Thermal Infrared Earth Imaging from the DSG. M.S. Ramsey[1] and P.R. Christensen[2], [1]Department of Geology, University of Pittsburgh, Pittsburgh, PA, 15260, mramsey@pitt.edu, [2]School of Earth and Space Exploration, Arizona State University, Tempe, AZ, 85287, phil.christensen@asu.edu.

Introduction: The general goal of NASA Earth Science research is to understand surface and atmospheric processes that lead to a better understanding of the Earth System. To advance this knowledge, data are used to model and monitor both short and longer-term change. In so doing, we enable more accurate prediction of those changes and improve our understanding of their consequences for life on Earth. Much of the data needed for this research are collected by an array of low Earth orbiting (LEO) and geostationary (GEO) satellite-based instruments coupled with ground and airborne measurements. However, these platforms do not provide data of the whole-Earth view at rapid timescales, which could be possible from the Deep Space Gateway in near-Lunar orbit.

An “Earth Observatory” at this location would offer a unique, stable, and serviceable platform for global, continuous, full-spectrum, unique views of the Earth needed to address a range of Earth Science issues over time. It would also provide instrument synergy among multiple LEO and GEO satellites for cooperative operations, enhanced calibration, and science. Depending on the final DSG location, full or somewhat limited views of the Earth will be possible. Earth-focused instruments on the Deep Space Gateway would be immediately useful for Earth science and instrument testing. Over a longer-term phased approach, however, time-dependent data of atmospheric composition, ecosystem health, and hazard monitoring could be possible.

The rotation of Earth as seen from the future DSG would provide unprecedented temporal views of transient phenomena. Furthermore, the Earth’s orbital precession would allow observations of the polar regions (something not possible with GEO satellites). However, the DSG will be many times further from Earth than GEO satellites, which makes acquiring data with useful spatial scales for smaller-scale processes more difficult.

Measurements: A dedicated Earth Observatory based on the DSG allows for global, continuous full-spectrum views of the Earth to address a range of Earth Science issues. The high temporal data frequency coupled with the ability to observe a given location for up to 12 hours enables detection and analysis of time-dependent atmospheric composition (i.e., global mapping of emissions, long-range transport of pollution plumes, greenhouse gases sources and sinks). This observational geometry makes new solid-earth, ecosystem and climate monitoring possible (i.e., volcanic eruptions, wildland fires, health and structure of vegetation, drought and land degradation). With climate change comes the critical need to observe changes in the cryosphere (i.e., ice shelf disintegration, sea ice change, snow cover cycles). Such a platform also allows the Sun-Earth system to be observed simultaneously, providing data on the Earth’s radiation balance and solar variability influence on climate. Finally, the numerous limb occultation opportunities over wavelengths from the visible (using stars) to the microwave (using GPS signals) to VHF (using communication signals) provide additional opportunities for observing the vertical structure of the Earth’s atmosphere.

Instrument Concept: Thermally-elevated features (volcanic, fire, and anthropogenic activity) are currently monitored at high spatial resolution with LEO-based instruments such as ASTER, TIRS and MODIS. These features are monitored at high temporal resolution by GEO-based observations. These sensors are not able to capture data at time scales really required for scientific and hazard analysis in near-real time; nor can they track a specific event over time.

A DSG-based instrument capturing high temporal frequency data could achieve the needed temporal frequency. Perhaps even more critically, it could serve in conjunction with LEO and GEO satellites in an enhanced sensor-web approach. Such an instrument could be phased, upgrading over time from a more simplified multispectral imager to a full spectral resolution imaging spectrometer. Full Earth views are critical for such a concept to be fully realized, but the telescope could be as small as 30-50 cm and achieve acceptable spatial resolution.

Thermal infrared (TIR) image-based and spectral-based data would be one important data set to consider for a DSG application. These data allow for the detection of thermally-elevated features as well as detailed compositional analysis of atmospheric and surface processes. Instruments in Earth and Mars orbits have shown the scientific importance of these data and a recent observation of Earth from a great distance (Fig. 1) by the OTES instrument on the OSIRIS-REx Mission confirm these measurements are possible and quite useful [1].

At the 2007 Lunar Workshop in Tempe, AZ, we summarized a concept of a modest TIR imager having a 30 cm aperture with a 0.2° IFOV and a 2,048 pixel array (similar to the HiRISE Camera Mars Reconnaissance Orbiter) that would provide 10 km/pixel (TIR) data [2]. Such an imager would only cover a 1,000 km x 1,000 km field of view during a given scan. A complete Earth view could be built up over time. However, if the sensor was made pointable, it could be integrated into a sensor web concept with LEO and GEO satellites to target quickly any given location on Earth. Alternatively, the instrument could target a particular location and track it throughout the 12-hour period that it would be in view. Examples targets necessitating this tracking option would be wildfires, large volcanic plumes or pollution events.

Such an instrument could be part of an initial suite on the DSG designed be upgradeable over time. This would involve astronaut involvement to upgrade focal plane arrays, incorporate new technologies, operate in research mode, and provide real-time link between GEO and LEO observations.

References: [1] Christensen P.R. (2016) Looking Forward – A Next Generation of Thermal Infrared Planetary Instruments, AGU Fall Mtg., P33H-01. [2] Ramsey, M.S. (2007) Earth Science Report, NASA Advisory Council Workshop on "Science Associated with the Lunar Exploration Architecture".

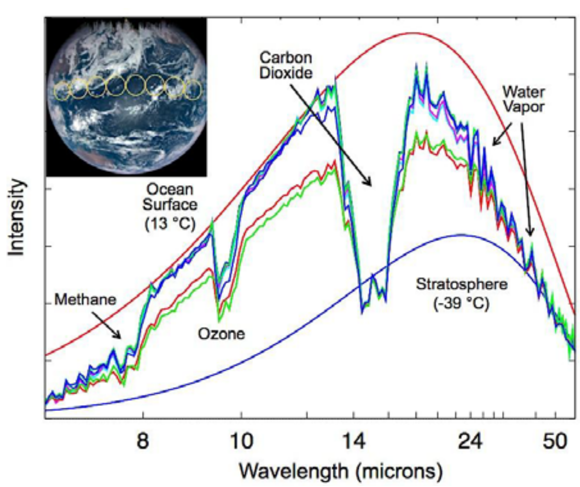

Figure 1. Showing almost entirely ocean and clouds, planet Earth (upper left) appears misnamed in this view taken by OSIRIS-REx on Sept. 22, two hours after its closest approach to Earth. The circles, each about 500 miles in diameter, indicate where the OTES spectrometer made its observations.