

Radiometric Accuracy and Commercial UAVs: A Clash of Cultures?

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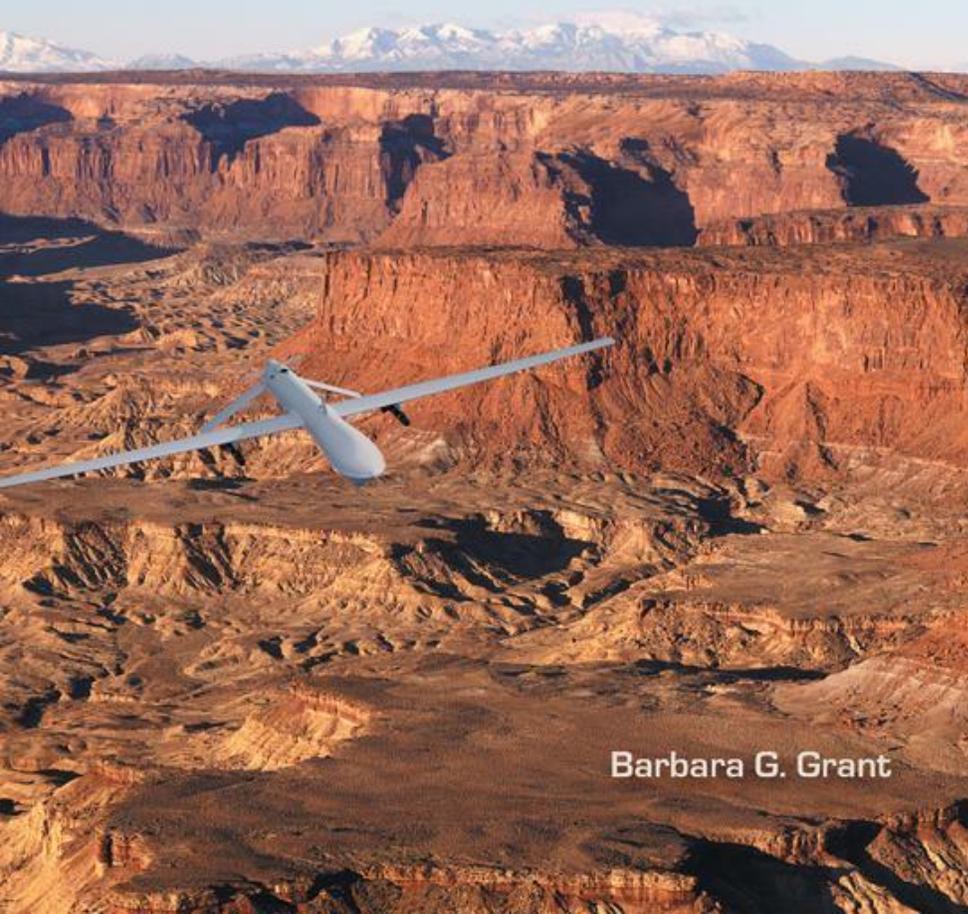
Photonics Media Webinar

**Tuesday, July 7, 2020
1:00 PM EDT**



Getting Started with UAV Imaging Systems

A RADIOMETRIC GUIDE



Barbara G. Grant

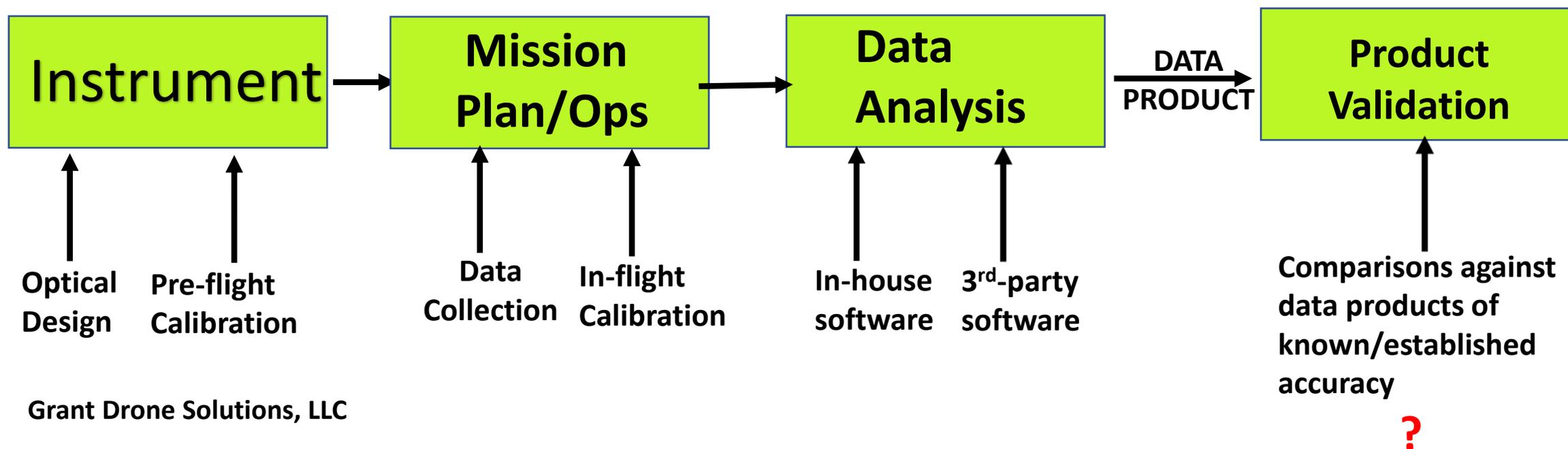
My Background in this Problem

- 30+ year professional in electro-optics/radiometry, satellite emphasis
- Involved in UAVs since 2014, several publications
- Book published in 2016
- Attended ASPRS UAS Mapping Meeting in 2016
- Take aways:
 - 1) Optical instruments from a high-end imager to an action camera can be used to create a map
 - 2) Third party software is used not only to create a map, but also to correct for unwanted optical effects from the camera: “It’s in the software.”

Mapping and Radiometry are Different Applications (and their needs often conflict)

- In Remote Sensing, Radiometry is chiefly concerned with providing an accurate value for a surface target parameter (e.g. reflectance, temperature); while Mapping provides geospatial accuracy— accurate locations and distances.
- The focus on increasing spatial resolution for mapping applications—many have ground projections of IFOVs on the order of a few inches—is opposite to most radiometric needs.
- Imaging with an overlap, typically performed in mapping, is unhelpful to radiometric data gathering.
- Atmospheric transmittance is important to radiometry, not so important in mapping.

Steps to Generate the Data Product



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Do Optical Designs Matter?

- A Rhetorical Question for most in the Photonics field—*Of course, they do!!*
- *This is why good cameras are not the cheapest.*
- Current FAA weight limit on sUAS is 55 lb.
- In the UAV field, it can sometimes be heard, “Better accuracy requires another zero” (i.e. the camera costing \$1,000 would be far better performing at \$10,000—prohibitive for most drone owners.)

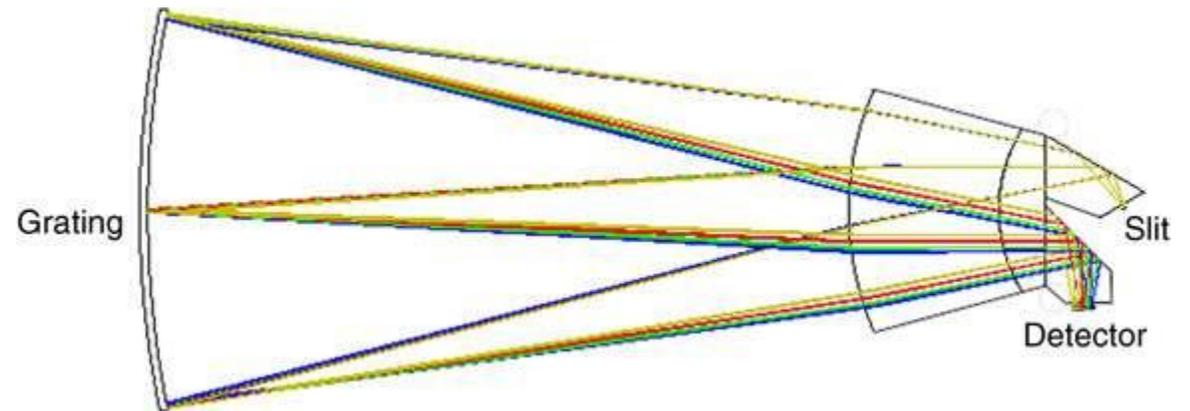
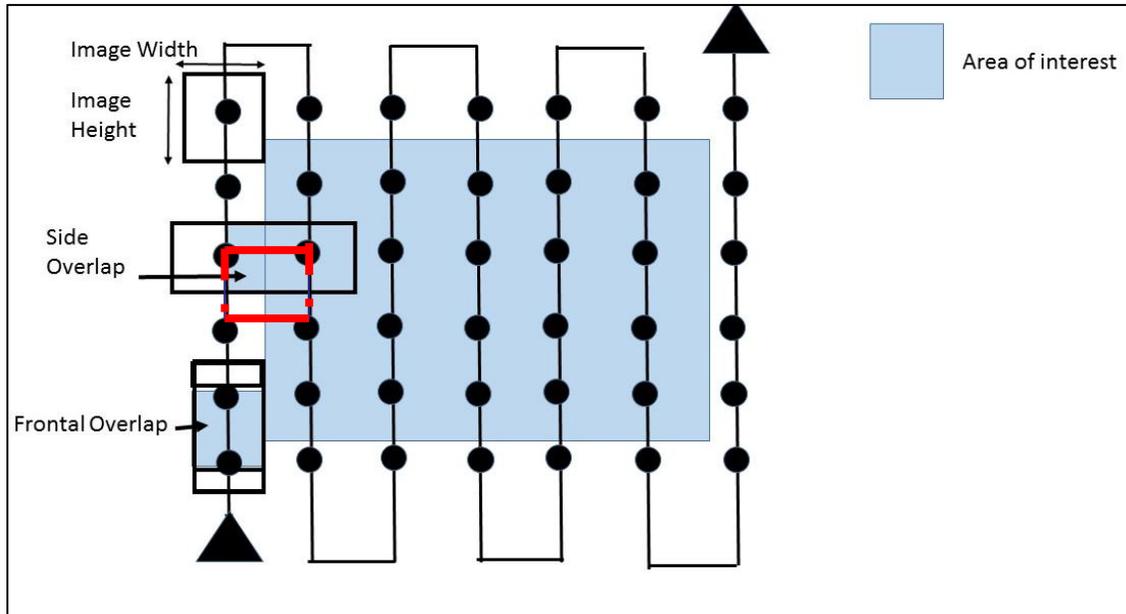


Image credit: JPL

A better question:

What accuracy is required to do the job?

Typical UAV Flight Path for Mapping

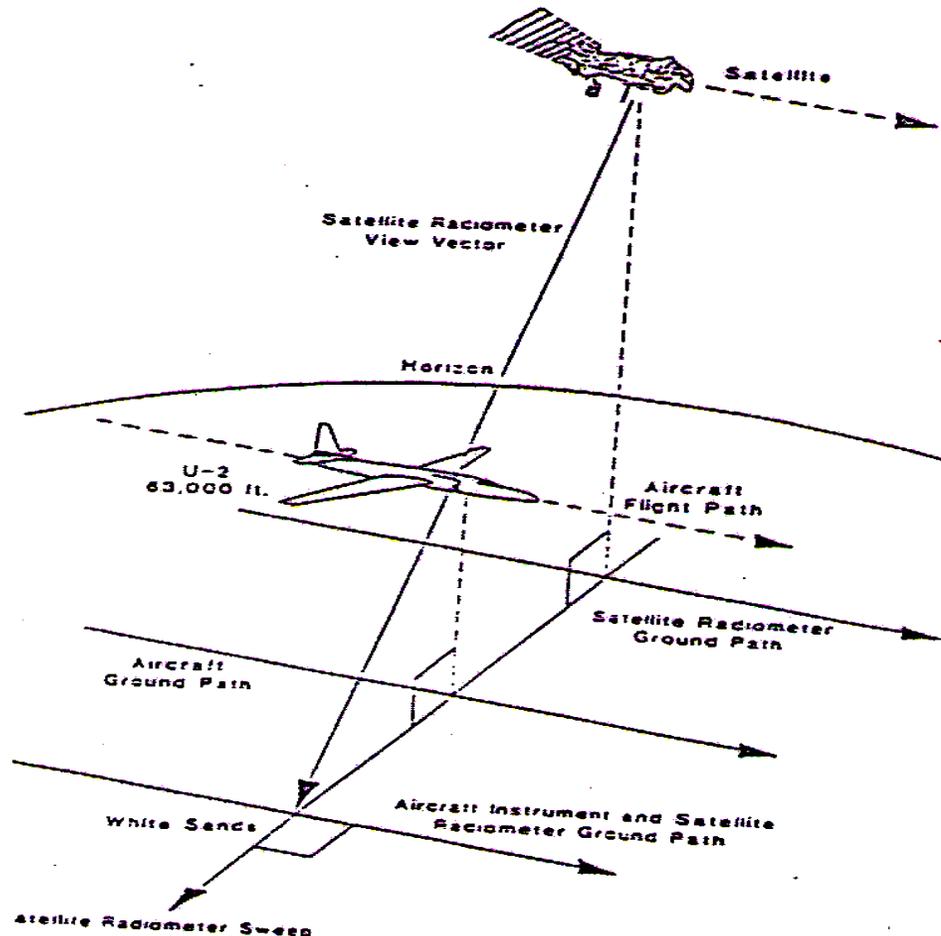


- Mapping requires overlap (75% overlap is a reasonable figure for mapping)

<https://www.propelleraero.com/blog/collect-quality-drone-data-part1-bare-earth/>

- Illumination conditions vary as the aircraft flies back and forth
- Imaged at nadir rather than oblique angles
- Big Question: How does this aid the radiometry of the area under study?

Satellite or High Altitude Aircraft

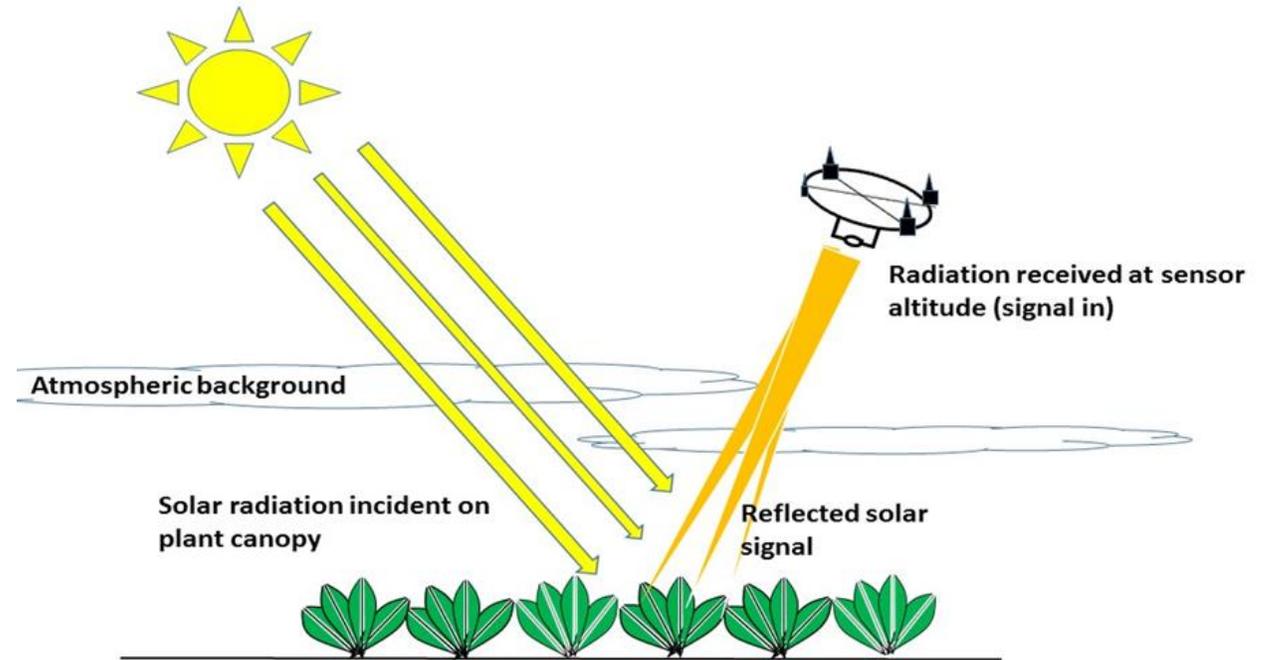


- Satellite scans across-track or along-track
- High altitude aircraft (U-2 variant) deployed along same collection path
- Heights of platforms are known
- Atmospheric correction performed
- Correction for spectral bandpass performed
- **THIS IS ONE WAY CROSS-CALIBRATION IS ACCOMPLISHED.**

NDVI* via Remote Sensing

$$NDVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}}$$

- IFOV Co-registration must be accomplished in order to accurately calculate NDVI (another processing task—problem is, the IFOV of most UAVs is very small, to begin with.)



Credit: Grant Drone Solutions, LLC

****NDVI is “Normalized Difference Vegetation Index, a measure of plant water stress. The Greek ρ is canopy reflectance over a narrow spectral band. Values range from -1 to 1; bigger is better.***

The Drone Operator “Pilot”

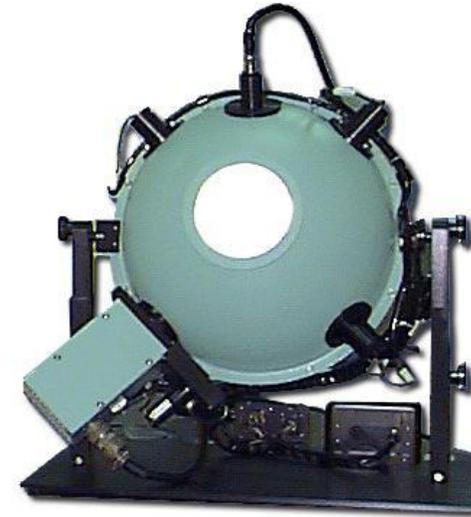
- UAV Imaging relies on a drone operator, also called a pilot.
- Pilot must be at least 16 years old, FAA certified and adhere to FAA Part 107 regulations for sUAS.
- Pilot sets flight plan, including the angle at which drone will image.
- If a reflectance target is used, pilot is the one making ground measurements of the target, following specific measurement instructions.



<https://www.wikihow.com/Become-a-Drone-Pilot#/Image:Become-a-Drone-Pilot-Step-4.jpg> (non-commercial share-alike 3.0 unported)

Radiometric Calibration Comparisons

- For satellite imaging the earth, preflight calibrations are typically performed using an integrating sphere
- Earth resources satellites have on-board calibrators and protocols in place for cross-calibration with other satellite imagers, as well as ground-based vicarious calibration
- UAV mfrs. calibrate at their facility before shipping the drone to purchaser.
- **There is no standard procedure for UAV imager calibration, pre-flight or in the field—*The Wild West of drones.***



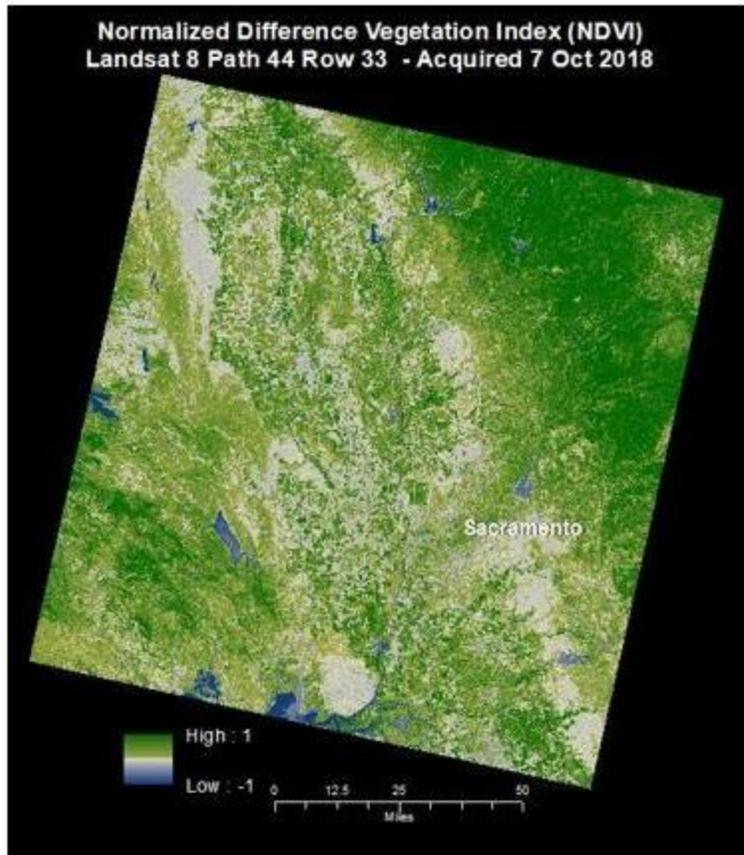
https://en.wikipedia.org/wiki/Integrating_sphere#/media/File:Commercial_Integrating_Sphere.jpg
<http://www.electro-optical.com/html/datashts/visible/isv400.asp>

Some instrument mfrs. with legacy in other markets (e.g. DoD, machine vision) have adapted procedures to the commercial drone world.

Use of Reflectance Panel in the Field

- Some vendors recommend measuring a calibrated reflectance panel before/after a collection run due to changing illumination conditions during flight.
- Some researchers have recommended using several panels of different reflectances during the flight, to cover target dynamic range (*A. Iqbal et. al., Simplified radiometric calibration for UAS-mounted multispectral sensor, "European Journal of Remote Sensing, 2018)*
- Quality of panels varies, so does price. Many used in the field cost \$750; how does their accuracy compare to panels costing twice that amount?

Processing the Result—And Validating It.



Credit: USGS.gov

- UAV users often use third-party processing software to process the data, apply the calibration algorithm (developed at manufacturer for the camera) and visualize the result (NDVI map, for example). There are several companies in this arena
- Large-scale comparison with the satellite data product NDVI has yet to occur (though some drone vendors state that their maps *validate* satellite data)
- But validation of a quantitative product such as NDVI is tough because of the difference in spatial resolution UAV to satellite imager.
- In fact, the small pixel size ensures that the UAV will image part of a leaf, not a canopy.

Is there a Solution for Accurate Radiometry in Commercial UAVs?

- A Qualified YES, if...
 - The Typical Mapping Pattern is replaced with imaging a swath (some UAVs already do this)
 - Larger IFOV to enable better comparisons with higher res. satellite data
 - Atmospheric transmittance is accounted for (NOTE: This will become much more of an issue when FAA raises the height limit)
 - Quality of imager improves, to reduce instrument effects
 - Effects of platform are well-understood (same result should be obtainable on different platforms—fixed wing should not produce different result than quadcopter.)
- But...even if one is not using a UAV for accurate radiometry, valuable data can still be provided, allowing the agricultural user information on where in the field to look for areas of interest.

B. Grant Partial Bibliography

SPIE Press Books: *The Art of Radiometry* (co-author), *Field Guide to Radiometry*, and *Getting Started* (mentioned above.)

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- *Helping you choose platforms, sensors, and data analysis approaches to meet your specific needs*
- *Business analysis—**is this the right field for your company?***
- *Focusing on accuracy AND utility—**getting YOUR job done, right***

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