# Net of Innovation

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PROPERTY DRONE CONSORTIUM

# Table of Contents

## The Challenges and Solutions to Safe Outdoor Testing

Use of small unmanned aerial systems (UAS) for claims and risk assessment inspections is a disruptive innovation that will yield new property data products in addition to safety benefits. Organizations that can quickly integrate UAS operations into their business will establish themselves as technological leaders. There are many challenges that need to be overcome for UAS integration to be successful on a large scale.

There is no shortage of UAS manufacturers entering the market but few specifically target inspections. Most of the lower end consumer systems (i.e. DJI, 3DR) target pro and semi-pro photographers and videographers. There few high-end systems that focus specifically on structure inspections. The industry has not seen any that provide a turnkey solution with the necessary automation and process workflow for a successful integration.

In experimenting with high-end UAV systems it can be weeks, if not months, of lead time from order to delivery. In at least one case a section 333 application was processed and approved faster than the unmanned aerial vehicle (UAV) vendor could deliver. Depending solely on UAS vendors to develop and deliver innovative solutions for property inspections does not appear to be a winning strategy.

Over the long term UAS vendors will likely develop systems that meet requirements for property inspections and other more niche markets. In the short term, however, organizations that can proactively develop their own standards, systems and retrofits will fill the current gap. The regulatory and technological environment around unmanned systems is changing at a furious pace. An agile development methodology with short iterations of prototyping, testing and re-evaluation of both internal and external changes is likely the best approach.

One of the most challenging aspects of implementing a plan to collect and utilize imagery and data from UAS are the fairly stringent regulations that the Federal Aviation Administration (FAA) has in place. UAS test flights for commercial purposes in the U.S. National Airspace (NAS) are regulated by the FAA. Even with the recently relaxed regulations that permit Section 333 exemption holders to fly designated UAS in many locations and under a certain altitude, there remain daunting pilot, equipment and flight notification requirements.

What is needed is a way to conduct unlimited test flights in the outdoors (with full access to GPS) without concern of the UAS becoming a runaway. In order for an organization to quickly innovate, there needs to be a way to quickly prototype and test including flying in short iterations without the regulatory overhead associated with current FAA exemptions.

EagleView Technology Corporation consulted FAA officials at the Rochester, NY Flight Standard District Office and developed a solution that will enable Property Drone Consortium (PDC) members and the Rochester Institute of Technology (RIT) to conduct UAS test flights on RIT's campus. The latter is important because RIT is a key player in the development of UAS and remote sensing technologies.

EagleView designed a large (100' x 250' x 45') outdoor enclosure that is covered on all sides by netting that allows the GPS signals to pass through while preventing UAVs from escaping and violating the NAS. The enclosure was designed to minimize environmental and wildlife impacts and to last for many years. The local FAA office approved the concept and stated that such an enclosure would effectively remove NAS restrictions even though the location is within five miles of an active airport with a control tower.

Experts in the fields of bird netting, free-standing structures, safety fencing and more were engaged and involved in the development of the solution. It is not as simple as hanging bird netting from cables strung between poles; the loads that will be placed on the structure will be significant due to the size of the enclosure. The enclosure will provide a major advantage to the PDC and to RIT in remaining at the lead of development of UAS technologies.

The netted enclosure will allow for flights of a wide variety of models of UAS. Because the area inside the enclosure is not in the NAS, testers can fly any UAS model, not just the ones that are associated with the Section 333 exemptions. NOTAMs are not required nor is a pilot with a pilot's license or certificate needed for operating the vehicles. Flights can occur during the day or at night and under most any weather conditions, all while maintaining operator and observer safety and compliance with FAA regulations.

The size of the enclosure will be most suited to multirotor UAS flight testing, but small, fixed-wing UAS flight testing could also occur. The enclosure will be large enough to allow the construction of small buildings and mock-ups for flight testing around structures, and data collection at close and very close ranges. Object detection, collision avoidance, sensor-controlled and programmed flight around complex

objects will be able to be performed in nearly real-world conditions. A great deal of knowledge will be attained through this facility.

## Types of Testing a Netted Enclosure Enables

### *Flight Plan Testing*

Initially UAS property inspections can be flown manually over properties with ideal characteristics such as minimal obstructions and simple roof lines. Even under these circumstances it will require a skilled operator that can navigate around a structure, maintain an appropriate distance to achieve the required image resolution, while ensuring that they have complete coverage of the structure. In addition, the operator needs to ensure that the UAS stays inside the lines of the property owner's parcel so it is not trespassing on a neighbor's property (depending on air right laws). When considering medium to high winds this quickly becomes a difficult task.

Property-centric flight planning used in conjunction with a UAS equipped with GPS and various object sensor technologies can significantly reduce the burden on the operator. A property-centric flight planning solution would map out a plan to automate the UAS flight and ensure complete coverage of a given property and all the structures on it. The operator could then focus on the safety aspects of the flight.

A netted enclosure the size of a small parcel allows flight plan testing that has been customized for a property and/or structure. It creates a controlled environment to ensure that a UAS executing an errant flight plan will not fly off.

### *GNSS a.k.a. GPS*

*Global navigation satellite system (GNSS) is the generic term for GPS that will be used in this section going forward. GNSS is used instead of GPS because there are multiple GNSS systems offered by the U.S., Russia, China, the EU, etc. GPS is the GNSS created and maintained by the United States government.*

GNSS in combination with other sensors such as a barometer is the most popular means for a UAS to know where it is in the world. UAS conducting property inspections will be in close proximity to structures they are capturing, meaning position accuracy is critical. The U.S. GPS offers accuracy of

roughly 3.5 meters per FAA real-world data but accuracy and the overall reliability can be improved with a variety of methods. One example is real-time kinematics (RTK) which can use a reference station to achieve centimeter level accuracy. Another example is one-chip, multi-GNSS receivers that increase reliability by combining the United States' GPS and Russia's GLONASS constellations.

GNSS signals are relatively high frequency and low power by the time they are received on the surface of the earth. This makes it very difficult to test UAS systems that use GNSS positioning inside a building and in many cases, even in close proximity to a building.

An outdoor net provides an ideal enclosure for testing GNSS technologies on UAS and the reliability of GNSS under different conditions. GNSS signals can easily pass through the net while the net ensures that a UAS equipped with an unproven or prototype GNSS does not become a runaway. Flight plans can be executed repetitively to verify that a particular GNSS solution is statistically reliable enough for daily operations in a residential neighborhood.

## *Obstacle Avoidance and Collision Detection*

A UAS performing a property inspection will need to operate inside parcel boundaries, over and around the structures while avoiding trees, utility lines and the structures being captured. Obstacle avoidance systems will help prevent collisions with obstructions that could not be accounted for in the flight planning. A UAS obstacle avoidance system may implement multiple sensor types to overcome the weaknesses of any one sensor. Ultrasonic transducers and laser range finders are examples.

In the event that obstacle avoidance and human intervention fails it will be important for the UAS to detect collisions and handle them appropriately. For example, a multicopter with exposed propellers might shut the propellers down to minimize the amount of damage done. A multicopter with fully enclosed propellers may simply bounce off the obstruction and dynamically map the obstruction location in the flight plan.

A lot of obstacle avoidance and collision detection testing can be done indoors but eventually there is a point where real outdoor flight testing needs to be done. This is another area where a netted enclosure can provide a real-world testing environment and prevent the UAS from running away in the event of a failure.

## *Imaging*

Initially UAS property inspections may focus on capturing damage for claims in the RGB visible light spectrum but more advanced applications may implement multi-spectral, thermal and various other sensor technologies. Much of this testing can be done indoors under controlled lighting conditions and outdoors with feet on the ground but ultimately imaging sensors will need to be tested outdoors and in flight.

Testing outdoors is required to see how imaging systems perform in real-world, uncontrolled lighting situations. Flight testing imaging sensors is required to see how the sensor is affected by vibration, radio frequency (RF) noise and supply voltage ripple. In addition it is important to evaluate sensor cycle time and sensitivity under various lighting conditions. This will help determine how fast the UAS can move during a capture to ensure coverage and mitigation of motion blur. Focus and optic performance also need to be tested to verify any applicable depth of field given the operating distance between the UAS and a structure under inspection.

An outdoor netted enclosure is ideal for this kind of testing because it allows natural light through.

## *Radio Range Testing*

A UAS may implement multiple radios for control, video, telemetry, etc. Range testing can be done on the ground but outdoor flight testing is necessary to establish how the various radio links will behave in flight. The motors and electronic speed controls on a UAS may generate electronic noise that can interfere with its ability to receive a control signal.

The largest multicopter vendors including DJI, Parrot, and 3DR all use the crowded 2.4 Ghz spectrum for multicopter control. In some cases they are using Wi-Fi and in others it is one of the RC protocols. Some systems use the 5.8 Ghz spectrum for either dual-band Wi-Fi or analog/digital video transmission. In any case it will be important to perform flight testing to see how interfering devices such as Wi-Fi access points, phones, etc. will effect range and bandwidth. Systems that use the 5.8 Ghz band are likely to be more problematic when traversing behind a structure in a first person view (FPV) scenario. This is because higher frequencies generally have poor penetration and reflection characteristics. They therefore suffer greater attenuation in situations where there is no direct line of sight.

Performing in-flight range testing inside a net is essential to ensure the UAS will not run away if/when one of the RF links fails. Repetitive testing can help establish maximum safe operation ranges with different platforms and radios.

## *Penetration Testing and Vulnerability Assessment (security)*

Rarely does a week go by without a new data breach incident or a new security exploit discovered in an operating system, software package, etc. Unmanned systems have a microcontroller running software and communicate using protocols that may have security exploits like any other device that runs software. There have already been reports of drone hacks and, given the media attention, it is likely they will become a favorite target for hackers.

Penetration testing (pen testing) and vulnerability assessment will be critical to ensure that any UAS platform does not present an easy target for hackers. In an effort to rush UAS platforms to market, many vendors may have put security on the back burner. Some platforms appear to have little or no security measures in place to prevent a malicious user from taking control of the UAS in operation.

Since this type of testing may compromise the UAS flight controller or control system it will be important to perform the testing in a netted enclosure to prevent a runaway.

## *First-person View Testing*

Currently the FAA requires direct line of site for all sanctioned UAV operations (even with a 333 exemption) but in the future they may allow first person view (FPV) operations via video. Testing FPV operations will need to occur inside a netted enclosure until the FAA approves FPV operations. Even then, it will still be important to perform FPV range testing inside a netted enclosure to prevent runaway incidents.

## *Testing Off-the-shelf and Prototype UAS Platforms*

Part of the task of developing a property inspection reference platform involves testing new, off-the-shelf UAS platforms as well as prototypes developed in-house. In both cases where a particular platform has not been proven it makes sense to conduct at least the initial flight test in a netted enclosure to prevent the UAS under test from running away. This also allows for immediate testing of new and prototype platforms without filing and waiting for FAA COA approval.

## Understanding the Importance of Testing

As the FAA continues to allow exemptions, the types of testing that will become available for researchers will grow but utilizing contained (netted enclosures) for safe research is critical. As new UAVs come into the market researchers will need the ability to contain them allowing research to move faster and safer for all involved.