectrograph so that the spectral lines may be measured. The calibration input is required to be fed to the science fibre at the very front end and via a separate channel to the fore-optics.

b. The illumination to the science fibre will also optionally include a white light passing through a gas cell to provide extra absorption lines.

c. The calibration unit will be temperature stabilised and will include a set of shutters so that the lamps can be left running for long periods after stabilising.

The conceptual design of the sub-system layout is illustrated in Figure 5.

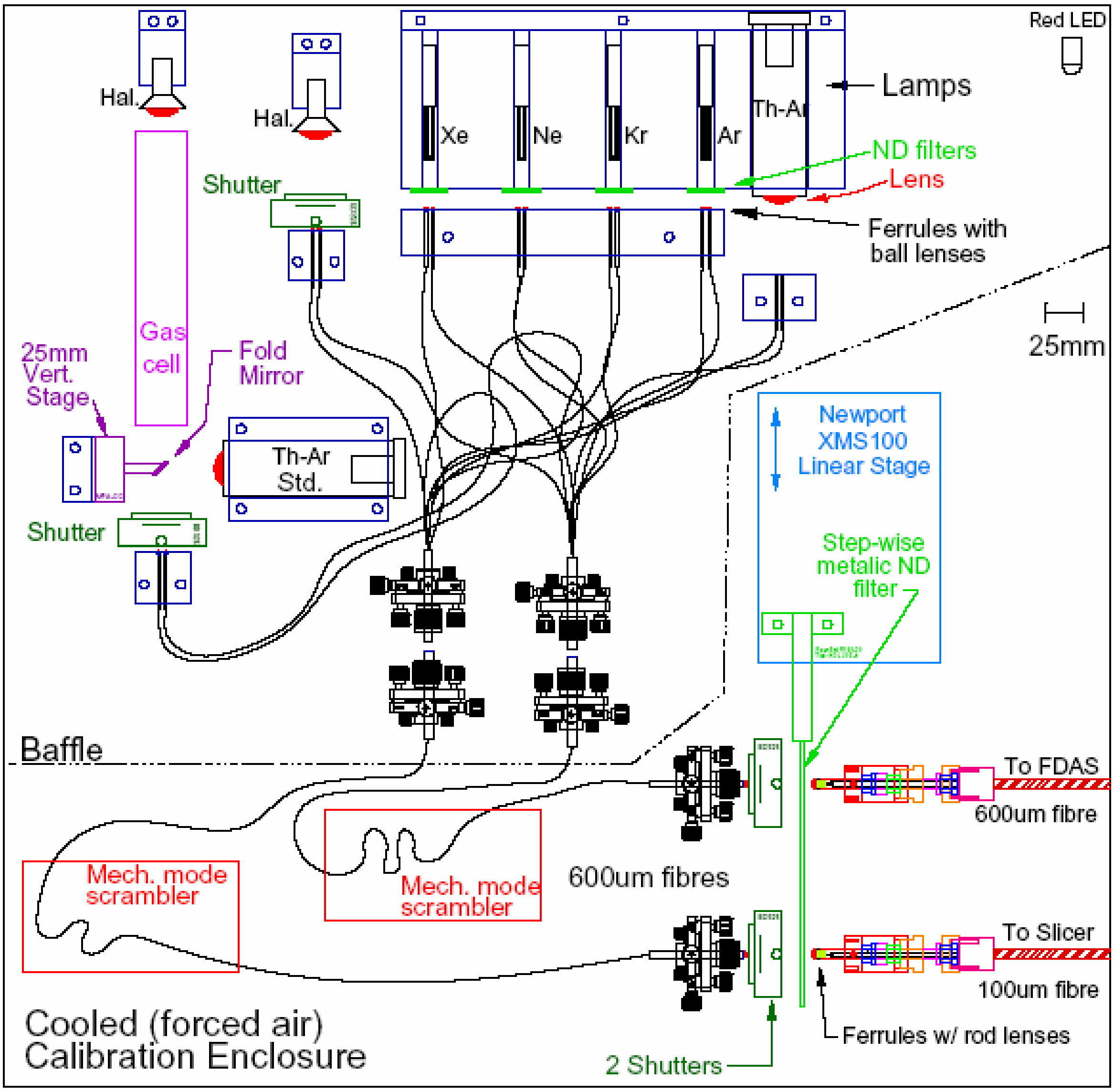

Figure 5 Calibration Unit layout

3.7.2.1 Interface Definition

The sub-system interfaces are defined in Table 6.

Table 6 Calibration Unit Interface Definition

Description	Interface with	Type
Shutters	Instrument control	Digital
Power	Instrument control	TBD
Fibre connection	Fore-optics fibre	Ferrule connector
Fibre connection	Fibre Deployment and Acquisition Unit	Fibre cable
Coolant	Gemini services (ICD 1.9/3.6)	Glycol

3.7.2.2 Calibration Sources

a. The calibration source shall have lines spread over the 0.97 - 1.7um windows

b. Line density shall be ≥1 per 100 wavenumbers, and ≤1 per 1 wavenumber

3.7.2.3 Line stability

The spectral lines shall remain stable to better than 1 m/s over an observation.

3.7.2.4 Intensity

The calibration unit shall provide greater than 6 million photons onto the detector in 0.1 seconds.

3.7.2.5 Gas Cell Absorption

The absorption lines in the gas cell shall have absorption greater than 20% and less than 90%

3.7.3 FORE-OPTICS FIBRE

The fore-optics fibre assembly will scramble the spatial information in the fibre so that motion of the object does not affect the centroid of the spectrum. It will also agitate the fibre so that mode noise of the fibre does not affect the spectrum. The fibre will be split at the interface to the cryostat and the light from the science fibre will be distributed into seven smaller fibres. The calibration fibre and the seven science fibres will then be arranged in a line to form the spectrograph slit. All fibres will be agitated so as to remove mode noise from each one. The conceptual design of the sub-system layout is illustrated in Figure 6 below.

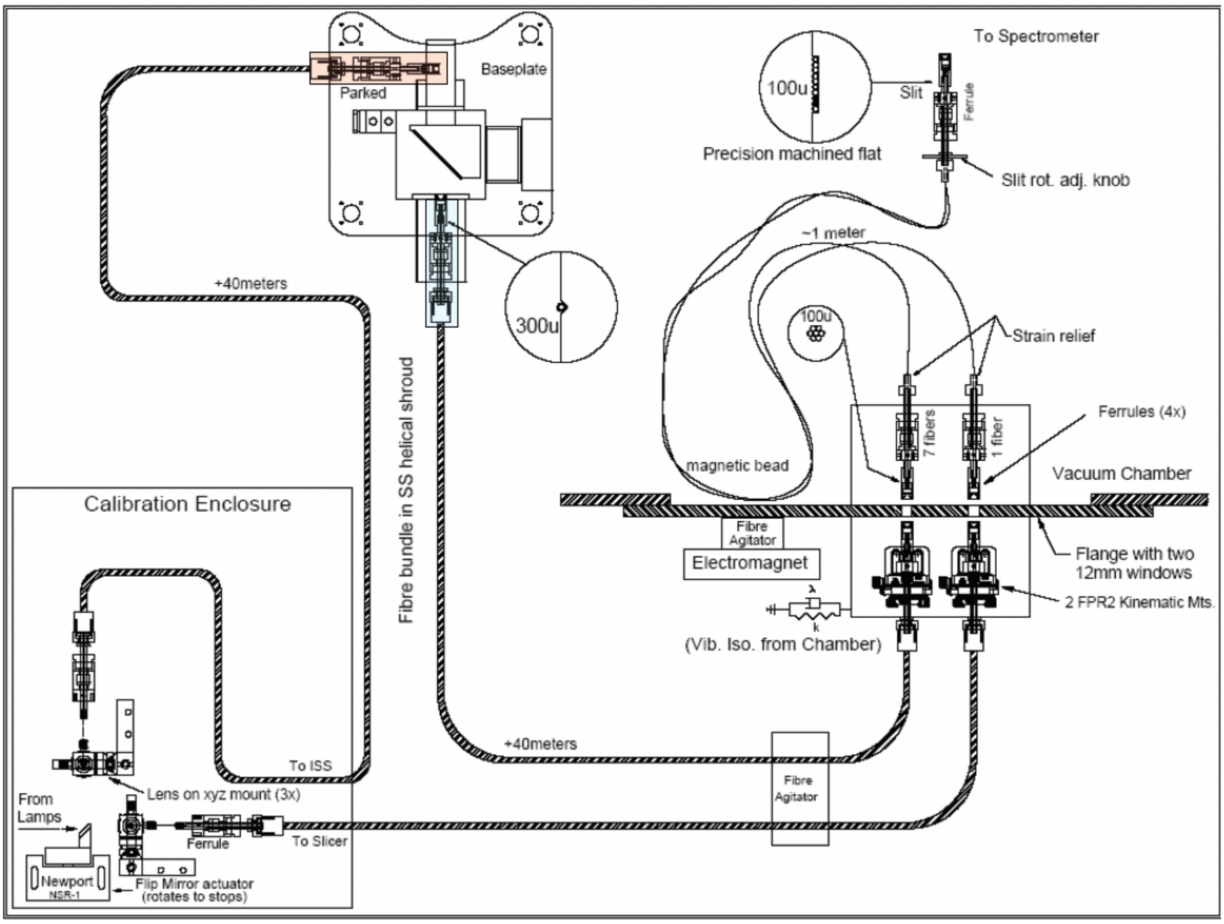

Figure 6 Fore Optics Fibre layout

3.7.3.1 Interface Definition

The sub-system interfaces are defined in Table 7.

Table 7 Calibration Unit interface definition

Description	Interface with	Type
Agitator Control	Instrument control	Digital
Power	Instrument control	TBD
Fibre connection	Fibre deployment and acquisition unit	Fibre cable
Fibre connection	Calibration unit	Fibre cable
Slit	Spectrograph	8 fibres

3.7.3.2 Fibre output diameter

The output of the fibre shall be 100 ± TBD microns diameter.

3.7.3.3 Throughput

a) The throughput of each fibre, fibre scrambler and agitator shall be ≥ 0.69

b) The throughput of the image slicer shall be ≥0.7

3.7.3.4 Scrambling

The spatial information in the input beam shall be scrambled by a factor of ≥1000.

3.7.3.5 Slit Stability

The fibres which make up the slit shall remain stable to each other to better than 0.1 microns.

3.7.3.6 Focal Ratio Degradation

The focal ratio degradation in the fibres shall be ≤10%

3.7.4 INFRASTRUCTURE

a. The infrastructure will support all other sub-systems by providing power, data connections, mechanical support and cooling for sub-system electronics. Electronic control functions for the cryostat and associated vacuum and cooling equipment are contained within this sub-system including monitoring of its own status/health. The infrastructure will be located in the pier lab.

b. A shutter will be provided to allow the detector dark current to be measured and to allow the detector to be blanked when not observing to avoid persistence problems.

3.7.4.1 Interface Definition

The sub-system interfaces are defined in Table 8:

Table 8 Infrastructure Sub-System Interface Definition Table

Description	Interface with	Type
Temperature sensors	Instrument Control system	analogue
Pressure sensors	Instrument Control system	analogue
Power	Gemini services (ICD 1.9/3.6)	Electrical
Coolant	Gemini services (ICD 1.9/3.6)	Glycol
Helium	Gemini services (ICD 1.9/3.6)	Helium
Detector thermal control	Spectrograph	Analogue
Optical interface	Fore-optics fibre	Window mount
Mechanical mounting	Gemini	Interface drawing TBD

3.7.4.2 Temperature Control

3.7.4.2.1 Operating Temperature

a. The temperature of the cryostat shall be ≤200K

b. The temperature of the spectrograph camera shall be ≤190 K

c. The temperature of the detector shall be ≤69K

3.7.4.2.2 Temperature Stability

The temperature of all parts of the instrument within the cryostat shall be stable to

a) ≤0.05K over 24 hours with a goal of 0.01 K

3.7.4.3 Vacuum Systems

Instrument Cryostat Vacuum systems shall be compatible with the Gemini services provided as defined in ICD 1.9/3.6.

3.7.4.4 Cryogenic and Vacuum requirements

3.7.4.4.1 Evacuation time

The instrument shall pressure shall be low enough to allow cooling to commence within 24 hours of pumping commencing.

3.7.4.4.2 Cool Down Time

a) The instrument shall reach operating temperature within 48 hours of cool-down commencing.

b) The instrument temperature shall reach the specified stability within 96 hours of cool down commencing.

3.7.4.4.3 Warm up time

The instrument shall warm up safely within 48 hours of warm up commencing.

3.7.5 SPECTROGRAPH

The spectrograph sub-system will be the part of the instrument that disperses the light into its spectral components. The design will follow the HARPS solution of a white pupil spectrograph. It will be totally enclosed in a cryostat to minimise the effect of temperature and pressure variations on the centroid of the spectral lines.

The light from the fore-optics fibre will enter the cryostat via a window and will then be split into seven smaller fibres plus one calibration fibre. These fibres will form the slit which is the input to the spectrograph.

The detector assembly will form part of the spectrograph sub-system and will includes the infrared detector and the associated control electronics.

The conceptual design of the sub-system layout is illustrated in Figure 7

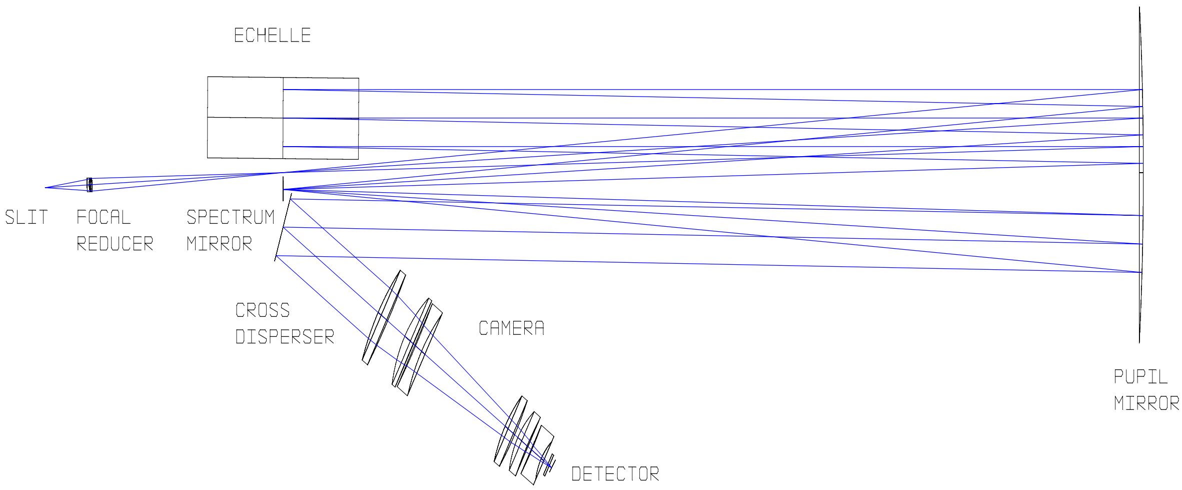

Figure 7 Spectrograph layout

3.7.5.1 Interface Definition

The sub-system interfaces are defined in Table 9.

Table 9 Spectrograph Interface Definition Table

Description	Interface with	Type
Mechanical mounting	Infrastructure	Thermal, mechanical
Cabling	Infrastructure	Thermal, mechanical
Thermal wicks	Infrastructure	Thermal, mechanical
Input slit	Fore-optics fibre	Virtual slit output from 8 fibres
Detector LED	Instrument control system	Digital
Detector data	Instrument control system	Digital data
Telluric maps	Instrument control system	Digital data

3.7.5.2 Slit Length

The slit length shall be 0.9mm.

3.7.5.3 Slit width

The slit width shall be 0.077 mm.

3.7.5.4 Throughput

The throughput of the spectrograph shall be ≥0.3 at the centre of the waveband.

3.7.5.5 Image Quality at Detector

The image quality at the detector shall be better than

a. 50% Encircled Energy Diameter ≤ 0.8 pixel (AD02, SR_14(a)).

b. 80% EED ≤ 1.6 pixels (AD02, SR_14(b)).

3.7.5.6 Stability

The spectrum shall remain stable to 0.1 pixels in an observation lasting up to 1 hour.

3.7.5.7 Order Separation

There shall be at least 5 pixels separation between the orders.

3.7.5.8 Extent of Spectrum

The output spectra shall cover less than 2040 pixels at the detector.

3.7.5.9 Detector Geometry

3.7.5.9.1 Format

The detector focal plane array shall consist of 2 x (2048 x 2048) detectors.

3.7.5.9.2 Pixel Size

The detector pixel pitch shall be 18 μm ± TBD.

3.7.5.9.3 Stability

The detector position shall remain stable to ≤0.05 pixels in one hour.

3.7.5.10 Detector Performance

3.7.5.10.1 Spectral range

The spectral range of the detectors sensitivity shall be greater than or equal to the total spectral range requirement of the instrument.

3.7.5.10.2 Dark Current

The dark current shall be ≤ 0.1 electrons/sec/pixel (AD02, SR_2).

3.7.5.10.3 Persistence

a) As a goal the arrays shall be selected so that the persistence is minimised.
b) 2 minutes following a destructive read at <=75% well fill, the persistence current shall be less than 0.1 e/s.

3.7.5.10.4 Well Depth

The well depth shall be no less than 1×10^5 electrons

3.7.5.10.5 Flat Field

The flat field non-uniformity shall be ≤0.2%

3.7.5.10.6 Linearity

After calibration, the linearity of each pixel in the array shall be ≤ 0.1% of the signal.

3.7.5.10.7 Read Noise

The read noise shall be ≤ 5 electrons with multiple non-destructive reads.

3.7.5.10.8 Cosmetic Quality

a. Non-uniformity of QE shall be ≤10% (sigma / mean ≤10% in the QE histogram) at all wavebands.

b. The number of bad pixels shall be less than 3% i.e. ~ 4x104 pixels in 2kx2k array. These pixels should not be clustered (AD02, SR15(1)).

c. Any contiguous square of size 30x30 pixels shall not contain more than 200 bad pixels. The bad pixels include both hot pixels and dark pixels.

d. A hot pixel is counted when its dark generation is greater than 3e-/sec. above the mean dark generation. A dark pixel is the one whose response is less than 50% of the local mean signal level.

3.7.5.10.9 Glow Centres

With 1024 non-destructive reads the dark current shall be ≤0.02 e/s/pixel.

3.7.5.10.10 Cross Talk

a. The detector cross talk from any pixel shall not degrade the PSF by more than 37% and be symmetrical into all neighbours to ≤1%

b. The detector cross talk shall vary by less than 1% per year of operation.

3.7.5.10.11 Quantum Efficiency

The detector quantum efficiency shall be ≥ 60% across the waveband of the instrument.

3.7.5.10.12 Cut-Off Wavelength

The long wavelength cut-off shall be 1.75 microns (for the detector).

3.7.5.11 Detector Readout Electronics

3.7.5.11.1 Readout Modes

The detector shall have the following readout modes:

a. Single Read

b. Correlated double sampling

c. Non-destructive read

d. Destructive read

e. Fowler Multiple Sampling

3.7.5.11.2 Readout Speed

The full array shall be readout in less than 2 seconds

3.7.5.11.3 Maximum Exposure

The array shall be capable of integrating for at least 1800 seconds

3.7.5.11.4 Co-addition

The controller shall be able to co-add at least 50 integrations

3.7.5.11.5 Dark Current Measurement

TBD.

3.7.5.11.6 Sub-array Performance

The detector shall allow read-out of at least 100, sub-arrays, independently of the rest of the detector.

3.7.5.11.6.1 Sub-array Size

The size of the sub-arrays shall be selectable between 1 pixel and 5x5 pixels.

3.7.5.11.6.2 Sub Array Readout Speed

The sub-array shall be destructively read within 1.5 seconds

3.7.5.11.7 Calibration Lines

The brightest calibration lines shall be destructively read during the course of an observation so that they do not saturate.

3.7.6 INSTRUMENT CONTROL SYSTEM

The instrument control sub-system will perform top-level configuration and control of other sub-systems. It will provide user interfaces and consist of software components that plug in to Gemini software. The sub-system will be primarily software but will run on two workstations. One will be located in the telescope dome and will convert the output from the acquisition camera into an offset for the telescope and will control the mechanism which drives the pick-off mirror into the field. The other will be located in the Pier lab and will contain the rest of the instrument control functions.

The sub-system layout is illustrated in Figure 8.

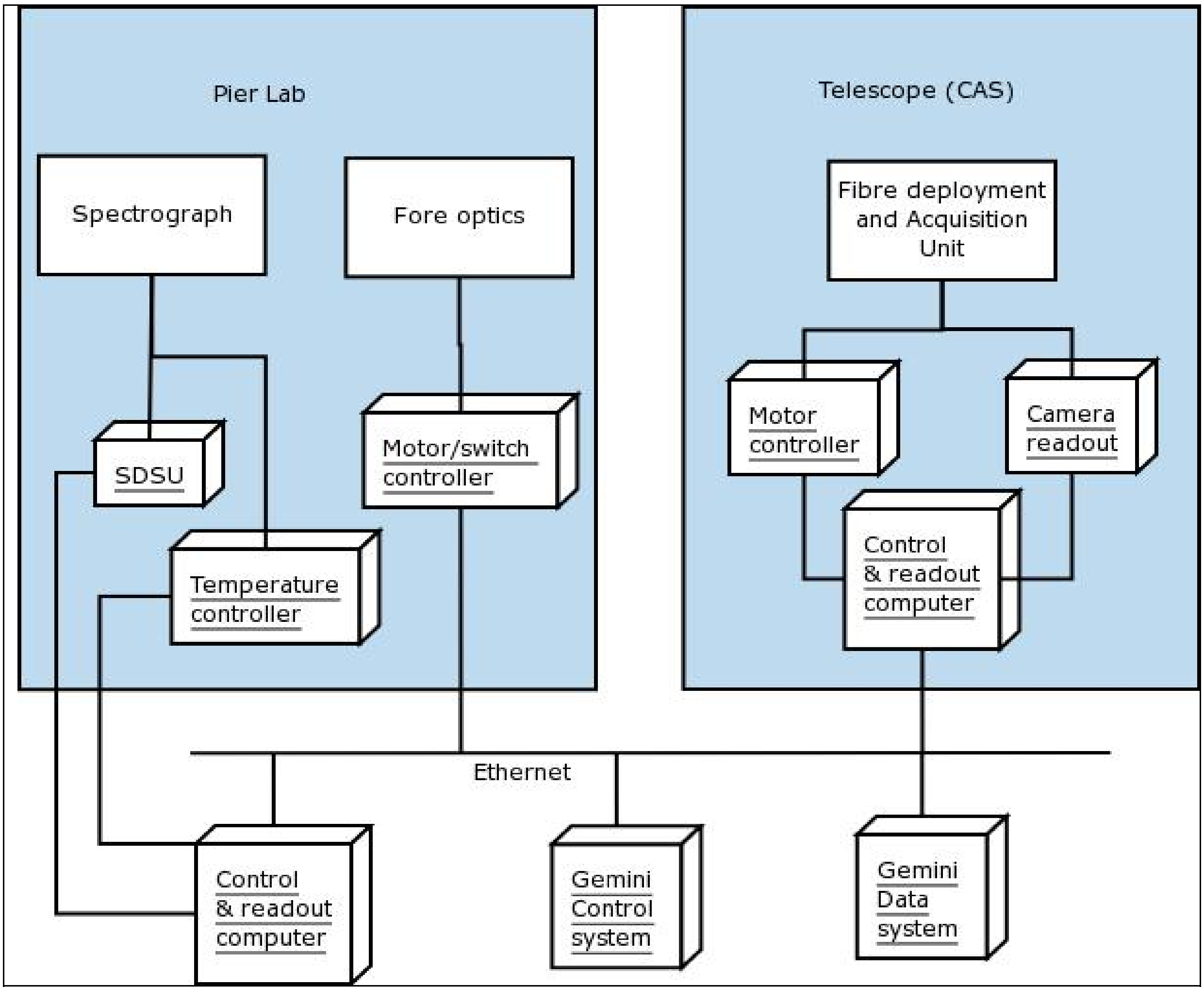

Figure 8 Instrument Control architecture

3.7.6.1 Interface Definition

The sub-system interfaces are defined in Table 10.

Table 10 Instrument Control System Interface Definition Table

Description	Interface with	Type
Power	Gemini	Mains power TBD W
Coolant	Gemini	Glycol at temperature Flow rate TBD
Alarms	Gemini	Ethernet
Guiding Offsets	Gemini	Ethernet
Observation Control	Gemini	Ethernet
Deployable pick-off mirror control	Deployment and Acquisition Unit	Ethernet
Temp sensors	Deployment and Acquisition Unit	Analogue

Table 10 Instrument Control System Interface Definition Table

Description	Interface with	Type
Fibre Viewer images	Deployment and Acquisition Unit	Ethernet
Stage Position Feedback	Deployment and Acquisition Unit	Analogue
Fibre agitator (x2)	Fore-optics Fibre	
Temp sensors	Fore-optics Fibre	
Flat Field Halogen Lamp on/off	Calibration Unit	
Gas Cell Halogen Lamp on/off	Calibration Unit	
Argon lamp on/off	Calibration Unit	
Krypton lamp on/off	Calibration Unit	
Neon lamp on/off	Calibration Unit	
Xenon lamp on/off	Calibration Unit	
ThAr lamp on/off	Calibration Unit	
Flat Field Halogen Lamp shutter	Calibration Unit	
Gas Cell Halogen Lamp shutter	Calibration Unit	
Ar, Kr, Ne, Xe shutter	Calibration Unit	
Th-Ar lamp shutter	Calibration Unit	
Lamp Intensity	Calibration Unit	
Flip mirror in/out	Calibration Unit	
Detector flood LED	Calibration Unit	
Temperature	Calibration Unit	
Stage Position Feedback	Calibration Unit	
Stage + limit	Calibration Unit	
Stage - limit/home	Calibration Unit	
Vacuum Pumps	Infrastructure	
Closed Cycle Cooler	Infrastructure	
Temp sensors	Infrastructure	
Pressure sensors	Infrastructure	
Cabinet temperature sensors	Infrastructure	
Detector flat field source	Spectrograph	
Detector shutter	Spectrograph	
Detector Heater	Spectrograph	
Temp sensors	Spectrograph	
LED ON	Spectrograph	
Telluric map	Spectrograph	

Table 10 Instrument Control System Interface Definition Table

Description	Interface with	Type
Fibre Viewer Shutter	FDAS	Electrical

3.7.6.2 Standards

The instrument control software shall conform to all relevant Gemini standards as listed in RD04.

3.7.6.3 Instrument System Control

TBD – Insert Gemini standard references

3.7.6.4 OH Emission Lines

The position of OH emission lines shall be determined at the start of an observation and the relevant detector pixels set to destructively read during the observation.

3.7.6.5 Engineering Interface System

User Functions TBD

3.7.6.6 Alarms

The instrument control system shall alert the telescope system of any situations that require manual intervention.

3.7.7 DATA PIPELINE

a. The data pipeline shall convert the raw data from PRVS into a useful scientific product. It is entirely software and may be run at the Gemini observatory or off line at the astronomer's home institute.

b. The input shall be a FITS file from the instrument control sub-system.

c. The FITS headers shall contain all of the necessary information for the data pipeline.

d. The output files will have the atmospheric, telescope and instrument effects removed.

e. The exact software platforms which the pipeline shall run on shall be agreed at PDR

3.7.7.1 Interface Definition

The sub-system interfaces are defined in Table 11

Table 11 Data Pipeline Interface Definition Table

Description	Interface with	Type
Observation data	Gemini	Ethernet
OH mask information	Instrument Control System	Ethernet
Reduced Data	Gemini	

3.7.7.2 Functional Requirements

a. The software shall enable:

   i. The interpretation of observation proposal preparation products.

   ii. Checking of on-sky and calibration data.

   iii. Data analysis.

   iv. The quick-look function.

   v. Pipeline data processing.

b. Support the acquisition mode.

c. Determine target centroids.

d. Calibrate raw frames.

e. Remove bias and dark.

f. Flat field.

g. Add wavelength scale.

h. Running S/N estimate.

i. Co-add object frames.

j. Ratio co-added spectra by telluric standard.

k. Flux calibrate co-added spectra.

3.7.7.3 Data

a. The data processing code shall operate upon and generate FITS files natively.
b. No translation between different formats is acceptable.
c. Data processing code must be integrated with the Gemini OLDP system.
d. Results shall be viewable with any image display program that can view FITS images of the type written by the instrument.
e. The instrument shall be capable of handling 800 x 17 Mbyte frames per 8 hour observing night.

3.7.7.4 Observing Modes

Normal/major observing modes within the OCDD shall be supported with processing code for quality checking at the telescope.

Algorithms required for processing the instrument data in the major observing modes shall be provided.

3.7.7.5 Low Level Processing

OLDP shall not be used to provide very low-level instrument processing.

3.7.7.6 Test Suite

a. An automated test suite demonstrating proper operation of the data processing code in all major observing modes shall be provided.

b. The test suite shall be standalone and automated

3.7.7.7 Code

a. All data processing code shall be delivered in source code format and shall be licensable such that Gemini can make changes and distribute the code to interested parties.

b. Tasks should be written to operate independently, and care should be taken in the granularity of tasks to maximise efficiency in the OLDP.

3.7.7.8 IRAF specific requiremnets

All IRAF scripts shall be capable of running in non-interactive mode. This means that;
a. The only required/positional parameter is the primary input.
b. All other parameters are given default values.
c. All Gemini IRAF tasks used with the OLDP shall contain two parameters in common.
d. Logfile – which specifies the name of the log file the job will produce.
e. Status – which specifies the exit status of the script.

3.7.7.9 OH Lines

The data pipeline shall generate a table of the location of OH lines within a sky observation data set.

3.7.7.10 Centroid Determination

The centroid of the spectral lines shall be determined to 0.001 pixels (AD02, SR_7).

Reduced Data Product

The data pipeline shall produce files which are suitable for extraction of radial velocity data.

3.7.7.11 Reduced Data Product

The data pipeline shall produce files which are suitable for extraction of radial velocity data.

3.7.7.12 Background Removal

The instrument background shall be removed to better than 0.03 e/s/pixel

3.7.7.13 Radial Velocity Code

Radial velocity code shall be provided to allow verification of instrument performance during development (including component for earth's barycentre correction) .

3.7.7.14 Third Moment

The third moment of the spectral response function shall be measured to $\leq$1 part in 1000.

a) On each calibration line during a daytime calibration

b) As an average over all calibration lines during a single observation.

4 PERFORMANCE VERIFICATION

An acceptance test plan will be prepared following the PDR. This section indicates the method that will be used to verify each requirement as well as the link to the relevant science and observatory requirements. The current state of compliance is also indicated.

Each performance item in the previous section is verified either by:

a. Inspection (I)

Inspection is defined as non-destructive visual, auditory, olfactory, tactile, simple physical manipulations; gauging and measurement inspection verification that the equipment as manufactured conforms to the documentation to which it was designed.

b. Analysis (A)

Analysis is defined as the verification that a specified requirement has been met through the technical evaluation of the equations, charts, reduced data and/or representative data.

c. Demonstration (D)

Demonstration is defined as a non-instrumented test where success is determined by observation alone. Included in this category are simple quantitative measurements such as dimensions, time to perform tasks etc.

d. Test (T)

Test is defined as the verification that a specified requirement is met by a thorough exercising of the applicable element under appropriate conditions in accordance with the test procedures.

The method of verification is defined in Table 12, it also identifies the source and traceability information for each requirement.

The unique top level requirement which is the source of the requirement is shown in the last column. These requirements are all defined in the science requirements document (AD02).

Table 12 Performance Verification Table

Paragraph	Parameter	Verification Method	Source Document	Compliance Status
1	INTRODUCTION	Heading		
1.1	PURPOSE	N/A		
1.2	ASSUMPTIONS	N/A		To be confirmed by PDR
2	DOCUMENTS AND DRAWINGS	N/A		
2.1	APPLICABLE DOCUMENTS	N/A	SoW	
2.2	GEMINI INTERFACE DOCUMENTS		SoW	
2.2.1	Science Instrument ICDs		SoW	
2.2.2	Software ICDs		SoW	
2.3	REFERENCE DOCUMENTS			
2.4	ACRONYMS AND ABBREVIATIONS			
2.5	DEFINITIONS			
3	REQUIREMENTS			
3.1	ITEM DEFINITION		SoW	

Table 12 Performance Verification Table

Paragraph	Parameter	Verification Method	Source Document	Compliance Status
3.1.1	Block Diagram			
3.1.2	Interfaces			
3.1.2.1	Functional Interfaces			
3.1.2.2	Physical Interfaces			
3.1.2.3	Modes of Operation			
3.1.2.4	Optical Interfaces		TBD	
3.1.2.5	Signal Interfaces		Gemini ICD	
3.1.2.5.1	Power Sources		Gemini ICD	
3.1.2.5.2	Digital Communication		Gemini ICD	
3.1.2.5.3	Video Interfaces		Gemini ICD	
3.1.2.5.4	Analogue Signals		Gemini ICD	
3.1.2.5.5	Synchronisation Signals		Gemini ICD	
3.1.3	Major Component List			
3.1.4	Gemini Furnished Equipment			
3.2	CHARACTERISTICS			
3.2.1	Functional Requirements			
3.2.1.1	Spectral Dispersion		SR_1	
3.2.1.2	Wavelength Calibration		SR_1, SR_7	
3.2.1.3	Acquisition and guiding		SR_11	
3.2.1.4	Engineering Interface System		SoW	
3.2.1.5	Cooling Systems		SoW	
3.2.1.6	Data Reduction		SoW	
3.2.2	Performance Requirements		Heading	
3.2.2.1	Acquisition and guiding		SR_3	
3.2.2.2	Observational Efficiency		SR_3	
3.2.2.3	Vibration		SR_7	
3.2.2.4	Structural Stability		SR_7	
3.2.2.5	Surface Temperature		Gemini ICD	
3.2.2.6	Power Dissipation		Gemini ICD	
3.2.2.7	General Mechanism Requirements			
3.2.2.7.1	Independent Operation			
3.2.2.7.2	Temperature			
3.2.2.7.3	Position Control			
3.2.2.8	Instrument Profile			
3.2.2.9	Spectral Range		SR_6	
3.2.2.10	Spectral Resolving Power		SR_4	
3.2.2.10.1	Spectral Sampling		SR_5	
3.2.2.10.2	Spectral Stability		SR_7	
3.2.2.11	Stray Light and Ghosting		SR_10	
3.2.2.12	Thermal Radiation		SR_10	
3.2.2.13	Flat Field Quality		SR_2	
3.2.2.14	Acquisition Accuracy		SR_11	
3.2.2.15	Field Of View		SR_9	
3.2.2.16	Detector Quantum Efficiency		SR_2	
3.2.2.17	Throughput		SR_8	
3.2.2.18	Image Quality		SR_13, SR_14	
3.2.2.18.1	At the Detector		SR_14	

Table 12 Performance Verification Table

Paragraph	Parameter	Verification Method	Source Document	Compliance Status
3.2.2.18.2	At the Object Fibre		SR_13	
3.2.2.19	Handling			
3.2.2.20	Electrical Interlocks			
3.2.2.21	Standards			
3.2.3	Physical Characteristics			
3.2.3.1	Mass			
3.2.3.2	Centre of Gravity			
3.2.3.2.1	Dynamic Mass Moment			
3.2.4	Reliability			
3.2.5	Maintainability			
3.2.5.1	Re-alignment			
3.2.5.2	Handling			
3.2.5.3	Access			
3.2.6	Environmental Conditions			
3.2.6.1	Ambient Air Temperature			
3.2.6.2	Ambient air temperature rate of change			
3.2.6.3	Altitude			
3.2.6.4	Relative Humidity			
3.2.6.5	Wind Speed			
3.2.6.6	Vibration			
3.2.6.7	Gravity Component			
3.2.6.8	Grounding			
3.2.7	Transportability			
3.2.7.1	Ambient Air Temperature			
3.2.7.2	Temperature Shock			
3.2.7.3	Altitude			
3.2.7.4	Relative Humidity			
3.2.7.5	Wind Speed			
3.2.7.6	Vibration			
3.2.7.7	Gravity Component			
3.2.7.8	Shock			
3.3	DESIGN AND CONSTRUCTION			
3.3.1	Materials Processes and Parts			
3.3.1.1	Cleanliness			
3.3.1.2	Packaging			
3.3.2	Electromagnetic Radiation			
3.3.3	Workmanship			
3.3.4	Interchangeability			
3.3.5	Safety			
3.3.5.1	Electrical			
3.3.5.2	Mechanical			
3.3.5.2.1	Externally Powered Moving Parts			
3.3.5.2.2	Handling			
3.3.5.3	Interlock System			
3.4	DOCUMENTATION			
3.5	LOGISTICS			

Table 12 Performance Verification Table

Paragraph	Parameter	Verification Method	Source Document	Compliance Status
3.6	PERSONNEL AND TRAINING			
3.7	MAJOR COMPONENT CHARACTERISTICS			
3.7.1	Fibre Deployment and Acquisition System			
3.7.1.1	Interface Definition			
3.7.1.2	Image Quality			
3.7.1.2.1	Object Fibre			
3.7.1.2.2	Fibre Viewer			
3.7.1.3	Field of View			
3.7.1.4	Repeatability			
3.7.1.5	Stability			
3.7.1.6	Numerical Aperture			
3.7.1.7	Throughput			
3.7.1.8	Fibre Viewer			
3.7.1.8.1	Sensitivity			
3.7.1.8.2	Field of View			
3.7.1.8.3	Readout Speed			
3.7.1.8.4	Exposure time			
3.7.1.8.5	Read-out Mode			
3.7.1.8.6	Co-addition			
3.7.1.8.7	Output			
3.7.1.8.8	Pixel Size			
3.7.1.9	Fibre Routing			
3.7.1.10	Mass			
3.7.1.11	Centre of Gravity			
3.7.1.11.1	Dynamic Mass Moment			
3.7.2	Calibration Unit			
3.7.2.1	Interface Definition			
3.7.2.2	Calibration Sources			
3.7.3	Fore-Optics Fibre			
3.7.3.1	Interface Definition			
3.7.3.2	Fibre output diameter			
3.7.3.3	Stability			
3.7.3.4	Throughput			
3.7.3.5	Scrambling			
3.7.3.6	Slit Stability			
3.7.4	Infrastructure			
3.7.4.1	Interface Definition			
3.7.4.2	Temperature Control			
3.7.4.2.1	Operating Temperature			
3.7.4.2.2	Temperature Stability			
3.7.4.3	Vacuum Systems			
3.7.4.4	Cryogenic and Vacuum requirements			
3.7.4.4.1	Evacuation time			
3.7.4.4.2	Cool Down Time			

Table 12 Performance Verification Table

Paragraph	Parameter	Verification Method	Source Document	Compliance Status
3.7.4.4.3	Warm up time			
3.7.4.5	Pressure			
3.7.5	Spectrograph			
3.7.5.1	Interface Definition			
3.7.5.2	Slit Length			
3.7.5.3	Slit width			
3.7.5.4	Throughput			
3.7.5.5	Image Quality at Detector			
3.7.5.6	Stability			
3.7.5.7	Order Separation			
3.7.5.8	Extent of Spectrum			
3.7.5.9	Detector Geometry			
3.7.5.9.1	Format			
3.7.5.9.2	Pixel Size			
3.7.5.9.3	Flatness			
3.7.5.9.4	Co-Planarity			
3.7.5.9.5	Stability			
3.7.5.10	Detector Performance			
3.7.5.10.1	Spectral range			
3.7.5.10.2	Dark Current			
3.7.5.10.3	Persistence			
3.7.5.10.4	Well Depth			
3.7.5.10.5	Flat Field			
3.7.5.10.6	Linearity			
3.7.5.10.7	Read Noise			
3.7.5.10.8	Cosmetic Quality		SR_15	
3.7.5.10.9	Glow Centres			
3.7.5.10.10	Cross Talk			
3.7.5.10.11	Quantum Efficiency			
3.7.5.10.12	Cut-Off Wavelength			
3.7.5.11	Detector Readout Electronics			
3.7.5.11.1	Readout Modes			
3.7.5.11.2	Readout Speed			
3.7.5.11.3	Maximum Exposure			
3.7.5.11.4	Co-addition			
3.7.5.11.5	Dark Current Measurement			
3.7.5.11.6	Sub-array Performance			
3.7.6	Instrument Control System			
3.7.6.1	Interface Definition			
3.7.6.2	Standards			
3.7.6.3	Instrument System Control			
3.7.6.4	OH Emission Lines			
3.7.6.5	Engineering Interface System			
3.7.7	Data Pipeline			
3.7.7.1	Interface Definition			
3.7.7.2	Functional Requirements			
3.7.7.3	Data			

Table 12 Performance Verification Table

Paragraph	Parameter	Verification Method	Source Document	Compliance Status
3.7.7.4	Observing Modes			
3.7.7.5	Low Level Processing			
3.7.7.6	Test Suite			
3.7.7.7	Code			
3.7.7.8	IRAF specific requirements			
3.7.7.9	Telluric Absorption Lines			
3.7.7.10	OH Lines			
4	PERFORMANCE VERIFICATION			
4.1.1.1.1	Pixel size			
4.1.1.1.2	Readnoise			
4.1.1.1.3	Dark current			
4.1.1.1.4	Well depth			
4.1.1.1.5	Integration Time			
4.1.1.1.6	Format			