Pre-launch Testing and Post-launch Performance

Assessment of pre- and post-launch calibration and performance characterization for operational remote sensing systems

- Pre-launch and on-orbit measurement techniques
- Instrument transition from the laboratory to space environments
- Application of ground calibration results to on-orbit measurements
- Operational sensor calibration lessons learned

1:10

Leveraging the GPM Microwave Imager (GMI) Calibration Standard
David Draper, David Newell, Quinn Remund, Michael Berberich, Don Figgins – Ball Aerospace & Technologies

ABSTRACT: Next-generation defense weather satellite system require accurate measurements of top-of-atmosphere brightness temperatures to determine ocean surface vector winds, tropical cyclone intensity, and other environmental products necessary to support our war fighters. At Ball Aerospace, we have built the Global Precipitation Measurement (GPM) Microwave Imager (GMI) designed to be the radiometric calibration standard for a group of national and international passive microwave instruments in the GPM constellation. Ball and Remote Sensing Systems supported the initial on-orbit operations to verify calibration performance and provide a final set of operational calibration algorithms. The GMI instrument was launched onboard the GPM spacecraft on February 28th, 2014. GMI has operated nearly continuously since March 4th, 2014. This paper presents GMI’s on-orbit performance and calibration results and provides a top-level overview of how the GMI can be leveraged for next-generation defense weather missions.

1:35

The Experimental Hyperspectral Imaging Microsatellites SPARK-01 and -02: Radiometric Calibration and Overall Performance
Hao Zhang, Zhengchao Chen, Bing Zhang – Key Laboratory of Digital Earth Science, Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences; Benyong Yang – Hefei Institutes of Physical Science, CAS

ABSTRACT: At 3:22 am UTC on 22 December 2016, two wide-swath push broom hyperspectral imaging microsatellites, SPARK-01 and -02, which were manufactured by the Shanghai Engineering Center for Microsatellites for experimental aims, were successfully launched at the Jiuquan satellite launch center by the CZ-2D rocket. SPARK-01 and -02 have spectral ranges of 400–1000 nm, a swath of ~100 km, a spatial resolution of 50 m and 2048 pixels along the cross-track direction. This report will give a comprehensive introduction to the radiometric performance of the satellites and data acquiring status. Due to the lack of on-board calibration device and less measurements before launch, the radiometric calibration coefficients were determined for these two satellites via a calibration experiment performed from the end of February to the beginning of March 2017 at the high-altitude, homogenous Dunhuang calibration site in the Gobi Desert in China. In-situ measurements, including ground reflectance, direct transmittance, diffuse-to-global irradiance ratio, and radiosonde vertical profile, were acquired. A unique relative calibration procedure was developed using actual satellite images. This procedure included dark current computation and non-uniform correction processes. The former was computed by averaging multiple lines of long strip imagery acquired over open oceans during nighttime, while the latter was computed using images acquired after the adjustment of the satellite yaw angle to 90 degree. This technique was shown to be suitable for large-swath satellite image relative calibration. After relative calibration, reflectance, irradiance, and improved irradiance-based methods were used to conduct absolute radiometric calibrations in order to predict the top-of-atmosphere (TOA) radiance. The calibration uncertainty is estimated to be less than 6%.

Although these two experimental hyperspectral satellites have been decommissioned till April of 2017, a huge hyperspectral data, mostly over China and neighboring regions, have been acquired during half a year period. A number of dark current images and 90 degree yaw angle images were acquired to evaluate the relative stability of radiometric performance among the cross track pixels. Also, the relative differences of the response of detectors were also evaluated under different radiance levels by acquiring yaw 90 imageries over desert,
common ground surface, snow/ice (i.e. Antarctic regions) and a comprehensive model for the relative radiometric correction of spark 01/02 was also refined. Furthermore, other radiometric performance was also evaluated, like signal-to-noise ratio, spectral wavelength shifts, bad pixels, etc.

2:00

**Initial Pre-Launch Imaging and Spectral Characterization of Landsat 9 Thermal Infrared Sensor-2**

Aaron Pearlman, Boryana Efremova – GeoThinkTank LLC; Joel McCorkel, Amy Simon, Jason Hair, Dennis Reuter – NASA Goddard Space Flight Center; Matt Montanaro – Rochester Institute of Technology; Brian Wenny – Science Systems and Applications, Inc. (SSAI); Allen Lunsford – Catholic University of America

**ABSTRACT:** The Thermal Infrared Sensor-2 (TIRS-2) scheduled to launch in December 2020 aboard Landsat 9 will continue Landsat’s four decade-long legacy of providing moderate resolution thermal imagery from low earth orbit (at 705 km) for environmental applications. Like the Thermal Infrared Sensor aboard Landsat 8, it is a pushbroom sensor with a cross-track field of view of 15° and provides two spectral channels at 10.8 and 12 µm. To ensure radiometric, spatial, and spectral performance, a comprehensive pre-launch testing program is being conducted at NASA Goddard Space Flight Center at the component, subsystem, and instrument level. This effort will focus on the results from the subsystem level testing to assess TIRS-2 imaging performance including focus, spatial performance, and stray light rejection. It is also used to provide a preliminary assessment of spectral performance. The TIRS-2 subsystem is placed in a thermal vacuum chamber with the calibration ground support equipment, which provides a flexible blackbody illumination source and optics to assess imaging performance. Spectral performance is tested using a spectral response test setup with its own illumination source outside the chamber that propagates through the calibration ground support equipment in an optical configuration designed for this purpose. The results show that TIRS-2 performance is expected to meet all of its performance requirements with few waivers and deviations.

2:25

**Preflight Characterization of the OCO-3 Imaging Spectrometer**


**ABSTRACT:** The Orbiting Carbon Observatory 3 is expected to complete its final thermal vacuum test in April 2018. The test program was largely the same as for OCO-2, where the radiometric, spatial, spectral, and polarimetric properties of the spectrometer were measured. Dozens of requirements were verified, including spectral resolution above 17,000 and absolute radiometric performance to within 5%. Notable changes to the hardware include a different telescope with a wider field of view, context cameras, and a Pointing Mirror Assembly. The instrument was illuminated with its internal calibration lamps, an external integrating sphere traceable to NIST standards, diffuse sunlight, collimated light on movable stages, and tunable lasers. Retrievals of uplooking measurements were validated against a collocated TCCON station.

2:50

**Calibration and On-Orbit Validation of the NOAA-20 CrIS Interferometer**

Kori Moore, Mark Esplin, Joe Kristl, Deron Scott, Ben Esplin – USU/Space Dynamics Laboratory

**ABSTRACT:** On November 18, 2017, the JPSS-1 satellite was launched into polar orbit and renamed NOAA-20. Included in its instrument suite is the Cross-Track Infrared Sounder (CrIS) that collects spectra used for atmospheric soundings with twice-daily global coverage. CrIS creates radiometrically calibrated spectra at 0.625 cm-1 resolution covering three spectral regions from 4 to 15 micrometers, with a 3x3 focal plane array and a nadir footprint of 14 km. NOAA-20 joined the orbit of its predecessor, Suomi National Polar-orbiting Platform (SNPP), with a half-orbit delay to provide better near-nadir coverage for the globe. NOAA-20 CrIS is a copy of the CrIS instrument on SNPP with a few electronics upgrades. The SNPP CrIS has performed well over its six years on orbit and continues to collect valuable data. NOAA-20’s CrIS data is in provisional status during further comparisons before an expected upgrade to full operational status later in 2018. The NOAA-20 CrIS sensor had extensive ground calibration and has been undergoing further on-orbit validation since data collection began on January 4, 2018. Performance optimization on orbit resulted in only small changes to select pre-launch settings due to the robust on-ground calibration. In addition, on-orbit CrIS noise levels are similar to on-ground testing. This presentation will cover the results of JPSS-
1/NOAA-20 CrIS noise characterization, calculated as the Noise Equivalent change in Radiation (NEdN), from both on-ground and on-orbit testing. In summary, the NOAA-20 CrIS instrument has performed well to date, meeting specified NEdN requirements. It performs comparable to SNPP CrIS, which still meets NEdN requirements. In addition, the relative responsivity (RR) of the NOAA-20 detectors has been tracked since on-orbit data collection began. RR was calculated as the difference between detector responses when viewing deep space and internal calibration targets. The NOAA-20 CrIS RR has thus far been stable after instrument optimization updates were applied on-orbit. The SNPP CrIS has performed very well in regards to RR—values are within 2% of initial RR for all but the shortest wavelengths, which have shown RR degradation of no more than 6% over the spacecraft lifetime. The latest updates on NOAA-20 and SNPP CrIS NEdN and RR will be included.

3:30

Yaw Maneuver Derived Vignetting Functions for NOAA-20 VIIRS
Jeff McIntire – Science Systems and Applications, Inc. (SSAI); Jack Xiong – NASA Goddard Space Flight Center

ABSTRACT: The NOAA-20 spacecraft (formerly JPSS-1) executed a series of yaw maneuvers on January 25 and 26, 2018 designed to validate / characterize the transmittance functions of the Visible Infrared Imager Radiometer Suite (VIIRS) instrument solar diffuser (SD) and solar diffuser stability monitor (SDSM) views. On orbit, only the product of the attenuation screen transmittance and SD bidirectional reflectance distribution function (BRDF) can be measured for the VIIRS detector and SDSM SD views. For the SDSM solar view, the attenuation screen transmittance was directly measured. All three transmittance functions were compared to the at-launch functions derived from pre-launch characterization and their effect on the instrument responsivity estimation and SD degradation trending on-orbit was investigated. While both the SD views showed good agreement with the at-launch values (within 0.1 – 0.2 % averaged over a given orbit), the differences in the SDSM solar screen vignetting function relative to the pre-launch estimate impacted the SD degradation by ±1 %. Although the vignetting function derived from the yaw maneuvers considerably improved the SD degradation trending, significant oscillations in the trending remained. The angular sampling provided by the yaw maneuver data was too coarse to capture the fine structure of the vignetting function; additional maneuvers may be added to improve the fidelity of the function. An uncertainty analysis was also conducted on all transmission functions derived.

3:55

Calibration/Validation Activities for GOES-16 and GOES-17 Products
Jon Fulbright – ASRC Federal; Elizabeth Kline – SGT, Inc.; David Pogorzala – IAI, Inc.; Kathryn Mozer, Matthew Seybold – NOAA/NESDIS/OSPO

ABSTRACT: The Geostationary Operational Environmental Satellite-R (GOES-R) series is the next generation of NOAA geostationary environmental satellites. The first satellite in the series, GOES-16 became the operational GOES-East satellite in December 2017. GOES-17, the second satellite in the series, was launched on March 1, 2018 and is currently in its Post-Launch Test phase. The satellites carry six instruments dedicated to the study of the Earth’s weather (ABI), lightning (GLM), the Sun (EXIS and SUVI), and and in-situ space environment (MAG and SEISS). For both satellites, a series of Post-Launch Test and Post-Launch Product Tests have been or are being conducted to validate, calibrate, and characterize both the instruments and the data products. In this talk, we describe some of the major cal/val activities that have taken place since launch for both satellites, focusing mainly on ABI and GLM. We will give the first status of the GOES-17 instruments, and an update of the status of the GOES-16 products, and the path forward.
**The CAESAR New Frontiers Mission: Overview and Imaging Objectives**

**ABSTRACT:** The Comet Astrobiology Exploration Sample Return (CAESAR) mission will acquire and return to Earth for laboratory analysis a minimum of 80 g of surface material from the nucleus of comet 67P/Churyumov-Gerasimenko (67P). CAESAR will characterize the surface region sampled, return the collected solid sample in a pristine state, and return evolved volatiles by capturing them in a separate gas reservoir. A key to mission success is to select a sample site that provides high science value, and that is fully compatible with safe and successful sampling. Key supporting objectives are to characterize the sample site and its geophysical and geomorphic context, and to study the comet environment to identify spacecraft hazards including moonlets, jets and plumes.

These mission objectives drive a number of key imaging requirements that in turn drive camera designs and calibration: detecting 50-cm objects from 500 km; resolving 2.5-cm particles from 650 m; obtaining 5° and 30° field of view optical navigation images; identifying 1-cm particles from 50 m; imaging at multiple colors, matching a subset of the Rosetta OSIRIS filter bandpasses; documenting the sample site before, during, and after sampling at sub-cm resolution; and documenting sample acquisition during sampling and packaging inside the return capsule. In order to accomplish these goals, CAESAR carries a high-heritage suite of six well-calibrated cameras of varying fields of view and focal ranges: narrow angle camera (NAC), medium angle camera (MAC), touch-and-go camera (TAGCAM), two navigation cameras (NAVCAMs), and a sample container camera (CANCAM).

**4:50**
**The CAESAR New Frontiers Mission: Camera Suite Calibration Planning**
Joe Tansock, John Seamons, Alan Thurgood – USU/Space Dynamics Laboratory; Alex Hayes – Cornell University; Jason Soderblom – Massachusetts Institute of Technology

**ABSTRACT:** The Comet Astrobiology Exploration Sample Return (CAESAR) mission has been awarded Phase A study by NASA. The CAESAR mission is to acquire and return to earth a sample of the comet 67P/Churyumov-Gerasimenko. The camera suite on the spacecraft consists of 6 cameras. This suite consists of a narrow angle camera (NAC), medium angle camera (MAC), touch-and-go camera (TAGCAM), sample container camera (CANCAM), and two navigation cameras (NAVCAMs). Following optical and mechanical validation at the sensor vendor, the Camera Suite is delivered to Space Dynamics Laboratory (SDL) for calibration. Camera designs were determined from mission requirements. The formulated pre-launch calibration plan quantifies camera performance at anticipated operational environmental conditions, verifies camera requirements, is heritage-based, utilizes existing equipment to reduce cost and schedule, and enhances the science value of camera data. The development of this plan and a subsequent pre-launch calibration matrix will be discussed. In-flight calibration verifies and validates the pre-launch calibration, monitors and updates calibration, and quantifies camera performance. In-flight considerations and a preliminary calibration matrix will also be discussed.