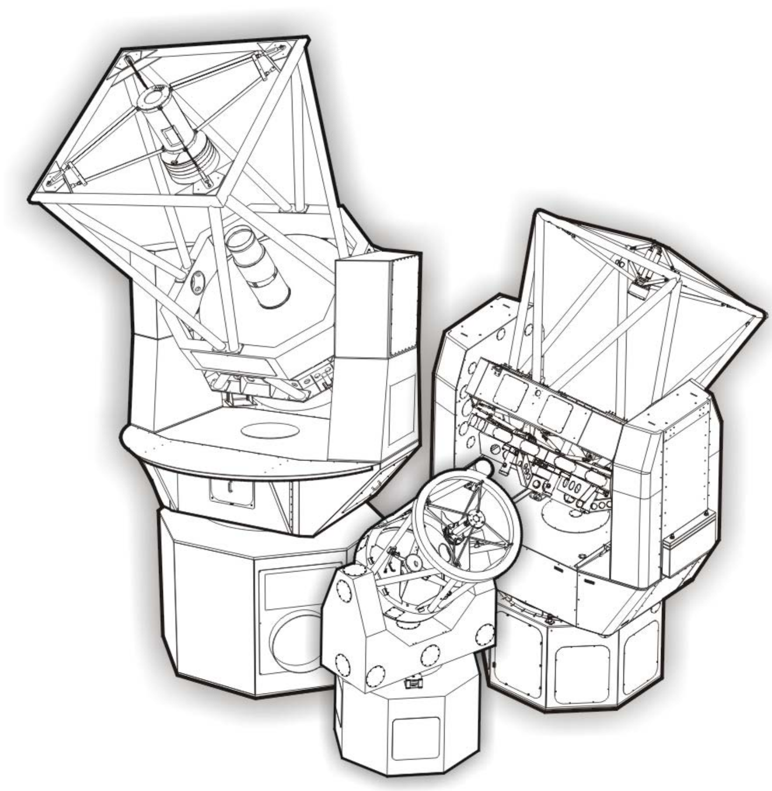
EOS Technologies, Inc.

AUTOMATED PLANET FINDER TELESCOPE

Direct Drive Preliminary Design Note

DN-6581-1



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DIRECT DRIVE DESIGN NOTE

1. INTRODUCTION

1.1 SCOPE

This document describes the Automated Planet Finder (APF) Telescope direct drive motor design. The original friction drive design has been replaced with the direct drive option in order to improve performance and reduce maintenance. This document describes the method used to make motor and mounting choices for both azimuth and elevation drive systems.

1.2 CONFIGURATION STATUS

This document has been configured as DN-6581 and is a designated controlled document under the EOST Quality System.

1.3 DEFINITIONS

All items in this document are defined with respect to the APF telescope. In many instances, both SI and English units are included for convenience. In all cases, the SI units shall govern.

2. MOTOR SIZING

Motor sizing is determining two basic factors. One, the amount of torque required to operate the telescope under maximum acceleration and velocity conditions and, two, the physical size of the motor versus outside diameter space and center hole requirements. The following parameters are used to calculate the required torque for the telescope axes.

Azimuth Inertia $J_{AZ} = 42300 \frac{Kg}{m^2}$ (solidworks)

Elevation Inertia $J_{EL} = 21000 \frac{Kg}{m^2}$ (solidworks)

Max. AZ Acceleration $\alpha_{AZ} = 1 \frac{\deg}{\sec^2}$ (specifications)

Max. EL Acceleration $\alpha_{EL} = 1 \frac{\deg}{\sec^2}$ (specifications)

Max. AZ Velocity $\Theta_{AZ} = 2 \frac{\deg}{\sec}$ (specifications)

Max. EL Velocity	$\Theta_{EL} = 2\ \frac{\deg}{\sec}$ (specifications)
Max. AZ cable wrap torque	τ_{AZ} = 10 N·m (estimate BHC)
Max. AZ cable wrap torque	τ_{EL} = 50 N·m (estimate BM)
Max. disturbance torque	τ_d = 100 N·m (estimate BHC)
Max. AZ tare torque	τ_{AZ_tt} = 330 N·m (estimate BM)
Max. EL tare torque	τ_{EL_tt} = 100 N·m (estimate BM)

Gyroscopic resistance torque is a function of elevation inertia and axes velocities and has the same impact on both azimuth and elevation,

$$\tau_g = J_{EL} \cdot \theta_{EL} \cdot \theta_{AZ} \qquad \tau_g = 25.588 Nm$$

2.1 AZIMUTH MOTOR SIZING

Azimuth torque needed to drive the telescope is,

$$T_{AZ} = J_{AZ} \cdot \alpha_{AZ} + \tau_{AZ} + \tau_d + \tau_g + \tau_{AZ\_tt} \qquad T_{AZ} = 1.204 \cdot 10^3\ Nm$$

Ideally the azimuth drive motor will have a factor of two torque margin. This leads to a final design motor torque of $\underline{T_{AZ} = 2.408 \cdot 10^3\ Nm}$ or in motor manufacturing terms $\underline{T_{AZ} = 1.776 \cdot 10^3\ ft \cdot lb}$

For the azimuth drive system we are using a Kollmorgan QT-235XX-2 with a 10 inch stack height. This motor produces a maximum torque of 2000 ft/lbs with a torque sensitivity of $K_t = 52.8 \frac{ft \cdot lbs}{amp}$. See QT-235XX.pdf for more details.

2.2 ELEVATION MOTOR SIZING

Elevation torque needed to drive the telescope is,

$$T_{EL} = J_{EL} \cdot \alpha_{EL} + \tau_{EL} + \tau_d + \tau_g + \tau_{EL\_tt} \qquad T_{EL} = 6.615 \cdot 10^2\ Nm$$

Ideally the elevation drive motor will have a factor of two torque margin. This leads to a final design motor torque of $T_{EL} = 1.233 \cdot 10^3\ Nm$ or in motor manufacturing terms $T_{EL} = 9.904 \cdot 10^2\ ft \cdot lb$

For the elevation drive system we are using the same Kollmorgan QT-235XX as used for azimuth but with a 5 inch stack height instead of 10 inch. This motor produces a maximum torque of 1000 ft/lbs.

3. ATTACHMENT

3.1 AZIMUTH ATTACHMENT

The 1 meter telescope direct drive design used a motor attached between the yoke base and the telescope base. While performance was excellent, the assembly and shipping of the telescope was complicated by the fact that the motor had to be disassembled and re-assembled. This design has been modified for the Lick 2.4 meter telescope to have a separate motor assembly containing the motor, azimuth bearing, encoding components and limit switch assembly. The separate motor assembly allows the motor alignment to be maintained during shipping of the telescope as well as simplifying the yoke base and telescope base designs. See figures 1 and 2 below. The azimuth assembly is shown in detail in the “Lick azimuth assembly.pdf” document.

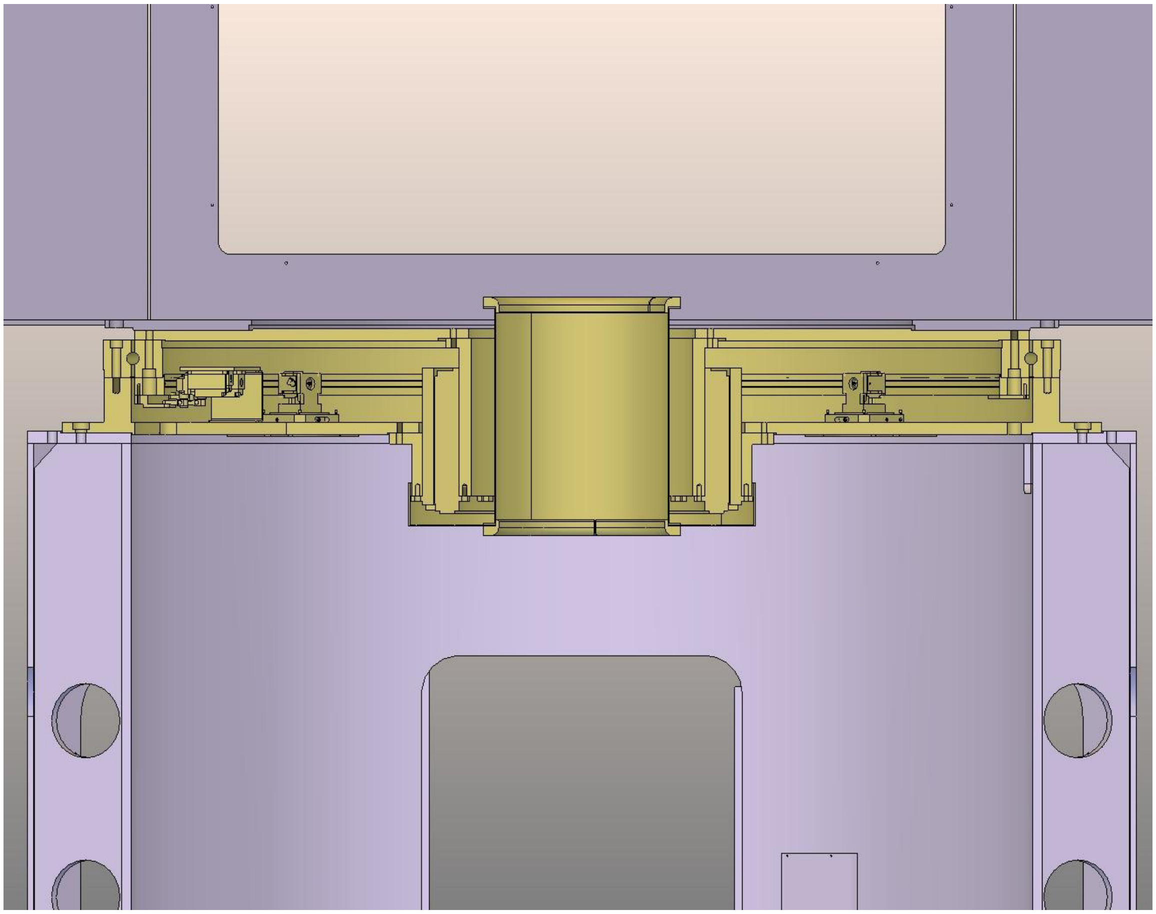

Figure 1 Lick 2.4m Azimuth Motor Assembly

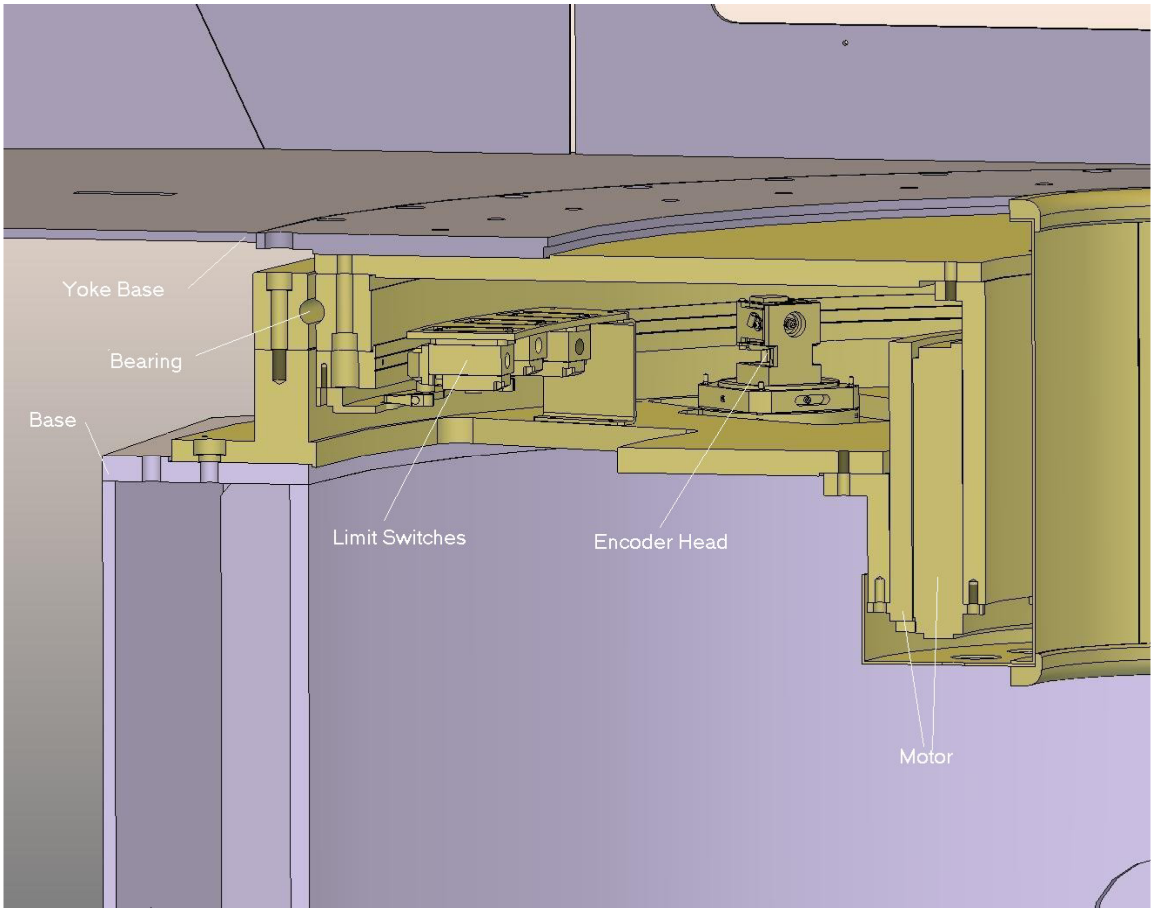

Figure 2 Lick 2.4m Azimuth Motor Assembly

3.2 ELEVATION ATTACHMENT

The elevation direct drive motor design for the Lick 2.4 meter telescope has remained the same as the 1 meter telescope drive design. The motor size has been increased to compensate for the additional torque requirements of a larger telescope. The motor bolts to the elevation inner bearing race (telescope center section) and the elevation tine. See figures 3 and 4 below.

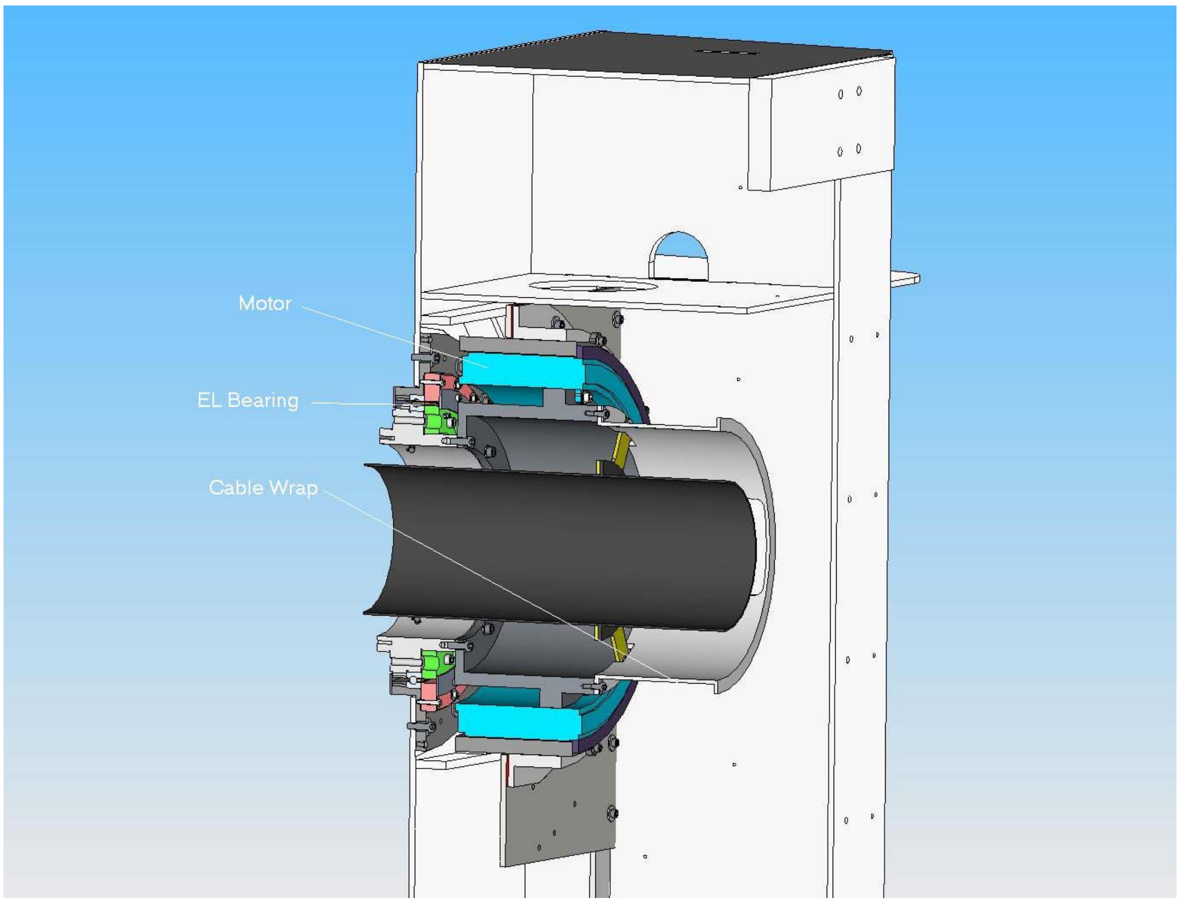

Figure 3 Elevation Direct Drive

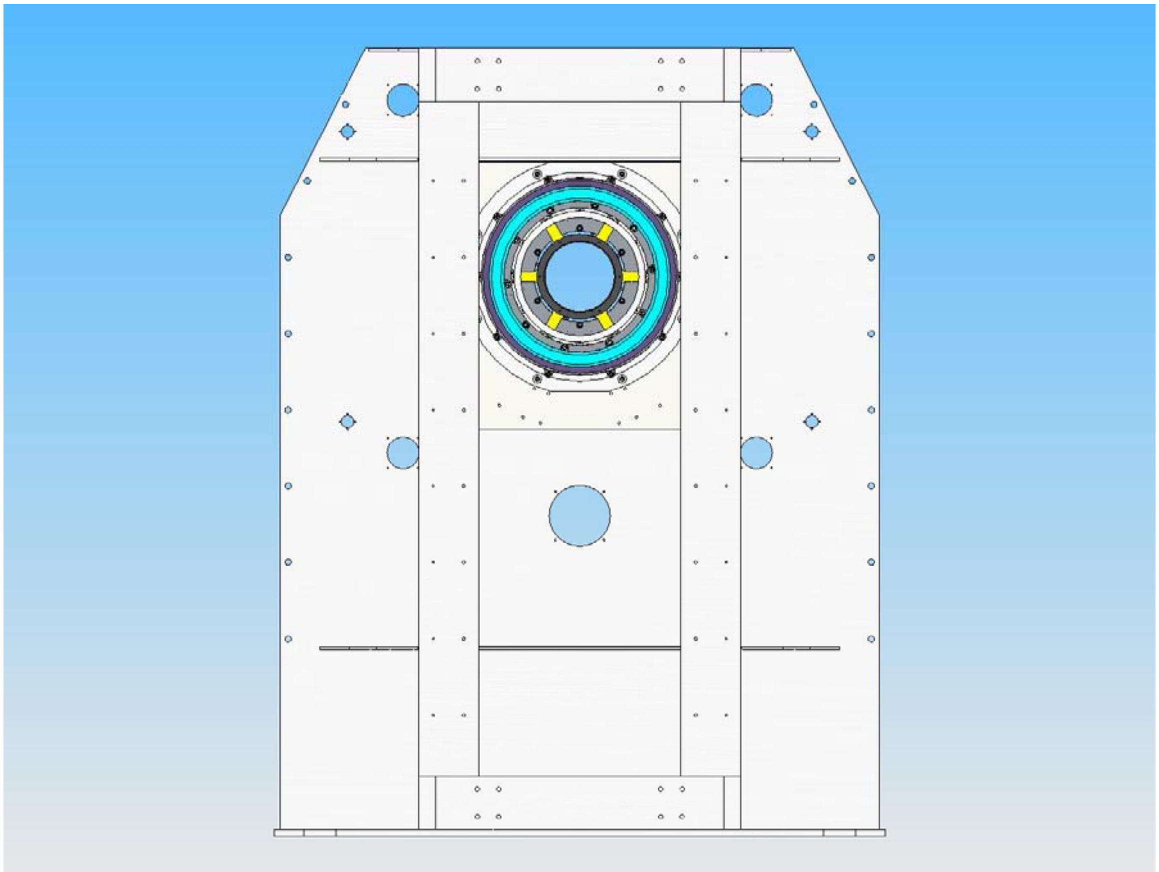

Figure 4 Elevation Direct Drive

4. CABLE INTERFACE

4.1 AZIMUTH CABLE INTERFACE

Azimuth motor cables as well as limit switch and encoder cables run from the control rack to the azimuth motor assembly through the enclosure cable wrap and a connector panel on the telescope base. This is the standard EOST co-rotating enclosure setup. There are no cables passing through the azimuth motor.

4.2 ELEVATION CABLE INTERFACE

Elevation motor cables use the standard setup where cables run from the control rack, through the yoke base, to the motor on the tine. There is a disconnect panel is at the point where all cables pass into the yoke base.

5. MOTOR REMOVAL

The requirement for a motor to be removed is not expected during the lifetime of the telescope.

5.1 AZIMUTH MOTOR REMOVAL AND INSTALLATION

The azimuth motor is packaged in the azimuth motor assembly. Motor removal is only required for replacement and not required for shipping. A fixture and rail system is designed to allow the motor stator to be lowered inside the base, rotated 90 degrees for door alignment, and moved through the door. After the stator is removed the rotor can be unbolted and lifted out of position. Motor weight, rotor and stator, is approximately 430 pounds.

Installation is simply bolting the rotor into place on the alignment pins followed by using the fixture to move the stator into place. Stator alignment is maintained by the installation fixture which is bolted into the azimuth motor assembly bottom plate.

5.2 ELEVATION MOTOR REMOVAL AND INSTALLATION

The elevation motor is fixed to the elevation bearing and requires no disassembly for shipping. Before motor removal, all cables will need to be unfastened from the cable wrap, disconnected from the yoke panel, and pulled into the center section of the telescope. A fixture is designed to allow the stator to be unbolted and slid away from the tine for removal. The rotor can then be unbolted and removed.

Installation involves bolting the rotor to the inner bearing using integrated pins for alignment followed by using the fixture to move the stator into place and bolting to the outer bearing race. Cables will need to be re-routed to the yoke base and re-attached to the elevation cable wrap. Cable routing will be included in the elevation motor installation procedure.

6. MAINTENANCE AND AUXILIARY EQUIPMENT

Motor brush replacement is the only required maintenance for either motor. Motors are driven at maximum rated velocity for 24 hours prior to installation on telescopes to allow brushes to wear in. Brush replacement is not expected within the first 10 years of use.

Auxiliary equipment includes fixtures to allow assembly and disassembly of both motors as well as removal of the azimuth motor. The fixtures EOST uses will remain at EOST for use on other telescopes but will be made available to Lick if the situation arises where a motor needs to replaced. Manufacturing drawing of these fixtures will also be made available to Lick to allow on-site fixtures to be purchased at a later date.