Applications for Unmanned Aerial Vehicles in Electric Utility Construction

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Abstract
This paper is based on the results of a research project involving electrical utility contractors and electric utility companies. Utility contractors are currently considering how Unmanned Aerial Vehicles (UAVs), can be leveraged for utility line inspection work. They see an opportunity to expand business by offering UAV inspection services at significantly lower costs than traditional manned helicopter inspection. Utility companies have a large amount of assets, many of which currently require significant costs to monitor via manned helicopters.

Currently, the United States (US) Federal Aviation Administration's (FAA) Special Airworthiness Certificate for small UAVs allows utilities to research, test, and train flight crews. Initial aircraft cost can be less than a few thousand USD total, including ground controllers with controls similar to a Sony PlayStation®. These UAVs can be configured with compact cameras and sensors for location, compass direction, and elevation. Additional capabilities include heavier payloads, LIDAR sensors, 15 megapixel cameras, and high definition multispectral cameras.

The landscape of quickly improving hardware and solidifying FAA regulations brings about a critical opportunity to leverage UAVs for Transmission, Distribution, and Substation (TD&S) monitoring, along with requisite qualifications, safety, and training.

Keywords
Unmanned Aerial Vehicle, Unmanned Aerial System, Federal Aviation Administration

1. Introduction

In recent years, Unmanned Aerial Vehicles (UAVs) have moved from strictly military platforms to domains including agriculture, real estate, filmmaking, law enforcement, utilities, and construction. Although the US Federal Aviation Administration (FAA) is still working to finalize rules that balance safety with commercial and recreational interests, companies around the globe have been pouring funds into this exploding sector. Companies are required to establish a training program to demonstrate safe operation and insurance is

provided via a rider to their current insurance policy (at no extra cost)[1].

By 2025, there will be an estimated 100,000 new jobs related to UAVs created, with an $82 billion impact on the national economy from 2015-2025 (Figure 1). Unmanned Aerial Vehicles (UAVs)

ɵf sk their insurance broker and carnumerous tasks, relative to traditional approaches. rier for as separate aviation policy, or ask for the ISO UAV endorsement to their general

liability policy that would cover the incidental use of drones"

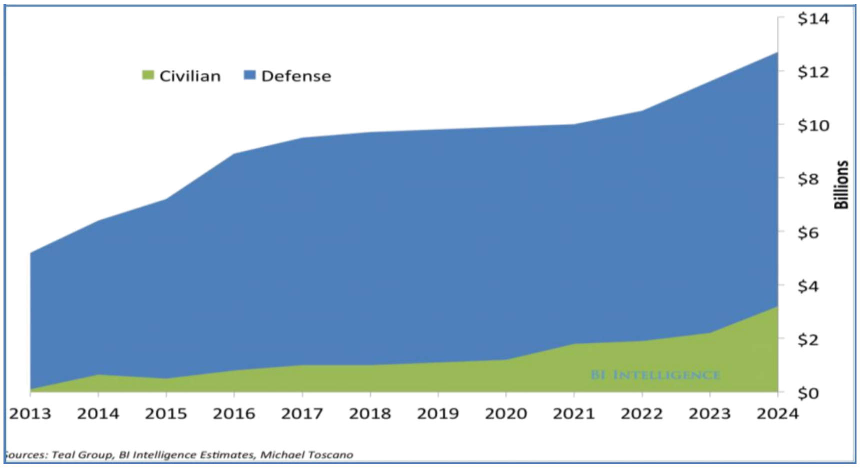

Figure 1: Global Aerial Drone Market

2. Current State of UAV Capabilities

2.1 Literature Review

A recent issue of Constructor magazine (Herbert 2015) reported that there is great potential for the use of UAVs on construction jobsites for many applications, including up-close inspections of energized lines, thermal imaging, general Maintenance and Operations (M&O), and storm damage assessment; all without the use of major equipment (bucket trucks, helicopters, etc.) and with no impact on the environment. Other opportunities include generating marketing materials and aerial views of installations to augment utility maps and records. Previously, the FAA restricted UAV use to experimental or exceptional purposes, however, in February of 2015 the agency proposed a rule to allow UAVs for "non-recreational operation" under certain conditions. The agency has also proposed a "more flexible" framework for UAVs less than 4.4 pounds, which would be the case for aerial inspection work.

An Electric Power Research Institute (EPRI) report (Phillips 2008), states that "Technology developments in sensors, robotics, unmanned vehicles, satellite and wireless data communications could be leveraged to enable the development of an effective automated inspection system for transmission line/tower monitoring applications." The report further conceptualizes the instrumentation of electric power utility towers with sensor technology designed to increase the efficiency, reliability, safety, and security of electric power transmission.

Vukojevic (2016) states that there are three pillars of implementation of small Unmanned Aerial Systems (sUAS): the safety aspect, operational excellence, and the business case aspect. As the emerging technology manager at Duke Energy, Vukojevic spearheaded a sUAS pilot project with two objectives: 1. understand the capabilities of different vertical takeoff and landing platforms, and 2. Understand the fixed-wing *Puma* platform manufactured by AeroVironment along with advanced payloads. The pilot program performed coal pile inspection, vegetation management, and assessed military-grade versus commercial-platforms.

Hickman (2015) proposes many commercial uses for drones within several market areas, including construction, energy, insurance, real estate, research, and retail delivery. Specific applications include monitoring and documenting project progress; inspection of pipelines, utility lines, and other infrastructure; inspection of operational assets; surveying and assessing site risks; assessment with site surveys; collection of climactic data; and delivery of purchases within a specified radius.

An international perspective (Transpower New Zealand Ltd. 2015), categorizes Remotely Powered Aircraft Systems (RPASs) into two classes, line-of-sight operations and beyond line-of-site operations. Potential applications include visual inspection, corona detection, thermal inspection, under-build inspection, and vegetation management.

Soar Environmental Consulting, Inc. near Fresno, CA offers environmental inspections utilizing UAVs (Witcher 2015). The company's CEO states that California hydroelectric assets must be inspected twice a year, and that UAVs provide a safer and more efficient alternative to a manned hike via a nearly vertical ascent.

2.2 Analysis of Current, Popular UAV Suppliers and Models

An abbreviated list of commercial platforms costing less than $5,000 USD is presented in Table 1. The three main differentiators between the platforms are 1) range of communication, 2) flight time, and 3) load/platform capabilities. There are anticipated near-term improvements to all three of these capabilities.

Table 1: UAV Capabilities – Abbreviated Chart

Manufacturer	Model	Price (USD)	Payload	Customizable Payload?	Flight Time (minutes)	General Notes
Yuneec	Typhoon 4K	$900	4K camera	No	25	
DJI	Phantom 4	$1,400	4K Camera	No	28	Limited Sense & Avoid Technology
3D Robotics	Solo (Enterprise Edition)	$2,649	Go Pro	Multiple Cameras	20-25	US Made, Mapping Software Included
DJI	Matrice 100	$4,300	FLIR/ DSLR	Yes	40	Vision Processing, 360 degree obstacle avoidance, FLIR Options
DJI	Inspire Pro	$4000 +	360, 3 axis 4k Camera	Yes	15	Similar to Inpsire 1 but with upgraded gimbal, camera, and controls
DJI	S1000	$4000 +	DSLR Camera	Yes	15	

Communication is typically limited by line of sight. Satellite communication is possible for higher-end platforms and there have been proposals for other communication capabilities, e.g., using the cell-phone network. However, current Section 333 rules require that all UAS operate within visual line of sight of the pilot.

Flight time is limited by battery capabilities and weight. Industry has long recognized battery capacity as a limiting factor for many applications (e.g., notebook computers) but significant improvements have not been forthcoming. There have been recent successful flights of research vehicles that use fuel cells, however.

Hopefully such batteries will come to the commercial market in the next few years, potentially improving flight times by an order of magnitude.

Novel platform capabilities are constantly being implemented, from the ability to mount new types of cameras and sensors to the ability to interact with the environment, such as manipulating small objects or drawing water samples from a lake. It is likely many of the most revolutionary improvements will be in this area as research and industry finds new tasks that can be accomplished with low weight, low power sensors/actuators. One recent improvement is to use sensors for better situational awareness - to reduce the risk of collisions – the DJI Phantom 4 is the first to provide a rudimentary version of such a system.

3. Review of US UAS Legislation for Permitted Uses

Legislation is changing rapidly to meet the growing needs of the UAS market. In 2015, 45 states considered 168 bills related to drones. Twenty states–Arkansas, California, Florida, Hawaii, Illinois, Louisiana, Maine, Maryland, Michigan, Mississippi, Nevada, New Hampshire, North Carolina, North Dakota, Oregon, Tennessee, Texas, Utah, Virginia and West Virginia–passed 26 pieces of legislation.

During the first half of 2016, at least 41 states have considered legislation related to UAS[2]. Fourteen states–Alaska, Arizona, Idaho, Indiana, Kansas, Louisiana, Oklahoma, Oregon, Rhode Island, Tennessee, Utah, Vermont, Virginia and Wisconsin–have passed 26 pieces of legislation (Table 2). This is the same amount of legislation passed as all of 2015.

Table 2: 2016 UAS State Legislation

State	Bill	Summary
Alaska	HB 256	Requests the Department of Fish & Game evaluate the use of UAS for aerial survey work and report findings related to safety and cost-savings compared to manned aircraft.
Arizona	SB 1449	Prohibits certain operation of UAS, including operation in violation of FAA regulations and operation that interferes with first responders. The law prohibits operating near, or using UAS to take images of, a critical facility. It also preempts any locality from regulating UAS.
Idaho	SB 1213	Prohibits the use of UAS for hunting, molesting or locating game animals, game birds and furbearing animals.
Indiana	HB 1013	Allows the use of UAS to photograph or take video of a traffic crash site.
	HB 1246	Prohibits the use of UAS to scout game during hunting season.
Kansas	SB 319	Expands the definition of harassment in the Protection from Stalking Act to include certain uses of UAS.
	SB 249	Appropriates funds that can be used to focus on research and development efforts related to UAS by state educational institutions. The law specifies a number of focuses for the research, including the use UAS for inspection and surveillance by the department of transportation, highway patrol and state bureau of investigation. It requires that the director of UAS make recommendations regarding state laws and rules that balance privacy concerns and the need for "robust UAS economic development" in the state
Louisiana	SB 73	Adds intentionally crossing a police cordon using a drone to the crime of obstructing an officer. Allows law enforcement or fire department personnel to disable the UAS if it endangers the public or an officer's safety.
	HB 19	Prohibits using a drone to conduct surveillance of, gather evidence or collect information about, or take photo or video of a school, school premises, or correctional facilities. Establishes a penalty of a fine of up to $2,000 and up to

[2] http://www.ncsl.org/research/transportation/current-unmanned-aircraft-state-law-landscape.aspx (National Conference of State Legislatures, accessed July 19, 2016)

State	Bill	Summary
		six months in jail.
	HB 335	Authorizes the establishment of registration and licensing fees for UAS, with a limit of $100.
	HB 635	Adds the use of UAS to the crimes of voyeurism, video voyeurism and peeping tom.
	SB 141	Specifies that surveillance by an unmanned aircraft constitutes criminal trespass under certain circumstances.
Oklahoma	HB 2599	Prohibits the operation of UAS within 400 feet of a critical infrastructure facility, as defined in the law.
Oregon	HB 4066	Modifies definitions related UAS and makes it a class A misdemeanor to operate a weaponized UAS. It also creates the offense of reckless interference with an aircraft through certain uses of UAS. The law regulates the use of drones by public bodies, including requiring policies and procedures for the retention of data. It also prohibits the use of UAS near critical infrastructure, including correctional facilities.
	SB 5702	Specifies the fees for registration of public UAS.
Rhode Island	HB 7511/ SB 3099	Gives exclusive regulatory authority over UAS to the state of Rhode Island and the Rhode Island Airport Corporation, subject to federal law.
Tennessee	SB 2106	Creates the crime of using a drone to fly within 250 feet of a critical infrastructure facility for the purpose of conducting surveillance or gathering information about the facility.
	HB 2376	Clarifies that it is permissible for a person to use UAS on behalf of either a public or private institution of higher education, rather than just public institutions.
Utah	HB 126	Makes it a class B misdemeanor to operate a UAS within a certain distance of a wildfire. It becomes a class A misdemeanor if the UAS causes an aircraft fighting the wildfire to drop a payload in the wrong location or to land without dropping the payload. It is a third degree felony if the UAS crashes into a manned aircraft and a second degree if that causes the manned aircraft to crash.
Vermont	SB 155	Regulates the use of drones by law enforcement and requires law enforcement to annually report on the use of drones by the department. It also prohibits the weaponization of drones.
Virginia	HB 412	Prohibits the regulation of UAS by localities.
	HB 29 & HB 30	Appropriate funds to Virginia Tech for UAS research and development.
Wisconsin	SB 338	Prohibits using a drone to interfere with hunting, fishing or trapping.
	AB 670	Prohibits the operation of UAS over correctional facilities

4. UAV Platform Capabilities and Best Management Practices

A UAV program should consider the means of data collection, processing, and visualization, see Figure 2.

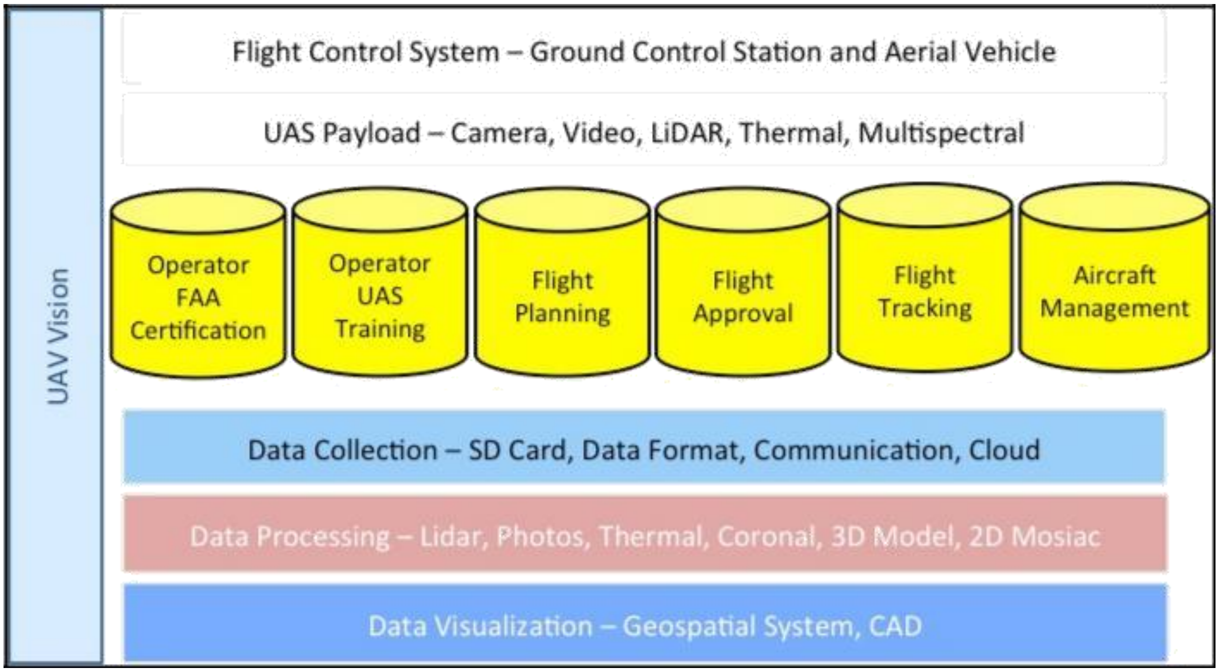

Figure 2: UAS Program Vision – Beyond the UAV and Sensors

4.1 Sample Optical Inspections

4.1.1 Pole Top Inspections

Pole Top Inspections could include an identification of pole/structure condition/deterioration, pole attachments, or assessment of hardware/equipment condition (Figure 3).

Figure 3: Pole Top Inspections

4.1.2 Distribution Line Inspections

Distribution Line Inspections could include monitoring a circuit after a fault to identify any abnormalities or defects with equipment (Figure 4).

Figure 4: Distribution Line Inspection

4.1.3 Land and Facility Inspections

Land and facility inspections could include a review of a flood area or a rooftop survey of facility assets (Figure 5).

Figure 5: Land and Facility Inspections

4.1.4 Infrared Inspections

An example of an infrared inspection could be a review of hot spots within a substation. The technology identifies the areas in the substation that could potentially need to be replaced (Figure 6).

Figure 6: Infrared Substation Inspection

4.2 Light Detection and Ranging (LIDAR) Inspections

LIDAR is a surveying technology that measures distance by illuminating a target with a laser light. An example is shown in Figure 7.

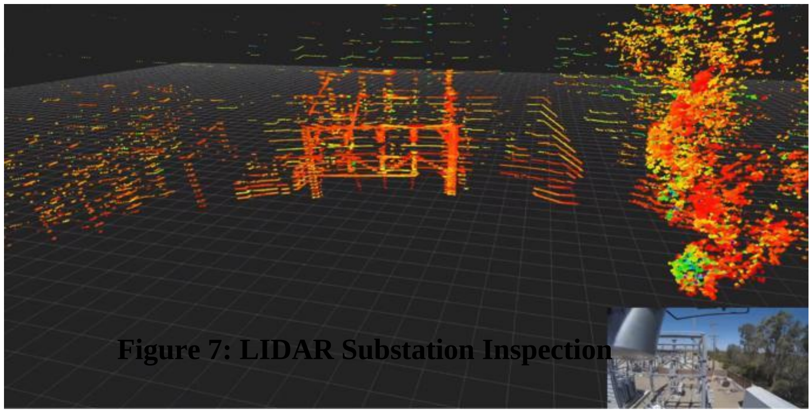

Figure 7: LIDAR Substation Inspection

4.3 Line Spooler

Line spoolers are used to launch a finger line string over a cross arm for initial installation of a new overhead line. The "Lucky Line Launcher" provides power and accuracy for placing lines up to 100' vertically, or horizontally up to 250' uses a 22 caliber shot gun cartridge to fire the line. A line spooler is attached to the UAS, which allows the Finger Line String to be reeled out as the UAS is in flight. The UAS would then land in the desired location at which the Finger Line String could be easily located and detached (Figure 8).

Figure 8: Line Spooler

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