High Resolution Imagery Collection Utilizing Unmanned Aerial Vehicles (UAVs) for Post-Disaster Studies

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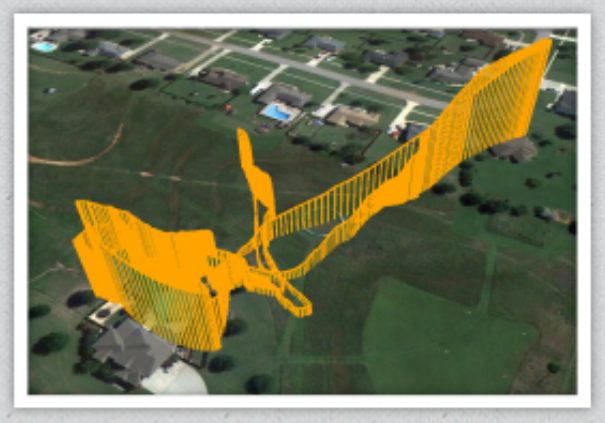


Presentation Outline

- Data Collection Limitations and Needs
- UAV Background and Usage for Disaster Studies
- Example UAV Imagery in Disaster Studies
- UAV Laws and Regulations
- Takeaways

Current Disaster Imagery Collection Methods

LOWER RESOLUTION **HIGH RESOLUTION**

NOAA
GSD:50cm

Pictometry
GSD:15cm

Ground-Based

Pictometry
GSD:15cm

USGS Oblique
GSD: ~100cm

Pictometry
GSD:15cm

Pictometry
GSD:15cm

Ground Sample Distance (GSD)- distance between pixels centers as measured on the ground

Ground-Based Imagery Collection Access Limitations

Common limitations include (Adams, Levitan and Friedland, 2012)

- Access
  - Blocked or washed out roads
    - Downed trees and power lines, water, debris, etc.
  - Post-disaster security roadblocks
  - Fences
  - Private property considerations
  - Safety considerations
- Image
  - Limited view of roofs
  - Sometimes can see only street view

Limitations of Combined Aerial & Ground-Based Data Collection

Hurricane Ike in Galveston, Texas (2008)

Neighborhood level NOAA aerial imagery (GSD= 50cm)

Per-building zoom of the NOAA imagery

- Roof damage as the southwest portion of the roof is discolored
- Degree of damage is difficult to determine for this multi-level roof
- Photograph provides no information on the façade damage.

Ground-based image of the Structure

- Details of wind damage to the roof not visible from the ground
- Storm surge has destroyed the stairs (Limited Access)

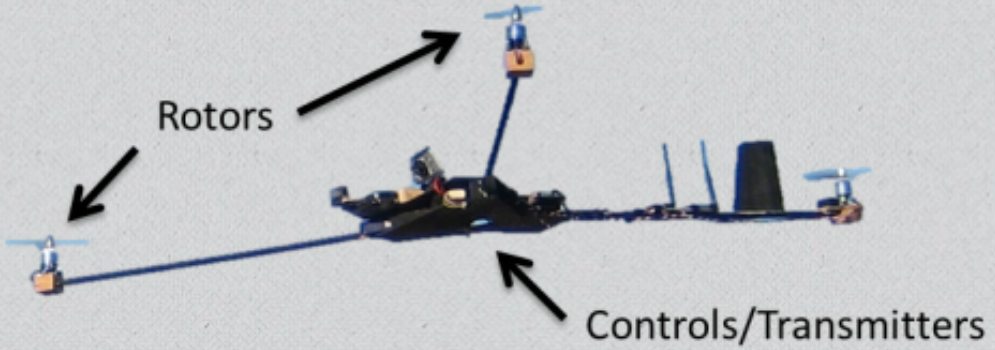
Example UAV Usage in Disaster Events

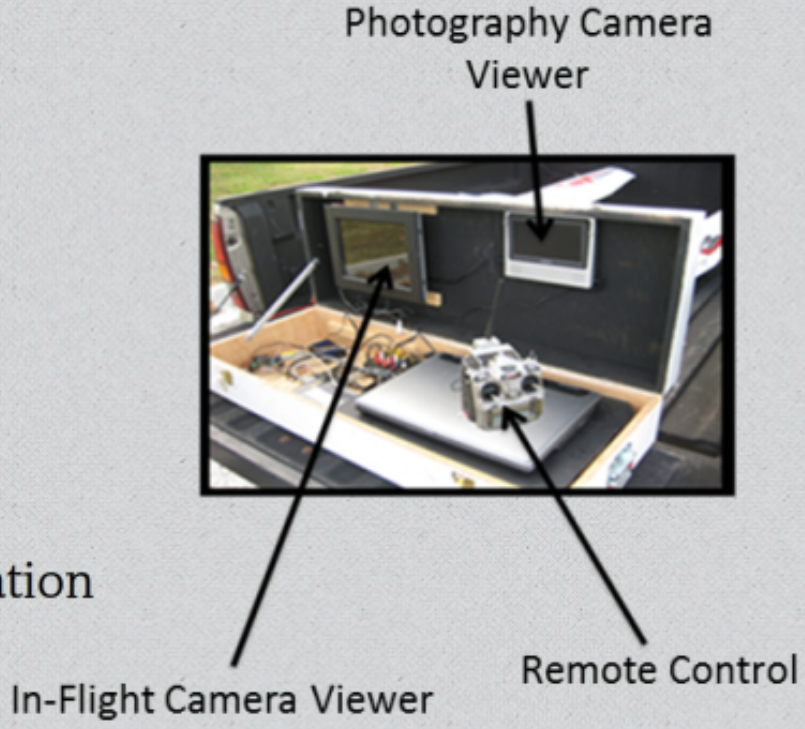
- Hurricane Katrina, Mississippi in 2005 (Pratt et al. 2006)
  - Helicopter UAV
  - Structural damage assessments of multistory commercial buildings
- Typhoon Morakot, Tawian in 2009 (Chou et al., 2010)
  - Helicopter UAV
  - Collect post-disaster imagery to support
    - Post-disaster reconnaissance, Disaster restoration, Reconstruction assessments
- L'Aquila, Italy Earthquake in 2009 (Quaritsch, Kruggl et al., 2010)
  - Quad-copter UAV
  - Fire service response support
- Haiti Earthquake in 2010 (Huber, 2011)
  - Fixed-wing UAV
  - Orphanage reconnaissance investigation
- Tohoku Earthquake and Tsunami, Japan in 2011 (Reavis and Hem, 2011)
  - T-Hawk Micro UAV with radiation sensors
  - Fukushima Daiichi plant investigation
- Hurricane Sandy, New York in 2012 (United Press International, 2013)
  - UAV-based cameras equipped with infrared and ultraviolet filters
  - Detect unseen damage such as power line failures

T-Hawk Micro UAV
www.thawkmav.com

Unmanned Aerial Vehicle Specifications

- Flight Characteristics:
  - Up to 20 min flight time
  - Mission radius of 3.5 km
  - Altitude of 100 meters
  - Max speed of 45 kph
- UAV Physical Specifications:
  - Three 1 meter legs
  - Three 300 watt motors
  - Max payload of ~1.5 kg
- Software:
  - On board- Arducopter 2.7.3
  - Ground Control Station - Ardupilot-mega
  - Navigation Capabilities:
    - Flight Home, Position Hold, Waypoint Navigation





Case Study Investigating UAV Capabilities Following a Tornado

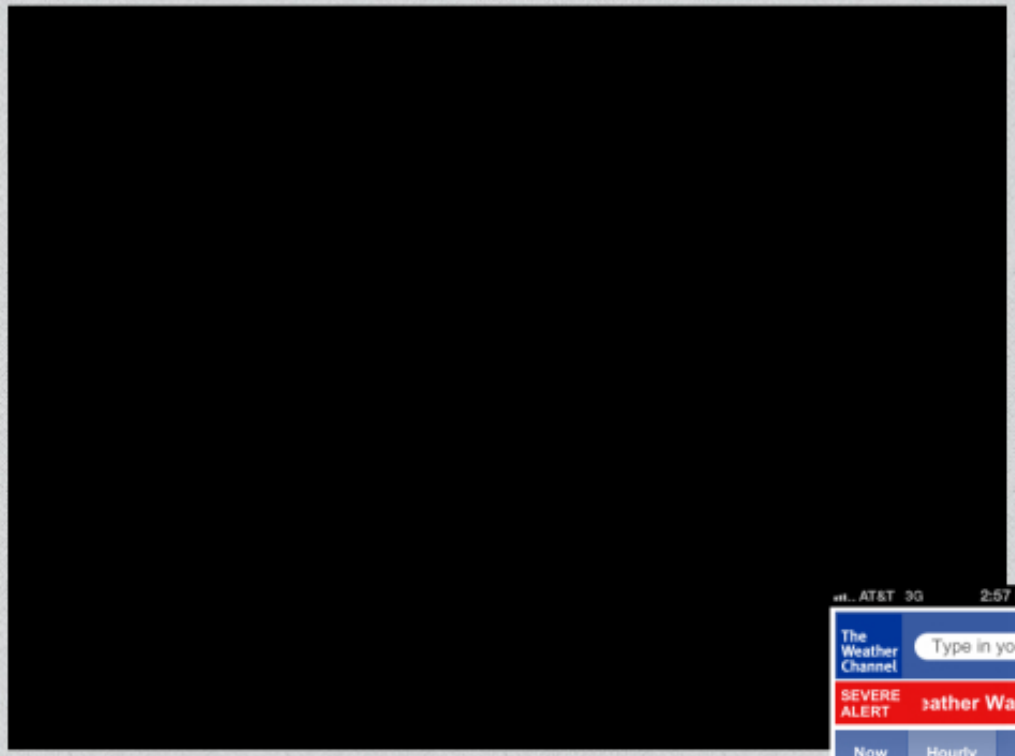
EF 3 tornado in Athens, AL on March 2, 2012

Close approach for ground-based photos limited by:

- Fences
- Unstable nature of damaged structure
    - Particularly due to 30mph wind gusts the day of investigation

Extent of damage beneath roof lines are difficult to quantify based on ground-based imagery

UAV Configuration and Control



- Tri-Copter UAV used for aerial imagery acquisition
- Wind gusts up to 30mph
- Manually controlled
- Semi and fully autonomous flight capabilities

- Nadir-facing 12.1MP camera
- Remote shutter
- Altimeter, compass and Lat/Lon
- Oblique-mounted GoPro Hero 2 video camera
  - 1080p, 1920x1080 @ 30fps

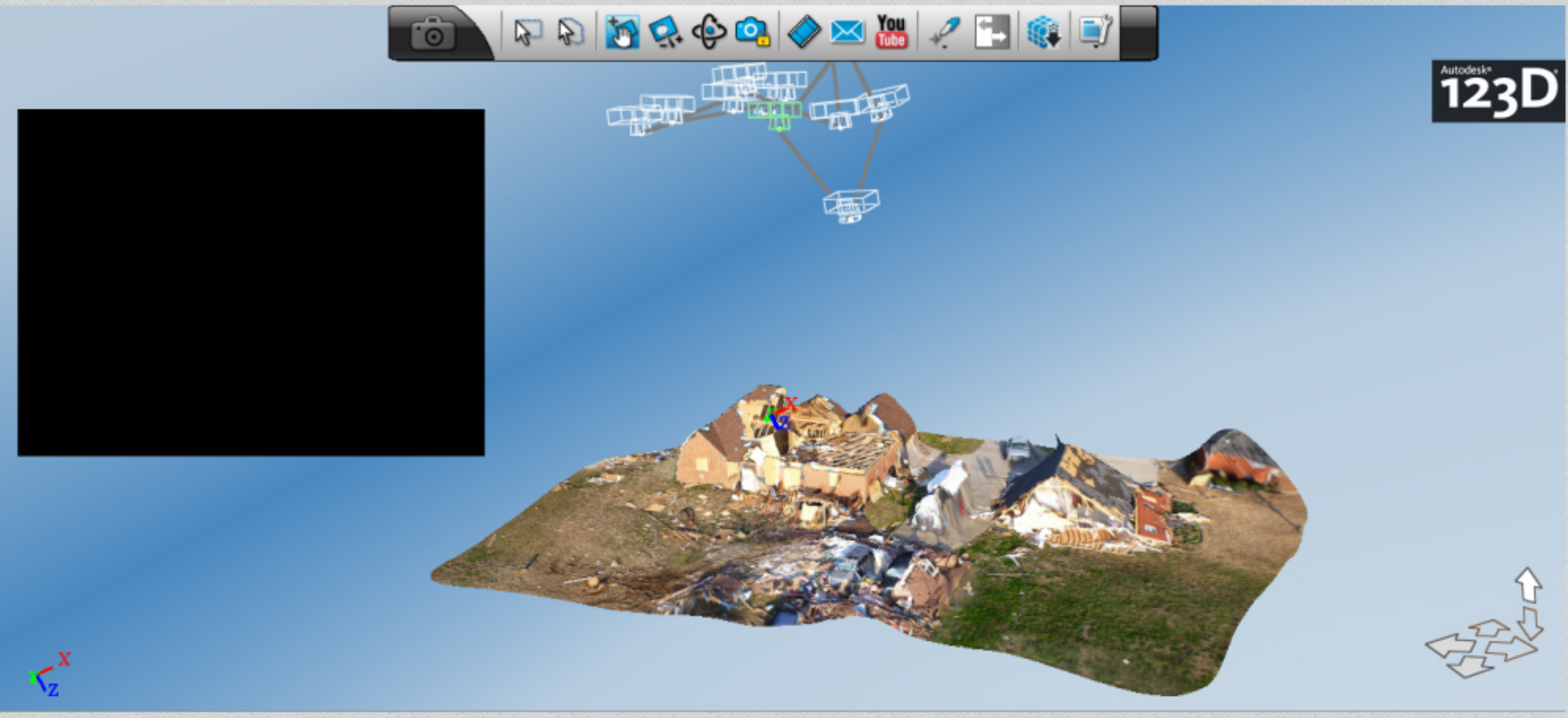
UAV-Based Nadir Imagery: No Zoom

UAV-based still image of Structure 1 taken by the nadir-mounted digital camera, with GSD approximately 0.7 cm.

UAV-Based Nadir Imagery: Zoomed

Further close-up of the southwest corner of Structure 1. This demonstrates the full resolution capabilities of the UAV-mounted camera. Construction materials and damage to the roof covering, roof sheathing, and ceiling beneath the roof joists are clearly visible.

UAV-Based Imagery Source Locations & 3D Mesh



- Spatial representation of nadir imagery acquisition
- 10 images used to construct 3D mesh
- Point cloud export available for further analysis including measurements using photogrammetry principals

3D Mesh Flyover and Actual Flyover Video

Hurricane Isaac NOAA vs. UAV Imagery

NOAA Imagery

GSD ~25cm

UAV Imagery

GSD <10cm

Hurricane Sandy Tethered Balloon-Based Imagery

Tethered Balloon-based Imagery

UAV Laws, Regulations and Important Dates

- Certificate of Airworthiness (COA)
  - Issued by the Federal Aviation Administration (FAA)
    - Good for up to 2 years
    - Monthly reports are required
  - Only Public entities at this time
    - No commercial usage at this time
    - Public entity self-certifies airworthiness
- Emergency Response COAs
  - Must have COA for training purposes
    - COA should define district for emergency response
    - 1 hour notice to FAA required before usage
  - Emergency Response outside of defined COA
    - 24 hour notice to FAA required before usage
- 2015 Congressional Mandate on UAV Regulations Creation
  - Extent and integration plans are not required by mandate (just set regulations)
  - Some commercial usage allowances are expected
  - Emergency response has unique rules
  - COAs must still be sought

Conclusions

- Demonstrated Capabilities of Micro-UAVs for Disaster Optical Imagery Collection
  - User-controlled for custom acquisitions
  - Acquisition possible in windy conditions (up to 30 mph gusts)
  - Acquisition possible in cloudy conditions (as long as ceiling > hundred meters)
  - Nadir and oblique imagery
  - Still and video optical imagery
  - Sub-cm GSD
    - 1-2 orders of magnitude better than commercial satellite and aerial imagery
- Applications
  - Optical data collection of individual buildings/facilities and neighborhood-scale areas
  - 3D model creation for visualization constructed from multiple nadir images
  - Dimensional measurements (plan dimensions and heights) using overlapping nadir images and photogrammetric tools
- Disasters
  - Demonstrated applications following tornadoes and hurricanes
  - Literature documents other applications following
    - Earthquakes, tsunamis, fires, hurricanes and typhoons

Emerging UAV Technologies and Capabilities

- UAV Technology Rapidly Improving
  - More efficient/lighter power options enabling longer flight times and larger payloads
  - Enhanced payload stabilization platforms
  - Greater wind tolerance
  - Costs decreasing
- Advances in Flight Control and Navigation
  - Commercial and Open-source Options
  - Manual, Semi-autonomous and Fully-autonomous
  - Reduced expertise/training needed to operate
- Potential Platform Apart from Optical Sensors
  - Multispectral including:
    - Infrared (IR)
    - Ultraviolet (UV)
  - Radar and LiDAR
  - Air Quality
  - Meteorological (pressure, temperature, humidity)
  - Radiation

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