

Requirements
For the Cassegrain ADC

Sean Adkins
W.M. Keck Observatory

September 23, 2003
Version 1.3.2

Table of Contents

1	Introduction.....	1
2	Scope and Applicability.....	1
3	References.....	2
3.1	Related Documents.....	2
3.2	Referenced Standards.....	3
3.3	Referenced Drawings.....	5
4	Revision History.....	6
5	Background.....	7
6	Overall System Requirements.....	8
6.1	Performance Requirements.....	8
6.1.1	Parametric Performance Requirements.....	8
6.1.2	Operational Performance Requirements.....	9
6.2	Implementation Requirements.....	9
6.2.1	Feature Implementation Requirements.....	9
6.2.2	Common Practice Implementation Requirements.....	11
6.2.3	Standards Implementation Requirements.....	11
6.2.4	Regulatory Implementation Requirements.....	11
6.3	Design Requirements.....	14
6.3.1	Technological Design Requirements.....	14
6.3.2	Regulatory Design Requirements.....	15
6.3.3	Standards Related Design Requirements.....	15
6.3.4	Integration Related Design Requirements.....	15
7	Optical Requirements.....	16
7.1	Performance Requirements.....	16
7.1.1	Parametric Performance Requirements.....	16
7.1.2	Operational Performance Requirements.....	18
7.2	Implementation Requirements.....	18
7.2.1	Feature Implementation Requirements.....	18
7.2.2	Common Practice Implementation Requirements.....	19
7.2.3	Standards Implementation Requirements.....	19
7.2.4	Regulatory Implementation Requirements.....	19
7.3	Design Requirements.....	19
7.3.1	Technological Design Requirements.....	19
7.3.2	Regulatory Design Requirements.....	20
7.3.3	Standards Related Design Requirements.....	20
7.3.4	Integration Related Design Requirements.....	20
8	Mechanical Requirements.....	21
8.1	Performance Requirements.....	21
8.1.1	Parametric Performance Requirements.....	21
8.1.2	Operational Performance Requirements.....	21
8.2	Implementation Requirements.....	22

Table of Contents

8.2.1	Feature Implementation Requirements	22
8.2.2	Common Practices Implementation Requirements	25
8.2.3	Standards Implementation Requirements	26
8.2.4	Regulatory Implementation Requirements	26
8.3	Design Requirements	26
8.3.1	Technological Design Requirements	26
8.3.2	Regulatory Design Requirements	27
8.3.3	Standards Related Design Requirements	27
8.3.4	Integration Related Design Requirements	27
9	Electronic/Electrical Requirements	29
9.1	Performance Requirements	29
9.1.1	Parametric Performance Requirements	29
9.1.2	Operational Performance Requirements	30
9.2	Implementation Requirements	30
9.2.1	Feature Implementation Requirements	30
9.2.2	Common Practices Implementation Requirements	31
9.2.3	Standards Implementation Requirements	31
9.2.4	Regulatory Implementation Requirements	32
9.3	Design Requirements	35
9.3.1	Technological Design Requirements	35
9.3.2	Regulatory Design Requirements	36
9.3.3	Standards Related Design Requirements	36
9.3.4	Integration Related Design Requirements	36
10	Safety Requirements	37
10.1	Performance Requirements	37
10.1.1	Parametric Performance Requirements	37
10.1.2	Operational Performance Requirements	37
10.2	Implementation Requirements	37
10.2.1	Feature Implementation Requirements	37
10.2.2	Common Practice Implementation Requirements	38
10.2.3	Standards Implementation Requirements	38
10.2.4	Regulatory Implementation Requirements	38
10.3	Design Requirements	38
10.3.1	Technological Design Requirements	38
10.3.2	Regulatory Design Requirements	38
10.3.3	Standards Related Design Requirements	38
10.3.4	Integration Related Design Requirements	39
11	Software Requirements	40
11.1	Performance Requirements	40
11.1.1	Parametric Performance Requirements	40
11.1.2	Operational Performance Requirements	40

Table of Contents

11.2	Implementation Requirements	42
11.2.1	Feature Implementation Requirements	42
11.2.2	Common Practice Implementation Requirements	43
11.2.3	Standards Implementation Requirements	43
11.2.4	Regulatory Implementation Requirements	43
11.3	Design Requirements	43
11.3.1	Technological Design Requirements	43
11.3.2	Regulatory Design Requirements	43
11.3.3	Standards Related Design Requirements	44
11.3.4	Integration Related Design Requirements	44
12	Interface Requirements	45
12.1	Performance Requirements	45
12.1.1	Parametric Performance Requirements	45
12.1.2	Operational Performance Requirements	45
12.2	Implementation Requirements	45
12.2.1	Feature Implementation Requirements	45
12.2.2	Common Practice Implementation Requirements	45
12.2.3	Standards Implementation Requirements	46
12.2.4	Regulatory Implementation Requirements	46
12.3	Design Requirements	46
12.3.1	Technological Design Requirements	46
12.3.2	Regulatory Design Requirements	46
12.3.3	Standards Related Design Requirements	46
12.3.4	Integration Related Design Requirements	46
13	Reliability Requirements	47
14	Spares Requirements	47
15	Service and Maintenance Requirements	47
15.1	Cleaning of Optics	47
16	Documentation Requirements	48
16.1	Drawings	48
16.1.1	Introduction	48
16.1.2	Drawing Standards	48
16.1.3	Dimensions and Tolerances	49
16.1.4	Surface Finish Descriptions	49
16.2	Manuals	49
16.2.1	Operating Manuals	49
16.2.2	Maintenance Manuals	49
16.3	Software	50
16.4	Test Data	50
17	Glossary	51

Figures and Tables

Figure 1: Cassegrain ADC Configuration..... 9
Figure 2: ADC Components and Interconnections..... 10
Figure 3: ADC Software Architecture 41

Table 1: Referenced Standards 3
Table 2: Referenced Drawings..... 5
Table 3: Operating Environment 8
Table 4: Materials not Suitable for use in Equipment at the Summit of Mauna Kea 14
Table 5: Cassegrain ADC Typical Performance Requirements 16
Table 6: Cassegrain ADC Goal Performance Requirements 17
Table 7: ADC Module Optical Adjustments 18
Table 8: ADC Module Mechanical Performance Requirements 21
Table 9: Glossary of Terms..... 51

1 INTRODUCTION

This document describes the requirements for the Cassegrain Atmospheric Dispersion Corrector (ADC) for the Keck I telescope at the W.M. Keck Observatory (W.M.K.O.) operated by the California Association for Research in Astronomy (CARA).

The Cassegrain ADC will provide correction over the full Cassegrain field of view (FOV) for the Keck I telescope configured with an $f/15$ secondary mirror. The ADC is initially intended for use with the Low Resolution Imaging Spectrograph (LRIS) but it will also be useable with future Cassegrain instruments.

The purpose of a requirements document is to define and communicate the observatory's expectations for the design and implementation of a new scientific instrument for the Keck Observatory. As the procuring organization, CARA authors the requirements document in collaboration with the instrument design team.

A requirements document describes the new instrument in terms of the needed scientific and technical performance. The document also expresses specific requirements for implementation or design where those requirements are essential to satisfactory integration and interoperation of the instrument with the observatory systems. The requirements document also references consensus standards approved by recognized standards organizations for specific guidance on technical matters related to implementation, compatibility and safety.

The document avoids prescribing specific design or implementation solutions except for solutions that embody the observatory's unique knowledge or experience. The document establishes requirements for the new instrument that will guide the various design phases of the instrument through to detail design.

2 SCOPE AND APPLICABILITY

This document establishes requirements for all aspects of the Cassegrain ADC. This document also establishes requirements for changes to related sub-systems and software of the Keck I telescope and the LRIS instrument as required.

This revision of the document is the final version for the preliminary design phase of the project.

3 REFERENCES

3.1 Related Documents

Koo, David C., David Cowley, and Lee Laiterman. *Conceptual Design (Phase A) Report for an Atmospheric Dispersion Corrector for the Low Resolution Imaging Spectrograph (LRIS)*. Santa Cruz, California: UCO/Lick Observatory, University of California Santa Cruz, October 31, 2002

Koo, David, Drew Phillips, Lee Laiterman, Vernon Wallace, David Cowley and Sean Adkins. *Atmospheric Dispersion Corrector for the Low Resolution Imaging Spectrograph Delta Conceptual Design Report*. Waimea, Hawaii: W.M. Keck Observatory, February 2, 2003

Cowley, David. *ADC – Preliminary Design Phase Project Plan: Revision 1.2*. Santa Cruz, California: UCO/Lick Observatory, University of California Santa Cruz, May 14, 2003

Adkins, Sean. *Draft Interface Control Document For the Cassegrain ADC, Version 1.2*. Waimea, Hawaii: W.M. Keck Observatory, September 23, 2003.

3.2 Referenced Standards

Table 1 lists the standards documents referenced in this document in the order they appear. Unless otherwise noted all references to standards are for information.

Table 1: Referenced Standards

Source (Organization or Standardizing Body)	Number	Title
International Code Council (ICC)	IBC-2003	2003 International Building Code
ATA	Spec 300-2001.1	Specification for Packaging of Airline Supplies
OSHA	Title 29 CFR Part 1910 ¹	Occupational Safety And Health Standards
ANSI / ASME	Y14.18M-1986 ¹	Optical Parts (Engineering Drawings and Related Documentation Practices)
Department of Defense	MIL- STD-171E	Finishing of Metal and Wood Surfaces
Telcordia	GR-63-CORE	NEBS™ Requirements
Underwriters Laboratories Inc.	Standard for Safety 508	Industrial Control Equipment
National Electric Manufacturers Association	250-1997	Enclosures for Electrical Equipment (1000 Volts Maximum)
ANSI	Y14.5M-1982 (R1988)	Dimensioning and Tolerancing
ASME	Y14.100M-2000-2001	Engineering Drawing Practices
FCC	Title 47 CFR Part 15	Radio Frequency Devices
Council of the European Communities	EMC 89/336/EEC	
CENELEC	EN 50082-1:1997	Electromagnetic compatibility – Generic immunity standard – Part 1: Residential, commercial and light industry
National Fire Protection Association	2002 edition ¹	National Electric Code
County of Hawaii	1995 edition	Hawaii County Code 1983 (1995 edition)
Institute of Electrical and Electronics Engineers	802.3U revision 95	Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method & Physical Layer Specifications: Mac Parameters, Physical Layer, Medium Attachment Units and Repeater for 100 Mb/S Operation (Version 5.0)

1. Normative reference.

Table 1: Referenced Standards, Continued

Source (Organization or Standardizing Body)	Number	Title
CARA	KSD 8 ¹	KTL: the Keck Task Library
CARA	KSD 46a ¹	DCS Keyword Reference Manual (partial)
CARA	KSD 201 ¹	How to Set Up a config.mk Build
CARA	KSD 210 ¹	WMKO Software Standards
CARA	KSD 50 ¹	Keck II C Style and Coding Standards
Department of Defense	MIL-HDBK-217F-2	Reliability Prediction of Electronic Equipment
Naval Surface Warfare Center	NSWC 98/LE1	Handbook of Reliability Prediction Procedures for Mechanical Equipment
ANSI	ANSI Y14.1-1995 ¹	Decimal Inch Drawing Sheet Size And Format
ANSI	ANSI Y14.34M-1996 ¹	Parts Lists, Data Lists, And Index Lists: Associated Lists
ANSI	ANSI Y14.3M-1994 ¹	Multi And Sectional View Drawings
ANSI	ANSI Y14.17-1966 ¹	Fluid Power Diagrams
CARA	KSD 3 ¹	Software Items for Acceptance Review

1. Normative reference.

3.3 Referenced Drawings

Table 2 lists the drawing numbers, revisions and date, source and title for all drawings referenced in this document.

Table 2: Referenced Drawings

Drawing #	Revision/Date	Source	Title
110-10-07	C/6-12-03	CARA	Keck I Telescope Travel Limits
199-10-02	B/11-11/90	TIW	Transfer Module, sheets 1 - 4
608-TT-00	B	Schwartz-Hautmont/TIW	W.M. Keck Telescope Tertiary Tower Elevations, sheets 1 - 17

4 REVISION HISTORY

Revision	Date	Author	Reason for revision / remarks
1.0	June 5, 2003	SMA	Original Issue
1.1	June 18, 2003	SMA	Incorporated CARA comments
1.2	July 31, 2003	SMA	Incorporated UCO/Lick comments
1.3	Sept. 23, 2003	SMA	Finalize requirements, incorporate additional UCO/Lick comments

Due to the difficulties in documents with moderately complex formatting such as this one, the Microsoft Word "Track Changes" feature is not useable. To see the changes in this document since the previous revision, use the "Tools, Track Changes, Compare Documents" drop down menu sequence and compare this document to the previous version. It is not recommended that you attempt to print the results. The file name and date for the previous version is "Cassegrain ADC Requirements.1.2.doc", dated July 31, 2003.

5 BACKGROUND

The original Keck Telescope design included a design for an atmospheric dispersion corrector. An ADC was not constructed at that time, and several years later, a phase A study was initiated by J. Nelson to resume development of an ADC that would be installed as part of the telescope and serve all instruments. This study determined that moving the ADC in and out of the field of view in front of the tertiary tower was a very difficult problem and this approach was abandoned. In October of 2001 the need for an ADC was again raised and the Keck Observatory Science Steering Committee (SSC) approved and funded the Phase A study of an ADC for LRIS alone.

In December of 2002 a review of the conceptual design was held and the review committee decided to not accept the design then presented but instead recommended that the design study be extended to include the additional design and/or evaluation of certain items and the presentation of these at a delta conceptual design review meeting. This review meeting was held in February of 2003. The result of this review was the recommendation to proceed with the design and development of a full aperture Cassegrain ADC. This recommendation was approved by the SSC and by the CARA board in April of 2003.

The Cassegrain ADC will be designed and built by the Technical Facilities group of the UCO/Lick Observatory located on the Santa Cruz campus of the University of California Santa Cruz (UCSC). The UCO/Lick and UCSC staff and professors participating in the project are:

Principle Investigator – Joe Miller
Project Scientist, Optical Designer, and Deputy PI – Drew Phillips
Optician – David Hilyard
Mechanical Engineer – Vern Wallace
Electronic Design – Barry Alcott
Software – Will Deich
Project Management – David Cowley

CARA personnel will also participate in the ADC project:

Instrument Program Manager – Sean Adkins
Mechanical Engineer – Drew Medeiros
Support Astronomer – Greg Wirth
Software Engineer – Al Conrad
Electronics Engineer – Grant Tolleth
Instrumentation Engineer – Bill Mason

6 OVERALL SYSTEM REQUIREMENTS

6.1 Performance Requirements

6.1.1 Parametric Performance Requirements

6.1.1.1 Operating Environment

The ADC must operate at sea level for testing in normal laboratory environments and at the summit of Mauna Kea during its normal operating lifetime. The expected environmental conditions for the ADC are listed in Table 3.

Table 3: Operating Environment

<i>Parameter</i>	<i>Min.</i>	<i>Typ.</i>	<i>Max.</i>	<i>Units</i>	<i>Notes</i>
Temperature	-5	0	+30	° C	Average annual temperature at 4,205 meters is 0° C
Humidity	0	-	95	%	Relative, non-condensing
Altitude	0	4,146	4,200	M	Above sea level, the nominal Keck altitude is 4,146 M

6.1.1.2 Air Borne Contaminants

The weather conditions at the summit of Mauna Kea include frequent high winds resulting in some air borne contaminants, particularly dust and insects. Instruments must be protected during installation and handling against the entry of these contaminants, particularly optical surfaces, precision mechanisms and fine pitch or fiber optic connectors.

6.1.1.3 Shock and Vibration

The United States Geological Survey (USGS) has assigned the big island of Hawaii to seismic zone 4. The seismic zone system is defined in the “International Building Code” (IBC) published by the International Code Council (ICC) in 2003. Seismic zone 4 indicates that there is a 10% probability that over a 50 year period there will be severe ground shaking with an effective peak ground acceleration of 0.4 g or more.

Equipment and components installed at the summit of Mauna Kea must be mounted or restrained so that they will remain in place when forces of 1 g are experienced in any direction.

Instruments must tolerate vibrations produced by external systems and must control the transmission of internally generated vibration as described in section 8.1.2.3.

6.1.1.4 Audible Noise

Unless otherwise specified or accepted the Cassegrain ADC and any outboard electronics or computers should not at any time produce audible noise in excess of 50 dBA at a distance of 1 meter. This is a standard office operating environment maximum noise level. This includes

intermittent noises from pumps and variable speed cooling fans. Audible warning signals for emergency or fault conditions are exempt from this requirement, but they must be provided with a silence after delay feature or a manual silencing switch.

6.1.2 Operational Performance Requirements

There are no overall system operational performance requirements.

6.2 Implementation Requirements

6.2.1 Feature Implementation Requirements

It is anticipated that the Cassegrain ADC will be implemented in two components, an optics module and an electronics module. The optics module will be designed to cover the full 20 arc minute field of view at the Keck I Cassegrain position when located in front of the nominal Cassegrain focal position. The distance between the optics module aperture(s) and the Cassegrain focal position of course determines the exact minimum diameter of the clear aperture through the optics module.

The basic design of the optics module will utilize two prisms of opposite orientation that are adjustable in separation. During operation this separation is adjusted as a function of zenith distance to compensate for the changing atmospheric dispersion due to the change in airmass.

The optics module should be an independent module installed in the tertiary tower of Keck I as shown in Figure 1.

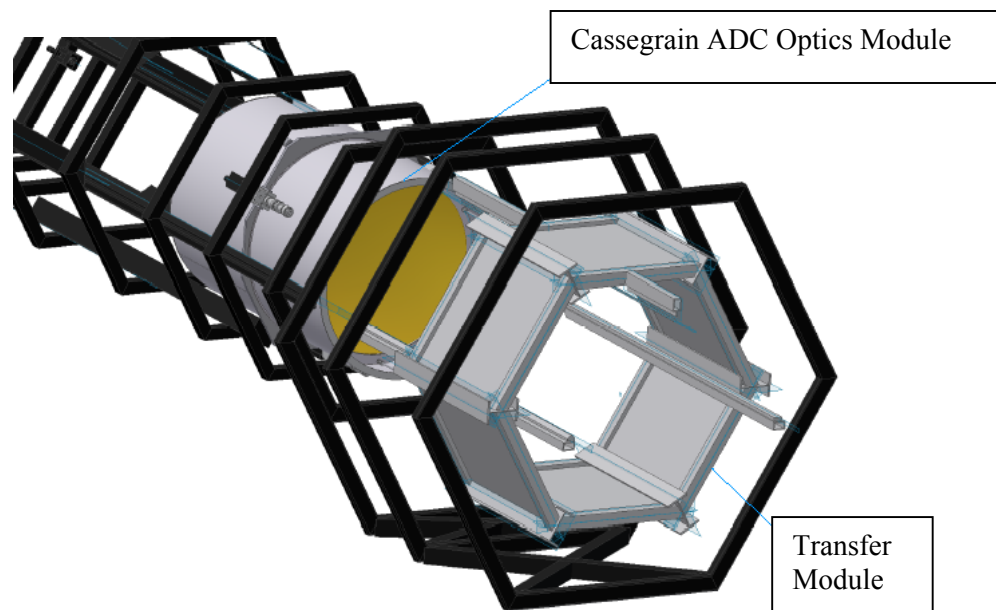


Figure 1: Cassegrain ADC Configuration

The existing Keck I transfer module will be used to install and remove the optics module from the telescope. A jack stand will be provided at the back of the transfer module parking position to support and store the optics module when the transfer module is in use for other purposes, such as serving as a counterweight for the tertiary mirror.

Three defining points must be added to the tertiary mirror tower, and some analysis is required to determine the optimum locations for these in terms of the structure of the tertiary mirror tower. The radial location of the defining points will also have to be planned so that they are compatible with the forward Cassegrain module and the tertiary mirror modules. The determination of the mounting points for the ADC will be part of the work performed by CARA during the preliminary design phase.

The Cassegrain ADC will have a single axis of motion control that will be implemented using a computer based control system in a small actively cooled electronics enclosure located remotely from the ADC. The components of the ADC and their interconnections will generally be as shown in Figure 2. Note that glycol cooling details are not shown.

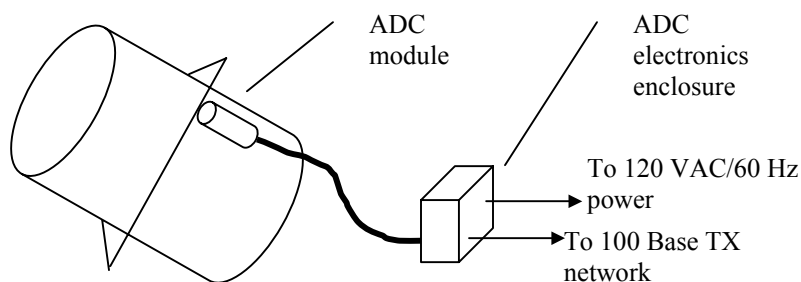


Figure 2: ADC Components and Interconnections

In the descriptions that follow and in all other project documentation it is recommended that the following names and definitions for the components of the ADC be adopted:

Cassegrain ADC: the complete system including the ADC module, electronics enclosure, target computer and software.

ADC module: the telescope mounted optics module of the Cassegrain ADC.

ADC jack stand: a fixture at RT4 on Keck I that holds the ADC module when the transfer module is required for other purposes.

ADC electronics enclosure: a shielded, glycol cooled NEMA 4 enclosure containing at least the motion control system for the ADC.

ADC target computer: the computer that runs the ADC target software. This may be part of the ADC electronics enclosure or it may be a separate computer.

ADC target software: the ADC target software is an application that runs on the ADC target computer. This software implements the ADC keyword service, implements the ADC motion control system and acts as a DCS client to communicate with the DCS and DCSGUI.

ADC host computer: the computer that runs the user interface for the ADC, probably the K1server computer, which is a Sun workstation, running Solaris.

ADC host software: a DCSGUI control row, running on the ADC host computer (K1server). The ADC host software communicates with the DCS service to control and monitor the ADC.

6.2.2 Common Practice Implementation Requirements

None.

6.2.3 Standards Implementation Requirements

6.2.3.1 Shipping Containers

All shipping containers must be designed to provide adequate protection for the equipment during transport. Unless otherwise specified single use containers suitable for the size, weight and shipment method to be employed are acceptable. For guidance in the design of suitable containers consult Air Transport Association (ATA) Spec 300, 2001.1 edition, "Specification for Packaging of Airline Supplies".

6.2.4 Regulatory Implementation Requirements

The Cassegrain ADC shall comply in all respects with the applicable requirements of the Occupational Safety and Health Administration (OSHA) as established by Code of Federal Regulations (CFR) 29 Part 1910 "Occupational Safety And Health Standards", particularly subpart O, section 1910.212 and subpart S sections 1910.302 through 1910.304.

The requirements of Subpart O, section 1910.212 that may apply to the Cassegrain ADC are summarized as follows:

1. Machine guarding must be provided to protect the operator and other employees from hazards such as those created by ingoing nip points or rotating parts.
2. Guards shall be affixed to the machine.
3. Revolving barrels and drums shall be guarded by an enclosure that is interlocked with the drive mechanism so that the barrel or drum cannot revolve unless the guard is in place.

The requirements of Subpart S, sections 1910.302 through 1910.304 may be summarized as follows:

1. Listed or labeled equipment shall be used or installed in accordance with any instructions included in the listing or labeling.
2. Conductors shall be spliced or joined with splicing devices suitable for the use or by brazing, welding, or soldering with a fusible metal or alloy. Soldered splices shall first be so spliced or joined as to be mechanically and electrically secure without solder and then soldered. All splices and joints and the free ends of conductors shall be covered with insulation equivalent to that of the conductors or with an insulating device suitable for the purpose.
3. Parts of electric equipment which in ordinary operation produce arcs, sparks, flames, or molten metal shall be enclosed or separated and isolated from all combustible material.
4. Electrical equipment may not be used unless the manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product may be identified is placed on the equipment. Other markings shall be provided giving voltage, current, wattage, or other ratings as necessary. The marking shall be of sufficient durability to withstand the environment involved.
5. Each disconnecting means for motors and appliances shall be legibly marked to indicate its purpose, unless located and arranged so the purpose is evident.
6. Live parts of electric equipment operating at 50 volts or more shall be guarded against accidental contact by approved cabinets or other forms of approved enclosures.
7. A conductor used as a grounded conductor shall be identifiable and distinguishable from all other conductors. A conductor used as an equipment grounding conductor shall be identifiable and distinguishable from all other conductors.
8. No grounded conductor may be attached to any terminal or lead so as to reverse designated polarity.
9. A grounding terminal or grounding-type device on a receptacle, cord connector, or attachment plug may not be used for purposes other than grounding.
10. Conductors and equipment shall be protected from overcurrent in accordance with their ability to safely conduct current.
11. Overcurrent devices may not interrupt the continuity of the grounded conductor unless all conductors of the circuit are opened simultaneously.
12. Overcurrent devices shall be readily accessible to each employee or authorized building management personnel. These overcurrent devices may not be located where they will be exposed neither to physical damage nor in the vicinity of easily ignitable material.
13. Fuses and circuit breakers shall be so located or shielded that employees will not be burned or otherwise injured by their operation due to arcing or suddenly moving parts.
14. Circuit breakers shall clearly indicate whether they are in the open (off) or closed (on) position.
15. The path to ground from circuits, equipment, and enclosures shall be permanent and continuous.
16. Metal enclosures for conductors shall be grounded.

17. Exposed, non-current-carrying metal parts of fixed equipment, which may become energized, shall be grounded.
18. Exposed non-current-carrying metal parts of cord and plug connected equipment, which may become energized, shall be grounded.
19. Non-current-carrying metal parts of fixed equipment, if required to be grounded, shall be grounded by an equipment grounding conductor, which is contained within the same raceway, cable, or cord, or runs with or encloses the circuit conductors. For DC circuits only, the equipment grounding conductor may be run separately from the circuit conductors.

For the purposes of the foregoing approved means acceptable to the authority enforcing the applicable subpart. The authority enforcing the applicable subpart is the Assistant Secretary of Labor for Occupational Safety and Health. The definition of “acceptable” indicates what is acceptable to the Assistant Secretary of Labor, and therefore approved within the meaning of the applicable subpart. Approved for the purpose means approved a specific purpose, environment, or application described in a particular standard requirement. Suitability of equipment or materials for a specific purpose, environment or application may be determined by a nationally recognized testing laboratory, inspection agency or other organization concerned with product evaluation as part of its listing and labeling program.

6.3 Design Requirements

6.3.1 Technological Design Requirements

6.3.1.1 Materials Suitability and Safety

Certain environmental conditions (low temperature and pressure) at the summit of Mauna Kea make certain materials unsuitable for use in instrument construction. Materials used in the construction, lubrication or packaging of instruments must not produce hazardous by-products such as gases or other contaminants under the conditions of operation and use at the summit of Mauna Kea. No mercury may be used in any component of the Cassegrain ADC.

Table 4 lists specific materials that should not be used.

Table 4: Materials not Suitable for use in Equipment at the Summit of Mauna Kea

Material Type	Common Name	Reason(s) for Unsuitability
Adhesive, insulator	RTV silicone rubber ¹	Outgases during curing
Adhesive	Cyanoacrylates	Outgases during curing, subject to hydrolytic degradation
Conductor	Mercury ²	Reactive, salts formed are toxic
Insulator	Acrylic	Outgases, hygroscopic, brittle at low temperatures
Plated finish	Cadmium ²	Outgases, reactive, hazardous
Insulator	Cellulose Acetate Butyrate	Hygroscopic
Insulator	Glass-Reinforced Extruded Nylon	Outgases, hygroscopic
Insulator	Kapton	Subject to hydrolytic degradation
Insulator	Neoprene	Outgases
Insulator	Nylon	Outgases
Insulator	Phenolic ³	Hygroscopic
Insulator	Polychlorinated Biphenyls ²	Combustion produces highly toxic gases

Notes:

1. Neutral cure RTV silicones may be acceptable provided that the cured silicone and the surrounding area are cleaned after assembly.
2. Use is or soon will be highly regulated.
3. Electrical grade phenolic is not hygroscopic.

6.3.2 Regulatory Design Requirements

None.

6.3.3 Standards Related Design Requirements

None.

6.3.4 Integration Related Design Requirements

None.

7 OPTICAL REQUIREMENTS

7.1 Performance Requirements

7.1.1 Parametric Performance Requirements

7.1.1.1 Typical Parameters

The Cassegrain ADC should provide the optical performance described in Table 5.

Table 5: Cassegrain ADC Typical Performance Requirements

<i>Parameter</i>	<i>Min.</i>	<i>Typ.</i>	<i>Max.</i>	<i>Units</i>	<i>Notes</i>
FOV	20	-	-	arcmin	1
Working zenith distance	0	-	60	degrees	2
Nominal design wavelength range	0.31	-	1.1	μm	3

Notes:

1. This is the diameter of the unvignetted field of view at the focal position for a Cassegrain instrument installed after the ADC in the tertiary tower of Keck I.
2. This is the range of telescope zenith distances for which correction of dispersion is desired.
3. The “nominal design wavelength range” defines the range of optical wavelengths for which the ADC design will be evaluated.

7.1.1.2 Goal Parameters

The optical performance requirements shown in Table 6 are desired as design goals.

Table 6: Cassegrain ADC Goal Performance Requirements

<i>Parameter</i>	<i>Goal</i>	<i>Min.</i>	<i>Max.</i>	<i>Units</i>	<i>Notes</i>
Dispersion correction	< 0.05	-	0.1	arcsec, RMS	1,2
Peak dispersion	< 0.06	-	0.2	arcsec	1,3
Correction non-uniformity	<0.1	-	1	%, peak	4
Transmission	>95	90	-	%	5
Transmission non-uniformity	<0.05	-	0.1	%, peak	4
Effect on image quality	<0.5	-	0.6	FWHM, arcsec	6
Image quality non-uniformity	<10		40	%, peak	4
Ghost images	<10 ⁻⁵	-	<10 ⁻⁴	-	7
Differential Distortion	<0.08	-	<0.1	arcsec, RMS	8
Differential Rotation	<0.002	-	< 0.05	degrees	

Notes:

1. Dispersion is displacement of the image at a given wavelength with a wavelength of 0.45 μm as the reference; dispersions can therefore be positive or negative with respect to this wavelength.
2. For a zenith distance of 60 degrees over the full working wavelength range with no specific limit on the maximum distance between the prisms.
3. Peak value at any wavelength in the working wavelength range for a zenith distance of 60 degrees with no specific limit on the maximum distance between the prisms.
4. This is the peak variation over the full ADC FOV (20 arcmin).
5. This is the transmission over the correction wavelength range.
6. All zenith distances, all prism separations, all field points.
7. Intensity of the ghost image compared to the parent image at minimum prism separation.
8. In X and Y across the ADC FOV.

7.1.2 Operational Performance Requirements

The ADC module will be suitable for mounting in the tertiary mirror tower of the Keck I telescope prior to the focal position of a Cassegrain instrument on Keck I. At present the only Cassegrain instrument on Keck I is LRIS. LRIS is expected to work with the Cassegrain ADC without optical modifications. The ADC module should also be capable of operation with future Cassegrain instruments within the framework of reasonable assumptions about non-AO performance for the Keck I telescope and subject to the wavelength range established for operation of the ADC.

The ADC module should require only one adjustment during normal operation, which is to set the amount of dispersion correction as a function of zenith distance. Adjustments for optical alignment should be one time adjustments at commissioning of the ADC module on the telescope and should not require re-adjustment unless major repairs or modifications are made to the ADC module. These adjustments may be internal to the ADC module or external to the module provided that they are supplied as part of the module.

It is especially important that during routine installation and handling no alignment or other adjustments be required for the ADC module.

Table 7 summarizes the optical adjustments that should be provided.

Table 7: ADC Module Optical Adjustments

Adjustment	Description	Notes
Dispersion Correction	Adjusts dispersion correction as a function of zenith distance	Operational adjustment
Rotation	Adjusts the horizon line of the ADC relative to the true horizon	One time adjustment
Centering	Adjustment in X, Y to adjust the ADC FOV to be centered on the telescope Cassegrain position FOV	One time adjustment
Focus Position Offset	Adjustment in Z to place the ADC in the correct position with respect to the Cassegrain instrument focal position on the telescope	One time adjustment
Tilt	Adjustment in pitch and yaw to align the correction axis of the ADC with the optical axis of the telescope Cassegrain position	One time adjustment

7.2 Implementation Requirements

7.2.1 Feature Implementation Requirements

It is understood that the operation of the ADC will result in focus and pointing corrections being required during an observation when the ADC is tracking the telescope zenith angle. The design

of the ADC optics will be analyzed and the required corrections as a function of zenith angle will be identified. It will be the responsibility of CARA to modify the pointing model for use with the ADC to incorporate the required corrections.

It is also understood that it may be possible to develop a planning tool that will aid users in optimizing the performance of the Cassegrain ADC with respect to residual distortion, focus and pointing. However, it is the decision of CARA that such a tool will not be provided with the initial delivery of the Cassegrain ADC.

7.2.2 Common Practice Implementation Requirements

None.

7.2.3 Standards Implementation Requirements

None.

7.2.4 Regulatory Implementation Requirements

None.

7.3 Design Requirements

7.3.1 Technological Design Requirements

The range of zenith distances over which the ADC will provide a given amount of correction for atmospheric dispersion is directly related to the maximum separation distance between the prisms. The optical design of the ADC should take into account the image quality produced by the telescope and required by typical instruments. It should be noted that while the only Cassegrain instrument on Keck I is LRIS, it is also desirable that the design of the ADC accommodate the possibility of use with other instruments. In particular the image quality issues should be reviewed and the impact of any off-axis optimization for LRIS to the on-axis image quality should be explained and discussed with CARA.

Optical materials for the ADC should be chosen to maximize throughput and stability. The large size of the optics raises the possibility of sag or deformation, and the size and weight of the optics present challenges for the mounts and supporting structure. Optical materials and coatings should also be chosen for durability. The large optic size will increase the need for cleaning.

The ADC module should include baffling or barrel ridges on the inside of the optical tube as needed to ensure that stray light and internal reflections are prevented from reaching the input of the associated instrument. The interior should be finished in a manner that limits reflections from the sidewalls over the working wavelength range of 0.31 μm to 1.1 μm .

7.3.2 Regulatory Design Requirements

None

7.3.3 Standards Related Design Requirements

Drawings for optical components should conform to American National Standards Institute (ANSI) / American Society of Mechanical Engineers International (ASME) standard Y14.18M-1986 "Optical Parts (Engineering Drawings and Related Documentation Practices)".

7.3.4 Integration Related Design Requirements

The ADC should not vignette the field of view of the Keck I telescope at the Cassegrain position for an instrument at the nominal focal position. The ADC should not vignette the science field of the LRIS instrument at any rotation angle of LRIS when LRIS is in its normal operating position at the Cassegrain focal position of the Keck I telescope.

8 MECHANICAL REQUIREMENTS

8.1 Performance Requirements

8.1.1 Parametric Performance Requirements

The ADC module should weigh less than 550 kg.

The ADC electronics module should weigh less than 100 kg.

The ADC module mechanism for adjusting the separation of the prisms should provide the mechanical performance shown in Table 8.

Table 8: ADC Module Mechanical Performance Requirements

<i>Parameter</i>	<i>Min.</i>	<i>Typ.</i>	<i>Max.</i>	<i>Units</i>	<i>Notes</i>
Dispersion position repeatability	-	0.05	0.1	%	1
Dispersion position, absolute accuracy	-	0.1	0.25	%	1
Separation travel speed	-	1	0.8	°/s	2

Notes:

1. Percent of full scale
2. The travel time for a full slew of the telescope from horizon to zenith is 72 seconds at a speed of 0.8 °/s.

8.1.2 Operational Performance Requirements

8.1.2.1 Operating Temperature Range

The ADC module must operate properly over the full environmental temperature range and over the full elevation travel of the Keck I telescope as given in CARA drawing 110-10-07, revision C.

8.1.2.2 Impact and Shock

The ADC module will encounter shocks in various axes, primarily vertical during handling and horizontal during installation and removal from the tertiary mirror tower, of up to 20 g for up to 10 milliseconds duration. The adjustment and operation of the ADC should not be affected by shocks of these magnitudes and durations.

During normal telescope operation the drive system may impart shocks of up to 1 g in any direction and of varying duration. The adjustment and operation of the ADC should not be affected by shocks of these magnitudes and durations.

8.1.2.3 Vibration

The ADC module and ADC electronics module should be checked for vibration during normal operation (dispersion axis moving and stationary) using normally accepted methods for vibration testing. Vibration generated by the ADC module must not exceed vibration limits established by measurement of vibration at the Cassegrain position of the Keck I telescope during normal observing modes.

CARA will provide measurement data on the Cassegrain position of the Keck I telescope as soon as possible (September 29, 2003). This data will be used to assess the tolerance of the ADC module to telescope vibration and to establish a threshold for vibration generated by the ADC module. This is expected to be an iterative process.

8.2 Implementation Requirements

8.2.1 Feature Implementation Requirements

8.2.1.1 ADC Module

The Cassegrain ADC module should be constructed as a single unit for installation in the tertiary mirror tower of the Keck I telescope. A separate enclosure may be provided for electronics to control the ADC.

The ADC module envelope allowances are given in CARA drawing 1080-C1101, "Cassegrain ADC Mid-Cass envelope". The ADC module is compatible with installation in the tertiary mirror tower of the Keck I telescope prior to the focal position of a Cassegrain instrument, based on the dimensions for the tertiary mirror tower shown in Schwartz-Hautmont/TIW drawing 608-TT-00, revision B, sheets 1 – 17.

The ADC module should be compatible with the existing Keck I tertiary transfer module shown in TIW drawing 199-10-02, revision B, sheets 1 – 4.

The ADC electronics module envelope allowances are given in CARA drawing 1080-C1101.

8.2.1.2 Defining Points

The mounting of the ADC in the tertiary mirror tower should be via three defining points that provide performance similar to that provided by the defining points for the forward Cassegrain module and the tertiary mirror module.

The defining points should use air motors and related components compatible with the other defining points on the Keck I telescope. All required valves, regulators and interconnections should be provided with and be part of the ADC module.

8.2.1.3 ADC Module Structure

The ADC module must incorporate structural and mounting components that will maintain its integrity and ensure secure mounting during an earthquake as required by seismic standards for a zone 4 earthquake zone. The ADC electronics module must incorporate mounting provisions that ensure secure mounting during an earthquake as required by seismic standards for a zone 4 earthquake zone (see section 8.2.3 below).

The ADC module must provide a structure that maintains the position of the ADC optical elements so that the required optical performance is maintained over the full range of ADC working angles (zenith distances of 0 to 60 degrees) in the Keck I telescope Cassegrain position.

8.2.1.4 Prism Separation Mechanism

The ADC should have only one motion control axis to adjust the separation of the two prisms in the ADC optical path. These prisms should move equal distances from a common center so that the center of gravity for the ADC remains constant.

The ADC module mechanism for adjusting the separation of the prisms must maintain the center and tilt of the prisms to the value required to meet the optical performance requirements for image quality and uniformity.

8.2.1.5 Optical Mounts

The optical mounts in the ADC module should protect the prisms from mechanical shock and thermal distortion while also providing a mount that maintains the center and tilt of the prisms to the value required to meet the optical performance requirements for image quality and uniformity.

The optical mount materials and nearby components must be compatible with the cleaning method specified for the optics including any solvents that may be required for cleaning.

8.2.1.6 Access and Covers

Components requiring routine service or maintenance should be accessible by removing a single cover secured by no more than 8 fasteners.

The ADC module should be provided with removable covers for the front and rear of the module that completely protect the exposed optical surfaces from dust and from damage due glancing or direct horizontal blows or impacts while in the storage position or moving from storage to the telescope. A typical scenario for the calculation of forces involved is as follows:

A person moving at a normal walking pace (~ 1.3 m/s) carrying a 3 meter length of schedule 80 1-1/4" pipe (~ 14 kg) walks directly towards one end of the ADC module. The pipe strikes the cover. The person carrying the pipe does not loose his grip on the pipe and for the purposes of this analysis the Δv in the collision is -1.3 m/s.

The cover should be able to resist the resulting force without damage to the optics, optical mounts or the prism separation mechanism.

8.2.1.7 Handling

The ADC module should incorporate handling provisions that allow it to be transferred to and from the tertiary mirror tower using the existing Keck I transfer module. The ADC will normally be stored at RT4 in the transfer module. Because the transfer module is also required to install and remove the tertiary mirror module, the ADC module must be provided with a means to remove it from the transfer module and hold it at the RT4 storage position.

8.2.1.8 Glycol Cooling

The temperature rise of coolant through the ADC module should be less than 3 °C. The heat load should be less than 1800 watts.

The temperature rise of coolant through the ADC electronics module should be less than 3 °C. The heat load should be less than 1800 watts.

All glycol cooling should be plumbed with braided stainless steel hose and stainless steel fittings. Custom manifolds should be used rather than arrangements of "T" fittings and hose. Permanent connections should be made with JIC 37° flare compression fittings or SAE straight thread O-ring fittings. Teflon tape should not be used to seal threaded connections.

Removable connections should be made with 1/2" Parker Hannifin series FS quick disconnect fittings. The instrument supply coupler is male and the return coupler is female.

Where required King Instrument Company flow meters and needle valves are preferred for flow metering and control applications. Where variable gravity orientations are encountered a spring loaded variable area flow meter, such as the in-line flow meters manufactured by the Hedland Division of Racine Federated Inc. should be employed. The Hedland T303 stainless steel models are preferred.

All glycol cooling systems should be provided with a flow switch, Proteus Industries Inc. type 100B110 is preferred, to generate a loss of coolant alarm. This flow switch should interrupt power to the affected system unless a separate over-temperature detection system is provided to remove power from the affected system.

8.2.2 Common Practices Implementation Requirements

8.2.2.1 Fit and Finish

All steel or iron components of the ADC should be plated or painted to prevent rust. This includes fasteners and rivets. Welds not ground to the surface or joint profile should be of dress quality. All welds and castings will be stress relieved prior to painting.

Machined components should be free of tool marks, scratches and material flaws such as inclusions or voids.

Unless otherwise specified all external enclosure and exposed structural elements should be finished in Akzo Nobel 463-3-8 Flat Black epoxy paint applied in accord with the manufacturer's instructions.

8.2.2.2 Continuity of Shielding and Grounding

Dissimilar metals in contact under conditions where electrolytic corrosion may occur will be isolated by a dielectric finish or insulating spacers. Notwithstanding this requirement all components of enclosures that are required to provide protective grounding or EMI shielding must be electrically bonded at multiple points by threaded fasteners, finger stock, or a continuous conductive elastomeric gasket. If grounding straps are used they must be tin plated copper braids not less than 6 mm in width. Anodized aluminum parts must be free of anodizing at the points where electrical contact is required. Painted metal parts must be free of paint at the points where electrical contact is required.

8.2.2.3 Corrosion resistance

All metal components of the ADC module and ADC electronics module should be finished to prevent corrosion in the Mauna Kea summit environment over a normal 10 year lifetime of operation including handling, maintenance and repair.

All removable fasteners must be plated or treated to prevent corrosion.

Internal components may be plated or paint finished. A contractor who can show conformance to the requirements of MIL-STD-171E "Finishing of Metal and Wood Surfaces" or equivalent should perform any required painting, plating or anodizing.

8.2.2.4 Fasteners

Press fit studs or threaded inserts must be installed in the correct material (i.e. no aluminum inserts in steel) according to the manufacturer's instructions. Samples of such fasteners installed in the actual material should be obtained and subjected to pull out tests prior to use in an actual design.

Self tapping screws should not be used for removable covers or to secure components that will have to be removed for repair or replacement.

Fasteners should have either Phillips or hex socket heads. Hex socket button head fasteners should not be used except where space or specific function requires them. Undercut machine screws should not be used except in special cases where there is no other appropriate design alternative.

Prevailing torque locknuts or lock washers should of course be used and are preferred to thread locking compounds. Soft insert locknuts should have Kel-F or Vespel inserts, and should only be used where subsequent removal is not anticipated.

8.2.2.5 Lubricants

Lubricants must be suited for the low temperature environment encountered at the summit. The base oil in a grease lubricant should have a high viscosity index, a low pour point temperature and a low viscosity at the average operating temperature (based on a 0° C ambient). Greases using synthetic base oils such as Fluoroether or Silicone are preferred.

8.2.2.6 Lubricated Components

Exposed lubricated components such as gear trains or lead screws should be enclosed in a shroud or boot to prevent the collection of dust and dirt and also to prevent accidental contact that may result in the transfer of the lubricant to other surfaces.

8.2.3 Standards Implementation Requirements

The ADC module and the ADC electronics enclosure should meet the zone 4 earthquake survival requirements of Telcordia Standard GR-63-CORE, "NEBS™ Requirements". Additional information on these requirements will be supplied.

8.2.4 Regulatory Implementation Requirements

None.

8.3 Design Requirements

8.3.1 Technological Design Requirements

8.3.1.1 Drive Couplings

Shaft couplings for motors, encoders and other drive components should be pinned or locked so that the shaft and coupling cannot slip. Separable couplings should be used whenever possible for motors to facilitate motor replacement.

8.3.1.2 Component Ratings

Structural elements and fasteners in tension should be selected for a safety margin of 10 where failure of the structural element or fastener could cause injury to personnel or equipment. All other structures and fasteners should be designed with a safety factor of at least 5.

All mechanical moving parts should be selected for a 10 year operating lifetime in the Mauna Kea summit environment.

8.3.1.3 Enclosure

Enclosures for electrical and electronic components must provide a continuous shield to prevent the entry or emission of electromagnetic energy. No openings greater than 3 mm in diameter or 3 mm in width and 15 cm in length should be permitted on the exterior of any enclosure for electrical and electronic components. This includes gaps due to access covers, hinges or other enclosure components. Removable covers that do not make continuous contact with the enclosure must be provided with a fastener every 15 cm or with conductive gaskets or finger stock as described in section 8.2.2.2.

8.3.2 Regulatory Design Requirements

None.

8.3.3 Standards Related Design Requirements

Enclosures for electrical/electronic components and wiring should conform to the requirements of the Underwriters Laboratories Inc. (UL) Standard for Safety 508 "Industrial Control Equipment". See section 9.2.3 for a summary of the relevant requirements.

The ADC electronics module enclosure should be a commercially available NEMA type 4 or better enclosure. The requirements of a NEMA type 4 enclosure are given in National Electric Manufacturers Association (NEMA) standards publication 250-1997, "Enclosures for Electrical Equipment (1000 Volts Maximum)".

Mechanical drawings should conform to ANSI standard Y14.5M-1982 (R1988) "Dimensioning and Tolerancing" and ASME standard Y14.100M-2000-2001 "Engineering Drawing Practices".

8.3.4 Integration Related Design Requirements

8.3.4.1 Defining Points

See section 8.2.1.2.

8.3.4.2 Handling

See section 8.2.1.6.

9 ELECTRONIC/ELECTRICAL REQUIREMENTS

9.1 Performance Requirements

9.1.1 Parametric Performance Requirements

9.1.1.1 Power Dissipation

The ADC module must not radiate more than 50 watts of heat into the telescope ambient environment. All heat generated by the ADC module in excess of this amount must be carried away by a glycol based cooling system. A glycol supply and return connection will be provided as part of the telescope facilities. The ADC module design must specify the flow rate required to remove the additional heat generated by the ADC module.

The ADC electronics enclosure must not radiate more than 50 watts of heat into the telescope ambient environment. All heat generated by the ADC electronics enclosure in excess of this amount must be carried away by a glycol based cooling system. A glycol supply and return connection will be provided as part of the telescope facilities. The ADC electronics enclosure design must specify the flow rate required to remove the additional heat generated by the ADC electronics enclosure.

9.1.1.2 Compatibility

The ADC module and ADC electronics must be electrically compatible with the telescope environment.

9.1.1.3 Temperature and Humidity

The complete ADC module and ADC electronics system should be designed for operation in an ambient temperature range of $-10\text{ }^{\circ}\text{C}$ to $30\text{ }^{\circ}\text{C}$ and a relative humidity of 95%, non-condensing.

9.1.1.4 Power Supply

9.1.1.4.1 ADC Electronics Module

The ADC electronics module will operate from 120 VAC, 60 Hz power and will require less than 12 amperes of current at the rated voltage. The ADC module and ADC electronics module will operate normally when input power is supplied to the ADC electronics module over a voltage range of 108 VAC to 132 VAC and a frequency range of 57 to 63 Hz.

9.1.1.4.2 ADC Module

The ADC module will be supplied with power and control signals by the ADC electronics module. All power and control signals will be low voltage DC defined as not more than 60 volts DC. It is

preferred that when ever possible the current voltage product for any of these signals be not more than 100 volt-amperes.

A 100 volt-ampere limitation is consistent with the definition for class 2 DC, not inherently limited power sources, as given in the National Electric Code, 2002 edition, published by the National Fire Protection Association (NFPA).

9.1.1.5 Cable and Wire Ratings

All wire and cable will be rated for an ambient temperature range of -30°C to 100°C .

9.1.2 Operational Performance Requirements

None.

9.2 Implementation Requirements

9.2.1 Feature Implementation Requirements

The ADC electronics module should incorporate sufficient functionality that all local control and safety features required by the ADC module can be operated without a networked data communications connection or remote computer connection. The electronics module should be equipped with a local terminal connection (RS-232) for test and diagnostic purposes.

If the “ADC target computer” is a PC type computer located in the ADC electronics module it should be an industrial form factor (Compact PCI preferred) diskless computer that runs a CARA approved version of the Linux operating system. The computer should be equipped with a local terminal connection (RS-232) or monitor/mouse and keyboard connections for test and diagnostic purposes.

If a remote computer is used to control the electronics module (the “ADC target computer”) the computer should be a Sun workstation or server running a CARA approved version of the Solaris operating system.

The ADC electronics module should be equipped with a local control switch to defeat remote control during service and maintenance operations. The ADC module should be equipped with a motion stop switch to prevent motion of the mechanism during emergencies, service and maintenance.

All removable plug-in printed circuit boards should be equipped with positive retention features. Extractors should be provided for all circuit boards where high insertion and withdrawal forces are expected.

9.2.2 Common Practices Implementation Requirements

The ADC module and the ADC electronics module should not produce stray light from LED or lamp indicators, optical switches or optical shaft encoders.

LED or lamp indicators should not be used on the exterior of the ADC module or the ADC electronics module. Any indicators required for service should be concealed behind a cover or access door. Optical switches or shaft encoders must be optically baffled or enclosed so that no stray visible or infrared light is emitted into the telescope optical path or dome environment.

All parts of the ADC module visible from within the ADC light path and all parts of the exterior of the ADC module, and all parts of the exterior of the ADC electronics module should be examined with a night vision device with a light gain of at least 50,000¹. A person known to have normal photopic and scotopic visual sensitivity should conduct the examination under dark adapted conditions.

9.2.3 Standards Implementation Requirements

9.2.3.1 Electrical Safety

The design and construction of the ADC module wiring and the ADC electronics module should conform to the requirements of UL Standard for Safety 508 "Industrial Control Equipment". The relevant portions of UL 508 may be summarized as follows:

1. Specific metal gauge requirements are given in tables 6.1 (page 22) and 6.2 (page 23).
2. Specific details for doors and covers are given in section 6.4 (pages 24 through 27).
3. Specific requirements for the design of ventilation openings are given in section 6.9 (pages 31 through 33).
4. Specific details for controlling the accessibility of live parts are given in section 6.17 (pages 36 through 37 and figures on pages 38 and 39).
5. Requirements for insulating material that directly supports live parts are given in section 15 (pages 42B through 43). This includes printed circuit boards.
6. Specific requirements for the protection of control circuits are given in section 18.2 (pages 47 through 48B).
7. Specific requirements for internal wiring are given in section 21 (pages 50 through 56A).
8. Section 34 (page 68) gives specific requirements for the separation of circuits.
9. Section 35 (page 68A) gives specific requirements for optical isolators.
10. Specific details for required electrical spacings are given in section 36 (pages 68A through 73).
11. Specific details for grounding are given in section 40 (pages 79 through 82).
12. Table 43.1 (pages 84C through 84E and explanations on pages 84E and 84F) indicates the maximum permissible temperature rises for specific materials and components.

¹ This is a typical specification for generation III night vision monoculars such as the ITT 160 Night Mariner.

13. Table 43.2 (page 86) indicates the ampacity of various insulated conductors.
14. Section 49 (pages 99 through 100A) gives the requirements for dielectric voltage-withstand testing.
15. Section 62 (pages 128B and 128C) gives specific requirements for device ratings.
16. Section 63 (pages 128E through 133) gives specific requirements for markings. These are summarized in table 67.1 (pages 134A through 136B).
17. Additional requirements for programmable controllers are given in sections 177 through 193 (pages 196B through 201)

The design and construction of the ADC module wiring and the ADC electronics module should conform to the requirements of the National Electric Code. The applicable local electric code is the Hawaii County Code 1983, 1995 Edition. This code adopts the National Electric Code in its entirety and does not place any additional special requirements on the locations where the Cassegrain ADC will be installed or operated. The requirements given in section 9.2.4 are consistent with the applicable portions of the National Electric Code.

9.2.3.2 Electromagnetic Compatibility

Standards exist that specify the test conditions and limits for electromagnetic emissions and electromagnetic immunity. They do not give information on how to achieve compliance. In the absence of such information CARA believes that a satisfactory level of electromagnetic emission and immunity compliance can be achieved by following the requirements given in sections 8.2.2.2, 8.3.1.3 and 9.3.1.3.3 of this document.

For information on the permitted level of emissions and the required level of immunity the following standards may be consulted:

1. The conducted and radiated emissions limits for unintentional radiators are specified in Title 47 CFR Part 15, sections 15.107 and 15.109 for class B devices.
2. Electromagnetic immunity requirements are given in the Council of the European Communities Directive EMC 89/336/EEC, and the reference standard of the European Committee for Electrotechnical Standardization (CENELEC) EN 50082-1:1997 "Electromagnetic compatibility-Generic immunity standard-Part 1: Residential, commercial and light industry" published in the Official Journal of the European Community on March 1, 1998.

9.2.4 Regulatory Implementation Requirements

9.2.4.1 AC Line Connections

All AC line connected parts shall be fully enclosed so as to prevent accidental contact with live parts. All AC line connections shall utilize UL listed connectors and cables.

All power input connectors shall have an adjacent label indicating the voltage, frequency and current rating for which the equipment is designed.

9.2.4.2 Covers

Removable covers that permit access to circuits with voltages in excess of 36 volts RMS AC or 30 volts DC shall be marked with a warning label.

Removable covers that permit access to circuits of less than 36 volts RMS AC or 30 volts DC that are capable of fault currents in excess of 2 amperes shall be marked with a warning label.

9.2.4.3 Wiring

Internal wiring of 120 VAC circuits shall use UL type AWM stranded wire with an insulation thickness of at least 0.8 mm.

The insulation color of internal wiring and the conductors of multi-conductor cable for AC power wiring shall conform to the requirements of the National Electric Code. The insulation of neutral (grounded) conductors shall be white or gray in color. Neutral conductors shall be the same size as phase conductors except in cases where two or more phases are provided and harmonic currents are expected, in which case the neutral conductors shall be 125% of the size of the phase conductors.

The insulation of grounding conductors (protective or earth ground) shall be green or green with a yellow stripe.

Grounding conductors shall be the same size as the phase conductors.

Phase, neutral and ground conductors shall be sized using table 43.2 of UL 508.

9.2.4.4 Overcurrent Protection

A fuse or circuit breaker shall internally protect all AC line connected equipment. When a time delay fuse or time delay breaker is used the rating of the breaker shall not exceed 150% of the continuous full load current of the connected load. Where a non-time delay fuse is used the rating of the fuse shall not exceed 150% of the continuous full load current of the connected load. Where an instantaneous trip breaker is used the rating of the breaker shall not exceed 250% of the continuous full load current of the connected load.

The panel where the fuse or circuit breaker is located shall be clearly marked with the type and rating of the protective device.

9.2.4.5 Grounding and Shielding

The enclosures of AC line connected components shall be grounded in conformance with the requirements of the National Electric Code and any local codes. Grounding conductors shall be continuous and bonded to the enclosure in at least one point. The grounding point shall be specifically provided for the purpose and shall not be a screw or nut used for mounting components or covers. Any paint or surface treatment that acts as an insulator shall be removed in order to ensure a good electrical contact for the ground connection.

All components capable of generating electromagnetic emissions in excess of the limits established in the standards referenced in 9.2.3.2 above will be shielded and the shielding grounded to limit electromagnetic emissions to the levels allowed by the standards referenced in 9.2.3.2. All components susceptible to externally generated electromagnetic emissions in excess of the limits established in the standards referenced in 9.2.3.2 above will be shielded and the shielding grounded to protect those components from unintended operation due to external electromagnetic emissions of the levels established in the standards referenced in 9.2.3.2.

9.2.4.6 Terminations

Crimp terminals and compression screw terminals shall not be used to terminate more than the number of conductors specifically approved for the terminal. All crimp terminals and screw terminals used for AC line connected wiring must be UL recognized components. All crimp terminations shall be performed using the manufacturer's tooling in accord with the manufacturer's instructions.

9.2.4.7 Altitude Derating

The voltage ratings of relays, switches and insulated cables must be reduced to 80% of their rated value due to the altitude at the summit of Mauna Kea. Electrical spacings must also be increased by a factor of 1.25 to compensate for the increased altitude.

The normal dielectric withstand test specification for UL approved or listed components for use in AC line connected equipment operating from 120/240 VAC is 2500 VAC/60 Hz for one minute. Voltage ratings for all components should be checked for safety margin with respect to this rating using the following equation:

$$VI = \frac{2 * V + 1000}{AF}$$

where :

VI is the voltage isolation required for the altitude

AF is the altitude factor of 0.8 for 15,000 feet

V is the sea level rated working voltage

The resulting value for VI must be less than the dielectric withstand test specification voltage (2500 VAC) or a dielectric withstand test at altitude must be performed to ensure that the system is safe for the intended application.

9.3 Design Requirements

9.3.1 Technological Design Requirements

9.3.1.1 Motion Controller

The preferred motion controller is an appropriate Galil DMC series motion controller.

9.3.1.2 Power Ratings

All power dissipating components to be cooled by free air convection must be derated to 80% of their sea level absolute maximum average power dissipation ratings.

9.3.1.3 Wiring and Interconnections

9.3.1.3.1 Connector and Cable Mounting

Cable and wiring strain relieves should be designed so that strain relief and wiring integrity is not compromised by opening access doors or removing service access covers.

Connectors should not be mounted on service access covers or on access doors.

9.3.1.3.2 Cable and Wire Routing

Cables and wiring must be routed so that they do not interfere with the optical path of the instrument. Cables and wiring must be routed so that full travel of moving or adjustable parts is not affected and does not place a strain on the mounting or connections of any cables or wiring. Service loops should be provided when necessary, but all cables should be routed neatly and secured at regular intervals with wire ties or lacing cord.

9.3.1.3.3 Interconnections

External interconnections of low voltage AC and DC circuits should be shielded whenever there is a reasonable possibility that those interconnections will be subject to electromagnetic interference or unwanted coupling.

Cable shields should be terminated to the connector housings and not via a wire to a connector pin. Where it may be necessary to isolate shields due to common mode noise problems, cable shield terminations should be made to at one end of the cable only, with the end selected for termination being the one that is closest to the point in the system where the zero signal reference potential is

grounded. This is normally the location of the terminating load resistance for signal inputs and the location of the signal source for outputs.

Cable shields should be electrically continuous with the connector housing, and CARA prefers that no ground pigtailed or other wire connections separate from the connector housing be used. In cases where the design requires different practices those design requirements should be discussed with CARA.

All connectors should include pre-grounding pins that make circuit common connections (DC reference or AC protective ground) before all other connections during connector insertion and break circuit common connections (DC reference or AC protective ground) after all other connections during connector removal.

9.3.1.3.4 Data communications – connectors & formats

Data communications between the ADC electronics module (motion controller or motion controller and target computer), ADC target computer (if not part of the electronics module) and the ADC host computer will be via a 100-base TX network conforming to the Institute of Electrical and Electronics Engineers (IEEE) Standard 802.3U revision 95 “Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method & Physical Layer Specifications: Mac Parameters, Physical Layer, Medium Attachment Units and Repeater for 100 Mb/S Operation (Version 5.0)”.

Data connections to the ADC electronics module should be via a panel mounted 8 pin female connector equivalent in performance to connectors that conform to military specification MIL-C-38999 series IV.

9.3.2 Regulatory Design Requirements

See section 9.2.4.

9.3.3 Standards Related Design Requirements

Connectors used for low voltage AC and DC circuits should be types equivalent in performance to connectors that conform to military specification MIL-C-38999 series IV.

9.3.4 Integration Related Design Requirements

None.

10 SAFETY REQUIREMENTS

10.1 Performance Requirements

10.1.1 Parametric Performance Requirements

None.

10.1.2 Operational Performance Requirements

The normal operation of the Cassegrain ADC system must not produce any safety hazard to personnel or equipment. Interlocks, labeling and procedures must be provided to ensure the safety of personnel and equipment during maintenance and repair.

As part of the processes for design and pre-shipment reviews the safety of the system will be reviewed. In general it is expected that conformance to the requirements of this document and the referenced regulatory standards will ensure a safe system. However, additional evaluation of the safety of the system may be required in a specific safety review.

10.2 Implementation Requirements

10.2.1 Feature Implementation Requirements

10.2.1.1 Local Control

The ADC electronics module should be equipped with a local control switch to defeat remote control during service and maintenance operations. The ADC module should be equipped with a motion stop switch to prevent motion of the mechanism during emergencies, service and maintenance.

10.2.1.2 Mechanical

All areas of the ADC module where exposed moving parts can create a pinch hazard should be clearly marked with a hazard warning label or equipped with shrouds to prevent accidental contact.

10.2.1.3 Electrical

Removable panels that expose voltages in excess of 230 VAC/60 Hz or 500 VDC should be equipped with defeatable interlock switches that remove all voltages in excess of 36 volts AC or DC from all exposed connections and terminals.

See section 9.2.4 for additional electrical safety requirements.

10.2.2 Common Practice Implementation Requirements

None.

10.2.3 Standards Implementation Requirements

None.

10.2.4 Regulatory Implementation Requirements

See sections 6.2.4 and sections 9.2.3.

10.3 Design Requirements

10.3.1 Technological Design Requirements

No part of the ADC module mechanism should move when AC mains power is applied to or removed from the ADC electronics module. The ADC motion control hardware should inhibit all motion during a power on/reset.

The ADC motion control system should be designed so that loss of the encoder or disconnection of the motor cannot result in a “wind up” of the servo position command signal. Software features should be implemented to inhibit motion when the position error measured by the servo controller exceeds the smallest reasonable margin that reflects all of the expected operating conditions.

Limit switches should be closed when not actuated (N.C. contacts). Motion control software should be designed so that a disconnected limit switch will appear to be active, inhibiting further motion towards that limit. Motion control software should also be designed so that movement away from an active limit switch is restricted to a reasonable distance past the limit switch actuation point after which motion is stopped and an error indicated due to the apparent failure of the limit switch to open.

Position encoders should include a status loop through the connections to the encoder so that in the event of loss of the encoder connection (or intentional disconnection) all motion on the associated axis is inhibited.

10.3.2 Regulatory Design Requirements

As indicated in the sections for overall, mechanical and electrical requirements the design of the Cassegrain ADC must conform to all applicable regulatory requirements.

10.3.3 Standards Related Design Requirements

None.

10.3.4 Integration Related Design Requirements

None.

11 SOFTWARE REQUIREMENTS

11.1 Performance Requirements

11.1.1 Parametric Performance Requirements

During an exposure for the associated instrument (LRIS) the Cassegrain ADC target software in tracking mode should follow the telescope zenith distance so as to maintain the effective dispersion correction within 1% of the ideal value for all zenith distances. This translates to a worst case zenith distance error in the ADC target software's current zenith distance of 0.1 degrees (near 60 degrees zenith distance and a wavelength of 1.1 μm).

The repeatability of the Cassegrain ADC module motion control system should provide repeatable dispersion error correction settings within 0.1% of full scale or consistent with the position tolerances achieved by the mechanical mounting and motion control system whichever results in the least error.

11.1.2 Operational Performance Requirements

The Cassegrain ADC target software should gracefully recover from the interruption of TCP/IP network connections at any time without requiring a hardware or software reset. This disconnection may occur due to physical interruption of the network connection, or the power cycling or hardware reset/reboot of the device at the other end of the network connection.

The software should implement reasonable timeouts and handle all TCP/IP network errors so that recovery from a network fault is as automatic as possible. Depending on the hardware (see section 9.2.1) there may be two TCP/IP network connections, one from the motion controller to the target computer, and one from the target computer to the host computer.

The execution speed and command latency of the target software should be consistent with the needs of the intended application.

11.1.2.1 Software Architecture

The Cassegrain ADC software will consist of the components shown in figure 3.

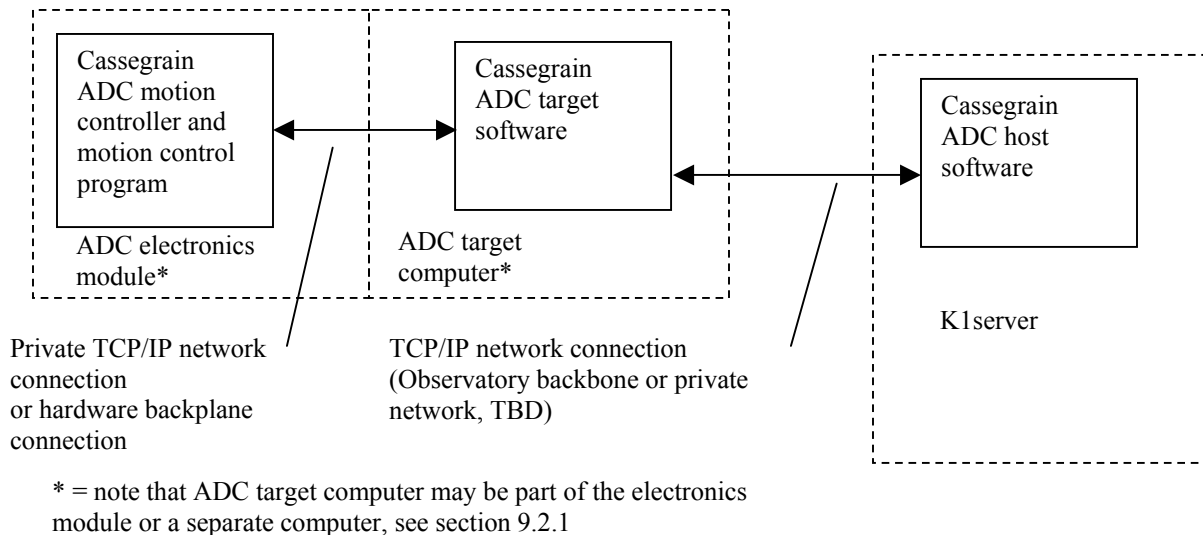


Figure 3: ADC Software Architecture

11.1.2.2 Target Software

The Cassegrain ADC target software will run on the ADC electronics module computer. The ADC target software implements the ADC keyword service, implements the ADC motion control system and acts as a DCS client to communicate with the DCS and DCSGUI. The ADC target software will communicate via TCP/IP with the Keck I telescope K1server.

11.1.2.2.1 ADC Keyword Service

The ADC target software should provide keywords compliant with the Keck keyword standards (KSD 8).

11.1.2.2.2 Motion Control System

The ADC target software should provide all functions required to control the prism separation adjustment mechanism in the ADC module.

11.1.2.2.3 DCS Client

The ADC should provide a DCS client using the Keck Task Library (KSD 8, KSD 28) providing the keyword interface and state machine defined in sections 3.5.1 and following of KSD 46a.

11.1.2.2.4 DCS

The Keck I telescope K1 server computer provides a DCS service conforming to KSD 46a.

11.1.2.2.5 Boot Host

The Keck I telescope K1 server computer will act as the boot host if a Linux operating system is used for the ADC target computer. Account name, password support and account privileges are TBD.

A password maintenance system will be implemented by an application program on the ADC target computer that allows CARA full control over all passwords used to access the ADC target application software and operating system.

11.1.2.2.6 Operating Modes

The operating modes of the Cassegrain ADC target software are anticipated to be the following:

1. Manual Control: this mode will provide direct manual selection of the dispersion correction setting of the ADC. The ADC target software should report the prism spacing in microns. In this mode the dispersion correction remains where it is set during changes in telescope elevation angle.
2. Tracking: this mode will cause the dispersion correction setting of the ADC to track changes in the telescope elevation angle. The tracking mode will automatically disengage during slewing of the telescope elevation. Telescope zenith distance will be interpolated to the required resolution from the time stamped DCS elevation keyword values received from the K1 server. The ADC target software should report the prism spacing in microns.
3. When in tracking mode the motion control speed of the ADC will be selected to ensure that during slewing of the telescope elevation the ADC dispersion correction will be established to match the demanded elevation position when the telescope arrives at the demanded position.

11.1.2.3 Host Software

The Cassegrain ADC host software will be written by CARA.

11.2 Implementation Requirements

11.2.1 Feature Implementation Requirements

The ADC target computer operating system and target application software should be configured to auto-boot and auto-execute at power on/reset.

A special test mode for ADC module diagnostics should be provided.

The tracking mode of the Cassegrain ADC must track the telescope zenith distance during an observation to the accuracy required in section 11.1.1.

The target software (application program and operating system) and the ADC electronics module should demonstrate by testing in a simulation environment at least 150 hours of continuous operation without a software fault or a crash of the target application software or the target computer operating system.

11.2.2 Common Practice Implementation Requirements

None.

11.2.3 Standards Implementation Requirements

The ADC target software should conform to the requirements of KSD 201 and KSD 210. All communications between the ADC target software and the Keck I DCS software should be via keywords conforming to the requirements of the Keck Task Library (KSD 8).

11.2.4 Regulatory Implementation Requirements

None.

11.3 Design Requirements

11.3.1 Technological Design Requirements

11.3.1.1 Target Software

The Cassegrain ADC target software should be written in C/C++ to run under the selected operating system. See section 9.2.1 for operating system and computer hardware requirements.

Communications with the host software should be via TCP/IP and the Keck Keyword Interface. CARA will define the keywords and will implement support for them analogous to Tables 9 and 10 of KSD 46a.

11.3.1.2 Host Software

The host software should be implemented as a DCSGUI control row.

11.3.2 Regulatory Design Requirements

None.

11.3.3 Standards Related Design Requirements

Software design and coding should comply with KSD 50 and KSD 210.

11.3.4 Integration Related Design Requirements

None.

12 INTERFACE REQUIREMENTS

12.1 Performance Requirements

12.1.1 Parametric Performance Requirements

12.1.1.1 Mechanical Interface

See section 8.1.1.

12.1.2 Operational Performance Requirements

12.1.2.1 Handling

See section 8.2.1.6.

12.2 Implementation Requirements

12.2.1 Feature Implementation Requirements

12.2.1.1 Optical Requirements

See section 7.1.2.

12.2.1.2 ADC Module Mechanical

See section 8.2.1.1.

12.2.1.3 Stray Light

See section 9.2.2.

12.2.1.4 LRIS Hatch

The LRIS optical entrance cover hatch currently opens outward. CARA will redesign this hatch to move parallel to the entrance face of LRIS so that it does not interfere with the ADC module.

12.2.2 Common Practice Implementation Requirements

12.2.2.1 Glycol Cooling

See section 8.2.1.7.

12.2.3 Standards Implementation Requirements

None.

12.2.4 Regulatory Implementation Requirements

None.

12.3 Design Requirements

12.3.1 Technological Design Requirements

None.

12.3.2 Regulatory Design Requirements

None.

12.3.3 Standards Related Design Requirements

None.

12.3.4 Integration Related Design Requirements

None.

13 RELIABILITY REQUIREMENTS

A process should take place to confirm that the Cassegrain ADC will provide a high level of reliability for a 10 year lifetime.

A recommended procedure to determine the reliability of the Cassegrain ADC is the use of the reliability prediction models for electronic components and systems given in MIL-HDBK-217F-2 "Reliability Prediction of Electronic Equipment" and the reliability prediction models for mechanical components and systems given in the Naval Surface Warfare Center "Handbook of Reliability Prediction Procedures for Mechanical Equipment", NSWC 98/LE1.

The MTBF as determined by the prediction models should then be used to establish the operating period before failure based on a 10 year period as follows:

$$R(t) = \exp\left(\frac{-t}{MTBF}\right)$$

where :

R(t) = probability of operation without failure for time t

t = time in hours

$$MTBF = \frac{1}{\sum (\text{all component failure rates})}$$

The probability of operation without failure for the Cassegrain ADC is expected to be more than 0.90 for this time period (t = 87600 hours). Software is not included in this requirement or the requested method of reliability assessment.

14 SPARES REQUIREMENTS

TBD

15 SERVICE AND MAINTENANCE REQUIREMENTS

15.1 Cleaning of Optics

Provision should be made for proper cleaning of the ADC module prisms. In particular the design should implement features as necessary to allow the annual performance of a cleaning procedure provided by the ADC design team.

16 DOCUMENTATION REQUIREMENTS

Unless otherwise specified all documents should be provided in electronic form on CD-ROM and printed in bound hardcopy form. The electronic form of documentation should be supplied in the editable file format of the software used to create the documentation and also in the Adobe® Portable Document Format (PDF) file format.

16.1 Drawings

16.1.1 Introduction

The drawing package should conform to the following standards, unless otherwise indicated.

16.1.2 Drawing Standards

16.1.2.1 Format

Each sheet should conform to ANSI Y14.1-1995, "Decimal Inch Drawing Sheet Size and Format". Drawing size should be determined on an individual basis.

16.1.2.2 Title Block

The title block should identify the following:

- Development group
- Drawing number
- Title
- Designer
- Draftsman
- Scale
- Method for determining next higher assembly.

16.1.2.3 Parts Lists, Data Lists and Index lists

All drawings should include parts and materials lists in accordance with ANSI Y14.34M-1996, "Parts Lists, Data Lists, And Index Lists: Associated Lists". All items should be identified with an item number or other label (with reference to the drawing number if one exists) for each part or component with all information required for procurement.

16.1.2.4 Assembly Drawings

Assembly drawings should include all relevant views required to clearly define the assembly including isometric and exploded views.

16.1.2.5 Detail Drawings

All detail drawings should include all views, geometry, dimensions and feature controls required to duplicate the existing part in accordance with ANSI Y14.5M-1982 (R1988) "Dimensioning and Tolerancing".

16.1.2.6 Multi and Sectional View Drawings

Multi and Sectional View Drawings should be developed in accordance with ANSI Y14.3M-1994 "Multi and Sectional View Drawings".

16.1.2.7 Fluid Power

Fluid power system should include schematics in accordance with ANSI Y14.17-1966, "Fluid Power Diagrams".

16.1.3 Dimensions and Tolerances

Dimensions and tolerances should be indicated in accordance with ANSI 14.5M-1982 (R1988).

16.1.4 Surface Finish Descriptions

Surface finishes should be described in accordance with ANSI 14.5M-1982 (R1988).

16.2 Manuals

16.2.1 Operating Manuals

Operations manuals should be provided that detail all standard operating procedures, including software start-up, diagnostic testing, basic trouble shooting and routine operation.

16.2.2 Maintenance Manuals

Maintenance manuals should be provided and should include the following:

- Maintenance procedures that list all steps required to perform the specified maintenance
- Reference figures (with item numbers or labels) and relevant drawings
- Identification of all required tools and sources for specialty tools
- A list of all required maintenance supplies and where to obtain specialty supplies
- A preventive maintenance section that includes schedules of required maintenance

- A corrective maintenance section that includes a fault tree and detailed trouble shooting procedures
- A corrective maintenance section that includes repair procedures

16.3 Software

Software documentation should be consistent with the requirements of CARA document KSD-3 “*Software Items for the Acceptance Review*” as described in section 1 of that document.

16.4 Test Data

Data should be supplied for the results of all tests performed to verify conformance to the eventual specifications. These tests will be documented in part 1 of the ATP (to be drafted).

Test data should be supplied in the form of a written report, and the raw test data should also be provided on a CD-ROM.

17 GLOSSARY

Table 9 defines the acronyms and specialized terms used in this document.

Table 9: Glossary of Terms

Term	Definition
ADC	Atmospheric Dispersion Corrector
ANSI	American National Standards Institute
AO	Adaptive Optics
ASME	American Society of Mechanical Engineers International
ATA	Air Transport Association
CARA	California Association for Research in Astronomy
CENELEC	European Committee for Electrotechnical Standardization
CFR	Code of Federal Regulations
dBA	Sound level in decibels, measured using the A contour frequency weighting network
DCS	Drive and Control System
EIA	Electronic Industries Alliance
EMI	Electro Magnetic Interference
FOV	Field Of View
FWHM	Full Width at Half Maximum. The width across an optical beam profile where its intensity drops to half of its peak, or maximum, value. Unless otherwise indicated the beam is assumed to be symmetric about the optical axis
IBC	International Building Code
ICC	International Code Council
IEEE	Institute of Electrical and Electronics Engineers
KSD	Keck Software Document
LRIS	Low Resolution Imaging Spectrograph
MTBF	Mean Time Between Failures
NEBS	Network Equipment Building System
NEMA	National Electric Manufacturers Association
OSHA	Occupational Safety and Health Administration
SSC	Science Steering Committee
RT4	Rail Transport position 4, (Nasmyth deck, Keck I)
TBD	To Be Determined
UL	Underwriters Laboratories Inc.
USGS	United States Geological Survey
W.M.K.O.	W.M. Keck Observatory