

EUSO-SPB2 Telescope Optics and Testing

Viktoria Kungel (kungel@mines.edu), Randy Bachman, Jerod Brewster, Madeline Dawes, Julianna Desiato, Johannes Eser, William Finch, Lindsey Huelett, Angela V. Olinto, Justin Pace, Miroslav Pech, Patrick Reardon, Petr Schovaneck, Chantal Wang and Lawrence Wiencke on behalf of the JEM-EUSO Collaboration

Objective

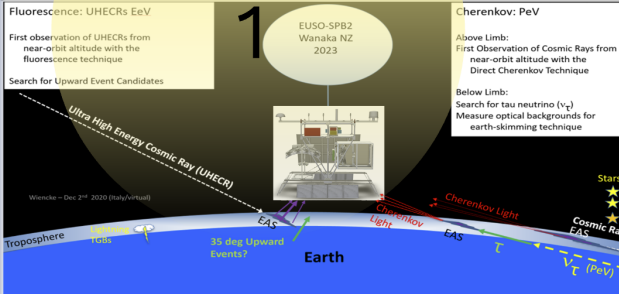


Figure 1: EUSO-SPB2 mission objective. First three ever observations of UHECR from near-orbit altitude with the fluorescence-, direct Cherenkov-technique, and search for tau neutrinos.

The **EUSO-SPB2** [1] will make the first observation of **UHECRs** from near-orbit altitude.

- Below the limb the **Cherenkov telescope** will search for tau neutrinos ν_τ .
- EUSO-SPB2 is primarily a technological and scientific pathfinder for **POEMMA** [2] (Probe Of Multi-Messenger Astrophysics).

Optics:

Fluorescence Telescope

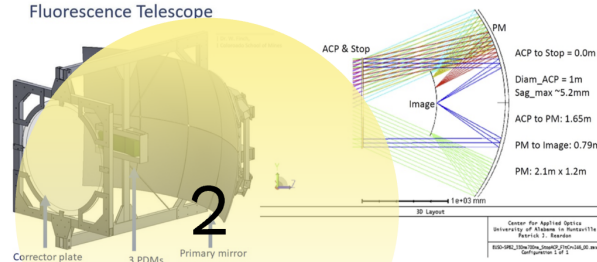


Figure 2: The fluorescence telescope design on the left and the corresponding raytracing model on the right

EUSO-SPB2 telescopes are a **modified Schmidt design** using a segmented spherical mirror.

- The fluorescence telescope has 3 photo detector modules (PDM) with a curved image surface, so that field correcting or flattening lenses are necessary to achieve a very small spot.
- The mirror segments of the **Cherenkov telescope** are aligned for **bi-focal focusing** so that light from outside the telescope makes two spots on the camera. This **distinguishes between direct cosmic ray hits** on the camera that produce one cluster of activated pixels.

Optomechanical hardware and laboratory tests:

The main goal of the laboratory tests carried out at Colorado school of Mines are to determine the

- Point Spread Function (PSF) and
- Optical Efficiency

of both telescopes, via the use of a **fabricated 1-m parallel test beam system**. Before that a **list of tests** will ensure that the mounted mirror segment are strong and stable, the spherical mirrors installed and focused in the telescopes and that the parallel beam system is working. After the PSF and optical efficiency characterization in the parallel beam, with no camera installed, a full telescope lab test with the 1-m parallel beam and camera will be carried out.

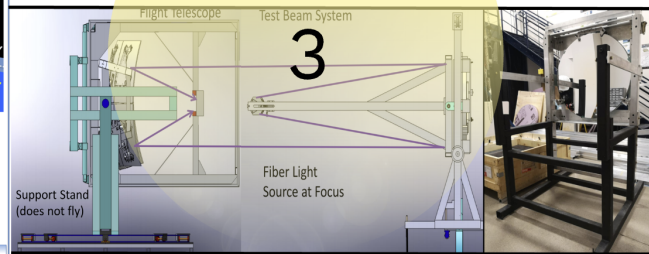


Figure 3: Test hardware and test stand for the 1-m test beam system. A schematic configuration of the fluorescence telescope on a supporting stand on the left and a 1-m parabolic mirror on the right. The fiber light source at the focus will have a new customized holding stand.

As part of the **operational design requirement of NASA** the mirror segment attachment system is tested in the lab. The **mirror segments are epoxy glued** to the metallic frame with EC-2216 adhesive on Kovar joints. The glue joints are **stress tested** under a static uniformly distributed load, in operational **atmospheric conditions**, i.e., in a thermal chamber for temperature below -40°C , and in a low-pressure environment of <7 mbar

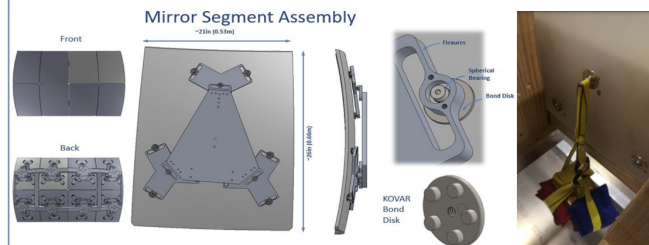


Figure 4: Mirror segment assembly. Each mirror segment is epoxy glued to 9 Kovar bond disks with EC2216. The photo shows a glue joint shear stress test with 42 lbs. load.

EUSO-SPB2 specifications:

Table 1: The EUSO-SPB2 hardware specification for both telescopes.

Telescopes	Fluorescence FT	Cherenkov CE
Wavelength Sensitivity	UV 300-420 nm	no filter (300-900 nm)
Energy Threshold	EeV	PeV
Sensor Type	MAPMT (Hamamatsu)	SiPM (S14521-6050CN)
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Pixel FOV	$(0.2 \times 0.2)^\circ$	$(0.4 \times 0.4)^\circ$
Time frame	1000 ns/bin	10 ns
Pointing (zenith angle)	nadir	Earth's limb ± 10

Field campaign:

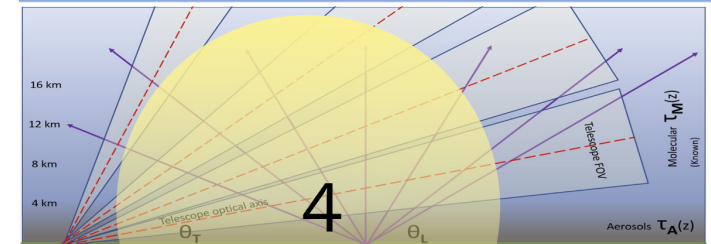


Figure 5: Field test configuration with the steerable telescope on the left and the steerable laser on the right with different inclination angles, θ_T and θ_L . The laser beam crosses the telescopes field of view high above the aerosol layer

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References

- [1] L. Wiencke et al., The Extreme Universe Space Observatory on a Super-Pressure Balloon II Mission. PoS(ICRC2019)466, 2019.
- [2] A.V. Olinto et al., The POEMMA (probe of extreme multi-messenger astrophysics) observatory. *Journal of Cosmology and Astroparticle Physics*, 2021(06):007, jun 2021.

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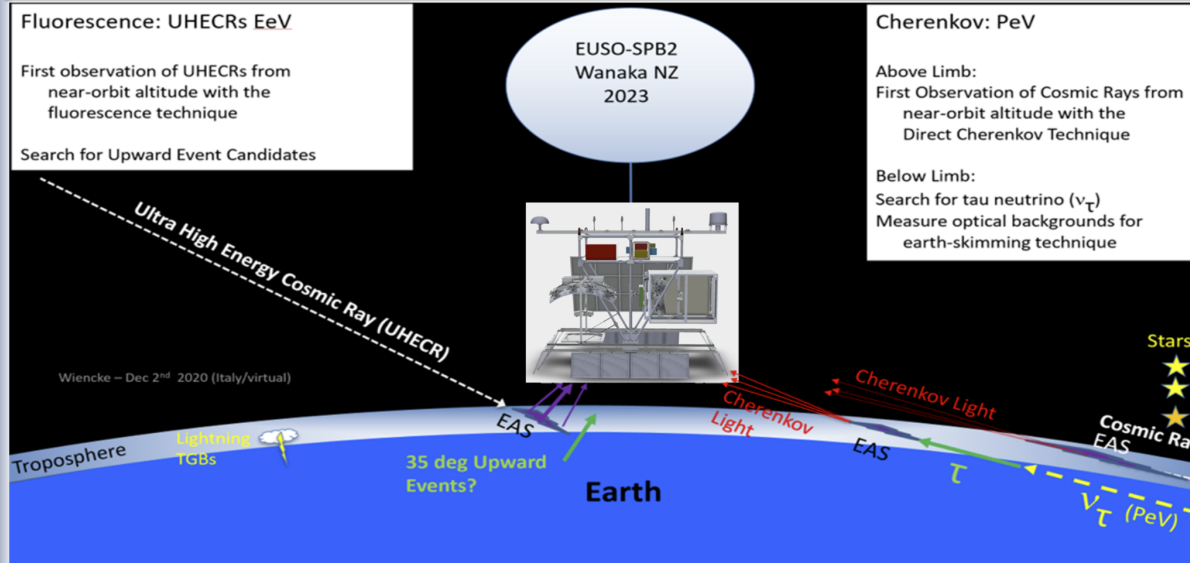


Figure 1: EUSO-SPB2 mission objective. First three ever observations of UHECR from near-orbit altitude with the fluorescence-, direct Cherenkov-technique, and search for tau neutrinos.

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Optics:

Optomechanical hardware and lab

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- **Point Spread Function**
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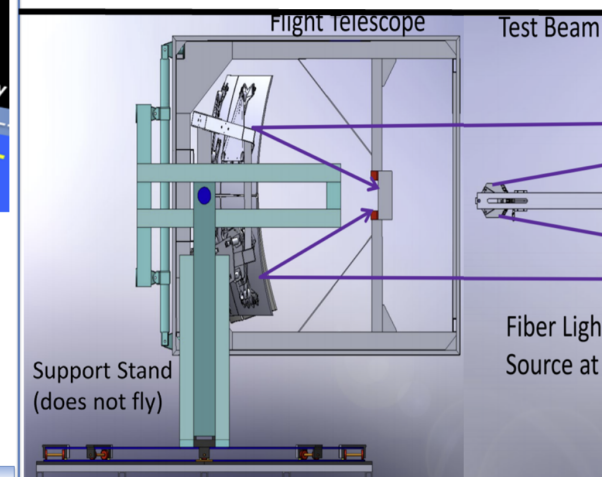


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Optics:

Fluorescence Telescope

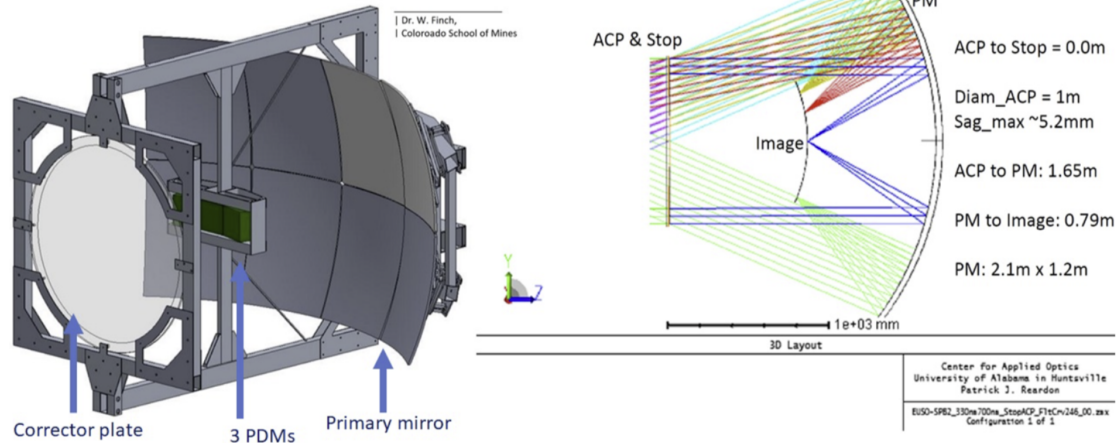


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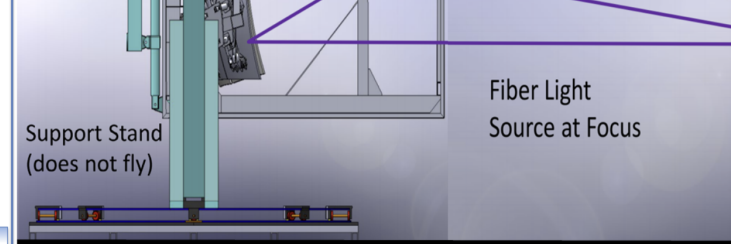


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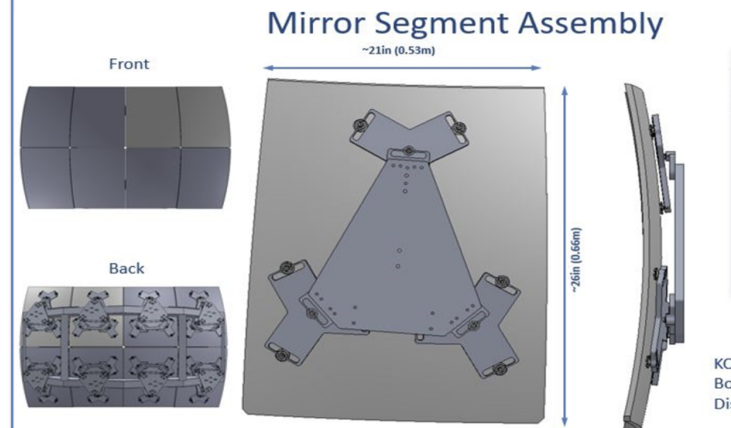


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EO-SPB2
aka NZ
023

Cherenkov: PeV

Above Limb:
First Observation of Cosmic Rays from near-orbit altitude with the Direct Cherenkov Technique

Below Limb:
Search for tau neutrino (ν_τ)
Measure optical backgrounds for earth-skimming technique

Stars

Cherenkov Light

EAS

Cosmic Ray EAS

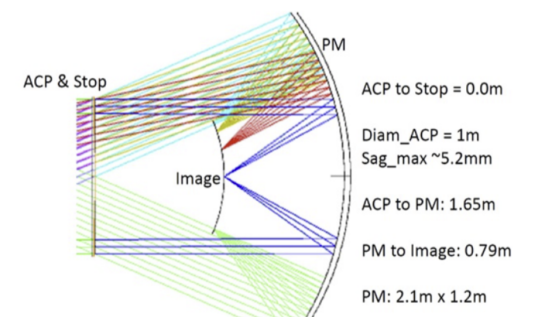
ν_τ (PeV)

Earth

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scientific pathfinder for **POEMMA** [2] (Probe



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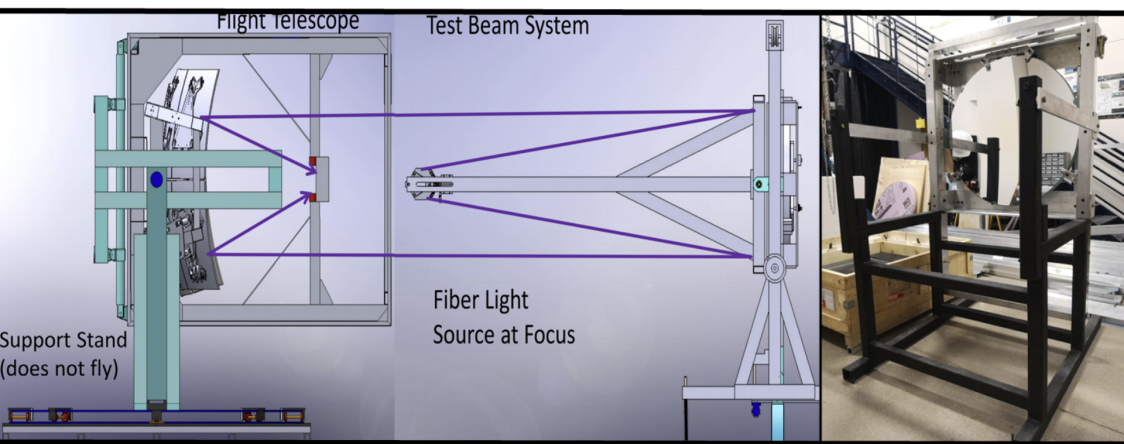


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EUSO-SPB2 specifications:

Table 1: The EUSO-SPB2

Telescopes	EU
Wavelength Sensitivity	U
Energy Threshold	Ee
Sensor Type	M
Field of View	3x
Pixel FOV	(0.
Time frame	10
Pointing (zenith angle)	na

Field campaign:

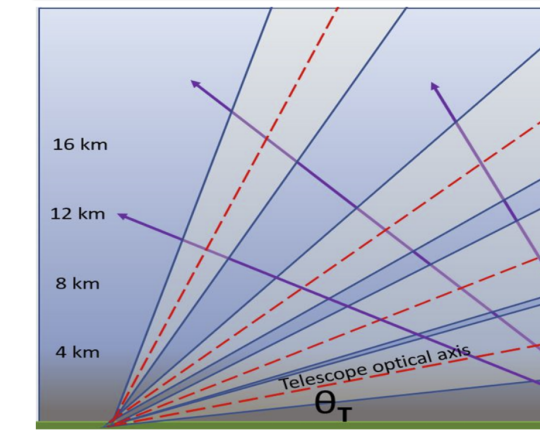
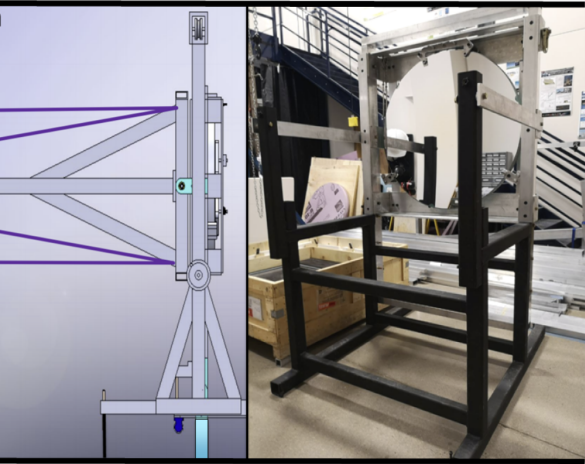


Figure 5: Field test configuration with the steera different inclination angles, θ_T and θ_L . The laser beam is shown at various heights (4 km, 8 km, 12 km, 16 km) and angles.

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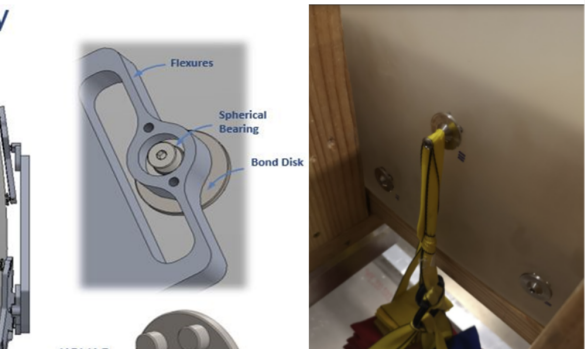
- **An**

Pixel FOV	(0.2x0.2)	(0.4x0.4)
Time frame	1000 ns/bin	10 ns
Pointing (zenith angle)	nadir	Earth's limb ± 10



test beam system. A schematic configuration of the system is shown on the left and a 1-m parabolic mirror on the right. The mirror is mounted on a new customized holding stand.

At NASA the mirror segment attachment points are epoxy glued to the metallic frame with the joints are stress tested under a static uniformly distributed load conditions, i.e., in a thermal chamber for the environment of <7 mbar



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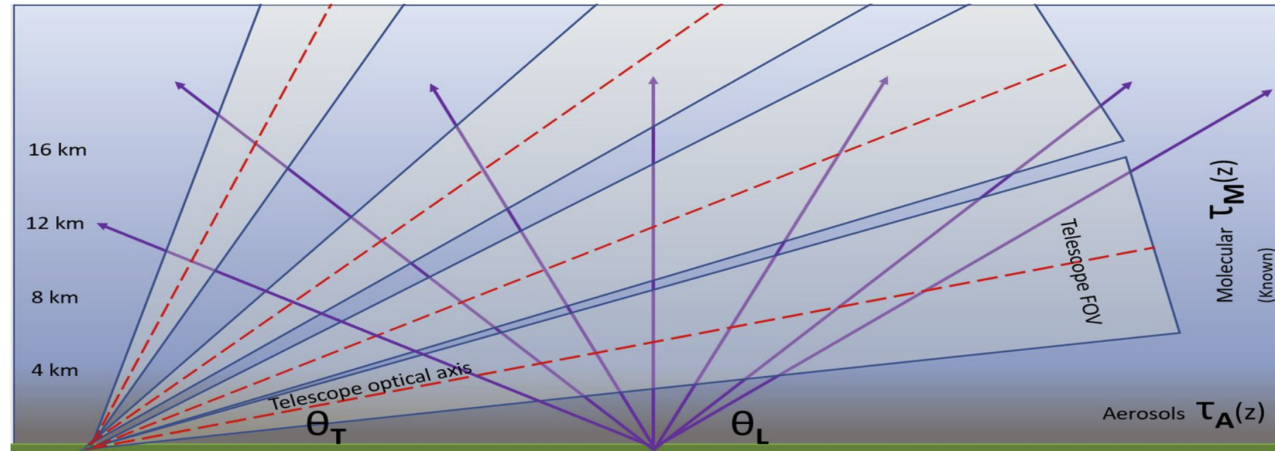


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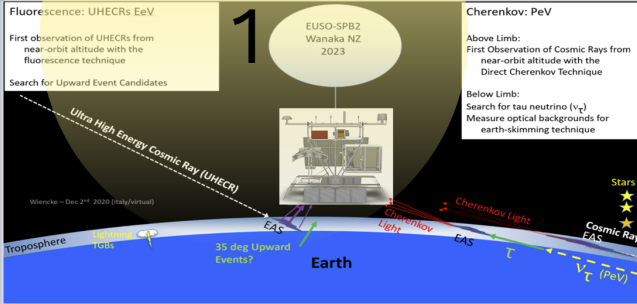


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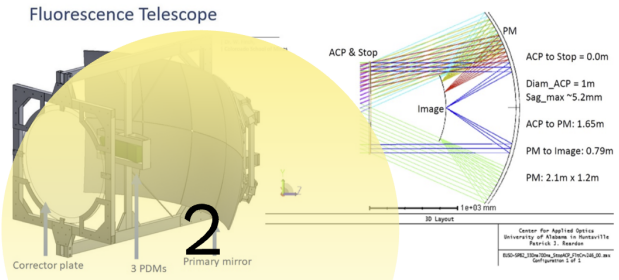


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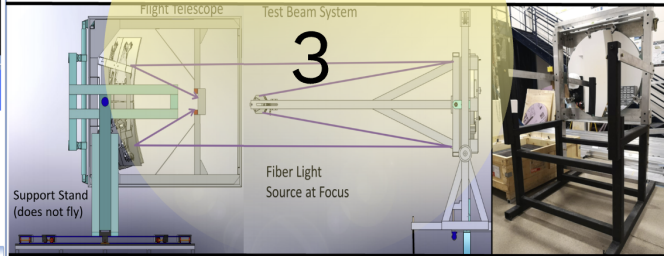


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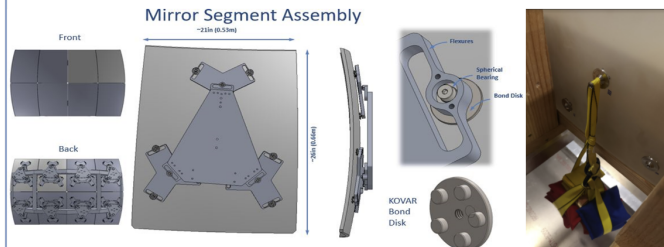


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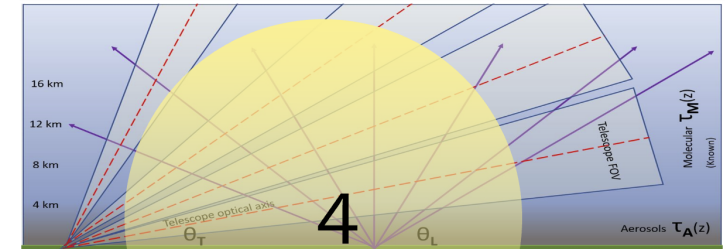


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