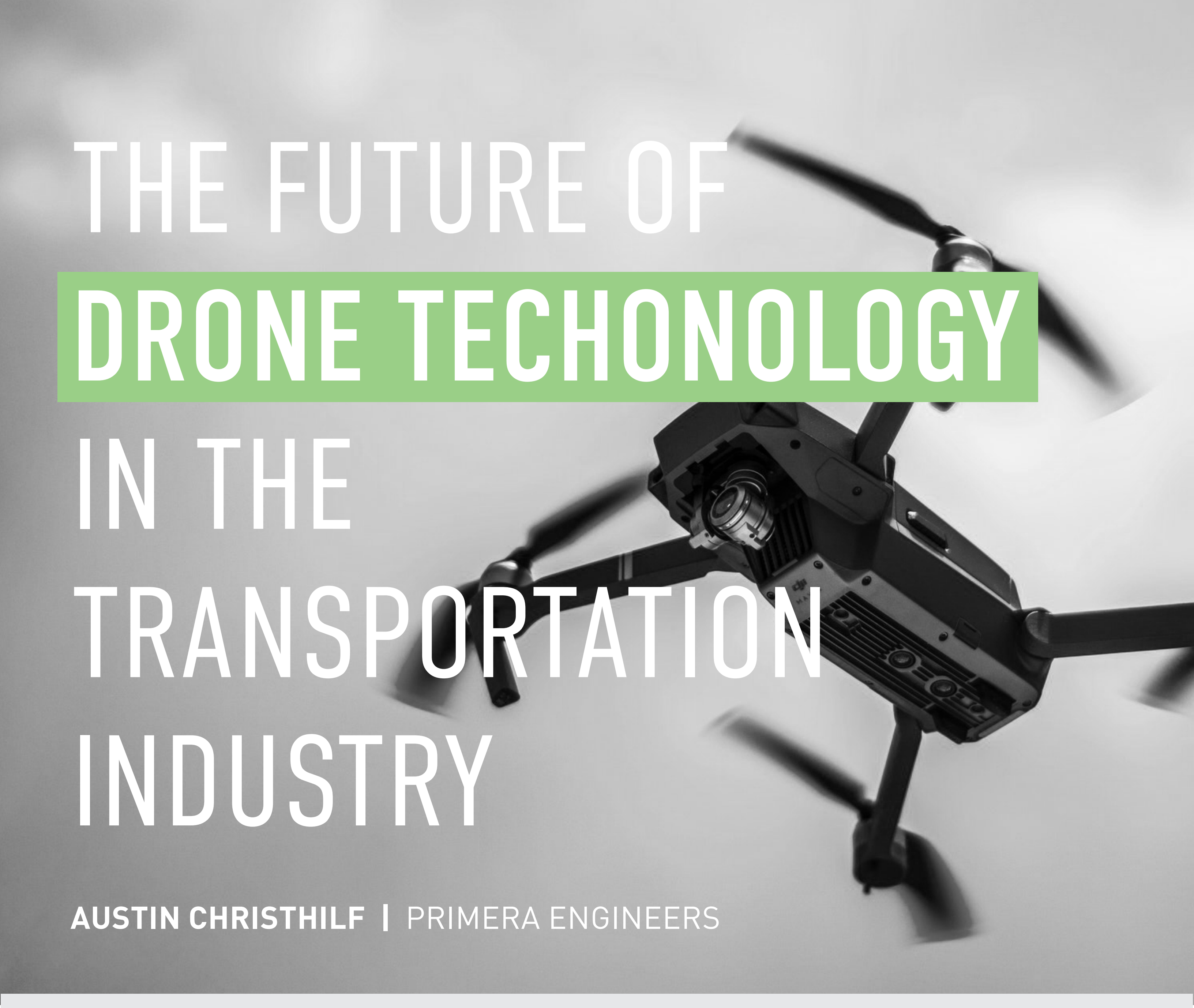

THE FUTURE OF DRONE TECHONOLOGY IN THE TRANSPORTATION INDUSTRY

AUSTIN CHRISTHILF | PRIMERA ENGINEERS

Unmanned Aerial Systems (UAS) and vehicles, or drones, have proliferated across private and public industries to augment existing services and enable new ones. It is important to note that not all Department of Transportation (DOT) UAS programs are created equal and many are still in their infancy. State DOTs need extensive time to develop a UAS case and integrate it into daily operations. An industry-wide survey found that the number of State DOTs utilizing UAS platforms has increased by 80% in 2019 and over 70% of all State DOTs have started to implement day-to-day internal drone usage[1]. As of mid-2019, State DOTs have had over 279 FAA-certified drone pilots on staff, an average of about eight pilots per state program. Here we will explore the nature of DOT UAS programs, why we should use UAS, what they look like, how to navigate the regulatory environment, and the primary considerations involved in creating a UAS program.

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WHY CONSIDER A UAS PROGRAM?

When developing new technology, the sky appears to be the limit with both benefits and use cases. Proponents argue that UAS platforms unlock new capabilities for DOTs and provide a cheaper, safer, and more effective execution of existing operations. UAS platforms have proven to be valuable in structural inspections when it comes to high mast lighting and bridges and construction applications involving surveys, project scoping, work zone traffic monitoring and routine status updates. In partnership with state DOTs, state emergency responders have utilized UAS platforms in response to fallen trees, wildfires, floods and avalanches.

To fully illustrate the potential benefits of UAS, let's examine their usage in bridge inspections. **In terms of cost savings, one study found that while direct costs for an average bridge inspection is around $4,800 for two workers and a truck, the equivalent drone inspection cost is $1,200 to collect all bridge inspection data**[2]. Moreover, a traditional bridge inspection requires high indirect costs from lane closures due to lengthy traffic delays. In addition to these quantifiable benefits, the qualitative benefits include quality and safety improvements. The use of drones can create traffic safety, fewer lane closures, and even eliminate the man-in-bucket high mast and bridge inspections. Additionally, UAS use can establish a higher-quality product (i.e. inspection quality) in the form of sophisticated asset documentation. This allows for efficient inspections because the relevant historical context can showcase clear, accountable information on how the asset has aged. Despite these benefits, new problems can arise while using UAS such as data processing and storage, ensuring inspection quality is not compromised, and public concerns around drone deployment. However, these barriers have been easily overcome by the DOTs through prudent planning and execution.

WHAT DO UAS PROGRAMS LOOK LIKE?

Successful DOT programs require a full understanding and expertise across the technology stack, from pre-flight software to post-flight data processing and management. Pre-flight planning software must be compatible with the capabilities of a given UAS because systems are anything but homogenous. UAS systems for professional

Image 1: The compact sensor suite on the head of a senseFly Albiris includes ultrasonic range sensing, thermal imaging, multiple visual camera sensors and lighting.

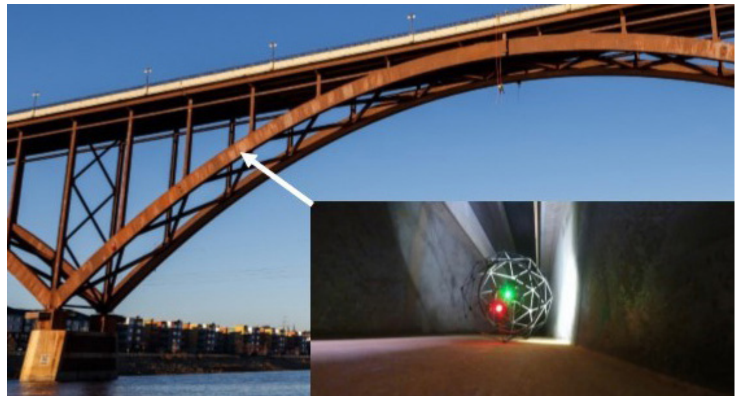

Image 2: Flyability Elios inside a box beam.

applications can cost anywhere from $1,000 to over $40,000. Despite this range, even basic UAS platforms offer a high value for those who can maximize their capabilities. These basic systems, from vendors such as DJI, provide the necessities for successful UAS usage, strong and reliable flight performance, obstacle avoidance sensor packages and high picture quality and fidelity. Such systems are more than capable of UAS DOT applications such as surveying, visual inspections, high mast inspections, construction management and traffic monitoring. Advanced use of such platforms, in conjunction with an advanced post-flight processing software, can automatically produce 3D CAD models of an asset for use and future reference.

Unlike the most basic UAS platforms, advanced platforms vary wildly in capabilities and form. Historically, sophisticated UAS platforms have separated the flight systems and the sensor suites (i.e. LiDAR, infrared, camera systems) to allow for flexible flight platforms. Unfortunately, these systems tend to end up extremely large and unwieldy, which make applications such as bridge inspections difficult with restricted access to tight spaces. Recently, however, companies such as senseFly and FlyAbility have developed all-in-one systems providing the ideal capabilities for applications, such as bridge inspections, by combining advanced sensor suites (visual and thermal imaging) into extremely small and nimble packages resistant to collision [Image 1]. The FlyAbility Elios, for example, is specifically designed for use inside confined spaces, and can conduct inspections inside steel box beams or in other locations inaccessible to humans [Image 2]. These new capabilities (such as confined footprints and thermal imaging) are much more than shiny toys; they result in real value-adds for DOTs. For example, a limited footprint can unlock new assets which you may inspect and document, and thermal imaging, such as the detection of bridge delamination, can provide new insights unable to be provided by visual inspection alone. Other technologies such as LiDAR can enable more accurate 3D modeling but can cost well over double the advanced UAS platform.

All these technological capabilities are unrealized without software and computational support from the office. Once a UAS inspection data collection has occurred onsite, a pilot must deliver tens of gigabytes of data necessary for uploading and processing. For purely visual asset management, such as quick pictures and videos, it is a painless process; however, sophisticated use cases involving

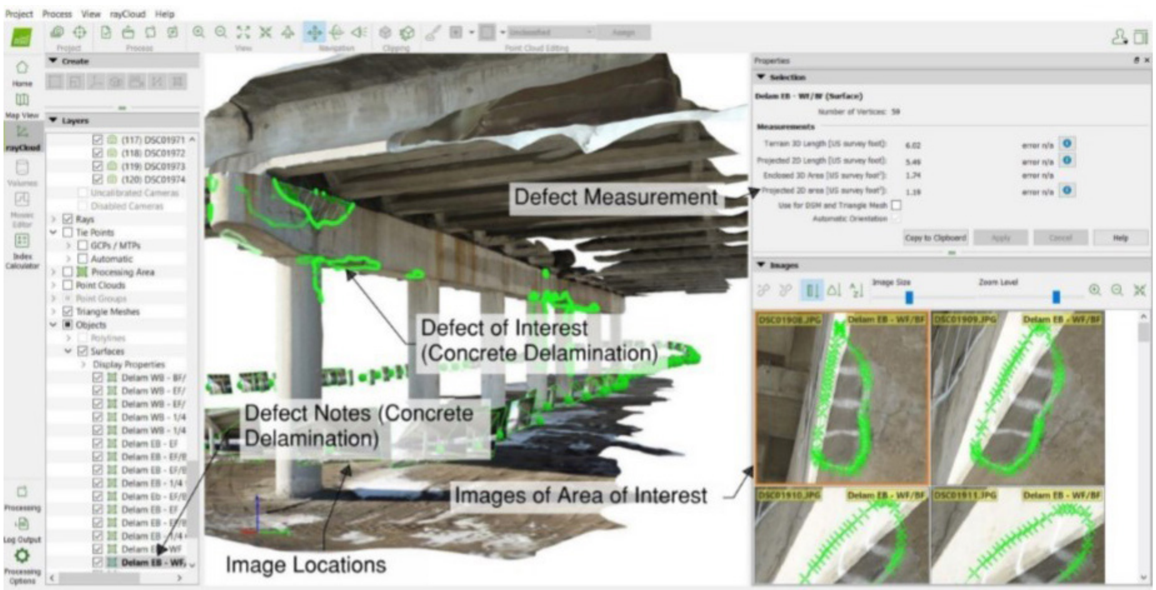

Image 3: PIX4d reality mapping software can visually show and map indicated points of interest from an inspection.

3D modeling can require extensive computational resources and time. Many DOTs have found these costs to be worth it; software such as Pix4D reality mapping utilizes imagery only to develop 3D models for bridge inspections which allow for quick visual glances expanded upon by an instant record keeping of all UAS images of any location on a bridge. In the software, areas of defect can be automatically mapped to the 3D model, as well as measured in the model to understand the scope of the issue (i.e. the surface area of a delamination) [Image 3].

The net result is that successful UAS deployment requires knowledge of the heterogenous field of UAS platforms and capabilities. Not all DOTs will find a cost-benefit case for all UAS platforms, and as a result, programs must be tailored to the needs of a DOT and its assets. This requires a clear technological expectation setting and intimate knowledge of incumbent processes to discover when and where UAS can replace or augment existing operations.

NAVIGATING THE UAS REGULATORY ENVIRONMENT

With any new technology, knowledge of all Federal regulations and best practices is necessary for safe deployment. The most basic Federal regulations involve: a FAA license for all DOT pilots, an avoidance of restricted airspace (such as around airports and helipads), height restrictions, and no flight at night, over people, or out of line of sight. These are the same rules and regulations that apply to all commercial and recreational drone operators (although recreational pilots do not require a license). In addition, the most successful DOTs will provide additional self-regulation through in-State restrictions or procedural requirements.

Successful UAS operations within existing regulations requires clear accountability and mission transparency. Successful programs require procedures with extensive pre-flight planning to be done by the operating pilot. This process will result in a clear flight path which abides by all laws and regulations, including location-specific air space restrictions. Next, a pilot must send a mission plan to a UAS program manager for approval. This provides clear accountability and operational line of sight for UAS programs, in addition to the mitigation of liability concerns and the ability to ensure all rules, laws and regulations are abided by during flight.

Of course, rules such as no flight at night, over people, or out of line of sight seem like extremely limited operational rules. However, DOTs have earned increased operation capabilities by reaching out to airspace stakeholders and beginning conversation. For example, the FAA's Integration Pilot Program saw its inaugural class full of state DOT operators looking to better integrate UAS pilots into the greater air space system by unlocking the ability to fly past line of site and at night, for participating members. In addition, discussions with other restricted airspace holders (such as airports) have enabled DOTs to conduct low flying bridge inspections while in certain, no fly height restricted zones. By engaging in conversation with stakeholders, UAS programs have the potential to enhance mission capabilities and become integrated members of the greater airspace.

CONSIDERATIONS WHEN CREATING A UAS PROGRAM

Now that there is a comprehensive understanding of the nature of UAS operations, there comes the question of programmatic development - how are others creating a sustainable and successful UAS program? It is important to ensure that UAS programs do not lose sight of their sole purpose - to augment existing operations and to enable new ones.

Program structures vary Nationwide, primarily driven by the heterogenous nature of the needs and wants of each individual state. Traditionally, programs involve an office and/or director within a DOT's Department or Office of Aeronautics/Aviation. By separating UAS program leadership from the office in which it will utilize operations, programs can work better towards programmatic improvements, and not just on day-to-day operations. Although most DOT programs serve internal operations, sustainable and future proof programs are designed with flexibility to look at other state department applications and use cases. In these cases, UAS programs can serve as consultants, mentors, and partners of peer State departments in developing their Concept of Operations, but they cannot provide direct oversight like DOT internal operations can. An independent UAS office also allows for easier cross departmental information sharing and discovery of new viable use cases as technology develops. In addition, the most advanced state programs leverage their partnerships with state universities to research potential applications and the farthest limits of current UAS capabilities.
Beyond management, force structure plays the most vital role in a successful UAS program implementation. At the most basic level, a UAS program needs to ensure that its tools are utilized in the field since integration can be difficult. Adapting a program force structure to encourage integration into existing operations is the best way to ensure lasting success. These decisions hinge both on the UAS platforms procured and the pilot force supporting them. During platform procurement, a DOT must first balance the cost of acquisition and operation of each UAS platform, as well as the specific benefit of its unlocked operations. This expands upon day-to-day operations integrating the balance between the use/unused paradox. The principle states that a DOT must procure enough UAS platforms to ensure access and availability that will encourage UAS

ABOUT THE AUTHOR

AUSTIN CHRISTHILF
ANALYST, *CONSULTING DIVISION*

Austin spent his summer learning with Primera's business consulting team. During his time at Primera, he embedded himself in various project teams to expand his knowledge with respect to capital expenditure, regulatory strategy, program development, and drone technology. As part of his experience, he did extensive research on drone technology in support of Primera's internal program. He is a recreational drone pilot and studies economics and policital science at the University of Chicago. An active member of PRISM Consulting Club, he does pro-bono consulting work for non-profit organizations across Chicago.

usage but must not acquire too many platforms that they sit unused and create program bloat and long-term unsustainability. This balancing act must be conducted on a platform-by-platform basis.

Finally, the staffing model for DOT pilots is crucial to program success. Programs need to consider the two primary staffing models: a pilot-focused model and an inspector-focused model. A pilot-focused model requires a DOT to acquire a team of dedicated pilots with no inherent technical knowledge, who can travel around the state conducting various operations. Although this can result in lean costs, there are concerns for the actual integration of day-to-day operations and the inspection quality since the pilot may not have a direct understanding of inspector needs. An inspector-focused staffing model oversees existing engineers and technical experts trained in drone operations and is staffed at their field office. These members are not full-time pilots, but instead conduct operations as the field office requests them. This model allows for a cleaner daily operation integration but can lead to possible cost bloating and less specific UAS piloting expertise.

UAS platforms have the opportunity to revolutionize the day-to-day operations of many state DOTs. DOTs developing these programs can capture benefits such as quicker, cheaper, and safer operations, in addition to revolutionary asset management data like automatically rendered 3D CAD models. However, to capture these benefits DOTs must be diligent in their planning and apply lessons learned across the country to their work. Hurdles such as developing the proper force structure and navigating the UAS regulatory environment are no easy tasks, but they are surmountable and a worthy investment for the realizable benefits. As more and more states begin to test daily operations, the lessons and principles outlined above should serve to aid in the development for revolutionary and sustainable UAS programs for their respective organizations.

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ASK THE EXPERT

FRANK ZUREK, PE
CIVIL ENGINEER/UAS PILOT, *TRANSPORTATION DIVISION*

Frank is one of Primera's resident civil engineering experts with a passion for advancements in multimodal transportation and complete streets. His expertise is the result of a decade of experience in the design and construction management of civil engineering projects. He previously worked at the Illinois Department of Transportation (IDOT) Division of Highways and the City of Chicago Department of Transportation (CDOT). He's spent his career focused on improving bicycle and pedestrian facilities across Illinois. He specializes in commercial unmanned aerial photography, is an active private pilot, and is licensed to fly drones commercially under an FAA Section 333 exemption and 14 CFR Part 107 rules.

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Connect with Frank at fzurek@primeraeng.com.