Implementation and Application of Unmanned Aerial Systems (UAS) in a Diverse Public Utility Environment

Abstract

The Lower Colorado River Authority (LCRA) will discuss how they started their internal Unmanned Aerial Systems (UAS) program. This will include an outline of the original business case, gaining authorization from the Federal Aviation Administration (FAA) to operate, and choosing/training pilots.

LCRA will then discuss the different types of drones, and how these apply to a particular scope. Specific work products will be explained, along with how these were chosen as the deliverable for a particular site, such as a substation, transmission line Right-of-Way, etc. Specific examples of the use of drones for substation and transmission lines will be discussed and also future application of this technology.

The subject of housing and distributing the data will also be discussed, as well as the integration of the resulting data in a GIS system. The product derived from the UAS is photography, which can then be converted to a 3D point cloud. These files can be very large, and you must have a plan of how you will effectively manage this.

Unmanned Aerial Systems (UAS) use at LCRA

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The Lower Colorado River Authority (LCRA) initiated its initial business case for the use of Unmanned Aerial Systems (UAS) in August of 2014. The proposed users of this technology were identified from business units across LCRA including Water, Transmission, Generation, and others. The benefits that were determined during this analysis were reduced cost, faster response times, and most importantly, a safer way of capturing data within dangerous environments.

In early 2015 LCRA management approved the decision to create an internal two-person team to pursue the use of UAS, and they began working with the Federal Aviation Administration (FAA) on gaining flight authorization. They also began training to become FAA certified pilots. LCRA received its first authorization to fly in late 2015. These authorizations, known as “Certificates of Authorization” (COA), were awarded to fly over four LCRA owned tracts in central and south Texas. The following spring, LCRA was issued a “333 Exemption” from then FAA. This exemption allowed LCRA to fly UAS as a government agency across their entire service area to inspect and map their critical infrastructure. Shortly thereafter a “Blanket COA” was issued to LCRA that would allow them to fly anywhere in the United States, within Class G airspace, and under 400 feet Above Ground Level (AGL). Finally, in August of 2016, FAA Part 107 went into effect. This is the current set of rules and regulations that most commercial operations conduct their flights within today. It allows commercial UAS flights to be performed within Class G airspace, under 400 feet AGL, under the supervision of an FAA certified Remote Pilot. LCRA currently has two FAA certified Private Pilots and four FAA certified Remote Pilots on staff.

LCRA's original pilots were chosen from their internal Surveying, Mapping, and GIS department. This is still where the UAS team is positioned inside of LCRA today. Knowing there would eventually be very large data sets including imagery and point clouds that would be produced, this department was already set up to house and distribute this data.

Aircraft then needed to be chosen that would be able to handle the wide variety of requests that would be coming from departments across LCRA. There two basic types of UAS aircraft. Rotary and Fixed Wing. Rotary type aircraft usually come with a variety of sensors that can be attached for different uses. These uses include high resolution still photos, video, mapping grade cameras, and Infrared cameras to name a few. Rotary are usually much more maneuverable than the fixed wing and have the ability to hover closely around subject matter. They also offer much higher zoom capabilities. Fixed wing aircraft are much lighter and are usually operated autonomously from a pre-flight designed flight plan. This allows for a much longer flight time and the ability to cover much larger areas of concern. LCRA currently operates both rotary and fixed wing aircraft.

There are several different types of products that the LCRA UAS team deliver to their customers. The following are some of the more popular. ***360° Panoramic Compositions*** are comprised of several still photos that are taken above a subject area, and then stitched together to create spherical imagery set. You can pan and zoom in on subject matter throughout this 360° image. We are performing these at most of our substation locations. They are useful to our project managers for meetings, as well as engineers to get pre-design stage visuals of the site. Construction also utilizes these to help plan their activities. ***Mapping deliverables*** are being supplied to our surveyors. The products we usually deliver to them are ***Orthophotography and topographic data.*** An example of this would be at a new substation site. We would fly a mapping mission over the proposed site in a grid pattern with the camera in a nadir position (straight down). Upon completion, we would process the georeferenced photos to stitch them together, creating a singular orthomosaic photo. We could then extract the coordinate data from the orthomosaic photo in the form of a point cloud. This point cloud has an x, y, and z value attached to each pixel. A typical project constrained by survey control will have a pixel approximately every inch. From the point cloud we can create standard survey deliverables such as contour maps, as-built maps, or do volumetric calculations. ***Inspection photos and video*** are another product that is highly sought. These are usually images of substation or transmission line equipment. They could be taken in a standard ***red-blue-green (RGB)*** format or with ***infrared (IR).*** These are done in a much safer manner than traditional methods because it does not involve putting a worker in a bucket truck or lift. Nor does it require the use of a hot stick or any other device by a worker. The UAS can get within a close distance of the subject matter without endangering human life. Although most of the time these flights are done from a distance from the equipment of 30 feet or more because of zoom capabilities. Another added benefit to using UAS for these inspections is that they can be done while equipment is still energized – a large cost savings.

Engineering Applications of UAS

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360° Panoramic views for preliminary design inspection

With the use of Unmanned Aerial Systems (UAS) drones, it is possible to gather important information of physical substation designs without leaving the office. This has many benefits: emerging engineers and designers can explore substations safely, resources are not spent traversing the transmission coverage area as this technology could eliminate the need for a field verification, project scopes can be refined more accurately, and more detailed inspections can be performed on remote equipment. By using UAS technology along with internally developed surveying applications, designers can make a field verification of a substation with simply a click of a button.

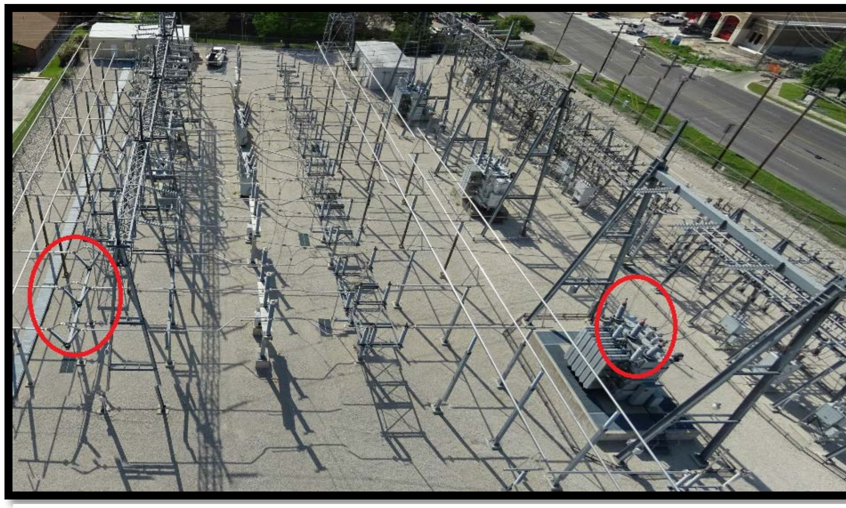

Figure 1. Panoramic View of Substation (highlighted locations indicate area of interest)

The image in Figure 1, shows a panoramic view of the substation. The red circles represent areas of interest where a user can zoom in for as-built configuration clarification as shown in Figures 2 and 3. Using the panoramic images, obtained with the use of a drone, tasks such as verifying the connector type on a switch and verifying externally mounted CT's on a transformer can be accomplished without a visit to the site.

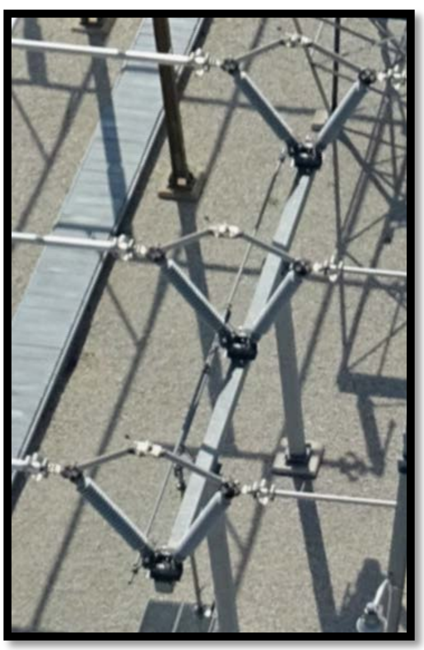

Figure 2. Center Break Switch Inspection

Figure 3. Transformer External CT Verification

Substation Video Footage

In addition to panoramic images, video footage of the existing perimeter fencing has been used to define future project scope. The footage has proven to be helpful in multiple ways including making site visits more efficient, and reducing the number of people needed at a site visit. By using drone footage, designers can identify elements that are not captured on engineering drawings and then can focus on obtaining details for these items during a site visit. Additionally, by reviewing drone footage prior to a site visit, design obstacles can be identified. For example, the image in Figure 4 shows an image of the flight path along the southwestern portion of this substation. This image shows perimeter fencing in close proximity to surrounding vegetation which required entrance modification, and perimeter interference due to adjoining distribution equipment.

Figure 4. Substation fence line video

Prior to having video footage available and due to obstacles and challenges, designers spent a significant amount of time visiting substation sites trying to make a determination on the best course of action for the placement of new substation equipment. Sometimes site visits require representatives from multiple disciplines including substation engineering, structural/civil engineering, construction/maintenance, and public safety/security personnel. Constructability reviews and coordination with all these groups could be done with footage review from the office reducing the number of personnel and man hours.

Point Cloud 3D Models

Aerial drones have the ability to capture point cloud images with use of multi-camera photogrammetric systems. The photogrammetry offers denser point clouds than LiDAR as the current LiDAR technology has the possibility of not capturing all imagery. With this data, a point cloud is created representing a three-dimensional model of the physical object(s) as shown in Figure 5. This could serve as a useful tool in capturing brown field substations and determining dimensions or clearances, without risking field personnel to exposure of live equipment using hand-held measuring devices. These 3D point clouds could also be used to develop solid models that can be used to create a complete 3D model of the substation.

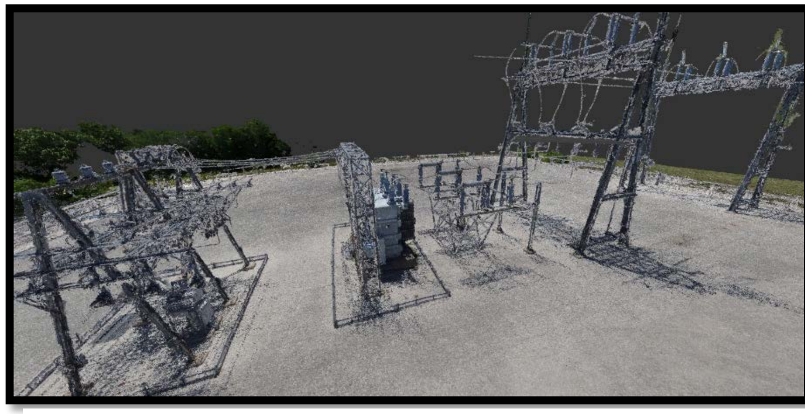

Figure 5. 3D point cloud using LIDAR

Over the past two decades, manufacturing companies have made the transition from 2D to 3D design and have seen dividends on investments in 3D design. Historical precedence of a shift in the nature of drafting was also witnessed in the early 1980's when the industry made the transition from manual drafting to 2D computer aided drafting. Currently, there is traction in the utility industry supporting three-dimensional modeling to capitalize on benefits over two-dimensional designs. All humans function on a day to day basis seeing objects in 3D, therefore it is advantageous to represent substation designs in 3D versus 2D. Increased fidelity in representation can add safety as it can help identify clearance issues that may be overlooked in traditional designs. 3D designs can also be defined as intelligent modeling due its ability to link all associated drawings to the 3D model, which are automatically updated when the master solid model is changed. Built-in metadata can also be defined in each part or assembly in a substation and with this information a parts list or bill of materials can be automatically generated. As a result of intelligent modeling, there is increased efficiency, added safety due to increased clarification/clearance identification, and drafting error elimination.

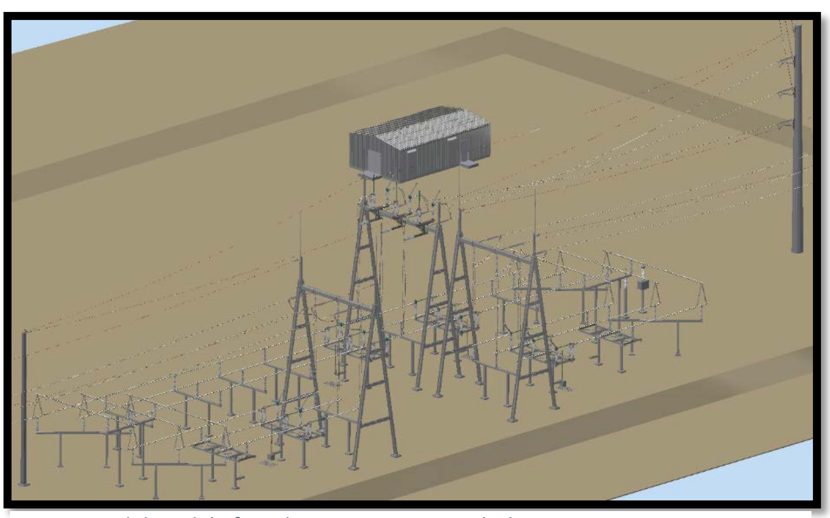

Figure 6. Solid model of a substation using Autodesk Inventor

Maintenance and Operations

Infrared – Substation connections, Transmission line connections

Another useful application for drones is the ability to mount infrared cameras as a payload to detect abnormal connections within the substation as well as connections that are more difficult to scan at heights that are not feasible on the ground. The infrared image presented below in Figure 7 shows loose connections on an autotransformer that were identified with the use of an infrared camera. From the image, a maintenance inspection identified a significant temperature difference between bushing terminals indicating a poor connection. A loose mechanical connection will have irregularly high resistance, which can ultimately progress to failure. The high resistance undergoes localized heating and this heating increases oxidation and mechanical creepage. Due to this creepage, the connection becomes less secure and then further heating occurs. At high temperatures, faulty connections have the potential of igniting nearby combustibles if they are present, resulting in catastrophic failure.

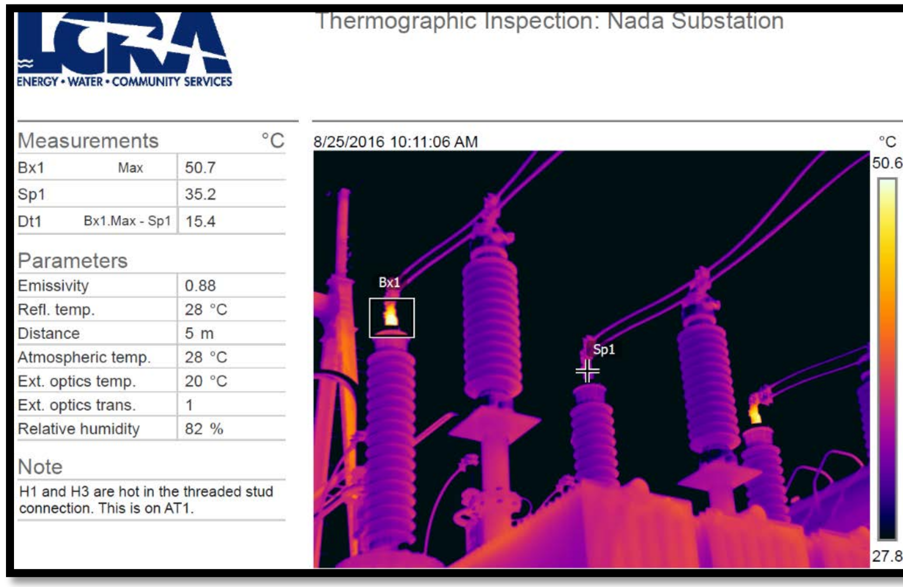

Figure 7. Infrared image of an abnormal connection at an autotransformer

With the use of a drone, a scan can be performed of the entire station from a birds eye view and issues can be identified in a more efficient manner.

Transmission Line Maintenance Road

In the project planning phase, for determining transmission line maintenance roads along the transmission line, and in adjacent areas, require inspection. Choosing the best maintenance road can significantly minimize maintenance costs. In a recently executed project, the land for a proposed maintenance road was inspected using drone footage. This analysis showed that the proposed road was going to be problematic and costly. The image obtained by drones in Figure 8 shows the land adjacent to the proposed road had large bodies of water that will problematic if flooding were to occur and could hinder maintenance crews from reaching desired destinations. In addition to large bodies of water, other challenges determined the best course of action was to choose another route.

Figure 8. Potential problematic transmission line maintenance road

Inspection of T-line damage, OPGW damage, Telecomm and Transmission Line Tower damage

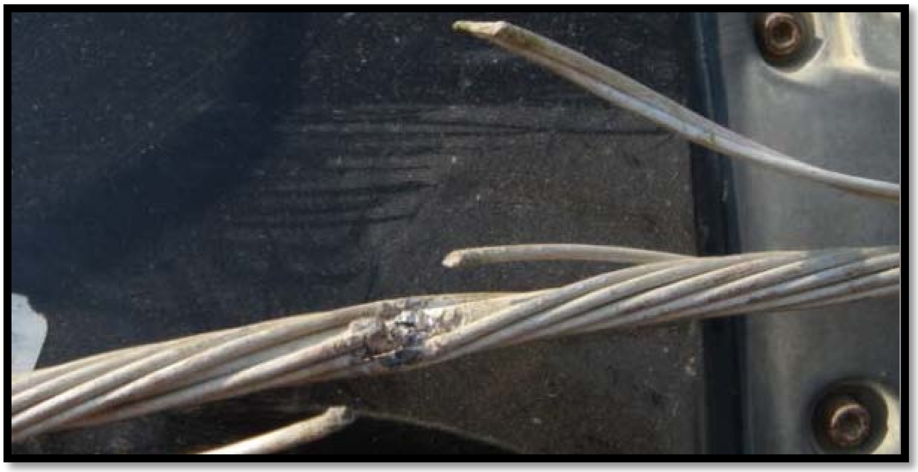

Figure 9. Lightning strike damage on transmission line shield wire.

Lightning strikes are a known threat to the system as shown in Figure 9. The damage shown is evidence of a direct lightning strike to a transmission line shield wire. This damage would be very difficult to detect at ground level using binoculars, and maintenance personnel would need to spend a significant amount of resources inspecting miles of transmission line. Inspecting at ground level could introduce inspection error oversight resulting in damaged equipment being overlooked. Aerial drones can drastically reduce the amount of inspection time and increase the failure detection rate. With multipurpose shield wire, such as Optical Ground Wire (OPGW) with integrated fiber strands, prevention of fiber strand damage can result in increased system reliability.

Figure 10. Transmission line shield wire showing evident damage in need of replacement

Mechanical damage of transmission lines or shield wires could also occur as shown in Figure 10. The shield wire shows damaged conductors that may have resulted from over tensioning, aeolian vibration causing strand fatigue, or a combination of the two. The loose strands can eventually come in contact with the live conductors resulting in a system fault.

Exposure to natural elements and phenomenon such as rain, ice, fog, flashover, and corrosion coupled with mechanical abnormality can accelerate the damage of transmission lines and shield wires. Therefore, a periodic UAS maintenance inspection can reduce or eliminate the occurrence of these type of faults caused by damaged equipment.

Equipment failure can occur in both aging and recently installed equipment. Manufacturers typically perform load tests for commissioning new large structures. During and after the load tests, drone inspection can help identify deformation or fractured elements in the structures. Although structures may have successfully been commissioned, it is possible for field failures to occur after installation. Figure 11. below illustrates a relatively new transmission line structure with a major weld fracture at the joint of a supporting arm. Weld defects can be identified by the manufacturer with methods such as non-destructive testing using magnetic particle testing. Although magnetic particle testing is a good method for detecting flaws in welding craftsmanship, it only reveals flaws towards the surface of the substrate and does not necessarily discover all manufacturing flaws. Very small internal flaws can exist and cause what is known as fast fracture. Fast fracture occurs when the stress intensity factor (which is a function of the geometry in the flaw) meets or exceeds the fracture toughness of the material. Counter measures should be performed to prevent or avoid fast fracture of large structures, as this will result in a disastrous failure that could cause serious injury or death. As an end user of equipment, periodic inspection and maintenance should be performed and would be another useful application for aerial UAS inspections.

Figure 11. Cracked joint at arm of transmission line structure

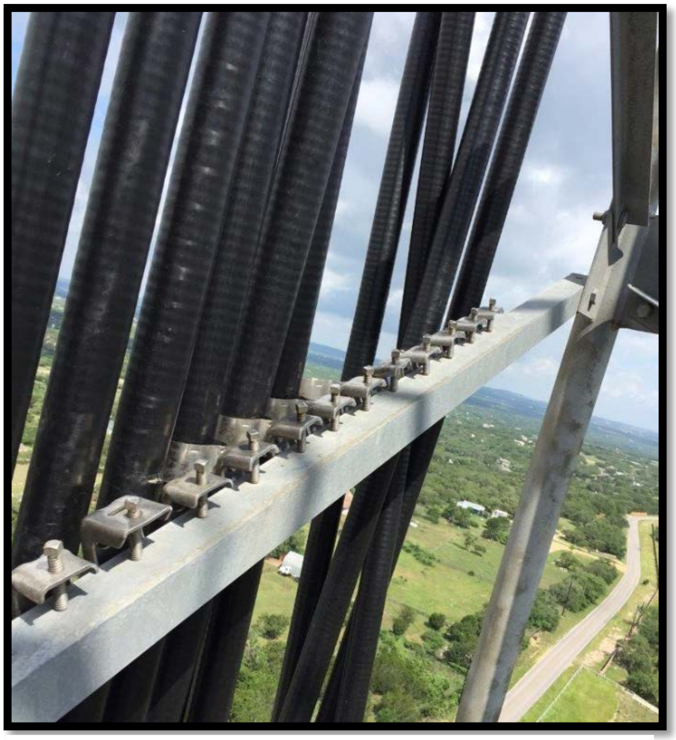

Figure 12. Microwave tower cabling damage

In Figure 12, the telecommunication cables have apparent damage that would be very difficult to identify unless an operator climbs the tower for inspection. Figure 13. shows cable damage that was caused by loose or damaged metallic cable restraints. From the image, the culprit for loose or damaged restraints is more than likely caused by the forces of high wind speed. Telecommunication towers require a large amount of time for a thorough inspection that also pose a safety risk for field personnel. Due to substatial heights that operators would need to climb creating a clear concern for safety of these individuals. With the utilization of UAS drones, inspection can be performed without the need of climbing the tower, thus decreasing or eliminating the risk of injury during inspection.

Figure 13. Microwave tower cabling damage

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