Unmanned Aerial Systems (UAS)

Complete Summit Workbook
Every Day Counts  |  Unmanned Aerial Systems (UAS)
Baltimore, Albany, St. Louis, Portland & Orlando  |  Fall 2018
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UNMANNED AERIAL SYSTEMS FOR INFRASTRUCTURE

Unmanned aerial systems (UAS), sometimes referred to as drones, are multi-use aircraft controlled from a licensed operator on the ground. The benefits of UAS are wide ranging and impact nearly all aspects of highway transportation—replacing boots on the ground, increasing accuracy, speeding up data collection, and providing access to difficult-to-reach locations.

UAS provide high-quality survey and data mapping that can be collected automatically or remotely, allowing for the mapping of large areas relatively quickly in comparison to traditional survey and mapping practices. Other uses include survey and imagery as part of emergency response events, where traditional surveying and mapping practices may be inadequate or sites are impossible to access.

UAS can supplement conventional activities, such as bridge safety inspection and routine construction inspection, to increase safety and collect data from otherwise unattainable perspectives.

Benefits

Safety. Keeping workers out of harm’s way is a major benefit of using UAS. Traditional bridge inspection requires setting up temporary work zones, detouring traffic, and using special access equipment or even climbing. UAS technology can speed data collection while reducing risk to work crews and the traveling public.

Accelerated Construction. UAS technology can accelerate the rate of data collection operations, such as survey or aerial photography, and facilitate exact quantity calculation and efficient payment to contractors. UAS can be used for routine inspections, such as flying a programmed path over silt fencing after a rain event to check for sediment buildup, and for high-risk inspections, such as crane or falsework construction.

Asset Maintenance. The ability to routinely and consistently map terrain and monitor conditions offers the potential for isolating problem areas before an emergency occurs, which can both save lives and reduce asset maintenance costs.
During an emergency event, UAS technology can be quickly and inexpensively used to survey the damage, allowing for better-informed and more efficient recovery operations.

These key benefits serve as the motivation for implementing UAS for infrastructure. Many use cases that capitalize upon these benefits have been realized by state departments of transportation (DOTs) and industry professionals, which were highlighted in the UAS summits held between October and December 2018.

TECHNICAL WORKING GROUP MEMBERS

To help inform the implementation plan for this innovation, professional expertise was gathered through stakeholders from the Federal, State, and Local governments, as well as from industry organizations. The members of this working group are listed below.

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<th>Name</th>
<th>Agency</th>
<th>Role Assignment</th>
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<tr>
<td>James Gray</td>
<td>Federal Highway Administration (FHWA)</td>
<td>UAS Team Lead</td>
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<td>Connie Yew</td>
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<td>Cameron Chasten</td>
<td>U. S. Army Corps of Engineers</td>
<td>USACE Representative</td>
</tr>
<tr>
<td>Rich Juliano</td>
<td>American Road &amp; Transportation Builders Association (ARTBA)</td>
<td>ARTBA Representative</td>
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PURPOSE OF THE WORKBOOK

The purpose of this workbook is to share information about UAS for infrastructure applications, specifically with respect to UAS summit activities. Five regional summits were held—in Baltimore, Maryland; Albany, New York; Portland, Oregon; St. Louis, Missouri; and Orlando, Florida.
The remaining pages of the workbook provide the presentations given by the FHWA, public sector, and industry presenters during the UAS sessions at the five regional summits.

**PRESENTER BIOGRAPHIES**

**James Gray, FHWA**

James Gray currently serves as the UAS and construction technology engineer, within the Office of Infrastructure, for the FHWA. Since joining the FHWA in 2006, James has held previous positions as a project engineer and a construction operations engineer with the Eastern Federal Lands Division. Prior to working with the FHWA, James worked for the Michigan DOT. James holds a masters degree in business administration from Pennsylvania State University and a bachelors degree in civil engineering from Michigan State University. James is also a licensed professional engineer in Michigan.

**Presentation: General Presentation (Portland, St. Louis, and Orlando)**

**Connie Yew, FHWA**

Connie Yew serves as the team leader for construction management in the FHWA Office of Infrastructure in Washington, DC. In this position, Connie leads national efforts to improve construction management practices and deploy innovative technologies in construction. Since joining the FHWA in 1983, Connie has held leadership positions to strengthen the FHWA’s stewardship and oversight roles by advancing management initiatives such as risk management and performance management. Connie holds a bachelors degree in civil engineering from the University of Maryland and a masters degree in public administration from the George Washington University. Connie is a licensed professional engineer in Maryland.

**Presentation: General Presentation (Albany)**

**John Haynes, FHWA**

John Haynes works nationally for the FHWA as the technical leader for the construction manager/general contractor (CM/GC) deployment in conjunction with the Every Day Counts Initiative. John also works locally in the FHWA Utah Division as the Innovation and Research Program manager. He oversees the Utah DOT research, Local Technical Assistance Program (LTAP), and innovative contracting programs under the FHWA’s Special Experimental Project No 14 (SEP-14). He also serves on the Utah State Transportation Innovation and
Research advisory councils. During his 35-year career John has also worked for the Eastern Federal Lands Highway Division, National Park Service, Office of the Architect of the Capitol, and as a private industry consultant. John is a registered landscape architect with a bachelor of science degree from the University of California at Davis.

Presentation: General Presentation (Baltimore)

Jennifer Wells, Minnesota DOT
Jennifer Wells is a state bridge inspection engineer with the Minnesota DOT (MnDOT). She has been an engineer with MnDOT for the past 17 years, with the last 12 years in fracture critical bridge inspection and 5 years in bridge design and bridge standards. Jennifer has a BSCE from Michigan Tech University and an MSCE from the University of Minnesota. She is a licensed civil engineer, a National Bridge Inspection Standards (NBIS) team leader, a Society of Professional Rope Access Technicians (SPRAT) Level 1 rope access technician, a Federal Aviation Administration (FAA) certified small unmanned aircraft system pilot, and a lead investigator on MnDOT drone research for bridges. The MnDOT Bridge Office Inspection Unit is responsible for managing the Minnesota bridge inspection program and conducting fracture critical inspections statewide on both the state and local system.

Presentation: Confined Space Inspection (Baltimore)

Glenn Stott, New Jersey DOT
Glenn Stott leads the New Jersey DOT (NJDOT) UAS initiatives. He is a retired Canadian AirForce jet instructor, C130 captain, test pilot, and flight commander. Later, he flew corporate jets and became a certified jet instructor in 160 different countries. Glenn is an FAA designated pilot examiner and was authorized by the national aviation authorities of Brazil, China, Russia, India, Canada, Mexico, Saudi Arabia, Australia, and New Zealand to grant their highest level of pilot certifications. Glenn’s UAS background started more than 20 years ago with remote controlled helicopters. In addition to his aviation experience, his understanding of emerging technologies also earned him part-time positions as an adjunct technology professor for both Kean and Seton Hall universities. Glenn is an FHWA EDC-5 UAS core implementation plan team member and the recipient of the American Association of State Highway and Transportation Officials’ (AASHTO’s) 2018 President’s Transportation Award for excellence in aviation.
Presentation: High Mast Lighting Inspection (Albany)

Tom Collins, Collins Engineers, Inc.
Tom Collins is the founder and executive chairman of Collins Engineers, Inc. Since opening in 1979, the firm’s services have expanded to include structural engineering services for above water concerns in the transportation, marine, energy, construction, and land development industries. As executive chairman, Tom oversees the development of the Collins strategic mission, nurtures and develops client relationships, and cultivates new business. He also participates in transportation structure-related research and the advancement of industry-wide standards. Consistent with his role as an early adopter of transportation technology, Tom continues to be on the forefront of industry innovation and currently sits on the Illinois Unmanned Aerial System Oversight Task Force.

Presentation: Bridge Inspection (Albany)

Paul Rogers, KPR Construction
Paul Rogers is a principal at North Carolina based KPR Engineering and is currently working toward a PhD in civil engineering at North Carolina State University. Paul has been providing construction, inspection, and testing services to a variety of clients, including the North Carolina DOT (NCDOT) and its Aviation Division, for more than 15 years. Paul holds more than a dozen inspection certifications from the NCDOT, the American Concrete Institute (ACI), and the International Construction Consortium (ICC). Paul is a member of several ASTM International committees, an FAA Part 107 UAS pilot, a licensed engineer, and a licensed building, marine, and highway contractor.

Presentation: Construction Inspection (St. Louis)

Basil Yap, North Carolina DOT
Basil Yap serves as program manager for the NCDOT Aviation Division’s Unmanned Aircraft Systems (UAS) Program. In this role, Basil envisions and directs efforts that position North Carolina as a global leader in UAS (or drone) safety, government integration, commercial and economic development, and knowledge creation. Among Basil’s accomplishments are working with the North Carolina legislature to establish UAS-specific laws addressing safety and privacy, establishing the NCDOT UAS Program Office, creating and managing the NC UAS knowledge test and permitting system, proposing and participating in the state’s FAA UAS Integration Pilot Program, leading NCDOT’s Hurricane Florence
UAS response, and creating and managing the state’s unmanned traffic management (UTM) system. Basil brings to his UAS work extensive experience in civil engineering, program and project management, policy development, and research design and analysis. In a previous role as an airport project manager with the Aviation Division, he worked directly with 17 airports to administer federal and state grants for airport development.

**Presentations:** Flooding (St. Louis); Construction Applications (Orlando)

**Paul Wheeler, Utah DOT**

Paul Wheeler is the Unmanned Aerial Systems program manager at the Utah DOT (UDOT). He is an instrument rated private pilot and serves on multiple national committees to help foster innovation through the use of unmanned aerial systems. Paul was named one of the top seven drone visionaries in civil infrastructure by the Commercial Unmanned Aerial Vehicle (UAV) Expo and has worked in many capacities within UDOT for the past 21 years. He has served as a technology advancement specialist, survey technology advisor, lead of the 3D visualization group, and construction land surveyor.

**Presentation:** Retaining Walls/Structural Inspections (Portland)

**Ivan Ramirez, Contra Costa Transportation Authority**

Ivan Ramirez is a professional engineer and the construction manager for the Contra Costa Transportation Authority (CCTA). He has an undergraduate degree in civil engineering from the State University of New York, Buffalo and a masters of business administration from the University of California, Davis. Ivan has worked in the construction industry for more than 27 years, spending approximately 20 years working for the California DOT (Caltrans) and the last seven for CCTA. During his tenure at Caltrans, Ivan worked his way up through the ranks to serve in various positions on major construction projects. Some of the most notable projects included the Caldecott 4th Bore Improvement Project, Devil’s Slide Bypass Project, San Francisco-Oakland Bay Bridge West Approach Seismic Retrofit, and New Carquinez Suspension Bridge. Ivan is responsible for overseeing CCTA’s $1.5 billion construction program, which includes the state highway system, the Bay Area transit system, and local government agencies. CCTA manages the advertisement, award, and administration process for all of its projects.

**Presentation:** Construction Quantities (Portland)
Robin Murphy, Texas A&M

Robin Murphy is the Raytheon Professor of Computer Science and Engineering at Texas A&M University and director of the Humanitarian Robotics and Artificial Intelligence Laboratory, a founding director of the Center for Robot-Assisted Search and Rescue, and an Institute of Electrical and Electronics Engineers (IEEE) fellow. Robin received her BME in mechanical engineering and an MS and PhD in computer science from the Georgia Institute of Technology. She helped found the fields of disaster robotics and human-robot interaction, concentrating on developing human-centered artificial intelligence (AI) for ground, air, and marine robots. Her work is captured in more than 150 scientific publications including the award-winning Disaster Robotics and a Technology, Entertainment, and Design (TED) talk. Robin has deployed robots to more than 27 disasters in five countries including the 9/11 World Trade Center, Hurricane Katrina, Fukushima, the Syrian boat refugee crisis, Hurricane Harvey, and the Kilauea volcano eruption. She has co-created an online professional course, Small Unmanned Aerial Systems for Emergency Management, reflecting the practical lessons from these disasters. Robin’s contributions to disaster robotics have been recognized with the Association for Computing Machinery (ACM) Eugene L. Lawler Award for Humanitarian Contributions, the Association for Unmanned Vehicle Systems International (AUVSI) Foundation’s Al Aube Award, and the Motohiro Kiso Award for Rescue Engineering Education.

Presentation: Earth Movement (Orlando)
FHWA General Presentation

Confined Space Inspection: Jennifer Wells, Minnesota DOT

High Mast Lighting Inspection: Glenn Stott, New Jersey DOT

Bridge Inspection: Tom Collins, Collins Engineers, Inc.

Construction Inspection: Paul Rogers, KPR Construction

Flooding: Basil Yap, North Carolina DOT

Retaining Walls/Structural Inspections: Paul Wheeler, Utah DOT

Construction Quantities: Ivan Ramirez, Contra Costa Transportation Authority

Routine Construction Applications: Basil Yap, North Carolina DOT

Earth Movement: Robin Murphy, Texas A&M
Unmanned Aerial Systems (UAS)

**What are they?**
- “Drones”
- Multi-use aircraft controlled from a licensed operator on the ground
- Coupled with sensors such as high definition cameras and LiDAR

**What are they used for?**
- Enhanced data acquisition for:
  - Structural Inspection
  - Construction Inspection
  - Emergency Response

**Benefits**
- Improved Safety
- Increased Efficiency
- Increased Quality
- Reduced Costs

"An average cost savings of 40% over traditional inspection methods"
- Minnesota DOT

“Workforce was 45% more productive and the project was completed ahead of schedule”
- Utah DOT

“Reduced lane closures and increased safety for both workers and the traveling public”
- New Jersey DOT

**Mission Statement**
To facilitate the National Deployment of Unmanned Aerial Systems (UAS) to increase safety and efficiency, while saving time and money for the taxpayers.

**Structural Inspection**
- Bridge Inspection
- High Mast Lighting
- Confined Space Inspection
- Retaining Walls
- Tunnels

**Construction Inspection**
- Surveying
- Routine Inspection
- Construction Quantities
- Pre-Construction/Project Scoping
- Work Zone Traffic Monitoring
Emergency Response

- Flooding Events
- Wind Events
- Earth Movement (landslides, mudslides, volcanoes)
- Fire Events
- Earthquakes

Core Implementation Team

<table>
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<tr>
<th>Name</th>
<th>Organization/Role</th>
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<tr>
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<td>Beth Yip</td>
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Opportunities and Obstacles

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<th>Obstacles/Threats</th>
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<td>UAS FAA Pilot Program</td>
<td>Lack of organizational structure at the state level</td>
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<td>Public perception</td>
<td>Resistance to change</td>
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<td>STIC and AID funding</td>
<td>No control over others using drones</td>
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<td>FAA regulations</td>
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How to achieve our mission?

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<th>Proposed Efforts</th>
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<td>Bridge Inspection Data Management Project</td>
<td>Regional Workshops</td>
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</table>
Confined Space Inspection:

Jennifer Wells, Minnesota DOT
Unmanned Aircraft Systems (UAS) – Confined Space Inspection

Jennifer L. Wells, P.E. | MnDOT Bridge Office

Overview

- Previous Research
  - Phase I – April to June 2015
  - Phase II – October 2015 to June 2016
  - Phase III – July 2016 – June 2018
- UAS Capabilities
  - Object Sensing
  - 360 Degree Camera
  - Non-GPS Operation
  - Photo, Video, and Thermal Imaging
  - CONFINED SPACE!

Items to Address

- Lack of Quality Inspections
  - Bridge element location – enclosed box girder designs, hollow abutments, steep slopes, piers in traffic
  - Deteriorated conditions not being assessed because NO ONE IS ACCESSING THEM!
- Access
  - Traditional methods – under-bridge inspection vehicles, ladders, lifts, rope access (LIMITED by lane closure availability…)
  - MnDOT Bridge Inspection Access Requirements
- Cost
  - Inspection by Traditional Access
- Maintenance Needs – National Highway System Bridge Age

Solution – Project GOALS

1. Metro District Bridge Inspection Program Implementation – based on the MnDOT Bridge Inspection Access Requirements and all previous research completed since 2015
2. UAS Specific Bridge List Development – report generated by parameters set in SIMS based upon previous research factors
3. UAS DOT User/Control Manual – as required by MnDOT Aeronautics (if UAS is in open airspace at all)
4. Identification of Sustainable Future Funding – Federal, State, Local, etc.

ULTIMATELY – District prototype to serve as model for all other agencies governed by the MnDOT Bridge Office Inspection Unit

Benefits

- Improve Quality of Bridge Inspection Data – ACCESS
- Improve Data Quality
  - Point clouds
  - Maps & Orthophanes
  - 3D Models/CAD
  - Virtual Reality
  - Web Sharing & Mobile Devices
- Improve Bridge Inspection Safety – Minimal Work Zones
- Reduce Traffic Impacts
- Reduce Costs:
  - Time
  - Staffing – two drone personnel, minimal to no work zone staff
  - Equipment

3D Model
3D Photo Log

Pier Modeling

Defect Detail

Infrared

Confined Space Inspections

Confined Space Inspections – Smith Avenue High Bridge
Confined Space Inspections – St. Croix Crossing

Flyability Elios Drone Video Link

https://www.youtube.com/watch?v=LdIoaOXEz64&feature=youtu.be

Conclusions

• Be connected with FAA and your state Aeronautics Office.
• Know your intended purpose for the drone – “off-the-shelf” UAS has limited inspection capabilities
• Using UAS for access is important but documentation and communication of results is more compelling
• UAS can supplement inspections as a tool
• Does not need to replace entire inspection
• Collaborate with other owners to share knowledge and promote future advancement

Now What?

• FHWA EDC-5 Team
• STIC Grant
  • Aeronautics
  • Districts
  • Others (i.e. BISC)
• Software/Data
  • Pix4D (6k-8k)Hs
• Licenses
• Field Supplies

Questions?

UAS Bridge Contact:
Jennifer L. Wells, P.E.
MnDOT Bridge Office
UAS Pilot Certificate #4122351
(651) 366-4578
jennifer.wells@state.mn.us
High Mast Lighting Inspection:

Glenn Stott, New Jersey DOT
How does NJDOT select UAS Projects?

The Bureau of Aeronautics leads the department’s UAS initiatives. Projects must have the potential to meet one or more of the following criteria to be considered for Aeronautics support:

- Increased Safety
- Increased Efficiency
- Save Time
- Save Money

241 out of 250 HMLP (High Mast Light Pole) inspections were completed with UAS.

The nine HMLP sites that could not be completed had the following issues:

- Five due to airspace issues
- Two due to dense vegetation
- One was too close to the roadway
- One had poor communication with the UAS (strong RFI)
### Additional Benefits

The UAS approach offers additional benefits that could not be quantified, such as:

- **Higher Quality Photographs** for analysis and documentation
- **Fewer Safety Risks**, lower **Vehicle Emissions**, and less **Time** – no driving to secondary inspections
- Eliminate safety and traffic impacts of a **Shoulder Closure** - no secondary inspections
- **Reduced Injury Exposure** to workers (both in work zones and in bucket trucks)

### Increased Safety:

- Reduced injury exposure to workers in work zones.
- Reduced injury exposure to personnel working high above the ground next to a busy roadway.
- Eliminates the risk of secondary crashes due to lane/shoulder closures.

### Increased Efficiency:

- Lower vehicle emissions.
- Reduced congestion due to a reduction in the amount of lane closures.
- Higher quality data and a detailed photo record of each defect that can be examined and discussed with a Supervisor back at the office.

### Saves Time:

- UAS crews do not require additional driving time to secondary inspections.
- A UAS crew can conduct inspections much faster than an inspection crew using a bucket truck.
- UAS enables the NJDOT to leverage the productivity of each structural inspector.

### Saves Money:

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Bucket Truck Approach (For all initial inspections)</th>
<th>Traditional Approach (Truck Approach for Secondary Inspection Only)</th>
<th>UAS Approach (Secondary Inspection Only)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (Labor-hours)*</td>
<td>3.312</td>
<td>1.264 – 1.552</td>
<td>1.476</td>
</tr>
<tr>
<td>Cost*</td>
<td>$477,022</td>
<td>$167,800 – $177,667</td>
<td>$180,025</td>
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<tr>
<td>Safety (cost)</td>
<td>$2,162 per pole requiring a lane closure (6)</td>
<td>$2,162 per pole requiring a lane closure (maximum 6)</td>
<td>$0</td>
</tr>
<tr>
<td>Efficiency (cost)</td>
<td>$1,736 per pole requiring a lane closure (6)</td>
<td>$1,736 per pole requiring a lane closure (maximum 6)</td>
<td>$0</td>
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<tr>
<td>Total Cost</td>
<td>$500,410</td>
<td>$190,868 – $201,055</td>
<td>$180,025</td>
</tr>
</tbody>
</table>

*Note: Assumes 10% of high mast light poles require a secondary inspection using the traditional approach. The range of values in the traditional approach accounts for the possible locations and access requirements of the poles requiring the secondary inspection.

Questions?
Bridge Inspection:

Tom Collins, Collins Engineers, Inc.
The Effectiveness of Unmanned Aerial Systems for Bridge Inspections

Presented by:
Thomas J. Collins, PE
Jennifer Wells, PE
Barritt Lovelace, PE

Inspection Access

Access Methods
- Aerial Work Platforms (AWP's)
- Rope Access and Structure Climbing
- Ladders

U.S. National Bridge Inspection Standards and MnDOT Requirements
- Hands On Inspection
- Non Hands on Inspection
- Measurements/Testing

Project Background

Assessment of UAS Technology

- Phase II and III Technology
  - Inspection-specific UAS
  - Object Sensing
  - Wide Range of Motion
  - Fly without GPS, under bridge decks
  - Photo, Video and Thermal Imaging
  - Confined Space

Assessment of UAS Technology

- Aeropoints
  - Provides precision ground control
  - Adds ability to geolocate assets and inspection results

Confined Space Inspections

Flyability Elios Drone
Video Link
Volume Calculations

Conclusions

- Know your intended purpose for the drone – “off-the-shelf” UAS has limited inspection capabilities
- Consult with aviation agencies to keep in line with laws and regulations
- Use UAS to improve safety
- Develop standard training and operational manuals
- Develop and track performance measures / metrics
- Expand use in other areas such as scoping and emergency response
- Develop standards for use with governing bridge organizations

Questions/Contact Information

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Construction Inspection:

Paul Rogers, KPR Construction
2018 EDC-5
St. Louis Summit

UAV Construction Inspection

Paul Rogers, PE

Tools of the Trade

Why UAV’s?

- INCREASE INSPECTION EFFICIENCY
- INCREASE INSPECTION EFFECTIVENESS
- LOWER THE COST OF INSPECTION

Which UAV is right for me?

Key Feature Recommendations

- SENSOR SIZE
- OBSTACLE AVOIDANCE
- WIDE ANGLE LENS
- ADJUSTABLE FOCAL LENGTH
- BATTERY TIME
- TOP MOUNTED CAMERA
- THERMAL CAMERA

UAV Size

- Tuss 5: Spirit of Butt’s Farm
- Crossed the Atlantic in 38 hours
- Built by a Maynard Hill

UAV Cost

- Consumer Level
  - DJI Spark
  - $350
UAV Cost
Commercial/Military
Lockheed Martin

UAV Operations
• Generally a two man team
  • Spotters (Visual Observer) – doubles as radio communications
  • UAV Pilot
• Airband radio
• Vehicle Lights/Strobes/Flagging
• UFR Map – Electronic and Paper
• Copy of current TFR’s and NOTAM’s

Construction Inspection
• Erosion Control
• Structure Inspection
• QA/QC
• Construction Progress

Stormwater/Erosion Control on Highway Projects
The Use of Small UAV’s can increase productivity and increase inspection quality.
• Access difficult locations by air
• Quickly scan long distances of silt fence
• Highly effective record keeping
• Easily communicate issues and inspect resolutions
• Final inspection of difficult to observe features
**Construction Inspection**

- Erosion Control
- Structure Inspection
- QA/QC
- Construction Progress

**Structure Inspection**

Key Feature Requirements

- Sensor Size
- Obstacle Avoidance
- Wide Angle Lens
- Adjustable Focal Length
- Battery Time
- Top Mounted Camera
- Thermal Camera
Bridges

- Concrete Segregation
- Shear Stud Placement
- Bolted Connections
- Puddle Welds
- Bracing
- Scour

Towers

- Evaluation of members and connections for design or repair
- Observation of construction and maintenance activities
- Access difficult to reach places with much less equipment and time

Construction Inspection

- Erosion Control
- Structure Inspection
- QA/QC
- Construction Progress

Maintenance & Construction QA/QC

Key Feature Recommendations

- Sensor Size
- Obstacle Avoidance
- Wide Angle Lens
- Adjustable Focal Length
- Battery Time
- Top Mounted Camera
- Thermal Camera
**QA/QC**
- Save time inspecting large areas.
- Verify testing and observations are representative of the project.
- Augment routine inspection tasks.
- Get a real-time aerial perspective that provides context to a current situation.

**Surface Treatment**
- Application consistency
- Coverage & overlap
- Aggregate placement
- Monitor and log activities over a long site
- Traffic control

UAV’s provide a unique perspective on materials, processes, progress, and end product.

**Surface Treatment Inspection**

**Thermal Imaging**
- Thermal Segregation in HMA
- Application temperature in surface treatments
- Application consistency in surface treatments
- Application consistency in pavement markings

Thermal cameras are available on a variety of reasonably affordable UAV Platforms.
Pavement Markings

- Significant part of construction and maintenance projects, often overlooked
- Can be difficult to check alignment for conformity to the plans
- Oblique and top-down photos allow for the best perspective
- Easily captured using an inexpensive UAV

Inspection Training

- Demonstrate processes with a unique perspective.
- Highlight common issues and how to identify them.
- Keep the attention of inspectors and contractors.

Construction Inspection

- Erosion Control
- Structure Inspection
- Maintenance QA/QC
- Construction Progress
**Construction Progress**

**Key Feature Recommendations**

- **Sensor Size**
- **Obstacle Avoidance**
- **Wide Angle Lens**
- **Adjustable Focal Length**
- **Battery Time**
- **Top Mounted Camera**
- **Thermal Camera**

**Progress Verification**
- Verify progress for pay applications and project milestones.
- Create an accurate representation for tracking and calculating Liquidated Damages.
- Video is often better in a legal setting. It is harder to manipulate and gives multiple perspectives of the same subject.

Aerial photos do not replace field verification procedures but can help provide context and perspective.

**Orthomosaics**

- High resolution images taken in an overlapping and usually automated with a variety of built-in or third-party applications.
- Images are stitched together using the automated collection application or can be stitched using cloud and desktop software.
- Completed files are in native picture formats or geo-referenced formats for GIS applications.

**Material Verification**

- Photographic log of delivered materials.
- Quickly count steel members, traffic control devices, and other invoice quantities.
- Verify square footage and linear footage pay items.

**Moving Forward....**

- Get trained and Part 107 Certified.
- Acquire a UAV.
- Start experimenting in your everyday inspection tasks.
- Educate and train your colleagues.
Flooding:

Basil Yap, North Carolina DOT
UAS for Flooding – Hurricane Florence

Basil Yap, UAS Program Manager
NCDOT Division of Aviation
October 2018

NCDOT UAS Role in Hurricane Florence Response

Post Hurricane Drone Video

NCDOT’s UAS Program Office clearly demonstrated its value in its first test in a disaster situation:
• Communicate conditions to the public to get people off the road.
• Monitor evacuation routes and traffic.
• Gather and push real-time information on infrastructure and road conditions.
• Post-storm damage assessment to plan for repairs.
• Coordinate with both state agencies and private sector UAS teams for efficient and safe operations

NCDOT UAS Command Center

State Agency Partners
• NC Dept. of Transportation
• NC Dept. of Public Safety
• NC State Highway Patrol
• NC Public Safety Drone Academy

On-Call Consultants
• Dronescape
• North State Engineering
• PrecisionHawk
• SM&E

Flights & Platform Information

• 15 UAS Teams
• Over 260+ flights
• Over 8000+ images & videos
• Live streaming of data
• >515 Gigabytes of Video and Photographs taken

Platforms used
• DJI
• senseFly eBee
Getting our Pilots ready

We asked our pilots to –
• Download the Airmap app on their phones.
• Create a DJI account.
• Get the drones updated and all batteries charged.
• Be prepared for overnight operations.
• Send:
  – Personal and emergency contact information
  – FAA license number
  – NC UAS permit number
  – Flight controller Serial Number.

Public Information Campaign

• 179,000 people in NC reached via Facebook
• 5,700 comments, shares and reactions
• 0 reported incidents of civilian drones interfering with response/recovery operations

NCDOT Pre-hurricane Assessment Flights

Mobilized Drone Teams & Traffic Management System

UAS Mission Workflow/Process

Live Streaming Video for Traffic Management
GIS Map of UAS Missions

Supported Agencies:
- NC Dept. of Transportation
- Highway Divisions
- Traffic and Mobility
- Rail Division
- Ferry Division
- NC Dept. of Public Safety
- Emergency Mgmt
- NC State Highway Patrol
- NC Dept. of Environ Quality
- Dam Safety
- NC National Guard
- US Coast Guard
- FEMA

UAS Mission Reporting

US 421 into Wilmington on 9/21/18

US 70 & US 258 in Kinston on 9-21-18
Boiling Springs Dam Breech

Roles/Capabilities of Manned/Unmanned

Manned Aircraft
- Can fly in poor weather than our current drone fleet
- Covers larger areas of the state quicker
- Transports drone crews to areas where roadways are cut off

Unmanned Aircraft
- Cost-effective way to deploy to multiple locations
- Crews can typically drive to location
- Can fly in hard-to-reach areas, (i.e. under bridges)
- Live streaming capabilities

Key Takeaways
- Key roles UAS played in this response:
  - Rapid assessment of traffic and infrastructure
  - Public communication and acceptance
  - Streaming video feeds

Looking ahead:
- Sharing data across all emergency responders
- Regular exercises to practice and refine our emergency processes and responses
- More weatherproof UAS for response during adverse weather
- Expanding capability through FAA Integration Pilot Program participation
Contacts

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NCDOT Division of Aviation  
UAS@ncdot.gov | 919-814-0550  
www.ncdot.gov/aviation/uas
Retaining Walls/Structural Inspections:

Paul Wheeler, Utah DOT
Unmanned Aerial Systems

Paul Wheeler

LEGEND:
- Trained Part 107 UAS Pilot
- Prospective UAS Pilots
- Current UAS Users

Structures

Structure Inspection
- Delamination (Thermal)
- Mapping
- Inspection

Wall Monitoring

Cross Section

Monitoring

UAS Program Users

2018 - 9 Remote Pilots
Hydro Demo

Hybrid Method
Use the Strengths of Your Tools

- Get the Most Benefits
- Reduce the Weaknesses
- Increase Productivity and Safety
- Combine Data from the Best Sources

- UAS
- LiDAR
- GPS Rover
- Total Station

Image Overlap

Characteristics

1. Trees
2. Rocks
3. Cornfields
4. Mountains

General

- Simple Objects Require a Single Measurement
- Complex Objects Require Multiple Measurements

Ground Sampling Distance

What do I really need?

Overlap Settings

Recommendations

Front

- 70% Front Minimum
- Dense Vegetation 80%
- 3D Models (e.g., Towers, Buildings) 90%

Side

- 60% Minimum
- Dense Vegetation 70%
- 3D Models (e.g., Towers, Buildings) 60% at different height levels

Quality Control/Quality Assurance

Random Verification Points

- Required on all Pre-Construction Surveys
- Softscape Surfaces
- Hardscape Surfaces
- Randomized
Quality Control/Quality Assurance

Statistical Report

- Understand Accuracy of Surface
- Required on all Pre-Construction Surveys
  - Software Surfaces
  - Hardstand Surfaces
- Provides Confidence in Surface

Machine Learning

Automation

- Pavement Condition
- Automated Crack Detection
- Obstacle Clearance

Building with UAS

What is Possible?

QUESTIONS?

Paul Wheeler
Lead Unmanned Aerial Systems Coordinator
Email: pwheeler@utah.gov
Phone: 801-965-4700
Construction Quantities:

Ivan Ramirez, Contra Costa Transportation Authority
Use of UAS in Highway Construction
EDC – 5 Portland, OR

WHAT WE DO
PEDESTRIAN
Make improvements to sidewalks, crosswalks, trails, and paths
LOCAL STREETS
Smooth traffic flow on major roads and invest in improvements such as repaving potholes and road surfaces
BUSSES
Invest in a reliable, comfortable and convenient bus network
SAFE ROUTES TO SCHOOLS
Focus on programs and projects aimed at bicycle and pedestrian safety for K-12 students
FERRIES
Expand the Bay Area ferry system by looking to ferries as an alternate commute method between West County and San Francisco
BICYCLE
Invest in safe routes and infrastructure improvements for bicyclists
BART
Improve BART service and stations, extend routes and increase parking at stations
HIGHWAYS
Complete Contra Costa’s highway system, and improve air quality and noise protection along these corridors
CARPOOLS/RIDESHARE
Implement programs to reduce traffic congestion by providing carpool and ridesharing incentives
PROGRAMS FOR SENIORS AND PEOPLE WITH DISABILITIES
Enhance transit options to improve mobility for seniors and people with disabilities

SR4/Balfour Rd Interchange Project Description
• The Balfour Road and Highway 4 intersection is currently signalized.
• This causes traffic backups during peak commute times.

Project Improvements
• The project will replace the at-grade intersection with a new interchange at this location.
• Roadway Excavation 130,000 CY
• Import Borrow 158,000 CY

Volumetric Calculations
SR4/Balfour Rd Project
• The Balfour Road and Highway 4 intersection is currently signalized.
• This causes traffic backups during peak commute times.

Contra Costa County, California

SR4/Balfour Rd Interchange Project Description
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Volumetric Calculations
SR4/Balfour Rd Project
• The Balfour Road and Highway 4 intersection is currently signalized.
• This causes traffic backups during peak commute times.
Aerial Lidar

- Lidar is a surveying method that measures distance to a target by illuminating the target with pulsed laser light and measuring the reflected pulses with a sensor.
- Lidar uses active sensors that supply their own illumination source. The energy source hits objects and the reflected energy is detected and measured by sensors. Distance to the object is determined by recording the time between transmitted and backscattered pulses and by using the speed of light to calculate the distance traveled.

Digital Surface Model (DSM) and Digital Terrain Model (DTM)

The difference between the Base DTM (LiDAR) and the monthly photogrammetry DTM represents the change in volume month to month.

Unmanned Aircraft System (UAS)

- UAS Flight Crew
  - UAS Pilot
  - Visual Observer/Sensor Operator
- FAA Certification and requirements
  - Part 107 License
  - Insurance
  - May require additional FAA clearances or waivers (case specific)

UAS Airframe Examples

Point Cloud Image

Project DTM
**Raw Data Collection**

- Photogrammetry Data
  - Point cloud
  - DTM

- 142 Gigabytes
- 36,254 images
- 1 cm pixel resolution

**Graphic Summary of Calculations**

- The processed DTM for the current month is subtracted from the DTM for the prior month. This difference between the months is the amount of Cut (-) and Fill (+) that occurred for the site.
- DTMs are tied to multiple known control points located throughout the project site.

**Challenges**

- Data management and data processing workflow challenges for the large amount of data collected.
- Client and construction contractor ability to manage large volumes of data and data formats.
- Client and construction contractor lack of familiarity with data formats and required applications.
- How to best account for discrepancies

**Summary of Cut/Fill to Date**

- Summary Cut/Fill Data
- Nearly 200,000 cubic yards of imported material to date
- Good agreement between invoices and UAS data
- Final reconciliation at construction complete
Conclusions

- Calculating volume changes on construction projects is complex.
- Large volumes of data can be collected and analyzed to make accurate estimates.
- Managing, processing, and accessing data requires significant storage space and computing power.
- UAS platforms can provide a cost effective solution for estimating earthwork volumes for quantity take-off purposes (QTO) especially for relatively large projects.

Other Uses - Communication

Other Uses - Damage Assessment

WHO WE ARE

- CCTA is a public agency formed by voters in 1988 to manage the county’s transportation sales tax program and to lead transportation planning efforts.
- CCTA is responsible for maintaining and improving the county’s transportation system by delivering critical transportation infrastructure projects to safely and efficiently, get people where they need to go.
- CCTA is the managing entity of AC Testing Site GoMentum Station.

Thank you

Thank you
Discrepancies Cut/Fill Data

- Potential Discrepancies introduced due to:
  - Compaction
  - Soil swell
  - Export of waste materials
  - Scraper and dump equipment not filled to capacity
  - Sewer and drainage system installation
  - Placement of concrete/asphalt
  - UAS data uncertainty
  - Errors introduced in data processing
  - Generation and disposal of project site waste material
Routine Construction Applications:

Basil Yap, North Carolina DOT
UAS for Highway Construction
Basil Yap, UAS Program Manager
NCDOT Division of Aviation
November 2018

UAS Program Office Role
- Regulatory: Permitting commercial N.C. UAS operators
- Education: Safety, opportunity
- Research: Technology benefiting state
- Flight Services: NCDOT, other state agencies, local governments
- Government Agency Integration: UAS program development and support

NCDOT Internal UAS Missions
- Airports
- Bridges
- Construction Projects
- Environmental Analysis
- Geotech Assessment
- Rail Corridors
- Storm Assessment
- Traffic Monitoring

NCDOT Fleet
- Division of Aviation (11)
- Communications (2) capture video and photographs of NCDOT events and projects throughout the state.
- Photogrammetry (1) focused on developing photogrammetry standards for UAS.
- Roadside Environmental (1) photograph jobsite erosion control measures and document the wildflower program.
- Geotechnical Unit (1) respond to landslides in the western part of the state.
- Environmental Analysis Unit (2) apply herbicide to invasive species on the coast.
- Safety & Risk Management (1) safety assessment of construction sites.
- Division 1 (2) storm assessment, project monitoring
- Division 5 (1) project inspection documentation

UAS Program Office Fleet
- DJI Inspire 2
- DJI Phantom 4
- DJI Matrice 200
- Yuneec Q500
- DJI Matrice 210
- Sensefly eBee Plus
- Yuneec H520

UAS for Highway Construction
- Pre-Construction
  - Traffic Counts & Visualization
- During Construction
  - Project Documentation & Project/Traffic Safety Monitoring
- Post Construction
  - Maintenance & Disaster Response
Pre-Construction

- Project Scoping
  - Traffic counts, driver behavior monitoring
- Public Meetings
  - Visualizations of future intersections/roadways

Intersection Visualization

During Construction

- Project Documentation
  - Weekly, monthly, photos/videos
- Erosion Control Monitoring
  - Post rain event photo/videos
- Traffic/Project Safety Monitoring
  - Traffic control monitoring, OSHA/worksite safety

Project Documentation

Project Documentation/Traffic Monitoring
Project Documentation

Erosion Control Monitoring

Construction Safety Assessment

Post Construction
- Structure Inspection
- Traffic monitoring
- Herbicide application
- Natural disaster response
  - Hurricane/storms
  - Landslides

Structural Inspection
Intersection Visualization

Herbicide Application
Utilizing UAS for Treatment of Australis phragmites at Bodie Island Lighthouse
- Part 137 Operation
- Needed COA
- State Agriculture Permit

Environmental Applications

Storm Damage Assessments

Post Hurricane Drone Video

Landslide Inspection
Landslide Inspection

NCDOT UAS Resource Page

Publicly available online:
- List of NC General Statutes
- Best Practices
- UAS Research Reports
- UAS Related Links
- FAA Resources
- Law Enforcement Resources
- Emergency Management Resources
- Airport Operator Resources
  - [https://connect.ncdot.gov/resources/Pages/AviationDivision/Resources.aspx](https://connect.ncdot.gov/resources/Pages/AviationDivision/Resources.aspx)

Contacts

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Earth Movement:

Robin Murphy, Texas A&M
Small Unmanned Aerial Systems for Detecting Earth Movement

Dr. Robin R. Murphy
Professor, Computer Science & Engineering
Center for Robot-Assisted Search & Rescue
Texas A&M

Special thanks to FHWA Every Day Counts as well as students, faculty, industry volunteers, and sponsors such as NSF, ONR, DARPA, ARL, DOE, SAVC

You Probably Have Questions...

• What do we mean by small UAS?
• How can small UAS be used to detect earth movement?
• Are there any case studies: landslides, levees, bridge embankments, etc.?
• What are the hidden costs or surprises?

Texas A&M: Leader in Engineering

• 3rd in Engineering Research (MIT, Georgia Tech)
• 144km from Houston
• 68,825 students
  – 20,000 graduate students
  – 16,000 Undergraduates in Engineering
  – 500 faculty in engineering

TAMU: Leader in Disaster Practice

Disaster City, College Station, TX

CRASAR: 14 UAS Responses

2014 Oso Mudslide
WHAT DO WE MEAN BY SMALL UAS?

But FAA “Small” Includes UAS That Can Go above 400’

Small: $1K-$30K, Fit in Backpack or Back of SUV, use under 400’ with Part 107

Fixed-Wing or Rotorcraft?

HOW CAN SMALL UAS BE USED TO DETECT EARTH MOVEMENT?
How: Data Products

Video and stills
Orthomosaics and DEM with 4cm per pixel accuracy

Exploit GIS Tools

Can Control Area and Privacy Concerns

How: When to Fly?

• Prevention/preparedness
  • Fly periodically
  • Fly immediately before the event, or a suspected event
    • Before flooding
    • After seismic anomaly (Collbran, CO, landside)

• Response (tactical and strategic)
  • May be flying for overwatch and safety
  • If size permits, fly recon of entire situation
  • Fly vulnerable spots or statistical sampling
  • Fly periodically (hourly, even every 15 minutes, day and night)
  • Fly mapping missions as needed, will have more time later
  • Inform public as appropriate
  • Document violations for later

• Recovery and Recovery
  • Detailed mapping
  • Monitor reconstruction
  • Post progress to public

How: When to Fly?
Case study: 2014 Oso Mudslides

- Flew where manned helicopters and people on foot could not
- During/immediately for safety, to cut channels in river
  - DEM to 3D map helped with visualization
- 6 months later video to public

Case study: Fort Bend County TX (Houston) flooding 2015-Harvey

- Flew vulnerable areas and new developments before rains and flooding
- During/immediately embedded with experts
  - Assess vulnerable spots such as bridge easements, levees
  - Verify flood inundation maps, GIS predictions

Case study: 2018 Kilauea Volcanic Eruption

- Flew frequently - day and night - to tactically monitor in real-time the progress and activity
- Was able to stream in real-time
- Less frequently, strategically map boundary, volumetrics
- Had to contend with smoke

WHAT ARE THE HIDDEN COSTS OR SURPRISES?

Other Possible Surprises

- Can fly and coordinate with manned aircraft
- But may not be able to fly due to weather or capture useful data due to smoke

You Need to Team With Domain Experts
Levee Inspection Requires Expertise

Need to know if this is seepage precursor to a breach

Too late to do much now…

Processing the Data: There is LOTS and Lots of Computation

Example:
Photogrammetrics
~800 images
• One ortho is ~150MB
• 8-24 hours of upload, cloud processing, download

May Not Be Easy to Get Right Info to Right Person…

Recap
• Small UAS are cost effective: You can do everything except night flying with a $1K DJI Mavic Pro
• Use them before, during, and after
• Remember to embed earth movement experts with UAS teams
• Expect other (manageable) hidden costs of data management

We’d Love to Collaborate and Learn With You!

• See my TED Talk, ACM Webinar and CRASAR webinars
• We offer classes in UAS for emergency professionals
• Datasets of UAV imagery at
  – HRAIL.CRASAR.ORG Hurricane Harvey
  – CDRP.CRASAR.ORG Hurricane Irma

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