ADVANCED UAS/DRONE TECHNOLOGY FOR SURVEYING & ENGINEERING

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McKIM&CREED

MCKIM & CREED BY THE NUMBERS

YEARS IN BUSINESS

38 YEARS

STAFF EMPLOYED

378 EMPLOYEES

INDUSTRY RANKINGS

1992 – PRESENT	ENR Top 500 Design Firm
2003 – PRESENT	ENR Top 200 Environmental
2003 – PRESENT	ENR Southeast Engineer Firms
2015 – PRESENT	POB Geospatial Top 100
2015 – PRESENT	Top 50 Trenchless Design firm

LOCATIONS

N. CAROLINA
Charlotte
Raleigh
Asheville
Wilmington

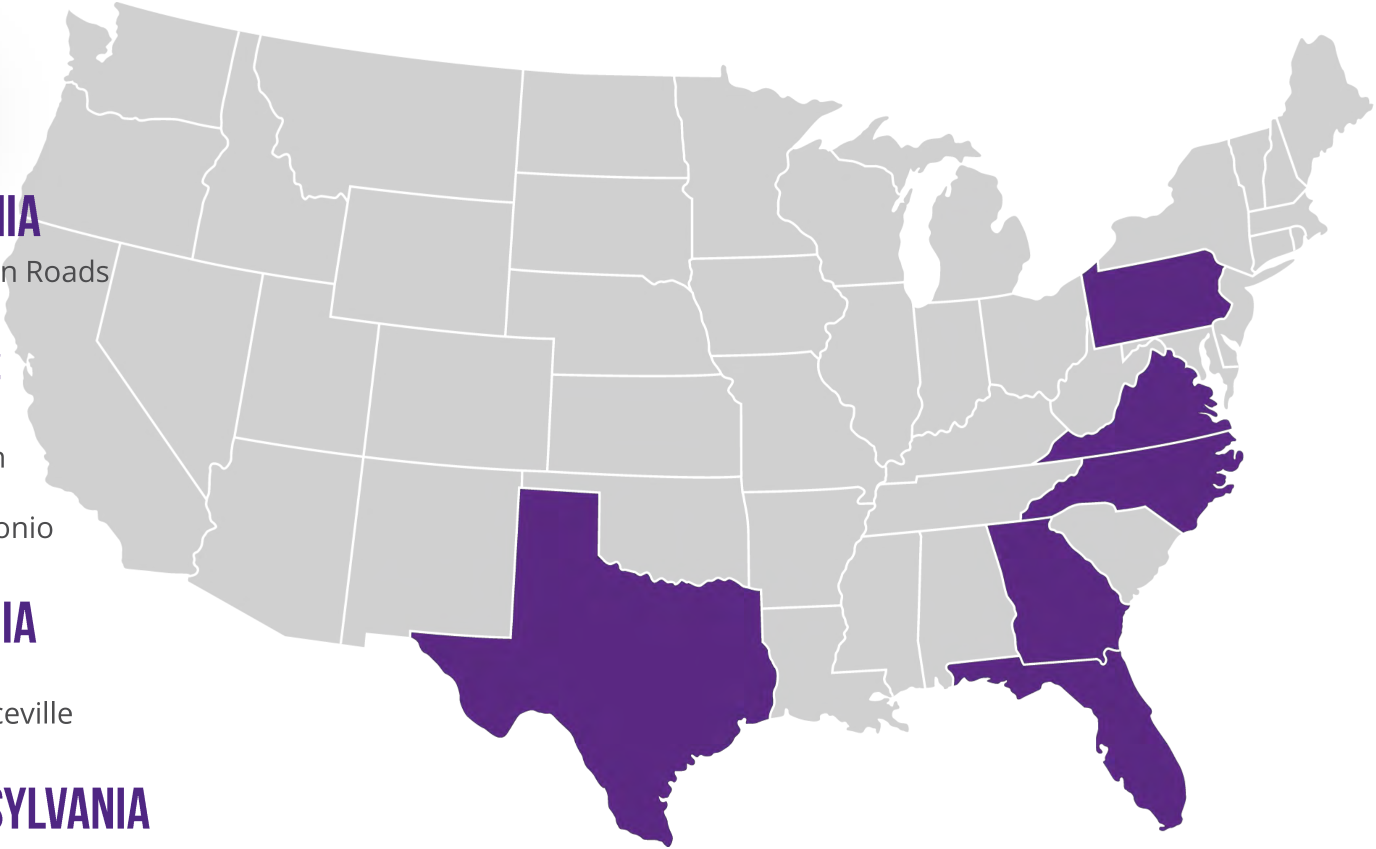
FLORIDA
Clearwater
Gainesville
Tampa
Daytona Beach
Orlando
Deland
Fort Myers
Sarasota
Palm Coast

VIRGINIA
Hampton Roads

TEXAS
Austin
Houston
Dallas
San Antonio

GEORGIA
Atlanta
Lawrenceville

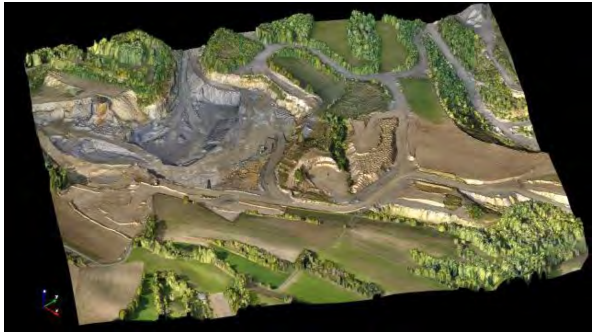
PENNSYLVANIA
Pittsburgh



Completed projects in 38 States. Can deploy our assets nationally/internationally.

MCKIM & CREED'S UAS FOCUS

- Small Drones, Big Sensors
- Imagery for orthophtography and photogrammetric extraction
- Autocorrelation for point cloud generation
- Adapting our current mapping production
- Processes to UAS collected data
- Near real time data processing



- **<u>Applications</u>**

- Small/Medium site mapping
- Volumetric Measurements
- Change Detection
- Inspections
- Construction Site Monitoring
- Damage assessment

PRESENTATION AGENDA

- **Photogrammetry Basics**
- **UAS as a Tool for Surveying & Mapping**
- **Wrightsville Beach - Proof of Concept and Results**
- **Masonboro Jetty- Proof of Concept and Results**

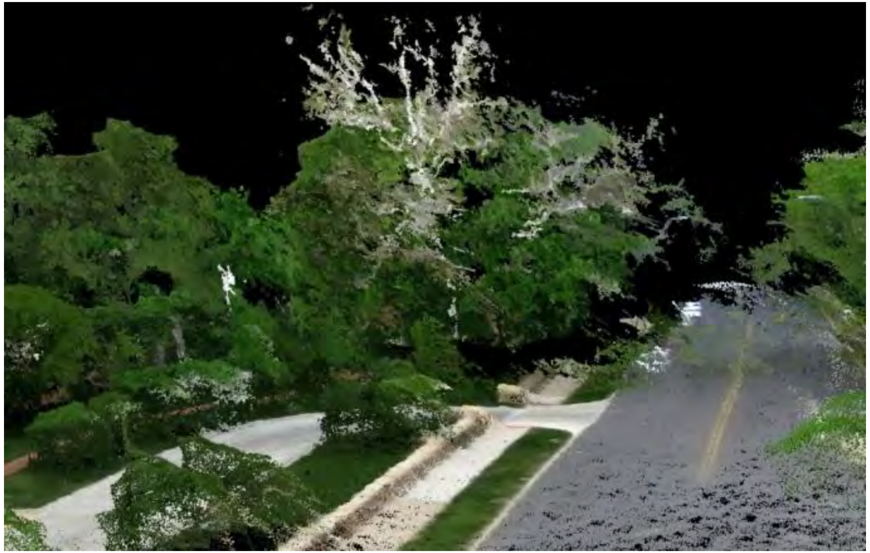
PHOTOGRAMMETRY BASICS

Photogrammetry Defined

- Photogrammetry = measuring with photographs
- Estimation of the geometric and semantic properties of objects based on images or observations from similar images.
- <u>Photogrammetry</u> is the art, science, and technology of obtaining reliable information about physical objects and the environment, through processes of recording, measuring, and interpreting images and patterns of electromagnetic radiant energy and other phenomena.
- <u>Remote Sensing</u> techniques are used to gather and process information about an object without direct physical contact.
- <u>Geographic Information System (GIS)</u> is an information system able to encode, store, transform, analyze, and display geospatial information.

PHOTOGRAMMETRY BASICS

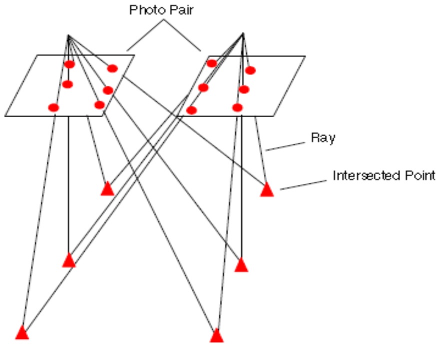
- Light source is needed (passive sensors)
- Occlusions and visibility constraints (vegetation)
- Other techniques such as survey may achieve higher accuracy measurements



PHOTOGRAMMETRY BASICS

- **Camera calibration**
  - **Focal length**
  - **Principal point**
  - **Distortion parameters**

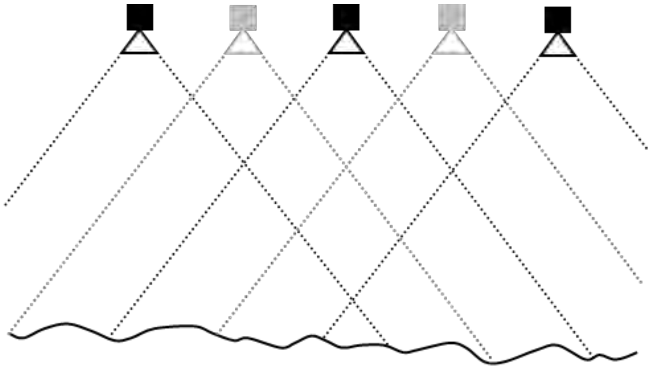
- **Aero triangulation (AT)**
  - **Image tie points**
  - **Bundle adjustment**

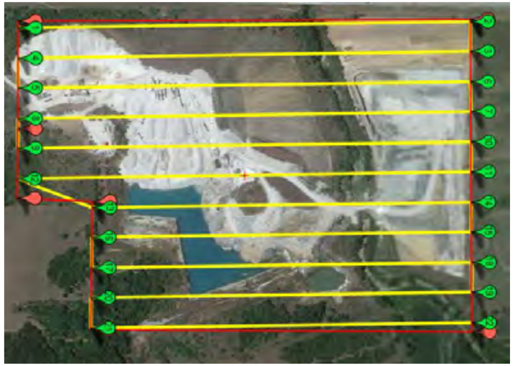


PHOTOGRAMMETRY BASICS

Image Acquisition

- Stereo imagery is collected with 60 – 80 percent forward overlap and 30 - 60 percent side lap.
- The interior orientation of the camera is resolved using tie points between images.
- Ground control is used to further tie the imagery.





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PHOTOGRAMMETRY BASICS

Advantages of Photogrammetry

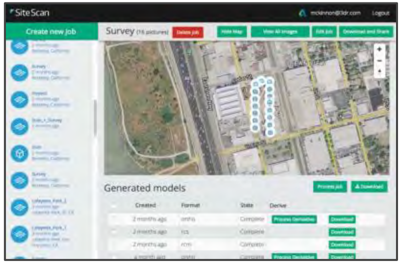
- Quickly acquire large scale data
- Dense coverage of large areas (Dense Image Matching)
- 2D and 3D measurements are possible.
- Ability to record dynamic scenes
- Flexible range (small projects but high accuracy, large and course models)
- XYZs can be extracted from each pixel, creating an extremely dense surface
- More than just geometry (image interpretation, object base classification, supervised classification)
- Recorded images document the measuring process
- Automatic data processing (to some degree)

UAS AS A TOOL FOR SURVEY AND MAPPING

Workflow

1 Collect

2 Process



3 Consume

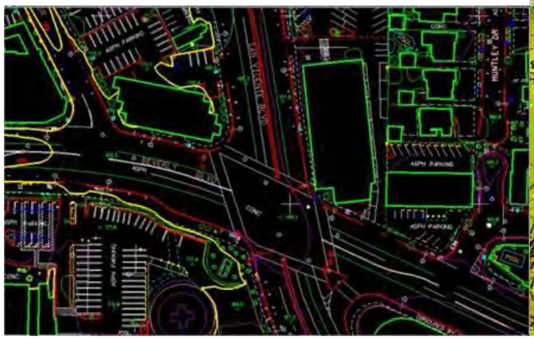
AUTODESK

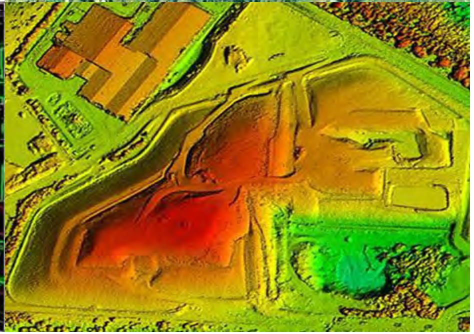
esri & other

UAS AS A TOOL FOR SURVEY AND MAPPING

Clients expect to receive mapping products that are familiar and consistent with their design process

- Planimetric and topographic mapping
- Orthophotography
- Classified point clouds
- DTM/DEM/DSM
- Contours
- Video





UAS AS A TOOL FOR SURVEY AND MAPPING

Orthophotography

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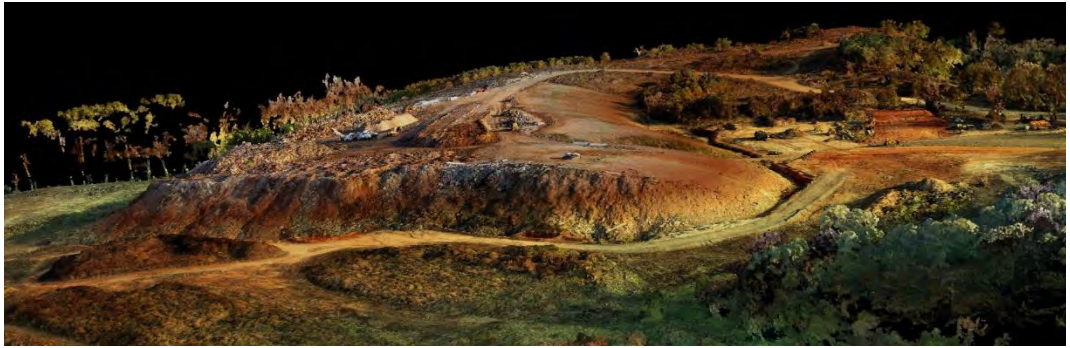
UAS AS A TOOL FOR SURVEY AND MAPPING

Classified Point Cloud

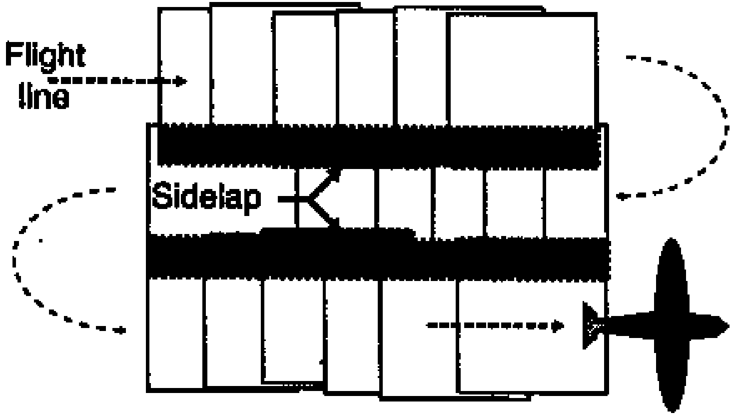


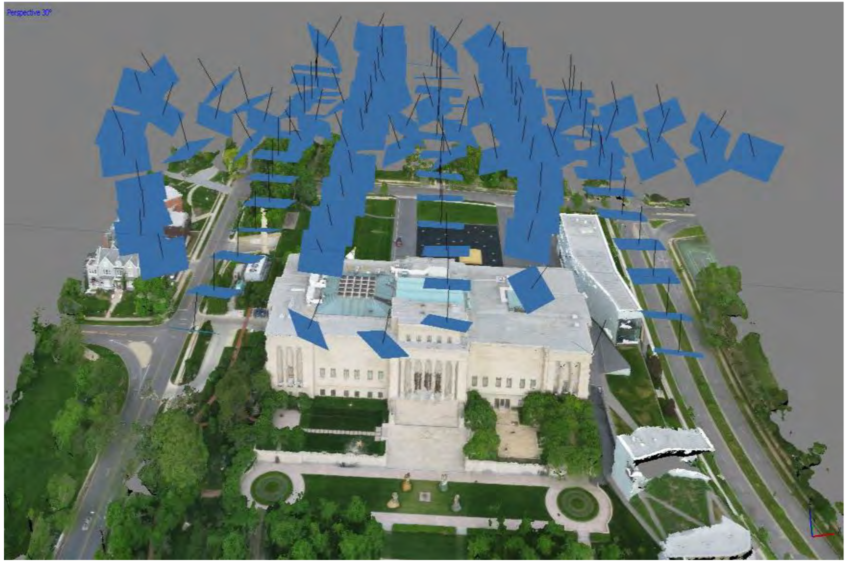
UAS AS A TOOL FOR SURVEY AND MAPPING

Planimetric and Contour Data

UAS AS A TOOL FOR SURVEY AND MAPPING

Like manned airborne platforms, UAS collects imagery used to produce mapping products with conventional photogrammetry concepts





- Stereoscopic overlap requires 55 – 65%
- Endlap to create *a Stereopair*

UAS AS A TOOL FOR SURVEY AND MAPPING

Image Autocorrelation and Bundle Adjustment

- All these use similar computer vision algorithms many from the OpenCV libraries
- Algorithms are very process intensive
- Cloud and workstation processing

PIX4D

Photoscan by Agisoft

DroneDeploy

DroneMapper

Correlator 3D

Drone2Map

WRIGHTSVILLE BEACH - PROOF OF CONCEPT

Site Scan

The Leading Aerial Analytics Platform

Hardware and Software

3DR

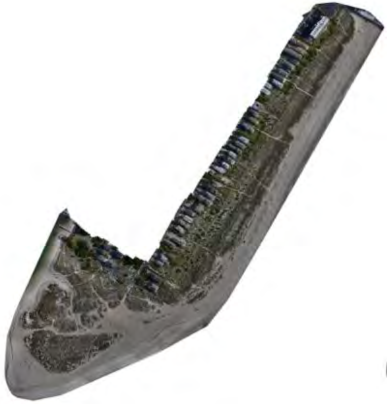
esri

WRIGHTSVILLE BEACH - PROOF OF CONCEPT

- **Goals**
  - Production of accurate high-resolution 2D and 3D geospatial products
  - Evaluate the use of drones for:
    - Beach Renourishment Surveys
    - Before vs. after storm survey
    - Volumetric Measurements
    - Construction Site Monitoring
  - Better understand UAS operational use patterns
  - Environmental/community impacts of using drones
  - Compare UAS accuracy with traditional surveying methods on real world projects.

WRIGHTSVILLE BEACH - PROOF OF CONCEPT

Total Area Processed

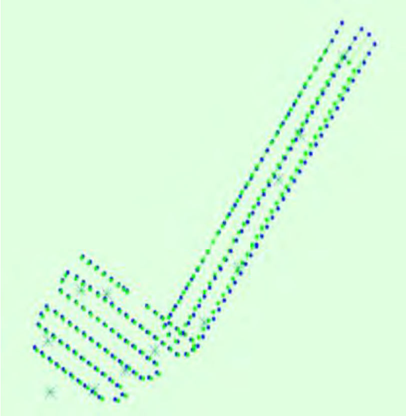


Oceanic Pier to
Masonboro Inlet
71.62 Acres

Ground Control Used

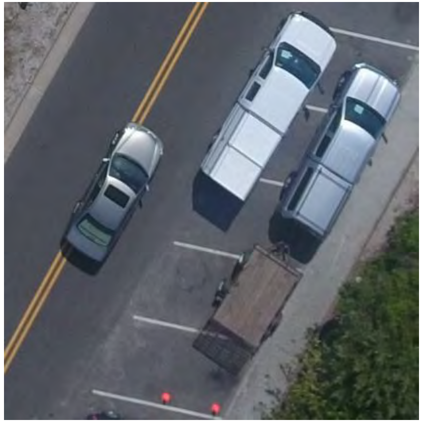
14 Points
Fully Surveyed

Photos Collected



Sony R10C
Total 195 / 1.25GB
Collection Time < 1hr / 2flts

Output Parameters



Horizontal GSD – 1.21 in
3D Points / Meter - 104

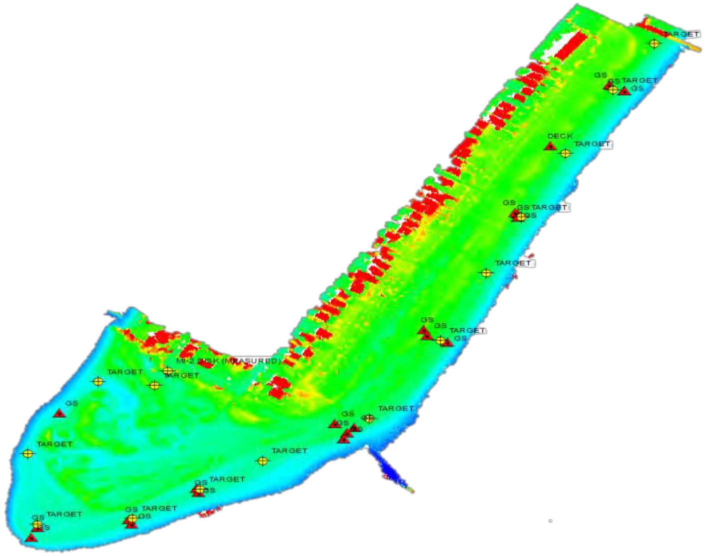
Processing Time: 4 hrs 32 mins
Products Produced: Orthos, DSM, Point Cloud, 3D Mesh
Overall Accuracy: Mean RMS 1.27 inches, or 3.23 cm

WRIGHTSVILLE BEACH - PROOF OF CONCEPT

Wrightsville Beach Flight

- McKim & Creed placed 14 survey targets on the beach
- 22 Blind check shots were collected randomly
- 2 Flights were flown with the Solo / R10C setup (400 Ft. AGL 1.21 Inch GSD)
- 1 Flight was flown using the Solo / GoPro setup (400 Ft. AGL 2.44 Inch GSD)
- 1 Flight was flown with a Phantom 4 (200 Ft. AGL 1.01 Inch GSD)

WRIGHTSVILLE BEACH - PROOF OF CONCEPT



Accuracy Reporting

- After Dense Image Matching (DIM), the Point clouds were compared to the blind checkpoints to verify accuracy.
- A TIN model was created in the ArcGIS extension LP360 to calculate the DeltaZ of each point. This is the same method used for verifying LiDAR point clouds.

WRIGHTSVILLE BEACH - PROOF OF CONCEPT

Results

DJI Results

```
--------- Report Summary ---------

X Error Mean:                0.000
X Error Range:               [0.000,0.000]
X Skew:                      0.000
X RMSE:                   0.000
X NMAS/VMAS Accuracy (90% CI):    ±0.000
X ASPRS/NSSDA Accuracy (95% CI):    ±0.000
X Accuracy Class:    ------


Y Error Mean:                0.000
Y Error Range:               [0.000,0.000]
Y Skew:                      0.000
Y RMSE:                   0.000
Y NMAS/VMAS Accuracy (90% CI):    ±0.000
Y ASPRS/NSSDA Accuracy (95% CI):    ±0.000
Y Accuracy Class:    ------


Planimetric Error Mean:                0.000
Planimetric Error Range:               [0.000,0.000]
Planimetric Skew:                      0.000
Planimetric RMSE:                   0.000
Planimetric NMAS/VMAS Accuracy (90% CI):    ±0.000
Planimetric ASPRS/NSSDA Accuracy (95% CI):    ±0.000
Planimetric Accuracy Class:    ------


Vertical Error Mean:                  -0.000
Vertical Error Range:                 [-0.839,1.481]
Vertical Skew **:                        1.173
Vertical RMSE:                     0.527
Vertical NMAS/VMAS Accuracy (90% CI):    ±0.867
Vertical ASPRS/NSSDA Accuracy (95% CI):    ±1.034
Vertical Accuracy Class:    0.53
Vertical Min Contour Interval:    1.59
```

GoPro Results

```
--------- Report Summary ---------

X Error Mean:                0.000
X Error Range:               [0.000,0.000]
X Skew:                      0.000
X RMSE:                   0.000
X NMAS/VMAS Accuracy (90% CI):    ±0.000
X ASPRS/NSSDA Accuracy (95% CI):    ±0.000
X Accuracy Class:    ------


Y Error Mean:                0.000
Y Error Range:               [0.000,0.000]
Y Skew:                      0.000
Y RMSE:                   0.000
Y NMAS/VMAS Accuracy (90% CI):    ±0.000
Y ASPRS/NSSDA Accuracy (95% CI):    ±0.000
Y Accuracy Class:    ------


Planimetric Error Mean:                0.000
Planimetric Error Range:               [0.000,0.000]
Planimetric Skew:                      0.000
Planimetric RMSE:                   0.000
Planimetric NMAS/VMAS Accuracy (90% CI):    ±0.000
Planimetric ASPRS/NSSDA Accuracy (95% CI):    ±0.000
Planimetric Accuracy Class:    ------


Vertical Error Mean *:                  -0.221
Vertical Error Range:                 [-0.535,0.171]
Vertical Skew:                      0.037
Vertical RMSE:                     0.310
Vertical NMAS/VMAS Accuracy (90% CI):    ±0.510
Vertical ASPRS/NSSDA Accuracy (95% CI):    ±0.608
Vertical Accuracy Class:    0.32
Vertical Min Contour Interval:    0.96
```

R10C Results

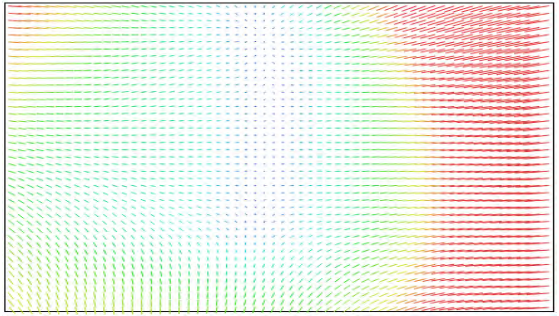
```
--------- Report Summary ---------

X Error Mean:                0.000
X Error Range:               [0.000,0.000]
X Skew:                      0.000
X RMSE:                   0.000
X NMAS/VMAS Accuracy (90% CI):    ±0.000
X ASPRS/NSSDA Accuracy (95% CI):    ±0.000
X Accuracy Class:    ------


Y Error Mean:                0.000
Y Error Range:               [0.000,0.000]
Y Skew:                      0.000
Y RMSE:                   0.000
Y NMAS/VMAS Accuracy (90% CI):    ±0.000
Y ASPRS/NSSDA Accuracy (95% CI):    ±0.000
Y Accuracy Class:    ------


Planimetric Error Mean:                0.000
Planimetric Error Range:               [0.000,0.000]
Planimetric Skew:                      0.000
Planimetric RMSE:                   0.000
Planimetric NMAS/VMAS Accuracy (90% CI):    ±0.000
Planimetric ASPRS/NSSDA Accuracy (95% CI):    ±0.000
Planimetric Accuracy Class:    ------


Vertical Error Mean *:                  -0.062
Vertical Error Range:                 [-0.258,0.190]
Vertical Skew:                      0.098
Vertical RMSE:                     0.137
Vertical NMAS/VMAS Accuracy (90% CI):    ±0.225
Vertical ASPRS/NSSDA Accuracy (95% CI):    ±0.268
Vertical Accuracy Class:    0.14
Vertical Min Contour Interval:    0.42
```

0.137 ft = 4.17 cm = 1.64 in

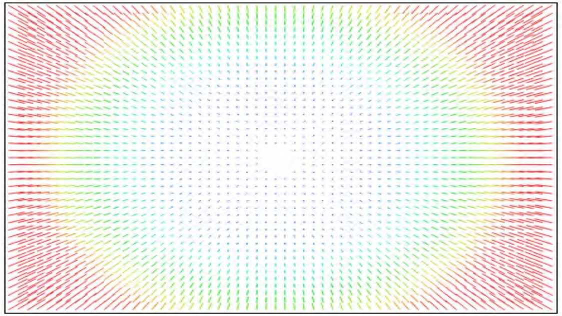
WRIGHTSVILLE BEACH - PROOF OF CONCEPT

Distortion Plots

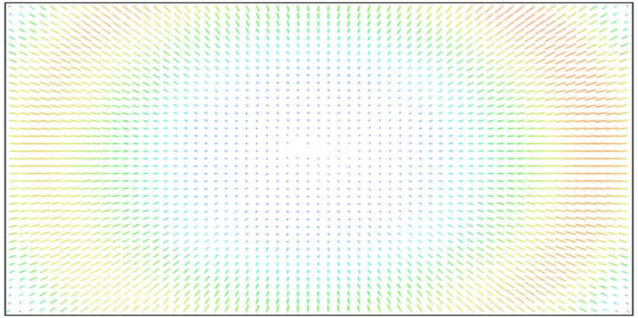
DJI Phantom 4



GoPro Hero 4 Black



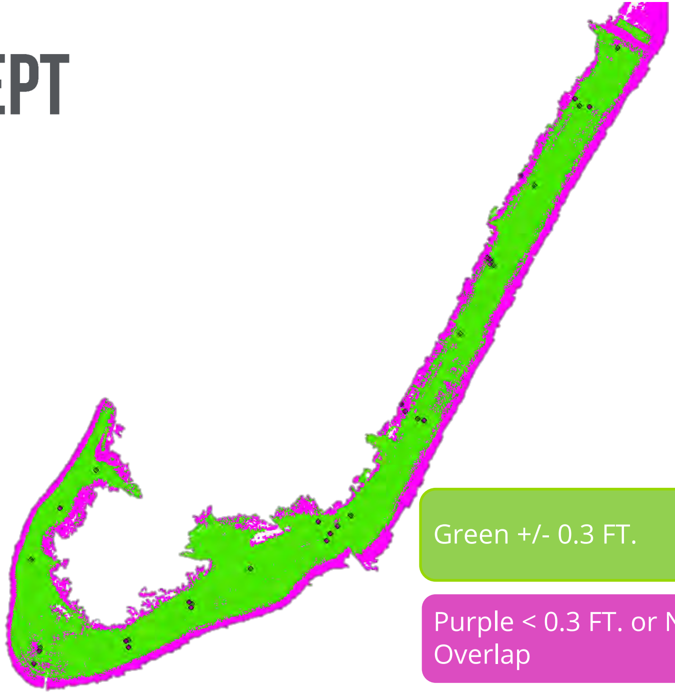
R10C 16mm



WRIGHTSVILLE BEACH - PROOF OF CONCEPT

Terrestrial LiDAR Analysis

- Terrestrial LiDAR was collected the same day by the Charleston USACE district
- The Terrestrial LiDAR was off by almost the same amount as the R10C data from the blind checkpoints.
- The error however was in the opposite direction creating an offset between the two datasets by 3 – 5 tenths
- By normalizing the terrestrial LiDAR surface to the UAS surface we were able to compare the overall fit of the two surfaces relative to each other
- The two surfaces matched well in most areas. The terrestrial data extended further out than the UAS data due to time of collection



Green +/- 0.3 FT.

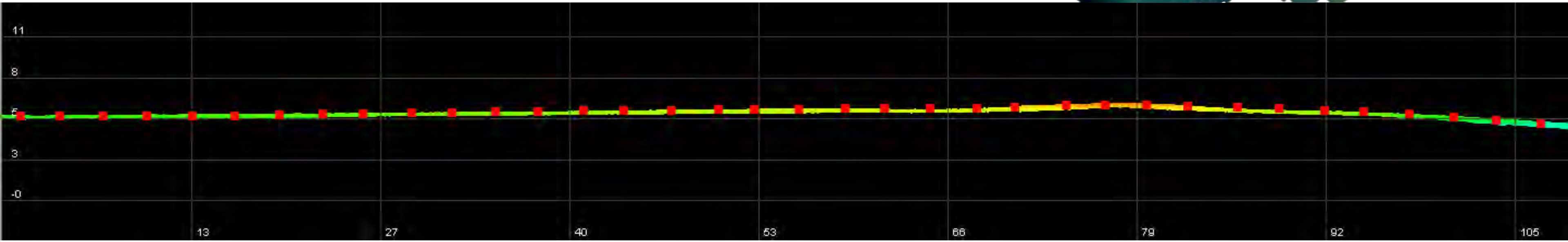
Purple < 0.3 FT. or No Overlap

```
Vertical Error Mean *:                    0.118
Vertical Error Range:                [0.023,0.200]
Vertical Skew:                           -0.333
Vertical RMSE:                       0.130
Vertical NMAS/VMAS Accuracy (90% CI):   ±0.214
Vertical ASPRS/NSSDA Accuracy (95% CI):   ±0.255
Vertical Accuracy Class:   0.14
Vertical Min Contour Interval:   0.42
```

WRIGHTSVILLE BEACH - PROOF OF CONCEPT

Beach Profiles

- Transects were collected of the beach earlier in the year.
- Beach profiles are spaced at 1,000 ft. To each other and 3 ft. downline.
- Both profiles and UAS data match well.



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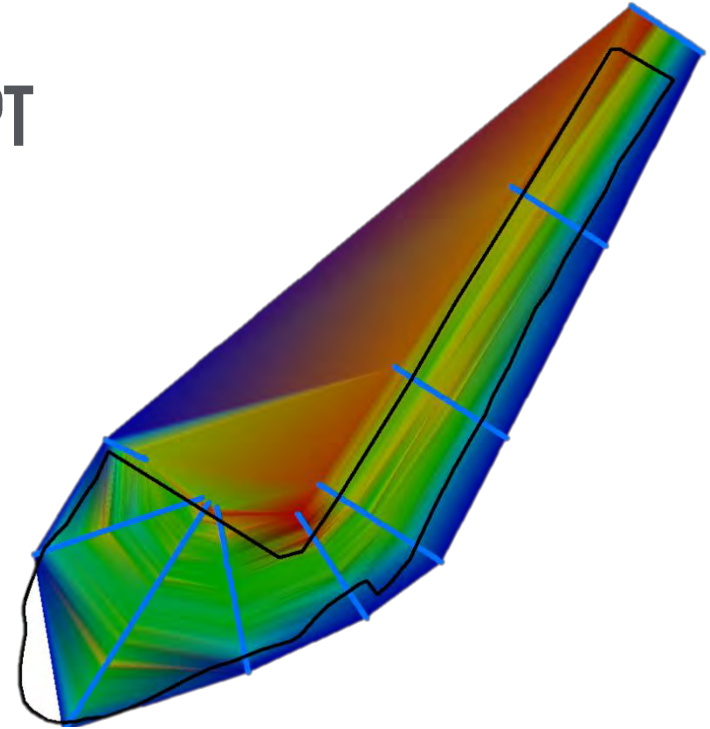
WRIGHTSVILLE BEACH - PROOF OF CONCEPT

Beach Profiles

Surface	# Points	Cut (Cu. Ft.)	Fill (Cu. Ft.)	Net Diff. (Cu. Ft.)
Profile Lines	7,589	4207225.6	2016795.7	2190429.9
Drone2Map	445,492,843	6285711.2	475396.7	5810314.5
Variance	2935072%	25%	-38%	83%



```
Vertical Error Mean *:                 1.015
Vertical Error Range:                [-0.763,3.991]
Vertical Skew:                       0.456
Vertical RMSE:                    1.723
Vertical NMAS/VMAS Accuracy (90% CI):   ±2.835
Vertical ASPRS/NSSDA Accuracy (95% CI):   ±3.377
Vertical Accuracy Class:   1.73
Vertical Min Contour Interval:   5.19
```

WRIGHTSVILLE BEACH - PROOF OF CONCEPT

Final business comparison: UAV vs. traditional methods

	Traditional surveying	Terrestrial LiDAR	Aerial LiDAR
Accuracy	Higher accuracy (0.07 ft / 2 cm)	Similar to Site Scan (0.13 ft / 4 cm)	Similar to Site Scan (0.13 ft / 4 cm)
Cost savings using Site Scan	~30%	~15%	~60%
Time	UAV captures greater details in less time	UAV much faster collection & processing. Similar mobilization & coverage	UAV much faster mobilization, collection & processing. Similar coverage.

MASONBORO INLET N. JETTY – PROOF OF CONCEPT

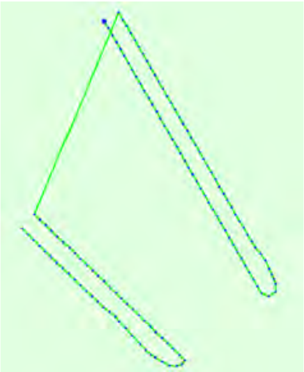
Total Area Processed

Masonboro Inlet
North Jetty
~20 Acres

Ground Control Used

No Surveyed Points
3 Map Derived Points
X,Y Only

Photos Collected



Sony R10C
Total 123 / .89 GB
Collection Time < 1hr / 1 flts

Processing Time: 21 mins
Products Produced: Orthos, DMS
Overall Accuracy: N/A

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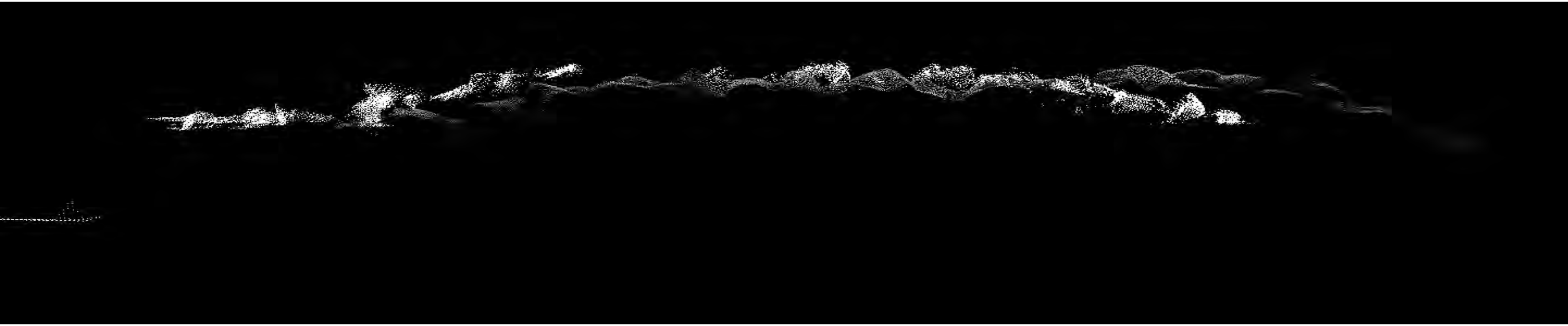
MASONBORO INLET N. JETTY – PROOF OF CONCEPT

MASONBORO INLET N. JETTY – PROOF OF CONCEPT

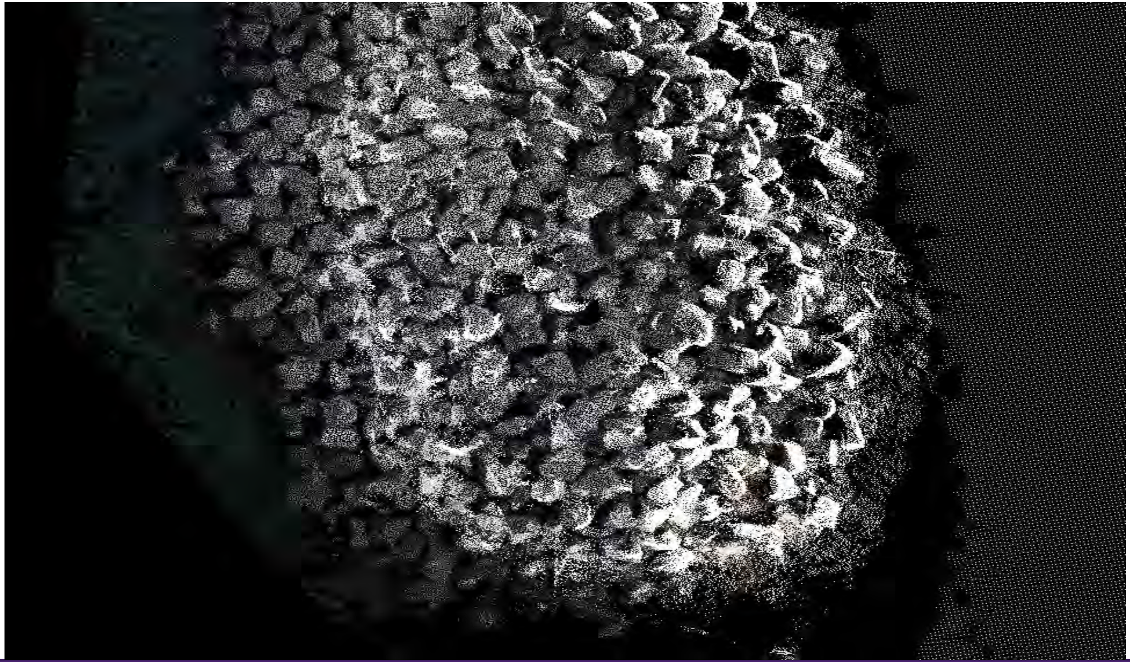
Overlapping the Surfaces

- No Control was collected for the Masonboro Inlet Jetties however LiDAR had been collected previously.
- Due to lack of control, the two scans did not line up however similar features could be identified in both scans.



MASONBORO INLET N. JETTY – PROOF OF CONCEPT

Overlapping the surfaces



MASONBORO INLET N. JETTY – PROOF OF CONCEPT

Final business comparison: UAV vs. traditional methods

	Traditional surveying	Terrestrial LiDAR (on survey boat)	Aerial LiDAR
Accuracy	Difficult and dangerous with conventional survey methods	Similar to Site Scan (0.13 ft / 4 cm)	Similar to Site Scan (0.13 ft / 4 cm)
Cost savings using Site Scan	/	~30%	~75%
Time	/	UAV much faster mobilization, collection & processing. Similar coverage.	UAV much faster mobilization, collection & processing. Similar coverage.

EAGLE ISLAND DISPOSAL SITE – PROOF OF CONCEPT

Goals:

- Measure the volume of material dredged by the river twice a year (before and after the dredging)
- Evaluate the ability to achieve the same accuracy as traditional surveying without putting people into harm's way
- Assess the viability of volumetric collection with UAVs

EAGLE ISLAND DISPOSAL SITE – PROOF OF CONCEPT

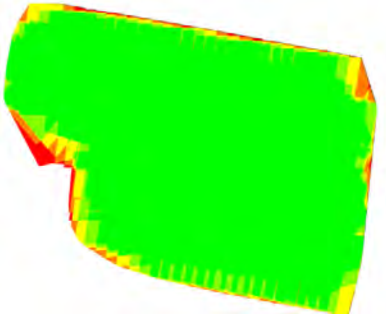
Total Area Processed

Partial Cells 1 & 2
106 Acres

Ground Control Used

7 Points
Fully Surveyed

Photos Collected



Sony R10C
Total 214 / 1.34GB

Output Parameters

Horizontal GSD – 1.32 in
3D Points / Meter - 104

Processing Time: 5 hrs 7 mins
Products Produced: Orthos, DSM, Point Cloud, 3D Mesh
Overall Accuracy: Mean RMS 2.64 inches

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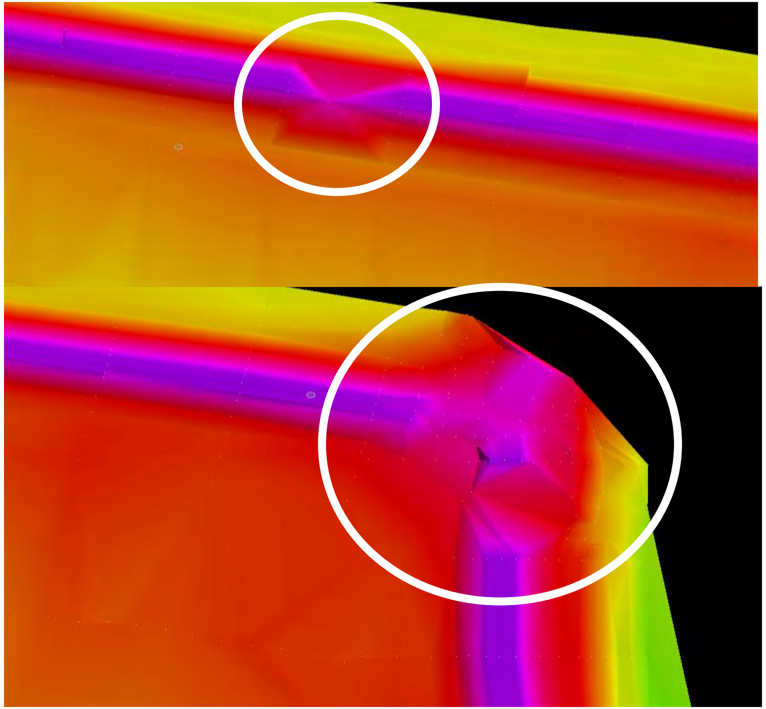
EAGLE ISLAND DISPOSAL SITE – PROOF OF CONCEPT

EAGLE ISLAND DISPOSAL SITE – PROOF OF CONCEPT

Traditional Survey Data

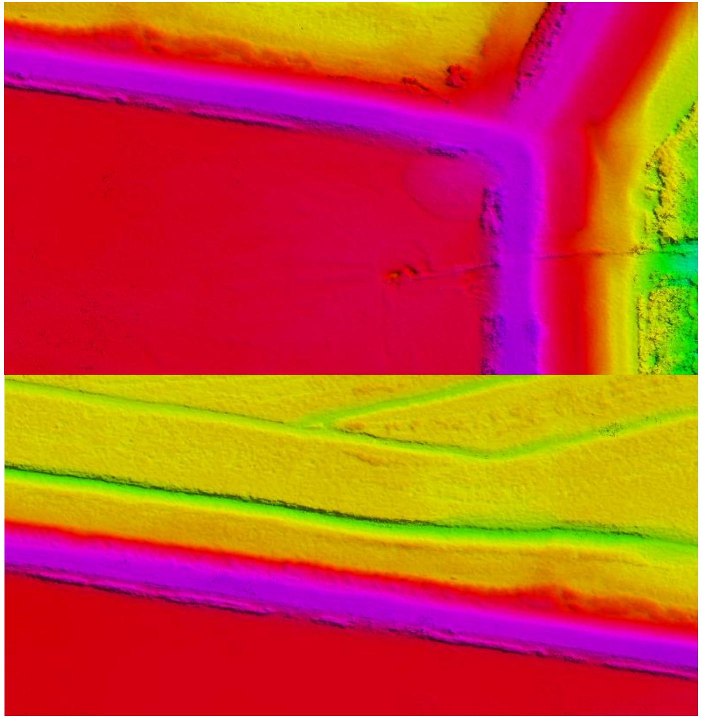
- Cell 1 (280 Acres approx.) was previously surveyed using conventional.
- 3642 individual survey shots were collected (2 weeks of work approx.)
- Irregularities in the surface model existed due to either bad elevations or incorrect triangulation



EAGLE ISLAND DISPOSAL SITE – PROOF OF CONCEPT

UAS Survey Data

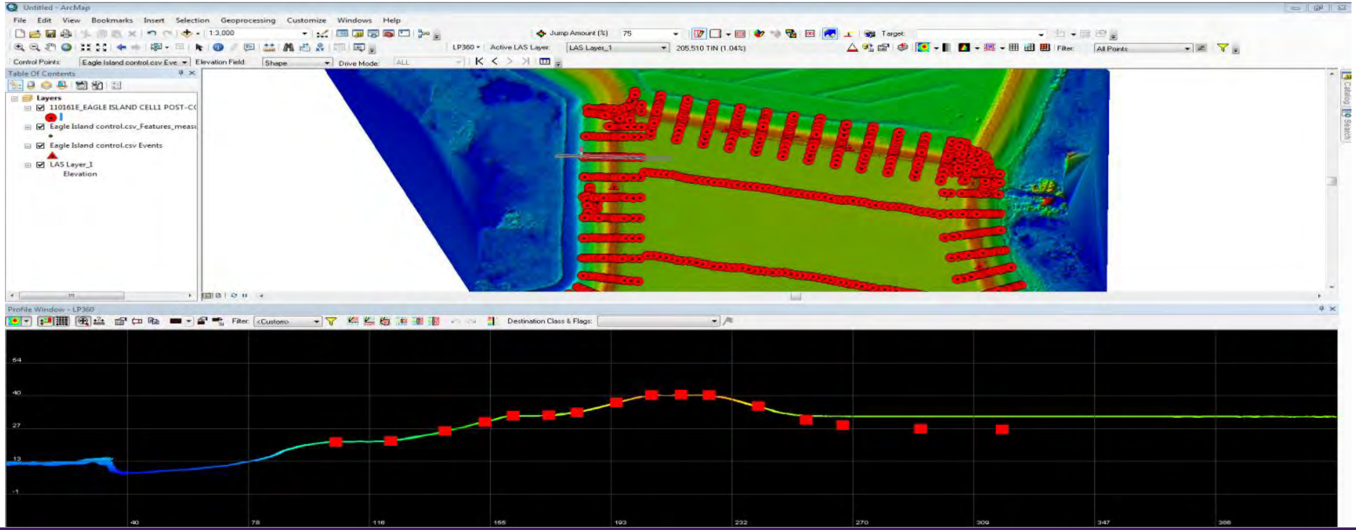
- Portions of Cell 1 and Cell 2 were collected in two 15 minute flights.
- 5 flights would be required to collect all of Cell 1 (half a day of flight and target survey approx.)
- 104 points per square meter vs. 0.07 (averaged from survey)



EAGLE ISLAND DISPOSAL SITE – PROOF OF CONCEPT

Accuracy Reporting

- No blind checkpoints were collected only control points.
- UAS and survey lined up very well on the dikes. The volume inside had changed however since the survey.



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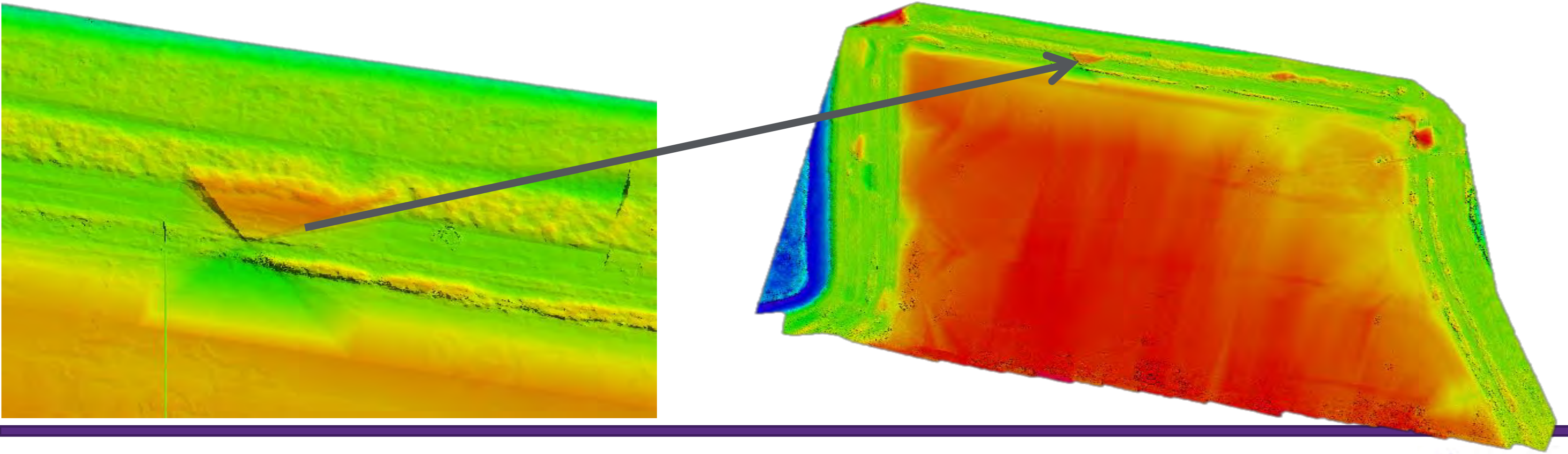
EAGLE ISLAND DISPOSAL SITE – PROOF OF CONCEPT

Surface Comparison

- The difference between data collections were normalized to visualize differences between datasets
- Most locations on the dike were less than 0.1 ft. up to 0.02 ft. difference between surfaces.
- In Places where the survey did not triangulate well, the differences were greater.



McKIM&CREED

EAGLE ISLAND DISPOSAL SITE – PROOF OF CONCEPT

Final business comparison: UAV vs. traditional methods

	Traditional surveying	Terrestrial LiDAR	Aerial LiDAR
Accuracy	Higher accuracy (0.07 ft / 2 cm)	Inadequate ground stability	Similar to Site Scan (0.13 ft / 4 cm)
Cost savings using Site Scan	~80%	/	~50%
Time	UAS captures greater detail in less time and is safer!	/	UAV much faster mobilization, collection & processing. Similar coverage.

CONCLUSION

- Business 101
  - Cost
  - Quality
  - Speed
- Esri's Drone2Map coupled with 3DR's Solo and Site Scan equate to a business paradigm shift that allows civil engineering and land surveyors to take advantage of the advancing drone industry.
- Advantages:
  - Less people (Cost)
  - More accurate (Quality)
  - Faster deliverable (Speed)
  - Greater safety

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COMMUNITY EFFORT

USACE Wilmington, City of Wrightsville Beach, UNC-W, NC Coastal Land Trust, Cape Fear Audubon

ACEC/NC ENGINEERING EXCELLENCE AWARDS

The **Grand Conceptor Award** was presented for a proof of concept (POC) by McKim & Creed and Esri. The purpose was to determine if unmanned aerial system technology (UAS/drones) can provide coastal communities with a faster, more cost-effective way to produce beach monitoring surveys.

These surveys are typically conducted twice a year—before and after hurricane season—and are used to:

1) Analyze a beach's performance in terms of erosion and accretion.

2) Plan and predict maintenance and renourishment activities.

3) Secure emergency funding for restoration.

The POC showed that municipalities can save up to 60% in time and money by using UAS for data collection.

Thank you for the opportunity.

QUESTIONS

ADVANCED UAS/DRONE TECHNOLOGY FOR SURVEYING & ENGINEERING

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