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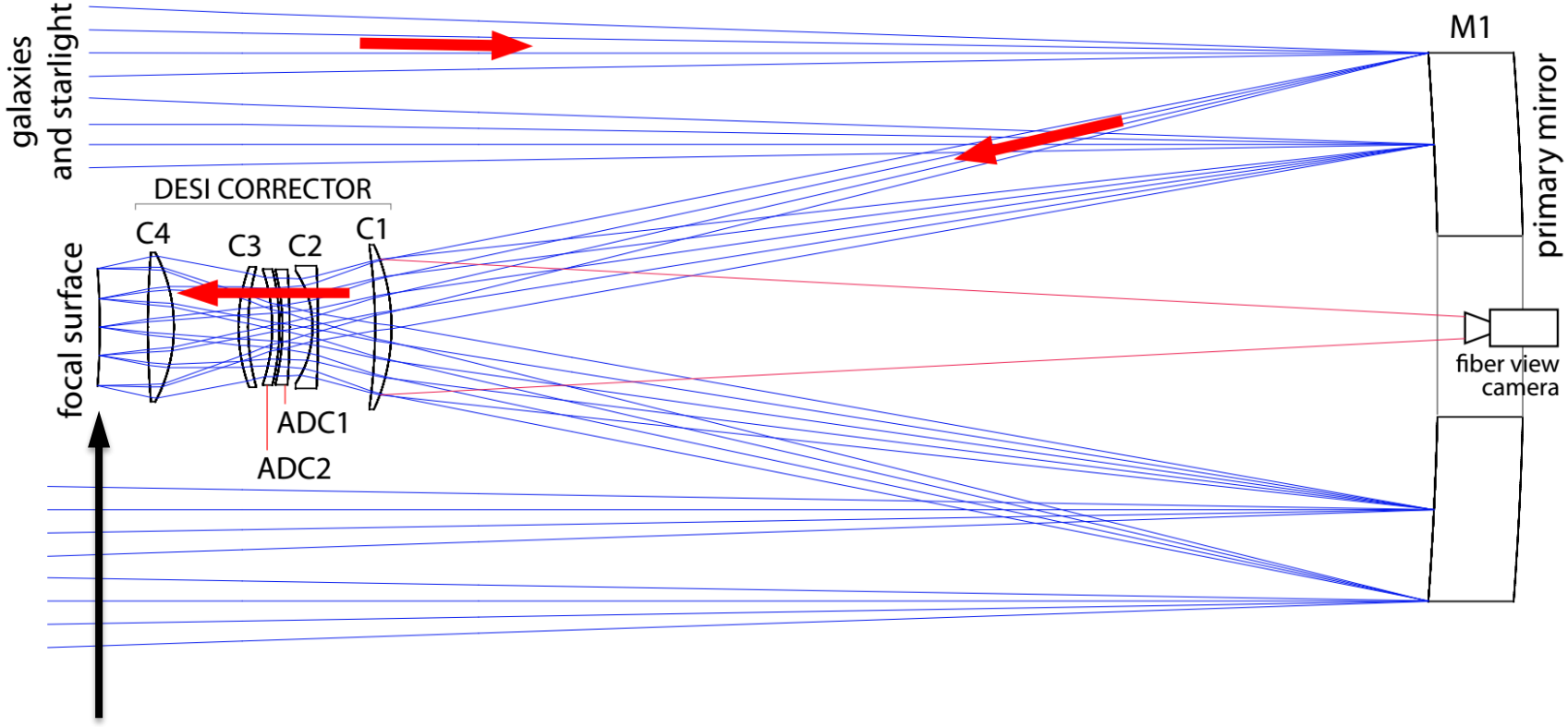
DESI Focal Plane System L2 Manager

2017-11-14

FUTURE TECH DISCUSSION -- FIBER POSITIONERS

Here is how the light from the galaxies gets to the robots

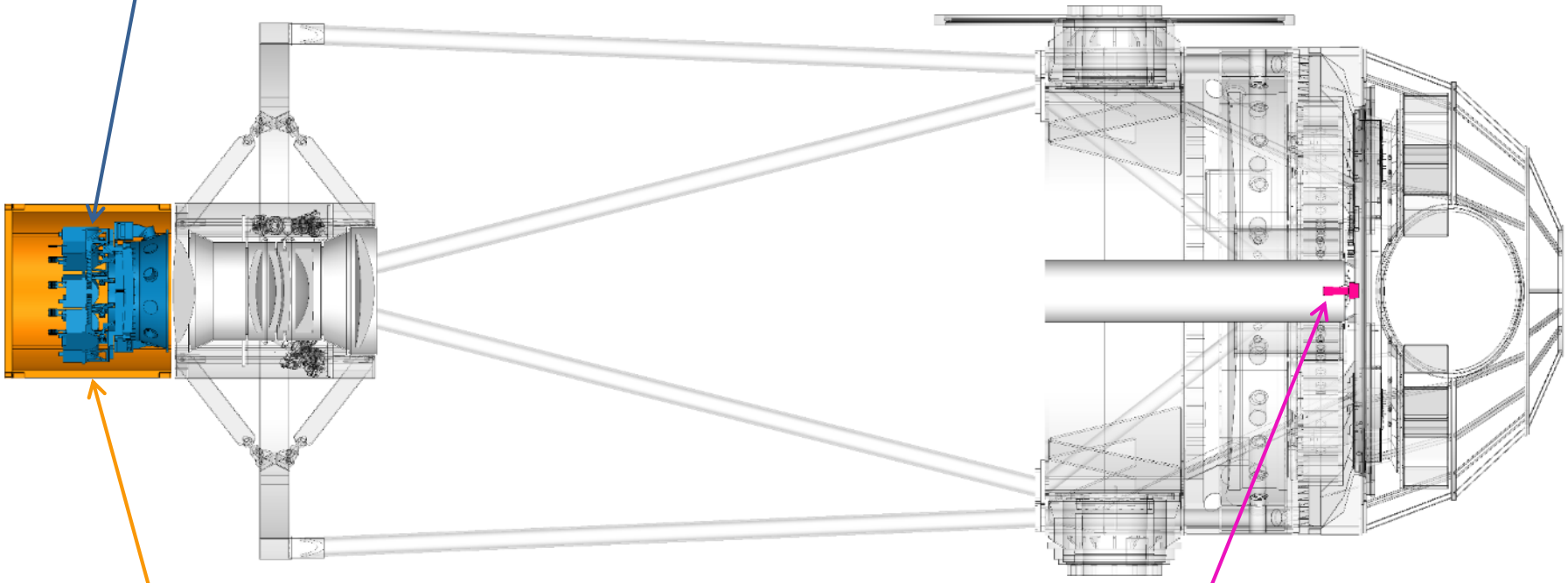


5000 fiber positioner robots here,
in the **Focal Plane System**

The DESI Focal Plane System has 3 main sub-assemblies

Focal Plate Assembly (FPA)

5000 Fiber positioners to individually target science fibers
120 Illuminated Fiducials (FIF and GIF) to scale fiber view camera image
10 Guide/Focus/Alignment (GFA) sensors for guiding, hexapod correction
10 Fiber Spool Boxes (FSB) terminate cables and distribute individual fibers



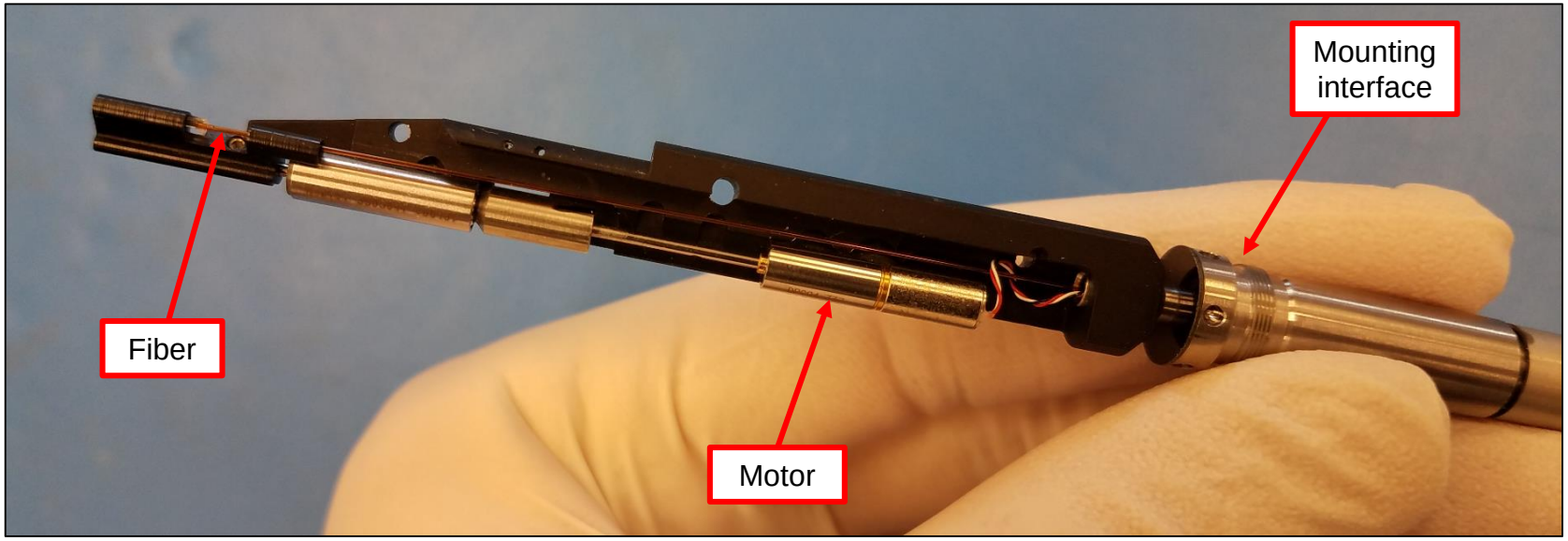
Focal Plane Enclosure (FPE)

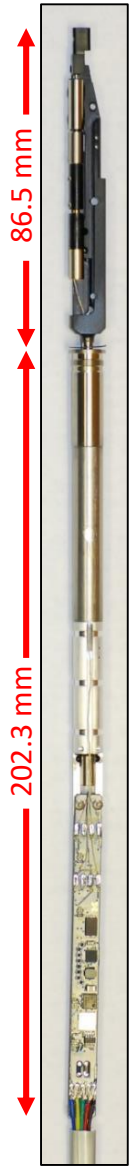
Thermal shroud to insulate dome air
Heat exchanger system to extract heat

Fiber View Camera (FVC)

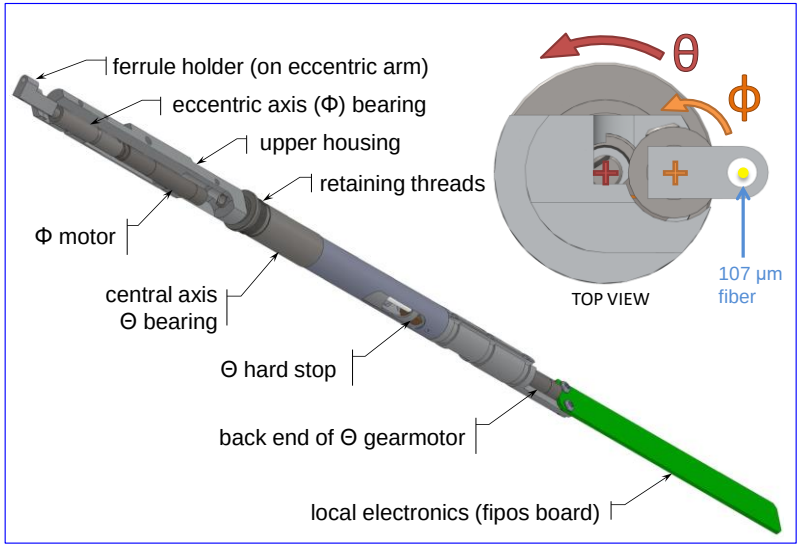
Mounted to primary cell, closes loop of positions of fibers with respect to GFAs

DESI Fiber Positioners

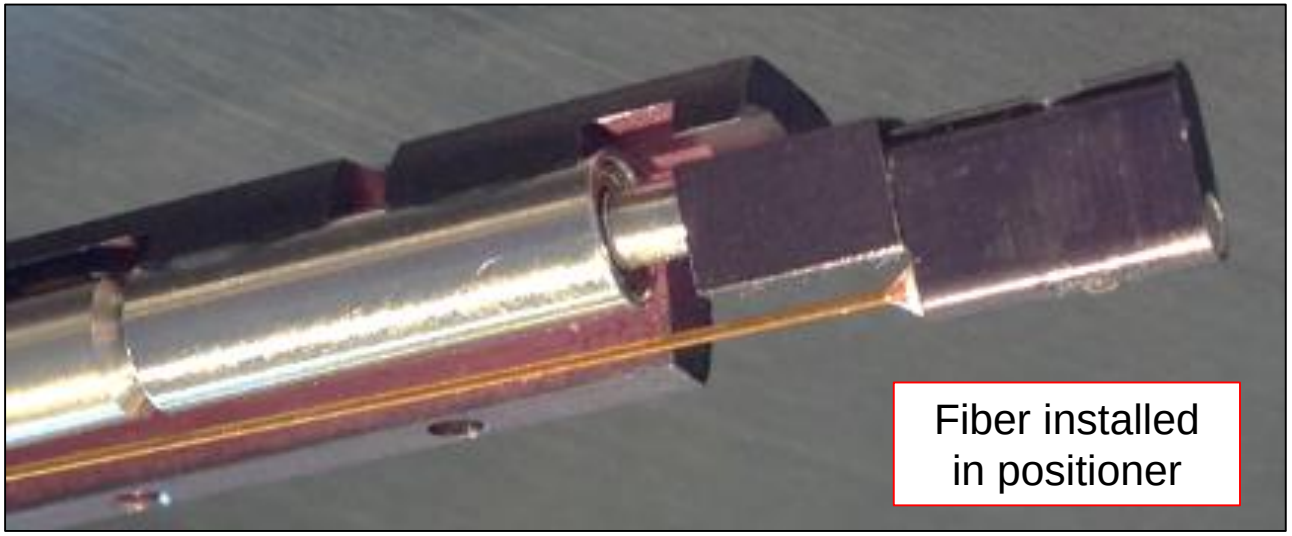


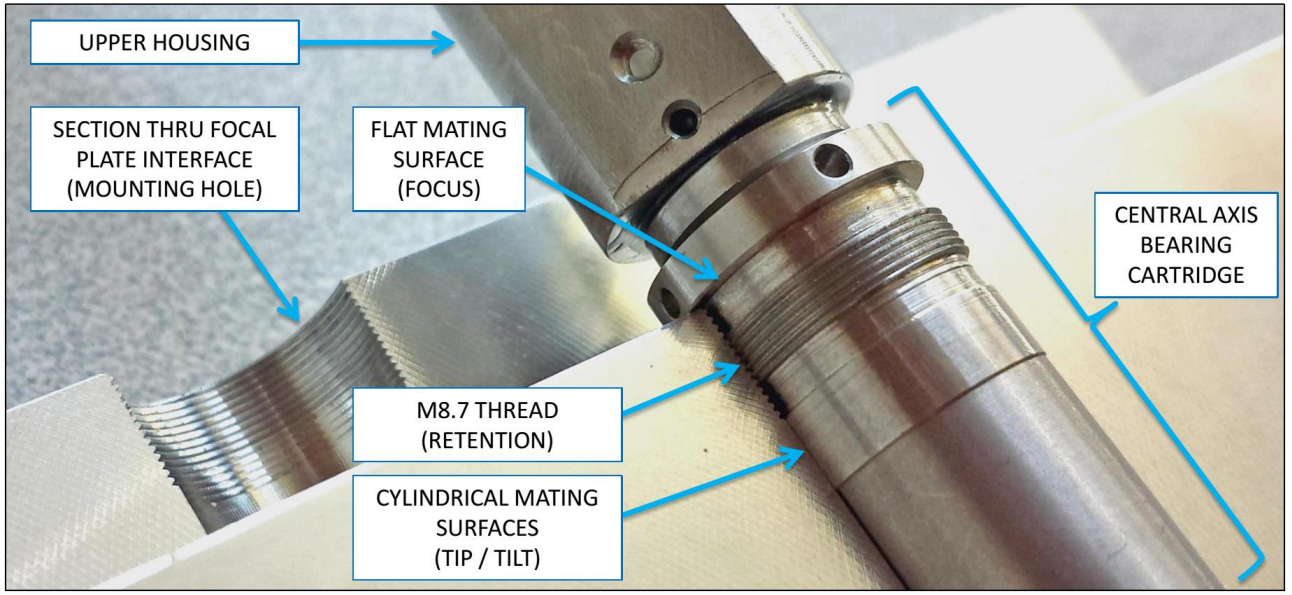


- 10.4 mm pitch between neighboring units
- 2 rotational axes
- Driven by independent ø4 mm 337:1 gear motors
- Integrated drive electronics
- 20 parts + 10 fasteners
- Developed by Berkeley
- Production by University of Michigan
- Blind moves: 25-50 µm max error
- After correction move: 1-2 µm RMS error
- Tested to 600,000+ repositionings (and counting...)
- Have produced over 1000 units (and counting...)

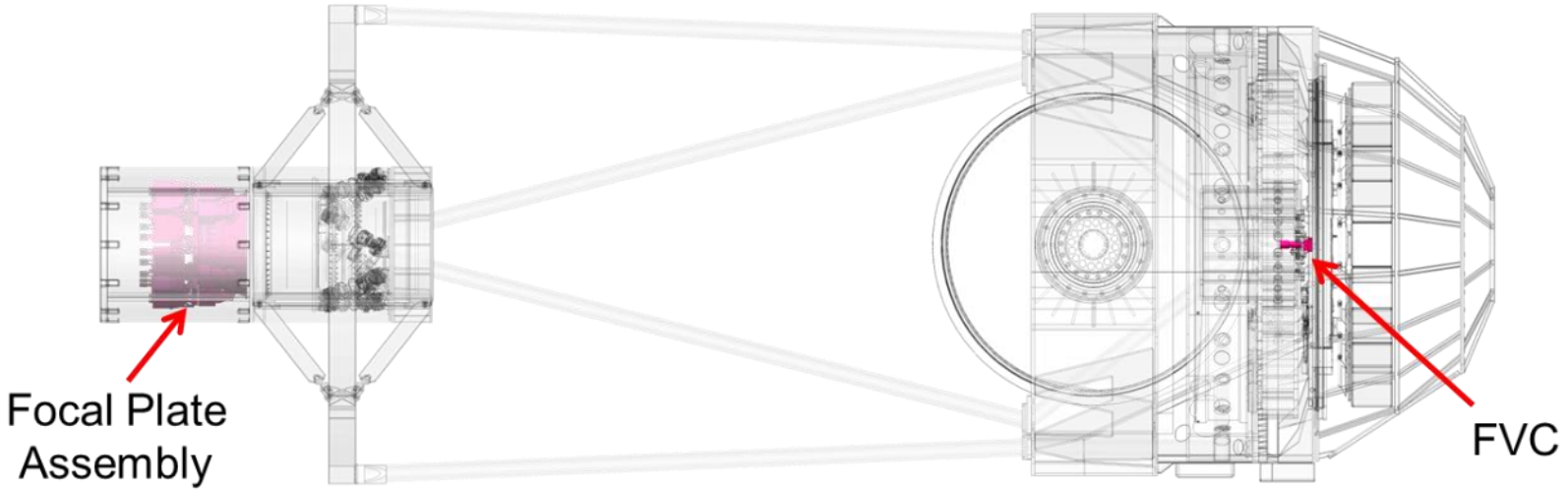


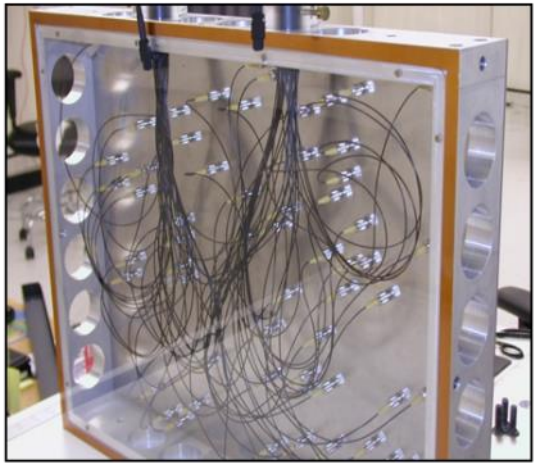
Positioner screws into petal like a sparkplug.
Fiber retained in positioner with a set screw + glue.



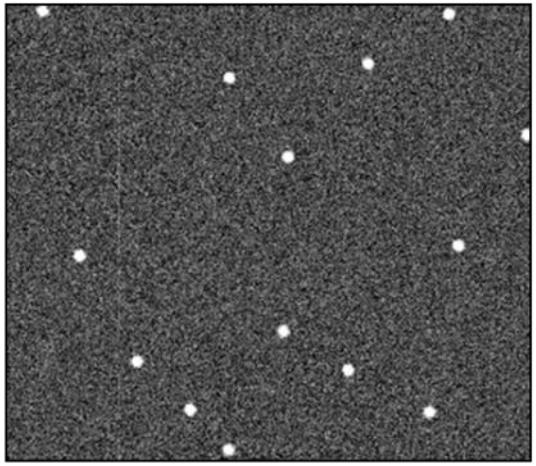


Positioners do not have encoders on motors. We close control loop by directly imaging backlit fibers with Fiber View Camera.

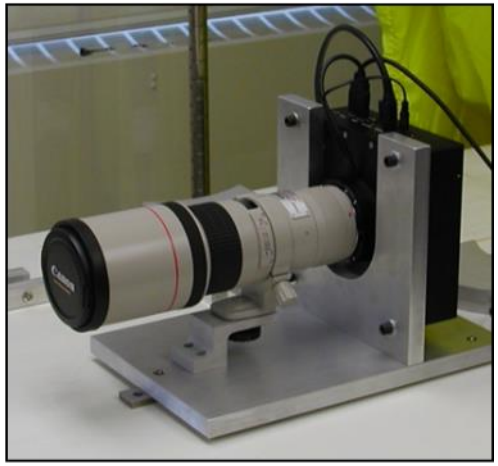




Test plate of backlit fibers.

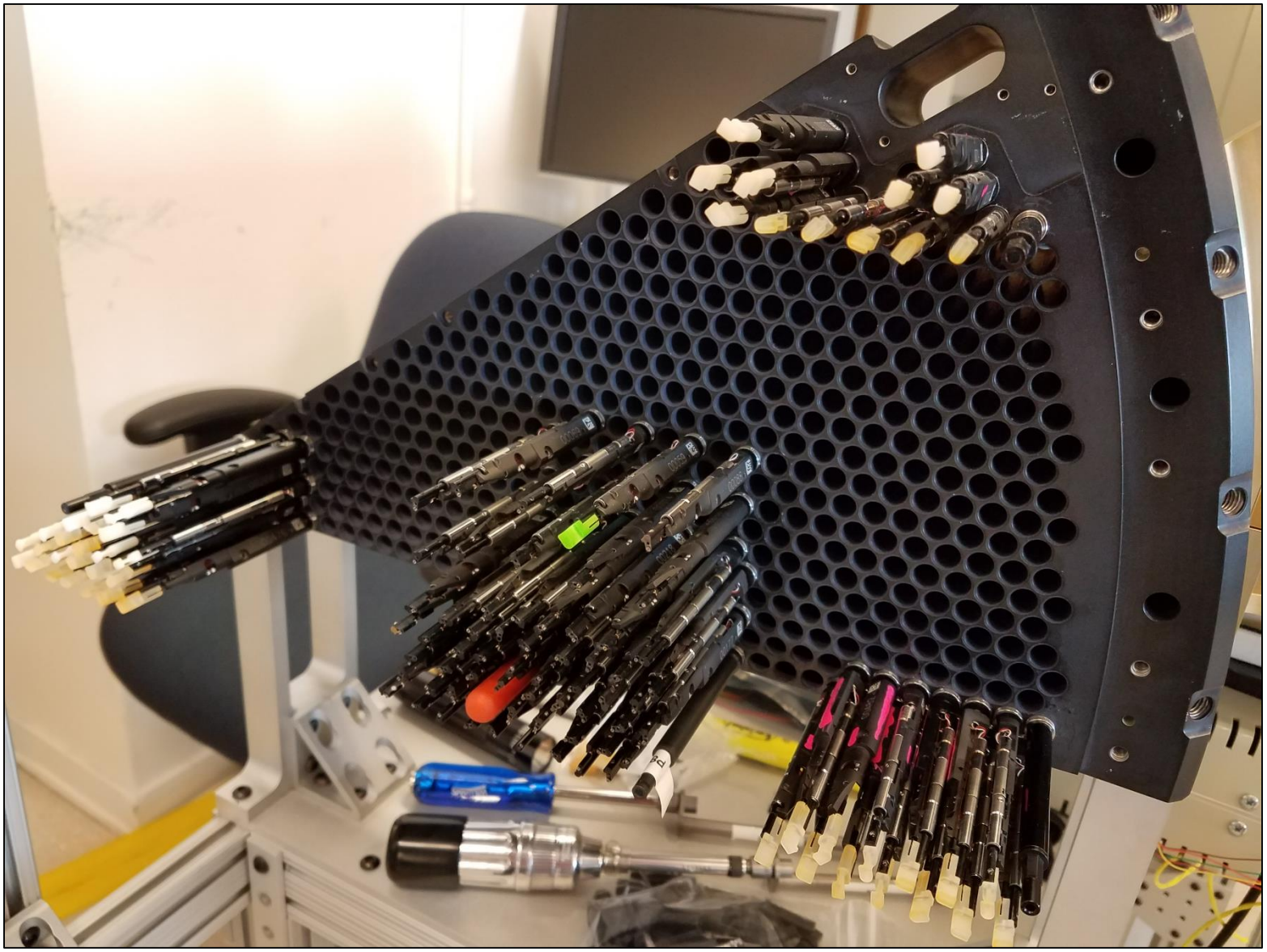


FVC measures centroids.

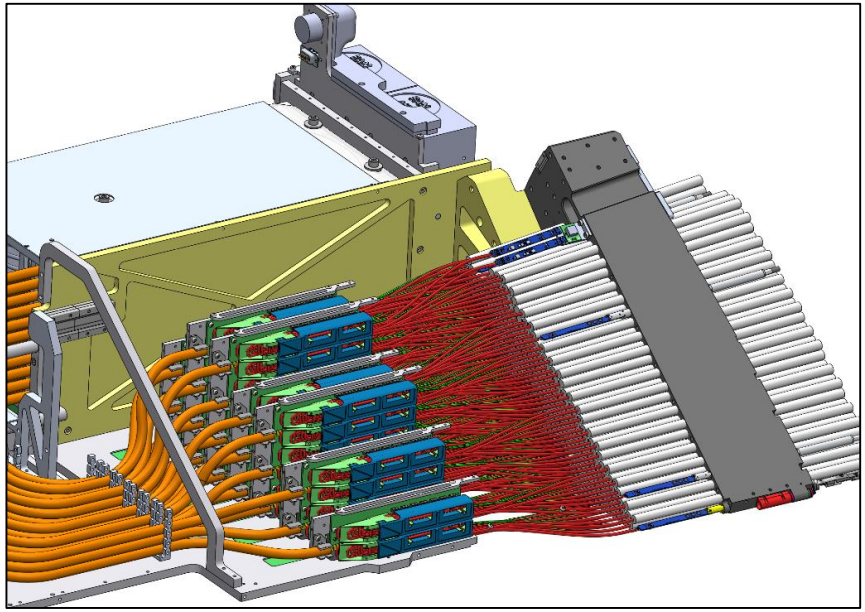


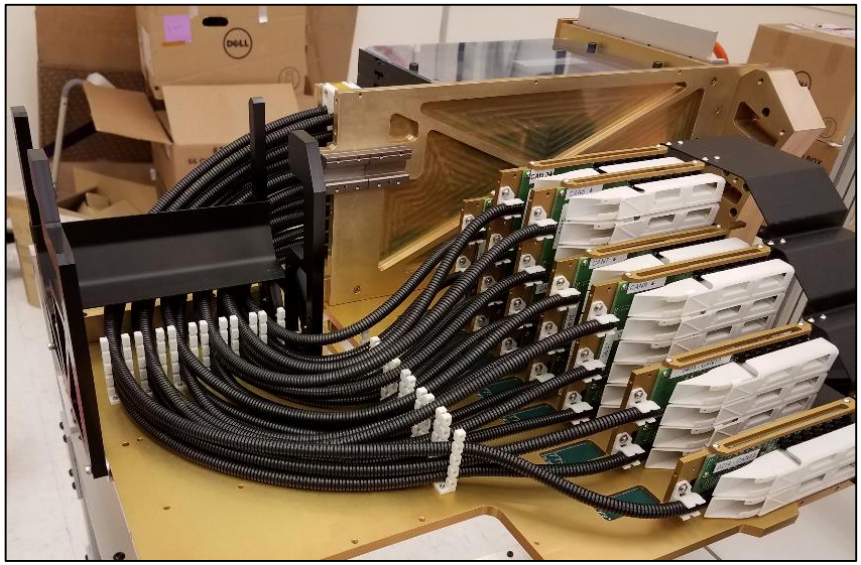
Yale test camera.

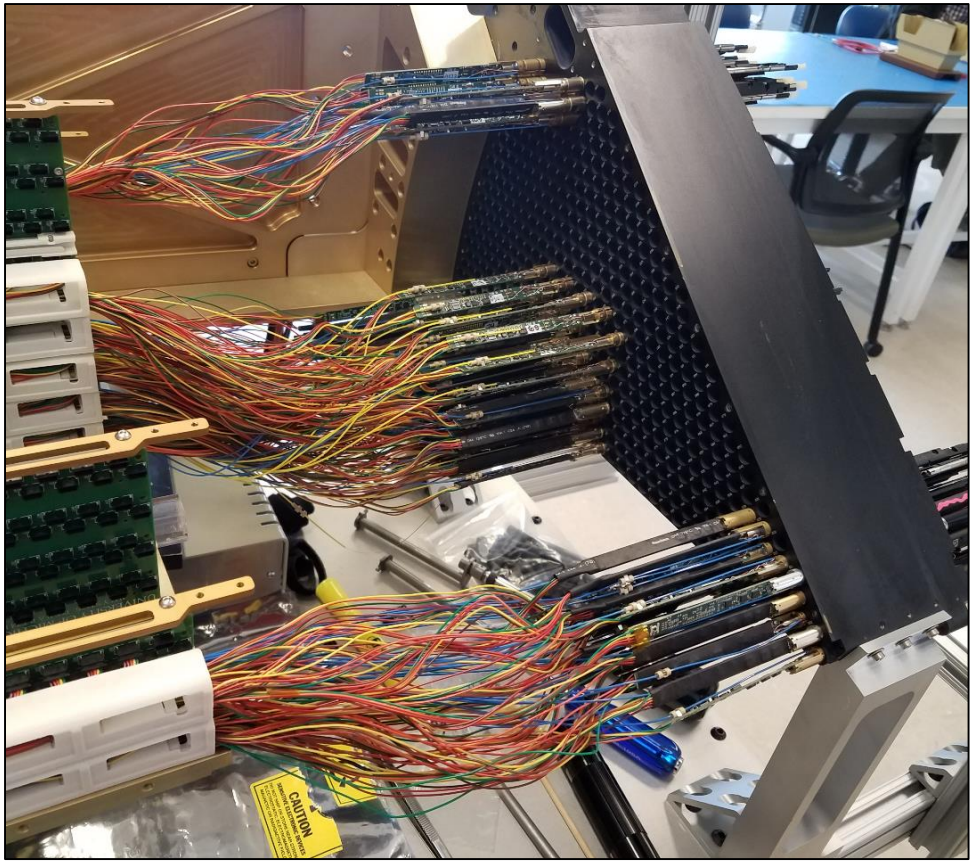
An engineering model petal assembly with 100 positioners was built and tested successfully in Spring 2017



Real world service routing, assembly sequence, and mechanical envelopes worked exactly as modeled in CAD



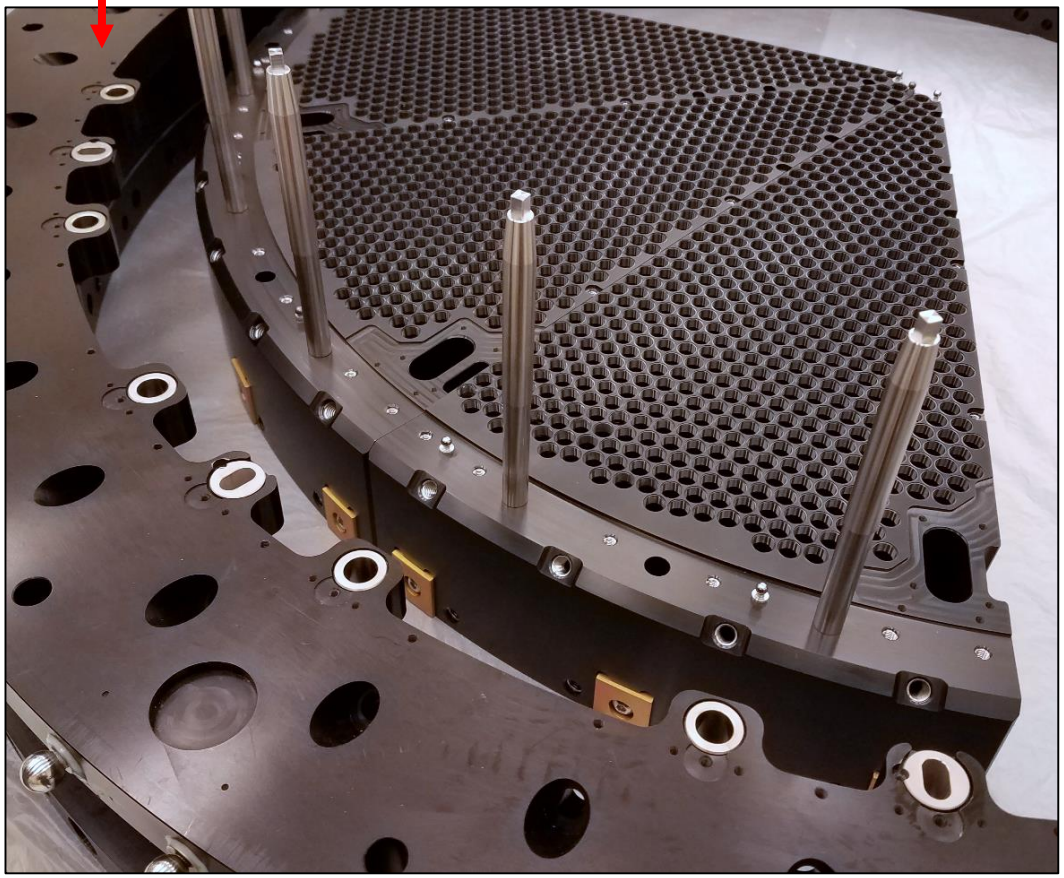


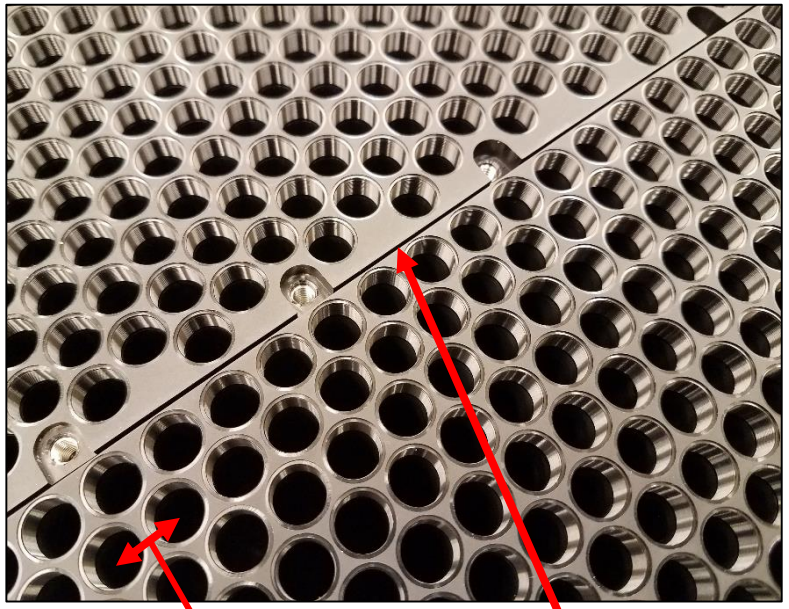


The DESI focal surface is an *asphere*, upon which 5000 fiber tips must patrol. Every mounting hole is CNC machined to a unique position and angle.

Not a flat, not a sphere. Not even the focal surface itself.

10 petals mount into ring

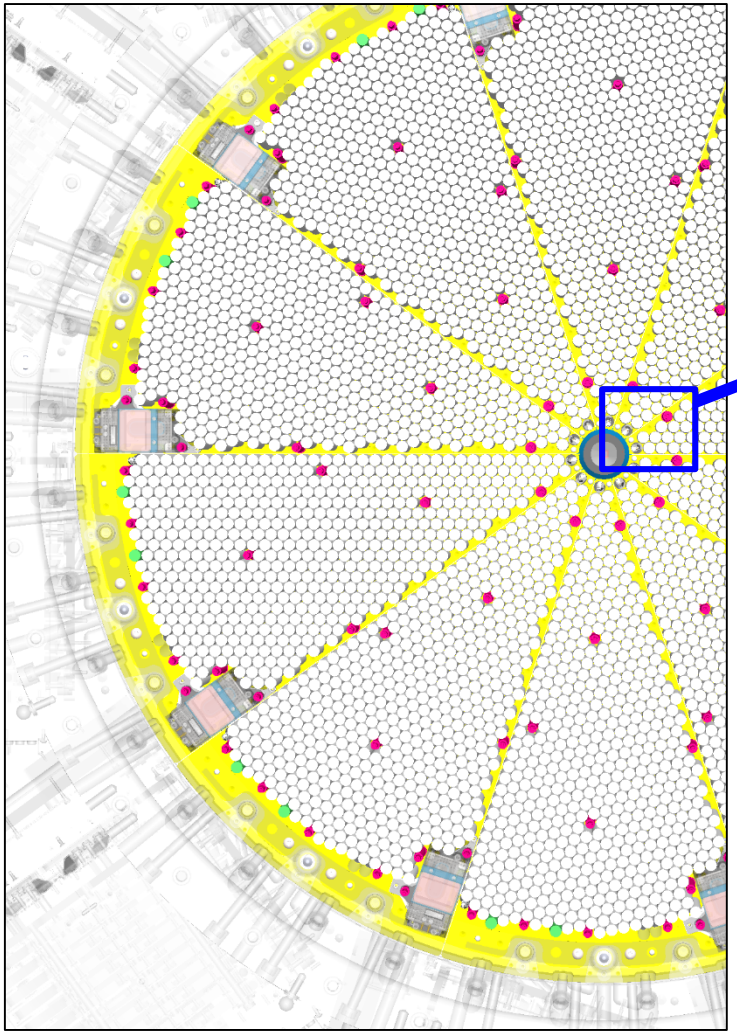


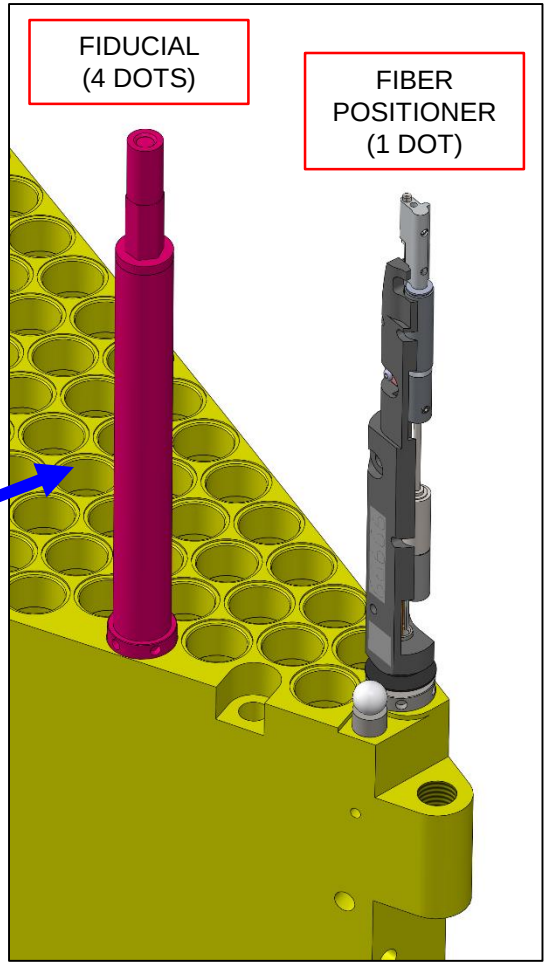


10.4mm typ., not HCP!

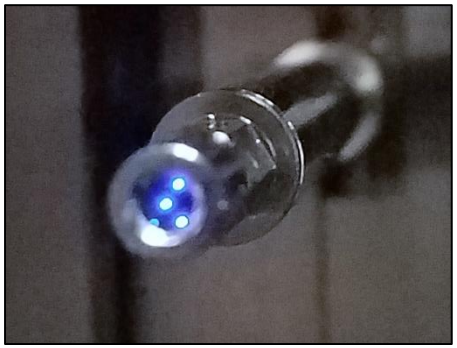
0.6 mm gap between petals!

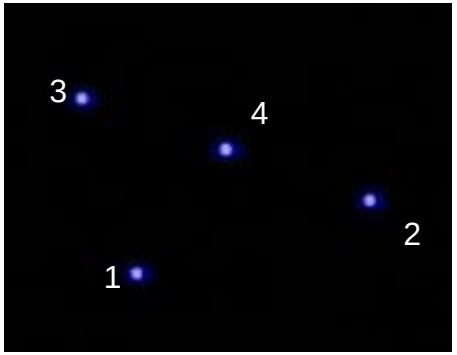
Fiducial point sources, embedded throughout the array constrain optical plate scale and distortion polynomials





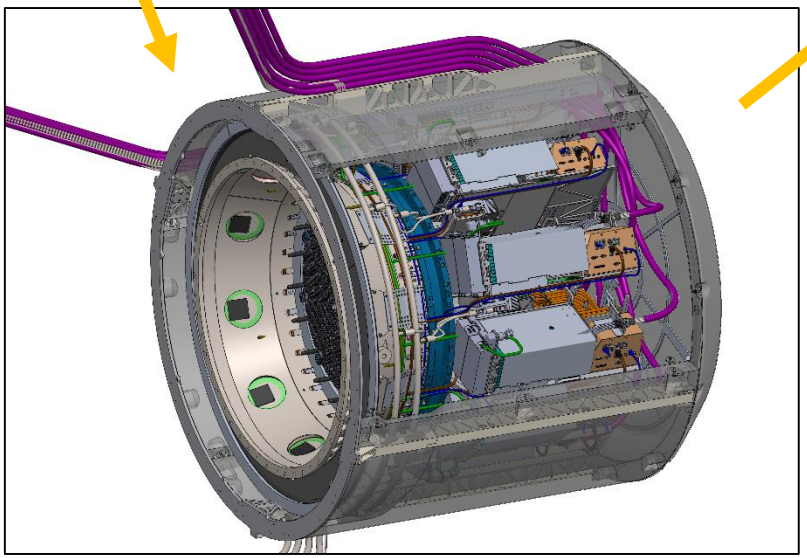
120 total fiducials
x 4 dots each





March 26, 2019: 0.6M focal plane parts will be flawlessly executing their designated tasks on the Mayall Telescope at Kitt Peak, Arizona.

Filter	Total Qty
Individual parts	675,194
Items we integrate	313,769
Unique items	459
Moving parts	416,730
Wires or fibers	61,148
PCBs	5,371
Fasteners	58,086
Electrical connectors	11,609



Brushless DC gearmotors

- On DESI we're using ø4 mm motors from Namiki
  - Two other competing vendors offer equivalent motors
  - This enabled us to make DESI positioners at 10.4 mm nominal pitch
  - 10.4 mm pitch has been do-able, though a little tight –> in my ideal world I would bump this up to ***11 mm***, which would actually save a lot of money / complexity in machining and assembly steps
  - Namiki has floated conceptual prototypes down around ø2 mm, but to my knowledge these are not yet proven reliable, and no other vendors are doing this
- Accuracy is basically limited only by the FVC – after correction moves we are at 1-2 um
- Blind move accuracy is 25-50 um worst case, depending on the particular positioner
  - This is ***with*** initial calibration from FVC, to determine 6 unique geometry parameters for every individual positioner
  - It is ***not*** something we'd achieve by simply ramming the internal hard stops inside the positioner mechanism
- We've tested lots of positioners now to 600,000+ moves and counting, and down to -20C and +35C → these things appear to be ***totally*** reliable
- Encoders are available from all vendors, but not necessary (nor particularly useful)

Assembly comments

- DESI positioners have many manually applied glue joints
  - These are slow to do, and take a lot of training / oversight / quality control
- We also have quite a few tiny screws
- In a future project, I would transition to a design with more press-fit joints as my number one enhancement
- We also have a number of challenges with handling the permanently spliced cables
  - time required to splice 5000 fibers
  - handling the 1 ton FP assembly with 10 enormous 45 m cables permanently attached
  - intricacies integration sequence and maintenance scenarios that these permanent attachments require
- To go to the next level of # of fiber positioners (say 25,000+), I would recommend a very serious trade study as to whether the splicing is really worth the complications
  - Once we actually start splicing DESI fibers in serious quantities, we will have at least one quantitative data point on the time cost
  - There are harder-to-quantify costs regarding the integration complexity

Scaling of focal plane

- On DESI, we packed 5000 positioners at mean pitch of 10.525 mm into a ø812 mm aspheric focal surface
- Rough rule of thumb you could extract from the final DESI design:
  - ultimate # of science positioners = **0.84***(FP_diam / pitch)^2
  - this 84% packing efficiency is obviously not some perfectly efficient HCP = 90.7%
  - instead it is a very real-world and practical number, that includes room for 100 fiducials, 10 guide/focus cameras, mechanical tolerances, aspherical geometry, mounting features, etc
- So if you wanted 25,000 positioners at say 11 mm pitch, you would need a focal surface that is ø1.9 m
- My personal intuition is that the right approach to scaling up in a next generation project is
  - don't try to squeeze positioners any smaller
  - instead focus on enabling a bigger ø focal surface
  - this focuses the "new technology" effort on what I consider the easy and monolithic stuff – a few ray traces done early on in the project
  - our DESI positioners work great and we truly now can manufacture 5000 of them in about 10 months – but it took 7 years and millions of $ to get to this point!

Focal plane layout summary			
Patterning code and results files	-	https://desi.lbl.gov/svn/code/focalplane/	
Results files from patterning	-	https://desi.lbl.gov/svn/code/focalplane/	
Corrector Prescription	-	per DESI-0329-v15	
FOV	deg	3.2	
Focal Surface Diameter	mm	811.8	3.2deg FOV equivalent
Positioner Envelope	-	per DESI-595-v4	positioner envelope based
Patrol Radius	mm	6.0	
Area	deg^2	8.042	
petals	-	10	
positioners	-	5000	
GFAs	-	10	
field fiducials (FIF)	-	100	
GFA fiducials (GIF)	-	20	
min pitch	mm	10.416	Note these tabulations of
max pitch	mm	15.605	
mean pitch	mm	10.525	
stdev pitch	mm	0.469	
mean uncovered area	-	0.067	Note these tabulations of
mean coverage density	-	1.103	value > 1 implies net over
positioner and fiducial coverage area	deg^2	7.504	
positioner coverage density	1/deg^2	666.3	i.e. positioners / deg^2

DESI-0530 gives all the details, as well as summaries, of the DESI focal plane layout