CANADA-FRANCE-HAWAII TELESCOPE CORPORATION

Instrument Design Specifications
And
Telescope Facilities
Reference Manual

Revision 2.4 December 2008

PART 1 - INSTRUMENT SPECIFICATIONS

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Preface

During instrument design and fabrication a large volume of technical data pertaining to the CFHT telescope and related facilities is invariably required. We have attempted to incorporate the most important of these data into one manual in order to provide you with a single, coherent reference.

The manual is divided into two parts. Part 1 outlines general technical specifications and requirements for new CFHT instruments, with emphasis placed on instrument maintainability. Part 2 provides technical summaries for various telescope systems.

In Part 1 - Technical Specifications - many of the requirements reflect rigid conditions imposed by existing telescope systems; others are of an operational nature. While many details outlined in this part of the manual are negotiable, our goal will be to provide not only an instrument that works well, but also one that is maintainable by talented, but not necessary expert, staff, located at a remote site, working under non-ideal conditions.

Departures from the requirements of Parts 1 and 2 which are not covered explicitly in the instrument contract should be discussed with the CFHT technical and scientific staff at as early an opportunity as possible. Generally speaking, for deviations from these requirements, a written agreement with the CFHT detailing both the proposed deviations and their purpose will be required.

Please remember that during contract evolution, CFHT will emphasize robust instrument operation and serviceability, and the delivery of comprehensive instrument documentation. In order to provide engineering support, instruments must be capable of being operated in a stand-alone mode using an instrument-specific intelligent controller. Documents detailing the operation and maintenance of the instrument are required at final acceptance tests.

In order to maintain an orderly project development, CFHT will assign an in-house instrument project scientist and engineer to oversee CFHT's interests in the project and to provide liaison between your team and CFHT staff. These individuals should be your primary contacts at the Corporation. All communications with CFHT regarding the project should be channeled through them. Generally, communications of an important nature should be in writing (e-mail or letter).

While developing instrument interfaces, please keep in mind that most of CFHT's original equipment was acquired through contracts to other institutions. Much of this equipment has subsequently been modified and upgraded at CFHT. In general, the originating institutions have NOT been apprised of these changes. Similarly, older CFHT documents may not reflect current device status. Therefore, if you require information not contained in this manual, please request current versions directly from the CFHT project staff. Do not assume that other institutions' documents pertaining to CFHT are up to date.

Generally, CFHT conducts instrument acceptance tests at the developer's facility prior to delivery to Hawaii. It has proven useful for both the developer and CFHT to divide these tests into several – usually three - stages, starting early in the final assembly of the instrument or of a critical subsystem. Our aim is to assist the developer in providing an instrument that will function reliably in the CFHT environment, and to provide CFHT technical staff with sufficient exposure to the inner workings of the instrument to effectively and knowledgeably address technical problems that arise in the course of subsequent routine operation.

PART 1 - INSTRUMENT SPECIFICATIONS

1. INSTRUMENT SPECIFICATIONS

1.1. Introduction:

Part 1 - Instrument Specifications - outlines the design details CFHT requires be incorporated into its instruments. For the most part these requirements are the product of the observatory's science and technical staff's hard-won experience in supporting equipment at the telescope and address many of the issues that make real-time instrument support by our staff possible.

To ensure that instruments arriving at the observatory can come on-line quickly, both instrument developers and CFHT need a set of guidelines and checklists that establish the observatory's minimum list of requirements. Part 1 of the manual establishes a basic list. More specific details will be included in the instrument contracts.

Contractors should be aware that costs associated with the implementation of the requirements of this manual are considered to be included in the instrument contract price. Modifications to any of the requirements can be obtained, after mutual written agreement, either by specific references in the Contract or, subsequently, by other written agreements with CFHT signed for both parties by their respective designated contract authorities.

PART 1 - INSTRUMENT SPECIFICATIONS

1.2. Site

1.2.1. Thermal and Humidity Environment

Instruments will be stored and operated in both the telescope dome environment and in heated laboratories.

- 1. The design operating temperature range for an instrument, and all associated equipment, shall be from -10°C to +30°C.

The dome environment experiences the full range of humidity from extremely dry to full condensed.

- 2. The design operating relative humidity range for an instrument and all associated equipment shall be from 0% to 100%.

The design may assume the availability of dry air to purge cavities. Either pipe nozzle or barbed hose fittings may be used.

Under storage the relative humidity can be expected to occasionally exceed 100 %. In particular, storm systems, which often arrive quickly, can elevate the humidity in the dome to well above saturation. The resulting condensation, which subsequently often freezes, is usually limited to exposed instrument surfaces.

- 3. The instrument design shall incorporate sufficient protection to ensure that condensation will not occur on critical surfaces. A light, sheet-metal shell over exposed components should suffice.
- 4. As noted in section 1.9.5, a heavy-duty, vinyl instrument cover is also required with the instrument.

1.2.2. Altitude

- 1. The instrument shall be designed for operation at altitudes between sea level and 5000 m.
- 2. Maximum electrical power dissipations shall be de-rated by 40% due to the reduction in air density experienced at the summit.
- 3. High voltage systems shall be rated for operation at an altitude of 5000 m or higher.

1.2.3. Seeing and Image Quality Control

In an attempt to eliminate self-induced image quality degradation, the observatory has implemented a policy of reducing to a minimum all power dissipated at the telescope.

Considerable attention should therefore be given to minimizing power dissipation within the instrument. In particular:

- 1. The instrument shall include a means for heat extraction. Glycol is available on the telescope and in storage.
- 2. The instrument design shall include a detailed power budget.

1.2.4. Remote Operation

The Observatory Automation Project (OAP), currently in progress, will allow nighttime observing from Waimea.

- 1. Instrument design shall not assume the availability of personnel at the summit during observations.

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- 2. The normal schedule of daytime summit personnel covers only four days a week. The instrument design shall not require daily intervention. Cryogenic systems must be suitable for unattended operation.
- 3. The target for instrument exchanges is about five hours, including removal of the previous instrument, installation of the new instrument, and checkout of the installation – including any calibrations requiring on-site personnel. The instrument design should not necessitate complicated procedures on exchange day.

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1.3. Mechanics

CFHT prefers metric hardware.

1.3.1. Modular Design

- 1. Instruments shall be modular.
- 2. All major systems and subsystems shall be easily removable from the instrument body. In particular, module removal shall be possible, preferably by hand, or with easily accessible lifting points, while the instrument is mounted on the telescope without requiring major instrument disassembly.
- 3. Access to instrument modules via the removal of a rigid, lightweight cover is acceptable, provided that cover removal and installation is possible while the instrument is on the telescope. Such a cover shall be fastened using captive hardware and shall have lifting handles.
- 4. The operating state of the instrument shall not be affected by cover removal. In particular, cables and connectors shall not be mounted to any cover.

1.3.2. Operational Pointing Limits

- 1. Instruments, together with all associated equipment, shall be capable of operating on the telescope from zenith to horizon in all directions and at all position angles.
- 2. The instrument and associated equipment shall not impose pointing limits on the telescope. In particular, Cassegrain instruments, including all associated detectors and equipment, shall clear both the polar axis horseshoe and south pier by at least 100 mm. See Part 2 - Cassegrain Environment and Cassegrain Bonnette - for appropriate dimensions. Prime focus instruments are restricted from accessing targets below 20 degrees elevation.

1.3.3. Permissible Weights and Moments

Maximum permissible instrument weights and moments for the Cassegrain Bonnette are detailed in Table 1.3.3.1 below. Assume zenith-to-horizon telescope pointing limits when calculating these moments.

Since the prime focus upper ends are currently dedicated to specific instruments, there are currently no available guidelines for prime focus instrument weights and limits.

Table 1.3.3.1 - Maximum Permissible Instrument Weights and Moments for the Cassegrain Bonnette

Mounting Face	Maximum Weight	Maximum Moment about center of mounting face	Maximum Moment about optic axis
C1	100 kg	600 Nm	
C2	300 kg	1800 Nm	
C3	450 kg	2700 Nm	
C4	750 kg	4500 Nm	
Side Ports	50 kg	150 Nm	
Heavy Instrument Mounting Pads	Unknown	Unknown	

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1.3.4. Cassegrain Rotation

Instruments designed for mounting at the Cassegrain focus must account for the rotation of the whole Cassegrain environment.

1.3.5. Actuator and Encoder Mounts

- 1. Devices, such as motors, solenoids and encoders, shall be mounted in a manner that allows their quick removal and replacement. Removal of an associated mechanical module can be required if the module can be quickly removed by hand from the instrument while it is on the telescope.
- 2. In order to allow quick device removal, cabling to all devices and modules must terminate in an accessible connector, both at the device and at any associated mechanical module interfaces.

1.3.6. Indexing of Traveling Components

- 1. Devices and assemblies that are driven between fixed locations shall incorporate a precise mechanical stop to define their rest positions. Devices shall not be INDEXED by the opening or closure of a limit switch that controls motor power.
- 2. Limit switches or similar power interrupting devices can be used to indicate that a device has reached a predetermined position, and should be used to remove power from a motor when a device drives beyond normal operating limits.

Further specifications are given in section 1.5.13.

1.3.7. Materials

Aluminum: Anodized aluminum or other corrosion-resistant alloy is preferred for structural elements.

- 1. Where mating aluminum parts will be separated on a regular or semi-regular basis, stainless steel threaded inserts such as “Helicoils” are required.

Stainless Steel: Stainless steel metric fastening hardware is preferred. [[[Is SS OK for structural elements - SB??]]]

Carbon Steel: The dome environment is harsh, with condensation an ever-present fact of life. Carbon steel parts, even those with a rust inhibiting surface treatment such as Parkerization, rust fairly quickly.

- 2. Carbon steel is permitted only if it is protected by a HARD and DURABLE protective paint or Cadmium plating.
- 3. Carbon steel fastening hardware is NOT permitted.

1.3.8. Paints and Surface Treatments

Paints are an acceptable surface treatment as long as they are HARD and DURABLE. Several modern epoxy enamels such as “Imron” or “Algrip” are satisfactory. [[[More – SB??]]]

- 1. Lightly sprayed paint or similar surface treatments, especially on surfaces with inadequate surface preparation, tend to chip and flake easily and are UNACCEPTABLE.

Anodizing is an acceptable surface treatment for aluminum. [[[What type - SB??]]]

Cadmium plating is a preferred surface treatment for non-stainless steels. [[[What type – SB??]]]

[[[What about galling of SS hardware on SS parts – SB??]]]

1.3.9. Component Identification

Metal parts shall be identified by etching or engraving a part number onto the part in a visible location.

1.4. Data Acquisition and User Interface Software

Instrument contracts are normally handled separately from contracts for related data acquisition/user interface software that runs on CFHT computers. The latter is normally provided by in-house CFHT software development staff and is not specifically addressed in this manual.

Control code, algorithms, and documents required for dedicated instrument control are considered to be part of instrument controllers. These are addressed in detail in section 1.6 of this manual under Instrument Control and are normally provided by the instrument contractor.

1.4.1. NEO

NEO (nominally “New Environment for Observing”) is a CFHT-developed programming environment for data acquisition. It acts as the interface between our queue observing system and the instrument. It also provides for command line interaction with and scripting control over the instrument that is used by queue and can be used by other interfaces. In the queue environment we usually do not provide graphical interfaces in NEO; the graphical interface is to the queue system. Low-level engineering interfaces, as described in section 1.6, are allowed to exist outside of NEO.

- 1. User interface and data acquisition software written to run on CFHT computers must use the NEO software architecture under Linux.

Short-term visitor instruments may provide their own computers and acquisition systems.

NEO's center is a program called “director” which accepts command lines from queue, a user, or a script. Running under director are “agents”, possibly on other computers, which do instrument and camera control. Each command is passed on to the appropriate agent, the agent carries out the command, and director returns a completion pass-or-fail indication. This process is single threaded.

For multi-threaded agents we use intent, action, and wait commands. The intent command allows the agent to get set for an action command, e.g., a new target position is provided to the telescope control system agent which can tell the telescope control system to go choose guide stars but not move the telescope. The action command tells the agent to start the intended command, e.g., tell the telescope control system to start slewing the telescope. The wait command is given after all actions that can be parallelized are active; it is the only command that blocks for completion. Further details are available from the CFHT software group. Agents can be provided as part of the instrument contract as appropriate.

The camera control agent is a special case.

- 2. If the images acquired are to enter the CFHT archive system, we require that our camera agent “DetCom” be used.

DetCom controls the detectors, creates the image FITS file, and initiates FITS header creation. The other agents that have FITS header information are queried for their values, which are added to the image file.

1.4.2. Status Server

A program called the “Status Server” keeps medium term status information. Values such as exposure time, current filter, telescope position, and weather data are saved there. FITS headers are generated by the various director agents and written to the Status Server. Temperature and telescope position based focus calculation coefficients are saved by the Status Server. Any status that should be monitored for error conditions, e.g., detector temperature or cryovessel vacuum levels, can have an alarm trigger equation associated with it to cause mail and phone messages on error.

1.4.3. Other CFHT Queue-Related Software

The queue observing system includes databases and user interface programs. These allow observation planning and execution through NEO. Any changes to the CFHT software environment needed to support a new instrument will be the responsibility of CFHT, based on discussions with the instrument scientists on the intended instrument use.

1.4.4. OAP

The Observatory Automation Project (OAP) is currently in progress. Its goals are improving overall reliability and allowing full nighttime operation from Waimea with no personnel at the summit. This will be the preferred operating mode and may impose some restrictions or changes to instrument software. CFHT shall be consulted for updated requirements.

1.4.5. Queue

CFHT normally operates in Queue Mode. Observation requests are prepared by astronomers and saved in a database. Each night observations are selected based on priorities, weather conditions, and observability, and carried out by Service Observers. Calibration data are shared and applied equally to all observation.

CFHT desires to continue operations in Queue Mode. Any instrument proposal requiring astronomer presence at the summit will have to be justified.

PART 1 - INSTRUMENT SPECIFICATIONS

1.5. Electronics

1.5.1. Environment

The CFHT observatory can present extreme environmental conditions for electronic systems. Accordingly, system designers must pay special care to environmental restrictions.

- 1. Electronics systems for use on the telescope, or in the 5th floor environment shall be rated for operation between -10°C and +30°C.
- 2. Electronics systems for use on the telescope, or in the 5th floor environment shall be rated for relative humidity ranging from 0% to 100%.
- 3. Electronics systems for use in the remainder of the building shall be rated for operation between +10°C and +30°C, at relative humidity ranging from 0% to 100%.

Cooling effectiveness is reduced due to the lower air density (roughly 40% of sea-level air pressure) at the observatory. As a working rule, derating a system by 40% may accommodate the lowered cooling efficiency at the summit.

1.5.2. Packaging

1.5.2.1. Chassis type

- 1. Chassis for telescope mounting shall be fully enclosed, with solid or screened panels and doors over all openings.
- 2. Standard, 19-inch rack mounting chassis are recommended. 19-inch racks are available in the computer room. Mountings for 19-inch racks are provided at Cassegrain focus.
- 3. Access panels shall be equipped with quick release, captive hardware. Plastic hardware for these applications is NOT permitted.

1.5.2.2. Circuit cards

All commercially supplied and custom designed circuit cards shall be printed circuit boards (PCBs). Other card types such as Speedwire or Wire Wrap are not permitted.

- 1. All PCBs shall be fabricated to appropriate industrial standards.
- 2. All circuit cards shall have all components permanently identified.
- 3. All circuit boards shall have markings to identify their subsystems and instrument. Silkscreen markings are preferred.
- 4. No wired changes or “deadbug” circuits are permitted.

1.5.3. Circuit Access

1.5.3.1. Board replacement

- 1. All electronic circuits shall be easily accessible for maintenance, troubleshooting, removal and replacement with the instrument mounted on the telescope or on its handling cart.

1.5.3.2. Modular design

- 1. Circuits shall be of a modular design using circuit boards. The use of card cages, versus direct mounting of circuit boards, is recommended.
- 2. Access to card cages shall be through doors or panels that are hinged or removable and use quick release hardware.

1.5.3.3. Test points and extenders

- 1. Circuit boards shall contain test points.
- 2. Test points shall be directly accessible on the board from the front of the card cage.
- 3. An extender shall not be required to access basic test points. However, an extender board must be supplied with all systems that require extending cards for detailed troubleshooting
- 4. The system shall be capable of normal operation with any circuit card extended.

1.5.3.4. Connections to cards

- 1. Connections to instrument circuit cards shall be made through a chassis mounted connector panel, and then to the circuit card. Direct connections from external devices to a local controller or circuit card are not permitted.

In general, rear connections to circuit cards are favored.

- 2. When connections are made to plug-in circuit cards, provisions shall be made for extending the connection to permit operating the card on an extender.

1.5.3.5. Test access

- 1. Controllers or other buss-oriented systems shall provide an easily accessible buss test point. This may be through an appropriate card for backplane type busses.

1.5.4. Maintenance

In recognition of the remoteness of the observatory, special considerations such as unobstructed, free access to the instruments, its subassemblies, boards and components shall be made for system maintenance. Additionally, operational requirements may dictate the capability for quick return to service.

If any of the components (hardware or software) of the instrument are proprietary, CFHT requires that vendor-supplied maintenance of that component be offered as a cost option.

1.5.5. Status Lights

LED or other status indicators on equipment are very useful. However, extraneous light at the telescope is not permitted. Any such indicators on telescope mounted instruments or associated hand paddles shall incorporate a means for turning off or covering these lights.

1.5.6. Power Sources

1.5.6.1. Telescope and control room power

- 1. AC 120 volt 60 Hz power connected through a single, standard 3 prong, grounded connection is available on the telescope and in the computer room. A minimum of 1000 VA is available at both locations. Circuit protection devices shall be panel mounted, accessible for resetting or changing, and their purpose shall be clearly and permanently labeled on the panel.

1.5.6.2. Instrument power supplies

- 1. Instruments shall incorporate their own power supplies.
- 2. All instruments using internal power supplies shall have easily accessible means of testing power supply operation. Some recommended solutions are LED's and test points. This point is covered in detail in section 1.5.10.1.
- 3. In order to reduce power dissipation, switching power supplies shall be used wherever possible. Use of linear power supplies should be restricted to very high

sensitivity analog hardware, such as detector support hardware, Even in such cases, the suitability of a properly filtered switching supply should be investigated.

1.5.7. Wiring and Cabling

1.5.7.1. Wiring, cables and fiber optics supplied with the instrument.

- 1. All cables required for the operation of the instrument, both while on the telescope and while in a stand-alone mode, shall be provided with the instrument.
- 2. External fiber optics used for communications shall be 62.5/125 um SC terminated if possible.

1.5.7.2. Termination

- 1. Hardwired cable or wire harness termination is not permitted. Both ends of all cables shall terminate in a connector. All devices such as motors, encoders, actuators, etc., shall be connected to the instrument through a connector at the device.

1.5.7.3. Chassis wiring

- 1. All wiring internal to electronics chassis, with the exception of panel controls and indicators, shall be terminated at standard board interconnections or back plane connections.

1.5.7.4. Cable construction

- 1. Cables between electronic junction boxes and panels shall be constructed of insulated, multi-stranded, color coded conductors using a wire gauge appropriate to the expected worst case current loads.
- 2. Cables fabricated with several individual conductors or conductor pairs shall be contained within an exterior protective sheath, such as tubing, or webbing. When possible, standard, commercially available cable should be used in preference to making custom cable bundles. To prevent the weight of a cable from being supported by individual conductors within connectors, the cable sheath must be mechanically clamped to the backshell of the connector.
- 3. All heavy cables shall be strain relieved at the connectors. Heavy cables shall be provided with an additional mechanical strain relief attached to the cable sheath, separate from the connector.
- 4. All external fiber optics cables that run through the telescope or span across multiple floors in the observatory shall be jacketed and have a rating for installation in risers.

1.5.7.5. General purpose instrumentation cabling system

- 1. All cabling between telescope-mounted instruments and the control rooms shall use the CFHT general-purpose-instrumentation cabling wherever possible.

This point is covered in section 2.12??????. Instruments using the instrumentation cabling shall incorporate the available cable shielding, with appropriate chassis and ground connections. Voltages on this cabling shall not exceed 50 volts peak.

1.5.7.6. Ribbon cable

- 1. Ribbon cable is generally not permitted outside of instrument chassis. It is not permitted as an interconnection between electronic chassis, or between chassis and panels or handsets.
- 2. Ribbon cable may be used within electronic chassis, but should terminate at a connector panel, where heavy-duty connectors and cables can carry the signals to the external devices.

1.5.8. Connectors

1.5.8.1. Marking

- 1. All connectors between electronics boxes, or between boxes and CFHT equipment shall be clearly and permanently labeled on panels and on both ends of all cables. This labeling must be consistent with a simplified interconnection diagram provided in the electronics manual.
- 2. Minimum marking for a chassis is a connector number - e.g. J4.
- 3. Minimum marking for a cable connector is a device and connector number, e.g.,

  BLUE WIDGET, J4
- 4. Long cables, which are permanently installed on the telescope, in control consoles, or in the building cable trays, shall be marked at both ends to indicate the cable connections. Minimum marking includes the intended connection on the proximate end, and the destination and connection at the other end, e.g.,

  BLUE WIDGET, J4; TO GREEN PANEL, J1

1.5.8.2. Connector types

The following connectors are recommended for all CFHT instruments. Other types of connectors are discouraged for new construction. If other types of connectors are preferred in a particular application, CFHT must approve their use.

1.5.8.2.1. MS connectors

- 1. Use of military (MS) connectors, with quick-release bayonet locks, is strongly recommended where connectors will be frequently connected and disconnected, or subject to strain or other external forces.
- 2. MS connectors shall be of the crimp type, and shall have built in strain relief.
- 3. Multiple MS connectors at the same location or on the same assembly must be unique. That is, it must not be possible to make improper connections. This shall be implemented through use of varied connector types, or through alternate keying of the connector shells.
- 4. Use of screw-on type MS connectors, or solder type MS connectors is not permitted.
- 5. MS connectors are not recommended for multiple fiber optic connections.

1.5.8.2.2. Fiber connectors

- 1. Use of SC duplex fiber connectors where frequent disconnections and connections are anticipated is highly recommended.
- 2. Use of SC, ST, FC and FDDI connectors is acceptable.
- 3. Use of MS connectors is strongly discouraged.

1.5.8.2.3. "D" connectors

- 1. Use of normal density "D" connectors (9, 15, 25, 37, and 50 pin) is permitted for connections which are not frequently connected and disconnected, and not subject to undue strain or external forces. Their use is discouraged in more severe environments.
- 2. Use of double density "DD" connectors is discouraged.
- 3. Protective shells and strain relief must be used on all "D" connectors. Standard brass connector shells provide poor strain relief and their use is discouraged. Alternatives should be investigated and used.

- 4. “D” connectors shall be of the crimp type. Solder type connectors shall not be used.
- 5. “D” connectors shall be provided with either screw lock hardware or slide lock hardware to secure connectors to the connector panel.

1.5.8.2.4. Coaxial connectors

- 1. Standard BNC and 00 gauge “LEMO” connectors are recommended.
- 2. Crimp BNC connectors are preferred over solder type.
- 3. Cable and shell type shall be matched so that an effective strain relief is provided.

1.5.8.2.5. ZIF (Zero Insertion Force) connectors

- 1. Use of ZIF connectors is recommended when connectors are built into mating hardware, and must align and mate when the hardware is assembled.
- 2. Contact CFHT for approved types of ZIF connectors.

1.5.8.2.6. RJ45

- 1. Use of standard, plastic, RJ45 connectors is permitted for Ethernet connections. For use on the telescope they shall be enclosed in MS connectors.

1.5.8.2.7. Plastic connectors

- 1. The use of plastic connector shells, plastic backshells, and plastic strain relief is not permitted outside of instrument chassis.
- 2. Use of mass terminated plastic connectors is not permitted outside of instrument chassis under any circumstance.

1.5.8.2.8. Strain Relief

- 1. All connectors used outside of chassis shall have an effective method of strain relief, so that loads are not taken on individual conductors.
- 2. Cable reinforcement at strain relief points, using jackets or sleeves, is encouraged.

1.5.8.3. Physical connections

- 1. All connector hardware shall be captive.
- 2. All connectors used outside of chassis shall have a positive means of physically securing the connector to the mating connector on the chassis. Twist locks, screw locks, slide locks, and other hardware provided by the manufacturers is usually sufficient.

1.5.8.4. Connector Placement

In addition to the connectors for instrument controllers, all instrument control and status signals shall be available at an accessible, external connector panel on the instrument. This panel is supplied for the purposes of troubleshooting and diagnostics. A laptop with displays that give full access to all signals shall be deemed a “panel” for this requirement, and the display code is subject to section 1.6 requirements.

The connector panel, local controllers, and any status displays shall be accessible while the instrument is on the telescope and while it is on its handling/storage cart.

1.5.9. Heat Output of Devices

- 1. CFHT is continually upgrading the telescope facility to improve image quality. To this end all non-essential sources of heat on or around the telescope should be eliminated. To further these efforts, contractors shall provide a detailed heat budget for both the complete instrument and for individual devices.

1.5.10. Diagnostic Design Requirements

- 1. Instruments shall be designed with diagnosis and troubleshooting in mind. Diagnostic design planning is critical in meeting operational goals of minimum equipment downtime. The following guidelines should be considered in the planning stages when designing new subsystems.

1.5.10.1. Subsystem Level Fault Identification

- 1. Subsystem power supply voltage levels shall be monitored with threshold circuits driving lighted indicators such as LEDs. The indicators shall be clearly visible at the front of the subsystem enclosure and marked with the nominal voltage of the corresponding power supply. An unlighted indicator signifies that the corresponding voltage is below tolerance. A switch may be provided to activate the indicators if the equipment is mounted in a location that precludes illumination. Power supply voltage monitor test jacks shall also be provided on the front of the subsystem enclosure. The subsystem power switch and primary fuse shall also be accessible from the front of the enclosure. All of these features may be placed behind doors or panels.

1.5.10.2. Module Level Fault Identification

- 1. Subsystem modules or boards shall have visible fault indicators wherever feasible. They may be located behind a cover or panel, but shall be easily accessed. Module fault indicators shall show positive illumination only when a fault is detected. Transient or intermittent module faults shall have latching indicators with manual resets. Fault indicators shall be specific to the module on which they are located. Test points and test jacks helpful in fault identification shall also be easily accessed without physically removing a module or extending it from its normal operating environment.

1.5.11. Hardware Design Considerations

- 1. The hardware shall incorporate a modular design. Functions shall be separated to different subassemblies or boards to facilitate troubleshooting and isolation of problems.
- 2. Axial or surface mounted components are acceptable. Use of devices with ball grid array mounting is discouraged.
- 3. The means, hardware and software, to read, write and verify files in situ on all applicable programmable devices shall be provided. CFHT must have access to all intellectual property related to a custom design firmware in as much as is required to fully understand the detailed operation of the firmware be it microcontroller code, PLC code or PLD/FPGA circuit. When selecting potential programmable devices the availability and potential future availability of the programmable shall be taken into consideration. Wholesale assembly language programming on micro-controllers or DSPs is highly discouraged when a high-level language compiler is available. C is the preferred programming language.
- 4. Programmable devices requiring removal and off-board programming shall be socketed.

1.5.12. Selection of Electronics Solutions

The following recommendations are made to contractors for choosing CFHT instrument electronic control systems and hardware.

1.5.12.1. Use of Commercially Available Parts

- 1. CFHT requires, wherever possible, the use of commercially available, off the shelf components, parts, subassemblies, circuit boards, interface PCB's, controllers, computers, etc. In cases where multiple commercial solutions exist, CFHT shall be contacted for aid in determining the preferred solution(s).

- 2. CFHT recognizes there are some areas of all instruments for which commercial units are unavailable in which case custom solutions are acceptable.
- 3. CFHT requires the provider to obtain written agreement or contractual reference for all non-commercial systems when valid commercially available solutions exist.
- 4. CFHT requires that modified commercial assemblies, circuit boards, components, etc be identified. Any spare commercial entities requiring modification shall be done so prior to delivery to CFHT.
- 5. Although this can sometimes be difficult to assess, preference shall be given to well-established suppliers of off-the-shelf devices who are in the position to provide replacements and support over the lifetime of the instrument, and who have established US distributors. This is particularly applicable to devices providing unusual solutions or that use custom buses specific to a certain manufacturer that interface directly to the instrument. Generic devices that are easily obtainable from alternate suppliers are exempt from this rule.

In particular, CFHT requests the use of Galil controllers for motion control, Allen-Bradley PLCs for generic control and monitoring, Lakeshore controllers for temperature control, BayTech remote power control units, Pearle terminal servers for terminal access, and Allied Telesyn switches. See section 1.6.1 for software support provided for these devices.

- 6. `When more than one Ethernet connection is needed to an instrument, a local switch shall be provided.

1.5.12.2. Use of Existing CFHT Solutions

- 1. In situations where commercially available, off the shelf solutions are not available, the circuit or system shall be a duplicate of an existing CFHT solution, if at all possible.

1.5.12.3. Hierarchy of Desired Solutions

The following is the list of solutions in preferred order:

- 1. Duplicate of commercially available solution in use at CFHT
- 2. Commercially available solution
- 3. Duplicate of a non-commercial solution available in use at CFHT
- 4. Original contractor designed solution

1.5.13. Motion Control Assemblies

Motion control assemblies refer to any electro-mechanical system that physically moves under control of a remote control panel or computer.

1.5.13.1. Limit switches

- 1. Most motion control systems have physical limits beyond which they must not be driven. If not capable of continuous, unimpeded operation they must be protected by electrical limit switches.
- 2. Direct acting switches, which sever motor power, are preferred over indirect switches, which operate through electronic logic.
- 3. End-of-travel switches that do not themselves remove motor power require mechanical or other means of device protection if the mechanism is driven at full speed into the mechanical stops.

- 4. "Soft" limits operating through the computer, which are backed up by direct acting, "hard" limit switches, are both acceptable and desirable.
- 5. All end-of-travel switches must be capable of unassisted reverse motion off the limit switch. For D.C. motor-driven devices this is most easily achieved by means of diodes across the switches.
- 6. There shall be no way of driving a system, which is on an end-of-travel limit switch, farther into the limit. This applies to both manual and computerized operation.
- 7. When possible, sealed non-contact switches such as optical, hall effect, or magnetic reed switches shall be used to limit wear and contamination issues.

1.5.13.2. Multiposition devices

These are devices with a few discrete positions.

- 1. Keep the drive system simple.
- 2. Use of single-speed DC motors and encoding and position control with switches is generally acceptable.
- 3. A mechanical registration system, such as a spring-loaded detent roller, Geneva mechanism, etc., shall be built into multiposition systems to assure accurate positioning with motor powered off.
- 4. Bi-directional operation, to minimize operating time, is desirable.

1.5.13.3. Continuous position devices

These are devices requiring fine positioning but which do not need to be actively and continuously servo controlled.

- 1. These devices shall be capable of operation in either direction. We generally require that the approach to a desired position be from a consistent direction if stepper-motor (non-servo) systems are used.
- 2. Stepping motor systems shall be designed to operate at greatly reduced holding power, or with power off when not moving. The system shall not move when power is removed or applied. In particular, the phases energized at power-on shall be identical to those at power-off.
- 3. Stepping motor systems may be operated without an absolute encoder if a reliable and precise initial reference is provided. Mechanical limit switches do not generally provide the required long-term accuracy.
- 4. Commercial stepping motor controller modules are acceptable provided that they permit low or no power holding operation.

1.5.13.4. Servo Controlled Devices

A servo system is a control system that drives its motor based on direct feedback from a position or velocity encoder.

- 1. It is important that servo control assemblies minimize heat near the optical path and in the image detection areas. Motors and amplifiers shall be powered only when movement is required. Remote location of high-powered servo amplifiers is preferred if reliable operation can be demonstrated.
- 2. Due to the electrical noise associated with the telescope environment, control loops shall be kept as short as possible.
- 3. Cables shall be well shielded and good grounding techniques shall be employed to prevent interference with detector signals.

- 4. Consideration shall be given to the structural configuration of the environment to prevent servo operation from exciting structural resonances.
- 5. Servo systems with mechanical travel restrictions shall have adequate limit switch protection.
- 6. Commercial servo system solutions that provide limit protection through micro-controllers shall be protected by an additional layer of direct-acting, hardware limit switches.
- 7. R.F. generated by servo amplifiers or computers shall be shielded so as not to interfere with astronomical detectors.
- 8. CFHT currently supports DC motor servo control solutions from Galil.

1.5.14. Instrument to Host Communication

- 1. Gigabit Ethernet is the preferred means of communication between the instrument and host computers. RS-232 is acceptable. Both are available on the telescope and in the computer room.
- 2. CAT5e twisted-pair terminated into a RJ45 connector is the standard physical connection. Duplex 62.5/ 125 um multimode fibers terminated into FDDI or SC connectors are available on the telescope and in the computer room if isolation is required.

1.5.15. Detectors

CFHT prefers that dedicated detectors be provided with the instrument.

1.6. Instrument Control

Instrument and detector control at CFHT typically involve the following computer systems:

i) Instrument Control Computers

An "Instrument Control Computer" is a local controller supplied with the instrument and used to control instrument devices directly. It is provided by the instrument vendor. Instrument control computers tend to be mechanical controllers rather than full-fledged computers. Recommendations are given in section 1.5.12.1, and the interface to our observing environment (NEO) is given in section 1.6.3.

ii) Detector Control Computers

A "Detector Control Computer" is a local controller supplied with a detector and is used to control detector read out and the shutter, if applicable. The detector control computer is usually a DSP based system adjacent to and connected directly to the detector, and it normally uses optical fibers to transmit pixel data to a "Detector Host". If the vendor provides the detector for the instrument, the recommendations in section 1.6.1.1 should be followed for hardware, and section 1.6.3 must be followed for the interface to NEO.

iii) Detector Host

A "Detector Host" is a Linux or Real-Time Linux based computer including an interface that accepts the pixel data stream from the detector control computer. Detector hosts operate in the summit computer room controlled environment. The detector control agent "DetCom" runs on the detector host. Detector host hardware, normally provided by CFHT, is briefly described in section 1.6.1.2, and the software is briefly described in section 1.6.3.

iv) Data Acquisition and User Interface Computers

The "Data Acquisition" and "User Interface" computers are part of the CFHT provided infrastructure. The data acquisition computer runs the acquisition control software, including director and any local agents. The user interface computer has three displays that display X Window System output from the acquisition computer. The data acquisition computer can also run quick-look pipelines and displays.

v) Telescope Control System Computers

The "Telescope Control System" (TCS) computers are also part of the CFHT provided infrastructure and are the only computers that directly control the telescope. The real time control is provided by an Input-Output Controller (IOC) running VxWorks and the Experimental Physics and Industrial Control System (EPICS). The IOC generates all signals needed for slewing, tracking, and guiding the telescope, reads all telescope position encoders, and controls some CFHT provided instrument adapters ("bonnettes" in CFHT parlance). A user interface computer provides a graphical interface for manual telescope operation.

Normally an instrument does not interact with the TCS computers. For an instrument that operates under the queue system, the queue system sends telescope positioning requests to TCS through the tcs agent and waits for completion before taking exposures. For an instrument that operates outside of the queue system, the observer provides object lists to the CFHT observing assistant (telescope operator) who controls the telescope through the TCS graphical interface. The one exception is offsets and guiding corrections generated by an instrument guider; we provide a software interface that allows guiding by the instrument. This interface accepts Right Ascension and Declination offsets and error corrections in arc seconds, normally at 1 Hz.

There can be additional computers needed for an instrument. Two examples are guide computers and adaptive optics control computers.

1.6.1. Instrument Control Computers

Instrument control includes moving motors, reading switches, monitoring temperatures and vacuums, and power switching. CFHT requests that the following software libraries/agents be used for controlling these the recommended devices.

i) Motors and switches - CFHT has developed a library that runs under Linux or VxWorks to control Galils over their RS-232 or Ethernet connections. We also have a motion control record for higher-level control under EPICS.

ii) Temperature monitoring and control - CFHT has an agent that communicates with the Lakeshore controllers for precise control.

iii) CFHT provides a library for communication with Allen-Bradley PLCs.

iv) Power switching - CFHT has an agent that allows remote/automatic control of BayTech power outlets.

v) More complex instrument control - For any instrument control that is outside the capabilities of the above options, for example adaptive optics correction or precise timing, we recommend a PC running Linux, possibly with real time Linux and/or EPICS. However a proposal suggesting this option will need justification.

1.6.1.1. Detector Control Computers

Except for MegaPrime CFHT uses San Diego State University (SDSU) - now Astronomical Research Cameras (ARC) - a.k.a. Leach, controllers for detector control.

1.6.1.2. Detector Hosts

CFHT uses a version of our standard Linux system hardware that supports the older PCI bus needed by the Leach fiber interface cards. We use a modified version of the Leach astropci driver and a locally written driver called lotuspci. Any detector system provided with an instrument should use the same set up.

1.6.1.3. Other Possibilities

VxWorks based real time hardware systems are possible though discouraged.

1.6.1.4. Local Control

A local, stand-alone terminal computer may be used for development and maintenance, but it shall not be required for operations on the sky. CFHT suggests that common maintenance functionality also be available from the instrument control agent.

1.6.2. Instrument Controllers

1.6.2.1. Communications

CFHT supports three communications media.

i) RS-232 - standard asynchronous serial communications

ii) Ethernet™ - as defined by IEEE 802.3 using 10BASE-T, 100BASE-T, and 1000BASE-T over CAT5e twisted pairs

iii) Optical fiber - detector pixel streams

1.6.2.2. Protocols

The interface computer shall initiate all communications. The interface computer shall command all instrument configuration changes. Configurations may be independently maintained by the agent or controller, e.g., atmospheric dispersion compensation adjustment. The agent or controller shall keep status information updated in the Status Server.

i) RS-232 communications to the instrument should be DCE standard at 9600 baud, 8 data bits, no parity, with XON/XOFF handshaking, and full duplex communication, if possible.

ii) Ethernet communications shall use UDP or TCP/IP protocols. Host names, IP addresses, and port numbers must be settable by CFHT.

iii) There is no protocol specified for pixel streams on optical fibers.

1.6.3. Instrument and Detector Control Software

Control software exists at four levels.

i) PLC "code" is subject to the requirements under Electronics in section 1.5.11, the interface to the requirements in section 1.4 and deliverables requirements in section 1.9.3 but not to other requirements in this section or in section 1.4.

ii) DSP code is usually written in assembly language but is otherwise considered software under section 1.4 and this section. DSP code is subject to deliverables requirement in section 1.9.3.

iii) Other contractor supplied software running on contractor supplied hardware shall meet the requirements of section 1.4 and this section.

iv) All software running on CFHT supplied hardware shall meet the requirements of section 1.4 and this section.

The top-level software shall be compatible with the director/agent model. Interfaces between lower levels naturally depend on the functional requirements, but CFHT suggests that all control network traffic to real computers be director/agent based, i.e., that agents run on the hosts "closest" to the controlled hardware. For network-based processors like Galil controllers this would be the session host computer.

Responsibility for software design, development, and testing will be discussed during project negotiations.

1.6.3.1. Low Level Device Control Interfaces

Low-level device control, whether done on a computer with directly attached hardware interfaces or by a PLC or Galil-type controller over a serial or Ethernet connection, shall provide command and status interfaces to higher-level software. The command interface shall include:

i) Device position requests - the command includes an absolute target position in appropriate engineering units (e.g., millimeters, microns, degrees of angle, or degrees of temperature, but not encoder counts), an offset target position in the same units, or a logical name for a position. The position request command normally does not start any movement; it only registers an intent to make a move at some future time. This allows scheduling multiple movements in a single threaded environment. Examples might be "filter r" indicating that the next filter change should be to the r filter and "focus abs 4.0" requesting that the next focus move be an absolute move to 4.0 mm. For simple devices, the position and move requests can be combined, e.g., filter change requests are typically handled this way. Position request commands return immediately, with success based on proper command format and possibly acceptable device status.

ii) Device move requests - the command indicates that a previously given position request is to happen. An example might be "filter go" indicating that the previous "filter r" command is to happen. Move request commands return immediately, with success based on proper command format and possibly acceptable device status.

iii) Device wait requests - the command indicates that all previous position and move requests must complete. This is the only blocking command, not returning until the move has finished, and returning success only if the device is in the requested position and failure otherwise. An example might be "filter wait" where a success return in the example case means that the r filter is stopped/locked in the beam. If a wait command is given after a position request but without a move request, the wait command implies a move request.

iv) Immediate requests - the command indicates an action request that will complete in less than a second or some configuration option that completes immediately. These commands are allowed to complete before returning success or failure. Examples might be "shutter open", "exposuretime 10", or "filename next". Immediate requests are not to be used for longer actions, even if the instrument itself is blocked until completion; other activities may be doable in parallel.

All non-immediate requests shall have time-outs defined. If a request does not complete within the time-out, it shall be deemed to have failed and shall cause an error condition.

The status interface shall include a method for returning complete device status to the caller, normally via the Status Server. Note that in the director/agent model there are no status commands per se; if the device control is done directly by an agent as is usually the case, see the next subsection for status output.

Error conditions shall be logged and cause a command failure. Automatic retries and/or recovery are acceptable but should not be used to hide non-functional hardware.

1.6.3.2. Agent Level Device Control Interfaces

The agent command interface is as described in the previous subsection, providing position, move, wait, and immediate requests. Command sequences will be given to the agent based on scheduling needs at a higher level, i.e., the intelligence needed to schedule multiple actions is kept up in session level scripts that know all the operations needed to accomplish an observation.

Except in a few special cases, agents do not return any instrument status values directly. As a side effect of move/wait commands, they update fields in the Status Server describing the current state of their controlled devices. At all times the Status Server values shall indicate the current device state, with a 1 Hz maximum update rate. In addition there shall be two special commands, "beginfits" which causes exposure start and dummy exposure end FITS header values to be recorded into the Status Server, and "endfits" which records any exposure end header values.

Failure returns are handled by the director/agent interface. Logging is provided by director via the cfht_logv() function. Messages come in debug, logonly, informational, status, warning, error and progress types.

Debug and logonly messages are generally not visible to the user. Informational messages appear in white; status, in green; warning, in yellow; and error, in red. Progress messages appear in a popup with a completion bar and percentage done value.

Logonly messages are to be used to record all useful operation detail, in both successful and unsuccessful conditions.

Informational messages can be used to show progress. Status messages are used to show the beginning and ending of major steps in carrying out commands. Warning messages are used to log concerns that do not stop observing.

Error messages indicate command failure. In general there should be no more than one error message output for a failed command just before the command returns, and it should be fairly general. All details on the error should have already output as logonly messages by lower levels of code that know the exact circumstances.

Agents usually provide three operational modes. Observing mode provides all the commands needed for queue operation. Safe mode provides dummy commands for anything that can interact with the telescope, used when the associated instrument is not actually on the telescope.

Engineering mode adds additional engineering level commands to observing mode such as low-level device control, parameter setting, or debugging.

CFHT provides libraries and a template program for developing agents. Whether CFHT or the instrument provider creates any necessary agents is open for discussion during system design.

1.6.3.3. Detector Control DSP Interfaces

The recommended detector control interface is the one provided by the CFHT detector controller program, DetCom. DetCom is primarily an SDSU controller oriented program, though a version of it is used with the SHARC DSP chips used on MegaCam.

If there is a requirement for a different interface, it shall provide for initialization, loading DSP code, setting exposure parameters, exposure control, read out, and maintenance functions.

CFHT creates image files using the Flexible Image Transport System (FITS) conventions. A special interface shall provide several commands for setting FITS headers in all image files created. All files written by this interface shall pass the *cfitsio* verify program *fitsverify* tests. The control program shall also for FITS file creation containing exposure images and an interface to the Status Server FITS header convention.

1.6.3.4. Power Up State

For any device that loses state when it is powered off (e.g., it uses incremental encoders), it must be possible for the control software to determine that power has been cycled. A "home" command shall be provided to recover to a known state. Any configuration change requests before the home command shall fail.

1.6.3.5. Communication with TCS

CFHT provides code to access telescope parameters. The Queue system controls all telescope pointing. An instrument is allowed to request offsets and send guider corrections. An instrument is also allowed to request focus changes. All telescope parameters, e.g., right ascension, declination, and dome position, are stored in the Status Server. CFHT also provides routines for higher speed access to hour angle, right ascension, and declination directly in TCS.

1.6.3.6. Asynchronous Operations

The director environment is specifically designed for synchronous operations. When asynchronous control is needed, e.g., for an atmospheric dispersion compensator or a guider, an agent can start a subprocess to handle background operation of the continuous subsystem.

1.6.4. Software Standards

The following paragraphs define the direction for CFHT standards.

1.6.4.1. Languages

CFHT recommends the use of the C language for compiled programs and bash for scripted programs. User interfaces can be developed in GTK or Java. Any variations should be discussed early in the design phase. Perl, Tcl/Tk, and Python are available, but they are not actively used for instrument software. CFHT requests that variable names and comments be English.

For user interfaces, note that observational software is operated in command line mode by the queue system and requires very little interaction. Graphical interfaces may be needed for guider acquisition and visualization, for example, but instrument control is strictly command line driven. Instrument configuration displays may be developed for engineering and maintenance purposes, but they will not be used for observing.

1.6.4.2. Format

The general formatting for C programs is defined by the indent program parameter file at http://www.cfht.hawaii.edu/Software/.indent.pro . This uses a slightly modified version of GNU indent version 2.2.9 (at http://www.cfht.hawaii.edu/Software/indent-2.2.9-CFHT.tgz) with comment indents to a fixed column and case sub statements with a separate indent amount.

See the samples described in the next subsection.

The general formatting for bash scripts is similar to the C formatting, though it uses 4-space indentation. Open braces ("{") for functions go on the function name line. The "; then" of an if statement goes at the end of the last line of the if condition. See http://www.cfht.hawaii.edu/Software/Functions.sh for a sample. This is our bash script library module.

The use of case and underscores in variable names varies. CFHT requests that project provided code be consistent.

The use of typedef in C code is required; there should be no uses of "struct" in references to local structures. The enum construct should be used to define names for multi-valued field constants.

1.6.4.3. Commenting

CFHT recognizes that commenting is an individual art but requests that the following general pattern be followed. Each file should start with the creating institution's legalese; this will be retained at CFHT. Next should be a general description of the file contents, including a list of routines, if appropriate. The end of the header comments has been an RCS log in C files, though we will drop that with SVN. bash scripts generally do not have RCS logs to save on interpretation time.

Each data structure should be preceded by a block text comment describing each field. If the structure is complex, there should be a simple drawing in the comments, and a good drawing in the external documentation.

Each routine should be preceded by a block text comment describing the routine. There should be sections giving a description of the routine, how it is called, the input parameters, the output parameters, what the function return value is, and an explanation of any global variables referenced. The routine description audience is a caller of the routine, though internal algorithms and/or caveats can also be included.

Major sections of code should have comments describing their purpose. Individual lines should not have comments except to explain tricks or anything unobvious.

C code samples are available under http://www.cfht.hawaii.edu/Software/ in ss_api.h and ss_api.c, which are part of the Status Server interface and in dlog.h and ConfigFile.c, which are part of the PLC interface.

1.6.4.4. Building

CFHT uses a GNU make Makefile system for building and installing code, presently make version 3.81. The build portion understands compiling C, C++, and IDL code. The install portion also understands bash and Perl scripts, named "*.sh" and "*.pl", respectively. All project provided code shall use this system. See section 1.6.4.7 to obtain a copy.

1.6.4.5. Error Handling

All code shall check for error returns. All system calls that can reasonably be expected to fail must be checked to make sure they did not. This includes malloc(3) and file input/output, for example, but does not normally include printf(3) and friends, which should be called as

```
(void)printf("foo\n");
```

for example. scanf(3) and friends should be checked to make sure the correct number of fields were scanned.

All project provided code shall be written with functions that provide a method for detecting errors resulting from their being called. CFHT requests that this be handled with an explicit PASSFAIL type return value of PASS or FAIL. These are defined in cfht.h - see section 1.6.4.7

to obtain a copy. Functions that return null pointer values or special integer values (e.g., -1) should be avoided. Immediately preceding each FAIL return should be a logonly message including all locally available information about why an error is being returned.

1.6.4.6. Revision Control

CFHT currently uses RCS for revision control, but we will be migrating to SVN in the near future.

1.6.4.7. CFHT Environment

At CFHT our software is stored on an automounted file system under "/cfht". At a project site it can be installed under any convenient spot and will build relative to that. A partial copy of our software tree is available on request.

1.7. Optics

1.7.1. Component Mounting

Optical components shall be mounted in cells that are removable from the instrument. Removal shall be possible while the instrument is on the telescope or on its handling cart.

Cell mounting hardware and hardware geometry shall maintain optical alignment during installation and removal of the cell from the instrument, preferably without use of optical alignment fixtures or specialized alignment tooling.

1.7.2. Coatings

All optical coatings shall be sufficiently robust to withstand repeated cleanings. In particular, the use of soft (non-hardened) antireflection coatings is NOT acceptable.

1.7.3. Alignment Fixtures and Tooling

All optical alignment fixtures and specialized alignment tooling shall be provided with the instrument.

1.7.4. Special Optical Test Elements

All special optical elements used for testing of the optics (Computer Generated Hologram (CGH), custom null lenses, etc.) shall be provided with the instrument.

1.7.5. Component Identification

All optical elements shall be identified by a component label with an arrow indicating the direction of light propagation engraved on the edge of the optics and on the edge of their cells

1.7.6. Component Centering or Alignment Marks

Where requested by CFHT, large optics shall be provided with engraved markings at their optical centers, or with other identifying marks to be used for alignment.

1.7.7. Warning Labels

Mounting hardware for delicate or unusual optics shall be provided with appropriate warning labels, identifying the nature of the caution to be taken, e.g.,

CAUTION: CRYSTAL OPTICS, FRAGILE SURFACE COATINGS, EXPOSED CROSS HAIRS

1.8. Design Reviews

All facets of an instrument development contract shall undergo formal design reviews that include CFHT participation. CFHT reserves the right to require design changes to ensure that the resulting instrument meets these specifications and will operate in the CFHT environment. Depending on project complexity and functions, there may be any of mechanical, electronic, software, and optical design review sequences, usually in parallel. These may be combined as needed.

CFHT encourages regular consultation with CFHT staff during the development process. All design shall be preceded by a Requirements document and review and a Functional Specifications document and review. CFHT may request one, two, or three design review stages, depending on the complexity of the development proposed. Larger projects may be required to conduct a Conceptual Design Review (CoDR) and probably a Preliminary Design Review (PDR). All projects shall have a Final Design Review (FDR).

Note that the general design order is optical, mechanical, electrical, and finally software. The mechanical design depends on the optical design. The electronics design depends on what mechanics need controlling. The software design depends on what electronics are provided. Camera controller development parallels the general instrument sequence as does data reduction and analysis software.

1.8.1. Design Stages

1.8.1.1. Requirements Document

Prior to design initiation, project personnel and CFHT shall agree on the requirements to be met. This entails the production and review of a requirements document by a collaboration of project and CFHT staff. The resulting document shall guide the design process. For some projects the project contract may serve as the requirements document.

1.8.1.2. Functional Specifications Document

Following the requirements document acceptance, the project staff shall prepare a functional specification document. This document shall provide a description how each requirement is to be met, on the level of, e.g., the mechanical stages to be used, the general electronics to be proposed, the software modules to be written, or the kind of optical design to be created. After this document’s review, there should be agreement on the direction the actual design will take.

1.8.1.3. Conceptual Design Review

Large projects shall present a Conceptual Design Review (CoDR). For a CoDR the project staff shall prepare an initial design document in advance. For each section of the functional specifications document there should be a description of how that function will be implemented. The purpose is to get an overall design worked out and discussed. The goal is an agreement on the major design points with confidence that the design team is prepared to do a preliminary design.

1.8.1.4. Preliminary Design Review

Most projects shall present a Preliminary Design Review (PDR). For the PDR the project staff will prepare an intermediate design document in advance. The purpose is to get the high and intermediate level design agreed on. The document should provide a level of detail between that of the CoDR and FDR documents, i.e., it should describe most of the whys and how’s without being detailed enough to start building the instrument. After the PDR, all parties should feel satisfied that the requirements will be met by the detailed design.

1.8.1.5. Final Design Review

All projects shall present a Final Design Review (FDR). The project staff will prepare a final design document that will completely specify all details necessary to build the instrument satisfying all the requirements. After the FDR is successfully completed, work on the hardware and/or software may commence. Until this time no physical components or lines of software should have been touched. The only exception is ordering components with long lead times as agreed with CFHT staff at earlier discussions.

During the FDR there will be initial discussions of acceptance testing. This will normally lead to a brief outline of what tests will be needed to verify that the requirements are met by the instrument.

1.8.2. Mechanical Designs

1.8.2.1. CoDR

The CoDR shall point to key requirements and discuss the projected mechanical designs. A 3-D conceptual design model encompassing all major parts, materials, and functionality of the overall system should be evaluated. Proposed experiments and prototypes for the design to support design reliability and maintainability shall be established. Preliminary finite element analysis or simulations for critical design features must be shaped. A Draft interface definition document shall be formed.

1.8.2.2. PDR

The PDR shall display how all of the requirements are being met in the mechanical design. An updated 3-D detailed design model demonstrating all major and minor parts, materials, and functionality of the overall system should be presented. Experiment findings and prototype results for the design concept shall be demonstrated. Intermediate supporting finite element analysis or simulation findings should be critiqued. All material and vendor selections should be flushed out and the baseline interface definition document shall be confirmed. Major long lead items should be identified.

1.8.2.3. FDR

The FDR shall present the final design in a finished state before fabrication, assembly and integration of components and subsystems commence. It shall include a finished 3-D system model presenting all major and minor subassemblies, parts, components, and hardware. It shall include a complete drawing data package including a system level drawing tree, bill of materials, and system level assembly and subassembly detailed drawings. Final design prototype demonstrations and experimental results shall be supplied. The design documentation shall present a schedule showing subsystem and component level fabrication activities and testing. It will cover a proposed risk mitigation plan and decision points for fabrication problems. Manuals and procedures for troubleshooting and assembly with a table of contents shall be provided. Specific instructions given for specialized handling or storage requirements will be required.

1.8.3. Electronic Designs

1.8.3.1. CoDR

The CoDR documents for electronic designs, which include motion control system (Galil) and command and control system (PLCs), shall include, where applicable, conceptual system design, draft interface definition document, and preliminary analyses or simulations.

1.8.3.2. PDR

The PDR documents shall include, where applicable updated preliminary system design, interface definition document, detailed analyses or simulations, prototype results, preliminary system, subsystem, schematic and interconnect drawings, flow charts of DSP, PLC, PLD, FGPA or microcontroller code, identification of major components, error analyses, and design verification in relation to the Functional Specification Document. Major long lead items may be procured after PDR.

1.8.3.3. FDR

The FDR is the last stage prior to the final fabrication, assembly and integration of components and subsystems. FDR documents shall include, where applicable, updated PDR documents, detailed schematics, interconnect and layout drawings, risk assessment, proposed manuals with table of contents, and handling and storage document.

1.8.4. Software Designs

1.8.4.1. Functional Specifications Document

This document shall propose the set of functions the software will provide. These are logical functionality, not programming language functions. For an agent, for example, this could detail the commands to be implemented and their operation. The document should cover each requirement indicating how the requirement will be met.

1.8.4.2. CoDR

Very large software projects and smaller projects by groups unfamiliar with the CFHT software environment may be required to present a CoDR. At a CoDR a document describing the overall software design and methodology shall be available. It will discuss the underlying hardware environment that the software is to control, the ways the software will interface to the CFHT environment described in this document, and the initial proposed solutions for meeting the requirements document.

At this point there shall have been no lines of code written.

1.8.4.3. PDR

After the basic software design is understood medium and large projects shall present a PDR document and discussion. This document shall review the requirements and discuss how they are to be met. It shall describe the control and data flow at the level of major modules.

At this point there may be the start of interface definitions in program files, but still no lines of code should have been written.

1.8.4.4. FDR

Prior to any major coding effort there shall be an FDR. It will discuss a detailed design document that includes data structure definitions, control flow, command processing, instrument control, interfaces with the CFHT system, and status and error reporting. The detail shall be sufficient for a coder to implement the software. There shall be a test plan outline.

At this point the data structure definitions should be fairly complete, and function stubs may exist matching the proposed program structure, but relatively little code should have been written. The goal of the FDR is give approval of the design so that coding can begin.

1.8.4.5. Code Reviews

Major software development shall include code reviews with CFHT personnel. Code reviews will be informal in that no extra preparation is expected. They are intended verify that the software will fit into the CFHT environment and to begin CFHT staff familiarization.

1.8.5. Optical Designs

1.8.5.1. CoDR

The CoDR document shall present the design solution or solutions developed to meet the requirements laid out in the requirements document. The document shall include the advantages and disadvantages of the various design solutions. At the discretion of CFHT, the CoDR and the PDR may be combined into one review if the optical system is deemed simple enough.

1.8.5.2. PDR

After the basic form of the design is agreed on, a PDR document and discussion shall be produced. This document shall contain details of the optical design including basic fabrication tolerances and interface requirements for the mechanical mounting of the optics. Also included will be all analyses and simulations necessary to demonstrate compliance of the design with the requirements.

1.8.5.3. FDR

The FDR is the last review prior to fabrication of optical components. The FDR documents shall include optical fabrication drawings with all specifications necessary for fabrication included, a tolerance analysis demonstrating that the fabrication specifications will allow the optics to meet the requirements, final mechanical interface specifications approved by the mechanical design group, necessary updates to all analyses and simulations from the PDR document, and a list of proposed tests to show conformance with requirements.

1.9. Documentation and Deliverables

1.9.1. General

- 1. The detailed manuals and drawings outlined below are considered part of the instrument and are assumed to be included in its contract purchase price.
- 2. Each document page shall contain a page number and a release date or version number.
- 3. At least two copies of each drawing and manual shall be provided in English and on 8 1/2"x 11" or A4 stock.

1.9.1.1. Manuals

- 1. Manuals shall be provided on computer media in a format compatible with Microsoft WORD software.
- 2. Each manual shall contain, apart from the text:

  i) a Title or Cover Page
  ii) a Table of Contents
  iii) a List of Illustrations
  iv) an Index

1.9.1.2. Drawings

- 1. All drawings shall be numbered.

1.9.2. Mechanical

1.9.2.1. Drawings

- 1. All mechanical drawings and illustrations shall be provided on computer media in formats readable and modifiable by AutoDesk, AutoCAD or AutoDesk Inventor.
- 2. An overall detailed assembly drawing with multiple views or 3-view cutaway drawing shall be provided showing all major and minor subassemblies.
- 3. A complete set of assembly drawings and dimensioned fabrication drawings sufficient to fabricate any component of the instrument shall be provided.
- 4. All parts shall be numbered and dimensioned.
- 5. Commercial parts shall be identified on the drawings together with:

  i) the manufacturer's name,
  ii) the manufacturer's part or model number,
  iii) the quantity required.

- 6. There shall be a master drawing list giving a structural idea of the overall design in a drawing tree.
- 7. Either European or North American drawing standards are acceptable, but must be clearly identified on the drawings.
- 8. All special symbols shall be identified in a separate symbol table provided as an instrument drawing.

1.9.2.2. Manuals

- 1. Mechanical Assembly Procedure and Maintenance manuals shall be provided. They shall contain:

i) instructions for the mechanical assembly and disassembly of all major modules,
ii) all specialized assembly procedures,
iii) alignment procedures
iv) a list of all specialized tools required for instrument maintenance or adjustment,
v) a list of all commercial parts used in the instrument, including, for each:
  - 1. an overview of the instrument operation,
  - 2. a drawing reference numbers indicating the assembly in which the part is used,
  - 3. the manufacturer's name, address, telephone number, and telefax number,
  - 4. the model or part number,
  - 5. a manufacturer's specification sheet,
  - 6. the supplier's, name, address, telephone number, e-mail address and web address.

vi) a maintenance plan including preventive maintenance procedures and schedules.

1.9.2.3. Tools

All special tools needed for instrument assembly, disassembly, and maintenance shall be provided.

1.9.3. Electronics

1.9.3.1. Drawings

- 1. A system block diagram detailing signal flow, major subsystems and functions shall be provided.
- 2. A drawing detailing overall system component layout, cable interconnections, connector identifications, and cable names shall be provided.
- 3. Detailed wiring interconnection diagrams shall be provided for each cable, showing:

  i) connector types,
  ii) connector pinouts,
  iii) connector names or labels,
  iv) signal and cable names,
  v) wiring color codes.
- 4. Detailed electronics circuit diagrams shall be provided for all circuits, indicating:

  i) device numbers or labels,
  ii) device types,
  iii) device pinouts,
  iv) all interconnections,
  v) a circuit board name.
- 5. All changes or jumpers on circuit boards shall be highlighted.
- 6. All signal paths and power runs shall be clearly identified, and signal directions indicated.
- 7. All references to signals and connections from and to other drawings or devices shall be clearly identified.
- 8. Circuit timing diagrams shall be provided.
- 9. Electronic symbols should follow the US ANSI standards.

- 10. Logic notation should be consistent with the device manufacturer's symbols. The use of "inverted" logic symbols is not acceptable.
- 11. Diagrams should be on size A (A4) or B (A3) sheets suitable for binding in a manual.
- 12. Diagrams shall be compatible with OrCAD 10.0. They shall include schematic layout and PCB layout forms.
- 13. Gerber files for PCB creation shall be included.

1.9.3.2. Manuals

- 1. A written systems and operational description shall be provided.
- 2. A detailed written description of circuit cards and subsystem functions, including critical signals and timing shall be provided.
- 3. Flow chart, source and binary listing of the contents with sufficient comments, of all programmable devices including PLCs, DSPs, PLDs, FPGAs, PROMs and microcontrollers.
- 4. A list of all commercial components shall be provided, including:
  - i) a drawing reference number indicating where the part is used,
  - ii) the manufacturer's name, address, telephone number, and telefax number,
  - iii) the model or part number.
  - iv) a data or manufacturer's specification sheet,
  - v) the supplier's, name, address, telephone number, e-mail address and web address.

1.9.4. Control

1.9.4.1. Drawings

- 1. A loop block diagram for all servo systems shall be provided indicating components, summing points and signal paths.
- 2. Open and closed loop gain and phase response curves (transfer-functions) shall be provided for all servo systems. Bode plot approximations are acceptable whenever system poles and zeros are adequately spaced.
- 3. Flow diagrams showing the interrelation and timing of all "firmware" routines shall be provided.

1.9.4.2. Manuals

- 1. A written control system overview, detailing system operation shall be provided.
- 2. A written firmware system description providing a detailed explanation of the operation of each code module, including required inputs and all possible outputs shall be provided.
- 3. A complete, documented and commented firmware listing in assembly or higher-level language shall be provided.
- 4. For servo systems, the transfer function of each loop component, together with system open loop and closed loop transfer functions shall be provided in the form of algebraic expressions.

1.9.5. Software

Software deliverables are source code, internal program documentation, and user manuals.

1.9.5.1. Source Code

The source code for all included software shall be provided in a format readable by a Linux PC-based system. This is to include host-based programs and lower level instrument controller software, such as LabView programs used for maintenance, PLC code, Galil programs, and DSP code. Any approved variation from the CFHT build system must include build/compile instructions and any non-standard tools required.

CFHT must be able to make changes to the delivered code, recompile, debug, and test the changes, and run the modified program with the instrument. This subsection is to be interpreted so as to allow that to happen.

The use of any proprietary systems that do not meet this subsection must be discussed with and approved by CFHT before the FDR.

CFHT requests that the delivery is in the form of the RCS or SVN repository used during project development.

1.9.5.2. As Built Documentation

The FDR document should be updated to match the actual implementation and provided in machine-readable form. LaTex, Word .doc or .rtf, and Frame .fm files are acceptable. As with the source code, CFHT must be able to maintain the documentation to match code changes.

This documentation's goal is facilitating code understanding. It should include at least the following sections.

i) summary of requirements
ii) summary of functional specification
iii) overall code organization
iv) data structure description - This will include diagrams, field definitions, and how the structures fit into the overall organization.
v) functional flow and/or data flow - The intent here is to describe how each of the requirements is handled by the code; not a function-by-function description, but a pointer into the code and an idea of what happens.

After studying this document one should be able to find the code section that handles each requirement. The low level comments in the code would then be expected to complete the understanding of processing the requirement.

1.9.5.3. User Manuals

A user manual or manuals shall be provided covering all aspects of using the software. This is to include the observing interface and any maintenance or engineering interfaces the software provides. The manuals must be provided in one of the formats described in section 1.9.5.2.

1.9.6. Optics

1.9.6.1. Drawings

- 1. A complete set of optical specification drawings sufficient to fabricate all custom optics, or other commercial optical components shall be provided.
- 2. An overall optical assembly drawing showing all optical components and systems, the directions and positions of major optical rays, and the direction of any available adjustments shall be provided.
- 3. Conformance data for all custom optical components showing that the components met specification shall be provided in electronic format.

- 4. Spot diagrams detailing critical device performance over the design field and spectral range shall be provided.
- 5. As-built optical model(s) for all instrument optical systems shall be provided electronically in Zemax format when possible. If Zemax format is not possible, as-built optical model listing(s), sufficient to re-create the model(s) in Zemax, for all instrument optical systems shall be provided electronically in text format.

1.9.6.2. Manuals

- 1. Optical alignment instructions detailing in particular any preferred procedures, and the use of alignment fixtures and tooling shall be provided.
- 2. An optical efficiency budget giving the efficiency of each surface, and an overall optical efficiency for the instrument shall be provided.
- 3. A list of mirror and anti-reflection-coatings for each surface, shall be provided, detailing:

  i) the manufacturer's name, address, telephone number, e-mail address and web address,

  ii) type of coating and its specifications,

  iii) optical efficiency of coatings, including efficiency tracings files.
- 1. A list of all custom optical components detailing all necessary manufacturing specifications shall be provided.
- 2. A list of all commercial optical components shall be provided, including:

  i) the manufacturers name, address, telephone number, e-mail address and web address,

  ii) the model or part number,

  iii) a datasheet or copy of catalogue entry,

  iv) the supplier's name, address, telephone number, e-mail address and web address

PART 1 - INSTRUMENT SPECIFICATIONS

1.10. Storage and Handling

1.10.1. Instrument

- 1. An instrument shall be provided with lifting points above its center of gravity and any necessary spreader bars or handling equipment required for mounting the instrument on the telescope or onto its handling cart.

1.10.2. Storage/Handling Cart

- 1. The instrument shall be provided with a handling cart that shall hold the instrument in the orientation normally used on the telescope. The cart is intended for instrument storage and for handling while off the telescope.
- 2. Instruments intended for use at the Cassegrain focus shall be mounted on the handling cart in such a way as to not inhibit the mounting of the instrument to the Cassegrain Bonnette.
- 3. The cart shall have locking, soft rubber wheels at least 150 mm in diameter and, if for use at the Cassegrain focus, jack screws at each corner.
- 4. Access to the instrument by an overhead crane or other handling equipment will not be impeded while the instrument is on the cart.
- 5. The instrument will be capable of performing all electromechanical functions while on the cart. Access to control electronics, connectors and power supplies for routine maintenance and troubleshooting of the instrument shall not be impeded by the cart structure.
- 6. The cart shall have at least one pair of lifting points, together with all necessary spreader bars or specialized slings to permit transportation of the cart plus instrument by crane.
- 7. The cart shall contain an open shelf onto which all necessary fastening hardware and tools for mounting the instrument to the telescope can be stored.

1.10.3. Handling Electronics Equipment

- 1. All auxiliary electronics or control equipment not mounted as part of the instrument shall be rack mounted in 19" racks, using standard rack panels.
- 2. Storage shelves or drawers for all associated cables, hoses etc. shall be provided with the handling cart or with associated electronics storage.

1.10.4. Weight and Moment Identification

- 1. Labels shall be affixed to the cart and electronics racks indicating instrument weight and moments about the instrument mounting face.

1.10.5. Cover

- 1. The instrument shall be provided with a weatherproof cover with closures sufficient to allow component access and ease of cover installation and removal.
- 2. The cover shall be identified by the instrument name in 100 mm high, white letters affixed to it.
- 3. The cover shall be designed to fit over the instrument and its storage cart and reach to within 100 mm of the floor.

1.11. Acceptance Tests

- 1. In general, contractors should expect acceptance testing to be divided between assembly tests and inspections, tests of the integrated instrument at the fabrication site, and a final instrument acceptance test on site at CFHT.
- 2. The testing shall include operating cold tests in a 0 degrees Celsius environment.
- 3. CFHT reserves the right to on-site inspections of the instrument and reviews of project development at any time during instrument development or fabrication.
- 4. Specific details of inspection and acceptance tests should be agreed upon in writing between the contractor and CFHT well before the tests are to be conducted. It remains the contractor's responsibility to detail these tests to CFHT's satisfaction. In the event that a list of tests agreeable to CFHT are not provided, CFHT reserves the right to impose whatever tests it deems essential to guarantee the successful operation of the instrument.
- 5. Instruments will generally NOT be deemed acceptable for delivery to the observatory unless all associated documents and diagrams outlined in this manual are available at the time of final inspection at the developer's site.

1.11.1. Mechanical

Instrument acceptance testing shall also include the following.

- 1. Assembly and disassembly procedures – the CFHT staff will follow the assembly and disassembly manual to take the instrument apart, examine all parts, put the instrument back together, and align the instrument.
- 2. Stress testing – the instrument will be operated at 0 degrees Celsius through all movement ranges at angles from zenithal to horizontal in north/south/east/west directions, and it must maintain alignment through these tests.

1.11.2. Software

Prior to software delivery CFHT will conduct acceptance testing of any project provided software. The first stage will be a review of the FDR test plan outline as implemented and pursued, followed by an evaluation of the test results.

The developed test plan should include unit testing in which all the code is exercised, integration testing in which the hardware and software pieces are shown to work as a system, and functional testing which shows how all of the project requirements are met. After a successful review, CFHT will conduct its own functional testing of the whole system.

1.11.3. Optical

Prior to instrument delivery, CFHT will conduct acceptance tests on all of the optical systems contained within the instrument. The test plan will be based on, but not limited to, the proposed tests from the FDR document.

The final test plan shall include tests to demonstrate compliance with all requirements. In some cases (e.g., total transmission), the test may be an analysis based on as-built measurements instead of a direct measurement, but this should only be done when direct measurements are extremely impractical. In general specialized test equipment needed to perform the tests will be provided by the contractor.

1.12. Training

The vendor shall provide training sufficient to allow CFHT technical staff to:

i) mount/dismount the instrument from the telescope,
ii) verify correct operation,
iii) operate the instrument,
iv) perform sufficient troubleshooting to identify failed subassemblies.

The travel and per diem costs of this training will be covered by CFHT on a per incident basis. All other costs of providing this training are part of the contract for supplying the instrument.

1.13. Glossary

These acronyms are used in this document.

10BASE-T	10 Megabit per second Ethernet over CAT5 cable
100BASE-T	100 Megabit per second Ethernet over CAT5 cable
1000BASE-T	1 Gigabit per second Ethernet over CAT5e cable
AC	Alternating Current
ANSI	American National Standards Institute
ARC	Astronomical Research Cameras (formerly SDSU)
BNC	Bayonet Neill-Concelman (co-axial cable connector)
CAT5	Category 5 (dual twisted pair cable for network connections)
CAT5e	Category 5 Extended (dual twisted pair cable for 1 Gigabit network connections)
CFHT	Canada-France-Hawaii Telescope
CGH	Computer Generated Hologram
CoDR	Conceptual Design Review
DC	Direct Current
DCE	Data Computer Equipment (the computer end of RS-232 cables)
DD	Double Density
DSP	Digital Signal Processor
EPICS	Experimental Physics and Industrial Control System
FDDI	Fiber Distributed Data Interface (a fiber connector)
FDR	Final Design Review
FITS	Flexible Image Transport System (a convention for astronomical image files
FPGA	Field Programmable Gate Array
GNU	Gnu's Not Unix (a computer programming organization)
GTK	Graphics Tool Kit (an X windows system graphics programming library)
IDL	Interactive Data Language (a programming language for data analysis and graphical display)
IEEE	Institute for Electrical and Electronics Engineers
IOC	Input/Output Controller (an EPICS computing element)
IP	Internet Protocol
LED	Light Emitting Diode
LEMO	A connector manufactured by the Swiss LEMO Corporation
MS	MicroSoft
NEO	New Environment for Observing (the CFHT data acquisition programming environment)

PART 1 - INSTRUMENT SPECIFICATIONS

OAP	Observatory Automation Project (a CFHT project to allow observing from Waimea)
PC	Personal Computer
PCB	Printed Circuit Board
PCI	Peripheral Component Interconnect (a PC bus)
PDR	Preliminary Design Review
PLC	Programmable Logic Controller
PLD	Programmable Logic Device
PROM	Programmable Read-Only Memory
RCS	Revision Control System (a software management system)
RJ45	(more properly called an 8P8C - a connector for network cables)
RS-232	(more properly called RS-232C - a specification for terminal/computer communication)
SC	Siemon Connector (a fiber optic cable connector)
SDSU	San Diego State University (a detector controller developed there)
SHARC	Super Harvard ARChitecture (an Analog Devices DSP chip)
SVN	SubVersioN (a software management system)
TCP	Transmission Control Protocol
TCS	Telescope Control System
UDP	User Datagram Protocol
US	United States
VA	Volt-Amps
XOFF	transmission OFF (serial communications stop)
X	the X Window System
XON	transmission ON (serial communications start)
ZIF	Zero Insertion Force (a type of integrated circuit socket)

PART 1 - INSTRUMENT SPECIFICATIONS

2. TELESCOPE FACILITIES

The section head will need Page break before turned off