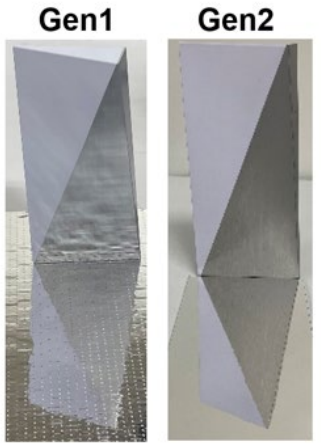
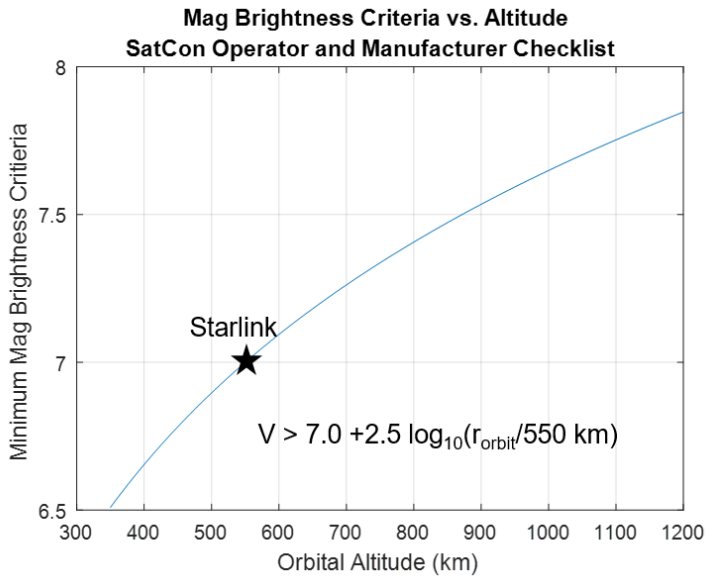
Mitigating Starlink Satellite Brightness

- Brightness Target
  - Derived from non-linear cross talk of Vera Rubin Sensor
- Component Scatter Measurement
  - 1,000+ scatter measurements of candidate materials
  - Developed / procured in-house measurement capabilities
- Modelling
  - Ray tracing analysis utilized for complex geometries
  - In-house MATLAB code developed to create satellite level predictions combining ray tracing results with simplified calculations for flat surfaces
    - 0.16 mag standard deviation error from latest on-orbit correlation set
  - Constellation level python analysis to understand night sky impact at any location for planned constellations
- Starlink v1 learnings and validated modelling informed Starlink v2 design, which is planned for flight soon on Starship
- Mitigation strategies utilized:
  - Materials and layout
    - Starlink v1.5 inter-cell material darkened
    - SpaceX dielectric mirrors scatter light away from earth and can be shared with industry
  - CONOPs
    - Knife-edging satellite to sun during orbit raise
    - Solar array terminator tracking has been baked into Starlink v2 power budget
  - Observer resources for planning
    - SpaceX shares both propagated ephemerides and covariance (statistical uncertainty of the predictions) data on Space-Track.org

Dielectric Mirror



Brightness Target



Terminator Tracking Mitigation

Sun Tracking
Ideal Power Generation

Brightness Mitigation
Reduced Power Generation