Thermal-Optical Performance of the GPS III Laser Retroreflector Array

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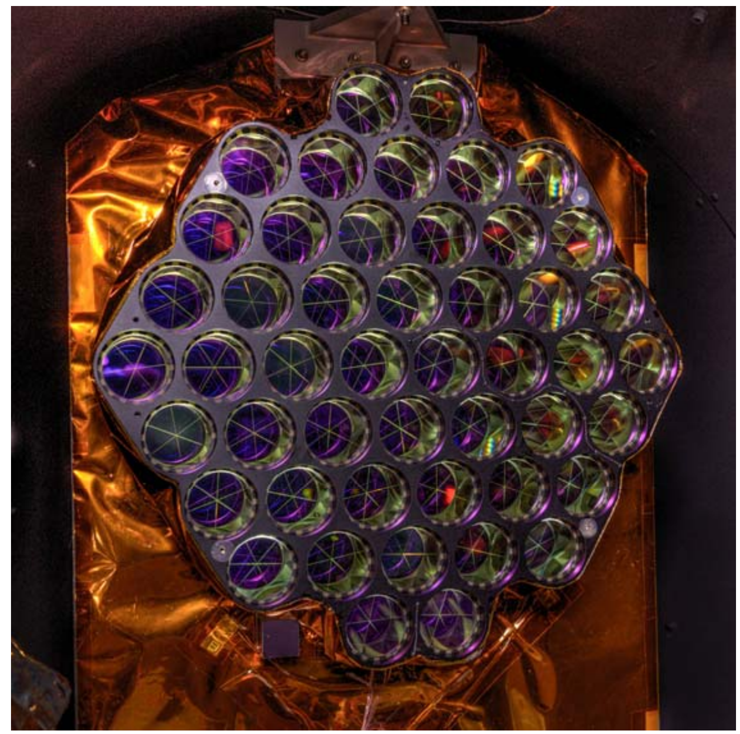
GPS Laser Retroreflector Array

- SLR to GPS will contribute significantly towards improving the accuracy and stability of the International and WGS84 Terrestrial Reference Frames.
- GPS will then provide a means to accurately and uniformly distribute this new accuracy to all systems utilizing GPS.
- Delivery of at least 22 arrays for GPS IIIF (SV-11 launch availability in 2026).



Geodetic Objectives

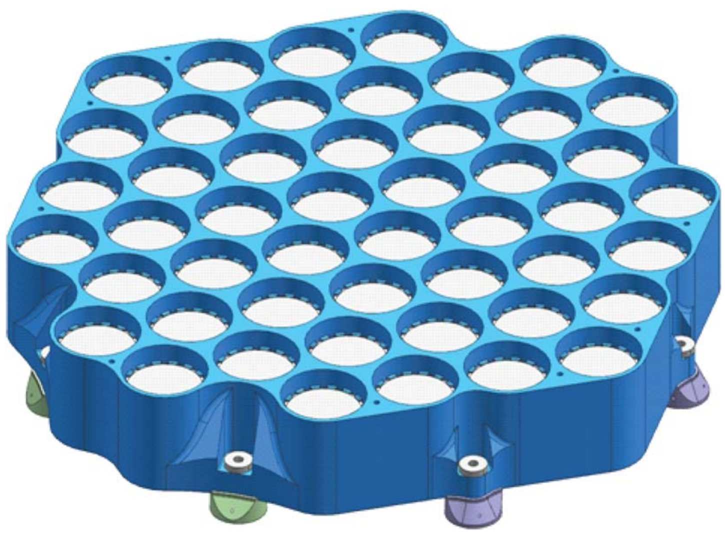
- Achieve a stable geodetic reference frame with accuracy at least ten times better than the anticipated user requirements for positioning, navigation, and timing.
- Maintain a close alignment of the WGS-84 reference frame with the ITRF.
- Provide a quality assessment capability independent of current radiometric measurements used to determine GPS orbits and clock performance.
- Ensure interoperability of GPS with other GNSS's (GLONASS, Galileo) through a common, independent measurement technique.

Cross Section Requirement

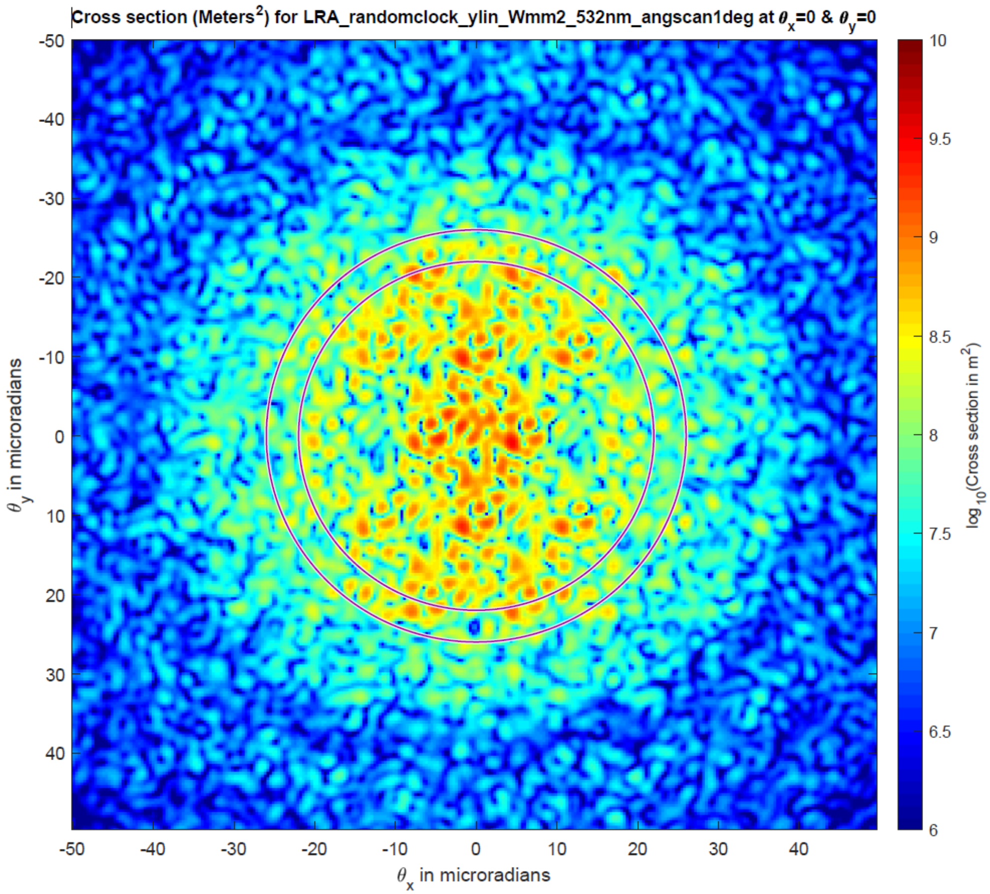
- ILRS Standard for an "Effective Cross-Section" of 100 million square meters for satellites at GNSS altitudes.
  - https://ilrs.cddis.eosdis.nasa.gov/docs/retroreflector_specification_070416.pdf

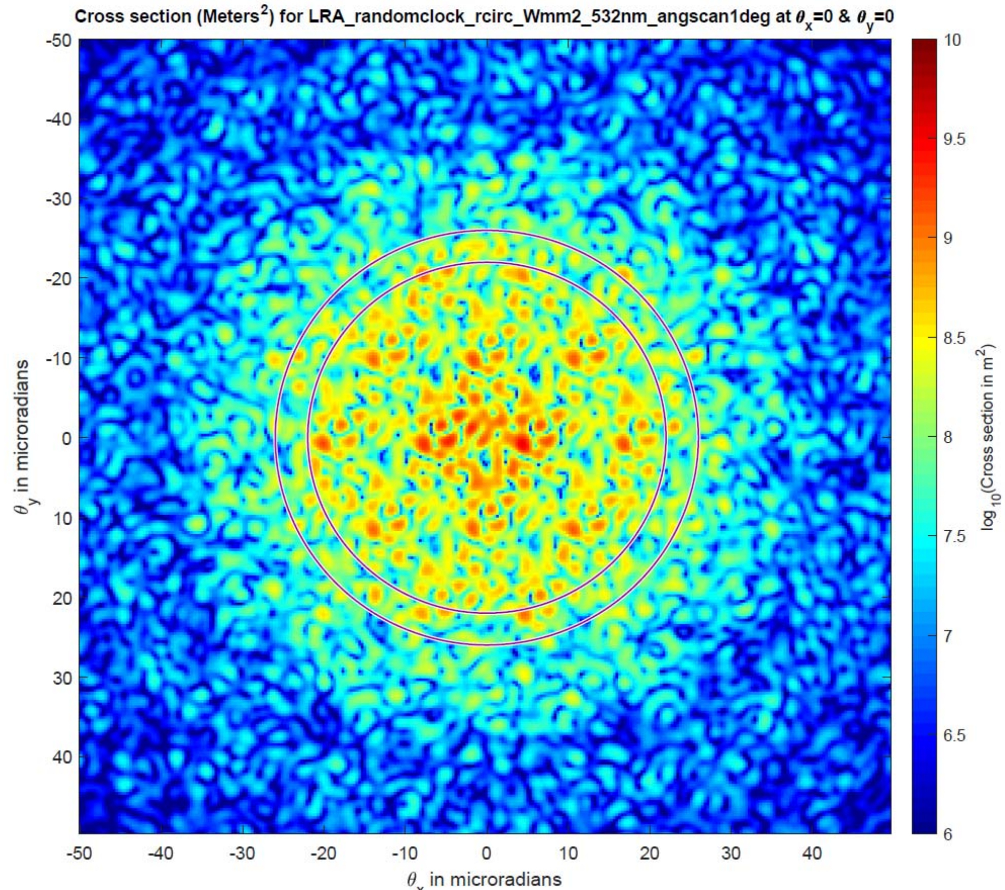
Array Design Overview

- Planar Array – 16 inch diameter
- 48 recessed 1.6 inch diameter Suprasil-1 cubes
- Random clocking
- Slight 0.2 arcsec dihedral angle spoiling
- Uncoated back sides
- Front surfaces coated with an antireflection coating optimized for 532nm and 1064nm
- Total array weight: 17.5 lbs.
- Thermally isolated from the spacecraft (standoffs & blanketing)



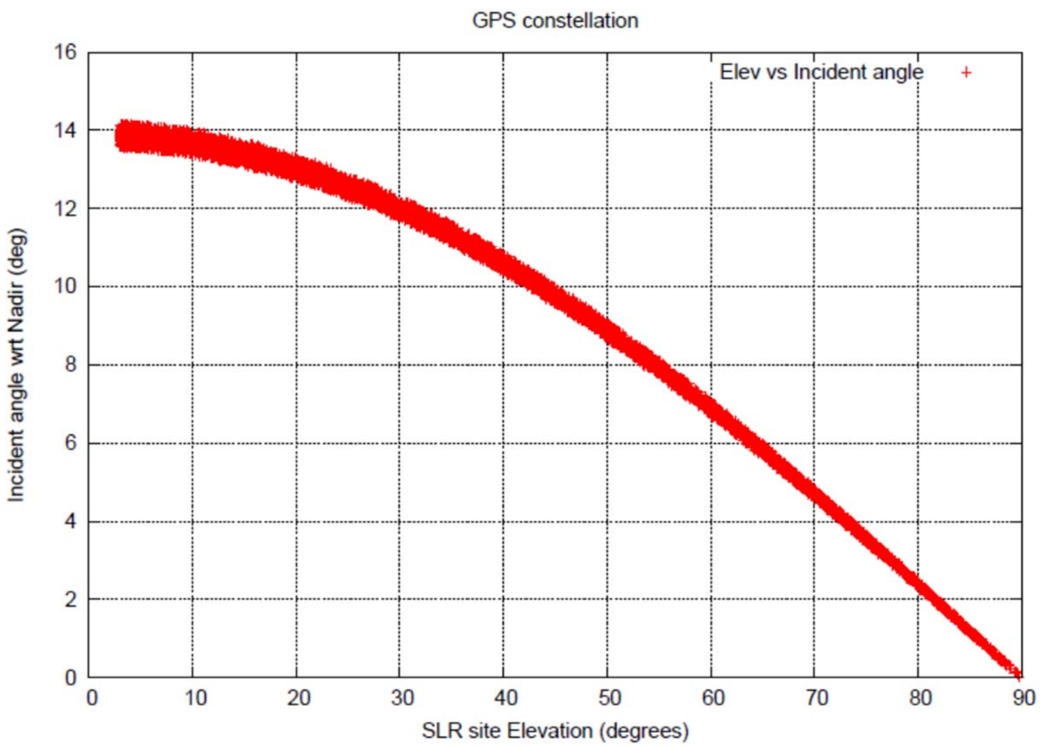
Predicted Cross Section/FFDP

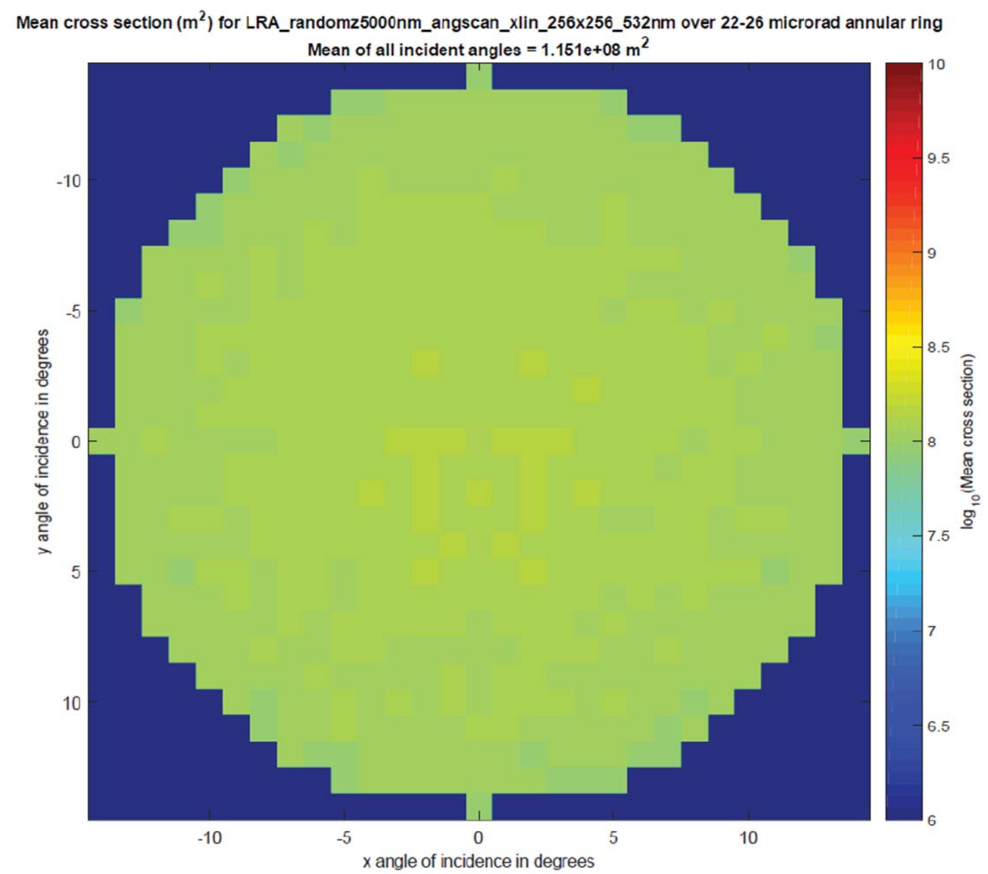




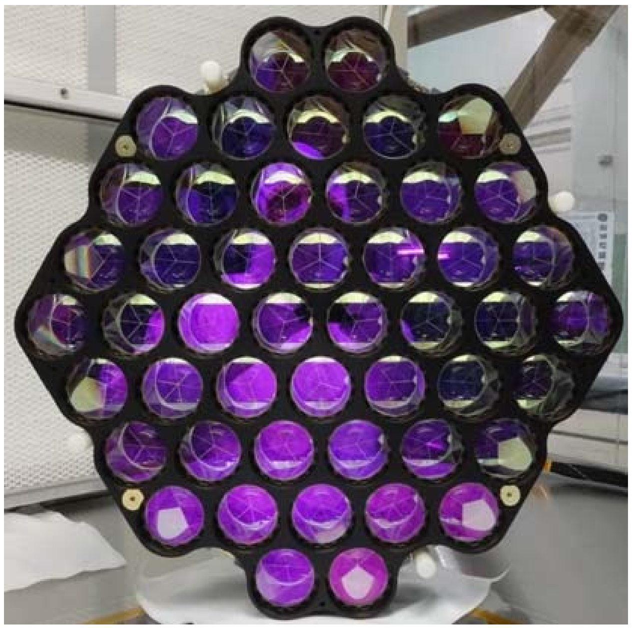
Velocity Aberration: 22-26 μrad

Incident Angle - Predicted Cross Section

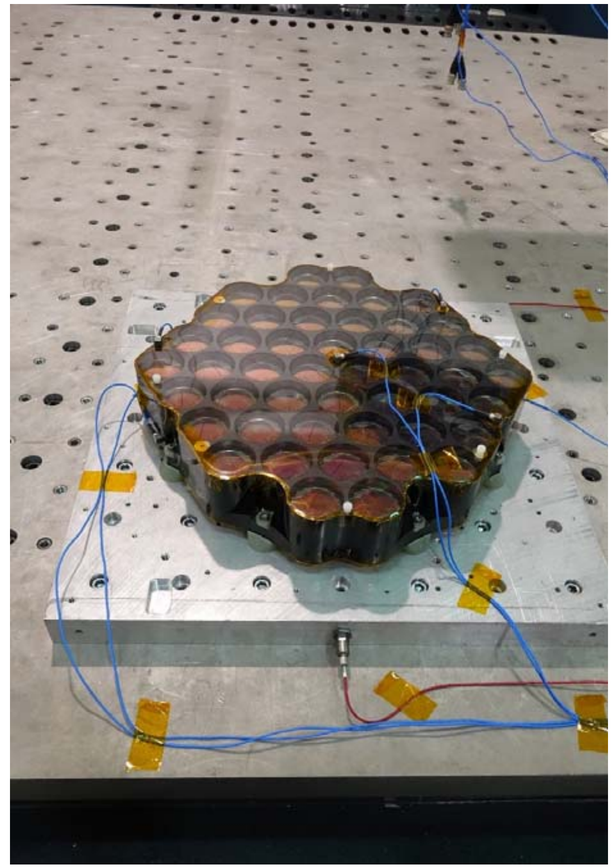




Engineering Qualification Model (EQM)



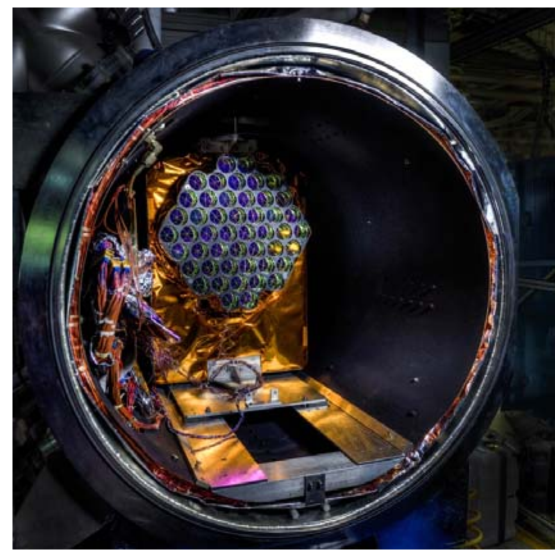
EQM After Assembly



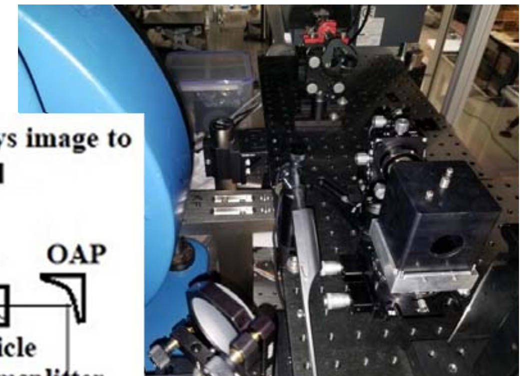
EQM Vibration Verification

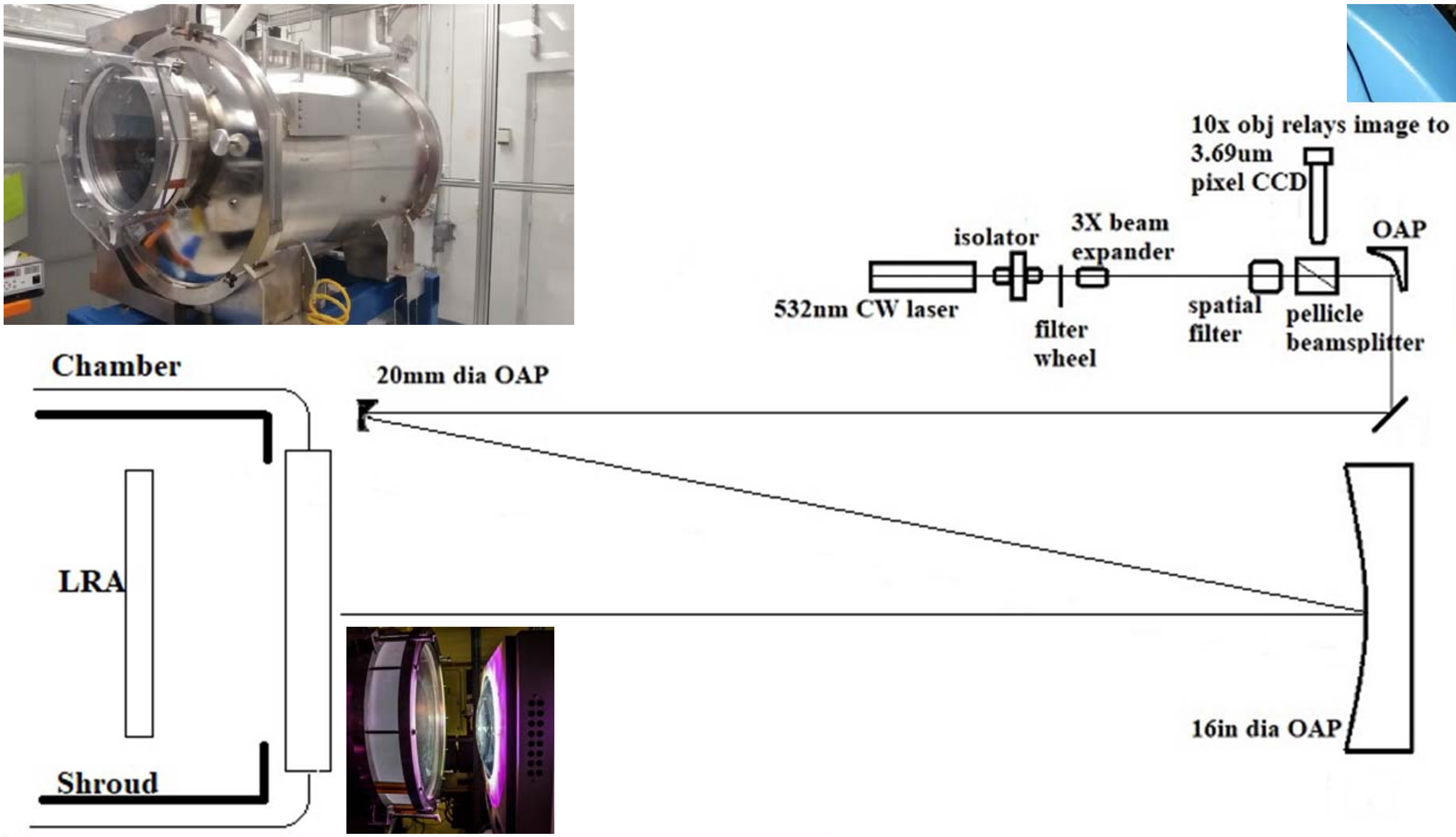
Thermal-Optical Testbed Salient Features

- 32” ID x 48” L vacuum chamber with roughing, turbo and cryo pumps
- 16 inch clear aperture window
- Controlled thermal environment via blanketed and painted shroud, actively cooled (LN_2) and heated
- Solar simulator providing 12 inch diameter 0.8 suns through window
- Thermal monitoring via thermocouples
- Simulate orbit orientation (variable AOI) via internal vertical axis rotation stage driven by a stepper motor
- 532 nm CW, power stabilized laser source - currently linear polarized
- Source plate optics feeding a 16 inch off-axis parabola (OAP) providing a collimated 16 inch beam through the chamber window
- Return beam focuses onto a 10x objective feeding a 3.69 micron pixel CCD

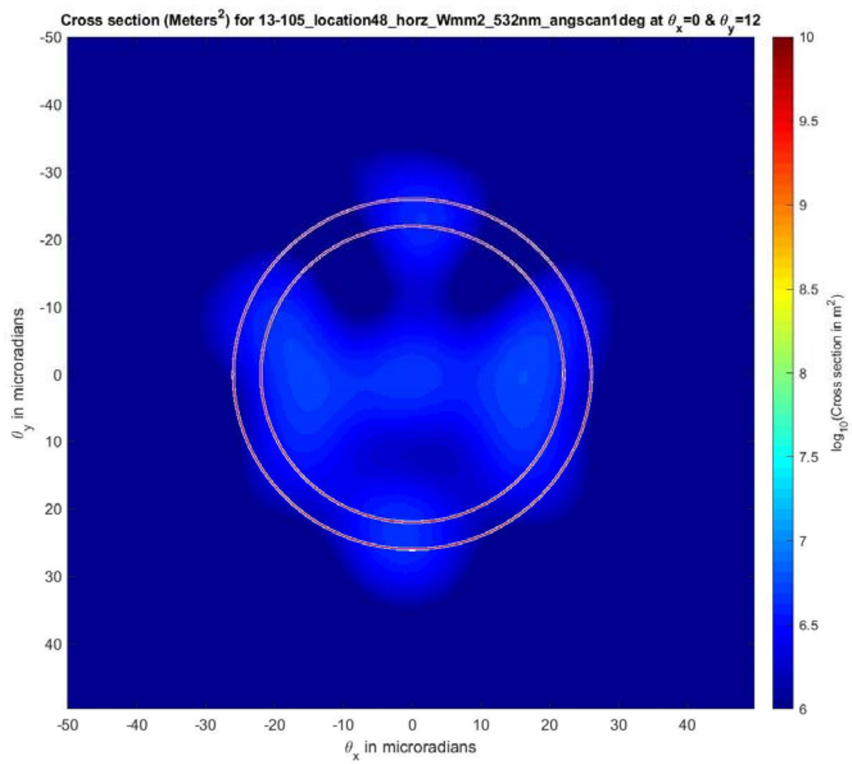


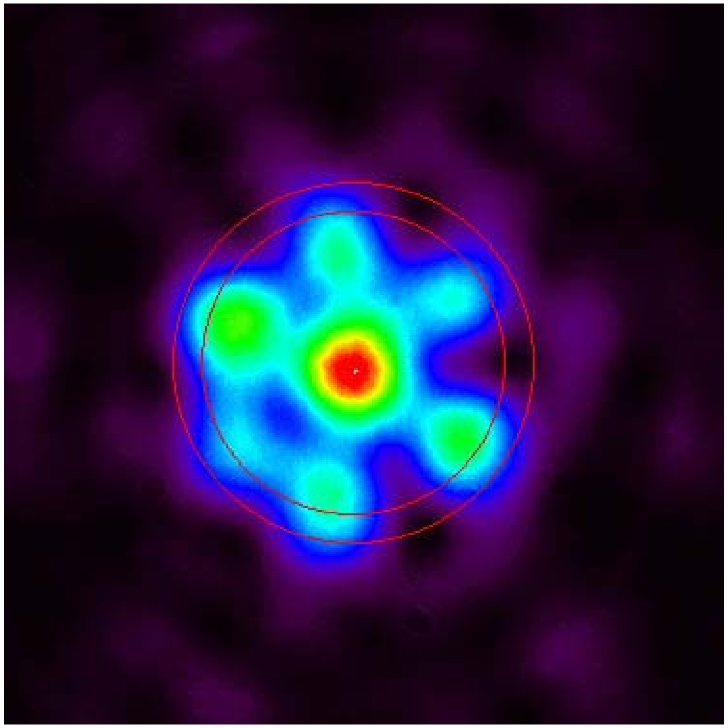
Testbed Optical Layout



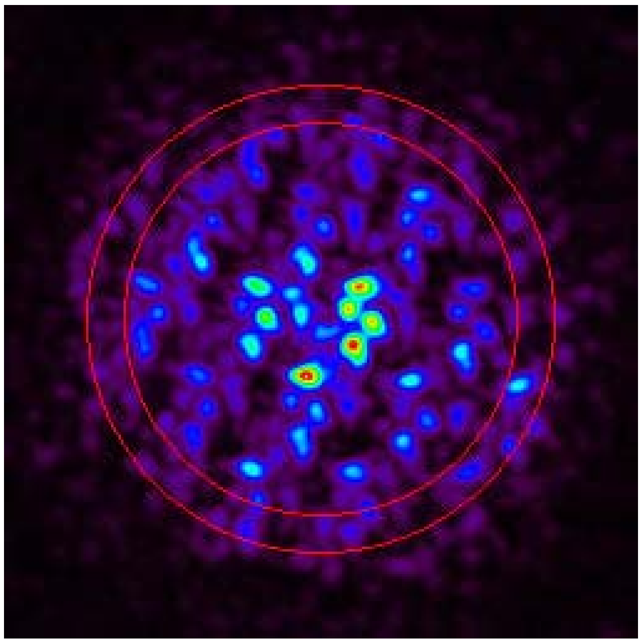


Individual Cube Models and Measurements

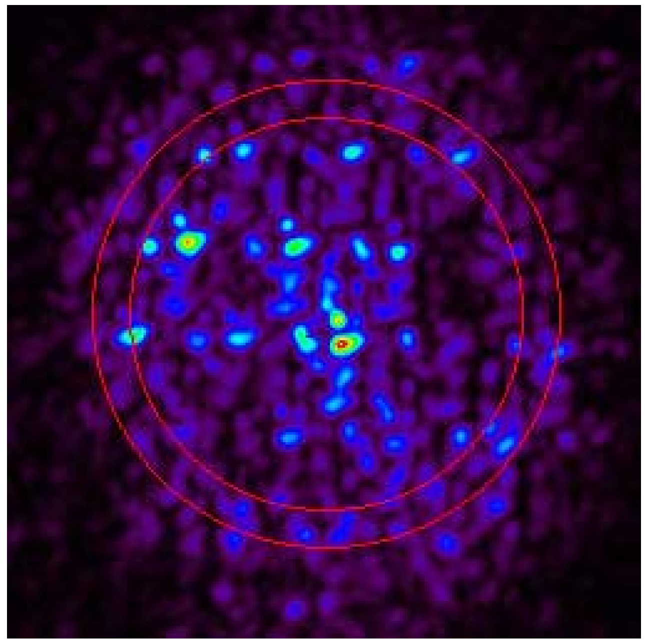




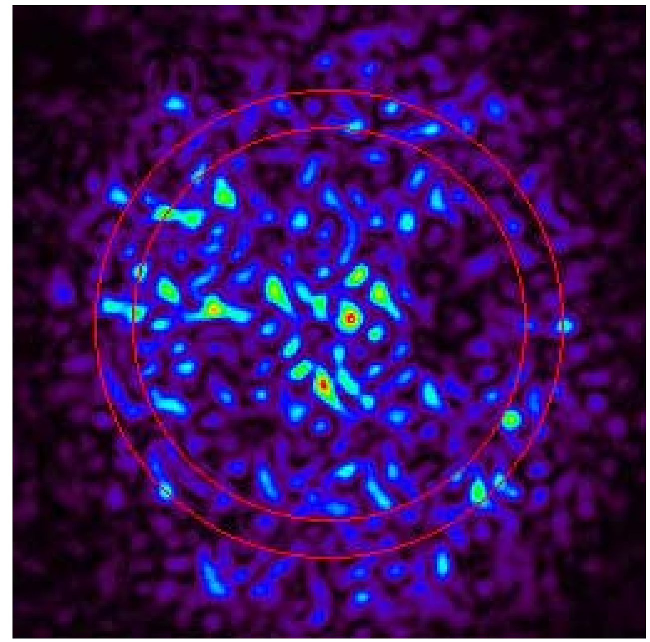
Ambient FFDP Measurements



0° Laser AOI
Mean OCS = 152×10^6 m^2

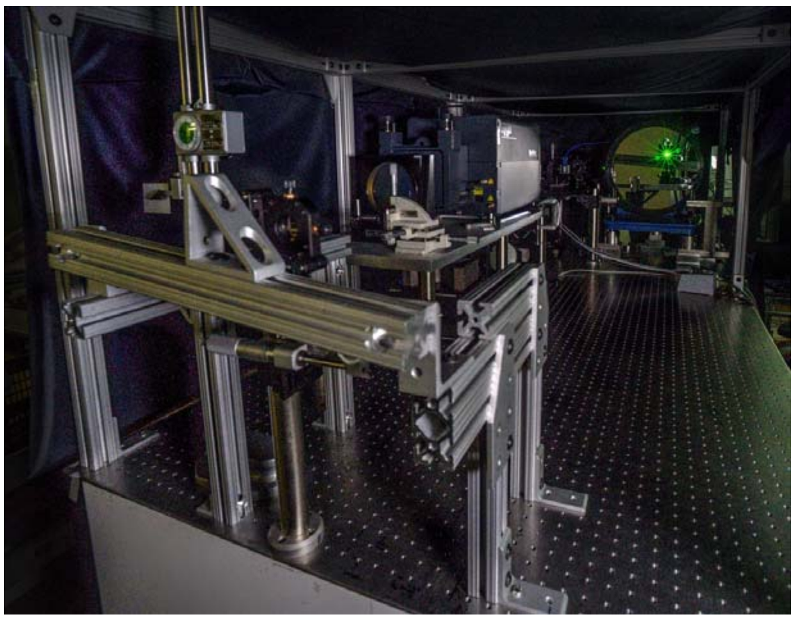


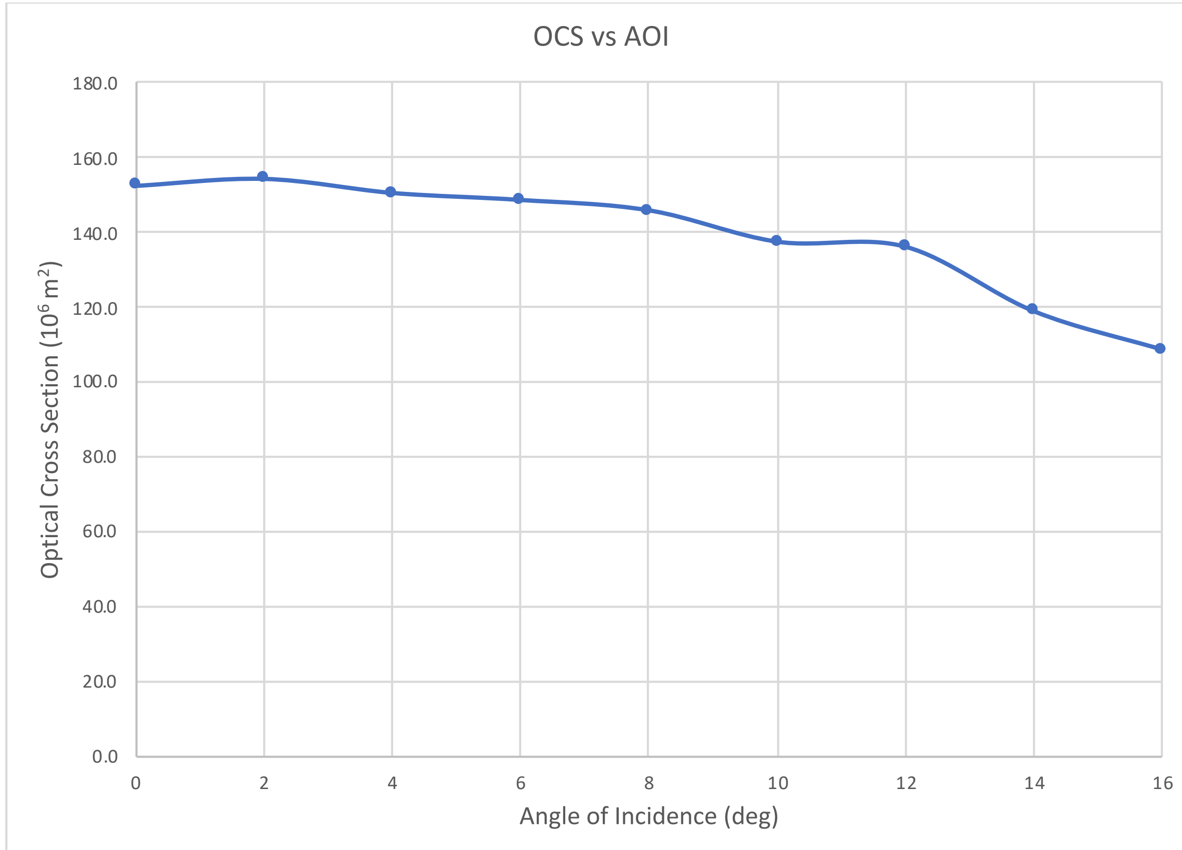
14° Laser AOI
Mean OCS = 119×10^6 m^2



16° Laser AOI
Mean OCS = 109×10^6 m^2

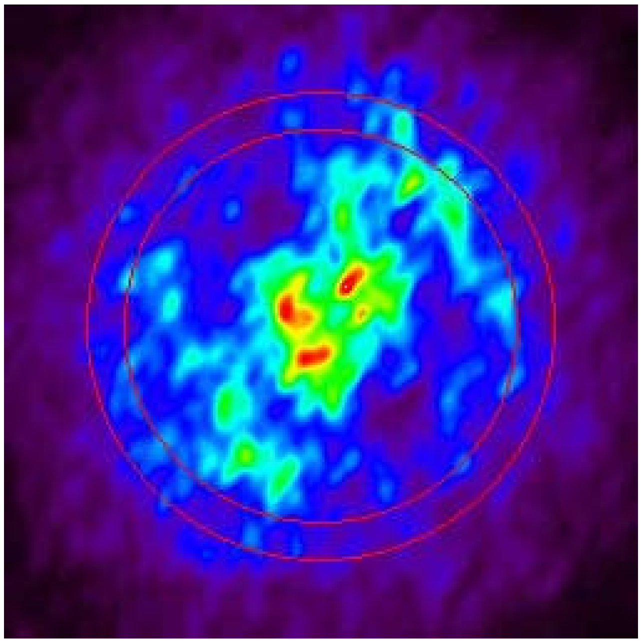
Mean Cross Section vs Laser Angle of Incidence



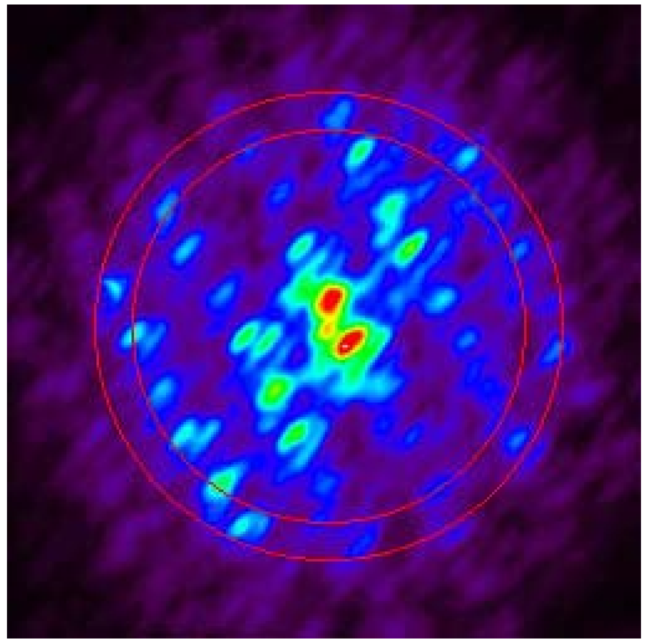


Preliminary result - some pixel count to OCS calibration issues remain

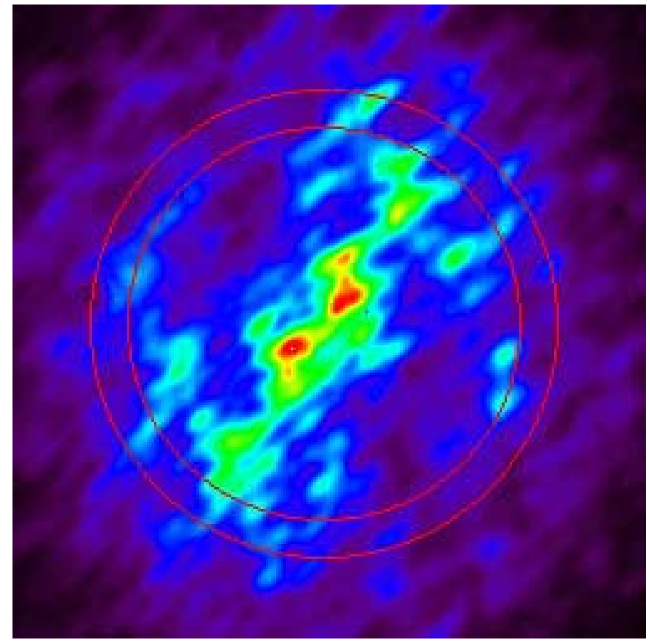
FFDP vs Solar AOI (Steady State)



0° AOI
Mean OCS = 151×10^6 m^2

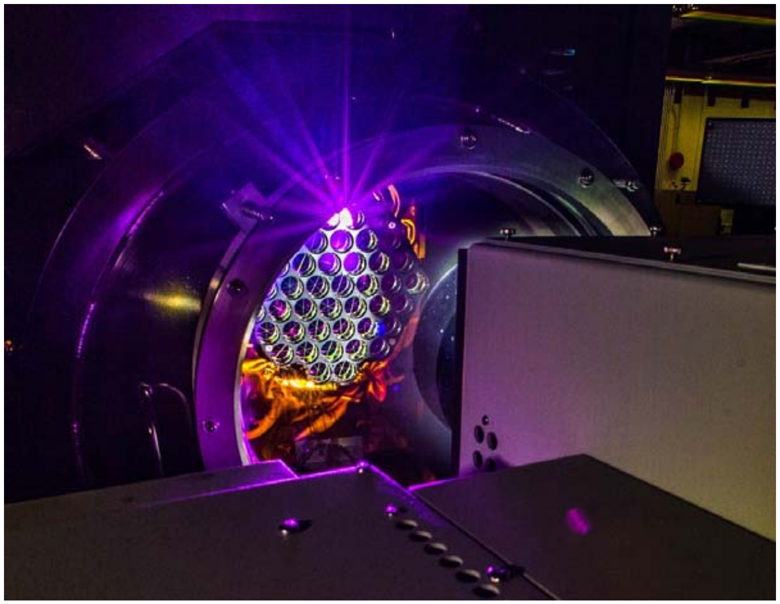


19° AOI
Mean OCS = 187×10^6 m^2

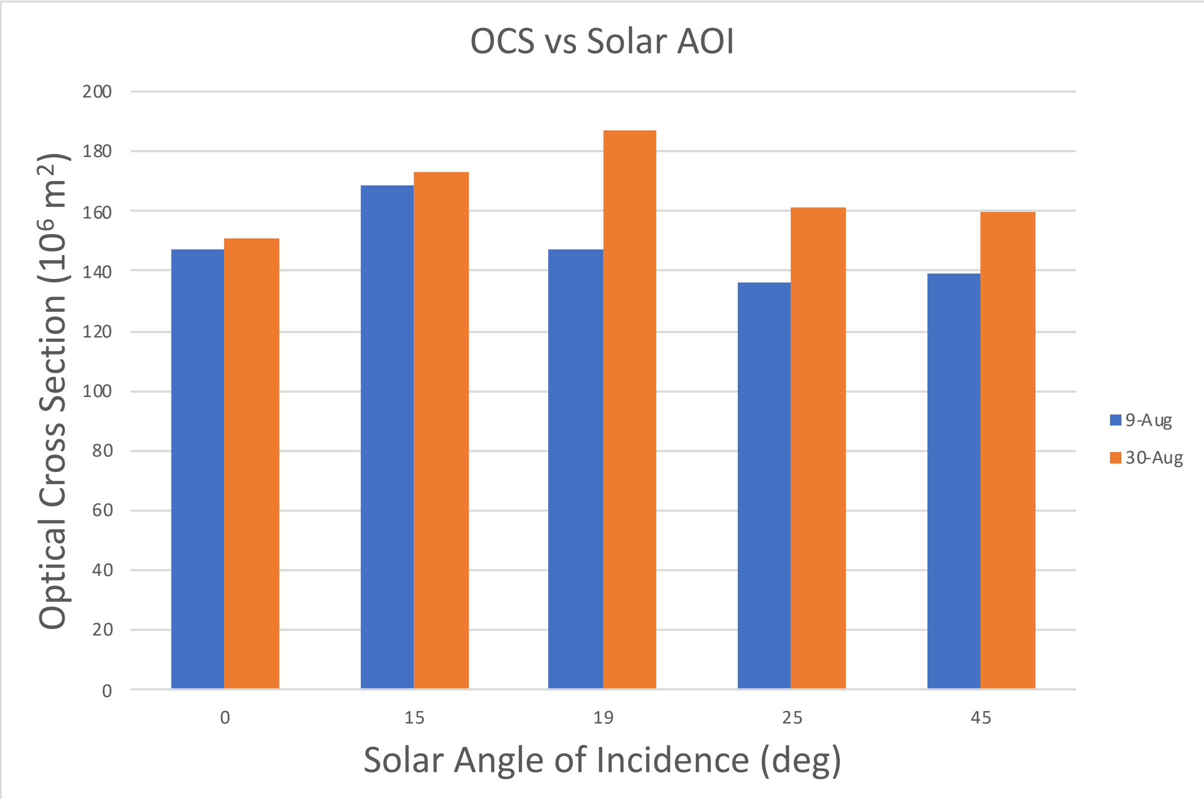


25° AOI
Mean OCS = 161×10^6 m^2

Mean Cross Section vs Solar AOI (Steady State)



Solar breakthrough occurs around 19°



Preliminary result - some pixel count to OCS calibration issues remain

Conclusions

- Demonstrated the GPS-LRA meets the ILRS cross section requirement over the range of SLR incidence angles.
- The cross section remains stable throughout the full range of solar incidence, including past the breakthrough angle.
- Full thermal-optical performance verification will be performed over the coming weeks, including:
  - Cold Test - soak the array to -18°C
  - Transient Test - sweeping through solar beam at orbital speeds
  - Deliberate Gradient Test - thermal gradients generated across the LRA with heaters