Probe of Extreme Multi-Messenger Astrophysics (POEMMA) Probe Mission

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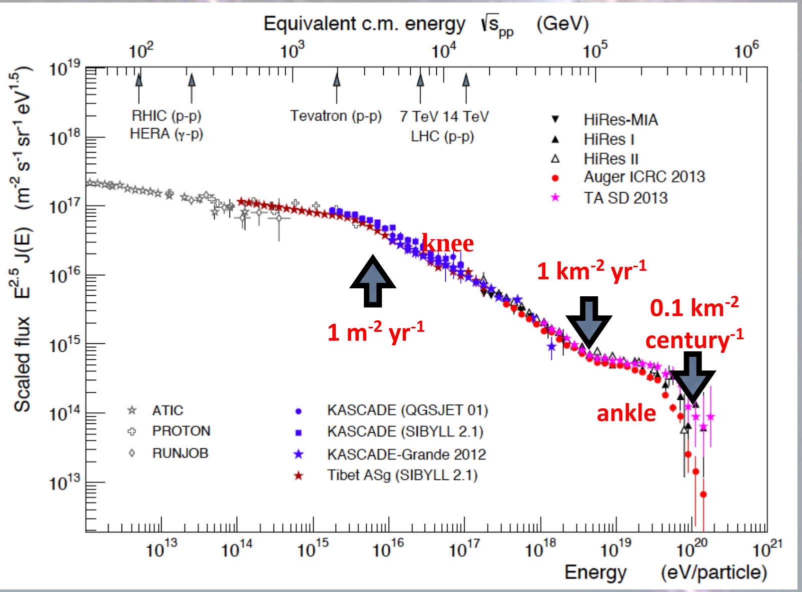
NASA Probe Studies for 2020 Decadal Survey

- NASA funding 10 Probe Class (below 1B$) Mission (18 mos) Studies in Preparation for the 2020 Decadal Survey - POEMMA: Probe of Extreme Multi-Messenger Astrophysics
- PI responsible for the final report (due NLT Dec 2018)
- NASA will submit these studies to the Decadal Survey
- Decadal Survey Committee will have the option to prioritize any of these mission concepts, or recommend a competed line of Probes (similar to Explorers)
- Selection based on Science Merit (cost, schedule)

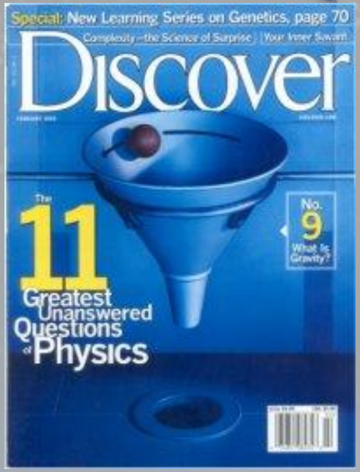
PI	Affiliation	Short title	Design Lab/Prog Office
Camp, J.	NASA's GSFC	Transient Astrophysics Probe	IDC/PCOS-COR
Cooray, A.	Univ. California, Irvine	Cosmic Dawn Intensity Mapper	TeamX/ExEP
Danchi, W.	GSFC	Cosmic Evolution through UV spectroscopy	IDC/PCOS-COR
Glenn, J.	Univ. of Colorado	Galaxy Evolution Probe	TeamX/ExEP
Hanany, S.	Univ. of Minnesota	Inflation Probe Mission Concept Study	TeamX/ExEP
Mushotzky, R.	Univ. of Maryland	High Spatial Resolution X-ray Probe	IDC/PCOS-COR
Olinto, A.	Univ. of Chicago	Multi-Messenger Astrophysics	IDC/PCOS-COR
Plavchan, P.	Missouri State Univ.	Precise Radial Velocity Observatory	No design lab funded/HQ grant
Ray, P.	Naval Research Lab	X-ray Timing and Spectroscopy	IDC/PCOS-COR
Seager, S.	MIT	Starshade Rendezvous	TeamX/ExEP

Extensive Air Showers (EASs)

Ultra-High Energy Cosmic Ray Flux

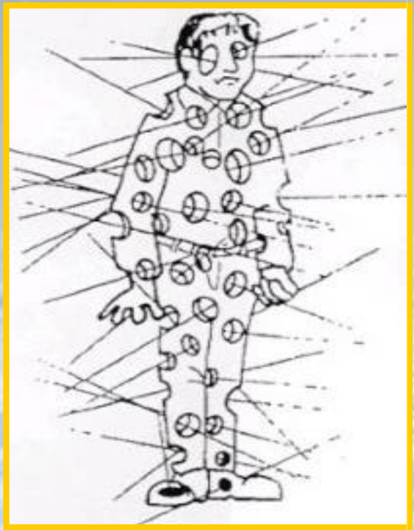


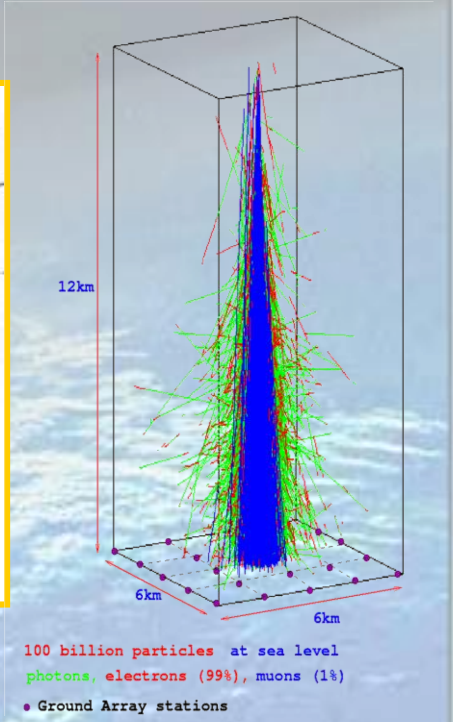
3×10^{20} eV = 50 joules = 1 Tyson = UHECRs traveling at 99.99999999999999999999% of the speed of light



Origin of UHECRs 1 of 11 unanswered questions in Physics - still unanswered

- Cosmic rays are charged particles such as protons, electrons and nuclei of atoms
- They are NOT electromagnetic radiation (aka light)
- Cosmic rays are of great importance in biology as they are responsible for many genetic mutations and to spacecraft as they cause single event upsets (SEUs) in computers
- They interact with nitrogen in the atmosphere to produce EASs
- More than a hundred secondary particles of swarm through our body every second!
- The air fluorescence will be a luminous disc (equal to 100W light bulb) a few meters thick, 1 km across moving at nearly the speed of light. The wavelengths of interest are in the 300 – 400 nm region.





Starting Point Design

- 2 formation-flying spacecraft (OWL concept)
- f/1 Schmidt camera, 45° FoV,
- 10 m diam. primary mirror deployable (OWL: 7m)
- 4.3 m diam. corrector lens
- 8 m^2 focal plane with ~500,000 pixels
- (~ 0.06^O pixel ~1 km^2 projected on the ground at 1,000km altitude)
- 14 m^2 effective aperture (OWL: 7.07 m^2)
- weight TBD ~2400 kg;
- power consumption TBD ~600 W

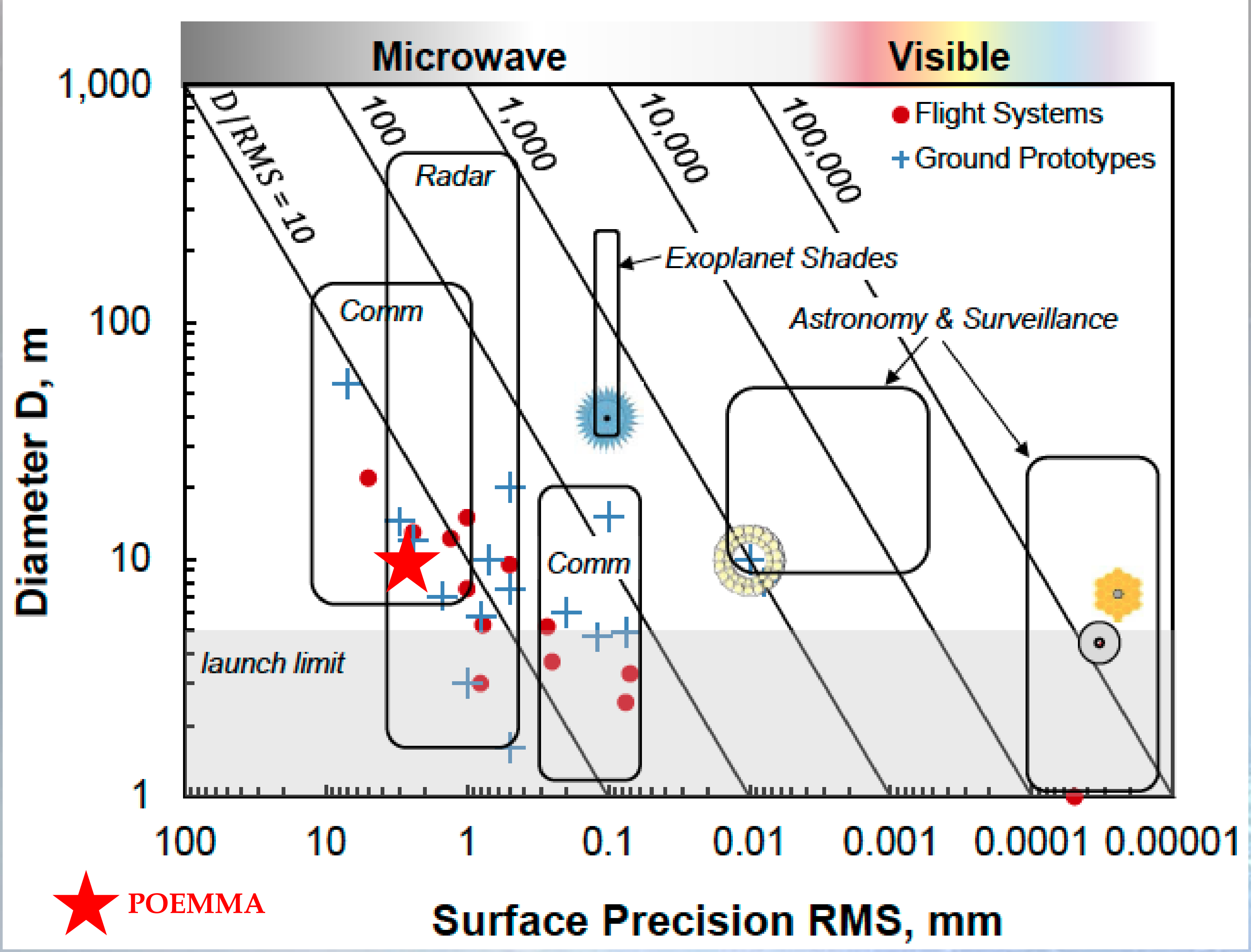
First Order Properties	POEMMA	OWL
Aperture	3.70 m	3.0 m
Focal Length	2.86 m	3.0 m
F/#	0.78	1
Stop	4.4 m shifted from corrector plate	corrector plate
RMS Spot Radius (.36um)	~1.5mm	1.5mm
Primary Mirror diameter	6.7 m (segmented)	3.8 m (monolith)
Corrector diameter	3.8 m (segmented)	3 m (monolith)
Corrector Thickness	12.6 - 47.5 mm (segmented)*	100 mm (monolith)

- Corrector:
  - Corrector Mirror Distance: +/- 1cm
  - Tilt to axis: +/- 1 degree
  - Decenter: <|+/- 0.5cm
  - Fabrication: Segmented aspheric fabrication concerns
  - Radius: Low sensitivity (Corrector thickness is important)

- Mirror
  - Fab: (more like microwave antenna than imaging mirror)
  - ¼ to 1 wave in visible is more than sufficient quality.
  - Radius: = +/- 0.2cm (refocus to correct fab error)
  - Thickness – Focal Plane Distance: +/- 0.1cm
  - Decenter: +/- 0.1cm
  - Tilt to axis & petals: +/- 0.02 degrees, 1.2 arcmin

- Focal Plane
  - Tilt to axis: +/- 0.1 degree

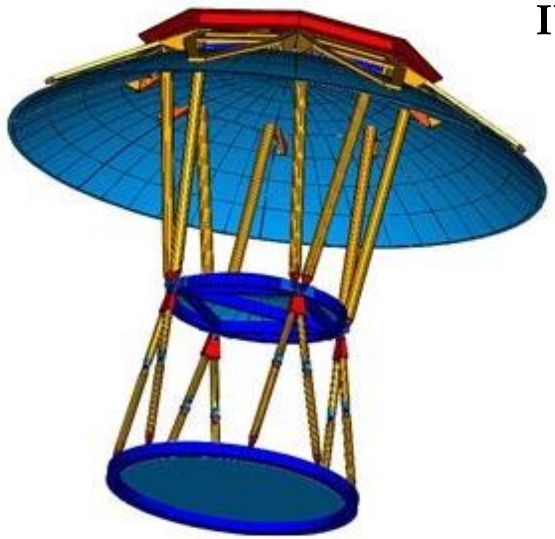
Large Reflectors - Current State of the Art

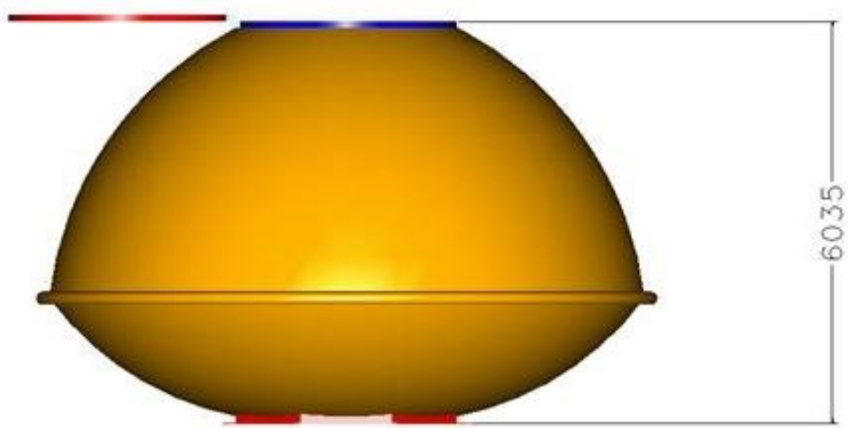


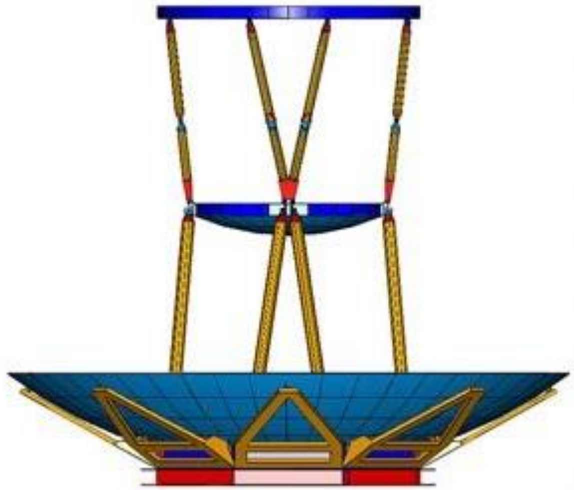
CAD Views of OWL

Instrument Synthesis and Analysis Laboratory

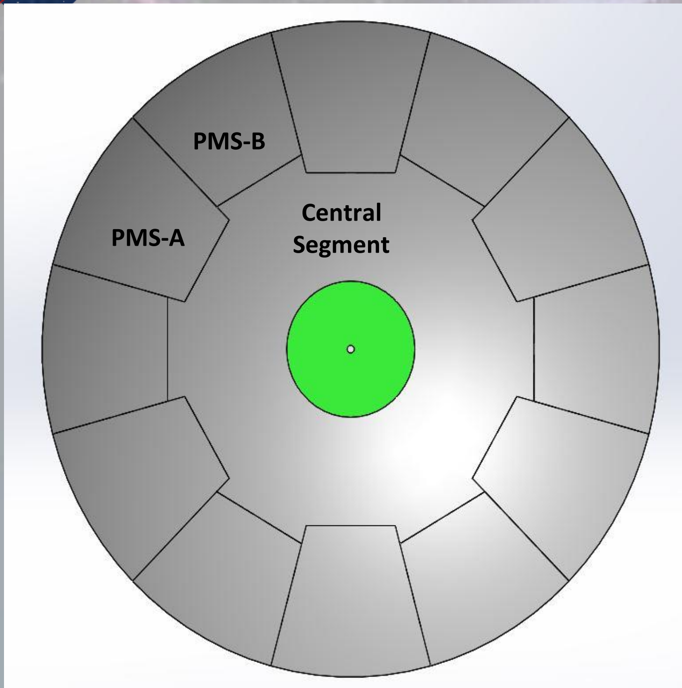
OWL – Orbiting Wide-Angle Light Collectors
IDL Study - 2001

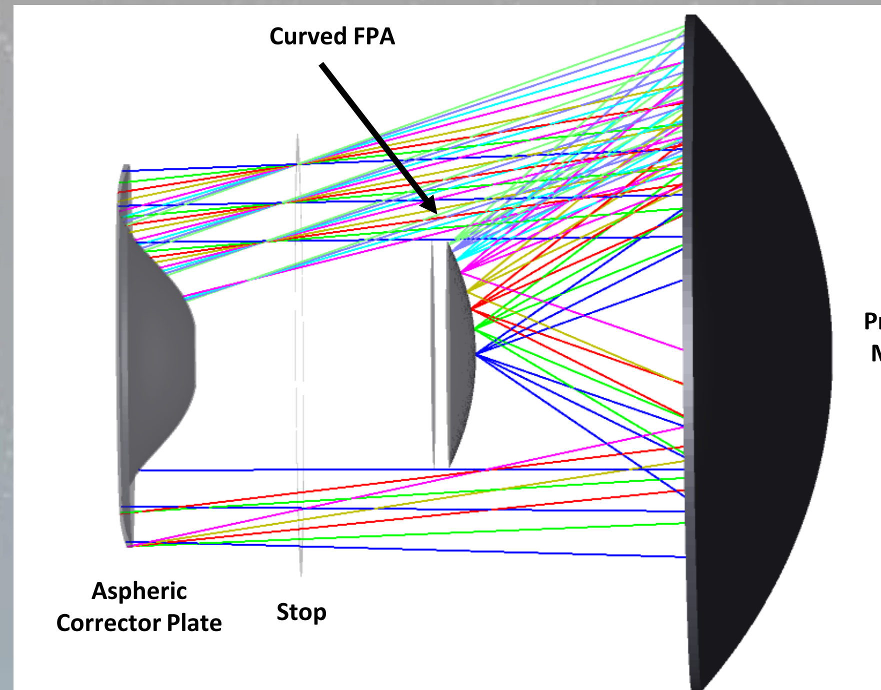






POEMMA Optical Layout





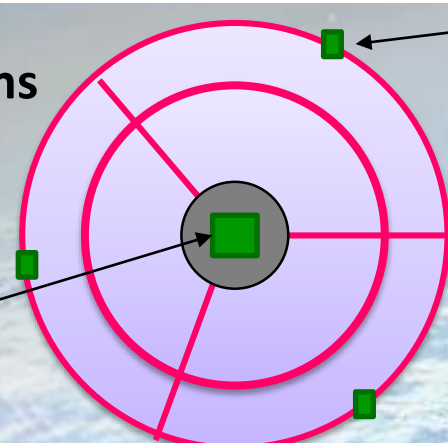
Corrector Lens

Side View

60mm edge thickness
12.7mm center thickness
~465kg

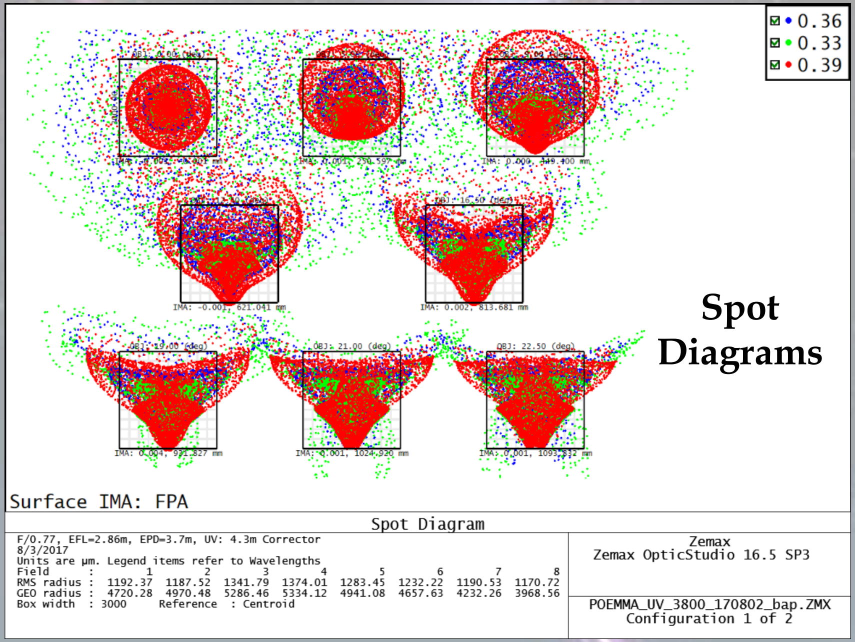
Corrector Lens

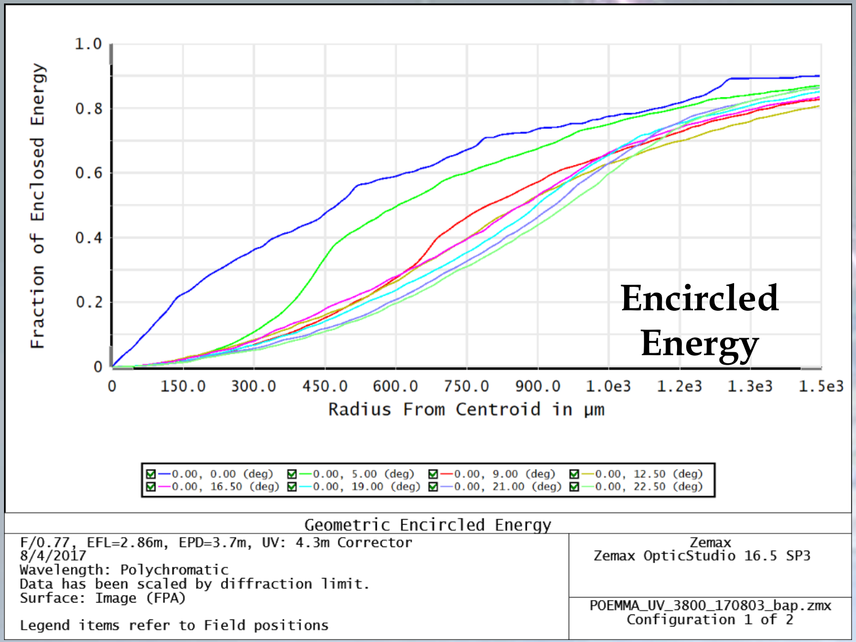
Top View



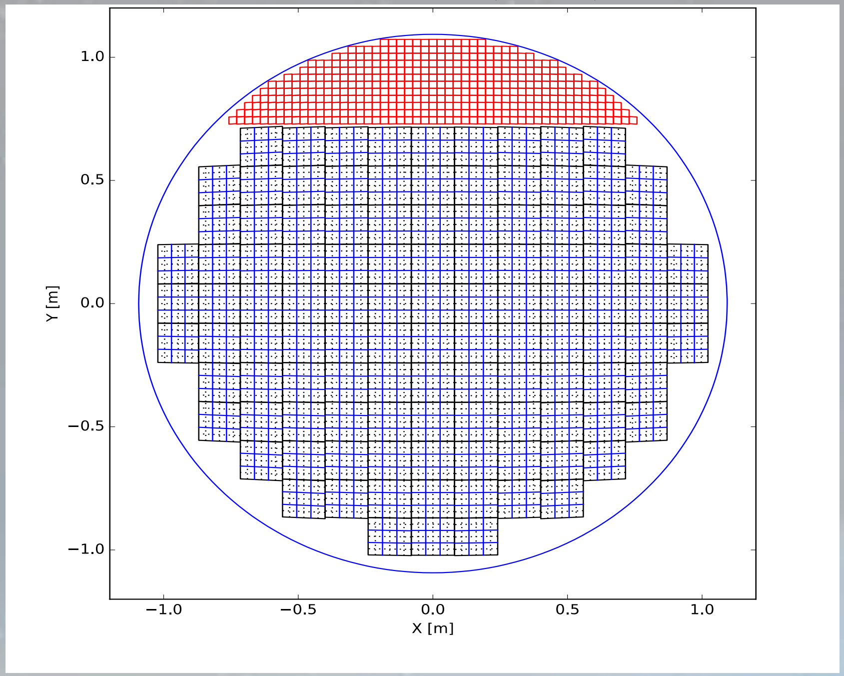
3 pie segments,3 annulus segments
Division at inflection point
Spines align with tripod

Optical Performance





Cherenkov (SiPM)

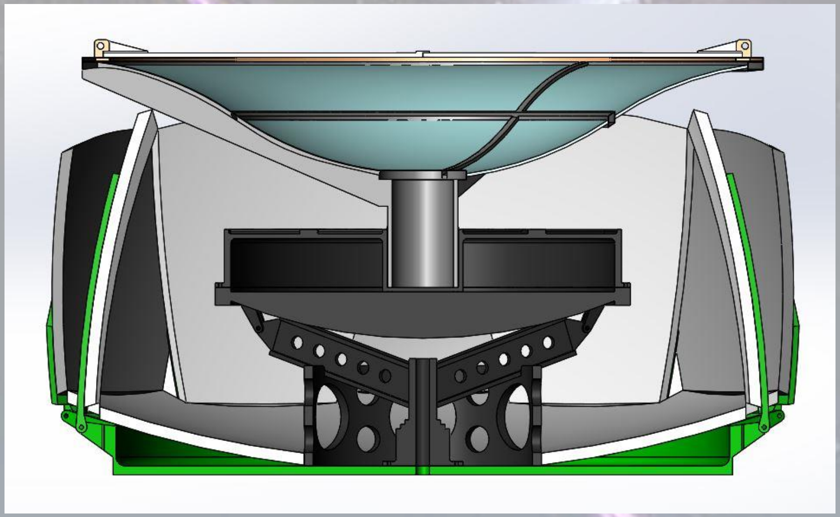


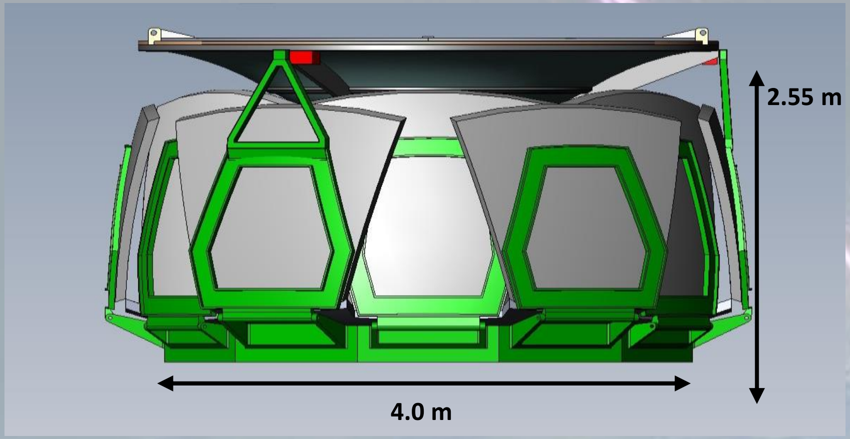
Fluorescence (PDM)

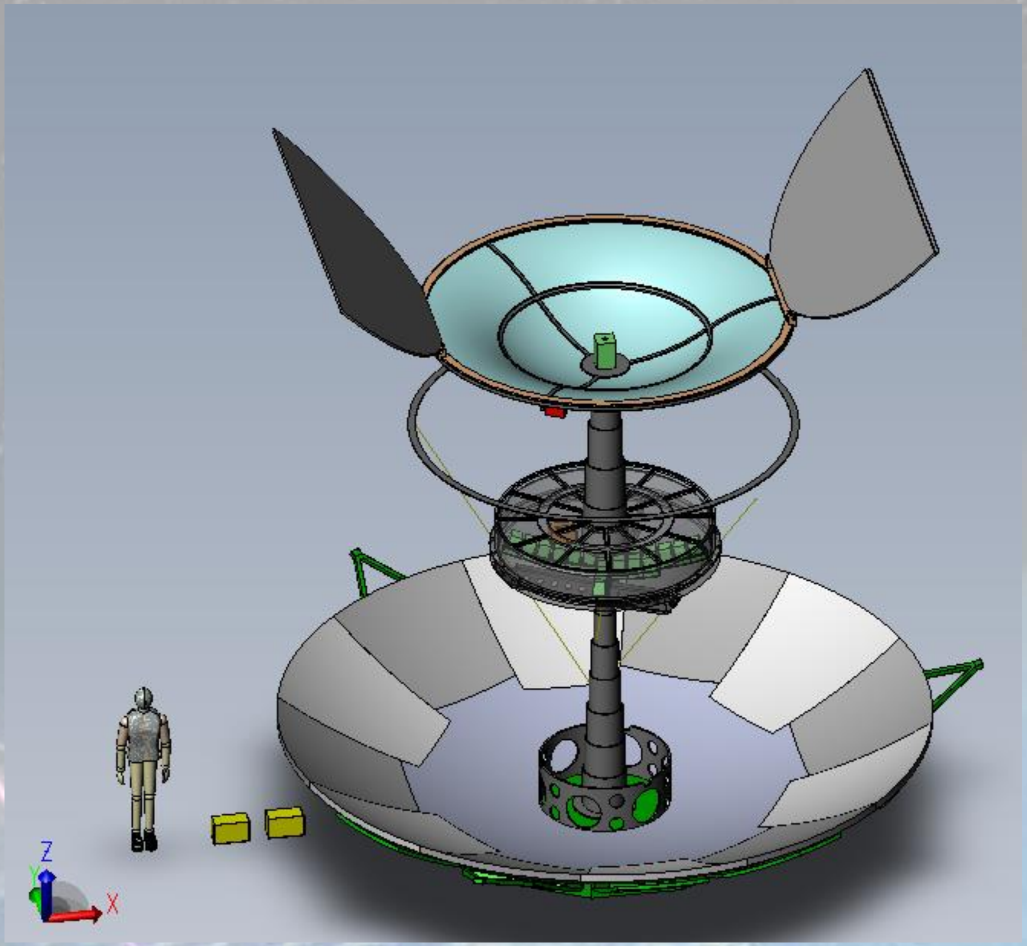
The POEMMA focal surface is composed of a hybrid of two types of cameras:

- **90% of the focal surface is dedicated to the POEMMA fluorescence camera**
  - **multi-anode photomultiplier tubes (MAPMTs) with typical time between images is 1 msec**
- **Cherenkov camera occupies the crescent moon shaped edge of the focal surface which images the limb of the Earth**
  - **composed of Silicon photo-multipliers (SiPMs)**

IDL Mechanical Design



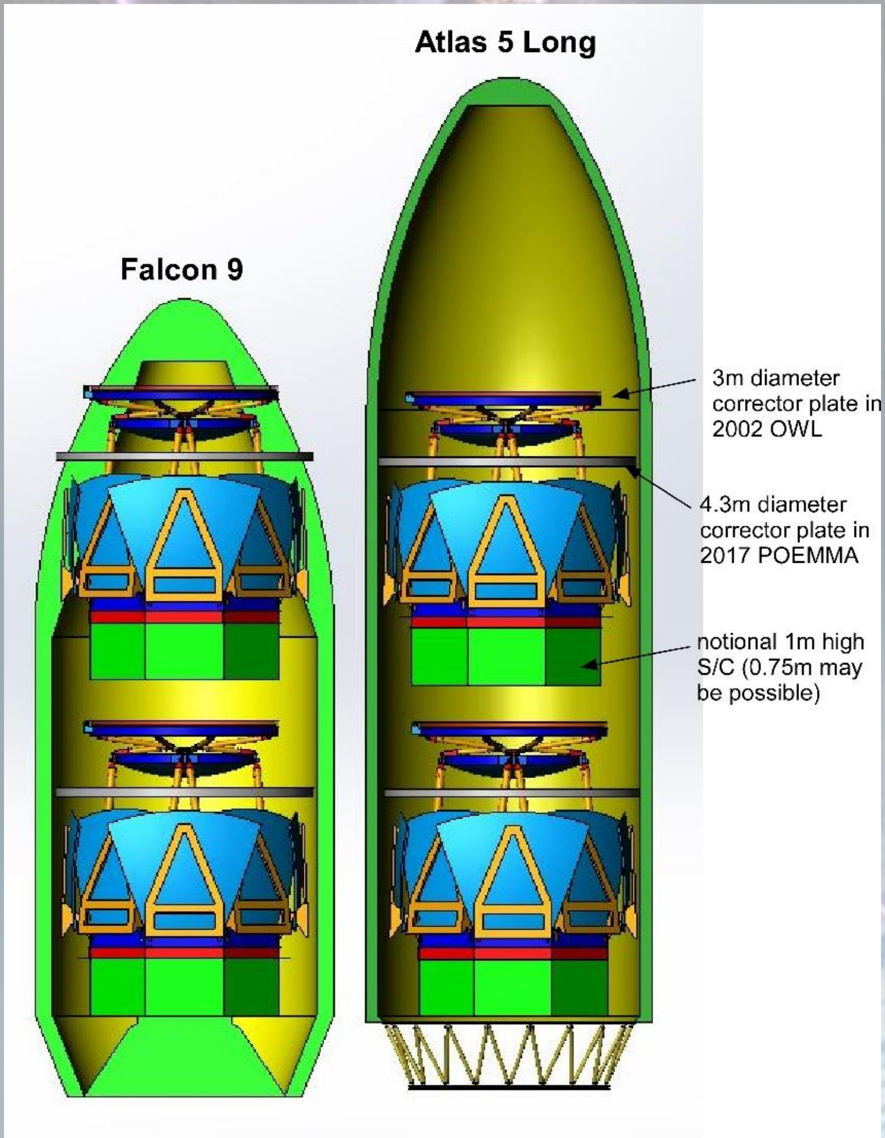


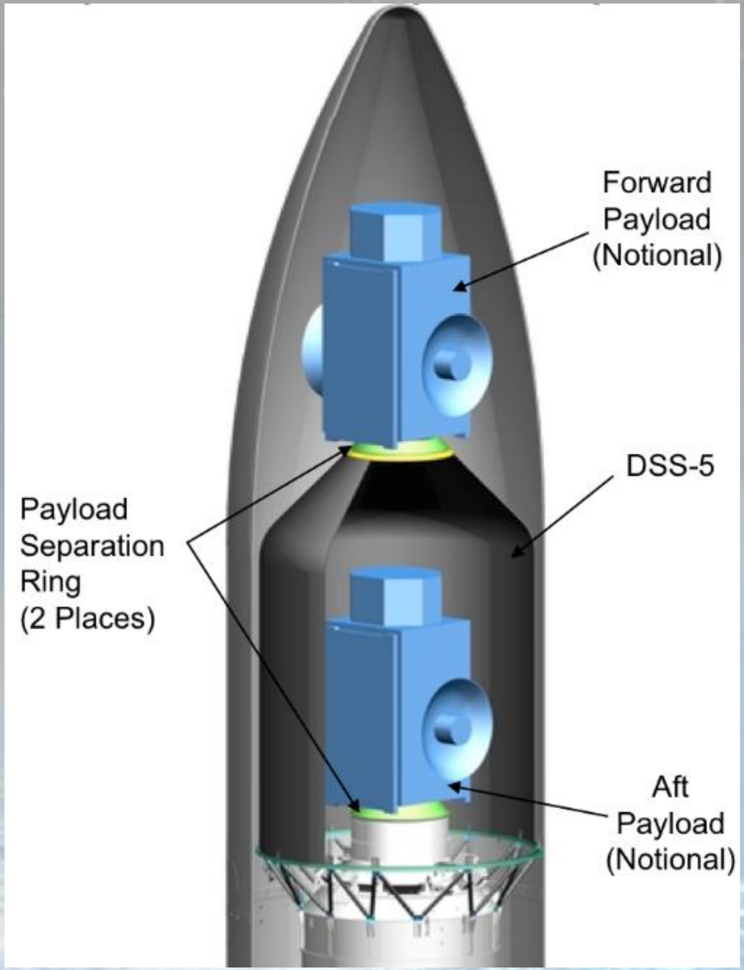


Design of light shield not considered in IDL study

- Trade between inflatable (hemispheric deployment) and conical shape
  - Issue with sequential PM Petal deployment if using conical shape shield
  - Complexity and reliability of hemispherical deployment
  - Use MMOD resistant materials (i.e. Kevlar29) sparingly – mass and packaging considerations
  - Thermally transmissive

Launch Configuration

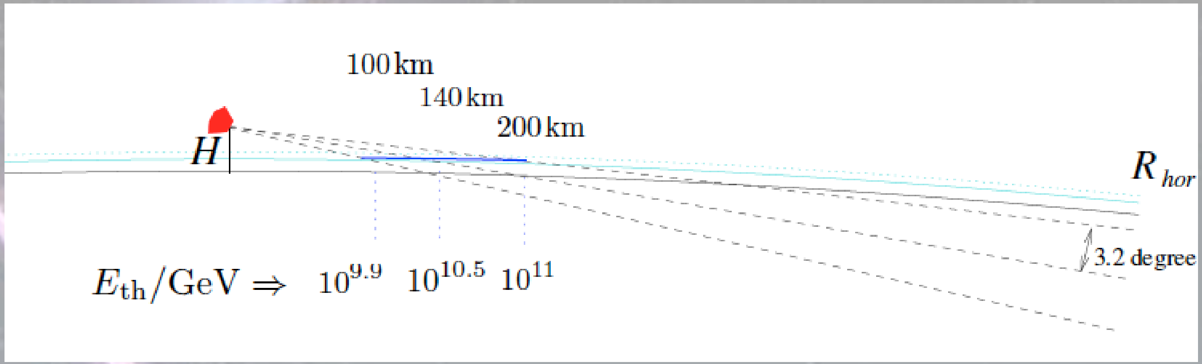




Atlas 5 with DSS-5

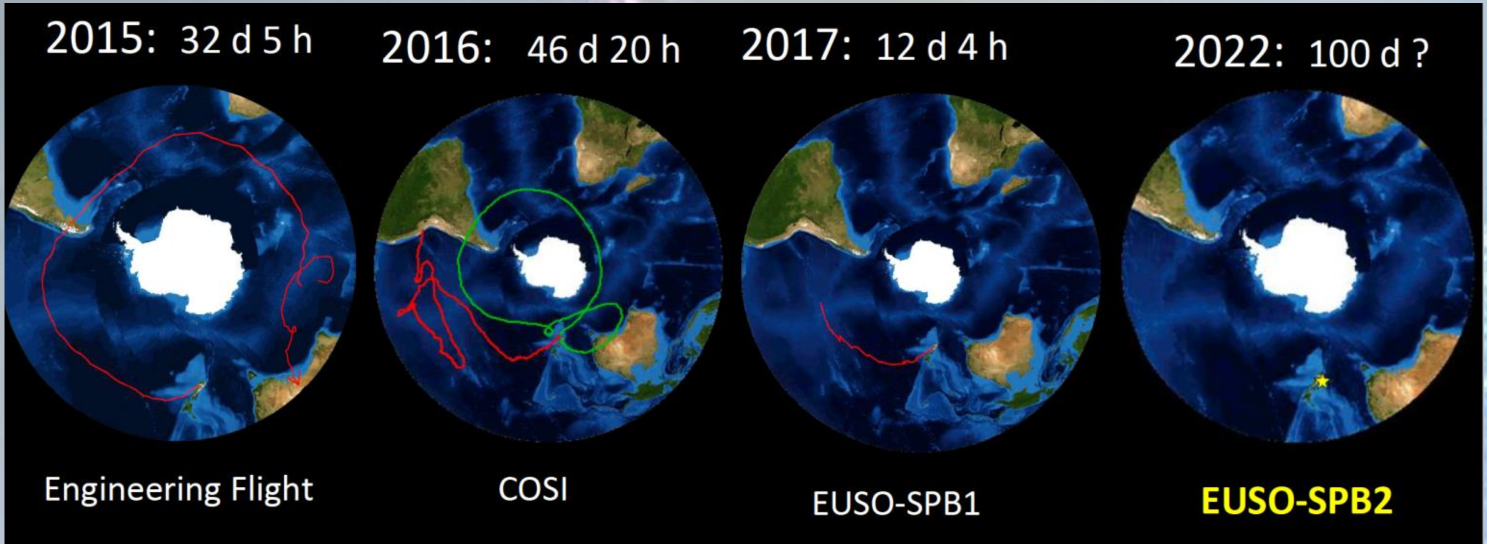
EUSO-SPB2
Overview

EUSO-SPB2 Observation Approach

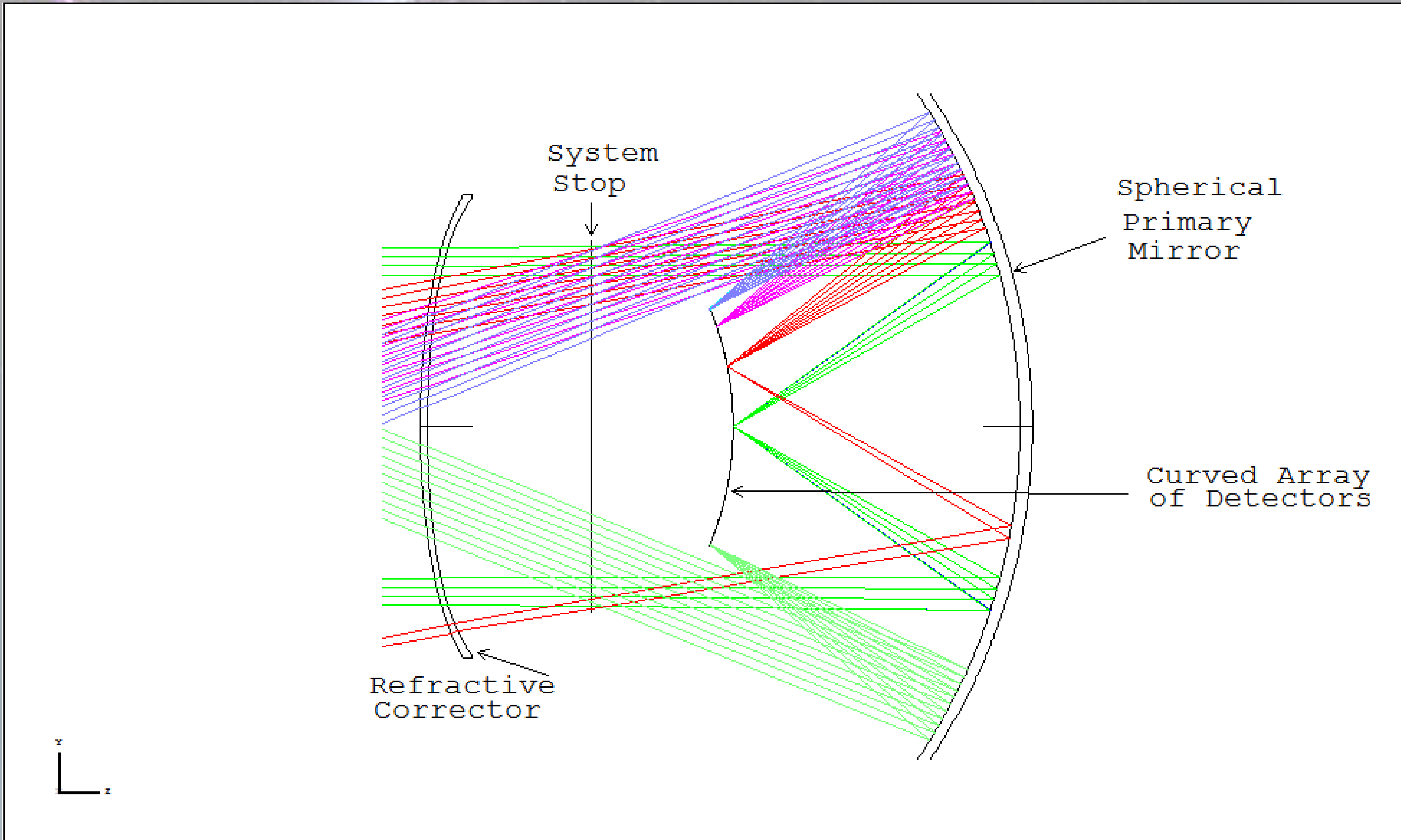


- Detect high altitude UHECR and UHEv through Cherenkov signal
- Pathfinder for POEMMA Instrumentation:
  - Schmidt camera: corrector, stop, mirror, coatings
  - Detector technology (MAPMT, SiPM, others), filters
  - Corrector material: PMMA vs glass
  - Limb field of view

- Background measurement for upward going EAS shower
- Detect EAS showers through fluorescence



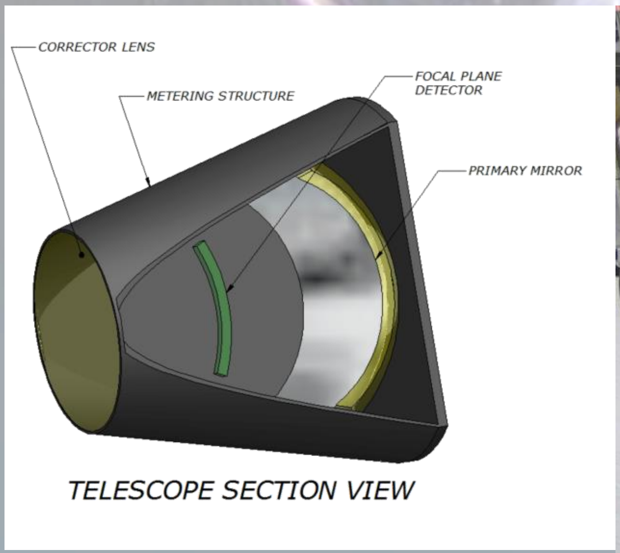
SPB-2 -Optics



3D Layout

Scale: 0.0667	300.00 Millimeters	Center for Applied Optics University of Alabama in Huntsville Patrick J. Reardon
		EUSO-SPB2_Chr.zmx Configuration 1 of 1

SP2 Telescope



Optics FoV: 29°x3.2°

- Corrector Plate: PMMA ~1m^2
- Image resolution: 1mm
- Pixel size: 3mm square
- Mirror: 1.8(H) x 1.1(V) split

Ring Imaging Cherenkov, RICH, mirror for the Alpha Magnetic Spectrometer, AMS-02, which is operating on the International Space Station since May, 2011. Composite Mirror Applications, Inc. (CMA), in Tucson, AZ produced a conical mirror 1.3m diameter 0.5m in height, from high modulus carbon fiber, flight qualified composite materials, having an optical surface on the inside of the cone. The flight model mirror was completed to specification, yielding nearly 2m^2 of replicated optical surface area and weighs 8 kg.

Replicated carbon fiber RICH mirror for AMS-02, Robert C. Romeo, 2006

EUSO-SPB2 Gondola