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DOE/SC-ARM-TR-281

Multispectral and Thermal Imager Onboard Aerial Platforms Instrument Handbook

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August 2022

ARM

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Acronyms and Abbreviations

3D	three-dimensional
AAF	ARM Aerial Facility
API	application programming interface
ARM	Atmospheric Radiation Measurement
DLS	downwelling light sensor
EVI	enhanced vegetation index
FOV	field of view
GNDVI	Green Normalized Difference Vegetation Index
GPS	Global Positioning System
HFOV	horizontal field of view
JPL	Jet Propulsion Laboratory
NDVI	Normalized Difference Vegetation Index
NDWI	Normalized Difference Water Index
NIR	near infrared
RGB	red, green, and blue
UAS	uncrewed aerial system
USB	universal serial bus
USGS	U.S. Geological Survey
VFOV	vertical field of view

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1.0 Instrument Title

Cam-air or landcover-air

2.0 Mentor Contact Information

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3.0 Vendor/Developer Contact Information

MicaSense, Inc.
1300 N Northlake Way, Suite 100
Seattle, Washington 98103
Ph: 206-279-9972
https://micasense.com/contact/

4.0 Instrument Description

The MicaSense Altum imager is an off-the-shelf, synchronized multispectral and thermal camera, combined with a Global Positioning System (GPS) unit and downwelling light sensor (DLS). The Altum takes images of the land surface within its field of view (FOV) across five visible bands and one longwave infrared thermal band. The sensor records the radiance and converts it to digital numbers. Imagery is radiometrically corrected, taking into account the sensor calibration, lens distortions, vignette effects, sun angle, and atmospheric effects (scattering and absorption). The photogrammetry software Agisoft PhotoScan v 1.4 is used to align and stitch the images into a larger composite image using the technique of structure from motion image capture to construct a dense cloud and 3D model of the surface, which is used to produce a digital elevation model of the terrain surveyed and orthomosaic imagery. Land surface leaf area index, albedo, and surface skin temperature are provided for the user. The user can perform raster calculations on the imagery to produce various other vegetative indices, which are used to indicate plant health and land surface characteristics, including Normalized Difference Vegetation Index (NDVI), Green Normalized Difference Vegetation Index (GNDVI), Normalized Difference Water Index (NDWI), surface temperature, and Enhanced_vegetation_index (EVI). This code is provided with the readme file for each data set. The images have a resolution of 20-60 cm/pixel, which are subsampled to 100 cm/pixel.

5.0 Measurements Taken

The sensor collects blue, green, red, red edge, near infrared, and longwave infrared (thermal).

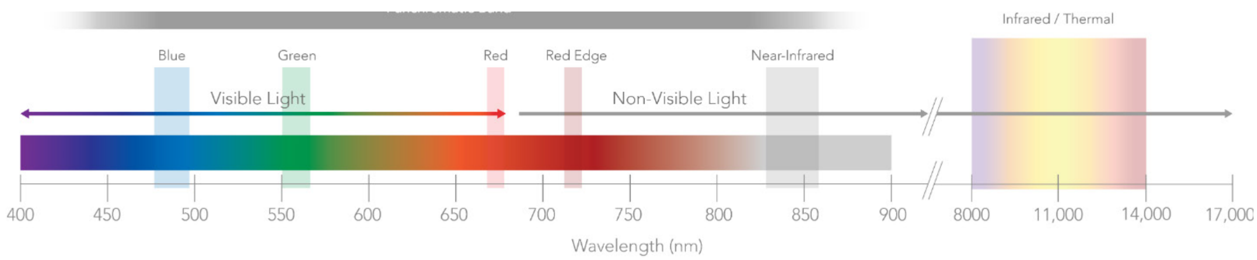


Figure 1. Image from micasense.com.

6.0 Links to Definitions and Relevant Information

Manufacture's website. Documentation (user guide and integration manual at bottom of page):

https://micasense.com/altum-pt/

Manufacturer's flight calculator to estimate the storage and time it will take to collect your data:

https://micasense.com/flight-calculator/

ARM website data source for higher-level product:

https://arm.gov/data/data-sources/landcover-air-184

7.0 Data Object Description

The color of each pixel in these images represents a value of an index for an area of $1m^2$. These data can be analyzed to validate or support climatological models.

Data format: jpg, tif, kml, kmz, txt, pdf

File naming convention: png, tif, kml, kmz, pdf, txt

8.0 Data Ordering

Data can be ordered from https://adc.arm.gov/discovery/#/

9.0 Data Plots

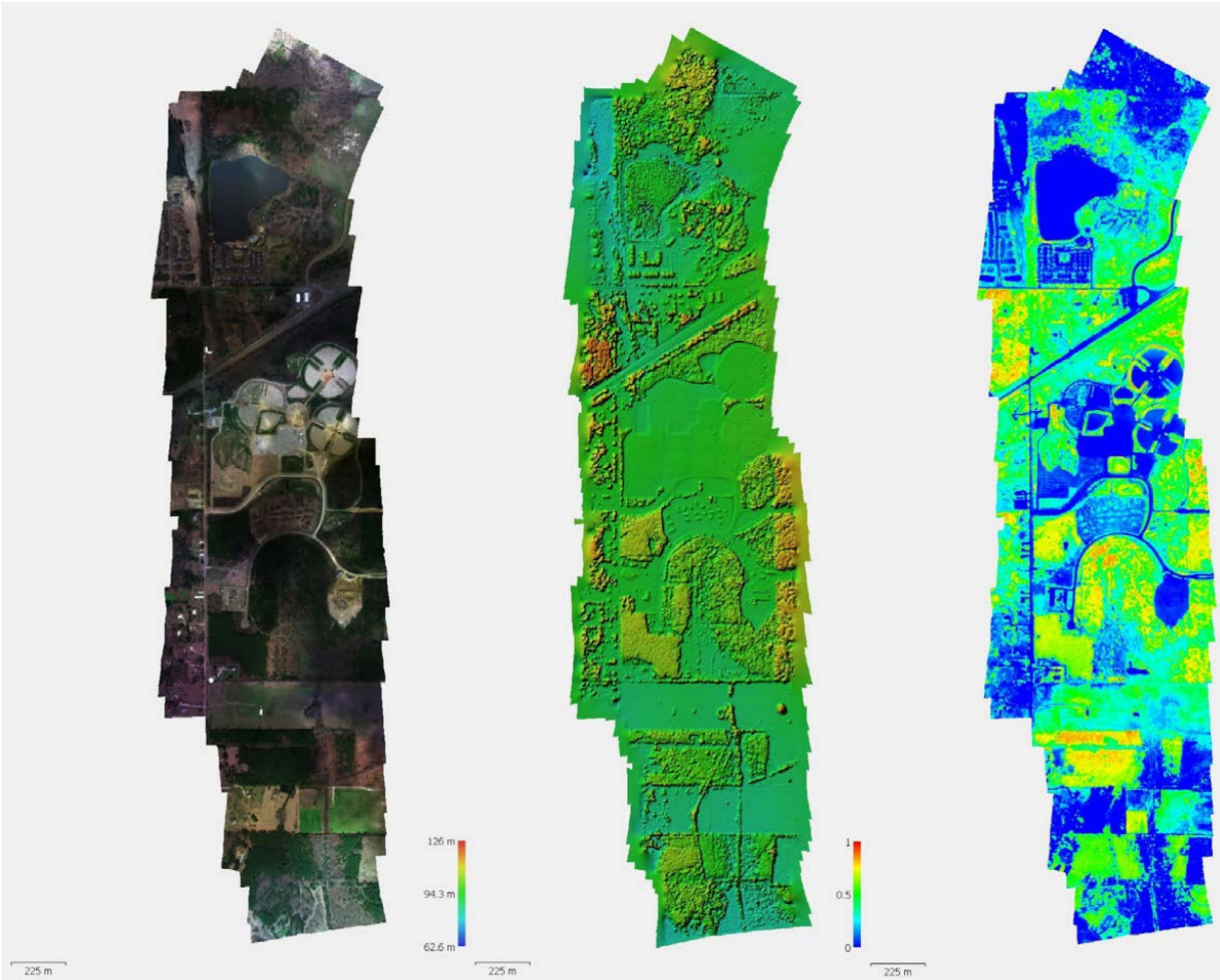


Figure 2. Right to left: True-color, digital elevation model, NDVI generated from a single flight leg on 03/11/2021.

10.0 Data Quality

Raw imagery is processed using Agisoft MetaShape following the structure-from-motion workflow established by the U.S. Geological Survey (USGS; https://doi.org/10.3133/ofr20211039). Our data products are further corrected for incoming solar radiance using imagery metadata extracted using the MicaSense Python library. Effects from scattering or flying at higher altitudes are assessed using tarps of known reflectance (11% and 48%) at the surface. Images are collected with 75% overlap to ensure good sample coverage. Image products use multiple tie points at the surface to constrain GPS precision within 10 m. Imagery is subsampled to have 100 cm/pixel resolution.

11.0 Instrument Mentor Monthly Summary

Not applicable.

12.0 Calibration Database

We recommend the Jet Propulsion Laboratory (JPL) image library, which records the standard reflectance value for many surface types: https://www.jpl.nasa.gov/images.

13.0 Technical Specification

13.1 Units

100 cm/pixel

13.2 Range

The imager has its narrowest field of view at 44 degrees. Therefore, the width of the surface sampled depends on the altitude of the camera. The following formula can determine the width of the area sampled.

$$2 * A * \tan 22° = W$$, A = altitude, W = image width

Field of view:

- Multispectral 50.2° HFOV x 38.4° VFOV
- Thermal 57° HFOV x 44° VFOV

13.3 Accuracy

Blue 475(32), Green 560(27), Red 668(14), Red Edge 717(12), NIR 842(57)

Sensor resolution: 2064 × 1544 (3.2MP per MS band); 320 × 256 thermal infrared

The thermal imagery is accurate to ± 5 K.

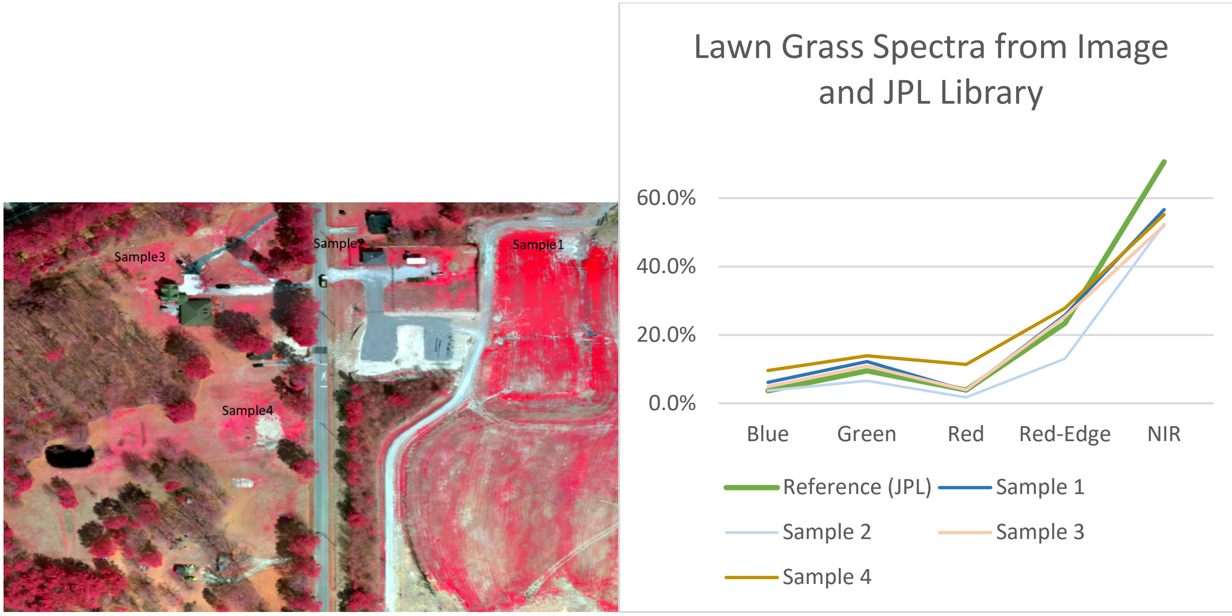


Figure 3. Lawn grass spectra from imagery compared to reference in JPL library.

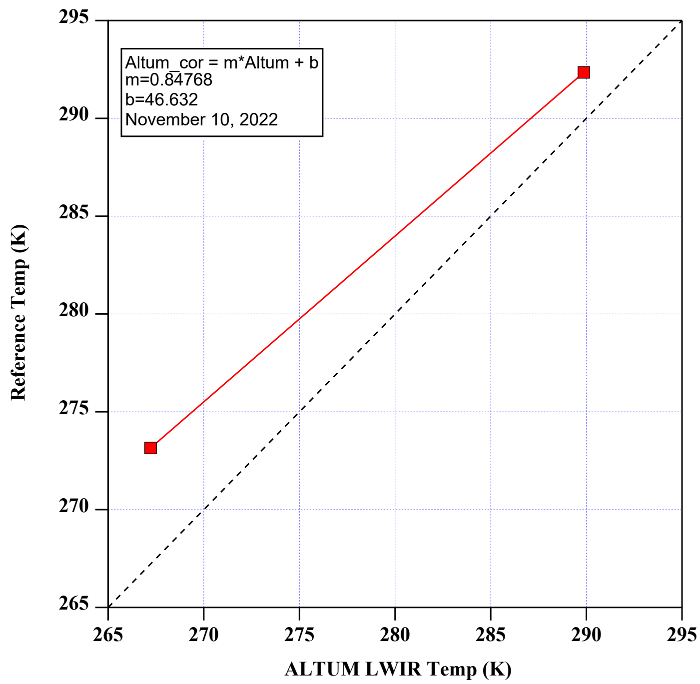
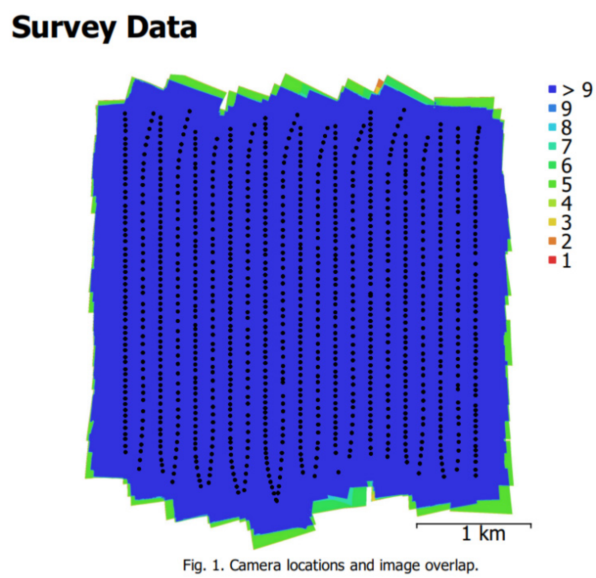


Figure 4. Thermal imager temperature compared to two-point black body calibration.

13.4 Repeatability

RGB color output has 12.4 MP (global shutter, aligned with all bands).



Number of images:	6,390	Camera stations:	5,540
Flying altitude:	553 m	Tie points:	22,045,944
Ground resolution:	23.5 cm/pix	Projections:	69,746,680
Coverage area:	13.5 km²	Reprojection error:	0.366 pix

Figure 5. Image overlap and resolution assessment from Agisoft MetaShape.

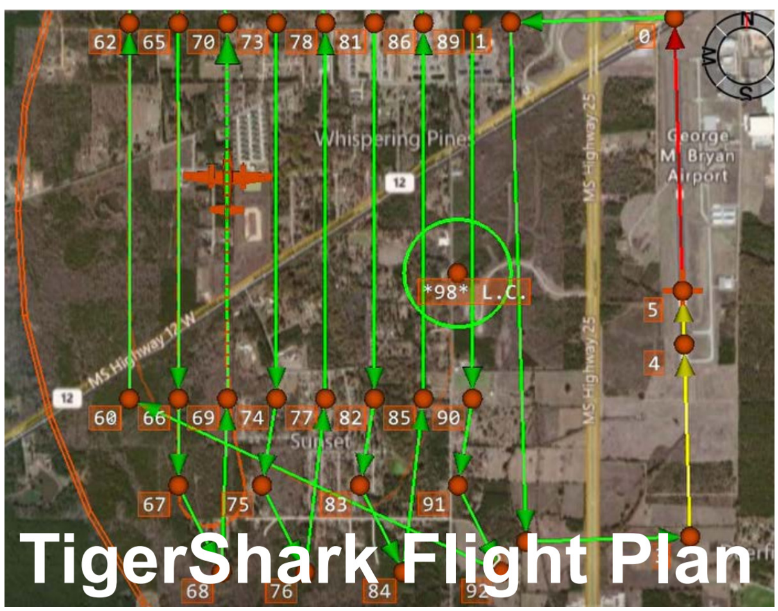


Figure 6. Sample flight plan.

13.5 Sensitivity

Uncrewed aerial system (UAS) imagery is often collected in suboptimal conditions, such as on partial cloudy days. The final imagery products are sensitive to quantitative geometric and radiometric corrections used. We base our correction schema on that described in Iqbal et al. 2018. First, the digital numbers recorded are converted to sensor radiance using camera calibration information. Second, the sensor radiance is converted to Earth's radiance using an empirical line method to remove atmospheric distortions. We use two ground panels of different reflectance values to cover the range of dark to bright pixels for this calibration and validation in flight.

$$\text{Surface } \textit{reflectance} = \text{slope} \times \text{DN} \pm \text{intercept}$$

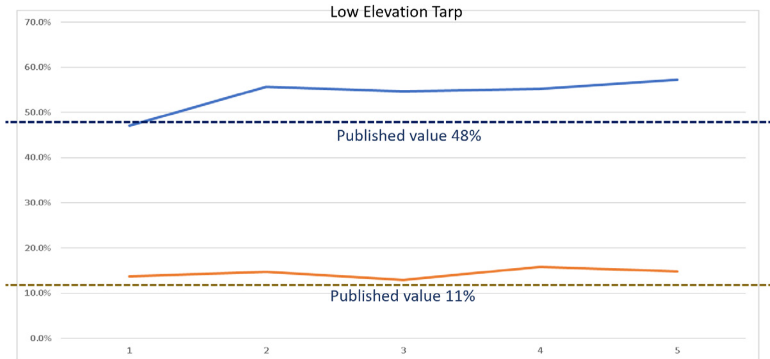


Figure 7. Calculated reflectance, altitude 2000 ft.

13.6 Uncertainty

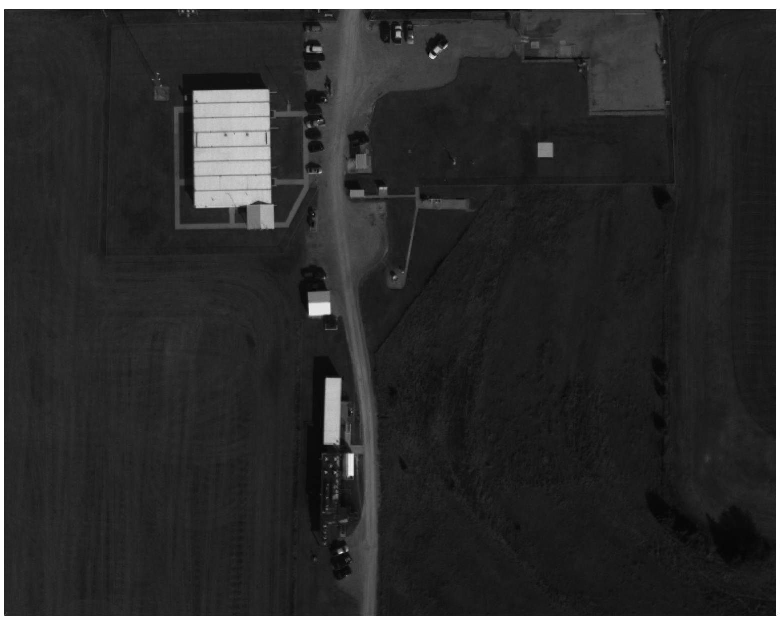


Figure 8. U.S. Department of Energy Atmospheric Radiation Measurement (ARM) user facility Southern Great Plains site and reflectance tarps.

13.7 Input Voltage

7.0V - 25.2V DC

13.8 Input Values

The camera takes input from a GPS sensor and a DLS.

13.9 Output Values

Multispectral and panchromatic imagery have an output bit-depth of 12, and thermal imagery has an output bit-depth of 16. Ambient light and sun angle as measured by the DLS as well as GPS information are included in the metadata output with each image.

14.0 Instrument System Functional Diagram

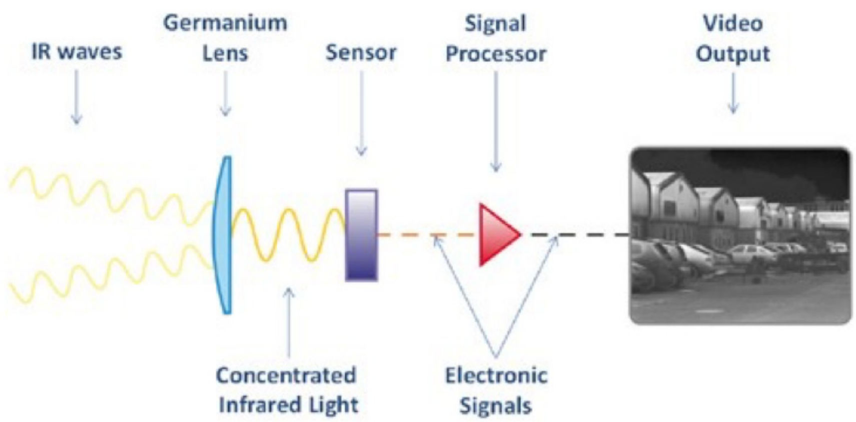


Figure 9. Generic schematic of how thermal imagers capture thermal signature. Image source: https://support.thermal.com/hc/en-us/articles/115001285630-What-is-Thermal-Imaging- The same concept is true for the other wavelengths.

15.0 Instrument Measurement Theory

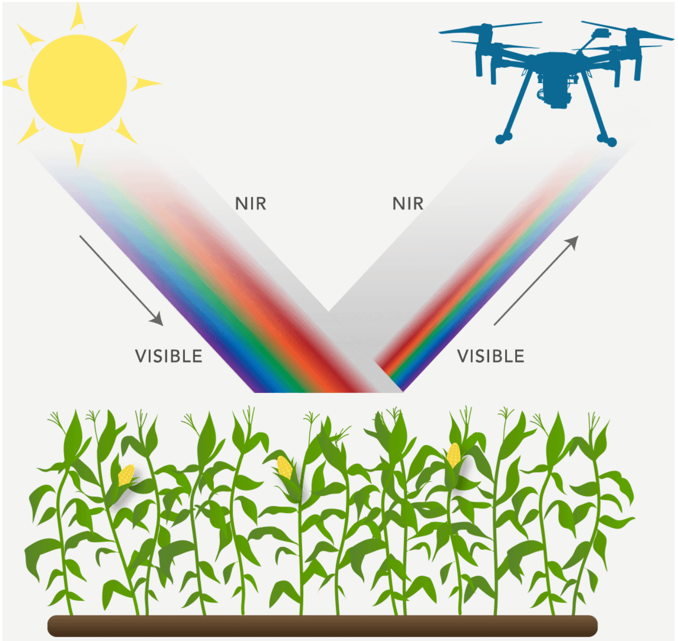


Figure 10. Image from micasense.com.

Light energy from the sun is either absorbed, transmitted, or reflected. The sensor captures light reflected from the plant canopy. Plants typically absorb blue light and red light, while reflecting some green light. They also reflect a much larger amount of near-infrared (NIR) light. This light is captured in five spectral bands. Multispectral cameras work by imaging different wavelengths of light. Professional multispectral cameras have multiple imagers, each with a special optical filter that allows only a precise set of light wavelengths to be captured by that imager. The output of the camera is a set of images for that particular wavelength. These sets of images are then stitched together to create geographically accurate mosaics, with multiple layers for each wavelength. Mathematically combining these layers yields vegetation indices (micasense.com).

16.0 Setup and Operation of Instrument

16.1 Setup

The camera should be installed in a manner that gives it an unobstructed view of the surface directly beneath the aircraft, and it should point straight down at all times. Use of a gimble would help to ensure this. The use of vibration dampening between the aircraft and the sensor mounting platform is recommended.

The DLS should be installed with the six-pin connector facing forward. It should be the highest point on the aircraft to avoid effects of shadows and kept away from any devices that could interfere with GPS signals. Each time it is turned on, allow it to calibrate in the absence of movement or vibrations.

A connection to the camera must be established via any Wi-Fi or ethernet capable device. The password for the Wi-Fi access point is “micasense.” Once connected, the sensor’s webpage can be accessed by typing “192.168.10.254” in the address bar of an internet browser, and the sensor should be ready to configure and use.

Onboard the ARM Aerial Facility (AAF) ArcticShark UAS, the camera is installed on the dorsal side of the payload bay via a 3D-printed mount. The DLS is installed in a custom bracket on the ventral side of the air vehicle such that it can be ‘unclipped’ to perform the magnetometer calibration during preflight. The onboard computer communicates with the camera via a wired connection using API commands.

16.2 Operation

The sensor has multiple modes that can be configured on the webpage. These modes are:

- Timer Mode
- External Trigger Mode
- Overlap Mode
- Manual Exposure Mode.

17.0 Software

Firmware must be downloaded from https://atlas.micasense.com, and updates can be downloaded from https://www.micasense.com/firmware-updates.

18.0 Calibration

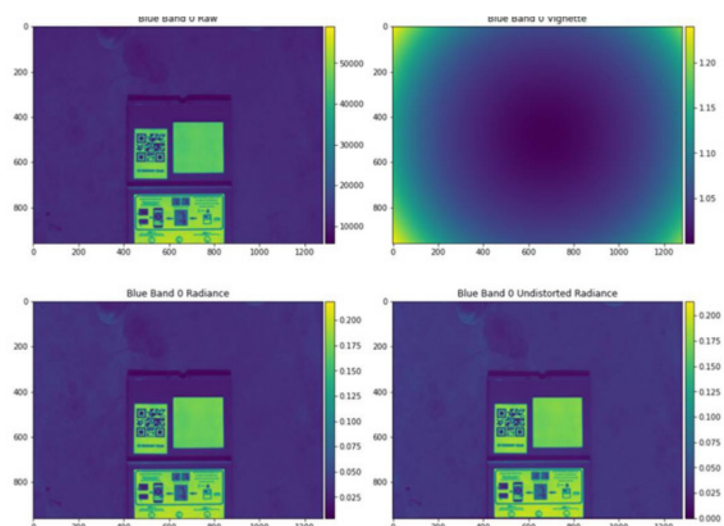


Figure 11. Post-processing image of calibration panel capture.

Calibration occurs pre- and post-flight using a reflectance panel provided by MicaSense. Using MicaSenses' own Python library, each true-color band can be corrected for vignette and radiance distortions. The thermal imager is calibrated by the company, but on soft down days the imager is compared to a black body source and an ice bath. The company thermal calibration is FLIR LWIR thermal infrared 8-14 um radiometrically calibrated.

19.0 Maintenance

Lenses are capped when not in use to reduce instances of damage. Lenses should be cleaned regularly. The external flash drive used for photo storage should be routinely replaced and reformatted to make sure it does not fill up.

20.0 Safety

The instrument should be fully powered down before removing the USB or else the image files can become corrupted.

21.0 Citable References

Agisoft PhotoScan User Manual Professional Edition, Version 1.4. 2018. https://www.agisoft.com/pdf/photoscan-pro_1_4_en.pdf

Altum-PT Integration Guide. 2022. Micasense Inc. https://support.micasense.com/hc/en-us/articles/4419868608407-Altum-PT-Integration-Guide?_ga=2.5076147.1850471322.1655824616-1502579303.1655486374&_gl=1*1fa3ror*_ga*MTUwMjU3OTMwMy4xNjU1NDg2Mzc0*_ga_6LNE28MQ61*MTY1NTgyNDYyMy4zLjAuMTY1NTgyNDYyMy4w.

https://www.jpl.nasa.gov/images

Iqbal, F, A Lucieer, and K Barry. 2018. "Simplified radiometric calibration for UAS-mounted multispectral sensor." *European Journal of Remote Sensing* 51(1): 301−313. https://doi.org/10.1080/22797254.2018.1432293

Over, Jin-Si, A Ritchie, C Kranenburg, J Brown, D Buscombe, T Nobel, C Sherwood, J Warrick, and P Wernette. 2021. Processing Coastal Imagery with Agisoft Metashape Professional Edition, Version 1.6 – Structure from Motion Workflow Documentation. USGS Open-File Report 2021-1039. https://doi.org/10.3133/ofr20211039

Tutorial (Intermediate Level): Radiometric calibration using reflectance panels in PhotoScan Professional 1.4. Agisoft. https://www.agisoft.com/pdf/PS_1.4_(IL)_Refelctance_Calibration.pdf

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