Concepts for Remote Identification

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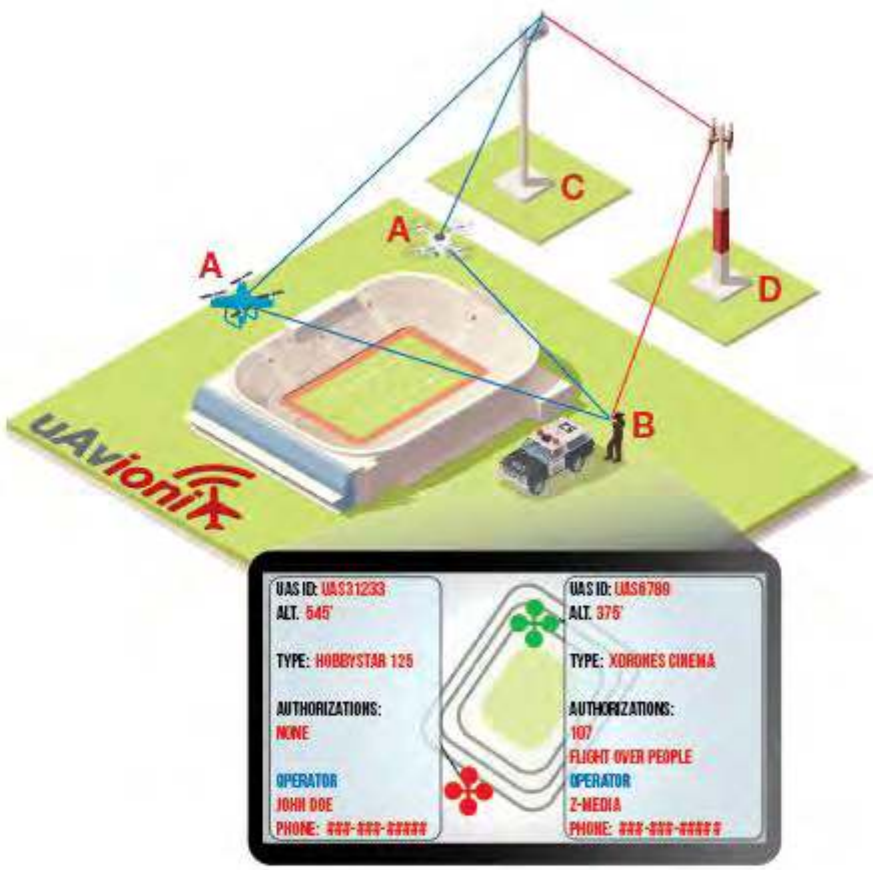

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1 Introduction

uAvionix Corporation is pleased to provide this response to AUVSI's Call for Papers (CFP) on Remote Identification (RID) for Small UAS (sUAS). uAvionix recognizes the importance of Remote Identification as a required next step in drone regulation as published in a blog article just two days prior to the AUVSI CFP was released. In this paper, we present core concepts of an RID solution which can be used both in and out of an internet-denied environment, fits the size and cost constraints of the industry, and provides a basic level of anti-spoofing capability. In support of this response, uAvionix has collaborated with the following organizations for the noted content:

- AirMap: Drone ID for secure verification of a sUAS unique identity.
- Harris Corporation: For potential infrastructure usage and testing location through a joint sUAS services network at the Northern Plains UAS Test Site.

2 About uAvionix

Founded with the specific intent of providing small size, weight, and power consumption (SWaP) components for sUAS communications, navigation, and surveillance (CNS) – uAvionix is the leading avionics solution provider for sUAS. With a product line consisting of Technical Standard Order (TSO) certified GPS receivers, ADS-B receivers and transceivers, and Mode A/C/S transponders, uAvionix has developed custom application specific integrated circuit (ASIC) solutions which range from 1 gram to 70 grams with transmit power outputs ranging from 0.01W to 200W.

At the core of its receive/transmit (Rx/Tx) radio products is a custom-built software defined radio (SDR) which can not only operate within the ADS-B and Mode A/C/S protected aviation spectrum frequencies, but also in open industrial, scientific, and medical (ISM) radio bands applicable in the US and internationally.

All solutions provided within this paper leverage existing ASIC and hardware components within the uAvionix product line – resulting in Technology Readiness Levels (TRL) at the high end of the scale (6-9).

Figure 1: uAvionix solutions range from 1 to 70 grams

3 Assumptions

uAvionix has made the following assumptions regarding the requirements for a RID solution.

1. The primary purpose of the RID solution is for law enforcement or security personnel to remotely identify the sUAS aircraft and operator through a number of key parameters to be transmitted from an RID transmitter onboard the sUAS and received by receivers which may be handheld, permanently mounted, onboard other aircraft, or anywhere within range of the RID transmitter.
2. Other functions beyond the primary purpose stated may serve to increase the utility of the RID system, but benefits of additional functions must be weighed against additional cost or time to feasible widespread deployment. For example, an RID solution may aid in surveillance or Detect and Avoid (DAA) applications, but any such specific requirements may delay implementation of RID.
3. Data items transmitted from the sUAS RID would include at a minimum the FAA UAS registration number and sUAS position. This concept is not unlike a license plate on a vehicle or an N-Number on an aircraft which can be used by an eyewitness of a dangerous event to provide information to law enforcement for further investigation.
4. Considerations for spectrum congestion must be considered. With the potential for very high density sUAS traffic in the future, efficient use of spectrum is required to not adversely affect system performance. Means for mitigating spectrum use include, but are not limited to low-power transmissions, minimal transmission payload, transmission intervals, frequency modulation, and transmission only as a result of interrogation.
5. Size, Weight, and Power Consumption (SWaP) of any RID airborne devices should be consistent with sUAS platforms. The smallest aircraft should be targeted to support the maximum number of sUAS possible. This includes popular consumer models which are being used for professional purposes.
6. Considerations for anti-spoofing or source verification should be included.
7. The cost/price of RID devices should support regulatory mandates which would require compliant RID devices on significant quantity of sUAS – possible quantities for consideration include:
    - RID devices on all sUAS over 0.55lbs (consistent with Part 107 registration requirements)
    - RID devices on all sUAS registered to licensed Part 107 operators or organizations
8. Installation options should range from solutions which are an integrated part of the sUAS "out of the box" as delivered by the sUAS OEM to those that are purchased and installed as "add on" or "aftermarket" units.
9. The ground based component should offer a range of options which include receivers which are portable in nature, those which can be permanently installed, and those which work with and without LTE or internet coverage areas.

4 Technology Description

The overall solution is architected to work with or without internet connectivity and provide maximum flexibility and deployment options. At its core, the following components establish the basic functionality.

1. Airborne RID transmitter which broadcasts sUAS position and operator identifying data.
2. Ground based RID receivers. Options for pocket-sized mobile receivers for roaming security personnel as well as permanently fixed receivers for persistent monitoring.
3. Mobile app or apps which can operate in an internet denied or internet available environments to provide sUAS position and operator identifying information to viewer, as well as connectivity to the FAA registration database, UTM service providers, and publicly trusted TLS/SSL certificate for anti-spoofing capabilities such as AirMap's Drone ID.

Figure 2 shows an overview of the uAvionix RID Operational Concept in an internet/LTE denied environment, while Figure 3 shows the RID Operational Concept in an environment with internet/LTE access.

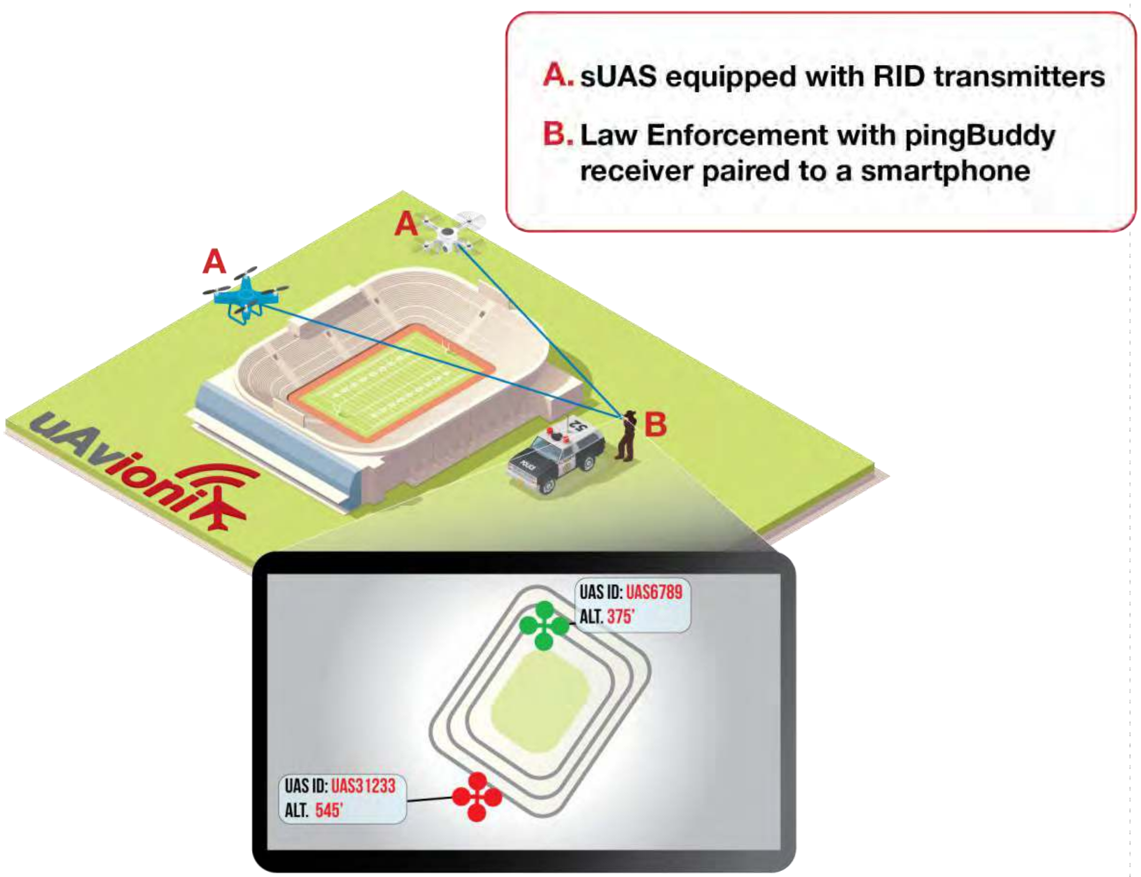

Figure 2: uAvionix Remote ID Operational Concept without Internet/LTE Connectivity

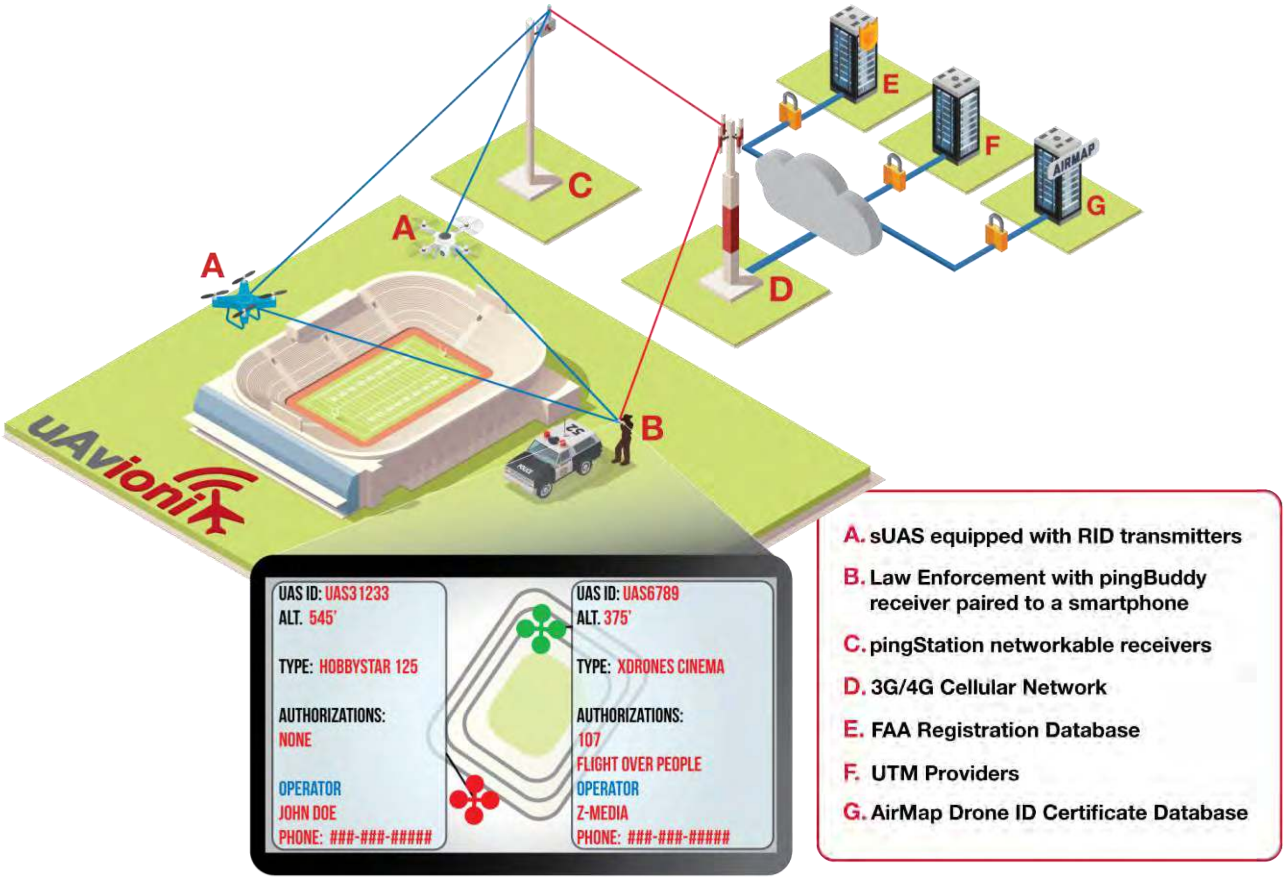

Figure 3: uAvionix Remote ID Operational Concept with Internet/LTE Connectivity.

The following description assumes the regulatory environment mandates RID equipment onboard the sUAS. Depending upon the extent of the mandate and upon the level of integration supported by the sUAS OEM, the RID transmitter may be integrated tightly into the sUAS aircraft, or carried as a separate "stick on" solution. Prior to the operation, the sUAS operator will configure the identifying information into the RID through the use of an app. Figure 5 is a screenshot of an existing configuration app for uAvionix products which connects via Wi-Fi hotspot to the device for parameter configuration. The fields in the app shown in the screenshot would be adapted to the appropriate fields for the RID device. The RID will transmit at a minimum the sUAS registration number and position data (latitude, longitude, altitude) of the sUAS and optionally a TLS/SSL AirMap Drone ID signature that can be used for source validation. uAvionix proposes transmitting minimal data at no greater than 1Hz at low power (discussed below) in order to enable efficient use of spectrum at scale. This basic data will allow visual correlation of the aircraft with the position on a map, optionally provide a digital signature for source validation, and provide either law enforcement or an uninvolved visual observer with the ability to report to law enforcement basic information which may be used to investigate an incident further.

Two different types of receivers are envisioned. A portable receiver would allow security personnel to receive the RID signal, and through a Wi-Fi hotspot within the receiver itself, would allow the user to observe the sUAS location on a map within an app with the identifying information. The mobile receiver and app will work in an internet denied environment in this basic mode. If in an internet available environment, additional features in the app would provide more information such as registration and flight plan data through integration with the FAA registration database and/or UTM-like applications such as PrecisionHawk's LATAS or AirMap platforms. Figure 4 shows a sample air traffic mapping application using existing uAvionix products to display nearby air traffic. The app display would be customized for the RID functionality.

In addition to the portable receiver, a networkable fixed-base receiver would allow a permanent installation to provide RID coverage in desired areas, such as sports arenas or other populated areas – and populate any number of mapping or UTM like applications.

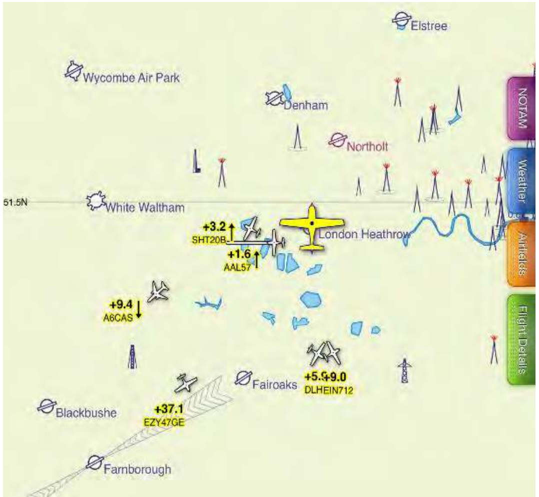

Figure 4: uAvionix receivers connect to a number of existing airspace awareness apps using a Wi-Fi hotspot connection and GDL90 protocol.

5 Technology Operational Concept

5.1 User Interface (UI) Applications

There are two different types of UI applications. Configuration apps, and RID display apps. The configuration app is used by the UAS Operator, and the RID display app is used by law enforcement or security personnel.

5.1.1 Configuration Application

The configuration application is produced by uAvionix and is used currently to program user specific configurations into uAvionix transmitting devices. Each device (including the proposed RID) includes a Wi-Fi hotspot capability. Upon connecting to the hotspot using an iOS or Android device, the user launches the "Ping" app which provides the capability to configure aircraft and pilot specific parameters as required. Upon entering the configuration data and selecting "Update" – the device is programmed with the configuration data which is stored in non-volatile memory for persistent storage.

Figure 5: The Existing Ping Configuration App will be Modified to Include Remote ID Specific Parameters

5.1.2 RID Display Applications

The RID Display Application is used to observe and identify sUAS while in flight. The app has a "standalone" mode which can be used in an internet/LTE denied environment – and a "connected" mode which provides additional information if connected to additional receivers and databases through the internet.

5.1.2.1 Standalone Mode (Internet Denied)

Figure 6: pingBuddy Mobile Receiver displaying traffic on an iOS Application

When in standalone mode, only data received from the RID transmissions within range of the connected mobile app is available. This would include all parameters determined to be appropriate for the RID transmission, including at a minimum the FAA registration ID, digital signature, and position information of the sUAS. This data is used to plot the sUAS on a basic map, which is stored as a downloaded item onboard the iOS or Android device. When using a mobile receiver (see "pingBuddy" in Section 5.8), the user will connect to the Wi-Fi hotspot in the pingBuddy receiver to establish a data connection. The data will be transferred over Wi-Fi to the RID Display application, which will then display the sUAS location, altitude, and available threat information on a map display. Tapping the sUAS on the map will bring up any additional information available from the RID transmissions. Figure 6 illustrates the mobile receiver with a Wi-Fi connection to an iPad mini, displaying local air traffic. Basic validation can be accomplished in this environment. The application will know if the transmissions came from the correct private key and the information was not spoofed. Upon connection to the internet at a later time, the app would check the Certificate Revocation List (CRL) to ensure the certificate was not on it and that the private key has not been compromised.

5.1.2.2 Connected Mode (Internet Available)

When in connected mode, additional information may be available to the user. This can include a direct connection to the FAA registration database for user lookup functions, or connections to Unmanned Traffic Management (UTM) systems for sUAS flight plan and aircraft data. The CRL can be accessed during real-time, and notify the user if the private key has been compromised or if the key was not on the CRL. If utilizing a permanent ground based network of receivers (see Section 5.8), connected mode will allow all sUAS tracked by the network of receivers to be displayed in the app.

5.2 Supporting Infrastructure

The uAvionix proposal includes the ability to operate in an environment with no supporting communications infrastructure – to include LTE or internet connectivity - by providing the ability to connect to a pocket-sized mobile receiver (pingBuddy). This provides maximum flexibility for security operations.

However, the solution also has the ability to take advantage of internet/LTE connectivity by providing additional capabilities and options beyond the basic identification provided by the mobile receiver. In addition to connectivity to FAA registration databases and UTM applications, the uAvionix solution also offers the ability to permanently install a network of RID receivers for permanent coverage of defined areas. If internet/LTE connectivity is available, the app provides the capability for the surveillance data provided by those networks.

5.3 Technology Readiness Levels (TRL)

The proposed solution offers a basic TRL 9 capability immediately, with decreasing levels of TRL as more complex options are integrated.

The proposed solution utilizes existing uAvionix hardware solutions which are fielded at TRL 9 to include both airborne and ground components. Software/firmware updates are required to shift communications into an ISM frequency band and configure the transmitted data “payload”. However, such software modifications are minor and the software/firmware is assessed to be at TRL 8.

The iOS and Android configuration application updates are currently in operational use at TRL 9 and would require only minor updates to include FAA registration and pilot information.

AirMap’s Drone ID is operational at TRL 9.

For technology/demonstration purposes – uAvionix will map the RID data into the existing GDL 90 protocol which is used by a large number of airspace traffic awareness applications. A purpose-built application is possible, but not necessary for technology demonstration purposes. Under this structure, any of the following iOS or Android apps in Figure 7 will be able to display RID targets:

- SkyDemon
- iFly GPS
- ForeFlight
- Fltplan Go
- FlyQ EFB
- Naviator
- AvPlan
- WingX Pro
- Aerovie
- Avare
- EasyVFR

Figure 7: Compatible GDL 90 Applications

Integration of all high TRL components into a single application and hardware suite are at mid-levels of TRL (4-6).

uAvionix can have hardware and configuration software ready for operational testing/demonstration **within 30 days** from notification of desire to continue which would include the following:

- RID Hardware (transmitters and receivers)
- RID Configuration Application
- Usage of existing GDL 90 compliant display application

Additional functionality, including integration of AirMap Drone ID and White Space database integration (See Section 5.5.2) may take an additional 90 days.

In consultation with this response, Harris Corporation has offered a location which to integrate and test an RID network. A recently announced partnership between Harris and the Northern Plains UAS Test Site for the creation of a Beyond Visual Line of Sight (BVLOS) network for drone operations offers infrastructure for integration of an RID network for demonstration and testing.

5.4 Reliability Assurance / Continuity of Service

All uAvionix equipment is built to high performance and quality standards. Products are designed and assembled in the USA, HALT and HASS tested, IPC-610 class II soldering, production functional testing.

uAvionix recently achieved its first Technical Standard Order (TSO) from the FAA. The TSO signifies that the FAA has examined, audited, and approved the quality and manufacturing processes for consistent high quality critical aviation avionics.

Optional functions requiring internet/LTE capability are subject to the reliability and availability of those service providers.

5.5 Spectrum

uAvionix ADS-B equipment currently operates within the protected aviation spectrum for ADS-B in both the 978MHz and 1090MHz frequency ranges. However, the underlying software defined radio at the core of uAvionix technology has some limited ability to frequency shift into other bands. (See also Section 6.1 regarding an option for an ADS-B only based solution.)

uAvionix recommends the following two options for frequency usage. Both options offer superior free space path performance and obstacle penetration.

5.5.1 Repurposing Distance Measuring Equipment (DME) Lower Bands

Distance Measuring Equipment (DME) are navigation aids used by manned aircraft. Recent discussions with FAA indicate that there may be an opportunity to repurpose a subset of the DME frequency bands for UAS surveillance. This has a precedent, as a similar repurposing was undertaken for 978MHz Universal Access Transceiver (UAT) ADS-B technology. The primary advantage for this recommendation is the selected frequencies can remain in the “aviation protected spectrum” range and remain under the purview of the FAA for enforcement of infringements. uAvionix can easily adopt current receivers to the 960MHz to 1090MHz range, with better performance at the low end.

5.5.2 TV White Space

White Spaces refer to frequencies allocated to a broadcasting service but are not used locally. This can be due to lack of TV or radio stations assigned specific frequencies in a region, or due to freed spectrum as a result of technical changes (such as the switch to digital television). A TV White Space database, or geolocation database – provides frequencies that are available for use in a specific geographic location. The advantage to this solution is that the geolocation database is a known entity within the industry and the frequencies are freely available without requiring a spectrum license. The disadvantage is that it adds complexity to the overall solution in that the RID device would “frequency hop” based upon its location, and a mechanism would be required to update the database whenever changes are made.

5.5.3 Other Less Desirable Options

The following are other frequency options that have stated limitations:

- 315MHz and 433MHz are legacy ISM bands used for garage door openers and keyless entry systems.
- 915MHz is an ISM band principally used for cordless landline phones.
- Any frequency above 1GHz will have multipath and fading issues due to the short wavelength, and requires line of sight (LOS).

It is expected that further discussion would be required with FAA and FCC regarding which frequency would be most desired.

In order preserve spectrum capacity and avoid system degradation at scale and high sUAS traffic volumes, uAvionix recommends very low power transmissions. The following are recommended power settings and their associated ranges of visibility within LOS.

Transmission Power	LOS Range
10mW	0.5 Miles
100mW	4 Miles
500 mW	10 Miles

For reference, a recent study published by MITRE indicated that 10mW ADS-B transmissions would support 14,000 sUAS under 500’ within a 30 mile diameter airspace without degradation.

Usage of LTE and internet communication networks were discussed in Section 5.2.

5.6 Limiting Factors

A limiting factor of the uAvionix or other solutions is in regards to the level of integration required with the host sUAS aircraft electrical and/or autopilot system.

All solutions offered will likely require a power source. The most reliable solution is to pull power from the sUAS system. In doing so, battery life and the resultant flight time for electrical sUAS is potentially reduced. The uAvionix RID device is estimated to require 90mA from the host sUAS, which is significantly less than is required from an LTE modem (typically 500mA), and will have negligible impact on flight time. Most professional grade sUAS are equipped with suitable auxiliary power source outlets, but there is a subset of all aircraft that do not have this capability, in which case a battery is required.

If the solution is instead paired with a portable battery – not only is reliability lowered, but increased weight on the aircraft would result in an overall size and weight degradation as compared to the integrated power source.

Many of the value-added features discussed within Section 6 require some level of integration with the sUAS autopilot. These features increase overall safety and security, but require the regulatory bodies to consider regulations on the autopilot interfaces.

The anti-spoofing digital signature is in itself a limiting factor. As minimal payload is desired for spectrum efficiency – the inclusion of the digital keys in each message itself increases the size of the RF payload to many times the size of the sUAS position and identification data itself. In turn, this results in reduced spectrum capacity. For full implications, spectrum utilization should be modeled analyzed.

5.7 Airborne Component

uAvionix is proposing to repurpose existing hardware, updated with new firmware for an RID device. The following components will be integrated into the existing uAvionix FYXNAV form-factor. FYXNAV is the world's smallest and lightest TSO certified GPS receiver and antenna. It weighs just 27 grams, has a 42mm diameter and an 18mm height.

Figure 8: The uAvionix RID will exist in a form factor similar to the existing FYXNAV GPS receiver.

The RID product in its base form will include the following:

- GPS Receiver and antenna
- 10mW (suggested) Transmit/Receive radio on TBD frequency. See Section 5.5.
- Persistent memory for configuration storage
- Integrated barometer for approximate height above launching point
- Wi-Fi for hotspot configuration.

The uAvionix base RID device is designed to be a "stick-on" device with no required electrical or data integration to the sUAS. However, aircraft and autopilot integration provides several additional benefits which are discussed in Section 6.

5.7.1 RID Chip

uAvionix also has the capability to provide the RID Tx/Rx chip to sUAS OEMs for direct integration into the aircraft to leverage the existing sUAS GPS, power, and autopilot connectivity. The RID chip is smaller than a dime and weighs only 1 gram.

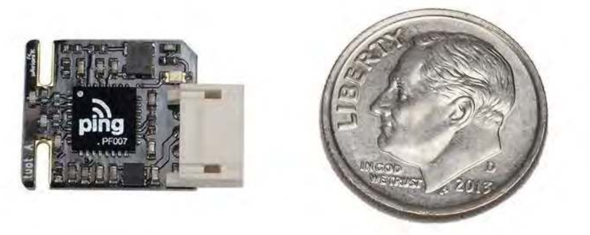

Figure 9: The uAvionix Ping RID Chip Can Be Integrated Directly into sUAS through OEM Integration for "Out of the Box" functionality.

5.8 Ground Component

Much like the airborne component, the ground component consists of existing uAvionix product hardware repurposed with updated firmware to meet the RID mission and frequency. Figure 10 illustrates the pingBuddy mobile receiver and PingStation permanent receiver.

Figure 10: uAvionix portable "pingBuddy" receiver (Left) and networkable, fixed installation receiver "pingStation" (Right)

5.8.1 pingBuddy Mobile Receiver

The pingBuddy mobile receiver in its current form is a dual-frequency ADS-B receiver powered by micro-USB connector with integrated Wi-Fi for wireless connectivity to Electronic Flight Bag (EFB) applications. An updated firmware for the RID mission will frequency shift from the ADS-B frequencies to the target RID frequency. pingBuddy is small enough to fit in the pocket or glove compartment of every police cruiser. pingBuddy was recently featured by Flying Magazine's Gear Review as a Pilot Must Have item.

In single quantities, pingBuddy currently retails for $149, which is already an affordable solution. With high quantities, pingBuddy could reach $40-$60 each.

5.8.2 pingStation Receiver

PingStation is a dual band (978MHz and 1090MHz), networkable ADS-B receiver with a Power-Over-Ethernet (POE) interface enclosed in an IP67 rated protective enclosure. PingStation provides ground surface or low-altitude surveillance within line of sight of the antenna, with range dependent upon the output power of the transmitting ADS-B transceiver. PingStation is robust enough to be permanently mounted outdoors in harsh environmental conditions, and small enough to be used as a mobile asset for roaming operations. Installation is simple with included pole-mount bracket, and a single POE cable which provides both power and data communications. Configuration is accomplished via a simple web interface. An integrated GPS provides precision timestamping for messaging.

PingStation networks can be deployed either as a wired LAN/WAN configuration, or as a wireless network leveraging LTE modem technology for easy installation and deployment.

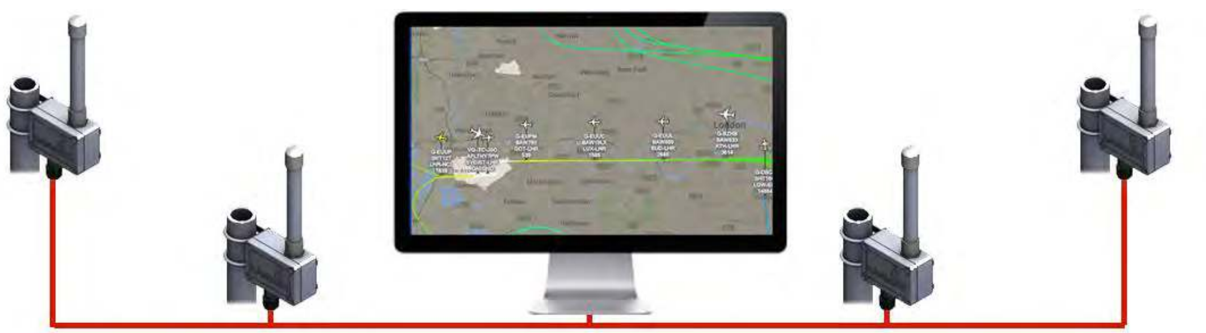

Figure 11: Multiple PingStations may be networked together to provide a wide area low-altitude RID and surveillance volume.

Rather than frequency shift the ADS-B receiver within PingStation to the target RID frequency, uAvionix will add an additional RID receiver to the existing PingStation enclosure. This then will provide low-altitude ADS-B surveillance as well as low-altitude RID coverage within LOS of any of the networked PingStation receivers.

PingStation has an open protocol that can be used to integrate the surveillance and RID data into any geospatial information system (GIS) display or airspace awareness display – both cloud based and locally managed. The cloud based solution would allow the RID display app to access a wide region of surveillance and RID data.

6 Value added Options

In addition to the base functionality described herein – uAvionix brings the capability to add value-added functionality that would benefit the operator, security personnel, and all airspace users.

6.1 Low Power ADS-B Only Solution

The use of low power ADS-B as the Remote ID protocol and frequency itself has significant merit. Rather than shifting to another frequency, remaining in the ADS-B spectrum (particularly 978MHz UAT) significantly increases safety benefits due to interoperability with manned aviation. Low power (0.01W-0.1W) provides electronic conspicuity from 1-5 miles to nearby aircraft while being compatible with the spectrum capacity at high traffic densities as outlined in a recent MITRE publication titled "ADS-B

Surveillance System Performance with Small UAS at Low Altitudes." uAvionix recently published an article on this concept.

6.2 Two way communications – remote "land now" signal.

The uAvionix RID device is both a transmitter and receiver. This enables authorized security personnel to send a signal to the RID to command the autopilot to perform any number of functions. To enable this functionality, the FAA would need to consider mandating "hooks" into sUAS autopilot systems to respond to remote commands which would be unable to be overridden by the operator. Examples of simple remote commands are:

- Land Now
- Return to Home
- Hover/Orbit
- Proceed to GPS Waypoint
- Kill Switch

All of the above commands could be implemented with simple discrete IO, with the exception of the GPS waypoint, which would require the ability to transmit a "go to" location.

6.3 Low Power Inert and Alert ADS-B

Given the heritage in ADS-B, the uAvionix RID applications have the ability to "listen" for nearby manned aircraft transmitting ADS-B position information. If the nearby manned aircraft encroaches within a predefined radius (for example 3NM), the RID device can begin to transmit a low-power (10mW-500mW) ADS-B "beacon" signal that would alert the manned aircraft of the sUAS presence from 1-10 miles away.

6.4 sUAS to sUAS Mesh Network to Extend Range

In addition to broadcasting its own RID position and identification information, each RID device can act as a "repeater" for other RID devices which may be out of range of a ground receiver. Signals from each RID device would be intelligently rebroadcast by other airborne RID devices, extending the effective range of any ground based receiver by leveraging the airborne receivers as repeaters. This could even be deployed selectively and intentionally by security personnel who would purposely launch a repeater RID sUAS which would be used as a high-altitude receiver. See Figure 12.

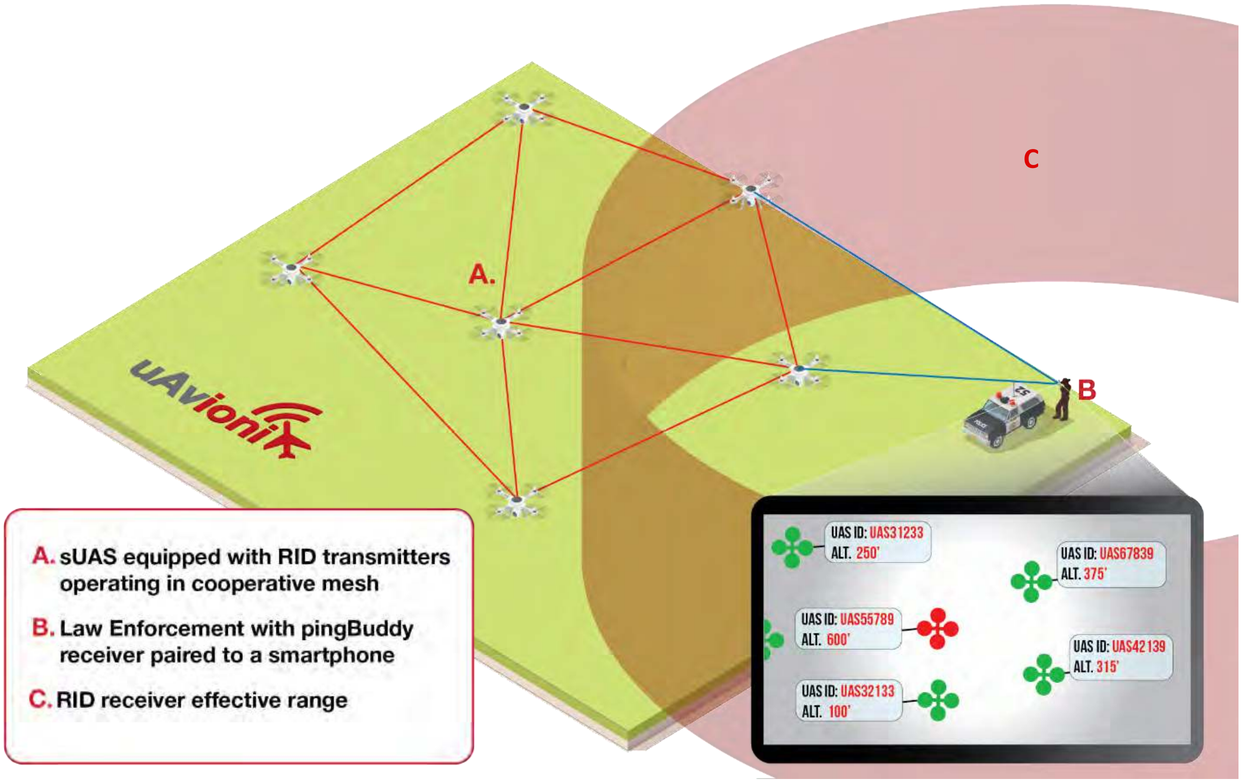

Figure 12: A Mesh Network of Intelligent RID Repeaters Extends the Effective Range of any One Receiver.

6.5 Black Box Data Recorder

Integrated onboard storage of the host aircraft sUAS, as well as data regarding nearby sUAS (leveraging the onboard receiver) can be implemented to aid in incident investigations. The advantage of leveraging the onboard receiver is that meaningful data can be retrieved regarding the sUAS involved in the incident even if the target sUAS is destroyed and data is not retrievable from its own systems.

7 Benefits of the uAvionix Concept

In summary, there are many benefits to the proposal concept that uAvionix is offering for a Remote ID Solution.

- The airborne solution meets the SWaP profile required for sUAS.
- The unit costs at scale support a regulatory mandate for RID equipment on board all registered sUAS, or sUAS operating under Part 107.
- The receiver solutions offer both low cost portability and low cost fixed installation options.
- The solution can operate with or without internet/LTE infrastructure.
- High TRL levels for basic components, allowing for near-term widespread deployment.
- Value added options which increase security, increase safety to other manned aircraft, and extend range without additional infrastructure

Finally, uAvionix suspects that many offered solutions will use LTE as a backbone technology for the offered solutions. Therefore, below are some comparison points for LTE solutions for consideration.

7.1 LTE Solution Comparison

As compared to a solution that requires an internet or LTE backbone to deliver the RID security services, the uAvionix proposal has the following advantages:

- Lower lifecycle cost. Both an onboard RID LTE device and security personnel operator device require a recurring subscription based data plan. The uAvionix solution requires neither, although additional services are available with an internet/LTE connection.
- LTE modems onboard the sUAS will require a higher power draw resulting in shorter flight times due to increased power consumption directly from the sUAS or through added weight of a larger battery.
- Both the sUAS and the receiver need to be within coverage of the LTE network for the system to function.
- Technological obsolescence and end of life (EOL). Non-dedicated infrastructure and networks such as LTE are dependent on carrier technology lifecycles, which risks relatively near term obsolescence when compared to traditional aviation infrastructure.
- LTE frequency bands vary widely by region, and present a difficult challenge when designing and certifying product. A single, internationally compatible solution provides greater coverage and higher security.