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NASA Infrared Telescope Facility

Dome Drive Servo Upgrade Project

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1.0 Summary

The dome drive amplifiers and motors will be replaced at the IRTF to provide more reliable operation, increased torque, and reduced maintenance. The expected completion of this project is August, 2012. The same vendor that assisted in the CFHT dome upgrade was selected to assist in the IRTF dome upgrade..

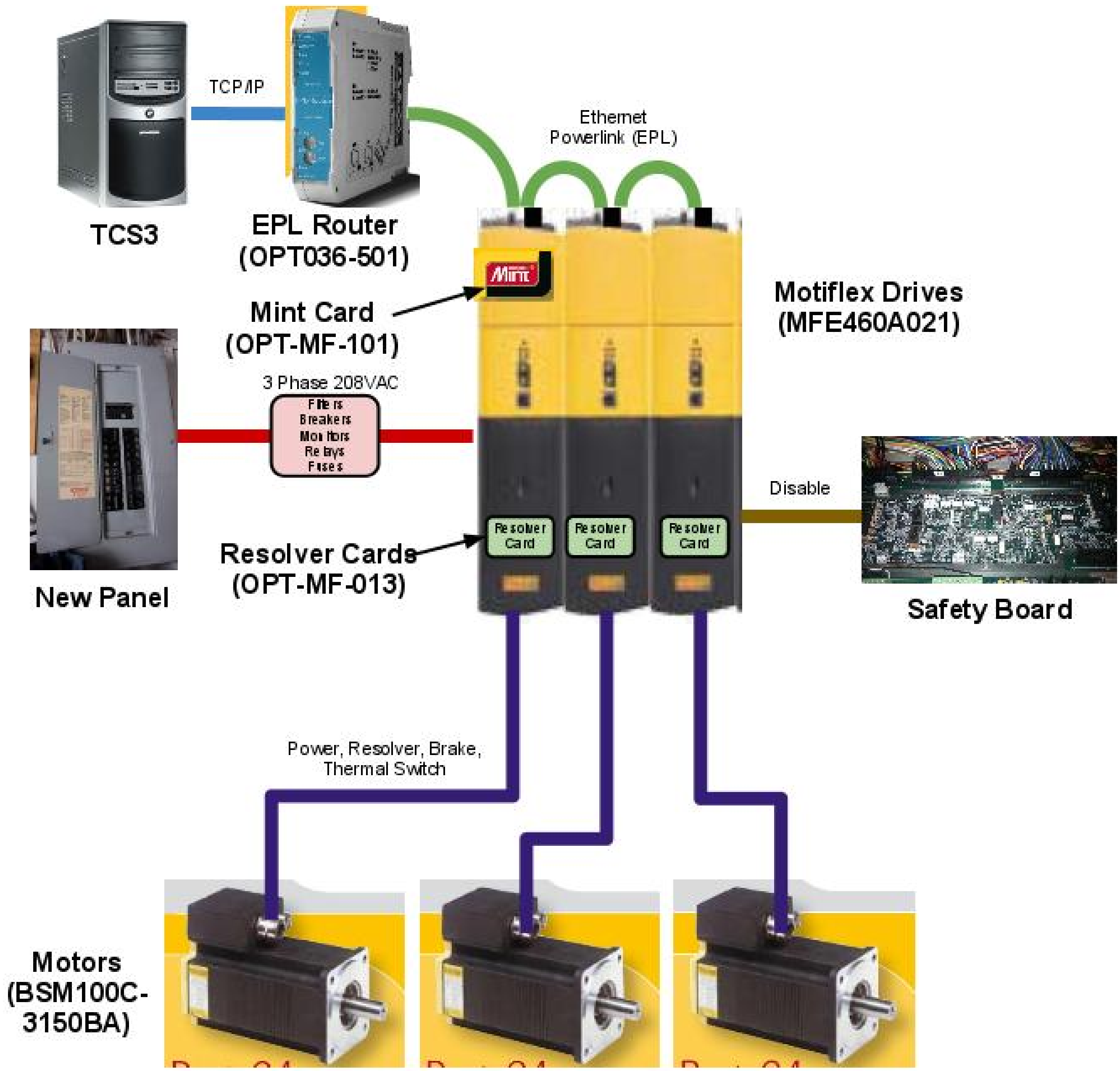
2.0 Background

The NASA IRTF dome drive electronics have been in use for over 30 years. While this system has been fairly reliable over this time period, over the last few years, it has experienced a much higher frequency of stalls. The issues may be mechanical, electrical, or both. Everything in the system is original and is suspect. Regardless of the performance of the system, the age of the components make it more difficult to maintain. Additionally, higher torque motors are desired.

3.0 Project Scope

The project involves replacing all electrical equipment between the TCS3 PC and the motor gearboxes plus software changes to TCS3. In addition a lab test system will also need to be built. See diagram below:

The project can be broken down into major tasks/items:
1) 3 phase 208VAC wiring and sub panel
2) Servo to motor wiring
3) Motors
4) Motor mounting plates and shaft adapters
5) Servo drives
6) Misc. interface and electrical equipment - routers, relays, regen resistors, etc.
7) Software
8) Lab test system



Project Overview Block Diagram

4.0 Project Tasks

Each project task is detailed in the following subsections. Summarized technical information is given, but for more in depth, detailed technical information, see the "Dome Motor Upgrade"

spreadsheet document. It is also a google doc at:
https://docs.google.com/spreadsheet/ccc?key=0AgDomi_LyO2MdFRudmlwRXVOdk5zUlFkNFV1S2FKclE&hl=en_US#gid=0

4.1 3 Phase 208VAC Wiring

The power demand of the new system is higher due to larger, more powerful motors being used. The wiring and associated breakers must be sized to accommodate peak power. This requires running separate power for each of the 3 amplifiers, which equates to 9 wires. Currently, there are no sub panels that have enough excess capacity to run these additional wires. An electrical contractor will have to be contracted to install the panels and wiring to the TCS room or the possibly the loading dock area (location is under discussion).

Parameter	Value	Comment
Continuous Current per motor & drive total (motor)	~13A (11.4A motor)	
Maximum Current per motor & drive total	35A (29A motor)	<30A total is probably more realistic, but doesn't change breaker/circuit size.
Recommended breaker size	40A	

3 Phase 208VAC Wring

4.2 Servo to Motor Wiring

New wiring will have to be run from the servo to the motors. These motors use higher voltage than the previous motors (~280V vs ~70V) and have more power wires (3 vs. 2). There are also new resolvers for each motor. In addition, it is recommended to use shielded wire to prevent unwanted radiated emissions in the dome. For these reasons, rigid, metal conduit will be used for physical protection and additional shielding. The wiring itself will consist of 4 bundles - power, resolver, brakes, and thermal switch. All bundles will also be shielded. Since an electrical contractor will install the AC power wiring, it is proposed that the same contractor complete the rigid conduit and wiring installation at the same time. The wiring will be specified and purchased by the IRTF. The length of the runs is quite long, so an appropriate amount of wire will need to be purchased.

Item	Value	Comment
Conduit Runs	3	3 motors

Power Wire	40A rating	4 wires: 3 phase + earth, long run
Brake Wire	1.4A rating	Twisted, shielded pair, 24V, 1.4A
Thermal Switch	<1A rating	Twisted, shieled pair
Resolver	<1A rating	3 Twisted, shielded, pair (sin, cos, ref)

Servo to Motor Wiring Types

4.3 Motors

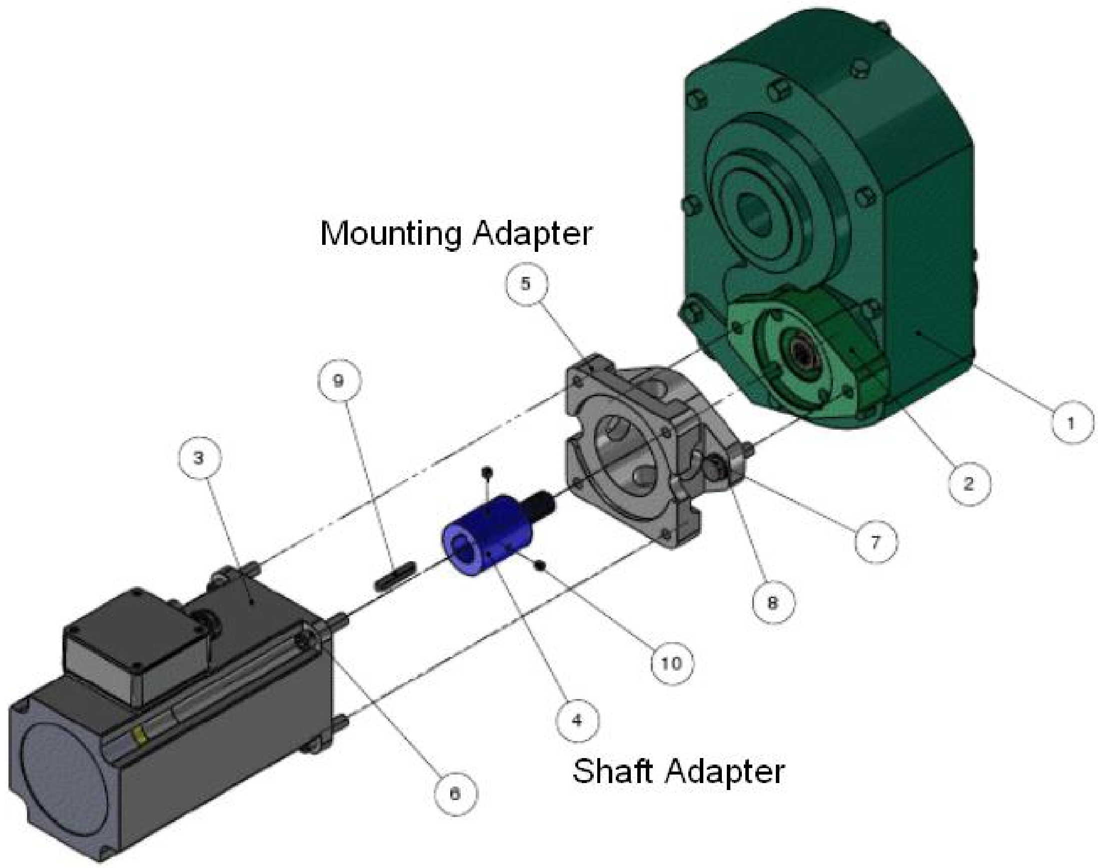
AC servo motors by Baldor with approximately double the continuous current of the DC Kollmorgen motors were selected. AC motors have the inherent advantage of no brushes, which means very little maintenance.

Parameter	Value	Comment
BSM100C-3150BA Continuous Torque	125 lb-in	"BA" = Brakes, Resolver. 11.4A continuous
TTB-2953-1011-A	66 lb-in	Present, Kollmorgen, DC motor

Motor Comparison

4.4 Motor Mounting Plate and Shaft Adapter

The new Baldor motors have different mounting holes than what is on the gearboxes. Therefore an adapter plate will have to be made. In addition, the shaft sizes are different, so they will also require adapters. Both of these items will have to be custom machined.



Motor Adapters

4.5 Servo Drives

The servo drives selected are from the same vendor as the motors, which is Baldor. The drives are specified to work with these motors by the vendor. There are many models in the same line, with the only differentiating factor being current rating. Since the IRTF is at an elevation of around 13,796 (Mauna Kea peak), the drives must be derated for the altitude. This simply means that a drive with a higher current rating must be selected. The MFE460A021 by Baldor was selected.

Parameter	Value	Comment
MFE460A021 Continuous Current Rating	21A	Continuous, up to 3300 ft
Derating Factor	35%	(13,796ft-3,300ft)*1.1%/330ft=35%
MFE460A021 Continuous Current Derated	14A	13,796 ft
BSM100C-3150BA Motor, Continuous Current	11.4A	

Servo Current Drive Derating vs. Motor

The servo drives will need optional cards. One card is for the resolver input (recommended by the Baldor) and all 3 drives will need this. The second card is a "Multi-axis programmable Mint Machine Module" which is only needed by the master drive and allows it to control the other two axes.

Item	Comment
OPT-MF-013 Resolver input option	For resolver feedback. Recommended by Baldor for being more standard.
OPT-MF-101 Multi-axis programmable Mint Machine Module	Controls up to 5 axes of interpolated motion. There are 3 motors for the dome.

Servo Drive Option Cards

4.6 Miscellaneous Interface & Electrical

There are many small, but important items that must be included in the project. The table below lists these items and their function. Not every item will be listed below. Please see the project spreadsheet for more detailed information. Link is given earlier in document.

Item	Part Number	Function
TCP/IP to Powerlink Router	OPT036-501	Allows TCP/IP ethernet PC to connect to Servo Powerlink ethernet
Regen Resistors	TGHLV25R0JE	Dissipates energy when motors decelerating. Dome causes motors to act as generators.
Reactors	RL-05502	Power filtering and protection for drives.
Breakers	C40A3P	Local breakers to remove power
3 phase monitor	84873004	Monitors 3 phase power. Can be used to indicate that power is on and when power faults occur.
Ethernet cat5e cables	Multiple, part number based on length/color	Shielded cable connects servo drives together
Contactors/Relays	P40P42D12P1-24	Allows local disconnection of power. 40A rated, 24V coil.

Fuses & Holders	FWC-32A10F / CB1038-3	Another layer of faster protection in addition to breakers
Connectors	Multiple, TBD	Minor items, but required to connect things together

Miscellaneous Items

4.7 Software

4.7.1 TCS3 Software

TCS3 will have to be modified. The older system used analog signals for the command and telemetry. The new system uses an ethernet based system for commands and telemetry. It's a must simpler setup, but requires software changes to accommodate it.

Baldor provides free tools and software. Some of the tools will be helpful for setup and testing, however, the Active X libraries will not be of any use since they are for Windows only. The IRTF uses Linux and has its own GUIs and front end, which will remain unchanged. Essentially, there are underlying commands that are sent over ethernet to the controller and it's a matter of learning the command set for the controllers.

4.7.1 Servo Drive Software

The actual control algorithm is implemented on a master servo. This is probably the most important and interesting aspect of the project. The master servo has an additional card installed that allows it to control other devices over the Powerlink Ethernet and have expanded programming capabilities. This removes the need for a stand alone controller. The programming language is the Mint programming language by Baldor, which is free to use.
The algorithm is very similar to CFHT's. The TCS3 sends a velocity command to the servo master, which provides a current command to itself and the other two drives. There are velocity mismatch bounds placed on the motors to ensure that they are approximately the same speed while matching current. This creates a smooth operation with minimum disturbances.

Baldor rep on the CFHT control scheme:

"On the control scheme – we actually did speed matching with torque override. Essentially, we had a master control that was strictly in velocity mode. We buffered the encoder of the master into the 1st slave (120 degrees apart as well) – for velocity control. However, we also took the current output of the master and brought it into one side of a differential input on the follower. We brought the current output of the follower into the other side of the differential input thus being able to compare currents of the master to the follower. We ran a sloppy PID loop with a set point of 0, allowing for a maximum speed variation of something like 10 RPM to match current. This allowed us to balance the current, without erratic speed or torque changes enabling a smooth system."

4.8 Lab Test System

A temporary lab system will need to be made that mimics the summit system to a practical degree. Essentially, 3 motors, 3 drives, a load of some sort (e.g. brakes), and associated miscellaneous electronics will need to be mounted on something, perhaps a piece of plywood for example. The lab cabling would simply be very short versions of the summit cabling. It will be integrated to with the lab TCS3 system for testing.

4.0 Project Schedule & Budget

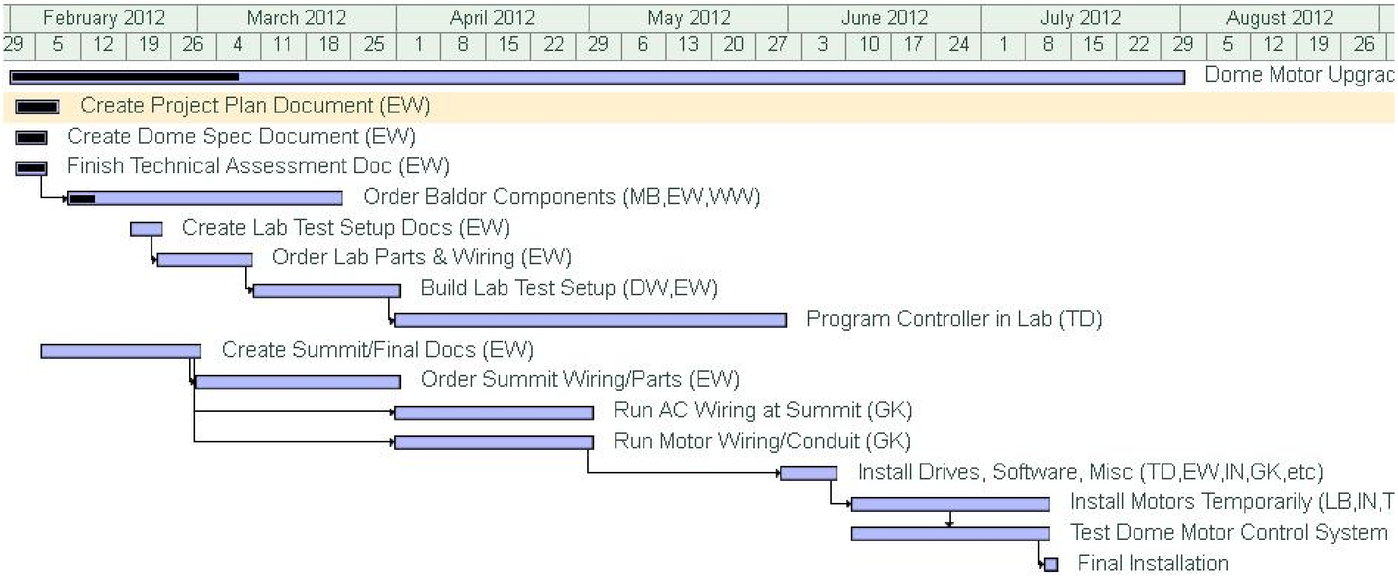
Haven't found a way to embed the google spreadsheet. Inserting a graphic will make it out of date almost instantly, however, it still supplies the the most important information.

Here is the link to the spreadsheet:
https://docs.google.com/spreadsheet/ccc?key=0AgDomi_LyO2MdFRudmlwRXVOdk5zUlFkNFV1S2FKclE&hl=en_US#gid=0

There is a "Gantt" tab and a "Cost" tab in the spreadsheet.

			Quantity			$48,210.35	TOTAL COST
Part Number	Description	Vendor	Required	Spares	Unit Cost	Sub Total	Comment
BSM100C-3150BA	Motor, AC Servo, resolver	Baldor	3	2	$3,086.66	$15433.3	
MFE460A021	Servo Drive	Baldor	3	2	$3,176.52	$15882.6	
OPT-MF-013	Resolver Card	Baldor	3	2	$445.91	$2229.55	
OPT-MF-101	Multi-axis programmable Mint Machine Module	Baldor	1	1	$1,492.00	$2984	
OPT036-501	Powerlink router	Baldor	1	1		0	
FWC-32A10F	Fuses, 32A	Mouser	9	3	$18.56	$222.72	
CB1038-3	Fuse Holders, 3 fuses	Mouser	3	1	$23.66	$94.64	
P40P42D12P1-24	Contactors, 40A, 3 pole	Mouser	3	1	$122.22	$488.88	
TGHLV25R0JE	Power Resistor, 25 ohm, 200W	Mouser	3	0	$46.58	$139.74	Test to determine if required or what power rating is needed.
RL-05502	Reactor, 55A, 0.5 mH	Galco	3	1	$330.33	$1321.32	
84873004	3 phase monitor	Newark	3	1	$90.98	$363.92	
9926253540	Breaker, 40A, DIN Rail, 3 phase	Digikey	3	1	$54.59	$218.36	
SF61108CY OR005	4 x 8AWG wire with shield, 100ft	Allied Electronics	3	0	$610.44	$1831.32	Guessing 300 ft right now. Need to measure.
-	Motor to Gearbox adapter plate	Manoa	3	0		$2000	Shop time
-	Motor Shaft Adapter	TBD	3	1	-	$5000	Estimation. Out for quote.
-	Contractor, Summit AC Power Installation & Motor Conduit	Local - Hilo	-	-	-	Getting quote.	

Material & Contractor Cost
(jpg image - see spreadsheet for latest)



Project Gantt

Predecessor	ID	Name / Staff	Start Date	Finish Date	% Complete
	0	Dome Motor Upgrade Project	2/1/2012	8/1/2012	19%
	1	Create Project Plan Document (EW)	2/2/2012	2/8/2012	100%
	2	Create Dome Spec Document (EW)	2/2/2012	2/6/2012	100%
	3	Finish Technical Assessment Doc (EW)	2/2/2012	2/6/2012	100%
3	4	Order Baldor Components (MB,EW,WW)	2/10/2012	3/23/2012	10%
	5	Create Lab Test Setup Docs (EW)	2/20/2012	2/24/2012	0%
5	6	Order Lab Parts & Wiring (EW)	2/24/2012	3/9/2012	0%
6	7	Build Lab Test Setup (DW,EW)	3/10/2012	4/1/2012	0%
7	8	Program Controller in Lab (TD)	4/1/2012	5/31/2012	0%
	9	Create Summit/Final Docs (EW)	2/6/2012	3/1/2012	0%
9	10	Order Summit Wiring/Parts (EW)	3/1/2012	4/1/2012	0%
9	11	Run AC Wiring at Summit (GK)	4/1/2012	5/1/2012	0%
9	12	Run Motor Wiring/Conduit (GK)	4/1/2012	5/1/2012	0%
12	13	Install Drives, Software, Misc (TD,EW,IN,GK,etc)	5/31/2012	6/8/2012	0%
13	14	Install Motors Temporarily (LB,IN,TD,EW)	6/11/2012	7/11/2012	0%
14	15	Test Dome Motor Control System (TD,EW,IN)	6/11/2012	7/11/2012	0%
15	16	Final Installation	7/11/2012	7/11/2012	0%
(yellow)	=	Task is difficult to estimate. New controllers with new software.			

Task & Complete Table for Gantt