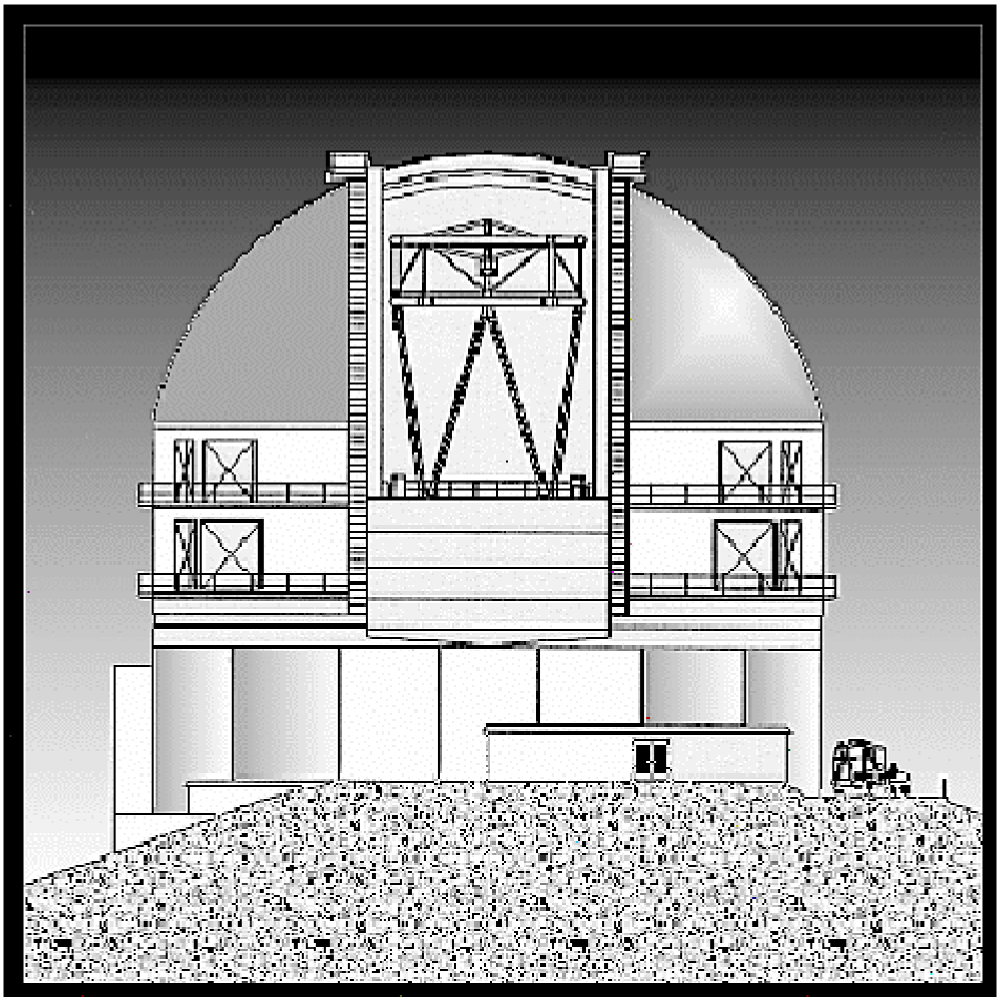
GEMINI
8-M Telescopes
Project

SPE-C-G0053

Mount Control System
Package Requirements Specification



John Wilkes
Controls Group/RGO

19 January 1995

GEMINI PROJECT OFFICE 950 N. Cherry Ave. Tucson, Arizona 85719
Phone: (520) 318-8545 Fax: (520) 318-8590

Table of Contents

1. INTRODUCTION

1.1 PURPOSE

This document is a deliverable of the system design phase of the Gemini mount control system work package. It's purpose is to formally define the baseline specification of the mount control system functions.

The audience of this document is:

- The SDR reviewing panel.
- Individuals workina on subsequent phases of the project.
- Individuals workin on connected Gemini work packaces

1.2 SCOPE

The mount control system provides the basic ability to slew and track the telescope. It also interfaces to a number of secondary systems that are required to provide services. The MCS is intended as an engineering interface to the mount and its subsystems - it is intended that the telescope could be run from here for initial setup and engineering work. It is not intended as an interface where the telescope would meet specification. It is essential to the success and longevity of the Gemini project that the details of these devices are hidden from the rest of the system. For instance, it should be possible to feed a continuous stream of demanded positions, velocities, and accelerations to the servo system without knowing whether it can actually make use of this information.

1.3 DEFINITIONS, ACRONYMS AND ABBREVIATIONS

The following is a list of abbreviations used in this document and related MCS documents.

A&G	Acquisition and Guiding
ADC	Analogue to Digital Converter
ADR	Assembly Design Review
ATP	Acceptance Test Plan. This consists of a Test-Procedure Specification as defined in IEEE Std 829-1983.
CDR	Critical Design Review
CPU	Central Processing Unit
CSDD	Control System Design Description
CSS	Control System Simulator
DAC	Digital to Analogue Converter
DC	Direct Current
DSP	Digital Signal Processor
ECS	Enclosure Control System
EPICS	Experimental Physics and Industrial Control System
EPLD	Erasable Programmable Logic Device
FCS	Functional Control System

FDE	Friction Driven Encoder
GUI	Graphical User Interface
H/W	Hardware
HWILS	Hardware In the Loop Simulation
Hz	Hertz
I/F	Interface
1/0	Input / Output
I/P	Input
ICD	Interface Control Document
ics	Instrument Control System
IOC	Input Output Controller
IPI	Implementation Phase I
IP2	Implementation Phase 2
IP3	Implementation Phase 3
iss	Instrument Support Structure
kHz	One thousand hertz.
kN	One thousand Newtons.
LAN	Local Area Network
ml	Primary Mirror
M2	Secondary Mirror
MCS	Mount Control System
O/P	Output
OCS	Observatory Control Svstem
OPI	OPerator Interface
OSS	Optical Support Structure
PCB	Printed Circuit Board
PCS	Primary (mirror) Control System
PDR	Preliminary Design Review
PLC	Programmable Lo2ic Controller
PLD	Programmable Looic Device
PMAC	Proorammable Multi-Axis Controller
PRS	Package Requirements Specification
PTP	Package Test Procedure. This consists of a Test Plan, a Test-Design Specification and a Test-Case Specification as defined in IEEE 829-1983.
RGO	Royal Greenwich Observatory
S/W	Software
SDD	Software Design Description
SDR	System Design Review
SRS	Software Requirements Specification
TBD	To Be Determined
TBEG	Telescope Building and Enclosure Group
TCS	Telescope Control System
TTL	Transistor Transistor Logic
VAT	Value Added Tax
VE	Virtual Encoder

VME	Versa Module Eurocard (The Meaning is Obsolete)
WP	Work Package
WPD	Work Product Document

1.4 REFERENCES

[I] IEEE Std 830-1984 "IEEE Guide to Software Requirements Specifications".

[2] Peregrine McGehee "Gemini Software Designrn Description", chapter 14 - "Details of the Mount Control Svstem"

[3] RPT-TE-G0018 "Gemini 8M Telescope Critical Design Review", Volume I, section 6.3 "Telescope Components and Assemblies"

[4] Trade Study. PCS 1/0 Subsystem and Related Issues. J. F. Maclean et al. 9 December 1994.

1.5 OVERVIEW

The format of this document conforins to IEEE Std 830-1984 "IEEE Guide to Software Requirements Specifications". Section 3 follows prototype outline I as specified in section 6.3.2 of the IEEE Std 830-1984.

2. GENERAL DESCRIPTION

This section does not state specific requirements; it only makes those requirements easier to understand.

2.1 PRODUCT PERSPECTIVE

The MCS is part of the Gemini Telescopes Project. It is responsible for the interface between the telescope computer system and the mount hardware. It exists along side a number of other control systems that fulfill similar purposes in other areas of the telescope. Fig. 2.1 shows, in block diagram form, how the MCS fits in the overall Gemini control system.

2.2 PRODUCT FUNCTIONS

The MCS contains the following subsystems.

- Servos and Drives Subsystem.
- Encoder Subsystem.
- Interlock Interface Subsystem.
- Protection Hardware.
- Counterweights Subsystem.
- Service Wrap-ups Subsystem.
- Monitoring Subsystem.

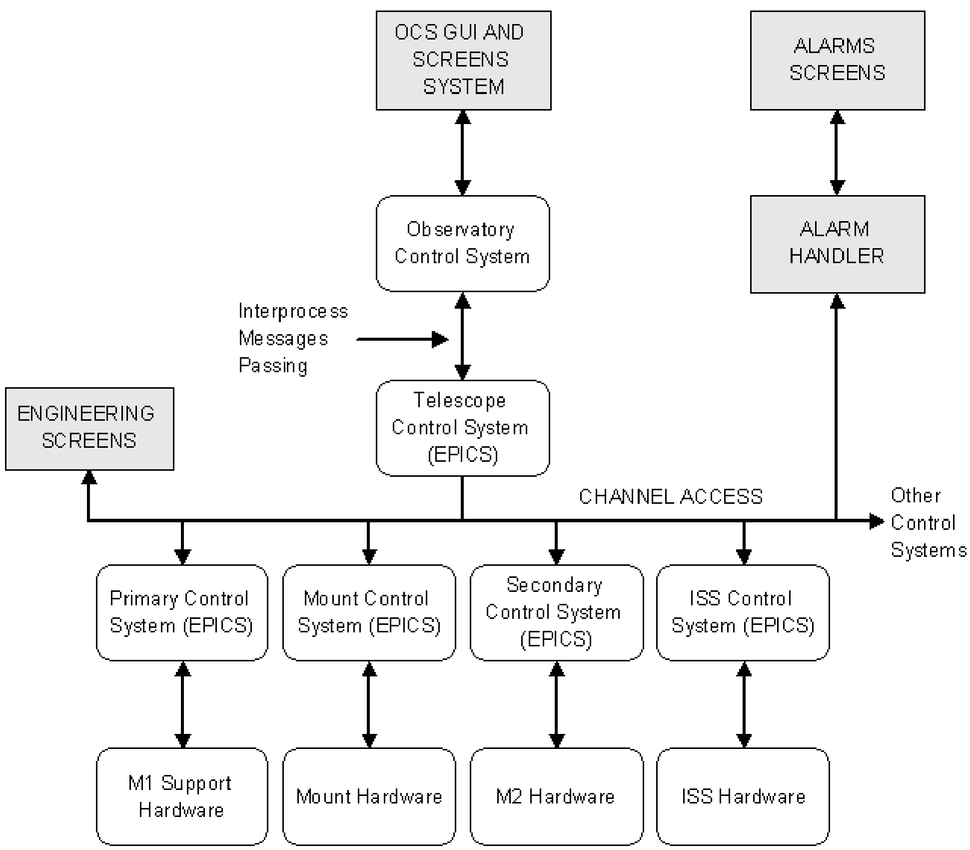


FIG. 2.1 - Relative Position Of Mount Control System

2.3 USER CHARACTERISTICS

There are three distinct levels of use for the MCS.

- Use of the MCS through the TCS for normal astronomical control of the telescope.
- Use of the MCS through the engineering screens for engineering use of the telescope.
- Use of the MCS by those responsible for its maintenance and extension.

2.4 GENERAL CONSTRAINTS

- The MCS will be implemented in a dedicated VME crate located near the mount base. This VME crate may have multiple CPU's in order to handle all of the functionality required.
- The VME crate control CPU (MVME-167 M68040) A-ill run the VxWorks operating system. The MCS software will be implemented using the EPICS database system.
- There will be a two headed Sun Workstation permanently connected to the mount control VME crate via ethernet in order to control the system from the enclosure floor. A li-httiaht cover will be provided for this console as not to impact the required enclosure darkness during observing

2.5 ASSUMPTIONS AND DEPENDENCIES

The following is a list of assumptions which apply to the specific requirements of the MCS WP as described in Section 3.

- The MCS WP is only responsible for the cabling to/from the MCS IOC.
- It is assumed that the encoder subsystem will be an 'off the shelf' product with a small amount of H/W to be desicned.
- It is assumed that the PN4AC card will fulfill the required purpose.
- It is assumed that no signal conditioning or transducers are to be procured by the MCS WP. The monitoring subsystem is simply an ADC function.
- The only hardware involved with the Protection subsystem to be provided by the MCS WP is that to provide altitude sensing and velocity over speed.
- It is assumed that any chan-e in drive method will not impact the requirements of the mcs WP.
- It is assumed that the power amplifiers, drives and encoders for the service wrap-ups are to be provided by a separate WP.
- It is assumed that the brakes will be controlled by the interlock system.
- It is not a requirement of the MCS to monitor the:
  - Ml dry gas flush system.
  - Top-end ring latching mechanisms.
  - IngSitu Ml Cleaning Interface,

  It is assumed that this is an interlock system function,
- It is not a requirement of the MCS to provide an 'in position' state to higher level svstems. It is assumed that this is a TCS function.

3. SPECIFIC REQUIREMENTS

3.1 FUNCTIONAL REQUIREMENTS

Specific requirements for each subsystem are detailed below. Most subsystems comprise of two parts - Hardware and Software. The software part of each subsystem will be implemented using the EPICS database. The Hardware part will be implemented using one or more VME compatible PCB's and associated electronics. The inter-face between the two parts is described in section 3.2.3.3.

3.1.1 Servos And Drives Subsystem

3.1.1.1 Introduction

There are two servo systems needed to point and track the telescope line of sight - elevation and azimuth. A third axis, the cassearain rotator, is needed to maintain field orientation and is the subject of a separate work package under the control of the Instrument Group.

Both the azimuth and elevation axes employ friction-type drive svstems to supply the required torque for all telescope slewing, tracking, and offsetting operations. To simplify design and manufacture, the two drive svstems use identical motor housings and motors (i.e. identical rollers, bearings, motors., and housing design). The azimuth drive consists of four drive units and the elevation drive consists of two drive units. Each drive unit consists of two motors. For a fuller description of the drive configuration see reference [3].

It is yet undecided how many servo loops will need to be provided by the MCS. The options are:
- One per motor.
- One per drive unit
- One per axis.

The decision shall be made as part of the preliminary design phase.

3.1.1.2 Inputs

00010 The elevation and azimuth servo subsystems shall accept a stream of time stamped position, velocity, and acceleration commands from the TCS at 20 Hz.

00020 The elevation and azimuth servo systems shall accept position information from the encoder subsystem at the servo rate.

00030 The elevation and azimuth servo systems shall receive a drive condition sic,nal from the interlock interface subsystem. These signals indicate the state of the power amplifiers and the brakes of the main drives.

The servo subsystem shall receive the following inputs from the mount hardware:

00040 Tacho information from each tachometer at the servo rate. The tachometers are analogue devices (type : Inland TG-5723) and there is one per drive motor. They have an analog noise of about 0.1 % of sional, a lag of 2 ms and a maximum rate of 47 rad/sec = 450 RPN4

00050 The drive current of each motor at 20-50 Hz.

3.1.1.3 Processing

00060 It shall be the responsibility of the hardware to close the servo loops.

00070 The hardware of the servo subsystem shall be implemented using a digital signal processor programmed with suitable servo algorithms. If possible, this should be the Gemini standard DC servo svstem which is the Delta Tau PMAC-VME DC Servo controller that is based on the Motorola 56000 family of DSP'S. The primary interface to this DC Servo controller is via an EPICS DC - SERVO record as defined by the Gemini Standard Instrument Controller Work Packaoe undertaken at RGO.

00080 The sampling frequency of the servos (the servo rate) will be between 200 Hz and 2 kHz.

00090 If a drive is 'stopped' (i.e. the drive condition signal indicates that the power amplifiers are disabled and the brakes are on) then the output of relevant servo shall be zero and any movement command shall be ignored.

3.1.1.4 Outputs

00110 The servo subsystem shall provide a demand signal proportional to the required torque to each the drive amplifiers at the servo rate. The drive amplifiers are Inland BLMI-325 and there is one per motor.

00120 The elevation and azimuth servo systems shall provide a drive enable signal to ihe interlock interface subsystem.

The servo subsystem shall provide the following outputs to the MCS IOC at 20-50 Hz:

00130 The demand signals as applied to the power amplifiers.

00140 The tacho signal of each motor.

00150 The drive current of each motor.

3.1.2 Encoder Subsystem

3.1.2.1 Introduction

The encoders for the elevation and azimuth axes are a combination of mechanical switches, magnetic position sensors, tape and FDE incremental encoders, and resolvers. The intent of the encoder subsystem is to hide the details of the phvsical encoding scheme and provide a device independent virtual encoder to hiaher level systems.

For more detail of the individual encoders, see reference [3].

3.1.2.2 Inputs

The encoder subsystem shall receive the following inputs from the mount hardware.

00160 Four tape encoder head outputs per axis - up to 2 MHz Pulse stream.

00170 One FDE output per axis - up to 2 MHz pulse stream.

00180 72 azimuth and 22 elevation fiducials - One signal from each fiducial.

00190 Two azimuth topple brackets. The position of these brackets shall be used to resolve the azimuth position ambiguity at MCS IOC power-up. The valid topple bracket states are summarized in the following table.

AZIMUTH ANGLE	OUTER BRACKET	INNER BRACKET
-270 < AZ < -90	Not Toppled	Toppled
-90 < AZ < 0	Not Toppled	Not Toppled
0 < AZ < 90	Not Toppled	Not Toppled
90 < AZ < 270	Toppled	Not Toppled

00200 One FDE load cell output per axis - analogue voltage.

00210 The resolver signal of each motor at 20-50 Hz.

00220 The encoder subsystem shall receive a configuration command from the MCS IOC.

3.1.2.3 Processing

00230 The encoder subsystem shall implement one of a variety of algorithms in order to produce an output. These algorithms shall include, but not be limited to:

- The average of the outputs of all four tape encoder heads.
- The average of the outputs of any two of the tape encoder heads.
- The output of any one of the tape encoder heads.
- The output of the FDE.

00240 There may also be systematic corrections to apply to each encoder input. The encoder subsystem shall apply these in real time.

00250 The encoder subsystem shall have a calibration mode in which the systematic corrections for each encoder input can be derived.

00260 In order to avoid position ambiguity and to allow zero setting to occur at any position, the virtual encoder shall have a resolution of at least a 30 bits. A 32 bit resolution is preferred.

NOTE: For the Gemini telescope azimuth axis, the required resolution is 0.005 arcsecs over ±270° range which is to one part in 388,800,000 or 29 bits. To allow an encoder zero set to occur anvwhere, the effective range of the encoder becomes ±540° hence the need for an extra bit.

00270 It shall be possible to directly connect a computer to the encoder subsystem order to run diagnostics and tests.

3.1.2.4 Outputs

00290 The encoder subsystem shall provide a virtual encoder output (~2 kHz, 32 bit parallel word) to each axis of the MCS servo subsystem.

NOTE: Given a maximum velocity of 2 °/s, an encoder resolution of 0.005 arcsecs and a sampling frequency of 1 kHz, the maximum number of encoder pulses in one sample period will be 720. This can be covered by 10 bits, but to resolve any direction ambiguity an extra bit is added, hence the interface between the VE and the servo svstem need only be 11 bits wide.

The encoder subsystem shall provide the folloa,ing outputs, for each axis, to the MCS IOC:

00300 Slow Virtual Encoder output - 20-50 Hz. 32 bit parallel word.

00310 4x tape head output - 20-50 Hz, 32 bit parallel words.

00315 FDE output - 20-50 Hz, 32 bit parallel word.

00320 An indication of fiducial position - 20-50 Hz.

00325 Position of the Azimuth Topple brackets at 20-50 Hz.

00330 FDE load cell reading - 20-50 Hz.

00340 The resolver signal of each motor at 20-50 Hz.

3.1.3 Interlock Interface Subsystem

3.1.3.1 Introduction

The interlock system is part of another work packace within the controls group. It has ultimate control over the power to the brakes and drive power amplifiers. The MCS must be capable of generating interlock requests in order to immobilize to telescope. The best wav to interface to the interlock system is via the standard Gemini TTL 1/0 board, the XYCOM XVME240 -Digital Input/Output Module.

In order that the interlock interface subsystem can handle all interfaces to interlock system, it must interface with other MCS subsystems that need to communicate with the interlock system. This is shown in Fig. 3.1.3. 1.

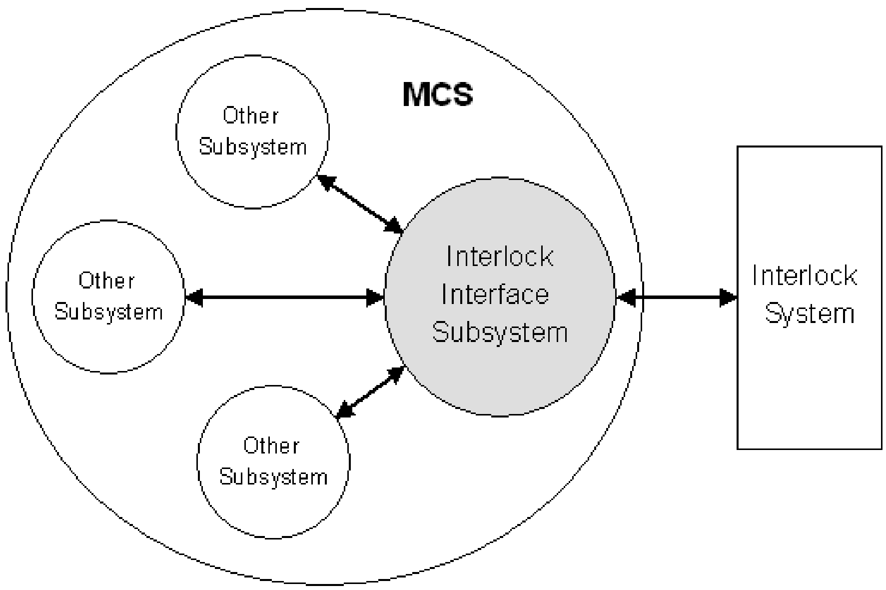


Figure 3.1.3.1 - Role Of Interlock Interface Subsystem

3.1.3.2 Inputs

00350 Each input from the interlock system will be comprised of two TTL signals, one being the complement of the other. These shall be interpreted based on the following logic table:

$x \setminus \bar{x}$	0	1
0	IsSet	IsClear
1	IsSet	IsSet

00360 The interlock interface subsystem shall receive drive condition signals from the interlock system for the following drives:

- Azimuth drive.
- Elevation drive.
- Cable wrap drives.

- Cable twister drive.
- 4 counterweight drives.

00370 The interlock interface subsystem shall receive drive enable signals from the servos/drives subsystem for each of the main axis drives.

00380 The interlock interface subsystem shall receive drive enable signals from the service wrap-ups subsystem for each of the cable wrap drives and the cable twister drive.

00390 The interlock interface subsystem shall receive drive enable signals from the counterweight subsystem for each of the counterweight drives.

3.1.3.3 Processing

N/A

3.1.3.4 Outputs

00400 Each output to the interlock svstem shall be comprised of two TTL signals, one being the complement of the other.

NOTE: The interlock system will set or clear interlocks based on the following logic table:

$x \setminus \bar{x}$	0	1
0	Set	Clear
1	Set	Set

00410 The interlock interface subsystem shall provide drive enable signals to the interlock system for the following drives:

- Azimuth drive.
- Elevation drive.
- 2 cable wrap drives.
- Cable twister drive.
- 4 counterweight drives.

00420 The interlock interface subsystem shall provide drive condition signals to the servos/drives subsystem for each of the main axis drives.

00430 The interlock interface subsystem shall provide drive condition signals to the service wrap-ups subsystem for each of the cable wrap drives and the cable twister drive.

00440 The interlock interface subsystem shall provide drive condition signals to the counterweight subsystem for each of the counterweight drives.

00445 The interlock interface subsystem shall provide all the drive condition signals and all the drive enable signals to the MCS IOC at 20-50 Hz.

3.1.4 Protection Hardware

3.1.4.1 Introduction

A number of subsystems require active protection in order to guarantee safety. One of the most important of these is the over velocity protection svstem for the telescope. The system must actively check that the velocit-,, of the different axes is within safe limits and take appropriate action if it is determined either that the system is not safe or that the status of the svstem is undetermined.

T'he velocity limits of the axes have lower values in the recions around the end of travel stops. The over velocity protection system must be able to sense the velocity and region of each axis. The current baseline for doing this is use rnercury switches (for elevation) and micro-switches (for dzimuth) to determine the region and a signal derived from a friction driven tacho-cenerator to determine velocity.

It is a requirement of the Interlock system implement the intelligence of over velocity protection system. However, it is the MCS that must provide the position and velocity information.

3.1.4.2 Inputs

None

3.1.4.3 Processing

N/A

3.1.4.4 Outputs

The MCS shall provide the following outputs to the Interlock system:

00450 Binary signals indicating whether., or not, the azimuth axis is near to one of it's limits. The actual position will depend upon the size of the impact allowed by the damper system.

00460 Binary signal indicating whether, or not, the elevation axis is near to one of it's limits. T'he actual position will depend upon the size of the impact allowed by the damper system.

00470 An analogue signal indicating the velocity of the azimuth axis.

00480 An analogue signal indicating the velocity of the elevation axis.

3.1.5 Counterweights Subsystem

3.1.5.1 Introduction

Although the telescope is designed to be well balanced in any of the upper end and instrument cluster configurations it is anticipated that (possiblv small) trim weights are required to balance the telescope. These weights are remotely controlled and remotely monitored.

The system is comprised of two axial and two cross-axial balance devices mounted to the outside face ofthe center section assembiv ('Axial' is defined here as along the axis of the OSS and 'cross-axial' is perpendicular to the OSS axis and to the elevation rotation axis). The counterweight units are located on the same side of the OSS as the elevation disks.

For a fuller description of the OSS counter balance assemblv, refer to reference [3].

3.1.5.2 Inputs

00490 The counterweights subsystem shall receive a demanded position at 20-50 Hz, for each of the balance devices, from the MCS IOC.

00500 The counterweights subsystem shall receive drive condition signals from the interlock interface subsystem for each of the counterbalance drives.

00510 The counterweights subsystem shall receive a position sional at a suitable servo rate, for each of the balance devices, from the counterweight hardware.

3.1.5.3 Processing

00520 It shall be possible to remove the power from the weight motors and the weights will remain in their last commanded position. This could be accomplished either by the use of electrically actuated brakes and/or mechanical design of drive system.

00530 The position of the weights shall be maintained in a look up table that shall be used to automatically set them in the correct position based on the current telescope configuration.

00540 In order to triin the telescope, some metric of the extent of its out of balance condition shall be provided. The sucaested metric is the asymmetries in the azimuth and elevation axis drive unit drive currents.

00550 If a drive is 'stopped' (i.e. the drive condition signal indicates that the power amplifiers are disabled and the brakes are on) then the output of the relevant servo shall be zero and any movement command shall be ignored.

3.1.5.4 Outputs

00560 The counterweight subsystem shall provide a demand sianal proportional to the required torque to each of the drive amplifiers at a suitable servo rate.

00570 The counterweights subsystem shall provide drive enable sianals to the interlock interface subsystem for each of the counterweight drives.

The counterweight subsystem shall provide the following outputs at 20-50 Hz, for each of the balance devices, to the MCS IOC:

00580 Actual position.

00590 The demand signals as applied to the power amplifiers.

3.1.6 Service Wrap-ups Subsvstem

3.1.6.1 Introduction

In order to provide power, data services, neta-orkino, cryogenics, and other services to the cassegrain focus it is necessan, to provide a means of passina the services throuah the azimuth, elevation, and casse-rain bearings. The cassegrain cable twister is a separate work packaoe and is under the control of the Gemini Instrument Group. In order to minimize the disturbance torque introduced into the motions of the different axes it is advisable to drive the service separately from the telescope axis. This does not remove the effects of reaction torque. It is intended to separately servo the service wrap-ups and to drive them as a follower to the axis they are connected to.

There is one azimuth twister and two elevation cable wraps. For a description of the configuration of these, refer to reference [3].

3.1.6.2 Inputs

00610 The service wrap-ups subsystem shall receive an input, at a suitable servo rate, from a differential encoder from each drive (azimuth twister and two elevation wraps), indicating the position relative to the associated main axis.

00615 The service wrap-ups subsystem shall receive an input at 20-50 Hz, from each drive, indicating motor current.

00620 The service wrap-ups subsystem shall receive drive condition signals from the interlock interface subsystem for each of the cable wrap drives and for the cable twister drive.

3.1.6.3 Processing

00630 If a drive is 'stopped' (i.e. the drive condition si-nal indicates that the power amplifiers are disabled and the brakes are on) then the output of the relevant servo shall be zero.

3.1.6.4 Outputs

00640 The service wrap-ups subsystem shall provide a demand signal, at a suitable servo rate, proportional to the required torque to each of the drive amplifiers (azimuth twister and two elevation wraps).

00650 The service wrap-ups subsystem shall provide drive enable signals to the interlock interface subsystem for each of the cable wrap drives and for the cable twister drive.

The service wrap-ups subsystem shall provide the following outputs, at 2050 Hz, for each of the drives (azimuth twister and two elevation wraps), to the MCS IOC:

00660 The demand signal as sent to the power amplifiers.

00670 The differential encoder read back.

00680 Motor drive current.

3.1.7 Monitoring Subsvstem

3.1.7.1 Introduction

It is the responsibility of the MCS to provide a generic means of monitoring the many physical quantities that have been identified. This shall be implemented with a field bus svstem based upon CANbus as used bv the PCS, see reference [4]. There will be a number of bus stations at strategic points around the telescope and enclosure. Signals can be brought to these bus stations to be interfaced to the monitoring system.

There is no requirement to provide anv kind of signal conditioning at the front end of the monitoring subsystem. There is no requirement to provide any output capability.

The following sections show the sort of input that is to be monitored.

3.1.7.1.1 Monitoring and Metrology

In addition to the standard encoders used to determine the current position of the telescope various different types of sensors may be implemented. This includes networks of temperature sensors, strain -auges, and accelerometers distributed along the mount structure. In order to reduce wind shake of the telescope it may be necessary to use ros. These gyros would be connected to the pier, the mount, the tube, and possibly the optics ingorder to calculate their current position. Due to the inevitable drift of these devices it is still necessary to have a natural guide star. The intent is to decrease the sampling requirement on the A&G fast guiding sensor (currently 200 Hz) by providing an alternate sensor. If. as we suspect, most of the dynamic deflection of the telescope in the presence of wind is due to bulk motion of the telescope and pier on the soil, then a gyro strapped to the pier should be able to sense a large portion of this error signal.

3.1.7.1.2 Electrical Systems Interface

In order to meet the 2% down time requirement it is necessary to monitor the status Of Critical electrical systems. The intent is to prevent problems by a system of periodic monitoring and preventative maintenance. In this system critical electrical systems could be monitored for voltage level, high frequency content, and (for AC systems) conformance with frequency stability specifications. In order to be effective such a system must establish a standard means of interfacing to any electrical system. This standard could be used by fabricators in order to make their systems compatible.

3.1.7.1.3 Mirror Covers

The status of the mirror covers must be monitored. This will be an analovalue that represents the mirror cover position.

3.1.7.1.4 Telescope Thermal Control

A series of fans shall be used to cool the mount and the drive assemblies. These fans shall be onerated Manually via -;witches in the control room but their on/off status shall be monitored by the MCS. A number of fans shall be placed at the mount base. Each azimuth and elevation drive unit consistin.)f a pair of drive motors shall also have its own cooling fan.

The fan status interface will be simple digital I/O directly into the MCS IOC.

3.1.7.2 Inputs

00690 The monitoring subsystem shall be capable of accepting analogue signals of a generic format.

00700 The monitoring subsystem shall be capable of accepting binary signals of a generic fon-nat (e.g. TTL).

00710 The monitoring subsystem shall be capable of accepting digital words of a generic format and handshaking method.

It is the responsibility of the individual sensors produce outputs in the standard format.

3.1.7.3 Processing

00730 The ADC's contained in the monitoring subsystem shall have a minimum resolution of 12 bits.

3.1.7.4 Outputs

00740 The monitoring subsystem shall make available digital representations of all the measured quantities to the MCS IOC at a maximum rate of I Hz.

3.2 EXTERNAL INTERFACE REQUIREMENTS

3.2.1 User Interfaces

The MCS shall provide user interfaces via the following svstems.

3.2.1.1 OCS Consoles And Screens

The consoles and screens provided by the OCS shall have fine grained control and monitoring capability of the mount. As shown in Fi-. 2.1, this capability is provided via the TCS. The TCS uses EPICS Channel Access to set the appropriate parameters in the MCS's database and then issues an event that causes the MCS to match the system with those parameters.

00750 The MCS shall provide the relevant interface to the TCS so the OCS requirements can be fulfilled.

3.2.1.1.1 **OCS** Consoles

00760 The following commands shall be available to the OCS:

- All Servo Subsystem functions
- All Encoder Subsystem functions
- All Counterweights Subsystem functions
- All Service Wrap-ups Subsystem functions
- All Monitoring, Subsystem functions

3.2.1.1.2 **OCS** Screen System

The mount control system shall provide the following items to the different screens.

00770 **Encoder Screen**

- Azimuth
  - Incremental FDE
  - Drive unit resolvers. There are 8 of these.
  - Incremental inductive tape encoder. There are 4 readina heads.
  - Fiducials
  - Tachometers
  - Drive motor currents

- Elevation
  - Absolute Incremental FDE
  - Drive unit resolvers. There are 4 of these.
  - Incremental inductive tape encoder. There are 2 reading heads.
  - Fiducials
  - Tachometers
  - Drive motor currents
- Axial Counterweight Position
  - Absolute encoders. There are 2 of these - one for each counterweight assembly.
- Cross-axial Counterweight Position
  - Absolute encoders. There are 2 of these - one for each counterweight assembly.
- Azimuth Wrap
  - Differential encoders.
- Elevation Wrap
  - Differential encoders. There are two of these - one for each wrap.

00780 **Limit Screen**

- Mirror Cover Status

00790 **Alarms Screen**

- Power.
  - Mains alarm
  - Power amplifier temperature alan-n
  - Power amplifier over-current alarm.

3.2.1.2 Drives Subsystem

00800 It may also be possible to directly control the drives in a stand-alone mode by directly connecting **a** workstation or terminal. The intent is to use the capabilities provided by the manufacturer of the drives and not to create or add functionality to these systems. If there is no built in capability for direct control of the drives then none shall be provided.

3.2.1.3 Engineering Screens

00805 The MCS shall provide **a** set of control and status screens that will normally be used on the console located on the mount base. The contents of these screens shall be sufficient to operate the mount in an enoineering mode. It should be a simple task to add functionality to these screens.

Here are some examples of the type of screen that may be needed

- MCS testing/acceptance.

- Balancing telescope.
- Debugging different subsystems.
- Examining limits, positions etc. of all the subsystems

3.2.2 Hardware Interfaces

This subsection details the hardware interfaces that the MCS shall provide to the mount hardware. The following naming conventions apply:

Buses
SignalName(1:N) means a bus of N separate signals called SignalName1, SignalName2,..., SignalNameN.

Signal Types

TP	Differential Twisted Pair. There will be two signals with the same name except one will have the suffix H (active high), the other will have the suffix _L (active low).
O/P	output.
I/P	Input.
IL	Interlock Signal. This consists of two complementary, single ended TTL signals.
AnMon	An analogue sional in the aeneric format of the monitoring subsystem.
BiMon	A binary signal in the generic format of the monitoring subsystem.
WoMon	A digital word in the generic format of the monitoring subsystem.

3.2.2.1 Servo Subsystem

NAME	DESCRIPTION	TYPE
AzDemand(1:8)_H/_L	Azimuth Drive Demand (One per motor).	TP-O/P
AzCurrent(1:8)_H/_L	Azimuth Drive Current (One per motor).	TP-I/P
AzTacho(1:8) H/ L	Azimuth Tachometer Sionals (One per motor).	TP-I/P
ELDemand(1:8)_H/_L	Elevation Drive Demand (One per motor).	TP-O/P
ElCurrent(1:8)_H/_L	Elevation Drive Current (One per motor).	TP-I/P
ElTacho(1:8) W L	Elevation Tachometer Signals (One per motor).	TP-I/P

3.2.2.2 Encoder Subsystem

NAME	DESCRIPTION	TYPE
AzTapeA(1:4)_H/_L	Azimuth Tape Head A Counts (One per tape head)	TP-I/P
AzTapeB(1:4) _H/ _L	Azimuth Tape Head B (Quad) Counts (One per tape head)	TP-I/P
AzFdeA _H/_L	Azimuth Friction Driven Encoder A Counts	TP-I/P
AzFdeB_H/_L	Azimuth Friction Driven Encoder B (Quad) Counts	TP-I/P
AzFiducial(1:72)_H/_L	Azimuth Fiducial Micro Switches	TP-I/P

NAME	DESCRIPTION	TYPE
AzResolver(1:8)	Azimuth Resolver Signals (One per motor).	TBD-I/P
AzOuterTopple _H/ _L	Azimuth Outer Topple Bracket Position.	TP-I/P
AzinnerTopple _H/ _L	Azimuth Inner Topple Bracket Position.	TP-I/P
AZVE	Azimuth Virtual Encoder Output	32 bits-O/P
ElTapeUp(1:4)_H/_L	Elevation Tape Head A Counts (One per tape head)	TP-I/P
ElTapeDown(]:4)_H/_L	Elevation Tape Head B (Quad) Counts (One per tape head)	TP-I/P
ElFdeUp_H/ _L	Elevation Friction Driven Encoder A Counts	TP-I/P
ElFdeDown_H/_L	Elevation Friction Driven Encoder B (Quad) Counts	TP-I/P
ElFiducial(1:22)_H/_L	Elevation Fiducial Micro Switches	TP-I/P
EIResolver(1:8)	Elevation Resolver Signals (One per motor).	TBS-I/P
ElOuterTopple _H/ _L	Elevation Outer Topple Bracket Position.	TP-I/P
EllnnerTopple_H/_L	Elevation Inner Topple Bracket Position.	TP-I/P
EIVE	Elevation Virtual Encoder Output	32 bits-O/P

3.2.2.3 Interlock Interface Subsystem

NAME	DESCRIPTION	TYPE
AzDriveEnable_H/_L	Enables the Azimuth Power Amplifiers and releases the Brakes (Via Interlock System).	IL-O/P
AzDriveCond _H/ _L	Indicates the condition of the Azimuth Drive.	IL-I/P
ElDriveEnable_H/_L	Enables the Elevation Power Amplifiers and releases the Brakes (Via Interlock System).	IL-O/P
ElDriveCond _H/ _L	Indicates the condition of the Elevation Drive.	IL-I/P
WrapDriveEnabie(1:2)_H/_L	Enables Cable Wrap Power Amplifiers and releases the Brakes (Via Interlock System).	IL-O/P
WrapDriveCond(]:2)_H/ _L	Indicates the condition of the Cable Wrap Drive.	IL-I/P
TwistDriveEnable_H/_L	Enables the Cable Twister Power Amplifiers and releases the Brakes (Via Interlock System).	IL-O/P
TwistDriveCond _H/ _L	Indicates the condition of the Cable Twister Drive.	IL-I/P
BalDriveEnable(1:4)_H/ _L	Enables Counterweight Power Amplifiers and releases the Brakes (Via Interlock System).	IL-O/P
Ba]DriveCond(1:4)_H/_ L	Indicates the condition of the Counterweight Drive.	IL-I/P

3.2.2.4 Counterweights Subsystem

NAME	DESCRIPTION	TYPE
AxBalDemand(1:2) _H/_L	Axial Counterweight Demand	TP-O/P
AxBalEncoder(1:2)	Axial Counterweight Encoder Reading	TBD-I/P
CaxBalDemand(1:2) _H/_L	Cross-Axial Counterweight Demand	TP-O/P
CaxBalEncoder(1:2)	Cross-Axial Counterweight Encoder Reading	TBD-I/P

3.2.2.5 Service Wrap-Ups Subsystem

NAME	DESCRIPTION	TYPE
TwistDemand_H/_L	Azimuth Cable Twister Demand Sional	TP-I/P
TwistEncoder	Azimuth Cable Twister Differential Encoder	TBD-I/P
TwistCurrent _H/_L	Azimuth Cable Twister Drive Current	TP-I/P
WrapDemand(1:2)_H/_L	Elevation Cable Wrap Demand Signal	TP-I/P
WrapEncoder(1:2)	Elevation Cable Wrap Differential Encoder	TBD-I/P
WrapCurren@(1:2) _H/_L	Elevation Cable Wrap Drive Current	TP-I/P

3.2.2.6 Monitoring Subsystem

The monitoring sybsystem is to be implemented with a CAN bus. The inputs specified below will interface to the MCS via the standard bus terminals as specified in Section 3.1.7.1. This set of inputs is the minimum set, the monitoring subsystem is to be designed to be easily expandable.

NAME	DESCRIPTION	TYPE
AzPreload(1:4)	Azimuth Hydraulic Pre-load (One per drive unit).	AnMon - I/P
ElPreload(1:2)	Elevation Hydraulic Pre-load (One per drive unit).	AnMon - I/P
AzFdePreload	Azimuth Friction Driven Encoder Load Cell Output	AnMon - I/P
ElFdePreload	Elevation Friction Driven Encoder Load Cell Output	AnMon - I/P
Gyro(1:N)	Gyroscope Network (N Gyroscopes).	AnMon - I/P
Temperature(1:N)	Temperature Network (N Temperature Sensors).	AnMon - I/P
Force(1:N)	Strain Gauge Network (N Strain Gauges).	AnMon - I/P
Accel(1:N)	Accelerometer Network (N Accelerometers).	AnMon - I/P
Tilt(1:N)	Tilt Meter Network (N Tilt Meters).	TBD - I/P
Disp(1:N)	Displacement sensor network (N Displacement Sensors).	AnMon - I/P
UpsVolts	UPS voltage level	TBD - I/P
UpsFreq	UPS frequency content - on-line spectral analysis	TBD - I/P
UpsFreqStab	UPS frequency stability of line.	TBD - I/P
NonUpsVolts	Non-UPS voltage level.	TBD - I/P
NonUpsFreq.	Non-UPS frequency content - on-line spectral analysis	TBD - I/P
NonUpsFreqStab	Non-UPS frequency stability of line.	TBD - I/P
ServoAmpVolts	Servo Amp voltage level.	TBD - I/P

NAME	DESCRIPTION	TYPE
ServoAmpFreq	Servo Amp frequency content - on-line spectral analysis	TBD - I/P
ServoAmpFreqStab	Servo Amp frequency stability of line.	TBD - I/P
MirrorCover	Monitor mirror cover position.	AnMon - I/P
MountFan	Operation Of The Fans On The Mount Base	BiMon - I/P
AzimuthFan(1:4)	Operation Of The Fans On The Azimuth Drive Assemblies	BiMon - I/P
ElevationFan(1:4)	Operation Of The Fans On The Elevation Drive Assemblies	BiMon - I/P

3.2.3 Software Interfaces

The MCS shall provide software interfaces via the following systems.

3.2.3.1 TCS

00810 The mount control system shall accept azimuth and elevation parameters (A, A’, A") (E, E’, E") for the target position, velocity, and acceleration of the two mount axes, together with the time that these targets should be attained. These parameters may be sent once or they may be continuously delivered at up to 20 Hz.

00820 In addition to the targets the MCS shall accept the following commands from the TCS.

- STOP; halt and put the brakes on.
- MOVE; servo to the current taroet.
- PARK; move to a predetermined position and put telescope in park state.
- ENCODER CONFIG; configure the encoders.
- ZERO SET; zero different parts of the svstem.
- UNWRAP; take out the cable wrap.
- LOG ON/OFF; enable and disable logging for diagnostic purposes.

00830 The mount shall return the following values to the TCS.

- Encoder readings
- Drive demand
- Servo errors
- Alarins
- Status

00840 The above data values shall be contained in an EPICS database that shall communicate with the TCS via channel access.

3.2.3.2 MCS Initialization Files

00845 The default values for anythino which is not resident in the EPICS database when the MCS is rebooted shall be contained in an initialization file that will be stored locally.

3.2.3.3 EPICS/Hardware Interface

The following tables describe the internal interface between the EPICS software and the hardware of each subsystem.

GENERAL FUNCTIONS

Function	Description	Range	Frequency	Type
Power	turn power on/off to entire unit	ON|OFF	<0.1Hz	digital switch
Health	monitor overall status of device	ON|OFF	20-50Hz	digital i/p
Servo Params	up/down load servo parameters	Data	<0.1Hz	digital i/o
Heart Beat	incrementing counter		20-50Hz	digital i/p
Watch Dog	shutdown mount systems if host dies		20-50Hz	digital i/o

SERVO SYSTEM FUNCTIONS

Function	Description	Range	Frequency	Type
AZ Target	commanded azimuth angle actual	± 270°	20-50 Hz	DC Servo - output
AZ Velocity Target	commanded azimuth velocitv	± 2.0°/sec	20-50 Hz	DC Servo - output
AZ Accel. Taroet	commanded azimuth acceleration	± 0.1°/sec	20-50 Hz	DC Servo - output
AZ Actual	actual azimuth angle	± 270°	20-50 Hz	DC Servo - input
AZ Actual Velocity	actual azimuth velocity	± 2.0°/sec	20-50 Hz	DC Servo - input
AZ Actual Accel.	actual azimuth acceleration	± 0.1°/sec	20-50 Hz	DC Servo - input
AZ Error	azimuth angle error	± 270°	20-50 Hz	DC Servo - input
AZ Velocity Error	azimuth velocity error	± 2.0°/sec	20-50 Hz	DC Servo - input
AZ Accel. Error	azimuth acceleration error	± 0.1°/sec	20-50 Hz	DC Servo - input
El Target	commanded elevation angle	0-93°	20-50 Hz	DC Servo - output
El Velocity Target	commanded elevation velocity	± 0.75°/sec	20-50 Hz	DC Servo - output
El Accel. Target -	commanded elevation acceleration	± 0.025°/sec	20-50 Hz	DC Servo - output
El Actual	elevation angle actual elevation	0-93°	20-50 Hz	DC Servo - input
El Actual Velocity	actual elevation velocity	± 0.75°/sec	20-50 Hz	DC Servo - input
El Actual Accel.	actual elevation acceleration	± 0.025°/sec	20-50 Hz	DC Servo - input
El Error	elevation angle error	0-93°	20-50 Hz	DC Servo - input
El Velocity Error	elevation velocity error	± 0.75°/sec	20-50 Hz	DC Servo - input
El Accel. Error	elevation acceleration error	± 0.025°/sec	20-50 Hz	DC Servo - input

DRIVE FUNCTIONS

Function	Description	Range	Freq.	Type
Azimuth Drive Motors (4x2)	command a drive rate	0-2°/Sec.	20-50 Hz	analog o/p
Azimuth Drive Motors (4x2)	monitor drive current	0-50 Amps	20-50 Hz	analog i/p
Azimuth Tachometers (4x2)	monitor tachometer readout	0-450 RPM	20-50 Hz	digital i/p
Azimuth Resolvers (4x2)	monitor drive unit resolvers	0-360°	20-50 Hz	digital i/p
Azimuth Pre-load (4)	monitor hydraulically applied pre-load	0-25 kN	20-50 Hz	analog i/p
Elevation Drive Motors (2x2)	command a drive rate	0-2 °/Sec.	20-50 Hz	analog o/p
Elevation Drive Motors (2x2)	monitor drive current	0-50 Amps	20-50 Hz	analog i/p
Elevation Tachometers (2x2)	monitor tachometer readout	0-450 RPM	20-50 Hz	digital i/p
Elevation Resolvers (2x2)	monitor drive unit resolvers	0-360°	20-50 Hz	digital i/p
Elevation Pre-load (2)	monitor hydraulically applied pre-	0-25 kN	20-50 Hz	analog i/p

	load			
Interlock Interface	Connection to interlock system. Needs to remove azimuth and elevation drive power if interlock is set.		1 Hz	Interlock Interface

ENCODER SYSTEM FUNCTIONS

Function	Description	Range	Freq.	Type
Configure Azimuth Virtual Encoder	Instruct virtual encoder system how to combine raw encoder values into 32-bit quantity.	N/A	N/A	Command
Azimuth Virtual Encoder	Encoder system mixes tape/ fidicials/ FDE into a sincle virtual encoder.	32 Bit	20-50 Hz	digital i/p
Azimuth Tape Encoders (4)	Inductosyn incremental tape encoder readout.	32 Sit	20-50 Hz	digital i/p
Azimuth Fiducials (36 or 72)	monitor reference sionals	36/72 Bit Word	20-50 Hz	digital i/p
Azimuth FDE	FDE incremental encoder readout	32 Bit	20-50 Hz	digital i/p
Azimuth FDE Load Cell	FDE incremental encoder load cell readout	TBD	20-50 Hz	analog i/p
Azimuth Topple Bracket	Position of azimuth topple bracket	1-4	20-50 Hz	digital i/p
Configure Elevation Virtual Encoder	Instruct virtual encoder system how to combine raw encoder values into 32-bit quantity	N/A	N/A	Command
Elevation Virtual Encoder	Encoder system mixes tape/ fidicials/ FDE into a single virtual encoder.	32 Bit	20-50 Hz	digital i/p
Elevation Tape Encoders (2)	Inductosyn incremental tape encoder readout.	32 Bits	20-50 Hz	digital i/p
Elevation Fiducials (11 or 22)	monitor reference signals	11/22 Bit Word	20-50 Hz	digital i/p
Elevation FDE	FDE incremental encoder readout	32 Bits	20-50 Hz	digital i/p
Elevation FDE Load Cell	FDE incremental encoder load cell readout	TBD	20-50 Hz	analog i/p
Elevation Topple Bracket	Position of elevation topple bracket	1-4	20-50 Hz	digital i/p

COUNTERWEIGHTS SYSTEM FUNCTIONS

Function	Description	Range	Freq.	Type
Axial Balance Target (2)	Demanded counterweight weight position.	0-970 mm	20-50 Hz	digital o/p
Axial Balance Position (2)	Actual counterweight weight position via encoder.	0-970 mm	20-50 Hz	digital i/p
Axial Balance End-of-travel Condition(2x2)	End of travel (±) limit switch status.	SET | CLEAR	20-50 Hz	digital input switch
Axial Balance Brakes (2)	Counterweight braking system.	ON | OFF	20-50 Hz	digital output switch
Cross-axial Balance Target (2)	Demanded counterweight weight position.	0-770 mm	20-50 Hz	digital o/p
Cross-axial Balance Position (2)	Actual counterweight weight position via encoder.	0-770 mm	20-50 Hz	digital i/p
Cross-axial Balance End-of-travel Condition (2x2)	End of travel (±) limit switch status.	SET | CLEAR	20-50 Hz	digital input switch

Cross-axial Balance Brakes (2)	Counterweight braking system.	ON | OFF	20-50 Hz	digital o/p

SERVICE WRAP-UPS SYSTEM FUNCTIONS

Function	Description	Range	Freq.	Type
Azimuth Cable Twister Encoder	Differential encoder read back.	TBD	20-50 Hz	digital i/p
Azimuth Cable Twister Drive Current	Monitor cable twister motor drive current.	0-50 Amps.	20-50 Hz	analog i/p
Elevation Cable Wrap Encoder	Differential encoder read back.	TBD	20-50 Hz	digital i/p
Elevation Cable Wrap Drive Current	Monitor cable wrap motor drive current.	0-50 Amps.		analog i/p

MONITORING & METROLOGY SUBSYSTEM

Function	Description	Range	Frequency	Type
Gyros	Gyroscope network.	TBD	1 Hz	digital i/p
Temperature Sensors	Temperature sensor network.	TBD	1 Hz	digital i/p
Strain Gauges	Strain Gauge network	TBD	1 Hz	digital i/p
Accelerometers	Accelerometer network.	TBD	1 Hz	digital i/p
Tilt meters	Tilt meter network.	TBD	1 Hz	digital i/p
Displacement sensors	Displacement sensor network. Measures displacement of trunnion relative to columns.	TBD	1 Hz	digital i/p

ELECTRICAL SYSTEMS INTERFACE SYSTEM FUNCTIONS

Function	Description	Range	Freq.	Type
UPS Voltage Level	Monitor UPS voltage level.	TBD V	1 Hz	analog i/p
UPS Frequency content	.Monitor UPS frequency content - on-line spectral analysis	TBD	1 Hz	array analog i/p
UPS Frequency Stability	Monitor UPS frequency stability of line. (60 Hz Mauna Kea, 50 Hz Cerro Pachon).	TBD	1 Hz	analog i/p
Non-UPS Voltage Level	Monitor Non-UPS voltage level.	TBD V	1 Hz	analog i/p
Non-UPS Frequency content	Monitor Non-UPS frequency content - on-line spectral analysis.	TBD	1 Hz	array analog i/p
Non-UPS Frequency Stability	Monitor Non-UPS frequency stability of line. (60 Hz Mauna Kea, 50 Hz Cerro Pachon).	TBD	1 Hz	analog i/p
Servo Amp Voltage Level	Monitor Servo Amp voltage level.	TBD V	1 Hz	analog i/p
Servo Amp Frequency content	Monitor Servo Amp frequency content - on-line spectral analysis.	TBb	1 Hz	array analog i/p
Servo Amp Frequency Stability	Monitor Servo Amp frequency stability of line. (60 Hz-Mauna Kea, 50 Hz Cerro Pachon).	TBD	1 Hz	analog i/p

MIRROR COVER FUNCTIONS

Function	Description	Range	Freq.	Type
Mirror Cover Position	Monitor mirror cover position.	OPEN | CLOSED	<0.1 Hz.	digital i/p

TELESCOPE THERMAL CONTROL SUBSYSTEM

Function	Description	Range	Freq.	Type
Mount Fan Status (N)	The fans on the mount base will be monitored (N fans).	ON | OFF	<0.1 Hz.	digital input switch
Azimuth Drive Fan Status (4)	The fans on the azimuth drive assemblies will be monitored.	ON | OFF	<0.1 Hz.	digital input switch
Elevation Drive Fan Status (4)	The fans on the elevation drive assemblies will be monitored.	ON | OFF	<0.1 Hz.	digital input switch

3.2.4 Communication Interfaces

The MCS shall provide communication interfaces via:

3.2.4.1 The Time Bus

The time within the MCS VME crate is set to ±5μs from the time bus.

3.2.4.2 The Control LAN (Channel Access)

All of the control/status information to/from the MCS comes via the Channel Access ethernet. There is no event bus or synchro bus connection to the MCS.

3.3 PERFORMANCE REQUIREMENTS

3.3.1 Static Numerical Requirements

The MCS shall support a number of users via the ethernet control LAN. It may be necessary to have some form of lock out to prevent MCS access when the mount is being controlled from the mount base engineering screens.

3.3.2 Dynamic Numerical Requirements

Given that the MCS has to receive time related data over the ethernet, and that time delays on the ethernet are indeterminate, it is important that the MCS shall be able to operate sufficiently with lost or late data.

3.4 DESIGN CONSTRAINTS

3.4.1 Standards Compliance

00850 The work shall be carried out in compliance of the "Mount Control System Work Description" Work Scope No. 9414257-GEMO I 0 1 6.

00860 Where appropriate, documentation shall follow the following IEEE standards.

- Work Product Documents shall follow IEEE 1063-1987 "IEEE Standard for Software Documentation".
- The SDD shall follow IEEE 1016-1987 "IEEE recommended Practice for Software Design Descriptions".
- Test Documentation shall follow IEEE 829-1983 "IEEE Standard for Software Test Documentation".

00870 Wherever possible the reviewing process shall follow MIL-STD-1521B "Technical Reviews and Audits for Systems, Equipments and Computer Software"

3.4.2 Hardware Limitations

00875 The hardware used shall be based on the work products of the *Standard Instrument Controller* being performed by Andrew Johnson/RGO.

3.5 ATTRIBUTES

3.5.1 Availability

00880 In order to meet the 2% downtime requirement, the MCS must have a hich availability. This translates to engineering requirements to be able to retrv failed operations, operate with some subsystems inactive (if not needed) etc.

3.5.2 Security

When the MCS is in Engineering Mode and beina controlled by an operator stationed at the MCS OPI located at the mount base most other accesses will be disallowed by use of the channel access security mechanism available in EPICS R3.12 and above. For monitoring and logging purposes channel access reads from the MCS database of selected process variables will be allowed.

The MCS must only accept channel access writes from machines on its "local net"

3.5.3 Maintainability

It is a goal that 85% of all failures be detected through built in test; this means that the MCS must have built in tests that can be:

a) run continuously to test system,
b) run periodically to test specific parts,
c) run in the background to check svstem health.

3.6 OTHER REQUIREMENTS

00890 The MCS shall be able to be run in a standalone mode with all other peer systems and master systems disconnected or turned off.

00900 The MCS shall respond to some kind of watchdog from the TCS so the TCS can tell if the MCS is alive or not.

4. APPENDICES

4.1 APPENDIX A - Requirements Cross Reference

PRS Req. No.	- REFERENCE
00010	- Gemini SDD §14.5.1
00020	- Gemini SDD §14.5.2.3
00030	- New
00040	- Gemini SDD §14.5.2.1
00050	- Gemini SDD §14.5.2.1
00060	- Gemini SDD §14.5.1
00070	- Gemini SDD §14.5.1.1
00080	- New
00090	- New
00110	- Gemini SDD §14.5.2.1
00120	- New
00130	- Gemini SDD Table 14-3
00140	- Gemini SDD Table 14-3
00150	- Gemini SDD Table 14-3
00160	- Gemini CDR VI §6.3.3.1
00170	- Gemini CDR VI §6.3.3.3
00180	- Gemini CDR VI §6.3.3.1
00190	- Gemini SDD §14.5.5.1
00200	- Gemini SDD Table 14-4
00210	- Gemini SDD §14.5.2.3
00220	- Gemini SDD §14.5.2.3
00230	- New
00240	- New
00250	- New
00260	- Gemini SDD §14.5.2.3
00270	- Gemini SDD §14.5-2.3
00290	- Gemini SDD §14.5.2.3
00300	- Gemini SDD Table 14-4
00310	- Gemini SDD Table 14-4
00315	- Gemini SDD Table 14-4
00320	- Gemini SDD Table 14-4
00325	- Gemini SDD §14.5.5.1
00330	- Gemini SDD Table 14-4
00340	- Gemini SDD Table 14-4
00350	- Gemini SDD §14.5.4.5
00360	- New
00370	- New
00380	- New
00390	- New
00400	- Gemini SDD §14.5.4.5
00410	- New
00420	- New
00430	- New
00440	- New
00445	- New
00450	- New

PRS Reg. No.	- REFERENCE
00470	- New
00480	- New
00490	- Gemini SDD Table 14-8
00500	- New
00510	- Gemini CDR VI §6.3.6
00520	- Gemini SDD §14.5.6
00530	- Gemini SDD §14.5.6
00540	- Gemini SDD §14.5.6
00550	- New
00560	- New
00570	- New
00580	- Gemini SDD Table 14-8
00590	- Gemini SDD Table 14-8
00610	- Gemini SDD Table 14-9
00615	- Gemini SDD Table 14-9
00620	- New
00630	- New
00640	- New
00650	- New
00660	- New
00670	- Gemini SDD Table 14-9
00680	- Gemini SDD Table 14-9
00690	- New
00700	- New
00710	- New
00730	- New
00740	- New
00750	- New
00760	- Gemini SDD §14.3.2
00770	- Gemini SDD §14.3.3.1
00780	- Gemini SDD §14.3.3.2
00790	- Gemini SDD §14.3.3.3
00800	- Gemini SDD §14.5.2
00805	- New
00810	- Gemini SDD §14.3.1.1
00820	- Gemini SDD §14.3.1.1
00830	- Gemini SDD §14.3.1.1
00840	- Gemini SDD §14.3.1.2
00845	- New
00850	- MCS Work Scope
00860	- MCS Work Scope §3
00870	- MCS Work Scope §3
00875	- MCS Work Scope §3.1 (c)
00880	- New
00890	- New
00900	- New

00460 - New

MCS SDR WORK PRODUCTS

- Project Gantt Chart
- Work Breakdown Structure
- MCS Costing + Equipment List
- Ward + Mellor Environmental Model:
    - ◊ Context Diagram
    - ◊ Event & Response List
- Document List