Civil & Construction Engineering

COLLEGE OF ENGINEERING

Emerging Surveying and Mapping Technologies

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OSBEELS Symposium

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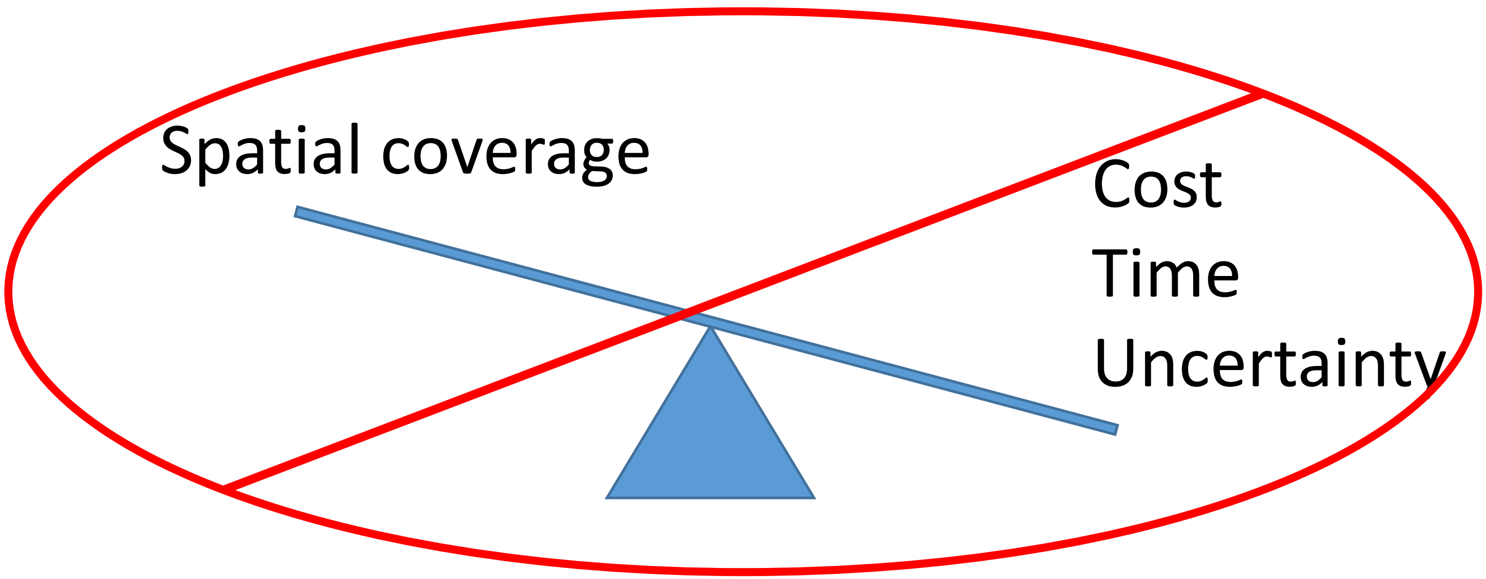
Salem, Oregon

“Boots-on-the-ground” field surveys

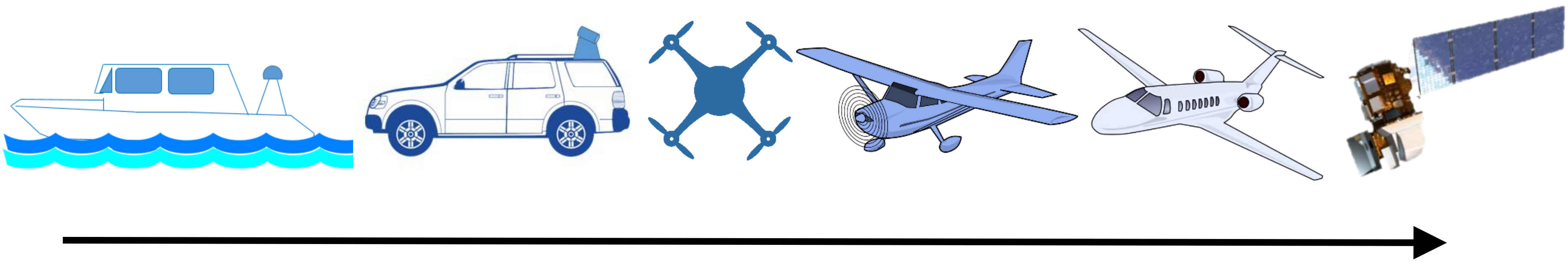
Desired improvements

Spatial coverage (area)	↑
Time	↓
Cost	↓
Spatial uncertainty	↓



Can't be done, due to inherent tradeoffs between these goals!

Alternative: moving survey platform

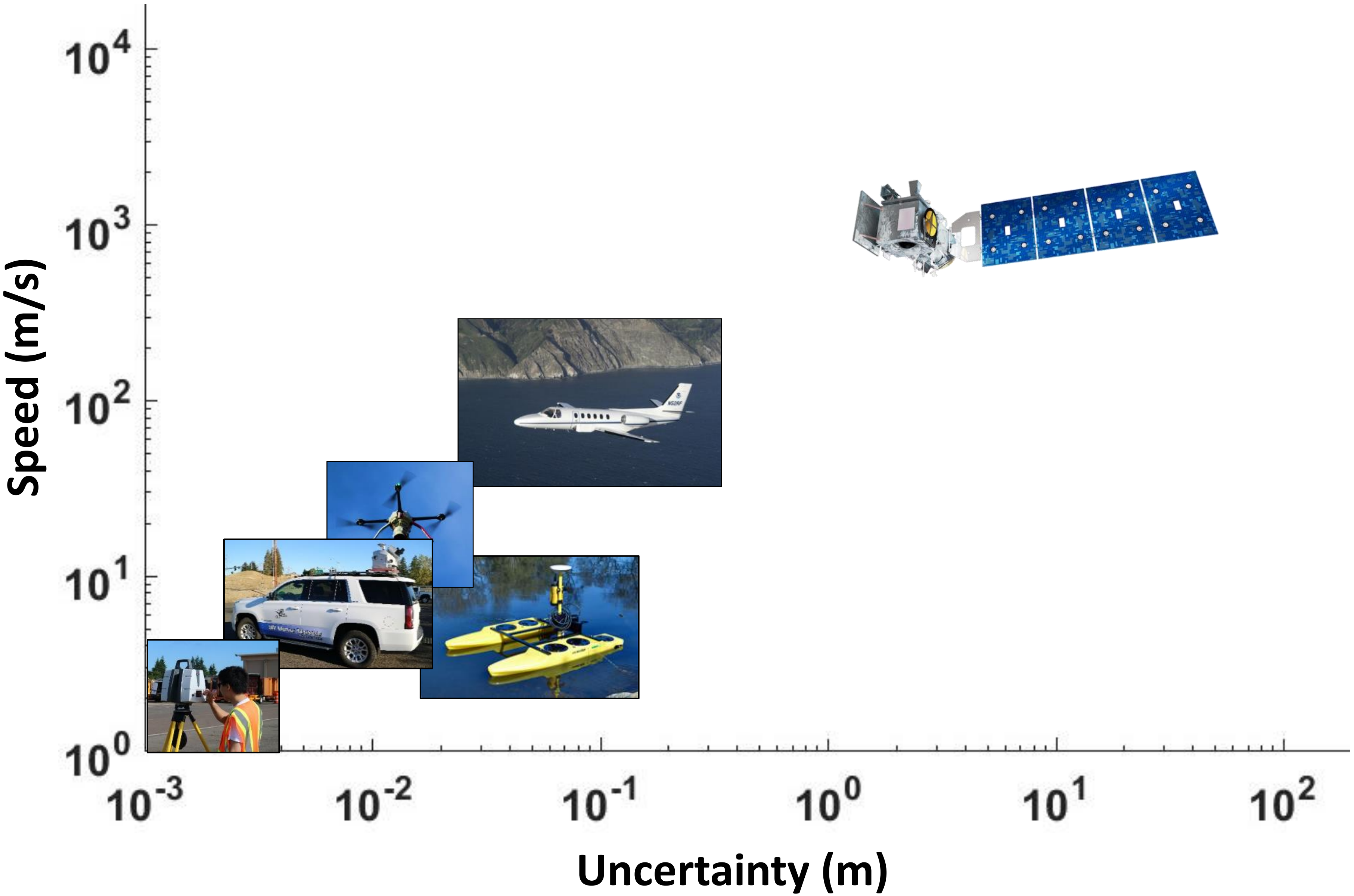


Survey speed

- Nearly certain to cover more ground quickly
- What's the tradeoff? Accuracy
- Objective function:

$$\min\{cost + time\}$$
$$\text{subject to } \{accuracy \ \leq spec\}$$

Inherent Tradeoffs

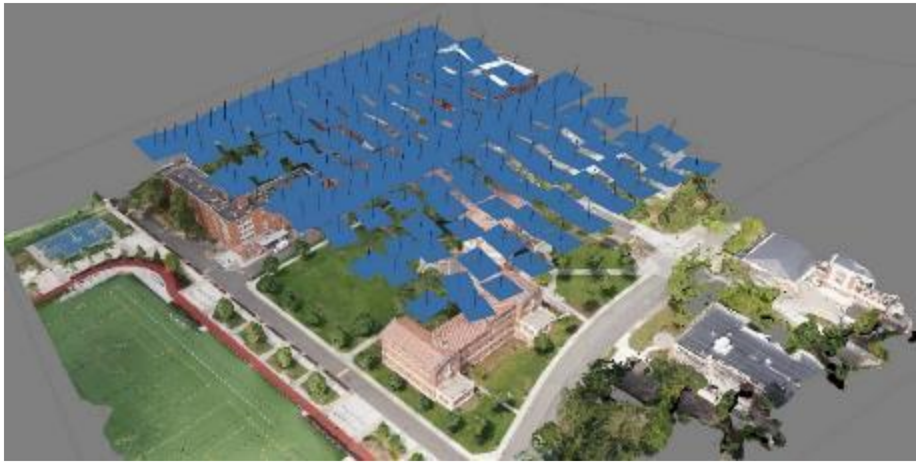


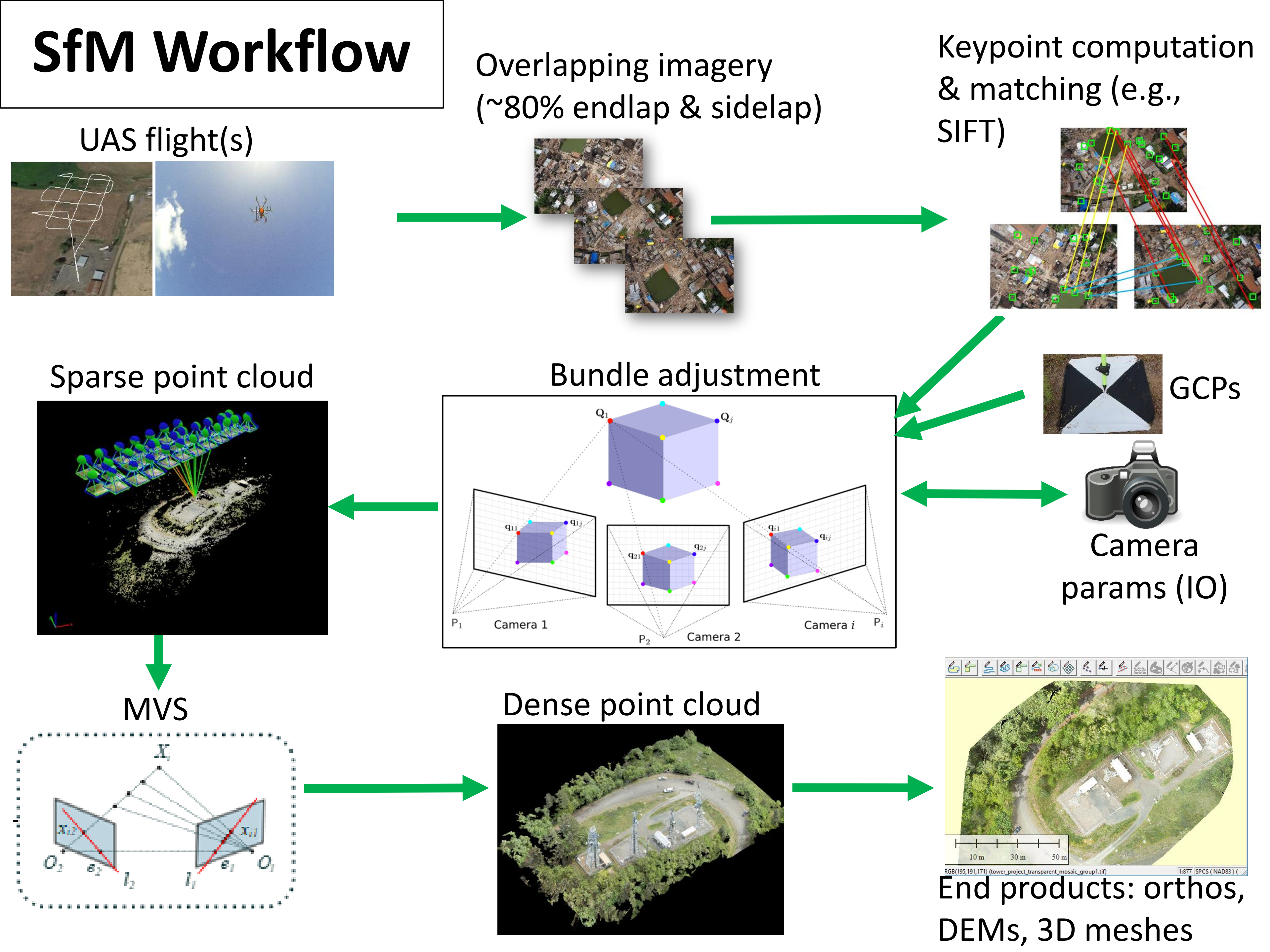
Emerging tools & technologies

- Autonomous/unmanned vehicles
  - UAS, ASVs, ROVs
  - UAS-based lidar and Structure from Motion (SfM) photogrammetry
- Direct georeferencing: GNSS-aided INS
  - Smaller, cheaper, lighter carrier-base based GNSS and MEMS INS
- New advances in airborne and mobile lidar
  - Single photon and Geiger mode lidar
  - Topographic-bathymetric lidar
  - Satellite-based lidar
- *How do we quantitatively assess, compare, and optimize for our operational use?*

UAS + SfM Photogrammetry

- SfM
  - Relatively new photogrammetric approach
  - Leverages advanced image matching algorithms from the field of computer vision
  - Can work with a wide range of viewing geometries and consumer-grade cameras
    - *Well suited to UAV imagery!*
  - Highly automated, easy to use software




SfM Workflow
UAS flight(s)
Overlapping imagery
(~80% endlap & sidelap)
Keypoint computation
& matching (e.g.,
SIFT)
GCPs
Bundle adjustment
Camera 1
Camera 2
Camera i
Camera
params (IO)
Sparse point cloud
MVS
Dense point cloud
End products: orthos,
DEMs, 3D meshes

Empirical accuracy assessments, per *ASPRS Positional Accuracy Standards for Digital Geospatial Data* & *FGDC NSSDA*

≥20 well-distributed checkpoints

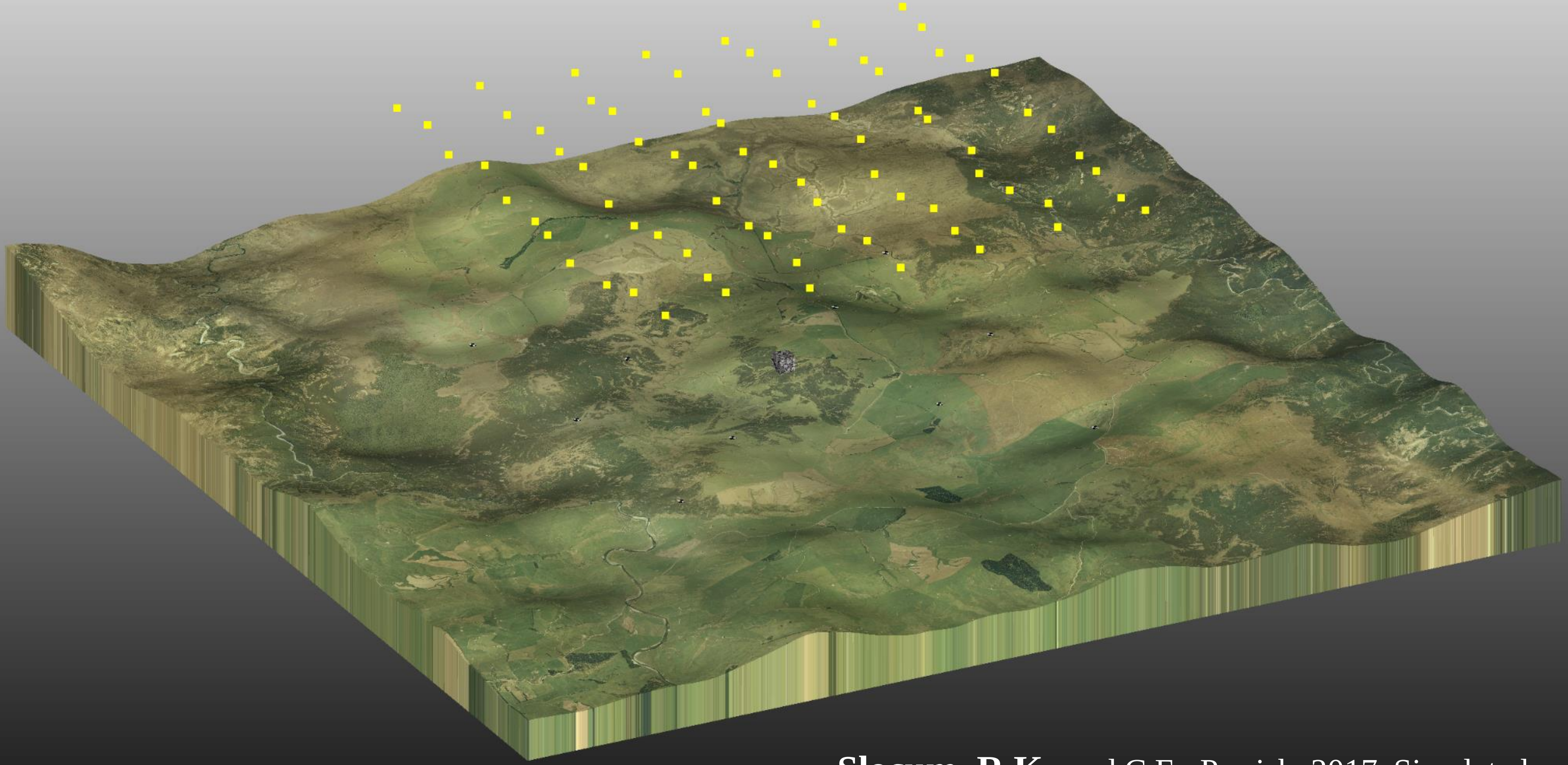
RTK GNSS

Post-processed static GNSS

$$RMSE_z = \sqrt{\frac{\sum \left(z_{datai} - z_{checki} \right)^2}{n}}$$

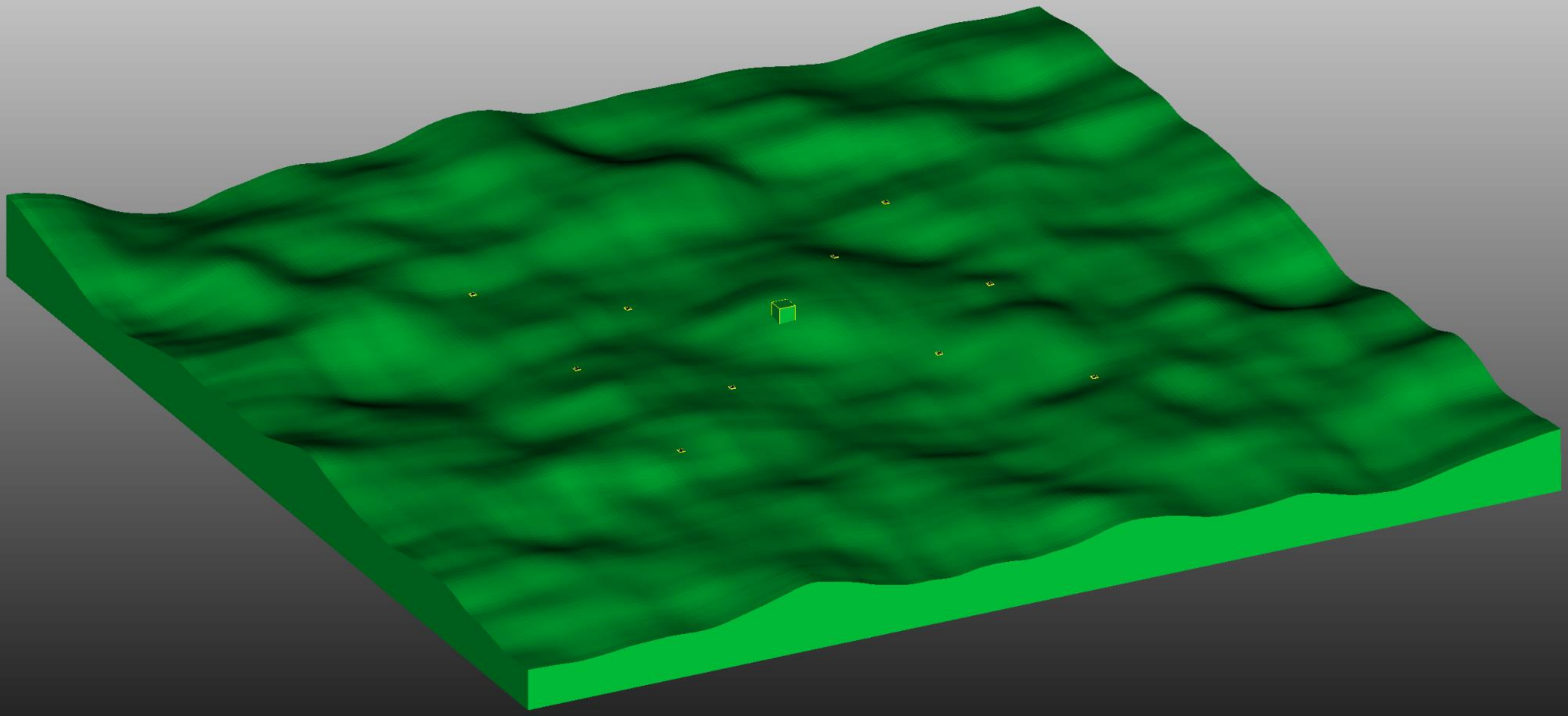
$$Accuracy_z = 1.96\left(RMSE_z \right)$$

simUAS

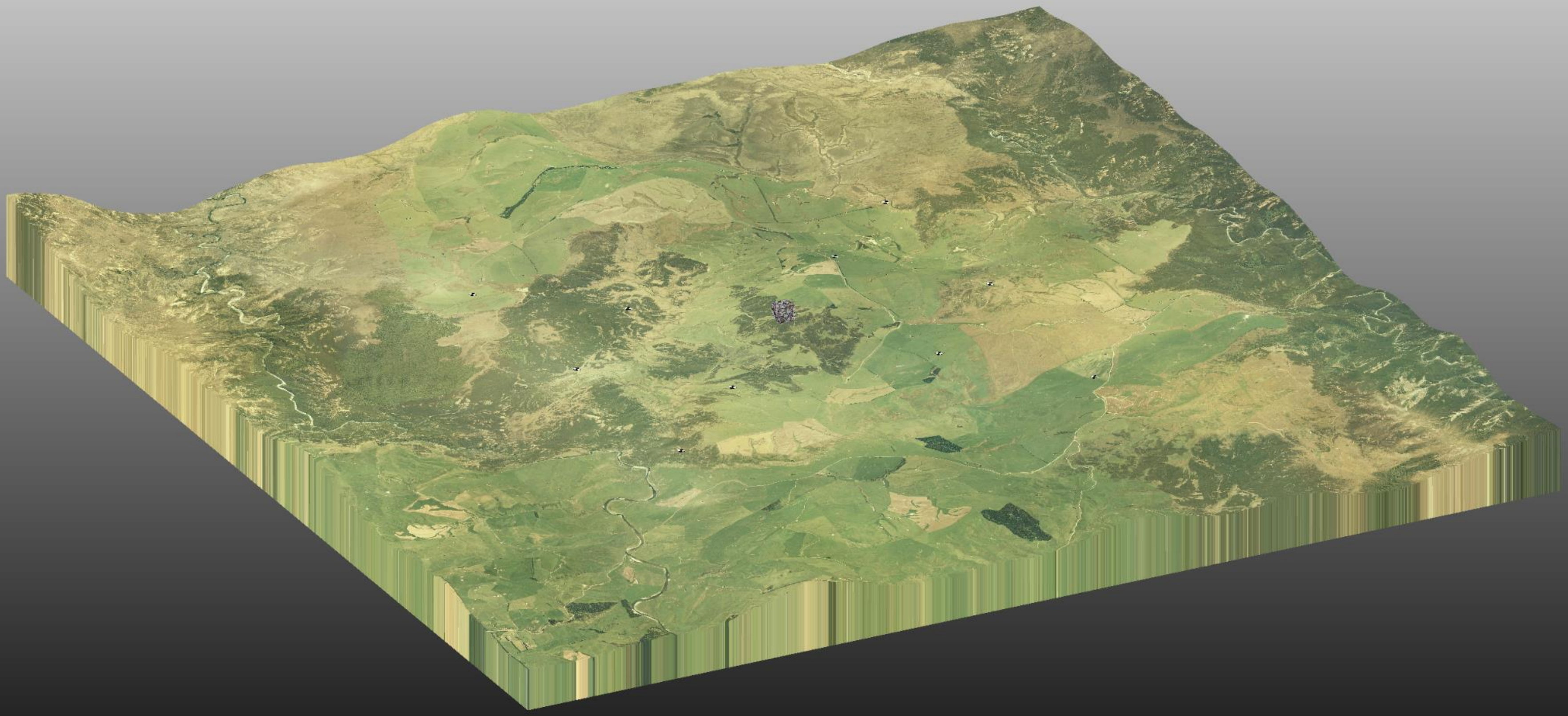


Slocum, R.K., and C.E., Parrish, 2017. Simulated Imagery Rendering Workflow for UAS-Based Photogrammetric 3D Reconstruction Accuracy Assessments. *Remote Sensing*, Vol. 9, No. 4:396.

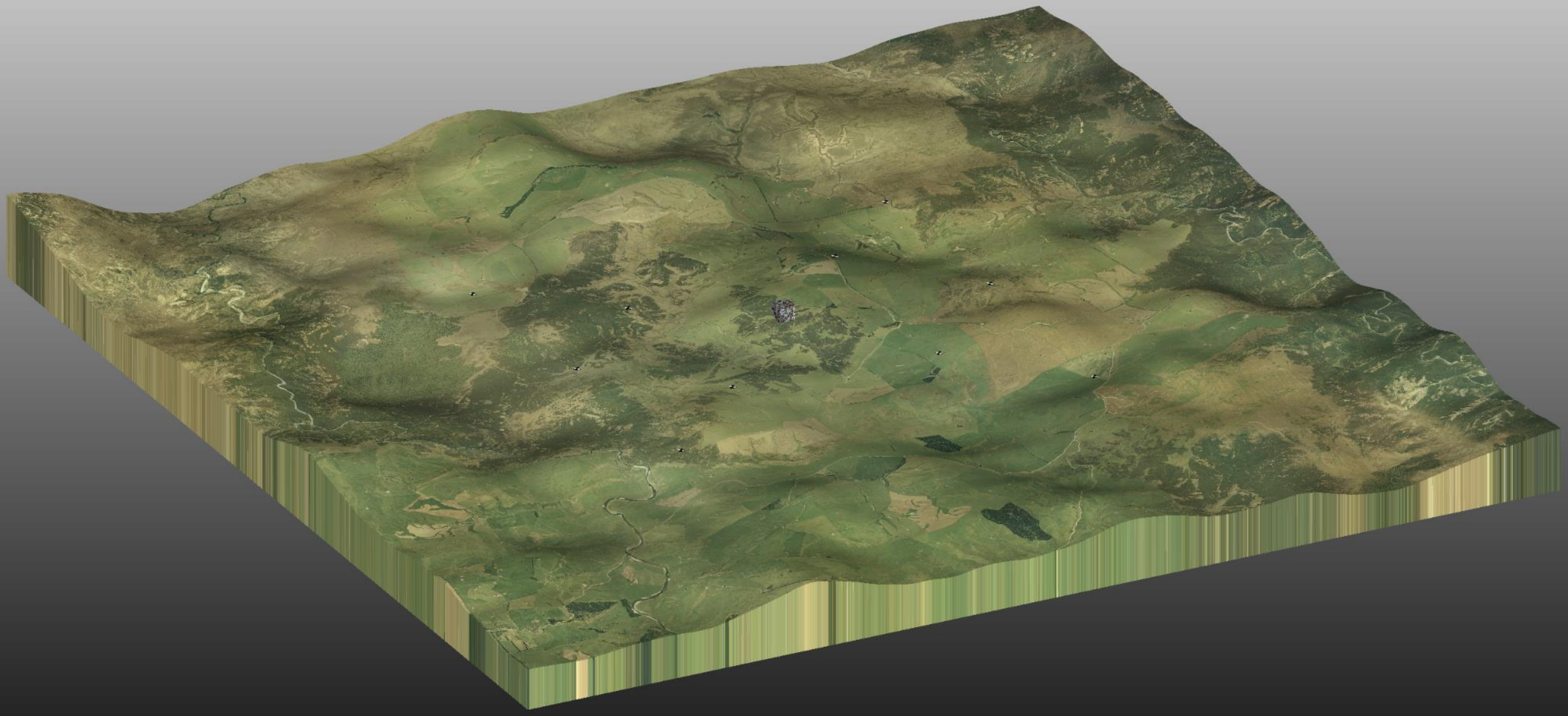
1. Generate Model



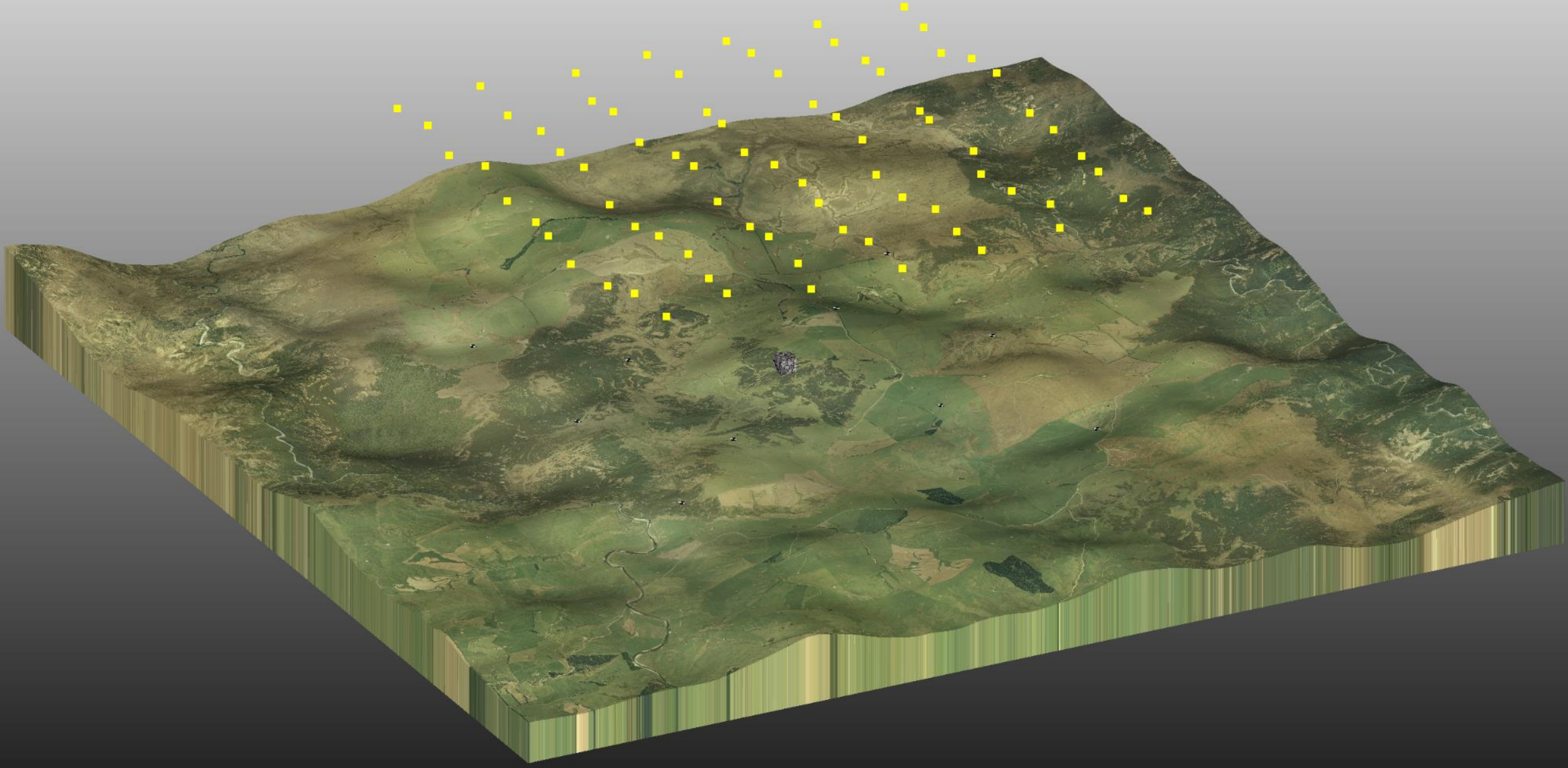
2. Texture Model



3. Add Lighting to Scene



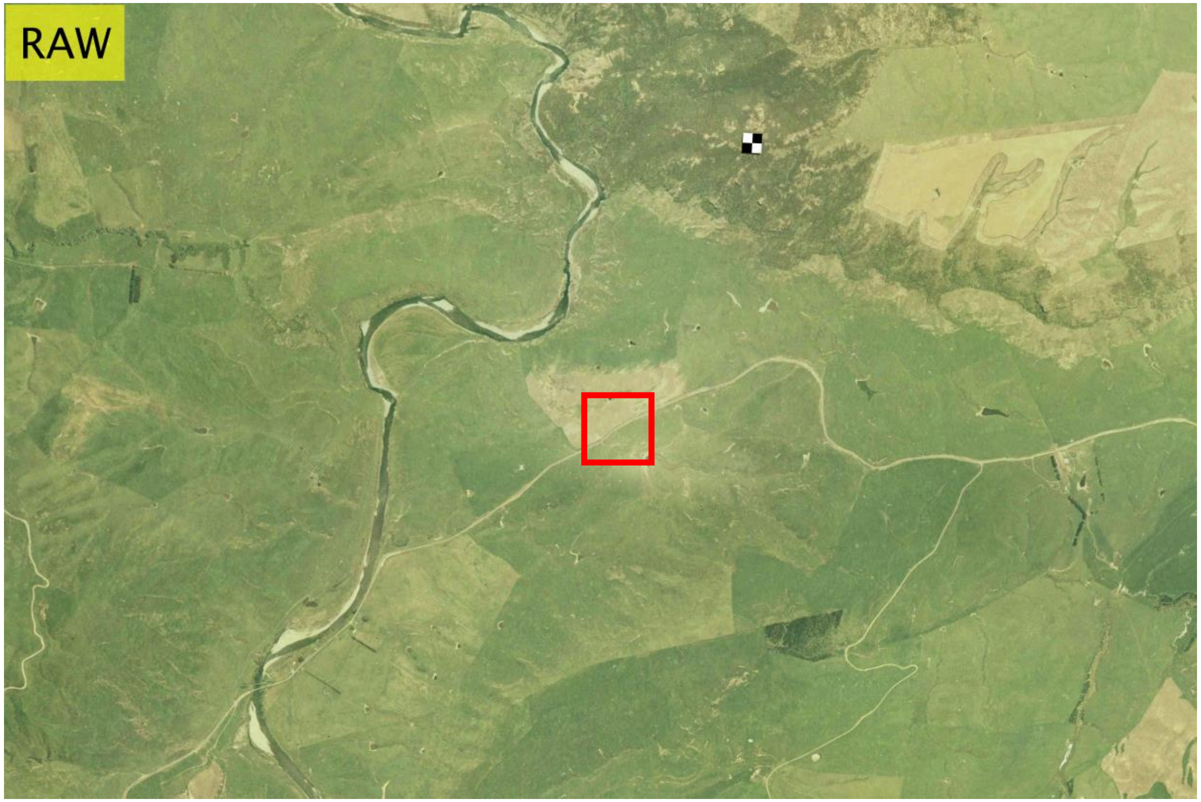
4. Add Cameras



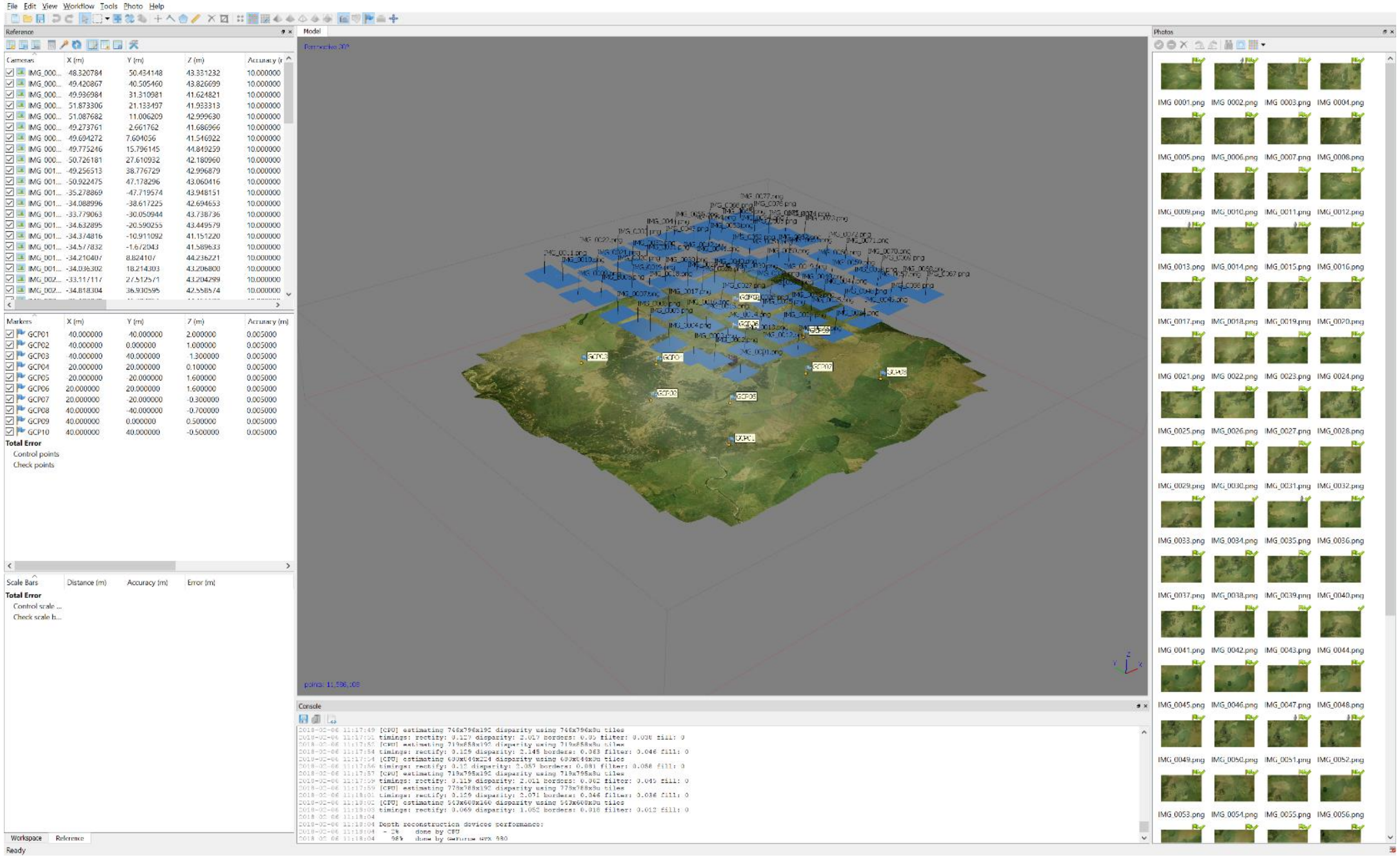
5. Render Imagery

6. Postprocess Imagery

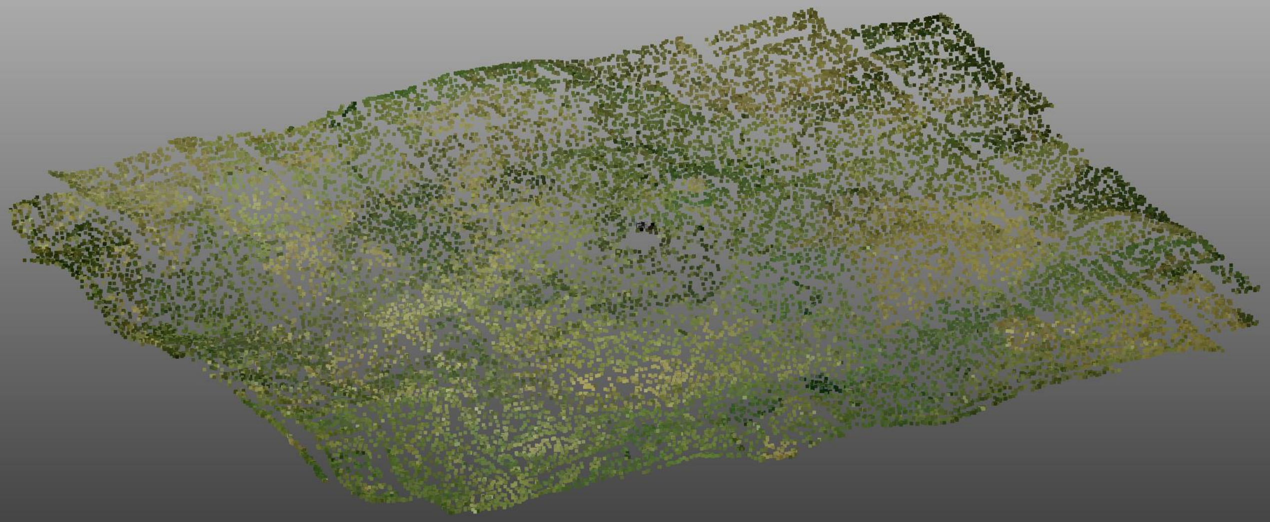
- Lens Distortion
- Vignetting
- Gaussian Noise
- Salt/Pepper Noise
- Gaussian Blur



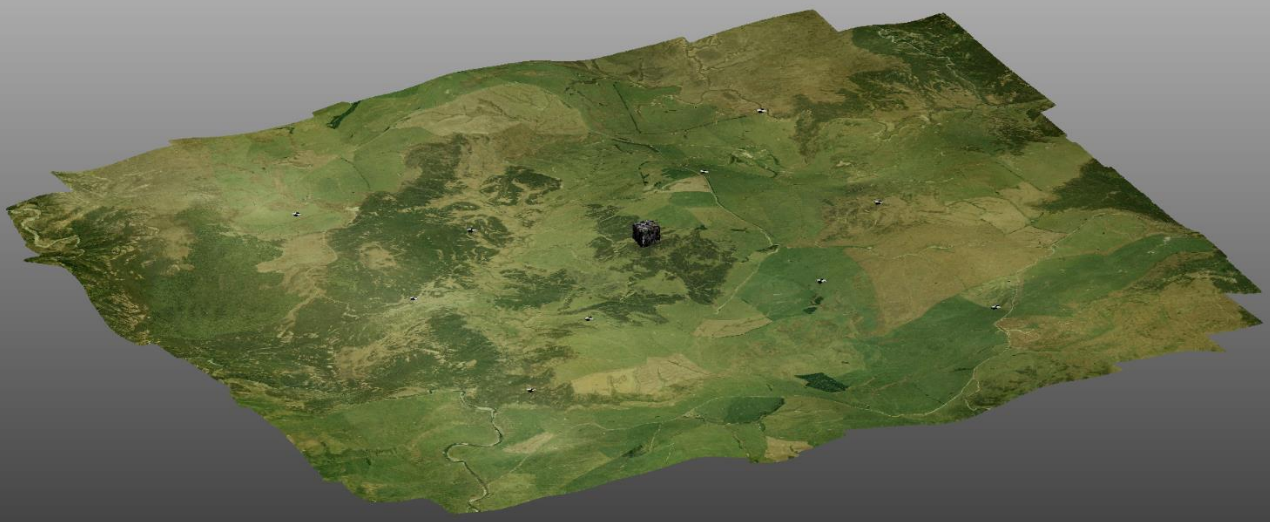
7. Process Using Commercial SfM



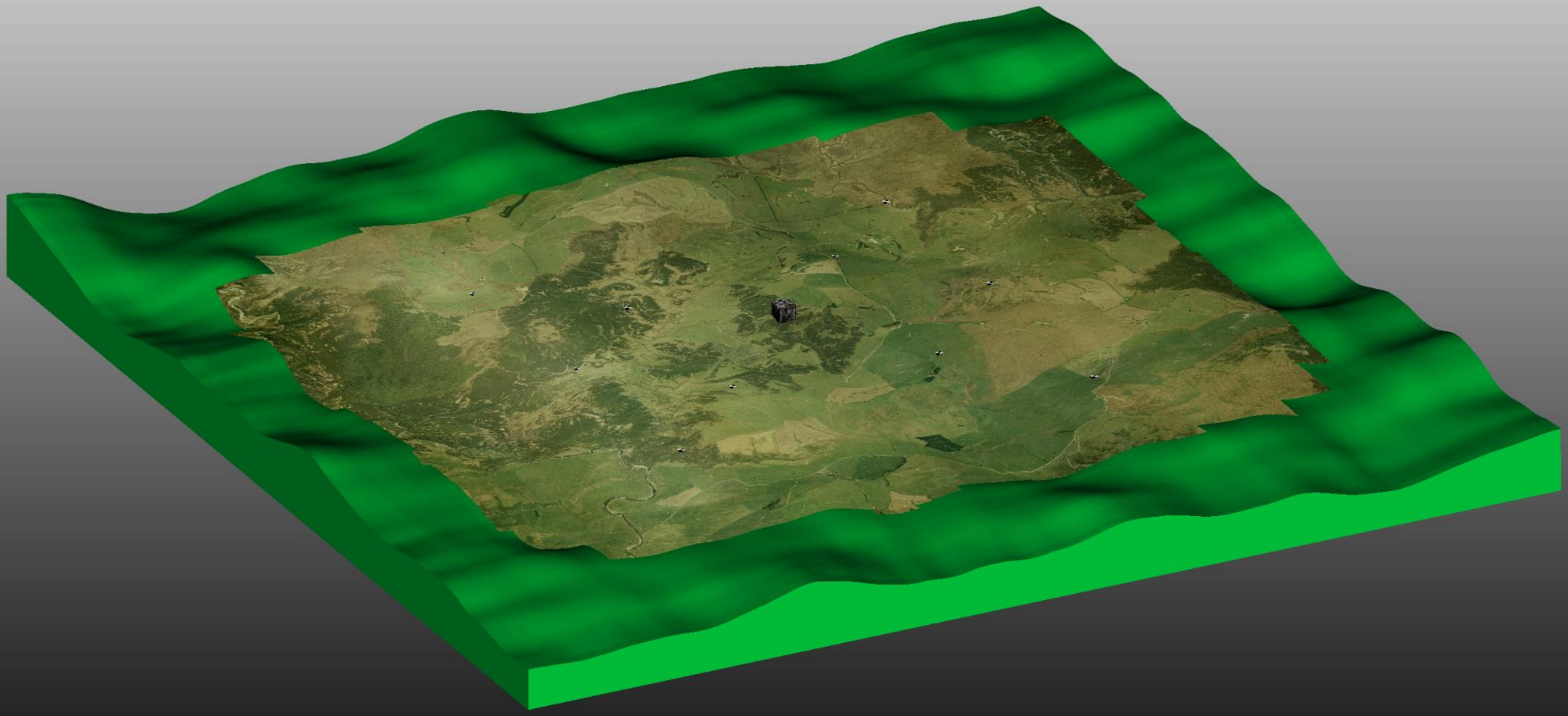
8. Generate Sparse Pointcloud



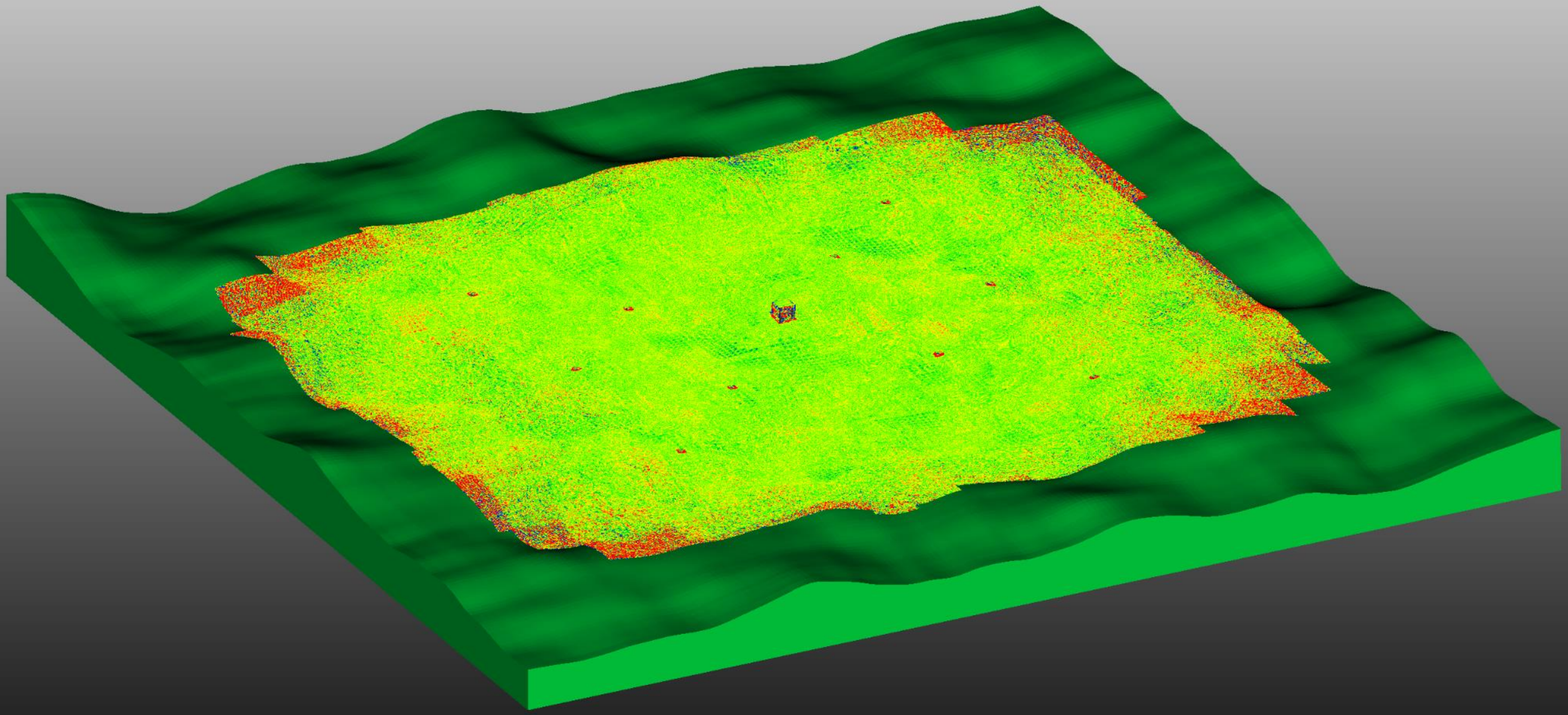
9. Generate Dense Pointcloud



10. Compare Dense Pointcloud to Mesh



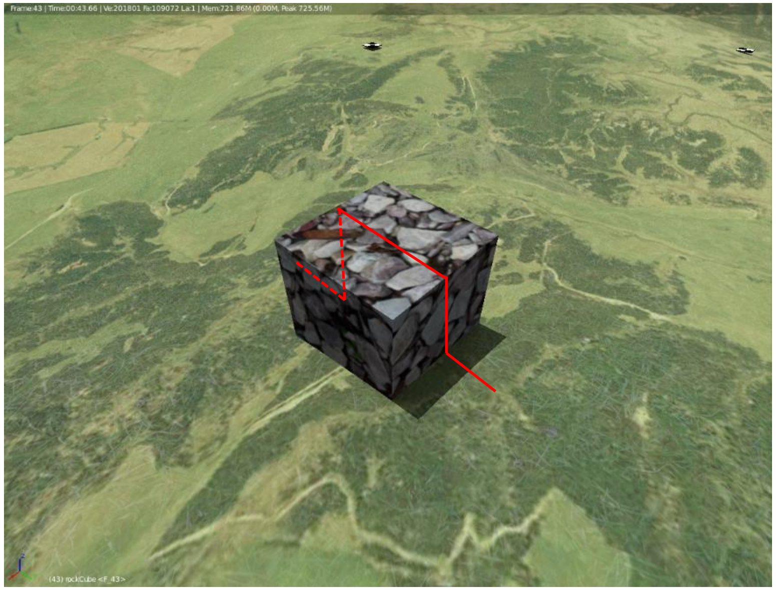
11. Compute Cloud to Mesh Distances

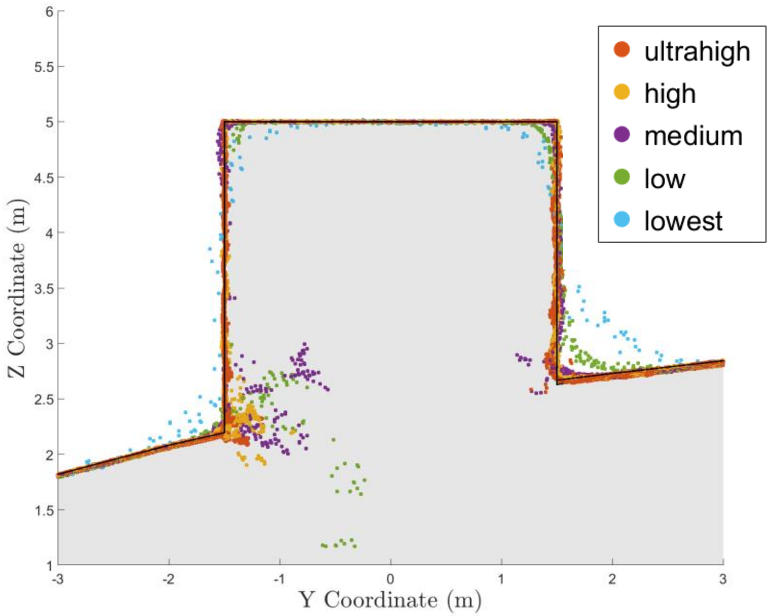


CloudCompare

Qualitative Results

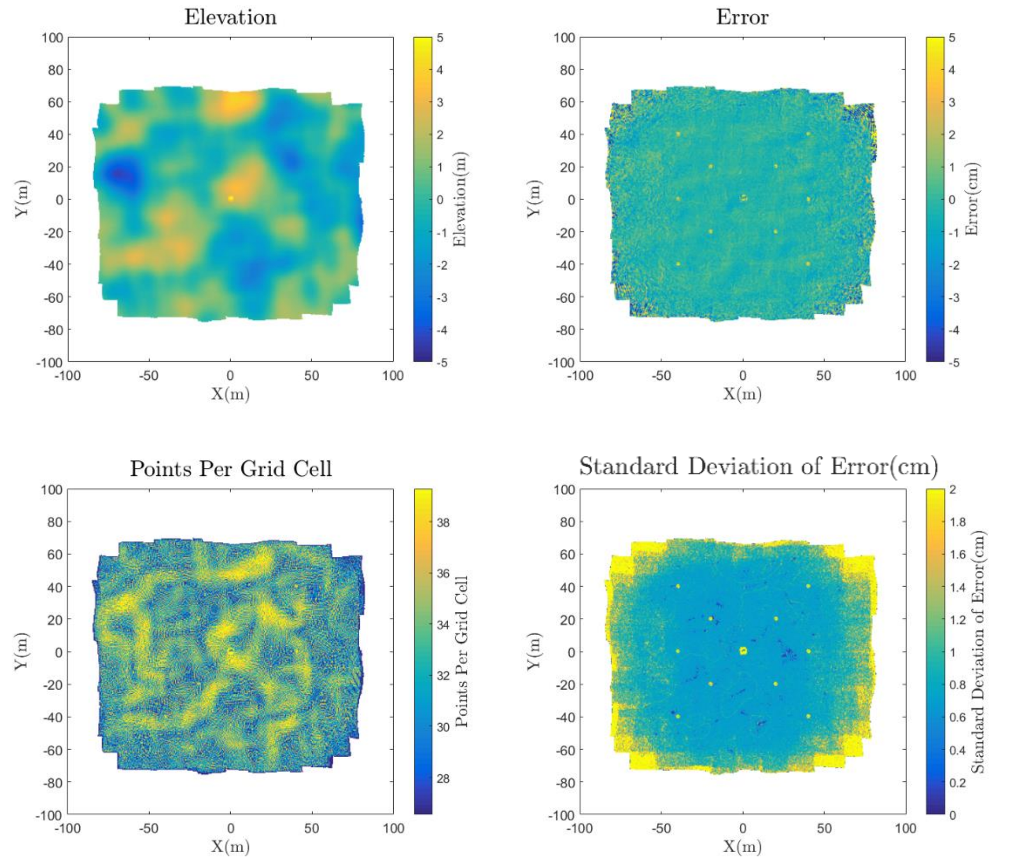
Lower Photoscan Dense Quality = round corners

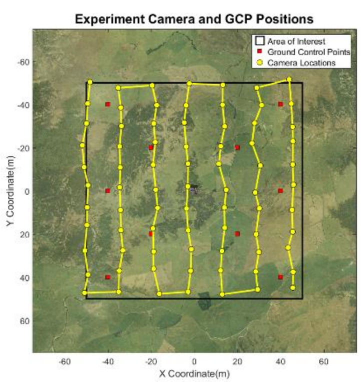




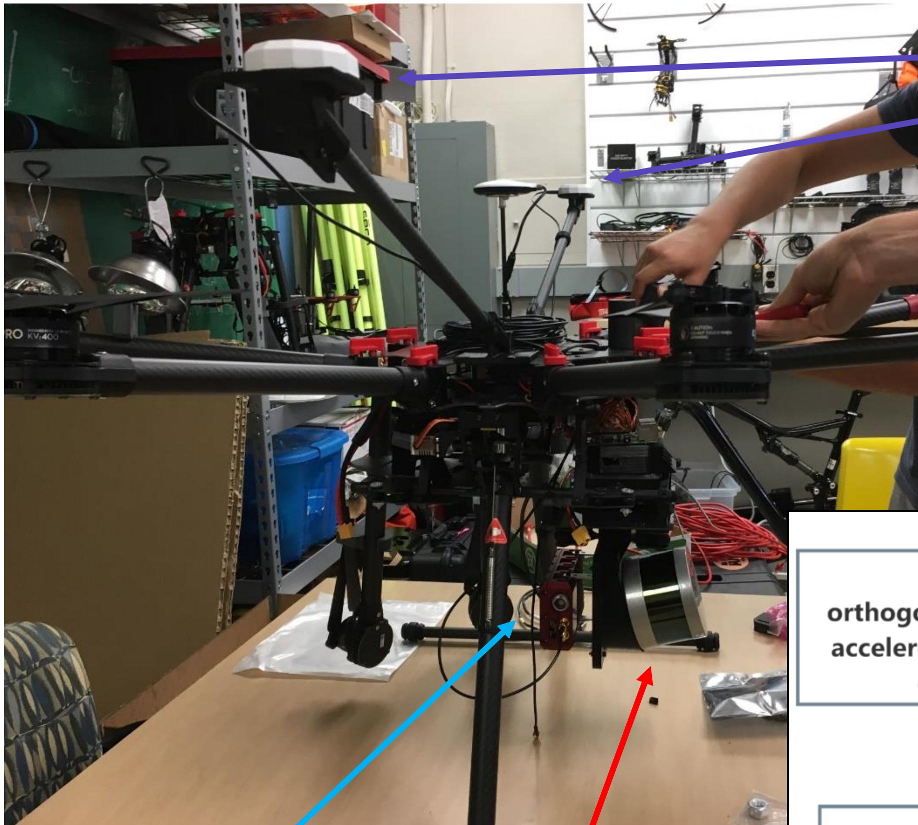
Quantitative Results

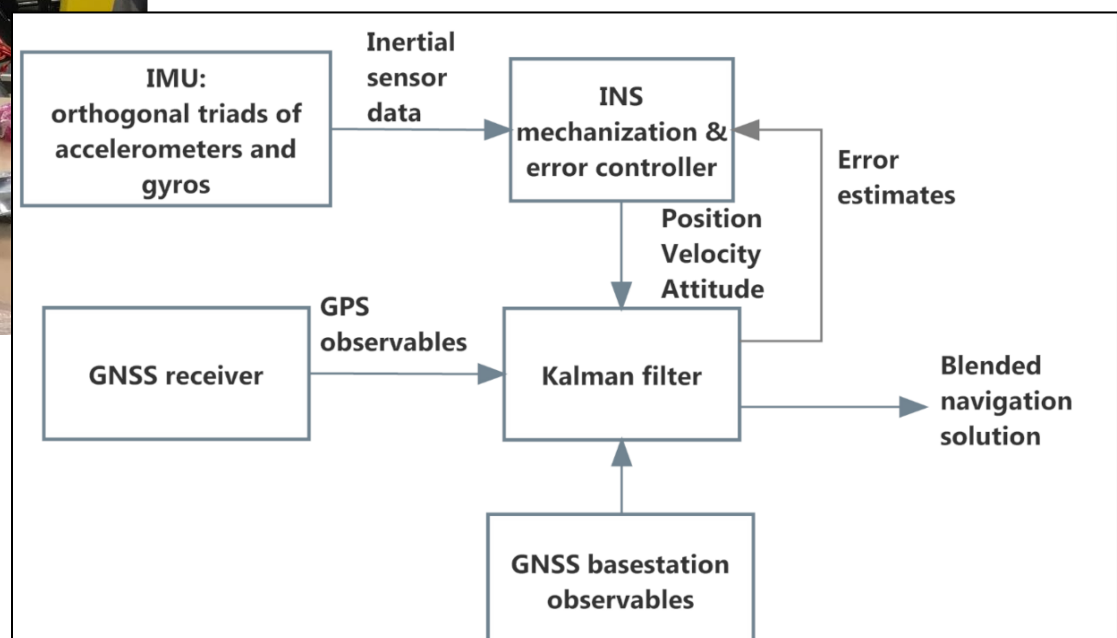
Compute error by comparing to groundtruth mesh



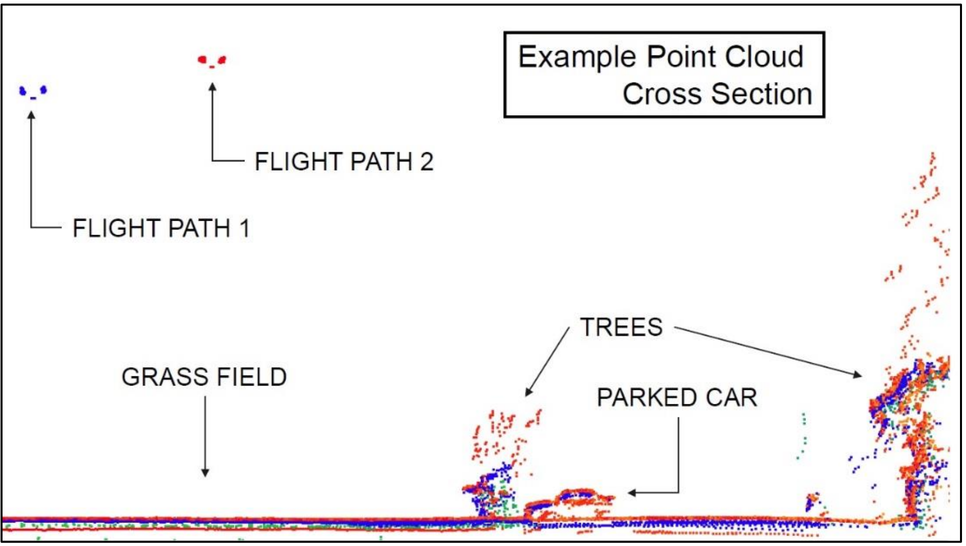


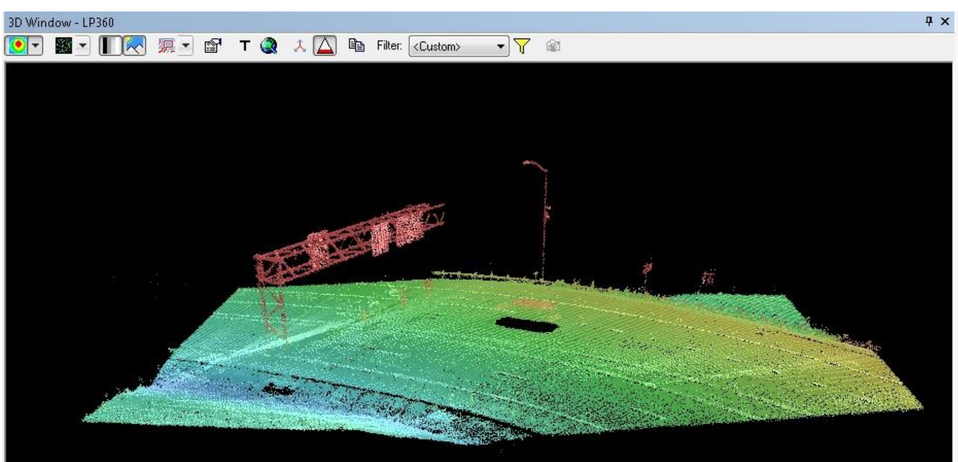
Another option: Direct Georeferencing

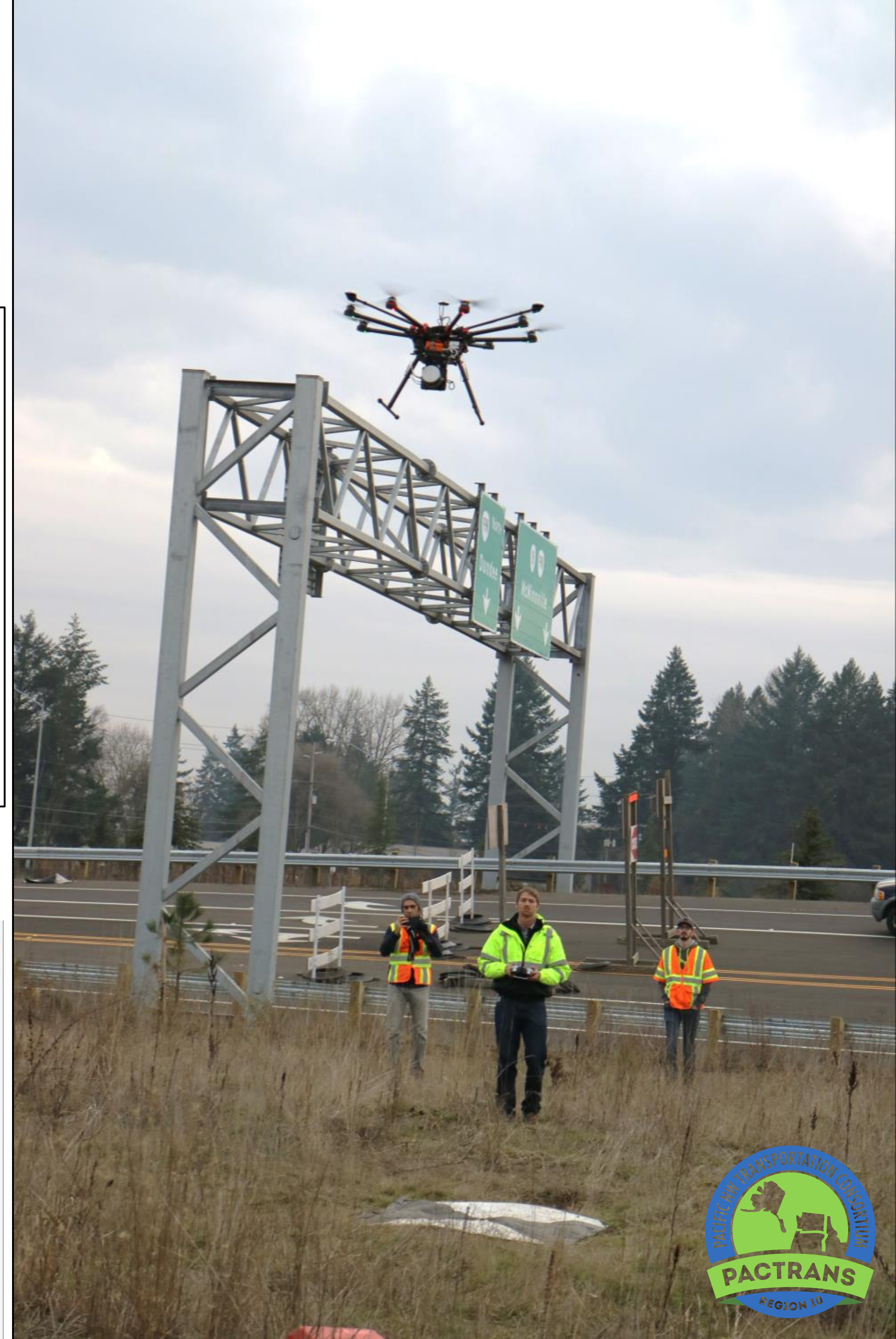




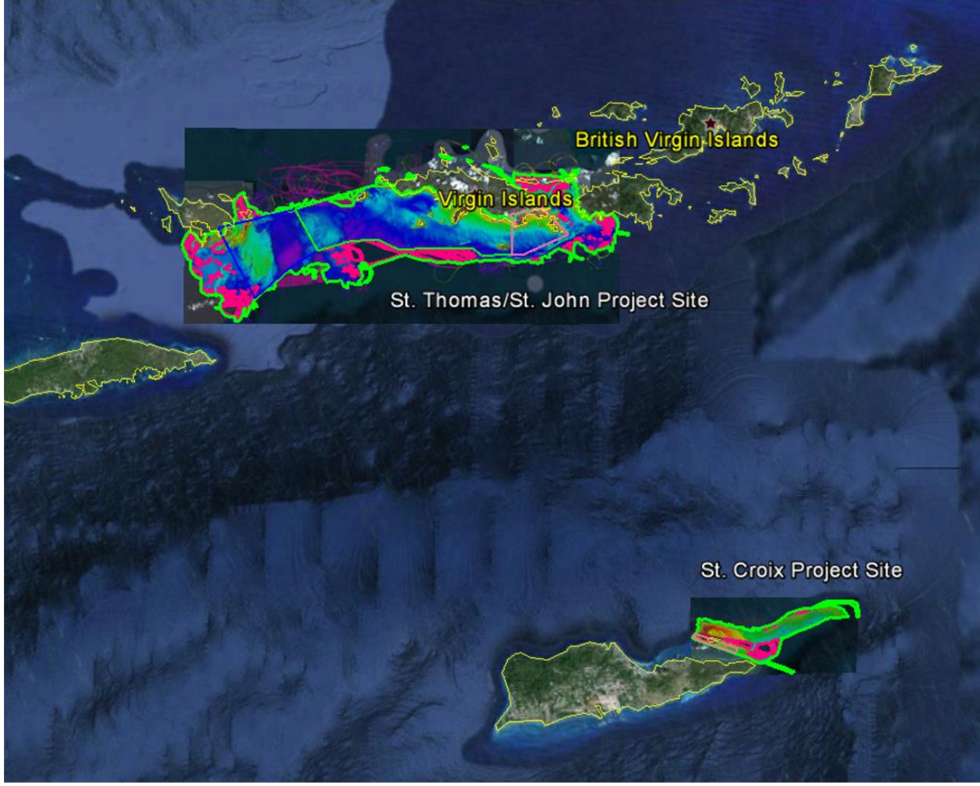
DG for UAS-lidar

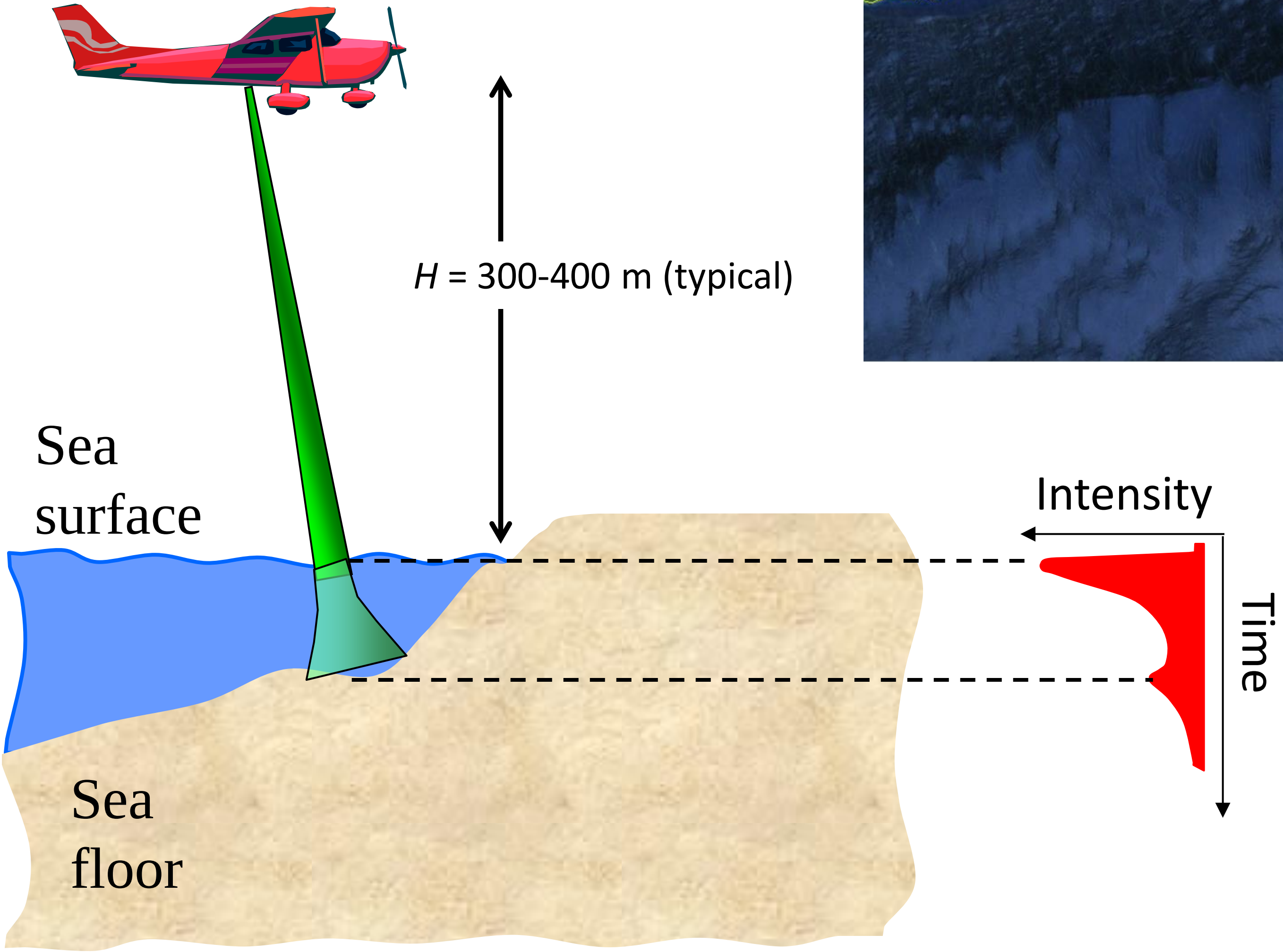




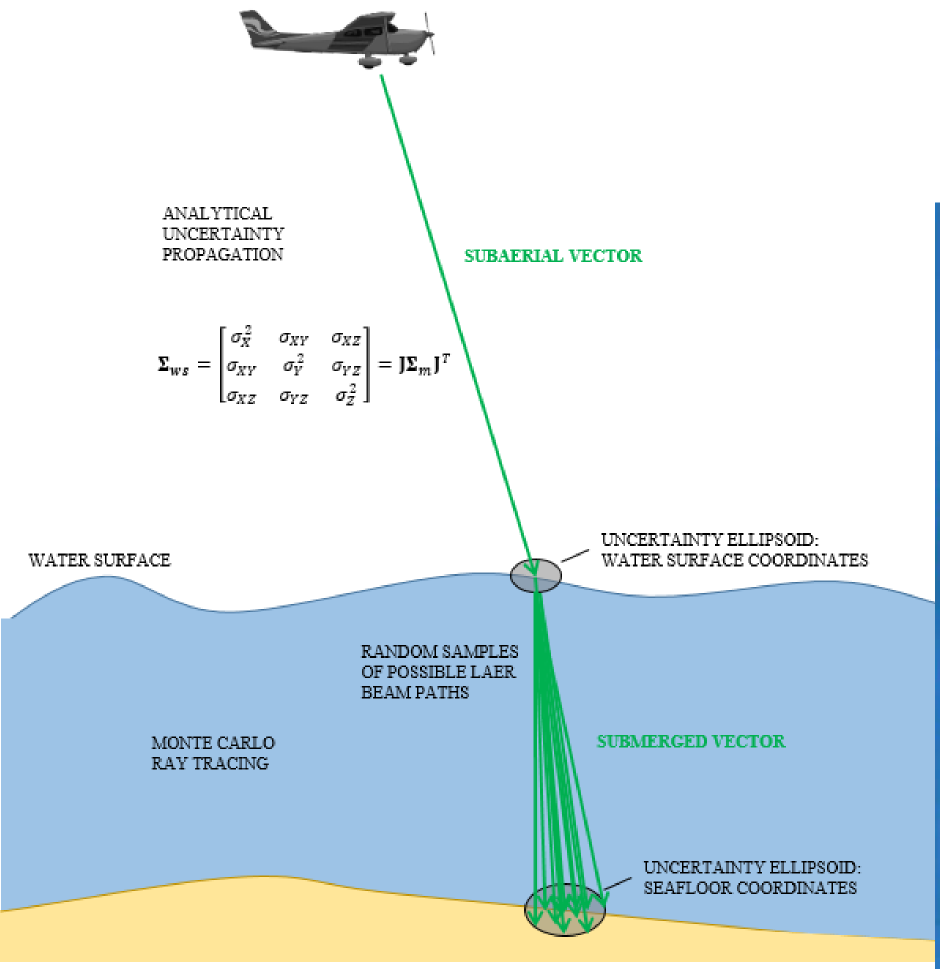


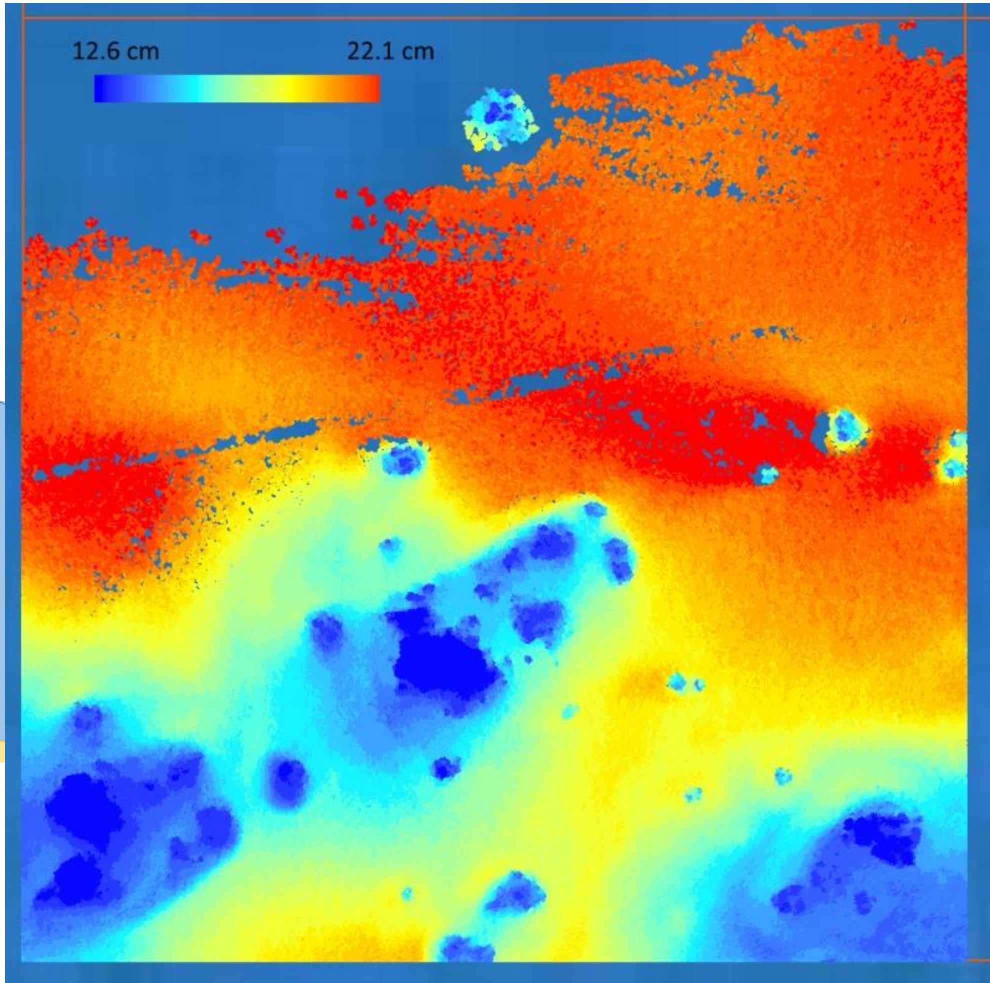
Topographic-Bathymetric Lidar



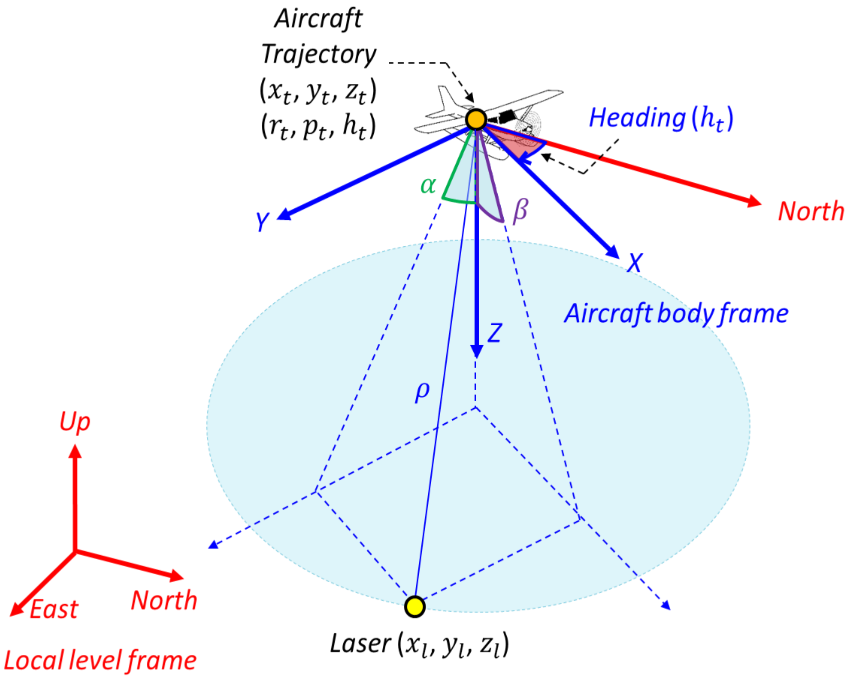


Topo-Bathy Lidar Uncertainty Modeling





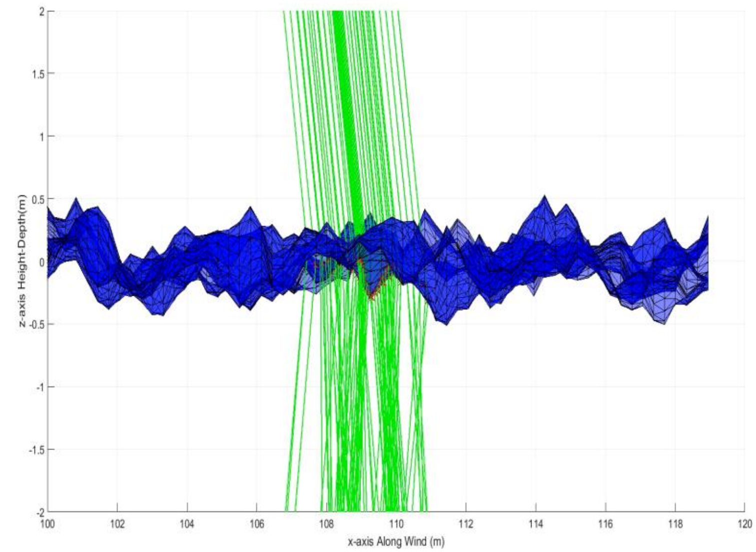
Subaerial Uncertainty

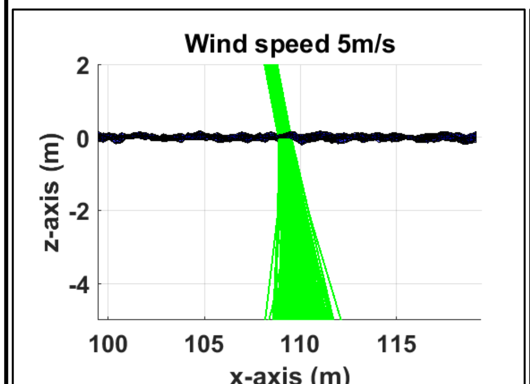


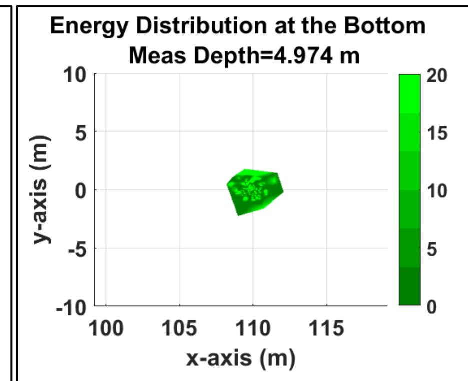
$$\begin{bmatrix} x_l \\ y_l \\ z_l \end{bmatrix} = \begin{bmatrix} x_t \\ y_t \\ z_t \end{bmatrix} + R_b^l R_{ls}^b \begin{bmatrix} 0 \\ 0 \\ -\rho \end{bmatrix} + \begin{bmatrix} \Delta x \\ \Delta y \\ \Delta z \end{bmatrix}_M$$

$$\Sigma = \begin{bmatrix} \sigma_X^2 & \sigma_{XY} & \sigma_{XZ} \\ \sigma_{XY} & \sigma_Y^2 & \sigma_{YZ} \\ \sigma_{XZ} & \sigma_{YZ} & \sigma_Z^2 \end{bmatrix} = J \begin{bmatrix} \sigma_\alpha & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \sigma_\rho \end{bmatrix} J^{\mathrm{T}}$$

Subaqueous Uncertainty

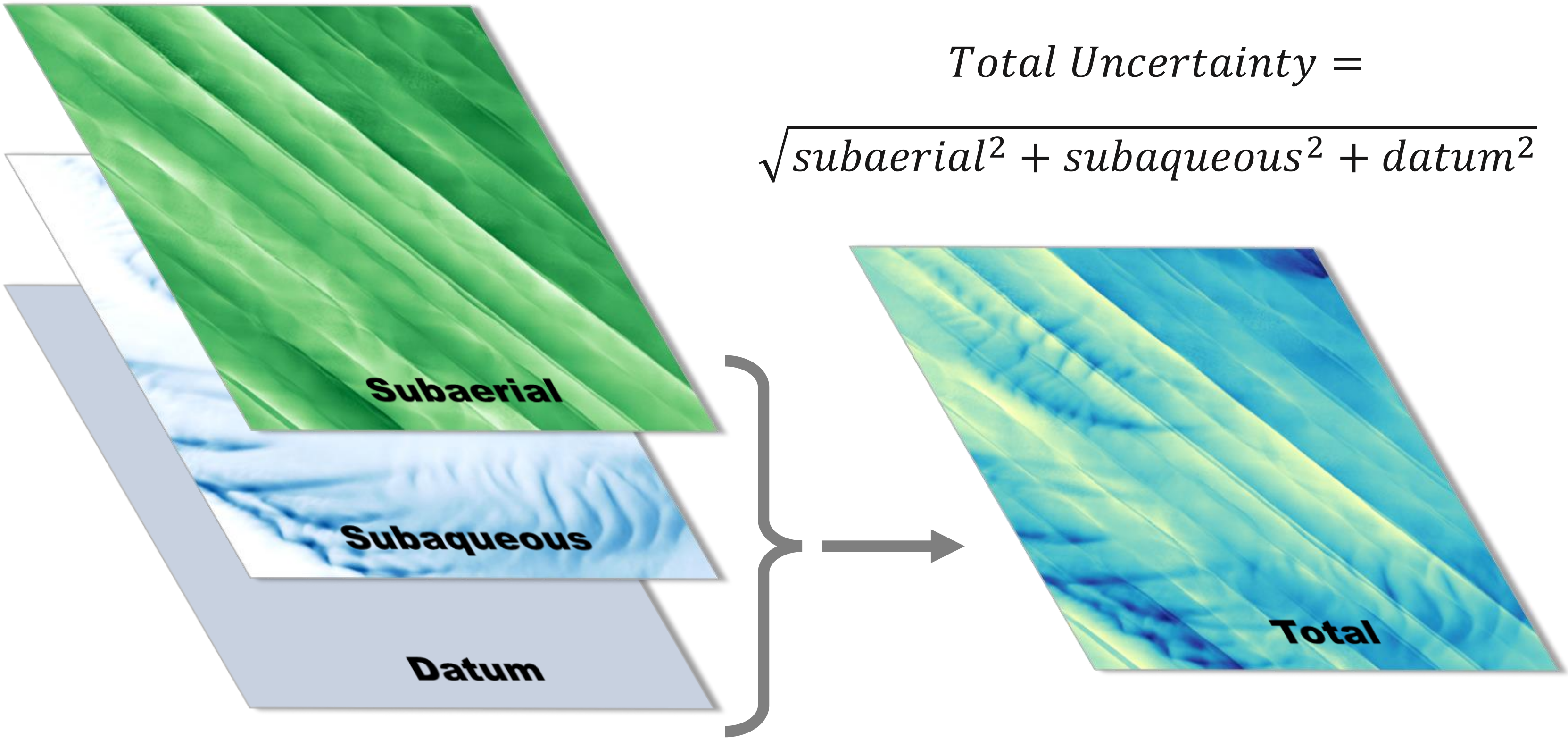


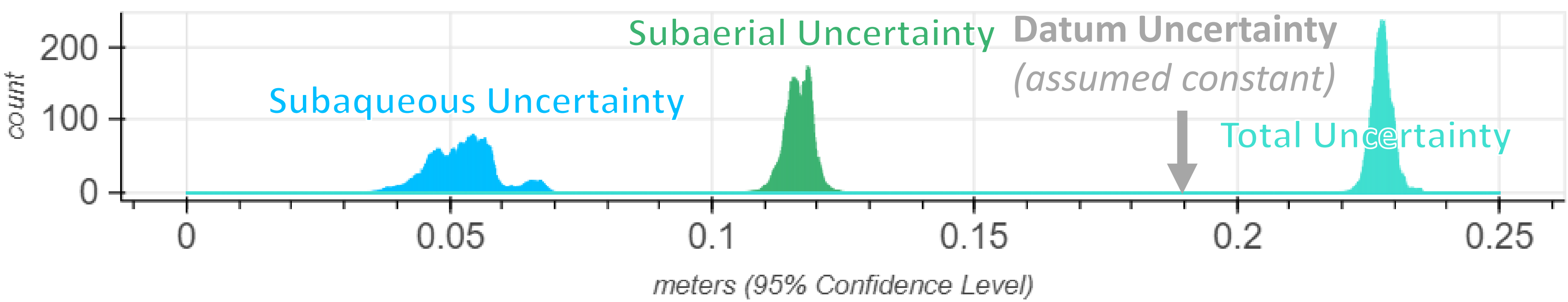




Combining component uncertainties

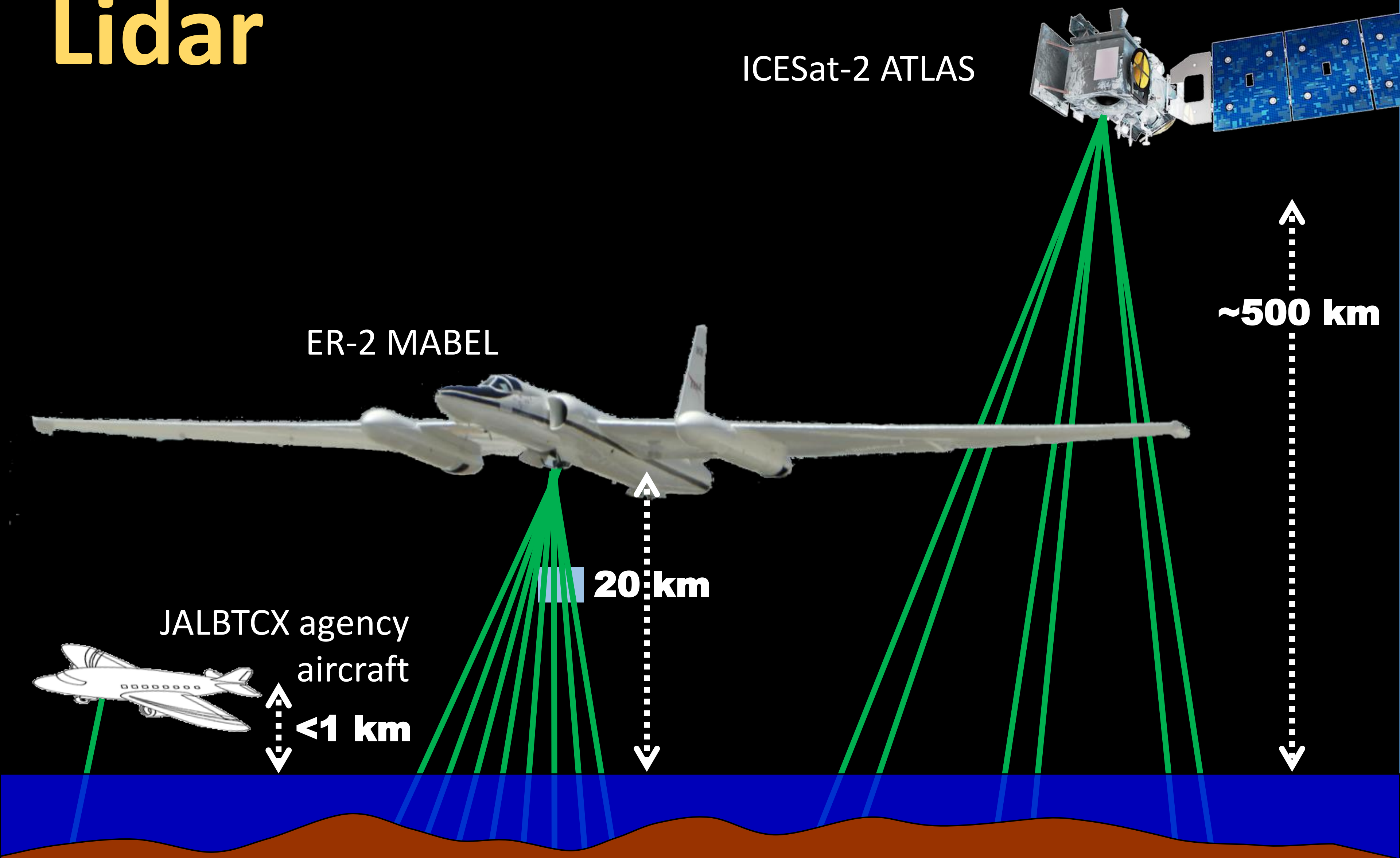
$$Total\ Uncertainty = \sqrt{subaerial^2 + subaqueous^2 + datum^2}$$

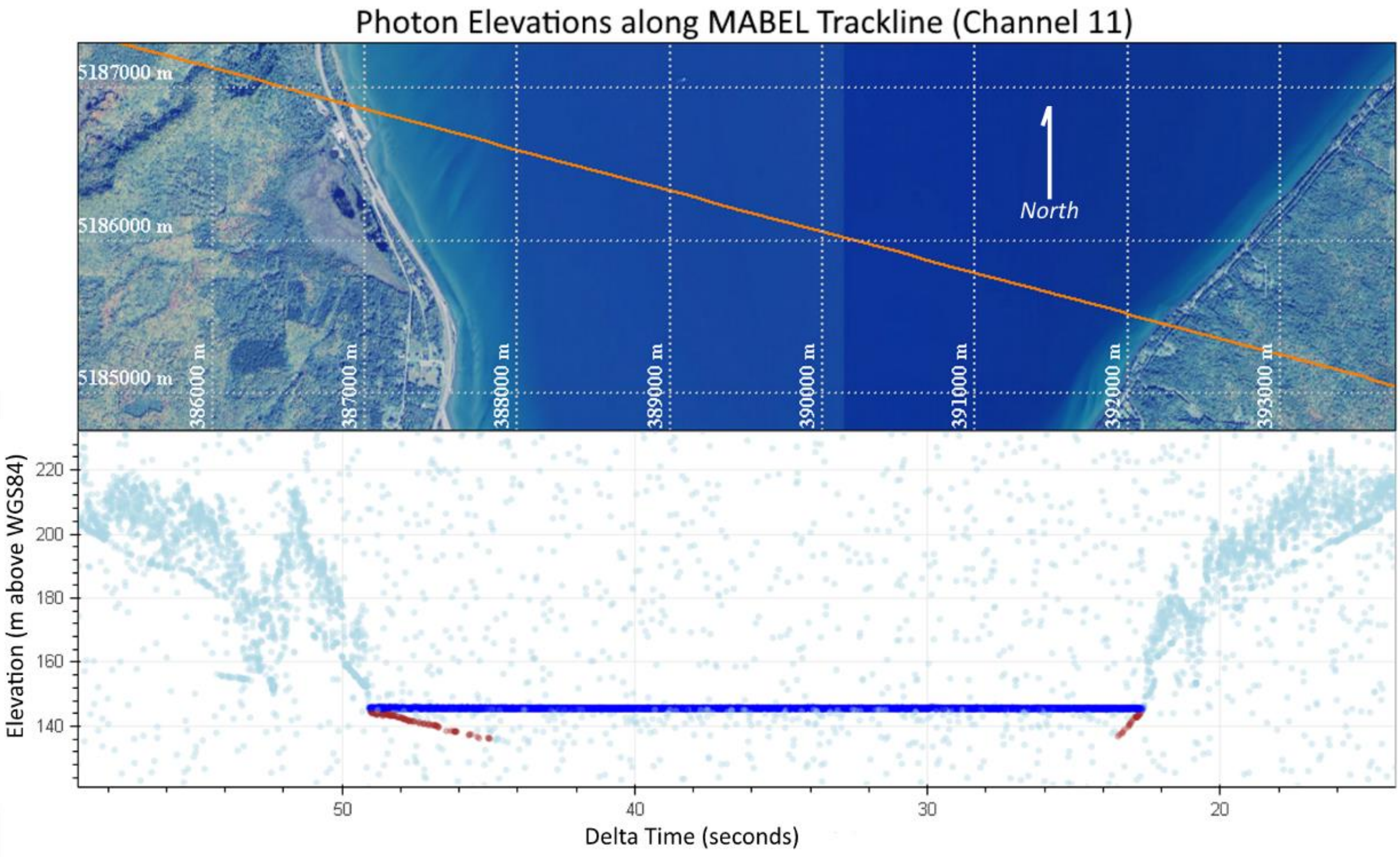




Space-based Lidar

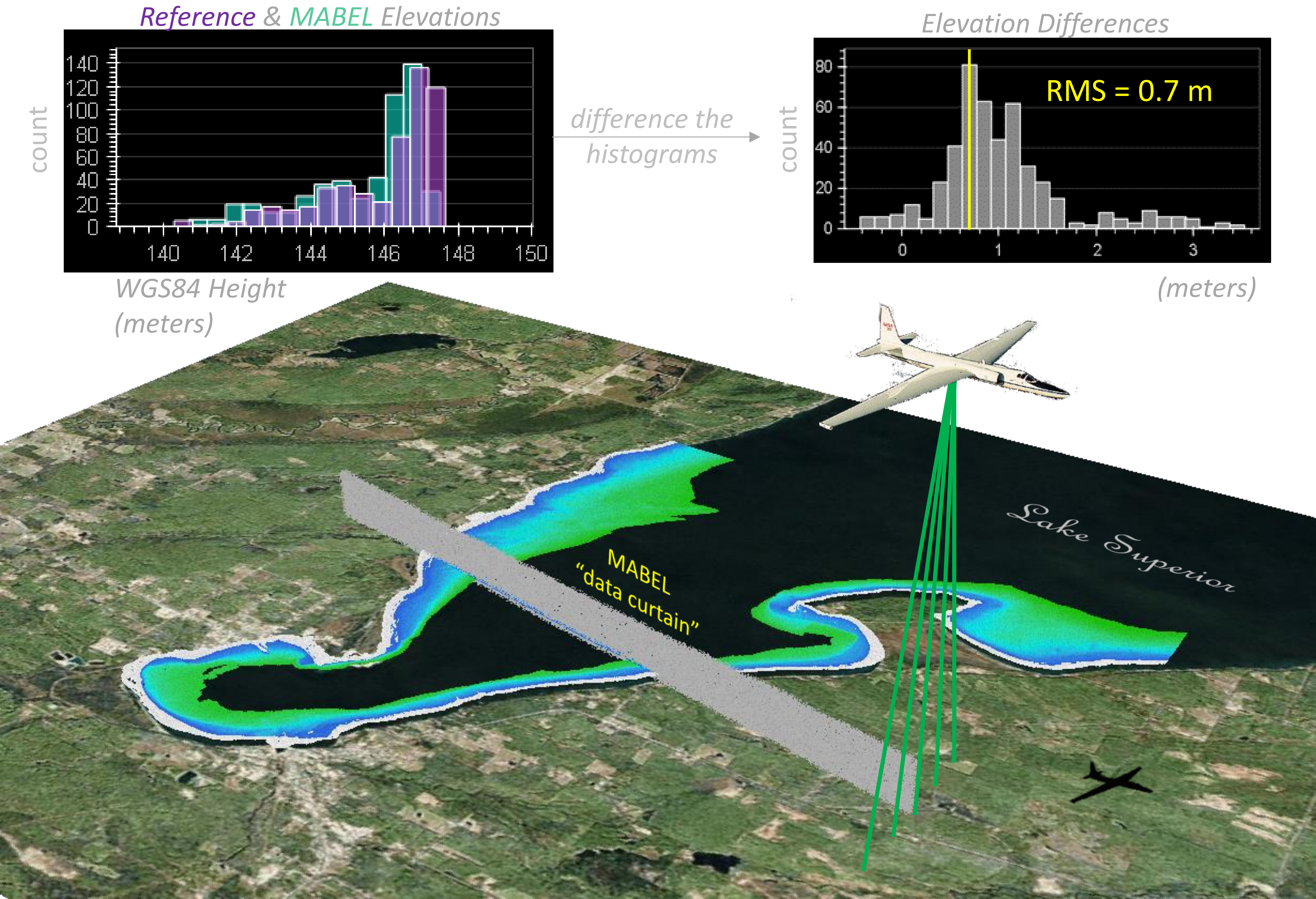
ICESat-2
ICE, CLOUD, AND LAND ELEVATION SATELLITE-2





Forfinski-Sarkozi, N.A., and C.E. Parrish, 2016. Analysis of MABEL Bathymetry in Keweenaw Bay and Implications for ICESat-2 ATLAS. *Remote Sensing*, Vol. 8, No. 9.

Comparison with Reference Bathymetry



Unsolved Challenges

- When more data becomes too much data
  - Big data, AI/machine learning, cloud processing
  - Data -> information -> insight
- Linking empirical accuracy assessments and modeled uncertainties
- Sensor/technology-neutral assessment methods
- Standards, guidelines, and best practices!!
  - In an era of accelerating growth in new mobile/airborne surveying and mapping technologies, need ways of dismissing hype and ensuring appropriate technology use to ensure specs of job are met

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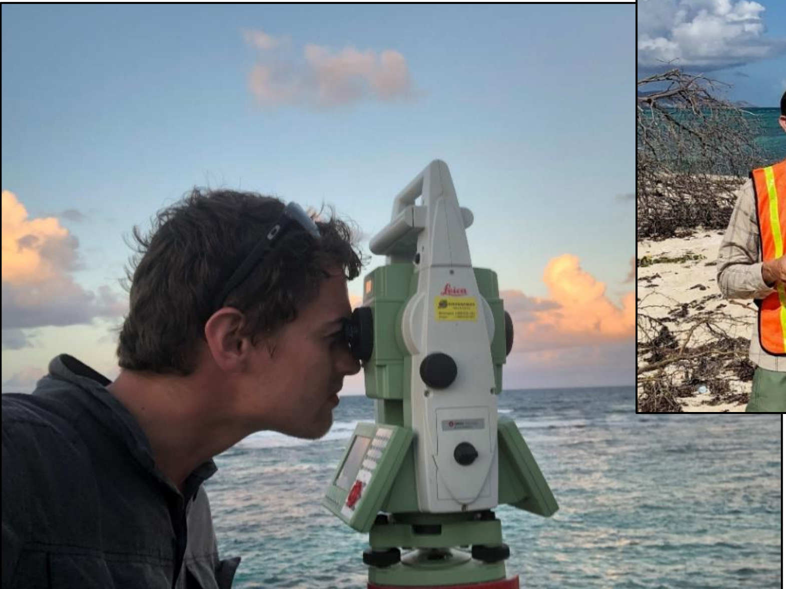
  - Richie Slocum
  - Chase Simpson
  - Nick Forfinski-Sarkozi
  - Matt Gillins
- Postdocs
  - Jaehoon Jung
  - Firat Eren (UNH)



Acknowledgements

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  - NASA Research Opportunities in Space and Earth Sciences (ROSES): Grant # NNX15AQ22G: "ICESat-2 Algorithm Development for the Coastal Zone"
  - Department of the Interior, USGS: AmericaView Grant # G14AP00002: "OregonView"
  - NOAA CIMRS Grant # NA11OAR4320091A:
    - "Seafloor Reflectance Mapping from EAARL-B Topobathymetric Lidar Data in the U.S. Virgin Islands" (2015)
    - "Enhanced EAARL-B Lidar Processing and Waveform Analysis for the U.S. Virgin Islands" (2016)
    - Optimizing UAS Imagery Acquisition and Processing for Shallow Bathymetric Mapping (2017-2018)
  - ODOT, Agreement 30530, WO 16-05: "Eyes in the Sky: Bridge Inspections with Unmanned Aerial Vehicles"
  - PacTrans UTC Region 10: 69A3551747110-UWSC10003: "An Airborne Lidar Scanning and Deep Learning System for Real-time Event Extraction and Control Policies in Urban Transportation Networks "

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USGS science for a changing world

NOAA

Oregon Department of Transportation

PACTRANS REGION 10

Questions

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