Utilization of Unmanned Aerial Systems (UAS) for Vegetation Mapping and Restoration

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Invasive Species Management Branch
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Jacksonville District UAS team
UAV – THE NEED

• High resolution imagery for invasive species management and environmental restoration
• High temporal resolution (ability to quickly reacquire)
• Waterproof landing
• Responsive to users
• Sufficient payload capacity for future development
USACE Program Mission

Provide a Reliable Data Collection Tool to Support Aerial Mapping and Environmental Reconnaissance Missions
UAV - History

- 2005: Starts with ERDC, USGS, University of Florida (UF) and Jacksonville District (SAJ)
- 2006-2010: Airframe/Payload Development
- 2010: Transition to operations
- 2011: SAJ designated UAV Southeast Division (SAD) Regional Center of Expertise.
- 2012: New Payload. Mosaic Solution
- 2012-2013: Turn-Key Production Environment
- 2014: “Metric” Payload. Gimbaled EO/TIR Video
- 2015+: Increase Support for Military Customers
A lot of parts/wires etc.

Getting there...
GCS Current Version

- Everything in one case
- Panasonic TB, Combox, RC Controller, etc.
- Power Redundancy
- ~50 lbs

Stand is helpful…
Airframe Evolution

- Airframe development
- “Truck” for geospatial payload

2006-2008: Polaris
2008-2009: Shoe/NOVA
2009-2010: NOVA/NOVA Block II
NOVA System Components
NOVA BLOCK III

- “Commercialized” version of the Block II
- 6 cell lithium battery
- Connection improvements
- Established safety record with AED
- Procerus Kestrel Autopilot
Fully Autonomous
2.7 m Wingspan
15 lbs. w/ Payload
~750 acres per lift @ 300m altitude
~50 kilometers per lift @ 300m altitude
~3.5cm @ 300m altitude
Absolute spatial accuracy typically 2-4 meters (no ground control)
Block II = 60 minute duration
Block III = 90 minute duration
Standard Mapping Payload Details (MP21)

- Camera Body: Rebel EOS T2i
- Sensor: APS-C CMOS 5184x3456
- Single Board Micro PC
- Lens: Voigtlander Ultron 40mm F2 SL Aspherical
- Positioning: Xsens Mti-G (L1 with WAAS)
Camera Body: Rebel SL1
Sensor: APS-C CMOS 5184x3456
Single Board Micro PC
Lens: Voigtlander Ultron 20mm F2 SL Aspherical
Positioning: Novatel OEMStar (L1 with WAAS)
Image Capture
High Resolution Mosaic – 250 images
Constraints
Constraints

We only fly in approved airspace, typically:
• Below 1200’
• 5 nm outside of airports
• 30 nm for large airports (MIA, TPA).
• Flight in this airspace possible, requires COA

AR 70-62 requires AWR:
• Airworthiness Qualification Level (AQL) 3
• Not undergone rigorous airworthiness qualification
• Avoid flying over people, roads, homes, etc.
• Limited to Line Of Sight operation (LOS)
• Depends on conditions, typically 1.5km
Class G Airspace = GOOD for the most part.
NOVA: Applications

APPLICATIONS
NOVA: Applications

- Pre/active/post construction monitoring
- Asset/infrastructure management
- Invasive species surveillance and monitoring
- Vegetation mapping
- Environmental restoration/engineering
NOVA: Applications

- Pre/active/post construction monitoring
- Asset/infrastructure management
- Invasive species surveillance and monitoring
- Vegetation mapping
- Environmental restoration
Fisheating Bay
Lake Okeechobee
Fisheating Bay

Legend
- Red: Target Area
- Green: Roads
- Blue: Canals
Luziola subintegra
Luziola subintegra

Sacciolepis striata

Luziola subintegra
Mixed Emergent/Float
# Analysis

**Processed Data**

<table>
<thead>
<tr>
<th>Class</th>
<th>Subclass</th>
<th>Area (m²)</th>
<th>% Total</th>
<th>% Class</th>
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<tbody>
<tr>
<td>Water</td>
<td>Open Water</td>
<td>50,281</td>
<td>20%</td>
<td>72%</td>
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<td></td>
<td>Decomposing (Submerged)</td>
<td>19,712</td>
<td>8%</td>
<td>28%</td>
</tr>
<tr>
<td>Vegetation</td>
<td>Frog’s Bit, Water Hyacinth, &amp; Cupscale</td>
<td>46,944</td>
<td>19%</td>
<td>26%</td>
</tr>
<tr>
<td></td>
<td>Decomposing (Emergent)</td>
<td>45,889</td>
<td>18%</td>
<td>25%</td>
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<tr>
<td></td>
<td>Water Lettuce</td>
<td>29,899</td>
<td>12%</td>
<td>16%</td>
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<tr>
<td></td>
<td>Luziola</td>
<td>26,386</td>
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<td>15%</td>
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<tr>
<td></td>
<td>Lotus</td>
<td>22,433</td>
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<td>12%</td>
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<tr>
<td></td>
<td>Shadow/Unclassified</td>
<td>8,757</td>
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<td>5%</td>
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<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>250,000</strong></td>
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</table>
Species Matrix Classification (ENVI)
March 2012
142 acres

17 active nests
July 2012
537 acres

29 active nests
September 2012
17 acres

1 active nest
## “Ground Truthing Ourselves”

### March

**IA Group Estimate – 168 acres**

**Actual - 142 acres**

<table>
<thead>
<tr>
<th>Area of Lake</th>
<th>Average</th>
<th>%</th>
<th>FWC</th>
<th>SFWMD</th>
<th>AAM</th>
<th>USACE</th>
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<tbody>
<tr>
<td>1. Torrey &amp; Kreamer</td>
<td>31.25</td>
<td>3%</td>
<td>10</td>
<td>25</td>
<td>75</td>
<td>15</td>
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<tr>
<td>2. Ritta</td>
<td>88.75</td>
<td>9%</td>
<td>250</td>
<td>35</td>
<td>50</td>
<td>20</td>
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<tr>
<td>3. East Wall - Coot Bay</td>
<td>18.75</td>
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<td>25</td>
<td>25</td>
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<td>4. West Wall - Whidden</td>
<td>420.00</td>
<td>43%</td>
<td>500</td>
<td>395</td>
<td>325</td>
<td>460</td>
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<td>5. Fisheating Bay</td>
<td>88.75</td>
<td>9%</td>
<td>200</td>
<td>60</td>
<td>40</td>
<td>55</td>
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<tr>
<td>6. Hamey - Indian Prairie</td>
<td>76.25</td>
<td>8%</td>
<td>150</td>
<td>40</td>
<td>75</td>
<td>40</td>
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<tr>
<td>7. Indian P - Kissimmee</td>
<td>8.75</td>
<td>1%</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>5</td>
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<tr>
<td>8. King's Bar</td>
<td>11.25</td>
<td>1%</td>
<td>20</td>
<td>15</td>
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<tr>
<td>9. Kissimmee - Taylor Cr.</td>
<td>168.75</td>
<td>17%</td>
<td>300</td>
<td>175</td>
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<td>100</td>
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<td>10. Taylor Cr - Chancey</td>
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<td>50</td>
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<td>50</td>
<td>45</td>
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<tr>
<td><strong>TOTALS</strong></td>
<td>967.50</td>
<td>100%</td>
<td>1515</td>
<td>855</td>
<td>745</td>
<td>755</td>
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“Ground Truthing Ourselves”

July

IA Group Estimate – 1310 acres

Actual – 537 acres

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<tr>
<th>Area of Lake</th>
<th>Average</th>
<th>%</th>
<th>FWC 1</th>
<th>FWC 2</th>
<th>SFWMD</th>
<th>AAM</th>
<th>USACE</th>
</tr>
</thead>
<tbody>
<tr>
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<td>38.00</td>
<td>2%</td>
<td>100</td>
<td>20</td>
<td>45</td>
<td>15</td>
<td>10</td>
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<tr>
<td>2. Ritta</td>
<td>70.00</td>
<td>3%</td>
<td>200</td>
<td>50</td>
<td>60</td>
<td>30</td>
<td>10</td>
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<tr>
<td>3. East Wall - Coot Bay</td>
<td>89.00</td>
<td>4%</td>
<td>270</td>
<td>40</td>
<td>50</td>
<td>45</td>
<td>40</td>
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<td>4. West Wall - Whidden</td>
<td>222.00</td>
<td>9%</td>
<td>400</td>
<td>200</td>
<td>210</td>
<td>135</td>
<td>165</td>
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<tr>
<td>5. Fisheating Bay</td>
<td>249.00</td>
<td>10%</td>
<td>320</td>
<td>300</td>
<td>125</td>
<td>250</td>
<td>250</td>
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<tr>
<td>6. Harney - Indian Prairie</td>
<td>79.00</td>
<td>3%</td>
<td>120</td>
<td>150</td>
<td>75</td>
<td>20</td>
<td>30</td>
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<tr>
<td>7. Indian P. - Kissimmee</td>
<td>111.00</td>
<td>5%</td>
<td>100</td>
<td>150</td>
<td>200</td>
<td>40</td>
<td>65</td>
</tr>
<tr>
<td>8. King's Bar</td>
<td>151.00</td>
<td>6%</td>
<td>250</td>
<td>150</td>
<td>175</td>
<td>100</td>
<td>80</td>
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<td>1310.00</td>
<td>53%</td>
<td>1000</td>
<td>500</td>
<td>1550</td>
<td>2000</td>
<td>1500</td>
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<td>100</td>
<td>250</td>
<td>160</td>
<td>95</td>
<td>100</td>
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<tr>
<td><strong>TOTALS</strong></td>
<td>2460.00</td>
<td>100%</td>
<td>2860</td>
<td>1810</td>
<td>2650</td>
<td>2730</td>
<td>2250</td>
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</table>
Object-based Classification

Dr Amr Abd-Elrahman, PhD
Geomatics Lead
University of Florida
Gulf Coast Research & Education Center

Roshan Pande, Post-Doc

Tao Liu, Post-Doc
Object-based Classification

Goal:
• Map Invasive plants using spectral, textural and contextual object-based classification

Objectives:
• Identify best spectral and textural features and segmentation scale(s)
• Test different machine learning classifiers e.g. Regression Tree (CART), Support Vector Machine (SVM), and Artificial Neural Network (ANN)
• Develop spectral, textural and contextual rules based on multi-scale segmentation
Examples of Segmentation at different scales

Segmentation: course (300) scale

Segmentation: medium (75) scale
Jacksonville District UAS Team
Results of Preliminary Study

- Scale level 75 was better in separating most classes, while level 40 was found good at further separating small patches.
- Scale level 110 was too coarse and combined vegetation classes. Scale level 15 was found too fine to separate textured classes (e.g. Willow, Cattail, etc.). However it provided valuable textural input for higher scale level.
- Scale level 300 didn’t separate individual vegetation species but it can broadly separate water and roads from wetlands.
- Input of spectral values as well as textural information from Haralick indices and sub-object related textures provided better classification results.
- In preliminary study, SVM and ANN yielded better results than Maximum Likelihood method.
- Pixel based classification produced low overall accuracy (51% for Maximum Likelihood 54% for ANN ). Visual results will be shown later.
Results of Preliminary Study, cont

- We considered 4 segmentation scales in further analysis:
  - Very fine scale (L15): Initial classification is run in this level. Result is used for input for further classification.
  - Fine scale (L40): It separates small patches of plant species in mixed class area. Final classification is performed on L40 and L75 levels.
  - Medium scale (L75): It is expected to separate most major classes with some mixed classes (e.g. lotus mixed with other species).
  - Coarse scale (L300): to be used for course delineation of invasive plants.
Training data
Broad categorization

- Road
- Water
- Wetlands
Example: Classified/Combined Maps

- Original image
- Classified map L75 scale
- Combined map
- Classified map L40 scale
Accuracy Assessment

- Classified maps were matched against assessment data set and error matrices were developed.
- Accuracy values (overall accuracy and Kappa coefficients) were computed and used for assessment and comparison.

<table>
<thead>
<tr>
<th>Classifier</th>
<th>Overall</th>
<th>Kappa</th>
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<tbody>
<tr>
<td>SVM</td>
<td>70.32%</td>
<td>0.654</td>
</tr>
<tr>
<td>ANN</td>
<td>69.44%</td>
<td>0.643</td>
</tr>
<tr>
<td>ML</td>
<td>58.18%</td>
<td>0.516</td>
</tr>
<tr>
<td>Pixel based SVM (downsized)</td>
<td>57.37%</td>
<td>0.513</td>
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<tr>
<td>Pixel based ML</td>
<td>50.94%</td>
<td>0.451</td>
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<tr>
<td>Pixel based ANN</td>
<td>53.62%</td>
<td>0.476</td>
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</table>
Lettuce and Lily

Lettuce

Lily
Lettuce

Lower portion: Mixed and boat disturbed areas
Lettuce
Hyacinth

Smartweed
Lettuce vs. Lily

- Spectrally similar.
- Lettuce is more “yellowish” but varies in color at different locations.
- Most areas are correctly assigned. Some are confused with other classes, especially Lily and sometimes Smartweed.
Classification Using Convolutional Neural Network (CNN)

- One type of feed-forward artificial neural network
- Workhorse for a lot of recording-breaking deep learning frameworks for computer vision tasks

Distinguish features:

3D volumes of neurons
- One single layer can be extended to multiple layers

Local connectivity
- Allow locally learned features to combine together to represent global feature

Shared weights
- Each filter is applied to the entire image to create one layer

Extract training data
One data item
TRAIN, VALIDATION AND TEST

Total 930366

Systematically select 60000

Shuffle

Testing 6000 (First testing set)

Validation 4000

Training 50000
Second Testing Set
Architecture

Theano website
http://deeplearning.net/software/theano/
## Result

Table 1: Accuracy of CNN result of first testing set

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<tr>
<th>Approach</th>
<th>Overall Accuracy</th>
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<td>CNN approach based on the first testing data set</td>
<td>79.88%</td>
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<td>Best accuracy of object approach on the second testing data set</td>
<td>70.78%</td>
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</table>

<table>
<thead>
<tr>
<th>Approach</th>
<th>Classifier</th>
<th>Overall accuracy</th>
<th>Kappa coeff.</th>
</tr>
</thead>
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<tr>
<td>Object based</td>
<td>SVM</td>
<td>70.78%</td>
<td>0.659</td>
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<td></td>
<td>ANN</td>
<td>69.44%</td>
<td>0.643</td>
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<td></td>
<td>ML</td>
<td>58.18%</td>
<td>0.512</td>
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<td>Pixel based on high resolution (8 cm) images</td>
<td>SVM</td>
<td>56.84%</td>
<td>0.503</td>
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<td>ANN</td>
<td>50.94%</td>
<td>0.441</td>
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<td>ML</td>
<td>53.62%</td>
<td>0.471</td>
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<td>Pixel based on low resolution (30 cm) image</td>
<td>SVM</td>
<td>61.93%</td>
<td>0.560</td>
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<td></td>
<td>ANN</td>
<td>53.89%</td>
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<tr>
<td></td>
<td>ML</td>
<td>52.81%</td>
<td>0.464</td>
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Blue Head Ranch
NRCS Wetland Restoration Project (WRP)
Classifying Training Data

Species delineation to identify cogon grass (neon green)
### Vegetation Classification System for South Florida Natural Areas, 2009

<table>
<thead>
<tr>
<th>MD</th>
<th>Species</th>
<th>Class</th>
<th>Level</th>
<th>Description</th>
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<tr>
<td>73</td>
<td>Piper</td>
<td>15</td>
<td>4</td>
<td>Mixed Broadleaf (Evergreen Conifer)</td>
</tr>
<tr>
<td>74</td>
<td>Polygon</td>
<td>16</td>
<td>4</td>
<td>Mixed Broadleaf (Evergreen Conifer)</td>
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<tr>
<td>75</td>
<td>Polygon</td>
<td>17</td>
<td>4</td>
<td>Mixed Broadleaf (Eucalyptus)</td>
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<tr>
<td>76</td>
<td>Polygon</td>
<td>18</td>
<td>4</td>
<td>Mixed Broadleaf (Sheoak)</td>
</tr>
<tr>
<td>77</td>
<td>Polygon</td>
<td>19</td>
<td>4</td>
<td>Mixed Broadleaf (Eucalyptus)</td>
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<tr>
<td>78</td>
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<td>20</td>
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<tr>
<td>80</td>
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<td>22</td>
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<td>Mixed Broadleaf (Sheoak)</td>
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</table>

**Classifying Training Data, cont**

Jacksonville District UAS Team
Classifying Training Data, cont

<table>
<thead>
<tr>
<th>FID</th>
<th>Shape *</th>
<th>ID</th>
<th>Class_ID</th>
<th>Name</th>
<th>Level</th>
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<td>MFgJ</td>
<td>Soft Rush</td>
<td>4</td>
<td>Graminoid Freshwater Marsh</td>
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<tr>
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<td>Polygon</td>
<td>2</td>
<td>MFg</td>
<td>Mixed Graminoid</td>
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<td>2</td>
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<td>Su4</td>
<td>Saw Palmetto</td>
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<td>Saw Palmetto Shrubland</td>
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<td>Polygon</td>
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<td>Su4</td>
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<td>Saw Palmetto Shrubland</td>
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<td>Saw Palmetto</td>
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UNCLASSIFIED
Jacksonville District UAS Team

BUILDING STRONG
POC: Victor Wilhelm Jr
Species Identification/Classification

Species delineation to identify cogon grass (neon green)
RESTORATION…NEED DSMs?

SJ1 Upland Disposal Area, St. Augustine, Florida

Sometimes the vertical relief is not readily apparent in imagery.
Future
GOT DSMS?

Repair volume and debris removal estimation
Watch Your Step…

SJ1 Upland Disposal Area, St. Augustine, Florida

• ~1.2 meter washout
• Rapid assessment of road/levee conditions
Point Clouds with RGB values

- We can create dense RGB point clouds from imagery
- Point clouds can be filtered for bare earth surfaces
Future: Payloads
Metric Payload

True purpose built geospatial/remote sensing imaging payload
“Metric” Payload

• 16MP CCD (presently 29MP CCD)

• Increased Radiometric Resolution: 8 and 12 bit

• Multispectral

• Stable optics

• High precision L1/L2 GPS

• Omnistar and RTK
Future: Multi-Rotor VTOL for “Everyone”

- “Turn Key”: No assembly and minimal flight planning
- COTS
- Optional HUD via smartphone app
- Minimal cost ~$3K per “kit”
- Minimal training (2-3 days)
- Minimal flight crew
  - one operator
  - one observer
- Think biologists, park ranges, engineers, etc.

- ~20 minute flight time
- 300 gram capacity
- Live video feedback
- Water quality sampling
Multi-Rotor VTOL

- Access to previously difficult/impractical mission sites where landing approach not sufficient
- Carries fixed wing NOVA payloads
- Identical avionics to fixed wing
Jon Morton
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