UK CAA AIRSPACE MODERNIZATION STRATEGY – ELECTRONIC CONSPICUITY SOLUTIONS – A CALL FOR EVIDENCE

CONSULTATION RESPONSE: UAVIONIX CORPORATION

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1 Introduction and Background

uAvionix is pleased to present the following response to the United Kingdom (UK) Civil Aviation Authority's (CAA) Consultation on Airspace Modernization Strategy, titled "Electronic Conspicuity (EC) Solutions, A Call for Evidence" on a new strategy.

uAvionix was founded in 2015 with the mission of bringing safety solutions to the unmanned aviation industry in order to aid in the integration of Unmanned Aircraft Systems (UAS) into National Airspace Systems (NAS). A fundamental principle of that mission is to provide solutions which would provide all airspace users a common situational awareness of the airspace around them to enhance safety. Naturally, Automatic Dependent Surveillance-Broadcast (ADS-B) became a foundational technology to build upon due to the growing number of manned aircraft equipping with ADS-B around the world. Providing ADS-B IN and, in some use cases, ADS-B OUT technologies for UAS furthered that goal. Through the evolution of that technology and our company, we have now developed and received Technical Standard Order (TSO) certification for ADS-B and Global Positioning System (GPS) solutions for the General Aviation (GA), UAS, and airport markets.

2 Consultation Feedback

2.1 Closed Questions

2.1.1 Should the CAA act to coordinate the adoption of interoperable EC solutions in targeted blocks of airspace?

Yes

2.1.2 Do you agree with our strategy to coordinate the full adoption of interoperable EC solutions in targeted blocks by using location specific mandates?

Yes

2.1.3 What EC functions should the CAA focus on when coordinating adoption?

4) a combination depending on the need. (see further feedback)

2.2 Open Questions

2.2.1 What evidence should be used?

The following articles, studies, and white papers discuss and categorize the benefits achieved as a result of the U.S. implementation of ADS-B:

1. "Study Shows Accidents Less Likely with ADS-B IN"[i] – AOPA April 18, 2019. "A study that examined the effect of Automatic Dependent Surveillance – Broadcast (ADS-B) In on general aviation and air taxi accident rates found a significant reduction in the likelihood of an accident, which decreased by 53 percent, for aircraft equipped with ADS-B In."
2. "Measured Impact of ADS-B In Applications on General Aviation and Air Taxi Accident Rates"[ii] – Regulus Group.

3. “Expanding ADS-B Radio Station Coverage to Increase Safety Benefits and ADS-B Out Equipage for General Aviation”[iii] – letter from AOPA to FAA Surveillance and Broadcast Services Office – Jan 23, 2017.
4. “ADS-B: Seeing Clear Benefits – Pilots Praise ADS-B Traffic Information”[iv] – AOPA July 5, 2016.
5. “Prevent Midair Collisions: Don’t Depend on Vision Alone”[v] – National Transportation Safety Board (NTSB) – NTSB Safety Alert – November 2016.

2.2.2 Have all the options been considered?

uAvionix has the following additional options for consideration.

2.2.2.1 Mandatory ADS-B IN for UAS in all locations

There is growing recognition that any UAS operation operating Beyond Visual Line of Sight (BVLOS) will be required to have an adequate Detect and Avoid (DAA) capability to mitigate risk of a collision with manned aircraft. ADS-B IN functionality is now available at a Size, Weight, Power, and Cost (SWaP-C) profile conducive to sUAS equipage. uAvionix, as well as other manufacturers, now provide ADS-B IN receivers as OEM modules and add-on functionality for small UAS (see Figure 1). uAvionix receivers can be found in high profile UAS Original Equipment Manufacturers (OEMs) such as X (Google Wing), Quantum Systems, and Cube Pixhawk autopilot systems.

Figure 1: uAvionix ADS-B Dual-Band Receivers are available as aftermarket and OEM options

By enforcing ADS-B IN equipage nationwide on BVLOS or even commercial UAS, manned/GA aircraft owners have additional incentive to equip with ADS-B OUT to make their aircraft conspicuous to any UAS operating in their vicinity. In this way, CAA has the opportunity to initiate a virtuous circle, providing yet another safety enhancing benefit to GA pilots who equip with ADS-B OUT, even if they do not fly within the airspaces identified by CAA.

2.2.2.2 Very Low-Altitude ADS-B Out for Manned Aircraft

Manned operations at low altitudes are possibly at the greatest risk of a Mid-Air Collision (MAC) with UAS, while affording the pilot minimal reaction time. Specifically, helicopter operations and crop-spraying operations are placed at significant risk as UAS operations increase. CAA should consider expanding its location-based approach to also include mandatory ADS-B OUT on helicopter and crop-spraying aircraft regardless of geographical location. Used in conjunction with a mandatory ADS-B IN rule for commercial UAS operations, some level of assurance is provided that a UAS will have sufficient forewarning to keep well clear of an oncoming low-altitude aircraft.

2.2.2.3 Inert and Alert (I&A) for UAS

uAvionix has pioneered a concept for leveraging the safety benefits of ADS-B OUT for UAS while being respectful and efficient with the spectrum, as described in our Concept of Operations (CONOPs) - “Inert and Alert: Intelligent ADS-B for UAS NAS Integration.”[vi] The CONOPS outlines a spectrum mitigation approach called “Inert and Alert (I&A),” which is an intelligent ADS-B transceiver system that mitigates concerns raised by regulators by monitoring the UAS ownship position relative to controlled airspace, Temporary Flight Restrictions (TFRs), altitude, and other aircraft conditions in order to ONLY transmit when transmission is determined to be necessary for safety or compliance purposes.

Through a combination of an onboard database, communications with the UAS autopilot, GPS position, receipt of ADS-B transmissions, receipt of Mode A/C/S transmissions, and integration with other onboard sensors such as primary radar, the I&A ADS-B transceiver remains dormant in "listen mode" until only one or more of the following conditions is met:

- The Unmanned Aircraft (UA) detects nearby traffic within 7NM and within 2000ft of altitude.
- The UA exceeds 400ft Above Ground Level (AGL) in altitude.
- The UA breaches or approaches TFR boundaries.
- The UA breaches or approaches controlled airspace boundaries.
- The UA enters a "Lost Link" state where positive control by the Pilot-In-Command (PIC) is compromised.
- The Remote Pilot-In-Command (RPIC) manually commands transmission.

The scenarios identified above and described in this CONOPs require various forms of complexity and integration with onboard systems ranging from "standalone" capabilities requiring no integration to full integration with the autopilot and/or other sensors.

2.2.3 Do you have any specific feedback on the suggested approach?

uAvionix offers the following for further consideration:

2.2.3.1 Interoperability

The CAA's proposal is dependent upon "interoperable" EC technologies. To achieve success, CAA needs to define what it means by interoperable solutions relatively quickly. The best way to define interoperability would be with specification of spectrum and protocol.

uAvionix is aware of at least four non-interoperable systems currently deployed within the UK for EC purposes:

- 1090MHz ADS-B [both downlink format (DF) 17 and DF-18]
- 978MHz Universal Access Transceiver (UAT) ADS-B
- 868MHz FLARM
- 869.5MHz PilotAware "P3i"

These technologies are "non-interoperable" because they operate on different frequencies and with different protocols. What makes them appear interoperable at first glance is the ability of avionics equipment manufacturers to incorporate more than one radio/antenna pair into any given product. The uAvionix SkyEcho[vii], PilotAware Rosetta[viii], and LX Navigation FLARM EAGLE[ix] are all examples of such products with multiple technology capabilities.

With the exception of 978MHz UAT, each technology identified above has a significant user base in the UK, which presents a growing problem for the CAA. One way to address this is to specify the required EC technology for the transmit or "OUT" function of the EC device, while encouraging the receive or "IN" functionality to receive multiple technologies. Over time and through product attrition, the "selected" OUT technology will migrate to become the dominant technology.

Another aspect of interoperability is whether a worldwide standard, and therefore a worldwide market, exists for the technology and resulting products. Choosing a technology based on a worldwide standard and worldwide available frequencies enables market dynamics to lower the cost of ground and air equipment because the business case is worldwide, and not regional. Both 1090MHz ADS-B and 978MHz ADS-B are based on an international standard, even though 978MHz has been adopted only by the U.S.. Due to market drivers arising from the U.S. ADS-B mandate, however, many manufacturers have created dual-frequency ADS-B systems. FLARM does have a worldwide market, but the underlying frequencies and protocols change regionally, making it impossible for any manufacturer to develop a global solution. PilotAware primarily is used only in the UK.

PilotAware and FLARM suffer from another market disincentive: each is a privately-owned technology not based on a standard. A license fee is required for each, or to take advantage of its full capability. Safety-of-life interoperable solutions should not be beholden to a single privately held entity.

2.2.3.2 Spectrum Selection

There are four general types of spectrum which could be utilized for EC applications. Refer to Figure 2 for the cost vs. interference risk of these options.

1. Unlicensed Spectrum – Today, two of the four existing EC solutions are using unlicensed spectrum. These two systems are the 868MHz FLARM and 869.5MHz PilotAware technologies which operate in the Industrial, Scientific, and Medical (ISM) bands. Equipment operating in unlicensed spectrum **must not cause interference**, **must expect interference**, and **has no Right to Operate**. This means the spectrum is not legally protected for any specific use, including EC devices. Unlicensed spectrum is the lowest cost, but highest reliability risk of all spectrum options.
2. Licensed Shared Secondary Use – As a secondary user of licensed spectrum, a user has additional assurances over unlicensed spectrum in that only primary and secondary users should be operating in these frequencies. It is legally protected, but **must not cause interference**, and **must accept interference from primary and secondary users**, and has **no Right to Operate over other licensed users**.
3. Licensed Shared Primary Use - LTE is an example of licensed spectrum shared with other users. In this type of system, the expectation is that protection is provided against interference and other licensed users. The underlying "system" provides coordination and availability consistent with dynamic command.
4. Licensed Single Primary Use – In these cases, the frequency is provided for a specific use and not shared with secondary users. This type of application is common in aviation for specific uses, including 1090MHz and 978MHz ADS-B. Licensed Single Primary Use is the highest cost and lowest risk of all options.

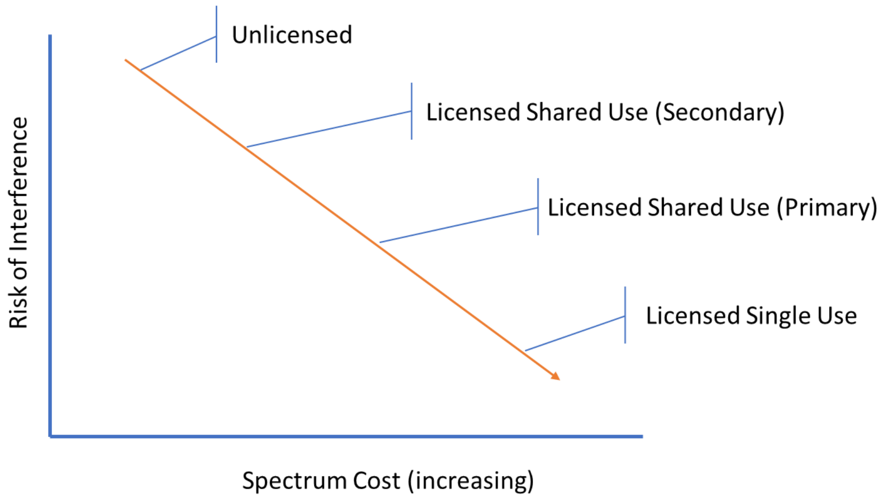

Figure 2: Spectrum Options: Interference Risk vs. Cost of Spectrum

2.2.3.3 GPS Integrity

The CAA mentions only briefly in its consultation the required integrity of EC solutions. Besides the frequency and protocol definition, CAA should also define the required integrity of the GPS solution, as defined by existing aviation standards. uAvionix recommends that GPS position sources for EC devices be required to have a minimum level (TBD) of Receiver Autonomous Integrity Monitoring (RAIM) and Fault Detection and Exclusion (FDE) functionality, and be Satellite-based Augmentation System (SBAS) compatible. This functionality serves as protection against faults induced by satellite errors or outages, as well as assurance of integrity.

For reference on the basic functionality of SBAS, RAIM and FDE:

> **SBAS** is a "civil aviation safety-critical system that supports wide area or regional augmentation through the use of Geostationary (GEO) satellites which broadcast the augmentation information. An SBAS augments primary Global Navigation Satellite System (GNSS) constellation(s) by providing GEO ranging, integrity, and correction information." SBAS's main goal is to provide integrity assurance, but it also increases the accuracy with position errors below 1 meter.[x]
>
> **RAIM** "provides integrity monitoring of GPS for aviation applications. In order for a GPS receiver to perform RAIM or Fault Detection (FD) function, a minimum of five visible satellites with satisfactory geometry must be visible to it. RAIM has various kinds of implementations; one of them performs consistency checks between all position solutions obtained with various subsets of the visible satellites. The receiver provides an alert to the pilot if consistency checks fail."[xi]
>
> **FDE** is an enhanced version of RAIM which uses a minimum of six satellites to not only detect a possibly faulty satellite, but to exclude it from the navigation solution so the navigation function can continue without interruption. The goal of FD is to detect the presence of a positioning failure. Upon detection, proper fault exclusion determines and excludes the source of the failure (without necessarily identifying the individual source causing the problem), thereby

allowing GNSS navigation to continue without interruption. The use of satellites from multiple GNSS constellations or the use of SBAS satellites as additional ranging sources can improve the availability of RAIM and FDE.[xii]

Refer to Figure 3 for the impact of Pseudorange Error on GPS solutions with and without RAIM (which here includes FDE).

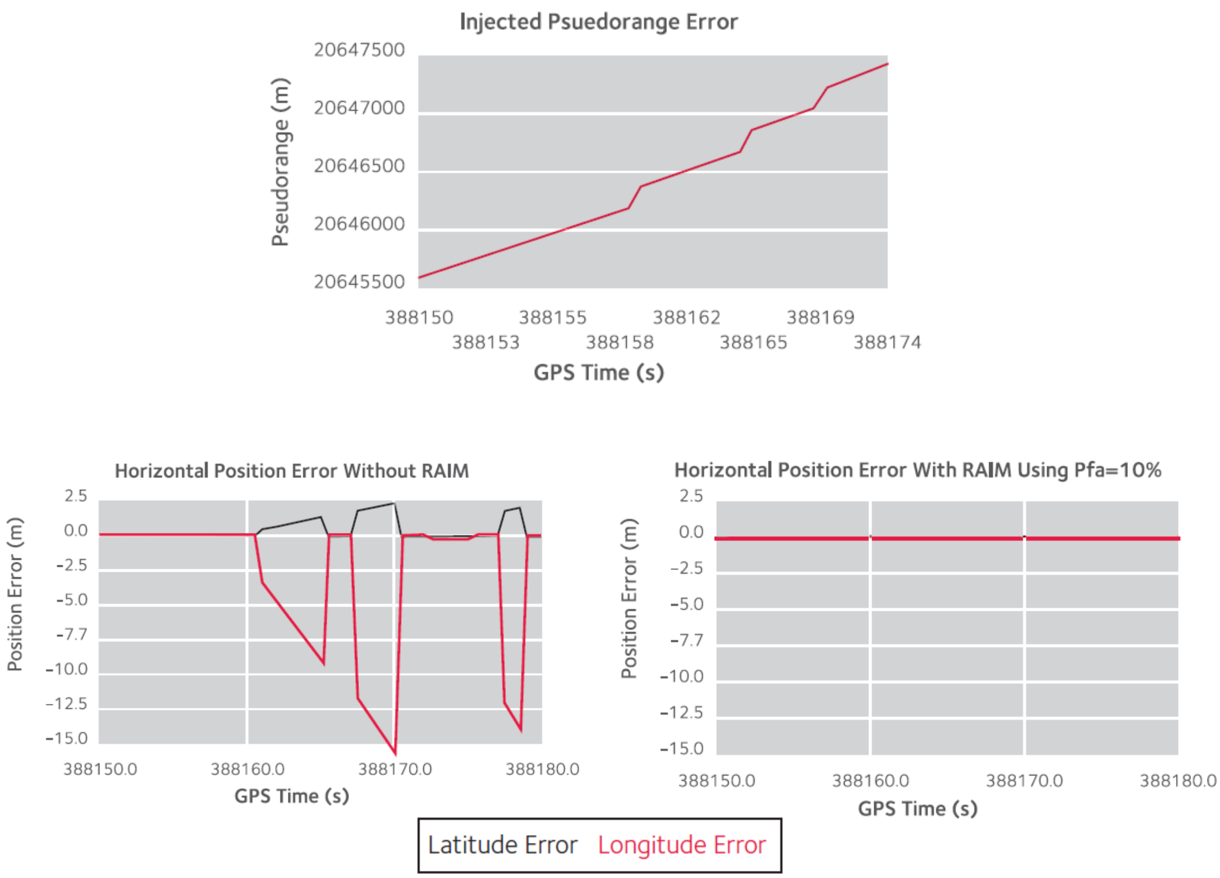

Figure 3: Injected Pseudorange Error (Top) and its effects on positioning error without RAIM (Bottom Left) and positioning error with RAIM (Bottom Right). Source: Novatel[xiii]

2.2.3.4 Product Pricing

While paragraph 75 indicates the CAA does not propose to rule out any alternative technologies to ADS-B, by defining interoperability as described in previous paragraphs, it will necessarily do so. Failing to do so will perpetuate the current state of non-interoperability, and drive product costs upwards as manufacturers are challenged to incorporate more and more radios and antennas into a single product for maximum interoperability.

2.2.3.5 Broadcast Systems

Currently uAvionix is aware of two broadcast systems in operation in the UK. uAvionix has been operating a 978MHz UAT Flight Information Services – Broadcast (FIS-B) trial, and PilotAware is operating a P3i based Traffic Information Service – Broadcast (TIS-B) solution. For demonstration purposes, uAvionix briefly operated a TIS-B service as a component of Operation Zenith[xiv] at Manchester Aerodrome in late 2018.

Broadcast systems can be used to implement interoperability by acting as a ground based "translator" from one frequency/protocol to another. Implementing a rebroadcast solution reduces the burden on avionics manufacturers and individual pilots, and shifts the burden to the ground system operator, who may be an Air Navigation Service Provider (ANSP), Unmanned Traffic Management (UTM) system provider, or Electronic Flight Bag (EFB) app developer. Access to the ground-based locations, communications infrastructure, and spectrum licenses can lead to costs that may not be recoverable without subsidy.

3 Conclusion

uAvionix is pleased to provide the included feedback to CAA. In general, uAvionix applauds CAA's efforts and methodology to implement interoperable solutions using an airspace-based requirement. Further definition of interoperability is required, however, which likely will exclude some existing technologies. Protected spectrum and GPS integrity for any system should be considered carefully as either reduces risk, but also can lead to increased cost. Finally, broadcast solutions may be an answer, but likely would require investment from the regulator to achieve the full benefits sought.

[i] https://www.aopa.org/news-and-media/all-news/2019/april/18/study-shows-accidents-less-likely-with-ads-b-in

[ii] https://download.aopa.org/advocacy/2019/dhowell_jking_DASC2019_V2.pdf?_ga=2.194020013.1807277395.1557940052-2063396024.1555941727

[iii] https://download.aopa.org/advocacy/2019/AOPA_SBS_Letter.pdf?_ga=2.228190877.1807277395.1557940052-2063396024.1555941727

[iv] https://www.aopa.org/news-and-media/all-news/2016/august/pilot/adsb-seeing-clear-benefits

[v] https://www.ntsb.gov/safety/safety-alerts/Documents/SA_058.pdf

[vi] https://uavionix.com/downloads/whitepapers/Inert-and-Alert-CONOPS.pdf

[vii] https://uavionix.com/products/skyecho/

[viii] https://pilotaware.com/rosetta/

[ix] http://www.lxnavigation.com/flarm-eagle/

[x] https://gssc.esa.int/navipedia/index.php/SBAS_Fundamentals

[xi] https://en.wikipedia.org/wiki/Receiver_autonomous_integrity_monitoring#RAIM

[xii] https://en.wikipedia.org/wiki/Receiver_autonomous_integrity_monitoring#Fault_detection_and_exclusion

[xiii] [xiii] https://www.novatel.com/assets/Documents/Papers/RAIM.pdf

[xiv] https://www.operationzenith.com/