Observatory Automation Project
Preliminary Design Review
Electric Dome Drive System

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Scope

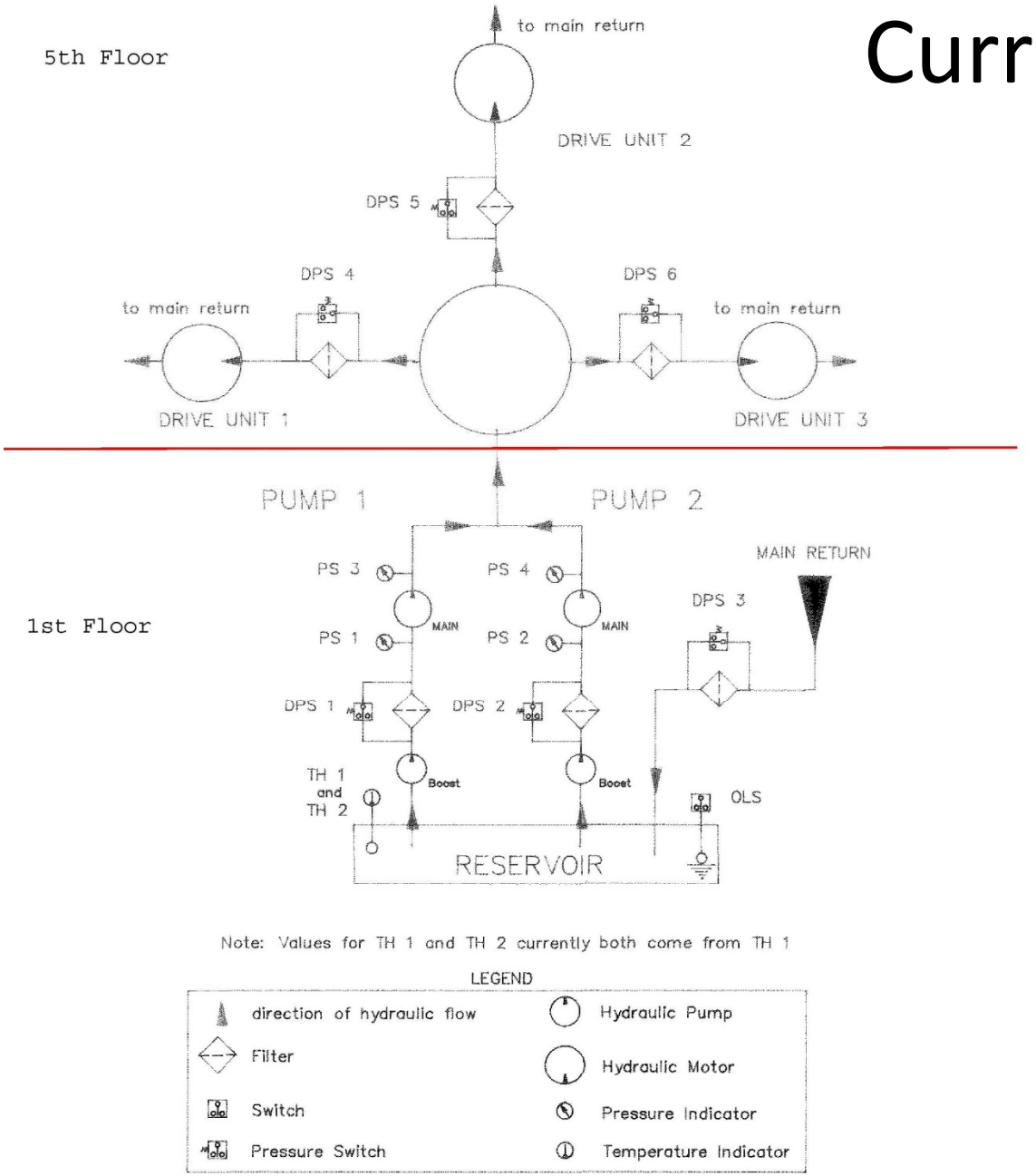
- Design solution to operate the Dome system with electronic drive units.
- Control remotely under the guidelines provided by the OAP project
- Outline the requirements for the system, document the existing system, discuss design alternatives, and detail the preliminary system design, interfaces, safety considerations, estimated costs and resources.

Requirements

Dome drive requirements needed for OAP

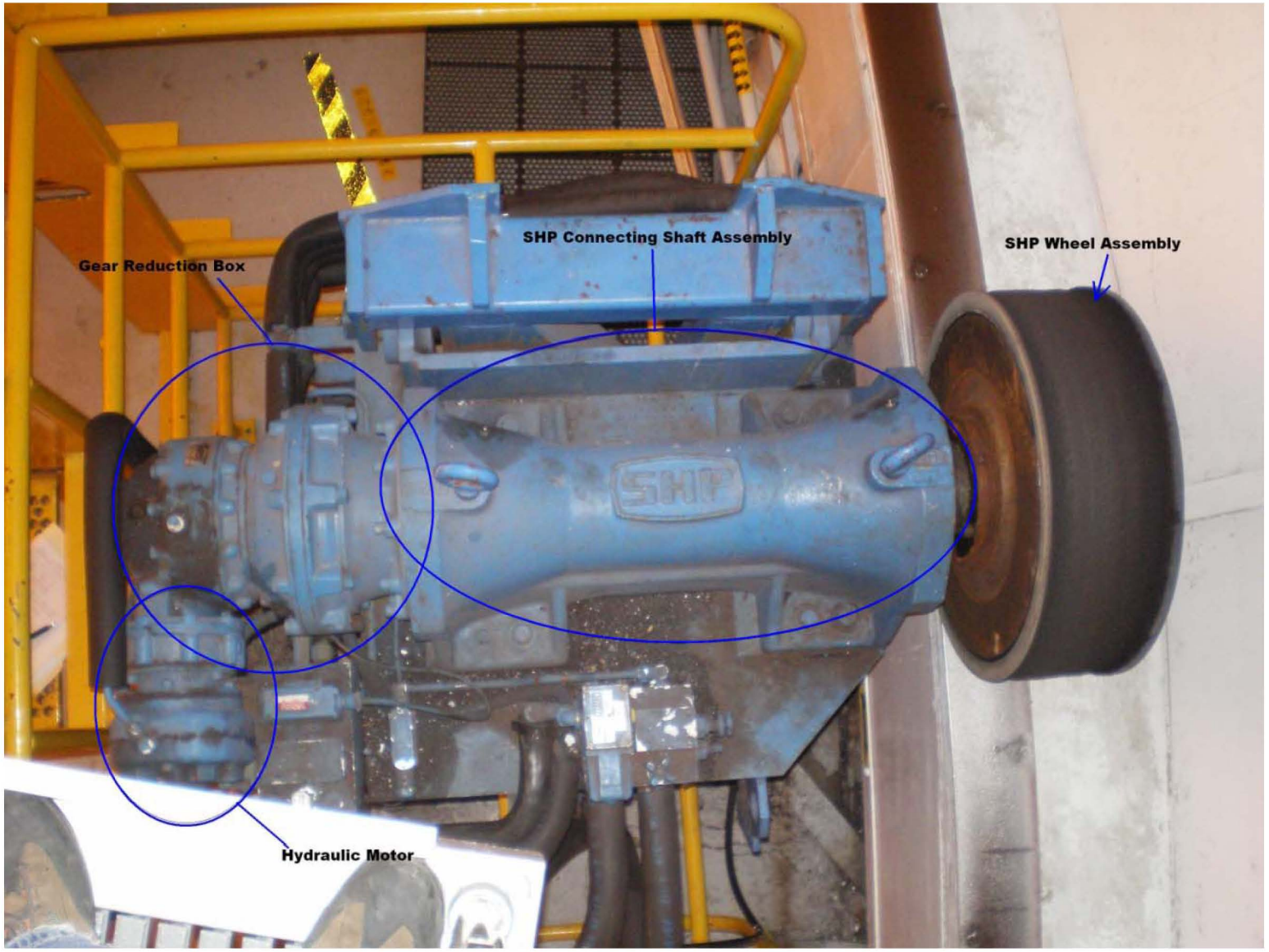
- **Remote Dome drive Operation**
  - The Dome drive must be capable of being operated in a “safe” reliable manner from Waimea.
- **Remote monitoring and status**
  - The electronic drive system shall provide necessary status and system information.
- **Manual Control**
  - The drive system control panel must allow local control of the drive system.
- **Preventative Maintenance**
  - The dome drive system shall provide access to all serviceable components and minimize the need for scheduled maintenance.
- **Improved Reliability**
  - The new electronic dome drive system should increase the reliability and minimize repairs.
- **Safe Interlocking**
  - The dome drive system shall provide safety interlocking to prevent unauthorized remote control of the drive system. It shall protect personal and other critical systems when/if other systems shutdown or malfunction

Current Hydraulic Drive System



- 5th Floor
  - Three (3) Hydraulic drive units
    - Hydraulic motors
    - Drive train (includes gear reduction box)
    - Hydraulic actuators
    - Servo valves, pressure switches,
      Filters, fittings, lines, etc.
- 1st Floor
  - Hydraulic power unit
  - Two (2) 20HP motors
  - Two (2) HP pumps
  - Two(2) LP pumps
  - 200 Gallon Reservoir
  - Filters, pressure switches, check valves, lines and fittings.

Dome Drive Unit Components



Design Alternatives from Feasibility study

Manufacture:

Baldor Technology

Vendor:

Kaman Industries

- Baldor proposes three (3) Baldor 22H Line Regen AC Motor Control Drive Units
- With three (3) Baldor RPM AC Motors

Manufacture:

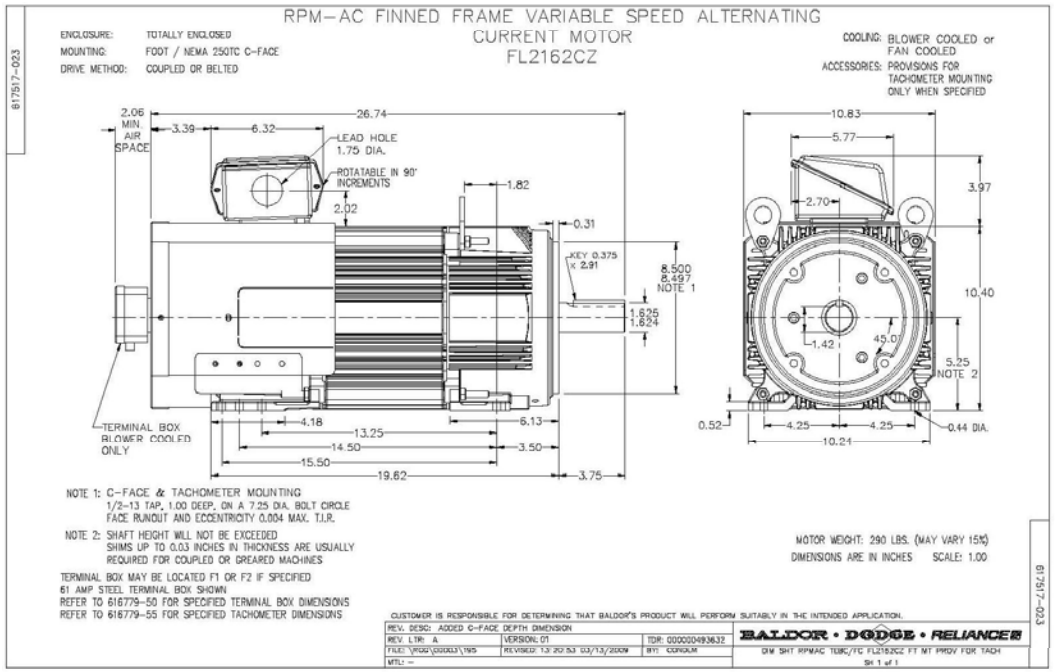
Rockwell Allen-Bradley

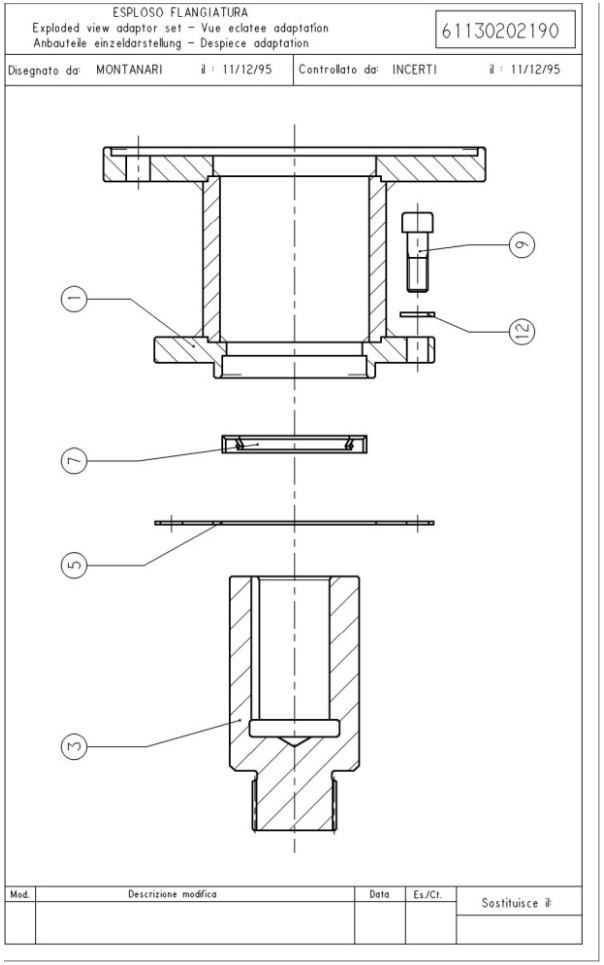
Vendor:

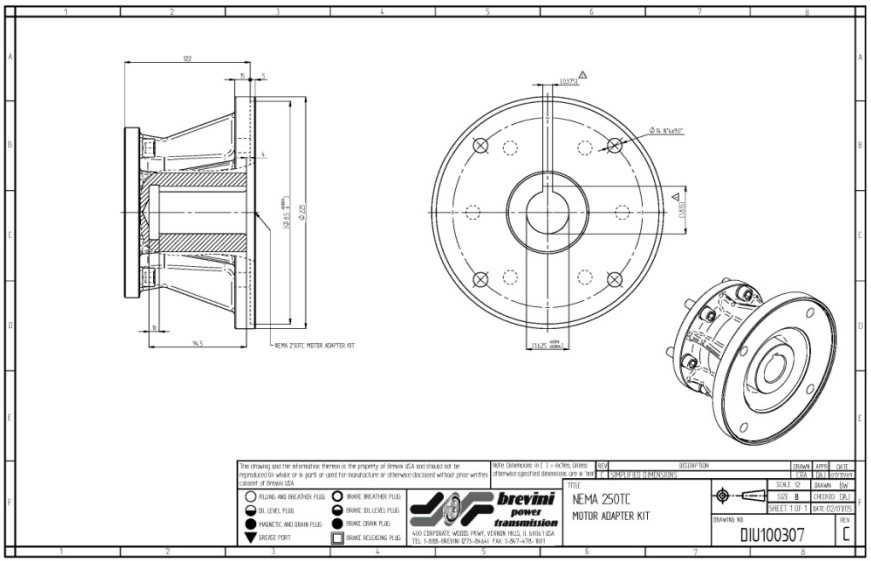
One Source

- Allen-Bradley proposes three (3) Air-cooled PowerFlex 755 Drive Units
- With three (3) Baldor RPM AC Motors

New Motors and Adapter

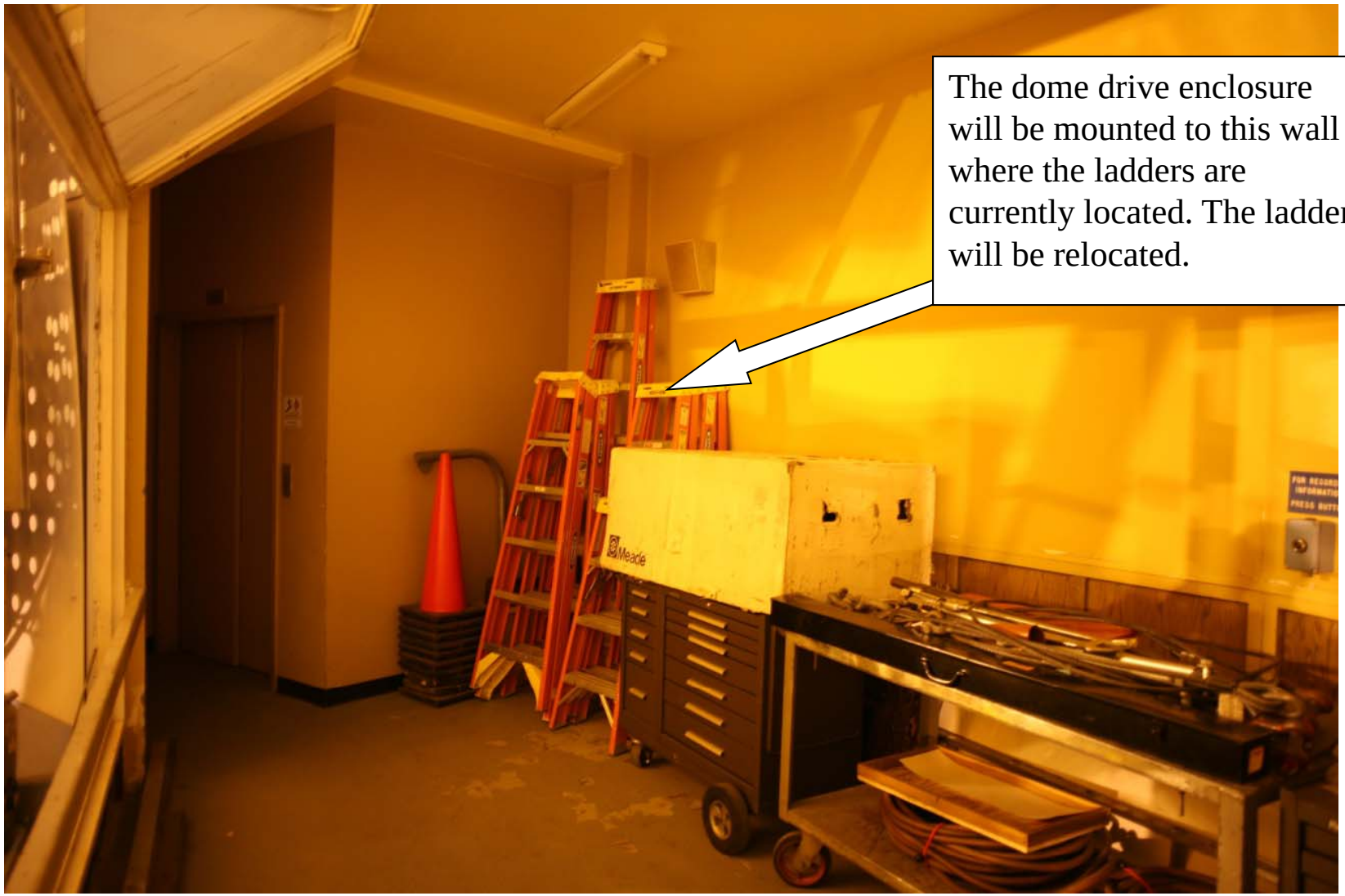






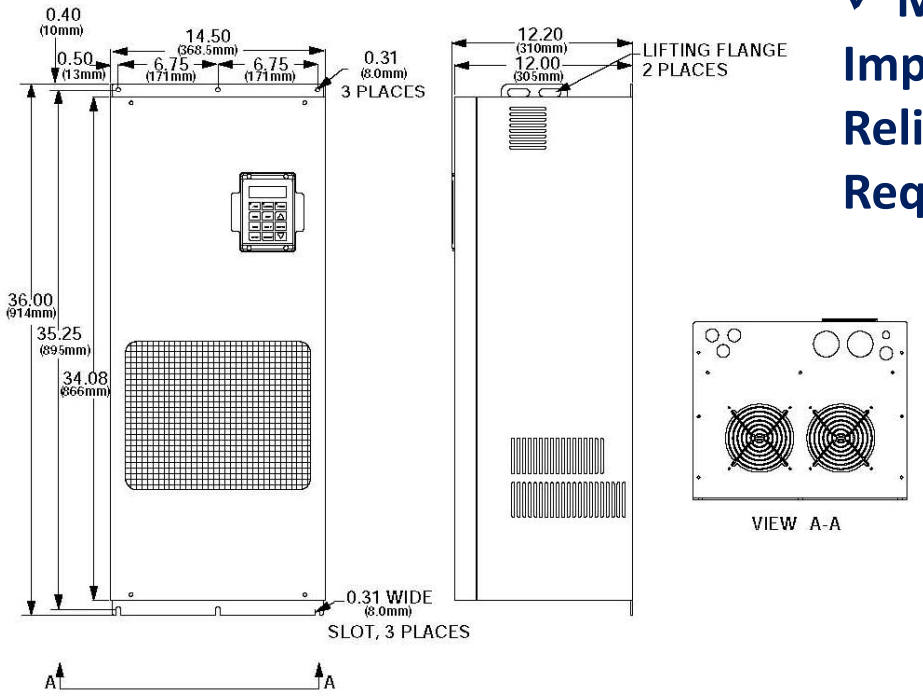
✓ **Meets Preventative Requirement**

New Location for Dome Drive cabinet



Dome Drive Motor Controller Cabinet

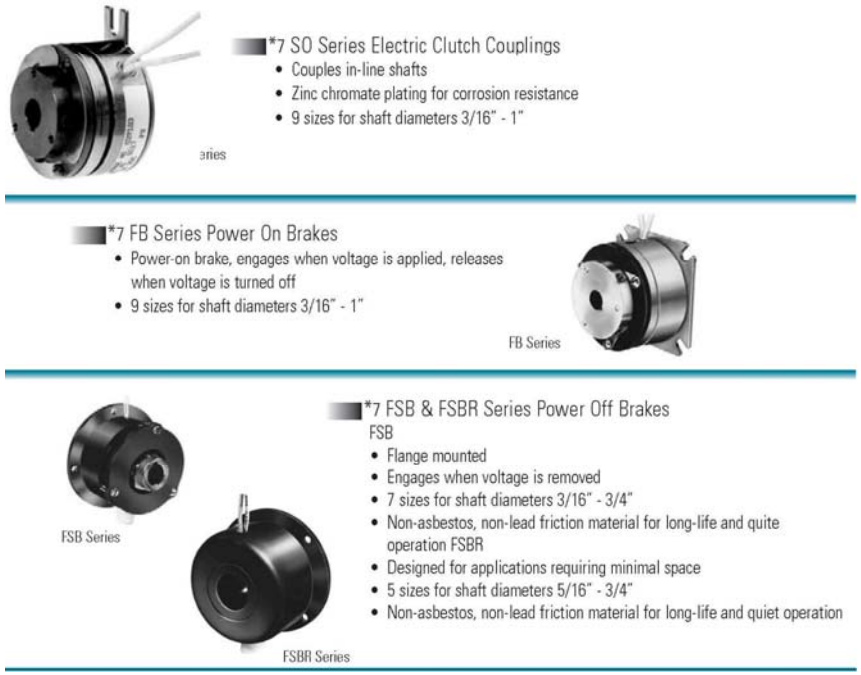
- **Drive unit enclosure electrical**
  - **New fuse disconnect and circuit breaker panel is included with the motor controller enclosure for either manufacture.**
  - **Electrical conduit needs to be installed from the fourth floor lama room to the 5th floor visitor's gallery**
  - **The DP4 distribution panel in the back of the lama room will be used to power the equipment on the fifth floor.**



✓ **Meets Improved Reliability Requirement**

Parking Brakes (not de-acceleration brakes)

	Pros	Cons
Option 1	✓ Uses weather PLC information already established and trusted. ✓ Does not require additional equipment to purchase, install, or maintain. ✓ Operating duration and wind parameters can be tweaked in PLC code.	o Excessive use will reduce motor lifetime. o Consumes electricity when being used.
Option 2	✓ Simpler installation and maintenance than option 3 or 4.	o Another electro-mechanical device to maintain. o Consumes continuous power during dome movement.
Option 3	✓ Could complicate the Motor adapter kit installation	o May require additional interface modifications to the adapter kit and motor coupling.
Option 4	✓ .	o May require additional interface modifications to the adapter kit and motor coupling.



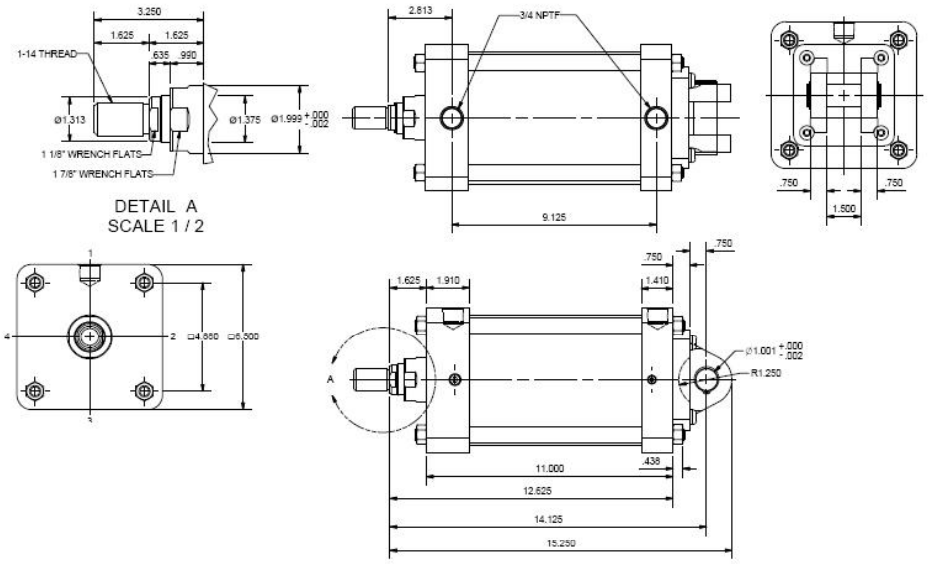
- **Spring set friction type brakes**
  - **Option 1: Motor brakes/Clutch**
  - **Option 2: Brake located on the end of the motor drive shaft**
  - **Option 3: Double C-face brake**
  - **Option 4: System brake**

✓ Meets Safe interlocking Requirement

Drive Unit Frame Actuator Pivot

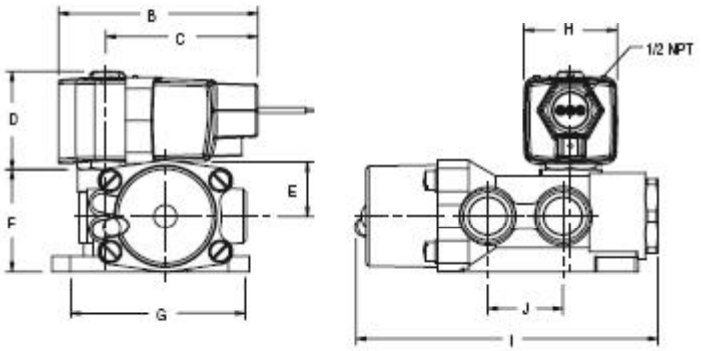
- Since the actuator depends on the hydraulic system pressure to function a replacement must be installed.
  - The actuator rotates the frame for replacement of the dome wheel and applies additional force to the dome drive wheel on the track.
- Replacement Actuator options:
  - Pneumatic actuator
    - Parker Hannifin
    - Numatics
    - Cylindrix

✓ Meets Improved Maintainability Requirement



Pneumatic Actuator

Solenoid Valve

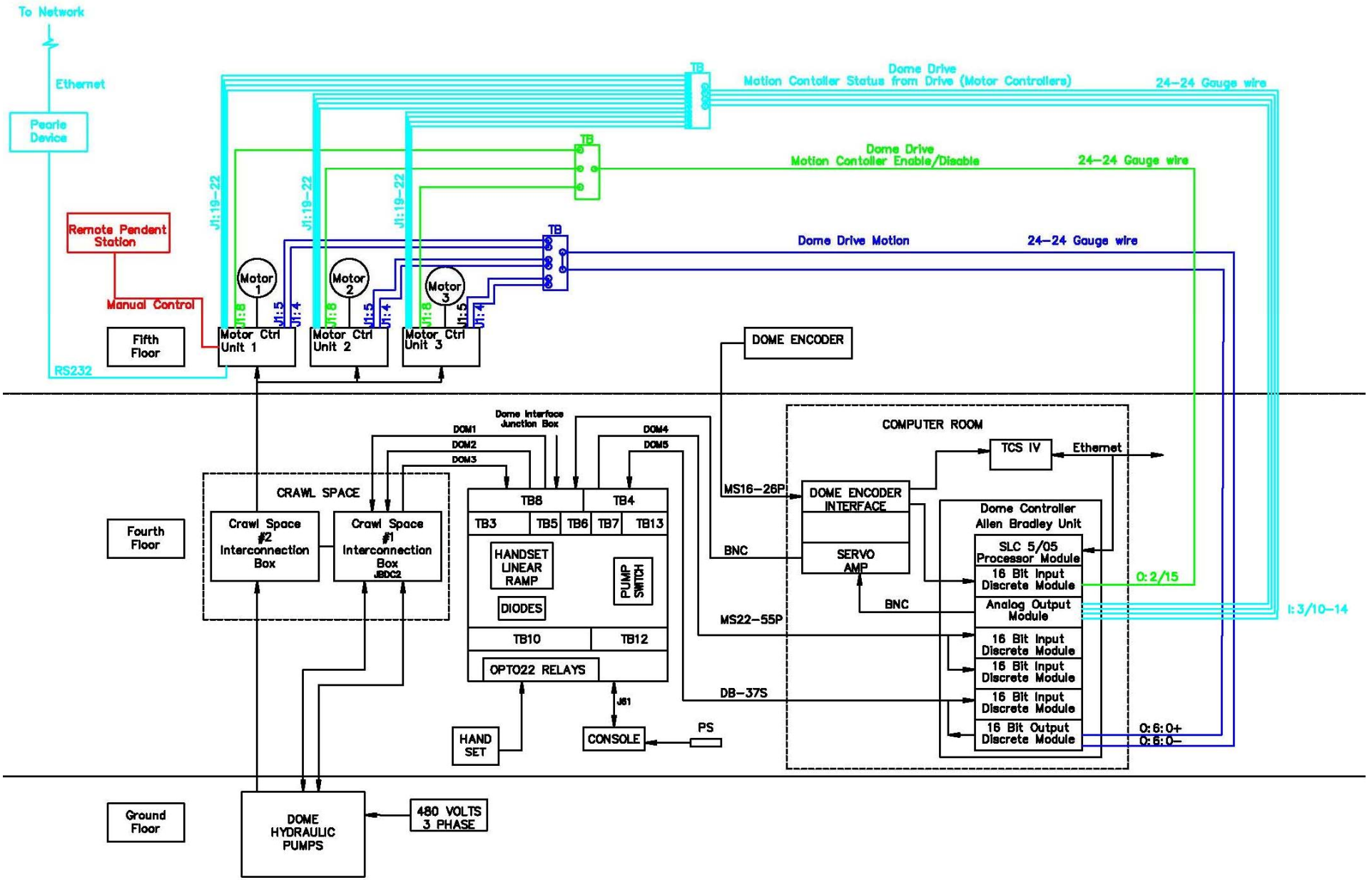


Heat Mitigation strategy

- Heat dissipation estimates
  - Motors
    - At Full Speed (3.4HP @ 60˚/min) ~ 95 Watts
      - **Meets requirement criteria**
  - Motor Controllers
    - At Full Speed (3.4HP @ 60˚/min) ~ 256 Watts
      - Worst case estimate

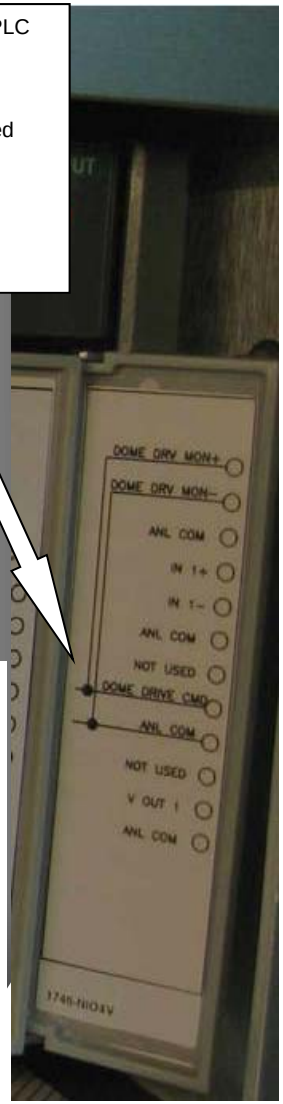
- Both the motors and motor controllers will be turned on/off and driven intermittently under automatic TCS or manual control.
  - To mitigate heat from the drive enclosure which houses the motor controllers, ducting and a fan could be installed.
  - The proposed location for the drive enclosure is on the 5th floor in the visitors' gallery.
  - The routing for the ducting will run from the top of the enclosure up the wall and terminate on the side wall of the 5th floor visitors staircase

PLC Block Diagram



Modified PLC Interface-Dome drive motion

•Dome drive PLC
•O:6:O ± pin connecters
•± 10V signal
•O:6:6 not used
•O:7:0 ± 10V
•O:6:8 Com

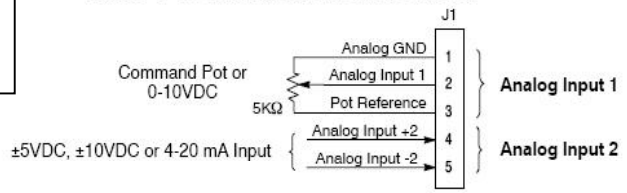


Analog Inputs

Two analog inputs are available: analog input #1 (J1-1 and J1-2) and analog input #2 (J1-4 and J1-5) as shown in Figure 3-13. Either analog input may be selected in the Level 1 INPUT block, Command Select parameter value. Analog input #1 is selected if the parameter value is "Potentiometer". Analog input #2 is selected if the parameter value is "+/-10Volts, +/-5 Volts or 4-20mA".

•Motor Controller
•Analog input #1
•Analog input #2

Figure 3-13 Analog Inputs and Outputs



See recommended terminal tightening torques in Section 7.

•The last module in the PLC rack is a 1746 NIO4V 2ch analog input/voltage output device

•This device currently outputs the ± 10V signal to the servo amp for the dome control movement.

•The wiring will interface from the O: 6: O ± pin connecters on the PLC to the J1:4&5 input pin connectors on the motor controllers

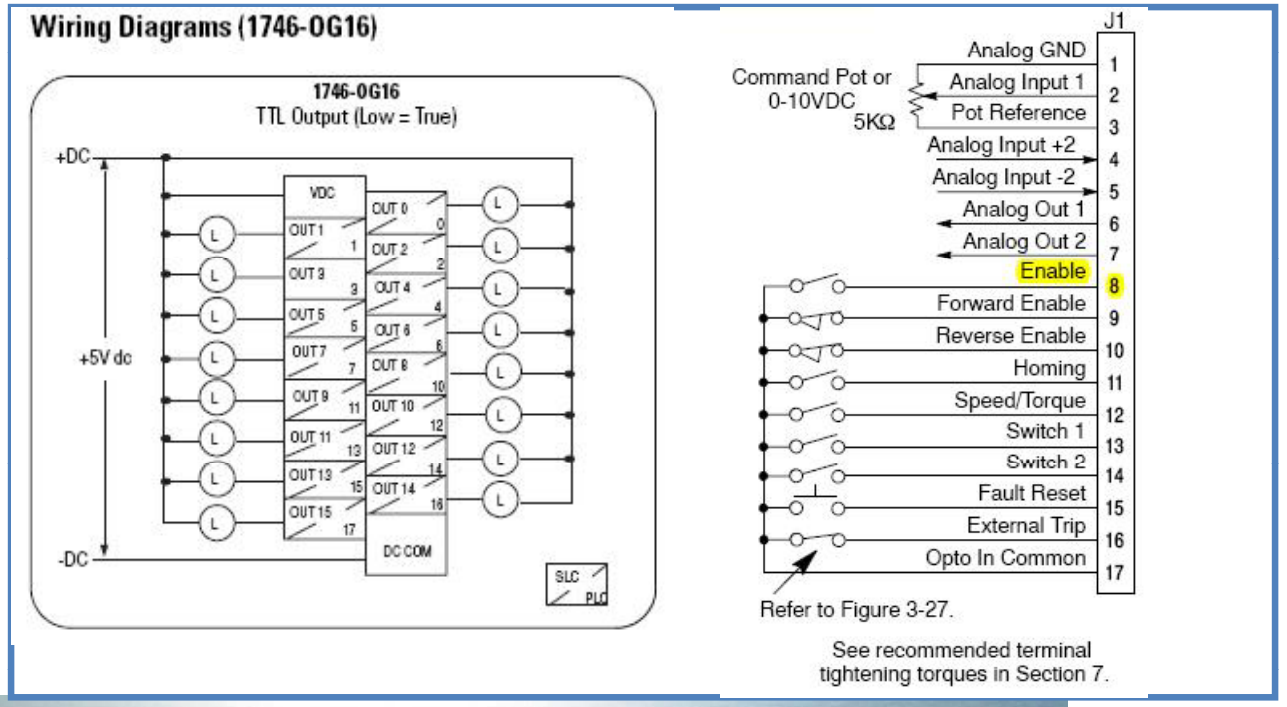
✓ **Meets Remote Dome Drive Operation Requirement**

Dome Drive-Motor Controller enable/disable

•One output pin connector available on the second module in the PLC rack which is a 1746-OG16, a 16 bit TTL (transistor-transistor logic) standard 5v computer interface output module

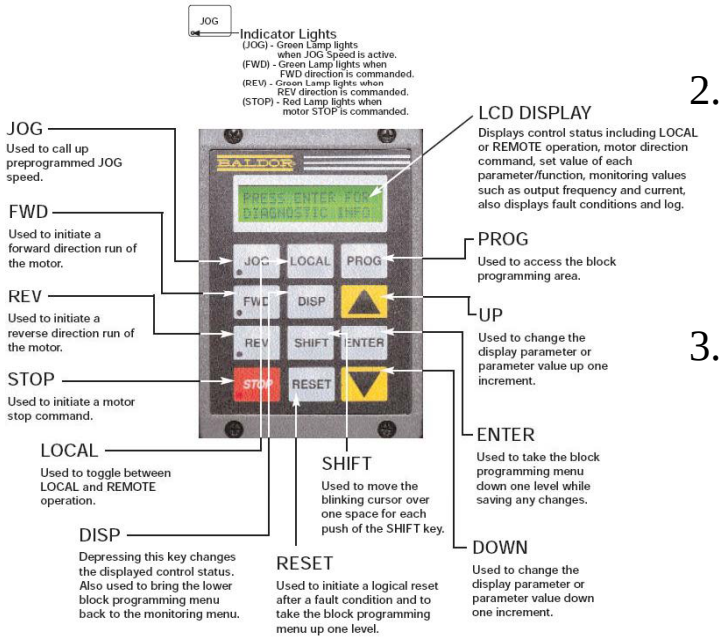
•This signal would be used to enable/disable the motor controllers.

•The wiring will interface from the O: 2/15 would be wired to J1:8 enable/disable pin connectors on the motor controllers



✓ **Meets Remote Dome Drive Operation Requirement**

Dome Drive Manual control-Via 5th floor



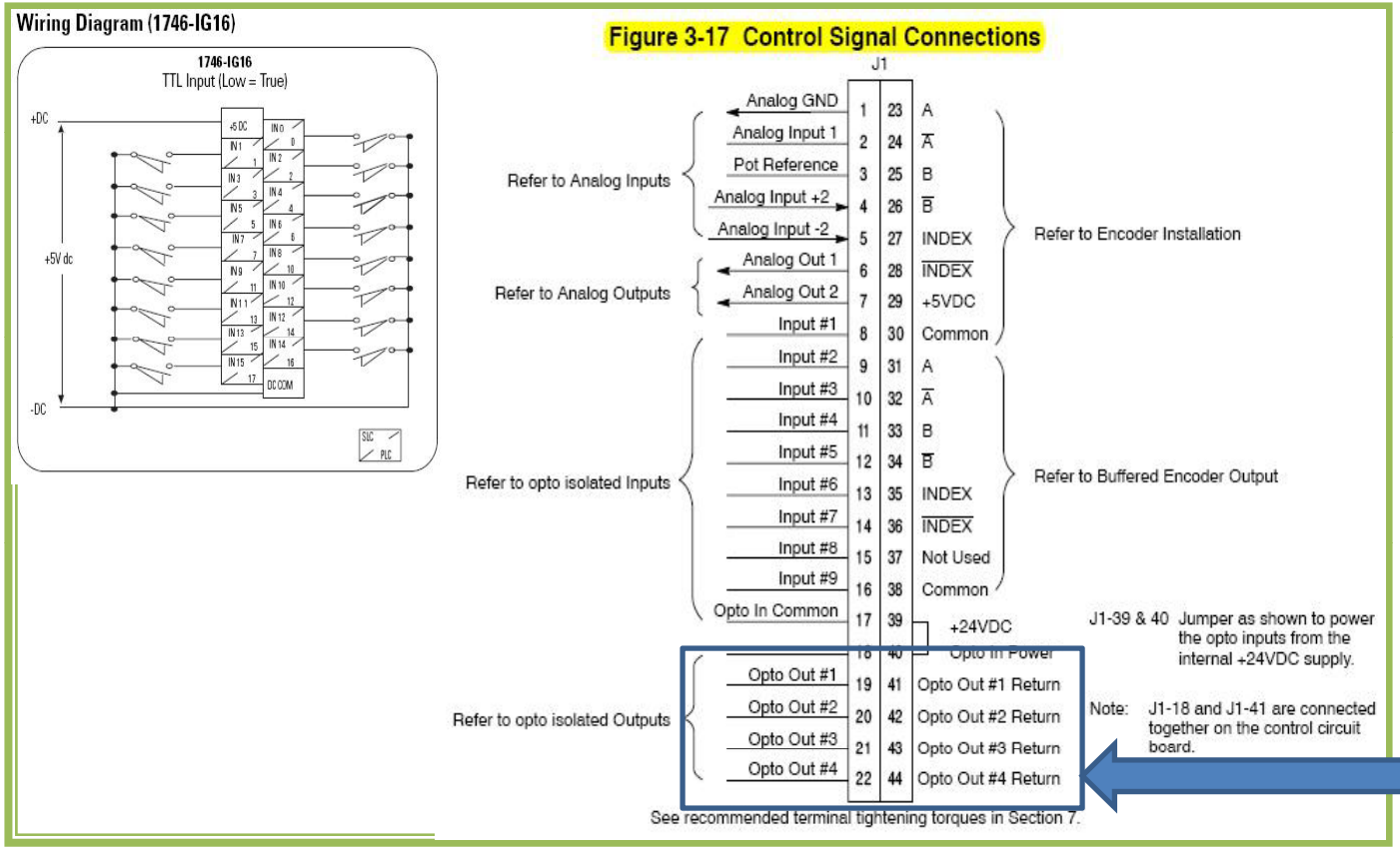
•Local Remote Switch on the 5th floor for selecting the automatic/manual/off configuration of the dome drive

<u>Options</u>

1. Remote pendent station (hand held control device) with a cord that plugs into the drive controller
2. Bipolar potentiometer speed reference could keep the 5th manual control panel the same
3. HIM (human interface module) which can operate the dome drive from the drive cabinet

✓ **Meets Manual Control Requirement**

Dome Drive Motor Controller Status



- Third module in the PLC rack is a 1746-IG16, a 16 bit TTL standard 5v computer interface Input module
- Device currently stores Dome status drive on/off, drive enable/disabled, dome ready
- The wiring will interface the I:3/10-14 pin connecters of the 1746-IG16, to the outputs J1:19, 20, 21, 22 pin connectors of the motor controllers.

✓ **Meets Remote Status Requirement**

Dome Drive Monitoring Status Information

Motor Controller

- The motor controllers store valuable data about the functionality and health of the drive system
- With OAP in mind, the chosen system needs to provide this information
- The Outputs can be chosen from a large table with parameters such as; speed, torque, voltage, current, etc

Communication Methods

1. Add output module cards to the motor controller unit which will provide 4 analog or digit signals.
   - This will require an empty slot in the PLC chassis for an analog input module card and the card itself.
2. Add serial interface communication (RS232) expansion boards to the motor controllers.
   - This would allow use to receive feedback information for status via and RS232 cable to a Pearle device
   - Using the Pearle device we could receive the information via and Ethernet cable and get the various status information we need.

✓ **Meets Remote Monitoring Requirement**

Motor Sizing Requirement		
Requirement	• Full running speed (60˚/min) - power output requirement	• Physical measurement of current system • 3.4 Horsepower (HP) output power needed per drive wheel
Motor inefficiency	• The RPM AC motors are 94% efficient, therefore the motor inefficiency that must be accounted for is an additional 6%	• 3.4 HP ÷ .94 = 3.6 Hp • The addition added to the requirement = 3.6 HP
Motor de-rating	• The Baldor RPM AC motors and Line Regen AC flux vector controllers have to be de-rated for 14,000ft elevation operation. • The de-rated was calculated to be 32.4%	• 3.6 HP ÷ .676 = 5.35 HP • The addition added to the requirement = 5.35 HP
Safety Factor	• From the requirements document of the dome drive electric upgrade • The safety factor = SF = 2.5-3	• 5.35 HP x 2.5 = 13.4 HP • 5.35 HP x 2.5 = 16.05 HP • The motors should be sized between • **13.4 HP to 16.05 HP per drive wheel (unit)**
Reasons for upgrading to a larger motor configuration, 20HP		
Maintenance	• A larger motor when compared to a smaller equivalent motor would have a longer run life and require replacement less often	
Drive train capacity	• The current drive train (gearbox is the limiting component) is rated to accommodate a 20HP motor	
Heat Production	• A larger motor with the same load as a smaller equivalent motor will produce less heat.	
Designing for the future	• Future projects may increase the weight of the dome and could affect later performance of the drive system	
Function	• If one drive fails, we could still operate at full speed (60˚/min) with two drives.	
Reliability	• A larger motor when compared to a smaller equivalent will have a longer lifetime at the same duty cycle.	
Cost difference	• The cost difference between a 15HP system and a 20HP is minimal.	
Unforeseen advantages	• Larger motors could provide the torque needed to break ice built up on the dome • Larger motors could provide the torque needed to battle high winds	

	Comparison of Baldor vs. Rockwell Allen-Bradley	
	Baldor	**Rockwell Allen-Bradley**
Motors	• Almost any motor will work with the proposed system • Recommends Baldor motors for driven applications	• Almost any motor will work with the proposed system • Recommends and specifies Baldor motors for driven applications
Regenerative	• The 22H motor controller is a proven and understood technology, Keck implementation	• The 755 Motor controller is a new line of motor controller products • One Source Supplier has little experience with newer technology.
Support	• Excellent engineering support from Baldor and Kaman • Oahu merchandise supplier for Baldor products is Kaman Industrial Technologies • Lower priced of the two for integration and commissioning	• Excellent track record over the years for support from Allen-Bradley. • Oahu merchandise supplier for Rockwell-Allen Bradley products is One Source Berkley Engineering
Communication	• Motor controller provides 4 optical (digit) outputs built into the unit. • Analog output cards can be added to the motor controller for feedback such as current, voltage, speed, etc. • RS232 serial interface using a Pearle device will allow Ethernet communication capabilities for remote status • Requires not additional software or processors	• Motor controller requires a Compactlogix processor to communicate with our SLC 505 • This Compactlogix processor requires a software upgrade to RSLogix 5000 • The processor allows communication by Ethernet IP cable directly to the SLC 505 • Adds another processor to maintain (with a spare) and additional software licenses to purchase and support
Versatility	• The 22H motor control is flexible and can be configured for different applications	• The 755 motor control is extremely versatile and can be configured for multiple applications

Time and resource estimates		Resource	Days	Description
Post PDR and Detailed Design Work	Hardware, mechanical	SB	1	Order Brevini Motor Adapter kit
				Order Spare Motor
		SB, Daycrew	3	Finalize Actuator selection
		SB	1	Order Pneumatic actuators
		SB, Daycrew	1	Order Pneumatic actuator lines, couplings, etc.
		SB, Daycrew	2	Remove the door casting and/or room walls as needed in the detector room.
		SB, Daycrew	3	Run pneumatic lines and fittings to actuators
		SB, Daycrew	3	Mount and install new Pneumatic Actuators
		SB, Daycrew	1	Test pneumatic actuator function, line pressure, and leak detection
		SB, Daycrew	4	Finalize Anti-rotation (brake) design and materials.
		SB,GM	8	PLC requirements for status and monitoring
				PLC Wiring design (±10V signal, Motor controller enable/disable, Manual Control, Local/Remote, status feedback)
		SB, DS, SG	5	Motor controller requirements and final configuration
	Software	SB, GM	10	PLC software upgrade
			5	PLC wiring block diagram
		TV, SB,GM	3	PLC requirements for status monitoring
			2	Overall GUI/status page design
		SB, GM	5	PLC software control code changes
			5	PLC software interface changes
		SB, TV, GM	5	Overall interface, control, and display.
		SB,GM	10	Testing with PLC Rack, motor controller and motor communication in Waimea
	Electrical	SB, Daycrew	2	Layout design for 2 sets of conduit (1/2” and ¾”) for the motor power and feedback cables.
				Layout design for the conduit from the 4th floor to the 5th floor. 460V power
		SB,LR	1	Order Conduit, electrical wiring, other materials.
		SB, LR, Daycrew	5	Install 2 sets of conduit (1/2” and ¾”) for the motor power and feedback cables.
				Install the conduit from the 4th floor to the 5th floor.
				Pull 1 awg. Electrical wire from the 4th floor to the 5th.
				Pull 8 gauge wires for motors, i.e. electrical wire from the drive units to the drive cabinet location.
		SB, GM	4	Create drawing layout of wiring diagrams
		SB, Daycrew, GM	2	Drive unit cabinet wiring layout
		SB, DS, Daycrew	2	Drive unit final specifications approval

Implementation (Integration)	Hardware, mechanical	SB	1	Order Drive unit package-Place P.O.
	Electrical	LR, SB	1	Cabinet wiring check. Test wiring continuity. -Test wiring connections from DP4 distribution panel to 5th floor.
			1	Motor Wiring Check, Test wiring continuity. -power and feedback cable from drive units to motor controller cabinet.
	Software	SB, GM	5	PLC integration, wiring, and test
		SB, GM	3	PLC consultation and troubleshooting
		SB, TV	2	Status/monitoring page test
		SB, Daycrew	2	Manual/automatic system tests
		LR, Daycrew, SB	2	Install new drive unit package enclosure (motor controllers)
	Electrical	LR	1	Connect 1awg wiring to the drive unit. Test functionality
		LR, SB, Daycrew	1	Finished motor controller package install and checkout.
	Hardware, mechanical	SB, Daycrew	2	Hydraulic motor retrofit work begins a few days before the motor control unit delivery is expected
				Remove old hydraulic motor and adapter kit from drive unit #2.
				Rotate Brevini gearbox 90 degrees
				Install new Brevini adapter kit on drive unit #2
				Install new Electric motor on drive unit # 2
				Install parking brake/clutch on electric motor (optional-TBD)
		WC, GM, SB	4	TCS Testing with new electric drive unit #2
		SB, Consultant	1	Motor controller consultant arrives on island
		SB, Daycrew, WC, GM, Consultant	2	Dome drive Consultation Commissioning and Testing-Begin day testing of VFD system.
				Test drive unit # 2 under electric motor control
		SB, Daycrew	1	Prefer to perform Unit #3 retrofit when F/8 is on telescope
				Remove old hydraulic motor and adapter kit from drive unit #3
				Rotate Brevini gearbox 90 degrees
				Install new Brevini adapter kit on drive unit #3
				Install new Electric motor on drive unit # 3
				Install parking brake/clutch on electric motor (optional-TBD)
		SB, Daycrew, WC, GM, Consultant	2	Test drive unit # 2 and 3 under electric motor control.
				New electric drive system Commissioned and ready for nightly operations-under two drive unit operations temporarily.
		SB, Daycrew	3	Remove old hydraulic motor and adapter kit from drive unit #1
				Rotate Brevini gearbox 90 degrees
				Install new Brevini adapter kit on drive unit #1
				Install new Electric motor on drive unit # 1
				Install parking brake/clutch on electric motor (optional-TBD)
	Software, Electrical	SB, GM, WC, Daycrew	5	Test drive unit # 1, 2 and 3 under electric motor control.
			3	Phase 1 Finished- Dome drive system now under electric drive system control.
	Software, Mechanical	SB, Daycrew	1	Monitor heat dissipation in visitor's gallery.
			1	Install heat mitigation equipment if needed.
				Phase 1 Complete
		Subtotal:	**44**	**Days**
		Subproject Total:	**140**	**Days –days for Phase 1, ~8-10 months**
Estimated completion date:		**Oct 2010**		

Equipment and Material Costs			
Component description	Allen Bradley	Baldor	Notes
22H Line Regen AC Flux Vector motor controller package drive system. *Baldor*		$38,293.00	Includes: Drive system package, includes 3X ZD22H425EL motor controllers and equipment needed to assemble the package, see appendix P for more detail.
ZD22H425EL motor controller (drive unit) – qty 1 *Baldor*		$12,722.46	Special pricing when purchased all at once, otherwise purchased separately $13413.67
20 HP RPM AC motors-qty 4 *Baldor*		$10,733.96	Special pricing when purchased all at once, $2683.49 each. Otherwise purchased separately $5268.27
Power flex 755 Regenerative AC motor controller package drive unit *Rockwell Allen-Bradley*	$52,718.00		Includes: Drive system package, see appendix Q. Includes four (4) motors and four (4) motor controllers. But is not quoted for the correct motors, and does not include some equipment the other quote does. Awaiting new quote which will be more accurate.
Support Engineer for Commissioning	$9,751.00	$5000.00	Plus travel expenses, i.e. airfare, lodging, rental car.
Electrical wiring upgrades	$5000.00		New 1awg wiring and conduit run from the 4th floor to the 5th floor, 8 gauge wire and conduit for the motor power runs.
Drive cabinet enclosure heat mitigation • Heat exchanger ~$400-500 includes dual fan • Glycol lines and fittings	$1500.00		Parts and materials needed to duct the heat from the drive enclosure.
Pneumatic actuators for the dome drive frames *Parker Hannifin*	$3,017.52		Includes: four (4) Pneumatic actuators, $632.68 each; 1 of which is a spare. And four (4) Rod clevis, Pins, etc.
Pneumatic Solenoid valves, air lines, and fittings	$3,120.00		Includes: four (4) Solenoid valves, lines and fittings.
Brevini Motor adapter kits-qty 4	$ 2,541.08		Includes 3 motor adapter kits and one spare kit. $635.27 each.
Brakes	$11,000.00		Optional, Includes 3 spring brake sets and one spare. $2,750.00 each
Misc materials and supplies	$750.00		
TOTAL	$89,397.60	$93,678.02	
	Allen-Bradley	Baldor	

Any Additional Questions or Comments?

Thank you for your time!