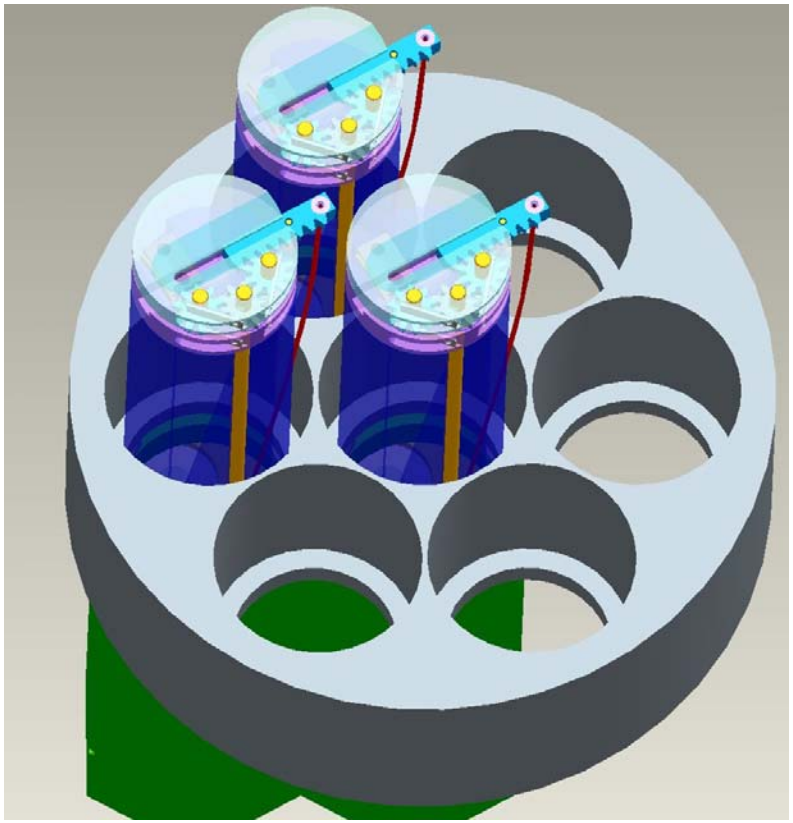
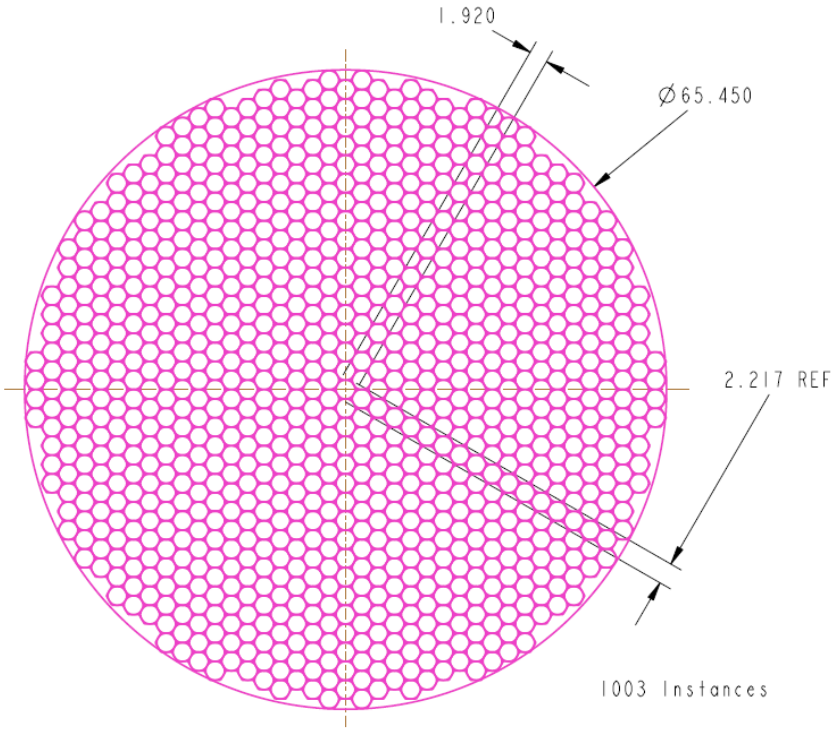
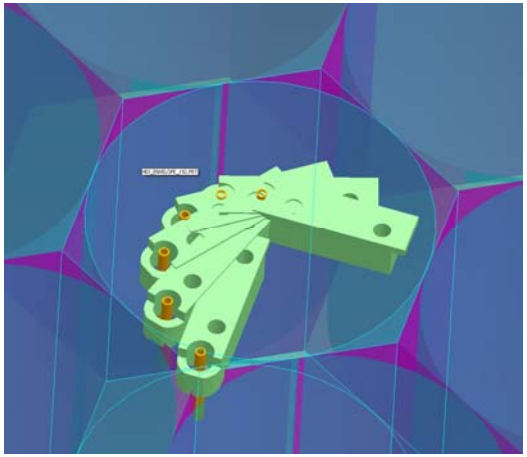
TPL Actuator Design



Positioning

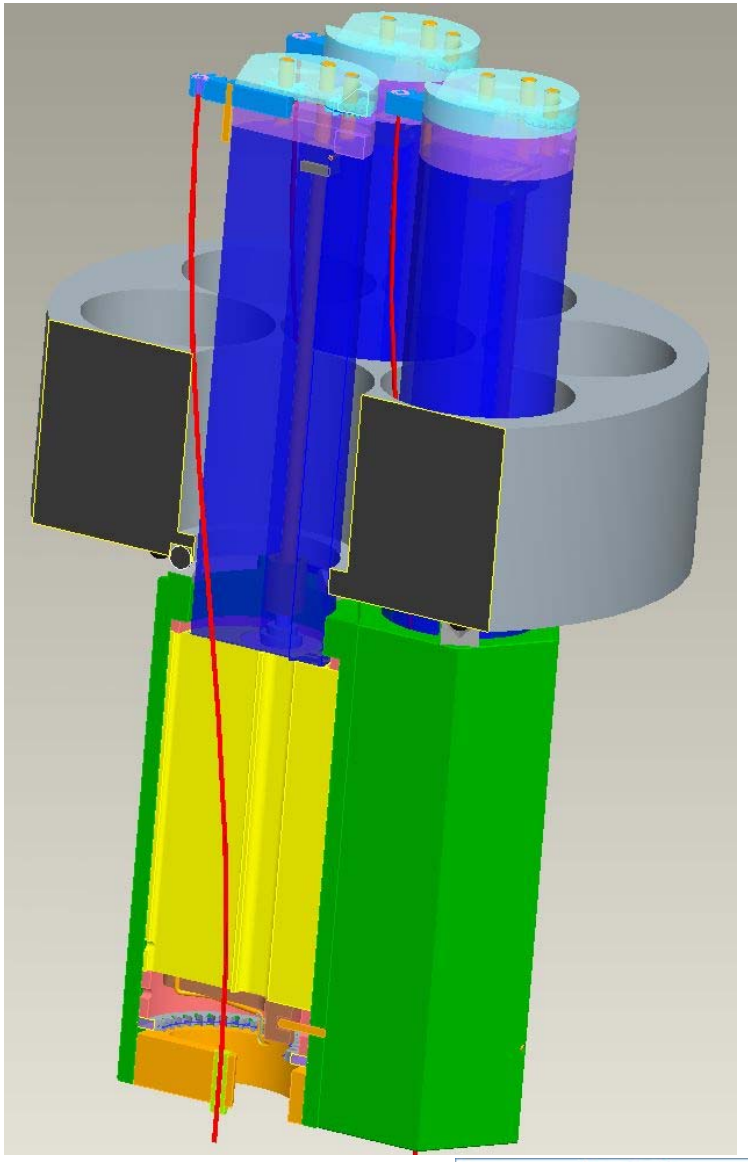
- Hexagonal positioning domain for efficient seamless coverage of focal plane
- R-Theta design allows coverage with minimal overlap into neighboring actuator territory (unlike orthogonal stages which have mechanism overhead)





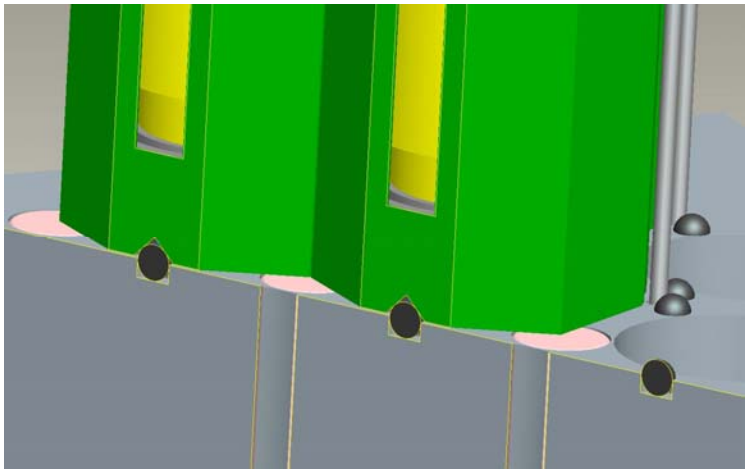
Fiber handling

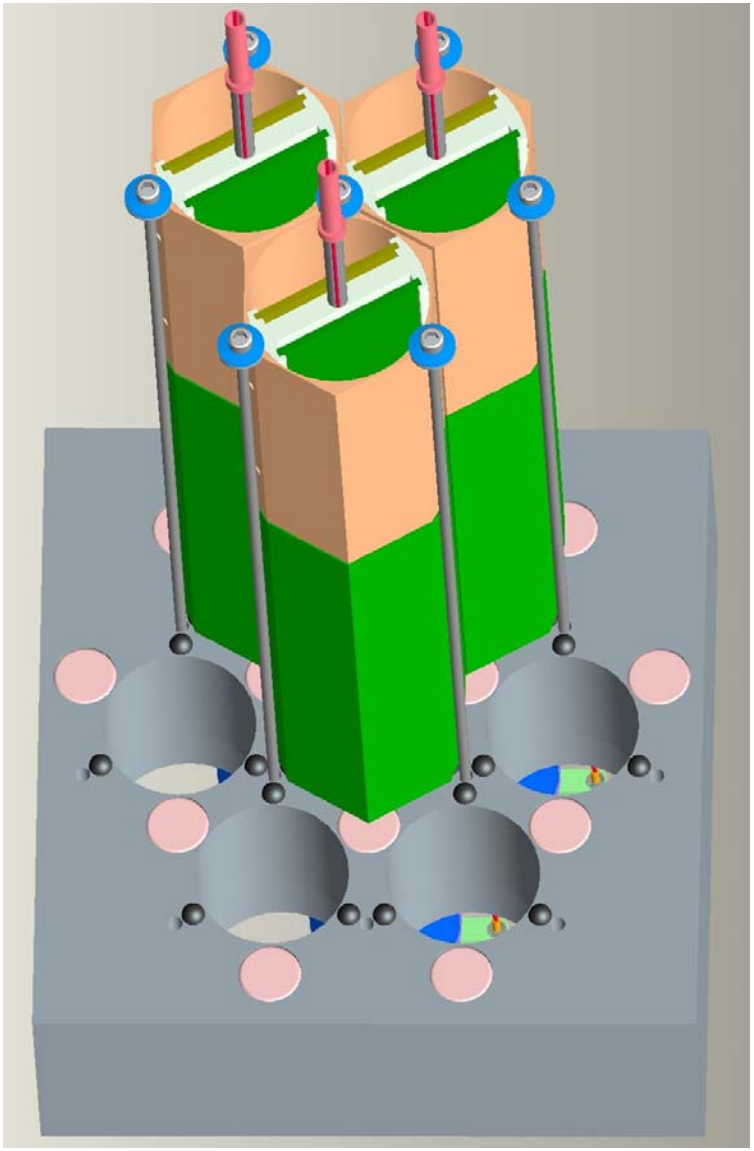
- Fiber input angle is determined by location in array
- Angle is held constant relative to r-theta actuator by 2 mm diameter isolation bearings in tip of radial axis
- Fiber is clad with flexible hypodermic needle tubing to resist rotation and for protection
- Back end of fiber is locked to the non-rotating body of the actuator to react any rotational forces induced by the actuator
- Fiber tube is slightly longer than nominal path to allow tube to translate and to provide an upward force to keep fiber ferrule in the tip of the radial axis
- Fiber assembly can be completely removed from below for maintenance replacement of the actuator



Array mounting & support

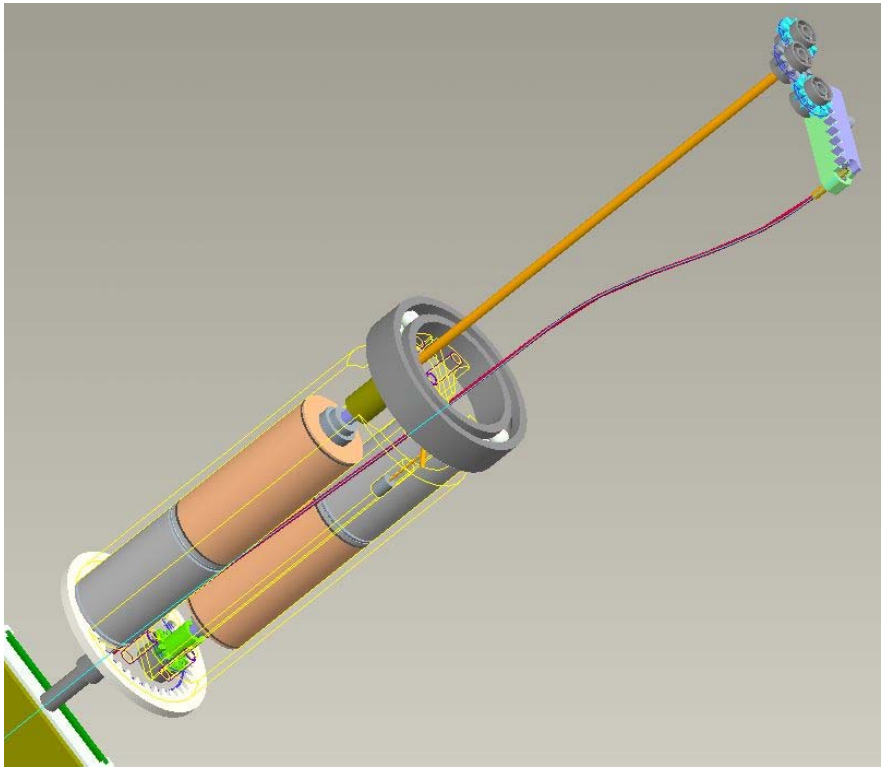
- One piece aluminum plate with kinematic ball & groove mounts
- Embedded magnetic retention aids in locating actuators
- 3-bolt fasteners secure modules to mounting plate





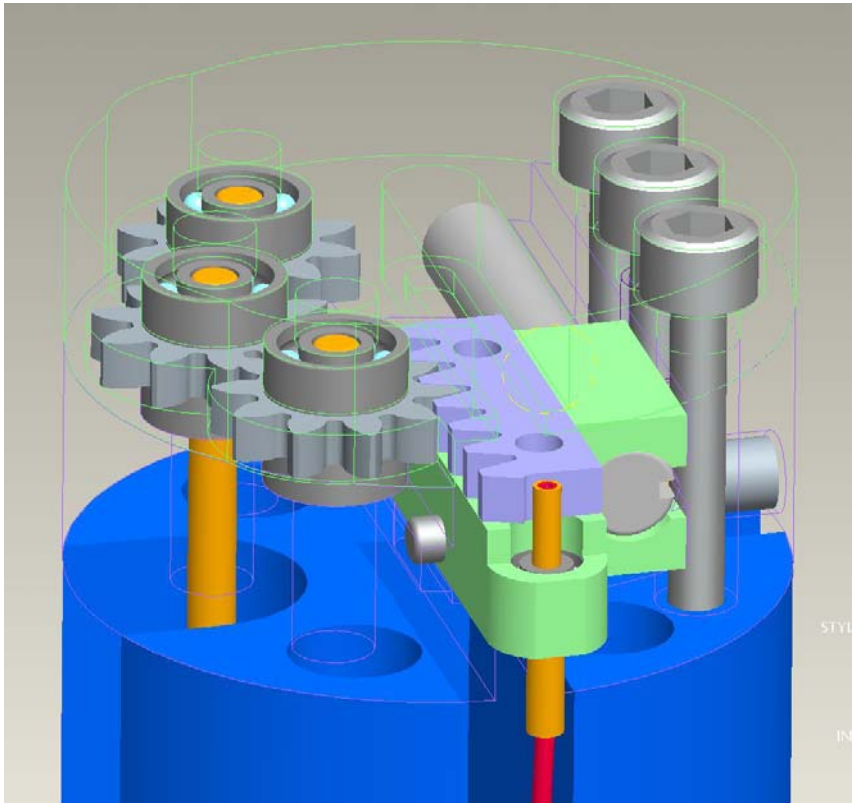
Motor arrangement

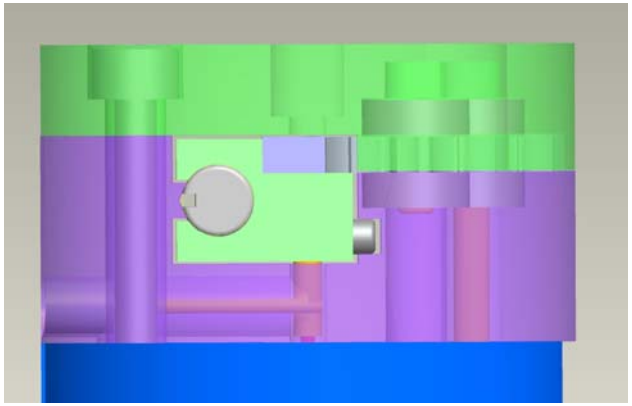
- Both motors mounted in a common rotator element
- Rotation motor uses pinion and static inside gear
- Radial translation motor drives rack with triple pinion
- Two drive pinions allow a long stroke by rack while “parked” position stays within actuator hexagonal envelope



Radial Axis Guide

- Slot guide changed to rail and bushing to simplify guide fit and gain efficiency
- 2 mm guide rail is glued into vee shaped support for easy installation
- 1mm pin anti-rotates assembly
- Only one critical fit in this assembly – other surfaces are now clearance





Ball bearing movements

- All rotational movements are supported by ball bearings ranging in size from:
  - 2 mm Diameter bearings for fiber positioner
  - 18 mm bearings for motor rotator

Motor actuators

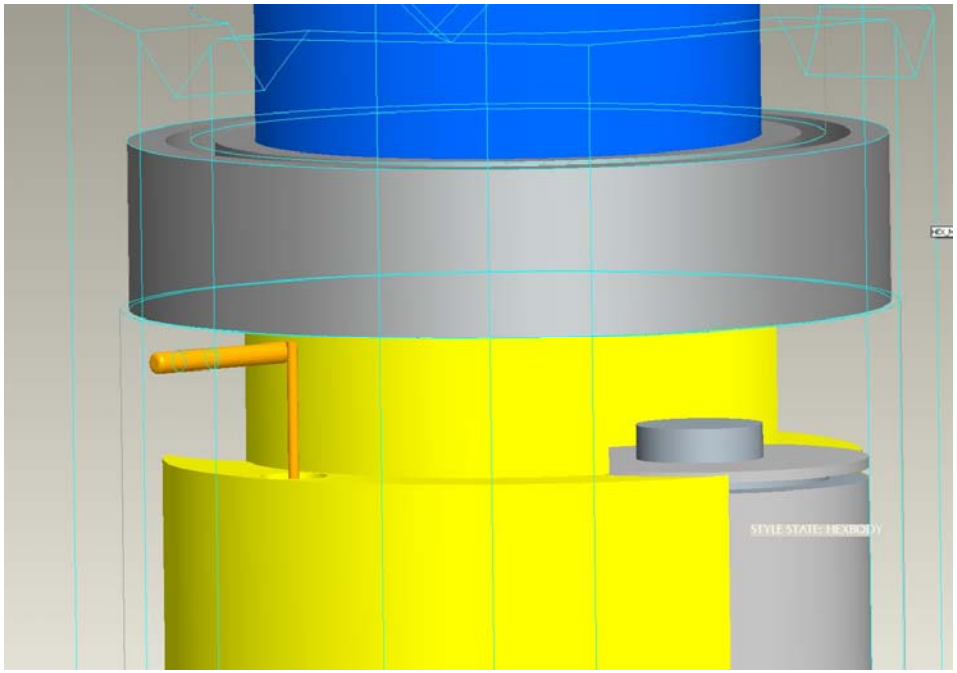
- 8 mm 2 phase step motors drive 120:1 reduction gearbox
- Gearboxes have ~ 3-5 deg. of backlash
- Output mechanism has frictional drag to maintain driven position
- Moves always position in one direction
- Motors are driven in half-step mode for 40 steps/rev
- 5 magnetic poles/rev determines power-off resolution

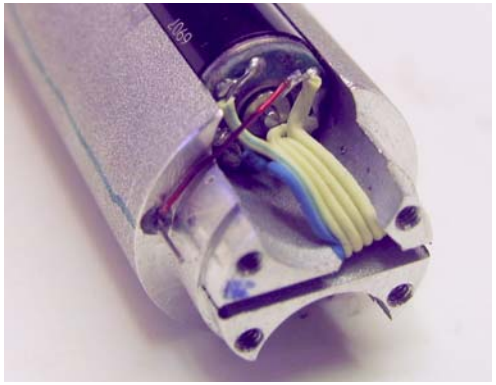
Recent Closed-Loop Encoder Introductions from Faulhaber (MicroMo)

- 8mm magnetic encoder with 32 – 256 lines resolution
- 6mm optical encoder with 50 lines resolution
- These systems could be run continuously with low power dissipation in static state

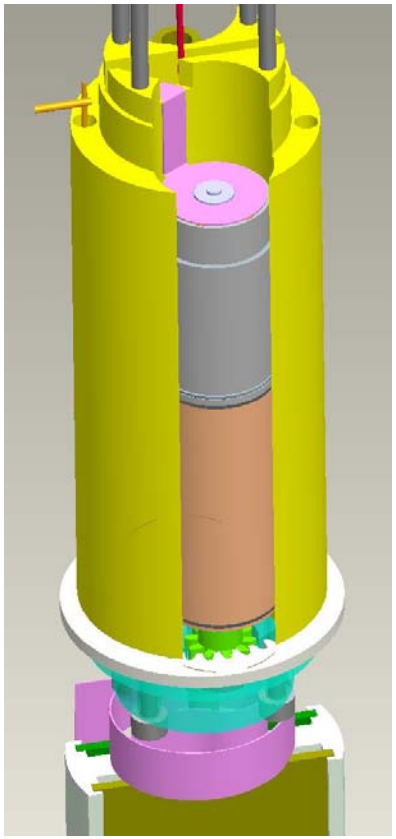
Indexing

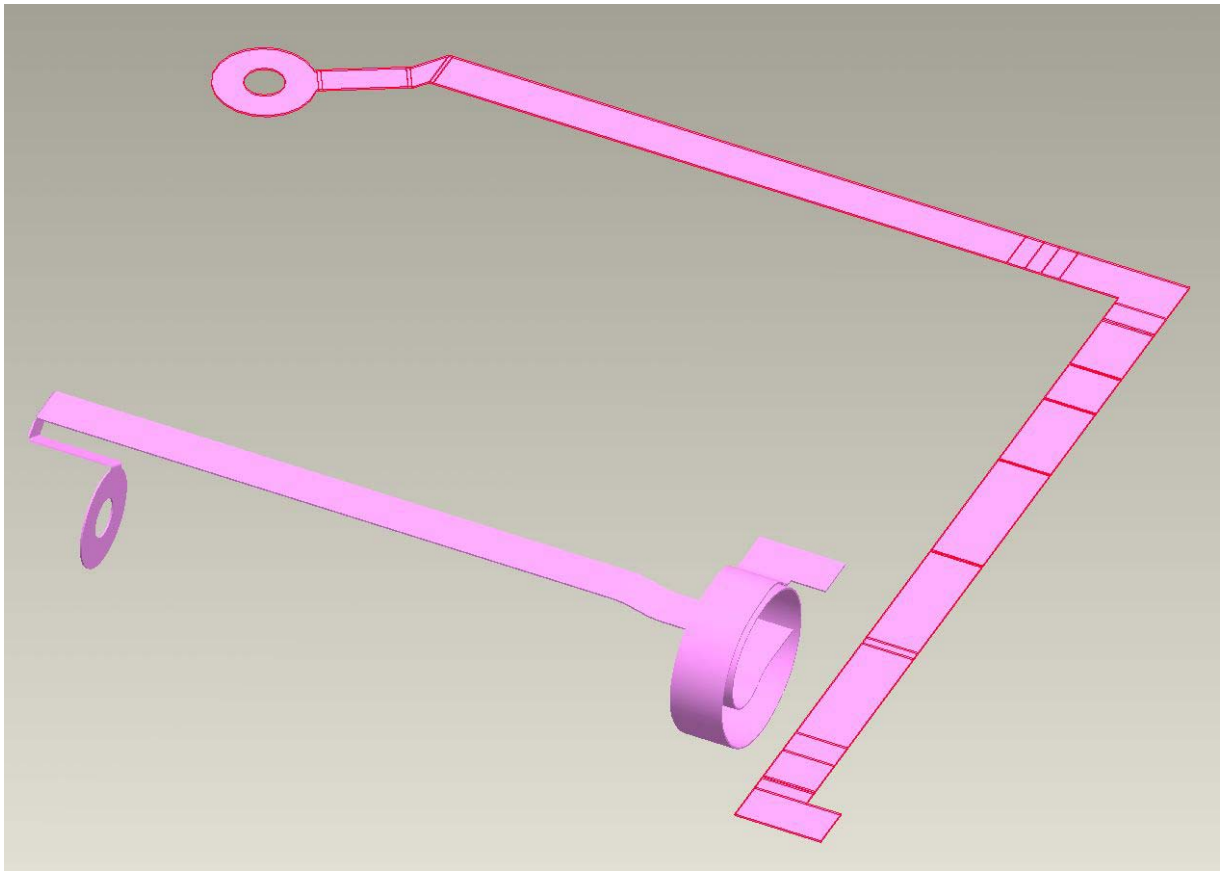
- Step motor is open loop with initial position reference being supplied by an index switch
- Switch consists of 2 gold-plated pins in a crossbar configuration
- One pin (actually a wire) has flexibility so that the switches can slightly over-travel and not change the zero point by over stressing the crossbars





Internal cabling

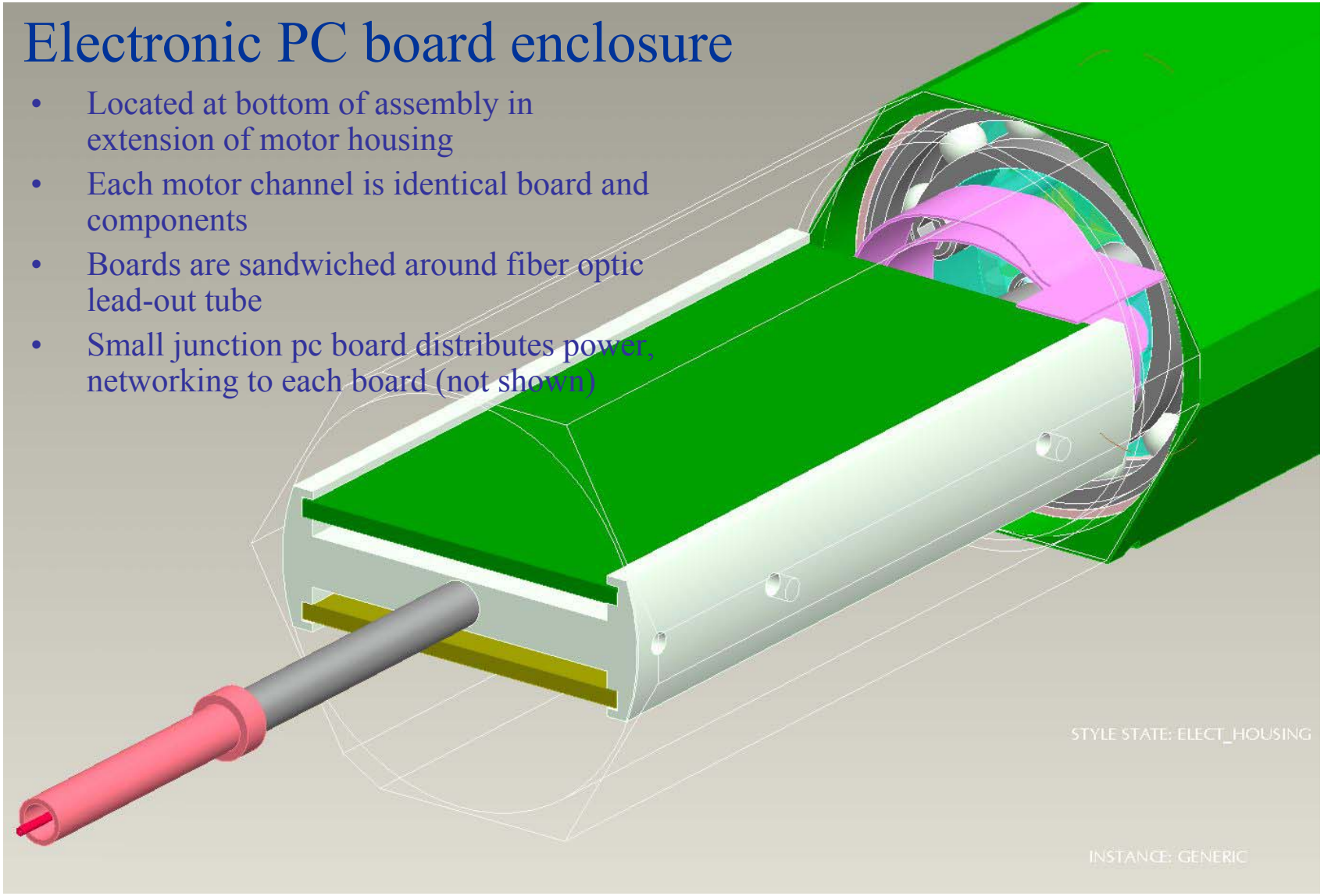




- Flex pcboard (Kapton substrate) simplifies wiring inside very cramped assembly
- Handles index switch connections as well as power leads to motors

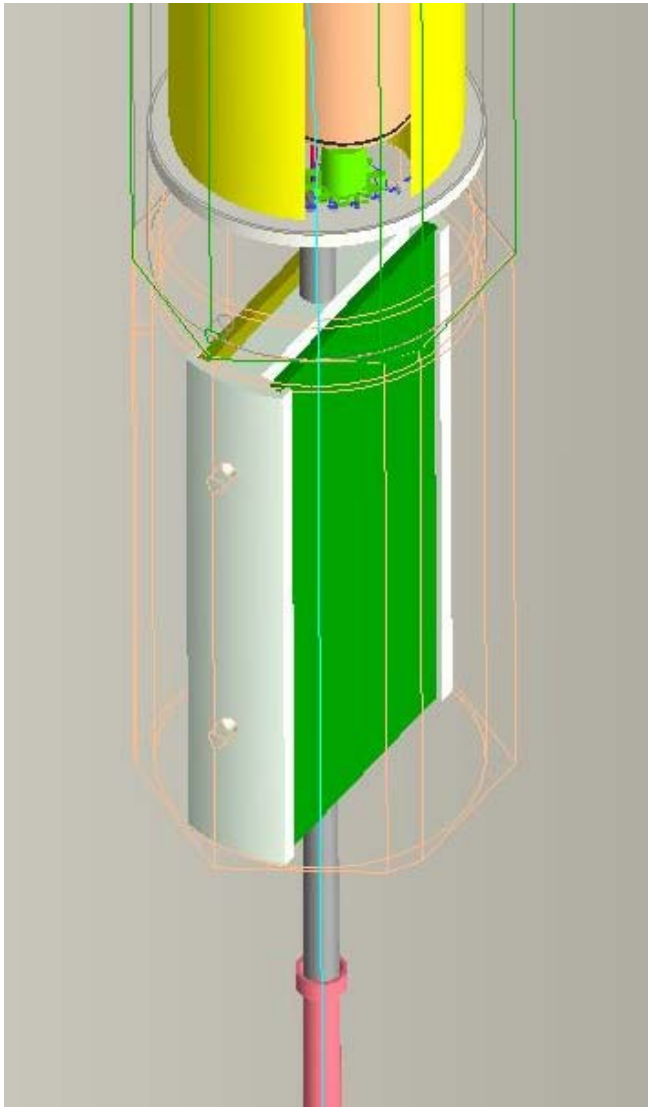
Electronic PC board enclosure

- Located at bottom of assembly in extension of motor housing
- Each motor channel is identical board and components
- Boards are sandwiched around fiber optic lead-out tube
- Small junction pc board distributes power, networking to each board (not shown)



Drive electronics

- Dual, In-actuator motor controller/driver boards provide IEEE422 network access to 2000 motors
- Chopper driver runs cool and delivers high stepping rate
- Automatic power-down of motor when not rotating
- Bottom location of drive electronics keeps heat from standby power dissipation away from telescope bore during motor off time
- Air is pulled from telescope bore through actuator array to remove this small amount of heat

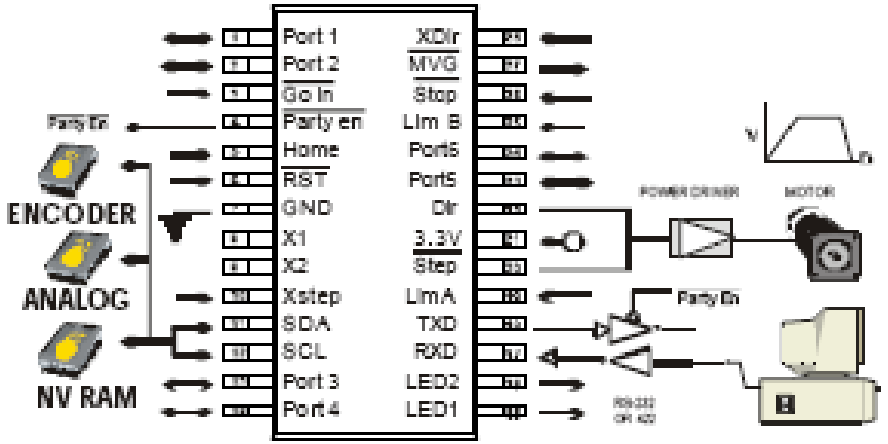


Host communications

- Networked communications for each motor in single chip controller
- 110 kbaud communication rate means fast total talk time for host to address 2000 motors
- Embedded routines in controller non-volatile memory offload command and monitoring from host

SMC-40 Controller

(28 Pin TSSOP Pkg.)



Motor positioning and power management issues

- To avoid radiating significant power into the optical bore, motors run time needs to be minimized (2000 motors x .16A at 5 volts = 1600W)
- This presents a challenge to accurate positioning because it is undesirable to have to re-zero all motors when re-applying power
- Motors have 40 (half-step) positions per revolution but only 5 magnetic poles per revolution
- Motor rotors will jump to the nearest magnetic pole when power is removed.
- Motors must be powered down only when at a magnetic pole to avoid position loss
- Radial axes must be parked in a retracted state during rotations and wait for rotational axes to complete their moves so neighboring radial arms do not crash into each other

Show system diagram

Motor controller helps to minimize power use

- Motor controller macro-programs automatically:
  - Measure zero offset to magnetic pole position at motor power-up
  - Drive in the same direction to eliminate backlash regardless of the initial direction of travel
  - Retreat to the nearest magnetic pole after achieving position so subsequent re-powering of drive will not cause position loss
  - Both axes have frictional drag built in to avoid "floating" off position when power is removed
  - Radial axis is parked during rotational move to avoid crashing; upon completion of rotational move, radial move is triggered
- Host modifies the internal programs of actuator controllers to deliver each new backlash-controlling compound move
- Programmed controller then executes the compound move autonomously while the host addresses the next motor in its task list

Show move state diagram

Global alignment of actuator elements

- Off-line test bed for verification and surveying of actuators
- Consists of vision camera and xy translation stage which translates to view each actuator
- Vision camera(s) measure location of light spot driven through fiber from linear array end
- Vision camera allows nominal positioning at ideal zero point of each actuator so “snapshots” of positions can be made
- Actuator database is automatically filled with reference position data to correct location errors in actuators

Picture or diagram

Position filtering

- Array input positions are filtered for:
  - nearness to one another so the relatively small overhead of the actuators does not cause a crash

More...