Evaluating Point Clouds – LiDAR and UAV's

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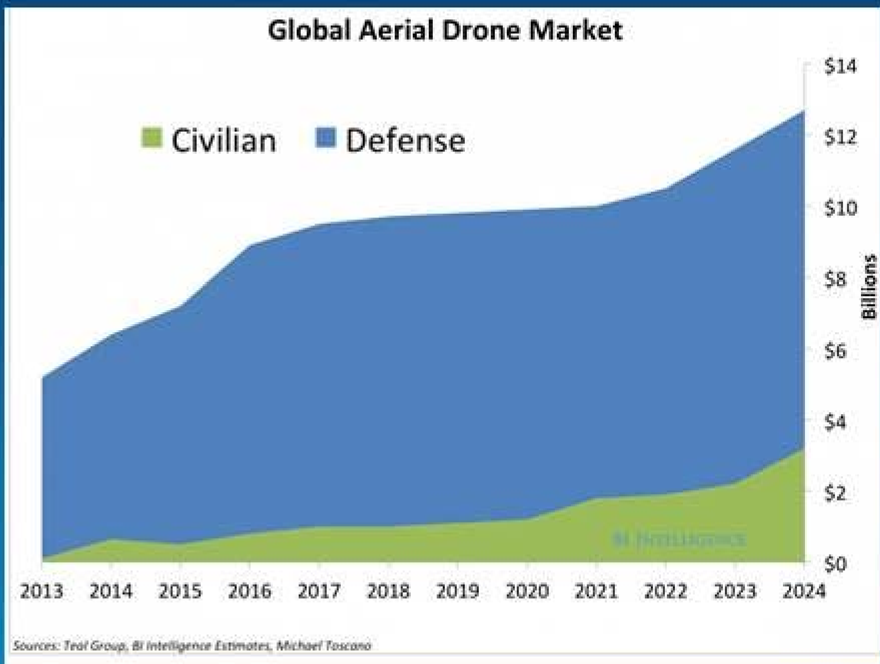
UAS Market



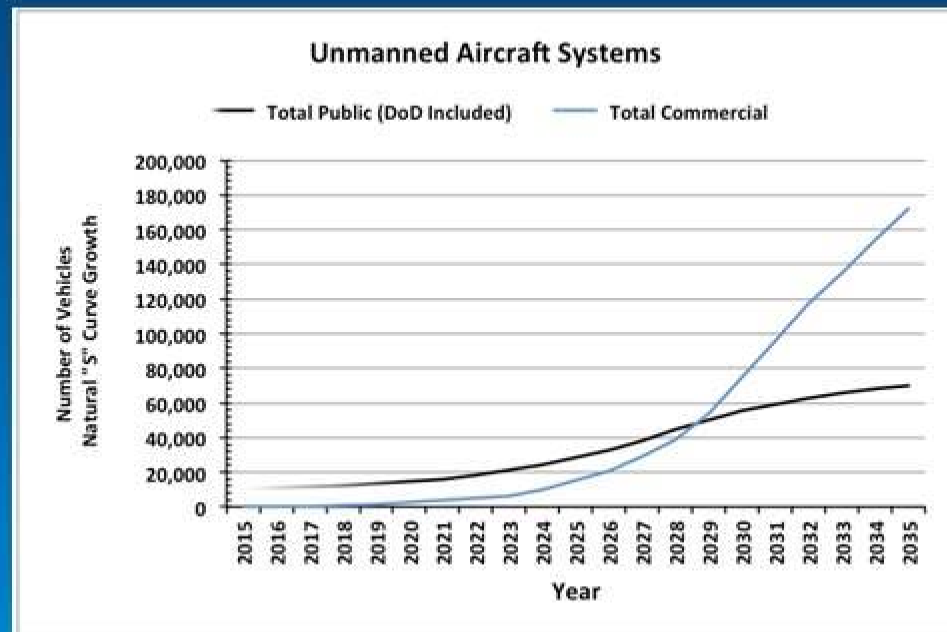


Figure ES-3 - Total UAS Forecast 2015 - 2035

Advantages of UAV systems for data collection

- Unparalleled temporal and spatial resolutions
- Inertial measurement unit (IMU) and GPS
  - Logging, attitude, location (L1, L2, GLONASS, RTK, PPK)
- Flexible deployment
  - *Relatively* simple operation
- Potential for very rapid data acquisition and processing
  - Find your errors "quickly"
- System! Closely tied hardware and software
- FAA Rule Changes

- Accelerated sensor development
  - Parrot Sequoia

Remote Sensing Paradigm

Everyone wants "good" data…

Remote Sensing Platform	Typical Spatial Resolution (GSD)	Typical Field- of- View (FOV)
Free Satellite (Landsat)	15-30m	50-250km
Satellite (Quickbird, WV2,3)	1-10 m	10-50 km
Aircraft (piloted)*	0.2-2 m	2-5 km
Miniature UAV	1-20 cm	50-500 m
Ground-based Scanning	< 1 cm	<2m

Wetland Applications of UAV Technology

- Sea Level Rise
- Tidal Fluctuations
- Wetlands Credits
- Erosion
- Stream Channel Change
- Vegetation Growth
- Vegetation Health
- Community Change
- Storm Damage

Landsat 8 OLI

Accurate elevation…

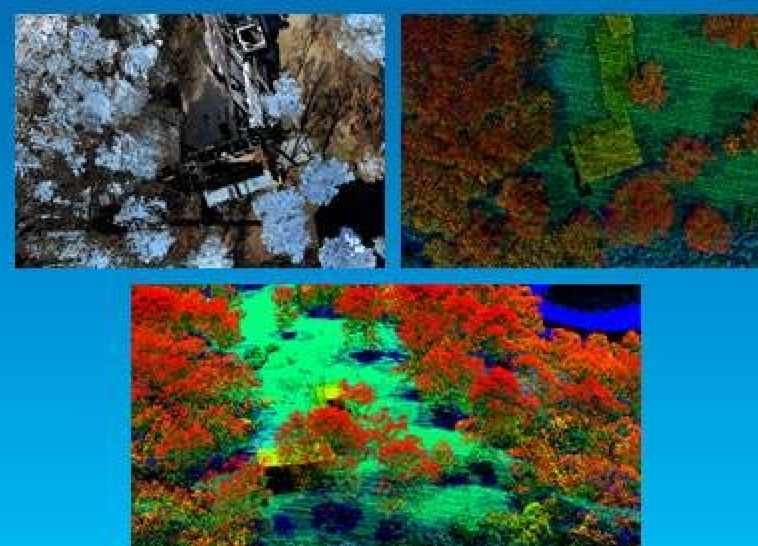
UAV Products vs LiDAR

UAV Products

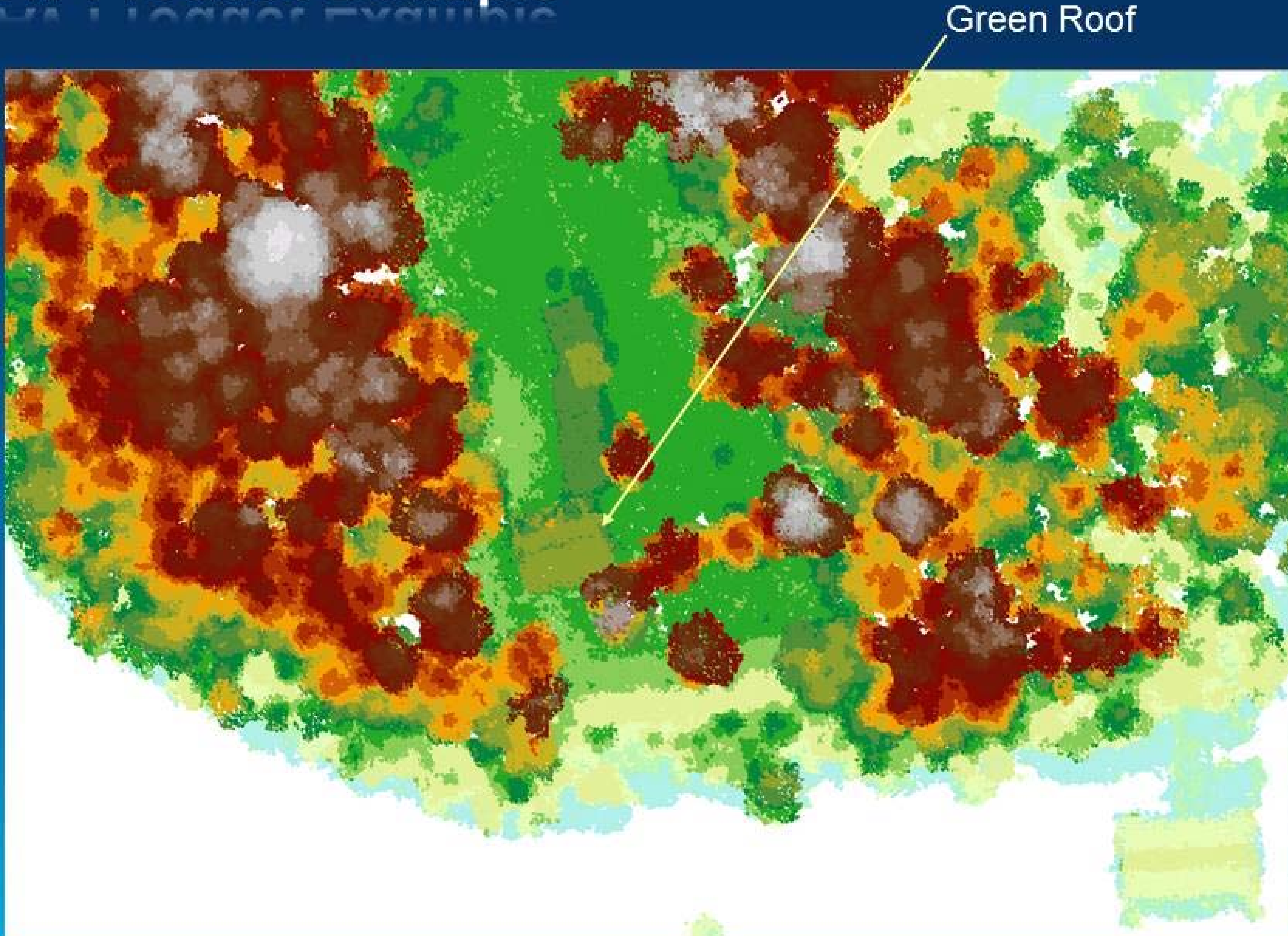
- Aerial Imagery
- Spectral Imagery
  - IR/Red-Edge, etc.
  - Indices (NDVI)
- Digital Surface Model
- Point Cloud
  - LAS/LAZ, etc.
  - "First return" LiDAR

LiDAR

- Point Cloud
  - Multiple Returns
    - First, Last, etc.
  - Classified Returns
    - Vegetation, etc.
  - Digital Surface Models
  - Bare earth/Elevation
- Intensity



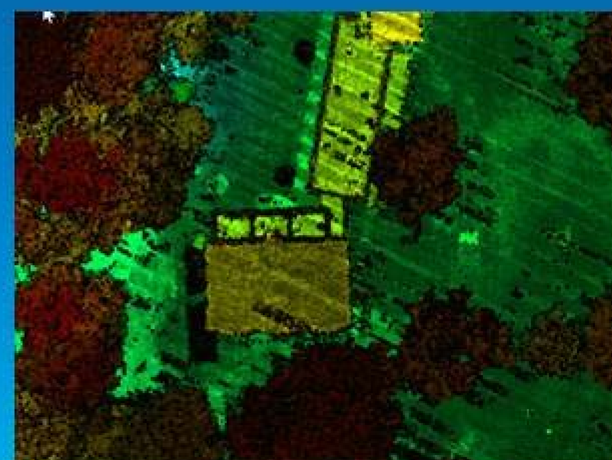
UAV Product Example



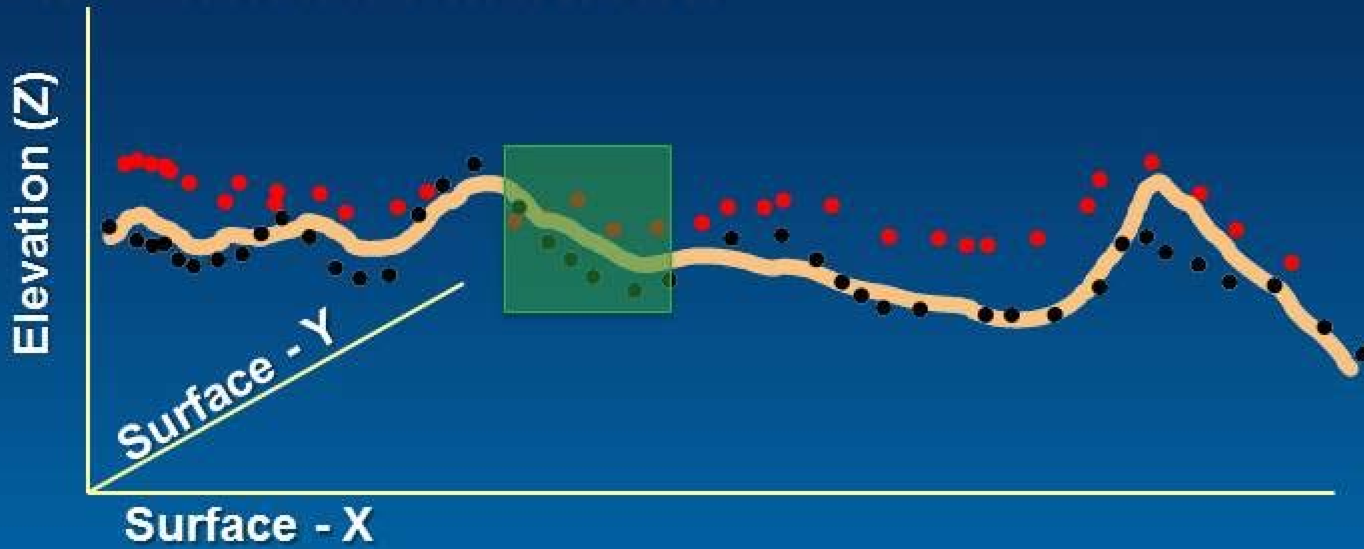
LiDAR in Wetlands

- Terrestrial Scanning
  - High density – get high

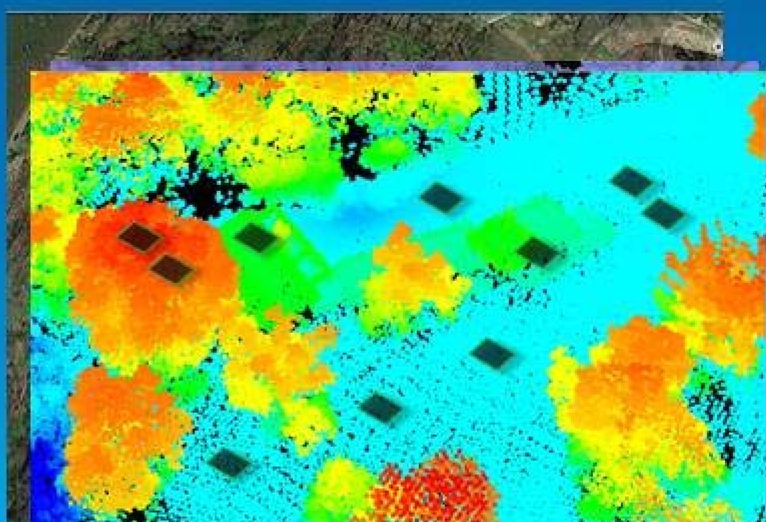
- Airborne Scanning
  - Choose your density – be rich



Conceptual Diagram



- First Return Lidar Pulse
- Digital Surface Model
- Point Cloud (UAV)



What does your MMU require?
Accuracy and precision?

Challenges for UAS/UAV data implementation

- Non-metric cameras providing imagery
  - ISO, Settings, etc.
- Sensor calibration
  - Histograms, Camera Settings, etc.
- Nadir Gimbal vs Pitch, Roll, and Yaw.
- Orthomosaic, Surface Models, Point clouds

- How do we integrate these data along with APSRS standardized products?
  - E.g. 1ft contours at NAVD88 (MSL)?
  - Support for vertical datum
  - Lack of geodetic control

Project Goals:

- Compare results of two different survey grade microUAS technologies using:
  - Raw onboard GPS and flight logs
  - Integration and use of ground control points
- Compare traditional and unique photogrammetric and remote sensing derivatives with UAV derived products
  - Geodetic Control
- Do different features and land cover types give the same vertical measurements?
  - Lidar vs UAV

Hardware:

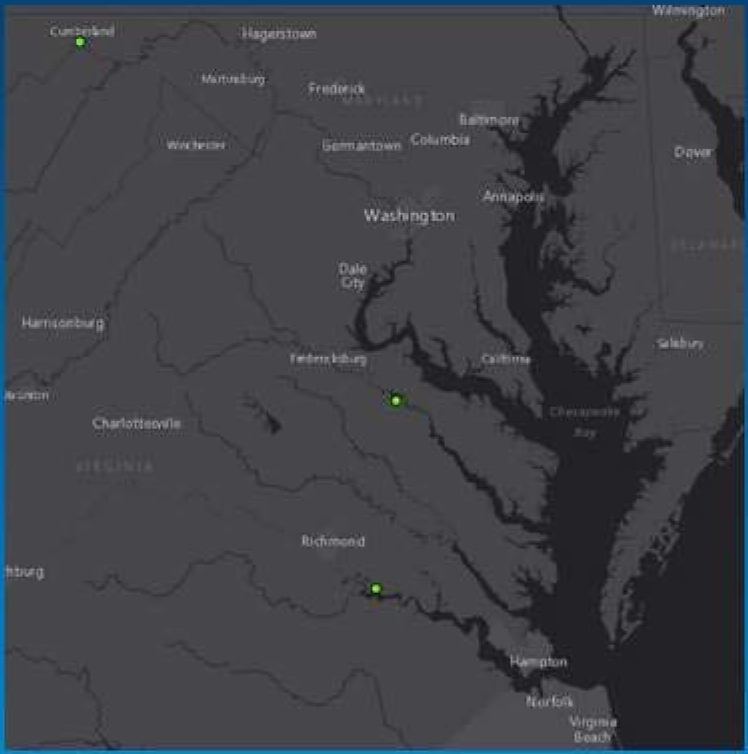
- **senseFly eBee RTK**
  - Global Navigation Satellite Systems
    - L1/L2 GLONASS GPS Receiver
  - RGB, NIR, Red-Edge Cameras
    - Sony/Canon 18mp, 3cm/5cm – 6-7 Seconds
  - Fully Autonomous 16mps
  - 1.5 lbs, ~30 min endurance

- **SmartPlane Freya**
  - Very Customizable and rugged
  - 45-50 minute endurance, 20mps
  - Post Processed GPS (PPK)
  - Ricoh GR 16.2 - 0.7 seconds

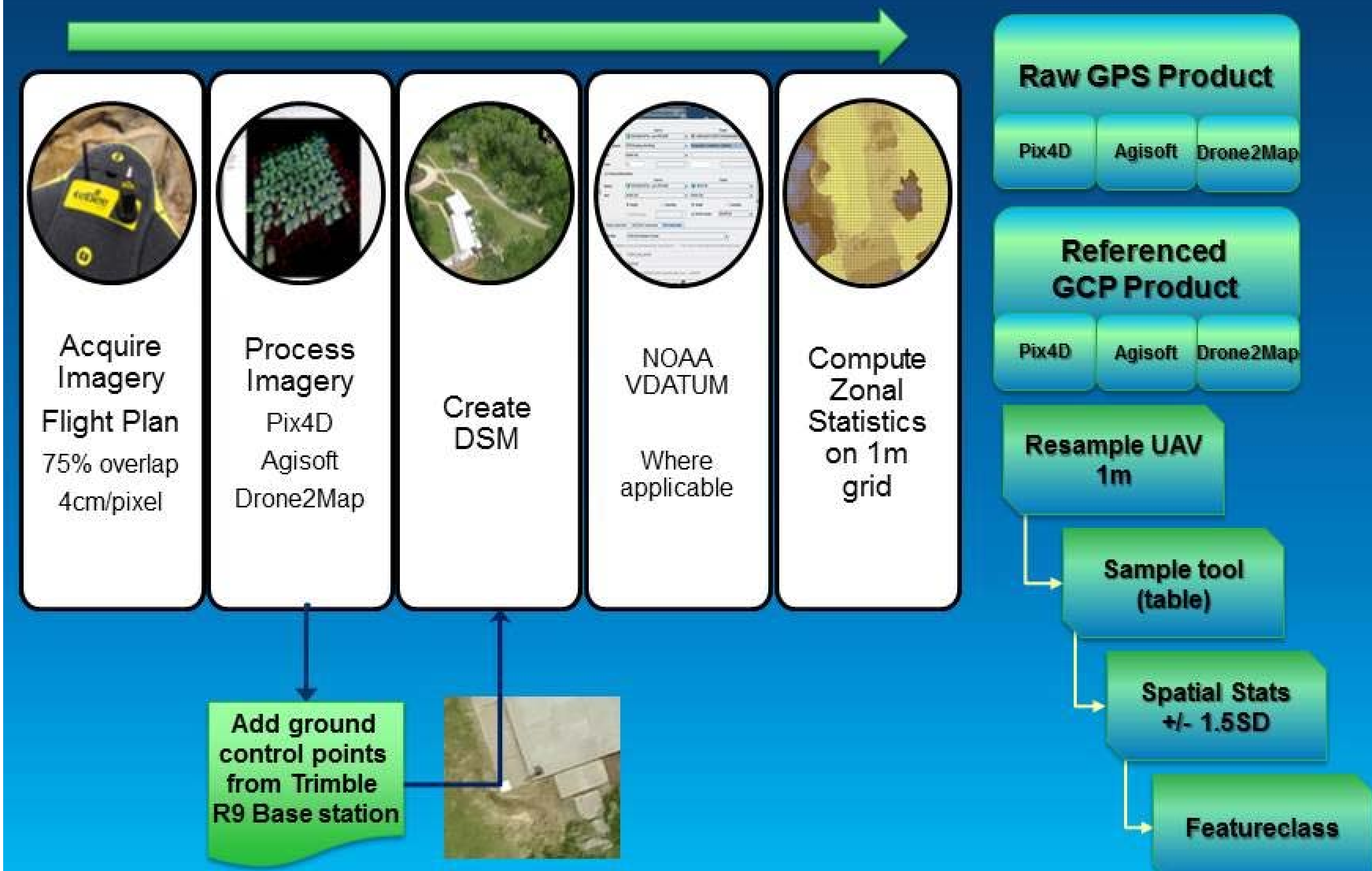
- **Trimble NetR9 Kinematic Base Station**

Study Site Locations

- VCU Rice Rivers Center
  - LiDAR (1550nm 2011, USGS 2012, CZMIL 2013)
  - LiDAR (1550nm 2012 – Mast/Terrestrial)
  - senseFly eBee RTK (2016)
  - 3DR Solo GoPRO Hero (in process)
- NOAA Geodetic Survey, Woolford, Virginia
  - LiDAR (1550 2013)
  - senseFly eBee RTK
  - senseFly eBee
- Cumberland, Maryland
  - LiDAR (USGS 2013 FEMA)
  - SmartPlane Freya (Jan 2016)



UAV Workflow



Results

Method comparison

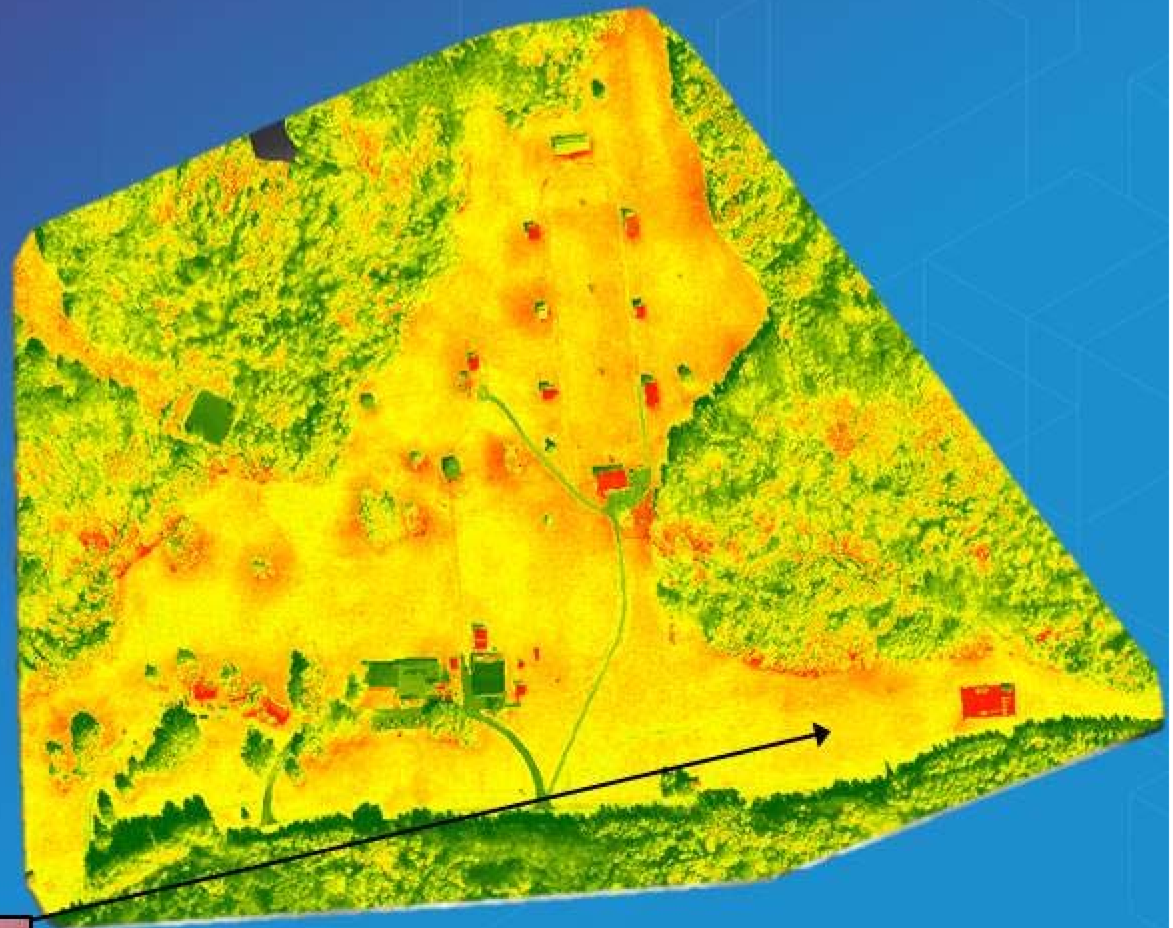
Method	Cost/Time	Processing Time	Area Size	Resolution
Terrestrial LiDAR	12 Hours ($190k)	4 hours[1]	30 acres	2cm/200hz
Aerial LiDAR	18 Hours ($20,000)	2 weeks delivery	350 acres	2cm/200hz
Micro UAS SmartPlane	4 hours ($30,000)	8 hours[2]	200 acres	3cm
Micro UAS senseFly eBee	4 hours ($50,000)	8 hours[3]	160 acres	5cm
Micro UAS – 3DR Solo multirotar	2 Hours ($1,500)	2 hours[4,5]	30 acres	2cm

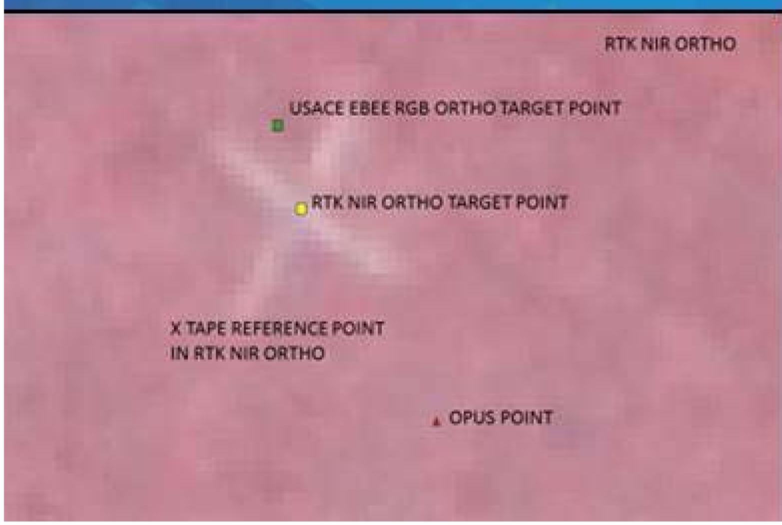
1 RiScan – Riegl
2 Agisoft
3 Pix4D
4 Drone2Map
5 Results pending

NOAA – National Geodedic Survey – Corbin, VA

RTK eBee was 0.25m closer to base station OPUS points vs Non-RTK UAS

- Stand alone VRS
- Trimble Base Station
  - Ashtech/Trimble
  - Horizontal Accuracy was 0.8 vs Base Station

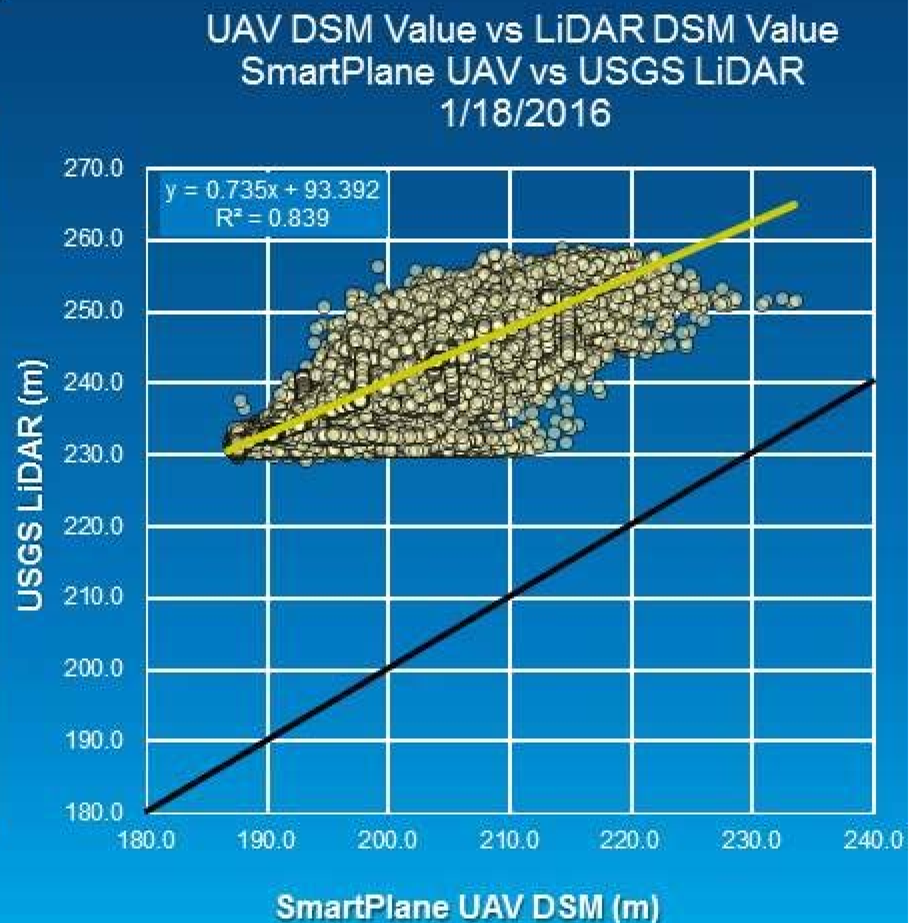




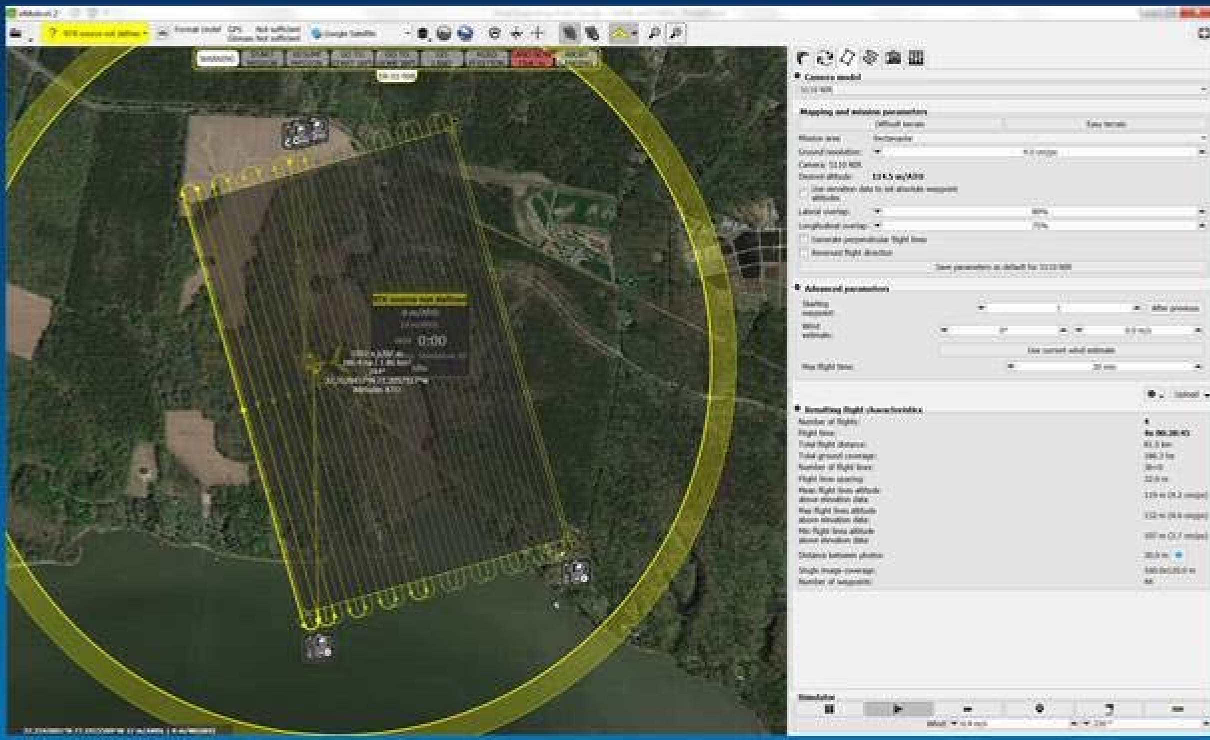
SmartPlane UAS vs LiDAR

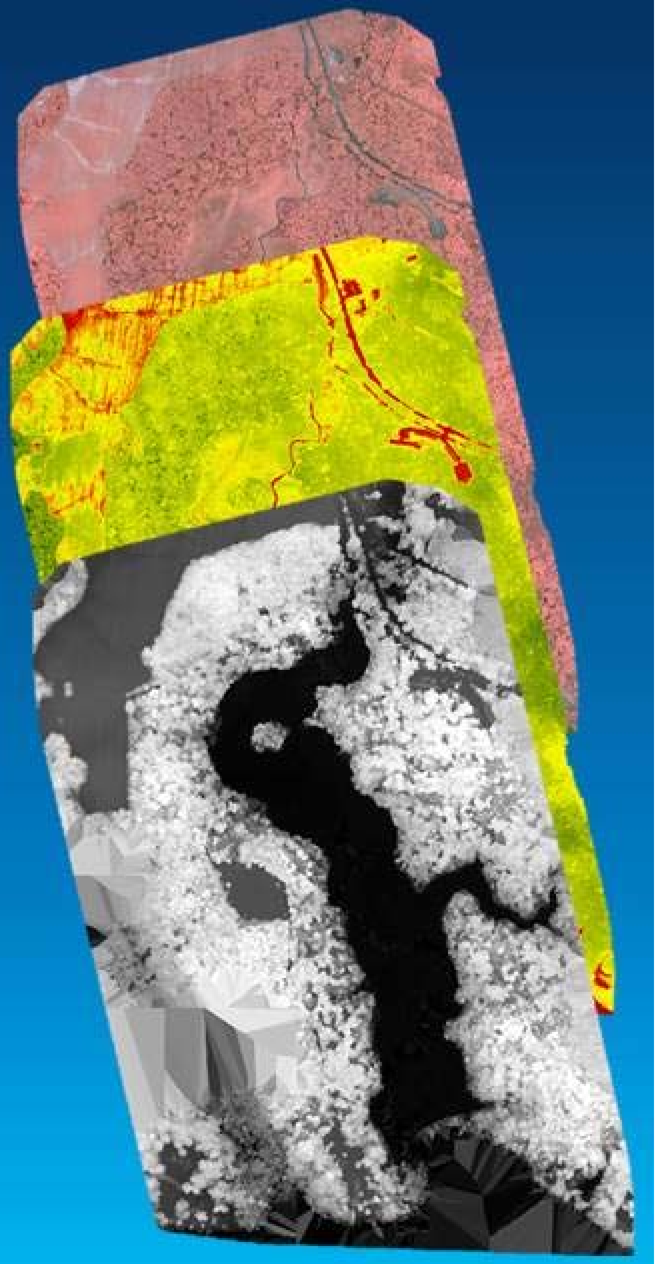
- **Location: Cumberland, Maryland**

Stand alone L1/2 GPS with no ground control

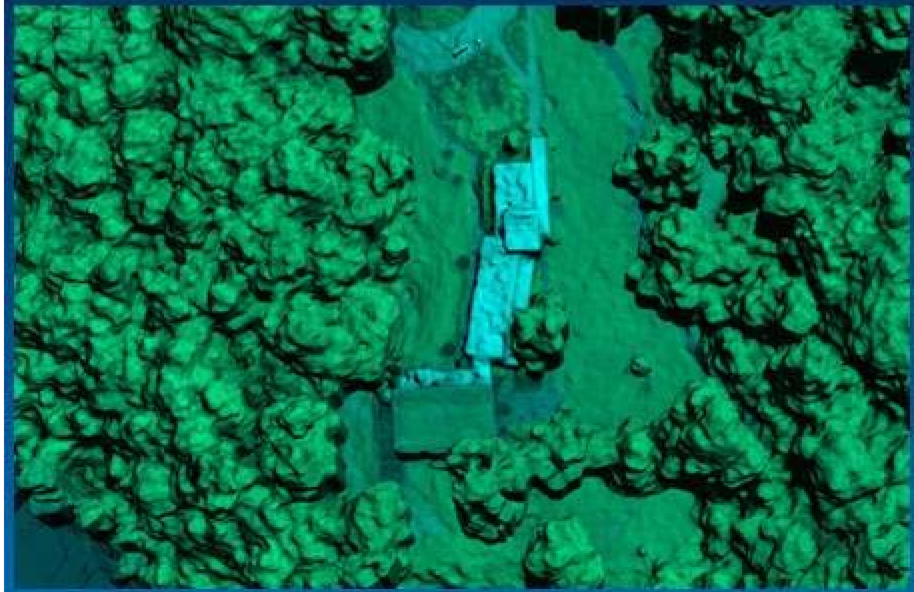


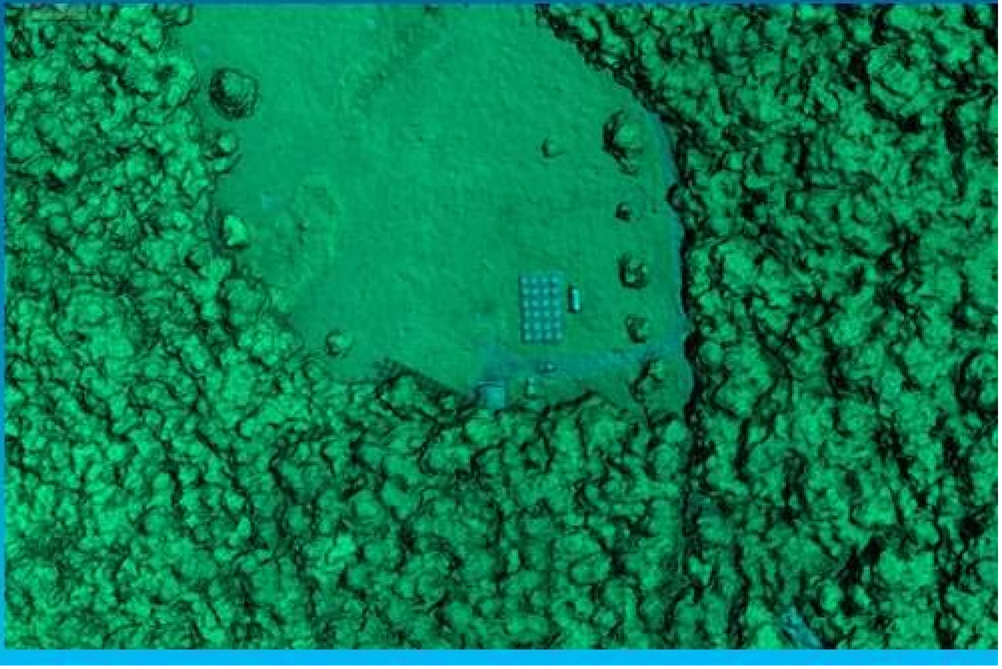
Flight Plan and Results

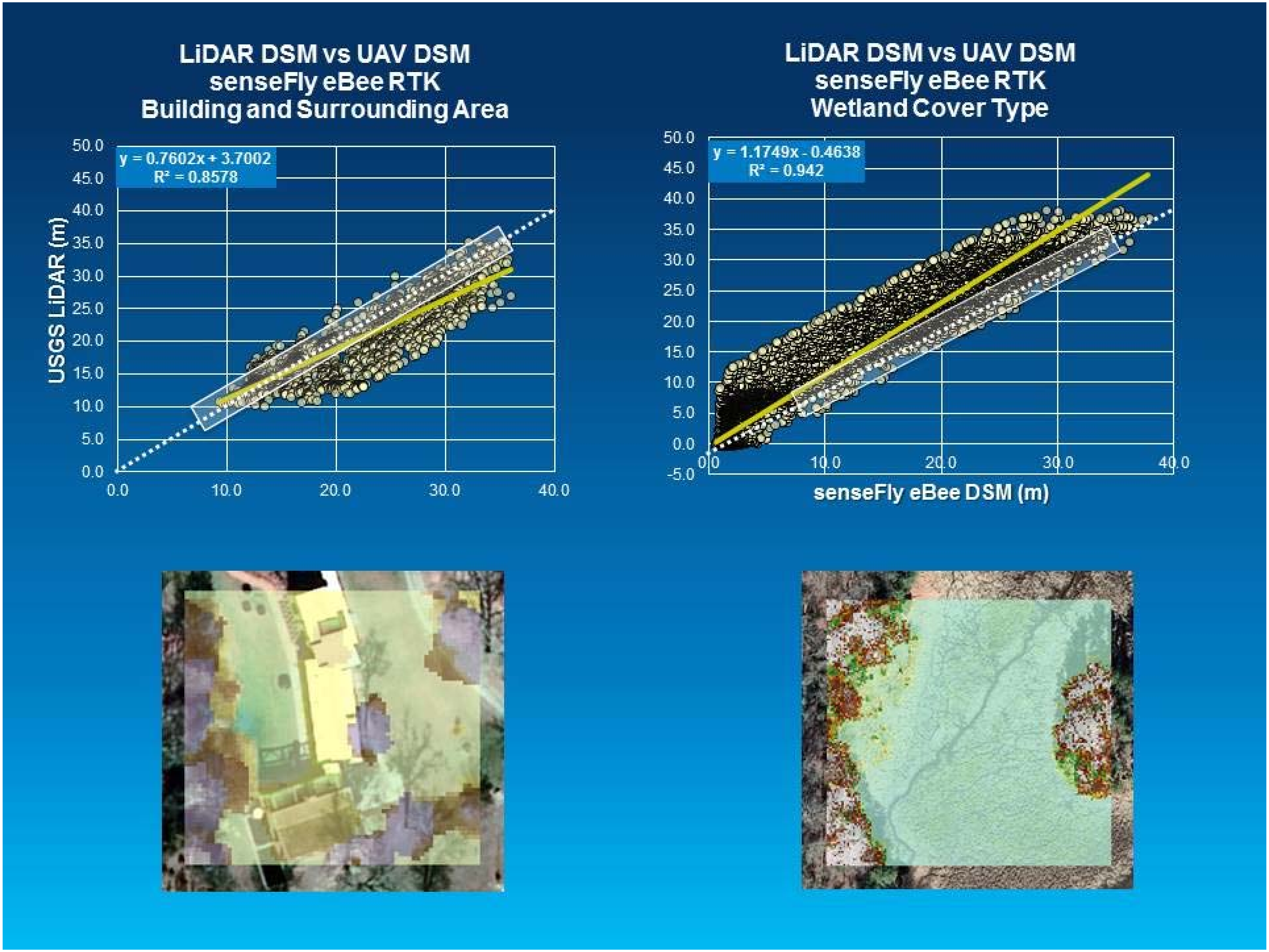




Digital Surface Model and Point Cloud

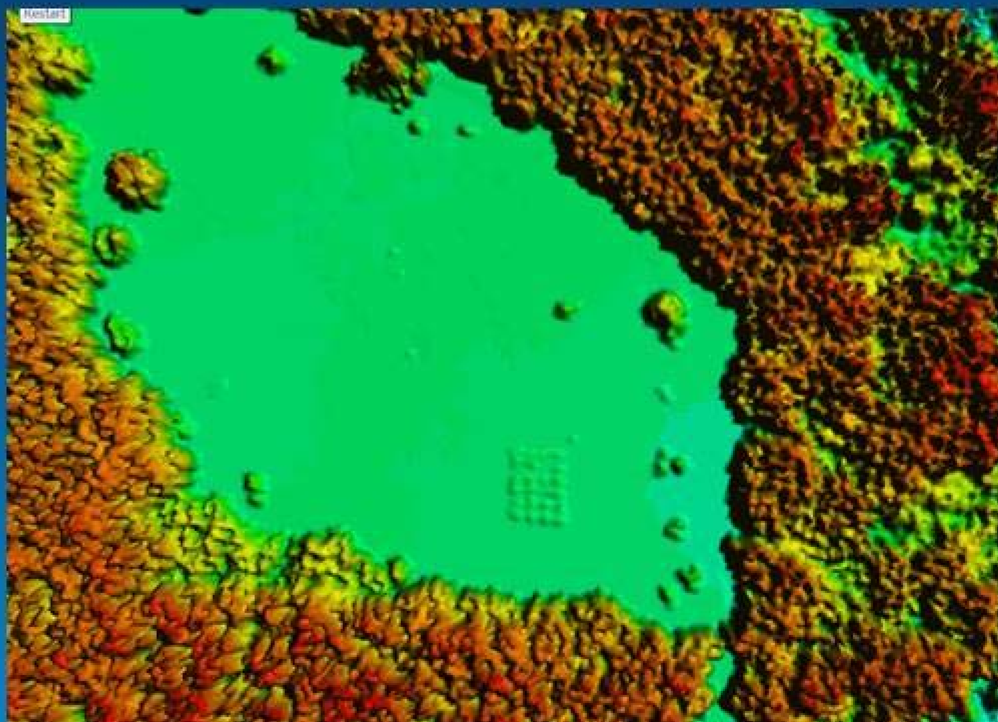


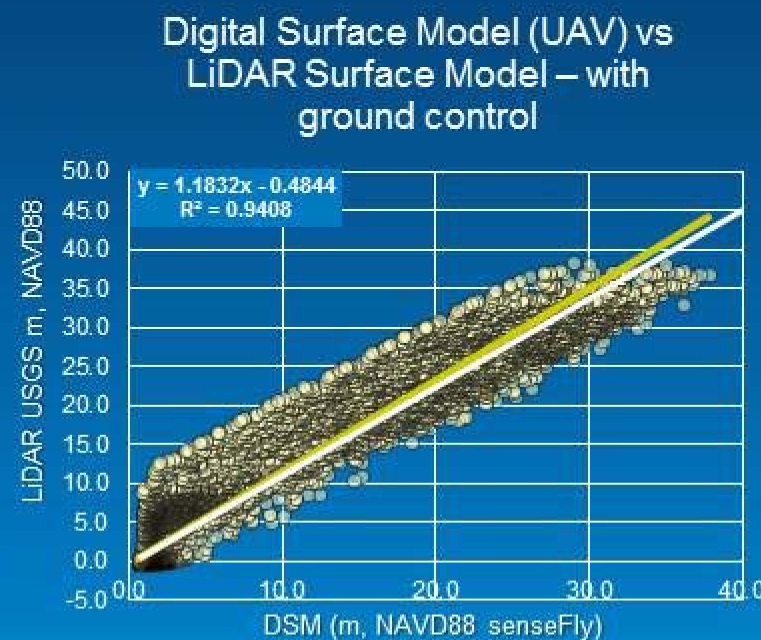




LiDAR DSM vs UAV DSM
senseFly eBee RTK
Building and Surrounding Area
y = 0.7602x + 3.7002
R² = 0.8578
USGS LiDAR (m)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
0.0
10.0
20.0
30.0
40.0
LiDAR DSM vs UAV DSM
senseFly eBee RTK
Wetland Cover Type
y = 1.1749x - 0.4638
R² = 0.942
-5.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
0.0
10.0
20.0
30.0
40.0
senseFly eBee DSM (m)

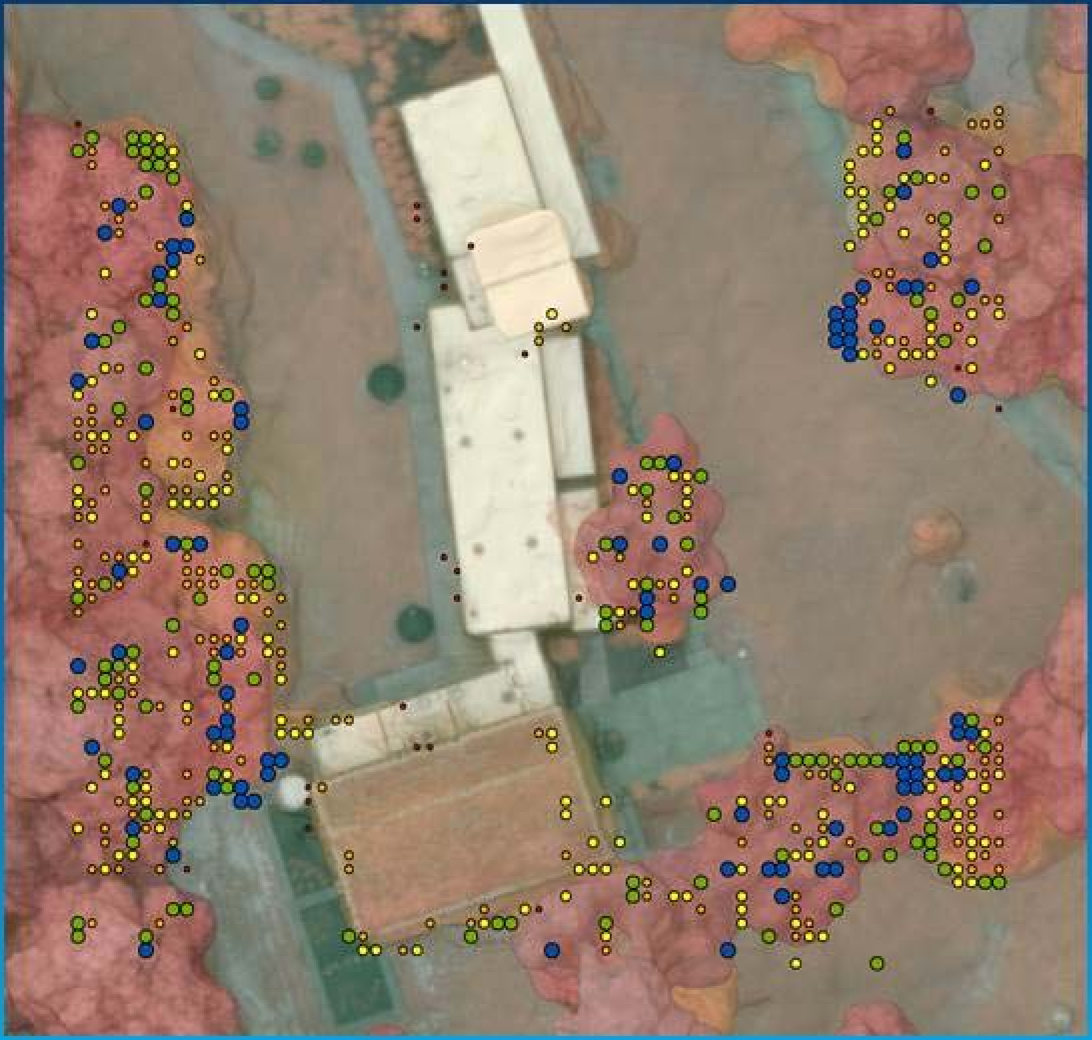
Digital Surface Model VS LiDAR Surface





5 Ground control points were placed in the scene to help the autocorrelation and bundle Adjustment.

Displaying differences in DSM vs LiDAR Surface



Results

- senseFly eBee RTK performed closer to OPUS solution compared to non-RTK
  - Better geodetic control
- SmartPlane Freya underestimated elevation
  - Ground control needed (PPK GPS)
- Elevation derived by senseFly eBee RTK explained 85% of the variation in USGS LiDAR elevation surface model
- Elevation derived by senseFly eBee RTK in wetland area explained 94% of the variation in USGS LiDAR elevation surface model
- Introducing ground control increased the explanatory power by 10%.
- Drone2Map took 8 minutes less to produce the same orthomosaic (rapid) vs Pix4D

Conclusions

- UAV derived elevation products could be used in surrogate of LiDAR, but altitude, attitude, and GPS are controlling variables
- Elevation surface models can differ because of "holes" in canopy, users should display where differences occur.
- Don't fire your surveyor - ground control is still needed – especially internal UAV GPS
- Matching vertical datums (NAVD88, GEOID12a, etc.) is critical
  - Support for vertical in 10.4
- Choose a platform that can combine mission planning and piloting to ensure data capture
- Flying perpendicular

Acknowledgments

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  Caron-East
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- senseFly