ITS RESOURCE CENTER

NJIT
New Jersey Institute of Technology

Activity 2:
ITS Technology Evaluation and Pilot Deployment

Small Unmanned Aircraft Systems (UAS) for Traffic Incident Management

Concept of Operations Report

Prepared for

State of New Jersey
Department of Transportation

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ITS Resource Center | NJIT

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Executive Summary

This document outlines the major goals, objectives and benefits of deploying Unmanned Aircraft Systems (UASs) for traffic incident monitoring. In addition to the purpose and need for UAS implementation into existing traffic incident monitoring practices, this document also describes the scope of the project, and the agencies, authorities and stakeholders that would be involved in the deployment of the system. Relevant reference documents are included to provide an adequate insight into existing Concept of Operations (CONOPS) documents and studies that identify the operational needs; the functional requirements: and the institutional rules and regulations. The operational description includes the roles and responsibilities of involved parties, potential locations, operational procedures, and organizational or personal profiles, interactions, and activities. The system overview includes: 1) description of the application through scope, goals and objectives, proposed locations and users; 2) application architecture through description of elements and users, information flow diagrams, components and interfaces. The operational and supporting environment is described through required facilities, equipment, hardware/software, personnel and changes to operational procedures.

Traffic and emergency monitoring systems are essential elements of Intelligent Transportation System (ITS) technologies that have been widely implemented throughout the country. Inadequate traffic monitoring has become a weakness in providing prompt emergency services. Flexible and adequately deployed surveillance systems can have significant roles in helping operations and maintenance priorities as well as providing the capability to respond quickly to non-recurring events and real-time conditions. Current traffic monitoring practices involve using various sensors such as inductive loop detectors and cameras located at fixed positions within the roadway system. While effective in providing traffic related information at particular location over time, these monitoring systems are immobile. In contrast, UASs of various configurations are mobile and can be highly effective traffic monitoring tools. The primary benefit of using a UAS equipped with a monitoring device as compared to a traffic camera comes from the fact that the UAS is a temporary, non-stationary structure and can be deployed for events of interest and in areas that are not visible from fixed camera poles. Advancements in the field of remote sensing using UASs can provide transportation agencies with readily available and rapidly deployable systems capable of collecting video stream, imagery and related data in wide-open spaces. The quality of video collected using a UAS equipped with a camera and a gimbal device is capable of providing similar quality that can be achieved by a typical traffic camera for traffic incident monitoring.

The scope of this document presents the background of deployment of UAS-based traffic incident monitoring and management, including the current state of the practice in the field, the purpose and need for the use of UAS and a review of current TSM practices. In addition to the referenced documents, functional requirements for the application, system overview and supporting environment, and operational scenarios are explained.

The anticipated benefits and potential impacts of UASs include:

- Deploying fixed, wired camera systems over a wide range requires massive financial and physical investment in permanent infrastructure. An aerial system based on UAS could have better coverage compared to existing stationary cameras on highways due to UAS movement along the roadway.
- Traffic monitoring through the deployment of an aerial system based on UAS is capable of operating where permanent infrastructure is not desirable due to financial, environmental, or other reasons.
- Comprehensive traffic operations are rarely recorded in rural areas because traffic monitoring systems in rural areas are typically not cost effective for sporadic incidents or construction. UAS application improves safety and enables faster data collection thus saving time and money.

1. Scope

1.1. Introduction, System Overview, and Purpose

1.1.1. Background

Unmanned aerial vehicles (UAVs) have been used for a variety of purposes, including: landscape filming, civil infrastructure inspection, commodity delivery, avalanche monitoring, and other civilian applications. Compared to manned aircraft, UASs generally have lower capital, i.e. construction, and operational, i.e. fuel, crew, and maintenance, costs than manned aircraft. UASs can fly much closer to the ground than manned aircraft. One of the greatest advantages of UAS is that they can potentially fly in physical or environmental conditions that would be too dangerous for manned aircrafts.

In recent years, small UAS (sUAS) have become increasingly popular due to advancements of cutting-edge flight control technologies including: GPS-based flight, automated flight assistance, and return home functionality. These technologies enable civilian operators to manipulate sUAS in an easy and safe manner, thereby creating additional sUAS applications. Moreover, an increasing amount of sUAV applications by agencies in the public domain have also been reported. For example, sUAV with traffic surveillance capability would offer a promising potential for tackling some of the challenges experienced by stationary traffic surveillance devices. The vertical take-off and landing (VTOL) capability reduces the time and space required for rapid deployment. In addition, with the GPS-based position-hold technology and hovering capability, sUAV would be suitable for swift and adaptable traffic surveillance uses. In this report, an innovative incident monitoring and management system utilizing a quadcopter sUAV is proposed to capture traffic conditions in instances where no stationary traffic surveillance devices are available.

1.1.2. Purpose and Need for the Use of UAS

As congestion continues to increase on many roadways, collecting timely and accurate traffic data is vital for traffic operations and management. Traditional traffic monitoring is achieved by deploying stationary traffic surveillance devices: radar sensors, video cameras, inductive loop detectors, etc., in the transportation network. In particular, traffic surveillance cameras have been widely adopted by transportation agencies for real-time traffic and incident management. By employing video analytics techniques, traffic surveillance cameras not only collect traffic data: counts, speed, and occupancy, but also provide live feeds to incident management operators. Cameras however are still incapable of capturing traffic conditions beyond their range of coverage. However, with advanced flight technology and portability of commercial off-the-shelf sUAS, the inflexibility of stationary traffic monitoring could be overcome. When equipped with streaming capability via wireless or commercial cellular networks, real-time video could be transmitted from the UAVs to remote traffic management centers via a ground station on site.

1.1.3. Relation to the TSM&O Capability Maturity Framework (CMF)

Transportation systems management and operations (TSM&O) activities focus on a variety of well-known strategies: ramp metering, road weather management, and incident management, and offer the potential to optimize the performance of existing infrastructure. The capability maturity framework (CMF) was adapted from a similar concept in IT industry called the Capability Maturity Model, and has been tailored to provide guidance to the transportation community when implementing technology-driven solutions [*1*] According to FHWA, the CMF classifies different dimensions and elements of organizations' or agency capabilities and integration in four levels, with Level 1 being the lowest and Level 4 being the highest, as shown in Figure 1.

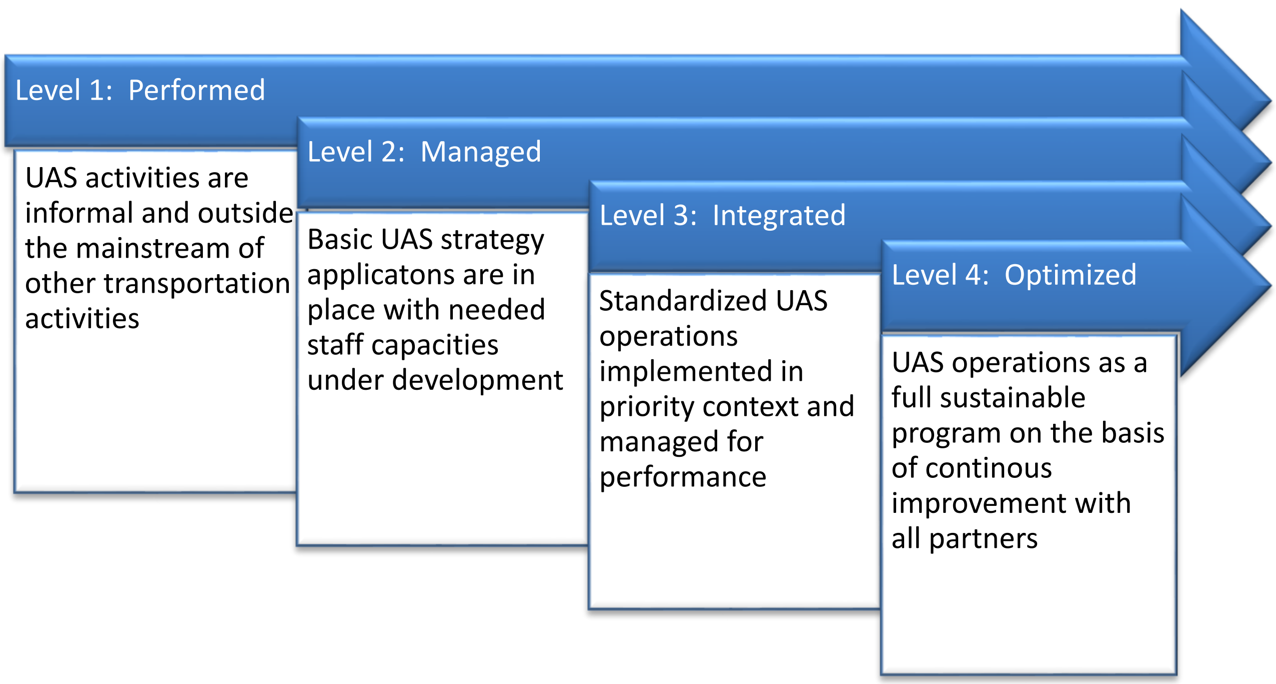

Figure 1. TSM&O CMF Improvement Level

Level 1 activities constitute of mostly ad hoc activities driven by champions within the organization and are usually informal. Level 2 Activities imply that the key processes, requirements are identified and basic implementation/application strategy is understood. Level 3 activates indicate that the key technical and business processes are developed, documented and integrated into the DOT, and there is a clear strategy how the UAS technology will be implemented and managed.

The highest level 4 activates imply fully constituted program with management in place and with the implemented continuous improvement processes.
When it comes to tasks associated with application of this approach to deployment of UAS in transportation system management and operations, they can be grouped into four stages as shown in Figure 2:

- Analysis of NJDOT Divisions;
- Identify operational requirements;
- Compare characteristics of available UASs; and
- Analysis of cost-benefit of each UAS.

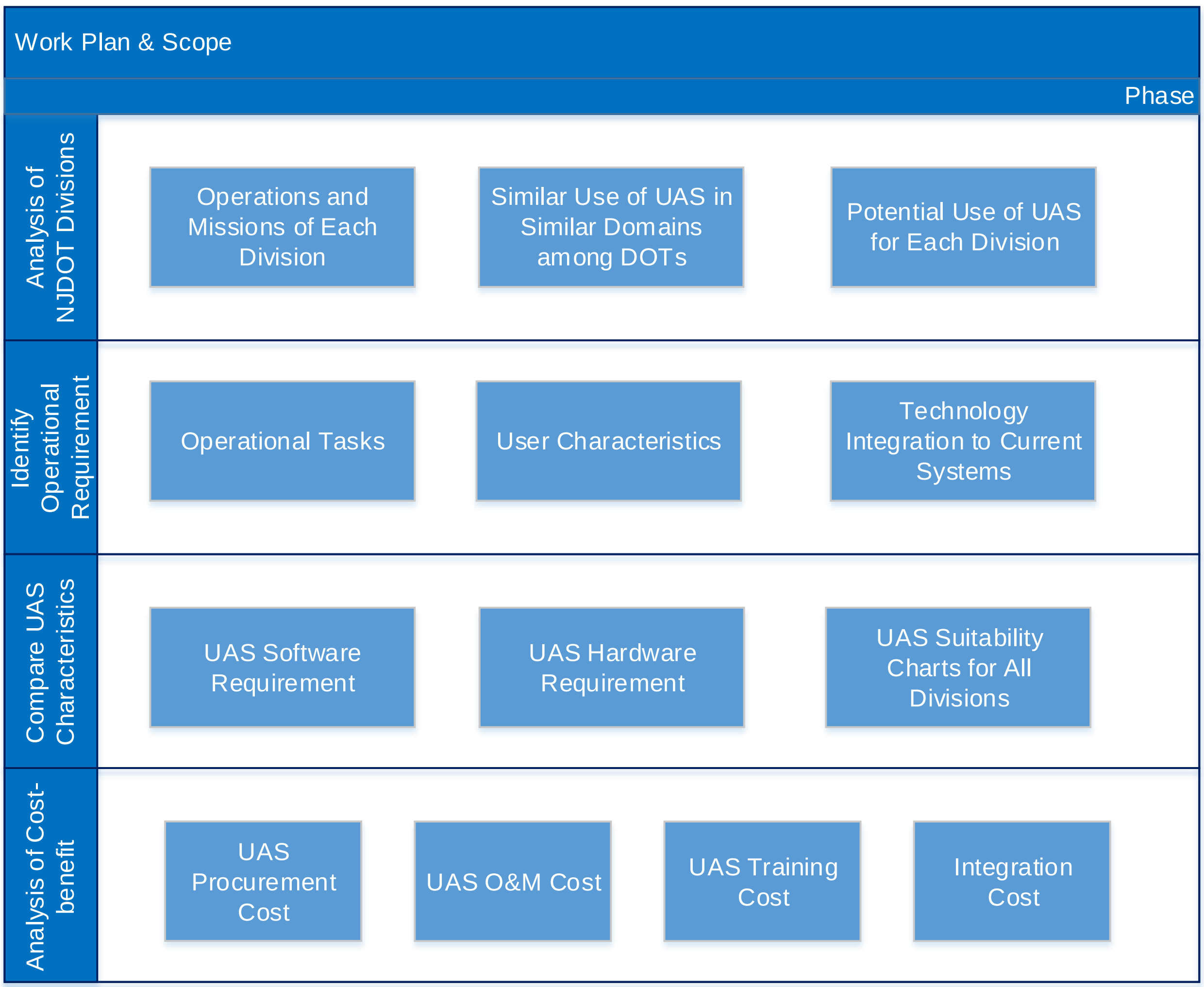

Figure 2. Integration UAS Work Plan & Scope

1.1.5. Boundaries on the Scope of CONOPS Development

To implement the concept of using UAS for traffic monitoring, it is necessary to identify the related entities that would be directly involved in the UAS operation. In Figure 3, five major entities have been identified: NJDOT through its Bureau of Aeronautics, Traffic Management Centers (TMCs), NJDOT Safety Service Patrol (SSP), fire department, and police department.

Figure 3. Boundaries of the UAS with Other Systems

1.1.6. Agencies, Authorities, and Stakeholders

New Jersey Department of Transportation-The Bureau of Aeronautics is the lead agency for Unmanned Aircraft Systems (UAS)/Drones operations at NJDOT. NJDOT, through its Bureau of Aeronautics fosters the development of an efficient air transportation system, promotes aviation safety. The Bureau has general oversight over various facilities.

Traffic Management Centers (TMCs) increase communication and coordination between agencies. Daily functions and responsibilities of a TMC Operator is to effectively manage incidents and traffic. One of the TMCs in Woodridge, NJ hosts the NJDOT, NJSP and the New Jersey Turnpike Authority (NJTA) and thus fostering effective and prompt traffic incident management.

The Incident Management Response Teams (IMRT), as partnership between the NJSP and NJDOT, respond to major incident scenes to expedite coordinated multi-agency response efforts.

NJDOT Safety Service Patrol (SSP), along with assisting disabled vehicles and drivers on our highways, SSP drivers also assist the NJSP and other responders by promoting safety and diverting traffic during incidents
The New Jersey State Police

The New Jersey State Police Incident Management Unit (IMU) serves as a member of IMRT and works with local, county, state, and federal agencies to promote statewide incident management initiatives.

The New Jersey Division of Fire Safety serves as the central focus for the State's fire service community and the general public in all matters relating to fire safety through the development and enforcement of the State Uniform Fire Code, public education programs and firefighter training programs.

1.2. Vision, Goal, and Objectives

With recent UAS regulations set forth by the CFR 107 Operation and Certification of Small Unmanned Aircraft Systems by FAA[1] , it is envisioned that the UAS-based traffic incident monitoring and management could lead to further design, development, and customization of UAS systems. The goals of this document include:

- To identify user requirements for each affected division and office within the NJDOT;
- To identify the required characteristics of a UAS for each affected division and office;
- To conduct cost-benefit analyses among different UASs in terms of design, maintenance and operational (M&O) cost, and safety; and
- To summarize the recent regulatory framework for UASs by FAA.

1 https://www.faa.gov/uas/media/Part_107_Summary.pdf

http://www.ecfr.gov/cgi-bin/text-idx?SID=e331c2fe611df1717386d29eee38b000&mc=true&node=pt14.2.107&rgn=div5 (Accessed Jan 2017)

2. Referenced Documents

2.1. Existing CONOPS for Relevant Applications

In this section, relevant research and deployment concerns with regard to UASs are discussed. Studies have been conducted to examine the advantages of using UAVs over manned aircrafts. However, limited research utilizing UAVs for traffic monitoring has been reported.

Florida DOT in 2005, initiated the use of UAV for traffic surveillance with the University of Florida by developing a proof of concept study of the Airborne Traffic Surveillance System (ATSS). During development of the concept FDOT conducted a UAV flight demonstration approved by the Federal Aviation Administration (FAA) as part of the ITS America Annual Meeting in 2001. A UAV was flown from Opa-Locka West Airport, north of Miami, on a 35-40-mile route along US-27, I-75, and the Florida Turnpike. Live video images were successfully linked to a ground station at the Opa-Locka West Airport. The area selected for a fly-by demonstration is sparsely populated.

Coifman et al. [18] proposed four potential applications for fixed-wing UAVs in transportation engineering. The first application was for measuring the level of service (LOS) and AADT of highways by using consecutive still-cut images obtained from UAVs. The authors proposed a mathematical approximation to deal with the lack of hovering capability of fixed-wing UAVs. The second application was to collect arrival and departure rates of vehicles at signalized intersections to estimate queues and delays. The third application was origin-destination (OD) estimation: to this end, the authors proposed a platoon-based OD estimation method that was only applicable for a small network. The fourth application was parking lot utilization monitoring. As discussed in the previous section of this report, fixed-wing UAVs have some inherent difficulties in traffic monitoring applications, despite post-processing algorithms that could be implemented to extract data from captured video feeds.

Ro et al. [4] conducted a study in 2007 to use a commercial UAV system, for traffic monitoring. UAV system (BAT III from MLB Company) consist of the 10 lbs aircraft that has a wing span of 6 ft, a GPS receiver which guides the autonomous flight; a radio control transmitter; a two-way data modem for data communications; a laptop as ground control; and a real-time video receiver. A field experiment was planned by the authors but no actual fight was conducted due to safety concerns and regulatory issues [*5*]. There were several issues encountered while trying to comply with the FAA regulations for aircraft. Most of these standards required compliance with the similar regulations that apply to manned aircraft.

In 2008, Washington State DOT researchers conducted a study to examine the applicability of UAS as an avalanche control tool. The MLB Bat UAS system [*6*] as well as a commercial rotary UAS, the Yamaha R-MAX, were tested. The authors concluded that the strict "see and avoid" rule required by FAA was a major obstacle and maintaining routine operation of UAVs would yet be a challenge for WSDOT [*7*].

Irizarry et al. [*8*] in 2014, conducted a study for Georgia Department of Transportation (GDOT explored the feasibility of using Unmanned Aerial Systems (UASs) in its operations. The study determined the operational requirements for each identified GDOT division/office considering its operation, user characteristics, working environment, and technology use. Based on the operational requirements UAV design characteristic are determined and ultimately cost-benefit analysis was conducted for each identified GDOT division/office to determine whether UAV application in that division/office can be financially justified or not.

Barfuss et al. [9] at Utah Water Research Laboratory developed an autonomous and multispectral remote sensing platform UAV named AggieAir. The in-house prototype of AggieAir is a fixed-wing aircraft that utilizes a bungee cord to launch. Additionally, VTOL UAVs were planned for traffic monitoring according to the report and field tests were conducted over rural wetlands in Utah. Due to safety concerns, however, the initial plan of flying over highways was suspended.

Hart et al. [10] studied the effectiveness and feasibility of using sAVs to perform roadway conditions assessments. They used a rotary UAV because of its high maneuverability, hovering capability, smaller size, and VTOL capability. Wind was found to be the most restrictive weather condition encountered. The UAVs becomes difficult to control under wind speeds of 5 to 10 mph; and the operation of the UAVs experienced significant interference when the wind speed exceeded 10 mph. In addition, the pilot needed to balance travel speed and battery usage.

The Minnesota Department of Transportation (MNDOT) has deployed a quadcopter, model: Aeyron Skyranger UAV, for bridge inspections research [11]. Four bridges in the State of Minnesota were chosen for the comparative tests. The researchers deployed the UAV to see if it could identify the issues that had been previously detected by traditional manual inspections. Results show that the drone footage was able to identify most of the issues discovered during visual inspections. The UAS could not identify the maintenance issues under the bridge decks, due to FAA regulations which do not allow UAVs to fly under bridge decks without a Certificate of Waiver or Authorization (COA). This report stated that none of the applications for COAs had been approved in time for the actual field assignments, and such delays could make using UASs for inspections cost-prohibitive as a tool.

The Michigan Department of Transportation (MIDOT), in partnership with the MichiganTech Research Institute (MTRI), demonstrated the use of various UAV technologies in helping MIDOT evaluate and manage its resources cost-effectively. Six types of rotary UAVs: Bergen hexacopter, DJI Phantom 2, Blackout Mini H Quadcopter, FPV factory Mariner Quadcopter, Walkera QR 100S, and Heli-Max 1 Si were tested [11]. The tested sites were diverse in nature as well, and included two bridges, two pump stations, two traffic sites and a roadway asset site. The distinctive deployments for MIDOT were in confined spaces including a pump station and a culvert. The experiments proved that UAS technology can help provide visual inspections from an overhead perspective for various transportation infrastructure in an inexpensive manner.

Based on the published literature, it was noticed that prior to 2008, most of the UASs used for traffic monitoring or bridge inspection were equipped with fixed-wing UAVs, that had been initially designed for military applications. The utilization of rotary UAS became popular since 2010, and has continued to gain momentum. With the advances in flight technology, both consumer grade and professional grade sUAV have been introduced to the civilian market, significantly increasing the accessibility while keeping costs down. While a full-size fixed-wing UAV is capable of ensuring a longer flight time and higher payloads, its maneuverability would be undesirable for traffic surveillance activities which primarily require VTOL and hovering capabilities. The FAA regulations are briefly discussed in the following section.

2.2. References for Operational Needs Identification

2.2.1. Charging Equipment

Most modern UASs are powered by battery. A fully-charged battery typically provides 15 to 25 minutes of flight time. It is more economical to link the charging station to the vehicle power grid instead of having multiple batteries available to replace the drained one. No more than a single spare battery is required for malfunction of a charging station. Constant power supply is vital for the sustainable operations of traffic incident management with UAS. But it is necessary to investigate and determine the optimal need for UAS batteries that would be needed per vehicle. The analysis would include the need for batteries per vehicle based on:

- How many incidents (or any events) would UAS would be assigned to per day;
- Incident severity;
- Impact of incident on traffic;
- Incident duration;
- Season (some studies show that the colder weather reduced the battery capacity); and
- Time needed to recharge the battery

2.2.2. Streaming Application Package

Since it is not the primary purpose for commercial-off-the-shelf UAS, it is often challenging to conduct seamless live video streaming depending on the quality of wireless communications. Among those that offer this capability, the video feed is typically directed to other commercial websites such as YouTube. This arrangement does not fulfill the requirements for safety and may cause difficulties when trying to integrate to the NJDOT network infrastructure. To address this issue, a customized program would need to be developed that will address the secure transmission of the video From the incident scene into the NJDOT web portal. The coordination with NJDOT IT in necessary to define security protocols to ensure the privacy laws/requirements are met.

2.2.3. Training

The classroom training will consist of modules that prepare individuals for obtaining New Jersey certification and the FAA UAV Operator Certificate, which are required to operate UAS. This training is also intended to educate potential operators on the theories behind flying, basic knowledge of general flight rules and regulations, a thorough understanding of the UAVs that will be used by the agencies, and other information that is pertinent to safe and efficient operations of UAVs. Much of the classroom training will be required to be completed prior to the initial hands-on training. The classroom instruction and self-study materials will consist of four modules which will include all of the information required to meet the New Jersey certification exam. The four modules have subsets of information in each to include:

1. Anatomy of a quadcopter:
    - A basic understanding of all of the components that make up a UAS for a better understanding of how they operate to better understand safe flight operations.
    - Knowledge of what parts of the UAV need to be inspected pre- and post-flight, how to identify any deficiencies in the operation of the UAV, and how to correct any issues, to ensure that the UAV is in a condition for safe operation prior to each flight.

2. FAA rules, regulations, laws, and policies:
    - Knowledge of the FAA rules, regulations, laws, and policies applicable to small UAV operations.

3. Navigation, weather, safety, and emergency operation:
    - How to avoid/clear obstacles during flight and what maneuvers can cause a collision hazard with a ground structure.
    - How to determine the classification of specific airspace and the requirements for operating in that airspace.
    - Knowledge of flight restrictions such as restricted/prohibited airspace or areas subject to a Temporary Flight Restriction (TFR) which pertain to small UAV operations in order to comply with the flight restrictions.
    - The effects of weather and micrometeorology (weather on a localized and small scale) on small UAV operations and what conditions are suitable for safe operation of small UAVs. This also includes knowing the official sources that can be used to provide forecasts and predictions in order to plan for the safe operation of the small UAV.

- How to calculate the weight distribution and load balancing of a small UAV to determine impacts on performance as well as available power for the operation.
- How to properly respond to an emergency during the operations of the small UAV.
- Knowledge and understanding of aeronautical decision-making/judgement and crew resource management. This includes understanding the decision-making/judgement that manned aircraft pilots engage in so they can anticipate how the manned aircraft will react to the small UAV. Knowledge and understanding of crew resource management will also be tested to ensure that the UAV operator knows how to operate properly and in a team environment when utilizing visual observers to assist the operations of the small UAV.
- Knowledge of the physiological effects of drugs and alcohol to include prescription and over the counter medicines and how that can impact the ability to safely operate a UAV.
- What factors to consider when assessing the surrounding/operating environment prior to flight and risks to consider including persons and property in the immediate vicinity.
- Emergency procedures to follow in the case a UAV becomes unsafe during flight (due to collision, malfunction, or other issues) which require that the operator discontinue the flight.

4. General aviation knowledge and academic content:
    - Knowledge and understanding of airport operations and radio communications procedures as well as standard terminology. This knowledge would pertain to operations near an airport, after prior ATC approval, so the UAV operation does not interfere with airport operations.

To operate a UAS, at least one of the crew members in a Safety Service Patrol (SSP) vehicle has to have a remote pilot certificate, which can be obtained through the passage of the initial airman knowledge test. Therefore, training would be desired for NJDOT staff to expedite the remote pilot certificate process. The list of a Knowledge Testing Centers (KTC[2]) in New Jersey, which administer initial and recurrent FAA knowledge examination is summarized in Appendix A.

2 https://www.faa.gov/training_testing/testing/media/test_centers.pdf (Accessed January 2017)

2.3. Functional Requirements for the Application

2.3.1. Airframe Configuration

Powered UAVs can be classified into two categories [10] based on the airframe configuration: 1) Fixed-wing (plane-configured) UAVs; and 2) Rotary (helicopter-configured) UAVs. Fixed-wing UAVs resemble traditional manned airplanes which are propelled forward by thrust from propellers, whereas rotary UAVs do not have wings protruding from the body of the aircraft, and they remain airborne by the downward thrust that is generated by the rotors working collaboratively. The propellant system working in conjunction with the air frame dictates the airborne procedure and its complexity. The majority of the fixed-wing UAVs require horizontal take-off and landing (HTOL). Hence, they are likely to require dedicated launching systems for deployment as well as dedicated systems for UAV recovery, which may become an issue for applications that require rapid deployment for traffic engineering applications. In comparison, rotary UAVs are not only capable of performing vertical take-offs and landings (VTOL), but they can also hover in the air to maintain a certain field of view. The VTOL capability of quadcopters ensures a minimal launching time and landing space capability. The close-to-the-ground flying path and the overhead visual perspective of the quadcopter can also help law enforcement personnel by expeditiously documenting the scene of a crash and, as a result, facilitate faster crash clearance rates.

2.3.2. Avionics

Avionics are the electronic systems used on an UAS, which typically include communications, navigation, and management systems for all components performing individual tasks. The level of modularization for avionics for UAV play a crucial role when it comes to maintenance and future upgrades. For instance, if the avionics are modular, commercial-off-the-shelf (COTS) components are readily available and can be used for replacement or enhancement. Additionally, modularized component are generally less expensive than their customized counterparts. However, one caveat of using COTS components is that an extended integration time may be needed.

2.3.3. Aerodynamics and Endurance

Endurance, or flight time, is mainly driven by the UAV categories: fixed-wing UAV and rotary UAV. Fixed-wing UAVs are able to achieve high cruising speed due to their optimized flying dynamics design. They are capable of gliding with minimal fuel consumption, provided certain speed thresholds (e.g., stalling speed) are met. Because of the fixed-wing configuration, they are also capable of carrying higher payload, compared to their rotary counterparts. Unlike fixed-wing UAVs, rotary UAVs do not have wings protruding from the body of the aircraft, and they maintain airborne status by the downward thrust that is generated by the rotors working collaboratively. The traditional rotary UAVs are single-rotor which have more moving parts than most common multi-copters. With all rotor blades fixed in pitch under the multi-rotor configuration, the thrust is adjusted by changing the speed of rotation of each rotor. The nose-down and forward movement of a quad-copter is achieved by increasing the speeds of the two rear rotors, creating a resulting thrust vector forward. Once the forward flight is established, the rotor speed has to be harmonized by the on-board flight control. Because of the flying dynamic, rotary UAVs require continuous power to stay airborne, plus extra consumption for acceleration. Consequently, rotary UAVs achieve less flight time per power unit (e.g., a full tank of gasoline, a battery) compared to fixed-wing UAVs.

2.3.4. Sensing and Avoidance

“Sense and avoid”, for UAVs, is a more suitable term for referring to the “see and avoid” principle for manned flight under visual flight rule. Some high-end CTOS UAVs have factory obstacle sensing systems that make the UAV aware of the surrounding obstacles and alter flight course; or halt to evade possible mid-air collision. Furthermore, the live view captured by the onboard camera that is streamed via Wi-Fi to the ground station, along with the other avionic readings, can significantly aids the operator.

2.3.5. Unattended Deployment and Return

Most rotary UAVs have the default setup for hovering when there is no control input entered by the operator. Another feature which become more essential is the return-home feature. For instance, the DJI Phantom 4 records the location of the start of the flight in GPS mode. Once the communication between the aircraft and the remote controller is disrupted or once the aircraft flies out of the communication range for more than twenty seconds, the aircraft will automatically execute the protocol by returning to the initial point where it took off with the help of a built-in control system with the GPS module.

2.3.6. High-Precision Operation

Due to the advancement in GPS location, most UAVs can obtain content tracking. Modern sUAV can be linked up to thirteen satellites simultaneously to have itself pinpointed in the air space. The hovering accuracy is often higher in the vertical direction than in the horizontal direction. The onboard flight control system adjusts the output to compensate for wind during normal operation. For traffic incident documentation, such high-precision operation is preferable.

2.3.7. Portability

Ease of transportation is vitally important in a traffic incident management application, since the entire UAS has to be transported in the SSP or NJSP vehicle. Furthermore, the setup of a ground station should be as compact as possible during operation due to limited vehicle storage capacity.

2.3.8. Vision-Based Data Extraction

Vision-based data extraction capability, such as video analytics, could be a very useful function for a UAS. With a vision based algorithm like pattern recognition, volume counting could be run on the drone itself. High-definition video streams tend to consume network bandwidth which may not always be available in deployment sites, especially in remote areas. Processing the data with the onboard computer could be a very attractive concept to avoid the bandwidth issue. In a typical traffic monitoring application, a UAS only needs to send basic traffic information: average speed, traffic flow rate, etc. to the TMC.

2.4. Institutional Rules and Regulations for the Application

As of June 2016, the latest FAA model aircraft regulations are only applicable to aircrafts whose payloads are no more than 55 lbs., unless the aircraft is certified by an aero-modeling community-based organization. For UAVs that are heavier than 55 lbs., a traditional COA is required prior to flight. Under FAA Section 333 exemptions, a Blanket COA can be granted by the FAA for flights below 400 feet for sUAV weighing less than 55 lbs. under the Visual Flight Rules (VFR) [*13*]. A COA is required, however, once the UAV is operated outside of the criteria of the blanket COA.

Starting in December 2015, the FAA implemented new requirements for UAS registration, which now mandates that the owner of any sUAV weighing between 0.55 lbs. and 55 lbs. register their sUAV online. For aircraft weighting more than 55 lbs., the traditional FAA aircraft registry is applied. For non-hobby flight, a COA issued by the Air Traffic Organization to a public operator for a specific unmanned aviation activity is required. As part of the FAA operational and technical review, provisions or limitations may be imposed as part of the COA approval to ensure the safety of operations with other airspace users. Some research considered current FAA rules (as of 2015) as onerous for requiring COA applications for bridge inspections and the associated delays incurred for obtaining the approvals are significant. However, the FAA is expected to amend the current regulatory framework regarding sUAV by removing many obstacles pertaining to regulatory requirements in the near future [11].

The FAA Modernization and Reform Act of 2012 [14] includes provisions to direct the FAA to develop a plan for integrating UAS into the national airspace systems. Most of the tasks from the act was scheduled to be completed by December 2015. The Code of Federal Regulation Title 14 (CFR-14): Aeronautics and Spaces stipulates relevant regulations. If the UAV is flown strictly for hobby or recreational purpose, CFR-14 Part 101 governs the regulations. The UAV must be less than 55 lbs., unless otherwise certified, to be considered as a model aircraft. Part 101 requires the UAV to be operated according to a community –based set of safety guidelines. For instance, the Academy of Model Aeronautics National Model Aircraft Safety Code specifies a flight restriction of 400 feet above ground level (AGL) within three miles of an airport (*15*). Lastly, Part 101 requires a UAV to yield the right-of-way to any manned aircraft and obtain prior permission by the air traffic control tower (ATC) when operating within five miles of an airport [16].

On August 29, 2016, the CFR Part 107 regulation, which governs non-recreational use: commercial or research, of UAVs became effective. The CFR Part 107 regulation only applies to UAVs weighing less than 55 lbs. Prior to the enactment of CDR Part 107, a flying drone used for commercial purpose had to apply for an exemption under the Section 333 provision of the FAA Modernization and Reform Act of 2012, a relatively lengthy approval processing which had render some potential applications, such as bridge underdeck inspections [*11*], practically infeasible. The key items of CFR Part 107[17] are listed below.

- Remote pilot airman certificate is required to operation a UAV for commercial purpose.
- The UAV should be operated with visual line-of-sign (VLOS) of either remote pilot-in-command (RPIC) or visual observer (VO). Minimum of three-mile visibility is required.
- VO may be used, but is not required.
- The UAV should not fly over persons who are not directly participate in the operation.
- The UAV must yield to right of way of any other aircraft.
- Maximum operation ground speed is 100 mph (87 nautical miles per hour).
- Operations in Class G airspace are allowed without permission of ATC. All other airspace (i.e. B, C, D, and E) require prior ATC permission to operate.
- Preflight inspection by RPIC is required to ensure safe operation, and the UAS has to be made available to the FAA upon request for inspection.
- RPIC must report to the FAA within ten days of any operation that results in serious injury or property damage of at least $500.

3. Operational Description

3.1. User Roles and Responsibilities

The primary users of UAS are Pilot in Command (PIC) and Visual Observer(VO). The FAA focuses on ensuring that UAS users have an appropriate level of understanding of the Title 14 of the Code of Federal Regulations (14 CFR) sections applicable to the airspace where UAS operate. UAS users are responsible for controlling their aircraft to the same standards as pilots of a manned aircraft. This chapter presents the roles and responsibility of PIC and VO.

3.1.1. Remote Pilot in Command

The position of the remote pilot in command would be somewhat analogous to the position of a pilot who controls the flight of a manned aircraft. Under the existing regulations, the PIC “is directly responsible for, and is the final authority as to the operation of the aircraft.” The existing PIC concept would provide similar benefits for small UAS operations. Accordingly, the FAA rule § 107.19(a), states:

- A remote pilot in command must be designated before or during the flight of the small unmanned aircraft.
- The remote pilot in command is directly responsible for and is the final authority as to the operation of the small unmanned aircraft system.
- The remote pilot in command must ensure that the small unmanned aircraft will pose no undue hazard to other people, other aircraft, or other property in the event of a loss of control of the aircraft for any reason.
- The remote pilot in command must ensure that the small UAS operation complies with all applicable regulations of this chapter.
- The remote pilot in command must have the ability to direct the small unmanned aircraft to ensure compliance with all applicable provisions.

3.1.2. Visual Observer (VO)

The definition of the VO is a trained person who assists the small unmanned aircraft operator in seeing and avoiding other air traffic or objects aloft or on the ground. The visual observer would do this by augmenting the operator as the person who must satisfy the see-and-avoid and visual-line-of-sight requirements for the operation of sUAS. The visual observer is required to be able to see the UAV and the surrounding airspace throughout the entire flight and be able to provide the PIC with the UAV's flight path and proximity to all aviation activities and other hazards sufficiently for the PIC to exercise effective control of the UAV to prevent the UAV from creating a collision hazard. If a visual observer is used during the aircraft operation, all of the following requirements must be met:

- The remote pilot in command, the person manipulating the flight controls of the small unmanned aircraft system, and the visual observer must maintain effective communication with each other at all times.
- The remote pilot in command must ensure that the visual observer is able to see the unmanned aircraft in the manner specified in §107.31.
- The remote pilot in command, the person manipulating the flight controls of the small unmanned aircraft system, and the visual observer must coordinate to do the following:
- Scan the airspace where the small unmanned aircraft is operating for any potential collision hazard; and
- Maintain awareness of the position of the small unmanned aircraft through direct visual observation.

3.2. UAS Operational Requirements

3.2.1. General Requirement

This chapter also addresses the qualifications of all UAS flight crew members, observers, maintainers, and other personnel, as appropriate. The following general operational requirements apply to all UAS pilots:

- One pilot in command (PIC) must be designated at all times.
- The PIC of an aircraft is directly responsible for, and is the final authority of, the operation of that aircraft.
- Each PIC controls only one unmanned aircraft (UA) at a time.
- Pilots are not allowed to perform concurrent duties both as the pilot and the visual observer (VO). In the case of Optionally Piloted Aircraft (OPA), the airborne pilot may assume the role of PIC at all times, but will only be the observer when the control station (CS) pilot operates the OPA.
- Unless undergoing initial qualification training, pilots must be qualified on the aircraft being flown.
- Only one PIC per aircraft is authorized, and the PIC must be in a position to assume the control of the aircraft.

3.2.2. Requirements for PIC and Operators

Particularly, PIC must maintain, at a minimum, a valid FAA medical certificate issued under 14 CFR part 67 or a valid state driver's license, depending on the type of pilot certificate held. This paragraph does not apply to operations conducted in accordance with the public aircraft statute as promulgated in 49 U.S.C. § 40102(a)[41]. In addition to the general requirements, special requirements for the designated PIC are as follows:

- Has been designated as PIC before or during the flight.
- Is responsible for the UAS flight operation as described under 14 CFR part 91, § 91.3.
- Is responsible for determining whether the UAS is in condition for safe flight.
- Must land as soon as safely practical when any condition occurs that causes operations to be unsafe.
- May be augmented by persons manipulating the controls. However, the PIC retains complete and overall responsibility for the flight.
- Has the ability to assume the duties of an internal or an external UAS pilot at any point during the flight.
- May rotate duties as necessary to fulfill operational requirements.
- Must have a thorough knowledge of the Certificate of Waiver or Authorization (COA) issued to the organization when conducting a public aircraft operation, and must retain a copy to reference during flight.
- Must be trained and qualified on the specific UAS for the conduct of the flight.
- May assume the duties of VO or PIC if piloting an OPA when the OPA is being utilized as a UAS and being flown by the CS pilot.
- Maintain an appropriate level of recent pilot experience for the position they are assigned in the UAS being operated.
- The certification requirement for the PIC depends on the type of operation conducted, which fall into two categories:
    - Civil operations require an FAA-issued pilot certificate.
    - Public operations do not require an FAA-issued pilot certificate.

The operators/applicants of UAS must provide documentation showing the pilots maintain an appropriate level of recent pilot experience in the UAS being operated, or as prescribed by the operator/applicant's recurrent training and currency program. This does not apply when the PIC is not required to be involved in the launch and recovery of the UAS operation or the operation is conducted in accordance with the public aircraft statute as promulgated in Title 49 of the United States Code (49 U.S.C.) § 40102(a)[41]. For those civil operations that require a certificated pilot, the PIC must have a flight review and maintain recent pilot experience in manned aircraft per part

61, as appropriate, to exercise the privileges of his or her certificate. The requirements for other operators are as follows:

- Operators/applicants must maintain individual training records for all UAS personnel.
- All training and testing will be documented in the individual's training record.

3.2.3. Reporting Requirements

The operations of UAS must be reported in a timely manner. For example, in case of an incidentor accident, the proponent must provide initial notification of the FAA (9-AJV-115-UASOrganization@faa.gov) and via the UAS COA On-Line forms (Incident/Accident) within 24 hours. Documentation of all operations associated with UAS activities is required regardless of the airspace in which the UAS operates. The requirements for reporting are summarized as follows:

- Name of Proponent, and aircraft registration number;
- UAS type and model;
- All operating locations, to include city name and latitude/longitude;
- Number of flights (per location, per aircraft);
- Total aircraft operation hours;
- The number and duration of lost link events (e.g., control, performance and health monitoring, or communications) per UAS, per flight;
- Takeoff or landing damage, and
- Equipment malfunction or failure to, but not limited to, control station, electrical system, fuel system, navigation system, on-board flight control system, and power-plant

3.3. Training

Training is needed for the agencies to develop a state specific training program that includes educating perspective users in not only the knowledge required by the FAA but also policies and procedures in New Jersey. Although the FAA CFR Part 107 for public agencies does not require a pilot certification, the potential UAS operators for New Jersey will still take and be required to pass the FAA knowledge exam and obtain the FAA Small UAV Pilot in Command License. As an outline for creating an all inclusive UAS training program, if the agency choses to certify their personnel under the FAA CFR Part 107 for public agencies, the following approach is proposed to handle UAS training for NJDOT:

- All NJDOT UAV Pilots will meet the training requirements that are established in the New Jersey sUAS Training Manual and be certified by the division or agency responsible for administering the sUAS Program.
- If experienced UAV Pilots can demonstrate flying proficiency to the division or agency responsible for administering the sUAS Program then some of the training requirements can be waived (see training flowchart Figure 4 below). This will be at the discretion of the division or agency responsible for administering the sUAS Program.
- All NJDOT UAV Pilots must be awarded their "FAA Small UAV Pilot in Command License" as part of the New Jersey DOT sUAS certification.
- After obtaining a "FAA UAV Pilot in Command License", all NJDOT sUAS Pilot students must also complete the entire training program and have each step in the process documented and signed off on by the sUAS Program Manager or designated representative.

All Visual Observers (VOs) must also complete sufficient training to communicate to the Pilot in Command (PIC) any information required to remain clear of conflicting traffic, terrain, and obstructions, maintain proper cloud clearances, and provide navigational awareness. This training, at a minimum, must include the following knowledge:

- Their responsibility to assist PICs in complying with the requirements:
    - Section 91.111, Operating Near Other Aircraft,
    - Section 91.113, Right-of-Way Rules: Except Water Operations,
    - Section 91.115, Right-of-Way Rules: Water Operations,
    - Section 91.119, Minimum Safe Altitudes: General, and
    - Section 91.155, Basic VFR Weather Minimums
- Air traffic and radio communications, including the use of approved air traffic control/pilot phraseology; and
- Appropriate sections of the Aeronautical Information Manual (AIM)

It is also necessary to take into considerations the cases of recertification and disqualification.

- Recertification: All NJDOT sUAS Pilots will be required to be recertified every two years
- Disqualification: Anyone found in violation of the New jersey or FAA rules and guidelines or flying a UAV in an unsafe manner set forth in these guidelines can be disqualified from the NJDOT UAS Program. It will be at the discretion of the UAS Program Manager to decide if an infraction warrants the removal of a NJDOT UAV Pilot from the UAS program.

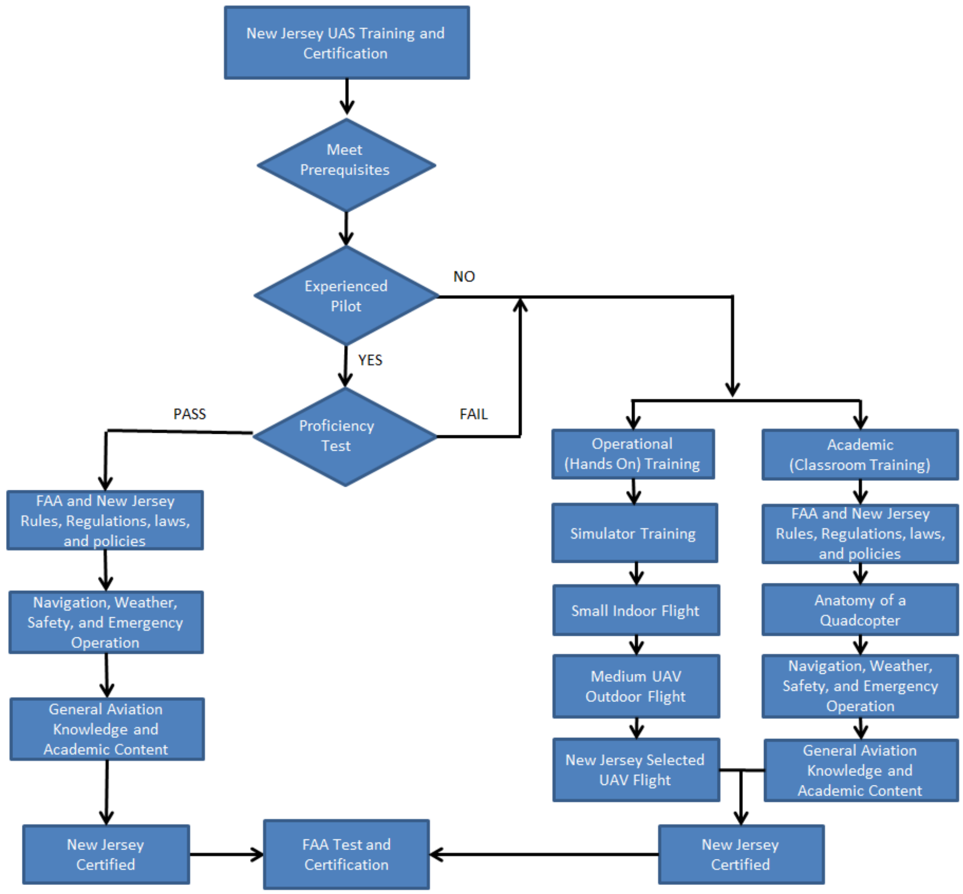

Figure 4. New Jersey UAS Training and Certification

3.4. Locations of the Application

The proponent must not operate in Restricted Areas, Prohibited Areas, Special Flight Rule Areas or the Washington DC Flight Restricted Zone. Such areas are depicted on charts available at http://www.faa.gov/air_traffic/flight_info/aeronav/. Additionally, aircraft operators should beware of and avoid other areas identified in Notices to Airmen (NOTAMS) that restrict operations in proximity to Power Plants, Electric Substations, Dams, Wind Farms, Oil Refineries, Industrial Complexes, National Parks, The Disney Resorts, Stadiums, Emergency Services, Military or other Federal Facilities unless approval is received from the appropriate authority prior to the UAS operations. The followings are the primary factors to be considered for the selection of application.

3.4.1. See-and-Avoid

The operator (and visual observer, if used) must be capable of maintaining a visual line of sight of the small unmanned aircraft throughout that aircraft's entire flight with human vision that is unaided by any device other than spectacles or contact lenses. If a visual observer is not used, the operator must exercise this capability and maintain watch over the small unmanned aircraft during flight. However, if an operation is augmented by at least one visual observer, then the visual observer can be used to satisfy the visual-line-of-sight requirements, as long as the operator always remains situated such that he or she can exercise visual-line-of-sight capability.

This proposed requirement does not require the person maintaining visual line of sight to constantly watch the unmanned aircraft for every single second of that aircraft's flight. The FAA understands and accepts that this person may lose sight of the unmanned aircraft for brief moments of the operation. This may be necessary either because the small UAS momentarily travels behind an obstruction or to allow the person maintaining visual line of sight to perform actions such as scanning the airspace or briefly looking down at the small UAS control station. The visual-line-of-sight requirement of this proposed rule would allow the person maintaining visual line of sight brief moments in which he or she cannot directly see the small unmanned aircraft provided that the person is able to see the surrounding operational area sufficiently well to carry out his or her visual-line-of-sight-related responsibilities. Anything more than brief moments during which the person maintaining visual line of sight is unable to see the small unmanned aircraft would be prohibited under this proposed rule.

To ensure that the operator's vision (and that of a visual observer, if used) of the small unmanned aircraft is sufficient to see and avoid other aircraft in the NAS, operator's or visual observer's vision of the small unmanned aircraft must be sufficient to allow him or her to:

- know the small unmanned aircraft's location;
- determine the small unmanned aircraft's attitude, altitude, and direction;
- observe the airspace for other air traffic or hazards; and
- determine that the small unmanned aircraft does not endanger the life or property of another.

Binoculars, onboard cameras, and other vision-enhancing devices (aside from spectacles or contact lenses) cannot be used to satisfy this proposed requirement because those devices restrict the user's peripheral field of vision. Since a pilot often uses peripheral vision to identify other aircraft in the NAS, a device that restricts peripheral vision hinders the user's ability to see other aircraft. This rule is not intended to prohibit the use of those devices. Rather, the proposed visual-line-of-sight requirement requires simply that at least one person involved in the operation, either the operator or a visual observer, must maintain an unenhanced visual line of sight of the small unmanned aircraft. Anyone else involved in the operation may use a vision-enhancing device (including first-person view) so long as that device is not used to meet the proposed requirements of §107.31 and §107.37.

3.4.2. Additional Visibility Requirements

To further ensure that a small UAS operator/visual observer can see and avoid other aircraft, the FAA requirements include:

- to limit the operation of small UAS to daylight-only operations; and
- to impose weather-minimum visibility requirements

First, the FAA prohibits the operation of a small UAS outside the hours of official sunrise and sunset. This decision is due to the relatively small size of the small unmanned aircraft and the difficulty in being able to see it in darker environments to avoid other airspace users. This rule also notes that most small unmanned aircraft would take place at low altitudes, and flying at night would limit the small UAS operator's ability to see people on the ground and take precautions to ensure that the small unmanned aircraft does not pose a hazard to those people. To ensure that small UAS operators and visual observers have the ability to see and avoid other aircraft, the FAA requires a minimum flight visibility of 3 statute miles (5 kilometers) from the control station for small UAS operations. A visibility of 3 statute miles currently is required for aircraft operations in controlled airspace. The reason for the increased visibility requirement is to provide the small UAS operator with additional time after seeing a manned aircraft to maneuver and avoid an accident or incident with the manned aircraft.

In addition, the FAA requires that the small unmanned aircraft must be no less than:

- 500 feet (150 meters) below clouds; and
- 2,000 feet (600 meters) horizontal from clouds.

This is similar to the requirements imposed on aircraft operating in controlled airspace under visual flight rules. The FAA has imposed these cloud-clearance requirements on small UAS operations because, as mentioned previously, small UAS operators do not have the same see-and-avoid capability as manned-aircraft pilots.

3.4.3. Confined Area of Operation Boundaries Horizontal Boundaries

Visual-line-of-sight requirements create a natural horizontal boundary on the area of operation. The visual-line-of-sight requirement would effectively confine the horizontal area of operation to a circle around the person maintaining visual contact with the aircraft with the radius of that circle being limited to the farthest distance at which the person can see the aircraft sufficiently to maintain compliance.

A small UAS operation could use multiple visual observers to expand the outer bounds of the horizontal circle created by the visual-line-of-sight requirement. However; if an operation uses a visual observer, the small unmanned aircraft must remain close enough to the operator at all times during flight for the operator to be capable of seeing the aircraft with vision unaided by any device other than corrective lenses. This rule would prevent the use of visual observers to expand the horizontal outer bounds of the confined area of operation. This approach also creates a safety-beneficial redundancy in that, while the operator is not required to look at the small unmanned aircraft in an operation that uses a visual observer, should something go wrong, the operator would be able to look up and see for him- or herself what is happening with the aircraft. The only exception for expanding the horizontal boundaries of operation of a small UAV would be to operate the UAV from a moving water-borne vehicle. Operation from a moving land based or aircraft is prohibited.

3.4.4. Vertical Boundaries

The altitude of the small unmanned aircraft cannot be higher than 400 feet above ground level, unless the small unmanned aircraft:

- Is flown within a 400-foot radius of a structure; and
- Does not fly higher than 400 feet above the structure's immediate uppermost limit.

The minimum distance of the small unmanned aircraft from clouds must be no less than:

- 500 feet below the cloud; and
- 2,000 feet horizontally from the cloud.

3.4.5. Mitigating Loss-of-Positive-Control Risk

Now that we have defined the confined area of operation, we turn to the question of how loss-of-positive-control risk can be mitigated within that area of operation. A mitigation method that works well for one type of small UAS used in one type of operation may not work as well in another operation that uses another type of small UAS. For example, in a loss-of-positive-control situation, a rotorcraft that loses operator inputs or power to its control systems would tend to descend straight down or at a slight angle while a fixed wing aircraft would glide for a greater distance before landing. Since the loss-of-positive-control risk posed by different types of small unmanned aircraft in various operations is different, small UAS operators will be allowed the flexibility to create operational and aircraft-specific loss-of-control mitigation measures. There are however requirements that each operator of a small UAV will be held accountable for which include:

- Prior to flight, the operator must ensure that all links between the control station and the small unmanned aircraft are working properly. This can be done by verifying control inputs from the control station to the servo actuators in the small unmanned aircraft. If the operator finds, during this preflight check, that a control link is not functioning properly, the operator would not commence flight until the problem with the control link is resolved.

- Adherence to a speed limit of 87 knots (100 miles per hour) on small unmanned aircraft calibrated airspeed at full power in level flight. If there is a loss of positive control, an aircraft traveling at a high speed poses a higher risk to persons, property, and other aircraft than an aircraft traveling at a lower speed. A speed limit would also have safety benefits outside of a loss-of-positive-control scenario because a small unmanned aircraft traveling at a lower speed is generally easier to control than a higher-speed aircraft.
- Operation of a small unmanned aircraft over a person who is not directly participating in the operation of that small unmanned aircraft is prohibited. One of the possible consequences of loss-of-positive-control is that the aircraft will immediately crash into the ground upon loss of control inputs from the operator. This prohibition on operating small unmanned aircraft over most persons will minimize the risk that a person is standing under a small unmanned aircraft if that aircraft terminates flight and returns to the surface. This prohibition would not apply to persons inside or underneath a covered structure that would protect the person from a falling small unmanned aircraft or operating over people directly participating in the operation of the small unmanned aircraft. Prior to flight, the operator must ensure that all persons directly involved in the small unmanned aircraft operation receive a briefing that includes operating conditions, emergency procedures, contingency procedures, roles and responsibilities, and potential hazards. A person is directly involved in the operation when his or her involvement is necessary for the safe operation of the small unmanned aircraft. By receiving a pre-flight briefing on the details of the operation and the hazards involved, the persons involved in the operation would be made aware of the small unmanned aircraft's location at all times and would be able to avoid the flight path of the small unmanned aircraft if the operator were to lose control or the aircraft were to experience a mechanical failure.

In order to mitigate the loss of positive control risk, prior to flight, the operator must become familiar with the confined area of operation by assessing the operating environment and assessing risks to persons and property in the immediate vicinity both on the surface and in the air. As part of this preflight assessment, the operator would need to consider conditions that could pose a hazard to the operation of the small UAS as well as conditions in which the operation of the small UAS could pose a hazard to other aircraft or persons or property on the ground. This pre-flight assessment requires the consideration of:

- local weather conditions;
- local airspace and any flight restrictions;
- the location of persons and property on the ground; and
- any other ground hazards.

After becoming familiar with the confined area of operation and conducting a preflight assessment, the operator is required to ensure that the small unmanned aircraft will pose no undue hazard to other aircraft, people, or property in the event of a loss of control of the aircraft for any reason. This proposed requirement allows the operator with flexibility to choose how to mitigate the hazards associated with loss of aircraft control. For example, if the operation takes place in a residential area, the operator could ask everyone in the area of operation to remain inside their homes while the operation is conducted. If the operation takes place in an area where other air traffic could pose a hazard, the operator would advise local air traffic control as to the location of his or her area of operation and add extra visual observers to the operation so that they can notify the operator if other aircraft are approaching the area of operation.

The above are just some examples of mitigation strategies that could be employed by the operator to ensure that the small unmanned aircraft will pose no hazard to other aircraft, people or property in the event of lost positive control. These examples are not intended to provide an exhaustive list, as there are different ways to mitigate loss of positive control. The proposed requirement would provide the operator with the flexibility to choose which mitigation method is appropriate for his/her specific operation to ensure any hazards posed by loss of positive aircraft control are sufficiently mitigated. No matter what mitigation option(s) the operator employs under this proposed rule, the operator must strive to always maintain positive control of the small unmanned aircraft. The operator would be in violation of proposed § 107.19(b) if he or she intentionally operates the small unmanned aircraft in a location where he or she will not have positive control over that aircraft.

3.4.6. Limitations on Operations in Certain Airspace

This proposed rule would place limitations small UAS operations in three areas related to airspace:

- controlled airspace (airspace other than Class G);
- prohibited or restricted airspace; and
- airspace where aviation activity is limited by a Notice to Airmen (NOTAM).

The FAA is proposing these requirements to reduce the threat to other users of the NAS in busy airspace or where most or all aviation activities would otherwise be limited.

3.4.7. Controlled Airspace

The FAA is seeking to limit the exposure of the small unmanned aircraft to other users of the NAS to minimize the risk of collision, which can occur both during controlled flight of the UAS or if the operator loses positive control of the small unmanned aircraft. This rule would prohibit small unmanned aircraft operations in Class A airspace. Class A airspace starts at 18,000 feet mean sea level and extends up to 60,000 feet (Flight Level 600). This rule would prohibit small UAS operations above 500 feet AGL and outside of visual line of sight. Small UAS operations would also be prohibited in Class B, Class C, Class D, and within the lateral boundaries of the surface area of Class E airspace designated for an airport without prior authorization from the ATC facility having jurisdiction over the airspace. That ATC facility would have the best understanding of local airspace, its usage, and traffic patterns and would be in the best position to ascertain whether the proposed small UAS operation would pose a hazard to other users or the efficiency of the airspace, and procedures to implement to mitigate hazards. A small UAS operator that intends to operate in controlled airspace must ensure that the proposed operations are planned and conducted in the safest manner possible. The small UAS operator can do this by working closely with the ATC facility that controls the airspace.

3.4.8. Prohibited or Restricted Areas

This rule would prohibit small UAS operations in prohibited and restricted areas without permission from the using or controlling agency as applicable. Prohibited and restricted areas are designated in 14 CFR Part 73. Prohibited areas are established when necessary to prohibit flight over an area on the surface in the interest of national security or welfare. No person may operate an aircraft without permission of the using agency in a prohibited area.

3.4.9. Areas Designated by Notice to Airmen (NOTAM)

This rule prohibits operation of small UAS in airspace restricted by NOTAMs unless authorized by ATC or a certificate of waiver or authorization. This would include NOTAMs issued to designate a temporary flight restriction (TFR). NOTAMs contain time-critical aeronautical information that is either temporary in nature, or not sufficiently known in advance to permit publication on aeronautical charts or other publications. For example, NOTAMs may be used to limit or restrict aircraft operations during emergency situations or presidential or VIP movements. They may also be used to limit aircraft operations in the vicinity of aerial demonstrations or sporting events. NOTAMs are available to the public on the FAA's website. Like other users of the airspace, small UAS operators would be required to review and comply with NOTAMs.

In order to limit or reduce the threat to other users of the NAS of a busy airspace CFR Part 107 places limitations on the operation of small UAV operations within controlled airspace areas. These limitations are listed below:

- Operation of a small UAV is prohibited in class A airspace which starts at 18,000 feet mean sea level and extends up to 60,000 feet; and
- Operation of a small UAV is also prohibited in Class B, Class C, Class D, and within the lateral boundaries of the surface area of Class E airspace which is designated for an airport without prior authorization from the ATC facility having jurisdiction over the airspace.

It is worth noting that the FAA factors in air traffic density, operations, and safety whether to designate controlled airspace. Pilots must have an ATC clearance to enter certain controlled airspace so that the ATC is aware of the UAV operations within its controlled airspace thereby lessening the risk of interference with other aircraft activities. A small UAS operator that intends to operate in controlled airspace must ensure that the proposed operations are planned and conducted in the safest manner possible. The small UAS operator can do this by working closely with the ATC facility that controls the airspace.

Prohibited and restricted areas are designated in 14 CFR Part 73. Prohibited areas are established when necessary to prohibit flight over an area on the surface in the interest of national security or welfare. No person may operate an aircraft without permission of the using agency in a prohibited area. Restricted areas are established when determined necessary to confine or segregate activities considered hazardous to non-participating aircraft. Although aircraft flight is not wholly prohibited in these areas, they are subject to restriction. The CFR Part 107 provisions concerning prohibited and restricted areas are similar to the Part 91 restriction on operations in these areas.

Small UAV operations in accordance with the CFR Part 107 are prohibited from operating within airspace restricted by a NOTAM unless authorized by ATC or a certificate of waiver or authorization. This includes NOTAMs issued to designate a temporary flight restriction (TFR). NOTAMs contain time-critical aeronautical information that is either temporary in nature, or not sufficiently known in advance to permit publication on aeronautical charts or other publications. NOTAMs are available on the FAA website (http://tfr.faa.gov/tfr2/list.html).

3.5. Operational Procedures and Sequences of the Implementation

Prior to each flight, the operator must inspect the small UAS to ensure that it is in a condition for safe operation. The operator could do this by, for example, performing a manufacturer-recommended preflight inspection or performing an on-the-ground test of the small UAS to determine whether safety-critical systems and components are working properly. If, as a result of the inspection, the operator determines that the small UAS is no longer in a condition for safe operation, then the operation of the small UAS would be prohibited until the necessary maintenance has been made and the small UAS is once again in a condition for safe operation. A small UAS that appears to be in a condition for safe operation prior to flight may become unsafe for operation during flight. For example, the small unmanned aircraft could sustain damage during flight rendering that aircraft unsafe for continuing the flight. As such, this proposed rule would require that the operator must discontinue the flight of the small unmanned aircraft when he or she knows or has reason to know that continuing the flight would pose a hazard to other aircraft, people, or property.

A small UAS operator must be able to ensure that, if powered, the small UAS has enough power to operate for its intended operational time and an additional five minutes. The 5-minute buffer would ensure that the small UAS has sufficient power to return to the operator, or another location, and be able to make a controlled landing. Additionally, control inputs to a small UAS may degrade as batteries lose charge because power to the flight control system(s) may be lost. Accordingly this proposed rule would help to ensure that the small UAS remains controllable throughout its intended operational time.

Weather conditions can severely impact the operations of a small UAV in several ways and localized weather reports should be accessed as close to flight time as possible and monitored during flight time as well. Small UAVs should not be used during severe weather conditions which include wind speed exceeding 10 m/s, snow, rain, or low visibility conditions caused by fog, smog, smoke or other conditions that limit visibility.

Prior to any flight a complete survey and identification of all possible hazards in the operating area should be conducted and noted. These factors should also be relayed to any crew members who are part of the flight operations team during the safety briefing so they are aware of any issues as well.

Being aware of your surroundings is one of the most important steps to take both prior to flight and during flights. By being aware of the surroundings and possible hazards a higher level of operator and civilian safety are realized as well as helping to ensure the longevity or health of the UAV.

Always check what the local legal requirements are for quadcopter safety in your area before flying your quadcopter.

- Weather (current, forecasted and solar);
- Power lines and transmission stations;
- Restricted airspace;
- Airport proximity;
- Trees, buildings, and other fixed objects;
- Stadiums or large gatherings of people;
- Flying over any people that have not given consent;
- Flight altitude; and
- Status of the UAVs system and operations to include the battery levels.

The logging of flight time for both training simulators and actual flight time by type of UAV is a requirement. There are several FAA regulations that pertain to the logging of flight time. These regulations must be adhered to at all times.

Due to the FAA regulations, internal standardized procedures for qualified pilot to deploy the UAS need to be established in order to avoid any violations. One of the most important factors is the classification of airspace where the intended deployment site is located. A tentative decision flow chart for the pilot is shown in Figure 5.

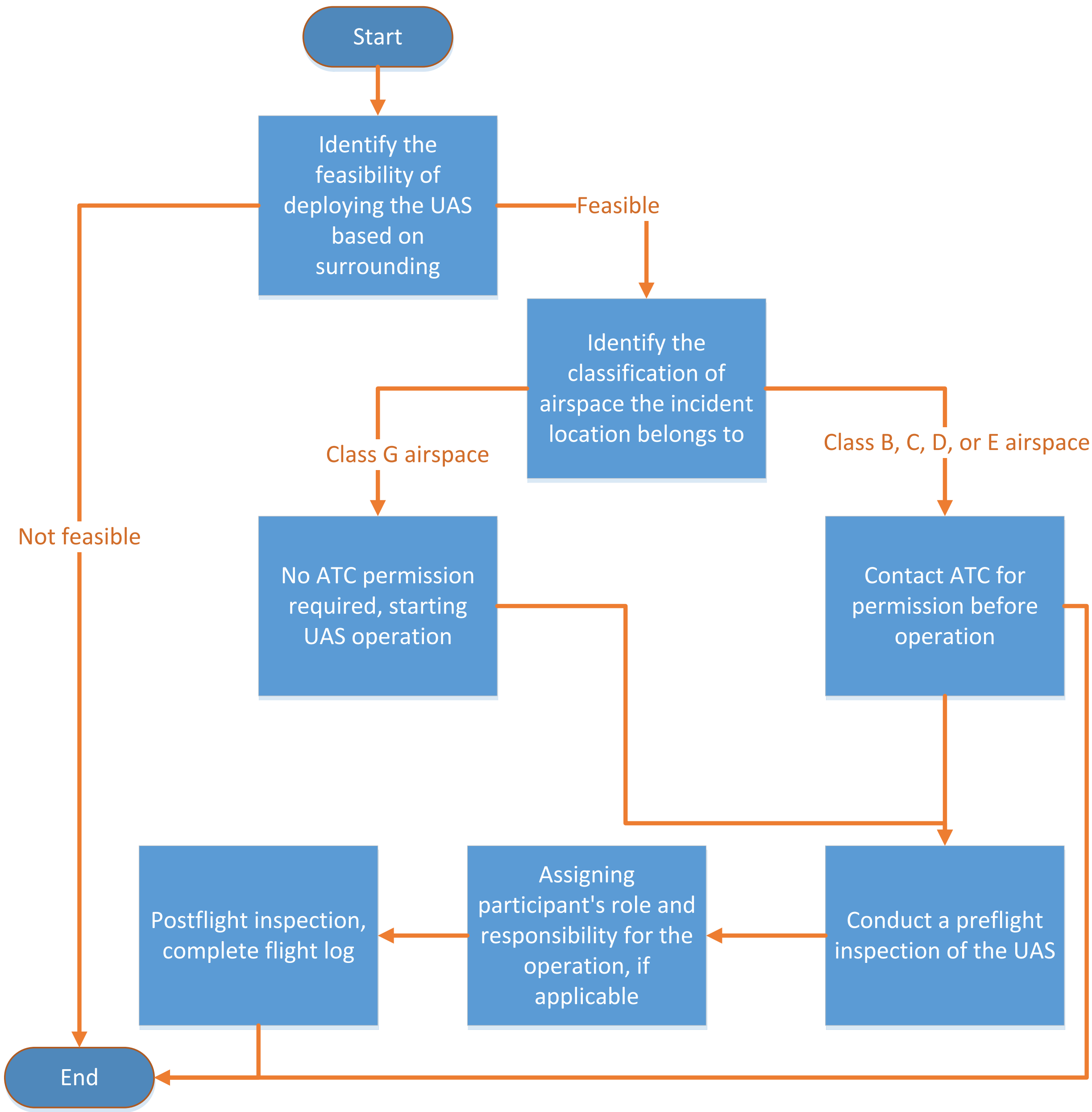

Figure 5. Deployment Decision Flow Chart

4. System Overview

4.1. Description of the Application

4.1.1. Scope

The UAS technology could be useful for many NJDOT functions, however, actual and specific requirements for each domain should be evaluated among the department divisions and offices. A typical UAS consists of six major components, as shown in Figure 5. Except for the UAV, the remaining components could be considered as ground station elements, including: a pilot for control; a communication link between the controller and the UAV; and a payload (sensors, cameras, control receiver etc.); that are all of critical importance in fulfilling the flight mission. A recovery system to stop and retrieve the aircraft may be needed, as shown in Figure 6, depending on the UAV configuration, which will be discussed later in this paper.

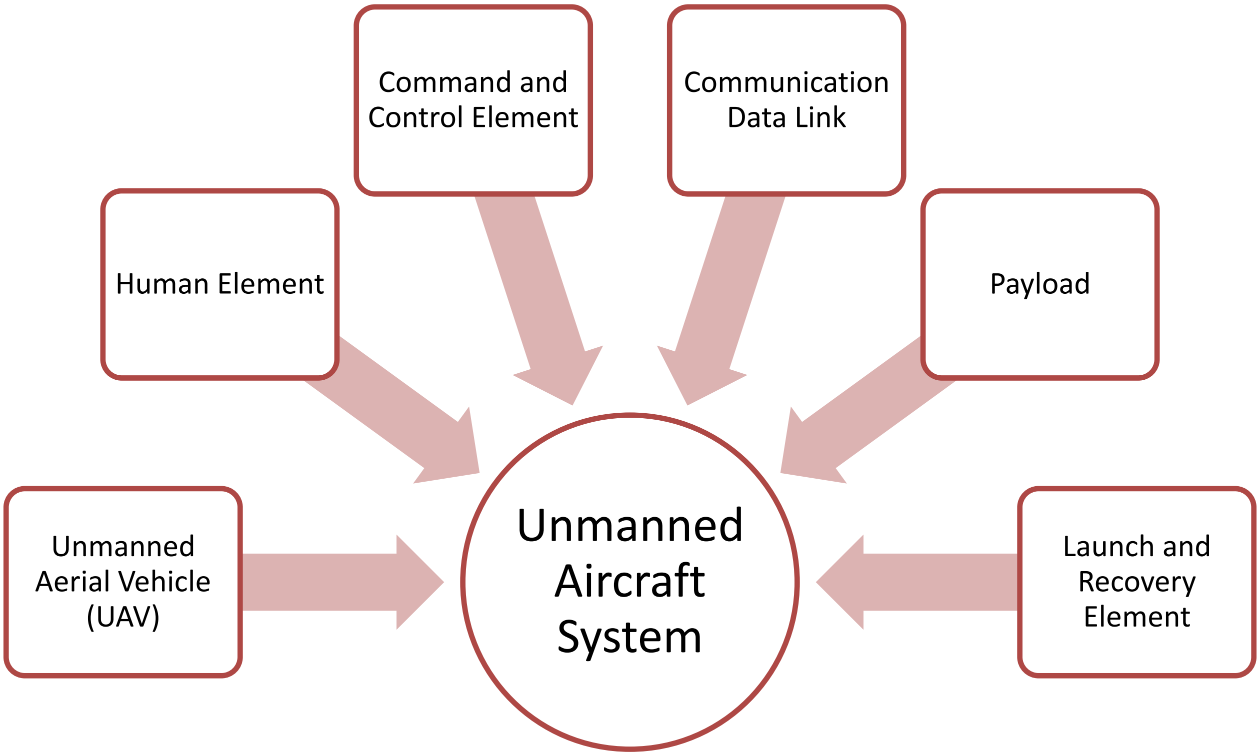

Figure 6. Composition of an Unmanned Aerial System (UAS)

4.1.2. Goal and Objectives

The primary goal is to successfully deploy and integrate the proposed UAS-based applications into the current NJDOT traffic incident management workflow with the potential future expansion into interagency, specifically police department and emergency medical service applications. Primary objectives are listed below.

- To evaluate the candidate UASs based on the need for traffic incident management and monitoring;
- To integrate the selected UAS into a SSP vehicle for pilot deployment test;
- To integrate the real-time monitoring capability for a traffic management center (TMC);
- To establish inter-agency protocol for UAS deployment in traffic incident management and other applications.

4.1.3. Proposed Locations

The pilot test site will be determined by carefully examining priority consideration of Class G airspace along with others factors including roadway classification and daily traffic volumes. Figures Figure 7 and Figure 8 show examples to determine potential test sites by taking into consideration the Class G airspace in New Jersey. The first location, shown in Figure 7, is adjacent to US 1 south of New Brunswick in Middlesex County. The second location, shown in Figure 8, is a segment of the Garden State Parkway between Middletown and Toms River in Monmouth and Ocean Counties.

4.1.4. Users

The Safety Service Patrol (SSP) crew within the NJDOT is the ideal user for the UAS. The primary goal of the SSP is to assist motorists whose vehicles have become disabled and to provide safety for emergency responders. The SSP is alerted when operators in the New Jersey State Police (NJSP) receive calls from motorists and they are typically among the first responders to a location.

The New Jersey State Police (NJSP) is designated to document the crash scene. The NJSP could utilize the UAS to perform its task more expeditiously, through the rapid deployment of UAS and the overhead perspective it offers.

Infrastructure inspectors within the NJDOT are also potential users who could benefit from using UAS to inspect hard-to-reach areas, such as bridge underdecks, and potentially unsafe environments, such as pump stations.

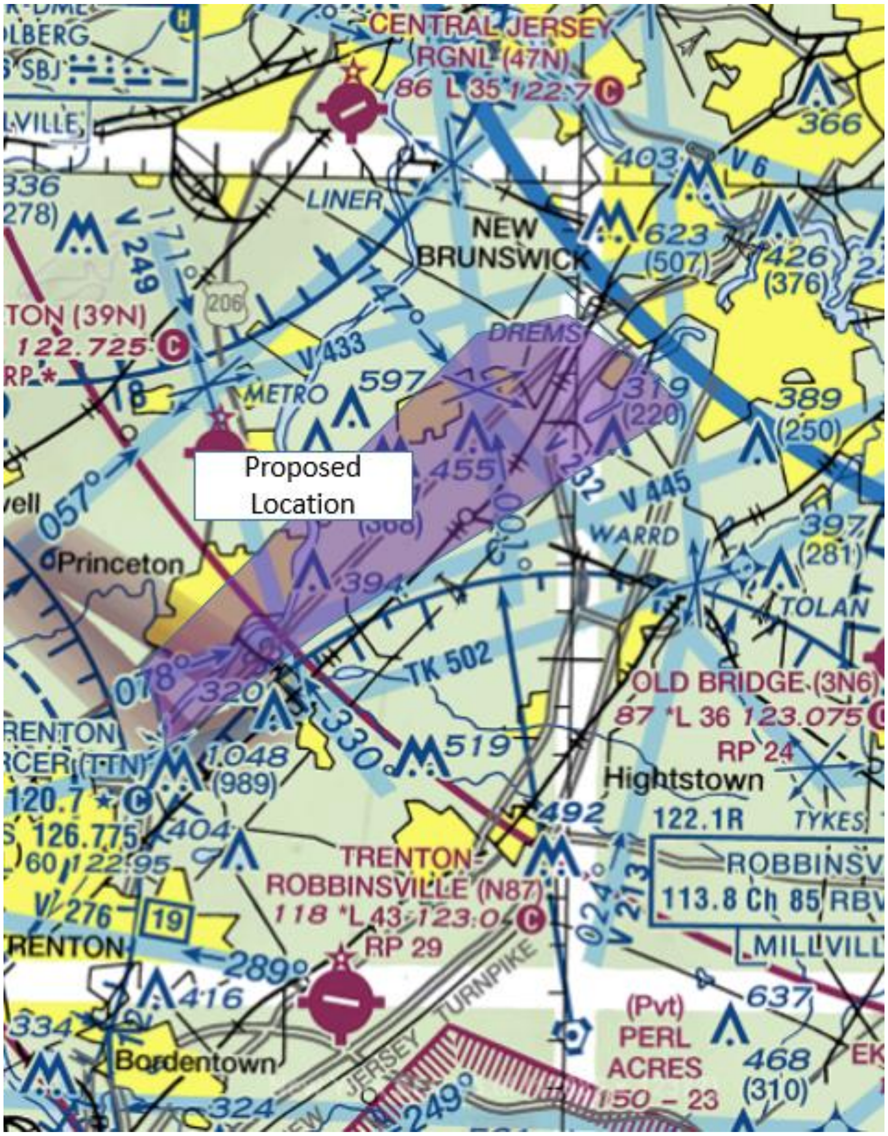

Figure 7. Class G Airspace around New Brunswick, NJ

Figure 8. Class G Airspace around Middletown, NJ

4.2. Application Architecture

4.2.1. User/Element Descriptions

Remote Pilot-in-command (RPIC), established by the FAA, is the person who has final authority and ultimate responsible for UAS operation and safety during flight. Regulations require that the UAS operator either obtain a remote pilot certificate or be under the direct supervision of a certificate holder. The procedure to obtain the pilot certificate for either first-time or existing pilots is illustrated in Figure 9.

Visual Observer (VO) is not required if the RPIC or the person under his or her direct supervision can maintain situational awareness to the aircraft's operational status, other air traffic and other potential hazards.

Assistant Staffs are optional as direct participants of the UAS operation.

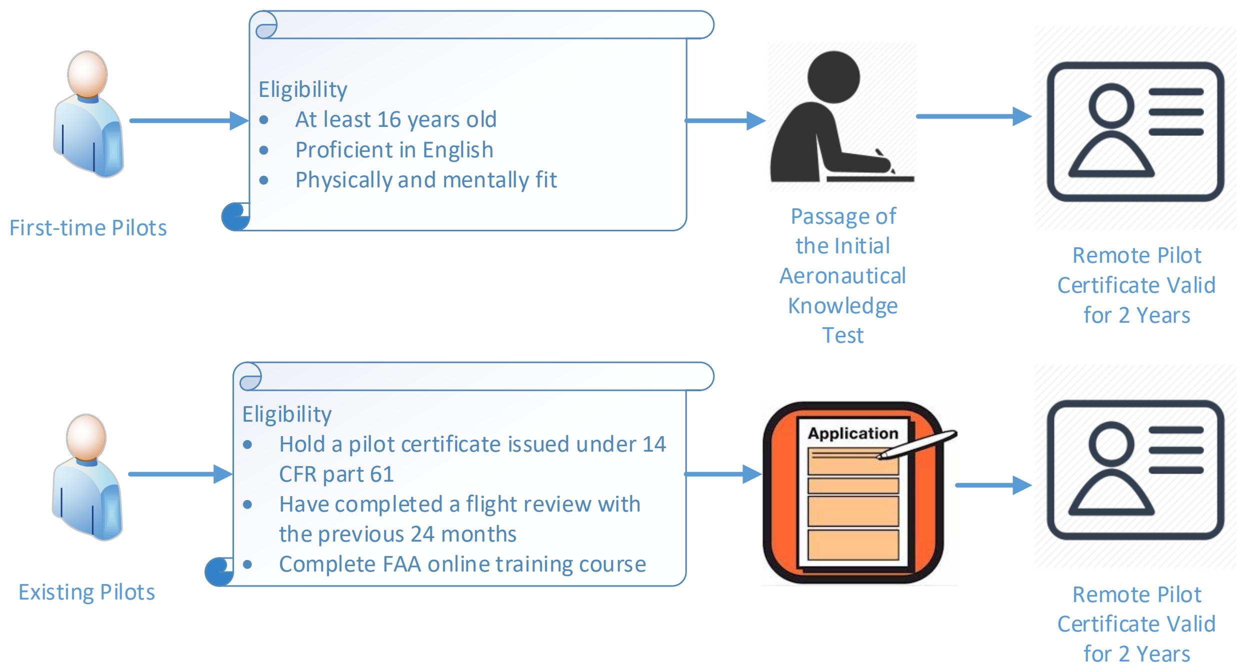

Figure 9. Process to Become a FAA Remote Pilot

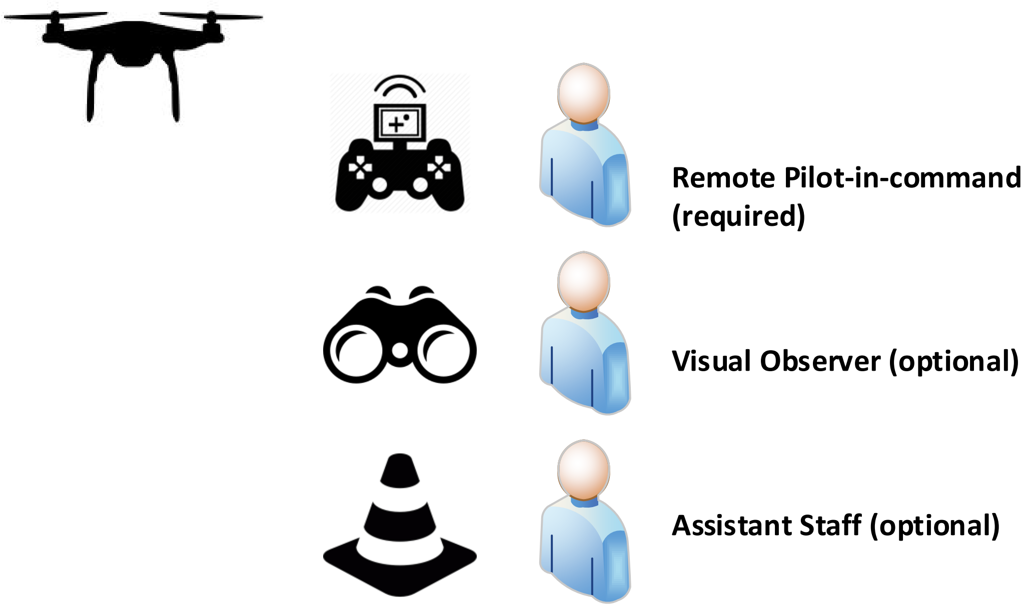

Figure 10. User Diagram for UAS Operation

4.2.2. Information Flow Diagrams

Live video footage of a roadway incident is one of the most crucial pieces of information for roadway incident management. Under current practice, live incident video footage is collected by closed-circuit television (CCTV) cameras that are closely located around the incident scene. From the limited areas covered by the available CCTVs, it is difficult, if not impossible, for any TMC to obtain all of the needed video footage of an incident scene. An sUAV is easy to launch as it requires no dedicated spaces to take off. Hence, a sUAV would be a suitable option for rapid deployment to capture video footage of a roadway incident which is out of range of the CCTV coverage area.

A high-level framework of a proposed quadcopter-based incident monitoring application is shown in Figure 11. Assuming a member of the SSP team is equipped with one or two quadcopter sUAV with a ground station on duty in case an incident occurs, the patrol team is able to deploy a quadcopter equipped with a First Person View (FPV)[3] video camera to reach the incident scene. The incident video footage captured is then transmitted to the ground station through a 2.4 GHz radio communications link. With only 0.6 miles of communication range for a 2.4GHz radio, the FPV transmitter is unlikely to be able to directly feed the live video footage to the local TMC. To

3 First-person view (FPV), also known as remote-person view (RPV), or simply video piloting, is a method used to control a radio-controlled vehicle from the driver or pilot's view point. Most commonly it is used to pilot a radio-controlled aircraft or other type of unmanned aerial vehicle (UAV).

enable a long distance video transmission from the quadcopter, we propose video streaming from the ground unit to a local TMC via a commercial 4G/LTE network, as shown in Figure 11.

Figure 11. High-level Framework for Quadcopter-based Incident Monitoring

4.2.3. Components and Interfaces

Component and interfaces of the proposed system are shown in the interconnect diagram in Figure 12.

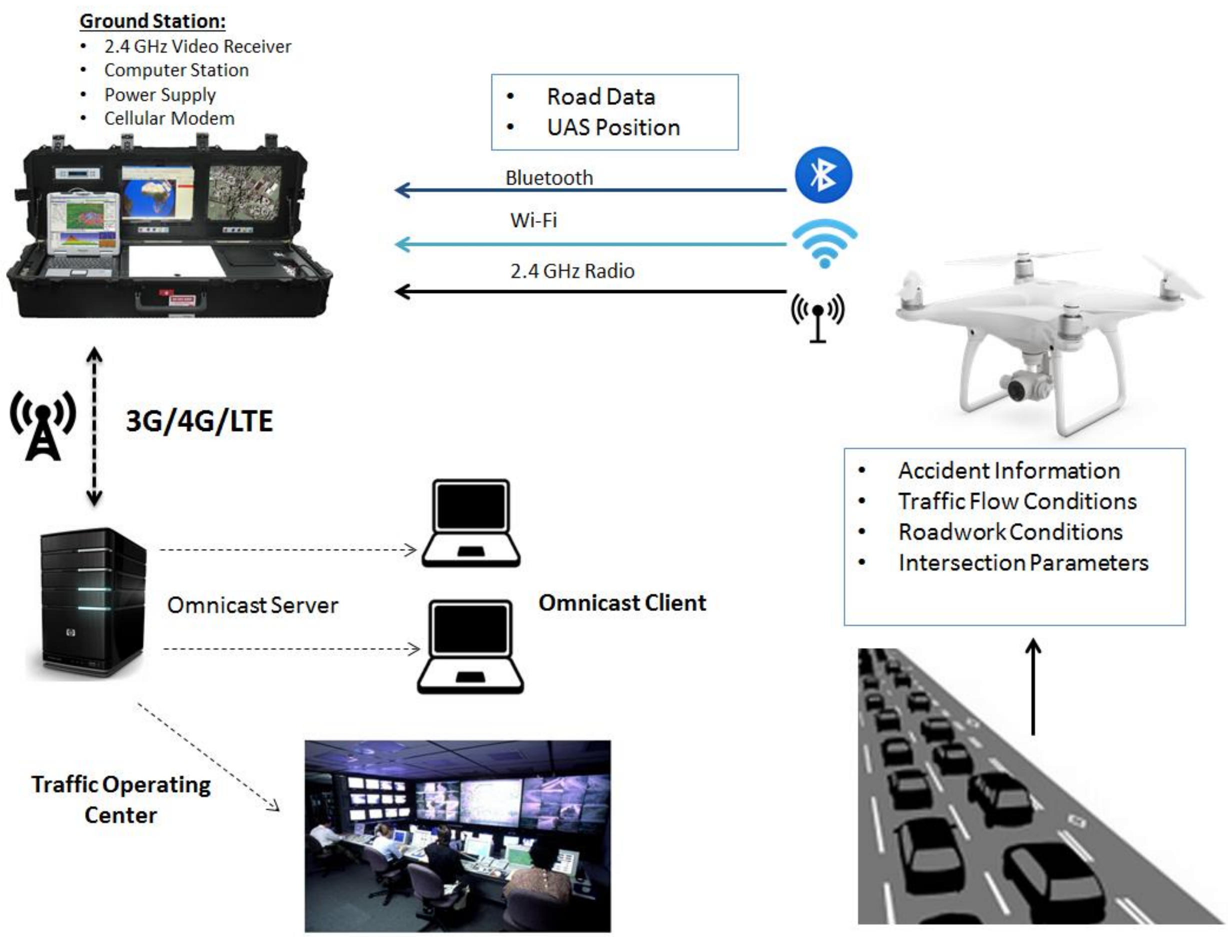

Figure 12. Components and Interfaces of the Proposed System Architecture

4.3. Application Capabilities and Functions

4.3.1. Operational Concept

Small UASs can be considered supplements to existing traffic monitoring devices. It is expected that more cutting-edge technologies: high-definition video recording for documentation; video analytics for traffic counting; and LiDAR for remote sensing; will be integrated into sUAVs. In the proposed application, a UAS is used as a complement for PTZ traffic cameras. It can be deployed to the traffic incident scene to provide valuable information about locations that are not within the range of the stationary traffic camera. Furthermore, its freedom of movement and overhead perspective offer additional information for the incident of interest, whether it is non-recurrent traffic congestion, or a roadway blockage due to a crash. Also, with a UAS equipped with live-streaming capability, the instant footage can be watched in the NJDOT traffic management center, to aid in properly allocating limited emergency resources.

4.3.2. Transportation System and ITS Architectures

Existing ITS architecture is designed to utilize real-time traffic data from cameras, speed sensors, etc. The collected information then flows into a Transportation Management Center (TMC) where it is integrated and processed (e.g. for incident detection), and may result in actions taken (e.g. traffic routing, DMS messages) with the goal of improving traffic flow. System architecture utilizes conventional data collection sources such as surveillance cameras and then shares relevant traffic related information with road users via the 511 website and DMS devices. Implementation of UAS provides an enhancement to existing systems, as shown in Figure 13, with the possibility of additional coverage for locations of interest where UAS is deployed. Additional aerial perspective for locations that are not visible through existing fixed location cameras could provide significant benefits for road users and operational staff. In addition, UAS implementation is not significantly different from adding additional analog or digital cameras into the existing architecture as the additional equipment such as ground stations and cellular communication modules can be implemented using existing technology.

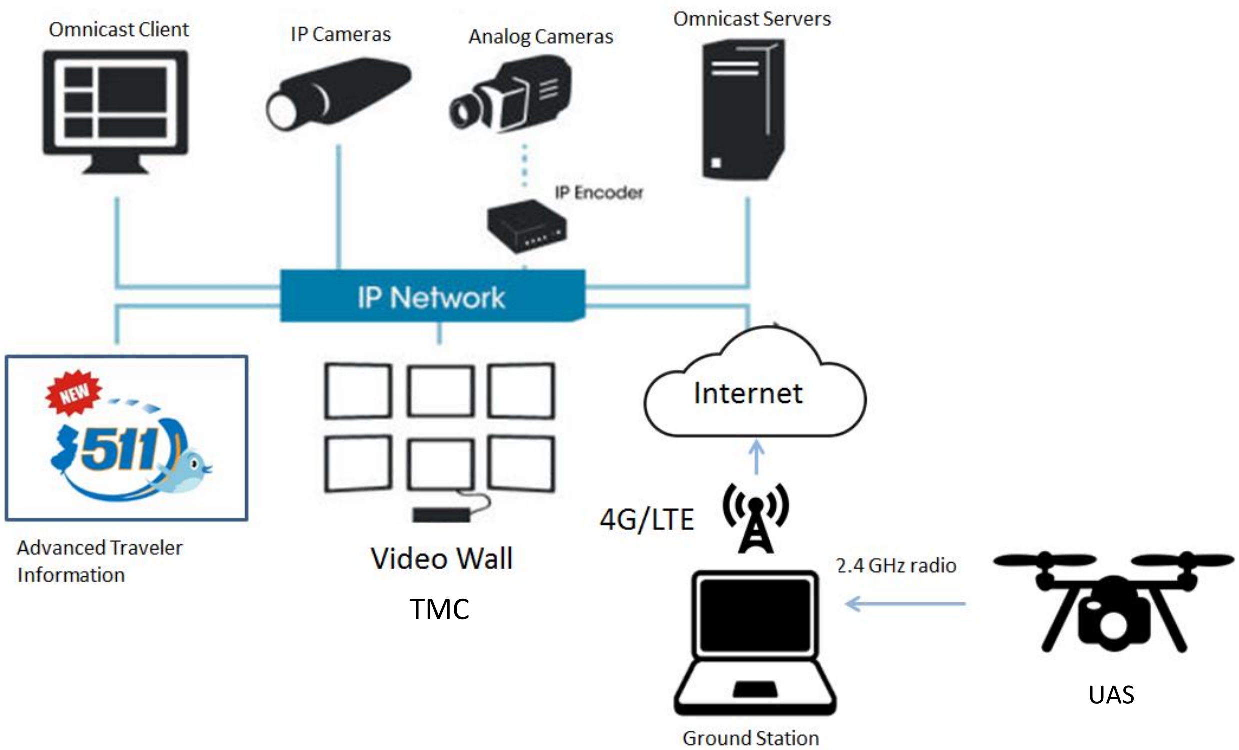

Figure 13 Proposed system architecture for UAS interface implementation

5. Operational and Supporting Environment

5.1. Facilities and Equipment

All NJDOT aircraft will be properly registered and maintained in accordance with the FAA rules and standards. It will be the responsibility of each divisions Pilot to ensure their aircraft meets all safety requirements; to include all software and firmware updates. Any additional equipment that will be attached to the UAVs will be approved by the UAS Program Manager.

NJDOT UAVs will have a yearly inventory and Preventive Maintenance inspection done prior to April 30th of each year or the UAV will be grounded until the inspection is complete. This inspection is in addition to the UAV safety inspections that should be conducted prior to each flight. Each division is responsible to perform the inventory and PM inspection and submit the proper paper work to the UAS Program Manager.

5.2. Hardware and Software

Software and hardware changes should be documented as part of the normal maintenance procedures. Software changes to the aircraft and control station as well as hardware system changes are classified as major changes unless the agency has a formal process accepted by the FAA. These changes should be provided to the UAS Integration Office in summary form at the time of incorporation.

A configuration control program must be in place for hardware and/or software changes made to the UAS to ensure continued airworthiness. If a new or revised Airworthiness Release is generated as a result of changes in the hardware or software affecting the operating characteristics of the UAS, notify the UAS Integration Office via email at 9-AJV-115-UASOrganization@faa.gov of the changes as soon as practical.

6. Operational Scenarios

6.1. Factor Identification

6.1.1. Congestion Conditions (Recurrent, Non-recurrent)

Traffic congestion occurs as roadway use increases, and is characterized by slower speeds, longer trip times, and increased vehicular queuing. When vehicles are fully stopped for periods of time and the cause is not visible from stationary camera poles, the drone application can extend the camera coverage in order to determine the cause of the congestion.

Figure 14. Congested Roadway Conditions

6.1.2. Traffic Incident/Accident

Traffic monitoring from air can be vital to ensure quick detection of the location of an incident and the level of response needed. Certain categories of incidents such as collisions, stopped/stalled vehicles, and debris on the roadway are often followed by severe congestion, especially during peak periods when it can be difficult for ground vehicles to quickly reach the crash location.

Figure 15. Incident Site

6.1.3. Planned/Unplanned Events (Concert, Inauguration, Demonstration, etc.)

The application of UAS can aid advanced planning and coordination to develop and deploy operational strategies, traffic control plans, protocols, and procedures needed to control traffic and to share real-time information with other stakeholders during the day of the event. Planned events such as concerts, inaugurations, demonstrations, etc. frequently require adequate traffic surveillance strategies that include roadways that are not covered by existing stationary surveillance systems.

Figure 16. Planned/Unplanned Events

6.1.4. Unanticipated Events (Natural Disaster, Emergency Evacuations, etc.)

After a large scale natural disaster event, such as a coastal storm, UASs may be deployed before it would be safe for ground vehicles to travel in the affected areas. Large evacuation efforts also require adequate aerial surveillance in order to cover the affected areas.

Figure 17. Unanticipated Events

6.1.5. Roadwork Activities

Drones can be used by surveyors and construction firms to conduct aerial inspections and evaluations of a roadwork site. In addition, users on the ground are able to survey a site in real-time and monitor impact of work zone or lane closure on prevailing traffic conditions.

Figure 18. Roadwork Site

6.1.6. Adverse (Inclement) Weather Events

In traffic operations practice, it is necessary to determine the cause of traffic congestion such as inclement weather conditions, crashes, etc. During inclement weather conditions traffic congestion can increase as the freeway capacity is reduced but the traffic demand remains at its typical level. During these conditions, it is important to determine if congestion is caused by weather conditions of some other factor such as a crash or recurrent traffic congestion.

Figure 19. Adverse Weather Conditions

6.2. Scenarios Development

Scenarios requiring potential UAS system deployment are summarized in Table 1 below. The main role of detection system is to determine the cause of incidents with the minimal cost of deployment .

Table 1. Scenarios and event detection method

Factor	Detection Methods			
	1	2	3	4
Congestion	CCTV	Traffic Analytics	Ground patrol	UAS
Incident/Accident	CCTV	Ground Patrol	UAS	Traffic Analytics
Planned/Unplanned Events	CCTV	Traffic Analytics	Ground patrol	UAS
Unanticipated Events	UAS	Ground Patrol	CCTV	-
Roadwork Activities	Ground patrol	UAS	-	-
Inclement Weather	CCTV	Ground Patrol	UAS	-

For certain factors, it is not possible to determine the cause utilizing conventional detection methods, in such cases deployment of UAS is recommended. On the other hand certain factors (i.e. roadwork activities or inspection) might have a UAS as a preferred detection method.

7. Next Step

The next steps in the process would be to determine the type of program to establish following the CFR Part 107 approach or the Exemption 333 and if each agency will be developing their own program or if this will be constructed as a statewide program. If the statewide program approach is selected then it would be beneficial to establish an in charge entity. This responsibility most likely would be best served by the Aeronautical Division of NJDOT to develop NJ policies and procedures which complement the current FAA regulations and rules. A basic NJ specific training with curriculum to include the NJ policies and procedures as well as the knowledge required to pass the FAA Pilot in charge certification test should be developed. The training and certification program should also be developed to certify the Pilots in charge at both the classroom level and hands on practical flying experience level. It would be beneficial to talk with other states that have implemented these types of programs to gain knowledge on the benefits of each approach. Once that determination is made that will guide the rest of the development of the program. Specialized training specific to each agencies anticipated uses for the UAS should also be developed and administered either by the aeronautical division or could be developed specifically by each agency to educate the pilots in command in the specific needs such as tactical flying for law enforcement, search and rescue for fire agencies, bridge and infrastructure inspections for NJDOT and other training specific to unique uses as they are identified and developed.

Appendix A: List of a Knowledge Testing Centers (KTC) in New Jersey

City	Site	Address	Phone
BEDMINSTER	SOMERSET AIR SERVICE	291 AIRPORT RD.	(908) 722-2444
FAIRFIELD	CENTURY FLIGHT ACADEMY	19 WRIGHT WAY	(973) 575-4800
FAIRFIELD	AIR FLEET TRAINING SYSTEM	35 WRIGHT WAY	(646) 239-3707
FAMINGDALE	**EAGLES VIEW AVIATION	1717 HIGHWAY 34 BUILDING #1	(732) 919-1927
LINCOLN PARK	AERO SAFETY TRAINING, LTD.	425 BEAVER BROOK ROAD, HANGAR 1	973-872-6213
MEDFORD	**FLYING W TESTING CENTER	60 FOSTERTOWN ROAD	(609) 267-7673
MILLVILLE	**BIG SKY AVIATION	103 LEDDON DR	(856) 825-3160
MORRISTOWN	CERTIFIED FLYERS II	50 AIRPORT ROAD, SUITE 140	(973) 539-4080
MORRISTOWN	AMERICAN FLYERS (MORRISTOWN)	50 AIRPORT RD., SUITE 120	(973) 267-3223
MORRISTOWN	A.T.P. - MMU	1 AIRPORT ROAD SUITE 212	(973) 984-4000
PRINCETON	PRINCETON AIRPORT	41 AIRPARK RD	(609) 921-3100
ROBBINSVILLE	**AIR MODS FLIGHT TRAINING CENTER	106 B SHARON ROAD	(609) 259-6877
SECAUCUS	PSI - SECAUCUS	110-B MEADOWLANDS PARKWAY	(201) 210-2411
TETERBORO	**TETERBORO SCHOOL OF AERONAUTICS	80 MOONACHIE AVE	(201) 288-6300
TRENTON	AIRLINE TRANSPORT PROFESSIONALS (ATP), INC. - TTN	MERCER COUNTY AIRPORT	(609) 538-8400
WEST WINDSOR	MERCER COUNTY COMMUNITY COLLEGE	1200 OLD TRENTON ROAD	(609) 586-2318

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