



Observatory Automation Project

Detailed Design Review

Electric Dome Drive System

Steven Bauman

Contributors: Sarah Gajadhar, Grant Matsushige, Ivan Look, Derrick Salmon, Ralph Taroma, Larry Roberts, Casey Elizares, Tyson Arruda, William Cruise, Tom Vermeulen, Jim Thomas, Karun Thanjavur

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1. Overview

Research into the existing hydraulic dome drive system for the observatory automation project (OAP) purposes has highlighted the obsolescence of the current system and prompted the exploration of options for upgrading it. OAP requires that the dome drive system be controlled and monitored remotely. The existing system can be remotely controlled via the telescope control system (TCS) if the hydraulic pumps on the first floor are turned on, however turning them on is currently a manual step. Also, information on the temperatures, pressures, and flows in the system are only available on manual gauges in the 1st floor machinery room and the 4th floor control room. The cost of additional instrumentation to outfit the existing system prompted feasibility studies for upgrading to either a more modern hydraulic drive system, or to an electric drive system.

After the feasibility study and conceptual design reviews of these options, the decision was made to pursue the electric drive system upgrade. Benefits of the new electric drive system are: reduced power consumption, reduced maintenance and repair costs, eliminated hydraulic leaks (safety and environmental consequences), and reduced manpower resources. From the preliminary design review the Baldor electric company was chosen as the manufacture of the drive system and motors. This review encompasses the detailed design or final design elements of the electric dome drive upgrade.

2. Background and Scope

This document solidifies a design solution to operate the Dome system with electronic drive units controlled remotely under the guidelines provided by the OAP project. It also meets the specifications of the dome drive electrical upgrade requirements document. This overview outlines the requirements for the system, changes to the existing system, the selected design from the alternatives at the PDR, and details of the final system design, interfaces, safety considerations, anticipated costs and resources.

The preliminary design document can be found:

- [OAP Dome Drive Preliminary Document](#)

3. Requirements

3.1. A Dome Drive Electric Upgrade Requirements document has been drafted to encompass specifications and goals of the upgrade. This review will highlight additional requirements for the upgrade.

- The dome drive electric upgrade requirements document can be found:
 - [The Dome drive electrical VFD system upgrade document](#)
- The appendices referenced in the requirements document can be found:

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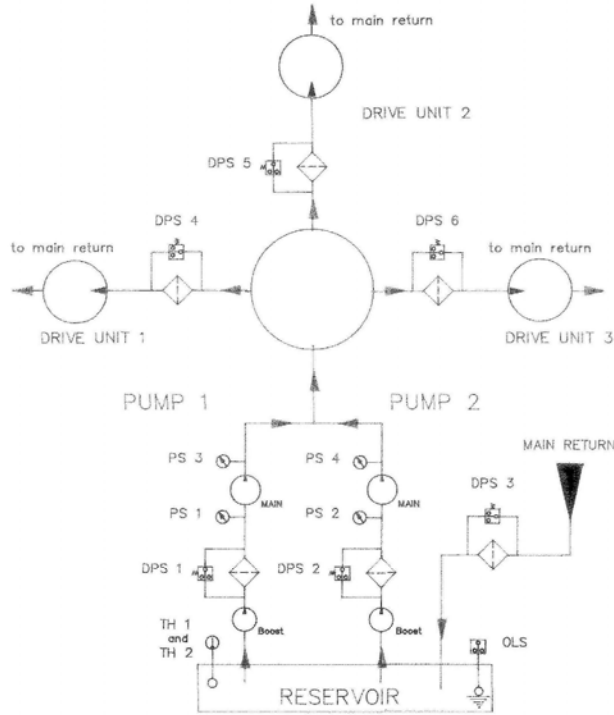
- [Dome Drive System upgrade requirements and appendices](#)
- Dome drive requirements needed for OAP
 - a) **Remote Dome drive Operation** The Dome drive must be capable of being operated in a “safe” reliable manner from Waimea.
 - b) **Remote monitoring and status** The electronic drive system shall provide necessary status and system information.
 - c) **Manual Control** The drive system control panel must allow local control of the drive system.
 - d) **Preventative Maintenance** The dome drive system shall provide access to all serviceable components and minimize the need for scheduled maintenance.
 - e) **Improved Reliability** The new electronic dome drive system should increase the reliability and minimize repairs.
 - f) **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.

4. Hydraulic System Design and Documentation

- 4.1. The hydraulic dome drive system consists of three drive units positioned 120° apart around the track on the 5th floor, which supports the telescope building dome rotation. The central hydraulic unit on the first floor supplies the necessary flow at the system pressure 1800 PSI at the pumps and 1775 PSI @ the 4th floor control room.

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Note: Values for TH 1 and TH 2 currently both come from TH 1

LEGEND

	direction of hydraulic flow		Hydraulic Pump
	Filter		Hydraulic Motor
	Switch		Pressure Indicator
	Pressure Switch		Temperature Indicator

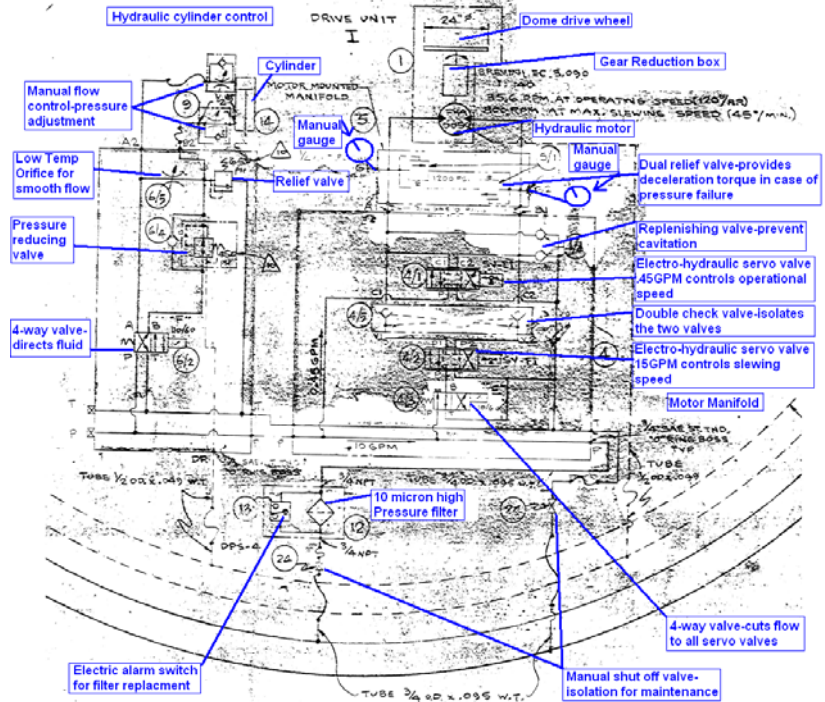


Figure 2: Hydraulic dome drive system – Heat exchangers not shown

5. Detailed System Design

- 5.1. The Baldor proposal outlines the parts and components needed to assemble an electric dome drive system for the 5th floor.
- 5.2. The proposal lists the three (3) motor controllers which are the heart of the system and details other items integrated into the cabinet, as well as the three (3) ZDFRPM21204C 20HP electric motors which provide the torque needed to rotate the dome.
- 5.3. The Baldor Proposal can be found:
 - [Baldor Electric Company Proposal and Kaman Industrial Technologies Quotation Electric Dome Drive](#)

6. Drive Unit Modifications

- 6.1. In each case, the hydraulic motor coupled directly to the drive train on each of the three drive units will be replaced with a Baldor 20 HP electric motor and Brevini motor adapter kit.

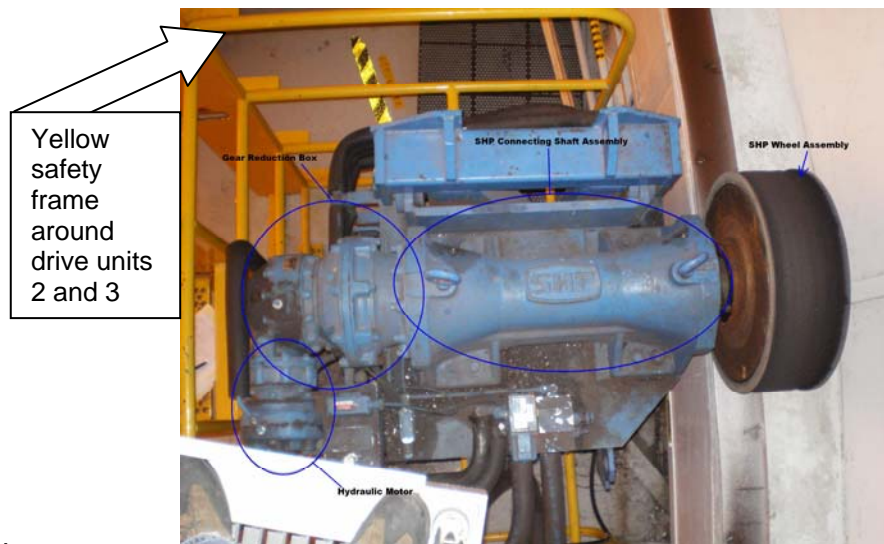


Figure 3: Dome Drive unit

- 6.2. The electric motor can be attached to the gear reduction box via an adaptor kit manufactured by the original manufacturer of the gearbox, Brevini; therefore no additional drive train modifications will be required on the three (3) dome drive units. The drawing for the motor adapter kit and parts list can be found below:
 - [Brevini Motor Adapter Kit Specifications Sheet](#)

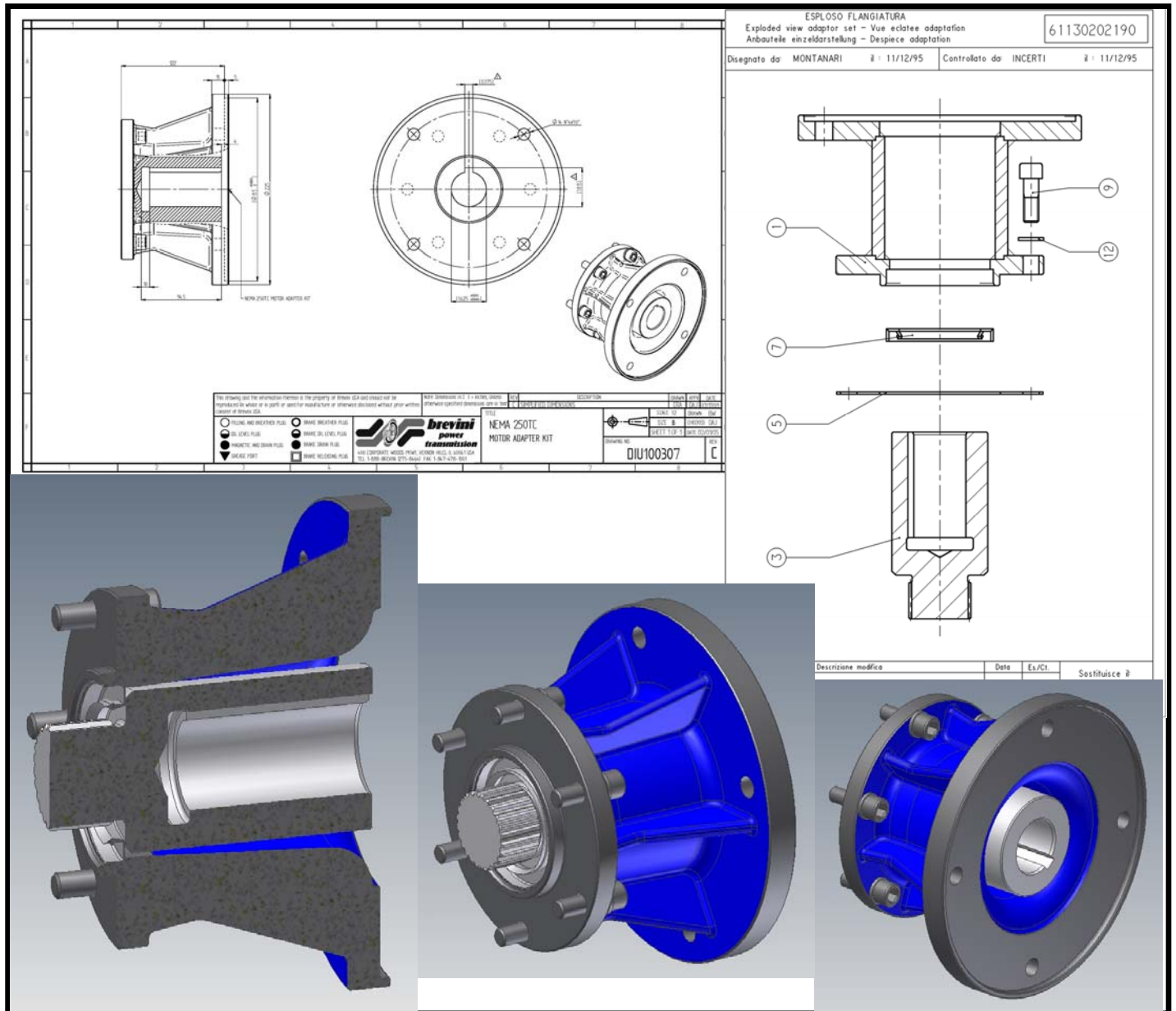


Figure 4: Brevini motor adapter kit drawing, exploded view, dimensions, and virtual model

- 6.3. To install the new electric motors on each drive unit first the supply and return hydraulic lines will need to be valved off, next the lines will need to be removed from the hydraulic motor, drained, and capped.
- 6.4. Now the hydraulic motor can be unbolted from the Brevini gear reduction box and set aside. The hydraulic motor is attached with six (6) M12x35 bolts, in some cases there is only five (5) bolts present. New bolts are provided with the adapter kit therefore the old bolts can be recycled.
- 6.5. Next the gear reduction box will need to be unbolted from the main shaft assembly and rotated 90 degrees to point input shaft upward.
 - The Brevini EC3090 unit weights ~116kg (256lbs).
 - This will remove the necessity to modify or remove the yellow frames around drive units 2 and 3, see figure 3.

- Originally the door opening that houses drive unit #1, see figure 7 was going to be left in place because the upward configuration fit but to achieve more room and better access the door frame will be modified and enlarged upward for equipment maintenance and repairs.
 - Since the gear reduction box will be mounted in position 2 vertically it will require a breather tube or expansion tube.
 - The gear unit must be completely full of oil, then the expansion tube or breather be fitted to the gear box.
 - Reference "[Appendix K Brevini-EC3090 Specifications Sheet](#)".
- 6.6. Once the gear reduction box has been rotated and fitted, the oil level will need to be changed since it will be working in a new configuration.
- An additional 0.6 gallons of SAE 80, 90 EP oil will need to be added to the gearbox to meet the manufactures recommended oil capacity for this position of operation. The gearbox could also be drained and 1.75 gallons of new oil could be added before operation.
 - Reference "[Appendix K Brevini-EC3090 Specifications Sheet](#)".
- 6.7. Next the electric motor can be mounted to the adapter kit assembly.
- Install the coupling to motor shaft using the keyway for alignment.
 - Install the flange to the motor C-face mounting surface using four (4) ½-13 x 1.75" long SHCS bolts. As a reference the threaded depth of the motor holes are 1.00".
 - Install the oil seal and gasket into the adapter flange.
- 6.8. Now the electric motor/adapter kit combination can be mounted to the Brevini gear reduction box, insert the male splinned shaft from the adapter into the female spline shaft of the gear reduction box.
- 6.9. Install the new six (6) M12x35 bolts into the adapter flange and torque them to the correct torque value.
- 6.10. A animated disassembly of the drive unit and reassembly can in the DDR PowerPoint presentation
- 6.11. The hydraulic power unit (on the 1st floor) will be replaced with a drive system cabinet consisting of the electronic motor controllers (drive unit). There will be one motor controller assigned per motor per drive unit.
- The motor control units will provide the necessary output to the motors to achieve the speed and torque. The motor controller units will also provide information required for remote operations and monitoring such as motor current, motor torque, motor speed, etc.
 - A depiction of one (1) motor controller can be found below in figure 5; it shows the basic dimensions of the unit.
 - The cabinet will house three (3) units plus the other components needed and listed in the above proposal [link](#).
 - Each motor controller unit weight ~ 200lbs. Therefore the cabinet will weigh between approximately ~650-800 lbs.

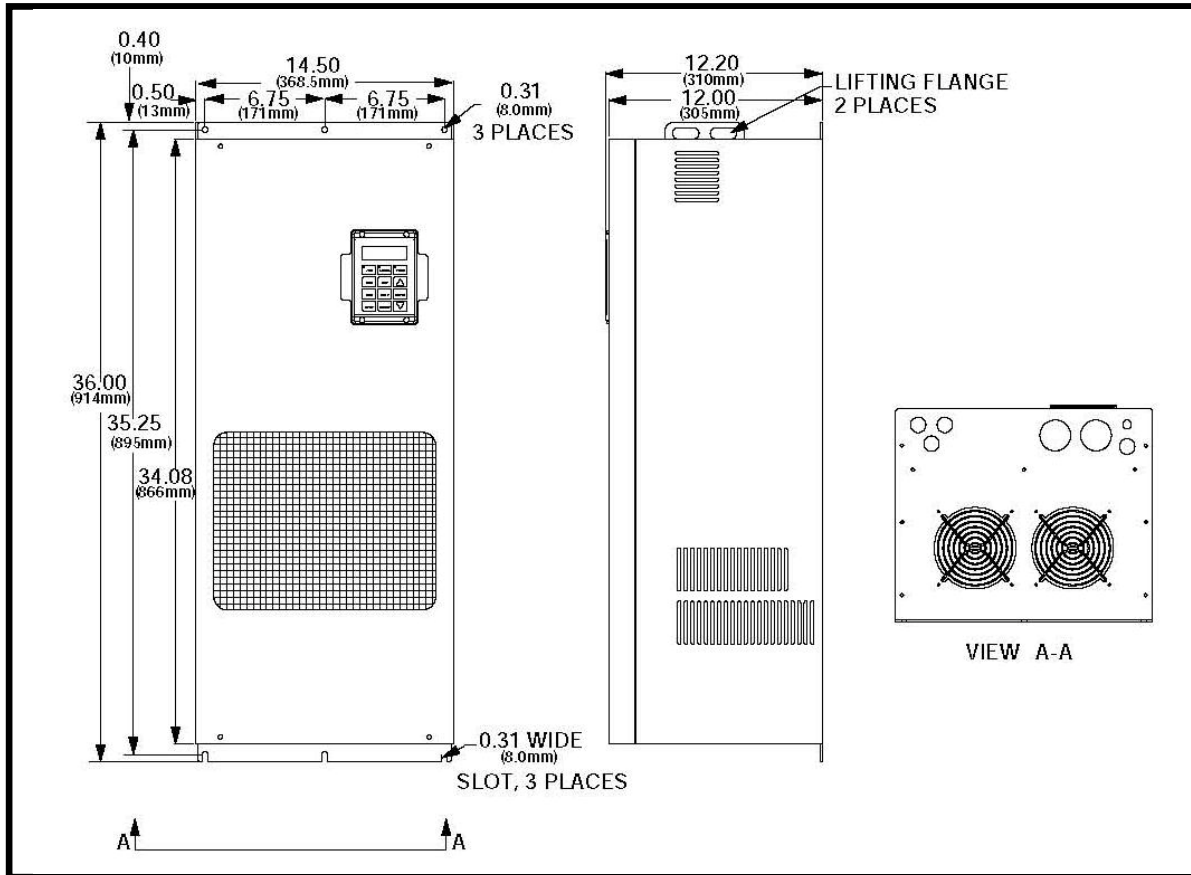


Figure 5: Motor controller example (drive unit)

6.12. The motor control information can be found below on confluence:

- Baldor 22H Line Regen AC Motor Control Drive Units
 - [Appendix G Series 22H Line Regen AC flux vector control Manual.pdf](#)
 - [Appendix H Series 21H and Series 22H Brochure.pdf](#)

6.13. The electric motor information can be found on confluence at the links below:

- RPM AC motor information, [Appendix M ZDFRPM21204C RPM AC 20HP Motor.pdf](#)

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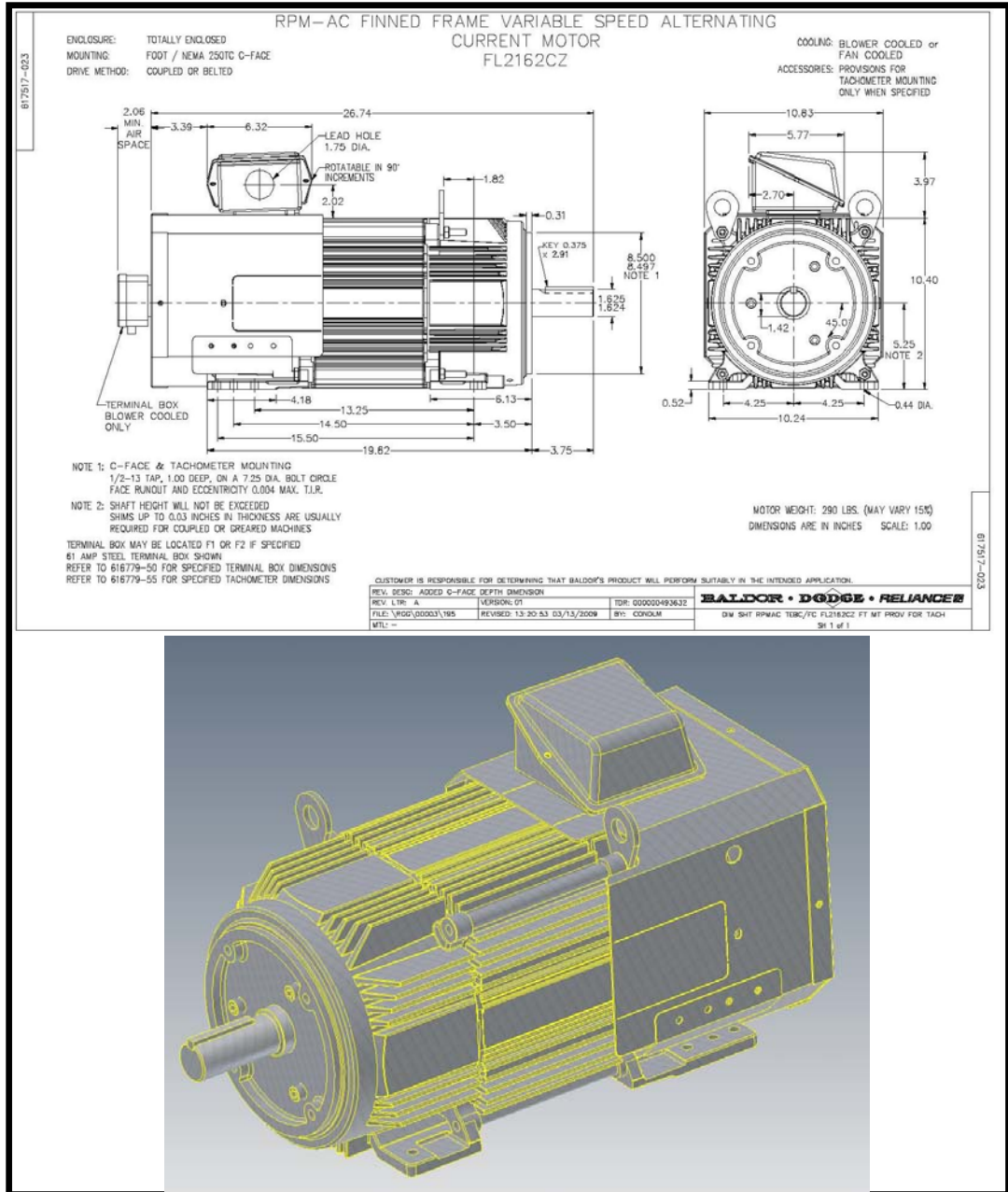


Figure 6: RPM AC Motor drawing, dimensions, and virtual model

- These motors are specifically designed around packing maximum torque into a small enclosed motor frame size. These motors remove the need to modify the safety frame around the drive units and eliminate modifications to the gear reduction box interface.
- Another benefit of the motors chosen was that they fit in the envelope between the mounting configuration and the upper door frame, see figure 7 below. However to make maintenance and repairs easier in the future it was decided to move the door frame up slightly which will increase the room around the where the motor will be mounted.



Figure 7: Drive Unit #1 upper door frame

7. Electrical upgrades

7.1. Drive unit cabinet

- The drive cabinet will encompass all the components and internal wiring needed to operate the motor controller units. See the proposal [link](#) for included parts.
- The [link](#) for the block diagram for the Baldor Drive Unit Cabinet.
- Electrical conduit will be installed from the fourth floor lama room to the 5th floor visitor's gallery.



Figure 8: Example motor controller enclosure



Figure 9: 5th Floor visitors' gallery-New location for dome drive cabinet

- The DP4 distribution panel in the back of the lama room will be used to power the equipment on the fifth floor.
 - Electrical wiring (4 strands of 1 awg.) will be pulled from the fourth floor to the fifth floor in preparation for the motor controller enclosure.
 - The electrical wiring will need to be connected to the motor controller enclosure.

7.2. Electrical wiring and control

- The [Detail Design Review for the Control of Electric Dome Drive System](#) explains the control of the system and the necessary wiring to achieve an interface to the cabinet, [created by G. Matsushige](#)
 - This [Block diagram](#) depicts changes in the existing system and cabling.

7.3. Motor electrical

- Electrical conduit (2 sets) will need to be installed and run from the drive enclosure cabinet to each drive unit, three (3) places.
- Electrical wiring will need to be pulled thru the conduit. The motors will require 4 strands of 8 gauge wire and a feedback cable which is about ½" in diameter.
- The complete parts list of the [electrical conduit and wiring components](#) and the new [circuit breaker](#).

7.4. Parking Brakes-not de-acceleration brakes

- Parking brakes will be researched, reviewed, and installed at a later date once the electric drive system is up and running and more time can be allocated.

7.5. Drive unit frame pivot actuator and solenoid valve

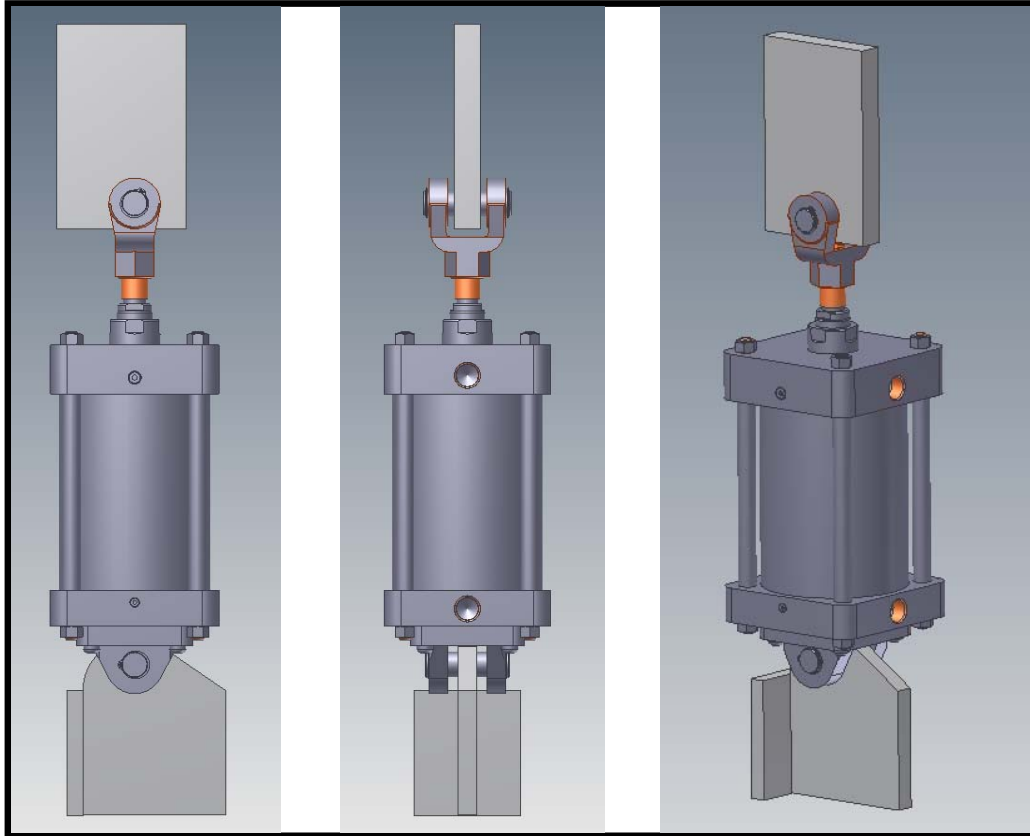


Figure 11: Virtual model isometric configuration views

- The Air actuator drawing and quotation for the actuator, pivot pins, and clevis:
 - [Parker Hannifin dome drive frame pivot actuator](#)
- Since the track that the dome wheel travels on varies at different locations around the diameter of the dome, the top clevis bracket of the pneumatic actuator will be modified slightly. About 0.5" of material will be machined off the bottom threaded mounting surface to allow for additional travel of the actuator.
- Currently the actuator system will not be operated remotely; it will be operated manually with a switch comparable to the old system.
- **Solenoid valve**
 - Each pneumatic actuator will require an ASCO 4-way solenoid valve to operate properly and function analogous to the current hydraulic actuators.
 - Solenoid valves have one pressure port, 2 cylinder ports, and either 1 or 2 exhaust ports.
 - Single solenoid operation (pressure and exhaust ports and cylinder ports alternate connection based on solenoid operation).
 - Low energy consumption ~ 2 Watts VDC or VAC

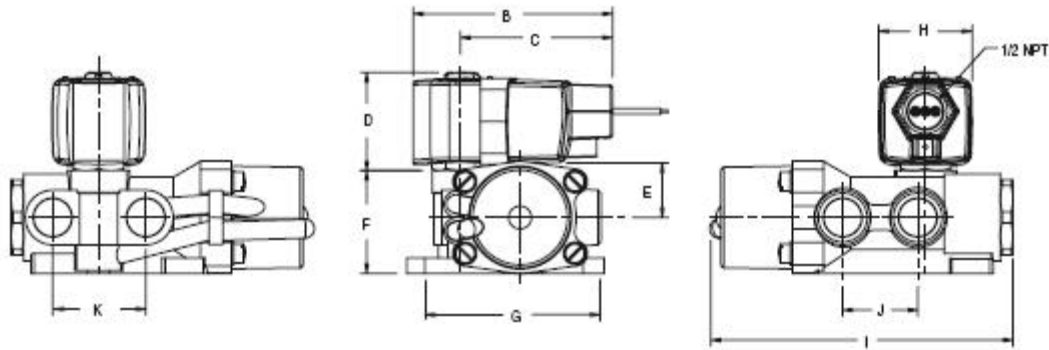


Figure 12: Solenoid valve

- The specification sheet and quotation for the ASCO valve can be found at:
 - [ASCO 4-way Solenoid valve](#)
 - The 2nd page of the Baldor cabinet schematic details the control of the actuators and solenoid valves.
 - [Baldor Cabinet Schematic](#)
- 7.6. Heat Mitigation strategy for the Drive cabinet enclosure and motors
- Heat dissipation requirements and estimates for the motors and motor controllers can be found in the following documents:
 - [15-03-000 Dome Drive Electric upgrade requirements](#)
 - [Appendix A 15-03-001 Dome drive calculations](#)
 - The Dome drive system will be operated intermittently throughout the night for telescope operations and even less during the day for instrument exchanges and maintenance therefore actual heat generation values are difficult to gauge precisely.
 - Motors
 - The estimated heat dissipation of ~95 Watts for the motors under load and ~45 Watts under no load appears to be minimal therefore no initial heat mitigation strategy will be designed. If the motors operate different than anticipated a heat mitigation design will be added at that time.
 - Motor controllers
 - Option A:
 - The motor controller cabinet is located in the visitors' gallery which is a sealed room and has no other heat generating sources; therefore the initial choice is to vent the cabinet's heat from the three (3) motor controllers and other components into the standard volume of air in the gallery.
 - Option B:
 - To further reduce heat in the gallery a hole could be made above the door to the visitor's staircase and install a standard fan. This would pull the air volume from the visitors' gallery into the air volume in the staircase and reduce the overall temperature of the room.
 - Option C:
 - A small Thermatron or Lytron heat exchanger using the building glycol could be added to the bottom of the cabinet which would reduce the temperature of the air volume inside the cabinet before it is introduced into the gallery environment.
 - Temperature monitoring
 - RTD's could be placed inside the visitor's gallery environment to determine current temperature of the room's air volume.
 - From the recorded values, plots will show the current range the visitor's gallery operates in

- Once the dome drive system is integrated and running this feedback mechanism will more precisely determine if additional heat mitigation is needed.
- Dome drive operation duration
 - The TCS system will provide feedback on the duration the motor controllers are left on during the night. With the operation period information, better estimates of the actual heat dissipation will be generated.
- Total system cost estimate ~\$1,500.00

8. Current PLC Interface

8.1. Dome Drive Control PLC (4th floor computer room)

- "[CFHT Dome Control Operational Manual](#)", created by G. Matsushige documents the existing control system very well.
 - This Manual describes the location of the PLC, the type, how it interfaces with the TCS, the PLC modules, schematic diagram of the dome controller, block diagram of the dome controller, etc.
- The [Block diagram](#) for the current system is also discussed in the [Detail Design Review for the Control of Electric Dome Drive System](#), also created by G. Matsushige.

9. Modified PLC Interface

- The [Detail Design Review for the Control of Electric Dome Drive System](#) explains the PLC control of the system, created by G. Matsushige
 - This [PLC Schematic](#) depicts the new system.
- Phase 2 will commence once the new system has been tested thoroughly and is operating correctly under remote operations, then the old system will be removed.

9.2. Phase 1

- Phase 1 will be the integration of the electric drive units into the current dome drive and PLC infrastructure while minimizing the number of PLC code changes. This allows testing and integration work to be performed during the day and switch back to normal operations in the evening.

9.3. Phase 2

- Phase 2 will incorporate items not covered in the essential infrastructure of the system, removing the old hydraulic system; lines, motors, valves, components, etc. and modifying the PLC configuration and PLC code. Since the current infrastructure encompasses module cards and ladder logic soon to be obsolete hydraulic components and inputs/outputs the PLC system should be cleaned up and some housekeeping should be performed to remove these instances. B. Cruise would also like to begin work with TCS to actively control the PID (Proportional Integral derivative) which controls the dome slew speed and acceleration profiles.

10. Draft Interface Definition

10.1. Integration

- See time and resource estimates – Implementation plan
- See also [implementation plan for control](#)

10.2. Mechanical interfaces

- Described above

10.3. Electrical Interfaces

- Described above

10.4. Optical interfaces

- None

10.5. Spares list

- See cost estimates

10.6. Dependences on subprojects

- The Dome Drive System must integrate with the TCS and OAP PLC control systems for autonomous operation.

10.7. Remote monitoring of the dome drive system will provide the following state/status:

- On/off state of motor controllers
- Rotation speed of each motor
- Amperage/torque of each motor
- Failure state of motor controllers (detection and notification)

11. Monitoring and status of the system

11.1. As discussed in the [control portion of the detailed design document](#) a RS232 communication to a Perle device will be used to gather the system information of the motor controllers. After the system has been integrated, verified, validated, and accepted parameters will be selected to log and data will be available on the status page via plots, graphs, and tables.

- Monitoring and status information work will begin after Phase 1 is complete.
- An example of the a monitoring tab on the status page

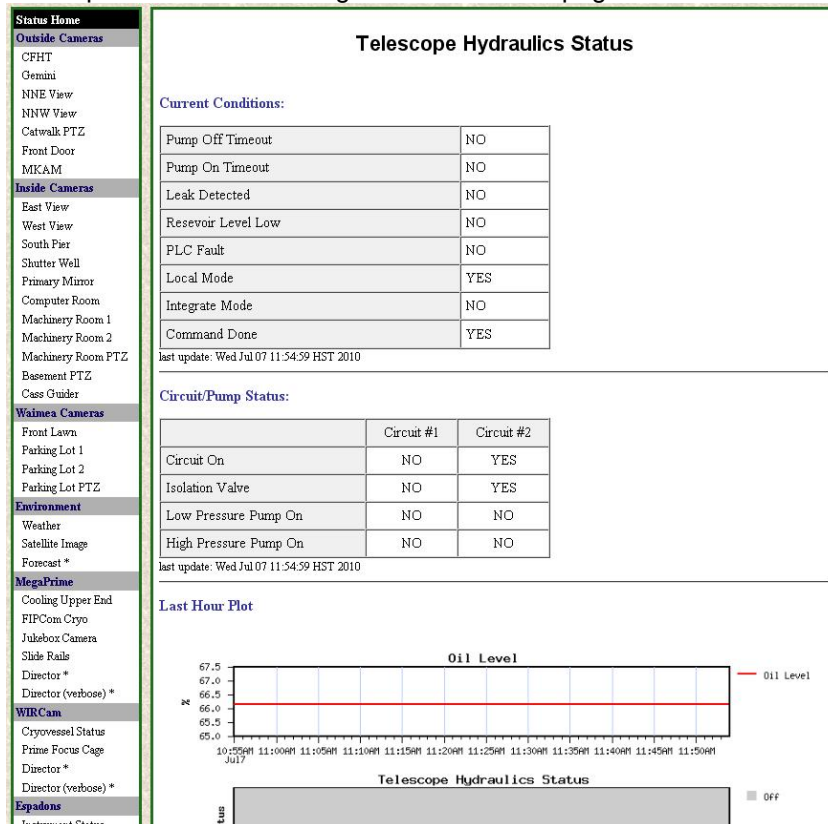


Figure 12: Example of the information available for monitoring and status of the system

12. Implementation Motor integration and testing

- See time and resource estimates – Implementation plan
- See also [implementation plan for control](#)

13. Safety implications

13.1. The new electric drive system introduces additional electrical equipment at the observatory with high voltage. However the same safety procedures and PPE will be used for installation and servicing only by qualified staff or service providers.

13.2. Lock Out/Tag out

- Main electrical breaker which supplies power to the panel during maintenance work by a qualified technician.
- Manual/off and automatic lockout for mechanical maintenance or instrumentation maintenance performed by qualified personnel.

13.3. The electrical dome drive system upgrade eliminates hazards of the existing hydraulic system, such as large leaks, slip hazards, environmental waste cleanup, and injuries to personnel from leak to name a few.

13.4. An Anti-rotation system (Clutch/Brake/chock/wedge/Anti-rotation device) must be in place to prevent unintentional movement of the dome when excessive winds are present.

14. Time and resource estimates – Implementation plan

14.1. Table of time, suggested person needed, and remaining design work and implementation

14.2. All values shown are estimates for time needed to complete the work listed.

14.3. The second semester schedule as well as Director of Engineering priority assignments influences operations and projects which will change priorities and influence schedule priorities.

14.4. The OAP telescope hydraulics project implementation work is also scheduled during the same timeframe.

		Resource	Days	Description
Detailed Design Review date:		~ July 15,2010		
Implementation (Integration)	Integration steps after DDR			
	Hardware, mechanical	SB,LF	1/2	Award the purchase order for the Baldor dome drive system,
	Baldor Cabinet Build			
	Hardware, mechanical	SB	1	Order Drive unit package-Place P.O. to Kaman and Baldor
		SB, Baldor	42	Baldor will begin and design the dome drive cabinet with all the components described in the proposal .
		SB, Daycrew, LR,GM		CFHT, Gary Tofanelli of Kaman, Krieg Richards and Bill Colton of Baldor will review the design make changes as needed and sign off or approve the plans for the cabinet build.
		Baldor/Kaman		The cabinet will be assembled, tested, and shipped to CFHT in 4-6 weeks by Baldor/Kaman.
	Room Modifications			
	Hardware, mechanical	SB, Daycrew	5	Using the footprint of the new electric motor/adaptor kit combo determine what amount to remove from the upper door area.
	Hardware, mechanical			Remove the door casting and/or room walls and modify as needed in the spacer room.

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				Develop and/or install provisions for lifting the 265lb gear reduction box and 290lb motor/adaptor combo.	
		Daycrew	1	Find a new location to relocate the ladders located in the 5 th floor visitor's gallery; move them to clear space for the new cabinet.	
		Actuator Integration and Test			
		SB, Daycrew, GM	1	Inspect the actuators, clevis brackets, and pivot pins for correct model # and dimensions	
				Test set-up for actuators, verify proof of concept on bench	
			2	Finalize the pneumatic lines running to each dome drive unit for the actuators	
				Finalize the location of the solenoid valve and plumbing on each dome drive frame	
				Modify the four (4) female rod clevis brackets	
			3	Record the position of the proportioning valve on the supply and return side of the actuator and valve off the actuators, record the turns needed to shut off the flow	
				Remove the upper and lower pivot pins on the old hydraulic actuator	
				Remove the actuator from the upper and lower brackets and place the actuator with the hydraulic lines still attached to a secure location will bungee cords	
				Modify the top and bottom brackets of the drive unit frame to accommodate the new pneumatic actuator	
		Install (1) one new Pneumatic Actuators actuator in the old units place, on drive unit #2			
		Test pneumatic actuator function (up/down), line pressure (loss of air), and check for leaks. Remove air supply and power to actuator. See control of air actuator plan, 7.4.d			
		3	Run the dome drive system with (1) one pneumatic actuator in place and monitor operational differences from the hydraulic actuators		
			Verification and validation of the pneumatic actuator replacement		
			Install the remaining pneumatic actuators following the steps discussed above.		
				Cap off the supply and return lines for each actuator and label accordingly. Label the actuators and store, discard, or recycle the units.	

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		Spare motor testing			
Implementation (Integration)	Hardware, mechanical	SB, Daycrew, LR	1	Receive spare electric motor and motor adapter kit.	
				Inspect motor adapter kit to verify correct dimensions.	
				Inspect motor to verify dimensions.	
		SB, Daycrew	2	Remove the spare dome drive unit from the crate and anchor it to a suitable stand (old cute stand) for test fitting.	
				Remove the hardware and hydraulic motor from the spare drive unit and annotate it with a time stamp, unit #, etc.	
				Remove the hardware and adapter plate from the spare drive unit and annotate it with a time stamp, unit #, etc.	
				Next unbolt the gear reduction box from the main shaft assembly and rotate it 90 degrees so the input shaft points up.	
				Drain the old oil from the gearbox, record the amount removed, and recycle.	
				2	Install a new breather tube or expansion tube and add required amount of oil to the gearbox.
					Install the electric motor to the new motor adapter kit.
					Mount the electric motor/adapter kit to the gear reduction box.
					Manually rotate the gear reduction box output shaft and check for smooth operation.
				Implementation (Integration)	Electrical
LR, Daycrew, SB	2	Install the temp circuit breaker and spare motor controller to an anchored cart or stand in the visitor's gallery.			
LR, Daycrew, SB, GM		1	Layout design for the conduit from the 4 th floor to the 5 th floor. 460V power		
	10	Install conduit from the 4 th floor electronics to the 5 th floor.			
	10	Pull 1 awg. Electrical wire from the 4 th floor to the 5 th .			
	3	Run and hook up 480V power to the temp circuit breaker.			
		Circuit breaker wiring check. Test wiring continuity. -Test 480V wiring connections from DP4 distribution panel to 5 th floor.			
		Run 480V power from the circuit breaker to the spare motor controller			

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				Run 8 gauge temp power conduit and cable to the test stand from the temp motor controller.	
				Wire up the motor on the test stand with 8 gauge power and the feedback cable.	
				Motor controller wiring check. Test wiring continuity. -Test wiring connections from temp circuit breaker to the motor controller.	
				Motor wiring Check, Test wiring continuity. -power and feedback cable from the spare motor controller to spare bench motor.	
Implementation (Integration)	Software and control	Spare motor controller testing			
			1	See section 7 for. implementation plan for the control of the system	
		GM	1	Modify the PLC Panel in the computer room	
			1	Cabling between computer room PLC and dome drive cabinet location 5 th floor.	
			2	PLC code modification	
			4	Integration of the controls	
			3	Testing of the PLC controls	
			3	Air actuator testing	
			4	Motor testing	
			2	Spare motor controller and spare bench motor testing complete. Awaiting Baldor cabinet for integration.	
		TV, SB,GM	3	PLC communication for status monitoring	
				RS232 to Perle communication for status monitoring	
Status page design					
Status/monitoring page test					
Implementation (Integration)	Electrical	Drive unit motor conduit and wiring			
		LR, Daycrew, SB	1	Finalize the layout design (floor plan) for the conduit from the 4 th floor to the 5 th floor. 460V power	
			2	Layout design (floor plan) for 2 sets of conduit (1/2" and 3/4") for the motor power and feedback cables.	
			5	Install 2 sets of conduit (1/2" and 3/4") for the motor power and feedback cables.	
			5	Pull 8 gauge wires for motors, i.e. electrical wire from the drive units to the drive cabinet location	
			1	Motor Wiring Check, Test wiring continuity. -power and feedback cable from drive units to motor controller cabinet	
		Drive cabinet integration			
		Hardware, Mechanical Electrical	SB,LF	1	Receive Baldor drive unit cabinet at HQ
			SB,RW	1	Transport the cabinet to the summit.
			SB, Daycrew	1	Install the cabinet in the 5 th floor visitor's gallery and secure it in place.
			LR	1	Connect 1awg wiring to the drive unit. Test functionality
			LR, Daycrew, SB, GM		Motor controller wiring check. Test wiring continuity. -Test wiring connections from circuit breaker and PLC to the motor controller.
			LR, SB, Daycrew	1	Finish motor controller cabinet install and checkout.
		Hardware,	Drive unit Integration		

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Implementation (Integration)	Mechanical Electrical	SB, Daycrew	2	Hydraulic motor retrofit can begins a few days before the cabinet is delivered or once the cabinet is integrated	
		3.		Remove hardware, old hydraulic motor, and adapter kit from drive unit #2.	
		5.		Remove hardware and rotate the Brevini gearbox 90 degrees so the input shaft is up.	
		6.		Assemble the new adapter kit/electric motor combination.	
		7.		Install new assembly to the Brevini gear reduction box on drive unit #2	
		WC, GM, SB	4	TCS/PLC/cabinet Testing with new electric drive unit #2	
		SB, Consultant	1	Motor controller consultant arrives on island (this can occur before the first unit is integrated or after)	
		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	
		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	
		See section 7 for. implementation plan for the control of the system			
Implementation (Integration)	Software, Electrical	SB, GM, WC, Daycrew	5	Test drive unit # 1, 2 and 3 under electric motor control.	
			1	Manual/automatic system tests	
			3	Phase 1 Finished- Dome drive system now under electric drive system control.	
		Phase 2			
		GM, SB, TV	2	PLC module bits and RS232 to Perle device information for status monitoring	
		TV, GM, SB	5	Monitoring and status page design	
		TV, GM, SB	5	Testing with status and monitoring page display	
		SB, Daycrew	1	Monitor heat dissipation in visitor's gallery.	
			1	Install heat mitigation equipment if needed.	

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			Phase 1 Complete	
		Subtotal:	~92	Days (many tasks will be in work during the same time period as well as the time allocated until the drive cabinet arrives)
Estimated completion date:		Oct 2010		

Table 1: Time and Resource Estimate

10. Cost estimates

10.1. The following table outlines the estimated costs for the dome electric drive system and the supporting components, equipment, and work needed for the overall system design.

10.2. Costs do not include shipping and handling, *unless noted*.

Equipment and Material Costs					
Item	Qty	Component description	Cost	Total	Notes/Includes:
1	1	Baldor ZD22H420EL drive panel package proposal	\$43,860.53	\$43,860.53	Drive system package, 3X motor controllers and equipment needed to assemble drive cabinet, for more information .
2	3	Baldor 20HP RPM AC ZDFRPM21204C motor	\$3,096.00	\$9,288.00	Drive system motors, 3X motors. 1 Master and 2 Slaves, for more information .
3	1	Baldor-spare 20HP RPM AC ZDFRPM21204C motor	\$3,096.00 *Shipping: *\$243.37	\$3,339.38	Spare drive system motor, special pricing when purchased as a package, for more information .
4	1	Baldor-spare ZD22H425EL motor controller	\$8,660.00 *Shipping: *\$243.37	\$8,903.38	Spare drive system motor controller, special pricing when purchased as a package, for more information .
5	1	Baldor applications engineer for drive commissioning	\$5000.00	\$5000.00	Plus travel expenses, i.e. airfare, lodging, rental car.
6	1	HFB3150-R, 150amp 600 volt 3 pole circuit breaker	\$650.00 *Shipping: *\$69.45	\$719.45	Southland Electrical Supply, for more information
7	1	Gexpro-Electrical conduit and wiring upgrades	\$3,868.84	\$3,868.84	New 1awg wiring and conduit run from the 4 th floor to the 5 th floor, 8 gauge wire and conduit for the motor power runs, for more information
8	4	<i>Parker Hannifin</i> Pneumatic actuators for the dome drive frames	\$623.67	\$2,530.68	Includes: four (4) Pneumatic actuators , (1) one is a spare, for more cost information .
10	4	<i>Parker Hannifin</i> Female Rod clevis brackets for the dome drive frames	\$50.95	\$203.80	Includes: Four (4) Female rod clevis , (1) one is a spare, for more cost information .
11	4	<i>Parker Hannifin</i> Pivot pins for the dome drive frames	\$21.85	\$87.40	Includes: four (4) Pivot pins, (1) one is a spare, for more cost information .
		Pneumatic Solenoid	\$655.00	\$2,620.00	Includes: four (4) Solenoid

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12	4	valves, air lines, and fittings			valves , (1) one spare, for more cost information .
13	4	Brevini Motor adapter kits-qty 4	\$606.70	\$ 2,426.80	Includes (4) motor adapter kits , (1) one spare kit, for more cost information .
14	1	Heat mitigation <ul style="list-style-type: none"> • Option1: Vent cabinet into the visitors gallery • Option 2: Fan above the stair access door • Option 3:Heat exchanger with glycol lines and fittings 	\$1,500.00	\$1,500.00	<ul style="list-style-type: none"> ❖ This is the cost for the third option in the heat mitigation. ❖ The second option will cost around \$600.00 ❖ Option 1 has no added costs
		Misc materials and supplies		\$1,000.00	
TOTAL				\$85,348.26	

Table 2: Equipment and Material Costs

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