TOROID

TOmographic Remote Observer of Ionospheric Disturbances

An FUV Photometer for Tomographic Observations of the Ionosphere

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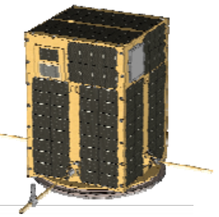
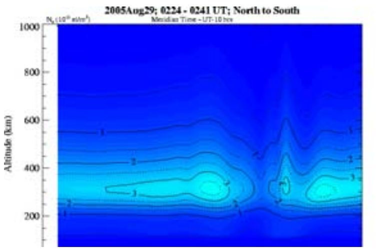


Science Mission

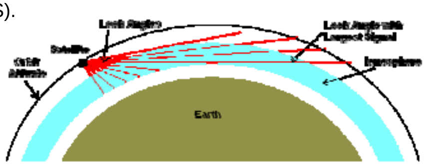
TOROID will measure FUV radiation at 135.6nm, created by the recombination of free electrons and atomic oxygen ions and, to a lesser degree, by the atomic oxygen ion-ion neutralization. These measurements will provide data to reconstruct a 2-dimensional vertical electron density profile using tomographic methods. This will allow detection and analysis of the Equatorial Anomaly (EA) and Equatorial Plasma Bubble (EPB) development and evolution possible with a resolution of 20km. Understanding these phenomena will assist in predicting and forecasting scintillations caused by plasma density irregularities (i.e. EPB), which reduce performance characteristics for the satellite to ground communication systems (i.e. GPS).



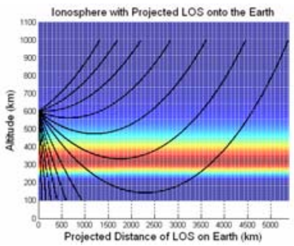
Typical tomographically reconstructed electron density profile created by Northwest Research Associates.

Signal Strength

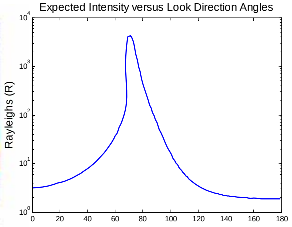
The largest signal acquired for the TOROID instrument would be in a look direction that crosses the most dense layer of the ionosphere twice.



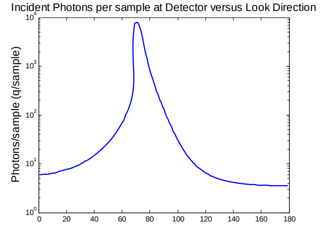
Look directions that cross through the ionosphere



Various look directions between 5º and 100º overlayed onto an (unrealistically consistent) electron density profile.



Expected emission intensities at various look angles (0º - 180º) in Rayleighs

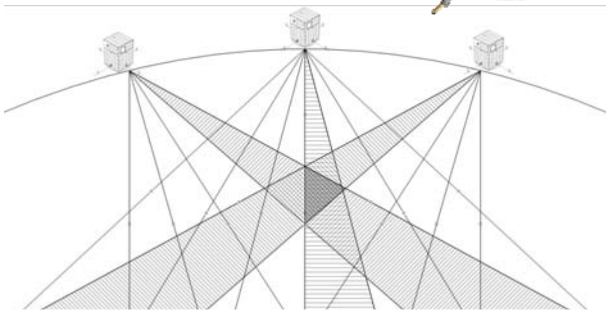


Expected photon flux incident on detector surface at various look angles (0º - 180º)

With an aperture set at 40mm (a small aperture for the expected weak signals), however, this dimension is consistent with the volume available on the satellite and the motor diameter. The FOV has been set at 1º, optimized with respect to the tomographic requirements (i.e. small FOV), the pointing knowledge and pointing accuracy of the spacecraft, and the necessary intensity to measure the signal strength. The reflectivity for the external and two filtering mirrors has been set at 40% for the above analysis. The external mirror will rotate at 1 Hz, causing a sample time of $T_s = T_{rot} \times FOV/360^o = 2.78$ ms. In the nadir direction, very few photons will reach the detector. However, in the look direction which crosses through the ionosphere twice, thousands or more photons will be incident on the detector. When measuring the ionosphere where the peak density is higher or lower, the photon rate will also be respectively increased or decreased.

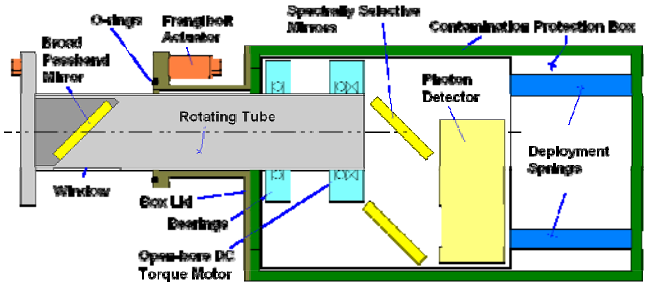
Tomography

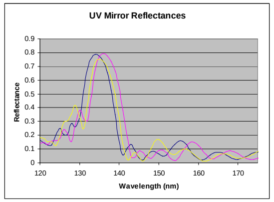
The TOROID mission is to take measurements of the airglow in the nightside ionosphere to enable the reconstruction of vertical electron density profiles. Using tomographic methods, the distribution of the radiation source (i.e. electron/atomic oxygen ion recombination) within all the pixels of a fragmentized vertical plane of the ionosphere can be determined and therefore electron density profiles can be generated. The algorithm consists of taking multiple measurements of the same location or pixel in the ionosphere from a number of positions along the satellite's orbit. This provides sufficient information to "parse" out the individual pixel airglow contributions. Since the TOROID instrument will be required to make all measurements from the altitude of ~600 km as it orbits the Earth, the measuring directions cannot all be orthogonal to each other. Thus, the satellite's accurate altitude, attitude, and instrument pointing knowledge are essential for calculating the pixel's geometry and local density in connection with all the other pixels in the plane.



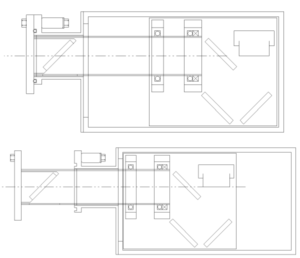
Photometer Design

The satellite is 3-axis stabilized. Therefore, an external rotating mirror has been designed to bend the incident light from the plane of the satellite's orbit to satisfy the methods for tomographic reconstruction, which require taking measurements in all 360º. This external mirror will rotate approximately 1 Hz. This rotating mirror will be broadband reflective in only the UV section of the spectrum. Once the UV radiation has entered the photometer, it will be reflected further on a number of spectrally selective mirrors. These mirrors will act as narrow band pass filters, passing light at the desirable wavelength (i.e. 135.6nm) and rejecting light at shorter and longer wavelengths. By using more than one spectrally selective mirror, the rejection ratio is increased. This is desirable since the 130.4nm spectral line, also produced by atomic oxygen recombination, is spectrally close to the 135.6nm emission line. The detector, a simple channeltron or channel electron multiplier (CEM), will be used for photon counting in pulse mode, and will be coated with cesium iodide to increase the detection efficiency.

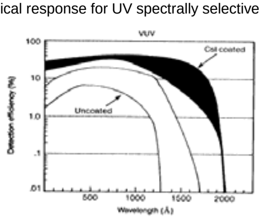




Typical response for UV spectrally selective mirrors.



TOROID photometer in retracted and extended positions. The photometer will require assembly in a clean environment and the evacuation of the containment box to increase lifetime of optical surfaces at UV radiation before and during launch. After outgassing the satellite on orbit, the external rotating mirror will be ejected and motor/mirror system will begin rotation. A frangibolt spring system is currently being investigated for this actuation.



Detector spectral response

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[Image] Burle Industries, Inc. (nd.) Channeltron Electron Multiplier Handbook for Mass Spectrometry applications.

[Image] High Freguency Active Auroral Research Program (HAARP), TEC Tomography Image Archive (http://www.haarp.alaska.edu/haarp/data.fcgi)