Scale^3

How (small) unmanned aerial vehicles can provide data at appropriate spatial, temporal, and spectral scales to monitor fine-scale ecological patterns and processes.

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2014 UAS Workshop Argonne National Labs

CMU Center for GIScience

- Research and Service Center
- Expertise:
  - UAS Remote Sensing
  - GeoSpatial Modeling
  - Cartography/Custom Mapping, GeoDatabase Development
  - Work closely with Institute for Great Lakes Research at CMU
- Clients:
  - Academic
  - Government
  - Non-Profit
  - Corporate

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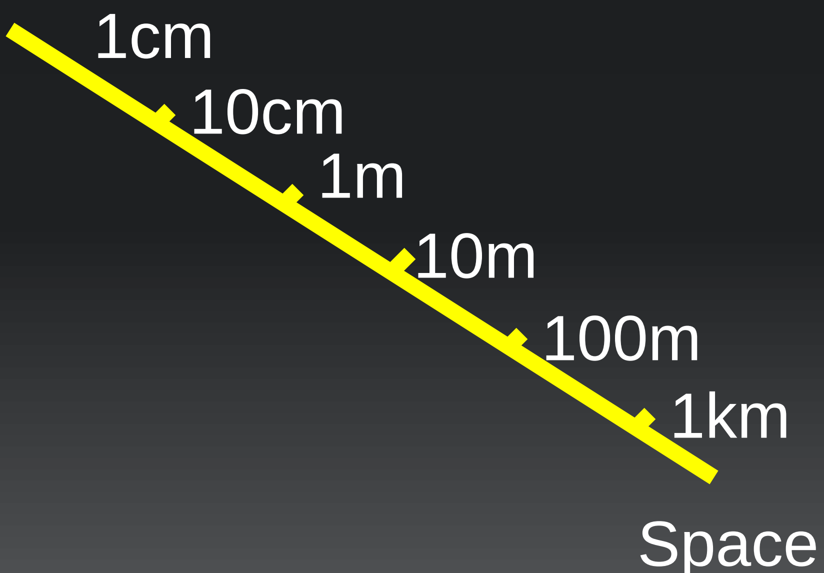
Outline

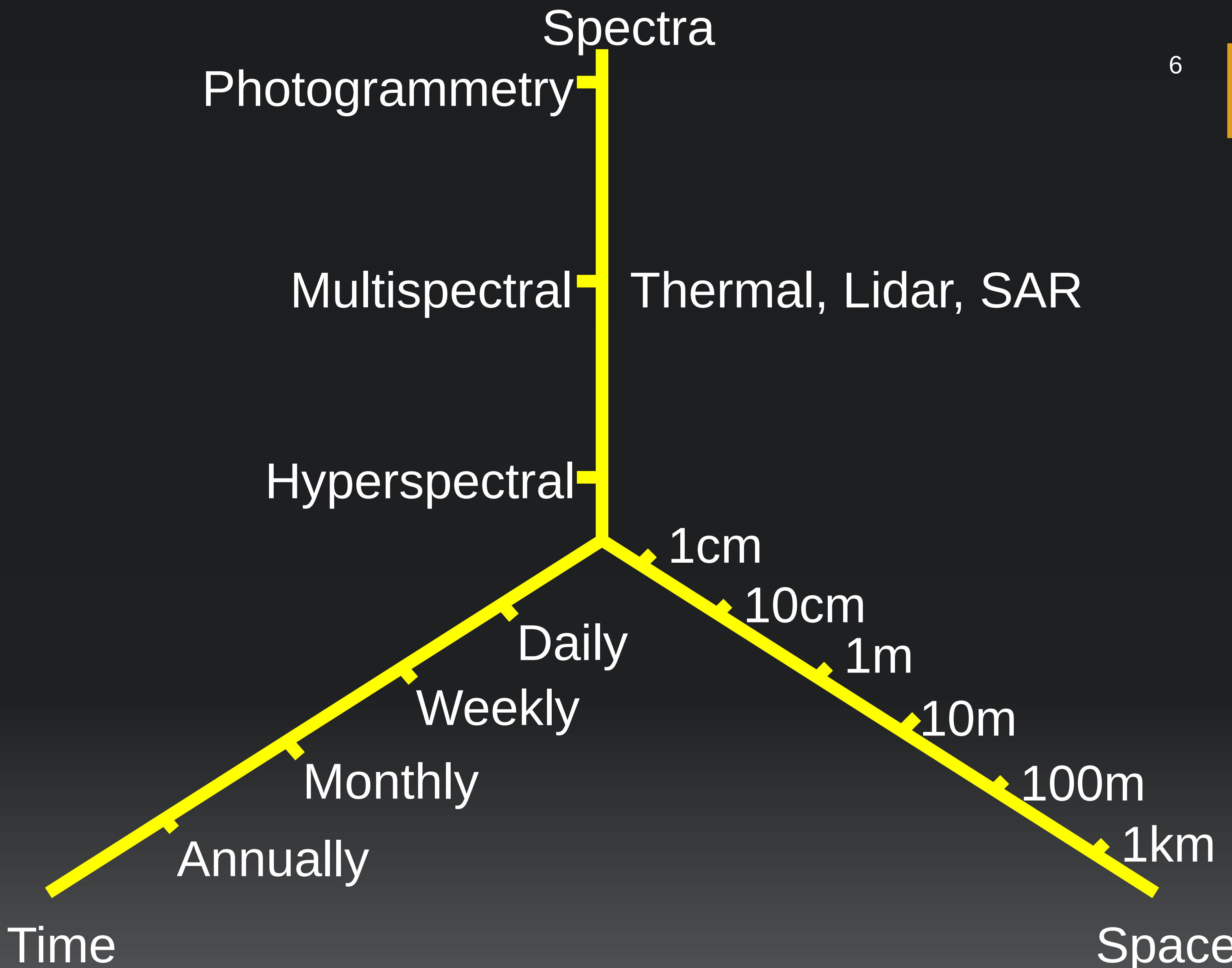
- Why sUAS? A Personal Perspective
- The Three Scales in Remote Sensing
  - Temporal
  - Spatial
  - Spectral
- UAS Remote Sensing Opportunities
- Conclusions

Scale(s) in Remote Sensing

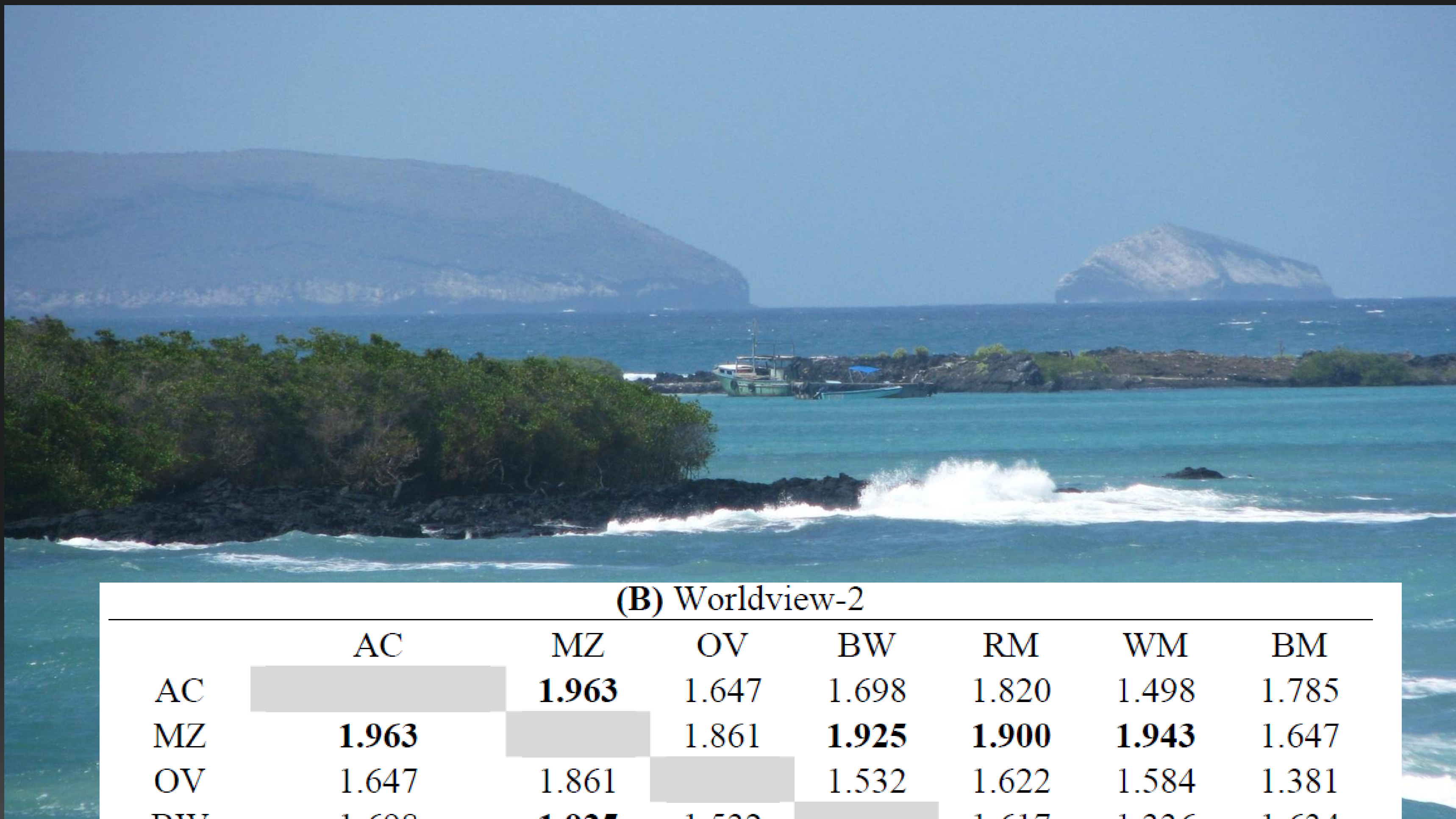
“ Explain the impact of scale in remote sensing”

– a doctoral comprehensive exam question


1cm
10cm
1m
10m
100m
1km
Space

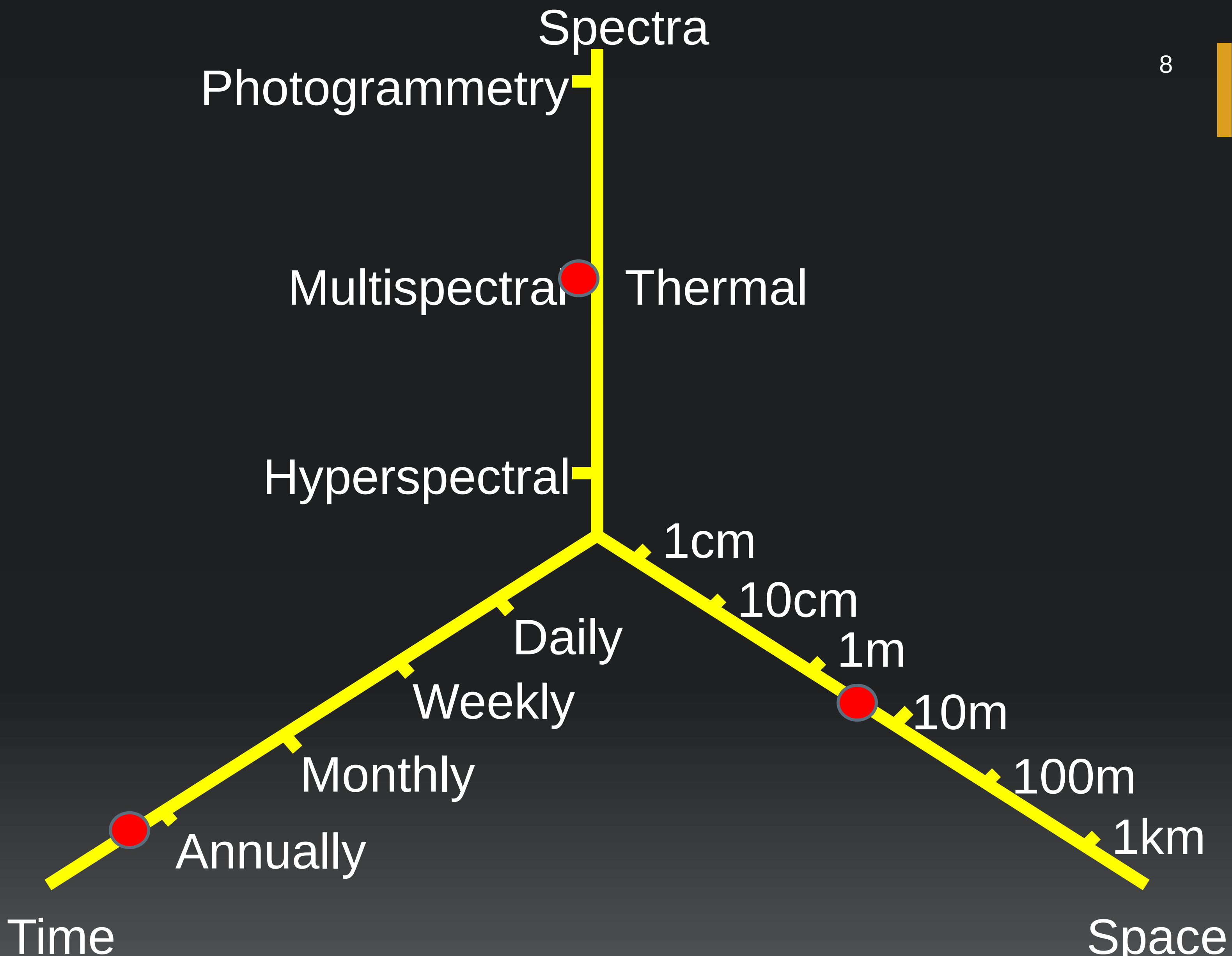

Spectra
Photogrammetry
Multispectral
Thermal, Lidar, SAR
Hyperspectral
1cm
10cm
1m
10m
100m
1km
Daily
Weekly
Monthly
Annually
Time
Space

Why UAS?



(B) Worldview-2

	AC	MZ	OV	BW	RM	WM	BM
AC		**1.963**	1.647	1.698	1.820	1.498	1.785
MZ	**1.963**		1.861	**1.925**	**1.900**	**1.943**	1.647
OV	1.647	1.861		1.532	1.622	1.584	1.381
BW	1.698	**1.925**	1.532		1.617	1.336	1.634
RM	1.820	**1.900**	1.622	1.617		0.866	1.226
WM	1.498	**1.943**	1.584	1.336	0.866		1.540
BM	1.785	1.647	1.381	1.634	1.226	1.540	


Spectra
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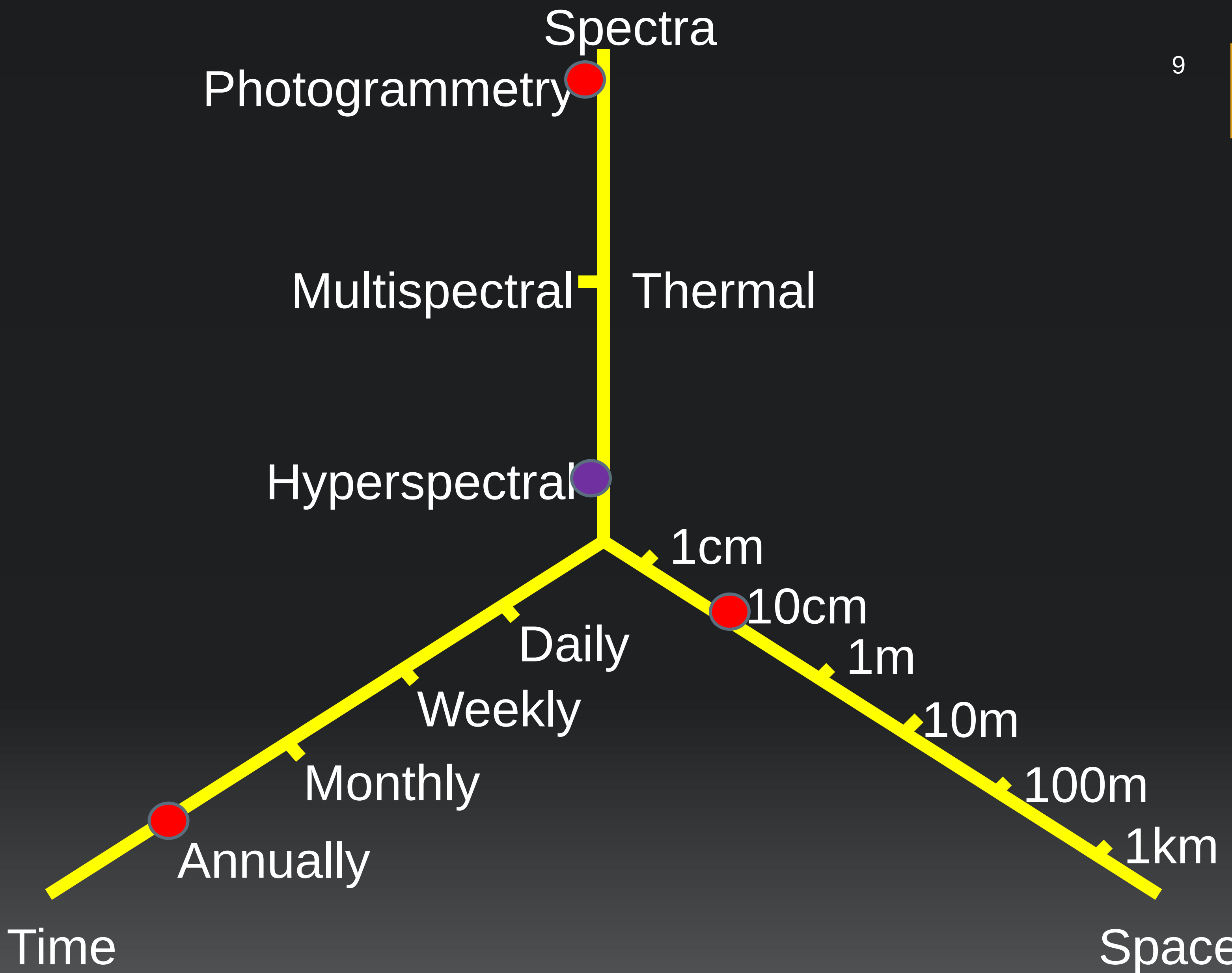

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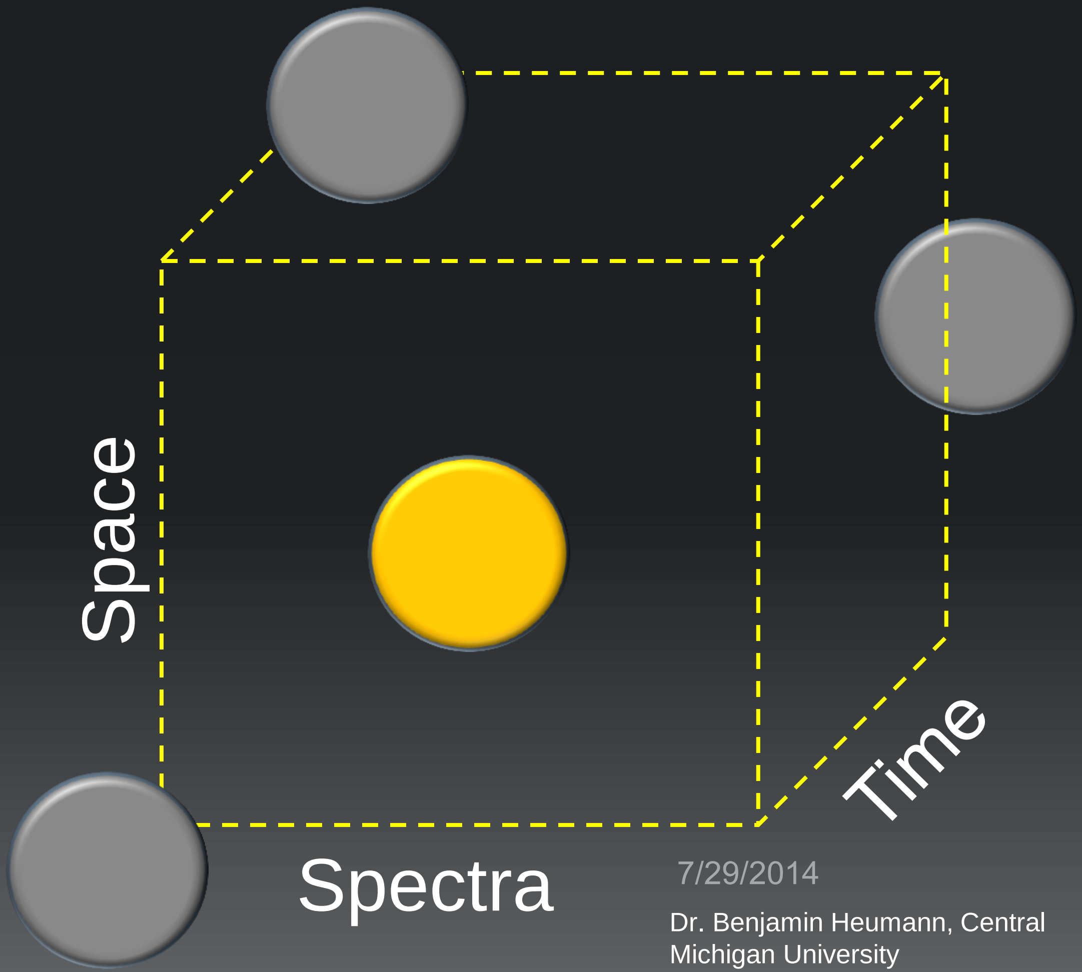
Scales of Remote Sensing

Scales of Detection: Extent and Resolution

- Temporal Scale
  - Revisit Time
  - Timing of Phenomenon
- Spatial Scale
  - Areal Extent
  - Pixel Size (Resolution)
- Spectral Scale
  - Color vs. Wavelength



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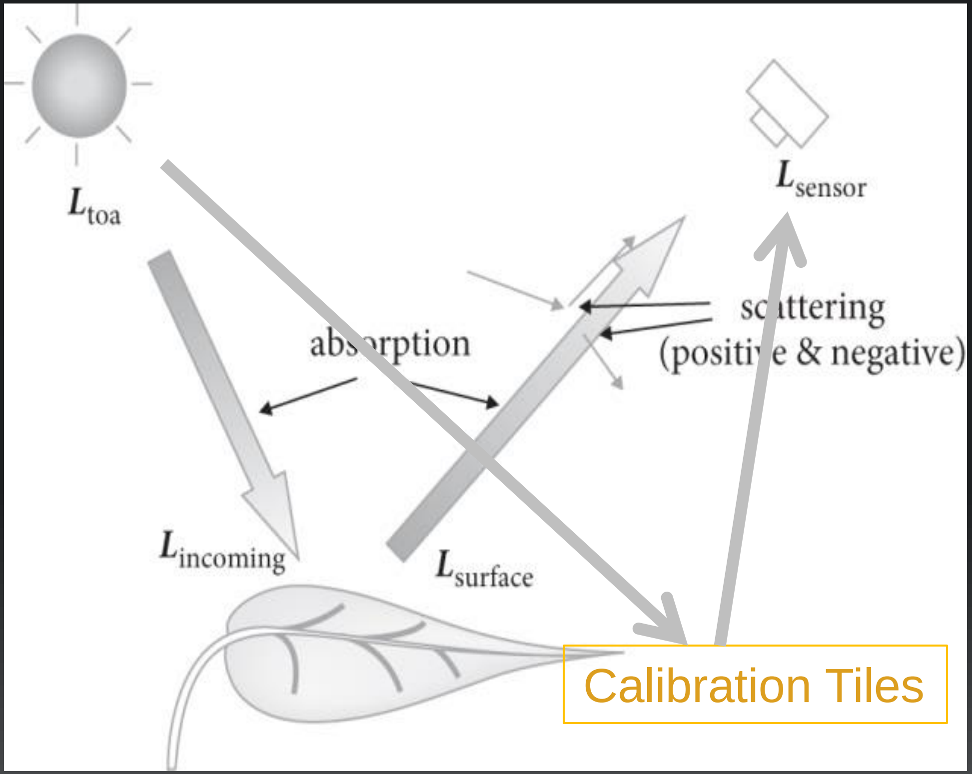
Photography vs. Spectroscopy

Spectroscopy

- How light interacts with matter
- Consistent, Robust, scientific measurement
- % Reflectance or Radiance – watts/sq m.
- Quantitative Analysis
- Requires advanced training and equipment

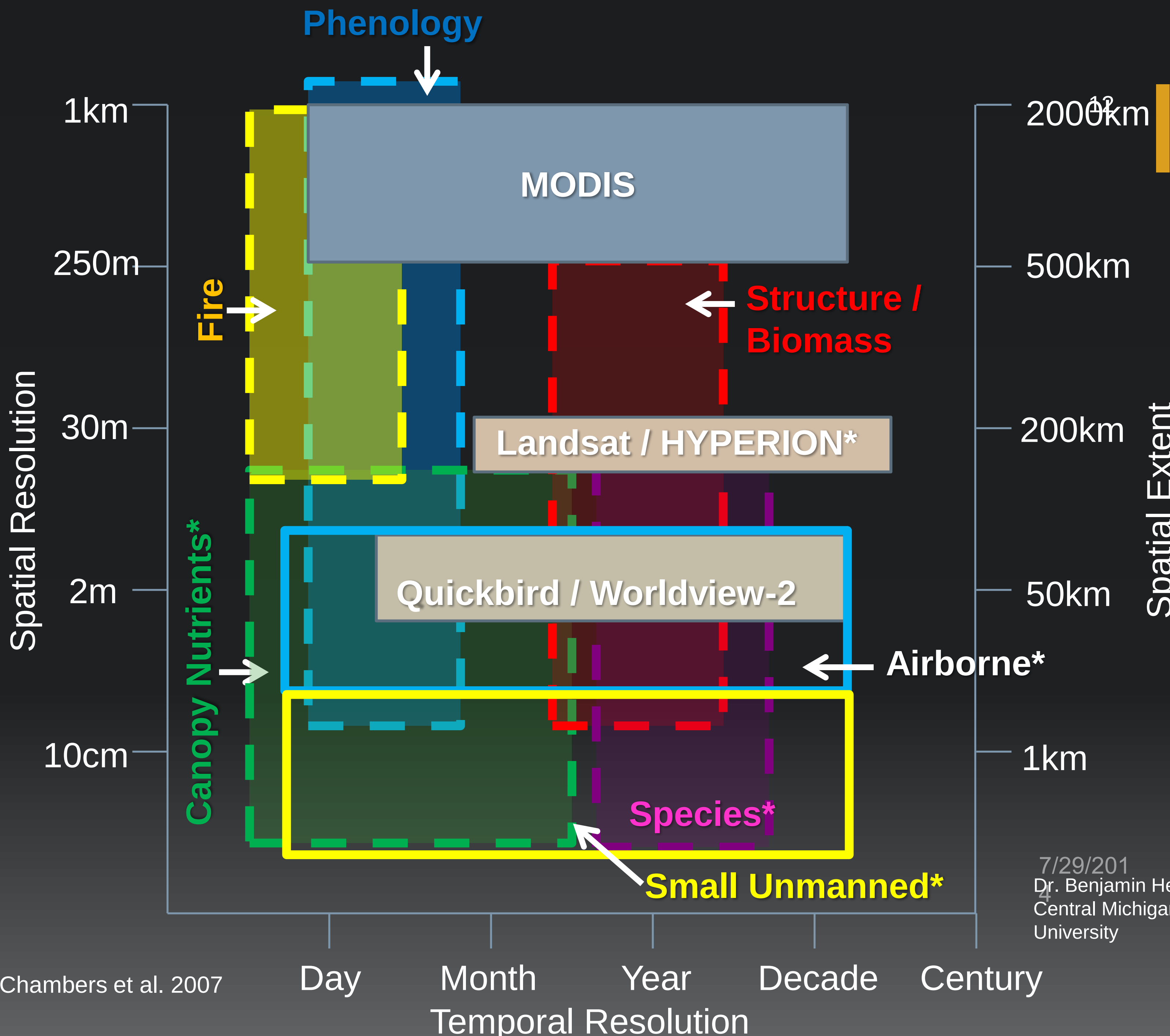
Photography

- Picture (can be NIR)
- Difficult to directly compare images
- CANNOT easily use vegetation indices or other quantitative analysis
- Existing expertise and equipment



Jones and Vaughan, 2010

Scales of Remote Sensing



After Chambers et al. 2007

Non-Imaging remote sensing

- sUAS can be a tool to collect samples in difficult terrain
- Example: Hyperspectral measurements of plants in wetlands using handheld spectroradiometer
  - **On the ground**
    - Sensitivity of equipment
    - Travel Time
    - Navigation Issues
    - Disturbance of field site
  - **In the air**
    - Predetermined sampling
    - Equipment is safe
    - Sampling is quick

Non-imaging sensors often less than 1/10th cost of imaging sensors

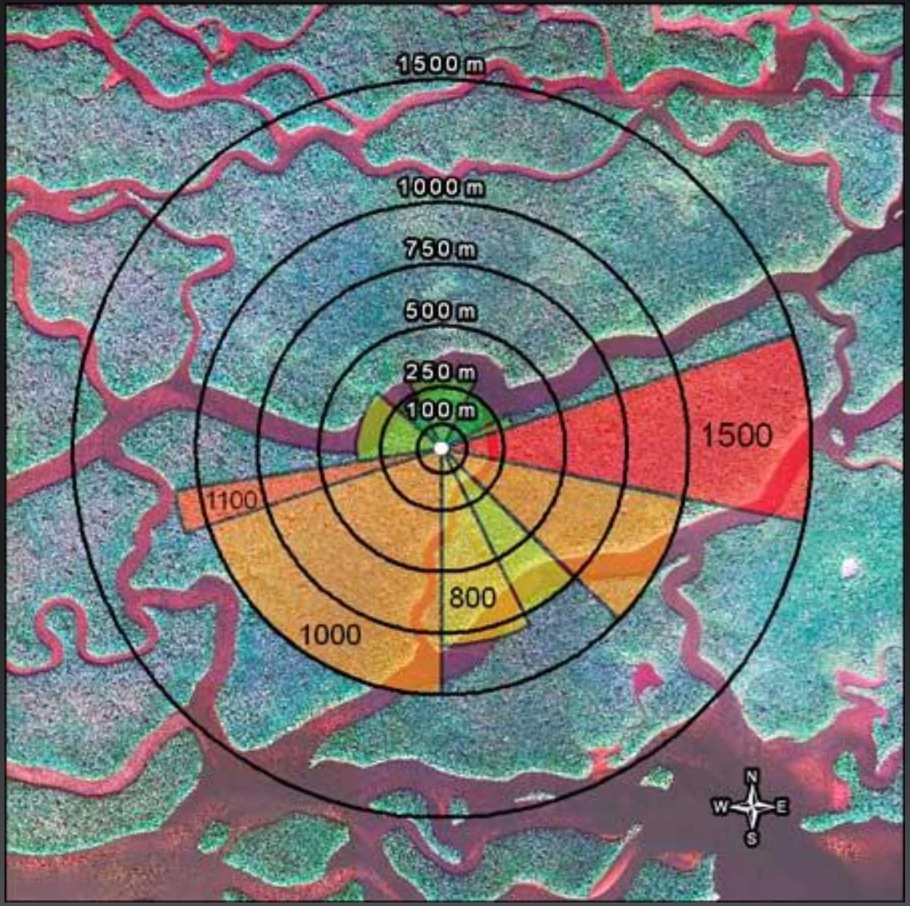
Opportunities for UAS Remote Sensing: Spatial

- Object of interest < pixel size
- Satellite & Manned Aircraft: Forests, Agriculture, Shrublands
- What about herbaceous vegetation?
  - Tundra / Alpine
  - Grasslands
  - Wetlands
    - Peatlands
    - Marshes

Photo credit: Smith, R.W.

Opportunities for UAS Remote Sensing: Spatial

- Fine-scale Patterns and Variability
  - Field Plots
  - Farm Field
  - Flux Towers



Barr et al. 2010

Opportunities for UAS Remote Sensing: Temporal

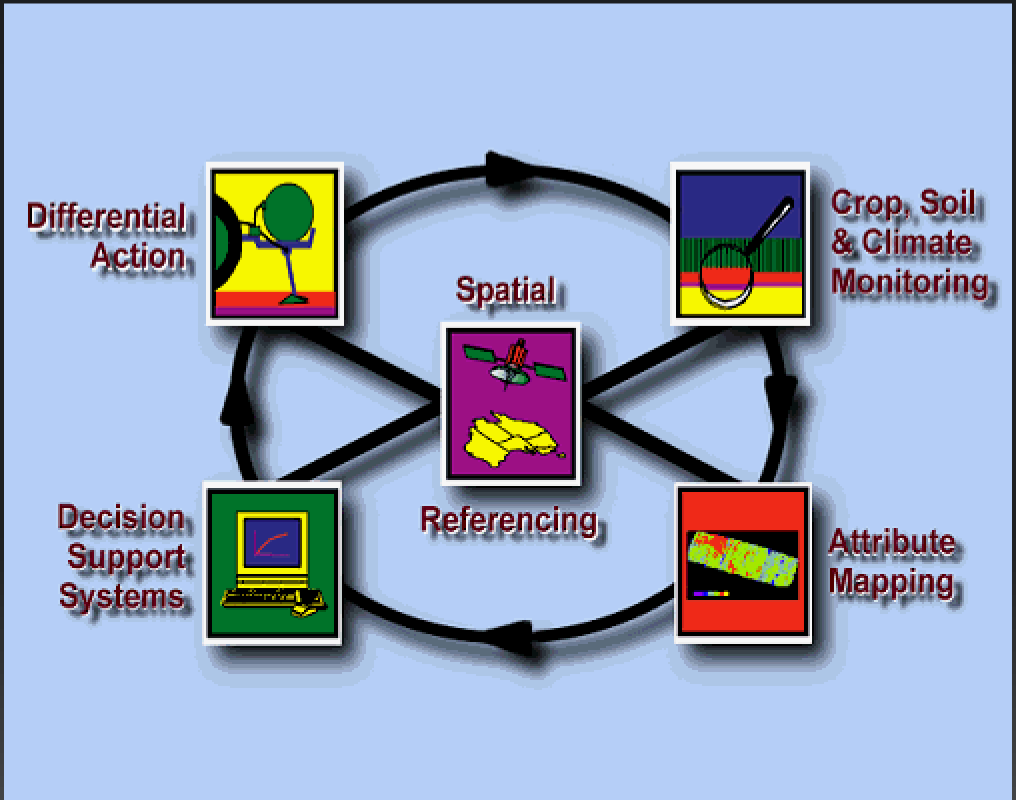
- Phenology
  - Leaf burst
  - Leaf senescence
  - Flowering
  - Fruiting
  - Insect Hatch

- Flexible and Rapid Deployment
  - Plant Pathogens
  - Invasive Species
  - Drought, Floods, Extreme Events

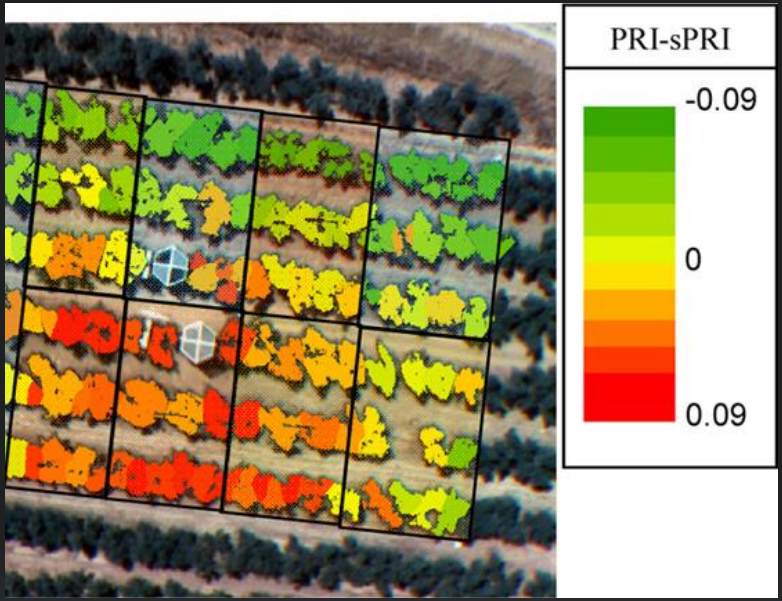
gardenamateur.blogspot.com

Fine Spatial Scale Phenology:
- Detection of individual flowers, leaves, fruits

Opportunities for UAS Remote Sensing: Precision Agriculture



Bratney and Whelan, 2001



Zarco-Tejada et al. 2008

Opportunities for UAS Remote Sensing: Multi-Dimensional Analysis

- Spectral-Temporal Signatures
  - Repeated image acquisition over the growing season

- Spectral-Spatial Classification
  - Object-based Image Analysis

- 4-D Analysis (X,Y,Time,Spectral)

- Scaling with larger-footprint imagery
  - Local → Regional → Global
  - Integrate UAS remote sensing with other platforms

Challenges for UAS Remote Sensing: Undiscovered Country

- New Methods and Platforms → Research Opportunity
- BUT → can be inconsistent with long-established protocols
- More proof-of-concept required for:
  - Sensors
  - Sensor Integration
  - Data Quality and Accuracy

Challenges for UAS Remote Sensing: Sensor Integration

Source: Leptron Industrial Robotic Helicopters

Source: Headwall Phonics

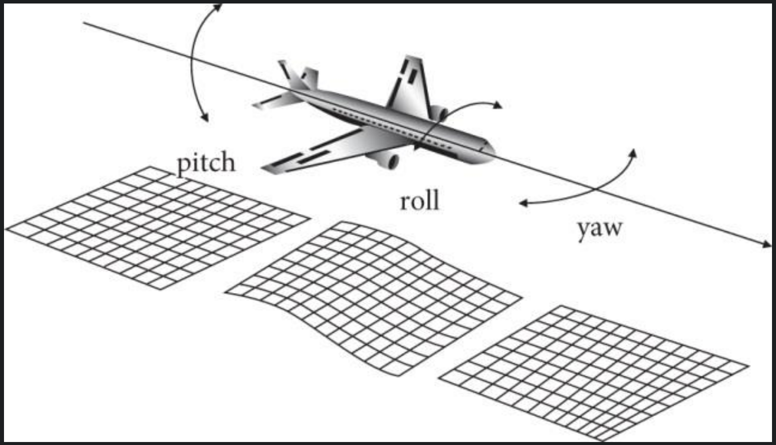
Challenges for UAS Remote Sensing: Platform Stability

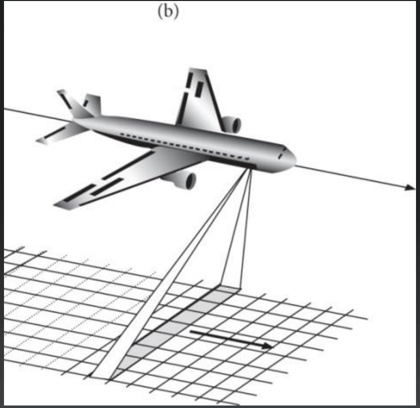
- Airborne Platforms are constantly adjusting Pitch, Roll, Yaw

- For 2-D imagers, post-processing can adjust.

- For 1-D imagers (most hyperspectral), post-processing is not possible and requires complicated corrections.

- Vibration isolation is also critical



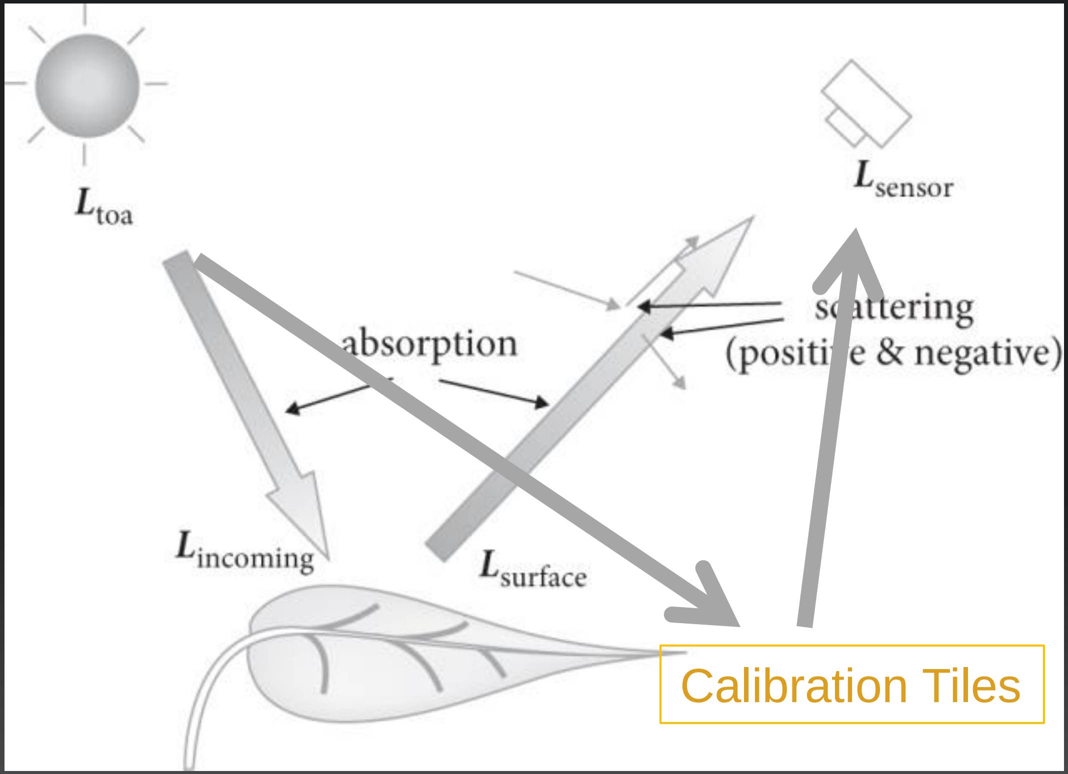


Jones and Vaughan, 2010

Challenges for UAS Remote Sensing: Sensor Calibration and Processing

Accurate Reflectance Measurements Require:

- In-Situ Calibration with multiple Calibration Tiles
- AND/OR
- Continuous Readings of Incoming Radiation (variable light conditions)



Jones and Vaughan, 2010

Current UAS Research Projects at CMU

Mapping Wetland Biodiversity

Location: Washtenaw County, MI

Mapping Pitcher’s Thistle

Location: Wilderness State Park, MI

Collaborators: Chicago Botanic Gardens, East Carolina University, Charleston College

Funded in-part by USFWS

Conclusions

- Remote sensing requires careful consideration of spatial, temporal, and spectral scales.

- UAS as a new platform provides new opportunities for flexible deployment (temporal scale) and low altitude image collection (fine-spatial scale).

- Type of spectral data has considerable tradeoffs between potential benefits and costs/efforts to achieve results.

Thank You – Questions?

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