OPAL CubeSatellite Flight and Line of Sight Integration Modeling

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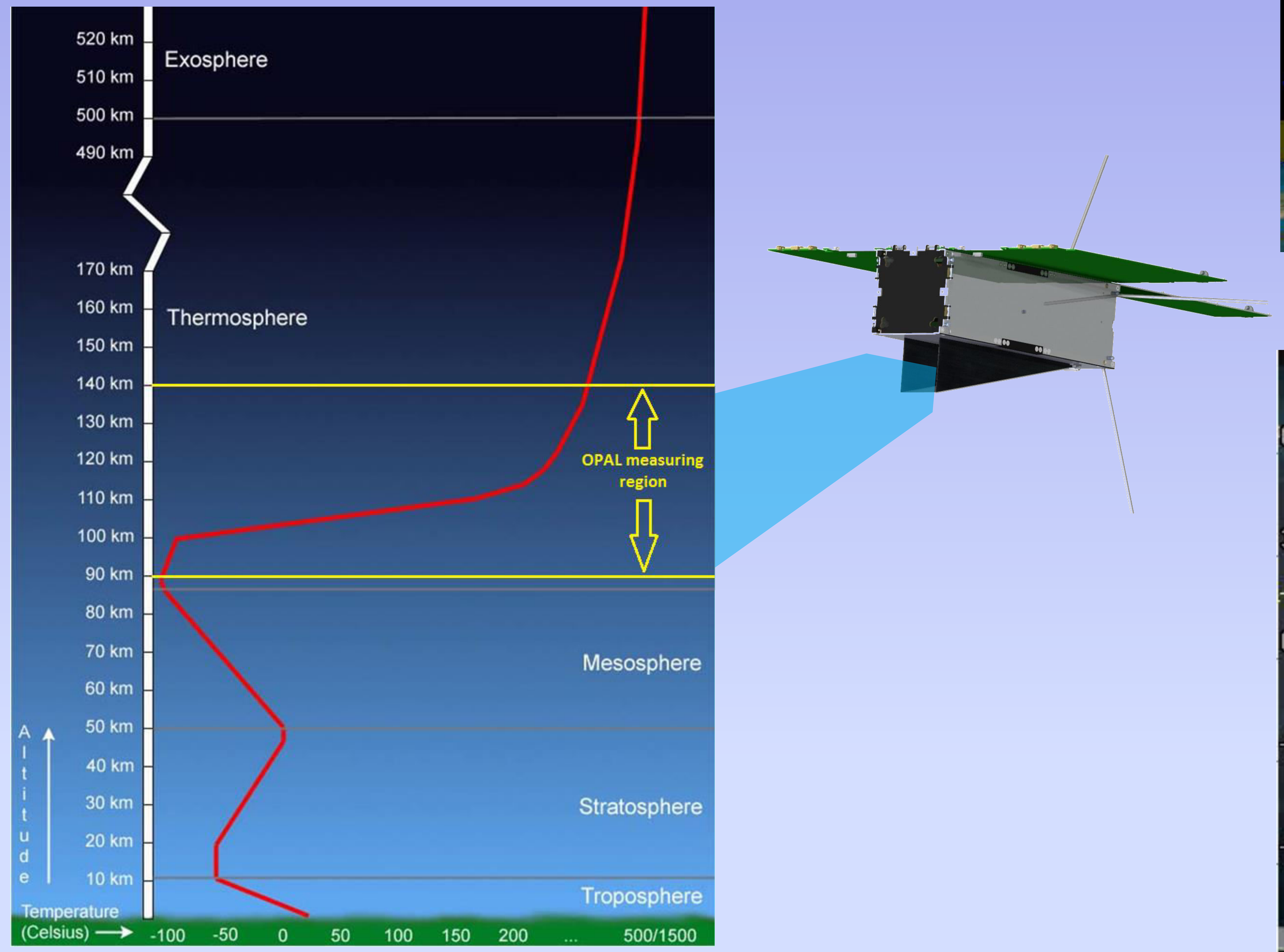
Optical Profiling of the Atmospheric Limb

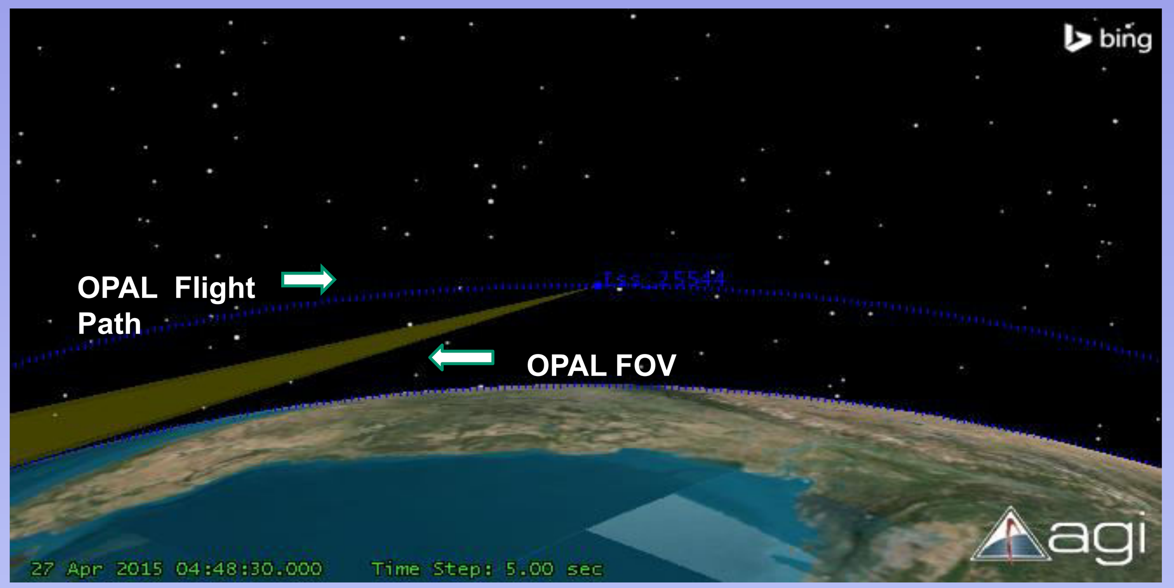
Mission Overview

Optical Profiling of the Atmospheric Limb (OPAL) 3U (10X10X30cm) CubeSat measuring Thermosphere temperatures [1]. OPAL will observe the temperature from 90-140km altitude through observing day-time emissions of O_2 A-band (~760nm) emissions.



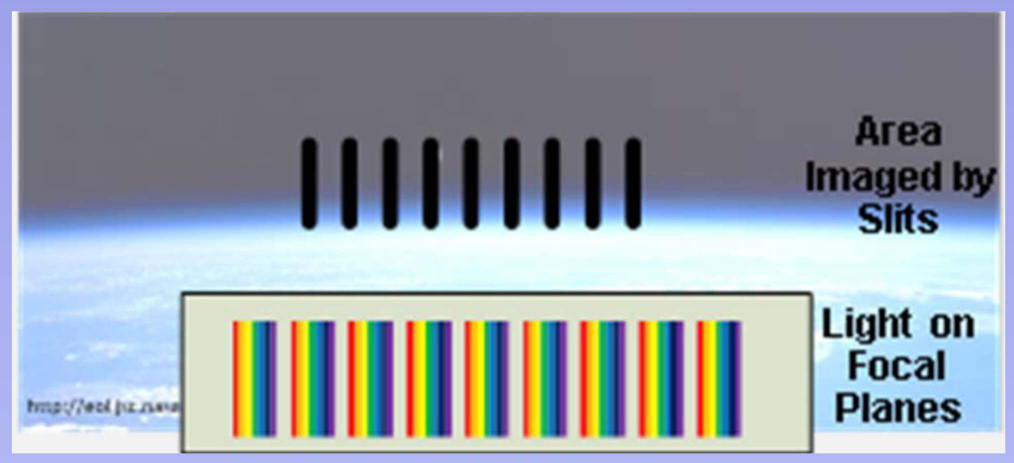
Plot of temperature vs. altitude with labeled atmospheric layers [2].

Flight Modeling



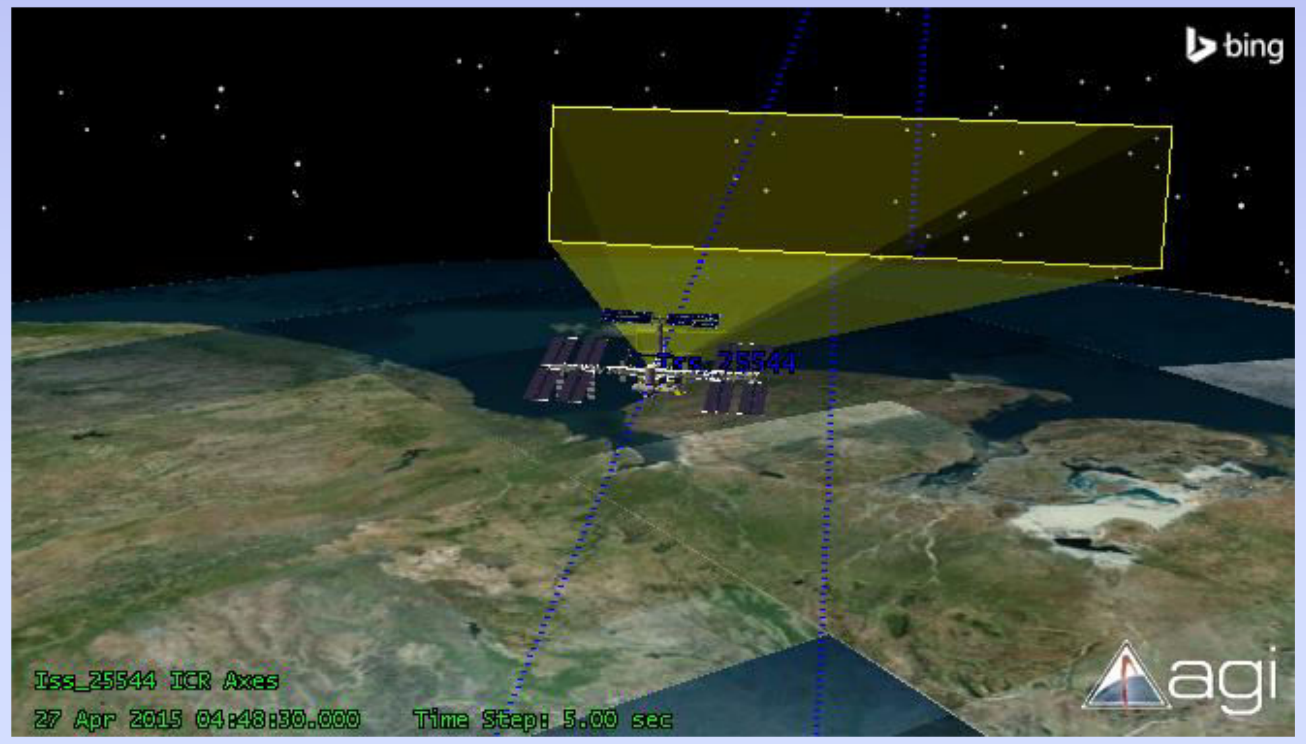
View of the tangential nature of the line of sight.

Using Matlab and Analysis Graphics Inc. (AGI) Systems Took Kit (STK), we model the OPAL position and velocity. The expected launch for OPAL is mid-2017 from the International Space Station (ISS), and is thus modeled with an orbit ~400km altitude. The OPAL instrument's field of view (FOV): width 11 deg height 2.5 deg.



Shows a cross section of the field of view of the OPAL imager through the 9 entrance slits that are the apertures of the imager [1].

2-D map of the OPAL model with Yellow representing sunlit regions, and red in the umbra regions.



Model of OPAL orbit (blue) with the FOV (yellow).

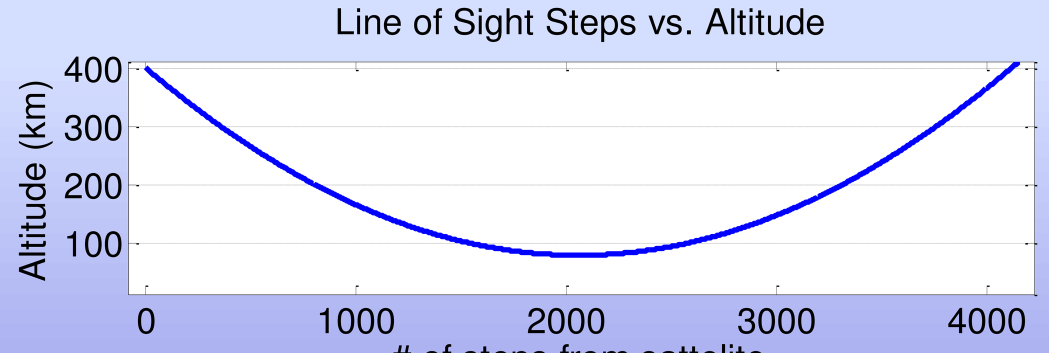
Line of Sight

OPAL measures the light emissions along its line of sight (LOS), therefore modeling of LOS is important.

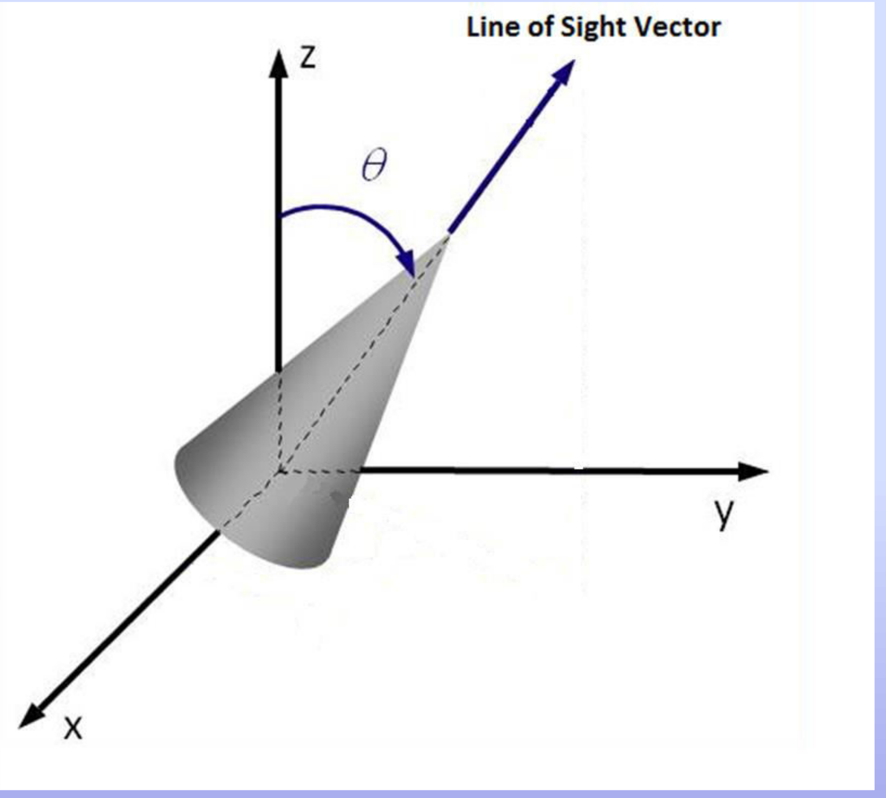
- **Express position (R) and velocity (V) of OPAL cubesat in Cartesian coordinates.**
- **Calculate a vector K perpendicular to both R and V (i.e. take cross product of R and V).**
- **Use the Rodrigues' Rotation Formula to obtain a vector in the line of sight.**
- **Step along the look direction in 1km steps.**

$$\begin{aligned}\mathbf{v}_{\mathrm{rot}} &= \mathbf{v}_{x\ \mathrm{rot}} + \mathbf{v}_{z\ \mathrm{rot}} \\ &= \mathbf{v}_{x\ \mathrm{rot}} + \mathbf{v}_{z} \\ &= (\mathbf{v} - (\mathbf{k}\cdot\mathbf{v})\mathbf{k})\cos\theta + (\mathbf{k}\times\mathbf{v})\sin\theta + (\mathbf{k}\cdot\mathbf{v})\mathbf{k} \\ &= \mathbf{v}\cos\theta + (\mathbf{k}\times\mathbf{v})\sin\theta + \mathbf{k}(\mathbf{k}\cdot\mathbf{v})(1-\cos\theta),\end{aligned}$$

Derivation of the Rodrigues' Rotation Formula. (with k being the vector perpendicular to v(rot) and theta as the angle rotated through).



Having the proper LOS gives the above graph of altitude as you move along the LOS. This minimum should be the 90km for OPAL minimum measured altitude.



Visual interpretation of the use of the Rodrigues' rotation formula. With Z=V, X=K, and Y=R (as described in the bullets).

References and Acknowledgements

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Members involved are: a student team at Utah State University, University of Maryland Eastern Shore and Dixie State University, supported by professional scientists and engineers from the Space Dynamics Laboratory, Hawk Institute and NASA is executing the OPAL mission.