**Radiometric calibration of earth science imagers using HyCalCam on the Deep Space Gateway platform.** J. J. Butler[1] and K. J. Thome[1], [1]NASA Goddard Space Flight Center.

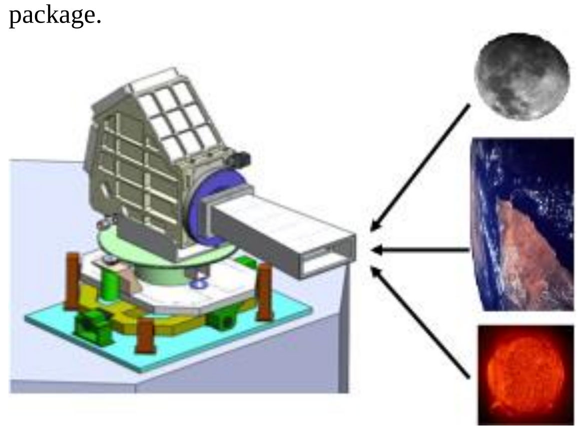
**Introduction:** The need to improve the accuracy of data obtained from Earth observing satellite instruments has been internationally recognized and extensively documented [1-5] with on-orbit sensor intercalibration identified as a key component. The importance of on-orbit instrument intercalibration in quantifying the relative biases between satellite instrument measurements and in bridging potential data gaps in measurement records is reinforced by the large number of existing intercalibration techniques [6]. Still, the major limitation of satellite sensor intercalibration is the lack of a high accuracy, on-orbit reference standard instrument with calibration traceable to the International System of Units (SI). Advances in the metrology of satellite instrument calibration, such as the National Institute of Science and Technology's (NIST) facility for Spectral Irradiance and Radiance Responsivity Calibrations using Uniform Sources (SIRCUS) [7, 8], and in on-orbit instrument calibration techniques using the Moon and well-characterized Earth surface sites can now be used in tandem to realize order of magnitude levels of improvement in satellite instrument intercalibration.

The HyCalCam instrument on the Deep Space Gateway platform in a cis-lunar orbit meets the requirements for an SI-traceable, high accuracy, reference standard for satellite instrument calibration. HyCalCam is an imaging spectrometer that combines views of the moon and earth to characterize the lunar surface and various terrestrial scenes for use as absolute calibration sources for LEO and GEO sensors. Measurements are referenced to solar views to place the data on an absolute, SI-traceable scale. Cost estimates based upon current instrument builds of a similar nature are <$60M for the sensor and gimbal interface that allows pointing of earth sites and solar views. Crew interaction would be needed for set up only and such efforts would be of similar nature as the CLARREO Pathfinder mission that is planned for the International Space Station.

Deployment and operation of the HyCalCam instrument on the Deep Space Gateway provides a large number of important benefits to Earth remote sensing. HyCalCam provides a factor of 4 to 10 improvement in current on-orbit radiance measurements of Earth targets such as pseudo-invariant calibration sites, sites used in Simultaneous Nadir Overpass (SNO) studies, vicarious ground and airborne campaign sites, and uniform natural atmospheric targets such as Deep Convective Clouds (DCCs). Lunar radiance measurements of the Moon by HyCalCam over a period of at least 3 years to ensure sufficient sampling of the Moon across phase and libration establishes the Moon as a on-orbit absolute radiometric standard or common "solar diffuser" for both LEO and GEO instruments capable of viewing the Moon. Absolute, SI-traceable lunar radiances and irradiances from HyCalCam could be used to bridge potential gaps in the acquisition of data used in Earth observation records. Since the Moon visible to on-orbit satellite instruments exactly repeats over a period of 18 years, satellite instruments which have acquired lunar images in the past could be retroactively calibrated using the lower uncertainty, absolutely calibrated lunar radiances and irradiances derived from HyCalCam.

**Sensor design:** The sensor design of HyCalCam is based on an Offner imaging spectrometer similar to that of the Climate Absolute Radiance and Refractivity Observatory (CLARREO) Reflected Solar Instrument design to provide rigorous SI traceable observations The instrument is designed to retrieve an at-sensor reflectance over the spectral range from 320 to 2300 nm with a 500-m GIFOV and a 100-km swath width. Modifications to the design would be needed to allow similar spatial resolutions from Deep Space Gateway orbits. Reflectance is obtained from the ratio of measurements of radiance while viewing the earth's surface to measurements of irradiance while viewing the sun.

The instrument approach is an Offner imaging spectrometer operating as a pushbroom scanner relying on heritage hardware to reduce sensor complexity. The sensor would rely on a MgCdTe focal plane to provide spectral coverage for the 320 to 2300 nm.. spectral range. An all-aluminum design limits the impacts of thermal effects on the sensor behavior. A final optical design would depend on the final orbit selected for the package.



**Operations:** The overall mass of the spectrometer sensor is 20 kg with an overall sensor mass including pointing gimbal and electronics of 70 kg based on similar past sensors and a recent balloon-borne sensor. Estimated volume for the sensor package is 50 cm x 20 cm x 30 cm. The senosr would require 100 W average power and 120 W peak power with a data volume of 70 Gb/day. The detector package requires a cryoradiator view to <180 K source (deep space ideal) and the sensor design makes use of an all-aluminum structure to minimize impacts from temperature changes.

The use of the sun as the calibration reference means that clear views of the solar disk are needed to allow conversion of the earth and lunar views to reflectance. A gimbal mount was designed to allow operation of the CLARREO RS to view solar disk, lunar surface, and earth surface. Solar disk views are required on a bi-weekly basis. The choice of orbit is ideally one which would allow a near-full disk view of the lunar surface with regular views of the earth's surface between 45 degrees north and south.

**References:** [1] Ohring G. B., Ed. (2007) Achieving satellite instrument calibration for climate change ($ASIC^3$), NOAA, 142 pp. [2] Ohring G. B. et al. (2005) *Bull. Amer. Meteor. Soc.,86*, 1303-1313. [3] GEO (2005) The Global Earth Observation System of Systems (GEOSS) 10-year Implementation Plan, 11 pp. [4] Global Climate Observing System (2011) Systematic observation requirements for satellite-gased data products for climate: 2011 update. GCOS-154 WMO, 128 pp. [5] Goldberg M. et al. (2011) *Bull. Amer. Meteor. Soc., 92*, 467-475. [6] Chander G. et al. (2013) *IEEE Trans. Geosci. Remote Sens., 51*, 1056-1080. [7] Brown S. W. et al. (2006) *Appl. Opt., 45*, 8218-8237. [8] Fox N. A. et al. (2011) *Philos. Trans. Roy. Soc., 369A*, 4028-4063.