Visible & Infrared Survey Telescope for Astronomy

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Change Record

Issue	Date	Section(s) Affected	Description of Change/Change Request Reference/Remarks
1.0 2.0	08/08/03 08/20/03	All Table 4.2.C	First Issue Axis Limits, per RID No. TELS_PDR_29
2.0 2.0	08/20/03 08/20/03	4.2.2.4 4.2, Table 4.2.2.2.B and C	Regeneration Cabinet, per RID No. TEL_PDR_24 AZ/ALT Initialisation, per RID No. TELS_PDR_40
2.0	08/20/03	Table 4.2.2.2.B and C, Table 4.2.2.3.B	PDU to LCU Interface, per RID No. TELS_PDR_51
2.0	08/20/03	4.2.2.7 Table	Corrected power supply vendor and part number
2.0	08/20/03	3	Added AD10 reference
2.0	08/20/03	4.2.1	Revised LVD & EMC Table
3.0	08/28/03	4.2.2.1.9	Per TELS_PDR_79 RID, meaning of "disable" has been clarified.
3.0	08/28/03	4.2.2.1.13	Per TELS_PDR_80 RID, LCU Mode section has been amended.
3.0	08/28/03	4.2.2.9	Per TELS_PDR_38 RID, the PMU section has been amended.
3.0	08/28/03	4.2.2.2	Per TELS_PDR_82 RID, correction to show that the Alt rate feedback is the derivative of encoder feedback
3.0	08/30/03	4.2.2.2	Per TELS_PDR_105 RID, added Preload Scheme Plot
3.0	08/30/03	Table 4.2.C	Per TELS_PDR_123 RID, AD03 calculations changed. AD03 updated values are updated here.
3.0	08/31/03	Table 4.2.C	Per TELS_PDR_104 RID, AD03 calculations changed. AD03 updated values are updated here.
3.0 3.0	08/31/03 08/31/03	4.3.2 Table 4.2.2.2.B and C, Table 4.2.2.3.B	Per TELS_PDR_89 RID, the Altitude encoder-sitting circumference updated. Added Single Motor message per RID No. TELS_PDR_88
3.0	09/15/03	Table 4.2.2.2.B and C, Table 4.2.2.3.B	PDU to LCU Interface, per RID No. TELS_PDR_51 Contractor's comments
3.0	09/15/03	4.2.2.2	AZ Bearing Lube Pump description, per RID No. TELS_PDR_22
3.0	09/15/03	4.2, 4.2.2.2, 4.2.2.3	Proposed LCU Interface change per RID No. TELS_PDR_40
3.0	09/15/03	4.2.2.2, 4.2.2.3, 4.2.2.6	Deletion of Overspeed Detection Unit on AZ and CASS axis (RID no. TELS_PDR_85 Contractor's Updated Response)
3.0 3.0	09/16/03 09/17/03	4.2, 4.2.2.1, 4.2.2.9 Figure 4.2.A	Per RID No. TELS_PDR_55, moving MCU and PMU to an Appendix Updated Figure 4.2.A
4.0 5.0	03/17/04 05/27/04	ALL Signature Block	Extensive Revision to Include Final Design Changes Per TELS_FDR1_038, modified signature block signees
5.0 5.0	05/27/04 05/27/04	4.2.1 Various	Per TELS_FDR1_039, clarified "Activate" terminology Per TELS_FDR1_040, re-organized doc
5.0	05/27/04	4.2.5.16	Per TELS_FDR1_041, added AD11 and corrected wording for Anemometer interfaces
5.0	05/27/04	4.2	Per TELS_FDR1_043, reworded function of MCU & PMU
5.0	05/27/04	4.2.8 (new)	Per TELS_FDR1_048, added para on break-out boxes
5.0	05/27/04	4.2.4.8, 4.2.5.14	Per TELS_FDR1_087, added Intlk signal to list and

			corrected typo
5.0	05/27/04	Various	Per TELS_FDR1_099, changed from Stow Pin Extended to Stow Pin Engaged
5.0	05/27/04	4.2.5.16	Corrected part number for anemometers
5.0	05/27/04	4.3.2, 4.3.3	Updated Alt and CASS Encoder Tape calculations
5.0	05/27/04	4.2.2	Updated MCS Performance summary table per the updated ADs

Table of Contents

1 Introduction

This Design Report summarises the design features of the Vista Mount Control System for all contract items subject of this contract. This Design Report addresses every applicable requirement specified in the AD01 Technical Specification to the item that is the subject of this Design Report.

2 Acronyms and Abbreviations

ALT	Altitude axis
AM	Amplitude Modulation
AZ	Azimuth axis
AZ/ALT PDU	Azimuth/Altitude Power Drive Unit
CASS	Cassegrain Rotator axis
CASS PDU	Cassegrain Power Drive Unit
CB	Circuit Breaker
CCU	Central Control Unit
CCW	Counter Clockwise
CW	Clockwise
CFE	Customer Furnished Equipment
DAC	Digital to Analogue Converter
DAQ	Data Acquisition Unit
DSP	Digital Signal Processor
DVM	Digital Volt Meter
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
EU	European Union
FOG	Fiber Optic Gyroscope
LCD	Liquid Crystal Display
LCU	Local Control Unit
LVD	Low Voltage Directive
LVDT	Linear Variable Differential Transformer
MCU	Mount Control Unit
MCS	Mount Control System
MTBF	Mean Time Between Failures
PMU	Portable Maintenance Unit
PWB	Printed Wiring Board
TFT	Thin Film Transistor
VER	VertexRSI
VIS	VISTA
VISTA	Visible and Infrared Survey Telescope for Astronomy
VPO	VISTA Project Office
TRE	Technical Report

3 Applicable and Referenced Documents

In this section all the documents referred to in the Design Report shall be listed.

	Title	Number & Issue
AD01	Technical Specification for the Telescope Structure Work-Package	VIS-SPE-ATC-01000-0006 Issue 3.0
AD02	Statement of Work for the VISTA Telescope Work Package	VIS-SOW-ATC-01000-0005 Issue 2.0
AD03	Motor and Brake Sizing Analysis Report	VIS-ANA-VER-01001-9003 Issue 4.0
AD04	Pointing and Tracking Analysis Report	VIS-TRE-VER-01001-9001 Issue 2.0
AD05	VISTA Control System & M1 Mirror Support Reliability and Availability Analysis Report	VIS-ANA-VER-01001-9004 Issue 3.0
AD06	Interface Control Document between the Electro-mechanical Hardware and the VISTA Control System	VIS-ICD-ATC-01000-0007 Draft Version 9.3
AD07	VLT Electronic Design Specification	VLT-SPE-ESO-10000-0015 Issue 5.0
AD08	Control System Power Budget Analysis Report	VIS-ANA-VER-01001-9005 Issue 4.0
AD09	VISTA Telescope Control System Simulation	VIS-ANA-VER-01001-9009 Issue 2.0
AD10	Electromagnetic Compatibility and Power Quality Specification, Part 2, Electromagnetic Disturbance Emission and Immunity Limits of Electric and Electronic Equipment	VLT-SPE-ESO-10000-0003 Issue 1.0

4 Design Report

4.1 Scope

This design report will summarise the design features of all of the sub-assemblies that comprise the Vista MCS in enough detail to demonstrate compliance with the technical specifications, AD01.

4.2 Design Description

The following Vista Cable Diagram, Figure 4.2.A, VPO drawing number VIS-DWG-VER-01001-9004, shows the equipment that comprises the VISTA Mount Control System. It denotes what is to be provided by VertexRSI Controls Division, VertexRSI Structures Division and what is provided by CFE (VPO or others). The major sub-assemblies of the MCS are:

AZ/ALT Power Drive Unit (AZ/ALT PDU)
CASS Power Drive Unit (CASS PDU)
Regeneration Cabinet
Isolation Transformer
Data Acquisition System
Optical Incremental Tape Encoders
AZ, ALT and CASS Drive Motors and Brakes
Interlock Switches (Travel Limits, Stow switches, Emergency Stops, etc)
Mount Control Unit (MCU)
Portable Maintenance Unit (PMU)

The equipment will be located in the following areas:

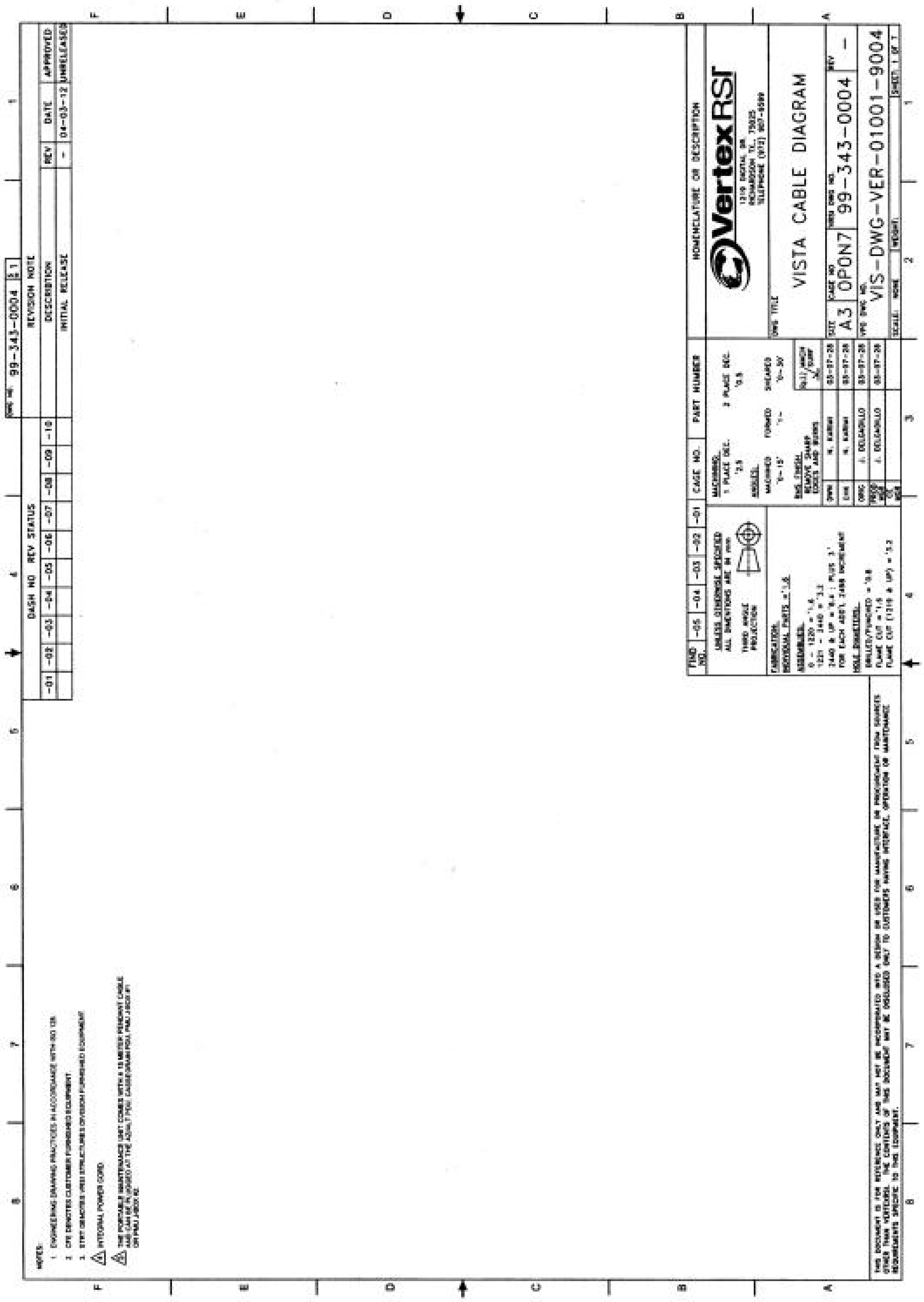
Equipment Room
- AZ/ALT PDU, CASS PDU, Regeneration Cabinet, Isolation Transformer
- MCU and Emergency Stop Panel – These units, along with the AZ, ALT and CASS LCUs will reside in the VertexRSI provided standard 19" equipment rack (**AD01 7.6, 11.1.1 spec**)

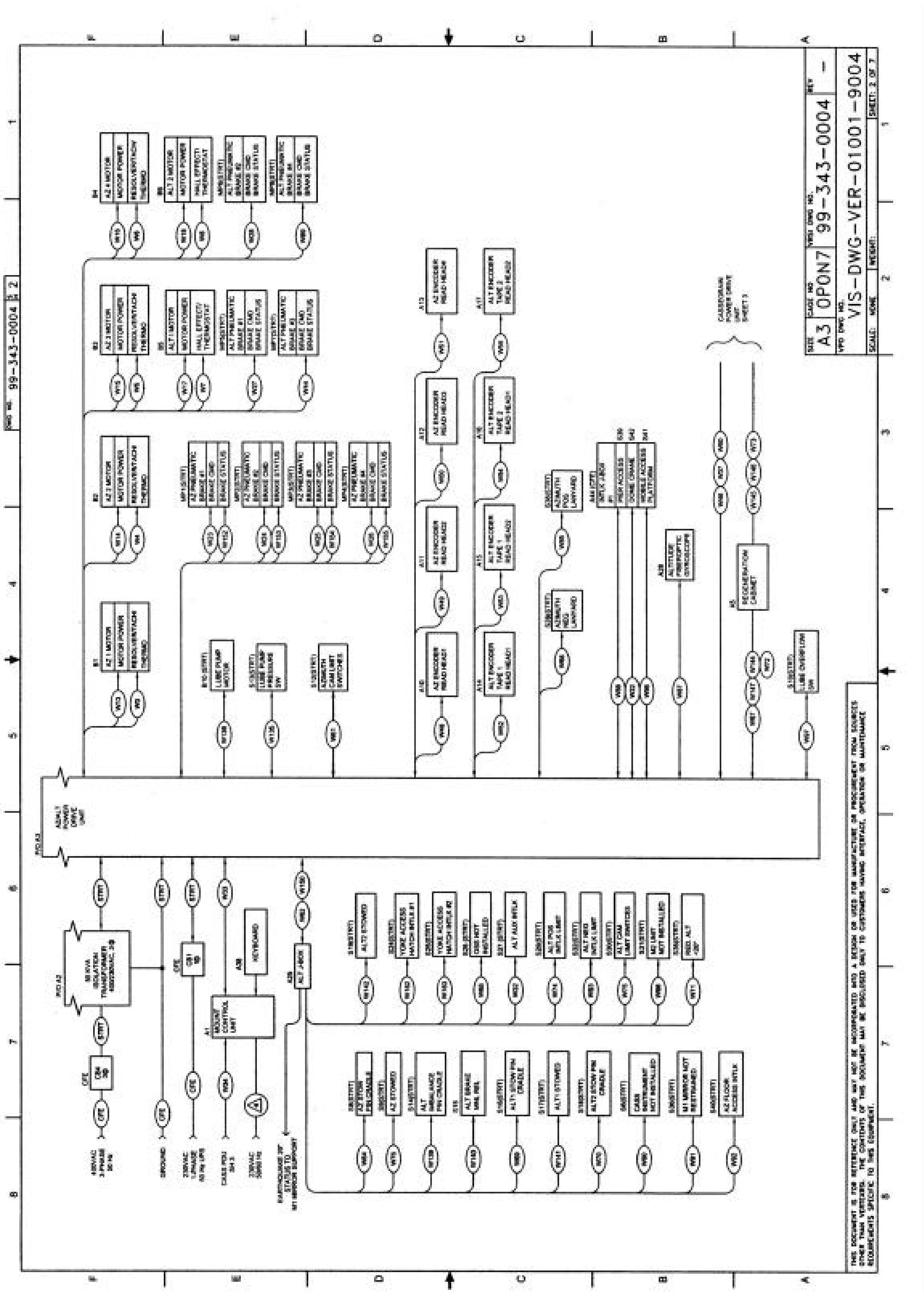
Inside Yoke Arm
- Data Acquisition Unit
- M1 Mirror Support LCU

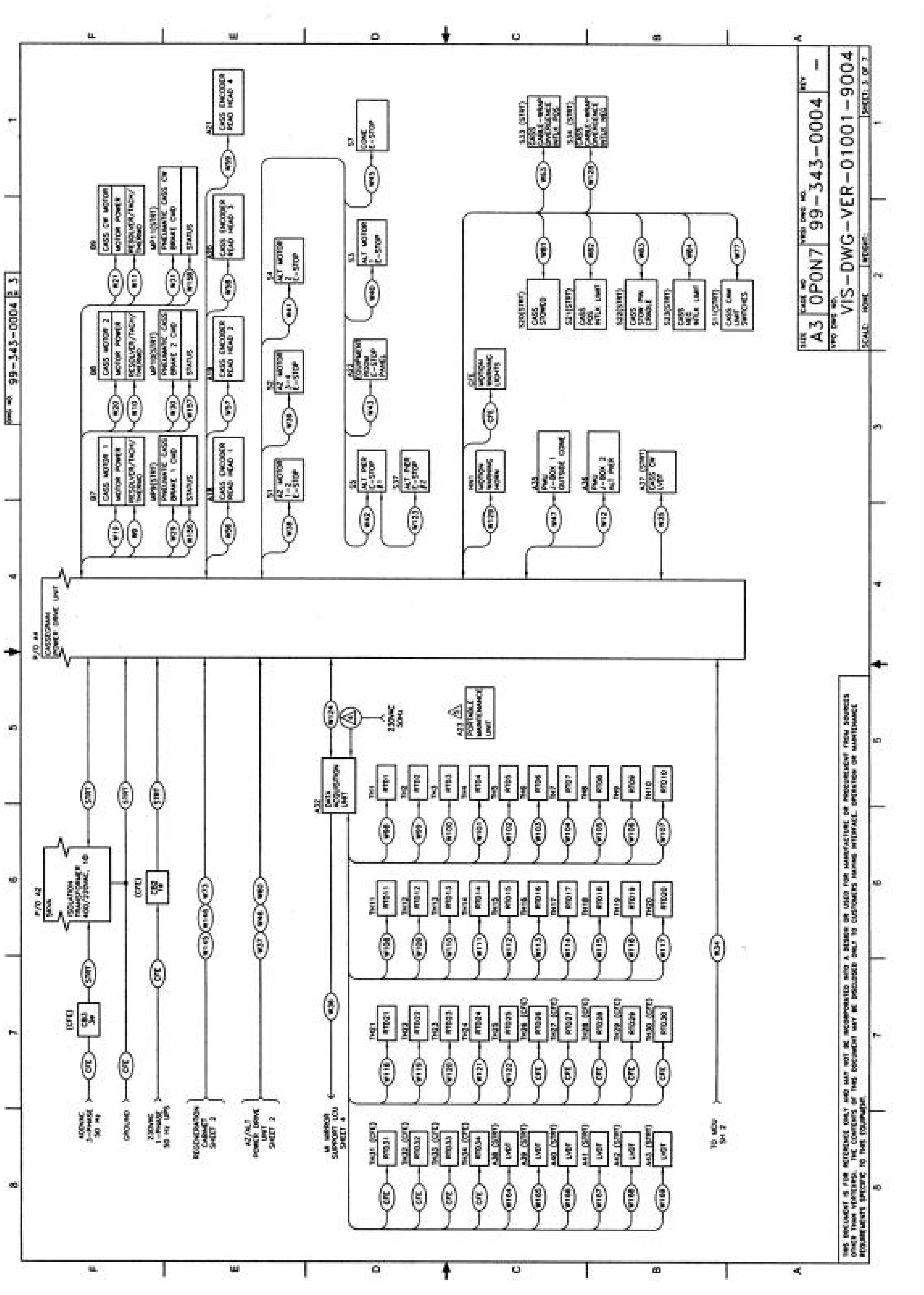
Pedestal Mount
- Remaining equipment

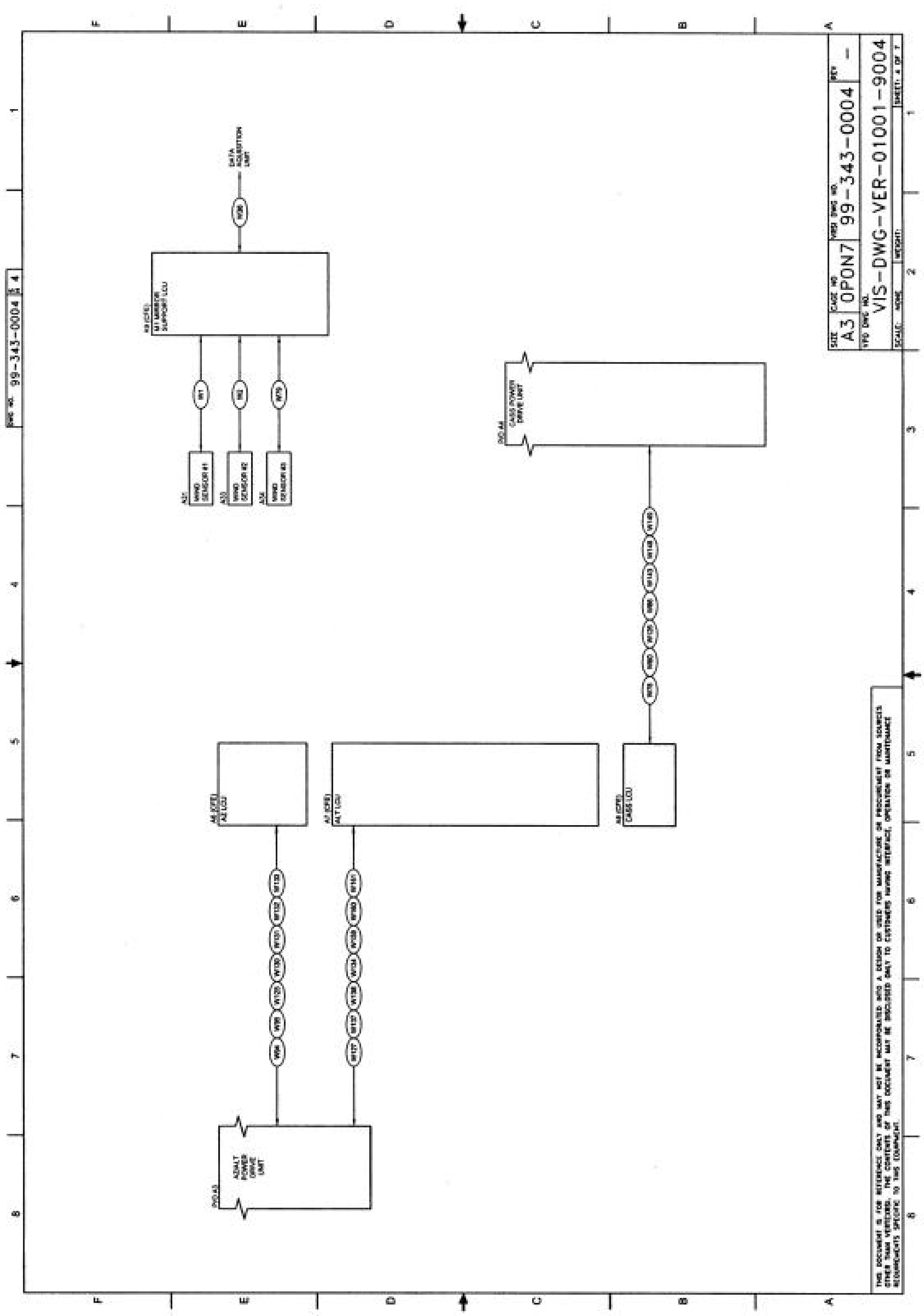
The MCU and the PMU are not part of the system being delivered to meet the requirements of AD01 and AD02, and thus can be considered as test equipment. For this reason the units' descriptions have been placed in Appendixes.

FIGURE 4.2.A – VISTA MOUNT CONTROL SYSTEM BLOCK DIAGRAM









A3
0P0N7
99-343-0004
VIS-DWG-VER-01001-9004

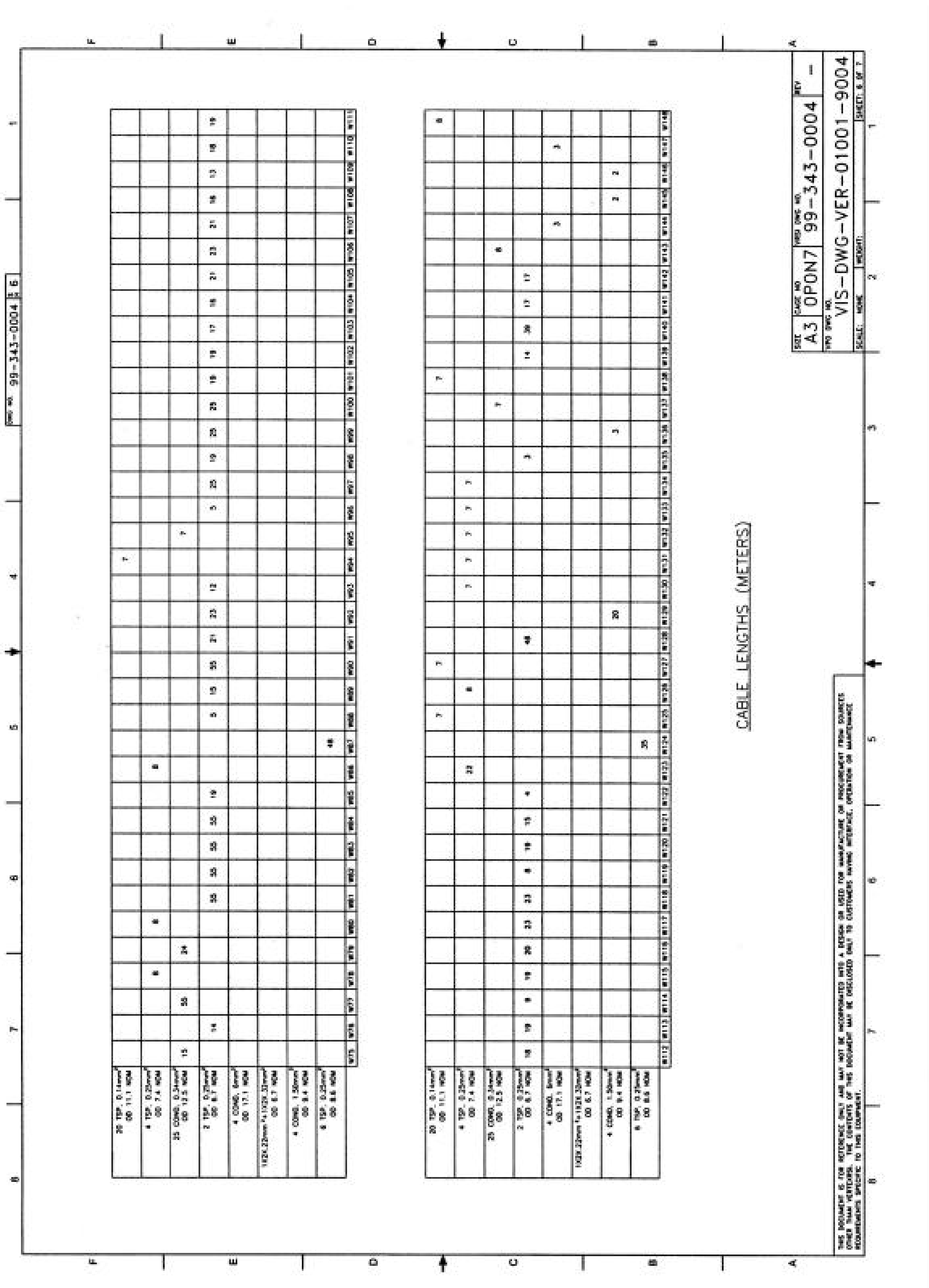
DWG NO. 99-343-0004 5

	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20	W21	W22	W23	W24	W25	W26	W27	W28	W29	W30	W31	W32	W33	W34	W35	W36	W37
20 TSP, 0.14mm^2 OD 11.1 NOM																																					
4 TSP, 0.25mm^2 OD 7.4 NOM																																					
25 COND, 0.34mm^2 OD 12.5 NOM	24	24										39																									2
2 TSP, 0.25mm^2 OD 6.7 NOM																						5	21	21	21	21	39	39	55	55	48	15	7	8	48		
4 COND, 6mm^2 OD 17.1 NOM													21	21	21	21	39	39																			
1X2X.22mm^2+1X2X.32mm^2 OD 6.7 NOM																																				10	
4 COND, 1.50mm^2 OD 9.4 NOM																			55	55	48																
6 TSP, 0.25mm^2 OD 8.6 NOM			21	21	21	21	39	39	55	55	48																										

	W38	W39	W40	W41	W42	W43	W44	W45	W46	W47	W48	W49	W50	W51	W52	W53	W54	W55	W56	W57	W58	W59	W60	W61	W62	W63	W64	W65	W66	W67	W68	W69	W70	W71	W72	W73	W74
20 TSP, 0.14mm^2 OD 11.1 NOM																																					
4 TSP, 0.25mm^2 OD 7.4 NOM	23	23	38	38	38	8		32			29	29	29	29	38	38	37	37	48	48	48	48															
25 COND, 0.34mm^2 OD 12.5 NOM									2	23													2	25	32												
2 TSP, 0.25mm^2 OD 6.7 NOM							15																			48	14	24	32		19	17	17	14	3	2	13
4 COND, 6mm^2 OD 17.1 NOM																														3							
1X2X.22mm^2+1X2X.32mm^2 OD 6.7 NOM																																					
4 COND, 1.50mm^2 OD 9.4 NOM																																					
6 TSP, 0.25mm^2 OD 8.6 NOM																																					

CABLE LENGTHS (METERS)

SIZE	CAGE NO	VRSI DWG NO.	REV
A3	0P0N7	99-343-0004	–
VPO DWG NO.	VIS-DWG-VER-01001-9004		
SCALE: NONE	WEIGHT:	SHEET 5 OF 7	



CABLE LENGTHS (METERS)
99-343-0004
VIS-DWG-VER-01001-9004
A3
0P0N7

DWG NO. 99-343-0004 SH 7

	W149	W150	W151	W152	W153	W154	W155	W156	W157	W158	W159	W160	W161	W162	W163	W164	W165	W166	W167
20 TSP, 0.14mm² OD 11.1 NOM	8																		
4 TSP, 0.25mm² OD 7.4 NOM											7	7	7			16	16	21	21
25 COND, 0.34mm² OD 12.5 NOM		32																	
2 TSP, 0.25mm² OD 6.7 NOM				21	21	21	21	56	56	46				11	11				
4 COND, 6mm² OD 17.1 NOM																			
1X2X.22mm² + 1X2X.32mm² OD 6.7 NOM																			
4 COND, 1.50mm² OD 9.4 NOM																			
6 TSP, 0.25mm² OD 8.6 NOM																			

	W168	W169	W170	W171	W172	W173	W174	W175	W176	W177	W178	W179	W180	W181	W182	W183	W184	W185	W186	TOTAL
20 TSP, 0.14mm² OD 11.1 NOM																				44
4 TSP, 0.25mm² OD 7.4 NOM	21	21																		885
25 COND, 0.34mm² OD 12.5 NOM																				321
2 TSP, 0.25mm² OD 6.7 NOM																				1881
4 COND, 6mm² OD 17.1 NOM																				171
1X2X.22mm² + 1X2X.32mm² OD 6.7 NOM																				10
4 COND, 1.50mm² OD 9.4 NOM																				183
6 TSP, 0.25mm² OD 8.6 NOM																				401

CABLE LENGTHS (METERS)

SIZE	CAGE NO	VRSI DWG NO.	REV
A3	0P0N7	99-343-0004	–
VPO DWG NO.	VIS-DWG-VER-01001-9004		
SCALE: NONE	WEIGHT:	SHEET: 7 OF 7	

Connectorized interconnection cabling will be provided for the MCS, including the cabling for the LCUs (AZ, ALT and CASS) **(AD01 11.1.1 spec).** The interconnection cables, as well as the hook-up cables (internal to the subassemblies) will be halogen free **(AD07 4.3.1.3.1 spec)**, and in conformance with the applicable DIN, VDE, IEC standards for cable construction and tests. The signal cables will be colour coded per DIN 47100 **(AD07 4.3.1.3.1 spec)**. The power cable conductors (1.5 mm^2 - 6 mm^2) will have black colour insulation marked with white numbers which identifies the conductor. The mains power hook up cables inside the subassemblies will be colour coded per DIN VDE 0293 as follows:

ϕ A	Black
ϕ B	Brown
ϕ C	Black
3ϕN	Blue
3ϕG	Yellow/Green
1ϕL	Brown
1ϕN	Blue
G	Yellow/Green

The AZ/ALT and the CASS PDU signal and low power connectors will be the MIL-C-38999, Series III type which offers the highest performance capabilities. The high power connectors will be the MIL-C-5015 type. EMI/RFI connector back-shells will be used (Mil Standard M85049) to provide excellent grounding of the cables' overall shield. This will provide excellent attenuation of any radiated emissions.

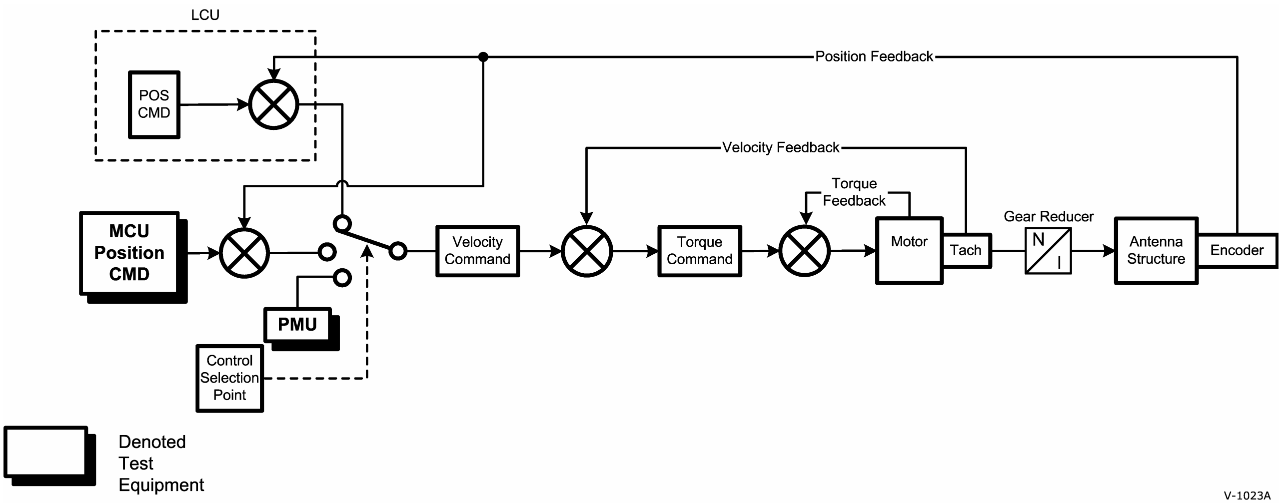
4.2.1 Mount Control System Control Loops/Points of Control

Figure 4.2.B, VISTA Control Loop Block Diagram, shows in block diagram format, the VISTA nested loops: Position, Rate and Current (Torque). The block diagram also depicts the three points of control for the mount: LCU, MCU and PMU. Since the MCU and PMU are not part of the system being delivered to meet the requirements of AD01 and AD02, these units can be considered test equipment.

As can be seen from Figure 4.2.B, when the MCU is in control, it issues Position Commands, when the LCU is in control it issues Velocity Commands, and when the PMU is in control it issues Velocity Commands.

By default, the LCUs will be offered control of the system. Once a unit takes control, the off-line units cannot acquire control until the on-line unit relinquishes control. A manual, mechanical switch in the AZ/ALT and in the CASS PDU will be used to Activate (allow the LCUs to take control of the mount) the LCUs. Once in control of their respective axis, LCU motor enables/disables and rate demands can be successfully issued independently. When the switch is placed to the alternate position, the LCUs relinquish control of the mount.

FIGURE 4.2.B – VISTA CONTROL LOOP BLOCK DIAGRAM



4.2.2 MCS Performance Summary

Following is a summary of mount performance requirements:

TABLE 4.2.C - Performance Requirements

AD01 Spec	VISTA SPECIFICATION	MCS CAPABILITY
8.3	**Axis Velocities and Accelerations** AZ Velocity +/- 2°/sec ALT Velocity +/- 2°/sec CASS Velocity +/- 3.6 °/sec AZ Acceleration +/- 0.5 °/sec^2 ALT Acceleration +/- 0.5 °/sec^2 CASS Acceleration +/- 1.0 °/sec^2	(Refer to AD03) AZ Velocity +/- 2°/sec ALT Velocity +/- 2°/sec CASS Velocity +/- 3.6 °/sec AZ Acceleration +/- 1.0 °/sec^2 ALT Acceleration +/- 1.0 °/sec^2 CASS Accel +/- 2.5 °/sec^2
8.5.2	**Open Loop Tracking** 0.10 arcsec rms over 15 secs 0.25 arcsec rms over 5 min	(Refer to AD04) 0.070 arcsec rms over 15 sec 0.217 arcsec rms over 5 min

AD01 Spec	VISTA SPECIFICATION	MCS CAPABILITY
8.4.2	**Quasi Static Pointing Error** Non-Repeatable Full Sky < 1.0 arcsec rms 0.17 deg < 0.1 arcsec rms 2 deg < 0.25 arcsec rms 60 deg < 0.5 arcsec rms Total Full Sky < 15 arcsec rms 0.17 deg < 0.1 arcsec rms 2 deg < 0.5 arcsec rms 60 deg < 8 arcsec rms	(Refer to AD04) Non-Repeatable 0.460 arcsec rms 0.087 arcsec rms 0.154 arcsec rms 0.460 arcsec rms Total 28.0arcsec rms 0.117 arcsec rms 1.02 arcsec rms 23.2 arcsec rms
10.5.2	**Cass Tracking Requirements** Non-Repeatable Full Sky 9.3 arcsec rms 60 deg 1.2 arcsec rms Total Full Sky 31 arcsec rms	(Refer to AD04) Non-Repeatable 0.68 arcsec rms 0.68 arcsec rms Total 10.02 arcsec rms
11.1.4.1 11.1.6	**100 % CASS Motor Overhead** **Encoder Resolution** Azimuth < 0.01 arcsec Altitude < 0.01 arcsec Cass < 0.015 arcsec	(Refer to AD03) 224 % (Refer to Calculation's Section 4.5) Azimuth 0.003 arcsec Altitude 0.002 arcsec Cassegrain 0.003 arcsec
11.1.8.1	**Axis Limits** Vicinity AZ Not Specified ALT Not Specified CASS Not Specified Pre-Interlock AZ +140°, -320° ALT -1°, 91° CASS +188°, -368° Interlock AZ +144°, -324° ALT -2°, 92° CASS +192°, -372° End Stop AZ +148°, -328° ALT -4°, 94° CASS +196°, -376°	Vicinity AZ +140°, -320° ALT -1°, +91° CASS +188°, -368° Pre-Interlock AZ +141°, -321° ALT -2°, 92° CASS +189°, -369° Interlock AZ +142°, -322° ALT -3°, 93° CASS +190°, -370° End Stop AZ N/A ALT -5.8°, 96.8° CASS N/A

AD01 Spec	VISTA SPECIFICATION	MCS CAPABILITY
11.1.10	**Braking Deceleration** AZ 4°/s^2 to 60°/s^2 ALT 8°/s^2 to 60°/s^2 CASS 16°/s^2 to 120°/s^2	(Refer to AD03) AZ 13.9 °/s^2 ALT 5.9 °/s^2 CASS 74.9 °/s^2
13.2.1	**Overall Availability** > 363 nights/yr (99.45 %)	(Refer to AD05) 99.93 %
13.2.2	**MTBF** 3 years	(Refer to AD05) 8.8 months

4.2.3 EU Electromagnetic and Safety Compatibility

The MCS will be compliant to the EU Council EMC (89/336/EEC) and Low Voltage Directives (73/23/EEC). Testing to the following standards and limits will show compliance to the EU Directives. The VLT AD10 limits will be a design goal, but compliance will be limited to the MCS stated limits.

TABLE 4.2.1 LVD & EMC Test Standards & Limits

STANDARD	TITLE	MCS LIMITS	AD10 LIMITS
EN 50081, Part 2	Electromagnetic Compatibility – Generic Emission Standard Part 2: Industrial Environment **(Class A)**	**CONDUCTED** 0.15 – 0.5 MHz QP 79, AVG 66 dBµV 0.5 – 30 MHz QP 73, AVG 60 dBµV **RADIATED (@ 10 m)** 30 – 230 MHz 39.5 dB(µV/m) 230 – 1000 MHz 46.5 dB(µV/m)	**CONDUCTED** 0.15 – 0.5 MHz 66-56 dBµV QP 0.5 – 5 MHz 56 dBµV QP 5 – 30 MHz 60 dBµV QP **RADIATED (10m)** 30 – 230 MHz 30 dB(µV/m) 230 – 1000 MHz 37 dB(µV/m)
IEC 61000-4-2	Electromagnetic Compatibility – Part 4: Testing and Measurement Techniques – Part 2: Electrostatic Discharge (ESD) Immunity	**LEVEL 2** 4KV Contact Discharge **LEVEL 3** 8KV Air Discharge	**LEVEL 3** 6KV Contact Discharge 8KV Air Discharge
IEC 61000-4-3	Electromagnetic Compatibility – Part 4: Testing and Measurement Techniques – Part 3: Radiated Radio-Frequency, Electromagnetic Field Immunity Test	**LEVEL 2** 80 to 1000 MHz 80% AM @ 1KHz 3 V/m	**LEVEL 3** 80 to 1000 MHz 80% AM @ 1KHz 10 V/m
IEC 61000-4-4	Electromagnetic Compatibility – Part 4: Testing and Measurement Techniques – Part 4: Electrical Fast Transient Immunity	**LEVEL 2** 0.5KV on I/O Signal and Control Lines 1KV on PS Lines	**LEVEL 2** 0.5KV on I/O Signal and Control Lines 1KV on PS Lines
IEC 61000-4-5	Electromagnetic Compatibility – Part 4: Testing and Measurement Techniques – Part 5: Surge Immunity	**CLASS 2** Line to Earth 1KV Line to Line 0.5 KV	**CLASS 3** Line to Earth 2KV Line to Line 1 KV
IEC 61000-4-6	Electromagnetic Compatibility – Part 4: Testing and Measurement Techniques – Part 6: Immunity to Conducted Disturbances, Induced by Radio-Frequency Fields	**LEVEL 2** 150 KHz to 80 MHz 3 Vrms 80% Mod.	**Not Specified**
IEC 61000-4-11	Electromagnetic Compatibility – Part 4: Testing and Measurement Techniques – Part 11: Immunity Requirement, Voltage Dips, Short Interruption and Voltage Variation	30% reduction (10ms) 60% reduction (100 ms) >95% reduction (5 sec)	30% reduction,10ms 50% reduction,0.1s >95% reduction,5sec
EN 61000-3-2	Electromagnetic Compatibility Part 3: Limits-Section 2: Limits for Harmonic Currents Emissions (Equipment Input Current <= 16A/phase)	**Class A Limits** Refer to Standard	**Not Specified**
EN 61000-3-3	Electromagnetic Compatibility Part 3: Limits-Section 3: Limitation of Voltage Fluctuations and Flicker in Low Voltage Supply Systems for Equipment with Rated Current <= 16A	**Class A Limits** Refer to Standard	**Not Specifie d**

4.2.4 AZ/ALT Power Drive Unit

Refer to the following representative photograph (Figure 4.2.2.1.A) and block diagram (Figure 4.2.2.1.B) of the AZ/ALT Power Drive Unit.

4.2.4.1 AZ/ALT PDU Power Feeds

Two power feeds are utilized by the PDU. 230 VAC, 1ϕ technical power gets routed through the logic circuit breaker, a single phase EMI filter for attenuation of conducted emissions and to two universal input switching power supplies. The PDU logic power supply is a 100 W switching power supply that has multiple outputs for delivering logic power to the various PWBs and other components in the PDU. The encoder power comes from a 45W power supply that will deliver power to the 4 Azimuth and 4 Altitude tape encoder read-heads (AD01 11.1.6 g spec), to the Heidenhain Encoder Splitter boxes (IBV606) and to the Heidenhain Interpolator boxes (IBV660B). The Heidenhain IBV 606 Encoder Splitter boxes will be utilized to split the encoder read-head sinusoidal signals. One output will be dedicated for use by the AZ/ALT PDU. The second sinusoidal output will be routed over to the AZ and ALT LCUs.

The second power feed comes from the output of the VertexRSI provided isolation transformer, which is 230 VAC, 3ϕ, Y-configuration. The power goes through the motor controller power disconnects and into 6 individual 3-phase EMI filters feeding the Azimuth and Altitude motor controller power supplies. The motor controller power supplies use the 3ϕ voltages and convert it to a DC bus voltage that feeds the motor controllers.

4.2.4.2 AZ/ALT PDU Motor Controllers

The motor controllers, configured for Current (Torque) mode, are used to drive the four Azimuth and the two Altitude Brushless DC motors. For Azimuth, motor resolvers are used by the motor controllers for sinusoidal commutation **(AD01 11.1.4.1 spec).** For Altitude, at start-up, trapezoidal commutation is accomplished using the motor's Hall Sensors **(AD01 11.1.4.1 spec).** Automatic switchover to sinusoidal commutation is done once a Hall Sensor transition index is received. A/B Incremental signals used for ALT motor's sinusoidal commutation come from the output of the Heidenhain Interpolator box (IBV 660B). One interpolator box is used per motor controller. The IBV 660B Interpolator boxes convert the tape encoder read-head 1Vpp signal into incremental encoder signals with a 25-fold interpolation factor. This results in approximately 113,650 counts per motor pole pair.

Figure 4.2.2.1.A - AZ/ALT POWER DRIVE UNIT (Photo is Representative)

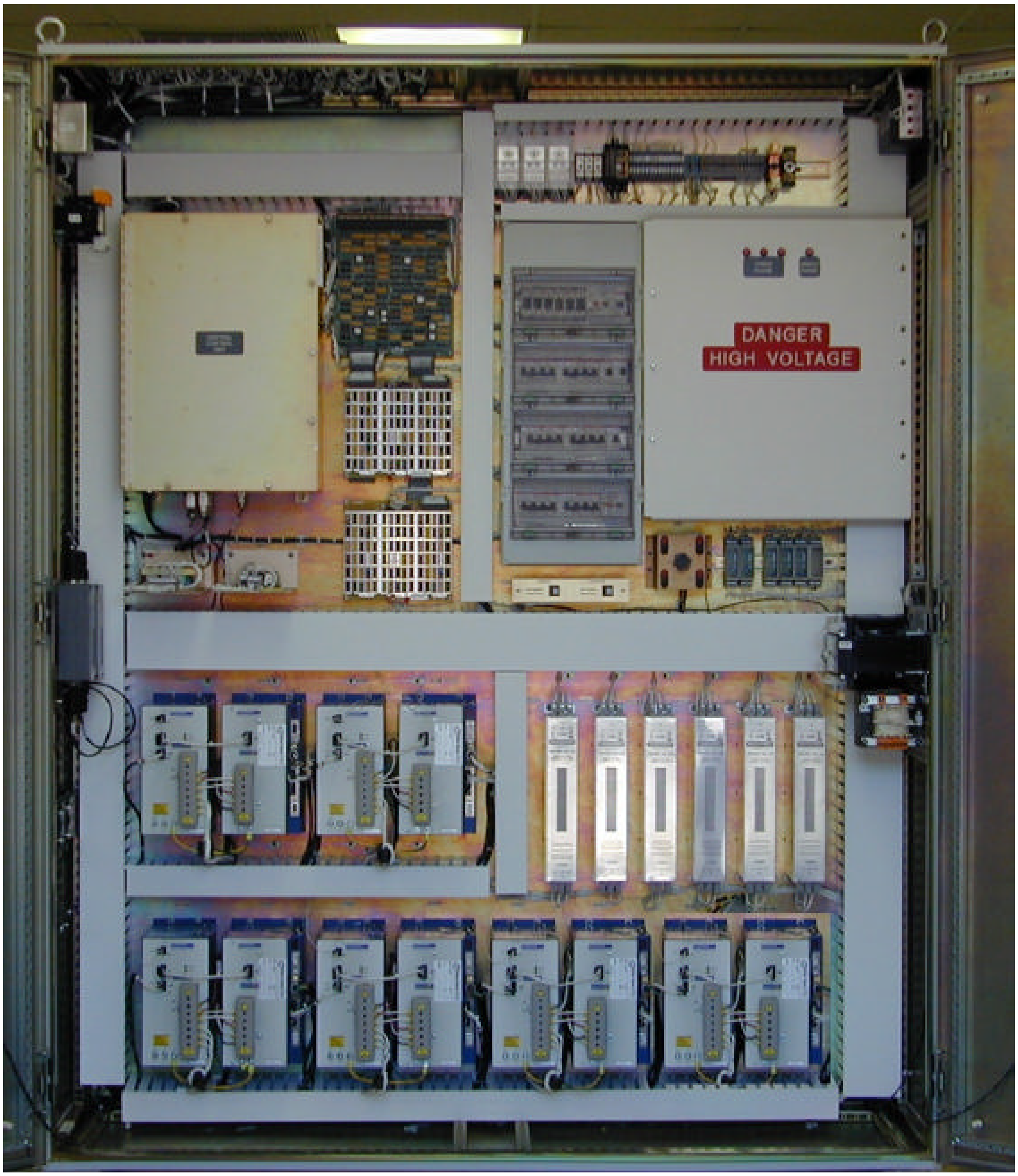
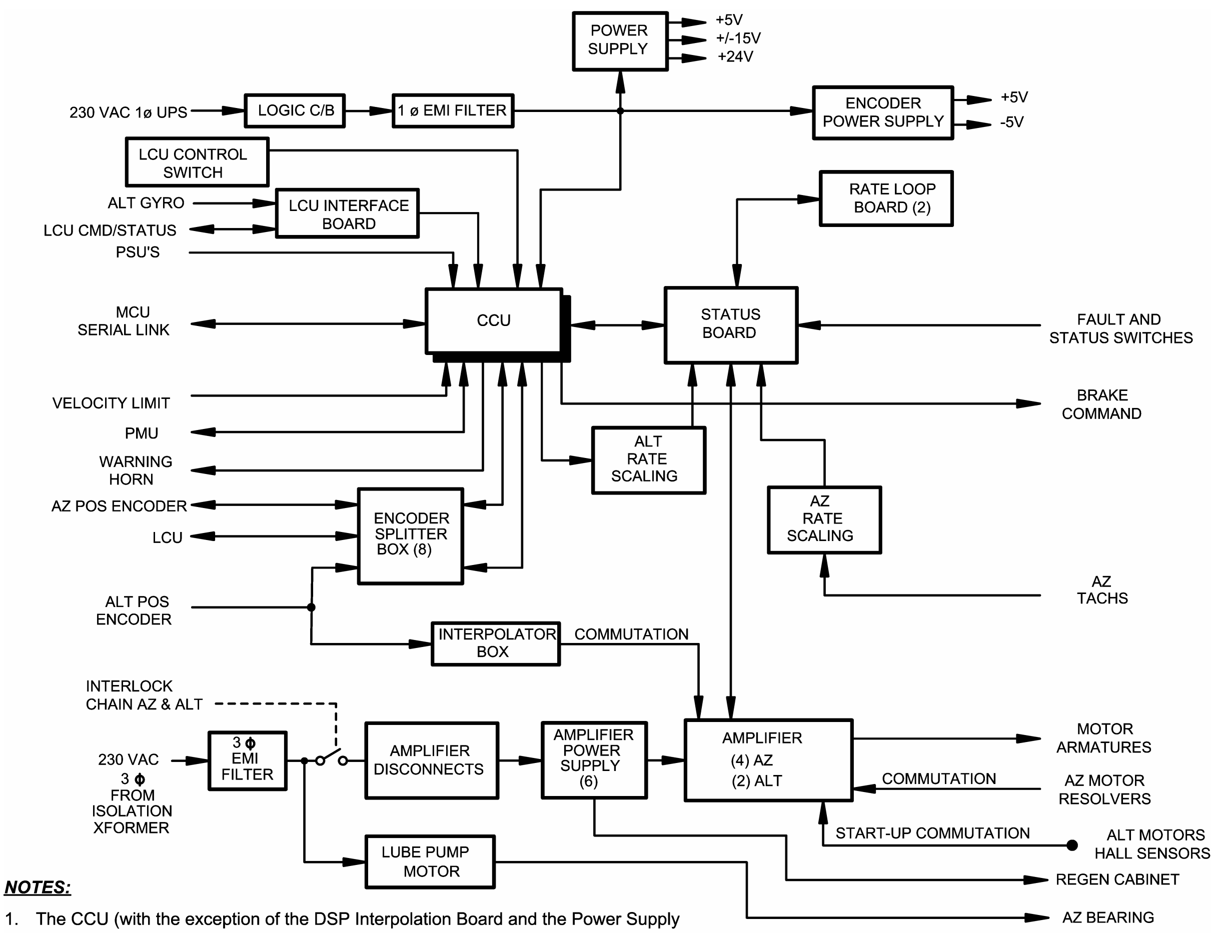


Figure 4.2.2.1.B - AZ/ALT PDU BLOCK DIAGRAM



NOTES:

1. The CCU (with the exception of the DSP Interpolation Board and the Power Supply that provides Logic Power to the DSP) is considered to be test equipment since it's not required to meet the specifications of AD01, AD02.
2. The Control Board is physically located in the CCU (mounted on the CCU door) but is totally electrically independent of the CCU.

Denoted Test Equipment

V-1015A

The motor controllers are matched to, and thus ideally compensated to the brushless DC motors that they drive. The current loop bandwidth of the motor controllers has been measured to be around 800 Hz, which would easily satisfy the demanding outer axis rate loops.

Resistive Regenerative units are connected to the motor controller power supply busses to dissipate the generated excess energy when the motors are being decelerated or back driven.

4.2.4.3 AZ/ALT PDU Lube System

The Azimuth bearing lube pump is energized from the AZ/ALT PDU. A pressure switch will detect and report a low-pressure fault. An overflow condition will be sensed by a level switch, which will report the fault. Both faults will be Disabling Faults of the Azimuth axis, but not of the lube pump motor power since the lube system has been designed to be ON at all times. Protection to the lube pump motor is provided via a thermal overload protection switch.

4.2.4.4 AZ/ALT PDU Status Board

The Status board provides extensive status and motor disabling capability. It interfaces to the AZ and ALT Rate Loop Boards, to the CCU Control Board and the motor controllers.

4.2.4.5 AZ/ALT Rate Loop Boards

The Rate Loop boards receive rate demands from the Status board and rate feedback from the motor tachometers (AZ)/CCU Digital Signal Processor (ALT) to close the rate loop. The Rate Loop boards generate current commands, torque bias (AZ only) and delta tach control (AZ only). Torque bias is used by the Azimuth axis to remove any backlash in the gear train by counter-torquing two motors against the other two (refer to Figure 4.2.2.1.C for the preload scheme plot). It can be seen that the preload type is a constant differential preload up until saturation level. The preload level will be approximately 25% of motor rated torque.

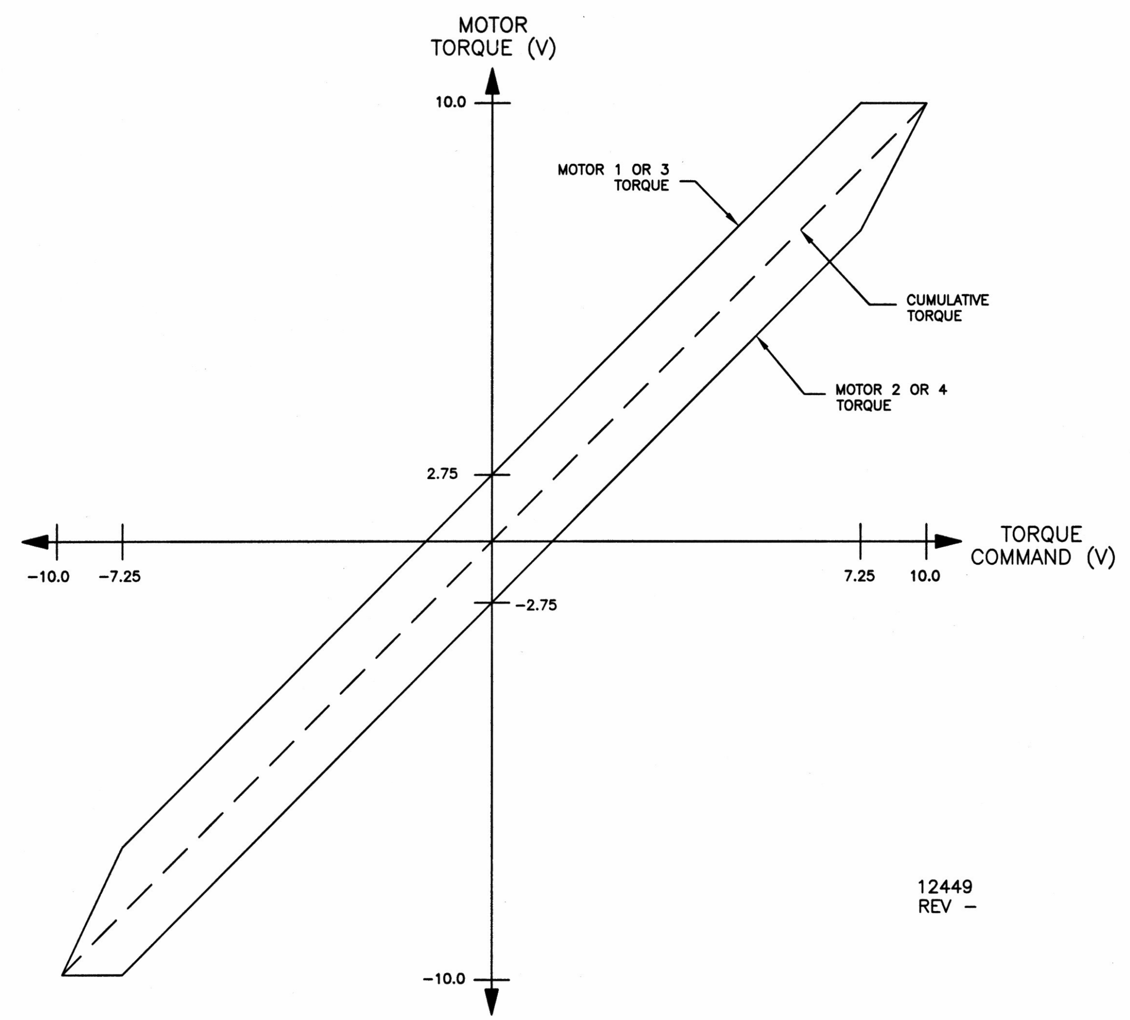
Delta tach circuitry ensures that motors run at the same speed, which results in load sharing.

The rate loop compensation is similar to that of the MCU Position Loop. However, the Rate Loop compensation will be set-up as a Type II Loop. The following break frequencies will be the starting point for the VISTA system.

Lag1	0.26 Hz
Lead	1.59 Hz
Lag2	19.03 Hz

During the integrated testing at Mexia, Texas, the optimal rate loop compensation will be determined.

4.2.2.1.C - Preload Scheme Plot



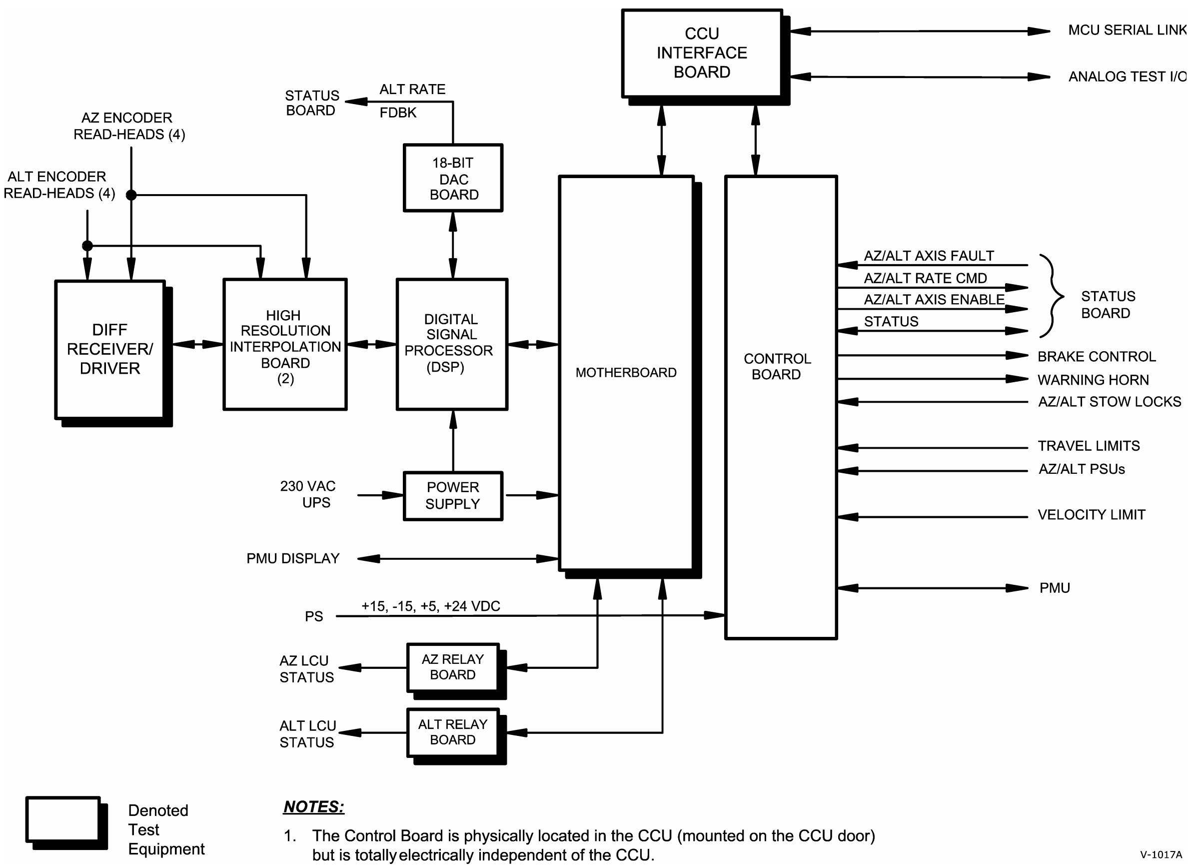
4.2.4.6 AZ/ALT Central Control Unit

Refer to the following AZ/ALT CCU Block Diagram, Figure 4.2.2.1.D. Only the CCU components that are required to meet the requirements of AD01 and AD02 are discussed in this section. The other components are considered test equipment and are discussed in Appendix C.

Logic Power is supplied to the off-the-shelf Pentium motherboard from a universal input 300W switching power supply. The power supply supplies power to the Digital Signal Processor and the DSP Accessory 8E (18-bit DAC) board.

The PDU Central Control Unit (CCU) houses the Digital Signal Processor and the DSP Accessory 8E (18-bit DAC) that are used to interface to the ALT Heidenhain Tape Encoder read-heads via the Heidenhain Encoder Splitter boxes (IBV606). The main function of the DSP is to produce the rate feedback information for the Altitude axis **(AD01 11.1.7 a spec)** via the 18-bit DAC board. The ALT rate feedback information, used to close the rate (velocity) loop is sent to the ALT Rate Loop board via the Status board. The rate feedback is the derivative of the tape encoder feedback. The software that produces the rate feedback resides in the DSP and is free running, meaning that once it has successfully booted, it doesn't depend on any condition for the algorithm to start producing velocity feedback signals. This ALT rate feedback signal is also provided to the ALT LCU for monitoring purposes. A DSP on-board relay is used to monitor the health of the DSP. When the PMAC has successfully booted-up and is operational, the relay is energized. If the DSP becomes "locked-up", the relay is de-energized. De-energizing of the relay results in the disabling of the ALT axis. A DSP Boot Failure would then get reported to the ALT LCU.

Figure 4.2.2.1.D - AZ/ALT PDU CCU BLOCK DIAGRAM



4.2.4.7 AZ/ALT Control Board

Although the Control board physically resides in the CCU, it is totally microprocessor and CCU independent. It provides an interface between the CCU computer (for monitoring purposes only) and external motor disabling connections to the mount structure.

The Control board receives rate commands and enable requests from the LCU, MCU or the PMU and generates directional enables, axis rates, brake release commands and status/faults to all control units. The Control board also contains the acceleration/deceleration limiting circuitry and the soft-stop circuitry that enables a controlled deceleration before applying the brakes (when not in an emergency stop condition).

4.2.4.8 AZ/ALT Interlocking

As dictated by **AD01 11.1.7 c spec,** if any of the following isolated contacts open, 3-phase power is removed from the azimuth and/or altitude motor controllers, and will independently remove the brake release command.

The Azimuth axis is composed of the following interlock chain:

Emergency Stops (AZ Motor 1-2, AZ Motor 3-4, Alt Motor 1, Alt Motor 2, Alt Pier, Equipment Room, and Cone E-stops)
AZ Positive/Negative Interlock Limit
AZ Stow Pin Engaged
AZ Overhead Dome Crane Interlock **(AD01 13.4.12 b spec)**
Yoke Access Hatch Interlock
AZ LCU Interlock
Pier Access Interlock
Mobile Access Platform Interlock

The Altitude axis is composed of the following interlock chain:

ALT Overspeed
Emergency Stops (AZ Motor 1-2, AZ Motor 3-4, ALT Motor 1, ALT Motor 2, ALT Pier, Equipment Room, and Cone E-stops)
ALT Positive/Negative Interlock Limit
ALT Stow Pin Engaged
ALT Auxiliary Drive Enabled Interlock **(AD01 11.1.12 spec)**
ALT Overhead Dome Crane Interlock **(AD01 13.4.12 b spec)**
ALT LCU Interlock
OSS Not Installed
CASS Instrument not Installed
M2 Unit not Installed
M1 Mirror Restraint Failure
Mobile Access Platform Interlock
AZ Floor Access Interlock

Per the requirements of AD07, the LCU should have the capability to turn ON and OFF power to the motor controllers. VertexRSI will partially comply with this requirement. It will be possible for the LCUs to remove power to the motor controllers by issuing an Interlock command, but when power needs to be restored (after clearing the fault condition), it would need to be done by manually turning on the tripped circuit breakers in the Power Drive Unit. By having the operator physically switching back ON the circuit breakers that tripped, it ensures that the operator is made aware of the problem that caused the Interlock chain to break so that the appropriate remedial action can be made in order to avoid the situation again. This is in line with VertexRSI's safety philosophy where software should not be allowed to clear a hardware condition. Furthermore, the design of the motor controller call out for resetting its Logic Power (single-phase) after an Under Voltage fault occurs (occurring after removal of 3-phase power). That means that the Logic Power to the amplifier has to be cycled and the 3-phase CB has to be turned back on in order to clear (close) an auxiliary switch that the control system is sensing to ensure that the motor controller is ready for operation. To clarify, not only does the Interlock Chain turn off power to the amplifiers but also an internal motor controller fault (ie overspeed, over-voltage, under-voltage, over-current etc) would result in removing 3-phase power to itself. Additionally, external interlock circuitry to the motor controller ensures that the proper powering sequence of the motor controllers is maintained.

It should also be mentioned, that regular activation (breaking) of the Interlock chain is highly not recommended since it compromises the reliability of the system. It's widely known that frequent cycling of power to electronic equipment drastically reduces the life of the equipment. Due to the reliability issue mentioned above, it's highly recommended that the Interlock chain not be broken except in emergency or maintenance conditions, as detected by the mount interlock switches (Emergency stops, Stow Pin Extended, etc).

A second set of the above Interlock contacts is routed over to the LCUs for monitoring purposes only. A third set of the Interlock contacts is fed to the PDU Control or Status board for fault reporting and axis disabling. This serves as an added safety level of protection, satisfying the operational safety spec of **AD01 13.4.11.**

4.2.4.9 Altitude Manual Drive System

The Altitude axis will have an Auxiliary Manual Drive System (**AD01 11.1.12 spec),** which will Interlock the direct drive motors upon activation. The detection method will be via a switch that senses that the Auxiliary Manual Drive System has been removed from its cradle position. This would break the Interlock chain and set the Altitude pneumatic brakes. While in Alt Auxiliary Drive mode, brake release command can only be accomplished by activation of the Alt Manual Brake Release momentary switch. This would ensure that a minimum of two persons are involved in the manual movement of the Altitude axis.

4.2.4.10 Altitude Imbalance

Since the Altitude axis has direct drive (no gearing between motors and axis) torquer motors, the Altitude axis is very susceptible to imbalance, a potential risk for personnel and/or hardware damage. In order to mitigate the risk, the following design has been implemented on the VISTA Mount Control System:

1. Stow cradles will be slotted to allow for a manual altitude imbalance check. When the Alt axis is stowed, the Alt axis manual brake release button can be actuated and a mechanical verification of the axis imbalance can be achieved.

2. An M2 Unit Not Installed switch will detect when the M2 mirror has been removed. If the M2 mirror if not present, the Alt axis will be Interlocked.

3. A Cassegrain Rotator Instrument not Installed switch will detect when the CASS has been removed resulting in the Interlocking of the Altitude axis.

4. An Optical Support Structure (OSS) switch will detect when the OSS has been removed. In this condition, the Altitude axis will be Interlocked.

The M1 Mirror Support system implements a scheme where the M1 Mirror is restrained when the ALT axis is below 20 degrees. For redundancy, two separate switches monitor the position of the ALT axis. If it is detected that the ALT axis is below 20° and the restraining system hasn't clamped the M1 Mirror, the Altitude axis is Interlocked.

4.2.4.11 AZ/ALT PDU EMC Treatments

The following AZ/ALT PDU design features will ensure that the discussed EU EMC standards are met:

Properly Shielded Conductive Gasketed Cabinets
Completely Connectorized PDU Enclosure
EMI/RFI Connector Bachshells
Properly terminated Shielded Cables
Motor Lead Ferrite Filters
1ϕ and 3ϕ EMI Filters

4.2.4.12 AZ/ALT PDU Major Subassemblies

The major subassemblies that make up the AZ/ALT PDU are listed below:

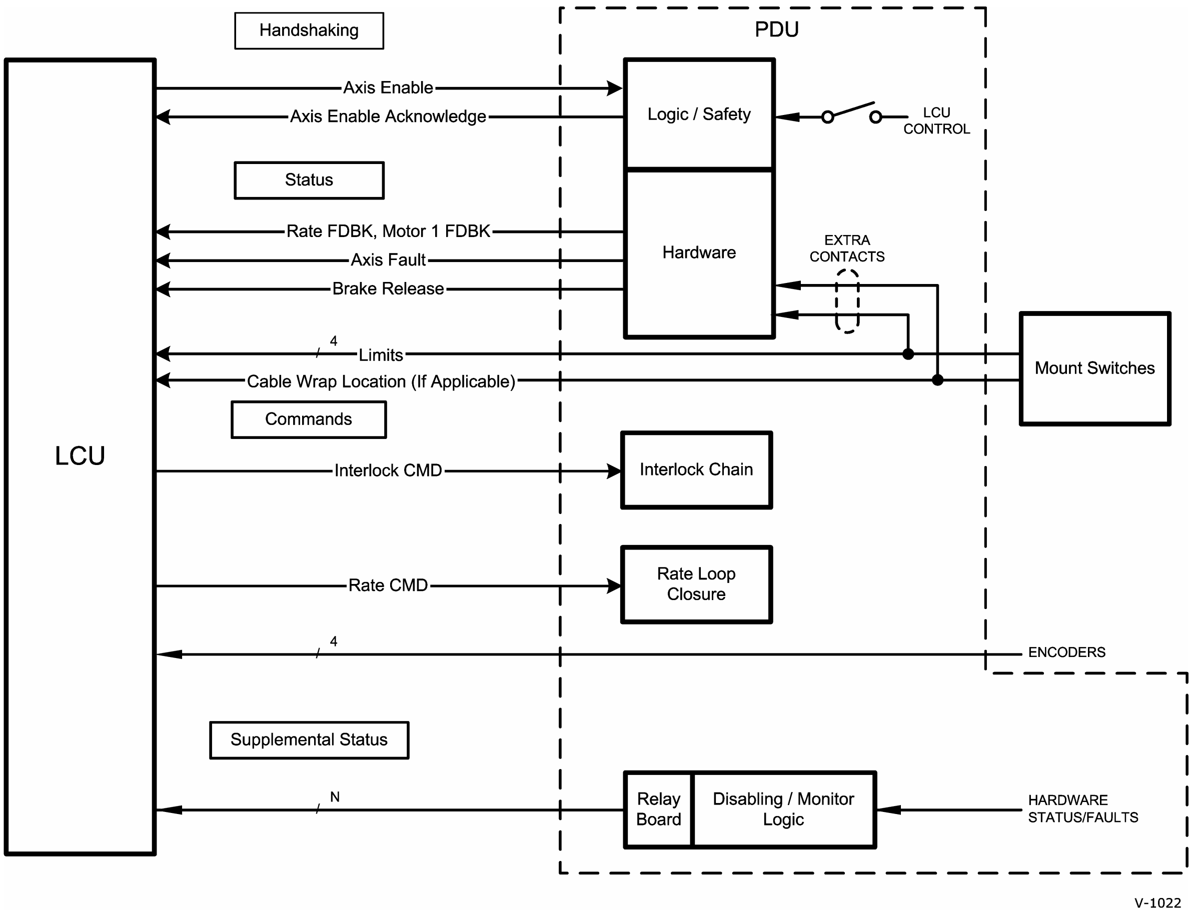
TABLE 4.2.2.1.A - AZ/ALT PDU Major Subassemblies

MANUFACTURER	MANUFACTURER PART NUMBER	DESCRIPTION
Kollmorgen Motion Technologies Group	SR30200 PA2800	Azimuth Motor Controller and Power Supply
Kollmorgen Motion Technologies Group Hoffman	SE30200 PA2800 PROLINE Series	Altitude Motor Controller and Power Supply AZ/ALT PDU Enclosure
Heidenhain	IBV660B	ALT Interpolator Box
Heidenhain	IBV 606	AZ/ALT Encoder Splitter Box
Integrated Power Design	SRW-100-4003	PDU Logic Power Supply
Integrated Power Design	SRW-45-2002	Encoder Power Supply
Finder	Various	Relays
Sprecher + Schuh	CS4C Series	Contactors
ABB Control Inc.	Various	Circuit Breakers
Schaffner	FN258-30/33	AZ/ALT 3ϕ EMI Filter
Schaffner	FN350-12/29	1ϕ EMI Filter
Entrelec Inc.	Various	Time Delay Relays
Wieland	DPST-8A/125	Power Switch
Shuttle Computer Group	G7VP2	CCU Motherboard
Delta Tau Delta Tau	Turbo PMAC2-PC Accessory 51P	DSP Card High Resolution Interpolator Card
Delta Tau	Accessory 8E	DSP DAC Accessory Bd
Antron	SP2-4300FB	CCU Power Supply

4.2.4.13 AZ/ALT LCU Interface

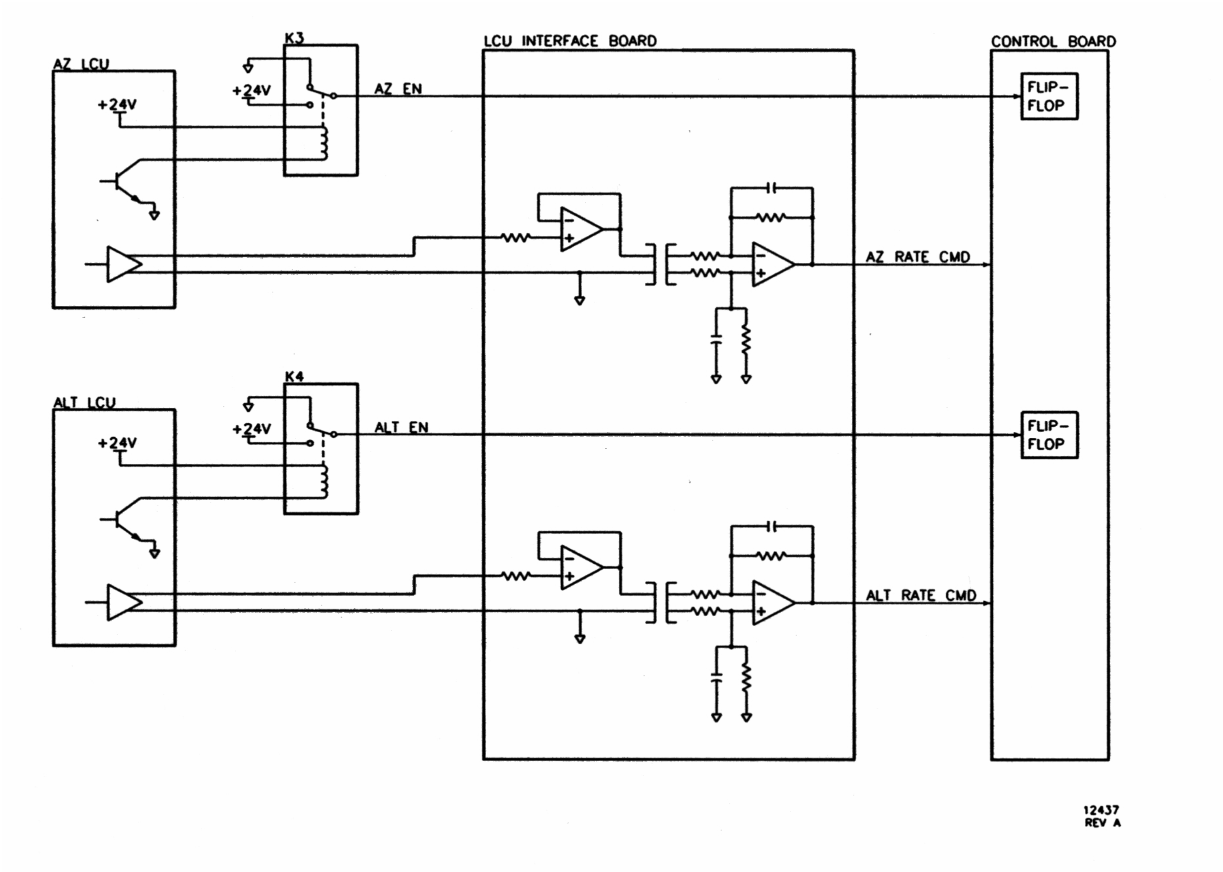
Refer to Figure 4.2.2.1.E, LCU Interface Block Diagram, it shows the handshaking, status, command and feedback information between the AZ/ALT PDU and to the AZ and ALT LCU. As mentioned earlier, the accepting/relinquishing handshaking is done from a manual, mechanical switch located in the AZ/ALT PDU. After the AZ/ALT LCUs have control of the mount, individual axis enables/disables can be issued independently.

Figure 4.2.2.1.E - LCU Interface Block Diagram



AD07 dictates that galvanic isolation is maintained between VertexRSI and LCU equipment. This is accomplished by the use of dry-contact closure for digital signals and the use of Isolation Amplifiers for analogue signals. Please refer to Figure 4.2.2.1.F - LCU Axis Control Logic Block Diagram. The LCU Interface board accepts a pulsed signal required by the Flip-Flop logic of the Control Board. Isolation Amplifiers will be used for the LCU-generated (rate commands) and the PDU-generated analogue signals (rate and current feedback).

Figure 4.2.2.1.F - LCU Axis Control Logic Block Diagram



Following are the AZ/ALT PDU to Azimuth LCU interfaces.

TABLE 4.2.2.1.B - AZ/ALT PDU to AZ LCU Interfaces

SIGNAL #	SIGNAL NAME	SIGNAL TYPE
CONTROL COMMAND-STATUS		
1	AZ Rate Demand	+/- 5 Vdc, +VE = +VE rate
2	AZ Rate Scale Factor	OCS Low = 2.0 deg/s, High = 0.2 deg/s
3	AZ Enable Command	OCS Low = AZ Enable
4	12V Relay	+12V DC Relay power (For items 2,3,40)
5	AZ Actual Rate Scale factor	DCC. Contacts Open = 2.0 deg/s, Closed = 0.2 deg/s
6	AZ LCU Available	DCC. Contacts Closed = AZ LCU Available
7	AZ LCU Enabled	DCC. Contacts Closed = AZ LCU Enabled
8	AZ LCU Active	DCC. Contacts Closed = AZ LCU Active
9	AZ Axis Enabled	DCC. Contacts Closed = AZ Axis Enabled
10	AZ Summary Fault	DCC. Contacts Open = AZ Disabled
11	Status Common	Isolated Return for above contacts
RELAYS		
12	AZ Brakes Released	DCC. Contacts Closed = Brakes Released
13	AZ Neg-Pos Interlock Limit	DCC. Contacts Open = Limit (I)(SF)
14	AZ-ALT CCU Off	DCC. Contacts Open = CCU Off
15	Yoke Access Hatch Open Intlk	DCC. Contacts Open = Hatch Open Intlk (I)(SF)
16	AZ Stow Pin Engaged Intlk	DCC. Contacts Open = Pin Extended Intlk (I)(SF)
17	Dome Crane Interlock AZ	DCC. Contacts Open = Crane Intlk (I)(SF)
18	Pier Access Interlock	DCC. Contacts Open = Access Intlk (I)(SF)
19	Mobile Access Platform Interlock	DCC. Contacts Open = Platform INLTK (I)(SF)
20	Relay Common	Isolated Return for above contacts
SWITCHES		

SIGNAL #	SIGNAL NAME	SIGNAL TYPE
21	AZ Neg Vicinity Limit	DCC. Contacts Open = Limit (SF)
22	AZ Pos Vicinity Limit	DCC. Contacts Open = Limit (SF)
23	AZ Neg Pre-Interlock Limit	DCC. Contacts Open = Limit (SF)
24	AZ Pos Pre-Interlock Limit	DCC. Contacts Open = Limit (SF)
25	AZ Velocity Limit (Axis limited to 0.5°/sec)	DCC. Contacts Open = Velocity Limited
26 27	AZ Cable Wrap AZ Parked	DCC. Contacts Open = Negative Direction Wrap DCC. Contacts Closed = Parked
28	Switch Common	Isolated Return for above contacts
	ENCODER	
29	AZ Tape Encoder Read-Head 1	Sin-Cos 1 V pp + Ref Mark (*)
30	AZ Tape Encoder Read-Head 2	Sin-Cos 1 V pp + Ref Mark (*)
31	AZ Tape Encoder Read-Head 3	Sin-Cos 1 V pp + Ref Mark (*)
32	AZ Tape Encoder Read-Head 4	Sin-Cos 1 V pp + Ref Mark (*)
	TACHOMETER	
33	AZ Sum Rate Feedback	+/- 5 Vdc (5 V = 2 °/sec)
	MOTOR AMPLIFIER	
34	AZ Motor #1 Current	+/- 5 Vdc (5 V = Motor Amplifier I Limit)
35	AZ Motor #2 Current	+/- 5 Vdc (5 V = Motor Amplifier I Limit)
36 37	AZ Motor #3 Current AZ Motor #4 Current	+/- 5 Vdc (5 V = Motor Amplifier I Limit) +/- 5 Vdc (5 V = Motor Amplifier I Limit)
38	Analogue Common	Isolated Analogue Return and DC Power 0V for Analogue Signals
	AZ LCU INTERLOCK COMMAND	
39	AZ LCU Intlk Cmd (To Remove Power to AZ Motor Controllers)	OCS Low = AZ LCU Intlk (via 12V Relay in PDU)

SIGNAL #	SIGNAL NAME	SIGNAL TYPE
ISOLATION AMPLIFIER POWER SUPPLIES		
40	+12V DC	Low Voltage Power (0V on item 38)
41	-12V DC	Low Voltage Power (0V on item 38)

(I) – Causes Interlock

(SF) – Causes Summary Fault

(OP) – Output from LCU

DCC – Dry-Contact Closure

OCS – Open-collector sink

(*) = Standard Heidenhain Read Head 15-way D-Sub connections.

Following are the AZ/ALT PDU to Altitude LCU Interfaces.

TABLE 4.2.2.1.C - AZ/ALT PDU to ALT LCU Interfaces

SIGNAL #	SIGNAL NAME	SIGNAL TYPE
1	ALT Rate Demand	+/- 5 Vdc, +VE = +VE rate
2	ALT Rate Scale Factor	OCS Low = 2.0 deg/s, High = 0.2 deg/s
3	ALT Enable Command	OCS Low = Enable
4	12V Relay	+12V DC Relay power (For items 2,3,67,36)
5	ALT Actual Rate Scale Factor	DCC. Contacts Open = 2.0 deg/s, Closed = 0.2 deg/s
6	ALT LCU Available	DCC. Contacts Closed = ALT LCU Available
7	ALT LCU Enabled	DCC. Contacts Closed = ALT LCU Enabled
8	ALT LCU Active	DCC. Contacts Closed = ALT LCU Active
9	ALT Axis Enabled	DCC. Contacts Closed = ALT Axis Enabled

SIGNAL #	SIGNAL NAME	SIGNAL TYPE
10	ALT Summary Fault	DCC. Contacts Open = ALT Axis Fault
11	Status Common	Isolated Return for above contacts
	RELAYS	
12	ALT Brakes Released	DCC. Contacts Closed = Brakes released
13	ALT Pos-Neg Interlock Limit	DCC. Contacts Open = Limit (I) (SF)
14	AZ-ALT CCU Off	DCC. Contacts Open = CCU Off (SF)
15	ALT Stow Pin Engaged	DCC. Contacts Open = Pin Extended (I) (SF)
16	Dome Crane Interlock ALT	DCC. Contacts Open = Crane Intlk (I) (SF)
17	ALT Overspeed Interlock (Speed > 125% slew rate)	DCC. Contacts Open = Overspeed (I) (SF)
18	ALT Auxiliary Drive Enabled Interlock	DCC. Contacts Open = Aux Drive On (I) (SF)
19	Relay Common	Isolated Return for above contacts
	SWITCHES	
20	ALT Neg Vicinity Limit	DCC. Contacts Open = Limit
21	ALT Pos Vicin ity Limit	DCC. Contacts Open = Limit
22	ALT Neg Pre-Interlock Limit	DCC. Contacts Open = Limit
23	ALT Pos Pre-Interlock Limit	DCC. Contacts Open = Limit
24	ALT Velocity Limit (Axis limited to 0.5°/sec)	DCC. Contacts Open = Velocity Limited
25	ALT Parked	DCC. Contacts Closed = Parked
26	Switch Common	Isolated Return for above contacts
	ENCODER	
27	ALT Tape Encoder Read-Head 1, Tape 1	Sin-Cos 1 V pp + Ref Mark (*)
28	ALT Tape Encoder Read-Head 2, Tape 1	Sin-Cos 1 V pp + Ref Mark (*)
29	ALT Tape Encoder Read-Head 1, Tape 2	Sin-Cos 1 V pp + Ref Mark (*)
30	ALT Tape Encoder Read-Head 2, Tape 2	Sin-Cos 1 V pp + Ref Mark (*)

SIGNAL #	SIGNAL NAME	SIGNAL TYPE
	RATE FEEDBACK	
31	ALT Sum Rate Feedback	+/- 5 Vdc (5 V = 2 °-sec)
	MOTOR AMPLIFIER	
32	ALT Motor #1 Current	+/- 5 Vdc (5 V = Motor Amplifier Current Limit)
33	ALT Motor #2 Current	+/- 5 Vdc (5 V = Motor Amplifier Current Limit)
34	Analogue Common	Isolated Analogue Return and DC Power 0V for Analogue Signals
	ALT LCU INTERLOCK CMD	
35	ALT LCU Intlk Cmd (To remove Power to ALT Motor Controllers)	OCS Low = Alt LCU Intlk (via 12 Vdc Relay in PDU).
	ISOLATION AMPLIFIER POWER SUPPLIES	
36	+12V DC	Low Voltage Power (0V on item 34)
37	-12V DC	Low Voltage Power (0V on item 34)

(I) – Causes Interlock

(SF) Causes Summary Fault

(OP) – Output from LCU

DCC – Dry-Contact Closure

OCS – Open-collector sink

(*) = Standard Heidenhain Read Head 15-way D-Sub connections.

4.2.5 CASS Power Drive Unit

Refer to the following representative photograph (Figure 4.2.2.2.A) and block diagram (Figure 4.2.2.2.B) of the CASS Power Drive Unit.

The CASS PDU design is very similar in design to the AZ/ALT PDU. Only the major differences between the two PDUs will be discussed here.

4.2.5.1 CASS PDU Motor Controllers

One of the major differences is the design of the motor controllers. Due to the small capacity needed to drive the Cassegrain rotator, the motor controllers have a built in power supply module and are powered from single-phase utility power. The single-phase utility power will be derived from the VertexRSI 3-phase to 1-phase isolation transformer.

4.2.5.2 CASS Cablewrap

The Cassegrain rotator cable wrap drive will be slaved and Interlocked to the Cassegrain rotator **(AD01 10.5.3c, e)** as depicted on Figure 4.2.2.2.C. An LVDT will be used to ensure that the cable wrap remains synchronised with the Cassegrain rotator axis. If for any reason a divergence is noted between the Cassegrain rotator axis and the cable wrap, all motor controller power will be removed via the Interlock Chain. Additionally, if the cablewrap motor or motor controller faults out, the Cassegrain rotator axis will be disabled.

Figure 4.2.2.2.A - CASS POWER DRIVE UNIT (Photo is Representative)

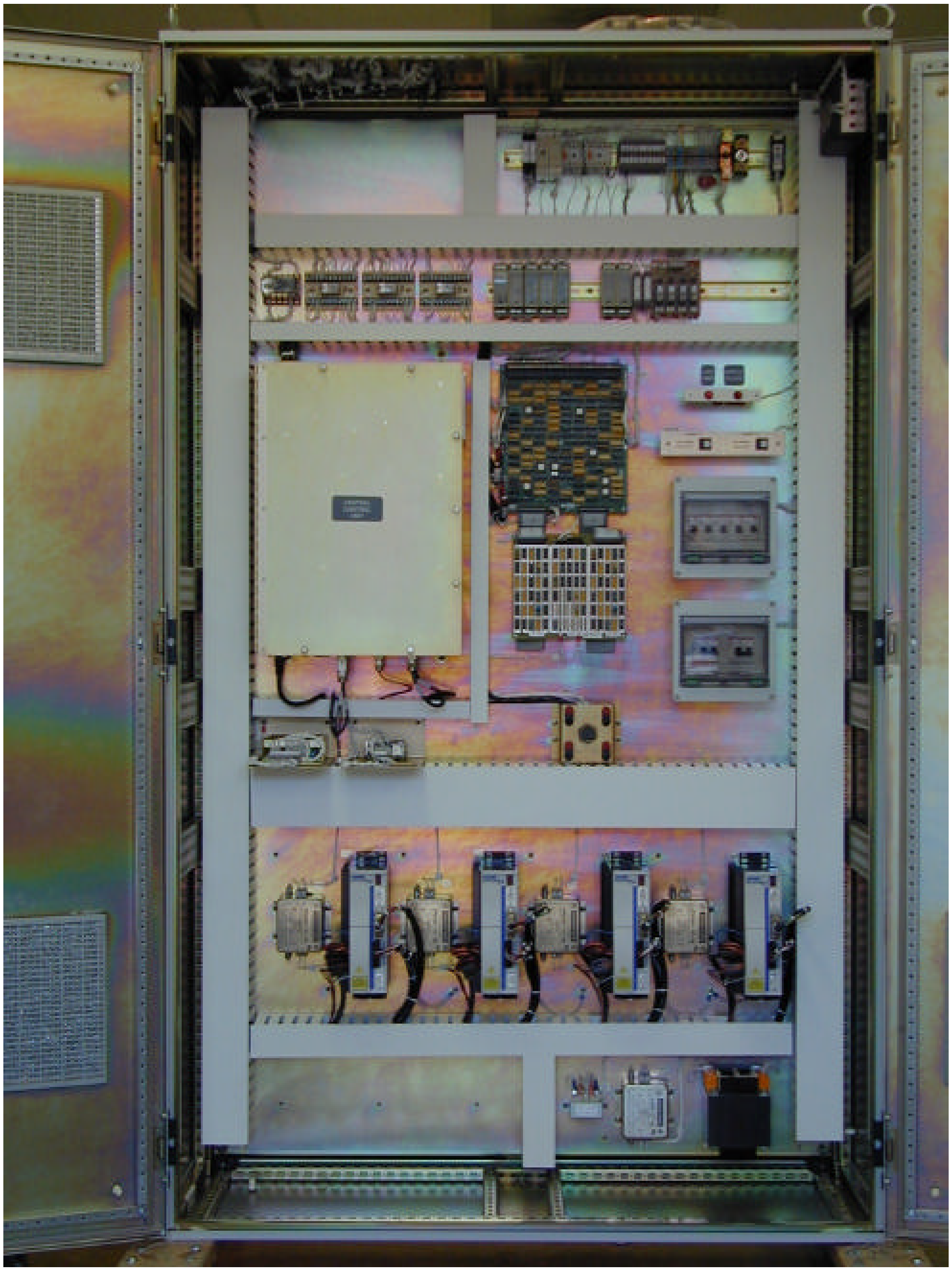


Figure 4.2.2.2.B - CASS PDU BLOCK DIAGRAM

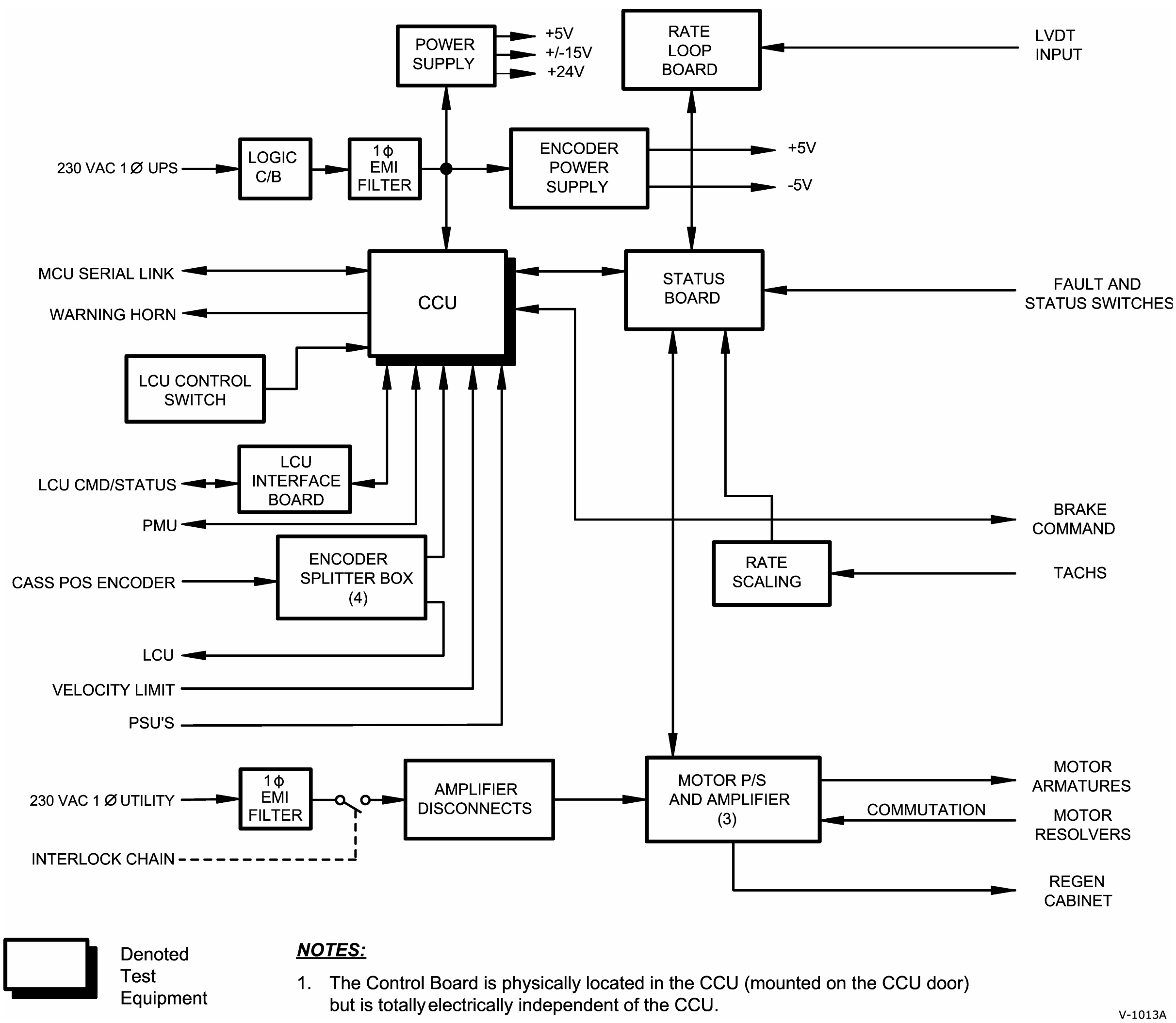
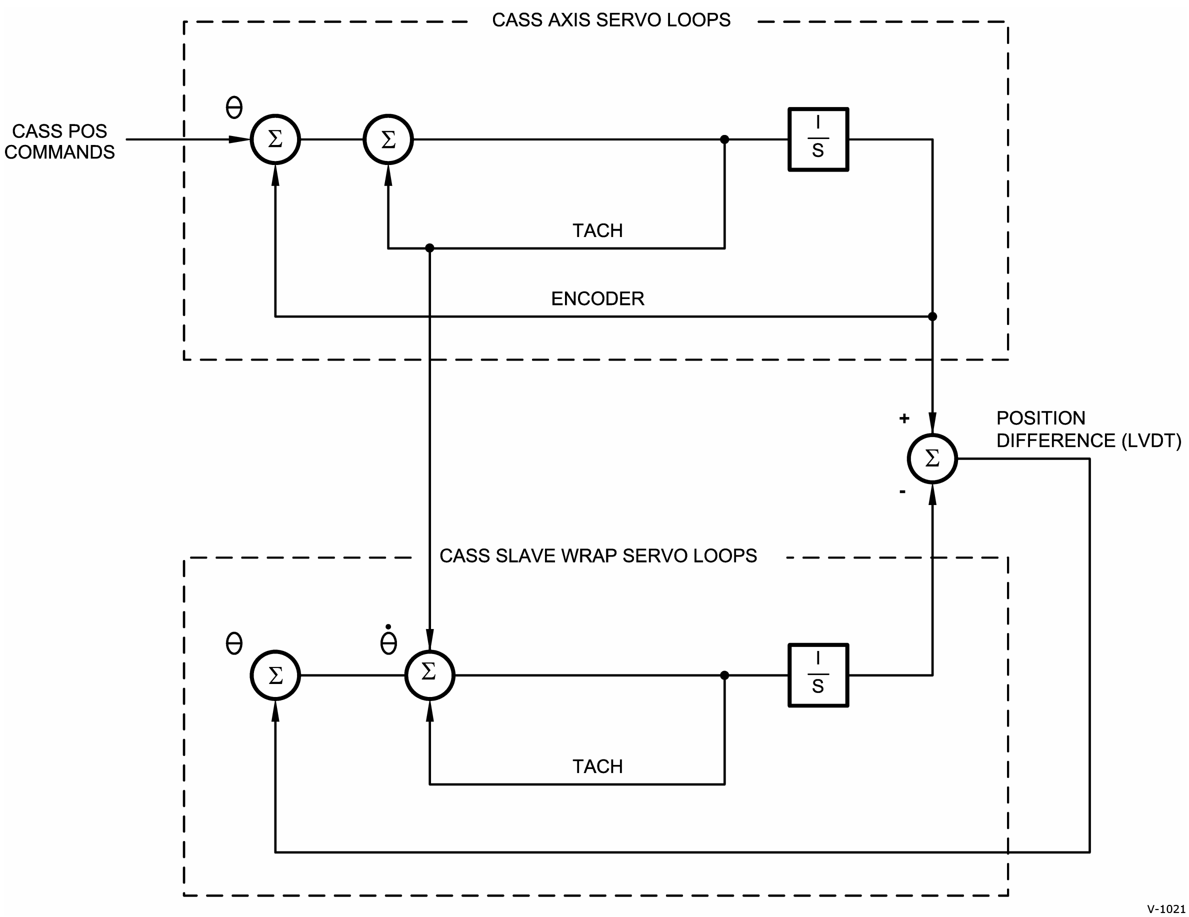


Figure 4.2.2.2.C – Cassegrain Rotator Cable Wrap Slaving



4.2.5.3 CASS Interlocking

The interlock chain will consist of the following contacts in series:

Emergency Stops (AZ Motor 1-2, AZ Motor 3-4, Alt Motor 1, Alt Motor 2, Alt Pier, Equipment Room, and Cone E-stops)
Cass Positive/Negative Interlock Limit
Cass Stow Pin Engaged
Cass/Cass Cable Wrap Divergence
Cass LCU Interlock

If any of the above isolated contacts open, power is removed from the Cassegrain (2) and Cassegrain cable-wrap (1) motor controllers and will independently remove the brake release command **(AD01 11.1.7 c spec).**

The same reliability concern by the frequent power cycling of the CASS motor controllers, as discussed in the AZ/ALT PDU section, is applicable to this axis.

A second set of the above Interlock contacts is routed over to the CASS LCU for monitoring purposes only. A third set of Interlock contacts is fed to the CASS PDU Control or Status board for fault reporting and axis disabling. This serves as an added safety level of protection, satisfying the operational safety spec of **AD01 13.4.11.**

4.2.5.4 CASS PMU Control Logic

The Cassegrain PDU also contains the circuitry for the PMU control logic. From the PMU, control of the AZ/ALT or of the CASS axis can be selected. Latching relays in the CASS PDU route either the AZ/ALT or the CASS control/status signals to the appropriate PDU for control of the axis. The PMU can be operated from the AZ/ALT PDU, CASS PDU, or at either PMU Junction box (2).

4.2.5.5 CASS Encoder Interface

As with Azimuth and Altitude axes, the Cassegrain rotator encoder scheme will consist of four read-heads mounted on a Heidenhain ERA 780c optical tape encoder **(AD01 11.1.6 g spec).** Heidenhain Encoder Splitter boxes are again used to obtain two buffered outputs; one going to the VertexRSI equipment and one going to VISTA's LCU IK320 Heidenhain Encoder boards.

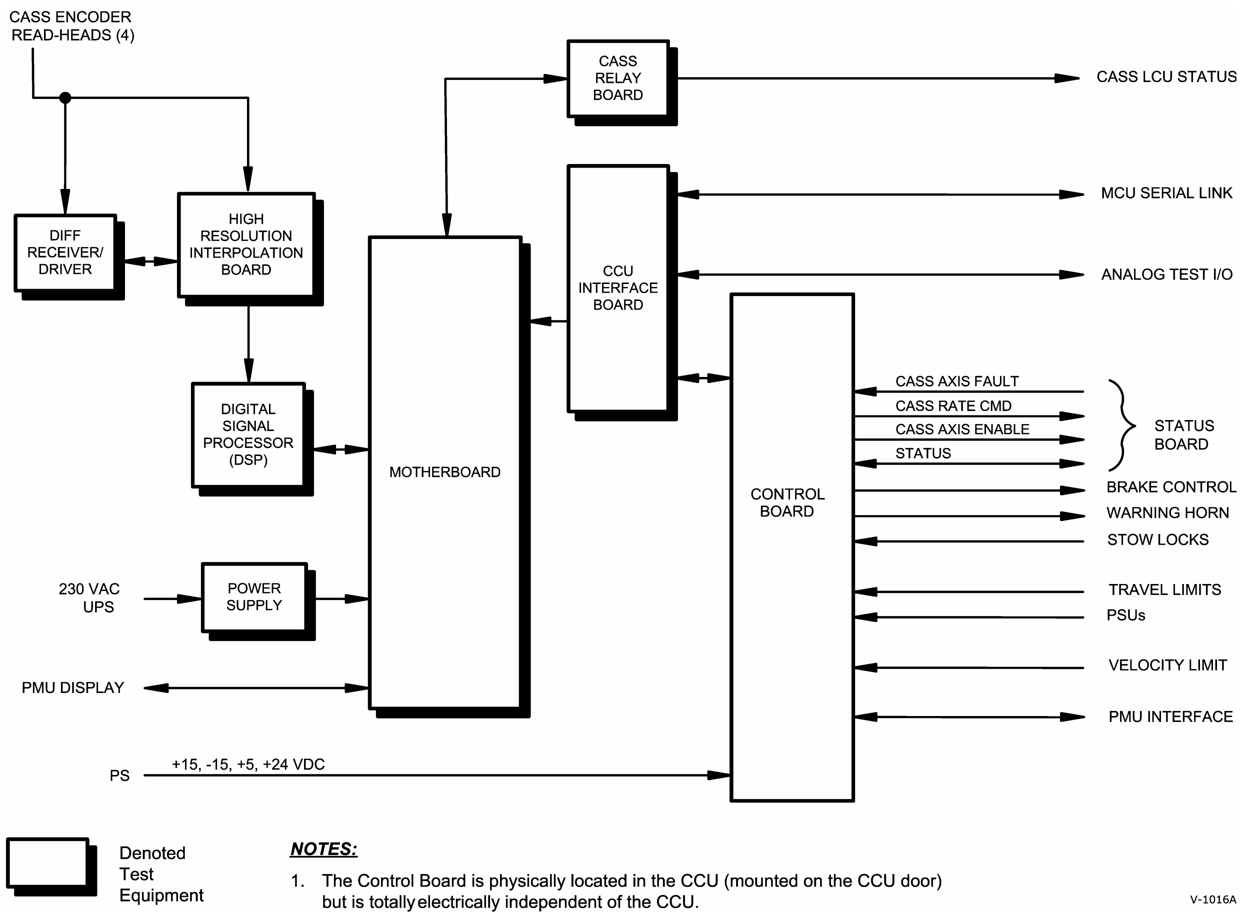
4.2.5.6 CASS EMC Treatments

The following CASS PDU design features will ensure that the discussed EU EMC standards are met:

Properly Shielded Conductive Gasketed Cabinets
Completely Connectorized PDU Enclosure
EMI/RFI connector backshells
Properly terminated Shielded Cables
Motor Lead Ferrite Filters
1ϕ (tech and utility) EMI Filters

4.2.5.7 CASS Central Control Unit

Figure 4.2.2.2.D - CASS PDU CCU BLOCK DIAGRAM



4.2.5.8 CASS Major Subassemblies

The major subassemblies that make up the CASS PDU are listed below:

TABLE 4.2.2.2.A - CASS PDU Major Subassemblies

MANUFACTURER	MANUFACTURER PART NUMBER	DESCRIPTION
Kollmorgen Motion Technologies Group	#CR06250	Cass Motor Controller
Hoffman	PROLINE Series	CASS PDU Enclosure
Heidenhain	IBV 606	CASS Encoder Splitter Box
Integrated Power Designs	SRW-100-4003	PDU Logic Power Supply
Integrated Power Designs	SRW-45-2002	Encoder Power Supply
Finder	Various	Relays
Sprecher + Schuh ABB Control Inc.	CS4C Series Various	Contactors Circuit Breakers
Schaffner	FN350-12/29	1ϕ EMI Filter
Entrelec Inc.	Various	Time Delay Relays
Shuttle Computer Group	G7VP2	CCU Motherboard
Delta Tau	Turbo PMAC2-PC	DSP Card
Delta Tau	Accessory 51P	High Resolution Interpolator Card
Antron	SP2-4300FB	CCU Power Supply

4.2.5.9 CASS LCU Interface

Refer to Figure 4.2.2.1.D, LCU Interface Block Diagram, it shows the handshaking, status, command and feedback information between the CASS PDU and the CASS LCU. As with the AZ/ALT PDU, a manual, mechanical switch in the CASS PDU will be provided to ensure that all LCU Interfaces are identical.

Following are the CASS PDU to Cassegrain LCU interfaces.

TABLE 4.2.2.2.B - CASS PDU to CASS LCU Interfaces

SIGNAL #	SIGNAL NAME	SIGNAL TYPE
	CONTROL COMMAND-STATUS	
1	CASS Rate Demand	+/- 5 Vdc, +VE = +VE rate
2	CASS Rate Scale Factor	OCS Low = 3.6 deg/s, High = 0.36 deg/s
3	CASS Enable Command	OCS Low = Enable
4	+12V Relay	+12V DC Relay power (For items 2,3,35)
5	CASS Actual Rate Scale Factor	DCC. Contacts Open = 3.6 deg/s, Closed = 0.36 deg/s
6	CASS LCU Available	DCC. Contacts Closed = CASS LCU Available
7	CASS LCU Enabled	DCC. Contacts Closed = CASS LCU Enabled
8	CASS LCU Active	DCC. Contacts Closed = CASS LCU Active
9	CASS Axis Enabled	DCC. Contacts Closed = CASS Axis Enabled
10 11	CASS Summary Fault Status Common	DCC. Contacts Open = CASS Axis Fault Isolated Return for above contacts
	RELAYS	
12	CASS Brakes Released	DCC. Contacts Closed = Brakes Released
13	CASS Neg-Pos Interlock Limit	DCC. Contacts Open = Limit (I) (SF)
14	CASS CCU Off	DCC. Contacts Open = CCU Off
15	CASS Stow Pin Engaged Intlk	DCC. Contacts Open = Pin Extended (I) (SF)

SIGNAL #	SIGNAL NAME	SIGNAL TYPE
16	CASS Cable-Wrap Divergence Intlk	DCC. Contacts Open = Divergence (I) (SF)
17	Relay Common	Isolated Return for above contacts
	SWITCHES	
18	CASS Neg Vicinity Limit	DCC. Contacts Open = Limit (SF)
19	CASS Pos Vicinity Limit	DCC. Contacts Open = Limit (SF)
20	CASS Neg Pre-Interlock Limit	DCC. Contacts Open = Limit (SF)
21	CASS Pos Pre-Interlock Limit	DCC. Contacts Open = Limit (SF)
22	CASS Velocity Limit (Axis limited to 0.5°-sec)	DCC. Contacts Open = Limit
23	CASS Cable Wrap	DCC. Contacts Open = Negative Direction Wrap
24	Switch Common	Isolated Return for above contacts
	ENCODER	
25 26	CASS Tape Encoder Read-Head 1 CASS Tape Encoder Read-Head 2	Sin-Cos 1 V pp + Ref Mark (*) Sin-Cos 1 V pp + Ref Mark (*)
27 28	CASS Tape Encoder Read-Head 3 CASS Tape Encoder Read-Head 4	Sin-Cos 1 V pp + Ref Mark (*) Sin-Cos 1 V pp + Ref Mark (*)
	TACHOMETER	
29	CASS Sum Rate Feedback	+/- 5 Vdc (5 V = 3.6 °/sec)
	MOTOR AM-PLIFIER	
30	CASS Motor #1 Current	+/- 5 Vdc (5 V = Motor Amplifier I Limit)
31	CASS Motor #2 Current	+/- 5 Vdc (5 V = Motor Amplifier I Limit)
32	CASS Cable-Wrap Motor Current	+/- 5 Vdc (5 V = Motor Amplifier I Limit)
33	Analogue Common	Isolated Analogue Return and DC Power 0V for Analogue Signals
	CASS LCU INTERLOCK COMMAND	
34	CASS LCU Intlk Cmd (To Remove Power to AZ Motor Controllers)	OCS Low = CASS LCU Intlk (via 12V DC Relay in PDU)
	ISOLATION AMPLIFIER NPOWER SUPPLIES	
35	+12V DC	Low Voltage DC Power (0V on item 33)

SIGNAL #	SIGNAL NAME	SIGNAL TYPE
36	-12V DC	Low Voltage DC Power (0V on item 33)

(I) – Causes Interlock

(SF) Causes Summary Fault

(OP) – Output from LCU

DCC – Dry-Contact Closure

OCS – Open-collector sink

(*) = Standard Heidenhain Read Head 15-way D-Sub connections.

4.2.5.10 Regeneration Cabinet

Refer to Figure 4.2.2.3 for a representative photograph of the Regeneration Unit. The Regeneration Cabinet is a free standing cabinet, used to house banks of high power resistors needed for energy dissipation when the Azimuth, Altitude, Cassegrain and Cassegrain CableWrap motors are being decelerated or back-driven. When a brushless motor is being decelerated or back-driven, it pumps up the motor controller power supply buss to levels that need to be dissipated externally in order not to incur a power supply over-voltage condition. The Regeneration Cabinet's high power resistors dissipate this excess energy.

For Azimuth, the braking resistors are rated for 4,000 W, 20 ohms. For Altitude, the resistors are rated for 360 W, 25 ohms. For Cassegrain, the braking resistors are rated for 850 W, 120 ohms. For Altitude, it is anticipated that the regeneration resistors will not be used, since the Kinetic energy of the motor/load minus the system losses will be smaller than the energy that the Motor Controller Power Supply BUS module can store.

Thermal switches with NC contacts interface to the AZ/ALT PDU and to the CASS PDU. If the thermal switches sense an over-temperature condition inside the power resistor enclosure, the contacts open, signalling to the PDUs to remove the axes motor enables. When the temperature cools off, the thermal switches automatically reset, but the axis enable command must be re-issued to continue with axis operation.

The Regeneration resistor box has been designed to be able to handle approximately 70% of the regeneration resistors' heat when all of the regeneration resistors are being used simultaneously before the thermal switch opens.

Under normal tracking conditions, due to the extremely benign axis dynamics, the average power that the resistors will see will be dominated by the preload level (AZ and CASS) and by the imbalance (ALT). As seen on the AD03, Motor and Brake Sizing Analysis report, wind loading doesn't affect AZ or CASS. Therefore the following continuous steady-state power dissipated in the Regeneration resistors while tracking will be as follows:

AZ 594 W
CASS 71 W

The above tracking dissipation values are well below the continuous rating (15% of AZ, 8% for CASS) of the regeneration resistors and thus will hardly produce minimal heat emissions, if any.

The instance where the most heat will be dissipated will be when the telescope is slewing from target to target. Per AD01, Technical Specification, the worse case scenario would be 45° slews on sky, with a 10-minute frequency. Therefore the acceleration/deceleration durations would be 2 seconds for AZ and ALT and 1.4 sec for CASS and the slew durations would be approximately 23 seconds for ALT, 66 seconds for AZ and 36 seconds for CASS. Therefore the duty cycles between changing targets would be approximately 4.5% for ALT, 12% for AZ and 6.5% for CASS. The low duty cycles result in negligible average power dissipated in the resistors, thus the above-mentioned dissipated tracking power is still valid when slewing from target to target.

The transient (peak) power seen by the resistors is the most when the motors are commanded to decelerate (since for accelerations, the AZ, CASS back-driven motors' regeneration levels would drop due to the high current command needed to accelerate). Therefore the transient power that the resistors would see would be:

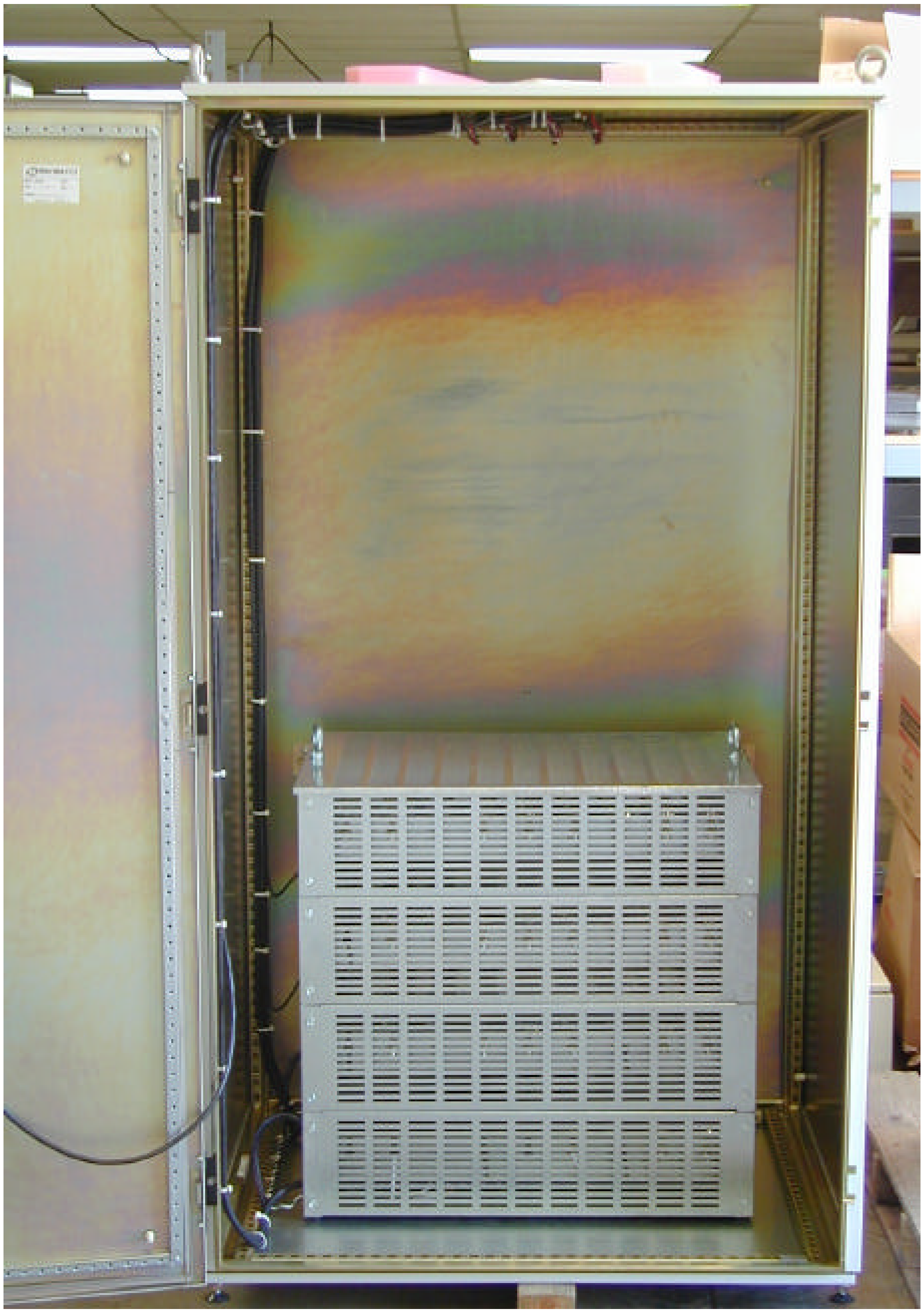
AZ 8.6A = 1,479 W (37% of rated)
CASS 1.09 A = 142 W (17% of rated)

The above values are still way below the rated values, and well below the thermal switch trip threshold. Therefore, conditions much more severe (having higher duty cycle) than those listed for this application would be needed in order to have an over temperature condition.

4.2.5.11 Isolation Transformer

The Isolation Transformer houses a 3-ϕ to 1-ϕ 5 KVA and a 3-Phase 50 KVA electro statically shielded transformers. The transformers secondary feed the AZ/ALT and the CASS PDU cabinets. This power is used to drive the brushless DC motors and the Azimuth bearing lube pump and other utility powered equipment.

Figure 4.2.2.3 - REGENERATION CABINET (Photo is Representative)



4.2.5.12 Data Acquisition System

The Data Acquisition System is comprised of the Data Acquisition Unit, 25 VertexRSI provided RTDs **(AD01 6.4.5a spec)** and conditioning modules for VISTA provided 15 additional temperature sensors **(AD01 6.4.5c & d spec).** 5 of these sensors will be located on the structure while the remaining 10 will be placed on the M1 mirror. It is assumed that the same type of conditioning modules will be used for the VISTA provided sensors as the ones used for the VertexRSI provided temperature sensors (100 ohm RTDs). The Data Acquisition Unit will reside inside the mount Yoke and will interface via the CANOpen protocol to the M1 Mirror Support LCU.

The RTDs to be provided by VertexRSI are a 3-wire platinum RTD manufactured by Pyromation, Inc having part number R3T1853RB1-F3B006-6. The 100 ohm platinum RTD **(AD01 6.4.3 spec)** has a temperature coefficient of 0.00385 and an accuracy of +/- 0.03% @ 0°C. For the operational temperature range of 0 to 15 °C, the corresponding accuracy of the RTD would be 0.08 to 0.10 °C. The location of the 25 VertexRSI Provided RTDs will be as follows:

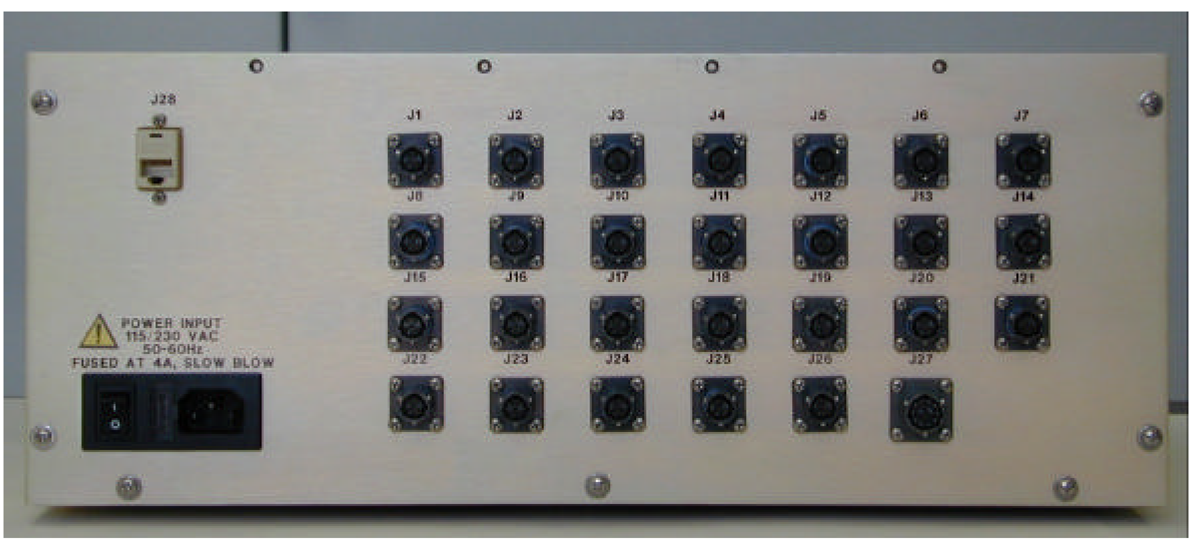
OSS Spyder	4
OSS Ring	2
OSS Tube	6
ALT Ring	4
ALT Bearing	2
Mirror Strt	3
Outside Pier	2
Inside Pier	2

As requested by VPO, VRSI is planning on using Beckhoff CANOpen hardware for the Data Acquisition Unit. The Beckhoff RTD modules have a published measurement accuracy of +/- 1 °C over the entire measurement range of – 250 °C to 850 °C. The RTDs to be provided have a temperature range of –200 to +200 °C, thus the Beckhoff measurement error would be reduced to approximately +/- 0.4 °C. Conversation with Beckhoff seems to indicate that the published 1 °C accuracy number is too conservative and that typical values are in the order of 0.5 °C, thus, for our temperature range, the measurement error would be approximately +/- 0.2 °C. This accuracy would be for the un-calibrated measurement, thus calibration of the measurement would yield accuracy values closer to the **AD01 6.4.3** 0.1°C accuracy spec. Since the Mount Control System is not required to obtain the temperature information, the M1 Mirror Support LCU would be responsible for the calibration of the RTDs.

Vista has exercised the M1 mirror LVDT option, thus six of the M1 mirror sensors will become the AC LVDTs. The last four sensors would remain the RTDs. AC LVDTs were selected over their DC counterparts for their superior accuracy. The accuracy of the LVDTs is comparable to that of the M1 load cells.

AD11 shows the interfaces between the M1 Mirror Support LCU and the Data Acquisition Unit, as well as the interfaces to the M1 Mirror Support electronics and anemometer interfaces

Figure 4.2.2.6 - DATA ACQUISITION UNIT (Photos are Representative)



The major subassemblies that make up the Data Acquisition System are listed below:

MANUFACTURER	MANUFACTURER PART NUMBER	DESCRIPTION
CONDOR D.C. POWER SUPPLIES, INC	HC24-2.4A+	Power Supply
Beckhoff	BK5120	CANOpen Bus Coupler
Beckhoff	KL3102	2 Channel Analogue Input Terminal
Beckhoff	KL3202	2 Channel Input Terminal PT100 (RTD)
Pyromation Incorporated	R3T1853 Series	3-Wire, Platinum RTD

4.2.5.13 Optical Incremental Tape Encoder

The position encoders to be used are the Heidenhain ERA 880C, distance-coded tape encoder, for the Azimuth, Altitude and Cassegrain Rotator axes.

The optical encoders contain gold line graduations, which reflect light in a defined direction, and diffusely reflecting gaps. These Heidenhain tape encoders operate on the principle of photo-electrically scanning very fine gratings. The photoelectric scanning of a substrate is the measurement of the change in light intensities using photovoltaic cells. When a line grating is moved relative to another grating with the same structure, the lines of two graduations alternately align. The resulting light-dark modulation is sensed by photovoltaic cells. Electronics in the tape encoder read-heads produces two sinusoidal waveforms that are shifted from each other by 90°, and have approximate amplitude of 1 V peak-to-peak as the scanning reticule is moved across the fixed scale tape.

The ERA 880C incremental encoders have a steel scale tape with a grating period of 40 microns. The tape encoders have a second (reference) track that consists of graduated disks next to the incremental grating. This reference track is distance-coded, which means that the number of graduations between reference marks is unique. An algorithm is then implemented to obtain an absolution axis position after traversing two consecutive reference marks.

4.2.5.14 AZ, ALT and CASS Drive Motors and Brakes

Brushless Motors were selected for the mount's axes movement. For Azimuth, four (4) 5,000 RPM, 10 HP motors were selected. For Altitude, two (2) 0.17 HP, 1/3 RPM frameless torquer motors were selected. For Cassegrain three (3) 1.3 HP, 3800 RPM brushless motors were selected. Refer to Figure 4.2.2.8.A, B & C for representative photographs of the axis motors.

The brushless digital motor controllers obtain shaft position information from an integral encoder to accomplish commutation of the motors. For Azimuth and Cassegrain Rotator, the position information comes from an absolute resolver. For Altitude the position information comes from Hall Sensors and from a Heidenhain Interpolation box (per motor) that digitises the optical tape encoder sinusoidal signals. The amplifiers commutate the DC voltage to create a rotating magnetic field.

The Azimuth and Cassegrain axes motors have DC tachometers installed to provide velocity feedback information for the Rate Loop boards to close the velocity loop. For the Altitude motors, the optical tape encoders are used by electronics in the AZ/ALT PDU CCU to produce an analogue voltage representative of the altitude motor's speed.

Each motor has an integral thermostat contact that opens if the motor overheats. When this occurs, the motor controller enable is removed, while the other motor(s) in the axis continue to remain operational. The status of this switch is reported to and displayed at the MCU and to the appropriate LCU. The thermostat contact automatically reset once the windings of the motor have cooled off.

These motors have military circular connectors that allow ease of replacement (with the obvious exception of the Altitude motors). The AZ and Cassegrain motors employ sealed bearings that do not require greasing. The motors are rated with an IP67 sealing specification.

VertexRSI will be using pneumatic brakes for all the axes.

The fundamental concept of brakes supplied by VertexRSI is that they are spring actuated, failsafe brakes. That is, the brakes will only release the mount for movement when voltage is applied to the brake control valve. Alternatively, loss of power will apply the brakes. Pressure sensors are used to indicate to the Mount Control System when the brake has the necessary compressed air to disengage the brake. If the pressure sensor fails to indicate this condition, a brake fault is issue to the appropriate PDU and the axis enable command is removed. The brake fault condition is reported to the MCU, LCU and to the PMU 2-line LCD display.

Figure 4.2.2.8.A - AZIMUTH MOTOR (Photo is Representative)

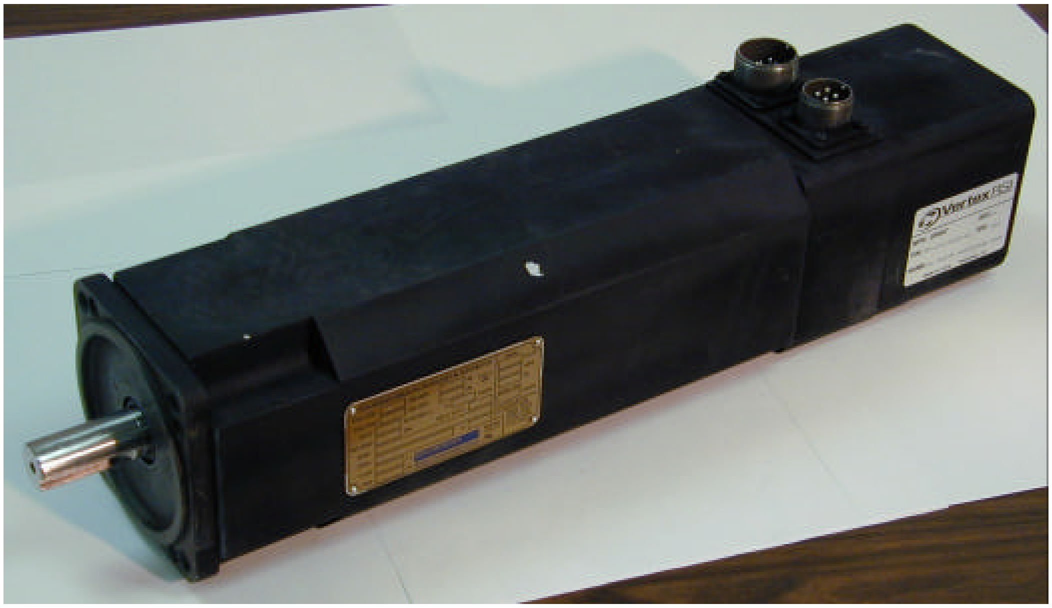
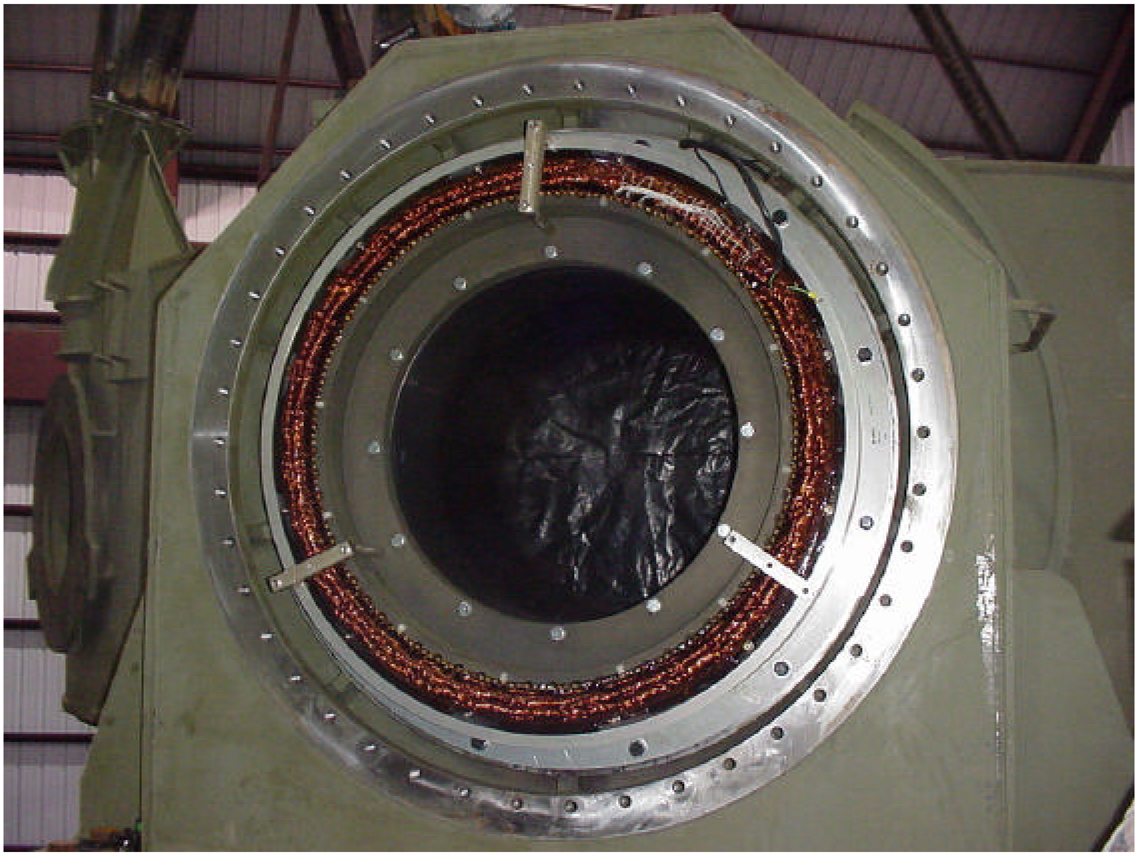


Figure 4.2.2.8.B - CASSEGRAIN MOTOR (Photo is Representative)

Figure 4.2.2.8.C - ALTITUDE MOTOR (Photo is Representative)



4.2.5.15 Mount Switches

VertexRSI Controls, Structures Division or VPO (or Others) will provide the following mount switches:

AXIS	FUNCTION	NAME
AZ/ALT/CASS	Travel Limit	Positive Vicinity Negative Vicinity Positive Pre-Interlock Negative Pre-Interlock Pos/Neg Interlock
AZ/ALT/CASS	Velocity Limit	Az Velocity Limit Alt Velocity Limit Cass Velocity Limit
CASS	Interlock	Cass-CableWrap Positive

AXIS	FUNCTION	NAME
		Divergence Lim Cass-CableWrap Negative Divergence Lim
AZ/CASS	CableWrap Sector	Azimuth CableWrap Cass CableWrap
AZ/ALT/CASS	Stow Pin	Stowed Stow Pin Engaged **(AD01 11.1.9 spec)**
AZ	Lube Pump	Pressure Low Overflow **(AD01 9.2.1 g spec)**
ALT	Imbalance	M2 Unit Not Installed CASS Instrument Not Installed OSS Not Installed ALT Imbalance Pin Cradle ALT Manual Brake Release
AZ/ALT	Mount Parked	AZ Mount Parked ALT Mount Parked **(AD01 13.4.12 spec)**
ALT	Aux Drive Intlk	ALT Aux Drive On Intlk
AZ/ALT/CASS	Emergency Stop	AZ Motor 1-2 E-stop AZ Motor 3-4 E-stop ALT Motor 1 E-stop ALT Motor 2 E-stop ALT Pier E-stop Equipment Room E-stop Cone E-stop
AZ	AZ Interlock	Yoke Access Hatch Intlk #1 Yoke Access Hatch Intlk #2 Pier Access Interlock Mobile Access Platform Intlk
ALT	ALT Interlock	M1 Restraint Failure Mobile Access Platform Intlk AZ Floor Access Interlock

There will be three (3) levels of over-travel protection in hardware for each axis. The levels of protection are: Pos/Neg Vicinity Limit, Pos/Neg Pre-Interlock Limit and Pos/Neg Interlock (lanyard/buffer) Limit. Upon the activation of the Limits, the following will occur:

Vicinity Limit: Fault is reported to the MCU and LCU-fed contacts open. Axis motors remain active and axis automatically backs-out of the limit condition.

Pre-Interlock Limit - Fault is reported to the MCU and LCU-fed contacts open. Axis motors are disabled. The Limit Override momentary switch (inside the appropriate Power Drive Unit) needs to be continuously depressed until the limit clears.

Interlock Limit - Fault is reported to the MCU and LCU-fed contacts open. Interlock chain is broken which causes removal of utility power (3-phase power (AZ/ALT) or 1-phase power (CASS)) to the axis motor controllers. Recovery of the Interlock Limit can only be done by manually (physically) moving the structure and clearing the Interlock Limit.

AD01 11.1.8.2 states "In maintenance mode it shall be possible to drive all axes to the Interlock limits under local engineering control at a reduced slew rate to verify the correct functioning of the Interlock system". VertexRSI will not comply with this requirement as it could result in a potential safety hazard. The control system hardware will not allow driving past the Pre-Vicinity Limits. Of course during the commissioning/testing of the system, temporary bypassing of travel limits are allowed/necessary in order for the activation of the 2nd and 3rd level of travel limit protection.

4.2.5.16 Anemometers

Three anemometers will be provided which will interface directly with the M1 Mirror Support LCU. As recommended, the anemometers are manufactured by GILL Instruments Ltd **(AD01 6.4.4 spec).** The manufacturer part number is 1086-PK-046. The recommended units don't come with RS485 interface, but will be provided with their standard RS-422 serial interface. The power requirement for the anemometers will come directly from the LCU, shown on Table 4.2.5.16, and is as follows: 9 to 30 Vdc, 120mA max.

TABLE 4.2.5.16 - M1 Mirror Support LCU Interfaces

SIGNAL #	SIGNAL NAME	SIGNAL TYPE
	ANEMOMETER (AD06 3.3 spec)	
1	Anemometer #1	RS-422 + Power
2	Anemometer #2	RS-422 + Power
3	Anemometer #3	RS-422 + Power

4.2.6 Material Parts

All fastening hardware utilized on the Mount Control Systems sub-assemblies will be metric. As agreed, modification of off-the-shelf assemblies or line-replaceable unit subcomponents to metric hardware will not be done. However, most sub-assemblies are already provided as metric units such as the Motor Controller Power Supplies, Motor Controllers, Encoder Interpolator and Splitter boxes, among others. For the sub-assembly hardware that will not be metric, it will be at least serviceable with a Phillips or flat blade screwdriver.

As previously discussed, chassis, covers, rear-panels, front panels, etc. used for the Mount Control System sub-assemblies, will not be made of metric steel.

4.2.7 Documentation

VertexRSI drawing number 93-100-2877 (VPO dwg no. VIS-DWG-VER-01001-9000), VISTA MCS Top Level Drawing, shows the list of deliverables for the mount control system. The parts list of this document shows the part numbers (VertexRSI as well as VPO part numbers) for the sub-assemblies that comprise the mount control system. This top level drawing also shows the configuration of the MCU and CCU Interface boards, the Status Board and the Control Board. The configuration is the component and circuit changes made to the baseline boards. In this manner, VertexRSI can build ahead baseline boards and then the board can be configured, per the Top Level drawing, to meet the program's specific requirements.

An Indentured Drawing List drawing, 99-343-0009, (VPO drawing no. VIS-DWG-VER-01001-9009) shows the list of deliverable drawings. A section of the O&M Manual gives a cross-reference between the VertexRSI and the VPO drawings.

4.2.8 Break-out Boxes

Seven break-out boxes will be provided per the requirements of AD07. The break-out boxes are not provided for all connectors. If connection between Unit A and Unit B has different types of connectors, a break-out box is only provided to connect to Box A, since there's no need to provide a break-out box for Box B.

For obvious safety reasons, break-out boxes are not provided for power (AC) or high voltage (AC or DC) connectors since the AD07 spec for the break-out boxes is implicitly for control signals. Additionally, two-wire circuits are not supplied with break-out boxes, as debug is simple, thus not requiring a break-out box.

4.3 *Tape Encoder Calculations*

4.3.1 Azimuth Tape Encoder Calculations

Azimuth Tape Encoder Resolution

Tape Sitting Diameter:	1638mm
Tape Sitting Circumference:	1638mm * Π = 5,145.9288 mm
Graduation Distance	40 e-6 mm = 25 lines/mm
# of Encoder Lines	25 lines/mm * 5,145.9288mm
	= 128,648.2192 lines
IK 320 Interpolation Factor	4096 counts/line * 128,648.2192 lines
	= 526,943,105.8 counts
Encoder Resolution	360°/526,943,105.8 counts = 6.832 e-7 deg
	= 0.0025 arc-secs

Azimuth Tape Encoder Accuracy

Encoder Accuracy of Graduation	+/- 3 microns = +/- 0.003 mm
Encoder Tape Circumference	5,145.9288mm = 360°
	= 0.070 °/mm
Encoder Accuracy (One Read-Head)	0.07 °/mm * 0.003 mm
	= 0.00021 ° = 0.755 arc-sec peak
Encoder Accuracy (4 Read-Heads)	= 0.755 arc-sec / 2 = 0.378 arc-sec peak

4.3.2 Altitude Tape Encoder Calculations

Altitude Tape Encoder Resolution

Tape Sitting Diameter:	1854mm
Tape Sitting Circumference:	1854mm * Π = 5,824.5128 mm
Graduation Distance	40 e-6 mm = 25 lines/mm
# of Encoder Lines	25 lines/mm * 5,824.5128mm
	= 145,612.8195 lines
IK 320 Interpolation Factor	4096 counts/line * 145,612.8195 lines
	= 596,430,108.7 counts
Encoder Resolution	360°/596,430,108.7 counts = 6.0359 e-7 deg
	= 0.0022 arc-secs

Altitude Tape Encoder Accuracy

Encoder Accuracy of Graduation	+/- 3 microns = +/- 0.003 mm
Encoder Tape Circumference	5,824.5128 mm = 360°
	= 0.0618 °/mm
Encoder Accuracy (One Read-Head)	0.0618 °/mm * 0.003 mm
	= 0.00019 ° = 0.668 arc-sec peak
Encoder Accuracy (4 Read-Heads)	= 0.668 arc-sec / 2 = 0.334 arc-sec peak

4.3.3 Cassegrain Rotator Tape Encoder Calculations

Cassegrain Tape Encoder Resolution

Tape Sitting Diameter:	1578 mm
Tape Sitting Circumference:	1578mm * Π = 4,957.433 mm
Graduation Distance	40 e-6 mm = 25 lines/mm
# of Encoder Lines	25 lines/mm * 4,957.433 mm
	= 123,935.8302 lines
IK 320 Interpolation Factor	4096 counts/line * 123,935.8302 lines
	= 507,641,160.5 counts
Encoder Resolution	360°/507,641,160.5 counts = 7.0916 e-7 deg
	= 0.0026 arc-secs

Cassegrain Tape Encoder Accuracy

Encoder Accuracy of Graduation	+/- 3 microns = +/- 0.003 mm
Encoder Tape Circumference	4,957.433 mm = 360°
	= 0.07262 °/mm
Encoder Accuracy (One Read-Head)	0.07262 °/mm * 0.003 mm
	= 0.00022 ° = 0.784 arc-sec peak
Encoder Accuracy (4 Read-Heads)	= 0.784 arc-sec / 2 = 0.392 arc-sec peak

4.4 Conclusions

This Design Report, along with the referenced analysis reports, has shown how the design of the VISTA Mount Control System is in compliance to AD01 Technical Specification. Non-compliant or partially compliant specifications are also addressed in this and on the referenced reports.

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Appendix A

Mount Control Unit

Appendix A - Mount Control Unit

The MCU will be used to show compliance to the pointing and tracking requirements of the mount, per **AD01 11.1.3 spec**. Following is a brief description of the MCU hardware and its modes of operation.

Refer to the following representative photograph and block diagram of the Mount Control Unit.

The MCU power supply is a 250W switching power supply with universal input. It supplies logic power (+5, +/- 15 Vdc) to the off-the-shelf motherboard and to the floppy and hard drive of the MCU.

The Motherboard is an off-the-shelf Pentium processor. System software is done on a real-time operating system (QNX) in C language. The motherboard has a built in IDE control function, which controls the Floppy Drive and the Hard Drive.

The Floppy Drive is a standard 3.5” drive that is used for backing-up system parameters.

The Hard Drive is a 16 Meg, solid-state, flash disc drive where the system software program and database resides.

The local display is a 250mm colour LCD that uses TFT technology.

The speaker sounds an audible alarm whenever there are new faults present. Additionally, contact closure status is available for summary and unacknowledged faults.

The MCU Interface board provides the interface between the MCU and the rest of the control system equipment. It provides the serial link to the AZ/ALT PDU and to the CASS PDU. This link is used for gathering of system faults & issuing of position commands to the PDUs Central Control Units.

As mentioned earlier, the MCU will be used to show compliance to the pointing and tracking requirements. The MCU Open Position Loop Bode plot is the position filtering that the MCU implements. The break frequencies are done digitally, through parameters in the MCU.
The LAG1 break frequency determines whether the position loop is a Type I or Type II. For this demanding application a Type II position loop is warranted, therefore, the LAG1 break frequency is disabled (taken to 0 Hz).

Below are the initial break frequencies that we will start-off with the integrated testing at Mexia, Texas.

	AZ	ALT
LAG 1	0.0 Hz	0.0 Hz
Lead	0.24 Hz	0.192 Hz
Crossover	1.00 Hz	0.80 Hz
Lag 2	10.00 Hz	10.00 Hz

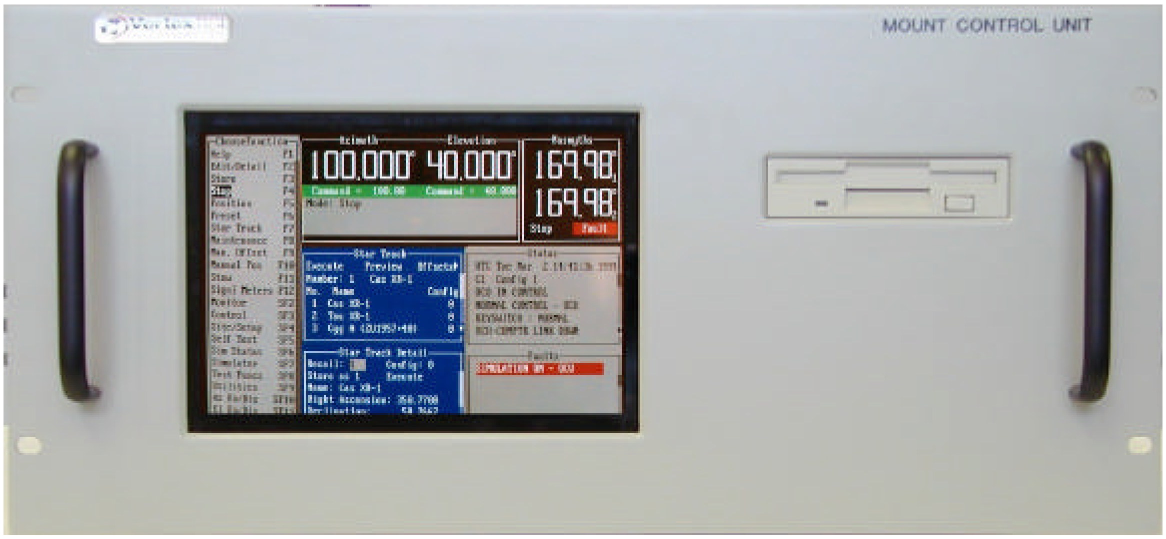
The single PI architecture that the LCU's Position Loop will implement is compatible with the MCU position loop architecture, with the exception of the absence of the LAG2 break shown on the Bode plot. VertexRSI will implement an active (hardware) low pass filter that will be added to the LCU rate command output so that the LCU position loop will be completely compatible with the MCU's. During the Integrated testing at Mexia, Texas, the optimal position loop compensation needed will be determined. VertexRSI will do a mapping of the optimal MCU position loop parameters to the ESO PI compensation loop parameters. In this manner, during the VPO testing period, the LCU can test the mount performance using the same Position Loop filtering that the MCU used for initial sell-off the Mount Control System.

The major subassemblies that make up the MCU are listed below:

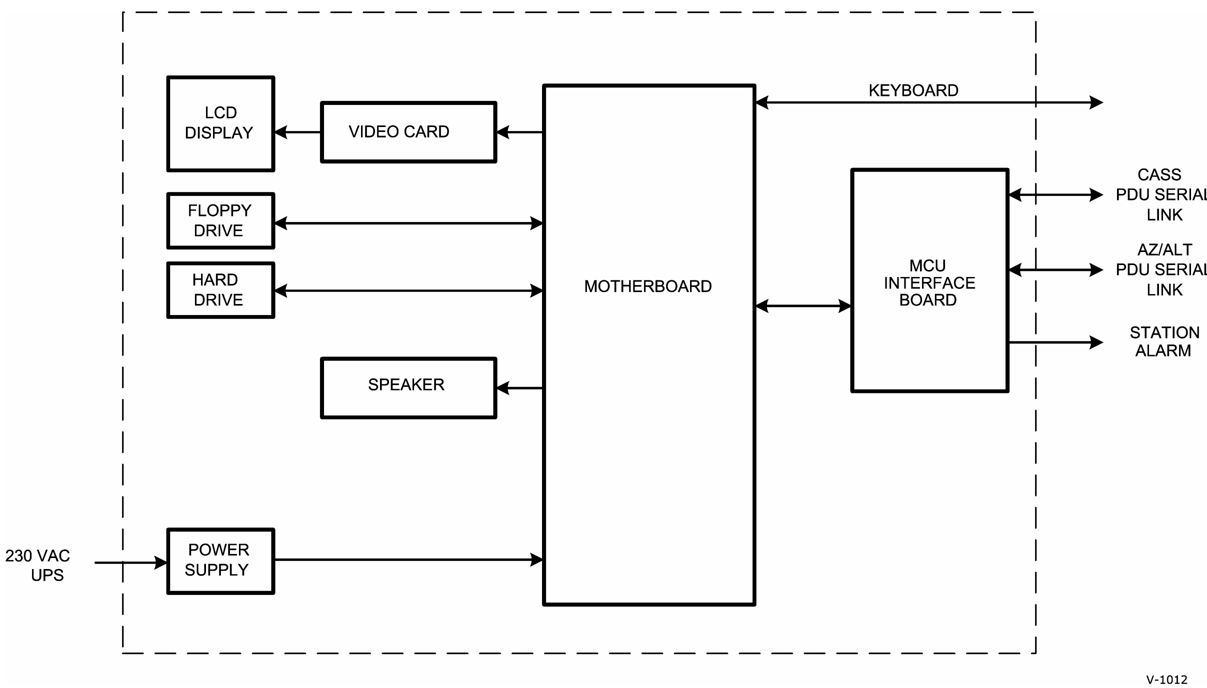
MANUFACTURER	MANUFACTURER PART NUMBER	DESCRIPTION
Antron	SP2-4300FB	MCU Power Supply
Shuttle Computer Group	G7VP2	MCU Motherboard
NEC Electronics	NL6448AC33-29	LCD Display
Touchstone Technology	ASM5051	LCD Controller Board
Chinon America Inc.	FZ-357	Floppy Drive
M-Systems Inc.	IDE-FD25-32	Hard Drive

Following are some of the MCU Modes of Operation and a brief description of each.

MOUNT CONTROL UNIT (Photo is Representative)



MCU BLOCK DIAGRAM



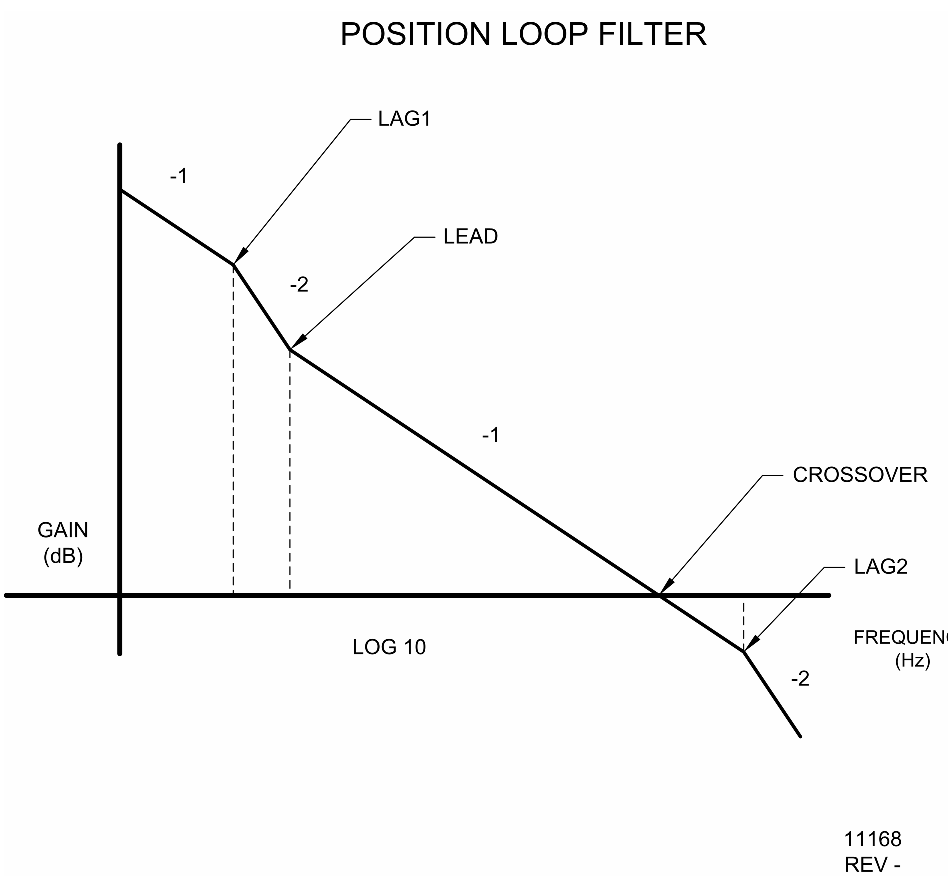
1. Position Track (Designate) Mode

Position Track accepts dynamic time tagged AZ/ALT/CASS position and velocity commands at a 20 Hz rate with three commands ahead in time. Interpolation smoothes the data to achieve excellent trajectory. Position Track can be used for both dynamic trajectories and point-to-point moves. The MCU 100BaseT Ethernet interface is provided for the Host Computer to command the Position Track mode.

2. Star Track Mode

The Star Track Mode continuously positions the mount on an internally calculated trajectory of a celestial object. The MCU allows the entry, storage and modification of trajectory elements for up to ten separate celestial targets. Other targets can be tracked by simply entering the target's Right Ascension and Declination parameters. Position and time offsets may be entered from the MCU for "fine-tuning" the trajectory predictions.

MCU Open Position Loop Bode Plot



3. Manual Position (Offset) Mode

The Manual Position (Offset) mode can be superimposed on trajectory pointing or positioning mode. It allows the operator to manually command position offsets to the position loop mode operating in conjunction. This allows the trajectory pointing mode or positioning mode to be fine-tuned.

4. Preset Position Mode

The Preset Position Mode contains 40 selectable AZ/ALT/CASS positions. Execution of the Preset Position Mode relocates the mount to a position defined by the stored positions.

5. Signal Meters

The MCU can display eight signals simultaneously in a bar graph format. Each signal has a minimum and maximum range selection. The first three signals selected are output to the AZ/ALT PDU Analogue Test Points located on the PMU bracket, the 4^{th} – 6^{th} signals selected are output to the CASS PDU Analogue Test Points located on the PMU bracket. The analogue voltages are limited to +/- 5Vdc. Additionally, the CCU Interface board provides the above mentioned 3 analogue test points from the AZ/ALT PDU and 3 analogue test points from the CASS PDU to the Data Acquisition Unit. The Data Acquisition Unit digitises these signals and the signals then become available over the CANOpen interface. These signals can be used for troubleshooting purposes.

The list of available signals is:

AZ, ALT, CASS Position Command
AZ, ALT, CASS Position Error
AZ, ALT, CASS Position Feedback
AZ, ALT, CASS Rate Command
AZ, ALT, CASS Encoder Velocity
AZ, ALT, CASS Sum Rate
AZ, ALT, CASS Current Command
AZ Motor 1, 2, 3, 4 Rates
ALT Motor 1, 2 Rates
CASS Motor 1, 2 Rates
CASS Cable Wrap Motor Rate
AZ Motor 1, 2, 3, 4 Current
ALT Motor 1, 2 Current
CASS Motor 1, 2 Current
CASS Cable Wrap Motor Current
AZ/ALT CCU + 15 V
AZ/ALT CCU – 15V
AZ/ALT CCU + 5 V
AZ/ALT +24 V
AZ/ALT Temperature (CCU)

CAS CCU + 15 V
CASS CCU – 15V
CASS CCU + 5 V
CASS +24 V
CASS Temperature (CCU)
AZ Read-Head 1, 2, 3, 4 Positions
ALT Read-Head 1, 2 Tape 1 Position
ALT Read-Head 1, 2 Tape 2 Positions
CASS Read-Head 1, 2, 3, 4 Positions
AZ Read-Head 1, 2, 3, 4 Position Errors
ALT Read-Head 1, 2 Tape 1 Position Error
ALT Read-Head 1, 2 Tape 2 Position Errors
CASS Read-Head 1, 2, 3, 4 Position Errors

6. AZ Jitter Image Stabilizer

The Azimuth Jitter Image Stabilizer compensates for Azimuth induced rotary jitter by feeding the Azimuth error signal into the active Cassegrain axis to counter rotate the image.

7. Cassegrain Slave Mode

The Cassegrain can be commanded to the Slave Mode whereas the Cassegrain Axis motion is generated based on the Azimuth and Altitude trajectories.

8. Stow Mode

Stow Mode's purpose is to drive the mount to a safe location and then lock the mount there with the stow pins. Upon entry into the Stow Mode, position commands are issued to drive the AZ/ALT/CASS axes to the predetermined location. The stow sequence is to drive to the designated position and once the location is reached, the axes enables are removed and the brakes are set.

9. Stop Mode

This mode disables the Azimuth, Altitude and Cassegrain axis drives. It is often referred to as Standby. "Disabling" signifies that the motor controller enables have been removed, it doesn't signify that the motor controller utility (3-ϕ) power has been removed.

10. Axis Disable

The Axis Disable is similar to Stop Mode with the exception that it allows single axis disable of the axis drives. This allows the operator the ability to eliminate motion on axes not of interest and focus on one axis for test or maintenance purposes.

11. Test Trajectories

Pre-mission test functions are onboard to support full axis known motion conditions. This allows fully expected performance to be reconfirmed during maintenance of critical mission event preparation. The following test functions are supported:

- t^2 ; Constant acceleration and deceleration to measure the system's static Acceleration Error Coefficient (Ka) per axis
- Flyby; Low target flyby of mount bcation to measure the system's dynamic Ka
- Constant Velocity; Measure running friction and position error.

12. Maintenance Mode

When the MCU is put in Maintenance Mode, control is transferred to the Portable Maintenance Unit (PMU). Once the PMU has accepted control, the MCU (and the LCUs) cannot take control back until the PMU relinquishes control.

13. LCU Mode

Upon power-up, the MCU will default to LCU mode. When in LCU mode, the AZ, ALT and CASS LCUs will be able to take control of the system via the manual, mechanical PDU switch. As with the Maintenance Mode, once the LCUs are in control of the system, the MCU and the PMU are unable to take control until the LCUs relinquishes control of the mount. LCUs Relinquishing control of the mount is made via the PDU switch.

If the MCU is in control of the mount and looses communication to the Power Drive Units, control is automatically offered to both the PMU and to the LCUs. Whichever unit takes control first will control the mount.

Whenever the unit that has control of the mount looses communication to the appropriate PDU, the MCS reverts to "STOP" mode, whereas all motor controller enables are taken away. For the LCUs, loosing communication signifies that the PDU manual switch has been switched from the "LCU" to the "PMU/MCU" position or the UPS power has cycled.

Appendix B

Portable Maintenance Unit

Appendix B - Portable Maintenance Unit

The Portable Maintenance Unit (PMU) is a microprocessor independent unit with the controls and status indicators to execute manual rate control for Azimuth, Altitude and Cassegrain Rotator axis. Refer to the following representative photograph of the PMU and of the PMU junction box. The PMU has a 15 meter connectorized pendant cable that may be interfaced at the AZ/ALT Power Drive Unit, the CASS Power Drive Unit or at junction box #1 or #2. The PMU can be plugged at any of the above-indicated ports at any time, regardless of which unit has control of the MCS. The PMU is capable of performing these operations as an autonomous, hand-held unit and is functionally and physically independent of the Mount Control Unit, the AZ, ALT and CASS LCUs, and microprocessor position loop closure electronics of the AZ/ALT and the CASS PDU.

The PMU is offered control when the MCU enters the Maintenance mode. Also, the PMU is automatically offered control by default when the MCU-AZ/ALT CCU or MCU-CASS CCU data link is down. Extra flexibility is provided by the monitor display window of the PMU where key parameters such as AZ, ALT and CASS position and fault messages may be observed. The unit has ON/OFF control to individually enable each axis and rate knobs to issue bi-directional, variable speed commands. Two ranges of axis velocities may be selected from the PMU. Low speed allows linearly variable commands from zero to 25% (AZ/ALT), 15% (CASS) of full slew velocities while high speed allows linearly variable commands from zero to full slew velocities. Thus, LO speed allows fine-tuning of the position, while HI speed allows quick mount repositioning. Summary axis faults and status are reported on the PMU using LED indicators and an LCD display. The LCD display also shows actual AZ/ALT/CASS position. Depressing the Rate Select/Display control select button, for approximately 3 seconds, toggles the LCD from the Position Indication to the Faults/Status Messages. The LCD display scrolls through the Faults/Status continuously and only the messages generated at either CCU are displayed.

PORTABLE MAINTENANCE UNIT (Photos are Representative)

PMU Junction Box

Appendix C

AZ/ALT & CASS Central Control Unit (CCU)

Appendix C - AZ/ALT and CASS Central Control Unit

Refer to the Figure 4.2.2.1.D, AZ/ALT PDU CCU Block Diagram and Figure 4.2.2.2.D, CASS PDU CCU Block Diagram. Only the CCU components that are considered to be test equipment (not required to meet the requirements of AD01 and AD02) are discussed in this section.

Logic Power is supplied to the off-the-shelf Pentium motherboard from a universal input 300W switching power supply. The power supply supplies power to the CCU Motherboard and to the boards that are plugged in to it.

The Digital Signal Processor (DSP) board has an 80 MHz processor and dual-ported RAM which provides a very high speed PC bus communications path to the CCU Interface board.

The CCU Interface board has a watchdog timer that resets an out of control computer microprocessor.

The CCU has the main function to execute the required position loop algorithms when the MCU is in control of the mount. The CCU receives the position commands from the MCU via a serial RS-232 link. The CCU Interface board also serves as the link between the CCU computer and the Control board.

The CCU firmware is also capable of compensating for repeatable mount mechanical errors (such as foundation tilt, azimuth bearing wobble, non-orthogonality, etc.).

The Differential/Receiver Driver board shown on the block diagrams, conditions the Heidenhain tape encoder reference pulses to be of the appropriate amplitude for interfacing to the Delta Tau Accessory 51P High Resolution Interpolator card. Since the Heidenhain tape encoders are incremental, after powering up the CCU, an encoder calibration procedure must be performed in order to calculate the absolute axis position. A Heidenhain provided formula is used to compute the axis absolute position after traversing two distance-coded reference marks. The computed axis absolute positions are sent to the MCU and to the PMU for display.

The CCU Interface board firmware, flash EPROM, is responsible for the interface to the Azimuth, Altitude and Cassegrain relay boards. These boards provide fault/status information to the LCUs via dry-contact closure. This ensures that the required galvanic isolation between VertexRSI and LCU units is maintained. The fault/status signals provided to the LCUs by the relay boards is shown below on Table 1 (AZ), Table 2 (ALT) and Table 3 (CASS).

TABLE 1 – AZ LCU Monitor Signals via CCU Relay Board

SIGNAL #	SIGNAL NAME	SIGNAL TYPE
1	AZ Brake Fault	DCC. Contacts Open = Fault
2	AZ Current Clamped	DCC. Contacts Open = I Clamped
3	AZ Preload Off	DCC. Contacts Open = Preload Off
4	AZ Motor Controller1 Flt	DCC. Contacts Open = Fault
5	AZ Motor Controller2 Flt	DCC. Contacts Open = Fault
6	AZ Motor Controller3 Flt	DCC. Contacts Open = Fault
7	AZ Motor Controller4 Flt	DCC. Contacts Open = Fault
8	AZ Motor 1 Overtemp	DCC. Contacts Open = Overtemp
9	AZ Motor 2 Overtemp	DCC. Contacts Open = Overtemp
10	AZ Motor 3 Overtemp	DCC. Contacts Open = Overtemp
11	AZ Motor 4 Overtemp	DCC. Contacts Open = Overtemp
12	AZ Motor Controller 1 3-Phase Off	DCC. Contacts Open = Fault
13	AZ Motor Controller 2 3-Phase Off	DCC. Contacts Open = Power Off
14	AZ Motor Controller 3 3-Phase Off	DCC. Contacts Open = Power Off
15	AZ Motor Controller 4 3-Phase Off	DCC. Contacts Open = Power Off
16	AZ Single Motor	DCC. Contacts Open = Single Motor
17	AZ Lube Pump CB Off	DCC. Contacts Open = CB Off (SF)
18	AZ Lube Pump Press Lo	DCC. Contacts Open = Pressure Low (SF)
19	AZ Lube Pump Overflow	DCC. Contacts Open = Overflow (SF)
20	AZ Disabled	DCC. Contacts Open = AZ Disabled
21	AZ Stowed	DCC. Contacts Open = AZ Stowed
22	AZ-ALT Control Board Fault	DCC. Contacts Open = Fault
23	AZ-ALT Status Board Fault	DCC. Contacts Open = Fault
24 25	AZ-ALT PMU in Control AZ-ALT Regen Overtemp Fault	DCC. Contacts Open = PMU in Control DCC. Contacts Open = Fault (SF)
26	AZ Motor #1/#2 Emergency Stop	DCC. Contacts Open = Emergency Condition (I)(SF)
27	AZ Motor #3/#4 Emergency Stop	DCC. Contacts Open = Emergency

		Condition (I)(SF)
28 29	ALT Motor #1 Emergency Stop ALT Motor #2 Emergency Stop	DCC. Contacts Open = Emergency Condition (I)(SF) DCC. Contacts Open = Emergency Condition (I)(SF)
30	ALT Pier Emergency Stop	DCC. Contacts Open = Emergency Condition (I)(SF)
31	Equipment Room Emergency Stop	DCC. Contacts Open = Emergency Condition (I)(SF)
32	Cone Emergency Stop	DCC. Contacts Open = Emergency Condition (I)(SF)
33	Common	Isolated Return for above contacts

DCC – Dry-Contact Closure
(I) – Causes Interlock
(SF) – Causes Summary Fault

TABLE 2 – ALT LCU Monitor Signals via CCU Relay Board

SIGNAL #	SIGNAL NAME	SIGNAL TYPE
1	ALT Brake Fault	DCC. Contacts Open = Fault (SF)
2	ALT Current Clamped	DCC. Contacts Open = I Clamped
3	ALT Motor Controller1 Flt	DCC. Contacts Open = Fault
4	ALT Motor Controller2 Flt	DCC. Contacts Open = Fault
5	ALT Motor 1 Overtemp	DCC. Contacts Open = Overtemp
6	ALT Motor 2 Overtemp	DCC. Contacts Open = Overtemp
7	ALT Motor Controller 1 3-Phase Off	DCC. Contacts Open = Power Off
8	ALT Motor Controller 2 3-Phase Off	DCC. Contacts Open = Power Off
9	ALT Single Motor	DCC. Contacts Open = Single Motor
10	ALT Disabled	DCC. Contacts Open = ALT Disabled
11	ALT Stowed	DCC. Contacts Open = ALT Stowed
12	AZ-ALT Control Board Fault	DCC. Contacts Open = Fault
13	AZ-ALT Status Board Fault	DCC. Contacts Open = Fault
14	AZ-ALT PMU in Control	DCC. Contacts Open = PMU in Control

15	AZ-ALT Regen Overtemp Fault	DCC. Contacts Open = Fault (SF)
16 17	AZ Motor #1/#2 Emergency Stop AZ Motor #3/#4 Emergency Stop	DCC. Contacts Open = Emergency Condition (I) (SF) DCC. Contacts Open = Emergency Condition (I) (SF)
18	ALT Motor #1 Emergency Stop	DCC. Contacts Open = Emergency Condition (I) (SF)
19	ALT Motor #2 Emergency Stop	DCC. Contacts Open = Emergency Condition (I) (SF)
20	ALT Pier Emergency Stop	DCC. Contacts Open = Emergency Condition (I) (SF)
21	Equipment Room Emergency Stop	DCC. Contacts Open = Emergency Condition (I) (SF)
22	Cone Emergency Stop	DCC. Contacts Open = Emergency Condition (I) (SF)
23	ALT Brake Manually Released	DCC. Contacts Open = ALT Brakes Manually Released
24	M2 Unit Not Installed	DCC. Contacts Open = Not Installed (I) (SF)
25	CASS Instrument Not Installed	DCC. Contacts Open = Not Installed (I) (SF)
26	DSP Boot Failure	DCC. Contacts Open = DSP Failure (SF)
27	ALT Imbalance Pin Cradle	DCC. Contacts Open = Not in Cradle
28	OSS Not installed	DCC. Contacts Open = OSS Not Installed (I) (SF)
29 30	M1 Mirror Restraint Failure AZ Floor Access Interlock	DCC. Contacts Open = M1 Restraint Failure (I) (SF) DCC. Contacts Open = Access INLTK (I) (SF)
31	Mobile Access Platform Interlock	DCC. Contacts Open = Access INLTK (I) (SF)
32	Common	Isolated Return for above contacts

DCC – Dry-Contact Closure
(I) – Causes Interlock
(SF) – Causes Summary Fault

TABLE 3 – CASS LCU Monitor Signals via CCU Relay Board

SIGNAL #	SIGNAL NAME	SIGNAL TYPE
1	CASS Brake Fault	DCC. Contacts Open = Fault
2	CASS Current Clamped	DCC. Contacts Open = I Clamped
3	CASS Preload Off	DCC. Contacts Open = Preload Off
4	CASS Motor Controller1 Flt	DCC. Contacts Open = Fault
5	CASS Motor Controller2 Flt	DCC. Contacts Open = Fault
6	CASS Cable-Wrap Motor Controller Flt	DCC. Contacts Open = Fault (SF)
7	CASS Motor 1 Overtemp	DCC. Contacts Open = Overtemp
8	CASS Motor 2 Overtemp	DCC. Contacts Open = Overtemp
9	CASS Cable-Wrap Motor Overtemp	DCC. Contacts Open = Overtemp (SF)
10	CASS Motor Controller 1 1-Phase Off	DCC. Contacts Open = Power Off
11	CASS Motor Controller 2 1-Phase Off	DCC. Contacts Open = Power Off
12	CASS Cable-Wrap Motor Controller 1-Phase Off	DCC. Contacts Open = Power Off (SF)
13	CASS Single Motor	DCC. Contacts Open = Single Motor
14	CASS Disabled	DCC. Contacts Open = CASS Disabled
15	CASS Stowed	DCC. Contacts Open = CASS Stowed
16	CASS Control Board Fault	DCC. Contacts Open = Fault
17	CASS Status Board Fault	DCC. Contacts Open = Fault
18	CASS PMU in Control	DCC. Contacts Open = PMU in Control
19	CASS Regen Overtemp Fault	DCC. Contacts Open = Fault (SF)
20	AZ Motor #1/#2 Emergency Stop	DCC. Contacts Open = Emergency Condition (I) (SF)
21	AZ Motor #3/#4 Emergency Stop	DCC. Contacts Open = Emergency Condition (I) (SF)
22	ALT Motor #1 Emergency Stop	DCC. Contacts Open = Emergency Condition (I) (SF)
23	ALT Motor #2 Emergency Stop	DCC. Contacts Open = Emergency Condition (I) (SF)

24	ALT Pier Emergency Stop	DCC. Contacts Open = Emergency Condition (I) (SF)
25	Equipment Room Emergency Stop	DCC. Contacts Open = Emergency Condition (I) (SF)
26	Cone Emergency Stop	DCC. Contacts Open = Emergency Condition (I) (SF)
27	Common	Isolated Return for above contacts

DCC – Dry-Contact Closure
(I) – Causes Interlock
(SF) – Causes Summary Fault