Tuesday, September 22, 2020 | 2:45 p.m.

Technical Session

Sensor Calibration and Testing for Hosted Small Satellite Payloads

Examining small satellite payload calibration testing processes and methods, including accuracy and precision, to discover ways to reduce cost and schedule while still meeting mission requirements

- Discussions about how new calibration and testing techniques and equipment can be applied to meet mission requirements while maintaining small satellite cost and schedule constraints
- Novel techniques and sources used to perform radiometric calibration of miniaturized payloads
- Trade-offs between performing testing at the sub-system, ground, and/or on-orbit levels
- Calibration planning for upcoming small sat missions
- Opportunities to cross calibrate multiple copies of the same sensor when they view the same scene
- Methods for more efficient, cost-effective small systems analysis, without degrading quality

2:35

On-orbit Calibration Methodology for Planet SuperDove Satellites

Arin Jumpasut, Alan Collison, Ignacio Zuleta – Planet

ABSTRACT: Planet currently operates a constellation of over a hundred satellites that collect a current image of the Earth each day. These satellites were launched over several years and cover several evolutions in design. The latest design are the Superdove satellites. One of the key advancements is a new payload with eight spectral bands, six of which are interoperable with Sentinel-2 and two of which are unique. This presentation will describe the on-orbit calibration methodology developed for this new design, results of the initial calibration and highlight some of the future improvements going forward.

2:55

The Spectral Response of Planet Doves: Pre-launch Method and Results

Caroline Pritchett, Nicolas Smith, Arin Jumpasut, Juan Fernandez-Saldivar, Ignacio Zuleta – Planet

ABSTRACT: Planet currently operates the largest constellation of Earth observation satellites. Known as Doves, these satellites are multispectral imaging systems operating in the visible and near IR wavelengths. Over the years, Planet has been iteratively improving our payload hardware and ground calibration systems so our data can better provide meaningful insights to the remote sensing community. Our latest payload iteration, called SuperDove, is natively interoperable with Sentinel-2. With these payload advancements, enhanced calibration and characterization are necessary while still keeping cost down and the schedule agile. Here we detail the method and results of the pre-launch spectral characterization of SuperDove. We compare the sequential spectral improvements from Dove-Classic to SuperDove and the continued compatibility across payload iterations. Additionally, we demonstrate how extensive automation of the data collection and analysis allows for efficient and uniform pre-launch characterization across satellites.

3:15

Using Lunar Observations to Radiometrically Assess the CUMULOS' Visible Camera

Spencer Farrar, David Moyer, Kelly Collett, Dee Pack – The Aerospace Corporation

ABSTRACT: With the proliferation of CubeSats operating commercial off-the-shelf (COTS) instruments, it is necessary to assess the operational and performance limitations inherent with these reduced-cost systems, to understand applicability to specific mission areas. One of these limitations, as it pertains to the weather and environmental remote sensing mission area, is the limited satellite volume to house on-board calibrators (OCs) which characterize the instrument's calibration while in orbit. Since most, if not all, Visible/Infrared payloads on CubeSats do not implement OCs, the instrument's precision and stability can be significantly degraded as compared to their more expensive counterparts, such as the National Oceanic and Atmospheric Administration (NOAA) Visible Infrared Imaging Radiometer Suite (VIIRS) or the United States Geological Survey (USGS) Landsat 8 instruments. To improve instrument calibration for these systems, radiometrically

stable and well-known target sources can be used as on-orbit vicarious calibration targets, such as homogeneous Earth scenes and the Moon.

The Aerospace Corporation's Weather Remote Sensing Systems (WRemSS) Office implementation of the RObotic Lunar Observatory (ROLO) model was applied for on-orbit radiometric assessment of Aerospace's CubeSat Multispectral Observing System (CUMULOS) on NASA JPL's Integrated Solar Array and Reflectarray Antenna (ISARA) CubeSat. ISARA is a 3U CubeSat launched 12 Nov. 2017 on Cygnus Orbital ATK CRS OA-8 with CUMULOS taking up ~1U of volume. CUMULOS was designed as a compact payload for testing low-cost commercial cameras for weather and Earth environmental monitoring. It can measure surface temperature, detect fires and other environmental hotspots, take cloud cover pictures, and provide nighttime lights imaging by using three compact cameras: a visible wavelength camera, a short-wavelength infrared camera, and a long-wavelength infrared system microbolometer camera. The payload consists of three optics and sensor pairs: a panchromatic, visible CMOS camera, a short-wavelength infrared InGaAs camera, and a long-wavelength infrared microbolometer camera. This paper we will describe the CUMULOS instrument, present our radiometric stability assessment of the visible CMOS camera using the ROLO model, trending of dark field subtraction, anomalies, and lessons learned.

3:35

A Radiometrically Calibrated CubeSat Sensor: CUMULOS

John Santiago, Dee Pack, Ray Russell – The Aerospace Corporation; Richard Rudy – Kookoosint Scientific

ABSTRACT: The CubeSat Multispectral Observing System (CUMULOS) was a three-camera secondary payload that flew on the Integrated Solar Array and Reflectarray Antenna (ISARA) 3U CubeSat mission, with the goals of researching the use of commercial cameras for Earth remote sensing, and demonstrating unique nighttime remote sensing capabilities. CUMULOS was deployed on 6 December, 2017 by the Cygnus CRS OA-8E mission into an approximately 450-km circular 52° inclination orbit. After the successful conclusion of the primary ISARA mission, the CUMULOS payload was activated and achieved first light on 11 June, 2018. The CUMULOS mission ended a bit over a year later, when battery charging and power systems limitations prevented new imaging experiments from being performed, after the last successful collect on 15 June, 2019. Three separate cameras comprised the CUMULOS payload: 1) a visible ON Semiconductor (VIS) Si CMOS camera, 2) a FLIR Tau SWIR thermoelectrically stabilized shortwave infrared (SWIR) InGaAs camera, and 3) a FLIR Tau 640 longwave infrared (LWIR) vanadium oxide microbolometer. A critical part of the CUMULOS mission was investigating how the three relativity inexpensive commercial, off-the-shelf (COTS) focal planes and associated cameras would perform in a variety of nighttime related settings to produce high quality imagery and radiometrically calibrated images if possible. The three sensors had nadir ground sample sizes of 133, 450, 306-m for VIS, SWIR and LWIR respectively. Ground-based calibration measurements were performed on the CUMULOS cameras, the first of our cubesat sensors on which we attempted radiometric calibration. Issues associated with this first-time effort led to a non-ideal state of the ground (pre-launch) calibration. This paper will briefly outline what was attempted on the ground, but will primarily focus on what calibrations were performed on orbit to allow radiometric calibration to be completed. The on-orbit activities included: 1) combining observations and models of stars α Tau and α Lyra to derive irradiance responsivity values, and to derive radiance responsivity calibration terms, 2) programming dithers into stellar calibration experiments to improve background subtraction to find dim objects, and 3) augmenting ground darks with very low exposure time images taken during collections, and/or dark deep space frames. It was typically found that the dark frames taken on orbit were superior to dark frames taken on the ground only for the SWIR sensor. The SWIR sensor suffered from a high and growing number of hot pixels (radiation damage) that caused problems identifying stellar objects, and degraded science quality images. The LWIR calibration is still being worked. In this paper we will: 1) address the stellar calibration of the VIS and SWIR sensors on-orbit and compare different datasets to assess the accuracy and repeatability of those calibrations, 2) show how the SWIR sensor's hot pixels changed and increased over time and the methods used to suppress them, and 3) present images taken by the CUMULOS VIS and SWIR sensors and compare them to VIIRS images of the same region at the same time.

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3:55

Hurdles for Getting Smallsat Data Sets into NOAA Operational Forecasts

B. Guenther – Stellar Solutions

ABSTRACT: Small satellite opportunities in the US and abroad have blossomed into what seems to be a boundless new Space Age. The infrastructure for building and launching small satellites has matured rapidly. One aspect that seems to be lagging is getting these datasets into operational weather forecasting applications. Within this exciting new world, with seemingly unbounded opportunities, one must wonder "What could go wrong." Coming with an experience base on satellite missions spanning more than a half century now, starting with the Orbiting Geophysical Observatory – 6 in June, 1969, the author of this presentation will offer some examples of what could go wrong. Some instances would seem best solved by the Government for supporting these opportunities, and other instances would seem to require engineering solutions by the Smallsat community developers. Radiometric performance for Small Sat missions will get special attention. The ideas presented are solely the presenter's point of view and do not represent any official positions of either NOAA or Stellar Solutions.