Deep Space Gateway Ecosystem Observatory (DSGEO). K. F. Huemmrich[1] , P. E. Campbell[2] and E. M. Middleton[3], [1]Joint Center for Earth Systems Technology, University of Maryland Baltimore County, Code 618, NASA Goddard Space flight Center, Greenbelt, MD 20771, karl.f.huemmrich@nasa.gov, [2]Joint Center for Earth Systems Technology, University of Maryland Baltimore County, Code 618, NASA Goddard Space flight Center, Greenbelt, MD 20771, petya.k.campbell@nasa.gov, [3]Code 618, NASA Goddard Space flight Center, Greenbelt, MD 20771, elizabeth.m.middleton@nasa.gov

Objectives: To advance global understanding of the dynamics in terrestrial ecosystem function, photosynthesis and environmental stress responses using vegetation spectral reflectance, thermal, and fluorescence signals. This requires global observations collected throughout the year to describe the two key temporal variables: seasonal change and diurnal variability. Observations would be at spatial scales relevant to global ecosystem models (1-10 km).

To accurately quantify plant photosynthesis and stress responses, DSGEO would provide a full description of the energy pathways of sunlight absorbed by chlorophyll (Chl) in ecosystems. The absorbed sunlight by Chl can be determined from reflectance wavelengths across the visible through shortwave infrared spectra, as the fraction of photosynthetically active ration absorbed by chlorophyll (fAPARchl). The energized Chl molecules release energy as they return to the ground state, and this energy is either used for photochemistry (leading to carbon fixation); or is actively discarded for photoprotection as heat in the form of non-photochemical quenching (NPQ) or as chlorophyll fluorescence emissions. Chlorophyll fluorescence (such as Solar Induced Fluorescence, SIF) can be directly measured in atmospheric windows (e.g., O2-A &B, Fraunhofer lines), while the energy dissipated by NPQ can be inferred from changes in spectral reflectance.

Measurements of Chl and other pigments from spectral reflectance can provide information about the photoprotective processes that plants use to mange longer-term (days to weeks) stress conditions while estimations of vegetation nutrients (e.g. nitrogen) and water content describe physical constraints on canopy/ecosystem photosynthesis. Thermal infrared (TIR) measurements of surface temperature provide further information on vegetation stress responses and evapotranspiration, linking ecosystem water and carbon cycles, as well as improving cloud detection and screening.

Instruments: 1) an imaging spectrometer with 5-10 nm spectral resolution covering from 400-2400 nm to measure plant pigments, nutrients, water content, and structural materials, 2) a second imaging spectrometer with high spectral resolution of 0.1-0.3 nm over 650-800 nm to measure red and far-red chlorophyll fluorescence necessary for describing activity in both Photosystems II and I., and 3) a thermal sensor imaging at multiple wavelengths in the 4-12 µm region for measurements of surface temperature and emissivity.

Instrument characteristics. Similar existing instruments include the Hyperion imaging spectrometer on Earth Observing 1 (EO-1), GOES (Geostationalry Operational Sattelite) and EPIC (Earth Polychromatic Imaging Camera) on DSCOVR (Deep Space Climate Observatory). Information on these instruments are included below to provide a sense of expected mass, size, and power requirements for DSGEO:

Hyperion
Volume (L x W x H, cm) 39x75x66
Weight (Kg) 49
Avg Power (W) 51
Peak Power (W) 126
Aperture (cm) 12 (we would need a larger aperture telescope)

EPIC Telescope:
Aperture, effective focal length
FOV, wavefront error
Cassegrain type with adjustable secondary for on-orbit focus
30.5 cm diameter, 282 cm
0.61º, 0.054 waves rms at 633 nm on-axis
Instrument power; total mass: 32 W (electronics), 30 W (operational heaters); 63.2 kg

GOES (12-15) imager:
5 channels covering VIS, MWIR and TIR
Mass (kg) 140, Power (W) 130,

Operations: From the vantage point of an orbit near the moon, each month the instruments would be able to collect multiple days of Earth views under a range of solar phase angles. In a two week period Earth views would go from surface dawn, through midday, into the afternoon, and finally sunset under consistent view angles. This differs from missions in geosynchronous orbit, by enabling observation of the entire Earth with a single set of instruments to produce a new consistent diurnal-seasonal dataset. Further, by being in an orbit near the ecliptic, a lunar Earth observatory views farther poleward during the high latitude summers when ecological activity in those regions are at their highest.

Secondary Activities: Along with the primary mission there are a number of secondary activities for the DSGEO:

1) Support exobiology studies by providing full Earth reflectance spectra collected at a range of phase angles and throughout the seasons. These spectra will provide a baseline of Earth's spectral characteristics to compare with observations from future exoplanet observatories in the search for Earth-like planets.

2) Many Earth viewing remote sensing satellites use lunar views for instrument calibration. The DSGEO instruments could be turned toward the moon for detailed descriptions of lunar spectral characteristics. The DSGEO hyperspectral measurements can be convolved to match the spectral bands of other instruments providing improved standards for calibration of other Earth-observing missions.

3) DSGEO observations of total solar eclipses on the Earth provide natural experiments in the Kautsky Effect. The Kautsky Effect occurs following illumination of a dark-adapted leaf, when there is a rapid rise in fluorescence from Photosystem II (PSII), followed by a slow decline. Such observations from various ecosystems would provide the first large-area canopy-level evaluation of this effect leading to improved understanding of photosynthetic processes at this global modeling scale.

4) From an observatory located near the moon, during the period of the full moon most of the Earth will be in darkness and not suitable for reflectance or fluorescence observations. The DSGEO spectrometer could be equipped with a high-gain mode where observations of nighttime Earth lights could be observed in a few broad spectral bands. Further, the TIR sensor would continue to be usable during Earth nighttime detecting fire and volcanic activity. The nighttime lights and fire information can be merged with the ecosystem observations in a consistent dataset to study human and disturbance effects on ecosystems.

5) While DSGEO would mostly be autonomous, there are benefits for it to be deployed on a human-tended station. Sensors on satellites often have solar diffusers, calibration standard panels, and/or calibration lamps, to describe changes in instrument response over time. Unfortunately, on unmanned satellites these calibration standards can change over time with no way to describe that change, creating uncertainties in instrument calibration. On the DSG, crew could periodically swap out instrument calibration standards (e.g. solar diffusers), returning the old one to Earth for evaluation of change over time and replacing it with a new well-characterised standard, thus providing a significant improvement in data quality, and aid in the development of accurate measurement time series.