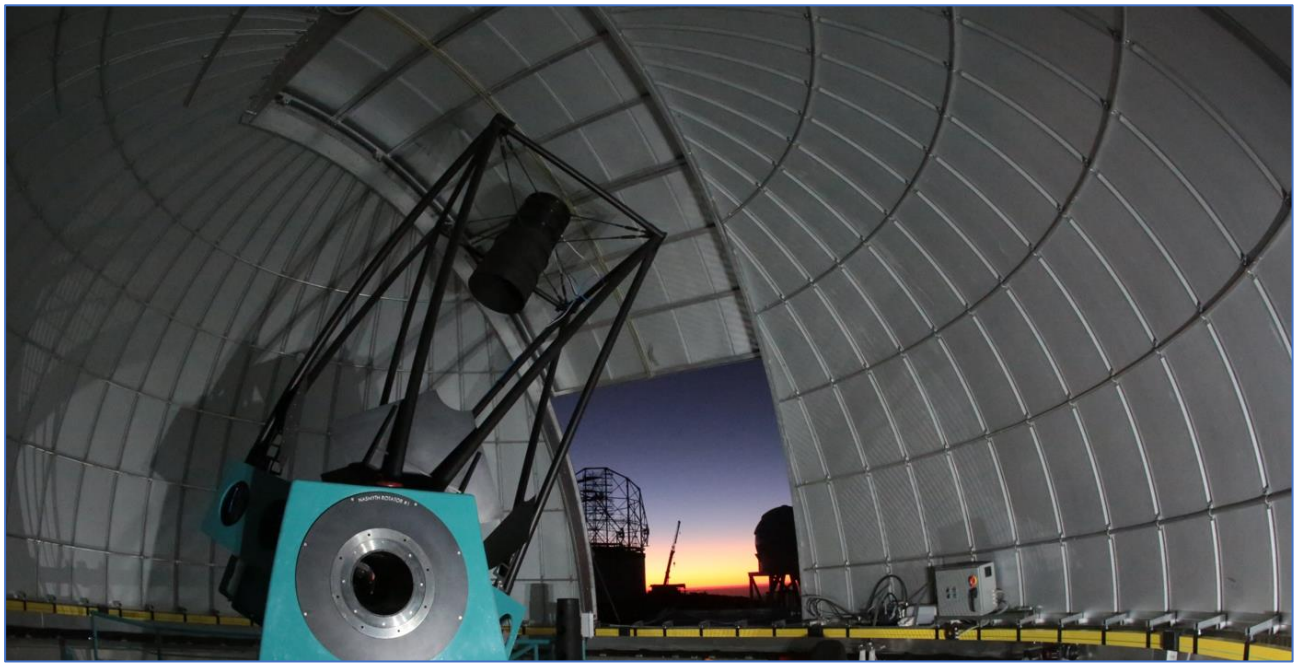
ACE SmartDome™

For LSST Auxiliary Telescope

Based on a

CompactRio System



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VERSION 2022-05-24

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1.0 INTRODUCTION

1.1 DOCUMENT OVERVIEW

This document describes the dome control system for the LSST AT. It is a modified version of the ACE SmartDome™ controller, based on a National Instruments Compact Rio hardware.

1.2 WARNINGS

WARNING: The shutter doors can automatically open or close without warning. If you are performing maintenance on the shutter doors TURN OFF the power to the shutter control box to prevent unwanted motion.

1.3 TECHNICAL SUPPORT

Manufacturer: Astronomical Consultants & Equipment, Inc.

Email: support@astronomical.com

1.4 OUTLINE DESCRIPTION

The LSST AT is housed in a 9.3 meter (30ft 6in) enclosure from Ash manufacturing company.

The basic outline of the control system is presented in Figure 1-1.

The dome has two shutter doors. The main door moves up to reveal the zenith. The second door hinges outwards to reveal the horizon. The second door (called the dropout) can only be opened once the main door has been opened by approximately 150mm as there is an overlapping weather seal. An interlock switch monitors the status of the main door to prevent damage to the weather seal. When closing, the dropout shutter must be fully closed before the main door can enter the interlock zone. If the main shutter door enters the interlock zone without the dropout being fully closed then all shutter door motion will stop. The only allowed action is to open the main shutter out of the interlock zone.

Electrical power to the rotating part of the dome is provided through a set of insulated conductor bars or slip rings (provided by LSST). This is a 480V three-phase connection.

The Shutter Control Box (SCB) is mounted on the rotating part of the dome, just to the right of the shutters. This is a stand-alone box which allows operation of the shutter doors all by itself. It has four push buttons to OPEN or CLOSE the main shutter door, and DOWN (open) and UP (close) for the dropout shutter. They are primarily intended to be used for maintenance and in emergencies, when the main dome control system is inoperative.

Limit switches provided feedback status for the shutter doors, and each door has an absolute encoder that reports the percentage of “open”.

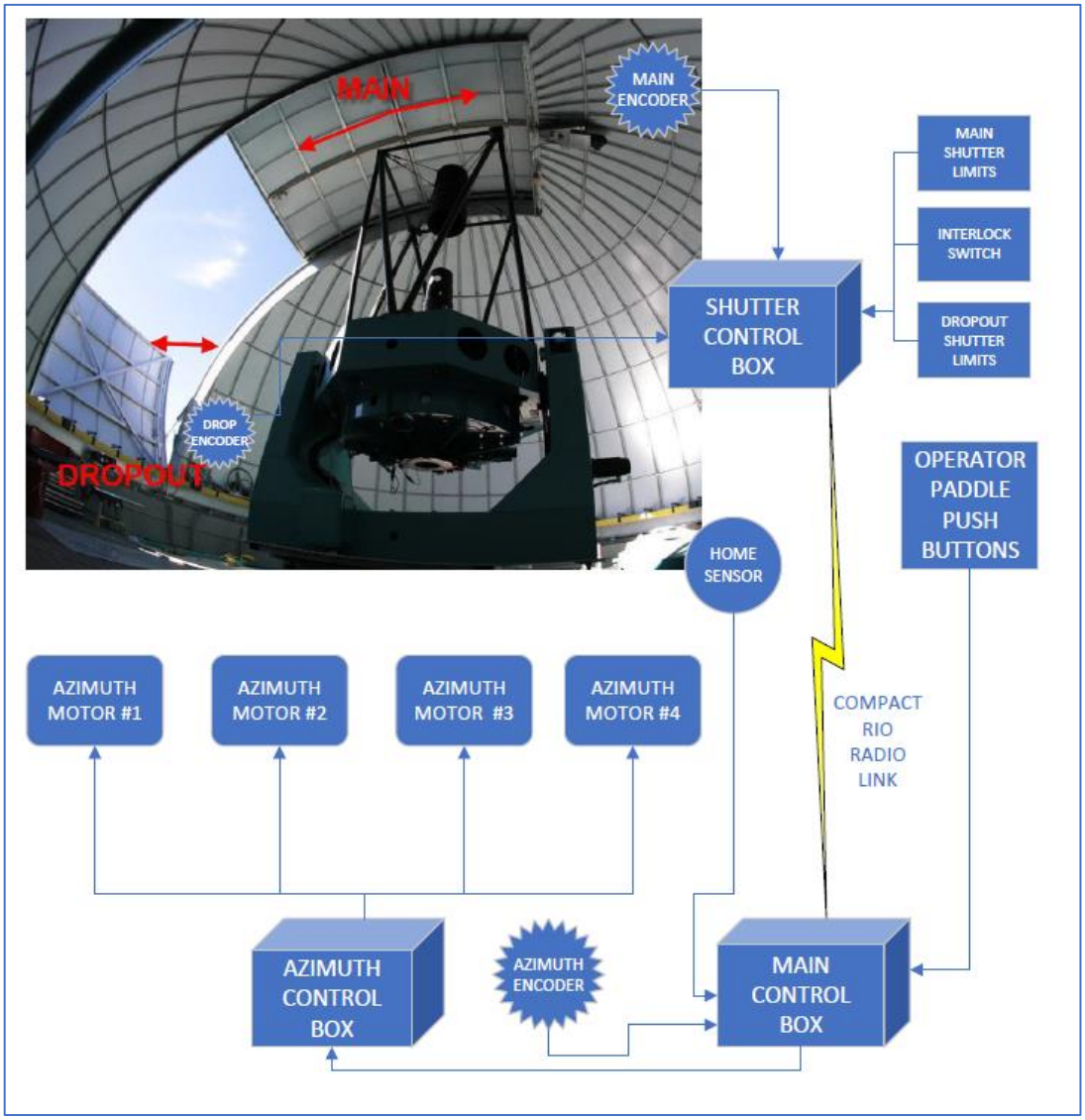


FIGURE 1-1 DOME CONTROL SYSTEM BASIC BUILDING BLOCKS

Under normal operating conditions the dome is controlled via the Main Control Box (MCB) which is located at the ground floor level. Another enclosure just to the right of it, the Azimuth Control Box, contains a Variable Frequency Drive (VFD).

The Main Control Box receives instructions from the host computer and communicates with the Shutter Control Box via a Compact Rio wireless ethernet link. Most of the electronics in the MCB deal with azimuth control and azimuth encoding. If this link fails, the shutter doors will automatically close after a timeout period.

Dome rotation is achieved through a set of four equispaced motors mounted on gearboxes which drive a rack-and-pinion style track. An absolute encoder, attached to the output shaft of one of the gearboxes, records the dome azimuth position. An azimuth home sensor provides a redundant means of parking the dome at a pre-determined position. It can also be used to resynchronize the azimuth absolute encoder

For convenience, a paddle box with a set of operator buttons for manual control of the dome, is located on the dome floor at the top of the staircase. The paddle buttons can be used to open and close the lower and upper shutter and to rotate the dome in the clockwise or counter-clockwise direction.

2.0 HARDWARE DESCRIPTION

2.1 INTRODUCTION

The ACE SmartDome™ system for the Auxiliary Telescope is based on a CompactRio system.

The system comprises the following major components:

- Main Control Box
- Shutter Control Box
- Operator paddle with push-buttons
- Environmental Sensors

The Main Control Box is located on the ground floor the dome. It controls all the functions of the dome.

The Shutter Control Box is on the rotating part of the dome. It only controls the two shutter doors.

The operator paddle is located at the top of the staircase. It allows an on-site person to operate the dome independently of the software (and requires the Main Control Box to be on).

Environmental sensors can be attached to both the Main Control Box and the Shutter Control Box.

2.2 SHUTTER CONTROL BOX

The Shutter Control Box (SCB) is an intelligent stand-alone device that manages the two shutter doors. It does not rely on a functioning Main Control Box.

WARNING: The shutter doors can automatically open or close without warning. If you are performing maintenance on the shutter doors or using a crane to lift items into the building, TURN OFF the SCB to prevent unwanted motion.

2.2.1 Push Buttons

The SCB has push buttons on the front panel. These can be used by a local operator. There is also an On-Off switch at the side of the box.

The Ash dome has two shutter doors. The main door moves up to reveal the zenith. The second door hinges outwards to reveal the horizon. It can be left closed to act as a windshield on windy nights but access to the horizon is blocked.

The second door (called the dropout) can only be opened once the main door has been opened by approximately 300mm as there is an overlapping weather seal attached to the main door. An interlock switch monitors the status of the main door to prevent damage to the weather seal. When closing, the dropout shutter must be fully closed before the main door can enter the interlock zone. If the main door is closing and it reaches the interlock zone without the dropout door closed, then motion of the main door will stop to prevent damage to the weather seal.

The push button functions are:

CLOSE	Closes the main shutter door
OPEN	Opens the main shutter door
UP	Closes (raises) the dropout door
DOWN	Opens (lowers) the dropout door
On-Off	Located on the side of the box. Disables shutter door motion.

The push buttons are momentary. The operator must keep pressing the button to create motion.

The UP – DOWN buttons will only work when the main shutter is partially open, out of the interlock zone.

The CLOSE button will stop working if the dropout shutter is not fully closed and the main shutter reaches the interlock zone.

2.2.2 Limit Switches

The SmartDome monitors the status of the limit switches on each door.

There are four conditions:

SHUT	Door is at the closed limit
OPEN	Door is at the opened limit
AJAR	Door is at an intermediary position
FAULT	A system wiring error has been detected and the door cannot move

The limit switches are wired normally closed. When a limit is reached the switch becomes open and the motor stops. If the system detects both limits to be open at the same time a FAULT condition occurs, and the door cannot be moved.

The interlock switch is also wired normally closed and opens when the main door is within 150mm of closed. The status of the interlock is available from the Compact Rio.

2.2.3 Shutter Encoding

Each shutter door is equipped with an absolute Heidenhain rotary encoder, model ROQ-437. The encoders are simultaneously read by a Compact Rio SEA9510 module.

The percentage of open is reported for each door, being 0 for SHUT and 100 for OPEN.

The value of the raw encoder counts for SHUT and OPEN for each door are also reported in the Full Engineering Status. See Section 3.2.3 for more details.

2.2.4 Shutter Control Box Hardware

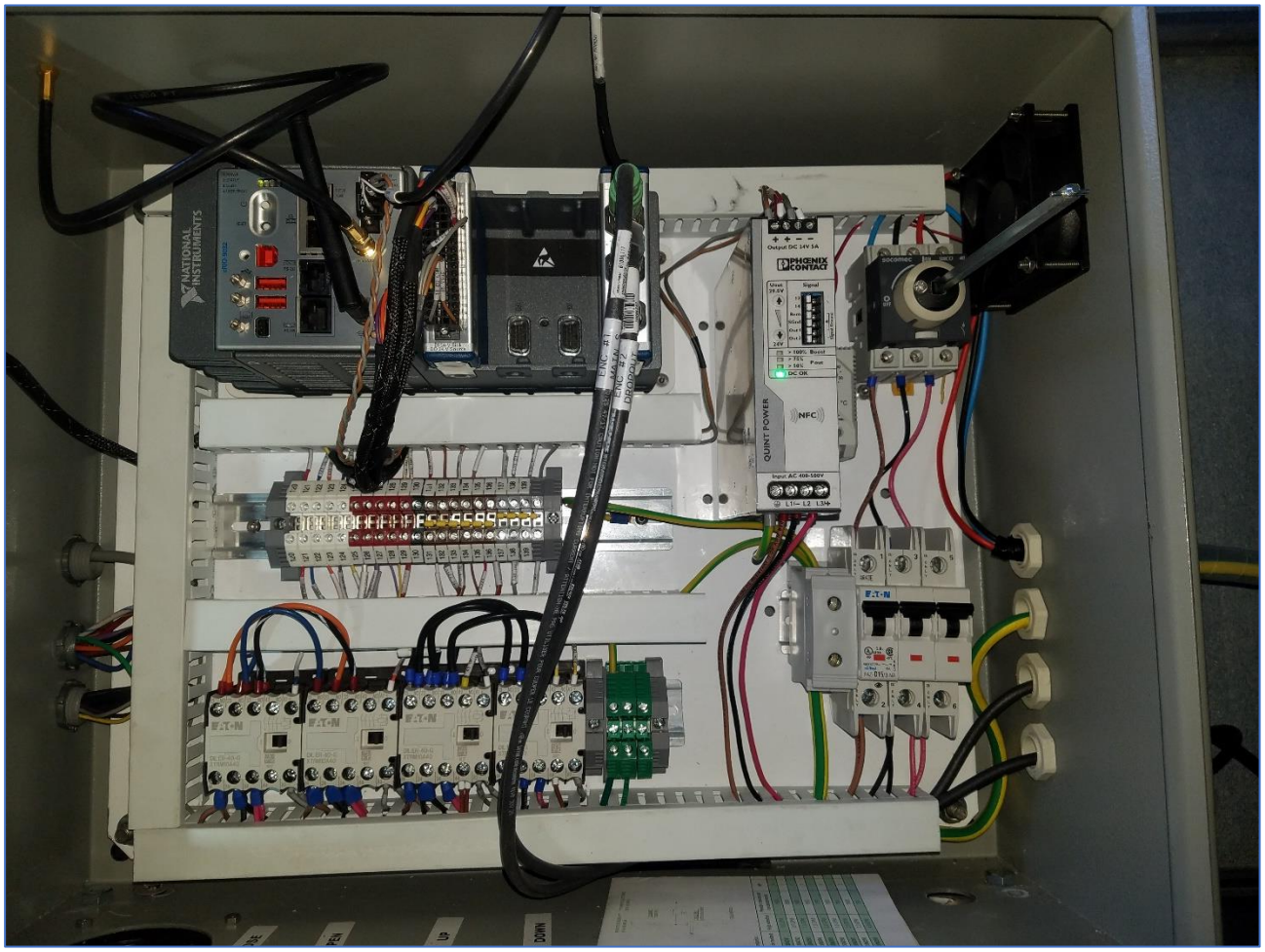


FIGURE 2-1 SHUTTER CONTROL BOX

2.2.4.1 Enclosure

The Shutter Control Box enclosure is a Hubbell-Weigmann ultimate series single door cabinet model N4121620081PTC. It measures 406 x 508 x 203 mm (16x20x8 inches).

The cabinet is locked. To undo, insert the key, turn the key, then grab the latch underneath the handle, and turn the handle 90 degrees clockwise.

2.2.4.2 DC Power Supply

A Phoenix Quinnt series 4 power supply, with 3-phase 400-500 VAC input and DC 24V 5A output, model 2904620 is used.

2.2.4.3 NI 9032 Compact Rio

The heart of the ACE SmartDome™ is a National Instruments 9032 Compact Rio. This is an embedded Intel Atom E3825 1.33 GHz real-time processor with reconfigurable FPGA.

The cRIO-9032 has two ethernet ports and an IEEE 802.11 a/b/g/n 2.4 GHz / 5GHz wireless ethernet. The expansion chassis can accept up to four modules, and two are populated.

2.2.4.4 NI-9375 Digital I/O Module

The NI-9375 is a c-Series module with 16 Digital Input channels and 16 Digital Output channels. The device is sinking input and sourcing output. The Digital Input lines are compatible with 24 V logic levels, and the digital output lines are compatible with 24 V signals, based on the power supply used.

The channels are isolated from each other and from earth ground.

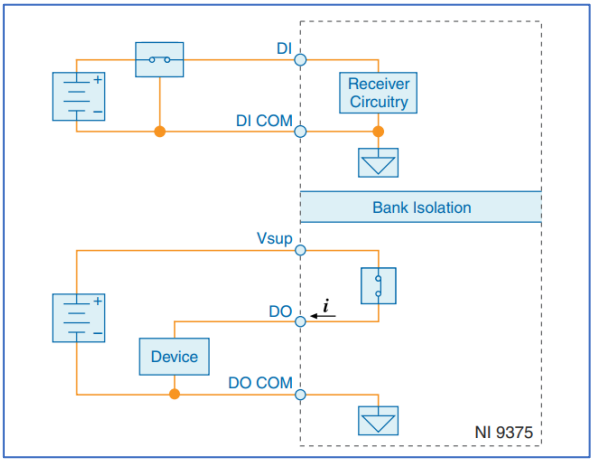


FIGURE 2-2 NI-9375 ELECTRICAL ISOLATION

The module is certified over the temperature range -40C to +70C.

The module is available with either a D-Sub 37 connector or spring terminals. We are using the spring terminal version.

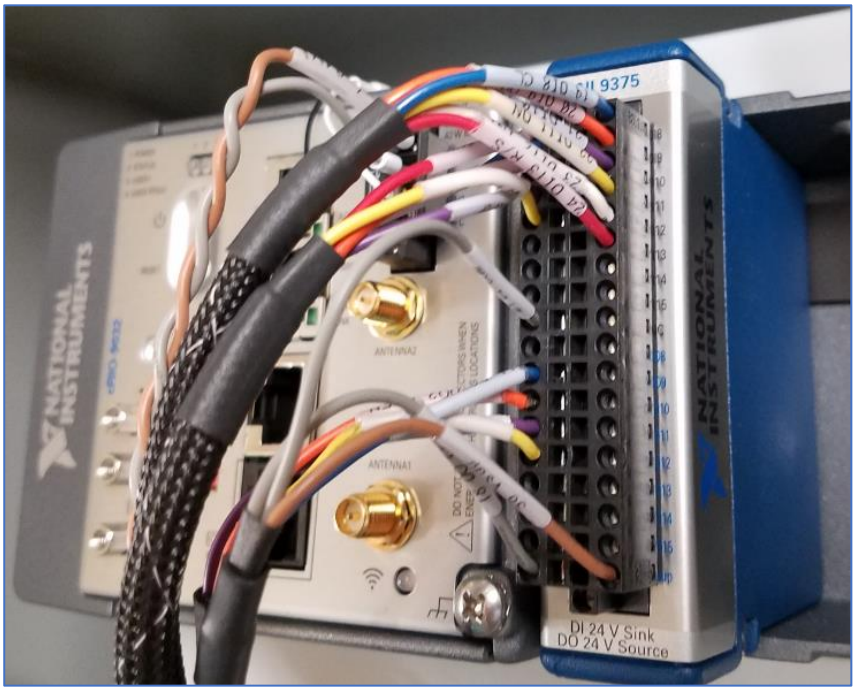


FIGURE 2-3 COMPACT RIO NI-9375 DIGITAL I/O MODULE

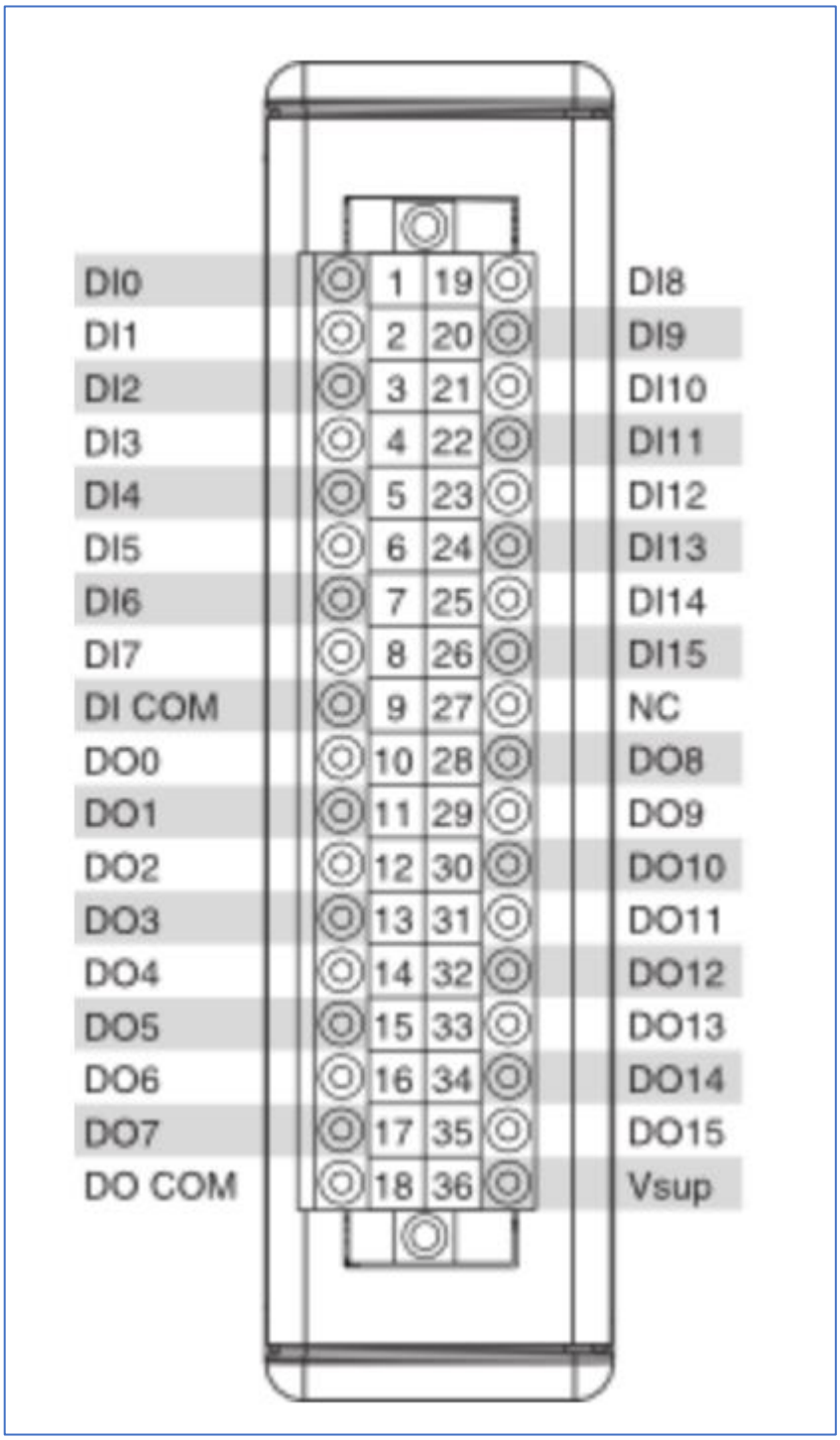


FIGURE 2-4 NI-9375 PINOUTS

Signal	Description
DI	Digital input signal connection
DI COM	Common reference connection for the digital inputs
DO	Digital output signal connection
DO COM	Common reference connection for the digital outputs
Vsup	Voltage supply connection (+24V)
NC	No connection

The NI-9375 connections are routed to a terminal strip for further distribution.

The I/O assignments are as follows:

NI9375 D-SUB	Function	TERM	SHUTTER CONTROL BOX Allocation	Notes / Route to
1	DI0	120	EMERGENCY STOP Button	
2	DI1	121	CLOSE Button	
3	DI2	122	OPEN Button	
4	DI3	123	UP Button	
5	DI4	124	DOWN Button	
6	DI5			
7	DI6			
8	DI7			
9	DI COM	136	DC Power Supply COM	
19	DI8	125	CLOSE Limit	
20	DI9	126	OPEN Limit	
21	DI10	127	UP Limit	
22	DI11	128	DOWN Limit	
23	DI12	129	INTERLOCK	
24	DI13	130	RAIN / SNOW Sensor	
25	DI14			
26	DI15			
10	DO0			
11	DO1		CLOSE Contactor Coil	Contactor CL A1
12	DO2		OPEN Contactor Coil	Contactor OP A1
13	DO3		UP Contactor Coil	Contactor UP A1
14	DO4		DOWN Contactor Coil	Contactor DN A1
15	DO5			
16	DO6			
17	DO7			
18	DOCOM	137	DC Power Supply COM	
28	DO8			
29	DO9			
30	DO10			
31	DO11			
32	DO12			
33	DO13			
34	DO14			
35	DO15			
36	Vsup	131	DC Power Supply +24V	

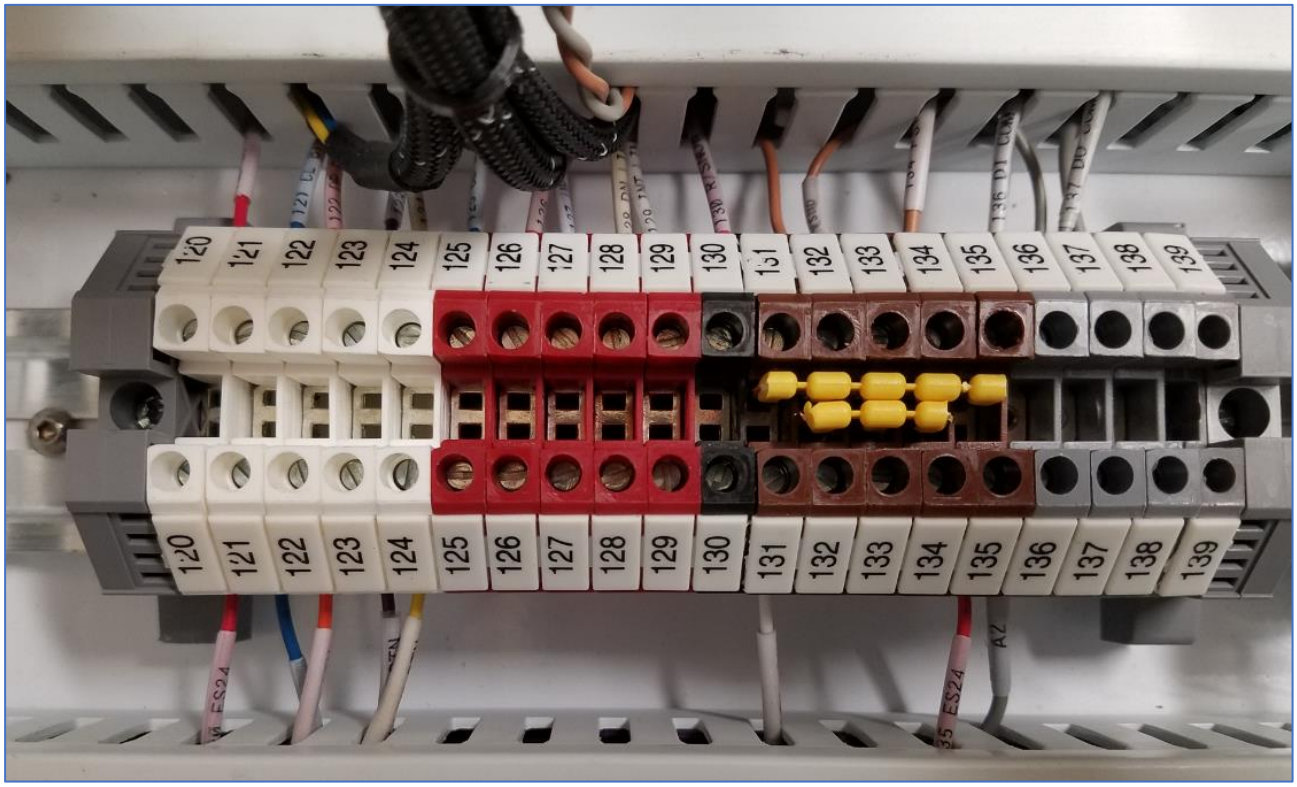


FIGURE 2-5 SHUTTER CONTROL BOX LIMITS AND PUSH BUTTONS TERMINAL STRIP

2.2.4.5 SEA 9510 Encoder Module

The position of the Heidenhain absolute encoders used on the main shutter door and dropout door are read by an SEA 9510 module.

This module has inputs for three encoders using an industry-standard M12 connector. The encoders also have an M12 connector. The pin assignments are as follows:

M12 Male	Function	Cable Wire Color	CPC-9 Male
1	NC	WHT	1
2	NC	BRN	2
3	DATA +	GRN	3
4	DATA -	YLW	4
5	GND	GRY	5
6	CLOCK +	PNK	6
7	CLOCK -	BLU	7
8	VCC	RED	8
9	SHIELD	SHIELD	9

The encoder for the main shutter door is connected to Input #1, and the encoder for the dropout door is connected to Input #2.

2.2.4.6 Shutter Motor Contactors

The shutter motors are controlled by 4-pole single throw NO 24 VDC contactors.

We have used an Eaton series contactor, manufacturer part number DILER-40-G(24VDC).

2.2.4.7 Fans and Thermostat

The enclosure is actively vented by using two 240 VAC cooling fans. The ball-bearing axial fans are Orion model OA109AP-22-1TB

The fans only operate when the enclosure is above a pre-determined temperature (22°C) set by a thermostat. The thermostat is a Stego model 011479-00.

2.3 MAIN CONTROL BOX

The Main Control Box (MCB) is located on the ground floor of the observatory. The MCB controls the dome azimuth and it also communicates with the SCB to control the two shutter doors.

2.3.1 Push Buttons

The MCB has two push buttons mounted on the front of the enclosure.

They are a red emergency stop twist-lock mushroom button and a blue reset button.

The view of the dome from the ground floor is restricted by the observing floor. Therefore, an operator paddle located at the top of the staircase, has push buttons with the following functions:

ESTOP	Stops all motion. For emergency use only.
CLOSE	Closes the main shutter door
OPEN	Opens the main shutter door
UP	Closes (raises) the dropout door
DOWN	Opens (lowers) the dropout door
REVERSE	Rotates the dome in a negative or left direction
FORWARD	Rotates the dome in a positive or right direction

If the operator paddle ESTOP button is activated it must be release and the RESET button pressed on the MCB, followed by the RESET button on the main telescope control cabinet, to retore full functionality.

2.3.2 Azimuth Home Sensor

The dome can be rotated without limits in either direction.

There is a Home sensor which allows the dome to be parked at a particular (TBD) azimuth, with an accuracy of ±6 mm. This can be useful if trying to align the telescope with a flat field screen mounted on the dome.

The sensor is a Honeywell roller plunger switch, model ZE-Q22-2S

2.3.3 Dome Azimuth Encoder

The dome azimuth encoder is attached to one of the azimuth drive gearboxes. It is the same model encoder that is used on the shutter doors, a Heidenhain absolute rotary encoder ROQ-437.

The dome azimuth track has 1437 holes. The sprocket drive gear has 12 teeth. So the drive shaft of the azimuth gearbox rotates 119.75 times per 360 degrees. The encoder outputs 4096 counts per revolution, so the total number of counts per 360 degrees is 490,496.

2.3.4 Dome Azimuth Gearbox and Motor

The azimuth is driven by four 368 Watt (1/2 HP) motors. The motors are attached to a 40:1 speed reducer, as shown in Figure 2-6, which also shows the absolute encoder.

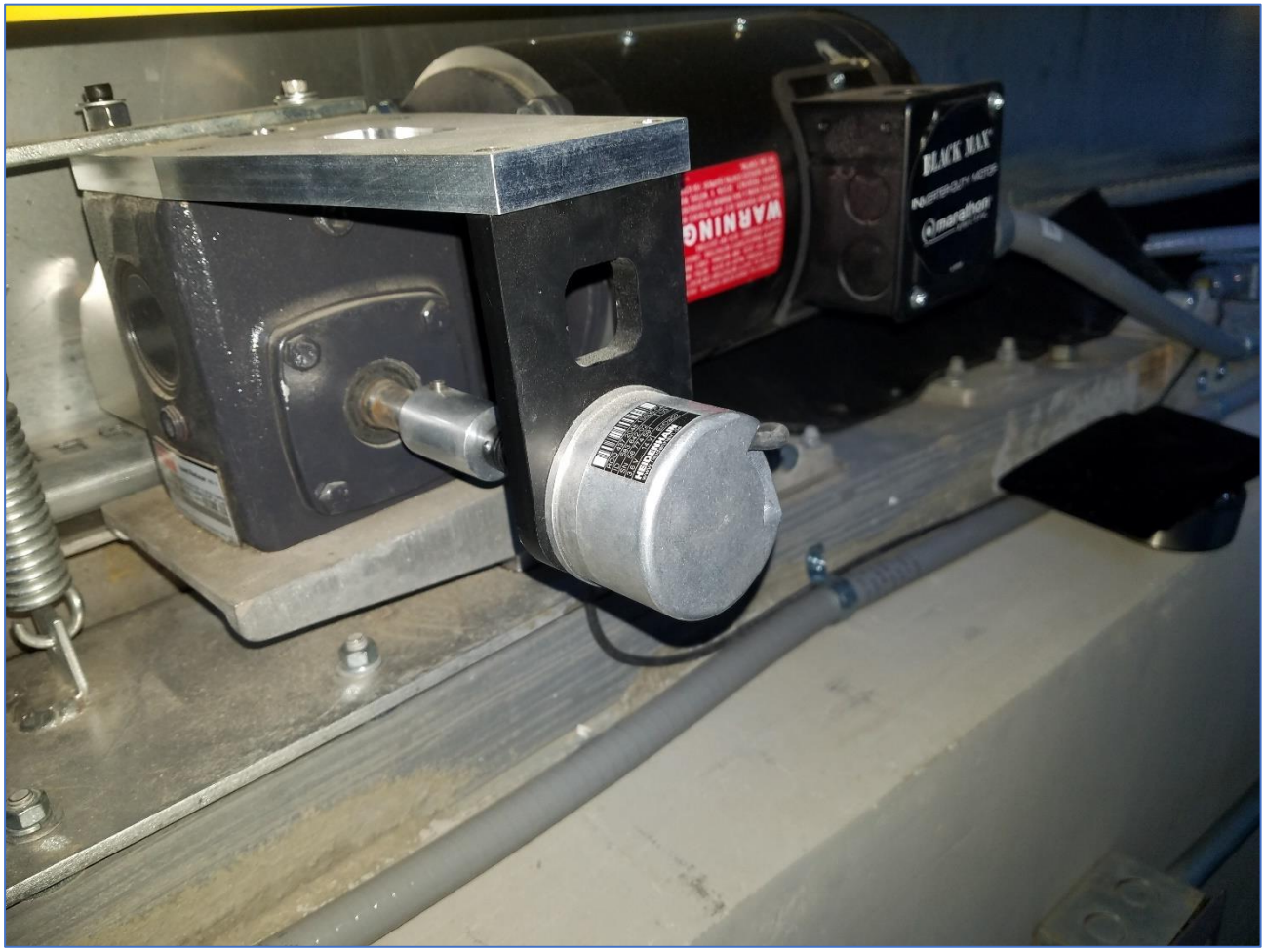


FIGURE 2-6 AZIMUTH DRIVE MOTOR, SPEED REDUCER, AND ABSOLUTE ENCODER

The motor is a Marathon Black Max Y534 which is a high-performance inverter duty 3-phase 230/460 VAC device. It is wired for high voltage (460 VAC) and has a base speed of 1800 RPM when driven at a base frequency of 60 Hz.

The gearbox is a Dayton 4Z002 56C right angle model, with a 40:1 reduction ratio.

When the motor is driven at 115Hz the output shaft of the gearbox turns at

((115 / 60) * 1800) / 40 = 86.25 RPM

The shaft turns around 119.75 times per 360 degrees. Therefore, when driven at high speed the dome rotates once every 83 seconds, or approximately 4.3 degrees/s.

The variable frequency drive is accordingly set to a nominal high speed value of 115 HZ. The low speed value is set to 12 Hz, or 0.45 degrees/s.

2.3.5 Main Control Box Hardware

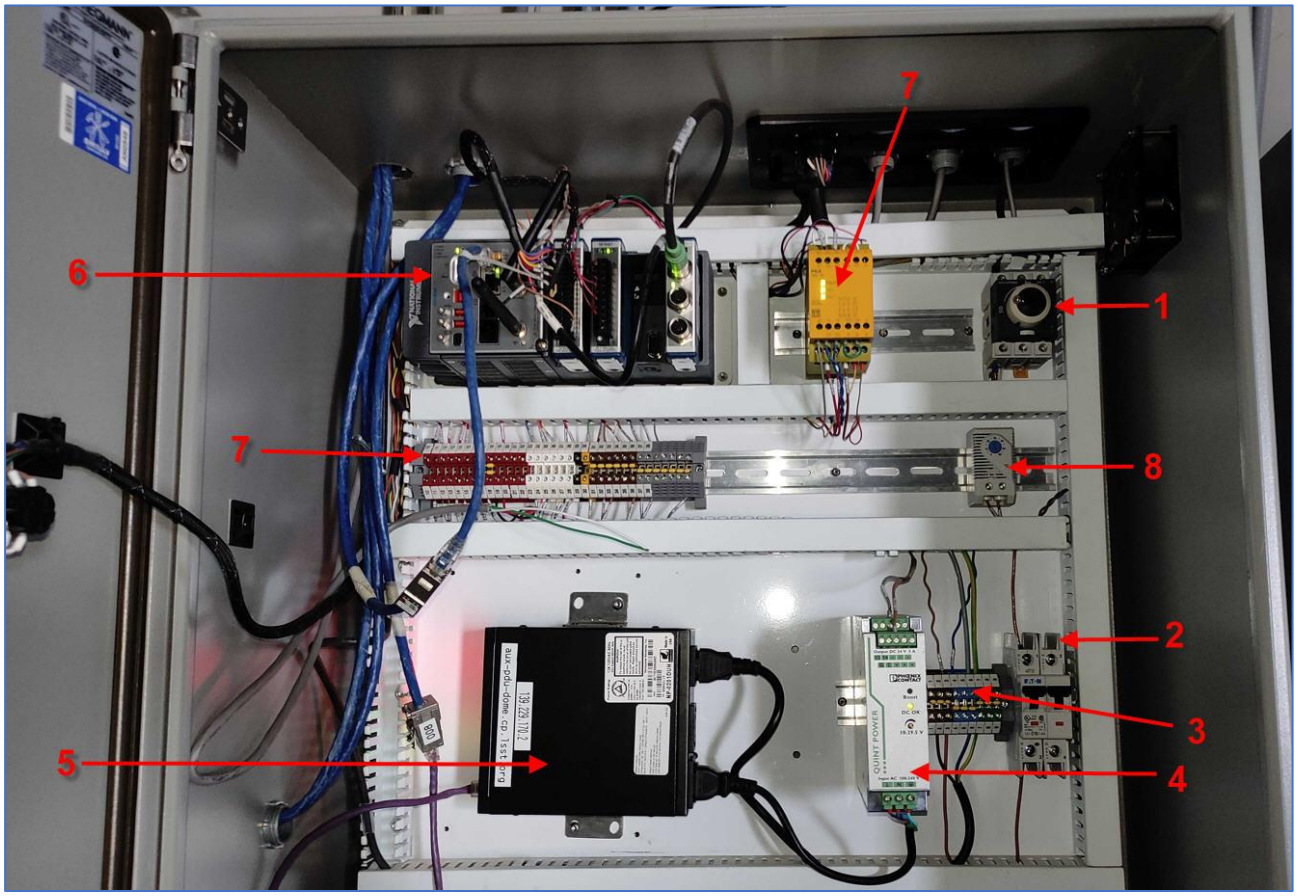


FIGURE 2-7 MAIN CONTROL BOX

The main control box has an isolation switch (1) which is activated from the front of the enclosure. Power passes through a supplemental circuit breaker (2) to a distribution terminal strip (3). A 24V DC power supply (4) is fed from a remote-controlled switched PDU (5). This way the Compact Rio (6) can be remotely power-cycled. A distribution terminal strip (7) provides convenient wiring to the variable frequency drive and the push buttons. The dome is included in the emergency stop system, using a PILZ controller (7). An emergency stop switch and a reset switch are mounted on the front of the enclosure. A thermostat (8) is used to control a 24 VDC fan (not seen but at the top right of the enclosure).

2.3.5.1 Enclosure

The Main Control Box enclosure is a Hubbell-Weigmann ultimate series single door cabinet model N4122424123PTC. It measures 609 x 609 x 305 mm (24x24x12 inches).

The cabinet door is locked and cannot be opened unless the main disconnect switch is turned off. To undo, insert the key, turn the key, then grab the latch underneath the handle, and turn the handle 90 degrees clockwise.

2.3.5.2 Main Disconnect Switch

The main disconnect switch is a Socomec 22003004-UL rated 600 VAC,40A, 65kVA SCCR, UL508 DIN-rail mountable device. The front-door mounted rotary knob has a lockout feature that is ordered separately (part 148E1111) with a connecting shaft (part 14070532).

2.3.5.3 Circuit Breaker

An Eaton FAZ-C30-2-A type UL489 circuit breaker is installed.

2.3.5.4 Power Supply

A Phoenix Quinnt DC 24V 5A power supply, with 240 VAC single phase input, model 2866750, is used.

2.3.5.5 NI 9032 Compact Rio

The heart of the ACE SmartDome™ is a National Instruments 9032 Compact Rio. This is an embedded Intel Atom E3825 1.33 GHz real-time processor with reconfigurable FPGA.

The cRIO-9032 has two ethernet ports and an IEEE 802.11 a/b/g/n 2.4 GHz / 5GHz wireless ethernet. The expansion chassis can accept up to four modules, and two are populated.

2.3.5.6 NI-9375 Digital I/O Module

The NI-9375 is a c-Series module with 16 Digital Input channels and 16 Digital Output channels. The device is sinking input and sourcing output. The Digital Input lines are compatible with 24 V logic levels, and the digital output lines are compatible with 24 V signals, based on the power supply used.

For more details refer to the Shutter Control Box description.

The Main Control Box I/O assignments are as follows:

NI9375 D-SUB	Function	TERM	MAIN CONTROL BOX Allocation	Notes / Route to
1	DI0	12	EMERGENCY STOP Button	
2	DI1	18	CLOSE Button	
3	DI2	19	OPEN Button	
4	DI3	20	UP Button	
5	DI4	21	DOWN Button	
6	DI5	22	FORWARD	
7	DI6	23	REVERSE	
8	DI7	25	Azimuth HOME Sensor	
9	DI COM		DC Power Supply COM	
19	DI8			
20	DI9			
21	DI10			
22	DI11			
23	DI12			
24	DI13	24	Environmental Senor	Sensor logic NO.
25	DI14			
26	DI15			
10	DO0			
11	DO1			
12	DO2			
13	DO3			
14	DO4			
15	DO5		FORWARD rotation	To VFD input DI1
16	DO6		REVERSE rotation	To VFD input DI2
17	DO7		HIGH SPEED	To VFD input DI3
18	DOCOM		DC Power Supply COM	To VFD input DCM
28	DO8			
29	DO9			
30	DO10			
31	DO11			
32	DO12			
33	DO13			
34	DO14			
35	DO15			
36	VSup		DC Power Supply +24V	

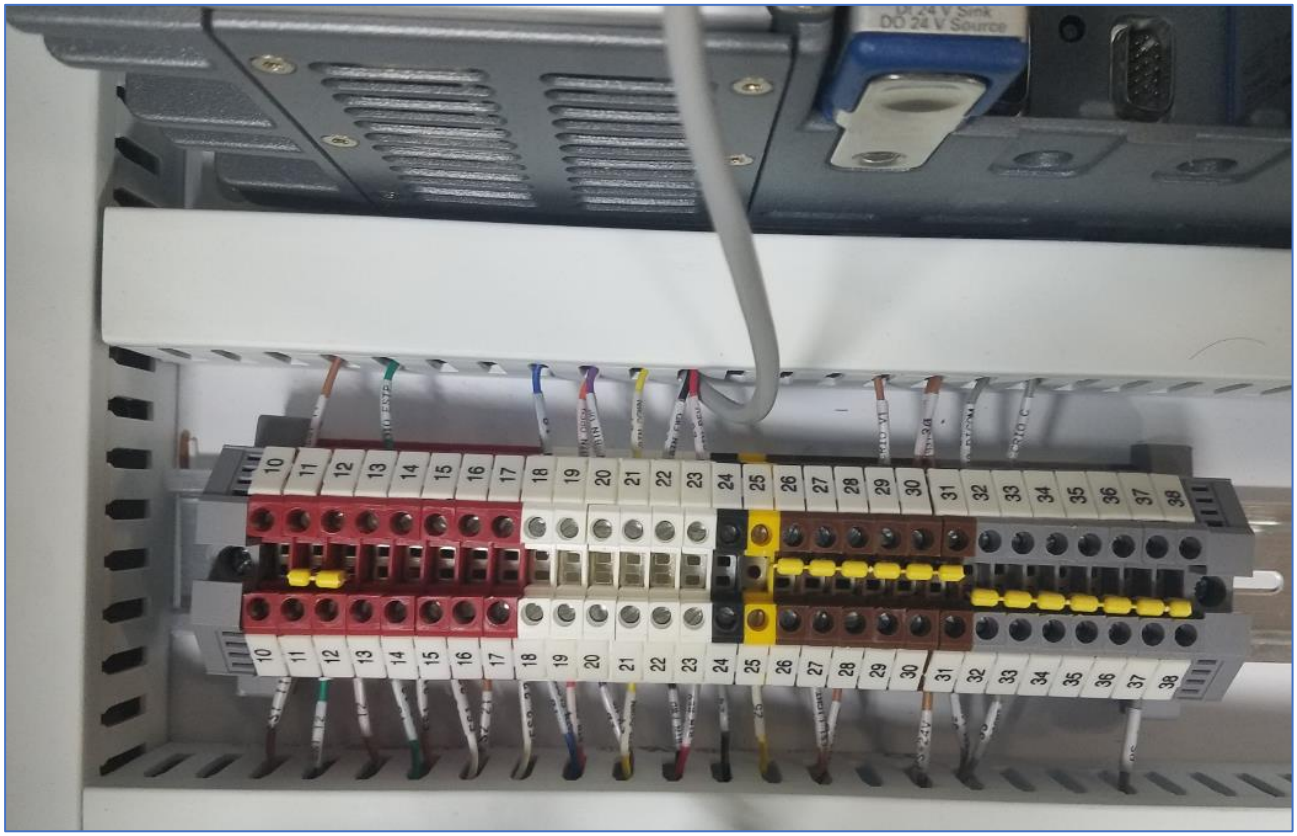


FIGURE 2-8 MAIN CONTROL BOX PUSH BUTTONS AND SENSORS TERMINAL STRIP

2.4 AZIMUTH CONTROL BOX

The dome is rotated in azimuth using four inverter-duty AC motors using a Variable Frequency Drive (VFD) The VFD is housed in its own enclosure, identical to the MCB enclosure and to the right of it.

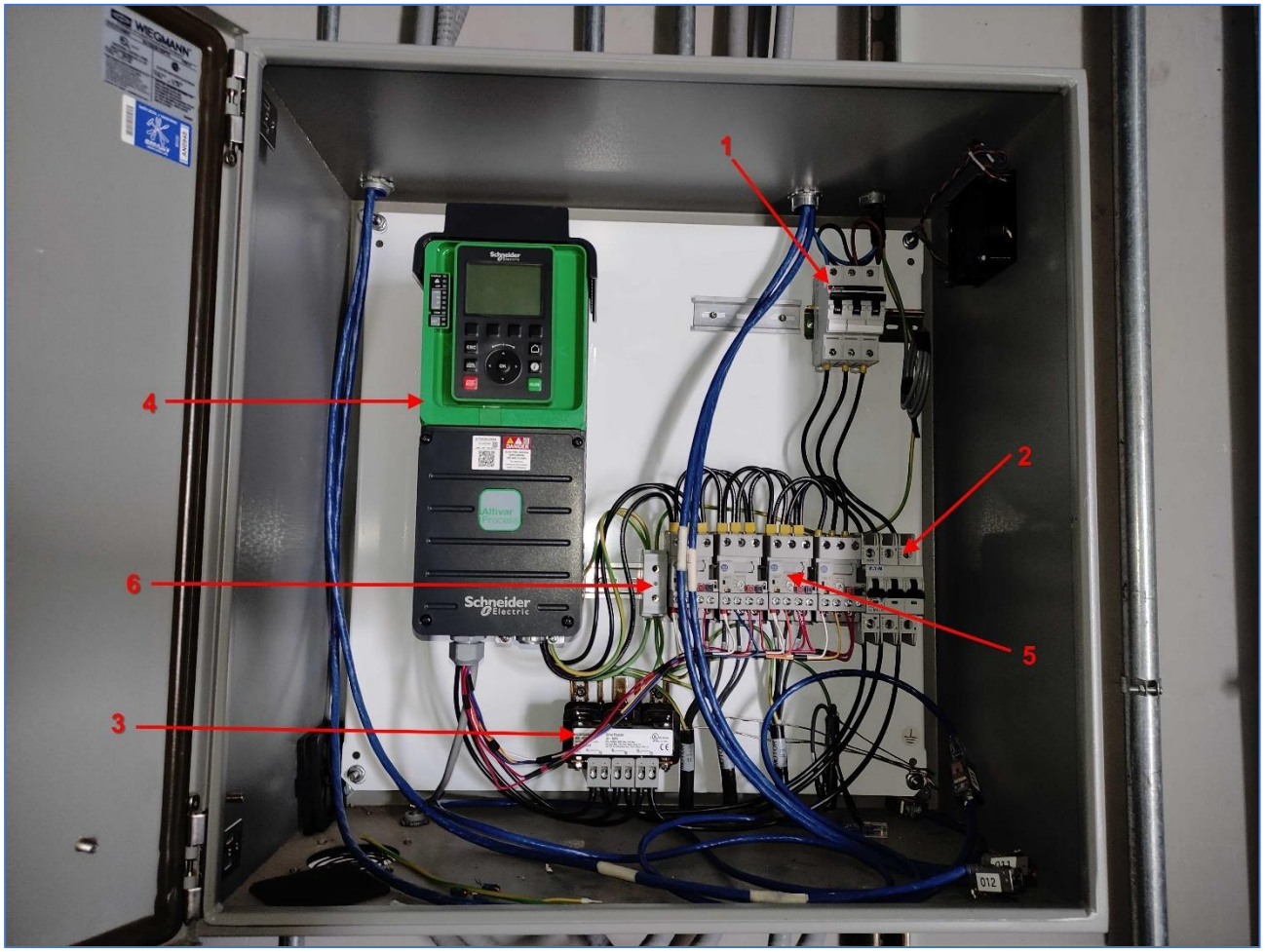


FIGURE 2-9 AZIMUTH CONTROL BOX

The Azimuth Control Box has a main disconnect switch (1) which feeds a circuit breaker (2). Power passes through a line reactor (3) to protect the Variable Frequency Drive (4) from voltage transients. Output from the VFD passes through four overload devices (5) and the feeds the four azimuth drive motors. A junction for common ground (6) simplifies the wiring.

2.4.1 Azimuth Control Box Hardware

2.4.1.1 Enclosure

The Azimuth Control Box enclosure is a Hubbell-Weigmann ultimate series single door cabinet model N4121620081PTC. It measures 406 x 508 x 203 mm (16x20x8 inches).

2.4.1.2 Main Disconnect Switch

The main disconnect switch is a Socomec 22003004-UL rated 600 VAC,40A, 65kVA SCCR, UL508 DIN-rail mountable device. The front-door mounted rotary knob has a lockout feature that is ordered separately (part 148E1111) with a connecting shaft (part 14070532).

2.4.1.3 Circuit Breaker

An Eaton FAZ-C30-2-A type UL489 circuit breaker is installed.

2.4.1.4 Line Reactor

An Automation Direct line reactor, model LR-45P0, is used to protect the drive from voltage transients.

2.4.1.5 Variable Frequency Drive

A single Schneider Electric Altivar ATV930 is used to drive the four motors

2.4.1.6 Overload Protection

A single VFD controls the four azimuth motors and its current output is set to four times the rating of each motor. Therefore, overload protection is required for each motor. An Allen Bradley electronic overload relay, Allen Bradley type 193-T-3P is used for this purpose

2.5 PROGRAMMING THE ALTIVAR 930 USING THE GRAPHICAL DISPLAY TERMINAL

The Altivar 930 VFD has been programmed for two-speed control to allow sidereal tracking and rapid slew between objects.

It uses two-wire control, meaning that motion continues as long as the manual push-button (or digital I/O bit) is active.

FIGURE 2-10 ALTIVAR 930 GRAPHICAL DISPLAY TERMINAL

The Altivar User Interface is shown in Figure 2-10. A touch-wheel is the primary input device. The UP/DOWN arrows are used for selecting different menus, and the LEFT/RIGHT arrows are used to select digits when setting a numerical value of a parameter. Digits are changed by rotating the touch-wheel, and the value saved by pressing OK. Rotating the wheel also moves up/down through the menus.

The very top line of the display can be customized. It is currently set to show the real-time value of the output frequency, in Hz.

For more information refer to the ATV900 Programing Manual.

2.5.1.1 Main Menu

The MAIN MENU has eight submenus.

1	Simply Start	
2	Dashboard	
3	Diagnostics	
4	Display	
5	Complete settings	
6	Communication	
7	File Management	
8	My preferences	

We only discuss parameters that have been altered from the default settings to create a multi-speed controller.

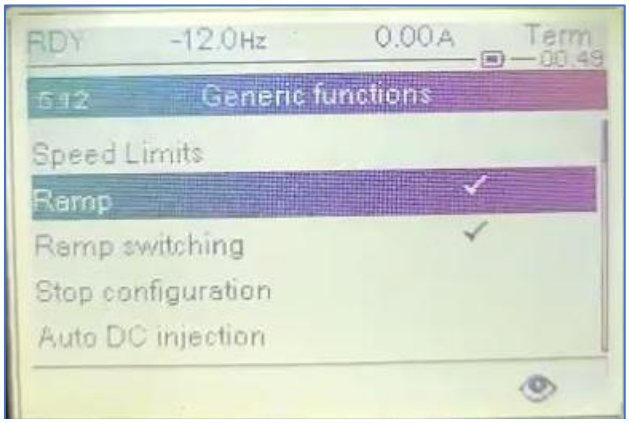
2.5.1.2 Simply Start Menu

The Simply Start menu has three sub-menus, one of which is again called Simply Start. This sub-menu contains the basic motor parameters. The parameters are shown in the following screen capture:

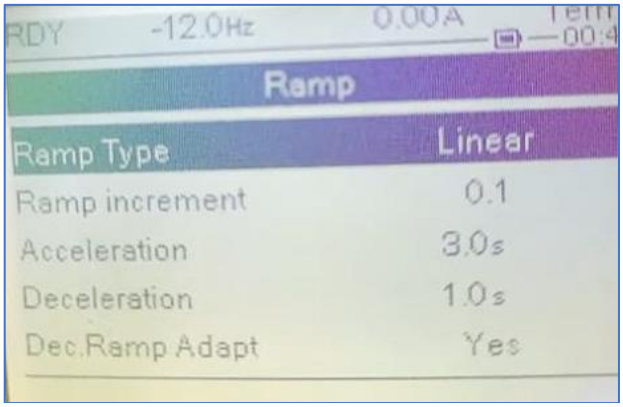
The motor current is set to four times the rated value of the motor since the single VFD is driving four motors. Overload protection is provided through four electronic contactors.

2.5.1.3 Complete Settings Menu

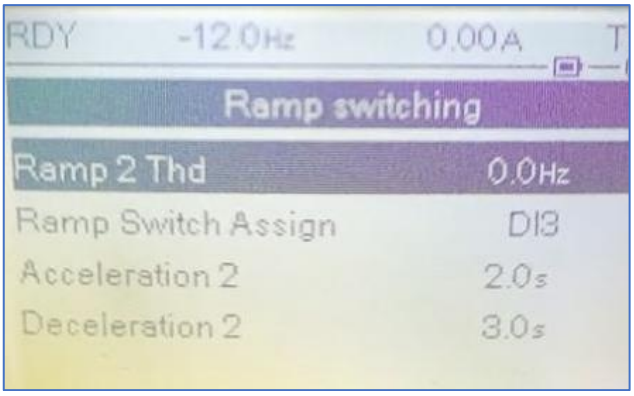
Under the Generic Functions section select Ramp and Ramp Switching as shown in the following screen capture:



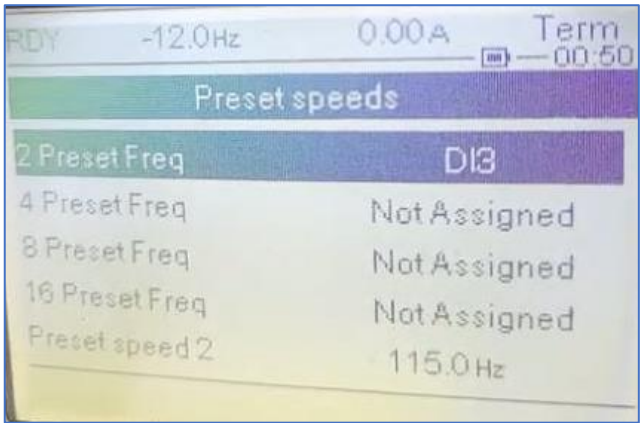
In the Ramp sub-menu the ramp type is linear and acceleration and deceleration time are specified. These are the settings for the slow speed (12Hz) motion.



In the Ramp switching sub-menu the ramp switching for High Speed (115Hz) is controlled by DI3 going high and Acceleration 2 and Deceleration 2 are used with the High Speed motion.



In the Preset Speed sub-menu of the Complete Settings menu the control bit for high speed and the high speed frequency are defined. (The drive is capable of 16 speeds and we are using just two).



The input speed bit is on digital channel DI3 (read as “Digital Input Three”). DI1 is used for Forward and DI2 is used for reverse, which are the default settings.

The high speed frequency is set to 115 Hz. This is sufficient to turn the dome at 4.3 degrees per second.

3.0 SOFTWARE DESCRIPTION

There are two Compact Rio 9032 devices in the system, one for the Shutter Control Box, and one for the Main Control Box which also deals with azimuth.

The intent is to send all commands through the Main Control Box. However, it is possible to connect directly with the Shutter Control Box to perform specialized engineering tasks. In the event of a MCB failure, the shutters will automatically close after 600 seconds (default).

3.1 FIRMWARE FEATURES

The firmware has been designed to provide maximum protection for the telescope.

Accordingly, when operated using the recommended settings the dome shutters will automatically close if any of the following conditions are met:

- ✓ Communication with the Shutter Control Box is lost
- ✓ The rain-snow sensor is activated and the Rain-Snow feature is enabled

3.2 CONTROL SOFTWARE COMMANDS

Commands are sent over a telnet TCP-IP connection to the SmartDome Compact Rio.

Although it is possible to connect directly to the Shutter Control Box, the normal mode of operation is to connect only to the Main Control Box. The MCB will relay commands and status to/from the SCB.

To start a telnet session issue the command

```
telnet auxtel-dome-crio-main.cp.lsst.org 17310
```

When connected the system responds with a > prompt.

```
Last login: Tue Apr 12 11:54:57 on ttys002
Craig-Lages-MacBook-Pro:~ cslage$ telnet auxtel-dome-crio-main.cp.lsst.org 17310
Trying 139.229.170.45...
Connected to auxtel-dome-crio-main.cp.lsst.org.
Escape character is '^]'.

ACE Main Box
>
```

FIGURE 3-1 ESTABLISHING A TELNET CONNECTION

3.2.1 HELP

Type help for a list of the commands.

```
> HELP
Firmware Version 2.06
?      Short Status
+      Full Status
ST     Stop all motion
CL     Close Main Door
OP     Open Main Door
UP     Close (rise) Dropout Door
DN     Open (lower) Dropout Door
SO     Synchronized Open (Both doors open together)
SC     Synchronized Close (Both doors close together)
AO     Auto shutdown ON
AF     Auto shutdown OFF
RO     Rain ON
RF     Rain OFF
CO     Cloud Sensor ON
CF     Cloud Sensor OFF
HM     Rotate to home position
d MV   Move to Azimuth (d=degrees,0.0<=d<360)
d TOL  Tolerance (d=degrees,0.0<=d<3)
d HZ   Define home position (d=degrees,0.0<=d<360)
d HS   High speed threshold (d=degrees,0.0<=d<10)
d CS   Coast (d=degrees,0.0<=d<6)
d LM   Encoder counts for 360 degrees
t WT   Watchdog Timer (t=seconds,600 typical)
t RD   Set reverse direction motion delay (t=seconds,0<=t<6)
t AT   Set Azimuth motion timeout (t=seconds,120<=t<600)
t RS   Set Rain / Cloud activate delay (t=seconds,1<=t<10)
t DT   Set Door Move Timeout (t=seconds,30<=t<=600
t HT   Set the Host Comm Timeout Period (t=seconds,1<=t<=3600)
AEP    AZ Encoder Count Positive
AEN    AZ Encoder Count Negative
CFS    Save current configuration
CFR    Recall last saved configuration
HELP   Display this list of available commands
>
```

FIGURE 3-2 HELP DISPLAYS ALL AVAILABLE COMMANDS

3.2.2 ? (Short Status)

Typically, the **?** command is issued at 2 to 5 HZ so the status can be updated in real time.

Issuing a **?** command will return the current status of the dome.

Output for the **?** command	Line	Comments
MAIN AJAR 035 DROP SHUT 000 [ON] 00 Posn 134.14 RR 020 >	1	MAIN (OPEN AJAR SHUT) percentage open
	2	DROP (OPEN AJAR SHUT) percentage open
	3	Auto-Shutdown [ON] or [OFF] & sensor code
	4	Posn or Home plus DDD.dd degrees
	5	See code table below
	6	> prompt

Line 1 gives the status of the main shutter door. Valid states are OPEN, SHUT and AJAR (partially open). In addition the percentage of open is reported. Closed is 0% and opened is 100%.

Line 2 gives the status of the dropout shutter door. Valid states are OPEN, SHUT and AJAR (partially open). In addition the percentage of open is reported. Closed is 0% and opened is 100%.

Line 3 reports the auto shutdown status. The default should be ON. It can be turned OFF for engineering purposes. When the auto shut down is ON the dome will close is there is a loss of communication between the MCB and the SCB, if there is a loss of communication between the MCB and the host computer, or if one of the environmental sensors is triggered and the RAIN parameter is turned on.

The environmental sensor on the dome skin is a rain-snow sensor. If it is triggered the code is 01. The environmental sensor on the MCB is typically a cloud sensor. If it is triggered the code is 02. If both are triggered the sensor code will be 03. If none are triggered the sensor code is 00.

Line 4 reports the position in decimal degrees to 0.01 degrees. If the dome is on the home azimuth sensor then Posn changes to Home.

Line 5 has the following Code options:

First Field	Second Field	Comments
RR		Last rotation was to the right
RL		Last rotation was to the left
--		The system has not rotated since boot-up
	000	No motion
	001	Moving right
	002	Moving left
	004	Closing main door
	008	Opening main door
	016	Closing dropout
	032	Opening Dropout
	064	Dome seeking home
	128	Emergency Stop switch activated

If there is no motion the code is 000. Otherwise, for one or more current motions the return code is the sum of the codes given in the table. For instance, if the main door and the dropout door are both opening while the dome is moving left the return code will be 008 + 032 + 002 = 042.

3.2.3 + (Full Engineering Status)

Issuing the **+** command gives the full engineering status. It is intended for engineering setup purposes only. Under normal operating conditions all the pertinent information can be obtained by using the ? command. Use the **+** command when setting parameters and checking their values.

```
>+
MAIN AJAR 035
DROP SHUT 000
[ON] 00
Posn 134.14
RR 020
Emergency Stop Active:  0
SCB radio link OK:      1
Home Azimuth:         90.00
High Speed (degrees):  6.00
Coast (degrees):      0.20
Tolerance (degrees):   1.00
Encoder Counts per 360: 490496
Encoder Counts:       1485289
Last Azimuth GoTo:     99.50
Rain-Snow enabled:     1
Cloud Sensor enabled: 1
Watchdog Reset Time:   600
Dropout Timer: 100
Reverse Delay:  2
Main Door Encoder Closed: 1856
Main Door Encoder Opened: 456540
Dropout Encoder Closed: 7156
Dropout Encoder Opened: 10321
>
```

FIGURE 3-3 SYSTEM STATUS OUTPUT FOR THE + COMMAND

The first five lines are identical to the output of the short status **?** command.

3.2.4 ST

The **ST** command stops all motion and cancels any pending actions.

3.2.5 CL

The **CL** command closes the main shutter door. Note that the dropout door must be fully closed before the main door can enter the interlock zone and completely close. There is no need to worry about this in the software; the firmware handles all cases and it is not possible to crash the doors into each other. The **SC** command is the preferred way to close the dome.

Related commands: **SC**

3.2.6 OP

The OP command opens the main door only.

Related commands: **SO**

3.2.7 UP

The **UP** command closes (raises) the dropout shutter door. It will only be accepted if the main shutter door is not in the interlock zone.

Related commands: **SC**

3.2.8 DN

The **DN** command opens (lowers) the dropout shutter down. If the main door is in the interlock zone the **DN** command will become active when the main door moves out of the interlock zone.

Related commands: **SO**

3.2.9 SO

The **SO** (**S**ynchronized **O**pen) command is the optimal way to open both shutter doors.

Both doors open together. If both are fully closed the main door will start to open and when it has left the interlock zone the dropout door will start to open. The dropout door will become fully opened before the main door becomes fully opened, so in this sense the motion is not fully synchronized..

3.2.10 SC

The **SC** (**S**ynchronized **C**lose) command is the optimal way to close both shutter doors.

If both doors are fully opened, then both doors will close together. This will be the normal case.

The dropout door must get to its closed state before the main door enters the interlock zone. If the doors are not fully opened but the main door is 25% more opened than the dropout door then both doors will close together. Otherwise the dropout door will close first, and when fully closed the main door will then close.

3.2.11 AO

The **AO** (**A**utomation **O**n) command enables the automatic shutdown of the observatory.

If the SCB loses contact with the MCB or the MCB loses contact with the host computer then the watchdog will time out and the dome will close, without warning. For this reason always turn off this feature and the SCB power when performing maintenance on the dome shutter doors.

When the **AO** command is active line 3 of the status command will report [ON].

Related commands: **AF RO RF**

3.2.12 AF

The **AF** (**A**utomation o**F**f) command disables the automatic shutdown of the observatory. Issue this command when performing maintenance on the observatory. However, for normal operations this is an unsafe condition as the dome is not protected from failures and bad weather.

When the **AF** command is active line 3 of the status command will report [OFF]. The dome will not close unless commanded to do so by the operator.

3.2.13 RO

The **RO** (**R**ain **O**n) command enables the rain snow sensor which is mounted on the rotating part of the dome. If rain is sensed the dome will close and it will not be allowed to open until the rain sensor shows all clear.

The **RO** command should always be active unless the rain-snow sensor is faulty. The status of the **RO** command can be found in the + command.

3.2.14 RF

The **RF** (**R**ain o**F**f) command disables the rain snow sensor which is mounted on the rotating part of the dome. If rain is sensed the dome will NOT close but the system will still report RAINING. The status of the RF command can be found in the + command.

Unless there is a faulty rain sensor which is causing unwanted closures, the rain sensor should be enabled with the **RN** command.

3.2.15 CO

The **CO** (**C**loud sensor **O**n) command enables the cloud sensor. This is an optional item that can be mounted outside the observatory. If cloud is sensed the dome will close and it will not be allowed to open until the cloud sensor shows all clear.

The **CO** command should always be active unless the cloud sensor is faulty. The status of the **CO** command can be found in the + command.

3.2.16 CF

The **CF** (**C**loud sensor o**F**f) command disables the optional cloud sensor. If cloud is sensed the dome will NOT close but the system will still report CLOUDY. The status of the **CF** command can be found in the + command. Unless the cloud sensor if faulty, the sensor should be activated using the **CO** command.

3.2.17 HM

The **HM** (Home) command sends the dome to the predefined Home azimuth. It will rotate the dome taking what it believes is the shortest path. However, this command does not rely on the encoder position. Rather, it rotates until the sensor is seen. The dome will then stop and reverse direction, travelling back to the home sensor at slow speed, and will stop on the home sensor.

Once the home sensor is reached the encoder counts will be set to show the dome at the pre-defined home azimuth position.

Related commands: **HZ**

3.2.18 d MV

The **MV** (MoVe) command moves the dome to the requested position in degrees where 0<=d<360.

The dome will take the shortest path from the current position.

Issue the move command to update the dome position when the telescope is tracking. If the dome is still within **TOL** degrees of the commanded position the dome will not move.

When tracking satellites or other rapidly moving objects the **MV** command can be issued frequently in real time to create a position profile for the dome.

Related commands: **TOL**

3.2.19 d TOL

The **d TOL** (Tolerance) command defines the minimum allowed move, in degrees, where 0.0<=d<3.

This prevents the dome from constantly oscillating a small amount around the current position.

3.2.20 d HZ

The **d HZ** command defines the Home Azimuth. The home sensor can be placed at any convenient point in the dome, but it is typically where the dome will be parked at the end of the night, using the **HM** command.

The current value of the home azimuth set by **HZ** is reported by the **+** command.

Related commands: **HM**

3.2.21 d HS

The **d HS** (**H**igh **S**peed) command determines the minimum distance in degrees the dome must move to invoke high speed motion, where 0.0 <= d < 10.

Typical values are between 4 and 7 degrees.

The **CS** coast command and the tuning of the Variable Frequency Drive are intimately related to the **HS** parameter and must be tuned by the installation engineer.

Related commands: CS

3.2.22 d CS

The **d CS** (Coast) command determines the amount of freewheeling or overshoot of the dome. The **CS** parameter is invoked by the firmware when moving at slow speed. Typical values of the coat are 0 to 1.0 degrees, and allowable values are 0.0<=d<6. This parameter is set by the installation engineer when tuning the Variable Frequency Drive.

Related commands: **HS**

3.2.23 d LM

The **d LM** (**L**earn **M**anual) command allows for manual entry of the number of encoder counts per 360 degrees. Since the dome encoder has 4096 counts per rev and is attached to a 12-tooth sprocket running on a 1437 tooth circular track at the LSST AT the number of counts is set at 490,496.

3.2.24 t WT

The **t WT** (**W**atchdog **T**imer) command sets the time interval between loss of communication and the dome closing, where 0 < t < 1000. In practice, to allow for host computer reboots, etc., we have found a time of 600 seconds (10 minutes) to be an acceptable value. If bad weather occurs in the watchdog timer 600 seconds interval, the dome will close if the rain-snow sensor is enabled.

3.2.25 t RD

The **t RD** (**R**eversal **D**elay) sets the delay between reversing motor directions for the shutter doors, where 0 < t <= 6) seconds. For a 240 VAC system this parameter can be set to 0.0.

3.2.26 CFS

The **CFS** (Configuration File Save) command writes all the parameters to an external file.

3.2.27 CFR

The **CFR** (**C**onfiguration **F**ile **R**ecall) command loads all the parameters from an external file.

3.3 WEB BROWER INTERFACE

An interface for engineering setup has been provided.

Simply enter the IP address of the cRio into a browser:

`auxtel-dome-crio-main.cp.lsst.org`

Engineering-level parameters will be displayed, such as raw encoder counts, the status of the push buttons, the status of the doors, and so on.

A sample screen capture is shown in Figure 3-4

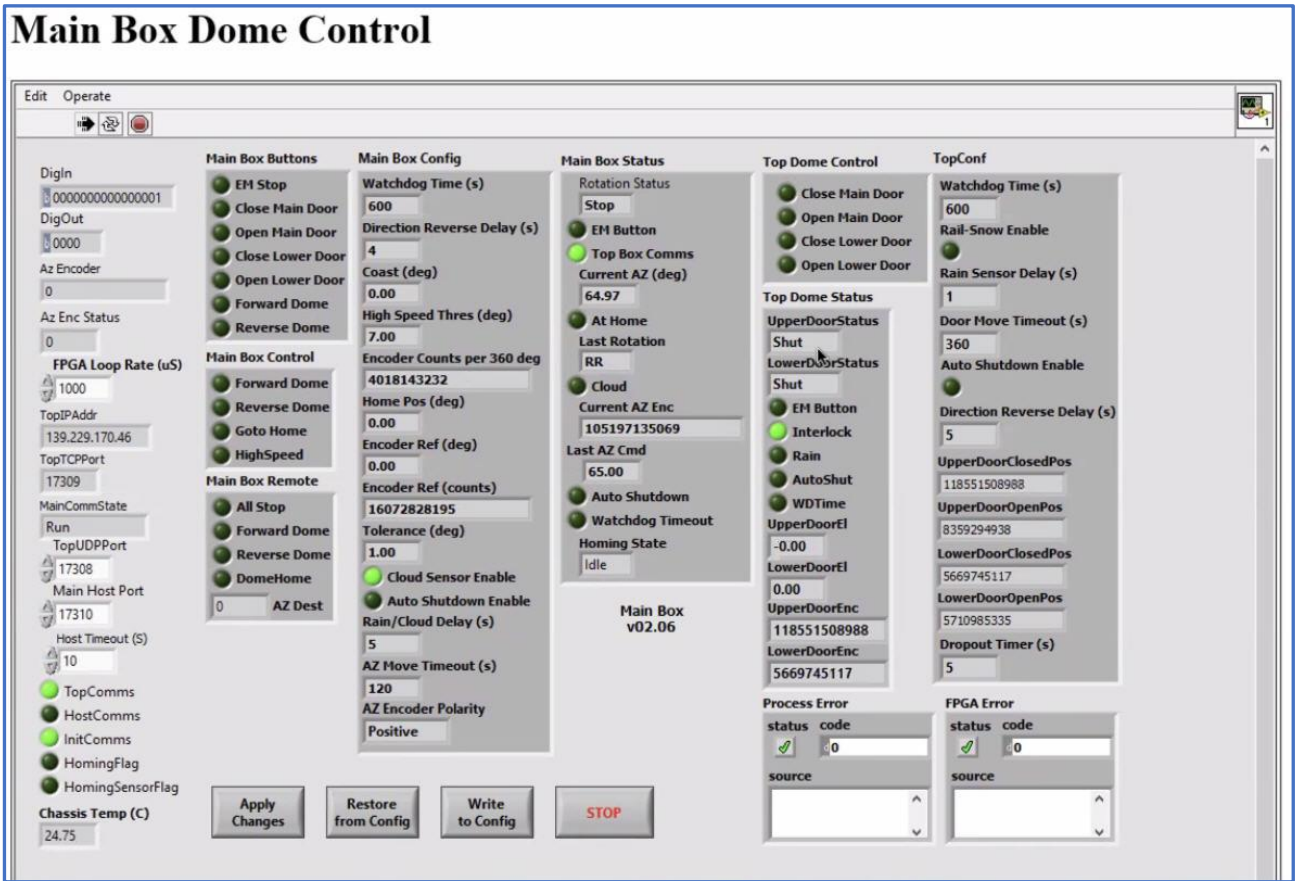


FIGURE 3-4 ENGINEERING WEB-BROWSER INTERFACE

4.0 ELECTRICAL SCHEMATICS

The electric schematics were created using Microsoft Visio. A set of pre-canned Electra stencils were used to speed up the drawing process, but this software is not required to edit the documents.

The original Visio documents have been provided but have also been saved as PDF documents, and this is the best way to view them. However, they are presented in this chapter for easy reference.

The original document contains 5 drawing pages:

Page #	Description
1	Table of Contents
2	SmartDome Main Control Box
3	SmartDome Shutter Control Box
4	SmartDome Azimuth Control Box
5	SmartDome Push Button Diagram

Pages 2 thru 5 are presented below.

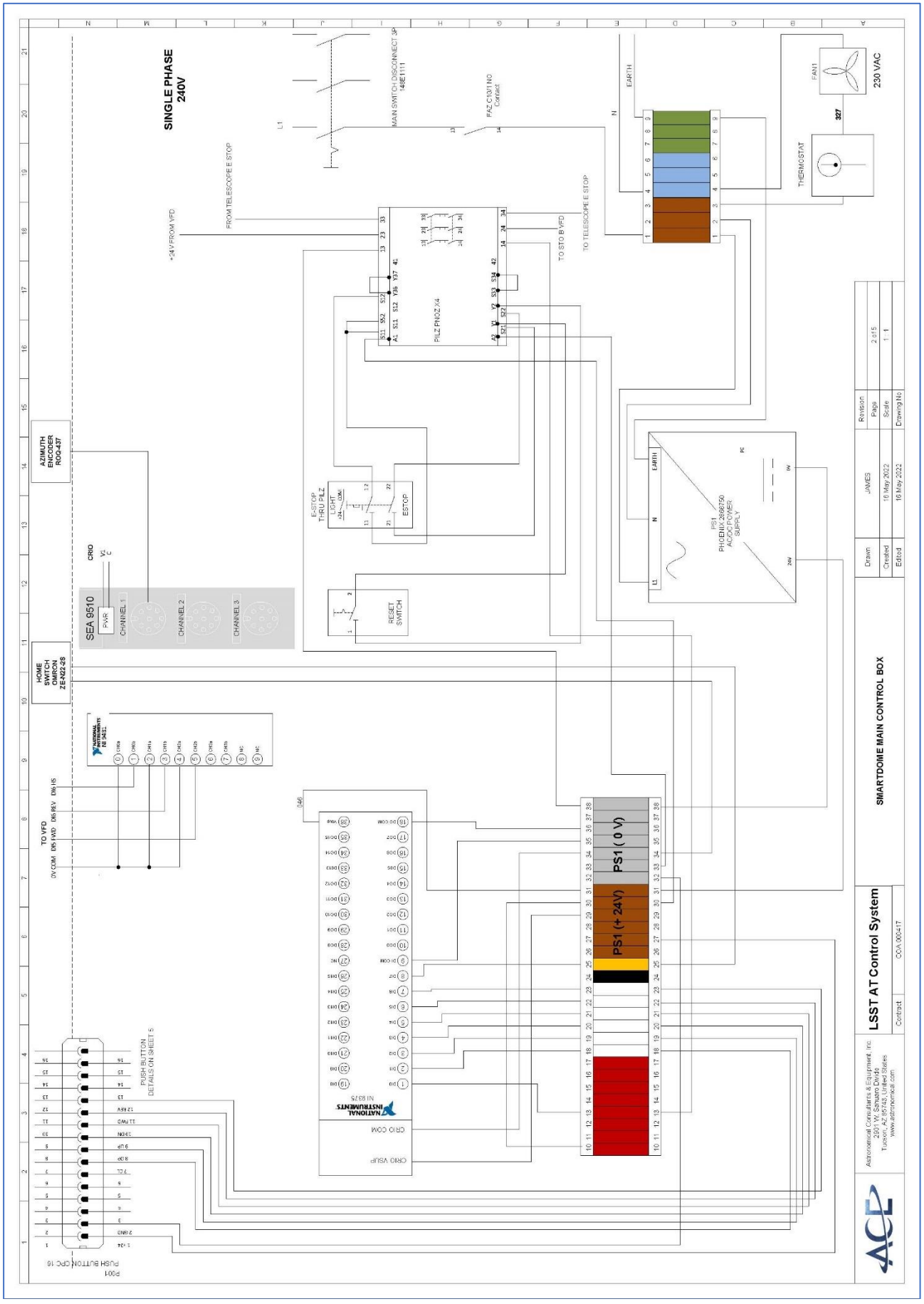


FIGURE 4-1ELECTRICAL DIAGRAM - SMARTDOME MAIN CONTROL BOX

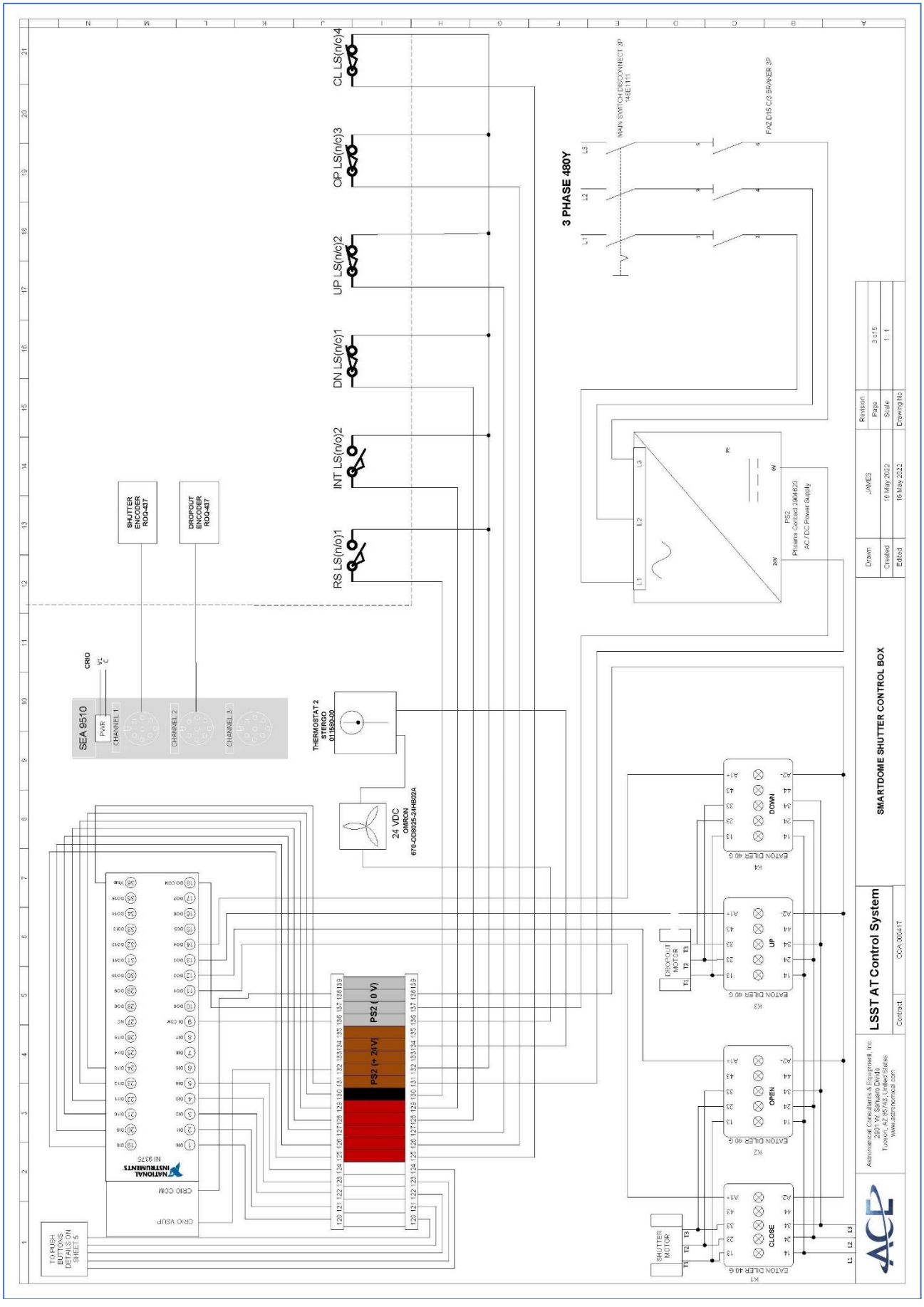


FIGURE 4-2 ELECTRICAL DIAGRAM - SMARTDOME SHUTTER CONTROL BOX

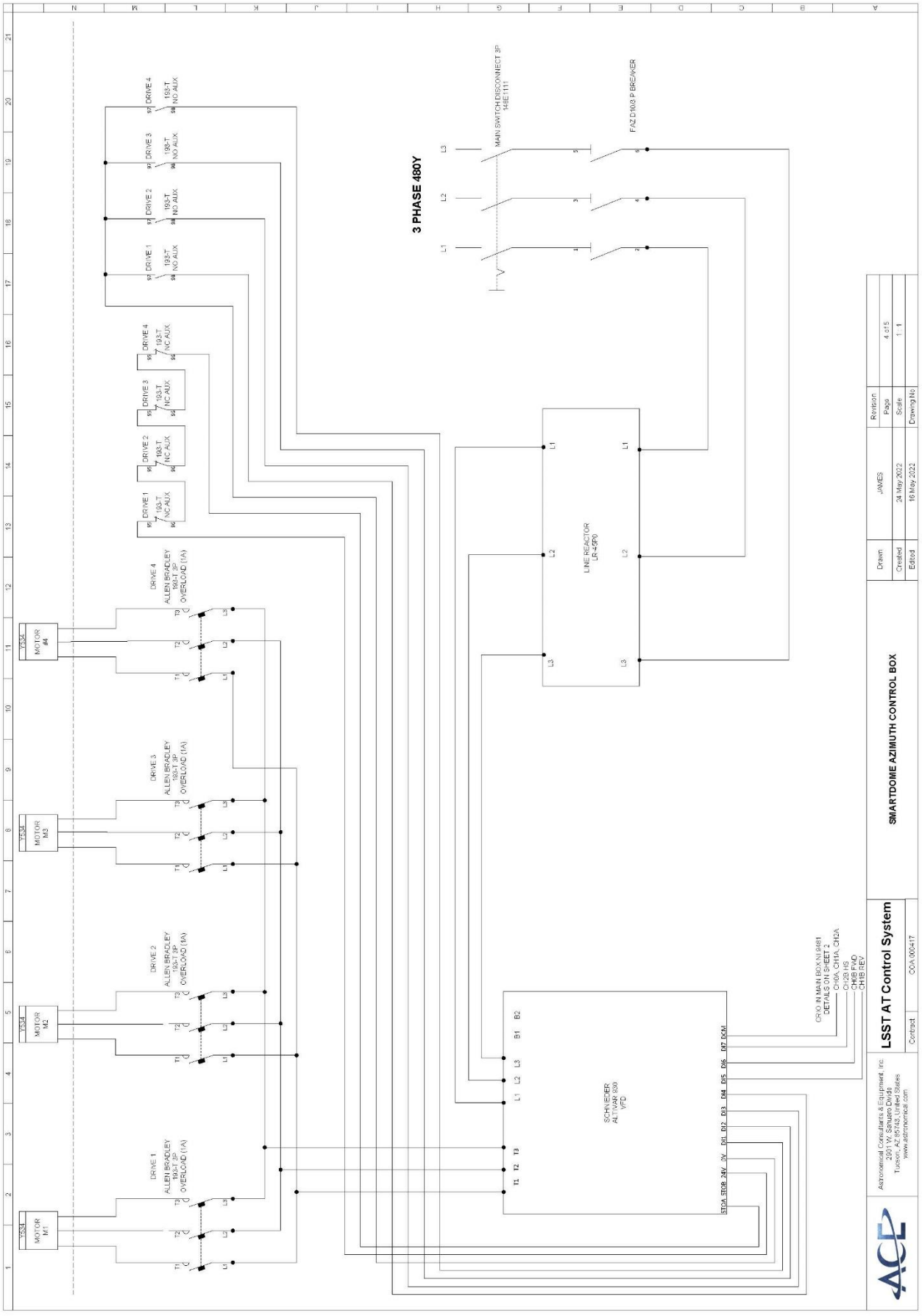


FIGURE 4-3 ELECTRICAL DIAGRAM - SMARTDOME AZIMUTH CONTROL BOX

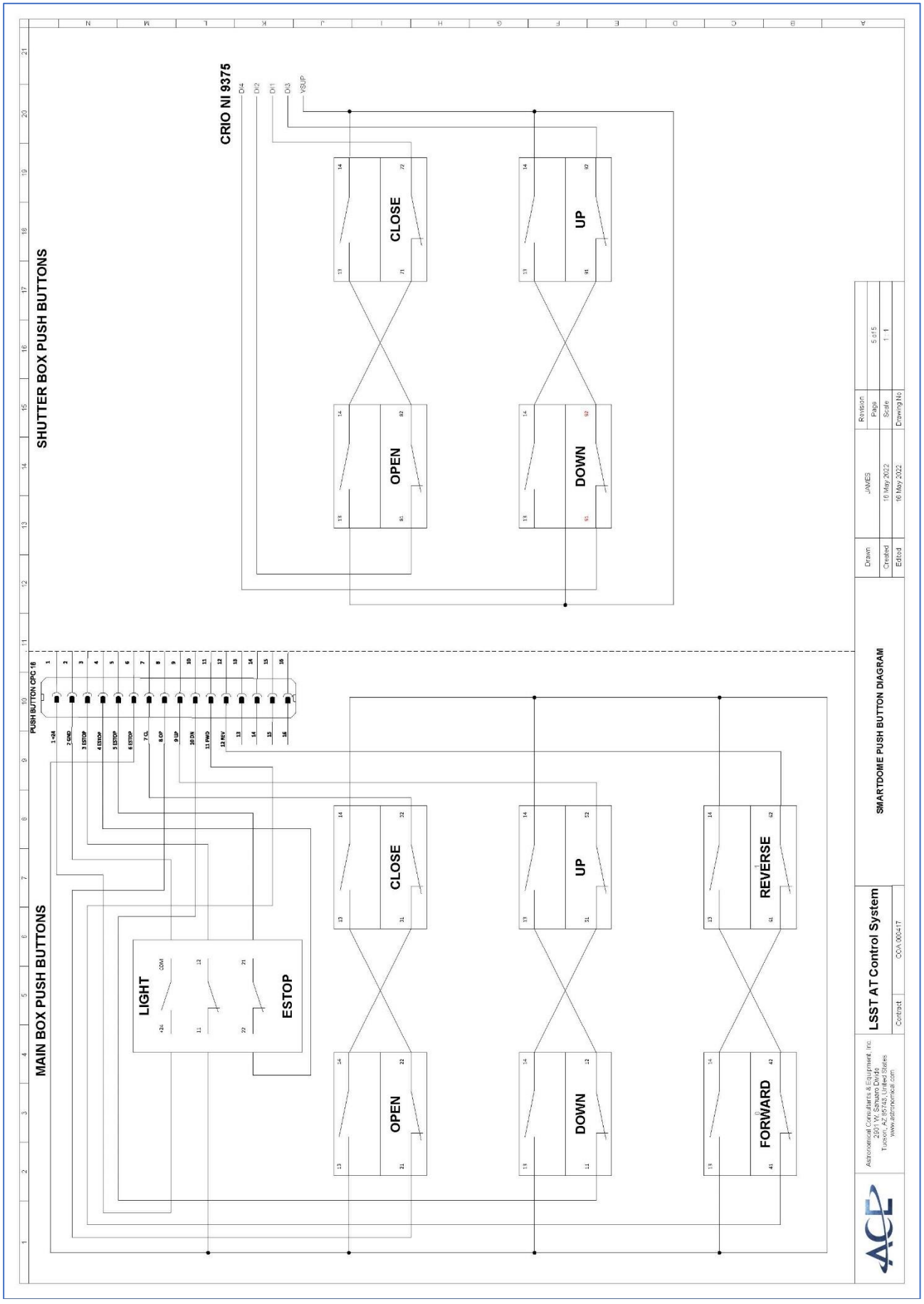


FIGURE 4-4 ELECTRICAL DIAGRAM – PUSH BUTTON REMOTE BOX