5 UNIQUE USES of Drones and Lidar by Government Organizations
Airborne lidar has been traditionally used by governmental organizations to perform large-scale land surveying efforts, collecting data for applications from forestry and agriculture to environmental restoration. While fixed-wing airplanes are the most common platforms for collecting lidar data over broad areas, the development of improved drone technologies and smaller on-board lidar sensors have contributed a broadening of UAS-based surveying applications. These smaller systems are more versatile because they can be deployed rapidly and are becoming a more economical solution for small-to-mid-sized areas that need to be scanned. In addition, the growing power of computer processing, 3D imaging technologies, and the emergence of new mobile surveying tools have made it easier to both collect and work with the data that is collected.

US government agencies are taking on projects that incorporate some of this new technology, often using lidar and UAS together for mapping and data collection. From road project planning and environmental research to uncovering ancient archeological sites, lidar and drones are providing a plethora of new data to government agencies. The five projects in this report demonstrate the potential of utilizing new sensors and platforms in real-world projects managed by government organizations.
Uncovering Lost Details in Canyon of the Ancients National Monument

When officials of Canyons of the Ancients National Monument Crow Canyon Archeological Center wanted to map the area to ensure they’d uncovered all of the formerly inhabited spots in the historically preserved site in previous surveys, officials from the Bureau of Land Management chose a lidar-equipped drone for the task.

The project was performed to accurately survey the Canyons of the Ancients National Monument to create a high-resolution terrain model of the Sand Canyon Pueblo site. In order to better monitor the future condition of the site, Crow Canyon Archaeological Center officials wanted a new way to visualize the site. Collection of baseline data was needed, in order for land managers to plan ongoing preservation.

Performed in October and November 2018, the survey was done by Routescene Inc. (a part of the Mapix Technologies group of companies), which designed and developed the Routescene UAV lidar solution. The full system’s hardware, software and workflow were used to produce the final data. Caddis Aerial, a professional drone survey service company in Colorado, helped with the drone flights.

The team used a DJI M600 Pro drone, as well as Routescene’s QA Monitor software, to monitor the real-time in-flight quality of the data being collected as the survey was being performed, and Routescene’s LidarViewer Pro, for data processing.

“The software provides a framework on which to build a lidar processing workflow, using the Filter Development Toolkit to develop and apply specific filters to the collected point cloud, to achieve as quickly as possible the most accurate final deliverable,” says Emma Thomas, director of Mapix Technologies Ltd.

“The lidar image provides the best tool for visualizing this ancient site in detail to better monitor the future condition of the site. Lidar has provided baseline data for the Canyons of the Ancients land managers to plan ongoing preservation.”
“In this case, more than 3.2 billion points were collected, and it was important that the high resolution of the data was maintained during analysis to create a digital terrain model. The filters used in an automated sequence were sector reduction, laser ID reduction, coordinate conversion, grid creation, the purpose-built ‘Bare Earth tool,’ a skim grid, and a LAS export filter. This process virtually removes all the vegetation from the site, to expose in detail the structures that the archaeologists were interested in. The resolution of the final output was an impressive 400 points/m².”

Three flights were performed to cover the entire site, and each flight took 10 minutes. A total of 24 flight lines were flown, in order to ensure the data that was as high resolution and as accurate as possible. More than 3.2 billion points were collected.

At the end of the survey day, the team was able to provide Crow Canyon Archaeological Center with an initial bare earth terrain map from the site. Further work by Routescene to provide a full analysis and a Quality Control report was done the week after the survey. Next, the archaeologists at Crow Canyon Archaeological Center spent several weeks comparing the new lidar data with their other historical documents.

Success was achieved, beyond expectations. Various 700-year-old ancestral structures, previously unknown at the Colorado site, were identified in the survey.

“We were excited by the final results presented,” says Mark D. Varien, Executive Vice President of the Research Institute at Crow Canyon Archaeological Center. “The lidar image provides the best tool for visualizing this ancient site in detail to better monitor the future condition of the site. Lidar has provided baseline data for the Canyons of the Ancients land managers to plan ongoing preservation.”

“The impact of this survey approach is truly astonishing. It illustrated how the tool could be used to record undocumented sites with unprecedented precision. It removed the need for a painstaking ground survey and the speed of delivery of such detailed results is impressive. It has accelerated our understanding – the results indicate the pueblo was more extensive than we had previously imagined. We are now able to concentrate our future work in a small finite area – to study the new-found kivas in more detail.”
CCTA Balfour Road Interchange Mapping Provides Authority With New Survey Process

Using drones and lidar for mapping of construction sites is a strong area of growth. Using drones can help construction teams to better plan and manage their assets, as well as to document their progress. On a large California highway project, officials used drones to map an area requiring tons of earth moving; improving the speed and the safety of the mapping process.

From August through September 2017, in partnership with the Alta Vista Solutions engineering firm, Contra Costa Transportation Authority used drones equipped with lidar on the Balfour Road interchange, a $74 million highway project, providing a live feed of the work, as well.

“We were trying to keep surveyors [in areas] where they were safer,” explains Randy Iwasaki, executive director of CCTA. “Our goal was to minimize risk, for the owner and the contractor.”

The drone work proved to be safer for surveyors than other methods of surveying, because construction workers did not need to stand near traffic to gather the information about the site. The drone-gathered data was especially critical for this job because engineers expected to need to move a lot of earth to complete the project. Testing the new process was virgin ground for CCTA.

“The partnership was unique—using lidar tech and drones,” says Ivan Ramirez, director of construction for CCTA. “We had to import a lot of dirt to raise the level of the grade.”

With help from Alta Vista, which proposed the method, the site was surveyed with a lidar-equipped drone. The area was a mile long;
5 UNIQUE USES OF DRONES AND LIDAR BY GOVERNMENT ORGANIZATIONS

120 feet by 5,280 feet. Part of the idea behind implementing the tech was to see how well it worked, to see how well it obtained the most accurate measurements, and to see if it would streamline operations.

CCTA officials cautioned that they weren’t attempting to make any workers’ jobs obsolete, by adding drones to their toolbox.

“We’re not trying to take the surveyor’s job,” Iwasaki says. “We used the lidar-equipped drones [on the Balfour Road project] to calculate the amount of dirt brought onto the site by the contractors... The process provided [a survey map] with 100,000 points, versus one with hundreds of points. We found that with drones, it gives you a different perspective of the project... Now, we can get a drone shot that shows the project’s progress, with a birds-eye view of the project.”

While the Balfour Road test of the lidar-Equipped drones was considered by officials to be a success, implementing the newly tested tech in other CCTA projects is occurring on a case by case basis. A lidar-equipped drone was also used by CCTA on the I-680 HOV Lane project.

CCTA uses Building Information Modeling (BIM) for its construction projects, ensuring that all information is digital. Onsite managers monitor the progress of the BIM model with their iPads.

“The Balfour Road project had a lot of dirt being moved,” Iwasaki says. “Other projects have a lot of other factors and with 3D, you can immediately see if you’re building [according to the plans].”

National Estuarine Research Reserves Survey uses Drones to Gather Lidar and Multispectral Imagery Data for NOAA

Scientists from the Office for Coastal Management and their partners tested how well drones and lidar work to map marsh habitat in three estuarine research reserves. They sought to evaluate the quantitative spatial accuracy of both imagery and lidar results and evaluate how these technologies could help them in mapping habitats.
Performed in Spring and Fall of 2017, the drone surveys were a test run for NOAA.

“We’ve been trying to see how drones fit into our toolbox,” says Kirk Waters, PhD, BJCP, a physical scientist for NOAA’s Coastal Management Applied Sciences program. “We wanted to see how well the technology would do, and whether it would meet the specifications we look for.”

Using two drones with a pilot and a spotter over six days, covering two square miles of space per flight, the team surveyed three estuarine research reserves. NOAA came up with mixed results from testing the technology in various ecosystems.

“In some cases, it met our specifications, but in all cases, it could meet those requirements, but you had to limit the area you covered when using drones,” Waters says.

The project provided imagery and elevation data needed for research. And while a plane with lidar might cover a 2-square-mile area in just a half-hour, the logistics and cost of getting a plane to a site are not always ideal, especially compared to using a drone. Having a plane come to a site to survey could cost $10,000 to $15,000 and can’t be done on the fly—it can take days or weeks to set it up.

“With a drone, you can get out there quickly and do the flights faster,” Waters says. “If you are doing a smaller area, it makes sense to use drones. It’s not for a large area.”

The areas covered by the test flights were Rush Ranch in San Francisco Grand Bay National Estuarine Research Reserve, the Grand Bay National Wildlife Refuge in Mississippi, and the Jacques Cousteau NERR in New Jersey.

Getting accurate solid earth elevation is critical to understanding marsh vulnerability to sea level rise, Waters says. Lidar-drone technology can penetrate the ground with a smaller laser footprint and higher point density, which could provide a detailed data that is
Currently unattainable from surveys done by manned aircraft, NOAA wanted to see if that supposition was correct.

Following the flights, it took seven months for all of the imagery processing from the lidar-equipped drone.

“You get into this volume of [gathered] data, which is a problem if you do this big area with tiny little pictures,” Waters says.

The research team used Precision Hawk’s Lancaster 5 fixed-wing drone for the work. They used the test as a way to determine if they could use drones and lidar to make a habitat map with the data gathered. The higher resolution data is useful for that, Waters says.

While Waters’ department found the test helpful and that they could use drones and lidar for similar data-gathering in the future, the test hasn’t yet led to any major breakthroughs for NOAA. They found the drones and lidar to be good for covering smaller areas. But they aren’t changing their whole system because of it.

“We examined if that kind of data would be more helpful in the creation of these maps. It can be. You can see a lot more detail in there,” Waters says. “Most of what we were doing was looking at those accuracies... It was really more focused on is the data meeting specifications. Overall, it could meet the specifications. But it’s not the be-all end-all, it’s another tool.”

**USGS Colorado Water Science Center**

“2019 Aquatic Airshow” Demonstrates New Tech

The USGS officials and independent scientists congregated to test using sensor-mounted drones. They wanted to see how well the technology could gauge stream stage, velocity, bathymetry and discharge. They also hoped to evaluate whether the tools will enable them to get accurate and safe measurement of rivers, particularly when they are flooded or containing debris or ice. They performed the tests with a variety of equipment.

“The sensors include Doppler velocity radar and video cameras to measure surface water velocities; lidar to measure surface water elevations; ground-penetrating radar and multi- and hyperspectral cameras to measure water depths; cameras to measure water width; and global navigation satellite systems to measure the position of the UAS and sensor while in flight,” says John Fulton, USGS surface water specialist. “Conventional methods used commonly by the USGS serve as ground truth and provide a measure of how fast, accurate, and safe UAS-based measurements are compared to ground-based river measurements.”

So far, USGS has learned that the sensors can be integrated on drones, can be flown safely, and can collect data that is consistent with conventional ground-based measurements. They also found that new types of data can be collected, such as surface velocities of rivers.

The evaluation is a work in progress, as the Airshow is an annual event.

“The first Aquatic AirShow was held in March 2018 on the Arkansas River near Parkdale, Colorado. Alpha-generation sensors were tested by the USGS, NASA Ames Laboratory for Advanced Sensing, Guideline Geo, and Sommer Messtechnik. Earlier missions were conducted in October 2017 near Deckers, Colorado, and in July 2018 in Alaska. Because each mission targeted a different river size and type, the applicability of UAS-based measurements will be assessed for a range of river sizes and flow conditions. We hope to analyze and report on all of the data collects by the end of 2020,” Fulton says.

USGS scientists are evaluating the gathered data and modeling created from the testing. That evaluation should be completed by late 2020.

“The preliminary UAS-derived data suggest that for some river systems, velocity, depth, width, and discharge can be measured within 1%-30% of conventional methods,” Fulton says.
Thus far, USGS officials have found a fairly high degree of accuracy of data obtained from the new method.

“The preliminary UAS-derived data suggest that for some river systems, velocity, depth, width, and discharge can be measured within 1%–30% of conventional methods,” Fulton says.

But could such technology some day benefit the extreme sports types on America’s rivers, or other recreational boaters, in addition to kayakers?

“We anticipate UAS-based river data such as velocity, depth, width, and discharge will be available to the public, state and federal government agencies, including water resource and emergency management agencies,” Fulton says. “Therefore, the river enthusiast community will have access to the data.”

“UAS-based measurements are typically acquired from a single cross-section or location in a river. Typical flights are limited to 5–15 minutes. The data could be delivered to agencies such as the National Weather Service to assist with flood forecasting; the U.S. Army Corps of Engineers to manage navigational channels; and the U.S. Bureau of Reclamation to manage water supplies.”

These days, USGS has more uses in mind for the newly tested technology, including river applications; and survey applications, such as when UAS-based ground-penetrating radars are flown over roadways to measure water depth associated with flood search and rescue efforts and ice thickness measurements related to flooding; and also, for alpine applications.

“The USGS, Colorado Department of Transportation, Guideline Geo, and researchers from the University of Southern California and Colorado School of Mines are evaluating the use of UAS-based ground-penetrating radars to measure snow depth, density, and snow-water equivalent to assess avalanche risk,” Fulton says.

### Specialized Lidar Measures Greenhouse Gas for Atmospheric Carbon and Transport (ACT) America

In addition to focusing on space exploration, NASA performs myriad Earth-science focused studies that include the use of satellites and sub-orbital instruments to study the environment on Earth. In 2015, NASA began a series of campaigns to track and monitor the transport of atmospheric carbon throughout the atmosphere. The project, named the Atmospheric Carbon and Transport – America (ACT America), consists of airborne campaigns across the United States to study the movement of carbon dioxide and other greenhouse gases.

ACT America employs a remote sensing method, Multi-functional Fiber Laser LiDAR (MFLL) developed by L3Harris that is capable of using lasers to analyze atmospheric carbon dioxide (CO2). The measurements it collects will provide new insights into the carbon cycle and can inform climate-change mitigation efforts.
The funding for ACT America was awarded to Penn State University, and the MFLL data was used to collect data on four of the flight campaigns. After MFLL was developed, L3Harris Technologies ultimately licensed the technology to Spectral Sensor Solutions.

While CO2 sensors have been used in atmospheric science for many years, L3 Harris Technologies had developed its technology for a number of years prior to working on ACT-America. L3Harris (then ITT) approached NASA Langley Research Center with the measurement concept in 2004 and began working with them to evaluate and improve the technology in 2005.

“Since 2005, NASA has been evaluating a number of active remote sensing approaches, of which the Harris-developed technology was one of the key players. The L3Harris technologies were found to be the most mature after over a decade of technology evaluation flights that were conducted with NASA Langley over a wide range of atmospheric and geographic conditions in order to evaluate the suitability of the technology for space,” says Jeremy Dobler, PhD, VP Environmental Sensing Division, Spectral Sensor Solutions LLC.

“Active remote sensing, like the MFLL does not suffer from the same challenges that current passive sensors do and has the potential to provide data both day and night across all latitudes.”

The project consisted of five 6-week field campaigns, each of which was focused on a different region: the North Eastern Corridor, the Midwest, and the Southern Gulf area. Surveyors spent two weeks working in each location. Flights covered frontal boundaries, fair weather, and anthropogenic and biogenic sources and sinks of CO2.
In addition to helping NASA with its science goals, the project helped further refine the MFLL technology. Data collected on the mission was fed back to develop better thermal control, sampling rates and the consolidation of processing. In 2016 data from the ACT America campaign was used to evaluate and improve the data collection of NASA’s first dedicated remote sensing satellite studying atmospheric carbon dioxide from space, the Orbiting Carbon Observatory – 2 (OCO-2). The findings from the ACT-America campaigns should be able to advance the science accuracy of CO2 measurements and the prediction of sources and sinks of atmosphere carbon dioxide at regional and continental scales. Sensor Spectral Solutions continues to have collaborative discussions with NASA. It is currently supporting publications and data analysis from the ACT-America campaign.

About the Author

Jonathan Barnes is an award-winning journalist and technical writer who has contributed to ENR magazine, BuiltWorlds, Cadalyst, Bridge Design and Construction, and many other publications. In addition to ENR, he currently writes for AEC Next News, SPAR 3D, xyHt magazine and other media. He’s written for Facebook, Ondaka, Procore and others.

About the Editor

Carla Lauter is the editor of Geo Week News, the Geo Week Newsletter, SPAR3D.com and the SPAR 3D Newsletter. Before joining Geo Week and SPAR 3D, Carla spent ten years working on NASA and National Science Foundation projects focusing on Earth science communication. Most recently, she worked on web-based outreach and online interactives for NASA Earth Science satellite missions measuring sea level, salinity, and ocean color from space.
About International Lidar Mapping Forum
International Lidar Mapping Forum (ILMF) is a technical conference & exhibition focused on airborne, mobile, hand-held, and underwater lidar as well as emerging remote-sensing and data collection tools and technology used for applications including Asset Management, Civil Infrastructure, Coastal Zone Mapping, Emergency Services & Disaster Response, Land and Natural Resource Management, and Urban Modeling. For more information, visit: www.lidarmap.org

About Geo Week
Geo Week is a multi-event collaboration including participation from several geospatial organizations. In 2020 Geo Week hosts the ASPRS Annual Conference, the MAPPS Federal Programs Conference, and the 20th edition of the International Lidar Mapping Forum (ILMF). Each event features its own unique conference program and comes together for inclusive networking activities and a single vendor-neutral exhibit hall. For more information, visit: www.geo-week.com

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